Extra Class Exam Study Guide

Workshop Course Book for July 2020 to June 2024

The Villages Amateur Radio Club
The Villages, Florida 32162
www.k4vrc.com

Amateur Extra Class Workshop

All Amateur Radio Operators,

Amateur radio has been around for a long time and has grown itself into a worldwide community of licensed hams on the airwaves with all sorts of communications technology. Ham radio attracts those who have never held a microphone as well as deep technical experts who grew up with a soldering iron and computer. Your United States Amateur Service license gives you the most powerful wireless communications capability available to any private citizen anywhere in the world. In the United States, amateur radio licensing is governed by the Federal Communications Commission (FCC) under strict federal regulations. Licenses to operate amateur stations for personal use are granted to individuals of any age once they demonstrate an understanding of both pertinent FCC regulations and knowledge of radio station operation and safety considerations. December 2012 marked one hundred years of amateur radio operator and station licensing by the United States government. Operator licenses are divided into different classes, each of which correlates to an increasing degree of knowledge and corresponding privileges. Over the years, the details of the classes have changed significantly, leading to the current system of three open classes and two grandfathered but closed to new applicants. The top US license class is Amateur Extra Class. The Extra Class license requires an applicant pass 35 of a 50-question multiple-choice theory exam. Those with Amateur Extra licenses are granted all privileges on all US amateur bands.

The ARRL Extra Class License description says it best; "General licensees may upgrade to Extra Class by passing a 50-question multiple-choice examination. No Morse code test is required. In addition to some of the more obscure regulations, the test covers specialized operating practices, advanced electronics theory and radio equipment design. Non-licensed individuals must pass Element 2, Element 3 and Element 4 written exams to earn an Extra License. The FCC grants exam element 3 credit to individuals that previously held certain older types of licenses. The HF bands can be awfully crowded, particularly at the top of the solar cycle. Once one earns HF privileges, one may quickly yearn for more room. The Extra Class license is the answer. Extra Class licensees are authorized to operate on all frequencies allocated to the Amateur Service."

The Extra Class workshop is specially presented for those with amateur radio experience who want to learn more. The workshop will cover a vast amount of material in five classes. It is intended to help members advance in the hobby we love and give a little boost to those on the fence.

Looking forward to congratulating you in your advancement to Amateur Extra Class,

George K2DM

George Briggs
President
The Villages Amateur Radio Club

PS All amateur radio operators are welcome to use and share this document. Comments about this document can be sent by means of the club website contact form; https://www.k4vrc.com/contact-us.html Please include; a detailed description of the issue with exam question ID and page number.

Table of Contents

Revisions

Original Release – 6/24/20

Incorporated comments, errata updates and typographical errors – 11/2/20

Introduction

Just Enough for Understanding

Studying for the Amateur Extra is not easy for most people and this class is designed to help you with the difficult parts. Normally the class size is small allowing more time to address the how and why questions. This is not intended to be traditional classroom experience instead you should expect a much more informal discussions about electronics as it relates to HAM radio not Electrical Engineering. Too bad most of the well-known ham radio license manuals spend way too much content on theory and fail to stay within the scope of the exam. This is not to say just teach the test. A good example is the diode, you need to know the types, forward voltage and reverse bias. You do not need an understanding of semiconductor theory. Simply put there is only five classes (about 15 Hours in class room time) to gain an introductory level understanding of the technology and the Code of Federal Regulations Title 47, Telecommunication. Part 97, Amateur Radio Service. The class format is just enough information for context and essential understanding needed to pass the licensing test.

Less Math for more Comprehension

Historically most HAMs have problems passing the license exam due to the math required. It may relieve some of your concerns to know the question pool has reduced the number of questions requiring calculations in favor of comprehension questions in the last three releases. You still need to use a small amount of math to solve problems but just add, subtract, multiple and divide. This class will focus on thinking through the questions and avoiding the trigonometry to solve problems. Working the example problems in class will help you be at ease with using the math required. Thinking carefully about the wording of the question will often lead to the only correct answer without any math! This means many multiple-choice questions can be solved logically without doing the math and the discussion from this class will help you avoid selecting the wrong answer.

Five Classes

The five classes will meet for about three hours once a week. Each topic begins with an overview of the homework assignment for context followed by review of the questions covered. Understanding is reinforced with your questions and discussion. To prepare for class;

- Individual reading of chapter prior to class
- Pay attention to the **BLUE** text, they are the phrases used on the exam
- The **Editors Notes** are included for context and more understanding but are not test questions
- Work sample problems prior to class
- When reviewing the questions make a "I need help" list for discussion in class
- Use the **Fundamentals and Substance** section to supplement your reading and take notes
- Class Review of assignment, discussion and help with problems
- Individual practice tests (online or Apps) at home between classes

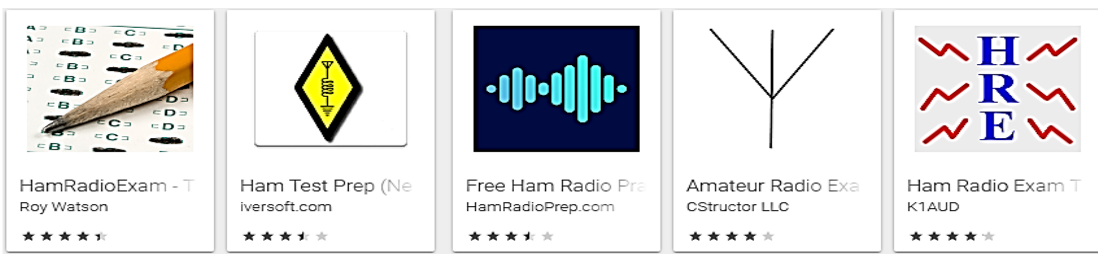
If you attend all classes, keep up with readings, and take practice tests conscientiously, preparing can be a relatively pain-free process. Pain-free does not mean work-free! Take practice tests online from multiple sites or different APPs. Many past students have found that preparing for the exam for 60 minutes per day, five or six days per week, will leave them well-prepared at exam time. Don't cram at the end as hitting hard at the last minute simply don't work for most people and they experience declining returns on their efforts when they attempt to study for two and three hours straight.

Learning Aids

You are encouraged to use every study resource that works for you. In general people retain more details from a hard copy document. Print the **Fundamentals and Substance** section so you can take it with you to study, write on it, underline or highlight the text for reference later. Place a copy of this guide on an eReader. Purchased books are not required but if you do have questions from other sources they will be discussed during the open review at the end of each class.

Take online practice tests online, but not more than once a day.
http://arrlexamreview.appspot.com/
https://hamexam.org/
https://hamstudy.org/

Many people have found using a test App on their phone or tablet is a helpful tool



https://play.google.com/store/apps
https://www.apple.com/ios/app-store/

Dave Casler KE0OG Videos lectures on YouTube are highly recommended.

https://dcasler.com/ham-radio/

Memory Retention

Make sure to review and expand upon the Fundamentals and Substance section after completing each class. The Fundamentals and Substance subsection that was solely created as a tool for test preparation by helping you make connections between topics and serves as quality review material for after each class. The information is in the form of class notes with all of the important information you need to know. The notes are organized into easily digestible headings and bullet points to organize topics with the key words, main subpoints and summary are all written in one place. You should find using will be most useful when learning about new topics that include a lot of detail. This section is not intended to be a substitute for studying the class material in fact you will need to complete your reading assignment and attend class in order to effectively use these notes.

CLASS 1 – REGULATIONS

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E1A Operating Standards

E1B Station restrictions and special operations

E1C Rules pertaining to automatic and remote control

E1F Miscellaneous rules

E1D Amateur space and Earth stations; telemetry and telecommand rules

E1E Volunteer examiner program

E2C, E2D, E2E Operating methods

Class One Fundamentals and Substance

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E1A Operating Standards

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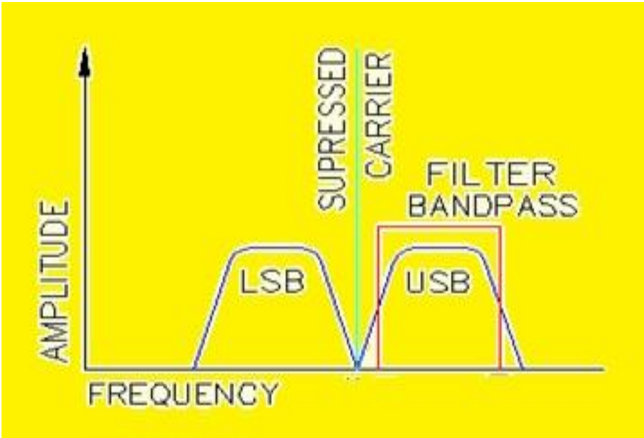
Upper Sideband (USB) emissions will be **3 kHz above** the carrier frequency

Lower Sideband (LSB) emissions will be **3 kHz below** the carrier frequency



18.068 MHz is illegal for LSB AFSK emissions on the 17M band RTTY

Transceivers display LSB carrier frequency of phone signals 3 KHz above the lower band edge

14.149 MHz is the maximum legal carrier 20M frequency for 1 KHz BW USB AFSK digital signals

3.601 MHz LSB Phone is beyond the edge of the phone band segment

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E1A01 (A) [97.305, 97.307(b)] Which of the following carrier frequencies is illegal for LSB AFSK emissions on the 17 meter band RTTY and data segment of 18.068 to 18.110 MHz? A. 18.068 MHz B. 18.100 MHz C. 18.107 MHz D. 18.110 MHz

E1A02 (D) [97.301, 97.305] When using a transceiver that displays the carrier frequency of phone signals, which of the following displayed frequencies represents the lowest frequency at which a properly adjusted LSB emission will be totally within the band? A. The exact lower band edge B. 300 Hz above the lower band edge C. 1 kHz above the lower band edge D. 3 kHz above the lower band edge

E1A03 (C) [97.305, 97.307(b)] What is the maximum legal carrier frequency on the 20 meter band for transmitting USB AFSK digital signals having a 1 kHz bandwidth? A. 14.070 MHz B. 14.100 MHz C. 14.149 MHz D. 14.349 MHz

E1A04 (C) [97.301, 97.305] With your transceiver displaying the carrier frequency of phone signals, you hear a DX station calling CQ on 3.601 MHz LSB. Is it legal to return the call using lower sideband on the same frequency? A. Yes, because the DX station initiated the contact B. Yes, because the displayed frequency is within the 75 meter phone band segment C. No, the sideband will extend beyond the edge of the phone band segment D. No, U.S. stations are not permitted to use phone emissions below 3.610 MHz

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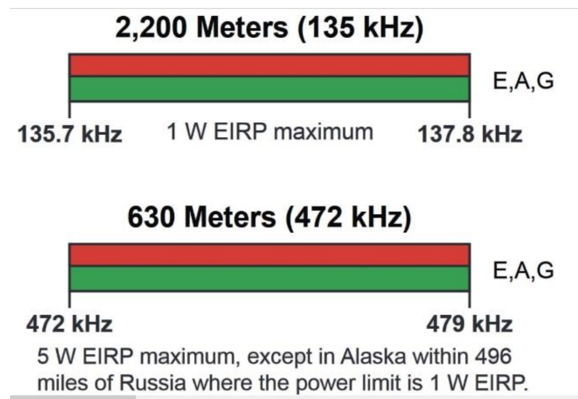
General, Advanced and Amateur Extra class licensees are authorized to use 2200M & 630M Amateur Bands

Amateurs wishing to operate these bands must first register with the Utilities Technology Council online at https://utc.org/plc-database-amateur-notification-process/ . You need only register once for each band.

***630M 472 - 479 KHz: 5 W EIRP maximum**, except in Alaska within 496 miles of Russia where the power limit is 1 W EIRP*

2200M 135.7 – 137.8 1 W EIRP maximum



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E1A07 (C) [97.313(k)] What is the maximum power permitted on the 2200 meter band? A. 50 watts PEP B. 100 watts PEP C. 1 watt EIRP (Equivalent isotropic radiated power) D. 5 watts EIRP (Equivalent isotropic radiated power)

E1A14 (D) [97.313(l)] Except in some parts of Alaska, what is the maximum power permitted on the 630 meter band? A. 50 watts PEP B. 100 watts PEP C. 1 watt EIRP D. 5 watts EIRP

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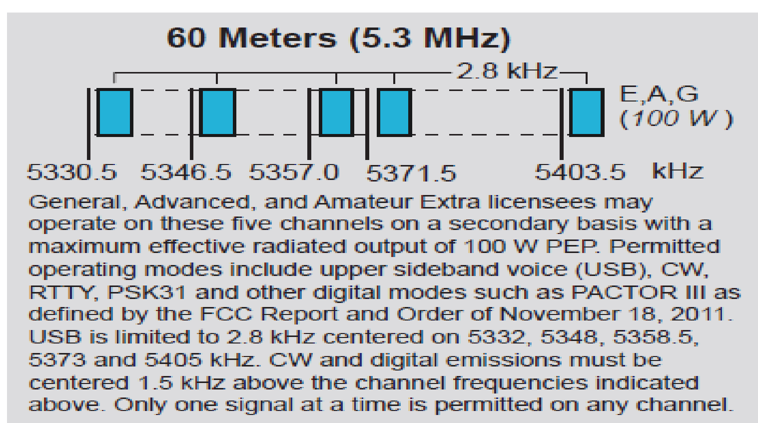
100 watts PEP effective radiated power relative to the gain of a half-wave dipole is the maximum power output permitted on 60M

The CW carrier must be at the center frequency of the channel on 60M

The maximum bandwidth for a data emission on 60 meters is 2.8 kHz



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E1A05 (C) [97.313] What is the maximum power output permitted on the 60 meter band? A. 50 watts PEP effective radiated power relative to an isotropic radiator B. 50 watts PEP effective radiated power relative to a dipole C. 100 watts PEP effective radiated power relative to the gain of a half-wave dipole D. 100 watts PEP effective radiated power relative to an isotropic radiator

E1A06 (B) [97.303(h)(1)] Where must the carrier frequency of a CW signal be set to comply with FCC rules for 60 meter operation? A. At the lowest frequency of the channel B. At the center frequency of the channel C. At the highest frequency of the channel D. On any frequency where the signal's sidebands are within the channel

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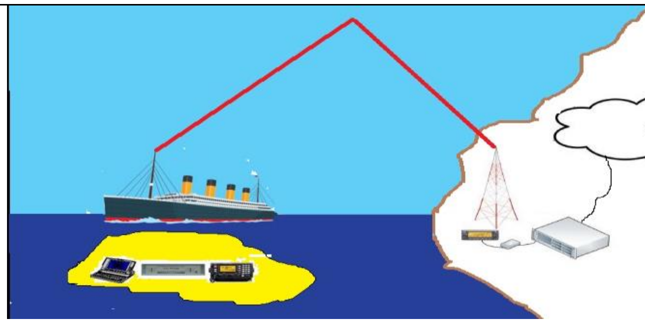

If a station in a **message forwarding system** inadvertently forwards a message that is in **violation** of FCC rules, the control operator of the **originating station is primarily accountable** for the rules violation

The first action you should take if your digital message forwarding station inadvertently forwards a communication that violates FCC rules is to **discontinue forwarding the communication as soon as you become aware of it**

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E1A08 (B) [97.219] If a station in a message forwarding system inadvertently forwards a message that is in violation of FCC rules, who is primarily accountable for the rules violation? A. The control operator of the packet bulletin board station B. The control operator of the originating station C. The control operators of all the stations in the system D. The control operators of all the stations in the system not authenticating the source from which they accept communications

E1A09 (A) [97.219] What action or actions should you take if your digital message forwarding station inadvertently forwards a communication that violates FCC rules? A. Discontinue forwarding the communication as soon as you become aware of it B. Notify the originating station that the communication does not comply with FCC rules C. Notify the nearest FCC Field Engineers office D. All these choices are correct
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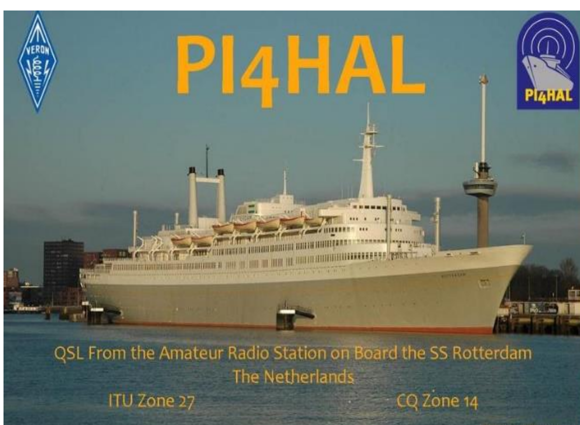

Operation of an amateur station is installed aboard a ship or aircraft must be approved by the master of the ship or the pilot in command of the aircraft

An FCC-issued amateur license or a reciprocal permit for an alien amateur licensee is required when operating an amateur station **aboard a US-registered vessel in international waters**

An FCC-issued amateur license or a reciprocal permit for an alien amateur licensee is required when operating an amateur station **aboard any vessel or craft that is documented or registered in the United States**

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E1A10 (A) [97.11] If an amateur station is installed aboard a ship or aircraft, what condition must be met before the station is operated? A. Its operation must be approved by the master of the ship or the pilot in command of the aircraft B. The amateur station operator must agree not to transmit when the main radio of the ship or aircraft is in use C. The amateur station must have a power supply that is completely independent of the main ship or aircraft power supply D. The amateur operator must have an FCC Marine or Aircraft endorsement on his or her amateur license

E1A11 (B) [97.5] Which of the following describes authorization or licensing required when operating an amateur station aboard a U.S.-registered vessel in international waters? A. Any amateur license with an FCC Marine or Aircraft endorsement B. Any FCC-issued amateur license C. Only General Class or higher amateur licenses D. An unrestricted Radiotelephone Operator Permit

E1A13 (B) [97.5] Who must be in physical control of the station apparatus of an amateur station aboard any vessel or craft that is documented or registered in the United States? A. Only a person with an FCC Marine Radio license grant B. Any person holding an FCC issued amateur license or who is authorized for alien reciprocal operation C. Only a person named in an amateur station license grant D. Any person named in an amateur station license grant or a person holding an unrestricted Radiotelephone Operator Permit
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E1B Station restrictions and special operations

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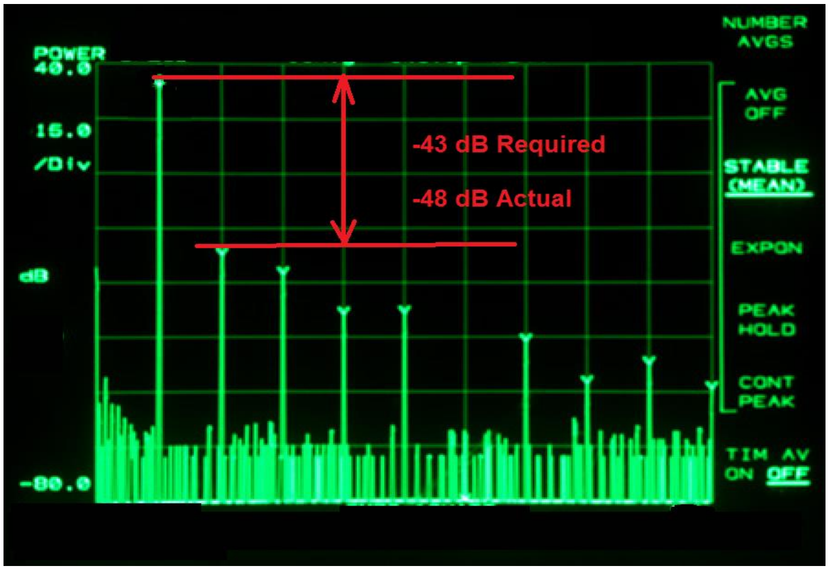
An emission outside its necessary bandwidth that can be reduced or eliminated without affecting the information transmitted constitutes a spurious emission

The mean power of any spurious emission must be at least - 43 dB relative to the mean power of the fundamental emission from a station transmitter or external RF amplifier installed after January 1, 2003, and transmitting on a frequency below 30 MHZ



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E1B01 (D) [97.3] Which of the following constitutes a spurious emission? A. An amateur station transmission made without the proper call sign identification B. A signal transmitted to prevent its detection by any station other than the intended recipient C. Any transmitted signal that unintentionally interferes with another licensed radio station D. An emission outside the signal's necessary bandwidth that can be reduced or eliminated without affecting the information transmitted

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DRM SSTV SSB transmissions in the HF phone bands DRM must conform to the maximum 2.8 kHz occupied bandwidth

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E1B02 (A) [97.307(f)(2)] Which of the following is an acceptable bandwidth for Digital Radio Mondiale (DRM) based voice or SSTV digital transmissions made on the HF amateur bands? A. 3 kHz B. 10 kHz C. 15 kHz D. 20 kHz

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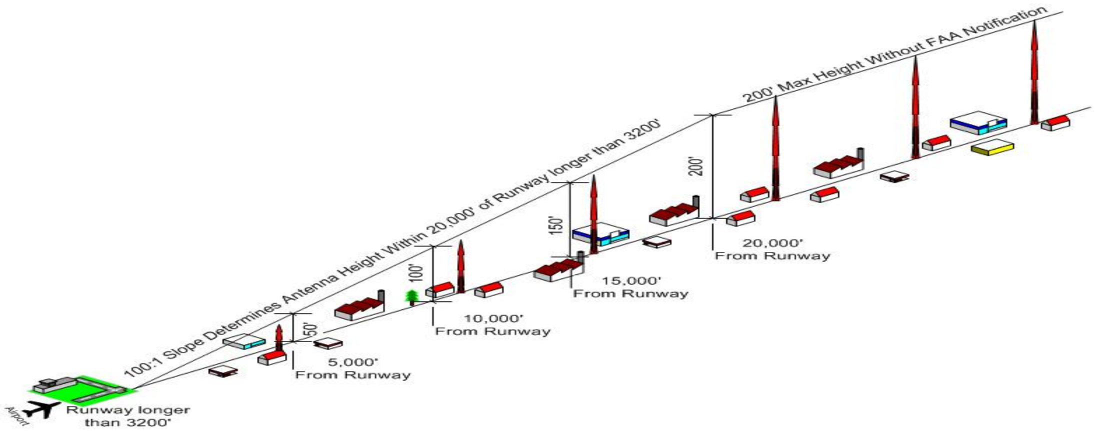
If you are installing an amateur station antenna at a site at or near a public use airport you may have to notify the Federal Aviation Administration and register it with the FCC as required by Part 17 of FCC rules



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E1B06 (A) [97.15] Which of the following additional rules apply if you are installing an amateur station antenna at a site at or near a public use airport? A. You may have to notify the Federal Aviation Administration and register it with the FCC as required by Part 17 of the FCC rules B. You must submit engineering drawings to the FAA C. You must file an Environmental Impact Statement with the EPA before construction begins D. You must obtain a construction permit from the airport zoning authority

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An Environmental Assessment must be submitted to the FCC before placing an amateur station within an officially designated wilderness area or wildlife preserve, or an area listed in the National Register of Historical Places

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E1B04 (C) [97.13, 1.1305-1.1319] What must be done before placing an amateur station within an officially designated wilderness area or wildlife preserve, or an area listed in the National Register of Historic Places? A. A proposal must be submitted to the National Park Service B. A letter of intent must be filed with the Environmental Protection Agency C. An Environmental Assessment must be submitted to the FCC D. A form FSD-15 must be submitted to the Department of the Interior

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Editor's note: FCC monitoring facility must protect that facility from harmful interference. Failure to do so could result in imposition of operating restrictions upon the amateur station by an EIC pursuant to Sec. 97.121 of this part. Geographical coordinates of the facilities that require protection are listed in Sec. 0.121 (c) of this chapter. There are 14 such stations listed in 47 CFR 0.121(b) and are shown below.

The National Radio Astronomy Observatory sites are located in Green Bank West Virginia, Socorro New Mexico, and Charlottesville NC.

The National Radio Quiet Zone is an area surrounding the National Radio Astronomy Observatory

Within 1 mile an amateur station must protect an FCC monitoring facility from harmful interference

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E1B05 (C) [97.3] What is the National Radio Quiet Zone? A. An area in Puerto Rico surrounding the Arecibo Radio Telescope B. An area in New Mexico surrounding the White Sands Test Area C. An area surrounding the National Radio Astronomy Observatory D. An area in Florida surrounding Cape Canaveral

E1B03 (A) [97.13] Within what distance must an amateur station protect an FCC monitoring facility from harmful interference? A. 1 mile B. 3 miles C. 10 miles D. 30 miles

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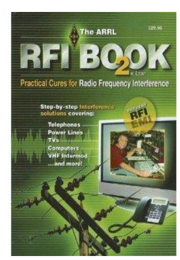

An amateur station could be required to avoid transmitting during certain hours on frequencies that cause the interference if its signal causes interference to domestic broadcast reception, assuming that the receiver(s) involved are of good engineering design

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E1B08 (D) [97.121] What limitations may the FCC place on an amateur station if its signal causes interference to domestic broadcast reception, assuming that the receivers involved are of good engineering design? A. The amateur station must cease operation B. The amateur station must cease operation on all frequencies below 30 MHz C. The amateur station must cease operation on all frequencies above 30 MHz D. The amateur station must avoid transmitting during certain hours on frequencies that cause the interference

E1B12 (A) [97.303(b)] What must the control operator of a repeater operating in the 70 cm band do if a radiolocation system experiences interference from that repeater? A. Cease operation or make changes to the repeater to mitigate the interference B. File an FAA NOTAM (Notice to Airmen) with the repeater system's ERP, call sign, and six-character grid locator C. Reduce the repeater antenna HAAT (Height Above Average Terrain) D. All these choices are correct

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Any FCC-licensed amateur station certified by the responsible civil defense organization for the area served may be operated in RACES

All amateur service frequencies authorized to the control operator are authorized to an amateur station participating in RACES

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E1B09 (C) [97.407] Which amateur stations may be operated under RACES rules? A. Only those club stations licensed to Amateur Extra Class operators B. Any FCC-licensed amateur station except a Technician Class C. Any FCC-licensed amateur station certified by the responsible civil defense organization for the area served D. Any FCC-licensed amateur station participating in the Military Auxiliary Radio System (MARS)

E1B10 (A) [97.407] What frequencies are authorized to an amateur station operating under RACES rules? A. All amateur service frequencies authorized to the control operator B. Specific segments in the amateur service MF, HF, VHF and UHF bands C. Specific local government channels D. Military Auxiliary Radio System (MARS) channels

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PRB-1 require state and local government zoning regulations to make reasonable accommodations affecting amateur radio (Does not apply for HOA & CCR)

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E1B07 (C) [97.15] To what type of regulations does PRB-1 apply? A. Homeowners associations B. FAA tower height limits C. State and local zoning D. Use of wireless devices in vehicles

E1B11 (B) [97.15] What does PRB-1 require of regulations affecting amateur radio? A. No limitations may be placed on antenna size or placement B. Reasonable accommodations of amateur radio must be made C. Amateur radio operations must be permitted in any private residence D. Use of wireless devices in a vehicle is exempt from regulation

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E1C Rules pertaining to automatic and remote control

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Editor's note: The question(s) below are addressed in E1A Operating Standards

E1C01 (D) [97.303] What is the maximum bandwidth for a data emission on 60 meters? A. 60 Hz B. 170 Hz C. 1.5 kHz D. 2.8 kHz

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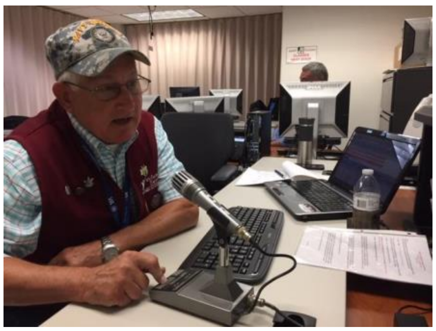

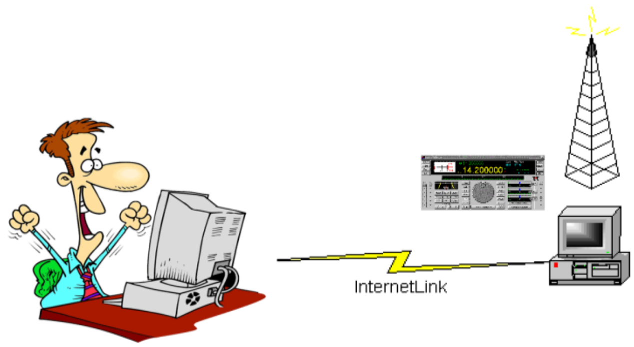

The use of devices and procedures for control so that the control operator does not have to be present at a control point is automatic control of a station

An automatically controlled station may NOT originate third party communications

3 minutes is the maximum permissible duration of a remotely controlled station's transmissions if its control link malfunctions

Editor's note: Station Control and Repeaters

A control operator must be present at the control point of a remotely controlled amateur station

A station controlled indirectly through a control link is a remotely controlled station

Direct manipulation of the transmitter by a control operator is meant by local control

Under automatic control the control operator is not required to be present at the control point

An automatically controlled station may retransmit third party communications when transmitting RTTY or data emissions

29.500 - 29.700 MHz are available for an automatically controlled repeater operation

Only auxiliary, repeater or space stations may automatically retransmit the radio signals of other amateur stations

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E1C03 (B) [97.109(d)] How do the control operator responsibilities of a station under automatic control differ from one under local control? A. Under local control there is no control operator B. Under automatic control the control operator is not required to be present at the control point C. Under automatic control there is no control operator D. Under local control a control operator is not required to be present at a control point

E1C05 (A) [97.221(c)(1), 97.115(c)] When may an automatically controlled station originate third party communications? A. Never B. Only when transmitting RTTY or data emissions C. When agreed upon by the sending or receiving station D. When approved by the National Telecommunication and Information Administration

E1C08 (B) [97.213] What is the maximum permissible duration of a remotely controlled station's transmissions if its control link malfunctions? A. 30 seconds B. 3 minutes C. 5 minutes D. 10 minutes

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Communications incidental to the purpose of the amateur service and remarks of a personal nature may be transmitted to amateur stations in foreign countries

Non-US Operating Agreements

European Conference of Postal and Telecommunications Administrations (CEPT) license Allows US amateurs to travel and operate from most of European countries Amateurs from CEPT countries can operate in the USA

International Amateur Radio Permit (IARP) Allows for operations in certain countries in Central and South America without seeking a special license or permit to enter and operate from that country

International Telecommunication Union Reciprocal Permit is an agreement between the US and a country that does not participate in either CEPT or IARP agreements

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E1C02 (C) [97.117] Which of the following types of communications may be transmitted to amateur stations in foreign countries? A. Business-related messages for non-profit organizations B. Messages intended for users of the maritime satellite service C. Communications incidental to the purpose of the amateur service and remarks of a personal nature D. All these choices are correct

E1C04 (A) What is meant by IARP? A. An international amateur radio permit that allows U.S. amateurs to operate in certain countries of the Americas B. The internal amateur radio practices policy of the FCC C. An indication of increased antenna reflected power D. A forecast of intermittent aurora radio propagation

E1C06 (C) Which of the following is required in order to operate in accordance with CEPT rules in foreign countries where permitted? A. You must identify in the official language of the country in which you are operating B. The U.S. embassy must approve of your operation C. You must bring a copy of FCC Public Notice DA 16-1048 D. You must append "/CEPT" to your call sign

E1C11 (A) [97.5] Which of the following operating arrangements allows an FCC-licensed U.S. citizen to operate in many European countries, and alien amateurs from many European countries to operate in the U.S.? A. CEPT agreement B. IARP agreement C. ITU reciprocal license D. All these choices are correct

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Editor’s note: The question(s) below are addressed in E1B Station restrictions and special operations

E1C10 (A) [97.307] What is the permitted mean power of any spurious emission relative to the mean power of the fundamental emission from a station transmitter or external RF amplifier installed after January 1, 2003 and transmitting on a frequency below 30 MHz? A. At least 43 dB below B. At least 53 dB below C. At least 63 dB below D. At least 73 dB below

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Editor’s note: The question(s) below are addressed in E8B Modulation and Demodulation

E1C07 (D) [97.3(a)(8)] At what level below a signal's mean power level is its bandwidth determined according to FCC rules? A. 3 dB B. 6 dB C. 23 dB D. 26 dB

E1C09 (B) [97.307] What is the highest modulation index permitted at the highest modulation frequency for angle modulation below 29.0 MHz? A. 0.5 B. 1.0 C. 2.0 D. 3.0

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Editor’s note: The question(s) below are addressed in E1A Operating Standards

E1C12 (D) [97.305(c)] On what portion of the 630 meter band are phone emissions permitted? A. None B. Only the top 3 kHz C. Only the bottom 3 kHz D. The entire band

E1C13 (C) [97.303(g)] What notifications must be given before transmitting on the 630 meter or 2200 meter bands? A. A special endorsement must be requested from the FCC B. An environmental impact statement must be filed with the Department of the Interior C. Operators must inform Utilities Technology Council (UTC) of their call sign and coordinates of the station D. Operators must inform the FAA of their intent to operate, giving their call sign and distance to the nearest runway

E1C14 (B) [97.303(g)] How long must an operator wait after filing a notification with the Utilities Technology Council (UTC) before operating on the 2200 meter or 630 meter band? A. Operators must not operate until approval is received B. Operators may operate after 30 days, providing they have not been told that their station is within 1 km of PLC systems using those frequencies C. Operators may not operate until a test signal has been transmitted in coordination with the local power company D. Operations may commence immediately, and may continue unless interference is reported by the UTC

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E1F Miscellaneous rules

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Only Technician, General, Advanced or Amateur Extra Class operators may be the control operator of an auxiliary station

Editor's note: Auxiliary Stations

> *Auxiliary Stations are amateur station, other than in a message forwarding system, that transmit communications point-to-point within a system of cooperating amateur stations*
>
> *Links to remotely controlled stations*
>
> *Cross-band repeat stations*

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E1F10 (B) [97.201] Who may be the control operator of an auxiliary station? A. Any licensed amateur operator B. Only Technician, General, Advanced or Amateur Extra Class operators C. Only General, Advanced or Amateur Extra Class operators D. Only Amateur Extra Class operators

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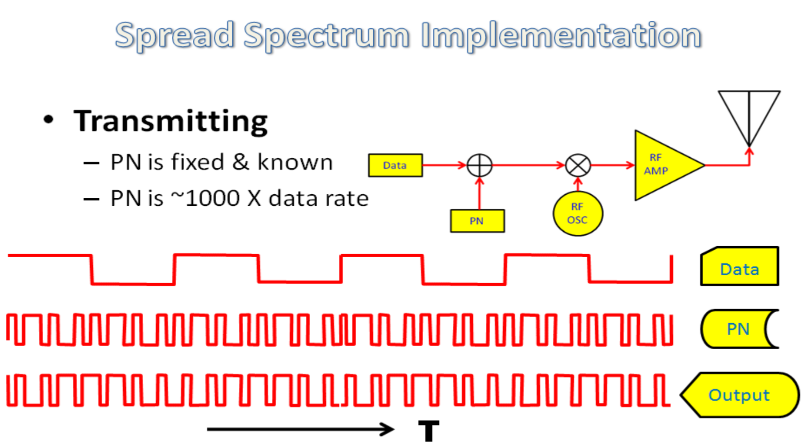
Spread spectrum transmissions permitted on amateur frequencies above 222 MHz

A station transmitting SS emission must not cause harmful interference

The transmitting station must be in an area regulated by the FCC

The transmission must not be used to obscure the meaning

10 W is the maximum transmitter power for an amateur station transmitting spread spectrum



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E1F01 (B) [97.305] On what frequencies are spread spectrum transmissions permitted? A. Only on amateur frequencies above 50 MHz B. Only on amateur frequencies above 222 MHz C. Only on amateur frequencies above 420 MHz D. Only on amateur frequencies above 144 MHz

E1F09 (D) [97.311] Which of the following conditions apply when transmitting spread spectrum emissions? A. A station transmitting SS emission must not cause harmful interference to other stations employing other authorized emissions B. The transmitting station must be in an area regulated by the FCC or in a country that permits SS emissions C. The transmission must not be used to obscure the meaning of any communication D. All these choices are correct

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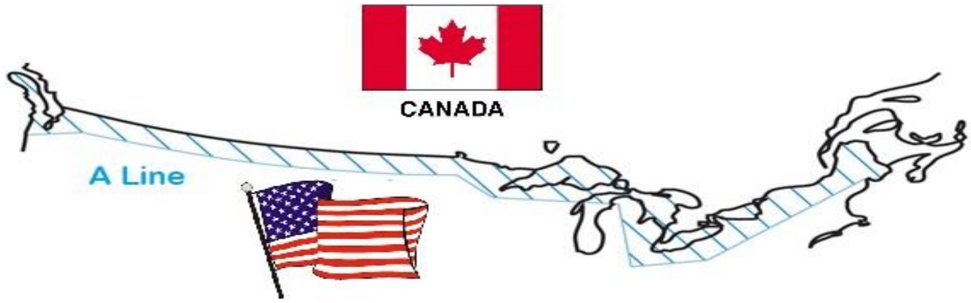


Canadian amateurs operating in the USA cannot exceed U.S. Amateur Extra Class privileges

LINE A is an area roughly parallel to of the US-Canadian border and about 75 miles south

North of Line A Amateur stations may not transmit on 420 - 430 MHz

==

E1F02 (C) [97.107] What privileges are authorized in the U.S. to persons holding an amateur service license granted by the government of Canada? A. None, they must obtain a U.S. license B. All privileges of the Amateur Extra Class license C. The operating terms and conditions of the Canadian amateur service license, not to exceed U.S. Amateur Extra Class license privileges D. Full privileges, up to and including those of the Amateur Extra Class license, on the 80, 40, 20, 15, and 10 meter bands

E1F04 (A) [97.3] Which of the following geographic descriptions approximately describes "Line A"? A. A line roughly parallel to and south of the border between the U.S. and Canada B. A line roughly parallel to and west of the U.S. Atlantic coastline C. A line roughly parallel to and north of the border between the U.S. and Mexico D. A line roughly parallel to and east of the U.S. Pacific coastline

E1F05 (D) [97.303] Amateur stations may not transmit in which of the following frequency segments if they are located in the contiguous 48 states and north of Line A? A. 440 MHz - 450 MHz B. 53 MHz - 54 MHz C. 222 MHz - 223 MHz D. 420 MHz - 430 MHz

==

External Power Amplifiers (Linears)

Dealers may sell non-certified linear amplifiers if they were purchased in used condition and resold to another amateur

Linears must satisfy the spurious emission standards *(-43 dBc)*

Editor's note: External Power Amplifiers (Linears)

> *Amateurs my build their own amplifier or modify amplifiers for use in an Amateur Radio station*
>
> *RF power amplifiers capable of operating on frequencies below 144 MHz may require FCC certification*
>
> *Must not be capable of amplifying the input signal by more than 15dB*
>
> *Must not amplify between 26 and 28 MHz (CB)*

==

E1F03 (A) [97.315] Under what circumstances may a dealer sell an external RF power amplifier capable of operation below 144 MHz if it has not been granted FCC certification? A. It was purchased in used condition from an amateur operator and is sold to another amateur operator for use at that operator's station B. The equipment dealer assembled it from a kit C. It was imported from a manufacturer in a country that does not require certification of RF power amplifiers D. It was imported from a manufacturer in another country and was certificated by that country's government

E1F11 (D) [97.317] Which of the following best describes one of the standards that must be met by an external RF power amplifier if it is to qualify for a grant of FCC certification? A. It must produce full legal output when driven by not more than 5 watts of mean RF input power B. It must be capable of external RF switching between its input and output networks C. It must exhibit a gain of 0 dB or less over its full output range D. It must satisfy the FCC's spurious emission standards when operated at the lesser of 1500 watts or its full output power

==

Special Temporary Authority can be granted for experimental amateur communications

Editor's note: Special Temporary Authority (STA)

Occasionally, a new mode is developed that is not covered under existing FCC rules

STAs are temporary, lasting long enough for experiments to be performed and information accumulated

STAs don't give amateurs exclusive use of a frequency nor does it wave all the rules

STAs may result in changes to the FCC rules but is not a waiver of any rule

==

E1F06 (A) [1.931] Under what circumstances might the FCC issue a Special Temporary Authority (STA) to an amateur station? A. To provide for experimental amateur communications B. To allow regular operation on Land Mobile channels C. To provide additional spectrum for personal use D. To provide temporary operation while awaiting normal licensing

==

No compensation for communications directly or indirectly (Not for Hire or Trade)

No transmissions are permitted in which you or your employer have a pecuniary (monetary) interest

Editor's note: Business & Payment

Your personal activities don't count as business

Talking to your spouse about shopping

Order a pizza over a phone patch

Radio swap nets on the air

Don't do it regularly or can become a business

==

E1F07 (D) [97.113] When may an amateur station send a message to a business? A. When the total money involved does not exceed $25 B. When the control operator is employed by the FCC or another government agency C. When transmitting international third-party communications D. When neither the amateur nor his or her employer has a pecuniary interest in the communications

E1F08 (A) [97.113(c)] Which of the following types of amateur station communications are prohibited? A. Communications transmitted for hire or material compensation, except as otherwise provided in the rules B. Communications that have political content, except as allowed by the Fairness Doctrine C. Communications that have religious content D. Communications in a language other than English

==

==

E1D Amateur space and Earth stations; telemetry and telecommand rules

==

Radio communications service using satellites for the same purpose as the amateur service.

Editor's note: Amateur Satellite Service Definitions:

> ***Earth Stations****: Stations operating at or* ***within 50 km*** *of the Earth's surface*
> ***Space Station****: Amateur station located* ***above 50 km*** *from the Earth's surface*
> ***Telecommand****: One-way Tx initiate, modify or terminate functions of a device at a distance*
> ***Telecommand Station****: An amateur station that transmits telecommand control functions*
> ***Telemetry****: One-way transmission of measurements from measuring instruments*

Space Telecommand Station

Earth Station

Space Station

A telecommand station transmits communications to initiate, modify or terminate functions of a space station

A telecommand station may transmit special codes intended to obscure the meaning of messages

A telecommand station is designated by the space station licensee, subject to the privileges of the class of operator license held by the control operator

1 Watt is the maximum transmitter power when operating a model craft by telecommand

Space Station more than 50 kilometers above the surface of the Earth

Earth Station less than 50 kilometers above the surface of the Earth

==

E1D02 (A) [97.211(b)] Which of the following may transmit special codes intended to obscure the meaning of messages? A. Telecommand signals from a space telecommand station B. Data containing personal information C. Auxiliary relay links carrying repeater audio D. Binary control characters

E1D03 (B) [97.3(a)(45)] What is a space telecommand station? A. An amateur station located on the surface of the Earth for communication with other Earth stations by means of Earth satellites B. An amateur station that transmits communications to initiate, modify or terminate functions of a space station C. An amateur station located in a satellite or a balloon more than 50 kilometers above the surface of the Earth D. An amateur station that receives telemetry from a satellite or balloon more than 50 kilometers above the surface of the Earth

E1D06 (A) [97.215(c)] What is the maximum permitted transmitter output power when operating a model craft by telecommand? A. 1 watt B. 2 watts C. 5 watts D. 100 watts

E1D10 (B) [97.211] Which amateur stations are eligible to be telecommand stations of space stations (subject to the privileges of the class of operator license held by the control operator of the station)? A. Any amateur station designated by NASA B. Any amateur station so designated by the space station licensee C. Any amateur station so designated by the ITU D. All these choices are correct

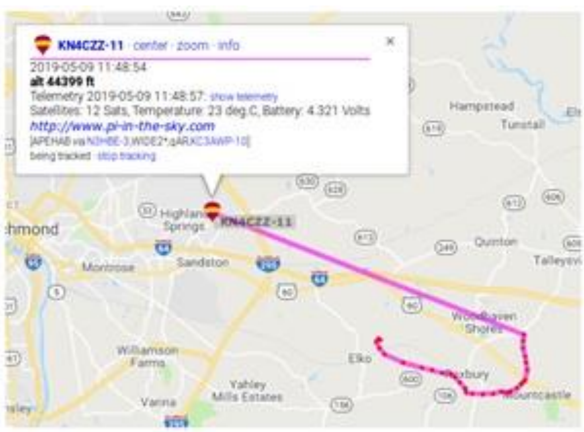
==

40m, 20m, 17m, 15m, 12m and 10m bands have HF frequencies authorized to space stations

2M, 70 cm, 23 cm, 13 cm bands have frequencies authorized to space stations

An Earth station is any amateur station, subject to the privileges of the class of operator license held by the control operator

Earth stations most post a copy of the station license and name, address, and phone of the station licensee and control operator



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E1D05 (D) [97.213(d)] What must be posted at the station location of a station being operated by telecommand on or within 50 km of the earth's surface? A. A photocopy of the station license B. A label with the name, address, and telephone number of the station licensee C. A label with the name, address, and telephone number of the control operator D. All these choices are correct

E1D07 (A) [97.207] Which HF amateur bands have frequencies authorized for space stations? A. Only the 40, 20, 17, 15, 12, and 10 meter bands B. Only the 40, 20, 17, 15, and 10 meter bands C. Only the 40, 30, 20, 15, 12, and 10 meter bands D. All HF bands

E1D08 (D) [97.207] Which VHF amateur bands have frequencies authorized for space stations? A. 6 meters and 2 meters B. 6 meters, 2 meters, and 1.25 meters C. 2 meters and 1.25 meters D. 2 meters

E1D09 (B) [97.207] Which UHF amateur bands have frequencies authorized for space stations? A. 70 cm only B. 70 cm and 13 cm C. 70 cm and 33 cm D. 33 cm and 13 cm

E1D11 (D) [97.209] Which amateur stations are eligible to operate as Earth stations? A. Any amateur station whose licensee has filed a pre-space notification with the FCC's International Bureau B. Only those of General, Advanced or Amateur Extra Class operators C. Only those of Amateur Extra Class operators D. Any amateur station, subject to the privileges of the class of operator license held by the control operator

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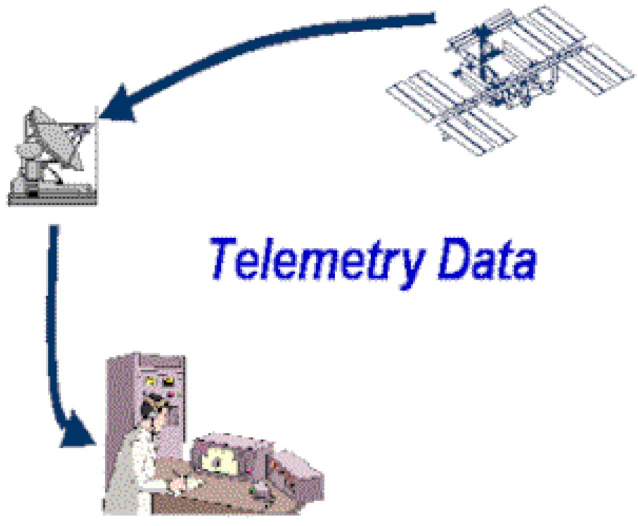


Telemetry is one-way transmission of measurements at a distance from the measuring instrument

Call sign identification is required for balloon-borne telemetry station

A space station, beacon station, or telecommand station may transmit one-way communications

==

E1D01 (A) [97.3] What is the definition of telemetry? A. One-way transmission of measurements at a distance from the measuring instrument B. Two-way transmissions in excess of 1000 feet C. Two-way transmissions of data D. One-way transmission that initiates, modifies, or terminates the functions of a device at a distance

E1D04 (A) [97.119(a)] Which of the following is required in the identification transmissions from a balloon-borne telemetry station? A. Call sign B. The output power of the balloon transmitter C. The station's six-character Maidenhead grid locator D. All these choices are correct

E1D12 (A) [97.207(e), 97.203(g)] Which of the following amateur stations may transmit one-way communications? A. A space station, beacon station, or telecommand station B. A local repeater or linked repeater station C. A message forwarding station or automatically controlled digital station D. All these choices are correct

==

E1E Volunteer examiner program

===

A Volunteer Examiner Coordinator (VEC) is an organization that has entered into an agreement with the FCC to coordinate amateur operator license examinations

The Volunteer Examiner (VE) accreditation process is the procedure by which a VEC confirms that the VE applicant meets FCC requirements to serve as an examiner

Three is the minimum number of qualified VEs required to administer an Element 4 amateur operator license examination

Three VEs must certify that the examinee is qualified for the license grant and that they have complied with the administering VE requirements

Preparing, processing, administering and coordinating an examination for an amateur radio license are out-of-pocket expenses that may be reimbursed VEs and VECs

The questions for all written US amateur license examinations are listed in a question pool maintained by all the VECs

A score of 74% is the minimum passing score on amateur operator license examinations

Each administering VE is responsible for the proper conduct and necessary supervision during an amateur operator license examination session

Immediately terminate the candidate's examination if a candidate fails to comply with the examiner's instructions during an amateur operator license examination

A VE cannot administer an examination to relatives of the VE as listed in the FCC rules

The penalty for a VE who fraudulently administers or certifies an examination is revocation of the VE's amateur station license grant and the suspension of the VE's amateur operator license grant

The administering VEs must submit the application document to the coordinating VEC according to the coordinating VEC instructions after the administration of a successful examination for an amateur operator license

The VE team must return the application document to the examinee with the application form if the examinee DOES NOT PASS THE EXAM

===

E1E01 (A) [97.527] For which types of out-of-pocket expenses do the Part 97 rules state that VEs and VECs may be reimbursed? A. Preparing, processing, administering, and coordinating an examination for an amateur radio operator license B. Teaching an amateur operator license examination preparation course C. No expenses are authorized for reimbursement D. Providing amateur operator license examination preparation training materials

E1E02 (C) [97.523] Who does Part 97 task with maintaining the pools of questions for all U.S. amateur license examinations? A. The VEs B. The FCC C. The VECs D. The ARRL

E1E03 (C) [97.521] What is a Volunteer Examiner Coordinator? A. A person who has volunteered to administer amateur operator license examinations B. A person who has volunteered to prepare amateur operator license examinations C. An organization that has entered into an agreement with the FCC to coordinate, prepare, and administer amateur operator license examinations D. The person who has entered into an agreement with the FCC to be the VE session manager

E1E04 (D) [97.509, 97.525] Which of the following best describes the Volunteer Examiner accreditation process? A. Each General, Advanced and Amateur Extra Class operator is automatically accredited as a VE when the license is granted B. The amateur operator applying must pass a VE examination administered by the FCC Enforcement Bureau C. The prospective VE obtains accreditation from the FCC D. The procedure by which a VEC confirms that the VE applicant meets FCC requirements to serve as an examiner

E1E05 (B) [97.503] What is the minimum passing score on all amateur operator license examinations? A. Minimum passing score of 70% B. Minimum passing score of 74% C. Minimum passing score of 80% D. Minimum passing score of 77%

E1E06 (C) [97.509] Who is responsible for the proper conduct and necessary supervision during an amateur operator license examination session? A. The VEC coordinating the session B. The FCC C. Each administering VE D. The VE session manager

E1E07 (B) [97.509] What should a VE do if a candidate fails to comply with the examiner's instructions during an amateur operator license examination? A. Warn the candidate that continued failure to comply will result in termination of the examination B. Immediately terminate the candidate's examination C. Allow the candidate to complete the examination, but invalidate the results D. Immediately terminate everyone's examination and close the session

E1E08 (C) [97.509] To which of the following examinees may a VE not administer an examination? A. Employees of the VE B. Friends of the VE C. Relatives of the VE as listed in the FCC rules D. All these choices are correct

E1E09 (A) [97.509] What may be the penalty for a VE who fraudulently administers or certifies an examination? A. Revocation of the VE's amateur station license grant and the suspension of the VE's

amateur operator license grant B. A fine of up to $1000 per occurrence C. A sentence of up to one year in prison D. All these choices are correct

E1E10 (C) [97.509(h)] What must the administering VEs do after the administration of a successful examination for an amateur operator license? A. They must collect and send the documents to the NCVEC for grading B. They must collect and submit the documents to the coordinating VEC for grading C. They must submit the application document to the coordinating VEC according to the coordinating VEC instructions D. They must collect and send the documents to the FCC according to instructions

E1E11 (B) [97.509(m)] What must the VE team do if an examinee scores a passing grade on all examination elements needed for an upgrade or new license? A. Photocopy all examination documents and forward them to the FCC for processing B. Three VEs must certify that the examinee is qualified for the license grant and that they have complied with the administering VE requirements C. Issue the examinee the new or upgrade license D. All these choices are correct

E1E12 (A) [97.509(j)] What must the VE team do with the application form if the examinee does not pass the exam? A. Return the application document to the examinee B. Maintain the application form with the VEC's records C. Send the application form to the FCC and inform the FCC of the grade D. Destroy the application form
==

E2C Operating methods

==

"self-spotting" is the prohibited practice of posting one's own call sign and frequency on a call sign spotting network

30 meters bands is amateur radio contesting generally excluded

During a VHF/UHF contest the weak signal segment of the band, with most of the activity near the calling frequency would have the highest level of activity

Send your full call sign once or twice when attempting to contact a DX station working a **pileup** or in a contest

Why might a DX station state that they are listening on another frequency?

A. Because the DX station may be transmitting on a frequency that is prohibited to some responding stations
B. To separate the calling stations from the DX station
C. To reduce interference, thereby improving operating efficiency
D. All of these choices are correct

The function of a **DX QSL Manager** is to handle **the receiving and sending of confirmation cards** for a DX station

Cabrillo format is a standard for submission of electronic contest logs

Ham radio **mesh network uses frequencies shared with unlicensed wireless data services (WIFI)**

A **wireless router running custom firmware** is used to implement an amateur radio **mesh network**

Discovery and link establishment protocols are used to form a **mesh network**

==

E2C01 (D) What indicator is required to be used by U.S.-licensed operators when operating a station via remote control and the remote transmitter is located in the U.S.? A. / followed by the USPS two-letter abbreviation for the state in which the remote station is located B. /R# where # is the district of the remote station C. / followed by the ARRL Section of the remote station D. No additional indicator is required

E2C02 (A) Which of the following best describes the term self-spotting? in connection with HF contest operating? A. The often-prohibited practice of posting one's own call sign and frequency on a spotting network B. The acceptable practice of manually posting the call signs of stations on a spotting network C. A manual technique for rapidly zero beating or tuning to a station's frequency before calling that station D. An automatic method for rapidly zero beating or tuning to a station's frequency before calling that station

E2C03 (A) From which of the following bands is amateur radio contesting generally excluded? A. 30 meters B. 6 meters C. 2 meters D. 33 centimeters

E2C04 (B) Which of the following frequencies are sometimes used for amateur radio mesh networks? A. HF frequencies where digital communications are permitted B. Frequencies shared with various unlicensed wireless data services C. Cable TV channels 41 through 43 D. The 60 meter band channel centered on 5373 kHz

E2C05 (B) What is the function of a DX QSL Manager? A. To allocate frequencies for DXpeditions B. To handle the receiving and sending of confirmation cards for a DX station C. To run a net to allow many stations to contact a rare DX station D. To relay calls to and from a DX station

E2C06 (C) During a VHF/UHF contest, in which band segment would you expect to find the highest level of SSB or CW activity? A. At the top of each band, usually in a segment reserved for contests B. In the middle of each band, usually on the national calling frequency C. In the weak signal segment of the band, with most of the activity near the calling frequency D. In the middle of the band, usually 25 kHz above the national calling frequency

E2C07 (A) What is the Cabrillo format? A. A standard for submission of electronic contest logs B. A method of exchanging information during a contest QSO C. The most common set of contest rules D. The rules of order for meetings between contest sponsors

E2C08 (B) Which of the following contacts may be confirmed through the U.S. QSL bureau system? A. Special event contacts between stations in the U.S. B. Contacts between a U.S. station and a non-U.S. station C. Repeater contacts between U.S. club members D. Contacts using tactical call signs

E2C09 (C) What type of equipment is commonly used to implement an amateur radio mesh network? A. A 2 meter VHF transceiver with a 1200 baud modem B. An optical cable connection between the USB ports of 2 separate computers C. A wireless router running custom firmware D. A 440 MHz transceiver with a 9600 baud modem

E2C10 (D) Why might a DX station state that they are listening on another frequency? A. Because the DX station may be transmitting on a frequency that is prohibited to some responding stations B. To separate the calling stations from the DX station C. To improve operating efficiency by reducing interference D. All these choices are correct

E2C11 (A) How should you generally identify your station when attempting to contact a DX station during a contest or in a pileup? A. Send your full call sign once or twice B. Send only the last two letters of your call sign until you make contact C. Send your full call sign and grid square D. Send the call sign of the DX station three times, the words this is,then your call sign three times

E2C12 (C) What technique do individual nodes use to form a mesh network? A. Forward error correction and Viterbi codes B. Acting as store-and-forward digipeaters C. Discovery and link establishment protocols D. Custom code plugs for the local trunking systems

==

E2D Operating methods

==

JT65 developed for weak-signal VHF/UHF such as EME

JT65 can decode signals with very low signal-to-noise ratio

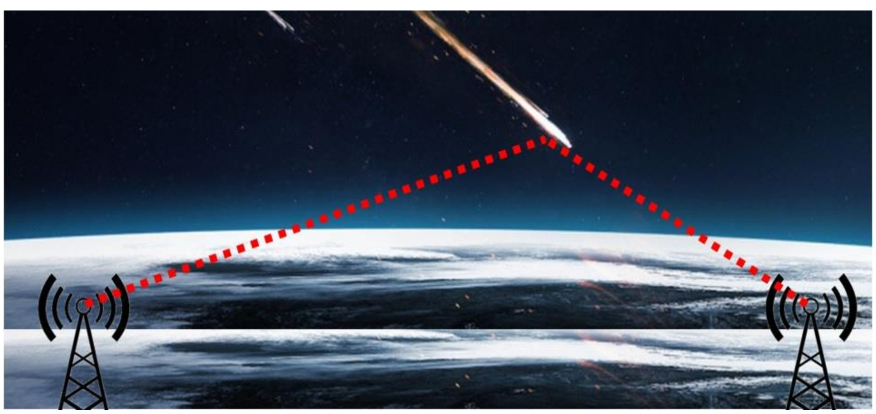
Time synchronous transmissions alternately from each station is a method of establishing **EME contacts**

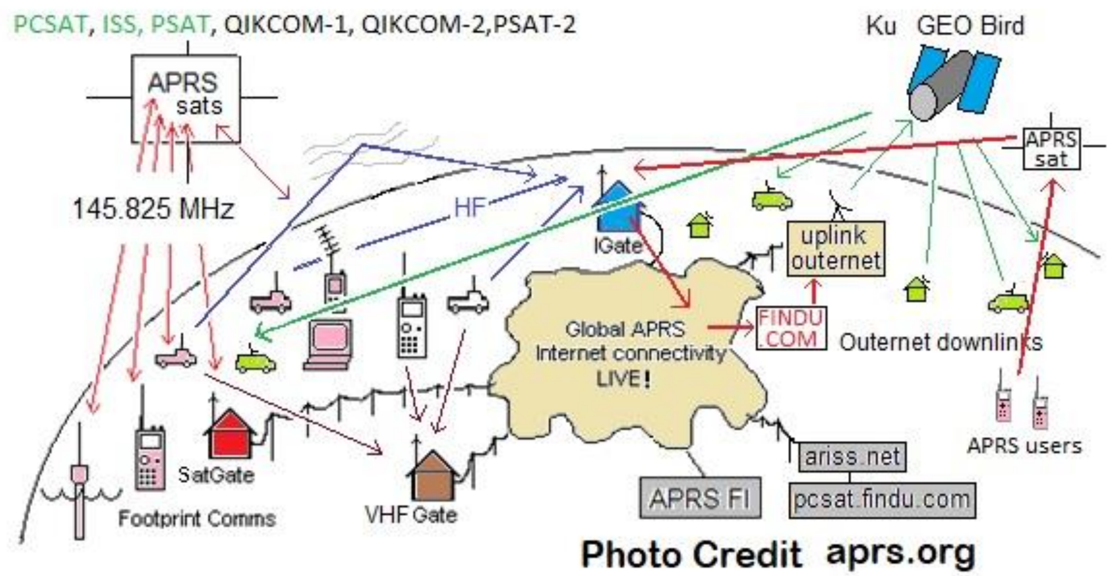
JT65 uses Multi-tone AFSK

MSK441 is especially designed for use for **meteor scatter** signals

Which of the following is a good technique for making **meteor scatter contacts**?

- A. **15-second** timed transmission sequences with stations alternating based on location
- B. Use of **special digital modes**
- C. Short transmissions with **rapidly repeated call signs and signal reports**
- D. All these choices are correct





AX.25 is the digital protocol is used by APRS

Unnumbered Information is used to transmit **APRS beacon data**

An **APRS** station with a GPS unit can automatically transmit information to show a **mobile station's position in Latitude and Longitude**

Latitude and longitude are used by the **APRS** network communicate your location

APRS is used to track, in real time, balloons carrying amateur radio transmitters

===

E2D01 (B) Which of the following digital modes is designed for meteor scatter communications? A. WSPR B. MSK144 C. Hellschreiber D. APRS

E2D02 (D) Which of the following is a good technique for making meteor scatter contacts? A. 15-second timed transmission sequences with stations alternating based on location B. Use of special digital modes C. Short transmissions with rapidly repeated call signs and signal reports D. All these choices are correct

E2D03 (D) Which of the following digital modes is especially useful for EME communications? A. MSK144 B. PACTOR III C. Olivia D. JT65

E2D04 (C) What technology is used to track, in real time, balloons carrying amateur radio transmitters? A. Ultrasonics B. Bandwidth compressed LORAN C. APRS D. Doppler shift of beacon signals

E2D05 (B) What is one advantage of the JT65 mode? A. Uses only a 65 Hz bandwidth B. The ability to decode signals which have a very low signal-to-noise ratio C. Easily copied by ear if necessary D. Permits fast-scan TV transmissions over narrow bandwidth

E2D06 (A) Which of the following describes a method of establishing EME contacts? A. Time synchronous transmissions alternately from each station B. Storing and forwarding digital messages C. Judging optimum transmission times by monitoring beacons reflected from the moon D. High-speed CW identification to avoid fading

E2D07 (C) What digital protocol is used by APRS? A. PACTOR B. 802.11 C. AX.25 D. AMTOR

E2D08 (A) What type of packet frame is used to transmit APRS beacon data? A. Unnumbered Information B. Disconnect C. Acknowledgement D. Connect

E2D09 (A) What type of modulation is used for JT65 contacts? A. Multi-tone AFSK B. PSK C. RTTY D. IEEE 802.11

E2D10 (C) How can an APRS station be used to help support a public service communications activity? A. An APRS station with an emergency medical technician can automatically transmit medical data to the nearest hospital B. APRS stations with General Personnel Scanners can automatically relay the participant numbers and time as they pass the check points C. An APRS station with a Global Positioning System unit can automatically transmit information to show a mobile station's position during the event D. All these choices are correct

E2D11 (D) Which of the following data are used by the APRS network to communicate station location? A. Polar coordinates B. Time and frequency C. Radio direction finding spectrum analysis D. Latitude and longitude

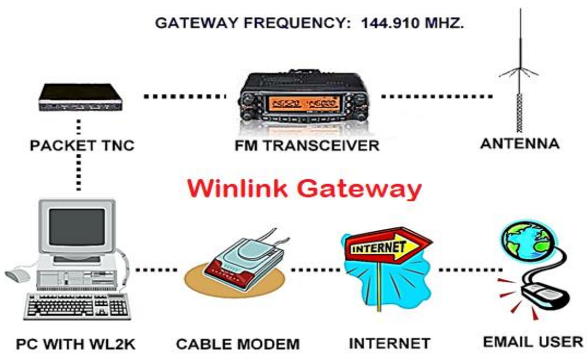
===

E2E Operating methods

===

300 baud is the most common data rate used for HF packet

PACTOR can be used to transfer binary files

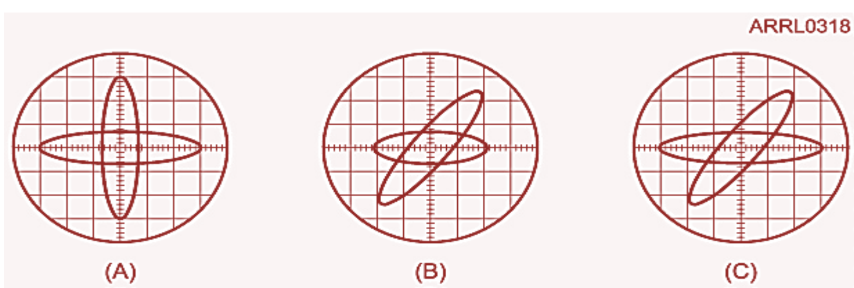


Editor's note: Winlink is a radio messaging transfer system that uses amateur-band radio frequencies

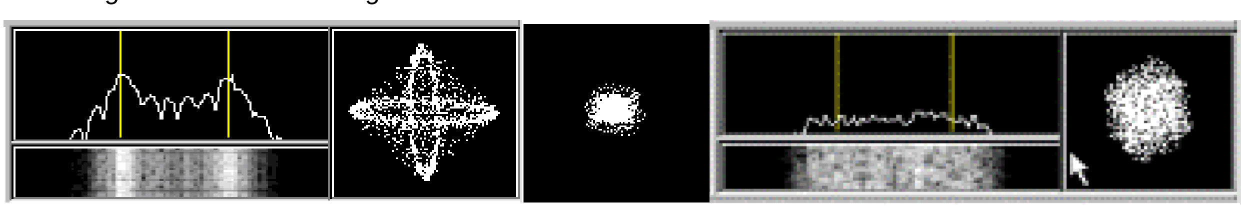
Selective fading has occurred when one of the ellipses in an FSK **crossed-ellipse display suddenly disappears**

Direct FSK applies the data signal to the transmitter VFO

AFSK audio phone conversion of tones into a string of ones and zeros



Editor's note: RTTY tuning display. Pattern A indicates that the signal has been tuned corrected. At B the receiver is slightly off frequency, while C indicates that the transmitting station is using a shift that differs from your processor or modem setting. Although hardly any RTTY operators use oscilloscope tuning today, modern tuning indicators still rely on the same principle. Below-Left properly tuned RTTY signal. Below-Right & Center loss of signal.



PSK31 uses a very narrow bandwidth (approximately 60 Hz at -26 dB) yet provides 50 word-per-

Forward Error Correction (FEC) is implemented in PSK31 by transmitting extra data that may be used to detect and correct transmission errors

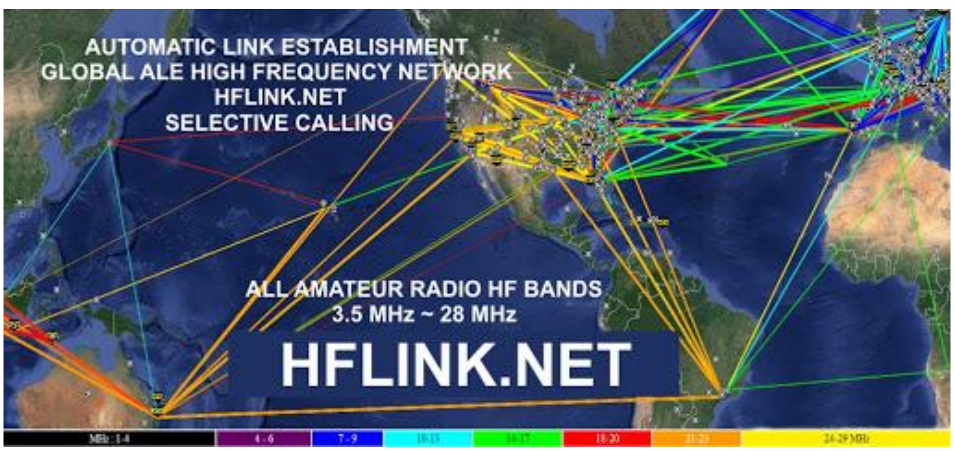
PSK31 uses **variable length coding** of characters **(Varicode)**

Glyph	Varicode
@	1010111101
A	1111101
B	11101011
C	10101101
D	10110101
E	1110111
F	11011011
G	11111101
H	101010101
I	1111111

The number of data bits sent in a single PSK31 character varies

Glyph	Varicode
`	1011011111
a	1011
b	1011111
c	101111
d	101101
e	11
f	111101
g	1011011
h	101011
i	1101

Editor's note: In PSK31 (1's) are represented by a tone with no phase shift compared to the previous bit and (0's) are tone with a 180-degree phase shift relative to the phase of the previous bit. The phase shift occurs during the zero-level modulation to minimize bandwidth. When the modulation level returns, the positions of the sine wave top and bottom are reversed from the previous bit. Thus, the phase changes by 180 degrees while the frequency remains constant. – AD7FO



To establish contact ALE stations constantly scans a list of frequencies, activating the radio when the designated call sign is received

FT4 contacts are organized as **alternating transmissions at 7.5 second intervals**

Which of the following is a possible reason that attempts to initiate contact with a digital station on a clear frequency are unsuccessful?

Your transmit frequency is incorrect
The protocol version you are using is not the supported by the digital station
Another station you are unable to hear is using the frequency
All of these choices are correct

===

E2E01 (B) Which of the following types of modulation is common for data emissions below 30 MHz? A. DTMF tones modulating an FM signal B. FSK C. Pulse modulation D. Spread spectrum

E2E02 (A) What do the letters FEC mean as they relate to digital operation? A. Forward Error Correction B. First Error Correction C. Fatal Error Correction D. Final Error Correction

E2E03 (C) How is the timing of FT4 contacts organized? A. By exchanging ACK/NAK packets B. Stations take turns on alternate days C. Alternating transmissions at 7.5 second intervals D. It depends on the lunar phase

E2E04 (A) What is indicated when one of the ellipses in an FSK crossed-ellipse display suddenly disappears? A. Selective fading has occurred B. One of the signal filters is saturated C. The receiver has drifted 5 kHz from the desired receive frequency D. The mark and space signal have been inverted

E2E05 (A) Which of these digital modes does not support keyboard-to-keyboard operation? A. PACTOR B. RTTY C. PSK31 D. MFSK

E2E06 (C) What is the most common data rate used for HF packet? A. 48 baud B. 110 baud C. 300 baud D. 1200 baud

E2E07 (D) Which of the following is a possible reason that attempts to initiate contact with a digital station on a clear frequency are unsuccessful? A. Your transmit frequency is incorrect B. The protocol version you are using is not supported by the digital station C. Another station you are unable to hear is using the frequency D. All these choices are correct

E2E08 (B) Which of the following HF digital modes can be used to transfer binary files? A. Hellschreiber B. PACTOR C. RTTY D. AMTOR

E2E09 (D) Which of the following HF digital modes uses variable-length coding for bandwidth efficiency? A. RTTY B. PACTOR C. MT63 D. PSK31

E2E10 (C) Which of these digital modes has the narrowest bandwidth? A. MFSK16 B. 170 Hz shift, 45-baud RTTY C. PSK31 D. 300-baud packet

E2E11 (A) What is the difference between direct FSK and audio FSK? A. Direct FSK applies the data signal to the transmitter VFO, while AFSK transmits tones via phone B. Direct FSK occupies less bandwidth C. Direct FSK can transmit faster baud rates D. Only direct FSK can be decoded by computer

E2E12 (A) How do ALE stations establish contact? A. ALE constantly scans a list of frequencies, activating the radio when the designated call sign is received B. ALE radios monitor an internet site for the frequency they are being paged on C. ALE radios send a constant tone code to establish a frequency for future use D. ALE radios activate when they hear their signal echoed by back scatter

E2E13 (D) Which of these digital modes has the fastest data throughput under clear communication conditions? A. AMTOR B. 170 Hz shift, 45 baud RTTY C. PSK31 D. 300 baud packet

===

Class One Fundamentals and Substance

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After completing each class be sure to use the Fundamentals and Substance subsection that was solely created as a tool for test preparation by helping you make connections between topics and serves as quality review material for after each class. Using these steps can be most useful when learning about new topics that include a lot of detail. The information is in the form of class notes with all of the important information you need to know. These notes are not a substitute for studying the class material in fact you will need to complete your class assignment in order to effectively use these notes. The notes are organized into easily digestible headings and bullet points to organize topics with the key words, main subpoints and summary are all written in one place.

===

HF Bands

Upper Sideband (**USB) emissions will be 3 kHz above** the carrier frequency

Lower Sideband (**LSB) emissions will be 3 kHz below** the carrier frequency

The mean power of any **spurious emission must be at least - 43 dB below** 30 MHZ

Dealers may sell non-certified linear amplifiers if they were purchased in used condition and resold to another amateur

630M – Max 5W EIRP 472 - 479 KHz

2200 M – Max 1W EIRP135.7 – 137.8

60M - Max 100 watts ERP, half-wave dipole, CW center of channel, max **bandwidth 2.8 kHz**

Ships, Aircraft and International

Operation aboard a ship or aircraft must be **approved by the master of the ship**

An amateur license is required when operating on United States registered craft

European Conference of Postal and Telecommunications Administrations (**CEPT**) license

International Amateur Radio Permit (**IARP**)

International Telecommunication Union **Reciprocal Permit** is an agreement between the US and a country that does not participate in either CEPT or IARP agreements

Control Operator

The use of devices and procedures for control so that the **control operator does not have to be present at a control point** is automatic control of a station

3 minutes is the maximum permissible duration of a remotely controlled station’s transmissions if its control link malfunctions

If a **message forwarding system** inadvertently forwards a message that is in violation of FCC rules, the **control operator of the originating station is primarily accountable** for the rules violation

An **automatically controlled station may NOT originate third party communications**

RACES

Any FCC-licensed amateur station **certified by the responsible civil defense organization** for the area served may be operated in RACES

All amateur service frequencies authorized to the control operator are authorized to an amateur station participating in RACES

Specials Restrictions

An amateur station antenna near an airport requires FAA notification & FCC registration (Part 17)

An **Environmental Assessment must be submitted to the FCC** before placing an amateur station within a **designated wilderness area or wildlife preserve, National Register of Historical Places**

The **National Radio Quiet Zone** is an area surrounding the National Radio Astronomy Observatory

Within 1 mile an amateur station must protect an FCC monitoring facility from harmful interference

An amateur station could be required to avoid transmitting during certain hours on frequencies that cause the interference if its signal causes interference to domestic broadcast reception, assuming that the receiver(s) involved are of good engineering design

Special Temporary Authority can be granted for experimental amateur communications

PRB-1 require government zoning regulations to make **reasonable accommodations**

Canada

Canadian amateurs operating in the USA cannot exceed U.S. Amateur Extra Class privileges

LINE A is an area roughly parallel to of the US-Canadian border and about 75 miles south

North of Line A Amateur stations **may not transmit on 420 - 430 MHz**

Amateur space and Earth stations

Telemetry is one-way transmission of measurements at a distance from the measuring instrument

Call sign identification is required for balloon-borne telemetry station

A space station, beacon station, or telecommand station may transmit **one-way communications**

A telecommand station transmits to initiate, modify or terminate functions of a space station

A telecommand station may transmit **special codes intended to obscure the meaning** of messages

A telecommand station is designated by the space station licensee, subject to the privileges of the class of operator license **held by the control operator**

Space Station more than 50 kilometers above the surface of the Earth

Earth Station less than 50 kilometers above the surface of the Earth

1 Watt is the maximum transmitter power when **operating a model craft by telecommand**

40m, 20m, 17m, 15m, 12m and 10m bands have HF frequencies authorized to space stations

2M, 70 cm, 23 cm, 13 cm bands have frequencies authorized to space stations

Earth stations most post a copy of the station license and name, address, and phone of the station licensee and control operator **(label your balloon)**

An Earth station is any amateur station, subject to the privileges of the class of operator license **held by the control operator**

Not for Profit or Business

Communications incidental to the purpose of the **amateur service and remarks of a personal**

No compensation for communications directly or indirectly (Not for Hire or Trade)

No transmissions are permitted in which you or **your employer have a pecuniary (monetary) interest**

Spread Spectrum

Spread spectrum transmissions permitted on amateur **frequencies above 222 MHz**

A station transmitting SS emission must not cause harmful interference

The transmitting station must be in an area regulated by the FCC

The transmission **code must not be used to obscure the meaning**

Volunteer Examiner program

A **Volunteer Examiner Coordinator (VEC) is an organization** that has entered into an agreement with the FCC to coordinate amateur operator license examinations

The questions for all written US amateur license examinations are listed in a question pool maintained by all the VECs

Preparing, processing, administering and coordinating an examination for an amateur radio license are out-of-pocket expenses that may be reimbursed VEs and VECs

The **Volunteer Examiner (VE)** accreditation process is the procedure by which a VEC confirms that the VE applicant meets FCC requirements to **serve as an examiner**

Three is the minimum number of qualified VEs required to administer an license examination

A VE cannot administer an examination to relatives of the VE as listed in the FCC rules

The penalty for a **VE who fraudulently administers** or certifies an examination is revocation of the VE's amateur station license grant and the **suspension of the VE's amateur operator license** grant

A score of 74% is the minimum passing score on amateur operator license examinations

Immediately terminate the candidate's examination if a candidate fails to comply with the examiner's instructions during an amateur operator license examination

The VE team must return the application document to the examinee with the application form if the examinee **DOES NOT PASS THE EXAM**

Operating methods

"self-spotting" is the prohibited practice of posting one's own call sign and frequency on a call sign spotting network

30 meters bands is amateur radio contesting generally excluded

During a VHF/UHF contest the weak signal segment of the band, with most of the activity near the calling frequency would have the highest level of activity

Send your full call sign once or twice when attempting to contact a DX station working a **pileup** or in a contest

Why might a DX station state that they are listening on another frequency?

A. Because the DX station may be transmitting on a frequency that is prohibited to some responding stations
B. To separate the calling stations from the DX station
C. To reduce interference, thereby improving operating efficiency
D. All of these choices are correct

The function of a **DX QSL Manager** is to handle **the receiving and sending of confirmation cards** for a DX station

Cabrillo format is a standard for submission of electronic contest logs

Ham radio **mesh network uses frequencies shared with unlicensed wireless data services (WIFI)**

A **wireless router running custom firmware** is used to implement an amateur radio **mesh network**

Discovery and link establishment protocols are used to form a **mesh network**

HF Digital Operating methods

MSK441 is especially designed for use for **meteor scatter** signals

Which of the following is a good technique for making **meteor scatter contacts**?

A. **15-second** timed transmission sequences with stations alternating based on location
B. Use of **special digital modes**
C. Short transmissions with **rapidly repeated call signs and signal reports**
D. All these choices are correct

JT65 developed for weak-signal VHF/UHF such as EME

JT65 can decode signals with very low signal-to-noise ratio

Time synchronous transmissions alternately from each station is a method of establishing **EME contacts**

JT65 uses Multi-tone AFSK

AX.25 is the digital protocol is used by APRS

Unnumbered Information is used to transmit **APRS beacon data**

An **APRS** station with a GPS unit can automatically transmit information to show a **mobile station's position in Latitude and Longitude**

Latitude and longitude are used by the **APRS** network communicate your location

APRS is used to track, in real time, balloons carrying amateur radio transmitters

300 baud is the most common data rate used for HF packet

PACTOR can be used to transfer binary files

Selective fading has occurred when one of the ellipses in an FSK **crossed-ellipse display suddenly disappears**

Direct FSK applies the data signal to the transmitter VFO

AFSK audio phone conversion of tones into a string of ones and zeros

PSK31 uses a very narrow bandwidth (approximately 60 Hz at -26 dB) yet provides 50 word-per-

Forward Error Correction (FEC) is implemented in PSK31 by transmitting extra data that may be used to detect and correct transmission errors

PSK31 uses **variable length coding** of characters **(Varicode)**

To establish contact ALE stations constantly scans a list of frequencies, activating the radio when the designated call sign is received

FT4 contacts are organized as **alternating transmissions at 7.5 second intervals**

Which of the following is a possible reason that attempts to initiate contact with a digital station on a clear frequency are unsuccessful?

- **Your transmit frequency is incorrect**
- **The protocol version you are using is not the supported by the digital station**
- **Another station you are unable to hear is using the frequency**
- All of these choices are correct

CLASS 2 - RADIO COMPONENTS AND SUBSYSTEMS

==

E6A Semiconductor materials and devices

E6B Diodes

E6C Digital ICs

E7A Digital circuits: digital circuit principles and logic circuits

E6F Electro-optical technology: photoconductivity

E6D Toroidal and Solenoidal Inductors

E6E Analog ICs: MMICs, IC packaging characteristics

E7B Amplifiers

E7F DSP filtering and other operations

E7H Oscillators and signal sources

E7C Filters and matching networks

E7D Power supplies and voltage regulators

E7G Active filters and op-amp circuits

Class Two Fundamentals and Substance

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E6A Semiconductor materials and devices

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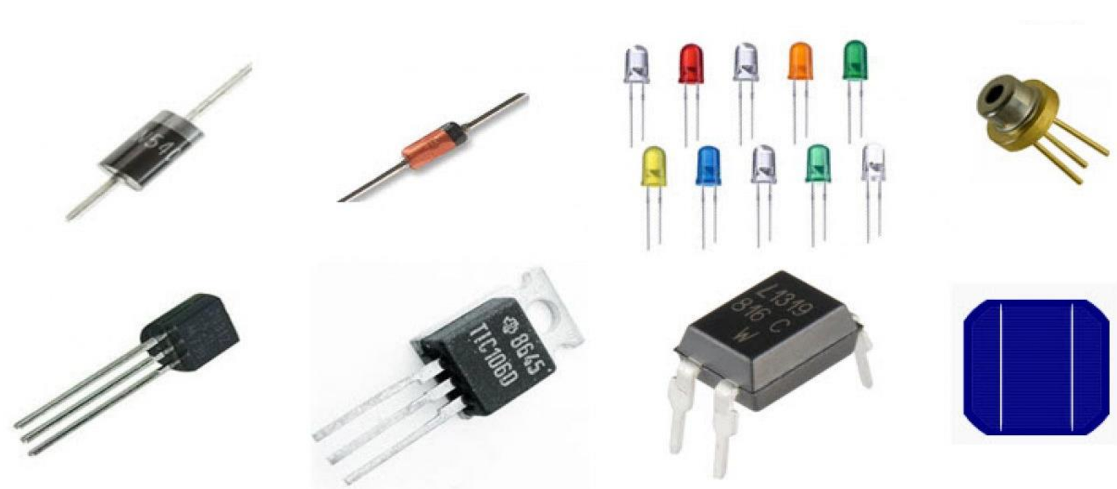
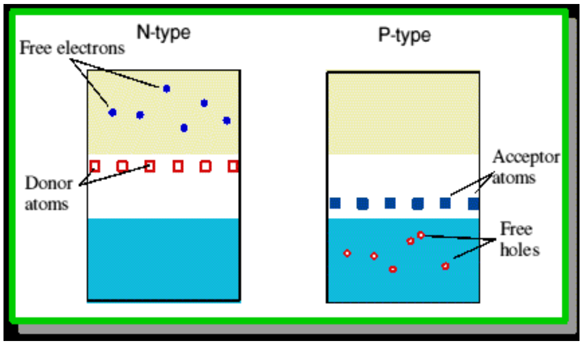


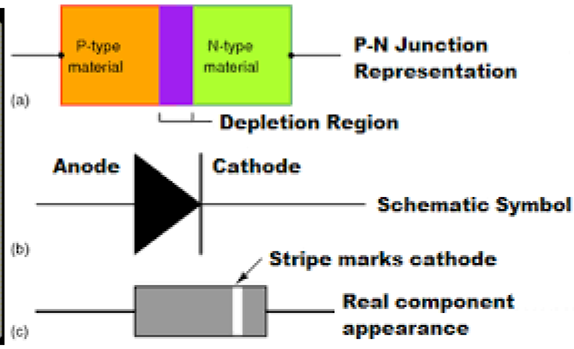
N-type semiconductor materials contains excess **free electrons**

Acceptor impurity is an impurity atom that **adds holes** to a semiconductor **crystal structure**

At **microwave frequencies gallium arsenide** is used as a semiconductor material in preference to germanium or silicon

PN-junction diode not conduct current when reverse biased because holes in P-type material and electrons in the N-type material are separated by the applied voltage, widening the depletion region





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E6A01 (C) In what application is gallium arsenide used as a semiconductor material? A. In high-current rectifier circuits B. In high-power audio circuits C. In microwave circuits D. In very low-frequency RF circuits

E6A02 (A) Which of the following semiconductor materials contains excess free electrons? A. N-type B. P-type C. Bipolar D. Insulated gate

E6A03 (C) Why does a PN-junction diode not conduct current when reverse biased? A. Only P-type semiconductor material can conduct current B. Only N-type semiconductor material can conduct current C. Holes in P-type material and electrons in the N-type material are separated by the applied voltage, widening the depletion region D. Excess holes in P-type material combine with the electrons in N-type material, converting the entire diode into an insulator

E6A04 (C) What is the name given to an impurity atom that adds holes to a semiconductor crystal structure? A. Insulator impurity B. N-type impurity C. Acceptor impurity D. Donor impurity

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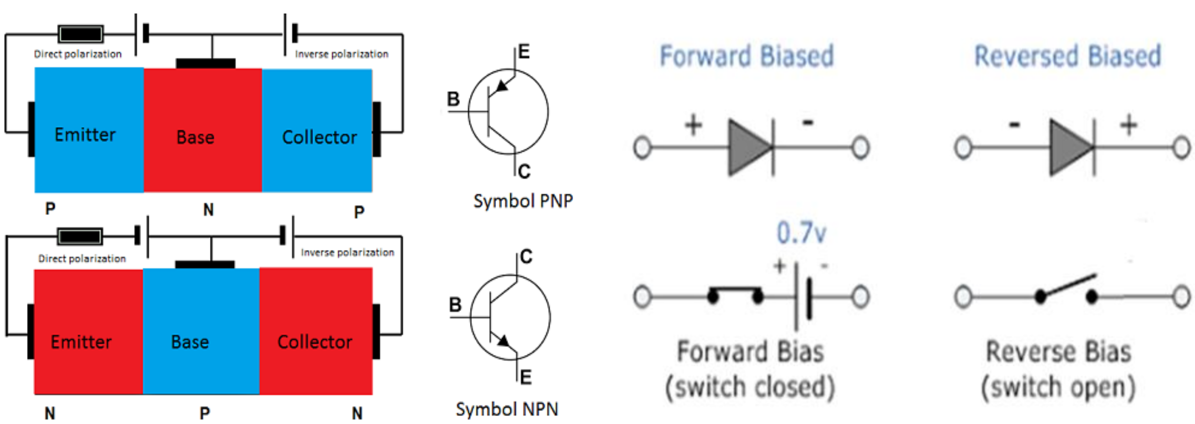
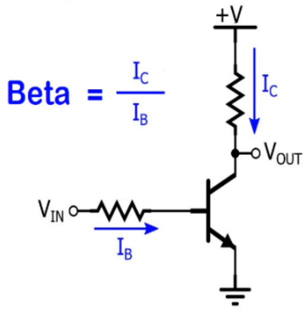


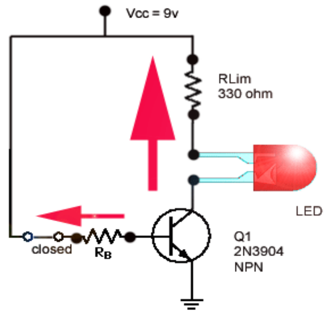
A **bipolar transistor has low input impedance**

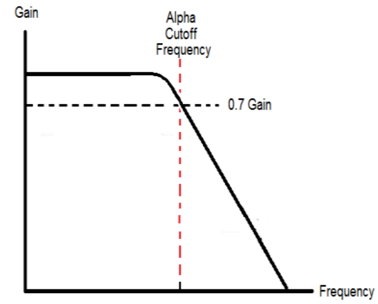
The change of **collector current with respect to base current** is the **beta** of a bipolar junction transistor

A silicon **NPN transistor is biased on** has a base-to-emitter voltage of approx. **0.6 to 0.7 volts**

Alpha cutoff is the frequency at which the gain of a transistor has decreased to **0.7 of the gain obtainable at 1 kHz**







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E6A06 (B) What is the beta of a bipolar junction transistor? A. The frequency at which the current gain is reduced to 0.707 B. The change in collector current with respect to base current C. The breakdown voltage of the base to collector junction D. The switching speed

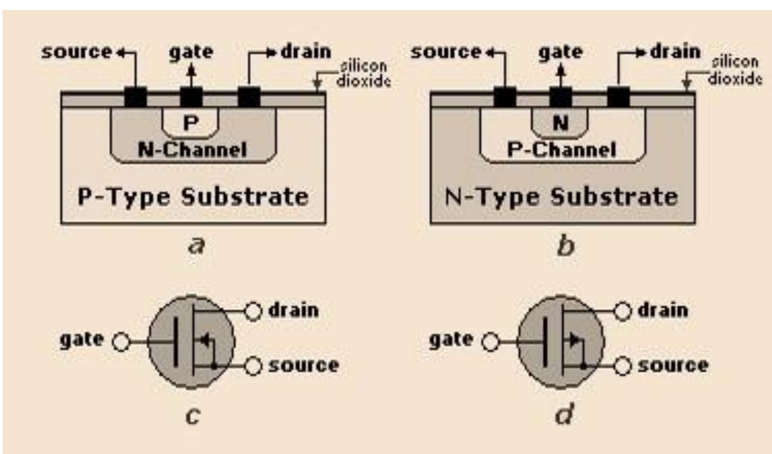
E6A07 (D) Which of the following indicates that a silicon NPN junction transistor is biased on? A. Base-to-emitter resistance of approximately 6 to 7 ohms B. Base-to-emitter resistance of approximately 0.6 to 0.7 ohms C. Base-to-emitter voltage of approximately 6 to 7 volts D. Base-to-emitter voltage of approximately 0.6 to 0.7 volts

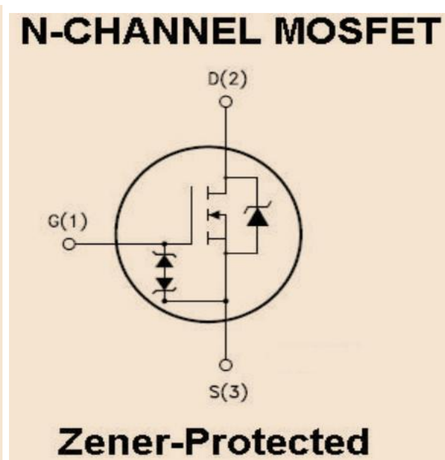
E6A08 (D) What term indicates the frequency at which the grounded-base current gain of a transistor has decreased to 0.7 of the gain obtainable at 1 kHz? A. Corner frequency B. Alpha rejection frequency C. Beta cutoff frequency D. Alpha cutoff frequency

An **FET has high input impedance**

Depletion-mode is when a FET that has a current between source and drain but no gate voltage

MOSFET devices have internally connected Zener diodes on the gates to reduce the chance of **static damage** to the gate





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E6A05 (C) How does DC input impedance at the gate of a field-effect transistor compare with the DC input impedance of a bipolar transistor? A. They are both low impedance B. An FET has lower input impedance C. An FET has higher input impedance D. They are both high impedance

E6A09 (A) What is a depletion-mode FET? A. An FET that exhibits a current flow between source and drain when no gate voltage is applied B. An FET that has no current flow between source and drain when no gate voltage is applied C. Any FET without a channel D. Any FET for which holes are the majority carriers

E6A12 (D) Why do many MOSFET devices have internally connected Zener diodes on the gates? A. To provide a voltage reference for the correct amount of reverse-bias gate voltage B. To protect the substrate from excessive voltages C. To keep the gate voltage within specifications and prevent the device from overheating D. To reduce the chance of static damage to the gate

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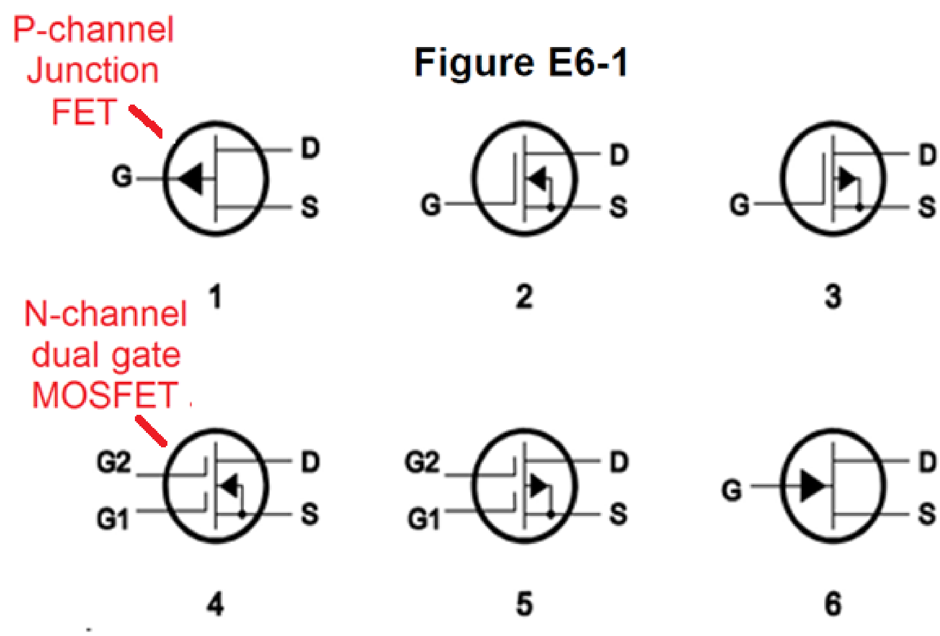

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E6A10 (B) In Figure E6-1, what is the schematic symbol for an N-channel dual-gate MOSFET? A. 2 B. 4 C. 5 D. 6

E6A11 (A) In Figure E6-1, what is the schematic symbol for a P-channel junction FET? A. 1 B. 2 C. 3 D. 6

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E6B Diodes

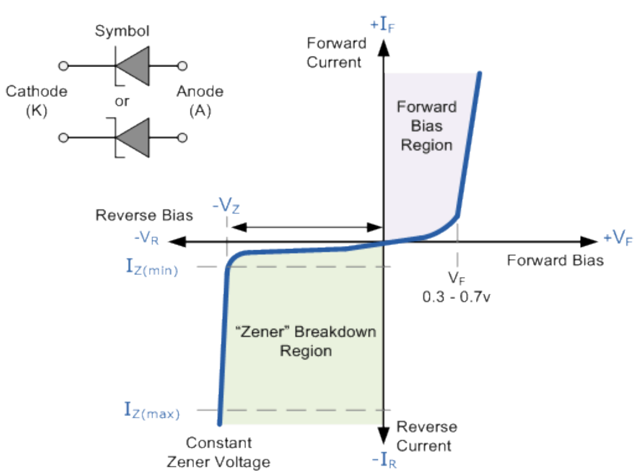
==

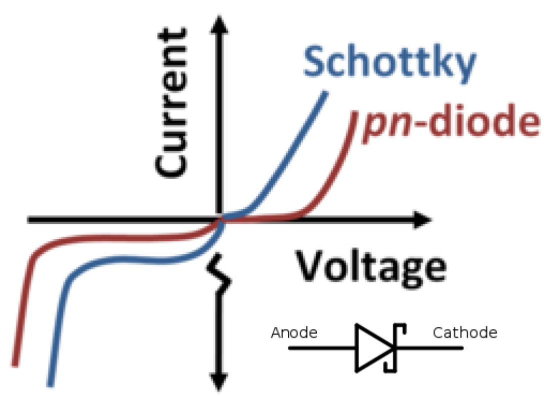
A **Zener diode** maintains a **constant voltage** drop under conditions of varying current

A **Schottky diode has less forward voltage drop** silicon diode when used as a power supply rectifier

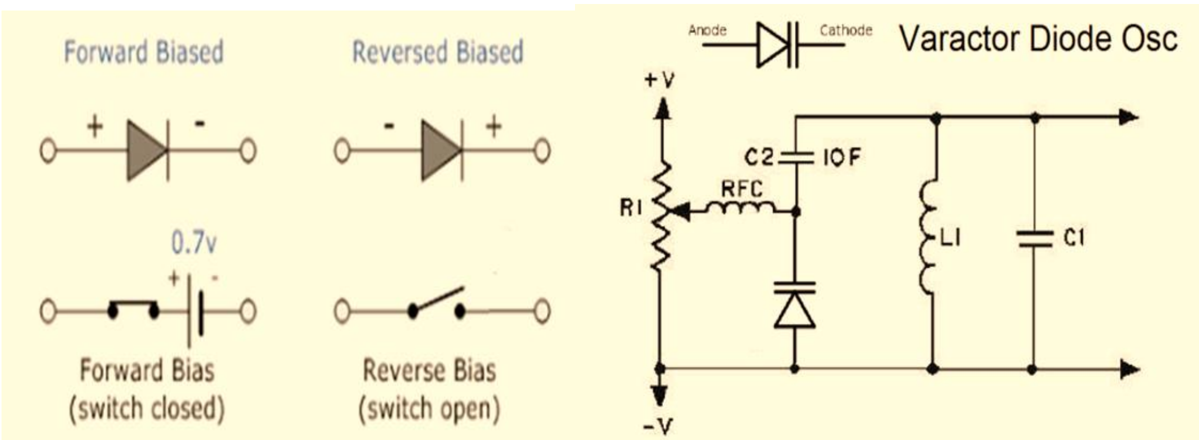
Schottky diode is a commonly used as a **VHF/UHF mixer or detector**

Metal-semiconductor junction describes a **Schottky diode**



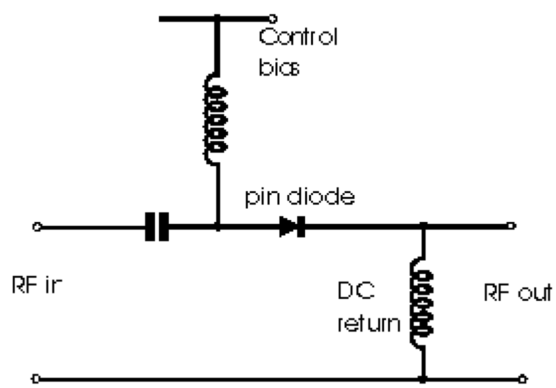


Excessive junction temperature is the failure mechanism when a **junction diode fails** due to excessive current



Forward bias is required for an **LED to emit light**

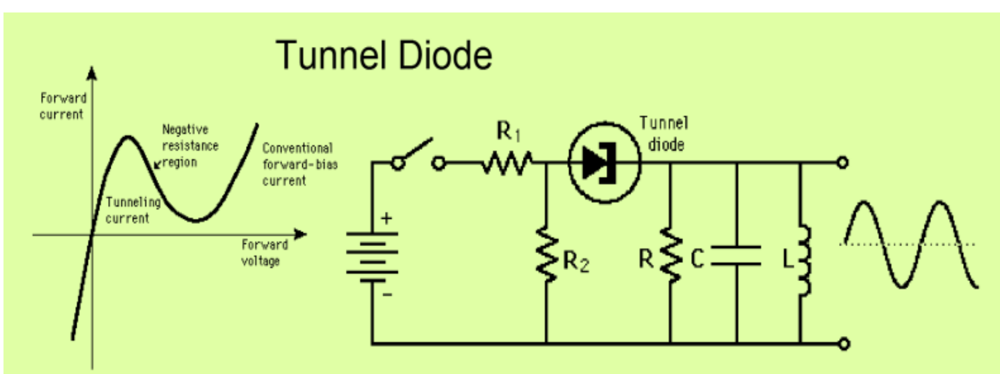
A **Varactor diode** is designed for use as a **voltage-controlled capacitor**



Low junction capacitance of a PIN diode makes it useful as an **RF switch**

An **RF detector** is a common use for **point contact diodes**

Forward DC bias current is used to **control the attenuation** of RF signals by a **PIN diode**



A **Tunnel diode** is capable of both **amplification and oscillation**

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E6B01 (B) What is the most useful characteristic of a Zener diode? A. A constant current drop under conditions of varying voltage B. A constant voltage drop under conditions of varying current C. A negative resistance region D. An internal capacitance that varies with the applied voltage

E6B02 (D) What is an important characteristic of a Schottky diode as compared to an ordinary silicon diode when used as a power supply rectifier? A. Much higher reverse voltage breakdown B. More constant reverse avalanche voltage C. Longer carrier retention time D. Less forward voltage drop

E6B03 (B) What type of bias is required for an LED to emit light? A. Reverse bias B. Forward bias C. Zero bias D. Inductive bias

E6B04 (A) What type of semiconductor device is designed for use as a voltage-controlled capacitor? A. Varactor diode B. Tunnel diode C. Silicon-controlled rectifier D. Zener diode

E6B05 (D) What characteristic of a PIN diode makes it useful as an RF switch? A. Extremely high reverse breakdown voltage B. Ability to dissipate large amounts of power C. Reverse bias controls its forward voltage drop D. Low junction capacitance

E6B06 (D) Which of the following is a common use of a Schottky diode? A. As a rectifier in high current power supplies B. As a variable capacitance in an automatic frequency control circuit C. As a constant voltage reference in a power supply D. As a VHF/UHF mixer or detector

E6B07 (B) What is the failure mechanism when a junction diode fails due to excessive current? A. Excessive inverse voltage B. Excessive junction temperature C. Insufficient forward voltage D. Charge carrier depletion

E6B08 (A) Which of the following is a Schottky barrier diode? A. Metal-semiconductor junction B. Electrolytic rectifier C. PIN junction D. Thermionic emission diode

E6B09 (C) What is a common use for point-contact diodes? A. As a constant current source B. As a constant voltage source C. As an RF detector D. As a high-voltage rectifier

E6B11 (A) What is used to control the attenuation of RF signals by a PIN diode? A. Forward DC bias current B. A sub-harmonic pump signal C. Reverse voltage larger than the RF signal D. Capacitance of an RF coupling capacitor

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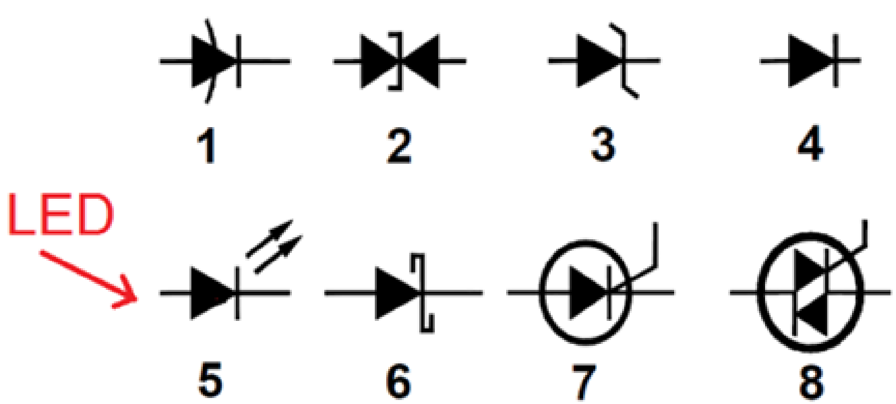
Figure E6-2



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E6B10 (B) In Figure E6-2, what is the schematic symbol for a light-emitting diode? A. 1 B. 5 C. 6 D. 7

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E6C Digital Integrated Circuits

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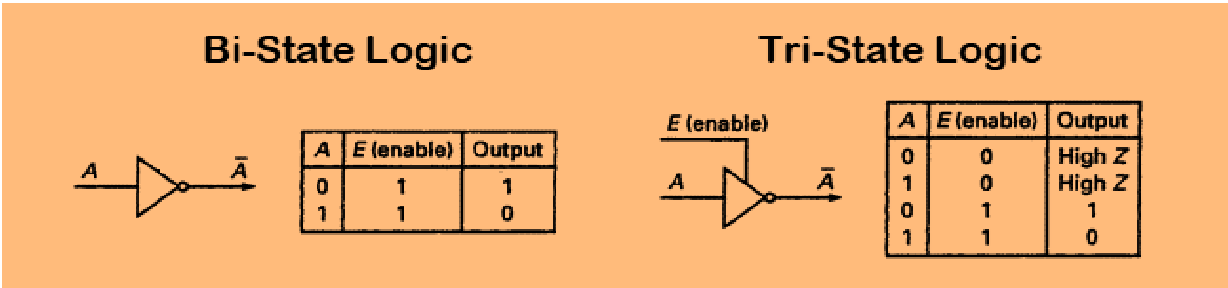
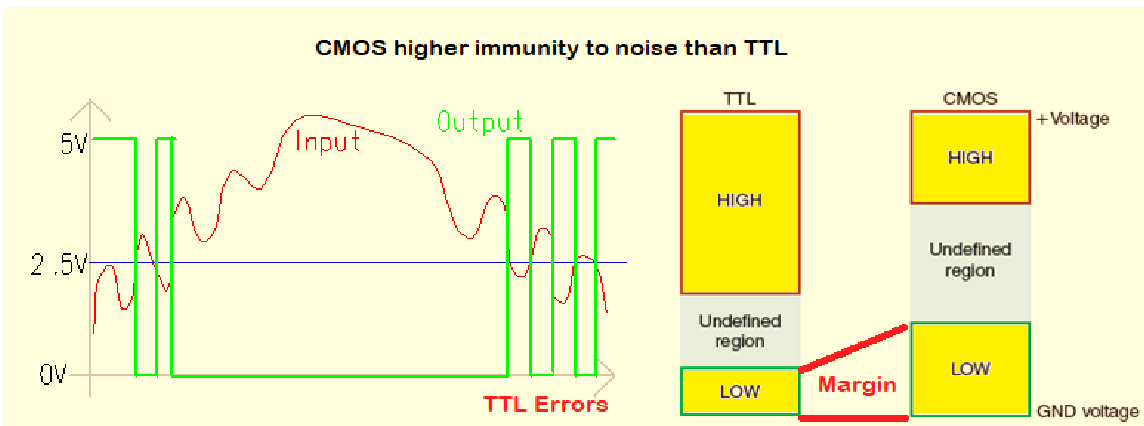


Bi-state logic are logic devices with **0 and 1** output states

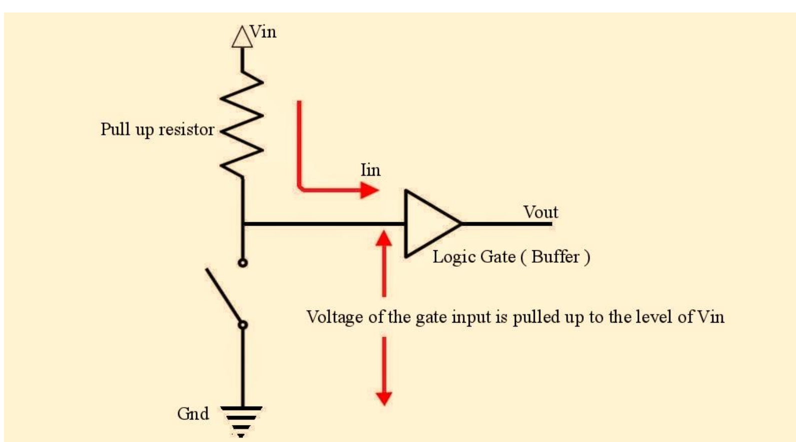
Tri-state logic are logic devices with **0, 1, and high impedance** output states



Lower power consumption is an advantage of CMOS logic devices over TTL devices

BiCMOS logic has the high input impedance of CMOS and the low output impedance of bipolar transistors

CMOS digital integrated circuits have high immunity to noise on the input signal because the switching threshold is about one-half the power supply voltage



A pull-up or pull-down resistor is connected to the supply to establish a voltage when an input or output is an open circuit

==

E6C03 (A) What is tri-state logic? A. Logic devices with 0, 1, and high-impedance output states B. Logic devices that utilize ternary math C. Low-power logic devices designed to operate at 3 volts D. Proprietary logic devices manufactured by Tri-State Devices

E6C04 (C) Which of the following is an advantage of BiCMOS logic? A. Its simplicity results in much less expensive devices than standard CMOS B. It is immune to electrostatic damage C. It has the high input impedance of CMOS and the low output impedance of bipolar transistors D. All these choices are correct

E6C05 (D) What is an advantage of CMOS logic devices over TTL devices? A. Differential output capability B. Lower distortion C. Immune to damage from static discharge D. Lower power consumption

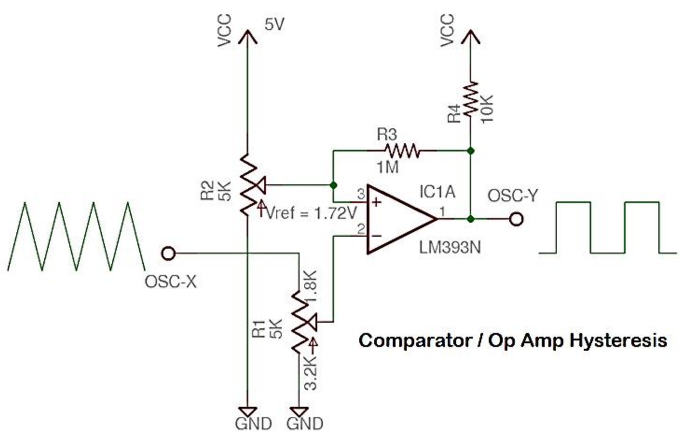
E6C06 (C) Why do CMOS digital integrated circuits have high immunity to noise on the input signal or power supply? A. Large bypass capacitance is inherent B. The input switching threshold is about two times the power supply voltage C. The input switching threshold is about one-half the power supply voltage D. Bandwidth is very limited

E6C07 (B) What best describes a pull-up or pull-down resistor? A. A resistor in a keying circuit used to reduce key clicks B. A resistor connected to the positive or negative supply line used to establish a voltage when an input or output is an open circuit C. A resistor that ensures that an oscillator frequency does not drift D. A resistor connected to an op-amp output that prevents signals from exceeding the power supply voltage

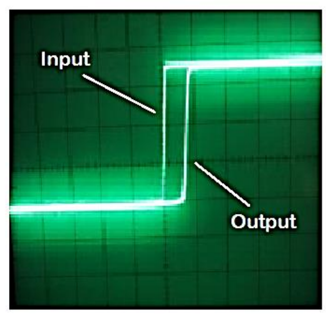
==

Hysteresis in a comparator prevents input noise from causing unstable output signals

When the level of a comparator's **input signal crosses the threshold the output state changes**



Comparator / Op Amp Hysteresis



Editor's note: Hysteresis can be added to a comparator circuit to improve its stability, especially when the input signal is noisy. The hysteresis of the circuit can be seen using an oscilloscope, time delayed output signal is slower to rise (and fall) but eventually reproduces the input signal. In the circuit above R1 adjusts the offset voltage of the OP Amp. R1 can change the output signal from a pulse to a square wave by changing the threshold.

==

E6C01 (A) What is the function of hysteresis in a comparator? A. To prevent input noise from causing unstable output signals B. To allow the comparator to be used with AC input signals C. To cause the output to change states continually D. To increase the sensitivity

E6C02 (B) What happens when the level of a comparator's input signal crosses the threshold? A. The IC input can be damaged B. The comparator changes its output state C. The comparator enters latch-up D. The feedback loop becomes unstable

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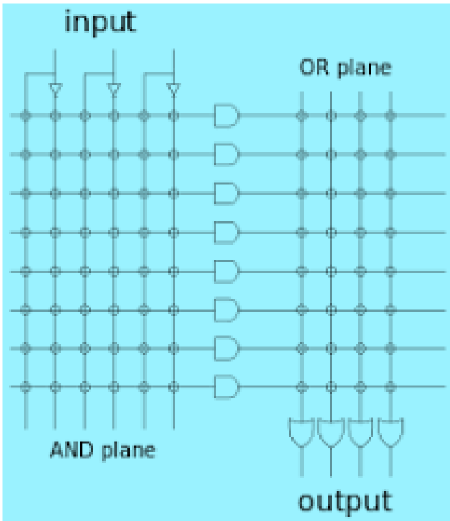
A programmable gates and circuits in a single integrated circuit is a **programmable logic device**



Programmable Gate Array (PGA)

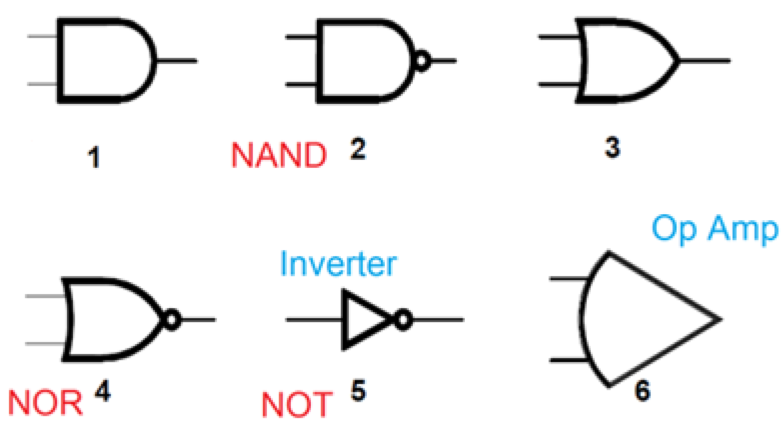
*Editor's note: A **programmable logic device (PLD)** is an electronic component used to build reconfigurable digital circuits. Unlike integrated circuits (IC) which consist of logic gates and have a fixed function, a PLD has an undefined function at the time of manufacture. There are three fundamental types of standard PLDs: PROM, PAL, and Field Programmable Gate Array (FPGA).*

==

E6C09 (B) What is a Programmable Logic Device (PLD)? A. A logic circuit that can be modified during use B. A programmable collection of logic gates and circuits in a single integrated circuit C. Programmable equipment used for testing digital logic integrated circuits D. A type of transistor whose gain can be changed by digital logic circuits

==

Figure E6-3



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E6C08 (B) In Figure E6-3, what is the schematic symbol for a NAND gate? A. 1 B. 2 C. 3 D. 4

E6C10 (D) In Figure E6-3, what is the schematic symbol for a NOR gate? A. 1 B. 2 C. 3 D. 4

E6C11 (C) In Figure E6-3, what is the schematic symbol for the NOT operation (inverter)? A. 2 B. 4 C. 5 D. 6

==

E7A Digital circuits: digital circuit principles and logic circuits

==

Bi-state logic are logic devices with **0 and 1** output states

A **TRUTH TABLE** is a list of inputs and corresponding outputs for a digital device

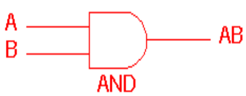
NAND gate produces a logic "0" at its output only when all inputs are logic "1"

OR gate produces a logic "1" at its output if any or all inputs are logic "1"

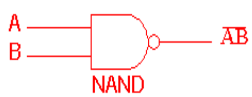
NOR gate produces a logic "0" at its output if any single input is a logic “1”

Positive Logic is the name for logic which represents a logic "1" as a high voltage

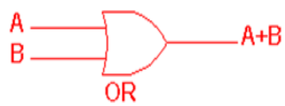
Negative logic is the name for logic which represents a logic "0" as a high voltage



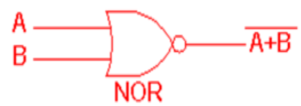
2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1



2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0



2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1



2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

==

E7A01 (C) Which circuit is bistable? A. An AND gate B. An OR gate C. A flip-flop D. A bipolar amplifier

E7A07 (D) What logical operation does a NAND gate perform? A. It produces logic 0 at its output only when all inputs are logic 0 B. It produces logic 1 at its output only when all inputs are logic 1 C. It produces logic 0 at its output if some but not all inputs are logic 1 D. It produces logic 0 at its output only when all inputs are logic 1

E7A08 (A) What logical operation does an OR gate perform? A. It produces logic 1 at its output if any or all inputs are logic 1 B. It produces logic 0 at its output if all inputs are logic 1 C. It only produces logic 0 at its output when all inputs are logic 1 D. It produces logic 1 at its output if all inputs are logic 0

E7A09 (C) What logical operation is performed by an exclusive NOR gate? A. It produces logic 0 at its output only if all inputs are logic 0 B. It produces logic 1 at its output only if all inputs are logic 1 C. It produces logic 0 at its output if only one input is logic 1 D. It produces logic 1 at its output if only one input is logic 1

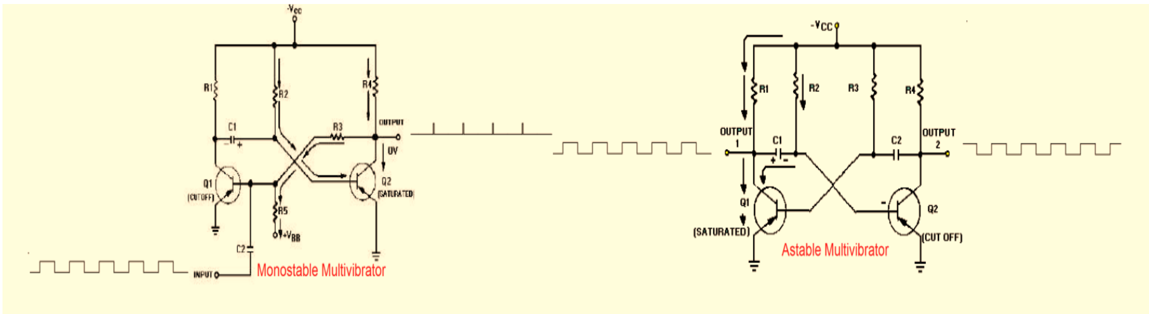
E7A10 (C) What is a truth table? A. A table of logic symbols that indicate the high logic states of an op-amp B. A diagram showing logic states when the digital device output is true C. A list of inputs and corresponding outputs for a digital device D. A table of logic symbols that indicate the logic states of an op-amp

E7A11 (D) What type of logic defines "1" as a high voltage? A. Reverse Logic B. Assertive Logic C. Negative logic D. Positive Logic

==

Astable multivibrator is a circuit that continuously alternates between two states without an external clock

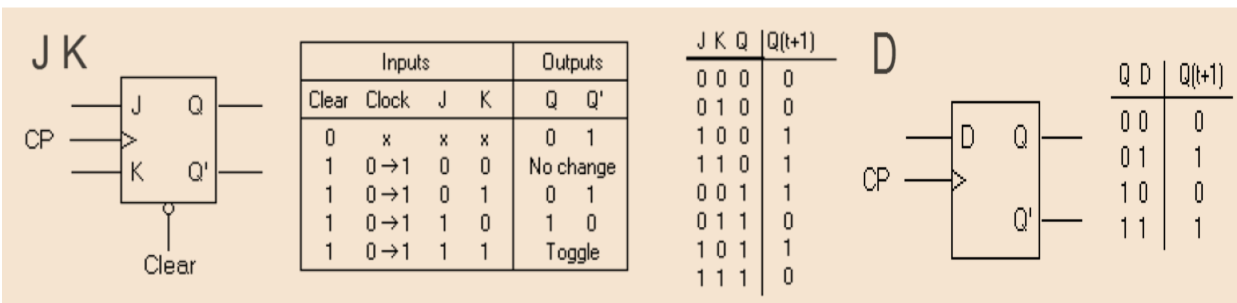
A **monostable multivibrator** switches momentarily to the opposite binary state and then returns, after a set time



A **flip-flop** can **divide** the frequency of a pulse train by **2**

Two flip-flops are required to **divide** a signal frequency by **4**

A decade counter produces one output pulse for every 10 input pulses



Editor's note: JK flip-flop is similar to an RS except that it toggles when both J and K are high. A D flip-flop output takes on the state of the D input when the clock signal transitions from low to high

==

E7A03 (B) Which of the following can divide the frequency of a pulse train by 2? A. An XOR gate B. A flip-flop C. An OR gate D. A multiplexer

E7A04 (B) How many flip-flops are required to divide a signal frequency by 4? A. 1 B. 2 C. 4 D. 8

E7A05 (D) Which of the following is a circuit that continuously alternates between two states without an external clock? A. Monostable multivibrator B. J-K flip-flop C. T flip-flop D. Astable multivibrator

E7A06 (A) What is a characteristic of a monostable multivibrator? A. It switches momentarily to the opposite binary state and then returns to its original state after a set time B. It produces a continuous square wave oscillating between 1 and 0 C. It stores one bit of data in either a 0 or 1 state D. It maintains a constant output voltage, regardless of variations in the input voltage

E7A02 (A) What is the function of a decade counter? A. It produces one output pulse for every 10 input pulses B. It decodes a decimal number for display on a seven-segment LED display C. It produces 10 output pulses for every input pulse D. It decodes a binary number for display on a seven-segment LED display

==

E6F Electro-optical technology: photoconductivity

==

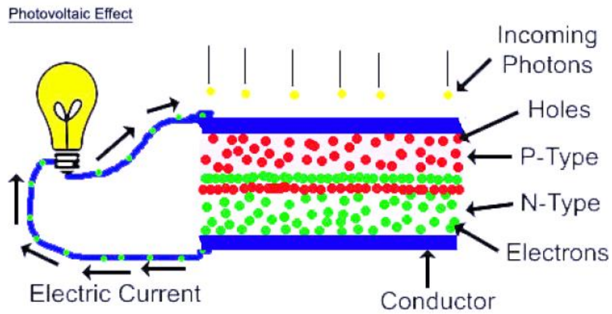
Electrons absorb the energy from light falling on a photovoltaic cell

The conversion of **LIGHT to ELECTRICAL** energy is the **photovoltaic effect**

Silicon is the most common type of **photovoltaic cell used for electrical power** generation

The **efficiency of a photovoltaic cell** is the relative fraction of light that is converted to current

0.5 V is the approximate open-circuit voltage produced by a fully-illuminated **silicon photovoltaic cell**



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E6F01 (C) What absorbs the energy from light falling on a photovoltaic cell? A. Protons B. Photons C. Electrons D. Holes

E6F04 (B) What is the photovoltaic effect? A. The conversion of voltage to current when exposed to light B. The conversion of light to electrical energy C. The conversion of electrical energy to mechanical energy D. The tendency of a battery to discharge when exposed to light

E6F09 (D) What is the efficiency of a photovoltaic cell? A. The output RF power divided by the input DC power B. Cost per kilowatt-hour generated C. The open-circuit voltage divided by the short-circuit current under full illumination D. The relative fraction of light that is converted to current

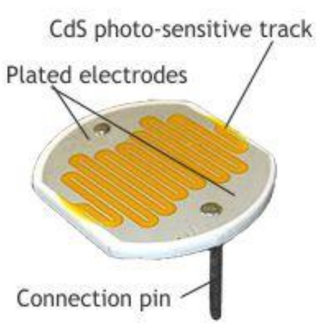
E6F10 (B) What is the most common type of photovoltaic cell used for electrical power generation? A. Selenium B. Silicon C. Cadmium Sulfide D. Copper oxide

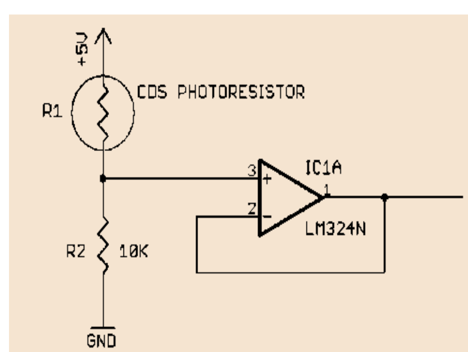
E6F11 (B) What is the approximate open-circuit voltage produced by a fully illuminated silicon photovoltaic cell? A. 0.1 V B. 0.5 V C. 1.5 V D. 12 V

==

A **crystalline semiconductor** is affected the most by photoconductivity

The **conductivity** of a photoconductive material increases **when light shines on it**





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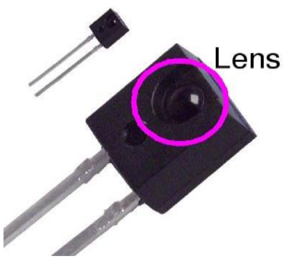
E6F02 (A) What happens to the conductivity of a photoconductive material when light shines on it? A. It increases B. It decreases C. It stays the same D. It becomes unstable

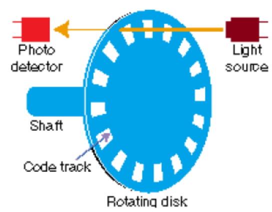
E6F06 (A) Which of these materials is most commonly used to create photoconductive devices? A. A crystalline semiconductor B. An ordinary metal C. A heavy metal D. A liquid semiconductor

==

opt isolators commonly are a combination of an **LED and a phototransistor**

An **optical shaft encoder** detects rotation of a control by **interrupting a light source** with a patterned wheel



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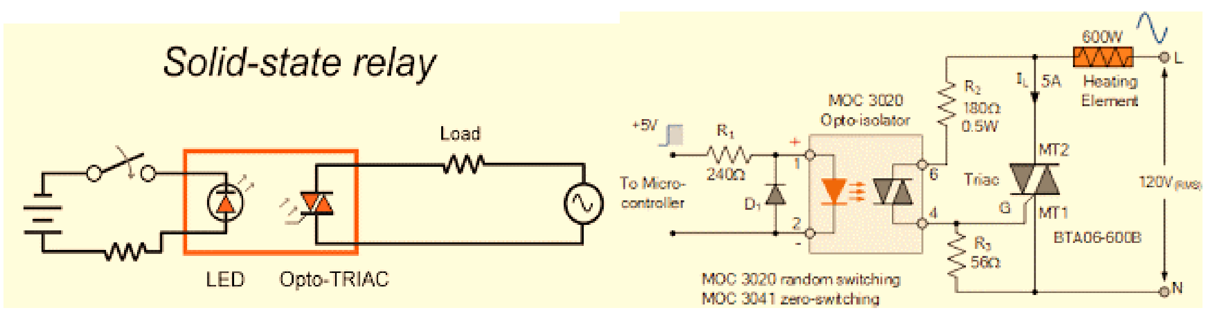
E6F03 (D) What is the most common configuration of an optoisolator or optocoupler? A. A lens and a photomultiplier B. A frequency modulated helium-neon laser C. An amplitude modulated helium-neon laser D. An LED and a phototransistor

E6F05 (A) Which describes an optical shaft encoder? A. A device that detects rotation of a control by interrupting a light source with a patterned wheel B. A device that measures the strength of a beam of light using analog to digital conversion C. A digital encryption device often used to encrypt spacecraft control signals D. A device for generating RTTY signals by means of a rotating light source

===

A **solid-state relay uses semiconductors** to implement the functions of an electromechanical relay

Optoisolators provide a very high degree of control circuit isolation when switching 120 VAC



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E6F07 (B) What is a solid-state relay? A. A relay using transistors to drive the relay coil B. A device that uses semiconductors to implement the functions of an electromechanical relay C. A mechanical relay that latches in the on or off state each time it is pulsed D. A semiconductor passive delay line

E6F08 (C) Why are optoisolators often used in conjunction with solid-state circuits when switching 120 VAC? A. Optoisolators provide a low impedance link between a control circuit and a power circuit B. Optoisolators provide impedance matching between the control circuit and power circuit C. Optoisolators provide a very high degree of electrical isolation between a control circuit and the circuit being switched D. Optoisolators eliminate the effects of reflected light in the control circuit

===

E6D Toroidal and Solenoidal Inductors

===

Ferrite and brass are commonly used as a **core material in** an inductor

Permeability of the core material determines the **inductance** of a toroidal inductor

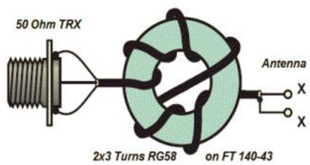
Powdered-iron toroids maintain their **characteristics at higher currents** rather than ferrite toroids

Brass core material decreases inductance when inserted into a coil

Powdered-iron toroids require **fewer turns** for a given inductance value than ferrite toroids

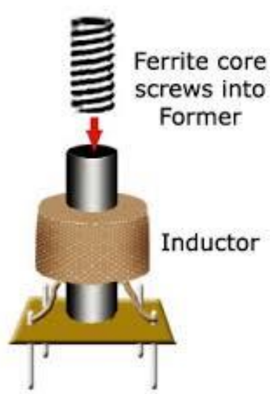
Saturation is when **flux density cannot increase** the magnetization of the material further,

Saturation can cause signal distortion (intermods & harmonics) in amplifiers and matching circuits.



Editor's note:

A variable inductor having an adjustable ferrite core is known as slug tuned inductor.
The value of inductance increases or decreases respectively, due to the movement of a core into or out of the coil winding.
A ferrite slug increases inductance when inserted.
A brass slug decreases inductance when inserted



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E6D04 (B) Which materials are commonly used as a core in an inductor? A. Polystyrene and polyethylene B. Ferrite and brass C. Teflon and Delrin D. Cobalt and aluminum

E6D06 (D) What core material property determines the inductance of an inductor? A. Thermal impedance B. Resistance C. Reactivity D. Permeability

E6D08 (B) What is one reason for using powdered-iron cores rather than ferrite cores in an inductor? A. Powdered-iron cores generally have greater initial permeability B. Powdered-iron cores generally maintain their characteristics at higher currents C. Powdered-iron cores generally require fewer turns to produce a given inductance D. Powdered-iron cores use smaller diameter wire for the same inductance

E6D11 (B) Which type of core material decreases inductance when inserted into a coil? A. Ceramic B. Brass C. Ferrite D. Powdered iron

E6D05 (C) What is one reason for using ferrite cores rather than powdered iron in an inductor? A. Ferrite toroids generally have lower initial permeability B. Ferrite toroids generally have better temperature stability C. Ferrite toroids generally require fewer turns to produce a given inductance value D. Ferrite toroids are easier to use with surface mount technology

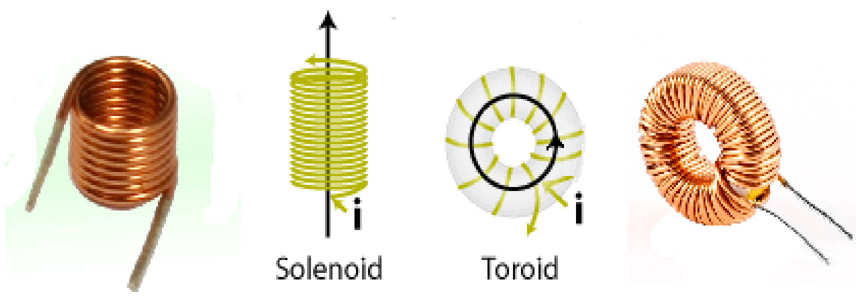
E6D01 (A) Why should core saturation of an impedance matching transformer be avoided? A. Harmonics and distortion could result B. Magnetic flux would increase with frequency C. RF susceptance would increase D. Temporary changes of the core permeability could result

E6D12 (C) What is inductor saturation? A. The inductor windings are over-coupled B. The inductor's voltage rating is exceeded causing a flashover C. The ability of the inductor's core to store magnetic energy has been exceeded D. Adjacent inductors become over-coupled

==

Toroidal cores confine most of the magnetic field within the core material unlike a solenoidal

Inter-turn capacitance is the primary cause of **inductor self-resonance**



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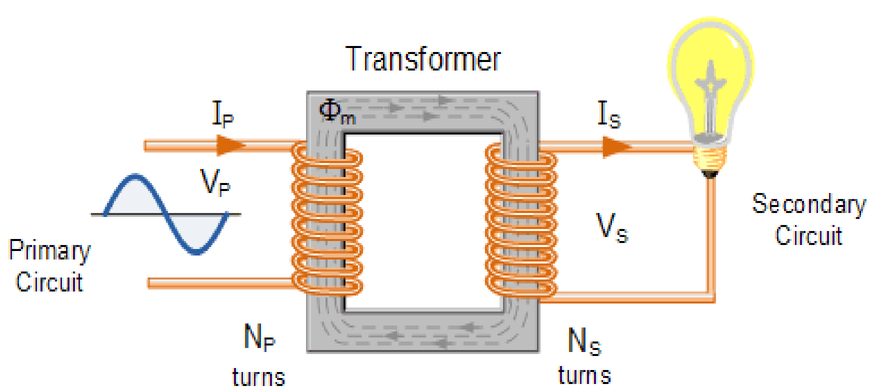
E6D10 (A) What is a primary advantage of using a toroidal core instead of a solenoidal core in an inductor? A. Toroidal cores confine most of the magnetic field within the core material B. Toroidal cores make it easier to couple the magnetic energy into other components C. Toroidal cores exhibit greater hysteresis D. Toroidal cores have lower Q characteristics

E6D13 (A) What is the primary cause of inductor self-resonance? A. Inter-turn capacitance B. The skin effect C. Inductive kickback D. Non-linear core hysteresis

==

Magnetizing current in the primary winding of a transformer is the current when no load is attached to the secondary



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E6D07 (A) What is current in the primary winding of a transformer called if no load is attached to the secondary? A. Magnetizing current B. Direct current C. Excitation current D. Stabilizing current

==

Ferrite beads are commonly used as VHF and UHF **parasitic suppressors** on amplifiers

==

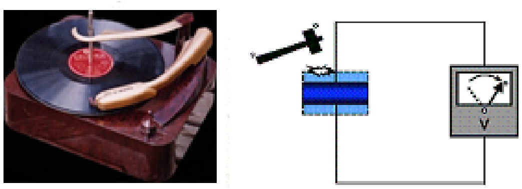
E6D09 (C) What devices are commonly used as VHF and UHF parasitic suppressors at the input and output terminals of a transistor HF amplifier? A. Electrolytic capacitors B. Butterworth filters C. Ferrite beads D. Steel-core toroids

==

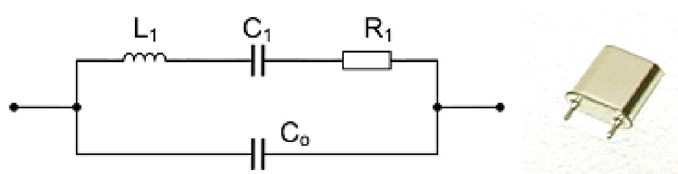
Physical deformation of a crystal by the application of a voltage is one aspect of the piezoelectric effect

A motional capacitance, motional inductance, and loss resistance in series, all in parallel with a shunt capacitor representing electrode and stray capacitance **is the equivalent circuit of a quartz crystal.**

Piezoelectric Effect



Equivalent Circuit of a Quartz Crystal



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E6D02 (A) What is the equivalent circuit of a quartz crystal? A. Motional capacitance, motional inductance, and loss resistance in series, all in parallel with a shunt capacitor representing electrode and stray capacitance B. Motional capacitance, motional inductance, loss resistance, and a capacitor representing electrode and stray capacitance all in parallel C. Motional capacitance, motional inductance, loss resistance, and a capacitor representing electrode and stray capacitance all in series D. Motional inductance and loss resistance in series, paralleled with motional capacitance and a capacitor representing electrode and stray capacitance

E6D03 (A) Which of the following is an aspect of the piezoelectric effect? A. Mechanical deformation of material by the application of a voltage B. Mechanical deformation of material by the application of a magnetic field C. Generation of electrical energy in the presence of light D. Increased conductivity in the presence of light

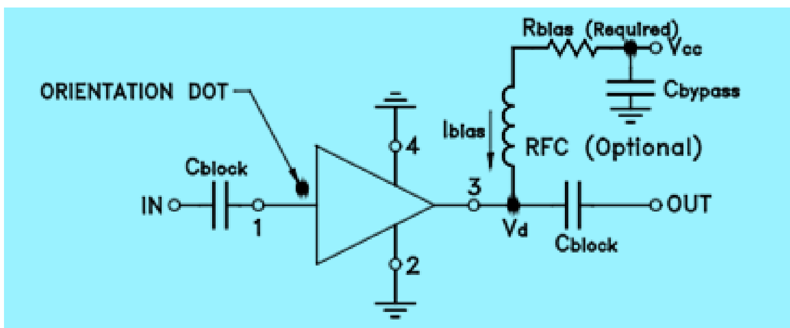
==

E6E Analog ICs: MMICs, IC packaging characteristics

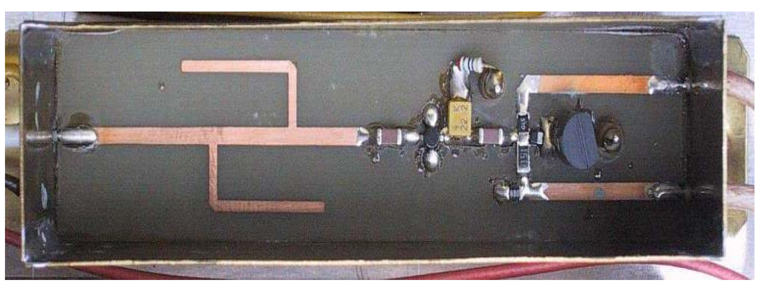
==

50 ohms is the most common input and output **impedance** of circuits that use **MMICs**

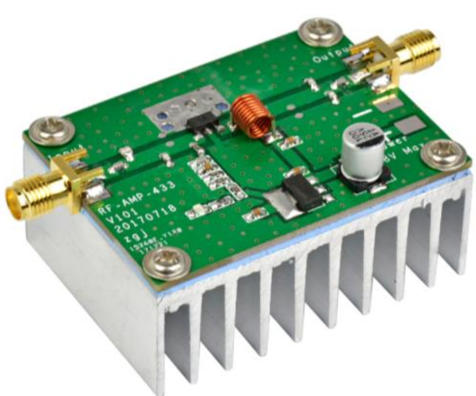
Controlled gain, low noise figure typical 2 dB, constant impedance makes the **MMIC** good for VHF to microwave circuits



The B**+ supply is furnished through a resistor** and/or RF choke connected to the **MMIC output lead**



Microstrip construction is typically used to construct a **MMIC** based microwave amplifier



At UHF & higher frequencies gallium arsenide is used as a semiconductor material

Gallium nitride is likely to provide the highest frequency of operation when used in MMICs

==

E6E01 (B) Why is gallium arsenide (GaAs) useful for semiconductor devices operating at UHF and higher frequencies? A. Higher noise figures B. Higher electron mobility C. Lower junction voltage drop D. Lower transconductance

E6E03 (D) Which of the following materials is likely to provide the highest frequency of operation when used in MMICs? A. Silicon B. Silicon nitride C. Silicon dioxide D. Gallium nitride

E6E04 (A) Which is the most common input and output impedance of circuits that use MMICs? A. 50 ohms B. 300 ohms C. 450 ohms D. 10 ohms

E6E05 (A) Which of the following noise figure values is typical of a low-noise UHF preamplifier? A. 2 dB B. -10 dB C. 44 dBm D. -20 dBm

E6E06 (D) What characteristics of the MMIC make it a popular choice for VHF through microwave circuits? A. The ability to retrieve information from a single signal even in the presence of other strong signals B. Plate current that is controlled by a control grid C. Nearly infinite gain, very high input impedance, and very low output impedance D. Controlled gain, low noise figure, and constant input and output impedance over the specified frequency range

E6E07 (D) What type of transmission line is used for connections to MMICs? A. Miniature coax B. Circular waveguide C. Parallel wire D. Microstrip

E6E08 (A) How is power supplied to the most common type of MMIC? A. Through a resistor and/or RF choke connected to the amplifier output lead B. MMICs require no operating bias C. Through a capacitor and RF choke connected to the amplifier input lead D. Directly to the bias voltage (VCC IN) lead

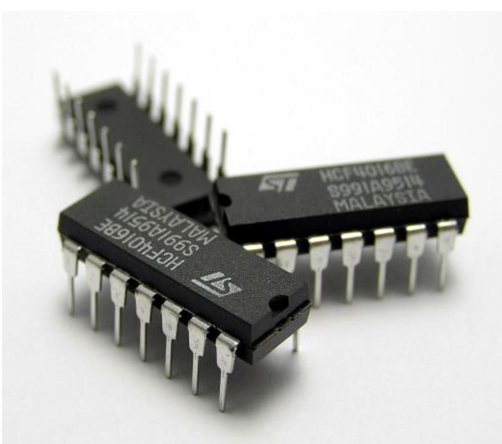
==

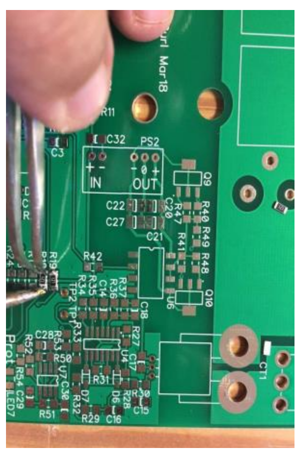
DIP (Dual in-line packages) is a common print circuit board **through-hole IC package**.

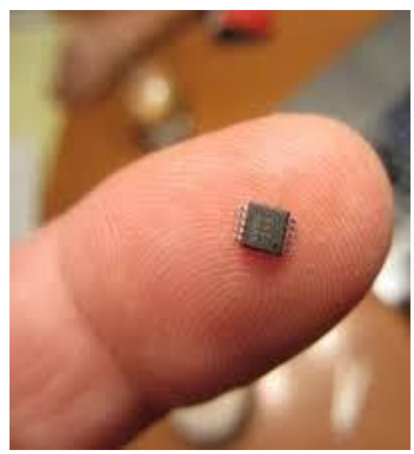
DIPs have two parallel rows of pins extending perpendicularly out of the package

(Below-Left)

DIP through-hole package ICs not typically used at UHF and higher frequencies due to excessive lead length







*Editor's note: Surface-mount technology (SMT) devices are called **a surface-mount device (SMD)** are mounted or placed directly onto the surface of printed circuit boards. (Above-Center & Above-Left.).*

S**urface-Mount Devices** are suitable for use at frequencies above the HF range

S**urface-Mount Devices** are leadless solving most p**arasitic effects**, smaller circuit area and shorter circuit-board traces.

==

E6E09 (D) Which of the following component package types would be most suitable for use at frequencies above the HF range? A. TO-220 B. Axial lead C. Radial lead D. Surface mount

E6E02 (A) Which of the following device packages is a through-hole type? A. DIP B. PLCC C. Ball grid array D. SOT

E6E10 (D) What advantage does surface-mount technology offer at RF compared to using through-hole components? A. Smaller circuit area B. Shorter circuit-board traces C. Components have less parasitic inductance and capacitance D. All these choices are correct

E6E11 (D) What is a characteristic of DIP packaging used for integrated circuits? A. Package mounts in a direct inverted position B. Low leakage doubly insulated package C. Two chips in each package (Dual In Package) D. A total of two rows of connecting pins placed on opposite sides of the package (Dual In-line Package)

E6E12 (C) Why are DIP through-hole package ICs not typically used at UHF and higher frequencies? A. Too many pins B. Epoxy coating is conductive above 300 MHz C. Excessive lead length D. Unsuitable for combining analog and digital signals

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E7B Amplifiers

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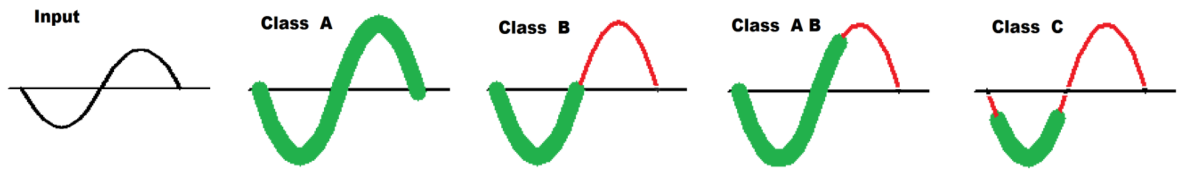
A **Class A** common emitter amplifier would bias normally be set half-way between saturation and cutoff

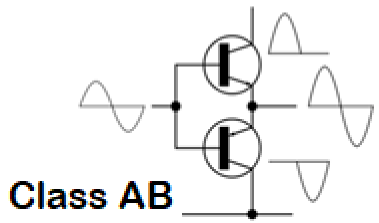
A **Class AB amplifier** operates more than 180 degrees but less than 360 degrees



Class AB designs commonly use a **Push-pull amplifier to eliminate even-order harmonics**

A **Class C** amplifier has Bias is set well into the cutoff region, operates less than 180 degrees

Signal distortion and excessive bandwidth result when a **Class C** amplifier is used to amplify a SSB phone signal

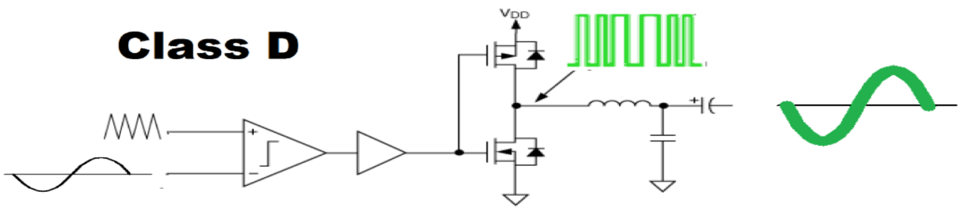


Editor's note: Class AB Amplifier is a combination of Classes A and B in that for small power outputs the amplifier operates as a class A amplifier but changes to a class B amplifier for larger current outputs. This action is achieved by pre-biasing the two transistors in the amplifiers output stage.

A **Class D** amplifier that uses switching technology to achieve high efficiency

A class **D amplifier** uses **low-pass output filter** to remove switching signal components

Switching amplifiers more efficient than linear amplifiers because the power transistor is at saturation or cutoff most of the time



Editor's note: Amplifier classes: Power amplifiers are classified primarily by the design of the output stage. Classification is based on the amount of time the output device(s) operate during each cycle of the input signal.

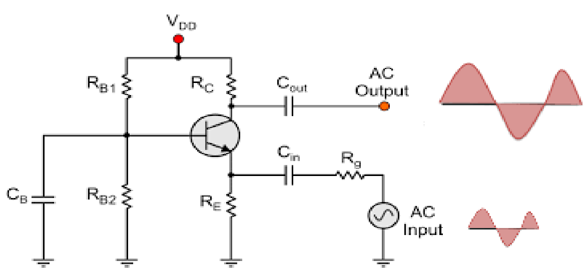
Class A operation is where the tube conducts continuously for the entire cycle of the input signal, or a bias current flow in the output devices at all times. The key ingredient of class A operation is that the output is always on. Conversely the output device is never turned off. Because of this, class A amplifiers are single-ended designs. Class A is the most inefficient of all power amplifier designs, averaging only around 20%. Because of this, class A amplifiers are large, heavy and run very hot. On the positive side, class A designs are inherently the most linear, and have the least amount of distortion. When driving an A class amplifier care should be taken to ensure the peak to peak input voltage stays within the linear range of the amplifier. - AD7FO

Class B has conduction occurring for only for ½ of the input cycle. Class B amplifiers typically have dual output devices operating 180º out of phase with each other in a push / pull configuration to allow the full cycle of the input to be amplified. Both output devices are never allowed to be on at the same time, bias is set so that current flow in a specific output device is zero without an input signal. Current only flows in each of the push / pull amplifier output amplifiers for one half cycle. Thus, each output amplifier is only on for ½ of a complete sinusoidal signal cycle. Class B push pull designs show high efficiency but poor linearity around the 0 voltage crossover region. This is due to the time it takes to turn one device off and the other device on, which translates into extreme crossover distortion. Thus, restricting class B designs to power consumption critical applications, e.g., battery operated equipment. Class B push / pull transmitter power amplifiers reduce or prevent even order harmonics in the output signal. - AD7FO

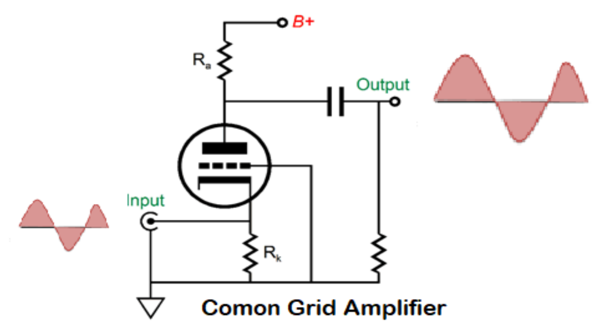
Class AB operation allows both devices to be on at the same time (like in class A), but just barely. The output bias is set so that current flows in a specific output device appreciably more than a half cycle but less than the entire cycle. That is, only a small amount of current is allowed to flow through both devices, unlike the complete load current of class A designs, but enough to keep each device operating so they respond instantly to input voltage demands. Thus, the inherent non-linearity of class B designs is eliminated, without the gross inefficiencies of the class A design. It is this combination of good efficiency (around 50%) with excellent linearity that makes class AB the most popular audio amplifier design. - AD7FO

Class C operation allows current flows for less than one half cycle of the input signal. The class C operation is achieved by reverse biasing the amplifier to point below cutoff and allows only the portion of the input signal that overcomes the reverse bias to cause current flow. The class C operated amplifier is used as a radio-frequency amplifier in frequency modulated or CW transmitters. - AD7FO

Class-D amplifier or switching amplifier is an electronic amplifier in which the amplifying devices (transistors, usually MOSFETs) operate as electronic switches, and not as linear gain devices as in other amplifiers. They operate by rapidly switching back and forth between the supply rails, being fed by a modulator using pulse width, pulse density, or related techniques to encode the audio input into a pulse train. The audio escapes through a simple low-pass filter into the loudspeaker. The high-frequency pulses are blocked. Since the pairs of output transistors are never conducting at the same time, there is no other path for current flow apart from the low-pass filter/loudspeaker. For this reason, efficiency can exceed 90%. - wikipedia.org



Common Base Amplifier



Comon Grid Amplifier

Common Base Amplifier Input on Emitter, output on collector, Low impedance input, High impedance output. Primarily used as an impedance converter

Editor's note: Ground Grid Amplifier Input on Cathode, output from plate, Low impedance input, High impedance output.

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E7B01 (A) For what portion of the signal cycle does each active element in a push-pull Class AB amplifier conduct? A. More than 180 degrees but less than 360 degrees B. Exactly 180 degrees C. The entire cycle D. Less than 180 degrees

E7B02 (A) What is a Class D amplifier? A. A type of amplifier that uses switching technology to achieve high efficiency B. A low power amplifier that uses a differential amplifier for improved linearity C. An amplifier that uses drift-mode FETs for high efficiency D. A frequency doubling amplifier

E7B03 (A) Which of the following components form the output of a class D amplifier circuit? A. A low-pass filter to remove switching signal components B. A high-pass filter to compensate for low gain at low frequencies C. A matched load resistor to prevent damage by switching transients D. A temperature compensating load resistor to improve linearity

E7B04 (A) Where on the load line of a Class A common emitter amplifier would bias normally be set? A. Approximately halfway between saturation and cutoff B. Where the load line intersects the voltage axis C. At a point where the bias resistor equals the load resistor D. At a point where the load line intersects the zero bias current curve

E7B06 (B) Which of the following amplifier types reduces even-order harmonics? A. Push-push B. Push-pull C. Class C D. Class AB

E7B07 (D) Which of the following is a likely result when a Class C amplifier is used to amplify a single-sideband phone signal? A. Reduced intermodulation products B. Increased overall intelligibility C. Signal inversion D. Signal distortion and excessive bandwidth

E7B13 (D) Which of the following describes an emitter follower (or common collector) amplifier? A. A two-transistor amplifier with the emitters sharing a common bias resistor B. A differential amplifier with both inputs fed to the emitter of the input transistor C. An OR circuit with only one emitter used for output D. An amplifier with a low impedance output that follows the base input voltage

E7B14 (B) Why are switching amplifiers more efficient than linear amplifiers? A. Switching amplifiers operate at higher voltages B. The power transistor is at saturation or cutoff most of the time C. Linear amplifiers have high gain resulting in higher harmonic content D. Switching amplifiers use push-pull circuits

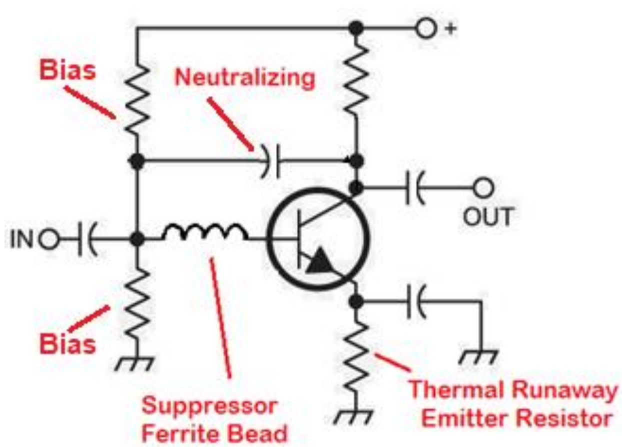
E7B18 (C) What is a characteristic of a grounded-grid amplifier? A. High power gain B. High filament voltage C. Low input impedance D. Low bandwidth

==

RF power amplifier be **neutralized b**y feeding **a 180-degree out-of-phase** portion of the **output back to the input**

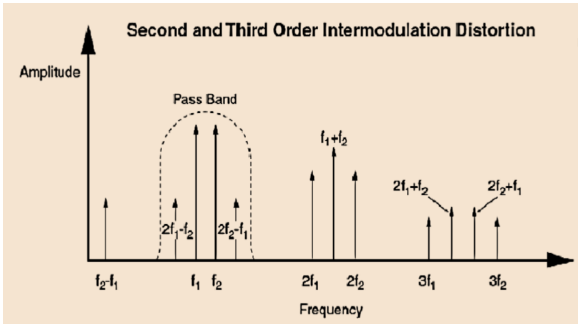
Install **parasitic suppressors and/or neutralize** the stage prevent unwanted oscillations in an RF power amplifier

Use a **resistor in series with the emitter** to prevent **thermal runaway** in a bipolar transistor amplifier



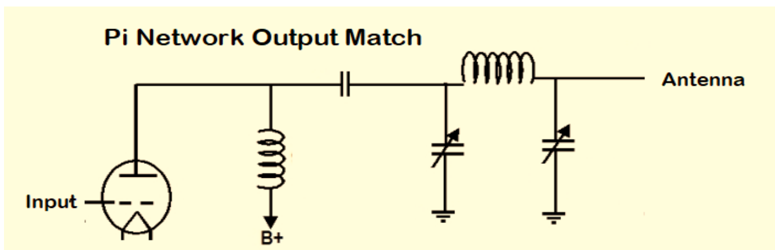
Intermodulation products in a linear power amplifier result in transmission of **spurious signals**

Third-order intermodulation products are relatively **close in frequency to the desired signal**



Intermod Product	Frequency
Second Order	$f_1 + f_2$
	$f_1 - f_2$
Third Order	$2f_1 + f_2$
	$2f_1 - f_2$
	$f_1 + 2f_2$
	$f_1 - 2f_2$

The typical HF vacuum tube RF amplifier has an VSWR m**ismatch between the final stage tube plate and the antenna** requiring a Pi Network for matching. **The tuning capacitor is adjusted for minimum plate current, and the loading capacitor is adjusted for maximum permissible plate** current



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E7B05 (C) What can be done to prevent unwanted oscillations in an RF power amplifier? A. Tune the stage for maximum SWR B. Tune both the input and output for maximum power C. Install parasitic suppressors and/or neutralize the stage D. Use a phase inverter in the output filter

E7B08 (C) How can an RF power amplifier be neutralized? A. By increasing the driving power B. By reducing the driving power C. By feeding a 180-degree out-of-phase portion of the output back to the input D. By feeding an in-phase component of the output back to the input

E7B15 (C) What is one way to prevent thermal runaway in a bipolar transistor amplifier? A. Neutralization B. Select transistors with high beta C. Use a resistor in series with the emitter D. All these choices are correct

E7B16 (A) What is the effect of intermodulation products in a linear power amplifier? A. Transmission of spurious signals B. Creation of parasitic oscillations C. Low efficiency D. All these choices are correct

E7B17 (A) Why are odd-order rather than even-order intermodulation distortion products of concern in linear power amplifiers? A. Because they are relatively close in frequency to the desired signal B. Because they are relatively far in frequency from the desired signal C. Because they invert the sidebands causing distortion D. Because they maintain the sidebands, thus causing multiple duplicate signals

E7B09 (D) Which of the following describes how the loading and tuning capacitors are to be adjusted when tuning a vacuum tube RF power amplifier that employs a Pi-network output circuit? A. The loading capacitor is set to maximum capacitance and the tuning capacitor is adjusted for minimum allowable plate current B. The tuning capacitor is set to maximum capacitance and the loading capacitor is adjusted for minimum plate permissible current C. The loading capacitor is adjusted to minimum plate current while alternately adjusting the tuning capacitor for maximum allowable plate current D. The tuning capacitor is adjusted for minimum plate current, and the loading capacitor is adjusted for maximum permissible plate current

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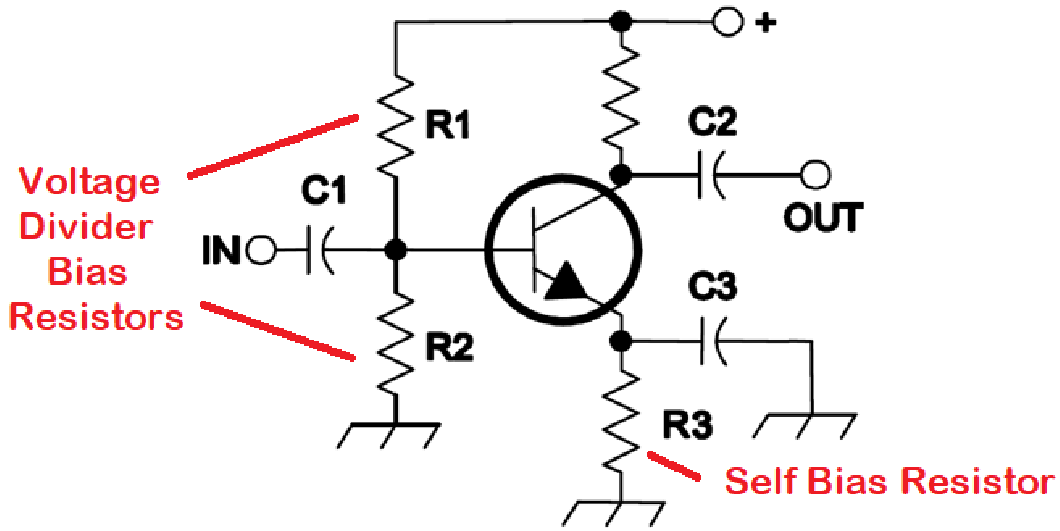
Common Emitter Amplifier

Figure E7-1



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E7B10 (B) In Figure E7-1, what is the purpose of R1 and R2? A. Load resistors B. Voltage divider bias C. Self bias D. Feedback

E7B11 (D) In Figure E7-1, what is the purpose of R3? A. Fixed bias B. Emitter bypass C. Output load resistor D. Self bias

E7B12 (C) What type of amplifier circuit is shown in Figure E7-1? A. Common base B. Common collector C. Common emitter D. Emitter follower

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E7F DSP filtering and other operations

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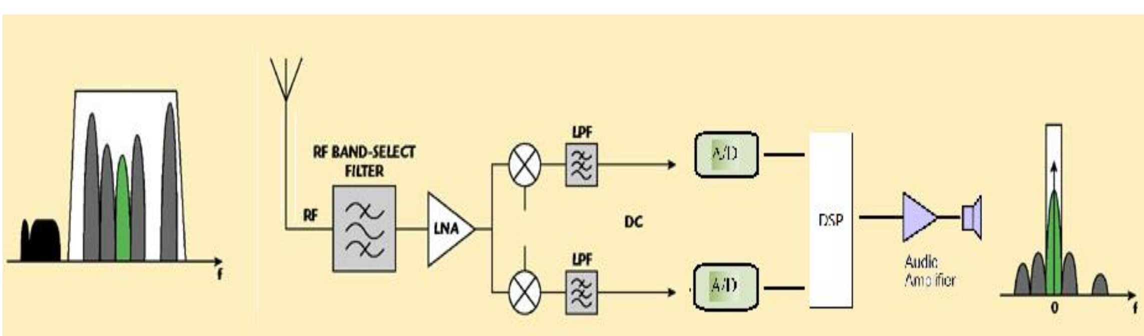


Direct digital conversion of RF is digitized by an analog-to-digital **converter without being mixed with a local oscillator** signal

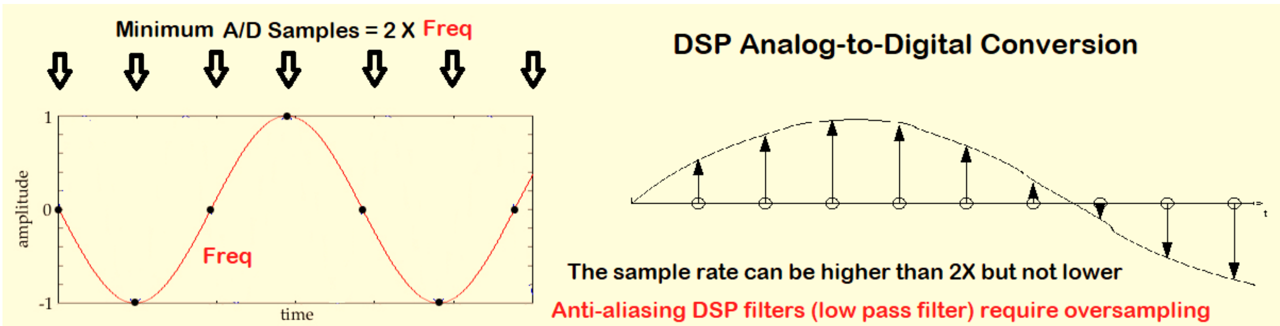
Editor's note: I and Q represent In-phase and Quadrature The "in-phase" or reference signal is referred to as "I," and the signal that is shifted by 90 degrees (the signal in quadrature) is called "Q."

Fast Fourier Transform converts a signal from its time domain to frequency domain and vice versa

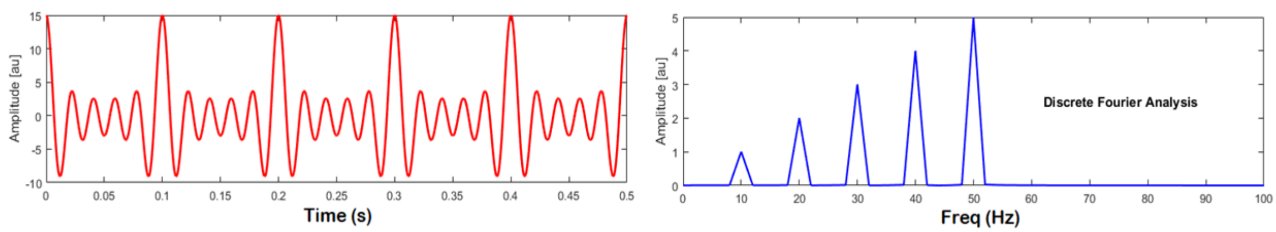
Direct digital conversion Sample Rate determines **Bandwidth**

Direct digital conversion bandwidth of a Direct Digital Conversion is 1/2 the **Sample Rate**.

Direct digital conversion sample rate must be at least twice the highest frequency of the signal



A discrete Fourier analysis of a sum of cosine waves at 10, 20, 30, 40, and 50 Hz



Editor's note: The Nyquist theorem Example: ADC has a sample rate of 1MHz, therefore the input maximum bandwidth can be 0.5MHz. The sample rate can be higher than 2X but not lower.

Reference voltage level and sample bits determine the **minimum detectable signal level** for an SDR receiver.

n	n^2	n^3	n^4	n^5	n^6	n^7	n^8	n^9	n^{10}
2	4	8	16	32	64	128	256	512	1,024

1 volt at a resolution of 1 millivolt requires 1024 samples or 2^10 bits

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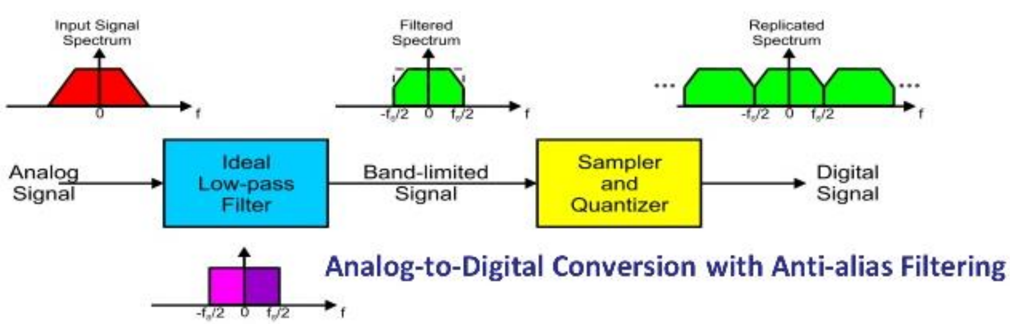
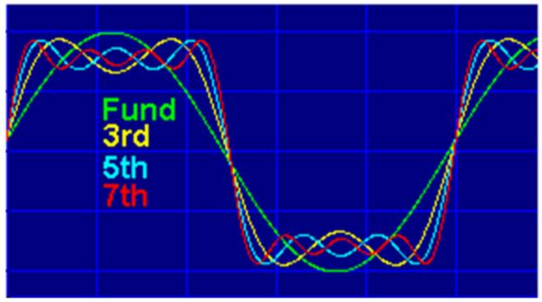


An anti-aliasing digital filter removes high-frequency signal components that would otherwise be reproduced as lower frequency components

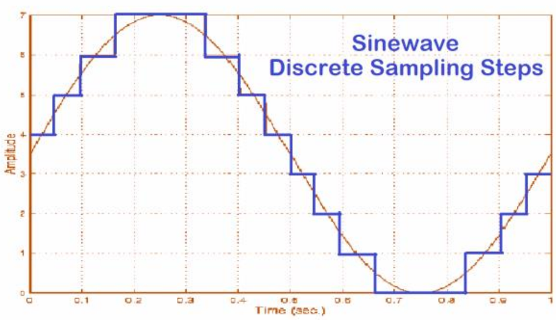
Editor's note: An anti-aliasing filter (AAF) is a filter used before a signal sampler to restrict the bandwidth of a signal, a low pass filter. An anti-aliasing filter will typically either permit some aliasing to occur or else attenuate some in-band frequencies close to the Nyquist limit. For this reason, many practical systems sample higher than would be theoretically required by a perfect AAF in order to ensure that all frequencies of interest can be reconstructed, a practice called oversampling.

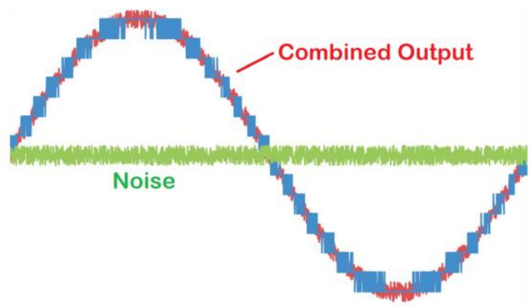


Editor's note: Fourier analysis of *a square wave pictured above shows a square wave is made up of a sine wave plus all of its odd harmonics.*

Decimation reducing the effective sample rate by removing samples

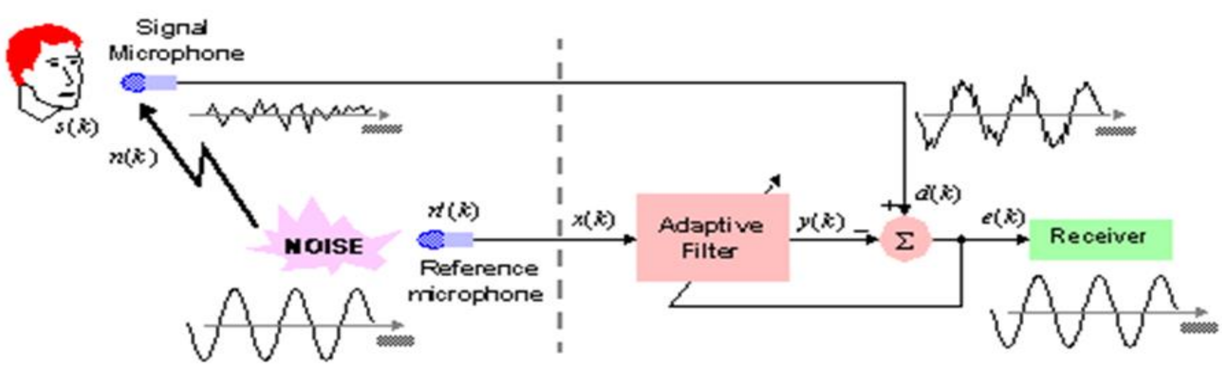
Editor's note: Decimators can be used to reduce the sampling frequency, whereas interpolators can be used to increase it. ... Sampling rate conversion systems are used to change the sampling rate of a signal. The process of sampling rate decrease is called decimation, and the process of sampling rate increase is called interpolation. However, you can do interpolation prior to decimation to achieve an overall rational ...an example is 4/5 Resampling.



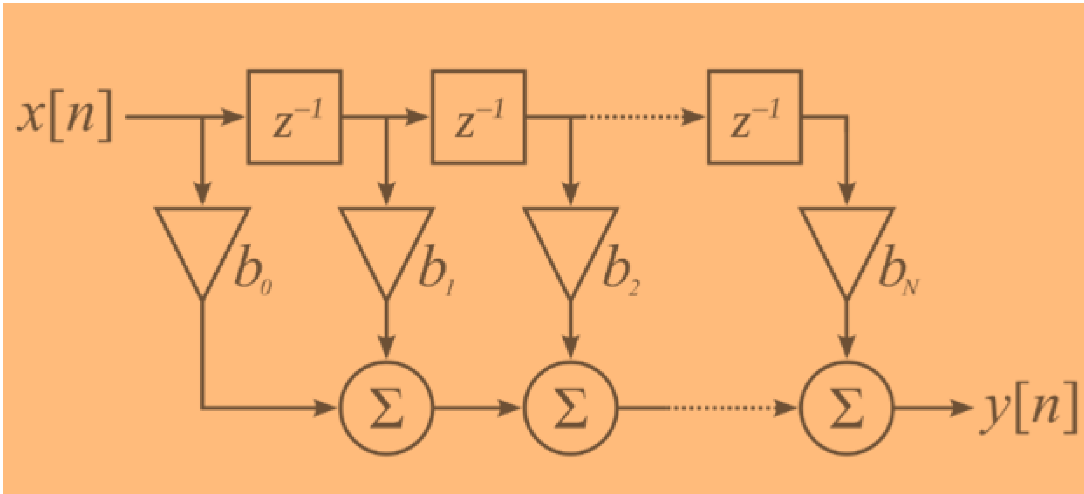


Editor's note: Adding a small amount of noise by dithering noise to the input signal allows a more precise representation of a signal over time.

An **adaptive filter DSP** audio filter can be used to remove **unwanted noise from a received SSB** signal

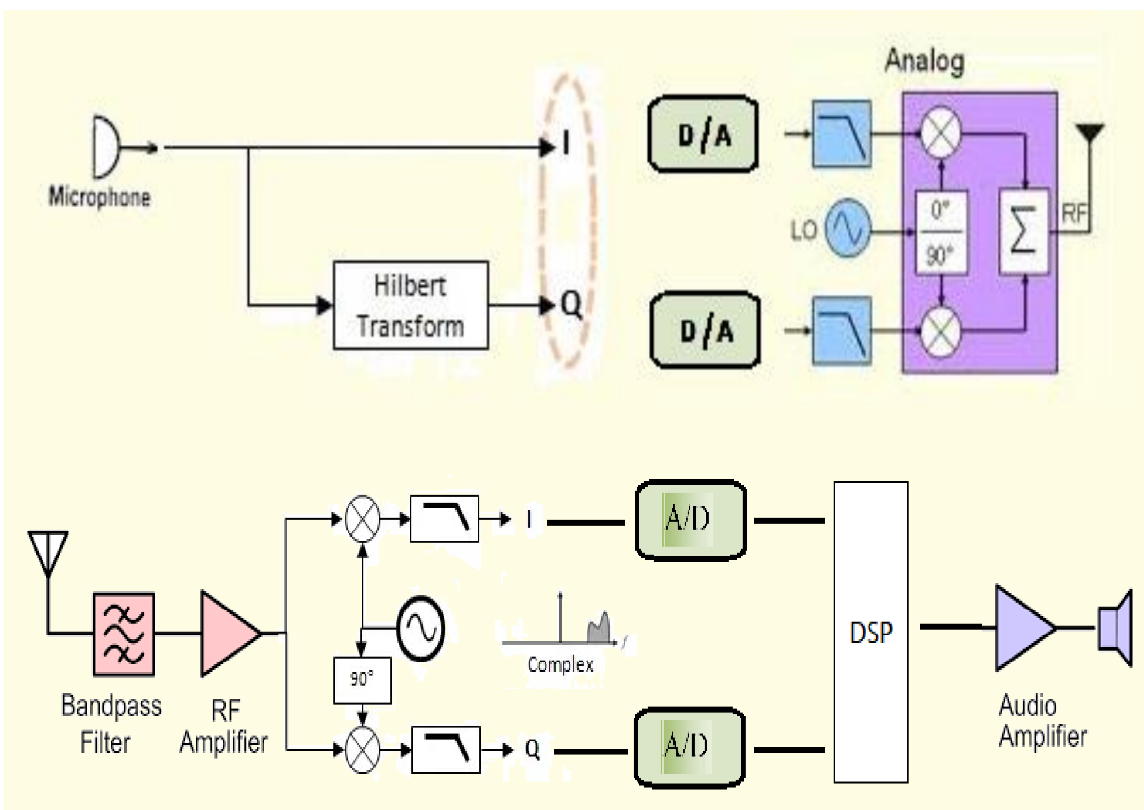


A direct form discrete-time **Finite Impulse Response (FIR) filter** of order N. The top part is an N-stage delay line with N + **function of taps**. Each unit delay is a z−1 operator in Z-transform notation.



More taps allow a digital signal processing filter to create a sharper filter response

A **Hilbert-transform is a DSP filter** might be used to generate an SSB signal



Editor's note: the Hilbert transform is a particularly simple representation in the frequency domain: it imparts a phase shift of 90° to every Fourier component of a function. Implementing a Hilbert transform enables us to create an analytic signal based on some original real-valued signal. And in the comms world we can use the analytic signal to easily and accurately compute the instantaneous magnitude of the original real-valued signal.

==

E7F01 (C) What is meant by direct digital conversion as applied to software defined radios? A. Software is converted from source code to object code during operation of the receiver B. Incoming RF is converted to a control voltage for a voltage controlled oscillator C. Incoming RF is digitized by an analog-to-digital converter without being mixed with a local oscillator signal D. A switching mixer is used to generate I and Q signals directly from the RF input

E7F02 (A) What kind of digital signal processing audio filter is used to remove unwanted noise from a received SSB signal? A. An adaptive filter B. A crystal-lattice filter C. A Hilbert-transform filter D. A phase-inverting filter

E7F03 (C) What type of digital signal processing filter is used to generate an SSB signal? A. An adaptive filter B. A notch filter C. A Hilbert-transform filter D. An elliptical filter

E7F04 (D) What is a common method of generating an SSB signal using digital signal processing? A. Mixing products are converted to voltages and subtracted by adder circuits B. A frequency synthesizer removes the unwanted sidebands C. Varying quartz crystal characteristics emulated in digital form D. Signals are combined in quadrature phase relationship

E7F05 (B) How frequently must an analog signal be sampled by an analog-to-digital converter so that the signal can be accurately reproduced? A. At least half the rate of the highest frequency component of the signal B. At least twice the rate of the highest frequency component of the signal C. At the same rate as the highest frequency component of the signal D. At four times the rate of the highest frequency component of the signal

E7F06 (D) What is the minimum number of bits required for an analog-to-digital converter to sample a signal with a range of 1 volt at a resolution of 1 millivolt? A. 4 bits B. 6 bits C. 8 bits D. 10 bits

E7F07 (C) What function is performed by a Fast Fourier Transform? A. Converting analog signals to digital form B. Converting digital signals to analog form C. Converting digital signals from the time domain to the frequency domain D. Converting 8-bit data to 16-bit data

E7F08 (B) What is the function of decimation? A. Converting data to binary code decimal form B. Reducing the effective sample rate by removing samples C. Attenuating the signal D. Removing unnecessary significant digits

E7F09 (A) Why is an anti-aliasing digital filter required in a digital decimator? A. It removes high-frequency signal components that would otherwise be reproduced as lower frequency components B. It peaks the response of the decimator, improving bandwidth C. It removes low-frequency signal components to eliminate the need for DC restoration D. It notches out the sampling frequency to avoid sampling errors

E7F10 (A) What aspect of receiver analog-to-digital conversion determines the maximum receive bandwidth of a Direct Digital Conversion SDR? A. Sample rate B. Sample width in bits C. Sample clock phase noise D. Processor latency

E7F11 (B) What sets the minimum detectable signal level for a direct-sampling SDR receiver in the absence of atmospheric or thermal noise? A. Sample clock phase noise B. Reference voltage level and sample width in bits C. Data storage transfer rate D. Missing codes and jitter

E7F12 (A) Which of the following is an advantage of a Finite Impulse Response (FIR) filter vs an Infinite Impulse Response (IIR) digital filter? A. FIR filters can delay all frequency components of the signal by the same amount B. FIR filters are easier to implement for a given set of passband rolloff requirements C. FIR filters can respond faster to impulses D. All these choices are correct

E7F13 (D) What is the function of taps in a digital signal processing filter? A. To reduce excess signal pressure levels B. Provide access for debugging software C. Select the point at which baseband signals are generated D. Provide incremental signal delays for filter algorithms

E7F14 (B) Which of the following would allow a digital signal processing filter to create a sharper filter response? A. Higher data rate B. More taps C. Complex phasor representations D. Double-precision math routines

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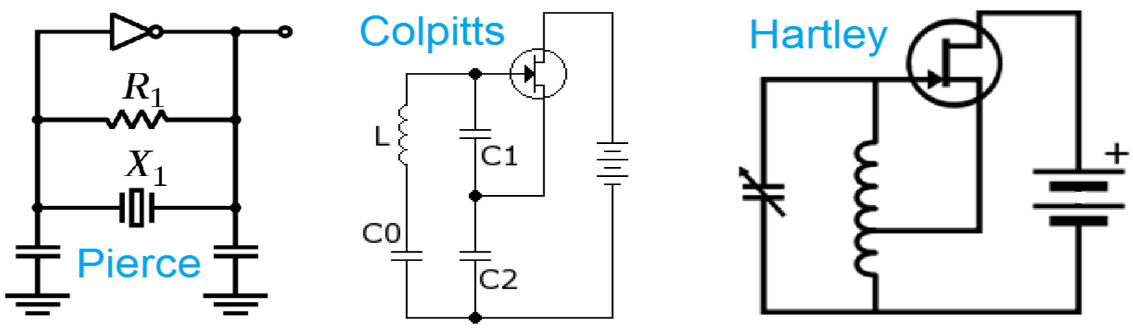
E7H Oscillators and signal sources

==

Colpitts, Hartley and Pierce are three oscillator circuits used in Amateur Radio equipment

Colpitts and Hartley oscillator circuits are commonly used in VFOs

Editor's note: For a circuit to oscillate it must have positive feedback with a gain greater than 1



Positive feedback supplied in a **Hartley** oscillator through a **tapped coil**

Positive feedback supplied in a **Colpitts** oscillator through a **capacitive divider**

Positive feedback supplied in a **Pierce** oscillator through a **quartz crystal**

Microphonic is a change in oscillator frequency due to mechanical vibration that can be reduced or stopped by **isolating the oscillator circuitry from its enclosure**

NP0 capacitors can be used to reduce thermal drift in crystal oscillators

Parallel capacitance must be provided to ensure that a **crystal oscillator provides the frequency** specified by the crystal manufacturer

GPS, rubidium oscillator and a temperature-controlled high Q dielectric resonator are techniques for providing highly accurate and stable oscillators

===

E7H01 (D) What are three oscillator circuits used in amateur radio equipment? A. Taft, Pierce and negative feedback B. Pierce, Fenner and Beane C. Taft, Hartley and Pierce D. Colpitts, Hartley and Pierce

E7H02 (C) What is a microphonic? A. An IC used for amplifying microphone signals B. Distortion caused by RF pickup on the microphone cable C. Changes in oscillator frequency due to mechanical vibration D. Excess loading of the microphone by an oscillator

E7H03 (A) How is positive feedback supplied in a Hartley oscillator? A. Through a tapped coil B. Through a capacitive divider C. Through link coupling D. Through a neutralizing capacitor

E7H04 (C) How is positive feedback supplied in a Colpitts oscillator? A. Through a tapped coil B. Through link coupling C. Through a capacitive divider D. Through a neutralizing capacitor

E7H05 (D) How is positive feedback supplied in a Pierce oscillator? A. Through a tapped coil B. Through link coupling C. Through a neutralizing capacitor D. Through a quartz crystal

E7H06 (B) Which of the following oscillator circuits are commonly used in VFOs? A. Pierce and Zener B. Colpitts and Hartley C. Armstrong and deForest D. Negative feedback and balanced feedback

E7H07 (D) How can an oscillator's microphonic responses be reduced? A. Use NP0 capacitors B. Reduce noise on the oscillator's power supply C. Increase the bias voltage D. Mechanically isolate the oscillator circuitry from its enclosure

E7H08 (A) Which of the following components can be used to reduce thermal drift in crystal oscillators? A. NP0 capacitors B. Toroidal inductors C. Wirewound resistors D. Non-inductive resistors

E7H12 (B) Which of the following must be done to ensure that a crystal oscillator provides the frequency specified by the crystal manufacturer? A. Provide the crystal with a specified parallel inductance B. Provide the crystal with a specified parallel capacitance C. Bias the crystal at a specified voltage D. Bias the crystal at a specified current

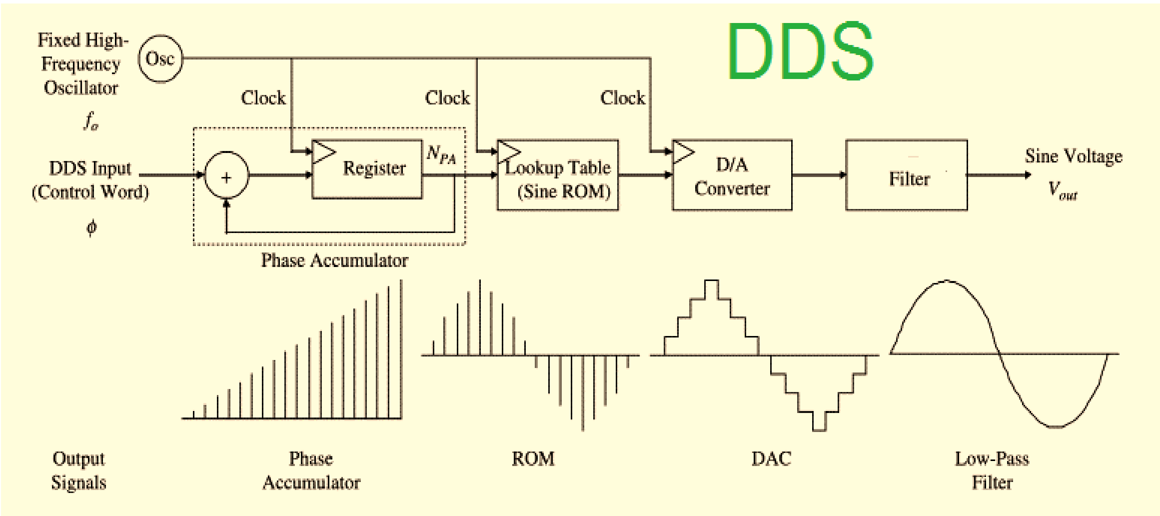
E7H13 (D) Which of the following is a technique for providing highly accurate and stable oscillators needed for microwave transmission and reception? A. Use a GPS signal reference B. Use a rubidium stabilized reference oscillator C. Use a temperature-controlled high Q dielectric resonator D. All these choices are correct

==

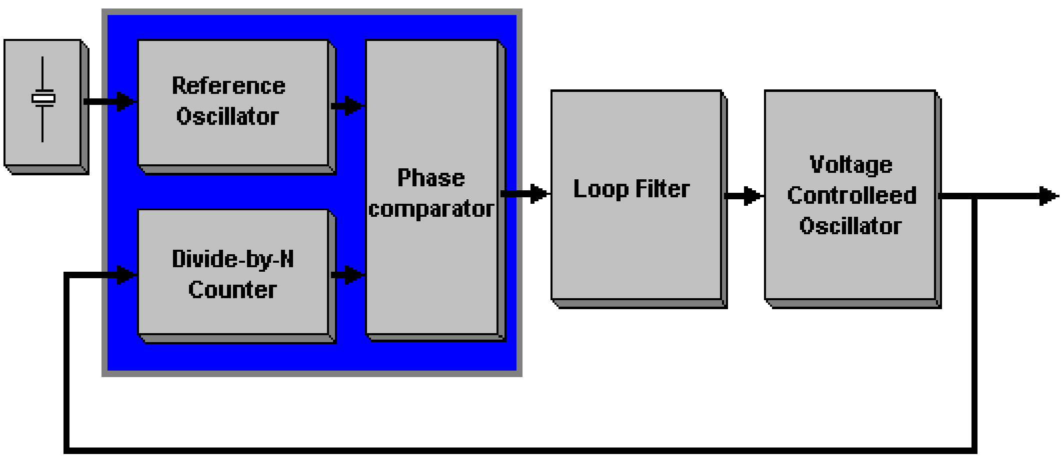
Phase accumulator is a principal component of a **Direct Digital Synthesizer (DDS)**

The amplitude values that represent a sine-wave output is contained in the **lookup table of a DDS**

Spurious signals at discrete frequencies are the major spectral impurity components of **DDS**



A **Phase-Locked Loop (PPL)** circuit an electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator



Frequency synthesis and FM demodulation are functions can be performed by a PLL

Editor's notes:

A Direct Digital Synthesizer (DDS) circuit uses a phase accumulator, lookup table, digital to analog converter and a low-pass anti-alias filter

A PLL is used as VFO because it has the same degree of frequency stability as a crystal oscillator

The frequency range over which the circuit can lock is the capture range of a PLL circuit

Why is the short-term stability of the reference oscillator important in because any phase variations in the reference oscillator signal will produce phase noise in the synthesizer output in a PLL

Phase noise is the major spectral impurity components of PLL

==

E7H09 (A) What type of frequency synthesizer circuit uses a phase accumulator, lookup table, digital to analog converter, and a low-pass anti-alias filter? A. A direct digital synthesizer B. A hybrid synthesizer C. A phase-locked loop synthesizer D. A diode-switching matrix synthesizer

E7H10 (B) What information is contained in the lookup table of a direct digital synthesizer (DDS)? A. The phase relationship between a reference oscillator and the output waveform B. Amplitude values that represent the desired waveform C. The phase relationship between a voltage-controlled oscillator and the output waveform D. Frequently used receiver and transmitter frequencies

E7H11 (C) What are the major spectral impurity components of direct digital synthesizers? A. Broadband noise B. Digital conversion noise C. Spurious signals at discrete frequencies D. Nyquist limit noise

E7H14 (C) What is a phase-locked loop circuit? A. An electronic servo loop consisting of a ratio detector, reactance modulator, and voltage-controlled oscillator B. An electronic circuit also known as a monostable multivibrator C. An electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator D. An electronic circuit consisting of a precision push-pull amplifier with a differential input

E7H15 (D) Which of these functions can be performed by a phase-locked loop? A. Wide-band AF and RF power amplification B. Comparison of two digital input signals, digital pulse counter C. Photovoltaic conversion, optical coupling D. Frequency synthesis, FM demodulation

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E7C Filters and matching networks

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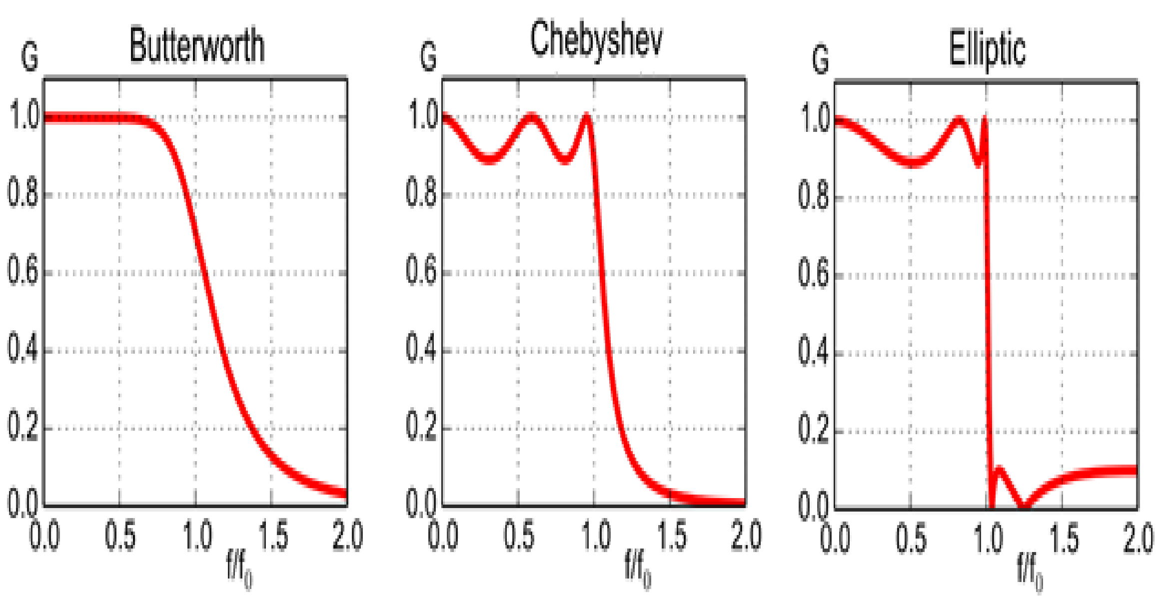
An **elliptical filter** has extremely sharp cutoff with one or more notches in the stop band

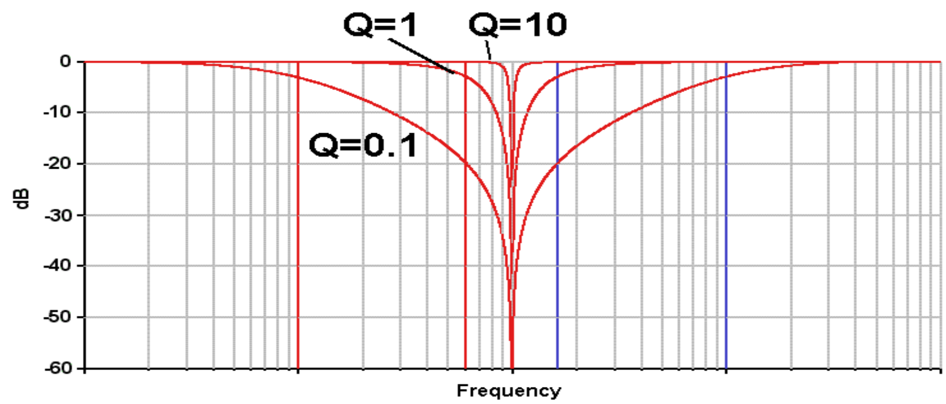
Chebyshev filter has ripple in the passband and a sharp cutoff.



Editor's note: The Butterworth filter is a type of signal processing filter designed to have a frequency response as flat as possible in the passband. The desired signal will pass through the filter without attenuation.

The Q of Pi-networks can be controlled is one advantage of a Pi-matching network over an L-matching network consisting of a single inductor and a single capacitor

The **Q of Pi networks can be varied** depending on the component values chosen



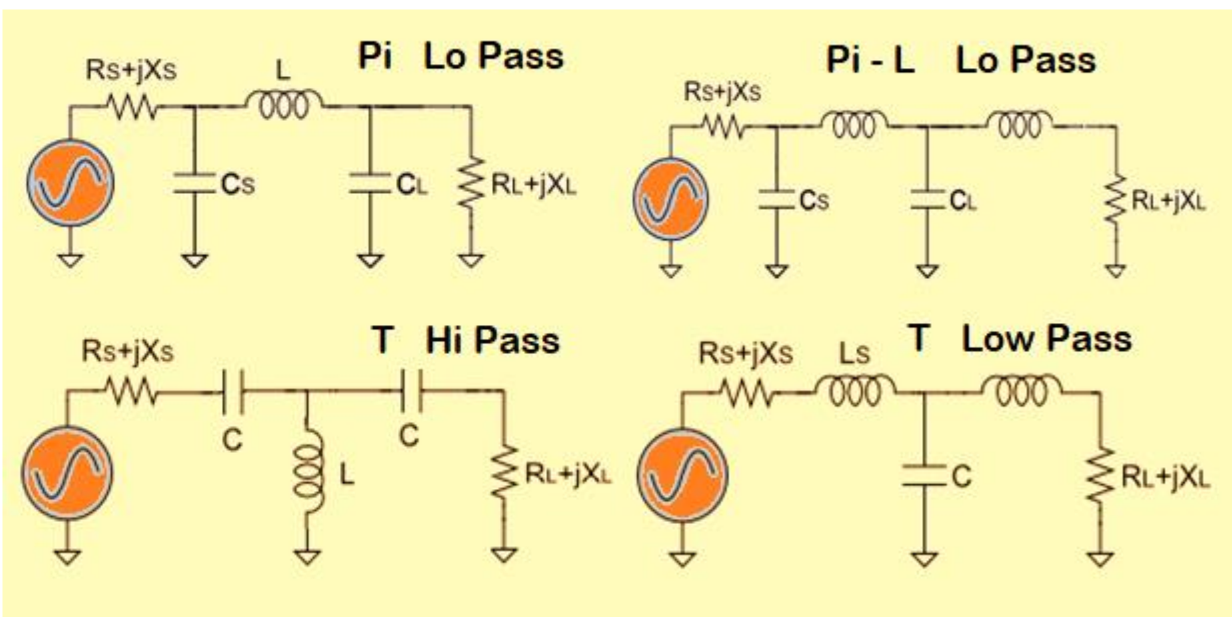
A **low-pass filter Pi-network** has a capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between input and output

A **Pi-L network** with a series inductor on the output is used for matching a **vacuum-tube final** amp to 50-ohm output

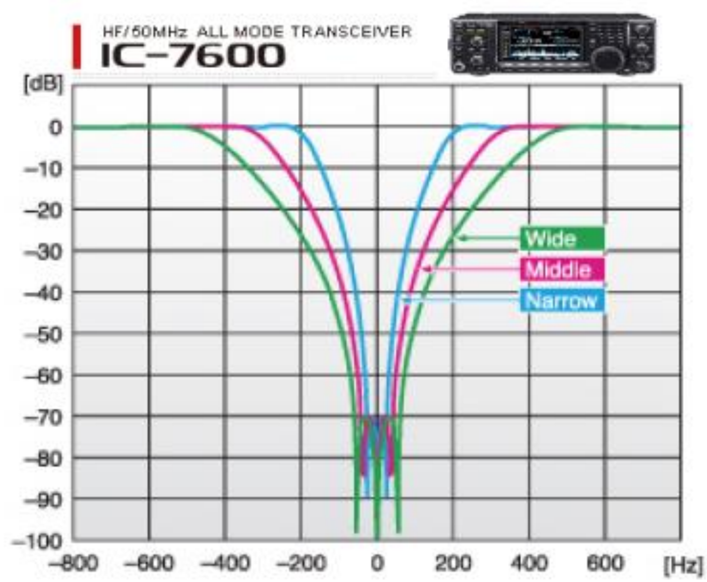
An **impedance-matching** circuit transforms a complex impedance to a resistive impedance by **cancelling the reactive** part of the impedance and changes the resistive part to a desired value

A **Pi-L-network** has **greater harmonic suppression** over a Pi-network for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna

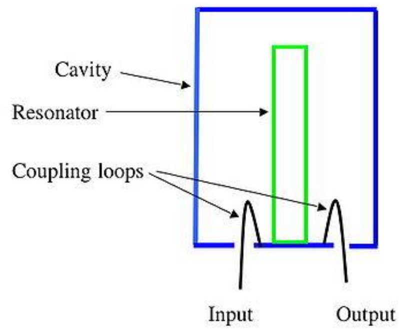
A **T-network** with series capacitors and a parallel shunt inductor is a **high-pass filter**



Shape factor describes a receiving filter's ability to **reject signals occupying an adjacent channel**

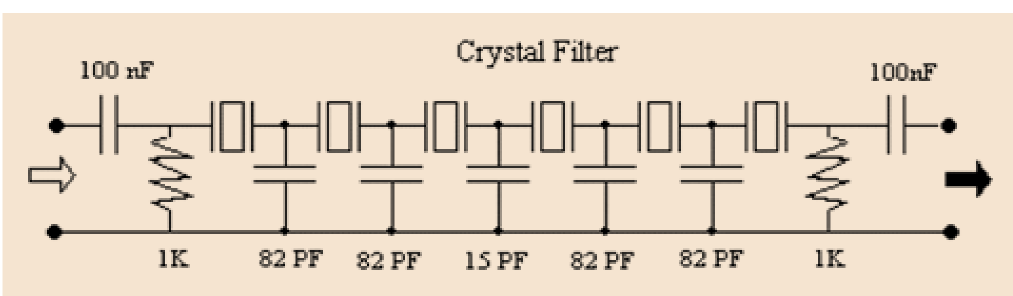


A **cavity filter** would be the best choice for use in a 2M repeater duplexer



A **crystal lattice filter** is a filter with **narrow bandwidth and steep skirts** made using quartz crystals

The **relative frequencies of each crystal** determine the bandwidth and response shape of a **crystal ladder filter**



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E7C01 (D) How are the capacitors and inductors of a low-pass filter Pi-network arranged between the network's input and output? A. Two inductors are in series between the input and output, and a capacitor is connected between the two inductors and ground B. Two capacitors are in series between the input and output, and an inductor is connected between the two capacitors and ground C. An inductor is connected between the input and ground, another inductor is connected between the output and ground, and a capacitor is connected between the input and output D. A capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between input and output

E7C02 (C) Which of the following is a property of a T-network with series capacitors and a parallel shunt inductor? A. It is a low-pass filter B. It is a band-pass filter C. It is a high-pass filter D. It is a notch filter

E7C03 (A) What advantage does a series-L Pi-L-network have over a series-L Pi-network for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna? A. Greater harmonic suppression B. Higher efficiency C. Does not require a capacitor D. Greater transformation range

E7C04 (C) How does an impedance-matching circuit transform a complex impedance to a resistive impedance? A. It introduces negative resistance to cancel the resistive part of impedance B. It introduces transconductance to cancel the reactive part of impedance C. It cancels the reactive part of the impedance and changes the resistive part to a desired value D. Reactive currents are dissipated in matched resistances

E7C05 (D) Which filter type is described as having ripple in the passband and a sharp cutoff? A. A Butterworth filter B. An active LC filter C. A passive op-amp filter D. A Chebyshev filter

E7C06 (C) What are the distinguishing features of an elliptical filter? A. Gradual passband rolloff with minimal stop band ripple B. Extremely flat response over its pass band with gradually rounded stop band corners C. Extremely sharp cutoff with one or more notches in the stop band D. Gradual passband rolloff with extreme stop band ripple

E7C07 (B) Which describes a Pi-L-network used for matching a vacuum tube final amplifier to a 50-ohm unbalanced output? A. A Phase Inverter Load network B. A Pi-network with an additional series inductor on the output C. A network with only three discrete parts D. A matching network in which all components are isolated from ground

E7C08 (A) Which of the following factors has the greatest effect on the bandwidth and response shape of a crystal ladder filter? A. The relative frequencies of the individual crystals B. The DC voltage applied to the quartz crystal C. The gain of the RF stage preceding the filter D. The amplitude of the signals passing through the filter

E7C09 (D) What is a crystal lattice filter? A. A power supply filter made with interlaced quartz crystals B. An audio filter made with four quartz crystals that resonate at 1 kHz intervals C. A filter using lattice-shaped quartz crystals for high-Q performance D. A filter with narrow bandwidth and steep skirts made using quartz crystals

E7C10 (B) Which of the following filters would be the best choice for use in a 2 meter band repeater duplexer? A. A crystal filter B. A cavity filter C. A DSP filter D. An L-C filter

E7C11 (C) Which of the following describes a receiving filter's ability to reject signals occupying an adjacent channel? A. Passband ripple B. Phase response C. Shape factor D. Noise factor

E7C12 (A) What is one advantage of a Pi-matching network over an L-matching network consisting of a single inductor and a single capacitor? A. The Q of Pi-networks can be controlled B. L-networks cannot perform impedance transformation C. Pi-networks are more stable D. Pi-networks provide balanced input and output

==

E7D Power supplies and voltage regulators

==

The conduction of a control element is varied to **maintain a constant output voltage** in a **LINEAR** voltage regulator.

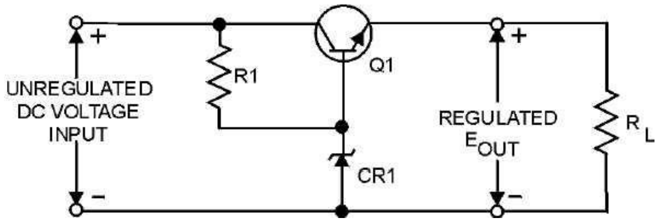
The pass transistor maintains a constant output voltage in a **linear** voltage regulator circuit over a wide range of load current.

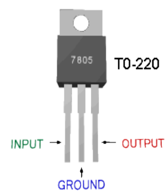
Minimum input-to-output voltage required to maintain regulation is the **drop-out voltage.**

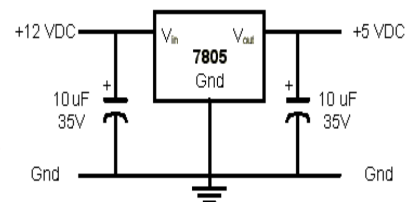
Voltage difference from input to output multiplied by output current is **the power dissipation.**

A **Zener diode** is typically used as a stable **reference voltage** in a linear voltage regulator

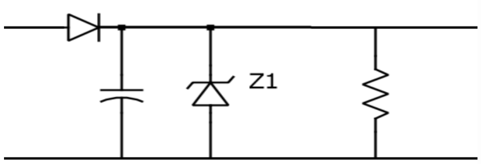
Of the linear voltage regulators, a **series regulator** usually makes the **most efficient use** of the primary power source

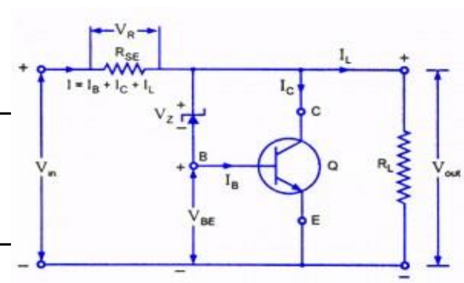






A **shunt regulator** is a linear voltage regulator with a **constant load** on the unregulated voltage source

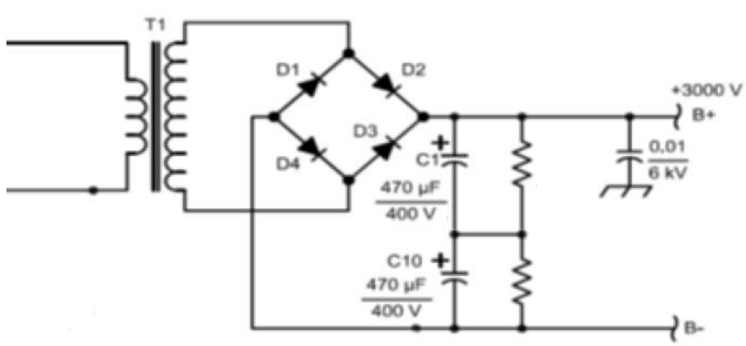




Transistor Shunt Voltage Regulator

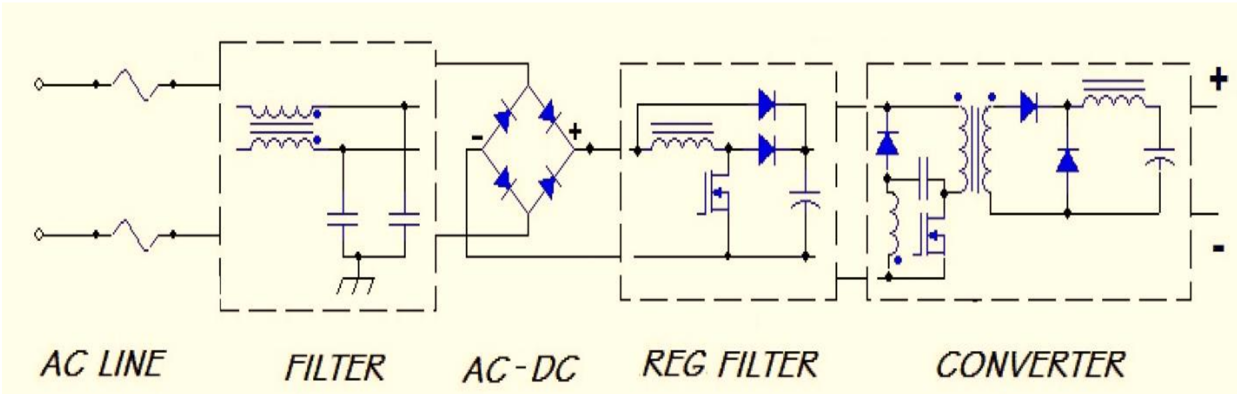
When several electrolytic **filter capacitors are connected in series** to increase the operating voltage of a power supply filter circuit, why should resistors be connected across each capacitor?

A. To equalize, as much as possible, the voltage drop across each capacitor
B. To provide a safety bleeder to discharge the capacitors when the supply is off
C. To provide a minimum load current to reduce voltage excursions at light loads
D. All of these choices are correct

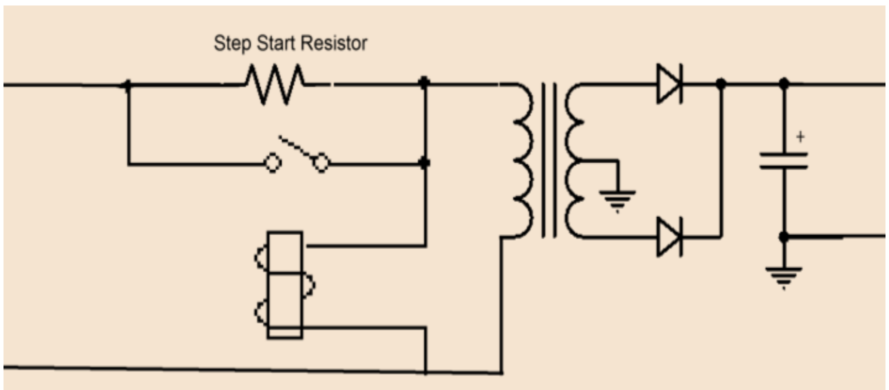


The control device's duty **cycle is controlled to produce a constant average** output voltage in a **SWITCHING** electronic voltage regulator

The **high frequency inverter** design uses much smaller transformers and filter components for an equivalent power output making it both **less expensive and lighter in weight** than a conventional power supply



A **"step-start" circuit** in a high-voltage power supply allows the filter capacitors to charge gradually



A solar power system uses a charge controller to prevention battery damage due to overcharge

==

E7D01 (D) How does a linear electronic voltage regulator work? A. It has a ramp voltage as its output B. It eliminates the need for a pass transistor C. The control element duty cycle is proportional to the line or load conditions D. The conduction of a control element is varied to maintain a constant output voltage

E7D02 (C) What is a characteristic of a switching electronic voltage regulator? A. The resistance of a control element is varied in direct proportion to the line voltage or load current B. It is generally less efficient than a linear regulator C. The controlled device's duty cycle is changed to produce a constant average output voltage D. It gives a ramp voltage at its output

E7D03 (A) What device is typically used as a stable voltage reference in a linear voltage regulator? A. A Zener diode B. A tunnel diode C. An SCR D. A varactor diode

E7D04 (B) Which of the following types of linear voltage regulator usually make the most efficient use of the primary power source? A. A series current source B. A series regulator C. A shunt regulator D. A shunt current source

E7D05 (D) Which of the following types of linear voltage regulator places a constant load on the unregulated voltage source? A. A constant current source B. A series regulator C. A shunt current source D. A shunt regulator

E7D09 (C) What is the main reason to use a charge controller with a solar power system? A. Prevention of battery undercharge B. Control of electrolyte levels during battery discharge C. Prevention of battery damage due to overcharge D. Matching of day and night charge rates

E7D10 (C) What is the primary reason that a high-frequency switching type high-voltage power supply can be both less expensive and lighter in weight than a conventional power supply? A. The inverter design does not require any output filtering B. It uses a diode bridge rectifier for increased output C. The high frequency inverter design uses much smaller transformers and filter components for an equivalent power output D. It uses a large power factor compensation capacitor to recover power from the unused portion of the AC cycle

E7D11 (D) What is the function of the pass transistor in a linear voltage regulator circuit? A. Permits a wide range of output voltage settings B. Provides a stable input impedance over a wide range of source voltage C. Maintains nearly constant output impedance over a wide range of load current D. Maintains nearly constant output voltage over a wide range of load current

E7D12 (C) What is the dropout voltage of an analog voltage regulator? A. Minimum input voltage for rated power dissipation B. Maximum output voltage drops when the input voltage is varied over its specified range C. Minimum input-to-output voltage required to maintain regulation D. Maximum that the output voltage may decrease at rated load

E7D13 (C) What is the equation for calculating power dissipated by a series linear voltage regulator? A. Input voltage multiplied by input current B. Input voltage divided by output current C. Voltage difference from input to output multiplied by output current D. Output voltage multiplied by output current

E7D14 (D) What is the purpose of connecting equal-value resistors across power supply filter capacitors connected in series? A. Equalize the voltage across each capacitor B. Discharge the capacitors when voltage is removed C. Provide a minimum load on the supply D. All these choices are correct

E7D15 (D) What is the purpose of a step-start circuit in a high-voltage power supply? A. To provide a dual-voltage output for reduced power applications B. To compensate for variations of the incoming line voltage C. To allow for remote control of the power supply D. To allow the filter capacitors to charge gradually

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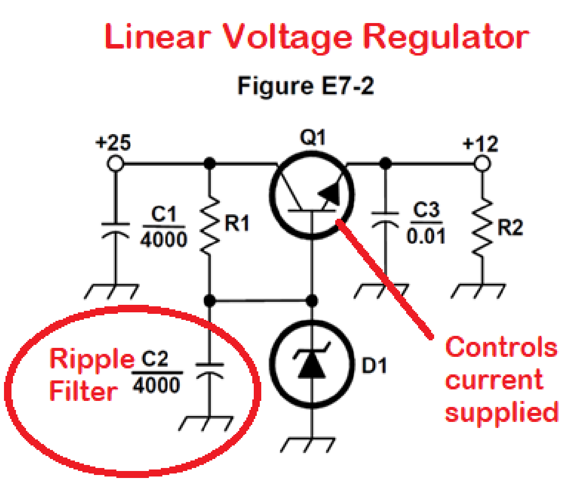

E7D06 (C) What is the purpose of Q1 in the circuit shown in Figure E7-2? A. It provides negative feedback to improve regulation B. It provides a constant load for the voltage source C. It controls the current supplied to the load D. It provides D1 with current

E7D07 (A) What is the purpose of C2 in the circuit shown in Figure E7-2? A. It bypasses rectifier output ripple around D1 B. It is a brute force filter for the output C. To self-resonate at the hum frequency D. To provide fixed DC bias for Q1

E7D08 (C) What type of circuit is shown in Figure E7-2? A. Switching voltage regulator B. Grounded emitter amplifier C. Linear voltage regulator D. Monostable multivibrator

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E7G Active filters and op-amp circuits

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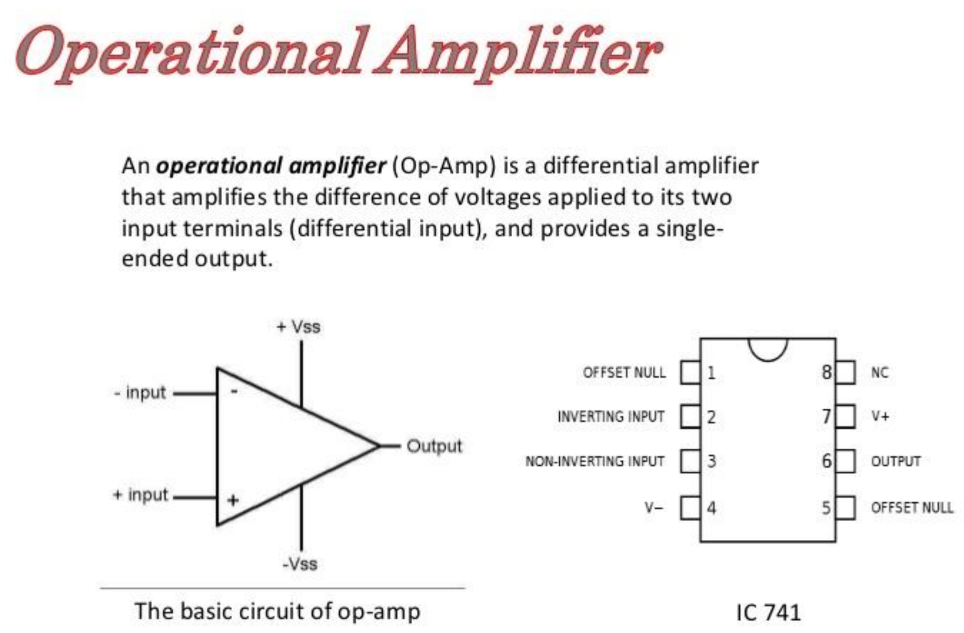


An integrated circuit operational amplifier is a **high-gain, direct-coupled differential amplifier** with very **high input** and very **low output** impedance

The typical **input impedance** of an integrated circuit **op-amp is very high**

The typical **output impedance** of an integrated circuit op-amp is **very low**

The **gain** of an ideal operational amplifier **does not vary with frequency**

The frequency at which the **open-loop gain of the amplifier equals one is the gain-bandwidth** of an operational amplifier

Restrict both gain & Q to prevent ringing and audio instability in a multi-section op-amp RC audio filter

Undesired oscillations added to the desired signal is the effect of **ringing in a filter**

Op-amp **input-offset voltage** is the differential input voltage needed to **bring the open-loop output voltage to zero**

==

E7G01 (A) What is the typical output impedance of an op-amp? A. Very low B. Very high C. 100 ohms D. 1000 ohms

E7G02 (D) What is ringing in a filter? A. An echo caused by a long time delay B. A reduction in high frequency response C. Partial cancellation of the signal over a range of frequencies D. Undesired oscillations added to the desired signal

E7G03 (D) What is the typical input impedance of an op-amp? A. 100 ohms B. 1000 ohms C. Very low D. Very high

E7G04 (C) What is meant by the "op-amp input offset voltage"? A. The output voltage of the op-amp minus its input voltage B. The difference between the output voltage of the op-amp and the input voltage required in the immediately following stage C. The differential input voltage needed to bring the open loop output voltage to zero D. The potential between the amplifier input terminals of the op-amp in an open loop condition

E7G05 (A) How can unwanted ringing and audio instability be prevented in an op-amp RC audio filter circuit? A. Restrict both gain and Q B. Restrict gain but increase Q C. Restrict Q but increase gain D. Increase both gain and Q

E7G06 (B) What is the gain-bandwidth of an operational amplifier? A. The maximum frequency for a filter circuit using that type of amplifier B. The frequency at which the open-loop gain of the amplifier equals one C. The gain of the amplifier at a filter's cutoff frequency D. The frequency at which the amplifier's offset voltage is zero

E7G08 (D) How does the gain of an ideal operational amplifier vary with frequency? A. It increases linearly with increasing frequency B. It decreases linearly with increasing frequency C. It decreases logarithmically with increasing frequency D. It does not vary with frequency

E7G12 (A) What is an operational amplifier? A. A high-gain, direct-coupled differential amplifier with very high input impedance and very low output impedance B. A digital audio amplifier whose characteristics are determined by components external to the amplifier C. An amplifier used to increase the average output of frequency modulated amateur signals to the legal limit D. A RF amplifier used in the UHF and microwave regions

==

Editor's note: An operational amplifier is one of the most useful linear devices that have been developed with integrated circuitry. While it is possible to build an op amp with discrete components, the symmetry of this circuit requires a close match of many components and is more effective, and much easier, to implement in integrated circuitry. The op amp approaches a perfect analog circuit building block. Ideally, an op amp has infinite input impedance (Zi), zero output impedance (Zo) and an open loop voltage gain (Av) of infinity. Obviously, practical op amps do not meet these specifications, but they do come closer than most other types of amplifiers. The gain of an op amp is the function of the input resistor and the feedback resistor. Gain in calculated by dividing the input resistor R1 value into the feedback resistor Rf. In figure E7-4 if the input resistor,R1, is 10,000 ohms and the feedback resistor ,Rf, 1s 1,000,000 ohms the gain would be 1,000,0000 / 10,000 or a gain of 100. The output is inverted in this configuration when the signal is feed into the negative pin of the op amp. This is the most commonly used configuration. Op amp can be configured in a non-inverting so the output signal is the same polarity as the input signal. – AD7FO

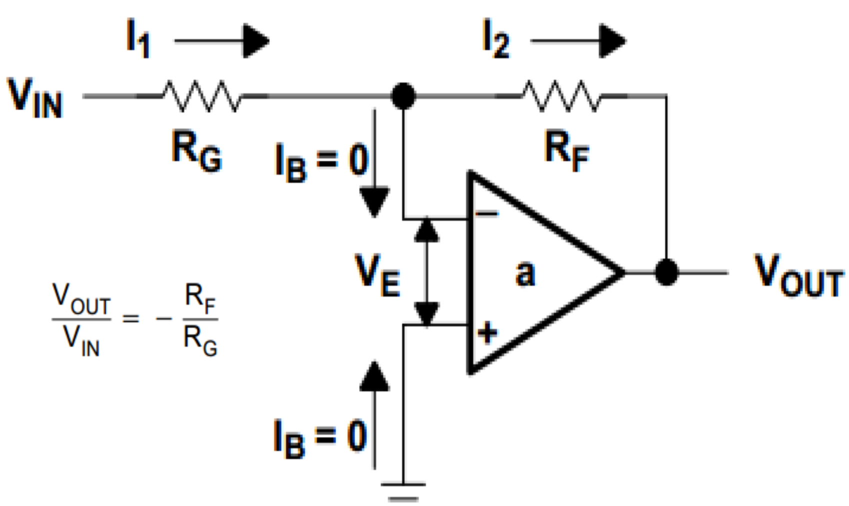
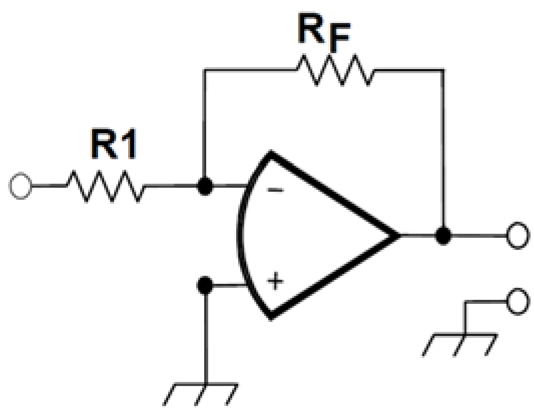


Figure E7-3



Gain = RF / R1

E7G07 (C) What magnitude of voltage gain can be expected from the circuit in Figure E7 3 when R1 is 10 ohms and RF is 470 ohms? A. 0.21 B. 94 C. 47 D. 24

Gain = RF /R1

Gain = 470/10

Gain = 47

E7G10 (C) What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 1800 ohms and RF is 68 kilohms? A. 1 B. 0.03 C. 38 D. 76

Gain = -RF /R1

Gain = 68K/1800

Gain = 37.78

E7G11 (B) What absolute voltage gain can be expected from the circuit in Figure E7-3 when R1 is 3300 ohms and RF is 47 kilohms? A. 28 B. 14 C. 7 D. 0.07

Gain = RF /R1

Gain = 47K/3300

Gain = 14.24

E7G09 (D) What will be the output voltage of the circuit shown in Figure E7-3 if R1 is 1000 ohms, RF is 10,000 ohms, and 0.23 volts DC is applied to the input? A. 0.23 volts B. 2.3 volts C. -0.23 volts D. -2.3 volts

Gain = RF /R1

Gain = 10K/1K

Gain = 10

V Output = Input x Gain

Vop = 0.23 x -10

Vop = - 2.3 V

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Class Two Fundamentals and Substance

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After completing each class be sure to use the Fundamentals and Substance subsection that was solely created as a tool for test preparation by helping you make connections between topics and serves as quality review material for after each class. Using these steps can be most useful when learning about new topics that include a lot of detail. The information is in the form of class notes with all of the important information you need to know. These notes are not a substitute for studying the class material in fact you will need to complete your class assignment in order to effectively use these notes. The notes are organized into easily digestible headings and bullet points to organize topics with the key words, main subpoints and summary are all written in one place.

==

Semiconductors

N-type semiconductor materials contains excess **free electrons**

Acceptor impurity is an impurity atom that **adds holes** to a semiconductor **crystal structure**

At **microwave frequencies gallium arsenide** is used as a semiconductor material in preference to germanium or silicon

PN-junction diode not conduct current when reverse biased because holes in P-type material and electrons in the N-type material are separated by the applied voltage, widening the depletion region

A **bipolar transistor has low input impedance**

The change of **collector current with respect to base current** is the **beta** of a bipolar junction transistor

A silicon **NPN transistor is biased on** has a base-to-emitter voltage of approx. **0.6 to 0.7 volts**

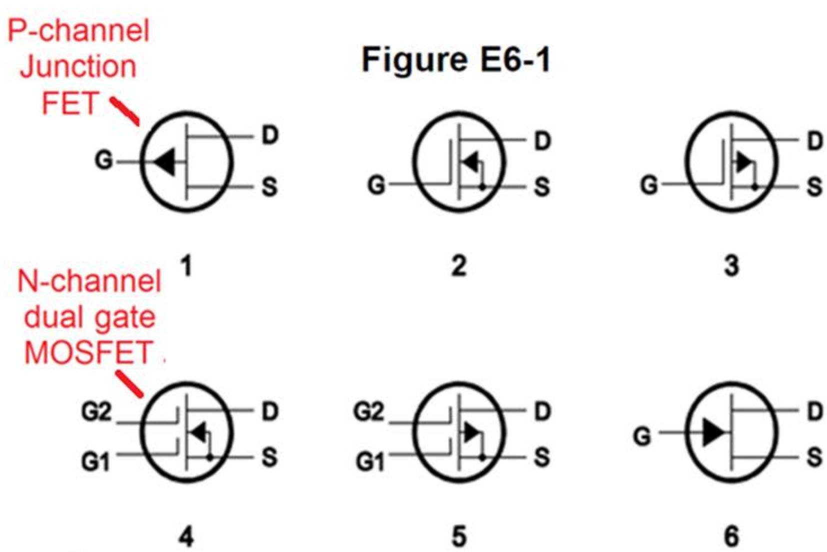
Alpha cutoff is the frequency at which the gain of a transistor has decreased to **0.7 of the gain obtainable at 1 kHz**

An **FET has high input impedance**

Depletion-mode is when a FET that has a current between source and drain but no gate voltage

MOSFET devices have internally connected Zener diodes on the gates to reduce the chance of **static damage** to the gate

Figure E6-1



Diodes

A **Zener diode** maintains a **constant voltage** drop under conditions of varying current

A **Schottky diode has less forward voltage drop** silicon diode when used as a power supply rectifier

Schottky diode is a commonly used as a **VHF/UHF mixer or detector**

Metal-semiconductor junction describes a **Schottky diode**

Excessive junction temperature is the failure mechanism when a **junction diode fails** due to excessive current

Forward bias is required for an **LED to emit light**

A **Varactor diode** is designed for use as a **voltage-controlled capacitor**

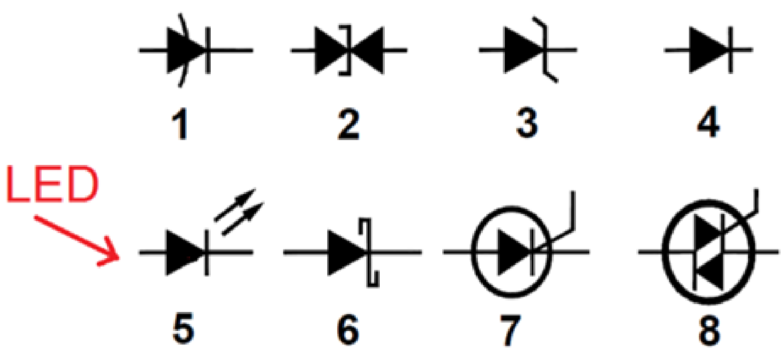
Low junction capacitance of a PIN diode makes it useful as an **RF switch**

An **RF detector** is a common use for **point contact diodes**

Forward DC bias current is used to **control the attenuation** of RF signals by a **PIN diode**

A **Tunnel diode** is capable of both **amplification and oscillation**

Figure E6-2



Integrated Circuits

Bi-state logic are logic devices with **0 and 1** output states

Tri-state logic are logic devices with **0, 1, and high impedance** output states

Lower power consumption is an advantage of CMOS logic devices over TTL devices

BiCMOS logic has the high input impedance of CMOS and the low output impedance of bipolar transistors

CMOS digital integrated circuits have high immunity to noise on the input signal because the switching threshold is about one-half the power supply voltage

A pull-up or pull-down resistor is connected to the supply to establish a voltage when an input or output is an open circuit

Hysteresis in a comparator prevents input noise from causing unstable output signals

When the level of a comparator's **input signal crosses the threshold the output state changes**

A programmable gates and circuits in a single integrated circuit is a **programmable logic device**

Digital Logic

Bi-state logic are logic devices with **0 and 1** output states

A **TRUTH TABLE** is a list of inputs and corresponding outputs for a digital device

Positive Logic is the name for logic which represents a logic "1" as a high voltage

Negative logic is the name for logic which represents a logic "0" as a high voltage

NAND gate produces a logic "0" at its output only when all inputs are logic "1"

OR gate produces a logic "1" at its output if any or all inputs are logic "1"

NOR gate produces a logic "0" at its output if any single input is a logic “1”

Astable multivibrator is a circuit that continuously alternates between two states without an external clock

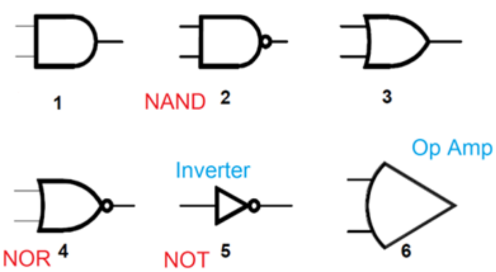
A **monostable multivibrator** switches momentarily to the opposite binary state and then returns, after a set time

A **flip-flop** can **divide** the frequency of a pulse train by **2**

Two flip-flops are required to **divide** a signal frequency by **4**

A decade counter produces one output pulse for every 10 input pulses

Figure E6-3



Electro-optical technology

Electrons absorb the energy from light falling on a photovoltaic cell

The conversion of **LIGHT to ELECTRICAL** energy is the **photovoltaic effect**

Silicon is the most common type of **photovoltaic cell used for electrical power** generation

The **efficiency of a photovoltaic cell** is the relative fraction of light that is converted to current

0.5 V is the approximate open-circuit voltage produced by a fully-illuminated **silicon photovoltaic cell**

A **crystalline semiconductor** is affected the most by photoconductivity

The **conductivity** of a photoconductive material increases **when light shines on it**

Optoisolators commonly are a combination of an **LED and a phototransistor**

An **optical shaft encoder** detects rotation of a control by **interrupting a light source** with a patterned wheel

A **solid-state relay uses semiconductors** to implement the functions of an electromechanical relay

Optoisolators provide a very high degree of control circuit isolation when switching 120 VAC

Inductors

Ferrite and brass are commonly used as a **core material in** an inductor

Permeability of the core material determines the **inductance** of a toroidal inductor

Powdered-iron toroids maintain their **characteristics at higher currents** rather than ferrite toroids

Brass core material decreases inductance when inserted into a coil

Powdered-iron toroids require **fewer turns** for a given inductance value than ferrite toroids

Saturation is when **flux density cannot increase** the magnetization of the material further,

Saturation can cause signal distortion (intermods & harmonics) in amplifiers and matching circuits.

Toroidal cores confine most of the magnetic field within the core material unlike a solenoidal

Inter-turn capacitance is the primary cause of **inductor self-resonance**

Magnetizing current in the primary winding of a transformer is the current when no load is attached to the secondary

Ferrite beads are commonly used as VHF and UHF **parasitic suppressors** on amplifiers

Analog Integrated Circuits

50 ohms is the most common input and output **impedance** of circuits that use **MMICs**

Controlled gain, low noise figure typical 2 dB, constant impedance makes the **MMIC** good for VHF to microwave circuits

The B**+ supply is furnished through a resistor** and/or RF choke connected to the **MMIC output lead**

Microstrip construction is typically used to construct a **MMIC** based microwave amplifier

At UHF & higher frequencies gallium arsenide is used as a semiconductor material

Gallium nitride is likely to provide the highest frequency of operation when used in MMICs

DIP (Dual in-line packages) is a common print circuit board **through-hole IC package**.

DIPs have two parallel rows of pins extending perpendicularly out of the package

DIP through-hole package ICs not typically used at UHF and higher frequencies due to excessive lead length

S**urface-Mount Devices** are suitable for use at frequencies above the HF range

S**urface-Mount Devices** are leadless solving most p**arasitic effects**, smaller circuit area and shorter circuit-board traces.

Amplifiers

A **Class A** common emitter amplifier would bias normally be set half-way between saturation and cutoff

A **Class AB amplifier** operates more than 180 degrees but less than 360 degrees

Class AB designs commonly use a **Push-pull amplifier to eliminate even-order harmonics**

A **Class C** amplifier has Bias is set well into the cutoff region, operates less than 180 degrees

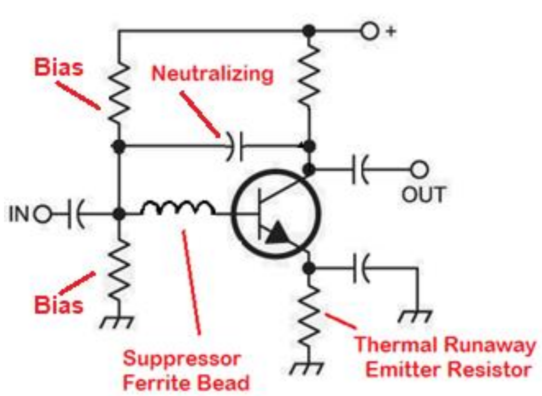
Signal distortion and excessive bandwidth result when a **Class C** amplifier is used to amplify a SSB phone signal

A **Class D** amplifier that uses switching technology to achieve high efficiency

A class **D amplifier** uses **low-pass output filter** to remove switching signal components

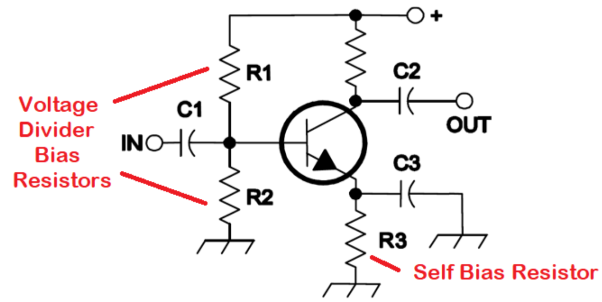
Switching amplifiers more efficient than linear amplifiers because the power transistor is at saturation or cutoff most of the time

Common Base Amplifier Input on Emitter, output on collector, Low impedance input, High impedance output. Primarily used as an impedance converter



Common Emitter Amplifier

Figure E7-1



RF power amplifier be **neutralized b**y feeding **a 180-degree out-of-phase** portion of the **output back to the input**

Install **parasitic suppressors and/or neutralize** prevent unwanted oscillations in an RF amplifier

Use a **resistor in series with the emitter** to prevent **thermal runaway** in a bipolar transistor amplifier

Intermodulation products in a linear power amplifier result in transmission of **spurious signals**

Third-order intermodulation products are relatively **close in frequency to the desired signal**

The typical HF vacuum tube RF amplifier has an VSWR m**ismatch between the final stage tube plate and the antenna** requiring a Pi Network for matching. **The tuning capacitor is adjusted for minimum plate current, and the loading capacitor is adjusted for maximum permissible plate** current

Digital Signal Processing

Direct digital conversion of RF is digitized by an analog-to-digital **converter without being mixed with a local oscillator** signal

Fast Fourier Transform converts a signal from its time domain to frequency domain and vice versa

Direct digital conversion Sample Rate determines **Bandwidth**

Direct digital conversion bandwidth of a Direct Digital Conversion is 1/2 the **Sample Rate**.

Direct digital conversion sample rate must be at least twice the highest frequency of the signal

Reference voltage level and sample bits determine the **minimum detectable signal level** for an SDR

1 volt at a resolution of 1 millivolt requires 1024 samples or 2^10 bits

An anti-aliasing digital filter removes high-frequency signal components that would otherwise be reproduced as lower frequency components

Decimation reducing the effective sample rate by removing samples

An **adaptive filter DSP** audio filter can be used to remove **unwanted noise from a received SSB** signal

A direct form discrete-time **Finite Impulse Response (FIR) filter** of order N. The top part is an N-stage delay line with N + **function of taps**. Each unit delay is a z−1 operator in Z-transform notation.

More taps allow a digital signal processing filter to create a sharper filter response

A **Hilbert-transform is a DSP filter** might be used to generate an SSB signal

Oscillators

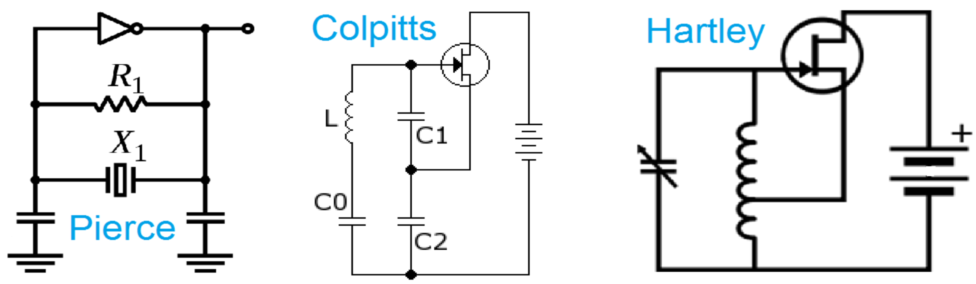
Colpitts, Hartley and Pierce are three oscillator circuits used in Amateur Radio equipment

Colpitts and Hartley oscillator circuits are commonly used in VFOs

Positive feedback supplied in a **Hartley** oscillator through a **tapped coil**

Positive feedback supplied in a **Colpitts** oscillator through a **capacitive divider**

Positive feedback supplied in a **Pierce** oscillator through a **quartz crystal**



Microphonic is a change in oscillator frequency due to mechanical vibration that can be reduced or stopped by **isolating the oscillator circuitry from its enclosure**

NP0 capacitors can be used to reduce thermal drift in crystal oscillators

Parallel capacitance must be provided to ensure that a **crystal oscillator provides the frequency** specified by the crystal manufacturer

GPS, rubidium oscillator and a temperature-controlled high Q dielectric resonator are techniques for providing highly accurate and stable oscillators

Phase accumulator is a principal component of a **Direct Digital Synthesizer (DDS)**

The amplitude values that represent a sine-wave output is contained in the **lookup table of a DDS**

Spurious signals at discrete frequencies are the major spectral impurity components of **DDS**

A **Phase-Locked Loop (PPL)** circuit an electronic servo loop consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator

Frequency synthesis and FM demodulation are functions can be performed by a PLL

Filters and Matching Networks

An **elliptical filter** has extremely sharp cutoff with one or more notches in the stop band

Chebyshev filter has ripple in the passband and a sharp cutoff.

The Q of Pi-networks can be controlled is one advantage of a Pi-matching network over an L-matching network consisting of a single inductor and a single capacitor

The **Q of Pi networks can be varied** depending on the component values chosen

A **low-pass filter Pi-network** has a capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between input and output

A **Pi-L network** with a series inductor on the output is used for matching a **vacuum-tube final** amp to 50-ohm output

An **impedance-matching** circuit transforms a complex impedance to a resistive impedance by **cancelling the reactive** part of the impedance and changes the resistive part to a desired value

A **Pi-L-network** has **greater harmonic suppression** over a Pi-network for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna

A **T-network** with series capacitors and a parallel shunt inductor is a **high-pass filter**

Shape factor describes a receiving filter's ability to **reject signals occupying an adjacent channel**

A **cavity filter** would be the best choice for use in a 2M repeater duplexer

A **crystal lattice filter** is a filter with **narrow bandwidth and steep skirts** made using quartz crystals

The **relative frequencies of each crystal** determine the bandwidth and response shape of a **crystal ladder filter**

Physical deformation of a crystal by the application of a voltage is one aspect of the piezoelectric effect

A motional capacitance, motional inductance, and loss resistance in series, all in parallel with a shunt capacitor representing electrode and stray capacitance **is the equivalent circuit of a quartz crystal.**

Power Supplies

The conduction of a control element is varied to **maintain a constant output voltage** in a **LINEAR** voltage regulator.

The pass transistor maintains a constant output voltage in a **linear** voltage regulator circuit over a wide range of load current.

Minimum input-to-output voltage required to maintain regulation is the **drop-out voltage.**

Voltage difference from input to output multiplied by output current is **the power dissipation.**

A **Zener diode** is typically used as a stable **reference voltage** in a linear voltage regulator

Of the linear voltage regulators, a **series regulator** usually makes the **most efficient use** of the primary power source

A **shunt regulator** is a linear voltage regulator with a **constant load** on the unregulated voltage source

The control device's duty **cycle is controlled to produce a constant average** output voltage in a **SWITCHING** electronic voltage regulator

The **high frequency inverter** design uses much smaller transformers and filter components for an equivalent power output making it both **less expensive and lighter in weight** than a conventional power supply

A **"step-start" circuit** in a high-voltage power supply allows the filter capacitors to charge gradually

A solar power system uses a charge controller to prevention battery damage due to overcharge

Operational Amplifiers

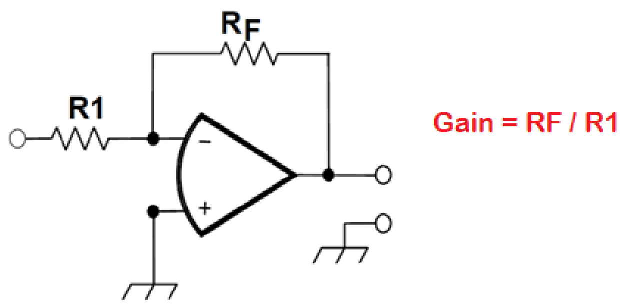
An integrated circuit operational amplifier is a **high-gain, direct-coupled differential amplifier** with very **high input** and very **low output** impedance

The typical **input impedance** of an integrated circuit **op-amp is very high**

The typical **output impedance** of an integrated circuit op-amp is **very low**

The **gain** of an ideal operational amplifier **does not vary with frequency**

Figure E7-3



The frequency at which the **open-loop gain of the amplifier equals one is the gain-bandwidth** of an operational amplifier

Restrict both gain & Q to prevent ringing and audio instability in a multi-section op-amp RC audio filter

Undesired oscillations added to the desired signal is the effect of **ringing in a filter**

Op-amp **input-offset voltage** is the differential input voltage needed to **bring the open-loop output voltage to zero**

CLASS 3 – WAVEFORMS, MODULATION, RECEIVERS, OPERATING METHODS, SPACE AND TELEVISION

==

E8A AC Waveforms

E4A Test equipment

E4B Measurement technique and limitations

E7E Modulation and Demodulation

E8B Modulation and Demodulation

E8C Digital signals

E8D Keying defects and overmodulation of digital signals

E4C Receiver performance characteristics

E4D Receiver performance characteristics

E4E Noise suppression and interference

E2C, E2D, E2E Operating methods

E2A Amateur radio in space

E2B Television practices

Class Three Fundamentals and Substance

==

E8A AC Waveforms

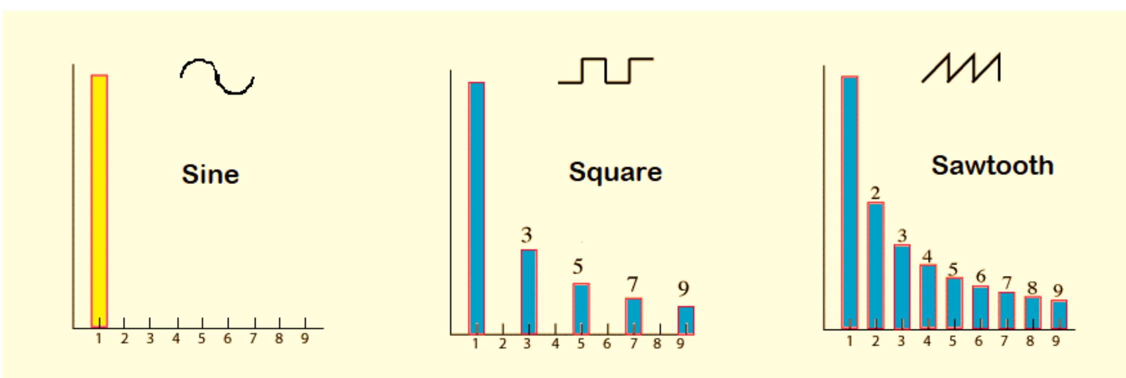
==

256 **different input levels can be encoded by an ADC with 8-bit resolution** or 2^8 bits

n	n^2	n^3	n^4	n^5	n^6	n^7	n^8	n^9	n^{10}
2	4	8	16	32	64	128	256	512	1,024

A Square wave is made up of a sine wave plus all of its odd harmonics

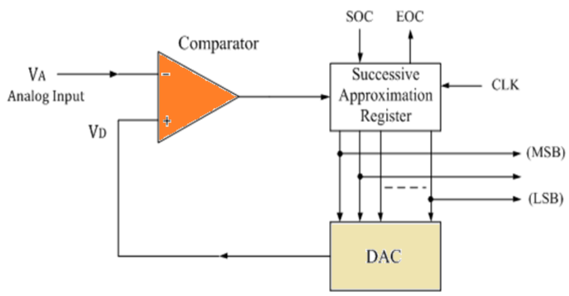
A Saw Tooth wave is made up of a sine wave plus all of its harmonics



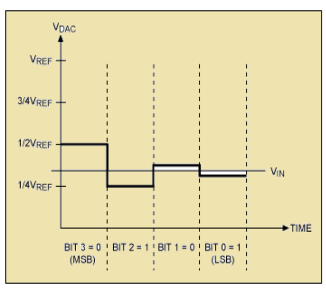
Editor's note: Fourier analysis of t*he wave pictured above shows each wave is made up of a sine wave plus a combination of harmonics.*

Successive Approximation ADC is a type of analog-to-digital converter that compares via a progressive quantization before finally converging upon a digital output for each conversion.

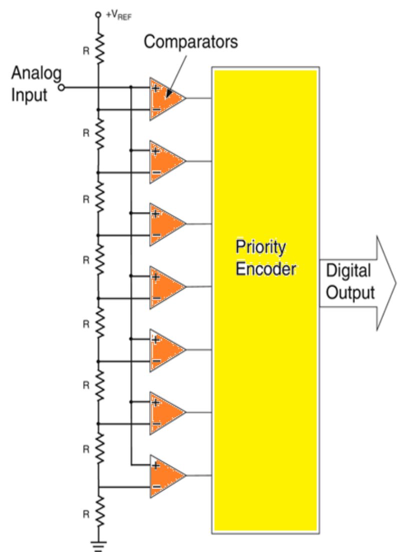
Flash ADC is a type of analog-to-digital converter that uses multiple comparator sat each to compare the input voltage to reference voltages simultaneously (also known as a direct-conversion ADC).



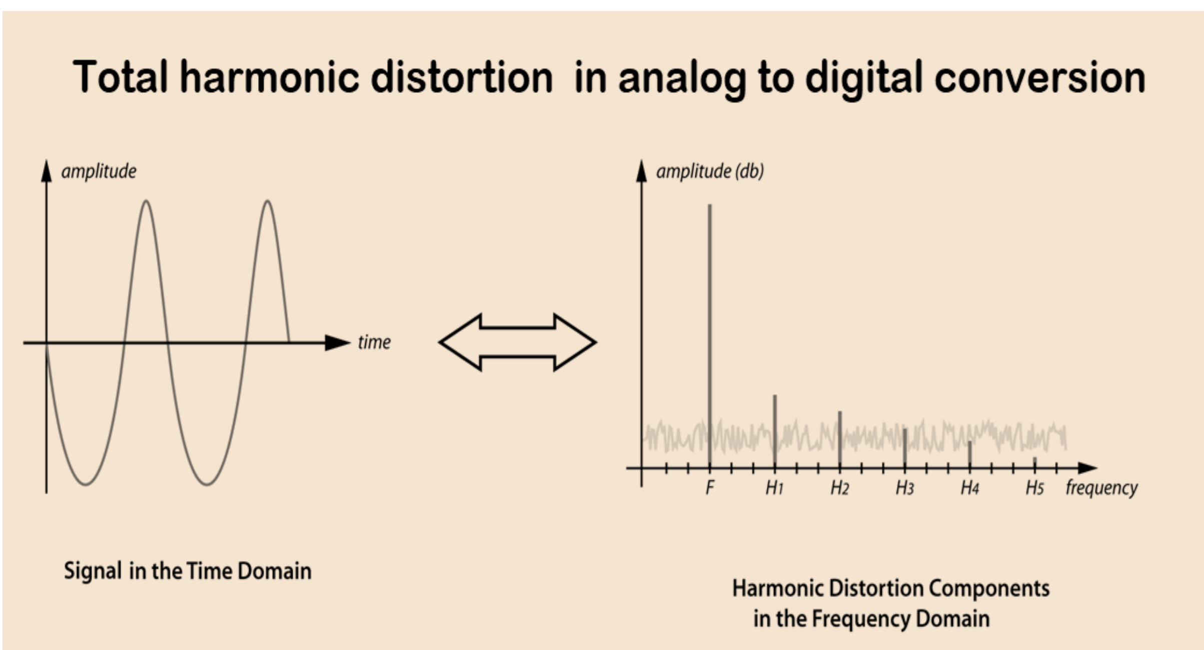
Successive Approximation



Flash

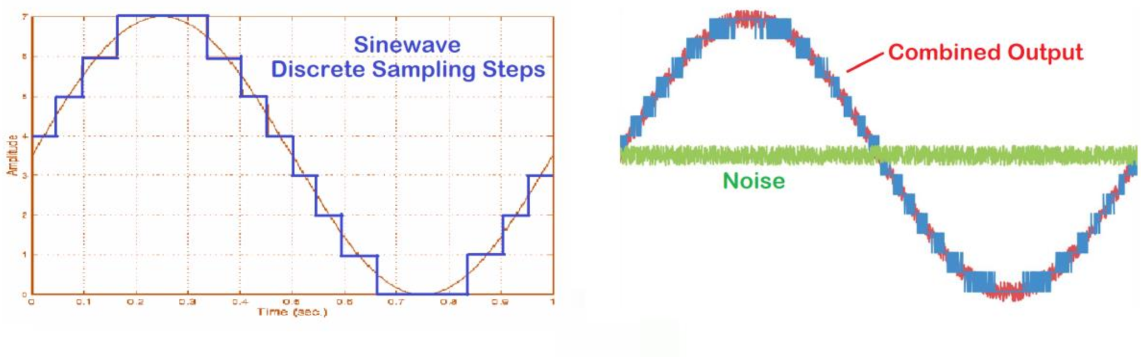


Total harmonic distortion is a measure of the quality of an analog-to-digital converter



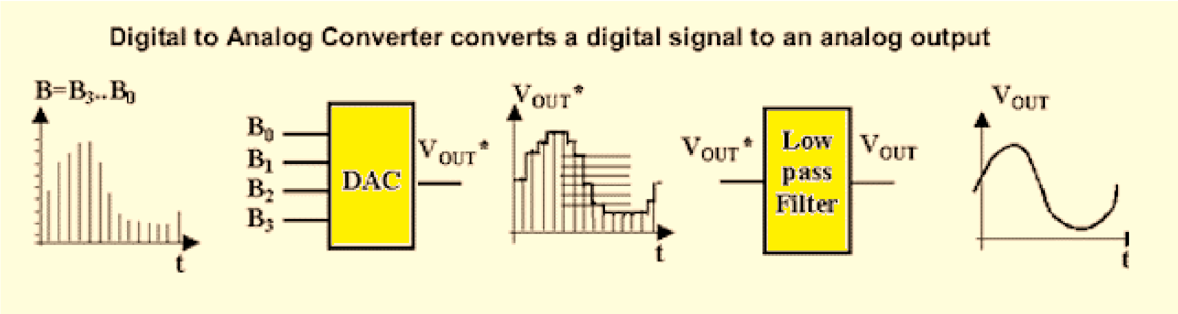
Editor's note: Total harmonic distortion is defined as the power of the harmonic content in the output of ADC with respect to the power at the fundamental frequency

A small amount of **noise added** to the input signal to allow more precise representation of a signal over time is **"dither" with respect to analog-to-digital converters**



Editor's note: Adding a small amount of noise by dithering noise to the input signal allows a more precise representation of a signal over time. Example: Dithering is a process that uses digital noise to smooth out colors in digital graphics and sounds in digital audio. Digital Graphics. All digital photos are an approximation of the original subject, since computers cannot display an infinite amount of colors.

A low-pass filter used in conjunction with a digital-to-analog converter remove harmonics from the output caused by the discrete analog levels generated



2:1 ratio of PEP-to-average power in a typical SSB phone signal

Speech characteristics determines the PEP-to-average power ratio of a SSB phone signal

Editor's note: Typical average power of a SSB voice transmission, for example, is 10-20% of PEP. The percentage of longer-term average power to PEP increases with processing, and commonly reaches ~50% with extreme speech processing.

==

E8A01 (A) What is the name of the process that shows that a square wave is made up of a sine wave plus all its odd harmonics? A. Fourier analysis B. Vector analysis C. Numerical analysis D. Differential analysis

E8A02 (A) Which of the following is a type of analog-to-digital conversion? A. Successive approximation B. Harmonic regeneration C. Level shifting D. Phase reversal

E8A03 (A) What type of wave does a Fourier analysis show to be made up of sine waves of a given fundamental frequency plus all its harmonics? A. A sawtooth wave B. A square wave C. A sine wave D. A cosine wave

E8A04 (B) What is "dither" with respect to analog-to-digital converters? A. An abnormal condition where the converter cannot settle on a value to represent the signal B. A small amount of noise added to the input signal to allow more precise representation of a signal over time C. An error caused by irregular quantization step size D. A method of decimation by randomly skipping samples

E8A05 (D) What of the following instruments would be the most accurate for measuring the RMS voltage of a complex waveform? A. A grid dip meter B. A D'Arsonval meter C. An absorption wave meter D. A true-RMS calculating meter

E8A06 (A) What is the approximate ratio of PEP-to-average power in a typical single-sideband phone signal? A. 2.5 to 1 B. 25 to 1 C. 1 to 1 D. 100 to 1

E8A07 (B) What determines the PEP-to-average power ratio of a single-sideband phone signal? A. The frequency of the modulating signal B. Speech characteristics C. The degree of carrier suppression D. Amplifier gain

E8A08 (C) Why would a direct or flash conversion analog-to-digital converter be useful for a software defined radio? A. Very low power consumption decreases frequency drift B. Immunity to out-of-sequence coding reduces spurious responses C. Very high speed allows digitizing high frequencies D. All these choices are correct

E8A09 (D) How many different input levels can be encoded by an analog-to-digital converter with 8-bit resolution? A. 8 B. 8 multiplied by the gain of the input amplifier C. 256 divided by the gain of the input amplifier D. 256

E8A10 (C) What is the purpose of a low-pass filter used in conjunction with a digital-to-analog converter? A. Lower the input bandwidth to increase the effective resolution B. Improve accuracy by removing out-of-sequence codes from the input C. Remove harmonics from the output caused by the discrete analog levels generated D. All these choices are correct

E8A11 (A) Which of the following is a measure of the quality of an analog-to-digital converter? A. Total harmonic distortion B. Peak envelope power C. Reciprocal mixing D. Power factor

==

E4A Test equipment

==

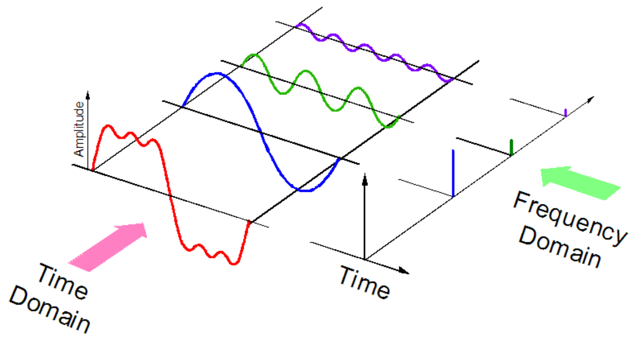
Sampling rate determines the **bandwidth** of a digital oscilloscope

Editor's note: The The highest frequency that can be digitized without aliasing is one-half the sample rate

A spectrum analyzer displays **frequency on the horizontal axis**

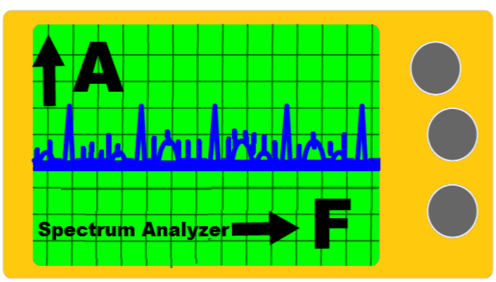
A spectrum analyzer displays **amplitude on the vertical axis**

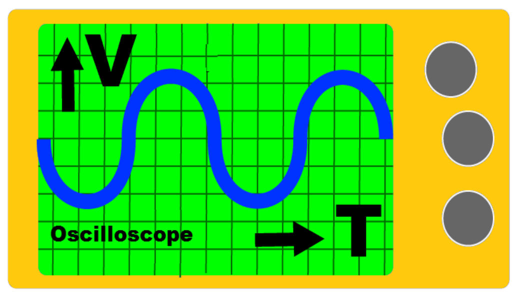
A **spectrum analyzer is used to display intermodulation distortion** products in an SSB transmission?



Editor's note:

An oscilloscope displays signals in the time domain
An Oscilloscope could be used for detailed analysis of digital signals
A spectrum analyzer displays signals in the frequency domain
A spectrum analyzer is used to display spurious signals from a radio transmitter

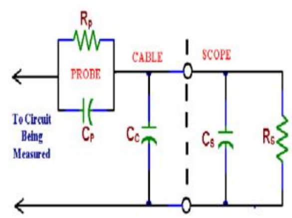


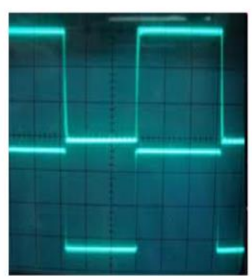


The **compensation of an oscilloscope probe** is adjusted until the horizontal portions of the displayed wave are as nearly **flat as possible**

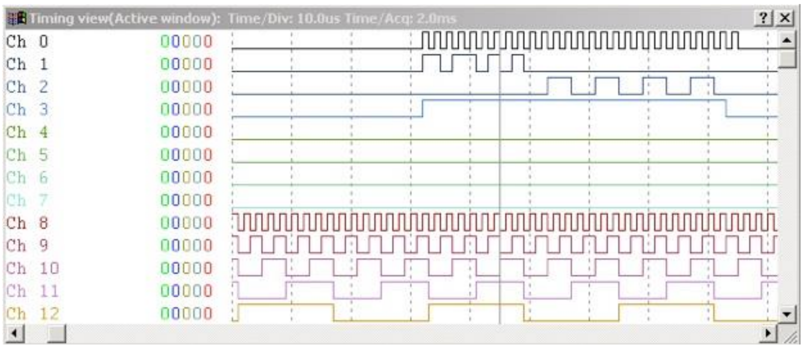
The effect of **aliasing in a digital or computer-based oscilloscope are false signals** being displayed

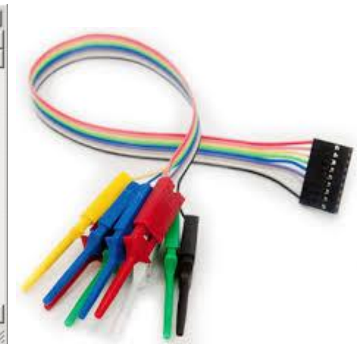
Keep the **oscilloscope probe ground** connection of the probe as **short as possible**





A Logic analyzer displays multiple digital signal states simultaneously





Editor's note: The logic analyzer is an electronic instrument that captures and displays multiple signals from a digital circuit. The captured data is converted into timing diagrams, state machine traces or data files.

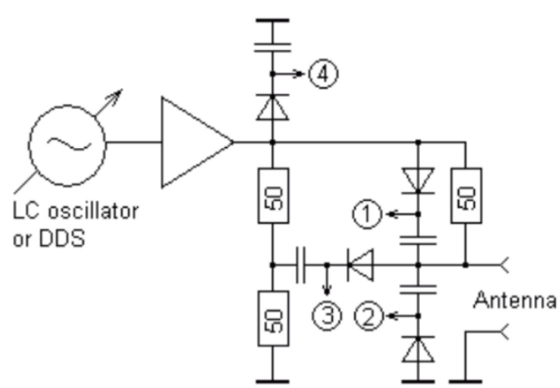
A **PRESCALER** divides a high frequency signal so a low-frequency counter can display the input frequency

Antenna analyzers do not need an external RF source to measure antenna SWR

An antenna analyzer measures SWR

Connect the **antenna feed line directly to the analyzer's** connector when measuring antenna resonance and feed point impedance

Editor's note: An antenna analyzer (also known as a noise bridge, RX bridge, SWR analyzer, or RF analyzer) is a device used for measuring the feed point impedance of antenna systems quantified by: VSWR, Resistance, Reactance in rectangular and polar coodanates.



Editor's note: Most HAMs use Antenna Analyzers based on diode detectors are the most common due to lower cost. The RF signal from LC oscillator or DDS is amplified and fed through the resistive bridge connected to the antenna. By using diode detectors and analog-to-digital converters built into the microcontroller, that calculates SWR and Impedances.

==

E4A01 (A) Which of the following limits the highest frequency signal that can be accurately displayed on a digital oscilloscope? A. Sampling rate of the analog-to-digital converter B. Amount of memory C. Q of the circuit D. All these choices are correct

E4A02 (B) Which of the following parameters does a spectrum analyzer display on the vertical and horizontal axes? A. RF amplitude and time B. RF amplitude and frequency C. SWR and frequency D. SWR and time

E4A03 (B) Which of the following test instruments is used to display spurious signals and/or intermodulation distortion products generated by an SSB transmitter? A. A wattmeter B. A spectrum analyzer C. A logic analyzer D. A time-domain reflectometer

E4A04 (A) How is the compensation of an oscilloscope probe typically adjusted? A. A square wave is displayed and the probe is adjusted until the horizontal portions of the displayed wave are as nearly flat as possible B. A high frequency sine wave is displayed and the probe is adjusted for maximum amplitude C. A frequency standard is displayed and the probe is adjusted until the deflection time is accurate D. A DC voltage standard is displayed and the probe is adjusted until the displayed voltage is accurate

E4A05 (D) What is the purpose of the prescaler function on a frequency counter? A. It amplifies low-level signals for more accurate counting B. It multiplies a higher frequency signal so a low-frequency counter can display the operating frequency C. It prevents oscillation in a low-frequency counter circuit D. It divides a higher frequency signal so a low-frequency counter can display the input frequency

E4A06 (A) What is the effect of aliasing on a digital oscilloscope caused by setting the time base too slow? A. A false, jittery low-frequency version of the signal is displayed B. All signals will have a DC offset C. Calibration of the vertical scale is no longer valid D. Excessive blanking occurs, which prevents display of the signal

E4A07 (B) Which of the following is an advantage of using an antenna analyzer compared to an SWR bridge to measure antenna SWR? A. Antenna analyzers automatically tune your antenna for resonance B. Antenna analyzers do not need an external RF source C. Antenna analyzers display a time-varying representation of the modulation envelope D. All these choices are correct

E4A08 (D) Which of the following measures SWR? A. A spectrum analyzer B. A Q meter C. An ohmmeter D. An antenna analyzer

E4A09 (A) Which of the following is good practice when using an oscilloscope probe? A. Keep the signal ground connection of the probe as short as possible B. Never use a high-impedance probe to measure a low-impedance circuit C. Never use a DC-coupled probe to measure an AC circuit D. All these choices are correct

E4A10 (D) Which of the following displays multiple digital signal states simultaneously? A. Network analyzer B. Bit error rate tester C. Modulation monitor D. Logic analyzer

E4A11 (D) How should an antenna analyzer be connected when measuring antenna resonance and feed point impedance? A. Loosely couple the analyzer near the antenna base B. Connect the analyzer via a high-impedance transformer to the antenna C. Loosely couple the antenna and a dummy load to the analyzer D. Connect the antenna feed line directly to the analyzer's connector

===

E4B Measurement technique and limitations

==

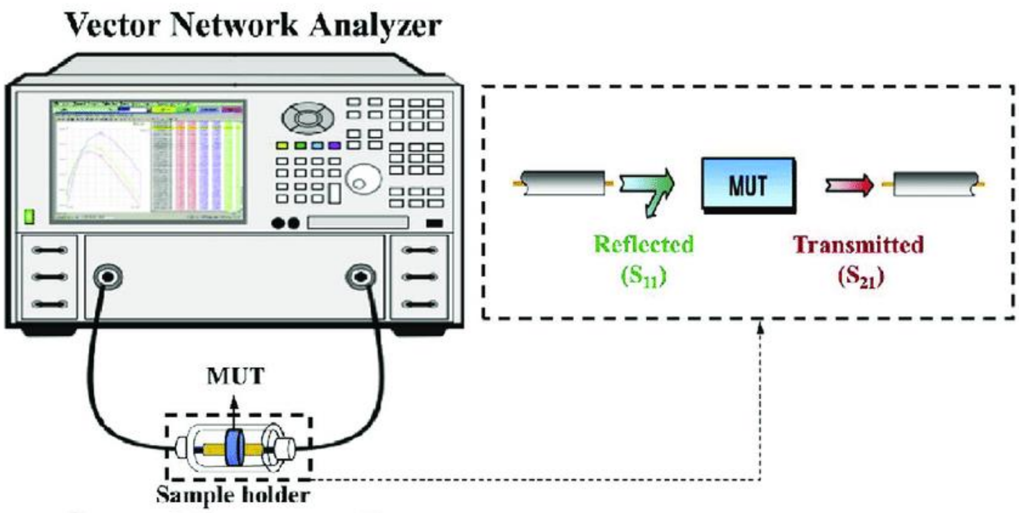
Input impedance, Output impedance and Reflection coefficient can be measured with a Vector Network Analyzer (VNA)

The VNA ports at which measurements are made are **represented by S parameters**

VNA S21 is equivalent to forward gain

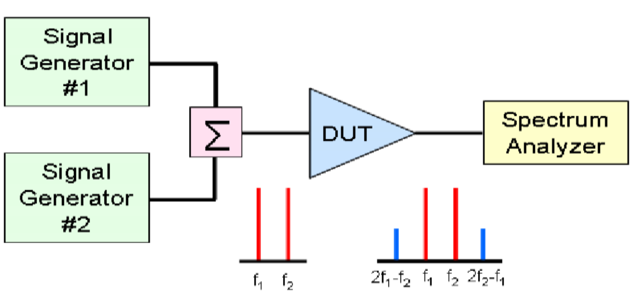
VNA S21 is equivalent to SWR (equivalent to return loss)

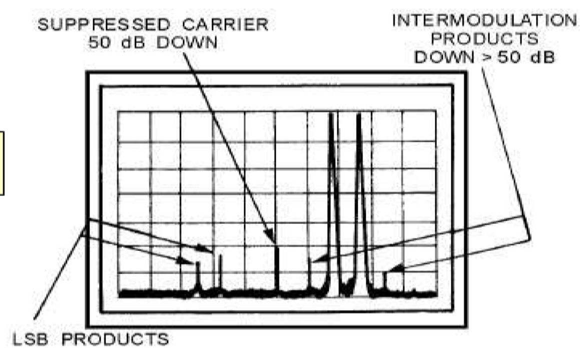
Short circuit, open circuit, and 50 ohms test loads are used to **calibrate a VNA**



*Editor's note: A vector network analyzer (VNA) is a test system that enables the RF performance of radio frequency and microwave devices to be characterized in terms of network scattering parameters, or S parameters. The VNA creates a signal and based on the received signal characterizes the device under test. S-parameters that describe transmission, such as **S21, are analogous to other familiar terms including gain**, insertion loss, or attenuation. S-parameters that describe reflection, such as **S11, correspond to voltage standing wave ratio (VSWR),** return loss, or reflection coefficient.*

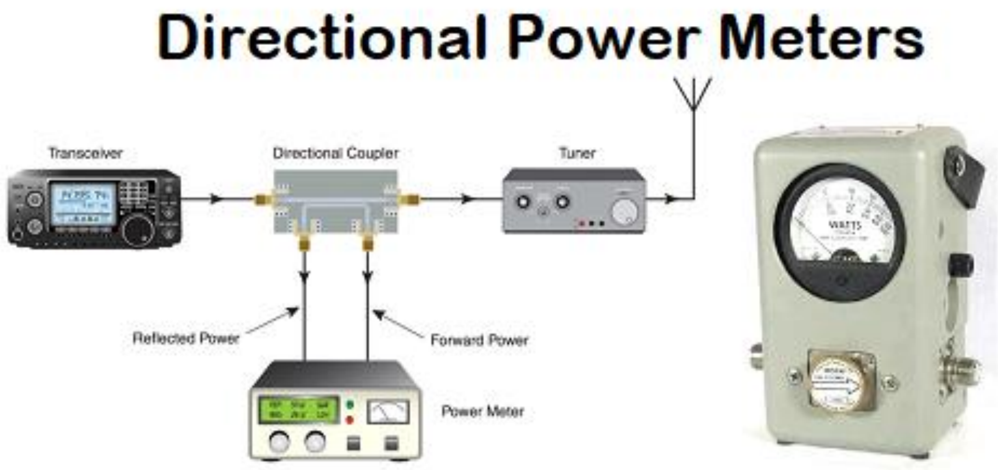
Intermodulation distortion (IMD) >> SSB TX non-harmonically **two tones** & observe RF on a spectrum analyzer



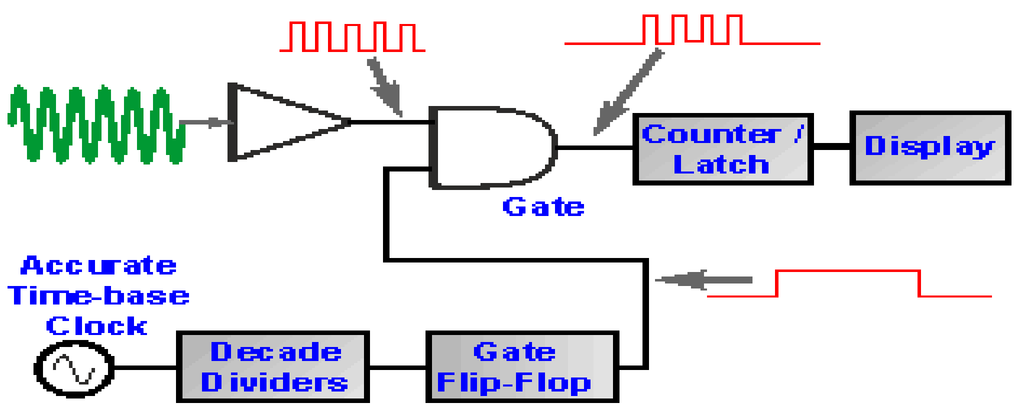


75 W is absorbed by the load when a directional power meter between a transmitter and load reads 100 W forward and 25 W reflected power

There is **more power going into the antenna if the current reading on an RF ammeter** placed in the antenna feed line of a transmitter **increases as the transmitter is tuned to resonance**



The accuracy of the **time base determines the accuracy** of a **frequency counter**

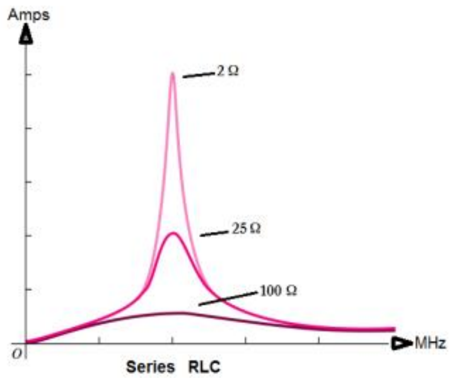


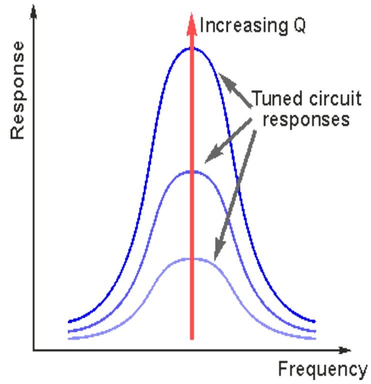
Editor's note: Frequency counters usually measure the number of cycles of oscillation, or pulses per second. A frequency counter counts the number of input pulses occurring within a specific period of time. The period measurement plus mathematical computation and provides improved resolution of low-frequency signals

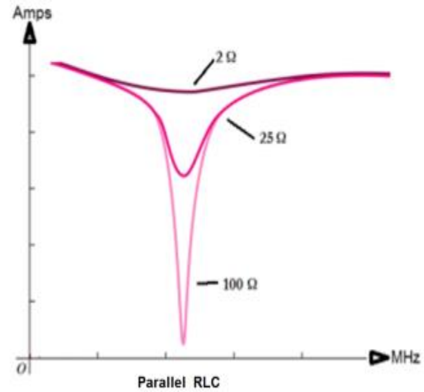
The full-scale reading of the voltmeter in ohms per volt rating will indicate the input impedance of the voltmeter

Editor's note: The sensitivity of such a meter can be expressed as "ohms per volt", the number of ohms resistance in the meter circuit divided by the full scale measured value. For example, a meter with a sensitivity of 1000 ohms per volt would draw 1 milliampere at full scale voltage; if the full scale was 200 volts, the resistance at the instrument's terminals would be 200000 ohms and at full scale the meter would draw 1 milliampere from the circuit under test. For multi-range instruments, the input resistance varies as the instrument is switched to different ranges.

The **bandwidth of the circuit's frequency response** can be used to measure the **Q** of a series-tuned circuit







Editor's note: The Q, or quality, factor of a resonant circuit is a measurement of the figure of merit corresponds to bandwidth in a series resonant circuit looks like a resistance at the resonant frequency. Since the definition of resonance is XL=XC, the reactive components cancel, leaving only the resistance to contribute to the impedance. The impedance is also at a minimum at resonance.

==

E4B01 (B) Which of the following factors most affects the accuracy of a frequency counter? A. Input attenuator accuracy B. Time base accuracy C. Decade divider accuracy D. Temperature coefficient of the logic

E4B02 (A) What is the significance of voltmeter sensitivity expressed in ohms per volt? A. The full scale reading of the voltmeter multiplied by its ohms per volt rating will indicate the input impedance of the voltmeter B. When used as a galvanometer, the reading in volts multiplied by the ohms per volt rating will determine the power drawn by the device under test C. When used as an ohmmeter, the reading in ohms divided by the ohms per volt rating will determine the voltage applied to the circuit D. When used as an ammeter, the full scale reading in amps divided by ohms per volt rating will determine the size of shunt needed

E4B03 (C) Which S parameter is equivalent to forward gain? A. S11 B. S12 C. S21 D. S22

E4B04 (A) Which S parameter represents input port return loss or reflection coefficient (equivalent to VSWR)? A. S11 B. S12 C. S21 D. S22

E4B05 (B) What three test loads are used to calibrate an RF vector network analyzer? A. 50 ohms, 75 ohms, and 90 ohms B. Short circuit, open circuit, and 50 ohms C. Short circuit, open circuit, and resonant circuit D. 50 ohms through 1/8 wavelength, 1/4 wavelength, and 1/2 wavelength of coaxial cable

E4B06 (D) How much power is being absorbed by the load when a directional power meter connected between a transmitter and a terminating load reads 100 watts forward power and 25 watts reflected power? A. 100 watts B. 125 watts C. 25 watts D. 75 watts

E4B07 (A) What do the subscripts of S parameters represent? A. The port or ports at which measurements are made B. The relative time between measurements C. Relative quality of the data D. Frequency order of the measurements

E4B08 (C) Which of the following can be used to measure the Q of a series-tuned circuit? A. The inductance to capacitance ratio B. The frequency shift C. The bandwidth of the circuit's frequency response D. The resonant frequency of the circuit

E4B09 (D) What is indicated if the current reading on an RF ammeter placed in series with the antenna feed line of a transmitter increases as the transmitter is tuned to resonance? A. There is possibly a short to ground in the feed line B. The transmitter is not properly neutralized C. There is an impedance mismatch between the antenna and feed line D. There is more power going into the antenna

E4B10 (B) Which of the following methods measures intermodulation distortion in an SSB transmitter? A. Modulate the transmitter using two RF signals having non-harmonically related frequencies and observe the RF output with a spectrum analyzer B. Modulate the transmitter using two AF signals having non-harmonically related frequencies and observe the RF output with a spectrum analyzer C. Modulate the transmitter using two AF signals having harmonically related frequencies and observe the RF output with a peak reading wattmeter D. Modulate the transmitter using two RF signals having harmonically related frequencies and observe the RF output with a logic analyzer

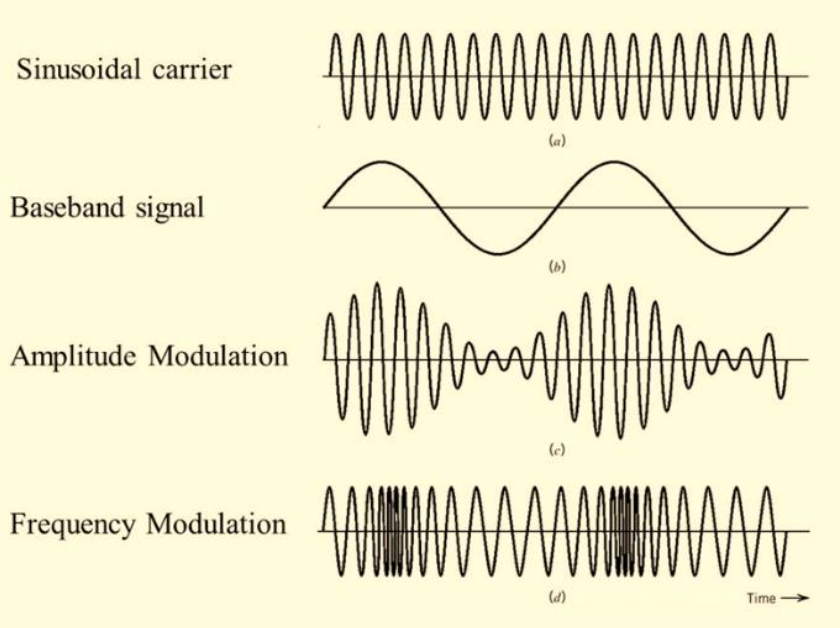
E4B11 (D) Which of the following can be measured with a vector network analyzer? A. Input impedance B. Output impedance C. Reflection coefficient D. All these choices are correct question text here

==

E7E Modulation and Demodulation

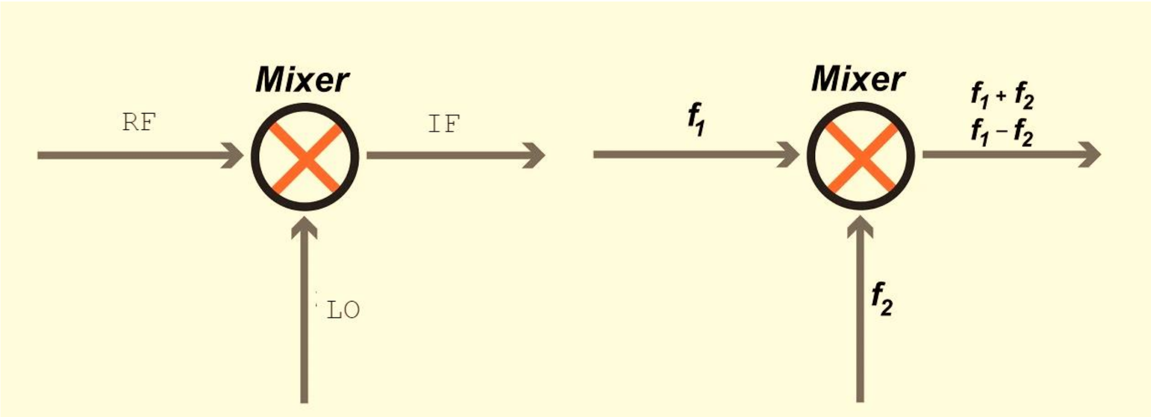
==

The frequency components present in **the modulating signal is called BASEBAND**

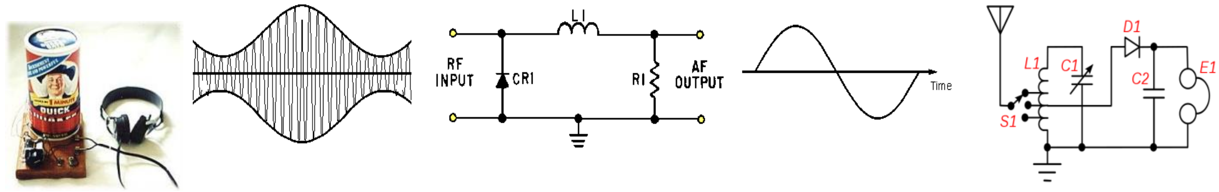


The two input frequencies along with their **SUM AND DIFFERENCE FREQUENCIES** appear at the output of a mixer circuit

SPURIOUS MIXER PRODUCTS are generated when an **excessive signal** energy reaches a mixer

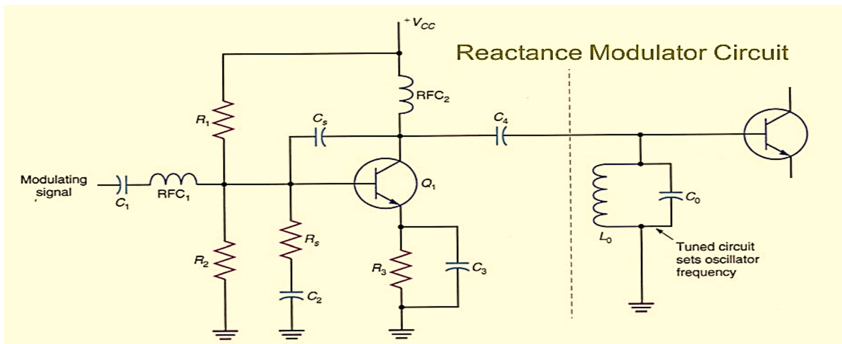


A **diode detector** functions by rectification and filtering of RF signals



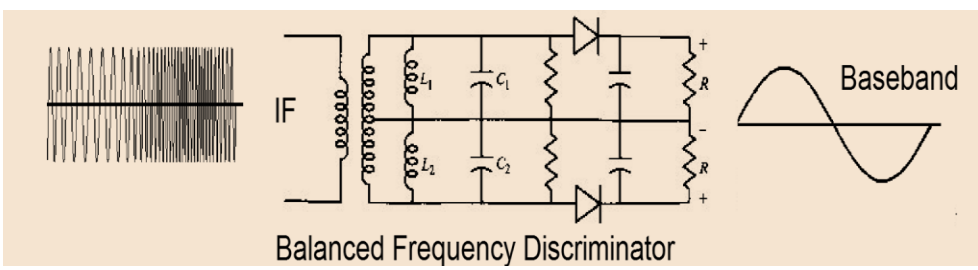
A **reactance modulator** on the oscillator can be used to generate **FM phone** emissions

The function of a **reactance modulator is to produce PM** signals by using an electrically variable inductance or capacitance



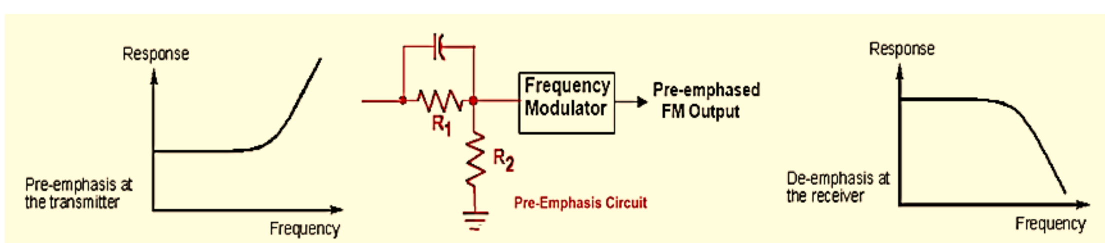
Editor's note: An analog phase modulator functions by varying the tuning of an amplifier tank circuit to produce PM signals

The **frequency DISCRIMINATOR** stage in a FM receiver is used for **detecting FM signals**

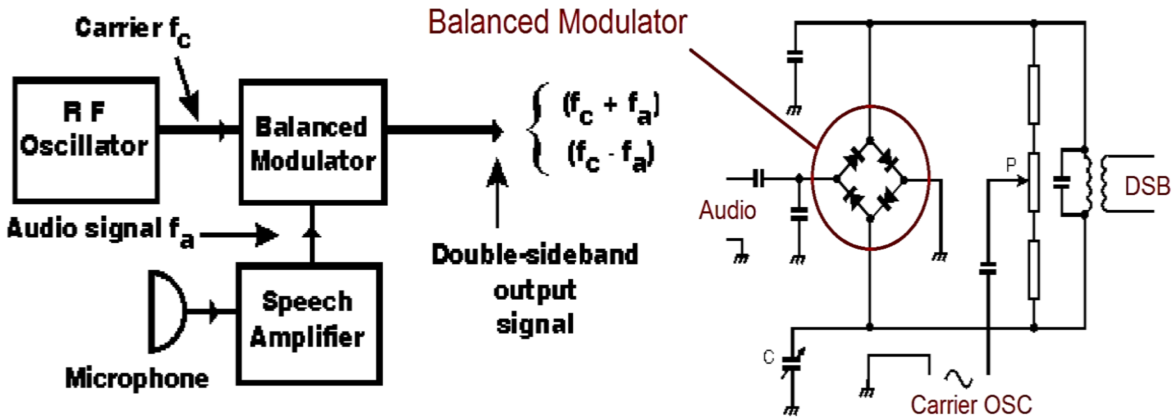


A **pre-emphasis** network circuit is added to an **FM transmitter** to **boost the higher audio** frequencies

De-emphasis commonly used in FM communications receivers for compatibility with **transmitters using phase modulation**

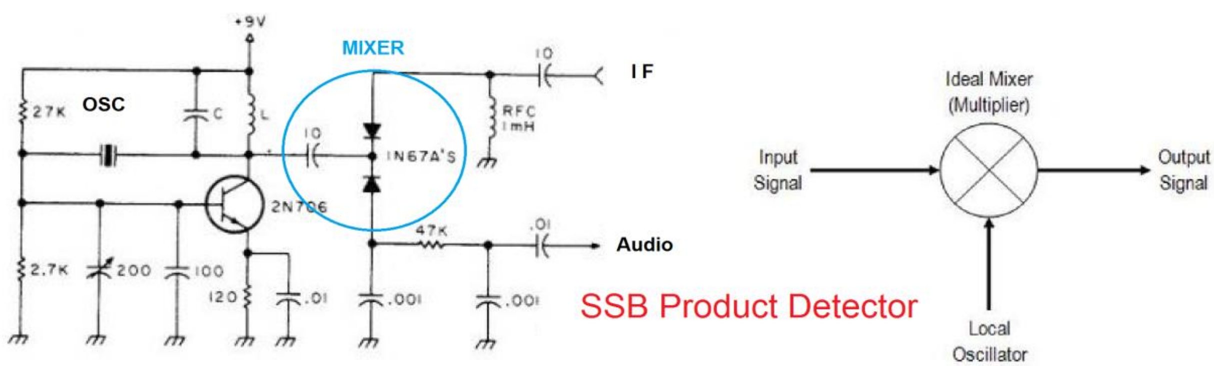


A **SSB phone** signal can be **generated** by using a **BALANCED modulator** followed by a filter



Editor's note: The principle of operation of a balanced modulator is when two signals at different frequencies are passed through a "nonlinear resistance" then at the output we get an AM signal with suppressed carrier, leaving only the USB and LSB. The device having a nonlinear resistance can be diode or a JFET or even a bipolar transistor.

A **PRODUCT detector** is well suited for demodulating **SSB** signals



Editor's note: A product detector a frequency mixer used for demodulation of SSB signals. The product detector takes the product of the modulated signal (IF) and a local oscillator, hence the name.

==

E7E01 (B) Which of the following can be used to generate FM phone emissions? A. A balanced modulator on the audio amplifier B. A reactance modulator on the oscillator C. A reactance modulator on the final amplifier D. A balanced modulator on the oscillator

E7E02 (D) What is the function of a reactance modulator? A. To produce PM signals by using an electrically variable resistance B. To produce AM signals by using an electrically variable inductance or capacitance C. To produce AM signals by using an electrically variable resistance D. To produce PM or FM signals by using an electrically variable inductance or capacitance

E7E03 (D) What is a frequency discriminator stage in a FM receiver? A. An FM generator circuit B. A circuit for filtering two closely adjacent signals C. An automatic band-switching circuit D. A circuit for detecting FM signals

E7E04 (A) What is one way a single-sideband phone signal can be generated? A. By using a balanced modulator followed by a filter B. By using a reactance modulator followed by a mixer C. By using a loop modulator followed by a mixer D. By driving a product detector with a DSB signal

E7E05 (D) What circuit is added to an FM transmitter to boost the higher audio frequencies? A. A de-emphasis network B. A heterodyne suppressor C. A heterodyne enhancer D. A pre-emphasis network

E7E06 (A) Why is de-emphasis commonly used in FM communications receivers? A. For compatibility with transmitters using phase modulation B. To reduce impulse noise reception C. For higher efficiency D. To remove third-order distortion products

E7E07 (B) What is meant by the term "baseband" in radio communications? A. The lowest frequency band that the transmitter or receiver covers B. The frequency range occupied by a message signal prior to modulation C. The unmodulated bandwidth of the transmitted signal D. The basic oscillator frequency in an FM transmitter that is multiplied to increase the deviation and carrier frequency

E7E08 (C) What are the principal frequencies that appear at the output of a mixer circuit? A. Two and four times the original frequency B. The square root of the product of input frequencies C. The two input frequencies along with their sum and difference frequencies D. 1.414 and 0.707 times the input frequency

E7E09 (A) What occurs when an excessive amount of signal energy reaches a mixer circuit? A. Spurious mixer products are generated B. Mixer blanking occurs C. Automatic limiting occurs D. A beat frequency is generated

E7E10 (A) How does a diode envelope detector function? A. By rectification and filtering of RF signals B. By breakdown of the Zener voltage C. By mixing signals with noise in the transition region of the diode D. By sensing the change of reactance in the diode with respect to frequency

E7E11 (C) Which type of detector circuit is used for demodulating SSB signals? A. Discriminator B. Phase detector C. Product detector D. Phase comparator

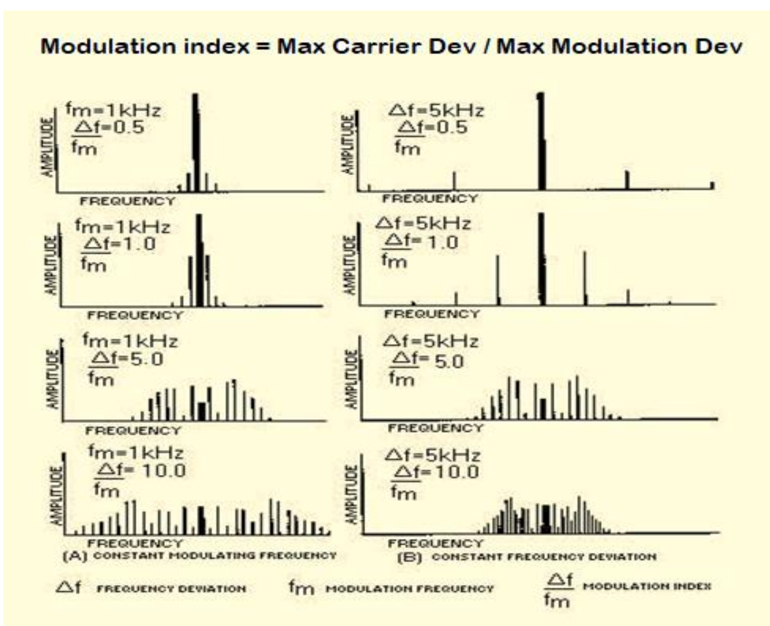
==

E8B Modulation and Demodulation

==

The maximum **carrier frequency** deviation compared to the highest audio **modulating frequency** is the **deviation ratio**

Modulation index is the term for the ratio between the frequency deviation of an RF carrier wave, and the modulating frequency of its corresponding FM-phone signal



Editor's note: The FM modulation index is equal to the ratio of the frequency deviation to the modulating frequency

E8B03 (A) What is the modulation index of an FM-phone signal having a maximum frequency deviation of 3000 Hz either side of the carrier frequency when the modulating frequency is 1000 Hz? A. 3 B. 0.3 C. 3000 D. 1000

Modulation index = Max Carrier Dev / Max Modulation

Dev = 3000 / 1000

Dev = 3

8B04 (B) What is the modulation index of an FM-phone signal having a maximum carrier deviation of plus or minus 6 kHz when modulated with a 2 kHz modulating frequency? A. 6000 B. 3 C. 2000 D. 1/3

Modulation index = Max Carrier Dev / Max Modulation

Dev = 6000 / 2000

Dev = 3

E8B05 (D) What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus-or-minus 5 kHz when the maximum modulation frequency is 3 kHz? A. 60 B. 0.167 C. 0.6 D. 1.67

Modulation index = Max Carrier Dev / Max Modulation

Dev = 5000 / 3000

Dev = 1.67

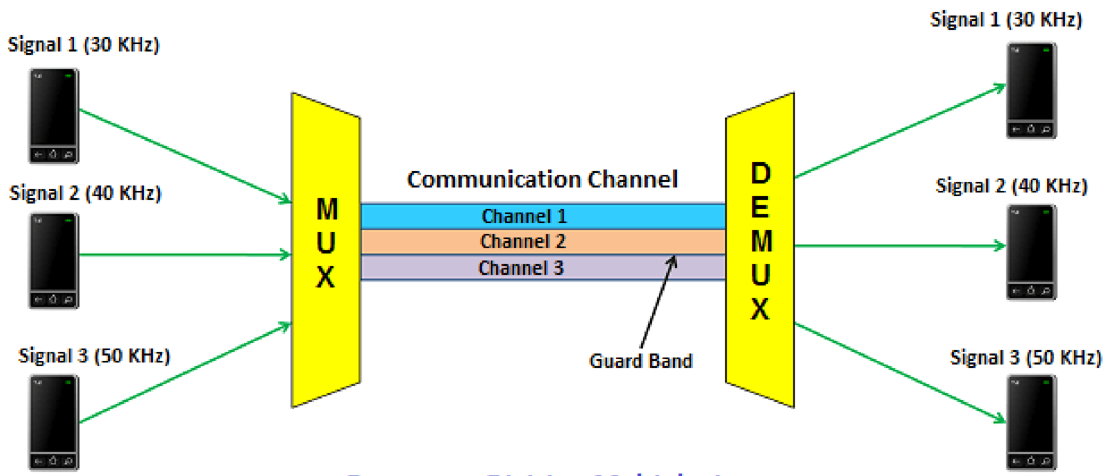
E8B06 (A) What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus or minus 7.5 kHz when the maximum modulation frequency is 3.5 kHz? A. 2.14 B. 0.214 C. 0.47 D. 47

Modulation index = Max Carrier Dev / Max Modulation

Dev = 7500 / 3500

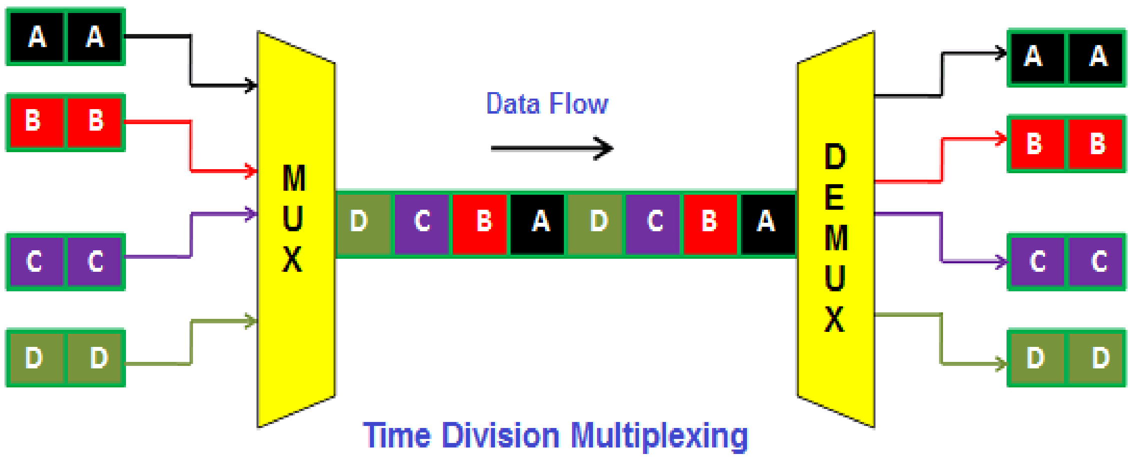
Dev = 2.14

FREQUENCY DIVISION MULTIPLEXING is two or more information streams are merged into a baseband, which then modulates the transmitter



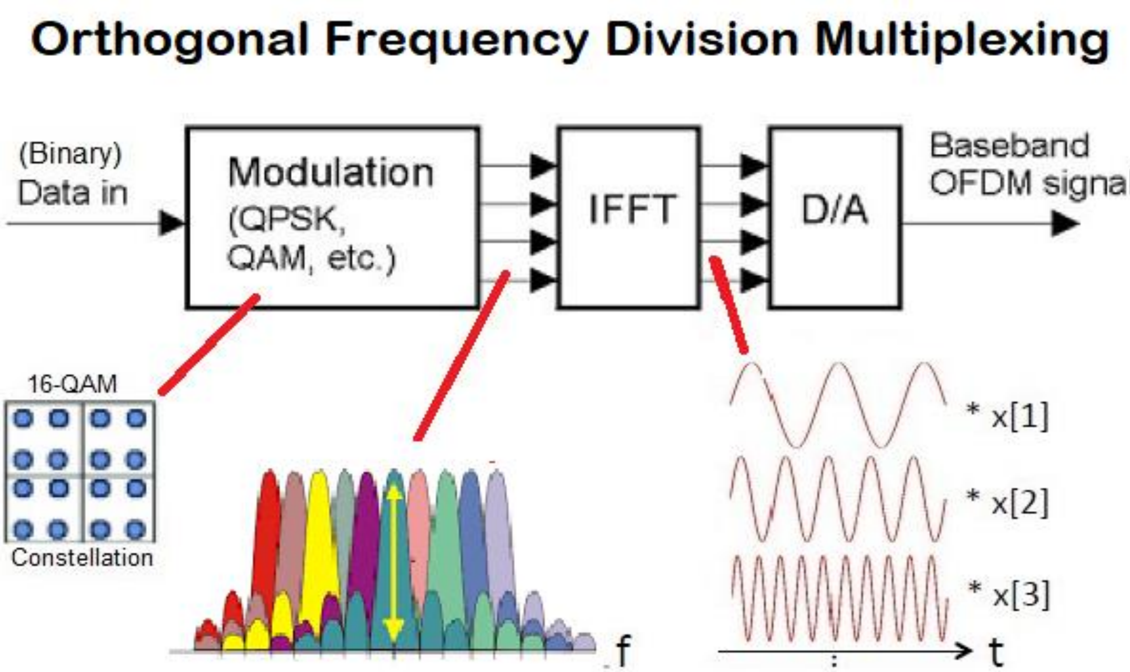
Frequency Division Multiplexing

Digital TIME DIVISION MULTIPLEXING is two or more signals are arranged to share discrete time slots of a data transmission



ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING is a technique used for **HIGH-SPEED DIGITAL MODES** in amateur communication

A digital modulation technique using **subcarriers at frequencies chosen to avoid intersymbol interference** describes ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING



*Editor's note: In telecommunications**, orthogonal frequency-division multiplexing (OFDM)** is a type of digital transmission and a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, used in applications such as digital television and audio broadcasting, DSL internet access, wireless networks, power line networks, and **WIFI 802.11G communications**.*

==

E8B01 (A) What is the modulation index of an FM signal? A. The ratio of frequency deviation to modulating signal frequency B. The ratio of modulating signal amplitude to frequency deviation C. The type of modulation used by the transmitter D. The bandwidth of the transmitted signal divided by the modulating signal frequency

E8B02 (D) How does the modulation index of a phase-modulated emission vary with RF carrier frequency? A. It increases as the RF carrier frequency increases B. It decreases as the RF carrier frequency increases C. It varies with the square root of the RF carrier frequency D. It does not depend on the RF carrier frequency

E8B03 (A) What is the modulation index of an FM-phone signal having a maximum frequency deviation of 3000 Hz either side of the carrier frequency when the modulating frequency is 1000 Hz? A. 3 B. 0.3 C. 3000 D. 1000

8B04 (B) What is the modulation index of an FM-phone signal having a maximum carrier deviation of plus or minus 6 kHz when modulated with a 2 kHz modulating frequency? A. 6000 B. 3 C. 2000 D. 1/3

E8B05 (D) What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus-or-minus 5 kHz when the maximum modulation frequency is 3 kHz? A. 60 B. 0.167 C. 0.6 D. 1.67

E8B06 (A) What is the deviation ratio of an FM-phone signal having a maximum frequency swing of plus or minus 7.5 kHz when the maximum modulation frequency is 3.5 kHz? A. 2.14 B. 0.214 C. 0.47 D. 47

E8B07 (A) Orthogonal Frequency Division Multiplexing is a technique used for which type of amateur communication? A. High-speed digital modes B. Extremely low-power contacts C. EME D. OFDM signals are not allowed on amateur bands

E8B08 (D) What describes Orthogonal Frequency Division Multiplexing? A. A frequency modulation technique that uses non-harmonically related frequencies B. A bandwidth compression technique using Fourier transforms C. A digital mode for narrow-band, slow-speed transmissions D. A digital modulation technique using subcarriers at frequencies chosen to avoid intersymbol interference

E8B09 (B) What is deviation ratio? A. The ratio of the audio modulating frequency to the center carrier frequency B. The ratio of the maximum carrier frequency deviation to the highest audio modulating frequency C. The ratio of the carrier center frequency to the audio modulating frequency D. The ratio of the highest audio modulating frequency to the average audio modulating frequency

E8B10 (B) What is frequency division multiplexing? A. The transmitted signal jumps from band to band at a predetermined rate B. Two or more information streams are merged into a baseband, which then modulates the transmitter C. The transmitted signal is divided into packets of information D. Two or more information streams are merged into a digital combiner, which then pulse position modulates the transmitter

E8B11 (B) What is digital time division multiplexing? A. Two or more data streams are assigned to discrete sub-carriers on an FM transmitter B. Two or more signals are arranged to share discrete time slots of a data transmission C. Two or more data streams share the same channel by transmitting time of transmission as the sub-carrier D. Two or more signals are quadrature modulated to increase bandwidth efficiency

==

E8C Digital signals

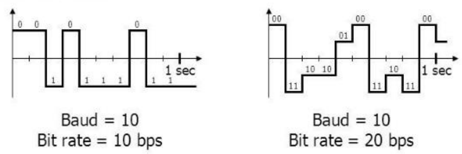
==

The **rate a waveform changes to convey information is the definition of symbol rate** in a digital transmission

Using a more efficient **digital code increases data rate be without increasing bandwidth**

Symbol rate and baud are the same

- **Baud** → How many times a signal changes per second
- **Bit rate** → How many bits can be sent per time unit per second
- Bit rate is controlled by baud and number of signal levels



MODULATION	BITS PER SYMBOL
BPSK	1
QPSK	2
8PSK	3
16QAM	4
32QAM	5
64QAM	6

0.5 KHz is the bandwidth of a 170-hertz shift, 300-baud ASCII transmission

BW = (K x shift) + B where K is 1.2 and B is baud

BW = (1.2 x 170) + 300

BW = 504 Hz

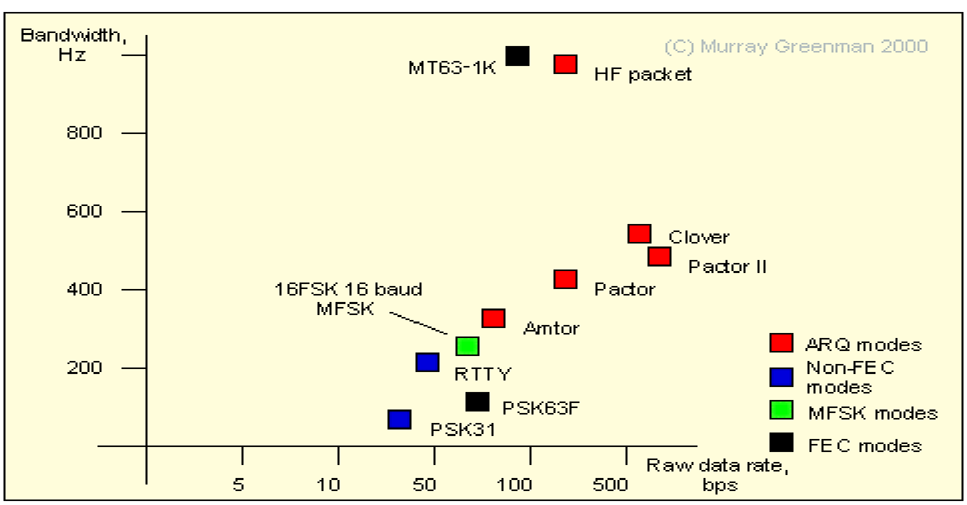
15.36 kHz is the bandwidth of a 4800-Hz frequency shift, 9600-baud ASCII FM transmission

BW = (K x shift) + B where K is 1.2 and B is baud

BW = (1.2 x 4800) + 9600

BW = 15,360 Hz

Editor's Note: Narrow band two state or digital modulation requires a bandwidth (BW) = (Constant Factor multiplied by Frequency Shift) plus the Baud rate. The constant factor depends on how much signal distortion. The constant commonly used for audio rates and amateur HF digital communications is 1.2.



Editor's Note: Common modulations for data emissions below 30 MHz

Keying speed and shape factor (rise and fall time) are factors affect the bandwidth of a transmitted CW signal

52 Hz is the approximate bandwidth of a 13-WPM International Morse Code transmission

$$BW = CW\ WPM \times 4$$

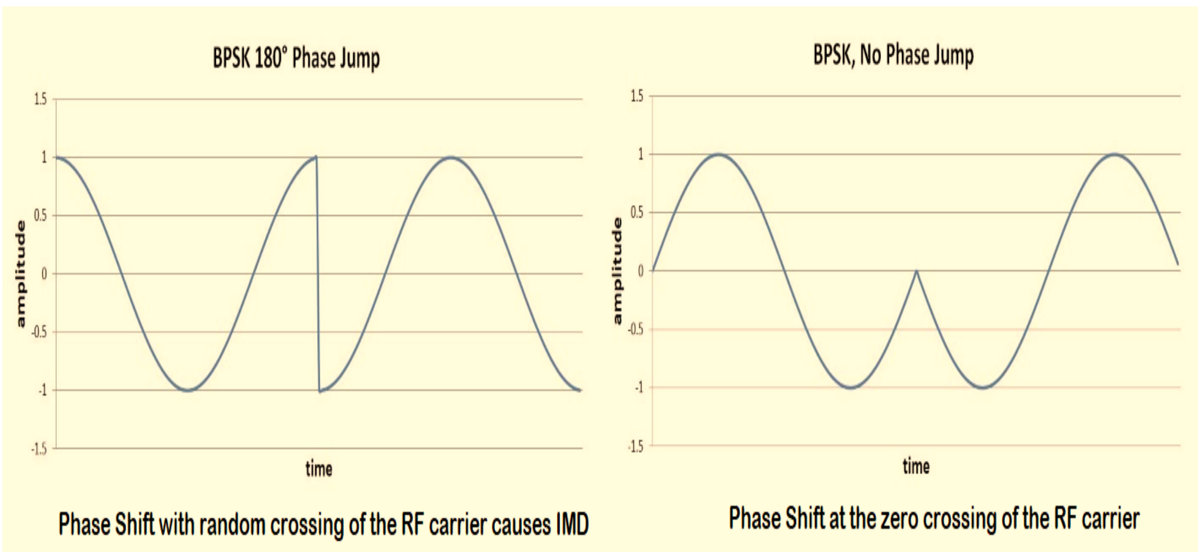
$$BW = 13 \times 4$$

$$BW = 52\ Hz$$

Sinusoidal data pulses minimize the bandwidth of a PSK31 signal

To minimize bandwidth the phase-shifting of a PSK signal is at the zero crossing of the RF signal

Forward Error Correction (FEC) is implemented by transmitting extra data that may be used to detect and correct transmission errors

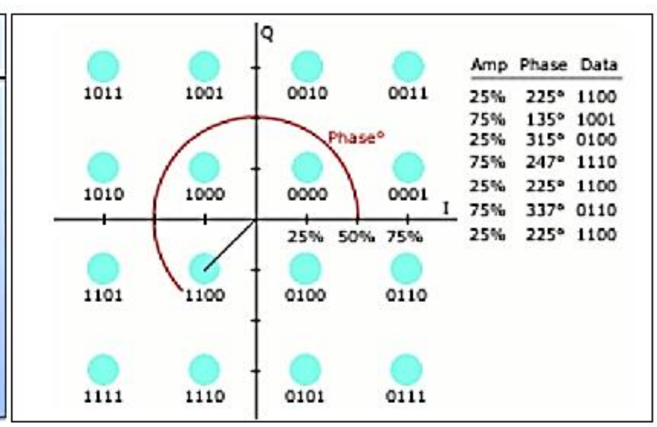


Phase Shift with random crossing of the RF carrier causes IMD

Phase Shift at the zero crossing of the RF carrier

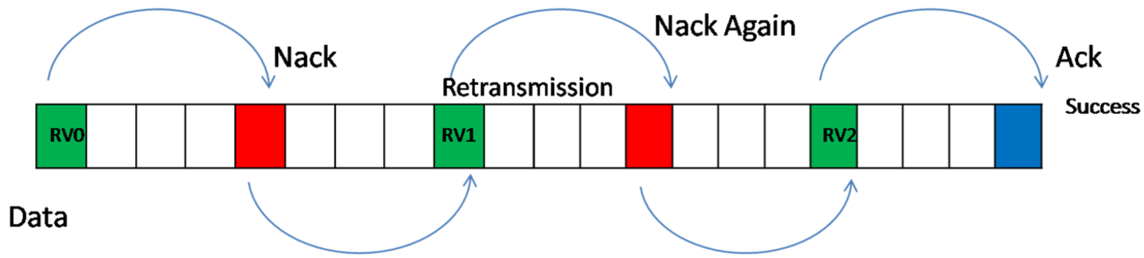
Gray code allows only one bit to change between sequential code values

Decimal	Binary	Gray
0	0 0 0 0	0 0 0 0
1	0 0 0 1	0 0 0 1
2	0 0 1 0	0 0 1 1
3	0 0 1 1	0 0 1 0
4	0 1 0 0	0 1 1 0
5	0 1 0 1	0 1 1 1
6	0 1 1 0	0 1 0 1
7	0 1 1 1	0 1 0 0
8	1 0 0 0	1 1 0 0
9	1 0 0 1	1 1 0 1



Editor's Note: A Gray code is an encoding of numbers so that adjacent numbers have a single digit differing by 1. The term Gray code is often used to refer to a "reflected" code, or more specifically still, the binary reflected Gray code.

With ARQ if errors are detected, a retransmission is requested



Editor's Note: Automatic repeat request (ARQ) is a protocol for error control in data transmission. When the receiver detects an error in a packet, it automatically requests the transmitter to resend the data.

==

E8C01 (C) How is Forward Error Correction implemented? A. By the receiving station repeating each block of three data characters B. By transmitting a special algorithm to the receiving station along with the data characters C. By transmitting extra data that may be used to detect and correct transmission errors D. By varying the frequency shift of the transmitted signal according to a predefined algorithm

E8C02 (C) What is the definition of symbol rate in a digital transmission? A. The number of control characters in a message packet B. The duration of each bit in a message sent over the air C. The rate at which the waveform changes to convey information D. The number of characters carried per second by the station-to-station link

E8C03 (A) Why should phase-shifting of a PSK signal be done at the zero crossing of the RF signal? A. To minimize bandwidth B. To simplify modulation C. To improve carrier suppression D. All these choices are correct

E8C04 (C) What technique minimizes the bandwidth of a PSK31 signal? A. Zero-sum character encoding B. Reed-Solomon character encoding C. Use of sinusoidal data pulses D. Use of trapezoidal data pulses

E8C05 (C) What is the approximate bandwidth of a 13-WPM International Morse Code transmission? A. 13 Hz B. 26 Hz C. 52 Hz D. 104 Hz

E8C06 (C) What is the bandwidth of a 170-hertz shift, 300-baud ASCII transmission? A. 0.1 Hz B. 0.3 kHz C. 0.5 kHz D. 1.0 kHz

E8C07 (A) What is the bandwidth of a 4800-Hz frequency shift, 9600-baud ASCII FM transmission? A. 15.36 kHz B. 9.6 kHz C. 4.8 kHz D. 5.76 kHz

E8C08 (D) How does ARQ accomplish error correction? A. Special binary codes provide automatic correction B. Special polynomial codes provide automatic correction C. If errors are detected, redundant data is substituted D. If errors are detected, a retransmission is requested

E8C09 (D) Which digital code allows only one bit to change between sequential code values? A. Binary Coded Decimal Code B. Extended Binary Coded Decimal Interchange Code C. Excess 3 code D. Gray code

E8C10 (C) How may data rate be increased without increasing bandwidth? A. It is impossible B. Increasing analog-to-digital conversion resolution C. Using a more efficient digital code D. Using forward error correction

E8C11 (A) What is the relationship between symbol rate and baud? A. They are the same B. Baud is twice the symbol rate C. Symbol rate is only used for packet-based modes D. Baud is only used for RTTY

E8C12 (C) What factors affect the bandwidth of a transmitted CW signal? A. IF bandwidth and Q B. Modulation index and output power C. Keying speed and shape factor (rise and fall time) D. All these choices are correct

==

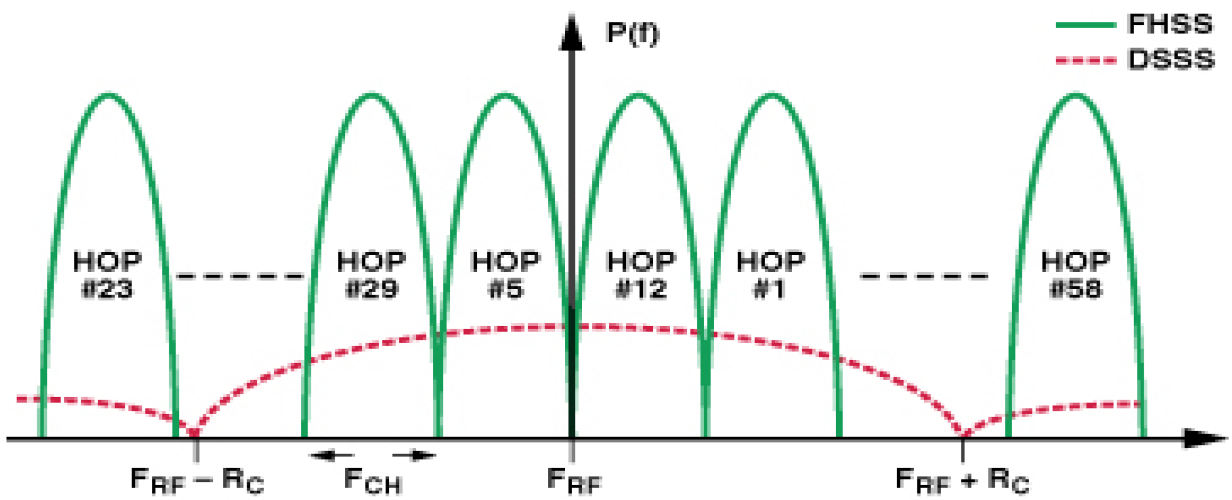
E8D Keying defects and overmodulation of digital signals

==

Signals not using the spread spectrum algorithm are suppressed in the receiver therefore resistant to interference

Direct sequence spread-spectrum (DSSS) communications technique uses a high-speed binary bit stream to shift the phase of an RF carrier

Frequency hopping spread-spectrum (FHSS) communications technique alters the center frequency of a conventional carrier many times per second in accordance with a pseudo-random list of channels



Editor's Note: Frequency hopping spread-spectrum (FHSS) does not spread the signal, as a result, there is no processing gain. The processing gain is the increase in power density when the signal is de-spread and it will improve the received signal's Signal-to-noise ratio (SNR). In other words, the frequency hopper needs to put out more power in order to have the same SNR as a direct-sequence radio

ASCII code has both **upper- and lower-case** text

Some types of **errors can be detected** by including a **parity bit** with an **ASCII** character stream

ASCII uses **seven or eight data bits** per character and no shift code

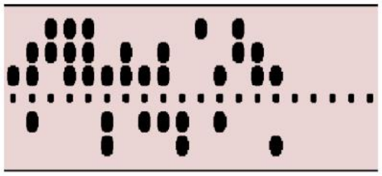
```
 !"#$%&'()*+,-./
0123456789:;<=>?
@ABCDEFGHIJKLMNO
PQRSTUVWXYZ[\]^_
`abcdefghijklmno
pqrstuvwxyz{|}~
```

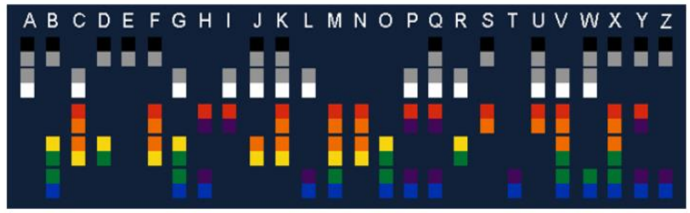
7 Bits = 2^7 = 128 Characters

0	*NUL*	16	*DLE*	32	SPC	48	0	64	@	80	P	96	`	112	p
1	*SOH*	17	*DC1*	33	!	49	1	65	A	81	Q	97	a	113	q
2	*STX*	18	*DC2*	34	"	50	2	66	B	82	R	98	b	114	r
3	*ETX*	19	*DC3*	35	#	51	3	67	C	83	S	99	c	115	s
4	*EOT*	20	*DC4*	36	$	52	4	68	D	84	T	100	d	116	t
5	*ENQ*	21	*NAK*	37	%	53	5	69	E	85	U	101	e	117	u
6	*ACK*	22	*SYN*	38	&	54	6	70	F	86	V	102	f	118	v
7	*BEL*	23	*ETB*	39	'	55	7	71	G	87	W	103	g	119	w
8	*BS*	24	*CAN*	40	(	56	8	72	H	88	X	104	h	120	x
9	*HT*	25	*EM*	41	)	57	9	73	I	89	Y	105	i	121	y
10	*LF*	26	*SUB*	42	*	58	:	74	J	90	Z	106	j	122	z
11	*VT*	27	*ESC*	43	+	59	;	75	K	91	[	107	k	123	{
12	*FF*	28	*FS*	44	,	60	<	76	L	92	\	108	l	124	|
13	*CR*	29	*GS*	45	-	61	=	77	M	93	]	109	m	125	}
14	*SO*	30	*RS*	46	.	62	>	78	N	94	^	110	n	126	~
15	*SI*	31	*US*	47	/	63	?	79	O	95	_	111	o	127	DEL

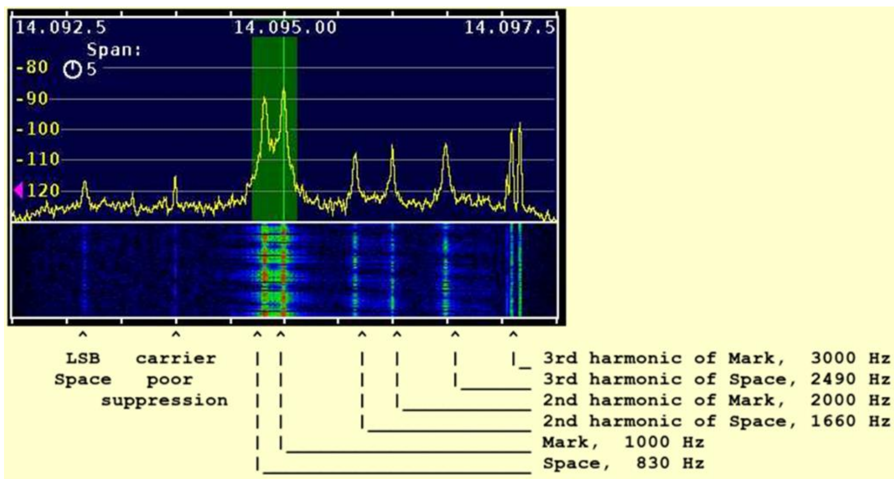
*Editor's Note: American Standard Code for Information Interchange (**ASCII**) is a digital code with the letters, numbers, and punctuation characters are represented by a 7 bit number.*

BAUDOT uses 5 data bits per character and uses 2 characters as **letters/figures shift codes**

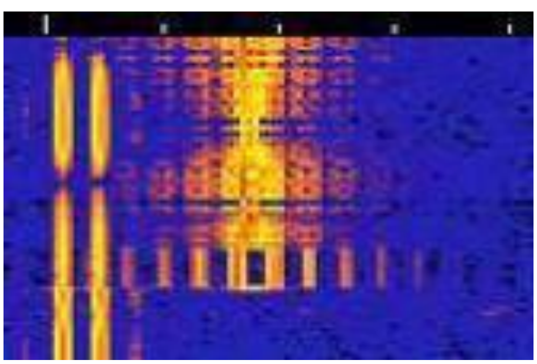




Excessive transmit audio levels common cause of overmodulation of AFSK signals and can cause spurious emissions and Intermodulation Distortion (IMD)

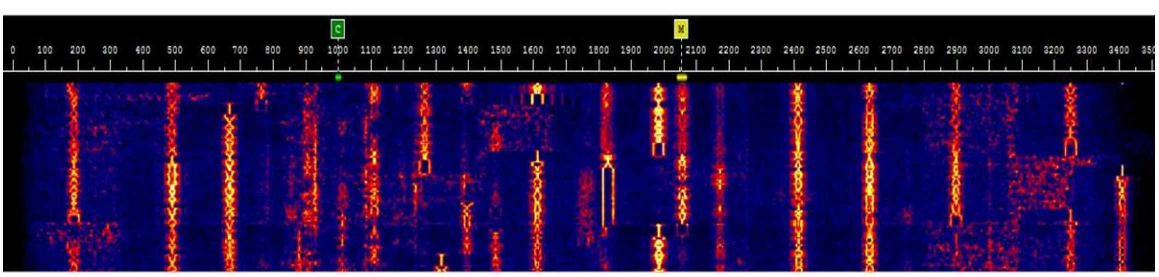


-30 dB an acceptable maximum IMD level for an idling PSK signal



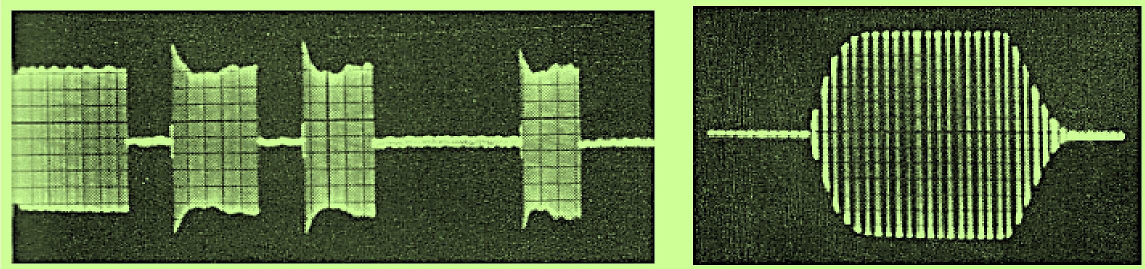
Editor's Note: Left - One overmodulated PSK31 signal that is badly distorted take up space for 8 signals. 23 Normal PSK31 signal shown below using the same bandwidth.

Editor's Note: PSK Inter-Modulation Distortion (IMD) is a report often exchanged during a PSK QSO as a figure of merit for the received signal. It is widely assumed that a very good IMD report for an idling signal is around -30db, a marginal report around -20db, with the worst possible at -10db.



The generation of key clicks is the primary effect of extremely short rise or fall time on a CW signal

Increase keying waveform rise and fall times is the most common method of **reducing key clicks**



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E8D01 (A) Why are received spread spectrum signals resistant to interference? A. Signals not using the spread spectrum algorithm are suppressed in the receiver B. The high power used by a spread spectrum transmitter keeps its signal from being easily overpowered C. The receiver is always equipped with a digital blanker D. If interference is detected by the receiver it will signal the transmitter to change

E8D02 (B) What spread spectrum communications technique uses a high-speed binary bit stream to shift the phase of an RF carrier? A. Frequency hopping B. Direct sequence C. Binary phase-shift keying D. Phase compandored spread spectrum

E8D03 (D) How does the spread spectrum technique of frequency hopping work? A. If interference is detected by the receiver it will signal to change frequencies B. If interference is detected by the receiver it will signal the transmitter to wait until the frequency is clear C. A binary bit stream is used to shift the phase of an RF carrier very rapidly in a pseudorandom sequence D. The frequency of the transmitted signal is changed very rapidly according to a pseudorandom sequence also used by the receiving station

E8D04 (C) What is the primary effect of extremely short rise or fall time on a CW signal? A. More difficult to copy B. The generation of RF harmonics C. The generation of key clicks D. Limits data speed

E8D05 (A) What is the most common method of reducing key clicks? A. Increase keying waveform rise and fall times B. Low-pass filters at the transmitter output C. Reduce keying waveform rise and fall times D. High-pass filters at the transmitter output

E8D06 (D) What is the advantage of including parity bits in ASCII characters? A. Faster transmission rate B. The signal can overpower interfering signals C. Foreign language characters can be sent D. Some types of errors can be detected

E8D07 (D) What is a common cause of overmodulation of AFSK signals? A. Excessive numbers of retries B. Ground loops C. Bit errors in the modem D. Excessive transmit audio levels

E8D08 (D) What parameter evaluates distortion of an AFSK signal caused by excessive input audio levels? A. Signal-to-noise ratio B. Baud C. Repeat Request Rate D. Intermodulation Distortion (IMD)

E8D09 (D) What is considered an acceptable maximum IMD level for an idling PSK signal? A. +10 dB B. +15 dB C. -20 dB D. -30 dB

E8D10 (B) What are some of the differences between the Baudot digital code and ASCII? A. Baudot uses 4 data bits per character, ASCII uses 7 or 8; Baudot uses 1 character as a letters/figures shift code, ASCII has no letters/figures code B. Baudot uses 5 data bits per character, ASCII uses 7 or 8; Baudot uses 2 characters as letters/figures shift codes, ASCII has no letters/figures shift code C. Baudot uses 6 data bits per character, ASCII uses 7 or 8; Baudot has no letters/figures shift code, ASCII uses 2 letters/figures shift codes D. Baudot uses 7 data bits per character, ASCII uses 8; Baudot has no letters/figures shift code, ASCII uses 2 letters/figures shift codes

E8D11 (C) What is one advantage of using ASCII code for data communications? A. It includes built-in error correction features B. It contains fewer information bits per character than any other code C. It is possible to transmit both upper and lower case text D. It uses one character as a shift code to send numeric and special characters

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E4C Receiver performance characteristics

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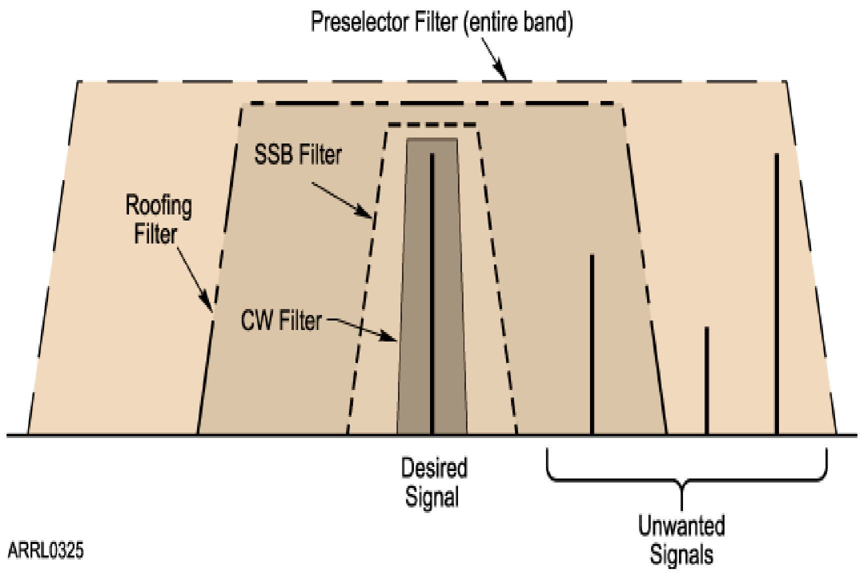
An attenuator be used to reduce receiver overload on the lower frequency HF bands with little or no impact on signal-to-noise ratio because atmospheric noise is generally greater than internally generated noise even after attenuation

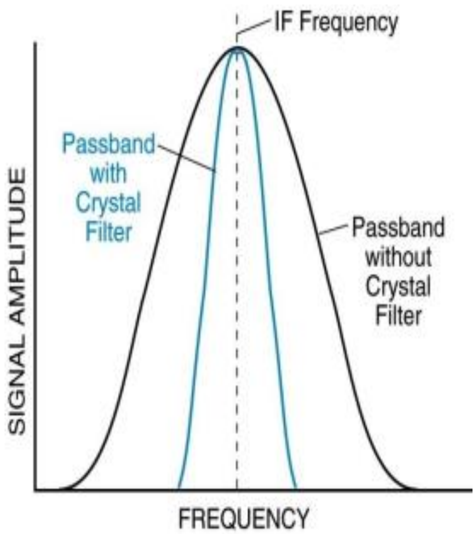
A **narrow-band roofing filter improves dynamic range** by attenuating strong signals near the receive frequency

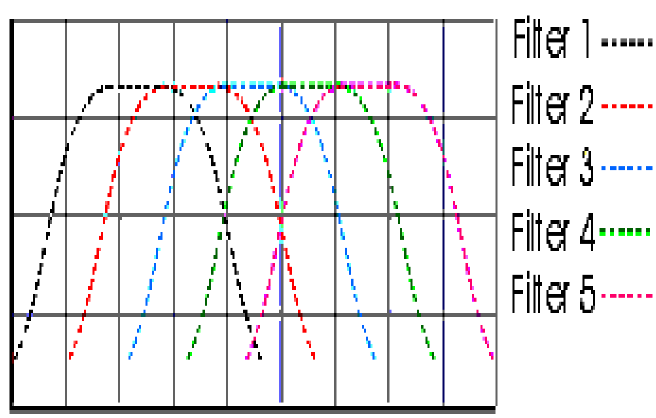


Editor's note: A typical multiple-conversion superheterodyne receiver has several stages of filtering. Preselector filters reject out-of-band signals. Roofing filters at the input to each IF further restrict receiver bandwidth, attenuating strong in-band signals that might overload the IF amplifiers. In the final IF stage, single-signal filters are used to select just the desired signal.

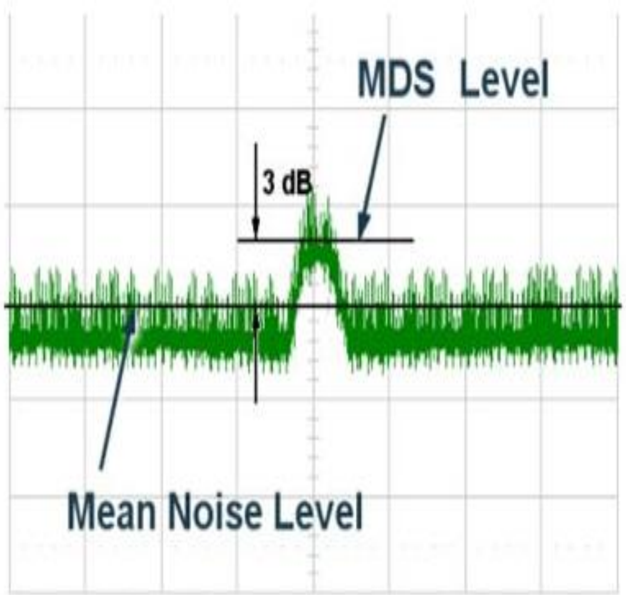
A **front-end filter or pre-selector** can be effective in **eliminating image signal interference**

Provides front end selectivity
Reject strong near out of band signals
Tunable input filter that passes the desired frequency.
Increases rejection of out of band signals.





Minimum discernible signal (MDS) represents the receiver minimum discernible signal



Minimum Discernible Signal

MDS of a receiver is the strength of the smallest discernible input signal.

Depends on noise figure and bandwidth.

MDS also called the receiver's noise floor.

Signal that produces same audio level as the receiver's noise.

Editor's note: The Minimum detectable signal (MDS) is the minimum power level that can be processed by a receiver to provide a relevant output. It is also known as the noise floor of the system. It can also be defined as the input signal power required to give a particular SNR.

The **noise figure of a receiver** >> ratio in dB of the noise generated by the receiver vs. theoretical minimum noise

The **theoretical noise** at the input of a perfect receiver at room temperature = **-174 dBm/Hz**

A CW receiver with the AGC off has an equivalent input noise power density **of -174 dBm/Hz.** What would be the level of an unmodulated carrier input to this receiver that would yield an audio output SNR of 0 dB in a **400 Hz noise bandwidth?**

You are given the MDS for the receiver in Hz but you need to determine the MDS for 400 Hz

BW Ratio [400 vs 1 Hz] = 10 X log (400 / 1)

BW Ratio [400 vs 1 Hz] = 10 x 2.6 = 26 dB

\- -

MDS for 400 Hz = (MDS @ 1 Hz) + (BW Ratio [400 vs 1 Hz])

MDS for 400 Hz = -174 + 26

MDS for 400 Hz = -148 dBm

Receiver **oscillator phase noise** causes nearby frequencies to **interfere with reception of weak**

Reciprocal mixing is the local oscillator mixing with adjacent strong signals to create interference to desired signals

What transmit frequency might generate an **image response signal in a receiver** tuned to 14.300 MHz and which uses a 455 kHz IF frequency?

IF of 455Khz and the signal on 14.300 MHz

BFO frequency = 14.3 + .455 = 14.755 MHz

IMAGE RESPONSE SIGNAL IN A RECEIVER

Image on 15.210 received because 15.210 – 14.755 MHz = 0.455 MHz (IF)

Editor's note: When a local oscillator signal is mixed with an incoming signal in generates the sum and the difference of the two signals. If we assume High side mix (the LO is higher than the tuned frequency then the LO will be the tuned frequency + 455KHz. A signal 455 KHz above the LO would also generate a 455 KHz IF spurious or image signal. So taking the receive frequency of 14.300 MHz and 2 times the IF frequency of 0.455 MHz (14.300 – (2x.455) we get 15.210 MHz – AD7FO.

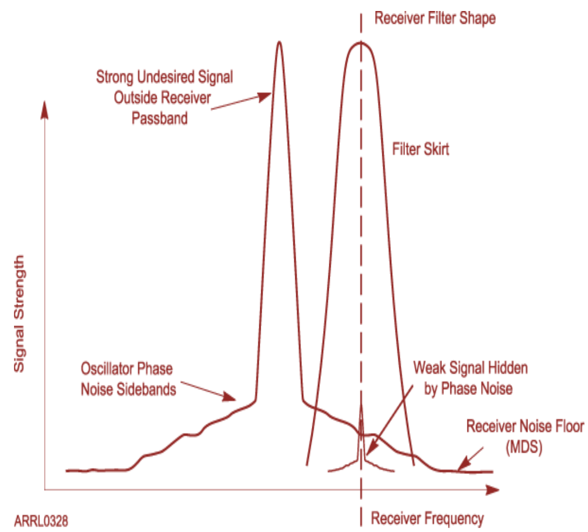
A **higher frequency IF** is EASIER design to **eliminate image responses**

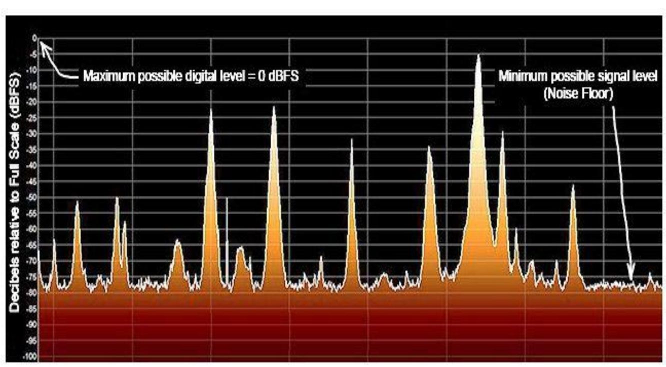
Receive bandwidth selected to match the modulation bandwidth, maximizing signal-to-noise ratio and minimizing interference is an advantage of having a **variety of receiver IF bandwidths**

An SDR receiver is overloaded when input signals exceed the ADC reference voltage

Reference voltage level and sample bits determine the **minimum detectable signal level** for an SDR receiver.

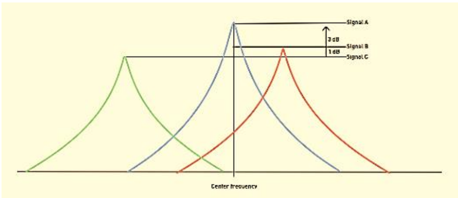
Analog-to-digital converter sample width in bits has the largest effect on an SDR receiver's dynamic range





Overloading occurs when a strong signal starts to saturate the ADC because the dynamic range was not high enough. Dynamic range is the ability of an SDR to receive weak signals when strong signals are nearby. The need for high dynamic range can be alleviated by using RF filtering.

Capture effect is the term for the suppression in an FM receiver of one signal by another stronger signal on the same frequency



Editor's note: FM capture effect, is a phenomenon associated with FM reception in which only the stronger of two signals at, or near, the same frequency or channel will be demodulated. ... Some types of radio receiver circuits have a stronger capture effect than others.

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E4C01 (D) What is an effect of excessive phase noise in a receiver's local oscillator? A. It limits the receiver's ability to receive strong signals B. It can affect the receiver's frequency calibration C. It decreases receiver third-order intercept point D. It can combine with strong signals on nearby frequencies to generate interference

E4C02 (A) Which of the following receiver circuits can be effective in eliminating interference from strong out-of-band signals? A. A front-end filter or pre-selector B. A narrow IF filter C. A notch filter D. A properly adjusted product detector

E4C03 (C) What is the term for the suppression in an FM receiver of one signal by another stronger signal on the same frequency? A. Desensitization B. Cross-modulation interference C. Capture effect D. Frequency discrimination

E4C04 (D) What is the noise figure of a receiver? A. The ratio of atmospheric noise to phase noise B. The ratio of the noise bandwidth in hertz to the theoretical bandwidth of a resistive network C. The ratio of thermal noise to atmospheric noise D. The ratio in dB of the noise generated by the receiver to the theoretical minimum noise

E4C05 (B) What does a receiver noise floor of -174 dBm represent? A. The minimum detectable signal as a function of receive frequency B. The theoretical noise in a 1 Hz bandwidth at the input of a perfect receiver at room temperature C. The noise figure of a 1 Hz bandwidth receiver D. The galactic noise contribution to minimum detectable signal

E4C06 (D) A CW receiver with the AGC off has an equivalent input noise power density of -174 dBm/Hz. What would be the level of an unmodulated carrier input to this receiver that would yield an audio output SNR of 0 dB in a 400 Hz noise bandwidth? A. -174 dBm B. -164 dBm C. -155 dBm D. -148 dBm

E4C07 (B) What does the MDS of a receiver represent? A. The meter display sensitivity B. The minimum discernible signal C. The multiplex distortion stability D. The maximum detectable spectrum

E4C08 (D) An SDR receiver is overloaded when input signals exceed what level? A. One-half the maximum sample rate B. One-half the maximum sampling buffer size C. The maximum count value of the analog-to-digital converter D. The reference voltage of the analog-to-digital converter

E4C09 (C) Which of the following choices is a good reason for selecting a high frequency for the design of the IF in a superheterodyne HF or VHF communications receiver? A. Fewer components in the receiver B. Reduced drift C. Easier for front-end circuitry to eliminate image responses D. Improved receiver noise figure

E4C10 (C) What is an advantage of having a variety of receiver IF bandwidths from which to select? A. The noise figure of the RF amplifier can be adjusted to match the modulation type, thus increasing receiver sensitivity B. Receiver power consumption can be reduced when wider bandwidth is not required C. Receive bandwidth can be set to match the modulation bandwidth, maximizing signal-to-noise ratio and minimizing interference D. Multiple frequencies can be received simultaneously if desired

E4C11 (D) Why can an attenuator be used to reduce receiver overload on the lower frequency HF bands with little or no impact on signal-to-noise ratio? A. The attenuator has a low-pass filter to increase the strength of lower frequency signals B. The attenuator has a noise filter to suppress interference C. Signals are attenuated separately from the noise D. Atmospheric noise is generally greater than internally generated noise even after attenuation

E4C12 (D) Which of the following has the largest effect on an SDR receiver's dynamic range? A. CPU register width in bits B. Anti-aliasing input filter bandwidth C. RAM speed used for data storage D. Analog-to-digital converter sample width in bits

E4C13 (C) How does a narrow-band roofing filter affect receiver performance? A. It improves sensitivity by reducing front end noise B. It improves intelligibility by using low Q circuitry to reduce ringing C. It improves dynamic range by attenuating strong signals near the receive frequency D. All these choices are correct

E4C14 (D) What transmit frequency might generate an image response signal in a receiver tuned to 14.300 MHz and that uses a 455 kHz IF frequency? A. 13.845 MHz B. 14.755 MHz C. 14.445 MHz D. 15.210 MHz

E4C15 (D) What is reciprocal mixing? A. Two out-of-band signals mixing to generate an in-band spurious signal B. In-phase signals cancelling in a mixer resulting in loss of receiver sensitivity C. Two digital signals combining from alternate time slots D. Local oscillator phase noise mixing with adjacent strong signals to create interference to desired signals

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E4D Receiver performance characteristics

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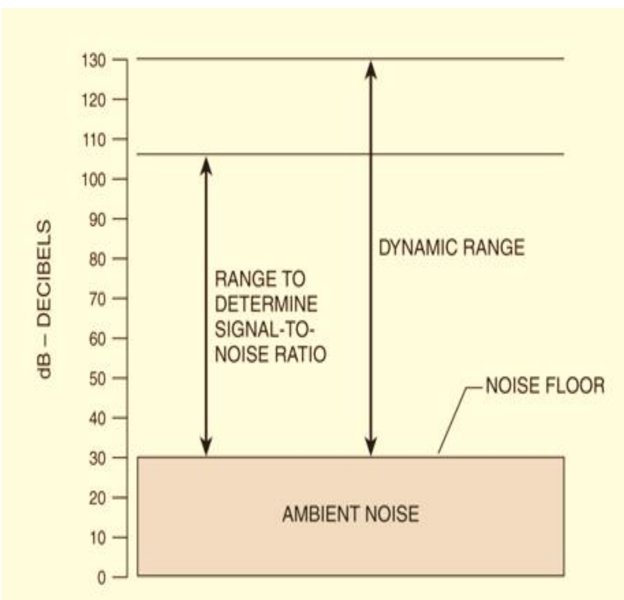
Blocking Dynamic Range (BDR) is the difference in dB between the noise floor and the level of an incoming signal which will cause 1 dB of gain compression.

Spurious signals caused by cross-modulation and desensitization from strong adjacent signals can be caused by **poor dynamic range** in a receiver



Dynamic Range is the ability of a receiver to tolerate strong signals outside of the normal passband.

The ratio between MDS and the largest input signal that does not cause distortion products.

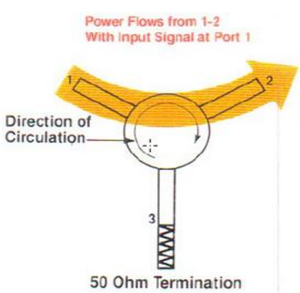
Dynamic range measurements are in dB.

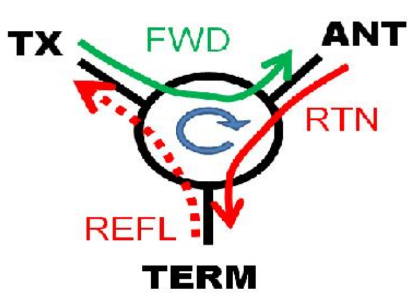
Blocking Dynamic Range (BDR)

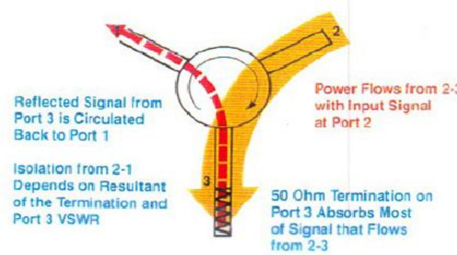
A strong input signal can cause the receiver to no longer respond linearly and gain to drop.

Causes weaker signals to appear to fade

A properly **terminated circulator** at the output of the transmitter may reduce or eliminate intermodulation in a repeater caused by another transmitter operating in close proximity







Desensitization is the reduction in receiver sensitivity caused by a **strong signal near the received frequency**

Strong adjacent-channel signals can cause receiver **desensitization**

Decreasing the RF bandwidth of a receiver **will reduce** the likelihood of receiver **desensitization**

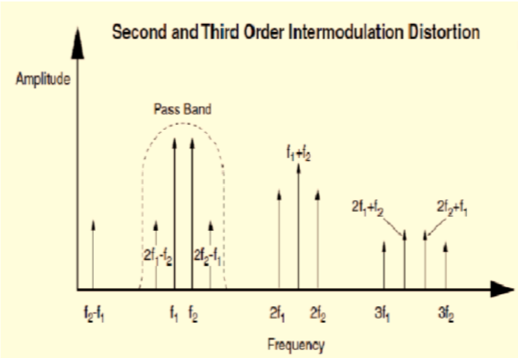
A **PRESELECTOR** increases the rejection of unwanted signals

Nonlinear circuits or devices causes intermodulation in an electronic circuit

Intermodulation is the term for spurious signals generated by the combination of two or more signals in a **non-linear device or circuit.**

Odd-order intermodulation products of two signals in the band of interest are likely **to be in band**

When the repeaters are in close proximity and the signals mix in the final amplifier of one or both transmitters intermodulation interference between two repeaters can occur



Intermod Product	Frequency
Second Order	$f_1 + f_2$
	$f_1 - f_2$
Third Order	$2f_1 + f_2$
	$2f_1 - f_2$
	$f_1 + 2f_2$
	$f_1 - 2f_2$

What transmitter frequencies would cause an intermodulation-product signal in a receiver tuned to 146.70 MHz when a nearby station transmits on 146.52 MHz? = A. 146.34 MHz and 146.61 MHz

There are many possible IMD solutions; You know 146.70 MHz = F_{IMD} and you know transmitter A (TX_a) = 146.52 MHz you are being asked to find transmitter B!

#1) 2nd $F_{IMD} = TX_a + TX_b$ > too high for the receiver

#2) 2nd $F_{IMD} = TX_a - TX_b$ > too low for the receiver

#3) 3rd $F_{IMD} = 2TX_a + TX_b$ > too high for the receiver

#4) 3rd $F_{IMD} = 2TX_a - TX_b$ > 146.70= (2 x 146.52) - TX_b

$TX_{b\,=}$ (2 x 146.52) - 146.70

$TX_{b\,=}$ (293.04) - 146.70 = **146.34 MHz**

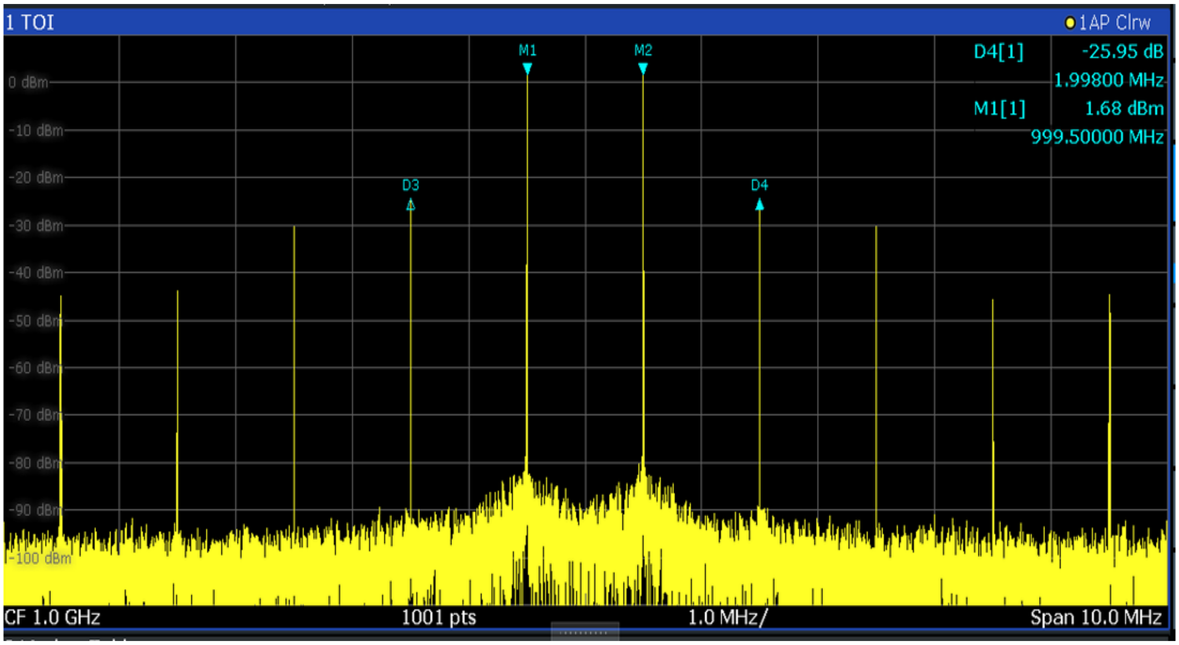
#5) 3rd $F_{IMD} = 2TX_b + TX_a$ > too high for the receiver

#6) 3rd $F_{IMD} = 2TX_b - TX_a$ > 146.70 = (2 x TX_b) - 146.52

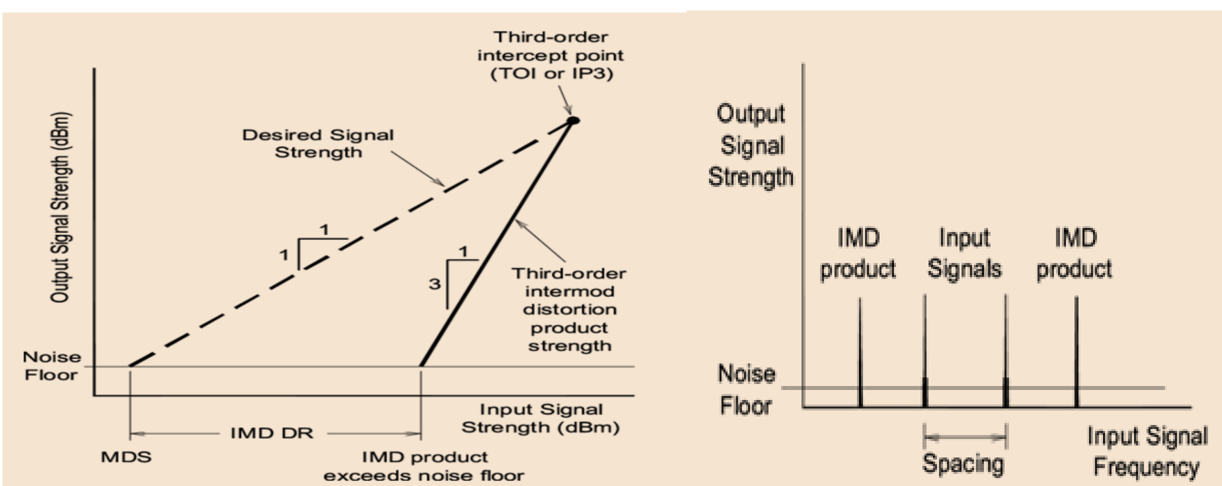
$TX_b =$ (146.70 + 146.52) / 2

$TX_b =$ (293.22) / 2 = **146.61 MHZ**

Receiver third-order intercept level of 40 dBm means a pair of 40 dBm signals will theoretically generate a third-order intermodulation product with the **same level as the input signals**



Editor's note: Third order intercept point is an ideal point as once the device reaches to 1 dB compression point the two curves will become parallel to each other and they will never cut. Which shows that the power for fundamental and third order component will not be same. but this parameter is very important in terms of characterizing a device.



Editor's note: Receiver output power for a desired signal and for third-order distortion products varies with changes of input signal power. The input signal consists of two equal-power sine-wave signas. Higher Intercept points represent better receiver IMD performance. The input signal power at which the level of the distortion products equals the output level for the desired signal is the receiver's intercept point. Example: A 40 dBm third-order intercept point means a pair of 40 dBm signals would produce and IMD product of same 40 dBm level.

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E4D01 (A) What is meant by the blocking dynamic range of a receiver? A. The difference in dB between the noise floor and the level of an incoming signal that will cause 1 dB of gain compression B. The minimum difference in dB between the levels of two FM signals that will cause one signal to block the other C. The difference in dB between the noise floor and the third-order intercept point D. The minimum difference in dB between two signals which produce third-order intermodulation products greater than the noise floor

E4D02 (A) Which of the following describes problems caused by poor dynamic range in a receiver? A. Spurious signals caused by cross-modulation and desensitization from strong adjacent signals B. Oscillator instability requiring frequent retuning and loss of ability to recover the opposite sideband C. Cross-modulation of the desired signal and insufficient audio power to operate the speaker D. Oscillator instability and severe audio distortion of all but the strongest received signals

E4D03 (B) How can intermodulation interference between two repeaters occur? A. When the repeaters are in close proximity and the signals cause feedback in the final amplifier of one or both transmitters B. When the repeaters are in close proximity and the signals mix in the final amplifier of one or both transmitters C. When the signals from the transmitters are reflected out of phase from airplanes passing overhead D. When the signals from the transmitters are reflected in phase from airplanes passing overhead

E4D04 (B) Which of the following may reduce or eliminate intermodulation interference in a repeater caused by another transmitter operating in close proximity? A. A band-pass filter in the feed line between the transmitter and receiver B. A properly terminated circulator at the output of the repeater's transmitter C. Utilizing a Class C final amplifier D. Utilizing a Class D final amplifier

E4D05 (A) What transmitter frequencies would cause an intermodulation-product signal in a receiver tuned to 146.70 MHz when a nearby station transmits on 146.52 MHz? A. 146.34 MHz and 146.61 MHz B. 146.88 MHz and 146.34 MHz C. 146.10 MHz and 147.30 MHz D. 173.35 MHz and 139.40 MHz

E4D06 (D) What is the term for spurious signals generated by the combination of two or more signals in a non-linear device or circuit? A. Amplifier desensitization B. Neutralization C. Adjacent channel interference D. Intermodulation

E4D07 (A) Which of the following reduces the likelihood of receiver desensitization? A. Decrease the RF bandwidth of the receiver B. Raise the receiver IF frequency C. Increase the receiver front end gain D. Switch from fast AGC to slow AGC

E4D08 (C) What causes intermodulation in an electronic circuit? A. Too little gain B. Lack of neutralization C. Nonlinear circuits or devices D. Positive feedback

E4D09 (C) What is the purpose of the preselector in a communications receiver? A. To store often-used frequencies B. To provide a range of AGC time constants C. To increase rejection of signals outside the desired band D. To allow selection of the optimum RF amplifier device

E4D10 (C) What does a third-order intercept level of 40 dBm mean with respect to receiver performance? A. Signals less than 40 dBm will not generate audible third-order intermodulation products B. The receiver can tolerate signals up to 40 dB above the noise floor without producing third-order intermodulation products C. A pair of 40 dBm input signals will theoretically generate a third-order intermodulation product that has the same output amplitude as either of the input signals D. A pair of 1 mW input signals will produce a third-order intermodulation product that is 40 dB stronger than the input signal

E4D11 (A) Why are odd-order intermodulation products, created within a receiver, of particular interest compared to other products? A. Odd-order products of two signals in the band of interest are also likely to be within the band B. Odd-order products overload the IF filters C. Odd-order products are an indication of poor image rejection D. Odd-order intermodulation produces three products for every input signal within the band of interest

E4D12 (A) What is the term for the reduction in receiver sensitivity caused by a strong signal near the received frequency? A. Desensitization B. Quieting C. Cross-modulation interference D. Squelch gain rollback

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E4E Noise suppression and interference

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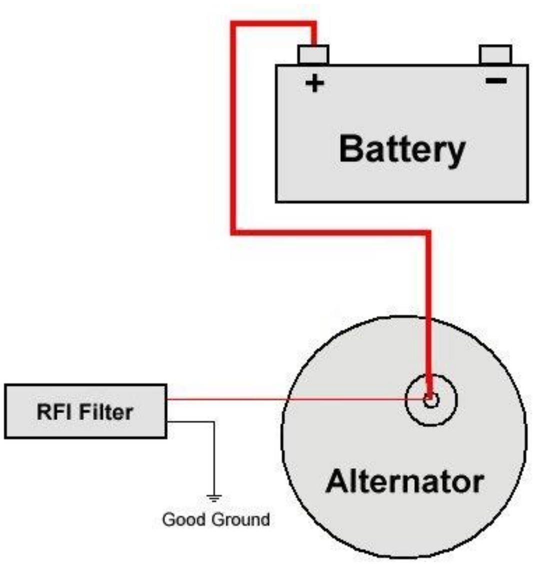
Common-mode currents on the shield and conductors can cause shielded cables to radiate or receive interference

Common-mode current flows equally on all conductors of an unshielded multi-conductor cable

Broadband white noise, ignition noise & power line noise can often be reduced with a **DSP noise filter**

A **noise blanker** may remove **signals which appear across a wide bandwidth**

Electric motor noise may be suppressed by installing a brute-force **AC-line filter in series with the motor leads**

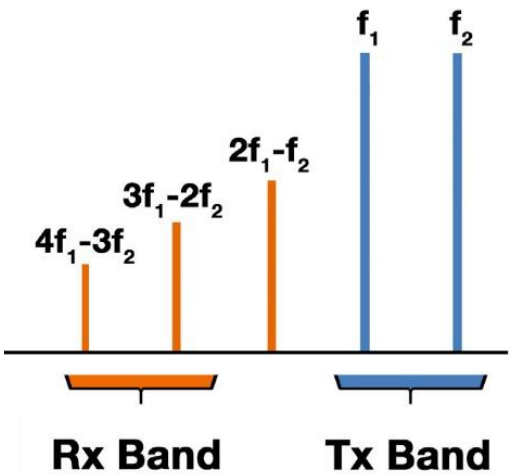


Alternator noise may be suppressed by connecting the radio's power leads **directly to the battery** and by installing **coaxial capacitors in line with the alternator** leads

Arcing thermostat contacts, defective **doorbell transformer** or a malfunctioning **illuminated advertising display** may cause a loud roaring or buzzing AC line interference that comes and goes at intervals

An **IF noise blanker** makes **nearby signals may appear to be excessively wide** even if they meet emission standards

Editor's note: This is because a peak of the signal is removed and the broader lower section is only received. The observed 3 dB bandwidth of the blanked signal would appear to be much wider than if referred to the original peak signal level. - AD7FO

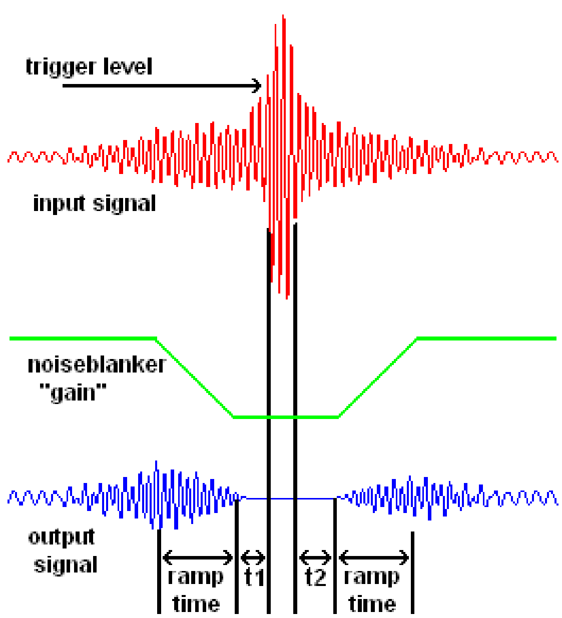


Nearby **corroded metal joints are mixing and re-radiating the broadcast signals** cause if you are hearing combinations of local AM broadcast signals within one or more of the MF or HF ham bands?

One disadvantage of using some types of **automatic DSP notch-filters** when attempting to copy CW signals is the **DSP filter can remove the desired signal at the same time as it removes interfering signals**

The appearance of **unstable modulated or unmodulated signals at specific frequencies** might be caused by the operation of a nearby **personal computer**

Editor's note: Corroded joints act like diodes and then function as a mixer generating sum and difference frequencies from nearby strong signals. - AD7FO



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E4E01 (A) What problem can occur when using an automatic notch filter (ANF) to remove interfering carriers while receiving CW signals? A. Removal of the CW signal as well as the interfering carrier B. Any nearby signal passing through the DSP system will overwhelm the desired signal C. Received CW signals will appear to be modulated at the DSP clock frequency D. Ringing in the DSP filter will completely remove the spaces between the CW characters

E4E02 (D) Which of the following types of noise can often be reduced with a digital signal processing noise filter? A. Broadband white noise B. Ignition noise C. Power line noise D. All these choices are correct

E4E03 (B) Which of the following signals might a receiver noise blanker be able to remove from desired signals? A. Signals that are constant at all IF levels B. Signals that appear across a wide bandwidth C. Signals that appear at one IF but not another D. Signals that have a sharply peaked frequency distribution

E4E04 (D) How can conducted and radiated noise caused by an automobile alternator be suppressed? A. By installing filter capacitors in series with the DC power lead and a blocking capacitor in the field lead B. By installing a noise suppression resistor and a blocking capacitor in both leads C. By installing a high-pass filter in series with the radio's power lead and a low-pass filter in parallel with the field lead D. By connecting the radio's power leads directly to the battery and by installing coaxial capacitors in line with the alternator leads

E4E05 (B) How can radio frequency interference from an AC motor be suppressed? A. By installing a high-pass filter in series with the motor's power leads B. By installing a brute-force AC-line filter in series with the motor leads C. By installing a bypass capacitor in series with the motor leads D. By using a ground-fault current interrupter in the circuit used to power the motor

E4E06 (C) What is one type of electrical interference that might be caused by a nearby personal computer? A. A loud AC hum in the audio output of your station receiver B. A clicking noise at intervals of a few seconds C. The appearance of unstable modulated or unmodulated signals at specific frequencies D. A whining type noise that continually pulses off and on

E4E07 (B) Which of the following can cause shielded cables to radiate or receive interference? A. Low inductance ground connections at both ends of the shield B. Common-mode currents on the shield and conductors C. Use of braided shielding material D. Tying all ground connections to a common point resulting in differential-mode currents in the shield

E4E08 (B) What current flows equally on all conductors of an unshielded multi-conductor cable? A. Differential-mode current B. Common-mode current C. Reactive current only D. Return current

E4E09 (C) What undesirable effect can occur when using an IF noise blanker? A. Received audio in the speech range might have an echo effect B. The audio frequency bandwidth of the received signal might be compressed C. Nearby signals may appear to be excessively wide even if they meet emission standards D. FM signals can no longer be demodulated

E4E10 (D) What might be the cause of a loud roaring or buzzing AC line interference that comes and goes at intervals? A. Arcing contacts in a thermostatically controlled device B. A defective doorbell or doorbell transformer inside a nearby residence C. A malfunctioning illuminated advertising display D. All these choices are correct

E4E11 (B) What could cause local AM broadcast band signals to combine to generate spurious signals in the MF or HF bands? A. One or more of the broadcast stations is transmitting an over-modulated signal B. Nearby corroded metal joints are mixing and re-radiating the broadcast signals C. You are receiving skywave signals from a distant station D. Your station receiver IF amplifier stage is defective

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E2A Amateur radio in space

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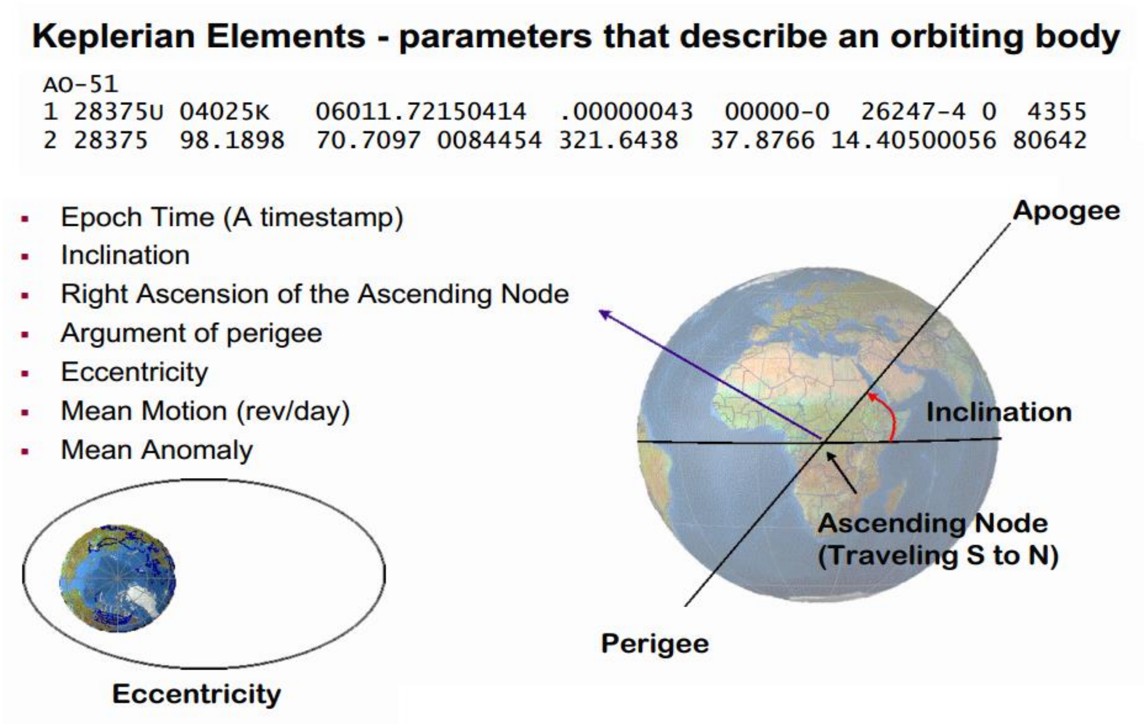
Keplerian elements are parameters that define the **orbit of a satellite**

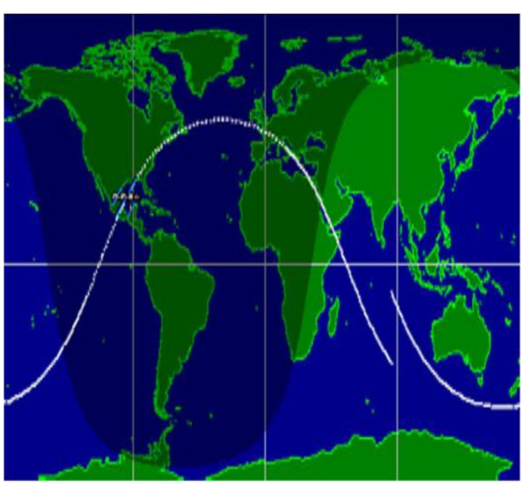


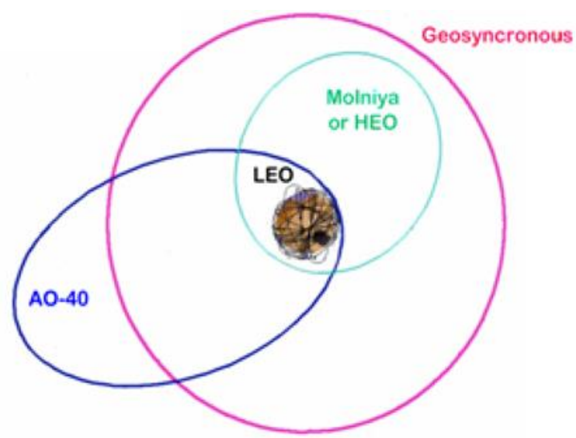
A **Geostationary** satellite appears to stay in one position in the sky

From south to north is the direction of an **ascending pass** for an amateur satellite

Digital store-and-forward functions on an amateur radio satellite stores digital messages in the satellite **for later download by other stations**

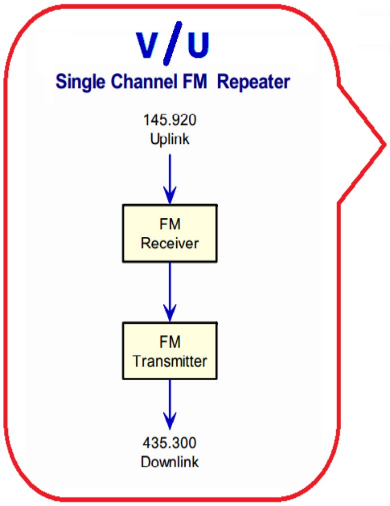
Store-and-forward is normally used by **low Earth orbiting digital satellites to relay messages** around the world





The letters in a satellite's **MODE** designator specify the **uplink and downlink** frequency ranges

L band is 23 cm and **S band is 13 cm** regarding satellite communications



HF Bands	29.300 – 29.500	200 KHz	Primary	Uplink & Downlink
V Band	145.800 – 146.000	200 KHz	Primary	Uplink and Downlink
U Band	435.000 – 438.000	3 MHz	Secondary	Uplink and Downlink
L Band	1260 – 1270	10 MHz	Secondary	Uplink Only
S Band	2400 – 2450 3400 – 3410*	10 MHz 10 MHz	Secondary Secondary	Uplink and Downlink Uplink and Downlink
C Band	5650 – 5670 5830 – 5850	20 MHz 20 MHz	Secondary Secondary	Uplink Only Downlink Only
X Band	10.45 – 10.5 GHz	50 MHz	Secondary	Uplink and Downlink
K Band	24.0 – 24.05 GHz	50 MHz	Primary	Uplink and Downlink
Q Band	47.0 – 47.2 GHz	200 MHz	Primary	Uplink and Downlink
W Band	75.5 – 76.0 GHz	500 MHz	Primary	Uplink and Downlink

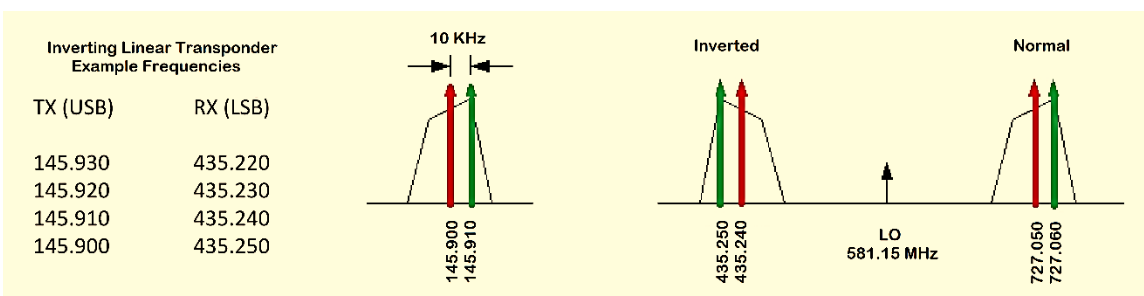
The following types of signals can be relayed through a **linear transponder**;

- **FM and CW**
- **SSB and SSTV**
- **PSK and Packet**

The following occurs when a satellite is using an **INVERTING LINEAR TRANSPONDER:**

- **Doppler shift is reduced** because the uplink and downlink shifts are in opposite directions
- **Signal position in the band is reversed**
- **Upper sideband on the uplink becomes lower sideband on the downlink,** and vice versa

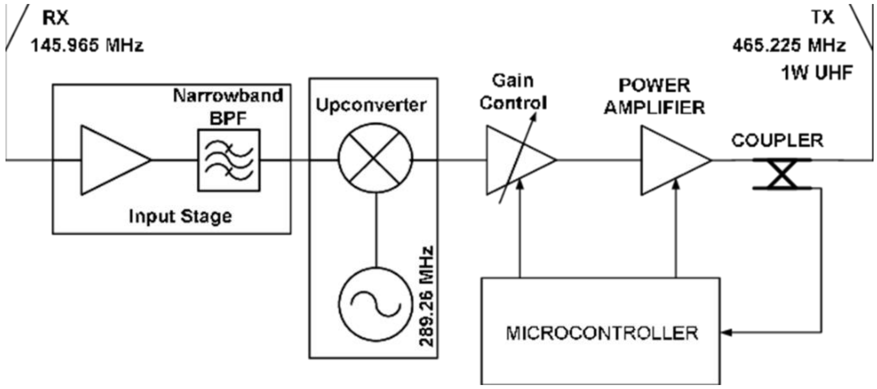
The signal is passed through a mixer and **the difference rather than the sum is transmitted in an inverting linear transponder**



A circularly polarized antenna can be used to minimize the effects of spin modulation and Faraday rotation

Editor's note: If the signal from an amateur satellite exhibit a rapidly repeating fading effect means the satellite is spinning

Limit YOUR power to a satellite which uses a **linear transponder** to avoid **reducing the downlink power** to others



Editor's Note: In a linear transponder the largest received signal sets the transponder output power. Signals less than the larger signal are attenuated and therefore are re-sent at a lower power than the larger signal. Using the minimum power needed to access the transponder will allow more users to have access to the transponder. – AD7FO

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E2A01 (C) What is the direction of an ascending pass for an amateur satellite? A. From west to east B. From east to west C. From south to north D. From north to south

E2A02 (D) Which of the following occurs when a satellite is using an inverting linear transponder? A. Doppler shift is reduced because the uplink and downlink shifts are in opposite directions B. Signal position in the band is reversed C. Upper sideband on the uplink becomes lower sideband on the downlink, and vice versa D. All these choices are correct

E2A03 (D) How is the signal inverted by an inverting linear transponder? A. The signal is detected and remodulated on the reverse sideband B. The signal is passed through a non-linear filter C. The signal is reduced to I and Q components and the Q component is filtered out D. The signal is passed through a mixer and the difference rather than the sum is transmitted

E2A04 (B) What is meant by the term mode? as applied to an amateur radio satellite? A. Whether the satellite is in a low earth or geostationary orbit B. The satellite's uplink and downlink frequency bands C. The satellite's orientation with respect to the Earth D. Whether the satellite is in a polar or equatorial orbit

E2A05 (D) What do the letters in a satellite's mode designator specify? A. Power limits for uplink and downlink transmissions B. The location of the ground control station C. The polarization of uplink and downlink signals D. The uplink and downlink frequency ranges

E2A06 (A) What are Keplerian elements? A. Parameters that define the orbit of a satellite B. Phase reversing elements in a Yagi antenna C. High-emission heater filaments used in magnetron tubes D. Encrypting codes used for spread spectrum modulation

E2A07 (D) Which of the following types of signals can be relayed through a linear transponder? A. FM and CW B. SSB and SSTV C. PSK and packet D. All these choices are correct

E2A08 (B) Why should effective radiated power to a satellite that uses a linear transponder be limited? A. To prevent creating errors in the satellite telemetry B. To avoid reducing the downlink power to all other users C. To prevent the satellite from emitting out-of-band signals D. To avoid interfering with terrestrial QSOs

E2A09 (A) What do the terms L band and S band specify regarding satellite communications? A. The 23 centimeter and 13 centimeter bands B. The 2 meter and 70 centimeter bands C. FM and Digital Store-and-Forward systems D. Which sideband to use

E2A10 (B) What type of satellite appears to stay in one position in the sky? A. HEO B. Geostationary C. Geomagnetic D. LEO

E2A11 (B) What type of antenna can be used to minimize the effects of spin modulation and Faraday rotation? A. A linearly polarized antenna B. A circularly polarized antenna C. An isotropic antenna D. A log-periodic dipole array

E2A12 (C) What is the purpose of digital store-and-forward functions on an amateur radio satellite? A. To upload operational software for the transponder B. To delay download of telemetry between satellites C. To store digital messages in the satellite for later download by other stations D. To relay messages between satellites

E2A13 (B) Which of the following techniques is normally used by low Earth orbiting digital satellites to relay messages around the world? A. Digipeating B. Store-and-forward C. Multi-satellite relaying D. Node hopping

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E2B Television practices

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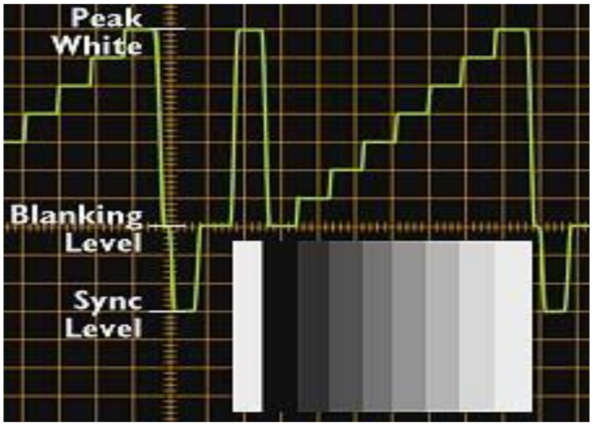
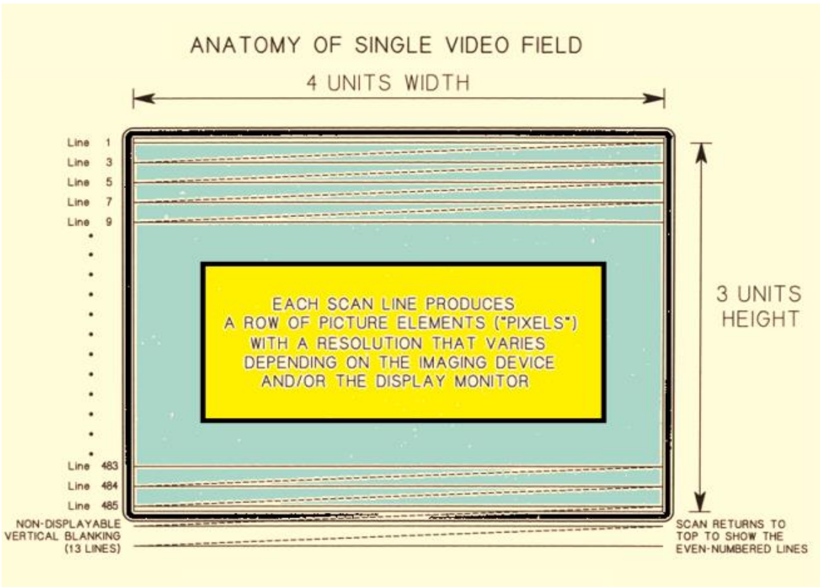
NTSC is the video standard used by North American Fast Scan ATV stations



30 frames per second are transmitted in a **fast-scan (NTSC) television** system

525 horizontal lines make up a **fast-scan (NTSC) television** frame

An **interlaced scanning** pattern generated by scanning odd numbered lines in one field and even numbered ones in the next in a fast-scan (NTSC) television system

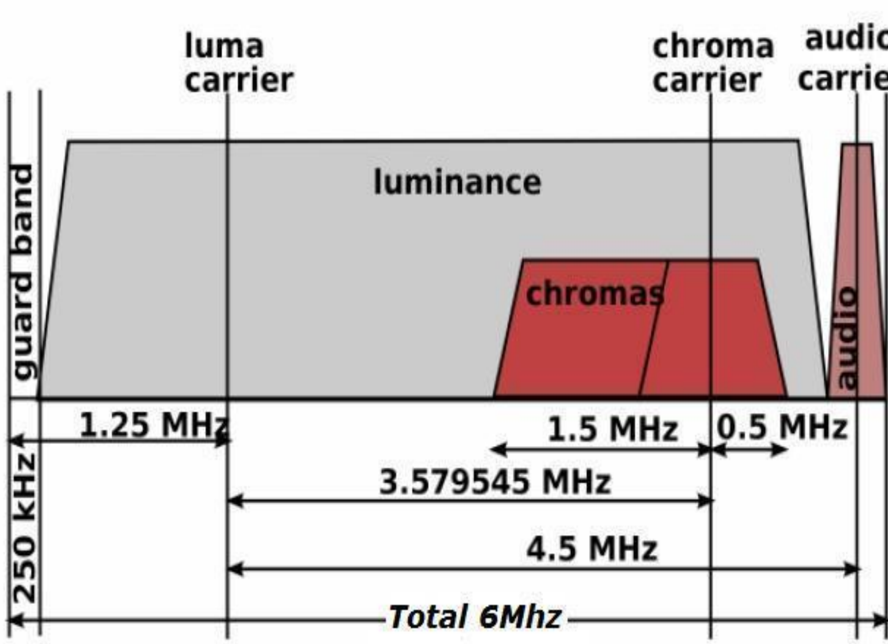


Chroma is the name of the signal component that carries color information in NTSC video

Vestigial sideband modulation is one complete sideband and a portion of the other sideband are transmitted

Vestigial sideband reduces bandwidth while allowing for simple video detector circuitry for standard fast- scan TV transmissions

Transmitting on channels shared with cable TV allows commercial analog TV receivers to be used for fast-scan TV operations on the 70 cm band



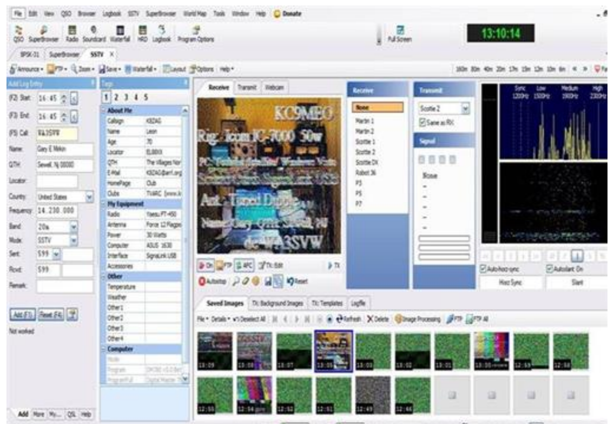
Tone frequency of an amateur slow-scan television signal **encodes the brightness** of the picture

Specific tone frequencies signal SSTV receiving equipment to **begin a new picture line**

The **Vertical Interval Signaling (VIS) code** transmitted as part of an SSTV transmission identifies the **SSTV Mode**

Digital Radio Mondiale (DRM) can be decoded using a receiver with SSB capability and a suitable computer

Color lines are sent sequentially in analog SSTV



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E2B01 (A) How many times per second is a new frame transmitted in a fast-scan (NTSC) television system? A. 30 B. 60 C. 90 D. 120

E2B02 (C) How many horizontal lines make up a fast-scan (NTSC) television frame? A. 30 B. 60 C. 525 D. 1080

E2B03 (D) How is an interlaced scanning pattern generated in a fast-scan (NTSC) television system? A. By scanning two fields simultaneously B. By scanning each field from bottom to top C. By scanning lines from left to right in one field and right to left in the next D. By scanning odd numbered lines in one field and even numbered lines in the next

E2B04 (A) How is color information sent in analog SSTV? A. Color lines are sent sequentially B. Color information is sent on a 2.8 kHz subcarrier C. Color is sent in a color burst at the end of each line D. Color is amplitude modulated on the frequency modulated intensity signal

E2B05 (C) Which of the following describes the use of vestigial sideband in analog fast-scan TV transmissions? A. The vestigial sideband carries the audio information B. The vestigial sideband contains chroma information C. Vestigial sideband reduces bandwidth while allowing for simple video detector circuitry D. Vestigial sideband provides high frequency emphasis to sharpen the picture

E2B06 (A) What is vestigial sideband modulation? A. Amplitude modulation in which one complete sideband and a portion of the other are transmitted B. A type of modulation in which one sideband is inverted C. Narrow-band FM modulation achieved by filtering one sideband from the audio before frequency modulating the carrier D. Spread spectrum modulation achieved by applying FM modulation following single sideband amplitude modulation

E2B07 (B) What is the name of the signal component that carries color information in NTSC video? A. Luminance B. Chroma C. Hue D. Spectral intensity

E2B08 (A) What technique allows commercial analog TV receivers to be used for fast-scan TV operations on the 70 cm band? A. Transmitting on channels shared with cable TV B. Using converted satellite TV dishes C. Transmitting on the abandoned TV channel 2 D. Using USB and demodulating the signal with a computer sound card

E2B09 (D) What hardware, other than a receiver with SSB capability and a suitable computer, is needed to decode SSTV using Digital Radio Mondiale (DRM)? A. A special IF converter B. A special front end limiter C. A special notch filter to remove synchronization pulses D. No other hardware is needed

E2B10 (A) What aspect of an analog slow-scan television signal encodes the brightness of the picture? A. Tone frequency B. Tone amplitude C. Sync amplitude D. Sync frequency

E2B11 (B) What is the function of the Vertical Interval Signaling (VIS) code sent as part of an SSTV transmission? A. To lock the color burst oscillator in color SSTV images B. To identify the SSTV mode being used C. To provide vertical synchronization D. To identify the call sign of the station transmitting

E2B12 (A) What signals SSTV receiving software to begin a new picture line? A. Specific tone frequencies B. Elapsed time C. Specific tone amplitudes D. A two-tone signal

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Class Three Fundamentals and Substance

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After completing each class be sure to use the Fundamentals and Substance subsection that was solely created as a tool for test preparation by helping you make connections between topics and serves as quality review material for after each class. Using these steps can be most useful when learning about new topics that include a lot of detail. The information is in the form of class notes with all of the important information you need to know. These notes are not a substitute for studying the class material in fact you will need to complete your class assignment in order to effectively use these notes. The notes are organized into easily digestible headings and bullet points to organize topics with the key words, main subpoints and summary are all written in one place.

==

AC Waveforms

256 **different input levels can be encoded by an ADC with 8-bit resolution** or 2^8 bits

A Square wave is made up of a sine wave plus all of its odd harmonics

A Saw Tooth wave is made up of a sine wave plus all of its harmonics

Successive Approximation ADC is a type of analog-to-digital converter that compares via a progressive quantization before finally converging upon a digital output for each conversion.

Flash ADC is a type of analog-to-digital converter that uses multiple comparator sat each to compare the input voltage to reference voltages simultaneously (also known as a direct-conversion ADC).

Total harmonic distortion is a measure of the quality of an analog-to-digital converter

A small amount of **noise added** to the input signal to allow more precise representation of a signal over time is **"dither" with respect to analog-to-digital converters**

A low-pass filter used in conjunction with a digital-to-analog converter remove harmonics from the output caused by the discrete analog levels generated

2:1 ratio of PEP-to-average power in a typical SSB phone signal

Speech characteristics determines the PEP-to-average power ratio of a SSB phone signal

Test equipment

Sampling rate determines the **bandwidth** of a digital oscilloscope

A spectrum analyzer displays **frequency on the horizontal axis**

A spectrum analyzer displays **amplitude on the vertical axis**

A **spectrum analyzer is used to display intermodulation distortion** products in an SSB transmission?

The **compensation of an oscilloscope probe** is adjusted until the horizontal portions of the displayed wave are as nearly **flat as possible**

The effect of **aliasing in a digital or computer-based oscilloscope are false signals** being displayed

Keep the **oscilloscope probe ground** connection of the probe as **short as possible**

A Logic analyzer displays multiple digital signal states simultaneously

A **PRESCALER** divides a high frequency signal so a low-frequency counter can display the frequency

Antenna analyzers do not need an external RF source to measure antenna SWR

An antenna analyzer measures SWR

Connect the **antenna feed line directly to the analyzer's** connector when measuring antenna resonance and feed point impedance

Measurements

Input impedance, Output impedance and Reflection coefficient can be measured with a Vector Network Analyzer (VNA)

The VNA ports at which measurements are made are **represented by S parameters**

VNA S21 is equivalent to forward gain

VNA S21 is equivalent to SWR (equivalent to return loss)

Short circuit, open circuit, and 50 ohms test loads are used to **calibrate a VNA**

Intermodulation distortion (IMD) >> SSB TX non-harmonically **two tones** & observe RF on a spectrum analyzer

75 W is absorbed by the load when a directional power meter between a transmitter and load reads 100 W forward and 25 W reflected power

There is **more power going into the antenna if the current reading on an RF ammeter** placed in the antenna feed line of a transmitter **increases as the transmitter is tuned to resonance**

The accuracy of the **time base determines the accuracy** of a **frequency counter**

The full-scale reading of the voltmeter in ohms per volt rating will indicate the input impedance of the voltmeter

The **bandwidth of the circuit's frequency response** can be used to measure the **Q** of a series-tuned circuit

Modulation

The frequency components present in **the modulating signal is called BASEBAND**

The two input frequencies along with their **SUM AND DIFFERENCE FREQUENCIES** appear at the output of a mixer circuit

SPURIOUS MIXER PRODUCTS are generated when an **excessive signal** energy reaches a mixer

A **diode detector** functions by rectification and filtering of RF signals

A **reactance modulator** on the oscillator can be used to generate **FM phone** emissions

The function of a **reactance modulator is to produce PM** signals by using an electrically variable inductance or capacitance

The **frequency DISCRIMINATOR** stage in a FM receiver is used for **detecting FM signals**

A **pre-emphasis** network circuit is added to an **FM transmitter** to **boost the higher audio** frequencies

De-emphasis commonly used in FM communications receivers for compatibility with **transmitters using phase modulation**

A **SSB phone** signal can be **generated** by using a **BALANCED modulator** followed by a filter

A **PRODUCT detector** is well suited for demodulating **SSB** signals

The maximum **carrier frequency** deviation compared to the highest audio **modulating frequency** is the **deviation ratio**

Modulation index is the term for the ratio between the frequency deviation of an RF carrier wave, and the modulating frequency of its corresponding FM-phone signal

Modulation index = Max Carrier Dev / Max Modulation

FREQUENCY DIVISION MULTIPLEXING is two or more information streams are merged into a baseband, which then modulates the transmitter

Digital TIME DIVISION MULTIPLEXING is two or more signals are arranged to share discrete time slots of a data transmission

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING is a technique used for **HIGH-SPEED DIGITAL MODES** in amateur communication

A digital modulation technique using **subcarriers at frequencies chosen to avoid intersymbol interference** describes ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

Digital Comms

The **rate a waveform changes to convey information is the definition of symbol rate** in a digital transmission

Using a more efficient **digital code increases data rate be without increasing bandwidth**

Symbol rate and baud are the same

Keying speed and shape factor (rise and fall time) are factors affect the bandwidth of a transmitted CW signal

52 Hz is the approximate bandwidth of a 13-WPM International Morse Code transmission

Sinusoidal data pulses minimize the bandwidth of a PSK31 signal

To minimize bandwidth the phase-shifting of a PSK signal is at the zero crossing of the RF signal

Forward Error Correction (FEC) is implemented by transmitting extra data that may be used to detect and correct transmission errors

Gray code allows only one bit to change between sequential code values

With ARQ if errors are detected, a retransmission is requested

Signals not using the spread spectrum algorithm are suppressed in the receiver therefore resistant to interference

Direct sequence spread-spectrum (DSSS) communications technique uses a high-speed binary bit stream to shift the phase of an RF carrier

Frequency hopping spread-spectrum (FHSS) communications technique alters the center frequency of a conventional carrier many times per second in accordance with a pseudo-random list of channels

ASCII code has both **upper- and lower-case** text

Some types of **errors can be detected** by including a **parity bit** with an **ASCII** character stream

ASCII uses **seven or eight data bits** per character and no shift code

BAUDOT uses 5 data bits per character and uses 2 characters as **letters/figures shift codes**

Intermodulation and Spurious Signals

Excessive transmit audio levels common cause of overmodulation of AFSK signals and can cause spurious emissions and Intermodulation Distortion (IMD)

-30 dB an acceptable maximum IMD level for an idling PSK signal

The generation of key clicks is the primary effect of extremely short rise or fall time on a CW signal

Increase keying waveform rise and fall times is the most common method of **reducing key clicks**

Receiver Performance

An attenuator be used to reduce receiver overload on the lower frequency HF bands with little or no impact on signal-to-noise ratio because atmospheric noise is generally greater than internally generated noise even after attenuation

A **narrow-band roofing filter improves dynamic range** by attenuating strong signals near the receive frequency

A **front-end filter or pre-selector** can be effective in **eliminating image signal interference**
Minimum discernible signal (MDS) represents the receiver minimum discernible signal

The **noise figure of a receiver** >> ratio in dB of the noise generated by the receiver vs. theoretical minimum noise

The **theoretical noise** at the input of a perfect receiver at room temperature = **-174 dBm/Hz**

MDS for 400 Hz = -148 dBm

Receiver **oscillator phase noise** causes nearby frequencies to **interfere with reception of weak**

Reciprocal mixing is the local oscillator mixing with adjacent strong signals to create interference to desired signals

A **higher frequency IF** is EASIER design to **eliminate image responses**

Receive bandwidth selected to match the modulation bandwidth, maximizing signal-to-noise ratio and minimizing interference is an advantage of having a **variety of receiver IF bandwidths**

An SDR receiver is overloaded when input signals exceed the ADC reference voltage

Reference voltage level and sample bits determine the **minimum detectable signal level** for an SDR receiver.

Analog-to-digital converter sample width in bits has the largest effect on an SDR receiver's dynamic range

Capture effect is the term for the suppression in an FM receiver of one signal by another stronger signal on the same frequency

Blocking Dynamic Range (BDR) is the difference in dB between the noise floor and the level of an incoming signal which will cause 1 dB of gain compression.

Spurious signals caused by cross-modulation and desensitization from strong adjacent signals can be caused by **poor dynamic range** in a receiver

A properly **terminated circulator** at the output of the transmitter may reduce or eliminate intermodulation in a repeater caused by another transmitter operating in close proximity

Desensitization is the reduction in receiver sensitivity caused by a **strong signal near the received frequency**

Strong adjacent-channel signals can cause receiver **desensitization**

Decreasing the RF bandwidth of a receiver **will reduce** the likelihood of receiver **desensitization**

A **PRESELECTOR** increases the rejection of unwanted signals

Nonlinear circuits or devices causes intermodulation in an electronic circuit

Intermodulation is the term for spurious signals generated by the combination of two or more signals in a **non-linear device or circuit.**

Odd-order intermodulation products of two signals in the band of interest are likely **to be in band**

When the repeaters are in close proximity and the signals mix in the final amplifier of one or both transmitters intermodulation interference between two repeaters can occur

Receiver third-order intercept level of 40 dBm means a pair of 40 dBm signals will theoretically generate a third-order intermodulation product with the **same level as the input signals**

Noise Suppression

Common-mode currents on the shield and conductors can cause shielded cables to radiate or receive interference

Common-mode current flows equally on all conductors of an unshielded multi-conductor cable

Broadband white noise, ignition noise & power line noise can often be reduced with a **DSP noise filter**

A **noise blanker** may remove **signals which appear across a wide bandwidth**

Electric motor noise may be suppressed by installing a brute-force **AC-line filter in series with the motor leads**

Alternator noise may be suppressed by connecting the radio's power leads **directly to the battery** and by installing **coaxial capacitors in line with the alternator** leads

Arcing thermostat contacts, defective **doorbell transformer** or a malfunctioning **illuminated advertising display** may cause a loud roaring or buzzing AC line interference that comes and goes at intervals

An **IF noise blanker** makes **nearby signals may appear to be excessively wide** even if they meet emission standards

Nearby **corroded metal joints are mixing and re-radiating the broadcast signals** cause if you are hearing combinations of local AM broadcast signals within one or more of the MF or HF ham bands?

One disadvantage of using some types of **automatic DSP notch-filters** when attempting to copy CW signals is the **DSP filter can remove the desired signal at the same time as it removes interfering signals**

The appearance of **unstable modulated or unmodulated signals at specific frequencies** might be caused by the operation of a nearby **personal computer**

Satellites

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A **Geostationary** satellite appears to stay in one position in the sky

From south to north is the direction of an **ascending pass** for an amateur satellite

Digital store-and-forward functions on an amateur radio satellite stores digital messages in the satellite **for later download by other stations**

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A circularly polarized antenna can be used to minimize the effects of spin modulation

Limit YOUR power to a satellite which uses a **linear transponder** to avoid **reducing the downlink power** to others

Television

NTSC is the video standard used by North American Fast Scan ATV stations

30 frames per second are transmitted in a **fast-scan (NTSC) television** system

525 horizontal lines make up a **fast-scan (NTSC) television** frame

An **interlaced scanning** pattern generated by scanning odd numbered lines in one field and even numbered ones in the next in a fast-scan (NTSC) television system

Chroma is the name of the signal component that carries color information in NTSC video

Vestigial sideband modulation is one complete sideband and a portion of the other sideband are transmitted

Vestigial sideband reduces bandwidth while allowing for simple video detector circuitry for standard fast- scan TV transmissions

Transmitting on channels shared with cable TV allows commercial analog TV receivers to be used for fast-scan TV operations on the 70 cm band

Tone frequency of an amateur slow-scan television signal **encodes the brightness** of the picture

Specific tone frequencies signal SSTV receiving equipment to **begin a new picture line**

The **Vertical Interval Signaling (VIS) code** transmitted as part of an SSTV transmission identifies the **SSTV Mode**

Digital Radio Mondiale (DRM) can be decoded using a receiver with SSB capability and a suitable computer

Color lines are sent sequentially in analog SSTV

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CLASS 4 - AC WAVEFORM TRANSMISSION CHARACTERISTICS AND QUANTIFICATION

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Using the Language of Waveforms as a HAM

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This section is not about the Extra Class License exam it is included solely to provide contextual meaning to the many ways science uses measurement systems with quantity to RF waveforms; VSWR, Reflection Coefficient, Return Loss, Forward Power, Reflected Power , Radiated Power, Rectangular Coordinates, Polar notation, Vectors, Smith Charts and Fast Fourier Transforms. AS a HAM understanding there are more ways to measure RF than frequency and SWR is good but the knowledge of where to find much more detailed RF yardsticks and their relationships will make you a better HAM.

Quantifying

Basic to the whole idea of weights and measures are the concepts of uniformity, units, and standards. Uniformity, the essence of any system of weights and measures, requires accurate, reliable standards of mass and length and agreed-on units. These quantities with physical dimensions to allow documenting, communicating and conversion between units; ratios, length, time, current, mass, temperature, luminance and substance. In radio we use units of; ratios, length, time, current, voltage and watts to express the invisible things that describe the magic that cannot be seen directly. Radio must have frequency, the rate at which something occurs is all about time and the number of waves that pass a fixed place in a given amount of time. Still each unit is the name of a quantity, such as meters or feet. Most of radio uses meters, seconds' and ratios.

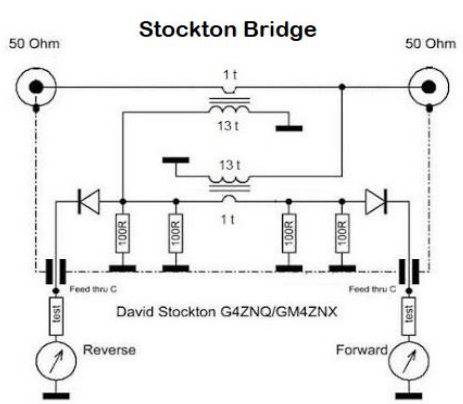
All about Wavelengths

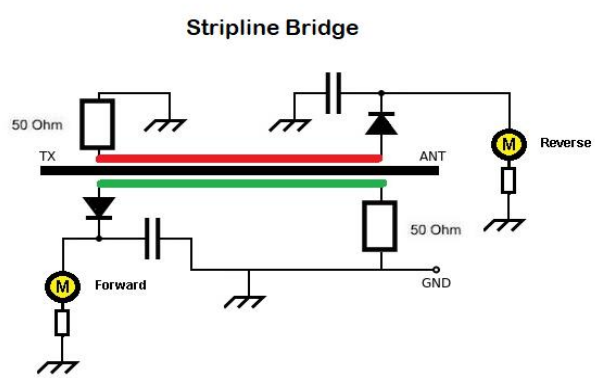
The basic building block of radio communications is a radio wave. Like waves on a pond, a radio wave is a series of repeating peaks and valleys. The entire pattern of a wave, before it repeats itself, is called a cycle. The wavelength is the distance a wave takes to complete one cycle. Yes, you are a HAM and already know about wavelengths but take a moment to look at this key parameter that determine the behavior of all antennas and transmission lines. Look at the basic Vertical 1/4 Wavelength Monopole antenna as an example. As long as the antenna is not near any objects the free space impedance of the quarter-wave monopole is the same, 37.5+j21.25 ohms independent of frequency. Changing your view point from frequency to wavelengths is an advantage when dealing with both understanding and practical considerations. If you have ever worked on a 1950's 40M tube radio with point to point wiring it would not be unusual to have a six-inch wire lead at RF. The same wire on a 70cm radio would devastating as six inches is 1/4 WL, but 1/4 WL of 40M is 35 feet. HAMs tend to think in frequency knowing with UHF and higher lead length is critical as an accepted rule without thinking. Looking at the wavelength involved the impacts are self-explanatory instead of just accepted practice.

On transmission lines RF currents tend to reflect from discontinuities in the cable such as connectors and joints, and impedance mismatches then travel back down the cable toward the transmitter. These reflections act as bottlenecks, preventing the RF power from reaching the antenna. Transmission lines use specialized construction, and impedance matching, to carry electromagnetic signals with minimal reflections and power losses. The distinguishing feature of most transmission lines is that they have uniform cross-sectional dimensions along their length, giving them a uniform impedance, called the characteristic impedance to prevent reflections by design. This applies to all types of transmission lines; parallel lines, coaxial cable, and PCB lines such as stripline and microstrip. The need for special designs like stripline makes sense for the wavelength of the waves. Using transmission lines become necessary when the transmitted frequency's wavelength is sufficiently short that the length of the cable becomes a significant part of a wavelength.

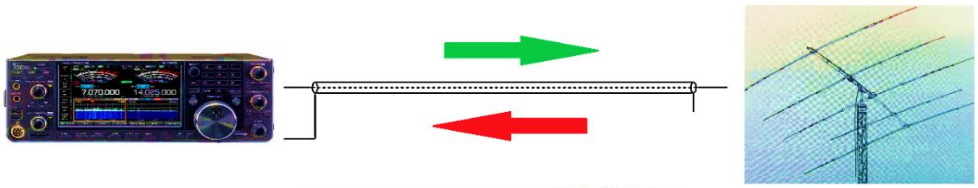
Voltage Standing Wave Ratio

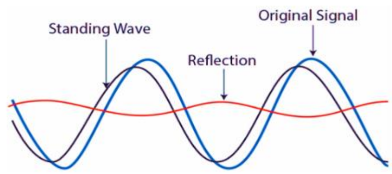
Starting with VSWR and reviewing the 622 questions in the current Extra Class pool the term “SWR” is used in 15 places including distractor answers. Nowhere is SWR required to be calculated, you are only are required to understand the meaning. As SWR is the most common measurement used by HAMs let’s look at transmission lines on how SWR applies with its physical properties. For most SWR is a measure of how efficiently RF power is transferred from a transmitter, through a transmission line, into an antenna. Commonly the yardstick for impedance matching of loads to the characteristic impedance of a transmission line. Impedance mismatches result in standing waves along the transmission line, and VSWR is defined as the ratio of the partial standing wave's amplitude at maximum to the amplitude at minimum along the line. Below are pictures and schematics of the two most common bridge circuits used to measure SWR, Stockton and Stripline bridges.





The Stockton uses a ferrite toroid as an RF current sampler and is limited to 300 MHz in most designs. The stripline uses coupled lines in close enough in proximity so that energy from one line passes to the other as a voltage sampler and can exceed a GHz in usable range. SWR is usually thought of in terms of the maximum and minimum AC voltages along the transmission line, thus called the voltage standing wave ratio, however both circuits use reference loads, typically 50 Ohms, to become forward and reverse power meters.





The magic comes as a ratio SWR can be determined from voltage, power or impedances.

$$\mathrm{SWR} = \frac{|V_{\max}|}{|V_{\min}|} \qquad \mathrm{SWR} = \frac{1+\sqrt{P_r/P_f}}{1-\sqrt{P_r/P_f}}. \qquad \mathrm{SWR} = \left(\frac{R_{\mathrm{L}}}{Z_0}\right)^{\pm 1}$$

Coefficient of Reflection

The Reflection Coefficient (Γ) indicates is the ratio of the reflected wave to that of **the incident wave by an impedance discontinuity in the transmission medium**. It is a ratio of the amplitude of the reflected wave to the forward wave. The reflection coefficient depends on the load impedance and the impedance of the transmission line. Although this is starting to sound like SWR the reflection coefficient is different than the VSWR. The reflection coefficient **quantifies the level of the incident waveform that is reflected**, whereas the standing wave ratio, be it a current standing wave ratio or a voltage standing wave ratio looks at the ratio of the peak and minimum voltage or current levels within the feeder arising from the forward and reflected power.

$$\Gamma = \frac{V_{\mathrm{ref}}}{V_{\mathrm{fwd}}} \qquad \Gamma = \left|\frac{Z_L - Z_0}{Z_L = Z_0}\right| \qquad \Gamma = \sqrt{\frac{P_{\mathrm{ref}}}{P_{\mathrm{fwd}}}}$$

The Reflection Coefficient (Γ) is not SWR but does have a direct relationship if you look closely at he formula below.

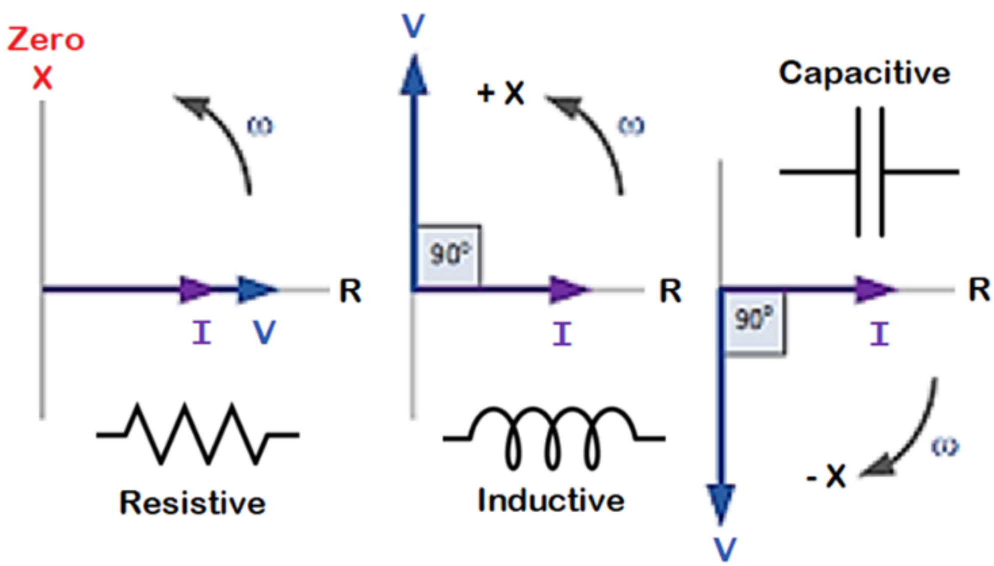
$$\mathrm{VSWR} = \frac{|V_{\max}|}{|V_{\min}|} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

At this point, you should begin to understand the importance of impedance matching: grossly mismatched impedances will lead to most of the power reflected away from the load. The tablebelow show the real-world relationships between; SWR, Reflection Coefficient, Return Loss, Forward Power, Reflected Power and Radiated Power.

SWR	Γ	RL dB	Forward W	Reflected W	Radiated
1.00	0.00	-66.02	1000	0	1000
1.10	0.05	-26.44	1000	2	998
1.20	0.09	-20.83	1000	8	992
1.30	0.13	-17.69	1000	17	983
1.45	0.18	-14.72	1000	34	966
1.50	0.20	-13.98	1000	40	960
2.00	0.33	-9.54	1000	111	889
3.00	0.50	-6.02	1000	250	750
5.00	0.67	-3.52	1000	444	556
10.00	0.82	-1.74	1000	669	331

Rectangular Coordinates

Sometimes SWR does not provide enough information you want to match or tune the antenna for maximum radiation. The maximum power theorem says that maximum power is transferred from source to load when the load resistance equals the source resistance and the load reactance equals the negative of the source reactance. It is necessary to have more details on the antenna impedance which is equivalent to a resistance in series with a reactance expressed as a complex number. The impedance caused by these two effects is collectively referred to as reactance and forms the imaginary part of complex impedance whereas resistance forms the real part. The complex number, with resistance is the ohms plus reactance in ohms. The reactance can be positive (Inductive) or negative (capacitive), written R + j.



In Rectangular Coordinates impedance is written R + j. In the example below 50 Ohms resistive with 80 Ohms inductive load would be R40 Ω + j80 Ω or common practice is R40+j80.

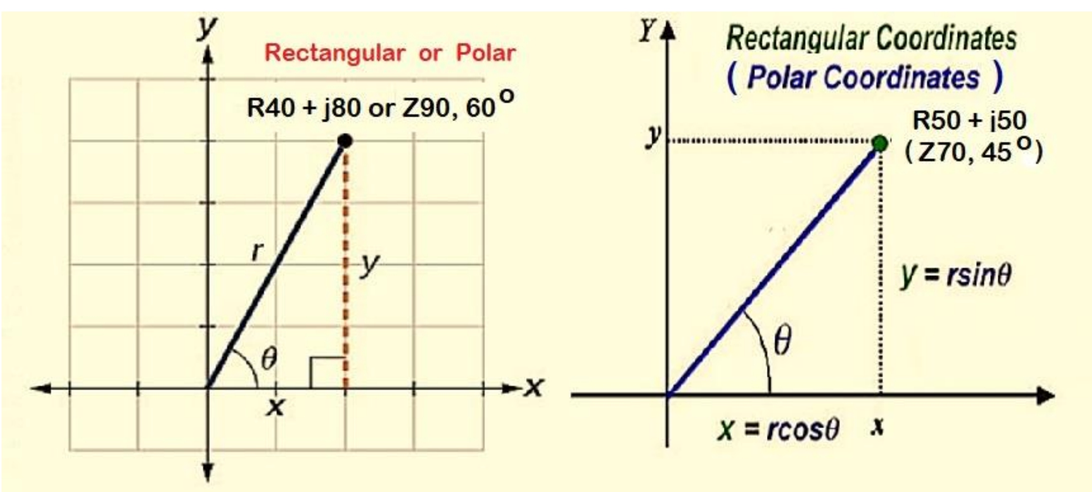
What is meant by "happy transmitter" is the concept that an antenna tuner presents a resistive load of 50 ohms to a transmitter. An indoor antenna tuner, and your antenna is a 5:1 match for your frequency 7 MHz, and the tuner brings it down to 1.0:1, but you do not get the same transfer of power to the antenna as you would if the tuner was remote at the antenna. The indoor tuner will deliver about 40W to the antenna but a remote tuner would provide 98W to the antenna. Remote tuners or antenna matching networks are always significantly better matching techniques. Rectangular Coordinates impedance information is required to design an antenna feedpoint matching network.

Polar Coordinates

Another way of stating a complex load impedance is with the concept of magnitude and phase, unlike resistance, which has only magnitude. The previous example antenna impedance was R40 + j80 would be Z90 Ohms, 60 Degrees. When a circuit is driven with direct current (DC), there is no distinction between impedance and resistance; the latter can be thought of as impedance with zero phase angle. The notion of impedance is useful for performing AC analysis of electrical networks, because it allows relating sinusoidal voltages and currents by a simple linear law.

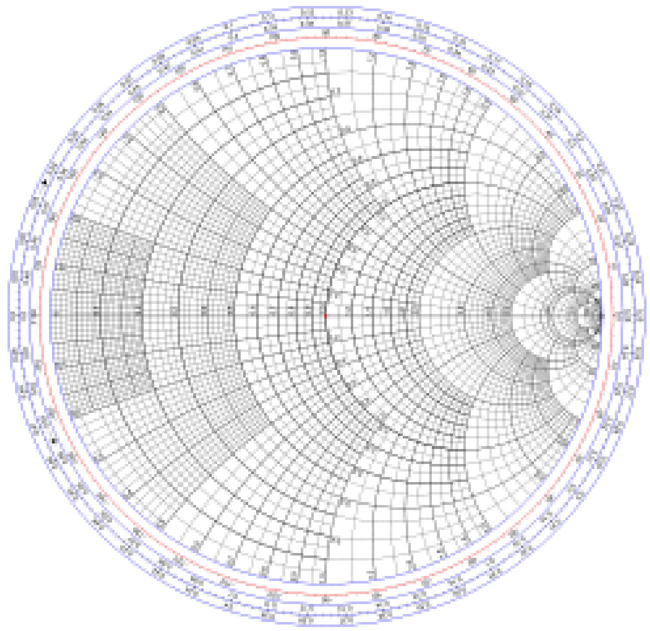
Magnitude of the complex impedance is the ratio of the voltage amplitude to the current amplitude

Phase of the complex impedance is the phase shift by which the current lags the voltage



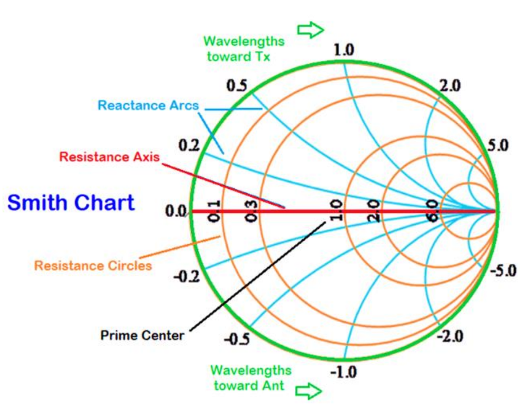
Smith Charts

The Smith chart, invented by Phillip H. Smith (1905–1987) in 1939 is a graphical calculator designed for electrical engineers specializing in RF design to assist in solving problems with transmission lines and matching circuits. A Smith chart can be used to perform an impedance match by bringing impedance to the center of the chart, which corresponds to a pure resistance of 50 Ω by adjusting the reactance values. This is achieved by designing a matching network, between the feed line and the antenna.



Consider that in 1939 computers as we know them today did not exists and only mechanical analog computers were the only alternative to pen and paper. The engineers did have the slide rule, an analog computer, as the desktop calculator until the 1970's to perform multiplication and division, and also for functions such as exponents, roots, logarithms, and trigonometry, but typically not for addition or subtraction. The slide rule is no longer used but the Smith Chart is still popular likely because it provides a visualization of the complexity of transmission lines and matching solutions. Smith Chart displays are still used today as paper plots just like SWR vs frequency plots and displays screen in Vector Network Analyzers and finite element antenna modeling.

Smith Charts are very intimidating, as they appear to have lines going everywhere. All those lines in the Smith Chart presents in one picture the complex impedances, SWR, Reflection Coefficient, and Return Loss. The chart has the added advantage of being a graphical tool for determining matching solutions. Smith Charts have the advantage of all information about the circuit is visible at once and no math is required. You do everything graphically, plot vectors and read the solution from the chart. For example, the transmission line length, adding discrete capacitors or inductors and even stub matching graphically. Essentially, everything you might need to know about is always right in front of you



Smith Chart

Resistance axis (only R straight line)

Resistance Circles (from Rt to Lt)

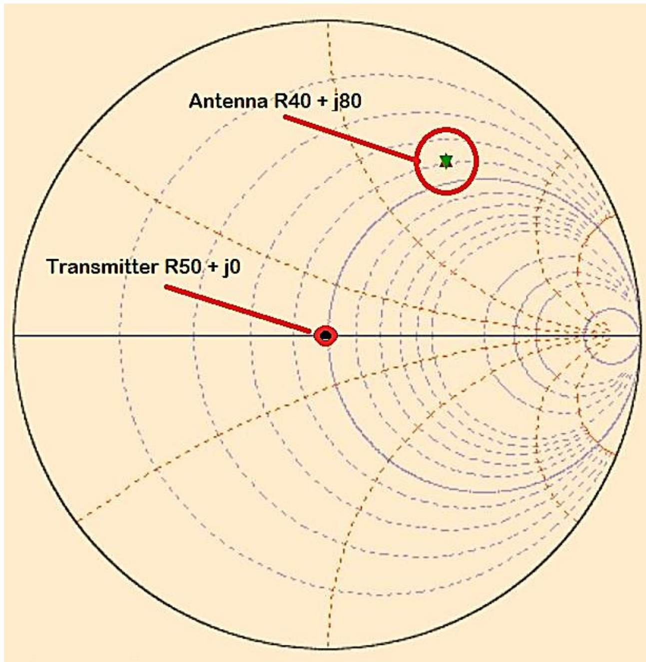
Reactance Arcs

Wavelengths are on outer circle edge

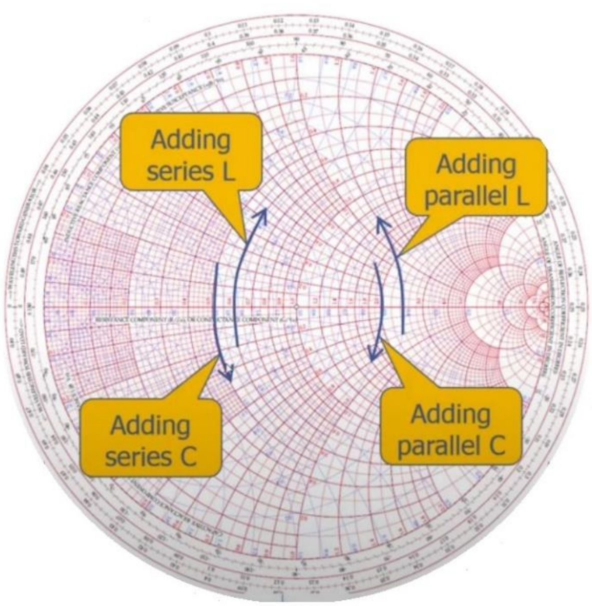
Reactance Circle is outer edge of circle

SWR Circles (from center out)

Below is a Smith Chart showing the previous example antenna impedance was R40 + j80 at the “1 PM” position and the transmitter at the center. The desire is matching the R40 + j80 to a RG58 / 50 Ohm resistive transmitter but using a Smith Chart.



Now we can look at designing a network to insert between them so that proper impedance matching occurs using the Smith Chart. Many solutions will do the job so it it better to pick a starting point based on practical considerations like as filter type structure, quality factor, and limited choice of components. The approach chosen to accomplish this calls for adding series and shunt elements on the Smith chart until the desired impedance is achieved. Graphically, it appears as finding a way to link the points on the Smith chart. Reactance components follow a simple set of rules on the chart;



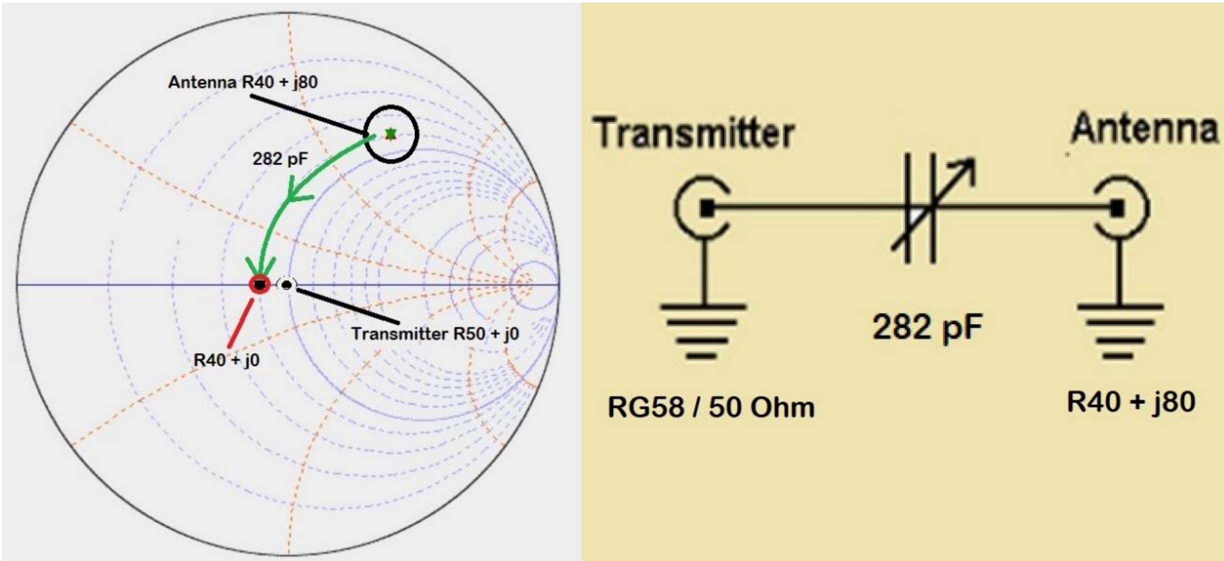
Series components follow lines of resistance (right to left increasing diameter circles)

Parallel components follow lines of reactance (left to right increasing diameter circles)

Length of the arc is equal to the component’s reactance at frequency in Ohms

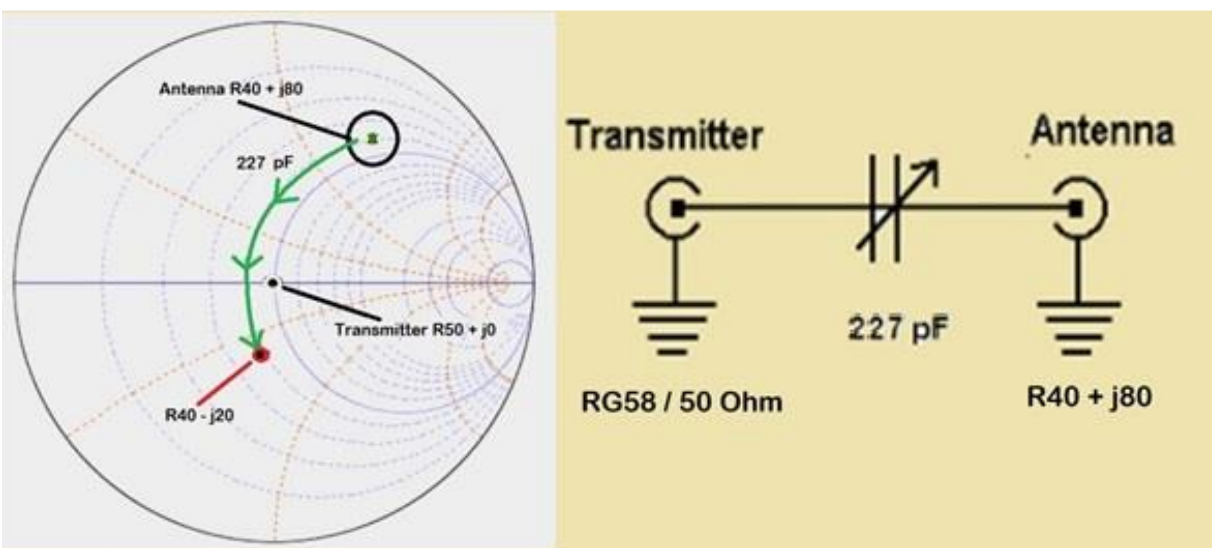
Inductive is upward capacitive is downward

Again, we want to match the R40 + j80 to a RG58 / 50 Ohm resistive 7 MHz transmitter at the center of the chart. To illustrate the approach a series capacitor is selected because I can see a downward arc on the resistive circle will bring us close to center as shown below;

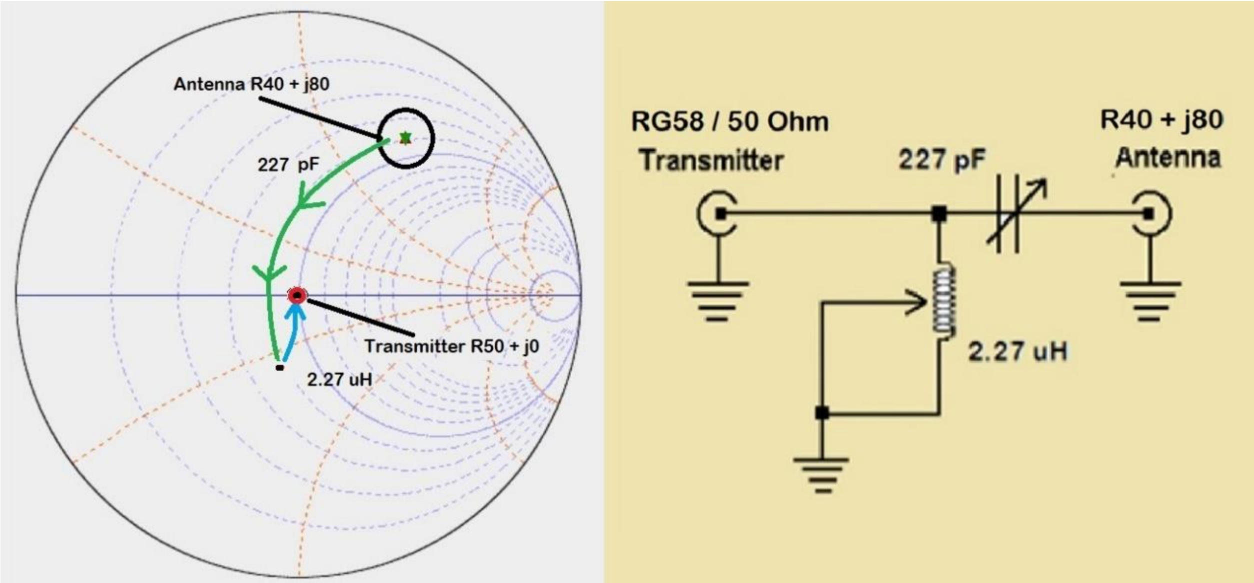


With the first the value of capacitance at 282pF the result impedance presented to the transmitter output is R40 + j0 for a SWR 1.25:1 From this point there are no series or parallel component additions that would result in a 50 Ohm match. The two simple options are a parallel capacitor or inductor, both require a different value for the series capacitor shown at 282 pF.

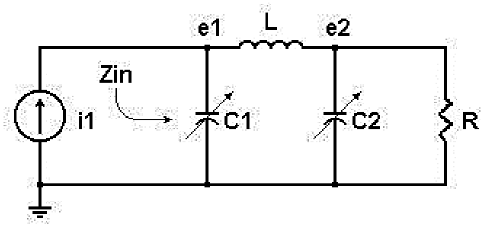
Choosing to use an inductor in parallel to replicate the more common antenna tuner configuration means a greater capacitive reactance value will be required as the inductor arc will be upward and counter-clockwise. The capacitor was 282 pF @ 7 MHz = 80 Ohms but more reactance requires the capacitance to decrease in a series circuit to 227 pF @ 7 MHz = 100 Ohms as shown below;



The addition of an inductor in shunt means a to move in the counter-clockwise direction on the admittance Smith chart until the value is found return a solution at the pure resistance line of the chart. After drawing the arc the arc length can be read from the scale. The final step is converting form reactance in Ohm to microhenries for the 7 MHz operating frequency, 2.27 uH.



The use of Smith Charts allows the graphical solution to transmission line and match network problems without the algebra or trigonometry. If the drawing of arc's and reading scales is still intimidating than the equations required for the same solutions are shown below.



$$H = \frac{e2}{i1} = \frac{R}{S^3 L\,C1\,C2\,R + S^2 L\,C1 + S\,R\,(C1 + C2) + 1}$$

$$Zin = \frac{e1}{i1} = \frac{S^2 L\,C2\,R + SL + R}{S^3 L\,C1\,C2\,R + S^2 L\,C1 + S\,R\,(C1 + C2) + 1}$$

Phase of Zin:

$$= \operatorname{atn}\left(\frac{(W\,R\,(C1 + C2) - W^3 L\,C1\,C2\,R}{(1 - W^2 L\,C1)}\right) - \operatorname{atn}\left(\frac{W\,L}{R\,(1 - W^2 L\,C2)}\right)$$

Time Domain vs. Frequency Domain

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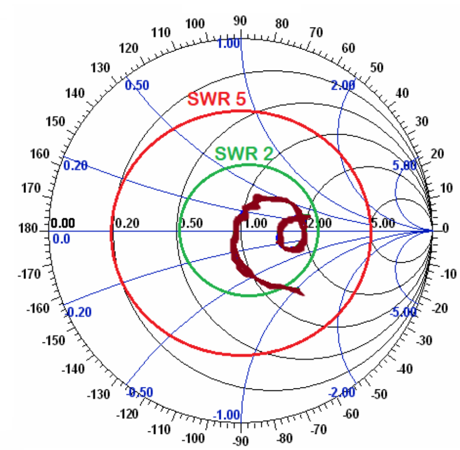
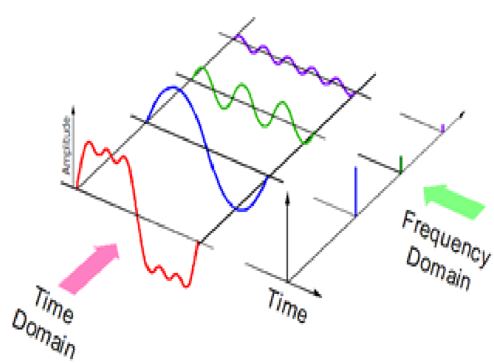
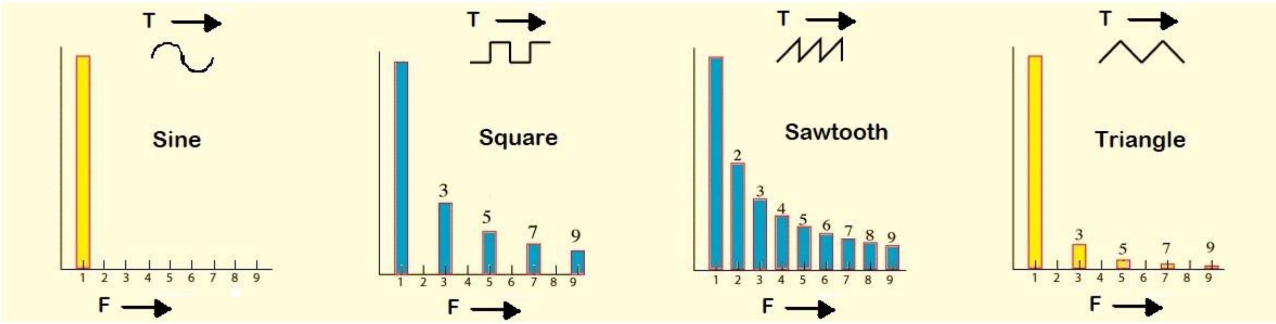
What is the frequency domain? And why is it so valuable for RF design, analysis, and testing? Perhaps one of the most fundamental steps in the process of gaining proficiency in RF design is learning to think in the frequency domain. For most of us, the vast majority of our early experience with electrical circuits and signals remains within the context of voltages and currents that are DC, static with respect to time. For example, when we measure the voltage of a battery with a multimeter, we have a static quantity, and when we look at a sinusoidal voltage on an oscilloscope, we have a time-varying quantity vs. time.

RF, on the other hand, is a world of frequencies. We do not send static voltages to antennas, and the oscilloscope is usually not an effective tool for capturing and visualizing the types of signal manipulation that are involved in wireless communication. Indeed, we can say that the time domain is simply not a convenient place for the design and analysis of RF systems. We need a different paradigm. Looking at radio in the frequency domain most of us have used “SWR bandwidth” as a term you'll often encounter when you're reading about antenna designs, or checking the specifications of commercial antennas. Basically, the SWR bandwidth is the frequency range after the antenna has been tuned at one frequency, over which the SWR is 2:1 or less. Below are commonly used frequency domain expressions of an antenna SWR vs. frequency; SWR Bandwidth and Smith Chart SWR.

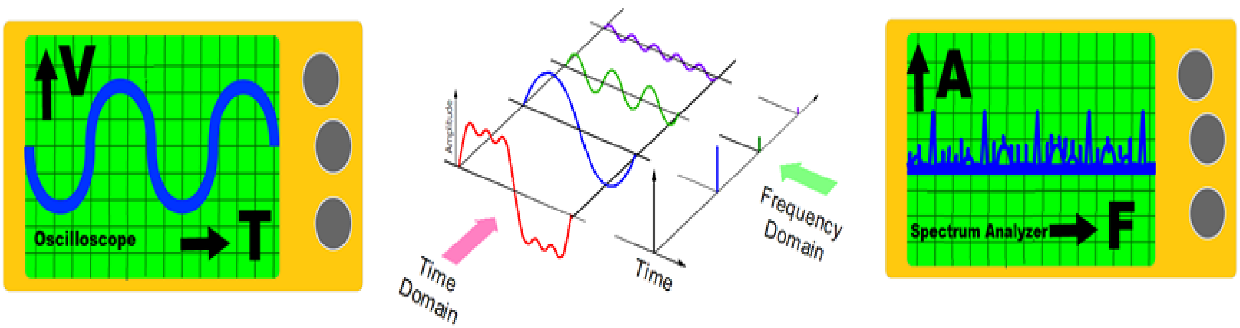


The Fourier transform is a math function that provides a method of describing a signal according to its frequency content. In Digital Signal Processing a signal is converted into its frequency components into its corresponding frequency domain. Initially people used DFT (Discrete Fourier Transform). Later on FFT (Fast Fourier Transform) was created. There is no difference between in the result from a discrete Fourier transform and a fast Fourier transform, these are software design issues. They both provide the same thing: a trigonometric series representing all the frequencies present in an input signal. Given equal inputs, both the DFT and the FFT produce exactly the same outputs.





Editor's note: Fourier analysis of t*he wave pictured above shows each wave is made up of a sine wave plus a combination of harmonics. A Square wave is made up of a sine wave plus all of its odd harmonic A Saw Tooth wave is made up of a sine wave plus all of its harmonics and a Triangle wave is a more complex.*



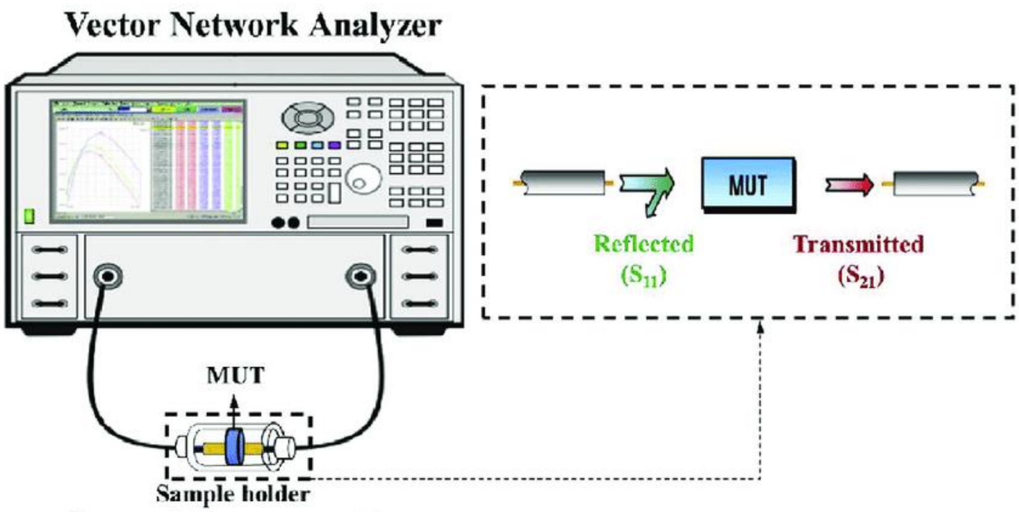
Digital signal processing is an analog-to-digital converter (ADC) converts the continuously variable analog signal into a discrete digital signal, the digital data is processed (changed in some useful way) and then a digital-to-analog converter (DAC) converts the digital signal back into an analog signal. Digital signal processing organizes signals into a frequency domain, the frequencies may be filtered in many different ways. For example, all frequencies above a desired cutoff value can be digitally eliminated (amplitude value set to zero), and all frequencies below a different cutoff value can be similarly eliminated, thereby leaving only a narrowed desired band of frequencies, as listed below;

Filter out RF noise
Filter out undesirable IF mixing products from the IF passband
Baseband notch filter, audio mixers, equalizers, compressors or expanders
Voice Shaping or Voice Speech Processor
Pantograph, Spectrum Analyzer, Waterfall Display (Frequency Domain Information)

DSP is used everywhere in all kinds of communications and the benefit of DSP is the data is transformed from RF to data without adding noise or errors from the conversion process. Independent of purpose numbers or demodulated bits; CW, AM, SSB, FM, FSK, PSK, MFSK (8, 16, 32, 64) Phase Modulator / Demodulators. Beyond to do to implement a digital signal processing system is come up with an equation that expresses the signal we'd like in terms of the signal we've got. DSP to do any of the following:

CW, SSTV, RTTY, PSK & QPSK (31, 63, 125) PACTOR, Hell, Oliva Data Encoder / Decoder
Callsign Extraction, Beacon Monitor…and other unbounded possibilities.

Vector Antenna Analyzer and Vector Network Analyzer (VNA) are a special form of DSP transceiver that measure both amplitude and phase of the fundamental and harmonics measurement systems. Network analyzers are used at RF frequencies operating frequencies can range from 5 Hz to 5 GHz. Using this fundamental signal information, microprocessors compute; VSWR, Reflection Coefficient, Return Loss, Forward Power, Reflected Power, Radiated Power, Rectangular Coordinates, Polar notation, Vectors, and Smith Charts.



A vector network analyzer (VNA) is a test system that enables the RF performance of radio frequency and microwave devices to be characterized in terms of network scattering parameters, or S parameters. The VNA creates a signal and based on the received signal characterizes the device under test. S-parameters that describe transmission, such as S21, are analogous to other familiar terms including gain, insertion loss, or attenuation. S-parameters that describe reflection, such as S11, correspond to voltage standing wave ratio (VSWR), return loss, or reflection coefficient.

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E5D AC and RF energy in real circuits

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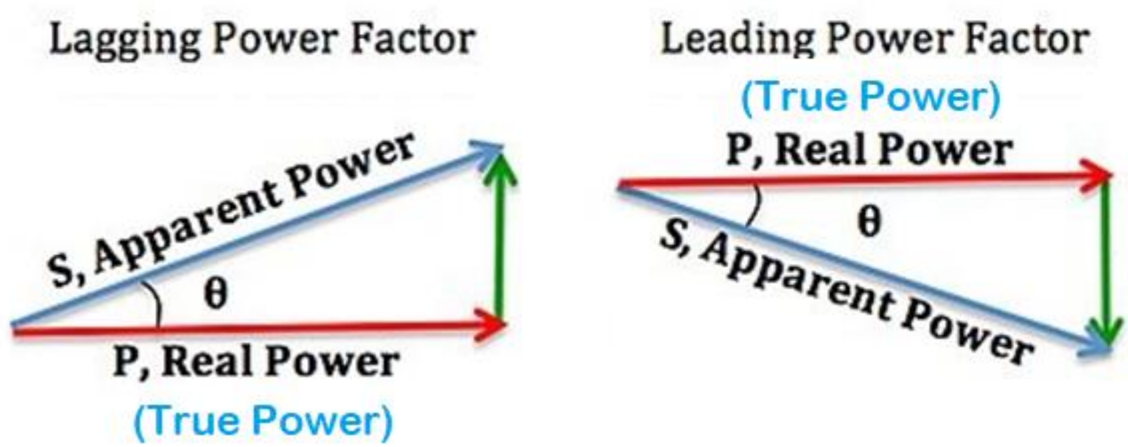
Wattless, nonproductive power is **REACTIVE POWER**

REACTIVE POWER in an AC circuit is exchanged between magnetic and electric fields, **but is not dissipated**

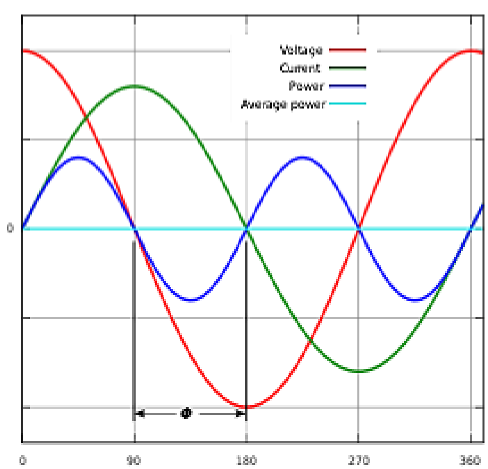
The true power be determined in an AC circuit where the voltage and current are out of phase by multiplying the apparent power by the power factor

POWER FACTOR = Real Power (Watts) / Total Power (V x A)

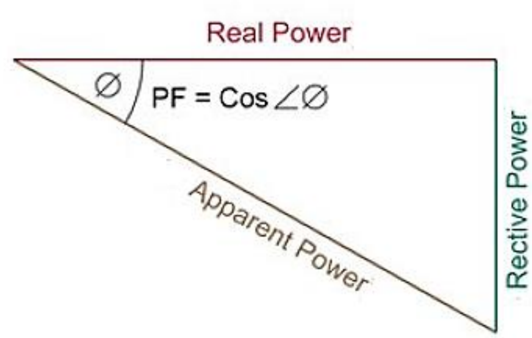
POWER FACTOR = COS of (Voltage to Current) Phase



Editor's Note: "Real"a.k.a. True power is power that does actual work - e.g: creating heat, lifting loads, etc. "Reactive power" is power where the current is out of phase with the voltage, and the "Volts x amps" doesn't do any real work. Current that charges a capacitor, for example or current that creates the magnetic field around a coil for another. "Apparent power" is the mathematical combination of these two.



Power Factor (pf) = $\frac{\text{W (Real Power)}}{\text{VA (Total Power)}}$



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E5D05 (C) What is the power factor of an RL circuit having a 30-degree phase angle between the voltage and the current? A. 1.73 B. 0.5 C. 0.866 D. 0.577

PF = COS 30° = 0.866

E5D07 (B) How many watts are consumed in a circuit having a power factor of 0.71 if the apparent power is 500VA? A. 704 W B. 355 W C. 252 W D. 1.42 mW

POWER FACTOR = Real Power (True Watts) / Total Power (V x A)

or

Real Power = PF x Total Power

Real Power = 0.71 x VA

Real Power = 0.71 x 500

Real Power = 355 W

E5D08 (D) How many watts are consumed in a circuit having a power factor of 0.6 if the input is 200VAC at 5 amperes? A. 200 watts B. 1000 watts C. 1600 watts D. 600 watts

POWER FACTOR = Real Power (True Watts) / Total Power (V x A)

or

Real Power = PF x Total Power

Real Power = 0.6 x VA

Real Power = 0.6 x (200V X 5A)

Real Power = 0.6 x 1000VA

Real Power = 600 W

E5D11 (C) What is the power factor of an RL circuit having a 60-degree phase angle between the voltage and the current? A. 1.414 B. 0.866 C. 0.5 D. 1.73

PF = COS 60° = 0.5

E5D12 (B) How many watts are consumed in a circuit having a power factor of 0.2 if the input is 100 VAC at 4 amperes? A. 400 watts B. 80 watts C. 2000 watts D. 50 watts

POWER FACTOR = Real Power (True Watts) / Total Power (V x A)

or

Real Power = PF x Total Power

Real Power = 0.2 x VA

Real Power = 0.2 x (100V X 4A)

Real Power = 0.2 x 400VA

Real Power = 80 W

E5D13 (B) How many watts are consumed in a circuit consisting of a 100-ohm resistor in series with a 100-ohm inductive reactance drawing 1 ampere? A. 70.7 watts B. 100 watts C. 141.4 watts D. 200 watts

Trick question Resistor only has **Real Power**

$W = I^2 R$ >> **Ohms Law**

$W = 1^2 \times 100$

W = 100 W

E5D15 (D) What is the power factor of an RL circuit having a 45-degree phase angle between the voltage and the current? A. 0.866 B. 1.0 C. 0.5 D. 0.707

PF = COS 45° = 0.707

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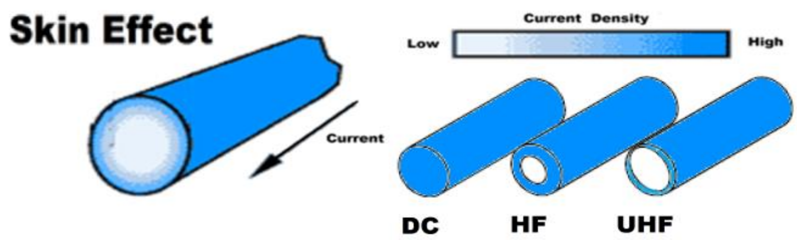
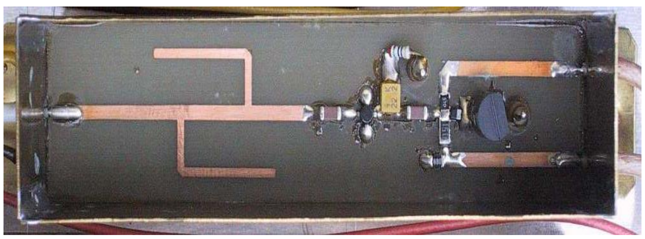
SKIN EFFECT >> As frequency increases, RF current flows closer to the surface of the conductor

Editor's Note: skin effect is why the resistance at RF currents is different at DC



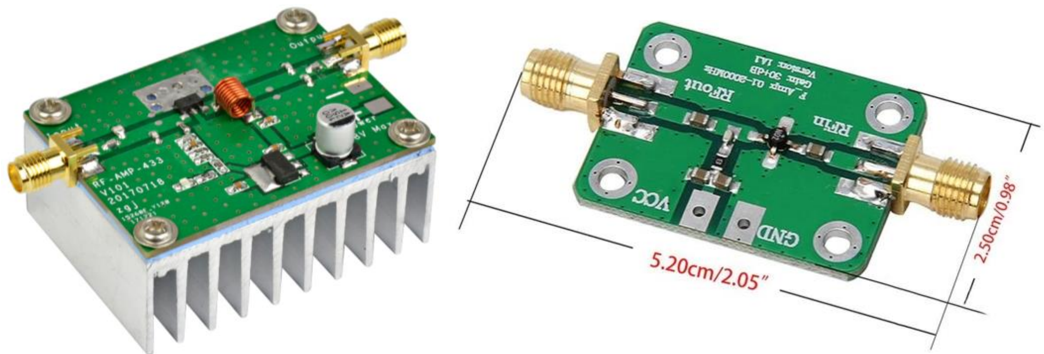
Precision printed circuit conductors above a ground plane that provide constant impedance interconnects at microwave frequencies is a **microstrip**



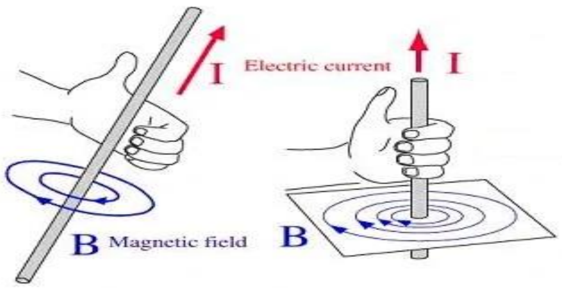
Short connections used at microwave frequencies to **reduce phase shift** along the connection

To avoid **unwanted inductive reactance**, it is important to **keep lead lengths short** for components used in circuits for VHF and above

Editor's Note: Microstrip construction is typically used to construct a MMIC based microwave amplifier



MAGNETIC FIELD is in a circle around a conductor



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E5D01 (A) What is the result of skin effect? A. As frequency increases, RF current flows in a thinner layer of the conductor, closer to the surface B. As frequency decreases, RF current flows in a thinner layer of the conductor, closer to the surface C. Thermal effects on the surface of the conductor increase the impedance D. Thermal effects on the surface of the conductor decrease the impedance

E5D02 (B) Why is it important to keep lead lengths short for components used in circuits for VHF and above? A. To increase the thermal time constant B. To avoid unwanted inductive reactance C. To maintain component lifetime D. All these choices are correct

E5D03 (D) What is microstrip? A. Lightweight transmission line made of common zip cord B. Miniature coax used for low power applications C. Short lengths of coax mounted on printed circuit boards to minimize time delay between microwave circuits D. Precision printed circuit conductors above a ground plane that provide constant impedance interconnects at microwave frequencies

E5D04 (B) Why are short connections used at microwave frequencies? A. To increase neutralizing resistance B. To reduce phase shift along the connection C. To increase compensating capacitance D. To reduce noise figure

E5D06 (D) In what direction is the magnetic field oriented about a conductor in relation to the direction of electron flow? A. In the same direction as the current B. In a direction opposite to the current C. In all directions; omni-directional D. In a circle around the conductor

E5D09 (B) What happens to reactive power in an AC circuit that has both ideal inductors and ideal capacitors? A. It is dissipated as heat in the circuit B. It is repeatedly exchanged between the associated magnetic and electric fields, but is not dissipated C. It is dissipated as kinetic energy in the circuit D. It is dissipated in the formation of inductive and capacitive fields

E5D10 (A) How can the true power be determined in an AC circuit where the voltage and current are out of phase? A. By multiplying the apparent power by the power factor B. By dividing the reactive power by the power factor C. By dividing the apparent power by the power factor D. By multiplying the reactive power by the power factor

E5D14 (A) What is reactive power? A. Wattless, nonproductive power B. Power consumed in wire resistance in an inductor C. Power lost because of capacitor leakage D. Power consumed in circuit Q

==

E5A Resonance and Q

==

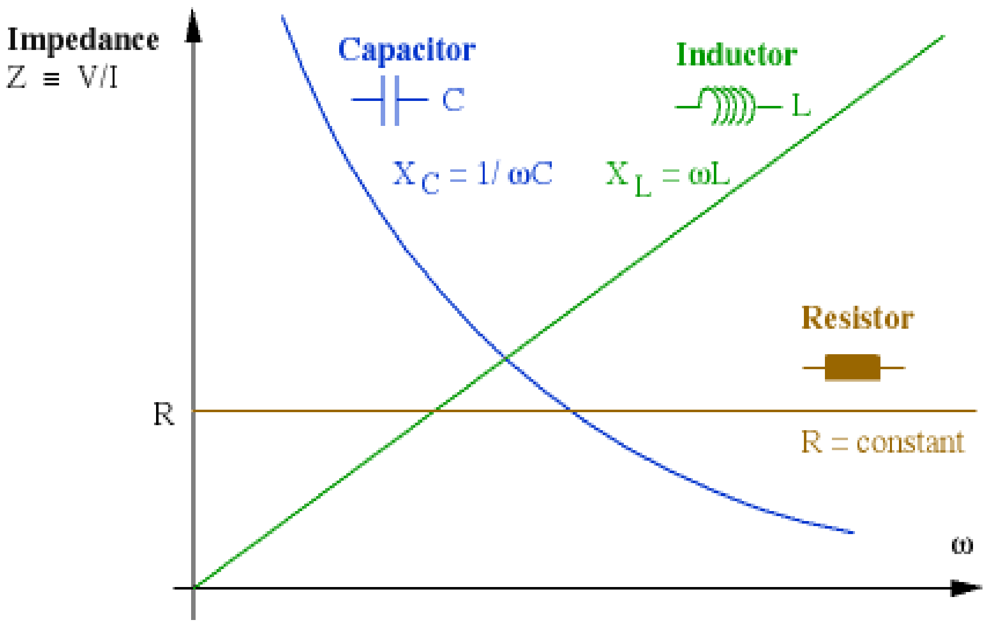
Resonance is the frequency at which the **capacitive reactance equals the inductive reactance**

Resonance can cause the voltage across **reactances** in series to be **larger than the voltage applied to them**

The magnitude of the impedance of a circuit with an **RLC all in parallel, at resonance is equal to circuit resistance (looks like R)**

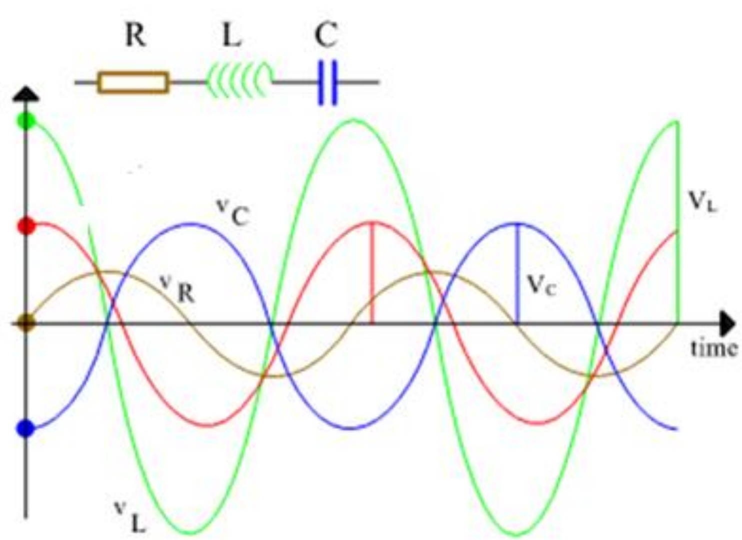
The **MAXIMUM CIRCULATING current of a parallel LC circuit occurs at resonance** within the components

MINIMUM current is at the **INPUT** of a **parallel RLC** circuit as the frequency is **resonance**



The **voltage and current are in phase** across a **series resonant** circuit at resonance

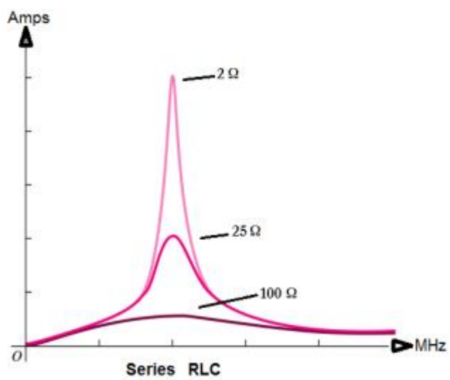
The **voltage and current are in phase** across a **parallel resonant** circuit at resonance

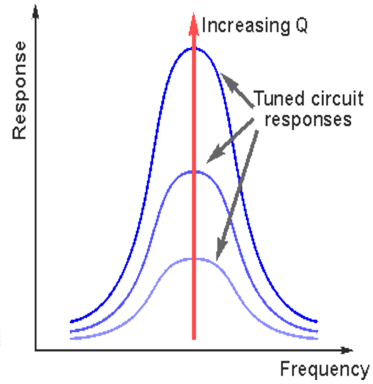


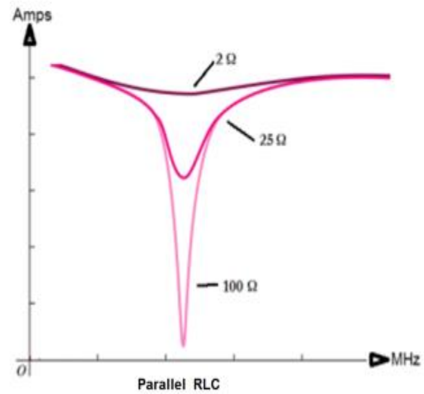
Increasing the Q of an impedance-matching circuit **decreases the bandwidth**

Increasing Q in a series resonant circuit **increases the internal voltages**

Lower losses increase Q for inductors and capacitors





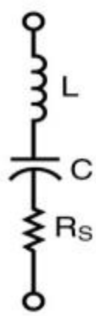


RLC **parallel** resonant circuit **Q = Resistance / Reactance = R / X**

RLC **series** resonant circuit **Q = / Reactance / Resistance = X / R**

Half Power Bandwidth = Resonant Frequency / Q of the Circuit

Series Resonant Circuit



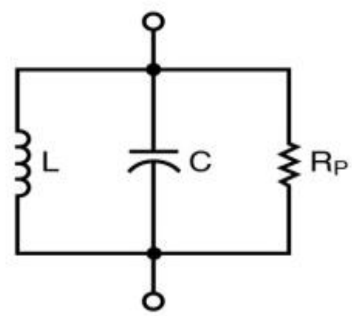
$$X_L = 2\pi f_r L$$

$$X_C = \frac{1}{2\pi f_r C}$$

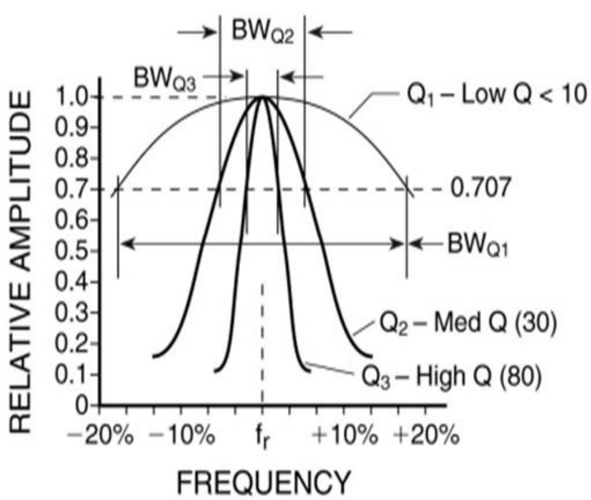
$X_L = X_C$ at f_r, the resonant frequency

$$Q = \frac{X_L}{R_S} \text{ or } \frac{X_C}{R_S}$$

Parallel Resonant Circuit



$$Q = \frac{R_P}{X_L} \text{ or } \frac{R_P}{X_C}$$



Resonant Frequency Formula

$$Fr = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}}$$

where 'f' = frequency in hertz
'L' = inductance in henrys
'C' = capacitance in farads

==

E5A01 (A) What can cause the voltage across reactances in a series RLC circuit to be higher than the voltage applied to the entire circuit? A. Resonance B. Capacitance C. Conductance D. Resistance

E5A02 (C) What is resonance in an LC or RLC circuit? A. The highest frequency that will pass current B. The lowest frequency that will pass current C. The frequency at which the capacitive reactance equals the inductive reactance D. The frequency at which the reactive impedance equals the resistive impedance

E5A03 (D) What is the magnitude of the impedance of a series RLC circuit at resonance? A. High, as compared to the circuit resistance B. Approximately equal to capacitive reactance C. Approximately equal to inductive reactance D. Approximately equal to circuit resistance

E5A04 (A) What is the magnitude of the impedance of a parallel RLC circuit at resonance? A. Approximately equal to circuit resistance B. Approximately equal to inductive reactance C. Low compared to the circuit resistance D. High compared to the circuit resistance

E5A05 (A) What is the result of increasing the Q of an impedance-matching circuit? A. Matching bandwidth is decreased B. Matching bandwidth is increased C. Matching range is increased D. It has no effect on impedance matching

E5A06 (B) What is the magnitude of the circulating current within the components of a parallel LC circuit at resonance? A. It is at a minimum B. It is at a maximum C. It equals 1 divided by the quantity 2 times pi, multiplied by the square root of inductance L multiplied by capacitance C D. It equals 2 multiplied by pi, multiplied by frequency, multiplied by inductance

E5A07 (A) What is the magnitude of the current at the input of a parallel RLC circuit at resonance? A. Minimum B. Maximum C. R/L D. L/R

E5A08 (C) What is the phase relationship between the current through and the voltage across a series resonant circuit at resonance? A. The voltage leads the current by 90 degrees B. The current leads the voltage by 90 degrees C. The voltage and current are in phase D. The voltage and current are 180 degrees out of phase

E5A09 (C) How is the Q of an RLC parallel resonant circuit calculated? A. Reactance of either the inductance or capacitance divided by the resistance B. Reactance of either the inductance or capacitance multiplied by the resistance C. Resistance divided by the reactance of either the inductance or capacitance D. Reactance of the inductance multiplied by the reactance of the capacitance

E5A10 (A) How is the Q of an RLC series resonant circuit calculated? A. Reactance of either the inductance or capacitance divided by the resistance B. Reactance of either the inductance or capacitance multiplied by the resistance C. Resistance divided by the reactance of either the inductance or capacitance D. Reactance of the inductance multiplied by the reactance of the capacitance

E5A13 (C) What is an effect of increasing Q in a series resonant circuit? A. Fewer components are needed for the same performance B. Parasitic effects are minimized C. Internal voltages increase D. Phase shift can become uncontrolled

E5A15 (A) Which of the following increases Q for inductors and capacitors? A. Lower losses B. Lower reactance C. Lower self-resonant frequency D. Higher self-resonant frequency

E5A11 (C) What is the half-power bandwidth of a resonant circuit that has a resonant frequency of 7.1 MHz and a Q of 150? A. 157.8 Hz B. 315.6 Hz C. 47.3 kHz D. 23.67 kHz

Half Power BW = Resonant Frequency / Q of the Circuit

$$\Delta \mathbf{F = Fr / Q}$$

$$\Delta \text{F = 7.1 MHz / 150}$$

$$\Delta \text{F = 7100 KHz / 150}$$

$$\Delta \text{F = 47.333 KHz}$$

E5A12 (C) What is the half-power bandwidth of a resonant circuit that has a resonant frequency of 3.7 MHz and a Q of 118? A. 436.6 kHz B. 218.3 kHz C. 31.4 kHz D. 15.7 kHz

Half Power BW = Resonant Frequency / Q of the Circuit

Δ F = Fr / Q

Δ F = 3.7 MHz / 118

Δ F = 3700 KHz / 118

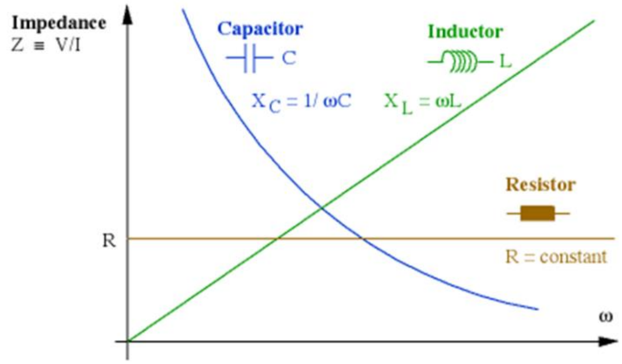
Δ F = 31.356 KHz

E5A14 (C) What is the resonant frequency of an RLC circuit if R is 22 ohms, L is 50 microhenries and C is 40 picofarads? A. 44.72 MHz B. 22.36 MHz C. 3.56 MHz D. 1.78 MHz

Resonant Frequency Formula

$$Fr = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}}$$

where 'f' = frequency in hertz
'L' = inductance in henrys
'C' = capacitance in farads



Fr = 1 / (2Π x √ LC)

Fr = 1 / (6.28318530718 X √ (50 X 10^-6 X 40 X 10^-12)

Fr = 1 / (6.28318530718 X √ (2000 X 10^-18)

Fr = 1 / (6.28 X 4.47 X 10^-8)

Fr = 10^8 / (6.28 X 4.47)

Fr = 10^8 / 28.1

Fr = 100,000,000 / 28.1

Fr = 3,558,812.7 Hz

Fr = 3.56 MHz

E5A16 (D) What is the resonant frequency of an RLC circuit if R is 33 ohms, L is 50 microhenries and C is 10 picofarads? A. 23.5 MHz B. 23.5 kHz C. 7.12 kHz D. 7.12 MHz

Fr = 1 / (2Π x √ LC)

Fr = 1 / (6.28318530718 X √ (50 X 10^-6 X 10 X 10^-12)

Fr = 1 / (6.28318530718 X √ (500 X 10^-18)

Fr = 1 / (6.28 X 2.24 X 10^-8)

Fr = 10^8 / (6.28 X 2.24)

Fr = 10^8 / 14.05

Fr = 100,000,000 / 14.05

Fr = 7117625.4 Hz

Fr = 7.12 MHz

==

E5B Time constants and phase relationships

==

Resistance & Conductance

Conductance is the reciprocal of Resistance: **G** = 1/R

Reactance & Susceptance

Susceptance is the reciprocal of Reactance: **B** = 1/X

Impedance & Admittance

Admittance is the reciprocal of Impedance: **Y** = 1/Z

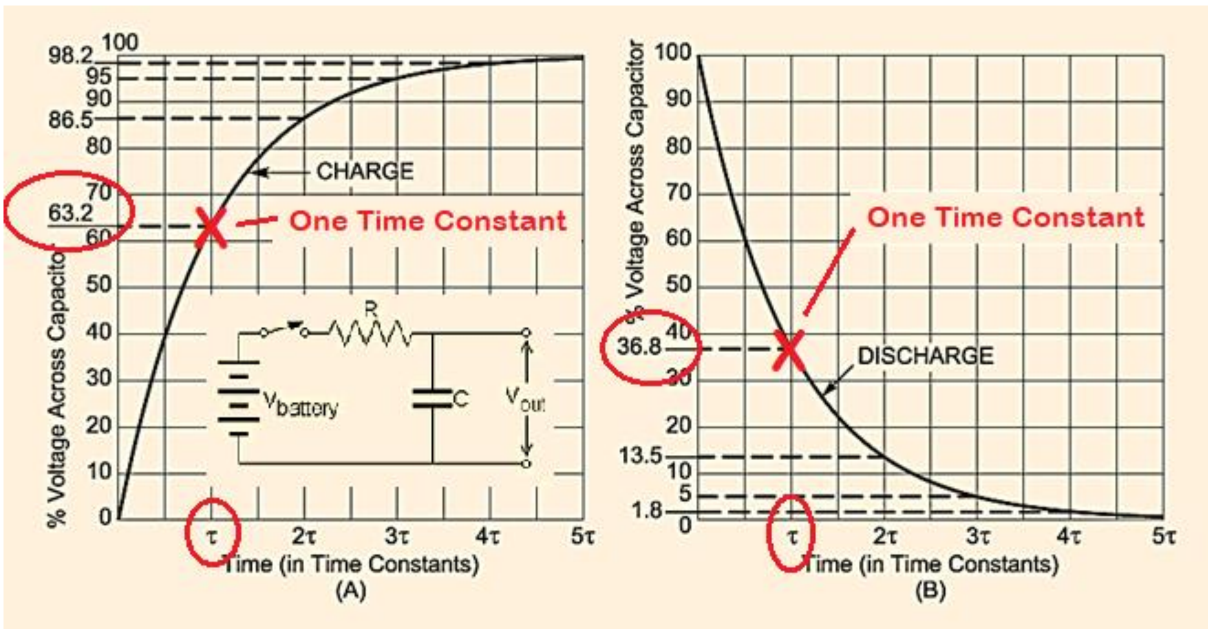
Susceptance is the imaginary part of admittance

One time constant is the time required for the capacitor in an RC circuit to **charge 63.2%**

One time constant is the time required for a charged capacitor in an RC circuit to discharge to 36.8%

The capacitor in an RC circuit is discharged to 13.5% of the starting voltage after two-time constants

One time constant = **TC (sec) = R (MΩ) x C (uF)** Check your decimal point!



Editor's note: When a voltage is applied to a capacitor through a resistance (all circuits have resistance) it takes time for the voltage across the capacitor to reach the applied voltage. At the instant the voltage is applied the current in the circuit is at a maximum limited only by the circuit resistance. As time passes the voltage across the capacitor rises and the current decreases until the capacitor charge reaches the applied voltage at which point the current goes to zero. - AD7FO

==

E5B01 (B) What is the term for the time required for the capacitor in an RC circuit to be charged to 63.2% of the applied voltage or to discharge to 36.8% of its initial voltage? A. An exponential rate of one B. One time constant C. One exponential period D. A time factor of one

E5B02 (D) What letter is commonly used to represent susceptance? A. G B. X C. Y D. B

E5B04 (D) What is the time constant of a circuit having two 220-microfarad capacitors and two 1-megohm resistors, all in parallel? A. 55 seconds B. 110 seconds C. 440 seconds D. 220 seconds

One time constant = TC (sec) = R (MΩ) x C (uF) Check your decimal point!

TC (sec) = R (MΩ) x C (uF)

TC = 0.5 x 440

TC = 220 Sec

E5B05 (D) What happens to the magnitude of a pure reactance when it is converted to a susceptance? A. It is unchanged B. The sign is reversed C. It is shifted by 90 degrees D. It becomes the reciprocal

E5B06 (C) What is susceptance? A. The magnetic impedance of a circuit B. The ratio of magnetic field to electric field C. The imaginary part of admittance D. A measure of the efficiency of a transformer

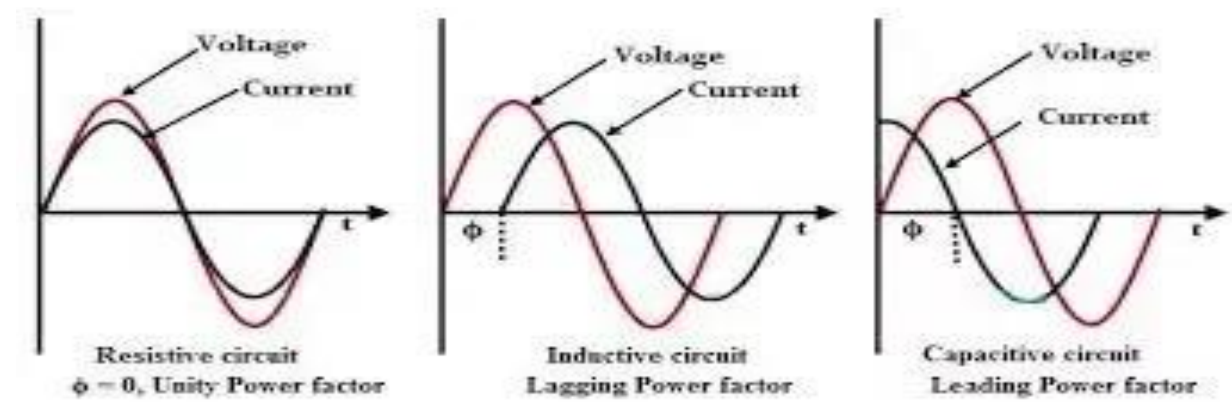
E5B12 (A) What is admittance? A. The inverse of impedance B. The term for the gain of a field effect transistor C. The turns ratio of a transformer D. The inverse of Q factor

==

Voltage same as Current phase angle in a Resistor

Voltage leads current by 90 deg through an inductor

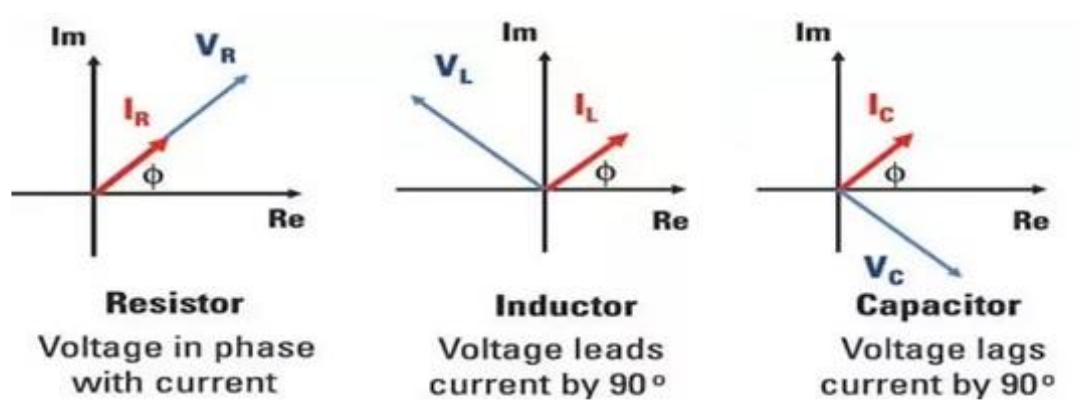
Current leads voltage by 90 deg through a capacitor



"ELI the ICE man"

Inductors – voltage (E) leads current (I)

Capacitors – current (I) leads voltage (E)



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E5B09 (D) What is the relationship between the AC current through a **capacitor** and the voltage across a capacitor? A. Voltage and current are in phase B. Voltage and current are 180 degrees out of phase C. Voltage leads current by 90 degrees D. **Current leads voltage by 90 degrees**

E5B10 (A) What is the relationship between the AC current through an **inductor** and the voltage across an inductor? A. **Voltage leads current by 90 degrees** B. Current leads voltage by 90 degrees C. Voltage and current are 180 degrees out of phase D. Voltage and current are in phase

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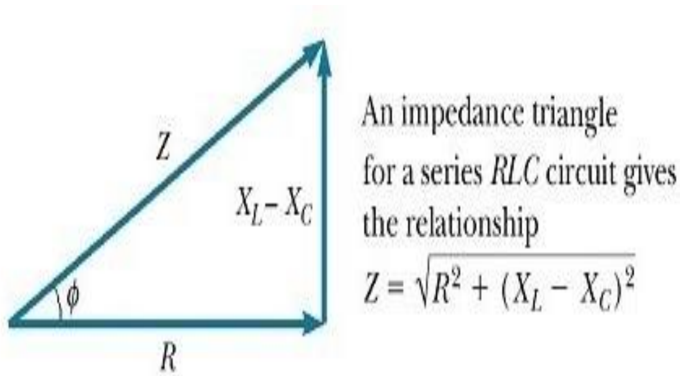
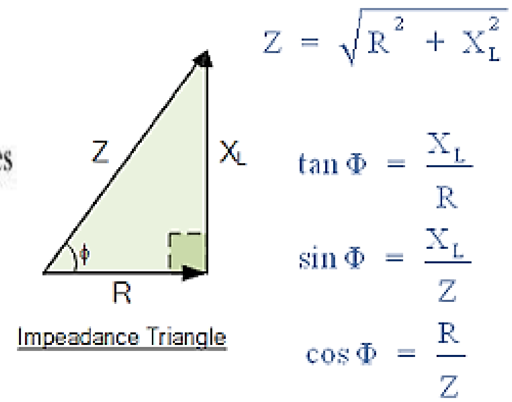
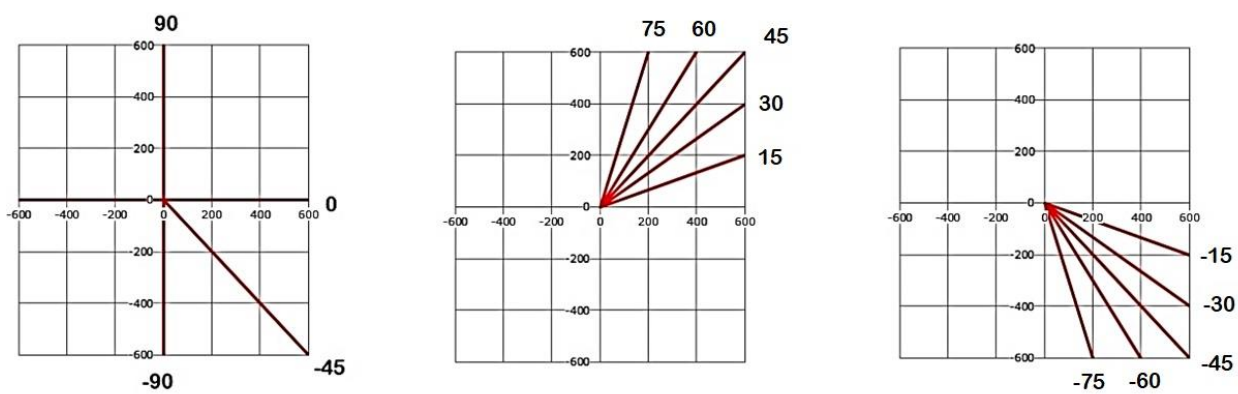
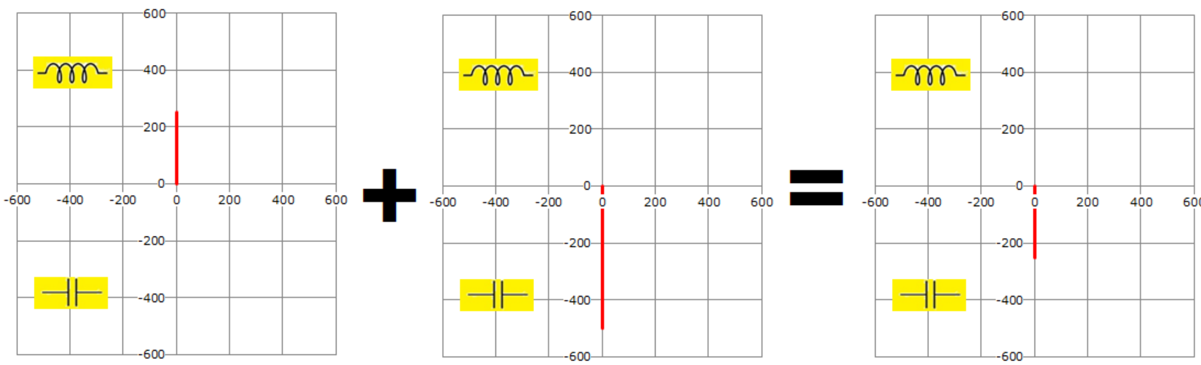




Editor's note: **EYEBALL ESTIMATING** *The problems on the exam are traditionally solved using trigonometry as shown above. An alternative method is to solve graphically. The first step in using a graphical method is visually estimating angles. The diagrams below show the quadrants are each 90°. Dividing the quadrant is 45°. The center and right graphs show ~ 15° increments can be estimated by eye to select the correct exam answer.*



Editor's note: The second step is to determine the net reactance graphically. The inductance is shown as positive and capacitance is negative on the graph. Example XC = 500 Ohms combined with XL = 250 Ohms. 500 is down combined with 250 equals 250 down.



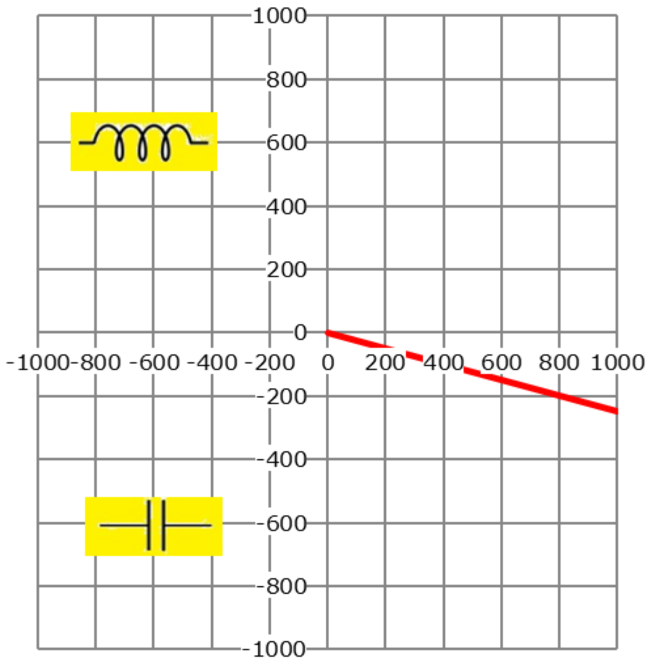
Editor's note: The third step is to determine the vector graphically. **EYEBALL ESTIMATED**

==

E5B07 (C) What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 500 ohms, R is 1 kilohm, and XL is 250 ohms? A. 68.2 degrees with the voltage leading the current B. 14.0 degrees with the voltage leading the current C. 14.0 degrees with the voltage lagging the current D. 68.2 degrees with the voltage lagging the current

R = 1000 Ohms combined with XC = 250 Ohms. The resulting vector is negative (capacitive ICE) and eyeball estimated at -15° vs. the math solution -14°.

Current leads voltage by 90 deg through a capacitor



A. 68.2° V lead

B. 14.0° V lead

C. 14.0° V lag

D. 68.2° V lag

E5B08 (A) What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 100 ohms, R is 100 ohms, and XL is 75 ohms? A. 14 degrees with the voltage lagging the current B. 14 degrees with the voltage leading the current C. 76 degrees with the voltage leading the current D. 76 degrees with the voltage lagging the current

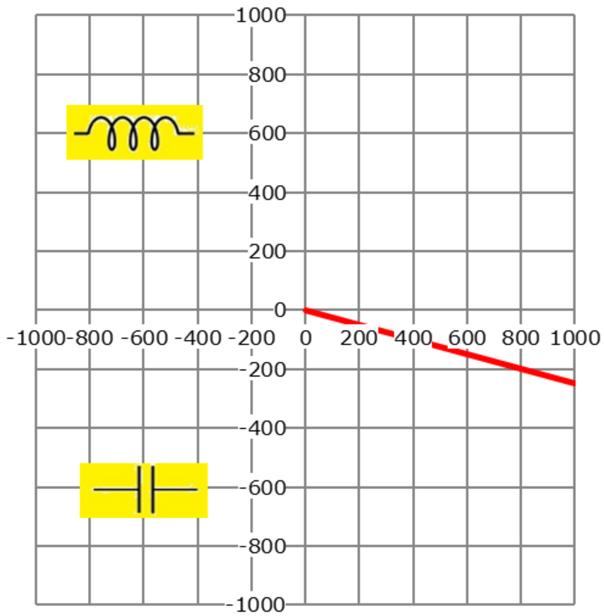
Θ = tan^-1 [(250-500)/1000]

Θ = tan^-1 [(-250)/1000]

Θ = tan^-1 (-0.25) = -14.036°

The vector is negative (capacitive ICE) and eyeball estimated at -15° vs. the math solution -14°.

Current leads voltage by 90 deg through a capacitor



E5B09 (D) What is the relationship between the AC current through a capacitor and the voltage across a capacitor? A. Voltage and current are in phase B. Voltage and current are 180 degrees out of phase C. Voltage leads current by 90 degrees D. Current leads voltage by 90 degrees

Voltage same as Current phase angle in a Resistor

Voltage leads current by 90 deg through an inductor

Current leads voltage by 90 deg through a capacitor

E5B10 (A) What is the relationship between the AC current through an inductor and the voltage across an inductor? A. Voltage leads current by 90 degrees B. Current leads voltage by 90 degrees C. Voltage and current are 180 degrees out of phase D. Voltage and current are in phase

Voltage same as Current phase angle in a Resistor

Voltage leads current by 90 deg through an inductor

Current leads voltage by 90 deg through a capacitor

E5B11 (B) What is the phase angle between the voltage across and the current through a series RLC circuit if XC is 25 ohms, R is 100 ohms, and XL is 50 ohms? A. 14 degrees with the voltage lagging the current B. 14 degrees with the voltage leading the current C. 76 degrees with the voltage lagging the current D. 76 degrees with the voltage leading the current

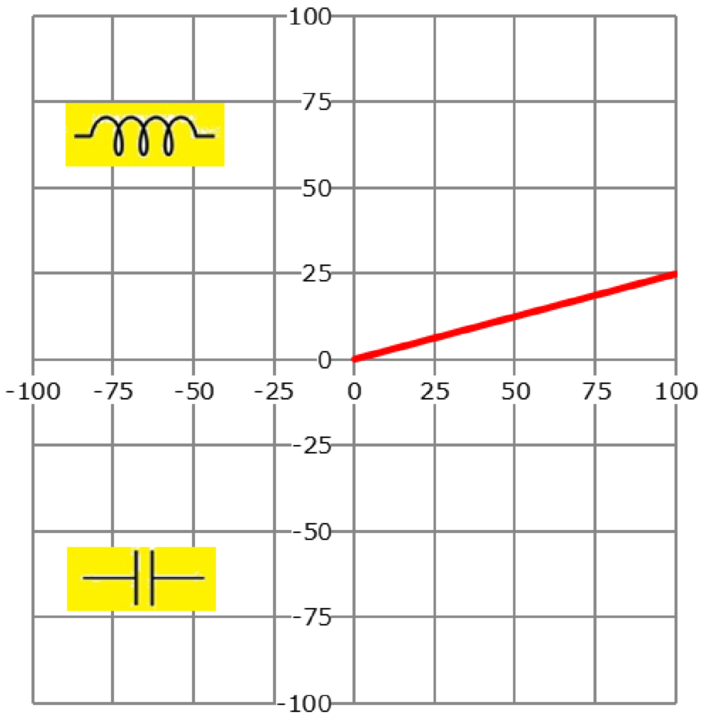
Θ = tan^-1 [(50-25)/100]

Θ = tan^-1 (+0.25)

Θ = +14.036°

The vector is Positive (inductive ELI) and eyeball estimated at +15° vs. the math solution +14°.

Voltage leads current by 90 deg through an inductor



E5B03 (B) How is impedance in polar form converted to an equivalent admittance? A. Take the reciprocal of the angle and change the sign of the magnitude B. Take the reciprocal of the magnitude and change the sign of the angle C. Take the square root of the magnitude and add 180 degrees to the angle D. Square the magnitude and subtract 90 degrees from the angle

==

E5C Coordinate systems and phasors in electronics

==

Polar coordinates display the phase angle of a circuit resistance, inductive and/or capacitive reactance

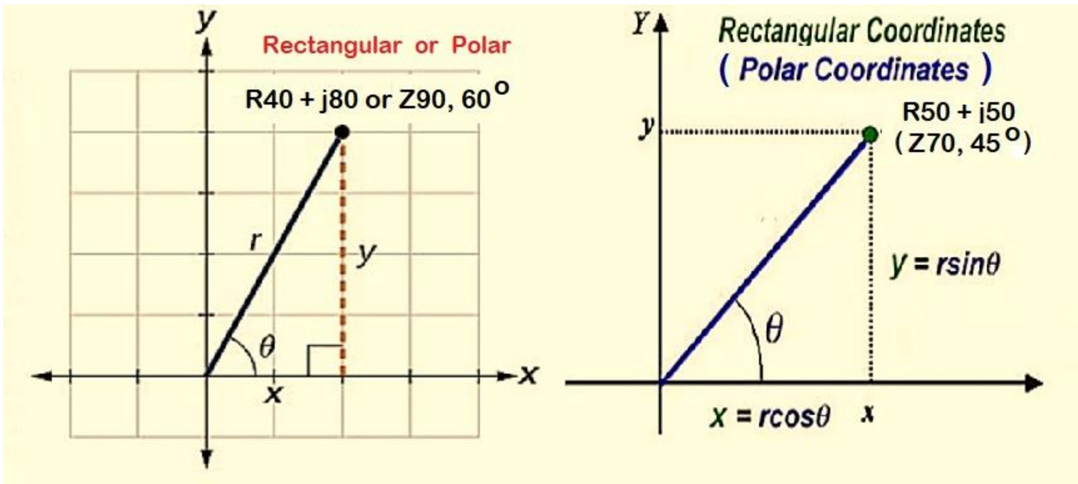
Phasor diagram is used to show the **phase relationship between impedances** at a given frequency

Rectangular coordinates to display the resistive, inductive, and/or capacitive reactance **(R + jX)**

Capacitive reactance in rectangular notation is – jX (negative)

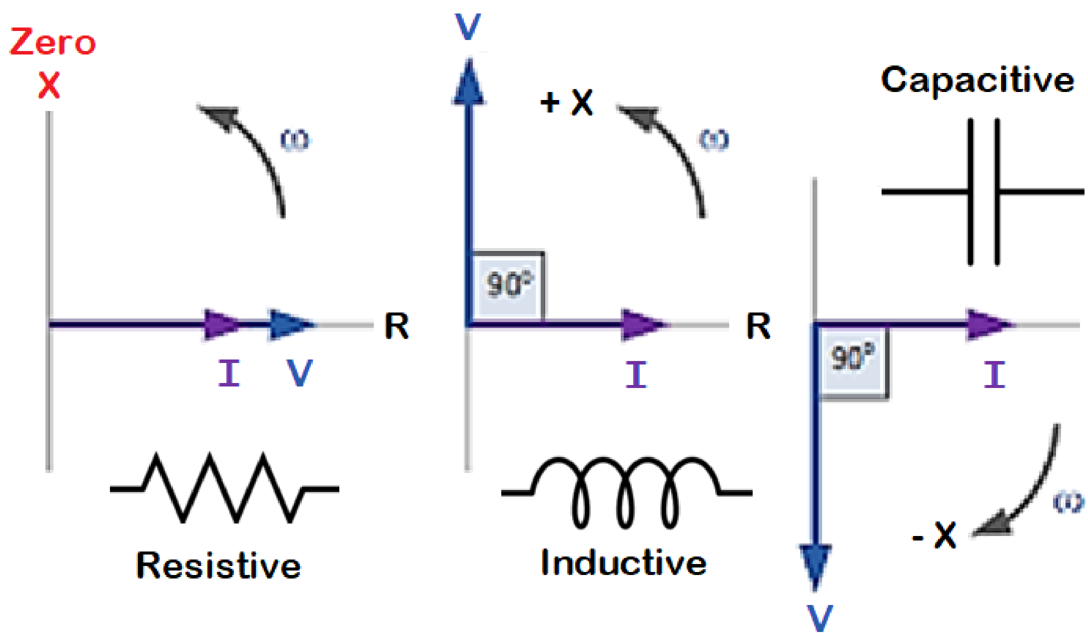
Inductive reactance in rectangular notation is + jX (positive)

The **X axis represents the resistive** component and the **Y axis represents the reactive** component using rectangular coordinates to graph the impedance of a circuit



The **horizontal axis** represents the **resistive component**

The **vertical axis** represents the **reactive component**



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E5C01 (A) Which of the following represents capacitive reactance in rectangular notation? A. -jX B. +jX C. Delta D. Omega

E5C02 (C) How are impedances described in polar coordinates? A. By X and R values B. By real and imaginary parts C. By phase angle and magnitude D. By Y and G values

E5C03 (C) Which of the following represents an inductive reactance in polar coordinates? A. A positive magnitude B. A negative magnitude C. A positive phase angle D. A negative phase angle

E5C04 (D) What coordinate system is often used to display the resistive, inductive, and/or capacitive reactance components of impedance? A. Maidenhead grid B. Faraday grid C. Elliptical coordinates D. Rectangular coordinates

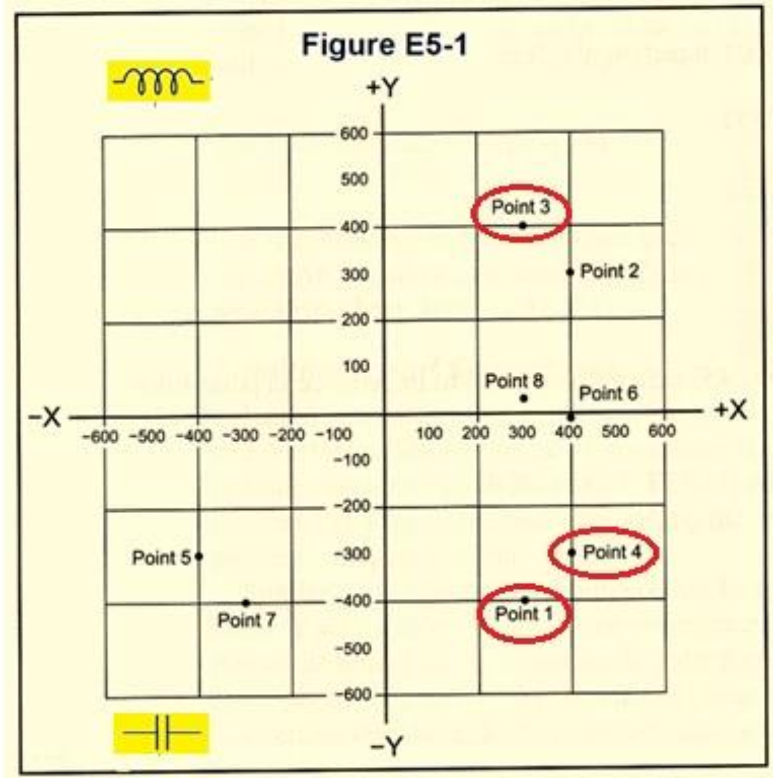
E5C05 (C) What is the name of the diagram used to show the phase relationship between impedances at a given frequency? A. Venn diagram B. Near field diagram C. Phasor diagram D. Far field diagram

E5C06 (B) What does the impedance 50-j25 represent? A. 50 ohms resistance in series with 25 ohms inductive reactance B. 50 ohms resistance in series with 25 ohms capacitive reactance C. 25 ohms resistance in series with 50 ohms inductive reactance D. 25 ohms resistance in series with 50 ohms capacitive reactance

E5C07 (D) Where is the impedance of a pure resistance plotted on rectangular coordinates? A. On the vertical axis B. On a line through the origin, slanted at 45 degrees C. On a horizontal line, offset vertically above the horizontal axis D. On the horizontal axis

E5C08 (D) What coordinate system is often used to display the phase angle of a circuit containing resistance, inductive and/or capacitive reactance? A. Maidenhead grid B. Faraday grid C. Elliptical coordinates D. Polar coordinates

E5C09 (A) When using rectangular coordinates to graph the impedance of a circuit, what do the axes represent? A. The X axis represents the resistive component and the Y axis represents the reactive component B. The X axis represents the reactive component and the Y axis represents the resistive component C. The X axis represents the phase angle and the Y axis represents the magnitude D. The X axis represents the magnitude and the Y axis represents the phase angle



E5C10 (B) Which point on Figure E5-1 best represents the impedance of a series circuit consisting of a 400-ohm resistor and a 38-picofarad capacitor at 14 MHz? A. Point 2 B. Point 4 C. Point 5 D. Point 6

R = 400 & X

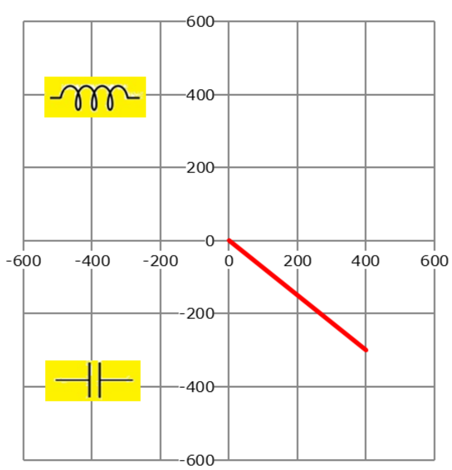
= 1/ (2 π FC) = X

= 1/ (2 x π x **MHz x uF**)

= 1/0.0033427

= -299.16 **Ω**

400 R – 300 j



Editor's note: Solving the question graphically requires the process of elimination. The R=400 has three possible point in Figure 5-1, points: 2, 4, 6. The reactance is given as a capacitance and frequency. Point 4 is the answer as the only negative (capacitive) point of the three points. FYI only 1, 3 & 4 are correct answers in the test pool questions.

E5C11 (B) Which point in Figure E5-1 best represents the impedance of a series circuit consisting of a 300-ohm resistor and an 18-microhenry inductor at 3.505 MHz? A. Point 1 B. Point 3 C. Point 7 D. Point 8

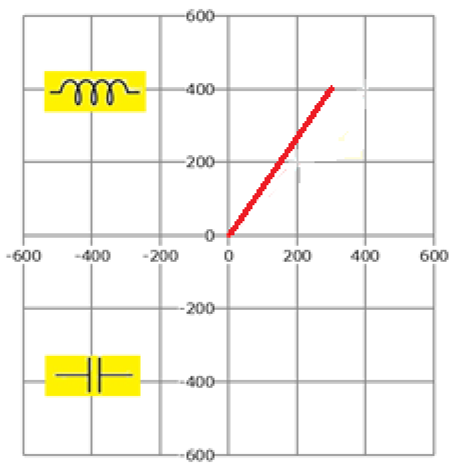
R = 300 & X

X = 2 π FL

X = 2 x π x **MHz x uH**

X = 396.41 **Ω**

300 R + 400 j



Editor's note: Solving the question graphically requires the process of elimination. The R=300 has three possible point in Figure 5-1, points: 1, 3, 8. The reactance is given as an inductance and frequency. Points 3 or 8 are the answer as the positive (inductive) point of the three points. Graphics alone will not solve the problem. Logical can be used as the MHz and Mico cancel each other the X will be several hundred. Point 3 is the answer as 8 is very small. FYI only 1, 3 & 4 are correct answers in the test pool questions.

E5C12 (A) Which point on Figure E5-1 best represents the impedance of a series circuit consisting of a 300-ohm resistor and a 19-picofarad capacitor at 21.200 MHz? A. Point 1 B. Point 3 C. Point 7 D. Point 8

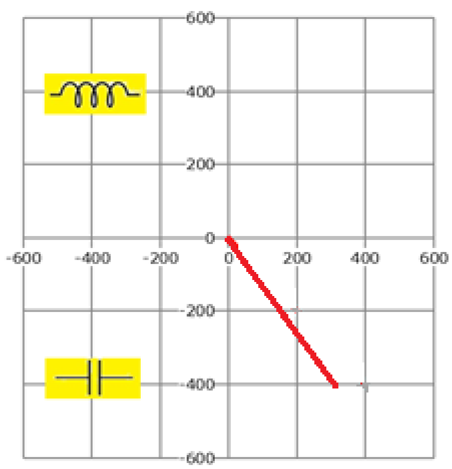
R = 300 & X

X = 1/ (2 π FC)

X = 1/ 0.002531

X = -395.12 **Ω**

300 R – 400 j



Editor's note: Solving the question graphically requires the process of elimination. The R=300 has three possible point in Figure 5-1, points: 1, 3, 8. The reactance is given as a capacitance and frequency. Point 1 is the answer as the only negative (capacitive) point of the three points. FYI only 1, 3 & 4 are correct answers in the test pool questions.

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E9E Matching: matching antennas to feed lines

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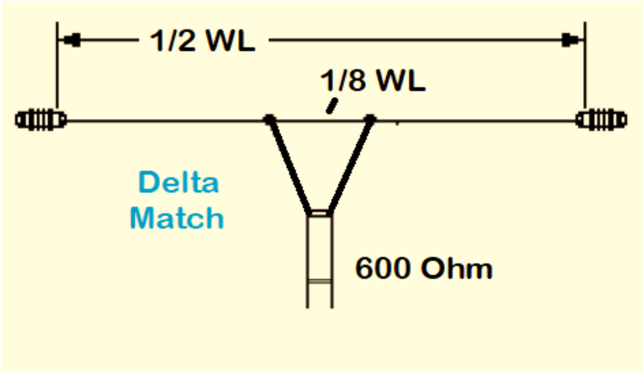
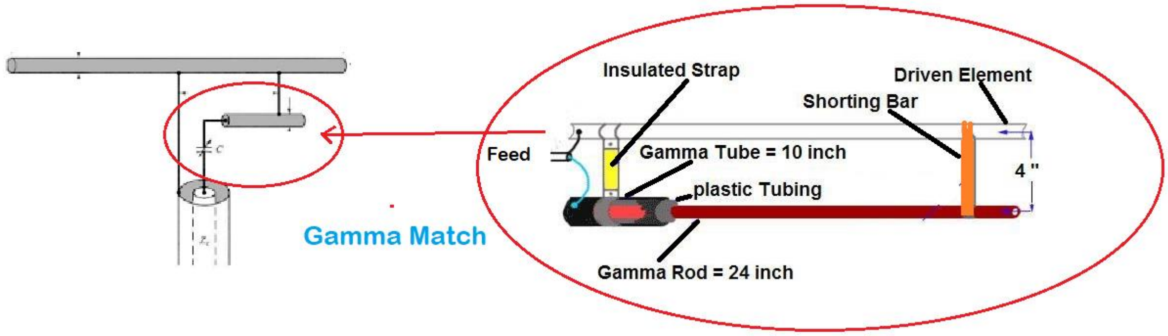
The **DELTA MATCHING** system matches a high-impedance transmission line to a lower impedance antenna by connecting the line to the driven element in two places spaced a fraction of a wavelength each side of element center



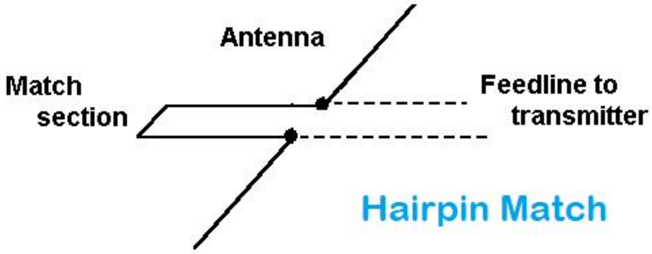
The **gamma match** that matches an unbalanced feed line to an antenna by feeding the driven element both at the center of the element and at a fraction of a wavelength to one side of center

A **Gamma match** is used to shunt-feed a grounded tower at its base

The **series capacitor** in a **gamma matching** network **cancels the inductive reactance** of the matching network



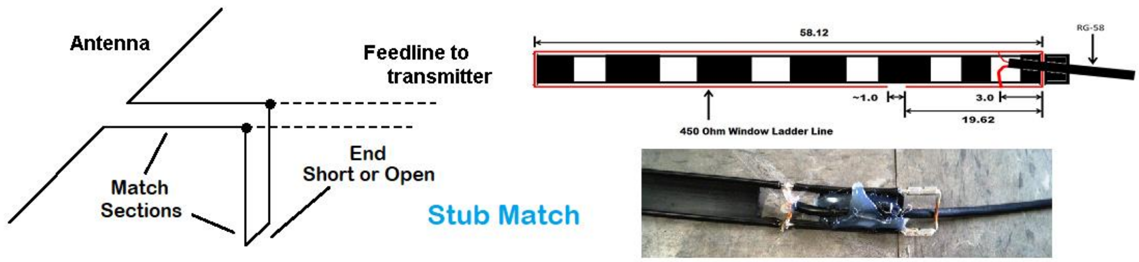
An **antenna's driven element capacitive** to be tuned to use a **hairpin matching** system



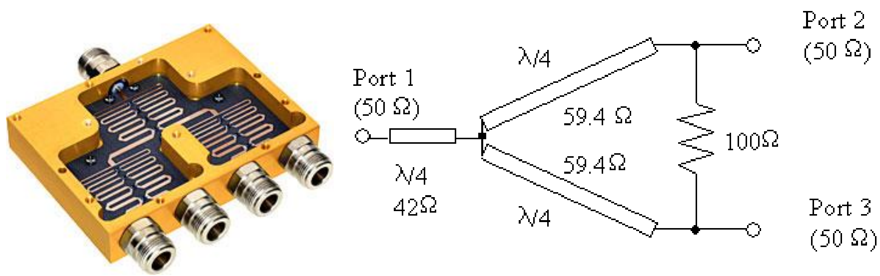
Editor's note: Hairpin matching is adding an inductance directly across the feed point of the antenna. The inductance may be a simple U-shaped wire or rods. This U-shape is of course the reason for the name hairpin and many applications of this matching style use that form of inductance.

The **stub match** uses a section of transmission line connected in parallel with the feed line at or near the feed point

Editor's note: The universal stub matching technique is an effective way of matching a feed line to a VHF or UHF antenna when the impedances of both the antenna and feed line are unknown

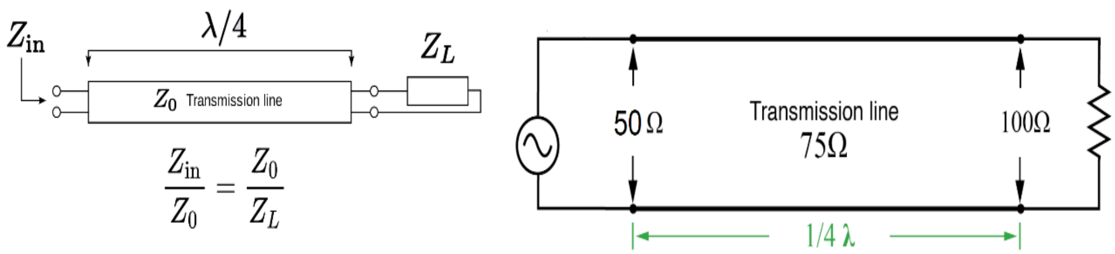


A **Wilkinson divider** divides power equally among multiple loads while two 50-ohm loads while maintaining 50-ohm input impedance



Insert a **1/4-wavelength piece of 75-ohm coaxial cable** transmission line in series between the antenna and the **50-ohm feed** cable to match an **antenna with 100-ohm** feed point impedance to a 50-ohm coaxial cable feed line

The primary **purpose of a phasing line** when used with an antenna having **multiple driven elements** is to ensure that each driven element operates in concert with the others to **create the desired antenna pattern**

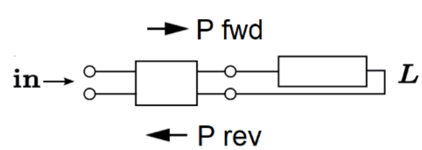


Editor's note: 50-Ω transmission line is to be matched to a resistive load impedance with ZL = 100 Ω via a quarter-wave 75 Ω shown above is a quarter-wave transmission line transformer.

Reflection coefficient describes the interactions at the load end of a **mismatched** transmission line

$$\text{SWR} = \frac{1 + |p|}{1 - |p|}$$

$$\text{Reflection Coefficient} = p = \sqrt{\text{P rev} / \text{P fwd}}$$



Editor's note: The reflection coefficient is also known as S11 or return loss. Voltage Standing Wave Ratio is a function of the reflection coefficient, which describes the power reflected from the antenna.

==

E9E01 (B) What system matches a higher-impedance transmission line to a lower-impedance antenna by connecting the line to the driven element in two places spaced a fraction of a wavelength each side of element center? A. The gamma matching system B. The delta matching system C. The omega matching system D. The stub matching system

E9E02 (A) What is the name of an antenna matching system that matches an unbalanced feed line to an antenna by feeding the driven element both at the center of the element and at a fraction of a wavelength to one side of center? A. The gamma match B. The delta match C. The epsilon match D. The stub match

E9E03 (D) What is the name of the matching system that uses a section of transmission line connected in parallel with the feed line at or near the feed point? A. The gamma match B. The delta match C. The omega match D. The stub match

E9E04 (B) What is the purpose of the series capacitor in a gamma-type antenna matching network? A. To provide DC isolation between the feed line and the antenna B. To cancel the inductive reactance of the matching network C. To provide a rejection notch that prevents the radiation of harmonics D. To transform the antenna impedance to a higher value

E9E05 (A) How must an antenna's driven element be tuned to use a hairpin matching system? A. The driven element reactance must be capacitive B. The driven element reactance must be inductive C. The driven element resonance must be lower than the operating frequency D. The driven element radiation resistance must be higher than the characteristic impedance of the transmission line

E9E06 (C) Which of these feed line impedances would be suitable for constructing a quarter-wave Q-section for matching a 100-ohm loop to 50-ohm feed line? A. 50 ohms B. 62 ohms C. 75 ohms D. 450 ohms

E9E07 (B) What parameter describes the interactions at the load end of a mismatched transmission line? A. Characteristic impedance B. Reflection coefficient C. Velocity factor D. Dielectric constant

E9E08 (C) What is a use for a Wilkinson divider? A. It divides the operating frequency of a transmitter signal so it can be used on a lower frequency band B. It is used to feed high-impedance antennas from a low-impedance source C. It is used to divide power equally between two 50-ohm loads while maintaining 50-ohm input impedance D. It is used to feed low-impedance loads from a high-impedance source

E9E09 (C) Which of the following is used to shunt-feed a grounded tower at its base? A. Double-bazooka match B. Hairpin match C. Gamma match D. All these choices are correct

E9E10 (C) Which of these choices is an effective way to match an antenna with a 100-ohm feed point impedance to a 50-ohm coaxial cable feed line? A. Connect a 1/4-wavelength open stub of 300-ohm twinlead in parallel with the coaxial feed line where it connects to the antenna B. Insert a 1/2 wavelength piece of 300-ohm twinlead in series between the antenna terminals and the 50-ohm feed cable C. Insert a 1/4-wavelength piece of 75-ohm coaxial cable transmission line in series between the antenna terminals and the 50-ohm feed cable D. Connect a 1/2 wavelength shorted stub of 75-ohm cable in parallel with the 50-ohm cable where it attaches to the antenna

E9E11 (A) What is the primary purpose of phasing lines when used with an antenna having multiple driven elements? A. It ensures that each driven element operates in concert with the others to create the desired antenna pattern B. It prevents reflected power from traveling back down the feed line and causing harmonic radiation from the transmitter C. It allows single-band antennas to operate on other bands D. It creates a low-angle radiation pattern

==

E9F Transmission lines

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Velocity factor of a transmission line is the transmission line velocity divided by the velocity of light in a vacuum

Electrical signals move more slowly in a coaxial cable than in air

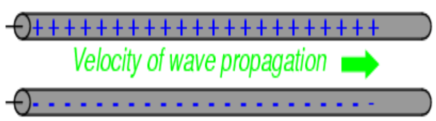
Dielectric has biggest effect on the **Velocity Factor** of a transmission line

The significant differences between **foam-dielectric** coaxial cable and **solid-dielectric** cable are;
- **reduced** safe operating **voltage** limits,
- **reduced losses** per unit of length and
- **higher velocity factor**

Coaxial cable with **solid polyethylene dielectric 0.66** is the typical velocity factor

Ladder line has lower loss than coaxial cable

Ladder line has 1.0is the typical velocity factor



$$\text{Velocity Factor} = \frac{\text{propagation velocity on the line}}{\text{speed of light in vacuum}}$$

Cable Length = Velocity Factor X [Speed of Light / Frequency] X Wavelength of Cable

Editor's note: The To determine the electrical length of a transmission line you need to multiply the velocity factor of the line (available from the supplier of the line) by the free space length. For the length in feet, this is (983.6 / frequency in MHz) velocity. For the length in meters, this is (299.8 / frequency in MHz) velocity.

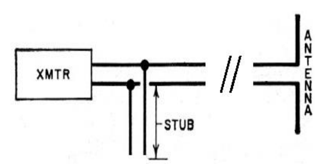
Transmission line is any integer multiple of 1/2 wavelength, the impedance equals other end

Transmission line is an odd multiple of 1/4 wavelength, the impedance inverted the other end

Transmission line 1/8 wavelength long, is capacitive with the other end open

Transmission line 1/8 wavelength long, is inductive with the other end shorted

Impedance of Coaxial Stubs		
Wavelength	Open Stub	Shorted Stub
1/8	Capacitive	Inductive
1/4	Low Imp.	High Imp.
1/2	High Imp.	Low Imp.



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E9F01 (D) What is the velocity factor of a transmission line? A. The ratio of the characteristic impedance of the line to the terminating impedance B. The index of shielding for coaxial cable C. The velocity of the wave in the transmission line multiplied by the velocity of light in a vacuum D. The velocity of the wave in the transmission line divided by the velocity of light in a vacuum

E9F02 (C) Which of the following has the biggest effect on the velocity factor of a transmission line? A. The termination impedance B. The line length C. Dielectric materials used in the line D. The center conductor resistivity

E9F03 (D) Why is the physical length of a coaxial cable transmission line shorter than its electrical length? A. Skin effect is less pronounced in the coaxial cable B. The characteristic impedance is higher in a parallel feed line C. The surge impedance is higher in a parallel feed line D. Electrical signals move more slowly in a coaxial cable than in air

E9F04 (B) What impedance does a 1/2-wavelength transmission line present to a generator when the line is shorted at the far end? A. Very high impedance B. Very low impedance C. The same as the characteristic impedance of the line D. The same as the output impedance of the generator

E9F05 (D) What is the approximate physical length of a solid polyethylene dielectric coaxial transmission line that is electrically 1/4 wavelength long at 14.1 MHz? A. 10.6 meters B. 5.3 meters C. 4.3 meters D. 3.5 meters

Cable Length = VF x WL/4
Cable Length = 0.66 x (300 / 14.1) / 4
Cable Length = 0.66 x (21.28 / 4)
Cable Length = 0.66 x 5.319
Cable Length = 3.511 M

E9F06 (C) What is the approximate physical length of an air-insulated, parallel conductor transmission line that is electrically 1/2 wavelength long at 14.10 MHz? A. 7.0 meters B. 8.5 meters C. 10.6 meters D. 13.3 meters

Cable Length = VF x WL/4
Cable Length = 1.0 x (300 / 14.1) / 2
Cable Length = 1.0 x (21.28 / 2)
Cable Length = 1.0 x 10.64
Cable Length = 10.64 M

Editor's note: A transmission line is a pair of parallel conductors exhibiting certain characteristics. Velocity factor is a fractional value relating to a transmission line's propagation at the speed of light in a vacuum.

E9F07 (A) How does ladder line compare to small-diameter coaxial cable such as RG-58 at 50 MHz? A. Lower loss B. Higher SWR C. Smaller reflection coefficient D. Lower velocity factor

E9F08 (D) Which of the following is a significant difference between foam dielectric coaxial cable and solid dielectric cable, assuming all other parameters are the same? A. Foam dielectric has lower safe operating voltage limits B. Foam dielectric has lower loss per unit of length C. Foam dielectric has higher velocity factor D. All these choices are correct

E9F09 (B) What is the approximate physical length of a foam polyethylene dielectric coaxial transmission line that is electrically 1/4 wavelength long at 7.2 MHz? A. 10.4 meters B. 8.3 meters C. 6.9 meters D. 5.2

Cable Length = VF x WL/4
Cable Length = 0.66 x (300 / 7.2) / 4
Cable Length = 0.66 x (41.66 / 4)
Cable Length = 0.66 x 10.417
Cable Length = 6.875 M

E9F10 (C) What impedance does a 1/8-wavelength transmission line present to a generator when the line is shorted at the far end? A. A capacitive reactance B. The same as the characteristic impedance of the line C. An inductive reactance D. Zero

E9F11 (C) What impedance does a 1/8-wavelength transmission line present to a generator when the line is open at the far end? A. The same as the characteristic impedance of the line B. An inductive reactance C. A capacitive reactance D. Infinite

E9F12 (D) What impedance does a 1/4-wavelength transmission line present to a generator when the line is open at the far end? A. The same as the characteristic impedance of the line B. The same as the input impedance to the generator C. Very high impedance D. Very low impedance

E9F13 (A) What impedance does a 1/4-wavelength transmission line present to a generator when the line is shorted at the far end? A. Very high impedance B. Very low impedance C. The same as the characteristic impedance of the transmission line D. The same as the generator output impedance

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E9G The Smith chart

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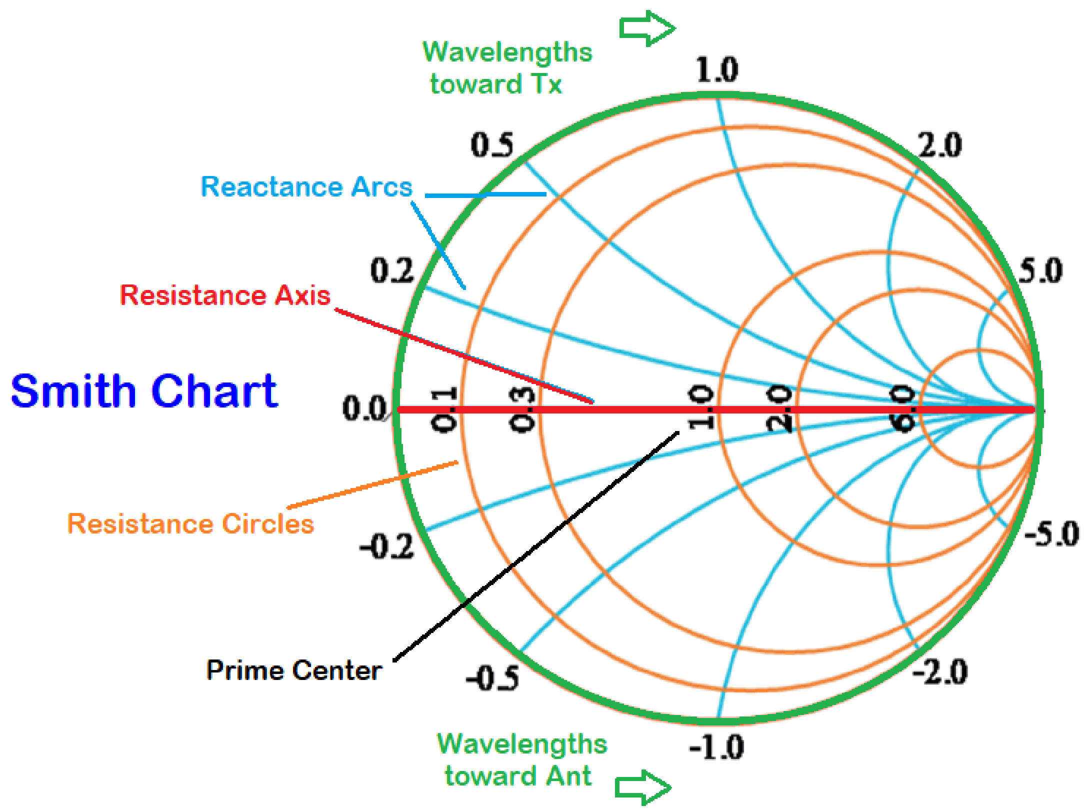
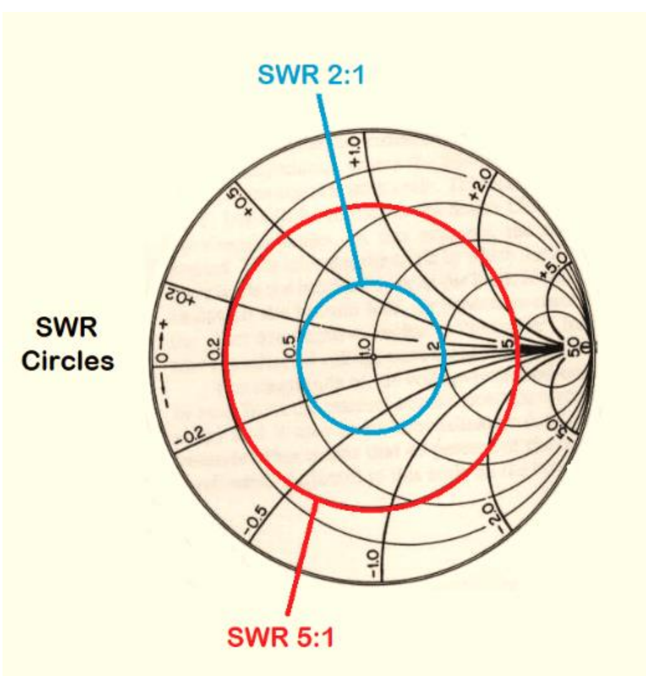




Smith Chart Key Terms

Resistance axis (only R straight line)

Resistance Circles (from Rt to Lt)

Reactance Arcs

Reactance Circle is outer edge of circle

SWR Circles (from center out)

Wavelengths are transmission line lengths

Resistance circles and reactance arcs is coordinate system is used in a Smith chart

Resistance and reactance are the two families of circles and arcs that make up a Smith chart

The **resistance axis** is the only straight line on a Smith chart

Reactance axis is the large outer circle on which the reactance arcs terminate

Points with **constant reactance are the arcs** on a Smith chart

Standing wave ratio circles are the third family of circles is often added to a Smith chart

Wavelength scales on a Smith chart are calibrated in fractions of transmission line electrical wavelength

Reassigning impedance values with regard to the prime center is the **process of NORMALIZATION** with regard to a Smith chart

Impedance along transmission lines can be calculated using a Smith chart

Impedance and SWR values in transmission lines is determined using a Smith chart

Determining the **length and position of an impedance matching stub** is a common use for a Smith chart

==

E9G01 (A) Which of the following can be calculated using a Smith chart? A. Impedance along transmission lines B. Radiation resistance C. Antenna radiation pattern D. Radio propagation

E9G02 (B) What type of coordinate system is used in a Smith chart? A. Voltage circles and current arcs B. Resistance circles and reactance arcs C. Voltage lines and current chords D. Resistance lines and reactance chords

E9G03 (C) Which of the following is often determined using a Smith chart? A. Beam headings and radiation patterns B. Satellite azimuth and elevation bearings C. Impedance and SWR values in transmission lines D. Trigonometric functions

E9G04 (C) What are the two families of circles and arcs that make up a Smith chart? A. Resistance and voltage B. Reactance and voltage C. Resistance and reactance D. Voltage and impedance

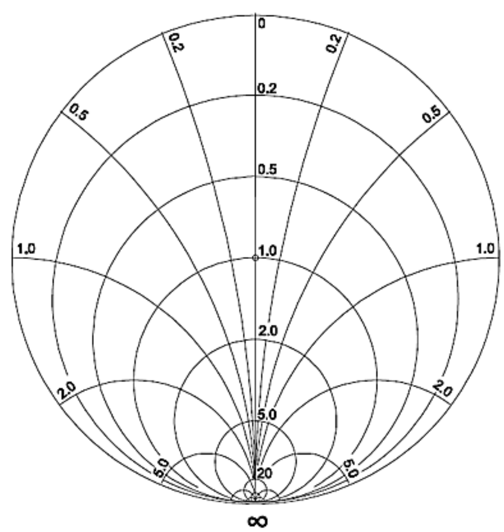
E9G05 (A) Which of the following is a common use for a Smith chart? A. Determine the length and position of an impedance matching stub B. Determine the impedance of a transmission line, given the physical dimensions C. Determine the gain of an antenna given the physical and electrical parameters D. Determine the loss/100 feet of a transmission line, given the velocity factor and conductor materials

E9G06 (B) On the Smith chart shown in Figure E9-3, what is the name for the large outer circle on which the reactance arcs terminate? A. Prime axis B. Reactance axis C. Impedance axis D. Polar axis

E9G07 (D) On the Smith chart shown in Figure E9-3, what is the only straight line shown? A. The reactance axis B. The current axis C. The voltage axis D. The resistance axis

E9G08 (C) What is the process of normalization with regard to a Smith chart? A. Reassigning resistance values with regard to the reactance axis B. Reassigning reactance values with regard to the resistance axis C. Reassigning impedance values with regard to the prime center D. Reassigning prime center with regard to the reactance axis

Figure E9-3



E9G09 (A) What third family of circles is often added to a Smith chart during the process of solving problems? A. Standing wave ratio circles B. Antenna-length circles C. Coaxial-length circles D. Radiation-pattern circles

E9G10 (D) What do the arcs on a Smith chart represent? A. Frequency B. SWR C. Points with constant resistance D. Points with constant reactance

E9G11 (B) How are the wavelength scales on a Smith chart calibrated? A. In fractions of transmission line electrical frequency B. In fractions of transmission line electrical wavelength C. In fractions of antenna electrical wavelength D. In fractions of antenna electrical frequency

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Class Four Fundamentals and Substance

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After completing each class be sure to use the Fundamentals and Substance subsection that was solely created as a tool for test preparation by helping you make connections between topics and serves as quality review material for after each class. Using these steps can be most useful when learning about new topics that include a lot of detail. The information is in the form of class notes with all of the important information you need to know. These notes are not a substitute for studying the class material in fact you will need to complete your class assignment in order to effectively use these notes. The notes are organized into easily digestible headings and bullet points to organize topics with the key words, main subpoints and summary are all written in one place.

==

Power Factor

Wattless, nonproductive power is **REACTIVE POWER**

REACTIVE POWER in an AC circuit is exchanged between magnetic and electric fields, **but is not dissipated**

The true power be determined in an AC circuit where the voltage and current are out of phase by multiplying the apparent power by the power factor

Trick question Resistor only has **Real Power**

POWER FACTOR = Real Power (Watts) / Total Power (V x A)

POWER FACTOR = COS of (Voltage to Current) Phase

PF = COS 30° = 0.866

PF = COS 60° = 0.5

PF = COS 45° = 0.707

UHF and Microwave

SKIN EFFECT >> As frequency increases, RF current flows closer to the surface of the conductor

Precision printed circuit conductors above a ground plane that provide constant impedance interconnects at microwave frequencies is a **microstrip**

Short connections used at microwave frequencies to **reduce phase shift** along the connection

To avoid **unwanted inductive reactance**, it is important to **keep lead lengths short** for components used in circuits for VHF and above

MAGNETIC FIELD is in a circle around a conductor

G B Y

Susceptance is the reciprocal of Reactance: **B** = 1/X

Admittance is the reciprocal of Impedance: **Y** = 1/Z

Susceptance is the imaginary part of admittance

Resonance and Q

Resonance is the frequency at which the **capacitive reactance equals the inductive reactance**

Resonance can cause the voltage across **reactances** in series to be **larger than the voltage**

The magnitude of the impedance of a circuit with an **RLC all in parallel, at resonance is equal to circuit resistance (looks like R)**

The **MAXIMUM CIRCULATING current of a parallel LC circuit occurs at resonance** within the components

MINIMUM current is at the **INPUT** of a **parallel RLC** circuit as the frequency is **resonance**

The **voltage and current are in phase** across a **series resonant** circuit at resonance

The **voltage and current are in phase** across a **parallel resonant** circuit at resonance

Increasing the Q of an impedance-matching circuit **decreases the bandwidth**

Increasing Q in a series resonant circuit **increases the internal voltages**

Lower losses increase Q for inductors and capacitors

RLC **parallel** resonant circuit **Q = Resistance / Reactance = R / X**

RLC **series** resonant circuit **Q = / Reactance / Resistance = X / R**

Half Power Bandwidth = Resonant Frequency / Q of the Circuit

Resonant frequency of an RLC circuit equals a formula or just remember 3.56 MHz or 7.12 MHz

RLC

Resonant Frequency

$$Fr = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}}$$

where 'f' = frequency in hertz
'L' = inductance in henrys
'C' = capacitance in farads

Time Constants

One time constant is the time required for the capacitor in an RC circuit to **charge 63.2%**

One time constant is the time required for a charged capacitor in an RC to **discharge to 36.8%**

The capacitor in an RC circuit is **discharged to 13.5%** of the starting after **two-time constants**

One time constant = **TC (sec) = R (MΩ) x C (uF)** Check your decimal point!

Phase Relationships

Voltage same as Current phase angle in a Resistor

Voltage leads current by 90 deg through an inductor

Current leads voltage by 90 deg through a capacitor

"ELI the ICE man"

Inductors – voltage (E) leads current (I)

Capacitors – current (I) leads voltage (E)

Rectangular and Polar Plots

Polar coordinates display the phase angle of a circuit resistance, inductive and/or capacitive reactance

Phasor diagram is used to show the **phase relationship between impedances** at a given frequency

Rectangular coordinates display the resistive, inductive, and/or capacitive reactance **(R + jX)**

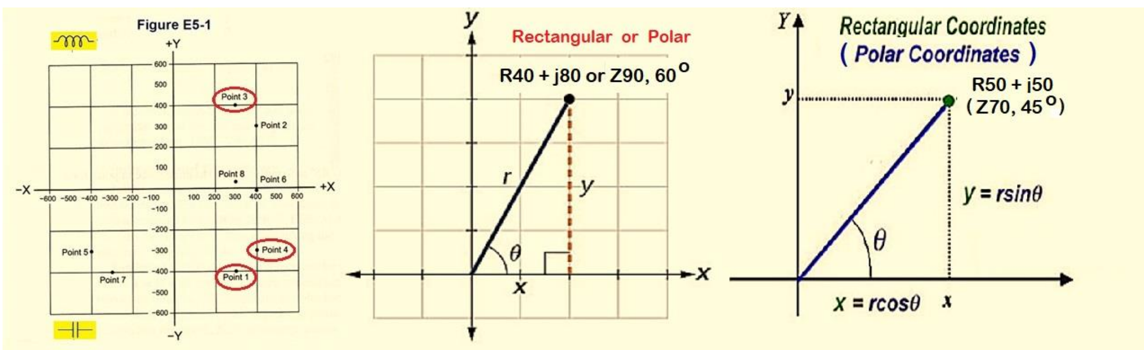
Capacitive reactance in rectangular notation is – jX (negative)

Inductive reactance in rectangular notation is + jX (positive)

The **X axis represents the resistive** component and the **Y axis represents the reactive** component using rectangular coordinates to graph the impedance of a circuit

The **horizontal axis** represents the **resistive component**

The **vertical axis** represents the **reactive component**



Matching Antennas to Feedlines

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Reflection coefficient is the interactions at the load end of a **mismatched** transmission line

Transmission Lines

Velocity factor of a transmission line is the transmission line velocity divided by the velocity of light in a vacuum

Electrical signals move more slowly in a coaxial cable than in air

Dielectric has biggest effect on the **Velocity Factor** of a transmission line

The significant differences between **foam-dielectric** coaxial cable and **solid-dielectric** cable are;
- **reduced** safe operating **voltage** limits,
- **reduced losses** per unit of length and
- **higher velocity factor**

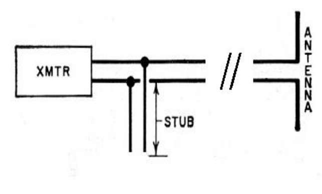
Coaxial cable with **solid polyethylene dielectric 0.66** is the typical velocity factor

Ladder line has lower loss than coaxial cable

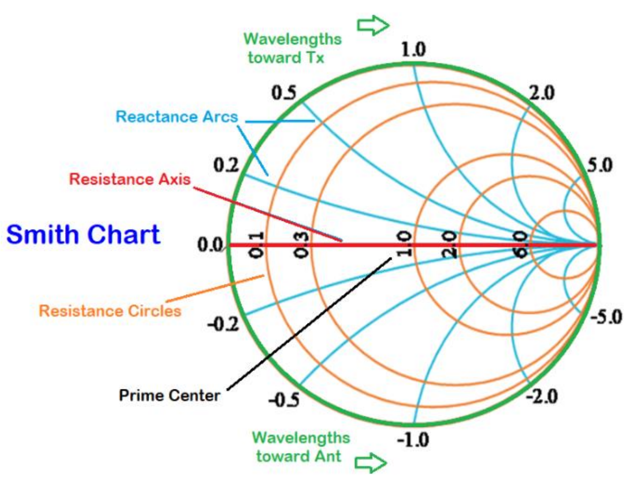
Ladder line has 1.0is the typical velocity factor

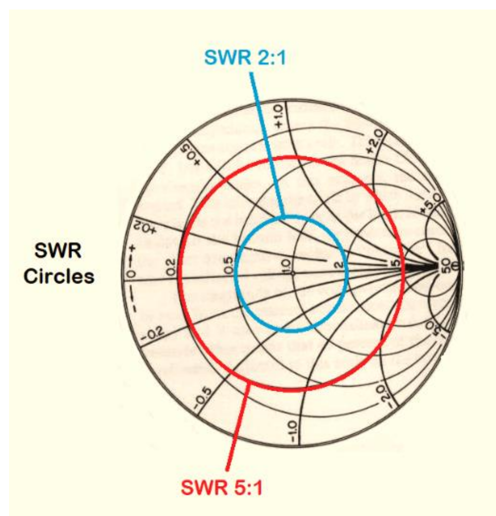
Cable Length = Velocity Factor X [Speed of Light / Frequency] X Wavelength of Cable

Impedance of Coaxial Stubs		
Wavelength	**Open Stub**	**Shorted Stub**
1/8	Capacitive	Inductive
1/4	Low Imp.	High Imp.
1/2	High Imp.	Low Imp.



Smith Charts





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SWR Circles (from center out)

Wavelengths are transmission line lengths

CLASS 5 – ANTENNAS, PROPOGATION AND SAFETY

===

E9A Basic Antenna parameters

E3A Electromagnetic waves

E9B Antenna patterns and designs

E9C Practical wire antennas

E9D Yagi antennas

E9H Receiving Antennas

E3B Transequatorial propagation

E3C Radio horizon

E0A Safety

Class Five Fundamentals and Substance

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E9A Basic Antenna parameters

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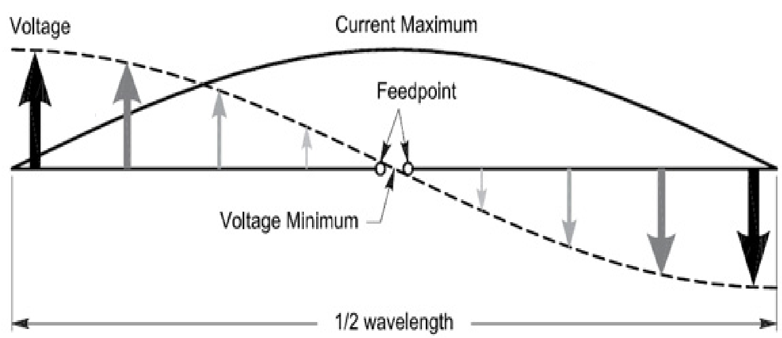
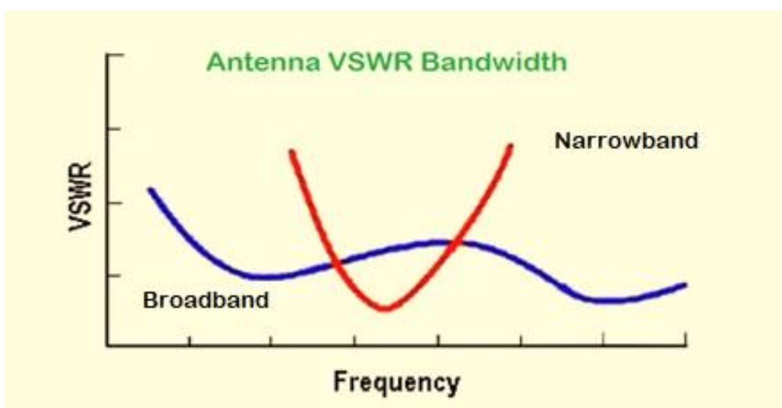
Feed point impedance is affected by antenna height

Editor's Note: Feed point impedance is the resistance and reactance seen at the antenna terminals



Antenna Bandwidth is the frequency range an antenna satisfies performance requirements, typically frequency range a feedpoint *(Editor's Note: aka VSWR is less than 2:1)*



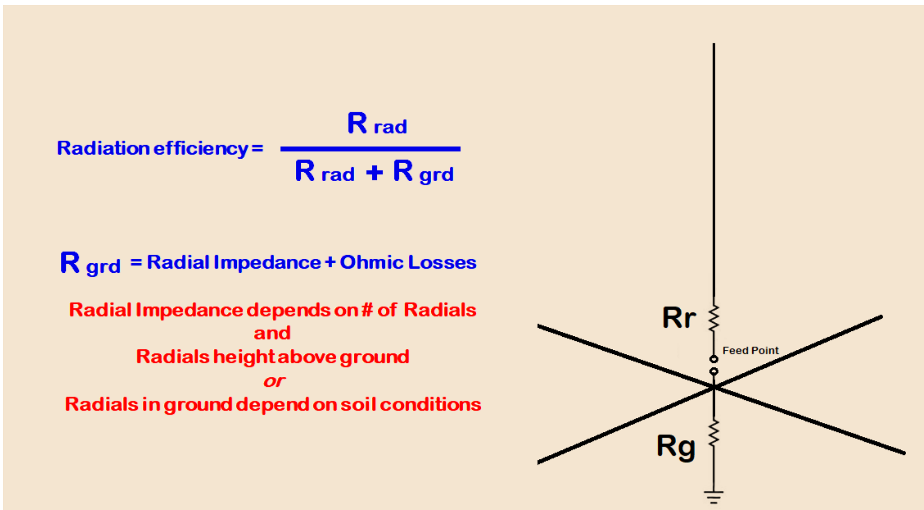
Antenna efficiency = (radiation resistance / total resistance) x 100%

Radiation resistance + Ohmic resistance equal the total resistance of an antenna system

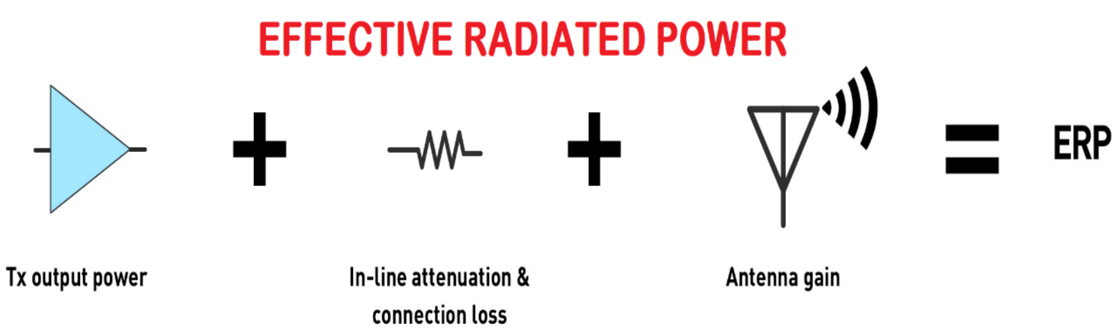
Radiation resistance + Ohmic resistance equal the total resistance of an antenna system

Installing a **RADIAL SYSTEM IMPROVES THE EFFICIENCY** of a ground-mounted **quarter-wave vertical antenna**

SOIL CONDUCTIVITY DETERMINES GROUND LOSSES for a ground-mounted vertical antenna operating in the 3 MHz to 30 MHz range



EFFECTIVE RADIATED POWER describes station output, taking into account all gains and losses



E9A02 (D) What is the effective radiated power relative to a dipole of a repeater station with 150 watts transmitter power output, 2 dB feed line loss, 2.2 dB duplexer loss, and 7 dBd antenna gain? A. 1977 watts B. 78.7 watts C. 420 watts D. 286 watts

ERP = Power X (Gain - Loss)

ERP = 150W X (7.0 - 2.0 - 2.2) dB

ERP = 150W X 2.8dB

Head math check 3dB is about 2 ratio so the answer is about 300W

2.8dB = Gain/loss ratio = 10^(dB/10) or 10^(2.8/10) or 10^.28 or 1.905

ERP = 150W X 1.905

ERP = 285.75W

E9A06 (A) What is the effective radiated power relative to a dipole of a repeater station with 200 watts transmitter power output, 4 dB feed line loss, 3.2 dB duplexer loss, 0.8 dB circulator loss, and 10 dBd antenna gain? A. 317 watts B. 2000 watts C. 126 watts D. 300 watts

ERP = Power X (Gain - Loss)

ERP = 200W X (10.0 - 4.0 - 3.2 – 0.8) dB

ERP = 200W X 2.0dB

Head math check 2dB is about 1.5 ratio so the answer is about 300W

2.0dB = Gain/loss ratio = 10^(dB/10)or 10^(2.0/10) or 10^.20 or 1.584

ERP = 200W X 1.584

ERP = 316.80 W

E9A07 (B) What is the effective isotropic radiated power of a repeater station with 200 watts transmitter power output, 2 dB feed line loss, 2.8 dB duplexer loss, 1.2 dB circulator loss, and 7 dBi antenna gain? A. 159 watts B. 252 watts C. 632 watts D. 63.2 watts

ERP = Power X (Gain - Loss)

ERP = 200W X (7.0 - 2.0 - 2.8 – 1.2) dB

ERP = 200W X 1.0dB

Head math check 1dB is about 1.2 ratio so the answer is about 240W

1.0dB = Gain/loss ratio = 10^(dB/10)or 10^(1.0/10) or 10^.10 or 1.2589

ERP = 200W X 1.2589

ERP = 251.78 W

Editor's note: There is another way to work these problems by converting the transmitter power to dBW. Here is the same problem as above in all dB math. You will get the same answer.

ERP = Power X (Gain - Loss)

ERP = (200W) + 7.0 - 2.0 - 2.8 – 1.2

ERP = 23.0103 dBw + 7.0 - 2.0 - 2.8 – 1.2

ERP = 24.0103 dBW

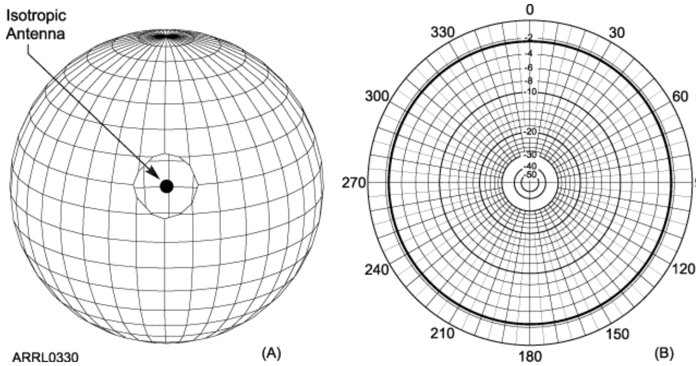
24.0103 dBW = 10^(dB/10)or 10^(24.0103/10) or 10^2.40103 or 251.7851 Watts

ERP = 251.78 W

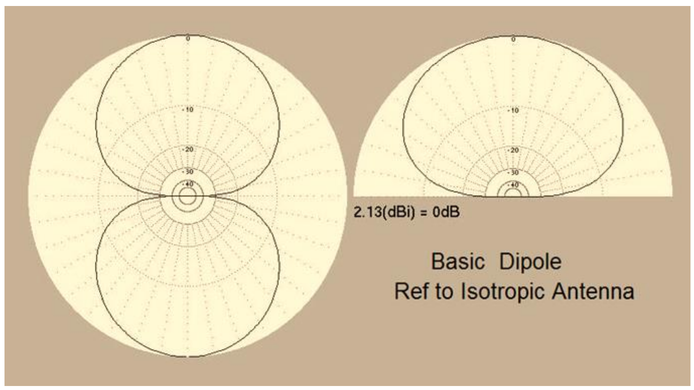
Editor's note: This method is good for complex transmission paths just add and subtract dBs and only convert at the TX end

An **ISOTROPIC** antenna is a theoretical antenna used as a reference for antenna gain

An **ISOTROPIC** antenna has no gain in any direction



DIPOLE ANTENNA GAIN is 2.15 dB reference to an **ISOTROPIC ANTENNA**



E9A12 (A) How much gain does an antenna have compared to a 1/2-wavelength dipole when it has 6 dB gain over an isotropic antenna? A. 3.85 dB B. 6.0 dB C. 8.15 dB D. 2.79 dB

Unknown Antenna = 6 dBi

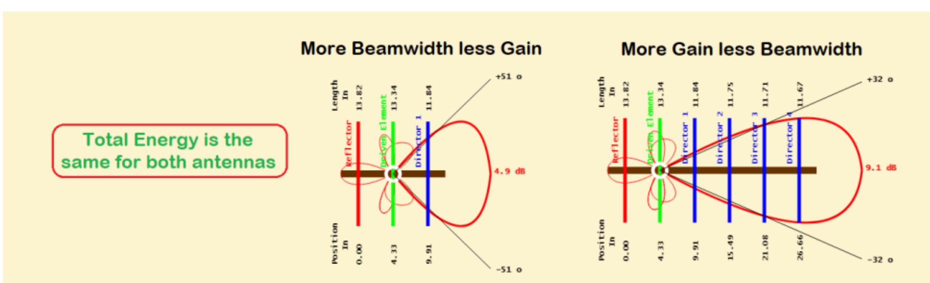
Generic Dipole Antenna = 2.15 dBi

dBi – 2.15dB = dBd (DP Gain)

6 dBi – 2.15 dBi = 3.85 dB

Unknown Antenna = 3.85 dB more than a Dipole Antenna

DIPOLE ANTENNA GAIN is 2.15 dB reference to an **ISOTROPIC ANTENNA**



Editor's Note: Antenna gain tells us the power transmitted by an antenna in a specific direction as compared to an isotropic antenna. This specification describes how strong a signal an antenna can send out or receive in a specified direction. One antenna concentrates more energy in one direction but the total energy is the same for both antennas.

==

E9A01 (C) What is an isotropic antenna? A. A grounded antenna used to measure Earth conductivity B. A horizontally polarized antenna used to compare Yagi antennas C. A theoretical, omnidirectional antenna used as a reference for antenna gain D. A spacecraft antenna used to direct signals toward Earth

E9A02 (D) see discussion in previous section

E9A03 (C) What is the radiation resistance of an antenna? A. The combined losses of the antenna elements and feed line B. The specific impedance of the antenna C. The value of a resistance that would dissipate the same amount of power as that radiated from an antenna D. The resistance in the atmosphere that an antenna must overcome to be able to radiate a signal

E9A04 (B) Which of the following factors affect the feed point impedance of an antenna? A. Transmission line length B. Antenna height C. The settings of an antenna tuner at the transmitter D. The input power level

E9A05 (D) What is included in the total resistance of an antenna system? A. Radiation resistance plus space impedance B. Radiation resistance plus transmission resistance C. Transmission-line resistance plus radiation resistance D. Radiation resistance plus loss resistance

E9A06 (A) see discussion in previous section

E9A07 (B) see discussion in previous section

E9A08 (B) What is antenna bandwidth? A. Antenna length divided by the number of elements B. The frequency range over which an antenna satisfies a performance requirement C. The angle between the half-power radiation points D. The angle formed between two imaginary lines drawn through the element ends

E9A09 (B) What is antenna efficiency? A. Radiation resistance divided by transmission resistance B. Radiation resistance divided by total resistance C. Total resistance divided by radiation resistance D. Effective radiated power divided by transmitter output

E9A10 (A) Which of the following improves the efficiency of a ground-mounted quarter-wave vertical antenna? A. Installing a radial system B. Isolating the coax shield from ground C. Shortening the radiating element D. All these choices are correct

E9A11 (C) Which of the following factors determines ground losses for a ground-mounted vertical antenna operating in the 3 MHz to 30 MHz range? A. The standing wave ratio B. Distance from the transmitter C. Soil conductivity D. Take-off angle

E9A12 (A) see discussion in previous section

E9A13 (C) What term describes station output, taking into account all gains and losses? A. Power factor B. Half-power bandwidth C. Effective radiated power D. Apparent power

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E3A Electromagnetic waves

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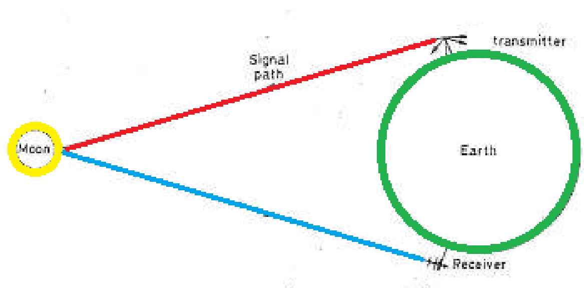
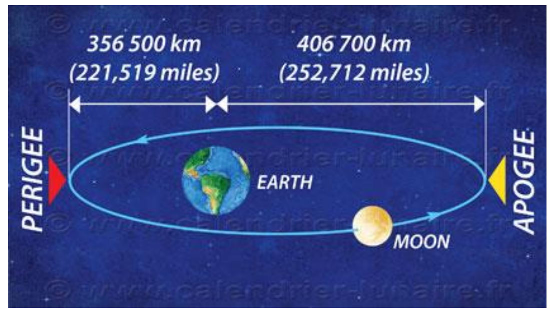
12,000 MILES is the maximum separation measured along the surface of the Earth between two stations communicating by **MOONBOUNCE**

A **FLUTTERY IRREGULAR FADING** characterizes **LIBRATION FADING** of an EME signal

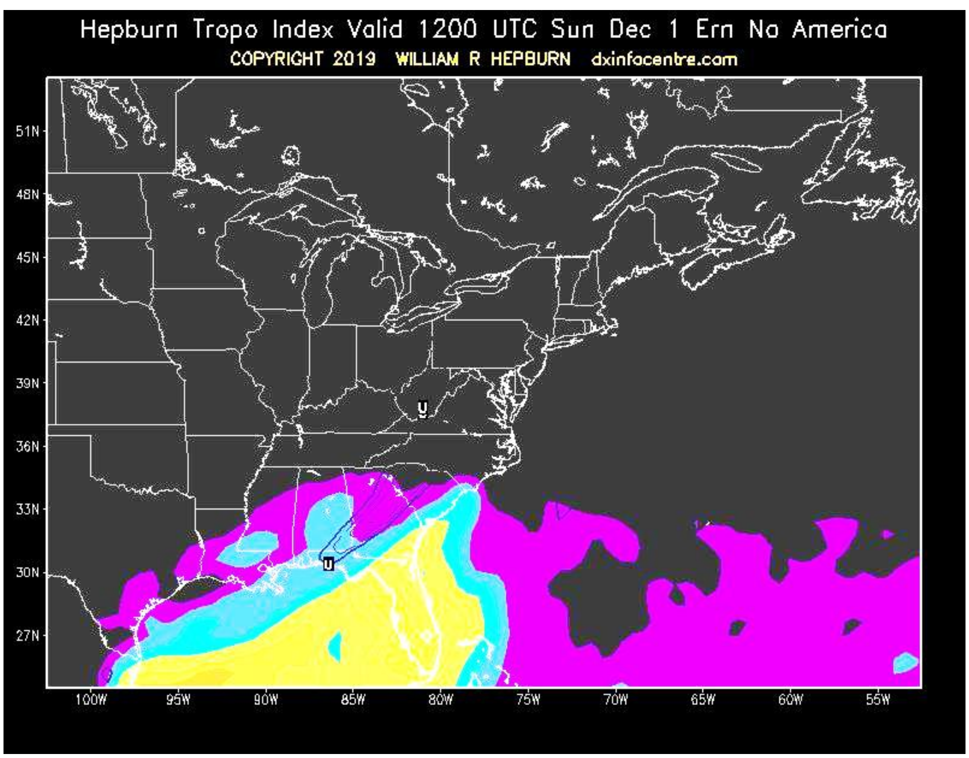
When the MOON IS AT PERIGEE EME contacts result in **THE LEAST PATH LOSS**





Editor's note: Amateur radio (ham) operators utilize EME for two-way communications. EME presents significant challenges to amateur operators interested in weak signal communication. EME provides the longest communications path any two stations on Earth can use. The "Moon bounce" technique was developed by the United States military in the years after World War II. The first successful reception of echoes off the Moon was carried out at Fort Monmouth, New Jersey on January 10, 1946 by John H. DeWitt as part of Project Diana. The Communication Moon Relay project that followed led to more practical uses, including a teletype link between the naval base at Pearl Harbor, Hawaii and United States Navy headquarters in Washington, D.C. In the days before communications satellites, a link free of the vagaries of ionospheric propagation was revolutionary.

HEPBURN MAPS predict the probability of **TROPOSPHERIC PROPAGATION**

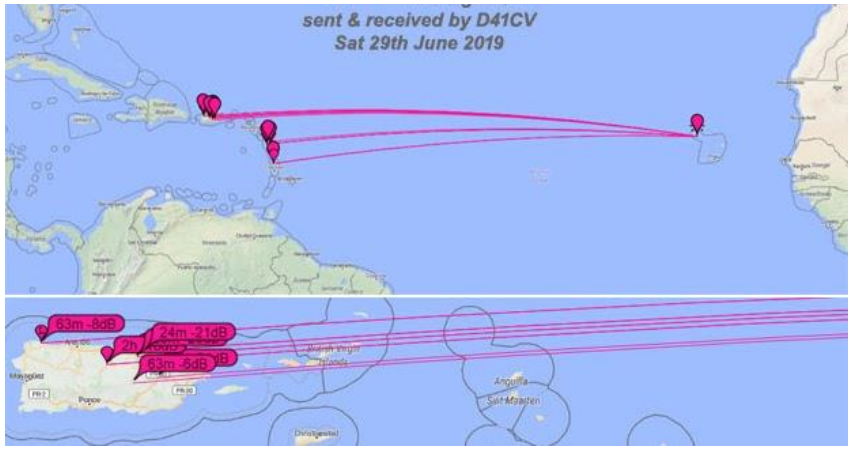


ATMOSPHERIC DUCTS capable of propagating microwave signals often form over **BODIES OF WATER**

TEMPERATURE INVERSION can create a **PATH FOR MICROWAVE PROPAGATION**

TROPOSPHERIC PROPAGATION of microwave signals occurs along **WARM AND COLD FRONTS**

Typical **range for TROPOSPHERIC PROPAGATION** of microwave signals is **100 MILES TO 300 MILES**



Editor's note: Tropospheric propagation called ducting or duct effect, occurs when there is a defined, horizontal boundary between air masses having different densities. When a cool air mass is overlain by a warm air mass, as is the case along and near warm fronts and cold fronts, radio waves at VHF and UHF are reflected at the boundary if they strike it at a near-grazing angle from beneath (within the cooler air mass). Because radio waves are also reflected from the earth's surface, the result can be efficient propagation for hundreds or, in some cases, upwards of 1,000 miles, as the waves alternately bounce off the frontal boundary and the surface.

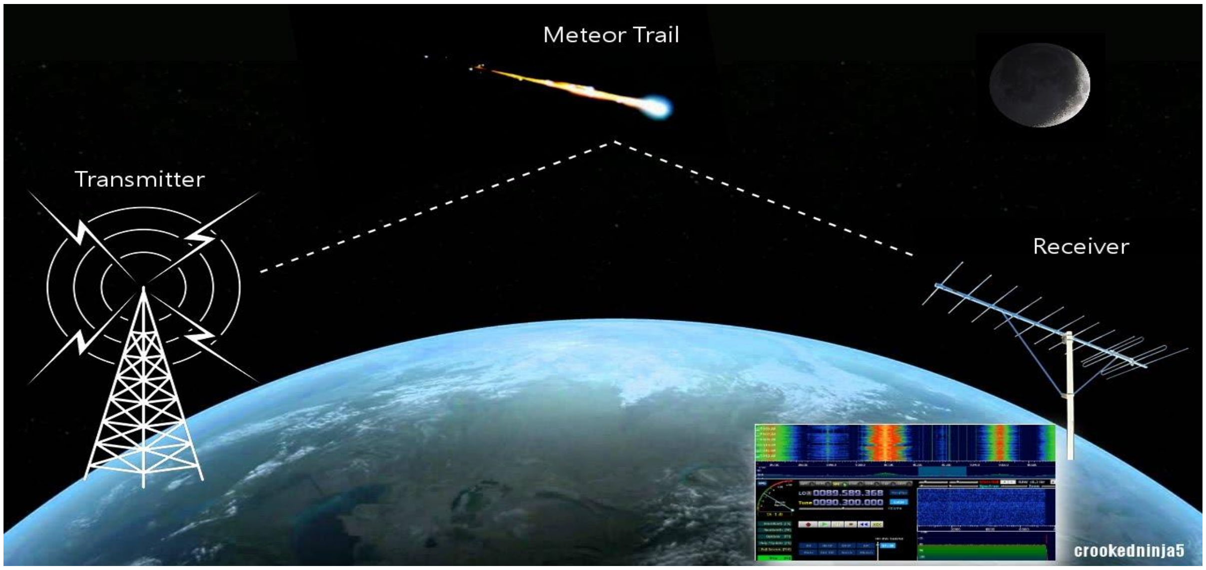
The interaction in the E layer of **CHARGED PARTICLES** from the Sun with **THE EARTH'S MAGNETIC FIELD** is the cause of **AURORAL ACTIVITY**

CW IS BEST FOR AURORAL PROPAGATION

Editor's note: Auroral borealis is caused by the collision of solar-wind particles with oxygen and nitrogen molecules in the upper atmosphere. These collisions partially ionize the molecules by knocking loose some of their outer electrons. VHF radio waves are reflected from the ionization created by an auroral curtain. VHF/UHF propagation up to 1,400 miles. Generally, auroral propagation is available only to stations in the northern states

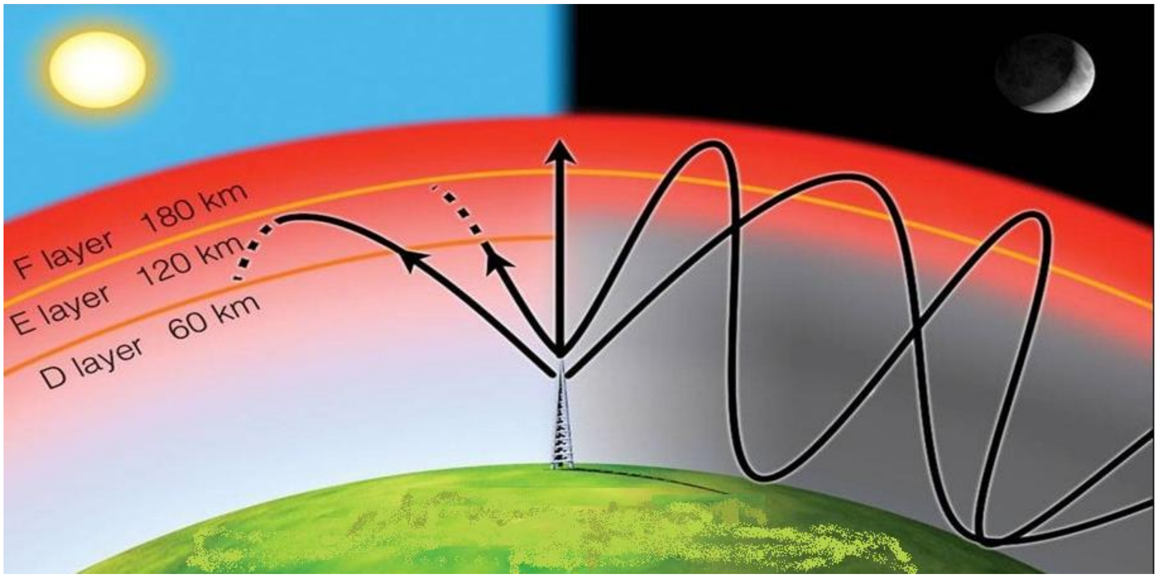
METEOR STRIKES THE E LAYER A CYLINDRICAL REGION OF FREE ELECTRONS is formed

28 MHz - 148 MHz is most suited for **METEOR SCATTER** communications



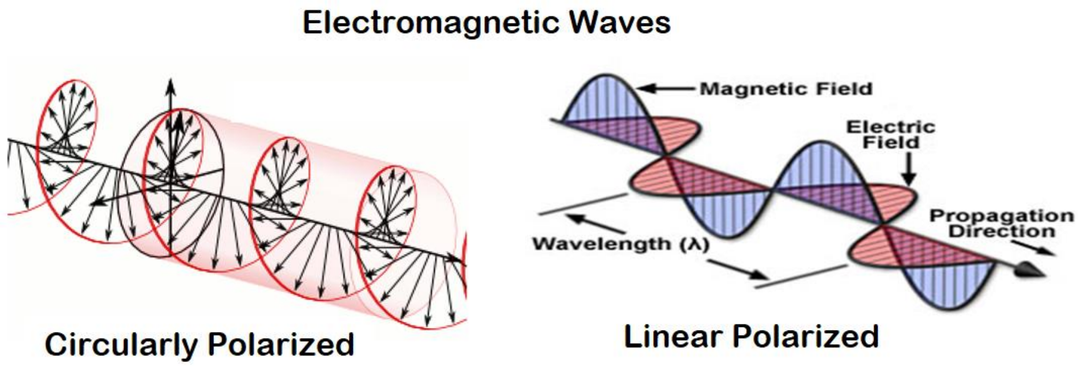
Editor's note: Meteor Scatter communications can be reflected by the ionized trail of a meteor (level of the E-layer, 50-75 miles). The ability of a meteor trail to reflect radio signals depends on the electron density. The best frequency range is between 28 and 148 MHz Meteor-scatter communication is best between midnight and noon. Meteor Showers – are predictable (Perseids in August, Geminids in December). FSK441 part of the WSJT software suite, HSCW 800 to 2,000 WPM.

Switching to a lower frequency HF band might help to restore contact when DX signals become too weak to copy across an entire HF band a few hours after sunset



Editor's note: Frequencies used by HF systems are generally higher during the day than they are at night because the disappearance of the sun effectively ends the ionization process. As a result of this, the D and E layers disappear while the F1 and F2 merge to form a single F layer.

Waves with a **ROTATING ELECTRIC FIELD** are **CIRCULARLY POLARIZED** electromagnetic waves



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E3A01 (D) What is the approximate maximum separation measured along the surface of the Earth between two stations communicating by EME? A. 500 miles, if the moon is at perigee B. 2000 miles, if the moon is at apogee C. 5000 miles, if the moon is at perigee D. 12,000 miles, if the moon is visible by both stations

E3A02 (B) What characterizes libration fading of an EME signal? A. A slow change in the pitch of the CW signal B. A fluttery irregular fading C. A gradual loss of signal as the sun rises D. The returning echo is several hertz lower in frequency than the transmitted signal

E3A03 (A) When scheduling EME contacts, which of these conditions will generally result in the least path loss? A. When the moon is at perigee B. When the moon is full C. When the moon is at apogee D. When the MUF is above 30 MHz

E3A04 (D) What do Hepburn maps predict? A. Sporadic E propagation B. Locations of auroral reflecting zones C. Likelihood of rain scatter along cold or warm fronts D. Probability of tropospheric propagation

E3A05 (C) Tropospheric propagation of microwave signals often occurs in association with what phenomenon? A. Grayline B. Lightning discharges C. Warm and cold fronts D. Sprites and jets

E3A06 (B) What might help to restore contact when DX signals become too weak to copy across an entire HF band a few hours after sunset? A. Switch to a higher frequency HF band B. Switch to a lower frequency HF band C. Wait 90 minutes or so for the signal degradation to pass D. Wait 24 hours before attempting another communication on the band

E3A07 (C) Atmospheric ducts capable of propagating microwave signals often form over what geographic feature? A. Mountain ranges B. Forests C. Bodies of water D. Urban areas

E3A08 (A) When a meteor strikes the Earth's atmosphere, a cylindrical region of free electrons is formed at what layer of the ionosphere? A. The E layer B. The F1 layer C. The F2 layer D. The D layer

E3A09 (C) Which of the following frequency ranges is most suited for meteor scatter communications? A. 1.8 MHz - 1.9 MHz B. 10 MHz - 14 MHz C. 28 MHz - 148 MHz D. 220 MHz - 450 MHz

E3A10 (B) Which type of atmospheric structure can create a path for microwave propagation? A. The jet stream B. Temperature inversion C. Wind shear D. Dust devil

E3A11 (B) What is a typical range for tropospheric propagation of microwave signals? A. 10 miles to 50 miles B. 100 miles to 300 miles C. 1200 miles D. 2500 miles

E3A12 (C) What is the cause of auroral activity? A. The interaction in the F2 layer between the solar wind and the Van Allen belt B. An extreme low-pressure area in the polar regions C. The interaction in the E layer of charged particles from the Sun with the Earth's magnetic field D. Meteor showers concentrated in the extreme northern and southern latitudes

E3A13 (A) Which of these emission modes is best for auroral propagation? A. CW B. SSB C. FM D. RTTY

E3A14 (B) What is meant by circularly polarized electromagnetic waves? A. Waves with an electric field bent into a circular shape B. Waves with a rotating electric field C. Waves that circle the Earth D. Waves produced by a loop antenna

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E9B Antenna patterns and designs

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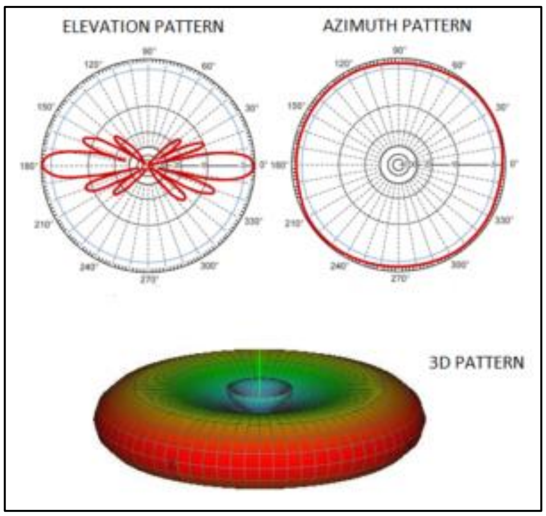
METHOD OF MOMENTS is a computer program technique used for **MODELING ANTENNAS**

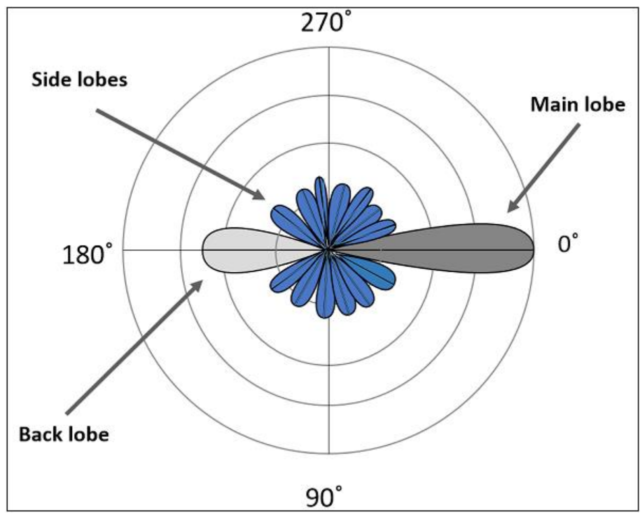
The principle of a **METHOD OF MOMENTS analysis is** modeled as a series of **segments, each having a uniform value of current**

A **disadvantage of decreasing the number of wire segments** is the computed feed point impedance may be incorrect

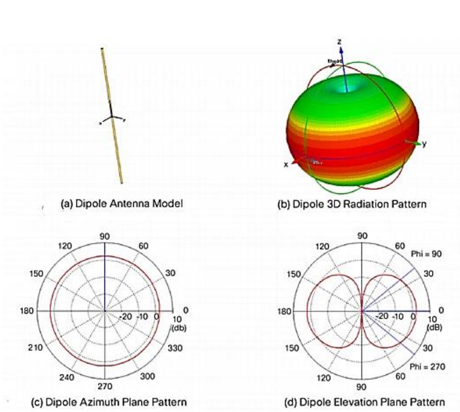
The region where the **SHAPE OF THE ANTENNA PATTERN IS INDEPENDENT OF DISTANCE IS THE FAR FIELD** of an antenna

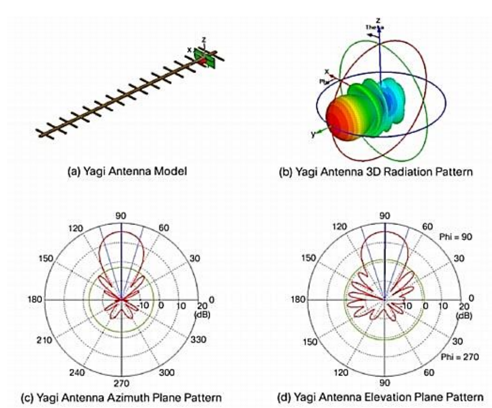
The **TOTAL AMOUNT OF RADIATION** emitted by a directional gain antenna compare with the total amount of radiation emitted from a theoretical isotropic antenna **ARE THE SAME.**





*Editor's note: The **Numerical Electromagnetics Code, or NEC**, is a popular antenna modeling system for wire and surface antennas. The code is based on the **method of moments** solution of the electric field integral equation (EFIE) for thin wires and the magnetic field integral equation (MFIE) for closed, conducting surfaces. It uses an iterative method to calculate the currents in a set of wires, and the fields that result.*





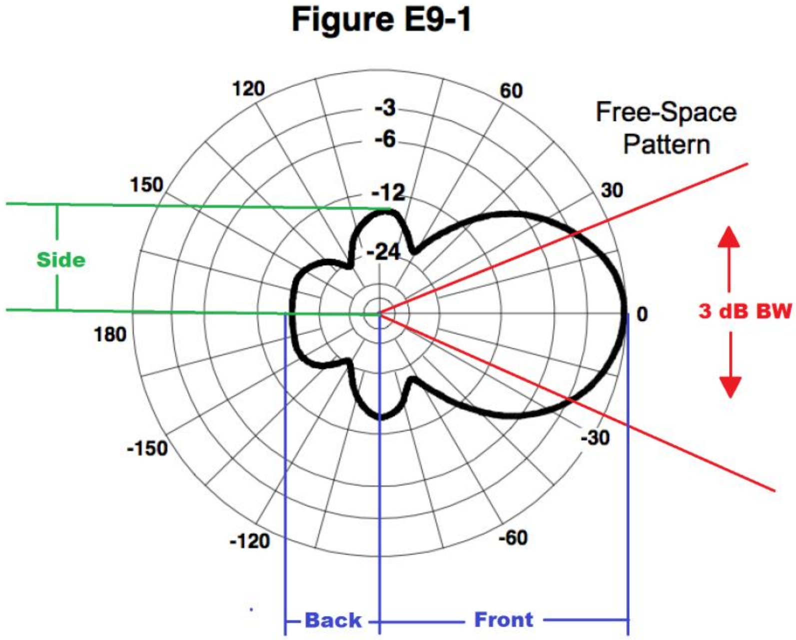


Figure E9-1, what is the Beamwidth? 50 degrees

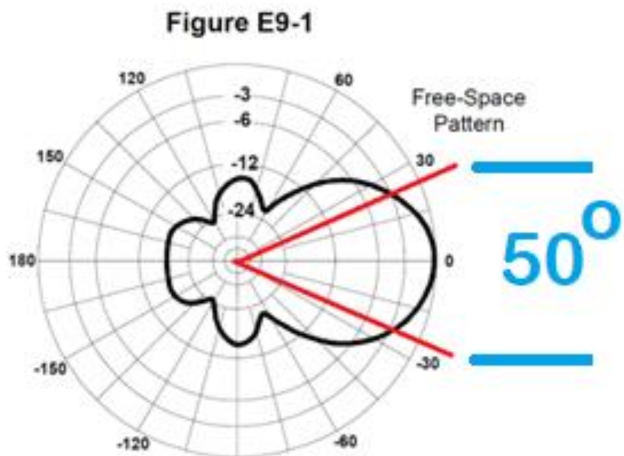


Figure E9-1, what is the front-to-back ratio? 18 dB

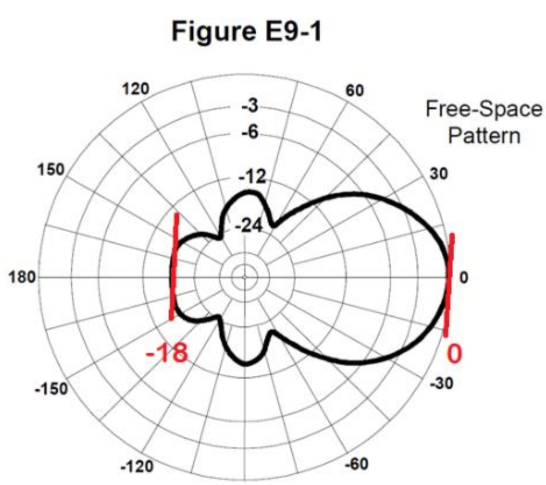


Figure E9-1, what is the front-to-side ratio? 14 dB

Figure E9-1

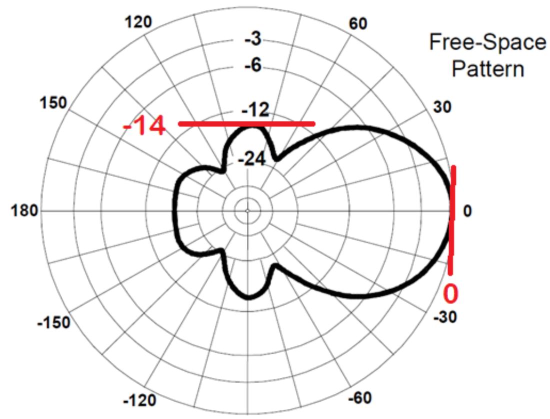
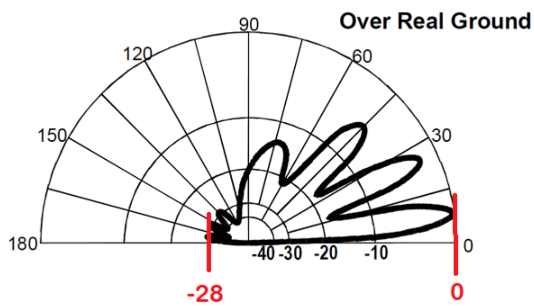
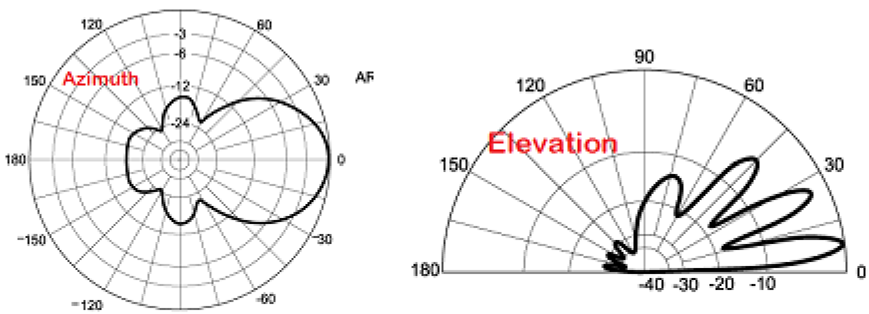


Figure E9-2, what is the front-to-back ratio? 28 dB

Figure E9-2

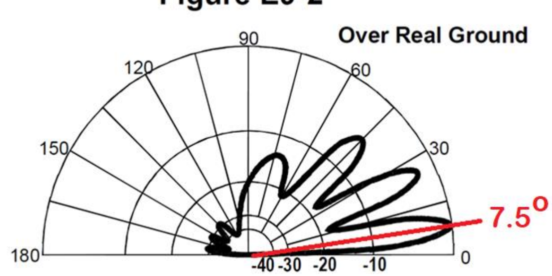


What pattern is shown in Figure E9-2? Elevation



ELEVATION ANGLE OF PEAK response in the pattern shown in Figure E9-2? 7.5 degrees

Figure E9-2



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E9B01 (B) In the antenna radiation pattern shown in Figure E9-1, what is the beamwidth? A. 75 degrees B. 50 degrees C. 25 degrees D. 30 degrees

E9B02 (B) In the antenna radiation pattern shown in Figure E9-1, what is the front-to-back ratio? A. 36 dB B. 18 dB C. 24 dB D. 14 dB

E9B03 (B) In the antenna radiation pattern shown in Figure E9-1, what is the front-to-side ratio? A. 12 dB B. 14 dB C. 18 dB D. 24 dB

E9B04 (B) What is the front-to-back ratio of the radiation pattern shown in Figure E9 2? A. 15 dB B. 28 dB C. 3 dB D. 38 dB

E9B05 (A) What type of antenna pattern is shown in Figure E9-2? A. Elevation B. Azimuth C. Radiation resistance D. Polarization

E9B06 (C) What is the elevation angle of peak response in the antenna radiation pattern shown in Figure E9-2? A. 45 degrees B. 75 degrees C. 7.5 degrees D. 25 degrees

E9B07 (C) How does the total amount of radiation emitted by a directional gain antenna compare with the total amount of radiation emitted from a theoretical isotropic antenna, assuming each is driven by the same amount of power? A. The total amount of radiation from the directional antenna is increased by the gain of the antenna B. The total amount of radiation from the directional antenna is stronger by its front-to-back ratio C. They are the same D. The radiation from the isotropic antenna is 2.15 dB stronger than that from the directional antenna

E9B08 (D) What is the far field of an antenna? A. The region of the ionosphere where radiated power is not refracted B. The region where radiated power dissipates over a specified time period C. The region where radiated field strengths are constant D. The region where the shape of the antenna pattern is independent of distance

E9B09 (B) What type of computer program technique is commonly used for modeling antennas? A. Graphical analysis B. Method of Moments C. Mutual impedance analysis D. Calculus differentiation with respect to physical properties

E9B10 (A) What is the principle of a Method of Moments analysis? A. A wire is modeled as a series of segments, each having a uniform value of current B. A wire is modeled as a single sine-wave current generator C. A wire is modeled as a single sine-wave voltage source D. A wire is modeled as a series of segments, each having a distinct value of voltage across it

E9B11 (C) What is a disadvantage of decreasing the number of wire segments in an antenna model below 10 segments per half-wavelength? A. Ground conductivity will not be accurately modeled B. The resulting design will favor radiation of harmonic energy C. The computed feed point impedance may be incorrect D. The antenna will become mechanically unstable

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E9C Practical wire antennas

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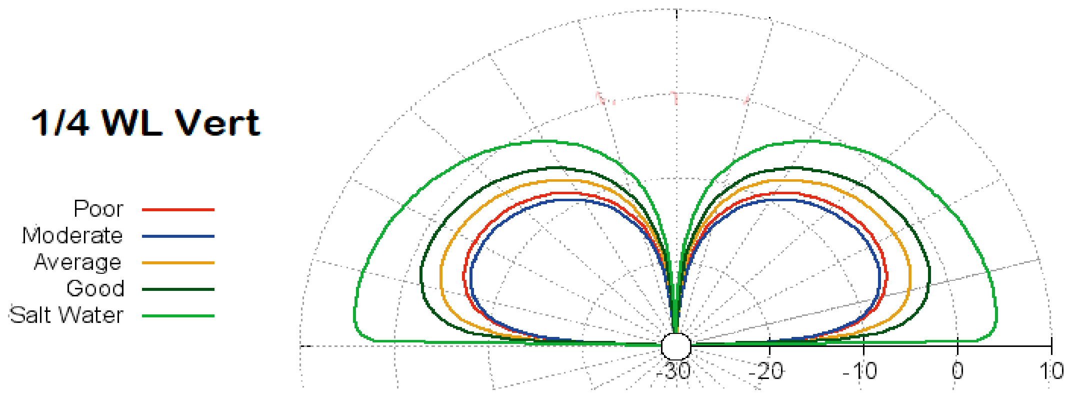
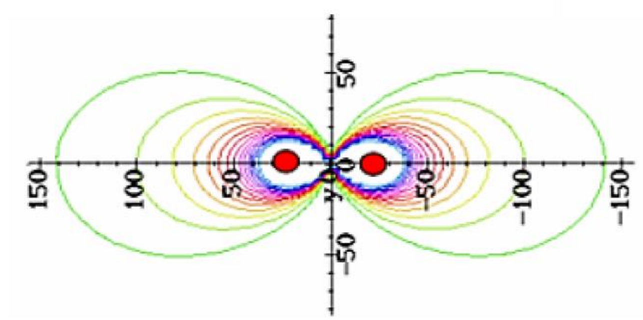
Low-angle radiation from a **vertically polarized** antenna **over SEAWATER WILL BE MUCH STRONGER**



Editor's note: Effects of Low conductivity soil losses reduce signal strength at low angles

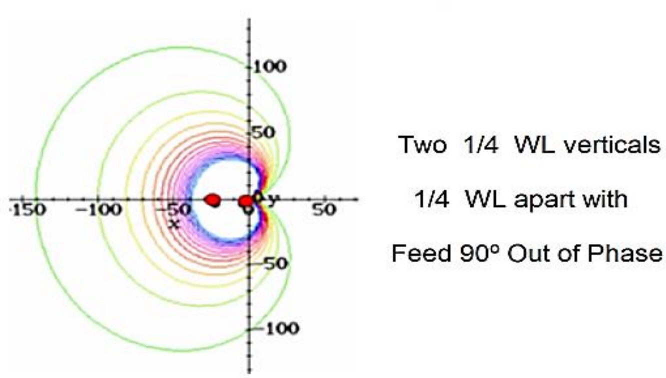
Editor's note: Effects of Low-angle radiation from a vertically polarized antenna over rocky soil will be much weaker

The radiation pattern **OF TWO 1/4-WAVELENGTH VERTICAL ANTENNAS SPACED 1/2-WAVELENGTH apart and fed 180 DEGREES OUT OF PHASE IS A FIGURE-8 ORIENTED** along the axis of the array

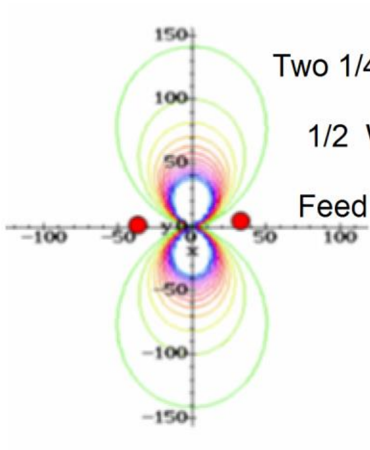


Two vertical ¼ WL antennas Feed points 180º out of phase

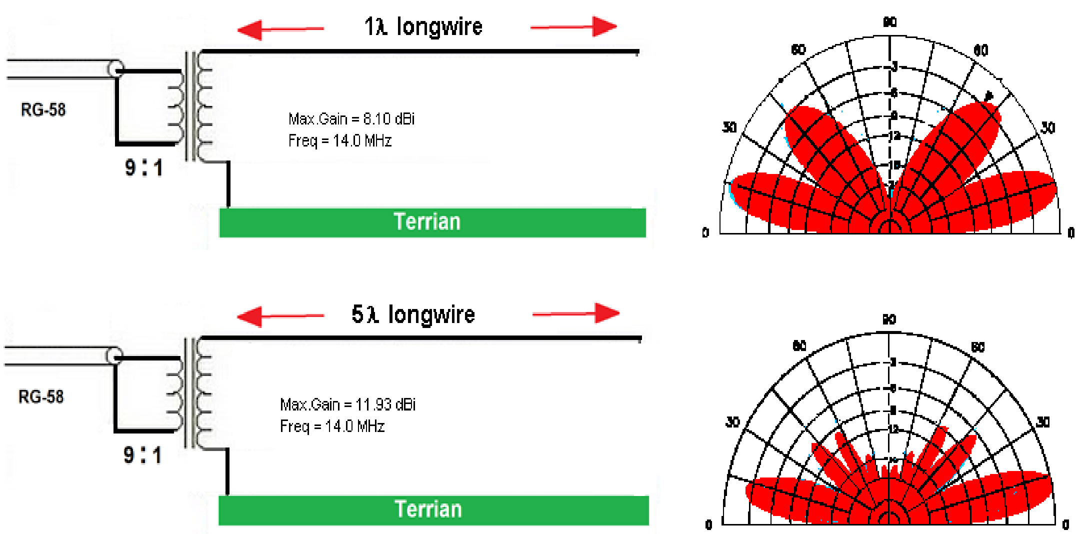
The radiation pattern **OF TWO 1/4-WAVELENGTH VERTICAL ANTENNAS SPACED 1/4-WAVELENGTH apart and fed 90 DEGREES OUT OF PHASE IS A CARDIOID** along the axis of the array

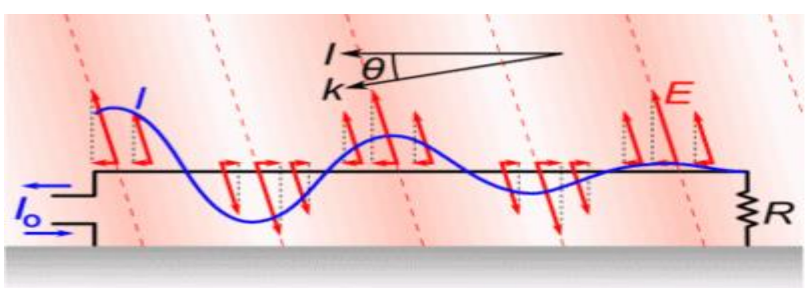


The radiation pattern **OF TWO 1/4-WAVELENGTH VERTICAL ANTENNAS SPACED 1/2-WAVELENGTH apart and fed IN PHASE IS A FIGURE-8 BROADSIDE TO** along the axis of the array



The lobes align more in the direction of the wire **long wire antenna as the wire length is increased**

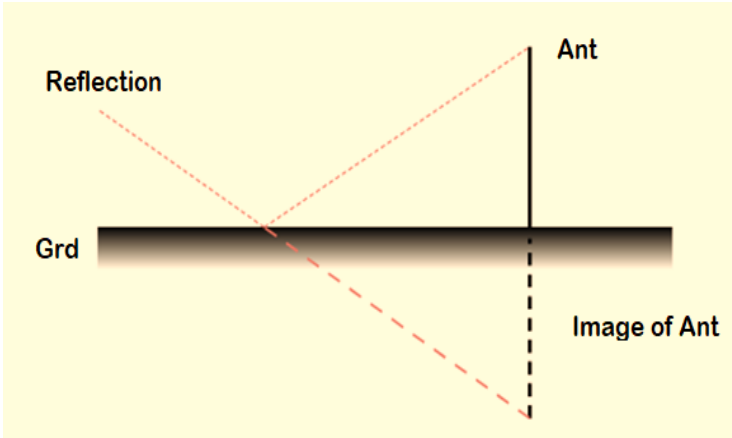




Editor's note: Out of phase cancel (antenna radiation & ground reflections), signal strength will decrease

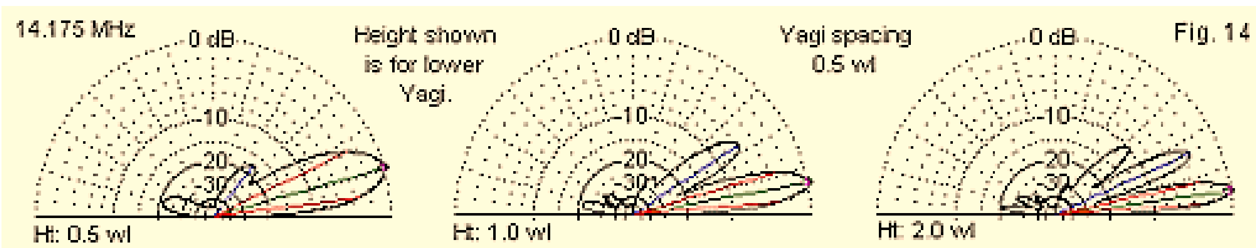
Editor's note: In phase reinforce (antenna radiation & ground reflections), signal strength will increase

The main lobe takeoff angle decreases in the downhill direction of a horizontally polarized antenna mounted on the side of a hill compare with the same antenna mounted on **flat ground**

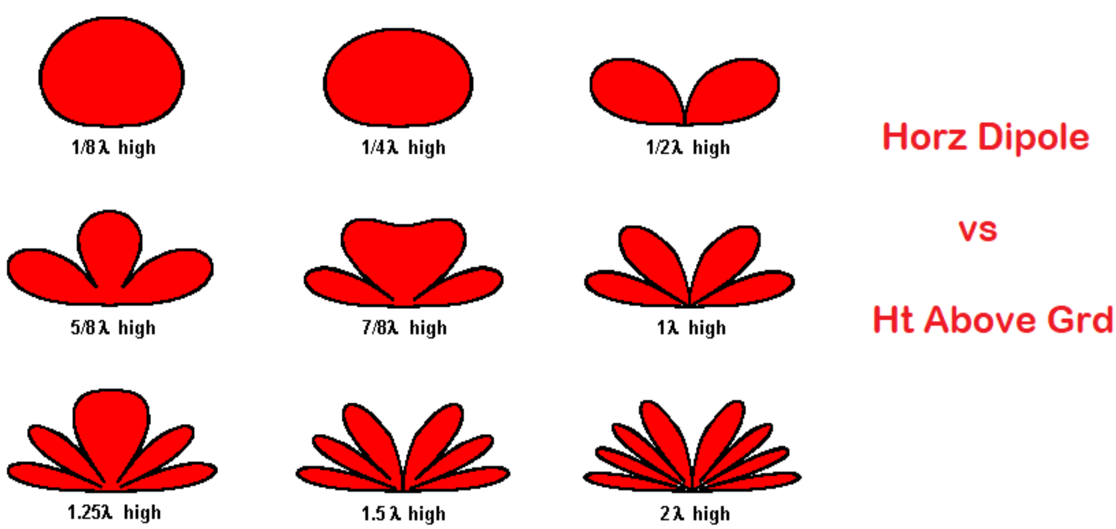


Editor's note: Effects of ground reflections and absorption on antenna systems efficiency is the losses in nearby ground, ground structures, or the antenna's ground system. Radiation pattern over ground is affected by the electrical conductivity of the soil

The radiation pattern of a horizontally polarized 3-element beam **antenna takeoff angle of the lowest elevation lobe decreases with increasing height above ground**



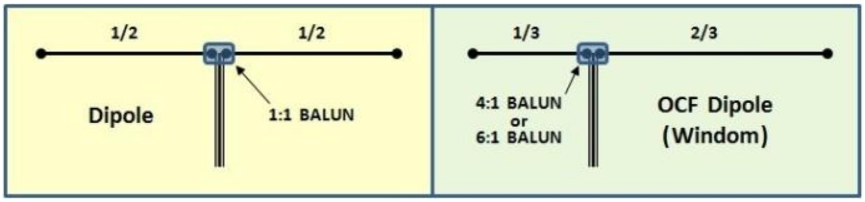
Elevation Patterns for a 20-Meter 2-Stack of 3-Element Yagis at Various Heights



Editor's note: Raising the antenna lowers the vertical takeoff angle of the peak radiation

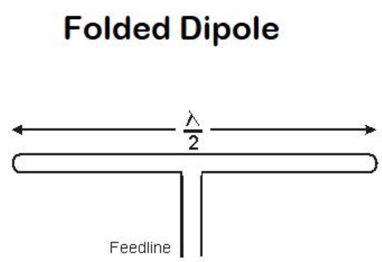
Editor's note: Horizontal antennas have less ground losses

An **OCFD antenna** is a dipole feed approximately 1/3 the way from one end with a 4:1 balun

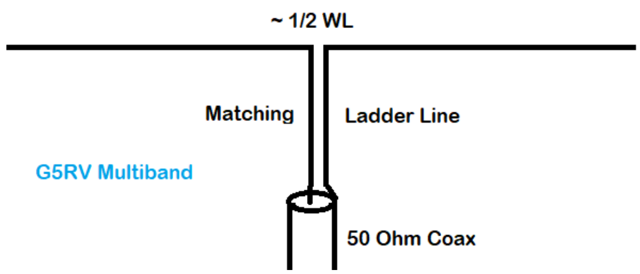


A folded dipole antenna is one wavelength of wire forming a very thin loop

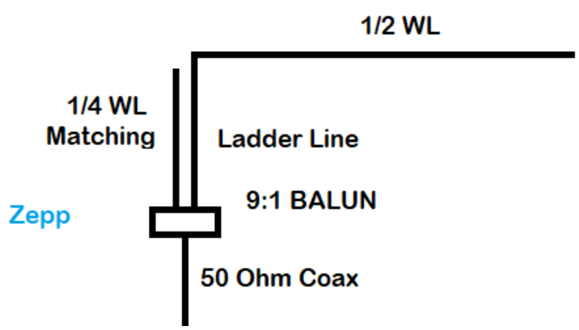
A folded dipole antenna has approximate feed point impedance of **300 Ohms**



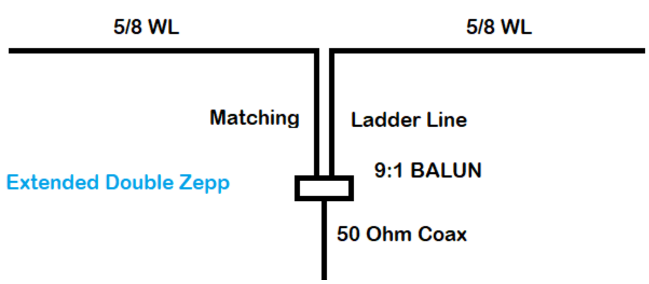
G5RV antenna is a multiband dipole antenna fed with coax and a BALUN open wire matching section



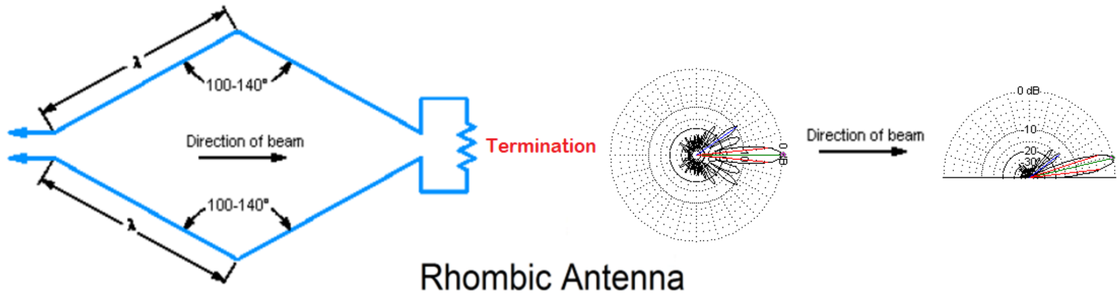
Zepp antenna is an end fed dipole antenna



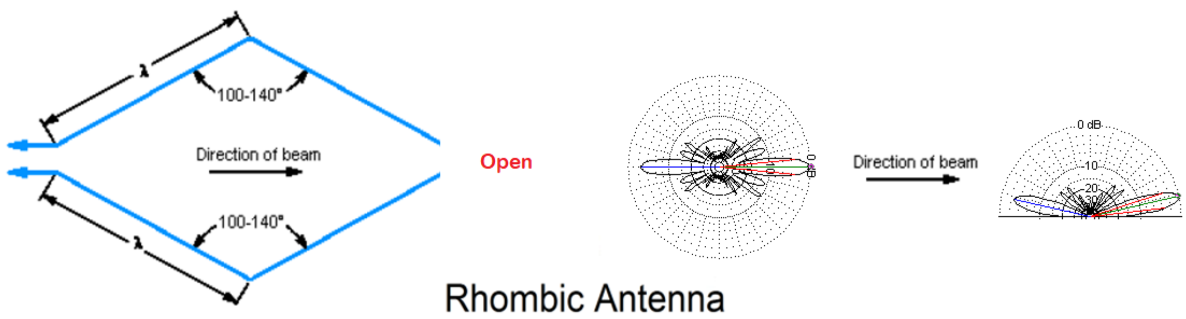
An **extended double Zepp antenna** is a center fed dipole with two 5/8 wave elements in phase



The **terminating resistor on a rhombic** antenna provides a unidirectional **directional radiation pattern**



Editor's note: The open ended on a rhombic antenna provides a bidirectional radiation pattern



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E9C01 (D) What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase? A. Cardioid B. Omni-directional C. A figure-8 broadside to the axis of the array D. A figure-8 oriented along the axis of the array

E9C02 (A) What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/4-wavelength apart and fed 90 degrees out of phase? A. Cardioid B. A figure-8 end-fire along the axis of the array C. A figure-8 broadside to the axis of the array D. Omni-directional

E9C03 (C) What is the radiation pattern of two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed in phase? A. Omni-directional B. Cardioid C. A Figure-8 broadside to the axis of the array D. A Figure-8 end-fire along the axis of the array

E9C04 (B) What happens to the radiation pattern of an unterminated long wire antenna as the wire length is increased? A. The lobes become more perpendicular to the wire B. The lobes align more in the direction of the wire C. The vertical angle increases D. The front-to-back ratio decreases

E9C05 (A) Which of the following is a type of OCFD antenna? A. A dipole fed approximately 1/3 the way from one end with a 4:1 balun to provide multiband operation B. A remotely tunable dipole antenna using orthogonally controlled frequency diversity C. A folded dipole center-fed with 300-ohm transmission line D. A multiband dipole antenna using one-way circular polarization for frequency diversity

E9C06 (B) What is the effect of adding a terminating resistor to a rhombic antenna? A. It reflects the standing waves on the antenna elements back to the transmitter B. It changes the radiation pattern from bidirectional to unidirectional C. It changes the radiation pattern from horizontal to vertical polarization D. It decreases the ground loss

E9C07 (A) What is the approximate feed point impedance at the center of a two-wire folded dipole antenna? A. 300 ohms B. 72 ohms C. 50 ohms D. 450 ohms

E9C08 (C) What is a folded dipole antenna? A. A dipole one-quarter wavelength long B. A type of ground-plane antenna C. A half-wave dipole with an additional parallel wire connecting its two ends D. A dipole configured to provide forward gain

E9C09 (A) Which of the following describes a G5RV antenna? A. A multi-band dipole antenna fed with coax and a balun through a selected length of open wire transmission line B. A multi-band trap antenna C. A phased array antenna consisting of multiple loops D. A wide band dipole using shorted coaxial cable for the radiating elements and fed with a 4:1 balun

E9C10 (B) Which of the following describes a Zepp antenna? A. A dipole constructed from zip cord B. An end-fed dipole antenna C. An omni-directional antenna commonly used for satellite communications D. A vertical array capable of quickly changing the direction of maximum radiation by changing phasing lines

E9C11 (D) How is the far-field elevation pattern of a vertically polarized antenna affected by being mounted over seawater versus soil? A. The low-angle radiation decreases B. Additional higher vertical angle lobes will appear C. Fewer vertical angle lobes will be present D. The low-angle radiation increases

E9C12 (C) Which of the following describes an Extended Double Zepp antenna? A. A wideband vertical antenna constructed from precisely tapered aluminum tubing B. A portable antenna erected using two push support poles C. A center-fed 1.25-wavelength antenna (two 5/8-wave elements in phase) D. An end-fed folded dipole antenna

E9C13 (B) How does the radiation pattern of a horizontally polarized 3-element beam antenna vary with increasing height above ground? A. The takeoff angle of the lowest elevation lobe increases B. The takeoff angle of the lowest elevation lobe decreases C. The horizontal beamwidth increases D. The horizontal beamwidth decreases

E9C14 (B) How does the performance of a horizontally polarized antenna mounted on the side of a hill compare with the same antenna mounted on flat ground? A. The main lobe takeoff angle increases in the downhill direction B. The main lobe takeoff angle decreases in the downhill direction C. The horizontal beamwidth decreases in the downhill direction D. The horizontal beamwidth increases in the uphill direction

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E9D Yagi antennas

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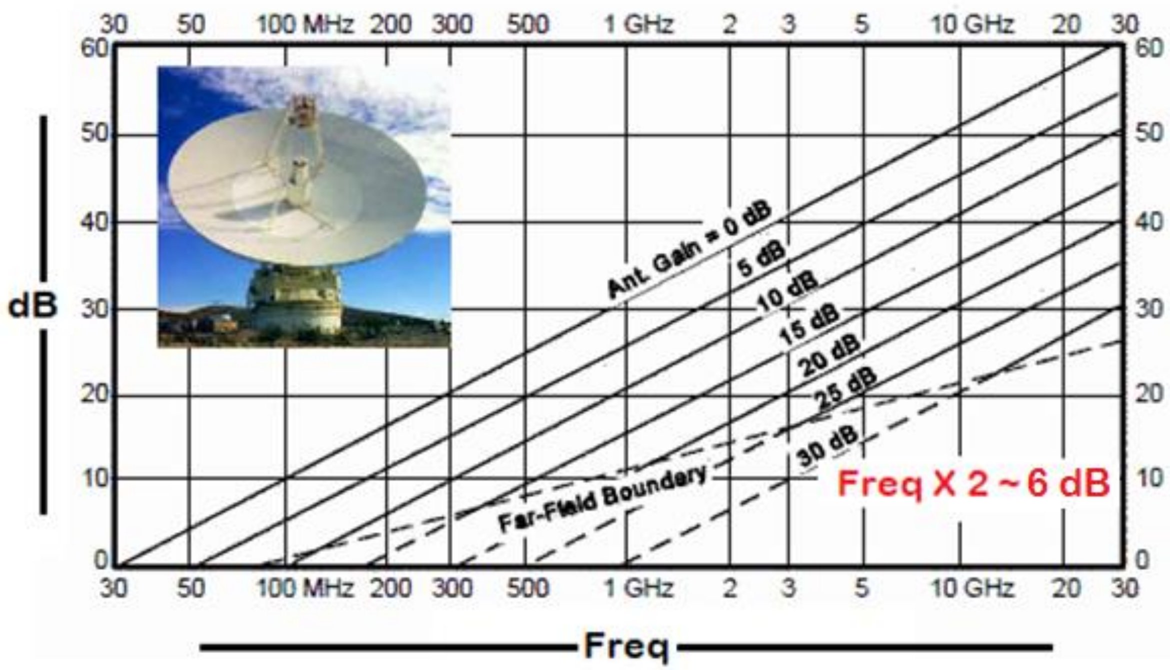
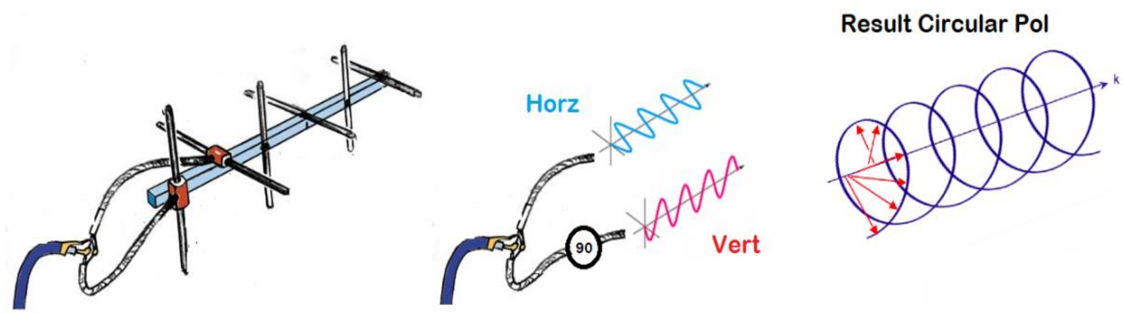
The gain of an ideal parabolic dish antenna **increases by 6 dB when the frequency is doubled**

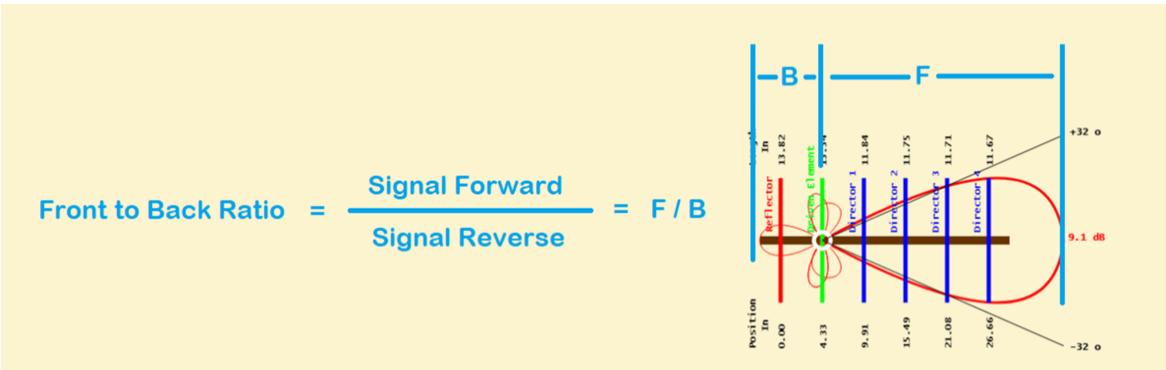


Editor's note: The gain of a parabolic antenna is proportional to the diameter^2. The doubling of results in the antenna size doubling in wavelengths and the gain is four times greater.

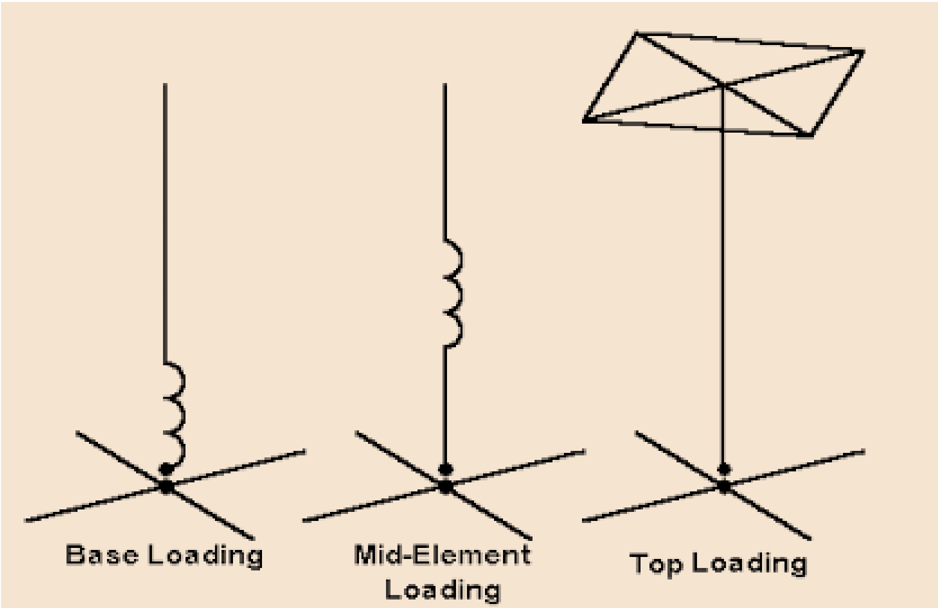
Two Linear Yagis perpendicular to each other with the driven elements at the same point on the boom and **fed 90 degrees out of phase produce circular polarization**



The **front-to-back ratio decreases** in a **Yagi antenna** is designed solely for max forward gain



Top loading in a shortened HF vertical antenna improves radiation efficiency



Place a high-Q loading **coil at center of the vertical radiator** to minimize losses in a shortened antenna

The function of a **loading coil on an HF mobile antenna is to cancel capacitive reactance**

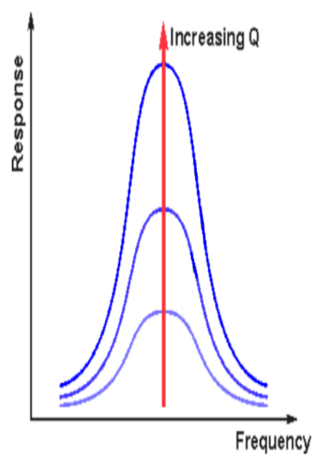
As the **Q of an antenna increases** the SWR bandwidth decreases

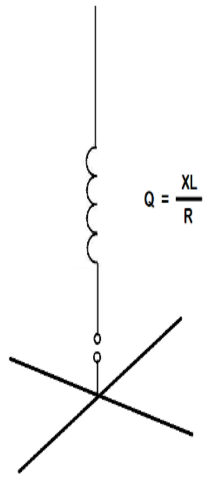
The **radiation resistance decreases and the capacitive reactance increases** when a fixed length HF mobile antenna is operated **below its resonant frequency**

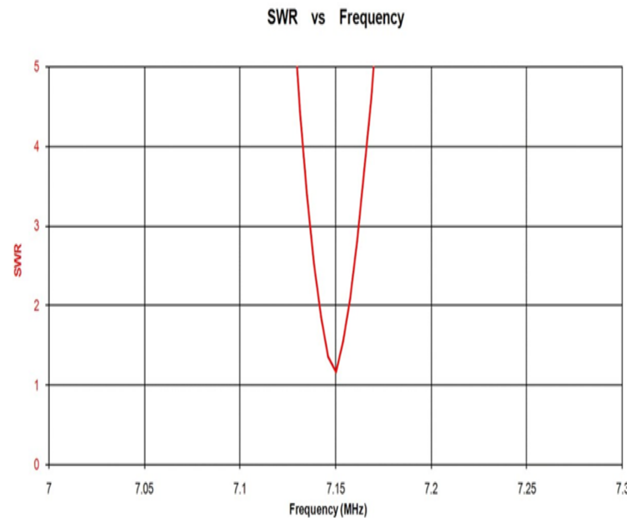
A high **Q loading coil be placed near the center of the vertical radiator to minimize losses** in a shortened vertical antenna

The **bandwidth decreases in an antenna shortened through the use of loading coils**

Top loading in a shortened HF vertical antenna improves radiation efficiency







Best RF station ground is a short connection to 3 or 4 interconnected ground rods driven into the Earth

A **wide flat copper strap** is best for minimizing losses in a station's RF ground system

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E9D01 (D) How much does the gain of an ideal parabolic dish antenna change when the operating frequency is doubled? A. 2 dB B. 3 dB C. 4 dB D. 6 dB

E9D02 (C) How can linearly polarized Yagi antennas be used to produce circular polarization? A. Stack two Yagis fed 90 degrees out of phase to form an array with the respective elements in parallel planes B. Stack two Yagis fed in phase to form an array with the respective elements in parallel planes C. Arrange two Yagis perpendicular to each other with the driven elements at the same point on the boom fed 90 degrees out of phase D. Arrange two Yagis collinear to each other with the driven elements fed 180 degrees out of phase

E9D03 (A) Where should a high Q loading coil be placed to minimize losses in a shortened vertical antenna? A. Near the center of the vertical radiator B. As low as possible on the vertical radiator C. As close to the transmitter as possible D. At a voltage node

E9D04 (C) Why should an HF mobile antenna loading coil have a high ratio of reactance to resistance? A. To swamp out harmonics B. To lower the radiation angle C. To minimize losses D. To minimize the Q

E9D05 (B) What usually occurs if a Yagi antenna is designed solely for maximum forward gain? A. The front-to-back ratio increases B. The front-to-back ratio decreases C. The frequency response is widened over the whole frequency band D. The SWR is reduced

E9D06 (B) What happens to the SWR bandwidth when one or more loading coils are used to resonate an electrically short antenna? A. It is increased B. It is decreased C. It is unchanged if the loading coil is located at the feed point D. It is unchanged if the loading coil is located at a voltage maximum point

E9D07 (D) What is an advantage of using top loading in a shortened HF vertical antenna? A. Lower Q B. Greater structural strength C. Higher losses D. Improved radiation efficiency

E9D08 (B) What happens as the Q of an antenna increases? A. SWR bandwidth increases B. SWR bandwidth decreases C. Gain is reduced D. More common-mode current is present on the feed line

E9D09 (D) What is the function of a loading coil used as part of an HF mobile antenna? A. To increase the SWR bandwidth B. To lower the losses C. To lower the Q D. To cancel capacitive reactance

E9D10 (B) What happens to feed-point impedance at the base of a fixed length HF mobile antenna when operated below its resonant frequency? A. The radiation resistance decreases and the capacitive reactance decreases B. The radiation resistance decreases and the capacitive reactance increases C. The radiation resistance increases and the capacitive reactance decreases D. The radiation resistance increases and the capacitive reactance increases

E9D11 (B) Which of the following conductors would be best for minimizing losses in a station's RF ground system? A. Resistive wire, such as spark plug wire B. Wide flat copper strap C. Stranded wire D. Solid wire

E9D12 (C) Which of the following would provide the best RF ground for your station? A. A 50-ohm resistor connected to ground B. An electrically short connection to a metal water pipe C. An electrically short connection to 3 or 4 interconnected ground rods driven into the Earth D. An electrically short connection to 3 or 4 interconnected ground rods via a series RF choke

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E9H Receiving Antennas

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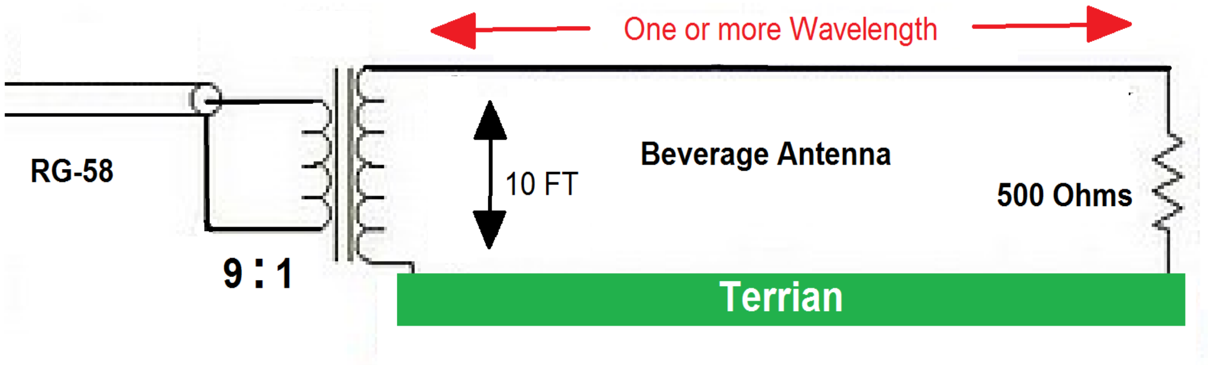
A **BEVERAGE** antenna should be **one or more wavelengths long**

Atmospheric **noise is so high that gain over a dipole is not important** for low band (160M & 80M) receiving antennas



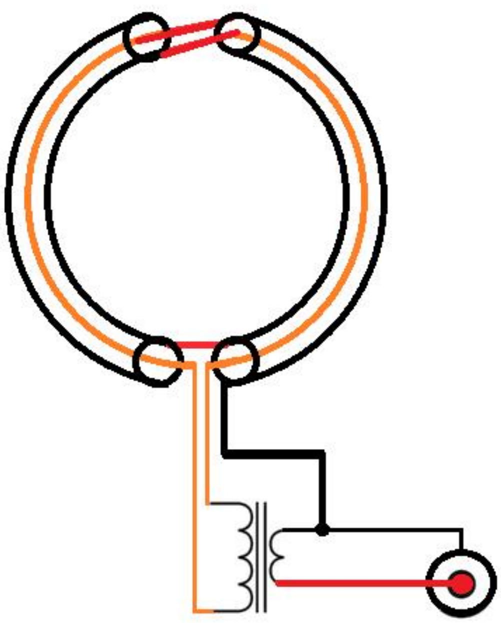
Editor's note: The Beverage antenna or "wave antenna" is a long-wire receiving antenna mainly used in the low frequency and medium frequency radio bands, invented by Harold H. Beverage in 1921. It is used by amateur radio, shortwave listening, and longwave radio DXers and military applications.

RECEIVING LOOP ANTENNA >> One or more turns of wire wound in the shape of a large open coil

The **output loop antenna** be increased by **adding turns** in the loop or **add area** to the loop

Placing a grounded electrostatic shield around a small loop direction-finding antenna **eliminates tracking errors** caused by strong out-of-band signals

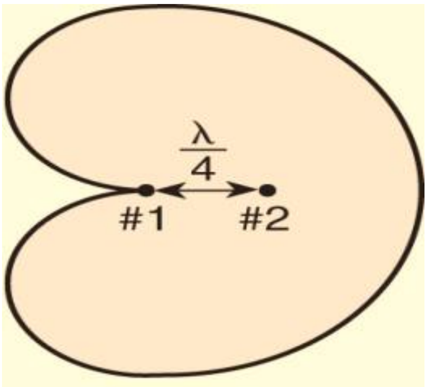
Editor's note: Shielded loop antenna is electro-statically balanced against ground, giving better nulls



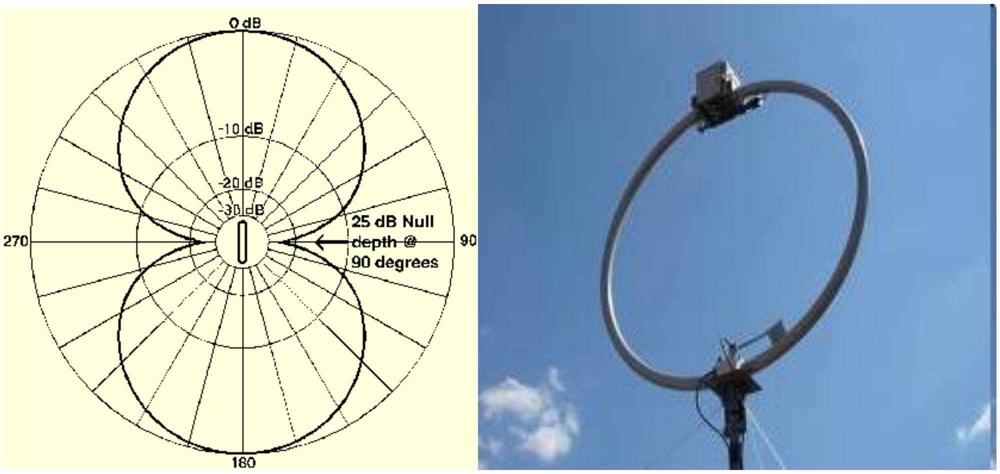
Receiving Directivity Factor (RDF) is forward gain compared to average gain over the entire hemisphere

To prevent **receiver overload which reduces pattern nulls an RF attenuation is used** when direction-finding

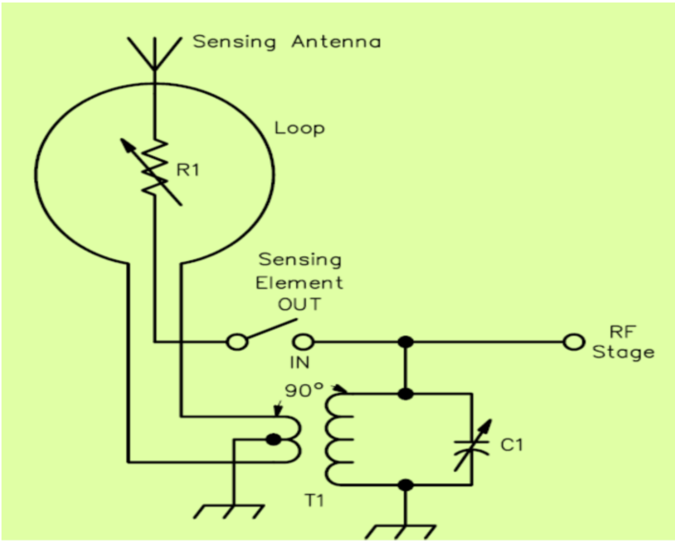
A **cardioid-pattern antenna** has a **very sharp single null** useful for direction finding



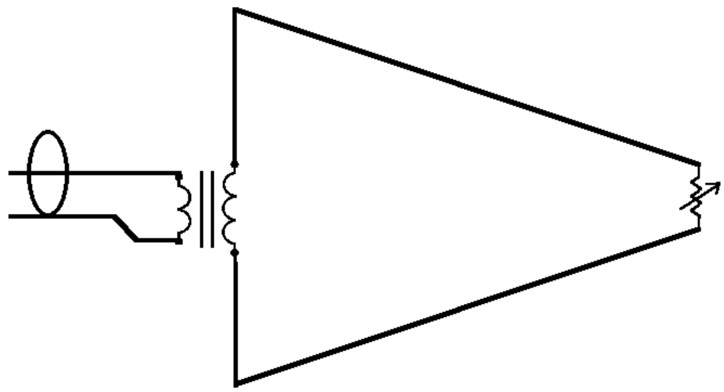
A small **wire-loop antenna has a bidirectional pattern**



A **sense antenna** modifies the pattern of a DF antenna array to provide a null in one direction

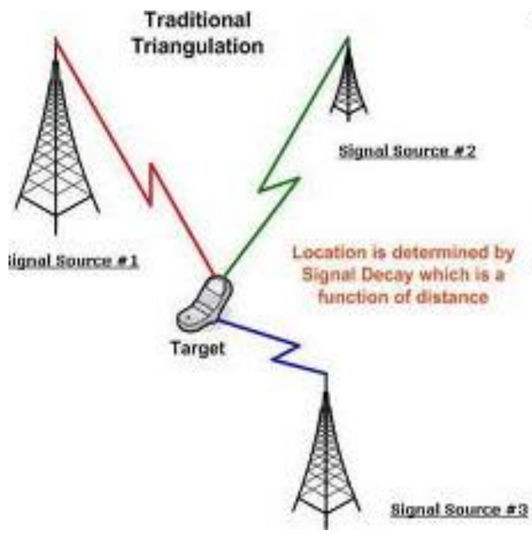


A **Pennant antenna** is a small, vertically oriented receiving antenna consisting of a **triangular loop terminated in approximately 900 ohms**



Editor's note: A Pennant antenna is a single-turn loops terminated on the side opposite the feedpoint. The termination effects a null off the end where the terminator is located, thereby producing a cardioid (heart-shaped) directional pick-up pattern. The antenna is broadband rather than resonant. The pattern produced holds up well over a wide frequency range.

The **triangulation** method uses headings from **several different receiving locations** to locate a signal



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E9H01 (D) When constructing a Beverage antenna, which of the following factors should be included in the design to achieve good performance at the desired frequency? A. Its overall length must not exceed 1/4 wavelength B. It must be mounted more than 1 wavelength above ground C. It should be configured as a four-sided loop D. It should be one or more wavelengths long

E9H02 (A) Which is generally true for low band (160 meter and 80 meter) receiving antennas? A. Atmospheric noise is so high that gain over a dipole is not important B. They must be erected at least 1/2 wavelength above the ground to attain good directivity C. Low loss coax transmission line is essential for good performance D. All these choices are correct

E9H03 (D) What is Receiving Directivity Factor (RDF)? A. Forward gain compared to the gain in the reverse direction B. Relative directivity compared to isotropic C. Relative directivity compared to a dipole D. Forward gain compared to average gain over the entire hemisphere

9H04 (B) What is an advantage of placing a grounded electrostatic shield around a small loop direction-finding antenna? A. It adds capacitive loading, increasing the bandwidth of the antenna B. It eliminates unbalanced capacitive coupling to the surroundings, improving the nulls C. It eliminates tracking errors caused by strong out-of-band signals D. It increases signal strength by providing a better match to the feed line

E9H05 (A) What is the main drawback of a small wire-loop antenna for direction finding? A. It has a bidirectional pattern B. It has no clearly defined null C. It is practical for use only on VHF and higher bands D. All these choices are correct

E9H06 (C) What is the triangulation method of direction finding? A. The geometric angles of sky waves from the source are used to determine its position B. A fixed receiving station plots three headings to the signal source C. Antenna headings from several different receiving locations are used to locate the signal source D. A fixed receiving station uses three different antennas to plot the location of the signal source

E9H07 (D) Why is RF attenuation used when direction-finding? A. To narrow the receiver bandwidth B. To compensate for isotropic directivity and the antenna effect of feed lines C. To increase receiver sensitivity D. To prevent receiver overload which reduces pattern nulls

E9H08 (A) What is the function of a sense antenna? A. It modifies the pattern of a DF antenna array to provide a null in one direction B. It increases the sensitivity of a DF antenna array C. It allows DF antennas to receive signals at different vertical angles D. It provides diversity reception that cancels multipath signals

E9H09 (B) What is a Pennant antenna? A. A four-element, high-gain vertical array invented by George Pennant B. A small, vertically oriented receiving antenna consisting of a triangular loop terminated in approximately 900 ohms C. A form of rhombic antenna terminated in a variable capacitor to provide frequency diversity D. A stealth antenna built to look like a flagpole

E9H10 (D) How can the output voltage of a multiple-turn receiving loop antenna be increased? A. By reducing the permeability of the loop shield B. By utilizing high impedance wire for the coupling loop C. By winding adjacent turns in opposing directions D. By increasing the number of turns and/or the area

E9H11 (B) What feature of a cardioid pattern antenna makes it useful for direction finding? A. A very sharp peak B. A very sharp single null C. Broadband response D. High radiation angle

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E3B Transequatorial propagation

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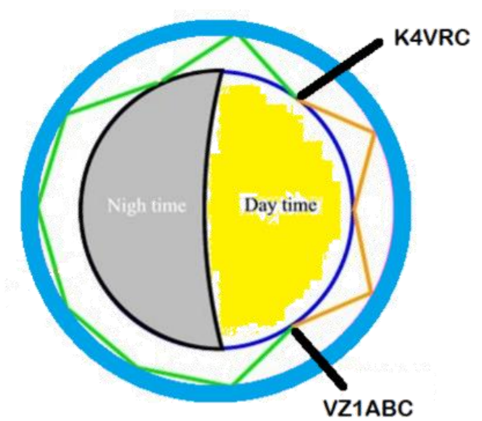
160M to 10M typically support long-path propagation

20M most frequently provides long-path propagation

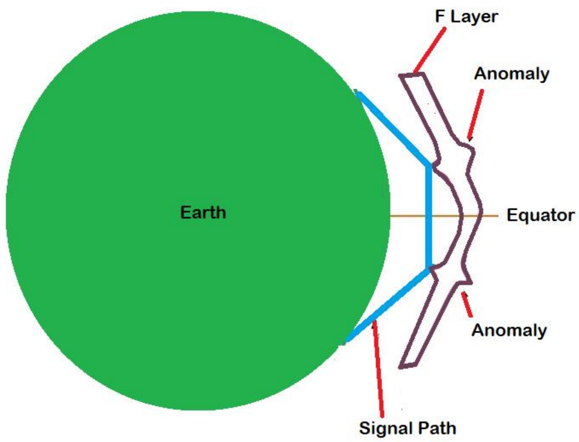


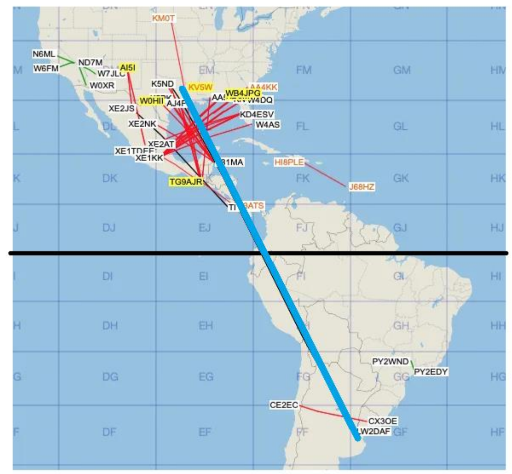
Editor's note: Long path propagation signal. vs. Short path propagation signals that also travelled along the long path (went all around the globe) Long path propagation signals that also travelled along the short path (went all around the globe) Signals that went multiple times around the globe.

T**ransequatorial propagation** is between two mid-latitude points at approximately the same distance north and south of the magnetic equator

5000 miles is the maximum range for signals using **transequatorial propagation**

Afternoon or early evening to is the best time of day for trans equatorial propagation

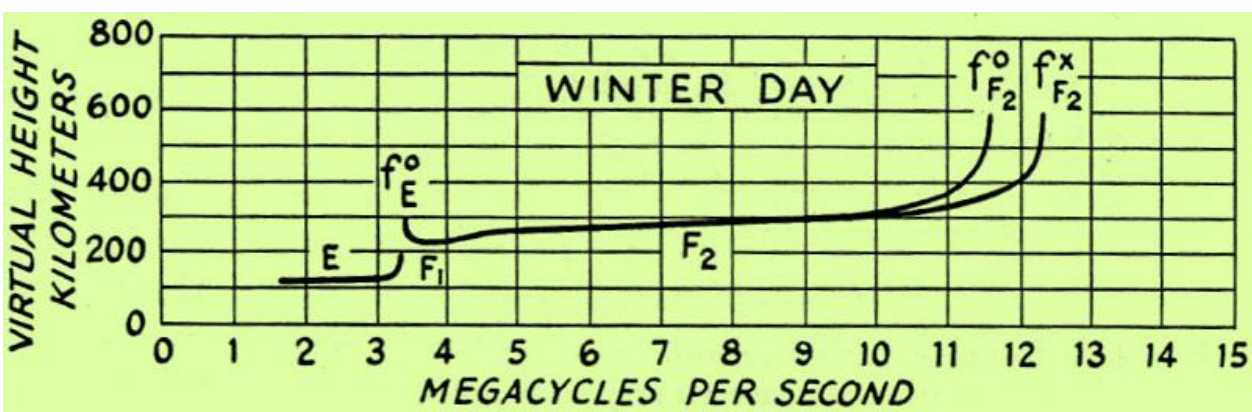




Editor's note: Trans equatorial Propagation (TE) is a form of F-layer ionospheric propagation. TE occurs between mid-latitude station approximately the same distance north and south of the Earth's magnetic equator (2,500 north and south of the equator). TE occurs on 50 & 144 MHz and to some extent 432 MHz. The high-density-ionization regions from approximately between 10 and 15 degrees on either side of the Earth's magnetic equator. Best time to look for them is March 21 & Sept 21.

Independent waves created in the ionosphere that are **elliptically polarized are "extraordinary" and "ordinary" waves**

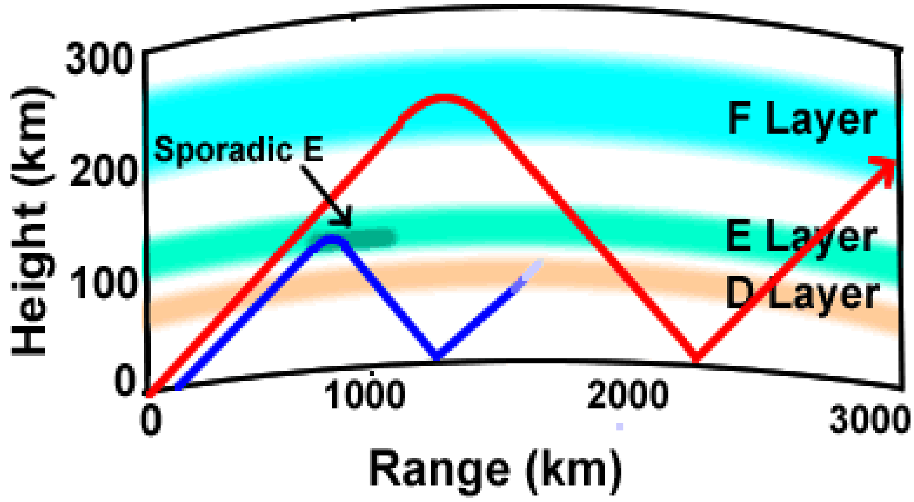
Linearly polarized radio waves that split into ordinary and extraordinary waves in the ionosphere become elliptically polarized



Editor's note: Near the critical frequency the waves are excessively retarded in the ionized layer, which accounts for the rise of the curve at the critical frequency. At the right of the curve appear two critical frequencies for the F2 layer. This is an indication of double refraction of the waves due to the earth's magnetic field, two components of different polarization being produced. ***One is called the "ordinary" wave and the other the "extraordinary" wave****. The symbols o and x, respectively, are used for these components.*

SPORADIC E propagation is likely to occur around the solstices, especially the **SUMMER SOLSTICE**

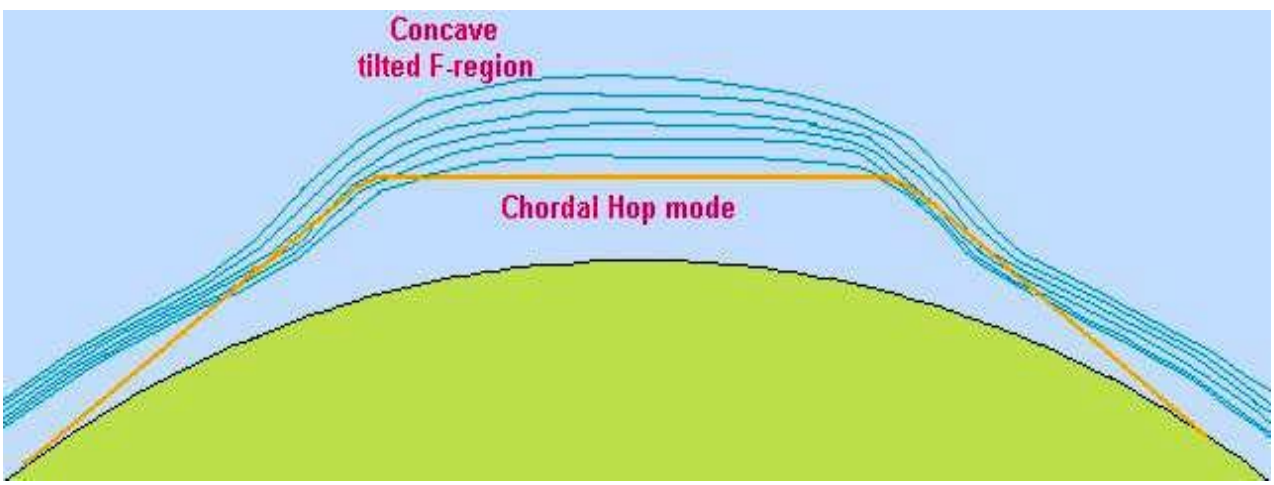
Sporadic E propagation can occur any time of day



Editor's note: Sporadic E propagation bounces signals off ionized atmospheric gas in the lower E region (located at altitudes of approx. 90 to 160 km). This occasionally allows for long-distance communication at VHF frequencies of 800–2200 km.

SUCCESSIVE IONOSPHERIC REFLECTIONS without an intermediate reflection from the ground is the primary characteristic of **CHORDAL HOP PROPAGATION**

CHORDAL HOP PROPAGATION EXPERIENCES LESS LOSS along the path than normal skip



Editor's note: Chordal Hop is when a signal approaches the ionosphere at a steep angle the signal penetrates the ionosphere and may pass right through, or be 'reflected' back (green ray, right). It is actually refracted rather than reflected. However, when a signal approaches the ionosphere at a grazing angle, the likelihood of 'reflection' is higher than for vertically approaching signals. The penetration is less and the attenuation is less. This 'chordal hop' process is believed to be common at night when the F layer is stable. Because there is no ground reflection involved, and less penetration of the ionosphere, the attenuation is much less than with other propagation mechanisms, and as a result signals are stronger.

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E3B01 (A) What is transequatorial propagation? A. Propagation between two mid-latitude points at approximately the same distance north and south of the magnetic equator B. Propagation between points located on the magnetic equator C. Propagation between a point on the equator and its antipodal point D. Propagation between points at the same latitude

E3B02 (C) What is the approximate maximum range for signals using transequatorial propagation? A. 1000 miles B. 2500 miles C. 5000 miles D. 7500 miles

E3B03 (C) What is the best time of day for transequatorial propagation? A. Morning B. Noon C. Afternoon or early evening D. Late at night

E3B04 (B) What is meant by the terms "extraordinary" and "ordinary" waves? A. Extraordinary waves describe rare long-skip propagation compared to ordinary waves, which travel shorter distances B. Independent waves created in the ionosphere that are elliptically polarized C. Long-path and short-path waves D. Refracted rays and reflected waves

E3B05 (C) Which amateur bands typically support long-path propagation? A. Only 160 meters to 40 meters B. Only 30 meters to 10 meters C. 160 meters to 10 meters D. 6 meters to 2 meters

E3B06 (B) Which of the following amateur bands most frequently provides long-path propagation? A. 80 meters B. 20 meters C. 10 meters D. 6 meters

E3B07 (C) What happens to linearly polarized radio waves that split into ordinary and extraordinary waves in the ionosphere? A. They are bent toward the magnetic poles B. They become depolarized C. They become elliptically polarized D. They become phase locked

E3B08 (x) Deleted Question

E3B09 (A) At what time of year is sporadic E propagation most likely to occur? A. Around the solstices, especially the summer solstice B. Around the solstices, especially the winter solstice C. Around the equinoxes, especially the spring equinox D. Around the equinoxes, especially the fall equinox

E3B10 (A) Why is chordal hop propagation desirable? A. The signal experiences less loss compared to multi-hop using Earth as a reflector B. The MUF for chordal hop propagation is much lower than for normal skip propagation C. Atmospheric noise is lower in the direction of chordal hop propagation D. Signals travel faster along ionospheric chords

E3B11 (D) At what time of day can sporadic E propagation occur? A. Only around sunset B. Only around sunset and sunrise C. Only in hours of darkness D. Any time

E3B12 (B) What is the primary characteristic of chordal hop propagation? A. Propagation away from the great circle bearing between stations B. Successive ionospheric refractions without an intermediate reflection from the ground C. Propagation across the geomagnetic equator D. Signals reflected back toward the transmitting station

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E3C Radio horizon

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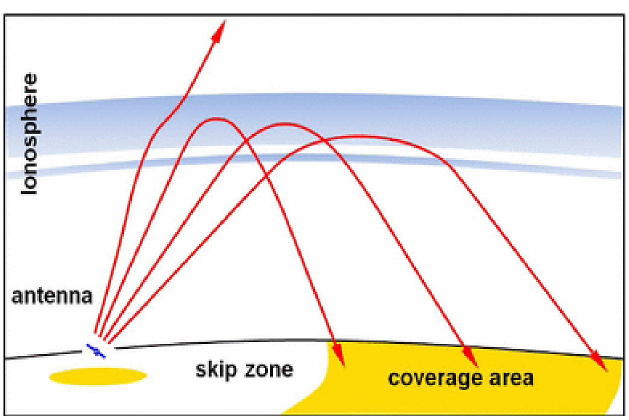
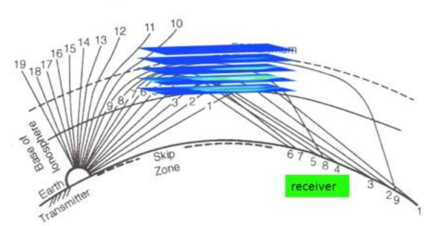
MODELING A RADIO WAVE'S PATH through the ionosphere is termed **RAY TRACING** in radio communications

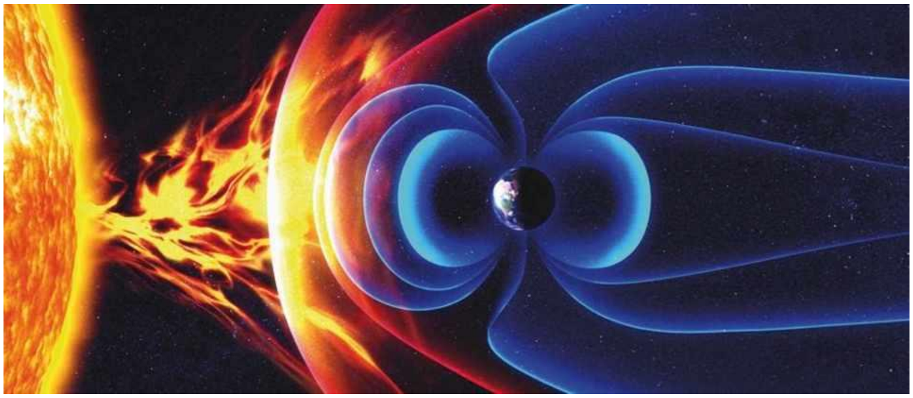


HF signals reflect off the ionosphere to other Earth locations and these paths can be ray-traced for given transmit/receive locations.



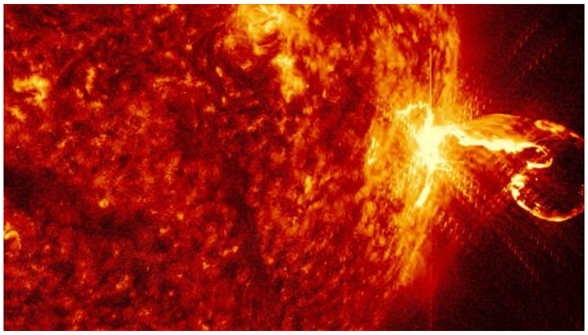
Increasing disruption of the geomagnetic field is indicated by a rising **A or K index**

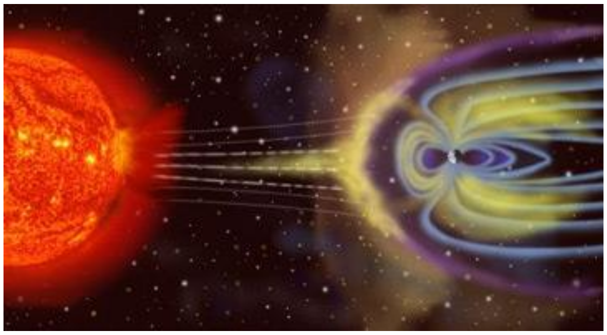
Polar signal paths are likely to experience high levels of absorption when the **A index or K index is elevated**



Editor's note: Frequently, the Earth's magnetosphere is hit by solar flares causing geomagnetic storms, provoking displays of aurorae. The short-term instability of the magnetic field is measured with the K-index. Extreme solar storms could result in blackouts and disruptions in artificial satellites.

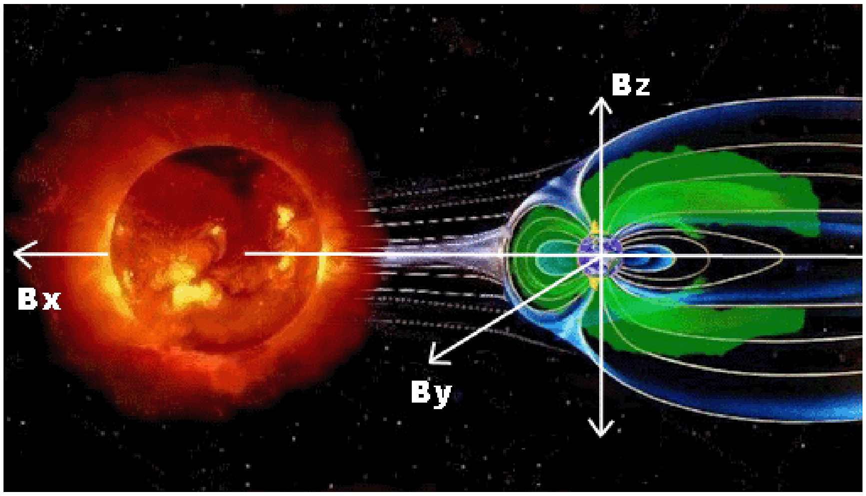
A sudden rise in radio **background noise** indicates a **solar flare** has occurred





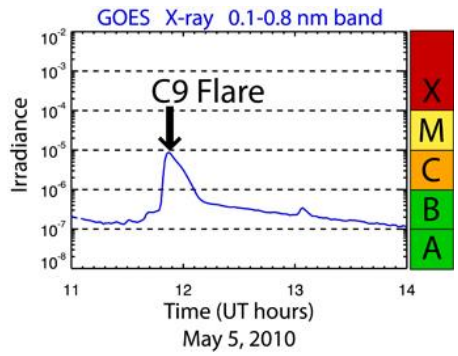
A Southward orientation of Bz increases the likelihood that incoming particles from the sun will **cause disturbed conditions**

Editor's note: **Bz** *(B sub Z) represents the direction and strength of the interplanetary magnetic field. :* ***"Bz"*** *is the component of the solar magnetic field that is dragged out from the solar corona by the solar wind flow to fill the Solar System.*



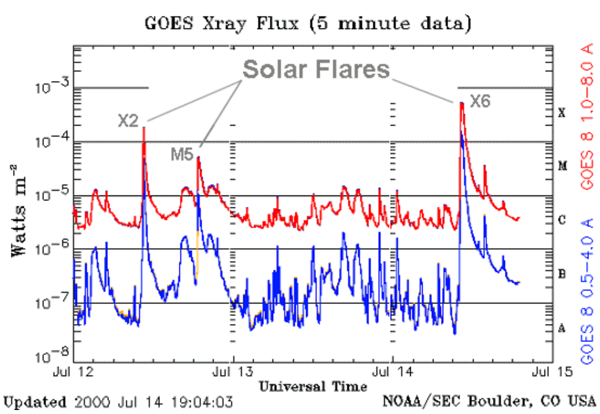
"X" indicates the greatest solar flare intensity

Jan 1976 - Dec 2000			Jan 2009 - Nov 2015		
Class	Number	Median	Class	Number	Median
B	8844	10	B	4041	10
C	16507	12	C	7015	14
M	1331	24	M	659	19
X	63	30	X	45	24
T	*26745*	*12*	*T*	*11760*	*13*



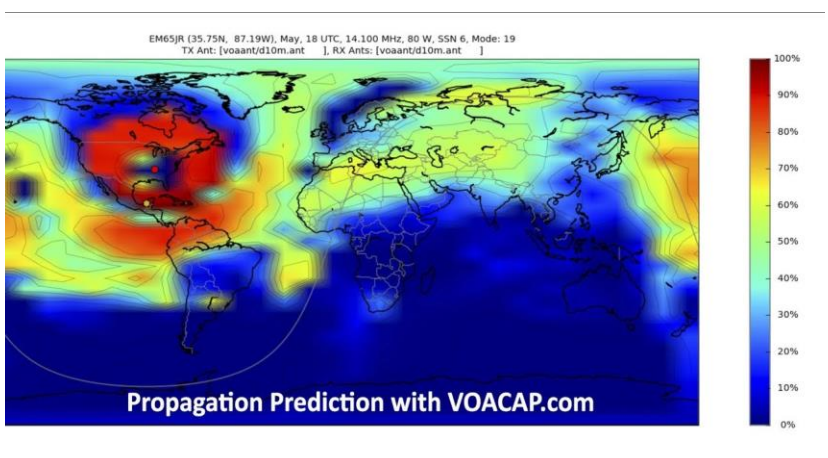
Editor's note: Solar flares are classified according to their strength. The smallest ones are A-class, followed by B, C, M and X, the largest. Solar flares are giant explosions on the sun that send energy, light and high-speed particles into space. These flares are often associated with solar magnetic storms known as coronal mass ejections (CMEs).

The intensity of an X3 flare is 50% greater than an X2 flare



Editor's note: Flare strength within a class is noted by a numerical suffix ranging from 1 to 9, which is also the factor for that event within the class. Hence, an X2 flare is twice the strength of an X1 flare, an X3 flare is three times as powerful as an X1, and only 50% more powerful than an X2. An X2 is four times more powerful than an M5 flare.

VOACAP software models **HF propagation**



*Editor's note: Voice of America Coverage Analysis Program (**VOACAP**) is a radio propagation model that uses empirical data to predict the point-to-point path loss and coverage of a given transceiver if given as inputs: two antennas (configuration and position), solar weather, and time/date.*

The **304A solar parameter** measures the UV emission at **304 angstroms**, correlated to solar flux index

Editor's note: The Sun generates electromagnetic radiation at various wavelengths, which ionize particular regions:

hard X-rays (1-10 Angstroms) ionizes the D region,
soft X-rays (10-100 Angstroms) ionizes the E region,
ultraviolet light (100-1000 Angstroms) ionizes the F region.

An extreme geomagnetic storm is termed a G5

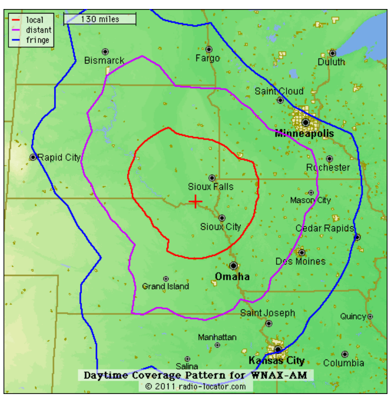
NOAA Space Weather Scales

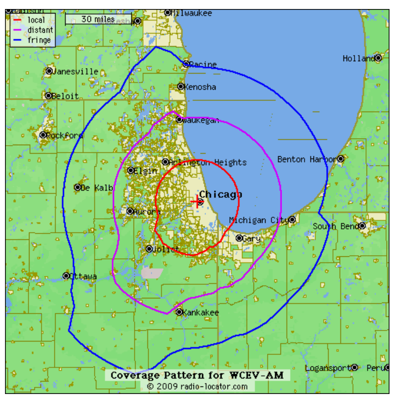
Category: Scale	Category: Descriptor	Effect (Duration of event will influence severity of effects)	Physical measure	Average Frequency (1 cycle = 11 years)
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**	Kp=8	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).**	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).**	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).**	Kp=5	1700 per cycle (900 days per cycle)

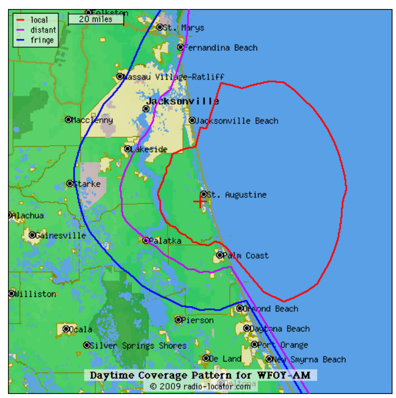
* Based on this measure, but other physical measures are also considered.
** For specific locations around the globe, use geomagnetic latitude to determine likely sightings (see www.swpc.noaa.gov/Aurora)

Vertical polarization is best for ground-wave propagation

The maximum distance of ground-wave propagation decreases as the signal frequency is increased



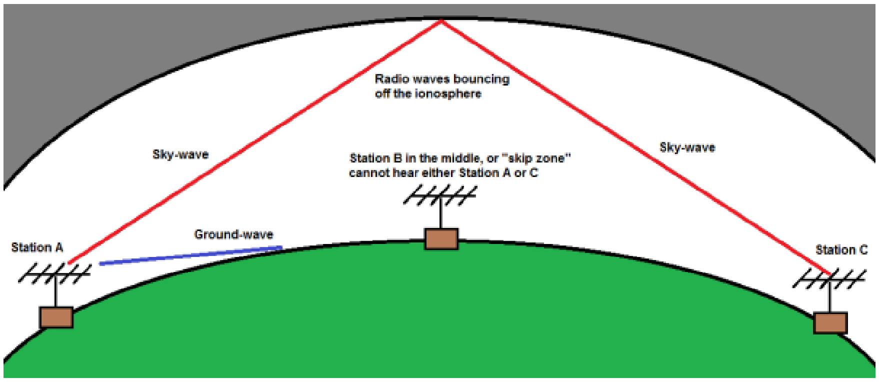




Editor's note: Vertical polarization is subject to considerably less attenuation than horizontally polarized signals. The difference can amount to several tens of decibels. It is for this reason that medium wave broadcast stations use vertical antennas,

VHF/UHF radio horizon distance exceed the geometric horizon by 15% of the distance

The radio-path horizon distance exceeds the geometric horizon by downward bending due to density variations in the atmosphere



Editor's note: Ground wave propagation can propagate a considerable distance over the earth's surface particularly below 4 MHz. Ground wave radio signal propagation is ideal for relatively short distance propagation on these frequencies during the daytime.

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E3C01 (B) What does the radio communication term "ray tracing" describe? A. The process in which an electronic display presents a pattern B. Modeling a radio wave's path through the ionosphere C. Determining the radiation pattern from an array of antennas D. Evaluating high voltage sources for x-rays

E3C02 (A) What is indicated by a rising A or K index? A. Increasing disruption of the geomagnetic field B. Decreasing disruption of the geomagnetic field C. Higher levels of solar UV radiation D. An increase in the critical frequency

E3C03 (B) Which of the following signal paths is most likely to experience high levels of absorption when the A index or K index is elevated? A. Transequatorial B. Polar C. Sporadic E D. NVIS

E3C04 (C) What does the value of Bz (B sub Z) represent? A. Geomagnetic field stability B. Critical frequency for vertical transmissions C. Direction and strength of the interplanetary magnetic field D. Duration of long-delayed echoes

3C05 (A) What orientation of Bz (B sub z) increases the likelihood that incoming particles from the sun will cause disturbed conditions? A. Southward B. Northward C. Eastward D. Westward

E3C06 (A) By how much does the VHF/UHF radio horizon distance exceed the geometric horizon? A. By approximately 15 percent of the distance B. By approximately twice the distance C. By approximately 50 percent of the distance D. By approximately four times the distance

E3C07 (D) Which of the following descriptors indicates the greatest solar flare intensity? A. Class A B. Class B C. Class M D. Class X

E3C08 (A) What does the space weather term G5 mean? A. An extreme geomagnetic storm B. Very low solar activity C. Moderate solar wind D. Waning sunspot numbers

E3C09 (B) How does the intensity of an X3 flare compare to that of an X2 flare? A. 10 percent greater B. 50 percent greater C. Twice as great D. Four times as great

E3C10 (B) What does the 304A solar parameter measure? A. The ratio of x-ray flux to radio flux, correlated to sunspot number B. UV emissions at 304 angstroms, correlated to the solar flux index C. The solar wind velocity at 304 degrees from the solar equator, correlated to solar activity D. The solar emission at 304 GHz, correlated to x-ray flare levels

E3C11 (C) What does VOACAP software model? A. AC voltage and impedance B. VHF radio propagation C. HF propagation D. AC current and impedance

E3C12 (C) How does the maximum range of ground-wave propagation change when the signal frequency is increased? A. It stays the same B. It increases C. It decreases D. It peaks at roughly 14 MHz

E3C13 (A) What type of polarization is best for ground-wave propagation? A. Vertical B. Horizontal C. Circular D. Elliptical

E3C14 (D) Why does the radio-path horizon distance exceed the geometric horizon? A. E-region skip B. D-region skip C. Due to the Doppler effect D. Downward bending due to density variations in the atmosphere

E3C15 (B) What might be indicated by a sudden rise in radio background noise across a large portion of the HF spectrum? A. A temperature inversion has occurred B. A solar flare has occurred C. Increased transequatorial propagation is likely D. Long-path propagation is likely

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E0A Safety

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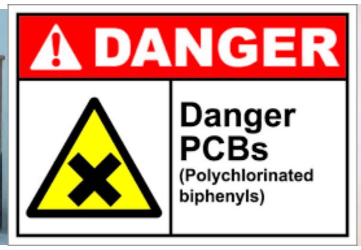
Only with **a carbon monoxide detector** can detect **CO** from an **emergency generator**

Editor's note: Carbon Monoxide – from generators or heating equipment during emergency operations

BERYLLIUM OXIDE is an insulating material commonly used as a thermal conductor for some types of electronic devices is extremely **TOXIC** if broken or crushed and the particles are accidentally inhaled

Editor's note: Beryllium & Beryllium Oxide – used in copper alloys to stiffen it, Spring Contacts, duplexer fingers. The oxide powder is carcinogenic and may cause skin burns. In solid form, it is safe to handle if not subjected to machining that generates dust. Beryllium oxide ceramic is not a hazardous waste under federal law in the USA.

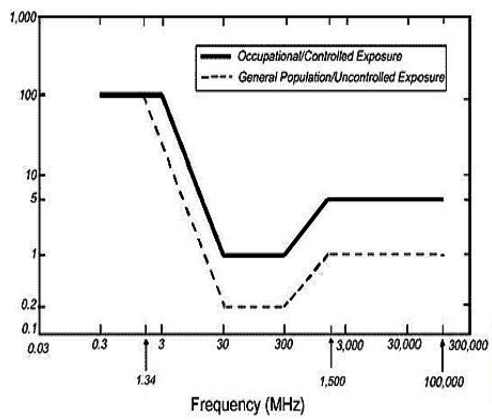
Polychlorinated biphenyls (PCB) is a toxic material may be present in some electronic components such as high voltage capacitors and transformers

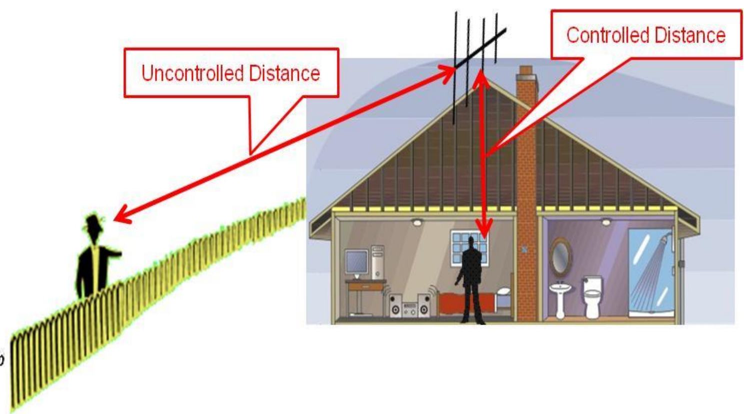




Editor's note: Polychlorinated biphenyls (PCB) were once widely deployed as dielectric and coolant fluids in electrical apparatus, carbonless copy paper and in heat transfer fluids. Common Amateur Radio applications were dummy loads and large capacitors. Because of their longevity, PCBs are still found in used equipment, even though their manufacture has declined drastically since the 1960s, when problems were identified. With the discovery of PCBs' environmental toxicity, and classification as persistent organic pollutants, their production was banned by United States federal law in 1978.

Make sure signals from your station are less than the **uncontrolled MPE limits when** evaluating RF exposure levels from your station

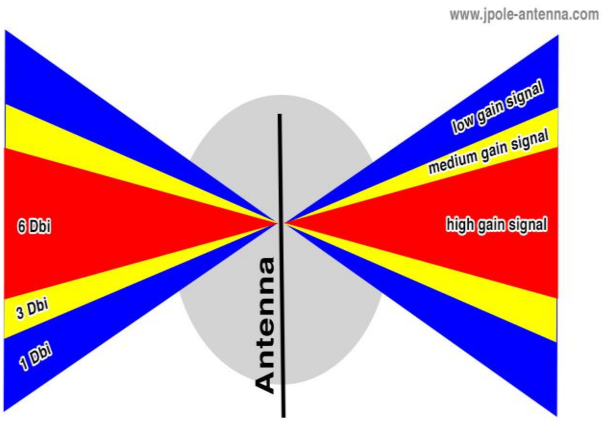
Over 30 to 300 MHz frequencies are the FCC human body RF exposure limits **most restrictive**

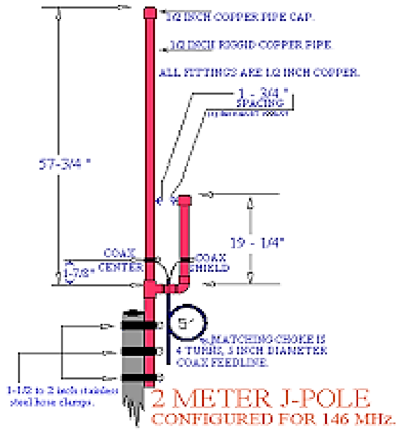




When evaluating a site with multiple transmitters operating at the same time each transmitter **that produces 5 percent or more of its MPE limit at accessible locations** the operators and licensees of which transmitters are responsible for mitigating over-exposure situations


H**igh gain antennas commonly used can result in high exposure levels** is one of the potential hazards of using microwaves in the amateur radio bands





SAR measures the **rate at which RF energy is absorbed** by the body

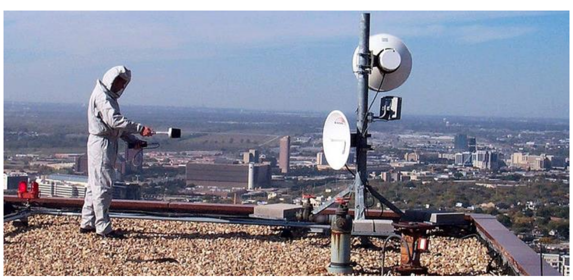
Localized **heating of the body from RF exposure in excess of the MPE limits** can result from using high-power UHF or microwave transmitter

The are there separate electric (E) and magnetic (H) field MPE limits because;

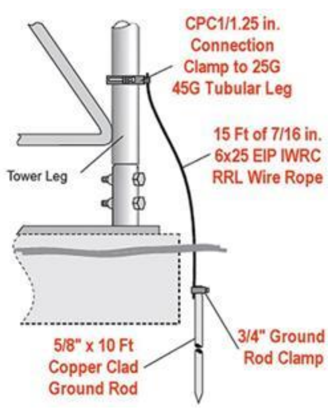
The **body reacts** to electromagnetic radiation from **both the E and H fields**

Ground reflections and scattering make the field impedance vary with location

E field and H field radiation intensity **peaks can occur at different locations**



Lightning protection is the primary function of an external earth connection or **ground rod**



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E0A01 (B) What is the primary function of an external earth connection or ground rod? A. Reduce received noise B. Lightning protection C. Reduce RF current flow between pieces of equipment D.

E0A02 (B) When evaluating RF exposure levels from your station at a neighbor's home, what must you do? A. Ensure signals from your station are less than the controlled Maximum Permitted Exposure (MPE) limits B. Ensure signals from your station are less than the uncontrolled Maximum Permitted Exposure (MPE) limits C. Ensure signals from your station are less than the controlled Maximum Permitted Emission (MPE) limits D. Ensure signals from your station are less than the uncontrolled Maximum Permitted Emission (MPE) limits

E0A03 (C) Over what range of frequencies are the FCC human body RF exposure limits most restrictive? A. 300 kHz to 3 MHz B. 3 to 30 MHz C. 30 to 300 MHz D. 300 to 3000 MHz

E0A04 (C) When evaluating a site with multiple transmitters operating at the same time, the operators and licensees of which transmitters are responsible for mitigating over-exposure situations? A. Only the most powerful transmitter B. Only commercial transmitters C. Each transmitter that produces 5 percent or more of its MPE limit in areas where the total MPE limit is exceeded. D. Each transmitter operating with a duty cycle greater than 50 percent

E0A05 (B) What is one of the potential hazards of operating in the amateur radio microwave bands? A. Microwaves are ionizing radiation B. The high gain antennas commonly used can result in high exposure levels C. Microwaves often travel long distances by ionospheric reflection D. The extremely high frequency energy can damage the joints of antenna structures

E0A06 (D) Why are there separate electric (E) and magnetic (H) field MPE limits? A. The body reacts to electromagnetic radiation from both the E and H fields B. Ground reflections and scattering make the field strength vary with location C. E field and H field radiation intensity peaks can occur at different locations D. All these choices are correct

E0A07 (B) How may dangerous levels of carbon monoxide from an emergency generator be detected? A. By the odor B. Only with a carbon monoxide detector C. Any ordinary smoke detector can be used D. By the yellowish appearance of the gas

E0A08 (C) What does SAR measure? A. Synthetic Aperture Ratio of the human body B. Signal Amplification Rating C. The rate at which RF energy is absorbed by the body D. The rate of RF energy reflected from stationary terrain

E0A09 (C) Which insulating material commonly used as a thermal conductor for some types of electronic devices is extremely toxic if broken or crushed and the particles are accidentally inhaled? A. Mica B. Zinc oxide C. Beryllium Oxide D. Uranium Hexafluoride

E0A10 (A) What toxic material may be present in some electronic components such as high voltage capacitors and transformers? A. Polychlorinated biphenyls B. Polyethylene C. Polytetrafluoroethylene D. Polymorphic silicon

E0A11 (C) Which of the following injuries can result from using high-power UHF or microwave transmitters? A. Hearing loss caused by high voltage corona discharge B. Blood clotting from the intense magnetic field C. Localized heating of the body from RF exposure in excess of the MPE limits D. Ingestion of ozone gas from the cooling system

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Class Five Fundamentals and Substance

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Antenna parameters

Feed point impedance is affected by antenna height

Antenna Bandwidth is the frequency range an antenna satisfies performance requirements, typically frequency range a feedpoint *(Editor's Note: aka VSWR is less than 2:1)*

Antenna efficiency = (radiation resistance / total resistance) x 100%

Radiation resistance + Ohmic resistance equal the total resistance of an antenna system

Radiation resistance + Ohmic resistance equal the total resistance of an antenna system

Installing a **RADIAL SYSTEM IMPROVES THE EFFICIENCY** of a ground-mounted **quarter-wave vertical antenna**

SOIL CONDUCTIVITY DETERMINES GROUND LOSSES for a ground-mounted vertical antenna operating in the 3 MHz to 30 MHz range

EFFECTIVE RADIATED POWER describes station output, taking into account all gains and losses

ERP = Power X (Gain - Loss)

An **ISOTROPIC** antenna is a theoretical antenna used as a reference for antenna gain

An **ISOTROPIC** antenna has no gain in any direction

DIPOLE ANTENNA GAIN is 2.15 dB reference to an **ISOTROPIC ANTENNA**

Electromagnetic waves

12,000 MILES is the maximum separation measured along the surface of the Earth between two stations communicating by **MOONBOUNCE**

A **FLUTTERY IRREGULAR FADING** characterizes **LIBRATION FADING** of an EME signal

When the MOON IS AT PERIGEE EME contacts result in **THE LEAST PATH LOSS**

HEPBURN MAPS predict the probability of **TROPOSPHERIC PROPAGATION**

ATMOSPHERIC DUCTS capable of propagating microwave signals often form over **BODIES OF WATER**

TEMPERATURE INVERSION can create a **PATH FOR MICROWAVE PROPAGATION**

TROPOSPHERIC PROPAGATION of microwave signals occurs along **WARM AND COLD FRONTS**

Typical **range for TROPOSPHERIC PROPAGATION** of microwave signals is **100 MILES TO 300 MILES**

The interaction in the E layer of **CHARGED PARTICLES** from the Sun with **THE EARTH'S MAGNETIC FIELD** is the cause of **AURORAL ACTIVITY**

CW IS BEST FOR AURORAL PROPAGATION

METEOR STRIKES THE E LAYER A CYLINDRICAL REGION OF FREE ELECTRONS is formed

28 MHz - 148 MHz is most suited for **METEOR SCATTER** communications

Switching to a lower frequency HF band might help to restore contact when DX signals become too weak to copy across an entire HF band a few hours after sunset

Waves with a **ROTATING ELECTRIC FIELD** are **CIRCULARLY POLARIZED** electromagnetic waves

Antenna patterns

METHOD OF MOMENTS is a computer program technique used for **MODELING ANTENNAS**

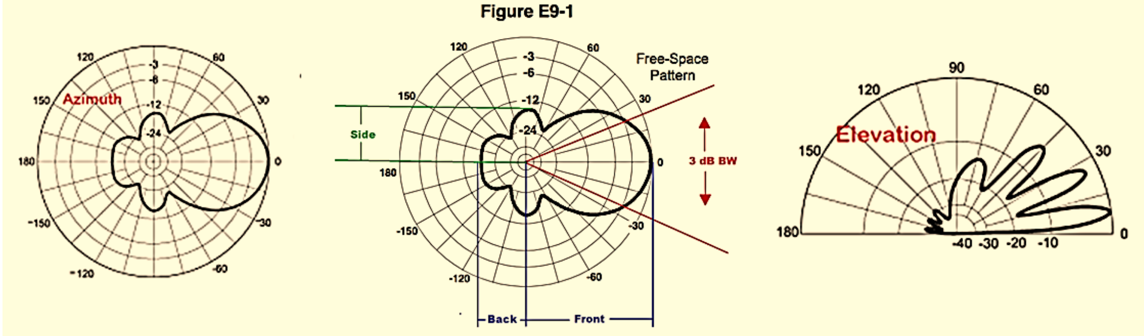
The principle of a **METHOD OF MOMENTS analysis is** modeled as a series of **segments, each having a uniform value of current**

A **disadvantage of decreasing the number of wire segments** is the computed feed point impedance may be incorrect

The region where the **SHAPE OF THE ANTENNA PATTERN IS INDEPENDENT OF DISTANCE IS THE FAR FIELD** of an antenna

The **TOTAL AMOUNT OF RADIATION** emitted by a directional gain antenna compare with the total amount of radiation emitted from a theoretical isotropic antenna **ARE THE SAME.**

Figure E9-1



Wire Antennas

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Low-angle radiation from a **vertically polarized** antenna **over SEAWATER WILL BE MUCH STRONGER**

The radiation pattern **OF TWO 1/4-WAVELENGTH VERTICAL ANTENNAS SPACED 1/2-WAVELENGTH apart and fed 180 DEGREES OUT OF PHASE IS A FIGURE-8 ORIENTED** along the axis of the array

The radiation pattern **OF TWO 1/4-WAVELENGTH VERTICAL ANTENNAS SPACED 1/4-WAVELENGTH apart and fed 90 DEGREES OUT OF PHASE IS A CARDIOID** along the axis of the array

The radiation pattern **OF TWO 1/4-WAVELENGTH VERTICAL ANTENNAS SPACED 1/2-WAVELENGTH apart and fed IN PHASE IS A FIGURE-8 BROADSIDE TO** along the axis of the array

The main lobe takeoff angle decreases in the downhill direction of a horizontally polarized antenna mounted on the side of a hill compare with the same antenna mounted on **flat ground**

The radiation pattern of a horizontally polarized 3-element beam **antenna takeoff angle of the lowest elevation lobe decreases with increasing height above ground**

An **OCFD antenna** is a dipole feed approximately 1/3 the way from one end with a 4:1 balun

A folded dipole antenna is one wavelength of wire forming a very thin loop

A folded dipole antenna has approximate feed point impedance of **300 Ohms**

G5RV antenna is a multiband dipole antenna fed with coax and a BALUN open wire matching section

Zepp antenna is an end fed dipole antenna

An **extended double Zepp antenna** is a center fed dipole with two 5/8 wave elements in phase

The **terminating resistor on a rhombic** antenna provides a unidirectional **directional radiation pattern**

Gain Antennas

The gain of an ideal parabolic dish antenna **increases by 6 dB when the frequency is doubled**

Two Linear Yagis perpendicular to each other with the driven elements at the same point on the boom and **fed 90 degrees out of phase produce circular polarization**

The **front-to-back ratio decreases** in a **Yagi antenna** is designed solely for max forward gain

Top loading in a shortened HF vertical antenna improves radiation efficiency

Place a high-Q loading **coil at center of the vertical radiator** to minimize losses in a shortened antenna

The function of a **loading coil on an HF mobile antenna is to cancel capacitive reactance**

As the **Q of an antenna increases** the SWR bandwidth decreases

The **radiation resistance decreases and the capacitive reactance increases** when a fixed length HF mobile antenna is operated **below its resonant frequency**

A high **Q loading coil be placed near the center of the vertical radiator to minimize losses** in a shortened vertical antenna

The **bandwidth decreases in an antenna shortened through the use of loading coils**

Top loading in a shortened HF vertical antenna improves radiation efficiency

Best RF station ground is a short connection to 3 or 4 interconnected ground rods driven into the Earth

A **wide flat copper strap** is best for minimizing losses in a station's RF ground system

Receiving Antennas

A **BEVERAGE** antenna should be **one or more wavelengths long**

Atmospheric **noise is so high that gain over a dipole is not important** for low band (160M & 80M) receiving antennas

RECEIVING LOOP ANTENNA >> One or more turns of wire wound in the shape of a large open coil

The **output loop antenna** be increased by **adding turns** in the loop or **add area** to the loop

Placing a grounded electrostatic shield around a small loop direction-finding antenna **eliminates tracking errors** caused by strong out-of-band signals

Receiving Directivity Factor (RDF) is forward gain compared to average gain over the entire hemisphere

To prevent **receiver overload which reduces pattern nulls an RF attenuation is used** when direction-finding

A **cardioid-pattern antenna** has a **very sharp single null** useful for direction finding

A small **wire-loop antenna has a bidirectional pattern**

A **sense antenna** modifies the pattern of a DF antenna array to provide a null in one direction

A **Pennant antenna** is a small, vertically oriented receiving antenna consisting of a **triangular loop terminated in approximately 900 ohms**

The **triangulation** method uses headings from **several different receiving locations** to locate a signal

Propagation

160M to 10M typically support long-path propagation

20M most frequently provides long-path propagation

T**ransequatorial propagation** is between two mid-latitude points at approximately the same distance north and south of the magnetic equator

5000 miles is the maximum range for signals using **transequatorial propagation**

Afternoon or early evening to is the best time of day for trans equatorial propagation

Independent waves created in the ionosphere that are **elliptically polarized are "extraordinary" and "ordinary" waves**

Linearly polarized radio waves that split into ordinary and extraordinary waves in the ionosphere become elliptically polarized

SPORADIC E propagation is likely to occur around the solstices, especially the **SUMMER SOLSTICE**

Sporadic E propagation can occur any time of day

SUCCESSIVE IONOSPHERIC REFLECTIONS without an intermediate reflection from the ground is the primary characteristic of **CHORDAL HOP PROPAGATION**

CHORDAL HOP PROPAGATION EXPERIENCES LESS LOSS along the path than normal skip

Radio Horizon

MODELING A RADIO WAVE'S PATH through the ionosphere is termed **RAY TRACING** in radio communications

Increasing disruption of the geomagnetic field is indicated by a rising **A or K index**

Polar signal paths are likely to experience high levels of absorption when the **A index or K index is elevated**

A sudden rise in radio **background noise** indicates a **solar flare** has occurred

A Southward orientation of Bz increases the likelihood that incoming particles from the sun will **cause disturbed conditions**

"X" indicates the greatest solar flare intensity

The intensity of an X3 flare is 50% greater than an X2 flare

VOACAP software models **HF propagation**

The **304A solar parameter** measures the UV emission at **304 angstroms**, correlated to solar flux index

An extreme geomagnetic storm is termed a G5

Vertical polarization is best for ground-wave propagation

The maximum distance of ground-wave propagation decreases as the signal frequency is increased

VHF/UHF radio horizon distance exceed the geometric horizon by 15% of the distance

The radio-path horizon distance exceeds the geometric horizon by downward bending due to density variations in the atmosphere

Safety

Only with **a carbon monoxide detector** can detect **CO** from an **emergency generator**

BERYLLIUM OXIDE is an insulating material commonly used as a thermal conductor for some types of electronic devices is extremely **TOXIC** if broken or crushed and the particles are accidentally inhaled

Polychlorinated biphenyls (PCB) is a toxic material may be present in some electronic components such as high voltage capacitors and transformers

Make sure signals from your station are less than the **uncontrolled MPE limits when** evaluating RF exposure levels from your station

Over 30 to 300 MHz frequencies are the FCC human body RF exposure limits **most restrictive**

When evaluating a site with multiple transmitters operating at the same time each transmitter **that produces 5 percent or more of its MPE limit at accessible locations** the operators and licensees of which transmitters are responsible for mitigating over-exposure situations

H**igh gain antennas commonly used can result in high exposure levels** is one of the potential hazards of using microwaves in the amateur radio bands

SAR measures the **rate at which RF energy is absorbed** by the body

Localized **heating of the body from RF exposure in excess of the MPE limits** can result from using high-power UHF or microwave transmitter

The are there separate electric (E) and magnetic (H) field MPE limits because;

> The **body reacts** to electromagnetic radiation from **both the E and H fields**
>
> **Ground reflections** and scattering make the field impedance vary with location
>
> E field and H field radiation intensity **peaks can occur at different locations**

Lightning protection is the primary function of an external earth connection or **ground rod**

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Math Equations for all Classes

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Operational Amplifier Gain = R rf / R input or remember the answers are 14, 38, 47 or -2V

FM Modulation index = Max Carrier Dev / Max Modulation or remember the answers range is 1.6 to 3

MDS conversion (dB vs BW) or just remember MDS for 400 Hz = -148 dBm

POWER FACTOR = Real Power (Watts) / Total Power (V x A) >>> PF = W / VA
or remember the answers are 80W, 100W & 600W

POWER FACTOR = COS of (Voltage to Current) Phase

Only three possible answers
PF = COS 30° = 0.866
PF = COS 60° = 0.5
PF = COS 45° = 0.707

RLC **parallel** resonant circuit **Q = Resistance / Reactance = R / X** need to know definition, no math

RLC **series** resonant circuit **Q = / Reactance / Resistance = X / R** need to know definition, no math

Half Power Bandwidth = Resonant Frequency / Q of the Circuit or remember 31 & 47 are answers

Resonant Frequency >>> Fr = 1 / (2Π x √ LC) or remember 3.6 MHz & 7.1 MHz are only answers

One time constant = **TC (sec) = R (MΩ) x C (uF)** need to know definition One answer220 uSec

Rectangular and Polar Plots Triganometry or just use your eyeball

Cable Length = Velocity Factor X [Speed of Light / Frequency] X Wavelength of Cable
or remember the answers are 3.5M, 6.9M & 10.6M

Antenna efficiency = (radiation resistance / total resistance) x 100% need to know definition, no math

Radiation resistance + Ohmic resistance equal the total resistance of an antenna system
need to know definition, no math

ERP = Power X (Gain - Loss)
or remember the answers are 252W, 286W & 317W

DIPOLE ANTENNA GAIN is 2.15 dB reference to an **ISOTROPIC ANTENNA**
or remember the only answer is 3.85 dB

V

W X Y Z