Extra Class Exam Study Guide

Workshop Course Book for July 2016 to June 2020

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

Amateur Extra Class Workshop

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 must cover a vast amount of material in six classes. This workshop will be conducted as peers sitting around a table discussing a technical topic. This is the format requested as specific technical topics not a rote review of the questions. The material in this study guide is formatted as abbreviated points or a quick reference format instead of slides. It is intended that the guide combined with the reference material supplied will have long-term value.

The workshop is specially presented for those with amateur radio experience who want to learn more. The workshop will primarily focus on technical aspects of the exam and regulatory questions are expected to be self-study. This 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

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Chapter 1 Introduction

How to best use this guide

This study guide is written to help you understand the radio theory with a practical slant, not just teach the answers, although the scope is limited to question pool topics due to the limited workshop time. This guide presents and explains the Extra Class License Exam questions by discussing each chapter question pool sub-group as an individual topic based on the ARRL Extra Class License Manual organization. This guide has eleven chapters that are aligned with the ARRL manual and divided into fifty-four topics in this guide which represent approximately one for each of the fifty exam questions. This study guide is not intended to circumvent reading the assigned ARRL manual chapter(s) but to support a better understanding of the radio theory.

Everything is provided as a PDF format for your use. Determine how you want to read your personal copy of this guide and supporting material. In today's world an electronic reader may be the right choice or if you prefer paper you can print out the workshop material and place it in a three-ring binder. Do not wait until the weekend prior to the workshop to prepare.

Read the ARRL textbook completely before the workshops. You will not understand everything but it will help put everything into perspective during the workshops.

Take online practice tests prior to the workshops but don't worry about the score yet.

Online Practice Tests

http://arrlexamreview.appspot.com/
https://hamexam.org/
https://www.eham.net/exams/
https://hamstudy.org/

A few days before each workshop read the ARRL textbook chapter(s) assigned and work the problems. It is a good idea to work your problems in a notebook and bring it to workshop for your reference and help finding where that decimal point got lost.

Review the exam question group(s) assigned in this study guide to help focus on the key takeaways and scribble down questions to ask during the workshop.

Again, take the online practice tests and review the questions you failed in your ARRL textbook and this guide.

If you are still having trouble, review the technical references on the workshop CD ROM. These documents have much more detail and are explained in different ways from the book. You will find over two hundred technical references on the workshop CD ROM and you are not expected to have time to read all of them. The references are arranged by Question Pool Group Number; E0, E1, E2… E9 followed by a subject title and number (i.e.1,2,3). Start with title #1 and progress to the higher numbers as they increase in detail. If you have questions about decibels or just want more information read "E9-dB-1" before "E9-dB-2".

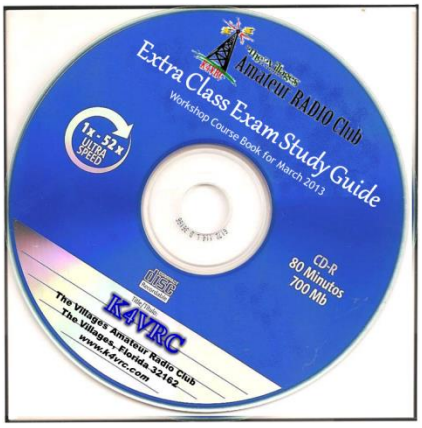
If you still are having difficulties with a question(s), the workshop discussion should clarify the problem. DO NOT BE SELF-CONSCIOUS if you are having trouble understanding; it is very likely the rest of the workshop is also not sure.

This will be a discussion group format so every workshop is intended to address your questions even if they are not part of assignment, just be considerate of the workshop's limited time.

The last workshop will be devoted to topic(s) as requested.

Supplies you will need

ARRL Tenth Edition of the Extra Class License Manual
ARRL Extra Class License Manual 11th Edition
for use July 1, 2016 to June 30, 2020
Available from ARRL, book stores or ham radio retailers



Pencil/pen and note pad to take notes and work out problems

The workshop CD-ROM

You will need access to a home computer to read the documents on the workshop CD-ROM and to take practice exams.

Scientific Calculator with the following functions;

- Add
- Subtract
- Divide
- Multiple
- Squares
- Square Roots
- Sine
- Cosine
- Arctan or tan-1 (Inverse Tangent)
- Base Ten Logarithms (10^x)

The formal test will require you to clear your memory so purchase a calculator with little or no memory. You want to use the same calculator during home study, practice tests, workshop exercises and the real test. Many points are lost to math errors so you want a calculator that you can operate with confidence.

SCIENTIFIC CALCULATOR

KEYS AND CONTROLS	
ON/C	Turns on your calculator / Clears display
CE	Clears the last entry
OFF	Turns off your calculator
0 - 9	Numerical Keys
•	Decimal Point
%	Percentage Key
=	Equal Key
+ - x ÷	Four Basic Function Keys
M+	Memory Plus Key
RM	Memory Recall
+/-	Changes the sign of the value entered.
√	Extraction of Square Root
2nd F	selects the 2nd functions which are above the keys
DRG	changes from degrees, radians, and grads

FUNCTIONS		
+ - x ÷	356 + 580 = 936 960 - 330 = 630	75 x 3 = 225 84 ÷ 4 = 21
Negatives	12 x 2 +/- ÷ 4 = -6	
Percentage	350 x 2 2nd F [%] = 7	
Ratio	250 ÷ 5 2nd F [%] = 5000	
Discount	450 - 6 2nd F [%] = 423	
Exponents	6 x + 2 = 8	
Roots	144 √ + 4 √ = 14	

Math you will need to use

Add, Subtract, Divide & Multiple
Squares & Square Roots
Sine & Cosine
Arctan or tan-1 (Inverse Tangent)
Base Ten Logarithms (10^x)

The workshop and license exam requires you to use a small amount of algebra and trigonometry to solve problems. Every equation you need to use is listed below. Working solving the example problems will help you be at ease with using the math. If you would like to learn a bit about trigonometry, or brush up on it, then you can but do not lose focus on the radio theory. These equations are more of an introduction and guide and the actual exam question calculations will be shown step by step during the workshop. For more help you should read the math reference material on your CD-ROM.

International System of Units (SI)—Metric Units

Prefix	Symbol	Multiplication Factor	
exe	E	10+18	1,000,000 000,000,000,000
peta	P	10+15	1,000 000,000,000,000
tera	T	10+12	1,000,000,000,000
giga	G	10+9	1,000,000,000
mega	M	10+6	1,000,000
kilo	k	10+3	1,000
hecto	h	10+2	100
deca	da	10+1	10
(unit)		10+0	1
deci	d	10-1	0.1
centi	c	10-2	0.01
milli	m	10-3	0.001
micro	µ	10-6	0.000001
nano	n	10-9	0.000000001
pico	p	10-12	0.000000000001
femto	f	10-15	0.000000000000001
atto	a	10-18	0.000000000000000001

Conversions

dB to ratio >> **ratio = 10 ^ (dB/10)** > **Solve for 5.2 dB** > ? = 10 ^ (5.2dB / 10) = 10 ^ 0.52 = **3.311**
0dB = 1 3 dB = 1.995 6 dB = 3.981 9dB = 7.943 12dB = 15.849

ratio to dB >> **dB = 10 x log (ratio/10)** > **Solve for 800** > ? = 10 x log (800) = 10 X 2.9031= **29.031dB**
2 = 3dB 75 = 18.75dB 500 = 26.99dB 1500 = 31.76dB

Inductor Impedance >> **Ω = 2 π FL** = 2 x π x MHz x uH
Solve for 18 uH @ 3.505 MHz > ? = 3.505 x 18 = **396.41 Ω**

Capacitor Impedance >> **Ω = 1/ (2 π FC)** = 1/ (2 x π x MHz x uF)
Solve for 38 pF @ 14 MHz >
? = 1 / (2 x 3.14 x 14 x 0.000038) = 1 / 0.00334096 = **299.32 Ω**

Series RLC Impedance >> **Freq = 1/[2π√(LC)]** *Note the R drops out!*
Solve for 40 pF + 50 uH + 22 Ω >
? = 1/[6.28x√(0.00005x0.00000000004)] = 1/(2.808501379739736e-7) = 3560618 Hz = **3.56 MHz**

Parallel RLC Impedance >> **Freq = 1/[2π√(LC)]** *Note the R drops out and use same equation for resonance!*
Solve for 10 pF + 25 uH + 47 Ω >
? = 1/[6.28x√(0.000025x0.00000000001)] = 1/(9.929551852911e-8) = **10.070948 MHz**

RC Time Constant >> **TC (sec) = R (MΩ) x C (uF)** **Solve for 440 pF + 500K Ω** > ? = 0.5 x 440 = **220 Seconds**

Polar to Rectangular Coordinates >> Magnitude at an angle or a vector >> **X = M x Cos θ and Y = M x Sin θ**
Solve for 200 at 30° >
X = 200 x Cos 30° = **173.20**
Y = 200 x Sin 30° = **100**

Rectangular to Polar Coordinates >> **Magnitude = √[X² + Y²]** and the **angle = tan^-1 [Y / X]**
Solve for X = 400 and Y = 300
M = √[400² + 300²] = √ 250,000 = **500**
θ = tan^-1 [300/400] = tan^-1 (0.75) = **36.87°**

Chapter 2 Operating Practices

General Operating

The Radio Amateur's Code

The Radio Amateur is

CONSIDERATE... He never knowingly operates in such a way as to lessen the pleasure of others.

LOYAL... He offers loyalty, encouragement and support to other amateurs, local clubs, the IARU Radio Society in his country, through which Amateur Radio in his country is represented nationally and internationally.

PROGRESSIVE... He keeps his station up to date. It is well-built and efficient. His ***operating practice*** is above reproach.

FRIENDLY... He operates slowly and patiently when requested; offers friendly advice and counsel to the beginner; kind assistance, cooperation and consideration for the interests of others. These are the marks of the amateur spirit.

BALANCED... Radio is a hobby, never interfering with duties owed to family, job, school or community.

PATRIOTIC... His station and skills are always ready for service to country and community.

*-- adapted from the original Amateur's Code, written by Paul M. Segal, W9EEA, in **1928.***

Operators are permitted to make contacts even if they **do not submit a log** during contest operation

"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

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

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

A ham radio **mesh network is Spread spectrum** in the 2.4 GHz band

Cabrillo format is a standard for submission of electronic contest logs

==========

E2C01 (A) Which of the following is true about contest operating? A. Operators are permitted to make contacts even if they **do not submit a log**

E2C02 (A) Which of the following best describes the term self-spotting in regards to contest operating? A. The generally prohibited practice of **posting one's own call sign and frequency on a spotting** network

E2C03 (A) From which of the following bands is amateur radio **contesting generally excluded? A. 30 meters**

E2C04 (A) What type of transmission is most often used for a ham radio **mesh network? A. Spread spectrum** in the 2.4 GHz band

E2C05 (B) What is the function of a **DX QSL Manager**? B. To handle the receiving and sending of **confirmation cards** for a DX station

E2C06 (C) During a VHF/UHF contest, in which band segment would you expect to find the highest level of activity? C. In the weak signal segment of the band, with most of the **activity near the calling frequency**

E2C07 (A) What is the **Cabrillo format**? A. A standard for submission of **electronic contest logs**

E2C08 (B) Which of the following contacts may be confirmed through the U.S. **QSL bureau** system? B. Contacts between **a U.S. station and a non-U.S. station**

E2C10 (D) Why might a DX station state that they are **listening on another frequency**?

A. 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 of 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

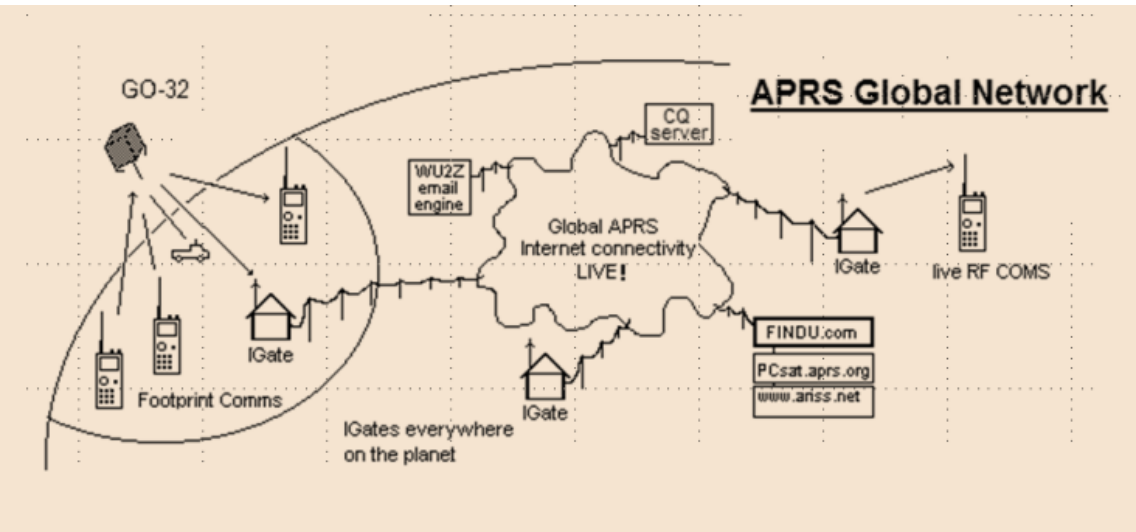
E2C12 (B) What might help to restore contact when DX signals become too weak to copy across an entire HF band a few hours **after sunset? B. Switch to a lower frequency** HF band

E2C13 (D) What indicator is required to be used by U.S.-licensed operators when operating a station via **remote control where the transmitter is located in the U.S.? D. No additional indicator is required**

Digital Mode Operating

The purpose of digital **store-and-forward** functions on an Amateur Radio satellite is to store 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



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

==========

E2D04 (C) What is the purpose of digital store-and-forward functions on an **Amateur Radio satellite? C. To store digital messages in the satellite for later download** by other stations

E2D05 (B) Which of the following techniques is normally used by low Earth orbiting **digital satellites to relay messages around the world? B. Store-and-forward**

E2D07 (C) What digital protocol is used by **APRS? C. AX.25**

E2D08 (A) What type of **packet frame is** used to transmit **APRS beacon data? A. Unnumbered Information**

E2D10 (C) How can an APRS station be used to help support a public service communications activity? C. An APRS station with a GPS unit can **automatically transmit information to show a mobile station's position during the event**

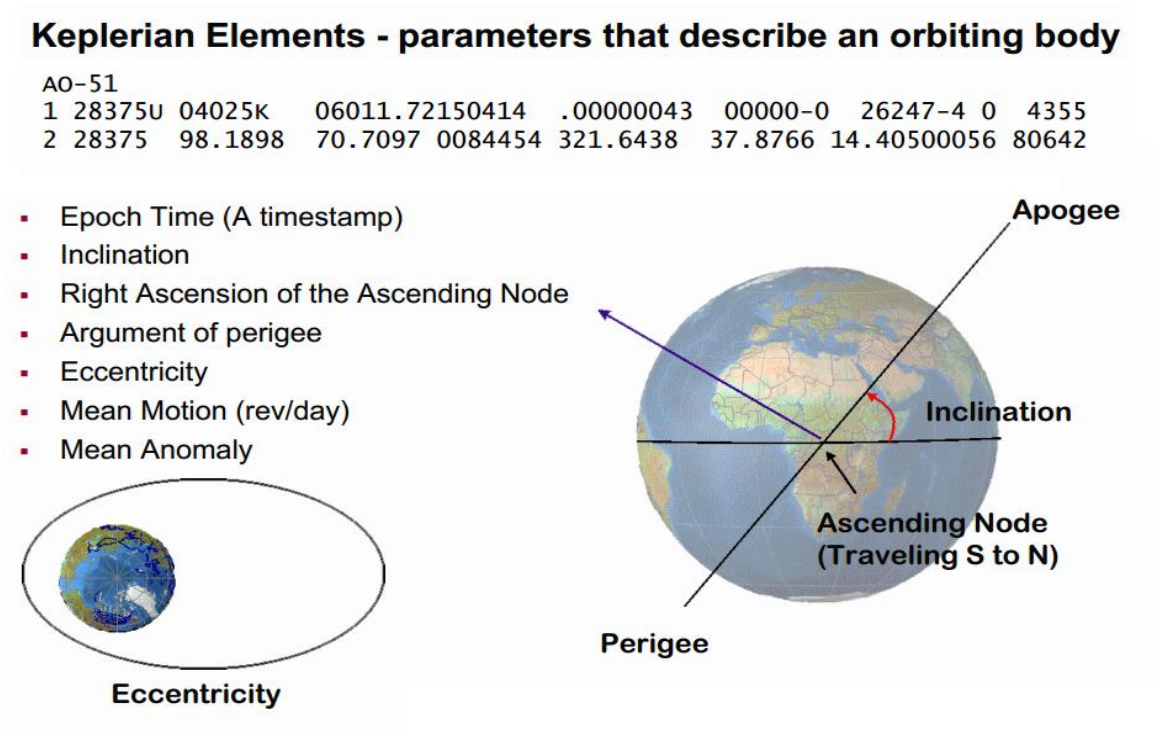
E2D11 (D) Which of the following data are used by the **APRS network to communicate your location? D. Latitude and longitude**

Amateur Satellites

A **Geostationary** satellite appears to stay in one position in the sky

The **orbital period** is the time it takes for a satellite to complete **one revolution around the Earth**

Calculations using **Keplerian Elements** for a satellite is one way to **predict the location** of a satellite

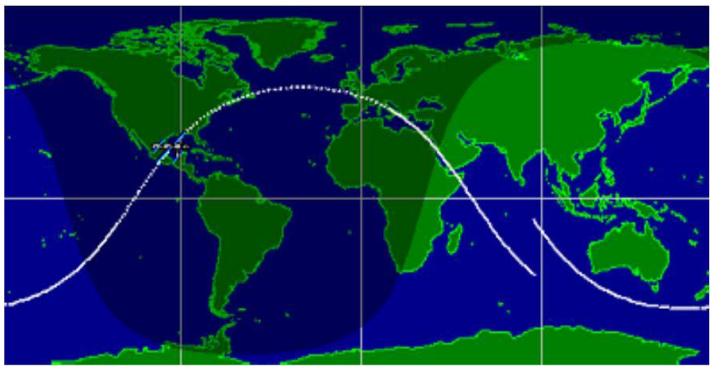


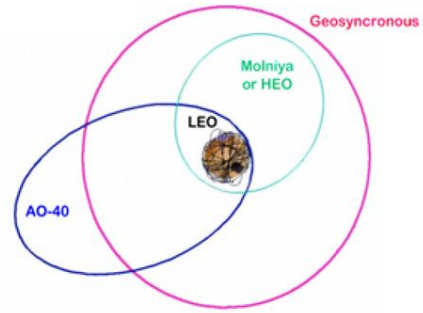
From south to north is the direction of an **ascending pass** for an amateur satellite

From north to south is the direction of a **descending pass** for an amateur satellite?

Satellites provide Amateurs a greatly increased communication range by using the repeaters, transponders, or store-and-forward equipment onboard Satellites orbiting the Earth

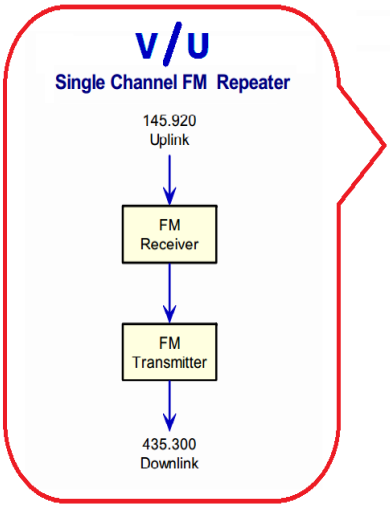
Most of the satellites can be accessed or used to relay signals with very modest equipment





The term **mode** (as applied to an amateur radio satellite) is the **uplink and downlink** frequency bands

The letters in a satellite's **mode** designator specify the **uplink and downlink** frequency ranges

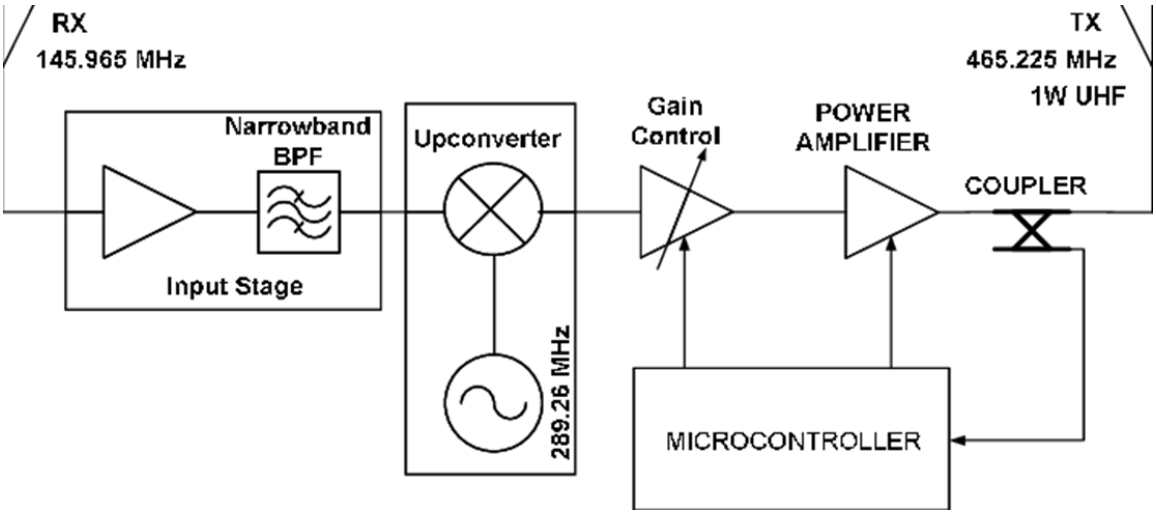


HF Bands	29.300 – 29.500	200 KHz	Primary	Uplink & Downlink
V Band	145.800 – 146.000	200 KHz	Primary	Uplink and Downlink
U Band	435.000 – 438.000	3 MHz	Secondary	Uplink and Downlink
L Band	1260 – 1270	10 MHz	Secondary	Uplink Only
S Band	2400 – 2450 3400 – 3410*	10 MHz 10 MHz	Secondary Secondary	Uplink 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

A circularly polarized antenna can be used to minimize the effects of **spin modulation** and Faraday rotation

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

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 of these choices are correct

==========

E2A01 (C) What is the direction of an **ascending pass** for an amateur satellite? C. From **south to north**

E2A02 (A) What is the direction of a **descending pass** for an amateur satellite? A. From **north to south**

E2A03 (C) What is the **orbital period** of an Earth satellite? C. The time it takes for a **satellite to complete one revolution** around the Earth

E2A04 (B) What is meant by the term **mode** as applied to an amateur radio satellite? B. The satellite's **uplink and downlink frequency bands**

E2A05 (D) What do the letters in a satellite's mode designator specify? D. The **uplink and downlink frequency ranges**

E2A06 (A) On what band would a **satellite receive** signals if it were operating in **mode U/V? A. 435-438 MHz**

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 of these choices are correct

E2A08 (B) Why should effective radiated power to a satellite which uses a linear transponder be limited? B. To avoid **reducing the downlink power to all other users**

E2A09 (A) What do the terms **L band and S band** specify with regard to satellite communications? A. The **23 centimeter and 13-centimeter** bands

E2A10 (A) Why may the received signal from an amateur satellite exhibit a **rapidly repeating fading effect? A. Because the satellite is spinning**

E2A11 (B) What type of antenna can be used to minimize the effects of **spin modulation and Faraday rotation? B. A circularly polarized antenna**

E2A12 (D) What is one way to **predict the location of a satellite** at a given time? D. By calculations using the **Keplerian elements** for the specified satellite

E2A13 (B) What type of satellite appears to stay in **one position in the sky? B. Geostationary**

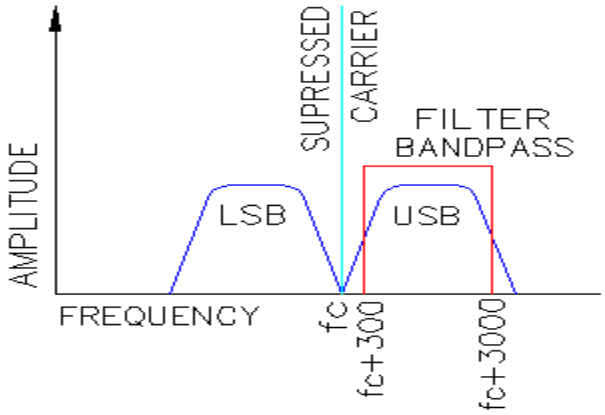
E2A14 (C) What technology is used to **track, in real time,** balloons carrying amateur radio transmitters? **C. APRS**

Chapter 3 Rules and Regulations

Operating Standards

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

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



With your transceiver displaying the carrier frequency of phone signals, you hear a DX station's CQ on **14.349 MHz USB it is NOT legal to return the call** using upper sideband on the same frequency

With your transceiver displaying the carrier frequency of phone signals, you hear a DX station calling CQ **on 3.601 MHz LSB it is NOT legal to return the call** using lower sideband on the same frequency

With your transceiver displaying the carrier frequency of CW signals, you hear a DX station's CQ on **3.500 MHz it is NOT legal to return the call** using CW on the same frequency

==========

E1A01 (D) When using a transceiver that displays the carrier frequency of phone signals, which of the following displayed frequencies represents the highest frequency at which a properly adjusted **USB emission will be totally within the band? D. 3 kHz below the upper band edge**

E1A02 (D) 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? D. 3 kHz above the lower band edge**

E1A03 (C) With your transceiver displaying the carrier frequency of phone signals, you hear a DX station calling CQ on **14.349 MHz USB.** Is it legal to return the call using upper sideband on the same frequency? C. **No**, **the sideband will extend beyond the band edge**

E1A04 (C) 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? C. **No, the sideband will extend beyond the edge** of the phone band segment

E1A12 (C) With your transceiver displaying the carrier frequency of **CW signals,** you hear a DX station's CQ on **3.500 MHz.** Is it legal to return the call using CW on the same frequency? C. **No, one of the sidebands from the CW signal will be out of the band.**

==========

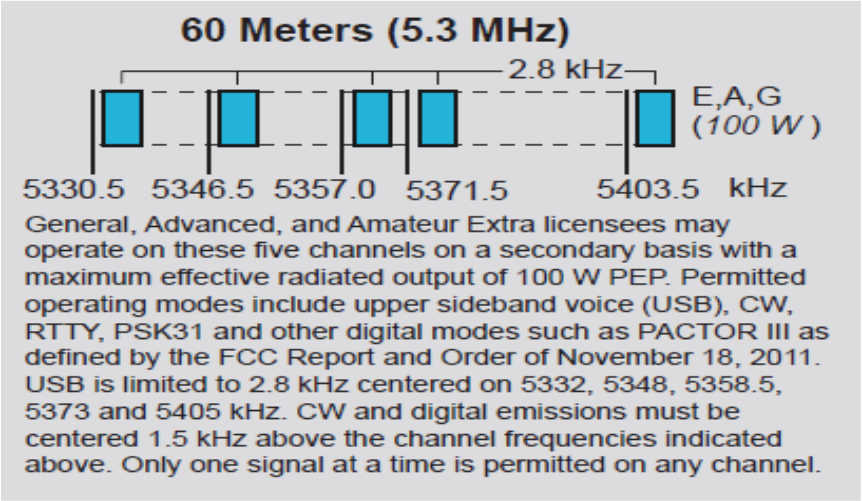
Operation is restricted to **specific emission types and specific channels** describes the rules for operation on the **60 meter band**

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

The **CW carrier must be at the center frequency** of the channel on the **60 meter band**

2.8 kHz is the maximum **bandwidth for a data emission on 60 meter band**

60 meter band is the only amateur band where transmission on specific channels rather than a range of frequencies is permitted



*Editor's note: **60-meter** band is restricted to 5 channels on a secondary basis*

5 channels specified as center frequencies
1.5 kHz SSB display offset
2.8 kHz bandwidth
USB only
100 watts ERP
RTTY & Data, no automatic control

==========

E1A05 (C) What is the maximum power output permitted on the **60 meter band? C. 100 watts PEP effective radiated power relative to the gain of a half-wave dipole**

E1A06 (B) Where must the carrier frequency of a **CW signal** be set to comply with FCC rules for **60 meter** operation? B. At the **center frequency of the channel**

E1A07 (D) Which amateur band requires transmission on **specific channels** rather than on a range of frequencies? D**. 60 meter band**

E1A14 (D) What is the maximum **bandwidth for a data emission on 60 meters? D. 2.8 kHz**

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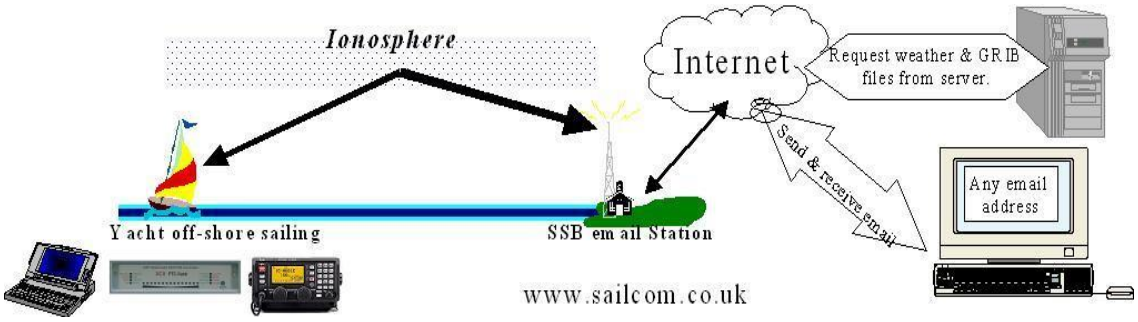


If a station in a **message forwarding system** inadvertently forwards a message that is in **violation** of FCC rules, the control operator of the **originating station is primarily accountable** for the rules violation

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**

==========

E1A08 (B) 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**? B. The control operator of the **originating station**

E1A09 (A) What is the first action you should 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

==========

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

A 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**

A 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**

==========

E1A10 (A) 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

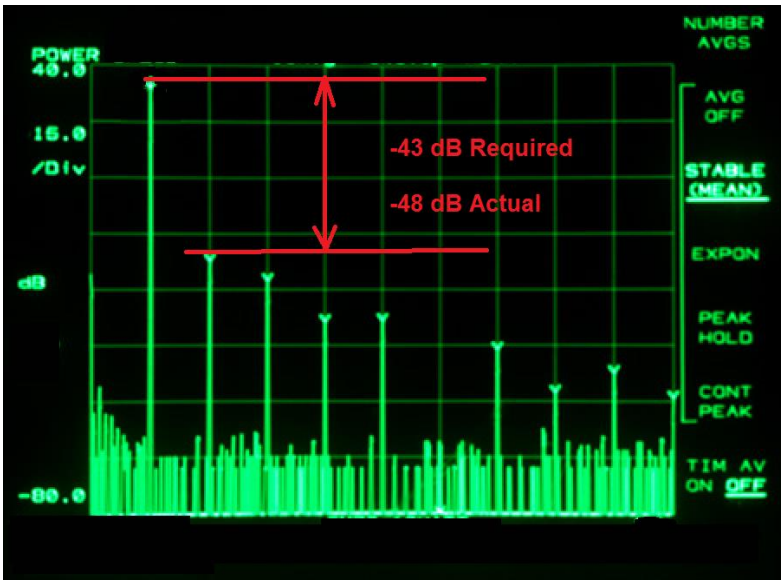
E1A11 (B) Which of the following describes authorization or licensing required when operating an amateur **station aboard a U.S.-registered vessel** in international waters? B. **Any FCC-issued amateur** license

E1A13 (B) 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? B. Any person holding an FCC-issued **amateur license** or who is authorized for alien reciprocal operation

==========

Station Restrictions

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

==========

E1B01 (D) Which of the following constitutes a **spurious emission**? D. An **emission outside its necessary bandwidth** that can be reduced or eliminated without affecting the information transmitted

E1B11 (A) 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**

==========

Locations of environmental importance or significant in American history, architecture, or culture might cause the physical location of **an amateur station apparatus or antenna structure to be restricted**

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

==========

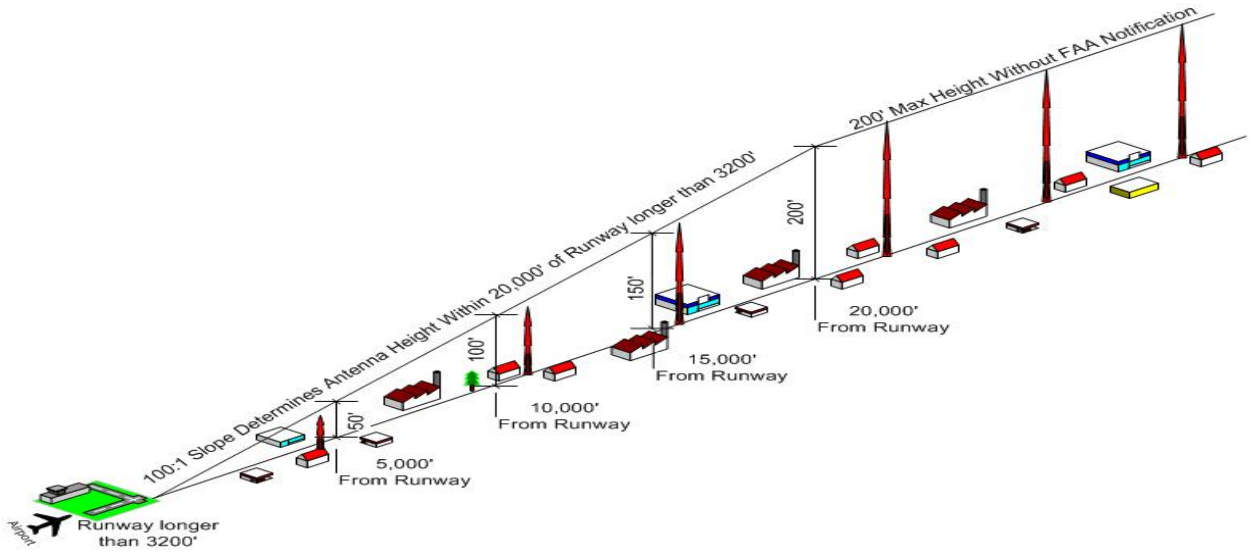
E1B02 (D) Which of the following factors might cause the physical location of an amateur station apparatus **or antenna structure to be restricted? D. The location is of environmental importance** or significant in American history, architecture, or culture

E1B04 (C) 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 Historical Places? C. An **Environmental Assessment must be submitted to the FCC**

E1B05 (C) What is the **National Radio Quiet Zone**? C. An area surrounding the **National Radio Astronomy Observatory**

==========

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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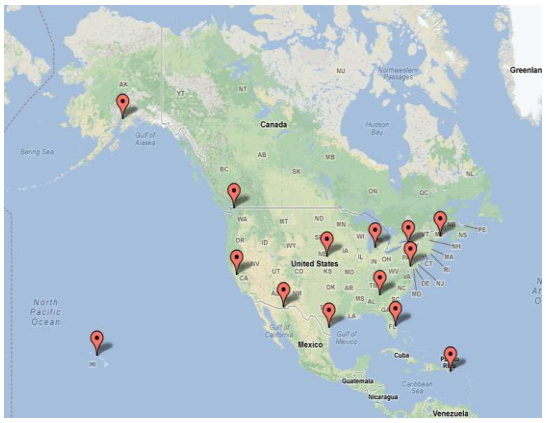
E1B06 (A) Which of the following additional rules apply if you are installing an amateur station antenna at a site at or near a **public use airport**? A. You may have to **notify the Federal Aviation Administration** and register it with the FCC as required by Part 17 of FCC rules

==========

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.

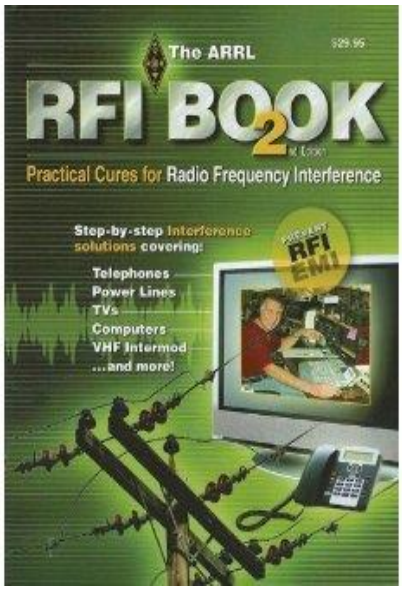
The National Radio Quiet Zone is an area surrounding the **National Radio Astronomy Observatory**

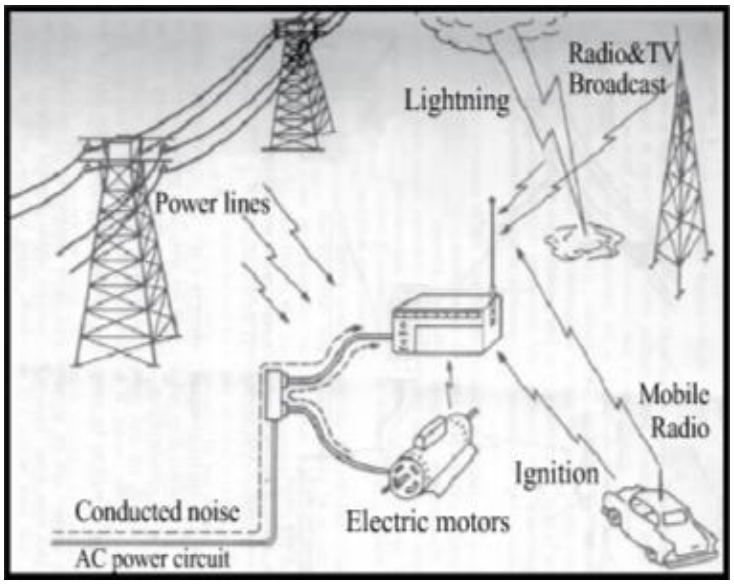
Within 1 mile an amateur station must protect an **FCC monitoring facility** from harmful interference

==========

E1B03 (A) Within what distance must an amateur station protect an **FCC monitoring facility** from harmful interference? A. **1 mile**

==========





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

==========

E1B08 (D) What limitations may the FCC place on an amateur station if its signal **causes interference** to domestic broadcast reception, assuming that the receiver(s) involved are of good engineering design? D. The amateur station **must avoid transmitting during certain hours on frequencies** that cause the interference

==========

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**

==========

E1B09 (C) Which amateur stations may be operated in **RACES**? C. Any **FCC-licensed amateur station certified by the responsible civil defense organization** for the area served

E1B10 (A) What frequencies are authorized to an amateur station participating under **RACES** rules? A. **All amateur service frequencies** authorized to the control operator

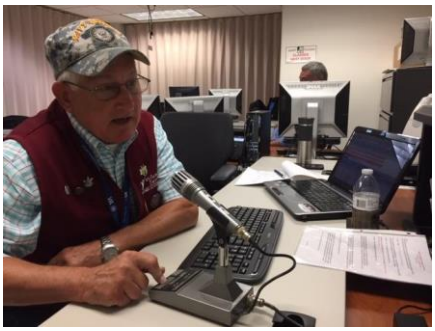
==========

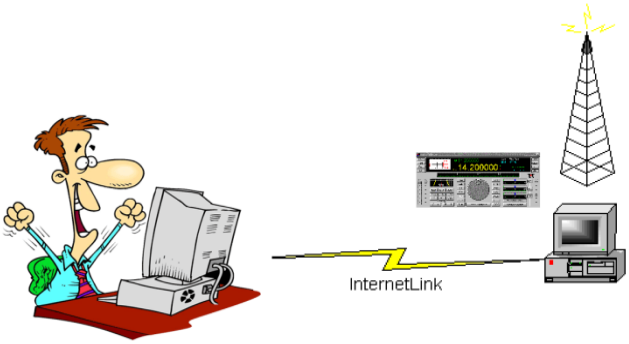
Station Control

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**





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E1C01 (D) What is a **remotely controlled** station? D. A station controlled indirectly **through a control link**

E1C06 (C) Which of the following statements concerning **remotely controlled amateur stations** is true? C. A **control operator must be present** at the control point

E1C07 (C) What is meant by **local control**? C. **Direct manipulation** of the transmitter by a 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**

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

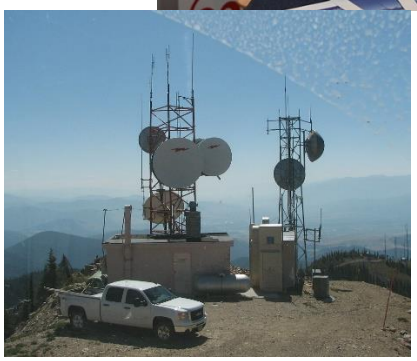
An **automatically controlled station may retransmit third party** communications when transmitting **RTTY or data emissions**

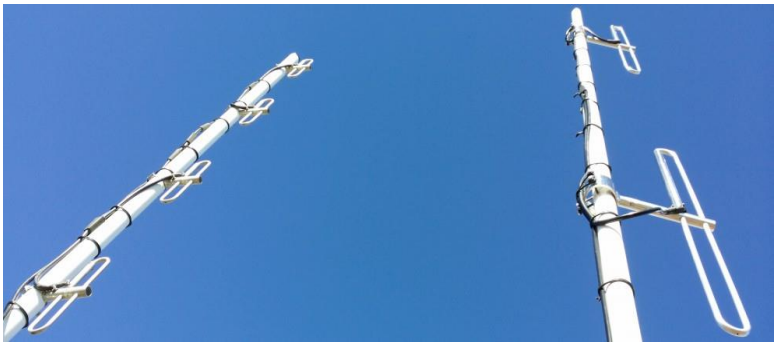
An **automatically controlled** station **may NOT originate third party** communications

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

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





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E1C02 (A) What is meant by **automatic control** of a station? A. The use of devices and procedures for control so that the control **operator does not have to be present** at a control point

E1C03 (B) How do the **control operator responsibilities** of a station under **automatic control** differ from one under local control? B. Under automatic control the control **operator is not required to be present** at the control point

E1C05 (A) When may an **automatically controlled station originate third party communications**? A. **Never**

E1C08 (B) What is the maximum permissible duration of a remotely controlled station's transmissions if its **control link malfunctions? B. 3 minutes**

E1C09 (D) Which of these frequencies are available for an automatically controlled **repeater operating below 30 MHz? D. 29.500 - 29.700 MHz**

E1C10 (B) What types of amateur stations may **automatically retransmit** the radio signals of other amateur stations? B. Only auxiliary, **repeater or space stations**

==========

Editor's note: 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*

==========

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

E1C11 (A) Which of the following operating arrangements allows an FCC-licensed US citizen to **operate in many European countries**, and alien amateurs from many European countries to operate in the US? A**. CEPT agreement**

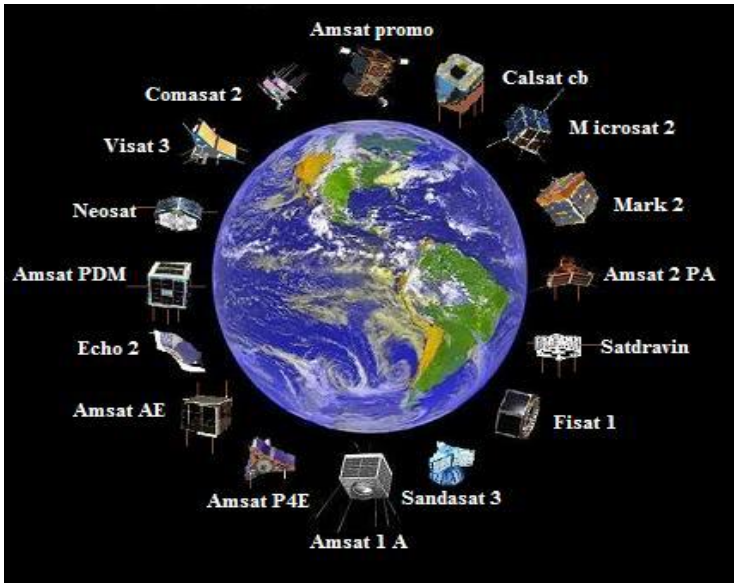
E1C12 (C) What types of communications may be transmitted to **amateur stations in foreign countries?** C. Communications incidental to the **purpose of the amateur service and remarks of a personal nature**

E1C13 (C) Which of the following is required in order to operate in accordance with **CEPT rules** in foreign countries where permitted? C. You must bring a copy of **FCC Public Notice DA 11-221**

==========

Amateur Satellite Service

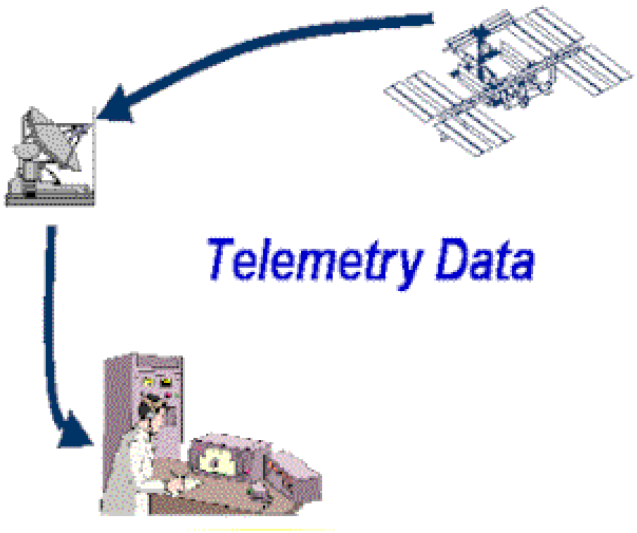
Radio communications service using stations on Earth satellites for the same purpose as the amateur service.



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*

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

A **space station** must **terminate transmissions by telecommand** when directed by the FCC



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

==========

E1D01 (A) What is the definition of the term **telemetry?** A. **One-way transmission of measurements** at a distance from the measuring instrument

E1D02 (C) What is the **amateur satellite service**? C. A radio communications service using **amateur radio stations on satellites**

E1D06 (A) Which of the following is a requirement of a space station? A. The space station must be **capable of terminating transmissions by telecommand** when directed by the FCC

E1D10 (B) Which amateur stations are eligible to be **telecommand stations? B. Any amateur station so designated by the space station licensee**, subject to the privileges of the class of operator license held by the control operator

E1D03 (B) What is a **telecommand station** in the amateur satellite service? A B. An amateur station that transmits communications to **initiate, modify or terminate functions of a space station**

E1D05 (C) What class of licensee is authorized to be the **control operator of a space station? C. Any class** with appropriate operator privileges

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 an amateur station within 50 km of the Earth's surface intended for communications with amateur stations **by means of objects in space**

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

All classes of licensee is authorized to be the **control operator of a space station**

==========

E1D11 (D) Which amateur stations are eligible to operate as **Earth stations? D. Any amateur station**, subject to the privileges of the class of operator license held by the control operator

E1D04 (A) What is an **Earth station** in the amateur satellite service? A. An amateur station within 50 km of the Earth's surface intended for **communications with amateur stations by means of objects in space**

E1D07 (A) Which amateur service **HF bands have frequencies authorized for space stations**? A. Only the **40 m, 20 m, 17 m, 15 m, 12 m and 10 m** bands

E1D08 (D) Which **VHF** amateur service bands have frequencies available for **space stations? D. 2 meters**

E1D09 (B) Which **UHF** amateur service bands have frequencies available for a **space station? B. 70 cm and 13 cm**

==========

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

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

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

==========

E1E01 (D) What is the **minimum number of qualified VEs** required to administer an Element 4 amateur operator license examination? D. **3**

E1E02 (C) **Where are the questions** for all written US amateur license examinations listed? C. In a **question pool** maintained by all the VECs

E1E03 (C) What is a **Volunteer Examiner Coordinator**? C. **An organization** that has entered into an agreement with the FCC to coordinate amateur operator license examinations

E1E04 (D) Which of the following best describes the **Volunteer Examiner** accreditation process? D. The procedure by which a VEC confirms that the **VE applicant meets FCC requirements** to serve as an examiner

E1E05 (B) What is the minimum passing score on amateur operator license examinations? B. **Minimum passing score of 74%**

E1E06 (C) **Who is responsible** for the proper conduct and necessary supervision during an amateur operator license examination session? C. **Each administering VE**

E1E07 (B) What should a VE do if a **candidate fails to comply** with the examiner's instructions during an amateur operator license examination? B**. Immediately terminate the candidate's examination**

E1E08 (C) To which of the following examinees may a **VE not administer an examination? C. Relatives** of the VE as listed in the FCC rules

E1E09 (A) 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

E1E10 (C) What must the **administering VEs** do after the administration of a successful examination for an amateur operator license? C. They must **submit the application document to the coordinating VEC** according to the coordinating VEC instructions

E1E11 (B) What must the VE team do if an examinee scores a passing grade on all examination elements needed for an upgrade or new license? B. **Three VEs must certify that the examinee is qualified** for the license grant and that they have complied with the administering VE requirements

E1E12 (A) 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**

E1E13 (B) Which of these choices is an acceptable method for monitoring the applicants if a VEC opts to conduct an **exam session remotely? B. Use a real-time video link** and the Internet to connect the exam session to the observing VEs

E1E14 (A) 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 license

==========

Miscellaneous Rules

Editor's note: ***Auxiliary Stations***

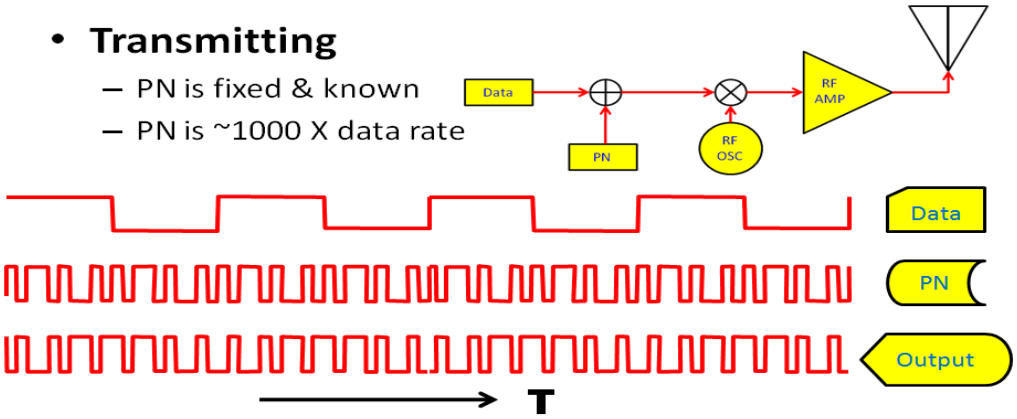
> *Auxiliary Stations are amateur station, other than in a message forwarding system, that transmit communications point-to-point within a system of cooperating amateur stations*
>
> *Links to remotely controlled stations*
>
> *Cross-band repeat stations*

==========

E1F12 (B) Who may be the control operator of an **auxiliary station**? B. Only Technician, General, Advanced or Amateur Extra Class operators

==========

Spread Spectrum Implementation



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

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

Which of the following conditions apply when transmitting **spread spectrum emission**?

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 of these choices are correct

==========

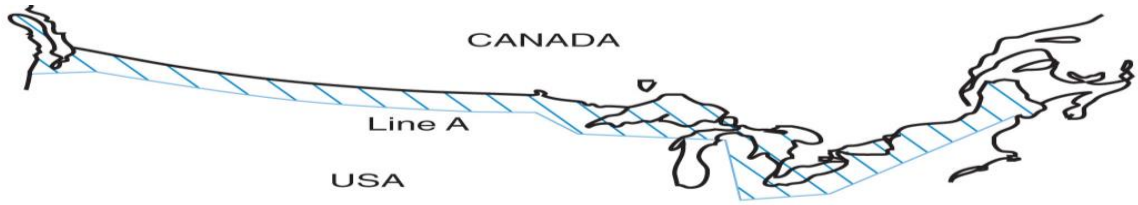
E1F01 (B) On what frequencies are **spread spectrum** transmissions permitted? B. Only on amateur frequencies **above 222 MHz**

E1F09 (D) Which of the following conditions apply when **transmitting spread spectrum emission**?

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 of these choices are correct

E1F10 (C) What is the maximum transmitter power for an amateur station transmitting **spread spectrum communications? C. 10 W**

==========



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

Amateur stations may not transmit on 420 - 430 MHz if they are located in the contiguous 48 states **and north of Line A**

==========

E1F02 (C) What privileges are authorized in the U.S. to persons holding an amateur service license granted by the Government of Canada? C. The operating terms and conditions of the **Canadian amateur service license, not to exceed U.S. Extra Class privileges**

E1F04 (A) Which of the following geographic descriptions approximately describes **"Line A"? A. A line roughly parallel to and south of the US-Canadian border**

E1F05 (D) 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? D. 420 - 430 MHz**

==========

Editor's note: ***External Power Amplifiers (Linears)***

RF power amplifiers capable of operating on frequencies below 144 MHz may require FCC certification

Certification

Satisfy the spurious emission standards (-43 dBc)

Must not be capable of amplifying the input signal by more than 15dB

Must not amplify between 26 and 28 MHz (CB)

Amateurs my build their own amplifier or modify amplifiers for use in an Amateur Radio station

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

==========

E1F03 (A) 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

E1F11 (D) 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? D. It must satisfy the **FCC's spurious emission** standards when operated at the lesser of 1500 watts, or its full output power

==========

Editor's note: ***Special Temporary Authority (STA)***

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

(Special Temporary Authority can be granted for experimental amateur communications

Spread Spectrum was an example

500 kHz communications

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) Under what circumstances might the FCC issue a **"Special Temporary Authority"** (STA) to an amateur station? A. To provide for **experimental amateur communications**

==========

Editor's note: ***Business & Payment***

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

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 (usually close deal on phone) Don't do it regularly or can become a business

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

==========

E1F07 (D) When may an amateur station send a **message to a business? D. When neither the amateur nor his or her employer has a pecuniary interest** in the communications

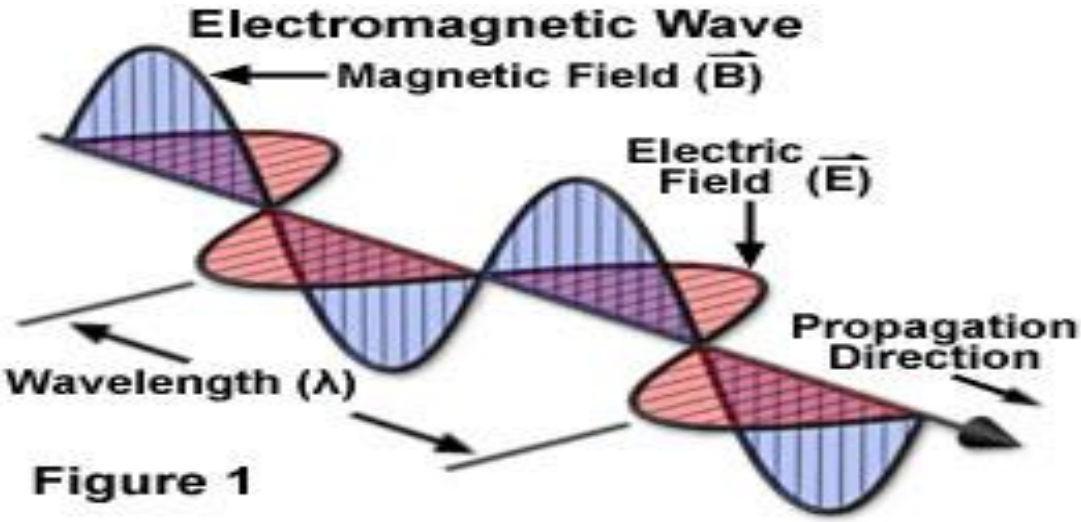
E1F08 (A) Which of the following types of amateur station **communications are prohibited?** A. Communications transmitted **for hire or material compensation**, except as otherwise provided in the rules

==========

Chapter 4 Electrical Principles

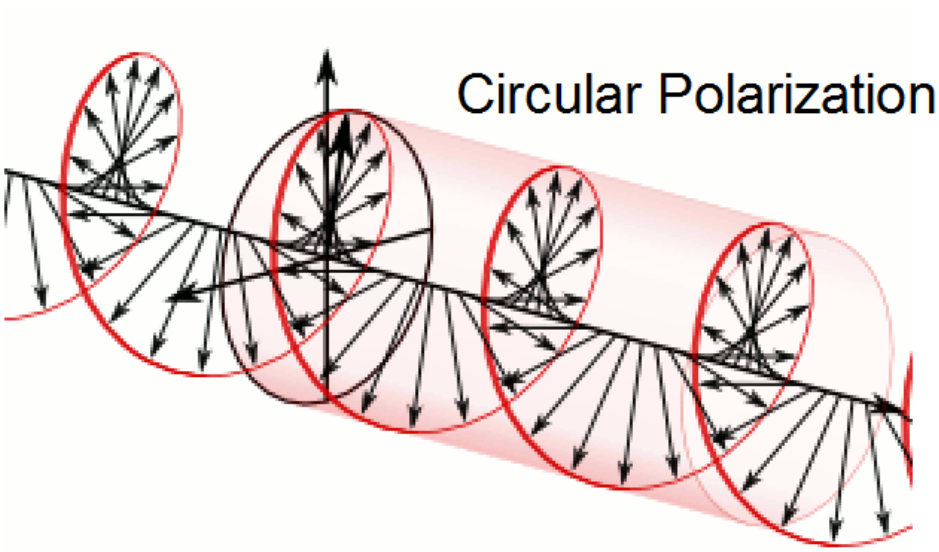
RLC Circuits / Q Factor / Resonant Circuits

A wave consisting of an electric field and a magnetic field oscillating at right angles to each other is an **electromagnetic wave**



Changing electric and magnetic fields propagate the energy **electromagnetic waves traveling in free space**

Waves with a rotating electric field are **circularly polarized** electromagnetic waves



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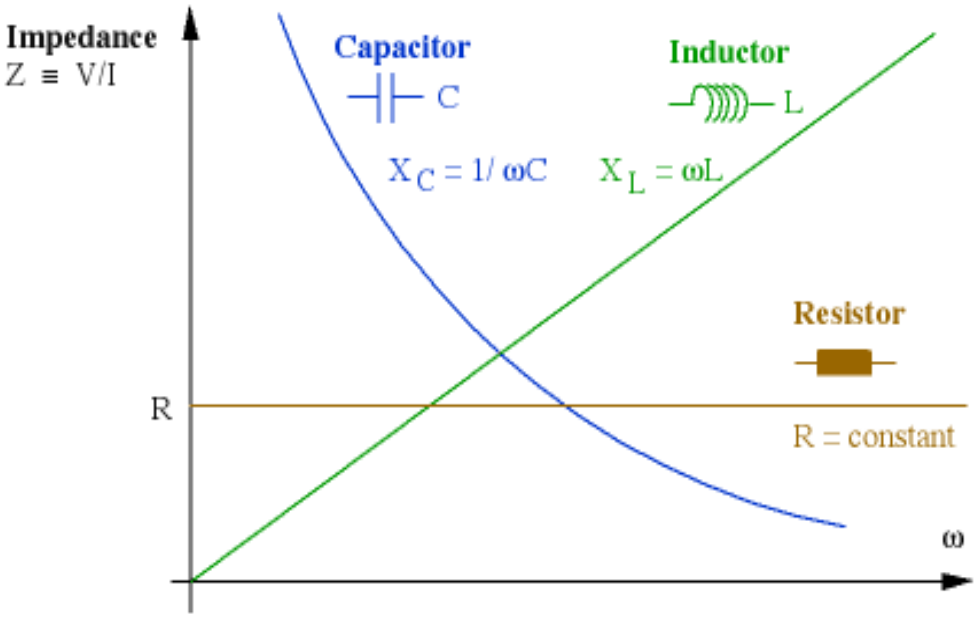
E3A15 (C) What is an **electromagnetic wave**? C. A wave consisting of an **electric field and a magnetic field oscillating at right angles** to each other

E3A16 (D) Which of the following best describes electromagnetic waves traveling in free space? D. **Changing electric and magnetic fields** propagate the energy

E3A17 (B) What is meant by circularly polarized electromagnetic waves? B. Waves with a rotating electric field

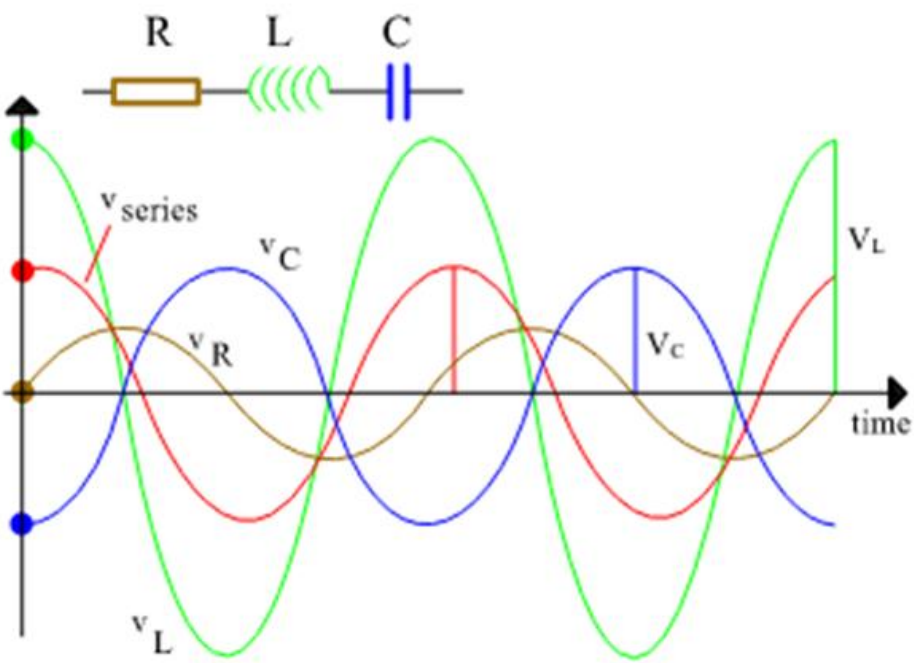
==========



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 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

==========

E5A01 (A) What can cause the voltage across reactance in series to be **larger than the voltage applied** to them? A. **Resonance**

E5A02 (C) What is **resonance** in an electrical circuit? C. The frequency at which the **capacitive reactance equals the inductive reactance**

E5A03 (D) What is the magnitude of the impedance of a series **RLC circuit at resonance**? D. Approximately **equal to circuit resistance**

E5A04 (A) What is the magnitude of the impedance of a circuit with a **resistor, an inductor and a capacitor all in parallel, at resonance**? A. Approximately **equal to circuit resistance**

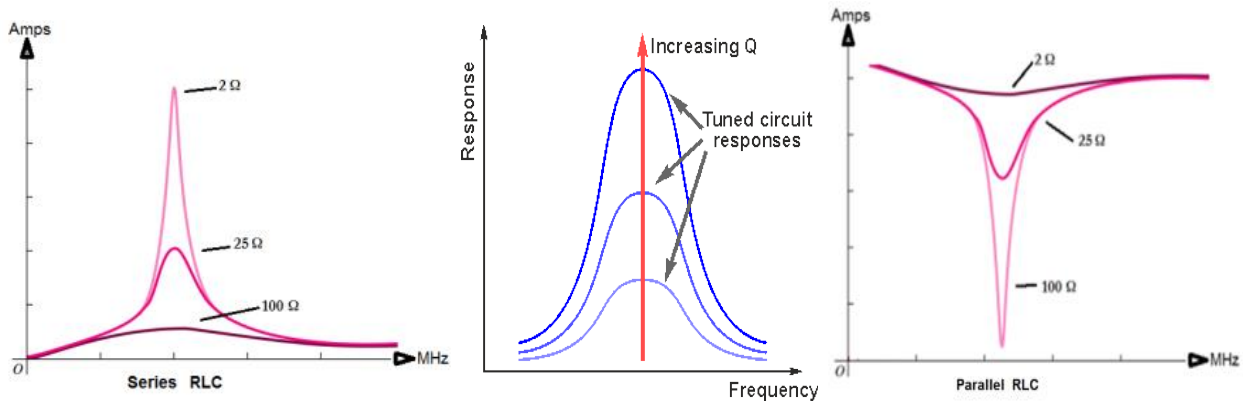
E5A05 (B) What is the magnitude of the **current at the input of a series RLC** circuit as the frequency goes through **resonance? B. Maximum**

E5A06 (B) What is the magnitude of the circulating **current within the components of a parallel LC circuit** at **resonance? B. It is at a maximum**

E5A07 (A) What is the magnitude of the **current at the input of a parallel RLC circuit at resonance? A. Minimum**

E5A08 (C) What is the phase relationship between the current through and the voltage across a **series resonant circuit at resonance? C. The voltage and current are in phase**

==========



The impedance of a **series RLC circuit at resonance is equal to circuit resistance** (looks like R)

Maximum current is at the input of a **series RLC** circuit as the frequency is **resonance**

==========

E4B15 (C) Which of the following can be used as a relative measurement of the **Q** for a series-tuned circuit? C. The **bandwidth of the circuit's frequency response**

E5A09 (C) How is the **Q of an RLC parallel resonant circuit** calculated? C. **Resistance divided by the reactance** of either the inductance or 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**

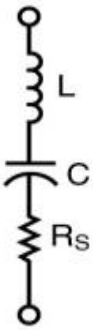
E5A13 (C) What is an effect **of increasing Q** in a resonant circuit? C. **Internal voltages and circulating currents increase**

E5A15 (A) Which of the following can **increase Q** for inductors and capacitors? A. **Lower losses**

E5A17 (A) What is the result of **increasing the Q of an impedance-matching circuit**? A. Matching **bandwidth is decreased**

==========

Series Resonant Circuit



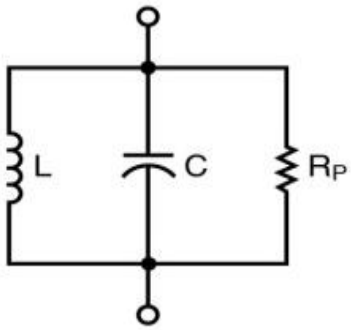
$$X_L = 2\pi f_r L$$

$$X_C = \frac{1}{2\pi f_r C}$$

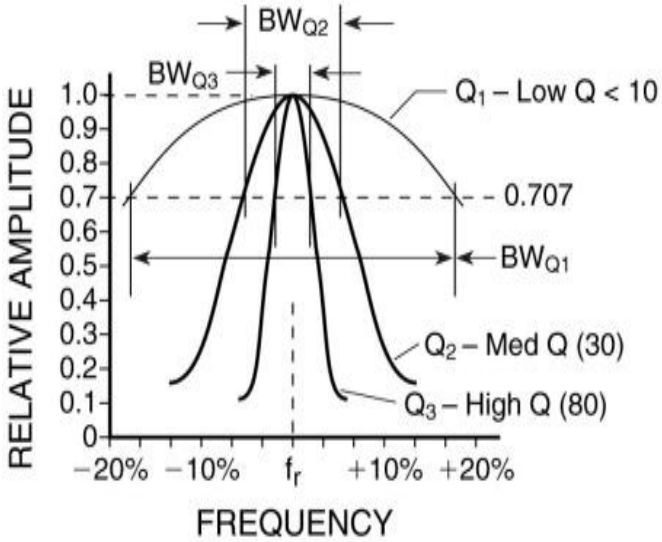
$X_L = X_C$ at f_r, the resonant frequency

$$Q = \frac{X_L}{R_S} \text{ or } \frac{X_C}{R_S}$$

Parallel Resonant Circuit



$$Q = \frac{R_P}{X_L} \text{ or } \frac{R_P}{X_C}$$



f_r = Resonant frequency in Hz

BW = Half-power Bandwidth (−3db)

$$Q = \frac{f_r}{BW}$$

$$\therefore BW = \frac{f_r}{Q}$$

==========

E5A11 (C) What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 7.1 MHz and a Q of 150? **C. 47.3 kHz**

Half Power BW = Resonant Frequency / Q of the Circuit

Δ F = Fr / Q

Δ F = 7.1 MHz / 150

Δ F = 7100 KHz / 150

Δ F = 47.333 KHz

E5A12 (C) What is the half-power bandwidth of a parallel resonant circuit that has a resonant frequency of 3.7 MHz and a Q of 118? C. 31.4 kHz

Half Power BW = Resonant Frequency / Q of the Circuit

Δ F = Fr / Q

Δ F = 3.7 MHz / 118

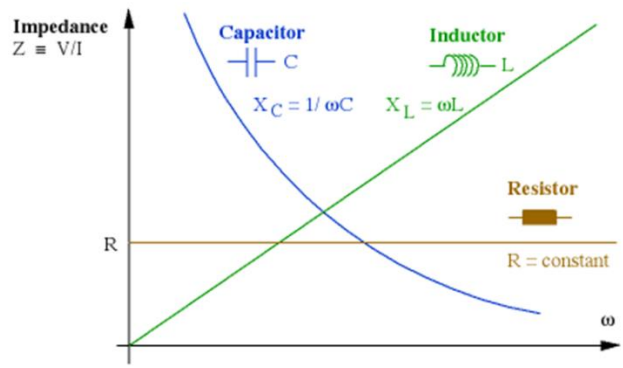
Δ F = 3700 KHz / 118

Δ F = 31.356 KHz

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



E5A14 (C) What is the resonant frequency of a series RLC circuit if R is 22 ohms, L is 50 microhenrys and C is 40 picofarads? **C. 3.56 MHz**

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 a parallel RLC circuit if R is 33 ohms, L is 50 microhenrys and C is 10 picofarads? **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

==========

RC Time Constant / E vs I Phase Angles

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

==========

E5B13 (D) What letter is commonly used to represent susceptance? D. B

E5B12 (A) What is admittance? A. The inverse of impedance

E5B03 (B) What happens to the phase angle of a reactance when it is converted to a susceptance? B. The sign is reversed

E5B05 (D) What happens to the magnitude of a reactance when it is converted to a susceptance? D. The magnitude of the susceptance is the reciprocal of the magnitude of the reactance

E5B06 (C) What is susceptance? C. The inverse of reactance

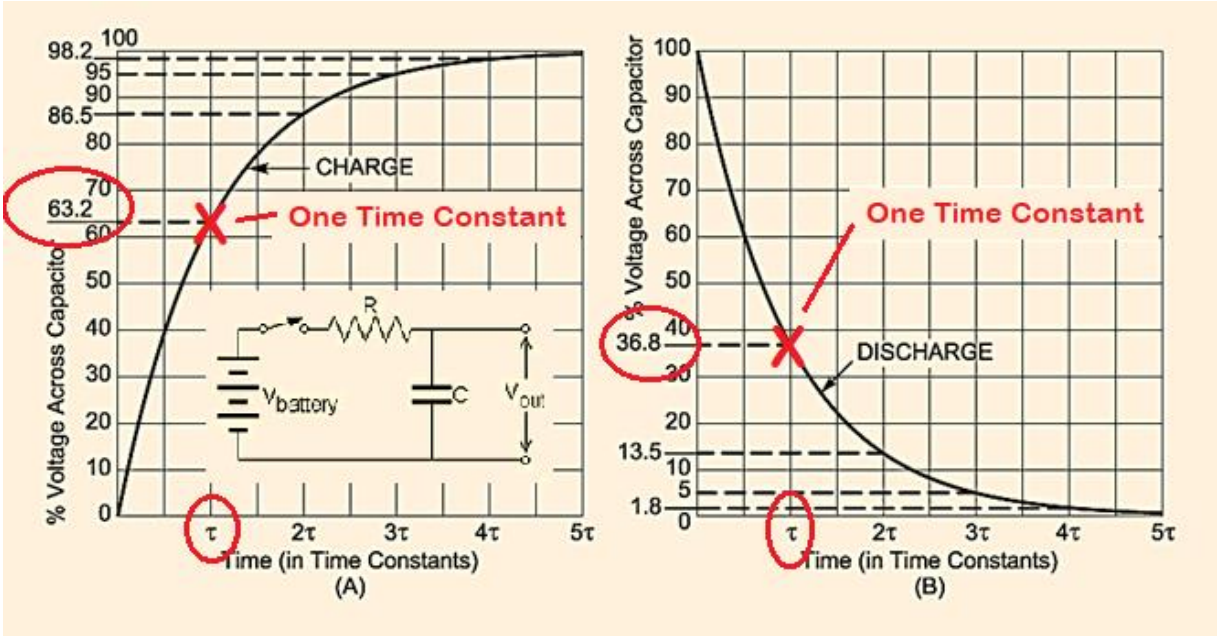
==========

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? B. **One time constant**

E5B02 (D) What is the term for the time it takes for a charged capacitor in an RC circuit to discharge to **36.8%** of its initial voltage? D. **One time constant**

E5B04 (D) What is the time constant of a circuit having two 220-microfarad capacitors and two 1-megohm resistors, all in parallel? D. 220 seconds

TC (sec) = R (MΩ) x C (uF) = 0.5 x 440 = 220 Sec

==========

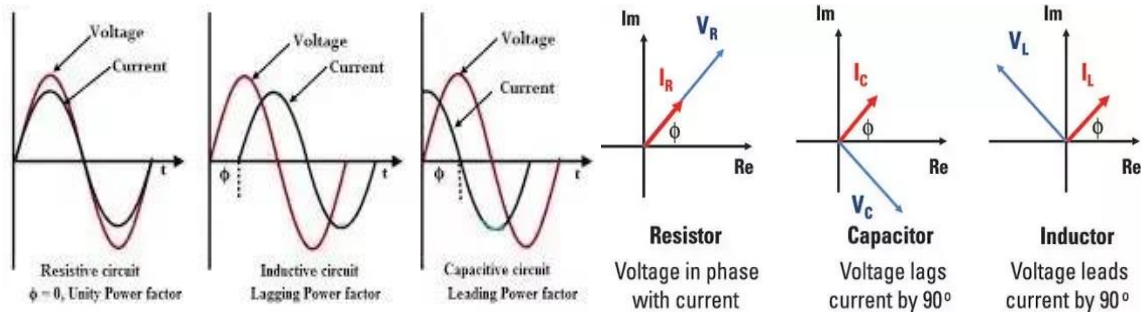
Rectangular Notation / Polar Coordinates

==========

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

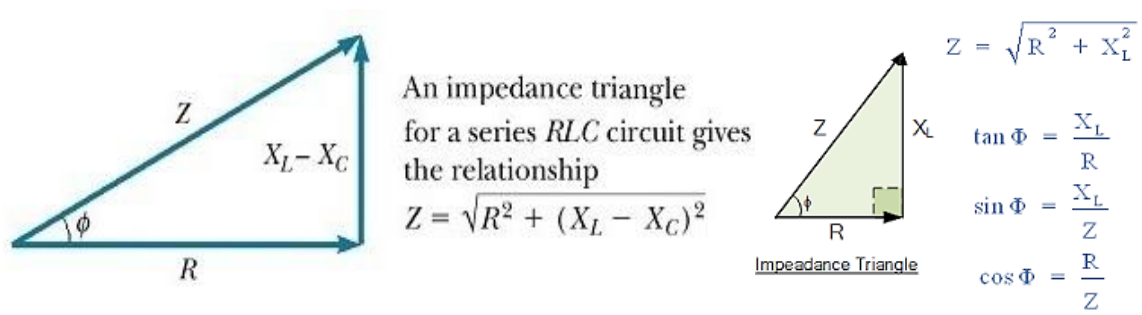
Inductors – voltage (E) leads current (I)

Capacitors – current (I) leads voltage (E)

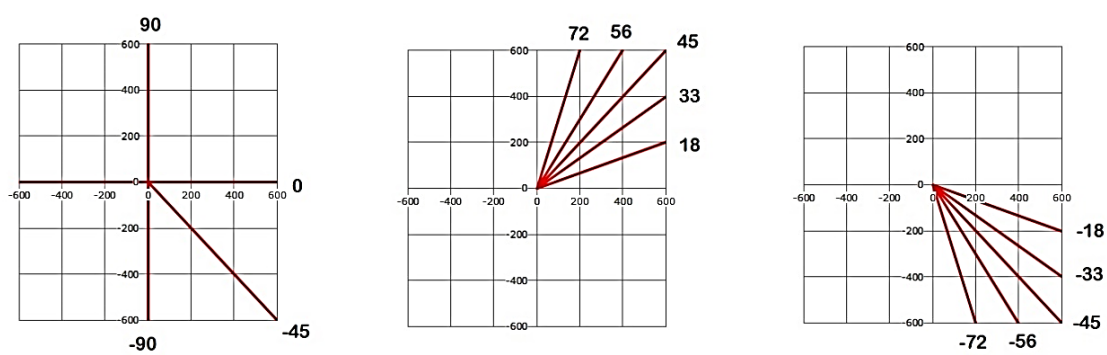
==========

E5B09 (D) What is the relationship between the current through a capacitor and the voltage across a **capacitor**? D. **Current leads voltage** by 90 degrees

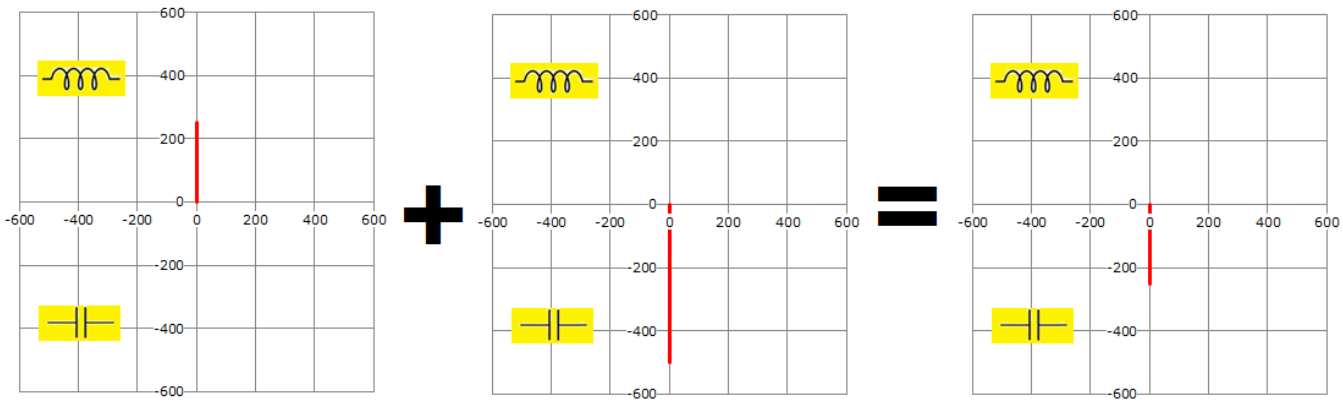
E5B10 (A) What is the relationship between the current through an inductor and the voltage across an **inductor**? A. **Voltage leads current** by 90 degrees



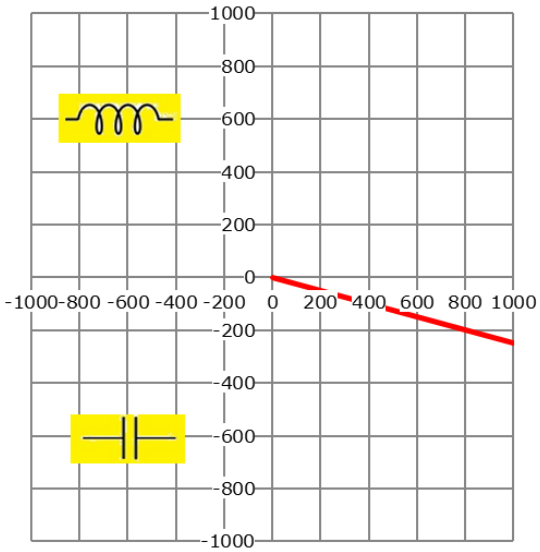
Editor's note: The problems on the exam are traditionally solved using trigonometry as shown above. An alternative method is to solve graphically. The first step in using a graphical method is visually estimating angles. The diagrams below show the quadrants are each 90°. Dividing the quadrant is 45°. 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. Example 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°.*



A. 68.2° V lead

B. 14.0° V lead

C. 14.0° V lag

D. 68.2° V lag

==========

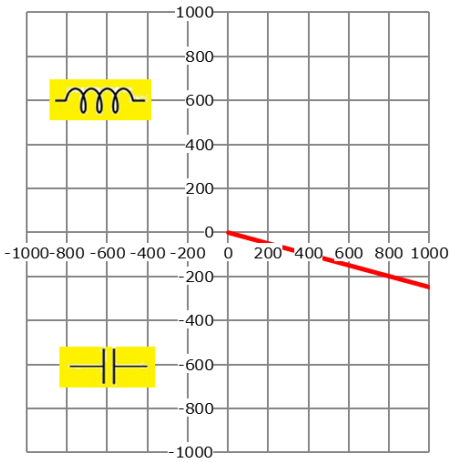
E5B07 (C) What is the phase angle between the voltage across and the current through a series RLC circuit if **XC is 500 ohms**, **R is 1 kilohm**, and **XL is 250 ohms**? C. **14.0 degrees with the voltage lagging** the current

Θ = tan^-1 [(250-500)/1000]

Θ = tan^-1 [(-250)/1000]

Θ = tan^-1 (-0.25) = -14.036°

Negative Phase = current ***lead voltage*** ***ICE***



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

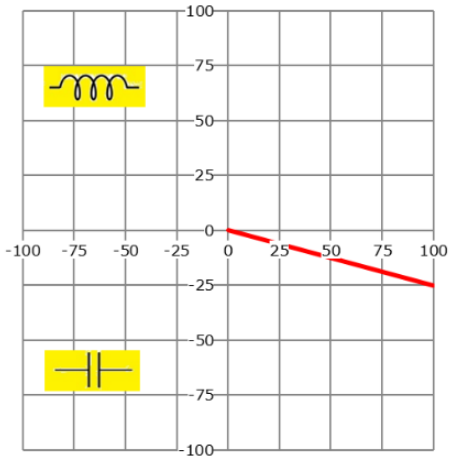
Θ = tan^-1 [(75-100)/100]

Θ = tan^-1 [(-25)/100]

Θ = tan^-1 (-0.25)

Θ = -14.036°

Negative Phase = current ***lead voltage*** ***ICE***



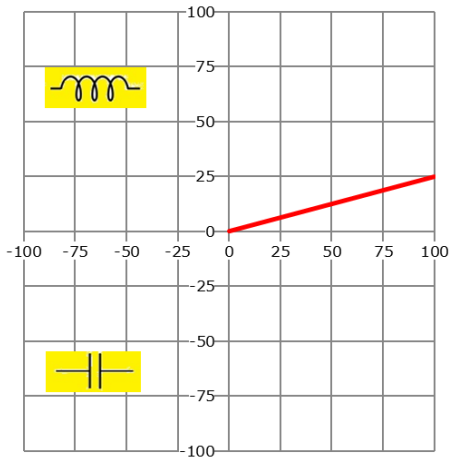
E5B11 (B) What is the phase angle between the voltage across and the current through a series RLC circuit if **XC is 25 ohms, R is 100 ohms, and XL is 50 ohms**? B. **14 degrees with the voltage leading** the current

Θ = tan^-1 [(50-25)/100]

Θ = tan^-1 (+0.25)

Θ = +14.036°

*Positive Phase = **voltage leads current** **ELI***



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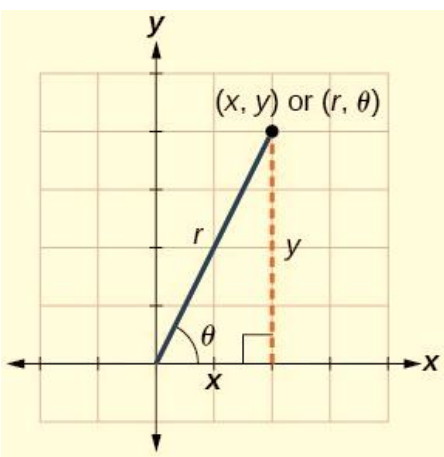
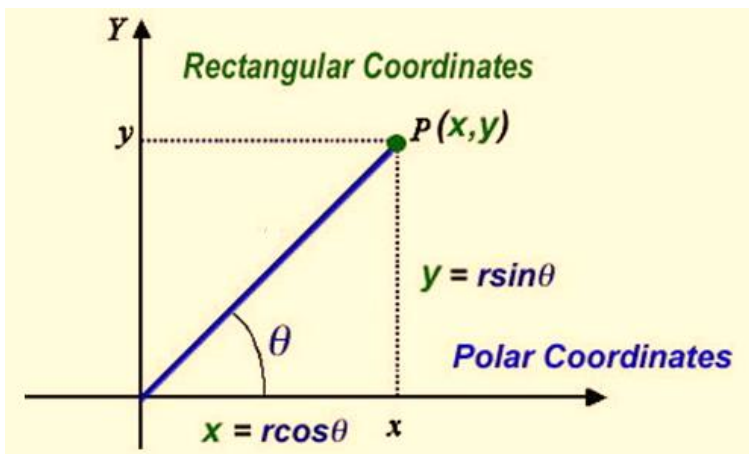
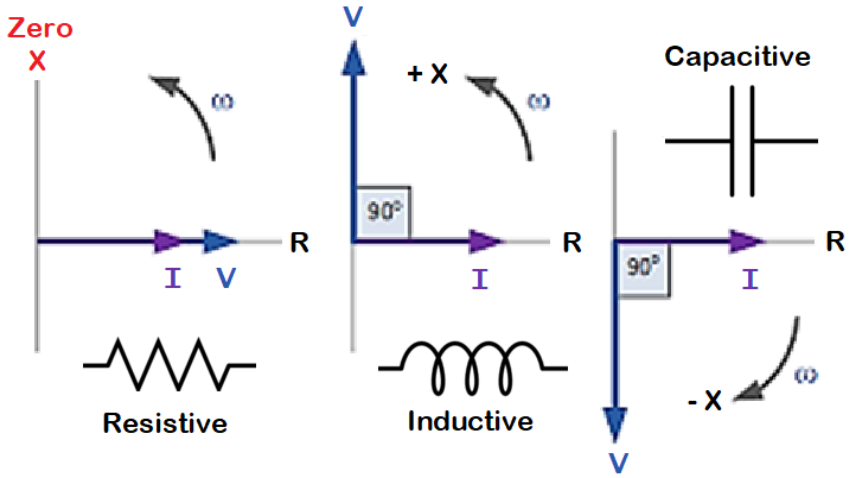
Rectangular coordinates to display the resistive, inductive, and/or capacitive reactance **(R + jX)**

Polar coordinates display the phase angle of a circuit resistance, inductive and/or capacitive reactance **(# Ω at angle °)**





The values along the horizontal and vertical axes **define a point on a graph** using rectangular coordinates



The **horizontal axis** represents the **resistive component**

The **vertical axis** represents the **reactive component**

==========

E5C13 (D) What coordinate system is often used to display **the resistive**, inductive, and/or capacitive **reactance components** of an impedance? D. **Rectangular coordinates**

E5C01 (A) Which of the following represents a capacitive **reactance in rectangular notation? A. -jX**

E5C06 (B) What does the impedance **50 – j25** represent? B. 50 ohms resistance in series **with 25 ohms capacitive reactance**

E5C09 (A) When using rectangular coordinates to graph the impedance of a circuit, what does the **horizontal axis represent? A. Resistive component**

E5C10 (B) When using rectangular coordinates to graph the impedance of a circuit, what does the **vertical axis represent? B. Reactive component**

E5C11 (C) What do the two numbers that are used to define a point on a graph using **rectangular coordinates represent**? C. The coordinate values along the **horizontal and vertical axes**

E5C12 (D) If you plot the impedance of a circuit using the rectangular coordinate system and find the impedance point falls on the right side of the graph **on the horizontal axis**, what do you know about the circuit? D. It is equivalent to a **pure resistance**

E5C05 (C) What is the name of the diagram used to show the **phase relationship** between impedances at a given frequency? C. **Phasor diagram**

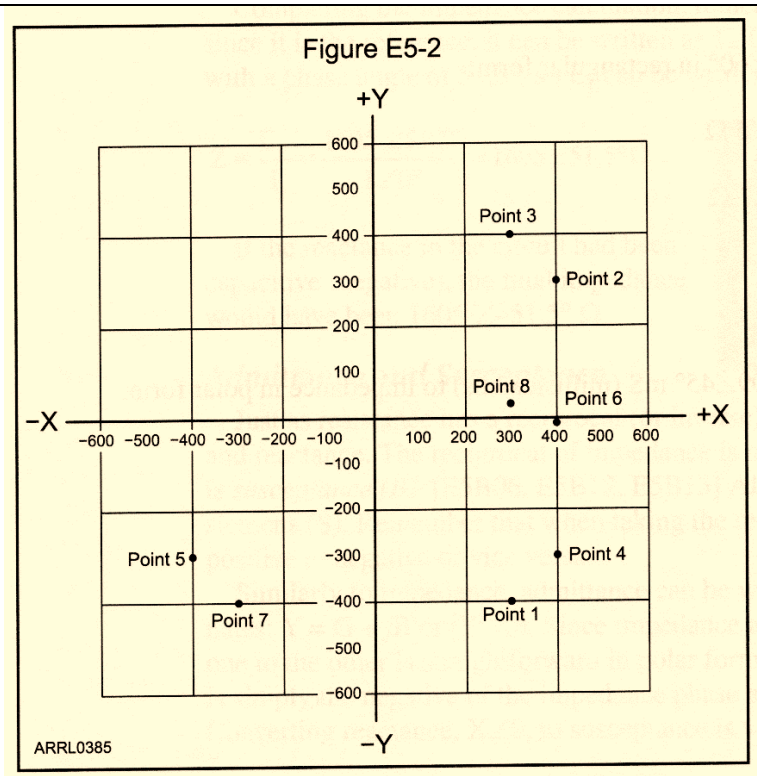
E5C07 (B) What is a **vector**? B. A quantity with both **magnitude and an angular** component

E5C08 (D) What coordinate system is often used to display **the phase angle** of a circuit containing resistance, inductive and/or capacitive reactance? D**. Polar coordinates**

E5C02 (C) How are impedances described in **polar coordinates**? C. By phase **angle and amplitude**

E5C03 (C) Which of the following represents an **inductive reactance in polar** coordinates? C. A **positive** phase angle

E5C04 (D) Which of the following represents a **capacitive reactance in polar** coordinates? D. A **negative** phase angle



E5C14 (B) Which point on Figure E5-2 best represents that impedance of a series circuit consisting of a 400 ohm resistor and a 38 picofarad capacitor at 14 MHz? B. **Point 4**

R = 400 & X

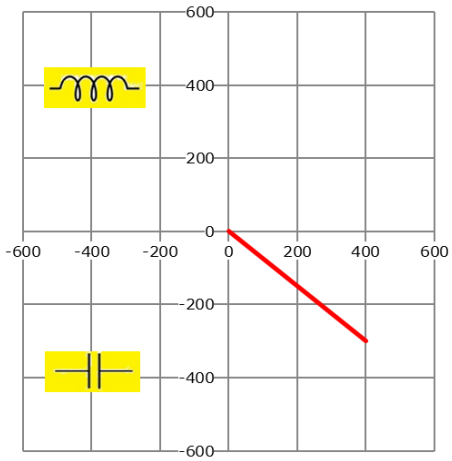
= 1/ (2 π FC) = X

= 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 5-2, 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.

E5C15 (B) Which point in Figure E5-2 best represents the impedance of a series circuit consisting of a 300 ohm resistor and an 18 microhenry inductor at 3.505 MHz? B. **Point 3**

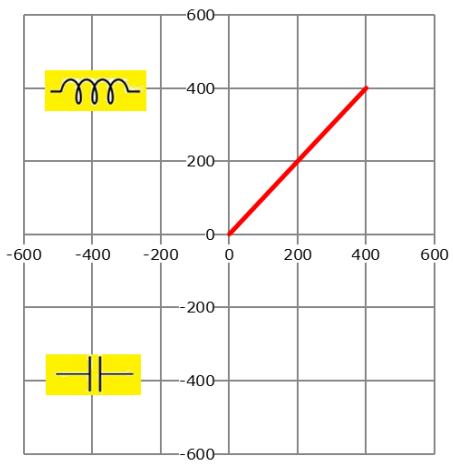
R = 300 & X

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 5-2, 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. As the MHz and Mico cancel each other the X will be several hundred. Point 3 is the answer as 8 is very small. X = 6 X 3.5 X 18 = 378

E5C16 (A) Which point on Figure E5-2 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**

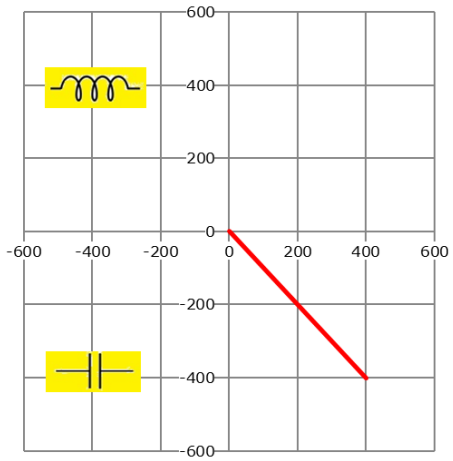
R = 300 & X

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 5-2, 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.

E5C17 (D) Which point on Figure E5-2 best represents the impedance of a series circuit consisting of a 300-ohm resistor, a 0.64-microhenry inductor and an 85-picofarad capacitor at 24.900 MHz? **D. Point 8**

R = 300 & XL + XC

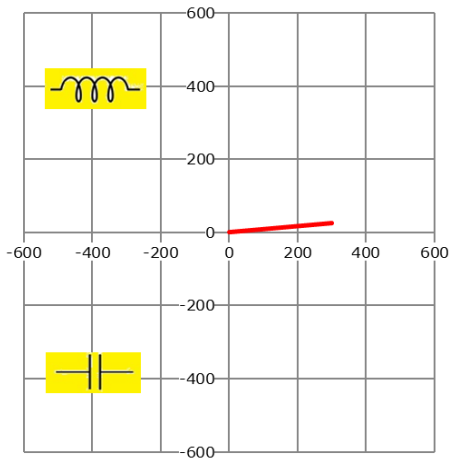
XL = 2 π FL = 100.13 **Ω**

XC = 1/ (2 π FC) = -75.20 **Ω**

X = 100 j – 75 j

X = 25 j

300 R + 25 j



Editor's note: Solving the question graphically requires the process of elimination. The R=300 has three possible point in Figure 5-2, points: 1, 3, 8. The reactance is given as an inductance, capacitance and frequency. Graphics alone will not solve the problem.

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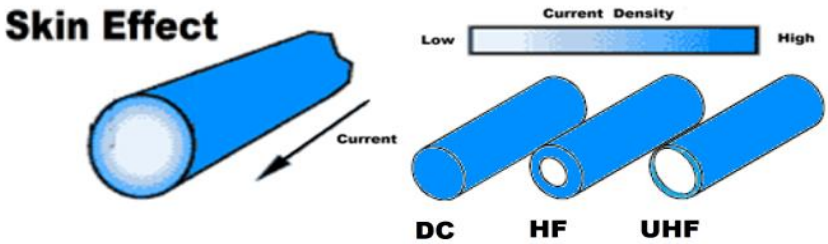
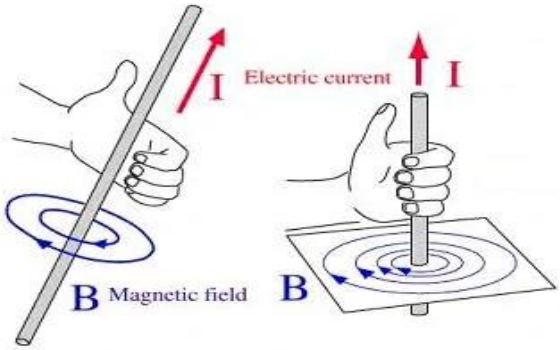
Skin Effect / E & H Fields / Power Factors



SKIN EFFECT >> As frequency increases, RF current flows closer to the surface of the conductor

SKIN EFFECT is why the resistance at RF currents is different at DC



Electric current creates a magnetic field

MAGNETIC FIELD around a conductor is determined by the left-hand rule

Current determines the **strength** of a magnetic field around a conductor

Potential energy is stored in an electromagnetic or electrostatic field

A **capacitor** stores electrical energy in an electrostatic field

==========

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

E5D02 (B) Why is it important to keep **lead lengths short** for components used in circuits for VHF and above? B. To avoid **unwanted inductive reactance**

E5D04 (B) Why are short connections necessary at **microwave frequencies**? B. To reduce **phase shift** along the connection

E5D05 (A) Which **parasitic characteristic** increases with conductor length? A. **Inductance**

E5D06 (D) In what direction is the magnetic field oriented about a conductor in relation to the direction of **electron flow? D. In a direction determined by the left-hand rule**

E5D07 (D) What determines the strength of a **magnetic field around** a conductor? D. The amount of **current flowing** through the conductor

E5D08 (B) What type of energy is stored in an **electromagnetic or electrostatic field**? B. **Potential energy**

E5D09 (B) What happens to reactive power in an AC circuit that has both **ideal inductors and ideal capacitors**? B. It is repeatedly exchanged between the associated magnetic and electric fields, but is **not dissipated**

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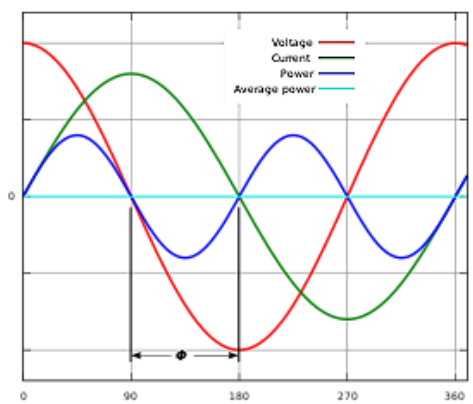
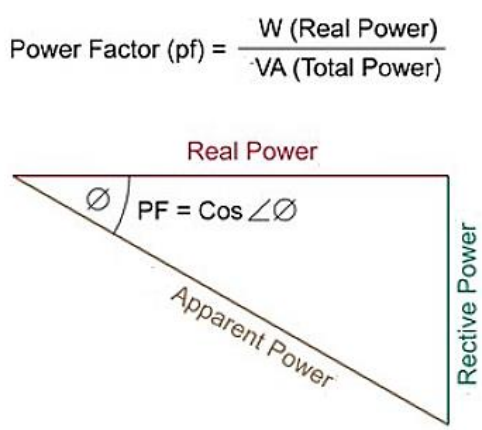


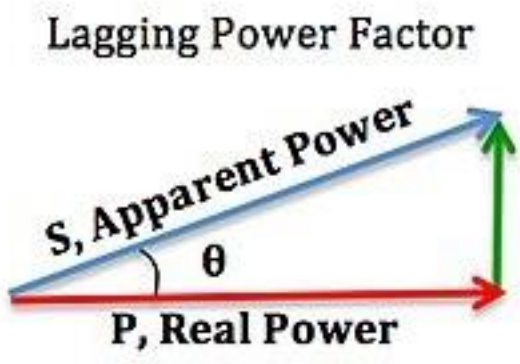


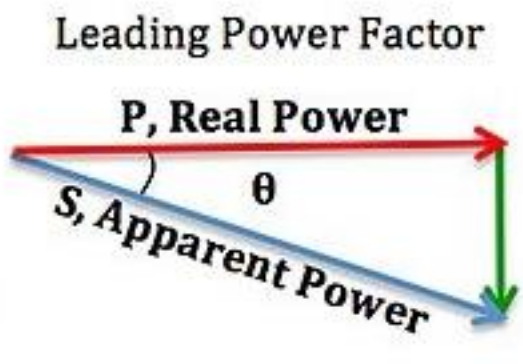
Wattless, nonproductive power is **REACTIVE POWER**

REACTIVE POWER in an AC circuit is exchanged between magnetic and electric fields, **but is not dissipated**

POWER FACTOR = Real Power (Watts) / Total Power (V x A)

POWER FACTOR = COS of (Voltage to Current) Phase





==========

E5D14 (A) What is **reactive** power? A. Wattless, **nonproductive** power

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 times the power factor

PF = COS (Voltage to Current Phase)

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? B. 80 watts

PF = Real Pwr / Total Pwr >> therefore >> **Real Pwr = PF x Total Pwr** = 0.2 x VA = 0.2 x 400 = 80 W

E5D13 (B) How much power is consumed in a circuit consisting of a 100 ohm resistor in series with a 100 ohm inductive reactance drawing 1 ampere? B. 100 watts

Trick question Resistor has **Real Power** >> therefore W = I^2 R >> **Real Pwr** = 1^2 x 100 = 100 W

E5D17 (D) How many watts are consumed in a circuit having a power factor of 0.6 if the input is 200 VAC at 5 amperes? D. 600 watts

PF = Real Pwr / Total Pwr >> therefore >> **Real Pwr = PF x Total Pwr** = 0.6 x VA = 0.6 x 1000 = 600 W

E5D18 (B) How many watts are consumed in a circuit having a power factor of 0.71 if the apparent power is 500 VA? B. 355 W

PF = Real Pwr / Total Pwr >> therefore >> **Real Pwr = PF x Total Pwr** = 0.71 x VA = 0.71 x 500 = 355 W

E5D11 (C) What is the power factor of an R-L circuit having a 60 degree phase angle between the voltage and the current? C. 0.5

PF = COS 60° = 0.5

E5D15 (D) What is the power factor of an R-L circuit having a 45 degree phase angle between the voltage and the current? D. 0.707

PF = COS 45° = 0.707

E5D16 (C) What is the power factor of an R-L circuit having a 30 degree phase angle between the voltage and the current? C. 0.866

PF = COS 30° = 0.866

==========

Inductor materials & design

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

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

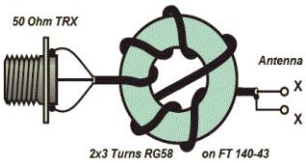
Toroidal cores confine most of the magnetic field within the core material unlike a solenoidal

20 Hz to 300 MHz is the usable frequency range of **inductors that use toroidal cores**

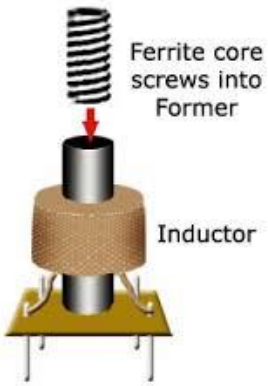
Ferrite beads are commonly used as VHF and UHF **parasitic suppressors** on amplifiers

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.


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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E6D15 (A) What is current in the primary winding of a transformer called if no load is attached to the secondary? A. **Magnetizing current**

E6D04 (B) Which materials are commonly used as a slug core in a variable inductor? B. **Ferrite and brass**

E6D14 (B) Which type of slug material **decreases inductance** when inserted into a coil? B. **Brass**

E6D05 (C) What is one reason for using ferrite cores rather than **powdered-iron** in an inductor? C. Ferrite toroids generally **require fewer turns** to produce a given inductance value

E6D06 (D) What **core material** property determines the inductance of a toroidal? D. **Permeability**

E6D07 (B) What is the usable **frequency range** of inductors that use toroidal cores, assuming a correct selection of core material for the frequency being used? B. From less **than 20 Hz to approximately 300 MHz**

E6D08 (B) What is one reason for using **powdered-iron cores** rather than ferrite cores in an inductor? B. Powdered-iron cores generally maintain their characteristics at **higher currents**

E6D09 (C) What devices are commonly used as VHF and UHF **parasitic suppressors** at the input and output terminals of a transistor HF amplifier? C. **Ferrite beads**

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

E6D12 (C) What is the definition of saturation in a ferrite core inductor? C. The ability of the inductor's core to **store magnetic energy is exceeded**

E6D17 (A) Why should **core saturation** of a conventional impedance matching transformer be avoided? A. **Harmonics and distortion** could result

E6D13 (A) What is the primary cause of inductor **self-resonance**? A. **Inter-turn capacitance**

==========

A_L VALUES

$$N\,turns = 100\sqrt{\frac{L(\mu H)}{A_L(\mu H / 100\,turns)}}$$

$$\text{Number of TURNS} = \sqrt{\frac{\text{Desired Inductance}}{A_L\ \text{Value}}}$$

$$N\,turns = 1000\sqrt{\frac{L(mH)}{A_L(mH / 1000\,turns)}}$$

==========

E6D01 (A) How many turns will be required to produce a **5**-microhenry inductor using a powdered-iron toroidal core that has an inductance index (A L) value of 40 microhenrys/100 turns? A. 35 turns

N = 100 x √ (L / AL) = 100 x √(5/40) = 100 x √(0.125) = 100 x 0. 0.353553 = **35.355** Turns

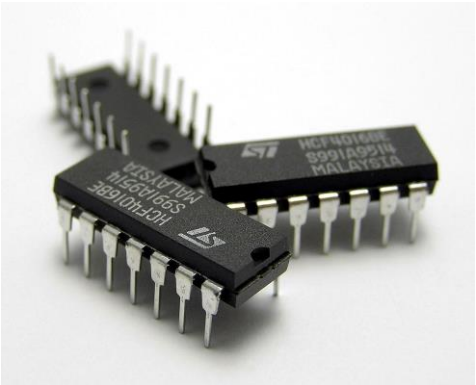
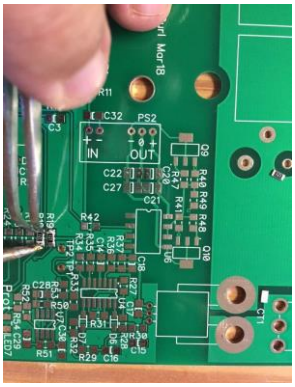
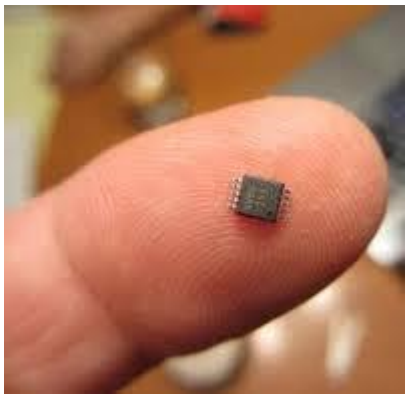
E6D11 (C) How many turns will be required to produce a **1**-mH inductor using a ferrite toroidal core that has an inductance index (A L) value of 523 millihenrys/1000 turns? C. 43 turns

N = 1000 x √ (L / AL) = 1000 x √(1/523) = 1000 x √(0.001912) = 1000 x 0.043727 = **43.727** Turns

==========

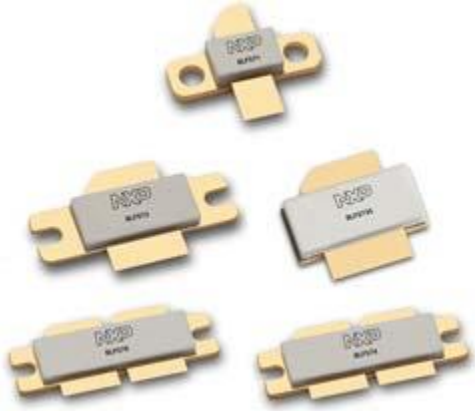
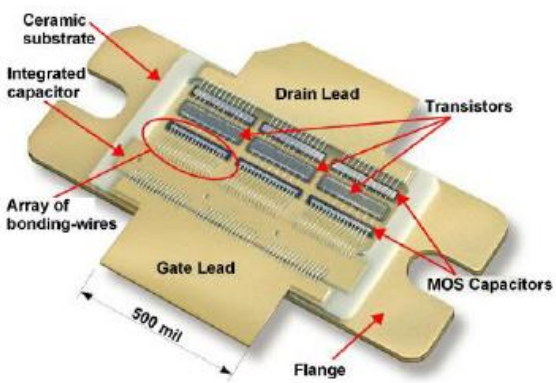
Component Packaging at RF

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 a rectangular, black, plastic housing. (Below-Left)

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.)

SMD devices are leadless solving most p**arasitic effects** in components dominate values when frequencies reach hundreds of megahertz, basic components such as resistors, inductors, and capacitors take on non-ideal characteristics.

Ceramic materials with high thermal conductivity used in high power RF ICs. (Above)

Ceramic packaging offers better heat conductivity than plastic, and can extend component life.

==========

E6E11 (D) What are the characteristics of DIP packaging used for integrated circuits? D. A total of two rows of connecting pins placed on opposite sides of the package **(Dual In-line Package)**

E6E02 (A) Which of the following device packages is a **through-hole** type? A. **DIP**

E6E09 (D) Which of the following component package types would be most suitable for use at frequencies above the HF range? D. **Surface-mount**

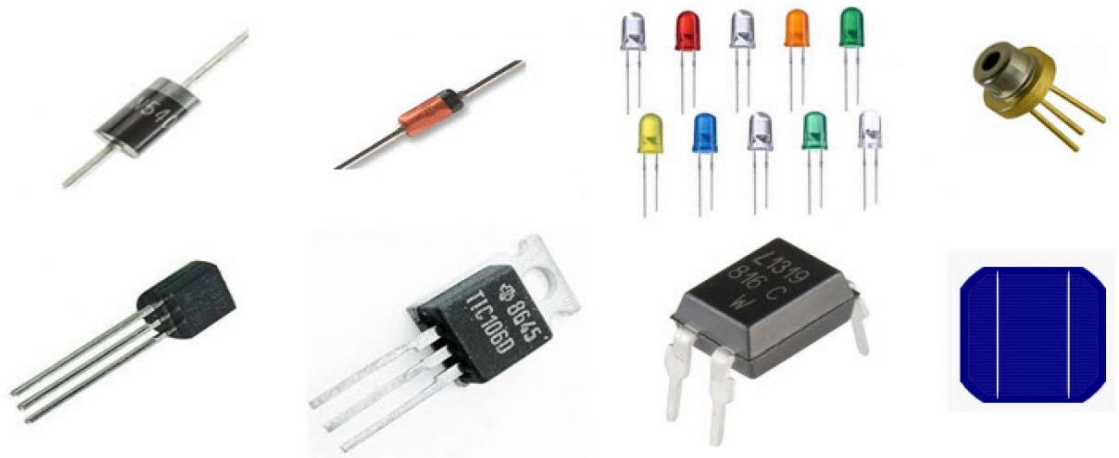
E6E10 (D) What is the packaging technique in which leadless components are soldered directly to circuit boards? D. **Surface mount**

E6E12 (B) Why are high-power RF amplifier ICs and transistors sometimes mounted in **ceramic packages? B. Better dissipation of heat**

==========

Chapter 5 Components and Building Blocks

Semiconductors



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

Free electrons are the majority **charge carriers in N-type** semiconductor material

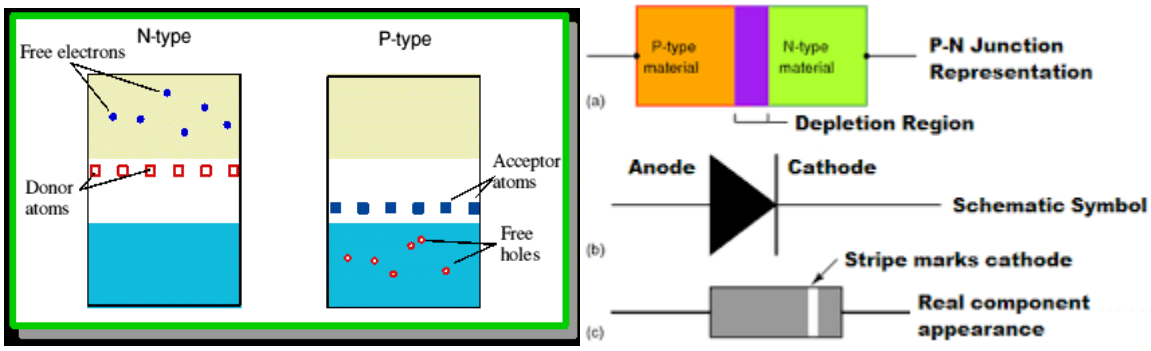
Holes are the majority **charge carriers in P-type** semiconductor material

A **P-type** semiconductor material contains an excess of **holes** in the outer shell of electrons

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

A **bipolar transistor has low input impedance**

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



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E6A04 (C) What is the name given to an impurity atom that **adds holes to a semiconductor** crystal structure? C. **Acceptor impurity**

E6A02 (A) Which of the following semiconductor materials contains **excess free electrons? A. N-type**

E6A16 (B) What are the majority charge carriers in **N-type** semiconductor material? B. **Free electrons**

E6A15 (B) Which of the following semiconductor materials contains an **excess of holes** in the outer shell of electrons? B. **P-type**

E6A01 (C) In what application is **gallium arsenide** used as a semiconductor material in preference to germanium or silicon? C. At **microwave frequencies**

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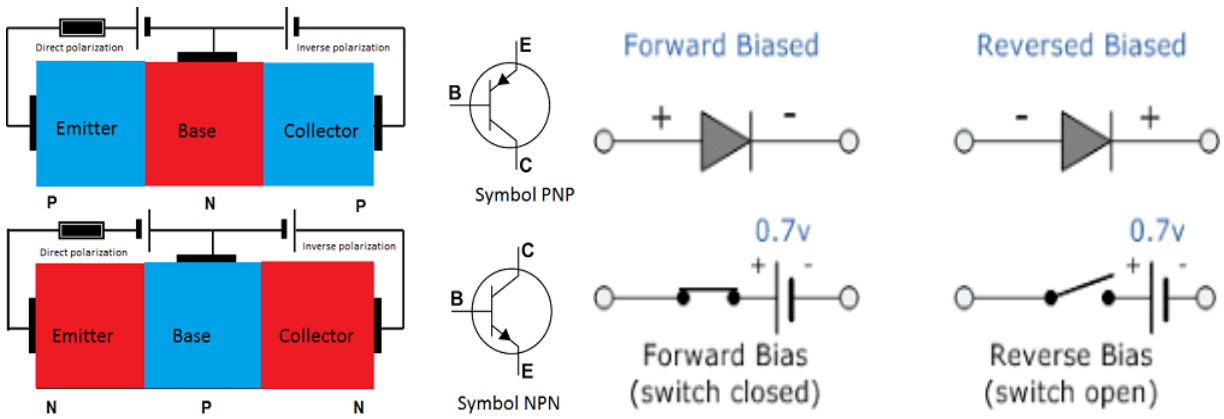


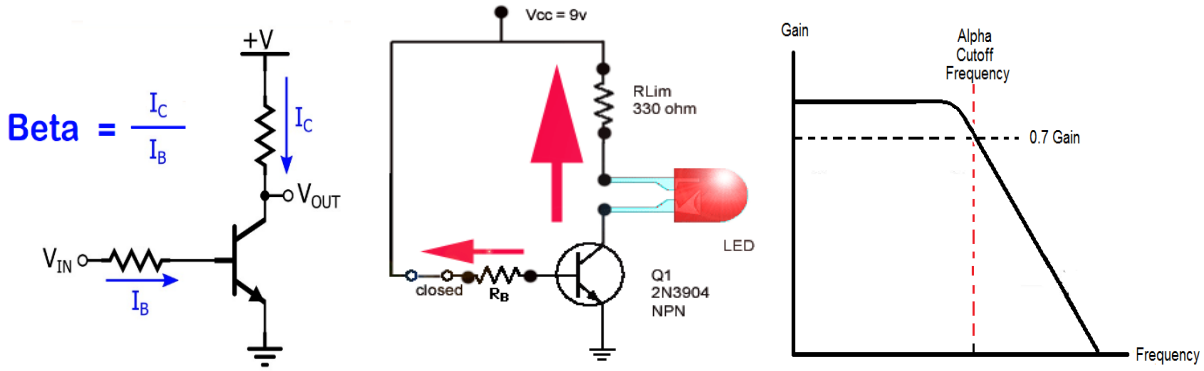
The **silicon diodes the forward bias voltage is 0.7 volts.**

Germanium diode forward bias voltage is 0.3 volts.

The change of **collector current with respect to emitter current** is the **alpha** of a bipolar junction transistor

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

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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E6A03 (C) Why does a PN-junction diode not conduct current when **reverse biased**? C. Holes in the P-type material and electrons in the N-type material are separated by the applied voltage**, widening the depletion region**

E6A05 (C) What is the **alpha** of a bipolar junction transistor? C. The change of **collector current with respect to emitter current**

E6A06 (B) What is the **beta** of a bipolar junction transistor? B. The change in **collector current with respect to base current**

E6A07 (D) Which of the following indicates that a **silicon NPN** junction transistor is biased on? 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? D. **Alpha cutoff frequency**

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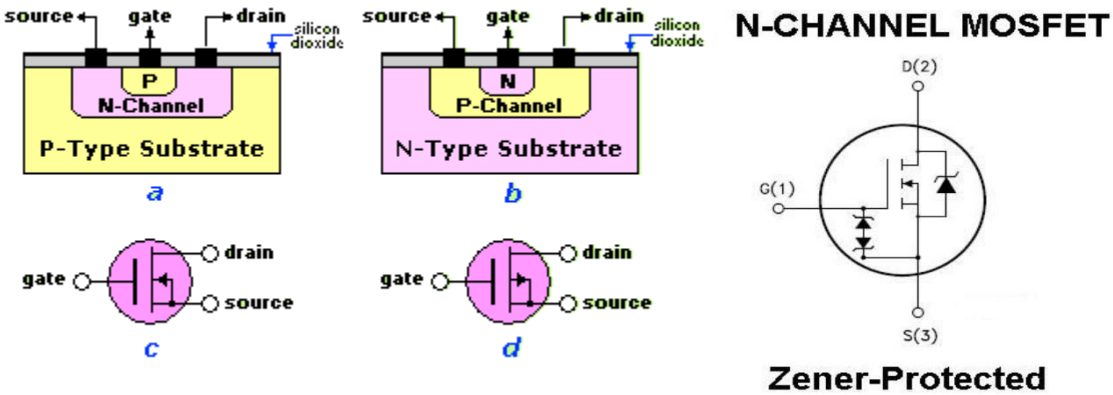


E6A17 (D) What are the names of the three terminals of a **field-effect transistor? D. Gate, drain, source**

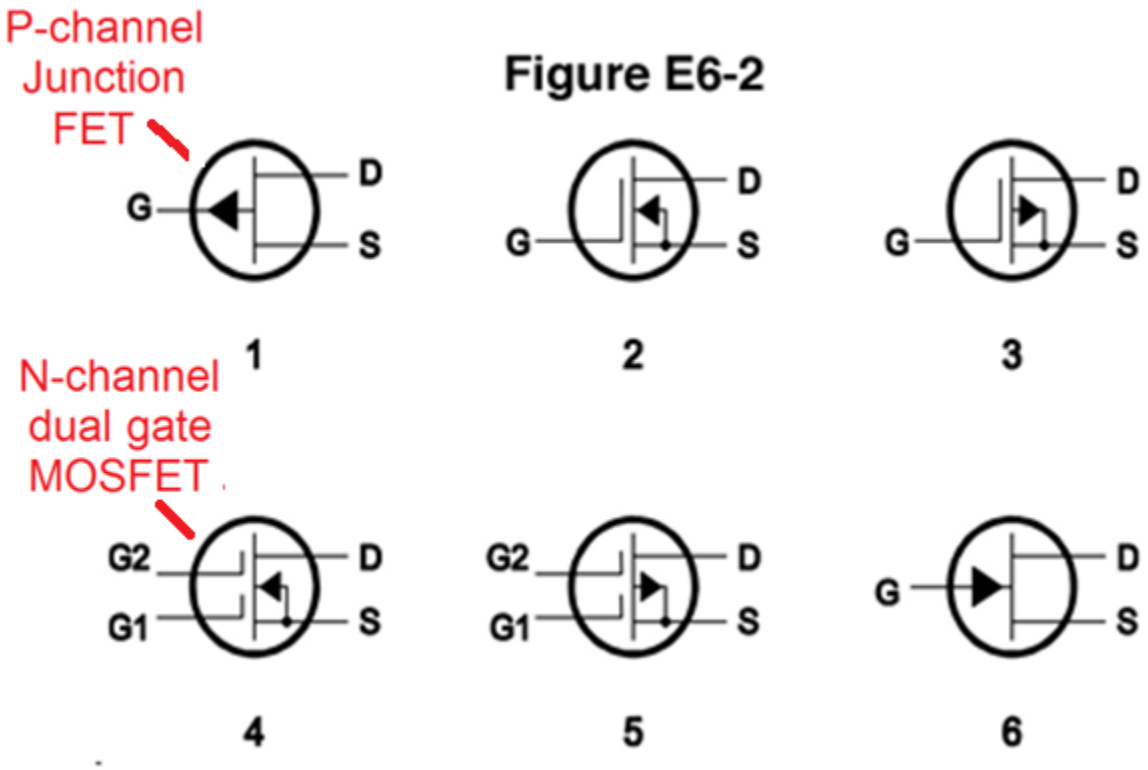
E6A14 (C) How does DC input impedance at the gate of a field-effect transistor compare with the DC input impedance of a bipolar transistor? C. An **FET has high input impedance**; a bipolar transistor has low input impedance

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

E6A12 (D) Why do many MOSFET devices have internally connected **Zener diodes on the gates**? D. To reduce the chance of the gate insulation being punctured by **static discharges or excessive voltages**

E6A13 (C) What do the initials **CMOS stand for? C. Complementary Metal-Oxide Semiconductor**

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



E6A10 (B) In Figure E6-2, what is the schematic symbol for an **N-channel dual-gate MOSFET**? B. 4

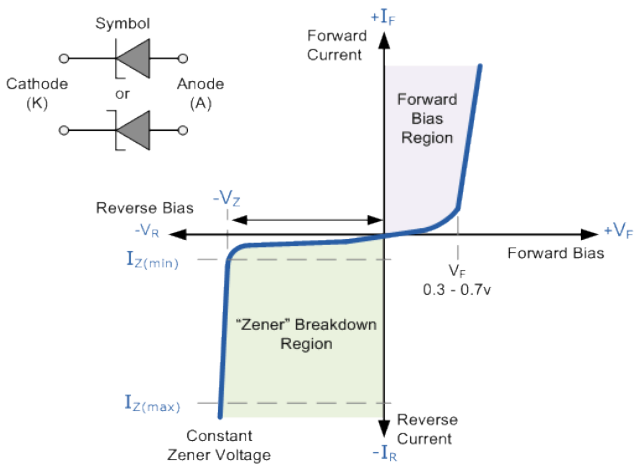
==========

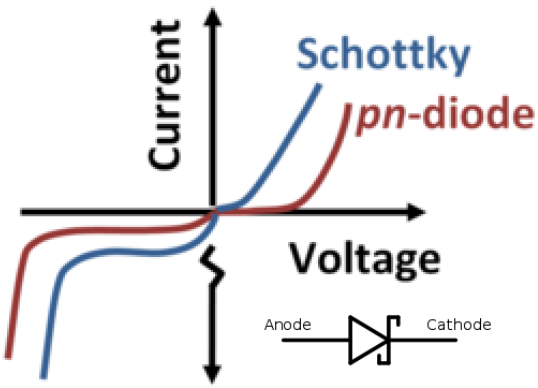
Diodes

Metal-semiconductor junction describes a type of semiconductor diode

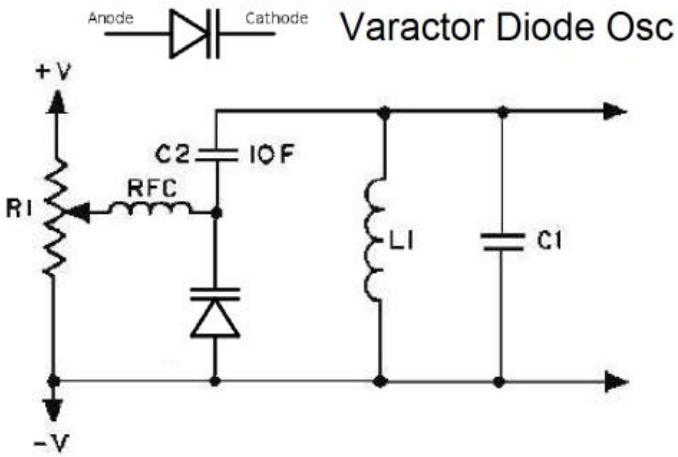
Excessive junction temperature is the failure mechanism when a **junction diode fails** due to excessive current

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

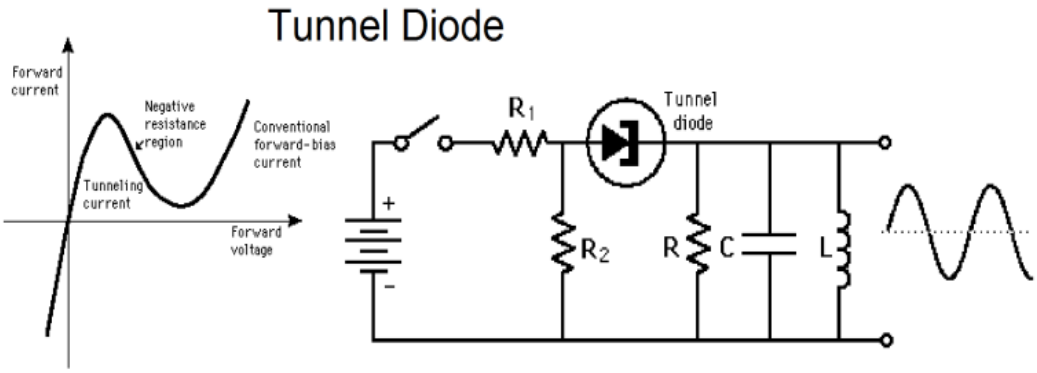




A **Schottky diode has less forward voltage drop** silicon diode when used as a power supply rectifier



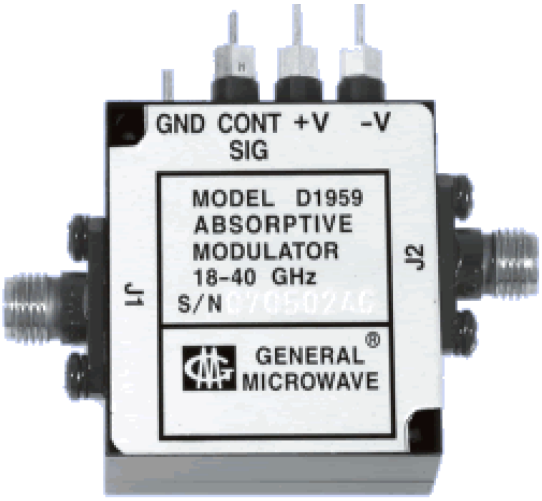
A **Varactor diode** is designed for use as a **voltage-controlled capacitor**

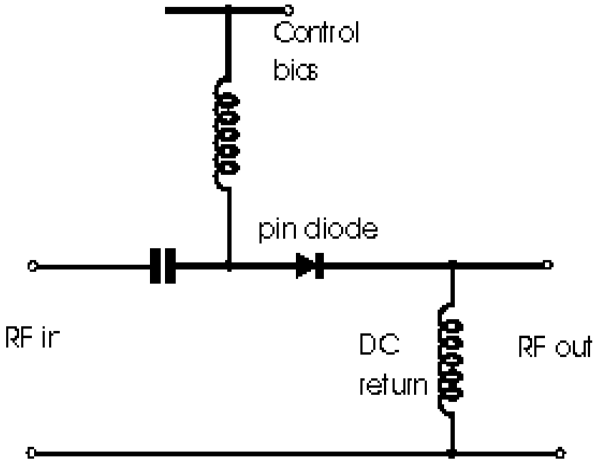


A **Tunnel diode** is capable of both **amplification and oscillation**

A **VHF / UHF mixer or detector** is a common use of a **hot-carrier diode**

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





A **PIN diode has a large region of intrinsic material** making it useful as an **RF switch or attenuator**

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

An **RF switch** is one common use for **PIN diodes**

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

==========

E6B01 (B) What is the most useful characteristic of a **Zener diode**? A. B. A **constant voltage** drop under conditions of varying current

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? D. **Less forward voltage drop**

E6B03 (C) What special type of diode is capable of both **amplification and oscillation? C. Tunnel**

E6B04 (A) What type of semiconductor device is designed for use as a **voltage-controlled capacitor? A. Varactor diode**

E6B05 (D) What characteristic of a **PIN diode** makes it useful as an RF switch or attenuator? D. A large region of **intrinsic material**

E6B11 (A) What is used to **control the attenuation of RF signals** by a PIN diode? A. Forward **DC bias** current

E6B12 (C) What is one common use for **PIN diodes? C. As an RF switch**

E6B06 (D) Which of the following is a common use of a **hot-carrier diode? D. As a VHF / UHF mixer** or detector

E6B07 (B) What is **the failure mechanism** when a junction diode fails due to excessive current? B. Excessive junction **temperature**

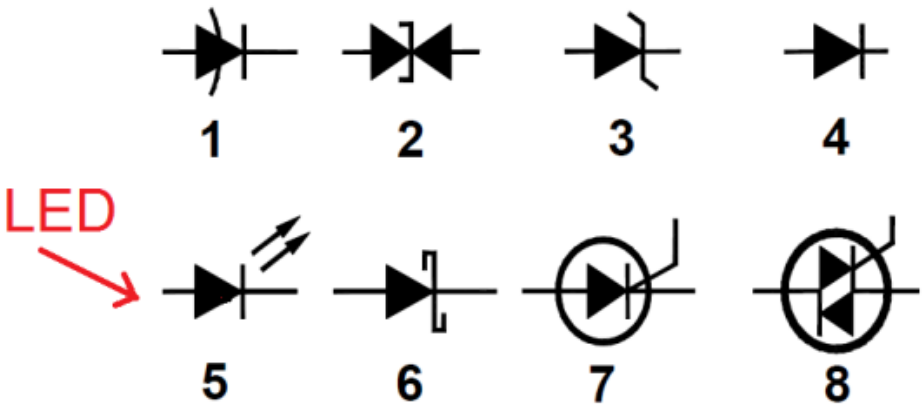
E6B08 (A) Which of the following describes a type of **semiconductor diode? A. Metal-semiconductor junction**

E6B09 (C) What is a common use for **point contact diodes? C. As an RF detector**

E6B13 (B) What type of bias is required for an **LED to emit light? B. Forward bias**

E6B10 (B) In Figure E6-3, what is the schematic symbol for a **light-emitting diode**? B. 5

Figure E6-3



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Digital Logic

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

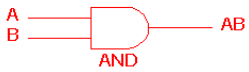
NAND gate produces a logic "0" at its output only when all inputs are logic "1"

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

==========

E7A11 (D) What type of logic defines "**1" as a high voltage? D. Positive Logic**

E7A12 (C) What type of logic defines "**0" as a high voltage? C. Negative logic**

E7A10 (C) What is a **truth table**? C. A **list of inputs and corresponding outputs** for a digital device

E7A08 (A) What logical operation does an **OR gate** perform? A. It produces a logic "1" at its output if any or **all inputs are logic "1"**

E7A09 (C) What logical operation is performed by a two-input exclusive **NOR gate**? C. It produces a logic **"0" at its output if any single input is a logic “1”**

E7A07 (D) What logical operation does a **NAND gate** perform? D. It produces a **logic "0"** at its output only when **all inputs are logic "1"**

E6C03 (A) What is **tri-state logic**? A. Logic devices with **0, 1, and high impedance** output states

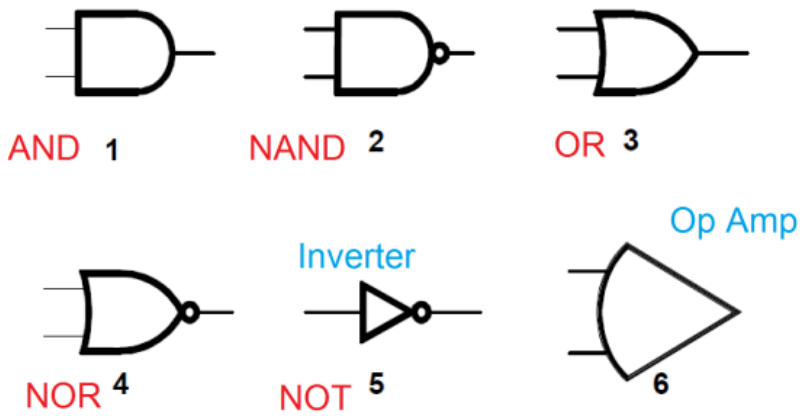
E6C04 (B) What is the primary advantage of **tri-state logic**? B. Ability to connect many device outputs to a **common bus**

E6C07 (B) What best describes a **"pull up" or "pull down" resistor**? 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

E6C05 (D) What is an advantage of **CMOS** logic devices over TTL devices? D. **Lower power** consumption

E6C06 (C) Why do **CMOS** digital integrated circuits have high immunity to noise on the input signal or power supply? C. The input **switching threshold is about one-half the power supply voltage**

Figure E6-5



E6C08 (B) In Figure E6-5, what is the schematic symbol for a **NAND** gate? B. 2

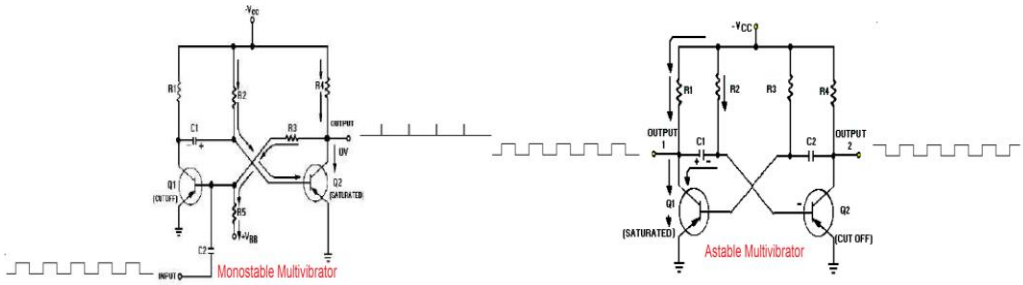
E6C10 (D) In Figure E6-5, what is the schematic symbol for a **NOR** gate? D. 4

E6C11 (C) In Figure E6-5, what is the schematic symbol for the **NOT** operation (inverter)? C. 5

==========

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

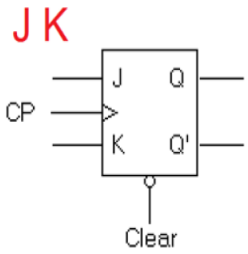
A **monostable multivibrator** switches momentarily to the opposite binary state and then returns, after a set time



A **flip-flop** is a bistable circuit

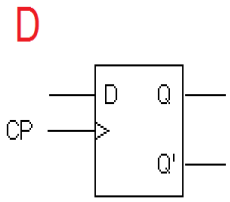
A **flip-flop** can **divide** the frequency of a pulse train by **2**

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



Inputs				Outputs	
Clear	Clock	J	K	Q	Q'
0	x	x	x	0	1
1	0→1	0	0	No change	
1	0→1	0	1	0	1
1	0→1	1	0	1	0
1	0→1	1	1	Toggle	

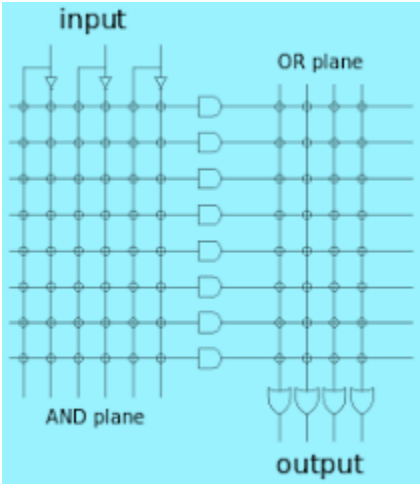
J K Q	Q(t+1)
0 0 0	0
0 1 0	0
1 0 0	1
1 1 0	1
0 0 1	1
0 1 1	0
1 0 1	1
1 1 1	0



Q D	Q(t+1)
0 0	0
0 1	1
1 0	0
1 1	1

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



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).*

==========

E7A01 (C) Which is a **bistable** circuit? A. C. A **flip-flop**

E7A03 (B) Which of the following can divide the frequency of a pulse train by 2? B. **A flip-flop**

E7A04 (B) How many **flip-flops** are required to divide a signal frequency by 4? **B. 2**

E7A02 (A) What is the function of a **decade counter** digital IC? A. It produces **one output pulse for every ten** input pulses

E7A05 (D) Which of the following is a circuit that continuously alternates between two states without an external clock? 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, after a set time, to its original state

E6C09 (B) What is a **Programmable Logic Device** (PLD)? A. B. A programmable collection of logic gates and circuits in a single integrated circuit

E6C12 (D) What is **BiCMOS logic**? A. D. An integrated circuit logic family using both bipolar and CMOS transistors

E6C13 (C) Which of the following is an advantage of **BiCMOS logic**? C. It has the high input impedance of CMOS and the low output impedance of bipolar transistors

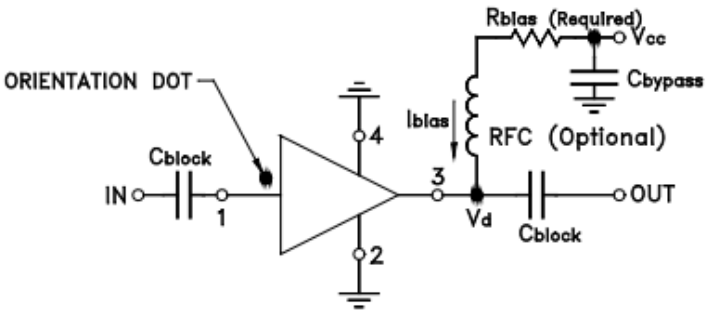
E6C14 (B) What is the primary advantage of using a **Programmable Gate Array (PGA)** in a logic circuit? B. Complex logic functions can be created in a single integrated circuit

==========

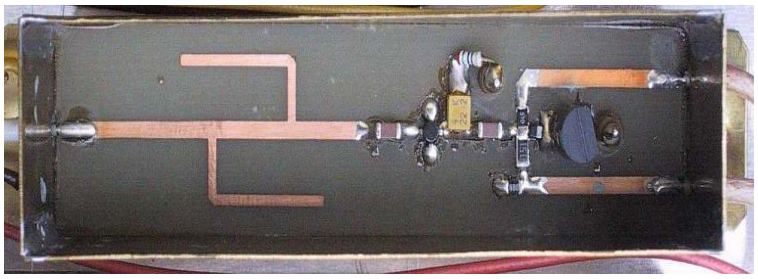
Special Function Integrated Circuits

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

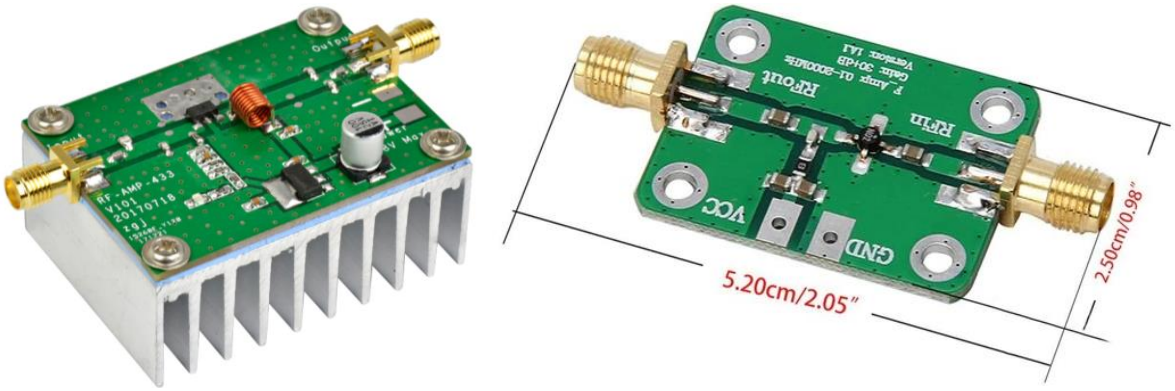
Controlled gain, low noise figure, constant impedance makes the **MMIC** good for VHF to microwave circuits



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



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

==========

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

E6E04 (A) What is the most common input and output impedance of circuits that use **MMICs? A. 50 ohms**

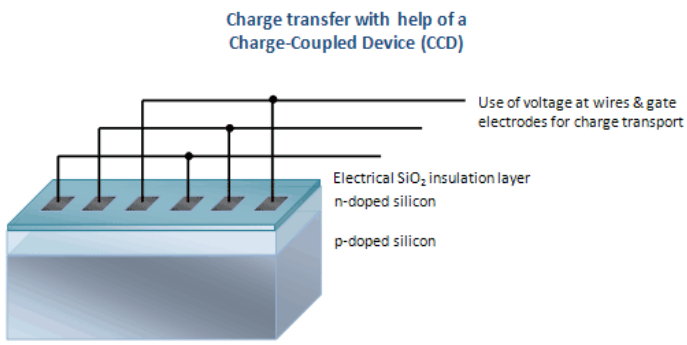
E6E06 (D) What characteristics of the **MMIC** make it a popular choice for VHF through microwave circuits? D. **Controlled gain, low noise figure,** and constant input and output impedance over the specified frequency range

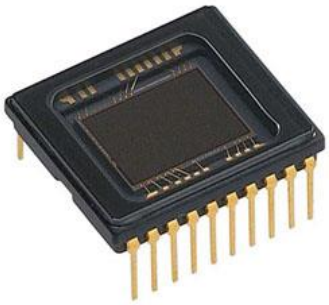
E6E08 (A) How is voltage from a **power supply** normally furnished to the most common type of monolithic microwave integrated circuit (MMIC)? A. Through a resistor and/or **RF choke connected to the amplifier** output lead

E5D03 (D) What is **microstrip?** D. Precision printed circuit conductors above a ground plane to provide constant impedance interconnects at microwave frequencies

E6E07 (B) Which of the following is typically used to construct a MMIC-based microwave amplifier? B. **Microstrip construction**

==========

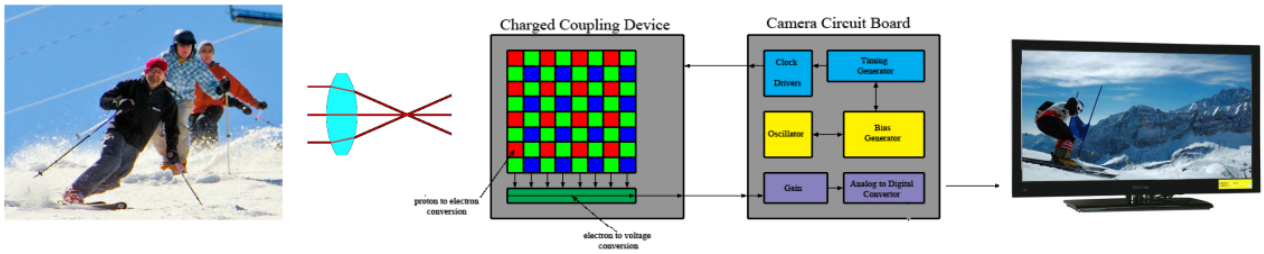




Editor's note: Charge-Coupled Devices use a thin silicon wafer chip. ... It is an integrated circuit etched onto a silicon surface forming light sensitive elements called pixels. Photons incident on this surface generate charge that can be read by electronics and turned into a digital copy of the light patterns falling on the device.

A **charge-coupled device (CCD) samples an analog signal** and passes it in stages from the input to the output

CCD in a modern video camera stores **photo-generated charges as signals corresponding to pixels**



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E6E01 (C) Which of the following is true of a **charge-coupled device (CCD)?** C. It samples an analog signal and passes it in stages from the input to the output

==========

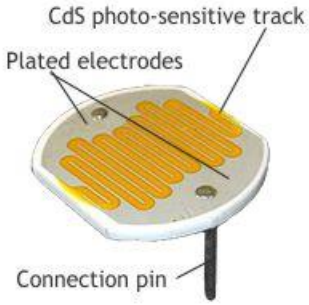
Optical & Display Devices

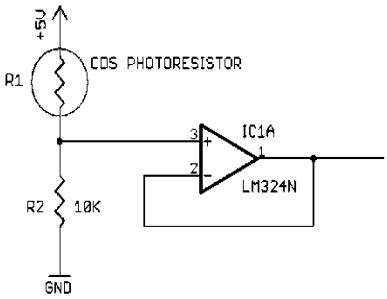
The **increased conductivity of an illuminated semiconductor** is **PHOTOCONDUCTIVITY**

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

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

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



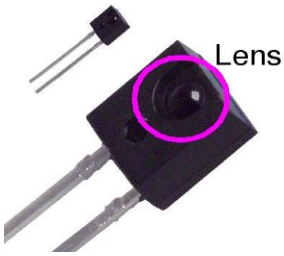


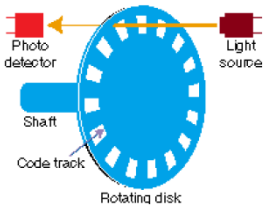
An **LED and a phototransistor** is the most common configuration of an **optoisolator** or optocoupler

A **solid state relay** uses semiconductor devices to implement the functions of an electromechanical relay

Optoisolators provide electrical isolation between a control circuit and the circuit being switched

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



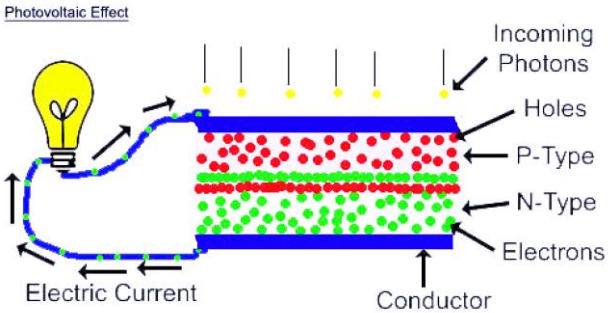


Electrons absorb the energy from light falling on a photovoltaic cell

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 (B) What is **photoconductivity?** B. The increased conductivity of an illuminated semiconductor

E6F02 (A) What happens to the conductivity of a **photoconductive material when light shines** on it? A. **It increases**

E6F04 (B) What is the **photovoltaic effect?** B. The conversion of **light to electrical energy**

E6F06 (A) Which of these materials is affected the most by **photoconductivity? A. A crystalline semiconductor**

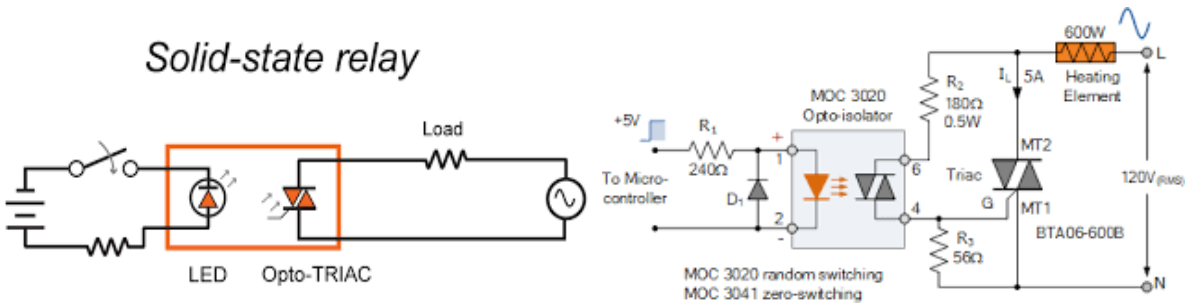
E6F09 (D) What is the **efficiency** of a photovoltaic cell? D. The **relative fraction of light that is converted to current**

E6F10 (B) What is the most **common type of photovoltaic cell** used for electrical power generation? B. **Silicon**

E6F11 (B) Which of the following is the approximate open-circuit voltage produced by a fully-illuminated **silicon photovoltaic cell? B. 0.5**

E6F12 (C) What absorbs the energy from **light falling on a photovoltaic cell? B. Photons**

==========



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E6F03 (D) What is the most common configuration of an optoisolator or **optocoupler? D. An LED and a phototransistor**

E6F07 (B) What is a **solid state relay**? B. A device that uses semiconductors to implement the functions of an electromechanical relay

E6F08 (C) Why are **optoisolators** often used in conjunction with solid state circuits when switching 120 VAC? C. Optoisolators provide a very **high degree of electrical isolation between a control circuit and the circuit being switched**

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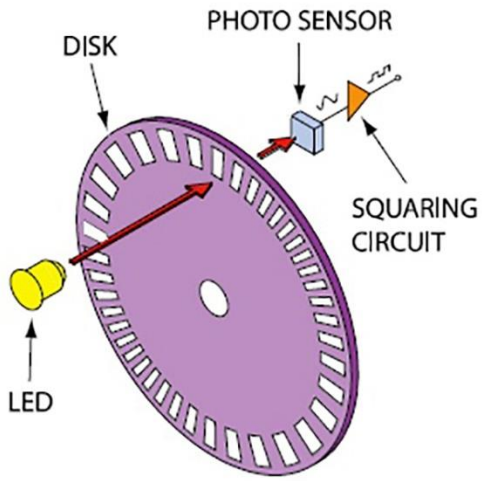

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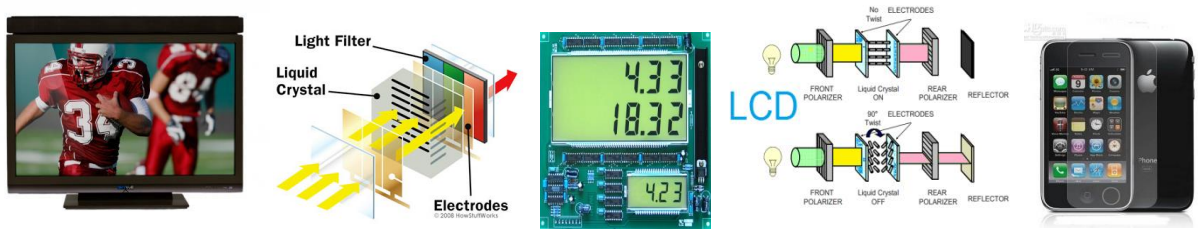
E6F05 (A) Which describes an **optical shaft encoder**? A. A device which detects rotation of a control by **interrupting a light source with a patterned wheel**

==========

A **liquid-crystal display (LCD)** uses **polarizing filters that become opaque when voltage is applied**

LCD devices consume less power than most other types of display devices



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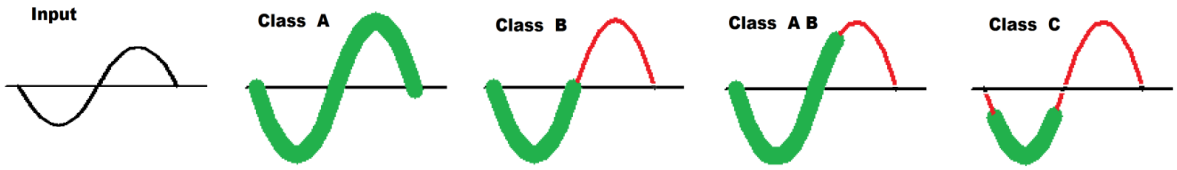
E6F13 (B) What is a liquid-crystal display (LCD)? B. A display using a crystalline liquid which, in conjunction with polarizing filters, becomes opaque when voltage is applied

E6F14 (B) Which of the following is true of LCD displays? B. They may be hard to view through polarized lenses

==========

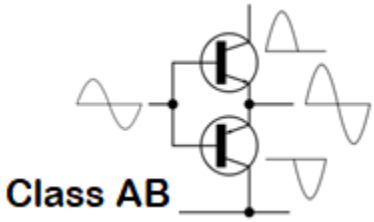
Chapter 6 Radio Circuits and Systems

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



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.

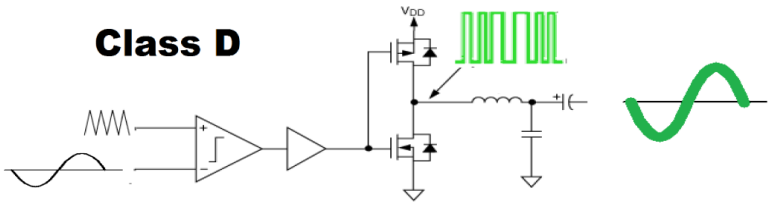
Class AB designs commonly use a **Push-pull amplifier to eliminate even-order harmonics**

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



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

==========

E7B04 (A) Where on the load line of a Class A common emitter amplifier would **bias normally** be set? A. Approximately **half-way between saturation and cutoff**

E7B01 (A) For what portion of a signal cycle does a **Class AB amplifier operate? A. More than 180** degrees but less than 360 degrees

E7B06 (B) Which of the following amplifier types reduces or **eliminates even-order harmonics? B. Push-pull**

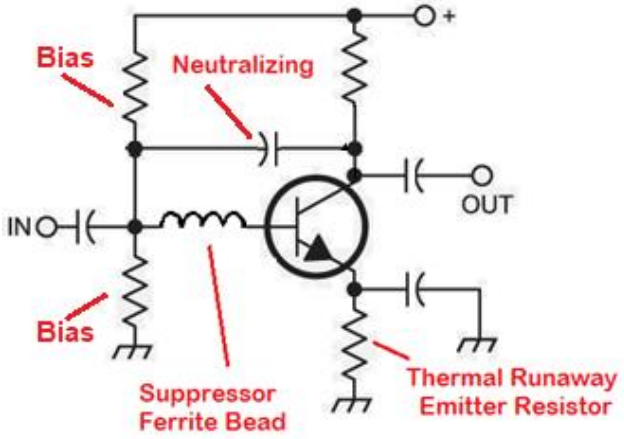
E7B07 (D) Which of the following is a likely result when a **Class C amplifier** is used to amplify a single-**sideband phone signal? D. Signal distortion and excessive bandwidth**

E7B02 (A) What is a **Class D amplifier**? A. A type of amplifier that uses switching technology to achieve **high efficiency**

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

E7B14 (B) Why are **switching amplifiers more efficient than linear** amplifiers? B. The power transistor is at **saturation or cut off** most of the time, resulting in low power dissipation

==========



Excessive gain or positive feedback may cause amplifier instability

Parasitics are oscillations that are not related to the operating frequency of an amplifier

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

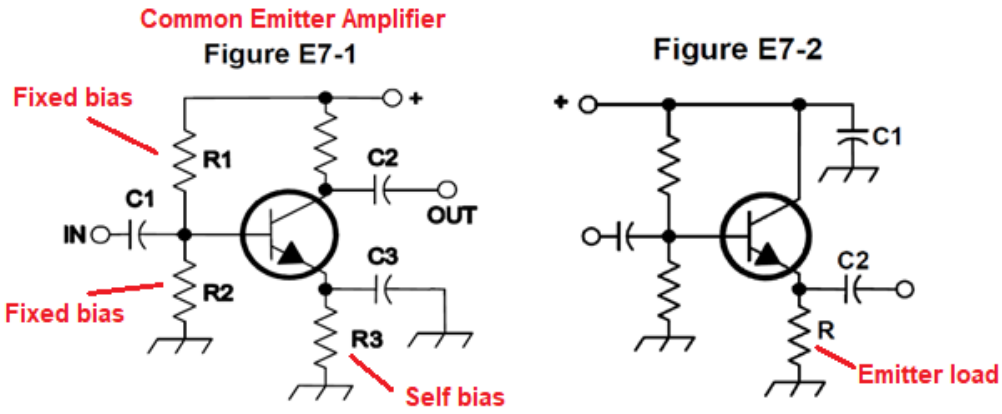
Use a **resistor in series with the emitter** to prevent **thermal runaway** in a bipolar transistor amplifier

==========

E7B05 (C) What can be done to **prevent unwanted oscillations** in an RF power amplifier? C. Install **parasitic suppressors and/or neutralize the stage**

E7B08 (C) How can an **RF power amplifier be neutralized**? C. By **feeding a 180-degree out-of-phase** portion of the output back to the input

E7B15 (C) What is one way to prevent **thermal runaway in a bipolar transistor amplifier**? C. Use a **resistor in series with the emitter**



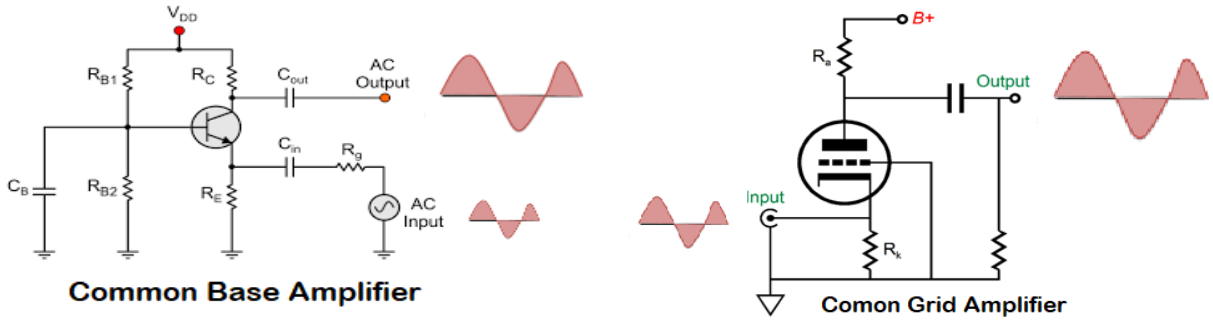
E7B10 (B) In Figure E7-1, what is the purpose of R1 and R2? B. Fixed bias

E7B11 (D) In Figure E7-1, what is the purpose of R3? D. Self bias

E7B12 (C) What type of amplifier circuit is shown in Figure E7-1? C. Common emitter

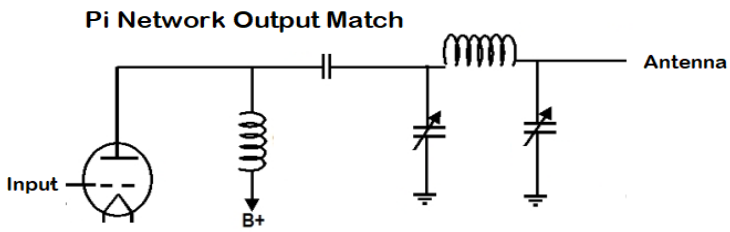
E7B13 (A) In Figure E7-2, what is the purpose of R? A. Emitter load B. Fixed bias C. Collector load D. Voltage regulation

==========



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

Ground Grid Amplifier Input on Cathode, output from plate, Low impedance input, High impedance output.



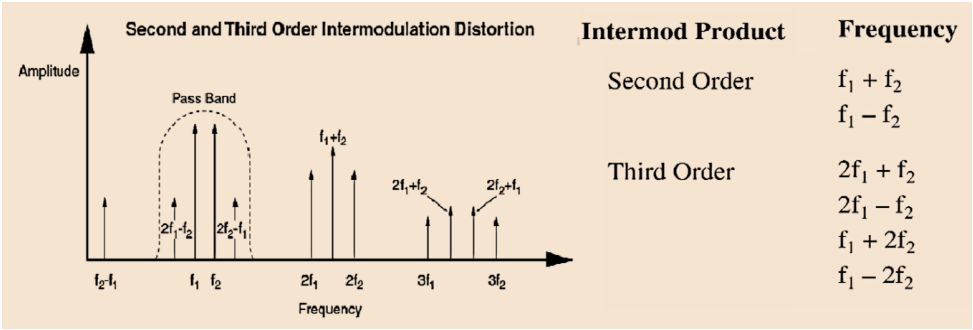
The typical HF vacuum tube RF amplifier has an VSWR mi**smatch between the final stage tube plate and the antenna** requiring a **Pi matching network for maximum power transfer** between the dissimilar **tube load impedance to antenna impedance,**

==========

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? D. The **tuning capacitor is adjusted for minimum** plate current, while the **loading capacitor is adjusted for maximum** permissible plate current

E7B18 (C) What is a characteristic of a **grounded-grid amplifier? C. Low input impedance**

==========



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

2 or more signals mixed to produce other signals

Even order products result in spurious signals

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

Nonlinearity produces distortion, resulting in harmonics

You can have low distortion or high efficiency, but not both

==========

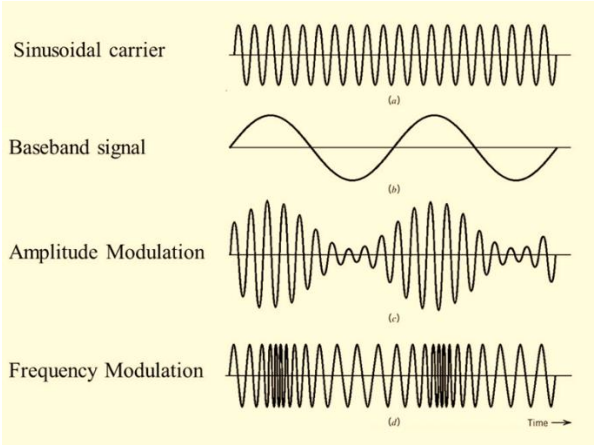
E7B16 (A) What is the effect of **intermodulation products** in a linear power amplifier? A. Transmission of **spurious signals**

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

==========

Modulation / Demodulation

The frequency components present in **the modulating signal is called BASEBAND**



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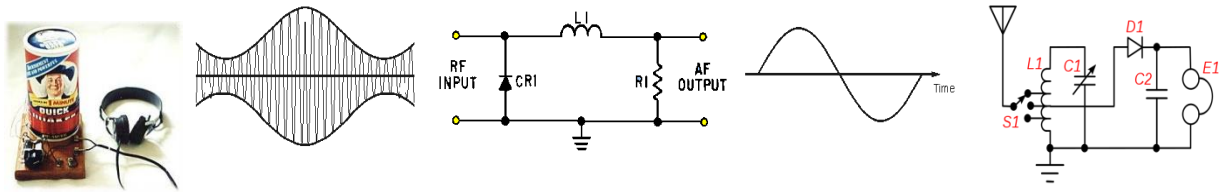
E7E07 (B) What is meant by the term **baseband** in radio communications? B. The frequency components present in the **modulating signal**

==========

A **diode detector** functions by rectification and filtering of RF signals



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E7E10 (A) How does a **diode detector function? A. By rectification and filtering** of RF signals

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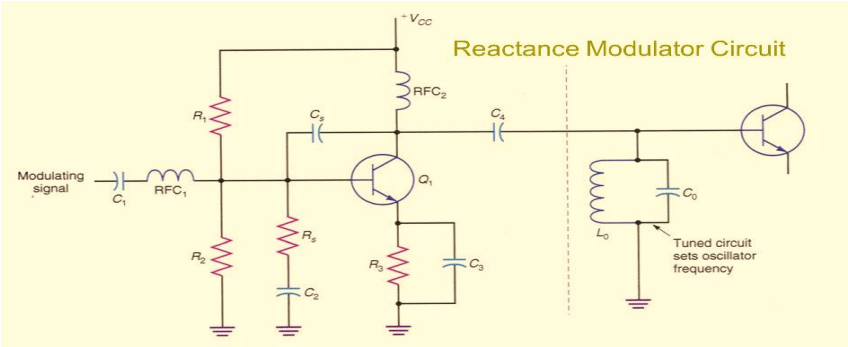


A **reactance modulator** on the oscillator can be used to generate **FM phone** emissions

The function of a **reactance modulator is to produce PM** signals by using an electrically variable inductance or capacitance

An analog **phase modulator** functions by varying the tuning of an amplifier tank circuit to **produce PM signals**

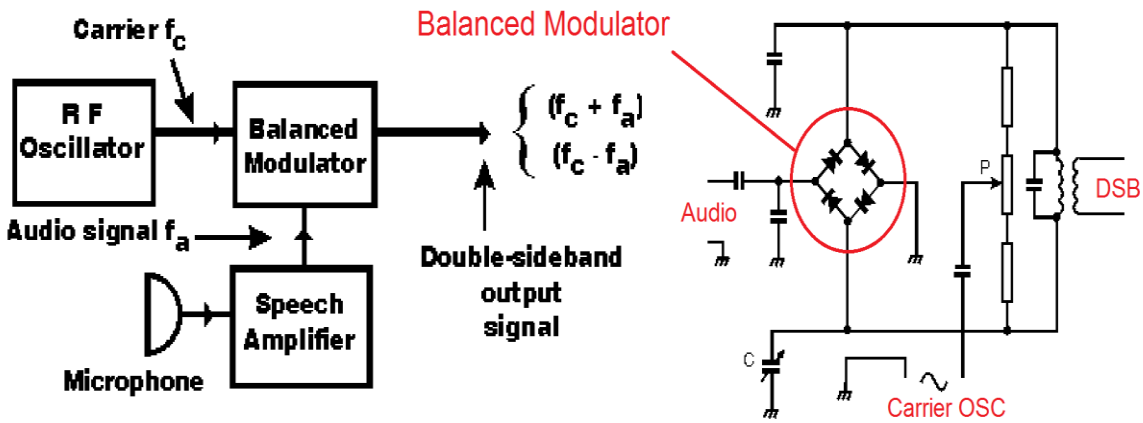
==========

E7E01 (B) Which of the following can be used to generate **FM phone** emissions? A. B. A **reactance modulator** on the oscillator

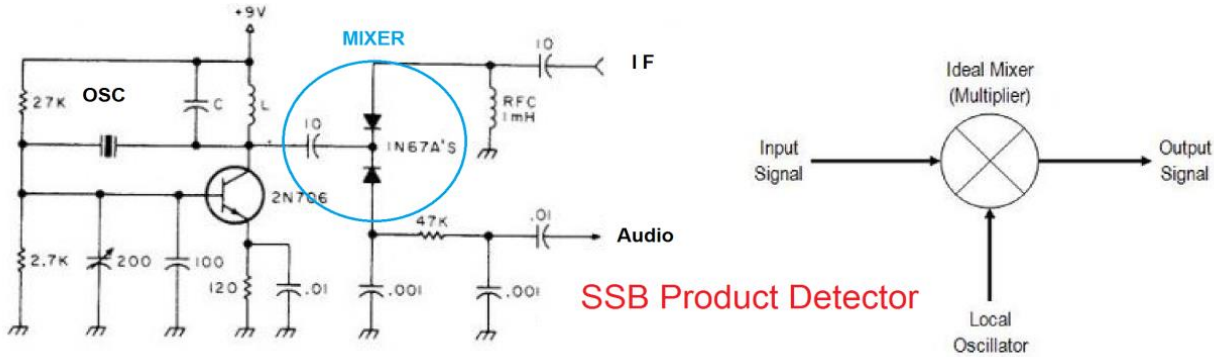
E7E02 (D) What is the function of a **reactance modulator? D. To produce PM signals** by using an electrically variable inductance or capacitance

E7E03 (C) How does an analog **phase modulator** function? C. By **varying the tuning of an amplifier tank** circuit to produce PM signals

==========



A **SSB phone** signal can be **generated** by using a **BALANCED modulator** followed by a filter



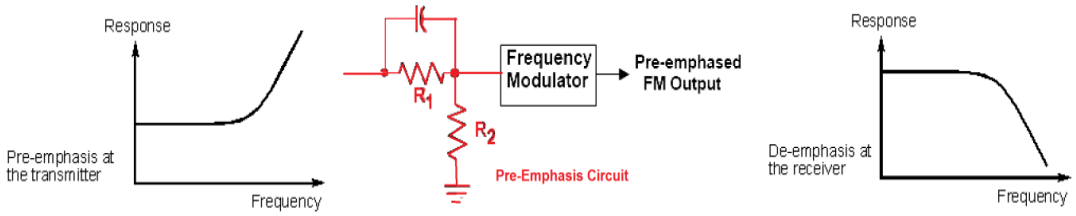
A **PRODUCT detector** is well suited for demodulating **SSB** signals

==========

E7E04 (A) What is one way a **single-sideband phone** signal can be generated? A. By using a **balanced modulator** followed by a filter

E7E11 (C) Which type of detector is used for **demodulating SSB signals? C. Product detector**

==========



A **pre-emphasis** network circuit is added to an **FM transmitter** to **boost the higher audio** frequencies

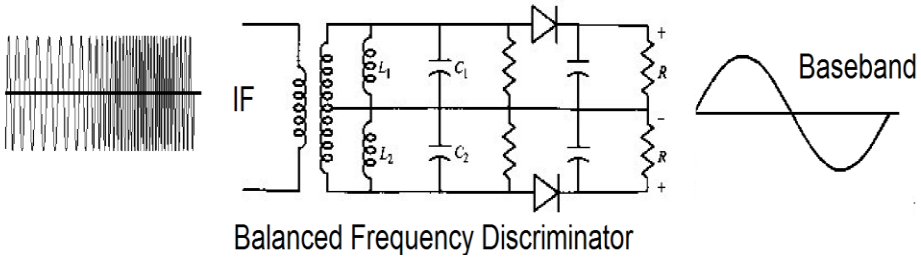
De-emphasis commonly used in FM communications receivers for compatibility with **transmitters using phase modulation**

==========

E7E05 (D) What circuit is added to an **FM transmitter to boost the higher audio** frequencies? 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

==========

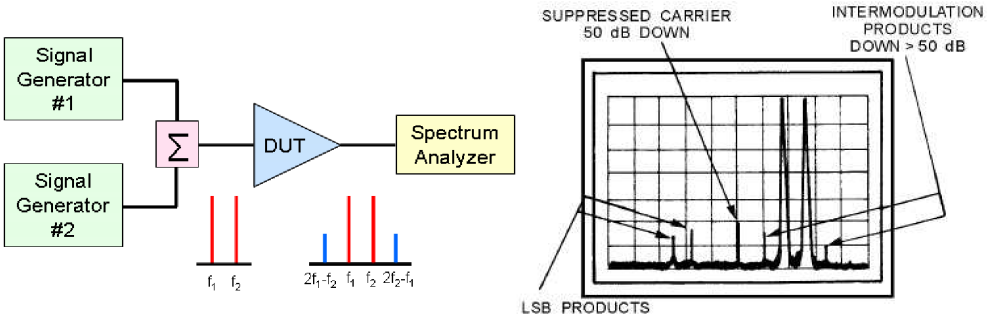


The **frequency DISCRIMINATOR** stage in a FM receiver is used for **detecting FM signals**

==========

E7E12 (D) What is a **freq discriminator stage in a FM** receiver? D. A circuit for **detecting FM signals**

==========



Input frequencies plus **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

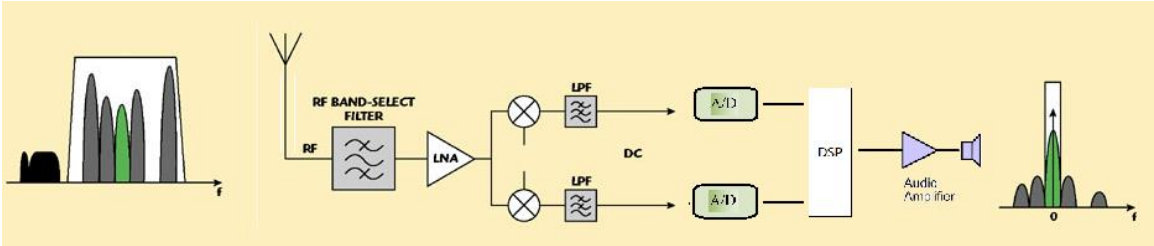
==========

E7E08 (C) What are the principal frequencies that appear at the output of a **mixer circuit? C. The two input frequencies along with their sum and difference frequencies**

E7E09 (A) What occurs when an **excessive amount of signal energy** reaches a mixer circuit? A. **Spurious mixer products** are generated

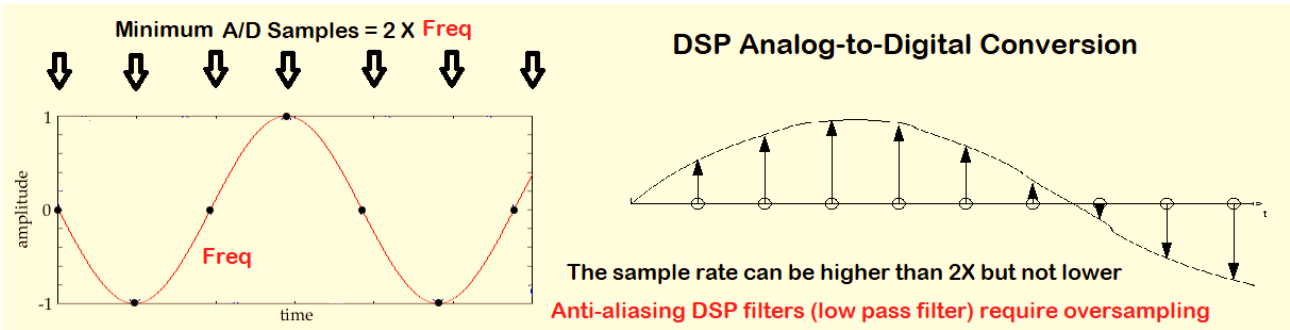
==========

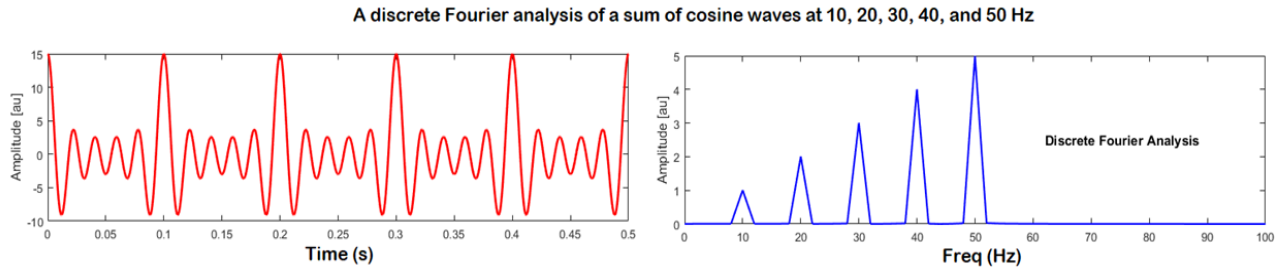
Digital Signal Processing



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

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

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

==========

E7F01 (C) What is meant by **direct digital conversion** as applied to software defined radios? C. Incoming RF is digitized by an analog-to-digital **converter without being mixed with a local oscillator** signal

E7F05 (B) How frequently must an analog signal be **sampled by an analog-to-digital** converter so that the signal can be accurately reproduced? B. At **twice the rate of the highest frequency** component of the signal

E7F17 (D) What do the **letters I and Q in** I/Q Modulation represent? D. **In-phase and Quadrature**

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? D. 10 bits**

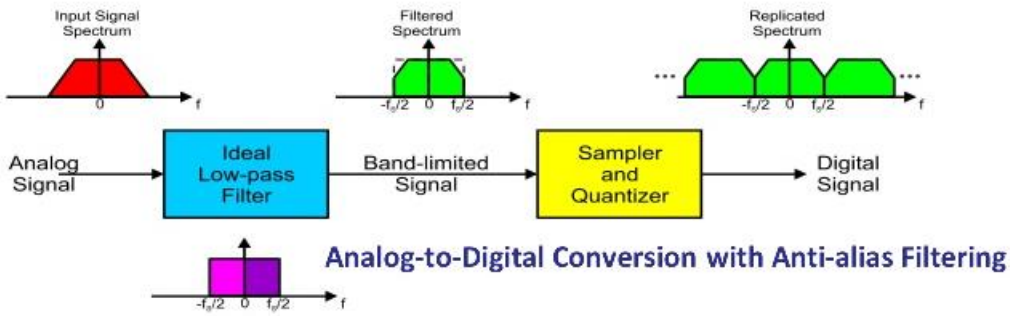
E7F07 (C) What functions can a **Fast Fourier Transform** perform? C. Converting digital signals from the **time domain to the frequency domain**

E7F10 (A) What aspect of receiver analog-to-digital conversion determines the **maximum receive bandwidth** of a Direct Digital Conversion SDR? A. **Sample rate**

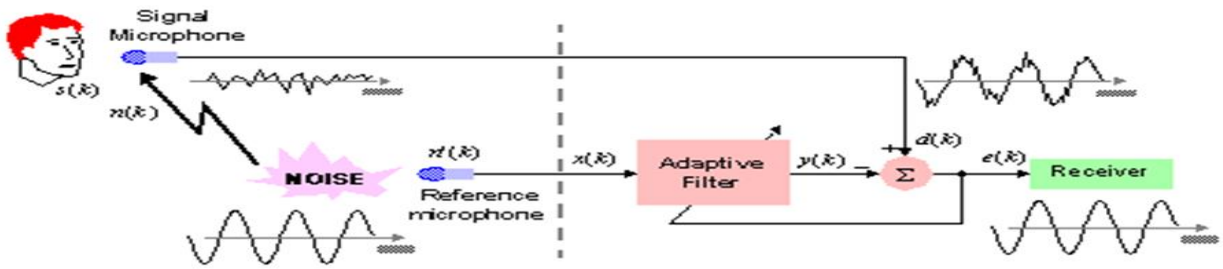
E7F11 (B) What sets the **minimum detectable signal level** for an SDR in the absence of atmospheric or thermal noise? B. **Reference voltage level and sample width in bits**

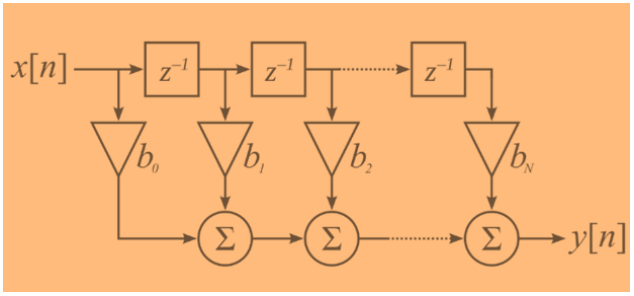
E7F12 (A) What digital process is applied **to I and Q signals** to recover the baseband modulation information? A. **Fast Fourier Transform**

==========



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.**





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.

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

==========

E7F09 (A) Why is an **anti-aliasing digital filter** required in a digital decimator? A. It removes high frequency signal components which would **otherwise be reproduced as lower frequency components**

E7F08 (B) What is the function of **decimation** with regard to digital filters? B. Reducing the effective sample rate by **removing samples**

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**

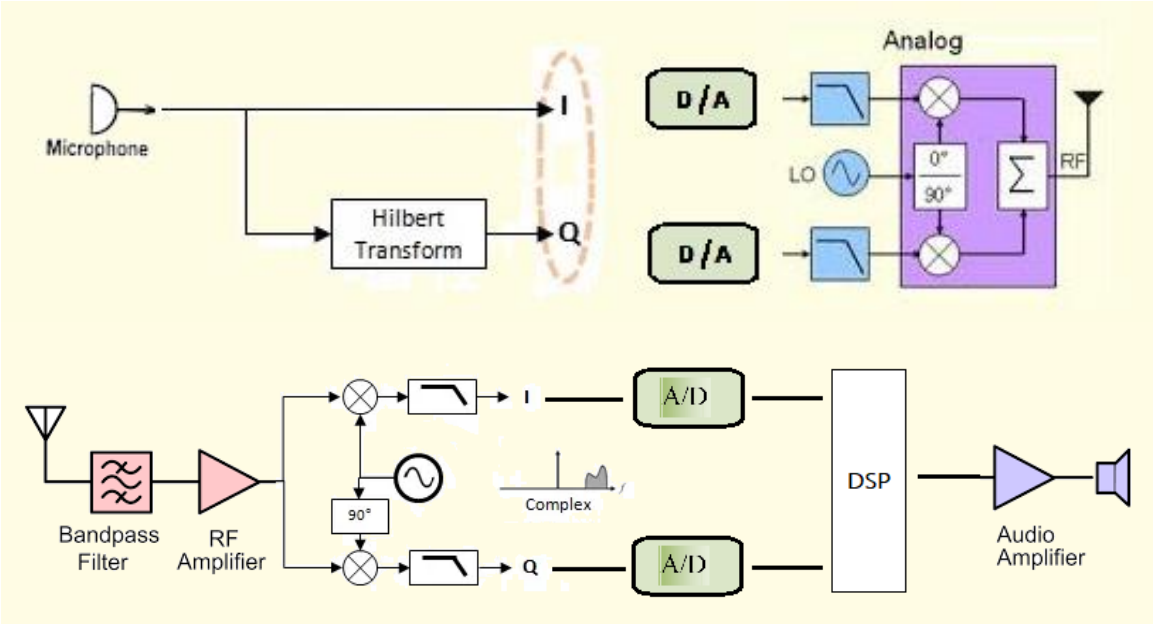
E7F13 (D) What is the **function of taps** in a digital signal processing filter? D. Provide incremental **signal delays** for filter algorithms

E7F15 (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 delay all frequency components** of the signal by the same amount

E7F14 (B) Which of the following would allow a digital signal processing filter to **create a sharper filter** response? D. **Double-precision math** routines

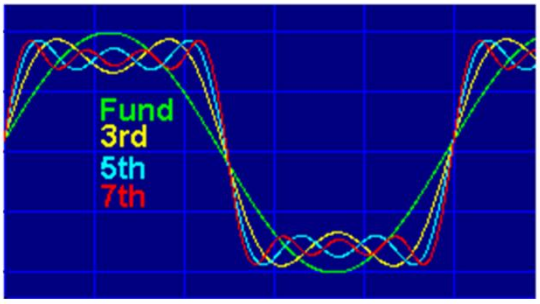
E7F16 (D) How might the **sampling rate** of an existing digital signal be adjusted by a **factor of 3/4**? D. **Interpolate by a factor of three, then decimate by a factor of four**

==========

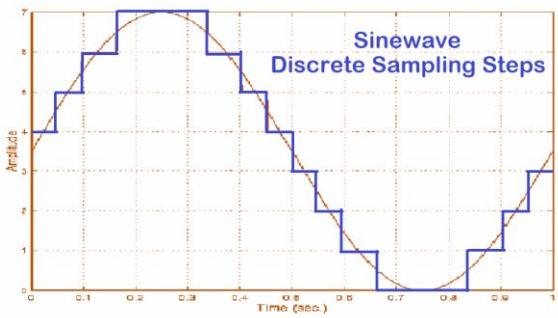


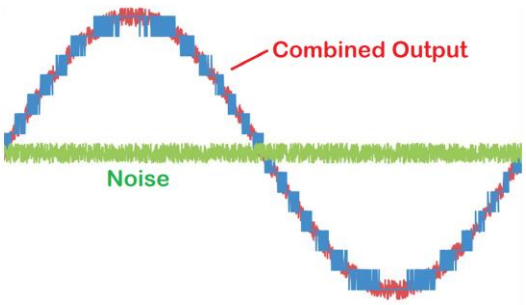
Editor's note: the Hilbert transform is a particularly simple representation in the frequency domain: it imparts a phase shift of 90° to every Fourier component of a function

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



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.*





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.

==========

E7F03 (C) What type of digital signal processing filter is used to **generate an SSB signal**? C. A **Hilbert-transform filter**

E7F04 (D) What is a common method of **generating an SSB** signal when using digital signal processing? D. **Combine signals with a quadrature phase** relationship

E8A01 (A) What is the name of the process that shows that a **square wave** is made up of a **sine wave plus all of its odd harmonics**? A. **Fourier analysis**

E8A04 (B) What is **"dither"** with respect to analog -to-digital converters? A B. A small amount of noise added to the input signal to allow **more precise representation of a signal over time**

E8A08 (C) Why would a **direct or flash** conversion analog-to-digital converter be useful for a software defined radio? C. Very high speed allows **digitizing high frequencies**

E8A09 (C) How many levels can an analog-to-digital converter with **8-bit resolution encode C. 256**

E8A10 (C) What is the purpose of a **low pass filter** used in conjunction with a **digital-to-analog converter**? C. **Remove harmonics** from the output caused by the discrete analog levels generated

E8A11 (D) What type of information can be conveyed using digital waveforms? A. Human speech B. Video signals C. Data **D. All of these choices are correct**

E8A12 (C) What is an advantage of using digital signals instead of analog signals to convey the same information? C. **Digital signals can be regenerated multiple times without error**

E8A13 (A) Which of these methods is commonly used to convert analog signals to digital signals? **A. Sequential sampling**

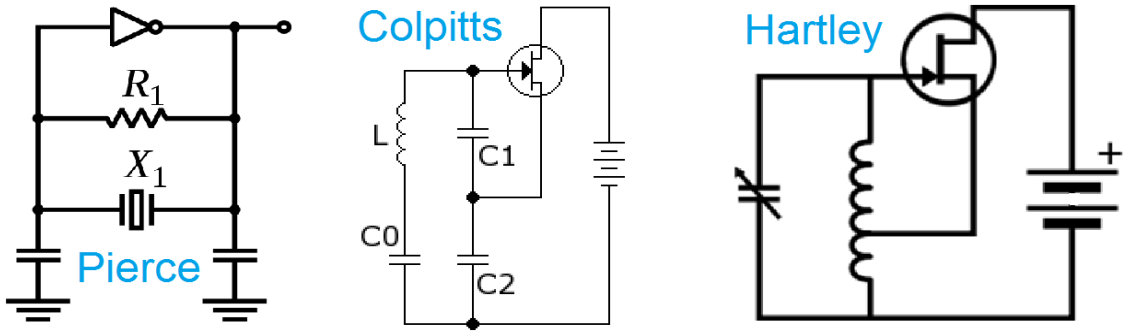
==========

Oscillators

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

Colpitts and Hartley oscillator circuits are commonly used in VFOs

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**

==========

E7H01 (D) What are three oscillator circuits used in Amateur Radio equipment? D. Colpitts, Hartley and Pierce

E7H03 (A) How is positive feedback supplied in a Hartley oscillator? A. Through a tapped coil

E7H04 (C) How is positive feedback supplied in a Colpitts oscillator? C. Through a capacitive divider

E7H05 (D) How is positive feedback supplied in a Pierce oscillator? D. Through a quartz crystal

E7H06 (B) Which of the following oscillator circuits are commonly used in VFOs? B. Colpitts and Hartley

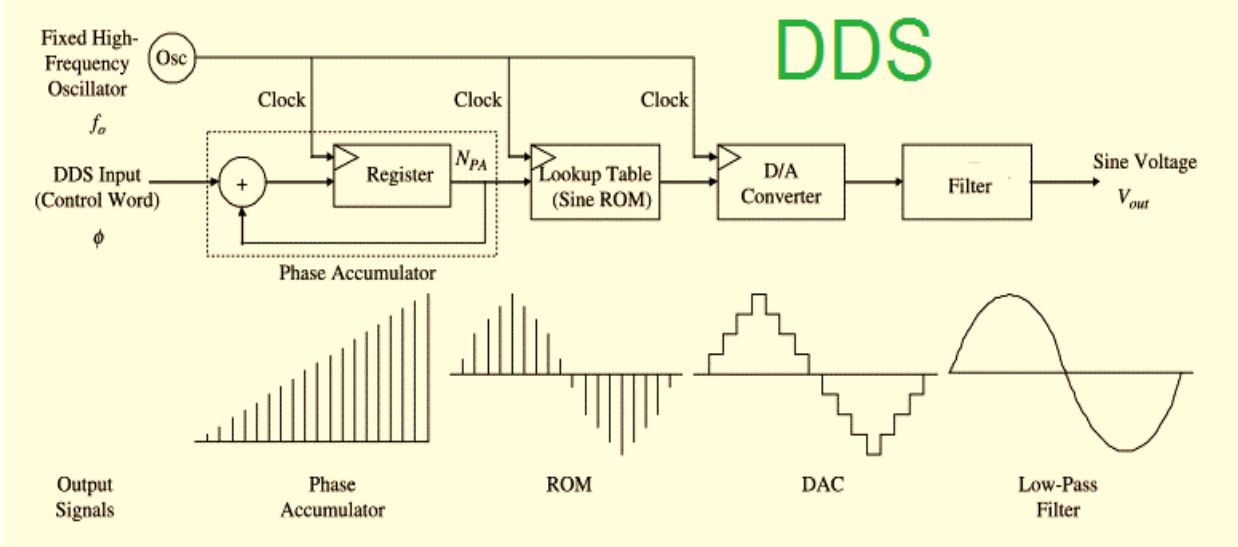
E7H02 (C) Which describes a microphonic? C. Changes in oscillator frequency due to mechanical vibration

E7H07 (D) How can an oscillator's microphonic responses be reduced? D. Mechanically isolating 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

E7H12 (B) Which of the following must be done to insure that a crystal oscillator provides the frequency specified by the crystal manufacturer? B. Provide the crystal with a specified parallel capacitance

==========



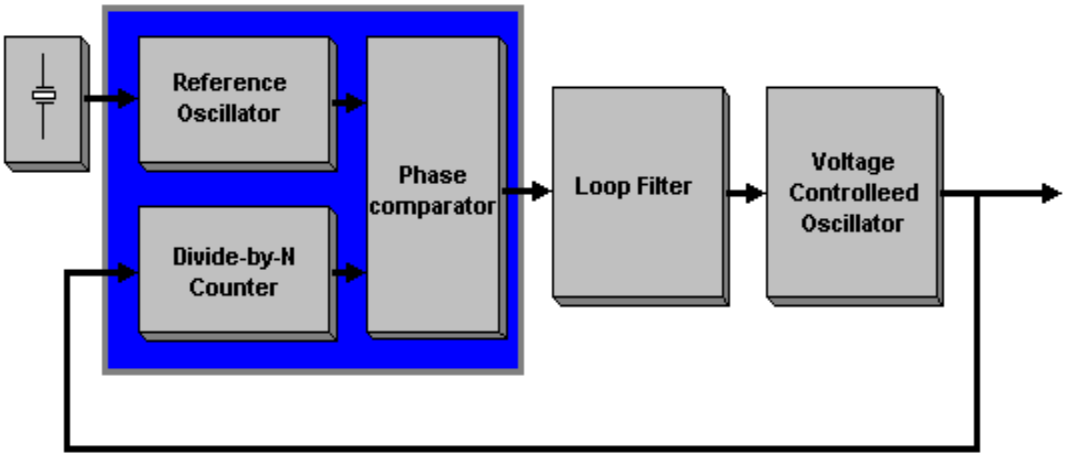
Phase accumulator is a principal component of a **Direct Digital Synthesizer (DDS)**

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

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



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

Frequency synthesis, FM demodulation can be performed by a **PLL**

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**

E7H10 (B) What information is contained in the **lookup table of a direct digital frequency synthesizer**? B. The amplitude values that represent a sine-wave output

E7H11 (C) What are the major **spectral impurity** components of direct digital synthesizers? C. **Spurious signals** at discrete frequencies

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 of these choices are correct**

E7H14 (C) What is a **phase-locked loop** circuit? C. An **electronic servo loop** consisting of a phase detector, a low-pass filter, a voltage-controlled oscillator, and a stable reference oscillator

E7H15 (D) Which of these functions can be performed by a **phase-locked loop**? D. **Frequency synthesis, FM demodulation**

==========

Operational Amplifier

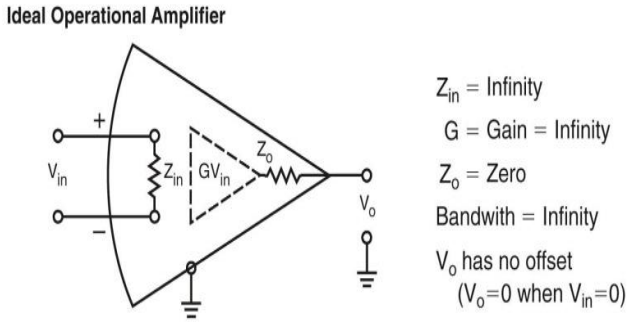
An integrated circuit operational amplifier is a **high-gain, direct-coupled differential amplifier** with very **high input** and very **low output** impedance

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

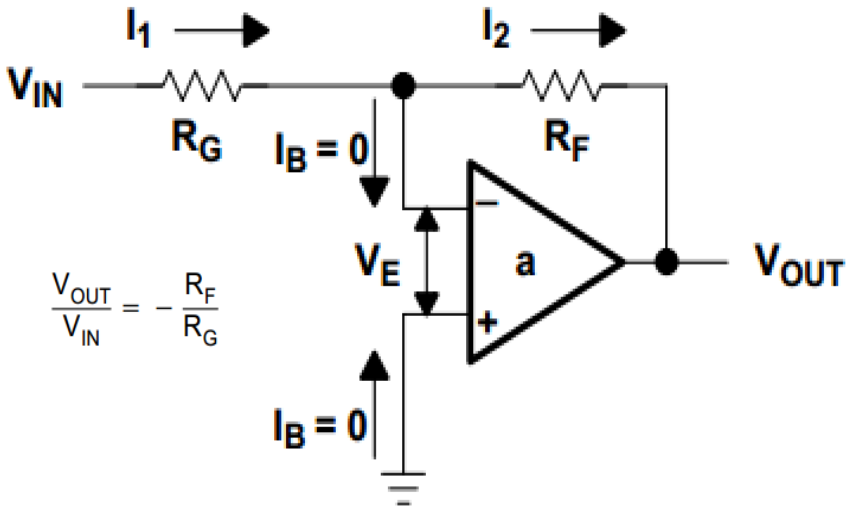
The typical **output impedance** of an integrated circuit op-amp is **very low**

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

The values of capacitors and resistors **external to the op-amp determines the gain** and frequency characteristics of an op-amp RC active filter



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



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

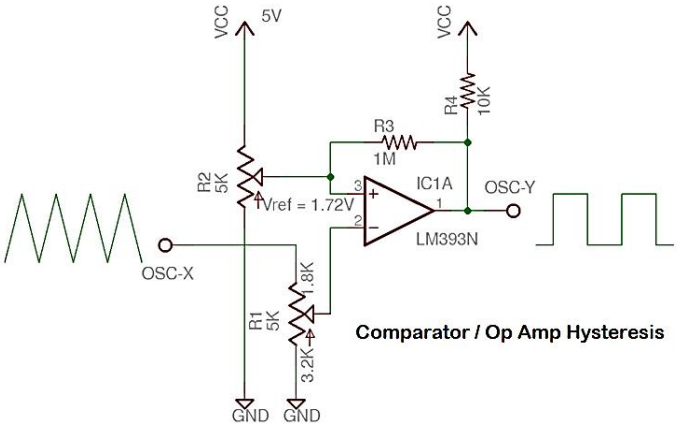
Undesired oscillations added to the desired signal is the effect of **ringing in a filter**

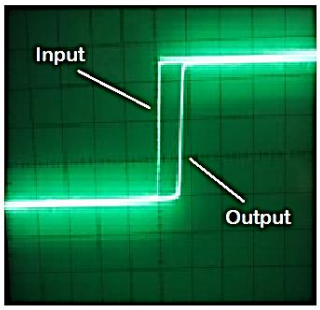
A **Polystyrene capacitor best** suited for use in high-stability op-amp RC active filter circuits?

As an audio filter in a receiver is an appropriate use of an **op-amp active filter**

Op-amps exhibit gain rather than insertion loss compared to LC elements for an audio filter

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





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.*

==========

E7G12 (A) What is an integrated circuit operational amplifier? A. **A high-gain, direct-coupled differential amplifier with very high input impedance and very low output impedance**

E7G01 (A) What is the typical **output impedance** of an integrated circuit op-amp? A. **Very low**

E7G03 (D) What is the typical **input impedance** of an integrated circuit op-amp? D**. Very high**

E7G04 (C) What is meant by the term op-amp **input-offset voltage**? C. The differential input voltage needed to bring the open-loop **output voltage to zero**

E7G02 (D) What is the effect of **ringing in a filter? D. Undesired oscillations** added to the desired signal

E7G05 (A) How can **unwanted ringing and audio instability be prevented** in a multi-section op-amp RC audio filter circuit? A. **Restrict both gain and Q**

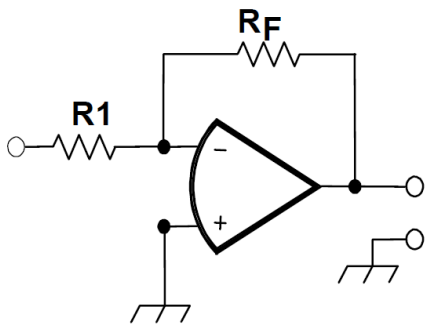
E7G06 (D) Which of the following is the most appropriate use of an **op-amp active filter? D. As an audio filter in a receiver**

E6C01 (A) What is the function of **hysteresis in a comparator**? A. To prevent input noise from causing unstable output signals

E6C02 (B) What happens when the level of a **comparator's input signal crosses the threshold** B. The **comparator changes its output state**

E7G08 (D) How does the gain of an ideal operational amplifier vary with frequency? D. It does not vary with frequency

Figure E7-4



E7G07 (C) What magnitude of voltage gain can be expected from the circuit in Figure E7-4 when R1 is 10 ohms and RF is 470 ohms? C. 47

Gain = - RF /R1

Gain = -470/10

Gain = -47

E7G10 (C) What absolute voltage gain can be expected from the circuit in Figure E7-4 when R1 is 1800 ohms and RF is 68 kilohms? C. 38

Gain = - RF /R1

Gain = -68K/1800

Gain = -37.78

E7G11 (B) What absolute voltage gain can be expected from the circuit in Figure E7-4 when R1 is 3300 ohms and RF is 47 kilohms? B. 14

Gain = - RF /R1

Gain = -47K/3300

Gain = -14.24

E7G09 (D) What will be the output voltage of the circuit shown in Figure E7-4 if R1 is 1000 ohms, RF is 10,000 ohms, and 0.23 volts dc is applied to the input? D. -2.3 volts

Gain = - RF /R1

Gain = -10K/1K

Gain = -10 >>

Vop = Input x Gain

Vop = 0.23 x -10

Vop = - 2.3 V

==========

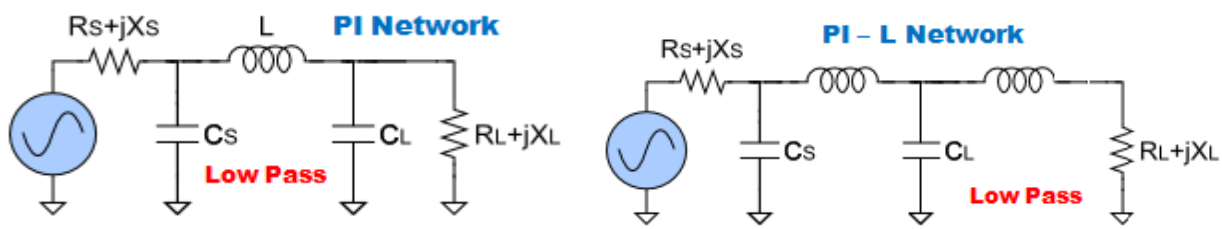
Filters & Networks

Pi Network is the common name for a filter network which is equivalent to two L networks connected back-to-back with the inductors in series and the capacitors in shunt at the input and output

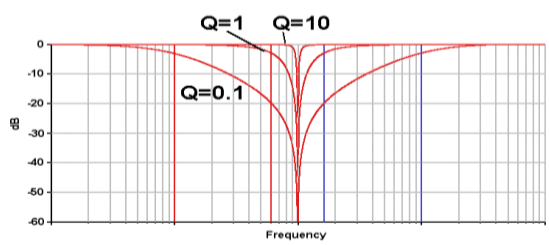
A **low-pass filter Pi-network** has a capacitor is connected between the input and ground, another capacitor is connected between the output and ground, and an inductor is connected between input and output

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

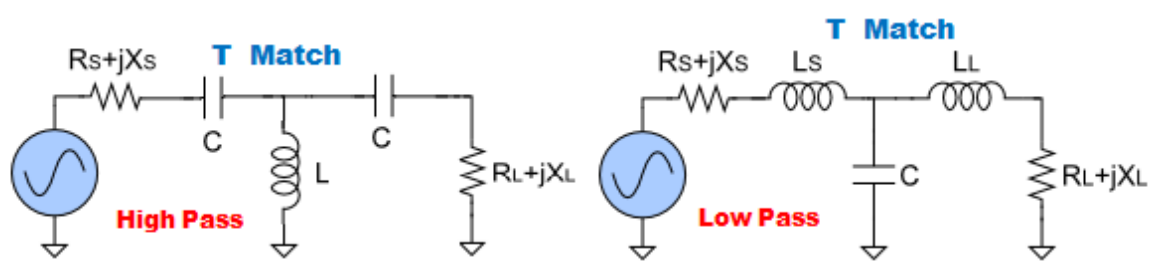


The **Q of Pi networks can be varied** depending on the component values chosen

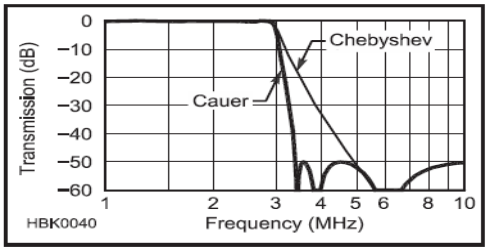


A **Pi-L-network** has **greater harmonic suppression** over a Pi-network for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna

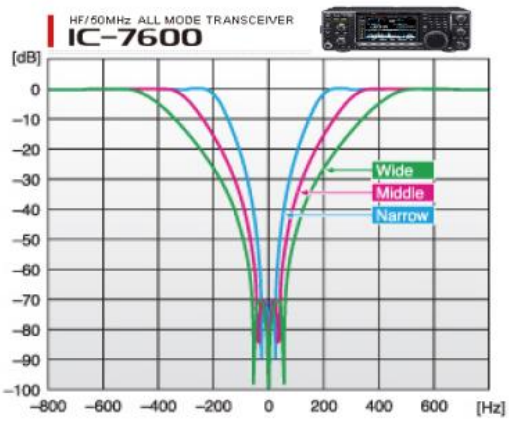
A **T-network** with series capacitors and a parallel shunt inductor is a **high-pass filter**



A **Chebyshev filter** is described as having ripple in the passband and a sharp cutoff?

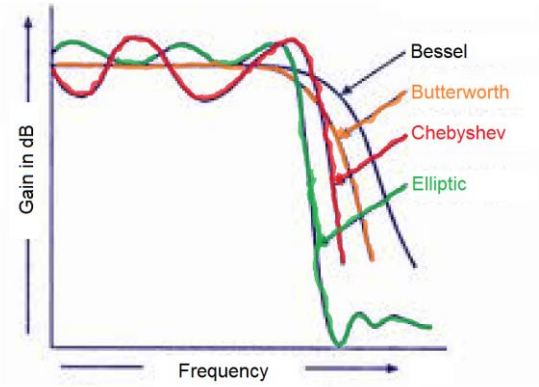


A **notch filter** would be used to attenuate an interfering carrier signal while receiving an SSB transmission



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.



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

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

==========

E7C01 (D) **How are the capacitors and inductors of a low-pass filter Pi-network** arranged between the network's 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? C. It is a high-pass filter**

E7C03 (A) What advantage does **a Pi-L-network have over a Pi-network** for impedance matching between the final amplifier of a vacuum-tube transmitter and an antenna? A. **Greater harmonic suppression**

E7C04 (C) How does an **impedance-matching circuit** transform a complex impedance to a resistive impedance? C. It **cancels the reactive part of the impedance and changes the resistive** part to a desired value

E7C05 (D) Which filter type is described as having **ripple in the passband and a sharp cutoff? D. A Chebyshev filter**

E7C06 (C) What are the distinguishing features of an **elliptical filter? C. Extremely sharp cutoff with one or more notches in the stop band**

E7C07 (B) What kind of filter would you use to attenuate an **interfering carrier signal while receiving an SSB transmission? B. A notch filter**

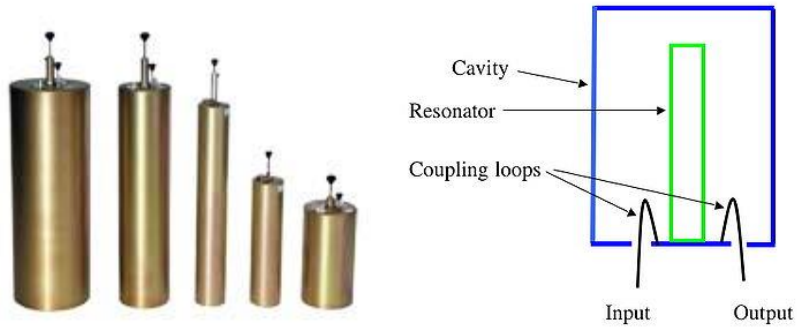
E7C11 (D) Which of the following is the common name for a filter network which is equivalent to **two L networks connected back-to-back with the inductors in series and the capacitors in shunt** at the input and output? D. **Pi**

E7C12 (B) Which describes a **Pi-L network** used for matching a vacuum-tube final amplifier to a 50-ohm unbalanced output? B. **A Pi network with an additional series inductor on the output**

E7C13 (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 varied depending on the component values chosen**

E7C14 (C) Which mode is most affected by **non-linear phase response in a receiver IF filter? C. Digital**

==========



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

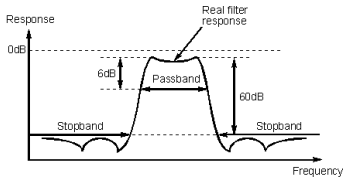
==========

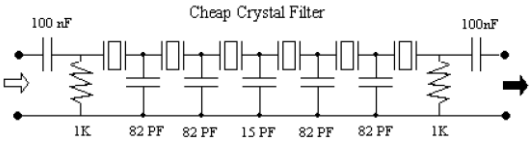
E7C10 (B) Which of the following filters would be the best choice for use in a 2 meter repeater duplexer? B**. A cavity filter**

==========

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

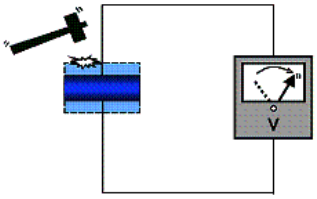
The **relative frequencies of each crystal** determine the bandwidth and response shape of a **crystal ladder filter**

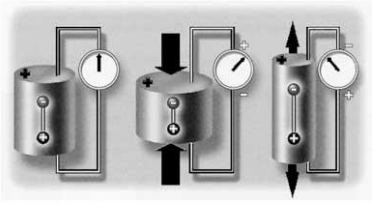




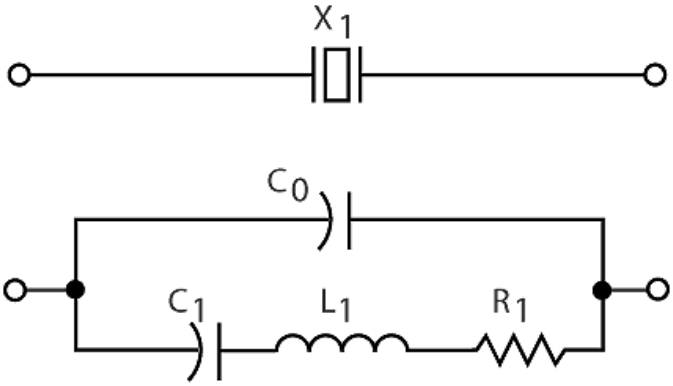
A **variable bandwidth crystal lattice filter** is a **"Jones filter"** as used as part of a HF receiver IF stage

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

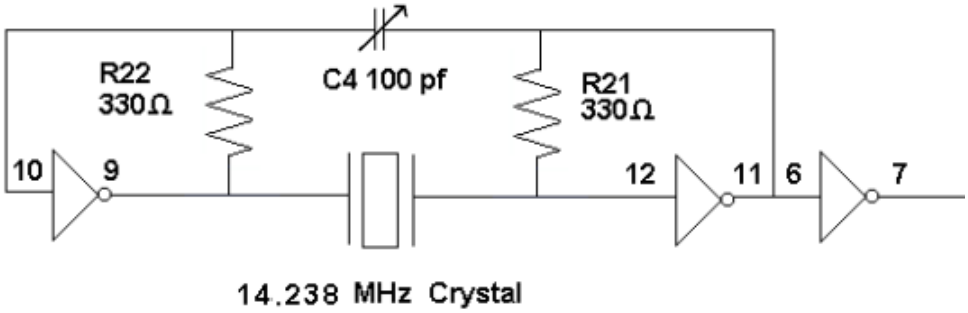




The **equivalent circuit of a quartz crystal** is motional capacitance, motional inductance and loss resistance in series, with a shunt capacitance representing electrode and stray capacitance



A **parallel capacitor** is added to ensure a **crystal oscillator** provides the **frequency specified**



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E7C08 (A) Which of the following factors has the greatest effect in helping **determine the bandwidth and response shape of a crystal ladder filter? A. The relative frequencies of the individual crystals**

E7C09 (B) What is a **Jones filter** as used as part of a HF receiver IF stage? B. A **variable bandwidth crystal lattice filter**

E7C15 (D) What is a **crystal lattice filter?** D. A filter with narrow bandwidth and steep skirts made using quartz crystals

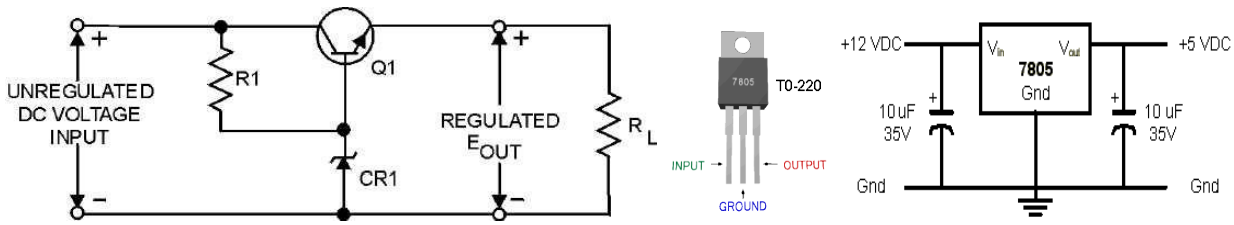
E6D02 (A) What is **the equivalent circuit of a quartz crystal**? A. Motional capacitance, motional inductance and loss resistance in series, with a shunt capacitance representing electrode and stray capacitance

E6D03 (A) Which of the following is an aspect of the **piezoelectric effect**? A. Mechanical deformation of material by the application of a voltage

==========

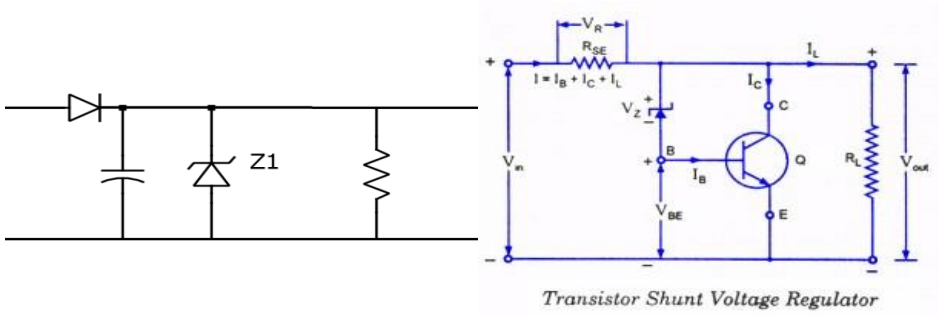
Power Supplies

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

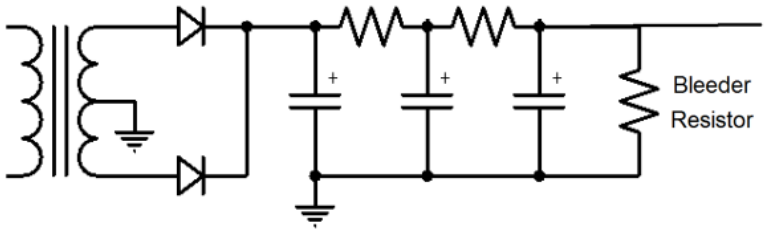


A **Zener diode** is typically used as a stable **reference voltage** in a linear voltage regulator?

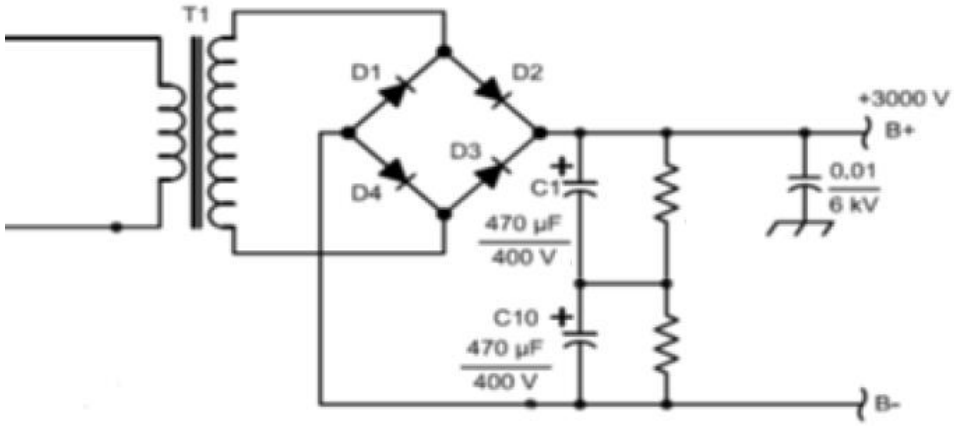
Of the linear voltage regulators, a **series regulator** usually makes the **most efficient use** of the primary power source



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

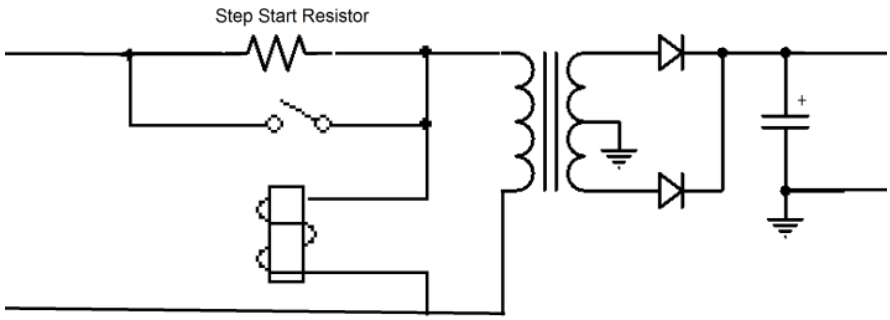


A **"bleeder" resistor** in a conventional (unregulated) power supply is used to improve output **voltage regulation**

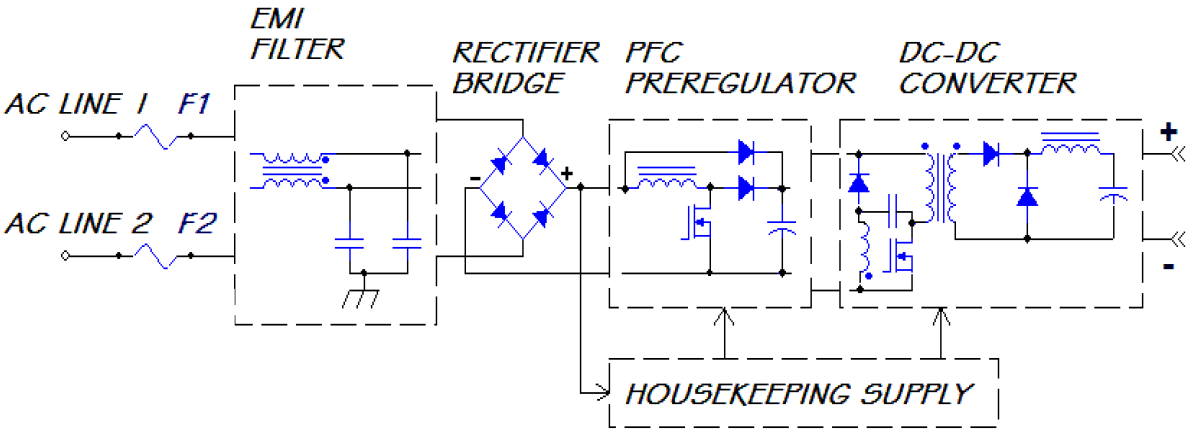


When several electrolytic **filter capacitors are connected in series** to increase the operating voltage of a power supply filter circuit, why should resistors be connected across each capacitor?

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



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



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

==========

E7D01 (D) What is one characteristic of a **linear electronic voltage regulator**? D. The **conduction of a control element is varied** to maintain a constant output voltage

E7D02 (C) What is one characteristic of a **switching electronic voltage regulator**? C. The control **device's duty cycle is controlled** to produce a constant average output voltage

E7D03 (A) What device is typically used as a **stable reference voltage** in a linear voltage regulator? A. A **Zener diode**

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

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

E7D09 (C) What is the main reason to use a **charge controller with a solar power system? C. Prevention of battery damage** due to overcharge

E7D10 (C) What is the primary reason that a high-frequency inverter type high-voltage power supply can be both less expensive and lighter in weight than a conventional power supply? C. The **high frequency inverter design uses much smaller transformers and filter components f**or an equivalent power output

E7D11 (D) What circuit element is controlled by a series analog voltage regulator to maintain a **constant output voltage? D. Pass transistor**

E7D12 (C) What is the **drop-out voltage** of an analog voltage regulator? C. **Minimum input-to-output voltage** required to maintain

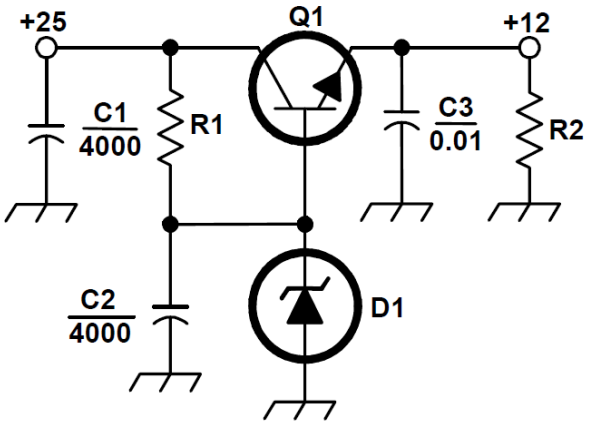
E7D13 (C) What is the equation for calculating **power dissipation by a series linear voltage regulator? C. Voltage difference from input to output multiplied by output current**

E7D14 (C) What is one purpose of a "**bleeder"** resistor in a conventional (unregulated) power supply? C. To **improve output voltage regulation**

E7D15 (D) What is the purpose of a "**step-start"** circuit in a high-voltage power supply D. To allow the **filter capacitors to charge gradually**

E7D16 (D) 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**

Figure E7- 3



E7D06 (C) What is the purpose of Q1 in the circuit shown in Figure E7-3? C. It **increases the current-handling capability of the regulator**

E7D07 (A) What is the purpose of C2 in the circuit shown in Figure E7-3? A. **It bypasses hum around D1**

E7D08 (C) What type of circuit is shown in Figure E7-3? C. **Linear voltage regulator**

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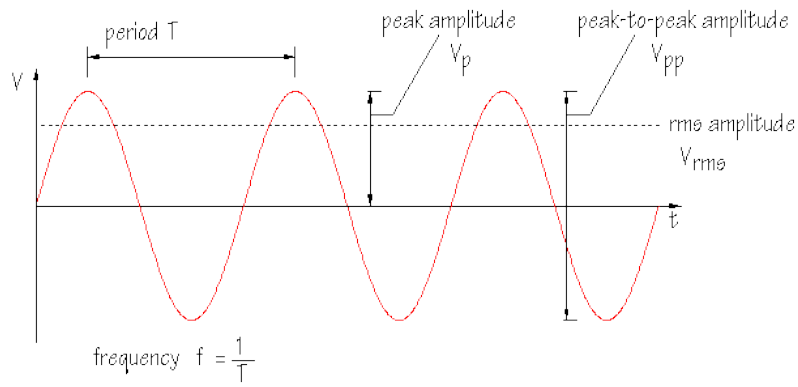
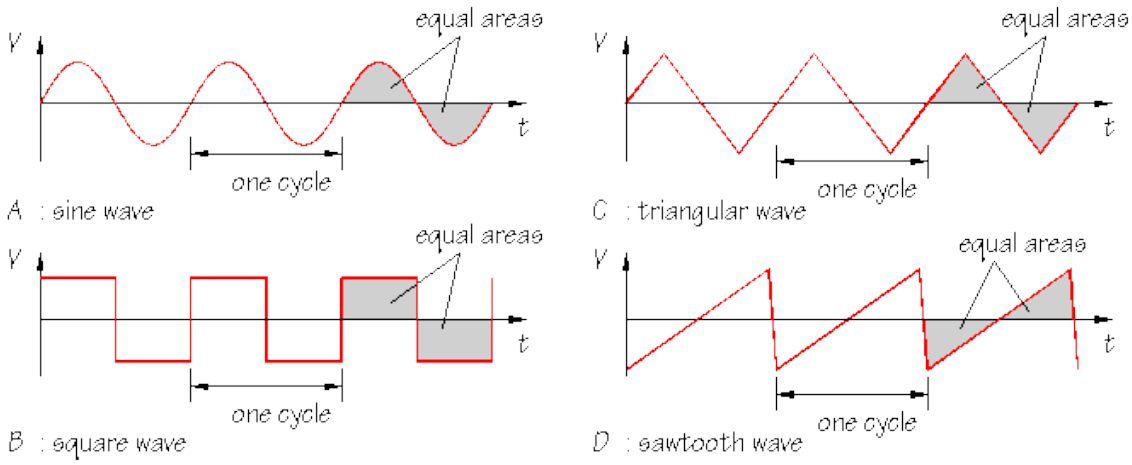
Chapter 7 Radio Signals and Measurements

Waveform Measurements

The **time required to complete one cycle** is the **period** of a wave

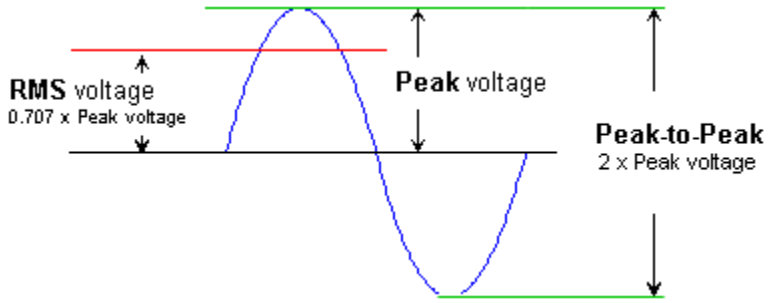


A **square wave** is made up of a sine wave plus **all of its ODD harmonics**



A **sawtooth** wave has a **rise time significantly faster** than its fall time (or vice versa)

A **sawtooth** wave is made up of sine waves of a given fundamental **frequency plus ALL ITS harmonics**



The **DC voltage** causing the same **amount of heating in a resistor** as the **RMS AC voltage**

Measuring the heating effect in a known resistor would be the most accurate way of measuring the **RMS voltage** of a complex waveform

2.5 to 1 is the approximate ratio of **PEP-to-average power** in a typical **SSB phone** signal

The **modulating signal determines** the **PEP-to-average** power ratio of a SSB phone signal

Irregular waveform is produced by **human speech**

==========

E8A02 (C) What type of wave has a rise time significantly faster than its fall time (or vice versa)? C. A **sawtooth wave**

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 of its harmonics? A. **A sawtooth wave**

E8A05 (D) What would be the most accurate way of measuring the **RMS voltage of a complex waveform**? D. By **measuring the heating effect** in a known resistor

E8A06 (A) What is the approximate **ratio of PEP-to-average power** in a typical single-sideband phone signal? A. **2.5 to 1**

E8A07 (B) What determines the **PEP-to-average power ratio** of a single-sideband phone signal? B. The **characteristics of the modulating signal**

==========

Test Equipment

An **oscilloscope** displays signals in the **time domain**

An **Oscilloscope** could be used for detailed **analysis of digital signals**

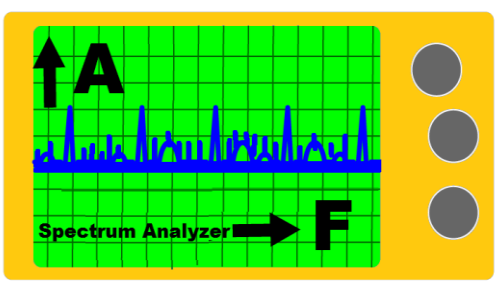
A **spectrum analyzer** displays signals in the **frequency domain**

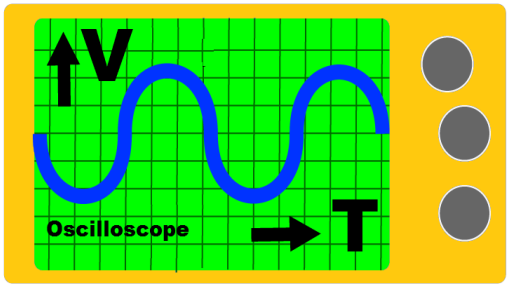
A spectrum analyzer displays **frequency on the horizontal axis**

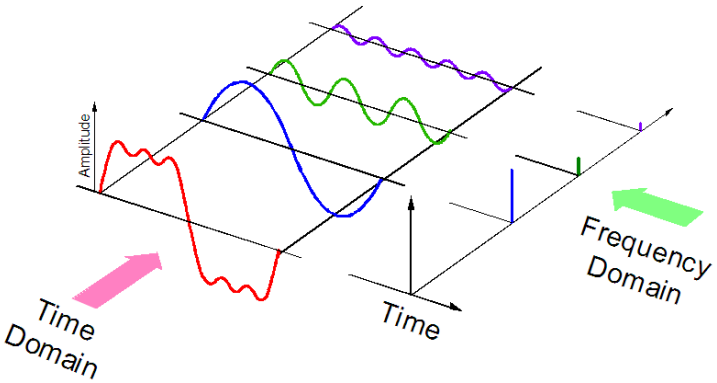
A spectrum analyzer displays **amplitude on the vertical axis**

A spectrum analyzer is used to display **spurious signals** from a radio transmitter

A spectrum analyzer is used to display intermodulation distortion products in an SSB transmission?

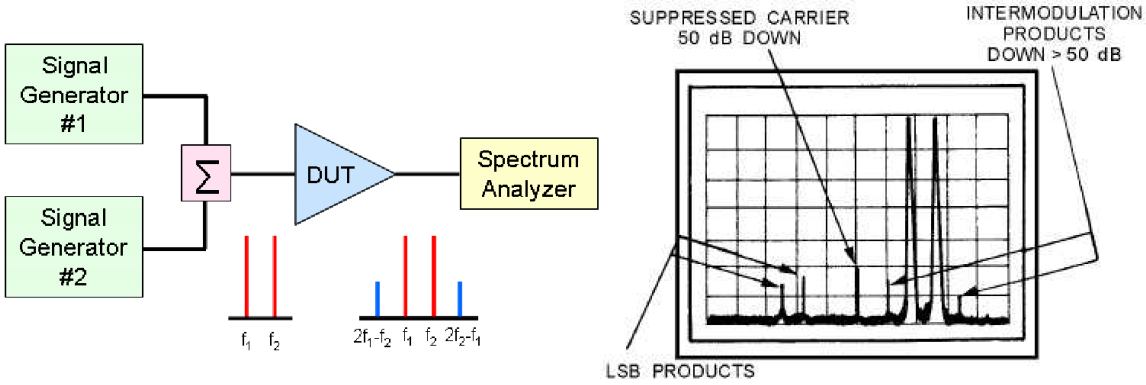




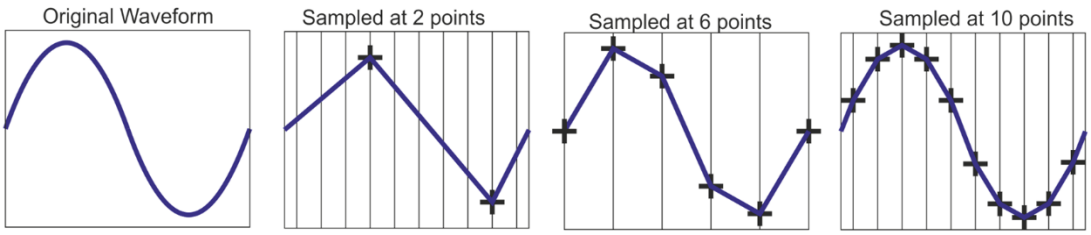


Attenuate the transmitter output signal going to the spectrum analyzer

Transmit into a dummy load, receive the signal on a second receiver, and feed the audio into the sound card of a computer running an appropriate PSK program describes a good **method for measuring the intermodulation distortion** of your own PSK signal



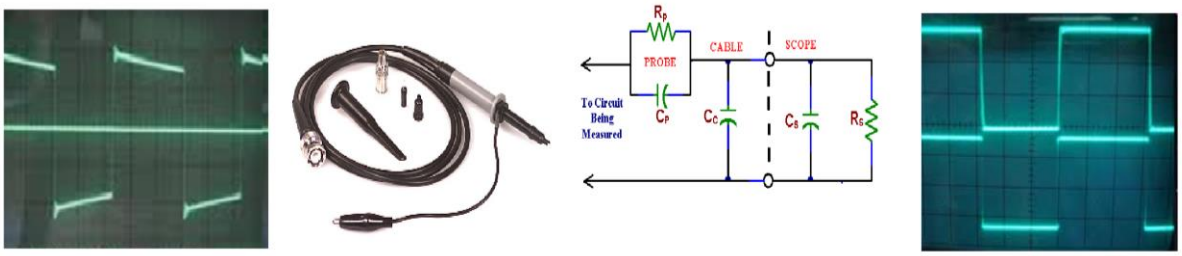
Intermodulation distortion (IMD) >> SSB TX non-harmonically **two tones** & observe RF on a spectrum analyzer



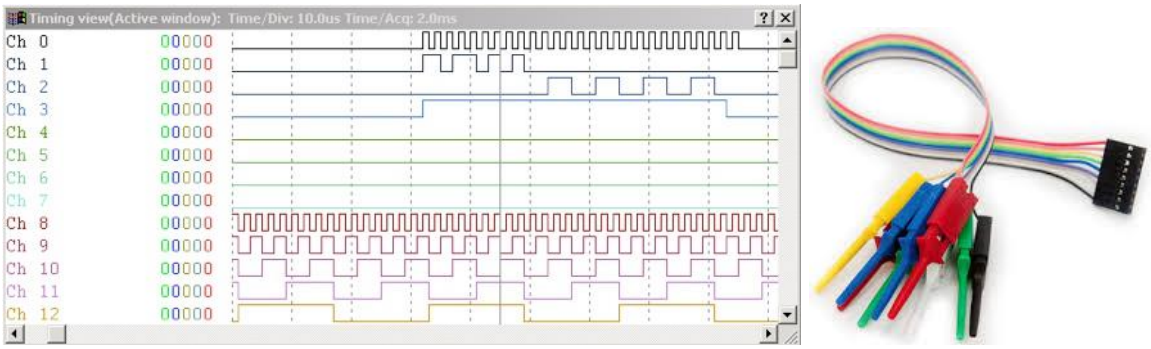
Sampling rate determines the **bandwidth** of a digital oscilloscope

The **highest frequency** that can be digitized without aliasing is **one-half the sample rate**

Keep the **oscilloscope probe ground** connection of the probe as **short as possible**



The **compensation of an oscilloscope probe** is adjusted until the horizontal portions of the displayed wave are as nearly **flat as possible**



*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.*

==========

E4A01 (C) Which of the following parameters determines the **bandwidth** of a digital or computer-based oscilloscope? C. **Sampling rate**

E4A09 (B) When using a computer's soundcard input to digitize signals, what is the **highest frequency** signal that can be digitized without aliasing? B. **One-half the sample rate**

E4A02 (B) Which of the following parameters would a **spectrum analyzer display** on the vertical and horizontal axes? B. RF **amplitude and frequency**

E4A03 (B) Which of the following test instruments is used to **display spurious signals and/or intermodulation distortion products in an SSB transmitter? B. A spectrum analyzer**

E4A04 (A) What determines the **upper frequency limit** for a computer soundcard-based oscilloscope program? A. Analog-to-digital **conversion speed of the soundcard**

E4A05 (D) What might be an advantage of a digital vs an analog oscilloscope?
A. Automatic amplitude and frequency numerical readout
B. Storage of traces for future reference
C. Manipulation of time base after trace capture
D. All of these choices are correct

E4A06 (A) What is the **effect of aliasing** in a digital or computer-based oscilloscope? A. **False signals are displayed**

E4A11 (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**

E4A12 (B) Which of the following procedures is an important precaution to follow when connecting a **spectrum analyzer to a transmitter output? B. Attenuate the transmitter** output going to the spectrum analyzer

E4B10 (B) Which of the following describes a method to measure intermodulation distortion in an SSB transmitter? B. Modulate the transmitter with two non-harmonically related audio frequencies and observe the RF output with a spectrum analyzer

E4A13 (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

E4A10 (D) Which of the following **displays multiple digital signal states simultaneously? D. Logic analyzer**

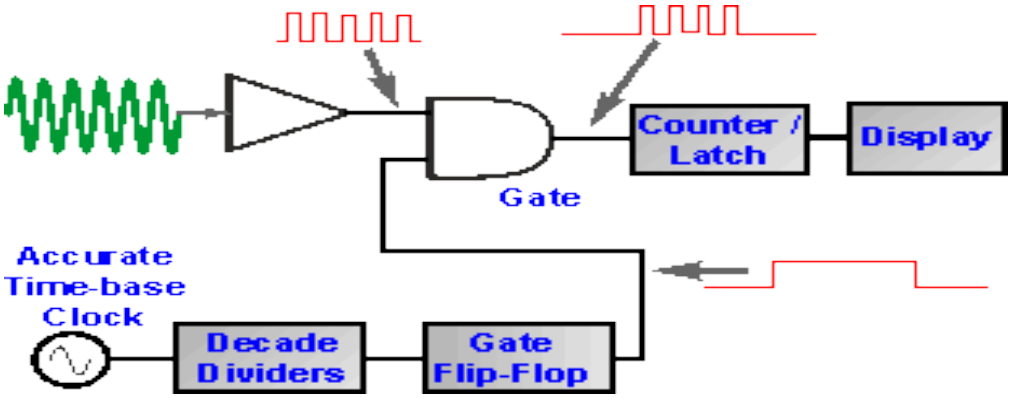
==========

Measurement Techniques

The accuracy of the **time base determines the accuracy** of a **frequency counter**

A **frequency counter** counts the **number of input pulses** occurring within a **specific period of time**

A **frequency counter** provides a digital representation of the frequency of a signal



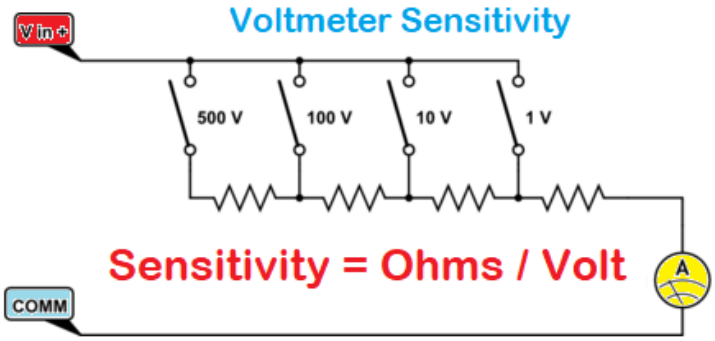
Period measurement plus mathematical **computation** is used by some counters

Period measurement provides improved resolution of low-frequency signals

A **PRESCALER** divides a high frequency signal so a low-frequency counter can display the input frequency

A **PRESCALER** would be used to reduce a signal's frequency by a factor of ten

E4B01 (B) Which of the following factors most affects the **accuracy of a frequency counter? B. Time base accuracy**



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E4A14 (D) What is the purpose of the **prescaler function on a frequency counter**? D. It divides a higher frequency signal so a low-frequency counter can display the input frequency

E4A15 (C) What is an advantage of a **period-measuring frequency counter** over a direct-count type? C. It provides improved resolution of low-frequency signals within a comparable time period

E4B03 (C) If a frequency counter with a specified accuracy of +/- 1.0 ppm reads 146,520,000 Hz, what is the most the **actual frequency** being measured could differ from the reading? **C. 146.52 Hz**

Error = Freq x Accuracy = (146.52 MHz) x (1 / 1,000,000) = **146.52 Hz**

E4B04 (A) If a frequency counter with a specified accuracy of +/- 0.1 ppm reads 146,520,000 Hz, what is the most the **actual frequency** being measured could differ from the reading? **A. 14.652 Hz**

Error = Freq x Accuracy = (146.52 MHz) x (0.1 / 1,000,000) = **14.652 Hz**

E4B05 (D) If a frequency counter with a specified accuracy of +/- 10 ppm reads 146,520,000 Hz, what is the most the **actual frequency** being measured could differ from the reading? **D. 1465.20 Hz**

Error = Freq x Accuracy = (146.52 MHz) x (10 / 1,000,000) = **1,465.20 Hz**

E4B02 (C) What is an advantage of using a bridge circuit to measure impedance? C. It is very preceise in obtaining a signal null

E4B08 (C) Which of the following is a characteristic of a good **DC voltmeter? C. High impedance input**

E4B12 (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

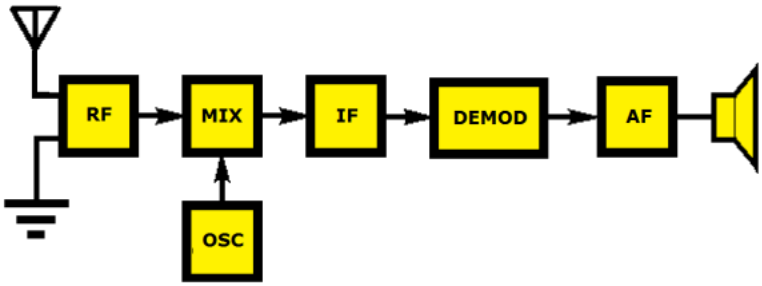
E4B14 (B) What happens if a **dip meter is too tightly coupled** to a tuned circuit being checked? B. A less accurate reading results

==========

Phase Noise, Image Rejection, Signal / Noise

A **narrow-band roofing filter improves dynamic range** by attenuating strong signals near the receive frequency

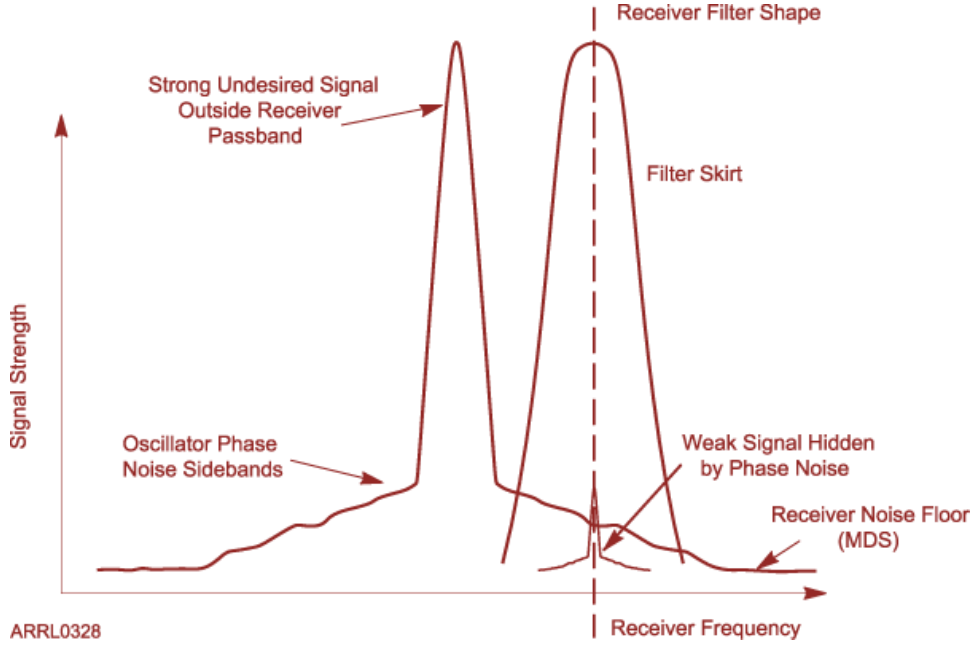
A **higher frequency IF** requires less for front-end circuitry to **eliminate image responses**



A **wide IF filter bandwidth** in a receiver causes **undesired signals** to be heard

LC, quartz crystal, ceramic resonator.

Reject unwanted mixing products and prevent spurious signals from slipping into the signal path.



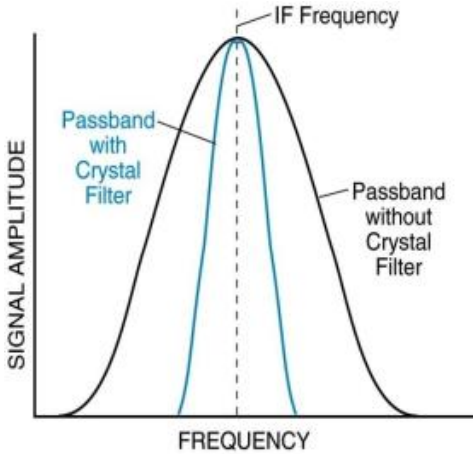
A **front-end filter or pre-selector** can be effective in **eliminating image signal interference**

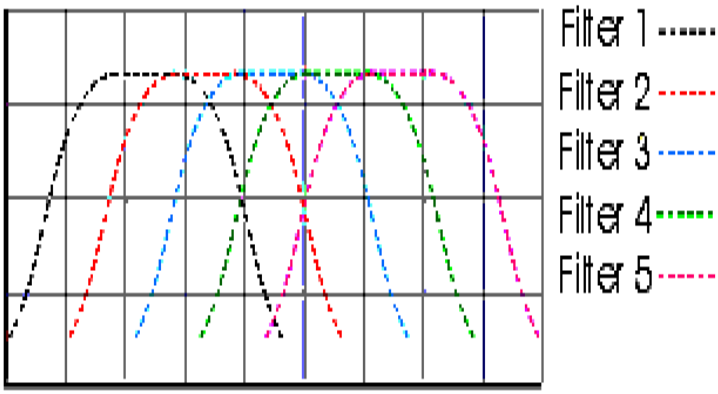
Provide front end selectivity

Reject strong near out of band signals

Tunable input filter that passes the desired frequency.

Increases rejection of out of band signals.





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E4C02 (A) Which of the following portions of a receiver can be effective in eliminating **image signal interference**? A. A **front-end filter or pre-selector**

E4C09 (C) Which of the following choices is a good reason for selecting a high frequency for the **design of the IF** in a conventional HF or VHF communications receiver? C. Easier for **front-end circuitry to eliminate image responses**

E4C12 (D) What is an undesirable effect of using too **wide a filter bandwidth in the IF** section of a receiver? D. **Undesired signals** may be heard

==========

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

E4C03 (C) What is the term for the blocking of one FM phone signal by another, **stronger FM phone signal? C. Capture effect**

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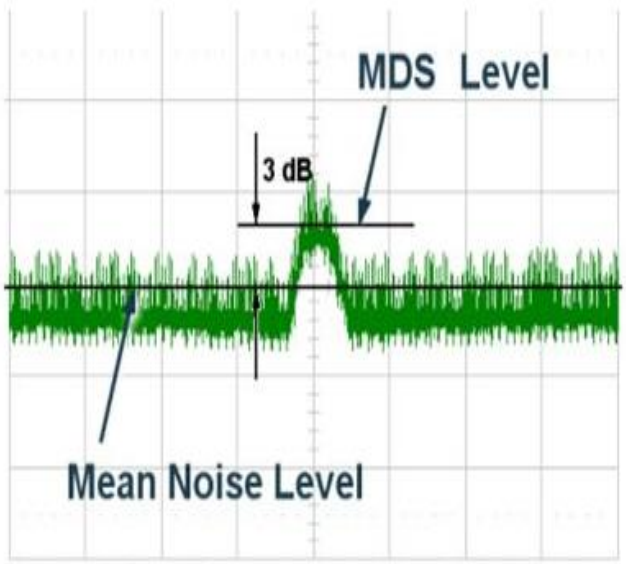

Minimum Discernible Signal

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.

Minimum discernible signal (MDS) represents the receiver minimum discernible signal

Lowering the receiver **noise figure improves weak signal sensitivity**

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**

Receiver **oscillator phase noise** causes nearby frequencies to **interfere with reception of weak signals**

Atmospheric noise is the primary source of noise that can be heard from receiver connected to an antenna

==========

E4C01 (D) What is an effect of excessive **phase noise** in the local oscillator section of a receiver? A D. It can cause **strong signals on nearby frequencies to interfere with reception of weak signals**

E4C07 (B) What does the **MDS** of a receiver represent? B. The **minimum discernible signal**

E4C15 (D) What is usually the primary source of **noise** that can be heard from an HF receiver with an antenna connected? D. **Atmospheric noise**

E4C04 (D) How is the **noise figure** of a receiver defined? D. The ratio in dB of the noise generated by the **receiver compared to the theoretical minimum noise**

E4C05 (B) What does a value of **-174 dBm/Hz** represent with regard to the noise floor of a receiver? B. The theoretical noise at the input of a **perfect receiver at room temperature**

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? D. -148 dBm**

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**

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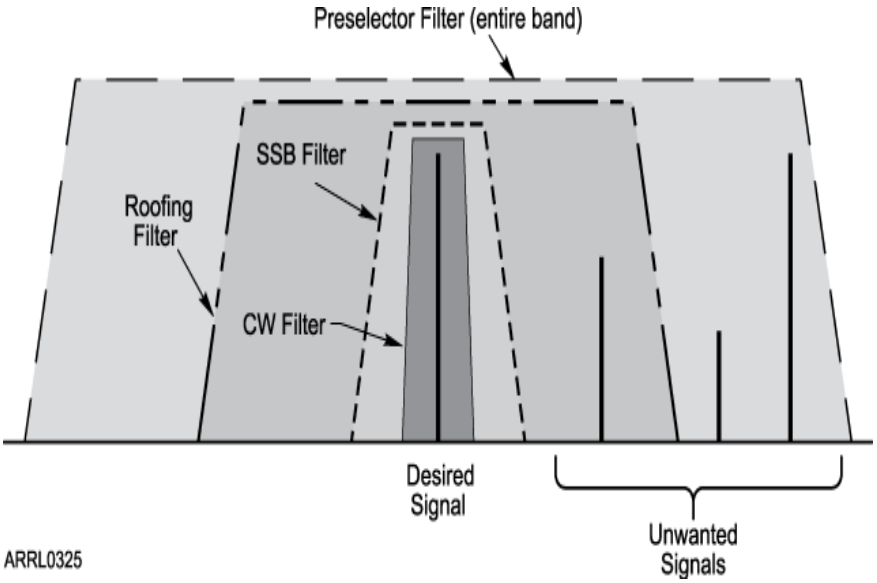
300 Hz is a desirable amount of **selectivity** for an **RTTY** HF receiver

2400 Hz is a desirable amount of **selectivity** for an **SSB phone** receiver



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.

==========

E4C10 (B) Which of the following is a desirable amount **of selectivity for an amateur RTTY** HF receiver? **B. 300 Hz**

E4C11 (B) Which of the following is a desirable amount of **selectivity for an amateur SSB** phone receiver? **B. 2.4 kHz**

E4C13 (C) How does a **narrow-band roofing filter** affect receiver performance? C. It **improves dynamic range** by attenuating strong signals near the receive frequency

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.

E4C14 (D) 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? D. 15.210 MHz

IF of 455Khz. Signal on 14.300 MHz

BFO tuned to 14.3 + .455 = 14.755 MHz

Image on 15.210 received because 15.210 – 14.755 MHz = 0.455 MHz.

If we raise the IF to 9 MHz, BFO is 14.3 + 9 = 23.3 MHz and the image frequency would be 23.3 + 9 MHz. Farther away from the desired signal and easier to filter.

E4C08 (C) An **SDR receiver is overloaded** when input signals exceed what level? C. The **maximum count value of the analog-to-digital converter**

E4C16 (A) Which of the following is caused by **missing codes in an SDR** receiver's analog-to-digital converter? A. **Distortion**

E4C17 (D) Which of the following has the largest effect on an **SDR receiver's linearity?** D. Analog-to-digital converter **sample width in bits**

Dynamic Range, IMD, 3rd Order Intercept

Dynamic Range

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.

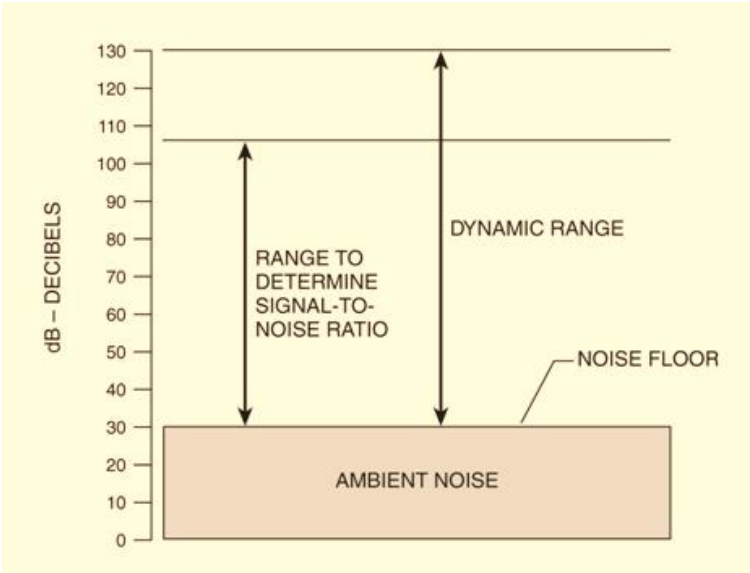
Causes weaker signals to appear to fade

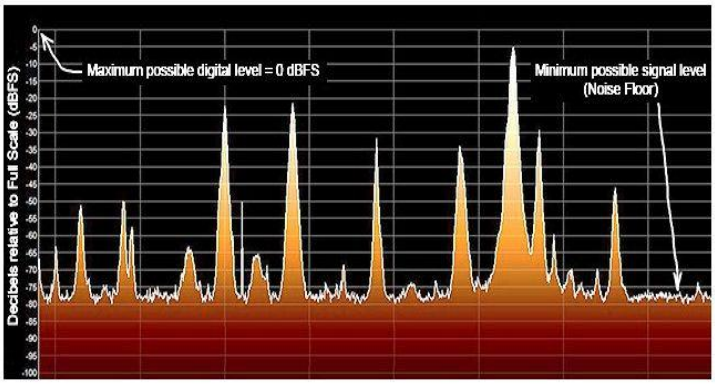
Gain compression or blocking.

Blocking may be observed as desensitization or desense…the reduction in apparent strength of a desired signal caused by a nearby strong interfering signal.

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.

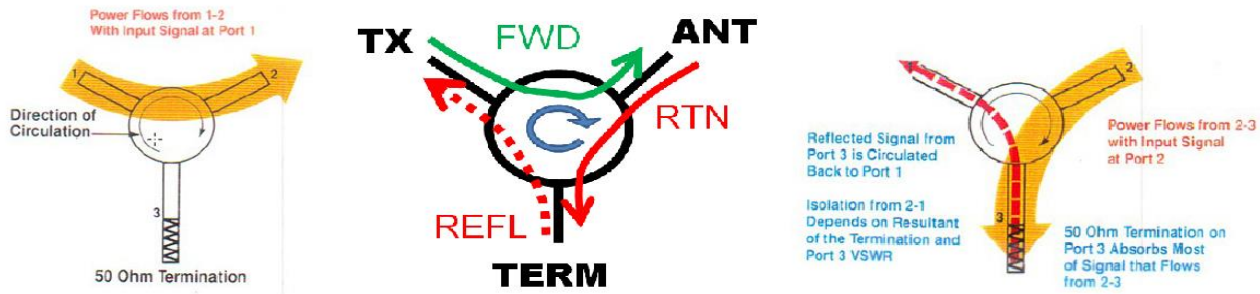
It may be possible to reduce the desensitization by using IF filters to reduce the receiver's RF bandwidth and reject the strong signals.





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.

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**

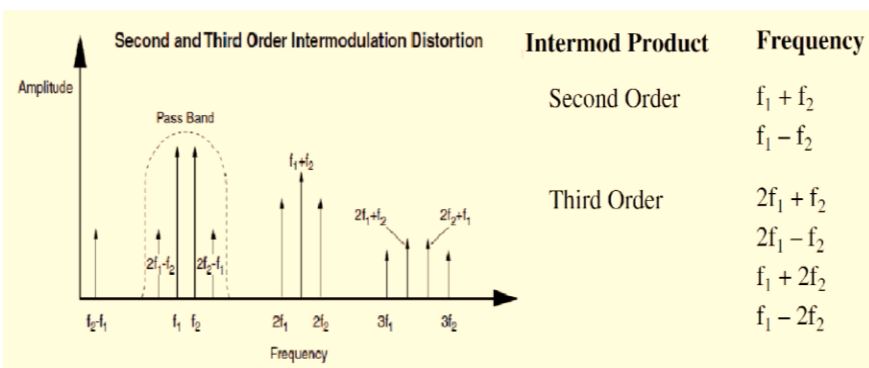
Strong adjacent-channel signals can cause receiver **desensitization**

Decreasing the RF bandwidth of a receiver **will reduce** the likelihood of receiver **desensitization**

A **PRESELECTOR** increases the rejection of unwanted signals

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**

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

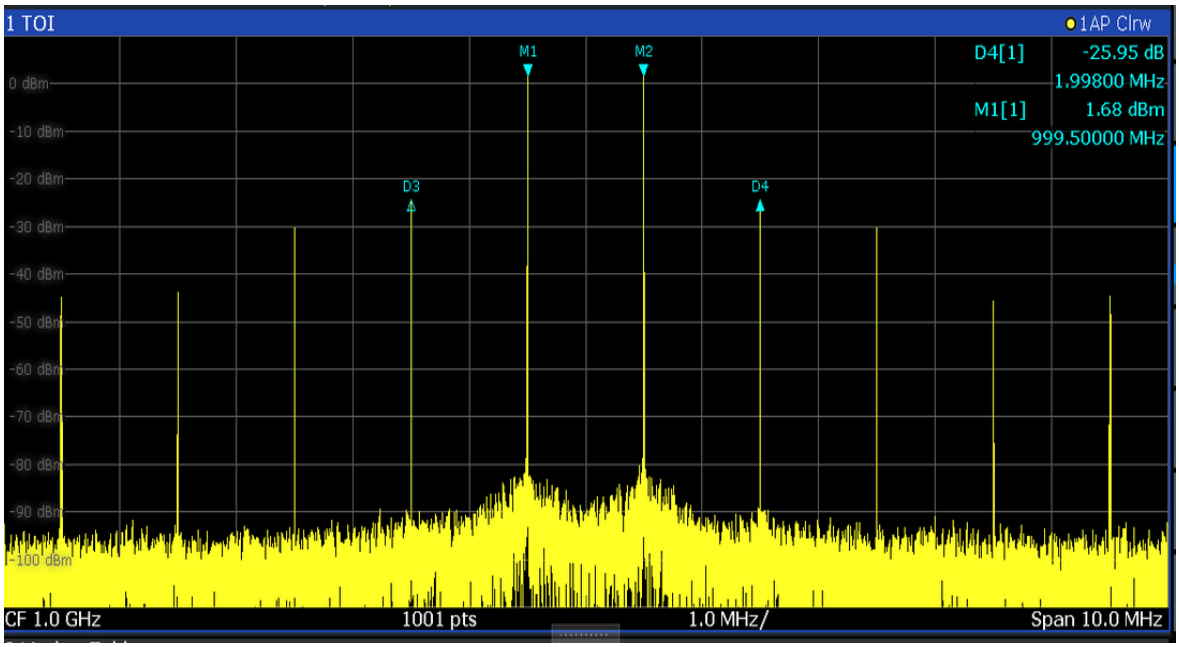
#2) 2nd $F_{IMD} = TX_a - TX_b$ > too low for the receiver

#3) 3rd $F_{IMD} = 2TX_a + TX_b$ > too high for the receiver

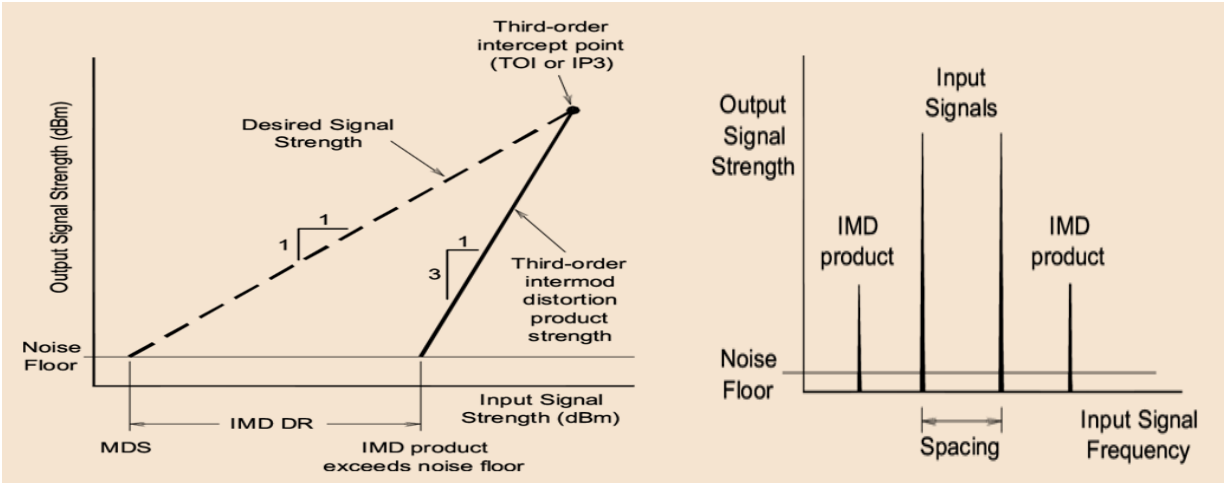
#4) 3rd $F_{IMD} = 2TX_a - TX_b$ > 146.70= (2 x 146.52) - TX_b >> TX_b = (2 x 146.52) - 146.70 = (293.04) - 146.70 = **146.34 MHz**

#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 = (293.22) / 2 = **146.61 MHZ**



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.

==========

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 which will cause 1 dB of gain compression

E4D02 (A) Which of the following describes two problems caused by **poor dynamic range** in a communications receiver? A. **Cross-modulation of the desired signal and desensitization** from strong adjacent signals

E4D03 (B) How can **intermodulation interference** between two repeaters occur? B. When the repeaters are in close proximity and the signals mix in the final amplifier of one or both transmitters

E4D04 (B) Which of the following may reduce or **eliminate intermodulation interference** in a repeater caused by another transmitter operating in close proximity? B. **A properly terminated circulator** at the output of the transmitter

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

E4D06 (D) What is the term for unwanted signals generated by the mixing of two or more signals? D. **Intermodulation interference**

E4D07 (D) Which describes the most significant effect of an off-frequency signal when it is **causing cross-modulation interference** to a desired signal? D. The off-frequency **unwanted signal is heard in addition to the desired signal**

E4D08 (C) What **causes intermodulation** in an electronic circuit? C. **Nonlinear circuits** or devices

E4D09 (C) What is the purpose of the **preselector** in a communications receiver? C. To increase **rejection of unwanted signals**

E4D10 (C) What does a **third-order intercept level of 40 dBm** mean with respect to receiver performance? C. A pair of 40 dBm signals will theoretically generate a third-order intermodulation product with the same level as the input signals

E4D11 (A) Why are **third-order intermodulation products** created within a receiver of particular interest compared to other products? A. The third-order product of two signals which are in the band of interest is also likely to be within the band

E4D12 (A) What is the term for the reduction in receiver sensitivity caused by a strong signal near the received frequency? A. **Desensitization**

E4D13 (B) Which of the following can cause receiver **desensitization**? B. Strong adjacent-channel signals

E4D14 (A) Which of the following is a way to reduce the likelihood of receiver **desensitization**? A. Decrease the RF bandwidth of the receiver

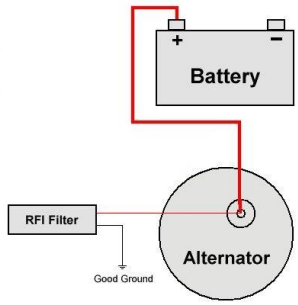
==========

Interference and Noise

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

Ignition noise can often be reduced by use of a receiver **noise blanker**

Thunderstorms are the major cause of **atmospheric static**

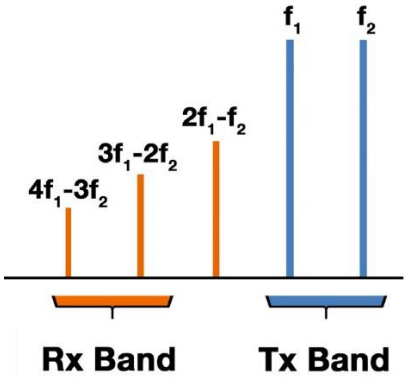
You can determine if line noise interference is being generated within your home by **turning off the AC power line main circuit breaker** and listening on a battery-operated radio

Common-mode signal at the frequency of the radio transmitter is picked up by electrical wiring near a radio antenna

An **IF noise blanker** makes **nearby signals may appear to be excessively wide** even if they meet emission standards

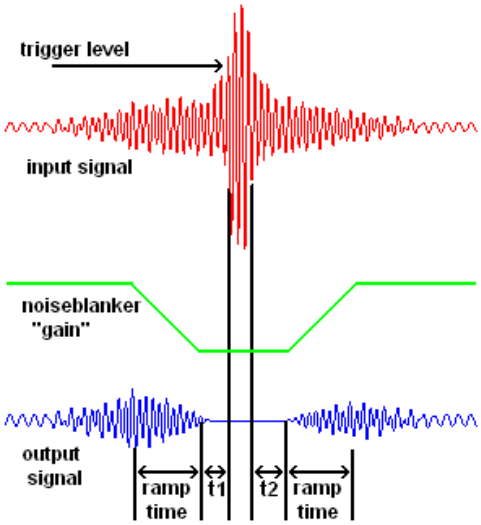
This is because a peak of the signal is removed and the broader lower section is only received. The observed 3 dB bandwidth of the blanked signal would appear to be much wider than if referred to the original peak signal level. - AD7FO

Interference caused by **a touch controlled electrical device** >> Rx **AC Hum** on SSB & CW, **slow drifting signal** or interfering **signal can be several kHz in width and usually repeats** at regular intervals across a HF band



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?

Corroded joints act like diodes and then function as a mixer generating sum and difference frequencies from nearby strong signals. - AD7FO



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**

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

The appearance of unstable modulated or unmodulated signals at specific frequencies might be caused by the operation of a nearby **personal computer**

==========

E4E01 (A) Which of the following types of receiver noise can often be reduced by use of a receiver noise blanker? A. **Ignition noise**

E4E02 (D) Which of the following types of receiver noise can often be reduced with a **DSP noise filter?**
- A. Broadband white noise
- B. Ignition noise
- C. Power line noise
- **D. All of these choices are correct**

E4E03 (B) Which of the following signals might a receiver noise blanker be able to remove from desired signals? B. Signals which appear across a wide bandwidth

E4E04 (D) How can conducted and radiated noise caused by an automobile alternator be suppressed? 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 noise from an electric motor be suppressed? B. By installing a brute-force AC-line filter in series with the motor leads

E4E06 (B) What is a major cause of atmospheric static? B. Thunderstorms

E4E07 (C) How can you determine if line noise interference is being generated within your home? C. By **turning off the AC power line main circuit breaker and listening on a battery-operated radio**

E4E08 (A) What type of signal is picked up by electrical wiring near a radio antenna? A. A **common-mode** signal at the frequency of the radio transmitter

E4E09 (C) What undesirable effect can occur when using an IF noise blanker? C. Nearby signals may appear to be **excessively wide even if they meet emission standards**

E4E10 (D) What is a common characteristic of interference caused by a touch controlled electrical device?

A. The interfering signal sounds like AC hum on an AM receiver or a carrier modulated by 60 Hz hum on a SSB or CW receiver
B. The interfering signal may drift slowly across the HF spectrum
C. The interfering signal can be several kHz in width and usually repeats at regular intervals across a HF band
D. All of these choices are correct

E4E11 (B) Which is the most likely cause if you are **hearing combinations** of local AM broadcast signals within one or more of the MF or HF ham bands? B. Nearby **corroded metal joints** are mixing and re-radiating the broadcast signals

E4E12 (A) What is one **disadvantage of using some types of automatic DSP notch-filters** when attempting to copy CW signals? A. The DSP filter can remove the desired signal at the same time as it removes interfering signals

E4E13 (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 of these choices are correct

E4E14 (C) What is one type of electrical interference that might be caused by the operation of a nearby personal computer? C. The appearance of **unstable modulated or unmodulated signals** at specific frequencies

E4E15 (B) Which of the following can cause shielded cables to radiate or receive interference? B. **Common mode currents** on the shield and conductors

E4E16 (B) What current flows equally on all conductors of an unshielded multi-conductor cable? B. **Common-mode current**

E6D16 (D) What is the common name for a capacitor connected across a transformer secondary that is used to absorb transient voltage spikes? **D. Snubber capacitor**

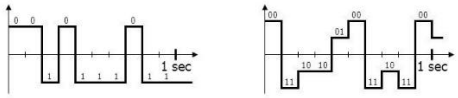
E6E05 (A) Which of the following noise figure values is typical of a **low-noise UHF preamplifier? A. 2 dB**

==========

Chapter 8 Modulation, Protocols and Modes

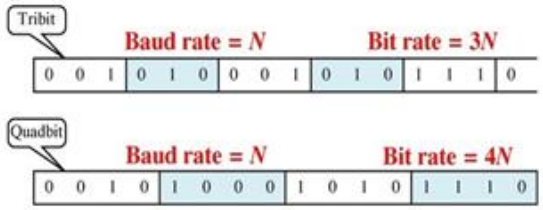
Symbol Rate & Bandwidth

- **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



Baud = 10
Bit rate = 10 bps

Baud = 10
Bit rate = 20 bps



Bit Rate and Baud Rate

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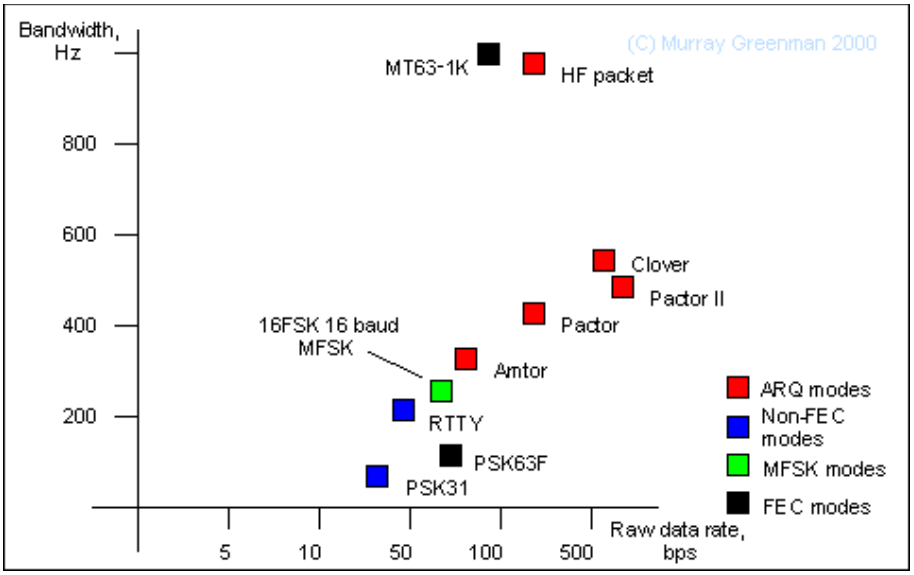
E8C02 (C) What is the definition of **symbol rate** in a digital transmission? C. The rate at which the waveform of a transmitted signal changes to convey information

E8C11 (A) What is the relationship between **symbol rate and baud?** A. They are the same

==========

Frequency Shift Keying



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.

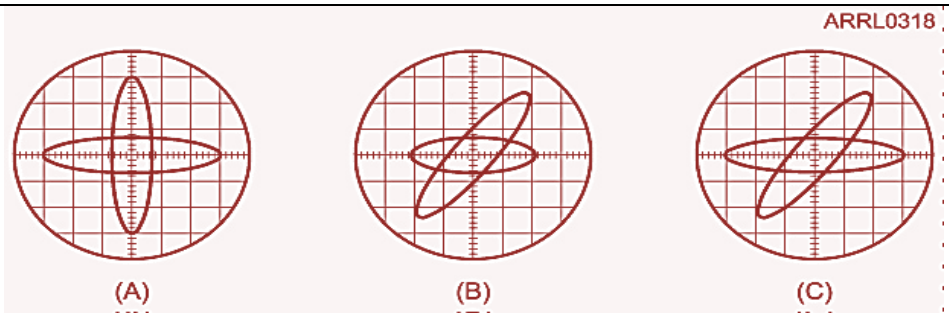
FSK modulation is common for data emissions below 30 MHz

170 Hz 300 baud ASCII J2D transmission bandwidth

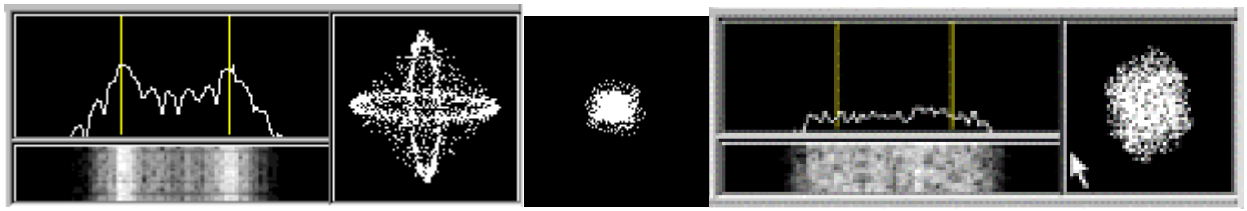
BW = (K x shift) + B where K is 1.2 and B is baud

BW = (1.2 x 170) + 300

BW = 504 Hz



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.



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

FSK and AFSK modulation conversion of tone into a string of ones and zeros

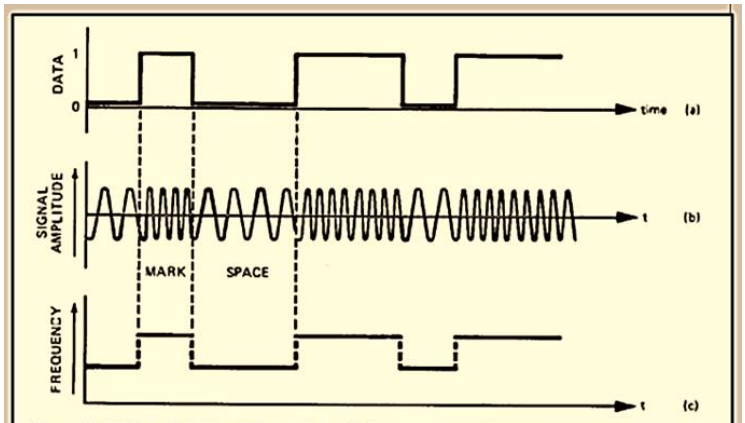
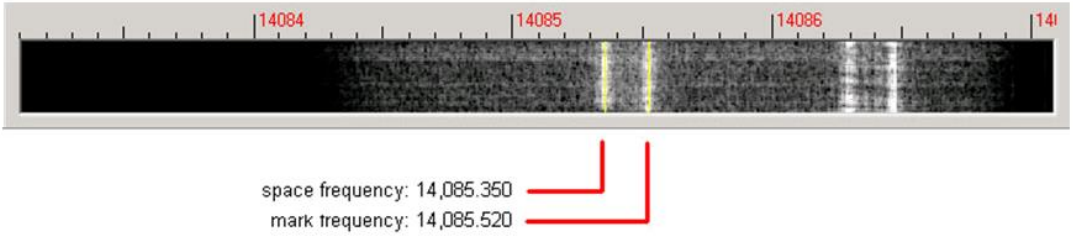
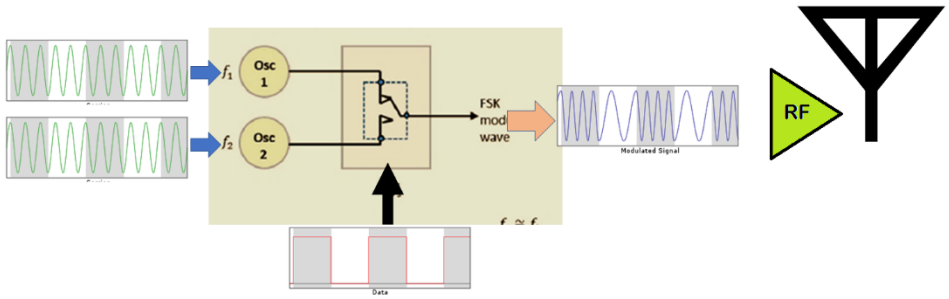


Figure 1. FSK modulation. Binary data (a) frequency modulates the carrier to produce the FSK signal (b) which has the frequency characteristic (c).

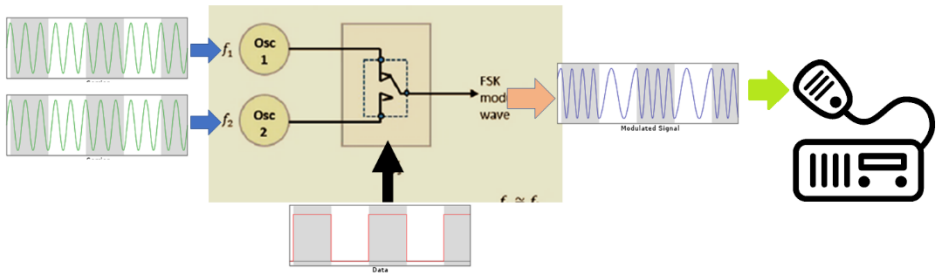


A RTTY transmitter sends out a continuous carrier that shifts frequency back and forth between two distinct frequencieskown as the SPACE frequency and the MARK frequency. The difference between the two is known as the SHIFT is normally 170 Hz.

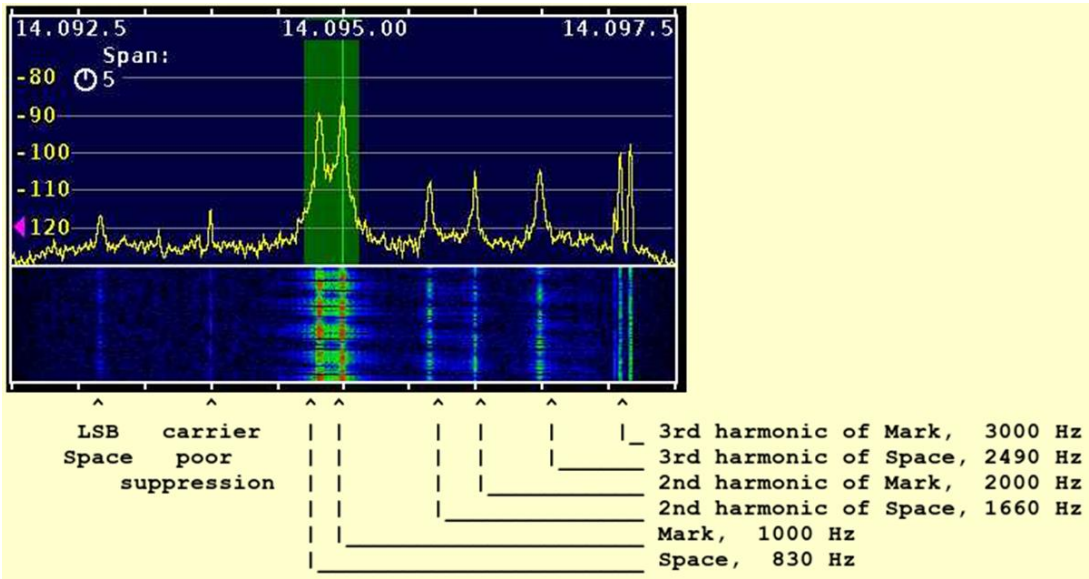
FSK signal are generated by changing an oscillator's frequency directly



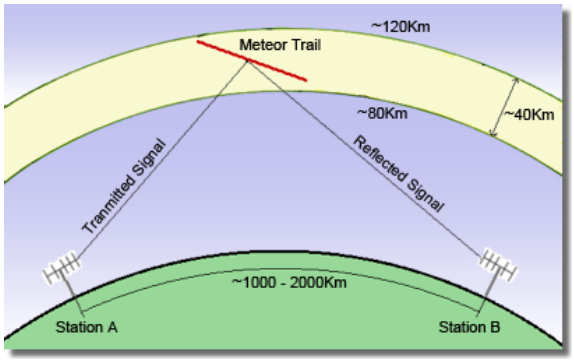
AFSK signals are generated as audio and transmiited as SSB Phone



Improper action of ALC distorts the signal and can cause **spurious emissions**



FSK441 is especially designed for use for **meteor scatter** signals



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E2D01 (B) Which of the following digital modes is especially designed for use for **meteor scatter signals? B. FSK441**

E2E01 (B) Which type of modulation is common for **data emissions below 30 MHz? B. FSK**

E2E04 (A) What is indicated when one of the ellipses in an FSK **crossed-ellipse display suddenly disappears? A. Selective fading has occurred**

E2E07 (B) What is the typical bandwidth of a properly modulated **MFSK16 signal? B. 316 Hz**

E2E11 (A) What is the difference between direct FSK and audio FSK? A**. Direct FSK applies the data signal to the transmitter VFO**

E8C06 (C) What is the necessary **bandwidth of a 170-hertz shift, 300-baud ASCII transmission? C. 0.5 kHz**

E8C07 (A) What is the necessary **bandwidth of a 4800-Hz frequency shift, 9600-baud ASCII FM transmission? A. 15.36 kHz**

E8D06 (B) Which of the following indicates likely **overmodulation of an AFSK signal such as PSK or MFSK? B. Strong ALC action**

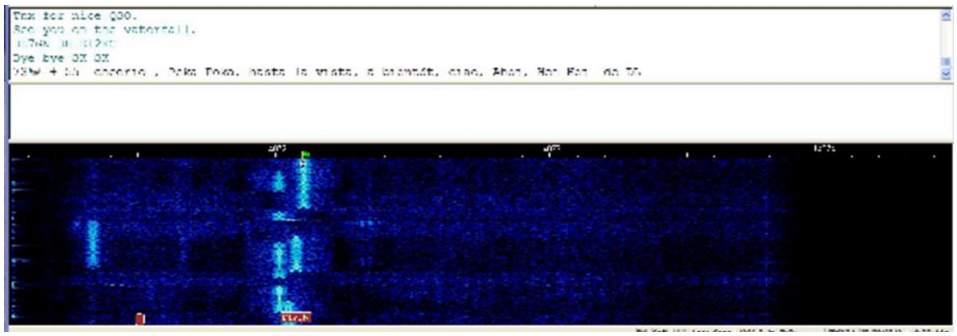
E8D07 (D) What is a common cause of **overmodulation of AFSK signals? Excess transmit audio levels**

E8D08 (D) What parameter might indicate that excessively high input levels are causing **distortion in an AFSK signal? D. Intermodulation Distortion (IMD)**

==========

Phase Shift Keying

Phase Shift Keying (PSK) PSK31 very popular keyboard to keyboard mode on HF



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

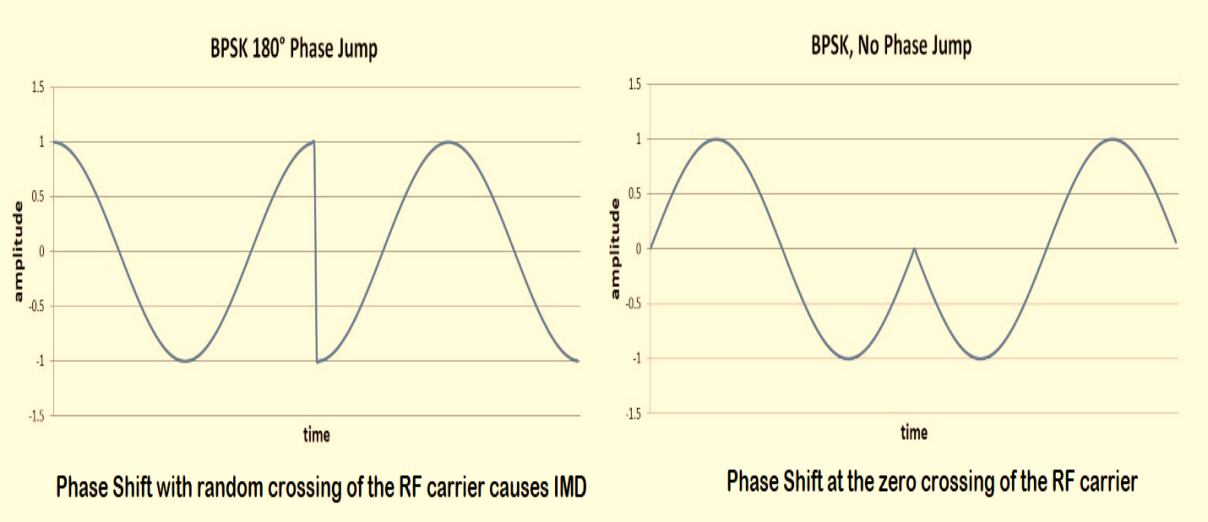
Glyph	Varicode
@	1010111101
A	1111101
B	11101011
C	10101101
D	10110101
E	1110111
F	11011011
G	11111101
H	101010101
I	1111111

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

Uses variable length characters (Varicode)

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



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E2E02 (A) What do the letters **FEC** mean as they relate to digital operation? A. **Forward Error Correction**

E2E09 (D) Which of the following HF digital modes uses variable-length coding for **bandwidth efficiency? D. PSK31**

E2E10 (C) Which of these digital communications modes has the **narrowest bandwidth? C. PSK31**

E8C01 (C) How is **Forward Error Correction** implemented? C. By transmitting extra data that may be used to **detect and correct transmission errors**

E8C03 (A) When performing phase shift keying, why is it advantageous to **shift phase precisely at the zero crossing of the RF carrier**? A. This results in the least possible transmitted bandwidth for the particular mode

E8C04 (C) What technique is used to **minimize the bandwidth** requirements of a PSK31 signal? C. Use of **sinusoidal data pulses**

E8C09 (D) What is the name of a digital code where **each preceding or following character changes by only one bit? D. Gray code**

E8C10 (D) What is an advantage of **Gray code in digital communications where symbols are transmitted as multiple bits D. It facilitates error detection**

E8D09 (D) What is considered a good minimum **IMD level for an idling PSK signal? D. -30 dB**

==========

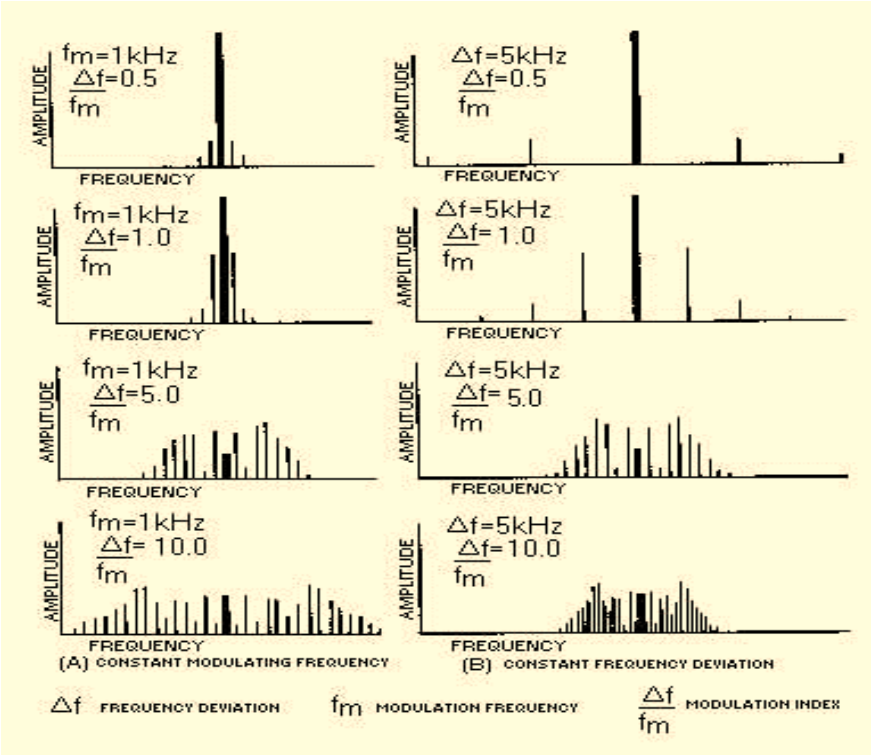
Frequency Modulation

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 Dev

The maximum **carrier frequency** deviation compared to the highest audio **modulating frequency** is the **deviation ratio**



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E1B07 (B) What is the **highest modulation index permitted** at the highest modulation frequency for **angle modulation? B. 1.0**

E8B01 (D) What 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? D. **Modulation index**

E8B02 (D) How does the **modulation index** of a phase-modulated emission vary with RF carrier frequency (the modulated 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

Modulation index = Max Carrier Dev / Max Modulation

Dev = 3000 / 1000

Dev = 3

E8B04 (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? B. 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? 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

Modulation index = Max Carrier Dev / Max Modulation

Dev = 7500 / 3500

Dev = 2.14

E8B09 (B) What is meant by **deviation ratio?** B. The ratio of the maximum carrier frequency deviation to the highest audio modulating frequency

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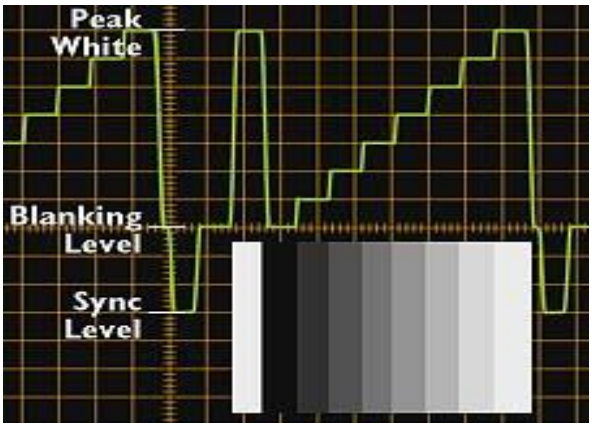
Amateur Television

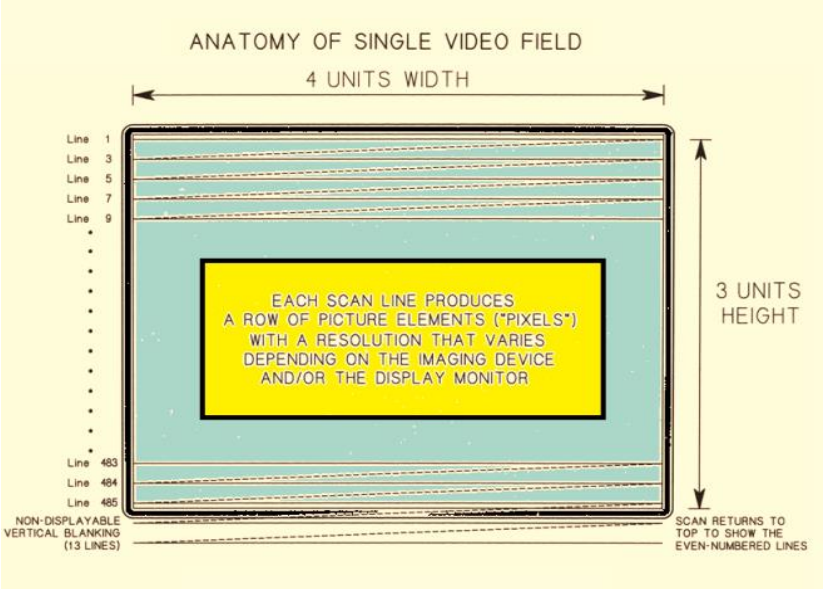
NTSC is the video standard used by North American Fast Scan ATV stations



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

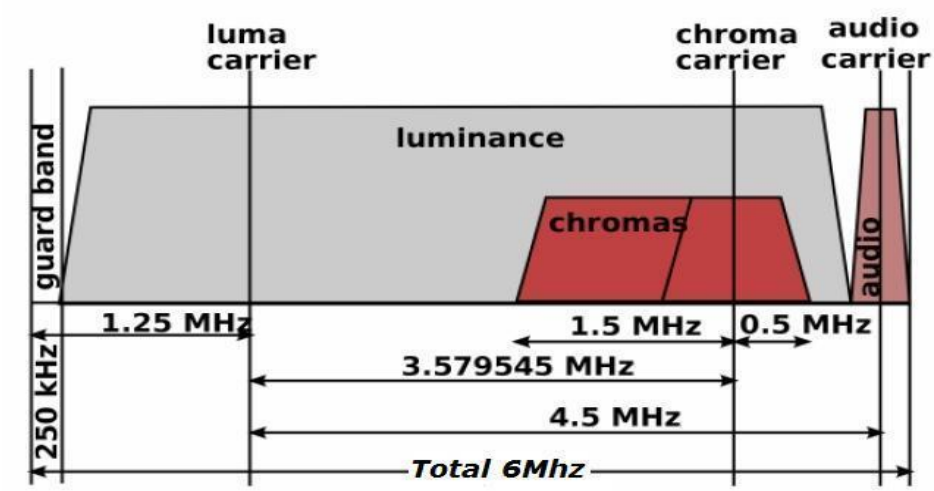


Chroma is the name of the signal component that carries color information in NTSC video

Blanking in a video signal is turning off the scanning beam while it is traveling from right to left or from bottom to top

Vestigial sideband reduces bandwidth while allowing for simple video detector circuitry for standard fast- scan TV transmissions

FM Amateur TV frequencies are; 1.2 GHz, 2.4 GHz, 10.25 GHz @ 17-21 MHz BW



1255 MHz is one likely to find FM ATV transmissions

Which of the following is a common method of transmitting accompanying audio with **amateur fast-scan** television?

A. Frequency-modulated sub-carrier
B. A separate VHF or UHF audio link
C. Frequency modulation of the video carrier
D. All of these choices are correct

Digital Radio Mondiale (DRM) can be decoded using a receiver with SSB capability and a suitable computer

Digital Radio Mondiale (DRM) based voice or SSTV digital transmissions made on the **HF amateur bands has a 3 KHz bandwidth**

Tone frequency of an amateur slow-scan television signal **encodes the brightness** of the picture

128 or 256 lines are commonly used in each frame on an **amateur slow-scan color television** 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**

==========

E2B01 (A) How many times per second is a new frame transmitted in a fast-scan (NTSC) television system? A. 30

E2B02 (C) How many horizontal lines make up a **fast-scan (NTSC) television frame? C. 525**

E2B03 (D) How is an **interlaced scanning pattern** generated in a fast-scan (NTSC) television system? D. By scanning odd numbered lines in one field and even numbered ones in the next

E2B04 (B) What is **blanking in a video signal**? B. Turning off the scanning beam while it is traveling from right to left or from bottom to top

E2B05 (C) Which of the following is an advantage of using **vestigial sideband for standard fast- scan TV** transmissions? C. **Vestigial sideband** reduces bandwidth while allowing for simple video detector circuitry

E2B06 (A) What is **vestigial sideband modulation**? A. Amplitude modulation in which one complete sideband and a portion of the other are transmitted

E2B07 (B) What is the name of the signal component that carries **color information in NTSC video? B. Chroma**

E2B08 (D) Which of the following is a common method of transmitting accompanying audio with amateur fast-scan television?

A. Frequency-modulated sub-carrier
B. A separate VHF or UHF audio link
C. Frequency modulation of the video carrier
D. All of these choices are correct

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)?** D. No other hardware is needed

E2B10 (A) 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**

E2B11 (B) What is the function of the **Vertical Interval Signaling (VIS) code** sent as part of an SSTV transmission? B. To identify the SSTV mode being used

E2B12 (D) How are analog SSTV images typically transmitted on the HF bands? D. Varying **tone frequencies representing the video** are transmitted using single sideband

E2B13 (C) How many **lines are commonly used in each frame** on an amateur slow-scan color television picture? C. **128 or 256**

E2B14 (A) What aspect of an amateur slow-scan television signal **encodes the brightness of the picture? A. Tone frequency**

E2B15 (A) What signals SSTV receiving equipment to **begin a new picture line? A. Specific tone frequencies**

E2B16 (D) Which is a video standard used by **North American Fast Scan ATV stations? D. NTSC**

E2B17 (B) What is the approximate **bandwidth of a slow-scan TV signal? B. 3 kHz**

E2B18 (D) On which of the following frequencies is one likely to find **FM ATV transmissions? D. 1255 MHz**

E2B19 (C) What special operating frequency restrictions are imposed on slow scan TV transmissions? C. They are **restricted to phone band segments and their bandwidth can be no greater than that of a voice** signal of the same modulation type

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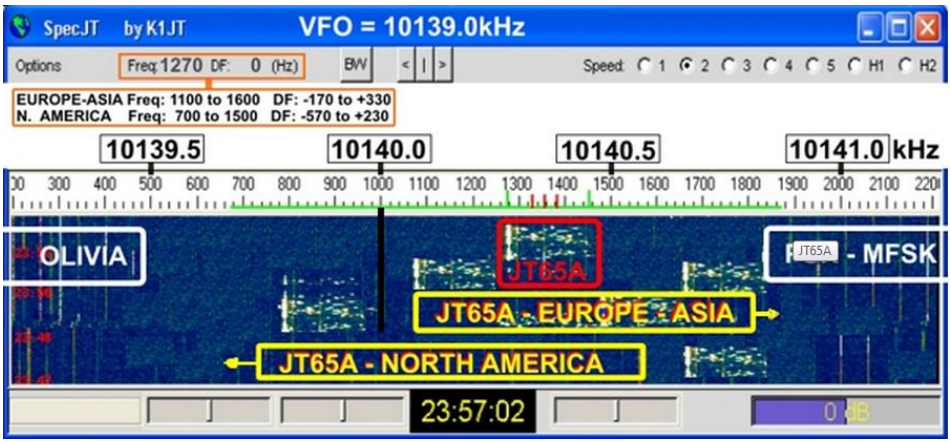
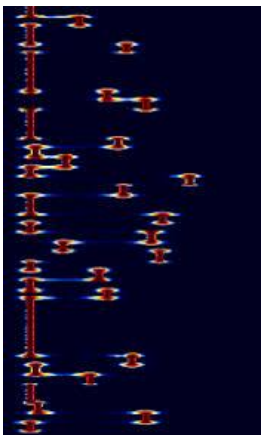
Weak Signal Communication





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

JT65 can decode signals well below noise level using FEC

JT65 uses Multi-tone AFSK

==========

E2D03 (D) Which of the following digital modes is especially useful for **EME communications? D. JT65**

E2D12 (A) How does JT65 improve EME communications? A. It can **decode signals many dB below the noise floor u**sing FEC

E2D13 (A) What type of modulation is used for **JT65 contacts? A. Multi-tone AFSK**

E2D14 (B) What is one advantage of using JT65 coding? B. The ability to **decode signals which have a very low signal to noise ratio**

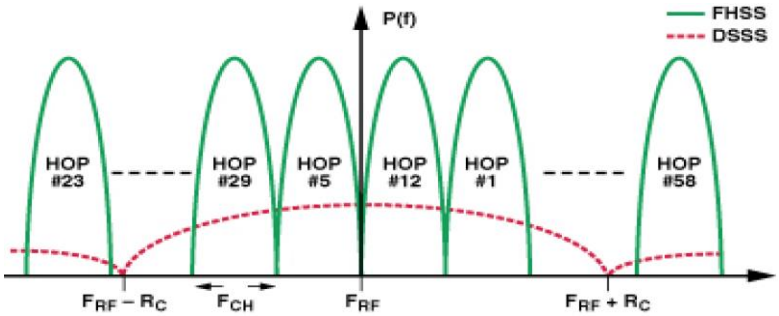
E2E03 (C) How is the timing of JT65 contacts organized? C. Alternating **transmissions at 1 minute intervals**

==========

Spread Spectrum

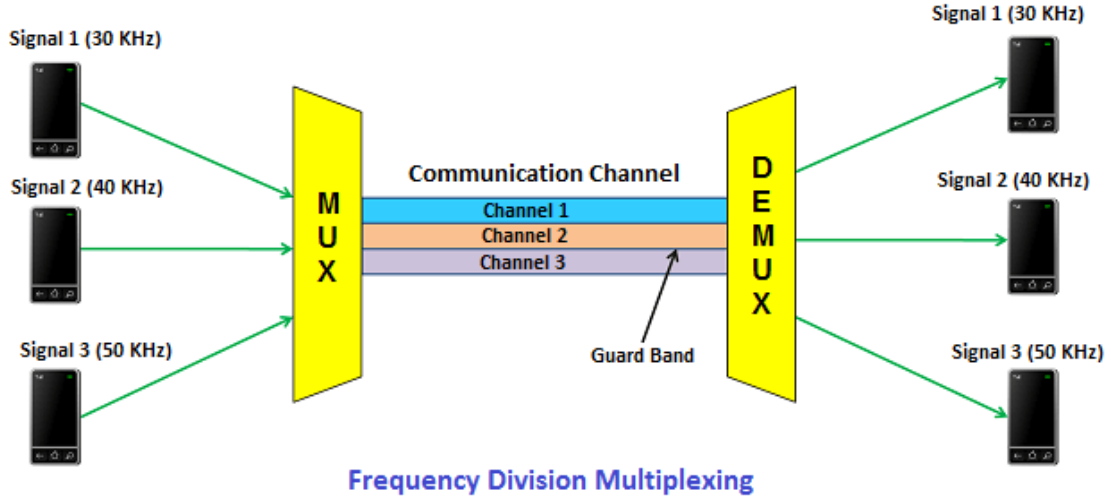
Spread-spectrum causes a digital signal to appear as wide-band noise to a conventional receiver

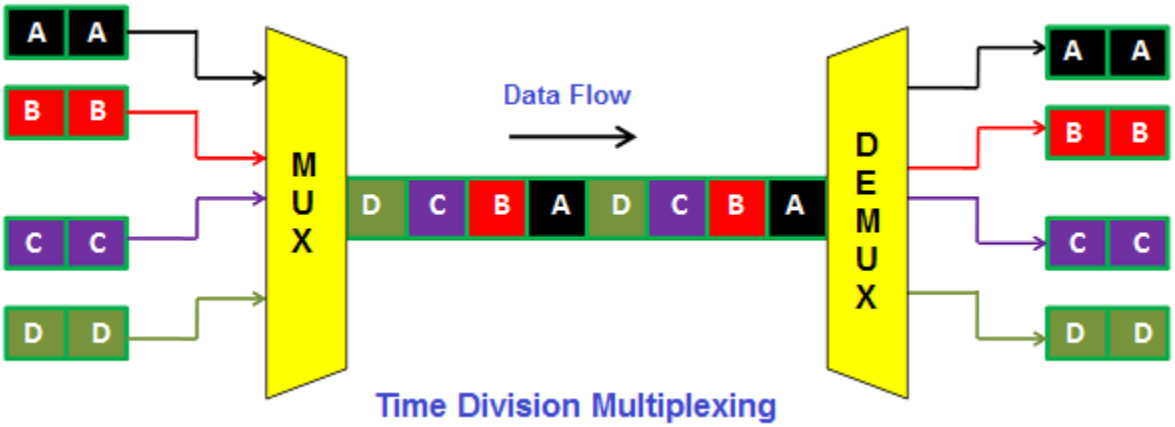
Direct sequence spread-spectrum (DSSS) communications technique uses a high-speed binary bit stream to shift the phase of an RF carrier



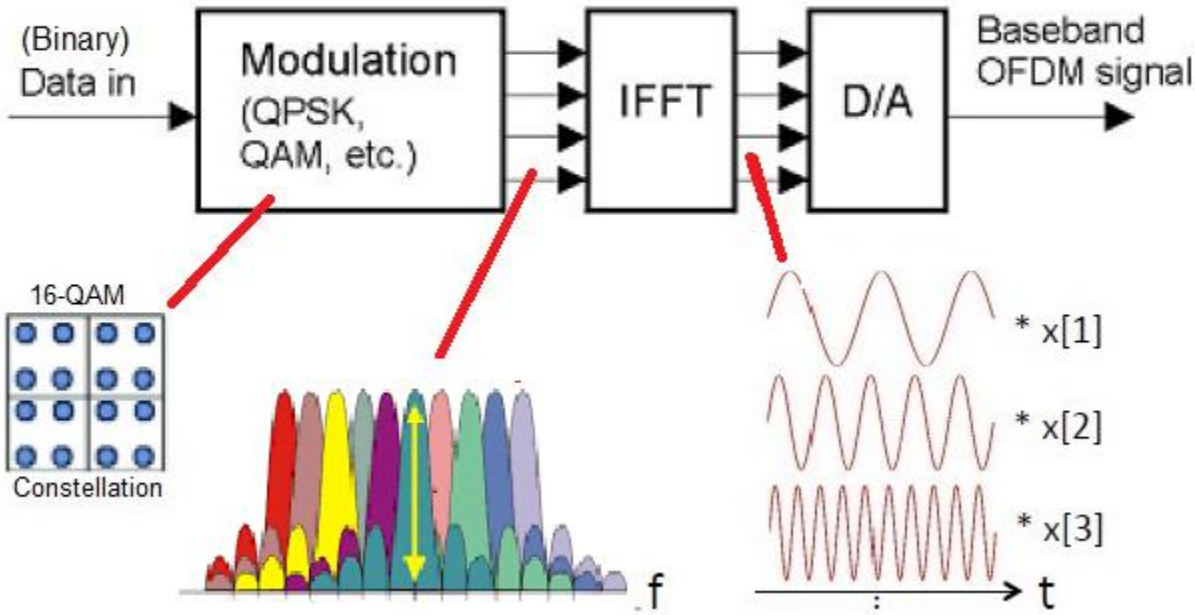
Frequency hopping spread-spectrum (FHSS) communications technique alters the center frequency of a conventional carrier many times per second in accordance with a pseudo-random list of channels

Frequency hopping **Spread-spectrum (FHSS)** communication is a wide-bandwidth communications system in which the transmitted carrier frequency varies according to some predetermined sequence





Orthogonal Frequency Division Multiplexing



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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

E8D02 (B) What spread spectrum communications technique uses a high-speed binary bit stream to shift the phase of an RF carrier? B**. Direct sequence**

E8D03 (D) How does the spread spectrum technique of **frequency hopping work**? D. The frequency of the transmitted signal is changed very rapidly according to a particular sequence also used by the receiving station

E2C09 (C) What type of equipment is commonly used to implement a ham radio **mesh network? C. A standard wireless router running custom software**

E8B10 (B) What describes **frequency division multiplexing**? B. Two or more information streams are merged into a baseband, which then modulates the transmitter

E8B11 (B) What is **digital time division multiplexing**? B. Two or more signals are arranged to share discrete time slots of a data transmission

E8B07 (A) **Orthogonal Frequency Division Multiplexing** is a technique used for which type of amateur communication? A. High-speed digital modes

E8B08 (D) What describes **Orthogonal Frequency Division Multiplexing**? D. A digital modulation technique using subcarriers at frequencies chosen to avoid intersymbol interference

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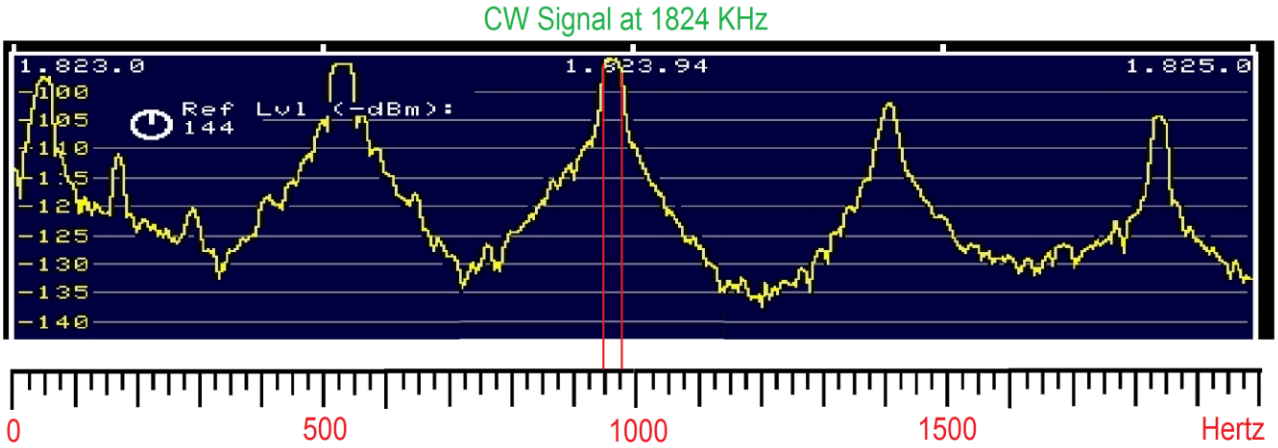
Special Modes & Considerations

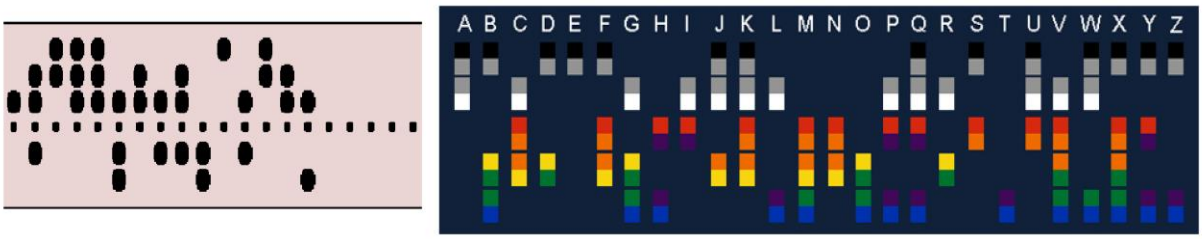
Morse code is a digital code consisting of **elements having unequal length**



The bandwidth of a 13-WPM international Morse code transmission? = C. Approximately 52 Hz

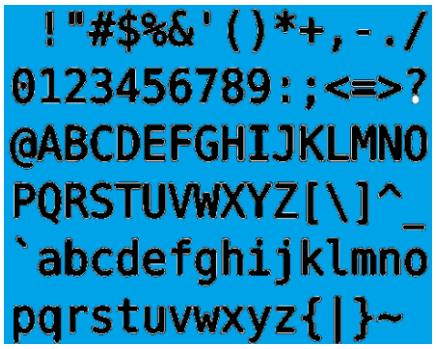
BW = WPM x 4 = 13 x 4 = 52 Hz

Baudot uses **five data bits** per character and uses two characters as shift codes



ASCII uses **seven or eight data bits** per character and no shift code

ASCII code has both **upper- and lower-case** text



7 Bits = 2^7 = 128 Characters

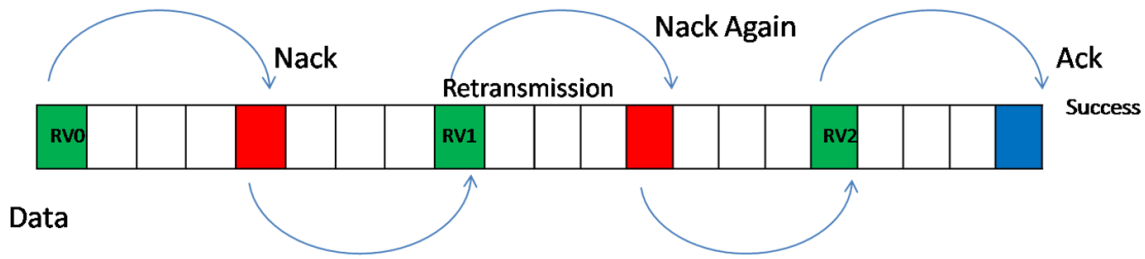
0	*NUL*	16	*DLE*	32	SPC	48	0	64	@	80	P	96	`	112	p
1	*SOH*	17	*DC1*	33	!	49	1	65	A	81	Q	97	a	113	q
2	*STX*	18	*DC2*	34	"	50	2	66	B	82	R	98	b	114	r
3	*ETX*	19	*DC3*	35	#	51	3	67	C	83	S	99	c	115	s
4	*EOT*	20	*DC4*	36	$	52	4	68	D	84	T	100	d	116	t
5	*ENQ*	21	*NAK*	37	%	53	5	69	E	85	U	101	e	117	u
6	*ACK*	22	*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

*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.*

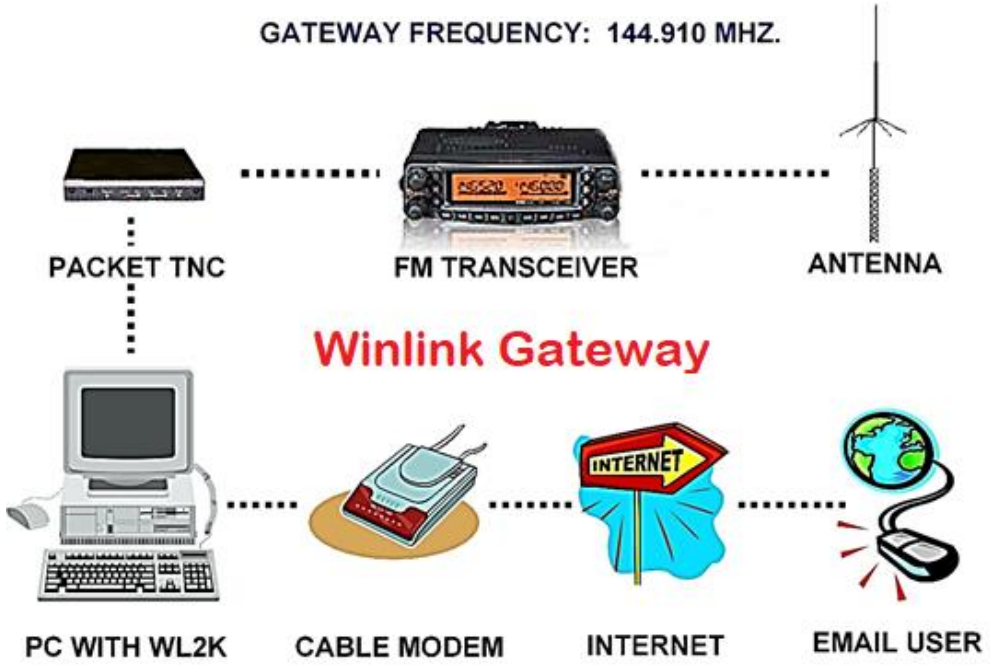
Some types of **errors can be detected** by including a **parity bit** with an **ASCII** character stream

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.

With **ARQ** if errors are detected, a **retransmission is requested**



Winlink is a radio messaging transfer system that uses amateur-band radio frequencies



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E2E08 (B) Which of the following HF digital modes can be used to **transfer binary files? B. PACTOR**

E8C08 (D) How does **ARQ** accomplish error correction? D. If errors are detected, a **retransmission is requested**

E2D09 (D) Which of these digital modes has the fastest data throughput under clear communication conditions? **D. 300 baud packet**

E2E06 (C) What is the most common data rate used for **HF packet? C. 300 baud**

E2E05 (A) Which type of digital mode does not support keyboard-to-keyboard operation? A. **Winlink**

E2E12 (C) Which type of control is used by stations using the **Automatic Link Enable (ALE) protocol?** A C. Automatic

E8C05 (C) What is the necessary bandwidth of a **13-WPM International Morse code transmission? C. Approximately 52 Hz**

E8D04 (C) What is the primary effect of **extremely short rise or fall time on a CW signal**? C. The generation of key clicks

E8D05 (A) What is the most common method of **reducing key clicks? A. Increase keying waveform rise and fall times**

E2E13 (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 the supported by the digital station
C. Another station you are unable to hear is using the frequency
D. All of these choices are correct

E8D11 (C) What is one advantage of using the **ASCII code** for data communications? C. It is possible to transmit both upper and lower case text

E8D12 (D) What is the advantage of including a **parity bit with an ASCII character** stream? D. Some types of errors can be detected

E8D10 (B) What are some of the differences between the **Baudot digital code and ASCII?** 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

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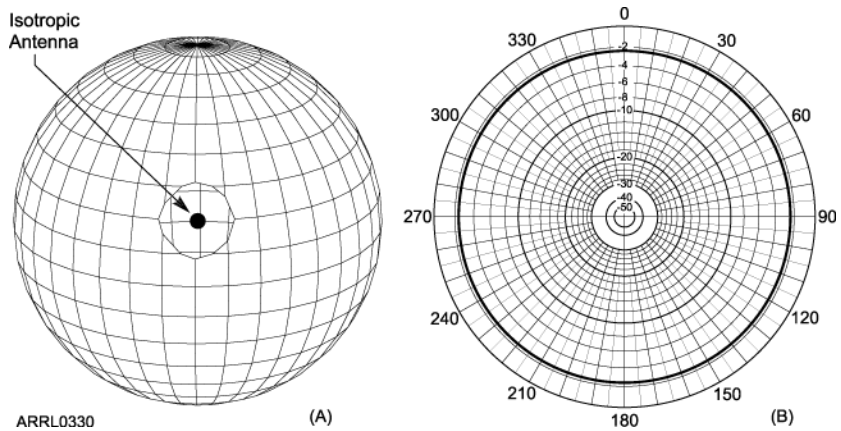
Chapter 9 Antennas and Feed Lines

Antennas Parameters

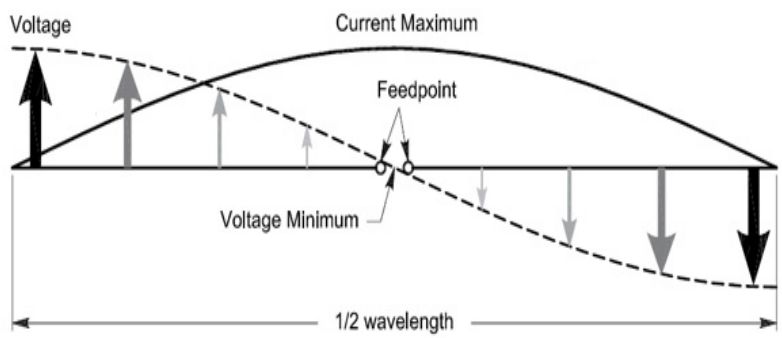
An **ISOTROPIC** antenna is a theoretical antenna used as a reference for antenna gain

An **ISOTROPIC** antenna has no gain in any direction



Feed point impedance is the resistance and reactance seen at the antenna terminals

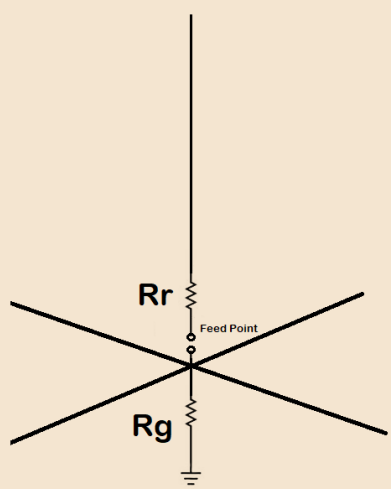
Radiation resistance + Ohmic resistance equal the total resistance of an antenna system



$$\text{Radiation efficiency} = \frac{R_{rad}}{R_{rad} + R_{grd}}$$

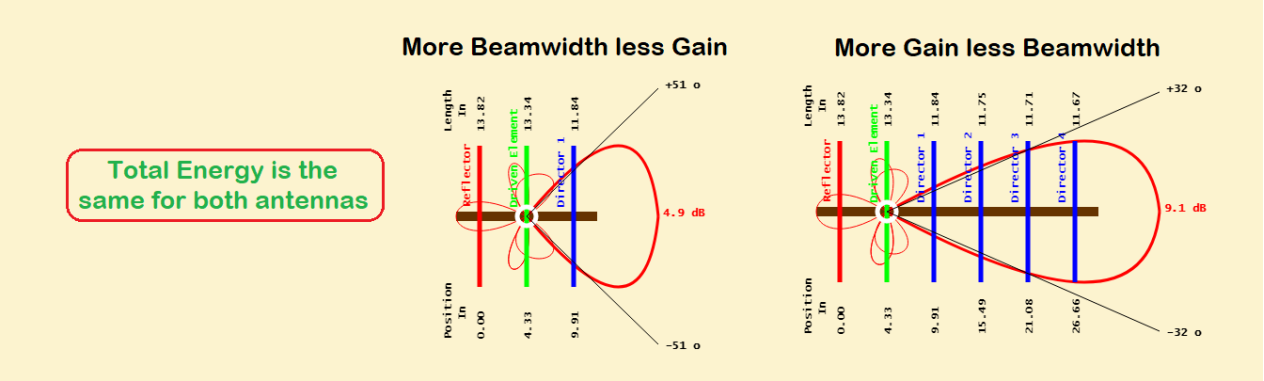
R_{grd} = Radial Impedance + Ohmic Losses

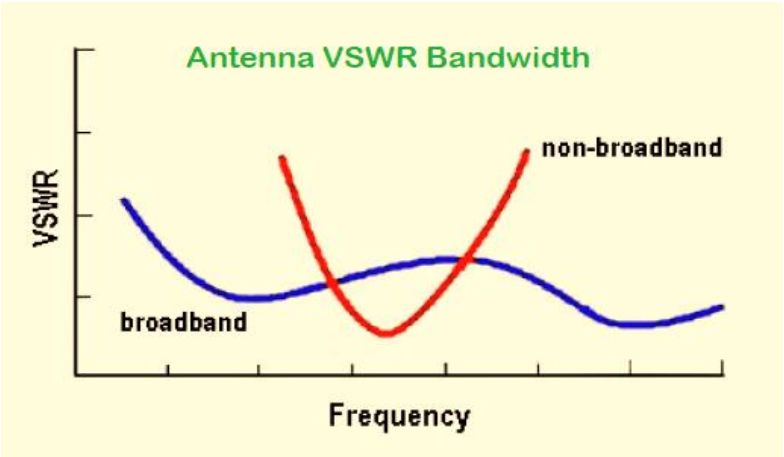
Radial Impedance depends on # of Radials
and
Radials height above ground
or
Radials in ground depend on soil conditions



Radiation resistance + Ohmic resistance equal the total resistance of an antenna system

Antenna efficiency = (radiation resistance / total resistance) x 100%





Antenna Bandwidth is the frequency range an antenna satisfies performance requirements, typically frequency range a feedpoint VSWR is less than 2:1.

==========

E9A01 (C) Which of the following describes an **isotropic antenna**? A. C. A theoretical antenna used as a reference for antenna gain

E9A02 (D) Which of the following antennas has no gain in any direction? D. **Isotropic antenna**

E9A03 (A) Why would one need to know the feed point impedance of an antenna? A. To **match impedances** in order to minimize standing wave ratio on the transmission line

E9A04 (B) Which of the following factors may affect the **feed point impedance** of an antenna? B. Antenna height, conductor length/diameter ratio and location of nearby conductive objects

E9A05 (D) What is included in the **total resistance of an antenna system? D. Radiation resistance plus ohmic resistance**

E9A14 (C) What is meant by the **radiation resistance** of an antenna? C. The value of a resistance that would dissipate the same amount of power as that radiated from an antenna

E9A06 (D) How does the **beamwidth of an antenna vary as the gain** is increased? D. It decreases

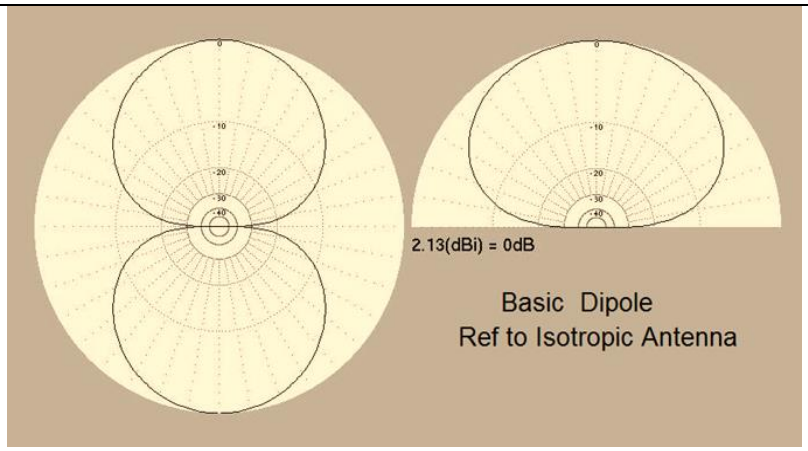
E9A08 (B) What is meant by **antenna bandwidth**? B. The frequency range over which an antenna satisfies a performance requirement

E9A09 (B) How is **antenna efficiency** calculated? B. (radiation resistance / total resistance) x 100 percent

E9A10 (A) Which of the following choices is a way to improve the **efficiency of a ground-mounted quarter-wave vertical antenna**? A. Install a good radial system

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? C. **Soil conductivity**

==========



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E9A07 (A) What is meant by **antenna gain**? A. The ratio of the radiated signal strength of an antenna in the direction of maximum radiation to that of a reference 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

Unknown Antenna = 6 dBi

Dipole Antenna = 2.15 dBi

Unknown Ant Gain – DP Gain >> 6 dBi – 2.15 dBi = 3.85 dB

Unknown Antenna = 3.85 dB more than a Dipole Antenna

E9A13 (B) How much **gain does an antenna** have compared to a 1/2-wavelength dipole when it has 12 dB gain over an isotropic antenna? B. 9.85 dB

Unknown Antenna = 12 dBi

Dipole Antenna = 2.15 dBi

Unknown Ant Gain – DP Gain >> 12 dBi – 2.15 dBi = 9.85 dB

Unknown Antenna = 9.85 dB more than a Dipole Antenna

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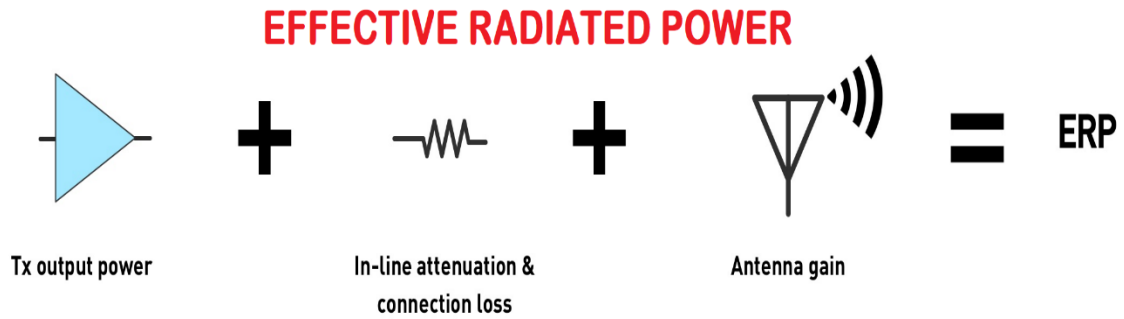

EFFECTIVE RADIATED POWER describes station output, including the transmitter, antenna and everything in between, when considering transmitter power and system gains and losses

==========

E9A18 (C) What term describes station output, taking into account **all gains and losses? C. Effective radiated power**

E9A15 (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? 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

E9A16 (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

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

E9A17 (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? B. 252 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 + 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

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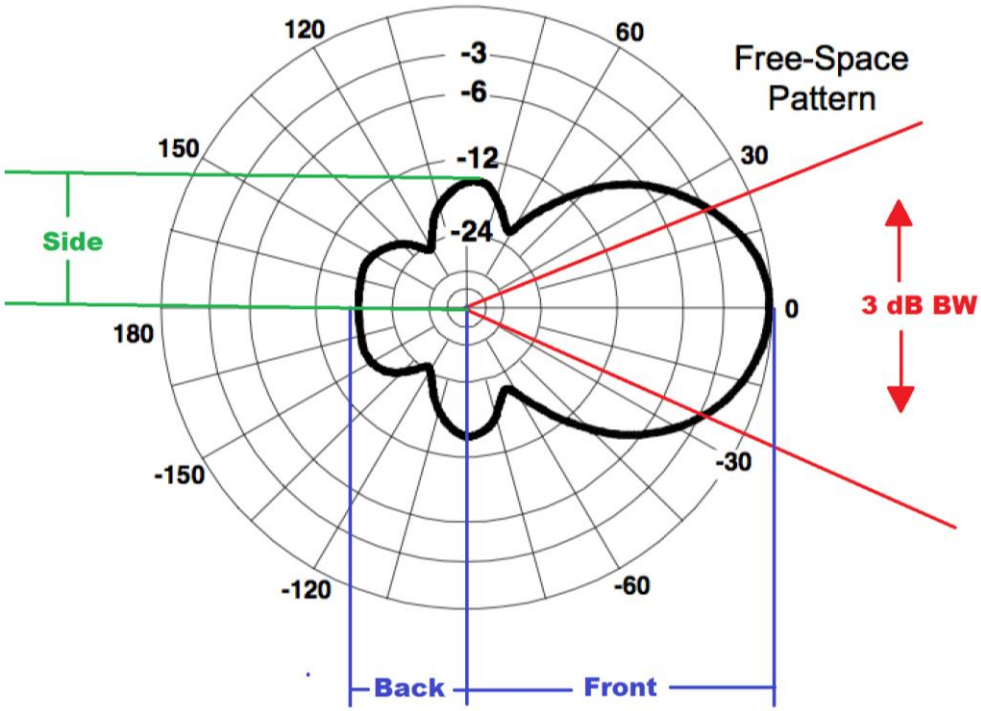
Antenna Patterns

Figure E9-1



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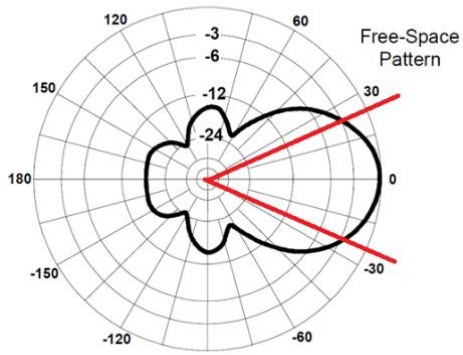
E9B04 (D) What may occur when a directional antenna is operated at **different frequencies** within the band for which it was designed? D. The gain may change depending on frequency

E9B07 (C) How does the **total amount of radiation** emitted by a directional gain antenna compare with the total amount of radiation emitted from an isotropic antenna, assuming each is driven by the same amount of power? C**. They are the same**

E9B08 (A) How can the **approximate beamwidth** in a given plane of a directional antenna be determined? A. Note the two points where the signal strength of the antenna is 3 dB less than maximum and compute the angular difference

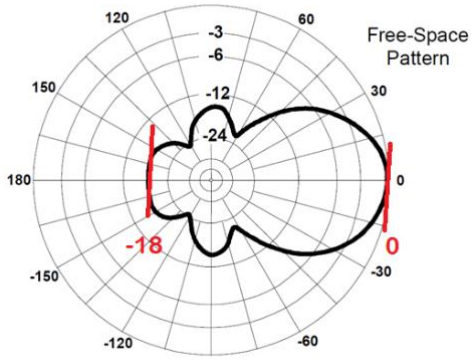
E9B01 (B) In the antenna radiation pattern shown in Fig E9-1, what is the **3-dB beamwidth**? B. 50 degrees

Figure E9-1



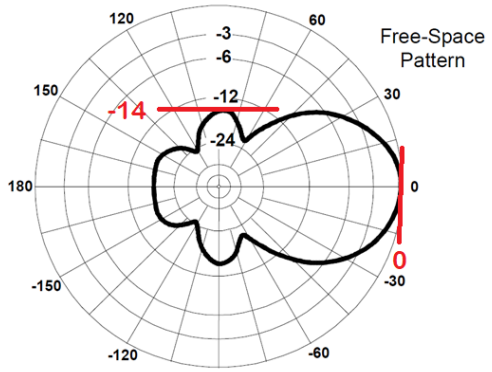
E9B02 (B) In the antenna radiation pattern shown in Fig E9-1, what is the **front-to-back ratio**? B. 18 dB

Figure E9-1

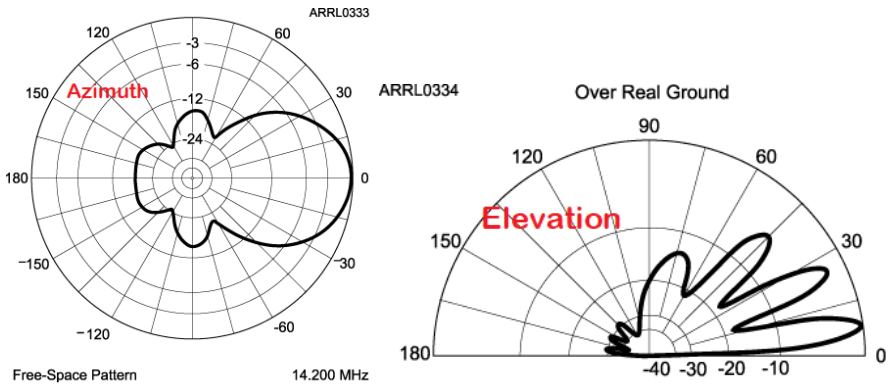


E9B03 (B) In the antenna radiation pattern shown in Fig E9-1, what is the **front-to-side ratio**? B. 14 dB

Figure E9-1

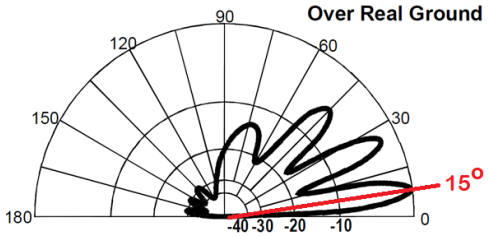


E9B05 (A) What type of antenna pattern **over real ground** is shown in Fig E9-2**? A. Elevation**



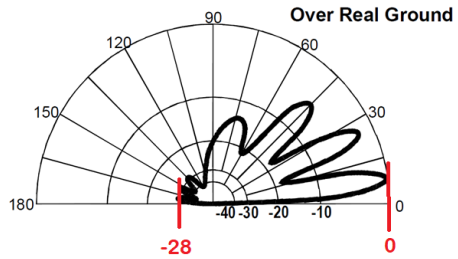
E9B06 (C) What is the **elevation angle of peak** response in the antenna radiation pattern shown in Figure E9-2? C. 7.5 degrees

Figure E9-2



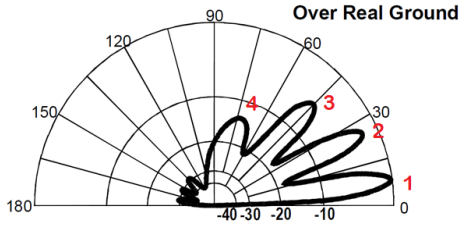
E9B15 (B) What is the **front-to-back ratio** of the radiation pattern shown in Fig E9-2? B. 28 dB

Figure E9-2



E9B16 (A) How many **elevation lobes** appear in the forward direction of the antenna radiation pattern shown in Fig E9-2? A. 4

Figure E9-2



*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.*

E9B09 (B) What type of computer program technique is commonly used for modeling antennas? **B. Method of Moments**

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

E9B11 (C) What is a **disadvantage of decreasing the number of wire segments** in an antenna model below the guideline of 10 segments per half-wavelength? C. The computed feed point impedance may be incorrect

E9B12 (D) What is **the far field** of an antenna? D. The region where the shape of the antenna pattern is independent of distance

E9B13 (B) What does the abbreviation NEC stand for when applied to antenna modeling programs? B. **Numerical Electromagnetics Code**

E9B14 (D) What type of information can be obtained by submitting the details of a proposed new antenna to a modeling program?

A. SWR vs. frequency charts
B. Polar plots of the far-field elevation and azimuth patterns
C. Antenna gain
D. All of these choices are correct

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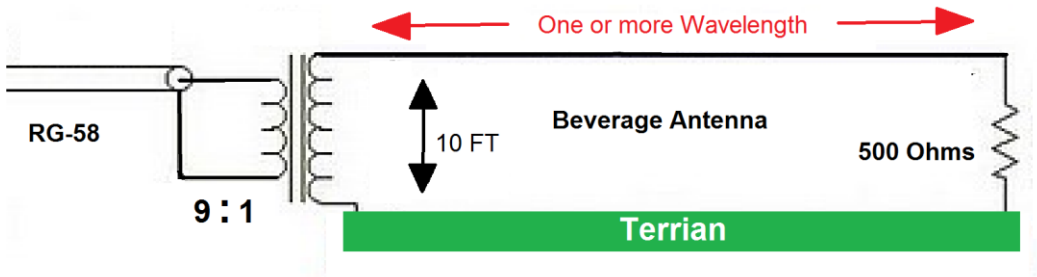
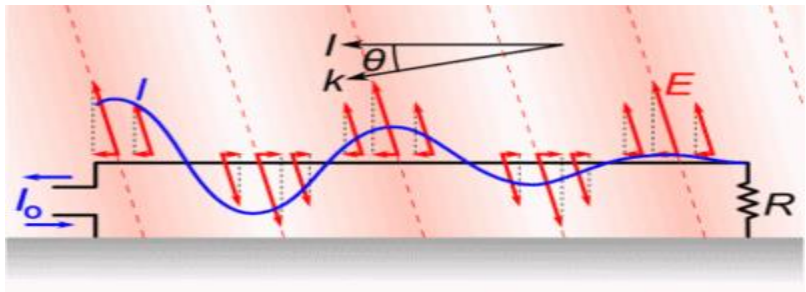
Wire and Monopole Vertical Antennas

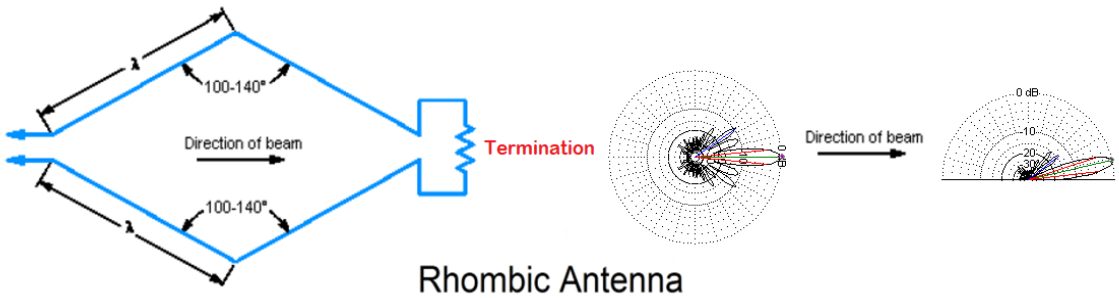
A **BEVERAGE** antenna should be **one or more wavelengths long**



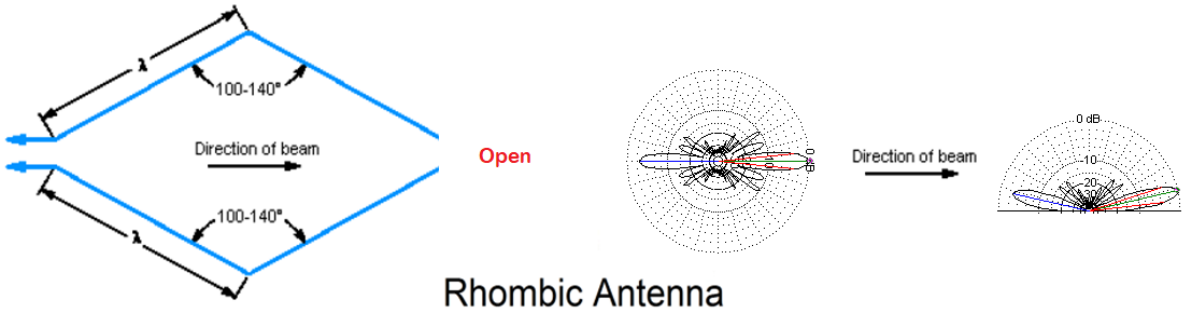


The lobes align more in the direction of the wire **long wire antenna as the wire length is increased**

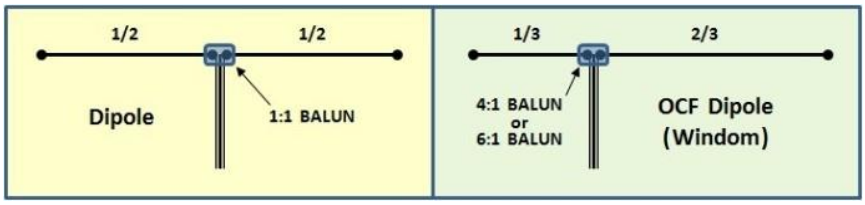
The **terminating resistor on a rhombic** antenna provides a **directional radiation pattern**



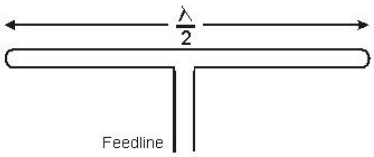
The **open ended on a rhombic** antenna provides a **bidirectional radiation pattern**



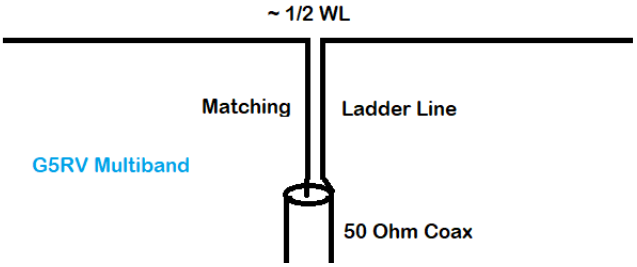
An **OCFD antenna** is a dipole feed approximately 1/3 the way from one end with a 4:1 balun



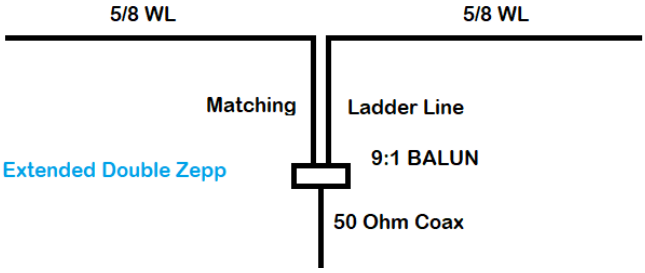
A folded dipole antenna is one wavelength of wire forming a very thin loop



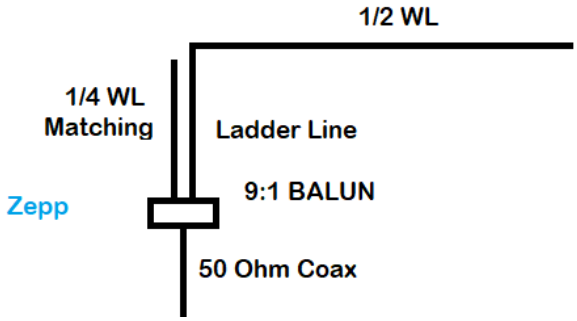
G5RV antenna is a multiband dipole antenna fed with coax and a balun open wire matching section



An **extended double Zepp antenna** is a center fed dipole with two 5/8 wave elements in phase



Zepp antenna is an end fed dipole antenna



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E9C04 (B) What happens to the radiation pattern of an unterminated **long wire antenna as the wire length is increased**? B. The lobes align more in the direction of the wire

E9C05 (A) What is an **OCFD antenna**? A. A dipole feed approximately 1/3 the way from one end with a 4:1 balun to provide multiband operation

E9C06 (B) What is the effect of a **terminating resistor on a rhombic antenna**? B. It changes the radiation pattern from bidirectional to unidirectional

E9C07 (A) What is the approximate feed point impedance at the center of a two-wire **folded dipole antenna? A. 300 ohms**

E9C08 (C) What is a **folded dipole antenna**? C. A dipole constructed from one wavelength of wire forming a very thin loop

E9C09 (A) What is a **G5RV antenna**? A. A multiband dipole antenna fed with coax and a balun through a selected length of open wire transmission line

E9C10 (B) Which of the following describes a **Zepp antenna**? B. An end fed dipole antenna

E9C12 (C) Which of the following describes an **extended double Zepp antenna**? C. A center fed 1.25 wavelength antenna (two 5/8 wave elements in phase)

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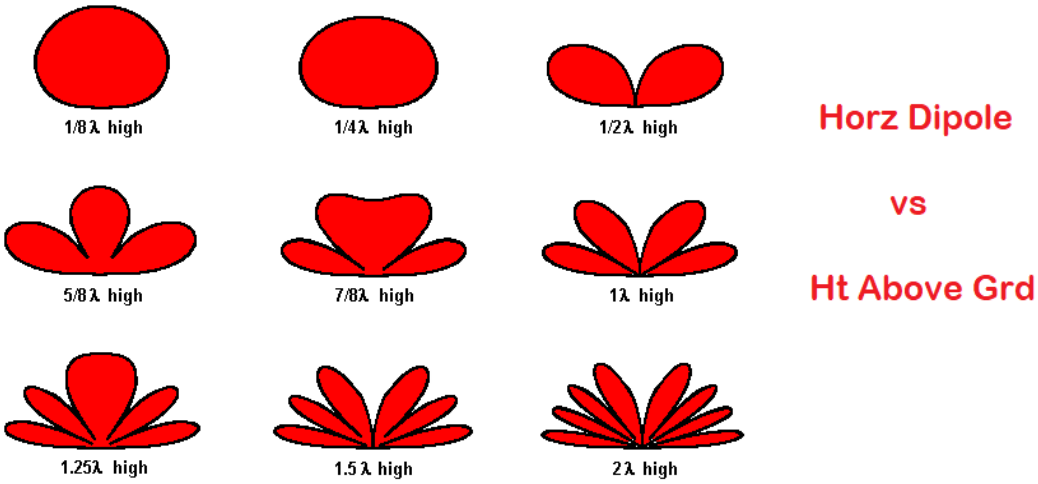
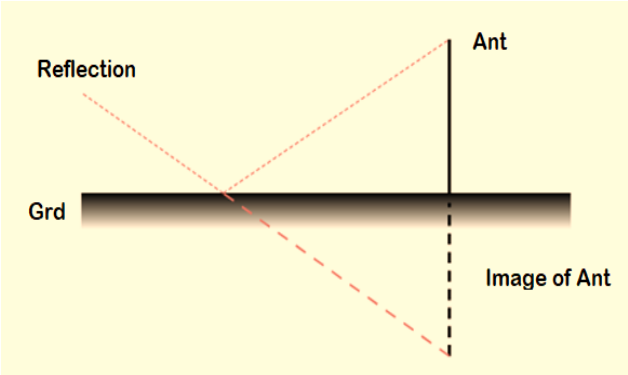
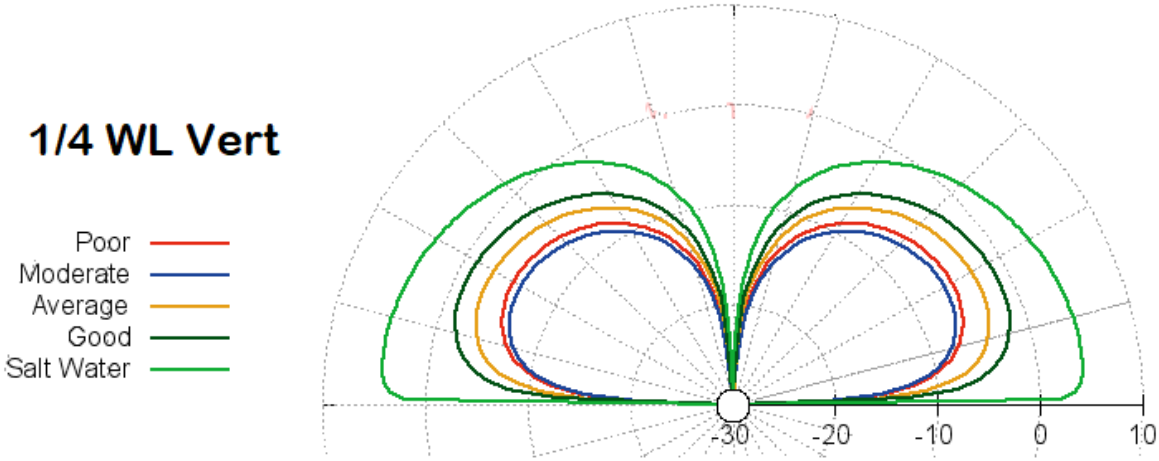




Editor's note: Effects of ground reflections and absorption on antenna systems efficiency is the losses in nearby ground, ground structures, or the antenna's ground system. Radiation pattern over ground is affected by the electrical conductivity of the soil



In phase reinforce (antenna radiation & ground reflections), signal strength will increase

Out of phase cancel (antenna radiation & ground reflections), signal strength will decrease

Low conductivity soil losses reduce signal strength at low angles

Low-angle radiation from a vertically polarized antenna **over seawater will be much stronger**

Low-angle radiation from a vertically polarized antenna **over rocky soil will be much weaker**

Raising the antenna lowers the vertical takeoff angle of the peak radiation

Horizontal antennas have less ground losses

==========

E9C11 (D) How is the far-field elevation pattern of a vertically polarized antenna affected by being mounted over **seawater** versus rocky ground? **D. The low-angle radiation increases**

E9C13 (C) What is the main effect of placing a vertical antenna over an **imperfect ground? C. It reduces low-angle radiation**

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? B. The main lobe takeoff angle decreases** in the downhill direction

E9C15 (B) How does the radiation pattern of a horizontally polarized 3-element beam antenna vary with its **height above ground? B. The main lobe takeoff angle decreases with increasing height**

==========

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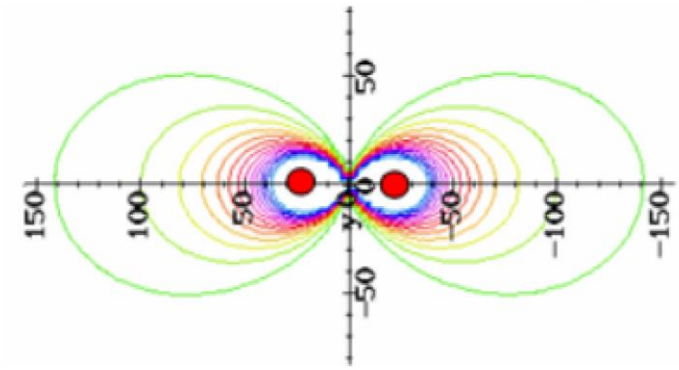
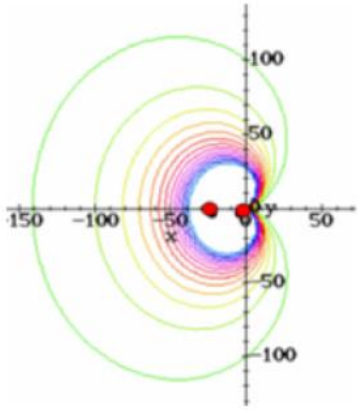
E9C01 (D) What is the radiation pattern of **two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed 180 degrees out of phase**? D. A figure-8 oriented along the axis of the array



Two vertical ¼ WL antennas Feed points 180º out of phase

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

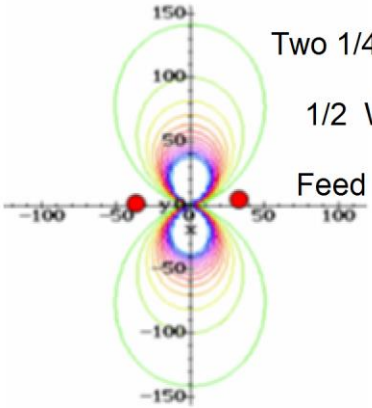


Two 1/4 WL verticals

1/4 WL apart with

Feed 90º Out of Phase

E9C03 (C) What is the radiation pattern of **two 1/4-wavelength vertical antennas spaced 1/2-wavelength apart and fed in phase?** C. A Figure-8 broadside to the axis of the array



Two 1/4 WL verticals

1/2 WL apart

Feed in Phase

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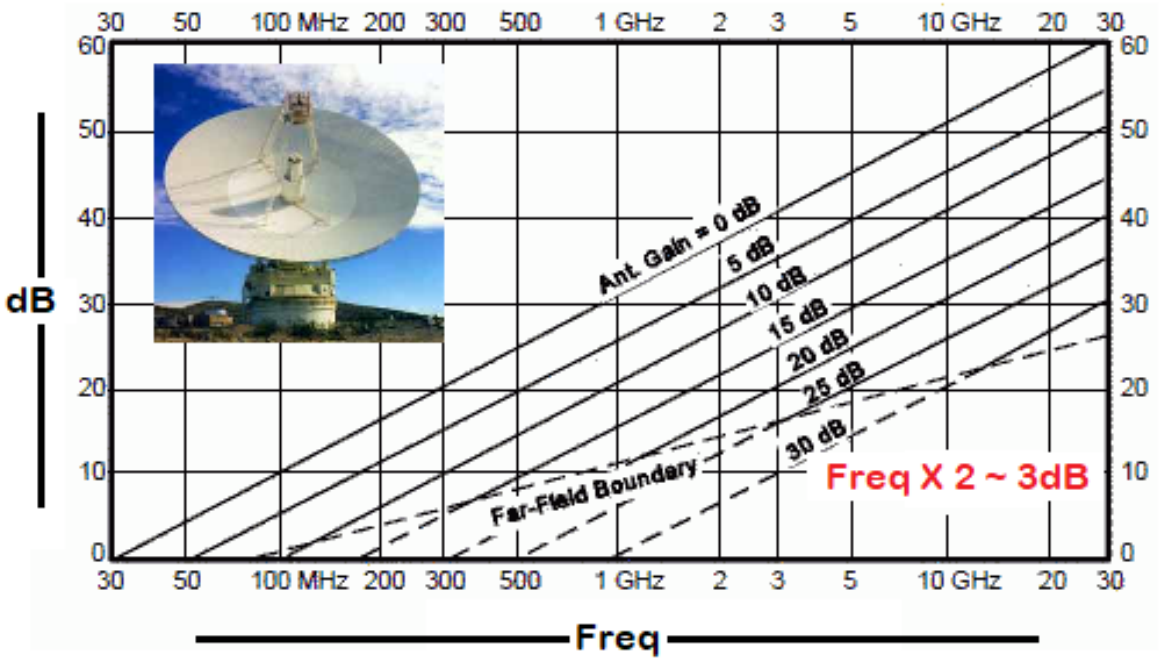
Directional & Short Antennas



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E9D01 (C) How does the gain of an ideal **parabolic dish antenna** change when the operating frequency is doubled? C. Gain increases by 6 dB

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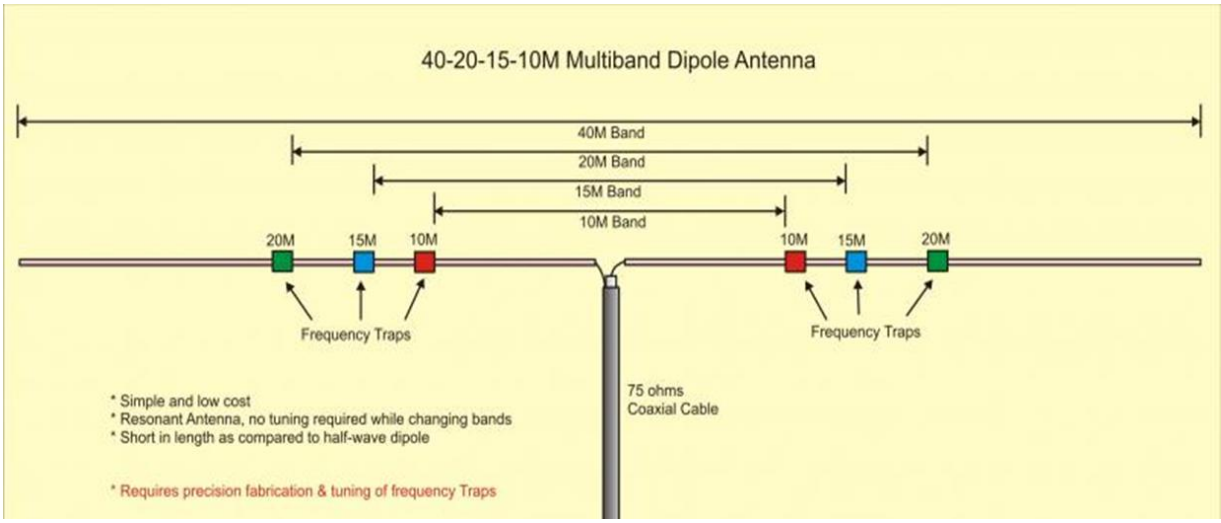

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E9D05 (A) What is a disadvantage of using a **multiband trapped antenna**? A. It might radiate harmonics

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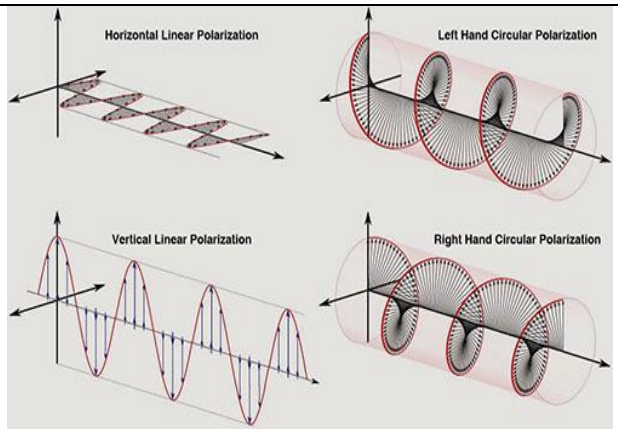

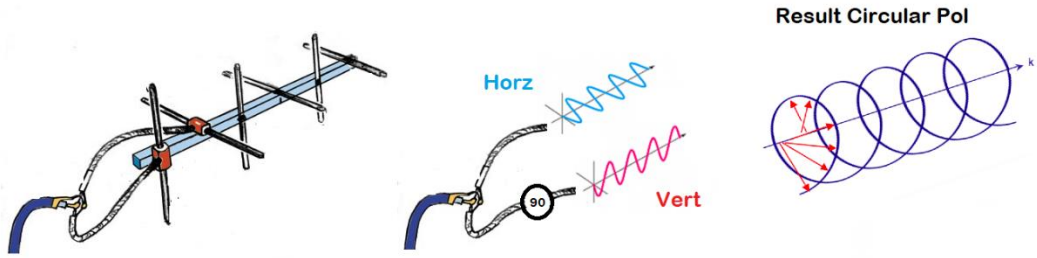

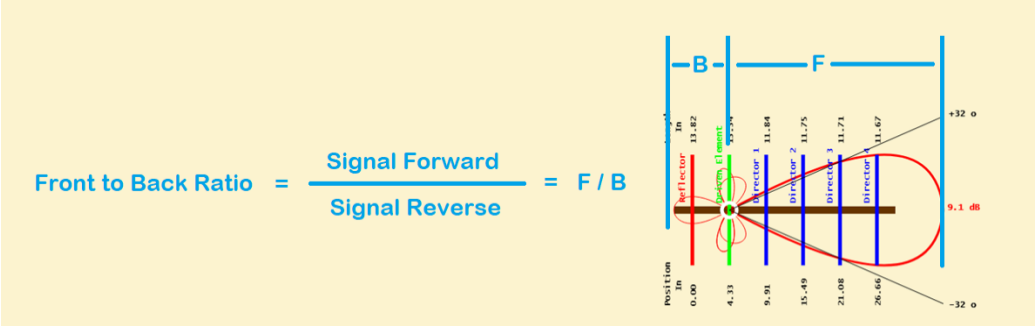

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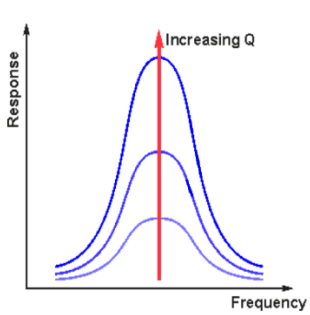
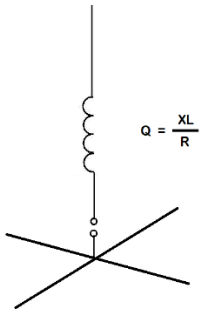
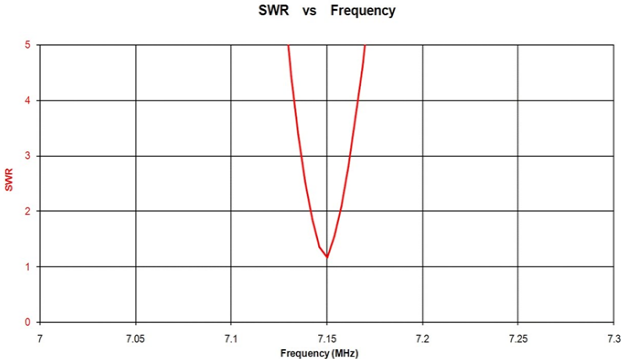
E9D02 (C) How can **linearly polarized Yagi antennas be used to produce circular polarization**? C. Arrange two Yagis perpendicular to each other with the driven elements at the same point on the boom and fed 90 degrees out of phase

E9D13 (B) What usually occurs if a **Yagi antenna** is designed solely for maximum forward gain? B. The front-to-back ratio decreases

==========







Place a high-Q loading **coil at center of the vertical radiator** to minimize losses in a shortened antenna

As the **Q of an antenna increases** the SWR bandwidth decreases

The **bandwidth decreases in an antenna shortened through the use of loading coils**

Top loading in a shortened HF vertical antenna improves radiation efficiency

==========

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

E9D04 (C) Why should an **HF mobile antenna loading coil** have a high ratio of reactance to resistance? C. To minimize losses

E9D06 (B) What happens to the **bandwidth of an antenna as it is shortened** through the use of loading coils? B. It is decreased

E9D07 (D) What is an advantage of using **top loading in a shortened HF vertical** antenna? D. Improved radiation efficiency

E9D08 (B) What happens as the **Q of an antenna increases**? B. SWR bandwidth decreases

E9D09 (D) What is the function of a **loading coil as used with an HF mobile** antenna? D. To cancel capacitive reactance

E9D10 (B) What happens to feed point **impedance at the base of a fixed-length HF mobile** antenna as the frequency of operation is lowered? B. The radiation resistance decreases and the capacitive reactance increases

==========

Best RF station ground >> 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

==========

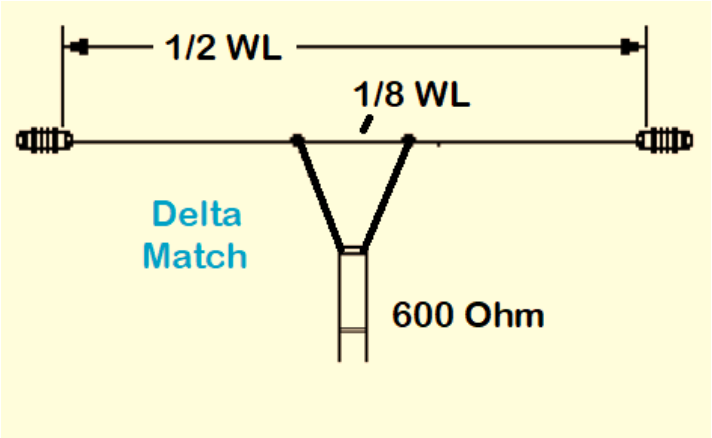
E9D11 (B) Which of the following types of conductor would be best for minimizing losses in a **station's RF ground system? B. A wide flat copper strap**

E9D12 (C) Which of the following would provide the best **RF ground for your station? C. An electrically-short connection to 3 or 4 interconnected ground rods driven into the Earth**

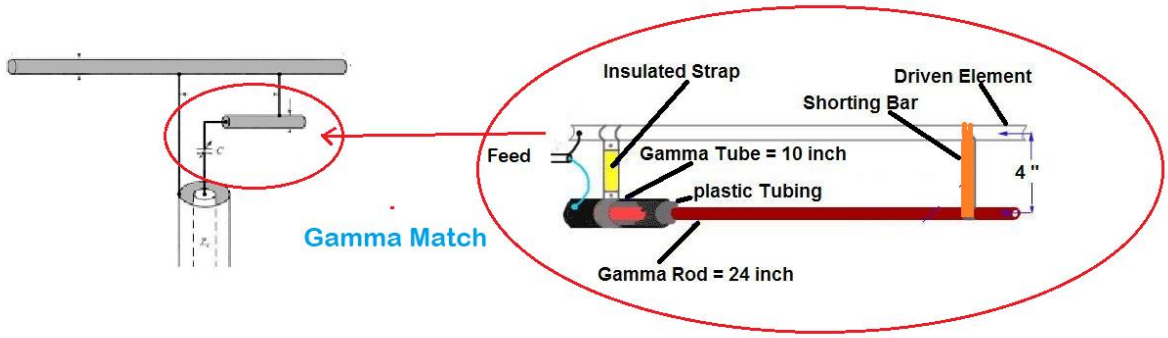
==========

Impedance Matching

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

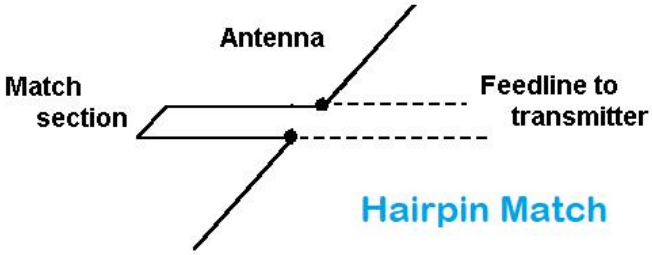


The **gamma match** that matches an unbalanced feed line to an antenna by feeding the driven element both at the center of the element and at a fraction of a wavelength to one side of center

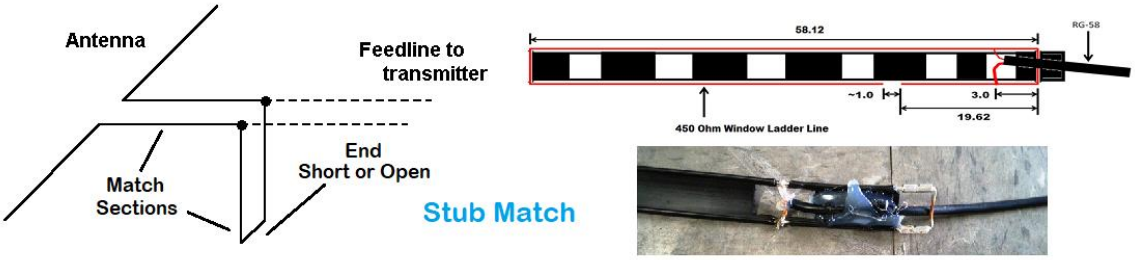


A **Gamma match** is an **effective match** of a 50-ohm feed to a **grounded tower** so it can be a **vertical antenna**

The **series capacitor** in a **gamma matching** network **cancels the inductive reactance** of the matching network

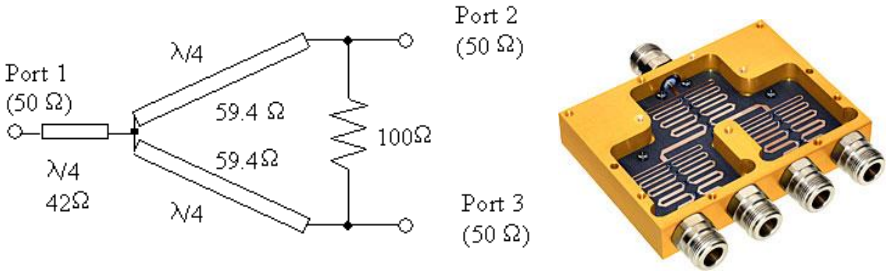


Hairpin matching is adding an inductance directly across the feed point of the antenna. The inductance may be a simple U-shaped wire or rods. This U-shape is of course the reason for the name hairpin and many applications of this matching style use that form of inductance.



The **stub match** uses a section of transmission line connected in parallel with the feed line at or near the feed point

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 preventing changes in one load from disturbing power flow to the others

==========

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? B. **The delta 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**

E9E09 (C) Which of these matching systems is an effective method of connecting a 50-ohm coaxial cable feed line to a grounded tower so it can be used as a vertical antenna **C. Gamma match**

E9E04 (B) What is the purpose of the series **capacitor in a gamma-type antenna matching** network? B. To cancel the inductive reactance of the matching network

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? D**. The stub match**

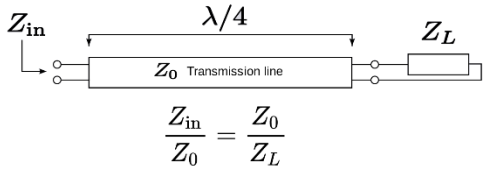
E9E05 (A) How must the driven element in a 3-element Yagi be tuned to use a **hairpin matching** system? A. The driven element reactance must be capacitive

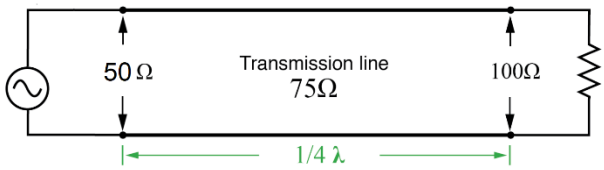
E9E06 (C) What is the equivalent lumped-constant network for a **hairpin matching system** on a 3-element Yagi? C. **A shunt network**

E9E11 (B) What 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? B. Use the **universal stub matching** technique

E9E13 (C) What is a use for a **Wilkinson divider**? C. It is used to divide power equally between two 50-ohm loads while maintaining 50-ohminput impedance

==========

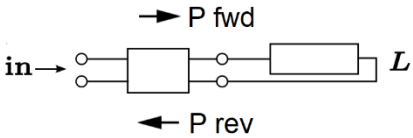




Editor's note: 50-Ω transmission line is to be matched to a resistive load impedance with ZL = 100 Ω via a quarter-wave 75 Ω shown above is a quarter-wave transmission line transformer.

$$SWR = \frac{1 + |p|}{1 - |p|}$$

$$\text{Reflection Coefficient} = p = \sqrt{P\ rev / P\ fwd}$$



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.

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**

==========

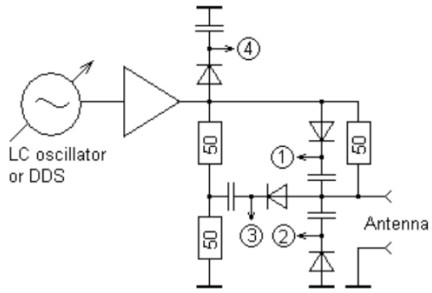
E9E07 (B) What term best describes the interactions at the load end of a **mismatched transmission line? B. Reflection coefficient**

E9E08 (D) Which of the following measurements is characteristic of a **mismatched transmission line? D. An SWR greater than 1:1**

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? 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

E9E12 (A) What is the primary purpose of a **phasing line** 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**

==========



Editor's note: 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.

==========

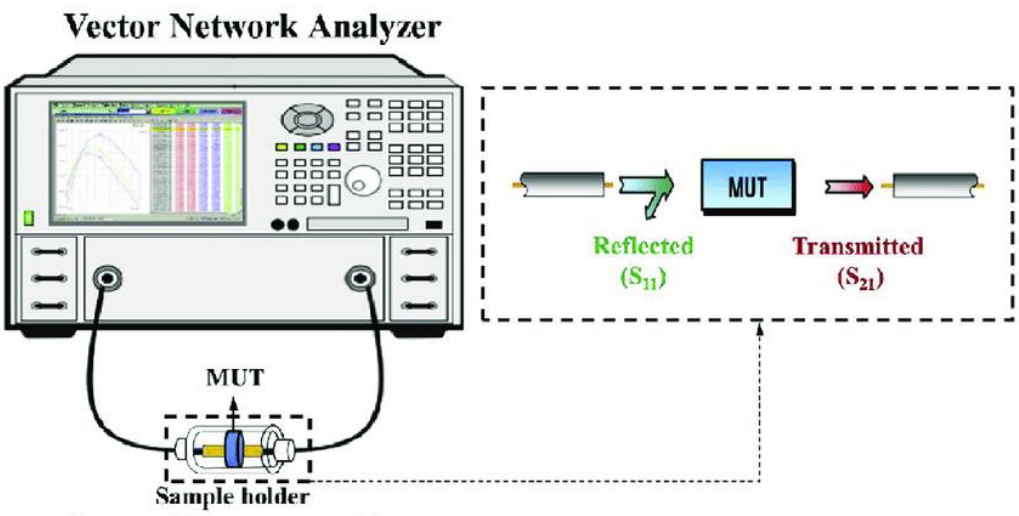
E4A07 (B) Which of the following is an advantage of using an antenna analyzer compared to an SWR bridge to measure antenna SWR? B. **Antenna analyzers do not need an external RF source**

E4A08 (D) Which of the following instruments would be best for measuring the SWR of a beam antenna? D. **An antenna analyzer**

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? D. 75 watts

E4B11 (D) How should **an antenna analyzer** be connected when measuring antenna resonance and feed point impedance? D. Connect the antenna feed line directly to the analyzer's connector

==========



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.*

==========

E4B17 (B) What three test loads are used to calibrate a standard RF **vector network analyzer**? B. Short circuit, open circuit, and 50 ohms

E4B07 (A) What do the subscripts of **S parameters** represent? A. The port or ports at which measurements are made

E4B13 (C) Which S parameter is equivalent to forward gain? C. S21

E4B16 (A) Which S parameter represents return loss or SWR? A. S11

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? D. There is more power going into the antenna

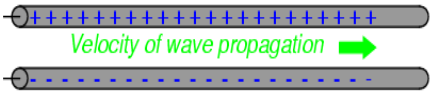
Transmission lines

Velocity factor of a transmission line is the transmission line velocity divided by the velocity of light in a vacuum

Velocity factor is the ratio of a signal speed through a transmission line to the speed of light in a vacuum

Electrical signals move more slowly in a coaxial cable than in air

Dielectric determines the **velocity factor** of a transmission line



$$\textbf{Velocity Factor} = \frac{\textbf{propagation velocity on the line}}{\textbf{speed of light in vacuum}}$$

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

==========

E9F01 (D) What is the **velocity factor** of a transmission line? 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 determines the **velocity factor** of a transmission line? C. Dielectric materials used in the line

E9F03 (D) Why is the physical length of a coaxial cable transmission line shorter than its electrical length? D. Electrical **signals move more slowly in a coaxial cable than in air**

E9F08 (A) What is the term for the ratio of the actual speed at which a signal travels through a transmission line to the **speed of light in a vacuum? A. Velocity factor**

E9F07 (A) How does **ladder line compare to small-diameter coaxial cable** such as RG-58 at 50 MHz? A. Lower loss

E9F16 (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 of these choices are correct

==========

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.

==========

E9F04 (B) What is the **typical velocity** factor for a coaxial cable with **solid polyethylene dielectric? B. 0.66**

E9F05 (C) What is the approximate physical length of a solid polyethylene dielectric coaxial transmission line that is electrically **one-quarter wavelength long at 14.1 MHz**? C. 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 **one-half wavelength long at 14.10 MHz**? C. 10 meters

Cable Length = VF x WL/2

Cable Length = 0.95 x (300 / 14.1) / 2

Cable Length = 0.95 x (21.28 / 2)

Cable Length = 0.95 x 10.64

Cable Length = 10.11 M

E9F09 (B) What is the approximate physical length of a solid polyethylene dielectric coaxial transmission line that is electrically **one-quarter wavelength long at 7.2 MHz**? B. 6.9 meters

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

==========

Transmission line is any integer multiple of **1/2 wavelength long, the impedance equals other end.**

Transmission line is an odd multiple of **1/4 wavelength long, 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.**

==========

E9F10 (C) What impedance does a **1/8-wavelength** transmission line present to a generator when the line is **shorted** at the far end? C. An inductive reactance

E9F11 (C) What impedance does a **1/8-wavelength** transmission line present to a generator when the line is **open** at the far end? C. A capacitive reactance

E9F12 (D) What impedance does a **1/4-wavelength** transmission line present to a generator when the line is **open** at the far end? D. Very low impedance

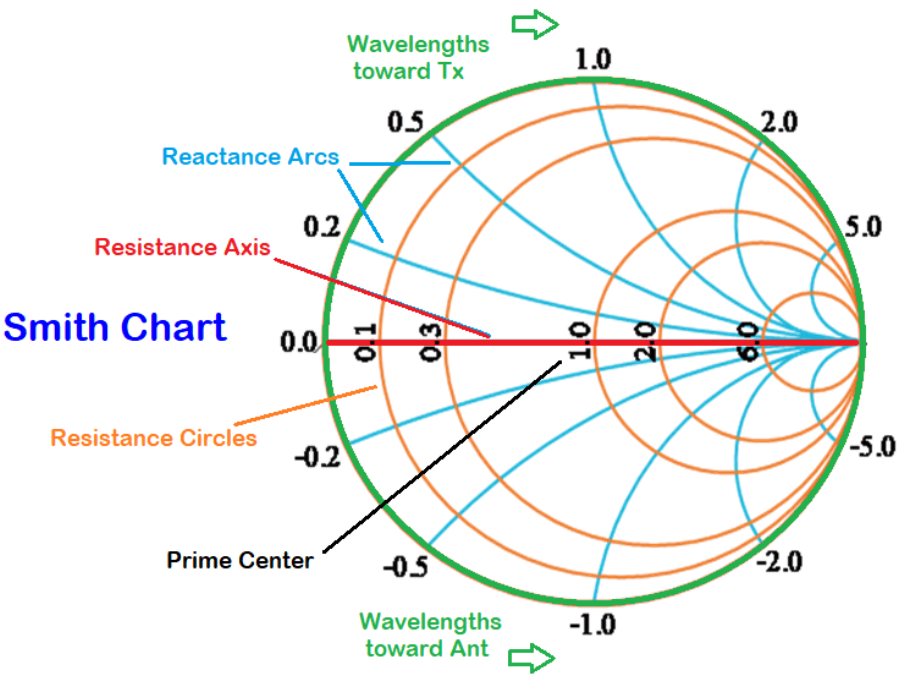
E9F13 (A) What impedance does a **1/4-wavelength** transmission line present to a generator when the line is **shorted** at the far end? A. Very high impedance

E9F14 (B) What impedance does a **1/2-wavelength** transmission line present to a generator when the line is **shorted** at the far end? B. Very low impedance

E9F15 (A) What impedance does a **1/2-wavelength** transmission line present to a generator when the line is **open** at the far end? A. Very high impedance

==========

Smith Charts



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E9G01 (A) Which of the following can be **calculated using a Smith chart? A. Impedance** along transmission lines

E9G02 (B) What type of coordinate system is used in a **Smith chart? B. Resistance circles and reactance arcs**

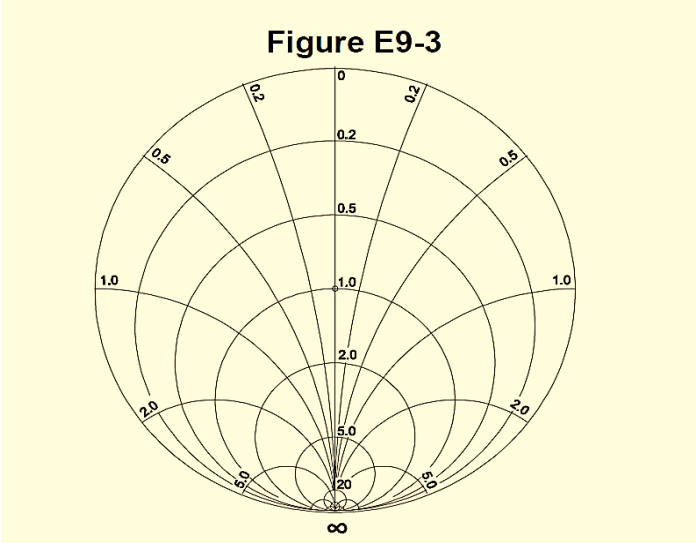
E9G04 (C) What are the two families of circles and arcs that make up a **Smith chart? C. Resistance and reactance**

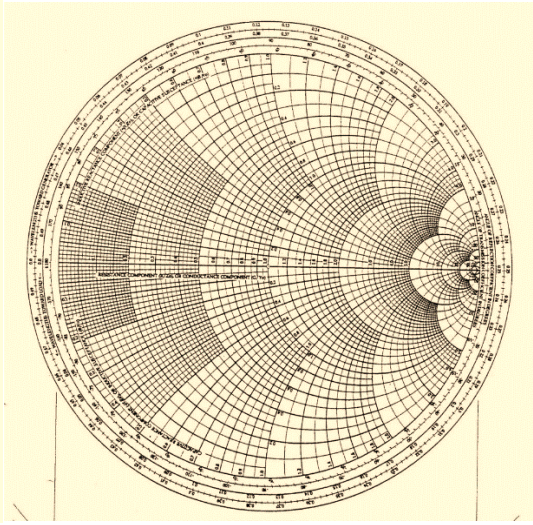
E9G03 (C) Which of the following is often determined using a **Smith chart? C. Impedance and SWR** values in transmission lines

E9G08 (C) What is the process of normalization with regard to a Smith chart? C. Reassigning impedance values with regard to the prime center

E9G10 (D) What do the arcs on a Smith chart represent? D. Points with constant reactance

E9G11 (B) How are **the wavelength scales** on a Smith chart calibrated? B. In fractions of transmission line electrical wavelength

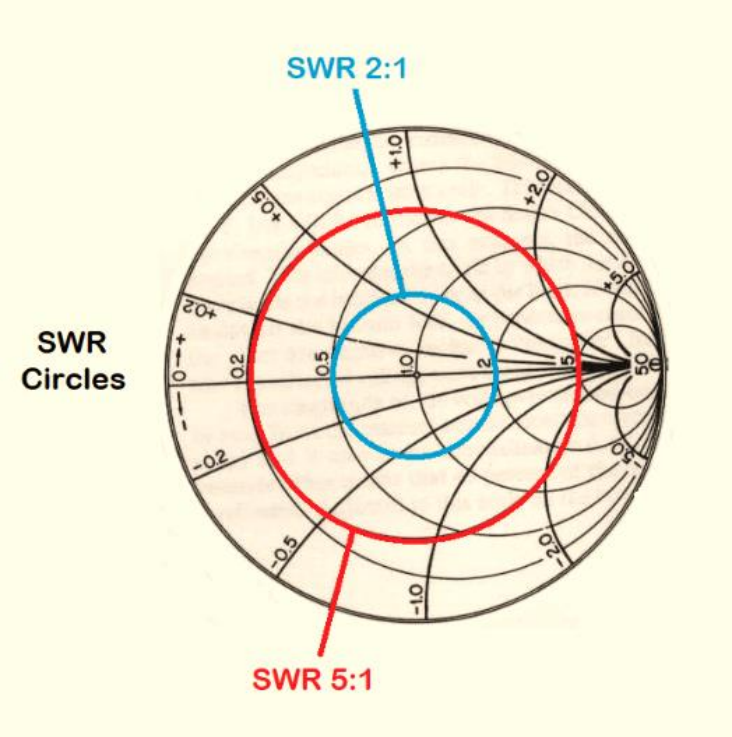




E9G05 (A) What type of chart is shown in Figure E9-3? A. **Smith chart**

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? B. **Reactance axis**

E9G07 (D) On the Smith chart shown in Figure E9-3, what is the only **straight line** shown? D. The **resistance axis**



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**

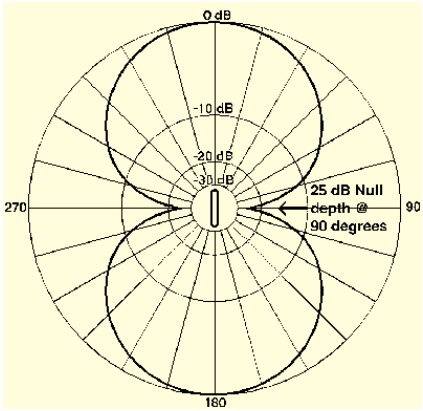
==========

Receiving Antennas

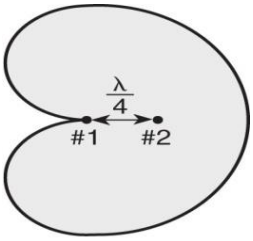
RECEIVING LOOP ANTENNA >> One or more turns of wire wound in the shape of a large open coil

The **output loop antenna** be increased by **adding turns** in the loop or **add area** to the loop

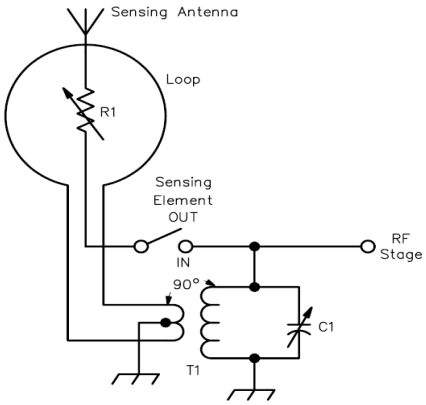
Shielded loop antenna is electro-statically balanced against ground, giving better nulls



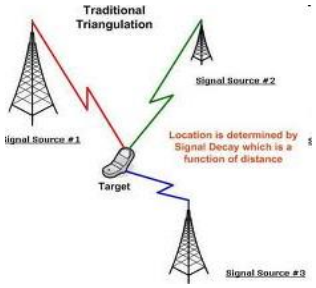
A **cardioid-pattern antenna** has a **very sharp single null** useful for direction finding



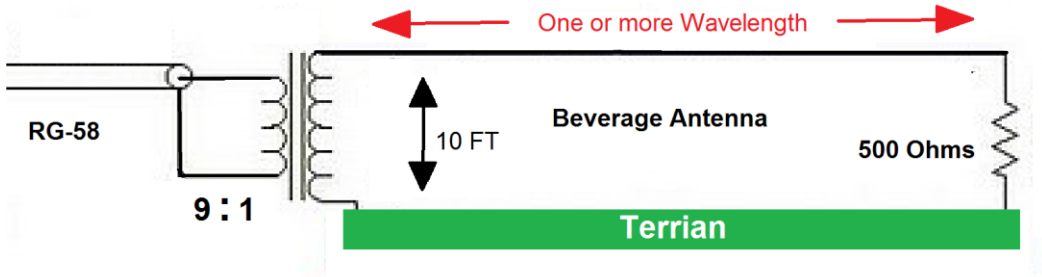
A **sense antenna** modifies the pattern of a DF antenna array to provide a null in one direction

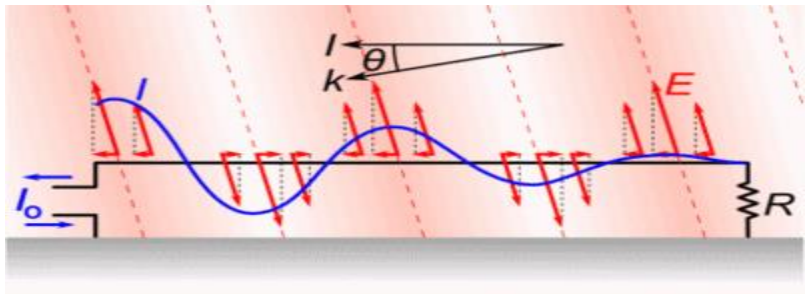


The **triangulation** method uses headings from **several different receiving locations** to locate a signal



A **BEVERAGE** antenna should be **one or more wavelengths long**





The lobes align more in the direction of the wire **long wire antenna as the wire length is increased**

==========

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? 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

E9H04 (B) What is an advantage of using a **shielded loop antenna** for direction finding? B. It is electrostatically balanced against ground, giving better nulls

E9H06 (C) What is the **triangulation method** of direction finding? C. Antenna headings from several different receiving locations are used to locate the signal source

E9H07 (D) Why is it advisable to use an **RF attenuator** on a receiver being used for **direction finding**? D. It prevents receiver overload which could make it difficult to determine peaks or 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

E9H09 (C) Which of the following describes the construction of a **receiving loop antenna**? C. One or more turns of wire wound in the shape of a large open coil

E9H10 (D) How can the output voltage of a multiple-turn **receiving loop antenna** be increased? D. By increasing either the number of wire turns in the loop or the area of the loop structure or both

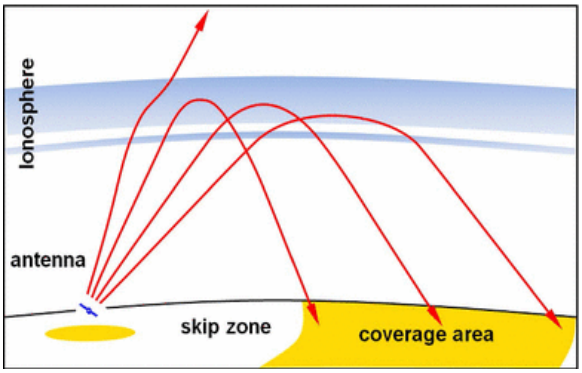
E9H11 (B) What characteristic of a **cardioid pattern antenna** is useful for direction finding? B. A very sharp single null

==========

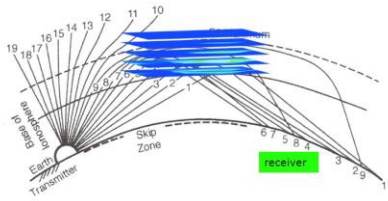
Chapter 10 Topics in Radio Propagation

Solar Effects

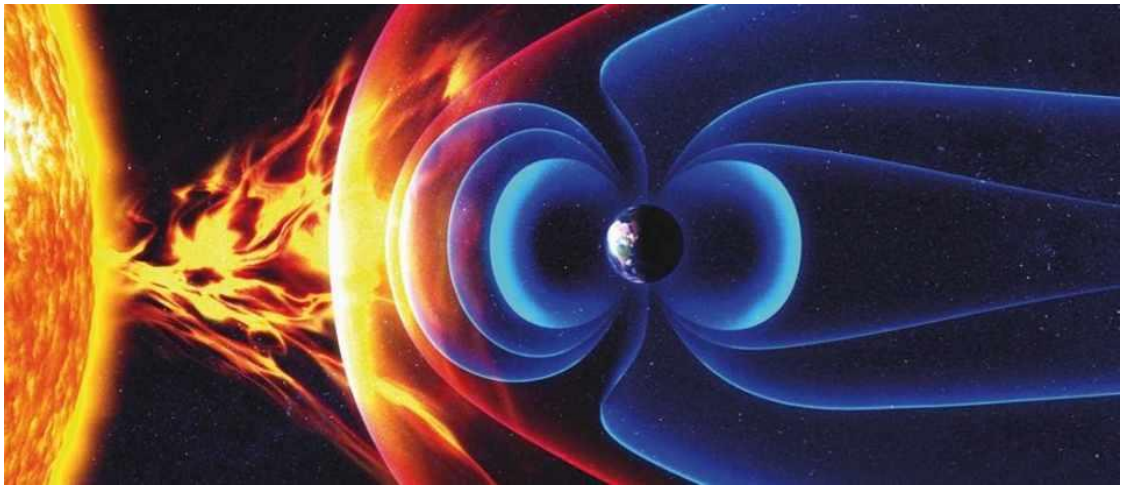
E3C01 (B) What does the term **ray tracing** describe in regard to radio communications? B. Modeling a radio wave's path through the ionosphere



HF signals reflect off the ionosphere to other Earth locations and these paths can be ray-traced for given transmit/receive locations.

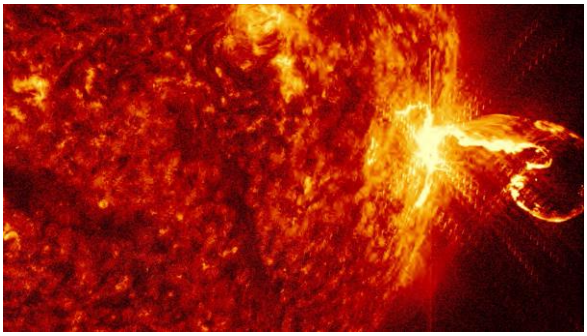


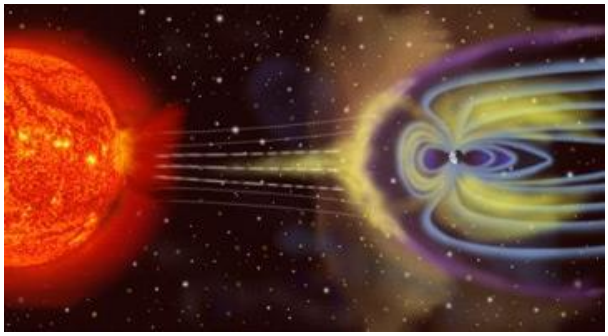
E3C02 (A) What is indicated by a rising A or K index? A. Increasing disruption of the geomagnetic field



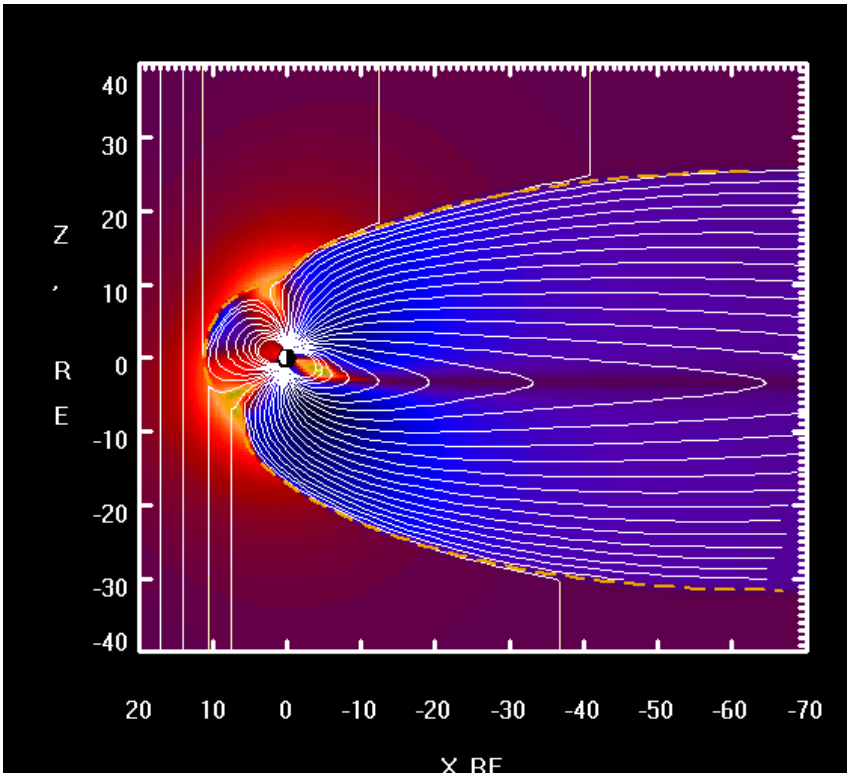
Editor's note: Frequently, the Earth's magnetosphere is hit by solar flares causing geomagnetic storms, provoking displays of aurorae. The short-term instability of the magnetic field is measured with the K-index. Extreme solar storms could result in blackouts and disruptions in artificial satellites.

E3C15 (B) What might a sudden rise in radio **background noise** indicate? B. A **solar flare** has occurred



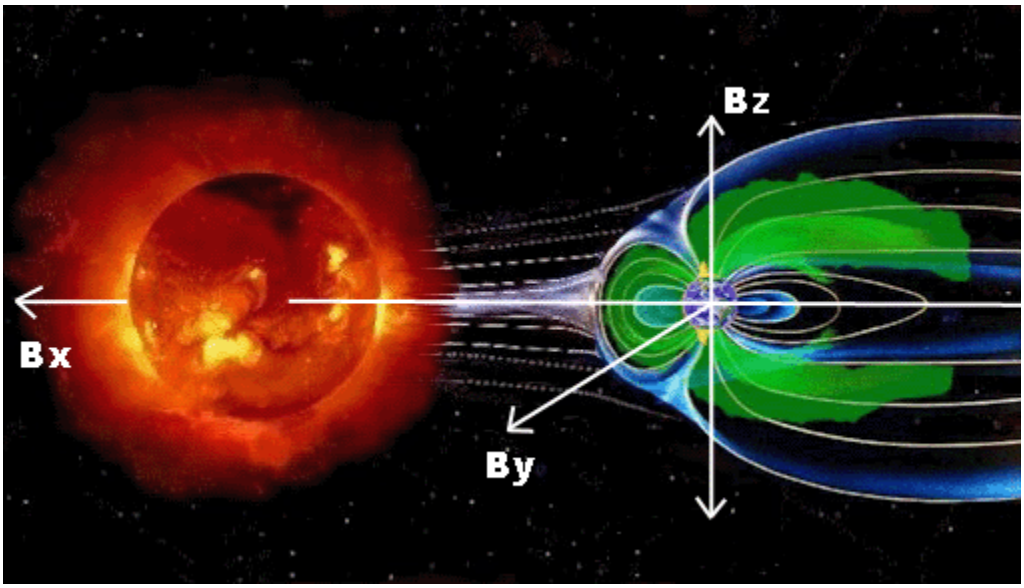


E3C04 (C) What does the value of **Bz** (B sub Z) represent? s C. Direction and strength of the interplanetary magnetic field

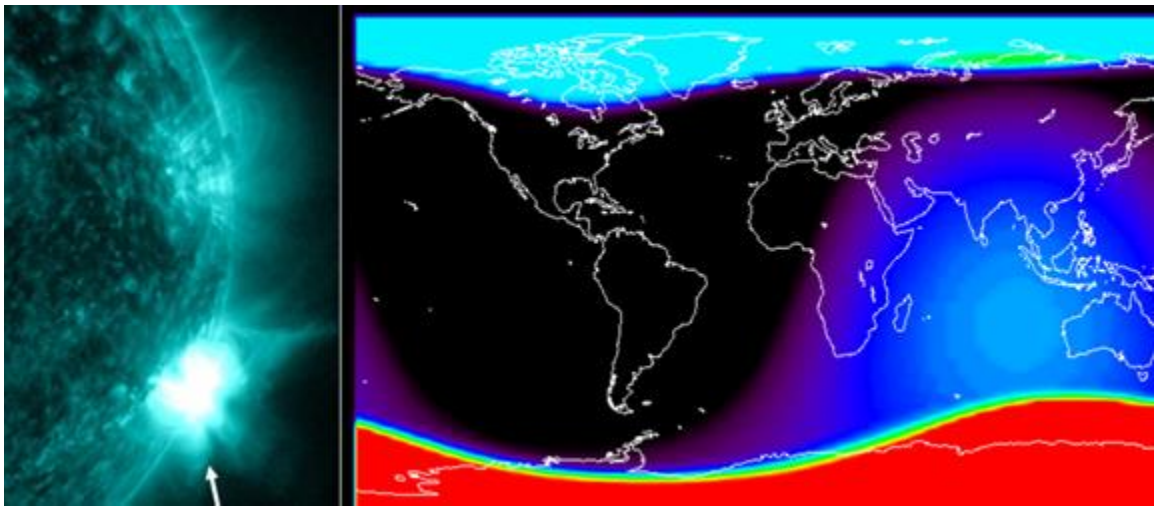


*Editor's note: **"Bz"** is the component of the solar magnetic field that is dragged out from the solar corona by the solar wind flow to fill the Solar System.*

E3C05 (A) What orientation of **Bz** (B sub z) increases the likelihood that incoming particles from the Sun will cause disturbed conditions? A. Southward



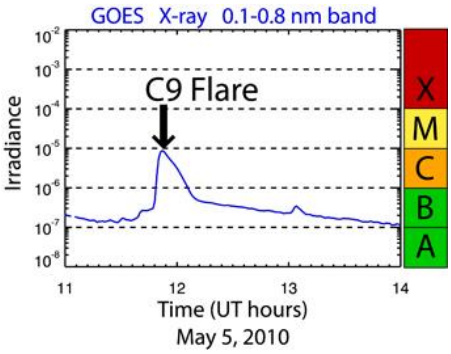
E3C03 (B) Which of the following signal paths is most likely to experience **high levels of absorption** when the A index or K index is elevated? B. Polar paths



Editor's note: The polar regions have maximum absorption in the HF Bands when K index is higher.

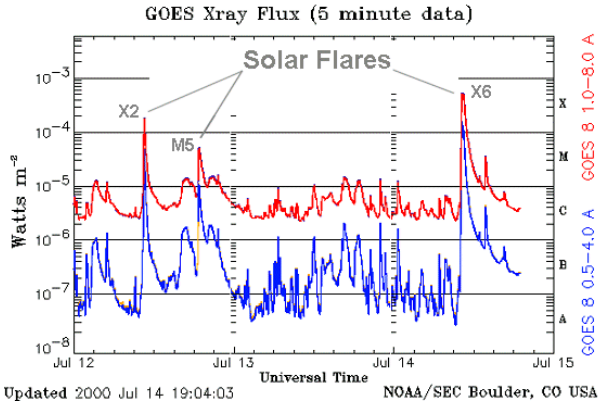
E3C07 (D) Which of the following descriptors indicates the greatest solar flare intensity? D. X

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).

E3C09 (C) How does the intensity of an X3 flare compare to that of an X2 flare? C. Twice as great



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.

E3C10 (B) What does the **304A solar parameter** measure? B. 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.

E3C08 (A) What does the space weather term **G5** mean? A. An **extreme** geomagnetic storm

NOAA Space Weather Scales

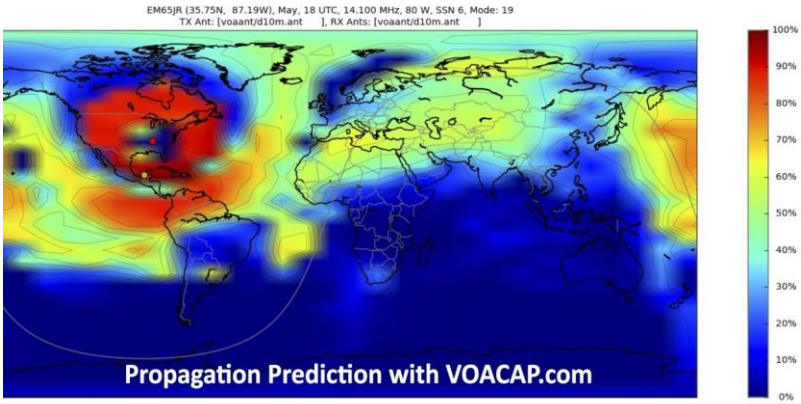
Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread 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)

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. X flares are both rare and extreme.

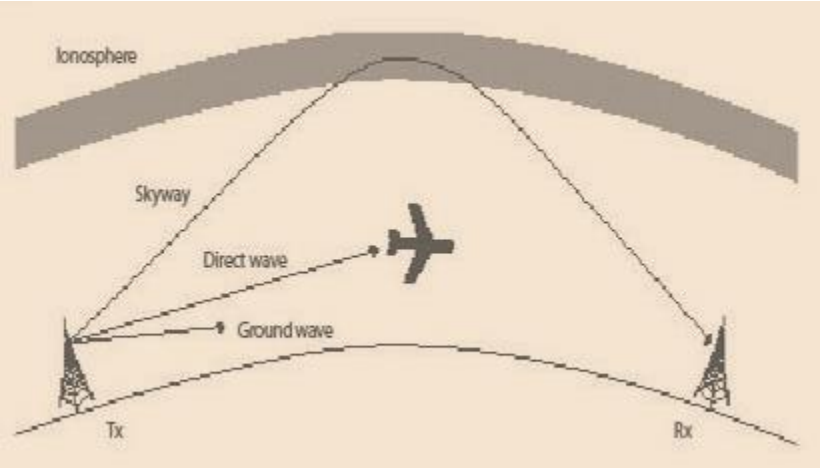
HF Propagation

E3C11 (C) What does **VOACAP** software model? C. **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.*

E3C12 (C) How does the maximum distance of **ground-wave propagation** change when the signal frequency is increased? C. It decreases



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. Diffraction with Vertical HF Antennas:

The lower part of the radio wave losing energy because of currents induced in the ground

This slows the lower portion of the wave causing the wave to tilt forward slightly, following the curvature of the Earth

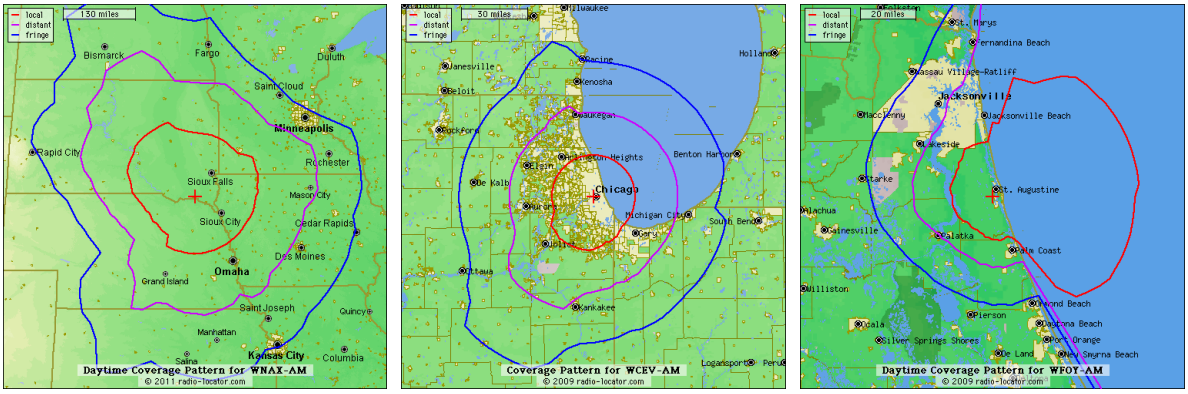
Tilting results in Ground-Wave propagation allowing low-frequency signals to be heard well beyond line of sight (160M & 80M)

Ground-wave propagation is lossy because the vertically polarized portion of the wave's electric field that extends into the ground is mostly absorbed

Loss increases with frequency (28 MHz = only a few miles)

Ground-wave is most useful during the daytime

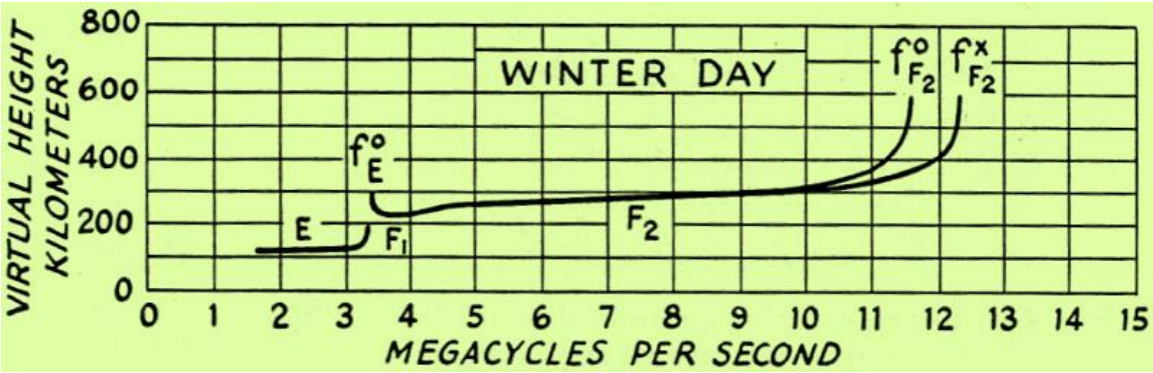
E3C13 (A) What type of **polarization is best for ground-wave propagation**? A. Vertical



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, even if they have to be made physically short by adding inductive loading. At distances that are typically towards the edge of the ground wave coverage area, some sky-wave signal may also be present, especially at night when the D layer attenuation is reduced. This may serve to reinforce or cancel the overall signal resulting in figures that will differ from those that may be expected.

E3B04 (B) What is meant by the terms **"extraordinary" and "ordinary" waves**? B. Independent waves created in the ionosphere that are **elliptically polarized**

E3B14 (C) What happens to linearly polarized radio waves that split into **ordinary and extraordinary** waves in the ionosphere? C. They become **elliptically polarized**

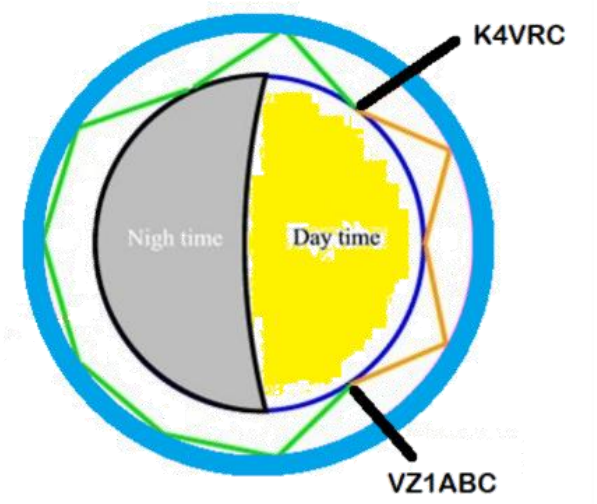


Editor's note: Near the critical frequency the waves are excessively retarded in the ionized layer, which accounts for the rise of the curve at the critical frequency. At the right of the curve appear two critical frequencies for the F2 layer. This is an indication of double refraction of the waves due 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.*

E3B05 (C) Which amateur bands typically support **long-path propagation**? C. 160 to 10 meters

E3B06 (B) Which of the following amateur bands most frequently provides **long-path propagation**? B. 20 meters

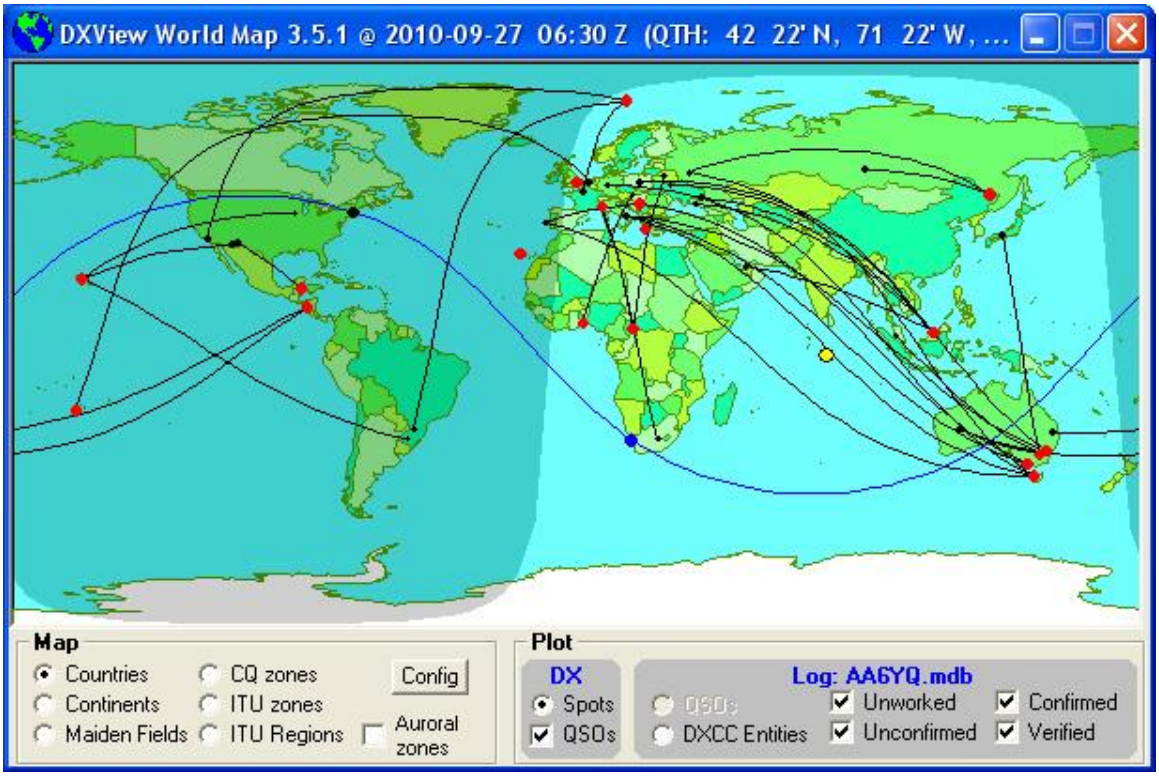
E3B07 (D) Which of the following could account for hearing an **echo on the received signal** of a distant station? D. Receipt of a signal by **more than one path**



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.

E3B08 (D) What type of HF propagation is probably occurring if **radio signals travel along the terminator between daylight and darkness**? D. Gray-line

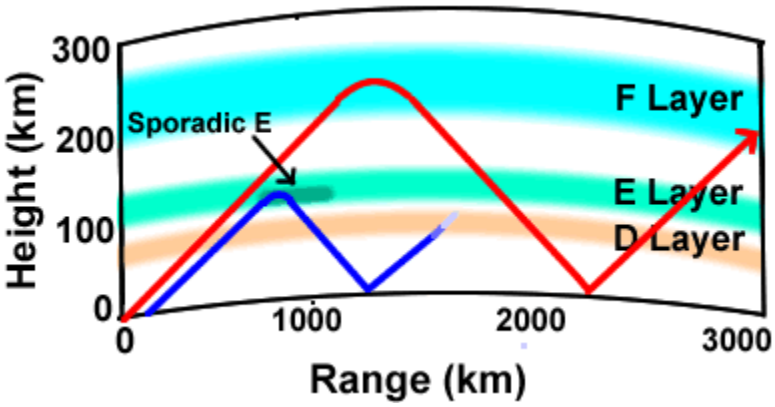
E3B10 (B) What is the cause of **gray-line propagation**? B. At twilight, D-layer absorption is low while E-layer and F-layer propagation remains high



Editor's note: Grey line or gray line propagation is a form of radio signal propagation that provides surprisingly long-distance radio communications at dawn and dusk sometimes when other forms of ionospheric propagation may not be expected to provide signal paths of these distances.

E3B09 (A) At what time of year is **Sporadic E propagation** most likely to occur? A. Around the solstices, especially the summer solstice

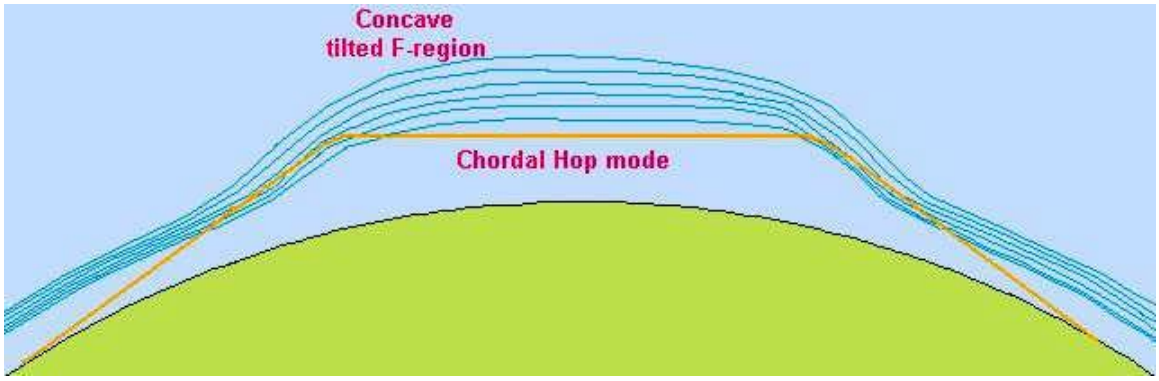
E3B11 (D) At what time of day is **Sporadic E propagation** most likely to occur? D. Any time



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.

E3B12 (B) What is the primary characteristic of **chordal hop propagation**? B. Successive ionospheric reflections without an intermediate reflection from the ground

E3B13 (A) Why is **chordal hop propagation** desirable? A. The signal experiences less loss along the path than normal skip propagation

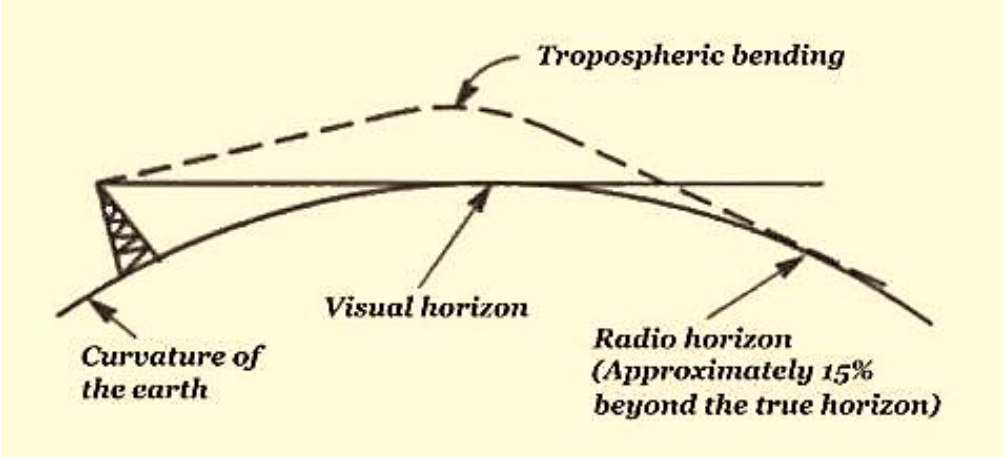


Editor's note: Chordal Hop is when a signal approaches the ionosphere at a steep angle the signal penetrates the ionosphere and may pass right through, or be 'reflected' back (green ray, right). It is actually refracted rather than reflected. However, when a signal approaches the ionosphere at a grazing 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.

VHF/UHF/Microwave Propagation

E3C14 (D) Why does the **radio-path horizon distance exceed the geometric horizon**? D. Downward bending due to density variations in the atmosphere

E3C06 (A) By how much does the VHF/UHF radio-path horizon distance **exceed the geometric horizon**? A. By approximately **15 percent of the distance**

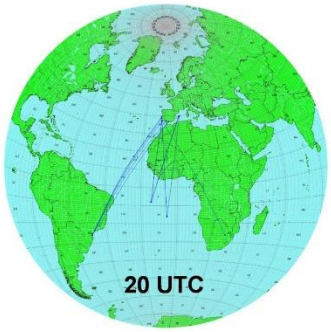


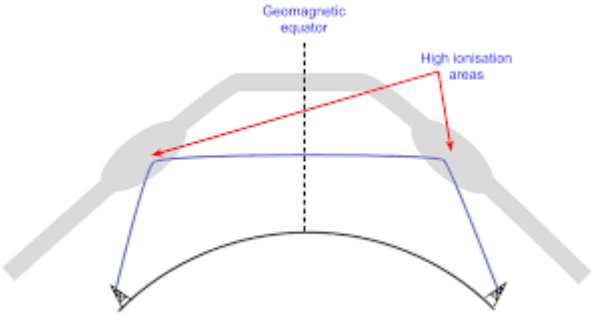
Editor's note: Line of Sight radio horizon does not consider RF signals don't propagate in straight lines: Because of the refractive effects of atmospheric layers, the propagation paths are somewhat curved. Thus, the maximum service range of the station is not equal to the line of sight (geometric) distance. Under normal weather conditions the maximum service range increases by 15%.

E3B01 (A) What is **trans equatorial propagation**? A. Propagation between two mid-latitude points at approximately the same distance north and south of the magnetic equator

E3B02 (C) What is the approximate **maximum range for signals using trans equatorial propagation**? C. 5000 miles

E3B03 (C) What is the best **time of day for trans equatorial propagation**? C. Afternoon or early evening





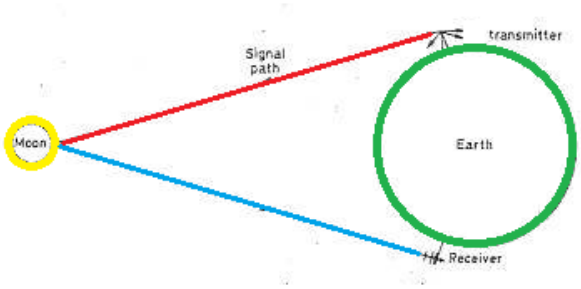
Editor's note: Trans equatorial Propagation (TE) is a form of F-layer ionospheric propagation. TE occurs between mid-latitude station approximately the same distance north and south of the Earth's magnetic equator (2,500 north and south of the equator). TE occurs on 50 & 144 MHz and to some extent 432 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.

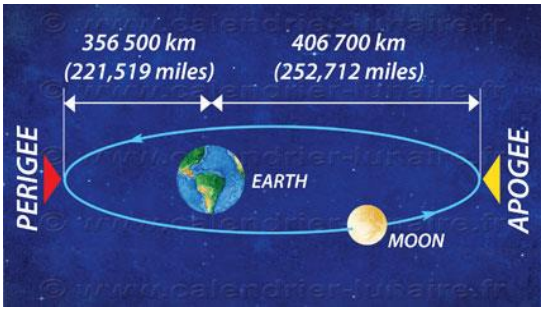
E2D06 (A) Which of the following describes a method of establishing **EME contacts**? A. Time synchronous transmissions alternately from each station

E3A01 (D) What is the approximate maximum separation measured along the surface of the Earth between two stations communicating by **moonbounce**? D. 12,000 miles, if the Moon is visible by both

E3A02 (B) What characterizes **libration fading** of an EME signal? B. A **fluttery irregular fading**

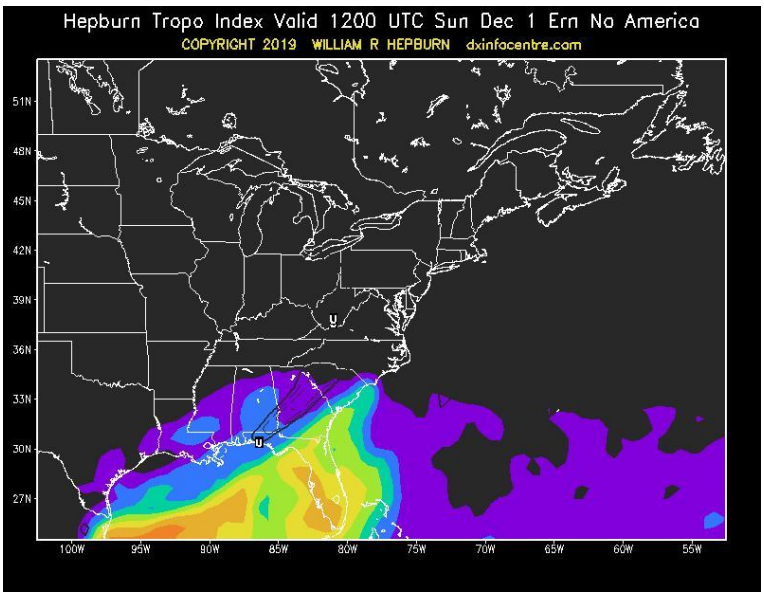
E3A03 (A) When scheduling EME contacts, which of these conditions will generally result in the **least path loss? A. When the Moon is at perigee**





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.

E3A04 (D) What do **Hepburn maps** predict? D. Probability of **tropospheric propagation**



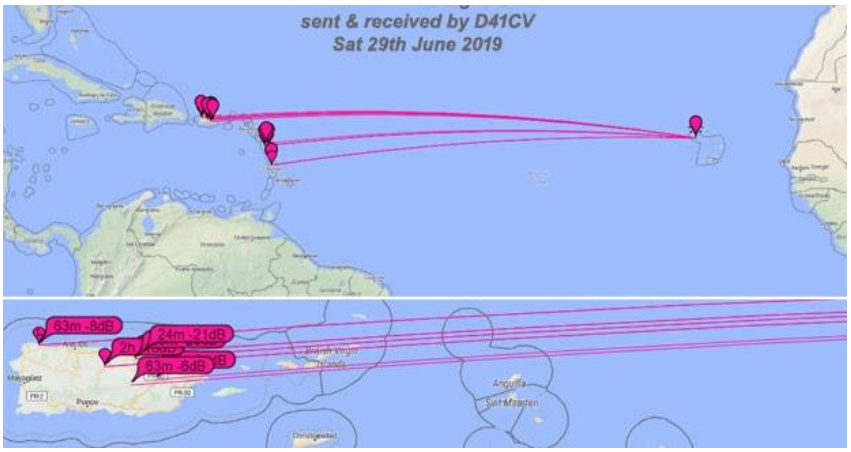
E3A05 (C) Tropospheric propagation of microwave signals often occurs along what weather related structure? C. **Warm and cold fronts**

E3A06 (C) Which of the following is required for **microwave propagation via rain scatter**? C. The rain must be within radio range of both stations

E3A07 (C) **Atmospheric ducts** capable of propagating microwave signals often form over what geographic feature? C. **Bodies of water**

E3A10 (B) Which type of atmospheric structure can create a path for microwave propagation? B. **Temperature inversion**

E3A11 (B) What is a typical **range for tropospheric propagation** of microwave signals? B. **100 miles to 300 miles**



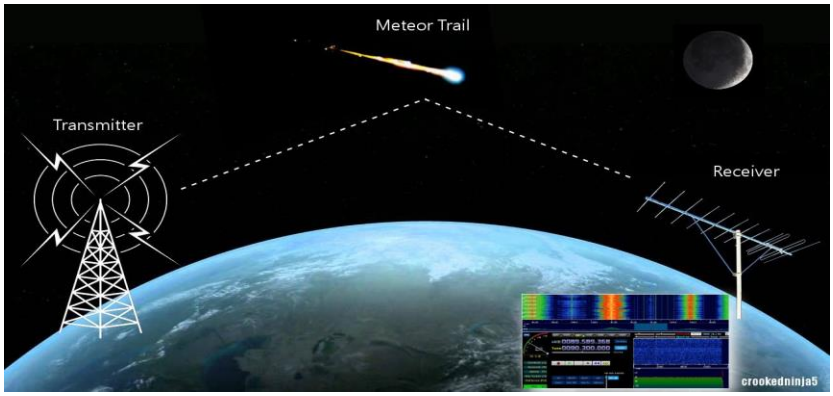
Editor's note: Tropospheric propagation called ducting or duct effect, occurs when there is a defined, horizontal boundary between air masses having different densities. When a cool air mass is overlain by a warm air mass, as is the case along and near warm fronts and cold fronts, radio waves at VHF 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.

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 high-speed CW or digital modes
C. Short transmission with rapidly repeated call signs and signal reports
D. All of these choices are correct

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

E3A09 (C) Which of the following frequency ranges is most suited for meteor-scatter communications? C. 28 - 148 MHz



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.

E3A12 (C) What is the cause of auroral activity? C. The interaction in the E layer of charged particles from the Sun with the Earth's magnetic field

E3A13 (A) Which emission mode is best for aurora propagation? A. CW

E3A14 (B) From the contiguous 48 states, in which approximate direction should an antenna be pointed to take maximum advantage of aurora propagation? B. North

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

Chapter 11 Safety

Hazardous Materials

E0A07 (B) How may dangerous levels of carbon monoxide from an emergency generator be detected? B. Only with a **carbon monoxide detector**



Editor's note: Carbon Monoxide – from generators or heating equipment during emergency operations

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? C. **Beryllium oxide**

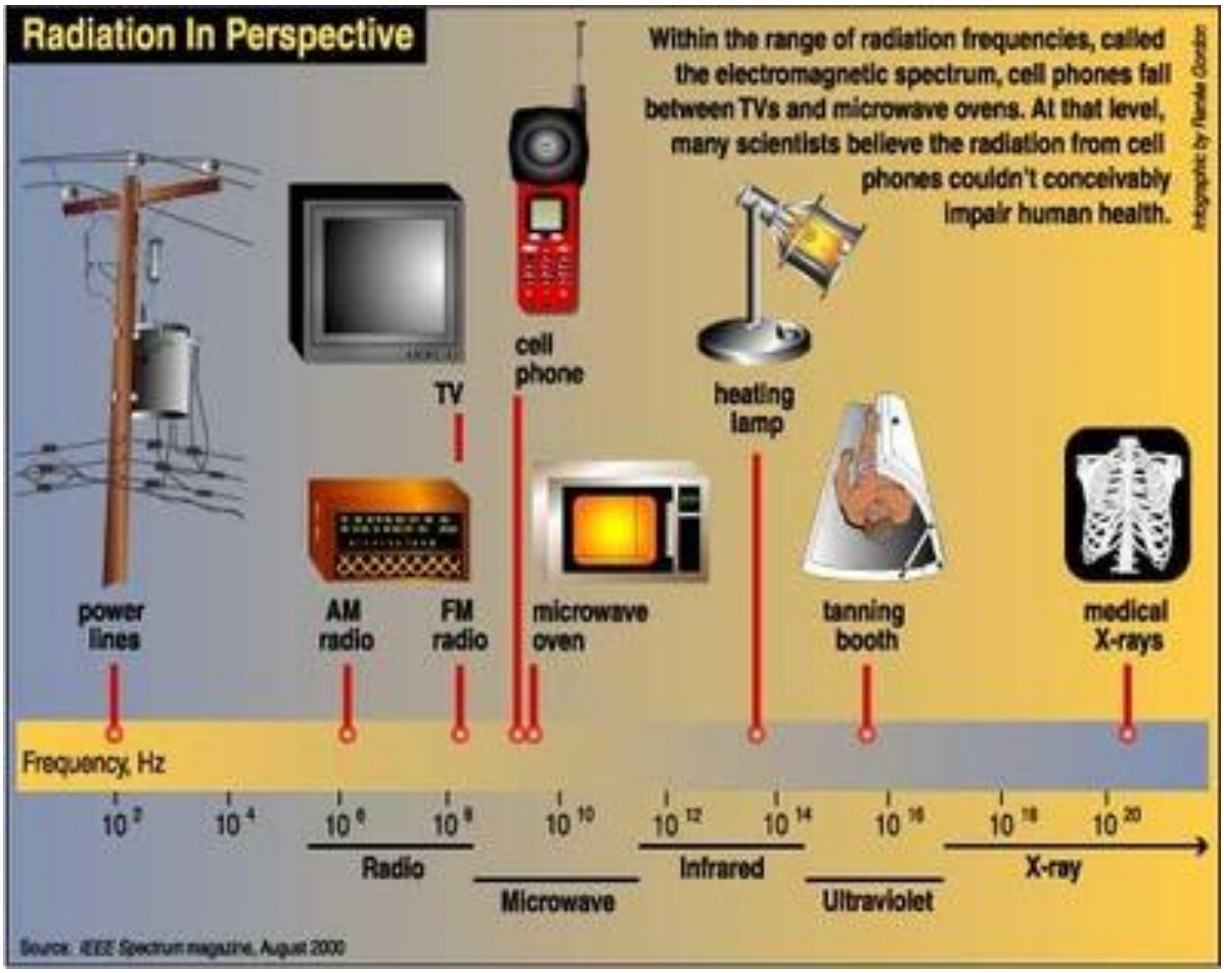

Editor's note: Beryllium & Beryllium Oxide – used in copper alloys to stiffen it, Spring Contacts, duplexer fingers. The oxide powder is carcinogenic and may cause skin burns. In solid form, it is safe to handle if not subjected to machining that generates dust. Beryllium oxide ceramic is not a hazardous waste under federal law in the USA.

E0A10 (A) What toxic material may be present in some electronic components such as high voltage capacitors and transformers? A. **Polychlorinated biphenyls (PCB)**

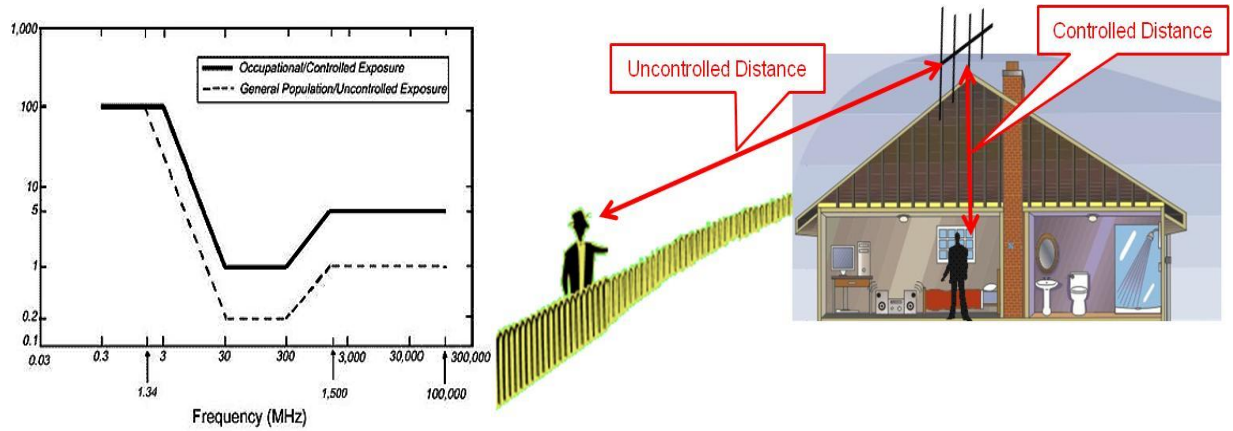
Editor's note: Polychlorinated biphenyls (PCB) were once widely deployed as dielectric and coolant fluids in electrical apparatus, carbonless copy paper and in heat transfer fluids. Common Amateur Radio applications were dummy loads and large capacitors. Because of their longevity, PCBs are still found 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.

RF Exposure

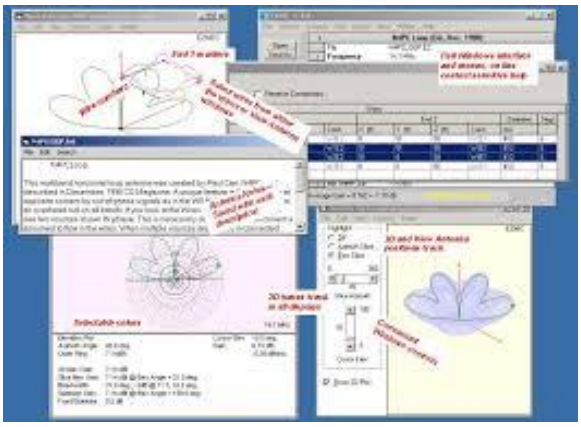
Radioactive materials emit ionizing radiation, while RF signals have less energy and can only cause heating



E0A02 (B) When evaluating RF exposure levels from your station at a neighbor's home, what must you do? B. Make sure signals from your station are less than the **uncontrolled MPE limits**

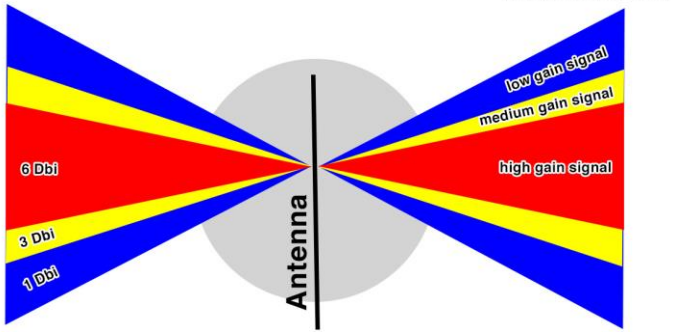


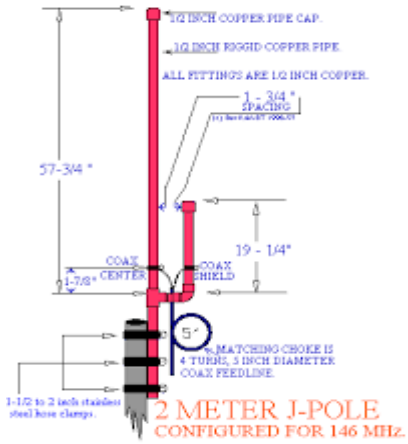
E0A03 (C) Which of the following would be a practical way to estimate whether the RF fields produced by an amateur radio station are within permissible MPE limits? C. Use an **antenna modeling program to calculate field strength** at accessible locations



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? C. Each transmitter **that produces 5 percent or more of its MPE limit at accessible locations**

E0A05 (B) What is one of the potential hazards of using microwaves in the amateur radio bands? B. The **high gain antennas commonly used can result in high exposure levels**





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**

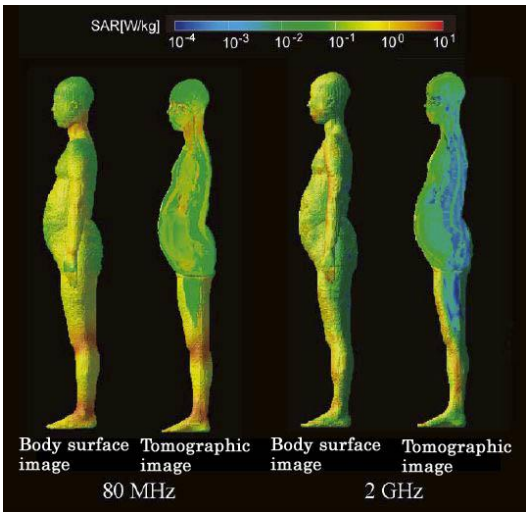
B. **Ground reflections** and scattering make the field impedance vary with location

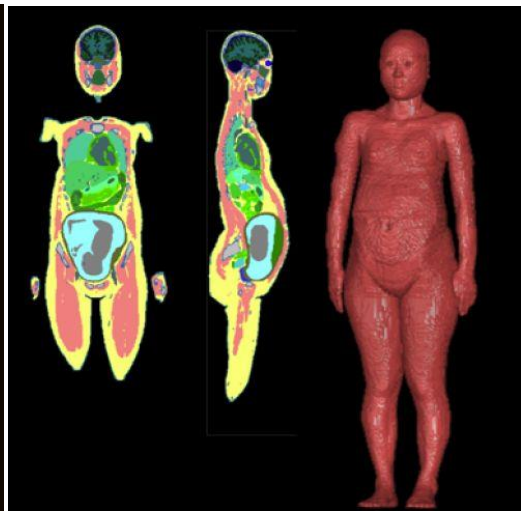
C. E field and H field radiation intensity **peaks can occur at different locations**

E0A08 (C) What does SAR measure? C. The **rate at which RF energy is absorbed** by the body

E0A11 (C) Which of the following injuries can result from using high-power UHF or microwave transmitters? C. Localized **heating of the body from RF exposure in excess of the MPE limits**

Editor's note: The body heating from RF exposure is analysis below is included to show how the body surface is heated by RF. This means the primary RF hazard in your shack is your skin and eyes.





The National Institute of Information and Communications Technology (NICT) disclosed a numerical model database of a whole-body Japanese pregnant woman. The database was jointly developed with Chiba University. Numerical Model Data of Pregnant Woman Disclosed for Electromagnetic Field Analysis The distribution of the Specific Absorption Rate (SAR) per unit mass, at the time of frontal exposure to radio waves. Frequencies: 80MHz and 2GHz. Strength: 1mW/cm2), is shown by color.

RF Safety for your Flagpole Antenna:

This document details a typical TVARC member's Flagpole Antenna RF hazard calculations that predict the power density levels in occupied areas around the system antenna. This "worst case" estimate assumes the true average-radiated power from the antenna based on the maximum transmitter output for each band are compared to the Maximum Permissible Exposure (MPE). The results are expressed in power density at distance for far field determine a safe environment directly at the flagpole antenna.

Density Calculation:

Power density from an isotropic antenna

$$P_D = \frac{P_t}{4\pi R^2}$$

where: P_t = Average Transmitter Power
R = Range from Antenna (i.e. radius of sphere)

The power density at a distant point from an antenna gain of Gt is the antenna gain.

Power density equals;

$$P_D = \frac{P_t G_t}{4\pi R^2}$$

Assumptions:

Assumes; 100 W Transmitter, SSB, 100 Feet RG-8X, VSWR 1.5, 10 M

Watts	100	Steady State Transmitter Power in Watts (Example 100W SSB or 25W AM)
Factor	0.20	Modulation Factor (Am, FM, RTTY & Digital = 1, CW = 0.4, SSB = 0.2)
dB	0.3	Tuner or Duplexer Loss in dB
dB	1.5	Cable Loss in dB
dB	0.5	BALAN or Antenna Impedance Matching Loss in dB
dB	0.0	Antenna Gain in dBi (Vert = 0, Dipole = 2.1, Random Wire = 0, etc)
Feet	1	Distance in Feet from Antenna to your head (Controlled)
Feet	2	Distance in Feet from Antenna to your property line (Uncontrolled)

Exposure Limits:

The FCC Second Memorandum and Order dated August 27, 1997 adopted a sliding scale for categorical exemption to routine RF radiation compliance testing based on peak envelope power (PEP) at various Amateur Radio operating frequencies. While the RF radiation exposure compliance levels are based on average power, the categorical exemptions from the requirement for periodic station compliance testing are based upon peak envelope power (PEP). Stations operating at or below these respective PEP levels are categorically excluded from having to perform a routine RF radiation evaluation. However, all stations, regardless of power level, still must comply with the RF exposure limits. OST/OET Bulletin #65 sets the Maximum Permissible Exposure (MPE) to field levels.

Density Results:

The calculated maximum power density for this station is shown at the top of the respective controlled and uncontrolled columns in the table below. The maximum MPE allowable strength of the RF fields around this station are listed descending in each column for the maximum frequency in each amateur band listed.

	0.8338	Controlled Power Density mW/cm2					
		0.1907	Uncontrolled Power Density mW/cm2				
	Max PD Allowed mW/cm2	Max PD Allowed mW/cm2		Routine RF Radiation Evaluations Required			
				Min MHz	Max MHz	Watts Peak	Amateur Band
OK	100.00	45.00	OK	1.80	2.00	500	160 M
OK	56.26	11.26	OK	3.50	4.00	500	80 M
OK	16.89	3.38	OK	7.00	7.30	500	40 M
OK	8.66	1.74	OK	10.10	10.15	425	30 M
OK	4.38	0.88	OK	14.00	14.35	225	20 M
OK	2.37	0.55	OK	18.07	18.17	125	17 M
OK	1.96	0.40	OK	21.00	21.45	100	15 M
OK	3.71	0.29	OK	24.89	24.99	75	12 M
OK	1.03	0.21	OK	28.00	29.70	50	10 M
OK	1.00	0.20	OK	50	54	50	6 M
OK	1.00	0.20	OK	144	148	50	2 M
OK	1.00	0.20	OK	222	225	50	1.25 M
OK	1.50	0.30	OK	420	450	70	70 cm

Safety CONOPS: The practical answer is operations in a safe environment that can be used under normal operating conditions without burden to the station operator. It is recommended that access to the planter be restricted when RF radiation is permitted. No additional precautions are required for a residential station as the operator has control over maintenance workers as the owner of the yard and controls both access and transmitter emissions. In reviewing the station MPE levels it has been determined the operator and neighbors have full unrestricted use of the yard during transmitter operation by taking the following actions.

- Radiating element inside PVC pipe to prevent direct contact
- Control Zone established by planter
- Control Zone = 1+ Feet
- Uncontrolled Zone = 2+ Feet
- Operator monitors site during transmissions

Grounding and Bonding

E0A01 (B) What is the primary function of an external earth connection or ground rod? B. Lightning protection