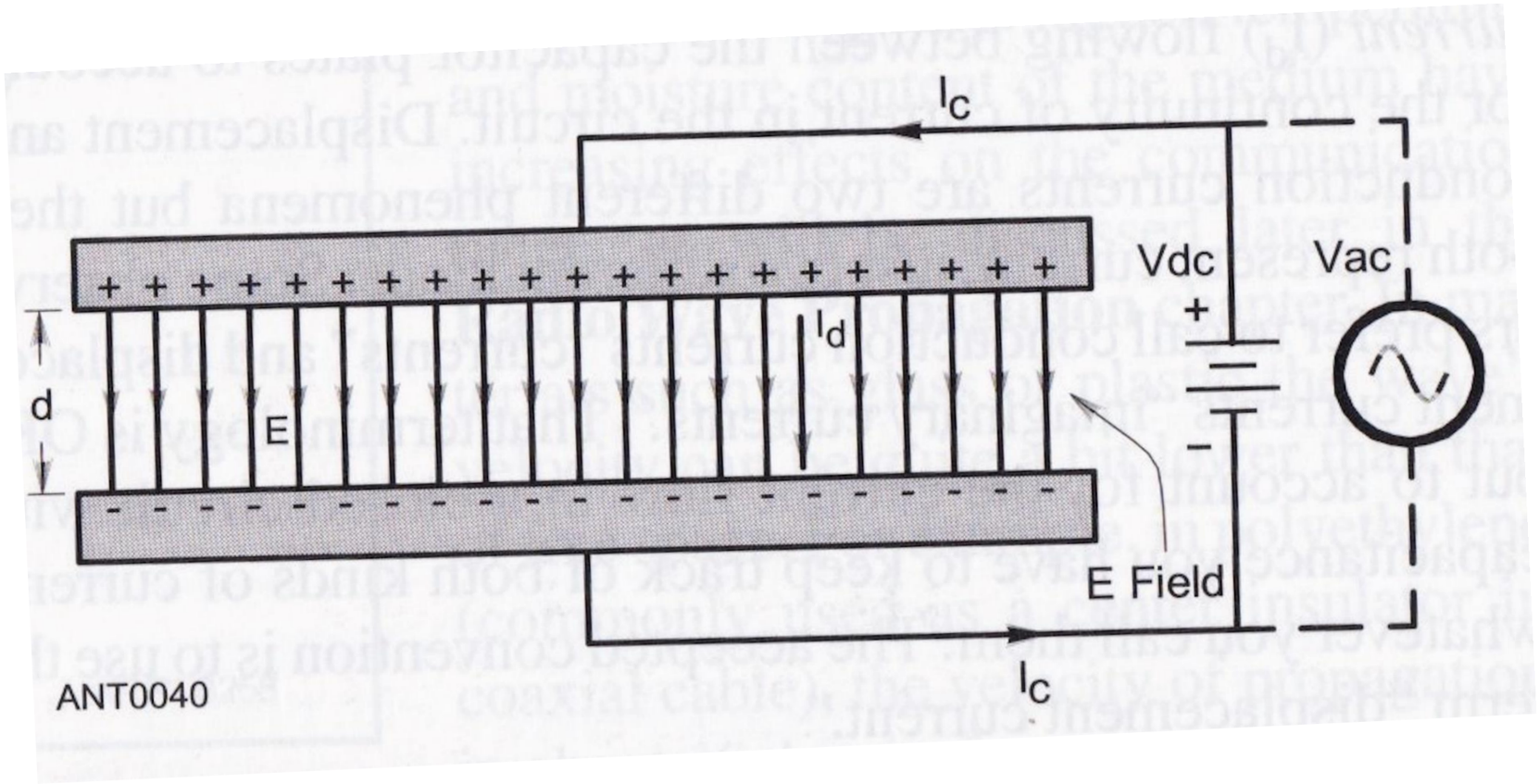
SCARS Tech License Course - Week 2

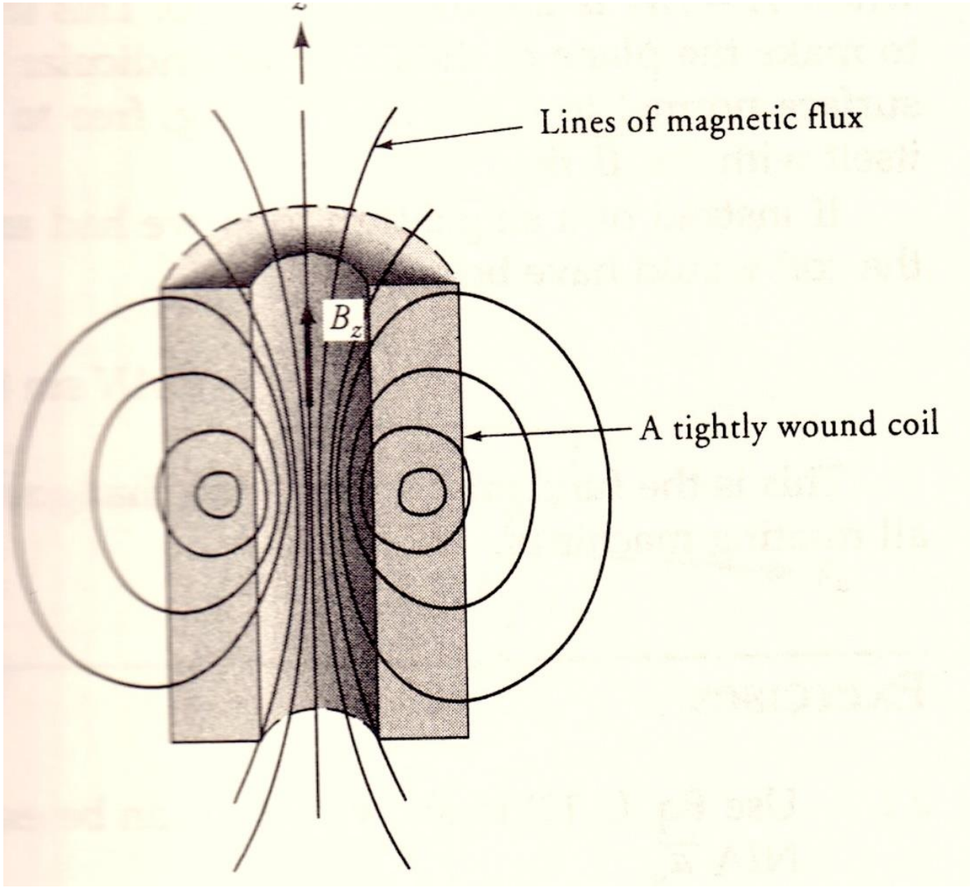
Radio and Signals Fundamentals

Phil Sinnett KD5UGO

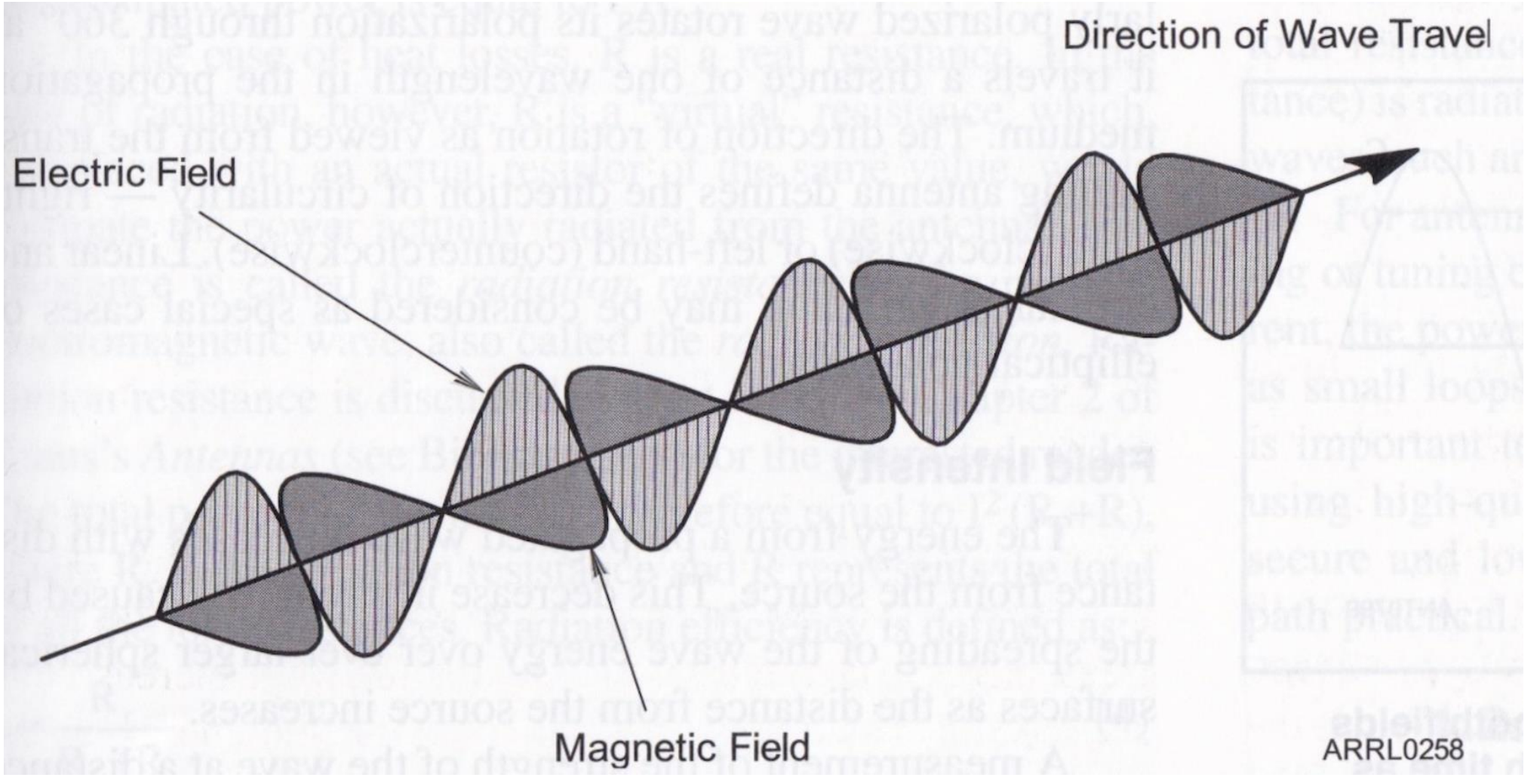
Ron LaSpisa K5RJL



Electric Field Between Two Plates



Magnetic Field from Current Flow in Coil

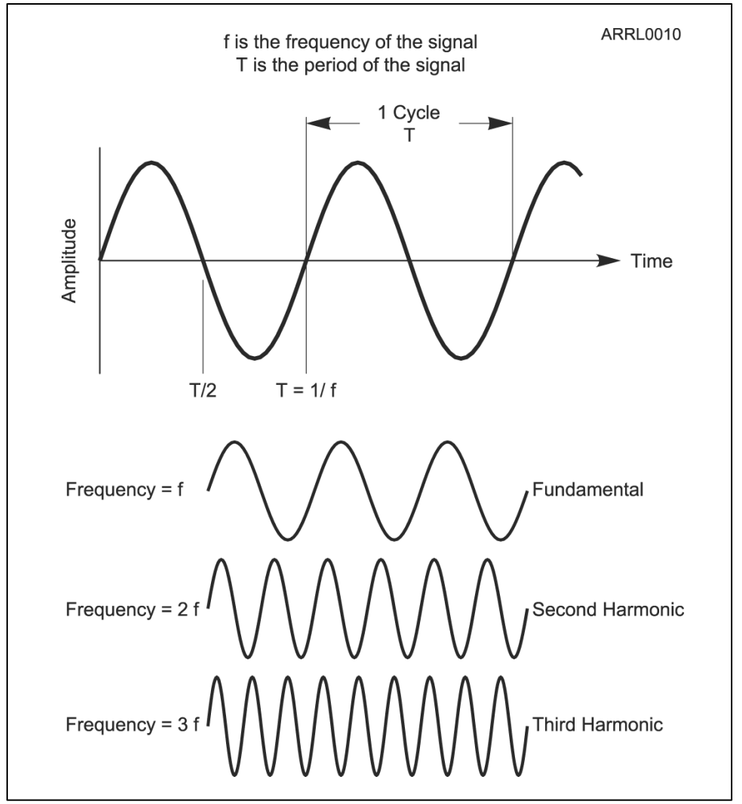


Electromagnetic Wave

Wave Vocabulary

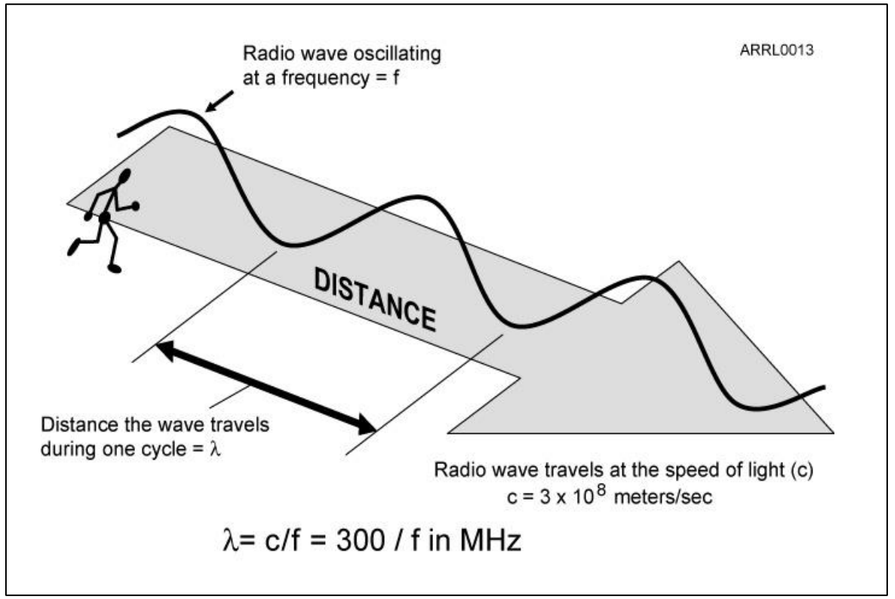
Before we study radio, we need to learn some wave vocabulary.

- Amplitude
- Frequency (hertz, Hz)
- Period (seconds,s)
- Fundamental
- Harmonics



Wavelength

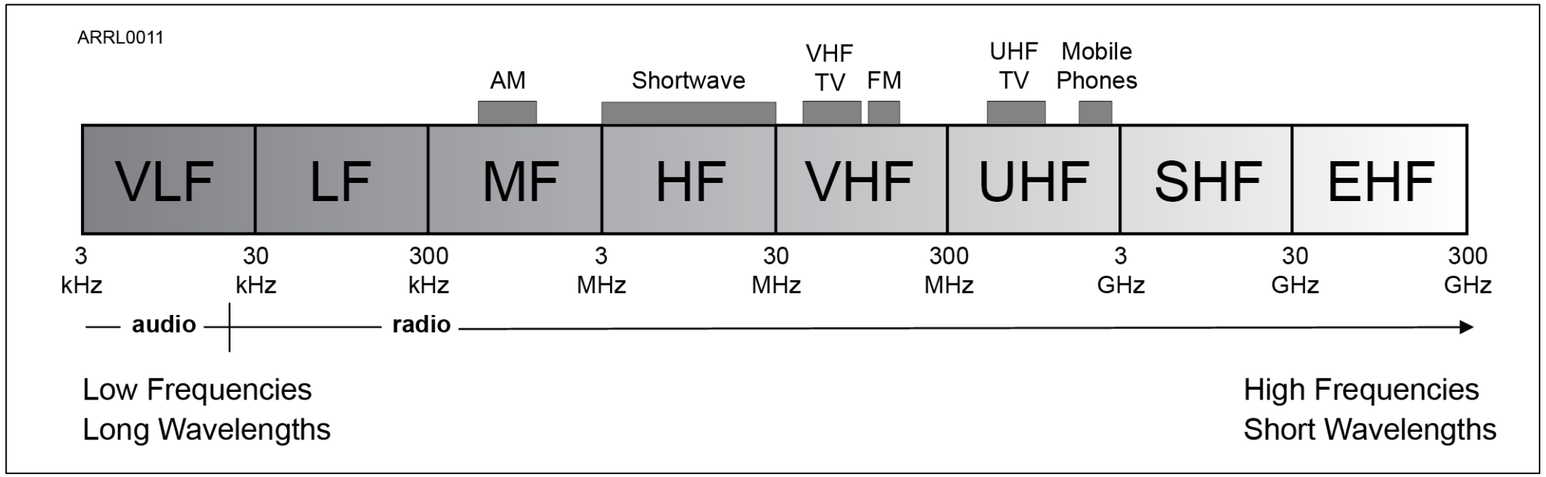
- *Wavelength* is the distance a radio wave travels during one cycle of the wave's electric and magnetic fields.
- λ (lambda) is the symbol for wavelength.
- Waves travel at the speed of light, c.
- Hams can refer to bands by frequency (50MHz) or wavelength (6 meters).



Electromagnetic Waves

- The electromagnetic spectrum is divided into ranges of frequencies in which electromagnetic waves behave similarly.
- Each range or segment has a different name.
- Waves with a certain range of frequencies which can be used for communication are called radio waves.

Radio Spectrum



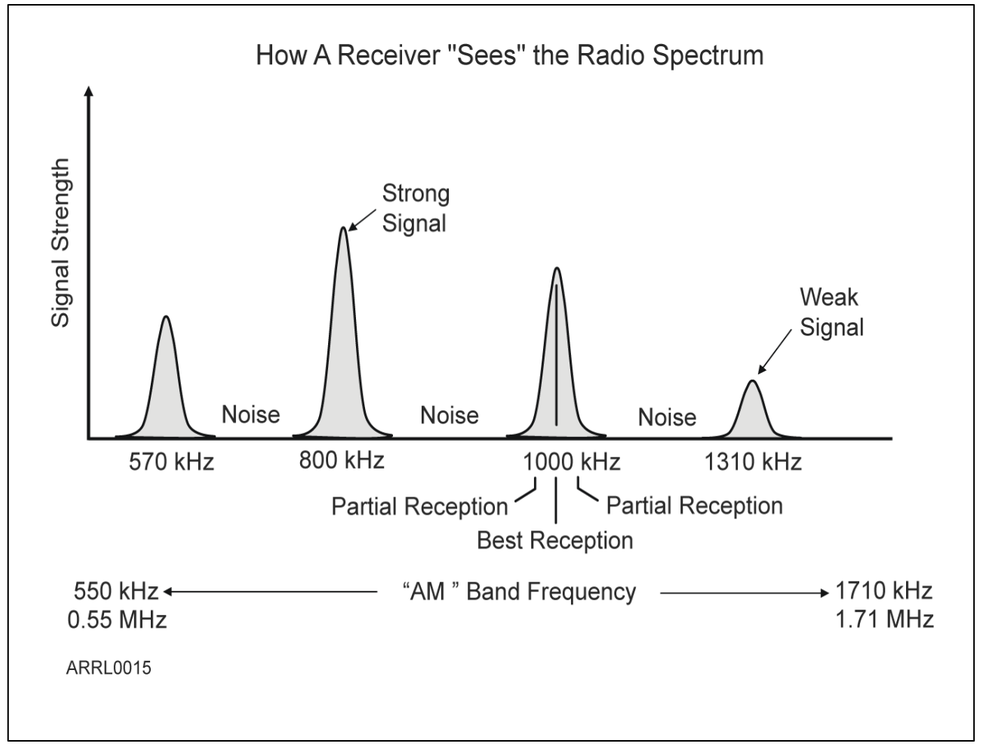
- The part of the electromagnetic spectrum Composed of radio waves is called the *Radio Frequency* or RF spectrum

Radio Spectrum

- Parts of the spectrum allocated for a common purpose are called a *band*, such as the “AM Band” or “CB Band”.
- Signals in these bands are usually of the same for commercial purposes.
- Hams share the band across many signals of different types.

Radio Signals

- A radio wave carrying information is a *radio signal*.
- Each signal occupies a range of frequencies.
- Receivers “tune in” a signal by listening at the signals frequency.



Electromagnetic Waves

- Moving electrons in an antenna take the place of the moving magnet.
- A signal from a transmitter can make the electrons in an antenna move, transferring energy from the signal to electromagnetic waves.

Electromagnetic Waves

- Electromagnetic waves are made up of electric and magnetic energy (fields).
- The electric and magnetic fields vary in the pattern of a sine wave.
- Electromagnetic waves travel at the speed of light.

Electromagnetic Waves

- The same process works “backwards” too.
- Electromagnetic waves encountering an antenna make its electrons move in sync with the wave.
- Electromagnetic energy is transferred from the wave to the electrons.
- The moving electrons create a signal that can be detected by a receiver.

US Amateur Radio Bands

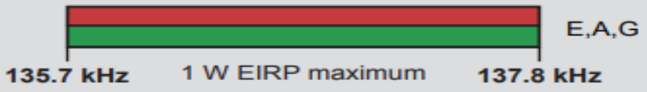
US AMATEUR POWER LIMITS

FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications.
(b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.

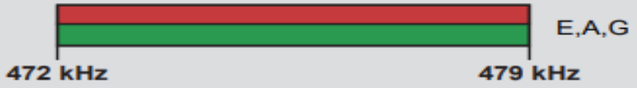
ARRL The national association for AMATEUR RADIO®

Amateurs wishing to operate on either 2,200 or 630 meters must first register with the Utilities Technology Council online at **https://utc.org/plc-database-amateur-notification-process/.** You need only register once for each band.

2,200 Meters (135 kHz)



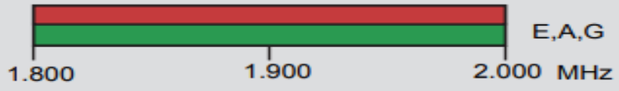
630 Meters (472 kHz)



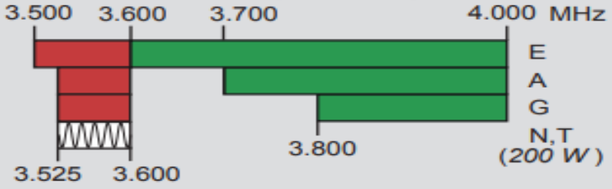
5 W EIRP maximum, except in Alaska within 496 miles of Russia where the power limit is 1 W EIRP.

160 Meters (1.8 MHz)

Avoid interference to radiolocation operations from 1.900 to 2.000 MHz



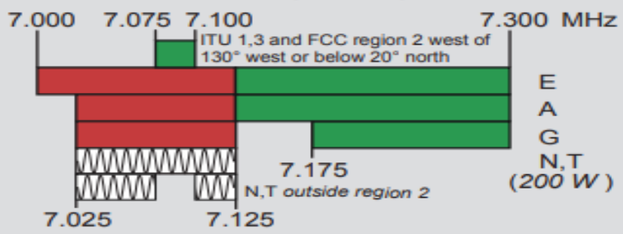
80 Meters (3.5 MHz)



60 Meters (5.3 MHz)

General, Advanced, and Amateur Extra licensees may operate on these five channels on a secondary basis with a maximum effective radiated power (ERP) of 100 W PEP relative to a half-wave dipole. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III. Only one signal at a time is permitted on any channel.

40 Meters (7 MHz)

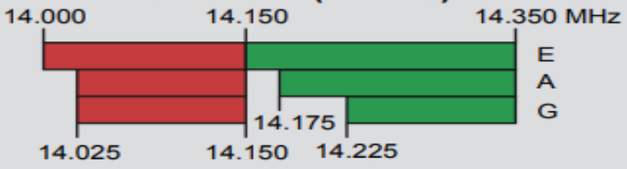


See Sections 97.305(c), 97.307(f)(11) and 97.301(e). These exemptions do not apply to stations in the continental US.

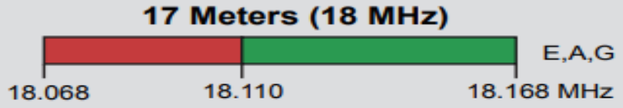
30 Meters (10.1 MHz)

Avoid interference to fixed services outside the US.

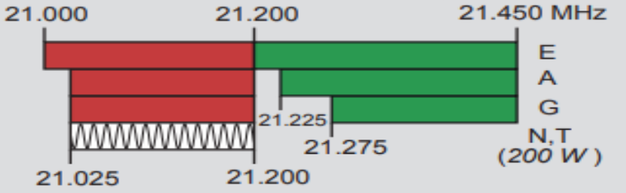
20 Meters (14 MHz)



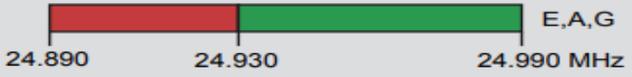
17 Meters (18 MHz)



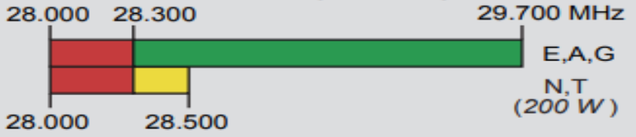
15 Meters (21 MHz)



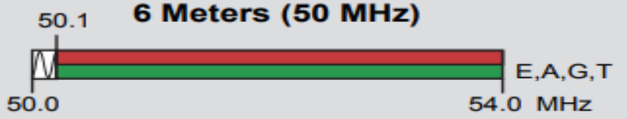
12 Meters (24 MHz)



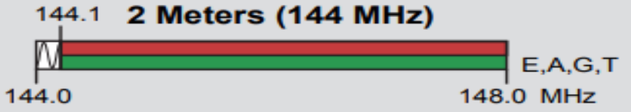
10 Meters (28 MHz)



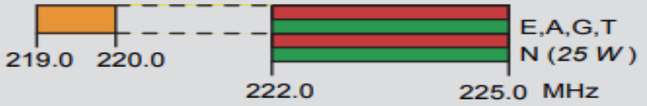
6 Meters (50 MHz)



2 Meters (144 MHz)

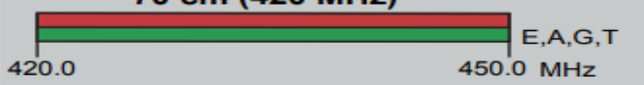


1.25 Meters (222 MHz)



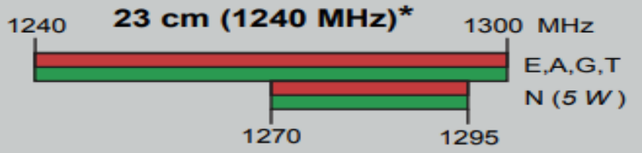
*Geographical and power restrictions may apply to all bands above 420 MHz. See *The ARRL Operating Manual* for information about your area.

70 cm (420 MHz)*



33 cm (902 MHz)*

23 cm (1240 MHz)*



All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	10.0-10.5 GHz ‡	122.25-123.0 GHz
2390-2450 MHz	24.0-24.25 GHz	134-141 GHz
3300-3500 MHz	47.0-47.2 GHz	241-250 GHz
5650-5925 MHz	76.0-81.0 GHz	All above 275 GHz

‡ No pulse emissions

KEY

Note:
CW operation is permitted throughout all amateur bands.

MCW is authorized above 50.1 MHz, except for 144.0-144.1 and 219-220 MHz.

Test transmissions are authorized above 51 MHz, except for 219-220 MHz

- = RTTY and data
- = phone and image
- = CW *only*
- = SSB phone
- = USB phone, CW, RTTY, and data
- = Fixed digital message forwarding systems *only*

E = Amateur Extra
A = Advanced
G = General
T = Technician
N = Novice

See *ARRLWeb at www.arrl.org* for detailed band plans.

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 rev. 9/22/2017

Practice Questions

What is the name for the distance a radio wave travels during one complete cycle?

A. Wave speed
B. Waveform
C. Wavelength
D. Wave spread

T3B01 HRLM (2-5)

What is the name for the distance a radio wave travels during one complete cycle?

A. Wave speed

B. Waveform

C. Wavelength

D. Wave spread

T3B01 HRLM (2-5)

How fast does a radio wave travel through free space?

A. At the speed of light
B. At the speed of sound
C. Its speed is inversely proportional to its wavelength
D. Its speed increases as the frequency increases

T3B04 HRLM (2-5)

How fast does a radio wave travel through free space?

A. At the speed of light

B. At the speed of sound

C. Its speed is inversely proportional to its wavelength

D. Its speed increases as the frequency increases

T3B04 HRLM (2-5)

How does the wavelength of a radio wave relate to its frequency?

A. The wavelength gets longer as the frequency increases
B. The wavelength gets shorter as the frequency increases
C. There is no relationship between wavelength and frequency
D. The wavelength depends on the bandwidth of the signal

T3B05 HRLM (2-5)

How does the wavelength of a radio wave relate to its frequency?

A. The wavelength gets longer as the frequency increases
B. The wavelength gets shorter as the frequency increases
C. There is no relationship between wavelength and frequency
D. The wavelength depends on the bandwidth of the signal

T3B05 HRLM (2-5)

What is the formula for converting frequency to approximate wavelength in meters?

A. Wavelength in meters equals frequency in hertz multiplied by 300
B. Wavelength in meters equals frequency in hertz divided by 300
C. Wavelength in meters equals frequency in megahertz divided by 300
D. Wavelength in meters equals 300 divided by frequency in megahertz

T3B06 HRLM (2-6)

What is the formula for converting frequency to approximate wavelength in meters?

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B. Wavelength in meters equals frequency in hertz divided by 300
C. Wavelength in meters equals frequency in megahertz divided by 300
D. Wavelength in meters equals 300 divided by frequency in megahertz

T3B06 HRLM (2-6)

What property of radio waves is often used to identify the different frequency bands?

A. The approximate wavelength
B. The magnetic intensity of waves
C. The time it takes for waves to travel one mile
D. The voltage standing wave ratio of waves

T3B07 HRLM (2-5)

What property of radio waves is often used to identify the different frequency bands?

A. The approximate wavelength

B. The magnetic intensity of waves

C. The time it takes for waves to travel one mile

D. The voltage standing wave ratio of waves

T3B07 HRLM (2-5)

What are the frequency limits of the VHF spectrum?

A. 30 to 300 kHz
B. 30 to 300 MHz
C. 300 to 3000 kHz
D. 300 to 3000 MHz

T3B08 HRLM (2-3)

What are the frequency limits of the VHF spectrum?

A. 30 to 300 kHz
B. 30 to 300 MHz
C. 300 to 3000 kHz
D. 300 to 3000 MHz

T3B08 HRLM (2-3)

What are the frequency limits of the UHF spectrum?

A. 30 to 300 kHz
B. 30 to 300 MHz
C. 300 to 3000 kHz
D. 300 to 3000 MHz

T3B09 HRLM (2-3)

What are the frequency limits of the UHF spectrum?

A. 30 to 300 kHz
B. 30 to 300 MHz
C. 300 to 3000 kHz
D. 300 to 3000 MHz

T3B09 HRLM (2-3)

What frequency range is referred to as HF?

A. 300 to 3000 MHz
B. 30 to 300 MHz
C. 3 to 30 MHz
D. 300 to 3000 kHz

T3B10 HRLM (2-3)

What frequency range is referred to as HF?

A. 300 to 3000 MHz
B. 30 to 300 MHz
C. 3 to 30 MHz
D. 300 to 3000 kHz

T3B10 HRLM (2-3)

What is the approximate velocity of a radio wave as it travels through free space?

A. 3000 kilometers per second

B. 300,000,000 meters per second

C. 300,000 miles per hour

D. 186,000 miles per hour

T3B11 HRLM (2-5)

What is the approximate velocity of a radio wave as it travels through free space?

A. 3000 kilometers per second

B. 300,000,000 meters per second

C. 300,000 miles per hour

D. 186,000 miles per hour

T3B11 HRLM (2-5)

What is the unit of frequency?

A. Hertz
B. Henry
C. Farad
D. Tesla

T5C05 HRLM (2-3)

What is the unit of frequency?

A. Hertz
B. Henry
C. Farad
D. Tesla

T5C05 HRLM (2-3)

What does the abbreviation “RF” refer to?

A. Radio frequency signals of all types

B. The resonant frequency of a tuned circuit

C. The real frequency transmitted as opposed to the apparent frequency

D. Reflective force in antenna transmission lines

T5C06 HRLM (2-3)

What does the abbreviation “RF” refer to?

A. Radio frequency signals of all types

B. The resonant frequency of a tuned circuit

C. The real frequency transmitted as opposed to the apparent frequency

D. Reflective force in antenna transmission lines

T5C06 HRLM (2-3)

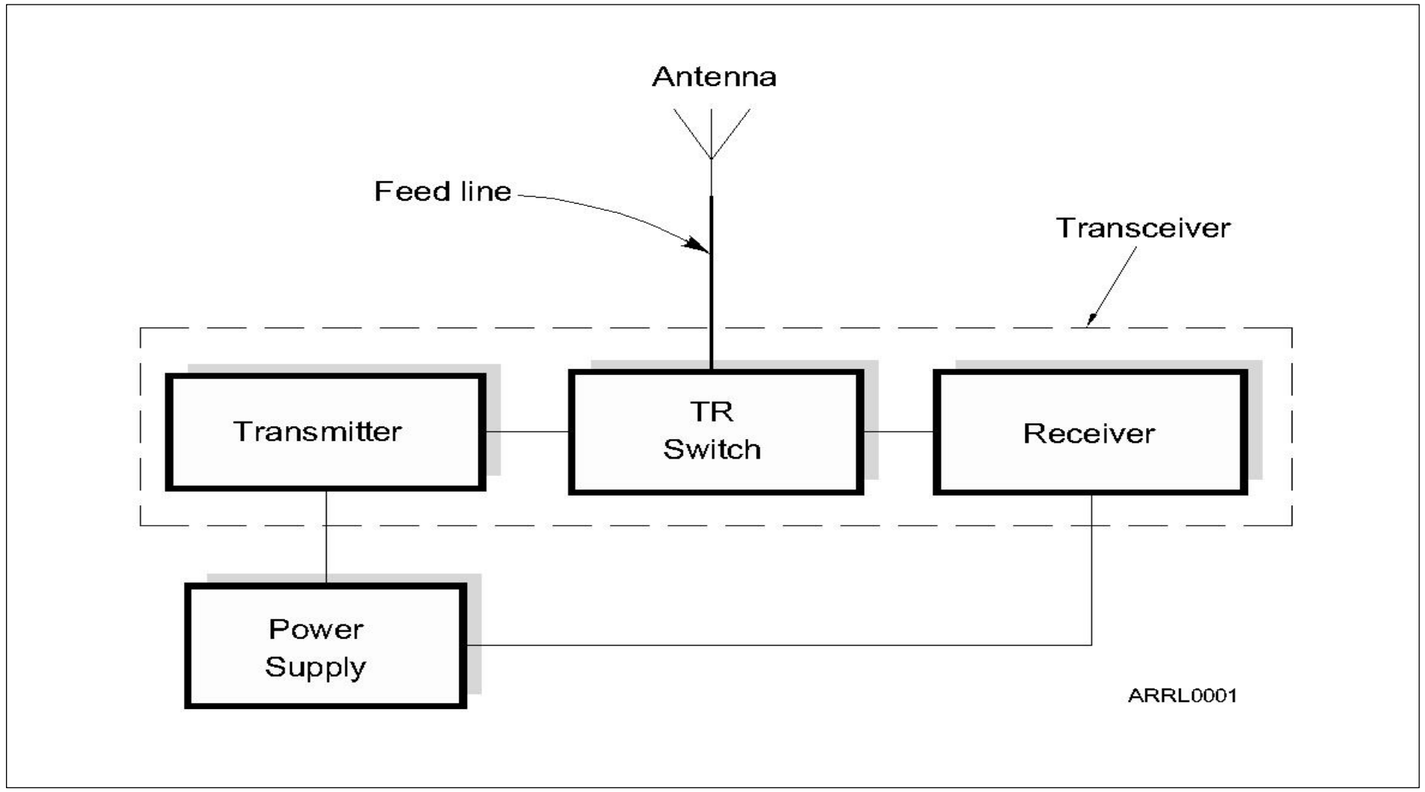
Technician License Course

Chapter 5

Lesson Plan Module – 5a

Modulation & Bandwidth

The Basic Radio Station



What Happens During Radio Communication?

- Transmitting (sending a signal):

- Information (voice, data, video, commands, etc.) is converted to electronic form.

- The information in electronic form is added to a radio wave.

- The radio wave carrying the information is sent from the station antenna into space.

What Happens During Radio Communication?

- Receiving

- The radio wave carrying the information is intercepted by the receiving station's antenna.

- The receiver extracts the information from the received wave

- The information is then presented to the user in a format that can be understood (sound, picture, words on a computer screen, response to a command, etc.).

What Happens During Radio Communication?

- Adding and extracting the information can be simple or complex.
- This makes ham radio fun…learning all about how radios work.
- Don’t be intimidated. You will be required to only know the basics, but you can learn as much about the “art and science” of radio as you want.

Adding Information – Modulation

- When we add some information to the radio wave, (the *carrier*) we *modulate* the wave.

- Turn the wave on and off (Morse code)

- Speech or music

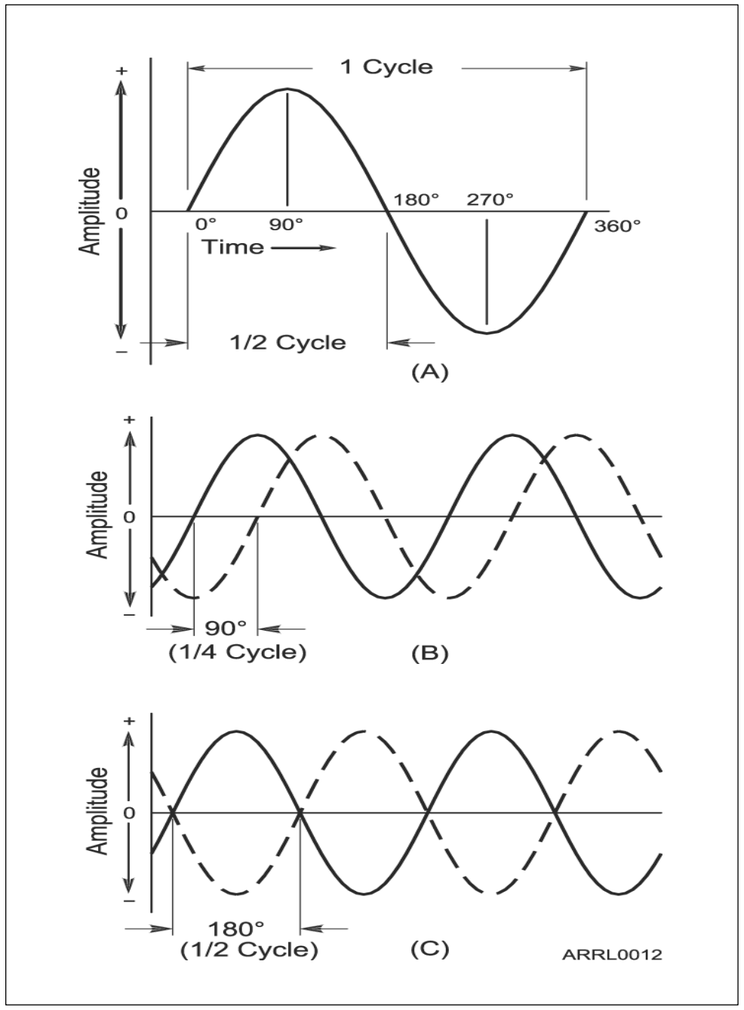
- Data

- Different modulation techniques vary different properties of the wave to add the information:

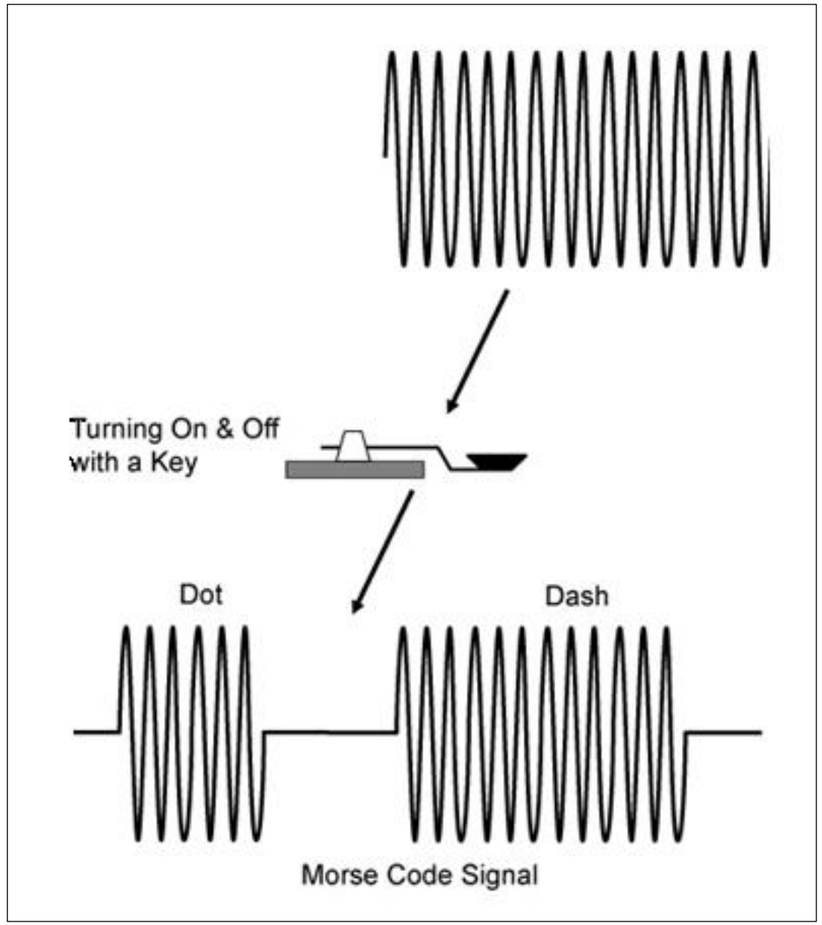
- Amplitude, frequency, or phase

Phase

- Along with frequency and period, another important property of waves is *phase*.
- Phase is a position within a cycle.
- Phase is also a relative position between two waves.

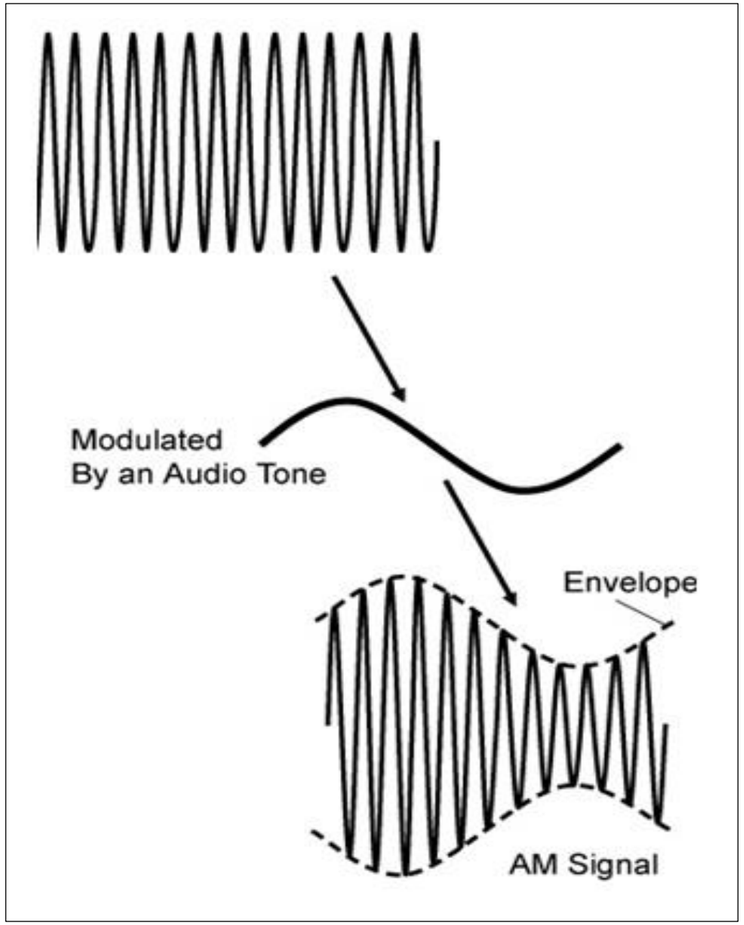


CW - Morse Code – On and Off



Amplitude Modulation (AM)

- In AM, the amplitude of the carrier wave is modified in step with the waveform of the information (the tone shown here).



Composite Signals

- The process of adding information to an unmodulated radio wave creates additional signals called *sidebands*.
- The sidebands and carrier work together to carry the information.
- The combination of carrier and sidebands creates a *composite signal*.

Bandwidth

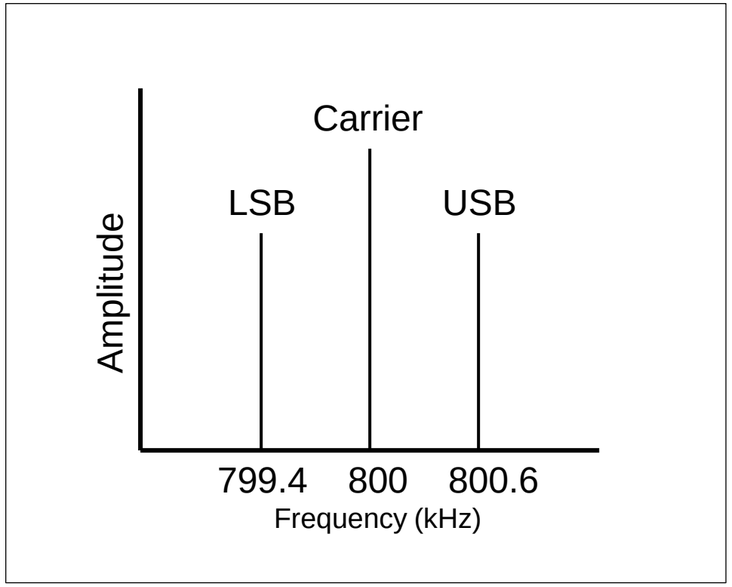
- The carrier and sidebands have different frequencies, occupying a range of spectrum space.
- The occupied range is the composite signal's *bandwidth*.
- Different types of modulation and information result in different signal bandwidths.

Characteristics of Voice AM

AM signals consist of three components:

- Carrier
- Lower sideband (LSB)
- Upper sideband (USB)

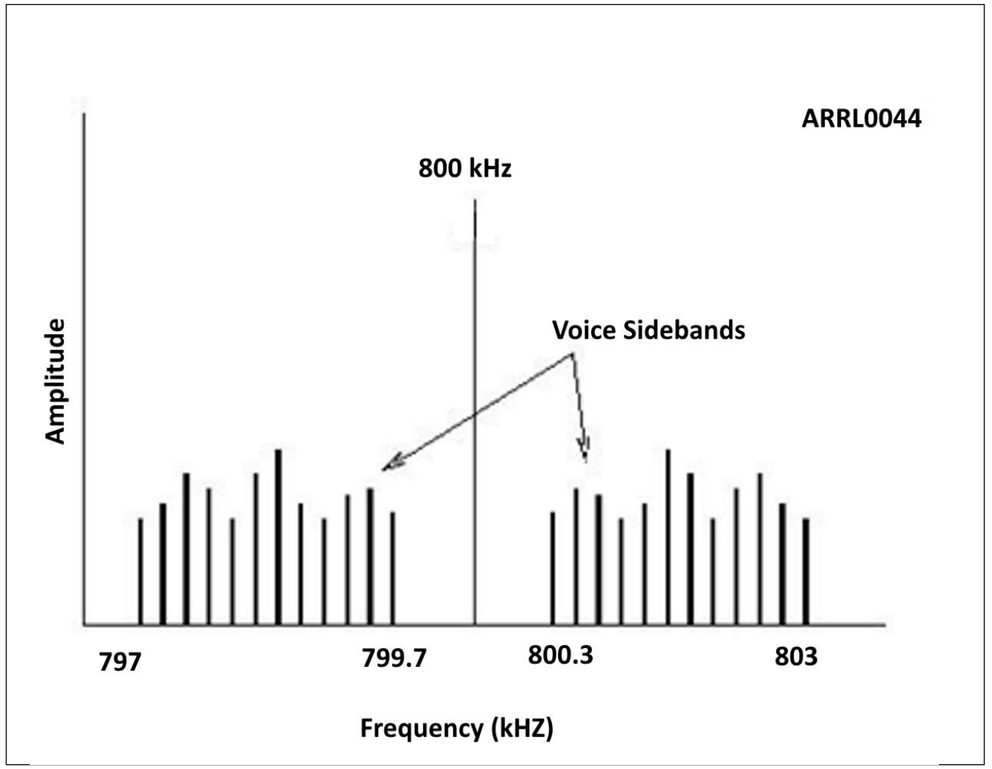
AM bandwidth is twice the information bandwidth.



AM signal being modulated by a 600 Hz tone

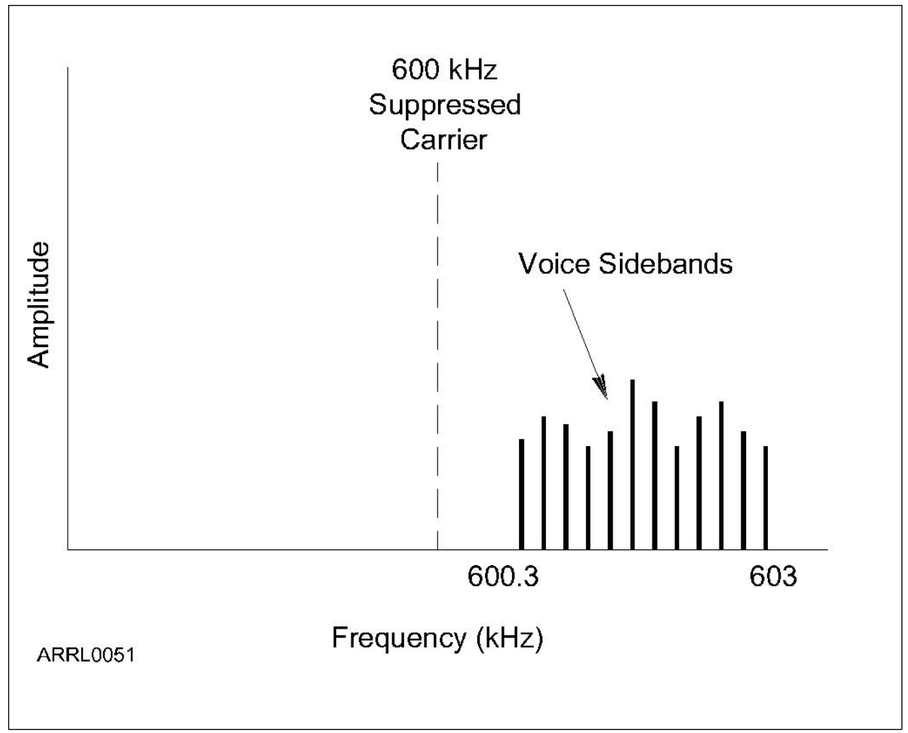
Characteristics of Voice Information

- Sounds that make up voice are a complex mixture of multiple frequencies from 300–3000 Hz
- Two mirror-image sets of sidebands are created, each up to 3000 Hz wide.
- AM voice signal bandwidth 2 x 3000 Hz = 6000 Hz



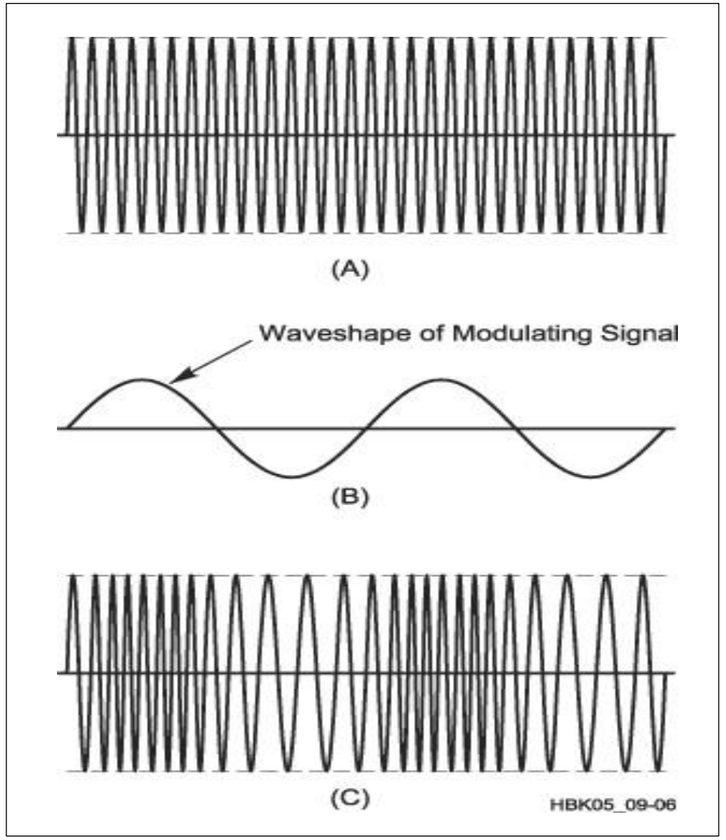
Single Sideband Modulation (SSB)

- The two sets of voice sidebands carry duplicate information.
- We can improve efficiency by transmitting only one sideband and reconstructing the missing carrier in the receiver.
- SSB bandwidth is only 3000 Hz for voice signals.



Frequency and Phase Modulation (FM and PM)

- Instead of varying amplitude, if we use the information to vary the carrier's frequency, *frequency modulation* (FM) is produced.
- FM bandwidth (for voice) is between 5 and 15 kHz.
- We can also shift the signal's phase back and forth, creating phase *modulation (PM)* that is very similar to FM.



FM modulation is a little tough to understand !!

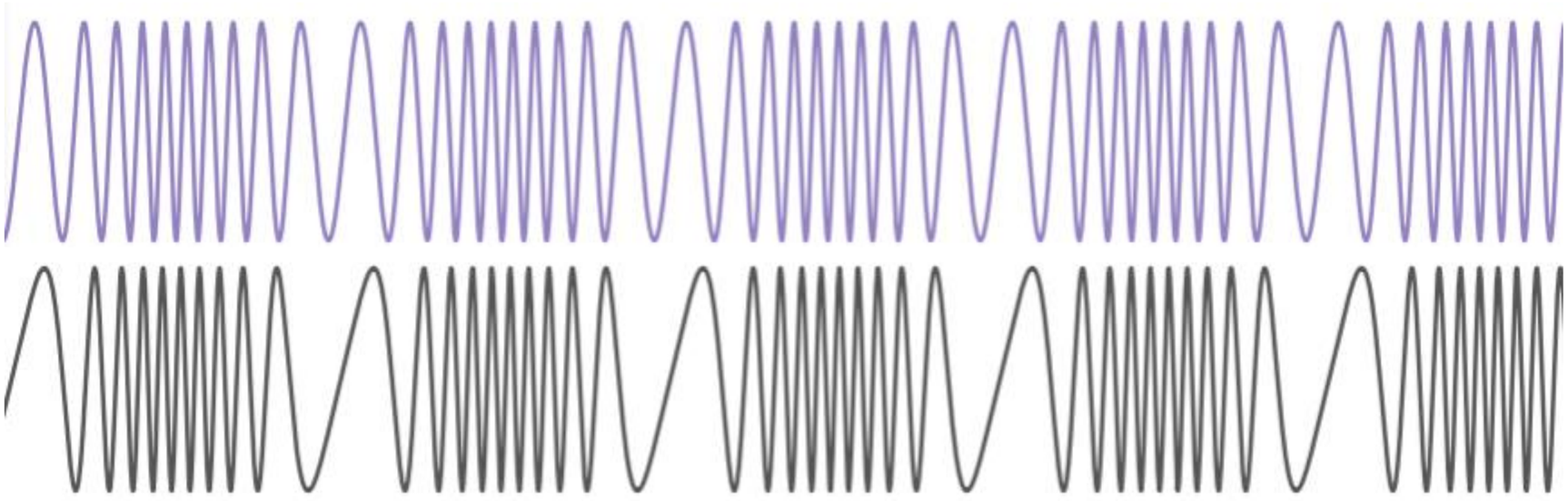
So let's look at some examples of how FM modulation looks in two different cases:

1. Pure tone gets louder (same frequency)

2. Pure tone is higher frequency (same loudness)

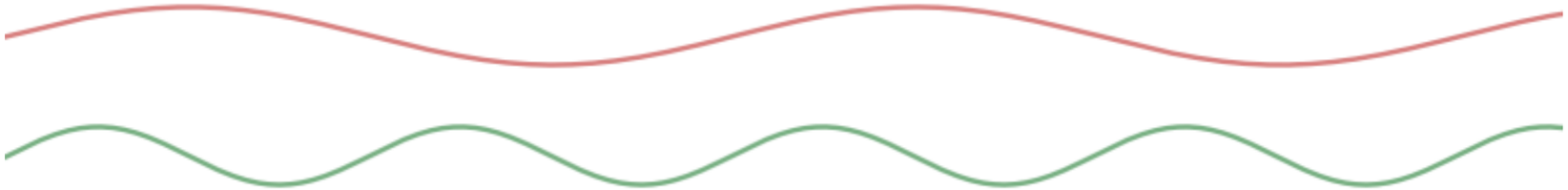
Pure Tone gets LOUDER

Larger amplitude, same frequency

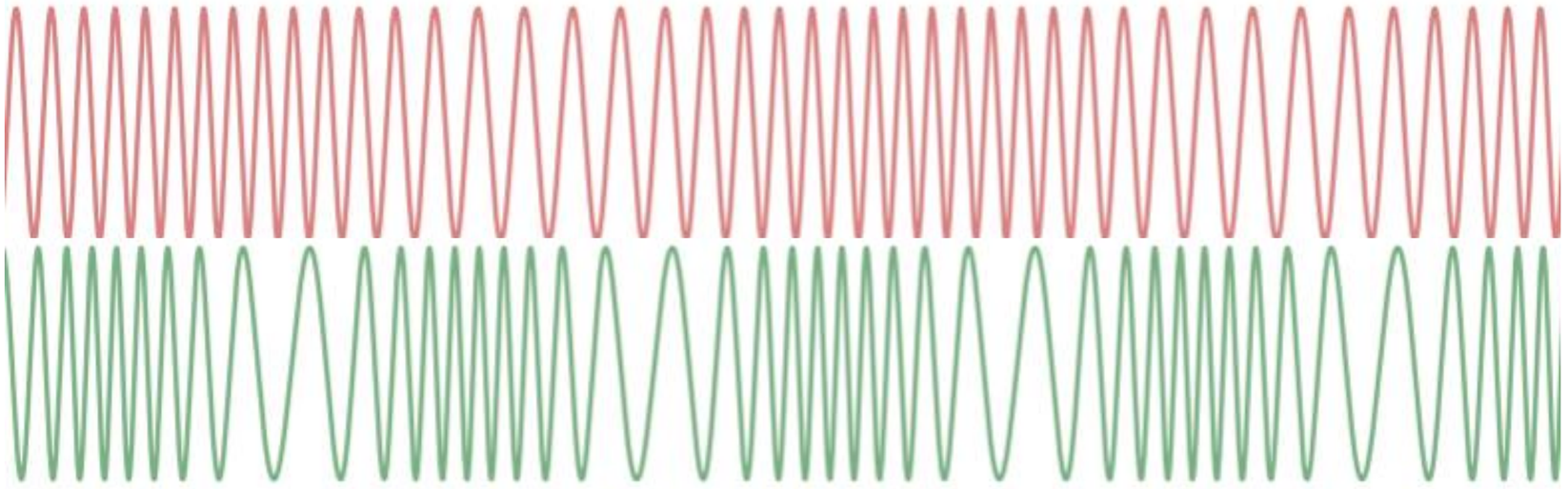


Highest frequency is higher, lowest frequency is lower

Pure Tone is **higher** FREQUENCY



Higher Frequency, same amplitude



More **compressions**, more expansions

New vocabulary definition:

Deviation

Deviation is the peak change in frequency of an FM carrier due to a modulating signal

Example in 2-meter FM:
Instantaneous frequency: 147.061 MHz (147,061 kHz)
Carrier frequency: 147.060 MHz (147,060 kHz)

Instantaneous Deviation = 1 kHz

Typical Signal Bandwidths

Signal Bandwidths

Type of Signal	*Typical Bandwidth*
CW	150 Hz (0.15 kHz)
SSB digital	500 to 3000 Hz (0.5 to 3 kHz)
SSB voice	2 to 3 kHz
AM voice	6 kHz
AM broadcast	10 kHz
FM voice	10 to 15 kHz*
FM broadcast	150 kHz
Commercial video broadcast	6 MHz

*On 10 meters below 29.0 MHz, FM voice must be narrowband (6 kHz max). As of early 2018, most VHF/UHF FM voice repeater signals are approximately 15 kHz wide although there is some narrowband equipment using 5-6 kHz.

US Amateur Radio Bands

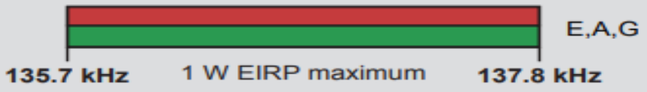
US AMATEUR POWER LIMITS

FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications.
(b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.

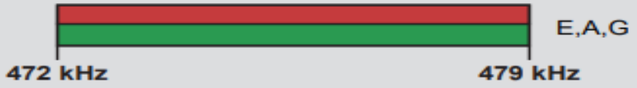
ARRL The national association for AMATEUR RADIO®

Amateurs wishing to operate on either 2,200 or 630 meters must first register with the Utilities Technology Council online at **https://utc.org/plc-database-amateur-notification-process/.** You need only register once for each band.

2,200 Meters (135 kHz)



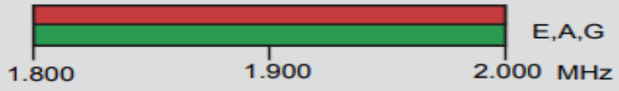
630 Meters (472 kHz)



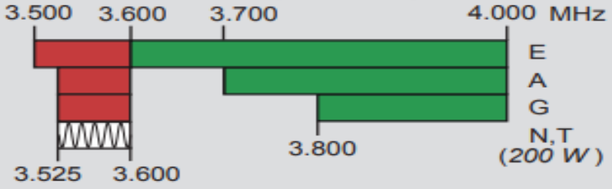
5 W EIRP maximum, except in Alaska within 496 miles of Russia where the power limit is 1 W EIRP.

160 Meters (1.8 MHz)

Avoid interference to radiolocation operations from 1.900 to 2.000 MHz



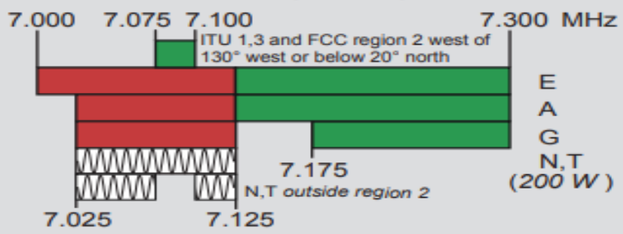
80 Meters (3.5 MHz)



60 Meters (5.3 MHz)

General, Advanced, and Amateur Extra licensees may operate on these five channels on a secondary basis with a maximum effective radiated power (ERP) of 100 W PEP relative to a half-wave dipole. Permitted operating modes include upper sideband voice (USB), CW, RTTY, PSK31 and other digital modes such as PACTOR III. Only one signal at a time is permitted on any channel.

40 Meters (7 MHz)

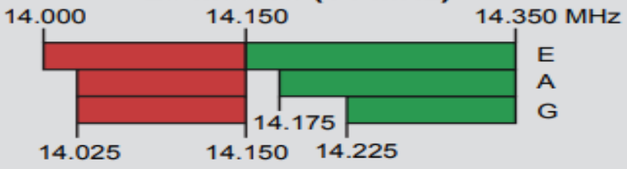


See Sections 97.305(c), 97.307(f)(11) and 97.301(e). These exemptions do not apply to stations in the continental US.

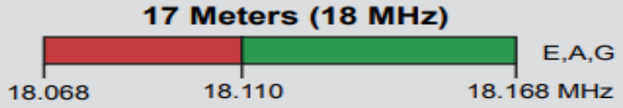
30 Meters (10.1 MHz)

Avoid interference to fixed services outside the US.

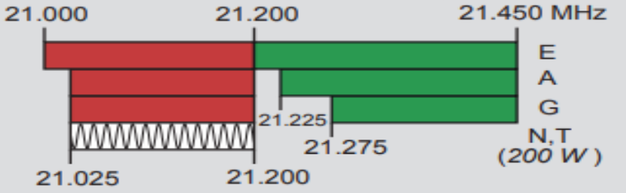
20 Meters (14 MHz)



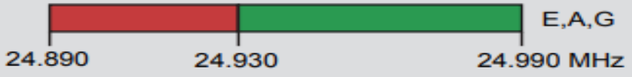
17 Meters (18 MHz)



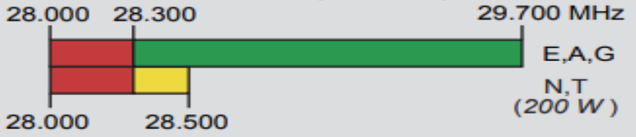
15 Meters (21 MHz)



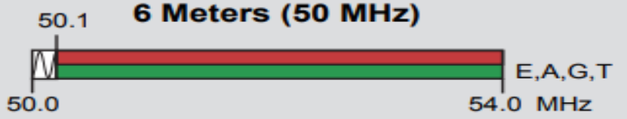
12 Meters (24 MHz)



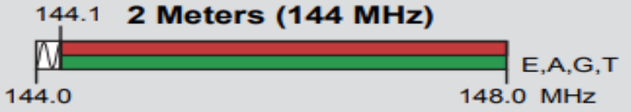
10 Meters (28 MHz)



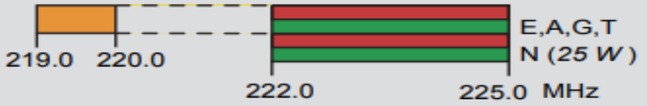
6 Meters (50 MHz)



2 Meters (144 MHz)

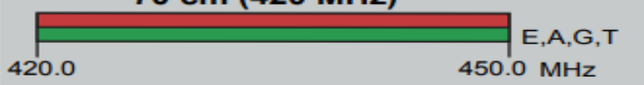


1.25 Meters (222 MHz)



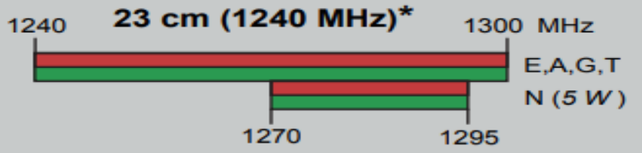
*Geographical and power restrictions may apply to all bands above 420 MHz. See *The ARRL Operating Manual* for information about your area.

70 cm (420 MHz)*



33 cm (902 MHz)*

23 cm (1240 MHz)*



All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	10.0-10.5 GHz ‡	122.25-123.0 GHz
2390-2450 MHz	24.0-24.25 GHz	134-141 GHz
3300-3500 MHz	47.0-47.2 GHz	241-250 GHz
5650-5925 MHz	76.0-81.0 GHz	All above 275 GHz

‡ No pulse emissions

KEY

Note:
CW operation is permitted throughout all amateur bands.

MCW is authorized above 50.1 MHz, except for 144.0-144.1 and 219-220 MHz.

Test transmissions are authorized above 51 MHz, except for 219-220 MHz

- = RTTY and data
- = phone and image
- = CW *only*
- = SSB phone
- = USB phone, CW, RTTY, and data
- = Fixed digital message forwarding systems *only*

E = Amateur Extra
A = Advanced
G = General
T = Technician
N = Novice

See *ARRLWeb at www.arrl.org* for detailed band plans.

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Toll-Free 1-800-326-3942 (860-594-0355)
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 rev. 9/22/2017

Practice Questions

Why should you not set your transmit frequency to be exactly at the edge of an amateur band or sub-band?

A. To allow for calibration error in the transmitter frequency display

B. So that modulation sidebands do not extend beyond the band edge

C. To allow for transmitter frequency drift

D. All of these choices are correct

FCC Rule: [97.101(a), 97.301(a-e)] T1B09 HRLM (2-10)

Why should you not set your transmit frequency to be exactly at the edge of an amateur band or sub-band?

A. To allow for calibration error in the transmitter frequency display

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FCC Rule: [97.101(a), 97.301(a-e)] T1B09 HRLM (2-10)

What determines the amount of deviation of an FM (as opposed to PM) signal?

A. Both the frequency and amplitude of the modulating signal
B. The frequency of the modulating signal
C. The amplitude of the modulating signal
D. The relative phase of the modulating signal

T2B05 HRLM (2-10)

What determines the amount of deviation of an FM (as opposed to PM) signal?

A. Both the frequency and amplitude of the modulating signal

B. The frequency of the modulating signal

C. The amplitude of the modulating signal

D. The relative phase of the modulating signal

T2B05 HRLM (2-10)

What happens when the deviation of an FM transmitter is increased?

A. Its signal occupies more bandwidth
B. Its output power increases
C. Its output power and bandwidth increases
D. Asymmetric modulation occurs

T2B06 HRLM (2-9)

What happens when the deviation of an FM transmitter is increased?

A. Its signal occupies more bandwidth

B. Its output power increases

C. Its output power and bandwidth increases

D. Asymmetric modulation occurs

T2B06 HRLM (2-9)

Which of the following is a form of amplitude modulation?

A. Spread spectrum
B. Packet radio
C. Single sideband
D. Phase shift keying

T8A01 HRLM (2-9)

Which of the following is a form of amplitude modulation?

A. Spread spectrum
B. Packet radio
C. Single sideband
D. Phase shift keying

T8A01 HRLM (2-9)

What type of modulation is most commonly used for VHF packet radio transmissions?

A. FM
B. SSB
C. AM
D. Spread spectrum

T8A02 HRLM (2-10)

What type of modulation is most commonly used for VHF packet radio transmissions?

A. FM

B. SSB

C. AM

D. Spread spectrum

T8A02 HRLM (2-10)

Which type of voice modulation is most often used for long-distance or weak signal contacts on the VHF and UHF bands?

A. FM
B. DRM
C. SSB
D. PM

T8A03 HRLM (2-11)

Which type of voice modulation is most often used for long-distance or weak signal contacts on the VHF and UHF bands?

A. FM
B. DRM
C. SSB
D. PM

T8A03 HRLM (2-11)

Which type of modulation is most commonly used for VHF and UHF voice repeaters?

A. AM
B. SSB
C. PSK
D. FM

T8A04 HRLM (2-10)

Which type of modulation is most commonly used for VHF and UHF voice repeaters?

A. AM
B. SSB
C. PSK
D. FM

T8A04 HRLM (2-10)

Which of the following types of emission has the narrowest bandwidth?

A. FM voice
B. SSB voice
C. CW
D. Slow-scan TV

T8A05 HRLM (2-10)

Which of the following types of emission has the narrowest bandwidth?

A. FM voice

B. SSB voice

C. CW

D. Slow-scan TV

T8A05 HRLM (2-10)

Which sideband is normally used for 10 meter HF, VHF and UHF single-sideband communications?

A. Upper sideband
B. Lower sideband
C. Suppressed sideband
D. Inverted sideband

T8A06 HRLM (2-11)

Which sideband is normally used for 10 meter HF, VHF and UHF single-sideband communications?

A. Upper sideband

B. Lower sideband

C. Suppressed sideband

D. Inverted sideband

T8A06 HRLM (2-11)

What is the primary advantage of single sideband over FM for voice transmissions?

A. SSB signals are easier to tune
B. SSB signals are less susceptible to interference
C. SSB signals have narrower bandwidth
D. All of these choices are correct

T8A07 HRLM (2-11)

What is the primary advantage of single sideband over FM for voice transmissions?

A. SSB signals are easier to tune

B. SSB signals are less susceptible to interference

C. SSB signals have narrower bandwidth

D. All of these choices are correct

T8A07 HRLM (2-11)

What is the approximate bandwidth of a single sideband voice signal?

A. 1 kHz

B. 3 kHz

C. 6 kHz

D. 15 kHz

T8A08 HRLM (2-5)

What is the approximate bandwidth of a single sideband voice signal?

A. 1 kHz

B. 3 kHz

C. 6 kHz

D. 15 kHz

T8A08 HRLM (2-5)

What is the approximate bandwidth of a VHF repeater FM phone signal?

A. Less than 500 Hz

B. About 150 kHz

C. Between 10 and 15 kHz

D. Between 50 and 125 kHz

T8A09 HRLM (2-5)

What is the approximate bandwidth of a VHF repeater FM phone signal?

A. Less than 500 Hz

B. About 150 kHz

C. Between 10 and 15 kHz

D. Between 50 and 125 kHz

T8A09 HRLM (2-5)

What is the typical bandwidth of analog fast-scan TV transmissions on the 70 cm band?

A. More than 10 MHz

B. About 6 MHz

C. About 3 MHz

D. About 1 MHz

T8A10 HRLM (2-5)

What is the typical bandwidth of analog fast-scan TV transmissions on the 70 cm band?

A. More than 10 MHz

B. About 6 MHz

C. About 3 MHz

D. About 1 MHz

T8A10 HRLM (2-5)

What is the approximate maximum bandwidth required to transmit a CW signal?

A. 2.4 kHz

B. 150 Hz

C. 1000 Hz

D. 15 kHz

T8A11 HRLM (2-5)

What is the approximate maximum bandwidth required to transmit a CW signal?

A. 2.4 kHz

B. 150 Hz

C. 1000 Hz

D. 15 kHz

T8A11 HRLM (2-5)

End of Week 2

https://w5nor.org/tech