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The ARRL General Class License Course

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LEVEL 2: General

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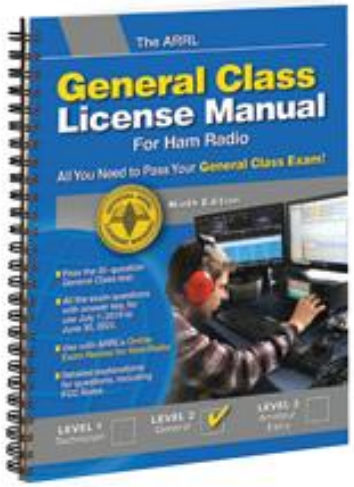

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Module 5b

ARRL General Class
Chapter 5 – Radio Signals & Equipment
(5.4, 5.5)

Receivers, HF Station Installation

Superheterodyne Receivers

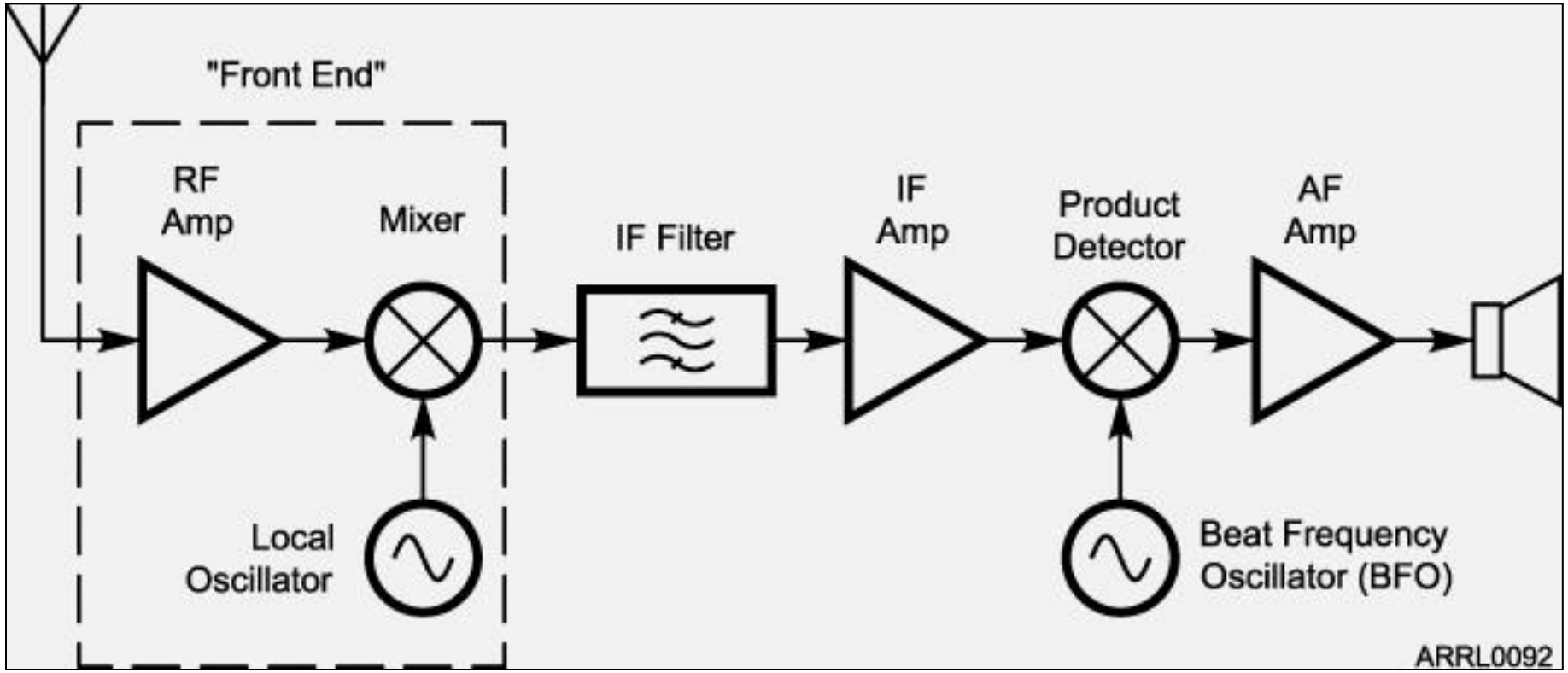
- Most receivers use by today's amateurs are *superheterodyne*
- Received signals are incredibly weak – on the order of nano or picowatts
  - Received signals are first strengthened by the *RF amplifier*, then applied to the RF input of a mixer
  - The *local oscillator* (LO) is adjusted so that the desired signal creates a mixing product at the *intermediate frequency* (IF)
  - A *detector* or *demodulator* stage follows the IF to recover the modulating information

Superheterodyne Receivers (cont.)

- The simplest possible superhet consists of a mixer connected to the antenna, an oscillator to act as the LO, and a detector that operates directly on the resulting IF signal
  - See Figure 5.16

Fig. 5.16

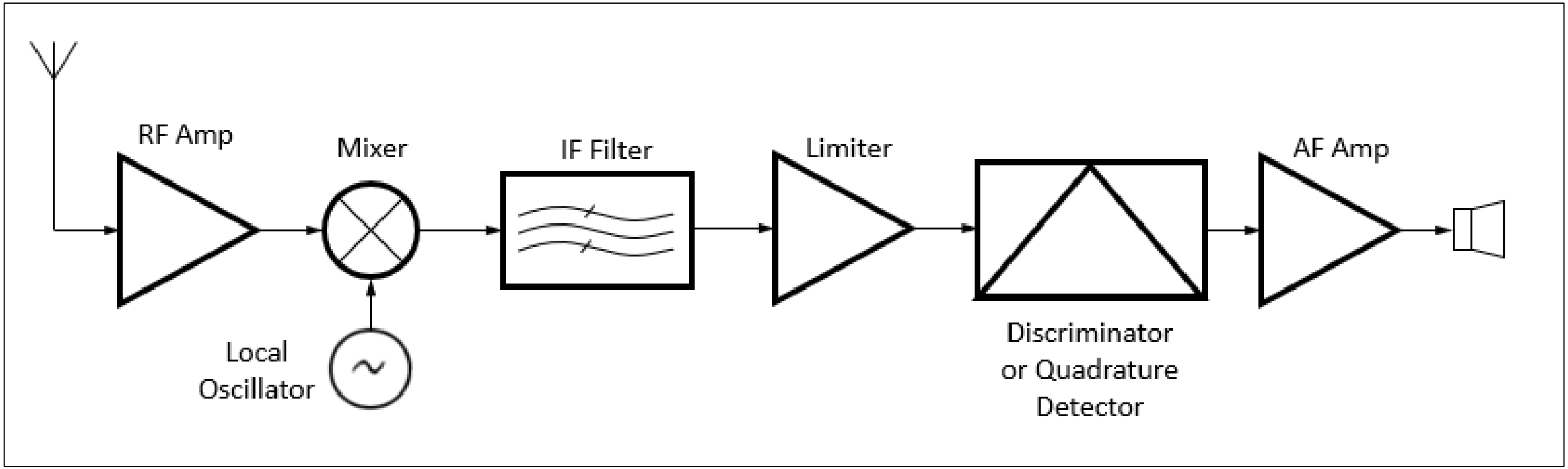
A superheterodyne receiver converts signals to audio in two steps. The front end converts the frequency of a signal to the intermediate frequency (IF) where most of the gain of the receiver is provided. A second mixer – the product detector – converts the signal to audio frequencies.



Superheterodyne Receivers (cont.)

- Once amplified to a more usable level, SSB and CW signals are demodulated by a *product detector*, a special type of mixer
- If an AM signal is being received, a *product detector* or *envelope detector* recovers the modulating signal
- Output of the detector is an audio signal amplified by an audio frequency (AF) amplifier and input to a speaker, headphones, or sound card

Fig 5.17: Once the FM signal is converted to the IF, hi-gain amplifiers called limiters change the signal to a square wave that only varies in frequency (not amplitude). A discriminator converts the frequency variations to audio.



Superheterodyne Receivers (cont.)

- The RF amplifier and mixer are the receivers front end
  - Processes weak signals at their original frequencies
  - A *preselector* is often used to reject *out-of-band* signals
  - A preamplifier (preamp) is used if additional sensitivity is needed (weak signals)

FM Receivers (Fig. 5.17)

- Similar to AM/SSB/CW superhets
  - The linear IF amplifier is replaced by a limiter
    - Limiter amplifies the received signal until all amplitude modulated info (noise) is removed and only a square wave of the varying frequency remains
    - Audio information is recovered by a *discriminator* or *quadrature detector* that replaces the product detector
- Superhets have some weaknesses, like all radio designs
  - Because there are mixing products at both the sum and difference frequencies, undesired signals can create their own mixing products at the IF … see next slide for examples (refer to Fig 5.4)

Superhet Mixer Weakness Example (see Fig 5.4)

In a mixer, with an RF Input or Input Frequency (f_1) and Local Oscillator (f_2), remember there are mixing products at …

$f_1 \pm f_2$ meaning $f_1 + f_2$ AND $f_1 - f_2$

With IF = 455 kHZ (0.455 MHz) and LO = 13.800 MHZ, you will have signals at …

$f_1 \pm f_2$ = 13.800 + 0.455 and 13.800 – 0.455 or 14.255 and 13.345 MHz

The signals at 14.255 and 13.345 will create their OWN mixing products. The first will be at 14.225 – 13.800 (LO) = 455 kHz. The second will be at 13.800 (LO) – 13.345 = 455 kHz.

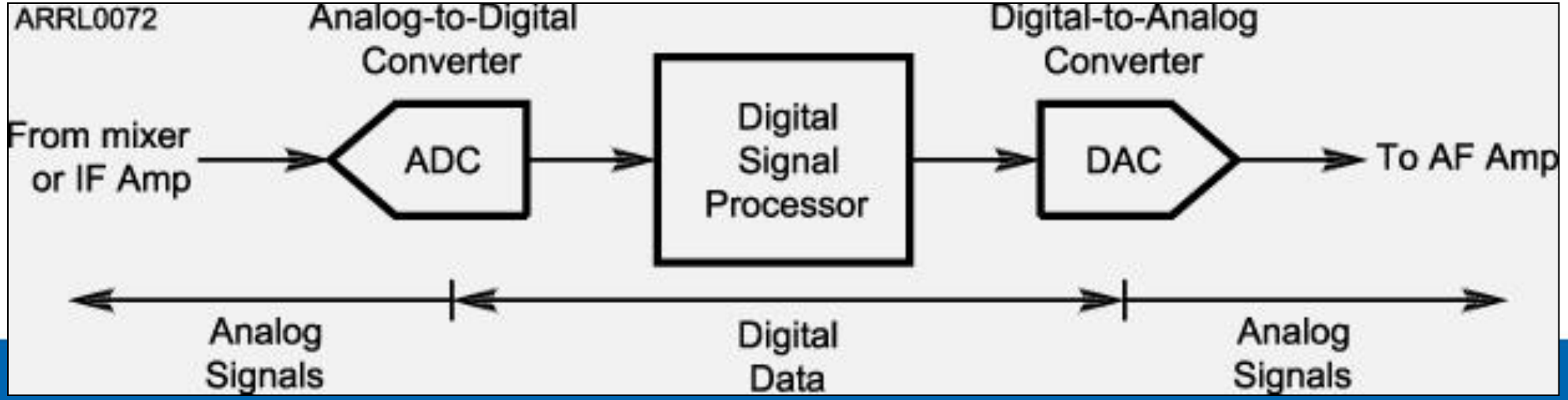
Assuming the receiver is set at 14.255 MHz, the undesired signal at 13.345 MHz is an *image response*.

FM Receivers (cont.)

- Another flaw is caused by the LO and other oscillator circuits. Leakage of signals into the signal path can cause steady signals to appear (called *birdies*).
- Figs 5.16 and 5.17 show *single-conversion* receivers, with only one mixer converting the signal from RF to IF
  - The IF stages provide most of the gain and selectivity
  - Filtering is applied at each IF (allows filter bandwidth selection for desired signal) … this gives the best received signal quality with the lowest unwanted noise and interference, maximizing the *signal-to-noise ratio* (SNR)

Digital Signal Processing (DSP)

- The general term for converting signals from analog to digital is *digital signal processing*
- Fig 5.18 (below): DSP systems use an analog-to-digital converter (ADC) to change the signal to digital data. A special type of microprocessor then performs the mathematical operations on the data to accomplish filtering, noise reduction, or other functions. A digital-to-analog converter (DAC) changes the processed data back to analog form for output as audio.



Digital Signal Processing (cont.)

- Two advantages over analog circuitry
  - Performance & flexibility
- DSP offers selectable preprogrammed filters and allow the operator to adjust the filter bandwidth and shape and even to define new filters
- Expensive functions in analog circuits can be implemented in DSP as a program without additional hardware

Managing Receiver Gain (RF Gain)

- When looking for weak signals, set RF gain to maximum (for highest receiver sensitivity)
- Lower RF gain volume to reduce background noise
- Automatic gain control (AGC) circuits vary gain of the RF and IF amplifiers so output volume stays constant for both weak and strong signals
  - AGC circuit changes the voltage that controls the IF amp gain. This voltage is read by the *S-meter* (measures *signal* strength).

RF Gain and AGC (cont.)

- S-meters are calibrated in *S-units*
  - One S-unit equals up to 6dB (fourfold) change in signal strength
- S-9 (a strong signal) is located at the midpoint of the display
  - Larger values to the right (20, 40, 60)
  - These correspond to “dB above S-9”
- Reading of “S-9 + 20 dB” is a signal 20 dB (100 times) stronger than an S-9 signal

Receiver Linearity

- If the received signal is distorted, spurious signals will appear just as if a transmitting station were emitting them
- The most common form of receiver nonlinearity is *overload* (also called *front-end overload*) or *gain compression*
- Solution to overload is to filter out the offending signal or reduce receiver gain (attenuator circuit). Proper use of attenuator and RF gain controls can dramatically reduce received noise distortion caused by strong signals.

Rejecting Interference and Noise

- IF filters narrow the receiver's passband (removes unwanted signals)
- Notch filters remove signals in a very narrow band of frequencies (such as a signal tone from an interfering carrier)
- Passband or IF shift adjust receiver's passband above or below the displayed carrier frequency (avoids interference on adjacent frequencies)
- Reverse sideband controls allow switching between receiving CW signals above carrier frequency (USB) and below it (LSB). Avoids interference by placing the signals on the "other side" of the carrier where filtering rejects them.

Rejecting Interference and Noise (cont.)

- Noise blankers sense short, sharp pulses in the IF signals and reduce the gain of the IF and audio amplifiers during the pulse … called *blanking*
  - If noise blankers are adjustable, it can be set to blank the receiver at different noise levels
- Noise reduction is performed by the DSP.
  - Removes hiss and noise from the audio that is not part of the desired speech, data, or CW
  - Increasing the noise reduction level may cause some of the desired signal to be removed (causes distortion) … use the least noise reduction require to minimize this

PRACTICE QUESTIONS

What is the purpose of the “notch filter” found on many HF transceivers?

A. To restrict the transmitter voice bandwidth
B. To reduce interference from carriers in the receiver passband
C. To eliminate receiver interference from impulse noise sources
D. To enhance the reception of a specific frequency on a crowded band

What is one advantage of selecting the opposite, or “reverse,” sideband when receiving CW signals on a typical HF transceiver?

A. Interference from impulse noise will be eliminated
B. More stations can be accommodated within a given signal passband
C. It may be possible to reduce or eliminate interference from other signals
D. Accidental out-of-band operation can be prevented

Which of the following is a use for the IF shift control on a receiver?

A. To avoid interference from stations very close to the receive frequency
B. To change frequency rapidly
C. To permit listening on a different frequency from that on which you are transmitting
D. To tune in stations that are slightly off frequency without changing your transmit frequency

What is one reason to use the attenuator function that is present on many HF transceivers?

A. To reduce signal overload due to strong incoming signals
B. To reduce the transmitter power when driving a linear amplifier
C. To reduce power consumption when operating from batteries
D. To slow down received CW signals for better copy

How does a noise blanker work?

A. By temporarily increasing received bandwidth
B. By redirecting noise pulses into a filter capacitor
C. By reducing receiver gain during a noise pulse
D. By clipping noise peaks

What happens as the noise reduction control level in a receiver is increased?

A. Received signals may become distorted
B. Received frequency may become unstable
C. CW signals may become severely attenuated
D. Received frequency may shift several kHz

Which of the following is an advantage of a receiver DSP IF filter as compared to an analog filter?

A. A wide range of filter bandwidths and shapes can be created
B. Fewer digital components are required
C. Mixing products are greatly reduced
D. The DSP filter is much more effective at VHF frequencies

What does an S meter measure?

A. Conductance
B. Impedance
C. Received signal strength
D. Transmitter power output

How does a signal that reads 20 dB over S9 compare to one that reads S9 on a receiver, assuming a properly calibrated S meter?

A. It is 10 times less powerful
B. It is 20 times less powerful
C. It is 20 times more powerful
D. It is 100 times more powerful

Where is an S meter found?

A. In a receiver
B. In an SWR bridge
C. In a transmitter
D. In a conductance bridge

How much must the power output of a transmitter be raised to change the S meter reading on a distant receiver from S8 to S9?

A. Approximately 1.5 times
B. Approximately 2 times
C. Approximately 4 times
D. Approximately 8 times

What circuit is used to process signals from the RF amplifier and local oscillator then send the result to the IF filter in a superheterodyne receiver?

A. Balanced modulator
B. IF amplifier
C. Mixer
D. Detector

What circuit is used to combine signals from the IF amplifier and BFO and send the result to the AF amplifier in some single sideband receivers?

A. RF oscillator
B. IF filter
C. Balanced modulator
D. Product detector

What is the simplest combination of stages that implement a superheterodyne receiver?

A. RF amplifier, detector, audio amplifier
B. RF amplifier, mixer, IF discriminator
C. HF oscillator, mixer, detector
D. HF oscillator, prescaler, audio amplifier

What circuit is used in analog FM receivers to convert IF output signals to audio?

A. Product detector
B. Phase inverter
C. Mixer
D. Discriminator

Which mixer input is varied or tuned to convert signals of different frequencies to an intermediate frequency (IF)?

A. Image frequency
B. Local oscillator
C. RF input
D. Beat frequency oscillator

If a receiver mixes a 13.800 MHz VFO with a 14.255 MHz received signal to produce a 455 kHz intermediate frequency (IF) signal, what type of interference will a 13.345 MHz signal produce in the receiver?

A. Quadrature noise
B. Image response
C. Mixer interference
D. Intermediate interference

Why is it good to match receiver bandwidth to the bandwidth of the operating mode?

A. It is required by FCC rules
B. It minimizes power consumption in the receiver
C. It improves impedance matching of the antenna
D. It results in the best signal-to-noise ratio

HF Installation

- HF operating, with loner wavelengths and higher field strengths, makes grounding and interference control much more important
- The General Exam focuses on three related areas …
  - Mobile installations
  - RF grounding
  - RF interference

Mobile Installations – Power Connections

- Mobile radios that can output 100 W require solid power connections capable of supplying 20 A or more
  - Solid state radios perform unpredictably with input voltage drops below the specified minimum power supply voltage
- Best power connection is direct to battery, heavy gauge wire, with both leads fused
  - Do NOT use cigarette lighter socket … usually rated for on a few amperes, and insufficient to supply a 100 W HF radio

Mobile Installations – Antenna Connections

- A limitation of mobile installations is that electrically short (smaller in terms of wavelength) antennas are less efficient that full-sized ones
  - Particularly true on lower frequency bands
- Tips to improve antenna performance
  - Use most efficient antenna you can
  - Make sure your ground connections to vehicle are solid
  - Mount antenna where it is clear of metal surfaces

Mobile Interference

- Different interference sources than home stations
  - Ignition noise (spark plugs firing) … n/a in diesel engines
  - Alternator whine
  - Vehicle's accessories
  - On-board control computers
  - Electric motors in fuel pumps, windows, and battery charging systems
  - Winch motors in 4X4 vehicles & trucks

Grounding & Bonding

- AC grounding prevents hazardous voltages from appearing on equipment chassis, creating a shock hazard
- To manage RF, bond equipment enclosures together (see Fig 5.19) … *Bonding* means to connect two points together to minimize voltage differences between them
- During digital operation, unwanted RF currents can cause distortion, erratic operation of computer interfaces, activate transmitter improperly, and garble digital protocols

Grounding & Bonding (cont.)

- Bonding basics …
  - Connect all metal equipment enclosures directly together or to a common RF bonding bus
  - Keep connections, straps, and wires SHORT
  - Use short, heavy conductors (#12 or #14 AWG) or strap
  - If strong RF is present, use a piece of wide flashing or screen under the equipment, connected to the bonding bus
- If ground connection is resonant at an odd number of ¼ wavelengths, it will generate high impedance, enabling RF voltages to exist on enclosures and cables

Grounding & Bonding (cont.)

- *Ground loops* are created by a continuous current path around a series of equipment connections
- Loop acts as a single-turn inductor … picks up voltages from magnetic fields (from transformers, ac wiring, etc.)
- Result is a “hum” in transmitted signals or that interferes with control or data signals
- Ground loops can be avoided by connecting all ground conductors to the RF bonding bus

RF Interference (RFI): Causes & Solutions

RFI	CAUSE	SOLUTION
Fundamental Overload	Radio/TV receivers unable to reject strong signals … causes distortion or inability to receive desired signal	Prevent signal by using filters in signal path
Common-mode & Direct pickup	From electronic equipment with internal electronics … picked up on outside of cable shields and conductors of unshielded connections	Block current with RF chokes
Harmonics	Spurious emissions from an amateur station may be received by radio or TV equipment	Use a low-pass filter at the transmitter
Intermodulation	Poor contacts between conductors picking up RF signals can create a nonlinear connection that acts as a mixer and mixing products from the signals	Find/repair the poor contact or block the RF signals
Arcing	A spark or sustained arc creates radio crackling or buzz over wide frequency range, (from power-line hardware)	May require power company to make repairs; filter specific equip.

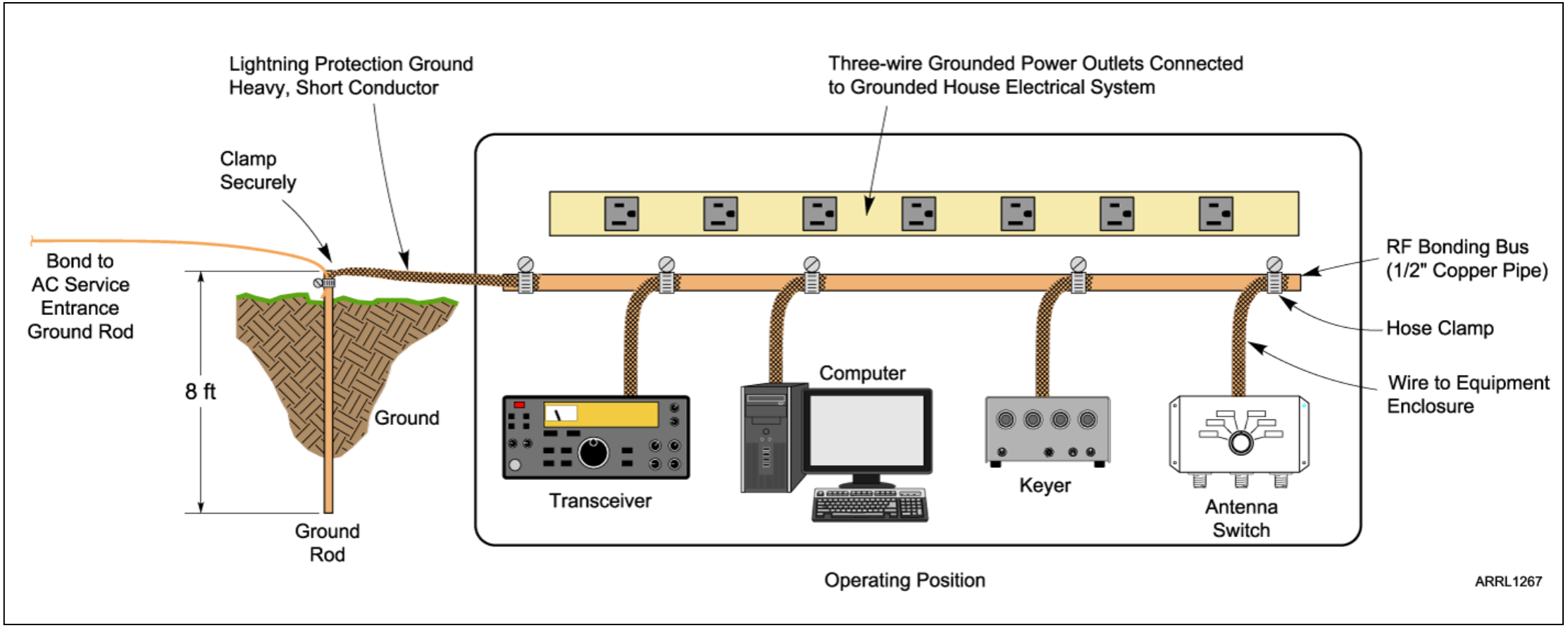
Common RFI Symptoms

- RFI is quite varied
- Some more common types are …
  - CW, FM, or data: Interference consists of ON/OFF buzzes, humming, clicks or thumps when the interfering signal is transmitted
  - AM phone: Equipment experiencing overload or direct detection will often emit a replica of the speaker's voice
  - SSB voice: Similar to AM phone, but voice will be distorted or garbled

Suppressing RFI

- Filters are effective and easy to install
- Block RF by placing an impedance in its path
  - Form conductor carrying RF current into an RF choke by winding it around or through a ferrite core
- Ferrite beads placed on cables to prevent RF common-mode from flowing on outside of cables/shields
- Interference to audio equipment and sensor connections can be eliminated by using a small (100 pF to 1 nF) bypass capacitor across balanced connections

Fig 5.19


Lightning Protection Ground
Heavy, Short Conductor
Three-wire Grounded Power Outlets Connected
to Grounded House Electrical System
Clamp
Securely
Bond to
AC Service
Entrance
Ground Rod
8 ft
Ground
Ground
Rod
RF Bonding Bus
(1/2" Copper Pipe)
Hose Clamp
Wire to Equipment
Enclosure
Computer
Transceiver
Keyer
Antenna
Switch
Operating Position
ARRL1267

PRACTICE QUESTIONS

Which of the following can be a symptom of transmitted RF being picked up by an audio cable carrying AFSK data signals between a computer and a transceiver?

A. The VOX circuit does not un-key the transmitter
B. The transmitter signal is distorted
C. Frequent connection timeouts
D. All these choices are correct

Which of the following might be useful in reducing RF interference to audio frequency devices?

A. Bypass inductor
B. Bypass capacitor
C. Forward-biased diode
D. Reverse-biased diode

Which of the following could be a cause of interference covering a wide range of frequencies?

A. Not using a balun or line isolator to feed balanced antennas
B. Lack of rectification of the transmitter's signal in power conductors
C. Arcing at a poor electrical connection
D. Using a balun to feed an unbalanced antenna

What sound is heard from an audio device or telephone if there is interference from a nearby single sideband phone transmitter?

A. A steady hum whenever the transmitter is on the air
B. On-and-off humming or clicking
C. Distorted speech
D. Clearly audible speech

What is the effect on an audio device when there is interference from a nearby CW transmitter?

A. On-and-off humming or clicking
B. A CW signal at a nearly pure audio frequency
C. A chirpy CW signal
D. Severely distorted audio

What might be the problem if you receive an RF burn when touching your equipment while transmitting on an HF band, assuming the equipment is connected to a ground rod?

A. Flat braid rather than round wire has been used for the ground wire
B. Insulated wire has been used for the ground wire
C. The ground rod is resonant
D. The ground wire has high impedance on that frequency

What effect can be caused by a resonant ground connection?

A. Overheating of ground straps
B. Corrosion of the ground rod
C. High RF voltages on the enclosures of station equipment
D. A ground loop

Which of the following would reduce RF interference caused by common-mode current on an audio cable?

A. Placing a ferrite choke around the cable
B. Adding series capacitors to the conductors
C. Adding shunt inductors to the conductors
D. Adding an additional insulating jacket to the cable

How can a ground loop be avoided?

A. Connect all ground conductors in series
B. Connect the AC neutral conductor to the ground wire
C. Avoid using lock washers and star washers when making ground connections
D. Connect all ground conductors to a single point

What could be a symptom of a ground loop somewhere in your station?

A. You receive reports of “hum” on your station’s transmitted signal
B. The SWR reading for one or more antennas is suddenly very high
C. An item of station equipment starts to draw excessive amounts of current
D. You receive reports of harmonic interference from your station

What technique helps to minimize RF “hot spots” in an amateur station?

A. Building all equipment in a metal enclosure
B. Using surge suppressor power outlets
C. Bonding all equipment enclosures together
D. Low-pass filters on all feed lines

Why must the metal enclosure of every item of station equipment be grounded?

A. It prevents a blown fuse in the event of an internal short circuit
B. It prevents signal overload
C. It ensures that the neutral wire is grounded
D. It ensures that hazardous voltages cannot appear on the chassis

Which of the following direct, fused power connections would be the best for a 100 watt HF mobile installation?

A. To the battery using heavy-gauge wire
B. To the alternator or generator using heavy-gauge wire
C. To the battery using resistor wire
D. To the alternator or generator using resistor wire

Why is it best NOT to draw the DC power for a 100 watt HF transceiver from a vehicle's auxiliary power socket?

A. The socket is not wired with an RF-shielded power cable
B. The socket's wiring may be inadequate for the current drawn by the transceiver
C. The DC polarity of the socket is reversed from the polarity of modern HF transceivers
D. Drawing more than 50 watts from this socket could cause the engine to overheat

Which of the following most limits an HF mobile installation?

A. “Picket fencing”
B. The wire gauge of the DC power line to the transceiver
C. Efficiency of the electrically short antenna
D. FCC rules limiting mobile output power on the 75-meter band

Which of the following may cause receive interference in a radio installed in a vehicle?

A. The battery charging system
B. The fuel delivery system
C. The vehicle control computer
D. All these choices are correct

How does a ferrite bead or core reduce common-mode RF current on the shield of a coaxial cable?

A. By creating an impedance in the current's path
B. It converts common-mode current to differential mode
C. By creating an out-of-phase current to cancel the common-mode current
D. Ferrites expel magnetic fields

What should be the impedance of a low-pass filter as compared to the impedance of the transmission line into which it is inserted?

A. Substantially higher
B. About the same
C. Substantially lower
D. Twice the transmission line impedance

What process combines two signals in a non-linear circuit or connection to produce unwanted spurious outputs?

A. Intermodulation
B. Heterodyning
C. Detection
D. Rolloff

END OF MODULE 5b

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Feel free to contact me if you find errors or have suggestions for improvement.