General License Class

Chapter 5

Radio Signals & Equipment

Signal Review

- Continuous Wave (CW)
  - A signal at one frequency whose amplitude never varies.
  - Normally used to refer to turning the signal on & off in a specific pattern to convey information.
    - Morse Code.

Signal Review

- Modulation
  - Changing a signal in some manner to convey information.
    - Can change amplitude (AM).
    - Can change frequency (FM).
    - Can change phase (PM).
    - A signal with no information is “unmodulated”.

Signal Review

- Modulation
  - Changing a signal in some manner to convey information.
    - Voice mode or phone.
      - Information is voice.
        - Analog.
        - Digital.
    - Data mode or digital mode.
      - Information is data.

Signal Review

- Amplitude Modulated Modes
  - Amplitude Modulation (AM).
    - Carrier plus two sidebands are transmitted.
    - Higher fidelity.
  - Single-Sideband (SSB).
    - Carrier & one sideband are suppressed.
      - Lower Sideband (LSB).
        - Only lower sideband is transmitted.
      - Upper sideband (USB).
        - Only upper sideband is transmitted.
    - Higher efficiency.
    - Less bandwidth.

Signal Review

- Angle Modulated Modes
  - Frequency Modulation (FM).
    - Frequency change proportional to amplitude of modulating signal.
    - Deviation = amount of frequency change.
  - Phase Modulation (PM).
    - Frequency change proportional to **both** amplitude and frequency of modulating signal.
  - Constant power whether modulated or not.

Signal Review

- Bandwidth Definition
  - All modulated signals have sidebands.
  - FCC defines bandwidth as:

§97.3(a)(8) -- *Bandwidth*. The width of a frequency band outside of which the mean power of the transmitted signal is attenuated at least 26 dB below the mean power of the transmitted signal within the band.

Signal Review

- Bandwidth Definition

Type of Signal	Typical Bandwidth
AM Voice	6 kHz
Amateur Television	6 MHz
SSB Voice	2 khz to 3 kHz
Digital using SSB	50 Hz to 3 kHz
CW	100 Hz to 300 Hz
FM Voice	10 kHz to 15 kHz

G8A02 -- What is the name of the process that changes the phase angle of an RF wave to convey information?

A. Phase convolution
B. Phase modulation
C. Angle convolution
D. Radian inversion

G8A03 -- What is the name of the process which changes the frequency of an RF wave to convey information?

A. Frequency convolution
B. Frequency transformation
C. Frequency conversion
D. Frequency modulation

G8A05 -- What type of modulation varies the instantaneous power level of the RF signal?

A. Frequency shift keying
B. Pulse position modulation
C. Frequency modulation
D. Amplitude modulation

G8A07 -- Which of the following phone emissions uses the narrowest frequency bandwidth?

A. Single sideband
B. Double sideband
C. Phase modulation
D. Frequency modulation

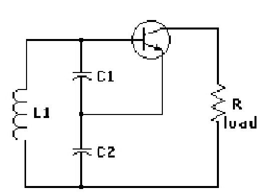
Radio's Building Blocks

- Oscillators
  - Generates signal at a specific frequency.
    - Sine wave.
    - Square wave.
  - Amplifier with positive feedback.
    - A_V = Amplifier gain.
    - β = Feedback ratio.
    - Loop Gain = A_V x β
    - If loop gain > 1 and in phase, circuit will oscillate.

Radio's Building Blocks

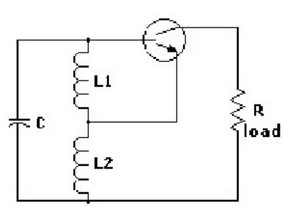
- Oscillators
  - Colpitts oscillator.

Frequency determined by values of L & C.



  - Hartley oscillator.

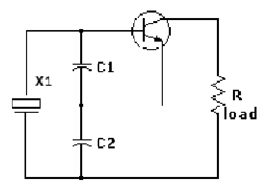
Frequency determined by values of L & C.



Radio’s Building Blocks

- Oscillators
  - Pierce oscillator.

Frequency determined by crystal.



  - Crystals.
    - Usually small wafer of quartz with precise dimensions.
    - Piezoelectric effect.
      - Crystal deforms mechanically when voltage applied.
      - Voltage generated when crystal deformed.

Radio’s Building Blocks

- Oscillators
  - Variable-frequency oscillator (VFO).
    - Make either L or C adjustable (usually C).
    - Not as stable.
    - Used to tune radio to different frequencies.

Radio’s Building Blocks

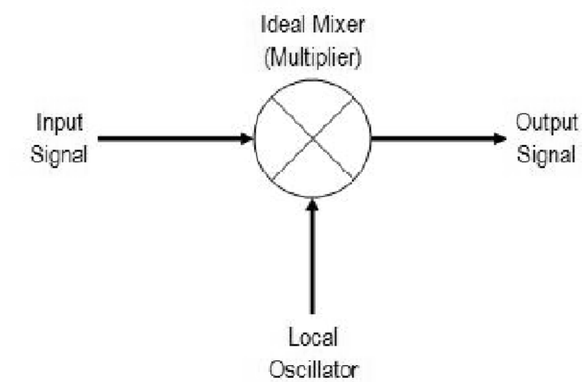
- Oscillators
  - Variable-frequency oscillator (VFO).
    - “Crystal-controlled” VFO’s.
        - Phase-Lock-Loop (PLL).
        - Direct Digital Synthesis (DDS)
      - Stability of crystal oscillator.
      - Can be controlled by software.

Radio’s Building Blocks

- Mixers
  - Mixing is also known as heterodyning.
  - Used to change the frequency of a signal.
  - Mathematically multiplies 2 frequencies together, generating 4 output frequencies.
    - $f_1 \times f_2 \Rightarrow f_1, f_2, f_1+f_2, f_1-f_2$
  - Operation of a mixer is similar to operation of detectors & modulators.

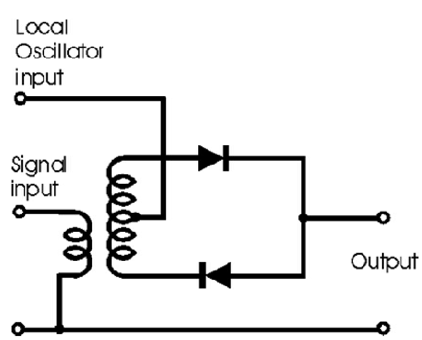
Radio's Building Blocks

- Mixers



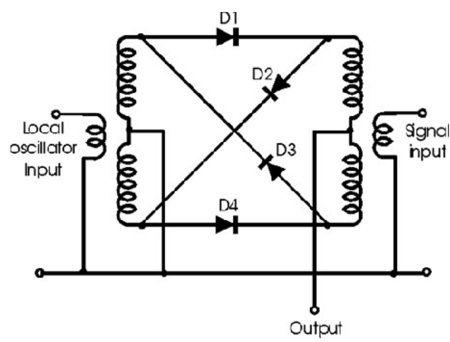
Radio's Building Blocks

- Mixers
  - Single-balanced mixer.
    - Local oscillator or input signal is suppressed, but not both.



Signal Processing

- Mixers
  - Double-balanced mixer.
    - f_{RF} & f_{LO} are suppressed leaving only sum & difference frequencies.



Radio's Building Blocks

- Multipliers
  - A multiplier stage creates a multiple of the input frequency.
  - An amplifier stage designed to have a lot of distortion (harmonics) & output circuit is tuned to the desired harmonic.
    - Class C amplifier.
  - Used in VHF/UHF transmitters to generate FM/PM modulated signal at a low frequency & then multiplied to the desired frequency.

Radio's Building Blocks

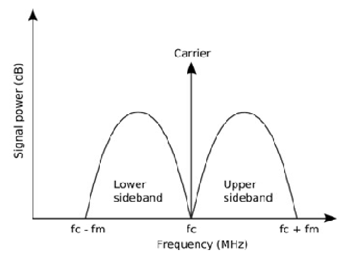
- Modulators
  - Amplitude Modulators.
    - Plate modulation.
      - Originally, AM was produced by varying the DC plate voltage to the final stage of a transmitter.
        - If solid-state transmitter, substitute collector or drain for plate.
      - Requires a LOT of audio power.
        - 1 kW transmitter needs 1 kW of audio!
    - Screen modulation.
      - Applied AF to screen voltage of final stage.
        - Less AF power required, but lower quality.

Radio's Building Blocks

- Modulators
  - Amplitude Modulators.
    - AM can be generated by mixing the modulating signal (f_M) with a carrier (f_C).
      - $f_C \times f_M \rightarrow f_C,\ f_M,\ f_C+f_M,\ f_C-f_M$
    - Using a single-balanced mixer, an AM signal is produced.
      - $f_C \times f_M \rightarrow f_C,\ f_C+f_M,\ f_C-f_M$
    - Using a double-balanced mixer, a double-sideband (DSB) signal is produced.
      - $f_C \times f_M \rightarrow f_C+f_M,\ f_C-f_M$

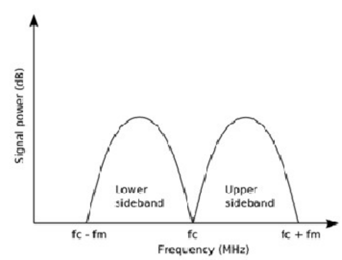
Radio’s Building Blocks

- Modulators
  - Amplitude Modulators.
    - AM can be generated by mixing the modulating signal (f_M) with a carrier (f_C).
      - $f_C \times f_M \Rightarrow f_C,\ f_M,\ f_C+f_M,\ f_C–f_M$



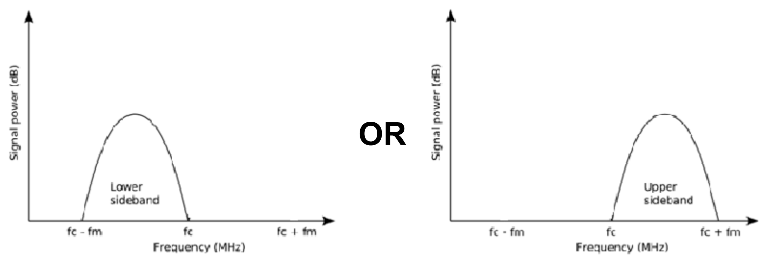
Radio’s Building Blocks

- Modulators
  - Amplitude Modulators.
    - Using a double-balanced mixer, a double-sideband (DSB) signal is produced.
      - $f_C \times f_M \Rightarrow f_C+f_M,\ f_C–f_M$



Radio's Building Blocks

- Modulators
  - Amplitude Modulators.
    - The double-sideband signal is then converted to a SSB signal by filtering out the unwanted sideband.
      - Filter method of SSB generation.



Radio's Building Blocks

- Modulators
  - Amplitude Modulators.
    - Phase method of SSB generation.
      - 2 double-balanced mixers.
      - 2 carrier signals 90° out-of-phase
      - 2 modulating signals 90° out-of-phase
        - REALLY difficult to create in hardware.
        - Easy to create in software.
          - Method used by software-defined radios.

Radio's Building Blocks

- Modulators
  - Amplitude Modulators.
    - Advantages of SSB.
      - Transmitter power used more effectively.
        - In AM signal, 1/2 of power is in carrier.
        - In AM signal, 1/2 of remaining power is in each sideband.
        - Sidebands carry same information.
        - In AM, only 25% of available power is used to transmit the information.
        - In SSB, 100% of transmitter power is used.
      - 1/2 the bandwidth of AM.

Radio's Building Blocks

- Modulators
  - Frequency & Phase Modulators.
    - Frequency modulation (FM).
      - Carrier frequency deviates in proportion to amplitude of the modulating signal.
    - Phase modulation (PM).
      - Carrier frequency deviates in proportion to both the amplitude and the frequency of the modulating signal.
    - By changing the audio frequency response of the modulator, an FM modulator can be used to generate PM and vice versa.

Radio’s Building Blocks

- Modulators
  - Frequency & Phase Modulators.
    - Both FM & PM sound the same on the air (almost).
      - Only difference is in frequency response of the audio.
    - Both FM & PM can be demodulated with the same circuitry.
    - Location of modulator circuit determines whether FM or PM is produced.
      - FM = modulation applied to oscillator circuit.
      - PM = modulation applied to amplifier stage following the oscillator.

G4D08 -- What frequency range is occupied by a 3 kHz LSB signal when the displayed carrier frequency is set to 7.178 MHz?

A. 7.178 to 7.181 MHz

B. 7.178 to 7.184 MHz

C. 7.175 to 7.178 MHz

D. 7.1765 to 7.1795 MHz

G4D09 -- What frequency range is occupied by a 3 kHz USB signal with the displayed carrier frequency set to 14.347 MHz?

A. 14.347 to 14.647 MHz
B. 14.347 to 14.350 MHz
C. 14.344 to 14.347 MHz
D. 14.3455 to 14.3485 MHz

G4D10 -- How close to the lower edge of the 40 meter General Class phone segment should your displayed carrier frequency be when using 3 kHz wide LSB?

A. At least 3 kHz above the edge of the segment
B. At least 3 kHz below the edge of the segment
C. Your displayed carrier frequency may be set at the edge of the segment
D. At least 1 kHz above the edge of the segment

G4D11 -- How close to the upper edge of the 20 meter General Class band should your displayed carrier frequency be when using 3 kHz wide USB?

A. At least 3 kHz above the edge of the band
B. At least 3 kHz below the edge of the band
C. Your displayed carrier frequency may be set at the edge of the band
D. At least 1 kHz below the edge of the band

G7B07 -- What are the basic components of virtually all sine wave oscillators?

A. An amplifier and a divider
B. A frequency multiplier and a mixer
C. A circulator and a filter operating in a feed-forward loop
D. A filter and an amplifier operating in a feedback loop

G7B09 -- What determines the frequency of an LC oscillator?

A. The number of stages in the counter
B. The number of stages in the divider
C. The inductance and capacitance in the tank circuit
D. The time delay of the lag circuit

G7C05 -- Which of the following is an advantage of a transceiver controlled by a direct digital synthesizer (DDS)?

A. Wide tuning range and no need for band switching
B. Relatively high power output
C. Relatively low power consumption
D. Variable frequency with the stability of a crystal oscillator

G8A04 -- What emission is produced by a reactance modulator connected to an RF power amplifier?

A. Multiplex modulation
B. Phase modulation
C. Amplitude modulation
D. Pulse modulation

G8A06 -- What is one advantage of carrier suppression in a single-sideband phone transmission?

A. Audio fidelity is improved
B. Greater modulation percentage is obtainable with lower distortion
C. Available transmitter power can be used more effectively
D. Simpler receiving equipment can be used

G8B01 -- What receiver stage combines a 14.250 MHz input signal with a 13.795 MHz oscillator signal to produce a 455 kHz intermediate frequency (IF) signal?

A. Mixer
B. BFO
C. VFO
D. Discriminator

G8B03 -- What is another term for the mixing of two RF signals?

A. Heterodyning
B. Synthesizing
C. Cancellation
D. Phase inverting

G8B04 -- What is the name of the stage in a VHF FM transmitter that generates a harmonic of a lower frequency signal to reach the desired operating frequency?

A. Mixer
B. Reactance modulator
C. Pre-emphasis network
D. Multiplier

Transmitter Structure

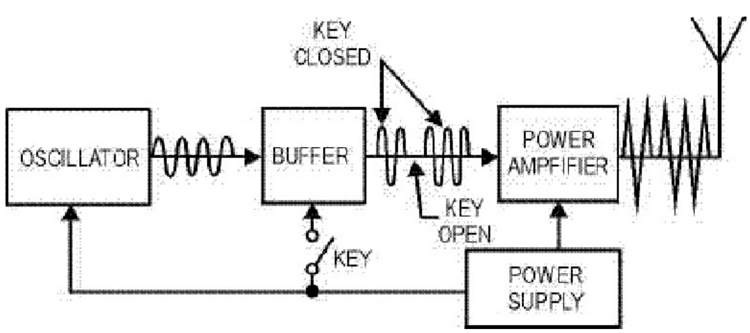
- AM Modes
  - CW, AM, & SSB
    - All are types of AM modes.
    - All can be generated with the same basic transmitter structure.

Transmitter Structure

- CW Transmitters
  - Oscillator.
    - Crystal controlled.
    - VFO
      - Add mixer for multi-band.
  - Buffer (optional).
    - Reduces “chirp”.
  - Power amplifier.
    - Non-linear okay.

Transmitter Structure

- CW Transmitters



Transmitter Structure

- AM Phone Transmitters
  - Add modulator between oscillator & mixer.
    - AM
      - Single-balanced mixer.
        - Or unbalance a double-balanced mixer.
    - SSB
      - Double-balanced mixer & sideband filter.
  - All amplifier stages following modulator **MUST BE LINEAR!**

Transmitter Structure

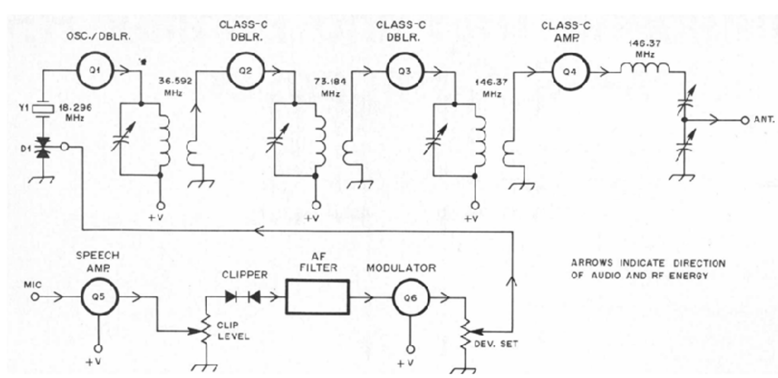
- AM Phone Transmitters
    - Signal should not occupy more bandwidth than that dictated by "good amateur practice".
      - On 60m, limit is 2.8 kHz by regulation.

Transmitter Structure

- FM Transmitters
  - Normally, FM modulation is accomplished at a low frequency & multiplied to operating frequency.

Transmitter Structure

- FM Transmitters



Transmitter Structure

- FM Transmitters
  - Not only is frequency multiplied, but deviation is also.
    - Smaller deviation is easier to accomplish with low distortion.
  - Amplifier stages do NOT have to be linear.
    - Multiplier stages by their very nature are not linear.

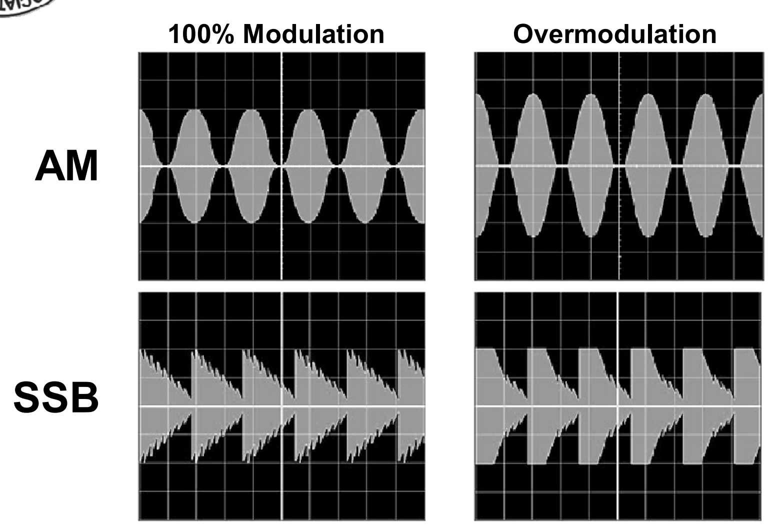
Transmitter Structure

- FM Transmitters
  - Bandwidth.
    - FCC also limits FM & PM transmissions to that dictated by “good amateur practice”.
    - FM & PM have an infinite number of sidebands.
      - Sidebands decrease in amplitude as difference from carrier frequency increases.
      - Bandwidth of FM & PM signals is:
        - $BW = 2 \times (f_D + f_m)$

Transmitter Structure

- Signal Quality
  - Overmodulation – AM modes.
    - Distorts audio.
    - Excessive bandwidth.
    - Caused by:
      - Talking too loudly.
      - Transmitter not adjusted properly.
        - Speak normally.
        - Adjust microphone gain so that ALC peaks at but does not exceed “0”.

Transmitter Structure



Transmitter Structure

- Signal Quality
  - Overmodulation – AM modes.
    - Two-tone test.
      - 2 tones MUST NOT be harmonically related.
        - ARRL Lab uses 700 Hz & 1900 Hz.
      - Observe transmitter output on an oscilloscope, or
      - Use spectrum analyzer to observe spurious signals.

Transmitter Structure

- Signal Quality
  - Speech processors.
    - a.k.a. – Speech compressor.
    - Increases average power.
    - Used to improve readability of SSB signals under poor conditions.
    - Improper adjustment can result in:
      - Distorted speech.
      - Splatter.
      - Excessive background pickup.

Transmitter Structure

- Signal Quality
  - Overdeviation – FM & PM modes.
    - Excessive bandwidth.
    - Audio distortion.
    - “Chopping” of received signal.
    - Most transmitters have circuits to limit deviation.

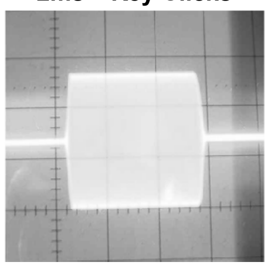
Transmitter Structure

- Signal Quality
  - Key clicks.
    - CW is actually an AM signal 100% modulated with a square wave.
    - A square wave consists of a fundamental and an infinite number of odd harmonics.
    - Therefore, a CW signal with a square keying envelope is infinitely wide!

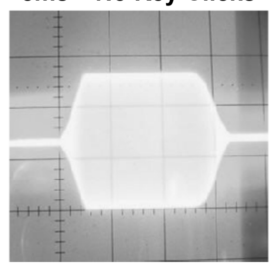
Transmitter Structure

- Signal Quality
  - Key clicks.
    - Add gradual rise & fall to keying signal.

2ms – Key Clicks



8ms – No Key Clicks



Transmitter Structure

- Signal Quality
  - Digital mode concerns.
    - Overmodulation results in:
      - Distortion.
      - Excessive bandwidth.
        - Splatter.
      - Inability of receiving station to decode signals.
    - Adjust signal so that ALC never reaches “0”.

Transmitter Structure

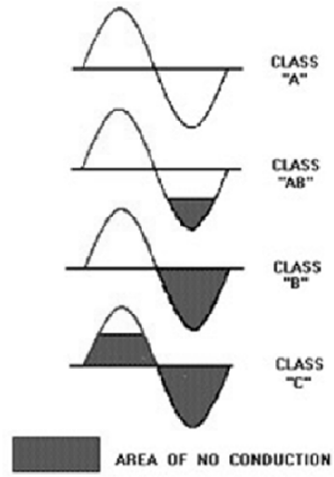
- Amplifiers
  - Linear & non-linear amplifiers.
    - Linear amplifiers.
      - Preserve the shape of the input waveform.
        - Low distortion.
      - Suitable for AM & SSB.

Transmitter Structure

- Amplifiers
  - Linear & non-linear amplifiers.
    - Non-linear amplifiers.
      - Do NOT preserve the shape of the input waveform.
        - High distortion.
      - Suitable for CW & FM.

Transmitter Structure

- Amplifiers
  - Amplifier Classes.
    - Class A
      - On for 360°
      - Best linearity (lowest distortion).
      - Least efficient.
    - Class AB
      - On for >180° but < 360°
      - More efficient than Class A.
    - Class B
      - On for 180°
      - More efficient than Class AB.
    - Class C
      - On for <180°
      - Most efficient.
      - **Non-linear.**

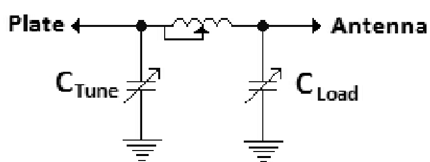


Transmitter Structure

- Amplifiers
  - Keying circuit.
    - Switches amplifier from receive (bypass) mode to transmit mode.
  - Keying delay.
    - Delay added to transmitter circuit.
    - Actual RF output is delayed a specified time to ensure that amplifier has completely changed over to transmit mode before RF power is applied.
      - Prevents "hot switching".

Transmitter Structure

- Amplifiers
  - Tuning & driving a linear amplifier.
    - Three main controls:
      - Band
      - Tune (or Plate).
      - Load (or Coupling).



Transmitter Structure

- Amplifiers
  - Tuning & Driving a Linear Amplifier.
    - Tuning procedure:
      1. Set amplifier meter to monitor plate current.
      2. Set amplifier to desired band.
      3. Apply a small amount of drive power.
      4. Adjust Tune for a dip (minimum) in plate current.
      5. Adjust Load for maximum output power.
      6. Repeat steps 4 & 5 until maximum power output is achieved.

Be careful NEVER to exceed maximum grid current!

Do not exceed maximum plate current!

Transmitter Structure

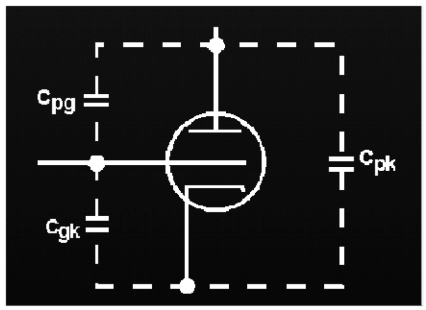
- Amplifiers
  - ALC.
    - Some amplifiers have an ALC output which can be used to automatically reduce the drive from the transceiver to prevent exceeding maximum drive level.

Transmitter Structure

- Amplifiers
  - Neutralization.
    - Triode tubes and semiconductors are susceptible to self-oscillation due to stray internal capacitances.
    - External components are added to cancel effect of stray capacitances.

Transmitter Structure

- Amplifiers
  - Neutralization.



Transmitter Structure

- Dual VFO's
  - Most HF transceivers have 2 VFO's.
    - May allow listening to 2 frequencies at once.
    - Allow operating in "split" mode.
      - Transmit on one frequency while listening on another.
        - DX & special event operations.
        - Working DX stations in another ITU region.

G4A03 -- What is normally meant by operating a transceiver in "split" mode?

A. The radio is operating at half power
B. The transceiver is operating from an external power source
C. The transceiver is set to different transmit and receive frequencies
D. The transmitter is emitting a SSB signal, as opposed to DSB operation

G4A04 -- What reading on the plate current meter of a vacuum tube RF power amplifier indicates correct adjustment of the plate tuning control?

A. A pronounced peak
B. A pronounced dip
C. No change will be observed
D. A slow, rhythmic oscillation

G4A05 -- What is a purpose of using Automatic Level Control (ALC) with a RF power amplifier?

A. To balance the transmitter audio frequency response
B. To reduce harmonic radiation
C. To reduce distortion due to excessive drive
D. To increase overall efficiency

G4A07 -- What condition can lead to permanent damage when using a solid-state RF power amplifier?

A. Exceeding the Maximum Usable Frequency
B. Low input SWR
C. Shorting the input signal to ground
D. Excessive drive power

G4A08 -- What is the correct adjustment for the load or coupling control of a vacuum tube RF power amplifier?

A. Minimum SWR on the antenna
B. Minimum plate current without exceeding maximum allowable grid current
C. Highest plate voltage while minimizing grid current
D. Maximum power output without exceeding maximum allowable plate current

G4A09 -- Why is a time delay sometimes included in a transmitter keying circuit?

A. To prevent stations from interfering with one another
B. To allow the transmitter power regulators to charge properly
C. To allow time for transmit-receive changeover operations to complete properly before RF output is allowed
D. To allow time for a warning signal to be sent to other stations

G4A12 -- Which of the following is a common use for the dual VFO feature on a transceiver?

A. To allow transmitting on two frequencies at once
B. To permit full duplex operation, that is transmitting and receiving at the same time
C. To permit monitoring of two different frequencies
D. To facilitate computer interface

G4B07 -- What signals are used to conduct a two-tone test?

A. Two audio signals of the same frequency shifted 90-degrees
B. Two non-harmonically related audio signals
C. Two swept frequency tones
D. Two audio frequency range square wave signals of equal amplitude

G4B15 -- What type of transmitter performance does a two-tone test analyze?

A. Linearity
B. Percentage of suppression of carrier and undesired sideband for SSB
C. Percentage of frequency modulation
D. Percentage of carrier phase shift

G4D01 -- What is the purpose of a speech processor as used in a modern transceiver?

A. Increase the intelligibility of transmitted phone signals during poor conditions
B. Increase transmitter bass response for more natural sounding SSB signals
C. Prevent distortion of voice signals
D. Decrease high-frequency voice output to prevent out of band operation

G4D02 -- Which of the following describes how a speech processor affects a transmitted single sideband phone signal?

A. It increases peak power
B. It increases average power
C. It reduces harmonic distortion
D. It reduces intermodulation distortion

G4D03 -- Which of the following can be the result of an incorrectly adjusted speech processor?

A. Distorted speech
B. Splatter
C. Excessive background pickup
D. All of these choices are correct

G7B08 -- How is the efficiency of an RF power amplifier determined?

A. Divide the DC input power by the DC output power
B. Divide the RF output power by the DC input power
C. Multiply the RF input power by the reciprocal of the RF output power
D. Add the RF input power to the DC output power

G7B10 -- Which of the following is a characteristic of a Class A amplifier?

A. Low standby power
B. High Efficiency
C. No need for bias
D. Low distortion

G7B11 -- For which of the following modes is a Class C power stage appropriate for amplifying a modulated signal?

A. SSB
B. CW
C. AM
D. All of these choices are correct

G7B12 -- Which of these classes of amplifiers has the highest efficiency?

A. Class A
B. Class B
C. Class AB
D. Class C

G7B13 -- What is the reason for neutralizing the final amplifier stage of a transmitter?

A. To limit the modulation index
B. To eliminate self-oscillations
C. To cut off the final amplifier during standby periods
D. To keep the carrier on frequency

G7B14 -- Which of the following describes a linear amplifier?

A. Any RF power amplifier used in conjunction with an amateur transceiver
B. An amplifier in which the output preserves the input waveform
C. A Class C high efficiency amplifier
D. An amplifier used as a frequency multiplier

G7C01 -- Which of the following is used to process signals from the balanced modulator and send them to the mixer in a single-sideband phone transmitter?

A. Carrier oscillator
B. Filter
C. IF amplifier
D. RF amplifier

G7C02 -- Which circuit is used to combine signals from the carrier oscillator and speech amplifier and send the result to the filter in a typical single-sideband phone transmitter?

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

G8A08 -- Which of the following is an effect of over-modulation?

A. Insufficient audio
B. Insufficient bandwidth
C. Frequency drift
D. Excessive bandwidth

G8A09 -- What control is typically adjusted for proper ALC setting on an amateur single sideband transceiver?

A. The RF clipping level
B. Transmit audio or microphone gain
C. Antenna inductance or capacitance
D. Attenuator level

G8A10 -- What is meant by the term flat-topping when referring to a single sideband phone transmission?

A. Signal distortion caused by insufficient collector current
B. The transmitter's automatic level (ALC) control is properly adjusted
C. Signal distortion caused by excessive drive
D. The transmitter's carrier is properly suppressed

G8A11 -- What is the modulation envelope of an AM signal?

A. The waveform created by connecting the peak values of the modulated signal
B. The carrier frequency that contains the signal
C. Spurious signals that envelop nearby frequencies
D. The bandwidth of the modulated signal

G8B06 -- What is the total bandwidth of an FM phone transmission having 5 kHz deviation and 3 kHz modulating frequency?

A. 3 kHz
B. 5 kHz
C. 8 kHz
D. 16 kHz

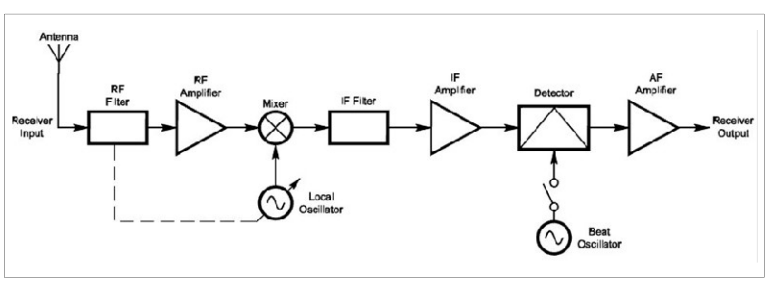
G8B07 -- What is the frequency deviation for a 12.21-MHz reactance modulated oscillator in a 5 kHz deviation, 146.52 MHz FM-phone transmitter?

A. 101.75 Hz
B. 416.7 Hz
C. 5 kHz
D. 60 kHz

Break

Receiver Structure

- Basic Superheterodyne Receivers
  - By far the most popular receiver architecture.



Receiver Structure

- Basic Superheterodyne Receivers
  - Incoming radio frequency (RF) signal is mixed (or heterodyned) with a local oscillator signal to produce an intermediate frequency (IF) signal
    - Superheterodyne means local oscillator frequency is higher than the input frequency.
      - Easier image rejection.
  - IF signal is amplified & filtered.
    - Sharp, narrow filters reject signals close to the desired frequency.

Receiver Structure

- Basic Superheterodyne Receivers
  - The IF amplifier in an FM receiver includes a "limiter" stage.
    - Amplifier stage with high gain so that signal "flat-tops", eliminating amplitude variations.
    - Diode "clipper" circuit.

Receiver Structure

- Basic Superheterodyne Receivers
  - Output from IF amplified is sent to a demodulator circuit.
  - Type of demodulator varies by mode.

Mode	Demodulator Type
AM	Product Detector or Envelope Detector
CW/SSB	Product Detector
FM/PM	Frequency Discriminator or Quadrature Detector

Receiver Structure

- Basic Superheterodyne Receivers
  - Product Detector.
    - Mixer fed with output of IF amplifier & output of beat frequency oscillator (BFO).
      - BFO frequency at or near IF frequency.
      - $f_{IF} \times f_{BFO} \rightarrow f_{AF}$
    - For SSB, the BFO frequency is set to the carrier frequency of the SSB signal.

Receiver Structure

- Basic Superheterodyne Receivers
  - Product Detector.
    - For CW, the BFO frequency is set a few hundred Hertz above or below the carrier frequency.
      - CWL – BFO frequency above carrier frequency.
      - CWU– BFO frequency below carrier frequency.
      - Switching between CWL or CWU can avoid interference from a signal close to the receive frequency.

Receiver Structure

- Basic Superheterodyne Receivers
  - Design challenges.
    - Images.
      - Two different frequencies when mixed with the local oscillator frequency will produce a signal at the IF frequency.
        - $f_{RF1} = f_{LO} + f_{IF}$
        - $f_{RF2} = f_{LO} – f_{IF}$
      - Unwanted frequency is called the “image”.

Receiver Structure

- Basic Superheterodyne Receivers
  - Design challenges.
    - Images.
      - The image frequency must be filtered out by the receiver “front-end”.
      - The farther the image frequency is from the desired frequency, the easier to filter out the image.
        - This is why a local oscillator frequency higher than the RF frequency is preferred.

Receiver Structure

- Basic Superheterodyne Receivers
  - Design challenges.
    - Birdies.
      - Local oscillator & other oscillators in the circuit can mix & produce signals at various frequencies. These “spurs” can cause interference to the desired signal.
    - Unwanted radiation.
      - Local oscillator signal can leak out through receiver front end to the antenna & be radiated.

Receiver Structure

- Basic Superheterodyne Receivers
  - Double-conversion & triple-conversion superheterodyne receivers.
    - 2 or 3 local oscillators with 2 or 3 different sets of IF amplifiers & filters.
      - Better filtering can be achieved at lower frequencies.
      - Increases susceptibility to images & birdies.

Receiver Structure

- Basic Superheterodyne Receivers
  - IF filtering.
    - Use filter whose bandwidth matches mode being used.
      - Best signal-to-noise ratio (S/N).

Receiver Structure

- Digital Signal Processing (DSP)
  - Part of practically all modern transceivers.
    - Replacing some of the analog circuitry.
  - Procedure:
    - Convert analog signal to series of numbers.
    - Process series of numbers mathematically.
    - Convert resulting series of numbers back to analog signal.

Receiver Structure

- Digital Signal Processing (DSP)
  - Advantages.
    - Performance.
      - Allows signal processing difficult to obtain by analog methods.
    - Flexibility.
      - Functions, options, & adjustments limited only by processor speed & memory.

Receiver Structure

- Digital Signal Processing (DSP)
  - Main uses.
    - Signal filtering.
      - A wide variety of filter widths & shapes can be defined.
      - Users can create their own custom filters.
    - Noise reduction.
      - Many types of noise can be detected & removed.
    - Notch filtering.
      - Automatically detect & notch out an interfering signal.
        - Most effective against carriers.
    - Audio frequency equalization.

Receiver Structure

- Digital Signal Processing (DSP)
  - Software-Defined Radio (SDR).
    - A software-defined radio (SDR) system is a radio communication system where components that have been typically implemented in hardware (e.g. mixers, filters, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a computer or embedded computing devices

Receiver Structure

- Digital Signal Processing (DSP)
  - Software-Defined Radio (SDR).
    - The ideal SDR receiver would be to attach an antenna to an analog-to-digital converter (ADC).
    - Similarly, the ideal SDR transmitter would be to attach a digital-to-analog converter (DAC) to an antenna.
    - Not feasible with current technology, so some compromise is necessary.

Receiver Structure

- Digital Signal Processing (DSP)
  - Software-Defined Radio (SDR).
    - Some analog processing still required.
    - Future is an all-digital radio.
    - Commercial SDR's now available for amateur use.

Receiver Structure

- Managing Receiver Gain
  - RF Gain & Automatic Gain Control (AGC).
    - RF Gain.
      - Start with RF gain set to maximum (highest sensitivity).
      - Adjust down for comfortable listening (lower noise).

Receiver Structure

- Managing Receiver Gain
  - RF Gain & Automatic Gain Control (AGC).
    - AGC.
      - Circuit to adjust gain of receiver to compensate for changes in signal strength.
        - Varying voltage used to adjust gain of RF & IF amplifiers.
      - AGC voltage is measured by S-meter.
        - "S" stands for signal strength.
        - Turning down RF Gain increases S-meter reading.
        - S-meter calibrated in "S" units.
        - 1 "S" unit = 6 dB difference in input voltage.
        - S-9 = 50µV at antenna input.

Receiver Structure

- Receiver Linearity
  - Just like a transmitter, non-linearity in a receiver results in spurious signals.
  - Overload.
    - Extremely strong signals can drive RF pre-amp into non-linear operation.
      - Distorted received audio for all signals.
    - RF attenuator control.
      - Helps avoid overload.
      - Use in combination with RF Gain control.

G4A01 -- 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

G4A02 -- 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

G4A11 -- 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

G4A13 -- 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

G4C11 -- Which of the following is a function of a digital signal processor?

A To provide adequate grounding
B. To remove noise from received signals
C. To increase antenna gain
D. To increase antenna bandwidth

G4C12 -- 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

G4C13 -- Which of the following can perform automatic notching of interfering carriers?

A. Band-pass tuning
B. A Digital Signal Processor (DSP) filter
C. Balanced mixing
D. A noise limiter

G4D04 -- What does an S meter measure?

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

G4D05 -- 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

G4D06 -- Where is an S meter found?

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

G4D07 -- 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

G7C03 -- 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

G7C04 -- What circuit is used to combine signals from the IF amplifier and BFO and send the result to the AF amplifier in a single-sideband receiver?

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

G7C07 -- 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, pre-scaler, audio amplifier

GG7C08 -- What type of circuit is used in many FM receivers to convert signals coming from the IF amplifier to audio?

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

G7C09 -- Which of the following is needed for a Digital Signal Processor IF filter?

A. An analog to digital converter
B. A digital to analog converter
C. A digital processor chip
D. All of the these choices are correct

G7C10 -- How is Digital Signal Processor filtering accomplished?

A. By using direct signal phasing
B. By converting the signal from analog to digital and using digital processing
C. By differential spurious phasing
D. By converting the signal from digital to analog and taking the difference of mixing products

G7C11 -- What is meant by the term "software defined radio" (SDR)?

A. A radio in which most major signal processing functions are performed by software
B. A radio which provides computer interface for automatic logging of band and frequency
C. A radio which uses crystal filters designed using software
D. A computer model which can simulate performance of a radio to aid in the design process

G8B02 -- 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

G8B09 -- 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 Station Installation

- Mobile Installations
  - Power Connections.
    - 100W HF rig requires 20A or more.
    - Connect both power leads directly to battery with heavy gauge (#10 or larger) wire.
      - Fuse BOTH leads at battery.
    - DO NOT use cigarette lighter socket.
    - DO NOT assume vehicle frame is a good ground connection.

HF Station Installation

- Mobile Installations
  - Antenna Connections.
    - Antenna is significantly shorter than 1/4 wavelength, especially on lower bands.
    - Entire vehicle becomes part of antenna system.
      - Pay attention to every detail.
    - Use most efficient antenna possible.
    - Solid RF ground connections to vehicle body.
      - Bonding straps between body panels.
    - Mount antenna as clear of body parts as possible.

HF Station Installation

- Mobile Installations
  - Mobile interference.
    - Ignition noise.
      - Noise blankers on modern tranceivers are usually effective.
      - Diesel engines do not produce ignition noise.
    - Alternator whine.
      - Direct battery connections help.
    - Vehicle computer.
    - Motor-driven devices.
      - Windshield wipers, fans, etc.

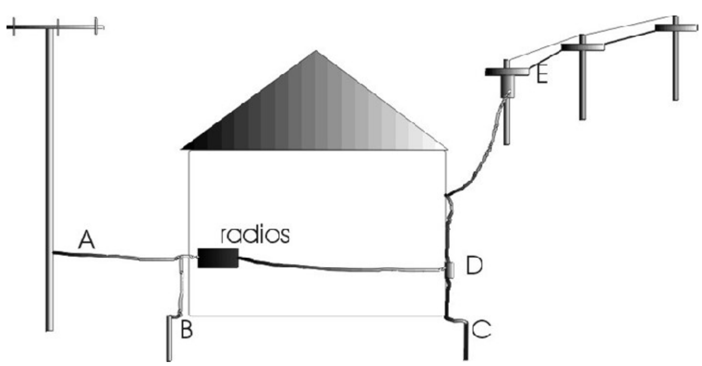
HF Station Installation

- RF Grounding & Ground Loops
  - AC safety ground required but not usually adequate for RF.
  - Additional RF ground is required.

For lightning safety, AC safety ground & RF ground system must be bonded together!

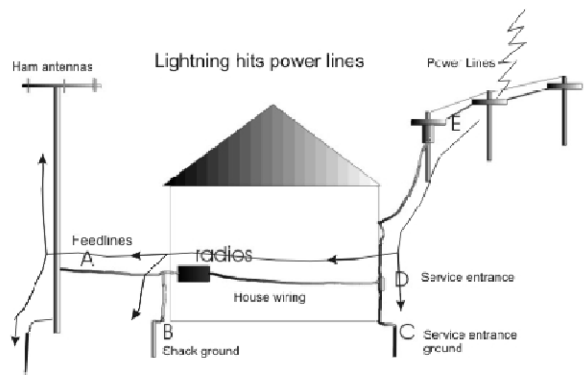
HF Station Installation

- RF Grounding & Ground Loops
  - Typical station installation.



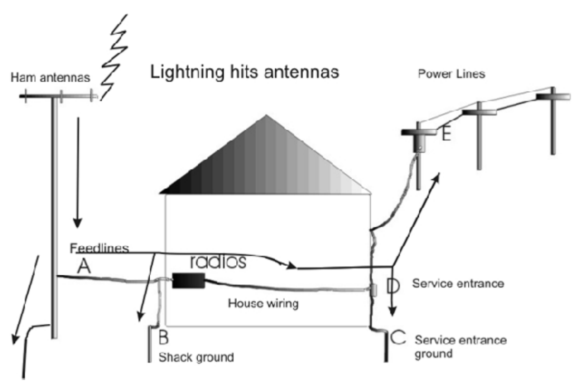
HF Station Installation

- RF Grounding & Ground Loops
  - Typical station installation.



HF Station Installation

- RF Grounding & Ground Loops
  - Typical station installation.



HF Station Installation

- RF Grounding & Ground Loops
  - RF Grounding.
    - Poor RF grounding can cause shocks or RF burns when touching equipment.
    - Poor RF grounding can cause hum or buzz on transmitted signal.
    - Poor RF grounding can cause distortion of transmitted signal.

HF Station Installation

- RF Grounding & Ground Loops
  - RF Grounding.
    - **ALWAYS** connect equipment to a single ground point in the shack.
      - Short piece of copper bar or pipe.
      - Use separate conductors for EACH piece of equipment.
      - Keep ground wires as short as possible.
    - **NEVER** “daisy-chain” equipment grounds.

HF Station Installation

- RF Grounding & Ground Loops
  - RF Grounding.
    - Connect shack ground point to a ground rod or a grounded pipe.
      - Use flat, wide conductor.
        - Copper strap.
        - Braid.
      - Keep ground wire as short as possible.
        - High impedance if length approaches 1/4λ.
        - No sharp (90°) bends.

HF Station Installation

- RF Grounding & Ground Loops
  - Ground loops.
    - Incorrect grounding can create ground loops.
    - Ground loops can cause hum or buzz on transmitted signal.
    - **ALWAYS** connect equipment to a single ground point with separate conductors for **EACH** piece of equipment.
    - **NEVER** "daisy-chain" equipment grounds.

HF Station Installation

- RF Interference (RFI).
  - Any amateur radio transmitter can cause interference to other nearby devices.
  - If amateur equipment is operating properly, responsibility to fix problem rests with owner of equipment being interfered with.
    - Try convincing your neighbor!

HF Station Installation

- RF Interference (RFI).
  - Fundamental overload.
    - Strong signal from amateur transmitter overwhelms receiver front-end.
    - Usually occurs in nearby TV or radio receivers.
    - Solution is to reduce strength of signal entering receiver.
      - Add high-pass filters to TV or FM receivers.
      - Add low-pass filters to AM receivers.
        - Usually VERY difficult to do since antenna is internal.

HF Station Installation

- RF Interference (RFI).
  - Common-mode & direct pick-up.
    - Common-mode.
      - RF is picked up by external wiring & conducted into interior of device.
      - Prevent RF from entering device.
        - The ferrite choke is your best friend!
        - By-pass capacitors.

HF Station Installation

- RF Interference (RFI).
  - Common-mode & direct pick-up.
    - Direct pick-up.
      - RF is radiated directly into interior of device.
      - Difficult to resolve.

HF Station Installation

- RF Interference (RFI).
  - Harmonics.
    - Amateur equipment is NOT operating properly.
      - Harmonics can fall on frequency of another receiver.
        - 2nd harmonic of 6m band falls in the FM broadcast band.
      - Reduce strength of harmonics being radiated.
        - Add low-pass filter to transmitter.

HF Station Installation

- RF Interference (RFI).
  - Rectification.
    - Poor connection between 2 conductors can act like a mixer.
      - Mixer products can fall on frequency receiver is tuned to.
    - Find & repair poor connection.

HF Station Installation

- RF Interference (RFI).
  - Arcing.
    - Any spark or sustained arc generates noise across a WIDE range of frequencies.
    - Can interfere with both amateur radio & consumer devices.

HF Station Installation

- RF Interference (RFI).
  - Arcing.
    - AC power line noise.
      - Nearly continuous crackling buzz.
        - Can come & go depending on temperature or humidity.
      - Defective power line insulators
    - Motors or welders.
      - Noise only present when offending equipment is operated.

HF Station Installation

- RF Interference Suppression
  - Filters.
  - Series resistance or inductance.
  - Parallel (by-pass) capacitors.
    - Small capacitor across wiring terminals

HF Station Installation

- RF Interference Suppression
  - Form wires & cables into a coil.
  - Snap-on ferrite chokes.
    - Prevent common-mode RF signals from entering device.
    - Prevent interference generated by device from being radiated.

G4A15 -- 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 of these choices are correct

G4C01 -- 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

G4C02 -- 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. The use of horizontal rather than vertical antennas

G4C03 -- 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

G4C04 -- What is the effect on an audio device or telephone system if 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

G4C05 -- 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

G4C06 -- 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

G4C07 -- What is one good way to avoid unwanted effects of stray RF energy in an amateur station?

A. Connect all equipment grounds together
B. Install an RF filter in series with the ground wire
C. Use a ground loop for best conductivity
D. Install a few ferrite beads on the ground wire where it connects to your station

G4C08 -- Which of the following would reduce RF interference caused by common-mode current on an audio cable?

A. Placing a ferrite bead 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

G4C09 -- 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

G4C10 -- 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

G4E03 -- 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

G4E04 -- Why is it best NOT to draw the DC power for a 100-watt HF transceiver from an automobile'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 being 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

G4E05 -- Which of the following most limits the effectiveness of an HF mobile transceiver operating in the 75 meter band?

A. “Picket Fencing” signal variation

B. The wire gauge of the DC power line to the transceiver

C. The antenna system

D. FCC rules limiting mobile output power on the 75 meter band

G4E07 -- Which of the following may cause interference to be heard in the receiver of an HF radio installed in a recent model vehicle?

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

G7C06 -- 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

Questions?

Next Week

Chapter 7

Antennas