



Chapter 5.1 ~ 5.5

Radio Signals
and Measurements

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Radio Signals and Equipment

* Chapter 5.1

Chapter 5 Radio Signals and Equipment

- 5.1 Basic Modes and Bandwidth**
- 5.2 Radio's Building Blocks**
- 5.3 Transmitters**
- 5.4 Receivers**
- 5.5 HF Station Installation**

5.1 Basic Modes and Bandwidth

(Page 5-1)

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

Phase modulation.

G8A03 – What is the name of the process that changes the instantaneous frequency of an RF wave to convey information? Frequency modulation.

G8A05 – What type of modulation varies the instantaneous power level of the RF signal? Amplitude modulation.

G8A07 – Which of the following phone emissions uses the narrowest bandwidth? Single sideband.

G8A13 – What is a link budget?

The sum of transmit power and antenna gain minus system losses as seen at the receiver.

G8A14 – What is link margin?

The difference between received power level and minimum required signal level at the inputs to the receiver.

5.1 Basic Modes and Bandwidth

(Page 5-1)

Chapter 5.1

Now we are going to start diving deeper into the building blocks inside a radio.

If you want to brush up on schematics and blocks diagrams, see the schematic symbols on Page 4-9 of the General Class Manual.

Component Schematic Symbols

(Page 4-9)

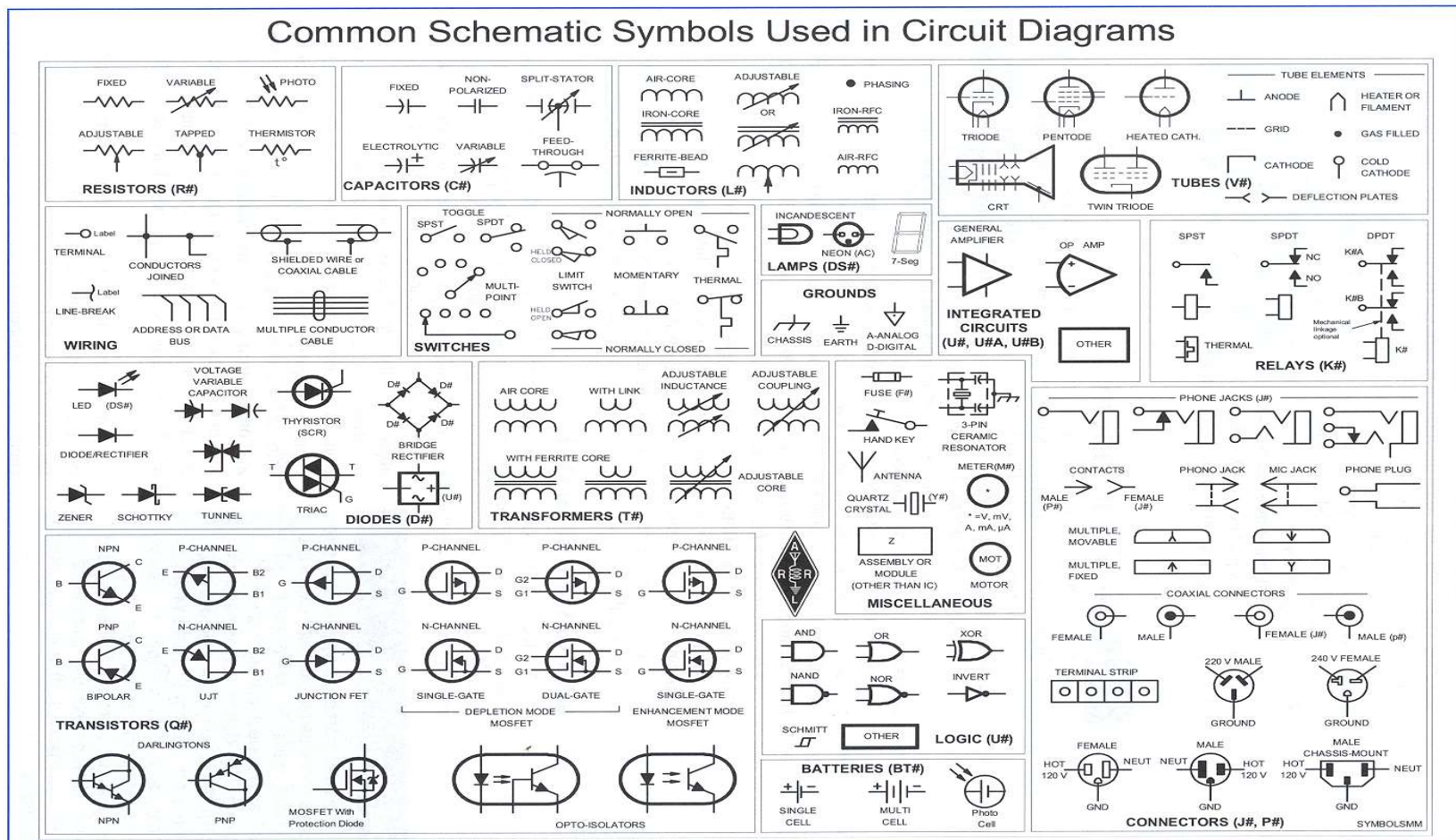


Figure 4-4 — These are the standard symbols used by the ARRL on schematic diagrams.

5.1 Basic Modes and Bandwidth

(Page 5-2)

Amplitude Modulated Modes

Varying the power or amplitude of a signal adds speech or data information and is called amplitude modulation or **AM**.

The information is contained in the signal envelope. This is the maximum values of the instantaneous power (peaks) of each cycle. [G8A05]

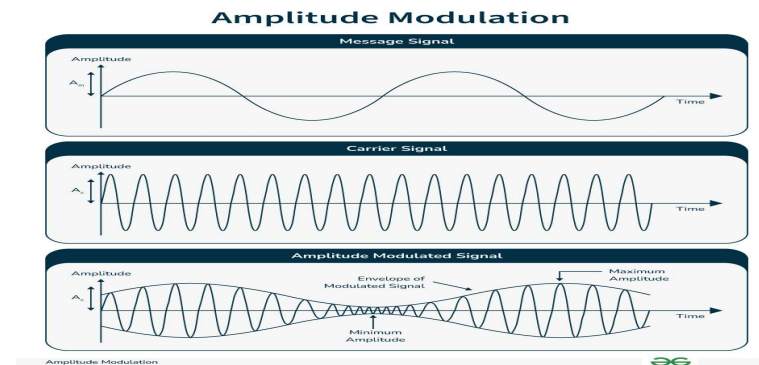
The AM signal is made up of the **carrier and two sidebands**. The carrier does not have any information, only the sidebands have data.

5.1 Basic Modes and Bandwidth

(Page 5-2)

Amplitude Modulated Modes

AM signal with the carrier and one sideband removed is called a single sideband signal **SSB**.



SSB transmissions have more range than AM because all the signal power is contained in the one side band which carries the information.

AM signals have a wider signal bandwidth and a fuller frequency response than SSB, so they sound "warmer". But there can be more noise on AM.

5.1 Basic Modes and Bandwidth

(Page 5-2)

Frequency and Phase Modulated Modes

Modes that vary the frequency of a signal to add speech or data are called frequency modulation **FM**. [G8A03]

The frequency is varied by the instantaneous amplitude of the modulating signal and is called **deviation**. [G8A02]

The same circuit can demodulate FM or PM signals. FM and PM signals have a constant power output.

5.1 Basic Modes and Bandwidth

(Page 5-2)

Bandwidth Definition

The FCC limits the **signal bandwidth** so that many stations and signal can share the limited amount of spectrum space. [G8A07]

See Table 5.1 for the typical bandwidths, sorted largest to smallest

Amateur TV – 6 MHz

FM voice – 5 to 16 kHz

AM – 6 kHz

SSB voice – 2 kHz to 3 kHz

CW – 100 Hz to 300 Hz

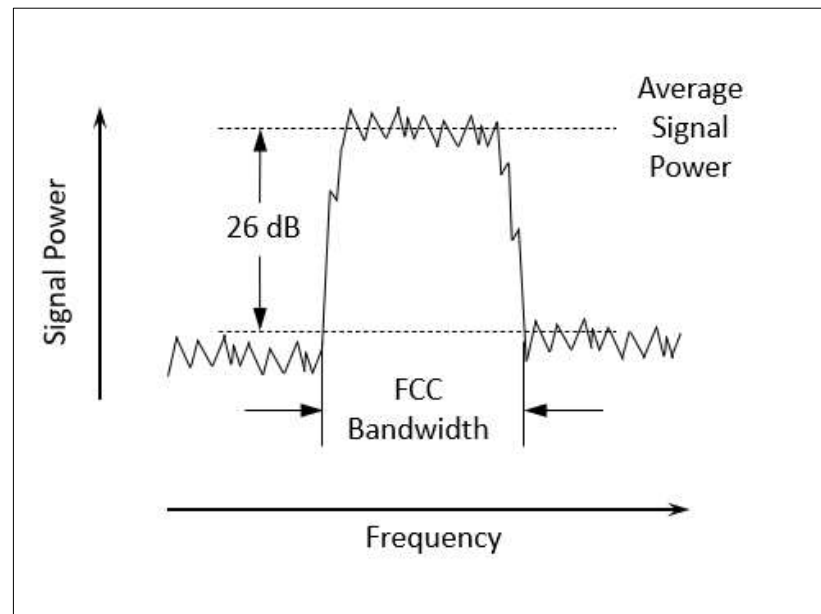
Digital using SSB – 50 Hz to 2.3 kHz (FT-8, JT-65, PSK31, RTTY, etc)

5.1 Basic Modes and Bandwidth

(Page 5-2)

Bandwidth Definition

Figure 5.1: The FCC defines bandwidth as **the width of a frequency band outside of which the mean [average] power of the transmitted signal is attenuated at least 26 dB below the mean power.**



5.1 Basic Modes and Bandwidth

(Page 5-3)

Link Budgets

A **link budget** is a telecommunications term that accounts for all the power gains and losses a signal will experience within a system. In amateur radio, this is transmit power and antenna gain minus any losses in the propagation path and cable losses in both stations. [G8A13]

A **link margin** is the difference between the minimum power level needed to receive the signal and the actual received signal. It is measured in dB. [G8A14]

5.1 Basic Modes and Bandwidth

(Page 5-3)

For more information

Continuous Wave (CW) is a radio signal at one frequency whose amplitude does not change.

The information is contained in the keying (On/Off) duration and spacing of the RF signal.

5.1 Basic Modes and Bandwidth

(Page 5-2)

For more information

Adding information to the signal by changing the frequency, phase angle or amplitude is called **modulation**.

Recovering the information from a modulated signal is called **demodulation**.

5.1 Basic Modes and Bandwidth

(Page 5-3)

For more information

If speech is used to modulate a signal, the result is a **voice mode** or **phone** signal. FM, AM, SSB are examples of voice mode signals.

If data is used to modulate a signal, the result is a **digital mode** signal. FT8, RTTY, CW, PSK31, JT65, SSTV and several other digital mode signals are used on the ham bands today.

5.2 Radio's Building Blocks

(Page 5-3 to 5-4)

G7B07 – Which of the following are basic components of a sine wave oscillator?

A filter and an amplifier operating in a feedback loop.

G7B09 – What determines the frequency of an LC oscillator?

The inductance and capacitance in the tank circuit.

G7C05 – Which of the following is characteristic of a direct digital synthesizer (DDS)?

Variable output frequency with the stability of a crystal oscillator.

G7C07 – What term specifies a filter's attenuation inside its passband? Insertion loss.

G7C09 – What is the phase difference between I and Q RF signals that software-defined radio (SDR) equipment uses for modulation and demodulation? 90 degrees.

G7C10 – What is an advantage of using I-Q modulation with software-defined radios (SDRs)? All types of modulation can be created with appropriate processing.

G7C11 - Which of these functions are performed by software-defined radio (SDR)? All of these choices are correct.

5.2 Radio's Building Blocks

(Page 5-3 to 5-4)

G7C12 – What is the frequency above which a low-pass filter's output power is less than half the input power? Cutoff frequency.

G7C13 – What term specifies a filter's maximum ability to reject signals outside its passband? Ultimate rejection. (Stop-band attenuation is a more commonly used term)

G7C14 – The bandwidth of a band-pass filter is measured between what two frequencies? Upper and lower half-power frequencies.

G8A04 – What emission is produced by a reactance modulator connected to a transmitter RF amplifier stage? Phase modulation.

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

G8B04 – What is the stage in a VHF FM transmitter that generates a harmonic of a lower frequency to reach the desired operating frequency? Multiplier.

G8B11 – What combination of a mixer's Local Oscillator (LO) and RF input frequencies is found in the output? The sum and difference (of those frequencies).

5.2 Radio's Building Blocks

(Page 5-4)

Chapter 5.2

Radios are made up from fundamental circuits.

In this section we will cover four types of circuits; (**Filters,**) **Oscillators, Mixers, Multipliers** and **Modulators**.

Today's radio use DSP (digital signal processing) to perform many of the functions that used to be done by analog circuits.

5.2 Radio's Building Blocks

(Page 5-4)

Filters

The function of a filter is to attenuate (reduce) or pass signals with a defined range of frequencies.

The filters we are going to learn about are **Low-Pass, High-Pass, Band-pass and Notch filters.**

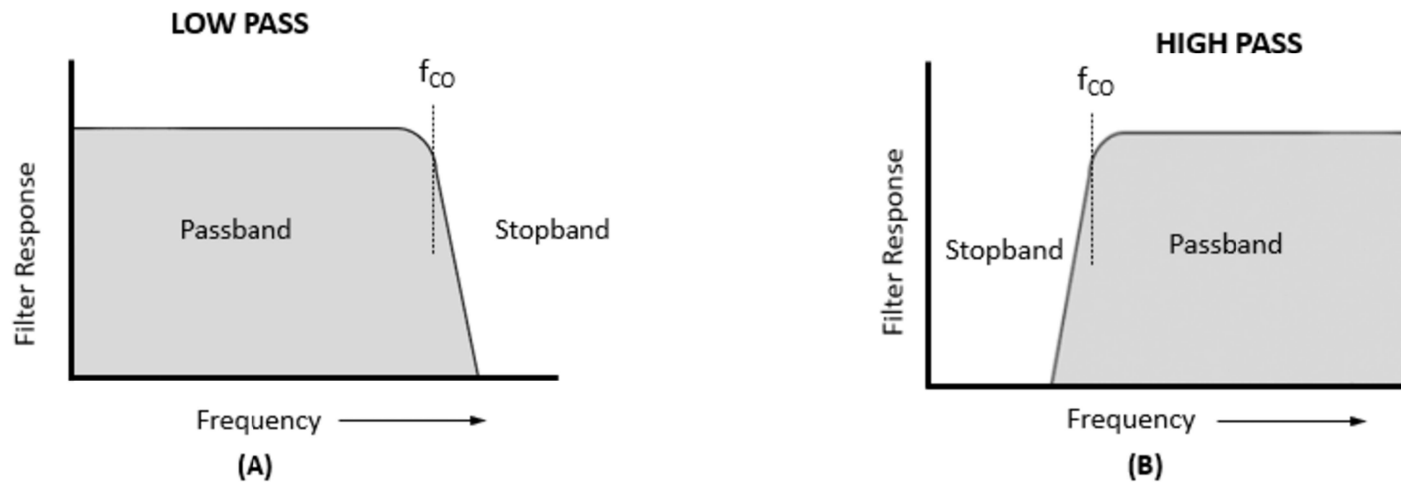
See Figure 5-2.

5.2 Radio's Building Blocks

(Page 5-4)

Filters

Figure 5.2 – Generic filter response curves showing how filters of different types affect signals. A larger filter response means less attenuation of the signal cutoff frequencies are shown as f_{co}



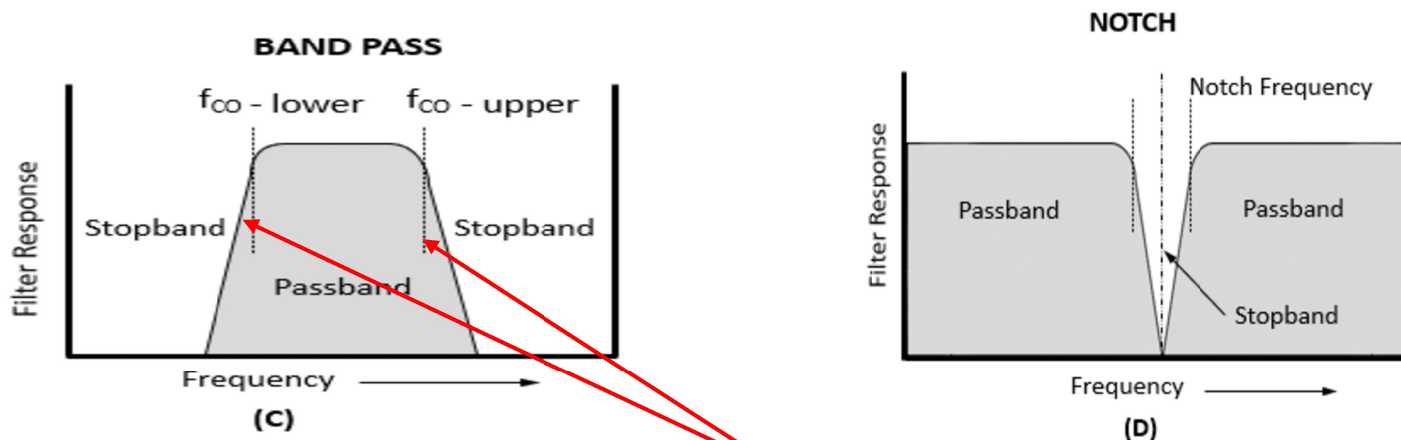
The cutoff frequency is the frequency at which the output signal power is reduced to one-half (-3dB) that of the input signal. Above a low-pass filter's cutoff frequency, the attenuation generally increases with frequency.

5.2 Radio's Building Blocks

(Page 5-4)

Filters

Figure 5.2 – Generic filter response curves showing how filters of different types affect signals. A larger filter response means less attenuation of the signal cutoff frequencies are shown as f_{co} .



The frequency range between the upper and lower cutoff frequencies is the filter's bandwidth.

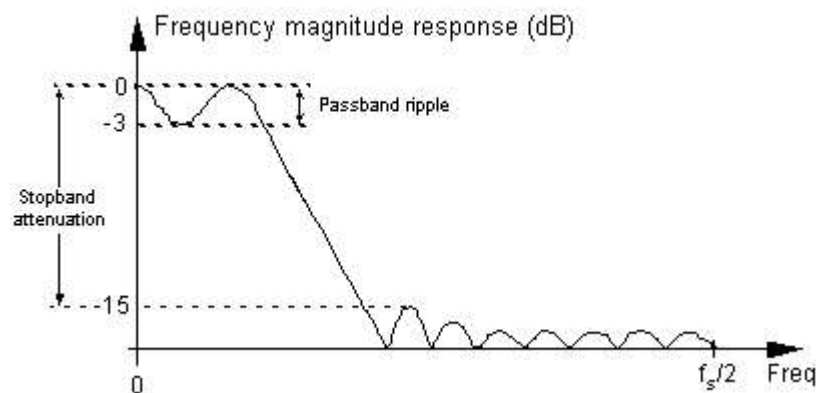
5.2 Radio's Building Blocks

(Page 5-5)

Filters – comment on question. [G7C13]

Google -"Ultimate rejection" in the context of a filter refers to the highest level of attenuation (signal suppression) a filter can achieve at frequencies far outside its passband, essentially indicating how effectively it blocks unwanted signals beyond its intended frequency range; it's a measure of the filter's overall ability to reject extraneous frequencies, often expressed in decibels (dB).

“Stop-band attenuation” is the industry term used for this number.



5.2 Radio's Building Blocks

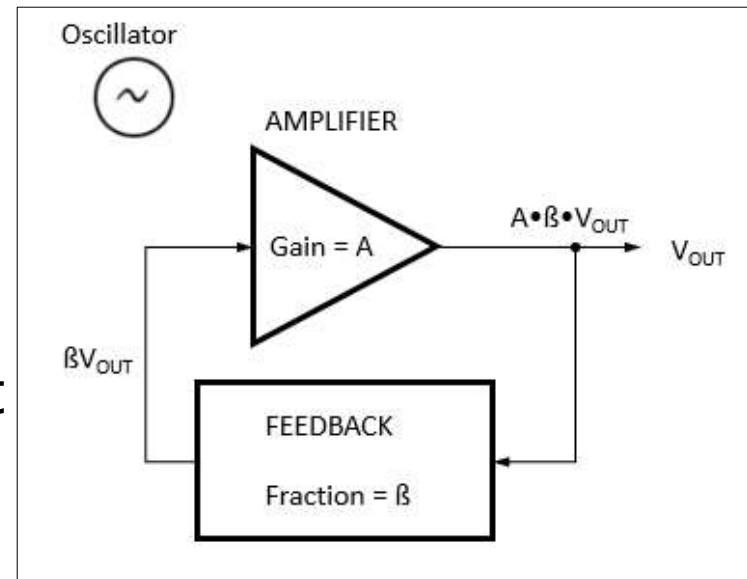
(Page 5-5)

Oscillators

The function of an **oscillator** is to produce a **pure sine wave** with no noise or distortion.

The **feedback circuit** in the oscillator must include a filter so that feedback is only present at the intended frequency.

LC oscillators are more stable than RC oscillators. Today, many oscillators are based on a crystal and DDS chip.



5.2 Radio's Building Blocks

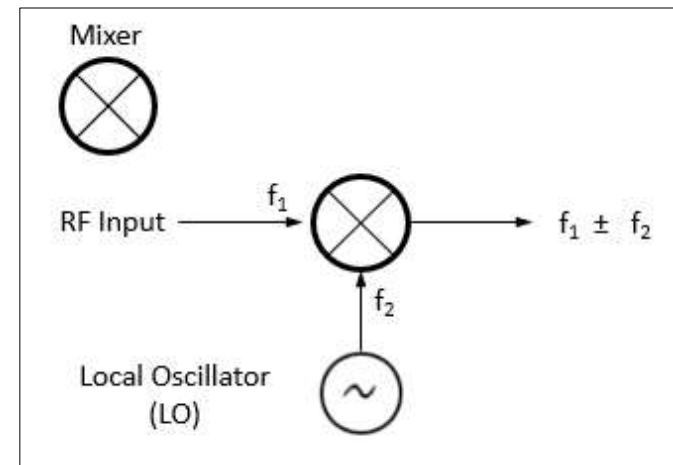
(Page 5-5 to 5-6)

Mixers

A key function in both receivers and transmitters is to be able to change the frequency of a signal. $F_1 \pm F_2$.

Comment - Mixer will produce **4 output frequencies**. The **output frequencies** will be **both input frequencies** along with the **sum and differences** of the input frequencies. **The book only mentions 2 frequencies being the sum and difference.**

The **local oscillator** is the frequency that you control to be able to receive the desired frequency.



5.2 Radio's Building Blocks

(Page 5-6)

Multipliers

Instead of the sum and difference of a mixer, a **multiplier** creates a **harmonic of the input frequency**. [G8B04]

Multipliers are often used when a stable VHF or UHF signal is required.

5.2 Radio's Building Blocks

(Page 5-6)

Modulators

Modulators are the circuits which perform the neat trick of adding information to a carrier signal by varying the carrier's **amplitude**, **frequency** or **phase**.

5.2 Radio's Building Blocks

(Page 5-6 to 5-7)

Amplitude Modulators

AM was first generated by varying the power supply voltage to the output circuit of a CW transmitter. As the voltage is varied, the **amplitude of the output signal** follows along. This is called plate modulation.

Care should be observed when operating close the edge of your licensed band. **USB** signals are modulated **higher** than the frequency on the dial and **LSB** is **lower** by about 3 kHz.

5.2 Radio's Building Blocks

(Page 5-6 to 5-7)

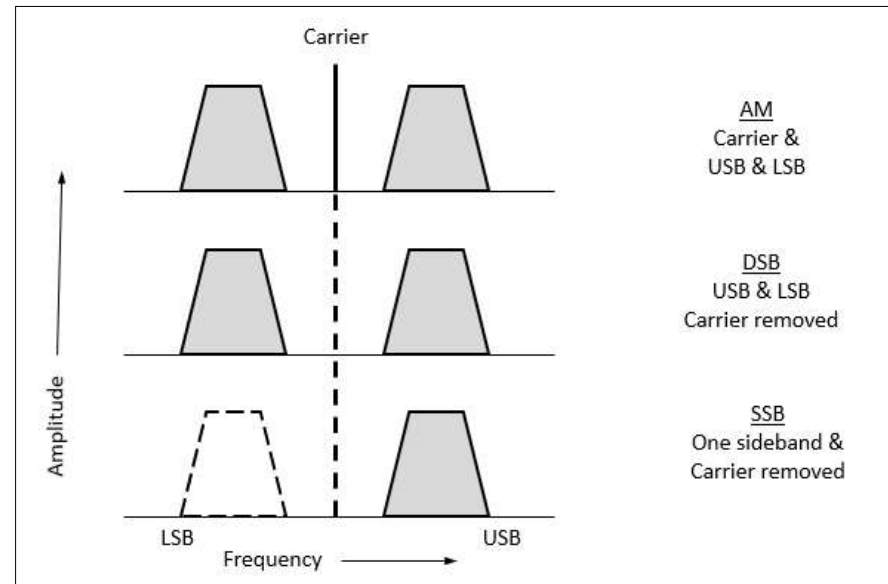
Amplitude Modulators

Figure 5.6:

The spectrum of 3 types of AM signals. Full AM has both sidebands and the carrier. The carrier is represented by the vertical line in the middle, and the sidebands contain speech or data signals that have been used to modulate the carrier.

DSB removes the carrier, but has the same bandwidth as full AM.

SSB removes one sideband and has the lowest bandwidth of the 3.



5.2 Radio's Building Blocks

(Page 5-6 to 5-7)

Amplitude Modulators

- DSB can be produced by a **balanced modulator** – special mixer where f_1 is the carrier and f_2 is the modulator
- SSB is generated by removing the unwanted sideband and carrier with a filter (filter method) or by combining signals with certain phase relationships (phasing method)
- Using only one sideband uses transmitted output power more effectively

5.2 Radio's Building Blocks

(Page 5-7)

Frequency and Phase Modulators

FM modulation only **changes the frequency**.

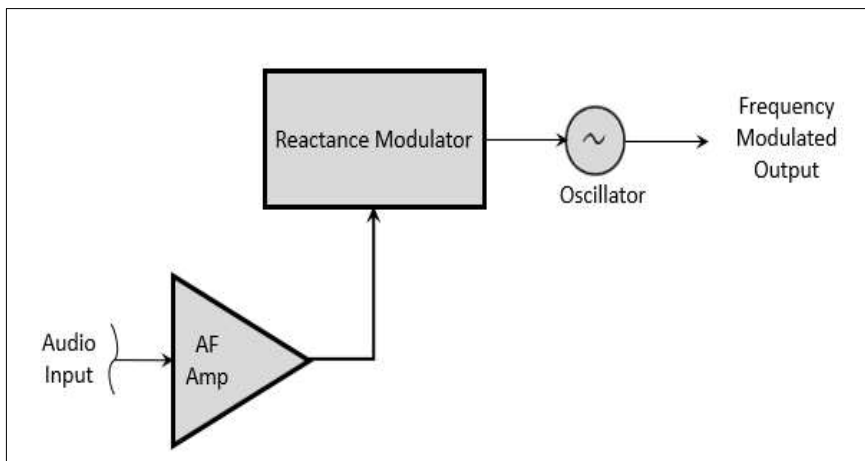
PM modulation **changes the frequency and amplitude** of the signal.

To create phase modulation, the inputs to a reactance modulator are an AF amplifier and oscillator. The phase is changed but the average frequency will not be changed.

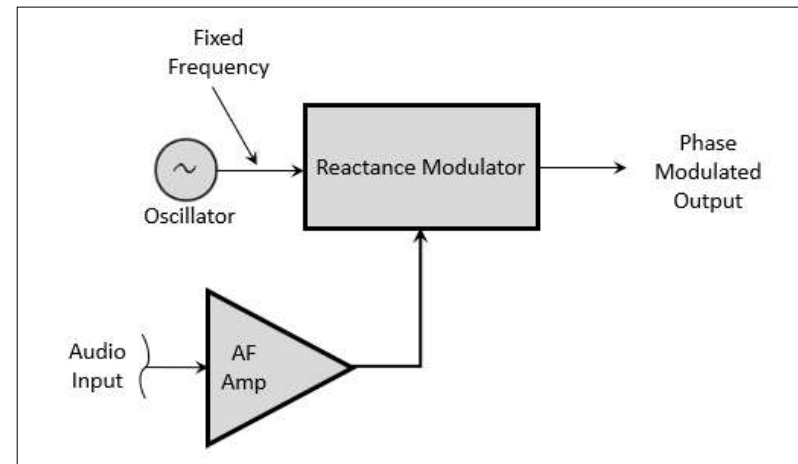
5.2 Radio's Building Blocks

(Page 5-7)

Frequency and Phase Modulators



(A) FREQUENCY MODULATION



(B) PHASE MODULATION

5.2 Radio's Building Blocks

(Page 5-7)

Quadrature Modulation

Quadrature modulation is also called **I/Q modulation**.

This modulation technique is used to create signals with any form of modulation needed.

This modulation technique is based on math and is used in DSP processing.

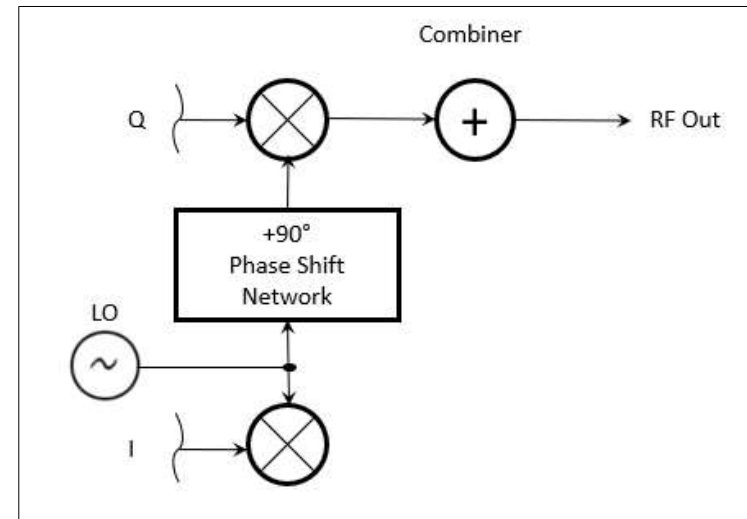


Fig 5.8: Block diagram of an I/Q modulator. **I** & **Q** are designators for input signals that can be analog signals or streams of digital data.

5.3 Transmitters

(Page 5-8)

G2A12 – What control is typically adjusted for proper ALC setting on an amateur single sideband transceiver?

Transmit audio or microphone gain.

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

Two non-harmonically related audio signals.

G4B08 – What type of transmitter performance does a two-tone test analyze? Linearity.

G4D01 – What is the purpose of a speech processor in a transceiver? Increase the apparent loudness of transmitted voice signals.

G4D02 – How does a speech processor affect a single sideband phone signal? It increases average power.

G4D03 – What is the effect of an incorrectly adjusted speech processor? All these choices are correct.

5.3 Transmitters

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

7.175 MHz to 7.178 MHz.

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

14.347 MHz to 14.350 MHz.

G4D10 – How close to the lower edge of the phone segment should your displayed carrier frequency be when using 3 kHz wide LSB?

At least 3 kHz above the edge of the segment.

G4D11 – How close to the upper edge of the phone segment should your displayed carrier frequency be when using 3 kHz wide USB? At least 3 kHz below the edge of the segment.

G7B10 – Which of the following describes a linear amplifier?

An amplifier in which the output preserves the input waveform.

5.3 Transmitters

(Page 5-8)

G7C01 – Which circuit is used to select one of the sidebands from a balanced modulator? Filter.

G7C02 – What output is produced by a balanced modulator?

Double-sideband modulated RF.

G8A08 – Which of the following is an effect of overmodulation?

Excessive bandwidth.

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

Signal distortion caused by excessive drive or speech levels.

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

The waveform created by connection the peak values of the modulated signal.

G8B06 – What is the total bandwidth of an FM phone transmission having 5 kHz deviation and 3 kHz modulating frequency? 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? 416.7 Hz

5.3 Transmitters

(Page 5-9)

Chapter 5.3

Transmitters produce **AM**, **CW**, **SSB** and **FM** signals.

The goal is for you to transmit a signal you can be proud of every time.

5.3 Transmitters

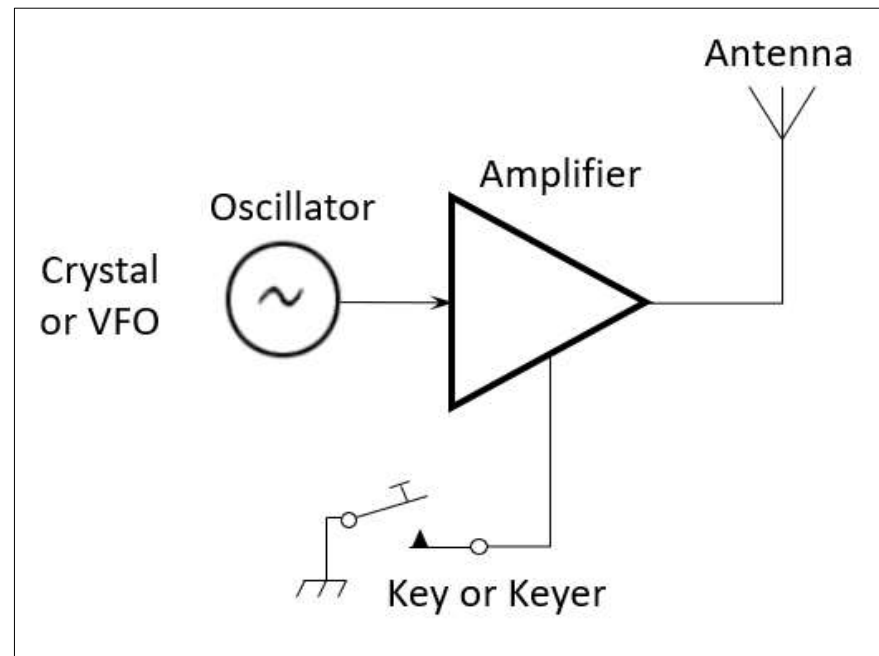
(Page 5-9)

CW Transmitters

The simplest transmitter is a two-stage CW transmitter consisting of an **oscillator** and an **amplifier** with the amplifier turned on and off by a key or keyer.

See Figure 5.9.

Figure 5.10 allows us to change the output frequency with the VFO (knob on transmitter).

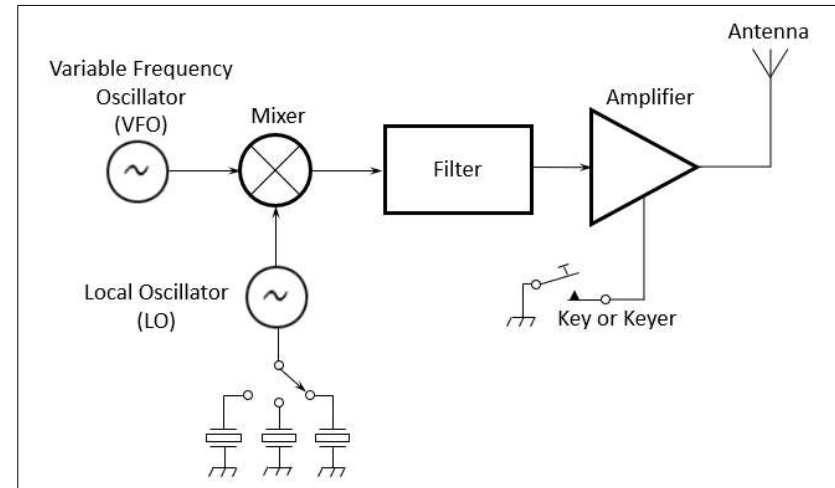


5.3 Transmitters

CW Transmitters

Fig 5.10:

By changing the frequency of the local oscillator (LO), the VFO's output can be shifted from band to band, creating a multi-band transmitter.



5.3 Transmitters

(Page 5-9 to 5-10)

SSB Phone Transmitters

Voice signals from a microphone are processed by a speech amplifier and input to the balanced modulator. [G7C02] The output is a **DSB signal**, so a **filter is required to remove the undesired sideband**. [G7C01]

160, 75(80) and 40 meters use **LSB**.

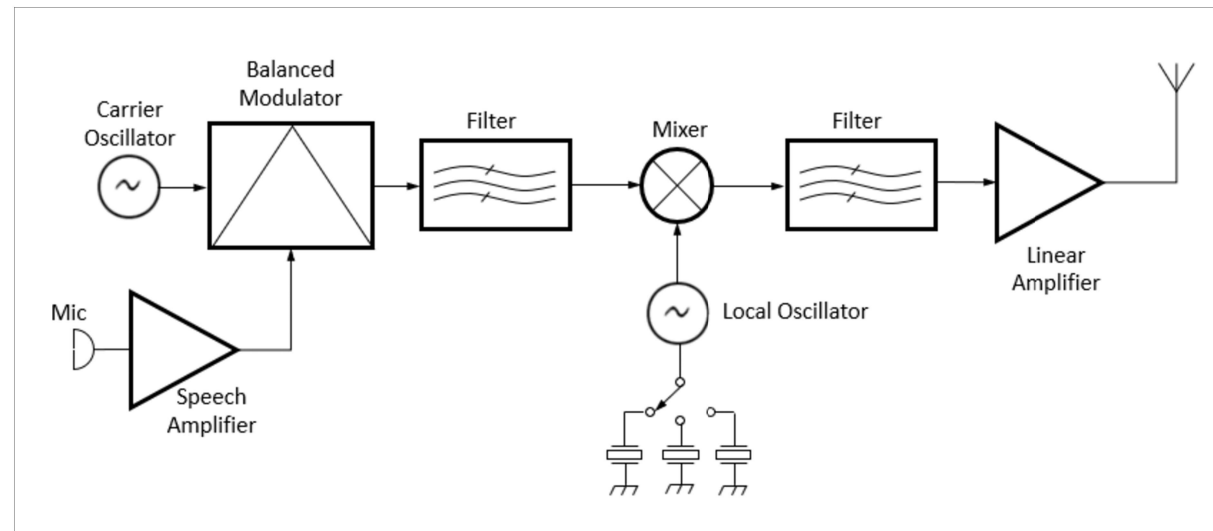
60, 20, 17, 15, 12 and 10 meters use **USB** signals. VHF and UHF use **USB** signals.

See Figure 5.14.

5.3 Transmitters

SSB Phone Transmitters

Fig 5.11:
Substituting the circuits to create an SSB signal for the VFO creates a multi-band SSB transmitter.



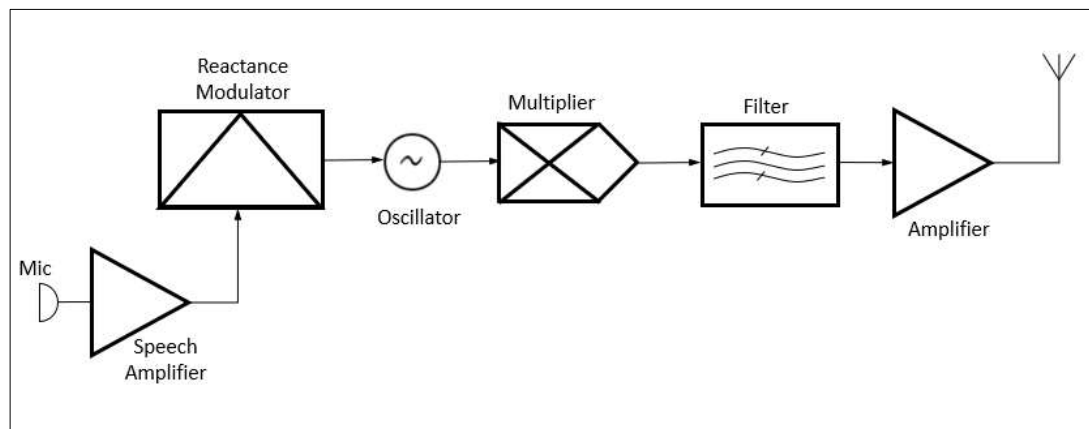
5.3 Transmitters

(Page 5-10 to 5-11)

FM Transmitters

Practical and inexpensive FM signals can be generated by **modulating at a low frequency and multiply it** to the desired band.

If the modulating frequency is about 12 MHz then 12th harmonic for transmission and the deviation needs to be 1/12th of the final deviation of 5 kHz so this would be 416.7 Hz. The final FM frequency is 146.52 MHz. [G8B07]



5.3 Transmitters

(Page 5-11)

Signal Quality

Operating a transmitter so that the on-the-air signal is **intelligible and does not have excessive bandwidth** is an important part of operating.

Poor signal quality causes excessive bandwidth and can interfere with other operators. Excessive microphone gain or poorly designed linear amplifiers that produce excessive harmonics are common sources of interference.

5.3 Transmitters

(Page 5-11)

AM Modes

All amplitude modulated signals (**CW, AM and SSB**) can be generated by the same basic transmitter structure.

Transmitters using DSP and SDR techniques perform the same modulation functions using mathematical operations in a computer chip.

5.3 Transmitters

(Page 5-11 to 5-12)

Overmodulation – AM Modes

If the amplitude of an AM or SSB signal is varied excessively then this is called **overmodulation** and can cause flat-topping or clipping. When output signal is clipping, then the signal will **generate spurious signals** and have **wider bandwidth** than allowed.

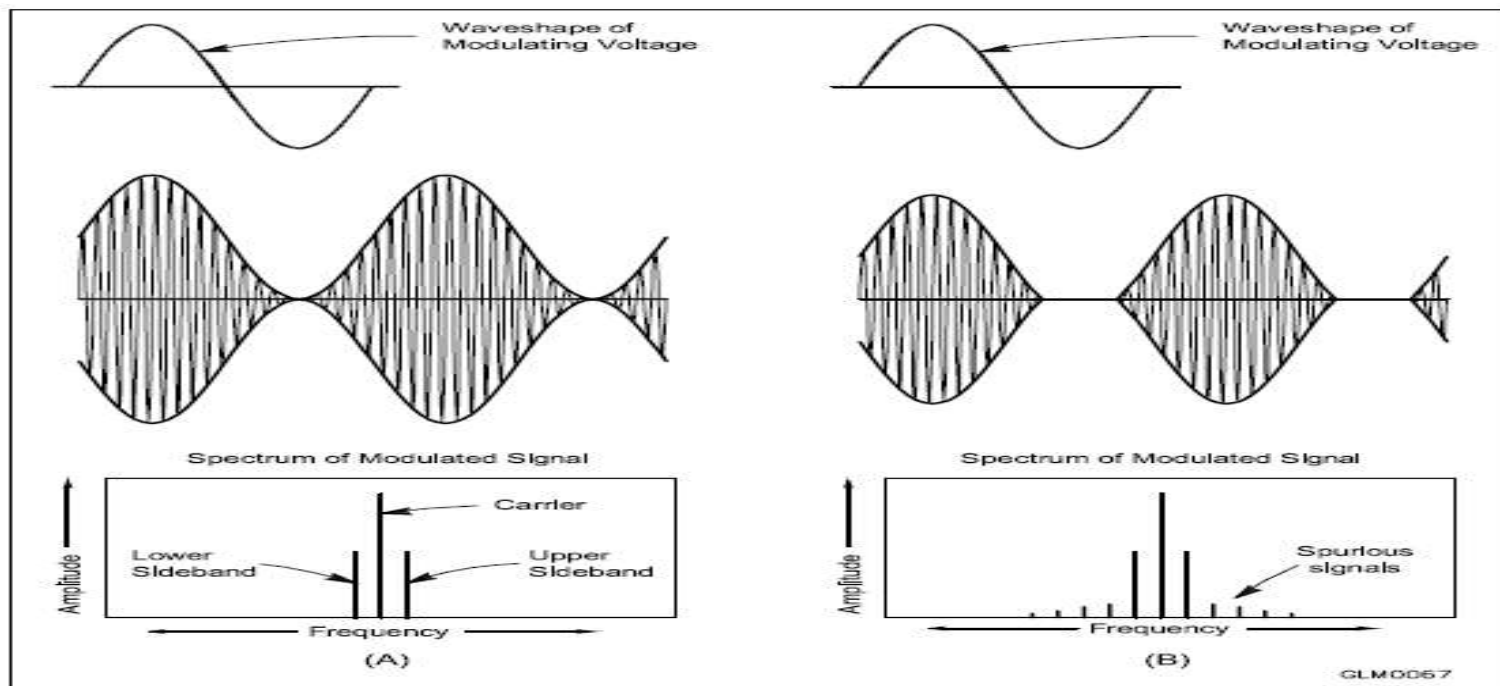
See Figure 5.13

Automatic level control (ALC) circuit should only activate on voice peaks. Two-tone test (700 and 1900 Hz) can be used to adjust gain and level settings for distortion free output. Reducing microphone gain to limit ALC response can help also.

5.3 Transmitters

(Page 5-11 to 5-12)

Overmodulation – AM Modes



5.3 Transmitters

(Page 5-12)

Controlling Sideband Frequency

When operating in SSB mode, the radio will show the carrier frequency even though all the energy is either above or below that displayed frequency.

That is the reason so much is said about paying attention to how close you operate to the band edges.

LSB mode – you should stay 3 kHz or more away from the lower edge of the band.

USB mode – you should stay 3 kHz or more away from the upper edge of the band.

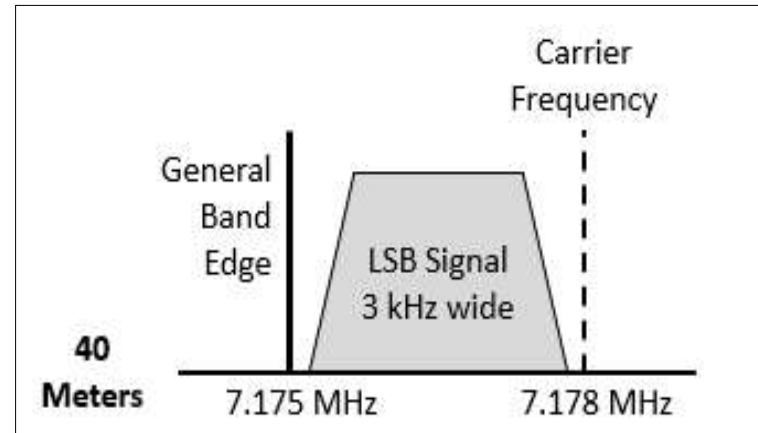
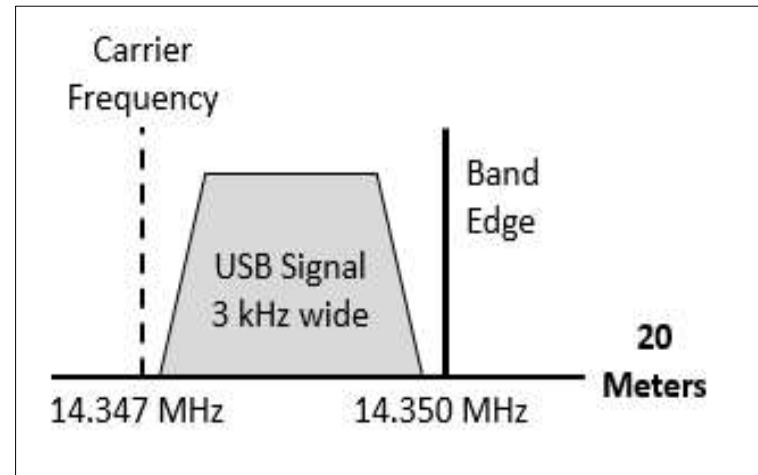
5.3 Transmitters

(Page 5-12)

Controlling Sideband Frequency

Figure 5-14

When sidebands extend from the carrier toward a band edge or a band segment edge, operate with a displayed carrier frequency no closer than 3 kHz to the edge frequency and be sure your signal is “clean.”



5.3 Transmitters

(Page 5-12 to 5-13)

Speech Processing

Voice signals have a very low average power as compared to CW. Human speech spreads its energy over a wide frequency range with only short periods of high sound levels. When transmitted over HF, an amplitude-modulated signal can be difficult to understand. Speech processing can **increase the average power** without creating distortion and make it easier to understand in difficult conditions. Speech processing requires careful adjustments because too much speech processing can cause distortion.

5.3 Transmitters

(Page 5-13 to 5-14)

Overdeviation – FM and PM

FM signals can be overmodulated but instead of distortion the **signal envelope has excessive deviation (frequency changes more than the receiver is expecting)**.

The result of overdeviation is **distortion of the received signal (not transmitted signal)** and might interfere with adjacent channels. The transmitter signal will not be distorted but will contain too wide of a frequency change (deviation) for the receiver to accurately demodulate it back to normal speech.

5.3 Transmitters

(Page 5-14)

Key Clicks

Key clicks are sharp transient clicking sounds heard on adjacent frequencies as the transmitter turns on and off too quickly during CW transmission. If the leading and trailing edges of the **CW key output are too steep (fast)** then key clicks may be generated. Most radios have configuration settings to control this condition. An RC circuit on the CW key can also help with this condition.

See Figure 5.15 Key closure is very sharp in example but the release is more gradual.

5.3 Transmitters

(Page 5-14)

Amplifiers

G4A04 – What is the effect on the plate current of the correct setting of a vacuum tube RF power amplifier's TUNE control? A pronounced dip.

G4A05 – Why is automatic level control (ALC) used with an RF power amplifier? To prevent excessive drive

G4A08 – What is the correct adjustment for the LOAD or COUPLING control of a vacuum tube RF power amplifier?

Desired power output without exceeding maximum allowable plate current.

G4A09 – What is the purpose of the delaying RF output after activating a transmitter's keying line to an external amplifier? To allow time for the amplifier to switch the antenna between transceiver and the amplifier output.

5.3 Transmitters

(Page 5-14)

Amplifiers

G7B01 – What is the purpose of neutralizing an amplifier? To eliminate self-oscillations.

G7B02 – Which of these classes of amplifiers has the highest efficiency? Class C

G7B04 – In a Class A amplifier, what percentage of the time does the amplifying device conduct? 100%

G7B08 – How is the efficiency of an RF power amplifier determined? Divide the RF output power by the DC input power

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

5.3 Transmitters

(Page 5-14 to 5-15)

Amplifiers

and conditions are poor, propagation conditions difficult or when running nets so that they can be heard easily.

Modes such as SSB require **linear amplifiers** that accurately reproduce the input signal waveform.

Class A is the most linear of all classes and is active for 100% of the signal's cycle.

Class B is active for one-half of the signal's cycle.

Class C amplifiers (CW) are active for less than one-half of the signal's cycle and would be considered non-linear.

Class AB is midway between Class A and B, linearity is not as good as Class A, but the efficiency is improved. Class AB is common for SSB signals.

5.3 Transmitters

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Tuning and Driving a Linear Amplifier

Amplifiers have three primary adjustments: **BAND**, **TUNE** and **LOAD**. 'No-tune' or 'auto-tune' amplifiers do not require adjustments by design or with microcontroller control.

With band switch set properly, use a small amount of power to adjust the TUNE control for minimize plate current and then adjust the LOAD control for maximum plate current. Then increase the drive to the normal value and recheck. Drive power should be checked on grid-driven amplifiers and solid-state amps so that excessive current does not occur.

5.3 Transmitters

(Page 5-16)

Neutralization

High power RF amps can become a VHF oscillator.

We want the amplifier to only amplify and not oscillate. If it oscillates on its own, it can overheat and produce excessive harmonics and destroy itself.

A little bit of **negative feedback** is sent back to the input with a variable cap to keep it from oscillating.

Once the neutralization process is done, it will not need to be done again unless the tubes are changed.

5.4 Receivers

(Page 5-16)

G4A01 – What is the purpose of the notch filter found on many HF transceivers? To reduce interference from carriers in the receiver passband.

G4A02 – What is the benefit of using the opposite or “reverse” sideband when receiving CW? It may be possible reduce or eliminate interference from other signals.

G4A03 – How does a noise blanker work? By reducing receiver gain during a noise pulse.

G4A07 – What happens as a receiver's noise reduction control level is increased? Received signals may become distorted.

G4A13 – What is the purpose of using a receive attenuator? To prevent receiver overload from strong incoming signals.

5.4 Receivers

(Page 5-16)

G4D04 – What does an S-meter measure?

Received signal strength.

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? It is 100 times more powerful.

G4D06 – How much change in the signal strength is typically represented by one S unit? 6 dB

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? Approximately 4 times.

G7C04 – How is a product detector used? Used in a single sideband receiver to extract the modulated signal.

5.4 Receivers

(Page 5-16 to 5-17)

G7C06 – Which of the following is an advantage of a digital signal processing (DSP) filter compared to an analog filter?

A wide range of bandwidths and shapes can be created.

G7C08 – Which parameter affects receiver sensitivity?

Input amplifier gain; Demodulator stage bandwidth; Input amplifier noise figure

G8B01 – Which mixer input is varied or tuned to convert signals of different frequencies to an intermediate frequency (IF)? Local oscillator

G8B02 – What is the term for interference from a signal at twice the IF frequency from the desired signal?

Image response

G8B09 – Why is it good to match receiver bandwidth to the bandwidth of the operating mode?

It results in the best signal-to-noise ratio

5.4 Receivers

(Page 5-17)

Chapter 5.4

“You can’t work them if you can’t hear them”

That makes the **receiver** just about the most important part of the ham shack.

DSP and SDR techniques are quickly replacing analog receivers.

Some of us will add that a decent antenna is also important to be able to communicate effectively.

5.4 Receivers

(Page 5-17 to 5-19)

Basic Superheterodyne Receivers

Most analog receivers today use some type of **superheterodyne** designs and is commonly called “superhet”.

The simplest combination of stages to make a superhet receiver is an **HF oscillator, mixer and detector**.

SSB and CW signals can be demodulated by a **product detector**. AM signals can use a product detector or envelope detector. FM signals use a **discriminator** or **quadrature detector** to demodulate information.

5.4 Receivers

(Page 5-17 to 5-19)

Basic Superheterodyne Receivers

Superhet receivers do have a weakness in that there can be two frequencies that will mix to produce the **IF frequency, typically 455 kHz**.

The mixer uses the sum and difference of the frequencies, so filtering is needed to select the correct frequency. The undesired frequency is called an **image frequency**.

5.4 Receivers

(Page 5-17 to 5-19)

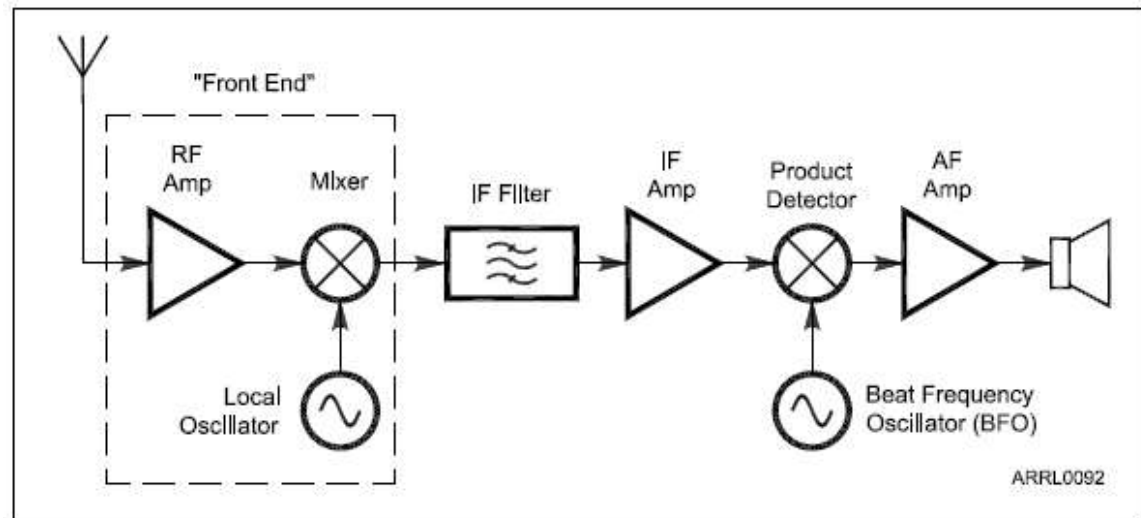
Basic Superheterodyne Receivers

Fig. 5.16

– the product detector –
converts the signal to
audio frequencies.

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.



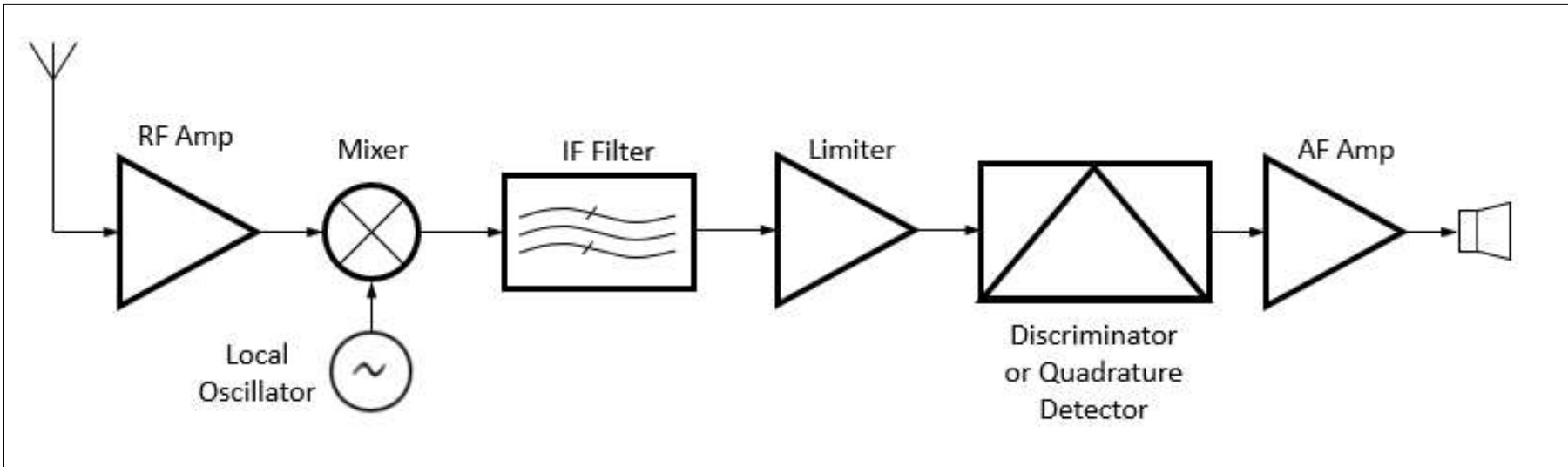
5.4 Receivers

(Page 5-17 to 5-19)

FM Receivers

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.



5.4 Receivers

(Page 5-19)

Digital Signal Processing

DSP technology requires an analog receiver front end to tune in a signal. **DSP technology replaces some/most of the analog circuitry with software.** Once prepared by the front end, the signal is converted into a digital form by the ADC (analog to digital converter), manipulated by software to decode the data and then converted back into analog by the DAC (digital to analog converter).

Radios with **DSP offer selectable filters to adjust filter bandwidth and shape.** Noise reduction is possible with DSP processing. **Notch filter and Noise Blanker (NB)** can remove noise sources from the desired signal.

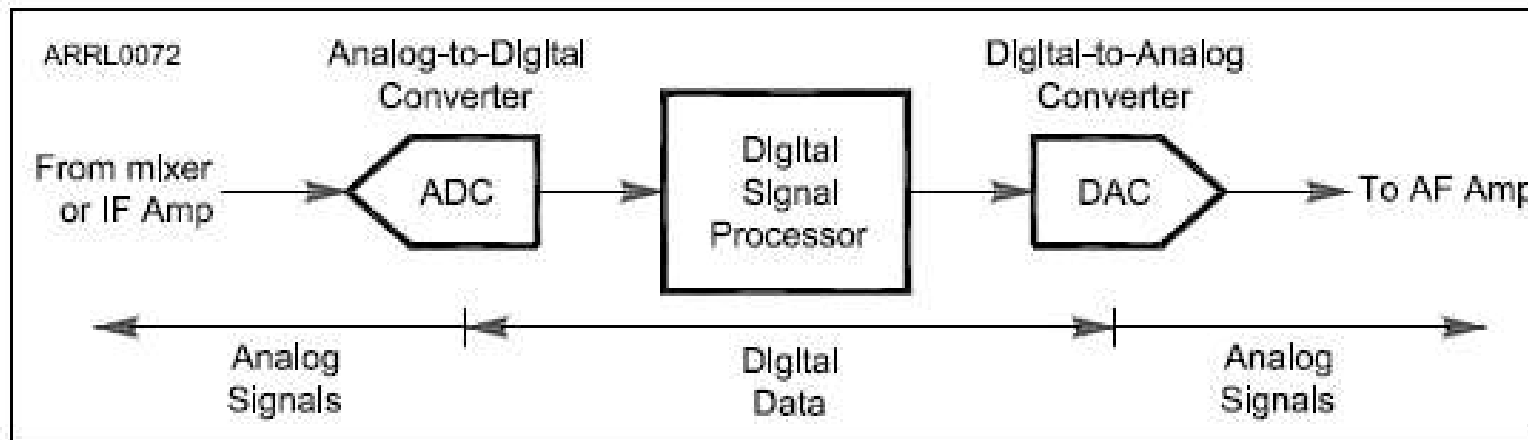
5.4 Receivers

(Page 5-19)

Digital Signal Processing

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.



5.4 Receivers

(Page 5-19 to 5-20)

Managing Receiver Gain

Receivers need a **lot of gain** to receive the weak signal from the antenna which may be only a few microvolts of RF signal.

Too little gain and we can't receive the signal, but too much gain can cause its own problems like feedback and/or oscillation.

5.4 Receivers

(not in book)

Managing Receiver Gain – S meter reading

S-reading	HF μV (50 Ω)	dBm	Signal Gen dB above 1 μV
S9+10dB	160.0	-63	44
S9	50.2	-73	34
S8	25.1	-79	28
S7	12.6	-85	22
S6	6.3	-91	16
S5	3.2	-97	10
S4	1.6	-103	4
S3	0.8	-109	-2
S2	0.4	-115	-8
S1	0.2	-121	-14

5.4 Receivers

(Page 5-20)

RF Gain and Automatic Gain Control

The amount of **receiver gain** is set by the RF gain control. Once you have tuned in a signal, maximum gain isn't required and may add extra noise to the signal audio. Lower values of gain can reduce the background noise heard quicker than the audio signal.

The automatic gain control **AGC** circuit adjusts receiver gain by changing the IF amplifier gain. This voltage is also read by the S meter and each unit is equal to 6 dB. S-9 is the midpoint of the S meter so a signal that is **+20 dB is 100 times** stronger than S-9.

5.4 Receivers

(Page 5-20)

Receiver Linearity

It is **important for the receiver and transmitter to be linear** when processing signals. If the received **signal is distorted in the receiver**, then it will appear the same as if the transmitting signal emitted them. Always check your receiver settings before claiming someone else has a bad signal.

The most common form of receiver non-linearity is **overload** or **gain compression**. Overload happens when the input signal is too large for the circuitry to handle. The solution to overload is to use the **attenuator** circuit to reduce the overall signal levels.

5.4 Receivers

(Page 5-21)

Rejecting Interference and Noise

IF filters will **narrow the receiver's passband and remove unwanted signals**. Once a signal is inside the passband of the receiver, it is difficult to remove it from the signal.

Notch filters remove a **very narrow band of frequencies**.

IF shift **adjusts the receiver's passband** above or below the displayed carrier to avoid signal on adjacent frequencies.

Reverse sideband controls allow the operator to switch between receiving CW signals above or below the displayed carrier frequency. This allows for more filtering of the nearby signal.

5.5 HF Station Installation

(Page 5-21 to 5-22)

G4C01 – Which of the following might be useful in reducing RF interference to audio frequency devices? Bypass capacitor

G4C02 – Which of the following could be a cause of interference covering a wide range of frequencies?

Arcing at a poor electrical connection.

G4C03 – What sound is heard from an audio device experiencing RF interference from a single sideband phone transmitter? Distorted speech

G4C04 – What sound is heard from an audio device experiencing RF interference from a CW transmitter?

On-and-off humming or clicking.

G4C05 – What is a possible cause of high voltages that produce RF burns?

The ground wire has high impedance on that frequency

5.5 HF Station Installation

(Page 5-21 to 5-22)

G4C06 – What is a possible effect of a resonant ground connection?

High RF voltage on the enclosures of station equipment

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

G4C09 – How can the effects of ground loops be minimized? Bond equipment enclosures together.

G4C10 – What could be a symptom of a ground loop in your station's audio connection? You receive reports of “hum” on your station's transmitted signal.

G4C11 – What technique helps to minimize RF “hot spots” in an amateur station? Bonding all equipment enclosures together

5.5 HF Station Installation

(Page 5-21 to 5-222)

G4C12 – Why must the metal enclosure of every item of station equipment be grounded?

It ensures that hazardous voltages cannot appear on the chassis

G4E03 – Which of the following direct, fused power connections would be the best for a 100-watt HF mobile installation? To the battery using heavy-gauge wire

G4E04 – Why should DC power for a 100-watt HF transceiver not be supplied by a vehicle's auxiliary power socket? The socket wiring may be inadequate for the current

drawn by the transceiver (transceiver needs about 20 to 25 amps)

G4E05 – Which of the following most limits an HF mobile installation? Efficiency of the electrically short antenna

5.5 HF Station Installation

(Page 5-21 to 5-222)

G4E07 – Which of the following may cause receiver interference to an HF transceiver installed in a vehicle?

The battery charging system; The fuel delivery system; The control computers

G6B10 – How does a ferrite bead or core reduce common-mode RF current on the shield of a coax cable?

By creating an impedance in the current's path

G6B05 – Which intermodulation products are closest to the original signal frequencies? Odd-order

G8B12 – What process combines two signals in a non-linear circuit to produce unwanted spurious outputs?

Intermodulation

G8B13 – Which of the following is an odd-order intermodulation product of frequencies F1 and F2?

$2F1 - F2$

5.5 HF Station Installation

(Page 5-22 to 5-23)

Chapter 5.5

A working station can be at home or in a vehicle.

HF operating has longer wavelengths and maybe higher power can make **RF grounding and interference control more important.**

The General class exam focuses on three related areas: **mobile installations, grounding and bonding and then RF interference.**

5.5 HF Station Installation

(Page 5-22)

Mobile Installations

Compact all-band, all-mode radios have increased HF mobile operations. Icom IC-7100, Yaesu FT-891 and Kenwood TS-480 are examples of these mobiles.

If you have issues getting a mobile system operating, please ask an Elmer or any knowledgeable ham for assistance.

5.5 HF Station Installation

(Page 5-22)

Power Connections

Mobile rigs are capable of outputting 100W and **can need more than 20 amps**, so good wiring is needed.

Cigarette lighter ports do not have enough power to run a 100 W radio. They can only provide about 8 amps.

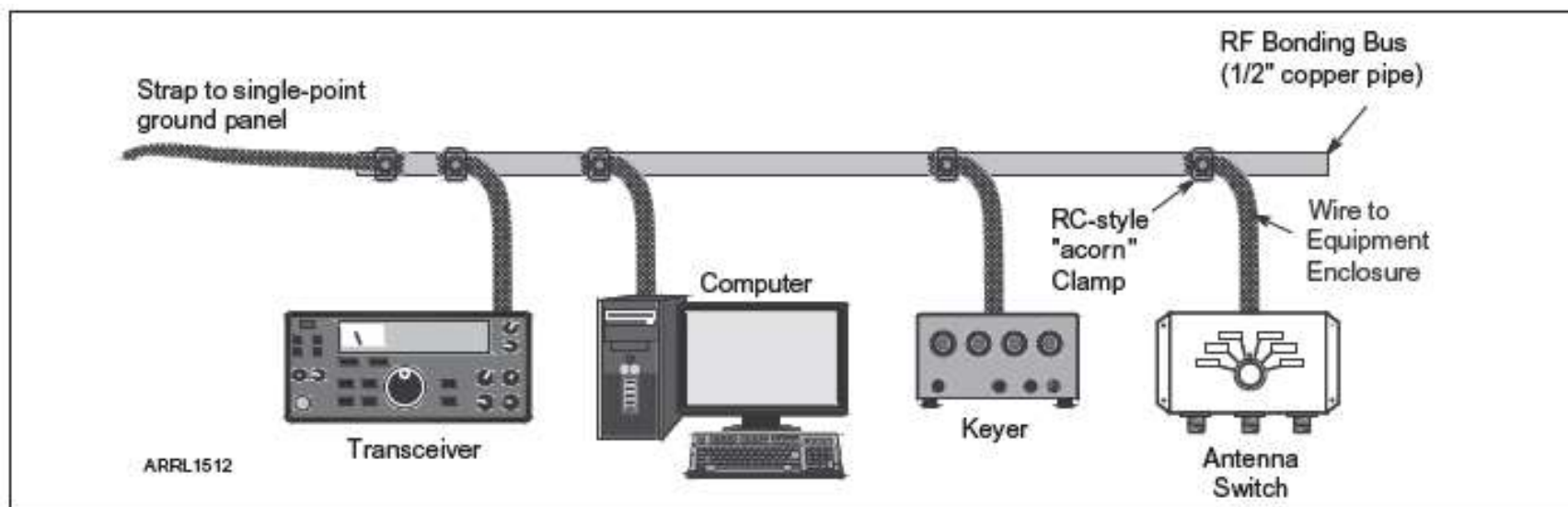
All the **vehicle body panels may not be connected to Chassis Ground** so you should check and add large ground straps, if needed. Wide straps provide better RF ground than a single wire.

5.5 HF Station Installation

(Page 5-22)

Grounding and Bonding

Figure 5.19 — This example of a typical RF bonding bus at the operating position helps keep all of the equipment at the same RF voltage.



5.5 HF Station Installation

(Page 5-23)

Antenna Connections

The most significant limitation of mobile operation is that the antenna system must be smaller than a home station. This is particularly true of 160 & 75/80 meter bands.

When mobile, the **entire vehicle becomes part of the antenna system**. Important points about mobile stations are for example: use the **most efficient antenna** you can get, make sure **RF ground connections** to the vehicle are good and **mount the antenna where it is clear of metal surfaces**.

5.5 HF Station Installation

(Page 5-23)

Mobile Interference

HF mobile interference is different from the home station. **Ignition noise** caused by spark plugs can be quite strong. Vehicle accessories and other systems can cause interference.

Common sources of interfering signals can include; **on-board vehicle computers, fuel pumps, window controls and battery charging systems.**

5.5 HF Station Installation

(Page 5-23 to 5-24)

RF Grounding and Ground Loops

Good station ground is important to prevent electrical shock but at HF and higher frequencies the AC safety ground can act more like an antenna than a ground. See Figure 5.19

Make all ground connections as short as possible to minimize voltage differences between your equipment.

If the ground connection approaches an odd number of $\frac{1}{4}$ wavelengths, then it will present a high impedance which will allow voltages to exist on your equipment.

Ground loops happen when a continuous path exists around a series of equipment enclosures.

5.5 HF Station Installation

(Page 5-24)

RF Interference (RFI)

Radiating a good signal means that you may discover some **unintentional listeners** in nearby receivers and consumer electronics.

Spurious emissions from HF station may be received by radio or TV equipment. Use a low-pass filter to remove the spurious emissions at the station and match the low-pass filter impedance with the impedance of the feed line used.

Any spark or sustained arc creates radio noise over a wide range of frequencies. **Remember Spark transmitters???**

5.5 HF Station Installation

(Page 5-25)

RF Interference Suppression

The best solution to many types of interference is to **keep the RF signals from entering the equipment.**

Ferrite beads and cores can be placed on cables to prevent RF common-mode current from flowing on the outside of cable braids or shields. Computer and video monitor cables have used them for years.

Interference to audio equipment can sometimes be eliminated by placing a small **bypass cap** (100 pF to 1 nF) across the balanced line or to ground on single ended line.

5.5 HF Station Installation

(Page 5-25)

Common RFI Symptoms

CW, FM or data – On/Off buzzes, humming and clicks/thumps when transmitting.

AM phone – equipment experiencing overload or direction detection can replicate the speaker's voice

SSB voice – similar to AM phone but distorted or garbled.

5.5 HF Station Installation

(Page 5-25)

Suppressing RFI

Distance from RF signal.

Filters to keep the RF signal from entering equipment.

Blocking the RF path by adding an RF choke. This could be a ferrite core on the coax cable or several turns of the coax cable made into a coil and taped together.

Thanks to:

* Information from:

- The ARRL Library
- ARRL General Class License Manual
- Gordon West General Class License Class
- Various websites