

Amateur Radio License

Propagation and Antennas

Today's Topics

- Antennas, and Associated Hardware
- Radios, Modulation

Antennas

Antenna

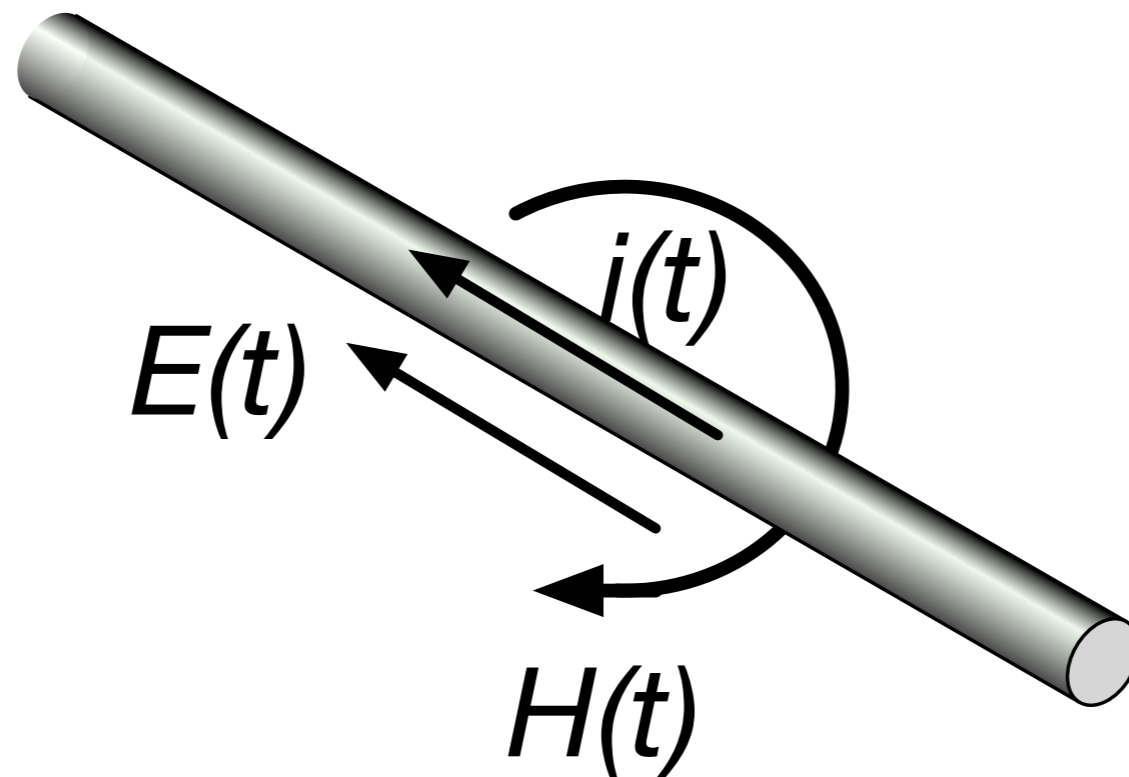
- Couples amplifier to propagating waves
- Currents on the antenna elements produce electric and magnetic fields in space
- Antenna dimensions matched to dimensions of the electromagnetic wave you want to generate

Types of Antennas

- Omni-directional: no direction preference
- Directional beam: Focuses energy in one direction
- Gain: How much the signal is enhanced in one direction, compared to a reference antenna.
Measured in dB, i.e. $10 \log_{10} (P/P_r)$
 - dBi : compared to an ideal isotropic antenna
 - dBd : compared to a dipole antenna

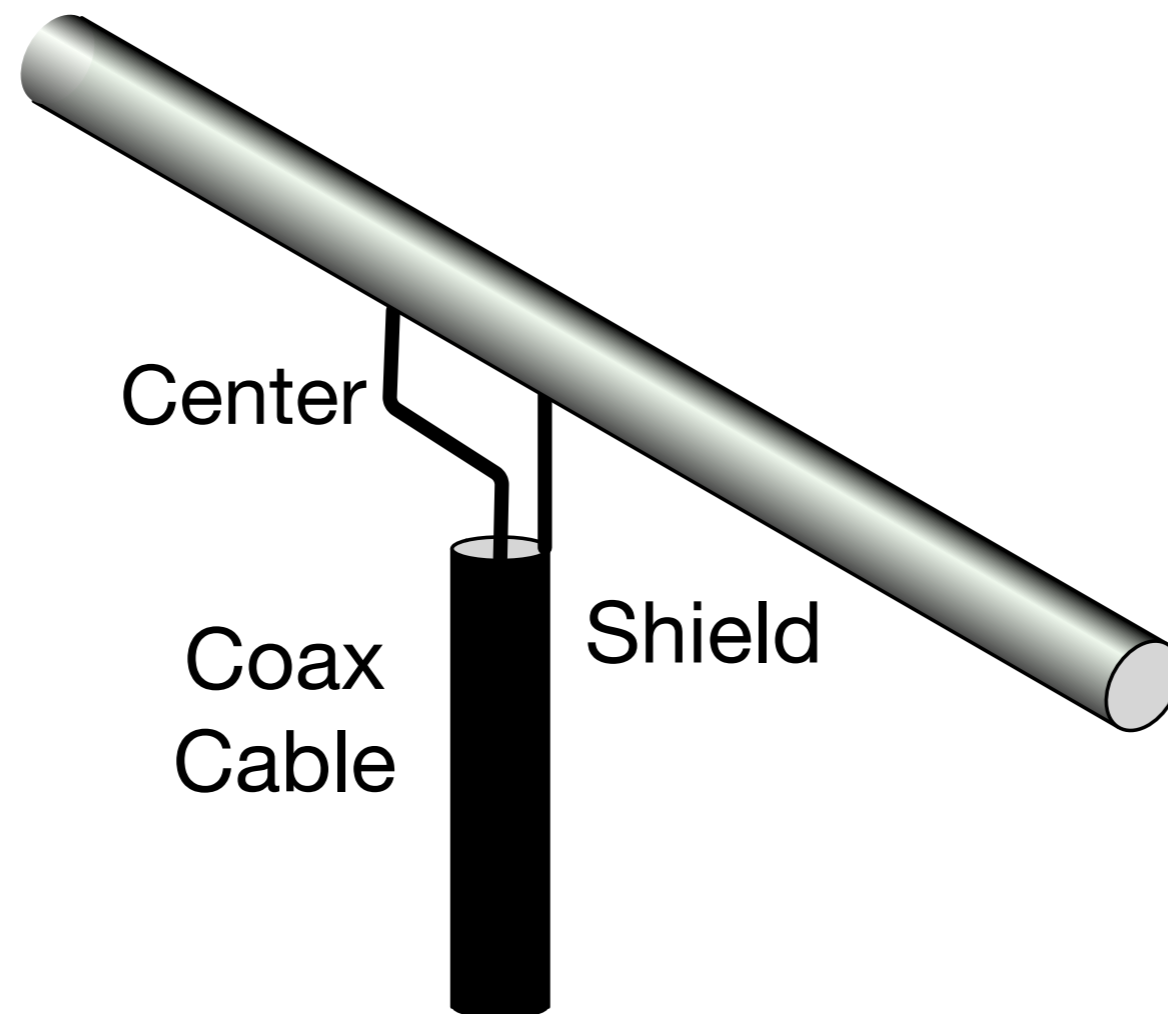
Current in a Conductor

- Current flows along conductor
- Electric fields parallel
- Magnetic fields perpendicular



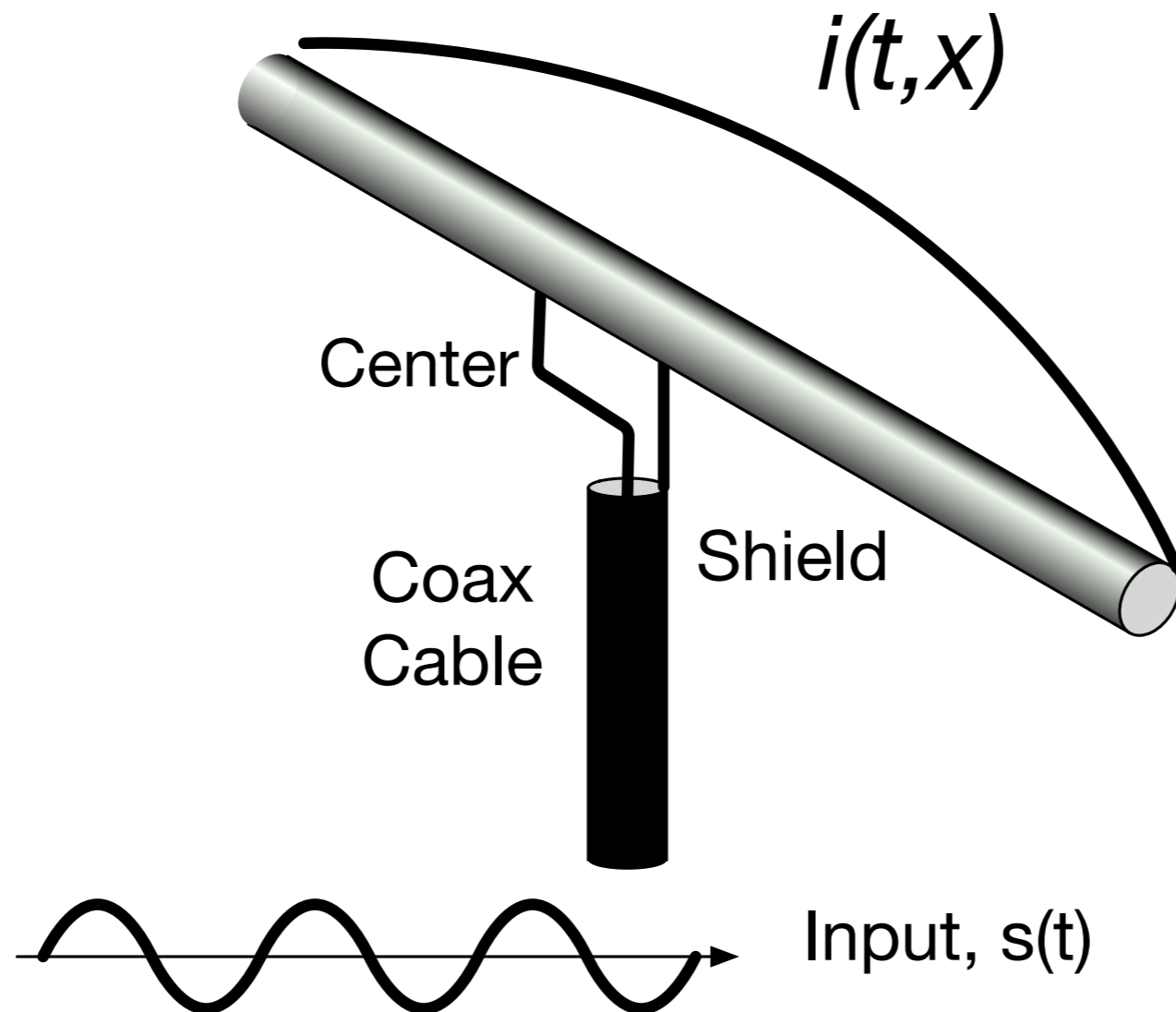
Dipole Antenna

- Drive the antenna at center, offset
- Sets the input impedance



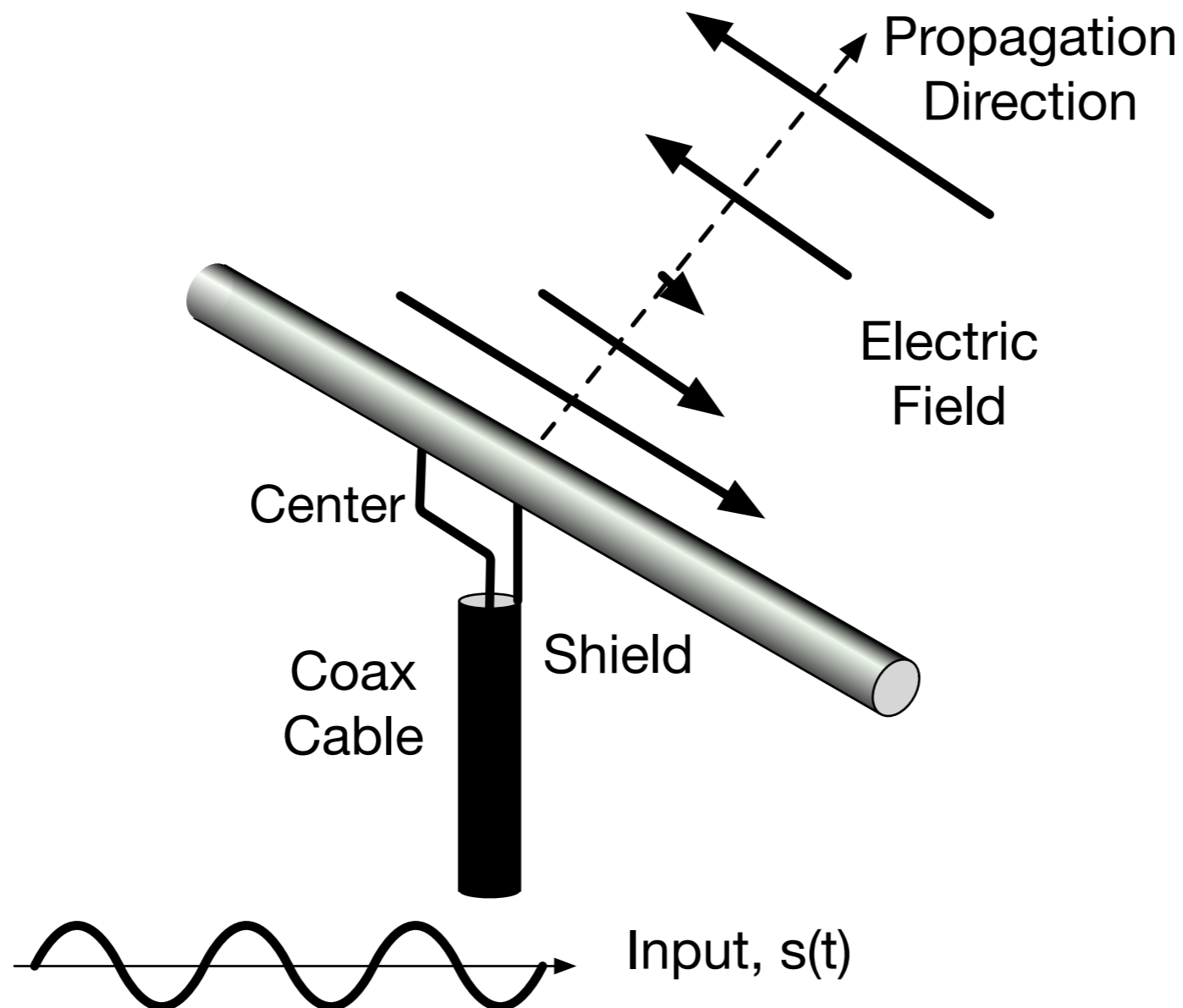
Dipole Antenna

- Sinusoidal input sets up half cycle of current along antenna
- Length should be $1/2$ wavelength for the frequency



Dipole Antenna

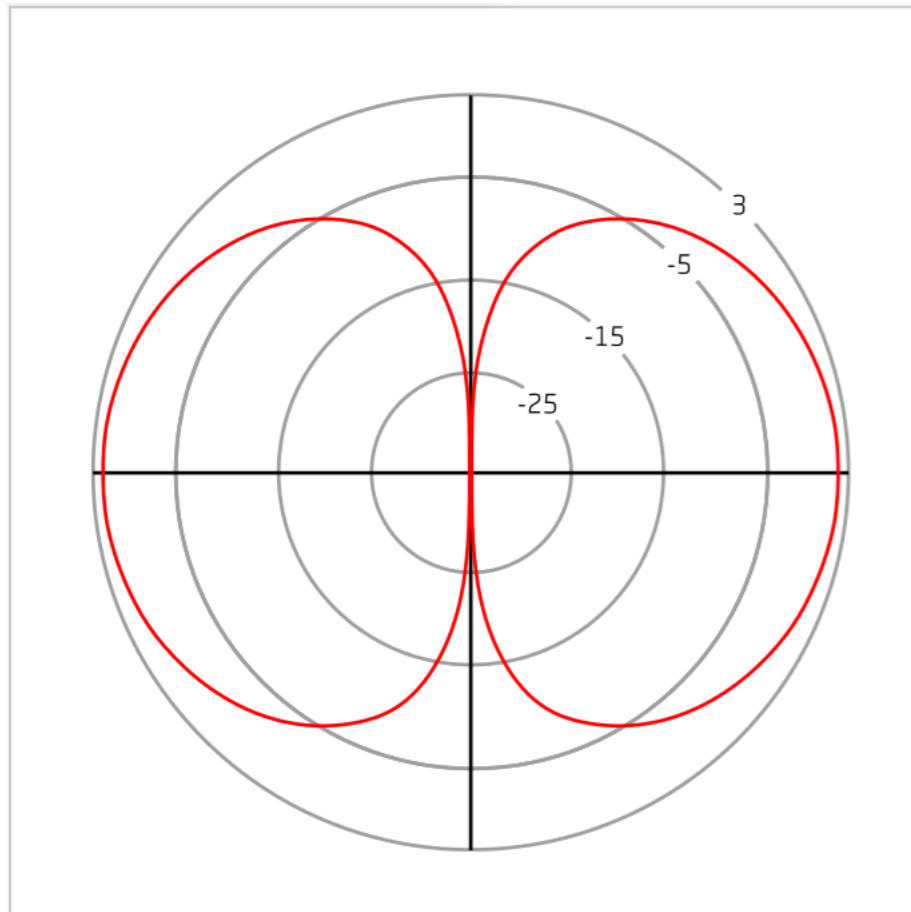
- Oscillating electric field propagates away from antenna



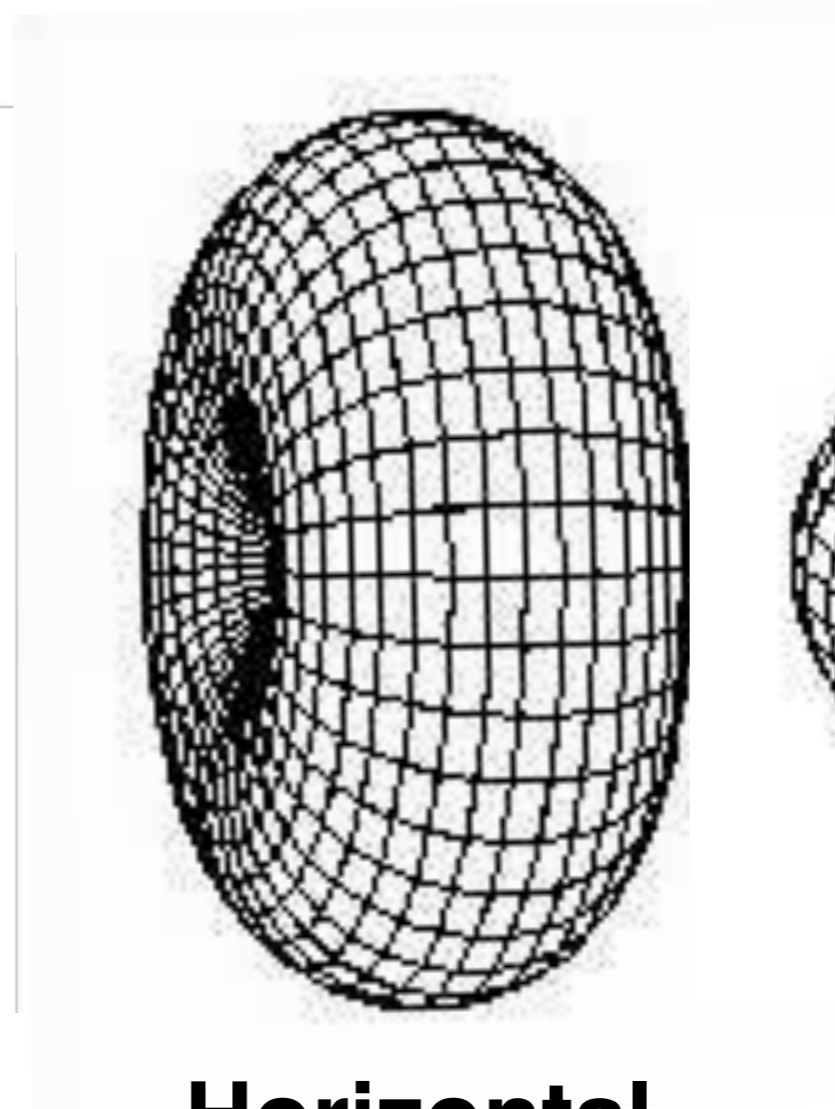
Dipole Antenna

- Length is $1/2$ wavelength of the transmit carrier frequency
- For 150 MHz one wavelength is 2 m, and the antenna should be 1 m long
- For 450 MHz, one wavelength is 67 cm, and the antenna should be 33 cm long

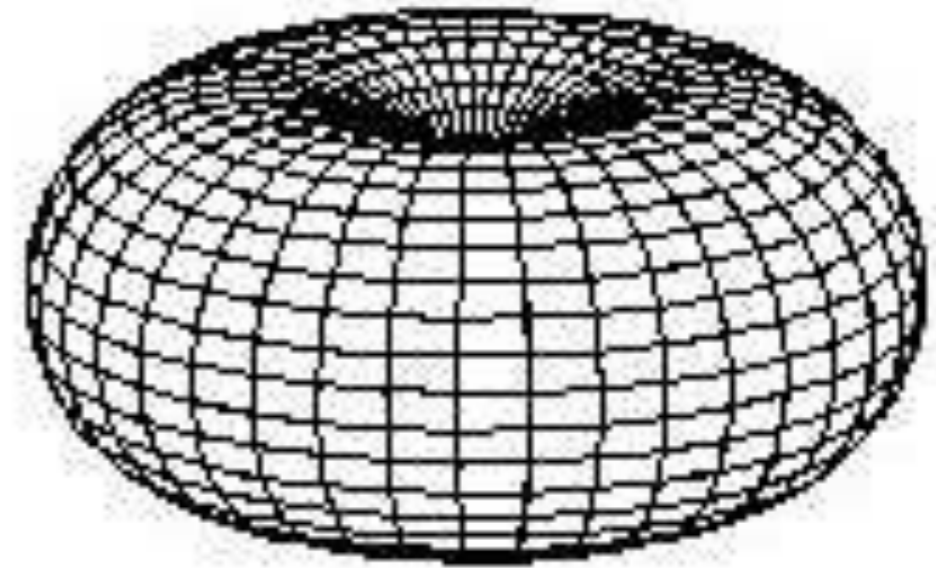
Dipole Radiation Pattern



Horizontal



Horizontal



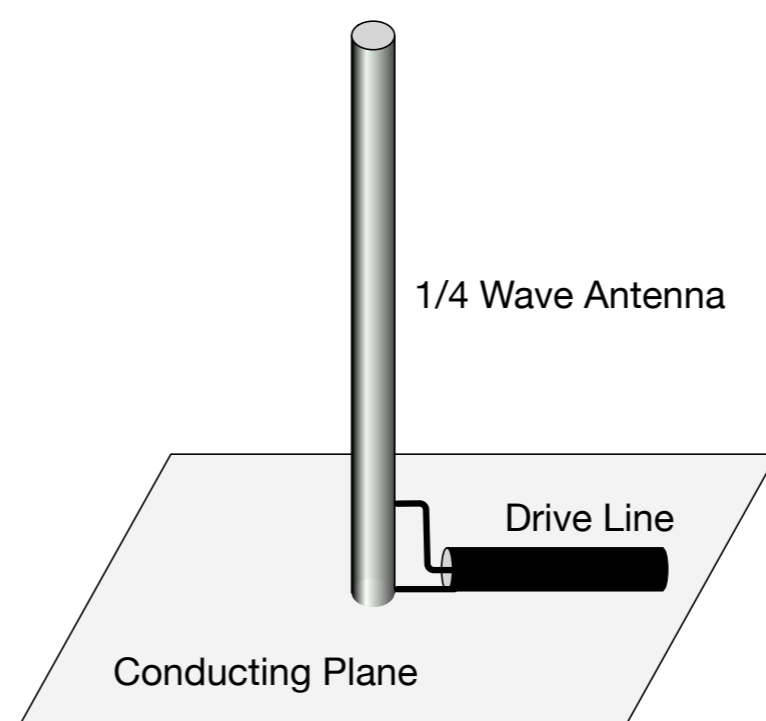
Vertical

Polarization

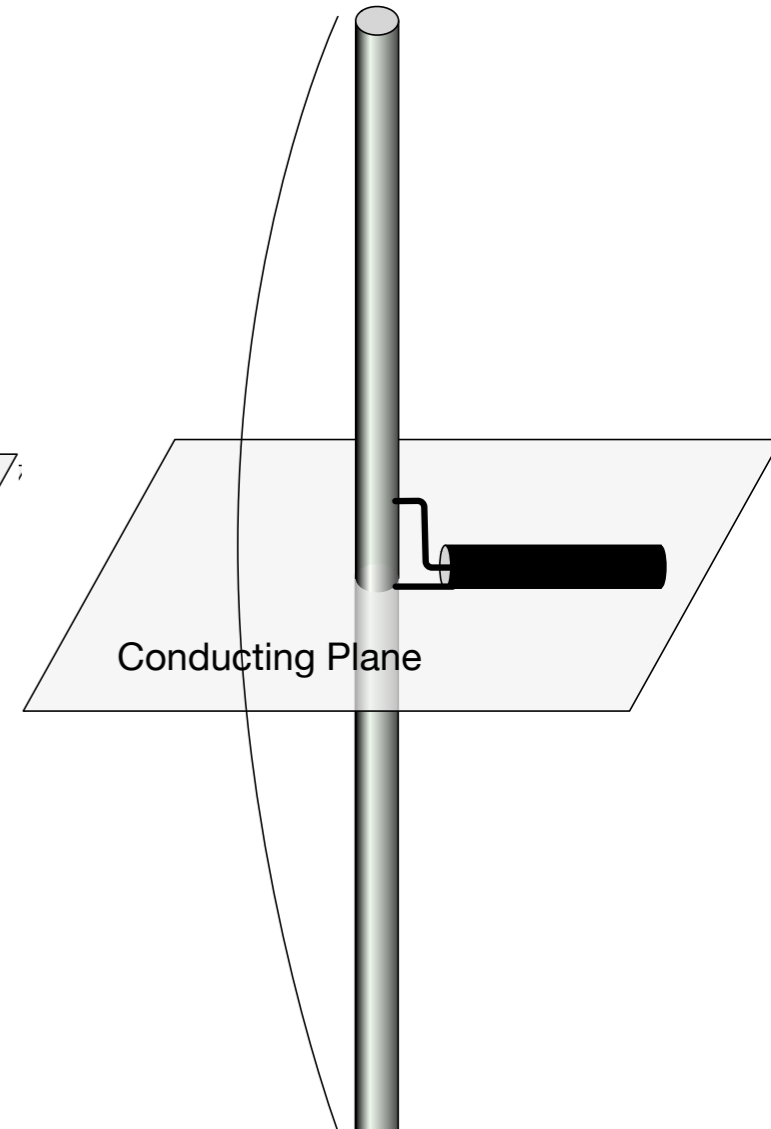
- Polarization is the direction of the electric field (horizontal, vertical, circular)
- A horizontal dipole has a horizontal polarization
- A vertical dipole has a vertical polarization
- If the transmitting and receiving antennas have different polarizations, there can be a very large signal loss

1/4 Wave Vertical Antennas

- Conducting surfaces (the earth, your car roof) act as current mirrors
- You get the second half of the antenna for free!

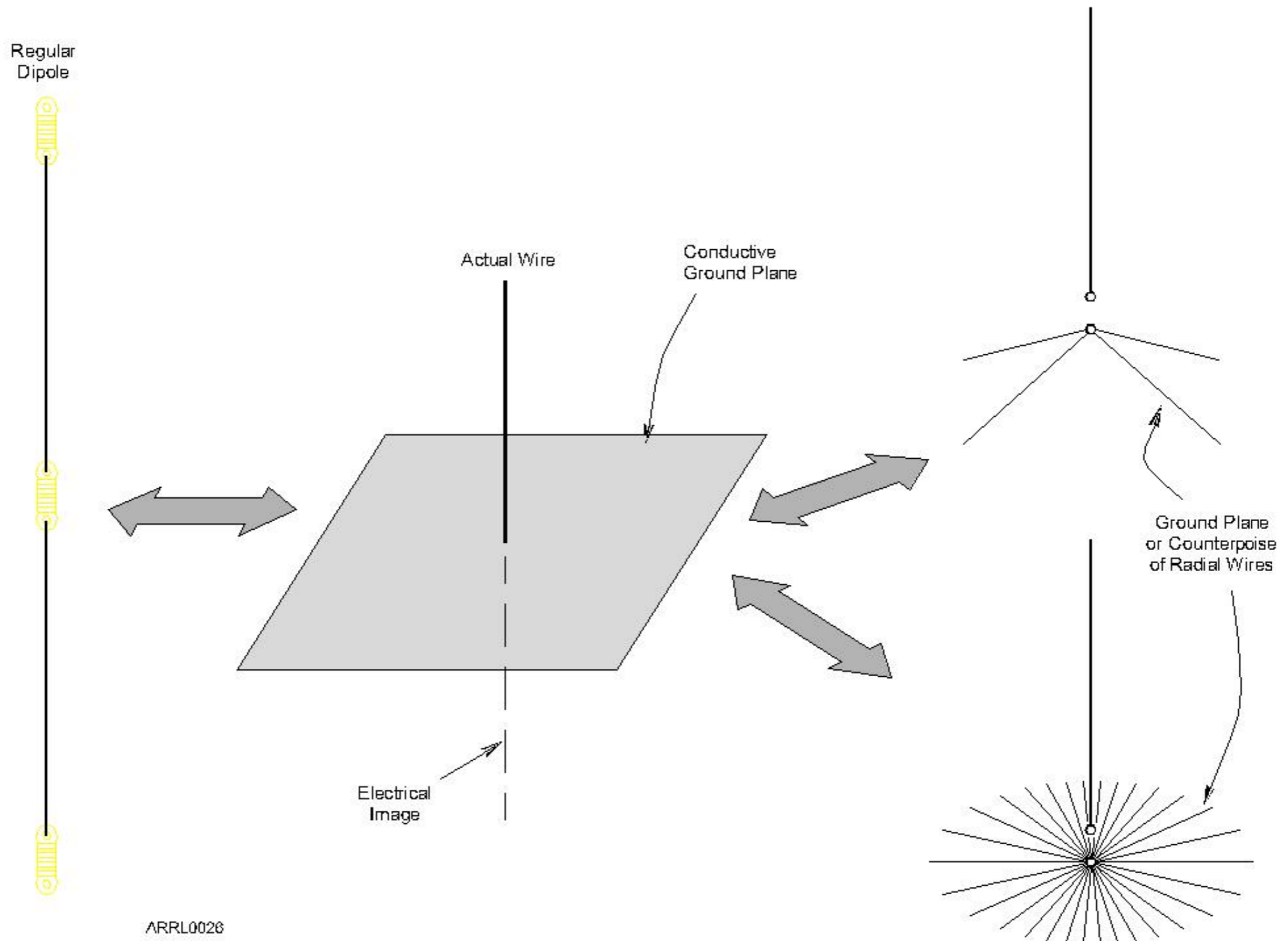


Antenna above
Conducting Plane

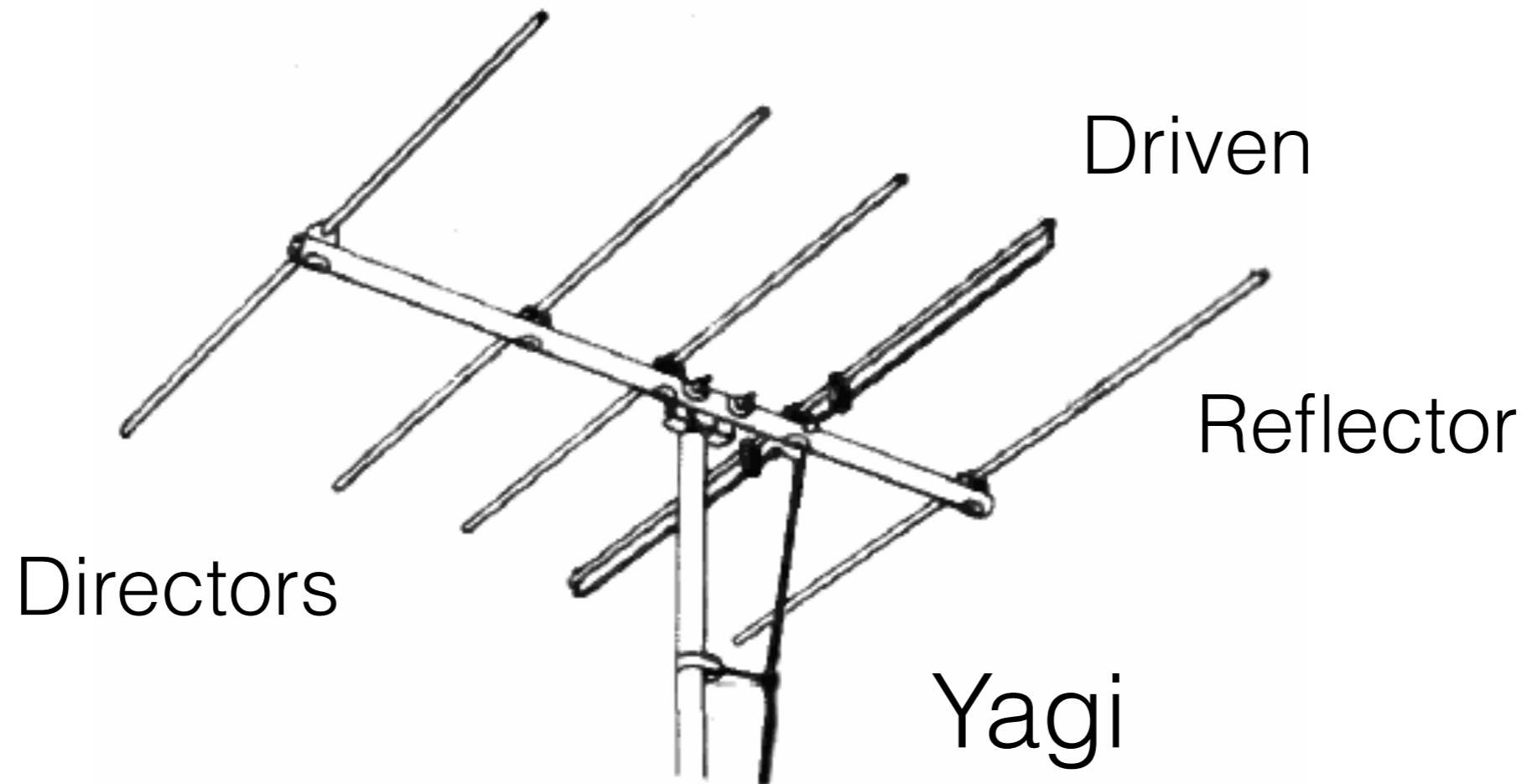


Effective Antenna

1/4 Wave Antennas

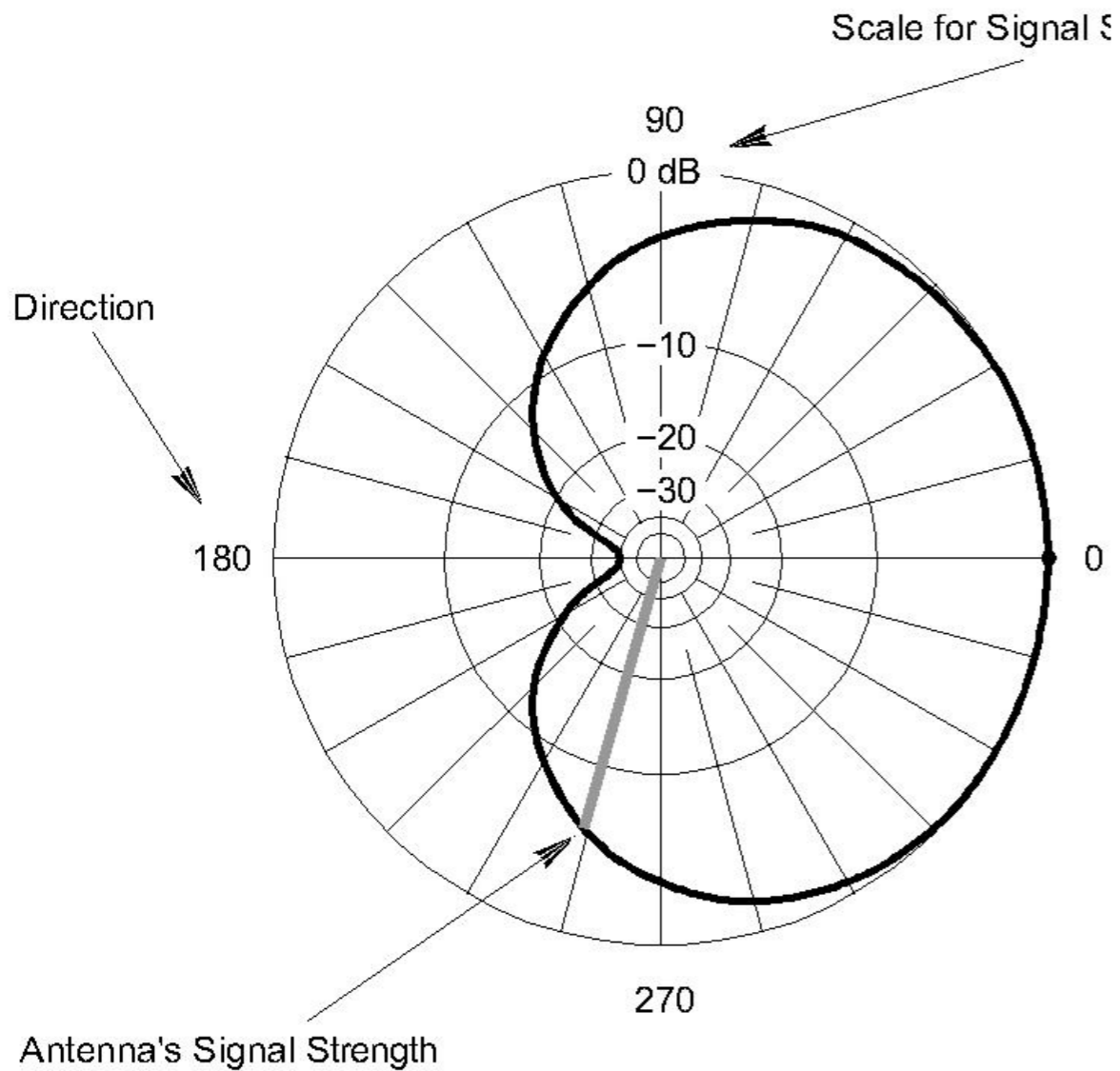


Beam Antennas



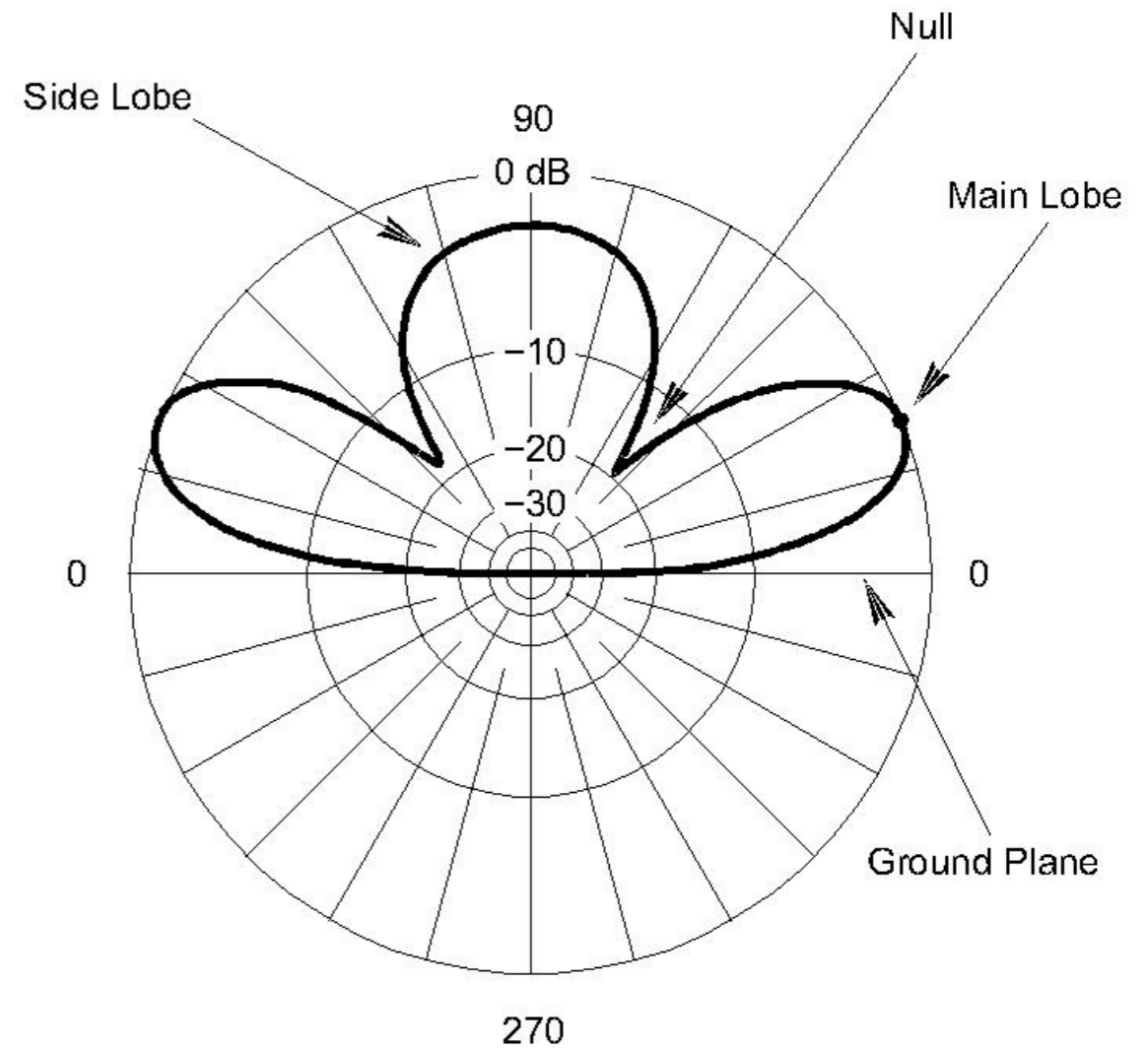
- Generally one driven element
- Directors to focus energy forward
- Reflectors to cancel out pattern to the rear

Radiation Patterns



Azimuthal Pattern

A



Elevation Pattern

ARRL0018

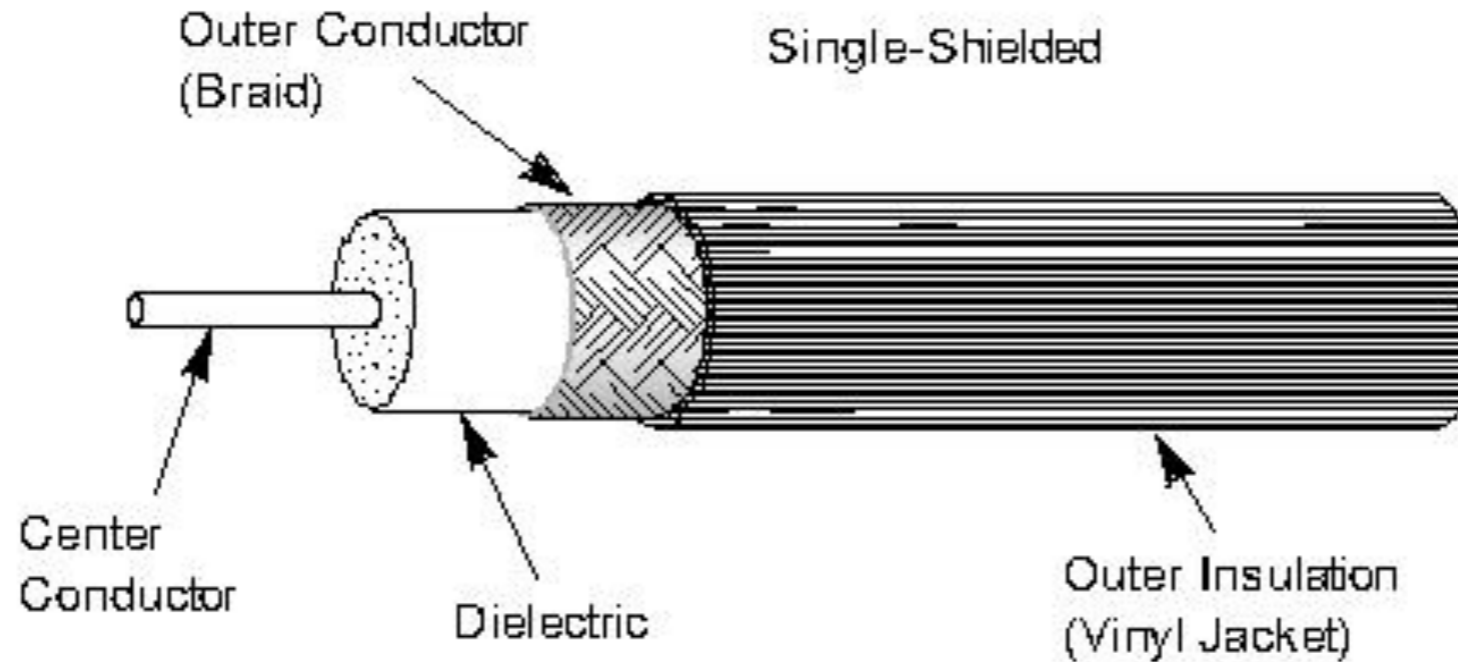
Feed Lines

- Balun
- Duplexer
- Antenna switch
- SWR meter
- Antenna analyzer
- Antenna tuner

Types of Coax

- RG-58 : most common
- RG-8 : low loss, large
- RG-8x : between RG-58 and RG-8 in size and loss
- RG-213 : low loss, large
- RG-174: micro coax, high loss
- Hardline : very low loss

Coax



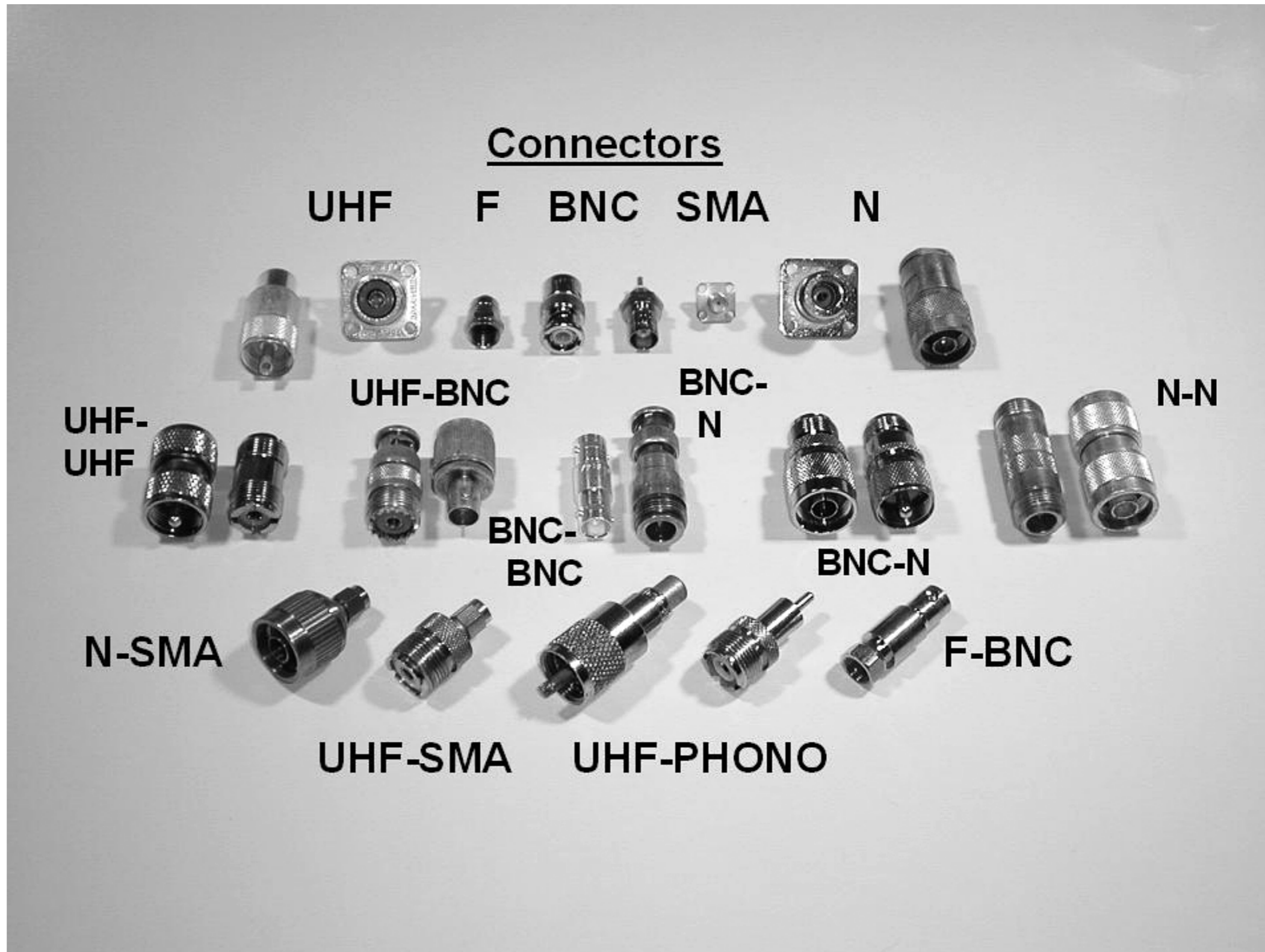
- Most common feed lines
- Commonly 50 Ohm impedance (there are others)
- Loss depends on frequency (in dB/100 ft)

Coax Cable Loss

Type	Impedance	Loss @ 30 MHz (dB/100ft)	Loss @150 MHz (dB/100ft)
RG-8	50	1.1	2.5
RG-58	50	2.5	5.6
RG-174	50	4.6	10.3
RG-213	50	1.1	2.5

Connectors

- SO-259, UHF
Common for HF
Up to 450 MHz
- N
Common
above 400 MHz
- BNC
up to GHz
- SMA
GHz and above



Connectors



UHF
HF, low VHF



BNC
up to 1 GHz



SMA
1 GHz and up

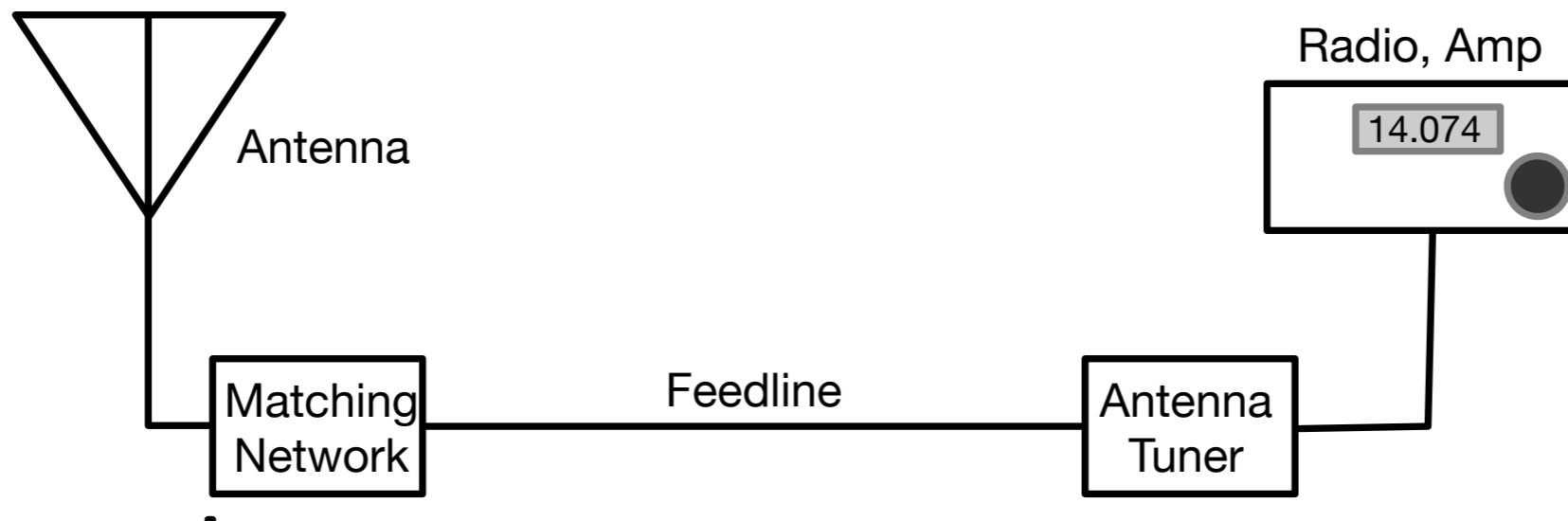
Connection to the Antenna

- Ideally, all the power from the feed line ends up in the antenna
- The feed line impedance and the antenna input impedance should be matched
- If the impedances are mismatched, some of the power is reflected back to the amplifier
 - Reduces transmit power
 - Increases line losses
 - Reduces amplifier output, can damage the amplifier

Standing Wave Ratio (SWR)

- Ratio of total to forward power
- Always in the form $X:1$, where X is greater than 1
- Perfect SWR is 1:1
- Semiconductor amps begin to have trouble at SWR of 2:1

Antenna Matching



- Matching Network : part of the antenna
 - Makes sure the antenna can accept the power from the feed line
- Antenna Tuner : adjustable matching network
 - Doesn't really tune the antenna
 - Makes the amplifier happy
 - You can still have a large standing wave on the feedline

Antenna Tuners



Measuring Antenna Matching

- Antenna Analyzer : measures the antenna input impedance, frequency response
- SWR Meter : measures SWR, forward and reflected power



Radios

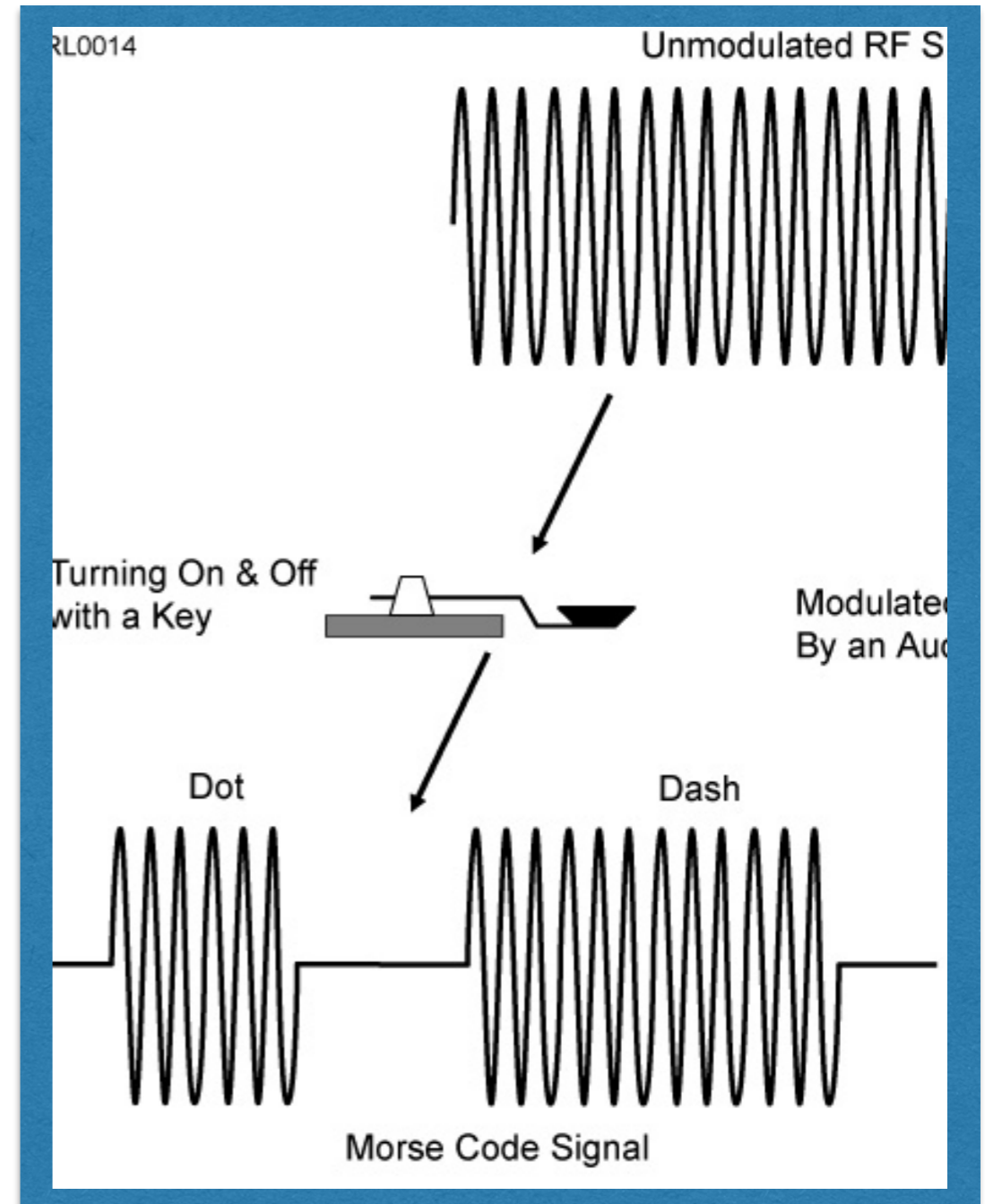
- Common Modulation Methods
- Signal Bandwidths
- Desktop, Mobile, and Handheld Radios

Types of Modulation

- Information is encoded in different ways
 - Morse Code (CW)
 - Amplitude Modulation (AM)
 - Frequency Modulation (FM)
 - Phase modulation (PM)
 - Many others

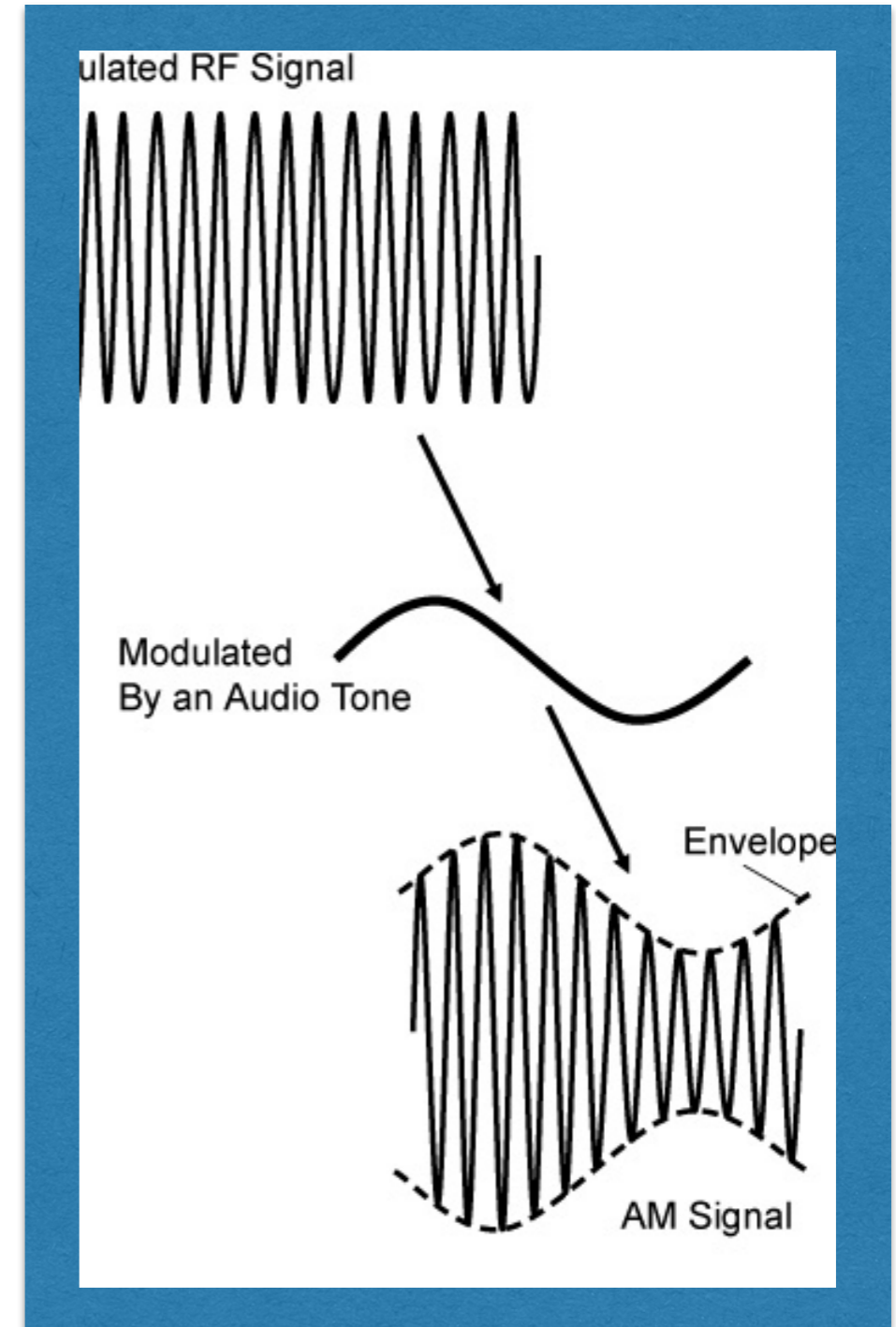
CW (Morse Code)

- Sequence of Dots and Dashes
- A continuous carrier is gated on and off



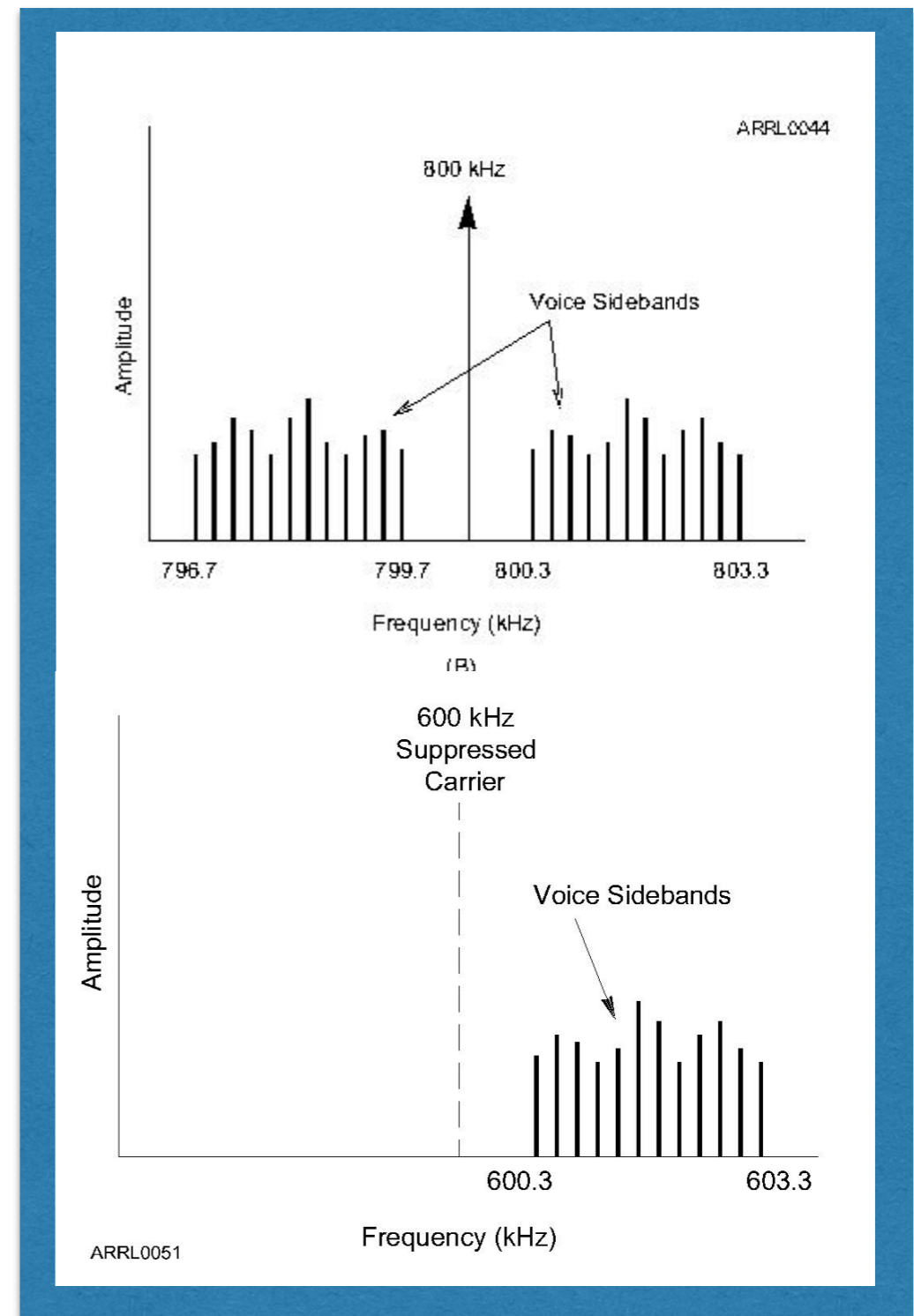
Amplitude Modulation (AM)

- The amplitude of a carrier is modulated (multiplied) by the signal we want to transmit.
- Several variations



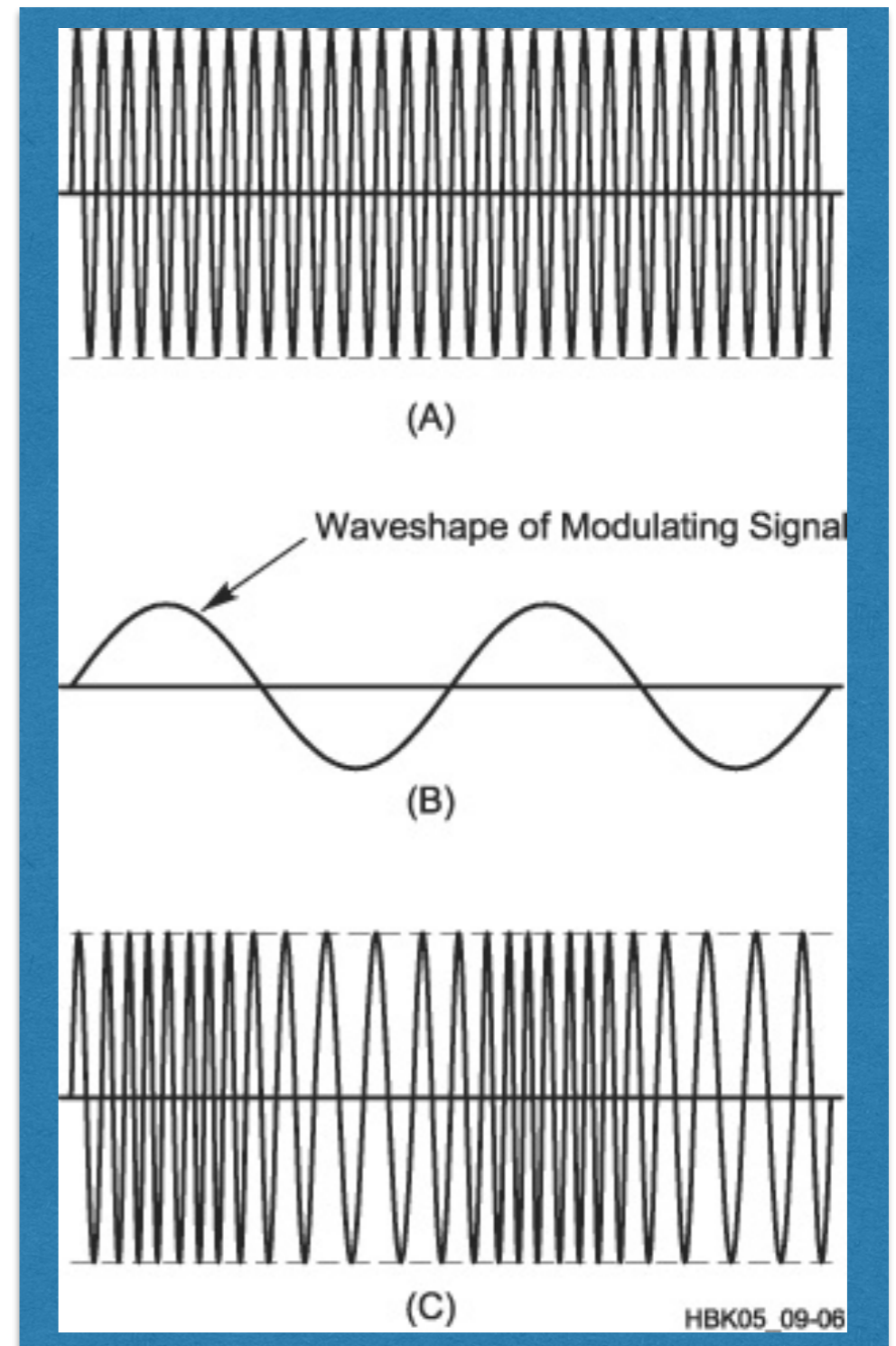
AM Signal Spectrum

- Carrier
- Upper side band (USB)
- Lower side band (LSB)
- Either sideband sufficient
- Voice bandwidth 300 Hz to 3 kHz, full bandwidth 6 kHz
- With SSB need 3 kHz
- Common for HF
Also weak signal VHF, UHF



Frequency Modulation

- Information encoded in frequency of carrier
- Wider bandwidth than AM
Voice 5-15 kHz
- More resistant to propagation effects
- Common for VHF/UHF handhelds and mobiles
- Also digital packet, voice



Typical Questions

- Why should you not set your transmit frequency to be exactly at the edge of an amateur band or sub-band? (T1B09)
- What might be the problem if a repeater user says your transmissions are breaking up on voice peaks? (T2B05)
- Which type of modulation is most commonly used for VHF and UHF voice repeaters? (T8A04)
- Which type of voice modulation is most often used for long-distance or weak signal contacts on the VHF and UHF bands? (T8A03)

Signal Bandwidths

Signal Type	Bandwidth
AM Voice	6 kHz
AM Broadcast	10 kHz
Commercial Video	6 MHz
SSB Voice	3 kHz
SSB Digital	0.5-3 kHz
CW (Morse Code)	150 Hz
FM Voice	5-15 kHz
FM Broadcast	150 kHz

Which of the following types of emission has the narrowest bandwidth? (T8A05)

A. FM voice

B. SSB voice

C. CW

D. Slow-scan TV

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Which sideband is normally used for 10 meter HF, VHF and UHF single-sideband communications? (T8A06)

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

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Remember “USB above 10 MHz”

What is the primary advantage of single sideband over FM for voice transmissions? (T8A07)

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

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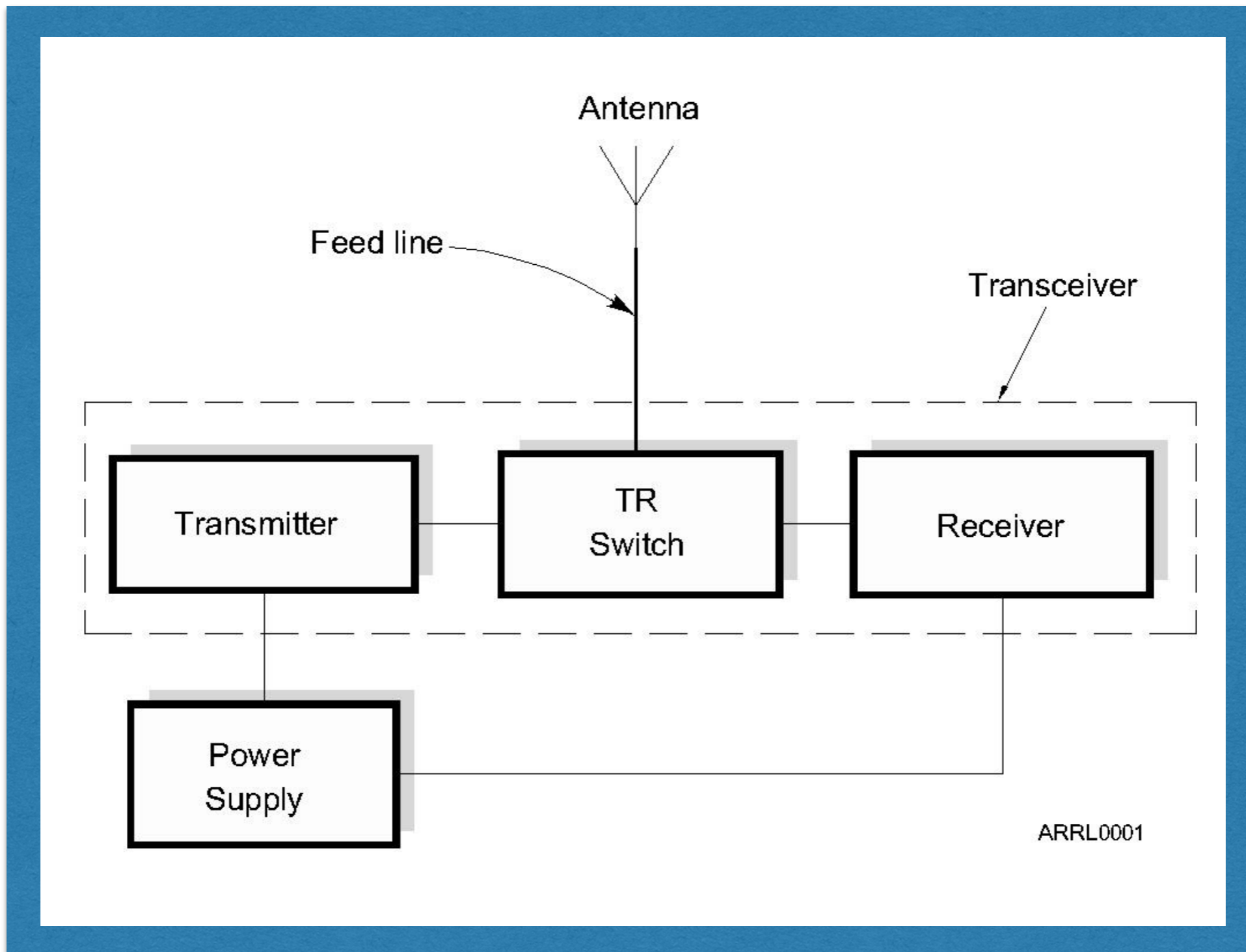
Other Questions

- What is the approximate bandwidth of a single sideband voice signal? (T8A08)
- What is the approximate bandwidth of a VHF repeater FM phone signal? (T8A09)
- What is the typical bandwidth of analog fast-scan TV transmissions on the 70 cm band? (T8A10)
- What is the approximate maximum bandwidth required to transmit a CW signal? (T8A11)

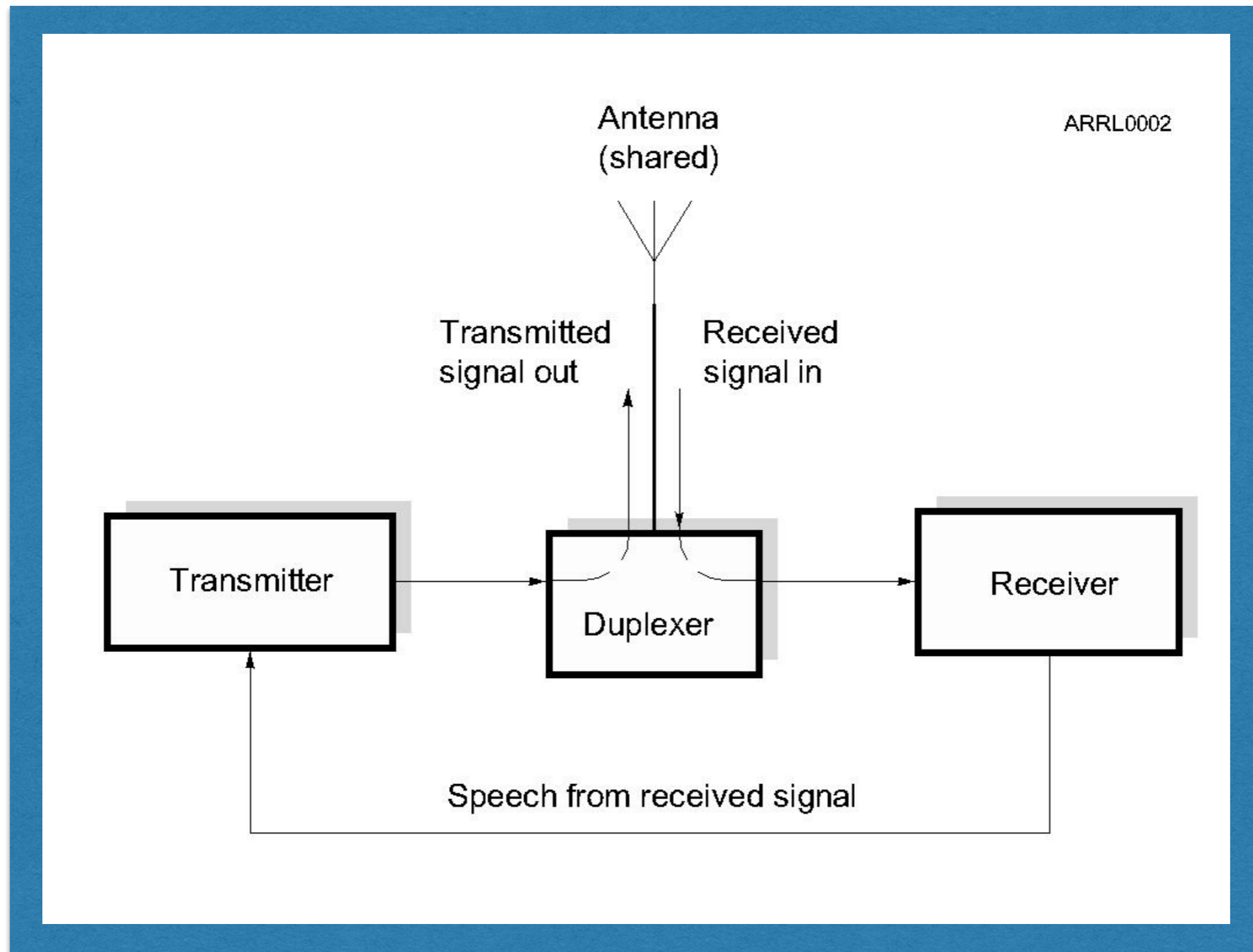
Radios

- Desktop Radios :
 - Many modes, complex
 - Mostly HF, 100W + Power Amps
- Mobile
 - FM, one or more bands
 - 50 W
- Handheld
 - FM, one or more bands, 5W
 - Simple, but lots of options

Basic Radio Components



Repeaters



Desktop Radio

- HF, may have VHF, UHF
- Lots of modes (FM, SSB, Digital Voice and Data)
- 100 Watts (+ power amps to 1500 W)



Mobile Radio

- Car or fixed
- One, two, more bands
VHF, UHF
- 50 Watts
- Always FM, may have
digital voice, data



Handheld Radios

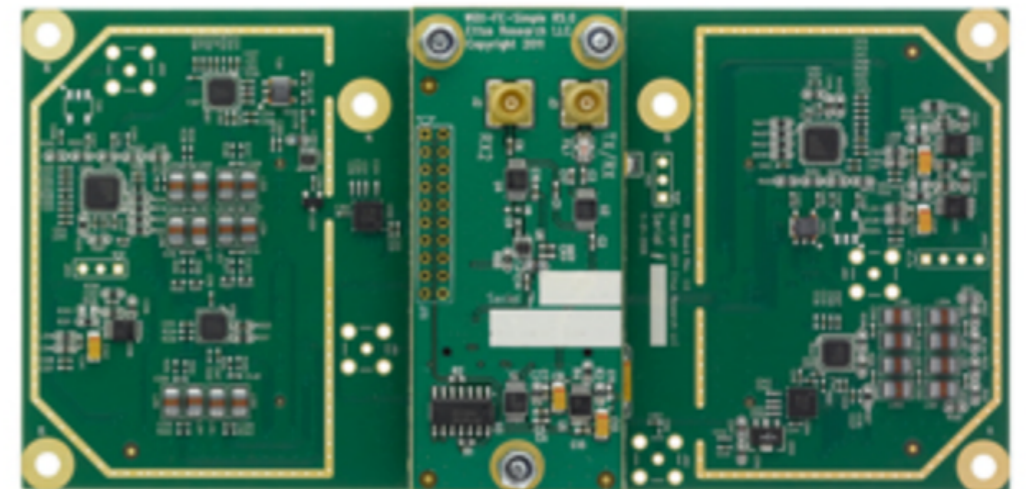
- VHF and/or UHF
sometimes 220 MHz, 1.2 GHz
- 5 Watts
- Always has FM, may have digital voice and data
- Can be complex to operate
Every button does three things
Programmed with a PC, software



SDR's

- Software defined radios
- USB peripheral
- Chassis + TX/RX daughtercards
- Direct digital synthesis and detection
- Needs amp, antenna, PC

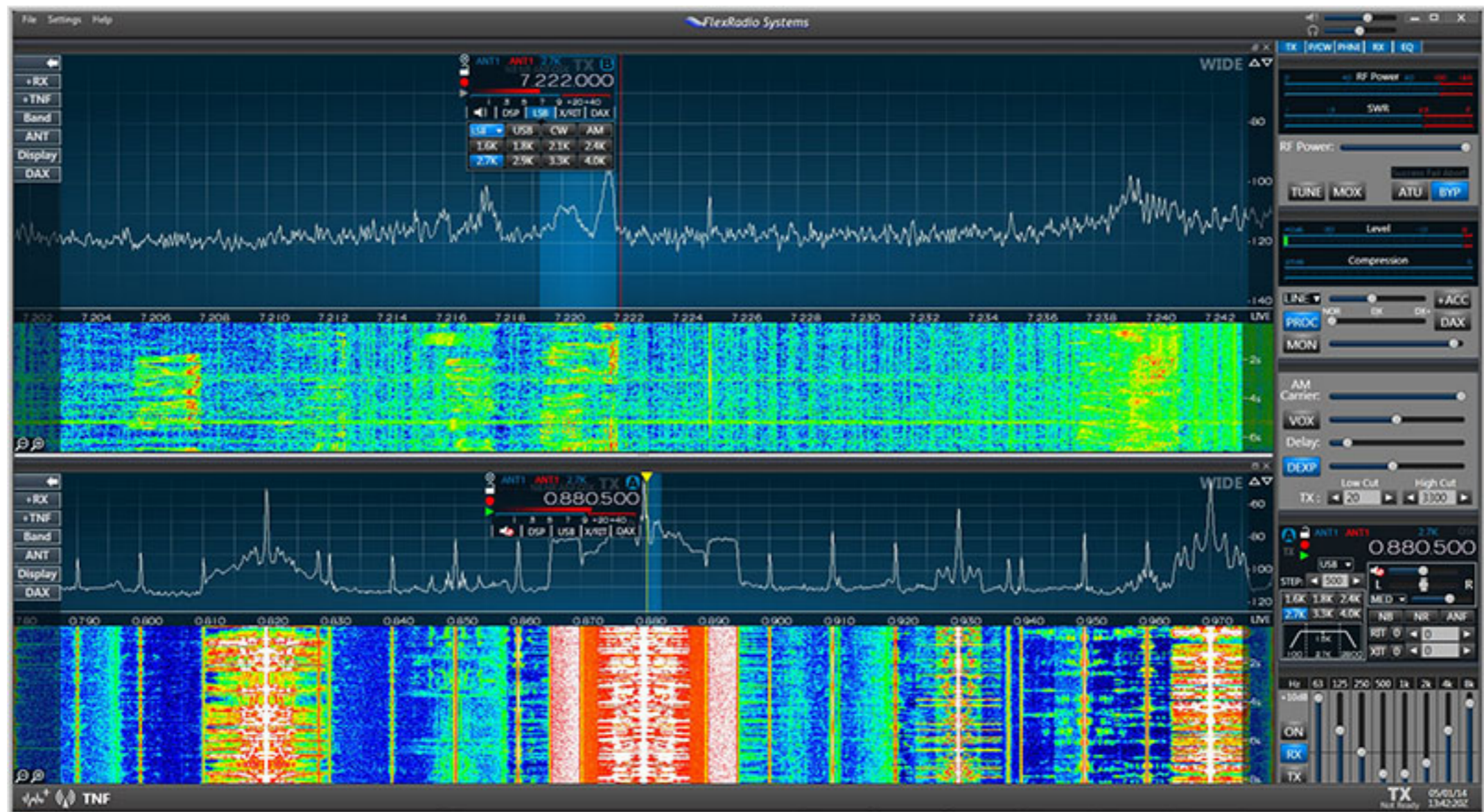
Ettus B100



WRX : 50 MHz to 2.2 GHz



Flex Radio



Major Transmitter Controls

- Tuning (VFO Dial, numeric input)
- Mode switch (FM, SSB, etc)
- Microphone : push-to-talk (PTT), voice activated (VOX), key
- Automatic level control
- Morse key



Modes

VFO

Major Receiver Controls

- Tuning (VFO dial, numeric input)
May be independent of transmit
- Automatic gain control (AGC), but not for FM
- Squelch control : shuts off speaker if signal too low
Common for FM
- Noise filters : match bandwidth of signal, suppress adjacent signals, blank spike noise
- Signal strength meter : S-meter from 1-9, with additional steps. Log scale with 6 dB per S unit (factor of 4 in power)

Filter

S-Meter



Squelch

AGC

Filter

VFO

What term describes the use of a sub-audible tone transmitted along with normal voice audio to open the squelch of a receiver (T2B02)

- A. Carrier squelch
- B. Tone burst
- C. DTMF
- D. CTCSS

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D. **CTCSS**

or PL code

What is the advantage of having multiple receive bandwidth choices on a multimode transceiver? (T4B08)

- A. Permits monitoring several modes at once
- B. Permits noise or interference reduction by selecting a bandwidth matching the mode
- C. Increases the number of frequencies that can be stored in memory
- D. Increases the amount of offset between receive and transmit frequencies

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Which of the following receive filter bandwidths provides the best signal-to-noise ratio for SSB reception? (T4B10)

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- B. 1000 Hz
- C. 2400 Hz
- D. 5000 Hz

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What can you do if you are told your FM handheld or mobile transceiver is over deviating? (T7B01)

- A. Talk louder into the microphone
- B. Let the transceiver cool off
- C. Change to a higher power level
- D. Talk farther away from the microphone

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Questions?