An Introduction to Radio Frequency Interference

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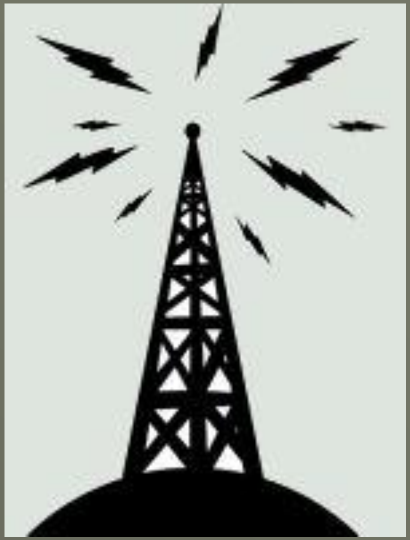
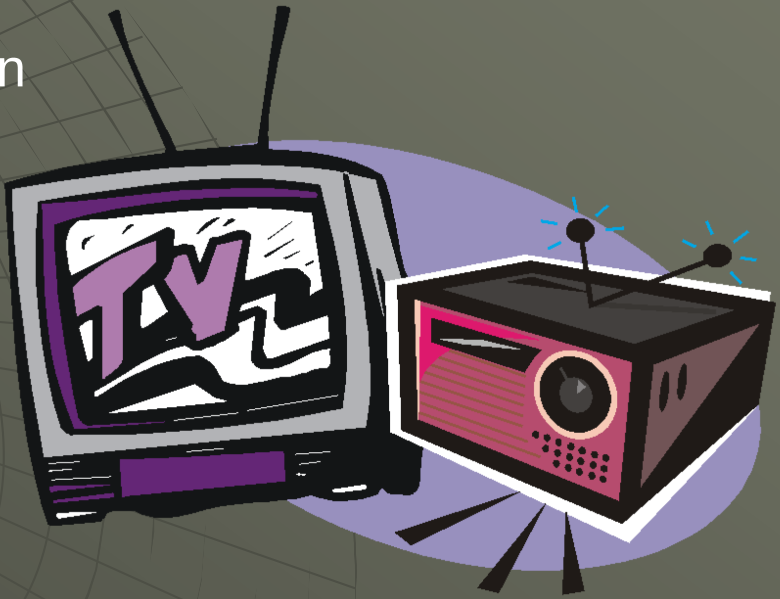
What is RFI?



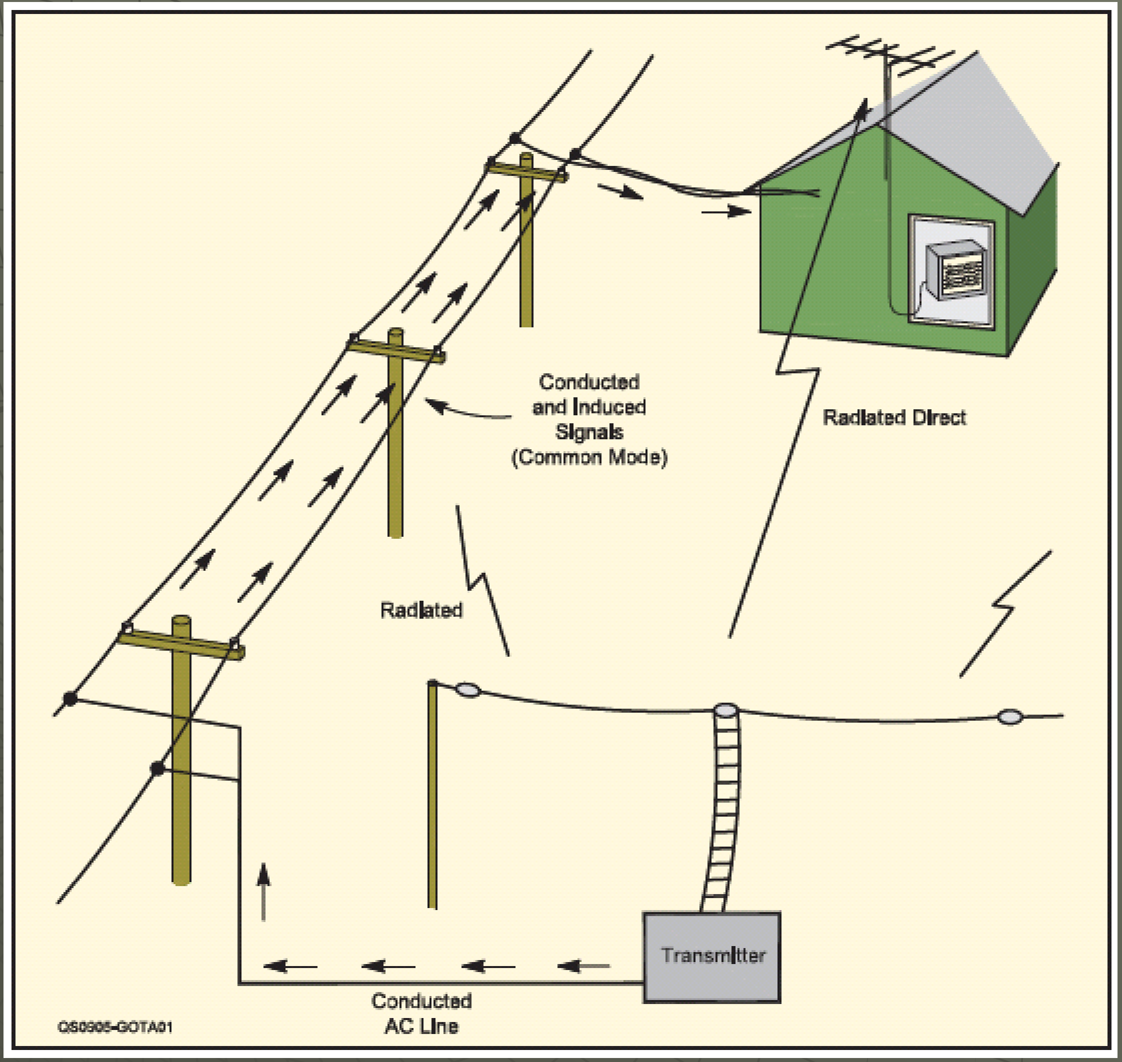
- RFI is an abbreviation for *radio frequency interference*
    - *Radio frequency* (RF): That part of the electromagnetic spectrum from a few kilohertz to just below the frequency of infrared light
    - *Interference*: Any unwanted interaction between electronic systems
- From a ham radio perspective, RFI can involve interference *to* amateur radio communications, or interference *from* amateur radio communications
- A few general types of RFI
    - Noise
    - Overload
    - Spurious emissions



How Does RFI Happen?

- Source - path - victim
  - Source of RF, transmission path, victim (device that responds to the RF)
  - Radiated and conducted RFI are common, but inductive coupling and capacitive coupling also are possible
- Differential mode versus common mode
- Types of RFI
  - Spurious emissions
  - Fundamental overload
  - External interference sources
  - Intermodulation

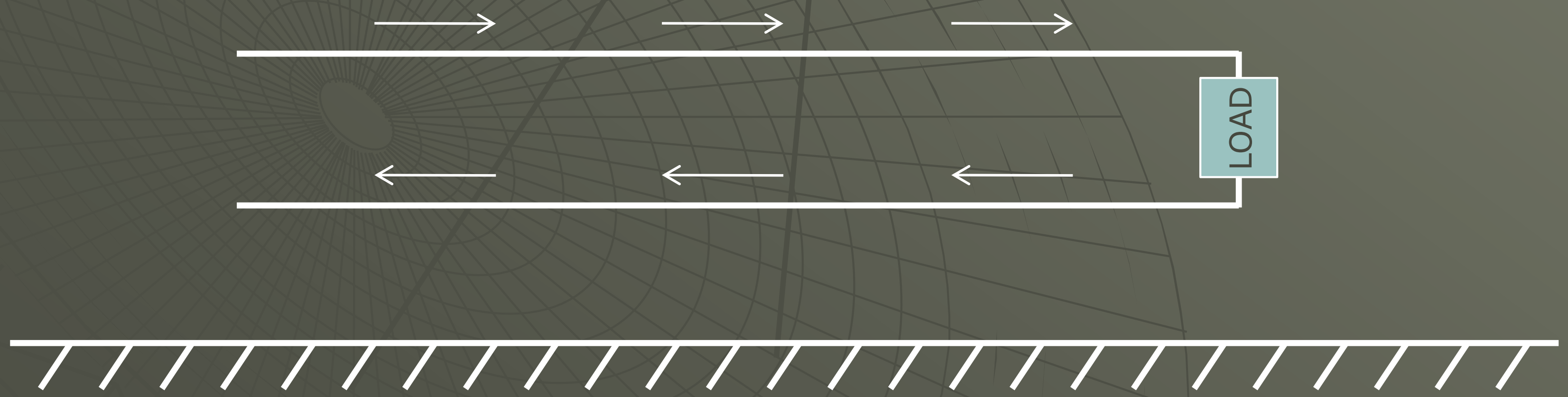
Conducted and Radiated RFI



Graphics source: ARRL

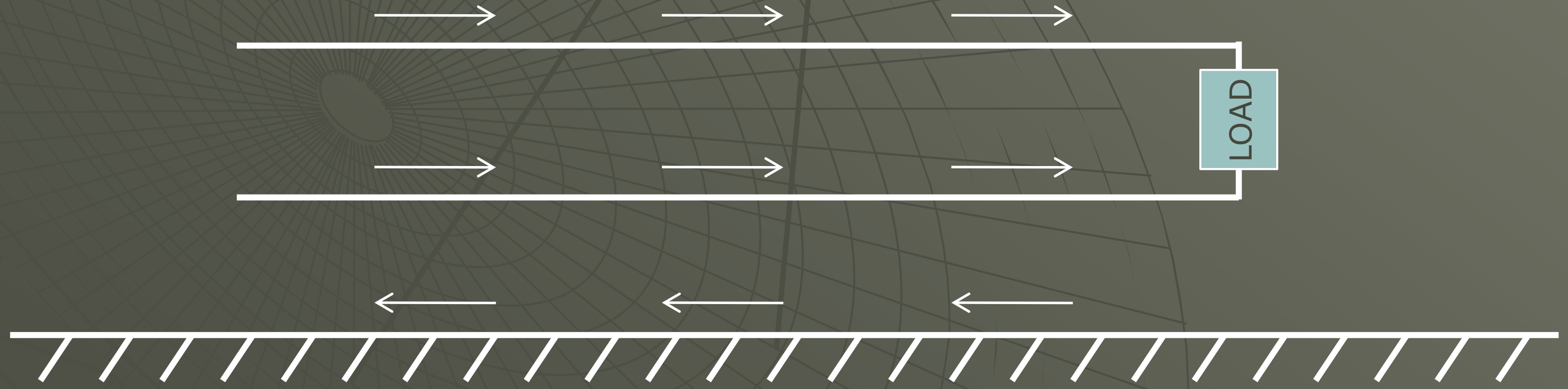
Differential Mode vs Common Mode

- A differential mode signal is one that exists between the conductors of a cable. At any given point along the cable, current flowing on one conductor is precisely balanced by current flowing in the other direction on the other conductor.



Differential Mode vs Common Mode

- A common mode signal is one that places equal voltage on all conductors—that is, the voltage between the two ends of the cable is different, but there is no voltage between the conductors. The ground reference may be the chassis, earth, etc., rather than one of the conductors.

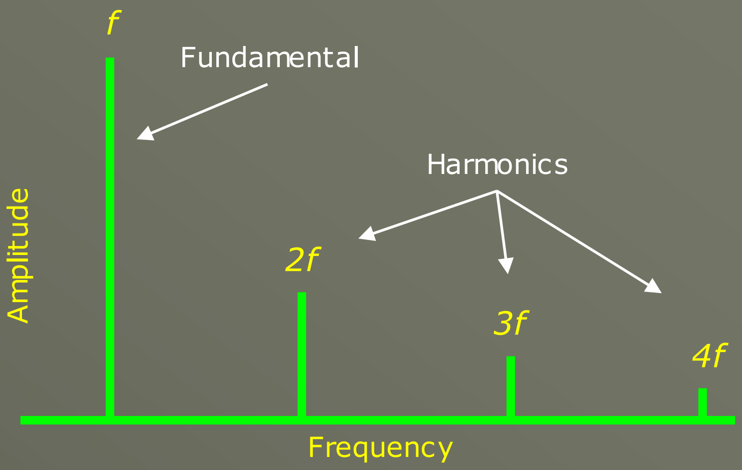


Spurious Emissions

• All transmitting equipment generates harmonics and other spurious signals to some extent, but those undesired signals are generally too weak to be a problem. But problems can happen!

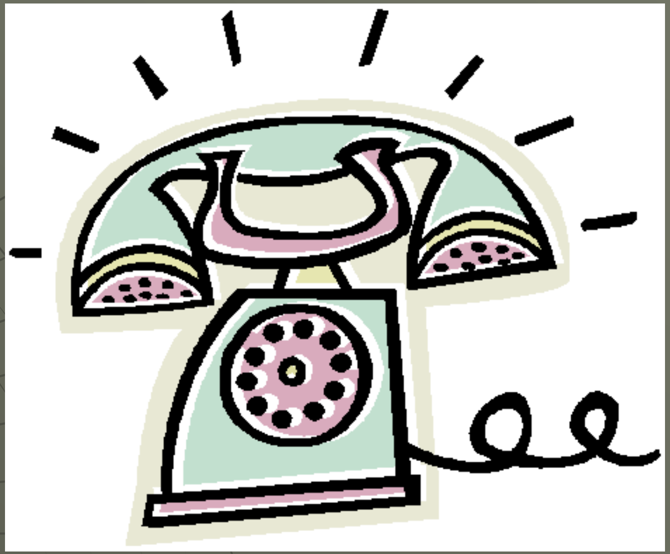
• Here's an example: Let's say your transmitter is emitting a strong second harmonic when you operate on 10 meters.

• If the transmitter's fundamental signal is at 28.4 MHz, the second harmonic is 28.4 MHz x 2 = 56.8 MHz, right in the middle of TV channel 2.



Fundamental Overload

- Most cases of interference are not caused by spurious emissions from transmitters. Rather, the interference is often caused by overload of the affected device by the transmitter's fundamental frequency.
- The affected device was likely not designed to function in the presence of strong external RF signals
- The fundamental signal can enter the device in a variety of ways, usually via wiring connected to it
- Most electronic devices and components respond to all electrical signals at their inputs, and if the input signal is too large for the device to handle, that device is overloaded

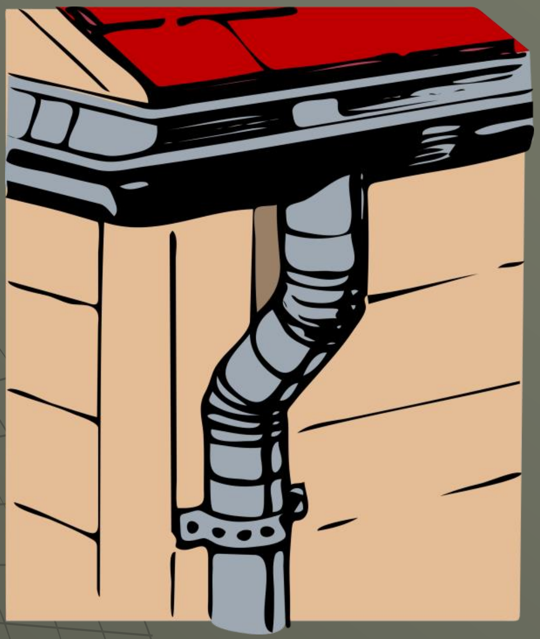


External Interference Sources

- This is a catch-all that includes interference to electronic equipment from any of a variety of sources external to the affected receiver or device
- One very common interference source is power line gap noise
- Other examples include interference from transmitters, cable TV signal leakage, telephone company DSL leakage
- Still more examples include devices such as computers, video games, switch-mode power supplies, grow lights, plasma TVs, some LEDs and CFLs

Intermodulation

- Intermodulation is a source of interference that arises from the combination of two or more signals at different frequencies in some kind of non-linear system.
- For example, you might hear strong interference at 14.1 MHz if there are two strong signals at 86.0 and 100.1 MHz that combine in a rectifying circuit such as an oxidized fence connection or rain gutter, or even in a component in the front-end of your receiver.



A Few Common RFI Sources

- Electrical interference
  - Power line, defective GFI outlets, thermostats, electric blankets, some CFL & LED bulbs, defective or poor quality lighting ballasts (e.g., grow lights), dimmers, touch lamps, arc welders
- Part 15 devices
  - Computers, monitors, home routers, switching power supplies, TVs (plasma displays are notorious sources of interference), consumer electronics devices
- Harmonics/spurious from other transmitters
- Intermodulation interference
  - Undesired mixing of two or more signals which creates even and odd order distortions
- RF interference that isn't RF interference: Hearing splatter on HF signals?
  - Try turning off the rig's noise reduction circuit. Those circuits can easily generate cross-modulation in the receiver.

MORE ON COMMON MODE INTERFERENCE

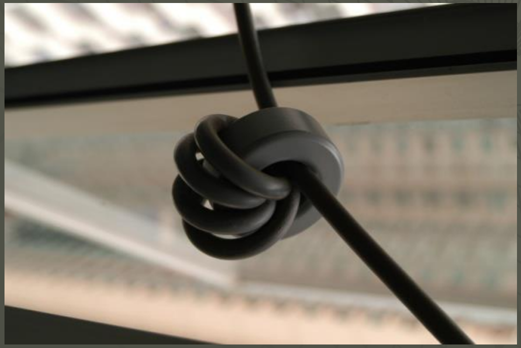
Common Mode Chokes: Your Best Friend

- Common mode chokes are VERY effective at combating common mode interference
  - Differential mode filters such as low-pass, high-pass, bandpass, and notch filters, are ineffective against common mode interference
- While a simple common mode choke can be made from multiple turns of coax—say, 10 feet of coax coiled into a 5 to 6 inch diameter multi-turn loop—the best ones make use of ferrite material in conjunction with multiple turns of wire
- For best performance, place the common mode choke as close to the affected device as possible
  - Sometimes it may be necessary to install common mode chokes on ALL conductors connected to the device

Common Mode Chokes: Your Best Friend

- #73 and #75 ferrite material work well at HF, and #43 and #61 at VHF

- An impedance of several hundred to several thousand ohms is required for best common mode choke performance



MORE ON DIFFERENTIAL MODE INTERFERENCE

AM Broadcast Band

- "I can't operate my HF rig near a local AM radio station's transmitter because I hear the AM station superimposed on desired signals. What's going on?"

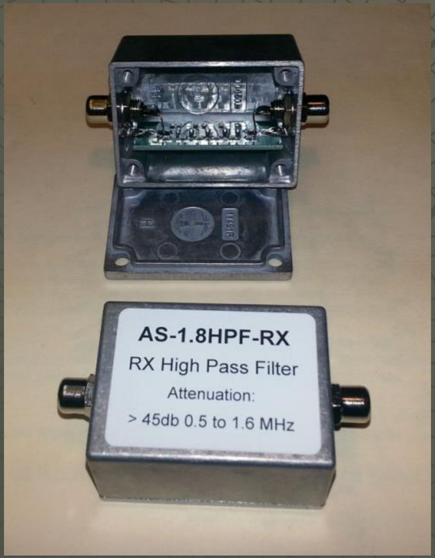
- The culprit is cross-modulation (abbreviated XMOD, and a form of intermodulation) and is most likely being generated in the diodes used for switching attenuators, filters, and other circuits in your radio.

- Switching in some attenuation may reduce or eliminate XMOD, unless the radio also uses diodes for switching the attenuator!

AM Broadcast Band

- The fix? An AM broadcast band notch filter installed in the transmission line

- Array Solutions has receive-only and transceive filters available



http://www.arraysolutions.com/

Transmitter Spurious and Harmonics

• Modern HF rigs are well-filtered, and seldom need an external low-pass filter

• If you're using an older "classic" rig or external amplifier, or maybe a homebrew rig, spurious and/or harmonic performance may not be up to par

• Several manufacturers have available legal-limit rated low-pass filters for the HF band
  - Note that many are designed to pass signals below 30 MHz, and will block the 6 meter band

Need Better Single-Band Performance?

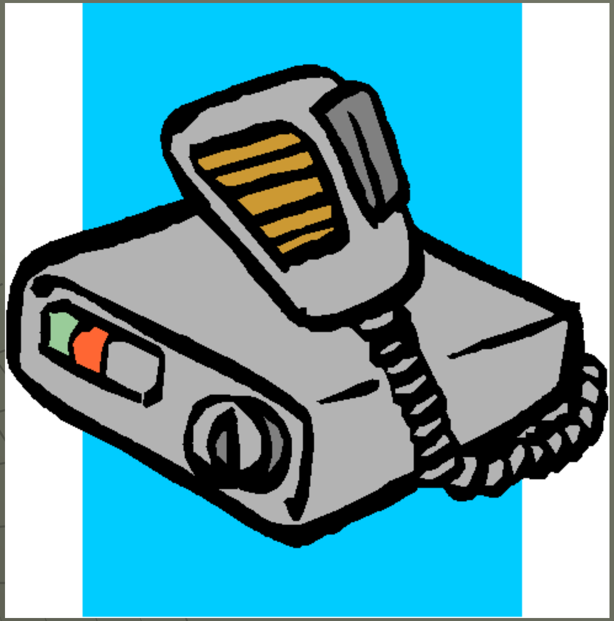
• Contest, DX, Field Day, or EOC operation often means multiple transceivers operating in close proximity

• Sometimes a transceiver is overloaded by a strong nearby out-of-band transmitter

• One solution is to install a single-band bandpass filter in the transmission line

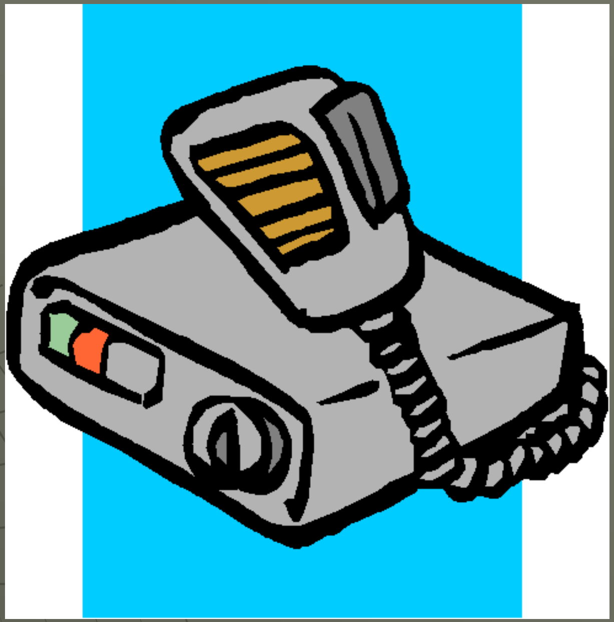
Mobile Operation

- Check with the automobile manufacturer for guidelines installing two-way radio equipment
- Antenna typically as far away from vehicle computer and electronics as possible (roof, trunk, rear bumper, etc.)
  - Some automobile glass might be passivated, and may not work well with on-glass antennas



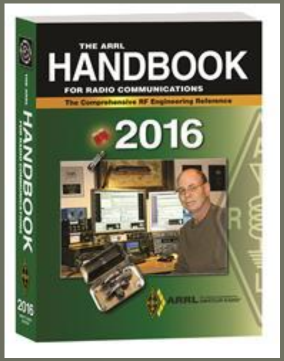
Mobile Operation

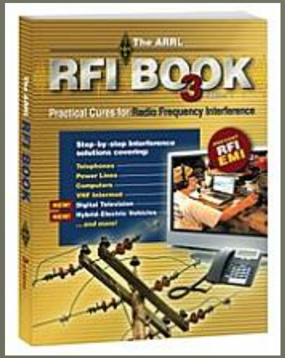
- Direct connection to battery using fused leads (both leads should be fused); route power leads away from vehicle electronics
- Good grounding to body or chassis at antenna
- Radio securely mounted (safety!), away from air bags. Do not obstruct access to instruments/controls, or external vision
- Generally unnecessary to ground the radio inside the vehicle

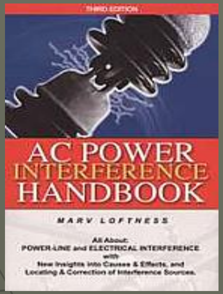


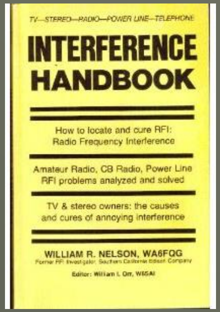
References

- *The ARRL Handbook*
- *The ARRL RFI Book, 3rd Ed.*
- *AC Power Interference Handbook, 3rd Ed*., by Marv Loftness
- *Interference Handbook*, by William R. Nelson (© 1981, Radio Publications, Inc., ISBN 0-933616-01-5)
- ARRL web site: http://www.arrl.org/radio-frequency-interference-rfi









Backup slides

λ/4 stub notch filter

- Need an easy-to-make and cheap notch filter?

- Take advantage of the impedance transformation properties of a quarter-wavelength (λ/4) tee “stub” in parallel with the transmission line

- A λ/4 tee stub that is open circuited at its far end appears short circuited at its input end. When that same stub is short-circuited at its far end, it appears open-circuited at its input end!

λ/4 stub notch filter

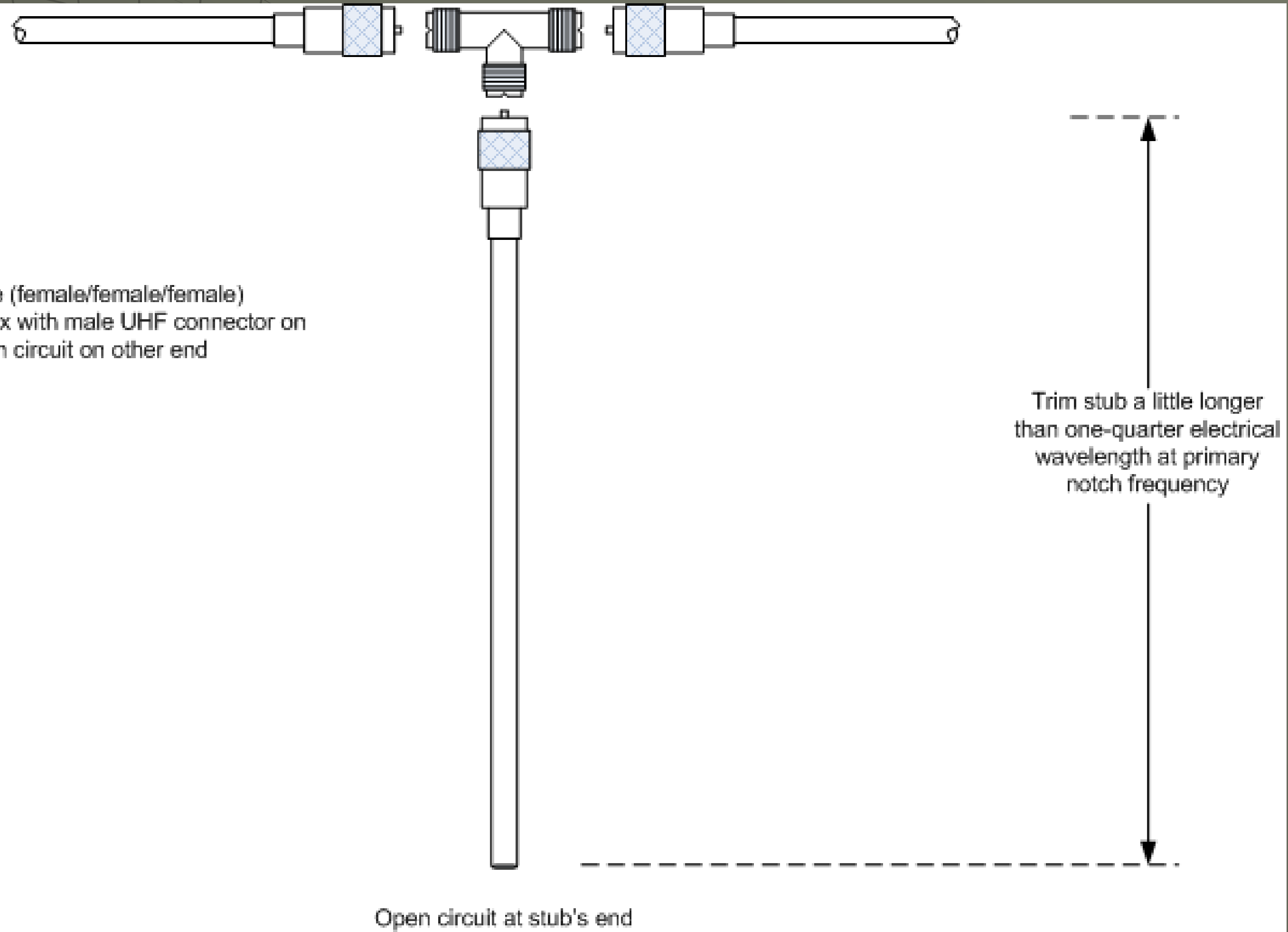
- When placed in parallel with a feedline, a *short-circuited* λ/4 tee stub has no effect at the fundamental frequency, but creates a notch at the 2nd harmonic of that frequency (and at other even-order harmonics, that is, 4th, 6th, 8th…)

- An *open-circuited* λ/4 tee stub creates a notch at the fundamental frequency (and at odd-order harmonics, that is, 3rd, 5th, 7th…)

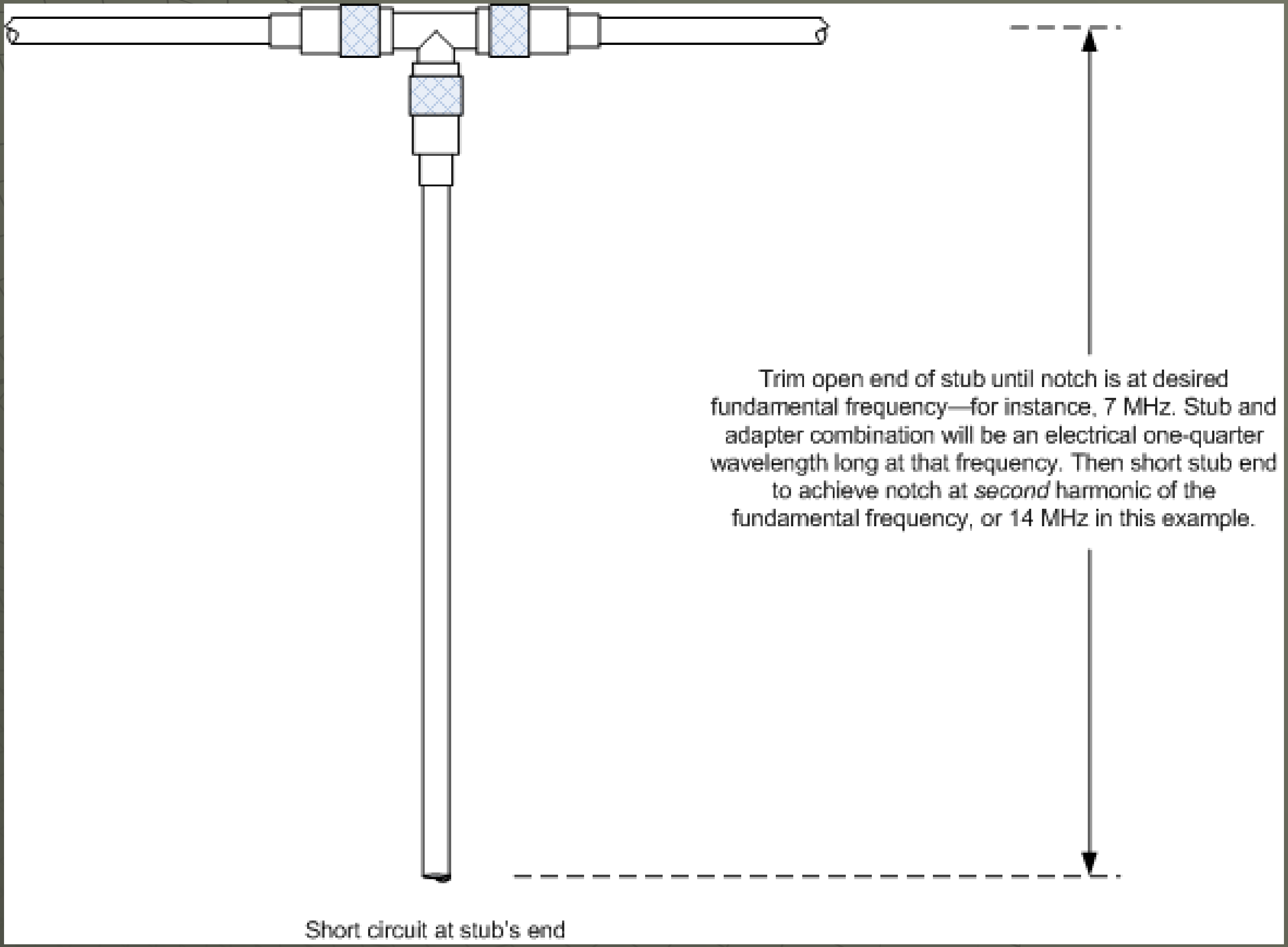
- Typical notch depth varies from 20 to 30 dB

Building a λ/4 tee stub notch filter

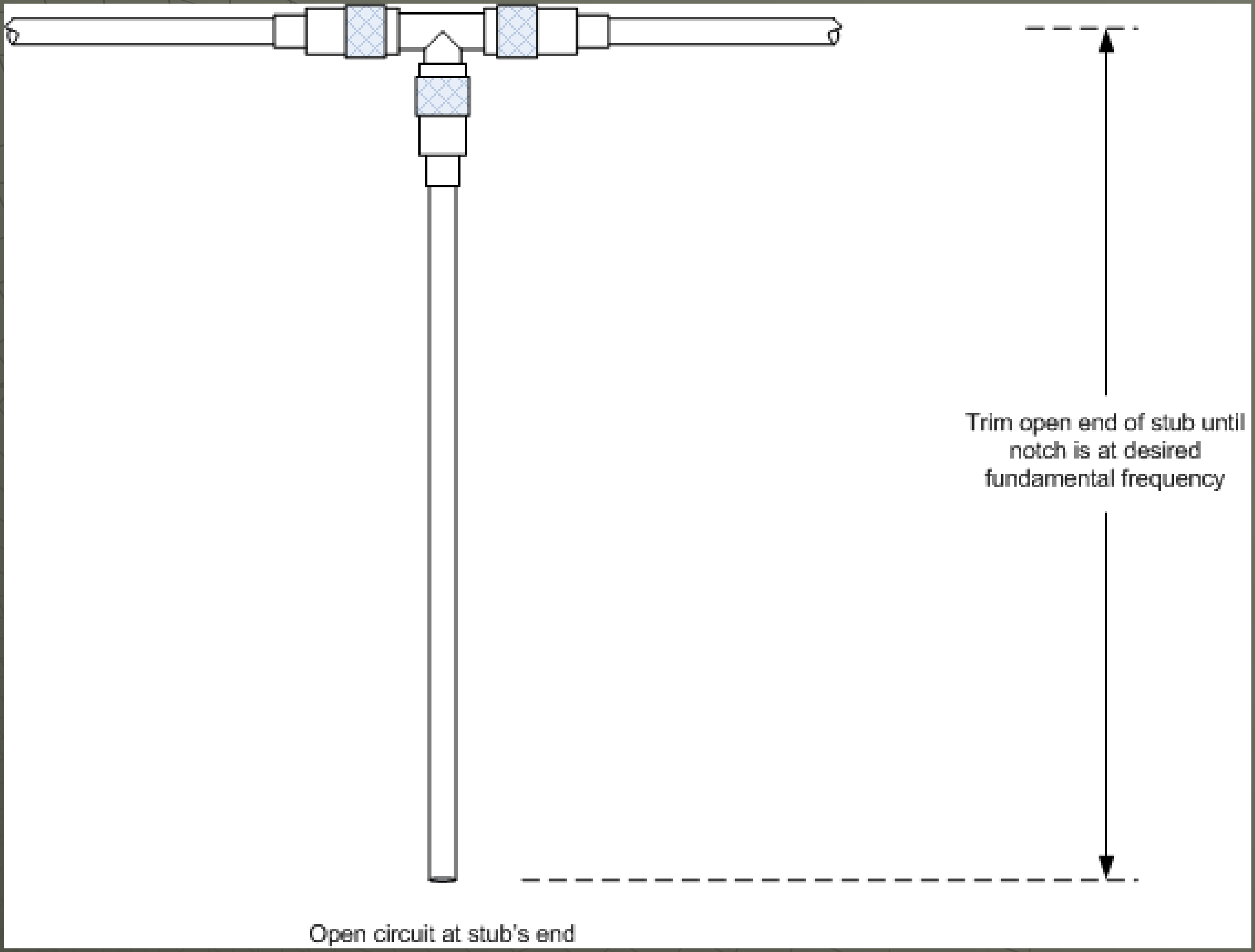
- 1 ea. UHF tee (female/female/female)
- Length of coax with male UHF connector on one end, open circuit on other end



Short-circuited tee stub notch filter



Open-circuited tee stub notch filter



Example Applications

• Harmonic suppression at a transmitter’s output (use short-circuited λ/4 stub to suppress 2^{nd} harmonic)

• Attenuate fundamental so harmonic can be observed on a spectrum analyzer (use open-circuited λ/4 stub to suppress fundamental)*

• Filter signals from nearby transmitters during a contest or Field Day operation

*Caution: Fundamental signal power should not exceed about 2 or 3 watts BEFORE the notch filter

Tips

- Use low-loss coax such as RG-8 or RG-213 for the stub to maximize notch depth

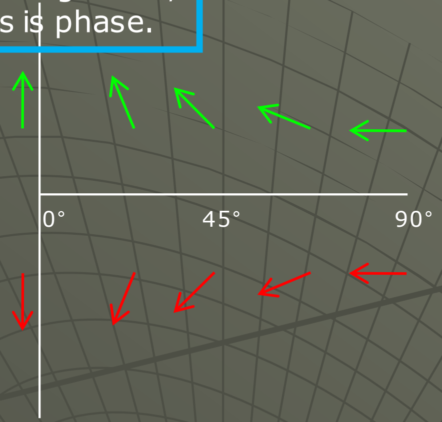
- Tee stub may be placed anywhere in feedline, even directly at transmitter output or receiver input

- Coaxial tee stub can be coiled up or left straight (protect exposed end from elements & accidental contact)

- Remember: Tee stubs create harmonic notches (odd-order for open-circuited $\lambda/4$ stubs, even-order for short-circuited $\lambda/4$ stubs)

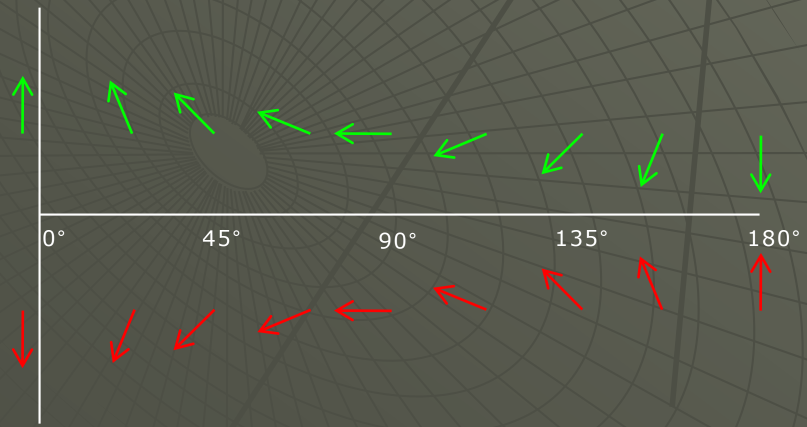
How it works

Vector (small arrow) represents the magnitude and phase of an RF signal. Arrow’s length is magnitude, direction it points is phase.



Open circuit: Reflected voltage is *in-phase* with incident voltage.

λ/4 stub at fundamental frequency



Short circuit: Reflected voltage is *out-of-phase* with incident voltage.

Original λ/4 stub is λ/2 long at 2nd harmonic