ABC's of RFI for Hams

Symptoms, Causes & Cures

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This presentation available on website

Are you the **SOURCE** of RFI?

IT'S ALL YOUR FAULT WITH THAT BIG ANTENNA!

Are you a **VICTIM** of local RFI?

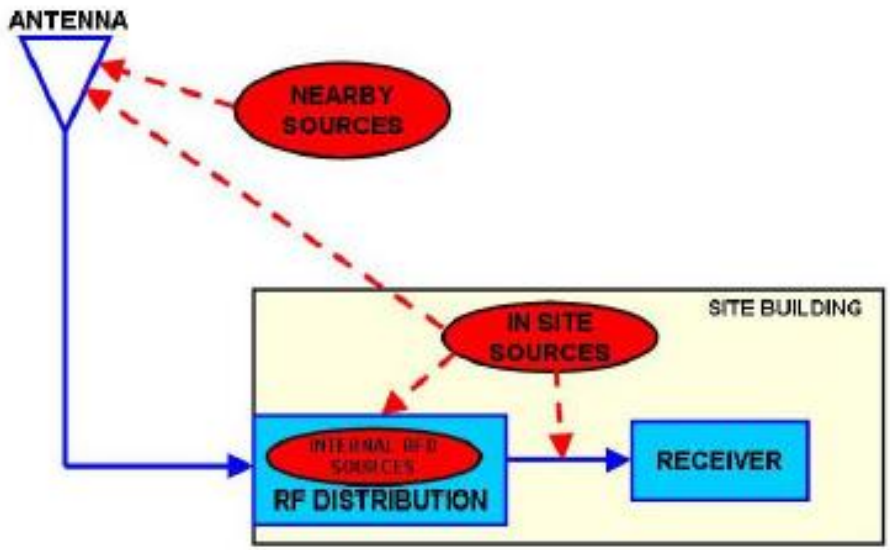


Figure 1 Block Diagram of On-Site Sources

QRN - High Noise Floor – Weak Signals – NO DX – No fun!

RFI Workshop Objectives

- Learn fundamentals of RFI - identify symptoms, pinpoint causes & apply simple cures
- What's a ferrite and how to choose & buy the right ferrite for your RFI issue
- How to use ferrites to solve the #1 RFI problem shared by all hams using HF radios
- How to use ferrites to solve transmitter RFI problems
- How to use ferrites to reduce your station noise floor
- How to keep your neighbor's and spouse happy!

Thinking cap time……

RFI 101

For Contesters, DX’ers, Rag Chewers, and Beginners too!

What is RFI?

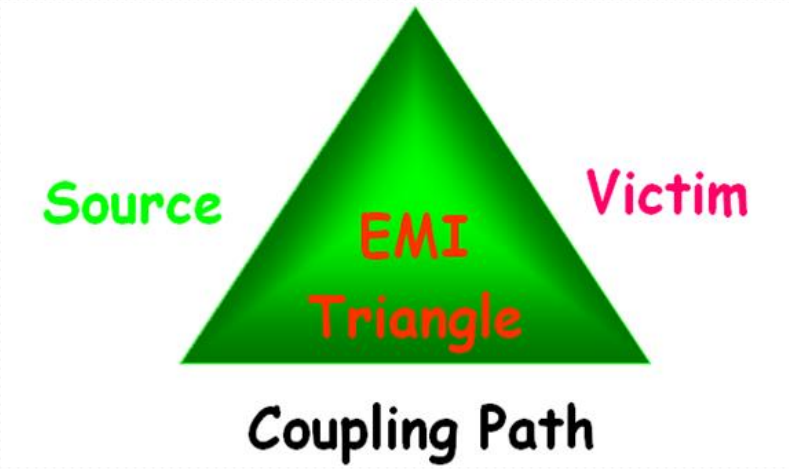
- Radio Frequency Interference/Electromagnetic Interference (RFI/EMI) – (100 KHz – 1 GHz)
  - A radio frequency disturbance that causes an unwanted interruption, degradation or unintended operation to an electrical circuit.
  - Common <u>Sources</u>
    - Radio Transmitters (Amateur, broadcast, consumer devices)
    - Natural: Sun, Cosmic noise, Lightning, atmospheric static
    - Motors, ignition systems, power lines, square wave generators
  - Common <u>Victims</u>
    - Any electronic device acting as an unintended “receiver” of RFI

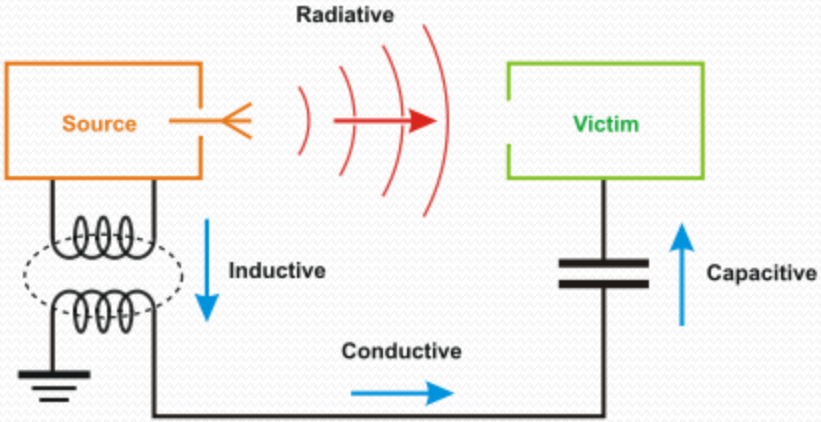
Got RFI in your shack/home?

- **TX Symptoms** – caused by <u>your transmitter or antenna</u>
  - Hot microphone – lip burns, distorted audio
  - Resonant antennas don't tune correctly or high SWR
  - Your voice/transmission causes interference with consumer electronic devices acting as ham radio frequency "receivers" (e.g. computers, TV/audio system, security system, garage door opener, telephone, sprinkler systems, etc.)
  - Wife Alarm goes off
- **RX Symptoms** – caused by <u>sources outside your shack</u>
  - High receive noise level not due to atmospheric conditions
  - Birdies, chirps, buzzes, clicks, broadband noise on receiver
  - Distorted receiver audio

How did you get RFI?

How is RFI Transferred?





All three parts must be present to have an RFI problem.

Multiple paths are very common:

1. Radiative - air
2. Conductive - wire
3. Inductive - wire
4. Capacitive - wire

How to identify the path(s)

Typical RFI receiving “antennas"

- 160-80-60-40-30 meter transmitters – “Long” - AC power lines, telephone/DSL lines, satellite/cable coax, long Ethernet cables, antenna feed line coax shield, antenna control/rotor cables, 2nd story ground wires
- AM Broadcast Receiver RFI – same as 160 – long “antennas”
- 20-6 meter transmitters – “Short” - speaker wires, device interconnect cables, mic cables, short Ethernet cables
- FM Broadcast Receiver RFI – short “antennas” – 3-6 feet long – device interconnect cables

- “Antennas” pick up RFI radiation and a <u>common mode current</u> is induced on all conductors from an RFI SOURCE

How do we reduce this current?

Reduce RFI current to reduce RFI

- An “antenna” is a wire with alternating current going through it creating an electromagnetic field of radiation, or conversely, a wire exposed to an electromagnetic field induces a current in the wire.
- Reducing the current through the wire, reduces the radiation from the wire or conducted through the wire
- High choking impedance (R) reduces RFI current, I (remember Ohm’s law: I=E/R)

- Typical solutions: Resonant traps, <u>ferrites</u>, filters with high choking impedance

Ferrites are your friend

Ferrite Topologies (Shapes)

Slip On Bead

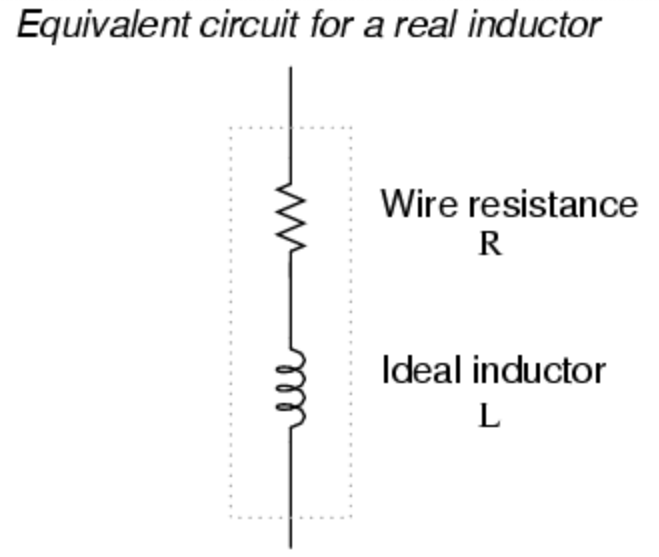
Snap On Bead

Toroid or Ring

Fuzzy Ferret – not!

- Cheap, easy to install, suppress RFI from 100 KHz - 2 GHz
- Work on all conductive paths (antenna feed line, AC/DC, I/O cables)
- Lots of options in size, shape to suppress most RFI path currents
- Are effective if you understand how to choose the correct ferrite and where to install for a particular RFI problem

How do Ferrites Work?

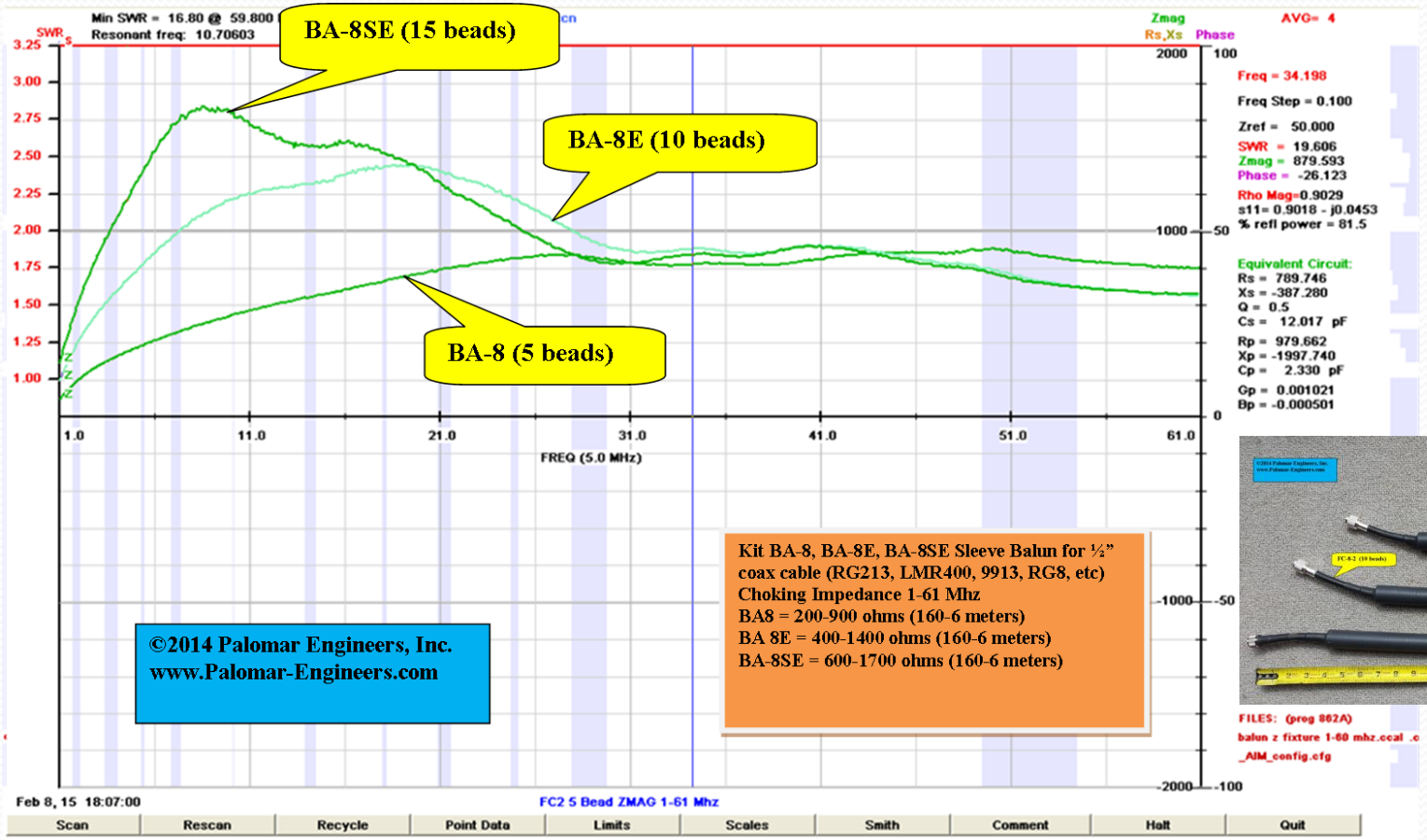


Picture shows One Turn coil through a snap on ferrite - typical bead with 1 turn has 50-300 ohms impedance depending of frequency

Inductive reactance varies with frequency ($X_L=2\Pi*f*L$) until resonance reached. <u>Increase reactance or impedance($Z=\sqrt{(X_L^2+R^2)}$ to decrease common mode current producing RFI</u>

Impedance (Choking Z) can be increased several ways.....

Ferrite Z adds in series

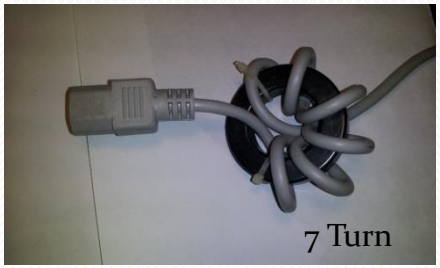


More beads =

higher choking Z (up to 30 MHz)

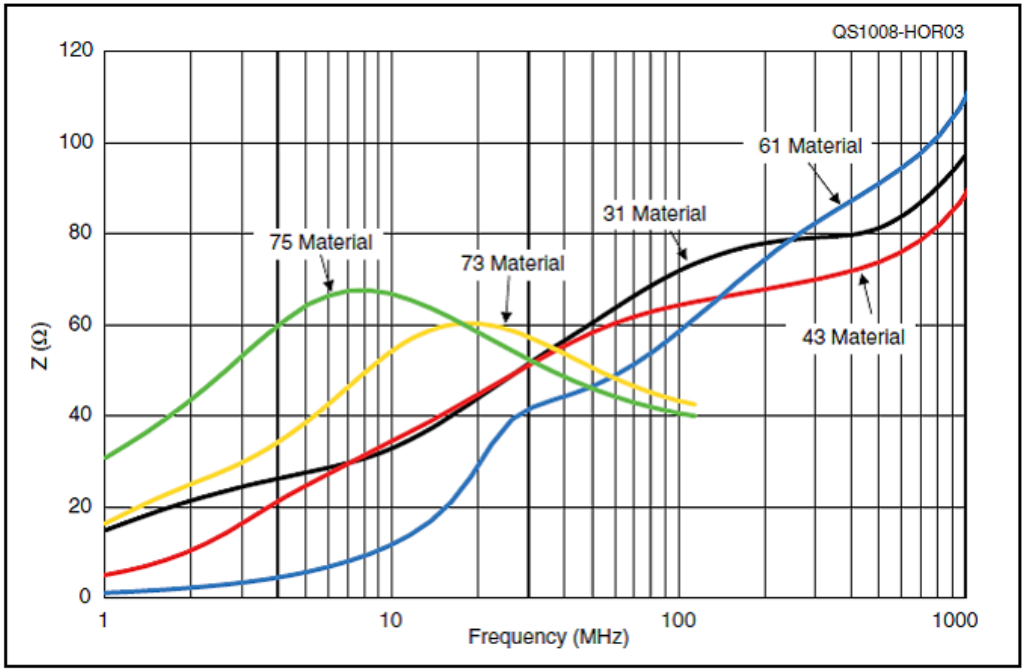
Choking Z Increases with $(\text{turns})^2$

- If 1 turn = Z, 2 turns = 4Z, 3 turns = 9 Z
- More Z = less wire current = less RFI radiated from wire or induced into wire.
- General rule is to have choking Z > 10X line impedance
- (e.g. > 500 Ω for 50 Ω cable but 5000 Ω is better)



How do we choose the correct ferrite for the RFI frequency?

Ferrite Mixes



Figures 3 — These curves show the impedance versus frequency of a single ferrite bead made of different types of ferrite material. Each bead is 3.50 mm × 1.30 mm × 6.00 mm. (Information courtesy of Fair-Rite Corporation)

Mix = chemical formula of the iron oxide with manganese-zinc (31, 73/77) or nickel-zinc (43, 61)

<u>Select mix for max Z at RFI fundamental frequency NOT frequency of receiver.</u>

(e.g. for 2 MHz us mix 73/77, for 30 MHz us mix 31 or 43)

Most popular ham frequency mixes are 31, 43, 61, 77.

Know how to buy

How to buy ferrites the wrong way!

=

DON'T BUY!!!!

- No Mix Designation, No Impedance Range, No Frequency Range = No No No!

Buying unknown ferrites is a waste of time and money!

How to buy Ferrites the right way

PALOMAR ENGINEERS ®

Ferrite Split Beads
10 Pack -1/2" ID
Common Mode Choke

Each Mix 31 bead provides:
71Ω/5 MHz
100Ω/10 MHz
156Ω/25 MHz
260Ω/100 MHz
260Ω/250 MHz

Part # FSB31-1/2-10

Palomar-Engineers.com

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BUY With CONFIDENCE!!

Product Labeling (Mix, Frequency, Impedance) + Known Vendor = Winner!

Ferrite Use Recap

- Determine RFI interfering frequency
- Choose proper mix (31, 61, 77) to suppress RFI fundamental frequency
- Choose Topology(slip, snap, ring) to fit the Path
- Install ferrites – retest for RFI suppression
- Consider additional Paths if RFI persists

Most popular Mix for HF is MIX 31

(Mix 77 for < 10 MHz, Mix 61 for 200-2000 MHz)

How can you use ferrites for RFI issues in your ham shack/home or your neighbor's home?

Transmitter RFI Solutions

Ham's Transmitter RFI Strategy

1
- **Eliminate/reduce RFI SOURCE**
  - (transmitter, amplifier, or antenna location)
- or

2
- **Choke the PATH**
  - (coax feedline, AC/DC power line)
- or

3
- **Protect the VICTIM**
  - (filter inputs to victim)

How does these steps apply to your ham shack?

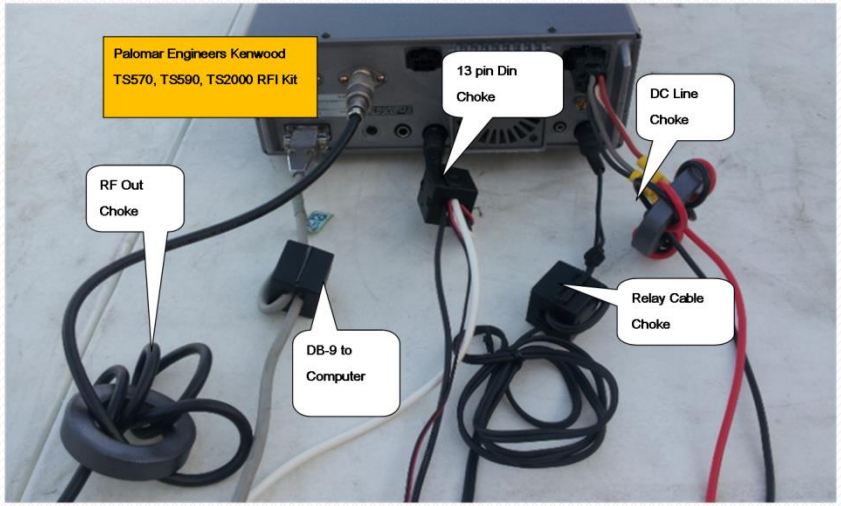
RFI Chokes for Transmitters/Amps

- Transmitter – Amplifier RFI suppression
  - All cables into/out of radios, amplifier, antenna tuners
  - Includes
    - ALL Coax RF feed lines
    - Rotor/Antenna Control lines
    - AC/DC power Lines
    - Computer – radio interconnects
    - Examples on next slides

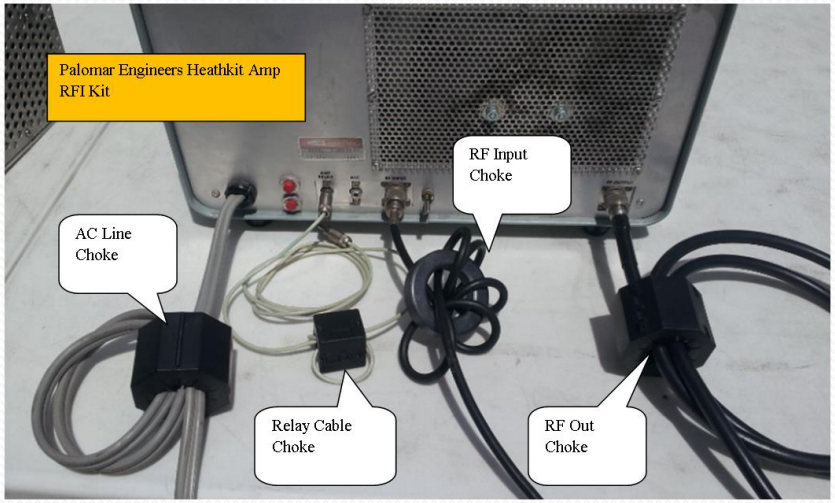
  - Recommendation: Get the transceiver and amplifier kits with mix, sizes, instructions already determined.

Transceiver/Amp RFI Kits

Transceiver RFI Kit



Linear Amplifier RFI Kit

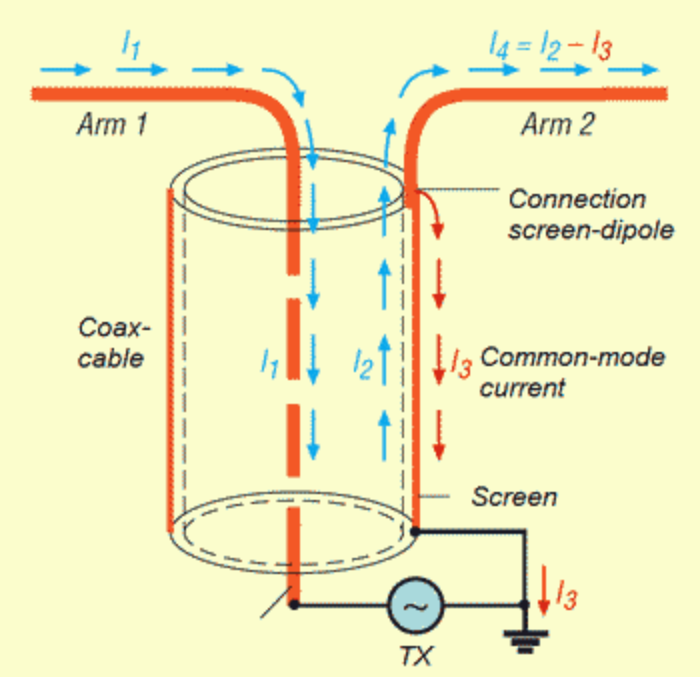


After transmitter/amp Source
RFI Suppression

#1 RFI problem is antenna feed line radiation –why?

Is your Dipole a Tripole?

- Coax <u>outside</u> of braid acts as extension of <u>transmitting</u> antenna



Coax braid (screen) is actually 2 conductors :
1 on the inside (normal RF signal) and 1 on the outside (common mode current) that turns dipole into tripole!

<u>Goal is to reduce common mode current with a feed line choke to keep all RF on antenna</u>.

1% common mode braid current = 2.75 watt radiation at 1500 watts input, or 1.6 watts at 500 watts input or .7 watts at 100 watts input

Antenna feed line choke options

Definition: Feed line choke: 1:1 (50Ω to 50Ω). Impedance transformer: <1:1 or > 1:1

EVERY coax feedline needs a feedline choke tuned to the antenna frequency!

EVERY rotor control, antenna selector needs a feedline choke!

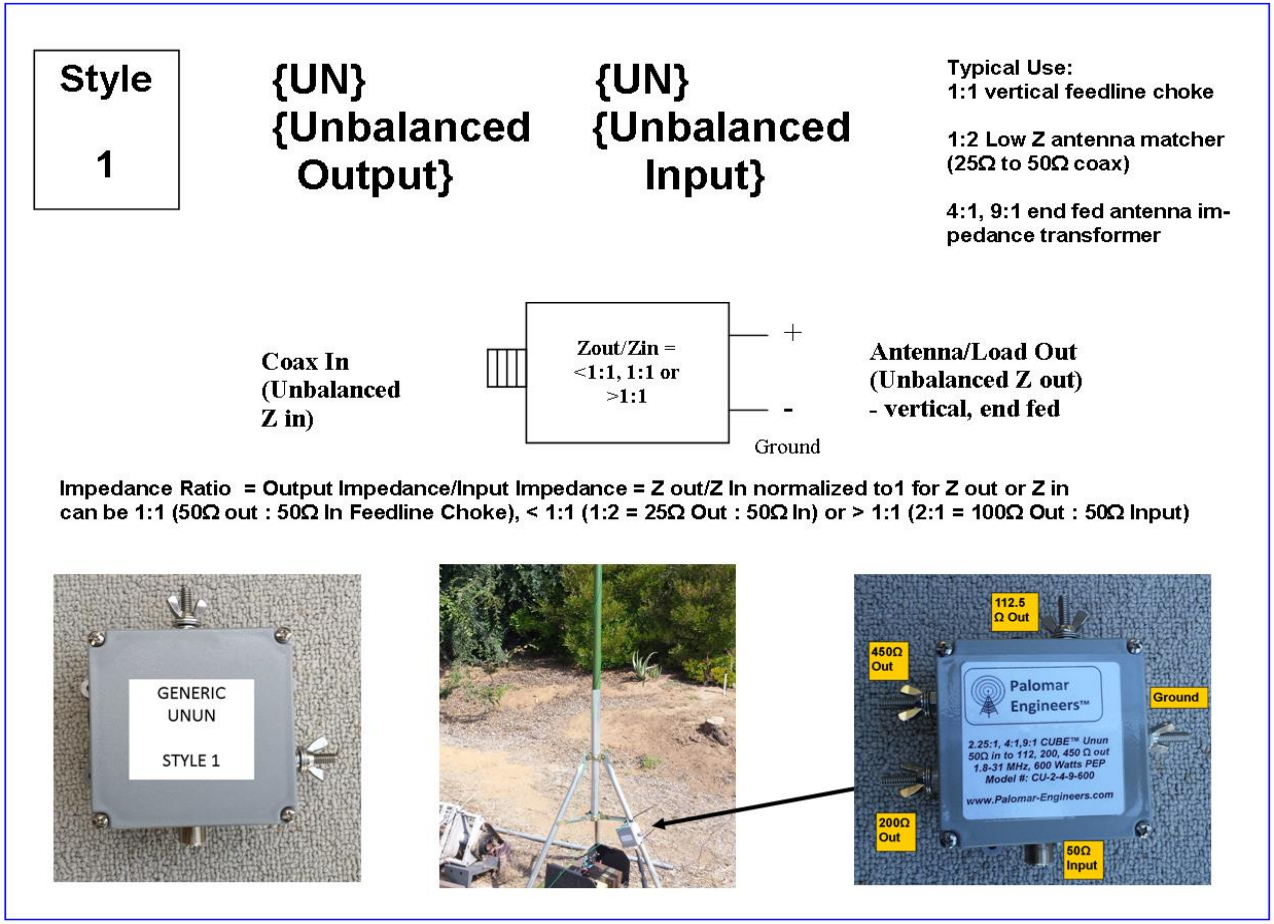
Feedline chokes are made with several <u>output options</u> dependent on antenna type and the output option determines whether it is an UNUN or BALUN:

- Ununs #1 (verticals, end fed antennas)
- Ununs #2 (coax in/coax out)
- Baluns (beams, dipoles, loops)

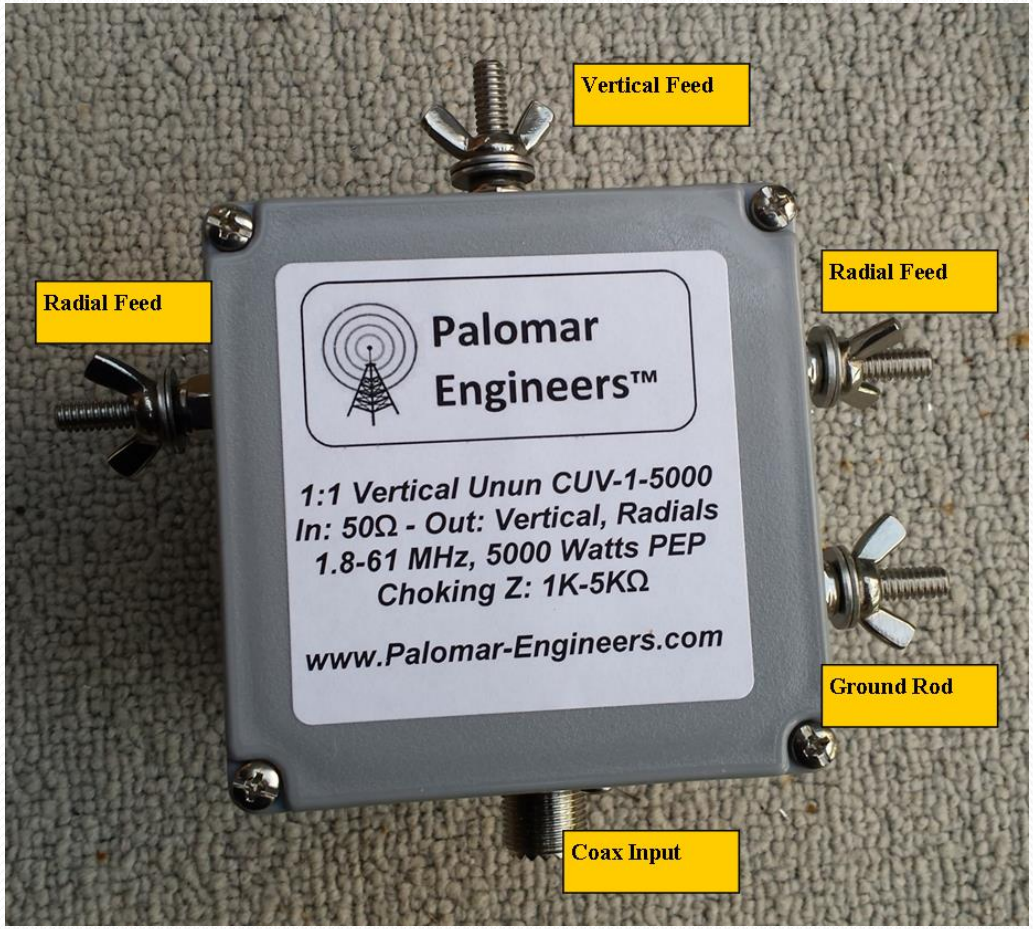
UNUN #1 (coax in, single output)

Applications:

Verticals, end feds



Vertical Unun feedline Choke



UNUN #2 (coax in, coax out)

Style 2

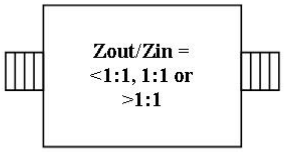
{UN} {Unbalanced Output}

{UN} {Unbalanced Input}

Typical Use:
1:1 Coax feedline choke

1.5:1 75 ohm to 50 ohm coax impedance trans-former

Coax In (Unbalanced Z in)



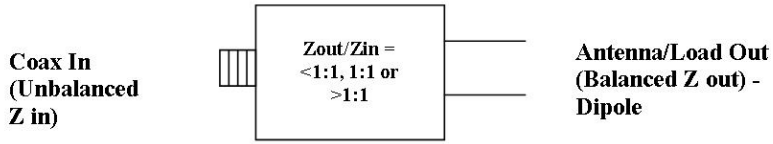
Coax/Load Out (Unbalanced Z out) - coax

Impedance Ratio = Output Impedance/Input Impedance = Z out/Z In normalized to1 for Z out or Z in can be 1:1 (50Ω out : 50Ω In Feedline Choke), < 1:1 (1:2 = 25Ω Out : 50Ω In) or > 1:1 (2:1 = 100Ω Out : 50Ω Input)

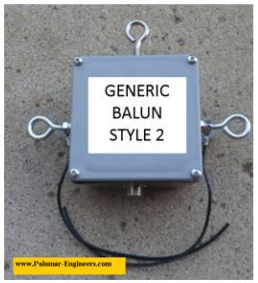
BALUN (coax in, balanced output)

{BAL}
{Balanced Output}

{UN}
{Unbalanced Input}



Impedance Ratio = Output Impedance/Input Impedance = Z out/Z In normalized to1 for Z out or Z in can be 1:1 (50Ω out : 50Ω In Feedline Choke), < 1:1 (1:2 = 25Ω Out : 50Ω In) or > 1:1 (2:1 = 100Ω Out : 50Ω Input)



Application:

Dipole, beam, loop, symmetrical antennas

Now some practical examples of feed line chokes

Coax Choke (aka “Ugly” balun)

Picture: Ugly balun at 7 Mhz, 16 turns, 4.5” diameter = 3,000 Z – 20 feet of coax – ONLY effective for 1-2 ham bands since acts as a high “Q” tuned choke using L and C of coax. Z = 1-3 KΩ

Feedline Chokes for all antennas

Medium choking Z (500-2000Ω) – 5KW for RG213

Sleeve Chokes (Snap on)

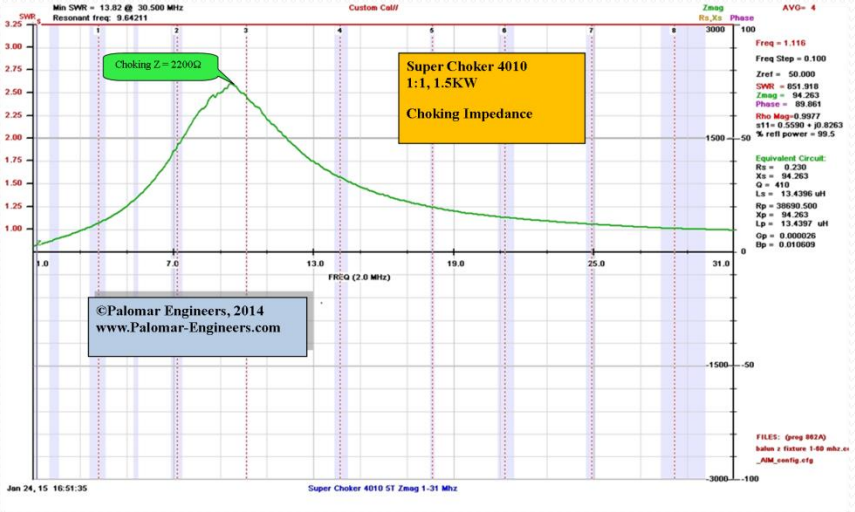
RG-8X (1/4” size)
150-500 ohms

RG-213 (1/2” size)
150-500 ohms

Clamp On Choke (FSB-1) = 1” ID

3 turns =
1K ohms
x 3 chokes
= 3kΩ
total Z

Super Choker (40-10 Meters)



Medium (1K-3KΩ) Choking, High Power, Contesting, Continuous modes (RTTY, AM, digital)

CUBE Chokes for all antennas

Highest Choking (5-15K ohms)

Power to 10KW PEP

Use: Inline choke, beam, dipole, loop, vertical

A $10 DIY Feed Line Choke

+ **C o a x** =

- Ring Ferrite + Coax Cable = feed line choke

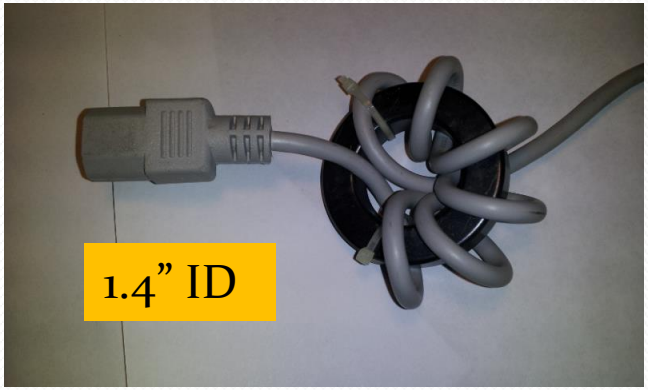
- Use at antenna feed point to keep RFI off coax
- Use at radio end of coax to reduce RFI “Noise”
- Use RG-8X, LMR240 for low power, RG303/400 for high power

Now AC/DC power line chokes

RFI Chokes – 120/240V AC Path

- Ring Toroids – most effective – usually 3-10 turns
- Snap Ons – convenient to use, usually 1-2 turns
  - Big Clamp On's – multiple turns, easy to install
  - Example pictures

AC Line Chokes



Palomar F240 (1.4”ID/2.4”OD) Choke –160-6 meters, Z = 2-5K range depending on frequency

RFI proof your transmissions recap

- Determine frequency range of RFI
- Choose proper mix (31, 61, 77) to suppress RFI
- Choose Choke Topology to fit the Path
- Install ferrites – retest for RFI suppression
- Consider additional Paths if RFI persists

If you need help

Call Palomar Engineers or view specific solutions at

www.Palomar-Engineers.com

What about →→

Receiver RFI Solutions

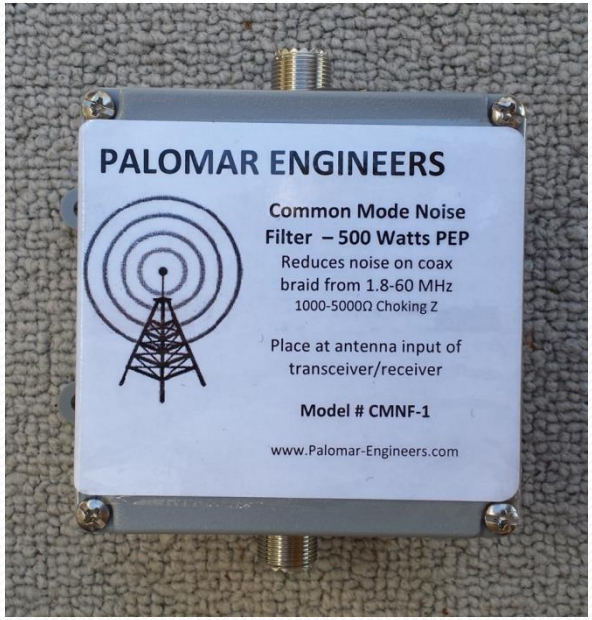
Less noise = Higher SNR = More DX!

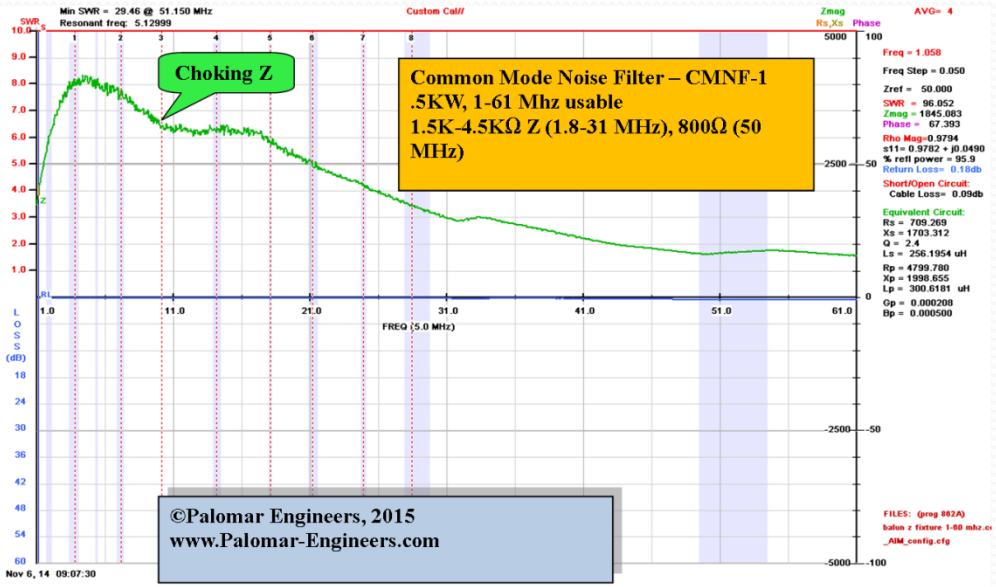
Receiver RFI Noise (man made)

- **SOURCES**: plasma TV, Uverse/DSL, Cable Boxes, HVAC, appliances with variable speed motors –square wave generators, LED lights, wireless metering systems, wall warts, switching power supplies, battery chargers, fluorescent lights, fish tank heaters, exercise equipment, computer "hash", solar system inverters
- **PATH**: antenna coax braid, AC/DC power lines, phone/DSL line, computer to radio interconnects
- **VICTIM**: radio receiver noise level is high
- **SOLUTION**: eliminate SOURCE, choke PATH

Coax Feed Line Noise Filters

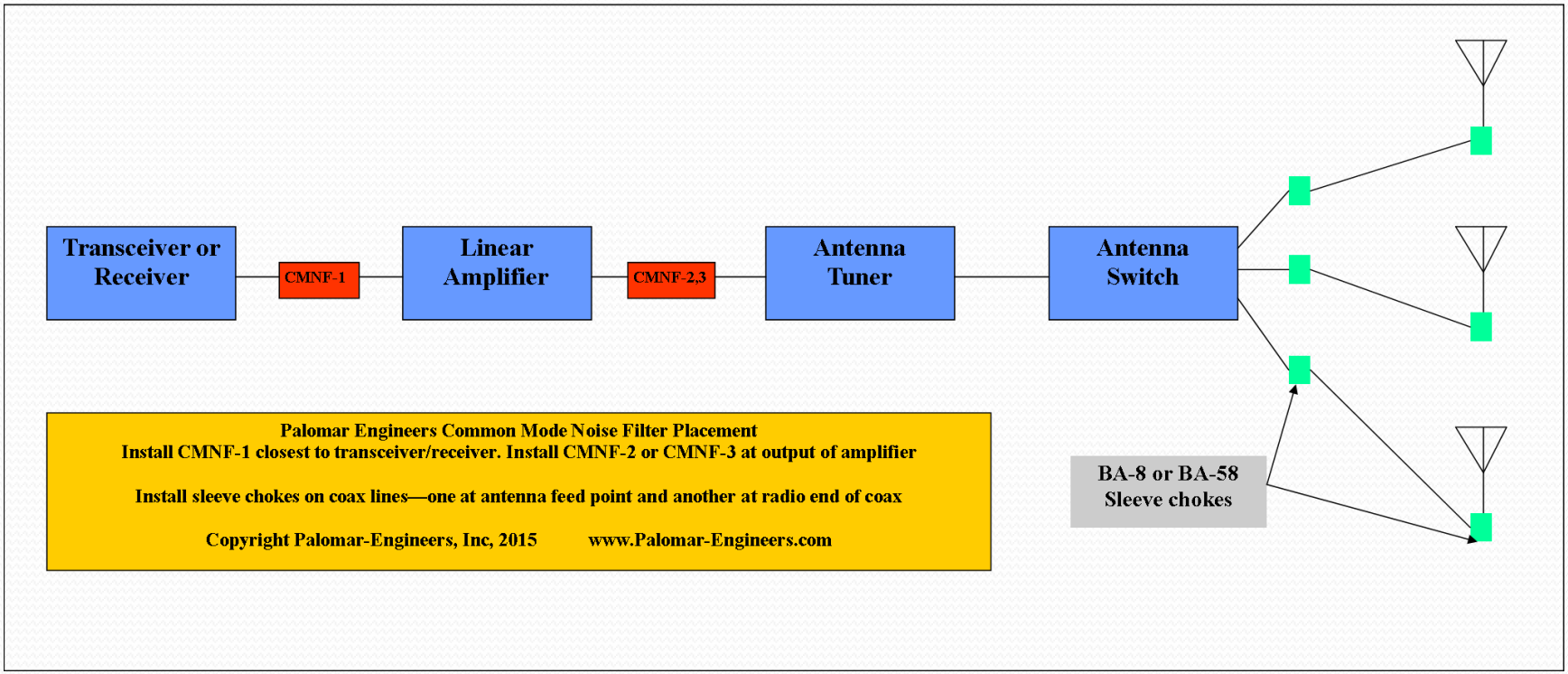
One of the best kept secrets in ham radio!!!





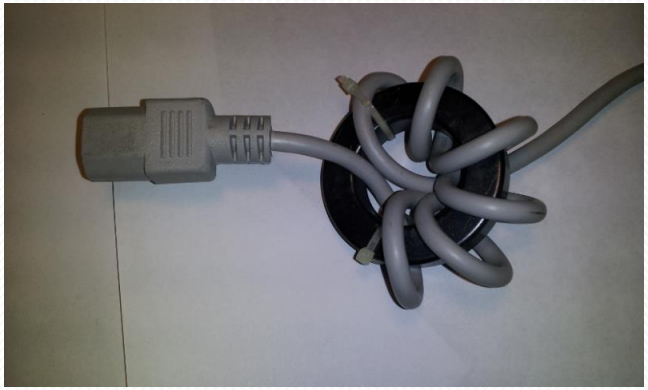
Placed at RADIO END of coax feed line

Coax Noise Filter Placement



Filter ALL coax lines, rotor, antenna control lines (STEPPIR)

AC Line/DC Power Chokes



Palomar F240 (1.4”ID/2.4”OD) Choke – 80-10 meters, Z = 2-5K range depending on frequency

Wall Wart RFI Kit

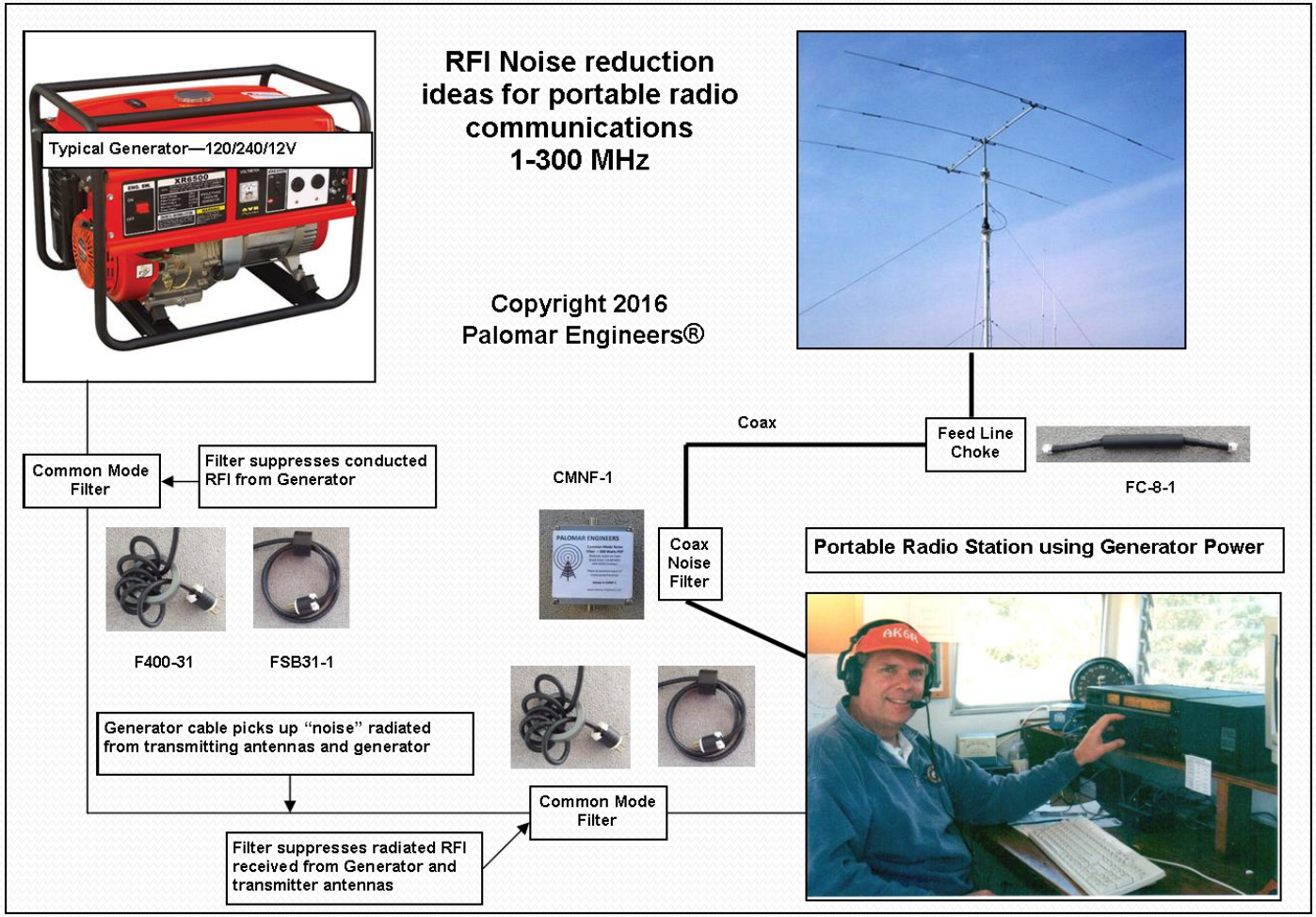
Wall Wart switching DC power supplies that plug into the AC power line plug and provide DC power to laptops, routers, battery chargers, cell phone chargers, etc are a known source of broadband RFI

A simple ferrite ring filter on the DC power line can help suppress the RFI noise affecting the device or keep the DC power cord from acting as an antenna and radiating RFI from the powered device.

RFI Filter on DC Cord

Economy 10 ring kit

Portable Operation RFI Kits



Mobile Operation RFI Kits

Reduce RFI to car electronics + car electronics RFI to radio

Coax Noise Filter

DC Power Noise Filter

Receiver RFI Noise Strategy

- Assess S-P-V for the RFI – You or someone else?
- PROTECT the VICTIM (Your receiver)
  - Coax noise filters on antenna feed lines
  - Chokes on AC/DC cords, Wall Warts – ring or snap on ferrites
  - Chokes on radio-computer interconnect cables
- ELIMINATE/ISOLATE the SOURCE
  - Chokes AC/DC power to source, snap on ferrites for all I/O
- All RFI solutions also apply to mobile, portable operations
- Call Palomar Engineers if you get stuck or need help

What about →→

Keep Your Neighbors Happy!

OR

Neighbor’s RFI Strategy

- Choke RFI SOURCE

Ham's Solution to Neighbor's RFI

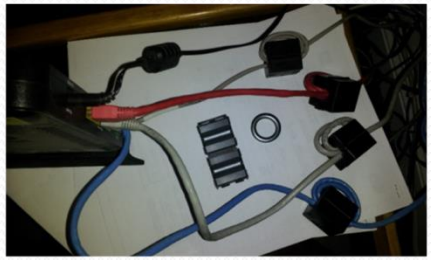
- Source (transmitter or antenna") – Path – Victim
  - Clean up your transmitter/shack first using techniques already discussed
- Assess Neighbor's Problem
  - Faulty device (device acting as receiver when not designed to be a radio receiver – e.g. Telephone, HDTV)
  - Determine frequency of "transmitter" that is causing the problem (may not be on all bands – may not be you!)
  - Find the path (or paths) to the Victim (Receiver)
  - Choose the RFI choke/Kit for the frequency and path
  - Choke the path, protect the device (externally)!

Neighborhood RFI Solutions

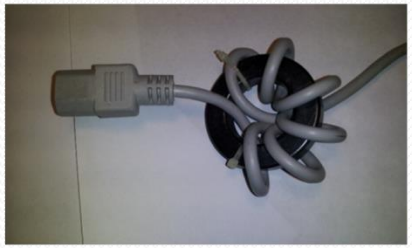
MY HOME or NEIGHBOR'S HOME

ALARM SYSTEM RFI

HOME THEATER RFI



COMPUTER RFI



MISCELLANEOUS RFI

GARAGE DOOR

TELEPHONE/DSL RFI

Recommendation: Use RFI kits for specific problems, have neighbor purchase and install – do not make mods to neighbors equipment! MOST problems are RFI picked up by AC power/phone lines so ferrite filters work well.

Test Time – Win a prize!

Prize Question #1

- Name 2 ways to increase the choking impedance of a ferrite choke?

Prize Question #2

- Name three ferrite mix numbers used by hams to suppress RFI

Prize Question #3

- What is one of the best kept secrets in ham radio?

Which vendor do you call when you have an RFI problem?

- Palomar Engineers

- Website: www.Palomar-Engineers.com
- Email: Sales@Palomar-Engineers.com
- Phone: 760-747-3343
- Bob Brehm, AK6R – Chief Engineer
- This presentation available on the website.