

ABC's of RFI for Hams

Symptoms, Causes & Cures



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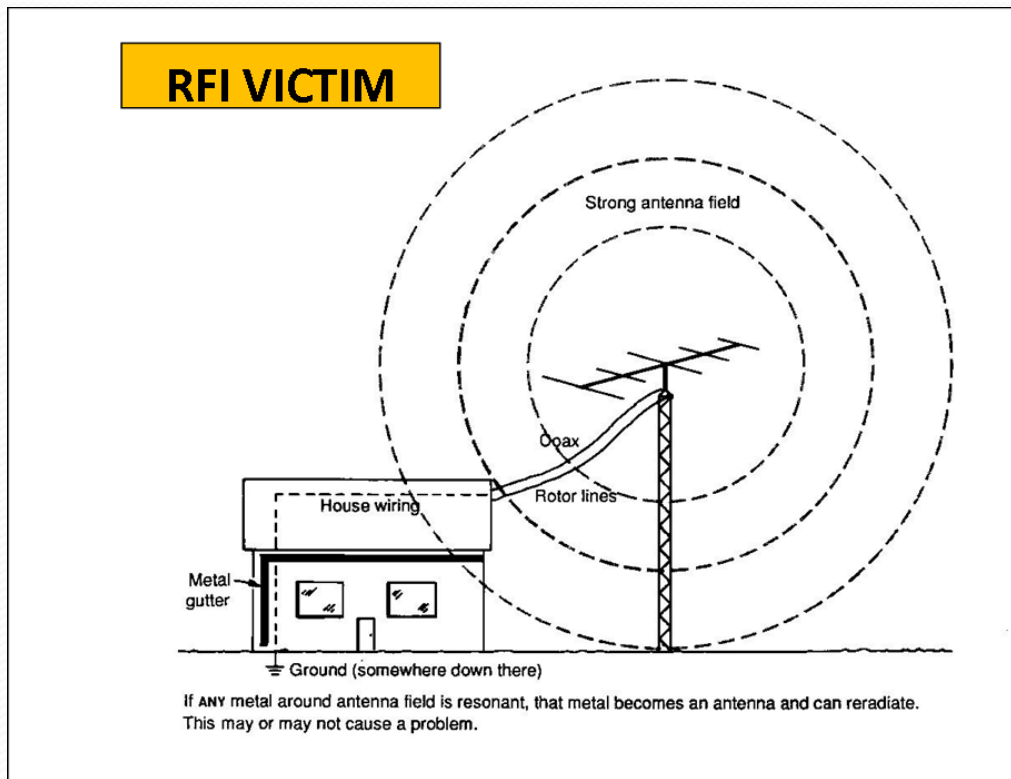
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Are you the **SOURCE** of RFI?



IT'S ALL YOUR FAULT WITH THAT BIG ANTENNA!

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



RFI Sources

- Ham Antenna
- Radiating Coax
- Electronic Devices
- Solar Systems
- Grow Lights
- HVAC motor
- Plasma TV
- DSL/Routers
- Switching power Supplies
- Washer/Dryer or other appliances

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 filter 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 coax-fed HF antennas
- How to use ferrites to solve transmitter RFI problems, reduce your receiver noise floor, and keep your neighbor's and spouse happy!
- Understand CONCEPTS with little or NO MATH required

Thinking cap time.....

RFI 101

For Contesters, DX'ers, Rag Chewers, Old Timers and Beginners too!



What is RFI?

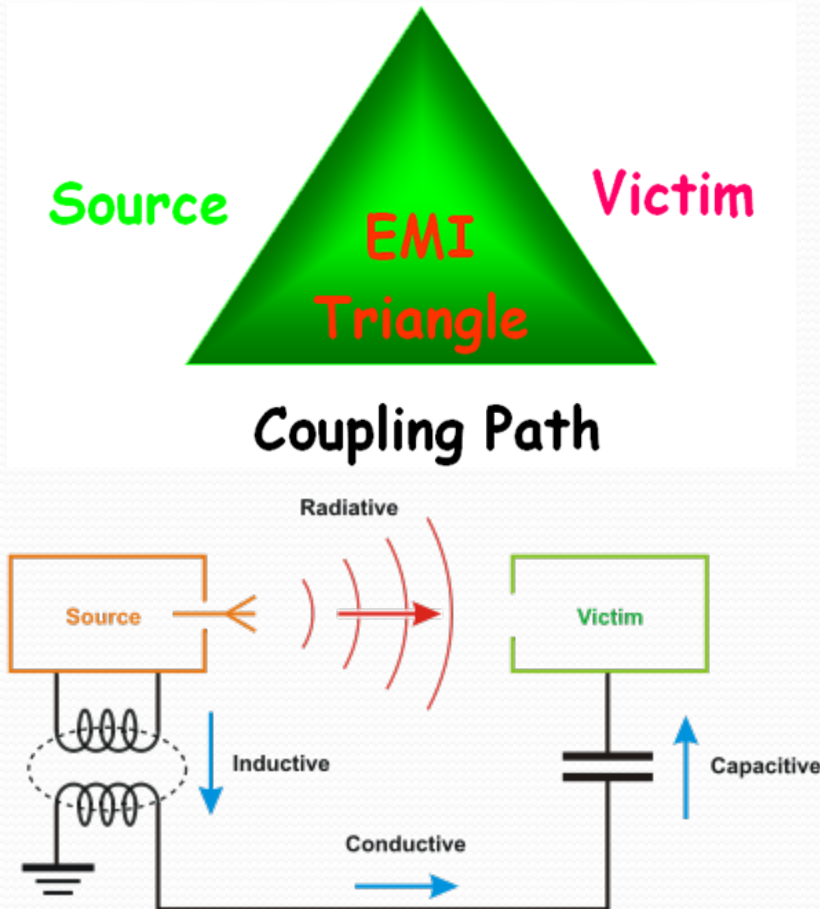
- Radio Frequency Interference/Electromagnetic Interference (RFI/EMI) – (100 KHz – 2 GHz)
 - A radio frequency disturbance that causes a malfunction to an electrical circuit so it functions improperly.
 - Common Sources
 - Sunspots, Cosmic noise, Lightning, atmospheric static (no fix)
 - Radio Transmitters -Ham, CB, broadcast, consumer devices)
 - Motors, ignition systems, power lines, square wave generators
 - Common Victims
 - Any electronic device that malfunctions by acting as an unintended “receiver” of RFI

Got RFI in your shack/home?

- **TX Symptoms** – caused by your transmitter or antenna
 - Hot microphone – lip burns, distorted audio
 - Antennas don't tune correctly, high SWR, radiating coax
 - 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, lights, etc.)
 - Wife Alarm goes off
- **RX Symptoms** – caused by sources outside your shack
 - 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

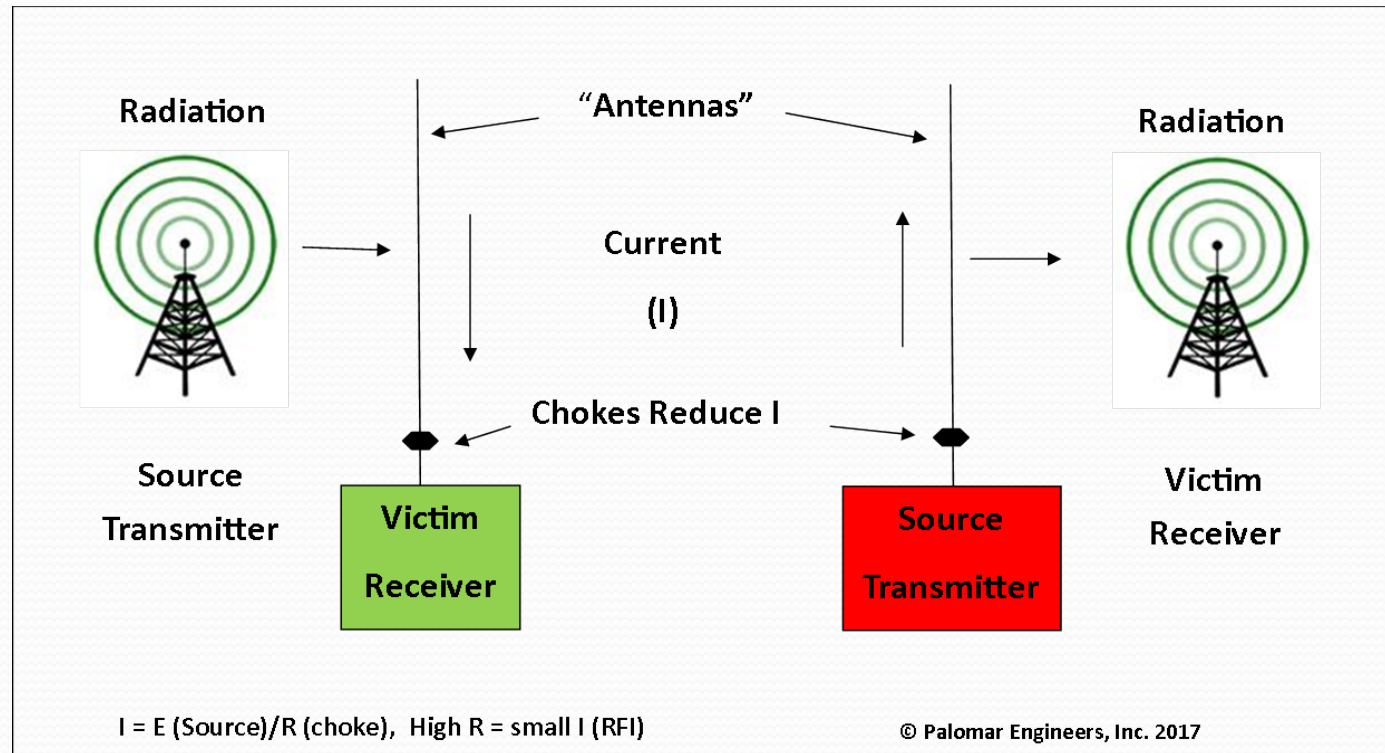
How to identify the path(s)

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 Transmitter 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 common mode current is induced on ALL conductors from an RFI SOURCE

How do we stop or reduce this current?

Reduce RFI current to reduce RFI



- Typical solutions: Resonant traps, ferrites, filters with high choking impedance

Ferrites are your friend



Ferrite Topologies (Shapes)



Slip On Bead



Snap On Bead



Toroid or Ring



Fuzzy Ferret – not!

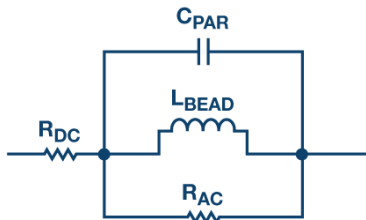
CHARACTERISTICS

- 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 ferrites work, how to choose the correct ferrite and where to install the ferrite for a particular RFI problem

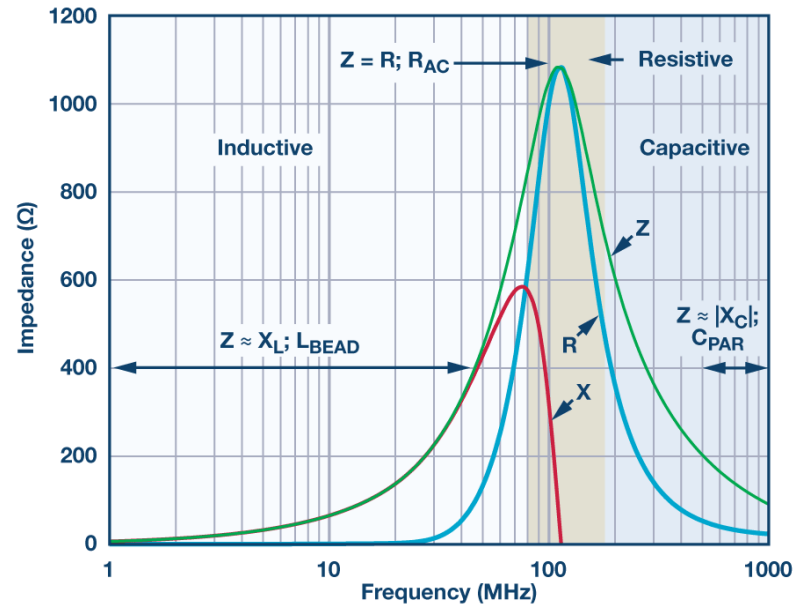
How do ferrites work?

How do Ferrites Work?

Simple Equivalent Circuit



(a)

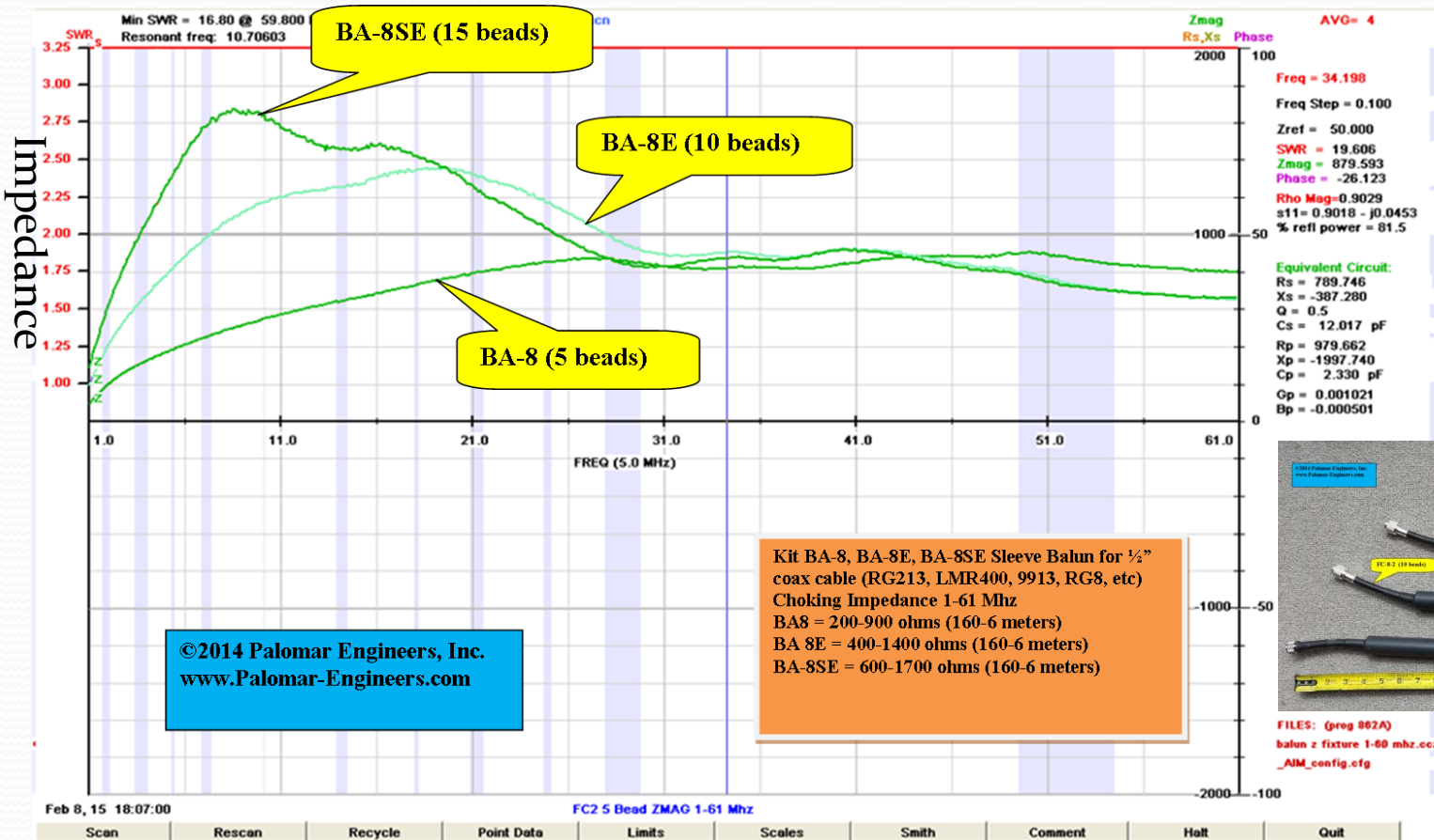


(b)

Ferrite beads are categorized by three response regions: inductive, resistive, and capacitive. To reduce high frequency interference (noise), the bead must be used in the resistive region where it acts like a resistor, which impedes the high frequency noise and dissipates it as heat.

How can resistance be increased?

Ferrite resistors add in series



More beads =
higher choking R (up to 30 MHz)

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Kit BA-8, BA-8E, BA-8SE Sleeve Balun for 1/2" coax cable (RG213, LMR400, 9913, RG8, etc)
Choking Impedance 1-61 Mhz
BA8 = 200-900 ohms (160-6 meters)
BA 8E = 400-1400 ohms (160-6 meters)
BA-8SE = 600-1700 ohms (160-6 meters)



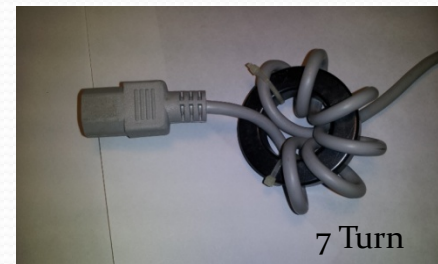
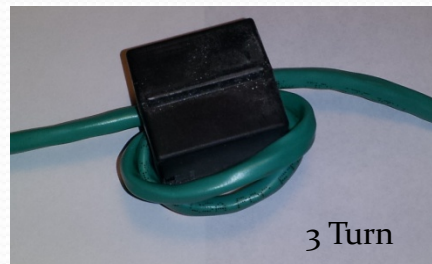
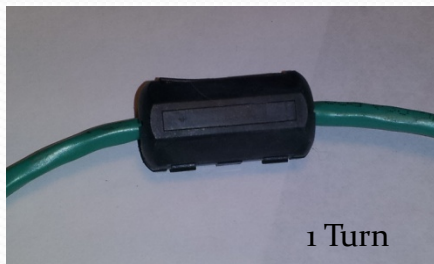
FILES: (prog 802A)
balun z fixture 1-60 mhz.ecal.co
_AIM_config.cfg

Frequency →

Impedance (Z) = Resistance +/- Reactance

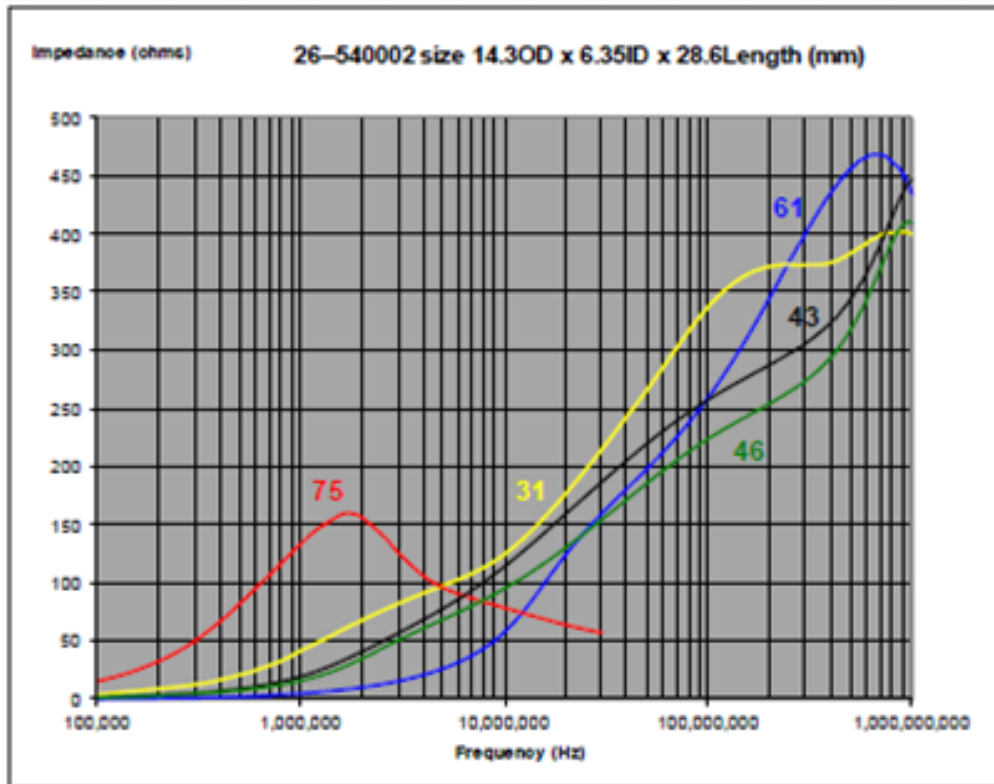
Choking Z Increases with (turns)²

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



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

Ferrite Mixes



Mix = chemical formula of the iron oxide with manganese-zinc (31, 75) or nickel-zinc (43, 61)

Select mix for max Z at RFI fundamental frequency NOT frequency of receiver.

Example:

for .1-10 MHz use mix 75/77

for 1-300 MHz use mix 31 or 43

for 200-2000 MHz use mix 61

Most popular ham frequency mixes are 31, 43, 61, 75, 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 like buying a box of rocks - 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

=

**BUY With
CONFIDENCE!!**

Part # FSB31-1/2-10

Palomar-Engineers.com

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

So let's recap RFI 101

Ferrite Use Recap

- Determine RFI interfering frequency & suspected Path
- Choose proper mix (31, 43, 61, 75/77) to suppress RFI fundamental frequency
 - Choose Topology (slip, snap, ring) to fit the Path
 - Install ferrites – retest for RFI suppression
 - Consider additional ferrites or Paths if RFI persists

Most popular Mix for HF is MIX 31 (1-300 MHz)
(Mix 75/77 for .1-10 MHz, Mix 61 for 200-2000 MHz)

Question: How and where do you put the ferrite band aid?

Ham 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 and/or reduce signal to victim)

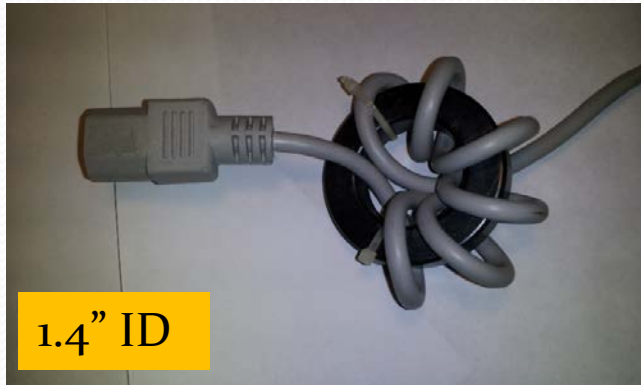
How does these steps apply to your ham shack?

RFI Chokes for Transmitters/Amps

- Transmitter – Amplifier - Antenna RFI suppression
 - All cables into/out of radios, amplifier, antenna tuners
 - Includes
 - ALL Coax RF feed lines or common line of coax switch
 - Rotor/Antenna Control lines
 - AC/DC power Lines including wall warts!
 - Computer – radio interconnects
 - Examples on next slides
- Recommendation: Filter ALL power cables to equipment and buy Palomar transceiver and amplifier RFI kits with mix, sizes, instructions already determined.

First: AC/DC Cables

RFI – AC/DC Line Chokes

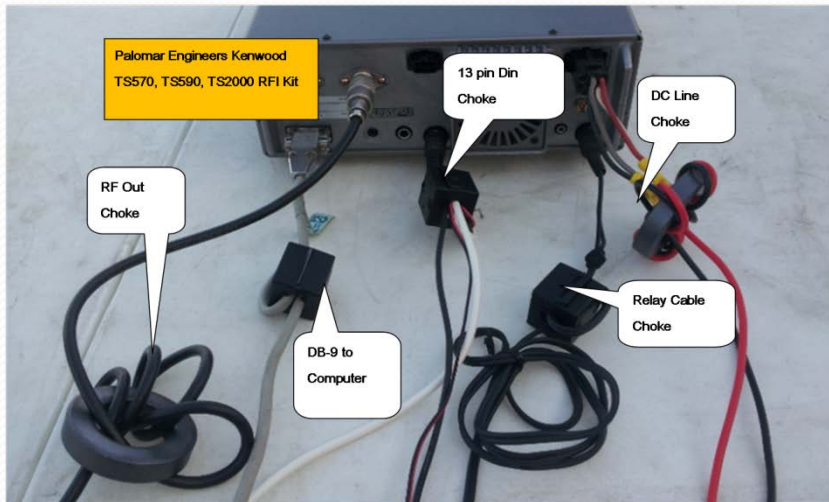


Palomar F240 (1.4"ID/2.4"OD) Choke –160-6 meters,
Z = 2-5K range depending on frequency and # of
turns through center

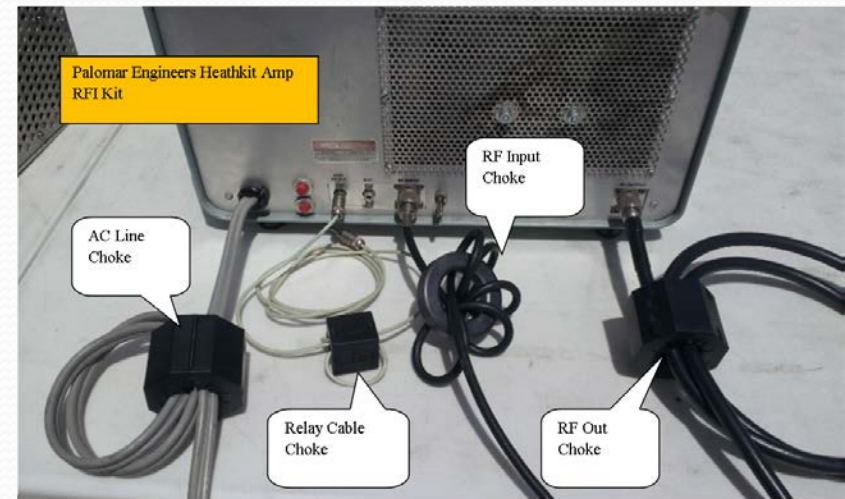
Transceiver/Amp RFI Kits

Palomar RFI kits for all brands of transceivers and amplifiers

Transceiver RFI Kit



Linear Amplifier RFI Kit

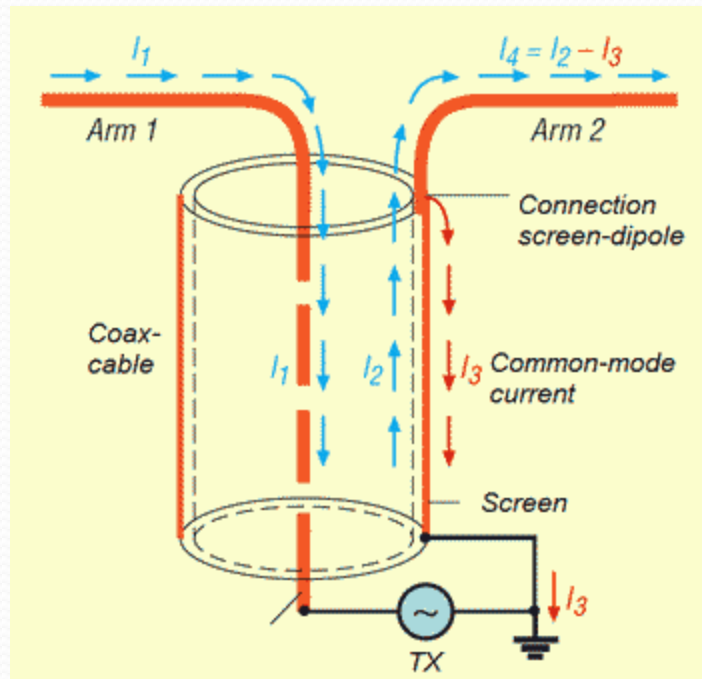


After Transmitter/Amp Source RFI Suppression

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

Is your Dipole a Tripole?

- Coax outside of braid acts as extension of transmitting antenna



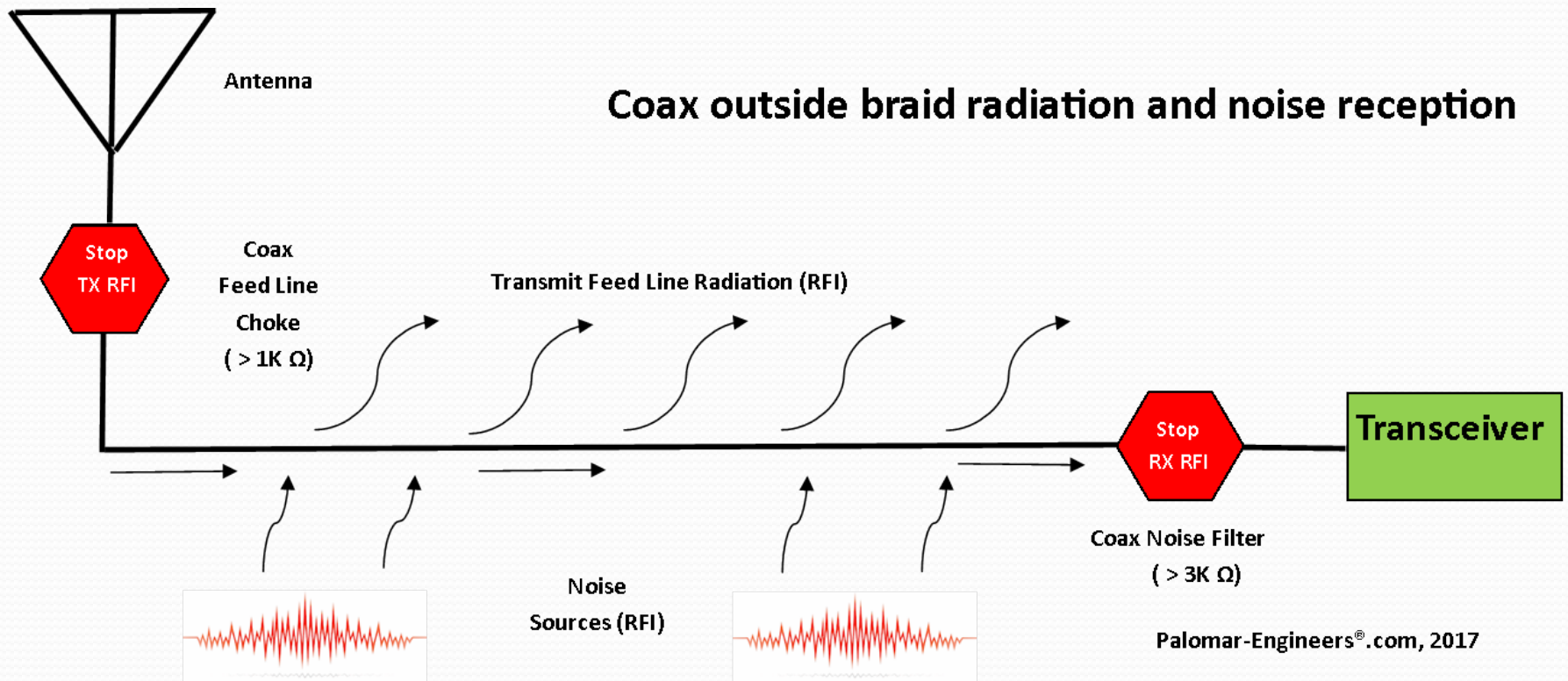
Coax cable has 3 conductors!

Coax braid is actually 2 conductors :
1 on the inside (normal RF signal), and
1 on the outside (common mode current)
that turns a dipole into tripole on transmit
or a second antenna on receive!

Goal is to reduce common mode current
with a feed line choke to keep all transmit
RF on antenna and use a coax noise filter to
minimize noise into receiver.

FYI: 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

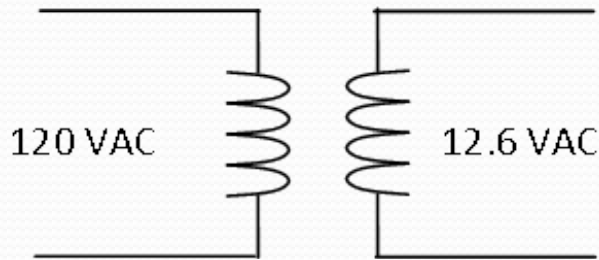
Typical Coax Fed Antenna System



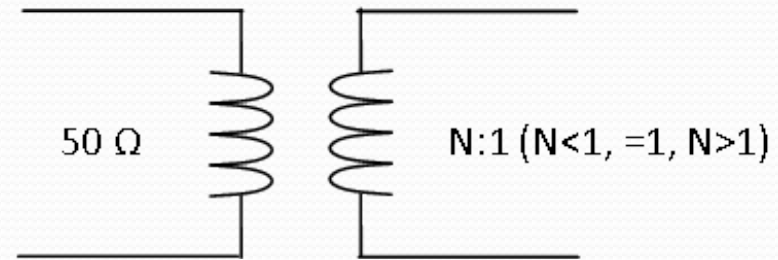
Impedance transformers & chokes

Impedance Transformers/Chokes

AC (60Hz) Transformer



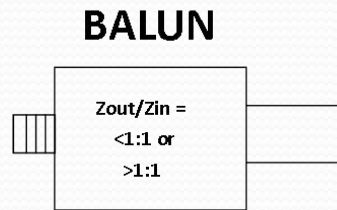
RF (1-2000 MHz) RF Transformer



- For $N=1$ (50Ω to 50Ω) – called a coax feed line choke or line isolator, or coax noise filter
- For $N=.25, .5, 2, 3, 4, 5, 6, 9, 12, 32, 64$ – called an impedance transformer ($<50\Omega$ output or $>50\Omega$ output)

Output Configurations

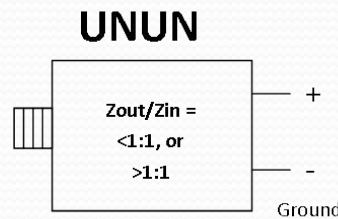
Balun or Unun Output Options



Dipoles
Loops
Ladder Line



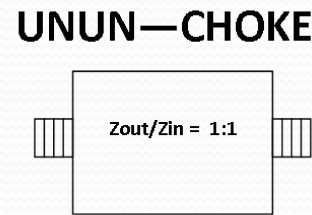
4:1 Coax to Ladder
Line Balun



Verticals
End Fed
Beverage



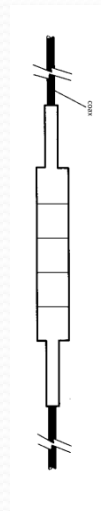
9:1 Coax to BULLET
End fed Antenna



Feed Point Choke
Line isolator
Noise Filter

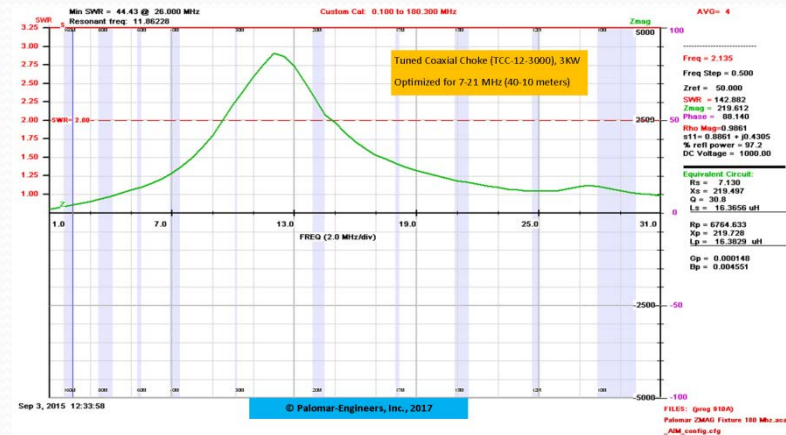
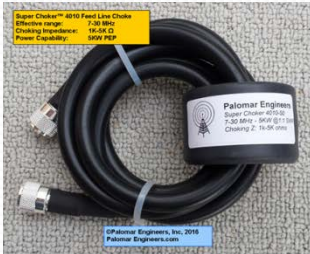


Coax
Noise
Filter

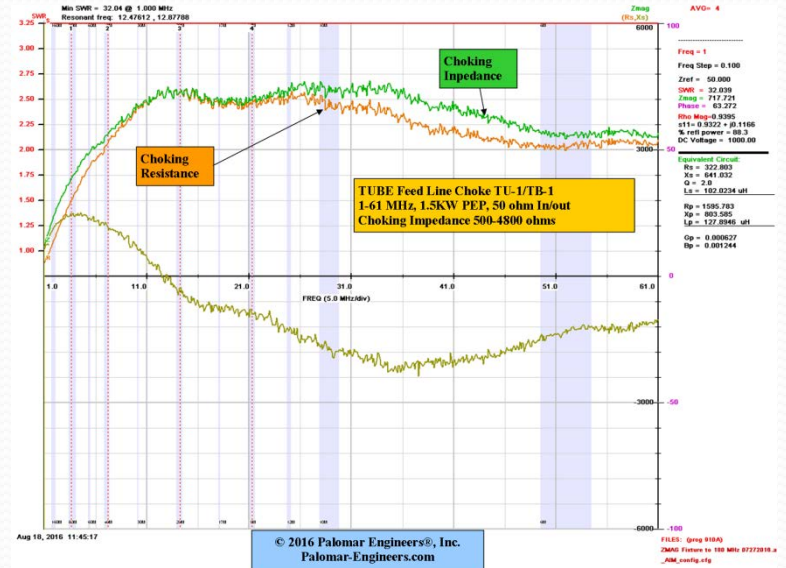
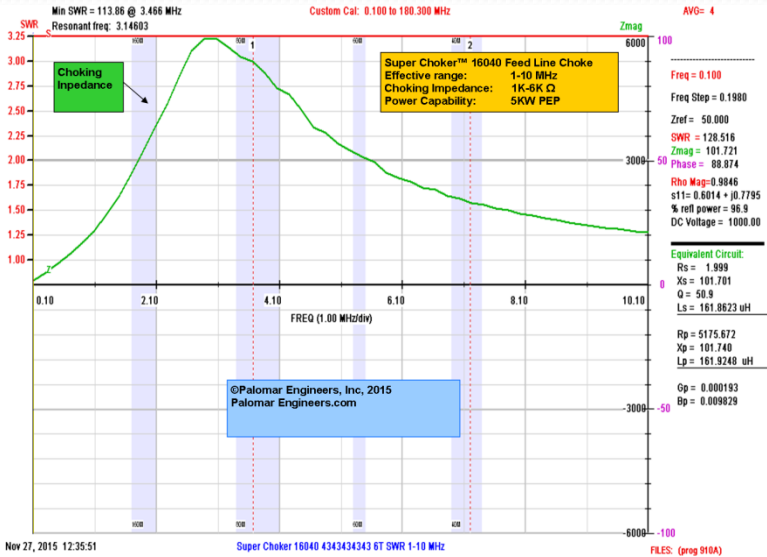


How to choose

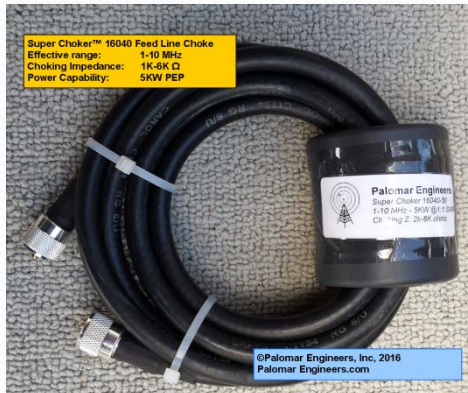
Choosing a Feed Line Choke



Choose choking impedance > 500Ω at frequency of use



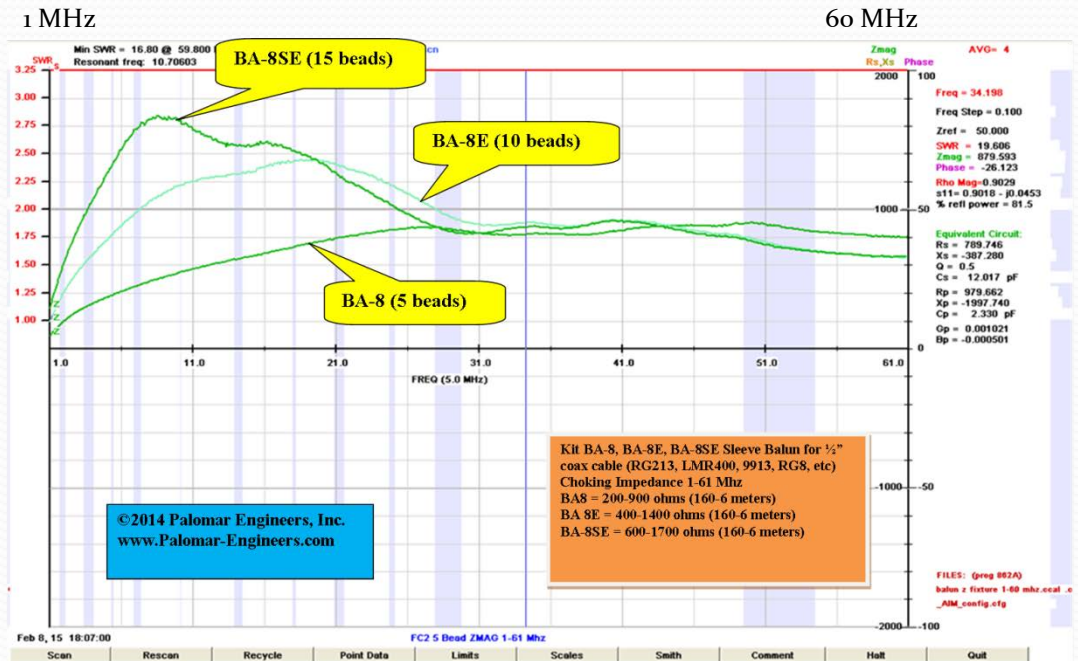
Super Choker
 1-10 MHz >2K
 5KW PEP
 1K-6K Z
 3 pounds
 Verticals
 AM/RTTY
 Contesting



Line isolator
 1-160 MHz >2K
 1.5KW PEP
 1K-6K Z
 1 pound
 All coax lines
 Optional
 ground, static
 bleeder



Feedline Chokes for all antennas



Medium choking Z (500-2000Ω) – 5KW PEP for RG213,
only 5 beads needed over 30 MHz

CUBE™ Chokes for all antennas



- Highest Choking (5-15K ohms)
- Power to 10KW PEP
- Use: Inline choke, beam, dipole, loop, vertical, 1:1 ladder line to coax interface (G5RV/ZS6BKW)

Let's Recap

RFI proof your transmissions recap

- Determine frequency range of RFI and Path
- Install AC/DC power and transceiver and amplifier RFI kits to suppress RFI
- Install a feed line choke in ALL antenna coax lines of your station at the antenna feed point with enough choking impedance at the frequency of use to minimize coax braid radiation
 - Install filters and chokes and retest for RFI suppression
 - Consider additional filters and paths if RFI persists

If you need help
Call Palomar Engineers or view specific solutions at
Palomar-Engineers.com

What about receiver noise? →→

Receiver RFI Solutions

Our Goal: Lower noise floor = Higher SNR = More DX!

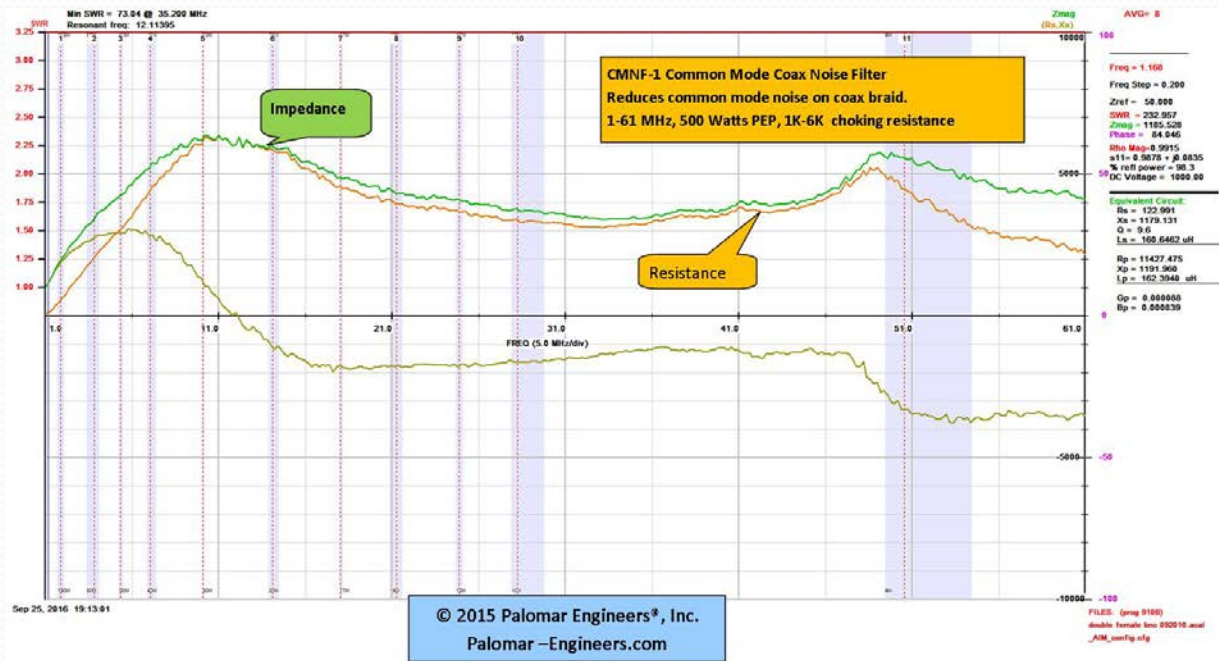


Receiver RFI Noise (man made)

- **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 – high noise level symptom
- **SOLUTION:** eliminate SOURCE, choke PATH, protect VICTIM – most “noise” from common mode current in AC/DC lines or coax braid acting as an additional receive antenna

Coax Feed Line Noise Filters

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



Placed at RADIO END of coax feed line to suppress common mode current on coax braid between antenna feed point choke and radio

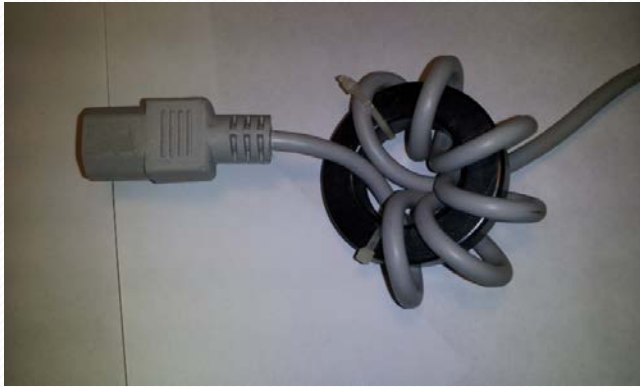
Choke location

Choking Impedance vs Attenuation

- Palomar Engineers specify RFI/EMI chokes in terms of impedance (in/out), but often the customer needs to know the attenuation to choose which product best suits the application. (1 “S” unit = 6db)

Choke Impedance (Z_{sc})	Attenuation (dB)
200	-9.5
500	-15.6
1000	-20.8
1500	-24.0
3000	-29.8
5000	-34.2
10000	-40.0

AC Line/DC Power Filters



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

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 rotor lines
 - Chokes on AC/DC cords, Wall Warts – ring or snap on ferrites
 - Chokes on radio-computer interconnect cables
- ELIMINATE/ISOLATE the SOURCE
 - Choke AC/DC power to source, snap on ferrites for all I/O
- 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 Strategy is different

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

- What are 2 ways to increase the choking impedance of a ferrite filter choke?
 - A) Use high resistance wire and multiple turns on bead
 - B) Use multiple beads and dual core braided wire
 - C) Use multiple beads in series with multiple turns
 - D) Use mix 31 and mix 77 beads in series with a single turn

Prize Question #2

Mix 75/77 is used in which frequency range to suppress RFI common mode current?

- A) 1-300 MHz
- B) 200-2000 MHz
- C) .1-10 MHz
- D) 1-2000 MHz
- E) CB Band Only

Prize Question #3

- What is one of the best kept secrets in ham radio?
 - a) Ladder line has more loss than coax
 - b) A coax wound choke can cover all frequencies from 160-6 meters
 - c) All ferrite mixes work on all frequencies
 - d) Coax noise filters reduce noise level in your receiver

Bonus Prize Question #4

- Which company is your best source for RFI solutions?

RFI Solutions Experts

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.