



RFI Solutions from KHz to GHz

RFI Tips, Tricks, & Techniques



Bob Brehm, AK6R

Chief Engineer

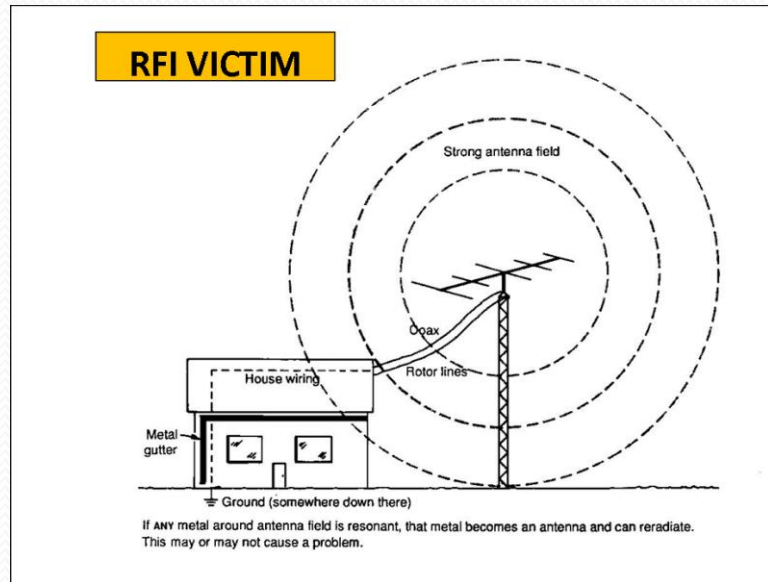
Palomar-Engineers.com

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Are you the **SOURCE** of RFI?



IT'S ALL YOUR FAULT WITH THAT BIG ANTENNA!

Maybe you got an award?



RFI Solutions from KHz to GHz

WORKED ALL NEIGHBORS

AWARDED TO

Amateur Radio Station _____

Who has caused persistent Radio Frequency Interference (RFI)
to neighbors adjacent to the radio station

Awarded this ____ day of _____, 20__

RFI Case Endorsements:

5

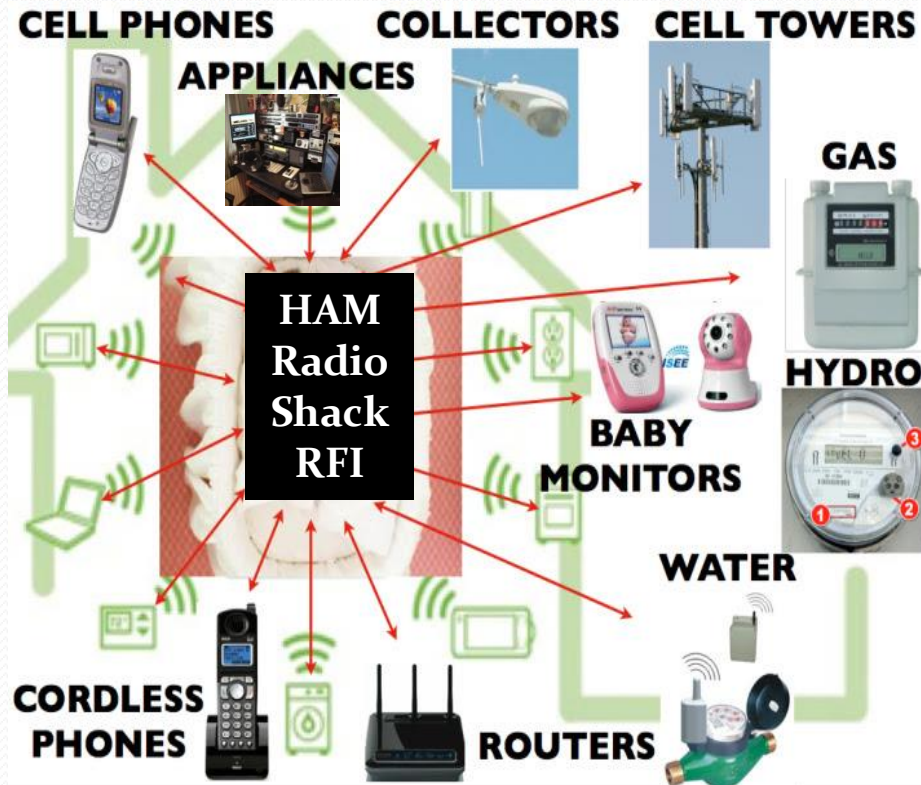
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25

50

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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!

What is RFI?

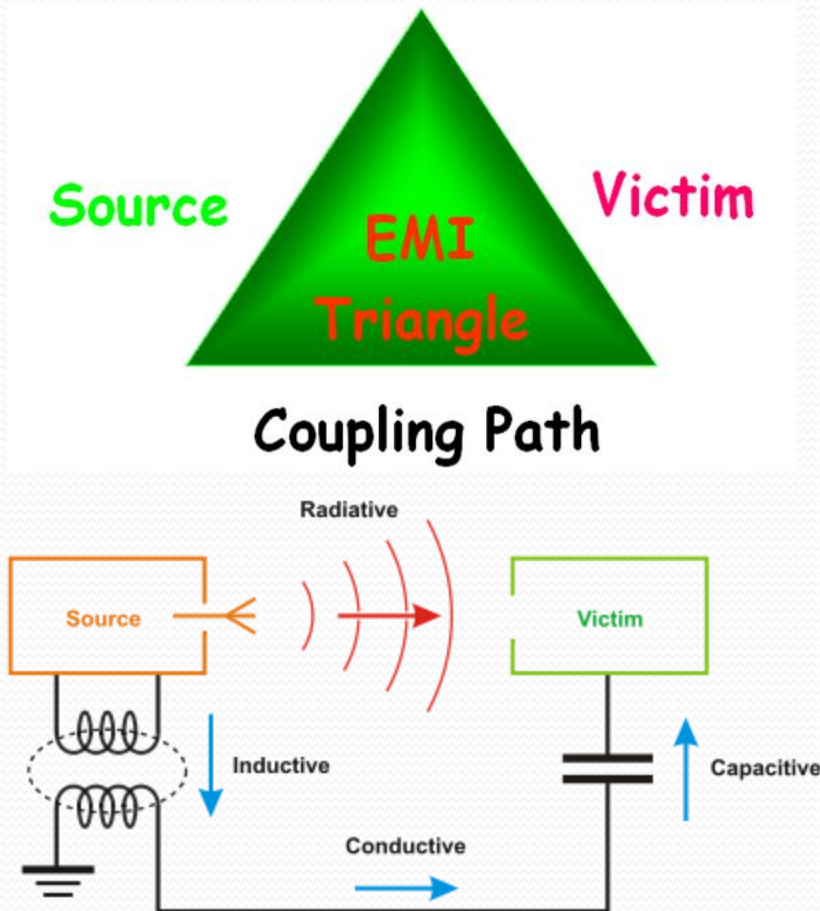
- *A radio frequency (>100 KHz) disturbance that causes an electrical circuit to function improperly*

Common Sources

- Sunspots, Cosmic noise, Lightning, atmospheric static, AC power lines (**no fix**)
- “Transmitters” -Ham, CB, AM/FM, electronic devices, speed controllers, inverters, switching power supplies, computer electronics, Cable/DSL/Ethernet (**can use filters to fix**)
- Common Victims
 - Any electronic device that malfunctions by acting as an unintended “receiver” of RFI

How do you get RFI?

How RFI is Transferred



Source (antenna) and **Victim** (antenna) coupled via **Path** (all must be present to have RFI)

Multiple paths are very common:

1. Radiative - air
2. Conductive – wire(s)
3. Inductive - wire
4. Capacitive - wire



How to find the source & path

Typical RFI in your shack/home

- **TX Symptoms** – caused by your transmitter or antenna
 - Hot microphone – RF 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.)
 - Spouse Alarm goes off
 - **RX Symptoms** – caused by sources outside your radio
 - High receive noise level not due to atmospheric conditions
 - Birdies, chirps, buzzes, clicks, broadband noise on receiver
 - Distorted receiver audio
- “Antennas” & paths

Typical RFI receiving “antennas”

- **AM broadcast, 160-80-60-40-30 meter RFI** – long “antennas” - 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 (avoid $\frac{1}{4}$ wavelength ground wires)
- **FM broadcast, 20 meter-UHF transmitter RFI**,– short “antennas” - speaker wires, device interconnect cables, mic cables, short Ethernet cables
- “Antennas” pick up radiated or conducted RFI and a common mode current is induced on ALL unshielded antenna conductors from an RFI SOURCE

So how do we reduce this current?

Curing RFI Issues



$$I \text{ (RFI Current)} = E \text{ (TX voltage)} / R \text{ (Choking resistance)}$$

- Shut down the SOURCE (Set E to zero)
- Choke the PATH (minimize E, increase R)
- Protect the VICTIM (Set R very high)

Objective: Minimize RFI current, I

Trivia Q: Why is current abbreviated with I and not C?

Using ferrites to cure RFI



Ferrite Fundamentals

How to:
Select
Buy
Configure
and Apply



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

Ferrite characteristics can be used to reduce RFI common mode current

Impedance


$$15 \text{ beads} = 1600\Omega$$


Impedance (Z) = Resistance +/- Reactance

Ferrite resistors increase as (turns)²

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



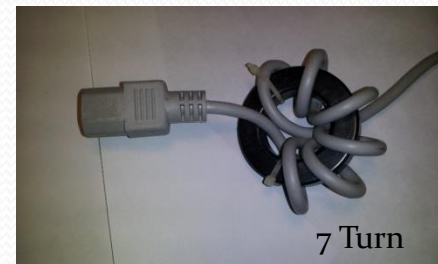
1 Turn

7 MHz: 100Ω



3 Turn

900Ω

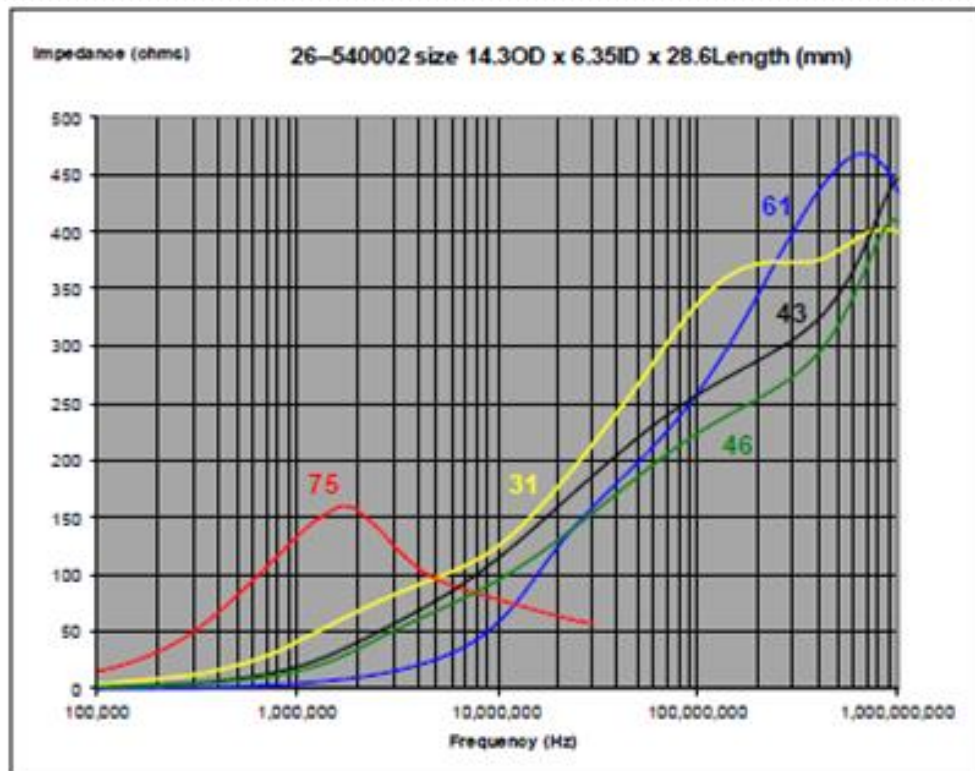


7 Turn

2500Ω

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

Ferrite Mix determines frequency range of effectiveness



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

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

Example:

for .1-10 MHz use mix 75

for 1-300 MHz use mix 31

for 20-250 MHz use mix 43

for 200-2000 MHz use mix 61

Most popular ham frequency mixes are 31, 43, 61, 75.

Wrong or unknown mix will probably not work so.....

Know how to buy

How NOT to buy ferrites!



=

**DON'T
BUY!!!**

- NO Mix Designation
- NO Resistance/Impedance Range
- NO Frequency Range = No No No!

Buying unknown ferrites is like buying a box of rocks - a waste of time and money!

Another Alternative?

How to buy Ferrites the **right** way!



Ferrite Split Bead
10 Pack -1/2" ID – Mix 31
RFI Range: 1-300 MHz
Part#: FSB31-1/2-10

Single turn, each bead provides:

| MHz | 5 | 10 | 25 | 100 | 250 |
|----------|----|-----|-----|-----|-----|
| Ω | 71 | 100 | 156 | 260 | 260 |

(2 turns=4X Ω , 3 turns =9X Ω , 4 turns = 16X Ω)

AC/DC/Coax/Audio-Video/Data Cables
Use multiple turns for best results

=

**BUY With
CONFIDENCE!!**

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 “Antenna”
 - 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 for .1-10 MHz, Mix 61 for 200-2000 MHz)

How and where do you put the ferrite band aid for transmitter RFI?

GOAL: **STOP** TRANSMIT RFI

Tip # 1: RFI Kits for HF Transceivers and Linear Amps

Tip # 2: Minimize coax cable radiation (HF or VHF)

Tip # 3: Install Solution Specific RFI Kits for VICTIMS



Tip #1 - Install Transceiver, Linear Amp RFI Filters

Goal: Minimize SOURCE RFI from radio and amplifier “antennas”



RFI Chokes for Transmitters/Amps

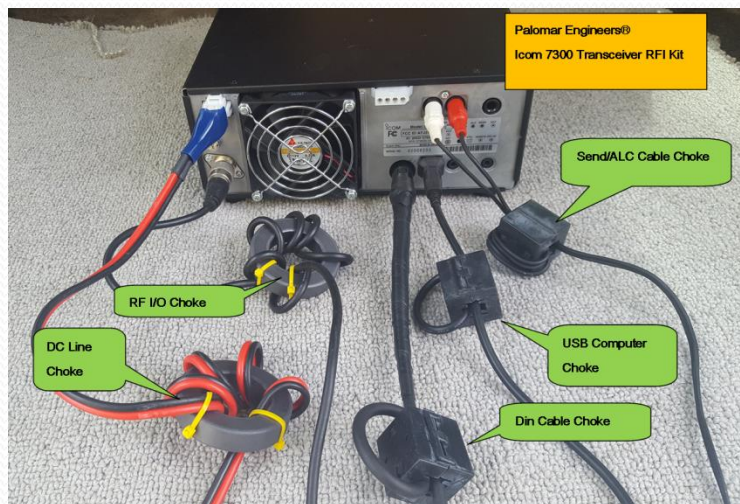
- Transmitter – Amplifier - Antenna RFI suppression
 - Choke all cables into/out of radios, amplifier, antenna tuners
 - Includes
 - ALL Coax RF feed lines or common line of coax switch
 - Rotor/Antenna Control lines
 - AC/DC power Lines including wall warts!
 - Computer – all radio interconnects, AC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

Transceiver/Amp Examples

Transceiver/Amp RFI Kits

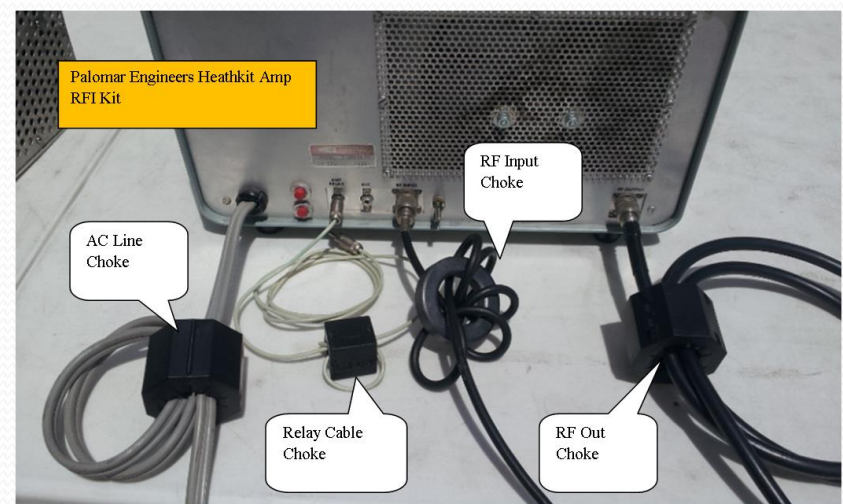
Palomar has RFI kits for all brands of transceivers and amplifiers

Transceiver RFI Kit



ICOM 7300

Linear Amplifier RFI Kit



HEATHKIT SB220

Clean up the RFI **SOURCE** first – your radio and amp

Tip #2. Stop Transmit RFI current on coax braid



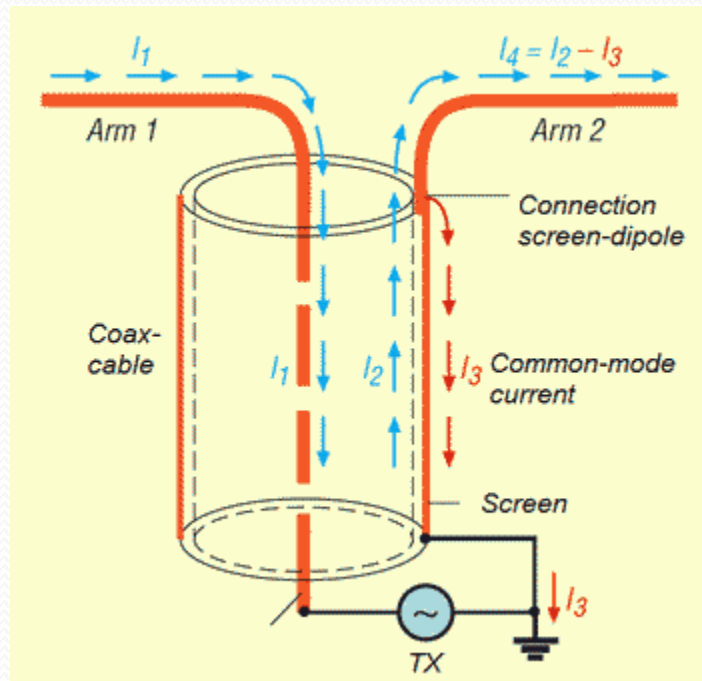
ALL coax fed antennas need a feed line
choke at the antenna feed point!!!!

OR

Your dipole will become a tripole or
Your unipole (vertical) will become a dipole
and your coax will radiate causing local RFI!

Is your Dipole a Tripole?

- Coax outside of braid acts as extension of transmitting antenna and extra receive antenna



Coax cable has 3 conductors!

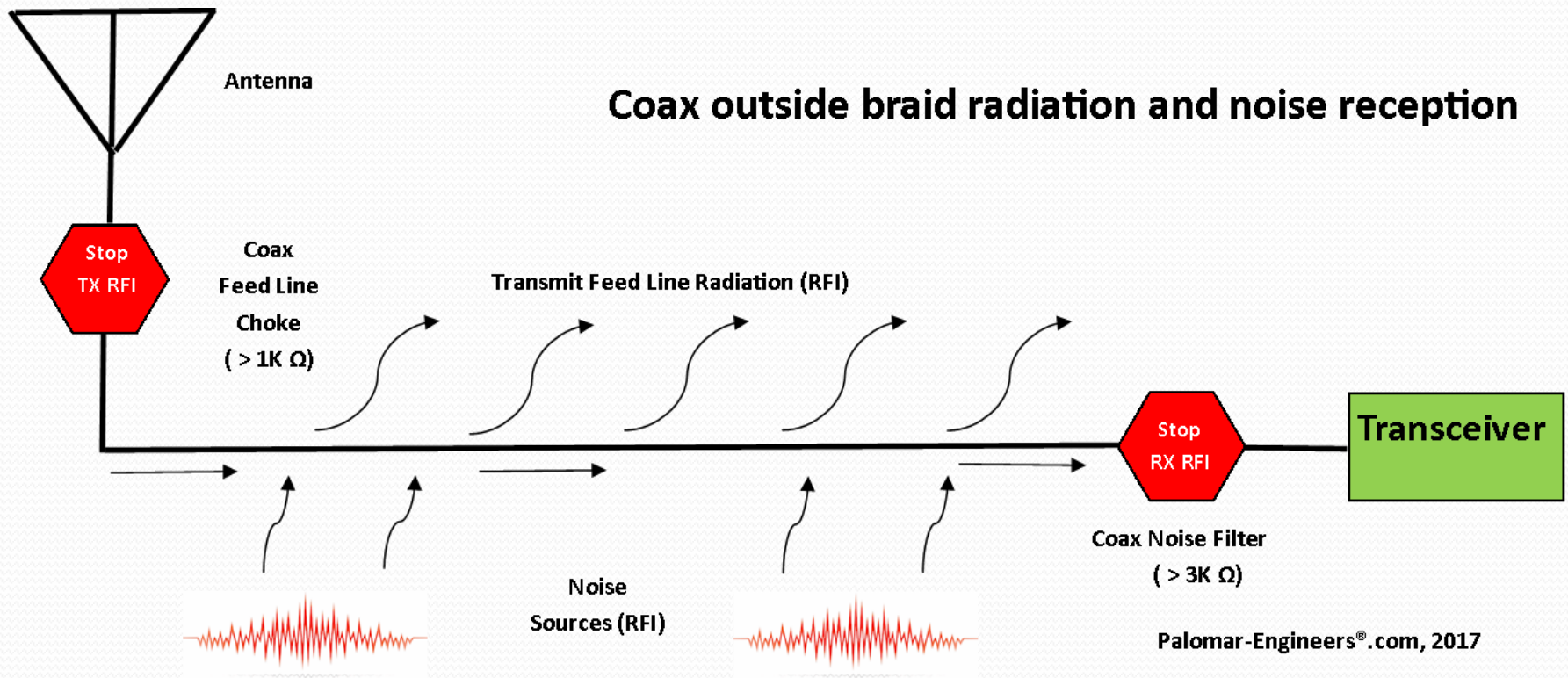
Coax braid is actually 2 conductors :
1 on the inside (normal RF signal), and
1 on the outside (common mode current)
that turns a dipole into tripole on transmit
or a second antenna on receive!

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

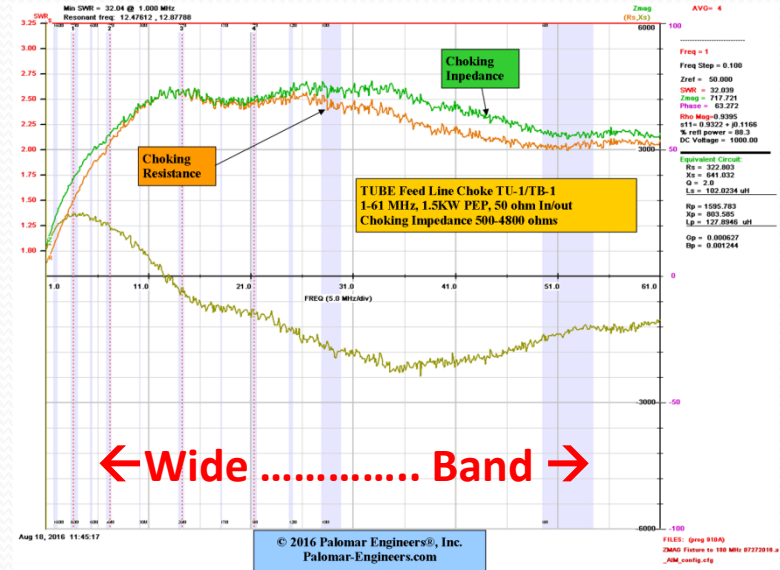
Typical Coax Antenna

Typical Coax Fed Antenna System



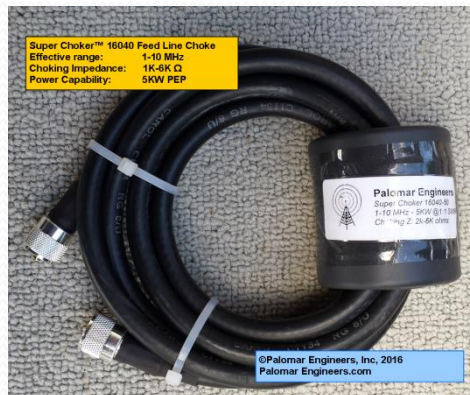
Technical requirements for feed line choke selection

Choose choking resistance > 500Ω over frequency range used



Super Choker

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

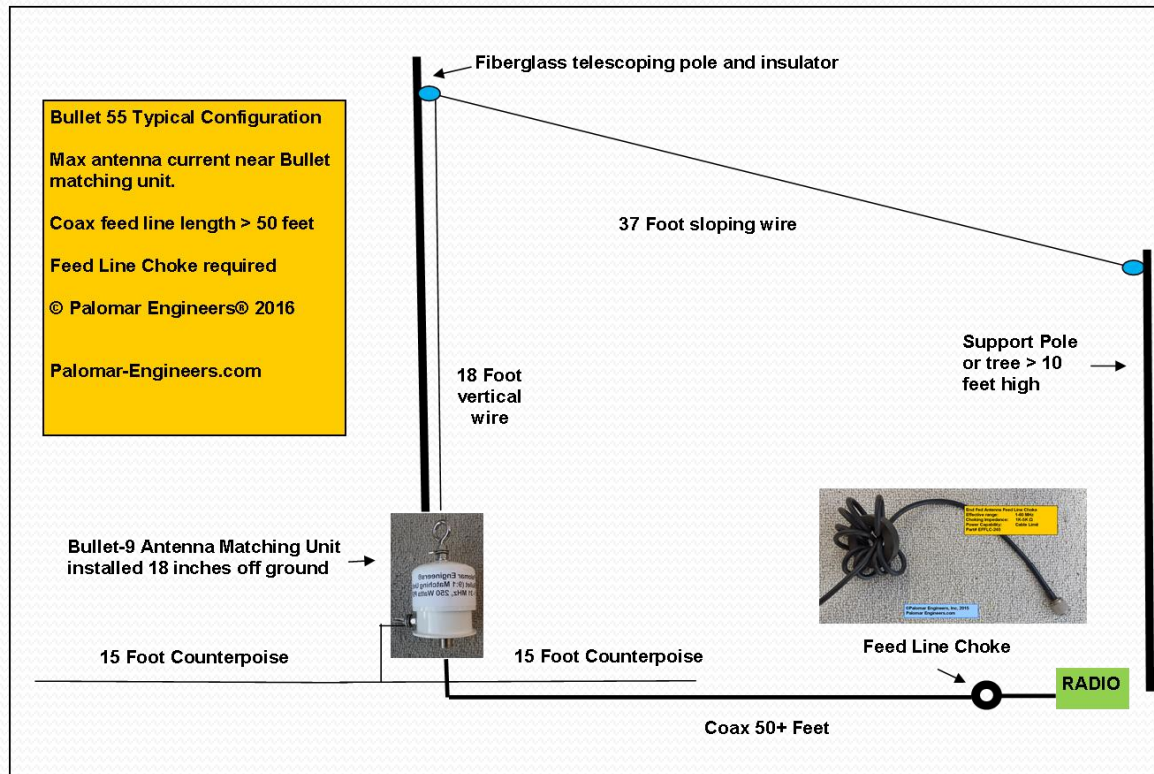


Line isolator

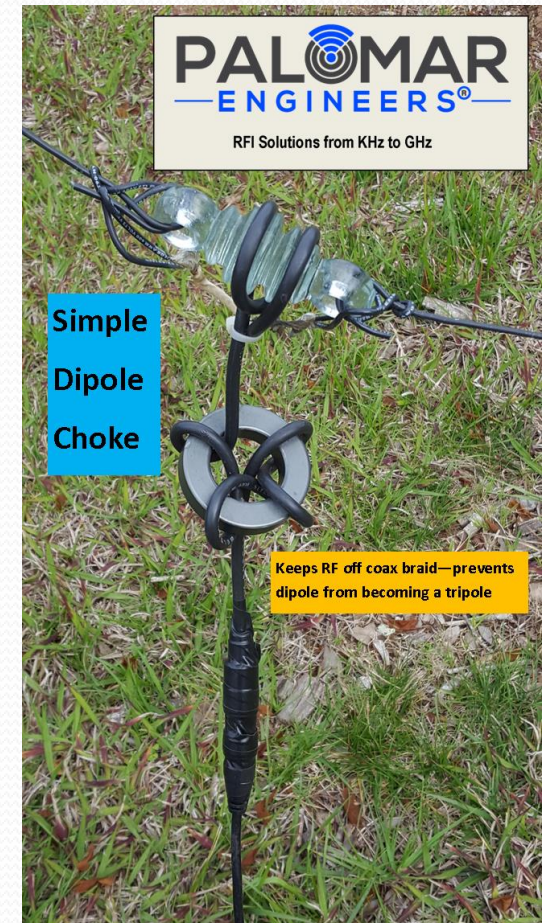
1-160 MHz >2K, 1.5KW PEP, 1K-6K ZΩ, 1 pound. All coax lines, Optional ground, static bleeder

DO NOT BUY CHOKES with NO SPECS!

Simple DIY Feed Line Chokes



Use 1.4" ID Ring with multiple turns



Let's Recap

Tip #3. Install Solution Specific RFI Kits

Our Goal: Minimize Transmit RFI to Home Electronics and Home
Electronics RFI to receiver

Garage Door Opener RFI Kit

Washer/Dryer/Refrigerator RFI Kits

Home Alarm RFI Kit

Computer Desktop, laptop, DSL/Router RFI Kits

Home Theater A/V Systems, Satellite Boxes

Sprinkler Systems



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.

Ham's Transmitter RFI Strategy

- 1
 - **Eliminate/reduce RFI SOURCE**
 - (transmitter, amplifier RFI kits, move antenna location)
- 2
 - or
 - **Choke the PATH**
 - (coax feedline chokes, AC/DC power line chokes)

Now What About Receiver RFI?

GOAL: **SUPPRESS** RECEIVE RFI

Tip # 4: Install Coax Noise Filters

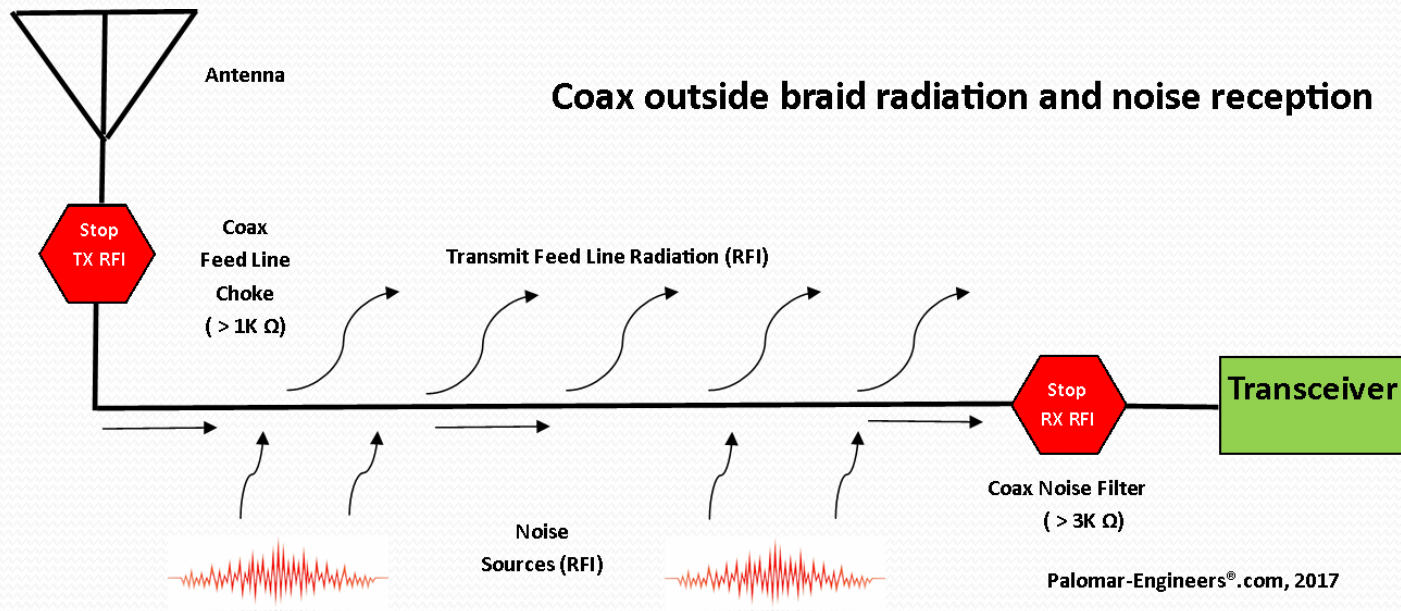
Tip # 5: Identify & Suppress Local RFI/Noise Sources



Receive RFI Problem

- Symptoms: High noise levels, spurs, buzzes, periodic signals across bands

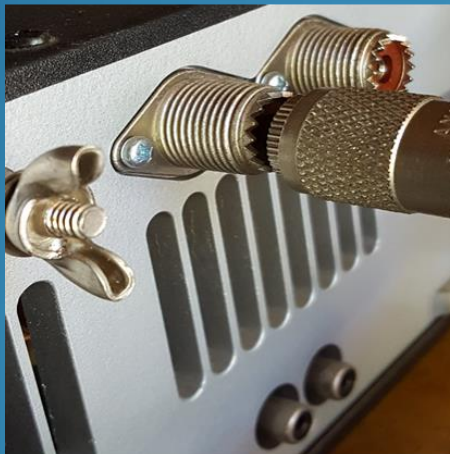
Typical Receive Chain Connections



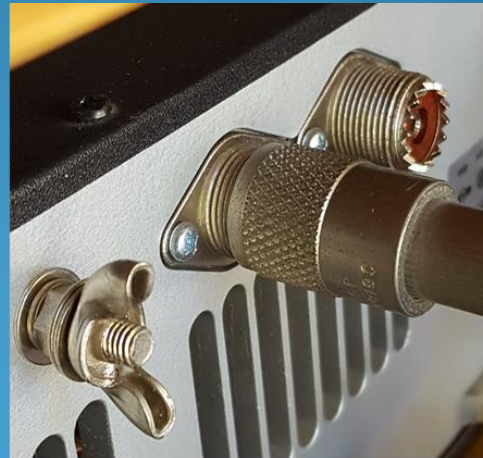
Tip #4. Install Coax Noise Filter to Suppress RX RFI

Less common mode noise current (RFI) = More DX!
How to select and install filters for maximum effect

Quick Test
for Common
Mode RFI



Coax Center Conductor Only—measure noise level



Coax Center Conductor and outer shield — measure noise level. If higher, then you have common mode noise



Coax Noise Filter Comparison

OK



Snap On Choke
500-1000 Ω
1-2 “S” Units

Better



Ring Choke
1K-2K Ω
2-4 “S” Units

Best



Noise Filter
2K-6K Ω
3-6 “S” Units

Criteria to Consider

- Adequate Choking Impedance (Z) > 500 Ω
- Effective Frequency Range where $Z > 500 \Omega$
- Sufficient Power Rating (PEP, Digital)
- Physical Size/Weight/Coax Diameter

First: Impedance

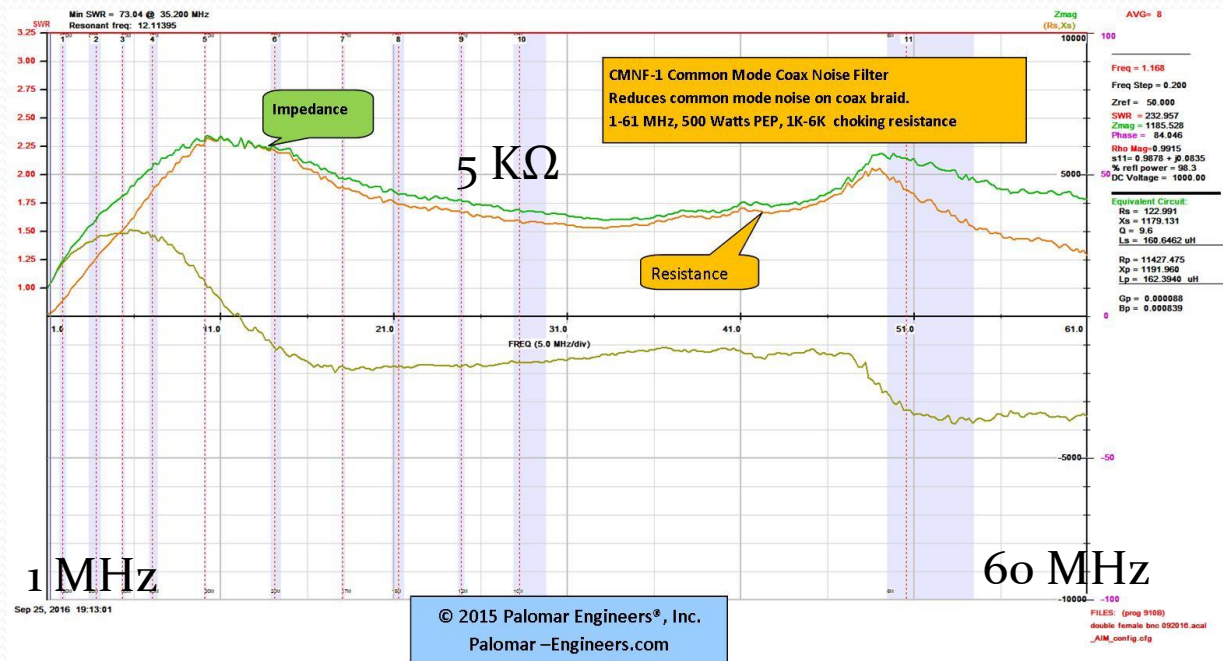
Choking Impedance vs Attenuation

- 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 | Attenuation (dB) |
|-----------------|------------------|
| 200 | -9.5 |
| 500 | -15.6 |
| 1000 | -20.8 |
| 1500 | -24.0 |
| 3000 | -29.8 |
| 5000 | -34.2 |
| 10000 | -40.0 |

Coax Noise Filter Specs

>>> 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

Now AC/DC Filters

Tip #5. Install AC/DC Noise Filters

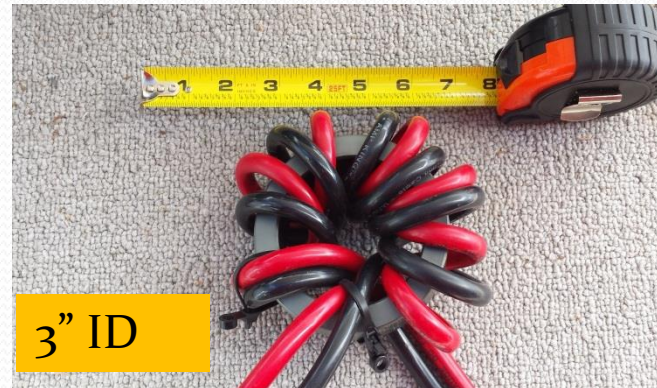
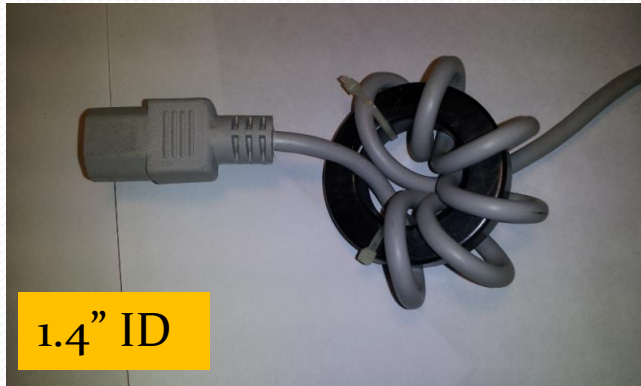
Lower Noise Floor = Higher SNR = More DX!

How to select and install filters for maximum effect

Goal is to reduce common mode RFI current superimposed on regular signal INTO “receiver”



RFI – AC/DC Line Chokes



Choose mix frequency range and size to fit cable – use multiple turns

Touch Lamps use 2 F240-75 Rings – 12 Turns each

Wall Warts

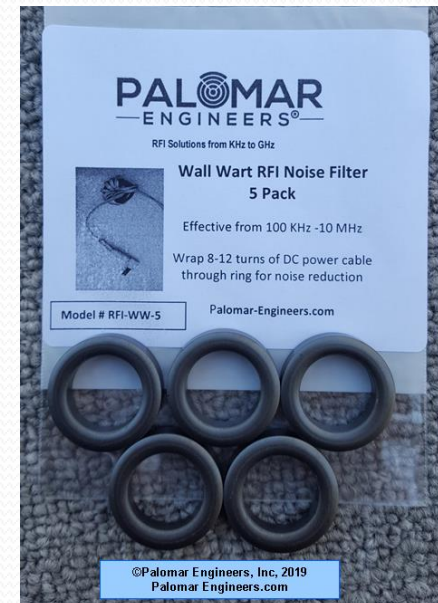
Wall Wart RFI Noise Reduction Kit

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 5 ring kit

Tip #6. Use Ferrite Combo RFI Kits for Newbies

Ferrite Combo Kits for Troubleshooting Multiple RFI Issues include multiple ferrite shapes and sizes covering multiple frequency ranges

$\frac{1}{2}$ " snap ons and 1.4" ID rings are the most popular sizes and can be used to solve most ham radio HF RFI problems



Combo pack of rings and split beads

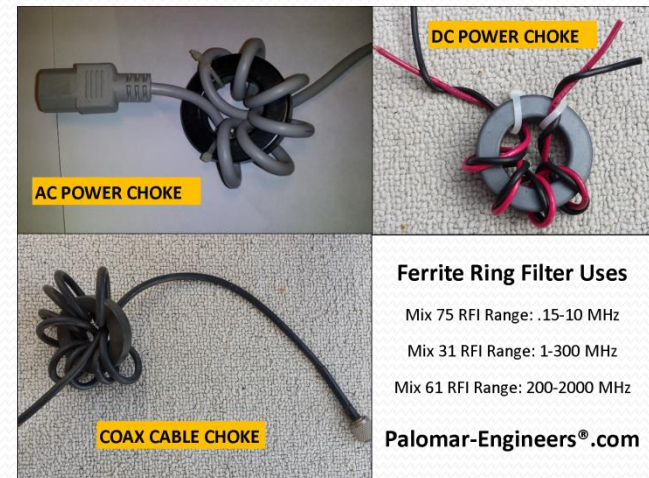
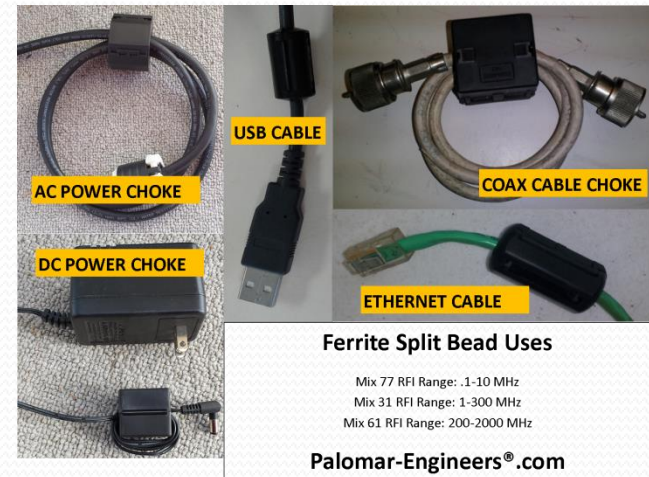
**Multi Ring + Snap On
Combo Pack—Mix 31**



Ring: F240-31(6) 1.4" ID
Snap On: 3/8"(6), 1/2"(5)
RFI Range 1-300 MHz

Part# MRSCP-31-17

- **Use Multiple turns for best results**



Test Time – Win A Prize

Prize Question #1

- What are 2 ways to increase the choking resistance of a ferrite filter?
 - A) Use high resistance wire and multiple turns on bead
 - B) Use multiple turns and double shield coax
 - C) Use multiple beads in series with multiple turns
 - D) Use mix 31 and mix 75 beads in series with a single turn

Prize Question #2

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

- A) 1-300 MHz
- B) 200-2000 MHz
- C) .15-10 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 if the coax is long enough
 - c) All ferrites work on all frequencies, so buy the cheapest
 - d) Coax noise filters reduce common mode noise level in your receiver so you can hear more stations
 - e) All extra class hams go to heaven

BONUS Question

Bonus Prize Question #4

- Which company is your best source for RFI solutions?



RFI Solutions from KHz to GHz

- 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.