PALOMAR ENGINEERS®

RFI Solutions from KHz to GHz

ABC's of RFI for Hams

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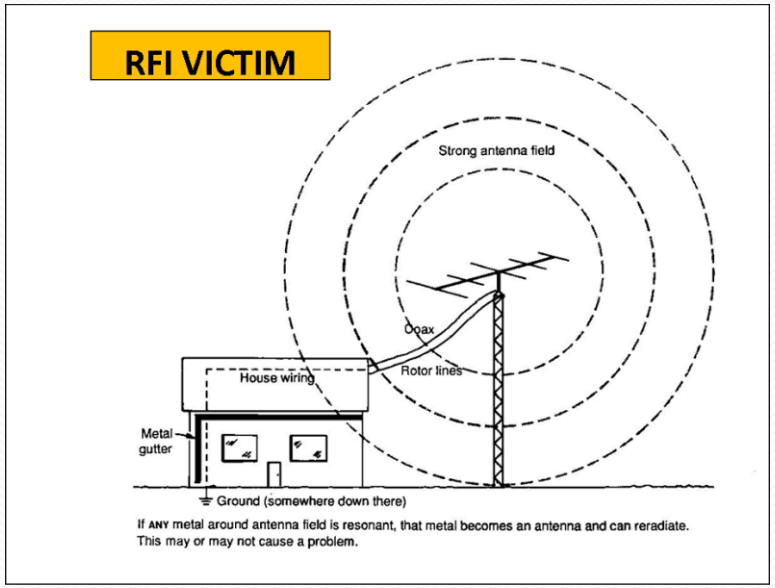
This presentation available on website

Palomar History

- Founded in 1965 by Jack Althouse, K6NY
- Reorganized in 2013 as RFI Solutions company by AK6R and spouse, Susan Kline
- Product Line
  - Ferrite Core Products
  - Baluns, Ununs & Feedline Chokes
  - Antenna Systems (OCF, End Fed, Loop, Terminated)
  - Kurt Sterba Books/Downloads
- Distribution: Ham Radio Outlet, Direct, Ebay
- Markets: Consumer, Commercial, and Military

Let's talk about RFI

Are you the **SOURCE** of RFI?



IT'S ALL YOUR FAULT WITH THAT BIG ANTENNA!

Maybe you got an award?

PALOMAR ENGINEERS®

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__

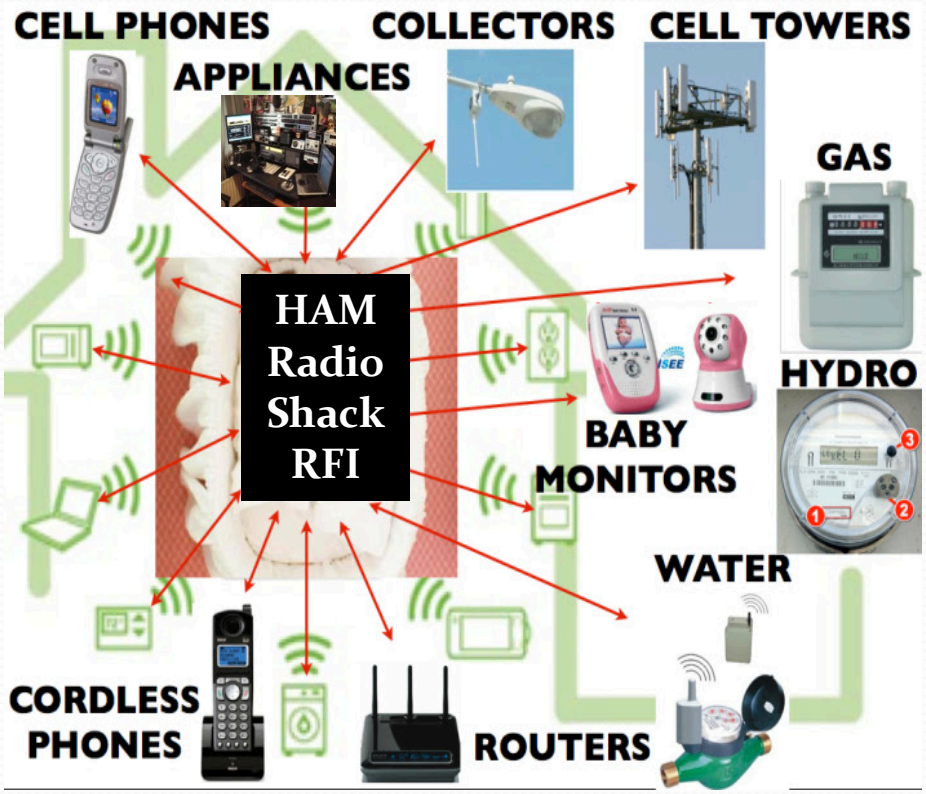
RFI Case Endorsements:

5 10 25 50

_____

Bob Brehm, AK6R
Chief Engineer

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

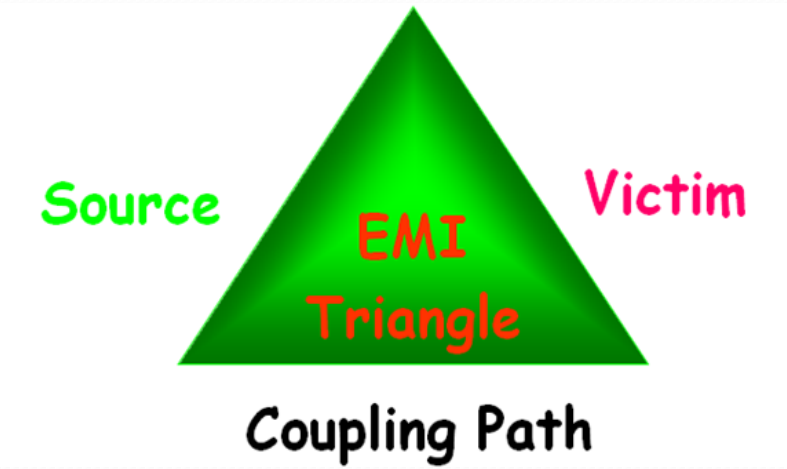
Thinking cap time……

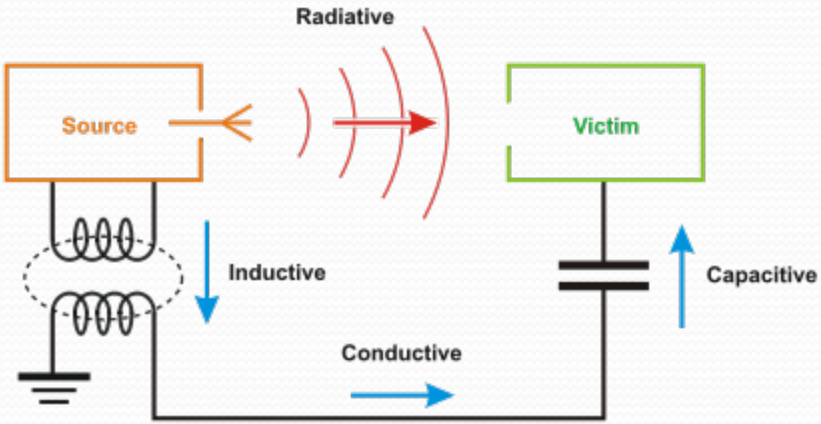
What is RFI?

- ***A radio frequency (>100 KHz) disturbance that causes an electrical circuit to function improperly***
  Common **<u>Sources</u>**
  - Sunspots, Cosmic noise, Lightning, atmospheric static, AC power lines (**no ferrite 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 **<u>Victims</u>**
  - Any electronic device that malfunctions by acting as an unintended "receiver" of RFI

How do you get RFI?

How RFI is Transferred





<u>Source</u> <u>(antenna) and</u> **<u>Victim</u>** <u>(antenna) coupled via</u> **<u>Path</u>** <u>(all must be present</u> 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 <u>your transmitter or antenna</u>
  - 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 <u>sources outside your radio</u>
  - High receive noise level <u>not due</u> to atmospheric conditions
  - Birdies, chirps, buzzes, clicks, broadband noise on receiver
  - Distorted receiver audio

"Antennas" & paths

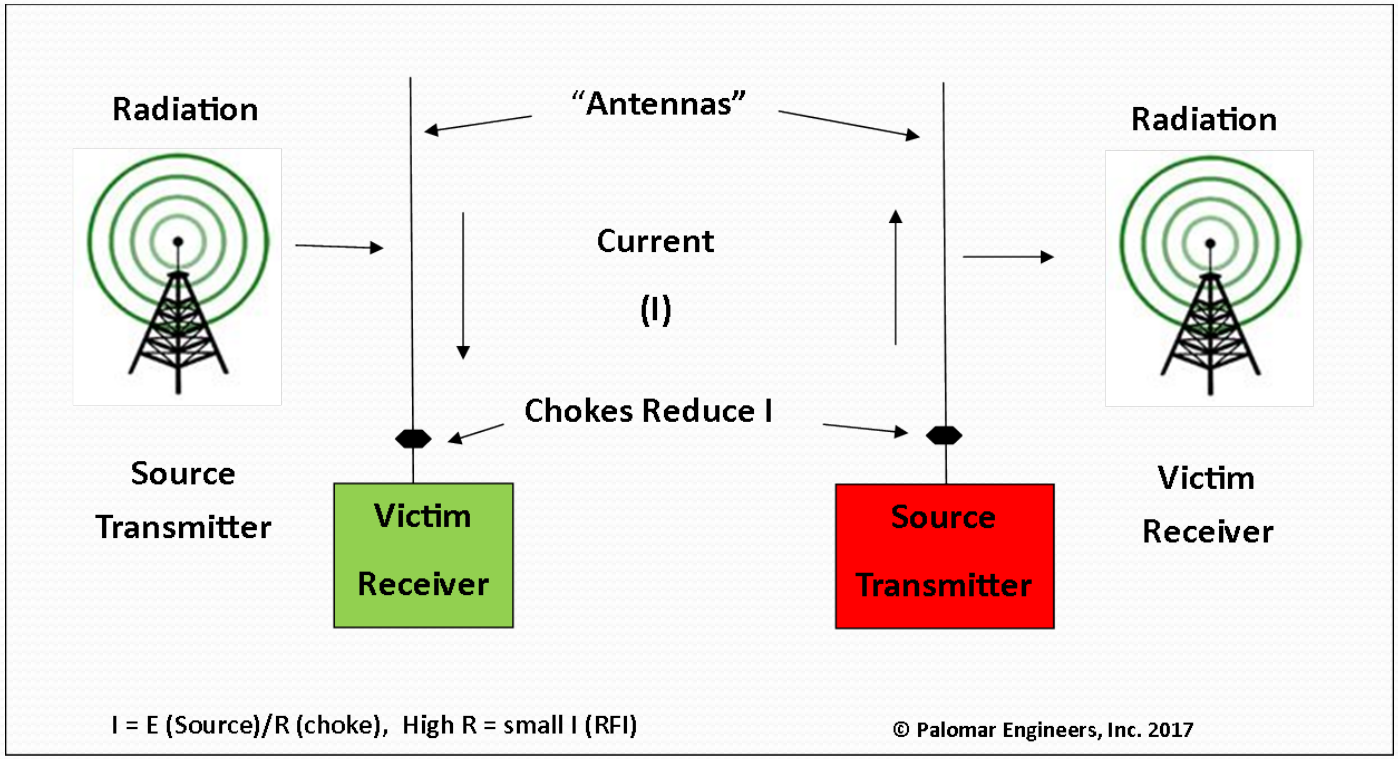
Typical RFI receiving “antennas"

- **AM broadcast, 160-80-60-40-30 meter RFI** – look for 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 ¼ wavelength ground wires, e.g. 16 Feet)
- **FM broadcast, 20 meter to 450 MHz RFI**,– look for short “antennas” - speaker wires, device interconnect cables, mic cables, short Ethernet cables

- “Antennas” pick up radiated or conducted RFI which induces a common mode current on ALL unshielded “antenna” conductors from an RFI SOURCE

So how do we reduce this current?

Reduce RFI current to reduce RFI!



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

Ohms law is your answer

Stop RFI = Minimize Current

I (RFI Current) = E (TX voltage)/R (Choking resistance)

- Shut down the SOURCE (Set E to zero)
- Choke the PATH (minimize E, increase R > 1000 Ω)
- Protect the VICTIM(Set R very high, >5000 Ω)

Objective: Minimize RFI current, I

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

Ferrites are your friends 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

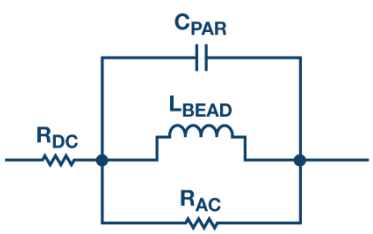
- Cheap, easy to install, suppress RFI from 100 KHz - 2 GHz
- Work on all conductive paths (antenna feed line, AC/DC, I/O cables)
- Lots of options in size, shape, frequency range to suppress RFI currents
- Are effective if you understand how ferrites work, how to choose the correct ferrite and where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

Ferrite characteristics can be used to reduce RFI common mode current

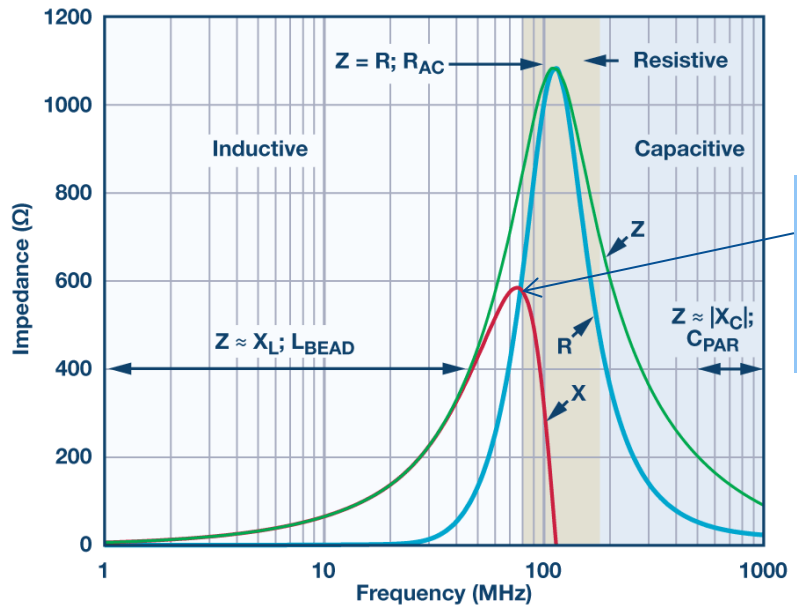
How do Ferrites Work?

Ferrites are frequency dependent "resistors"

Simple Equivalent Circuit



(a)



(b)

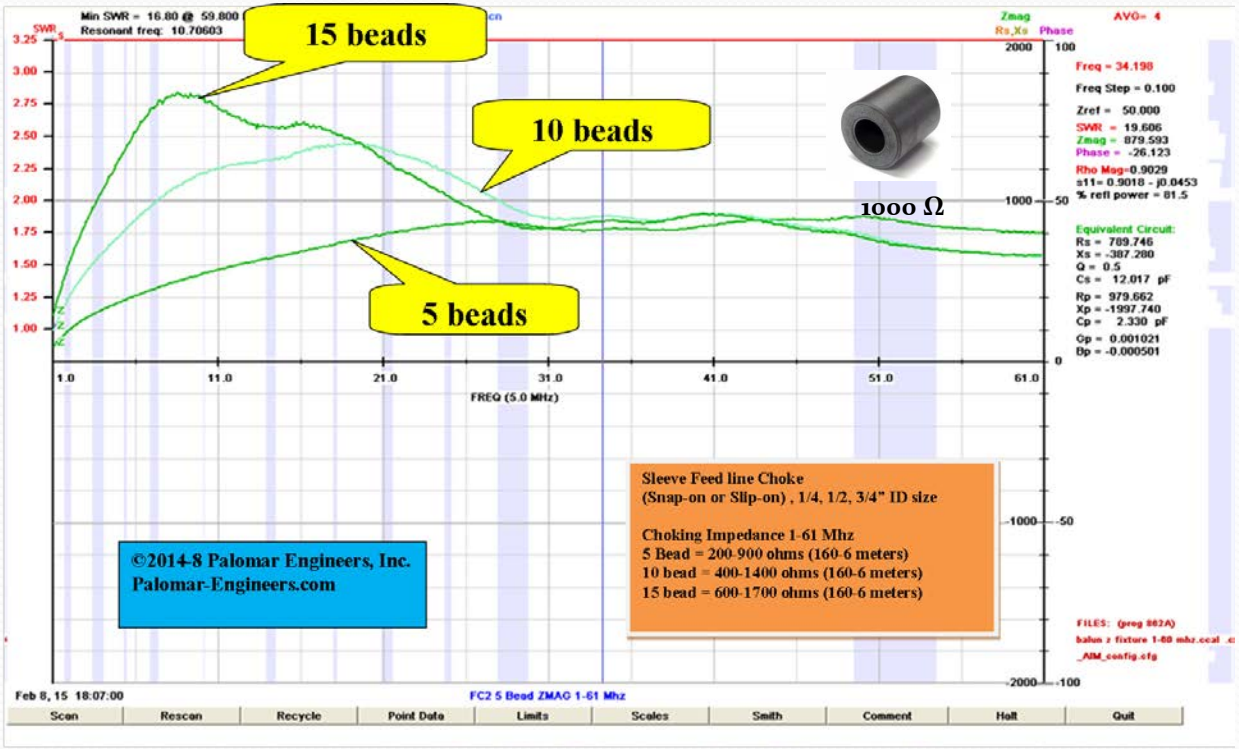
Resistive region starts here – 80 MHz to 300 MHz

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

How can resistance be increased?

Ferrites act like resistors (ΔF)

Impedance



Frequency (1-60 MHz) →

<u>beads add resistance in series, but frequency dependent</u>

higher choking R (up to 30 MHz in this example)

At 7 MHz:

5 beads = 400Ω
10 bead = 1000Ω
15 beads = 1600Ω

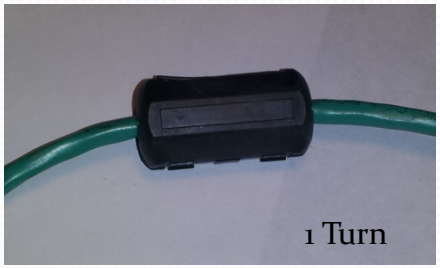
Feedline Chokes

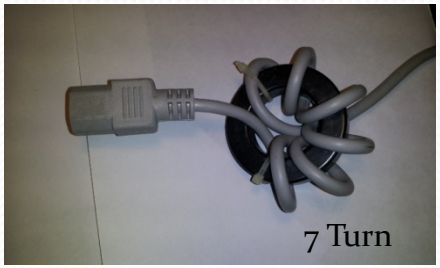
Impedance (Z) = Resistance +/- Reactance

Ferrites have one additional very useful property…

Ferrite resistance increases as (turns thru center)^2

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

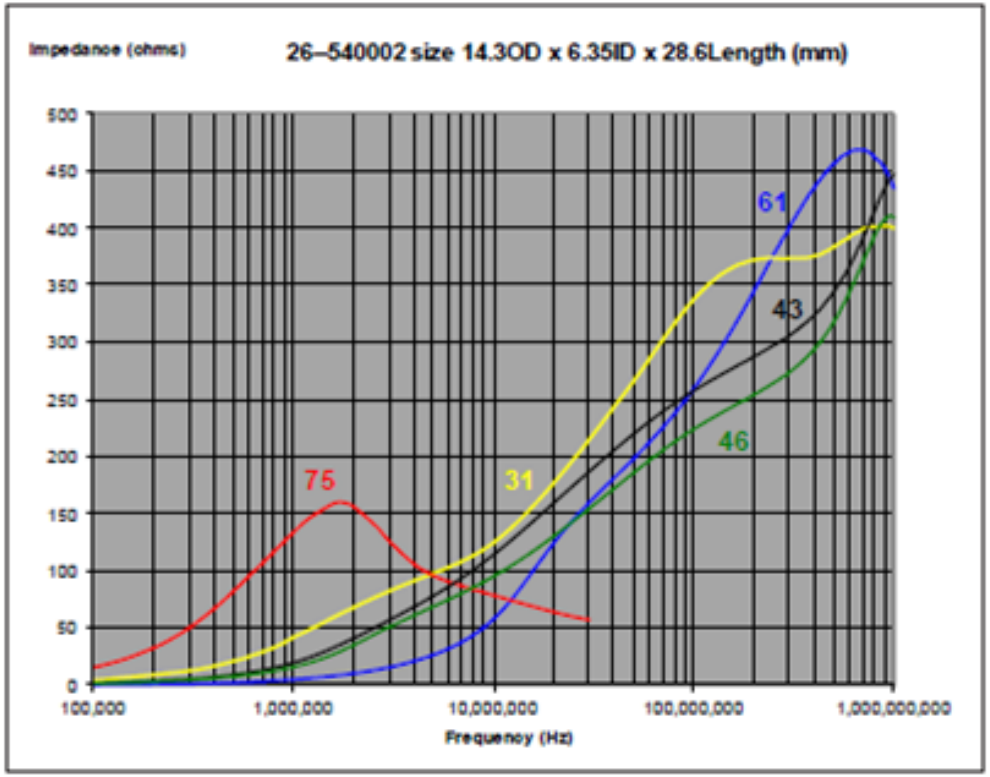




7 MHz: 100Ω 900Ω 6400Ω

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

Ferrite formula (Mix) determines effective frequency range



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 .1-5 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.

Selecting wrong or unknown mix will probably not work so.. How not to buy

How NOT to buy ferrites!

Amazon/eBay

Swap meet

=

DON'T BUY!!!

- **NO** Mix Designation
- **NO** Resistance/Impedance Range
- **NO** Frequency Range = No No No!
- Like Buying a resistor with an unknown resistance!

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!

PALOMAR ENGINEERS®

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=4XΩ, 3 turns =9XΩ, 4 turns = 16XΩ)
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) to suppress RFI <u>fundamental</u> frequency
- Choose Topology(slip-on, snap-on, ring) to fit the Path
  - Install ferrites on path – retest for RFI suppression
  - Consider additional ferrites or paths if RFI persists

<u>Most popular Mix for HF is MIX 31 (1-300 MHz)</u>
<u>(Mix 75 for .1-5 MHz, Mix 61 for 200-2000 MHz)</u>

How and where do you put the ferrite filter for <u>transmitter</u> 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 Filters for Transmitters/Amps

- Transmitter – Amplifier - Antenna RFI suppression
  - Choke <u>all</u> cables into/out of radios, amplifier, antenna tuners
  - Includes
    - <u>ALL</u> 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 cables to equipment using Palomar transceiver, amplifier and computer RFI kits with mix, sizes, instructions already pre-determined.

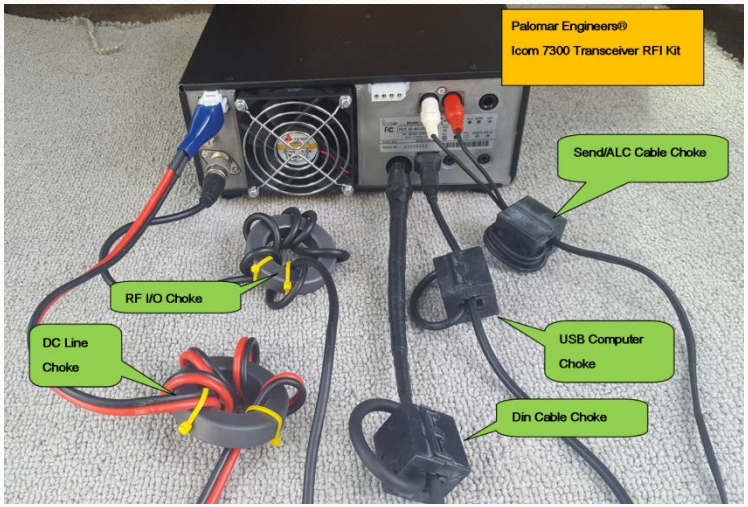
Buy it – Install it – Problem solved!

Transceiver/Amp Examples

Transceiver RFI Kits

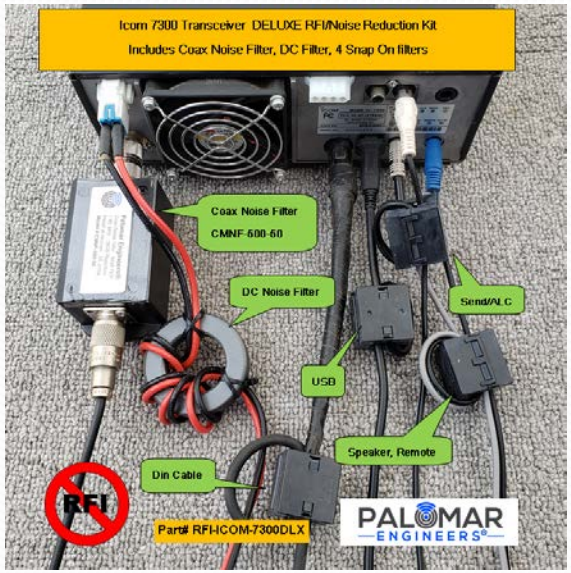
Palomar has RFI kits for all brands of transceivers

Transceiver Standard RFI Kit



ICOM 7300

Transceiver Deluxe RFI Kit with NF



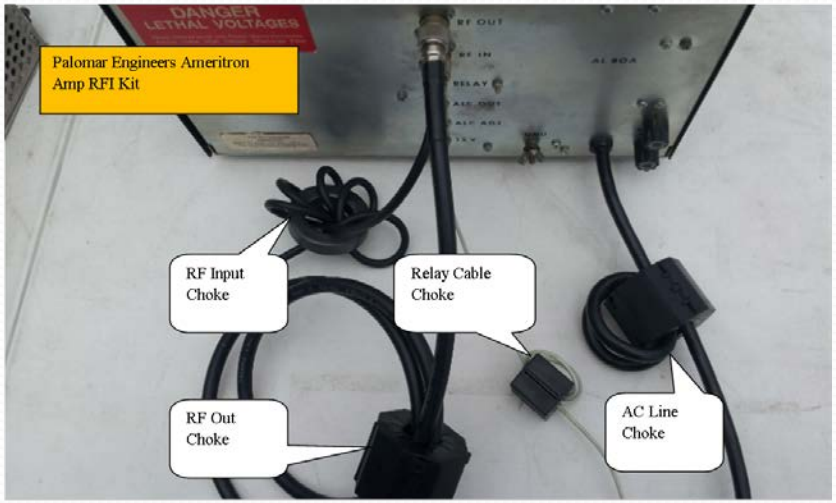
Clean up the RFI **SOURCE** first – <u>your radio</u>

Linear Amps too!

Linear Amplifier RFI Kits

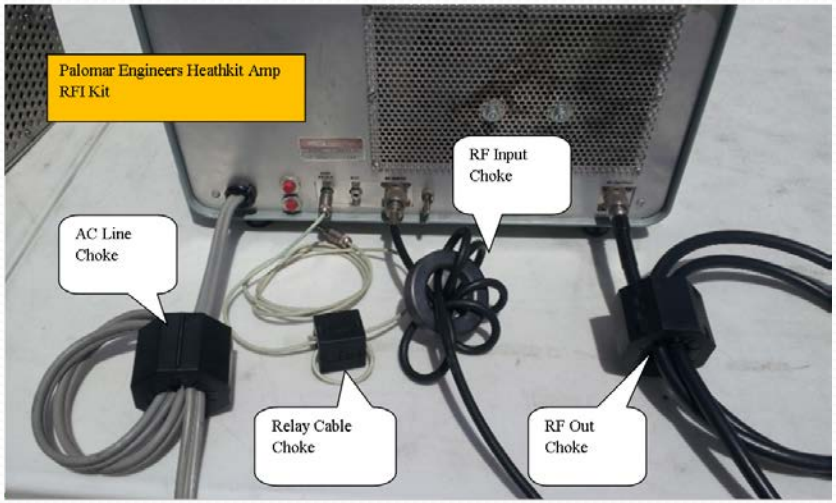
Palomar has RFI kits for all brands of linear amps

Transceiver RFI Kit



Ameritron 811

Linear Amplifier RFI Kit



HEATHKIT SB220

Clean up the RFI **SOURCE** first – <u>your radio and amp</u>

Solution Kits for Tube and Solid State Amps

Now coax feed lines

Tip #2. Stop Transmit RFI current on coax braid

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

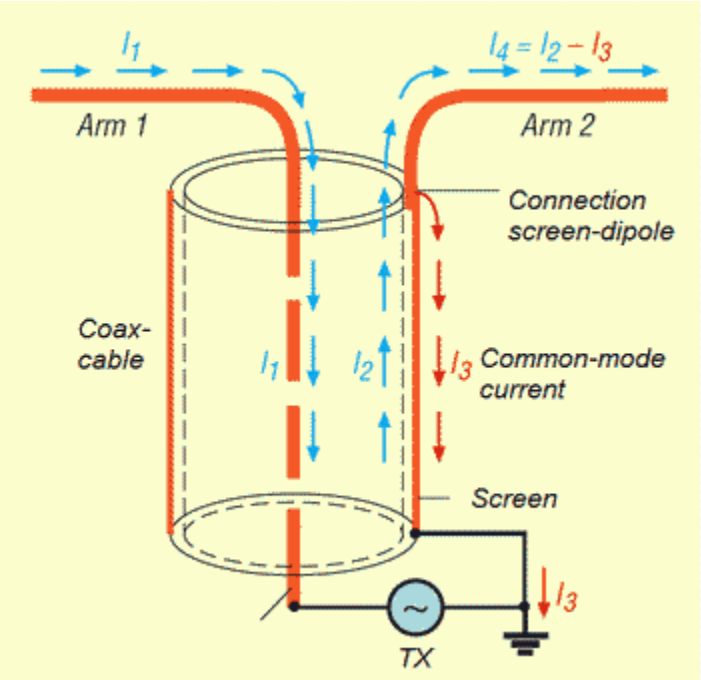
OR

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 <u>outside</u> of braid acts as extension of <u>transmitting</u> antenna and extra <u>receive</u> antenna



<u>Coax cable has 3 conductors</u>!

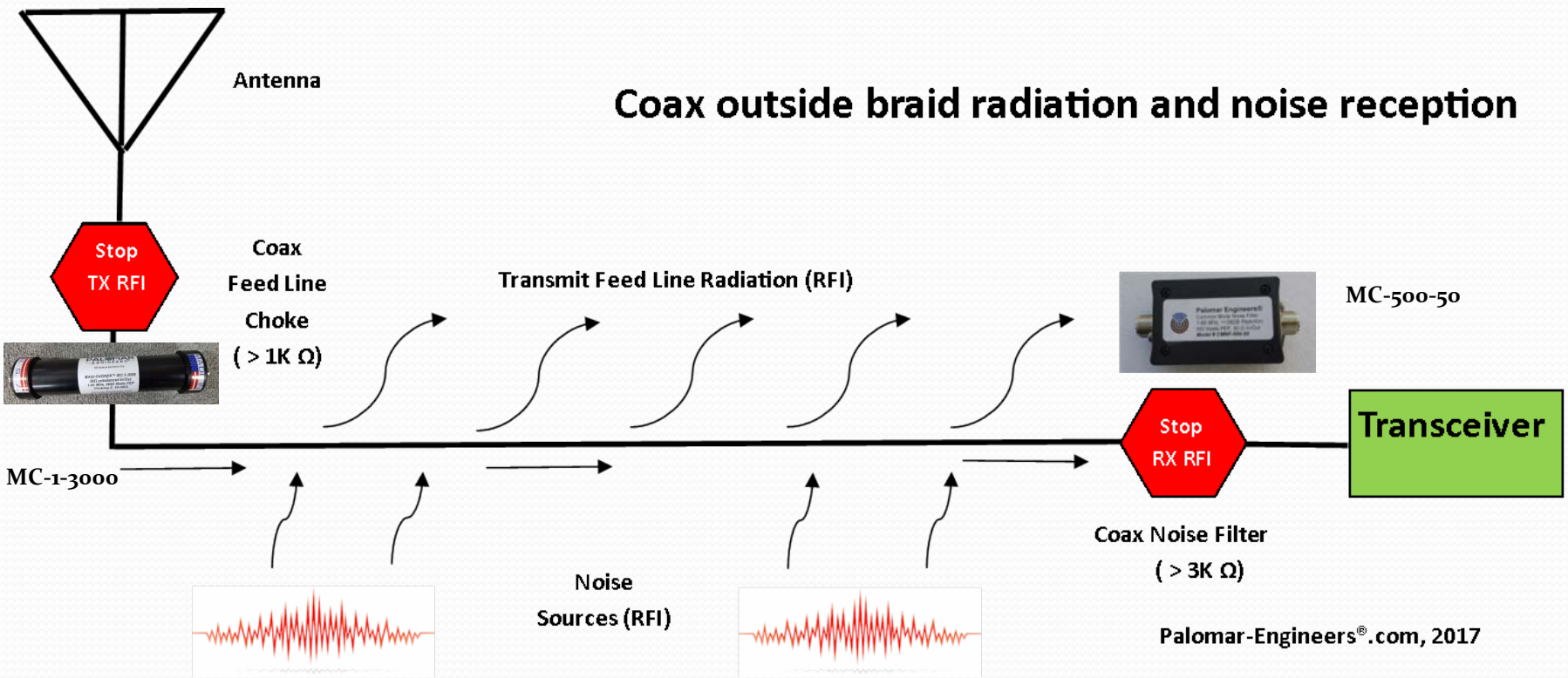
Coax <u>braid</u> is actually 2 conductors :
1 on the inside (normal RF signal), and
1 on the outside (common mode current)
that turns a dipole into tripole on transmit or a second antenna on receive!

<u>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.</u>

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

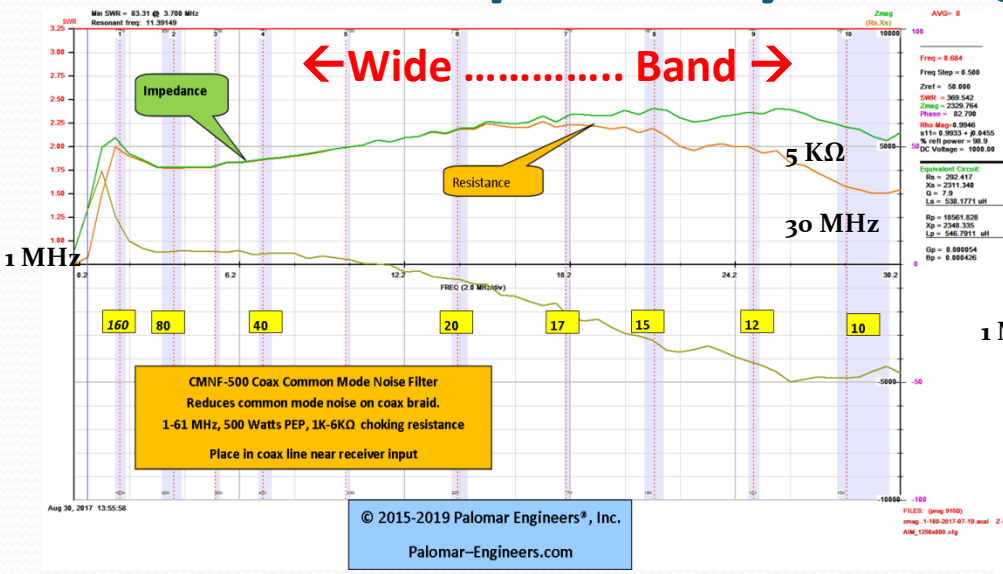
Typical Coax Antenna

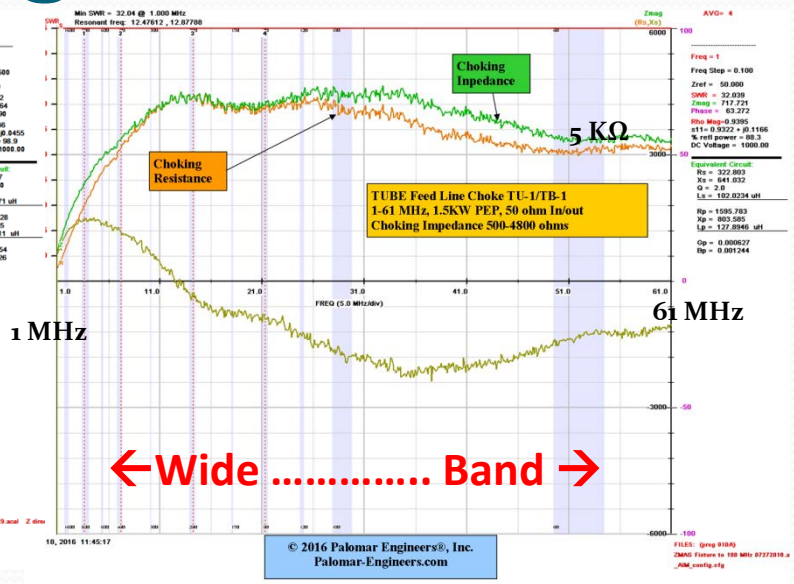
Typical Coax Fed Antenna System



Technical requirements for feed line choke selection

Choose choking resistance > 500Ω over frequency range used





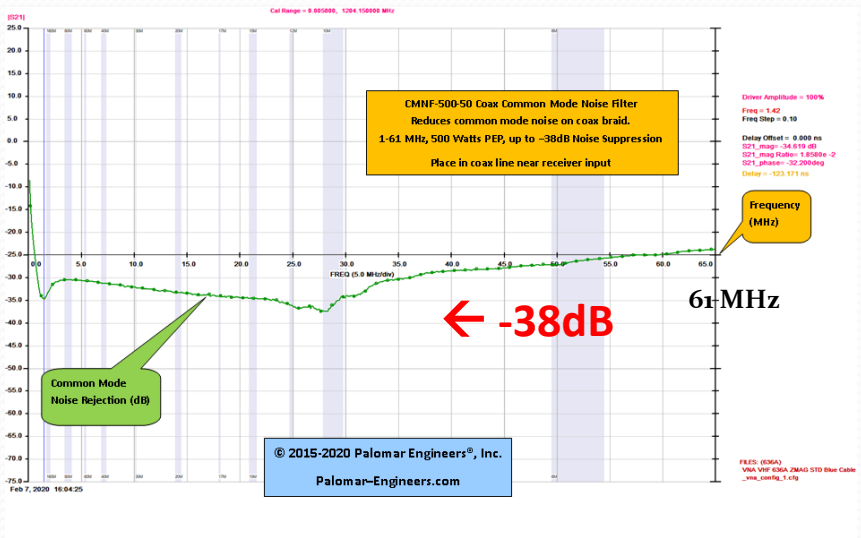
Coax Noise Filter (CMNF-500-50)
1-65 MHz >2K
500 Watts PEP, Up to 38 dB reduction (6 "S" units of common mode noise gone!

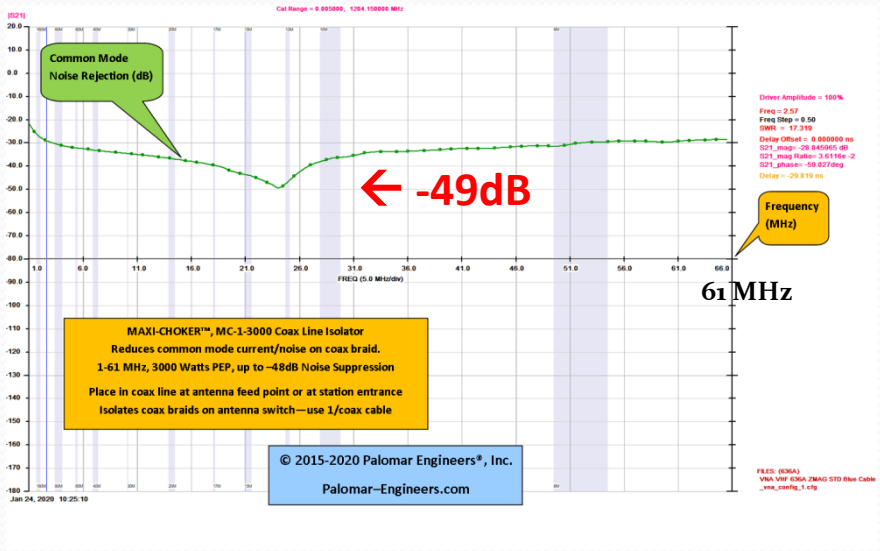
Line isolator (part# MC-1-3000 – 3KW PEP)
1-61 MHz >2K, 3KW PEP, 1K-6K ZΩ, 1 pound. All coax lines, Optional ground, static bleeder, up to 38db suppression!

Same data measured on VNA as CMRR →

Choose choke with CMRR > 20 dB over frequency range used

CMRR = Common Mode Rejection Ratio





Coax Noise Filter (CMNF-500-50)
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500 Watts PEP, Up to 38 dB reduction (6 "S" units of common mode noise gone!

Line isolator (part# MC-1-3000 – 3KW PEP)
1-61 MHz >2K, 3KW PEP, 1K-6K ZΩ, 1 pound. All coax lines, Optional ground, static bleeder, up to 49 dB suppression!

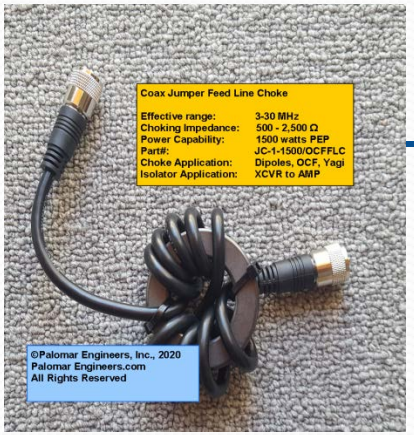
1 "S" unit = 6 dB, 36 dB = 6 "S" units

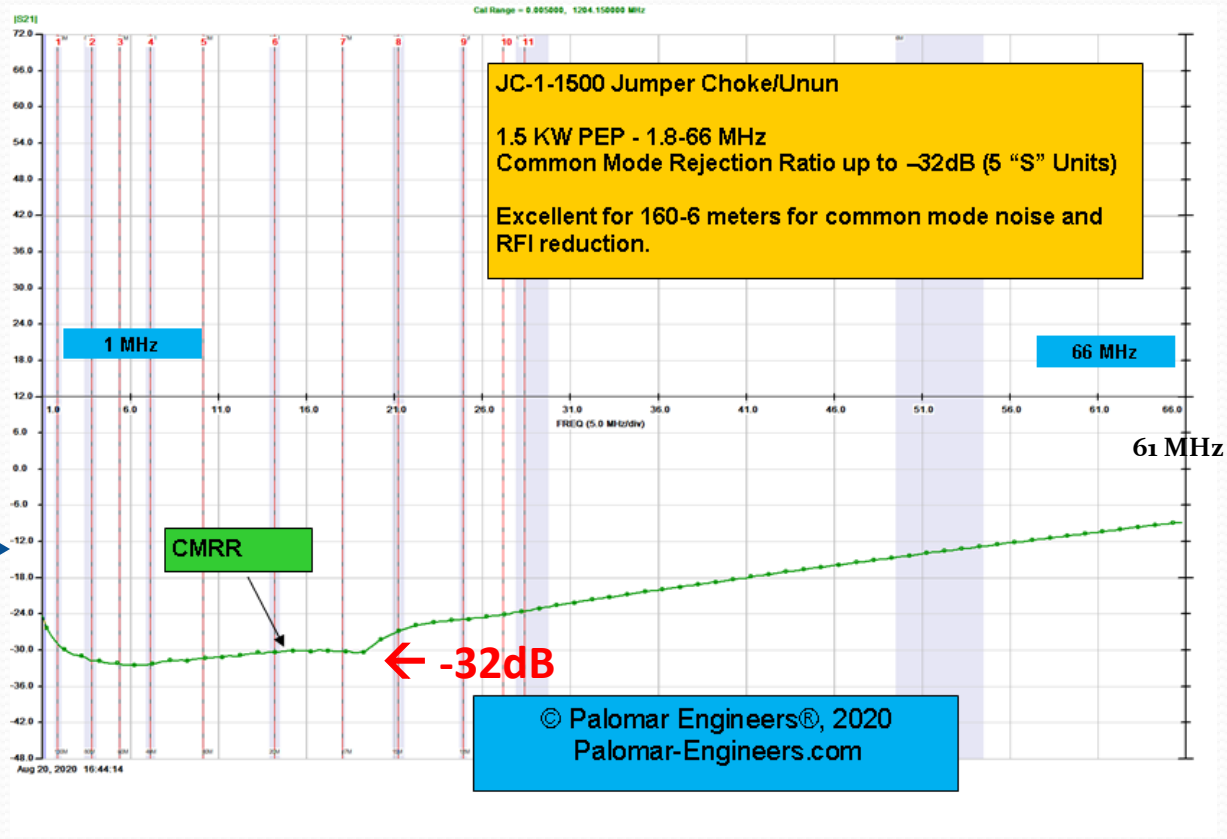
DO NOT BUY CHOKES with NO SPECS!

Simple DIY Feed Line Chokes

$10

$30

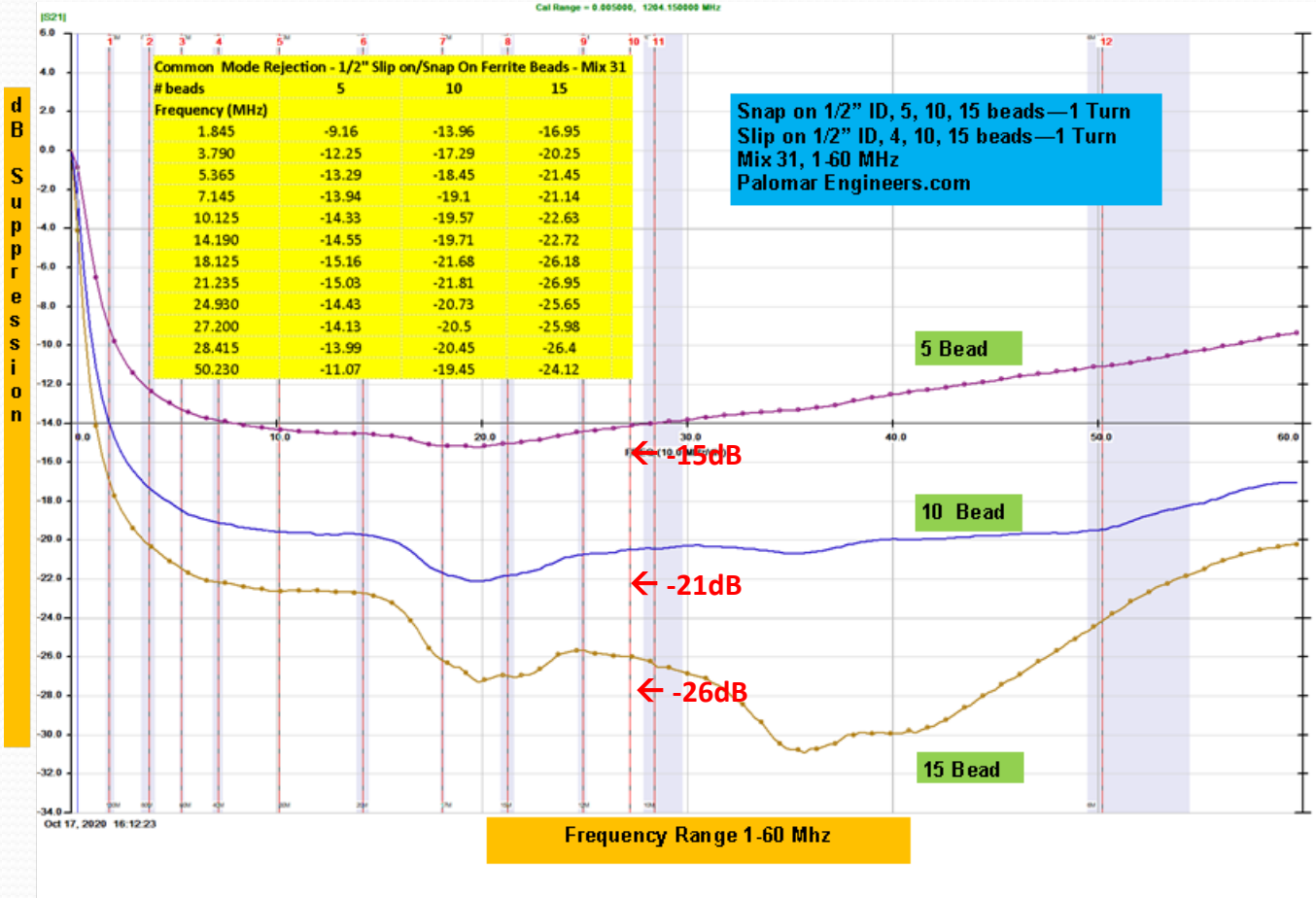




For HF use Mix 31, 1.4" ID Ring with multiple turns (10 turns = -32 db Common Mode suppression)

Next: Multi-bead chokes

Multi-Bead Chokes (Slip-On/Snap-On)



1/4, 3/8, ½, ¾, 1

Snap-on

61 MHz

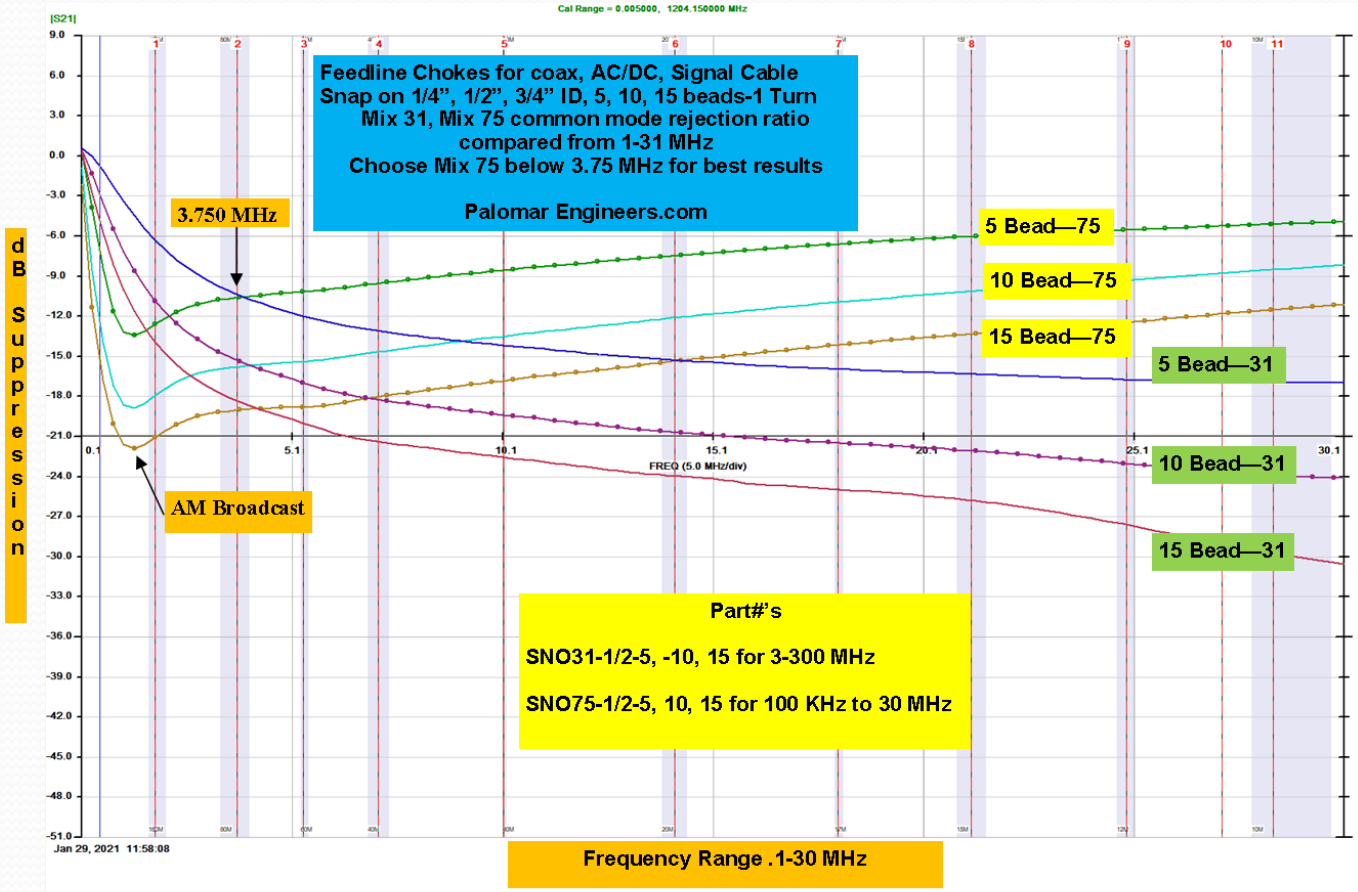
Slip-on

$15-$175

More beads = higher common mode suppression

Match to Mix

Match frequency to Mix



Mix 75 up to 10 dB better under 3.75 MHz!

RFI Kits

Tip #3. Install Solution Specific RFI Victim Kits

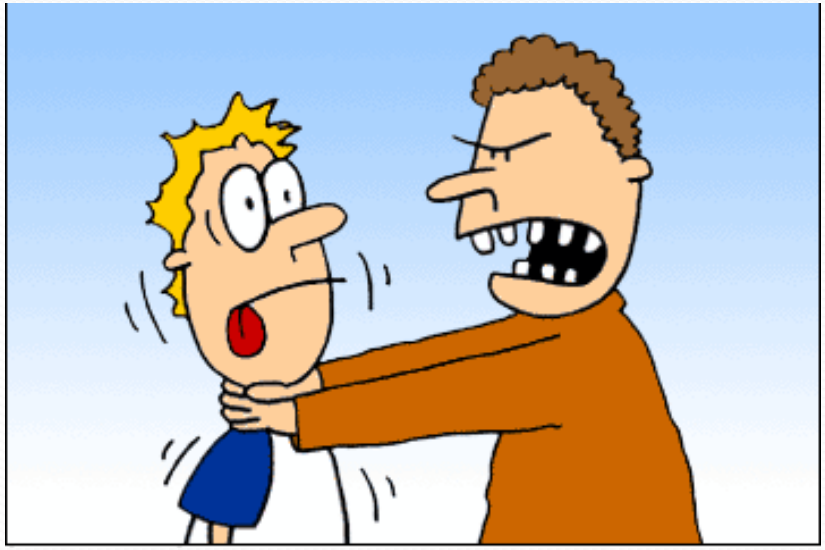
Our Goal: Minimize Transmit RFI to Electronic Devices in your home or your neighbor's homes

OR

Neighbor RFI Strategy→

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 (<u>may not be on all bands – may not be you</u>!)
  - 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)!

RFI Solution Kits to the rescue!

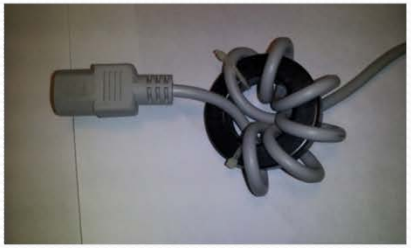
Transmit RFI Solutions

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 – <u>do not make mods to neighbors equipment</u>! MOST problems are RFI picked up by AC power/phone lines so ferrite filters work well.

TX RFI Recap

RFI proof your transmissions recap

- Determine frequency range of RFI and Path
- Install 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 AC/DC power filters on affected equipment and retest for RFI suppression
- Consider additional filters and paths if RFI persists

If you need help

Call or email (sales@Palomar- Engineers.com) or view specific solutions at **Palomar-Engineers.com**

What about receiver noise? →→

GOAL:
SUPPRESS RECEIVE RFI

Tip # 4: Install Coax Noise Filters

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

Receiver RFI Noise Strategy

- Assess S-P-V for the RFI – You or someone else is source?
- PROTECT the VICTIM (Your receiver)
  - Coax noise filters on antenna feed lines, ferrites on rotor lines
  - Ferrites on AC/DC cords, Wall Warts – ring or snap on ferrites
  - Ferrites on radio to 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

Simple common mode noise test →→

Receive RFI Solution

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

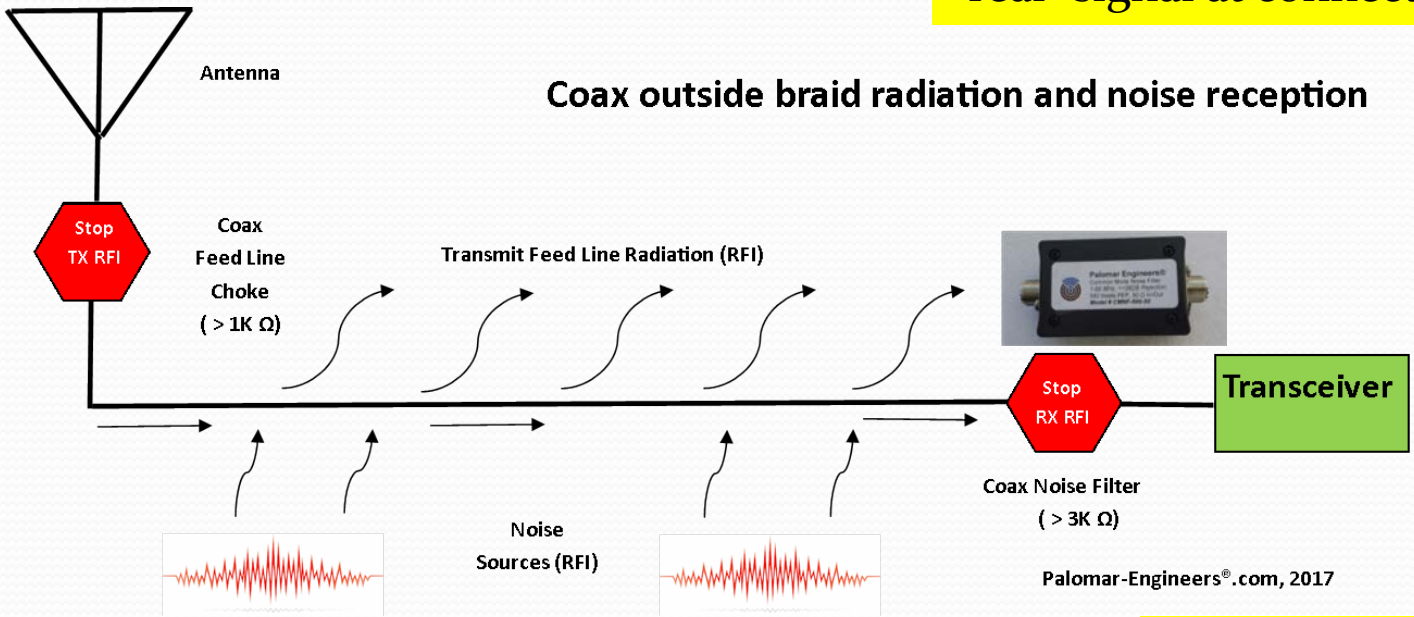
Coax Center Conductor and outer shield — measure noise level. If higher, then you have common mode noise

Receive RFI Problem

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

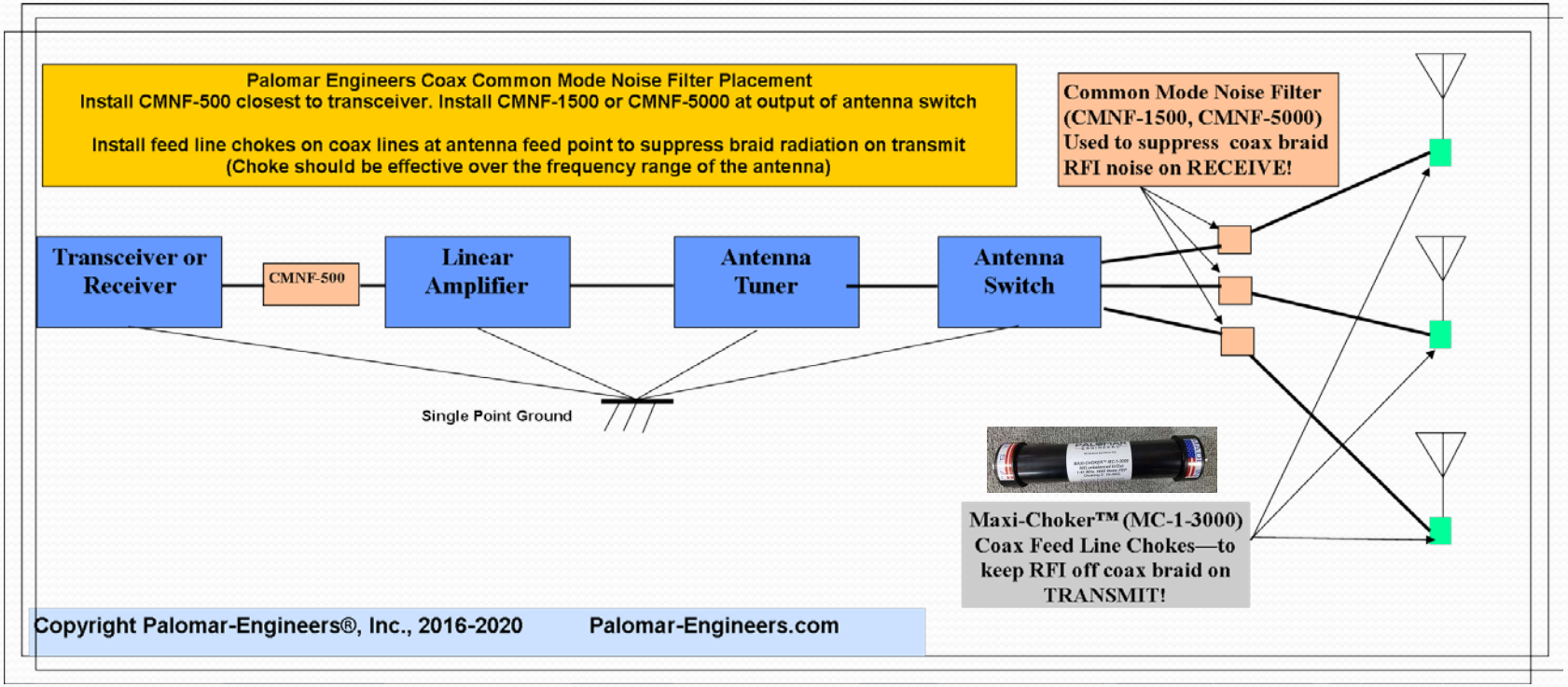
Coax braid acts as 2nd receive antenna and combines with "real" signal at connector!

Typical Receive Chain Connections



Where to install?

Coax Noise Filter Installation



Where to Install

- Choke at antenna for <u>TRANSMIT</u> RFI
- Noise Filter at Antenna Switch <u>RX</u> RFI
- Between Transceiver and Amplifier
- Single point ground system

2 port switch = 3 RX antennas!

Antenna Switch Problem

Coax Noise Filter Comparisons→

Coax Noise Filter Comparison

OK

$25
Snap On Choke
500-1000Ω
1-2 “S” Units
SNO-1/2-5

Better

$30
Ring Choke
1K-2KΩ
2-4 “S” Units
JC-1-1500

Best

$60
Noise Filter
2K-6KΩ
3-6 “S” Units
CMNF-500-50

Criteria to Consider

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

Coax Noise Filters

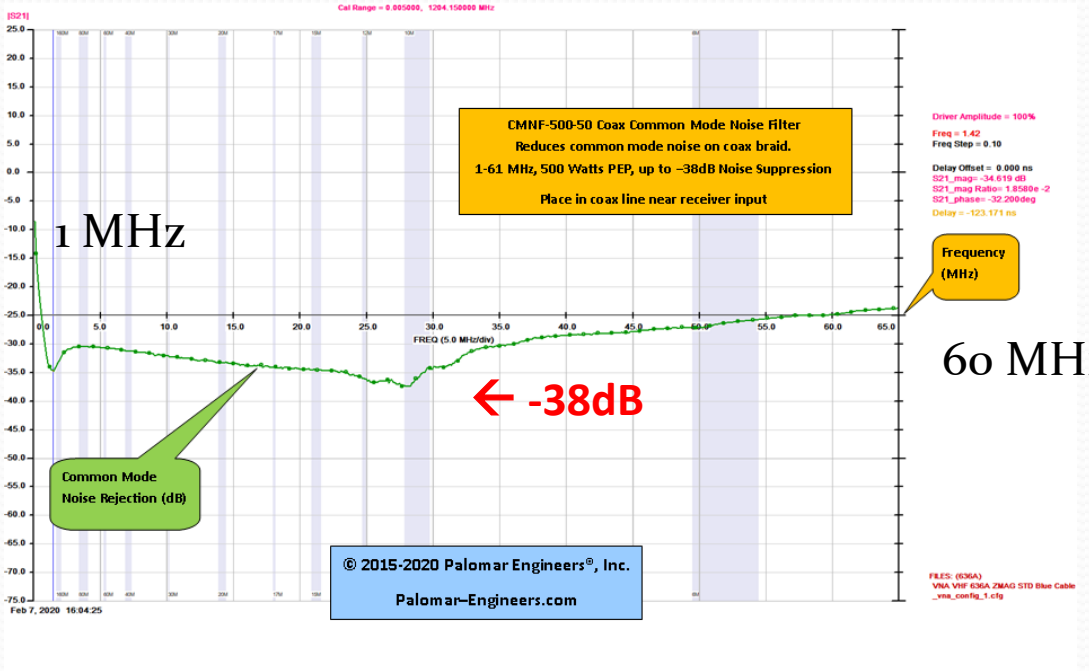
Coax Noise Filter Specs

TOP SECRET

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

1.5KW
or
5KW

500
Watts



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

1 “S” unit = 6 dB, -36dB = 6 “S” Units

Now AC/DC Path Filters

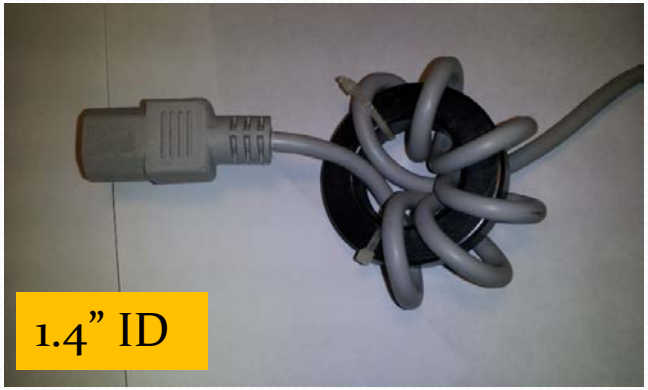
Tip #5. Install AC/DC Noise Filters

Lower Noise Floor = Higher SNR = More DX!

How to select and install filters for maximum effect

Goal is to reduce common mode RFI current from power supply

RFI – AC/DC Power Line Chokes

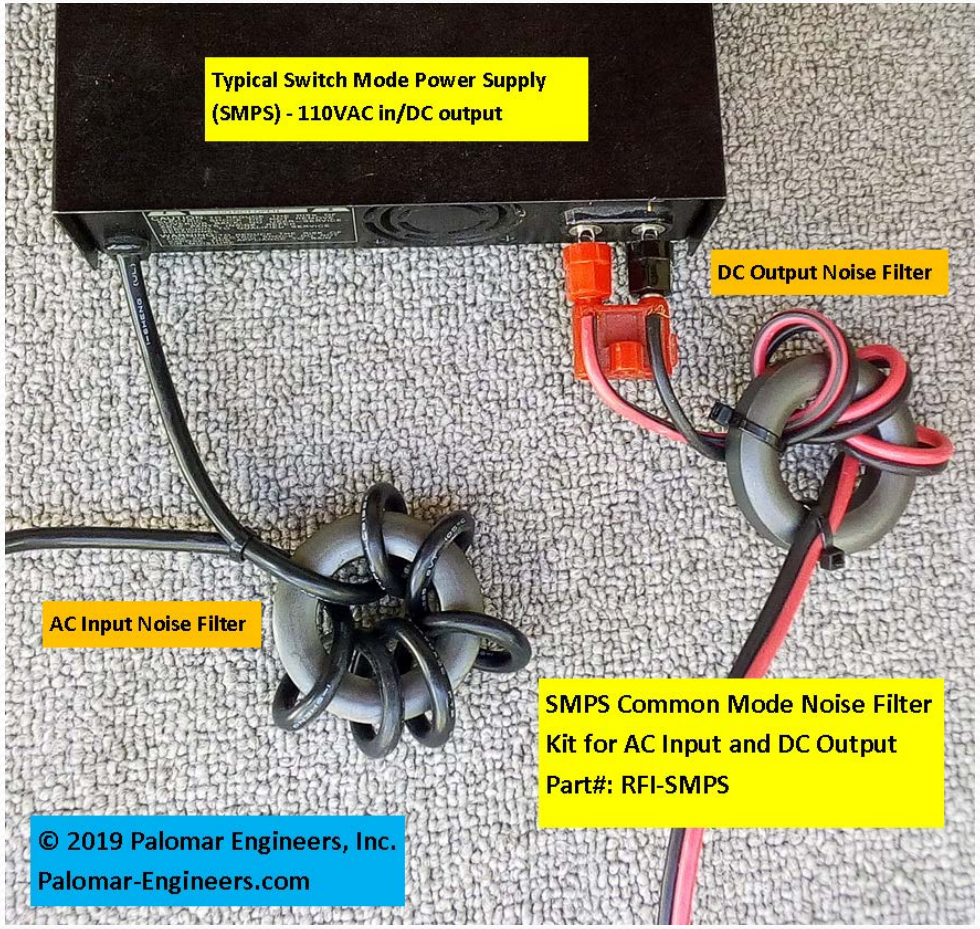


Choose mix frequency range and size to fit cable – <u>use max multiple turns</u>

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

SMPS Filters

Switch Mode Power Supply Filters



SMPS acts as RFI transmitter and uses DC cable and AC power line as its “antennas” – so filter both lines using Mix 75 to suppress switching frequency fundamental and all harmonics in ham bands.

Wall Wart Filters

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 or 10 ring kit

RFI Newbies Special

Receive RFI Solution

Transmit RFI Solution

Tip #6. Use Ferrite Combo RFI Kits for Newbies

Ferrite Combo Kits for Troubleshooting Multiple RFI Issues include <u>multiple ferrite shapes and sizes</u>

<u>or</u>

½" ID snap-ons and 1.4" ID rings are the most popular sizes and can be used to solve most ham radio HF RFI problems

Buy 9 Get 1 FREE!

Use Discount code "NEWBIE" – get 10% off orders thru 12/31/2021

Test Time for fun

Prize Question #1

- What are the 2 best 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 61 is used in which frequency range to suppress RFI common mode current?

- A) 1-300 MHz
- B) 200-2000 MHz
- C) .15-5 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?

PALOMAR ENGINEERS®

RFI Solutions from KHz to GHz

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