

RFI Proof Your Shack

Keep your neighbors happy

Work more DX!



Bob Brehm, AK6R
Chief Engineer
Palomar-Engineers.com

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What is RFI?

- Radio Frequency Interference/Electromagnetic Interference (RFI/EMI) – at radio frequencies
 - A radio frequency disturbance that causes an unwanted interruption, degradation, or obstruction to an electrical circuit.
 - Sources
 - Radio Transmitters (Amateur, broadcast, consumer devices)
 - Natural: Sun, Cosmic noise, Lightning, atmospheric static
 - Electro-mechanical devices (motors), ignition systems
 - All sources cause rapidly changing electrical currents in the effected device (VICTIM)

Got RFI in your shack/home?

- Symptoms – caused by your transmitter or antenna
 - Hot microphone – lip burns, distorted audio
 - Resonant antennas don't tune correctly or high SWR
 - Your voice/transmission causes interference with computer, TV, Stereo/Home Theater system, security system, garage door opener, microwave, telephone, DSL/cable modems/router, fax machine, touch on/off lamps, flickering lights, LED string lights, smoke/CO₂ alarm, answering machine, sprinkler system
 - Degradation of computer data throughput or loss of data , computer/internet stops working

Got RFI Noise in your shack?

- Symptoms – caused by outsiders
 - Clicks, buzzes, birdies, or chirps in your receiver on 1 or more bands
 - High noise level – periodic or varies by time of day
 - Receiver overload or desensing of front end with no signal present
 - Motor “noise” of varying/constant pitch – often caused by fans, heater/blower motors, heat pumps, fuel pumps
 - Florescent light crackle or buzzing or arcing sound
 - Power supplies, battery chargers, solar controllers, digital gear “GRUNGE”

RFI Types that can be suppressed

- About 60% of customers call to REACT to an RFI symptom in their shack/home or their neighbor's home they think is caused by their radio transmitter and/or antenna.
 - **TRANSMITTER RFI**
- About 40% of customers call to CURE an RFI problem caused by outside sources effecting their radio station
 - **RECEIVER RFI**

Got Neighborhood RFI?




IT'S ALL YOUR FAULT WITH THAT BIG ANTENNA!

RFI 101

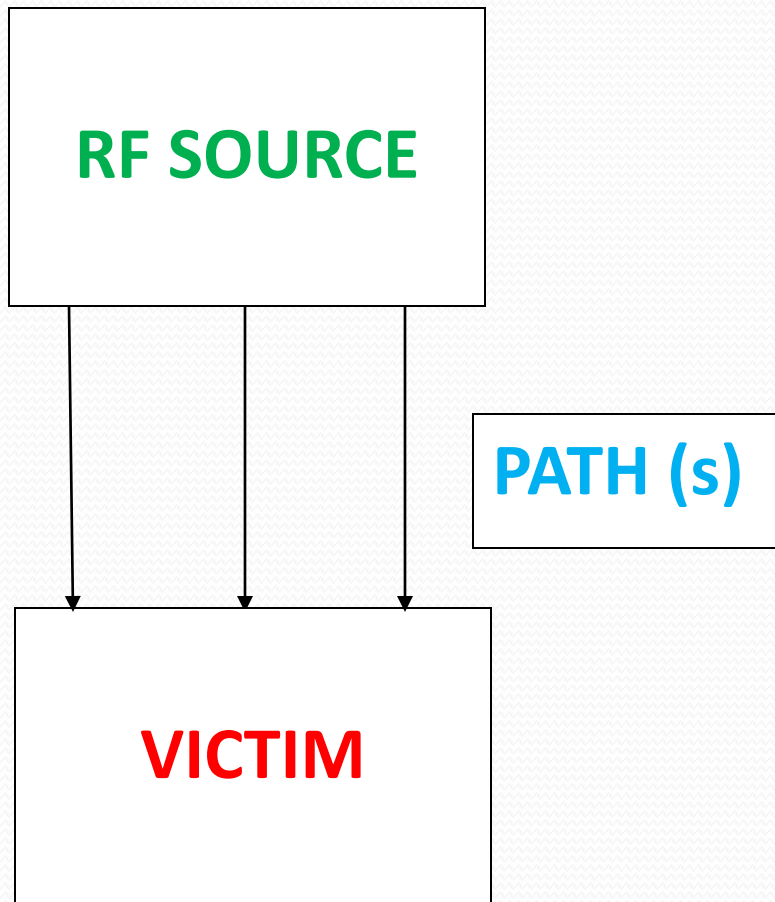
Causes and Cures to make ham radio more enjoyable





How is
RFI
Transferred?

RFI Transmission



RFI REQUIREMENTS

SOURCE of RF

Connecting **PATH(s)**

VICTIM of interference

All three of the above must be present to have an RFI problem.

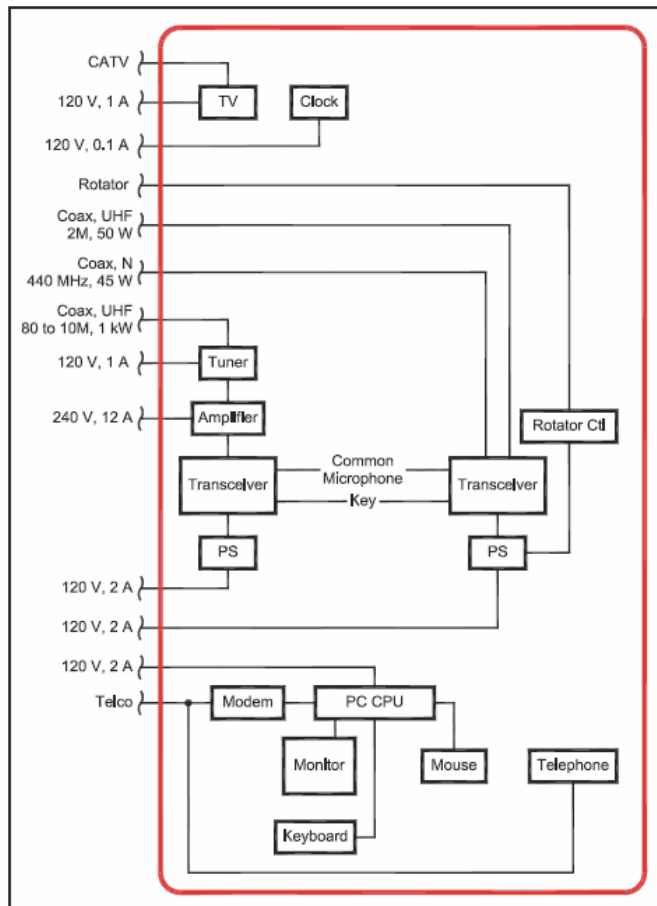
Cure

Eliminate the **SOURCE**, or
Choke the **PATH**, or
Protect the **VICTIM**

Source-Path-Victim in the Ham Shack

- **Source**
 - Transmitter
- **Path** (single or multiple wires in/out of equipment act as **TRANSMITTING** antennas)
 - Antenna (direct radiation)
 - Antenna Coax, rotator/antenna selector control lines
 - 120/240V AC wiring
 - Phone/DSL telephone service wires
 - Cable/Satellite coax
 - Device interconnect cables (mic, audio, speaker, video, power)
- **Victim** (Device receiving interference – I/O wires also act as **RECEIVING** antennas)

Typical Ham Shack



“ANTENNAS”

- Multiple AC Connections
- Multiple Antennas/Coax lines
- Telephone/DSL line
- Antenna Control Lines
- Satellite/Cable Coax feed

Antennas can **transmit and receive** common mode current at radio frequencies (RFI). Your antenna(s) radiate energy that is induced into shack “antennas” as common mode current

Typical “Antenna” Paths for RFI

- 160-80-60-40 meters – AC lines, Phone lines, satellite/cable coax, long CAT-5 cables, ham antennas coax shield, antenna rotor cables, 2nd story ground wires
- 20-6 meters – speaker wires, device interconnect cables, short Cat-5 cables
- AM Broadcast – same as 160 – long “antennas”

Antenna Lengths

Band	Freq Mhz	1/4 Wavelength (ft)	1/4 Wavelength (m)
160	1.9	129.42	39.45
80	3.75	65.57	19.99
80	3.52	69.86	21.29
40	7.15	34.39	10.48
30	10.1	24.35	7.42
20	14.2	17.32	5.28
17	18.1	13.59	4.14
15	21.3	11.54	3.52
12	24.8	9.92	3.02
11	27.2	9.04	2.76
10	28.5	8.63	2.63
6	50.25	4.89	1.49
2	146	1.68	0.51

wavelength (ft) = 983.6/freq (Mhz)

wavelength (m) = 299.7925/freq (Mhz)

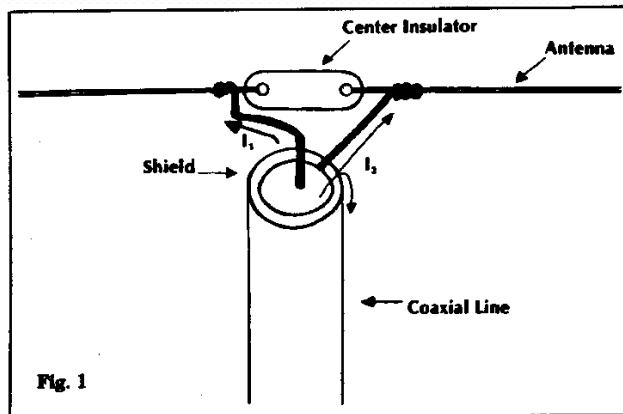
RFI Frequency “Antennas”

160-30M – typically longer
“antennas” like AC house wire,
telephone system, CAT5,
satellite/cable coax

20-2M – typically shorter
“antennas” like device
interconnect cables, speaker wire.
Audio, microphone cables

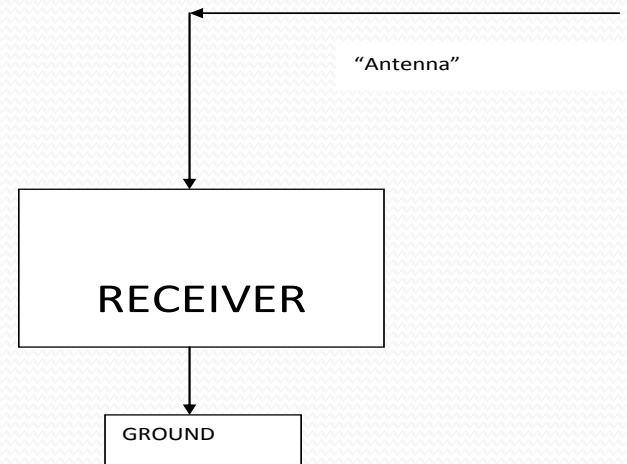
Is your Coax an “antenna”?

- Coax outside braid as a transmitting antenna



1% 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

- Coax outside braid as a receiving antenna



From antenna feed point to receiver, outside braid receives radiation from antenna and neighborhood devices

Measuring Coax Braid Current



- Common Mode Current (RF) meter – clamps on outside of coax cable, radials, device cables, AC/DC cables and measures current.
- With proper choking current will decrease

Reduce RFI current to reduce RFI

- $I = E/R$
- Where I = Common Mode Current
- E = voltage on coax
- R = Choking impedance ($Z=R+j$) to reduce I
- Higher Z means less I = less RFI
- An “antenna” is a wire with alternating current going through it creating an electromagnetic field of radiation.
- Reducing the current through the wire, reduces the radiation.
- Without choking the outside coax braid is an unwanted antenna

Ferrites Are your Friend for RFI



Slip On Bead



Snap On Bead

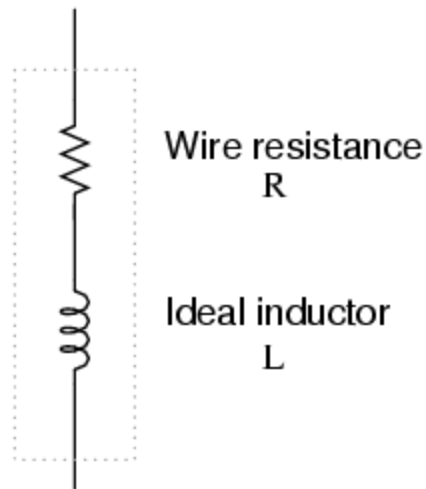


Toroid

- Cheap, easy to install, work on all ham frequencies
- Work on all paths (feed line, AC/DC, electronic devices)
- Lots of options in size, shape to fix most RFI problems
- Can be installed by almost anybody who understands how to choose the correct ferrite for a particular RFI problem.

Ferrite Equivalent Circuit

Equivalent circuit for a real inductor



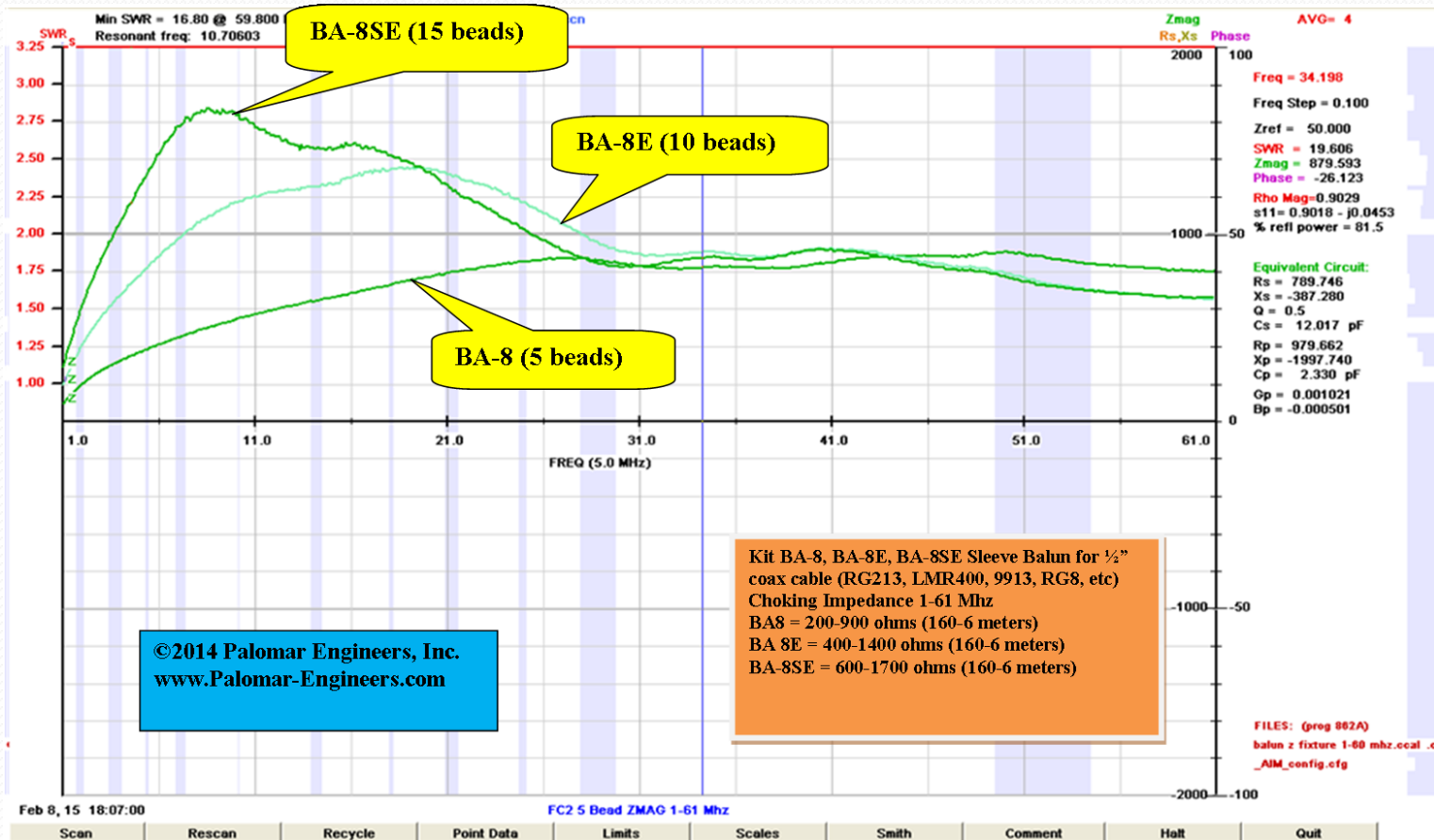
One Turn coil through a ferrite with reactance which varies with frequency ($X_L = 2\pi f L$). Reactance goes up as the square of the number of turns, e.g. 2 turns = 4X, 3 turns = 9x, until resonance reached

Multiple Ferrites in Series add



For additional choking impedance you can put chokes in series – use multiple mixes for broadband choking.

Multi-Bead Choking Z

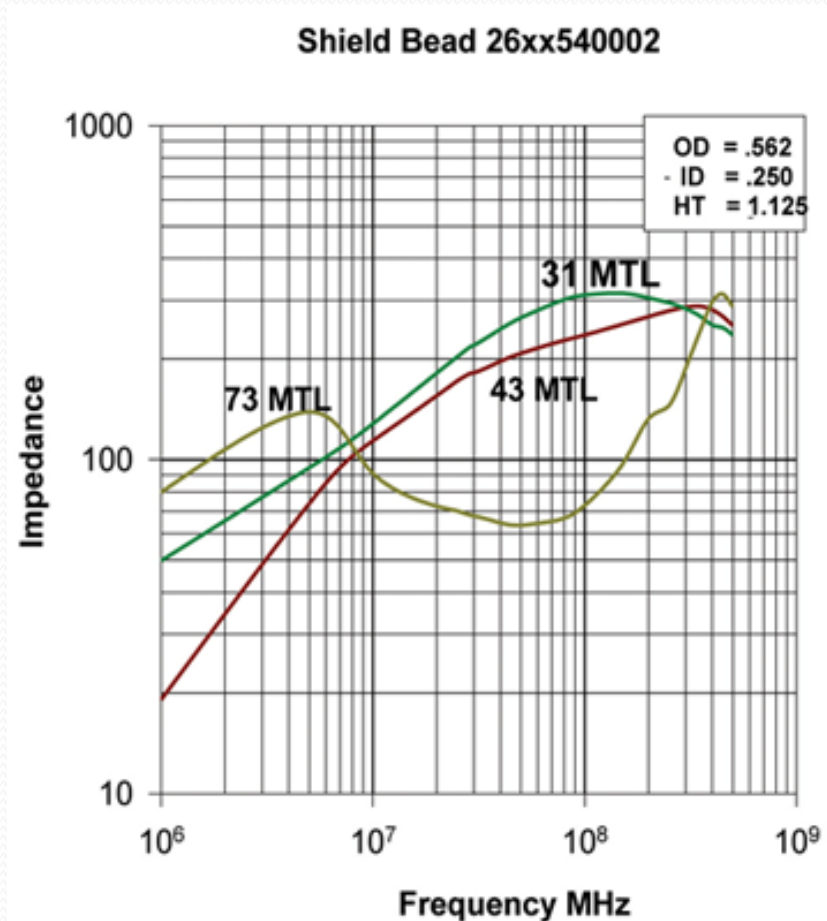


Z Varies with (turns)²

- 1 turn = Z
- 2 turn = 4Z
- 3 turn = 9 Z
- More Z = less current = less RFI



Ferrite Mixes

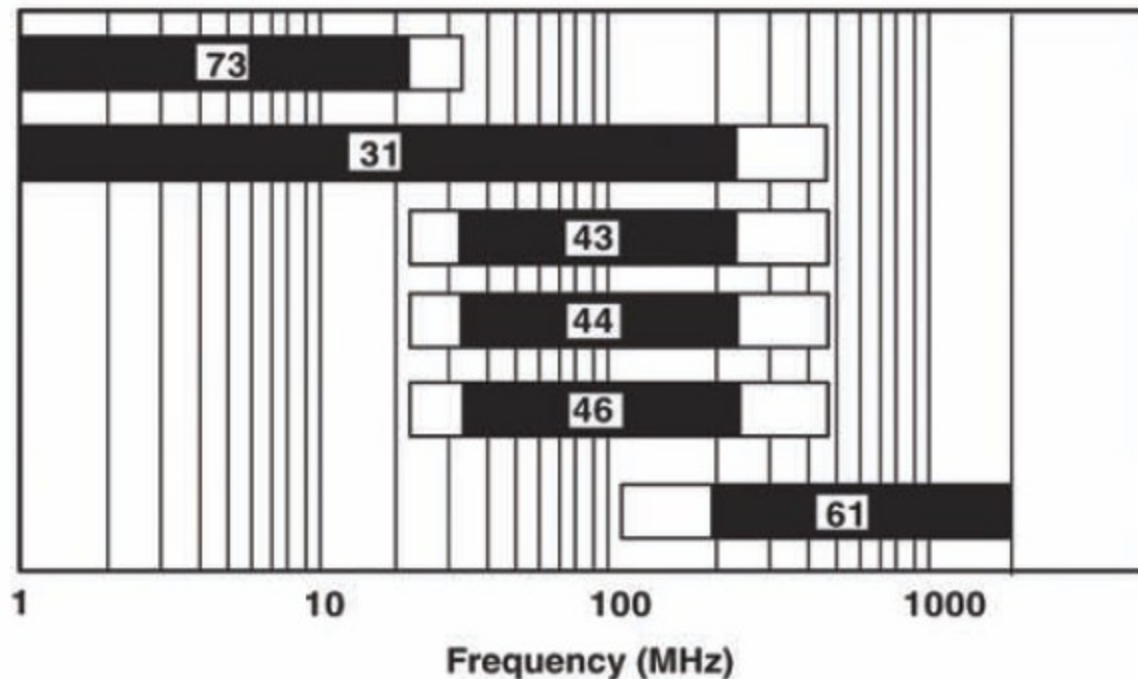


Different mixes for different frequency ranges of choking. Use at frequencies to the “left” of peak for chokes.

Most popular ham frequency mixes are 31, 43, 61, 77 – see website for ranges of each mix.

Ferrite Mix Selection - Chokes

Suppression Materials



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

RFI Proof Your Shack

Suppress TRANSMITTER RFI, reduce RECEIVER RFI/NOISE



RFI Strategy

- Eliminate/reduce RFI SOURCE
 - or
 - Choke the PATH
 - or
 - Protect the VICTIM

How does that apply to your ham shack/home?

Ham Shack RFI Solutions

PICK YOUR RFI SOLUTION KIT

MY RADIO ROOM



ANTENNA RFI



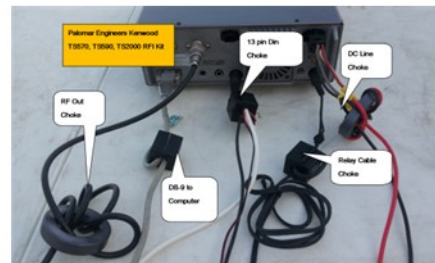
AMPLIFIER RFI



COMPUTER RFI



POWER LINE RFI



TRANSCEIVER RFI



NOISE REDUCTION

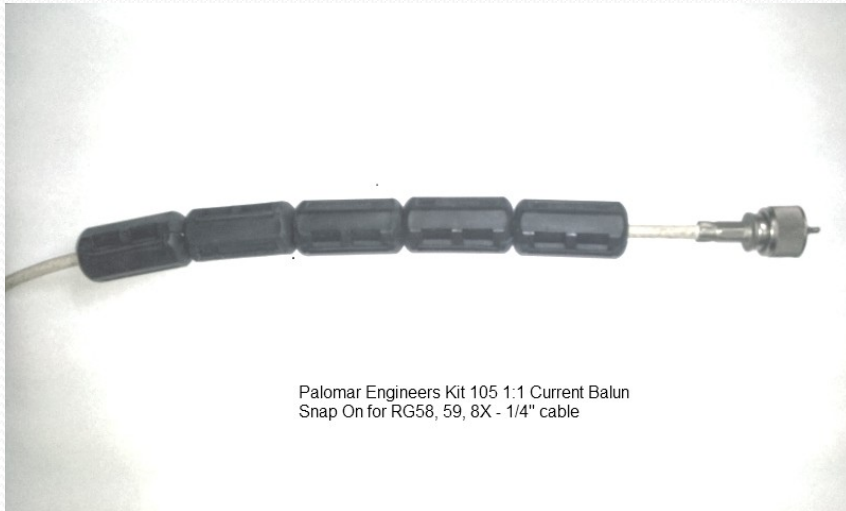
RFI Chokes for feed line path

- Path
 - Antenna feed line choke (aka 1:1 balun, 1:1 unun, line isolator, line choke, sleeve baluns)
 - Coax Air Wound – frequency dictates # turns for Z (5-10 turns at VHF, small diameter, 15-30 turns large diameter at HF)
 - In line (ferrite – toroids, split beads, sleeve beads)
 - 1:1 balun (voltage (DC grounded) or current)
 - Line isolators (w or w/o ground lug)
 - Examples

Coax Balun (aka “Ugly” balun)



Sleeve Baluns (Snap on)



RG-8X (1/4" size)
150-500 ohms



RG-213 (1/2" size)
150-500 ohms

Large Clamp On (FSB-1)



Sleeve Baluns (Slip on)



Palomar BA-8 Balun on Beam Antenna (RG-213)

Super Choker (40-10 Meters)



Super Choker 4010
10-11-12-15-20-30-40 meters
WWW.Palomar-Engineers.com

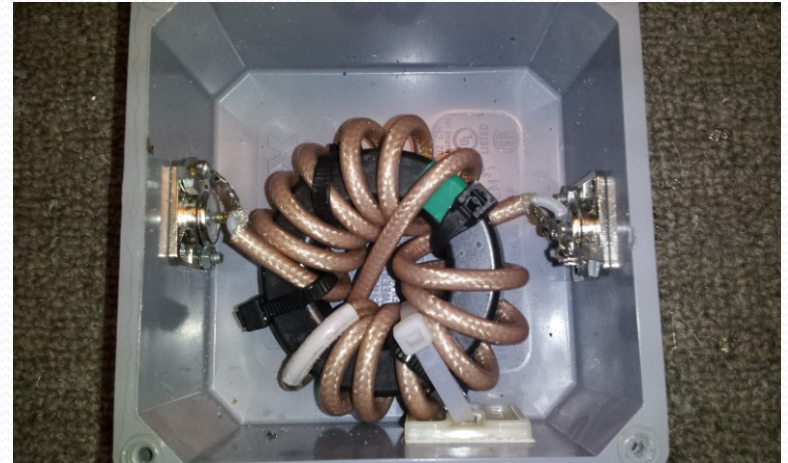
$Z = 800$ at 7Mhz , 5K at 14 Mhz, 800 at 29 Mhz
- 5 Turns, 3 cores

CUBE Baluns



BA-1-1500 (1:1, 1500w)
current balun
 $Z = 1k-6k$

Do It Yourself KIT



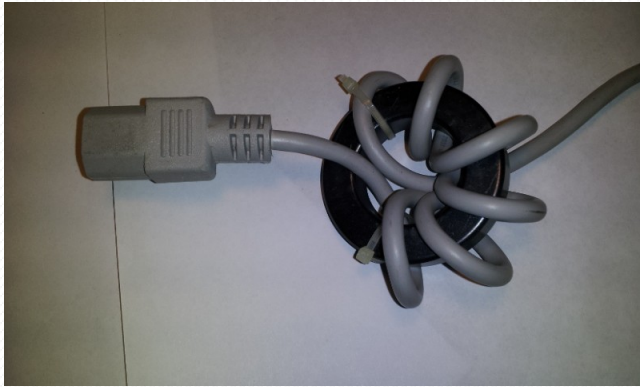
CB-1-5000 (1:1, 5000w)
current balun
 $Z = 3k-7k$

ASSEMBLED

RFI Chokes – 120/240V AC Path

- Toroids
- Snap Ons
 - Big Clamp On's – multiple turns, easy to install
 - Example pictures

Toroid Choke – AC Line



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

Toroid Choke – DC Power Line

- Wall power plug
- DC power - transceiver



Palomar F140 (1.4OD), $Z=1K$, 5 turn



Palomar F240 (1.4OD), $Z=2K$, 5 turn

RFI Chokes – Device Cables

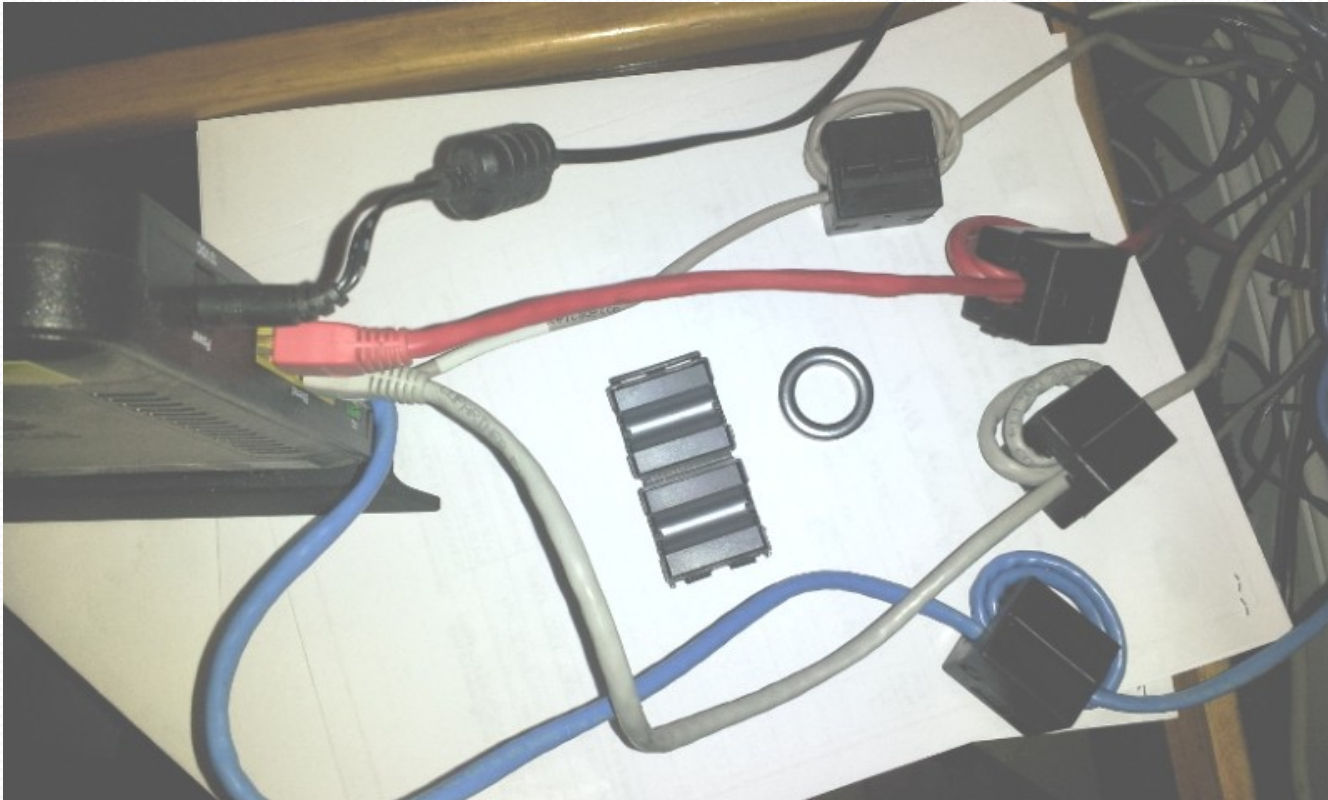
- Toroids
- Snap On
- All Input/Output Cables on device
- Longer cables more important to choke because they are better receiving antennas



RFI Kits for specific use

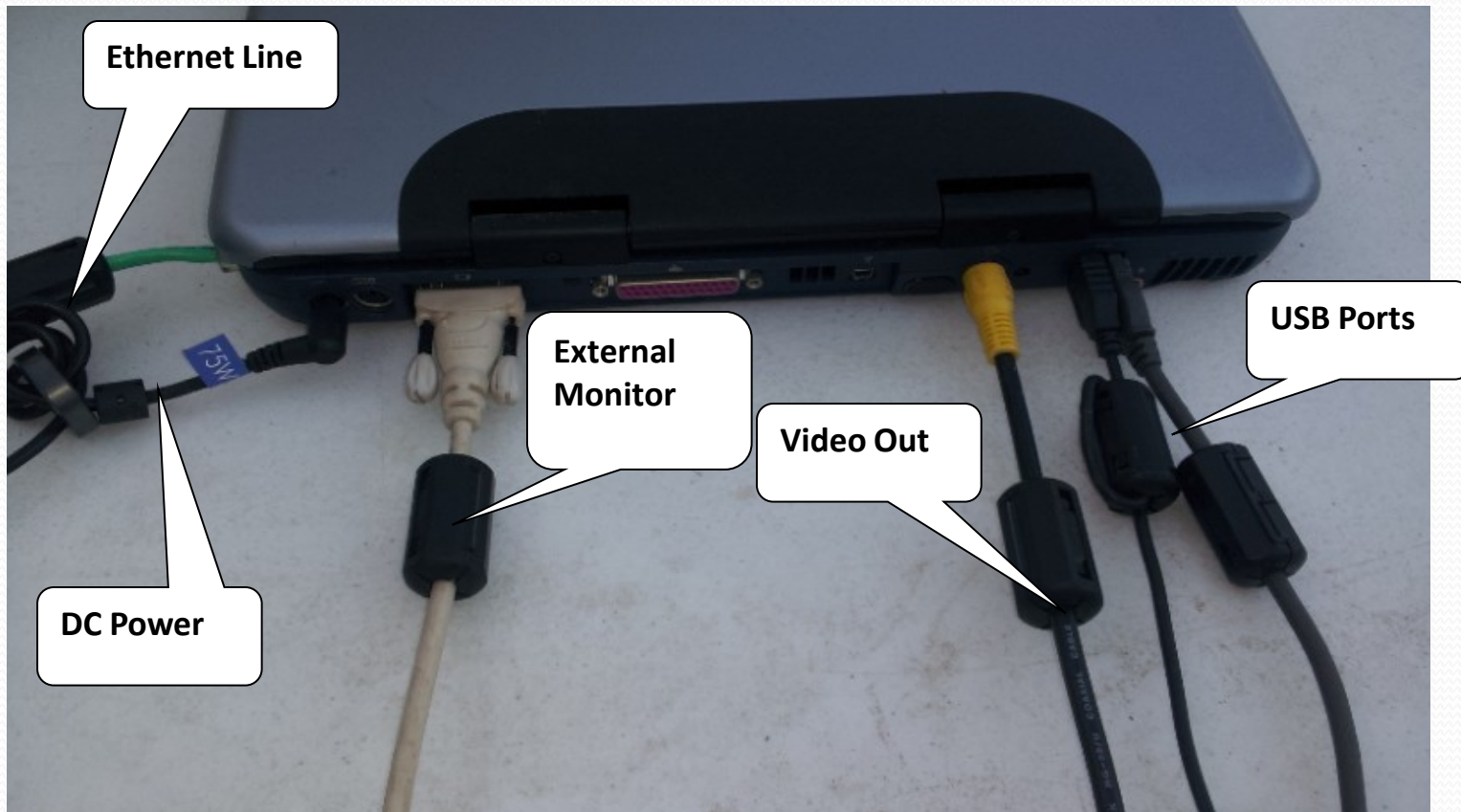
- Transmitter/Transceiver Kits
- Linear Amplifier Kits
- Computer Device Kits
 - Lap tops
 - Desktops
 - DSL Router
 - Network boxes

RFI Kits – Computer Devices

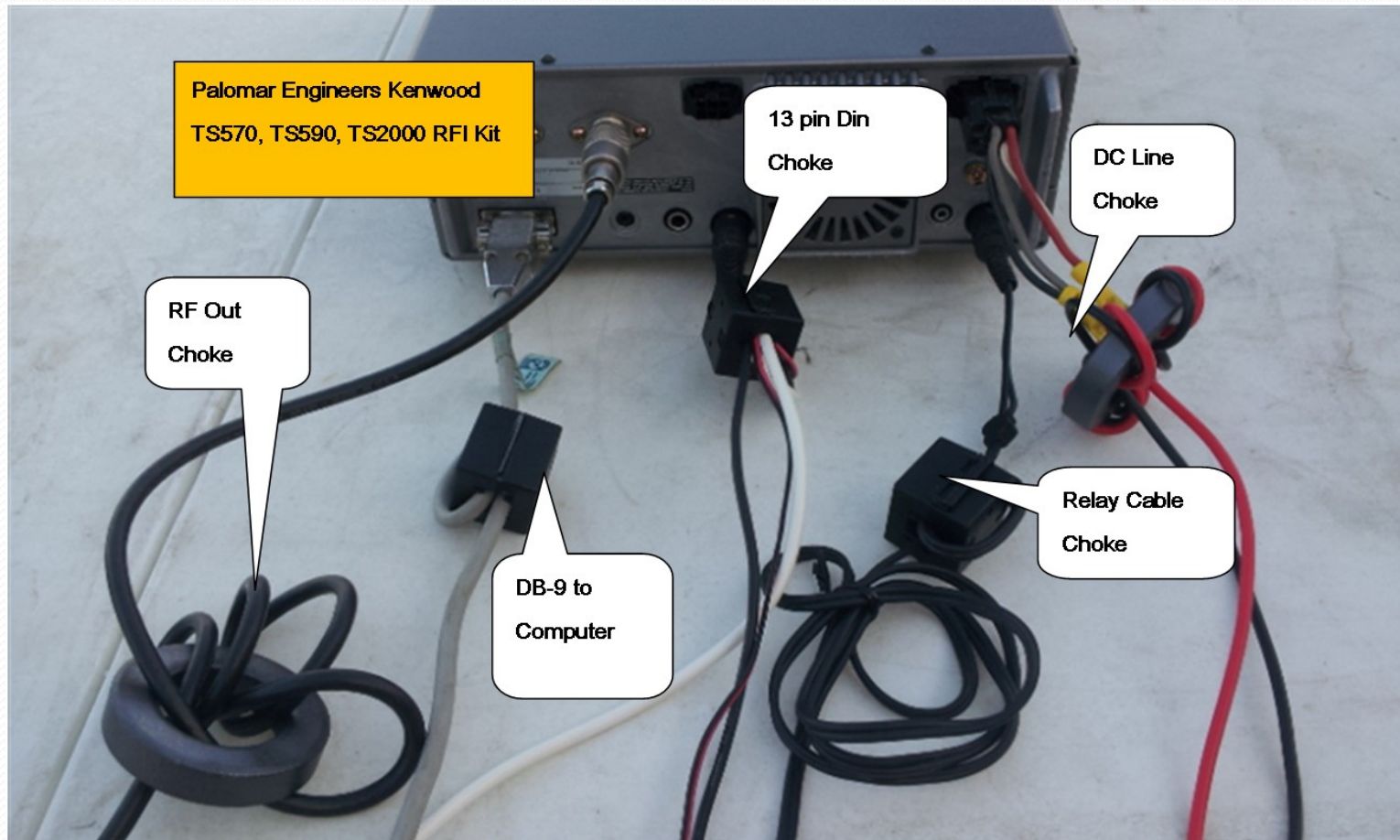


Palomar RFI-1A DSL Modem/Router RFI Kit

Laptop RFI Kit



RFI Kit - Transceivers

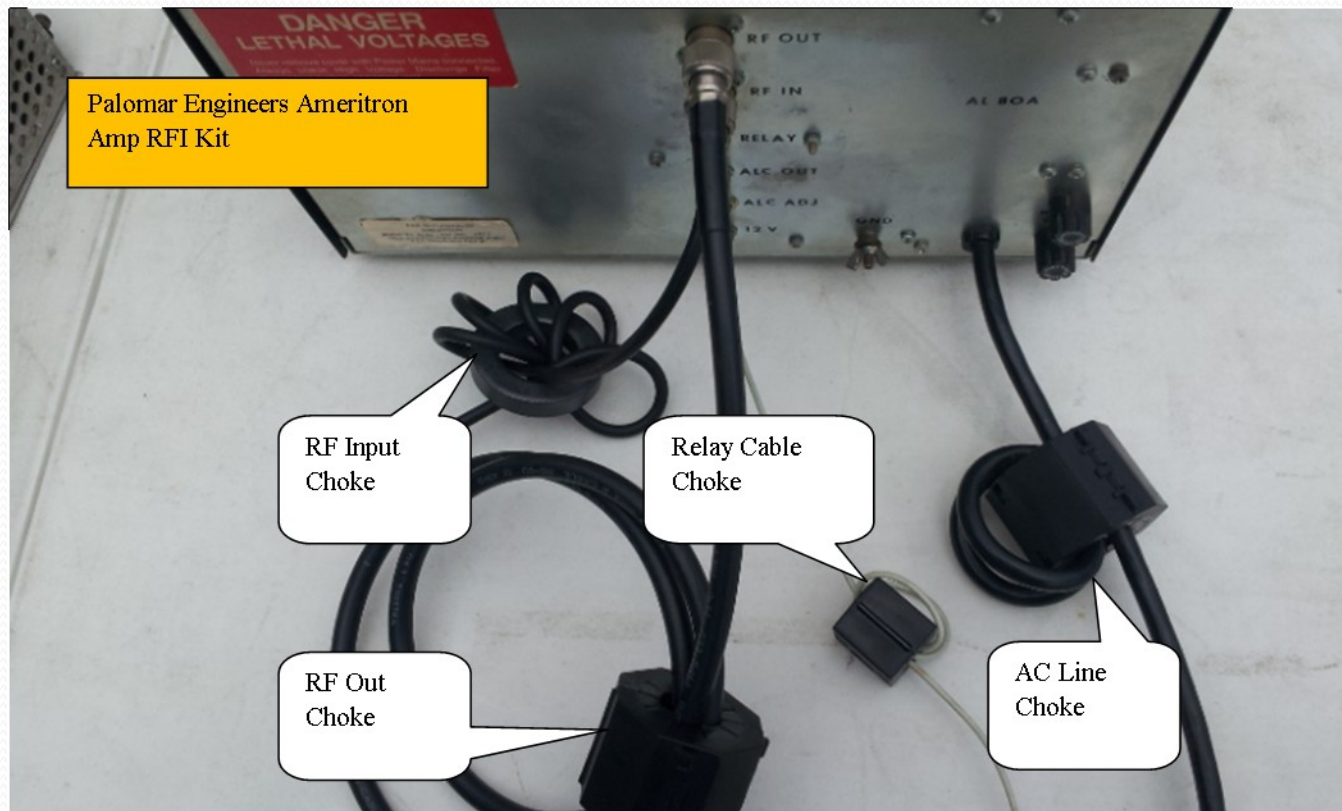


Amplifier RFI Kits – all brands



Alpha, Ameritron, Amp Supply, B&W, Collins, Command, Drake, Gonset, Hallicrafters, Hammarlund, Heathkit, Henry, Hunter, Icom, Kenwood, Palomar, Palstar, QRO, SBE, SWAN, Ten Tec, Tokyo-Hy-Power, Yaesu

RFI Kits - Amplifiers



RFI Proof Your Shack Summary

- RFI needs SOURCE-PATH-VICTIM (S-P-V)
- Define S-P-V for your shack
- Clean up SOURCE, Choke PATH, Protect VICTIM
- Choke all antennas, control lines on antenna end
- Common ground for all radio/computer equipment
- Choke all “Antenna” PATH(s) using individual ferrites and RFI kits at VICTIM
- Call Palomar Engineers if you get stuck or need help

Keep Your Neighbors Happy!



OR



Problem Isolation

- 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)
 - Determine frequency of transmitter that is causing the problem (may not be on all bands).
 - 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

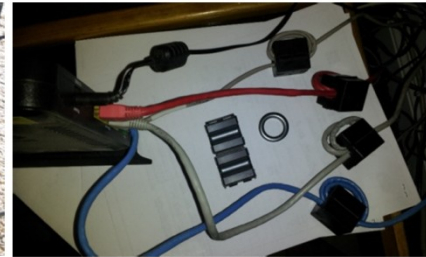
MY HOME or NEIGHBOR'S HOME



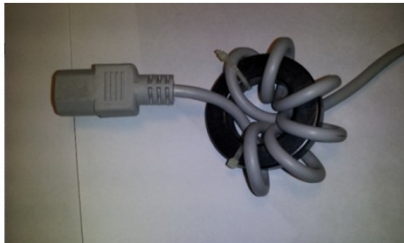
ALARM SYSTEM RFI



HOME THEATER RFI



COMPUTER RFI



MISCELLANEOUS RFI



GARAGE DOOR



TELEPHONE/DSL RFI

Work More DX

Tips, Tricks & Techniques to improve your signal/noise ratio

Tips & Tricks

- Reduce noise, interference relative to signal = more DX
- More efficient antenna (more signal) = more DX
- Less feed line loss (more signal) = more DX
- Noise from common mode currents can be significantly reduced using common mode chokes at the ham shack in addition to chokes at the antenna

Improve Signal/Noise Ratio

- Concentrate on reducing RFI causing common mode noise
 - Path is **Inside** your shack
 - 120/240v AC line, Coax interconnects, computer interfaces, audio/mic interfaces, radio-amp-tuner cables – ground shields to a real ground!
 - Path is **Outside** your shack – neighborhood RFI
 - Antenna coax – outside of braid/shield
 - Rotator or antenna control lines
 - 120/240V AC line
 - Telephone/Internet line
 - Device radiation (Plasma TV, treadmills, heat pumps, etc)

Improve Signal/Noise Ratio

- Solutions

- Common mode chokes at RECEIVING end (blocks common mode RFI into receiver) in addition to transmitting end (keeps RF on the antenna)
- Use common mode chokes (1:1 ununs) to choke noise on signal path AT THE RADIO/ANTENNA TUNER
 - Cube baluns – have hi Z (2K-10K ohms)
 - Sleeve baluns – snap on or slip on (200-1500 ohms Z)
 - Super Chokers (1.5-3K ohms)

Testimonial Case

- WOW...
- I just tried one of your toroids on my modest antenna system. I have a Hamstick on top of an all aluminum manufactured home. Its the best ground plane one could hope for, and I've made contacts to Korea on 40m with it.
- Before... on 40m I had an AM background noise of 5S units. I wrapped about 10 turns into one of the toroids right by the radio and the noise floor dropped to below 1 S unit (not readable on my TS-480s).
- You know... when I got this from you yesterday, I figured maybe 2 S units if that and the price was right... I am truly amazed by the results!!!

Bob K2IU (2/25/2014)

Efficient Antennas

- Better antenna patterns with unbalanced to balanced baluns to choke common mode feed line RFI at antenna
- Efficient matching baluns for antenna impedance transformation – right power rating, correct frequency range, correct ferrite mix
 - 1:1 baluns for dipoles, verticals, beams
 - 2:1 baluns for loops, low dipoles
 - 4:1 for OCF, Zepp, 31/43 ft verticals, log periodics
 - 9:1 for long wires, end fed, traveling wave

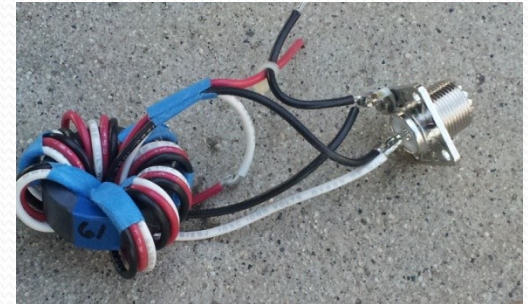
Antenna Matching Baluns/Ununs



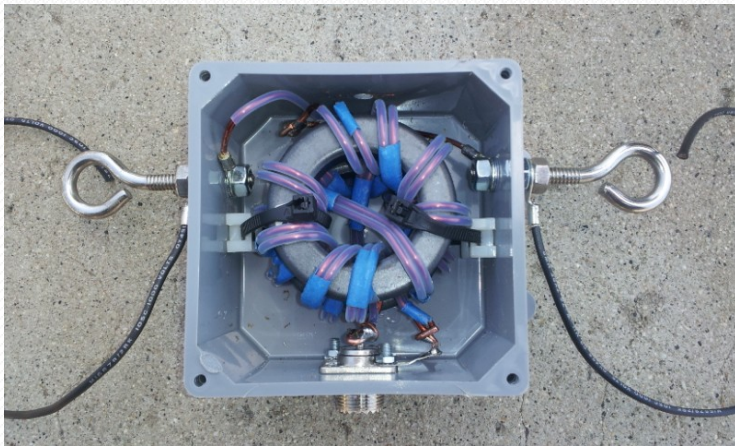
BA-2-1000 2:1, 1KW



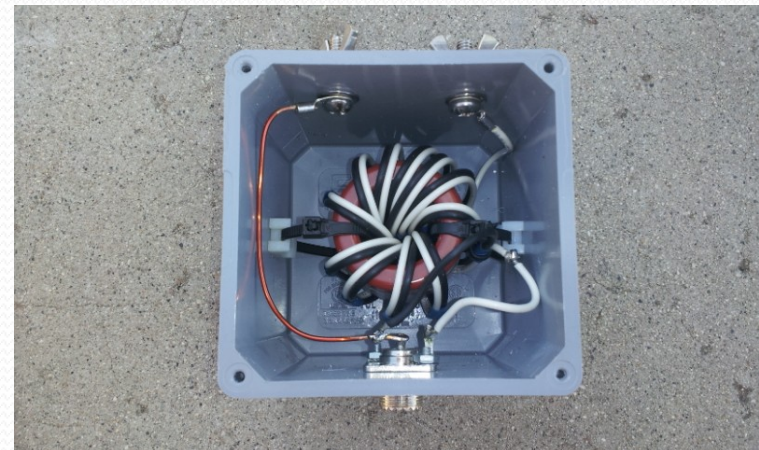
BA-4-250 4:1, 250W



BA-9-250 9:1, 250W

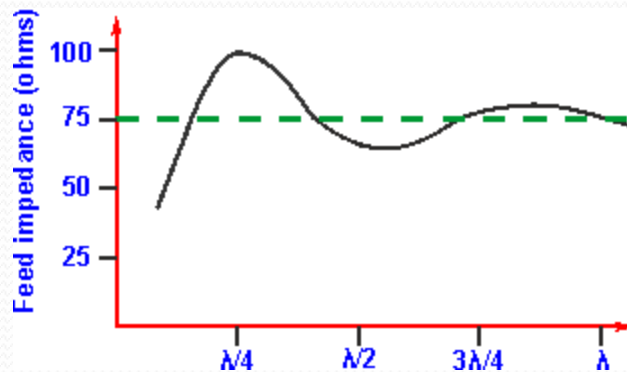


CB-4-5kwdc 4:1 dual core current balun , 5KW – OCF, Zepp



CB-1-1500 4:1 ladder line to coax antenna balun – Zepp, G5RV

Antenna Matching



Dipole Z vs height over ground

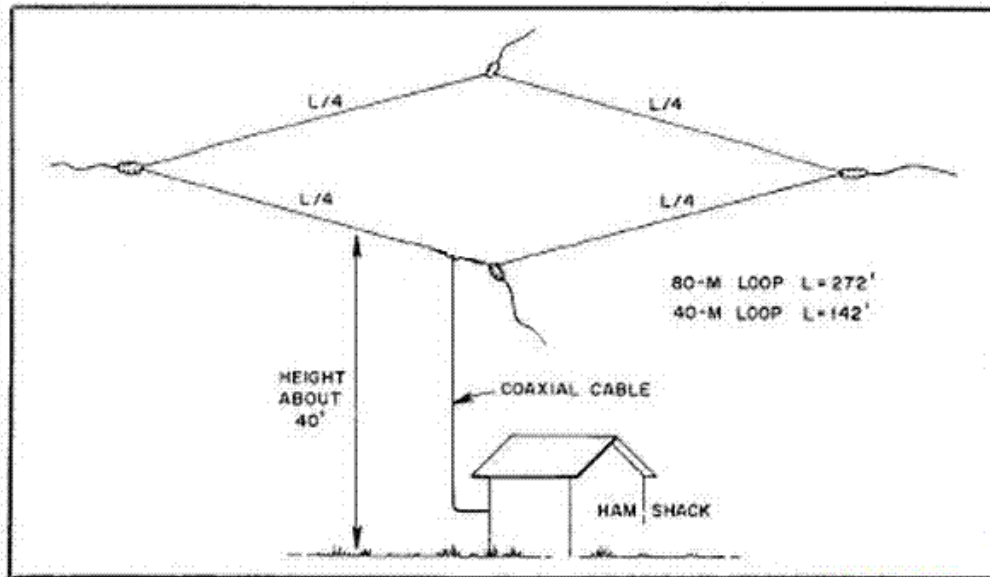
$\frac{1}{4}$ wavelength, $z=100$ ohms
– use 2:1 (50:100) to match

Band	Freq Mhz	1/4 Wavelength (ft)	1/4 Wavelength (m)
160	1.9	129.42	39.45
80	3.75	65.57	19.99
80	3.52	69.86	21.29
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10	28.5	8.63	2.63
6	50.25	4.89	1.49
2	146	1.68	0.51

wavelength (ft) = $983.6 / \text{freq (Mhz)}$

wavelength (m) = $299.7925 / \text{freq (Mhz)}$

Loop Skywires



The Loop is erected horizontal to the earth.

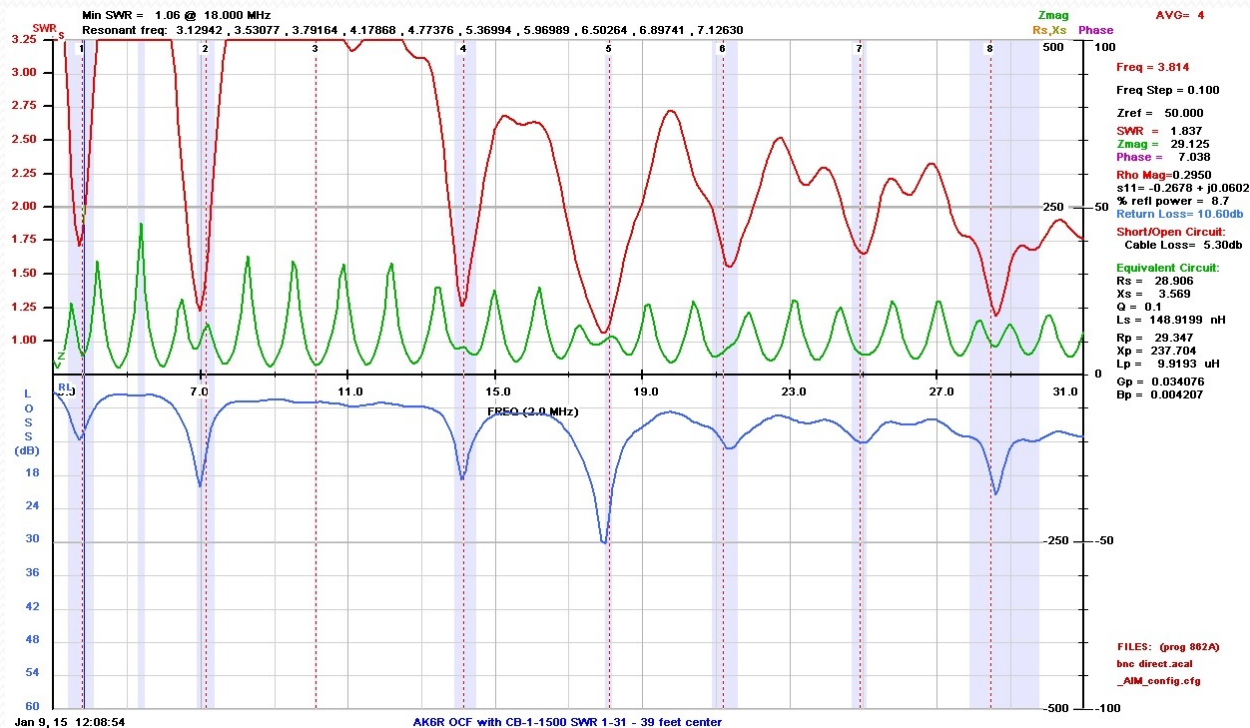
Low height ok, quiet antenna, multiple bands – good signal/noise ratio

Loop $Z = 100$ ohms
so use 50:100 balun
to match and 1:1
balun for RFI
isolation

OR

Use 450 ohm ladder
line to balanced
tuner or 4:1 ladder
line to coax balun

Off Center Fed Antenna



Multi-band (80-2 meters), omni-directional, coax fed, low SWR, gain on bands above 40 meters, works well as inverted V at 30 feet, but higher is better

Reduce Feed Line Loss

- Higher grade coax – lower loss (LMR240/400, etc)
- Better match of feed line to antenna at antenna = lower SWR = lower loss
- Use of ladder line
 - High SWR OK
 - Antenna tuner/balun needed – near 100% power to antenna
 - 1:1 or 4:1 antenna balun to interface 450 ohm to 50 ohm coax
 - All band antennas – Zepps, end feds, folded dipoles – larger bandwidth, higher gain on 40-10, stealthy

Ladder Line



Will tolerate high SWR ($>10:1$ with low loss, acts as impedance transformer, 450 ohm will take legal limit

Use 4:1 balun for ladder line to coax (balun feed line point 150-400 ohms) or 1:1 balun if feed point near 100 ohms.

More DX Summary

- Use Efficient Antennas
- Lower Feed line loss with higher grade coax or lower loss ladder line
- Reduce common mode noise on RECEIVER with Hi Z feed line chokes on PATH and RFI chokes on SOURCES

Current Ad in QST magazine

FERRITES FOR HAMS

Ferrite – Toroids, Slip-on, Snap-on

Mix 31, 43, 61, 77 for Baluns/Ununs, RFI/EMI
Quantity pricing for Clubs, DXpeditions

Antenna Balun/Unun - kits or assembled

1:1, 2:1, 4:1, 9:1 for dipoles, verticals, G5RV,
loops, OCF, end fed, NVIS, quad, yagi antennas

RFI Kits - home, mobile, or portable operation

Free Tip Sheet to cure RFI, reduce radio noise,
work more DX and keep your neighbors happy!

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WHICH ONE DO YOU WANT?

 ..OR.. 

PICK YOUR RFI SOLUTION KIT

MY RADIO ROOM

 ANTENNA RFI	 AMPLIFIER RFI	 COMPUTER RFI
 POWER LINE RFI	 TRANSCIVER RFI	 NOISE REDUCTION

MY HOME or NEIGHBOR'S HOME

 ALARM SYSTEM RFI	 HOME THEATER RFI	 COMPUTER RFI
 MISCELLANEOUS RFI	 GARAGE DOOR	 TELEPHONE/DSL RFI

Contact Info

- Website: www.Palomar-Engineers.com
- Email: ak6r@yahoo.com or Sales@Palomar-Engineers.com
- Phone: 760-747-3343
- Bob Brehm, AK6R – Chief Engineer
- This presentation available on the website.