RFI in the Ham Shack – Tips, Tricks and Traps

Radio Frequency Interference

Locate and minimize
those nasty RFI problems
while transmitting or receiving on HF or VHF

Rick Lapp, KC2FD

rick@ricklapp.net

Typical RFI Problems – while receiving

- **Broadband noise sources** (emitters):
  - Fluorescent (CFL) lighting
  - Switching Power Supplies
    - AC/DC Adapters
    - Battery chargers
    - Mobile phone chargers
  - Ethernet networking cables, switches, hubs
  - Power line noise – insulators, transformers, arcing etc

- Identifying a Broadband noise source:
  - Buzzing
  - Hash
  - Appears across a wide frequency band

Typical RFI Problems – while receiving, cont'd

- **Narrow Band noise sources** (emitters):
  - Computer Power Supplies
  - AC / DC adapters
  - Computer mother boards
  - Video monitors
  - Networking cables
  - Switching power supplies
  - TV or other residence electronics
  - Phone chargers
  - Battery chargers

- Identifying a Narrow Band noise source:
  - Single frequency signals and their harmonics
  - Often with hum or slight modulation
  - Not affected by propagation

Typical RFI Problems – while transmitting

- RFI while **Transmitting**, affecting:
  - Telephone, Entertainment systems, security systems, etc.
  - Broadband cable for TV, Internet and VOIP telephone
  - Shack equipment affected:
    - Microphone / audio inputs
    - CW keyers and keying circuits
    - Digital keying or audio inputs – for RTTY, FT8 etc.
  - Computers
    - Video monitors
    - Mouse input
    - Keyboard input
    - Sound card I/O
    - USB I/O
    - Transceiver / CAT interface
  - Ethernet network cables, switches, routers, modems, hubs
- More of a problem when running HF > 100W

Terms

- RFI – Radio Frequency Interference
  - **A disturbance** generated by external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, radiated or conducted.
- EMI – Electromagnetic Interference
  - Also called radio-frequency-interference (RFI) when **in the radio frequency spectrum**,
  - **disturbance** generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, radiated or conducted.
- Emitter
  - Unintentional radiator, a source of interference
- Emissions
  - Unintentional radiation by a source of interference
  - Emissions can be **radiated or conducted**

Terms, cont'd

- Susceptibility
  - Or lack of immunity, the **inability of equipment to perform** without degradation in the presence of RFI disturbance
- Grounding
  - The **connection** of an equipment case, chassis, bus, or frame to **earth** or other structure to ensure a common potential
- Bonding
  - creating **electrical conductivity between two objects or chassis's** by physical contact with an electrical connection
- Filtering
  - electronic passive device to **suppress conducted interference** present on a signal or power line
- Shielding
  - Reducing the electromagnetic field with **barriers** made of conductive or magnetic materials

Rules and Tips for RFI Reduction

- Identify and locate the emitter or source
- Always try to eliminate or minimize RFI

  AT THE SOURCE !
- Practice good RFI design and trouble shooting techniques **in this order**:
  - **Bonding**
  - **Grounding**
  - **Filtering**
  - **Shielding**

Bonding

- Keeps all equipment at same potential
  - Don't forget ant tuners, audio EQs, keyers and other misc. equipment
- Avoid ground loops and daisy chains by using **single point**, "**star**" or "**shack ground**"
  - Keep bonding wires short
  - Avoid small gauge, go with min of 18, 16, or 14
  - Stranded bonding or braid makes equipment moves easier

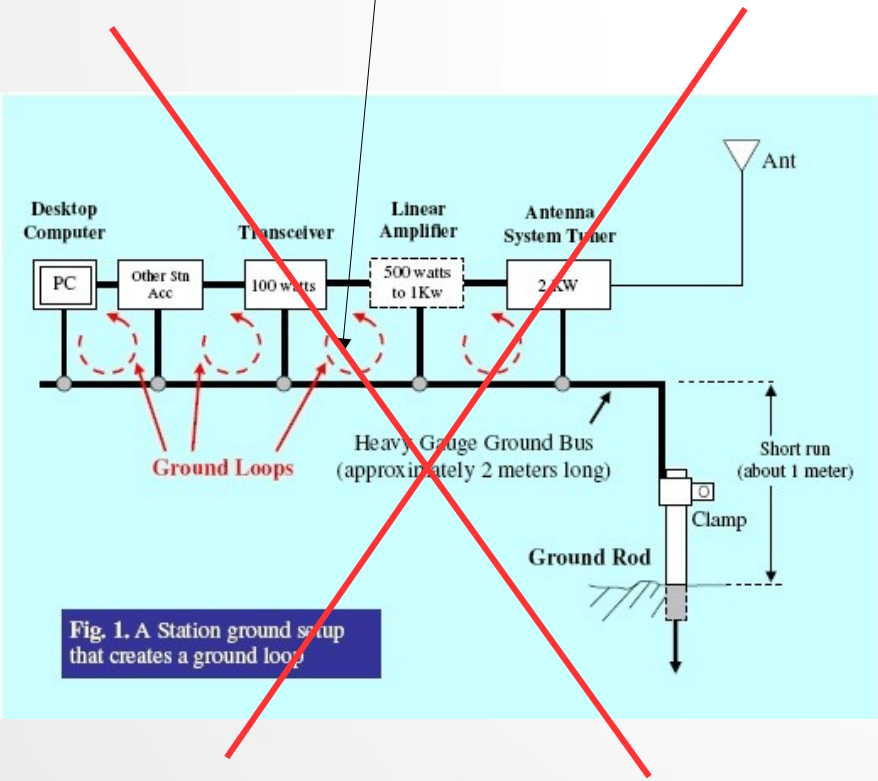


Fig. 1. A Station ground setup that creates a ground loop

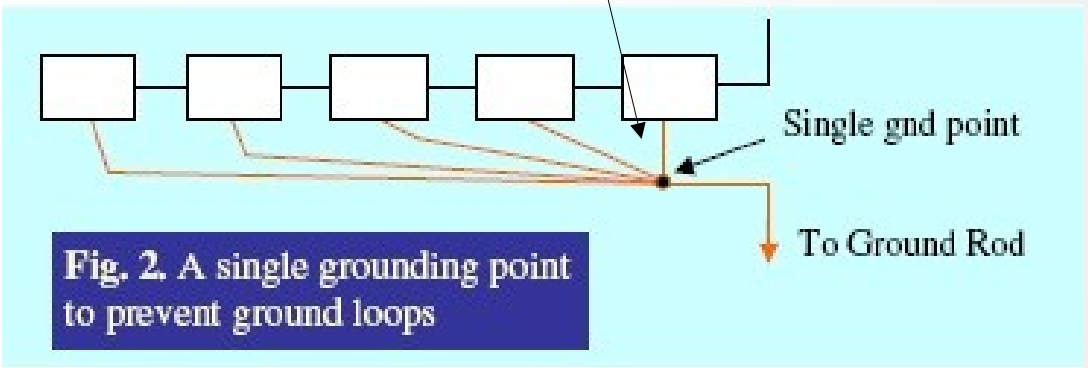
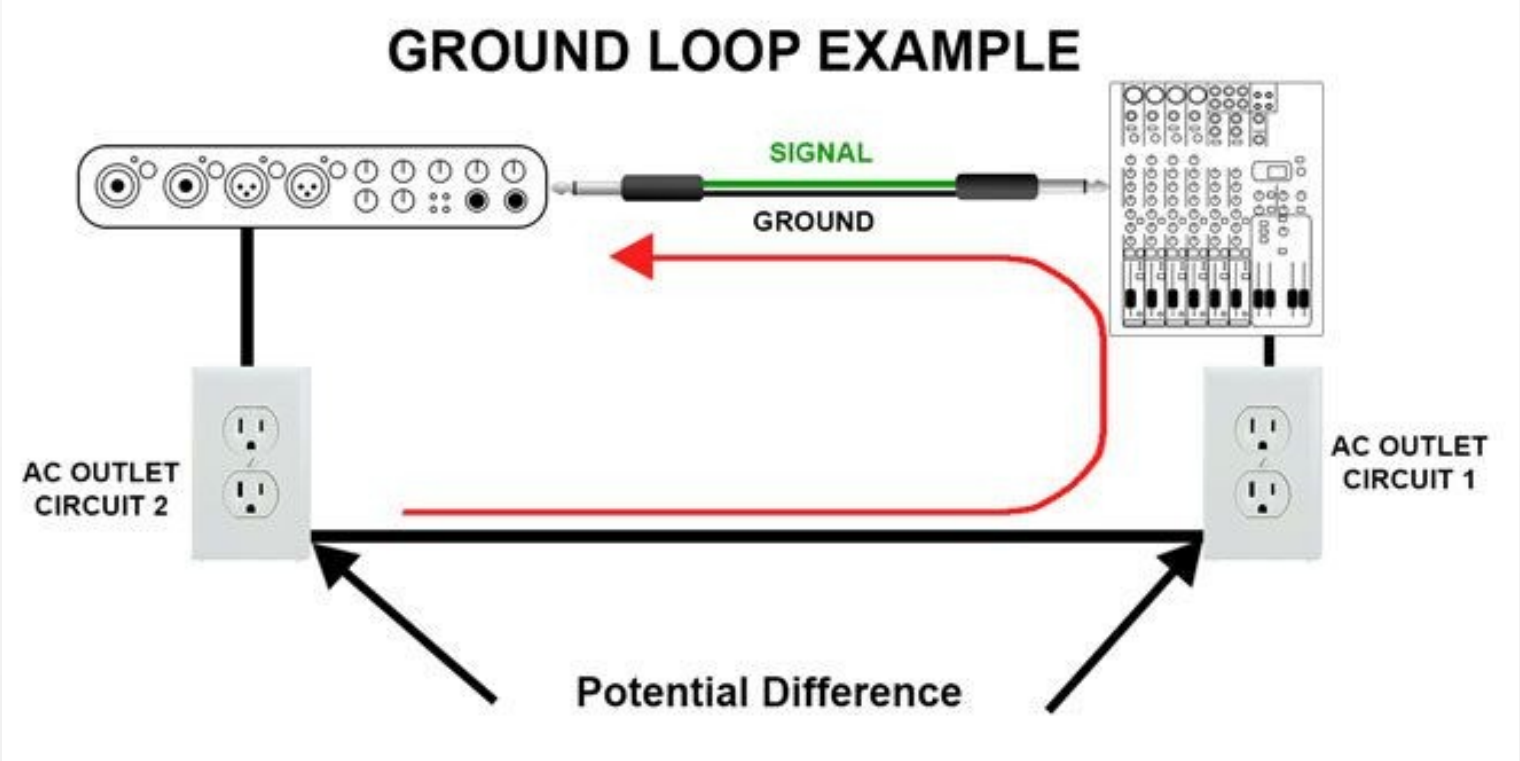


Fig. 2. A single grounding point to prevent ground loops

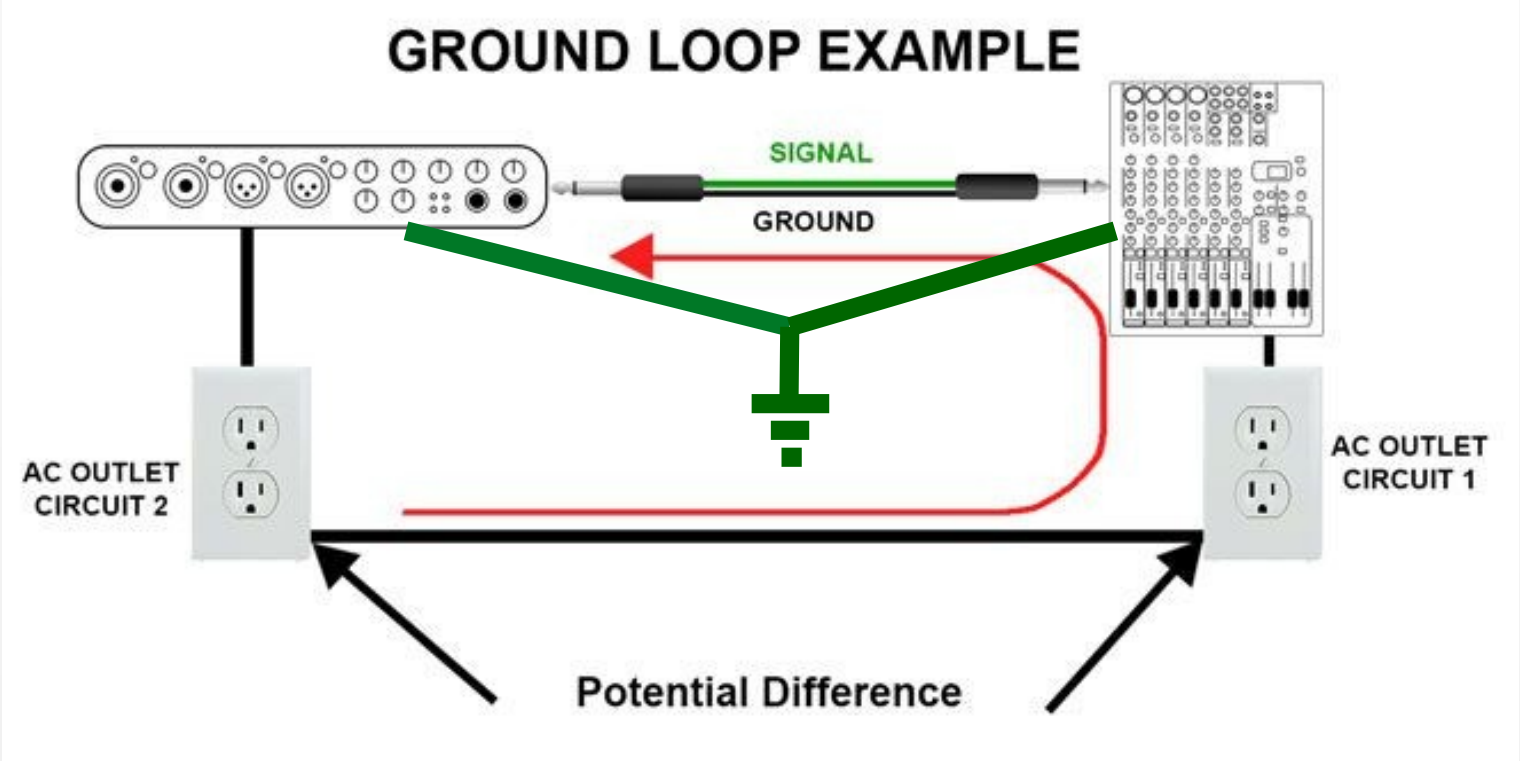
Bonding, cont'd
Example of AC ground loop

- Don't rely on the cable shield to keep equipment enclosures at same potential
- The ground terminals of different AC outlets may not all be at same potential
- The example below will induce a 60Hz hum on the audio cable and signal!
- The shield of the cable should only be used as a RETURN for the audio signal, not to bond equipment enclosures
  - Use a single wire to the single point star / shack ground to bond equipment enclosures together



Bonding, cont'd
Example of AC ground **and SOLUTION**

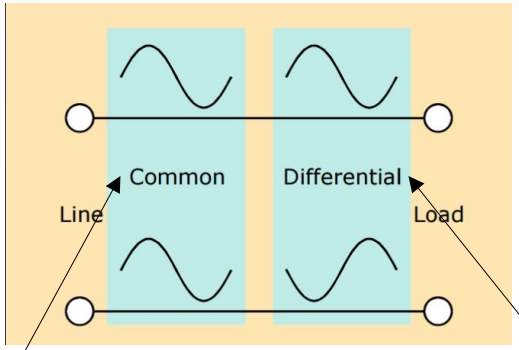
Use a wire or braid to a **single a point to bond equipment enclosures together**



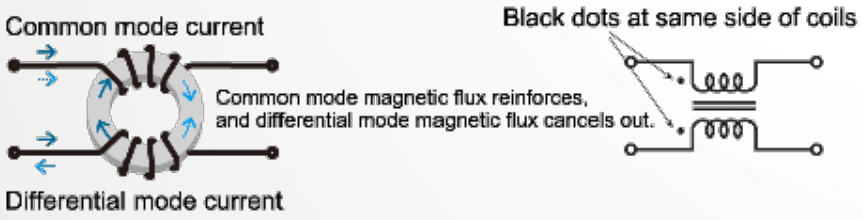
Grounding

- Typically, a ground rod driven into soil
  - Min 8 foot recommended depth
  - copper or galvanized steel rod
  - Min 8 AWG wire run **to <u>single point star / shack ground</u>** and equipment
- Can prevent equipment damage from nearby lightning strike
  - Lightning protection itself is a complex subject
- Provides a redundant safety ground for utility / AC feed
- Use of hot or cold water pipes is currently controversial - per NEC
- Maintains all equipment to same potential at “earth ground”
- Grounding of equipment to an outside ground is effective to provide:
  - A redundant SAFETY GROUND for AC Utility or house wiring faults
  - Lightning protection and safety
  - Does NOT necessarily provide a solution to RF issues

Filtering - Common Mode vs Differential Mode

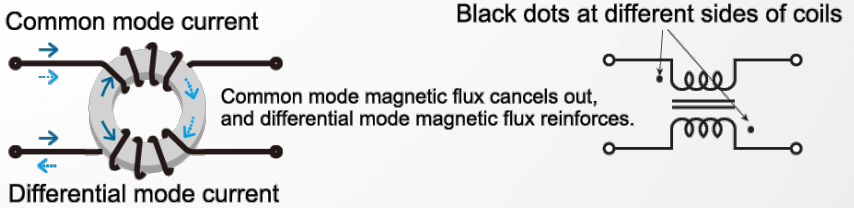


- Most communications / RF equipment produces, and is sensitive to **<u>Common Mode</u>** interference
  - RF Appears on the two signal lines simultaneously in the same direction and phase
  - A common-mode choke, produces equal and opposite magnetic fields that cancel one another.
  - A capacitor from each line to ground can also be used.



Common mode choke coil magnetic coupling and equivalent circuit

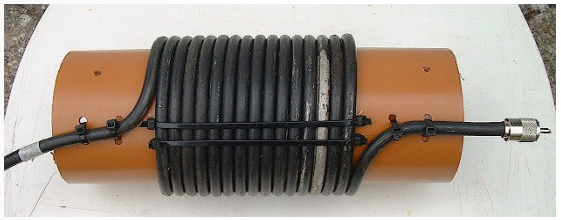
- **<u>Differential-mode</u>** appears on two lines of a closed loop – (car battery to mobile radio)
  - current flowing in opposite directions
  - This kind of interference appears in series with the desired signal
  - The solution is an inductor in series with the high side (and/or low side) of the line and a shunt capacitor across the lines.
    - Example: Alternator whine filter attenuator for DC leads of mobile rig
      - This filter must be designed carefully and must support the full current of the radio
      - Ferrite WILL NOT be effective for differential mode noise with a DC bias
      - Use powdered iron cores or cores with a 'distributed gap'



If the dot positions are opposite each other,
the magnetic field generation direction is different because of the different winding method.

Filtering, cont'd

- Examples of filters:
  - Baluns for antennas:

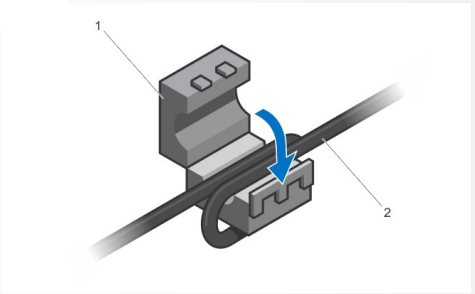


  - Ferrite cores for common mode interference:
    - Clamp-on

Toroid

Types of Ferrite cores

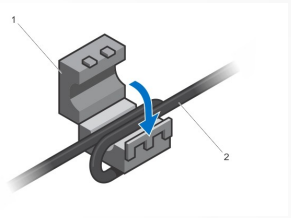
- Toroid
- Bead
- Clamp on
- Ribbon cable
- Can be wound with a single or multiple turns
- Cores are made of various material 'mixes'
  - Mix will determine effective attenuation at various frequencies
    - Refer to data sheets



Understanding Ferrite Cores

- Most RFI problems are solved with a Common Mode core configuration





- Differential Mode core configurations are usually used only in DC applications
  - 12V DC inputs to transceivers
  - Ferrites will saturate – use iron powder or Molypermalloy
- Winding techniques:

Coax

Bifilar

Segmented

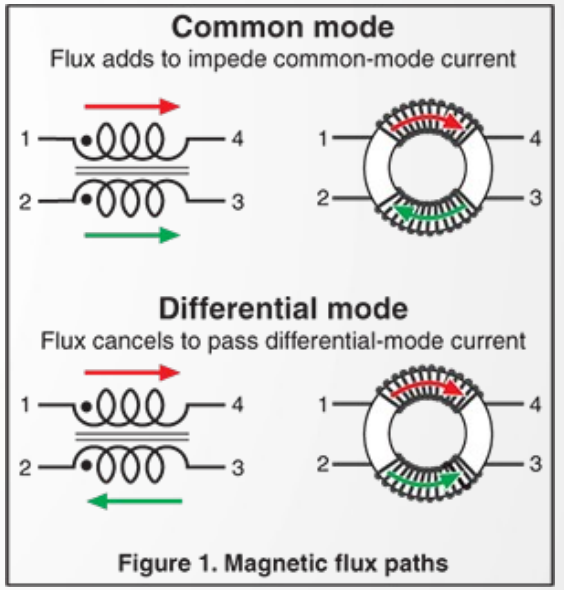
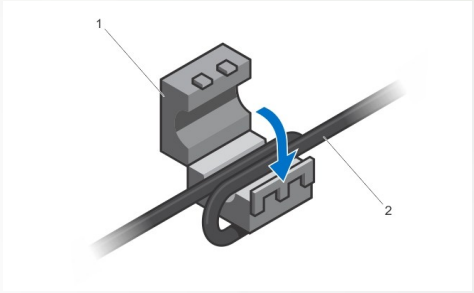


Figure 1. Magnetic flux paths

- Using ferrite makes a “low pass filter” on the cable it is applied to
- The ferrite dissipates the RF energy as heat in the core
  - Cores must be large enough to handle the dissipation caused by magnetic flux in the core when used as baluns or transmit feedline common mode chokes to prevent core saturation
- Turns on a core are counted by the number of times the wire passes through the inside of the core

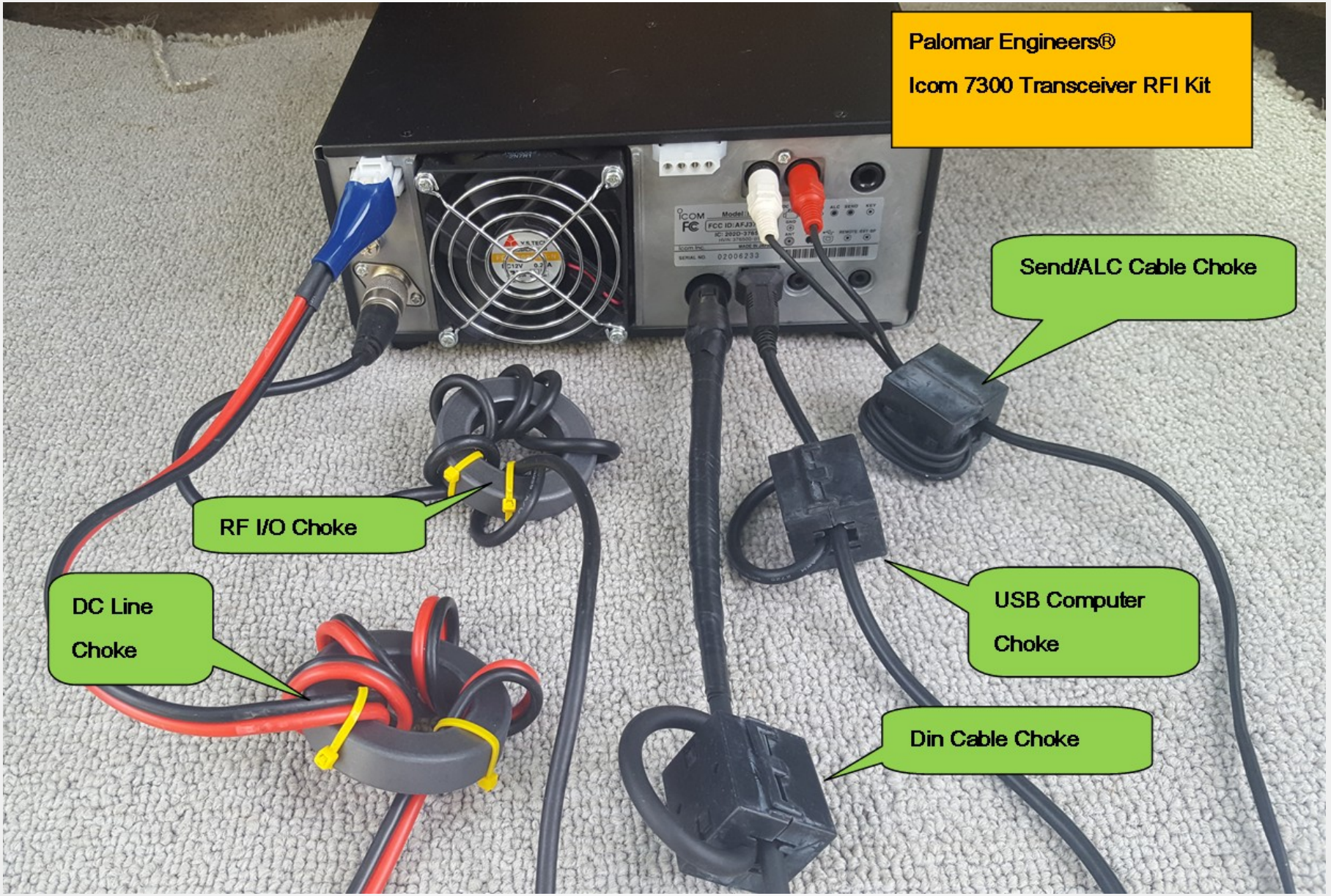
Selecting and Using Ferrite cores

- Fair-Rite mixes:
  - 31 - good for HF 160-20m
  - 43 - 20m and higher
- Size
  - Bigger is better
- Core shape
  - Toroid – most effective
  - Bead – usually smaller applications
  - Clamp-on – easy to install
- Number of turns
  - 2-4 turns usually best



Fair-Rite Part Nr	Form	Dimensions (inches) o.d.	i.d.	Length	Mix	Approx Cost 250 pc	1,000 pc	Freq Range (MHz)	
2631803802	Toroid	2.4	1.4	0.5	#31	< $5	< $3	0.5	200
2643803802	Toroid	2.4	1.4	0.5	#43	< $4	< $2	5	250
2661803802	Toroid	2.4	1.4	0.5	#61	< $4	< $2	50	150
2631625102	Cylinder RG6	0.625	0.312	1.125	#31		$0.65	1	300
2631102002	Cylinder RG8	1.02	0.505	1.125	#31		$1	1	300
0431178281	Clamp-On RG8X	0.648	0.354	1.125	#31			1	300
0431164181	Clamp-On RG8	1.22	0.51	1.55	#31	$3.25	$2	1	300
0431177081	Biggest Clamp-On	2	1.03	1.474	#31	< $11	< $7	1	150

Example: Clamp-on or Ferrite Toroids for common mode noise suppression



Locate and Identify the Source – Receiving problem (offending emitter)

- Use a sniffer
  - Portable receiver in the same band
  - AM mode is most effective to locate an offending emitter
  - Listen for relative signal strength as the receiver is moved
  - Is it conducted on power lines or radiated?
  - Is it broad band or narrow band?

- Turn off power to part or all of the building or residence to isolate the offending emitter with the main or individual circuit breakers at utility CB panel

- Methodically UNPLUG every electronic device on the offending branch
  - Most modern equipment remains on standby / low power, even when switched OFF

- Is it at your house, a neighbor or conducted on the power lines?
  - See video of actual Broadband RFI source found

- CATV has emissions on 145.25 (ch 18)

Solving common RFI problems

- Solving RFI problems requires good design practice but also, requires creativity and intuition
- HF operation while **transmitting**
  - Most common issues:
    - RF into the audio circuit
    - RF into the keying circuit
    - RF into the digital inputs
    - RF burns from touching microphone or chassis
  - Usually caused by poor **BONDING**, **GROUNDING** or RF on the feedline due to high SWR or **ANTENNA MISMATCH**
    - First, improve **BONDING, GROUNDING and ANT MATCH**
    - Then try **FILTERING**
    - Filter, using clamp-on or toroidal Ferrite cores
    - Ferrite filters should always be placed as close as possible to equipment INPUTS

Solving common RFI problems, cont'd

- HF operation, while **receiving**:
  - Use portable sniffer receiver at the frequency
    - For broadband, use AM mode
    - For narrowband, use SSB mode
  - Turn off equipment methodically to isolate the source
  - Power line issues:
    - Usually caused by arcing / breaking down insulators or loose connections at poles
    - Damp weather = insulation breakdown
    - Locate with an AM sniffer receiver

Solving common RFI problems, cont'd

- HF operation, **receiving or transmitting,** problems not at your QTH:
  - Noisy appliance at your **neighbor's house?**
  - Hope that you have a good relationship
  - Isolate the noisy emitter by sniffing or shutting off power
    - By branches or the main CB
  - Try relocating appliance or wiring slightly
  - Use ferrite cores on audio system cables or on telephone wiring
  - Inexpensive electronics tend to be more noisy and susceptible than higher quality ones

  - Rick's “6 Pack” or “Bagel Diplomacy”:
    - Approach your neighbor carefully
    - Find the offending appliance
    - Demonstrate the interference with the portable receiver
    - Offer to replace the offending appliance
    - You just spent $2,000 to $10,000 on a new rig

      Can you afford just $100 more, to replace your neighbor's poorly designed, non-FCC approved appliance?

Solving common RFI problems, cont'd

- Fluorescent (CFL) lighting
  - Use well known brand lamps; Phillips, GE, Sylvania etc.
  - avoid budget lamps

- New LED lamps seem to be much quieter on HF than fluorescent

Computer related RFI problems and solutions

- Common problems:
  - RF can be emitted from, or interfere with the computer in the shack
  - Received narrow band (birdies) on specific HF frequencies from computer CPU
  - Received wide band (hash) on several HF bands from computer Power Supply
  - More problems occur with low cost / not FCC accepted products
    - Spend a few more bucks and enjoy many dB of quiet receiver experience
  - RF into the keyboard, mouse or audio interference when transmitting high power HF
- Continue to follow the ground rules in this order:
  - **Bonding, grounding, filtering**
- Does turning off the computer (unplugging) eliminate the interference?
- Unplug cables one at a time to isolate one I/O
- Bond and ground the computer chassis
  - to the common (star) ground point in the shack
- Use ferrites on all I/O leads:
  - Video
  - USB
  - Keyboard
  - Mouse
  - A/C
  - Audio I/O

Shielding

- Shielding is most important to solve issues with:
  - Computer motherboard
  - Computer power supply
  - Any other switching power supply in the shack

- Computer case screws should all be installed and tight

Other sources of Interference?

- Social interference
  - Most common on contest weekends
  - No known solution, except for the on / off switch
  - Your notch filter will NOT work!
  - Even your DSP or SDR noise blanker will NOT work!

"Are you STILL on the radio?"

"The lawn needs cutting!"

"Take out the garbage!"

"I can hear Morse Code and I'm trying to sleep!!"

…….etc.

Resources

- Ferrite core manufacturers:
  - Fair-Rite
  - Amidon
  - Magnetics Inc.
  - Arnold

- Ferrite core sources:
  - Digikey
  - Mouser
  - Ebay

Summary

- Follow the simple rules:
  - Bonding
    - All equipment bonded to a single point
  - Grounding
    - The single point returned with 8 AWG to 8' copper rod
  - Filtering
    - Use ferrite clamp-on or toroids, close to inputs of the equipment being interfered with
- Be creative, some solutions may be unusual, unique!
- What RFI problems have you solved?