RADIO FREQUENCY INTERFERENCE (RFI) Notes
M.D.Lowell, N1LO October, 1998

Progress: Through July 1999 archive

Check http://www.qsl.net/n1lo for the latest update

The existence, accuracy, content and organization of any section may change at any time as new discoveries, understandings, and concepts arise. I add new sections whenever appropriate.

By Mark D. Lowell, N1LO. First posted in December 1999

This document is a series of notes that I have made concerning RFI and TVI problems and resolution after reading and digesting
the message archives of the RFI forum sponsored by the folks at www.contesting.com. The archive is located at:

http://www.contesting.com/_rfi/

ONLINE RFI REFERENCES
AMIDON Products Technical Reference
http://www.bytemark.com/amidon/content0.htm There is detailed explanation and design info here as well as an excellent section on EMI/RFI
http://www.bytemark.com/amidon/emi-rfi.htm
http://www.arrl.org/tis
http://www.fcc.gov/cib/Publications/tvibook.html

PUBLICATIONS FOR REFERENCE

A good book on EMI that every active ham ought to own is the ARRL's "Radio Frequency Interference: How to Find It and Fix It". They've updated it and it's now called "The ARRL RFI Book". I still need to buy the new one, but the old one is really excellent!

RESOLVING RFI ISSUES WITH A NEIGHBOR

DO's AND DON'TS
ARRL publishes an RFI pamphlet, written specifically to help explain interference to your neighbors. To get a couple of copies, send an SASE to the ARRL Technical Department Secretary, 225 Main St, Newington, CT 06111, along with a request for "2 RFI pamphlets." The text of this pamphlet is available on ARRL's Web page, but the actual printed pamphlet is more effective with your neighbor than a downloaded Web page, in most cases.

Don't take immediate responsibility for the problem. Make it clear that although you are the source of an outside radio signal, the neighbor's device is supposed to be designed to reject it.

Do not perform modifications on AC powered equipment that is not your own. Remember -- house AC power is dangerous and you may be blamed if anything EVER goes wrong with the device or house wiring. These modifications must only be performed by qualified service personnel!

Install a low-pass filter on your HF station.

For telephone interference problems, offer to loan the neighbor an RF resistant telephone (see telephone section) for testing and have him unplug all other phones.

In regards to problems with close neighbors complaining about your radio interfering with their computers: Tell them to take their problem up with the computer manufacturer. DO NOT, under any circumstances, work on a neighbor's computer even if he is a close friend.

The reason for this is that at a later date if and when any problem occurs (especially a data crash) you will be blamed. FCC rules on computer RFI are simple and clear cut. Computers are part 15 devices and as such they may not interfere with any licensed radio service and must accept any interference

GETTING THE FCC INVOLVED (?)

The FCC no longer investigates RFI complaints to telephone, TV or entertainment systems. You can call their 800 number (888-CALL-FCC) and listen to the FCC's RFI message. It is educational. You might want to give this number to your complaining neighbor since it tells him it's most likely his equipment at fault-not yours. You can also find out how to order the FCC's interference handbook which tells the same story. Get an extra one for the neighbor if you want to be nice of course.

Rectification and overload are both problems with the design of the affected equipment, and after decades of investigation, the FCC knows this. That's why their policy is such as it is now. The FCC cannot get laws enacted to correct this by forcing manufacturers to properly design stuff so they've backed off and are not doing anything about it themselves. If the neighbor is unwilling to cooperate, the FCC won't even want to talk with them. They are instructed by the FCC to contact the manufacturer who made the defective equipment for a solution. Sort of a "free market" solution.

One bit of advice: It really helps to clean up your TV/Stereo & telephones, so that you can point at your equipment saying "My TV/Stereo/Telephone doesn't get any interference, so it must be your equipment." While solving your own RFI issues you'll learn how to help your neighbors with theirs (should they finally ask for help). When helping a neighbor it's a good idea to have another local ham familiar with RFI act as a liaison or 3rd party who is not interested in the dispute. Contact your local club or the ARRL for the name of the local TS (Tech Specialist) who is willing to help out in this capacity.

USING LOW PASS AND BAND PASS FILTERS ON TRANSMITTERS

Almost any low-pass filter will offer at least 30-60 dB of stop-band attenuation. Good units are made by Bencher, Drake and ICE. Keep the jumper between the transmitter and filter as short as possible to prevent the jumper from becoming any kind of antenna for harmonics. In most cases, if the interference is caused by transmitter unwanted emissions, this will be quite enough to make the problem go away.

The main purpose of a low-pass xmit filter is so that when you DO have an interference problem, you can point to it with pride. Most cases of consumer interference are caused by fundamental overload, not transmitter harmonics. If the only requirement is to attenuate harmonics, the right solution is to use a lowpass filter or a harmonic notch filter - at any frequency. One important difference at VHF is that the percentage frequency change is usually much smaller than at HF. This means that the harmonic frequencies are essentially fixed, so harmonic notch filters using coax stubs can perform very well indeed. See the web page, http://www.ifwtech.demon.co.uk/g3sek, for details of the harmonic notch filters by G4SWX which have excellent performance, can be built in minutes, cost literally a few pennies, and can handle a kilowatt.

CHECKING A CABLE TV SYSTEM FOR LEAKS

If your neighbor is on cable, check that first. The easiest way to narrow this down is to see if there are leaks in the system. On cable, they use 2 frequencies to each channel. The easiest one to use to check for us is ch. 18. Its picture is sent very near 145.26 and its audio near 149.76. If you have a extended coverage receive 2 meter and a beam antenna, put it on 149.760 open up the squelch, and rotate it and listen for the voice leaks from ch. 18. Once you get the heading. take a HT and go for a walk. You very well may find it seems to be strong and then you may need to check for leaks in your own house. Get it as close as you can with the HT, use your body as a directional attenuator to get some directional headings on the HT.

Once you close in to the house, room, pole or what ever, you can remove the antenna from the HT to pin point the exact location of the leak. You may find the problem a Cable Ready TV tuner, a homeowner's own cable addition with non Cable TV rated RG59, a splitter with a unused port and no terminating resistor cap on it. This will not take much time, unless the leak is in your neighbor's house and he is not cooperative. Document the steps, and the results.

The "standard" splitters RS sells are in some cases quite leaky; however, the "gold" series ones they sell are pretty tight. They are much preferable.

GENERAL RFI-PROOFING MEASURES FOR DEVICES

Install ferrite toroids or ready-made filters on all conductors going into or out of the device. Use higher permeability cores (75 or more) for lower frequencies and medium permeability (43) for 30MHz & up.

Slip a grounded, tubular braid (from some old coax, perhaps) over connecting cords on the device.

Shield the device with a metal box, or wire screening.

Orient the device into a different position or move the antenna on the radio device.

Spray plastic enclosures with an EMI shielding spray to turn them into shielded cases, and ground them.

FINDING AND SELECTING FERRITE CORES

FERRITE MIX

The appropriate ferrite mix to use for HF and below is type 73, 75, and 77 for higher permeability. For VHF/UHF, use type 43.

Here is a source for cores suitable for HF:
Amidon Inc. P.O. Box 25867 Santa Ana, CA 92799 Telephone: (714) 850-4660
Part numbers are: small ferrite bead, number 75 material, FEB-75B-101, $4.50 PK/12
Larger core unit, number 77 material, FB-77-1024, $2.00 EA
Very large core, number 77 material, FT-240-77, $9.00 ea, (great for cables)

From an ARRL Handbook:

Magnetic Properties of Iron Powder Cores

Mix	Color	Material	æ	Temp	f (MHz)	Notes stability (ppm/øC)
26	Yellow/white	Hydrogen reduced	75	825	dc - 1	Used for EMI filters and dc chokes
3	Gray	Carbonyl HP	35	370	0.05 - 0.50	Stable, good Q for lower freqs
15	Red/white	Carbonyl GS6	25	190	0.10 - 2	Excellent stability, good Q
1	Blue	Carbonyl C	20	280	0.50 - 5	Similar to Mix-3, but better stability
2	Red	Carbonyl E	10	95	2 - 30	High Q material
7	White	Carbonyl TH	9	30	3 - 35	Like Mix-2&6, but better temp stability
6	Yellow	Carbonyl SF	8	35	10 - 50	V.good Q & temp. stab. for 20-50 MHz
10	Black	Powdered iron W	6	150	30 - 100	Good Q and stability for 40 - 100 MHz
12	Green/white	Synthetic oxide	4	170	50 - 200	Good Q, moderate temperature stability
17	Blue/yellow	Carbonyl	4	50	40 - 180	Like Mix-12, better temp stability
0	Tan	phenolic	1	0	100 - 300	Inductance varies greatly with windings

RADIO SHACK FERRITES

There was some discussion of the effectiveness of various ferrite chokes a few days ago. I have access to a HP 4194A Impedance Analyzer, so I put a couple of popular ferrites through a swept-frequency impedance analysis. I measured two of Radio Shack's products: the first is a cylindrical ferrite in a plastic holder, about 1.25 inches long by .75 inches in diameter. It opens up like a clamshell and clamps down on the wire. The opening is about 0.25 inches. The values shown are for a single wire through the ferrite. FREQ INDUCTANCE ESR (Equivalent Series Resistance)
300 kHz 2.07 uH 0.073 ohms
2.3 MHz 2.25 uH 6.9 ohms (the inductance peaks at this freq)
10 MHz 1.18 uH 54 ohms
20 MHz 0.80 uH 89 ohms
40 MHz 0.50 uH 130 ohms

The second Radio Shack ferrite is a rectangular device which opens up and allows the ferrite halves to be separated so multiple turns can be wrapped around it. It is 1.675 inches long by 1.125 inches wide by .375 inches thick. The opening is much larger in this ferrite, so more turns can be wrapped around it than the cylindrical one. The values shown are for a single wire through the ferrite. Unlike the cylindrical ferrite, there is no inductance peak.
FREQ INDUCTANCE ESR
300 kHz 0.39 uH 0.044 ohms
2.3 MHz 0.38 uH 0.6 ohms
10 MHz 0.29 uH 7 ohms
20 MHz 0.21 uH 11 ohms
40 MHz 0.18 uH 10 ohms

As with all coils, increasing the number of turns increases the inductance and ESR by the square of the increase. For example, if one turn gives 1 uH and 10 ohms, two turns will give 4 uH and 40 ohms, three turns would give 9 uH and 90 ohms and so on. One word of caution: Radio Shack is known for changing their product line at the drop of a hat, so use caution in applying these measurements.

One inexpensive source of toroids is to use deflection yoke cores from junk television sets or

monitors. They are bulky, even from a small tv, but work well. Multiple passes of the cable are possible to achieve high isolation reactance. These may not have the permeability for the frequency of interest, so experiment.

MAKING COMMON-MODE CHOKES

The easiest way to make a common-mode choke is to take a ferrite toroid and wrap about 5-15 turns of the feedline onto the toroid, forming a coil. This will attenuate common-mode signals nicely, without significant effect to the differential-mode signals INSIDE the feedline (the desired TV signals in the case of TVI). For lower HF, #73, #75, #77 or J type material is best; for upper HF and VHF, #43 is a good all around material.

To realize effective chokes in few turns it is a need to use materials whose permeability is very high, 2000 or more. Large cable, such as monitor cables, are impractical to wind. The solution here is to use large, split toroids and mate the halves tightly after winding the cable around each half.

"Some improvement" with ferrites indicates that more ferrites added may cure the problem. Radio Shack "Clamp-On Chokes" must have 5 turns or more to be effective on 80 meters. Split beads are about 10 times as good (Palomar FSB-1/2 or equivalent). Beads must be where leads enter the electronics box. Also treat the power cord and any other wires entering the box. If feasable, .001 mfd disc capacitors from the leads to ground on the box side of the ferrites will make the beads more effective.

FIXES FOR DEVICES SUSCEPTIBLE TO RFI

TELEPHONES

In most cases, filters will do it. These are widely sold and advertised. Radio Shack now sells telephone filters (the ARRL Lab helped hook them up with a K-Com, a good manufacturer of good filters!) I first recommend you learn about the problem. ARRL has a telephone-interference package available for download from our Web site, http://www.arrl.org/. If filters don't help, a ferrite toroid in the line next to the phone may work. Use as many turns as possible in the toroid. To summarize, interference to non-radio devices is not the fault of the transmitter. The FCC states in their material that telephones that pick up radio signals are improperly functioning as receivers. You may want to help your neighbor find a solution, but you are in compliance with FCC regs. First, simplify the problem. Disconnect all of the telephone devices. If you have an "RFI proof" phone (TCE Labs, Pro Distributors), plug it in and try it.

One such telephone is the Radio Shack model 43-591 phone for $19.95 (less if on sale). This phone is highly resistant to RFI. If it doesn't solve the problem, you can take it back to RS. For additional RF rejection, snip off one of the modular plugs that comes with the 6' cord, wind as many turns as possible on a 1/2" ID, 1" long ferrite bead, and then reinstall the modular plug. If it works, you have determined that there is no problem with the lines or telephone company equipment. Now, start adding devices back to the lines one at a time.

There is some info on the two RFI proof phones in the FCC's Interference Handbook (which is free if you ask for them at 888-CALL-FCC):
PRO Distributors 2811-B 74th Street Lubbock, TX 79423 (800)658-2027
TCE Labs RR9 Box 243D New Braunfels, TX 78133 (800)KILL-TVI

If you do have interference, try to eliminate it with filters. All of the filters should be mounted as close to the telephone as possible. First, try a telephone line filter. You can buy a commercial product, or make one with about 10 turns onto an FT-140-43 ferrite core. If the interference is primarily from 40 m and below, an FT-140-75 core may work a bit better. You may also have to filter the handset cord. K-Com sells handset filters. If the telephone or telephone device has a connection to the AC line, usually through one of the "wall cube" type supplies, you may need to try a common-mode choke on the power lead to the phone (10 turns on an FT-140-43 or -74).

In some cases, a telephone-line imbalance may create a differential-mode signal on the line. In this case, a 0.01 uF ceramic capacitor across the telephone line may cure interference that doesn't respond to conventional telephone (common-mode) filtering. The ARRL book, Radio Frequency Interference: How to Find It and Fix It, has a chapter on telephone interference.

VHF interference to wired telephones is not common, but it does happen. The use of indoor antennas does add to the problem. In general, you will need an RFI filter at each telephone or affected device. In addition, you may also need a separate filter for the handset cord, especially for frequencies about 14 MHz, or a ferrite core (about 10 turns should do) on the power-supply leads going to any of the telephones, answering machines, standalone modems, etc, especially for frequencies below 14 MHz. Many telephone filters are not effective at VHF. K-Com makes one specifically for the VHF range.
Contact: K-Com, PO Box 82, Randolph OH 44265 USA. Phone: 330-325-2110 Fax: 330-325-2525. Products/Services: FILTER-TELEPHONE EMI FILTER :
Filter models RF-1 (modular), RF-2 (wired) and RF-1 Coiled Cord (for handsets).

INSTALLING FILTERS INSIDE TELEPHONES

You can homebrew a telephone filter using 470 micro-Henry chokes and caps having a value anywhere in the range of 1000 to 3000 pF. Insert one choke in series with each telehone line (red and green, most commonly.) Install one cap in parallel across the red and green lines, at each end of the inductors (total count is two inductors and two caps.) You can add a second stage with two more series inductors and one more shunt cap in the middle of the network (total count is four inductors and three caps.)

Modern electronic telephones are potentially susceptible to radio-frequency interference [RFI] because they contain many silicon diodes which act as crystal rectifiers. The crystal rectifiers convert inaudible, RF energy into audio-frequency energy which can be heard in the earphone. This turns the telephone into a crystal-set/radio-receiver in the presence of moderate to strong RF signals. Electronic telephones also contain transistors which can amplify RF signals. This increases the RF-sensitivity of the telephone. The antenna for this unwitting radio receiver is the telephone wiring in the walls and attic of the building where the phone is located. The net effect is that people who live near an AM radio station may hear music over their telephones. People who live near airports may hear pilots talking with the control tower. Those who live near an amateur radio station may hear garbled speech in their telephones. A properly engineered telephone will not allow RF-energy to enter the telephone circuits
which contain the components that act as crystal rectifiers. Including an RF-energy filter in the design of a telephone would increase the retail price of the telephone by less than $1. There is considerable variation in RF susceptibility between different models of telephones from the same manufacturer. I don't know of any brand that is RF-proof without adding an

RF-filter or filters. Unfortunately, a few models of telephones are very susceptible to RFI and are sometimes virtually impossible to RF-proof with an external RF-filter. If you recently purchased a highly RF-susceptible telephone, and you saved the receipt and all of the packing material, don't hesitate to return the telephone. Tell the store manager that telephones are not supposed to pick up radio signals-and ask for a full refund. If the store manager tells you that the interference is the fault of the radio station, tell him that he needs to talk to an FCC engineer. This is the only way that the manufacturers will get the message. Radio Shack has a desk/wall-phone that is much more RF-resistant than the average telephone. The current price is around $30. In many cases, they can be operated without a filter if minor interference can be tolerated. With a RF-filter, they are often RF-proof.

RF-filter Installation
A telephone RF-filter will perform best if it is placed inside the telephone, close to the modular input jack. The input and output ends of the filter should not be placed next to each other. They need to be separated or the filter's ability to attenuate common-mode RF will be reduced. When opening a telephone case, it is advisable to place the push-button side of the phone down on a table so that the buttons will not fall out when the case is opened up. If the telephone's input modular socket is wired to a printed circuit board, it will be necessary to cut the two traces on the circuit board. The filter may be installed on the foil side of the board. The filter may be mounted on the component side of the board by drilling #55 - 60 holes near the cut traces. Mechanically, mounting the filter on the component side of the board is best. Electrically, it makes no difference.

If you want to install the RF-filter outside the telephone, the filter can be inserted into the modular cord between the phone and the wall outlet. To identify the polarity of the wires, mark one side of the cord at the area where it will be cut. Make the cut about 6-inches from the modular plug at the telephone end and solder the filter in series with the two ends, taking care not to reverse the polarity. Exposed conductors should be covered with plastic tape or shrink tubing.

Some pulse-dialing electronic-telephones will not tolerate much capacitance across the telephone line. In such cases, one or more of the shunt capacitors across the telephone line end of the filter can be eliminated.

Wall-mounted telephones can often be RF-proofed by installing a RF-filter in the wall outlet. The pair of 470æH inductances {the components with the green-body and axial leads} work on common-mode RF. Sometimes, it's necessary to use a 2-section filter to increase the attenuation of common-mode RF. To do this, connect two inductors in series, per side, with a third capacitor across their midpoints, as shown below. If a 2-section filter will not fix the problem, the telephone may be acting like a self-contained RF-detector. To completely eliminate RFI, such telephones can be placed inside a shielded metal box, along with the person using the telephone. This is not very practicable, so the best solution may be to discard the telephone. One way to test for such a telephone is to see if it can detect the presence of RF without being plugged in! If this is the case, the problem is self contained and an external RF- filter is not likely to help. Reportedly, a wooden stake and a hammer cures the problem every time.

Telephone answering machines and portable telephone base units may also require a ferrite split-core RF-filter choke on their power cords. This is done by wrapping at least 4-turns of the power cord on the core. More turns are usually better. Ferrite split-core chokes are sometimes useful as an external helper-filter for a telephone that still has a small amount of RFI after the internal RF-filter has been installed. Ferrite split core chokes {two per package}

are available from Radio Shackr as Snap-On Chokes, p-n 273-104.

Since it is possible for one RF-sensitive telephone to cause secondary interference to all of the other telephones on the same line, it is advisable to test each telephone individually for RF-susceptibility with all of the other telephones unplugged from the line. This approach will help sort out the telephones that need help from the ones that are OK. This test should be repeated on each offending telephone after RF filtering is installed.

Princess and TrimLine telephones are usually more difficult to RF-proof because the ringer is in the base unit, the dialing circuit is in the handset, and they are connected by the coil-cord which can act as a loading-coil/antenna. Thus, it may be necessary to install a filter on the telephone line input wires near the modular socket on the base unit, and install another filter in the handset. Desk type telephones, in which the dialing and ringer circuits are in the same enclosure, are usually easier to RF-proof.

Loosely twisted telephone wire splices in the wall or attic can contribute to RFI. The fix is to solder the splices or coat them with silver conductive paint.

If you have a telephone that receives interference on a particular band, even with a 2-section filter, the telephone may be at a RF-voltage-maximum in the telephone wiring. It may help to RF-ground the telephone wires at the wall outlet with a pair of 50pF to 300pF equal-value capacitors. The capacitors are for tuning out the inductive-reactance of the ground lead on the troublesome band. The optimum number of pF must be found experimentally. The best RF-ground is NOT a ground rod driven vertically into the soil. This is the case because HF energy can not penetrate more than a few inches into the earth. A better RF-ground is a horizontal conductor that is on or very near to the surface. All ground system connections that are subject to moisture should be soldered with 5% silver/95% tin solder. Often, an elevated 0.2-wavelength insulated counterpoise makes the most effective RF-ground. However, if such a counterpoise is connected to a ground rod at its far end, it becomes a high-Z RF choke.

TELEVISIONS

Virtually all problems are common mode currents flowing between the CATV shield and the electrical outlet or long speaker leads. 99% of the problems were cured by grounding the CATV shield to the safety ground of the electrical outlet powering the TV or VCR. This provides a direct path around the TV for common mode currents.

F-CONNECTORS

Consumer-installed F-connectors on coax jumpers are another common path for RFI if the connections are not tight or if the connector is not crimped or screwed onto the coax tightly enough, or if it is completely missing and the center conductor is just stuck into the female connector!

ANTENNA PREAMPS

Some thoughts:
1) Radio Shack TV/FM amps are just broadband amps with little protection from primary overload. Usually just a crude pi filter for hi-pass. I have found that cable TV grade Channel

Master and Jerrold are better engineered [more expensive, too!]
2) Wasn't there, now it is... Usually a good sign that there is a bad joint with corrosion in it, creating a diode rectifier/reradiator.

One of you may be the "proud" owner of a TV Translator station! Antenna maintenance is pretty well neglected by hams and unknown to the rest of the folks, but corrosion is a constant enemy of antennas and reception. I've even read of a chain link fence which did this! You may have to sleuth it like the powerline stories in this issue. Main rule: Only change one thing at a time. Don't get impatient and do a whole lot of things or you'll be out in the next snowstorm doing it all over again

AUDIO AMPLIFIERS

It's quite likely that the audio amplifier is performing RF detection. You need to place ferrites on the speaker cables as close to the audio output (right at the PC board if possible) with as many windings as possible. If it is audio detection, it won't matter at all how many ferrites you install on the power cord or cable TV or antenna cable although this will cut down on the amount of RF getting into the TV via those conductors. Direct pick-up onto speaker wires causes most problems. Don't go into the television if it is not your own.

SIMPLE COMMON-MODE CHOKE

A very simple and effective way to eliminate MOST cable RFI is as follows... Attach a 75-300 ohm balun to the incoming cable at the rear of the set...take another 75-300 ohm balun, and ..attach the 2 leads to the 2 leads you just ended up with, and you are back to 75 ohms....this isolates the shield, which is the source of most RFI (common mode). Top it off with a 75 ohm hi-pass filter to the set. Sounds simple, but the baluns are ferrite torroidal and the hi-pass filter adds an extra measure of harmonic protection. All parts are available at Radio Shack and are inexpensive.

COMPUTER KEYBOARDS

In cases where the keyboard is picking up RFI, there are several things you can try, short of replacing the keyboard. The single clamp-on beads are really not enough for 80 or 40 meters. Get some FT-140-43 ferrite cores (Amidon, Palomar, etc), or other cores you KNOW to be ferrite that will work in the HF range and warp about 10 turns of the keyboard cable onto a ferrite core, at both ends of the cable. This SHOULD make a significant difference, at least in the power threshold that causes the problem. If you find it goes from 15 watts to 95 watts, for example, you are on the right track. If it makes no difference, it may be the wiring in the keyboard itself that is causing the problem. (This could also be true if it goes from 15 watts to 50 watts, as an example: the problem could have a 15 watt threshold on the cable pickup and a 50-watt threshold on direct pickup.)

If it IS the keyboard, the easiest solution is to try another, such as the IBM Spacer Saver keyboard, which has been reported to be relatively RF immune. You could also TRY some of the EMI shielding sprays available, trying to get a good shield inside at least most of the keyboard. You could also try a shielded keyboard cable, grounded at either the computer or the keyboard end, or both. Flat 1/2-inch braided strap is usually hollow and can be used to shield your existing cable. If you do try sprays, try to ensure that both halves of the keyboard case will be electrically connected to each other and to the keyboard-cable shield. And

remember, these sprays are conductive paint; if the surface being sprayed is not clean and compatible with the spray, the paint could flake off later, putting bits of metal flakes inside the keyboard. The gibberish on the screen will probably return.

MFJ electronics sells an RFI proof computer keyboard (model MFJ-551) for $39.95.

YAESU ROTATORS

If you have a Yaesu 800 or 1000 series rotor and notice the control unit indicator moving during 2-meter band transmissions, try lifting the ground conductor on the AC supply cord by using a 3-prong to 2-prong plug adaptor.

GARAGE DOOR OPENERS

Fine the lines coming into the control head from the manual doorbell switch and the electric eye sensors. You must filter these at the control head by either soldering series inductors in each line to choke the RF or by winding these lines around ferrite toroids.
You may also want to try a simpler solution: Place a .01 mf cap cap across the leads at the terminal strip on the main unit.

STOPPING COMMON SOURCES OF INTERFERENCE TO RADIO EQUIPMENT

TOUCH LAMPS

RF Touch lamps are RF-operated devices that often cause, or are susceptible to, EMI problems. They have a free running oscillator that is very broad and rich in harmonic energy. This oscillator is hooked up to a touch plate that changes the frequency of the oscillator when a hand is placed near the plate. Unfortunately, this plate also acts as an antenna, radiating some of the energy of the oscillator, or picking up nearby radio signals. When the former happens, it can interfere with other services. When the latter happens, the circuitry inside the lamp reacts the same way that it would when the plate is touched -- the lamp changes states from "off" to "on". A box inside the lamp contains a circuit board through which AC line voltage is routed and which has a wire connected to the metal base of the lamp. When the lamp is plugged in, the signal generated by the lamp's circuitry signal is present at all times, regardless of whether the lamp is on or off. Although cases of moderate interference can sometimes be cured by using a "brute-force" type AC-line filter and/or a common-mode choke, most cases will require internal modification to the lamp.

The easiest route here is simply to get rid of these pesky things, and return them to the store, if possible.

A simple cure for those touch-controlled lamps that turn themselves on and off during nearby radio transmissions on 40 and 80 meter operation. A 1k ohm resistor in series with the signal input lead (from the lamp base) to the encapsulated circuit that operates the lamp may cured the problem for me. If this isn't sufficient, add an RF choke (100 uH, 139 mA) in series with the resistor. The choke alone may be enough to clear up the problem in some cases. If these cures don't work, it may be possible to shield the electronic switch module, but this must be done safely!

LIGHT DIMMERS

Radio Amateurs who have been cursed with RFI from solid-state light dimmers will be interested to know that at least one domestic manufacturer, Lutron, produces light dimmers that incorporate RFI suppression techniques. The Lutron NOVA series uses toroidal chokes that provide a significant level of RFI suppression, such as their model N-600, which will handle up to 600 watts of incandescent lighting.

Another brand light dimmer produces an S9+ reading at 230 kHz (an arbitrary noisy frequency). The N-600, by comparison, produced a reading of S3, a difference of about 40 dB. Admittedly, this is not zero, but installing the Lutron model should provide a reduction in RFI that is very gratifying.

NIGHT LIGHTS

Some night lights with sensor eyes can be a source of HF hash. The offending light type is a CdS photocell, an SCR (or TRIAC) and a small incandescent lamp. When the light level drops, the thing switches on and off at a rapid rate and hashes up everything in the area! The lamp light will visually feed back to the photocell. In this design, the little porthole for the photocell is removable. Take it out and cement a 3/8 inch ID x 1 inch long kraft paper tube in its place to shield the photocell from the lamp light. This should prevent the feedback oscillation. You can also look for better designs such as an electroluminescent disk which plugs in, runs all the time, draws about 12ma and shows nothing on a spectrum analyzer. They are supposed to have a minimum 10 year life and cost about $4.

AUTOMATIC LIGHTS

Similar to night lights, this is not uncommon to have a light controller (photoelectric) cause RFI due to arcing. This is usually caused by inferior workmanship or component breakdown causing a poor closure to the contacts. First thing to do is introduce yourself and explain the difficulty. Explain the causes and if left unattended may cause overheating due to the arcing. Eventually it will fail so why not put it out of it's misery and change it out? See if it's under warranty. If it is, you're home free but if isn't, feel out how he feels about changing it out. Many neighbors are willing to cooperate if given the chance.

LOW VOLTAGE LAMPS

Some really strong broad band noises have been discovered emanating from wall transformers powering various 12V consumer home interior lights. They are rated at an output of 12 volts at 60 Watts, which is a lot more current than a typically sized wall transformer usually puts out, and may be solid state, SCR-based devices. In this case, you will get no help from the FCC and very little from the manufacturer. If you are on good terms with the neighbor, you can offer to replace the device with a UL rated wall mounted transformer (that is really a transformer) if the output is ac, or a UL rated dc power supply if it is dc. Another option is to buy him a similar, but higher quality lighting system and trade with him. Pay an electrician to install it unless it will just plug in. The cost is probably less than $100 and it will certainly make your life more livable.

DIGITAL TEMPERATURE DISPLAYS

In one case, a faulty digital "Quadra-Temp" temperature readout for a solar water heating

system became a broadband RFI generator.

COMPUTERS

Computers can generate various birdies leaking from all cables. Strong broadband hash can be generated by the switching power supply. This hash is not affected by unplugging all cables from the PC. The root cause of this problem is that there is supposed to be a line filter in the PC board in the power supply, but it's usually just jumpered through with bus wire (can you say, make 'em cheaper?). You'll have to open the supply, then you'll probably see the footprint on the PC board where the filter should have been. If you have a small ferrite core, take a pair of wires from a 4-wire telephone cable, twist them together and made a bifilar winding of as many turns as you can on the ferrite core. Then install this in series with the bus wires. In one case, this reduced the noise by 30-40 dB.

Concerning RFI from PC to HF it is the need of stopping the rf flow and consequent radiation, along the interconnecting cables to outboard devices. The most practical way to do it is to keep 'em short, and placing chokes as close as it is possible to their ends where they enter the computer. To realize effective chokes in few turns it is a need to use materials whose permeability is very high, 2000 or more. Switching to a metal case is also effective.

Try installing an AC line filter on the computer cord to solve spontaneous re-boot problems. The RF can get into the AC wiring and extension cords laying on the ground.

Many of the new computers are omitting the RFI filter in the power supply that keeps the garbage from the switching mode supply from entering the AC mains. Excellent results are possible in virtually eliminating the interference by replacing the AC connector on the back of the power supply with an integrated AC connector and RFI filter such as the Corcom 6EF1. Replacement of the a.c. input connector with a filtered type is an easy one-hour job, start to finish and it will probably get rid of 95% of your problem. For the remainder you might want to play with snap-on chokes. The mounting hole for the connector must be widened a few millimeters on each side--something that can be done with a file in a minute or two. Just make sure there is enough room behind the connector position to clear the somewhat longer RFI filter. In some cases, you may need to bend a capacitor out of the way.

Some power supplies have a place on the circuit board for a filter but have eliminated the components to save some money, and have just placed jumpers in the positions where the components had been. It would be possible to make a new filter and add it to the existing location--or to add it between the circuit board and the existing connector----but the commercial Corcom filter is probably the best and easiest way to go. The commerical filter has 1.0 mH coils (bifilar rated at 6 amps in series with each side of the line. On the computer side each side of the AC line has 2800 pF to circuit ground. On the AC mains side of the filter there is a 9000 pF capacitor across the mains (not to ground). Just make sure that you use capacitors that are rated to be installed across the AC mains!

The filters are available from most US electronics suppliers for around $10 or so, but can often be found in the surplus market for $1-$2, such as the 3 amp version (3EF1, a little marginal). There is also a 3EF2 and a 6EF2 that will work and may be even easier to fit inside the power supply--their terminals come out the top/bottom rather than the end. If adding and AC mains RFI filter doesn't completely cure the problem then additional RFI suppression will be needed--but in my cases it eliminates the problem.

One example source: If you need one of these AC line filters, they are available for $5.41 ea. (part # 562-857-03/47) from Mouser Electronics.

You may also achieve reduction of video noise when powering the monitor from the accessory a.c. socket on the back of the computer p.s., instead of just a random socket in the station.

COMPUTER MONITORS

If the noise cannot be stopped, the frequency can be moved to allow operation in a certain band by changing the refresh rate of the monitor in the computer's control panel.

TELEVISIONS

First find the exact path the RFI is taking. To check the TV power cable with Radio Shack "clamp-on" cores, you must make 5 turns or so on the core to be effective. If no change disconnect the antenna cable. If RFI disappears, treat the cable with ferrite. Check anything else connected to the TV. If no change then the path is direct radiation from the TV and shielding is required. A coax cable from your receiver terminated in a small one turn wire loop can snoop (cautiously) around the TV chassis to find the source. Apply shielding to that area (cautiously and non-shorting). [ADD a 1:1 Balun at your antenna]

PACKET GEAR (TNC)

A TNC such as the MFJ 1278 generates low level broadband hash. This may be solved by strapping the TNC case to your station ground with a short piece of stranded copper wire.

If you are buying a TNC, get one with a metal case. If you have one with a plastic case, try covering it with foil or placing it inside another metal case or box and bonding the foil or box to your station ground.

AUTOMOTIVE SOURCES

FUEL PUMPS

This has become a problem in many Ford vehicles. Ford's Technical Service Bulletin, TSB-93-15-6 covers this RFI problem. They offer a fuel-pump filter that installs in the tank, right next to the in-tank fuel pump, which, if not covered by warranty, is a real pain to install, and may not work if you have a non-metallic fuel tank. The part number for the filter is F1PZ-18B925-A and may cost up to $60. A cheaper and much easier solution that some have had success with is to wind BOTH power wires going to the fuel pump around ferrite cores.

ELECTRIC FENCES

Check all the connections on the transformer to be sure they are tight. A poor or broken grounding conductor at the transformer box is a likely culprit. Check all standoff insulators for cracks, and make sure the wires are not touching anything except insulators. Inspect the

nails holding the insulators to posts or trees. Walk around the fence at night and listen and look for sparks to indicate trouble spots. Weeds and branches from bushes and trees touching the wires is also a common problem. Eliminate or refresh poor splices in lines. If the fence belongs to someone else, offer to perform the repair work yourself. Here are some more points suggested by one electric fence manufacturer:

1) Make sure the wire feeding the fence is insulated for 20K volts. Romex or other wire, not intended for this use, can arc if it gets close to anything else.
2) If there are splices in the wire, make sure the two sections are connected with a compression clamp sold for that purpose, and try to avoid mixing types of wire. Soldered and twisted connections are not recommended either.
3) Some nail-on type insulators have very, very little insulation between the nail and the wire. Replace them with good nail-in insulators made for electric fence use.
4) If there is much RF being generated, a 4,000-volt charger, for example, probably isn't delivering 200 volts to the fence. Interference always indicates something wrong that will reduce the voltage, and the efficiency, of the fence. This may help convince a fence owner to let you inspect the fence.

TRACING POWER LINE NOISE

DANGER!

THIS PORTION OF THE ARTICLE IS FOR INFORMATIONAL PURPOSES ONLY! DO NOT ATTEMPT ANY PHYSICAL CONTACT WITH POWER LINE EQUIPMENT INCLUDING POLES OR GUY WIRES TO LOCATE SOURCES OF RFI!
LEAVE THIS TO THE ELECTRIC COMPANY. IT IS THEIR RESPONSIBILITY.....NOT YOURS! ASSIST THEM ONLY WITH TRAINED POWER COMPANY PERSONNEL SUPERVISING YOU.
DO NOT ATTEMPT STATEMENTS IN RED IN THE ARTICLE!
Read this article first for valuable information pertaining to safety. Click here. THIS IS A MUST READ!

ELEVATED POWER LINES

If you can identify the exact pole that is having the problem, you can normally get things fixed pretty easily. Power companies have a legal requirement to not radiate noise so normally have special funding to fix these problems that is outside the normal maintenance accounts. The thing to remember is that most power company forms and documents list any form of power line interference as "TVI".

You will have good success using a cheap aircraft band portable. 108 to 136 MHz aircraft communications uses AM so receivers for that band have AM detectors. Line noise is much shorter range on VHF so you normally have to be much closer to a noise source to detect it. My best results was with a home-brew tunable HF am detector but the aircraft band receiver is almost as good. What you are looking for is loose hardware on the poles.

The primary noise source is usually slack bell insulators. Those bell shaped insulators you see at the ends of power line runs have metal parts which, if not electrically bonded, will arc at a 120Hz rate. Without sufficient tensioning, a thin oxide layer builds up in metal joints. They arc simply because they are in such close proximity to high voltage (usually 4, 7.5, or 12 KV!). You can spot slack bells quite easily since they usually sag under their own weight. If the line they are on was properly tensioned, they wouldn't sag. Bell insulators are

supposed to have metallic spring clips or soldered on jumper wires to prevent arcing but occasionally these things are damaged and no longer make contact. Another common source of pole top arcing is just loose hardware. Any kind of metal-to-metal contact, such as nuts, bolts, brackets, and braces, can loosen from the shrink and swell of poles with weather changes. When loose, oxide layers build up and arcing begins. Even though not directly connected to the power lines, these arcs can be so powerful that they couple into the line and propagate for miles. It is not uncommon for loose nuts and bolts on a pole top to loosen and arc so badly that the pole catches fire. Obviously, noise that goes away when the poles are wet and comes back when the poles are dry is a good candidate for loose hardware problems. It is a common task for a line maintenance crew to tighten hardware on pole tops. Transformers are rarely the source of line noise. I actually found only one noisy transformer and it was simply a loose high voltage connection to the top of the transformer. I could wiggle the guy wire on that pole a little and see the wire wobble. Noise bursts were produced as the wire wobbled.

What you do to locate a bad pole is to first narrow the search area down to a few poles. Carefully inspect the poles with binoculars for obvious loose or broken hardware. Then lightly kick suspect poles to see if the noise is changed or modulated by pole vibration. Unless the base is really stout, just turn your back to the pole and give it a mule kick.

Some louder sources could travel several miles on the lines though. If you are having trouble narrowing the search down, try another trick. Go to a convenient pole guy line and gently wiggle it to get the power lines to start swaying a little. Sometimes, loose hardware on a conductor run would show up from the line movement. One thing to watch out for, aside from the obvious danger of just being around power lines, is that you are not fooled by the noise peaks you will find near pole ground lines, guy lines, and other conductors running down poles. These things bring power line noise right down to you so might make you think you have found a source when all you have is a noise antenna.

Go out one dark night and walk along under the lines and listen by ear as well as radio and watch carefully at each pole. If there is a leak across an insulator (usually a cracked insulator) it may have a visible arcing.

Once you find a bad pole, write its address and any identifying numbers you can spot on it and turn a "TVI" report into the power company. The thing to watch though is that your report may not be written down correctly, the folks you talk to at the power company don't normally understand RF or think that anyone besides their own technician is incapable of understanding such an arcane subject. Try to get them to contact you and, preferably, allow you to be present when the work is done. If your problem report is just handed to a utility line repair foreman, he is likely to simply go to your home address and decide that he can hear the ball game on his truck radio just fine so not bother checking any further. You want to be able to give him the correct repair information so he will actually work on the real problem.

UNDERGROUND FEEDERS

Underground power feeders can also radiate EMI. A good leak detector for buried cables is a loop antenna and AM receiver tuned to somewhere below 540KHZ. Old cables often fill with water and malfunction for weeks before finally shorting to ground and blowing out the circuit. You may experience something similar. The leak detector can be good enough to get you within 5 feet of the actual problem.