Interference Primer - Parts 1 and 2 Derived from *QST* Lab Notes
(February and March 1992)

Ed Hare, W1RFI, Laboratory Supervisor, now grapples with one of the most difficult problems in Amateur Radio: electromagnetic interference, or EMI. EMI is a catch-all term for TVI, RFI, BCI and any other form of electromagnetically generated interference. Regardless of the terminology, the ultimate translation is trouble!

You may find this hard to believe, but nearly every person in the technically-developed world has experienced EMI. At the ARRL Laboratory we receive telephone calls and letters on the subject of EMI every day.

Let's start by defining the term interference. To some people, it implies action and intent. The statement, "You are interfering with my telephone," sounds like an outright accusation, doesn't it? For our purposes, let's define interference as any unwanted interaction between electronic systems--period. No fault. No blame. It's just a condition.

Each person involved in an interference problem has individual needs, a unique perspective and a varying degree of understanding of the technical and personal issues involved. On the other hand, each of them may have certain responsibilities toward the other, and should be prepared to address those responsibilities fairly.

Whenever I host an EMI technical forum at ARRL conventions or local club meetings, I always conduct an informal survey. I ask the members of the audience to raise their hands if they've ever had an interference problem. I can always count on a 30% response, and most of the elevated hands belong to individuals who have experienced some form of interference involving their ham stations. After taking a quick tally, I carefully explain that interference caused by electric motors, power lines, CATV leakage and spurious emissions from consumer devices must be included in the definition--as well as interference to the their own consumer electronics equipment from all of these sources. When I see the looks of enlightened surprise, I know it's time to repeat my survey. Before I even finish asking the question nearly every hand reaches for the sky!

So, now that I've convinced you that you may have a problem (as if you really needed convincing), let's move on to the questions and answers.

Q: My new neighbor, Sam, just knocked on my door said that my signals are tearing up his TV and telephones. He threatened to call the FCC if I didn't stop transmitting. Am I in serious trouble? What should I do?

A: Why don't we indulge in a bit of psychology first? Hams are great communicators over the airwaves, but some of us need practice when it comes to communicating face-to-face. You can't overestimate the importance of personal diplomacy when you're confronted with an EMI problem. The way you behave when your neighbor comes

knocking sets the tone for everything that follows. No matter what you think of your neighbor, you have to remember that the best solutions are built on cooperation and trust. Knowing all the technical tricks in the book won't do you a bit of good if your neighbor won't let you through the door!

Q: I don't know ... he seems pretty angry. What can I tell him?

A: It sounds like your neighbor has already branded you as the villain. He's angry and fully expects you to respond with denials and evasions. Don't do it! Begin by accepting the fact that he doesn't enjoy having his lifestyle hampered by EMI. Put yourself in his shoes. Admit that EMI is highly annoying. (Both of you can quickly agree on that point!) Calmly explain that you are responsible--by law--for the proper operation of your station. Assure him that you'll check your equipment right away and make any necessary corrections. With any luck, the situation will begin to calm down. Now is the time to explain to your neighbor that the root cause of his problem could also be from a source other than your station. Perhaps his own equipment is to blame. Before he has a chance to misunderstand the last point, tell him that you're willing to help him solve the problem--even if it's not your fault. Until the problem is resolved, try making some goodwill gestures. As a temporary measure, reduce your output power. (You may discover that you didn't need all those watts, anyway!)

If you have a beam antenna, don't point it at your neighbor's house. Above all, try to gain some perspective on the situation. Amateur Radio may be your passion, but it doesn't mean a thing to your neighbor. Attempting to justify EMI by saying "There was a rare DX station on 10 meters and I just had to work him" may just sound like ham "lingo" to him and probably won't get you very far.

A: Usually is the operative word. By helping him solve the problem, you'll be making a friend, not an enemy. What if, sometime in the future, you buy that new amplifier and start calling CQ when it's third down at the goal line with 30 seconds left in the game. If you blitz your neighbor's TV, he may be more understanding and less likely to do something rash. There are two basic things that can result in interference. Your transmitter may be emitting low-level signals outside the amateur bands. These signals, called harmonics or spurious emissions by the FCC (or spurs in common parlance), can be the direct cause of interference. FCC regulations are quite clear about spurious emissions: they must not cause interference to other services. The operator of a transmitter must take whatever steps are necessary to eliminate interference from this cause. This almost always involves additional filtering, grounding or shielding of the transmitting equipment. On the other hand, the world is filled with radio signals. Any piece of consumer electronics equipment should be able to respond only to signals it is designed to receive. The filtering and shielding in your neighbor's TV (or other equipment), however, may be inadequate to reject your strong fundamental signal. This condition is commonly called fundamental overload. Interference that results from Fundamental overload is really a no-fault situation.

Q: No-fault? That sounds like my auto-insurance policy.

A: Wow! There's a concept ... EMI insurance! With all of the EMI in the world today, can you imagine the steep premiums you'd have to pay? Instead, let's consider the following scenario:

You, as an amateur, have purchased a transmitter that meets all of the FCC requirements for proper operation. You have installed it in a well-engineered station with proper grounding and filtering. You know your station is clean because you don't interfere with your own equipment. You have done nothing wrong. The manufacturer of your neighbor's TV has designed and built the best possible product, constructed to meet hundreds of regulations set by dozens of federal regulatory agencies. The product has probably met a few voluntary standards set by independent associations as well. Within the constraints of the law, the manufacturer has done nothing wrong. Your neighbor has gone to the electronics store and has purchased a piece of equipment that has a fine reputation for quality and service. He has every right to expect his equipment to function as advertised. Clearly, your neighbor has done nothing wrong. Even so, when he turns on his set and you go on the air, you both have an interference problem. So who is at fault? It should be obvious that no single individual is to blame. Everyone has done everything correctly, but the system has failed!

Q: If the system isn't working, then we all share the blame.

A: That's right! EMI has been cited as one of the fundamental threats to the Amateur Radio service. Complex electronic circuitry is found in all sorts of devices used in the home. This results in a vast interference potential that didn't exist in earlier, simpler decades. One of our ARRL Laboratory Engineers recently noticed an advertisement for a computer-controlled ac-power outlet strip. He wryly observed that this wonderful new product would now allow him to interfere with his neighbor's extension cord! It's always important to remember our place as Amateur Radio operators in the overall scheme of things. Consider the fact that national governments extend to amateurs the privilege to operate in valuable portions of the radio spectrum. Amateurs have gained these privileges because the world benefits from our existence. In addition to the emergency communications services we provide, the world gains a reservoir of self-trained radio operators, skilled in operating practices and electronics technology. Solving your neighbor's EMI problem as well as your own is an excellent application of your technical skills.

Q: You implied that I had access to the technical resources to help my neighbor. What if I'm a new ham and I don't feel confident enough to call myself an EMI expert? How can I get some help?

A: Your ARRL Technical Coordinator (TC) is the first person to contact. The TC often has a cadre of assistants (Technical Specialists) available, and there may be one near you. If you have local clubs with EMI or TVI committees, they usually coordinate their activities through the TC. The TCs often have liaisons with local utilities such as

telephone and cable companies. Knowing the right individual to contact may prevent a repair person from pointing at your antenna and telling your neighbor, "It's all his Fault." Some people choose to call the TC only as a last resort, waiting until all diplomatic and technical solutions have failed. This is a bad idea! The TC is a volunteer and may choose not to participate in a situation that has deteriorated badly. Most of them prefer to be involved right from the start. They are often skilled (read: practiced) in the art of EMI negotiations.

Q: Okay, I'm convinced. How do I find my TC?

A: The easiest way to find your TC is to ask your ARRL Section Manager. Section Managers (SMs) are listed on the first few pages of any recent *QST* issue. Most SMs include their telephone numbers, but be considerate. Call during the day or early evening. You can also call ARRL Headquarters to ask for the name of your TC, but we do not give out their telephone numbers to protect their privacy.

Q: The TC, my neighbor and I all want to know the source of the problem. What should we do next?

A: Offer to arrange a test. Ask your neighbor to invite a friend to visit your shack during the test. In addition, ask you neighbor if it would be possible for one of your friends to monitor the test at your neighbor's home. Having impartial witnesses will make you and your neighbor more comfortable with the outcome -- whatever it may be. Be sure to choose your witness carefully. Select someone who is known for diplomacy and tactfulness. (Your TC is a great candidate for this role!) Your test must be thorough. Transmit on each band and mode you normally operate. If you have a beam antenna, aim it in different directions while you are transmitting. Try various power levels, too. Ask your friend to keep detailed notes of the results. A radio or telephone link between you and your friend is almost a necessity. Even if your test proves that your station is not at fault, don't just drop the problem in your neighbor's lap and say "Good luck!" Offer to help find a solution.

Q: My neighbor and I have agreed to stop blaming each other and work together to find a solution. But now he's accused me of causing interference during a football game that was televised last Sunday. I don't think I was even near my shack while it was on. What gives?

A: Even though it's not a legal requirement, it's a good idea to keep a detailed station log. Now that you're involved in an interference issue, it's a necessity! You should ask your neighbor to keep notes, too. Ask him to identify which piece of equipment experienced the interference, what channels or frequencies were involved, the date and time the interference occurred and a description of the interference and its severity. If you're lucky, a comparison between your log and his log may indicate that the interference isn't coming from your station. On the other hand, if your signal is the source of the problem, your neighbor is the lucky party--although he may not see it that way at first. As an Amateur Radio operator, you have access to the technical resources necessary to solve

the problem (either from your own knowledge and experience, or with the help of other hams like your Technical Coordinator or local EMI expert). This is not necessarily true if the source of the problem is a business-band or citizens-band transmitter, for examples.

Q: My neighbor's problem isn't limited to TVs. What about his telephones and other audio devices?

A: In almost all cases, interference to an audio device is caused by detection of your fundamental signal, just like a crystal-detector radio receiver. Your detected signal gets amplified along with the desired voice or music signal. This is clearly not the fault of the transmitting station. Up until recently, The FCC Interference Handbook was a good reference to have on hand when working on an interference problem, especially when discussing the situation with non-technical types. As the FCC has been converting web-based information, that book is no longer available.

You may also want to check out our page titled *What to Do if You Have an Electronic Interference Problem*, which can be found at: www.arrl.org/information-for-the-neighbors-of-hams

Q: Can I get any help from the consumer-equipment manufacturer?

A: The manufacturers also shoulder some responsibility for EMI problems. Public Law 97-259, enacted in 1982, gave the FCC the authority to regulate the susceptibility of consumer electronic equipment sold in the United States. The FCC, working with equipment manufacturers, decided to allow them to develop standards for EMI immunity and implement their own voluntary compliance programs. No system is perfect, especially a voluntary system, but the ARRL Laboratory staff has noted that EMI involving TVs, for example, seems to be decreasing. The manufacturers are making some real progress and we feel confident that they will continue to do so. One prominent manufacturer program is a contact data base that's maintained by the Electronic Industries Association (EIA). When you have an interference problem with a piece of consumer electronic equipment, contact the EIA to determine who you should get in touch with for assistance. The EIA also keeps a record of each report. (The EIA prefers that you write rather than call. The details a problem can often be communicated more clearly in written correspondence.)

Note: The Electronics Industries Association (EIA) was renamed Electronics Industries Alliance (EIA) in 1997. The Electronics Industries Alliance (EIA) ceased operations on February 28, 2011. At this time, the consumer sector of the EIA then became the Consumer Electronics Association (CEA).

You may be surprised to know that the number of reported cases of interference to consumer electronic equipment in recent years has been very small. This is our fault! Amateurs are notorious for not reporting EMI problems. Contact the EIA! Working with manufacturers makes them aware of the need to continue to develop better shielding and filtering methods. It also demonstrates to your neighbor that the manufacturer should receive a little of his anger and frustration too!

Q: In spite of my efforts, and the diplomatic skills of the Technical Coordinator, my neighbor must have called the FCC; I just got a letter from the FCC. What now?

A: Well, you could sell all of your equipment, cancel your license and take up basket weaving ... or you could sit down and answer the notice! The FCC's response to consumer-interference complaints varies slightly for each case, but similar steps are used to resolve all interference cases. You already have the first step in hand. Your letter from the FCC is stating that you and your neighbor are involved in a mutual problem. I hope both of you will get the message the FCC is trying to deliver--that it's in your best interests for you to find a solution that's acceptable to everyone. Years of experience in interference resolution has taught the FCC that imposed solutions are not the best solutions for local problems. You and your neighbor will be happier if you're able to find a solution and an understanding on your own. Your TC, acting as a third party, may be able to help you with the technical and interpersonal aspects of the problem. The first order of business is to answer the FCC letter as accurately as you can. If you've offered to cooperate with your neighbor and were turned away, say so. If your TC has been helping you solve the problem, explain what the TC has done and what conclusions have been reached. The FCC is interested in hearing that your station is grounded (keep in mind, however, that a station ground is not a cure-all for EMI!), properly filtered and that your station is well-designed. Tell the FCC whatever you think is important to the proper resolution of the case. Try to minimize emotional comments, extraneous data and fluff. If the FCC is satisfied with the answer, or if you and your neighbor find a solution, the case is closed. If not, the next steps are a bit more drastic. The FCC may inspect your station. In extreme cases, quiet hours may be imposed, limiting the times of day you are allowed to operate. The mere thought of quiet hours should give you plenty of incentive to cooperate fully with the FCC!

Q: Well, I've found some local helpers and they're really making progress. I'd like to know more about EMI. (I might want to offer assistance to another unfortunate ham someday.) Where can I learn more about EMI?

A: Reading this is a good start. We can't teach everything about EMI in a few pages, but we'll provide some important highlights. Several good books on the subject are readily available. Information on ordering these books is found in Appendix I at the end of this text. The best one is the ARRL book, *The ARRL RFI Book*. It was written by a number of authors ranging from ARRL Technical Coordinators to EMC (electromagnetic compatibility) engineers. The book covers EMI fundamentals and troubleshooting as they apply to transmitters, receivers, TVs (VCR and CATV), telephones, computers, audio devices and automobiles.

The *AC Power Interference Handbook* by Marv Loftness, KB7KK is also an excellent volume to add to your collection. Loftness is an EMC engineer with many years of experience in the power industry. It should be no surprise that his book is considered by many to be bible in the area of power-line interference locating.

For a more detailed description of these two books, see any ARRL catalog. Folks on the world wide web can find (or order) these books at: www.arrl.org/shop/What-s-New/

Over the years, most Amateur Radio magazines have published articles about EMI. These articles, including some classics from the 1950s and 1960s, are informative reading.

Photocopies of articles in League publication articles are available from the Technical Department Secretary. Contact ARRL Headquarters for information about these League services. American Radio Relay League, Administrative Headquarters, 225 Main St., Newington CT 06111 Tel: (860) 594-0200, email: reprints@arrl.org, Web: http://www.arrl.org/

End of Part 1 - Begin Part 2

In Part 1, we discussed electromagnetic interference (EMI) from a legal, diplomatic and psychological point of view. Now it's time to talk about specific solutions. Aided by the knowledge of many people who have assisted him over the years, Ed Hare, W1RFI, Laboratory Supervisor, will explore the fundamentals of electromagnetic compatibility (EMC) and offer some tips to exorcise those stubborn electro-magnetic gremlins!

It's impossible to discuss all the technical aspects of interference in two pages. Instead, we'll concentrate on some EMC basics. Like anything else in life, once you understand the basics, the rest follows easily. As I mentioned part 1, there are entire books devoted to EMC and EMI and I strongly recommend that you read them.

There are a few things to cover before we can get to specific cures. Several factors are present in any interference situation: a source of electromagnetic energy, an affected piece of equipment and a path from the interfering signal source to the affected equipment. A clear understanding of these factors is important to your overall grasp of the problem. Any EMI cure that is effected is going to involve a change made to the source, the path and the affected equipment.

Q: Well ... I'm the source, right? I mean, isn't my station always the source of interference?

A: Not necessarily! Remember: your station is only one of many possible interference sources. What about broadcast stations, taxicabs and police and fire services? What about cable TV leakage, unlicensed Part 15 devices (baby monitors, computers and so on)? Add power lines and electric motors to the list as well. They're all potential interference sources. Your neighbor's TV can even interfere with you!

Q: Aha! So that's what I've been hearing every 15 kHz on 80 meters! I'm still a little fuzzy on the path concept. Can you explain?

A: Interference can propagate via several possible paths. The easiest path to understand is the direct path. In this case, the interfering signal is transmitted by your antenna (or possibly by your feed line or ground leads) and travels directly to the hapless TV, VCR or whatever. Interference via this path is particularly difficult to control. Conducted interference travels from the source to the victim by wires. For example, a vacuum-cleaner motor may introduce RF noise into the ac-power system of your home--which conducts the noise directly into your amateur receiver! In most instances, however, you'll be dealing with a signal that's been induced into the external (or internal) wiring of the victimized equipment. Its wiring acts as an antenna, funneling the radiated signal to the location where it can generate the most misery. Technically speaking, all interference begins and ends as a conducted signal--no matter what happens in between. Understanding the subtle differences in signal paths is important, however. A successful diagnosis depends on determining how the EMI gains entry to the device. Armed with this vital knowledge, you're ready to start troubleshooting.

Q: Good! Where do I begin?

A: We touched on this point in Part 1, but I'll repeat it because it's the first rule of EMI control: Make sure your own house is EMI-free! Cure your own EMI (if any) first. If you're not experiencing interference on your own equipment, it will go a long way toward convincing your neighbor, and the FCC, that you're not the cause of the interference. Let's start in your shack. You need to be sure that your station is not a source of out-of-band spurious emissions--particularly of the VHF variety. The easiest way to reduce VHF spurs is to use a low-pass filter. It should be installed after the linear amplifier and any accessory equipment (SWR meter, TR switch and so on). A 50-ohm filter works best in a 50-ohm system, so you'll have to install it before the antenna tuner, if you have one. While grounding is not a cure-all for transmitter EMI, you must consider your ground system. If the FCC gets involved (let's hope not!), they'll want to know that your station is properly grounded. Improved grounding may provide a measure of EMI control since it effectively rearranges the RF voltage and current distribution, moving hot spots away from potential problem areas. Another important troubleshooting step is to make sure that your station is well engineered. Poorly soldered connectors, corrosion, a rat's nest of wiring or an overdriven amplifier can all contribute to or cause EMI. Neatness counts when it comes to diplomacy, by the way. If your neighbor has a chance to visit your station, its neatness will boost your credibility.

Q: I've tested my station from top to bottom and everything looks fine. When I checked around the house, I still found interference to my VCR, video-game machine, stereo TV and video intrusion monitor. All of these devices are connected to each other by an 8-way splitter! Where do I go from here?

A: I can hardly imagine a worse case! (I say "hardly" because we get some real strange telephone calls and letter here in the ARRL Lab!) Now is the time to state the second rule of EMI control: Simplify the problem! Connect the incoming CATV cable (or antenna feed line) to only one TV (assuming you have more than one). For the time being, completely disconnect the VCR and other video goodies. The result will uncover an

important clue. One troubleshooting technique is to try an EMI cure and see what happens. This brings us to the third rule of EMI control (and all other troubleshooting, for that matter): Always try the easy things first! This rule applies to the susceptible equipment and the suspected EMI source. Begin by installing the appropriate filter on your TV. For an antenna-connected TV this is a high-pass filter. (For a CATV-connected TV, a common-mode choke should be tried first.)

Q: Nope! It didn't work. What now?

A: Hmm... we may be dealing with a very susceptible TV. If the TV is of recent manufacture, however, that is less likely. In a two-wire system (such as a coaxial cable) there are two modes of propagation for conducted EMI: differential mode and common mode. In the differential mode, the signal travels down the center conductor and uses the shield (or other conductor) as its return path. In the common mode, all wires in the system act as one wire, with earth ground (usually through the ac wiring) forming the return. The resulting circuit is just like an end-fed antenna worked against earth ground. An in-line coaxial high-pass filter can be quite effective against differential-mode EMI signals, but ineffective when common-mode propagation is present. The high-pass filter blocks signals on the center conductor, but passes everything on the shield! This is a serious weakness because induced signals on antenna feed lines or CATV cables are predominantly common-mode in nature. Most of the high-pass filters that are commercially available are differential-mode filters. Unfortunately, common-mode signals are the ones most "commonly" seen. So let's try a different tactic. Leave the differential-mode high-pass filter and the ac-line filter in place. Now add a common-mode choke to the antenna feed line (or CATV cable) and the ac line. This places a high impedance in series with the incoming common- mode signal and the earth ground return. The EMI/RFI Resources Directory (at the end of this text) lists sources for common-mode chokes. Or, you can make a common-mode choke by wrapping 10 to 20 turns of the antenna feed line or CATV cable through a ferrite toroid. Follow the same procedure with the ac line. Use #75 (also known as "J"), #73 or #77 material if the interference is mainly from signals below 10 MHz. Use #43 ferrite material for the higher bands or low VHF. The mis-application of ferrites has led to a mis-conception that ferrites don't work for EMI control, so always use material of known characteristics. The permeability or frequency range of junk box ferrites may be unsuitable. The appendix lists several sources of ferrite material. The *ARRL Handbook for Radio Amateurs* also contains a complete reference list of component suppliers, among which are ferrite suppliers. (More information on this book is available in the ARRL catalog. For folks on the web, this is at www.arrl.org/shop/What-s-New/). If adding a choke doesn't eliminate the interference, you either have a spurious emission from your station (time to install that low-pass filter!), or the
TV circuitry is picking up the offending signal directly. If the latter is the case, refer to last month's column and contact the EIA to obtain assistance from the TV manufacturer.

Q: I installed the chokes and the TV looks much better! What about the other devices?

A: If you've cured the EMI at the TV, start hooking up the other devices one by one, eliminating any additional EMI as it appears. If you're lucky, you'll eliminate all of the

problems. If not, at least you can point to one particular piece of equipment and say, "That's the culprit!" As you put the system back together, do not create a tangle of wires and cables. All cables should be connected properly, routed neatly and no longer than necessary. An 8-foot piece of cable picks up a lot more RF energy than a 1-foot piece!

Q: Your suggestion made a big difference! Even so, I still see a trace of interference. What gives?

A: EMI control is a complex business. The tiny bit of interference could mean a lot of things. You may need a bit more attenuation of the common-mode or differential-mode signal. In some cases, an additional high-pass filter or common-mode choke may help. If you add more filters, experiment with their placement if possible. Sometimes a second filter works best when it's positioned a few feet away from the first one. You may also be dealing with interference that results from more than one cause.

Q: Well, my family is finally satisfied with the TV, but we still can't use the telephones. What can I do?

A: There is hope. Several companies manufacture telephone EMI/RFI filters and most work quite well. Some of these manufacturers are QST advertisers. Remember the three rules of EMI control and follow them religiously as you install the filters. A few companies also make interference-resistant telephones. Many of these companies are listed in the appendix. Carefully inspect the telephone system. Corroded wiring (common in damp basements) or a defective lightning protector (common in areas where the protector has done its job!) can rectify the RF signal. Unlike your TV problem, the resulting audio interference cannot be filtered out. Rectification can also occur in telephones and other devices connected to the system. Before you begin connecting filters, disconnect all telephones and accessories except one. Remember to use the systematic divide-and-conquer approach, beginning with one device and working forward. Take a careful look at the wiring while you're investigating the problem. Sometimes the twisted pair has been spliced with nonstandard wiring, such as zip cord. This type of jury-rigging is more prone to interference pickup. If you discover a problem with the lightning protector or outside wiring, leave those items for the telephone company to fix or replace. The responsibility for inside wiring may vary from one area to another. Check with your phone company for guidance. For more information on telephone interference, read the October 1992 QST "Lab Notes" column on Telephone Interference. An electronic copy of this information is available at http://p1k.arrl.org/pubs_archive/88327.

Q: Everything is fine now. I think I'll buy a bunch of filters and head on over to my neighbor's house!

A: Whoa! What kind of arrangement are you going to work out with your neighbor? What if there are other neighbors in the area experiencing similar problems? You may be setting yourself up to spend a lot of money on filters! Other than problems that originate from your station, you should consider yourself as an advisor, not a service technician or parts supplier! You may be walking into murky legal waters, too. Some states require you

to hold a repair license to perform even the simplest services--free or otherwise. Consider the future consequences of your actions as well. I recently heard of a well-meaning amateur who installed a high-pass filter on his neighbor's TV. When the picture tube on the old clunker suddenly went bad, the neighbor claimed that the filter caused the failure! This doesn't mean you should never offer a helping hand, but it does mean that you should look before you leap. You are the best judge of your neighborhood situation. Only you can decide what kind of assistance and diplomacy is appropriate.

Q: Thanks for the warning. By the way, I've found that EMI also makes my stereo act up. Do you have a magic cure for that too?

A: We're almost out of room, so I'll give you a short answer. Many problems with stereos can be traced to common-mode propagation on long speaker leads and interconnecting cables. You can often effect a cure by keeping wire lengths to a minimum. If you can't shorten the wires, use common-mode chokes. Low-value bypass capacitors can be used on input leads (try 100-500 pF), but do not use capacitors on speaker leads unless you check with the stereo manufacturer first. Adding capacitors to speaker wiring can cause some amplifiers to launch into an ultrasonic, full-power oscillation--often resulting in permanent damage. If you think you had a problem before you destroyed the family stereo, wait until you see what happens after you do! If you have any questions about ARRL EMI/EMC policies, or need help solving an EMI problem, contact the RFI Desk at ARRL Headquarters, 225 Main St., Newington, CT 06111 (860) 594-0200, Internet: rfi@arrl.org