# Lab Notes

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and the ARRL Laboratory staff.

# Interference Primer—*Part 2*

Last month 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, KA1CV, Senior Laboratory Engineer, will explore the fundamentals of EMI and offer some tips to exorcise those stubborn electromagnetic gremlins! —*WB8IMY*

I take the liberty of assuming that you've read Part 1 of our *Interference Primer*. For those who may have missed it, a copy of last month's column is available. Just send an SASE to the ARRL Technical Department Secretary. Ask for the February 1992 *QST* Lab Notes column, "Interference Primer—*Part 1*."

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

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 or 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. Even your neighbor's TV can interfere with *your* equipment!

***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. Take a look at Fig 1.

The easiest path to understand is the *radiated* path. In this case, the interfering signal is radiated 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.

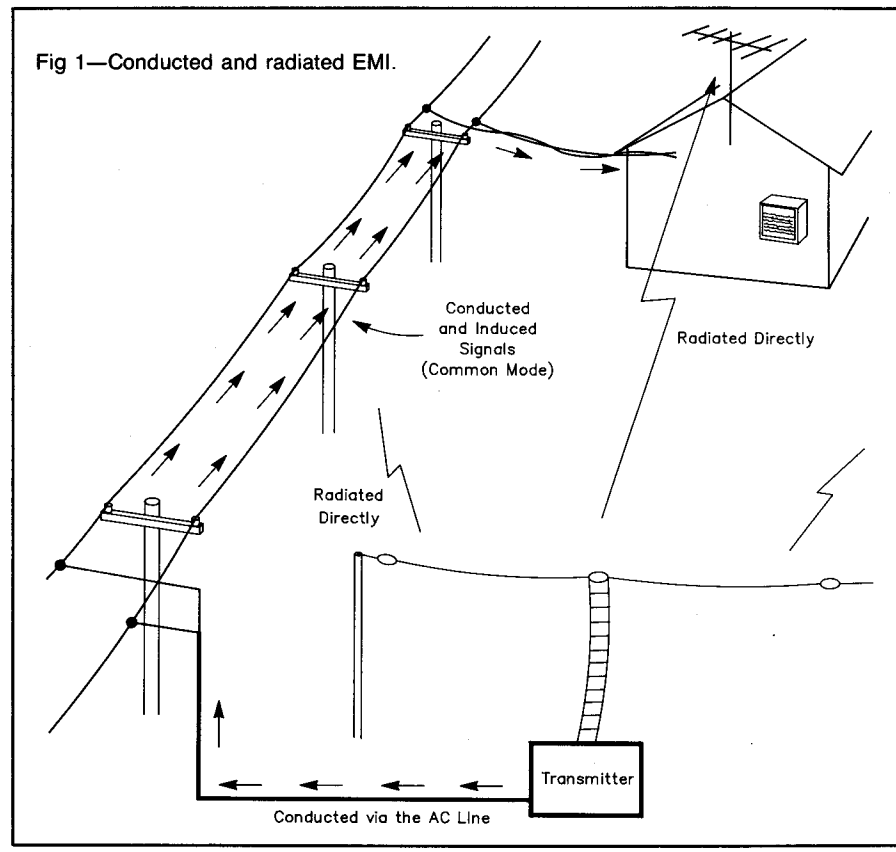


Fig 1—Conducted and radiated EMI.

*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 last month, 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

[1]Notes appear on page 83.

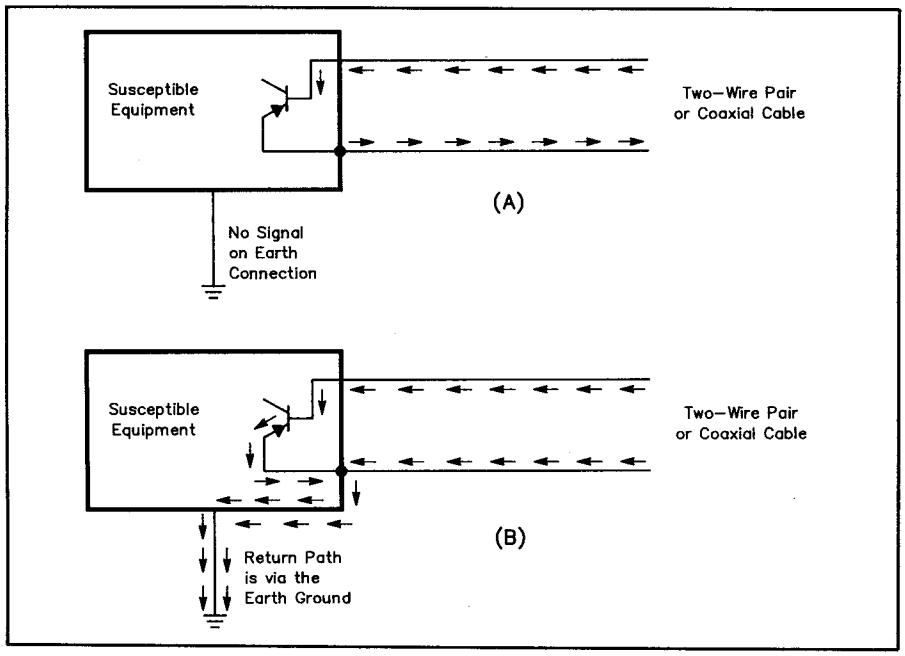


Fig 2—(A) Differential-mode signals are conducted between two wires of a pair. The signals are independent of earth ground. (B) Common-mode signals are in phase on all wires that form the conductor (this includes coaxial cable). All wires act as if they are one wire. The ground connection forms the return path, as with a long-wire antenna.

rearranges the 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 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 inspected 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! 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 a high-pass filter and an ac-line filter at your TV.

***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 isn't 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 (see Fig 2).

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 working 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. Unfortunately, common-mode signals are, well, the ones most commonly seen. Most of the high-pass filters that are commercially available are differential-mode filters.

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.

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 ferrite material if the interference is mainly from signals below 10 MHz. Use #43 ferrite material for the higher bands or low VHF. (The misapplication of ferrites has led to a misconception that ferrites don't work for EMI control.) Always use material of *known* characteristics. The permeability or frequency range of junk box ferrites may be unsuitable. Chapter 35 of the *ARRL Handbook* contains a complete reference list of component suppliers, among which are ferrite suppliers.

If this 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's 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. As you do so, avoid creating 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! 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!"

***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 trace 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.[2]

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.

***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!

### Next Month

In the April issue we'll begin the first of our occasional "How to Locate..." columns. In the first installment, Jon Bloom, KE3Z, our ARRL Laboratory Supervisor, will tell you how to find the Amateur Radio software you've been searching for all these years. Well, most of it anyway!

### Notes

[1]*Radio Frequency Interference: How to Find It and Fix It* is an excellent guide to solving EMI. It is available from your local dealer or direct from ARRL HQ. See the ARRL Publications Catalog elsewhere in this issue for ordering information.

[2]For more information on telephone interference, read "Basic Steps Toward Eliminating Telephone RFI" by Pete Krieger, WA8KZH, *QST*, May 1991, pp 22-25.

We welcome your suggestions for topics to be discussed in *Lab Notes*, but we are not able to answer individual questions. Please send your comments or suggestions to: Lab Notes, ARRL, 225 Main St, Newington, CT 06111. QST

# W1AW Schedule

**October 27, 1991-April 5, 1992** **MTWThFSSn = Days of Week** **Dy = Daily**

**W1AW code practice and bulletin transmissions are sent on the following schedule:**

| | | |
|---|---|---|
| UTC | Slow Code Practice | MWF: 0300, 1400; TThS: 0000; Sn: 0300 |
| | Fast Code Practice | MWF: 0000, 2100; TTh: 0300, 1400; S: 0300; Sn: 0000 |
| | CW Bulletins | Dy: 0100, 0400, 2200; M-F: 1500 |
| | Teleprinter Bulletins | Dy: 0200, 0500, 2300; M-F: 1600 |
| | Voice Bulletins | Dy: 0245, 0545 |
| EST | Slow Code Practice | MWF: 9 AM, 7 PM; TThSSn: 4 PM, 10 PM |
| | Fast Code Practice | MWF: 4 PM, 10 PM; TTh: 9 AM; TThSSn: 7 PM |
| | CW Bulletins | Dy: 5 PM, 8 PM, 11 PM; M-F: 10 AM |
| | Teleprinter Bulletins | Dy: 6 PM, 9 PM, 12 AM; M-F: 11 AM |
| | Voice Bulletins | Dy: 9:45 PM, 12:45 AM |
| CST | Slow Code Practice | MWF: 8 AM, 6 PM; TThSSn: 3 PM, 9 PM |
| | Fast Code Practice | MWF: 3 PM, 9 PM; TTh: 8 AM; TThSSn: 6 PM |
| | CW Bulletins | Dy: 4 PM, 7 PM, 10 PM; M-F: 9 AM |
| | Teleprinter Bulletins | Dy: 5 PM, 8 PM, 11 PM; M-F: 10 AM |
| | Voice Bulletins | Dy: 8:45 PM, 11:45 PM |
| MST | Slow Code Practice | MWF: 7 AM, 5 PM; TThSSn: 2 PM, 8 PM |
| | Fast Code Practice | MWF: 2 PM, 8 PM; TTh: 7 AM; TThSSn: 5 PM |
| | CW Bulletins | Dy: 3 PM, 6 PM, 9 PM; M-F: 8 AM |
| | Teleprinter Bulletins | Dy: 4 PM, 7 PM, 10 PM; M-F: 9 AM |
| | Voice Bulletins | Dy: 7:45 PM, 10:45 PM |
| PST | Slow Code Practice | MWF: 6 AM, 4 PM; TThSSn: 1 PM, 7 PM |
| | Fast Code Practice | MWF: 1 PM, 7 PM; TTh: 6 AM; TThSSn: 4 PM |
| | CW Bulletins | Dy: 2 PM, 5 PM, 8 PM; M-F: 7 AM |
| | Teleprinter Bulletins | Dy: 3 PM, 6 PM, 9 PM; M-F: 8 AM |
| | Voice Bulletins | Dy: 6:45 PM, 9:45 PM |

Code practice, Qualifying Run and CW bulletin frequencies: 1.818, 3.5815, 7.0475, 14.0475, 18.0975, 21.0675, 28.0675, 147.555 MHz.

Teleprinter bulletin frequencies: 3.625, 7.095, 14.095, 18.1025, 21.095, 28.095, 147.555 MHz.
Voice bulletin frequencies: 3.99, 7.29, 14.29, 18.160, 21.39, 28.59, 147.555 MHz.

Slow code practice is at 5, 7½, 10, 13 and 15 WPM.
Fast code practice is at 35, 30, 25, 20, 15, 13 and 10 WPM.

CW bulletins are sent a 18 WPM.

Code practice texts are from *QST*, and the source of each practice is given at the beginning of each practice and at the beginning of alternate speeds. For example, "Text is from February 1991 *QST*, pages 9 and 81" indicates that the main text is from the article on page 9 and the mixed number/letter groups at the end of each speed are from page 81.

On Fridays, UTC, a DX bulletin replaces the regular bulletin transmissions.

On Tuesdays and Saturdays at 2330 UTC, Keplerian Elements for active amateur satellites will be sent on the regular teleprinter frequencies.

Teleprinter bulletins are 45.45-baud Baudot, 100-baud AMTOR, FEC mode and 110-baud ASCII.

W1AW is open for visitors Monday through Friday from 11 AM to 11 PM EST and on Saturday and Sunday from 4:30 PM to 11 PM EST.

**If you desire to operate W1AW, be sure to bring a copy of your license with you. W1AW is available for operation by visitors between 1 and 4 PM Monday through Friday.**

**In a communications emergency, monitor W1AW for special bulletins as follows: voice on the hour, teleprinter at 15 minutes past the hour, and CW on the half hour.**

**W1AW will be closed on February 17, April 17 and May 25.**