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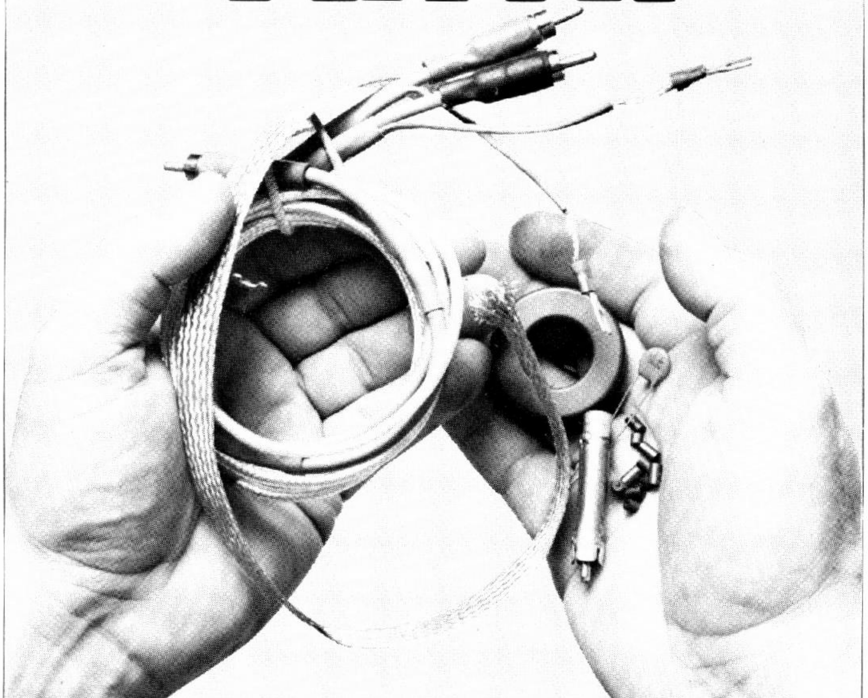
R.F.I.



For now, the solution to radio-frequency interference in your audio system lies (largely) in your own hands

By John McVeigh

Over one hundred thousand people complained to the Federal Communications Commission last year about radio-frequency interference coming through their stereo systems, church public-address systems, intercoms, TV's, electric organs, juke boxes, tape recorders, hearing aids, and only the FCC knows what else. This is a dramatic increase over the figures for such interference recorded the last time Stereo Review *surveyed the problem for its readers (November 1972), and the reason for it is clear: the tremendous growth in the use of citizens band (CB) radio equipment over the past few years.*

For those afflicted with this far-from-laughable electronic disorder, the big questions are two: What (who) causes it, and how can I stop it? Radio-frequency interference occurs when, for one reason or another, two electronic devices cannot function compatibly in the same environment. One or both will be adversely affected by electromagnetic radiation from the other. Power tools, fluorescent lights, thermostats, light dimmers, automotive ignition systems, radar, television, and radio transmitters (among many other things) all radiate electromagnetic energy. Television receivers, FM tuners, musical-instrument amplifiers, P.A. systems, tape decks, and audio preamps and amplifiers can all be influenced by this radiated energy, but our concern will be the RFI problems associated with audio systems.

A typical RFI incident starts in one of two ways. First, someone in your neighborhood is bitten by the "radio bug," gets a CB or ham license and some equipment, puts up an impressive-looking antenna, and starts transmitting. As luck has it, you immediately experience interference in your audio system, with the radio operator's voice being heard on top of whatever program source (tape, disc, or tuner) you are listening to—or perhaps only through your phono or tape inputs. Another RFI incident might start like this: you've lived down the block from a ham or CB'er for several years, and never had any interference problems. But now, after updating your component system with a new preamp, you're experiencing severe RFI. In either case, your natural reaction is annoyance or anger toward the ham or CB'er who is responsible for the interference. But *is* he responsible? Granted that it is his broadcast—it is also your equipment that is receiving it. Who should take steps to eliminate the interference?

The source of the interference might just as well be not a radio ham or a CB'er but a commercial AM, FM, or TV broadcaster. It might even be some doctor's diathermy machine. But the majority of cases reported to the FCC involve local radio amateurs or citizens-band operators and, because of the sheer numbers involved, odds are that you are more likely to experience RFI from one of them. The remedies that will be described here, however, are applicable to *any* RFI problem—TV "sync buzz" interference from commercial broadcasters and all the irritatingly noisy rest.

Amateurs and CB'ers usually broadcast signals that are *amplitude* modulated. As with conventional AM radios, this means that the operator's voice varies the strength of the radio-frequency *carrier* signal. To recover the original information (the voice) a *detection process* is necessary. This means converting the modulated radio-frequency signal back into an audio signal. But the signal transmitted by the radio station—any radio station—is composed *solely* of radio-frequency energy well beyond the highest frequencies to which *any* audio component is designed to respond. Even a "wide-band" power amplifier's frequency response extends only to 100 or 200 kHz at most. In contrast, the *lowest* frequencies allocated for amateur radio use (1,800 to 2,000 kHz) are far above the upper limits of the amplifier's frequency response. And CB frequencies at 27,000 kHz (27 MHz) are even further beyond the audio band.

Given ideal circumstances, therefore, radio-frequency and audio-frequency (roughly 20 to 20,000 Hz) equipment should be able to operate side by side without interference. But obviously these circumstances don't exist and there *is* a serious RFI problem in this country. What goes wrong is that the audio system for some reason detects the r.f. signal (which is far outside its bandwith) and converts its amplitude modulations into an audio signal just as an ordinary AM radio would. There are several points in an audio system at which such detection of an r.f. signal can take place, and once the r.f. signal has been detected (turned into audio), it is then amplified by all stages and components following its detection point and is finally heard at the speakers.

BUT audio components are not *supposed* to respond to r.f. signals. Why, then, do they do it? One reason lies in economics. In the fiercely competitive market of consumer electronics, most manufacturers try to offer their products at the lowest possible prices. This means that they will include (at least at the lower-cost end of a product line) as little "extraneous" material as possible. But what is extraneous, and what is essential? Many manufacturers define extraneous to mean anything that is not necessary to the meeting of published specifications or to operation in a "normal" environment. Those special circuits, shieldings, and extra parts that might allow an audio component to function in the presence of strong r.f. fields are deemed extraneous in most designs, and in most installations they probably are. If only, say, 5 per cent of all the audio components sold end up in locations where RFI is a problem, then why should 95 per cent of the buyers pay extra for shielding and filtering they do not need? Further, many engineers involved with the problem consider each RFI situation to be more or less unique in terms of the severity of the interference, the frequency and strength of the r.f. source, the characteristics of the audio equipment picking it up, and which specific "cures" may be required.

The majority of RFI cases now involve CB'ers rather than hams. Although hams generally use more powerful transmitters and thus generate stronger r.f. fields, they are fewer and further between. Simply because of their larger numbers, CB'ers are more likely to be causing RFI in audio components than radio amateurs are. Also, not every CB'er observes the 4-watt power limitation, and the use of illegal, high-power equipment can certainly enhance the probability of RFI.

Both radio amateurs and CB'ers are supposed to obey FCC regulations dealing with the purity of the signals they radiate, their power output, and other matters. Although different rules are applicable to each type of transmission, they essentially hold the *operator* responsible for insuring that spurious signals that could cause interference to *radio receivers* of other services are suppressed. An example of these spurious signals are harmonics that appear at multiples of the operating frequency. These harmonics can cause TV and FM interference, but they are usually too weak to pose a problem to audio components. Rather, it is the strong r.f. signal at the operating frequency, whether or not harmonics are radiated, that gets into audio systems. When a ham or CB operator is radiating a legal signal under the authority of a license issued to him by the FCC, his activities are not only protected by federal law; they are encouraged as well. Such operations are deemed to be "in the public interest" for a variety of reasons. However, it can also be said that the audiophile has a right (he has no specified "legal" right) to use *his* equipment unhindered in the privacy of his own home.

Shown in the facing-page photo are Verion cables, copper braid for cable shielding or grounding, an in-line low-pass input filter, capacitors, and ferrite forms.

The Federal government has (so far) adopted the position that the only available solution to this conflict of interests is to apply the remedies—such as are available—at the audio-equipment end. It therefore becomes the procedural and financial responsibility of the audiophile—not the ham or CB'er—to take the necessary steps to eliminate the interference. Fair or unfair, that *is* the current legal situation.

However, if the radio transmitter is being operated *illegally*, you can and should report the matter to the nearest field office of the FCC. Although the Commission does not have a large field staff, it will usually investigate a situation if several complaints are received. And if a CB'er is not licensed, does not identify himself with call letters (nicknames or "handles" do *not* count), talks continuously with another station for more than five minutes, uses obscene language or (worse) an illegal amount of power, the Commission can force him off the air, impose fines, and/or even imprison him. And you should note that this station is being forced off the air not because you experience RFI from its transmissions, but because it violates FCC operating rules!

With that station off the air, your RFI problems may cease—at least until the next one in your vicinity goes on the air. But if that operator obeys FCC regulations, RFI will plague you until *you* take steps to eliminate it in your audio installation.

Anti-RFI Procedures

The first step toward solving an RFI problem is to contact the manufacturer of your equipment for whatever advice he has to offer. Sometimes he will provide a few small parts that can easily be added to the components involved. If you have several different brands of components in your installation, write to *each* of the manufacturers. Note that under present law a manufacturer is not *compelled* to help you. The fact that his equipment is RFI-sensitive does not mean that there is any obligation or liability on his part. Of course, most manufacturers will do whatever they can to alleviate the problem short of redesigning the unit completely (that may ultimately be what is required). The radio operator is under no compulsion to help you either, but in the interest of good relations he may cooperate. Radio amateurs, who must pass electronics theory tests to receive their licenses, are often very helpful. CB'ers, however, need not be technically proficient to be licensed, and most probably wouldn't know where to start helping if they wanted to.

It goes without saying that you should approach a radio operator—assuming you can physically locate him—in a courteous and reasonable way (remember that he probably has the law on his side). Having been involved personally (on both sides) in a few RFI incidents, I can assure you that a bit of courtesy and tact can go a long way toward resolving any of these problems. Explain to the ham or CB'er the nature of the interference, the times you have noted it, and what kind of equipment you have. Unless the transmissions are blatantly illegal, *don't* call up or write to the FCC demanding immediate action—you simply won't get it. What you will get is a copy of "FO Bulletin No. 25," which states, in part, ". . . the Commission cannot give any protection to audio devices which respond to signals from a nearby radio transmitter. The problem is not caused by the improper operation or by technical deficiencies of the radio transmitter. . . . The only 'cure' is by treatment of the audio device. You should therefore contact a qualified technician, the dealer, or the manufacturer of your audio device . . . for assistance."

But don't despair! In many cases, RFI can be suppressed without expending large amounts of money or time. A qualified technician's services will sometimes be required, but often one or more simple external remedies can be applied without even getting inside your equipment, and no special tools or electronic technical experience are required.

The basic goal of RFI suppression in audio equipment is to prevent the radio-frequency signal from reaching that point in your equipment's circuits where it is converted (detected or demodulated) into an audio signal. There are three general ways of achieving this result: grounding, shielding, and filtering. In mild cases of RFI, only one of the three might be needed. More severe interference can require the combination of two or three methods. *Grounding* involves bringing the chassis of all components to an *earth* ground. This makes the metal chassis electrically "dead," preventing radio fields from passing through them. However, grounding must be done in exactly the right way or intolerable hum-producing "ground loops" will be generated (more on this later).

Shielding means protecting vulnerable circuitry by surrounding it with a grounded layer of metal, be it in sheet, screen, or braided form. The shield (if properly installed) prevents any signal from passing through it. When the shield prevents r.f. from reaching the sensitive circuits, signal detection—and RFI—can't take place.

The third method of suppressing RFI is *filtering*. It is accomplished by installing one or more devices at critical points in the audio system's signal path either to block the passage of r.f. or to shunt it to ground. The filter components most commonly used are capacitors, resistors, and inductors in the form of r.f. chokes (turns of wire wrapped on a cylindrical form), ferrite beads (small cylinders which are strung over wires like jewelry beads), and ferrite toroids or "rings." Each has specific advantages and disadvantages for use at a particular point in the audio system. Basically, the goal of filtering is to prevent r.f. from reaching critical stages in an amplifier without otherwise affecting the amplifier's performance.

Before any (or, if necessary, all) of these remedies are applied, you must first determine at what point(s) the r.f. signal is entering the system. The task can be made easier if the radio operator will cooperate by providing you with a series of test transmissions.

Let's assume that you have an audio system set up as in Figure 1 on the following page—a turntable, a tape deck, an FM tuner, a pre-amplifier, a power amplifier, and two speakers. (RFI-hunting procedures will generally be the same for systems using receivers or integrated amplifiers, but simpler because there are fewer component interconnections.) When the radio operator is transmitting, turn the preamp's selector switch to each position (phono, tape, tuner, etc.) and note when the RFI is experienced. You might get RFI in all modes or in just one or two. Typically, the phono input will yield the most intense r.f. interference because its active circuitry has the most gain (amplification).

It would be wise to pause right here and point out that the entire RFI-hunting procedure is illustrated in the large chart, Figure 2, on the previous two pages. This is not exactly the easiest procedure in the world to follow (no trouble-shooting system is), so in the interests of clarity and at the risk of redundancy I will be taking you through the chart by hand, so to speak, using slightly different language (if not procedures) at times that may dispel an occasional ambiguity. If you understand the purpose of the procedures, the step-by-step instructions will make far more sense. To return . . . .

After determining which program sources are affected, unplug the corresponding shielded cables from the preamp. If all modes are affected, remove all input cables. If the RFI still has not stopped, turn the volume control up and down. Does the loudness of the RFI change with the position of the control, or is it unaffected by it? In the former case, the signal is entering the system before the volume control. In the latter, the r.f. is being picked up after it. Often, the volume-control setting will have no influence on the RFI. If this is the case, unplug the cables from the preamp to the power amplifier. If the interference stops, the stage detecting the audio signal is in the preamp. If the interference persists, detection is taking place in the power amplifier.

Now you must find out how the signal is entering the component(s) detecting the r.f. signal. It can do so in one of three ways. First, the signal can be picked up by the a.c. power line and enter the audio component via its power cord. Second, the input and/or out-

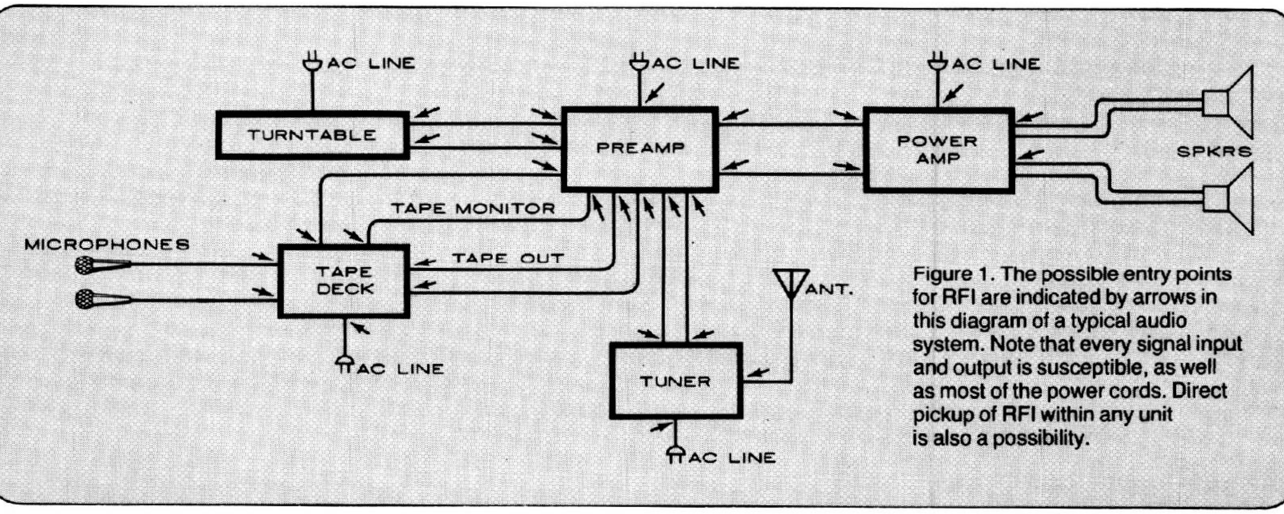


Figure 1. The possible entry points for RFI are indicated by arrows in this diagram of a typical audio system. Note that every signal input and output is susceptible, as well as most of the power cords. Direct pickup of RFI within any unit is also a possibility.

TRACKING DOWN RADIO-FREQUENCY INTERFERENCE

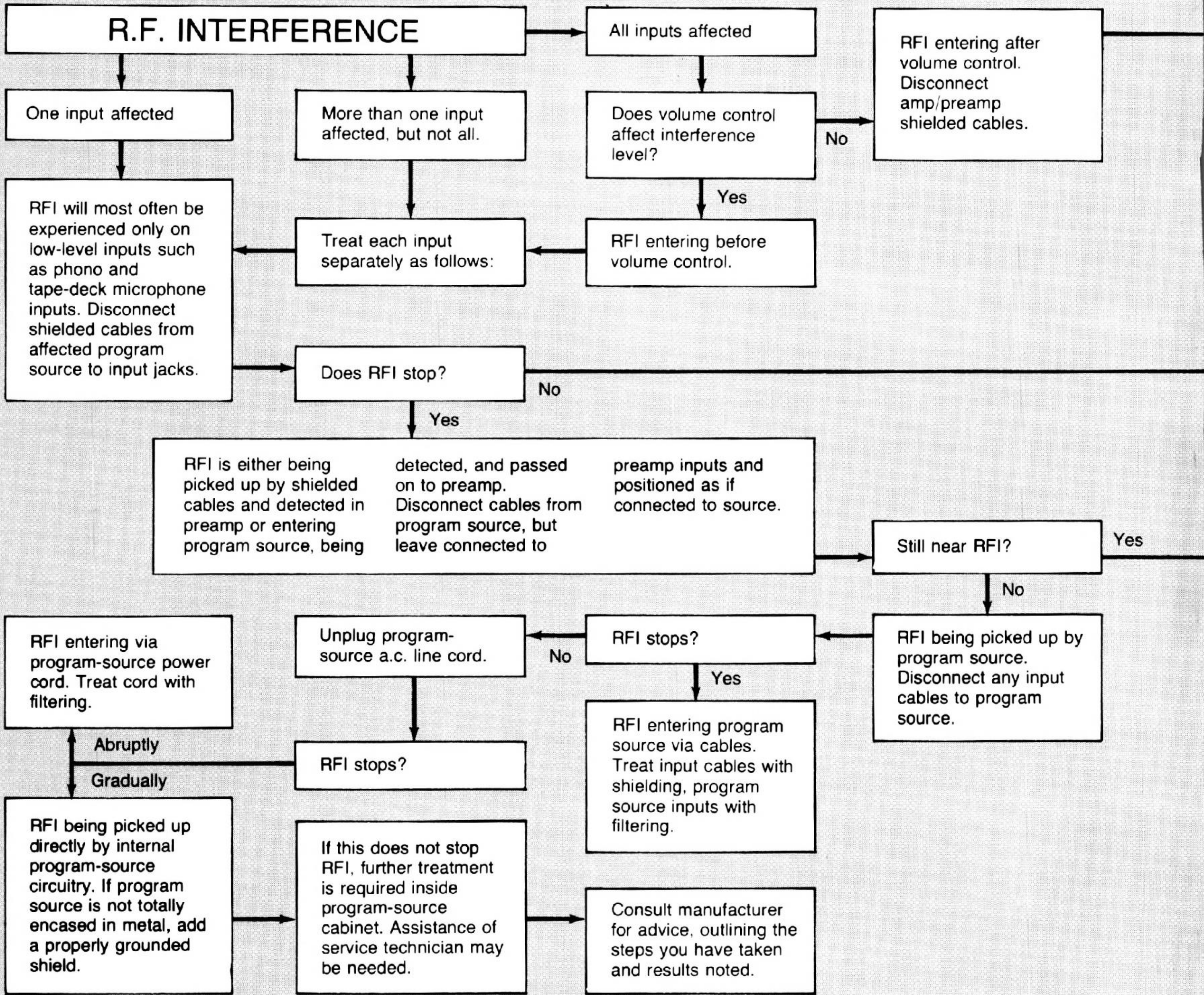
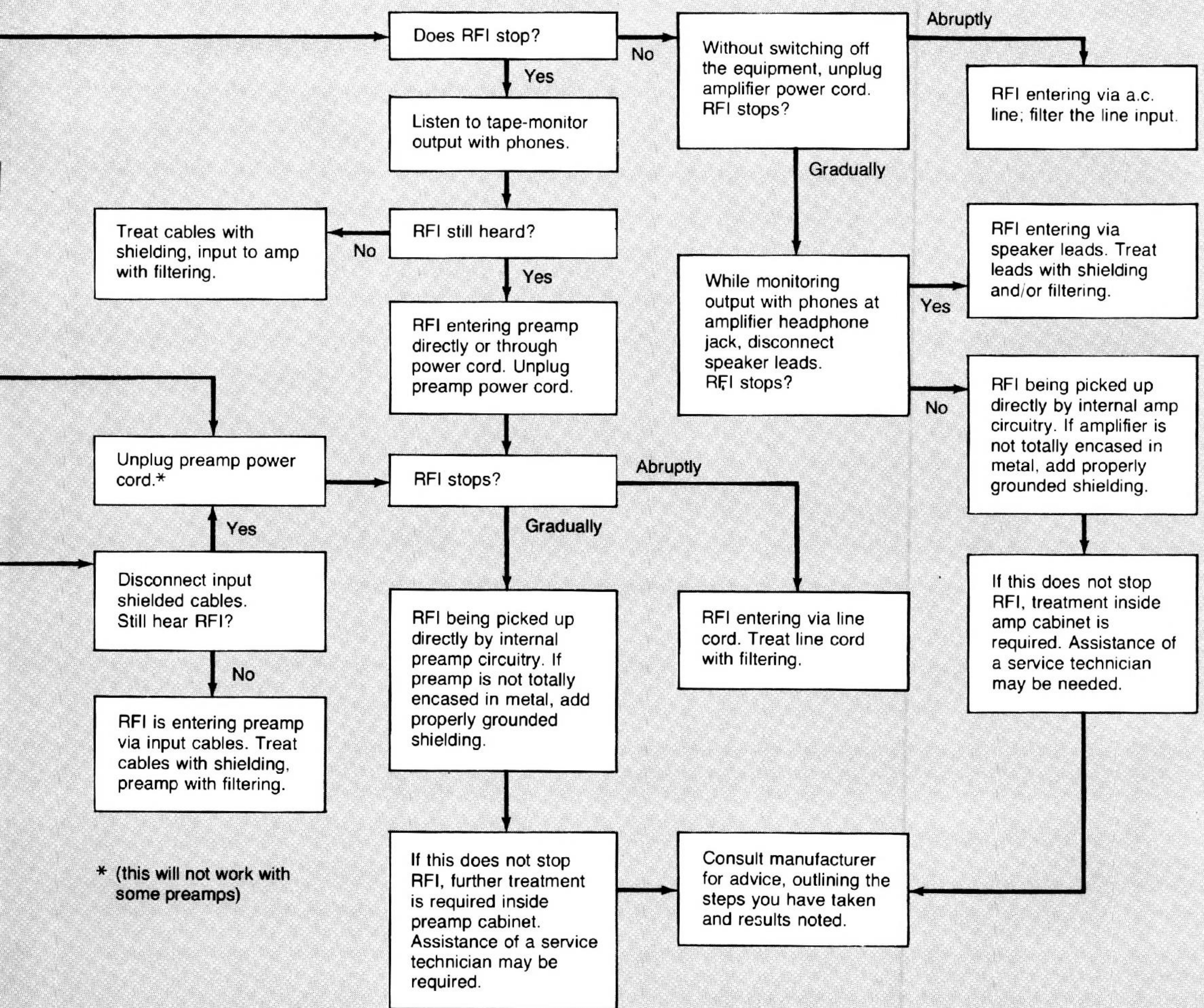


Figure 2.

put leads or cables can act as antennas and introduce the r.f. at their corresponding jacks. These two are the most common. The third—direct signal pickup within the component's enclosure—occurs only when the r.f. field is *really* strong. It is also the most difficult and inconvenient to counteract. In most cases, the first two can be dealt with through means external to the device.

If the preamp volume control does affect the RFI, plug in all the shielded cables in the system and switch the input selector to the affected input. (When there is more than one affected program source, repeat the following procedure for each. However, if the problem is in the power amplifier, don't bother—just read on.) Unplug the program source's a.c. power cord from its socket and wrap its full length around your hand. If the RFI stops, the r.f. signal is entering the component through the line cord. If this doesn't affect the interference, turn the preamp's volume control to near minimum and remove the shielded cables of that program-source component from its output jacks. Leave the cables plugged into the preamp and positioned as if they were connected to the source.

If this silences the RFI, the signal is being detected inside the source component. If it does not, try unplugging the cables from the input jacks of the preamp. In cases where the RFI stops after this has been done, the signal is being picked up by the cables and detected inside the preamp. If the RFI persists, there are only a few possibilities left. First, unplug the preamp's power cord and wrap it around your hand to inhibit its action as an antenna. If the RFI stops, the signal is getting into the preamp via the power cord. If



it continues, reconnect the power cord and remove the cables from the preamp output jacks but leave them plugged into the power amplifier and positioned normally. Cessation of interference indicates that the signal is being picked up somewhere within the preamp, where it is being rectified and passed on to the power amplifier. If RFI continues, unplug the cables from the input jacks on the power amplifier. If the RFI stops, it means that the cables are acting as antennas, passing the signal into the power amplifier where it is detected and amplified.

If you still (!) experience RFI, unplug the power amplifier's line cord. If the interference stops *instantly*, you have discovered the signal's route into the system. If the RFI dies away slowly as the amplifier's power-supply capacitors discharge, reinsert the power cord into its socket. Disconnect the speaker leads from the output terminals and check for the presence or absence of RFI either by watching the amplifier's power meters or by listening to a pair of headphones (make the effective length of the headphone cable as short as possible by wrapping it around your hand). In all but the rare cases where the r.f. signal is being picked up by internal amplifier wiring, this will kill any remaining RFI. You have isolated the signal's entry path to the speaker leads, which are often quite long and can work as very effective antennas.

Keeping RFI Out

The procedure just outlined, if followed methodically, will uncover one or more r.f. signal-entry paths. Now that you know where the signal is getting *in*, you can determine the steps

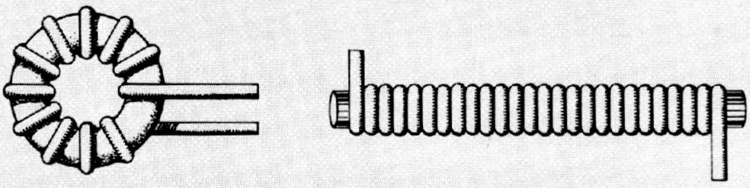


Figure 3. The proper way of wrapping cables and cords around ferrite rings and rods. The ferrite form should be kept near the component's rear panel.

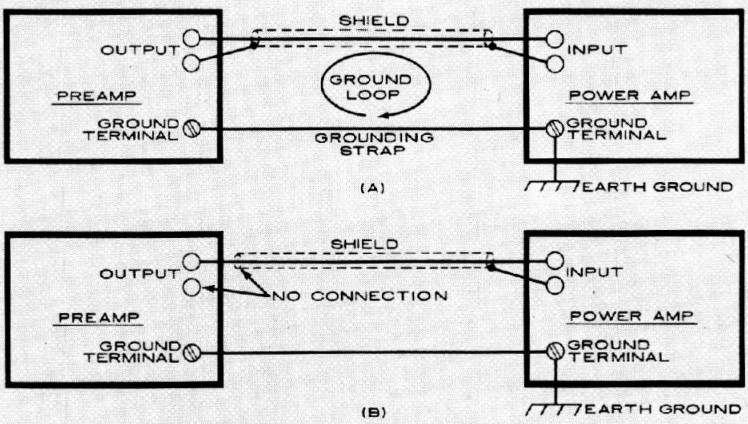


Figure 4. In (A), the existence of two separate ground paths between components creates the possibility of a ground loop. In (B), the shield of the signal cable is detached at one end, leaving only a single ground path.

necessary to keep it *out*. Signals riding in on the a.c. power line are easy to deal with, no matter which component is affected. All that's required is the installation of a "brute-force" line filter or a ferrite toroid or bar. [Line filters such as the Model C-509-L SA by the J. W. Miller Division of Bell Industries (they also manufacture filters for speaker outputs and phono-jack inputs), the Model CBBS-1 by Cornell Dubilier, and the Sprague Electric Company's Model F-500 (all rated to pass 5 amperes a.c., or about 550 watts) can be ordered from many radio-supply stores.] From the consumer's point of view, they are the easiest to use. All you do is plug the filter's line cord into the wall, ground the metal case (the screw holding the socket plate to the wall is often an effective grounding point), and plug the component's line cord into the socket on the filter case. The filter allows the 60-Hz a.c. power to reach the component but blocks any r.f. riding in on the line. Since such filters can pose a serious shock hazard if they malfunction, be sure to get one that bears the "UL" (Underwriters Laboratories) approval.

Ferrite bars and toroids (rings) perform the same function as brute-force filters—they let the a.c. power in but keep the r.f. out. They are also inherently safer than in-line filters. [Large electronics supply houses (especially those catering to radio amateurs) often stock them, but such distributors are not as common as they were in the past. Mail-order suppliers of ferrite materials are listed in the accompanying box.] Using ferrite forms is relatively simple. Wrap at least ten to twenty turns of power cord on the rod or around the ring (see Figure 3). Secure the ends with PVC electrical tape, and make sure you form the coil as close to the point where the cord enters the component as possible. That's all there is to it.

When the RFI is arriving at a component via another path, other steps must be taken. The first thing to do is to examine all wire connections, plugs, and clips. For example, if the pins of your phono cartridge are corroded and the clips are not making good contact, signal rectification could be taking place right at that point. The same holds true for the phono plugs of shielded cables. Make sure that *all* metal-to-metal joints are clean and secure. Crimp phono-plug shells or cartridge clips slightly to ensure firm contact with jacks or pins. Polish any corroded plugs or jacks with a fine grade of sandpaper. In some cases, simply cleaning up all the connections may be enough to stop r.f. interference.

Grounding

The next procedures to consider are grounding and shielding. These are allied remedies: a chassis acts as a shield, for example, but it won't be very effective as such unless it is grounded. It is important that *all* components in the system be properly grounded, but you must do this carefully. Otherwise, ground loops will result, possibly producing high hum levels. Figure 4 illustrates the point. At A, you can see that there are two conductors running between the chassis of the preamp and the power amplifier. This produces a ground loop. At B, both chassis are tied together by a common grounding strap, but the shield of the cable is not connected to the power amplifier's input jack. (Only one channel is shown for simplicity.) Here no ground loop is present. The general rule is to connect the chassis together with one conductor only.

A grounding strap of heavy copper braid or wire is the best candidate, but it may not prevent ground loops from occurring—especially if you are using commercially prepared patch cords with molded connectors (these invariably tie the shield to the connectors at both ends). The way to get around this is to disconnect the shield at one plug. Cut carefully around the cable near the point where it meets the plug. Severing the insulation will expose the shield wires, which can then be snipped and trimmed back so they won't accidentally come in contact with anything. Note, however, that some components (particularly preamps with "floating" input grounds) will not function when the shields are interrupted in this way. When reinstalling a component that has had its signal grounds altered, turn the volume down fully and advance it *very* cautiously just in case you have *set up* a hum situation.

Shielding

Although you might find that a good grounding system stops the RFI, more treatment may be required. Some very inexpensive audio components are packaged in wood or plastic enclosures and lack a metal "wrap-around" beneath the cosmetic shell. Plastic or wood cabinets offer no resistance to the passage of r.f., while metal cabinets *can* be effective r.f. shields. If your equipment does not have metallic cabinets or sub-enclosures and you have determined that the signal is being picked up and rectified *inside*, you will have to shield the affected components with metal.

Copper flashing or brass screening is ideal for this purpose. Staple the screening to the inside of the cabinet and solder all portions of the screening together, leaving as few gaps as possible—none, if you can manage it. It may be that when you reinstall the now-shielded cover the copper screening will be automatically grounded to the metal chassis. If not, solder a lead to the screening and connect it to the chassis at the main grounding tie point. Be very careful when installing the screening to prevent accidental short circuits between it and electrically "live" portions of the component circuitry. Don't allow it to droop. If necessary, staple thin cardboard *over* the screening to serve as an insulator between it and the chassis-mounted components. If installed properly, the screening will have no effect on the component's performance, but it will pevent r.f. from getting into the circuits. In most cases where the signal is not entering via the power line, patch cords, or speaker leads, a good grounding and shielding installation will eliminate the problem.

Now let's look at the remaining r.f. "ports of entry"—the speaker leads and interconnecting cables. These can act as antennas, picking up the r.f. and delivering it to the component, where it is rectified. The problem here is how to allow these leads (and the circuits connecting to them) to function normally with audio while blocking r.f.

There are several ways of doing this. The first is to use specially shielded leads. Most audio cables have the configuration shown in Figure 5A. It consists of an inner conductor, center insulation, and shielding wires that spiral around the inner conductor and insulation, plus an outer plastic jacket. Although the spiral shield is fairly effective at audio frequencies, it doesn't work too well at radio frequencies. To improve the shielding, you can either replace the patch cord with one made of coaxial cable (Figure 5B), such as RG-59-U, the type used in some TV or FM antenna installations, or you can slip tubular copper braid *over* the existing patch cord. Be sure to connect the braid to the system ground.

Where two conductors (speaker leads, for example) must be shielded, you can use the cable shown in Figure 5C. This type of cable is available in 18- and 16-gauge sizes and can be used for most speaker-wire runs. Again, be sure the braided shield is tied to the system ground. (This and all the cable shown in Figure 5 are available from large electronics supply houses under brand names such as Alpha and Belden. Copper braid can also be obtained from these sources.)

Filtering

The final method of RFI treatment is to install filters in the leads picking up RFI. Most useful in accomplishing this are discrete filters that employ ferrite bars, toroids, ferrite beads, and small capacitors. Let's consider the speaker leads first. They can pick up and deliver a strong r.f. signal to the output terminals of the amplifier. The r.f. is passed back to an earlier stage by the feedback loop where it is converted into audio. The audio is then treated by the later stages as a normal signal: it is amplified and ultimately heard through the speakers. The best cure is to block the r.f. before it gets into the circuits by using an appropriate filter, by forming r.f. chokes from the speaker leads and ferrite toroids or bars (Figure 3), by shielding the speaker leads with braid (or the use of braid-shielded, two-conductor cable as in Figure 5C), and/or by installing shunt capacitors and/or ferrite beads as necessary.

The proper way to install shunt capacitors is shown in Figure 6. Inexpensive disc ceramic capacitors rated at 250 volts (or higher) and 0.001 to 0.01 microfarad (μF) are suitable. The capacitors will appear as a short circuit to r.f. signals, preventing them from entering the power amplifier. However, they will essentially be open circuits (as if they weren't there) to the audio output signals. Thus they will have no adverse effect on frequency response. Some amplifiers might act up if a capacitor is installed directly across the speaker terminals; therefore, consult with the manufacturer of your amplifier before installing capacitors.

Ferrite forms can be used alone or together with shunt capacitors and/or cable shielding. Serious cases of RFI may require the use of all three suppression methods. Ferrite beads can also be used. One or more are slipped over the speaker lead as close to the amplifier terminals as possible. These devices act as resistances to r.f. but let audio signals flow unimpeded. Again, beads might reduce but not eliminate the interference in severe cases, and shielding, grounding, and the use of capacitors might also be required.

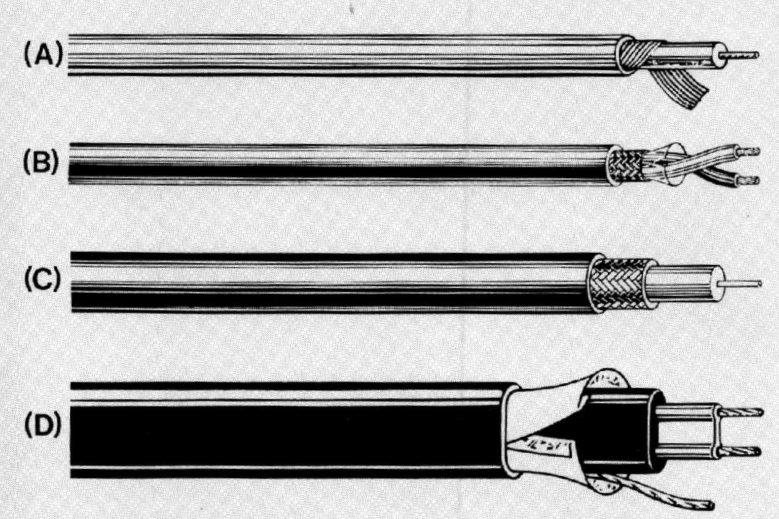


Figure 5. Various shielded cables. (A) is a standard type for patch cords. (B) has a braided copper sleeve for better shielding. (C) and (D) have two inner conductors plus shield and are useful for speaker cables (C) and antenna lead-ins (D).

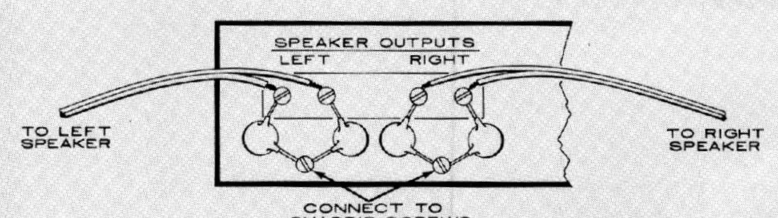


Figure 6. Disc capacitors of recommended value (see text) will shunt RFI picked up by the speaker wires to ground when connected as illustrated. The chassis screws shown can actually be any handy nearby grounding point.

Ferrite beads can also be used at the preamplifier and program sources. In some cases, beads will have to be mounted inside the component's cabinet on the "hot" leads at the input and output jacks. A small amount of unsoldering and resoldering will be required. Beads can also be mounted on the leads to a tape deck's record, playback, and erase heads (but this sort of delicate work is perhaps best left to an experienced technician). Shielded cables can also be treated with ferrite bars or rings, as in Figure 3.

FM tuners might be overloaded by strong short-wave radio signals. The use of shielded twin lead or coaxial antenna feedline can help, as can the installation of copper screening. (Chassis grounding is a *must* for this approach.) Sometimes a high-pass filter is needed to stop tuner overload. This type of filter blocks all signals below about 40 MHz, preventing CB and short-wave-amateur signals from reaching the antenna input but passing FM signals (above 88 MHz) without attenuation. The Drake TV-300-HP and TV-75-HP filters, designed for use with 300-ohm twin lead and 75-ohm coaxial feedlines, respectively, are well suited for this application. They are installed at the antenna terminals of the tuner. (Incidentally, these filters are also useful for stopping interference in television reception.) The Drake filters are available from many electronics supply houses.

Phono preamps are best treated with ferrite beads and bars or toroids. The use of *braid* shield or coaxial input leads is also important. Shunt capacitors are *not* usually desirable at the phono input because they can have a detrimental effect on frequency response. However, coaxial cable such as RG-59 can be used to replace spiral-shield input leads. The capacitance of this type of coax is even less than that of "low-capacitance" spiral shielded cable, making it totally compatible with stereo and CD-4 systems.

SOURCES OF FERRITE MATERIALS

• **Amidon Associates**, 12033 Otsego Street, No. Hollywood, California 91607, is a mail-order source for ferrite beads, toroids, and bars. Its FB-73B-101 ferrite bead offers greatest impedance to r.f. at about 10 MHz, and it will fit over No. 18 wire. Its FB-73B-801 will fit over heavier No. 12 wire Prices per dozen: $2 (FB-73B-101) and $3 (FB-73B-801). Two ferrite rods are available: the 30-61-4 (½-inch diameter, 4-inch length, $1.50) and the 30-61-7 (½-inch diameter, 7½-inch length, $2.50). The T-200-2 toroid is large enough for use as an r.f. choke on speaker leads and covers the frequency range from 1 to 30 MHz; price, $3.25.

• **Elna Ferrite Laboratories**, Box 395, Woodstock, New York 12498, is a mail-order source for Ferroxcube ferrite materials. Two toroids are available. The 400T 750-3C8 ($4.75) is useful for speaker leads; it is larger than the 528T 500-3C8 ($2.75), which is more convenient for use with input cables. The 56.590.65/4A6 and 56.590.65/3B (both $2 per dozen) ferrite beads are appropriate for use with smaller wires.

(Additional information is available from both these sources about other toroid sizes, magnetic properties, etc.; include a stamped, self-addressed envelope for reply.)

ANOTHER source of shielding materials is Verion, a company that manufactures patch cords, cables, and other grounding accessories. The Verion cables are triaxial in construction, with an outer shield that carries no signal. Write Verion, 75 Haven Avenue, Mount Vernon, New York 10553, for a free catalog.

SOURCES OF RFI FILTERS

IN many localities you may not be able to locate a supplier and will have to contact the manufacturer directly. Some major manufacturers are listed below and catalogs are available from them in most cases. In addition to line filters, a number of these companies offer devices intended for insertion in the signal path between components, and these may provide some degree of relief.

• **Bell Industries**, J. W. Miller Div., 19070 Reyes Avenue, Compton, California 90224.
• **Cornell Dubilier**, 150G Avenue L, Newark, New Jersey 07101.
• **Sprague Electric Co.**, 645G Marshall Street, North Adams, Massachusetts 01247.

If you are seeking shielded cable of any type, two major sources are:

• **Alpha Wire Corp.**, 711G Lidgerwood Avenue, Elizabeth, New Jersey 07207.
• **Belden Corp.**, Dept. G, Box 1100, Richmond, Indiana 47374.

THE great majority of RFI cases can be dealt with successfully using one or more of the techniques that have been outlined here. However, it is always easier to eliminate interference when you have the cooperation of the radio operator. Remember, though, that any costs involved must be borne by you. Although that might seem unfair, it is the law as promulgated by the administrative agency of the government in charge of such matters (the FCC). Some irate people have attempted civil lawsuits against radio-operator neighbors, but these suits have invariably failed—and on occasion even prompted harassment counter suits brought by the radio operators. The courts have consistently refused to penalize a radio operator when he abides by FCC regulations. Hams and CB'ers, however, are two different breeds of cat. The ham usually has a reasonable degree of electronic knowhow; the CB'er does not. It will be helpful to solicit a ham's cooperation in discovering how r.f. is getting into your system and in applying appropriate remedies; you won't get that cooperation by harassing him.

In response to the growing RFI problem, bills have been introduced in the last two sessions of Congress that would empower the FCC to set resistance-to-RFI standards for all home-entertainment devices. However, both times Congress has adjourned before acting on them and the bills have expired. But it seems only a matter of time before an RFI bill becomes law. Any standards adopted under such a law will be reasonable, we hope, and they should *not* be developed without the technical advice of the audio manufacturers who would be affected.

For the present, however unfair it might seem, you as a consumer must tackle the RFI problem on your own. As mentioned earlier, manufacturers anxious to keep their customers' good will often provide parts and advice. By all means, write to the manufacturer describing the nature of the interference and the model and serial numbers of the affected components. Armed with your persistence, his advice, and sometimes with the radio operator's cooperation, you *can* lick Radio Frequency Interference. □

John McVeigh *is an electrical engineer, an audiophile, and a radio amateur holding call letters WB2BLS. He is an associate editor with* Popular Electronics *magazine.*