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The Black Art of Antenna Design

— shedding some light on the workings of vertical whips

The purpose of this article is to correct some widespread misconceptions about antennas. These misconceptions, as will be explained later, are not confined to certain users of antennas, but evidently extend to some of the manufacturers as well. Unfortunately, there is a widely-held belief that antenna design is a "black art." While I do not wish to undermine the livelihoods of those well-qualified antenna engineers who thrive on perpetuating the notion that the operation of an antenna is incomprehensible to the layman, I do feel that some of the secrets should be revealed in the interest of the betterment of ham radio!

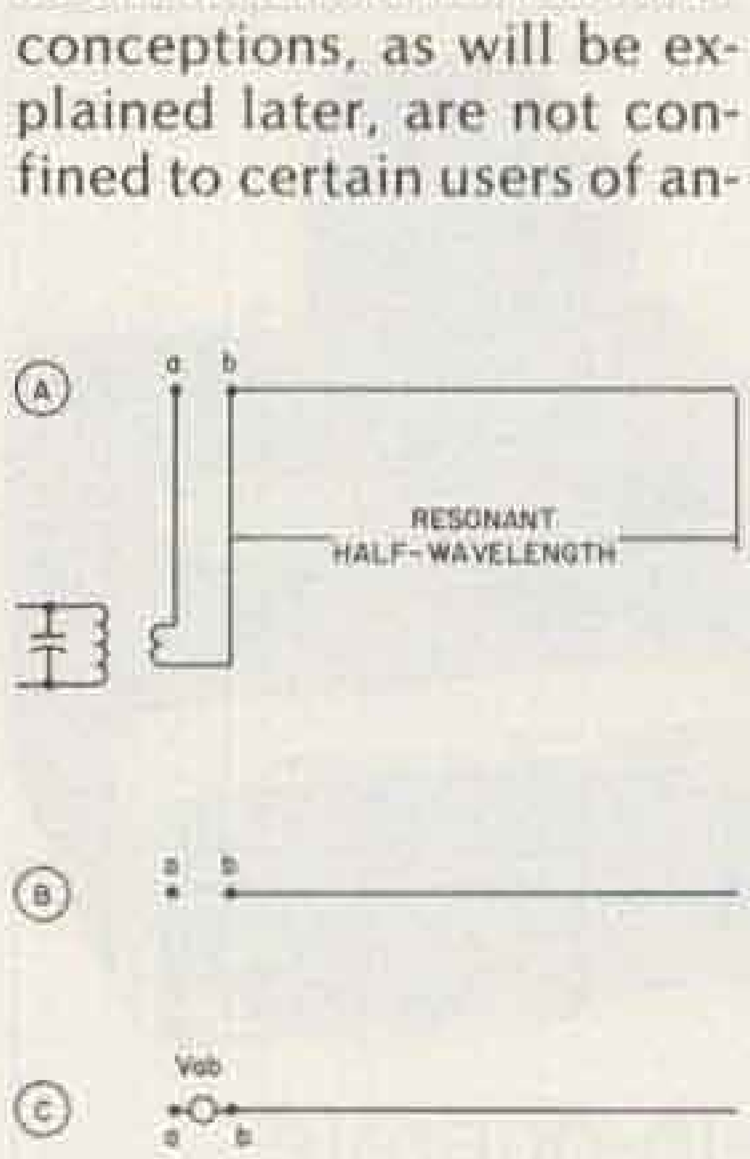

Fig. 1. (a) Zepp antenna with feedline. (b) Zepp with feedline removed. (c) The one-terminal impedance.

The Problem

The problem to be treated in this article is related to the way in which antennas are connected to transmission lines. We will exclude from the discussion microwave antennas such as horns or slots which are driven by waveguides. Practically all other antennas possess two terminals, the points at which one can say that the transmission line to the transmitter or receiver is connected, and the antenna begins.

Fig. 2. Current distribution on the Zepp antenna.

The problem arises from what I shall call the "one-terminal impedance" misconception. As a starting point, let's take a look at an old and time-honored antenna, popular in the early days of ham radio, known as the "Zepp," and shown in Fig. 1(a). The Zepp consists of a half-wave wire, usually mounted horizontally, driven at one end by a two-wire transmission line. The feedline is normally one quarter-wavelength long, and is usually coupled inductively to a tuned circuit at the driving end. The antenna is said to be "voltage fed" because the extremity of a wire antenna is a point of high voltage and low current.

You must surely agree that terminals A and B in Fig. 1(a) are the input terminals of the antenna because this is where the two-wire transmission line is connected. If we concentrate on the antenna alone, we have the situation portrayed in Fig. 1(b), where point B is one end of the half-wave antenna, while point A is a disembodied point hanging in the air. What, then, is the impedance terminating the transmission line? It is evidently infinite, because an impedance is the ratio of an ac voltage to an ac current. An ac voltage, V_{ab}, applied across the two terminals of an antenna should certainly excite the antenna. If such a voltage generator is applied across terminals A and B, as shown in Fig. 1(c), no current can flow, because the same current which goes out of one terminal of the generator must come into the other, and in this case, terminal A is not connected to anything. But there *must* be a finite current entering the antenna at the feed point, or there could be no power radiated by the antenna! Here lies the misconception which I have called "one-terminal impedance."

This dilemma was known to at least some of the early users of Zepp antennas, as can be verified by studying technical literature on the subject written 40 years ago. The truth of the matter is that the transmission line *must* also be a part of the antenna.

Since the horizontal part of the antenna is a half wave in length, there will be a standing wave of current along the wire with a magnitude of zero at the far extremity, maximum in the center, and small, *but finite*, at the driven end (see Fig. 2). The magnitude of this input current depends on the length-to-diameter ratio of the wire, and will be about 25 percent of the maximum current at the center for a length-to-diameter ratio of 100. The current on the transmission line wires will be composed of two components, the first of which is the ordinary transmission line component with equal and opposite currents on the two legs. This component is designated as I_t in Fig. 2. The second component is the antenna current, with equal amplitudes and equal directions on both legs, shown as I_a in Fig. 2. At point A, the total current must be zero. Thus, I_t and I_a must be equal in amplitude but 180° out of phase to add up to zero at A, and equal in amplitude but in phase to add up to the current entering the antenna at point B, labeled I_{ant}.

The transmission line currents are produced by the transmitter, usually through inductive coupling at the input end of the two-wire line. The antenna current is in the form of a standing wave on the antenna wire, but its distribution along the feedline is in some doubt. The electromagnetic field due to the transmission line currents alone is localized in the near neighborhood of the feedline, but the field due to the antenna currents is not so confined—in fact, it produces substantial radiation from the feedline. There will be coupling by this field to nearby objects such as to the building in which the transmitter is located, and to any electrical conductors nearby. The input end of the feedline will have inevitable capacitive coupling to the transmitter chassis, and the entire transmitter will be hot with rf, along with the house wiring. At higher power levels, the operator may receive rf burns when his lip brushes up against a metallic microphone! Frankly, the old Zepp antenna is a mess!

All of this is easily corrected by moving the feedline to the center of the half-wave dipole, which is a point of symmetry. The radiating antenna currents are now confined entirely to the antenna and no antenna currents are superimposed on the transmission line currents. Note, however, that this situation prevails only as long as a balanced transmission line is used to feed the antenna. If coaxial cable is used, then an appropriate "balance-to-unbalance" transformer, or balun, must be employed between the coaxial line and the antenna to inhibit currents from flowing on the outside of the coaxial cable.

While the old Zepp antenna is rarely used today, there are many other antennas in common use which must be driven from one extremity. These are the class of vertical whips in which the feedpoint is elevated above earth ground, highly popular for base station use in the VHF and UHF bands in amateur, commercial, and marine service. This class of antennas is used in an effort to obtain vertically-polarized radiation which is omnidirectional in azimuth. Unfortunately, the one-terminal impedance misconception, which should have been laid to rest 40 years ago, has reappeared with a vengeance!

Antennas are commercially available from a number of different manufacturers which consist of a vertical whip extending up from an impedance-matching network at the base, which is fed through a coaxial cable connector. The most popular lengths for the whip are 1/4, 1/2, and 5/8 wavelength. If this type of antenna is used on the outside metal surface of an automobile, there is no problem. One has a kind of highly-unbalanced dipole, one leg of which is the whip, the other being the outside metal surface of the car. The outer conductor of the coaxial cable is electrically connected (either conductively or capacitively) to the car body, while the center conductor couples to the whip. The same magnitude of current which enters the base of the whip must also spill out over the car body. If the antenna is mounted at a point of symmetry, ideally at the center of the rooftop, current will flow radially out from the base of the whip, as in the case of a vertical broadcast antenna system. The car top is an elevated "ground plane" of finite size. The radiation pattern will show only minor variations in azimuth, but the maximum radiation inten-

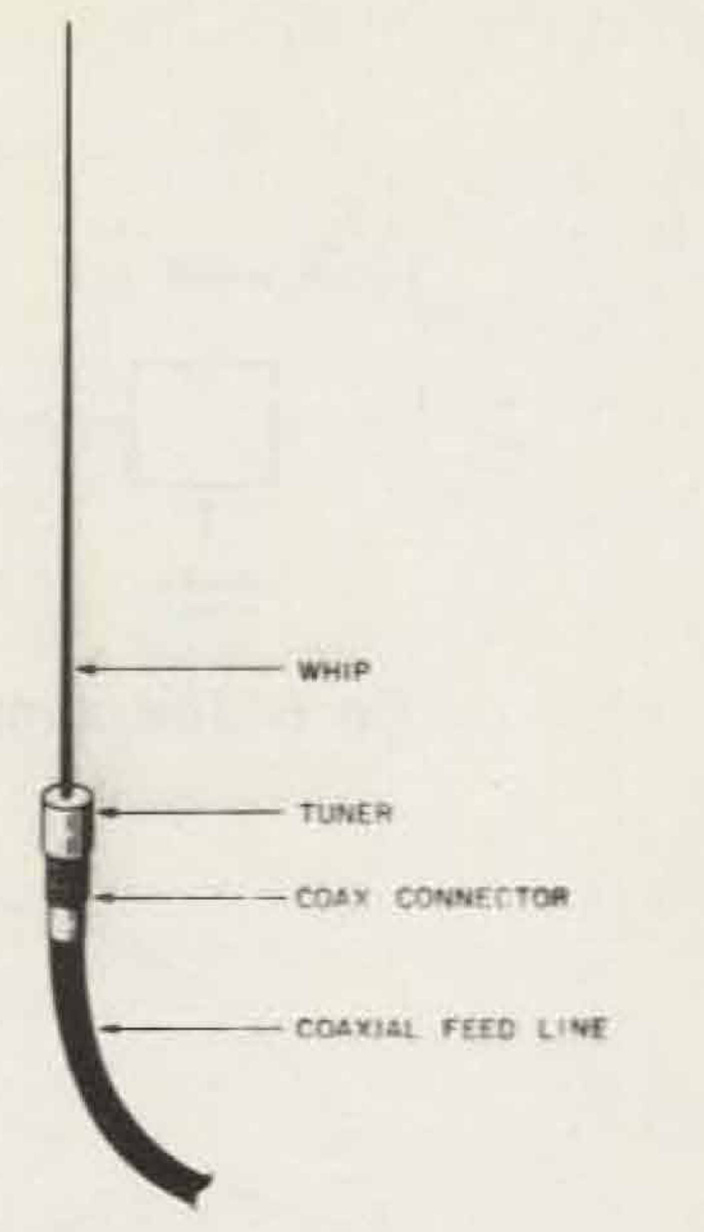

Fig. 3. Typical whip with base tuner connected to a coaxial line.

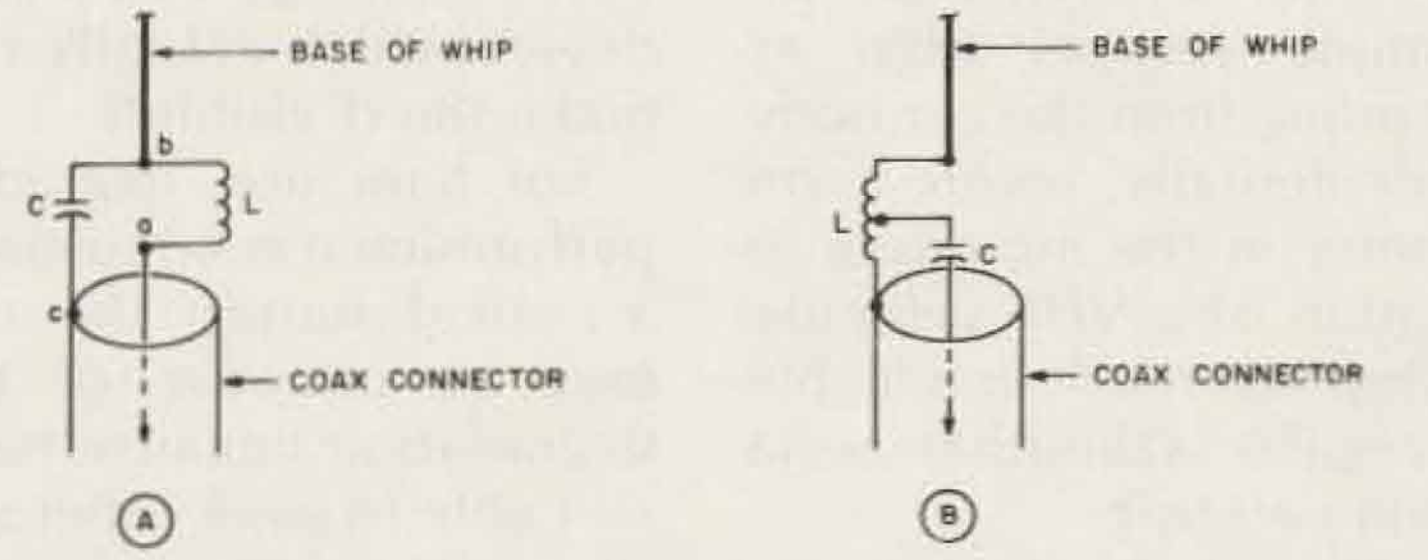

Fig. 4. Tuners for end-driven whips. (a) L-network. (b) Tapped-inductor.

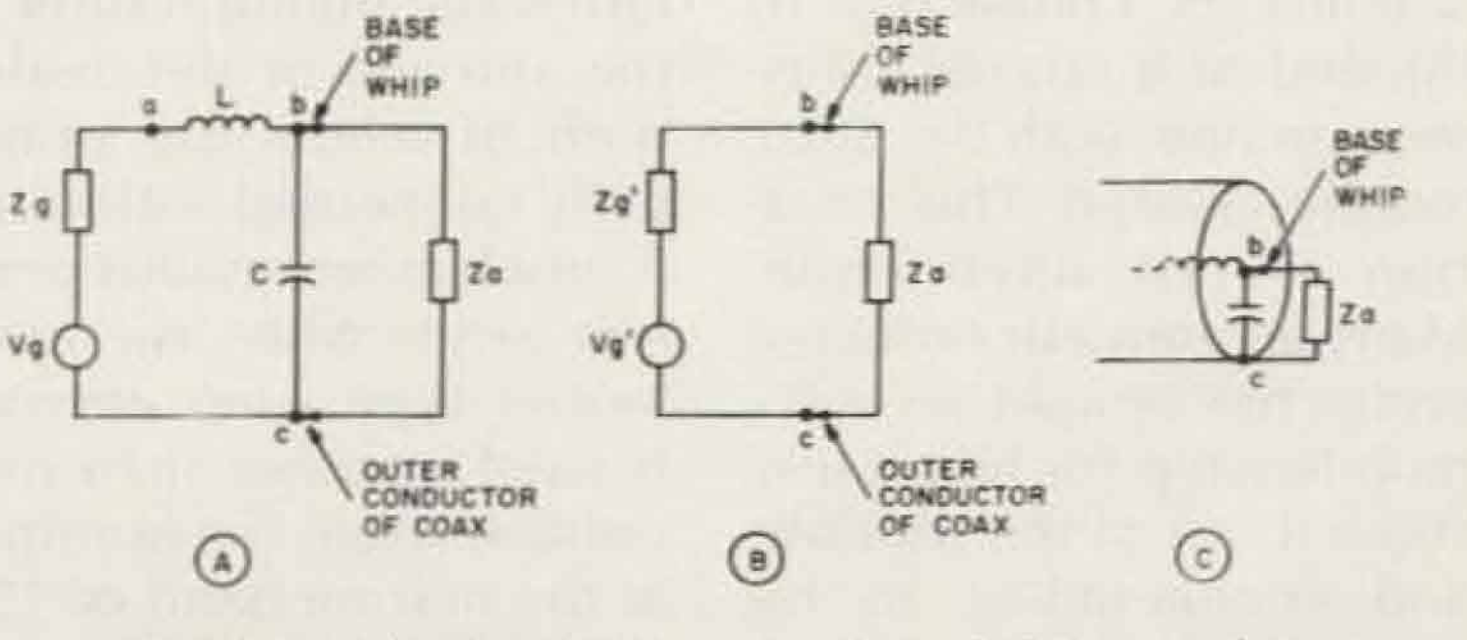

Fig. 5. Equivalent circuits of end-driven whip.

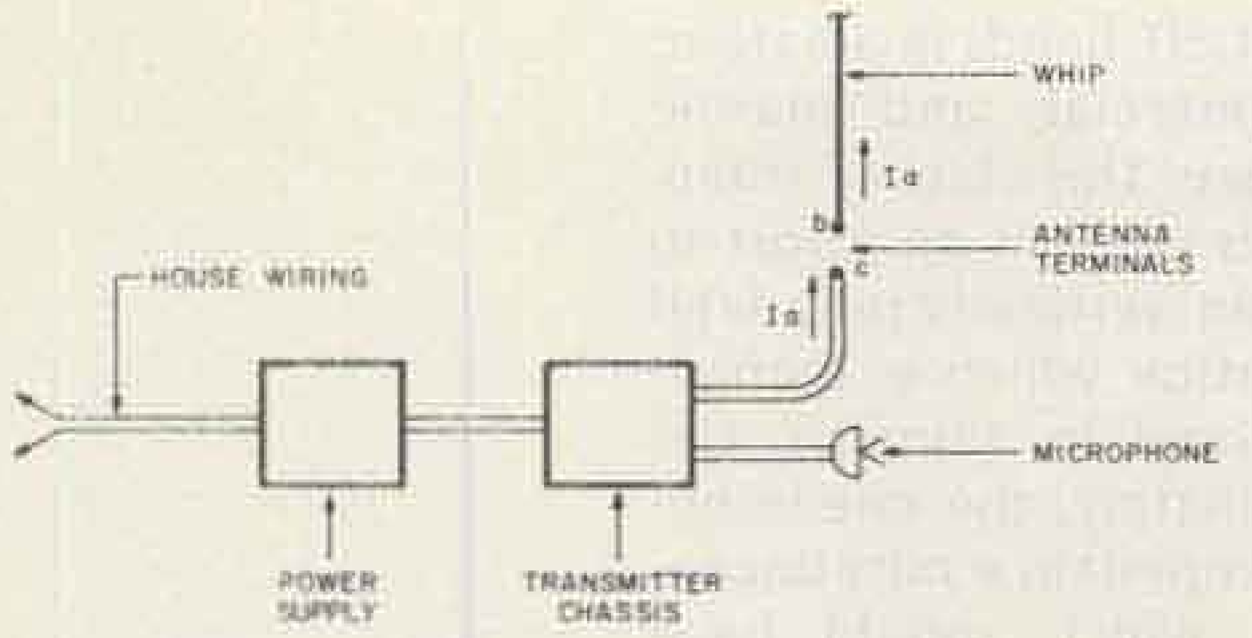

Fig. 6. The complete end-driven whip.

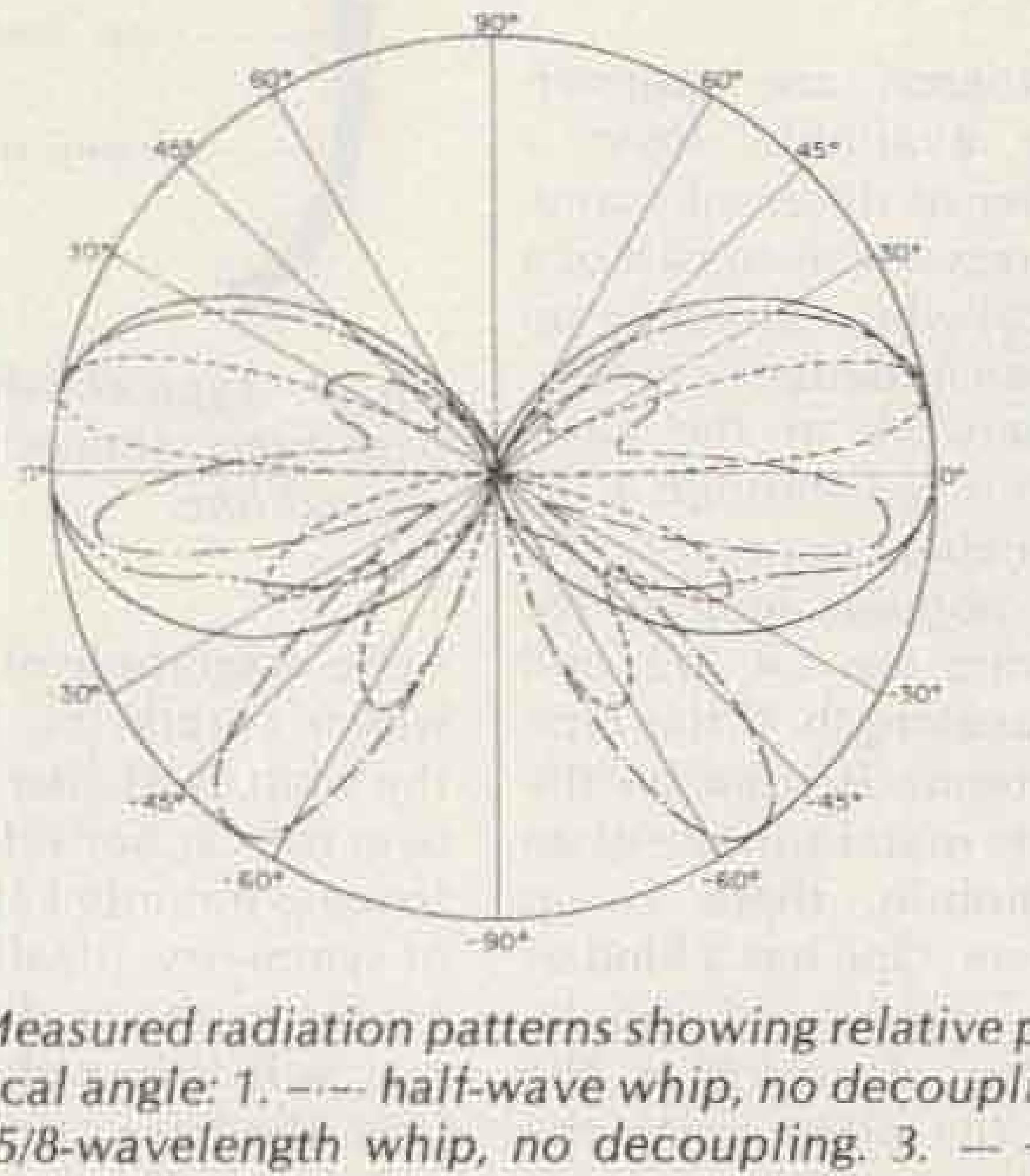

Fig. 7. Measured radiation patterns showing relative power vs. vertical angle: 1. —·— half-wave whip, no decoupling. 2. - - - - 5/8-wavelength whip, no decoupling. 3. — — — — half-wave whip with quarter-wave decoupling sleeve. 4. —— reference half-wave center-driven dipole.

sity will typically occur at some vertical angle above the horizon. This effect is usually tolerated as the price to pay for the simplicity and economy of the simple vertical whip extending from the car body. (Incidentally, severe asymmetry in the mounting location of a VHF vehicular whip can result in a highly-irregular azimuthal radiation pattern).

The great one-terminal impedance misconception rears its head again when an automotive-type whip antenna is connected to the end of a coaxial transmission line, with the automobile deleted. This situation is not uncommon. Many an amateur radio operator has bought an automobile whip for home use, stuck it out of the window, and connected it to his 2-meter base station through a length of coaxial cable. If he could only *see* where the rf was going, he would be shocked! (At the end of this article I will reveal the design of a handy device which actually *can* make the rf visible!)

For ham use, degraded performance is not usually a critical matter. The user may be unaware of the degradation because he is still able to work other stations. The user may be quite happy. Unfortunately, users rarely receive any technical guidance from either the manufacturer of the antenna or the dealer, both of whom are principally concerned with sales. A much more serious problem arises when the automotive-type whip antenna is used in other than ham radio service, for example, in the marine band of 156-162 MHz. If you happen to live in a coastal area where large marinas are located, look at the sailboats and see how many vertical whip antennas of the thin wire, automotive type are mounted on the mastheads. As will be explained below, this type of antenna system can produce severe degradation of the radiation pattern, caused by unwanted currents excited on the outside of the coax line as well as on the stays, shrouds, and the mast itself—all functioning as longwire antennas. The degradation in communications performance could result in tragedy because of the inability of the boater to summon help in an emergency situation. I cannot believe that the manufacturers and dealers of these antennas are aware of the problem; it is much more likely to be a matter of ignorance. It happens that there *do* exist well-designed vertically-polarized marine VHF antennas on the market, in which the radiating element is superbly decoupled from the coax line and mounting structure. It is unfortunate that in this consumer-oriented market, when the sailboater asks for a lightweight VHF antenna, the dealer happily sends him off to his (possible) doom with degraded communications capabilities!

Returning to the one-terminal impedance misconception, Fig. 3 portrays a typical coaxially-driven whip antenna with tuner in the base, connected to a coaxial cable. The antenna might be either a half-wave or 5/8-wavelength whip.

A popular network for impedance-matching the whip to the coax line is shown in Fig. 4(a). This is an L-network in a configuration useful for a load impedance whose resistive part is greater than 50 Ohms, as in the case of both the 1/2- and 5/8-wavelength whips. Another possible tuning network, using a tapped inductor, is shown in Fig. 4(b). Capacitor C in Fig. 4(b) is sometimes deleted, and the length of the whip is made variable in order to gain another tuning parameter.

We now come to another point about which I suspect there are misconceptions among many amateur radio operators. This concerns the respective roles of the *inside* and the *outside* of the coaxial line. The transmitter normally resides within a rather well-shielded box. The signal generated by the transmitter is conveyed *within* the coax line to the feedpoint of the antenna before it (the signal) emerges and first "sees the light of day." I like to call the shielded interior of the transmitter and the inside of the coax cable out to the antenna terminals the "inside world." The "outside world" consists of the whip antenna *and the outside surface of the outer conductor of the coax line!* This is the point missed by many users of antennas. They perceive of the coax line purely as a transmission line connecting their transceiver to the antenna, and fail to understand that it can also be a part of the antenna. Please understand that this is not a new or revolutionary concept, but has been well understood by antenna engineers during at least the last 35 to 40 years.

Looking down into the coax line between points A and C—see Fig. 4(a)—we can replace the "inside world" by a voltage source, V_g, in series with an internal impedance, Z_g. This is an application of Thevenin's theorem—well known to all electrical engineers. The voltage source drives the antenna impedance, Z_a, through the LC network, as shown in Fig.

5(a). The circuit can be simplified by including the tuner as a part of the effective source impedance, looking back toward the source at terminals B and C, as shown in Fig. 5(b). The effect of the tuner is to modify the source voltage to a new value, $V_{g'}$, and the source impedance to $Z_{g'}$. The tuner can properly be considered to be a part of the "inside world." You could just as easily mount the L and C elements just inside the coax line as shown in Fig. 5(c).

Aha! We now note that the load impedance terminating the coax line is connected across terminals B and C. If we disconnect the coax line with its tuner from the antenna, we are left with only one terminal (B), the other terminal having been carried away with the coax line! The one-terminal impedance problem has struck again.

We are led to the correct conclusion that the coax line must provide the other "half" of the antenna. Antenna currents *must* be carried on the outside of the coax line. Unlike the open-wire feedline of the Zepp antenna, where transmission-line and antenna currents were superimposed, the coax line forces the antenna currents to be entirely on the outside of the outer conductor. This results from the fact that a coaxial line forces currents *within* the line to be equal and opposite on the center conductor and inside wall of the outer conductor, respectively. The antenna current is forced to flow on the outside surface of the outer conductor.

The antenna is really a horrendously unbalanced dipole, as shown in Fig. 6, the two sides being (1) the whip itself, and (2) the outside of the coax line all the way to the transmitter, the outer box housing the transmitter, and, very possibly, many other conductors associated with the system, such as the microphone cable, leads to a power supply, house wiring, etc.

The magnitude of the antenna current at all points along the outside of the coax line is not easily predictable. One can be sure that at the feed point the instantaneous current, I_a, entering the whip must be exactly equal to the antenna current at the extremity of the outer conductor of the coax line (see Fig. 6). Below the feed point, the current on the outside of the coax will probably be in the form of standing waves produced by reflection processes at the bottom end of the coax-transmitter system. At the antenna terminals, the standing-wave amplitude on the outside of the coax could produce a current maximum (resonance), current minimum (anti-resonance), or anywhere in between. If there are many wavelengths of coax between the transmitter and the antenna terminals, there will be only a small percentage difference in frequency between resonance and antiresonance. The degradation of the radiation pattern is highest for antiresonance conditions on the cable, at which time the resulting radiation pattern in the vertical plane will be broken up into a mass of lobes. Additional degradation will result from power loss where the coax line is in close proximity to lossy materials, such as the wall of a house, the ground, etc. Also, horizontal runs of the coax between the antenna and the transmitter will radiate a component which is cross-polarized with respect to the radiation from the whip.

If you are skeptical, make up an rf sniffer like the one described at the end of the article, and convince yourself! Connect a 2-meter band, automotive-type whip at the end of a length of coaxial cable of arbitrary length—3 feet, 6 feet, 10 feet—whatever is available. Connect the other end to your 2-meter rig. Ten Watts of output power is a satisfactory level for good rf sniffing, but higher power produces more spectacular results.

First, while transmitting (on some unused frequency!), bring the coupling loop of the sniffer up toward the whip. For maximum coupling, the plane of the loop should lie in the plane containing the whip. Tune the loop with an insulated tuning tool to obtain maximum brightness in the indicator lamp. You can search along the whip and see the standing wave of current, since the loop is magnetically coupled and a point of maximum brightness means of a point of maximum current. Now search with the sniffer along the coax line below the antenna. Provided that your rig really is putting out the better part of 10 Watts, or more, the sniffer will light up merrily along the coax all of the way back to the rig!

I have performed this demonstration (with good effect) before a number of different ham groups. At one meeting, I also demonstrated a 2-meter model of a Zepp antenna, and showed how the feedline was strongly radiating. After the meeting was over, one of the old-timers present said to me, "That demonstration of the Zepp was like killing an old friend!" I prefer to think that I was helping kill an old bandit who had been

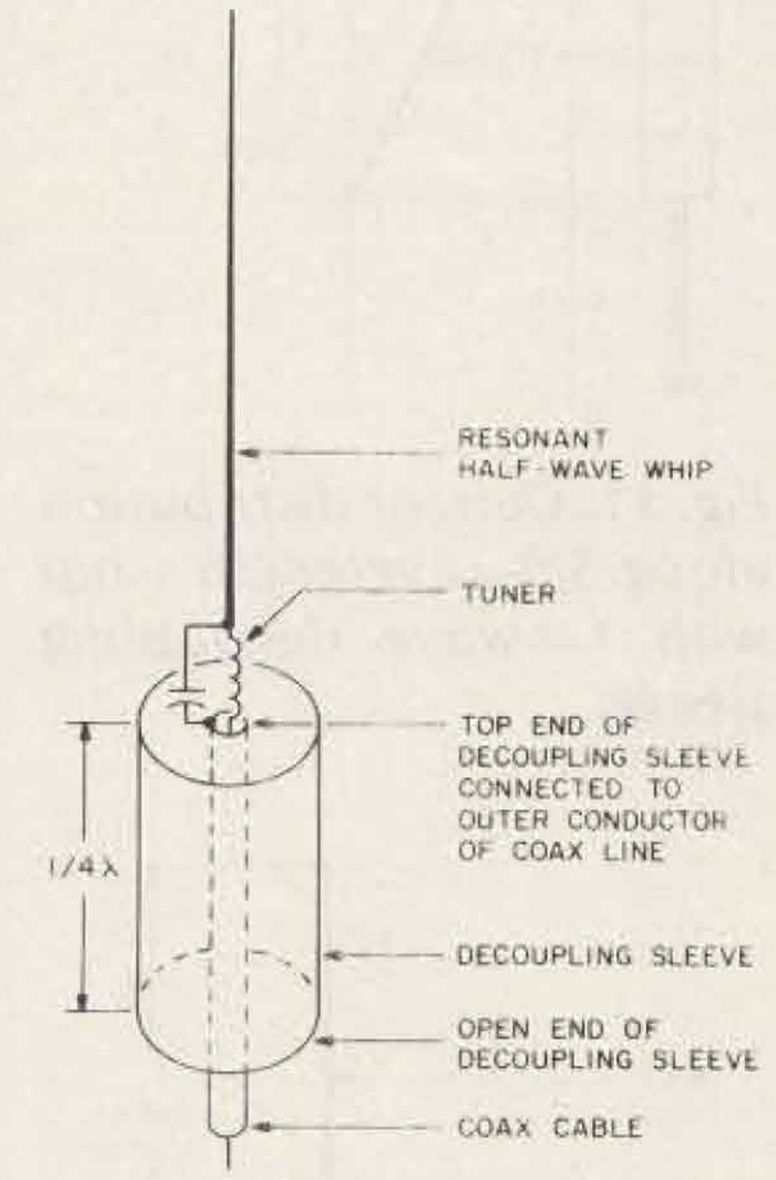

Fig. 8. Half-wave whip with quarter-wave decoupling sleeve.

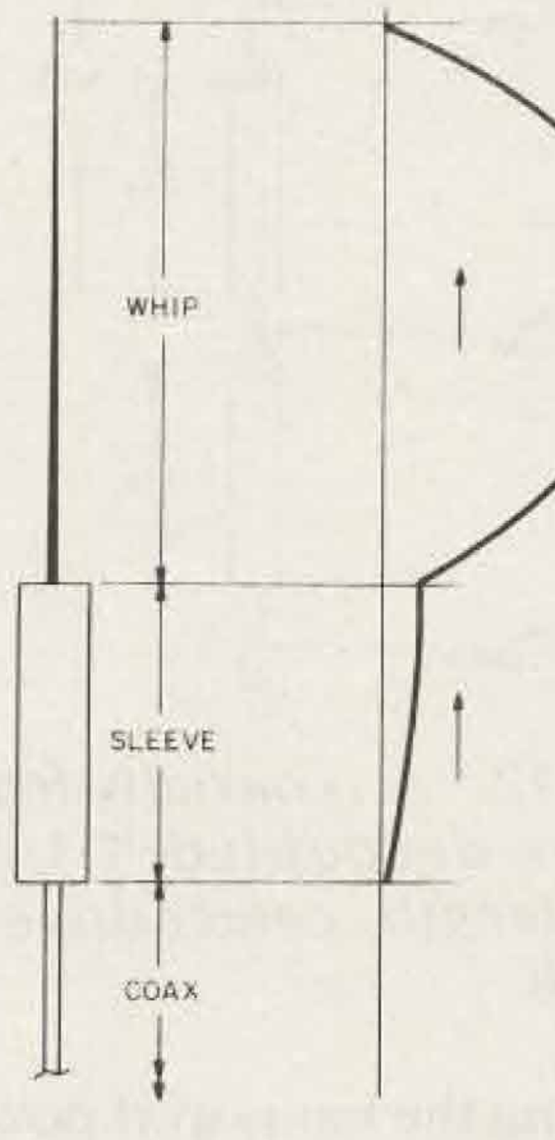

Fig. 9. Current distribution on a sleeve-decoupled half-wave whip.

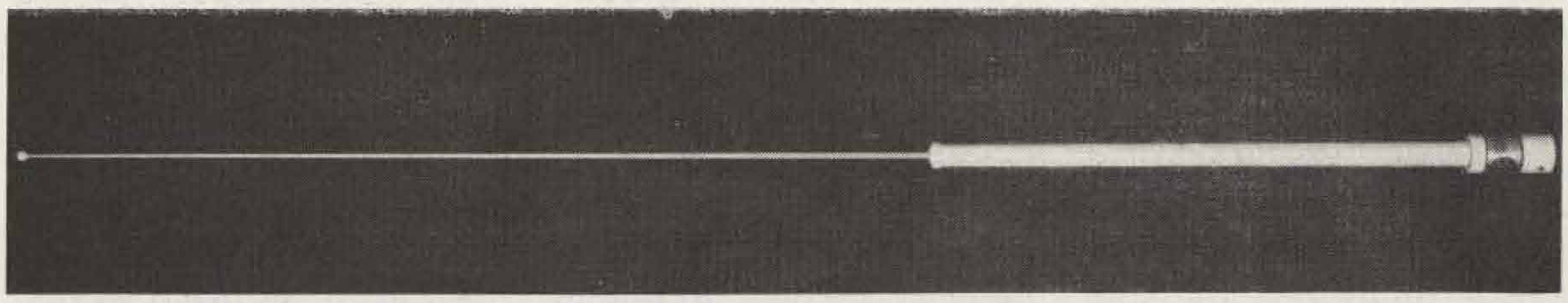

Fig. 10. Sleeve-decoupled half-wave whip designed for marine VHF use.

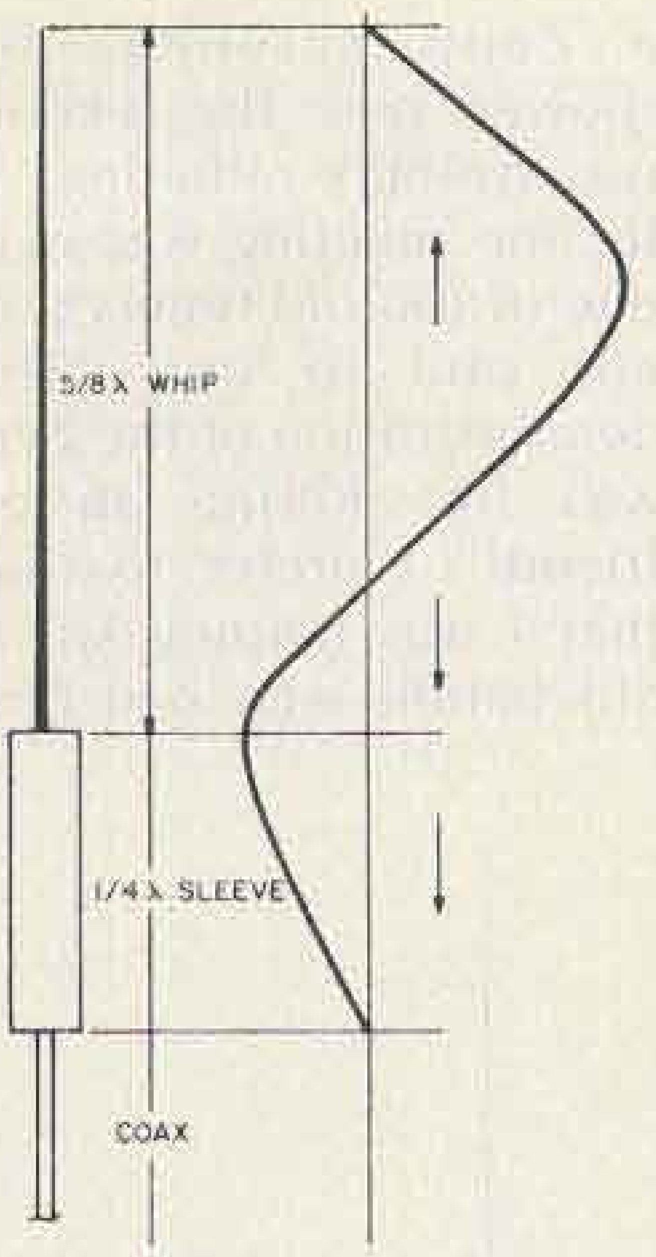

Fig. 11. Current distribution along 5/8-wavelength whip with 1/4-wave decoupling sleeve.

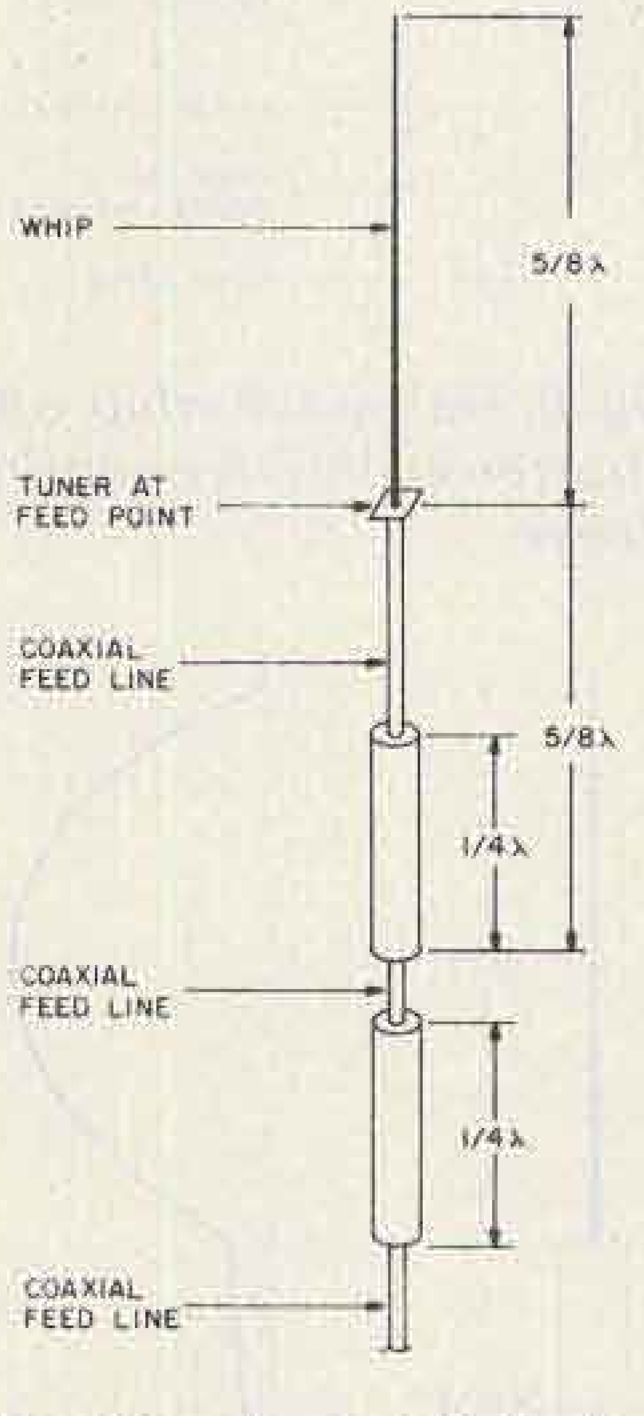

Fig. 12. A coaxially-fed, sleeve-decoupled 1-1/4-wavelength center-driven dipole.

robbing the hams of rf power for years.!

Some representative measured radiation patterns of whips showing the effects of radiation from the coax line are shown in Fig. 7. The azimuthal pattern of a vertical whip is necessarily omnidirectional. The radiation pattern in the vertical plane is most easily measured by supporting the whip horizontally above a turntable, and rotating it in the horizontal plane at a fixed height above the earth. A signal generator on the turntable drives the antenna, and the radiated signal is picked up at some distance away on a horizontally-polarized antenna, amplified, detected, and plotted on an automatic chart recorder, the paper drive of which is synchronized with the rotation of the turntable. The vertical polar diagrams of Fig. 7 were obtained in this way, using a commercial antenna pattern recorder and facilities of the University of Washington. The original recordings were made in terms of a decibel plot on an X-Y recorder, and were carefully replotted in a polar diagram to make the result more generally understandable.

Fig. 7 shows the relative radiated power versus vertical angle for 3 different end-fed whip antennas, all patterns normalized to a maximum value of unity. Each of these antennas was mounted horizontally, with the coaxial feedline extending out in line with the whip for a distance of 8½ feet, and then coming vertically down to near ground level, and then back to the turntable.

Pattern 1 is that of a commercial half-wave whip with tuner in the base. Note how the pattern is of "butterfly" shape, with lobes above and below the horizon. This is a typical result of the radiation from the coax combining in and out of phase with the component from the whip. The pattern would be much worse if even a greater length of coax extended down from the base of the whip, the main effect being to break up the vertical pattern into a mass of lobes, with no assurance that there would be a maximum of radiation toward the horizon.

Pattern 2 is that of a 5/8-wavelength whip with base tuner, and it exhibits considerably more severe degradation than the half-wave whip. This arises from the larger base current of a 5/8 whip than in a half-wave whip, resulting in a correspondingly larger "spill-over" current on the outside of the coax.

Pattern 3 is that of a half-wave whip with a quarter-wavelength decoupling sleeve, to be described in the next section. Only slight pattern distortion is evident, this being due to the small current necessarily excited on the decoupling sleeve.

Finally, pattern 4 is that of a center-driven balanced dipole which is used as a test antenna to calibrate the antenna range.

The Cure

The conclusion to be drawn from the above discussions and test results is this: Use your mobile whip antenna where it belongs (on your car) and be skeptical of any commercially-available antennas which are claimed to be designed for base station use but which consist of an end-driven vertical radiator with no decoupling system evident.

How then can you radiate a clean, omnidirectional, vertically-polarized signal from an end-driven whip antenna, and know that it is performing correctly? Again, we turn to the old pros, the antenna engineers who have known how to design such antennas for the last 40 years, and have been furnishing them to the commercial trade, to the military services, the government agencies, the telephone company, etc. These are the sophisticated users, who are not fooled by advertising claims, and who insist on proof of performance, including measured radiation patterns under specified conditions and measured gain figures, before they buy.

The solution to the problem of end-driving the whip is to employ a suitable "decoupling system" to inhibit the antenna currents from flowing down the outside of the coax. For the VHF bands, one of the most widely used and (when properly designed) highly effective systems employs a 1/4-wavelength section of tubing, extending down from the base of the whip over the outside of the coax line, as shown in Fig. 8. This system is very effective for half-wave whips, very poor for 5/8 whips, and only fair for 1/4-wave whips. (This last design has been called a "sleeve dipole" for many years.)

Note in Fig. 8, which shows a half-wave whip, that the outer conductor of the coax line at the base of the whip is folded down and over the coax in the form of a quarter-wave sleeve, which is open at the bottom. For good decoupling, the diameter of the sleeve must be considerably greater than the outer diameter of the coax line, at least in the order of 5 or 10 to one. Looking up into the open end of the sleeve, one sees a coaxial line with the sleeve as the outer conductor, and the outer surface of the feed coax as the inner conductor. This coaxial line is open at the bottom end, but terminated at its top end in a short circuit. At quarter-wave resonance, there is a high impedance between the lower lip of the sleeve and the inner coax line. This impedance is in the path of the "spill-over" current, and forces a current minimum to exist at this point. There is a portion of a standing wave of current on the outside of the sleeve, with maximum amplitude at the top of the sleeve. This maximum amplitude is small, since it must be equal to the base current entering the whip. The other end of the standing wave is at the open end of the sleeve, where the current amplitude is practically zero. The outside of the coax line below the sleeve is now very effectively decoupled from the antenna. The current distribution along the entire structure is shown in Fig. 9. The small section of a standing wave on the decoupling sleeve is in phase with the current on the whip, but has little effect on the radiation pattern, as was shown in Fig. 7. A commercially-available version of this antenna, designed for the 156-162-MHz marine VHF band, is shown in Fig. 10. This antenna is particularly attractive for masthead mounting on sailboats, because the decoupling sleeve prevents the stays, shrouds, mast, etc., from becoming inadvertent parts of the antenna.

A 5/8-wavelength whip cannot be decoupled effectively with a quarter-wave sleeve, as can be seen by the current distribution shown in Fig. 11. The standing wave of current along the whip has a phase reversal one half wavelength down from the top. The feedpoint current amplitude is 70 percent of the maximum current, and the current at the top of the decoupling sleeve must have the same amplitude and phase as the current at the base of the whip. The result is that even though the coax line below the sleeve may be fairly well decoupled, the radiation pattern of the antenna will be poor. Radiation toward the horizon from the upper and lower halves of the system tends to cancel, with maximum radiation occurring in lobes at high and low angles.

A more intelligent way to drive a 5/8-wavelength whip is to place the quarter-wave decoupling sleeve down below the feedpoint so that the open end of the sleeve is 5/8 wavelength below the feedpoint, as shown in Fig. 12. The antenna now becomes a center-driven 1-1/4-wavelength dipole, which happens to be the "magic" length needed to produce power gain toward the horizon of 3 dB with respect to an ideal vertical half-wave dipole. This is the maximum gain attainable from a center-driven dipole, and is certainly worth getting.

Experimental measurements have shown that a single quarter-wave sleeve terminating the bottom end of the 5/8-wavelength antenna is insufficient to provide good decoupling of the coax cable below. Unlike the case of the decoupling sleeve on the base-driven half-wave whip, there is now an antenna current maximum at the top end of the sleeve. The decoupling is found to be only partial, and the radiation pattern shows degradation from the currents on the

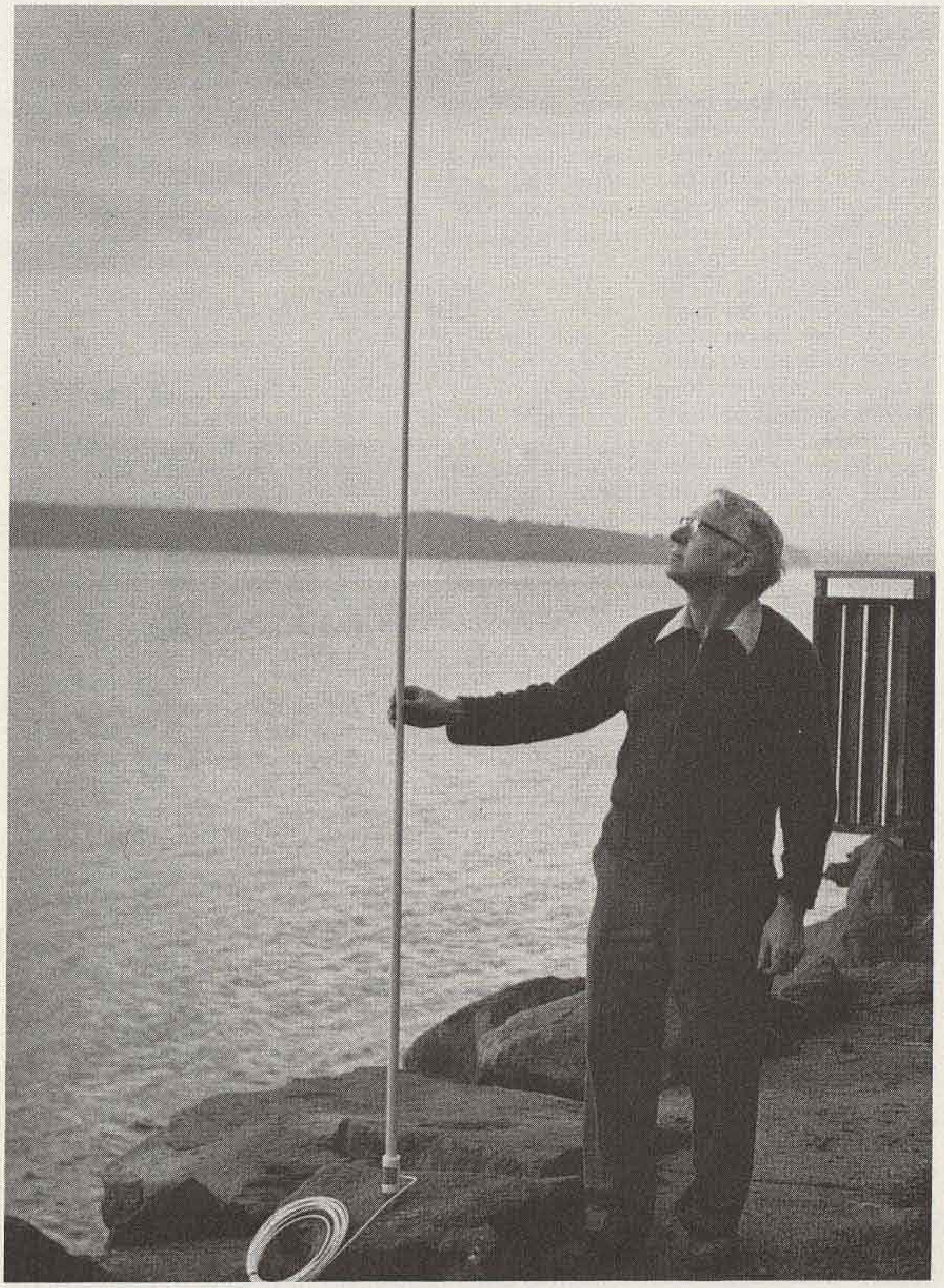

Fig. 13. Commercial VHF version of marine antenna shown in Fig. 12. Here, the author provides temporary (and decoupled) support.

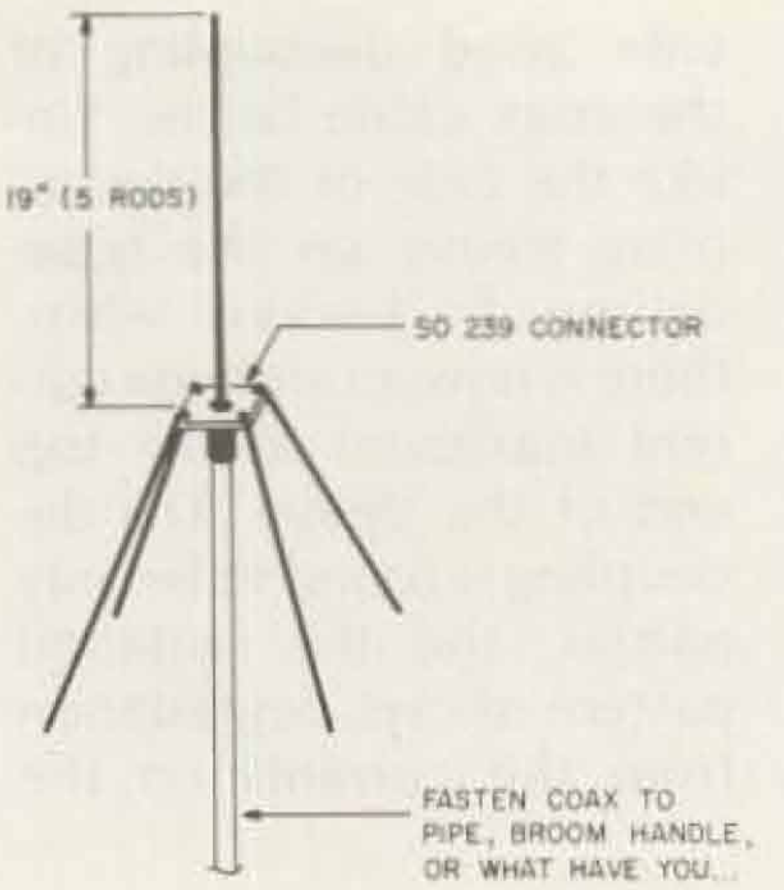

Fig. 14. The "famous" coat-hanger special.

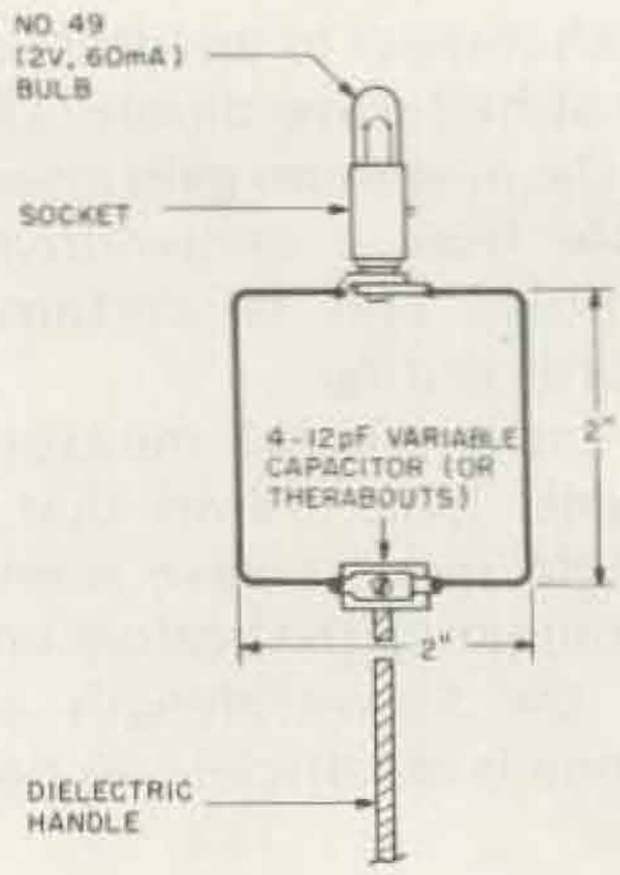

Fig. 15. An rf sniffer for the 2-meter band.

outside of the coax below the sleeve. The cure is to place a second quarter-wave sleeve below the first, as shown in Fig. 12. A commercial marine VHF antenna utilizing this construction is shown in Fig. 13. The upper 5/8 whip, the tuner, and the two quarter-wave sleeves are enclosed within a tapered fiberglass tube. The ratio of the diameter of the lower decoupling sleeve to the braid diameter of the coaxial line (RG-58A/U, in this case) is about 6 to 1, ensuring good decoupling.

This antenna produces a vertical radiation pattern very close to that of an ideal, isolated, center-driven 1-1/4-wavelength dipole in free space, unaffected by the feed cable at the bottom end. Another antenna based on the same principles has recently been announced for amateur radio service in the 2-meter band. It is designed for base station use and features twin decoupling sleeves of conical shape in order to obtain an adequately large mouth diameter in a rigid structure.

This article would be incomplete without a mention of the ideal antenna for the amateur who wishes to rush a 2-meter base station on the air on an absolutely minimal budget. This is the famous "coat hanger special," which actually *can* be made with coat hanger wire, and which performs spectacularly better than just about any automotive-type whip antenna when connected to the end of a length of coaxial cable. Fig. 14 shows the details.

This simple antenna, made on a UHF coaxial chassis connector, behaves like a vertical, center-driven half-wave dipole. Note that the 4 radial rods, referred to erroneously by many people as a "ground plane," are bent down at about a 45° angle from the horizontal. *Don't* mount these rods so that they extend out horizontally from the base of the whip. To do so will produce (1) a radiation pattern in which maximum radiation is lifted from the horizon, and (2) an input impedance of around 35 Ohms, resulting in a mismatch on a 50-Ohm cable. Bending the radial rods down at about a 45° angle (1) brings the maximum radiation intensity down to the horizon, and (2) brings the input impedance up to about 50 Ohms, giving an excellent impedance match. A low vswr over the entire 144-148-MHz band will be obtained.

Although a good antenna, the coat-hanger special is not the answer to all of the world's problems. It is driven at a point of current maximum, and there is no reason to believe that all of the spill-over current will be confined to the radial rods. Some current is bound to flow down the outside of the coax, and will produce standing waves of current, interfering with the radiation pattern of the antenna. The hope is that the 4 radial rods, being of resonant length, will hog the current, keeping the spill-over current along the outside of the coax small. To check your coat-hanger special, use your rf sniffer. If you detect appreciable rf on the coax below the antenna, try adding (or subtracting) about a quarter wavelength of coax to (or from) the feed cable. The reasoning behind this move is to try to make the outside of the coax change from an antiresonant to a resonant condition.

The Rf Sniffer

The rf sniffer alluded to in the previous discussions is easy to build from junk-box parts. Even if one buys all of the components at a radio store, the total cost is unlikely to exceed $2.00.

The sniffer consists of a loop of wire, a pilot light, and a tuning capacitor all connected in series. The relative positions of the 3 components is immaterial. You can put the tuning capacitor right next to the lamp if you wish, or connect it in series with the loop on the side opposite to the lamp. I like to use a 2-volt, 60-mA bulb (No. 49) because this produces good sensitivity. The capacitor can be a compression mica-type, a ceramic variable, a tubular plastic variable, a miniature air variable, etc.

The dimensions of the loop shown in Fig. 15 are suitable for the 144-148-MHz band. The actual capacitance required to achieve resonance will be a function of the loop area and the wire size. By using No. 20 copper bus wire and the loop dimensions shown, resonance will be obtained somewhere within the range of 4 to 12 pF.

While the light bulb can be soldered into the loop, a socket is recommended. The bulb can easily burn out, especially when you are showing your friends how poorly their antennas are decoupled! It is also convenient to glue the sniffer to the end of a stick, plastic tube, or rod, to prevent your hand from detuning the loop.

Conclusion

This article can be summed up as follows: 1) There is no such thing as a one-terminal impedance; 2) A whip antenna cannot be end-driven successfully from a coaxial transmission line unless an appropriate decoupling system is incorporated in the design.

When the ham attaches an automotive-type whip to a length of coax line to serve as a base station antenna, he is doing so at his own risk. Ideally, the manufacturer or the dealer should call the attention of the buyer to the bad effects of this kind of misuse of the product. This is similar to the responsibility of a manufacturer of medicine to call the buyer's attention to the possibility of adverse side effects! A more serious situation exists in the case of some end-driven base station antennas, currently on the market, which totally lack any form of decoupling.

Armed with information gained from this article, and with your rf sniffer in hand, you should now be able to approach the marketplace with a more critical eye, asking the dealer embarrassing questions about spill-over and decoupling, and insisting on proof of performance! So much of the electronic equipment offered to the amateur radio buyer today is truly representative of the state of the art that it is high time that we elevate the antenna to this same status. ■