This month we begin a three-part series on basic antenna information written by our own Lew McCoy, W1ICP. Included will be some antennas you can build and helpful hints on improving your station.

Basic Antenna Information Part I

BY LEW McCOY*, W1ICP

From the mail I receive, I note that no matter how many times I write about basic antenna information or feed lines, I still get requests for more. A lot of the mail comes from new amateurs, plus there is the continued intense interest in antennas by just about everyone else. When I listen on the air, I find that while antennas seem to be the main topic of discussion, there is a lack of basic knowledge on the subject. So here is another round, plus some cheapy antennas worth trying.

Feed Impedance—What Is It?

Every antenna must be fed radio frequency energy (RF) from the rig in order for the antenna to radiate. (That statement is certainly basic!) Where we attach the feed line to the antenna is of course called the feed point (see fig. 1). The feed point contains three different properties (only two if the antenna is exactly resonant). One of these is the radiation resistance, which is not a true resistance, but is that part of the antenna feed point that couples the RF to space and results in radiation. The radiation resistance is the important part of the feed point.

Next we have ohmic resistance, which is real resistance. This exists in the antenna wire, plus any hardware directly in the antenna, and the resistance in such things as insulators (or traps). Ohmic resistance is strictly a loss as far as the antenna is concerned. Any power is dissipated as heat in the ohmic resistance.

The last item in the feed point is reactance, which is also expressed in ohms. Reactance only exists when an antenna is operated off resonance. In other words, an antenna that is purely resonant will have no reactance. However, we can normally think of an antenna as only being purely resonant on a kiloHertz or two.

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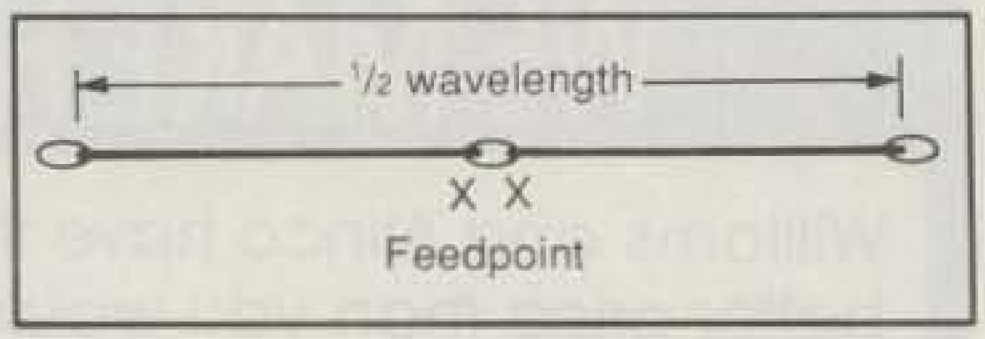


Fig. 1– This is a simple dipole. The feed point as discussed in the text is at X – X.

Whenever we change frequency from such a point, we introduce reactance, so the majority of the time we have reactance present.

If an antenna is too long for a frequency, it has inductive reactance; if it is too short, it has capacitive reactance. While reactance is expressed in ohms, you cannot dissipate power in a reactance. The reactance acts—in the simplest of language—as a gate or a door that stops the flow of power to the antenna. In order to get power into or through the impedance, you must introduce an equal amount of the *opposite* reactance into the circuit, which will cancel out the other reactance. This is called "tuning out the reactance." Once an amateur understands reactance, antennas and their feeding become much clearer.

Therefore, we find that the impedance of an antenna contains these three items, all listed in ohms. The exact value of the impedance will depend on many conditions, as we will see.

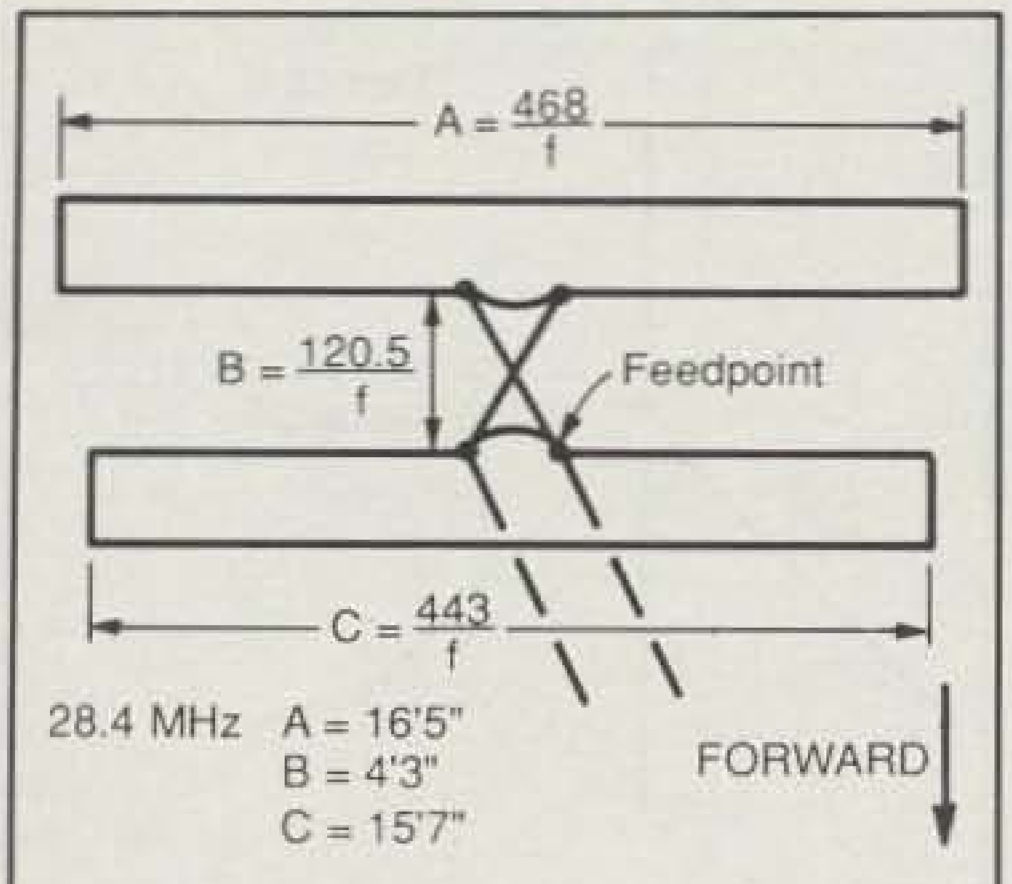
SWR—Standing Wave Ratio

Probably the most popular subject heard on the air is that of SWR—standing wave ratio. Amateurs treat SWR as they would the health of their mother-in-law or the IRS—with lots of interest and respect. A feed line has what is called a "characteristic impedance," and this is determined by the size and spacing of the conductors plus the dielectric of the material used to separate the conductors. Because these items remain constant, the characteristic impedance of a feed line always remains the same.

The standing wave ratio is determined by the antenna feedpoint impedance (in ohms) and the impedance of the feed line (also in ohms). We calculate the SWR by dividing one impedance into the other. For example, a 100 ohm impedance fed by a 50 ohm line would have an SWR of 2 to 1 (100/50). In the October 1951 issue of *QST* I had an article called "The Monimatch," which was about a rather simple circuit that would measure standing wave ratios in coaxial lines. The methods of measuring standing wave ratios were known, but no one actually had built an inexpensive working device at that time. The Monimatch was an easy-to-build, inexpensive unit that immediately caught on with the amateur fraternity. It was reasonably accurate, but what was important about the device was that it really changed the course of amateur radio. Amateurs who had been working out without any serious problems and who were perfectly happy with their system suddenly had a way to measure SWR, and what they found drove many of them up a wall (or I should say tower, so to speak). From that time on everyone using coaxial feed lines was very unhappy if he or she didn't have an SWR of 1 to 1, or very close to it.

Up to that point in time, in fact, we had transmitters that could couple any mismatched antenna load because the method to do so was built in. But as time went on there was less and less home-built gear, and the commercial gear gradually became fixed tuned devices that required a fixed load, usually 50 ohms and a 1 to 1 SWR. That is what we have today.

In order for modern transceivers to work efficiently, the antenna system load must be near a perfect match—or more bluntly, be less than 2 to 1 mismatch. This is the load presented at the antenna terminal of the transmitter. Let's digress for a moment and go back to impedances.



This is an antenna called the ZL-Special, which is a very excellent performer and to my knowledge has been around for many years. In fact, I used two different construction versions back in 1947. It consists basically of a driven element and reflector, both folded dipoles and both driven via a 135 degree phasing line. The antenna has a gain over a dipole of approximately 5 dB. Theoretically, and for a single angle, it could have an *infinite* front-to-back ratio. But in actual practice, in my own tests, I found it to be on the order of 20 dB—maybe slightly more (which is not a bad number by any means).

As people who know me can state, I love to make good-performing antennas. The ZL-Special can be constructed for relatively little cost. The antenna can be constructed from 300 ohm twin lead or 450 ohm open-wire line. Also, in the drawing are the formulas for each of the three pieces—the driven element, the reflector, and the phasing line. For example, the longest element is derived from 468 divided by the frequency (in megaHertz—468/28.5 MHz = 16.4 feet).

At the time I built mine bamboo fishing poles were common, so I merely taped the twin lead to the poles and then mounted the poles on some 2 × 2 wood supports. The boom was a 2 × 4. You could use the same techniques, but use PVC ½ inch diameter pipe to hold the twin lead. If you are only concerned about two directions, you can support the ends of the beam with two wooden or PVC rods and then flip the antenna over to change directions. Don't write and ask me how this antenna would work if it was suspended from one end, *a la* vertical. I don't know. If you try it that way (and it *should* work), write and let me know.

The feed-point impedance of this antenna is about 70 ohms. Certified Communications sells 70 ohm twin lead, so you could use that to the station and then a 1 to 1 balun into your rig. The 70/50 ohm mismatch is not worth worrying about. Still another method (and the one I used) is to feed with 300 ohm line (or the 450 ohm line), bring the feedline into the station Transmatch, and tune the system. The SWR in this case is not worth considering, and the system worked fine for me. This antenna, as I said, is an outstanding performer and costs very little.

Fig. 2– The ZL-Special, an outstanding performer which costs very little.

You know what the impedance is composed of by now, but what determines the value of the impedance?

There are many factors that control the impedance. The first and primary one is the length of the antenna. For example, an 80 meter half-wavelength antenna, about 130 feet long, would have a center impedance of 70 ohms (if the antenna was the correct height above a perfect ground). Of this 70 ohms about 68 ohms would be the useful radiation resistance, while only 2 ohms would be ohmic losses. This is very efficient. In fact, the simple half wavelength dipole is the most efficient antenna you can find. But instead of 80 meters, what happens to the antenna impedance when we go on 40? Here we have a full-wavelength antenna and the impedance goes up to 4000 ohms or so. With a 50 ohm coaxial feed this would mean an SWR of 80 to 1! I can guarantee your modern transmitter would be completely shut off with such a load.

We see therefore that the length of an antenna greatly affects the impedance. However (and keep this in mind as we discuss antennas), usually, regardless of the impedance, the bigger the antenna is for a given frequency, the better it is. There is an old joke in amateur radio about this: Always make your antenna as big as possible and put it up as high as possible. If it stays up, then it isn't big enough or high enough!

Another factor that controls the impedance is the height of the antenna above ground. Also, the antenna's proximity to trees, metal, power lines, etc. will affect the impedance. In a beam antenna the presence of the reflector and director greatly affect the impedance. I am not sure if it is *always* true, but usually the presence of other objects *lowers* the impedance. Also, shortening an antenna physically will always reduce the radiation resistance. For example, shortened verticals require matching devices to transform the impedance of the antenna to that of the feed line used.

The most startling example of a shortened antenna would probably be an 8 or 9 foot mobile whip used on 80 meters. The radiation resistance becomes a fraction of an ohm, while the ohmic resistance is on the order of a couple of ohms. Remember what I said at the start: The radiation resistance is the useful part of the impedance. Assuming you were running 100 watts into an 80 meter mobile whip, only a fraction of the power would be radiated because the ohmic losses would consume nearly all the power as heat. This is why it is so important to use good grounds in HF mobile work—just so you can reduce those ohmic losses and have a better ratio of ohmic to radiation resistance.

I don't want the uninitiated to be misled here. I am talking strictly about impedances of drastically shortened low-band verticals, not, for example, 20 meters and up, where full quarter-wavelength verticals are normally used. (On 20 meters a quarter wavelength is on the order of 16 feet or so.) In these cases the radiation resistance gets up to 30 ohms or so, meaning ground losses are not as pronounced.

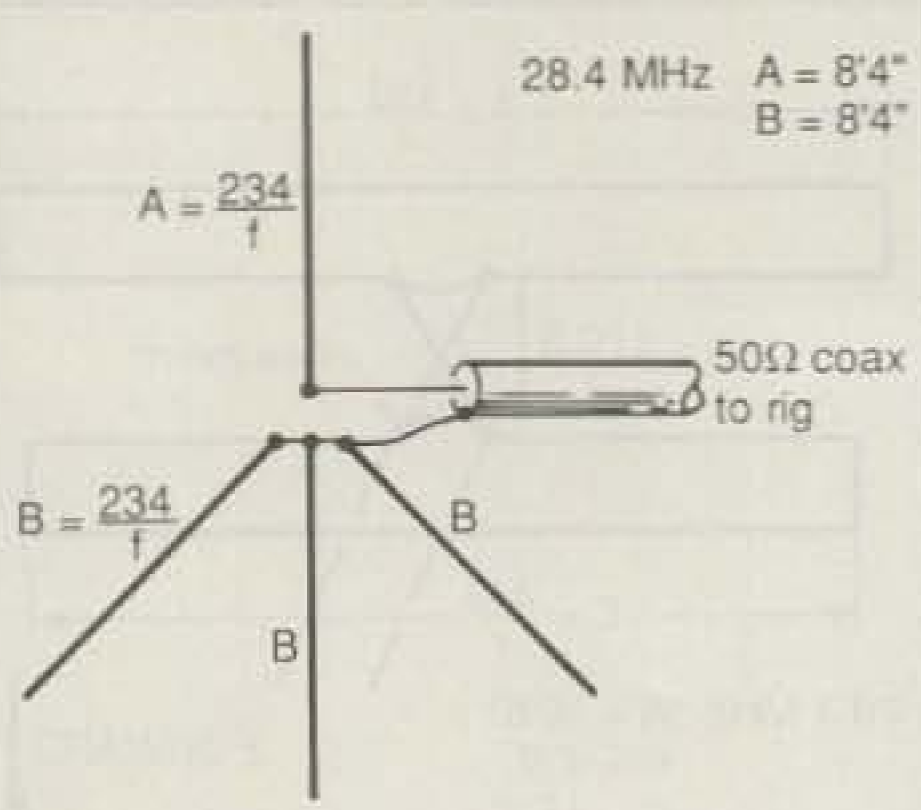
Antenna Gain— What Do We Mean?

One subject an amateur will hear probably more than any other is that of antenna gain. There are two basic ways in which we relate antenna gain, and now because of computers we are getting a third. The first is to rate gain of antenna as compared to an isotropic radiator. An isotropic radiator is really a theoretical antenna and does not exist in actual practice. Basically, an isotropic antenna is one which radiates equally well in *all* directions. The sun or a star would be a fairly good example of an isotropic radiator.

The second and more common method is to compare an antenna's gain with that of a common half-wavelength resonant dipole. When we compare antennas to an isotropic radiator, we rate them as decibels of gain over an isotropic, or dBi (when the antenna is compared to a dipole, dBd). The actual numbers are simple enough. Considering the isotropic to have zero gain, then a half-wavelength dipole has a gain of 2.14 dB compared to the isotropic radiator. (A half-wavelength dipole will have a figure-eight pattern with two main lobes, and it is these lobes which have the gain.) A three-element Yagi beam, for example, could have a gain of 7 dB over a dipole, or we could add 2.14 gain—9.14 dB gain over an isotropic.

The third measurement that is cropping up involves computer modeling. First let me state that with the advent of computers programs are now available which will completely analyze any antenna you can dream up. In this case we can have two ratings—(1) a thing called free space gain, which like the isotropic is a theoretical gain but is extremely useful in modeling and comparing antennas, and (2) the actual modeled gain over real ground.

In free space there is nothing to "modify" the antenna pattern unless you put something else directly in the antenna area when it is being modeled. When we model, say, a dipole over earth, we apply 3 dB gain to the antenna's major lobes. In addition, if the earth happens to be a perfect reflector, the sky signal is augmented by 3 dB with the signal reflected by the perfect earth. This is oversimplifying the explanation, but you could wind up with as much as 6 dB gain as compared to a free-space pattern. All this means is that there are three (or four if we count



This diagram shows a basic ground-plane vertical with three radials. This is one of the simplest antennas to build, and it is guaranteed to work. I use electrician's thin-wall ½ inch diameter tubing for the element. PVC is slipped over the base to make an insulated support. The formula for ¼-wave heights is given, and these lengths apply to both the vertical and the radials (wire).

As shown in the diagram, the antenna is fed at the base with 50 ohm coax, the inner conductor going to the vertical and the shield connecting to the three radials. The feed impedance of this antenna is on the order of 35 ohms, which is very close to a match. Having the radials slope downward raises the impedance, and at about a 45 degree slope the impedance will approximate 50 ohms. Many amateurs mount their verticals on wooden or insulated poles and then use the radials as part of the guying setup. The ends of the radials should be kept out of reach because of the possibility of RF burns. The antenna can be mounted at earth level, but performance always improves with height.

Fig. 3– A basic ground-plane vertical with three radials.

free-space modeling) methods of assessing gain.

To Match or Not To Match

You'll often hear the statement that the best antenna is a resonant antenna. I don't agree because the statement is misleading, and I will show you why. In the first place, as I pointed out in discussing impedance, an antenna is only going to be resonant for a very, very few kiloHertz. It would be fine if we were in the broadcast business and limited to a single frequency, but we are not. We QSY up and down the band or bands, many times with the same antenna, as the mood suits us. So raising your blood pressure over having a resonant antenna is pointless. What isn't pointless is that we must get the power into the antenna.

Our problem resolves itself down to a rather simple one: How much power can we get out of a modern solid-state transmitter before it shuts itself down, and/or when does the antenna system become reactive? In some cases you can tolerate a 2 to 1 mismatch in the antenna system, but I have found from experience that modern rigs tend to shut down at about 1.5 to 1 or slightly higher.

Antenna impedances can vary widely, from as low as a fraction of an ohm to well over 4000 ohms, and with plenty of reactance present. As I mentioned earlier, an 80 meter half-wavelength dipole has an impedance of about 70 ohms on 80, but when used on 40 it becomes a full wave with an impedance of 4000 ohms. Unfortunately, coaxial feed lines do not like high SWRs because the losses go up, as does the danger of line breakdown when using high power.

The problem that many amateurs, particularly newcomers, have is understanding reactance, mismatches, and the role a Transmatch plays. It can be a very complex subject for any given system. However, it is possible to simplify the subject to a certain degree. First, let me dispose of a few erroneous conclusions many amateurs reach. Some amateurs believe that if you have a very high SWR, the feed line will radiate (and cause things such as TVI and BCI). This is erroneous thinking. Regardless of the SWR, the SWR will not cause a line to radiate. Keep in mind that all two-conductor lines as we know them (including coax) are essentially balanced lines. I realize that many amateurs will jump up and down and say that coax is an unbalanced line, but if you really think about it, you will see that the two conductors in coax are symmetrical, or balanced as to each other. The important point here, though, is that being symmetrical, the RF currents flowing in each conductor cancel any radiation from the line (or are supposed to). Sometimes RF from the antenna will be coupled back to the feeder, creating a condition called parallel standing waves, and in such a case the feed line will radiate. However, this is not supposed to happen. (Much more about this condition later.)

Also, without becoming too technical, any reactance present at the antenna will exist in the system load—or should I say "can" exist but may be a different value. What is important here is that regardless of how bad this mismatch is, or how much the reactance is, it is possible with a Transmatch to adjust the device so that you always present a perfect 1 to 1 load at the transmitter. And again, we make the *system* resonant. What we are able to do is tune out the system load reactance, step the impedance up or down to match the 50 ohm output of the transmitter, and thus get maximum transfer of energy and good efficiency.

Antenna Installation

Covering the subject of antenna installations could require an entire book, but there are some basics worth noting here. I am going to treat feed-line radiation later, so I'll only touch on it briefly here. If the antenna has a desired pattern, then it is imperative that the feed line does not radiate. One way to help avoid the problem is to make sure of the manner in which the feed line comes away from the antenna. In a beam installation where a tower is used, it is important that *all* lines are brought down straight from the beam at least one-quarter to one-half wavelength (lowest frequency) from the antenna. In fact, if the lines can be buried at the bottom of the tower and carried underground to the station, this will create the best possible installation. Of course, you cannot bury open-wire lines. Try to bring the feed line down from the antenna as straight as possible and far as possible before going to the station.

Probably the most common type of multiband antenna (80 through 10, or even including 160) is an inverted Vee. Usually the center of the antenna is hung from the tower or a high support and the ends brought down. Many amateurs go to great lengths to try to orient such antennas for 80 or 40 so that they *think* they are getting the maximum lobe in a desired direction, as determined from handbook antenna patterns. The only problem here is that in order to obtain the desired pattern on these bands, the antenna has to be on the order of at least 60 feet high on 40 and twice that on 80. As you approach the earth, the patterns on these bands tend to become omnidirectional, so in essence you have to accept the fact that the antenna will be omnidirectional on these bands. I might add this is also true of strictly horizontal antennas. It is true that there is some vertical low-angle radiation from inverted Vees, but such patterns are very difficult to predict. The best test here is to put 'em up and try 'em.

In part two of the series we will continue this discussion.

(to be continued)

Last month we passed through the land of Reactance and Impedance on our way to understanding antennas. This month we pick up our travels when we study actual antenna systems.

Basic Antenna Information Part II

BY LEW McCOY*, W1ICP

In the first part of this series I discussed antenna impedances and reactance, plus how to handle them. Now let's get into actual antenna systems.

The "Best" Multiband System

For years I have pushed very hard for one type of multiband antenna system—so hard, in fact, that many amateurs call it the McCoy system. It would be dishonest for me to claim credit, because the antenna system existed long before I started extolling its virtues. Before discussing this and other systems please allow me to philosophize about amateurs and antennas, if I might.

From my years of observations (some 60 years to be exact) I have found that amateurs are essentially lazy, and I am no exception. Why? Such a statement is easy to prove.

After World War II coax feed line became very popular. At the same time television came along, creating severe problems for many, many amateurs. Amateur radio quickly went to completely shielded transmitters, shielded filters, and coaxial feed lines. This created antenna problems for amateurs who wanted to operate multiband but still maintain their 50 ohm integrity in filters and so on.

An amateur named Buchanan, W3DZZ, who was (and is) very smart, came up with the excellent concept of using traps (coils and capacitors) in dipoles and beams to "multiband" them in that he used a single coaxial feed line. (You learned about reactance earlier, and a "trap" is merely a device that presents an extremely high reactance to undesired frequencies, but the reactance doesn't exist on the desired frequency or band.)

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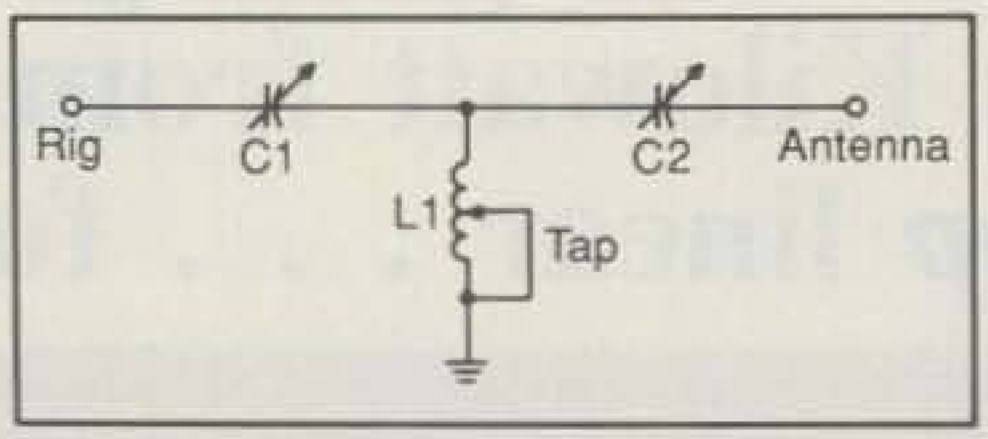


Fig. 1- This is the basic circuit used in many of today's Transmatches. This simple T network will match any load from zilch to zilch. The typical values are as follows: for C1, 250 pF, for C2, 300 pF, and the variable inductor 18 or more microHenries to cover from 80 through 10 meters. L1 could be a tapped inductor, but the matching range is not as great.

The impedance of these multiband beams and dipoles would stay somewhere near enough to 50 ohms so that amateurs could use 50 or 70 ohm coax. At that time, in 1953, the transmitters had very flexible amplifier tank circuits in the output of the rig. It was possible to tune out reactance and match the antenna *system* to the rig. Keep in mind that even with trap antennas it was well nigh impossible to have a match of 1.5 to 1 across some bands.

What I am repeating here is that with modern solid-state rigs, a darn near perfect load is required. In fact, I find it amusing, because most of the modern rigs are now marketed with built-in antenna tuners (that sometimes cost extra) which are really an extension of the old-fashioned tank circuits.

What you find with antennas is that it is virtually impossible to come up with a trap or "loaded" antenna that will cover all bands, particularly 80 through 10 meters, and all frequencies and stay below 2 to 1 SWR. There was one broadbanded 80 meter dipole marketed for a while which used a complex transformer in the feed point which was nearly a perfect match across the band, but I haven't heard of it in years. Also, you can install resistors in the antenna network to obtain broadbanding, but I consider this wasteful of power.

There is one approach to always maintaining a 1 to 1 load at the rig, and this is via the use of a Transmatch. If your normal SWR is no higher than 5 to 1 and you are running up to the legal limit, then I would consider it okay to use a Transmatch and a good grade of coax of the half inch diameter type, but *not RG 58/U!*

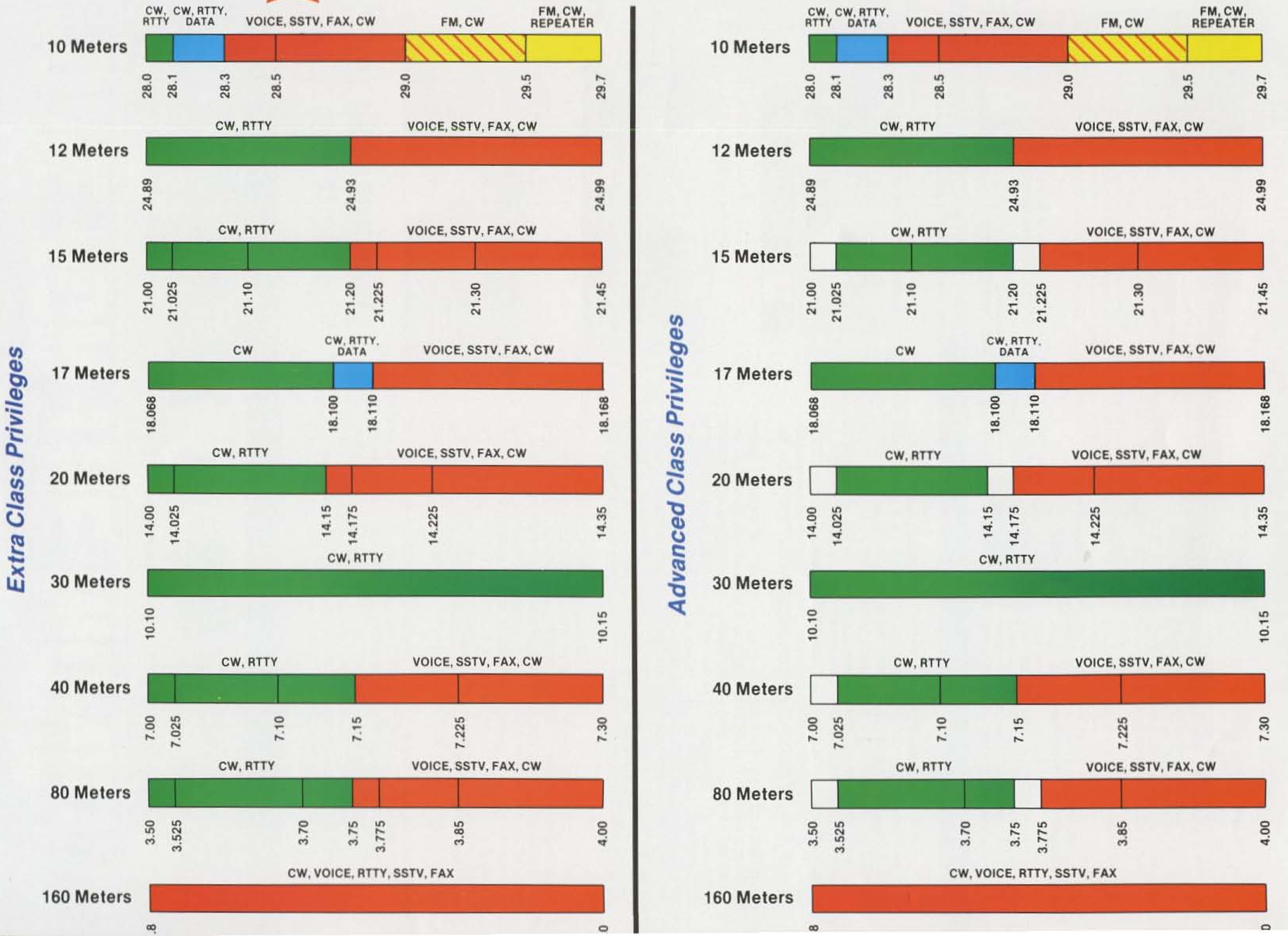
The Transmatch—Its Importance

As I stated, we rarely use a resonant antenna, but we can operate quite easily with an antenna system that is always resonant. An "antenna system" can consist of the antenna proper, the feed line, the ground connections or leads, material used to support the antenna, nearby objects, and so on.

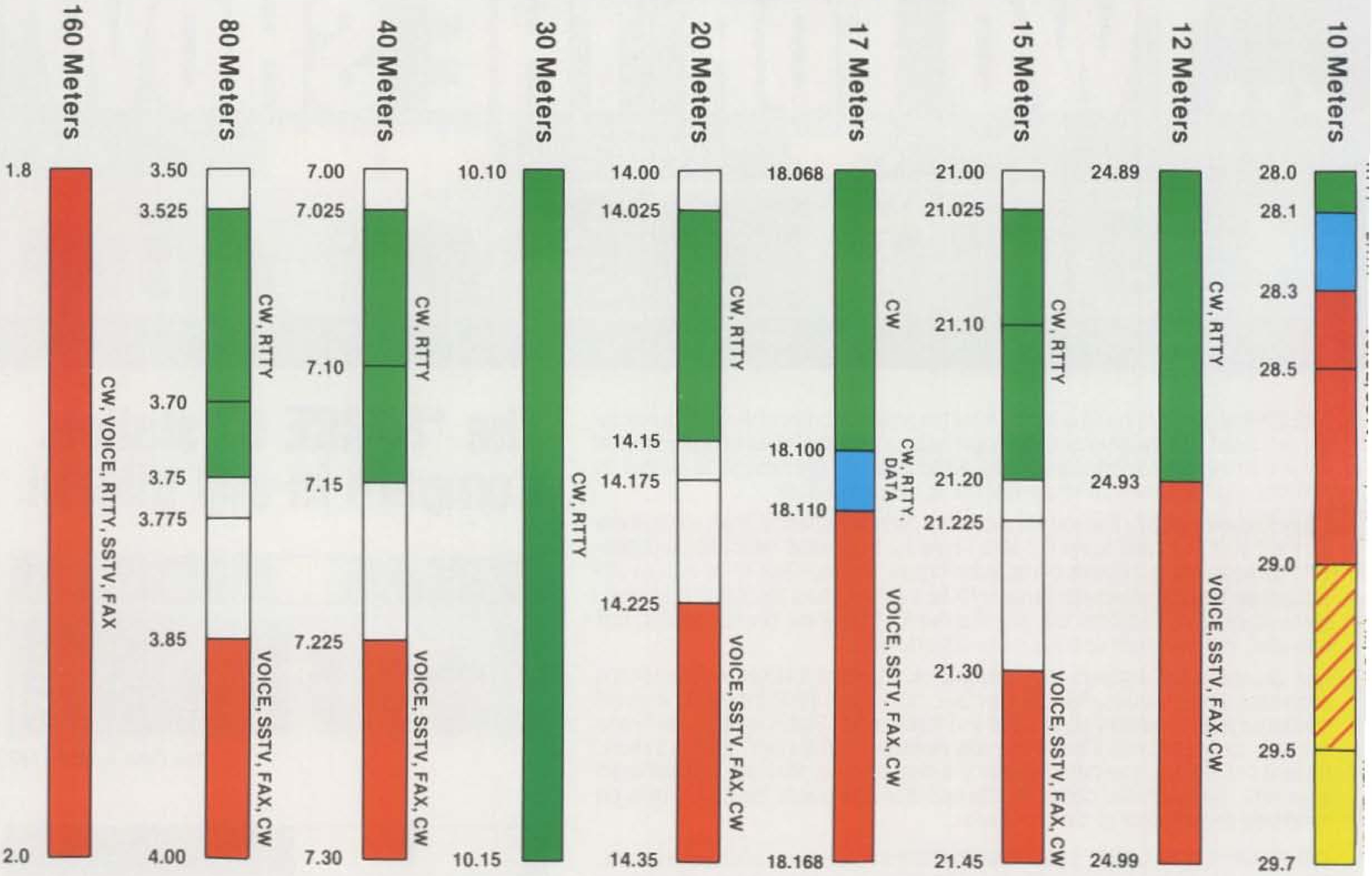
As I said earlier, we must "tune out" the reactance in order to get an antenna system to take power. We can do this by using a Transmatch (another but technically inappropriate name is "antenna tuner"). A Transmatch could be called an adjustable RF transformer and reactance "tuner-outer." It basically takes the antenna system load that is presented at the end of the feed line in your station and converts that load to a pure, non-reactive 50 ohm load—or in even simpler terms, a 1 to 1 load.

Fig. 1 shows the circuit of a basic Transmatch that is capable of converting any system load to a perfect 1 to 1 load, or very close to it. Also shown is a photo of a Transmatch that I built and described a few years back in *CQ* (September 1986). This unit, called "The No Holds Barred Transmatch," will match anything—and I do mean anything—and is not difficult to

H.F. Amateur Radio Frequency Chart



General Class Privileges



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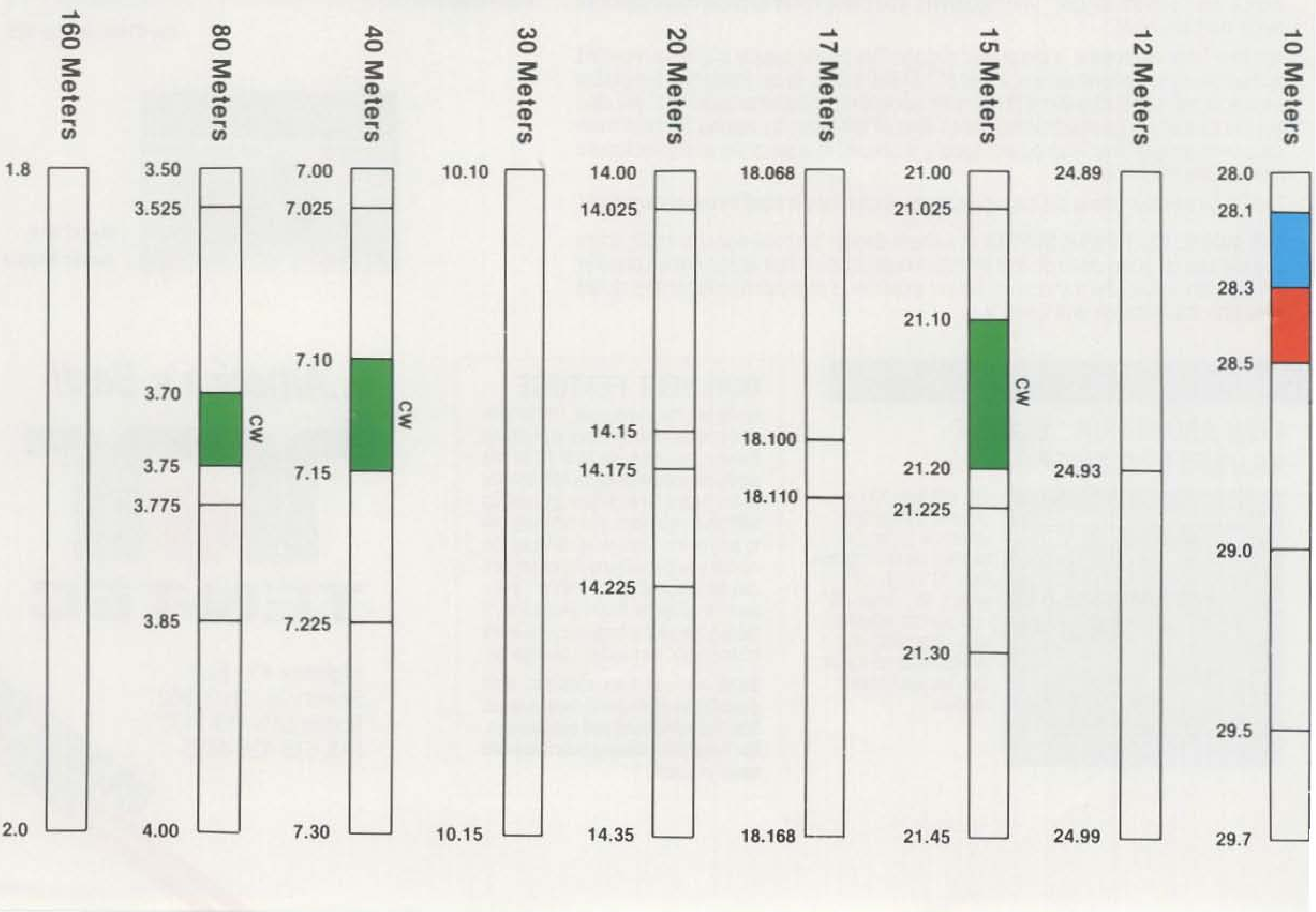
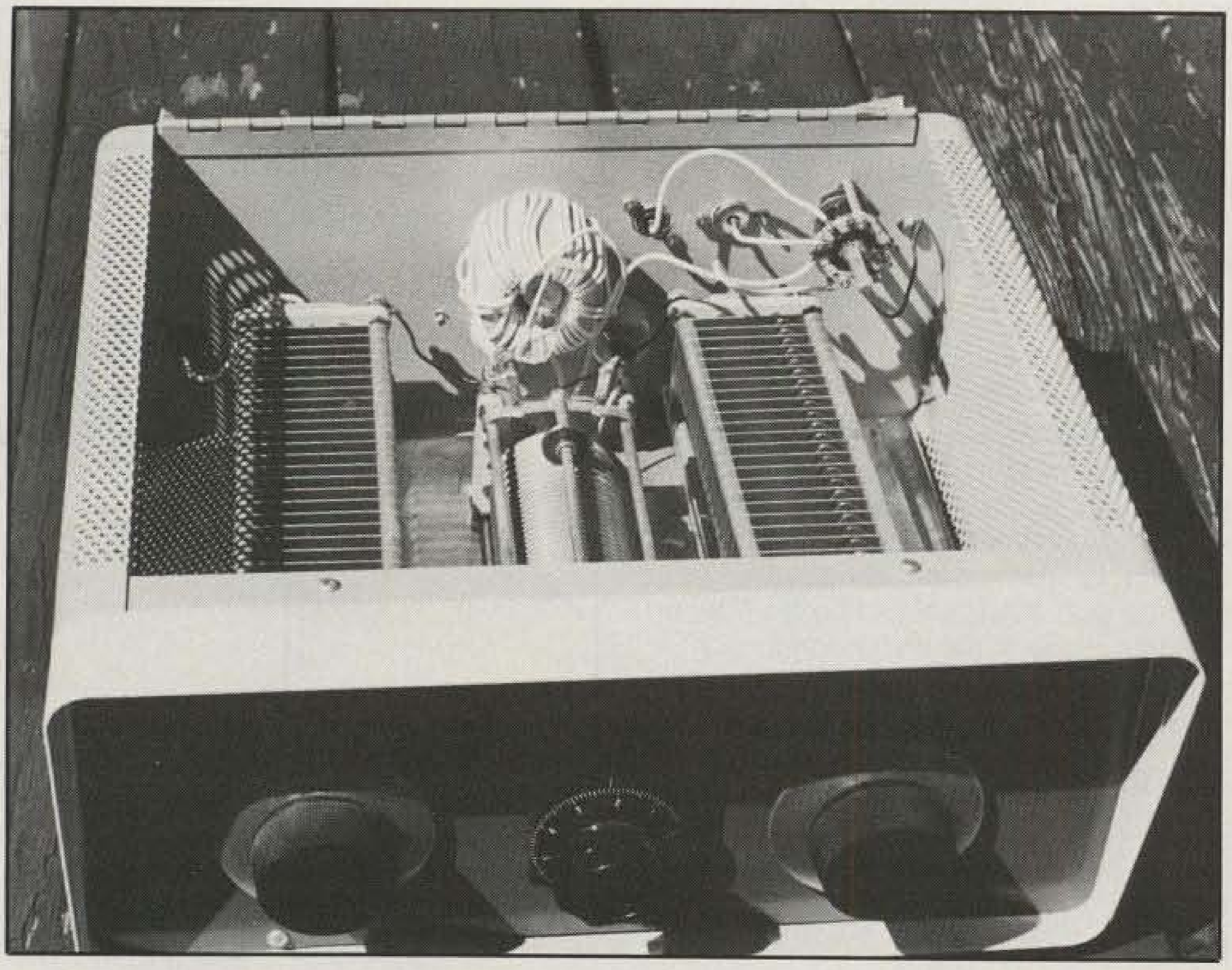


NOTES: (1). These charts are intended for general reference by Amateurs and can in no way include full details shared with fixed service outside the U.S. Use caution to avoid interference with these services. (6). Novices are also per-



This is an interior view of the No Holds Barred Transmatch. This unit will handle the legal limit and will match any *antenna load the user will encounter.*

build. (Photocopies of the article are available from *CQ* for $2.50 and an SASE. A kit of parts for The No Holds Barred Transmatch is available from Radiokit, P.O. Box 973-C, Pelham, NH 03076.)

When amateurs ask me what I suggest for a multiband antenna, my answer is nearly always the same: a dipole of indeterminate length, fed at the center with an open-wire-type line. By indeterminate length I mean finding two supports, making a wire that long, cutting it at the center, and installing an insulator. I feed this with an open-wire line. Oh, yes. How long should the feed line be? Simple. It should be long enough to reach your station. This is what many amateurs call the McCoy antenna system, but as I said above, it was around long before my time. I might add that the antenna works well in an inverted-Vee configuration.

What is the minimum acceptable length for such an antenna? Keep in mind that any piece of metal—even a paper clip—is an antenna or even a multiband antenna. However, as you have already learned, the shorter the antenna, the lower the impedance. As a general rule, the overall length of a multiband dipole, to keep losses low, would be on the order of one-quarter wavelength. In other words, about 60 feet for operation on 80 through 10. That doesn't mean a dipole 30 or 40 feet long won't work on 80 or even 160. It will, but just not as well. The feed line in such cases should be open-wire-line types.

As to length? Another myth in amateur radio is to make the feed line a half wavelength long or multiples thereof. Just think about how stupid this is when you operate all bands and all frequencies. The only time we are interested in using half-wavelength feed lines is to measure the antenna impedance, because the impedance repeats at the half-wave points. Even so, there isn't one amateur in 10,000 who would have the equipment to make such measurements, and the measurements would probably be useless after you got them. How long should a feed line be? Simple. Long enough to reach from your antenna to the rig!

Still another myth I have been hearing more and more is that certain feed-line lengths will change the antenna pattern. That is strictly hogwash. The purpose of a feed line is to carry the power from the rig to the antenna, do it as efficiently as possible, and most important, do it without radiating. If the line radiates, obviously it is an antenna. Keep in mind that in a properly operating feed line the currents or voltages in a balanced line cancel any radiation from the line.

So, is it as simple to make a multiband antenna by just making it reach between two points? The answer is mostly yes, but as I mentioned above, there are a couple of criteria worth following. As I said at the outset in the first part, make the antenna as long as you possibly can. In fact, once you exceed one-half wavelength for any given band, the longer antenna will produce multi-lobes with gain when used on the higher bands.

This is one of my arguments with the G5RV antenna. There is no doubt that this is a popular antenna, but when all is said and done, when used throughout the amateur bands, 80 through 10 meters, it is merely a *tuned system* consisting of a dipole 102 feet in length. In other words, for the antenna to work on all bands and all frequencies, it must be a tuned system using a Transmatch.

There is one very misleading statement made about this antenna which should be cleared up. The antenna proper is 102 feet overall, the center being connected to a 16 foot length of twin lead or open-wire-type line. The implication then is made that this 16 feet of feeders acts as *part of the antenna* (in other words, increasing the length of the antenna to 134 feet, 16 feet times two conductors). A fact of antenna life is that a feed line is not part of an antenna. A feed line should not radiate. If it does, it is an antenna.

Another common misunderstanding is that certain lengths of feed line will change the antenna pattern. Again, don't misunderstand. A feed line can radiate if it has what is called "parallel standing waves" present on the line. Normally this is a very undesired condition. As I told you in Part I, the feed line currents should cancel radiation. But if parallel standing waves are present, this phase relationship of cancellation ceases to exist and the line radiates. I said "normally," and I'll tell you why.

Feeder radiation may or may not be a serious problem. If you buy or construct a beam antenna, you expect a certain pattern as to gain, front-to-back, and front-to-side. However, if the coaxial feed line is radiating, the pattern can be shot to heck—or at the least be messed up. To illustrate this point it is worth telling you about something that happened to me years ago.

Some years ago there was an amateur radio distributor/manufacturer called World Radio in Council Bluffs, Iowa. They put together a package deal which included one of their transmitters, a tower, and a triband trap beam. The deal was popular, and many amateurs, including two neighboring amateurs who lived in south Texas, bought this setup. In other words, they had identical setups—almost!

The problem they encountered was that when they started to make signal comparisons, they found a great variation in the front-to-back patterns of the two antennas for each of the three bands—and I mean *great* variations. One amateur, for example, would have an S3 or 4 difference on 10 meters, while the other would have exactly what was claimed for the antenna.

The result of their confusion was a letter to me when I was working in the Technical Department of the ARRL. Much correspondence flowed back and forth, but I could arrive at no good answer. It turned out that I had to go to Texas on a lecture tour, so I arranged to visit these two amateurs. After much checking and observing I realized that the only difference was that the amateurs used different lengths of coax in their feed systems. I knew about line radiation, but at that time I did not think it important enough to mess up the patterns. Well, I was wrong. Using a grid dip meter I found that the outside of the outer conductors was resonant in the bands with which we were having the problems, so changing feed-line lengths corrected the problems, and both beams became identical as to front-to-back performance. The result was an article I wrote some years ago in *QST* called "When Is A Feed Line Not A Feed Line?"

Getting back to our discussion, suppose on the other hand you put up a multiband horizontal dipole and got feed-line radiation? Is this necessarily harmful? Probably not, because the feed-line radiation is going to go somewhere and work someone for you, because normally it would not be lost power but actual radiated power. To be honest, I prefer a feed line that doesn't radiate because I then know what to expect. Of course, if you are savvy, you are going to ask, "How do I stop my feed line from radiating?" That is a good question.

If we study a piece of coaxial cable, we find that we have a center conductor and

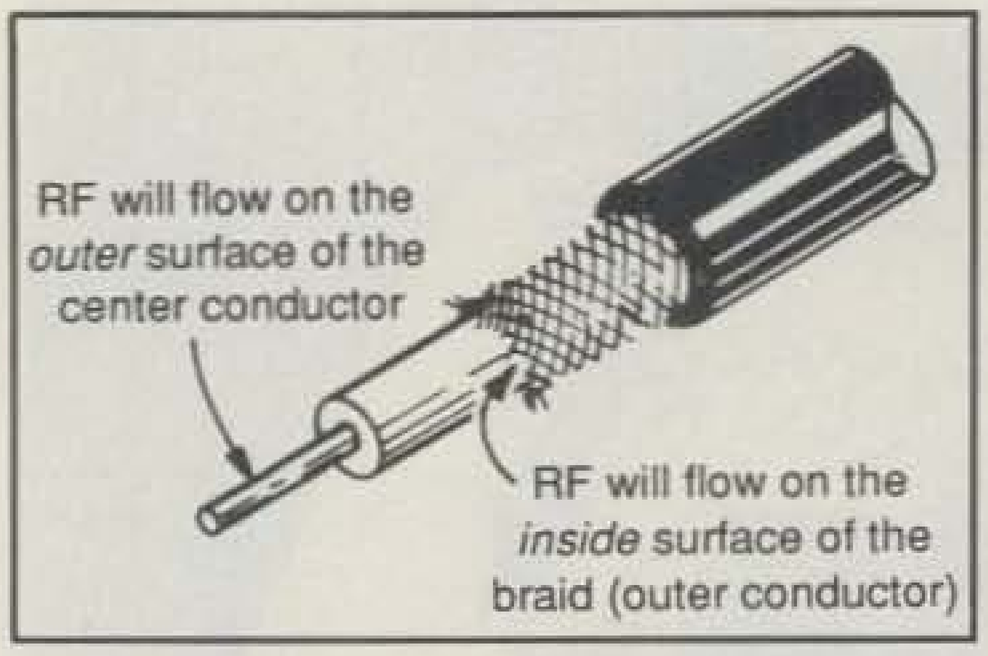


Fig. 2- If you were to cut a piece of coax flat or square across the end and view it, you would see that the RF flow is on the inside *of the outer conductor and on the* outside *of the outer conductor. As I pointed out, there should be no flow on the outside of the outer conductor.*

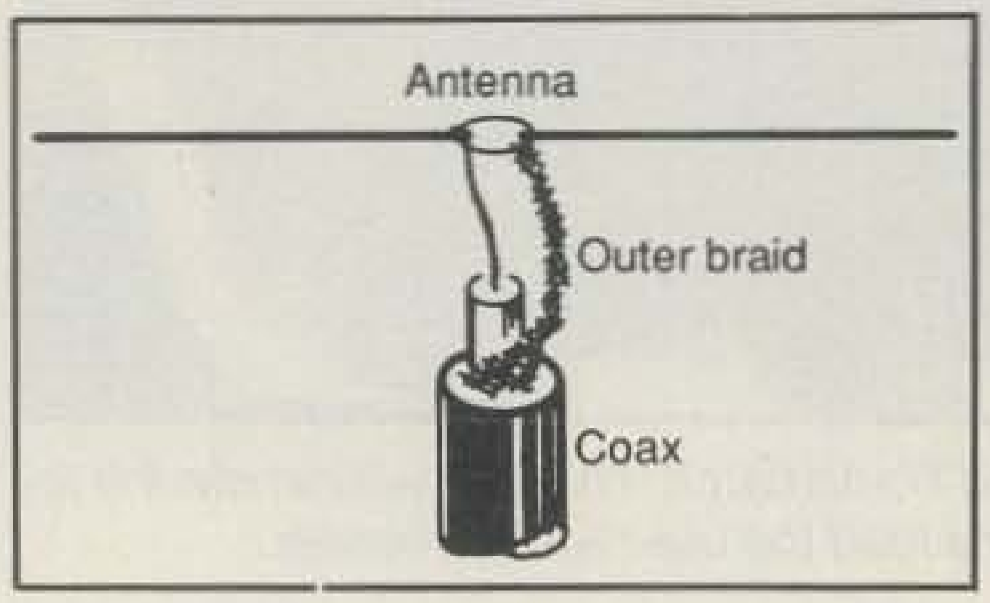


Fig.3- When connecting coax to an antenna directly, you should connect both the inside *and* outside *of the outer conductor to one side. (See text for explanation.)*

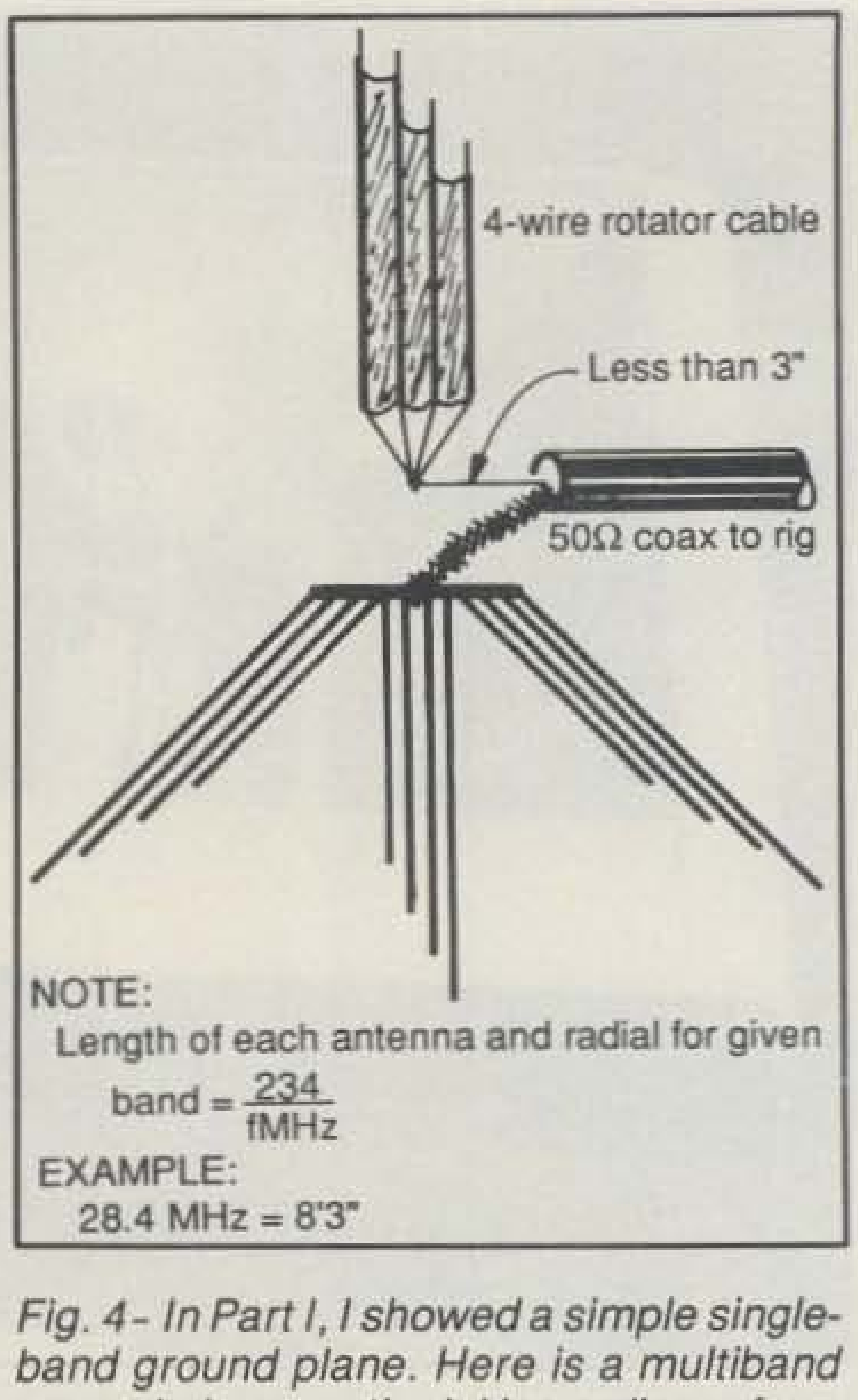
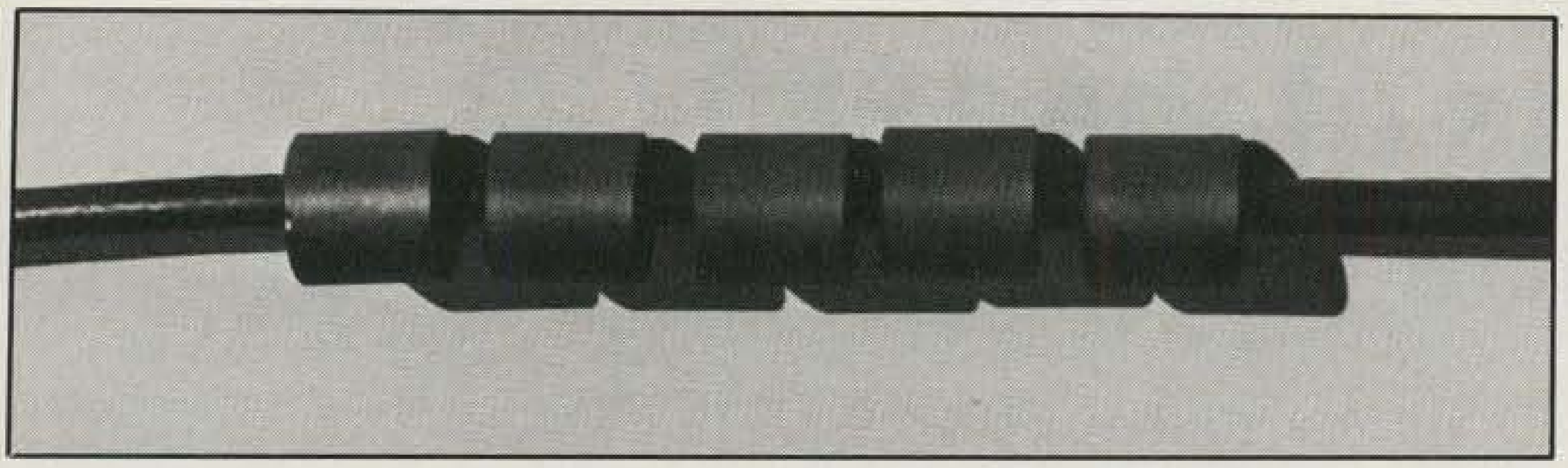


Fig. 4- In Part I, I showed a simple single-band ground plane. Here is a multiband ground-plane vertical. Use ordinary four-conductor TV rotor cable for the antennas. Simply peel back the insulation and cut the antennas and radials to the desired length. The antenna can be suspended, or the vertical section constructed as described previously.



Here is a photo of ferrites slipped over RG-8 type coax to make a sleeve choke as described. This material is available from Palomar Industries.

an outer conductor, the outer conductor being in the form of a sheath of copper strands. RF will flow on the *outside* of the inner conductor and on the *inside* of the outer sheath (see fig. 2). There should be no RF flowing on the outside of the outer conductor. When we connect the coax line to the dipole antenna as in fig. 3, we unavoidably must connect both the *inside* and *outside* of the outer sheath (the entire braid) to one side of the antenna.

Remember earlier I spoke of reactance and how it stops the flow of RF. In this case if there is no reactance at the antenna feed point to stop the flow of RF down the outside of the outer conductor, then we will have parallel standing waves. This isn't an easy concept to explain or understand, but it happens.

Antenna baluns are widely used by amateurs for the purpose of divorcing the feed line from the antenna to prevent such coupling of RF to the outside of the line. The word "balun" means "balanced to unbalanced." In my judgment baluns are fine when they work, and I would certainly recommend them. (The two amateurs in Texas both had baluns on their beams.) Unfortunately, baluns are not always the answer, and here is why.

If the length of the feed-line outer conductor from where it is attached to the antenna to where it ultimately reaches earth ground happens to be electrically resonant to the band or bands we are using, we can have a problem. Let me state first that we don't know where electrical ground is; the line goes through SWR and power bridges, tuners, switches, rigs, etc., before it finally reaches ground and establishes its length.

Let's backtrack a little here. Why are we concerned that the outside of the coax is resonant? Quite simple. The field of RF surrounding a transmitting antenna is very, very strong. Any wire or metal that is resonant and happens to be in that field is going to couple RF to itself, and in our case it happens to be the feed line. (You can see why a balun may or may not help the situation.) I recall when I first got into amateur radio I lived in a house that had old-fashioned knob and tube wiring. Whenever I went on 20 meter CW the lights would blink on and off. The answer was that the wiring was resonant on 20 and of course coupled enough power from the antenna to excite the lights!

So how do you find out if you have this problem? One of the simplest ways is with an RF power or SWR bridge. Nearly all amateurs have one or two. Parallel standing waves have one bad habit: They can get into your bridge and foul up the readings. One method of detecting the presence of parallel standing waves is to set the SWR bridge in the reflected-reading position and get enough of a reading so that you can observe the meter. You only need to run 25 watts or so (I don't recommend doing this at high power.). Once you have the reading, run your hand up and down the outside of the coax, holding your hand around the coax. Your body and hand have enough capacitance to affect the line reading if parallel standing waves are present.

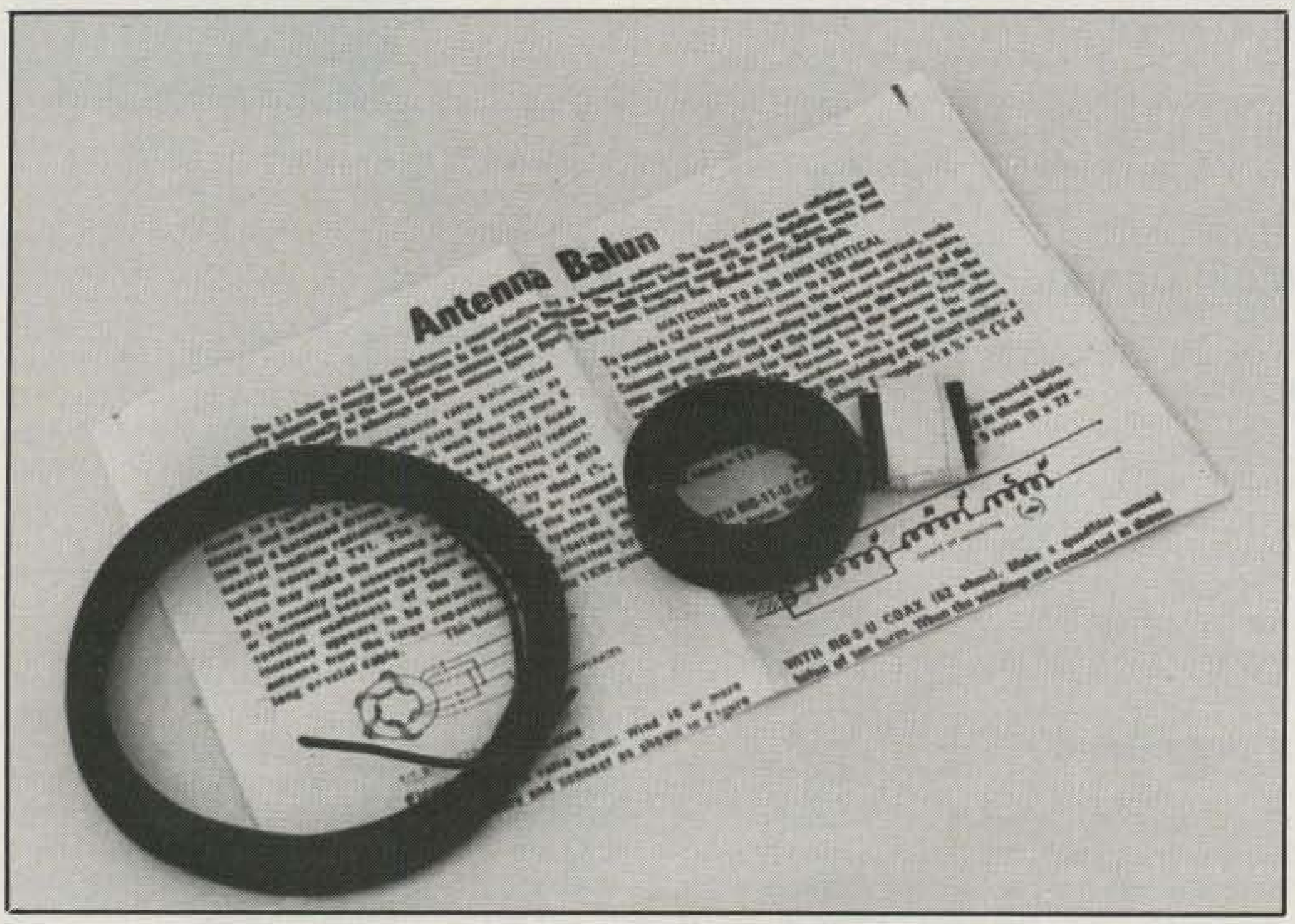
Another method is to use a grid dip-meter. Form a section of the coaxial line into a small loop to fit over the grid-dip coil. Then grid dip the coax (you are actually checking the outside of the outer conductor). If you find a dip in the band with which you are concerned, you should change the length of the line to move that dip out of the band. In other words, make the braid nonresonant. Oversimplifying, you have created a high-impedance and reactive path for that outer braid outer conductor at your antenna.

During WW II the Germans found that their intelligence operations were being compromised. They discovered that the enemy (us) was managing to detect the signals that were supposed to be enclosed inside the coax lines, when actually the signals were leaking to the outside. They found that by using toroidal chokes slipped over the coax, they could eliminate the problem. This cure works for us with antenna feed lines.

Walt Maxwell, W2DU, recently described curing RF on the outside of lines by using toroids slipped over the coax to act as a current choke to choke off the RF flow. (This system has proven very successful in my tests.) I strongly recommend the W2DU approach because a properly designed "sleeve balun" is a very low-loss device, and Walt Maxwell has made very extensive checks to prove the benefits of this type of balun.

I therefore recommend two steps: Use the sleeve balun and also make sure any lines are nonresonant. Then you should not have any problems. See Part III for more on this problem.

All this may be a tempest in a teapot if you'll forgive my cliches. However, I have seen and known many amateurs who bought a beam and then complained about front to back and so on when the fault was feed-line radiation. I know. I've been there. In Part III, I will discuss feed lines and more about antennas. CQ



This is a balun kit also marketed by Palomar, and it is quite simple to construct.