Tech Notes

Dirty Little Secrets I

If you read the ham mags with any regularity you may have noticed that some antenna manufacturers can't seem to tell the truth (certainly not the whole truth) about their products and that some of the great technical experts who review ad copy for obvious technical blunders don't seem to know enough about their subject to spot the real howlers.

In the ensuing pages we'll look at several widely advertised vertical antennas for which claims are made that could have come straight out of Dreamland. What their manufacturers seem to have in common is a hearty contempt for information found in *The ARRL Antenna Book* and for the typical ham's basic intelligence. At the very least they clearly believe that most hams have more money than brains, for each of these products costs much more than it should for what it delivers. This is not to say that one can't use these products to make contacts, for even a hopelessly inefficient antenna will perform well enough when conditions are good, but when conditions are poor and when the competition for relatively few DX stations on the band becomes more intense it's too late to start wondering if your antenna really lives up to the wonderful claims that persuaded you to buy it. At this writing (summer 1995) sunspot activity is well below its peak level of several years ago and should decline further into 1997 when we'll hit rock bottom and begin a new sunspot cycle. Until then there will be less DX on fewer bands during fewer hours of the day, and only those using good antennas can expect reliable and consistent performance.

An early indication that someone was trying to rewrite or to thumb his nose at the laws of physics was the appearance of an advertisement for a vertical antenna that supposedly operated with "No Earth Loss." If true, this claim could have revolutionized the AM broadcasting industry and earned the antenna developer a Nobel prize in a walk. But the claim was totally spurious for a very obvious reason: earth loss, after all, results from RF passing through and along lossy earth and has nothing to do with the antenna itself. The *ARRL Antenna Book* assures us that in most installations, earth losses can reduce efficiency by 50% or more unless a number of radials is used to enhance the surface conductivity of the earth beneath and around an antenna. Amateurs, it seems, must relearn this basic lesson every 11 years or so. The *ARRL Antenna Book* is quite clear on this point. If you want NO earth loss over most kinds of earth, you should count on running out more than 100 halfwave radial wires. Perhaps as few as fifteen 1/8-wave radials (17 ft. for 40 meters) will be good for maybe 60% efficiency, but with only two such radials efficiency is not likely to exceed 25%, and if the height of the vertical radiator is much less then 1/4 wavelength the efficiency will usually be much lower.

The fact that one manufacturer promised miracles that just weren't there and got away with it seems to have inspired others to come forth with equally preposterous claims. In large measure these claims ignore the problem of earth losses or rely on misleading information for their theoretical support when any is offered at all.

Another "no-radial" antenna is advertised as a "halfwave" on all bands from 40 through 10 meters, though its total height (22.5 ft.) is much too short for an honest halfwave below about 21 MHZ and only a portion of the radiator is used on that band. Yet, this antenna offers "exceptional HALFWAVE performance" when it's barely a quarter wavelength tall on any band and cant hope to deliver even QUARTER-wave performance on most bands. Does a quarter-wave perform better when it's called a "halfwave?" Or does a quarter-wave "halfwave" do a better job of compensating for increased earth loss resistance when radials can't be used because they would detune the antenna?

We'll come back to these two widely advertised antennas in a moment, but we promised to show you how to calculate efficiency, so we'd better say a bit about radiation resistance, earth losses, and loss in general.

Radiation resistance is that part of the antenna feed point impedance that represents power that is "lost" because of radiation—just what we want! It's not a real loss at all, but we treat it as such and assign it a value in ohms in order to facilitate calculations. The radiation resistance of any vertical conductor depends primarily on its height (or vertical length if you prefer). For most tubing and wire conductors the radiation resistance of a quarter-wave conductor (about 33 feet for 40 meters) is approximately 35 ohms.

If we erect such a vertical and connect the braid side of the coax feedline to a 4foot rod in soil of average conductivity we'll probably see an SWR of 1.7 or so right at the antenna. Measurements made elsewhere along the feedline will be less accurate. What does an SWR of 1.7 tell us? Simply that the total feedpoint impedance must be 1.7 X the characteristic impedance of our 50 ohm feedline, so we know that the impedance is made up of some 35 ohms of radiation resistance and another 50 ohms or so of loss resistance from one source or another.

NOTE: What is not radiation resistance is LOSS resistance that does us no good at all. EFFICIENCY IS MERELY THE RATIO OF THE ANTENNA'S RADIATION RESISTANCE TO ITS TOTAL FEEDPOINT IMPEDANCE, or 35 ohm/85 ohm = 41% in this case, or about what we might expect applying the information from The *ARRL Antenna Book* for skimpy or non-existent radial systems. SWR alone, by the way, tells us NOTHING about efficiency.

Here, then, is our dirty little secret to calculate the probable efficiency of an antenna; You need to know only it's radiation resistance and feedpoint impedance. Not that any information that has been available to the general public for nearly a century can be called "secret." Perhaps it's a secret only to those who look for enlightenment in amateur antenna ads? The manufactures don't usually volunteer such information because it's not in their interest to do so.

Suppose you don't know the radiation resistance of a particular antenna that interests you. If you can find out how tall it is you can use any edition of *The ARRL Antenna Book* from the last 40 years to look up the radiation resistance to a close approximation. The basic information hasn't changed for more than 50 years, so if you don't know the radiation resistance, the height (length) alone will be good enough.

Please note that in the above examples we assumed that the radiator was a full quarter wavelength so we could use the universally accepted value of 35 ohms for the radiation resistance. Another universally accepted value of radiation resistance is 75 ohms for a REAL halfwave antenna, and that's what some manufacturers want you to think you're getting. Keep these numbers in mind as we plow ahead.

To recapitulate briefly, the efficiency of an antenna may be calculated by dividing the radiation resistance by its total feedpoint impedance, if that or the SWR at the feedpoint is known. The only useful component of the feedpoint impedance is the radiation resistance, so naturally we want this to be as high as possible and we want the accompanying loss resistance to be as low as possible to maintain a high ratio of radiation resistance to loss resistance.

Radiation resistance depends almost entirely on the height of a vertical structure, and it decreases rapidly as height drops below a quarter-wavelength, even when some one insists on calling it a "halfwave."

The loss resistance from large-diameter (1/2 inch or more) conductors is quite low and can usually be ignored, but the same cannot be said for earth losses that can easily waste most of your applied power. In addition to earth losses, we should also be concerned with conductor losses from the trap circuits that are used to make a single conductor operate on a number of different frequency bands.

All this may seem like quite a bit to keep straight if you're seeing it for the first time, but take your time and read through it several times.

Let's return to our "no earth loss" antenna that we mentioned earlier. Their great "breakthrough" that supposedly allows this antenna to eliminate loss resistance in the surrounding real estate is its feedpoint.

Most quarter-wave (or shorter) verticals are fed at the base, a high-current and low-voltage point that is suited to low-impedance coaxial line. This one, however, is fed at the mid-point of the vertical radiator, and the feedline is tucked INSIDE the lower half of the radiator, emerging at the lower end. This elevated feedpoint, it's claimed, causes the radiation resistance to rise to approximately 50 ohms and simultaneously wipes out earth loss resistance over a wide area, much as 100 long radials might do. The increase in radiation resistance and the elimination of earth loss resistance thus allow the antenna to operate at "approximately 90% efficiency."

Alas for our dreams! All this is sheer rubbish. We've already observed that earth losses come from the earth and not from the antenna, and it seems that the effect of feeding a quarter-wave vertical at its midpoint is to LOWER rather than to increase the radiation resistance. Quoth The *ARRL Antenna Book:*

> For optimum performance, a short antenna should not be made shorter than the physical circumstances require, because efficiency decreases rapidly as antenna length is reduced. For example, a center fed antenna having an overall length of 1/4 wavelength (half-length 45°) has a radiation resistance of 2 X 7 = 14 ohms as shown in fig. 35. (16th ed., p. 2-43).

This excerpt appears in the course of discussion of short HORIZONTAL antennas whose efficiency is not greatly affected by earth losses at elevations of a quarter wavelength or more, and the Antenna Book goes on to say that such a horizontal antenna could be expected to show as much as 80% efficiency, even with greatly lowered radiation resistance.

But VERTICAL antennas are NOT suspended horizontally above the earth! Except for polarization, the above passage describes the antenna in question so closely that we might be tempted to imagine that the designer forgot that he was working on a vertical and ignored earth losses. Then, when the earth losses showed up in the form of increased feedpoint impedance, perhaps he imagined that what he was seeing was increased radiation resistance? In any case, earth losses will definitely affect a vertical's efficiency, so let's do another simple calculation to see how this "revolutionary new technology" might work in practice.

If, our radiation resistance is only 14 ohms instead of the anticipated 60 ohms our efficiency becomes 14 divided by the total feedpoint impedance, but just what is the total feedpoint impedance? We can be pretty sure that they haven't eliminated earth losses as claimed, and that if our SWR is close to 1:1 some 36 ohms of LOSS resistance has crept in from somewhere. No matter, loss is still loss, so efficiency should be no better than 14/50 = 28% and NOT the "approximately 90%" claimed.

Note the charts at the end of our text. These come from *ARRL Antenna Book* and may be used to estimate radiation resistance fairly closely. We'll have to convert height in feet to electrical degrees, but 90 degrees is the equivalent of 1/4 wave, 180 degrees of a halfwave, 270 degrees of a 3/4 wave, and so on. Now that you have an idea about how radiation resistance relates to efficiency and to conductor height you should have little trouble making your own calculations.

Here's another dirty little secret that really isn't because anyone who has read this far can see what's involved for himself; as the radiator is made shorter in terms of wavelength, the radiation resistance drops and any loss resistance in the circuit becomes an ever larger percentage of the total feedpoint impedance, so efficiency drops too.

Before the advent of the no-radial "halfwave" antenna those customers who sought to boost efficiency by installing a good radial system were often hit by a double whammy, for as earth loss resistance dropped below 50 ohms their feedpoint impedance dropped too as both efficiency and SWR went UP. They could have reasonable efficiency or relatively low SWR but usually not both, unless they were willing to fork over a small fortune for a "tuner" which would bring its own little bundle of loss resistance to the system.

The manufacturers were also caught in the middle, for if they told the customer to run out plenty of radials there was a good chance that he'd be screaming about high SWR a few days later. An unenviable situation for all concerned, and most manufacturers at one time or another have gone so far as to play down the importance of reducing earth losses, knowing that efficiency would suffer but that an extra dozen or more ohms of loss resistance in the feedpoint impedance would cut down the SWR complaints.

The no-radial "halfwaves" may have "solved" that problem by ensuring that enough loss resistance is on hand to bring the feedpoint closer to 50 ohms. Perhaps we're merely witnessing the continuation of a longer "reeducation" process, at the end of which most amateurs will be convinced that earth and other losses are a positive good that should be cultivated? Indeed, the people who make the "No earth loss" verticals seem to be headed down that path, for they tell us that:

> a multiband vertical must have earth loss to work! That's why a multiband vertical mounted on your roof won't work all the bands.

What this is supposed to mean is anyone's guess, alas!

Consider the no-radial "halfwave" antenna that we mentioned earlier. Essentially this is a multiple-trap design, by which we mean that parallel-tuned (antiresonant) L-C trap circuits are inserted along the radiator element at various points, where they present a high impedance to oncoming RF at the resonant frequency of the trap. One trap is used for each band, and each trap blocks current flow past it on that band, effectively removing the portion of the radiator above the trap from the circuit.

So what is the effective height of the radiator on each band? The overall height from the feedpoint to the tip of the antenna is only 22.5 ft., but only on 40 meters is the whole vertical element used to produce radiated field. A true QUARTERwave on 40 meters is more that 32 ft. tall, and we're about 10 ft. short, so our height in electrical degrees decreases to 60, and the radiation resistance is only 13 ohms or so. The seven 49 inch "counterpoise" radial rods at the feedpoint cannot radiate appreciably because any current flowing in any one rod will be horizontally polarized and largely canceled out by equal and opposite currents from other radial rods on the other side of the antenna.

We know the radiation resistance closely enough, but how do we determine the total feedpoint impedance so we can say something definite about efficiency? The short "counterpoise", by the way, will be next to useless in reducing earth losses because it covers so little surface area. The manufacturer has supplied SWR curves that are sufficiently close to 1:1 at resonance that we could probably use them if he hadn't also placed a toroidal matching circuit across the feedpoint for the sake of acceptable SWR on several bands. The matching unit is no doubt a good idea because on at least one band the combined radiation resistance and loss resistance will be so much greater than 50 ohms before matching that we couldn't easily separate out the loss resistance.

There's probably less chance for great inaccuracy when the radiation resistance plus loss resistance is well below 50 ohms, but we'll try it both ways, using (a) the manufacturers SWR information and (b) The *ARRL Antenna Book's* observation that a full quarter-wave vertical may be expected to operate at about 25% efficiency with two 1/8-wave radials and even less when the antenna is shorter than a quarter wave. It happens that both the little counterpoise assembly and the 1/8-wave radials for 30 meters have roughly the same overall length of conductor, so the two systems should be roughly equivalent.

So, then, if our radiator is 22.5 feet tall on 40 meters it has a height of approximately 60 degrees and the radiation resistance is about 13 ohms, and if SWR = 1:1 the loss resistance must be some 37 ohms, and efficiency must be 13/50 = 26%. That's very close to *The Antenna Book's* prediction of 25% for a full QUARTERwave (10 ft. TALLER than this one), so true efficiency is probably even less.

On 30 meters we're still below a real quarter wave because we're using only 18 or so feet of the radiator. This length corresponds to 67 electrical degrees, more or less, so we can expect a radiation resistance of about 40 ohms on this band. Assuming a reasonably low SWR, we can reckon with maybe 32 ohms of loss resistance for an efficiency of 18/50=36%. That's a bit more efficiency than The *ARRL Antenna Book* predicts, but over earth of fair to good conductivity it's possible.

On 20 meters the radiation resistance rises because the radiator is finally an honest quarter wave tall (90°), so radiation resistance should be about 35 ohms. The indicated SWR is 1:1, so the total feedpoint impedance after transformation could be as much as 55 ohms and efficiency 35/55 = 63.6%. This seems at odds with the 25% or so predicted by The ARRL Antenna Book, but we should remember that the total feedpoint resistance before matching had to be close to 35 ohms plus some unknown value of loss resistance and that the manufacturers SWR (1:1 after matching) hides all but 20 ohms of the loss resistance. In any case, if we had 37 ohms of earth loss on 40 meters and 32 ohms of earth loss on 30 meters we can probably expect about 30 ohms on 20 meters, in which case the true efficiency is probably closer to 35/65 = 53.8%. Recall that *The ARRL Antenna Book* tells us that the fifteen 1/8-wave radials (a much more extensive system) might be needed for 50% efficiency, so an even lower figure appears more reasonable.

On 17 and 15 meters the radiation resistance should be in the 35-50 ohm range with the same or slightly better efficiency as on 20 meters, and we begin to see efficiencies that seem to approach 100% on 10 meters but can't ever get there because of earth and coil losses. On 12 and 10 meters, in fact, the active part of the radiator is approximately 120 degrees tall. That's still not a halfwave, but it should be a little more efficient than a quarter wave for a fixed value of earth loss resistance. The manufacturers SWR of 1:1 at the feedpoint suggests that our approximately 100 ohms of radiation resistance IS the total feed point impedance! What's wrong with this? For one thing it means that there can't be any loss resistance at all, and that's an impossibility, considering the tiny counterpoise in use.

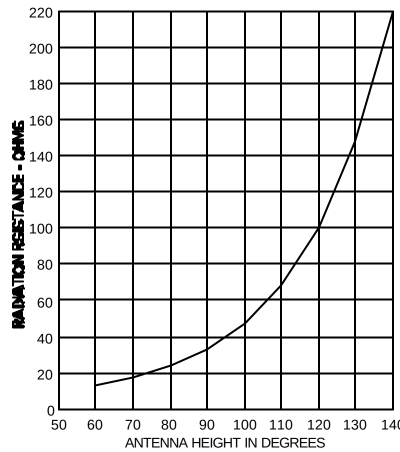

Fig. 49 — Radiation resistance vs. free space antenna height in electrical degrees for a vertical antenna over perfectly conducting ground, or over a highly conducting ground plane. This curve also may be used for center-fed antennas (in free space) by multiplying the radiation resistance by two; the height in this case is half the actual antenna length.

It's true that the area covered by the counterpoise becomes greater as the frequency increases, but so too does any earth loss resistance. The impedance transformation circuit does not do away with any earth loss resistance or transform it into anything useful; it merely transforms total feedpoint impedance (both radiation resistance and loss resistance) to a different value for the sake of better SWR. And it also complicates the task of identifying and separating the two using our simple technique.

All SWR tells us is total feedpoint impedance, and if an impedance matching circuit is used it may not even tell us that much, so it's up to us to sort out how much is radiation resistance, how much is earth loss resistance and how much is loss resistance from other sources. We could, of course, accept the manufacturers' claims at face value and skip all the tedious calculations, but if they're unwilling to tell the truth about something so basic as the height of a halfwave, well....

Remember that only that part of the radiator that is active on a particular band does anything for you. That's the part between the feedpoint and the trap for the band in use. Those sections of the radiator that are "trapped out" on other bands are just going along for the ride.

This particular design is not necessarily a "bad" one. It's just not very efficient, and the same will be true of any vertical antenna that ignores earth losses. The claim to "exceptional halfwave performance" is obviously something plucked out of the air, and even run of the mill QUARTER WAVE performance is probably beyond it on most bands for the same reason.

Curiously enough, the buyer is warned NOT to attempt to add radials to this system for fear of detuning it and increasing the SWR. Unless the manufacturer has refined this design it appears that there is no way at all to reduce earth losses further and to increase efficiency. To some this might seem a serious design flaw. To others, who won't take the trouble to understand what is involved, it probably won't matter, provided that they can continue to make contacts as sunspot activity continues to decrease and frequencies above 14 MHz become less useful.

The thrust of the no radial propaganda over the last few years has been to demonize radials as unsightly, inconvenient or unnecessary, depending on whatever theory supposedly applies in the case of a given design. Perhaps the basic if unspoken assumption behind the no radial "halfwaves" is that verticals don't work too well anyway, so why worry about efficiency? There may be a thread of logic here, for most verticals don't work nearly as well as they might simply because manufactures have been screaming "works with or without grounds radials" for decades. The claim is no truer than it was 20 years ago where efficiency is involved.

Some amateurs will no doubt conclude that what they need is more power. That's relatively expensive way to improve your signal reports when a few dollars worth of radial wire might do a better job, assuming that radials can be added to the no radial "halfwaves" without detuning them.

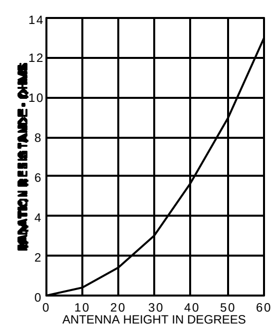

Fig. 50 — Same as Fig. 49, for heights below 60 degrees.

Finally, we should remember that the foregoing estimates and calculations are themselves only approximate. Errors in converting electrical degrees to so many feet and inches, errors in reading the charts and other minor inaccuracies will muddy the waters. Luckily, however, we can be off by quite a bit before any error becomes significant.