Vertical Antennas, Ad Hype and Technobabble
(A Self-defense Primer for the Beginner)

By Donald R. Newcomb W0DN

If you're still waiting for your first ham ticket you’ll soon be putting together your first station and looking for an antenna system for the bands on which you can operate; if you've been at it for a while you probably have a clearer idea of what it's all about. In either case, at some point you'll get around to choosing a new antenna system and, like everything else in this world you'll learn (perhaps the hard way) that some antennas are better than others for some purposes. You’ll also find that some models are vastly overrated and cost more than competing models that deliver superior performance. This is true of so many other things in our daily lives that it should come as no surprise.

Unfortunately or otherwise, amateur radio is a technical hobby, and many of the marvelous new devices in our ham shacks didn't exist only a few years ago. It's the rare individual who understands in detail the operation of all his equipment, and even many “old timers” don't have the specialized knowledge or test equipment (or patience) to troubleshoot their own gear. Antennas, however, are different in that their basic principles of operation have been known for well over 50 years. There have been very few “breakthroughs” in recent years (in spite of lavish multicolor ads shrieking a contrary message), and much of what passes for “innovative” amateur antenna design involves pouring old wine (or vinegar) into expensive new bottles. Indeed, there are very few amateur antennas in use on our HF bands that are NOT derived from the basic dipole of almost a century ago. This is not to say that there haven't been interesting developments over the years, but the fundamentals haven't changed significantly. We might even say that antennas are relatively low tech passive devices, at least when we consider the relative complexity of the latest solid state multi band HF transceiver. On the other hand, the relative simplicity of antennas allows the beginner to become reasonably familiar with the subject in a fairly short time and that is all to the good IF one can keep the fundamentals straight. That most amateurs seem to ignore them once they get on the air is something of a mystery, for there is no single item of station equipment that will have a greater influence on your signal than your antenna system. If that is properly designed and adjusted and installed correctly your other equipment can function at maximum effectiveness; if your antenna system isn’t doing the job the other gear may not do its job either.

So how does the beginner learn about the different antenna types and models? Usually, by word of mouth and from the ads in the ham magazines. Most manufacturers spend large sums of money to advertise their products, so it goes without saying that theirs are automatically the best buy or the most efficient models available anywhere, though the documentation provided may be nonexistent or even laughable. In theory at least, every magazine employs at least one “expert” to look at the ad copy submitted and to reject anything that's clearly fraudulent or simply off the wall, but some of it slips through from time to time, even in those places where we wouldn't expect to see it. Magazines depend for their existence on advertising revenues, so we mustn't expect them to crack the whip too hard on major advertisers who stray over the line. The best defense against today's overblown antenna technobabble is a little basic knowledge of the subject, but this can be acquired by anyone who's willing to devote a little time and thought to the matter.

In recent years several manufacturers have produced a “new” kind of vertical antenna for the ham bands, one that supposedly requires no ground or radial system at all. Other manufacturers have been claiming for years that their more conventional designs don't really require ground systems, and in a limited sense, they're right: a “cheap and dirty” ground rod will often be enough to allow a ground mounted vertical to accept power with reasonably low SWR and to radiate some of it if local ground conductivity is not too poor. Unfortunately, it's very poor in most places, at least in the HF range, and most applied power will usually be lost as heat in the local real estate unless one is willing to run out a number of radial wires to improve the conductivity. The earth exerts a great effect on RF in the HF range, and one needs to know something about this effect before he decides which kind of antenna stands the best chance of doing what he wants it to do in the light of his particular circumstances.

In general, we can say that the effect of lossy earth on vertically polarized energy is to absorb most of it, as noted. Horizontally polarized RF, on the other hand is affected in a different way: only a few percent of the applied power will be lost in the earth itself, but the radiation from a horizontal dipole will be directed upwards at the higher elevation angles that are useless for long distance communication in the HF range unless the horizontal antenna is a half wavelength or so above the earth. In short, it's a trade-off between high earth losses for a vertical antenna and high wave angles for a low horizontal antenna. A vertical may be quite a bit less efficient than a horizontal if nothing is done to reduce earth losses, but most of its radiation will still go out at the lower angles with respect to the horizon regardless of its height above ground. The upshot is that even a “lossy” vertical at ground level is often a more effective antenna for long-haul DX work than a full-size horizontal dipole which can't usually be placed high enough to provide much low angle radiation.

As an example of the kind of propaganda to which you can expect to be exposed we've prepared a simple little quiz borrowing here and there from some of the more startling claims and statements we've noted in recent antenna ads. If you're just getting started and don't have many answers don't feel too bad. A few hours spent reading the ARRL Antenna Book will help to put everything into perspective and to innoculate you against some of the more nonsensical notions that have found their way into print in recent years.

Mini Quiz on Vertical Antennas, Ground Systems and Loss

Q1 One manufacturer claims that it's possible to elevate the feed point of a 1/4-wave ground-mounted vertical, feed it as a loaded dipole and achieve efficiency approaching 90% with only three short radials or maybe none at all. This procedure, he assures us, virtually eliminates earth losses and increases the radiation resistance. What's wrong with this?

A1 What’s wrong with this? Almost everything Earth loss (also known as plain old ground loss) has been the limiting factor in vertical antenna performance since the days of Marconi, and it still is. The earth, in effect, becomes part of the total antenna circuit because current applied to the antenna necessarily flows in and along the earth, and there's no way to keep that from happening. If the earth were a perfect conductor there would be nothing to worry about, for nothing would be lost. But even the bent earth is such a poor conductor at radio frequencies that most of your applied power will be lost in the earth as heat unless something is done to make the local earth more conductive.

Anyone who can come up with a simple and effective technique to reduce earth loss resistance will easily revolutionize antenna design for the HF amateur bands and commercial MW broadcasting, but at least one company that makes vertical antennas for the amateur bands claims to have achieved just such a breakthrough. Their technique is to break a 1/4 wave vertical radiator in the center in order to feed it as a kind of dipole, This "center launch technology, it is claimed, "virtually eliminates earth losses", AND, it is further claimed, also increases the antenna radiation resistance to approximately 50 ohms, whereas the "conventional" 1/4 wave base fed vertical has a radiation resistance of only 35 ohms. So then, higher radiation resistance plus very greatly reduced earth loss resistance must mean much higher efficiency, so why run out thousands of feet of wire for a radial system? Why indeed? The ARRL Antenna Book tells us that something like 100 half wave radials are needed to do away with significant earth less, but this thrilling new design supposedly gets 90% efficiency from the elevated feed point alone! Yes, this "radically different vertical" certainly "gets it all out!" Does it really?

The ARRL Antenna Book (16th edition) tells us that "a center fed antenna having an overall length of one quarter wavelength has a radiation resistance of 14 ohms" (page 2-43). That's quite a bit less than the center launch people claim for THEIR antenna of this description, so who is right? 14 ohms is less than HALF the radiation resistance of a "conventional" (base fed) vertical of the same size, "the most inefficient antenna available for amateur use," or so the center launchers assure us. But if ARRL is right, their antenna must be even more inefficient! They further claim that they get a near perfect match to 50 ohm cable, so if we know the total antenna feed point impedance (50 ohms) and the antenna radiation resistance (14 ohms) we simply divide the latter by the former to arrive at the overall efficiency of the antenna

So then, efficiency = radiation resistance divided by total feed point impedance, or 14/50 ohms in the case of the center fed quarter wave vertical. That's 28%, a far cry from the "approximately 90%" claimed!

If we can believe the ARRL Antenna Book about radiation resistance we still have to wonder where the remaining 36 ohms of the center launch feed point impedance comes from. What is not radiation resistance MUST be loss resistance of one kind or another! An antenna of this size constructed of tubing has negligible conductor loss, and any loading devices shouldn't account for more than a few ohms, so most or those 36 ohms must represent earth loss. It appears, therefore, that this exciting new "technology" is no more effective in reducing earth losses than it is in raising radiation resistance. That should come as no surprise to anyone who stops to think for a moment, for if we ask ourselves where earth losses reside and why they're called earth losses rather than something else it's obvious that they occur in, along and under the earth beneath the vertical radiator and not in the radiator itself.

For most of this century the classic technique for reducing or eliminating earth losses has been to lay out a number of radial wires on or slightly under the earth around the vertical antenna. If earth losses were present in the radiator and could be affected by changing the feed point we'd have had a totally different theory of vertical antennas for the last half century! If someone comes up with a new and better technique that really proves effective in reducing earth losses or improving radiation resistance the MW broadcasters will adopt it, dig up their huge copper wire radial systems to sell as scrap, and the last place we'll read about it will be in the ham antenna ads!

Q2 A certain "no radial" 12 ft. "half wave" vertical supposedly achieves MAXIMUM efficiency through end loading and NEVER requires radials, counterpoises or ground planes because you don't have the kind of ground loss that's common with a quarter-wave vertical. "Maximum efficiency," presumably, means something approaching 100%, in which case earth and loading losses must be almost zero. How many doubtful or clearly false statements can you spot?

A2 Everything is doubtful. This little excerpt comes from an ad for a new entry on the "no-radial" vertical antenna scene, but it illustrates better than most some of the problems that confront the new amateur as he tries to make head or tail of what he sees in the antenna ads. This one is only 12 ft. tall, but it's supposedly a "half wave," even on 40 meters. On 6 meters, however, it becomes an "efficient full half wave" that provides "low angle radiation for lots of DX." What? Isn't it efficient and doesn't it provide low-angle radiation for lots of DX on ALL bands? Let's stick with efficiency and run a few simple calculations using the information the ad provides. The information in the ARRL Antenna Book indicates that a center fed vertical of this size has a radiation resistance of a bit under 4 ohms on 40 meters, the same as for a mere "quarter wave" of the same height. SWR, we learn, is 1.5 at resonance, in which case the feed point impedance will be either 33.3 or 75 ohms. Let's put the best possible face on things and assume 33.3 ohms, or 4 ohms of radiation resistance and only 29.3 ohms of loss resistance, whether from loading or from earth losses. So then, efficiency 4/33.3 = 12%--not very impressive, but much better than for a 75-ohm feed point impedance which would mean the same 4 ohms of radiation resistance and 71 ohms of loss resistance, in which case E 4/75 = 5.3%, enough to turn your 100 watter into a dandy little flea-power rig!

It would appear that on 40, meters "maximum efficiency" for a center fed antenna of this type and size means something well under 15%, but then we should probably not expect manufacturers to spell everything out in too much detail! Nor should we demand daily miracles from something that can't reasonably be expected to deliver them, and it's up to the buyer to have enough knowledge to know which questions to ask and how to read between the lines in order to answer them for himself when the promotional information provided is sketchy, irrelevant, misleading or just wrong for whatever reason. The suggestion that no radials or ground planes are ever needed because earth losses are somehow less for this kind of antenna than for a quarter wave vertical is simply wrong, unless you're reconciled to losing most of your applied power before you even start. On the other hand, it's possible to argue that with such low radiation resistance and/or massive loading losses the overall efficiency will be so low anyway that earth losses won't affect a basically hopeless situation. Whatever the ease, earth loss has everything to do with the conductivity of the earth at the antenna site and nothing at all to do with the antenna itself. Both the quarter-wave vertical and a much shorter "half wave" will have to contend with the same amount of earth loss resistance in a given installation, but the no-radial antenna may be unable to deal with it because the addition of radials, even when space permits, can de-tune a "ground independent" antenna.

What does "ground independent" mean anyway? At most it can mean that an antenna is independent or the earth for its resonance; to say that it's independent of the earth insofar as losses and wave angle are concerned (at least in the HF range) is certainly untrue. Perhaps the eagerness of some manufacturers to use the term "half wave" to describe an antenna that is barely a quarter wavelength tall on ANY HF band represents a conscious attempt to persuade the buyer that he's getting "more," though more of what (other than hype) is much less clear. Hype is a staple of the ad game, but its use in advertisements intended for technically literate customers indicates a basic contempt for their intelligence. Whatever the case, it certainly won't hurt you to know a bit more about antennas than you re likely to learn from the antenna ads! How long (or tall) is an antenna in terms of wavelength? Simply divide 468 by the length (or height) in feet to find the frequency at which an antenna is an honest half- wavelength. A 12 ft. antenna, for example is a real half wave at 468/12, or at 39 mHz. And how long (tall) is an honest half wave for 7 mHz? Simple: divide 468 by the frequency in mHz to get the length (or height) in feet, so 468/7 = 88.87 feet. The fundamentals are not at all hard to grasp, and they haven't changed significantly in living memory, so when people who manufacture ham antennas play fast and loose with words, their meanings and even basic units of measure it's wise for us to examine their other claims more carefully.

In the case of other vertical antennas you'll be exposed to more subtle inducements to part with your change. How can you tell when someone's dancing around the facts or building you an expensive snow job? One indication is a reluctance to say much-- or anything--about earth losses or how to avoid them, particularly where "no radial" vertical's are involved. Nor, probably, should we expect anyone to state flatly or even hint that his marvelous new creation may just have to swallow whatever earth losses it might encounter. Far safer to talk about the thrill of working DX and the joy of dispensing with unsightly radials, although avoiding radials is usually a good way to avoid DX. Another manufacturer even goes so far as to talk about the "user friendly features" of his no-radial model, among which he lists "compact size" immediately after claiming "exceptional HALF WAVE performance," as if the two characteristics were not fundamentally incompatible. Is this one a real half wave? It's 22.5 ft tall, so it might look like one at 21 mHz (466/22.5) except for the fact that a large portion of the radiator is "trapped out" or loaded on that and all successively lower frequency bands so that the total amount of radiator used on any band is well short of a half wavelength or even a mere quarter wavelength. This same manufacturer produces a throughly conventional vertical (uses radials) that stands taller than his no radial "half wave" and sells for quite a bit less. That one, he tells us, is merely a quarter wave! One might suspect that the recent tendency to label everything a "half wave" is an attempt to persuade the new ham that some great new operating experience awaits him when it almost certainly does not.

Q3 More than 100 l/2 wavelength radials under a quarter-wave vertical antenna at ground level will allow it to operate at over 90% efficiency and 15 1/8 wavelength radials will allow the same antenna to operate with an efficiency of about 50%. But with only two 1/8 wave radials (or none at all) the quarter wave will not operate much more efficiently than about 25%. A much shorter "half wave" vertical, however, will perform more efficiently without radials in the same situation because it's "ground independent." True or false?

A3 The radial information is taken from the ARRL Antenna Book, so that much is true. The part about short "half waves" outperforming taller quarterwaves, however, is total nonsense, as is the notion that even real halfwaves are unaffected by--or "independent" of--the earth beneath them.

Q4 One manufacturer claims that a 60 radial system that reduces earth loss to only four ohms will destroy a vertical's multi band operation because a multi band vertical MUST have earth loss to work! That's why a multi band vertical mounted on your roof won't work all the bands. Is there anything here that we should believe?

A4 This statement is totally devoid of sense and so chock-full or error that we can only wonder what, if anything, it is supposed to mean. There are thousands, perhaps tens of thousands of multi band vertical antennas playing quite well on rooftops all over the world. And why must multi band vertical antennas have earth loss to work? Perhaps you'll come across this ad in full in your search for an antenna. If you can make head or tail of it please explain it to us.

Q5 If you can avoid using radials and still achieve low SWR you can be sure that your vertical antenna is operating efficiently because the lower the SWR the greater the efficiency, always. True or false?

A5 We've already seen in the discussion of Question 2 that there's absolutely no necessary connection between low SWR and high efficiency. Flip back to Question 2 and recalculate the efficiency when the feed point impedance is exactly 50 ohms rather than 33.3 ohms. Our radiation resistance stays at four ohms or so, so our new efficiency is 4/50 or only 8% even though the new SWR is 1:1--down from 12% when the SWR was l.5! On the other hand, 1.5 SWR with a feed point impedance of 75 ohms is even worse. What matters is NOT the value of the feed point impedance and SWR but how much of the feed point impedance cones from loss resistance and how much from radiation resistance. Radiation resistance, unfortunately, depends on the size of the antenna and little else, and a short “stick” will remain a short stick with low radiation resistance, even when it's re-christened a “half wave.” If large values of earth loss resistance and/or loading resistance are required to raise the feed point impedance to the 50 ohm range for the sake of low SWR you've gained nothing. In short, low SWR all by itself tells us next to nothing about efficiency. If, however, we can look up the radiation resistance for a vertical antenna of a known height from a standard reference text such as the ARRL Antenna Book we can use our SWR information to calculate the probable efficiency. No, the ads won't give you that information (not the right information anyway) or invite you to figure it out for yourself, but anyone who has mastered 7th-grade math and is willing to learn a few basic principles can do it easily for himself.

It's the rare amateur who has the real estate, the time and the finances to install the PERFECT antenna system, so as a practical matter one usually has to make do with the available resources, A 100 ft tower is more desirable than a 40 footer, and 100 long radials are better than four or five shorter radials run out wherever they will fit, but on the typical short-haul rag-chew contact on the HF bands the difference often won t be significant. The people who designed the more expensive “no radial” vertical certainly know about earth losses and that their creations at or near ground level can't perform as efficiently as a conventional vertical over even a modest radial system, but you can hardly expect them to put that into their expensive ads! There are relatively few situations where vertical polarization is desired and where one simply can't find the room for any short radials at all. Perhaps in such rare cases a no radial vertical may be the beginner's only salvation, but usually a little experimentation and study will yield the same or better results with less wear and tear on your bank account!

What is the smallest radial system one can use and still get low SWR on most HF bands? That's a difficult question to answer with any precision because the earth's natural conductivity can vary considerably from one location to the next. In parts of the Midwest a simple ground rod will often suffice, whether any radials are used or not. Sandy or rocky soil is usually the least conductive, so count on needing at least a few radials (each as long as possible) at ground level to reduce the SWR to an acceptable level. Radials need NOT be buried, so where there's no danger of tripping up pedestrians they may simply be left on the surface. Remember that the primary reason for putting down radials is to enhance surface conductivity, reduce earth losses and thus increase overall efficiency. Lower SWR is merely a bonus.

To recapitulate briefly, if you want to guesstimate the probable efficiency of a vertical antenna on any particular band first find out how much of the antenna is really used on that band. Trap models use only the portion of the vertical radiator BELOW the trap for that band. Once you have the length in feet you'll need to convert that length to electrical degrees in order to use the information in the ARRL Antenna Book. Suppose, for example, that the vertical portion beneath the 15 M trap is 9 ft. tall. A full quarter-wavelength for 21 mHz = 234/21, about 11 ft. or 90 electrical degrees, so 9 ft. must be less than 90 degrees. How much less? 11 ft is to 90 degrees as 9 ft. is to x, so we can that 90/11 = x/9, so x = 73.6 electrical degrees. Right? Next, we look up the radiation resistance for 73.6 electrical degrees in Chapter 2 (Antenna Fundamentals) of the ARRL Antenna Book and read 20 ohms, more or less. Kid stuff! Now that we have the radiation resistance to a fair approximation, all we need to know is the loss resistance that makes up the rest of the feed point impedance. That's the hard part, but if we have some reliable SWR information we can figure that out too, although we won't be able to tell exactly how much is earth loss, how much is loading loss and so on. Put a little SWR indicator at the antenna feed point are run just enough power to get full scale deflection in the FORWARD position. If SWR reads 1:1 without any attempt at matching the line to the antenna you'll know that your 50 ohm impedance at resonance consists of 20 ohms of radiation resistance and some 30 ohms of loss resistance from whatever source or sources. To find overall efficiency simply divide the radiation resistance (20 ohms) by the total feed point impedance (50 ohms). In this case, we can see that our efficiency is 40%. That's not enough? OK. Just run out more radials. When the SWR begins to change you'll know that the earth loss resistance is dropping and the efficiency is going up It's just that simple. Remember, however, that SWR might go UP as the efficiency improves.

Suppose, however, that our lowest SWR is no lower than 1.5 with 50 ohm line? All that means is that the feed point impedance is either 50/l.5 or 50 x 1.5, and we're back to the situation we noted in the discussion of Question 2 where only the SWR information (1.5:1) was given. In that example, recall, feed point impedance was either 75 ohms or 33.3 ohms, and for a fixed value of radiation resistance the efficiency will depend on the loss resistance component of the feed point impedance.

If you've been able to follow this little discussion you're well on your way to becoming your own antenna expert, even if you've had to go back and read some passages several times. With a little more study and experience you'll be able to hack your way through the thickets of technobabble that are designed more to confuse than explain. Above all, don't hesitate to question and challenge claims that make little sense or seem to contradict one another. Reputable manufacturers will usually be happy to restate their sales pitch in simpler terms whenever they see a chance to do so, and if someone is proposing to trade his (or her) hard-earned shekels for his wares they can't do anything less.

The ARRL Antenna Book will help you enormously, even if you have to read some sections several times, and for lighter (but no less serious) reading we suggest Kurt N. Sterba's AERIALS, a compilation of antenna articles from the pages of Wordradio, and well as OM Kurt's monthly column in that publication. Contact Worldradio, P.O. Box 189490, Sacramento, CA 95818.