BENCHER, INC.

Choosing a Vertical

Selecting a Multi-Band Vertical

HF Vertical antennas have long been popular with hams and for good reason. They can be very effective antennas for their size, and have the advantage of taking up very little space. The typical vertical radiates at a low angle of elevation, usually the most effective angle for working extended ground wave and for working DX when skip is in. All verticals work against a ground or a ground image. The ground or ground image serves as the necessary reverse half of the antenna. (By way of illustration, the classic dipole antenna has two sides fed in opposite phase, usually by coax cable. In a simple dipole, one side of the antenna is fed by the center of the coax, the other by the coax shield. All real world antennas need two opposed sides so that the feed line, usually coax cable, can drive them. For verticals, the opposed side to the coax center lead may be the earth if the antenna is ground mounted and used with radials, tuned radials if elevated, or some form of counterpoise. When considering vertical antennas, a good way to think of the ground image is like a mirror, with the vertical antenna rising from the center of it.

The coax center goes to the vertical, the braid of the coax is attached to the ground side. The ground may be nothing more than a metal rod pounded into the ground plus the shield of the coax feeding the antenna, which capacitively couples to the earth it is lying on. But such grounds are very poor, like a very dark mirror, letting your RF energy be wasted in the earth as ground losses instead of transmitting it into the air. What is desired is a good ground system that will reflect the RF into the ionosphere. For ground mounted antennas radials are the only realistic way to achieve a good ground system.

For some reason several manufacturers' marketing departments have spent a great deal of money marketing "No-Radial" verticals. Indeed, they have tried to turn "radial" into a dirty word. They propose to modify the laws of physics in suggesting that their vertical antennas need no ground. But all vertical antennas need a ground to work against, and the better the ground the better the performance. Why do they trash this time honored antenna technique that gives outstanding results and requires a hour or so of work to install in such a way that it is invisible to the eye and lawnmower? Clearly, to obtain market advantage for their products. Their antennas do have a ground - the mounting stake pounded into the ground, and the coax running on the ground to the antenna.

Consider this: virtually every AM broadcast station on the air today uses a vertical with a well developed radial system. These are stations designed by professional engineers who use lab grade field strength test instruments. If the radio station's customers don't hear the station they are out of business. So they use radials. If a better antenna design existed they would use that instead.

Surely, some amateurs have limited space for an antenna, and an extensive radial system is not possible. But there is almost always a way to install an effective vertical one way or another that makes provision for a decent ground. In return, the operating benefits of a good antenna installation are most rewarding.

A "no radial" vertical will work people - sometimes even some pretty good DX - but a well designed vertical working against a good ground system is a substantially better antenna. A good ground - a bright and shiny mirror - has good conductivity and dielectric qualities, and serves to reflect and thus radiate the power fed to it. It is an active partner in the radiation of the RF energy from the transmitter. A poor ground, on the other hand, is a silent partner - it sucks up resources and gives little or nothing back in return, other than perhaps a good match to the transmitter. (A poor ground can also lead to RFI problems, such as TVI, telephone interference etc.)

Offering a good match to the transmitter is not the same thing as radiating RF. Far too many newer hams have been lead to believe that because an antenna has low SWR all is well. A vertical with a poor ground is entirely capable of offering a perfect match to the transmitter, with 1:1 SWR, yet with the ground absorbing much of the RF and turning it to heat, cooking earthworms perhaps but emphatically not radiating into space.

The same is true of a vertical of inefficient design in the antenna itself. Engineering analysis has proven that an inefficient vertical antenna needs only an inefficient ground, and that a superior ground under an inefficient vertical will not significantly improve its performance. This fact has proved a blessing to those antenna manufacturers who advertise their antennas as needing no radials.

This, by the way, also explains one brand of verticals that actually advertise their products as being "quiet" antennas. The antennas are quiet because they are horrendously inefficient and ineffective! (The company making these claims quotes from product reviews in several smaller ham magazines about how quiet and how effective their antenna was in tests. Curiously, they don't quote the review of the same antenna published in the world's largest ham radio magazine, which pointed out that the antenna was strangely DEAD on several important bands, both receiving and transmitting, even though that company advertises heavily in that magazine.)

Verticals have a reputation of being "noisy" antennas - and so they should - a good vertical receives signals from all directions, unlike antennas with definite patterns, such as yagis, quads or even dipoles. If a vertical is "quiet" something is wrong. Even if the SWR is good.

If you live along the east coast, working a log-full of European and African DX is no big deal, even with an inefficient "no radial" antenna. After all, there are easily a hundred DXCC countries little further from you than California, and with a path that is mostly salt water, frequently over easier north/south paths. But if you live in the dryer parts of the west, over thin and rocky soil, such antennas are guaranteed to lead to DX'ing frustration. East or West, there is no valid reason not to try to put up the best antenna you can, and if it is to be a ground-mounted vertical then you should try to get the best ground system under it you can reasonably manage.

What constitutes a decent ground? The ideal ground is considered to be 120 radials, of half a wavelength long, equally spaced around the antenna. Of course few can manage such an ambitious approach. A good ground would consist of 15 radials 1/4 wavelength long, using the wavelength of the lowest frequency band to be considered. An acceptable ground can be made of 8 radials at least 1/8 wavelength long - which would be only 16 feet on 40 meters. And even three or four radials of 10 feet or more is a good deal better than the casual stake in the ground. But putting down more radials will be well worth the effort, even if some of them can not be as long as others. More is better.

Ideally the radials would radiate from the base equidistant in spacing. But in reality the radials will work fairly well anywhere they are put. Bending a radial around a corner, a tree, the doghouse etc. or running it next to the driveway are all perfectly acceptable variations. Radial wire can be any copper wire from about #20 and larger, insulated or bare. Aluminum or steel wire will work, but are harder to get good connections with, and tend to corrode more rapidly.

Radials need not mess up a lawn either. A little trick works wonders - if you are putting down a radial system in a lawn, purchase some very large nails at the hardware store, preferably at least 4 inches long. Put a turn of radial wire around a nail, press the nail all the way into the earth. Draw the radial out perhaps ten feet, take a turn around another nail, lay it on the grass and pull it tight, then press that nail into the dirt. Draw the remaining wire out further, put another nail in, etc. If necessary, in between nails push in wire staples, perhaps cut and bent from a few inches of the wire from old coat hangars, to hold the wire tight to the ground. If done right, within about 6 weeks the radials will disappear into the thatch and will never bother the lawn or lawnmower.

A recent design effort by several manufacturers has involved adding a limited counterpoise as a standard part of the antenna. Such a counterpoise generally consists of a few rods or tubes perhaps six or seven feet long radiating horizontally from the antenna. The idea behind this is to capacitively couple with the real earth below. While such a counterpoise is definitely better than nothing, they do present several problems. For one, they are limited by the quality of the earth below them. Damp, loamy earth gives far better results than does sandy or rocky dry soil. Regardless of the soil quality, such a counterpoise works better for the higher bands than the lower bands, where it becomes progressively less efficient.

Another problem is that because of the variable nature of the soil the antenna is above, some tuning of the antenna will surely be required, even though the manufacturer is trying to keep the antenna installation extremely simple. However, lossy antennas with poor grounds may not require tuning for good SWR - the losses mask the matching problems - and also the weak signals. In such cases, the manufacturer's marketing department tries to make lemonade out of a lemon by calling the product "quiet", and bragging that their antenna requires no tuning.

When considering a "no-radial" vertical, remember - virtually every AM broadcast station uses verticals with radials - lots of radials. If professional broadcasters with years of research and experimentation behind them thought there was any better way to build a vertical than to use radials, they would certainly do so. Don't be confused by gobbledegook buzz words like "elevated asymetric feed." If that is so good, why isn't it used by professional broadcasters? Answer - it isn't.

Verticals With Traps

Most hams prefer to work multiple bands. When antenna possibilities are limited, this indicates a multi-band antenna. Unfortunately for the user, the most common design approach for multi-band antennas is to use traps. A trap is a combination of a coil and a capacitor. The combination is designed to prevent RF above the trap frequency from passing through the circuit, while RF below the frequency can move through.

This sounds great, but unfortunately traps force serious compromises. For one thing, ALL traps are lossy. The

ARRL Handbook states that traps attenuate RF between .5 and 1.5 db for every trap RF passes through. Consider for a moment a 40 - 10 meter trapped vertical, with traps for 10, 12, 15, 17 and 20 meters. The antenna should work well on 10 meters - on that band it is full size and there are no traps. But on say 20 meters, the RF has had to pass through the 10, 12, 15 and 17 meter traps. If the traps are "efficient" and only attenuate .5 db each, then your signal has lost 2 db - almost half your power! But if the traps are inefficient, you can lose as much as 6db - 75% of your signal! Wasted. And in a vertical, this loss is before we even get to grounding problems! Always remember, especially when reading expensive four color advertisements, that the term "High Performance Trap" is a classic oxymoron, like "Jumbo Shrimp".

Worse, that is not the entire problem with traps. Since each trap includes a coil, the antenna is physically shortened for the lower frequency bands. A full sized quarter wave vertical for 40 meters is about 33 feet high. But a trapped multiband vertical such as described above is typically somewhere between 15 and 18 feet high. While being physically more compact can be an advantage in some cases, it also inevitably means that the antenna is significantly less efficient, even ignoring trap losses. Further, all else being equal, the bandwidth is considerably narrower. And, being shorter, the antenna does not stick up as far, which means in turn your transmitted RF is more likely to get squirted into the trees, the powerlines, the neighbor's VCR etc., and not over the horizon into the DX station's log.

Another significant disadvantage of a trapped antenna is that the radiating part of the antenna is always at the bottom. The RF travels up the antenna from the coax feed point until it reaches the trap appropriate for that band, and stops there. So on 10 meters, the bottom of the antenna up to the first trap is hot, the rest cold, RF wise. On 15 meters, the RF passes through the 10 meter and 12 meter traps and travels up to the 15 meter trap and stops there. All the length of the antenna above that point is wasted for that band. But it would be better if the antenna could radiate at the top - clearer of trees, houses, TV feeds etc. But trapped antennas simply can not give you that option.

Taken in sum, traps are a poor way to design a multiband antenna. Traps are lossy, narrow the bandwidth, and on most bands do not fully utilize the full physical length of the antenna. There are other issues, such as impedance matching, that come in to play as well with trapped verticals, however we suggest you modestly avert your eyes, shudder, and move on.

But for the designer of trapped multiband verticals, all is not lost. Remember from above, research has demonstrated that having a significant ground system under a shortened antenna is a waste anyhow. A rather reliable rule of thumb is that the radials need be no longer than the vertical is high. Since the ground makes the image the vertical requires, the antenna only needs and can only use an image as good as the vertical radiator. A short, lossy antenna needs only a small and lossy ground - it simply can't do much better with more.

Clever marketing departments immediately jumped on this - "Since we have an inherently lossy antenna that won't work any better with a decent ground, we can offer it as a `No Radial' antenna! And without a decent ground, we can get better bandwidth too!" And so they did. (A good ground actually narrows the bandwidth, because the efficiency is higher. For a complete technical explanation of this and some other points briefly touched on here, see our Tech Notes entitled "Dirty Little Secrets" for a more exhaustive explanation.)

The Low Bands

For most hams, working bands like 80 and 160 meters is going to require something of a compromise in antenna size. But if shorter antennas were all that great, as some manufacturers would have you believe, the big guns on 80 and 160 would be using an eight foot whip with a big coil attached. Trust us on this - they don't.

Still, selection of a multiband vertical antenna based on the physical length of the antenna can be a major mistake. One commercial antenna for example is 45 feet tall. But that antenna has a feed point well above the base, so that the portion below the feed point is actually a part of the ground system, and the actual length of the radiating upper portion is significantly less. Also, that antenna brags about having "no radials", but states that a counterpoise of three wires of 57 feet each is required. But even though the wires are called a counterpoise instead of a radial system, they still are a radial system. And a pretty poor one at that. So, even though the antenna is taller, which is good, the efficiency is poor, which is bad. Adding more radials would seemingly make it work better, but the manufacturer tells you that more radials, sorry - counterpoise wires - in fact hurt the antenna. Which in reality confirms its very poor efficency. But at least that antenna has a well deserved reputation of being "quiet." And that's why.

Another well known brand of vertical, featuring "high-efficiency" traps, offers an 80 meter add-on to the top, bringing it to over 34 feet tall. This antenna configuration too requires several counterpoise wires. So, not only does it suffer from a poor ground, but 80 meter rf must pass through SIX traps. These traps are an rf killer, "high efficiency" or no. But here again, an antenna of poor efficency coupled with a poor ground gives a good match for good SWR, good bandwidth - and lousy performance.

A Better Way

Could there be a better way to design a multi-band vertical?

WØDN, Don Newcomb, then a professor at a major midwest university, thought so. Don developed and secured several patents on what is a truly superior design - the Butternut vertical. Don's patented antenna design is entirely different from other commercially offered vertical antennas. He started with a basic vertical, 26 feet long, and instead of festooning and limiting it with traps, he designed a multi-band matching network whose sole purpose is to match the 50 ohm coax to the antenna. Don's unique design uses the whole antenna to radiate on each band, with the exception of 6 and 15 meters, which will be discussed later.

This means that all of the antenna radiates on each band instead of a portion, as with the other allegedly comparable antennas offered. And, with the whole antenna radiating, the RF reaches the top of the antenna, instead of being choked off by lossy traps further down. Even though the physical length of the antenna is shorter than some competitive antennas for the low bands, the trap free design when coupled with a decent ground make it more than competitive on the bands.

There are other significant advantages too - being trap free the SWR bandwidth is considerably enhanced, even though an efficient ground serves to reduce it. (Which makes an interesting conundrum - a longer antenna has more bandwidth, but a more efficient ground narrows the bandwidth - the end result is that the bandwidth of an efficient antenna and an inefficient is often about the same. The only real difference then becomes that the efficient antenna radiates far more power than the inefficient antenna. Which would you want?)

At the higher bands the real length of the antenna exceeds 1/4 wavelength so that the angle of radiation is lower, enhancing DX performance.

The matching network used is an ingenious combination of high-Q coils fabricated from large diameter aluminum wire, and heavy duty high voltage ceramic transmitting capacitors. Needless to say, there are no traps, "high performance" or otherwise. Traps cause loss. Period.

On the Butternut vertical, for 15 and 6 meters a different approach is used. Decoupling stubs run parallel to the antenna, which result in the antenna radiating as a slightly extended, full-sized, trap free quarterwave vertical on fifteen meters, and as a 3/4 wavelength vertical on 6 meters.

The ingenious Butternut design lends itself to several different methods of mounting and installation. The antenna can be mounted above ground on a roof, and if that is the best solution a complete accessory roof mounting kit is offered. Also, roof mounted antennas require tuned radials for best efficiency. A compact set is offered as an option, but the manual accompanying the antenna describes the simple steps to make your own. Alternately, pieces of wire cut to length will do very well, and again complete instructions are offered in the manual.

Perhaps the most common installation method is ground mounting. With Butternut verticals, it is very simple - a 24" tube is pounded into the ground, and the antenna is mounted on top of it. No guy wires are required. Radials are placed on the ground radiating from the base of the antenna, and are attached to it. If the radials are properly installed (see above) they soon disappear into the thatch of the grass and the resulting installation will offer many years of superb performance.

Another way the antenna can be installed is with the accessory Counterpoise Kit. The antenna is mounted on a post or mast so that the base of the antenna is about seven feet above ground. The counterpoise assembly is mounted immediately below it. Any counterpoise must be considered a compromise for any vertical HF antenna, and if a proper radial system or a roof mounted installation with tuned radials is possible that would be the preferred approach. But when that is not possible the Butternut counterpoise creates a fairly effective artificial ground that still easily outperforms the "no-radial" and trapped antennas, even with their built-in counterpoises.

It should be noted that in the last year or so other vertical manufacturers have begun singing the praises of counterpoises so that they can retain their "no radial" design purity. One example is particularly ludicrous - where the manufacturer offers an 80 meter kit that calls for several "counterpoise wires placed on the ground around the antenna." To any casual observer these would look like radial wires but since the associated antenna is widely promoted as a no-radial vertical clearly they can't be radials. So instead we put a fig leaf over them and call them counterpoise wires. Right?

In any case, that design, even though it uses radials, has so many traps its performance on the low bands in particular is very limited.

For most users, what is the problem with radials? Especially when they add a considerable boost to your signal? True, in a few installations any significant radial system simply is not practical for reasons beyond the control of the operator. But even in such a setup Butternut verticals will work as well and usually outperform the no-radial designs, thanks to the trap free design that allows the whole antenna to radiate. An antenna with no radials is clearly better than no antenna at all, but if properly designed it will always work better with a radial or counterpoise system.

So OK. Instead of a Butternut you elect to put up a "no-radial" antenna and make it work better with radials. Right?

Maybe, maybe not. Indeed, probably not. How come? The problem here is that frequently the designer of the "no-radial" antenna was able to achieve a decent match and SWR on the amateur bands only thanks to the losses and poor coupling to ground inherent in his or her design. Adding radials to such an antenna improves the efficiency, and suddenly the losses that insured a good match start to disappear. The antenna impedance changes, beyond the controllable range of the tuning network. But not to worry - the manual for such antennas usually specifically tell you not to add radials - they warn you that the antenna will not tune - they just don't tell you why.

One last point to consider - all Butternut HF verticals work on 80 meters and can additionally be used on 160 meters with the accessory Butternut 160 meter Top Band Resonator. Only a few "competitive" vertical antennas operate on 80 meters even with accessory kits, and fewer still operate on 160.

There is a lot of gobbledygook around about multiband vertical antennas, most of it from manufacturers who are trying to gain sales by claiming to defy the laws of physics. Most of these claims are better suited to fertilizing roses rather than educating potential customers. They rely on a sad reality - almost any amateur who puts up their product will hear signals and work people, and then think he got his money's worth. He is excited, and tells all his friends what a great antenna he has. What that amateur does not realize is that other products that cost no more money will far outperform what he got snookered into buying, simply because he has no basis for comparison.

Another marketing technique you will see in the ads is comparing a certain vertical against another unnamed product, of course making the advertised product out to be far superior. And so it might prove - there have been some dreadful products marketed at one time and another, long since discontinued. Further often they have been in use for years, quietly deteriorating in the weather, and are fed with waterlogged coax. Then a new antenna with a new feed line is put up near by for the purposes of "A/B" testing. That it works better is then used in the advertisements to suggest that the advertised product is clearly better than ALL other such antennas. It should appear obvious that is probably not so.

If HF verticals without radials were as good as HF verticals with radials, Butternut would certainly manufacture such a product. After all, Butternut has been manufacturing verticals for over 20 years. No-radial verticals aren't rocket science. Anyone can make a lossy, low efficiency antenna. We know better - and so should you. If you purchase a Butternut vertical, and go to the trouble to install it properly, you will have installed the best multi-band design presently available, and the one that will give you the best results for years of trouble free operation.

For a further expansion on some of the technical points raised here, click here for the "Dirty Little Secrets From the Antenna Designer's Notebook".

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