• *Beginner and Novice*

Some Plain Facts about Multiband Vertical Antennas

BY LEW McCOY,* W1ICP

DURING DISCUSSIONS with newcomers, and old timers for that matter, it becomes apparent that there is considerable confusion as to what exactly a multiband vertical antenna is. The confusion concerns the method of feed, how much mismatch one can expect, how many radials are required, how the particular antenna is built for multiband use, plus some other points.

This article breaks the subject into simple language and provides the reader with sufficient expertise to assure him that he won't wind up with a system he really doesn't want. Before going into a discussion of the different types of multiband "verticals" we will offer some simple antenna facts.

Some Basic Theory

The term "multiband antenna" has come to mean many things to hams. With trap antennas, tapped coils, random wires, and so forth, there is plenty of reason for the confusion. Simply, a multiband antenna is one that can be used on more than one band. How we make it work on different bands is another story.

Basically, any piece of wire of *any* length can be classed as a multiband antenna. For example, a length of wire four feet long *could* be used on *any* amateur band, from 160-meters on up. However, how well the piece of wire would work is a completely different matter.

In the feed point of any antenna there is *radiation resistance*. The energy supplied to an antenna is dissipated in the form of radio waves and in heat losses in the wire and near by insulating materials. The radiated energy is the useful part, but so far as the transmitter is concerned it represents a power consumption just as much as does the energy lost in heating the wire. In either case the dissipated power is equal to I^2R: in the case of heat losses, R is a real resistance (ohmic losses), but in the case of radiation, R is an *assumed* resistance. This fictitious resistance is the radiation resistance. This brings us to our first important point about multiband antennas.

Whenever one reduces the size (length) of an antenna physically, the radiation resistance is reduced also. As an example, assume we have a 20-meter quarter-wave antenna, which is approximately 16 feet long. Let's imagine we made it out of No. 40 wire, which has a resistance of about one ohm per foot. The radiation resistance of a resonant quarter-wave vertical operated against a perfect ground is on the order of 35 ohms. In this case, the feed-point impedance of our antenna would be roughly 35 ohms in radiation resistance plus 16 ohms in ohmic resistance. If we were to feed 51 watts into this antenna 16 watts would be dissipated as heat (lost power) and the remainder–35 watts–would be radiated. Now, suppose we use this same antenna on 80 meters. As mentioned above, when we reduce the size of an antenna physically the radiation resistance is also reduced. On 80 meters our 16-foot antenna would have a radiation resistance on the order of one ohm! However, we would still have the ohmic resistance of 16 ohms. It doesn't take much figuring to realize that just about *all* of our power would be lost as heat.

Of course we wouldn't use No. 40 wire for such an antenna. More likely the antenna would be made from aluminum tubing and the ohmic losses would be very low, but probably still more than the radiation resistance. There is an old axiom in amateur radio that offers some pretty good advice: Always make the antenna as long as possible, and erect it as high as possible. Also, there is a joke that goes with that axiom – if such an antenna stays up, it is too small!

At this point we have only mentioned radiation and ohmic resistance in the antenna feed point. These are the two resistances that exist when the antenna is resonant. When the antenna is not resonant, there is reactance present in the feed point. Reactance is also expressed in ohms, but it

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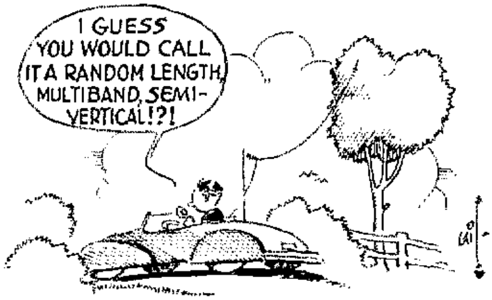


isn't a real resistance in the sense that power can be dissipated therein. We won't go into a long discussion on reactance because it would take up too much space. An excellent explanation can be found in the League publication, *Understanding Amateur Radio*. Simply, reactance can be likened to a gate or door that stops or hinders the flow of current into a circuit. When an antenna is operated at some frequency other than the resonant frequency there will always be reactance present. Keep in mind that with *any* antenna, multiband or otherwise, we always have a condition on some band or frequency where the antenna is not resonant. Therefore, there will be reactance at the feed point.

Types of Vertical Antennas

The basic and most popular type of vertical is one that is a quarter wavelength long and is operated against ground or in a ground-plane configuration. The antenna is usually made from tubing and the radials are wire. An ideal ground plane (simulated earth ground) would be a sheet of metal with a radius of one-quarter wavelength or more. However, this is only practical at vhf so the customary method is to use wires as the radials. Probably the number one question asked about ground-plane antennas is, "how many radials are required?" The answer is simply, the more radials used, the better the antenna will perform, at least up to a certain point. This should not be construed to mean that an antenna with only two or three radials won't work. Such an antenna will work, but for *maximum* performance one should consider 40 or more radials. If the reader is interested in performance data for a few radials versus many, he should read the recent article in *QST* by Sevick[1]

The feed-point impedance of quarter-wave ground plane is on the order of 35 ohms. The impedance can be raised by drooping the radials down until a 50-ohm match is obtained. Exactly how much droop is required depends on the number of radials.

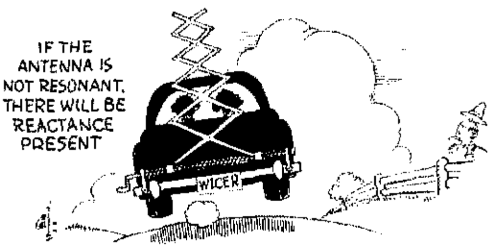
The quarter-wave ground plane is essentially a single-band antenna. However, a 40-meter quarter-wave vertical can also be used on 15 meters, a happy circumstance for the Novice. In this case, a 40-meter quarter wave works out to be three quarter waves on 15 and any *odd* multiple of quarter waves will provide a relatively low-impedance feed.

Multiband Verticals

When we get into the field of multiband verticals we find that considerable confusion exists. As pointed out previously, *any* antenna can be *called* a multiband antenna, but how we get power into such an antenna is another matter.

Up until the '50s any amateur multiband antenna was a system that usually consisted of an antenna, tuned feeders, and an antenna coupler. In the early '50s more and more amateurs started to

[1]Sevick, "The Ground-Image Vertical Antenna" *QST*, July, 1971.

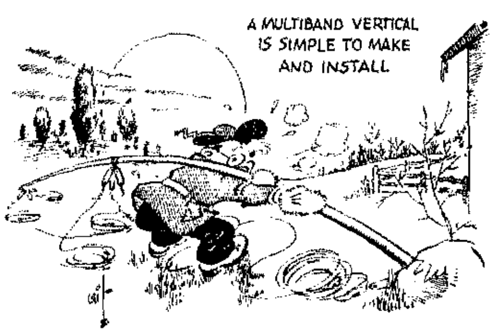


use coaxial cable for feeders, along with band-switching transmitters. The next logical step was the use of a multiband antenna system that required no adjustments and always presented a matched condition to the feed line – in other words, an antenna that had a 50-ohm feed-point impedance on every desired band and frequency within a given band. A logical development was the multiband trap antenna.

By inserting traps in an antenna it was possible to make an antenna "look" like a resonant half-wave dipole in whichever band was used; or, in the case of multiband verticals, making the vertical look like a resonant quarter-wave antenna for the desired band. However, and this is important as far as the newcomer is concerned, to our knowledge there is *no* multiband trap antenna that will provide a perfect match on all bands, *regardless* of what some antenna manufacturers may tell you. Many hams have spent countless hours trying to adjust trap antennas for that "perfect" match when actually, it is just about impossible to obtain such a condition.

Nontrap Multiband Verticals

Several antenna manufacturers sell multiband antennas that consist of a vertical piece of tubing, usually 16 to 20 feet long. The tubing is used with a loading coil at the ground end. By making appropriate taps and adjustments on the coil the antenna can be matched (or closely matched) on any given band. This type antenna has *no* traps. This in turn means that the coil taps and adjustments *must* be altered when one changes bands. Some misguided amateurs buy these antennas expecting all they need do is put them up and the antenna will work on all bands, automatically. Let's make one point clear: such an antenna *is* a multiband antenna, but requires adjustment *at the antenna* when one changes bands.



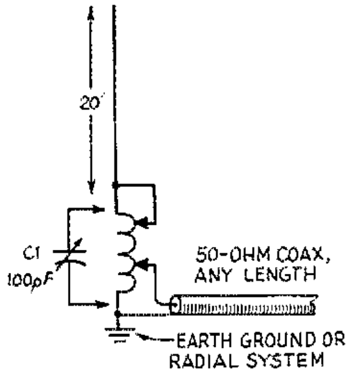


Fig. 1 – This is a typical multiband vertical antenna. A description of the system is given in the text.

Of course, the next question should be, "If the antenna is that simple can't I build my own?" Yes, it is a very simple multiband antenna to make and install. Two or three sections of inexpensive 10-foot TV mast sections can serve as the vertical radiating element. The mast can be supported on an insulator, such as a beverage bottle, and the mast guyed with nylon line. Fig. 1 shows a diagram of the antenna system. L1 should be a coil made of bare wire, No. 12 or 14, so that it can be tapped at every turn. A convenient coil size is 2-1/2 inches in diameter, six turns per inch, such as B & W 3905-1 stock. The number of turns required, assuming 80 meters as the lowest band to be used, should be about 30 turns with an antenna length of 25 feet.

Adjustment of the antenna requires the use of an SWR bridge. Connect the coax line across a few turns of L1 and make a trial position of the shorting tap. Measure the SWR, then try various positions of the shorting tap until the SWR reaches its lowest value. Then vary the line tap similarly. This should bring the SWR down to a low value. Small adjustments of both taps should provide an SWR close to 1. If not, try adding C1 and repeat the adjustment procedure, varying C1 each time until a match is achieved. Radials will enhance the performance of the antenna. The number of radials is up to the individual amateur.

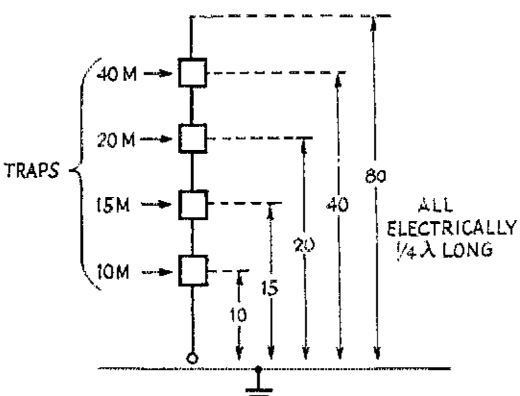


Fig. 2 – Drawing of the theoretical multiband trap vertical. In commercial practice, certain traps may be grouped together giving the impression that only a single trap is used.

Trap Verticals

As mentioned earlier, traps can be installed in a multiband vertical. These traps are usually parallel-tuned circuits and the objective is to make each section of the antenna work as a quarter-wave vertical or odd multiple thereof on the desired band. Fig. 2 shows an example of this type antenna.

The purpose in using this type antenna is to provide a system that always presents a matched condition for the feed line. Unfortunately, there is so much interaction between various sections of the antenna that it is impossible to come up with a *perfect* match on each band. What is an *acceptable* match is another story.

Amateurs as a whole are inclined to attach too much importance to an SWR of 1. They feel that if their SWR bridge isn't showing an absolute zero reflected power that something is horribly wrong and they won't work out. The plain fact is that using a feed line such as RG-8/U (assume a 100-foot length) one could have an SWR of as much as 5 to 1 and have *no* appreciable loss in the system. However, there is one clinker in this thinking!

In many instances commercially made transmitters and transceivers are designed by the manufacturer to work into a 50-ohm load only. They don't allow much leeway from this figure. When there is a mismatch in the antenna system, it can become impossible to load and tune the final amplifier of the transmitter. There just isn't enough tuning range in the tank circuit of the amplifier to handle the reactance that may be present in the load. There is a way around this problem however, and that is using a Transmatch in the feed line to disguise the mismatch.[2] The Transmatch can be adjusted so that the transmitter "sees" a 50-ohm load regardless of the mismatch at the antenna.

Elsewhere in this issue is an article by W1CQS/W4DWK describing the construction of a four-band trap vertical. The system is recommended to the Novice because it will work quite well on 40 and 15 meters.

The Harmonic Problems

Another consideration should be mentioned. As pointed out earlier, *any* antenna can be a multiband antenna. By the same token any harmonics generated in the transmitter that reach the antenna can be radiated. It is true that a single-band antenna will reject harmonic energy, but *not* completely. In the case of a multiband trap

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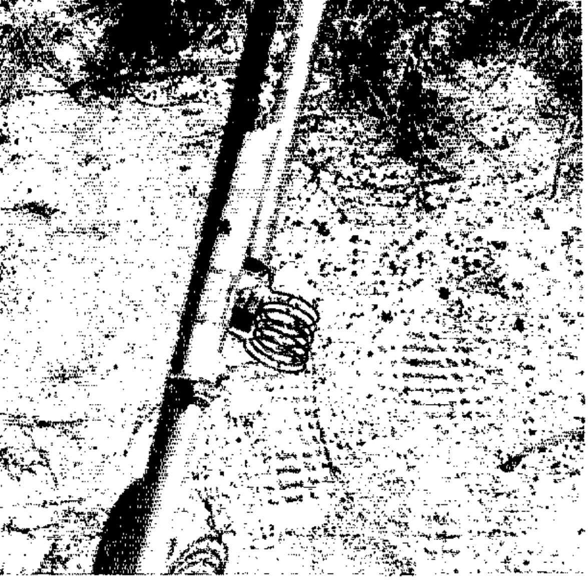
2 A suitable Transmatch is described in the transmission-line chapter of the 1972 edition of *The Radio Amateur's Handbook.*



This shows the trap. Two of the surplus transmitting micas, 50 pF each, were connected in parallel for the desired 100-pF value.

When the frequency has been adjusted, cut off the excess coil ends and mount it as per the sketch. Coat the assembly with Acrylic spray – the stuff used to waterproof automotive ignition cables. Use several coats. As for any doubts as to effective waterproofing, I have run a kW into this antenna for eight months in Florida weather, with no arcing. When I erected the antenna in Connecticut I used lacquer spray, and it is withstanding heavy rains. After the antenna is raised, check the antenna with an SWR bridge. If it shows a poor ratio, the coil assembly can be checked and adjusted with the antenna half raised. Also the angle of the radials with respect to the mast can be adjusted for the lowest SWR. The length of the supporting mast depends upon where you are going to place the antenna, of course. Mine has given good results with the lower end 25 feet from ground. Use 16-gauge TV masting for the support as 20 gauge is too flimsy and will bend and buckle while raising the vertical. The lower ends of the radials have varied from 10 to 4 feet from the ground, but try to keep about 45 degrees of droop.

Additional Notes

I used a TV mast bracket to hold the mast to the house. Also, I have raised this assembly by myself by pulling on one radial, first anchoring the two side radials to prevent side swing. I have used both RG-8/U (for a kW) and RG-58/U for 300 watts.

It may not be the best antenna but for a cheap, quick, unobtrusive, portable or permament antenna that will fit on a 60-foot lot, it is hard to beat. You will be able to work four bands. You will not be disappointed with the effective radiated power. It is excellent on 40 and 15, good on 20, and fair on 10. I even got it to work on 80, using a Transmatch. I have come out very well in DX pile-ups with some of the big boys. When I travel, the antenna is going with me.

Multiband Vertical Antennas

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antenna there is no rejection of some harmonics, simply because the antenna is designed to be resonant on all hf amateur bands. The solution to this problem is the use of a selective circuit installed in the feed line. A Transmatch is such a circuit and should provide adequate harmonic rejection.

Some Other Thoughts

The question is frequently asked, "should I mount my vertical on the ground, or get the base up in the air?" Getting the antenna up in the clear is always better than having it mounted at earth level and surrounded by rain gutters, house wiring, trees, power lines and so forth. However, getting the vertical antenna up in the air also means that radials, as many as possible, should be used. The average installation (if there is such a thing) usually consists of three or four radials (or more) cut for the lowest operating frequency. Such a system should give a good performance.

Another important matter is that of the earth ground. When verticals are mounted at ground level the ground losses can be very important. Too many amateurs buy their verticals, get a five-foot long TV-type ground rod and drive it into the earth at the base of the antenna. They think this provides a good ground connection. As a matter of fact, the TV-type ground rods are practically worthless for amateur work. A *good* ground rod is the type used by the power company for home installations. This is a rod that is heavily galvanized, 5/8 inch in diameter, and about 10 feet long. The amateur should be able to buy these rods from any wholesale electrical supply house. If possible, tie your ground connection to the water-system piping, assuming metal piping is used.

You'll hear the statement from fellow hams that verticals are poor antennas and radiate poorly in all directions. This isn't true because a vertical *can* be a good antenna, but you have to give it a fighting chance.