Tech Notes

Dirty Little Secrets 2

In our first DLS handout we discussed some of the problems involved in coaxing performance from a vertical antenna as well as some of the solutions that have been attempted. The major limitations will always be earth loss resistance and, on the lower frequency bands, low radiation resistance. Radiation resistance depends almost totally on the height (or vertical length) of the antenna conductor being used on a particular band, so of necessity vertical antennas for 86 and 40 meters are usually much shorter than a physical quarter-wave. Unfortunately, efficiency depends on keeping the radiation resistance as high as possible in relation to the total feedpoint resistance. The feedpoint impedance includes the radiation resistance, all the earth loss resistance and all the conductor/trap/loading-coil loss resistance--the total loss resistance of the entire antenna SYSTEM. In other words, the lossy earth (where most of the loss resistance is located) is usually the major contributor to the feedpoint impedance though it is certainly not the ONLY source of loss. If you can remember that efficiency equals the radiation resistance divided by the total feedpoint impedance you can see what happens to efficiency if only a few ohms of radiation resistance show up at your 50 ohm feedpoint.

This time we'll say a bit more about traps and loading coils, another rich source of loss resistance that can further reduce the efficiency of conventional multi-trap vertical antennas. These, recall, usually require a separate trap circuit for all but the lowest-frequency band to be used, and these traps necessarily add a certain amount of loading on each successively lower-frequency band, meaning progressively lower values of radiation resistance as the operating frequency is reduced. These traps are merely parallel-tuned L-C circuits that present a high impedance to RF energy at the frequency to which they're tuned (usually in the middle of some amateur band) and thus block current flow past the trap

In DLS-1 said a few words about what can and can't be done to reduce earth loss resistance and thus increase efficiency in the HF range. In practice this means adding a number of resonant radial wires to the antenna system if it's installed more than about 18 ft above the earth or a number of random length radial wires at or slightly below the surface if the antenna is mounted at ground level. In the second case one should try to make all radials at least as long as the antenna is tall and to distribute them more or less uniformly around the antenna. Where this is impossible it may be necessary to run radials out wherever they can go and to hope for the best, which will certainly be better than no radials at all, particularly if one or more radials can be hooked to a chain-link fence or other masses of metal at ground level. If necessary, radials can be run around foundations and bent as much as 90°. The object is to make the surface of the earth, at least within the first quarter-wavelength of the antenna, as conductive as possible to reduce earth losses. It's really quite simple: a few dollars worth of copper wire will often do more for your signal and DX country total than a thousand-dollar amplifier, so from an engineering standpoint it makes utterly no sense to design a vertical that cannot be used with radials even when the room is available. Yet that is the design approach taken by the manufacturers of the no-radial so called half waves that we discussed in DLS-1. These, give or take a few minor wrinkles, are essentially variations on ancient trap designs from the 50's or even earlier. So what do we do about trap and loading coil losses? For the most part we eat them on the erroneous assumption that they're the only way to get operation and that the convenience of covering a number of different bands with a single antenna far outweighs any sacrifices that may have to be made in efficiency and performance. In some cases we may have no choice but to make the sacrifices and pay the price. A vertical antenna for 75 meter mobile work just can't be 88 ft tall, so we load it seven ways from Sunday and don't lose any sleep over the fact that our efficiency may be only a few percent. Usually, however, we want somewhat better performance from a fixed antenna that is taller, but that calls for trap construction that isn't often seen in amateur radio antennas.

Most trap coils are wound on small diameters and use light wire,. typically #12 or smaller. Worse, their length/diameter ratio is usually very poor, larger coil diameters being preferred. Consult the ARRL Handbook for a more thorough discussion of trap Q and the relation between Q and loss. Typical trap and loading coil Q's are 100 or less, so the long, skinny traps that we see in most trap antennas are usually of this type.

Since most vertical antennas are less than a quarter wavelength tall at the lowest operating frequency and use less than a quarter-wavelength of the available radiator on any band the traps for the higher-frequency bands provide loading for the lower-frequency bands, thus lowering both radiation resistance and efficiency. An eight-band vertical using seven separate traps has seven possible sources of loss resistance in addition to the ever-present earth losses, and some "dipole" configurations employ even more. But some amateurs are willing to pay a small fortune for these inferior performers merely to obtain a low value of SWR in order to please their solid-state finals. In an earlier age this would have been called "dumb" or worse, but we've been conditioned to regard SWR greater than unity as a cosmic evil to be avoided at all costs. Unfortunately, no antenna (especially one that is electrically short) will maintain the same low value of SWR over an entire amateur band, so more often than not a poor devil must still run out and buy an equally expensive tuning unit to keep his finals happy. A far less costly solution, assuming that one already has an "antenna tuner," "transmatch," "ATU" (or whatever it's called) is to skip the antenna altogether, find a convenient tree limb, suspend a 25 ft vertical wire from it, and feed it in the center or at the lower end through 458-ohm "ladder line" or even TV ribbon.

True, the line SWR will usually be much higher than on coaxial line, but the antenna matcher will keep the solid-state finals happy, usually without adding any more loss to the system than a perfectly-matched coaxial line. In short, you can save the cost of a no-radial "half-wave" for the price of a few insulators, a hank of wire, and a length of ladder-line. Better still, you'll have eliminated a major source of loss by getting rid of all the lossy traps, and this super-economical antenna should play at least as well as any of the no-radial "half waves." And if you feed it at the base and connect a number of radials to the other side of the feedline it'll operate more efficiently than any of them because you'll have made a dent in the earth losses that are usually the major thief of efficiency and performance.

It's not a totally free ride, of course, for even the best tuning unit is not entirely free of losses of its own, though these will usually be slight because tuner components are generally of better quality than those found in antenna traps.

But how much loss are we talking about? Some experts reckon that 1 dB loss per trap is about average, and this seems to be as good an estimate as any, given the wide variation in materials and construction techniques, so let's take that as a starting point. If we have an 8-band trap antenna we should probably add another possible 7 dB of conductor loss. If we're already losing some 6 dB to earth losses (a virtual certainty with the no-radial designs) it's obvious that we'll have to add a KW amplifier to our 168 W transceiver to make up for the earth and conductor losses we have to swallow, maybe even two kilowatts!

Fortunately, all the traps in a “all band” antenna don't always come into play. When such an antenna is used on 20 meters, for example, any traps for higher-frequency bands act as lousy loading coils at the same time that the 20 M trap blocks current flow past it and reduces the height required for resonance as well as the radiation resistance, This is a true lose-lose situation. If a true quarter wave on 20 M is about 16 ft tall and offers a radiation resistance of about 35 ohms, what happens when the height used to radiate your signal is only 11 ft or so because the 10, 12, 15 and 17 M trap circuits contribute so much unnecessary loading? The first thing that happens is that your radiation resistance drops like a brick--from 35 to maybe as little as half that value. If your 20 N earth loss resistance is 15 ohms (as it probably is without a fair number of radials) you re down 3 dB already. Add another 4 dB of loss from the four traps now acting as loading coils and SHAZAM! Your KW now sounds like a 250-watter! If you now drop down to 40 M and fire up your effective radiation may reach “barefoot” power levels because any 20 and 30 M traps will also become lousy loading coils and drop your radiation resistance further.

The low-band DXer is often ahead of the game because he needs but a single trap or loading coil circuit to make a quarter wave vertical for 40 meters operate on 80 meters. Most amateurs, however, are lucky to have the room for a single vertical antenna of any description, so naturally they wish to use the same structure on as many HF bands as possible. But how to do this without adding another half dozen traps and their losses? The conventional multi-trap technology can't be the answer because it's a major part of the problem!

The Butternut designs, on the other hand seek to avoid traps wherever possible in order to limit conductor losses and to use as much of the antenna as possible in order to keep the radiation resistance as high as possible, all in the interest of maximizing efficiency. If you study the illustration for the HF9-X you'll see only four tuned circuits that produce useful resonances on SIX different amateur bands, and only one, the practically lossless 15 M stub de-coupler operates as a trap of any kind.

Remember, traps are tuned to a particular amateur band where they present a high impedance that prevents current flow past the trap and are inserted at a point that is a quarter wave above the feedpoint, so any part of the antenna radiator above the trap for a particular band contributes nothing to the radiated field.

The Butternut design approach is totally different. The first circuit above the feedpoint is parallel-tuned to provide the necessary inductive reactance for resonance on 80 or 75 meters, but it's not tuned to any frequency in any amateur band, so it doesn't block current flow past the circuit, and the entire 26 ft radiator is free to radiate. Immediately above the first circuit is another parallel-tuned circuit that provides the inductive reactance for resonance on 40 meters. This second circuit is independently resonant slightly below 11 MHz, so any 40 meter energy is similarly free to flow past it. The 30 meter circuit is a series-tuned low-impedance affair placed across a portion of the 40 M coil to remove a portion of its inductance so that the entire 26 ft radiator can resonate on 30 meters as a slightly extended quarter wave with a radiation resistance of approximately 40 ohms. Where are the 20 and 10 meter tuning circuits?

There aren't any! If the values of the components in the 40 and 30 circuits are chosen properly additional resonances appear at 20 and 10 meters. For 15 meters resonance is produced by a quarter wave “transmission line” decoupling section that divorces the upper section of the radiator from the circuit on that band and leaves the lower section to resonate as a full quarter wave. In short, the entire radiator is active on all bands but 15 meters, and the number of loading circuits and their attendant losses are kept to an absolute minimum. What does this mean? Simply that the entire antenna height can contribute to the radiated field on all bands but 15 meters and operate with higher radiation resistance than any “trap” design of comparable dimensions. This, in turn, means that for a given value of earth loss resistance the Butternut design MUST operate more efficiently than any of the “trap” designs. Well and good, you might say, but what about YOUR coils? Don't they have any losses? Yes, they do; any antenna that requires loading (inductive reactance) for resonance because it's electrically short will have SOME loss! But our L-C circuits are made of large-diameter self-supporting aluminum wire so that circuit Q easily exceeds 300. The 17 and 12 meter circuits are of similar construction so that they permit the whole radiator to carry current on those bands. On 30 meters the radiator is taller than a Quarter wavelength, so the circuit for that band is made to contribute a small amount of capacitive reactance for the sake of resonance and low SWR without, however, sacrificing the increase in radiation resistance above 35 ohms.

In the last paragraph we mentioned that the 80 M circuit is the FIRST tuning circuit above the antenna feedpoint in the Butternut designs. Placed four feet or so above the feedpoint, this circuit obviously CAN'T be a trap, for if it blocked 80 M current flow the portion of the antenna below the circuit wouldn't be long enough to resonate anywhere near that band. So why put them down so low? Two reasons: an antenna of any practical height can't be much over 30 ft tall before it starts to cost a fortune or to require an elaborate system of guy wires to stay up in a light breeze. In a moment we'll say a few words about base-, center- and end-loading, but why do all the conventional trap designs seem to stick the loading coil for the lowest-frequency band up near the top of the antenna above all the others where it can catch the full force of the wind? The answer, of course, is that they all use traps which have to be inserted at a quarter-wave point if the thing is to resonate without the help of some kind of expensive tuner on a higher- frequency band! For an 80 and 40 meter trap antenna the trap has to go at least 32 ft above the feedpoint where it chokes off current flow on 40 meters and simultaneously provides enough inductive reactance in conjunction with a capacitive “hat” of some kind (still more weight!) to load the same structure to resonance on 80/75 meters. How well would such a structure work if it stayed up? Probably fairly well on 40 meters because on that band the thing's a full quarter-wave tall and has a radiation resistance of close to 35 ohms and relatively little conductor loss. But how well would it play on 80 or 75 meters? First, however, we need to consider the relative merits of the several loading techniques available to the designer.

Base loading: this is the simplest and probably the oldest. One can take an electrically short antenna (less than a quarter wave) and add a loading coil to the base to replace the missing length as in figure 1. Its main advantage is simplicity because there's no need to break the conductor to insert the loading coil, so a fairly high-Q loading coil can usually be used without compromising the strength or survivability of the system. Unfortunately, base loading may not be the most efficient technique, especially if the antenna is physically much shorter than a quarter wave at the operating frequency. Now consider current distribution in a quarter wave antenna. It's greatest at the feedpoint and reaches a minimum value at the upper end of the antenna, so we can see that with base loading maximum current will flow in the loading inductor, in which case some cancellation is bound to occur with a corresponding reduction in radiation resistance and efficiency, particularly if a low-Q loading coil is used.

The chief advantage of center loading (figure 2) is that if the loading coil is placed in the center of the antenna the lower portion of the antenna can carry the high base current with relatively little attenuation. This technique increases the radiation resistance to some extent, but it also calls for high-Q loading coils because as the coil is placed higher up on the antenna structure ever more wire is required to replace the missing antenna conductor. More wire necessarily means greater loss resistance, so any improvement in increased radiation resistance may be largely offset by an even greater increase in coil loss resistance unless a hi-Q coil is used. Still, it's generally reckoned that for a coil of a given “Q” center loading usually strikes the best balance between radiation and loss resistance.

Finally, we come to end loading (figure C). This term is clearly a misnomer for the very obvious reason that any practical loading coil placed at the upper (low-current) end of an electrically “short” radiator must be made up of so much wire that the lost resistance would effectively wipe out any theoretical improvement because of increased radiation resistance. Is end loading really “the most efficient form of loading known” as the makers of one of the no-radial “half wave” vertical antennas assures us? The simple answer is that it perhaps COULD be, but it usually isn't because any coil of reasonable “Q” stuck atop a tall amateur vertical must be so large as to threaten the survivability of an un-guyed structure made of ordinary materials. The same manufacturer has announced a new low-band vertical antenna that is end loaded only in the sense that the loading coil, which appears to be of ordinary construction, is only the uppermost vertical of the antenna. Above that there's a horizontal capacitance “hat” that itself does not radiate appreciably, although it serves to reduce the amount of wire required in the loading coil to more or less manageable dimensions. High “Q,” of course, is another matter entirely. In any case, the claim that end loading is more efficient than any other is clearly overblown. If truth be told end loading is used because the loading coil must also function as a decoupling trap for 40 meter resonance, which is why it's inserted at the 33 ft point in the first place. There's no great harm in taking credit for bowing to necessity or even making a virtue of it, but one should not come away with the idea that end loading is always the most efficient technique in all circumstances. It's unfortunate that most of today's amateurs get most of their “knowledge” about antennas from ads in the magazines and that much of it is mere superstition or humbug in spite of the million-odd Antenna Books that ARRL claims to have sold over the years.

Beyond questions of efficiency there may be other reasons for placing the loading at a particular place on a low-frequency vertical. Most trap vertical antennas for the amateur bands are usually capable of sufficiently low-SWR bandwidth for operation over an entire band, at least at 7 MHz or higher, so frequent adjustment is usually not necessary. Below 7 MHz, however, a vertical antenna is usually so much shorter than a quarter-wavelength (about 88 ft for 75 meters) that SWR bandwidth is often no greater than about 100 kHz if any kind of radial system is used to reduce earth losses and increase overall circuit Q, so if the antenna is adjusted for lowest SWR at the upper end of 75 meters the SWR at the c.w. end of the band will often exceed 5:1. If the 40 M trap/80 M loading coil is at the top of the antenna the antenna must be brought down for adjustments--no easy matter, particularly when the antenna MUST be guyed. The Butternut designs, on the other hand, place all the lower frequency circuits within six ft of the feed point so that rapid QSY between 80 and 75 meters takes only a few seconds, even on a rainy night. So how well does our HF2V low-band antenna play compared to less versatile antennas of the same approximate size? There aren’t many such antennas on the market, but if you remember the points from DLS-1 you'll be able to figure things out for yourself. In theory, there should be no great difference between two antennas of the same height, so the only thing one needs to know is how much loss to attribute to each loading and trap circuit.

The HF2V can easily be outfitted with a simple top (end) loading kit for greater efficiency and bandwidth on 80 meters, but even without top loading it should be at least as effective as other designs. Moreover, it may be retro-fitted for operation on 160 M, 30 M and perhaps other bands as the current sunspot cycle hits bottom.

There seems to be a new no-radial vertical that covers 80 meters and has just come onto the market. Performance is supposedly "awesome," and the buyer is warned not to be surprised if he routinely works scarce DX! We'll have to check this new one out for possible inclusion in a later DLS bulletin. It sounds like a splendid prospect, for any designer who regularly thumbs his nose at earth losses and simple but effective ways to deal with them might decide to design a canoe without a bottom!

OK (you're probably saying to yourself) you guys do a great job of knocking the competition, but what about your own stuff? What makes it better or even as good as something else? A fair question! In the absence of any kind of organization that really cares a fig about protecting ham consumers from phony advertising claims where does one go for an honest or even thoughtful COMPARATIVE evaluation of competing products? Perhaps you'll find one in some of the foreign publications that don't have to heap routine praise on everything advertised in their pages to keep the stateside ad money rolling in. If you believe otherwise, ask yourself when you last read any kind of antenna "review" that didn't sound like a rehash of the manufacturer's ads! As for comparative reviews, forget it! Until some kind of reputable Consumers Report for ham gear comes along we'll have to rely on those hams who have used this or that antenna and have learned (the hard way) how well or poorly it performs. Even then, we have to remember that some people have higher expectations and more rigorous standards of excellence than others, so even first-hand reports from satisfied or unhappy customers have to be taken with a grain of salt. Still, for what they might be worth and on the theory that it doesn't hurt to "ask the man who owns one," here are a few unsolicited comments from our Kudos/Feedback file for the last year or so.

About four years ago I put up a Butternut HF6V vertical antenna, ground mounted with no radials, just a 18 ft stainless steel ground rod. About two years ago I added the 12 and 17 meters kit to it. Operating with a Kenwood TS636-S for one year and then a TS-948-S for the last three years (barefoot) I have worked a total of 368 countries--41 on 3.5 MHz, 119 on 7 MHz, 228 on 14 MHz, 167 on 18 MHz, 259 on 21 MHz, 162 on 24 MHz, 143 on 26 MHz and 132 on 10 MHz--all with about 110 watts and the Butternut antenna.

A better vertical cannot be bought, and if you want to use this data in any of your ads you can.
--WSHJ

AH1A used Butternut HF2V and HF6V vertical antennas exclusively on 80 meter SSB, 40 meter SSB and CW, and 30 meter CW. Of course, I have used these vertical antennas in my home station for years, so I knew that I could count on them to perform well from Howland Island.
--USC?

Please find enclosed a rough sketch of my installation of your HF6V-X... I do not normally write to any company regarding their product, but in this case I felt compelled to do so. This antenna is the cause of much jealousy among my ham radio friends. I seem to be very fortunate in making DX contacts on the 40 and above bands... and almost all of the United States on 40 and 17 meters! All contacts were made using 100 watts or less (sometimes much less).

My friends have GAP and Hustler antennas (vertical) and they can't touch some of the stations I work even though they are only a few miles away from me. I have considered the purchase of an amplifier, but haven't really needed it yet! I have been number one through some nasty pile-ups, though, and have been questioned many times about the type of equipment that I was using. It always makes me feel quite good when they ask what type of amp I'm using and I tell them that I don't own one! All the parts are well made and easy to put together. The antenna is very tough (it has withstood much ice load and several several thunderstorms with very high winds and hail beyond your specs for survival)... You've got a real winner from where I stand.
--NORTU

Please send me more information on your new HF9V-X antenna. I have one of your HF6V model antennas which is over 16 years old and is still my best DX and main antenna. Thanks for making such a great antenna that works GREAT! 80 through 10 meters with low SWR and bandwidth.
--KDSCQ

I have several questions about Butternut vertical antennas, but I thought you might be interested in my experience with an HF6V which I set up on the ground in my backyard ten years ago and fed with RG-8/U mini-coax. The antenna is still performing well with no treatment for corrosion and with the original coax. The coax and several miles of radials !WOW! were laid on the ground and allowed to sink beneath the grass on my two-acre lot.

I have always operated barefoot and have worked 315 countries overall with 120 countries on 80 meters and over 250 countries on each of the other four primary bands with this antenna. I made over 800 contacts, scored over a million points and took first place low power in the third call area for CQWW in 1992 using only the HF6V... I

set up a GAP DX-VIII vertical on a different place on my property, and although the SWR is great on the GAP, receiving and transmitting performance are markedly inferior to your antenna.
--KX3Y

I am using an HF6V in Florida and am fully satisfied with its operation and without having to use radials. Its low-loss coils and ease of tuning make it an ideal antenna for replacing trapped vertical.
--WA2NGU

Please send any information you have on your products, vertical antennas, info on making them better, etc. I sold my HF6V to get an R-5, sold that to get an R-7 and wised up and went back to the HF6V. At least now I know. Tnx for a great product.
--KG5UN

You guys make a hell of an antenna!
--KA2IO

I am the owner of of an HF6V vertical antenna I have owned and used it for nearly 2-1/2 years. I want to let you know how very pleased I am with its performance. In the time I have used the Butternut HF6V vertical I have worked 266 countries and achieved 5BDXCC with only 100 watts of power. This certainly says something for your product. This antenna is well engineered and durable. I use it on ALL bands, 80-10 meters, including the WARC bands, with a nearly perfect SWR on each of them. What more could anyone ask for?

I would appreciate it if you would send me a copy of the assembly instructions for my HF6V. I cannot locate the original copy and wish to do some basic maintenance... Thank you for your assistance and for making the finest vertical antennas available.
--VB2KSK

I have been using one of your HF6V-X vertical primarily on 80/40/30 for the past few months. Ground mounted and with a rather non-elaborate radial system (16 0.1 wavelength 3.5 MHz radials), I'm pleased to tell you that it performs as well as any vertical I've used over the some 40 years of being K5BGB.

In support of your ad, you'll probably be pleased to learn that. I'm an ex-R7 owner... The R7 was a bummer from the very beginning and went downhill from that point. With the HF6V-X my VK friends on 40 M tell me that my signal is consistently far better than it ever was with the R7. That speaks well for your antenna!
--K5BGB

It's often difficult to know what to make of a particular report from a given area because of the countless variables that can affect performance from one QTH to the next or from one operator to the next. And it's curious that most of those who volunteered the above comments acknowledge that their radial systems were nothing to rave about. Perhaps as the glaciers retreat in the northern climes the writers will consider running some out before the ground bakes and hardens in the summer sun, in the certain knowledge that we're facing several more years of low sunspot activity and that conditions will not begin to improve until after 1997 or so.

73 and DX!