Stealthy Vertical Long-Wire Antennas

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The long wire is arguably the least-expensive HF antenna. Some wire, a couple of trees for support, a feedline cable, an impedance matching transformer and a counterpoise comprise the list of parts. And if you're going for a vertically polarized long wire antenna, you can substitute a push-up mast for the trees.

A little time, a few parts; how hard can it be?

Actually, it can be rather difficult. Hams who try to install a long wire that will work on all HF bands typically meet with poor results: SWR is all over the place, and the unwary quickly find that their garden-variety antenna tuner yields a barely acceptable 3:1 SWR reading on 1 or 2 bands while other bands will not cooperate at all, exhibiting SWRs north of 20:1. To make matters worse, antenna efficiency is very low on the few bands where the tuner can "sort of" provide an impedance match.

What is missing from the equation is information on the necessary equipment and the sorcery required to pull the project off. Let's go through the typical trials and tribulations and try to shortcut the experimental process by a few dozen hours.

Roll the Instant Replay

The antenna is up and it doesn't work anywhere near expectations.

Eventually the experimenter is told - or reads - that end-fed antennas have an inherently high impedance at their feed points, so a Unun (Unbalanced to Unbalanced) matching network capable of mating the transmitter impedance to the very high antenna impedance is required. The ham buys or builds one, blindly shooting in the dark with respect to the ratio needed to match their transmitter's 50 ohm impedance to the antenna's much higher impedance.

Predictably, the Unun doesn't totally fix the problem. Next they are told - or read - that a counterpoise is needed and, well, everyone says you must use a ¼-wavelength buried counterpoise, so they bury a wire ¼ wavelength long at the lowest band they intend to use. The antenna still will not perform on all bands. They give up and move on to something less aggravating.

There's no need to do that. You see, thanks to John (Jack) Clarke, VE3EED (SK), there's some very useful information available about the wire lengths you can and cannot use for multiband long-wire antennas.

Clarke found that a long-wire multiband antenna cannot be a half wavelength long for any operating frequency or multiple. His analysis concluded that multiband end fed antennas work properly for only a small number of specific lengths, even with a high-ratio Unun for impedance matching.

Table 1 below shows wire lengths, in feet, for half wavelengths and multiples of nominal center frequencies for the HF bands. You do NOT want to use these lengths if you want a multiband long-wire. Pick the bands you intend to use and avoid all lengths shown for those bands.

Table 1:

Freq.	½ Wave	2nd Multiple	3rd Multiple	4th Multiple
3.8 MHz	123 feet	246 feet	369 feet	492 feet
7.2	65	130	195	260
10.1	46	92	138	184
14.2	33	66	99	132
18.1	26	52	78	104
21.3	22	44	66	88
24.9	19	38	57	76
28.5	16	32	48	64

What if you want to operate on all HF bands? Well, VE3EED kindly provided a list of recommended wire lengths that would be best for a multiband long-wire operating between 80 meters and 10 meters. (This was no easy task. Clarke manually went through all the permutations in table 1 and determined what lengths were available that did not appear in any combination of numbers regardless of band.)

Table 2:

29   35.5   41   58   71   84   107   119   148   203   347   407   423

For multiband work, cut your antenna to one of the 13 lengths shown in Table 2 above.

If you feed it via a 9:1 Unun and use the counterpoise system that I'll describe below, tuners with a wide impedance-matching range will be able to handle the majority of the remaining impedance mismatches.

The Inevitable Caveats

Hams obsess for hours trying to get the SWR down to 1:1, but it's a fool's errand. Anything below 2:1 SWR is good enough and will yield a signal level that's indistinguishable from a perfect match to the person on the other end of the path. (Don't accept anything above a ratio of 3:1 if you have a solid-state transceiver or amplifier. You want to protect your transistor finals.)

Also if you operate near the edge of some of the wider bands, you might wander into an area where the length of wire is near a half wave or the 2^{nd}, 3^{rd} or 4^{th} multiple for that frequency. On the wider bands, an antenna cut to one of the lengths shown in table 2 should work acceptably for most of the band but perhaps not at the band edges.

Finally, local conditions (fences, buildings, nearby metal objects) can have an undesirable effect on a long wire antenna just as they can on any antenna.

The Counterpoise

All antennas want to be a dipole when they grow up, and unbalanced antennas are no exception. Long-wires by definition have a single element and are end fed. In this respect, they're similar to an Inverted L antenna or a Zepp. They need something to take the place of the missing balancing element in order to energize the antenna. To force this square peg into a round hole, the term *counterpoise* lumbers into view.

Think of it as a *counterbalance.* To make current flow in our long-wire, current also needs to flow in a balancing element -- a counterbalance if you will – thereby creating a balanced antenna. For an HF long-wire (and its brethren), Mother Earth becomes the missing element. How is this accomplished? With a counterpoise.

Many amateur radio enthusiasts think of a counterpoise as a single wire a quarter wavelength long at the operating frequency. If it's a vertical long-wire, many also say that it must have 120 quarter-wave radials or it will have the RF radiating efficiency of a broomstick. After all, 120 radials is what AM broadcast stations use so it must be good engineering practice and the FCC must mandate it.

It is true that 120 quarter-wavelength radials will result in a uniform radiation pattern and increased antenna efficiency—absent interfering objects, like trees, houses, and other inconvenient realities of ham life. Needless to say, they are also devilishly labor intensive to install. And they are unneeded for amateur stations, with the possible exception of 160 meters.

The FCC doesn't require all those radials for AM broadcast stations, either.
What the FCC says is that if fewer than 90 radials are used, antenna efficiency must be determined and the analysis accepted by the commission. 120 radials do help compensate for ground conductivity problems, which in turn has an effect on the wave takeoff angle, but for Hams, the FCC doesn't care if you use 90 radials, or 120, or none, or how long they are.

As a matter of fact, for most amateur HF bands, the radials do not need to be a quarter-wavelength long. Radials of only 15 to 20 feet have been proven to be nearly as efficient as much longer radials as far as amateur HF band radiation is concerned, except at 160 meters[1]. Since that band sits just above the broadcast band, lots of quarter-wavelength radials, plus high ground conductivity, greatly improve surface wave propagation, something that is very important during daylight hours.

For the amateur HF bands above 75 meters, however, ground conductivity is mostly important because it influences the efficiency of return RF flow via the radials – efficiency that is needed day or night.

Ground Conductivity

The map in Figure 1 below shows that generally ground conductivity in the lower 48 ranges between 0.5 and 30 millimhos (or millisiemens) per meter.

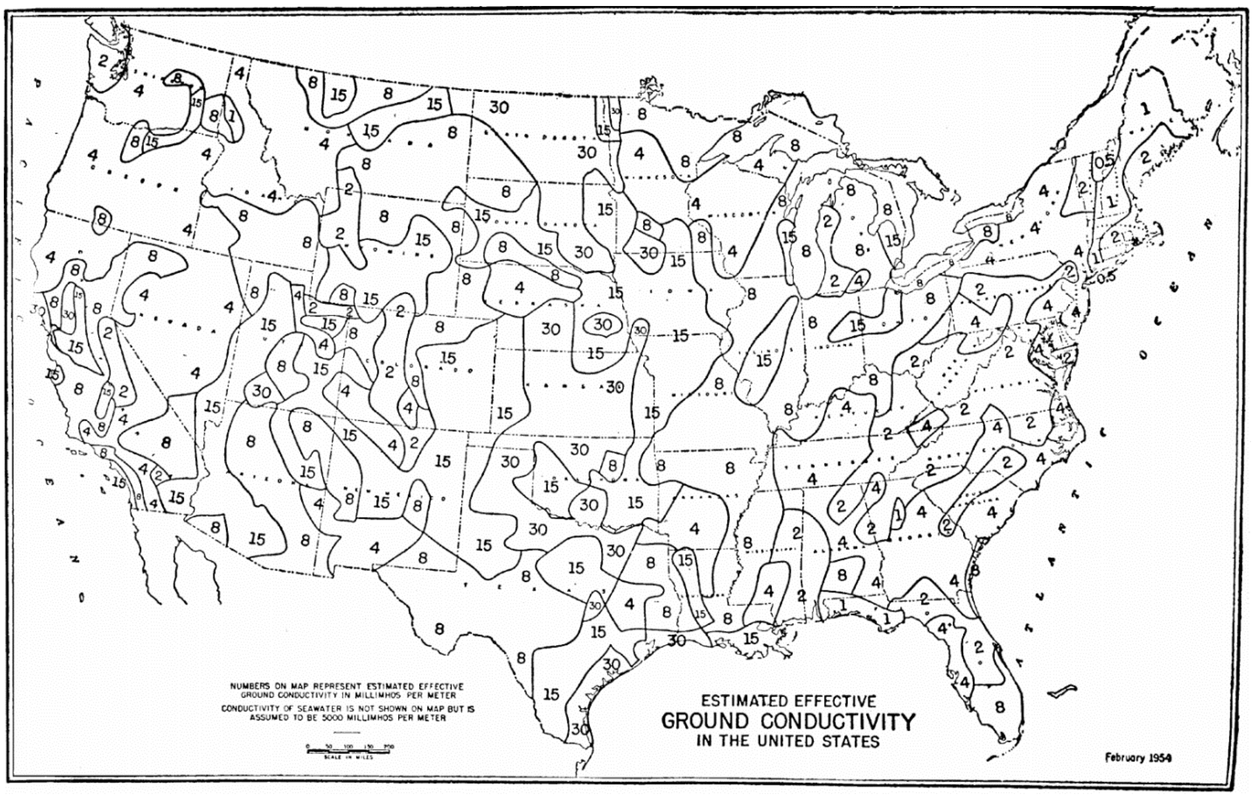


Figure 1

The lower the number in millimhos on the map, the poorer the conductivity of the earth. The poorer the conductivity, the more radials needed to effectively couple return flow so that more balancing current is flowing, which makes the antenna more efficient.

It would be nice, antenna-wise, if our ground had the conductivity of seawater (about 5,000 millimhos per meter). Few of us live with a saltwater bog in our backyard, though, so we have to put up with relatively low conductivity. This fact governs how many radials you will likely need to energize your antenna.

Generally speaking, in a low-conductivity area you should try something like 20 to 36 radials, each 15 to 20 feet long and equally spaced. In a higher-conductivity area, 12 to 20 equally spaced single-length radials should be acceptable.

Radials and Vertical Long-Wires

You will "get out" with a single radial. One quarter-wave wire is the classic amateur understanding of the word counterpoise for a horizontal antenna. For a vertical, a single radial will result in a radiation pattern that suffers, and the efficiency of the antenna will be very low. Four radials will add about 3 dB, or 1/2 an "S" unit of antenna efficiency; 12 radials will get you nearly a 6 dB increase (1 S" unit)[1] over a single radial.

From 40 meters and up, it's not worth bothering to try for small increases in antenna efficiency by using more than 32 radials[2].

However many you use, arrange them around the base of the antenna as symmetrically as possible. You should bury them a few inches deep, but you can also just peg them to the ground with landscaping staples. (If the latter, keep them as close to the ground as possible to maximize coupling—and to forestall disasters with the lawn mower.)

Lightning protection is a must, if you want to avoid having to replace your expensive gear in the event of a nearby strike. The protective device should be connected between the radiating element at the feed point and a copper rod five to eight feet long driven into the earth as close to the feed point as possible.

Nothing will protect your equipment from a direct hit, but a vertical long-wire antenna attached to a push-up fiberglass pole can be lowered when thunderstorms or high winds are approaching. There is no better way to minimize the chance of a lightning strike than to remove the target.

Safety Considerations

In every article you will ever read about antennas, you can count on being reminded, implored, and cajoled not to stick an antenna up in the air remotely close to power lines. This article is no different. Be vigilant!

And while we are on the subject of electrical dangers, keep unwary innocents away from the feed point of a long-wire antenna, where high voltage lurks. If possible, elevate the feed point to seven feet or more above the ground. Better yet for antenna efficiency, keep it close to the ground but cover it with a thick layer of high-grade insulation.

Is a Long-Wire Worth It?

Compared to single-band antennas, a vertical long-wire antenna will almost always come up short in terms of efficiency. Still, it's ideal for operators suffering from HOA Demonic possession because very few antennas can match its utility and stealth: simply pull down the telescoping mast when you are not operating and it disappears.

A maximum legal limit linear amplifier and high gain antenna is always going to outperform something like a long-wire fed with 100 watts. But I'm guessing that you're reading this article because you have neither unlimited funds nor several acres of non-HOA rule-infested real estate, so you're considering putting up an inexpensive, stealthy radiator.

Go for it. Choose one of the antenna lengths shown in Table 2 – the longer the better -, a multi-wire counterpoise, a wide-range tuner and a 9:1 Unun. You'll want a tuner capable of matching up to 800 ohms on its own. Such a tuner plus a 9:1 Unun stretches the total antenna matching range to well north of 3000 ohms. An 800 ohm capable tuner should be able to null out any remaining mismatch to less than 2:1. *(See Appendix A below for the example 35.5 foot vertical long wire antenna measurements. Note that in this case the SWR is more or less flat in the upper 2:/1 / low 3:1 range with a single excursion to ~5:1 for the 30 meter WARC band. A wide range antenna tuner handled this remaining mismatch with ease at KB9AT.)*

For power levels up to 125 watts, a rig-controlled auto-tuner--the LDG IT-100[3] is one example—along with the 9:1 Unun eliminates the nuisance of manually tweaking the antenna tuner when changing bands or frequencies.

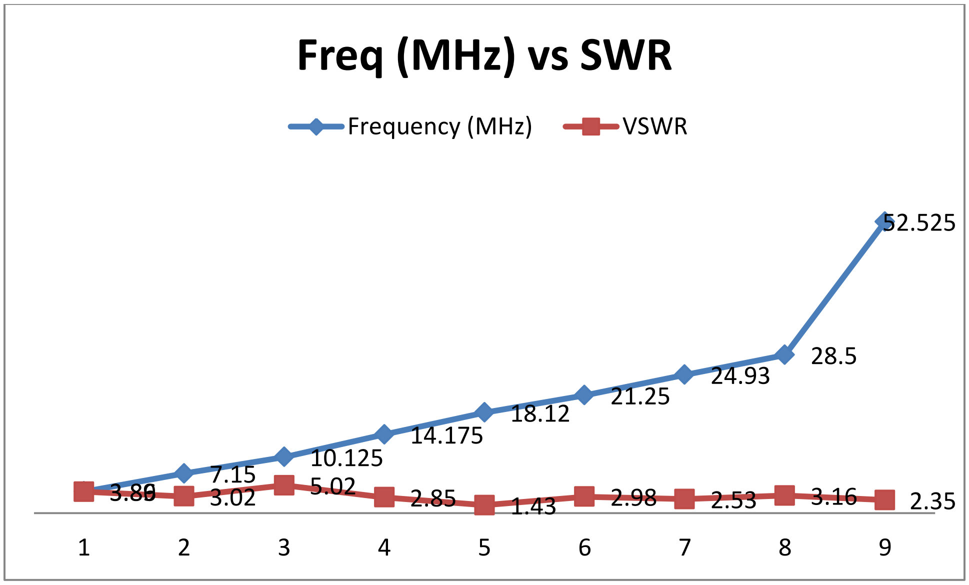
Obligatory Positive Reinforcement

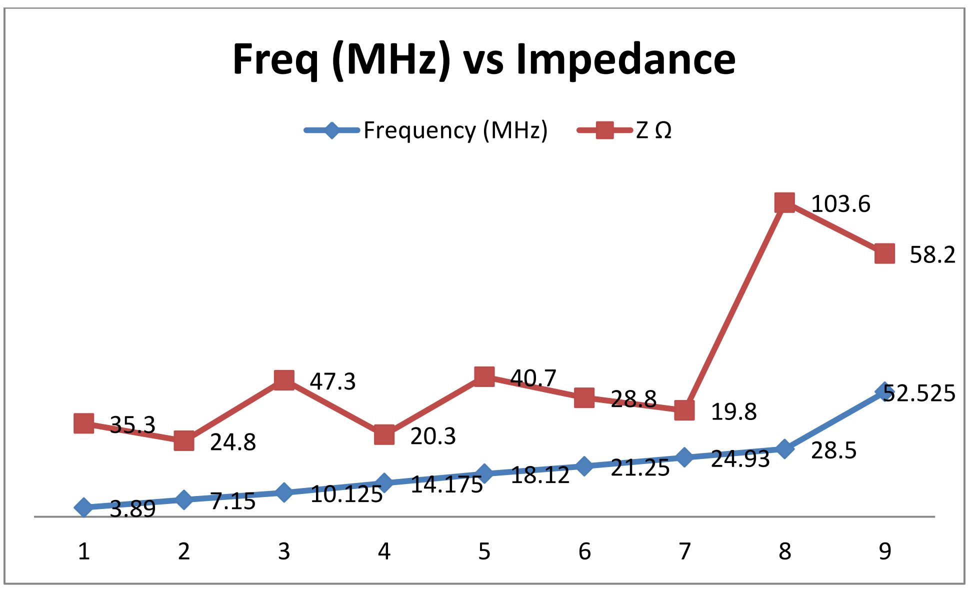
Do your best, given your time, experience, and interest in experimenting while keeping in mind all the while that this is a hobby: You're not building an AM broadcast station.

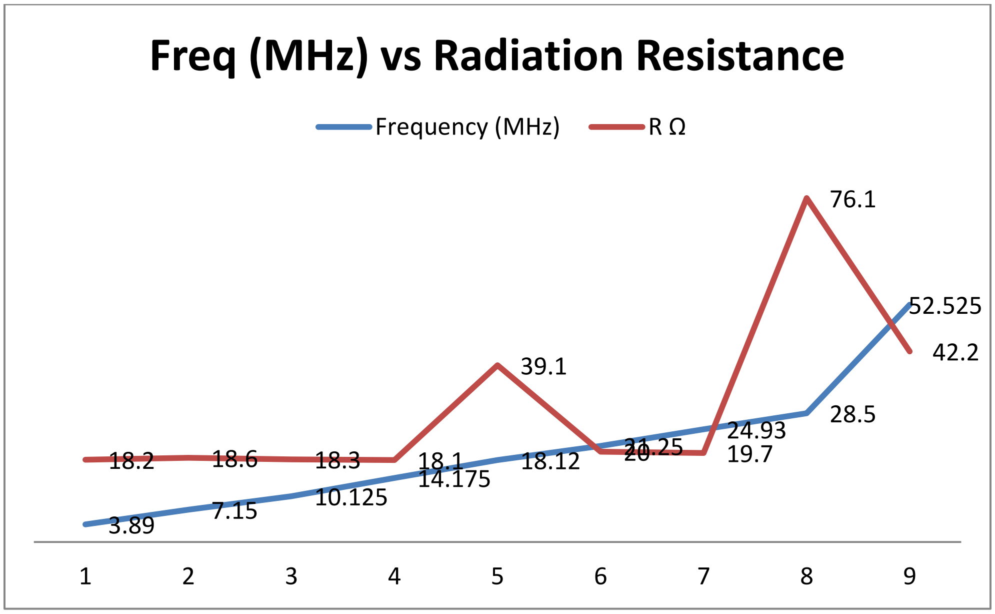
[1] RF Ground, Counterpoises, and Elevated Radials, Graham King G3XSD
[2] Analysis of the Inverted L Antenna, L.B. Cebik, W4RNL
[3] The LDG IT-100 is Icom-specific, but LDG and other companies offer variants for other radio brands. You can save money with an auto-tuner that isn't rig–controlled. Some of these tuners are manually operated, some are semi-automatic (i.e., you specify the operating band and it does the rest), and a few are fully automatic. If you're feeling flush, you can invest in a weatherproof auto-tuner that is mounted at the antenna feed point, which provides maximum antenna efficiency. But it won't be cheap.

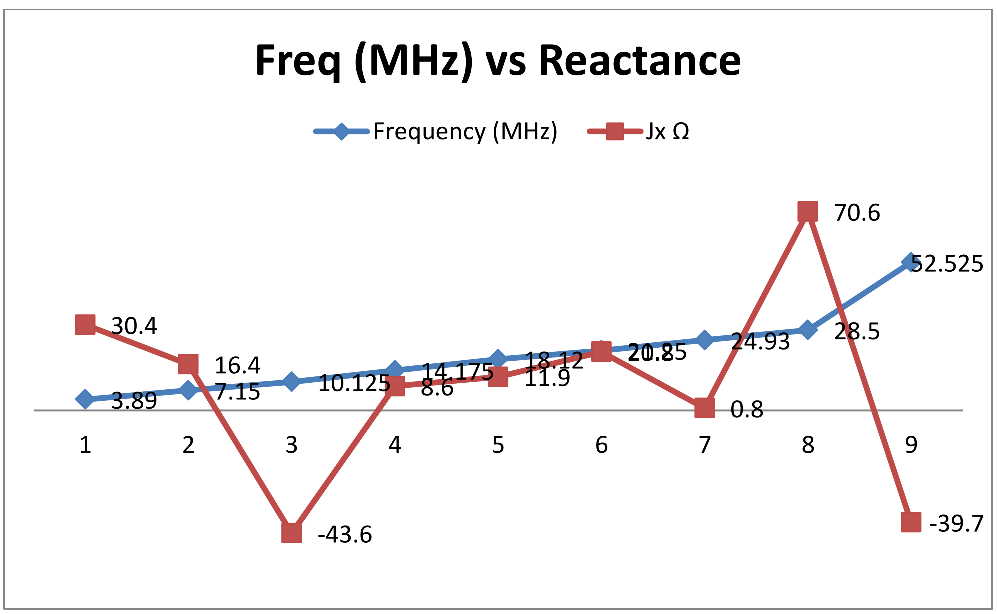
Appendix A

Graphical Measurements of a Ground Mounted 35.5 Foot Vertical Long Wire Antenna with 12 Radials, 25' Long, and 8 millimhos Ground Conductivity






Freq (MHz) vs Radiation Resistance
Frequency (MHz)
R Ω
76.1
52.525
42.2
39.1
28.5
24.93
19.7
18.2
18.6
18.3
18.1
14.175
18.12
3.89
7.15
10.125
1
2
3
4
5
6
7
8
9


Freq (MHz) vs Reactance
Frequency (MHz)
Jx Ω
70.6
52.525
30.4
28.5
16.4
24.93
3.89
7.15
10.125
8.6
14.175
18.12
11.9
0.8
1
2
3
4
5
6
7
8
9
-43.6
-39.7