Multi-band HF Antennas Part 1 – VA3TPV

Every now and again during research for background material for RSARS e-Library articles, a new source of really well written articles is discovered. **The Mississauga Amateur Radio Club Ontario Canada** produces a well written newsletter with interesting material from its club members, Ed Spingola's (VA3TPV) three articles describing Multi-band HF Antennas appear in the February, March, April 2010 editions of "***The Communicator***".

The Mississauga ARC and the author have given permission to the RSARS to reproduce these for inclusion in the e-library.

"It is the exchange of ideas and information that makes Ham Radio what it is "
Ed Spingola

Mario G8ODE RSARS 1691

http://www.marc.on.ca/marc/home.asp

The Communicator Newsletter of the Mississauga Amateur Radio Club

Multiband HF Antennas, Part 1
By Ed Spingola, VA3TPV

Antenna experimentation has always been a part of our hobby. The search for an all band HF antenna started as early as the first amateur radio operator connected a transmission line to an antenna. The first all band HF antenna reported in any amateur radio journal was the G5RV invented by Louis Varney[1,2,3]. This now famous antenna is produced both commercially and by countless homebrew enthusiasts. What is not widely known is that the G5RV has three cousins or related designs. This article will describe the G5RV and the three other variants.

Basic HF Multiband Antenna

What are we looking for in an ideal all band HF antenna? The antenna specifications are: a horizontally or inverted-V oriented, centre-fed dipole, connected with some length of parallel transmission line. The antenna system should have a good match i.e. a low SWR, on as many HF bands as possible without the use of an antenna tuner. Connection to a typical HF transceiver should be via 50 ohm coaxial cable. The requirement of a low SWR is mandated by the design of modern solid state transceivers which require an antenna SWR to be better than 1:2 otherwise automatic protection circuits start reducing the output power. The following Figure 1 shows the basic antenna design. The antenna system is constructed of a centre-fed dipole of length L1 being fed with a parallel transmission line of impedance Zo and length L2 to which is connected a length of 50 ohm coaxial cable towards the transceiver.

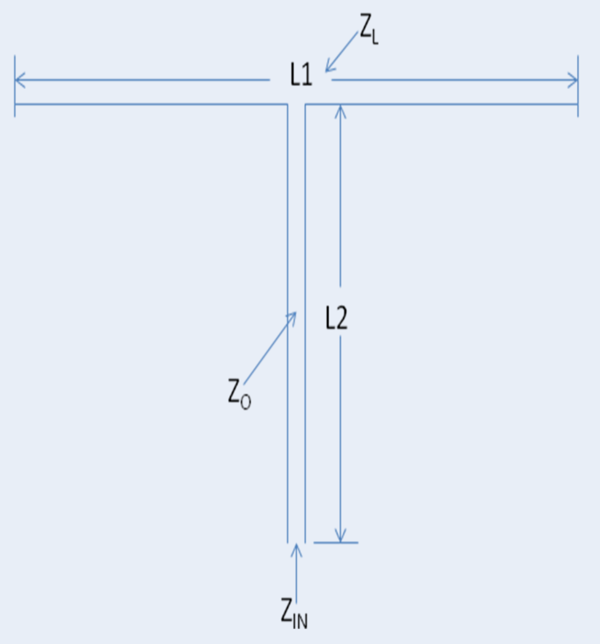

Figure 1: Basic HF Dipole Antenna G5RV

There is some debate in the literature as to whether Varney had intended his antenna to be classified as a mono-band or an all band antenna. The original centre-fed G5RV[1,2,3] is 3/2 wavelengths long (L1) on 20m with a transmission line matching section of 300 ohm open-wire line half-wavelength long on 20m. A length of 75 ohm coax of unspecified length connects to the transceiver through a balun at the coax to ladder line junction.

The G5RV works as follows: On 20m the dipole is 3/2 wavelengths long. Its feedpoint impedance is therefore low (90 ohms) and because the open-wire line is 1/2 wavelength long on that band (20m) it merely transfers that low impedance to its other end presenting a reasonable match to the feeder to the transceiver. On 40m, the feed point impedance is very high (and inductive) because the antenna is now three quarters of a wavelength, but the transmission line is now one quarter wavelength long and therefore functions as a quarter wave transformer. The high value of the antenna impedance (Z_L) is transformed to a much lower value (Zin) by the quarter wave transmission line transformer.

$$Zin = Zo^2 / Z_L$$

Where Zo is the characteristic impedance of the open-wire transmission line, typically 300 to 600 ohms.

On 15m and 10m the antenna/feedline combination again presents a reasonable impedance to the transmission line. However, in those days transceivers employed link coupling or pi-network to couple the transmitter energy to the transmission line. The link or pi-network was the antenna tuner. A far different situation occurs today with solid state transceivers.

In the G5RV L1 is 3/2 wavelength on 20 meters and L2 is a half a wavelength long.

The following are the specified G5RV parameters:

- L1 = 102 ft (31.1m)
- L2 = 34 ft (10.37m) x Velocity factor
- Z0 = 525 ohms
- Zin = 75 ohms

Typical performance characteristics of the G5RV are that it only matches well on 14 and 24 MHz without an antenna tuning unit. On the other bands the SWR is greater than 3:1.

W5ANB

The W5ANB antenna4 is the first cousin of the G5RV. Tait Nicholson, W5ANB, was the first to prove that the HF band performance, i.e. SWR of the G5RV could be improved upon by a careful selection of the dipole and feed line lengths. Nicholson wanted to keep things simple and mandated that no traps or matching unit be required for his antenna design. Nicholson constructed his antenna of two equal lengths of stranded wire attached to a length of 300 ohm twin lead transmission line. At the bottom of the transmission line was a choke balun made up of 7 feet 2 inches of RG-58/U.

The following are the specified W5ANB parameters:

- L1 = 88 ft 4 in. (31.1m)
- L2 = 36 ft 8 in.(11.18m) (Twin lead)
- L2 = 42 feet 6 inches (Open wire line)
- Z2 = 300 ohms
- Z4 = 50 ohms

The SWR of the W5ANB antenna is less than 3:1 on 10, 20, and 40 meters. Tuning was indicated to be critical on 15 meters and 80 meters was a problem with an SWR of between 5:1 and 8:1 across the band. This was remedied by using a loading coil of 44 inches of twin lead wound around a 7/8 inch diameter form.

In the above configuration the antenna operated satisfactorily at a height of 25 feet. It must be pointed out that in 1958, when the W5ANB antenna appeared, transceivers used vacuum tubes and the output finals and pi- matching networks could accommodate a higher SWR than today's solid state transceivers.

W5ANB proved that by a careful selection of the dipole and transmission line lengths, an HF antenna with better SWR performance
than the G5RV could be achieved

ZS6BKW

The next evolution in the search for the all band HF antenna was made by Brian Austin, ZS6BKW, now G0GSF, who in 1985 was a professor at the University of Witwatersrand, Johannesburg, South Africa. ZS6BKW[5,6,7] published an article in Radio ZS, the journal of the South African Radio League on an improved all band HF antenna. A further article appeared in the January and February issues of RadCom in 1993. ZS6BKW had used computer analysis to optimize L2 and Z2 to transform the impedance presented by L1 to satisfy some defined SWR criteria i.e. 2:1 on all of the bands of interest. This probably meant that the antenna could be used without an antenna tuning unit since this is around the point where automatic protection circuits start to work on modern solid state transceivers. The intent was to have this criterion on as many HF bands as possible. The ZS6BKW antenna is another sister to the G5RV. The ZS6BKW antenna does not require an antenna tuning unit on 40, 20, 17, 12, 10 and 6 meters.

The following are the specified ZS6BKW version 1 parameters:

- L1 = 93 ft 6 in. (28.5m)
- L2 = 43 ft 6 in.(13.3m) x Velocity factor
- ZO = 400 ohms
- ZIN = 50 ohms

The above lengths result in an SWR of better than 2:1 on five HF bands: 40, 20, 17, 12 and 10 meters. A bonus is 6 meters with an SWR of 1.5:1.

Note that the L2 values must be corrected based upon the velocity factor of the transmission line Z2.

The following are the specified ZS6BKW version 2 parameters:

- L1 = 90 ft 3 in. (27.5m)
- L2 = 40 ft .(12.2m) @ 0.9 Velocity factor
- Zo = 450 ohms
- Zin = 50 ohms

In the G5RV, L1 is 3/2 wavelength on 20 meters and L2 is a half a wavelength long. In the ZS6BKW, the L1 and L2 lengths have no simple relationship.

Analysis showed that the optimum lengths of L1 and L2 are about 1.35 and 0.62 wavelengths on 20 meters (14.20 MHz). It is interesting to note that L1 + L2 is approximately one wavelength long.

In addition there are a range of values of Z2 that will produce the best results on five HF bands and over the widest possible bandwidths on those bands. So if you want a simple HF antenna that will work on five HF bands, 40, 20, 17, 12, 10 and 6 meters, without an antenna tuning unit and all HF bands with one, the ZS6BKW is an antenna worth trying.

Antenna Patterns

The classic resonant one half wavelength dipole antenna radiation pattern is the figure-8 with maximum radiation broadside to the antenna. The radiation pattern for a 3/2 wavelength antenna resembles a clover leaf pattern with two additional lobes with additional lobes appearing at higher frequencies. This type of antenna must be carefully oriented to obtain maximum desirable radiation in the wanted directions.

Considerations

The resonant frequency and impedance of single wire dipole is a function of wire diameter, length, and the antenna height above ground. If the antenna is configured as an inverted V, the angle between the one half wave sections will also affect the resonant frequency and the impedance. Therefore each of the antennas described in this article will require some trimming to length to obtain the desired resonant frequency. There are various manufacturers of ladder line or window line with slightly different specifications. Measure the propagation velocity factor of the ladder line before cutting the transmission line to the required electrical length. For best results wire dipoles are not a calculate, measure, cut and install type of antenna. If you elect to purchase a commercially available G5RV or ZS6BKW antenna, they will still need to be tuned i.e. trimmed to your location.

Summary and Conclusion

If you are looking for a reasonably good multiband antenna, there are a variety of choices to try at your QTH. If you had previously considered the G5RV, the ZS6BKW is worth considering in that it has an acceptable SWR on 5 out of 8 of the HF bands.

If you elect to choose the G5RV, then you must employ an antenna tuning unit to obtain a reasonable SWR on the HF bands.

The ZS6BKW and the G5RV are both commercially available.

Don't expect your antenna installation to have the same SWR curves as typical published data for your antenna type. There will be variations due to differences in antenna height, ground conductivity, and proximity to surrounding objects.

Reference 7 is a good series of articles by L. B. Cebik, W4RNL, (SK), on the G5RV, W5ANB, and ZS6BKW antennas.

There are also numerous internet references to these antenna types.

Notes:

1. Varney, L., G5RV, An Effective Multiband aerial of simple construction, RSGB Bulletin, 1958, July, pp 19-20.

2. Varney, L., G5RV, The G5RV Multiband Antenna, HF Antenna Collection, David, Erwin, G4LQI.

3. Varney, L., G5RV, The G5RV Multiband Antenna....Up-To-date, The ARRL Compendium, Volume.

4. Nicholson, T., W5ANB, Compact Multiband Antenna Without Traps, QST, 1981, Nov. pp 26-27

5. Austin, B., ZS6BKW, RadioZS, June 1985.

6. N6RCK, Multiband Wire Antenna (Better than G5RV) **http://n5rck.tripod.com/wireband.html**

7. The ZS6BKW Antenna, **http://www.reflections.co.nz/wordpress/myuploads/zs6bkw-antenna-from-the-horses-mouth-byg0gsf-ex-zs6bkw-sprat-_130-spring-2007.pdf**

8. Cebik, L. B. , W4RNL, The G5RV Antenna System Re-visited, Parts 1, 2, and 3 **http://www.nonstopsystems.com/radio/G5RV-1.pdf**

9. The Wireman, **http://www.thewireman.com/**