Half-Sized G5RV Analysed

Vince Lear G3TKN/ZL1VL takes a closer, more technical and practical look at the half-sized G5RV antenna.

The G5RV multi-band doublet was designed by the late **Louis Varney, G5RV**, back in 1946. There have been various updates over the years in different magazines in addition to a vast amount of information relating to the antenna on the Internet. Many companies now market 'ready-made' versions for those who prefer not to make up their own.

A popular variation of the G5RV is the half-sized G5RV. This antenna is composed of a 15.54m centre fed top, and is often described as being able to operate between 7 and 28MHz. Despite the popularity of the antenna, I have never used a G5RV myself. I decided therefore, that it would be an interesting exercise to analyse the antenna in some detail, to help new and prospective users of this popular antenna to have a better understanding of its operation.

Theory of Operation

The theory of operation of the half-sized G5RV has two main 'lobes', to suit the two main ways of feeding it. The preferred method of feeding the antenna is to use open wire line (or 300/450Ω ladder line) all the way from its centre to a balanced antenna tuner unit (a.t.u.) at the operating position, **Fig. 1**.

The balanced feed method is the one recommended by G5RV in his original article, and he gives more detailed information about the design of balanced a.t.u.s for use with this feed arrangement at the same time.

If the antenna is fed as in Fig. 1, from a matching point of view, the actual length of the twin feeder becomes relatively unimportant, since a well designed balanced a.t.u. should match the wide range of impedances encountered on **all** amateur bands between 7 to 28MHz.

The impedances encountered will be a function of both antenna and feeder length. However, it may be advantageous not to have a length of open wire feeder that will produce a very high impedance (and hence high r.f. voltage) at the a.t.u. end. Were this the case, then on some frequencies of operation the high impedance could lead to arcing in the variable capacitors of the a.t.u. It can also sometimes cause r.f. feedback problems within the shack.

Second Method

The second method of feeding the G5RV, is to use coaxial cable coupled to the base of a 4.65m length of matching stub as shown in **Fig. 2**. This arrangement is the one most used for most commercially manufactured G5RVs in use.

The theory of operation for this second feed method is, that at 7MHz the antenna itself, plus the stub, function as a λ/2 dipole with its centre folded up. By this method, the matching stub offers inductive loading at the centre of the antenna.

On 14MHz, each leg plus the matching stub is approaching three quarters wave in length. This arrangement therefore gives a reasonably low impedance point, (although reactive).

On 28MHz, the top forms three half-waves, fed at the centre. (*Each half of the antenna may be viewed as an end-fed λ/2 antenna, with a λ/4 matching stub. The two halves of the antenna are effectively in series.* Ed.)

At the stub, which is near half-wave long on 28MHz, the impedance seen at the feedpoint of the antenna is reflected down to the base of the matching stub, where it's connected to the coaxial cable feeder.

However, the feedpoint impedance at the centre of a three half-wavelength (3λ/2) doublet is normally in the 90-100Ω region. So, the match to 50Ω coaxial cable, is slightly poorer, than when the coaxial cable is connected to the centre of a single half-wavelength antenna.

While on no band, does the antenna offer a perfect match, it does offer a workable match on the 7, 14 and 28MHz bands provided an a.t.u. is used! The purpose of the a.t.u. is to allow the transmitter to see a 50Ω non reactive and so deliver full power. The a.t.u. will in no way reduce the actual s.w.r. or losses on the coaxial cable feeder connected to the matching stub.

Radiation Pattern

With any centre-fed horizontal wire, the radiation patterns produced by the antenna on each frequency band, will depend on the antenna's overall length. That is assuming of course there's no radiation from the feeder itself (an unlikely case in real locations).

I used the antenna modelling programme *EZNEC* to analyse the free space patterns and gains for a 15.54m centre-fed wire. The radiation patterns for the horizontal wire

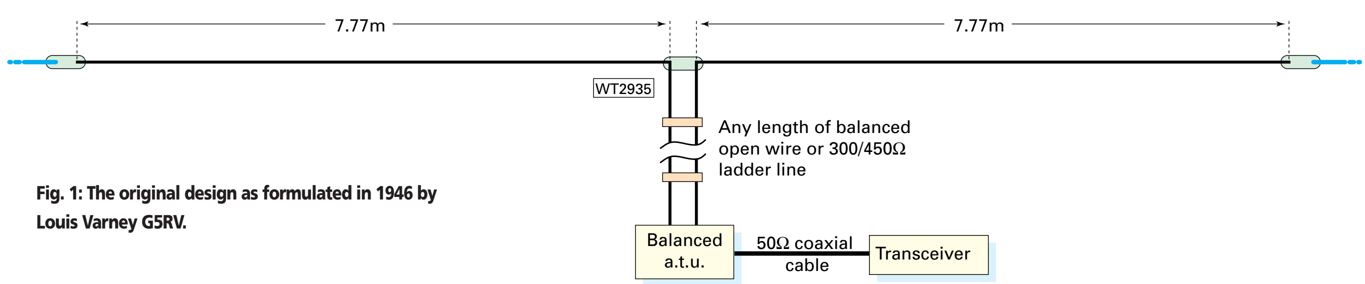


Fig. 1: The original design as formulated in 1946 by Louis Varney G5RV.

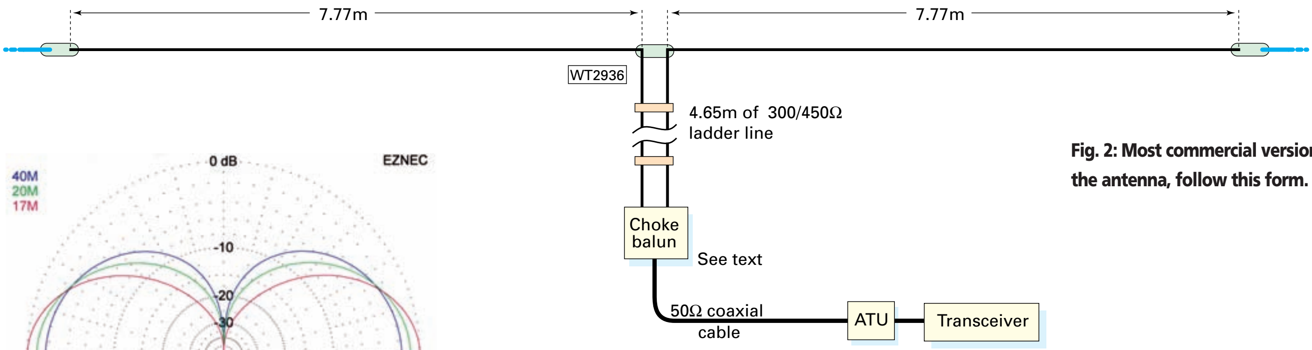


Fig. 2: Most commercial versions of the antenna, follow this form.

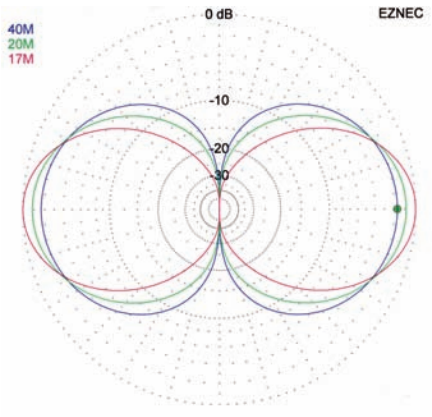


Fig. 3: The radiation patterns of the half-sized G5RV with the antenna mounted horizontally and fed with twin feeder .

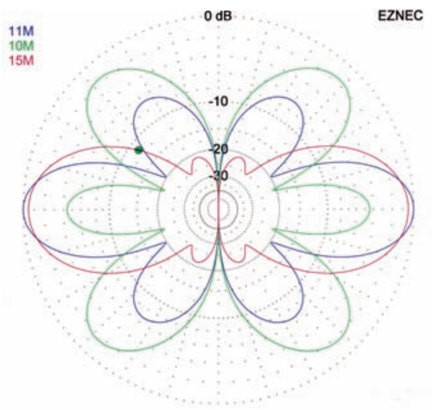


Fig. 4: The radiation patterns of the half-sized G5RV when fed via a coaxial feeder.

are shown in **Fig. 3** and **Fig. 4**. The gain figures are shown in **Fig. 5** for both horizontal and inverted-V configurations.

On 21 and 24.9MHz. when the half-sized G5RV is mounted horizontally, it behaves almost as if it's a double extended Zepp antenna It provides useful gain at these frequencies, although the broadside lobes become narrower, as seen in Fig. 4.

I found it rather disappointing to see how the calculated gain dropped off when the antenna's configured as an inverted-V with a 120° angle between the legs. However, on the plus side, *EZNEC* pattern analysis does show a broadening of the lobes in the inverted-V configuration. This has the advantage of filling in some of the deeper nulls that result when the antenna is completely horizontal.

It's important to realise that the *EZNEC* pattern analysis is calculated for a free space analysis. It will vary, perhaps widely, in a real location! In reality, antenna height, ground conditions and the general environment in which the antenna is placed, will affect its performance and the shape of the radiation lobes.

To obtain efficient operation on bands other than 7, 14 and 28MHz, the antenna must be fed with open wire line to a balanced a.t.u. at the shack end.

Computed Feedpoint

I modelled the antenna as if mounted 9m above an average ground to arrive at a computed feedpoint figure. The antenna was connected to a 4.65m matching stub and **Fig. 6** shows the impedances obtained at the base of the matching stub when it is made from both 300 and 450Ω slotted ribbon or ladder line. In practice, the impedances shown will vary somewhat depending on the height of the antenna above ground.

For the benefit of those not familiar with impedance presented in Cartesian form of (x±jy)Ω, the first number represents the resistive part of the impedance, while the second number (preceded by the letter j) represents the reactive part of the impedance. If the second part is 'plus' then the reactance is inductive. Whilst if the second part is negative, then this shows the reactance to be capacitive.

In a resonant system, the inductive and capacitive reactances cancel, so leaving just a pure resistance. If we are feeding an antenna with 50Ω coaxial cable, then ideally we want the resistive part to be as near 50Ω as possible.We would also want the reactance should be as near zero as possible.

Mismatched Line Loss

Inspection shows that feeding the stub with coaxial cable, rather than bringing the twin feeder to a balanced a.t.u. at the shack end, has the least merit. Coaxial cable is designed to be connected to a non reactive load whose resistive component is as near as possible to the characteristic impedance of the coaxial cable.

Failure to match the load to the characteristic impedance of the cable, results in a loss known as the mismatched line loss. These losses will increase with any combination of increasing: s.w.r., cable length or frequency. This extra loss is in addition to the normal matched line loss of the cable.

The actual impedance seen at the transmitter end of the coaxial cable will now be a function of the length of coaxial cable, since it is not operating in a matched condition. To highlight why I don't recommend feeding the matching stub with coaxial cable, let us look at the following example.

Consider the half-sized G5RV antenna fed at the base of its matching stub with 21m of RG213/UR67 (10mm dia cable). Using a matching stub of 450Ω ladder line, the impedance seen at the base of the matching stub at 14MHz is (90.45 – j206.8)Ω, Fig. 6. I then used **N6BV**'s *Transmission Line* programme to compute the impedance seen at the input (transceiver) end of the coaxial cable, as well as both the matched and mismatched line losses.

The impedance at the input end of the coaxial cable is now (83.86 – j140.16)Ω that results in an s.w.r. of 6.73:1. The matched case line loss is 0.546dB while the mismatched line loss is 1.881dB. The total loss on the feed system is now 2.427dB. In practice, it would be necessary to use an external a.t.u. (or auto tuner in the transceiver) to enable the p.a. stage to see a 50Ω resistive load to enable to deliver full power. However, as stated previously, this will not reduce the losses in the feeder system.

Although the antenna itself has a very free space gain of almost 0.6dBd, due to its increased length at 14MHz, this gain is wiped out by the feeder losses. In fact a resonant dipole would now give better performance. The situation becomes even worse if RG58/UR43 (5mm dia) coaxial were used. The total feeder for this cable is 4.554dB at 14MHz. On 7MHz the situation is not quite so bad, and total losses are calculated as only 0.525dB for RG213/UR67 feeder.

If the antenna is fed as shown in Fig. 1, the open wire feeder (450/300Ω ladder line) will still be operated in a mismatched condition. However, the major difference now is that the mismatched line loss is considerably less than for coaxial cable.

Into Practice

To put the computations into practice, I made up an half-sized G5RV as shown in

Frequency	Horizontal	Inverted V
7MHz	1.86dBi	1.81dBi
10MHz	2.21dBi	1.93dBi
14MHz	2.69dBi	2.17dBi
18MHz	3.52dBi	2.53dBi
21MHz	4.43dBi	2.83dBi
24.9MHz	4.91dBi	2.68dBi
28.5MHz	3.33dBi	2.0dBi

Fig 5: Free space main lobe gain of a 15.54m horizontal centre fed wire as predicted by EZNEC v3. The inverted V modelled had a 120° enclosed angle between its legs. dBi is reference to an isotropic radiator. A dipole has a gain of 2.15dBi. So, the gain in dBd (reference to a dipole) can be found by subtracting 2.15 from the above figures.

Frequency	450Ω	SWR	300Ω	SWR
7.1MHz	(19.77+ j20.6)Ω	3.026:1	(12.97 - j33.53)Ω	5.672:1
14.15MHz	(90.45 - j206.8)Ω	11.735:1	(38.15 - j69.54)Ω	4.381:1
28.5MHz	(107.1 - j49.5)Ω	2.697:1	(107 + j11.66)Ω	2.173:1

Fig. 6: Impedance as seen at the base of the matching stub for a horizontal half-sized G5RV at 9m over average ground as predicted by Eznec v3

Fig. 2. I fed the base of the matching stub via about 36m of 50Ω RG213/UR67 cable. Although, as I've said that this configuration has the least merit, it's the one that many amateurs choose to use. This is understandable, since it's easier to route coaxial cable than twin feeder.

I included an r.f. current mode choke balun at the base of the stub. More information on current mode choke baluns can be found in reference books. The r.f. choke balun was there to prevent any common mode current from flowing on the outer of the coaxial cable.

The antenna was erected at heights ranging from 6-12m. I also arranged the antenna in different configurations, from fully horizontal to an inverted-V form with an apex angle around 120°. These changes merely varied the s.w.r. slightly, and gave very minor changes of resonant frequency.

Connecting a MFJ Antenna Analyser to the base of the matching stub, I found the antenna showed resonances at around 6.9, 15.3MHz, and 27.6MHz. This was fairly close to the predicted resonances found using *EZNEC*.

The auto a.t.u. in my transceiver allowed me to run 100W into the antenna on 7, 14 and 28MHz. I was surprised to find that the auto a.t.u. in fact also allowed the transceiver to run 100W into the system on 18, 21 and 24MHz. Signals seemed well down on these bands when compared to dedicated resonant dipoles. The mismatched line losses on these frequencies would be quite high because of the severe mismatch on the coaxial feeder.

My general feeling was that the half-sized G5RV fed with 36m of coax gave its best performance on 7MHz. Computer predictions indicate it to be only slightly down on a full sized dipole at this frequency.

The antenna worked in a satisfactory manner on 14MHz, but comparisons against a dipole on a regular contact into Canada indicated that the dipole was better by at least 1 to 2 S units. It was unfortunate that at the time of testing the half-sized G5RV there was no propagation on the 28MHz band, so no contacts were made.

However, the match on 28MHz is reasonable since the antenna is three half-waves on this band and the half-wave matching stub simply reflects the near resistive match at the centre of the antenna to the bottom of the matching stub where it is connected to the cable. I calculated the total line losses to be 1.88dB on 28MHz when feeding the antenna with 36m of UR67 cable.

Recommendations By G5RV

As I've already mentioned, Louis Varney recommended the use of balanced feeder all the way between the antenna and a balanced a.t.u. And there's no doubt that this is the optimum way of feeding any G5RV antenna, particularly when it is used on the higher frequencies.

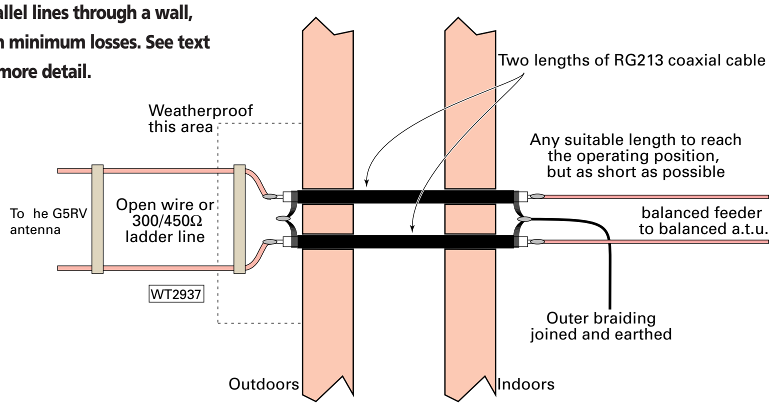
It's an unfortunate fact that many commercial a.t.u. manufacturers incorporate a 4:1 balun to achieve balanced to unbalanced conversion. This is the least desirable way to achieve this since the balun is likely to see highly reactive loads and will introduce further losses into the system. For a fuller discussion on the correct use of baluns see **www.w8ji.com** and look under Antennas.

A number of different circuits have been published for proper balanced a.t.u.'s. Louis Varney described an improved Z-match design to work with the G5RV antenna. But in more recent times, a number of commercial manufacturers have started to market balanced a.t.u.'s (without the use of a 4:1 balun) although their prices tend to be rather high.

If coaxial feeder is used between the base of the matching stub and transmitter, then it should be RG213/UR67 (10mm dia) and as short as possible. The antenna is really only suitable for use on 7, 14 and 28MHz when used in this way, as there's a very high mismatch on the 10, 18, 21 and 24MHz bands.

However, another solution for those not able to bring the balanced feeder right into the shack might be to use the arrangement shown in **Fig. 7**. The balanced feeder is connected (just prior to entering the shack) to the inner conductors of two short parallel lengths of RG213 coaxial cable. The outer braids of the two cables are strapped together at each end, but only at the transmitter end are the outer braids actually earthed.

Fig. 7:A method of feeding parallel lines through a wall, with minimum losses. See text for more detail.



Conclusion

In conclusion, the purpose of this article has been to analyse the half-sized G5RV, and suggest ways that it may be used more efficiently. It should be appreciated that most multiband antenna systems are compromises, and there is no one perfect antenna that will do everything.

However, the half-sized G5RV, if erected in a horizontal configuration and fed with balanced feeder to a well designed balanced a.t.u., is capable of providing seven band coverage between 7 to 28MHz inclusive. It also has the added advantage of a fairly predictable broadside pattern up to 24MHz, and some useful gain above 14MHz. **PW**

Further reading

HF Antenna Collection – Erwin David (G4LQI)
Backyard Antennas – Peter Dodd (G3LDO)
And for those with Internet access:
www.w8ji.com