Antenna Workshop THE G5RV ANTE

Opening the Antenna Workshop for us this month is Peter Dodd G3LDO, who takes a look at how the G5RV can become an even better general use antenna.

When a newcomer to the h.f. bands is looking for a suitable antenna a G5RV is sure to be one of the favourites. This antenna is regarded by many as the panacea to the multi-band antenna problem and you don't even have to make it - many antenna equipment retailers offer made-up G5RVs. So why has this antenna become so popular?

The late **Louis Varney G5RV**, designed the antenna over 40 years ago, primarily to give a clover leaf pattern and a low feed impedance on 14MHz. The usual commercially available G5RV, shown in **Fig. 1**, is fed in the centre and has a top of 31.3m, a total of three half-wavelengths on 14MHz.

The feed impedance on 14MHz is low because the feed-point is at the centre of the central half-wave section. The mid-band resonant feed impedance at that point is around 90Ω into the 10.36m matching section of open-wire feeder. The feeder is used as a 1:1 transformer, repeating the feed impedance at the lower end.

Because of this reflected 90Ω impedance, the lower end of the matching section can be connected to a length of 75Ω impedance coaxial cable (albeit with a balance to unbalance problem) as a convenient way of routing the feed to the transmitter in the shack. It was for these reasons the antenna became so popular.

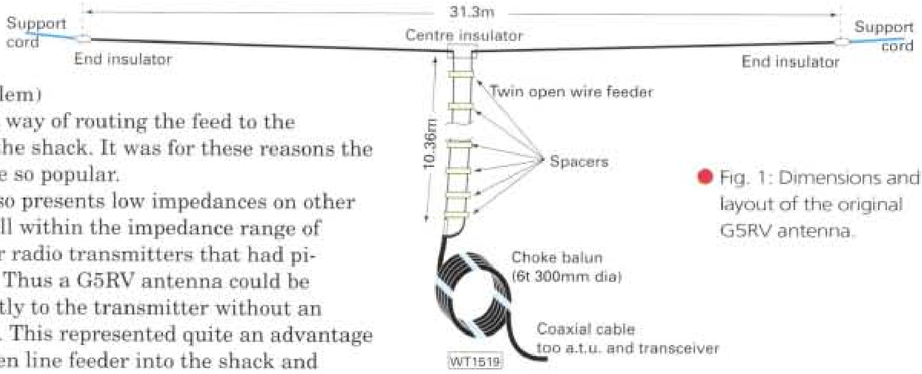


Fig. 1: Dimensions and layout of the original G5RV antenna.

The G5RV also presents low impedances on other bands, which fell within the impedance range of earlier Amateur radio transmitters that had pi-output circuits. Thus a G5RV antenna could be connected directly to the transmitter without an additional a.t.u. This represented quite an advantage over routing open line feeder into the shack and using an a.t.u.

However, for the G5RV to work the top dimension and the matching section must be as shown in Fig. 1. If 300Ω ribbon or slotted line is used then the length of the feed section must be adjusted to take account of the velocity factor. (multiply 10.36m by the velocity factor).

Additionally, the G5RV geometry cannot be altered by converting it into an inverted-V or bending the ends to fit into a small available space without upsetting its feed impedance. And on the 10, 18 and 28MHz bands the feed impedances can vary considerably.

Many modern all-solid state Amateur band transceivers have transmitter output stages that are easily damaged when operated with high s.w.r. on the feed cable to the antenna. Or, they have an 'a.l.c.' circuit that reduces power in some proportion to s.w.r. So, in these cases it's obvious that an a.t.u. between the low-impedance feeder and the transceiver is required.

To sum up, the G5RV antenna was suitable as a multi-band antenna in the days when Amateurs had longer gardens, used pi-output valved transmitters **and** before the WARC bands were allocated.

Louis Varney mentioned§**1** that the most efficient feeder to use is the open-wire variety, and may be used in conjunction with a suitable a.t.u. for matching. He added that by using 25.6m (84ft) of open-wire feeder the system will permit parallel tuning of the a.t.u. on all bands which brings us to the Open-Wire Tuned Dipole.

Tuned Doublet

The open-wire tuned dipole antenna, also know as the Tuned Doublet or random-length dipole is very simple, yet is a most effective and efficient antenna for multi-band use. This antenna is fed with balanced open wire tuned feeders, as shown in **Fig. 2.**

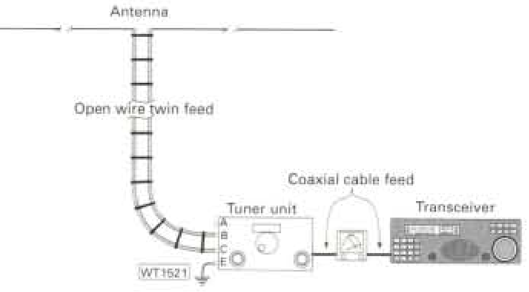
An a.t.u. is used to convert the unbalanced output from the transceiver to a balanced feed and also to take care of the wide variations of feed impedance on the different bands. The tuned doublet should be at least a quarter wavelength long at the lowest frequency of operation, where it radiates with an effectiveness of approximately 95% relative to a half-wave dipole.

However, the feed impedance of such a short antenna results in very high s.w.r. when fed with 450Ω line. While the antenna is quite efficient the impedances at the end of the tuned feeder will be outside the matching range of the average commercial a.t.u. using a toroidal balun to provide a balanced feed to the tuned feeders.

If you have the space then use a dipole with a length of about 3λ/8 on the lowest frequency. This is halfway between quarter-wave and half-wave and will work very well if you can't erect a full half-wave on 3.5MHz.

A 3λ/8 dipole has an effectiveness greater than 98% relative to a half-wave dipole, and the s.w.r. values are far easier to match, being in the region of 25:1 on 600Ω line, 24:1 on 450Ω line, and 25:1 on 300Ω line. This dipole, for 3.5MHz, is approximately 30m long, which means that any length from 27 to 30m will make an excellent radiator on all h.f. Amateur bands,

Fig. 2: The tuned open-wire dipole using a balanced tuned transmission line connected to the balanced output of the a.t.u. B and C. The real advantage of this antenna is that dipole length is not critical, because the tuner provides the impedance match throughout the entire antenna system, whatever the dipole length may be. If you are short of space the antenna could be cut for 3λ/8 of a wavelength on 7MHz and it will tune all bands from 7 to 28MHz. You can still put out a signal on 3.5 or even 1.8MHz by connecting the feeders together and using them as a single wire antenna feed A and using a good r.f. earth.



NNA A MULTI-BAND CENTRE FED ANTENNA

3.5 - 30MHz, including the WARC bands.

If you don't have room for a 27m length of straight wire for operation on 3.5MHz, a 3-5m portion of each end may be dropped vertically from each end support. There will be no significant change in radiation pattern on 3.5 and 7MHz. However, there will be a minor change in polarisation in the radiation at higher frequencies, but the effect on propagation will be negligible.

It is often thought that a high s.w.r. on a transmission line, such as that described above to connect the feeder to the a.t.u., will radiate. This doesn't happen, **provided** the currents on each conductor of the balanced feeder are the same i.e., they are balanced.

Balanced ATU

The multi-band antenna should, ideally, be fed using a balanced a.t.u. The classic balanced a.t.u. is the link-coupled or inductively coupled a.t.u. as shown in **Fig. 3**. The unbalanced input is inductively coupled to the main inductor. Since the mutual inductance between the coils is critical for maximum efficiency, the coupling is varied either by a movable link or by a series input capacitor as shown.

The arrangement shown in Fig. 3 is fine for one band. However, a single coil and link for all h.f. bands does not provide the best coupling ratios for all possible conditions and some of the best solutions use plug-in coils, one for each band. A home-made balanced a.t.u. using this approach was recently described by **Ted Garrott G0LMJ**[§2].

In Ted's design, a total of nine coils covered 1.8 - 28MHz. Two separate capacitors are used for output tuning, providing the facility of equalising the current in each feeder line, being monitored using two r.f. current meters.

There are few commercial balanced line tuners around, but two such tuners are the **Johnson Matchbox** (an old design, which does not include the WARC bands) and the **Annecke** (a more modern design made in Germany).

Internet antenna 'guru' **L.B. Cebik, W4RNL**, notes[§3] that for those seeking the most efficient transfer of power to balanced lines, nothing beats a properly designed and constructed link coupled a.t.u. However, for operators who change bands frequently, the inconveniences of plug-in coils may be worse than the losses inherent in more typical tuners. If you have internet access, check out the W4RNL website for a super a.t.u. and antenna tutorial.

The Z-Match

Another link coupled a.t.u. that has been around a long time is the Z-match. Originally designed as the tank circuit of a valved p.a. stage§**4**, the anode of which was connected to the top or 'hot' end of the multi-band tuned circuit. It was fed directly from the p.a. valve, with its internal (source) impedance of several thousand ohms

When the circuit was adopted as an a.t.u.§**5** the tank circuit is fed directly from a source which requires a 50Ω load via a 350pF variable coupling capacitor connected to the top (or 'hot') end of a multi-band parallel-tuned LC circuit.

In spite of the great difference between the required 50Ω load for the transmitter and the relatively high impedance of the tank circuit the Z-match enjoyed considerable popularity, most likely due to its simplicity. Z-match a.t.u. s were produced commercially and are easily available and cheap. An example of such a unit is the S.E.M. unit shown in **Fig. 4**.

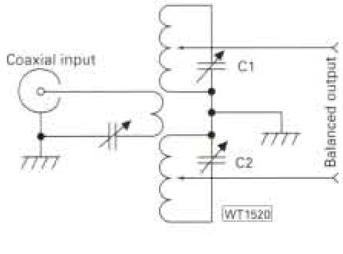


Fig. 3: Typical link-coupled antenna tuner circuit.

The T-Tuner

If you want to buy a new a.t.u. these days the only type available is what is known as the 'T-Tuner' or 'T-match'. This a.t.u. has enjoyed considerable popularity in the USA, being described as the 'Transmatch'. The T-network comprises two series variable capacitors with a variable inductance (usually a roller coaster) connected between the point were the two capacitors are connected and earth.

Fig: 4: The S.E.M. 'Transmatch' matching unit, which shows the general construction of a Z-match a.t.u.

The T-match has the advantage is that it can provide an acceptably wide range of impedance transformations without the requirement for large-value variable capacitors. Its disadvantage is that it is single ended and unbalanced. Most commercial T-match a.t.u. s provide a balanced out by incorporating a balun. The degree of balance is not as good as the balanced a.t.u. described earlier.

The MFJ VersaTuner V, shown in **Fig. 5** uses a T-match tuning arrangement. It has provision for selecting various antennas using a switch and has a cross-needle power and s.w.r. meter that is particularly convenient to use. The ability to switch in a dummy load is also a useful feature. In fact this is more than an a.t.u. – it is an antenna management system. *PW*

Fig. 5: Looking into the business 'bits' of the MFJ VersaTuner V.

REFERENCES

§1 The G5RV Multi-band Antenna, *Radcom*, July 1984

§2 'A balanced Line ASTU', Ted Garrott, G0LMJ, *Radcom* July/August 1998

§3 'Link Coupled Antenna Tuners: A Tutorial', L.B. Cebik, W4RNL, internet <http://www.cebik.com/radio

§4 'To Turrets - Just Tune', King W1CJL, *QST* March 1948

§5 'The Z-match Antenna Coupler', King W1CJL, *QST* May 1955

EFFECTIVE IMPROVEMENTS TO THE

Anthony Johnson G4DUC provides this month's second look at the ubiquitous G5RV antenna and says that it's possible to make some effective improvements to your set-up by altering the way you feed it!

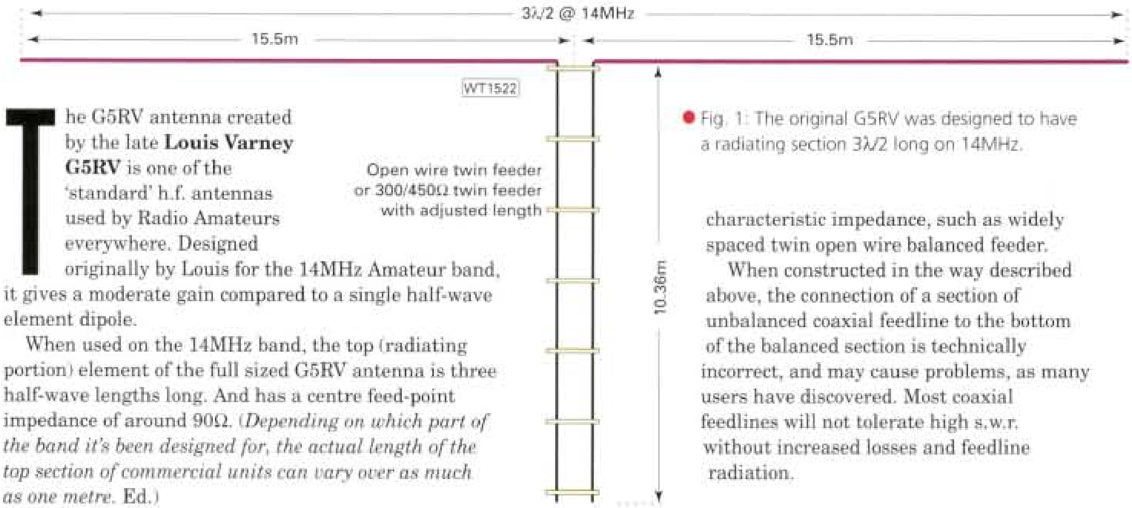


Fig. 1: The original G5RV was designed to have a radiating section 3λ/2 long on 14MHz.

The G5RV antenna created by the late **Louis Varney G5RV** is one of the 'standard' h.f. antennas used by Radio Amateurs everywhere. Designed originally by Louis for the 14MHz Amateur band, it gives a moderate gain compared to a single half-wave element dipole.

When used on the 14MHz band, the top (radiating portion) element of the full sized G5RV antenna is three half-wave lengths long. And has a centre feed-point impedance of around 90Ω. *(Depending on which part of the band it's been designed for, the actual length of the top section of commercial units can vary over as much as one metre.* Ed.)

In the original design a half wavelength (at 14MHz) section of open twin wire (or high impedance) feeder was used as an effective 1:1 impedance transformer so, reproducing, at the lower end of the section, the same 90Ω impedance that occurs at the feedpoint of the antenna element itself.

However, there is no need for this matching transformer at all if the antenna is used solely for the 14MHz band. It would be acceptable to connect a low impedance feedline directly to the centre of the top, radiating, element with no detriment to performance.

In Detail

Let's now look at the design, as shown on **Fig. 1** in a little more detail. One half of the radiating top element is 15.5m, now add in the length of the transformer section (10.36m) give an overall length of 25.86m. This is a wire length that is useful in relation to some Amateur bands, as it can provide an impedance which suitable for connecting to low impedance feedline.

The low impedance effect is not available on all bands, due mainly to high reactive impedance values, tending to give a high s.w.r. values. However, if the feedline is capable of operating efficiently under higher s.w.r. conditions then satisfactory results may be obtained.

As shown the radiating top section and the matching section of the antenna form a balanced doublet system. Ideally the matching section should be constructed with a high characteristic impedance, such as widely spaced twin open wire balanced feeder.

When constructed in the way described above, the connection of a section of unbalanced coaxial feedline to the bottom of the balanced section is technically incorrect, and may cause problems, as many users have discovered. Most coaxial feedlines will not tolerate high s.w.r. without increased losses and feedline radiation.

When a high s.w.r. exists in a section of coaxial cable, the outer braiding of the cable is forced to carry undesirable r.f. currents. Under these conditions, the feedline contributes a major part of the actual radiating system, and is a source of EMC and TVI/BCI problems if not corrected.

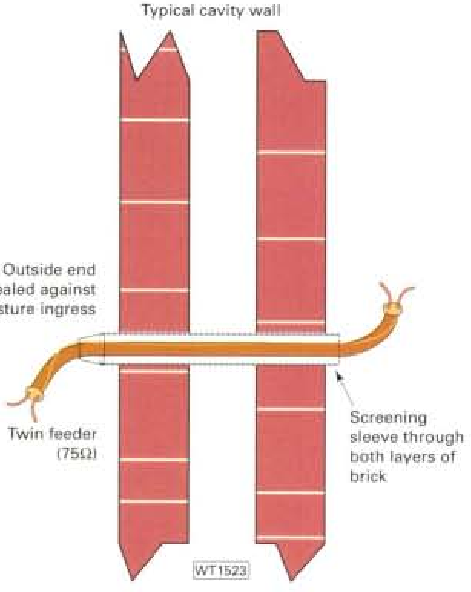


Fig. 2: Taking the twin 75Ω feeder through a cavity wall is easy if you follow this layout. Remember to weatherproof the outside of the sleeve though, otherwise a lot of water could come in when it rains.

Often Misunderstood

Another aspect of the G5RV antenna that is often misunderstood, is the true purpose of the vertically hanging impedance section. I've heard it said that 'that the matching section should hang vertically from the radiating element to give some vertically polarised radiation'. **This is not true!**

The real reason that the transformer section should hang vertically from the radiating element is to maintain system balance. It is advantageous to keep the whole system as symmetrical, both physically and electrically, as possible.

If we can accept the losses, the feeder radiation problem can be corrected. An effective means of correction is to 'choke off' the coaxial braid currents immediately they try to appear in the coaxial cable - at the point where the coaxial cable meets the balanced feedline. A current choke, immediately after the change-over from balanced to coaxial cable, is a method used, and all of the types of r.f choke that may be used have been published.

In his 'Antenna Workshop' article this month **Peter Dodd G3LDO** shows the use of a multi-turn looped cable method. Another r.f choke method that might be used to wind the coaxial cable itself, several times through a large ferrite ring (see later for more detail).

Technically Correct

It's technically correct to connect a balanced twin feeder to the bottom of the matching section. This action promotes and maintains system balance, eliminating undesirable feeder radiation.

A downside of using twin feedline is that it has a tendency to be 'user unfriendly'. In this application it cannot be buried in the ground or fastened to metallic structures without seriously affecting its performance.

If the matching section were continued back to the shack with a similar high impedance feedline, then the G5RV loses its identity - simply becoming a doublet antenna. However, this can provide multi-band operation with

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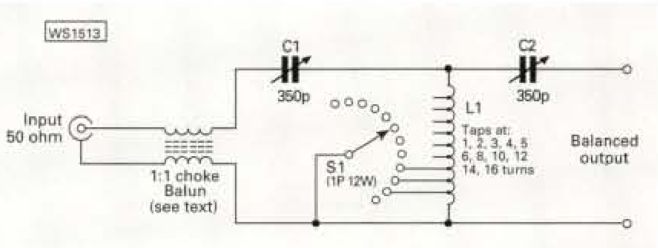


excellent efficiency and, used with a suitable balanced antenna tuning unit, provides effective results over the Amateur h.f. spectrum.

To maintain the identity of the G5RV, the ideal feeder to use is 75Ω balanced twin. Although, as with the coaxial feedline, there will still exist as high s.w.r. on some bands this feedline will improve the effectiveness of the system as a whole.

Also with 75Ω twin, the close spacing of the conductors makes it easy to maintain system balance when routing it past nearby structures or conducting objects. Providing the feeder doesn't run closer than about ten times the distance between the conductors, then system balance should be maintain.

This 'rule-of-thumb' distance when using the commonly available 75Ω twin is around 30mm minimum distance in reality. There may however, be some problems when routing the twin feeder into an indoor shack.

When getting coaxial feeder into the average shack, the usual way is to drill a ho;le through a window frame or the brickwork and pass the cable through. With 75Ω twin it's desirable to maintain an equally distributed capacitance around the cable, especially when other cables pass through the same hole.

Snug-Fitting

A snug-fitting narrow metal sleeve or a length of coaxial cable screen slipped over the feeder for the length of the hole will be effective in meeting the required conditions. The technique is shown in the illustration of **Fig. 2**. The metal sleeving must be electrically isolated from other conductor, to be effective. The outer point should also be suitably weatherproofed.

With the likely exception of the 14 and 28MHz bands, there may be a high s.w.r. on the feeder. Under these conditions the twin will act like a tuned feedline, meaning that a transformed reactive and resistive combination will be presented to the station's a.t.u.

Any available balanced output a.t.u. that incorporates a balun transformer in the output is not recommended for this setup, as the balun cannot deal with reactive components very well. They may give n apparent match, but this is often at the expense of wasted power dissipated in the balun rather than going to the antenna.

A 'proper' balanced a.t.u. such as the 'Z-match' is a much better option. Another simple solution to this problem is the following design which is flexible and capable of being optimised for each Amateur band. What is the arrangement that is so, flexible you may ask! The answer to that is a 'T'-match with a choke balun input circuit.

The circuit of the 'T'-match a.t.u. is shown in the circuit of **Fig. 3**, where you will see simplified circuit consisting of a single multi-tapped coil and two variable capacitors of 350-500pF. This arrangement provides an efficient power throughput with good balance however, to realise a balanced output it's necessary to 'float' the network and its case at r.f. potentials.

A convenient way of 'floating' the unit is to use a balun in the input to the circuit so, isolating the coaxial feed from the antenna feedline. As the balun is at the input and operates close to a resistive matched condition it works with maximum effectiveness.

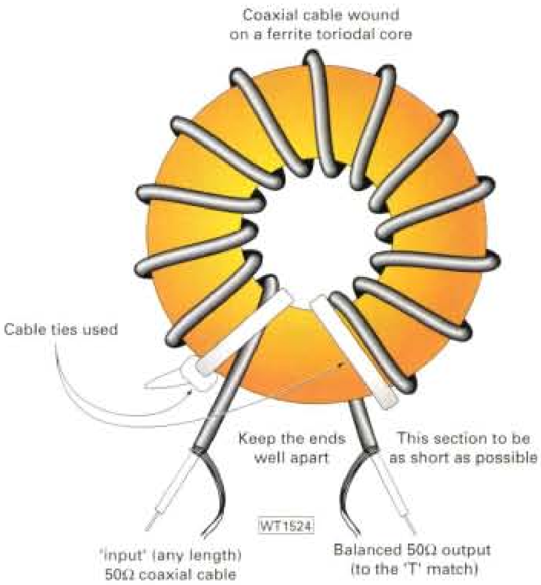
The coil, L1 consists of a single layer winding of 18 turns heavy gauge (1.5-2mm), spread over 100mm. The former used for L1, should be around 60-65mm diameter, be fairly robust and may be made from any material that doesn't absorb moisture. Plastic water piping makes a good former for this project.

The coil has taps at 1, 2, 3, 4, 5, 6, 8, 10, 12, 14 and 16 turns taken to a 12-way switch which should be of excellent quality and as large as possible. An alternative would be some form of plug and socket combination on the casing of the unit. But it's important not to use a metal case to house the unit as the closeness of the metal can change the effective balancing of the unit due to stray capacitance.

• Fig. 3: The circuit chosen by Anthony should be built in a solid insulated box. This is because the right-hand side of the circuit is 'hot' in terms of r.f. and may cause burns if care is not taken with the construction and operating it! (See text for more details of the tapped coil and capacitors).

Best Balun

The best type of balun, and one I've found effective in this situation, is the type made by winding 15 turns of RG58 coaxial cable on a large ferrite (type 61) toroidal core. this will work with up to around 1kW input. A smaller version could consist of 15 turns of RG303 coaxial cable on a 37mm type 61 ferrite toroidal core. This would be adequate up to around 100W input.



• Fig. 4: A suitable input balun consists of 15 turns (rather than the 12 turns illustrated) of coaxial cable on a type 61 ferrite toroidal core. Power levels of up to 1kW may be handled depending on the cable and ferrite sizes. (See text for more details).

As the unit and the controls are 'hot' at r.f. it's essential that all controls are non-metallic and that the unit is housed in a suitably strong and secure insulated box. All controls should have plastic shafts to the 'outside world' to protect the operator. If using a plug and socket arrangement for coil tappings **do not adjust the tappings when transmitting. Do so at your peril!**

In Use

In use this 'T'-match can be a little tricky to use, if you've never used one before so, a few words about how it's done. Until you've found out the best positions for the controls on each of your working bands, start with both capacitors around mid-range and the coil at its minimal inductance point (maximum number of shorted turns) then quickly try each capacitor in turn to give the lowest s.w.r. reading. Note its value!

Add more inductance then try again, taking note of the lowest value of s.w.r. if lower than before, note this new value before trying more inductance. Always use the minimum inductance possible on each band. As everyone's location and set-up is going to be different, I cannot say what values you will find for any band.

There may also be unfortunate feeder lengths that make setting on one or more bands difficult, but persevere try a different length of feeder!

Constructing, or modifying a G5RV antenna system with open wire feeder can result in a useful and effective multi-band antenna system that is a joy to use on all h.f. bands. I hope you enjoy the process! *PW*