Bill Ward's antenna workshop

The G5RV Revisited

Billy Ward G4NRE was asked about the G5RV by an M3, and to help, looked again at this popular antenna.

The G5RV – a favourite for generations of Amateurs!

Recently I had an M3 Amateur ask me to explain more about the G5RV antenna after he'd come across the antenna design in *PW*. The antenna, as many of us know, was designed by the late **Louis Varney G5RV** and it's been popular for many years.

There's much confusion regarding the 'classic' version of the G5RV antenna, using twin and open wire feeder. Referring to this version of the G5RV as a 'Classic' example is very misleading as the twin feeder – in this application – is not a feed line. Instead it's a matching stub as shown in **Fig 1**.

Thinking about it – I could fill *PW* with the technical descriptions of the workings of the G5RV, just what the twin feeder is used for and how it works on each band! Despite this I see no reason to 'go there' as long as it's clearly understood and that some radiation from the twin feeder occurs because it's part of the antenna and not the feeder line.

With coaxial cable a number of interference problems arise due to the radiation from the coaxial cable itself. And, as it's an unbalanced feeder line, it also picks up electrical noise. However, the pick-up might be small and the good points are that the cable is easy to route down metal poles.

To get it down into the shack you just stick a plug on each end and 'away you go' – attach the SO259 socket on the antenna tuning unit (a.t.u.). It's as simple as connecting up the electric kettle!

Loss & Radiation

Unfortunately, the G5RV antenna is not that easy to tune over a wide frequency range without loss and radiation from the coaxial cable itself. For example the RG8 (a popular size of coaxial cable) cable has an attenuation of 0.8dB per 30m (approx.100ft) at 14MHz and 1.2dB per 30m at 29MHz. This is clearly a very satisfactory cable for high frequency (h.f.) work but, being a 10mm (0.4inch) diameter cable, it's somewhat bulky to hang in free space from the average Radio Amateur's wire antenna. Instead, for the wire antenna we might choose a lighter 5mm (0.2inch) diameter cable, such as the RG-58 variation.

Let's now suppose we are aiming to feed an h.f. dipole antenna set at a height of half a wavelength above the ground for the band to be used. The radiation resistance at this height could be assumed to be 73Ω and a 75Ω 5mm cable, such as RG59, could be used to match the antenna through a 1:1 balun transformer at the antenna centre. Referring again to the RG59, which has an attenuation of 1.5dB per 30m at 14MHz and 2dB per 30m at 28MHz. Let's now look at the open wire feeder.

Open Wire Feeder

Open wire line is perfectly balanced, the fields around the two conductors are equal and opposite and hence radiation from the line is essentially cancelled. However, as the wires are a finite distance apart, there must be a small difference.

Instead of using RG8, we could use 450Ω open wire line via a 4:1 impedance ratio balun transformer. This feeder is quite light and flexible and hangs very well from a wire antenna and its attenuation for an s.w..r. of 1:1 is around 0.08dB/30m at 14MHz and 0.17dB/30m at 28MHz.

So, with the figures I've mentioned, it should become clear that, for an s.w.r. of 3:1, the attenuation of the open wire line is still only a fraction of a dB/30m at both frequencies. Obviously, it's far more efficient than the RG59 coaxial cable.

Differential Field

In practice, when balanced line feeders are used a differential field is created, which might be detectable close to the line. If the feeder runs, or is installed close to (let's say) a microphone lead within the radio shack, the differential field might be sufficient to cause radio frequency (r.f.) feedback, perhaps even more so than coaxial cable with its confined field. One way to reduce the differential field is to twist or 'barrel roll' the cable so that over a distance the differential effect is cancelled.

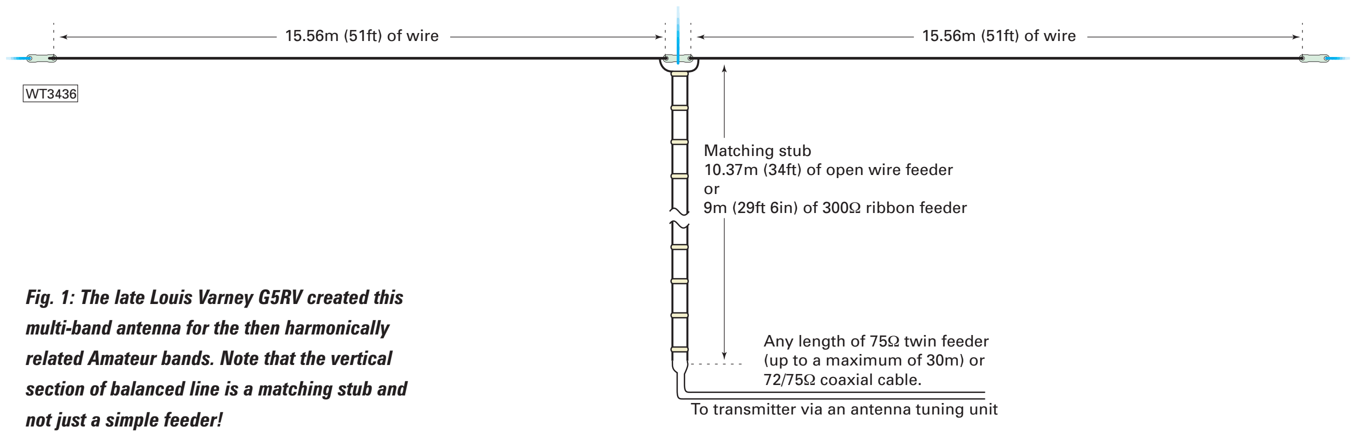

Fig. 1: The late Louis Varney G5RV created this multi-band antenna for the then harmonically related Amateur bands. Note that the vertical section of balanced line is a matching stub and not just a simple feeder!

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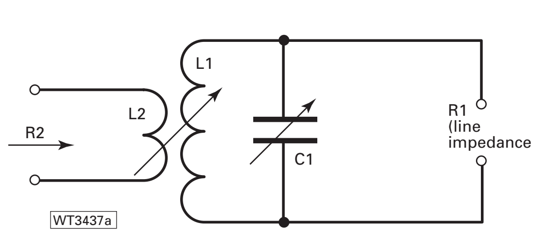

Fig. 2a: This circuit is used when the shack end of the feeder appears as a high impedance.

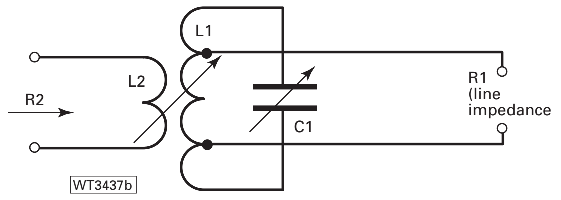

Fig. 2b: This circuit is for use when the shack end of the feeder appears as a lower impedance. The tapping points should be symmetrical from the outer point of the coil.

Incidentally, so little noise can be heard from the feed line that it's not unusual for the noise level to drop from a S8 to S4 when coaxial feed line is replaced with open wire.

Unbalanced Tuner & Balun

On paper, an unbalanced tuner, feeding a balun, connected to a ladder-line fed antenna should work well. However, in practice it doesn't work well and the reason for this lies in the balun!

As a rule of thumb, a balun should have about four times as many reactive ohms impedance as the resistive value of the load. This means that for use with a 600Ω balanced load, the balun should have a secondary winding reactance of about 2400Ω. For 3.5MHz (80m) operation, this works out to be more than 100μH of balun inductance! To create this much inductance on an appropriate m.f./h.f.-rated [μ=40] ferrite core, an impracticably large number of turns of wire would be required.

The use of a balun, in a high-impedance circuit, inevitably creates two, very sticky problems! More turns means more ampere-turns of magnetic flux in the balun's core, and high magnetic flux densities can cause the ferrite-core to saturate. This distorts the r.f. waveform and creates harmonics. These harmonics extend well into the ultra high frequency (u.h.f.) TV band. The remaining problem with using many turns of wire is that in doing so increases the winding-capacitance of the balun!

The high capacitance of the winding creates unwanted reactance and/or balun imbalance. This is especially true with the commonly used 4-to-1 bifilliar-wound balun, which does not have an evenly distributed winding capacitance like the trifilliar-wound balun. When enough turns are placed on the 4-to-1, bifilliar balun for satisfactory 3.5MHz operation, the inherent capacitive imbalance in the balun causes a progressively greater imbalance in the output voltage of the balun as the operating frequency increases.

This imbalance within the balun causes a differential r.f. current to flow through the ground wire on the tuner. Actually, I think that the term '4-to-1 balun' is misleading. They are much better suited for broadband, unbalanced-to-unbalanced 4-to-1 transformer service such as would be needed in the input circuit for a grid-driven Class-AB1 amplifier, whose grid terminating resistance was 200Ω.

There's also a problem with the substantial current flowing in the ground wire on any tuner. This is because **all conductors**, no matter how wide, have inductive reactance and the r.f. current that flows through the ground wire or strap can develop a large r.f. voltage on the tuner-end of the ground wire.

With 1000W on 21, 24 or 28MHz, the r.f. voltage on the "matches everything" tuner chassis can light a neon lamp brilliantly. It can also produce sparks with a graphite pencil and burn fingers!

The 1-to-1 trifilliar-wound balun solves the capacitive imbalance problem of the 4 to 1 balun. Unfortunately, it does not solve the problem of high capacitance in the windings themselves. And, more importantly, it does not solve the problem of core saturation due to the high magnetic flux-density created by the large number of turns required for any high-impedance balun.The bottom-line is: I think that high-impedance baluns are a very likely source of **grief** no matter how carefully they are engineered and constructed!

Easily Avoided!

Fortunately, all of the problems I've highlighted are easily avoided! The solution is simple – don't put the balun in the highest impedance part of the circuit. Instead, put the balun in the lowest impedance part of the circuit and build a balanced L-network tuner for the balanced output of the low-impedance balun.

So, (you may ask me) why have we been putting the balun in the wrong part of the circuit for these many years? A good question – but I'm not sure of the answer!

In most cases, the lowest-impedance part of the circuit is the 50Ω coaxial cable input to the a.t.u. and building a 'no grief' 1.8MHz to 30MHz 50Ω balun is easy!

No costly ferrite-cores are needed, just a short length of plasic pipe of 76mm to 127mm (3 to 5 inch), about 7.6m (25ft) of 50Ω coaxial cable plus some nylon cable ties. Solid dielectric coaxial cable is best for this application because foam dielectric has a tendency to allow a change in the conductor-to-conductor spacing over a period of time if it's bent into a tight circle. (This can eventually result in voltage breakdown of the internal insulation).

The required length of the plastic pipe depends on the diameter and length of the coax used and the diameter of the pipe. For RG-213/U coaxial cable, about 310mm (1ft approx.) of 127mm (5inch) size pipe is needed for a 1.8 to 30MHz balun. For 3.5 to 30MHz coverage, about 5.5 to 6m (18 to 20ft) of coaxial cable is needed. This length of coaxial cable is also adequate for most applications on 1.8MHz.

The number of turns is not critical because the inductance depends more on the length of the wire (the coaxial cable) than on the number of turns, which will vary depending on the diameter of the plastic pipe that is used. The coaxial cable is then close-wound as a single layer on the plastic pipe.

The first and last turns of the coaxial cable are secured to the plastic pipe with nylon cable ties passed through small holes drilled in the plastic pipe. The coil winding **must not be** placed against a conductor. The name of this simple but effective device is a choke-balun.

Some people build choke-baluns without a plastic coil-form, by scramble winding the coaxial cable into a coil and taping it together. However, the problem with scramble winding is that the first and last turns of the cable may touch each other. This creates two complications – the distributed capacitance of the balun is increased and the vinyl jacket of the cable is subjected to a high r.f. voltage. The single-layer winding on the plastic coil form construction method solves these problems since it divides the r.f. voltage and capacitance evenly across each turn of the balun.

A more compact (less ugly) 1-to-1 impedance ratio, 50Ω trifilliar wound (with wire) ferrite core balun could also be used but there would be some trade-offs. Ferrite cores aren't cheap! Additionally, the air core of the coaxial cable balun can't saturate like the ferrite-core and – unlike ferrite core wire wound baluns – single-layer wound coaxial cable baluns never (almost!) have an insulation breakdown problem.

Note: A trifilliar wound balun doesn't like to work into anything but a perfectly balanced load. With an imperfectly balanced load, the coaxial cable-balun won't, as does the trifiliar balun, generate a differential third r.f. current on the outside of the coaxial cable that brings the r.f. to the input of the tuner.

The choke-balun isn't fussy! It will work as well into a less-than-perfectly-balanced load as it will into a perfectly balanced load and do so without the possibility of creating a differential r.f. current on the station ground and frying the operator's fingers!

I suggest that the by far the best way to correct the impedance to 50Ω to suite a transmitter is to use a balanced a.t.u. (or as it should be called, an 'impedance matcher'). See **Fig. 2** for two versions of the simple balanced tuner for open wire feeder. All that has to be done is put as large a dipole as possible and then can feed it with 300/450Ω twin feeder and take care how it's terminated at the transmitting end.

Best Choice?

Whilst heavy duty coaxial cable seems the best choice of r.f. transmission line to run up a solid metal structure, such as a steel tower, I think that open wire line is often a better choice for wire antennas, particularly those functioning in multi-band operation. Because of its low transmission loss, the open wire line can be efficiently used on the high frequency bands with a high standing wave ratio or in a fully tuned mode. ●