Louis Varney's Aerial

A look at the history of the G5RV and its evolution over the years

by Brian Austin, G0GSF (formerly ZS6BKW)

There can hardly be a radio amateur anywhere who has not come across the G5RV. As aerials or antennas go it's probably the most ubiquitous there's ever been and judging by the commercial versions now offered for sale its popularity is certainly not about to wane. But what is it, how did it come about, how does it work and can it be improved?

These are all questions that have been asked from time to time yet the answers one hears are sometimes rather wide of the mark. But they need answering not only to honour the memory of the man who designed it but also to lay to rest some of the misconceptions and fallacies that abound, especially amongst those who have chosen, for some unaccountable reason, to call it the 'G5'. Could this be due to the current trend, so prevalent elsewhere, to contract the name of almost everything to its most banal, *vide* Man Utd, Ofcom or ASBO?

Louis Varney, G5RV

Louis Varney was G5RV. The fact that his callsign became famous as a piece of wire may be rather puzzling to the uninitiated and requires an understanding of amateur radio's sometimes peculiar patois. Antennas (or aerials if you prefer), when developed by radio amateurs, have always been known by the callsigns of their originators. The W8JK two-element array that took the world almost by storm well before the war was, of course, the brainchild of one of the most famous antenna experts there's ever been: the late Professor John Kraus, W8JK. And there are many others too, such as Dick Bird's G4ZU beam, W3DZZ's multiband dipole and VK2ABQ's minibeam that is now known as the Moxon rectangle without mentioning Les Moxon's (G6XN) callsign. So, rules are there to be broken too! But, for outlasting all of them the accolade must go to G5RV and his G5RV antenna. Though conceived in 1946 it is still going strong in a variety of guises.

But who was Louis Varney? He was born in 1911 when radio was in its infancy but was soon to come to the attention of the world for the part it played during the *Titanic* disaster the following year. Young Louis's interest in the subject was spurred on by the formation of the BBC in 1922 and he obtained an 'artificial aerial' licence with the callsign 2ARV in 1927. This was the route that had to be followed in order to qualify for a full amateur transmitting licence with its G-call. All applicants were required to demonstrate some familiarity with the art of radio transmission by carrying out suitable experiments, to the satisfaction of the Postmaster General, while using no more than 10W into a non-radiating aerial (a misnomer if ever there was one!), what we'd now call a dummy load. That done, Louis Varney then became G5RV in 1929[1].

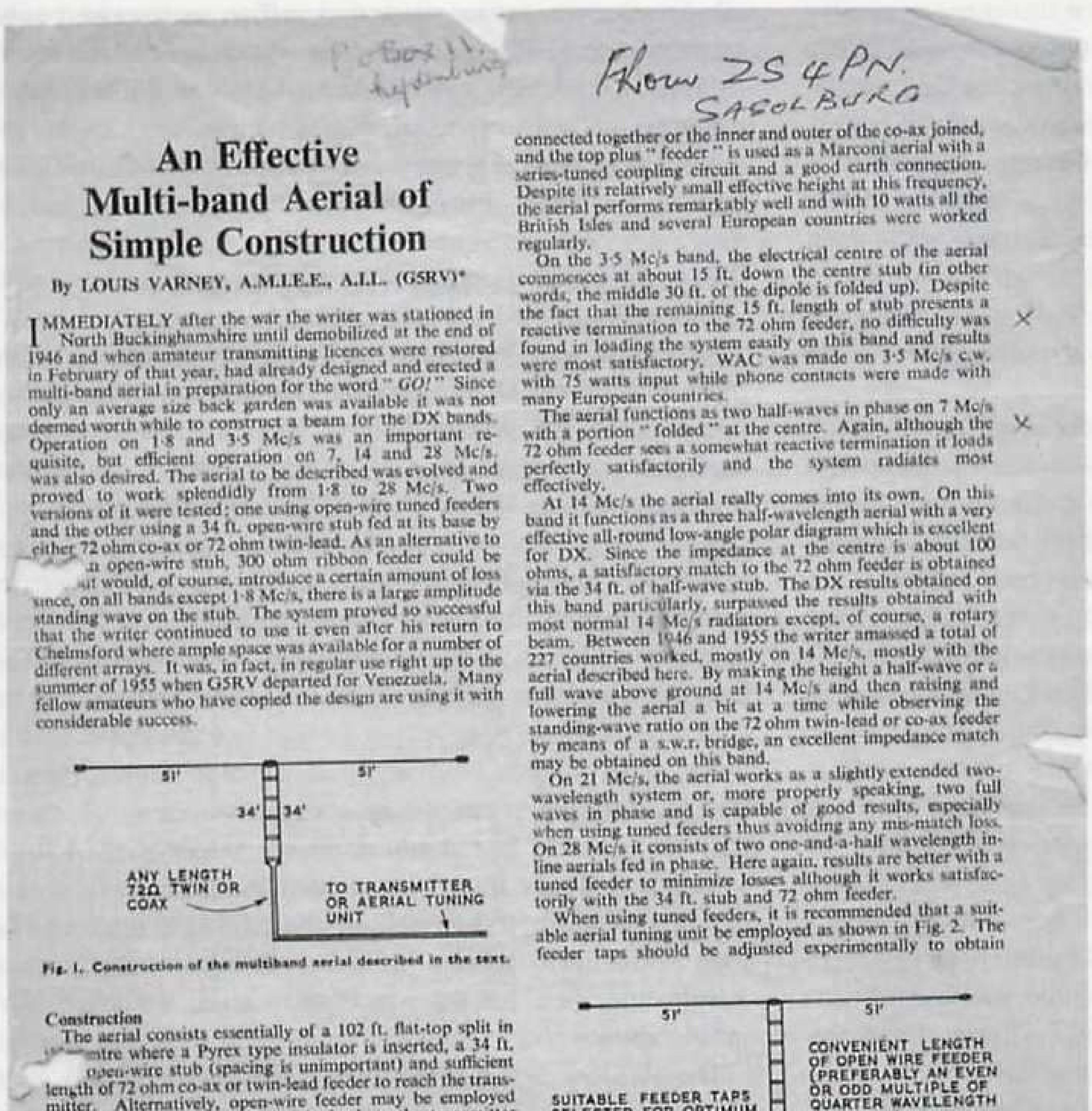
Louis Varney, G5RV (1911 – 2000) with acknowledgements to the editor of Mercury[1] *and Brigadier Johnny Clinch CBE, G3MJK*

He began his working life as a trainee engineer with the Marconi Company and rapidly progressed though its ranks. On the outbreak of war in 1939 his original intention of joining the Royal Navy came to nought but his competence in the field of radio brought him to the attention of Major R Keen, the internationally acknowledged expert in wireless direction finding or DF, as it was known. Keen recommended Varney to Brigadier Gambier-Parry (ex-G2DV), and a former BBC man, who was in charge of radio communications for British intelligence. After a searching interview, Varney was commissioned as a second lieutenant in the Special Communications No 3 (SCU3) based at Hanslope Park near Bletchley. This most secret of outfits was ostensibly part of the Royal Corps of Signals but actually fell under the control of MI6. There, under Major Keen, he took charge of the installation, calibration and maintenance of all the HF/DF stations situated at strategic points throughout England, Scotland and Northern Ireland.

Demobilization And That Dipole

In 1946, Louis Varney was demobilized from the army. With the hostilities now over radio amateurs everywhere were waiting expectantly for permission to resume normal amateur service. Varney was one of them and he had already given much thought to an antenna that would allow him to work on all the HF bands from the confines of an average size garden in Buckinghamshire. The antenna that emerged met all his expectations and soon it was being used by many other amateurs with equally good results. Even when he moved to a considerably larger property in Chelmsford he continued using it and it stayed in service until his departure abroad in 1955.

The design was published for the first time in 1958 when it appeared in the July edition of the *RSGB Bulletin* (the forerunner of the present *RadCom*). The title of the article was *An Effective Multi-band Aerial of Simple Construction*[2]. See below. The antenna soon became known as the G5RV and it wouldn't be too wide of the mark to say that it also soon became part of amateur radio folklore. In fact, its reputation spread much further afield once it was realized how effective it was when used even on frequencies for which it was not intended.



P O Box 11, [illegible]

From ZS 4PN.
SASOLBURG

An Effective Multi-band Aerial of Simple Construction

By LOUIS VARNEY, A.M.I.E.E., A.I.L. (G5RV)*

IMMEDIATELY after the war the writer was stationed in North Buckinghamshire until demobilized at the end of 1946 and when amateur transmitting licences were restored in February of that year, had already designed and erected a multi-band aerial in preparation for the word "*GO!*" Since only an average size back garden was available it was not deemed worth while to construct a beam for the DX bands. Operation on 1·8 and 3·5 Mc/s was an important requisite, but efficient operation on 7, 14 and 28 Mc/s. was also desired. The aerial to be described was evolved and proved to work splendidly from 1·8 to 28 Mc/s. Two versions of it were tested; one using open-wire tuned feeders and the other using a 34 ft. open-wire stub fed at its base by either 72 ohm co-ax or 72 ohm twin-lead. As an alternative to [illegible] a open-wire stub, 300 ohm ribbon feeder could be [illegible] it would, of course, introduce a certain amount of loss since, on all bands except 1·8 Mc/s, there is a large amplitude standing wave on the stub. The system proved so successful that the writer continued to use it even after his return to Chelmsford where ample space was available for a number of different arrays. It was, in fact, in regular use right up to the summer of 1955 when G5RV departed for Venezuela. Many fellow amateurs who have copied the design are using it with considerable success.

Fig. 1. Construction of the multiband aerial described in the text.

Construction

The aerial consists essentially of a 102 ft. flat-top split in [illegible] centre where a Pyrex type insulator is inserted, a 34 ft. [illegible] open-wire stub (spacing is unimportant) and sufficient length of 72 ohm co-ax or twin-lead feeder to reach the transmitter. Alternatively, open-wire feeder may be employed from the centre of the aerial right back to the transmitter output or a.t.u. The aerial should be supported at the optimum height for the band which is considered most important for DX working; that is, a half or full wavelength above ground. It is perhaps better to arrange this for 14 Mc/s at which frequency the aerial is designed to present a fairly close impedance match to 72 ohm co-ax or twin-lead via the 34 ft. stub which, in this case, acts as a one-to-one impedance transformer, i.e. a half-wave line. Details may be seen in Fig. 1 and Fig. 2.

Operation

On 1·8 Mc/s the transmitter end of the feeder (whatever type is used) is jumpered (i.e. the two feeder wires are connected together or the inner and outer of the co-ax joined, and the top plus "feeder" is used as a Marconi aerial with a series-tuned coupling circuit and a good earth connection. Despite its relatively small effective height at this frequency, the aerial performs remarkably well and with 10 watts all the British Isles and several European countries were worked regularly.

On the 3·5 Mc/s band, the electrical centre of the aerial commences at about 15 ft. down the centre stub (in other words, the middle 30 ft. of the dipole is folded up). Despite the fact that the remaining 15 ft. length of stub presents a reactive termination to the 72 ohm feeder, no difficulty was found in loading the system easily on this band and results were most satisfactory. WAC was made on 3·5 Mc/s c.w. with 75 watts input while phone contacts were made with many European countries.

The aerial functions as two half-waves in phase on 7 Mc/s with a portion "folded" at the centre. Again, although the 72 ohm feeder sees a somewhat reactive termination it loads perfectly satisfactorily and the system radiates most effectively.

At 14 Mc/s the aerial really comes into its own. On this band it functions as a three half-wavelength aerial with a very effective all-round low-angle polar diagram which is excellent for DX. Since the impedance at the centre is about 100 ohms, a satisfactory match to the 72 ohm feeder is obtained via the 34 ft. of half-wave stub. The DX results obtained on this band particularly, surpassed the results obtained with most normal 14 Mc/s radiators except, of course, a rotary beam. Between 1946 and 1955 the writer amassed a total of 227 countries worked, mostly on 14 Mc/s, mostly with the aerial described here. By making the height a half-wave or a full wave above ground at 14 Mc/s and then raising and lowering the aerial a bit at a time while observing the standing-wave ratio on the 72 ohm twin-lead or co-ax feeder by means of a s.w.r. bridge, an excellent impedance match may be obtained on this band.

On 21 Mc/s, the aerial works as a slightly extended two-wavelength system or, more properly speaking, two full waves in phase and is capable of good results, especially when using tuned feeders thus avoiding any mis-match loss. On 28 Mc/s it consists of two one-and-a-half wavelength in-line aerials fed in phase. Here again, results are better with a tuned feeder to minimize losses although it works satisfactorily with the 34 ft. stub and 72 ohm feeder.

When using tuned feeders, it is recommended that a suitable aerial tuning unit be employed as shown in Fig. 2. The feeder taps should be adjusted experimentally to obtain

Fig. 2. Multiband aerial with tuned feeders.

40' [illegible]
66' [illegible]
[illegible]

* *184 Gallywood Road, Chelmsford, Essex.*

R.S.G.B. BULLETIN JULY, 195

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A dog-eared and much annotated copy from the author's collection of the first page of Louis Varney's original 1958 article on the G5RV which appeared in the RSGB Bulletin

In the early 1960s the Rhodesian Army was equipped with a mixture of old AM equipment, most notably the WS62 of Second World War fame, and the Australian-designed A510 (known as the A10 in Rhodesia), as well as some of the earliest SSB sets (the Racal-SMD RT422B) to be deployed in a military role. The antenna that proved to be the mainstay of the army's high frequency (HF) communications was none other than the G5RV, manufactured in large numbers by the Signals Base Workshops in Salisbury, Rhodesia.

This may seem surprising given the fact that Varney's design was intended to work on just the harmonically related frequencies in the amateur bands. However, both the A10 and 422B had the facility to match into a wide variety of load impedances and the characteristics of the G5RV were such that it proved to be a most effective antenna on the military frequencies and saved the day on more than one occasion.

Given this versatility it is not surprising that the G5RV soon developed a mystique all of its own. But it had (and still has) its detractors too, so claims and counter-claims about its performance are to be heard reverberating around the amateur bands and in the columns of almost every amateur journal the world over. It has been misunderstood, misrepresented and generally maligned as often as its praises have been sung from the rooftops.

All operators of radio transmitters, not just amateurs, who

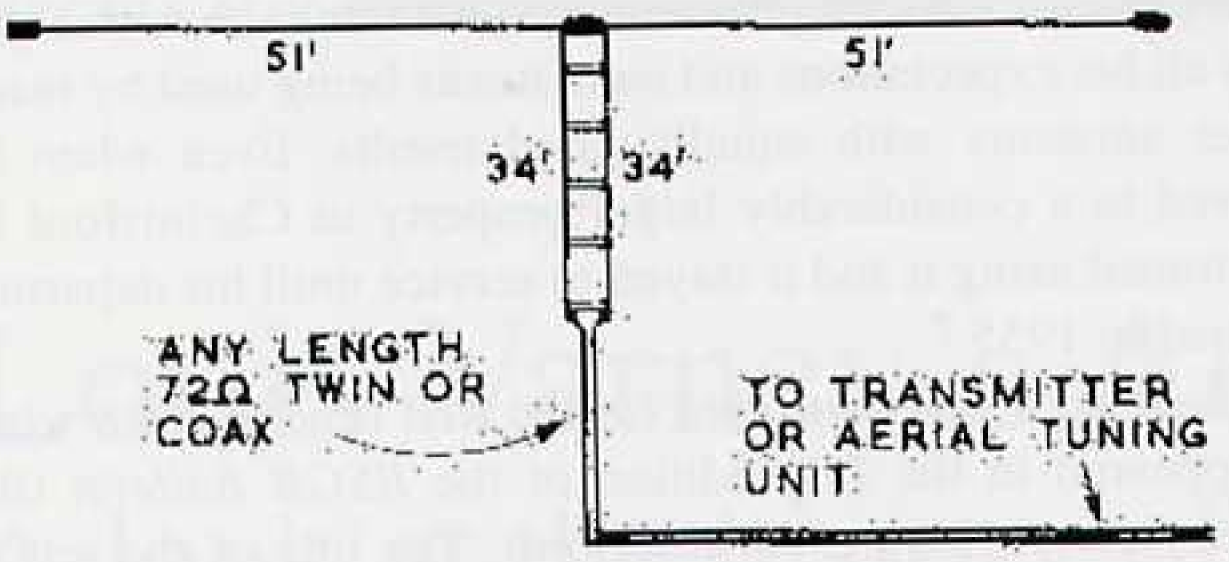


Fig.1. The configuration of the G5RV as drawn by Louis Varney in 1958

require the use of many frequencies to meet their communications needs, would dearly love to achieve optimum performance on all of them without having to change the antenna whenever the frequency band is altered, but few antennas are truly broadband devices. That ideal is almost as elusive as the pot of gold at the end of the rainbow. Fortunately, we can get fairly close to it with some antennas but they tend to be rather complex structures like log-periodic arrays or travelling wave antennas such as the rhombic, and neither is small so size has to be traded against bandwidth. The G5RV is no exception: it works well on some frequencies but not on all of them.

Wildfire

Since Louis Varney's multiband dipole suggested so much for so little it's not at all surprising that word soon spread like wildfire when it first appeared. Had the ultimate multiband antenna finally arrived? Well, it all depends on what your criteria are, so let's examine that original article to see what G5RV himself claimed. Reference to the diagram used by Louis Varney in his original article will help (**Fig.1**).

Notice that the G5RV consists of a dipole, doublet or even flat-top, if you like, which is 102 feet long. Though we're now supposedly all metricated this is one instance when it makes good sense to stick to feet and inches since Varney's article and drawings used them. It is fed at the centre by means of a special section of transmission line 34 feet long, which then connects directly (without a balun) to any length of 72-ohm twin lead or coaxial cable. In those days just after the war the standard 50-ohm coaxial cable we now all take for granted was by no means readily available. Even the 72-ohm variety had only just become popular after its introduction during the war. Most amateur's antennas still used twin feeders of one form or another.

Of very great importance to what follows in this article is the statement that appeared alongside Varney's own drawing (his Fig.1) of the antenna. He specified no particular length of 72-ohm line (as is sometimes claimed) and also said that it could be connected either directly to the transmitter or to an aerial tuning unit (ATU), and then on to the transmitter. Only much later, in 1984, when the controversy was raging about the ability of modern solid-state amateur transmitters to cope with the high standing wave ratio (SWR) sometimes much in evidence on that line did he decide that his antenna must be used with what he called an ASTU or antenna system tuning unit. His original article did not make any form of ATU/ASTU obligatory but suggested one only as an option.

In his 1958 article Varney also showed (in his Fig.2) the same length of antenna but fed, this time, with any convenient length of open-wire line without any twin lead or coax at its end. He added, in parentheses, the suggestion that it might be preferable to make that open wire feeder either an even or odd multiple of a quarter wavelength on 14MHz. Given the impedance transforming properties of unmatched transmission lines (which will be touched on below) that range of lengths may well produce significant changes in the impedance appearing at the input end of that line, and if the transmitter is to cope with them satisfactorily it will certainly require a matching network between the two. Varney showed a simple link-coupled tank arrangement that would do the trick allowing the use of 72-ohm coax for connection between the ATU and the transmitter.

It should be noted that this second antenna option is not the G5RV, as it is universally known these days. The fact that the flat-top is 102 feet long is of no real consequence at all. Any convenient length would suffice, as long at it is not much less than about a third of a wavelength at the lowest frequency on which it is to be used. Such multiband antennas are usually known as doublets and they work exceptionally well, as long as they're used with low loss transmission lines and an appropriate ATU.

The G5RV Antenna System

It should now be clear that the G5RV antenna is rather more than just 102 feet of wire. The 34-foot transmission line is really the crucial element and so it makes sense to consider the combination of the dipole and the special matching section of line as the G5RV antenna system.

Why Varney chose those dimensions could be explained mathematically but that is not necessary if one restricts the analysis, initially, to just the 20m (14MHz) band. Since 102 feet is three times 34 feet there is clearly some relationship between them that is being exploited in this antenna system. The next point to note is that 34 feet is round about a half wavelength on 20m. Now, any half-wavelength transmission line (or multiple of that length), regardless of its characteristic impedance, has the interesting property of being a 1-to-1 impedance transformer, such that the impedance at one end is simply transferred, unaltered, to the other end (as long as the line is lossless). Open-wire transmission line, as Varney specified, has very low losses at HF and so is ideal in this application.

The 102-foot dipole being three half-waves long will, when hung at a reasonable height above the ground, present at its mid-point a resistance of about 100 ohms at resonance, which actually occurs near the top of the band. Hence, at the input end of that 34-foot section the impedance will be the same. Connecting the 72-ohm twin lead or coax at that point means that the SWR on that transmission line running directly to the transmitter is simply their ratio, which is about 1·4-to-1. Clearly, no ASTU or any other form of impedance transformation is required to achieve that very acceptable degree of matching. Of course, any change in frequency either above or below resonance will cause the antenna impedance to change and to become reactive. The effect is to increase the SWR away from resonance and since the best match occurred at the high-frequency end it'll be somewhat worse lower down. A useful measure of any antenna is how wide its impedance or SWR bandwidth actually is.

How Does It Cope

Now we come to the clever part of the G5RV. How does it cope with the other amateur bands? Remember that in 1946, and even in 1958, none of the so-called WARC bands was yet available to the amateur service. Those from 160 to 10m were all harmonically related and for good reason too, bearing in mind that much of the equipment then in use was homemade and the filtering of harmonics may not have been of the best.

Consider now the 40m or 7MHz band. The antenna's impedance will be both high and reactive because 102 feet is not a resonant length at that wavelength. However, 34 feet happens to be about a quarter wavelength on 7MHz and such lengths (as well as their odd multiples) of transmission line have the interesting property of being able to transform open circuits into short circuits and vice versa, at least in theory. In reality, such a quarter-wave transformer, if connected to the centre of the 102-foot dipole, will turn the high impedance at the antenna into a much lower value at its input end. The hope is that by so doing it'll provide a reasonable match to the 72-ohm line and this is precisely what Louis Varney was aiming at. It should be noted that this special property of the quarter-wave transmission line involves not only its length but also its characteristic impedance unlike that in the half-wave case where the process is independent of the impedance of the line. Varney, however, stated that the spacing between its conductors, and hence its characteristic impedance, was unimportant. As will become apparent this is not entirely true, though it's not too wide of the mark.

How well did the G5RV achieve this impedance transformation in practice and, as a result, how well did it perform on the other bands? Anyone who has used a G5RV on 40m without any additional impedance matching (ATU, ASTU or whatever) at the transmitter will have realised that the SWR is a lot higher than modern solid-state transmitters will tolerate. This causes the protection circuit to come into play and the output power will be reduced in order to protect the RF power transistors. It turns out in reality that this state of affairs will exist on all bands except 20m and the SWR on the 72-ohm line can easily exceed 10-to-1 on some of them.

Why then did Louis Varney describe his antenna as a multiband device? One must remember that when he designed and used the G5RV very successfully without any additional impedance matching he was using a transmitter with a valve in the PA and probably a pi-coupler at the output that would've coped easily with that degree of mismatch. Modern, solid-state, transmitters are very different.

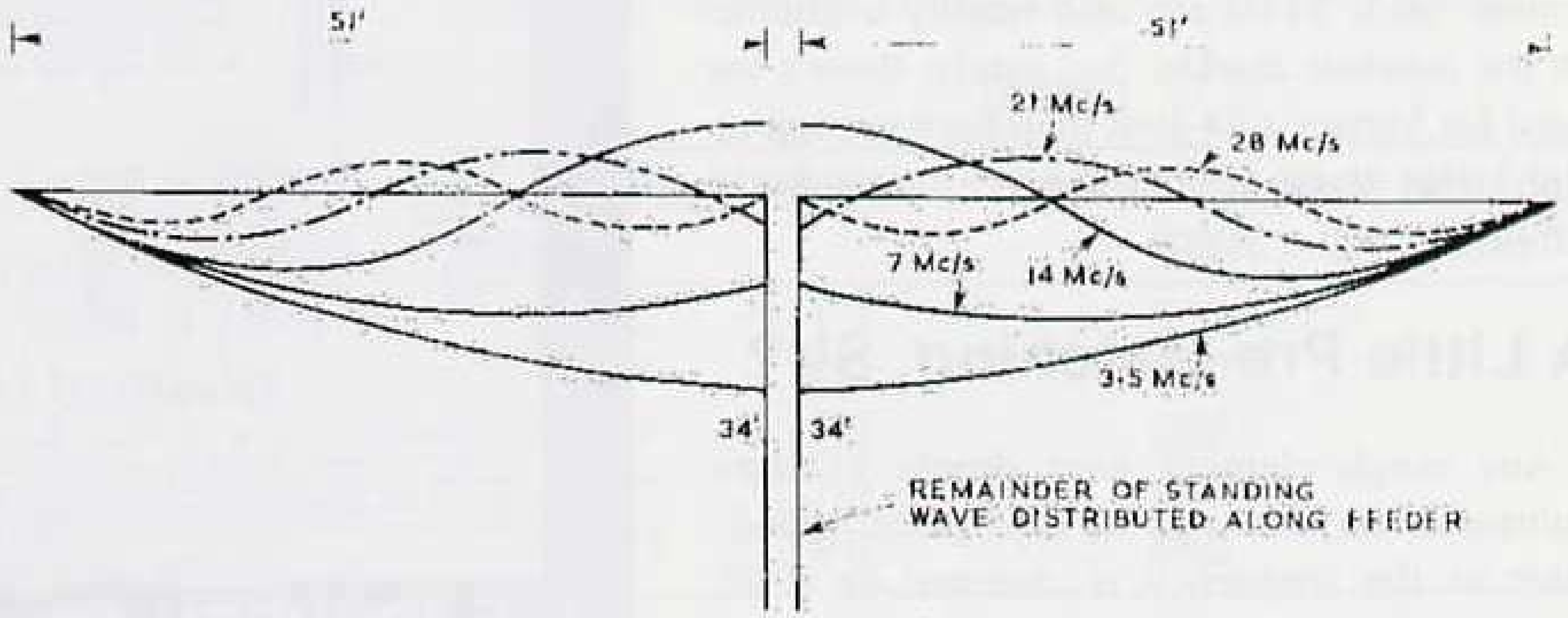


Fig.2. Standing waves of current along the G5RV as shown in that original 1958 article

Not A Multiband Antenna!

If the criterion of multiband performance is an SWR of less than 2-to-1 on more than one amateur band then Varney's G5RV fails to measure up to it. However, as will soon become clear, it contained the germ of a very good idea and with only some minor changes it can be made to function as a very effective multiband antenna – without the need for an ATU – on five of the eight HF amateur bands amongst which are some of the WARC allocations as well.

When he first described his antenna in 1958 Varney used a diagram (see **Fig.2**) that showed the distribution of the current standing waves along the antenna on each amateur band. As is well known, it's quite possible from such information to state whether the impedance at the feed point is high or low. Its actual value, however, is not as readily apparent. But for purposes of designing a method of feeding the antenna this is usually sufficient. Varney readily appreciated this and so he introduced his special 34-foot matching section to take care of those impedance changes. In essence, therefore, the 34-foot line behaved as an automatic ATU! That was a novel idea that few seemed to have cottoned onto before. Where his original account is somewhat misleading is his explanation of how the impedance matching actually worked.

When used on 80m, where the antenna is somewhat short, the 1958 article stated that the "electrical centre of the aerial commences at about 15ft. down the centre stub (in other words, the middle 30ft. of the dipole is folded up)". This is certainly an interesting way of looking at the behaviour of the antenna and its 34-foot stub but to suggest that the antenna actually starts life some way down the stub is stretching credibility for the simple reason that antennas are intended to radiate while transmission lines do not. Though they're closely related they are separate entities and must be treated as such.

What actually happens is that the 102-foot antenna, being less than a half wavelength on 80m, is non-resonant. Therefore, a standing wave appears on that 34-foot line due, simply, to the mismatch between its impedance and that at the antenna's terminals. The purpose of the 34 feet of transmission line is to transform whatever impedance appears at the antenna to some acceptable value that'll match, approximately, to the 72-ohm line that follows it, and to do so on all the other bands as well. That's a tall order, but in view of the harmonic relationship between all the HF amateur bands in 1946, and because of the magic of quarter-wave and half-wave transmission lines, it was just feasible that the G5RV might have achieved true multiband status.

In practice, however, things are not quite as simple as that because the antenna's driving point impedance does not cycle from one resonance condition to the next in such a simple harmonic way. Whereas the second resonance should ideally occur at twice the frequency of the fundamental, the third at three times and so on, what actually happens in typical thin wire antennas is that the sequence is more compressed with the second resonance actually occurring at about 1·9 times the fundamental; the third at about 2·96 times higher; the fourth at just 3·85 times and so on. By contrast, the quarter - and half-wave transmission line transformers operate at simple multiples of a quarter, a half, three-quarters and so on with the result that the two systems, when interconnected, rapidly fall out of step with each other and the ideal transformation is lost. But a solution is evident as long as we have some way of analysing what is happening within this fairly complex system.

But before coming to that it's interesting to note what happened when the first all solid-state transmitters appeared on the amateur market in the late 1970s. Since transistors will not tolerate anything like the same degree of mismatch as a valve or tube, steps had to be taken to reduce the SWR as seen by the transmitter to below some limiting value, usually 1·5 or even 1·3-to-1. Louis Varney was clearly aware of that problem because, in 1984, he revisited his famous antenna design and stated in an article published in *RadCom* that "Although the impedance match for 75-ohm twin lead or 80-ohm coaxial cable at the base of the matching section is good on 14MHz, and even the use of 50-ohm coaxial cable results in only about a 1·8:1 SWR on this band, the use of a suitable matching network is necessary on all the other HF bands"[4].

An immediate question now arises: why use a G5RV at all if an ATU is so necessary to achieve a good match and especially if almost any antenna can be matched on any frequency with a versatile ATU? This is exactly what the engineers designing equipment for the military were doing by means of very fast, automatic, ATUs that would match the proverbial piece of wet string to 50 ohms and on any frequency too. And nowadays, of course, such ATUs are also readily available on the amateur market. So, surely, there's no need for Varney's 34-foot matching section or stub? But there is and the reason is quite subtle.

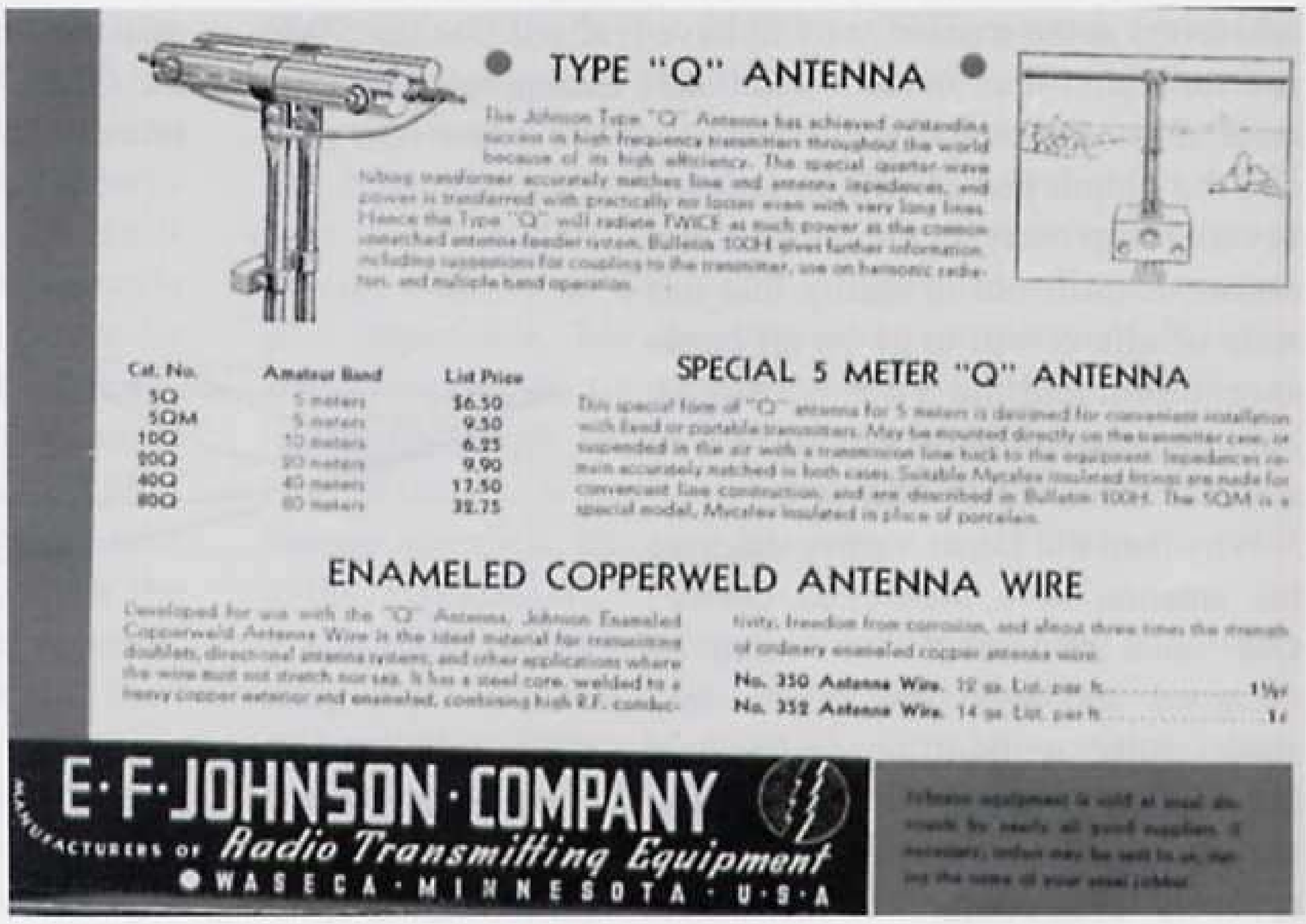
A Little Pre-Matching, Sir?

Any single-element wire dipole exhibits enormous variations in its feed point impedance as the frequency is changed or if its length is altered at a fixed frequency of operation. This is a natural consequence of the voltage and current distributions along the wire. Taken together, their changing ratio yields a rapidly varying impedance and this means that simple wire antennas have fairly narrow impedance bandwidths – measured in hundreds of kHz at most – so the SWR will change quite rapidly as the frequency is varied through resonance. To broaden the bandwidth requires either that the antenna conductor be made considerably thicker or the antenna must be fed with a transmission line having a characteristic impedance that approximates the geometric mean of the antenna's impedance variation.

This sounds complicated but Varney clearly appreciated its significance when he designed his antenna. The result was his 34-foot of high impedance line which functioned as a pre-matching device whose purpose was to decrease the range of impedance variation at its other end and, by so doing, it also flattened the SWR on the 72 ohm twin line to the transmitter. If an ATU were used at the transmitter that pre-matching process would considerably ease its task. For that reason the extra piece of transmission line was also known as a line-flattener in the days of yore.

What is interesting about all this is that there is very little new under the Sun as long as one knows where to start looking for it!

An antenna bearing some similarity to the G5RV appeared in the *ARRL Radio Amateur's Handbook* during the 1930s and '40s. It was known as the Q Antenna, and was developed by the E.F. Johnson Company. Its claim to fame is spelt out in their 1936 advertisement, see below, and amongst its many attributes, so we're led to believe, was the fact that it was suitable for "multiple band operation". The ARRL's own description is somewhat less breathless than the advertising and from it we learn that the secret of its performance is "the use of a quarter wave line (the 'Q-section') of special characteristics which acts as a matching transformer". However, careful reading of the *Handbook*[5] indicates that the centre-fed antenna must always be operated in its low impedance mode, in other words when it is an odd multiple of a half wavelength long or when the feed point is an odd number of quarter wavelengths from the end. This ensures that the antenna's impedance is always relatively low (typically 70 to 150 ohms) over a number of harmonically related bands.



● TYPE "Q" ANTENNA ●

SPECIAL 5 METER "Q" ANTENNA

Cat. No.	Amateur Band	List Price
5Q	5 meters	$6.50
5QM	5 meters	9.50
10Q	10 meters	6.25
20Q	20 meters	9.90
40Q	40 meters	17.50
80Q	80 meters	32.75

ENAMELED COPPERWELD ANTENNA WIRE

No. 350 Antenna Wire.

No. 352 Antenna Wire.

E·F·JOHNSON·COMPANY

MANUFACTURERS OF *Radio Transmitting Equipment*

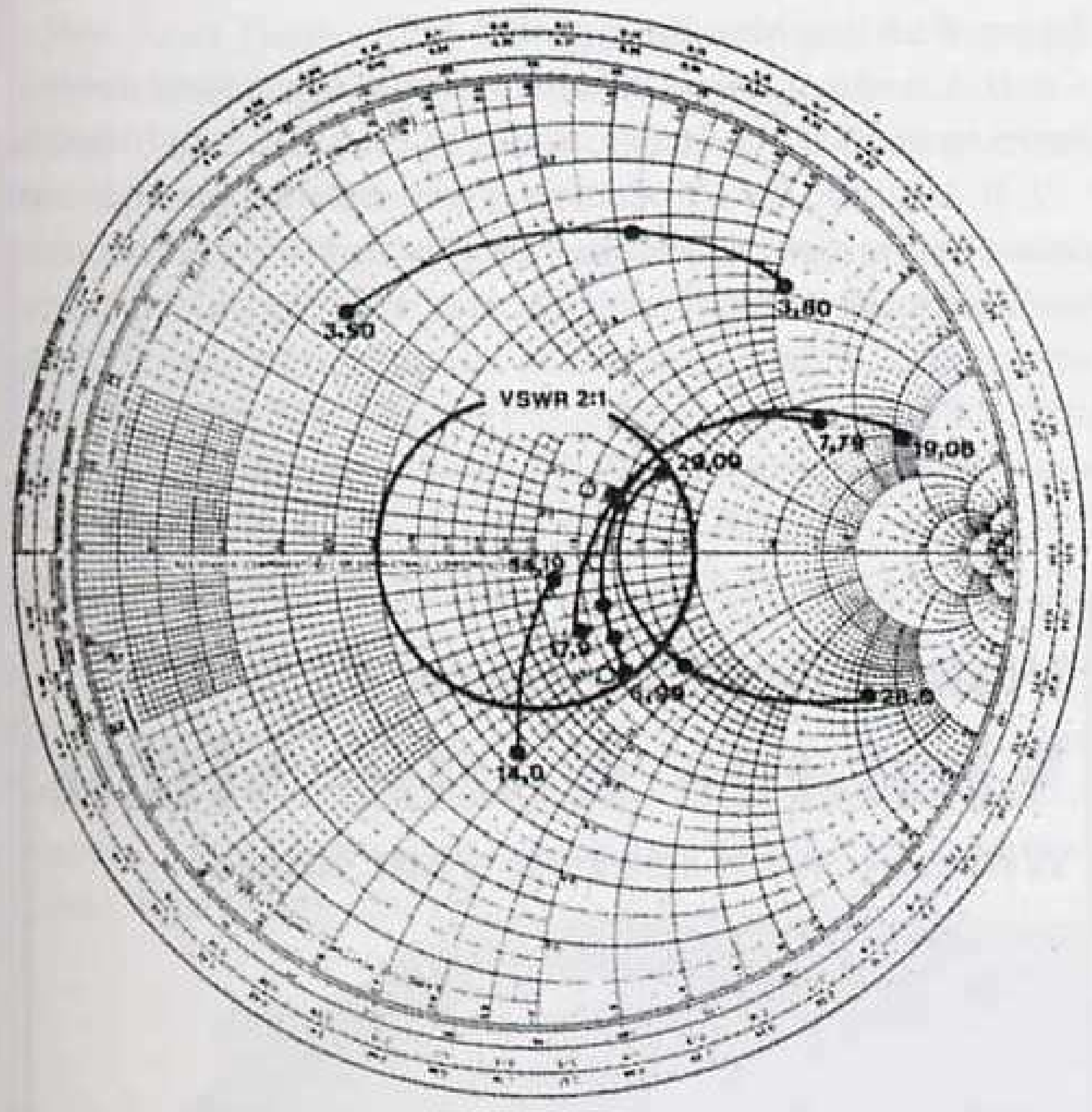
● WASECA · MINNESOTA · U·S·A

The 'Q Antenna' as advertised in the 1936 ARRL Handbook

The 'Q' matching section is solidly built using half-inch diameter copper tubing spaced 1·6 inches apart to yield a characteristic impedance of about 212 ohms. The special property of the quarter-wave transformer will then convert the antenna's impedance into values between 300 and 600 ohms thus allowing very long lengths of low loss, air-spaced transmission line to be used for connection to the transmitter. The 'Q' antenna was indeed a multi-band antenna as long as those bands were odd multiples of one another.

Collins Multi-Band Antenna

Also around that time the famous Collins Radio Co. developed what became known as the Collins Multi-Band Antenna and it was described as follows: "This antenna is suitable for operation on several bands due to the use of a compromise system of RF feeders"[6]. Why they were deemed to be a compromise is not clear. On closer inspection it is obvious that the antenna looked rather more like Varney's other version of the G5RV and existed in a variety of combinations of antenna and transmission line lengths. One in particular was very similar to the G5RV in that it had a 103-foot dipole fed via 82·5 feet of 300-ohm feeder, chosen to be the geometric mean between 75 and 1200 ohms, the "centre impedance of the antenna when used at harmonic frequencies". The rationale behind that special length of feed line was to produce a resistive match to the transmitter on as many amateur bands as possible. It achieved this on the 80, 40 and 20m bands while being quite able to cope with the high SWR that existed because of the inherently low loss in a feed line constructed of 0·25 inch diameter copper tubes spaced 1·5 inches apart. Its weight, though, over that length would have been another matter entirely!



The Smith Chart showing the measured performance of the ZS6BKW when erected at a height of 12m, taken from Ref 9

Varney never mentioned either the 'Q' or Collins antennas, but in view of their popularity before the war he may well have come across them.

We Can Do Better: Enter The 'ZS6BKW'

During the early 1980s, while living in South Africa, I became fascinated by Louis Varney's aerial and could see much mileage in analysing it mathematically by using the transmission line theory that clearly underpinned its behaviour. That led naturally to the use of another wonderful device from the world of transmission lines – the Smith Chart – and from there on it would have been very difficult to keep the computer at bay for too long, and so it too played a major part in what followed. All this analysis, simulation and much measurement, too, eventually saw the light of day in a number of articles starting with a brief summary in Pat Hawker's *Technical Topics* column in *RadCom* in 1982[7]. More details followed in a long article in *Radcom* in 1985[8] and then, in their full-blown mathematical form in[9], two years later. The outcome of all this was the ZS6BKW multi-band dipole.

The ZS6BKW will operate with a standing wave ratio of less than 2-to-1 – without an additional ATU – on five of the eight HF bands, including two of the WARC bands that are not harmonically related to the others. The configuration is exactly the same as the G5RV, only the lengths of the dipole or flat-top, which I called L1, and that of the matching section (L2) are different. The analysis also showed that the characteristic impedance (Z2) of the matching section is not too critical, but that optimum results are obtained for lines with Z2 between 300 and 400 ohms. The ZS6BKW is fed with 50-ohm coax rather than the 72-ohm line of the G5RV for the reason that all modern transceivers are intended to operate into 50-ohm coaxial cable. Since this necessitates connecting balanced and unbalanced lines together the question of a balun immediately arises.

Numerous tests showed that no measurable difference in feedpoint impedance could be detected with or without a balun. However, for the fastidious, a choke balun consisting of a number of ferrite beads might be used at the junction between the two transmission lines, or just 6 to 8 turns wound in the coax at that point would also suffice.

The details of the ZS6BKW are as follows: L1 = 28·5m (93·5 feet); L2 = 13·6m (44·6 feet) and Z2 = 400 ohms. With these dimensions the antenna, when erected 12m above the ground, produced the results shown in the table below.

Table 1

Centre Freq (MHz)	SWR	Bandwidth (kHz) between SWR = 2:1 limits
7·09	1·3	350
14·14	1·3	250
17·97	1·2	360
24·90	1·4	280
28·80	1·5	380

In practice, the velocity factor of L2 will depend upon its method of construction. If it's air-spaced a value of about 0·9 should be used whereas 0·85 is more typical of the commercial type with solid dielectric insulation. L2 should be multiplied by the appropriate figure, which yields 12·2m or 11·6m, respectively. Table 1 shows the measured performance of the ZS6BKW at a height of 12m when plotted on the Smith Chart. If 300-ohm line is preferred for Z2 then the lengths of L1 and L2 change only slightly, becoming 29·1m and 11·2m if one uses the solid dielectric line with a velocity factor of 0·85. The optimum frequencies will shift slightly but the SWR and bandwidths remain essentially the same.

Half-Size Or Twice-Size?

There is nothing in the make-up of the G5RV that says it can't be scaled. In other words if its dimensions were halved all its useable frequencies would double. Likewise, if those dimensions were doubled the lowest frequency on which the antenna would exhibit its useful features would halve. The half-size version is especially popular in the UK where the space to put up antennas is often limited. One frequently hears of it being used on the 40m band with much success, but just as the 80m band was not one of the frequencies that would produce a good match to the 72-ohm line in the standard version, so 40m falls into that category with the half-size version. With an ATU, of course, both can be made to work on almost any band. The idea of strapping the feeder together to operate on still lower frequencies is fine but then the antenna becomes a completely different beast altogether and it's certainly not the G5RV or anything related to it.

In Conclusion

Louis Varney designed his famous antenna almost sixty years ago as he was about to leave wartime service in the British Army, and it is still going strong today. However, there was room for improvement and an exercise by the author to do just that commenced almost 25 years ago, aided and abetted by the power of modern computing, the mathematical theory of transmission lines and the remarkable chart of one Phillip H. Smith, a member of the Technical Staff of the famous Bell Telephone Laboratories in New York. Who? Well, as they always say, that is another story entirely. ***RB***

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