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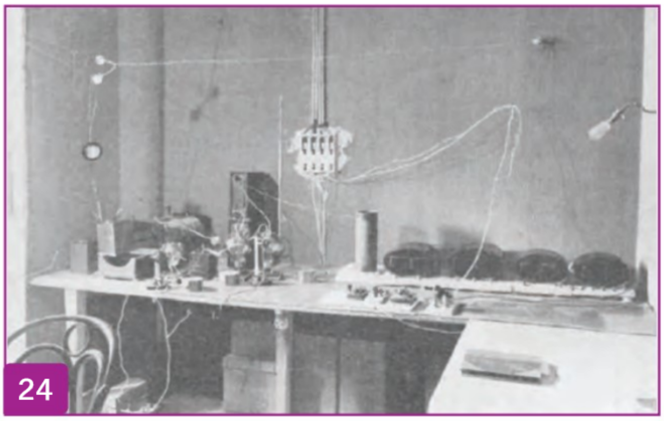
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Cover image: Season's Greetings from the RSGB
Design by Kevin Williams, M6CYB

RadCom THE RADIO SOCIETY OF GREAT BRITAIN'S MEMBERS' MAGAZINE
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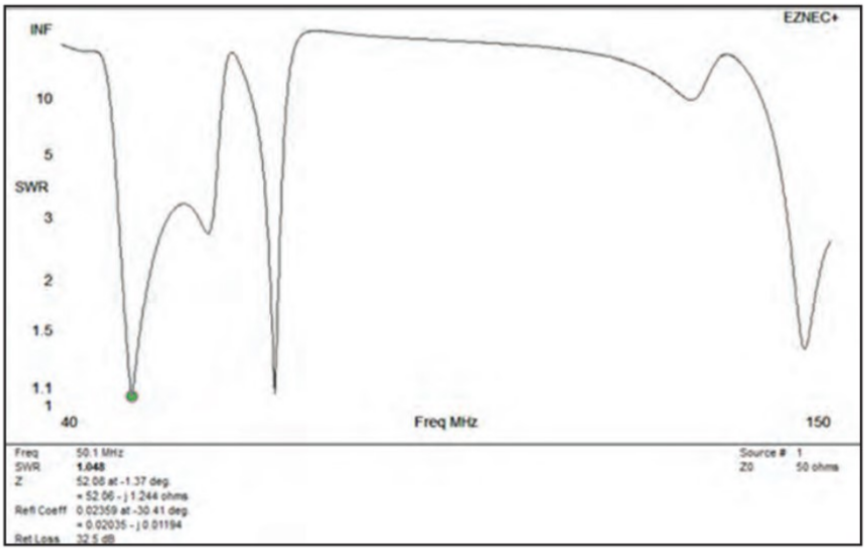
Errata for the RadCom article, November 2023, pp 40-43 'A small flexi beam for the 6, 4, and 2m bands' by John Hill, G8HUY

I fear that I provided the wrong dimensions for two of the elements of the antenna given in Table 1 of my article. My sincere apologies for this. The correct dimensions are given in the table to the right, and the EZNEC VSWR plot corresponding to an antenna with these dimensions is shown above that (my thanks to Neil, G4DBN for making the plot).
John, G8HUY



Element	Length (mm)	Diameter (mm)	Spacing (mm)	Notes
6m reflector	3080	10	0	Element spacing origin
4m reflector	2234	10	260	
2m reflector	1040	10	552.6	Opposite side of boom
6m driven	2770	10	789	
4m driven	2004	10	675	
2m driven	972	10	789	Opposite side of boom

QSL Matters

Following last month's column, concerning the reluctance of some clubs and individuals to collect their incoming cards for the price of a stamp, something happened to highlight this issue even more.

QSL sub manager Roy, M0RRV volunteer for, M1, M3, M5, M6 and M7 sub-groups retired unexpectedly for personal reasons. Roy has been a stalwart of the bureau for many years, covering the largest number of sub-groups of any volunteer. Through his emails and his website he has helped countless members, both new and old, and supported the bureau. We'll miss his help and support, especially at national shows.

As his resignation coincided with the latest despatch round to members, we collected his stock of uncollected cards, envelopes and information, in person. As expected, all was in 'apple-pie' order. The bureau currently doesn't have the capacity to take on the additional work of sorting such a large batch to individual callsigns.

Halifax and District ARS (HADARS) kindly volunteered to step in for a one-time emergency experience, for which the bureau is extremely grateful.

Over two evenings, members played 'patience' sorting and banding each of the five sub-groups down to individual callsigns. They separated those with and without collection envelopes. They re-visited those in the 90-day recycling batch to see if envelopes were now available before disposal.

The second sorting evening entitled 'envelope stuffing for beginners' raised quite a few eyebrows.

Here are some of their comments, heard more than once…

'Never realised how much work goes into this.'
'Why are so many interesting/ lovely cards going to waste?'
'Wish I'd worked this one.'
'Didn't know cards could be so interesting'

More than alarming was the discovery that around 60% of some 230+ envelopes posted had at least one First Class stamp on them. Many were First Large. The RSGB states that Second Class Standard is what is required and definitely the best choice.

Since 2010, the RSGB has operated a 'send-all-and-any' policy with no waiting, for many reasons. It speeds up throughput and cut delays for replies. With First Class stamps now costing £1.25, and Second Class Standard available for just 75p, it is clearly much better value and a 'no-brainer'.

Using the wrong stamp may be why many clubs and members elected not to collect. If it was, please send new envelopes.

What is clear is that very significant numbers are simply not following the guidelines for use of the bureau in any number of other ways. For example, very few placed their callsign and membership number in the top-left corner of a C5 envelope. Others failed to sequentially number envelopes or indicate the last one in the bottom-left corner so as to help identify when they need to send more.

M1, M3, M5, M6 and M7

Good news... several HADARS members found the experience described above both informative and a revelation. So much so that one-member, Ann Eastwood, M7ERT, subsequently volunteered to take on all of the groups. For contact details, see the list of sub-managers on the RSGB website: rsgb.org/main/operating/qsl-bureau
Richard J Constantine, G3UGF

New Products

Microham Arco Smart Antenna Controller

The ARCO is a modern rotator controller designed for reliable operation with virtually any rotator ever made, commercial or home brew. ARCO provides a lot of unique present-day functions not yet available in any other controller. Rotator motion is carefully controlled using auto-adapting, smoothly graduating/decaying speeds, reducing inertial stress and prolonging lifetime of the rotator, antennas and tower.

ARCO is a completely self-contained stand-alone rotator controller not requiring a computer or any external device or power supply for setup and operation, while providing a wide selection of interfaces for remote control when necessary. It features several ways of controlling azimuth or elevation heading using an uncluttered graphical user interface on a 7" touch screen. Azimuth heading is displayed on a great circle map, user centred to the rotator installation location, with four different radius settings, live grey line projection, several colouring options and automatic day/night colour schemes.

This product is available from hamradio.co.uk for £799.99

Rez Antenna Ranger 80 portable HF antenna kit

Get on the air fast with the Ranger 80™ HF antenna system. The Ranger 80™ is a rugged, base-loaded vertical antenna, designed for portable, rapid deployment.

The Ranger 80 will handle up to 200W SSB and 100W digital (50% duty cycle).

The included 9.3ft (2.8m) military whip sets up in seconds and collapses to a compact size for transport. When you're done making QSOs, the entire system packs neatly into the included backpack.

What's in the box?

Ranger 80 tuning coil base with radial puck, heavy-duty military whip, ground spike, 4 x 33' radials with silicone wire ties, military-style daypack
This product is available from moonrakeronline.com for £599.95.

Gerald Marcuse, G2NM Pioneer of Radio Book

By David Fry, G4JSZ

Gerald Marcuse, G2NM, enjoyed similar fame to Marconi during the early years of radio. His achievements are set out in detail: he was the first to contact South America, California, Australia and New Zealand by radio, was instrumental in the foundation of amateur radio organisations, making contact with the Hamilton-Rice expedition and assisting both the Police and Ambulance services to set up mobile communications.

The book (298 pages) is a full biography that records his Empire Broadcasts, his battles with the Post Office and the BBC, which had not accepted the appropriate frequencies, and a transcription of his experiences from an original tape along with details of his personal scrapbook and a record of his letters. He was President of the RSGB in 1929, assisting in the formation of the Civilian Wireless Reserve in 1937, and was elected an honorary Member of the RSGB in 1946.

The book is sold worldwide via Amazon in black and white, or in Colour via: marcuseg2nm@protonmail.com for £16. Copies of the original files and photos are available on a USB stick.

403A Noise Cancelling Headset NC-1 BT

The very comfortable NC-1 Bluetooth headset from 403A offers ideal suppression of external noise in any situation. Thus, thanks to ANC (active noise cancelling), you can perfectly concentrate on quiet and weak signals, even in noisy environments.

The NC-1 can also be used as a pure headset with excellent audio reproduction. For this purpose, the flexible microphone boom with electret microphone is detachable.

The operation of the headset can be wireless via Bluetooth, as well as wired. When operating the headset with a cable, the volume can be controlled via in-line remote control, and the microphone can be switched on and off.

The materials used have been carefully selected to ensure a high level of wearing comfort even over a period of several hours. The ear cups are movable and ensure an ideal fit to the head.

The integrated rechargeable battery is charged via a USB-C port (cable included).

Buttons on the ear cup can be used to adjust the volume and ANC, as well as turn the device on and off. An LED provides information about the respective operating status.

The headset, and all included accessories, can easily be stored in the included, sturdy zippered pouch.

Technical data

Product Name	NC-1
Type Of Microphone (Electr.)	Electret (Condenser)
Color	Black
Length Of Feedline [m]	2
Brand	403A
BT Version	5.0
Weight	320g

This product is available from hamradio.co.uk for £269.99

Antennas

Now that the 10m band, and the other higher HF bands, are beginning to liven up again, my attention has been drawn to thinking about antenna designs with small footprints which could be set up quickly.

My choice of available portable locations is also (unfortunately) popular with other members of the public, especially ramblers and walkers, effectively ruling out the more space-hungry antenna options such as dipoles or vertical antennas requiring radial systems, be they on the ground or elevated. As usual, my antenna of choice in this situation is a half-wave vertical antenna, as this requires no radial system. I have had great success with half-wave antennas in the past, having made a homebrew flowerpot design entirely out of RG-58 coaxial cable, and having used an efficient homebrew 56:1 transformer (impedance ratio) made by Colin, MM0OPX, a friend of mine and fellow antenna obsessive, which has fed a vertical half-wave of wire for a variety of the higher bands. Both options worked well, allowing me to haul in a lot of DX contacts when conditions allowed.

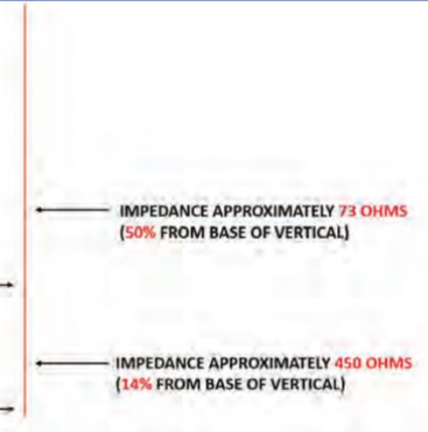


FIGURE 1: The typical range of impedances found at varying points of a half-wave length of wire.

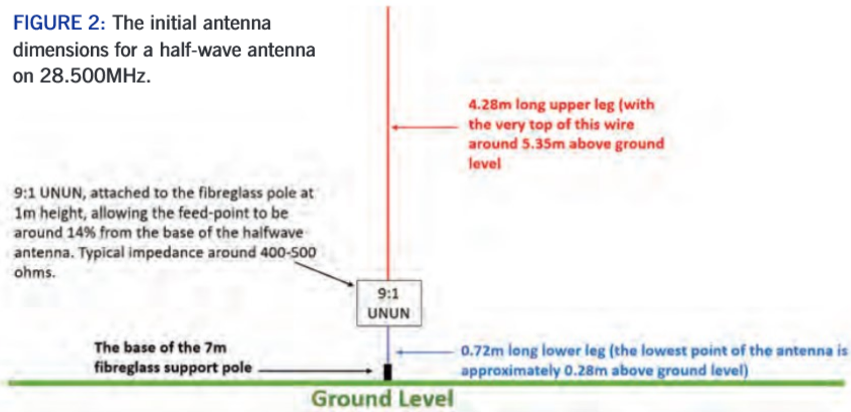


FIGURE 2: The initial antenna dimensions for a half-wave antenna on 28.500MHz.

Using a 9:1 UNUN

As ever, my antenna curiosity has got the better of me and I have started to consider an option for a 10m half-wave vertical which would allow the antenna to be fed as an off-centre-fed vertical half-wave dipole. I already had in my possession a commercial 9:1 UNUN, which I used much earlier in my licensed existence to end-feed vertical antennas. These are often used to provide a multi-band option by feeding the end of a long, often non-resonant, wire and this requires the deployment of a counterpoise or radial system, as well as a tuner to match the antenna to a variety of bands.

Typically, advice circulating around the use of a 9:1 UNUN advises against the length of the radiator wire being a quarter or half-wavelength in length (with the resulting low or high impedance respectively presented), on a given frequency, in order to provide a better opportunity for the UNUN to help achieve a decent match for the 50Ω coaxial cable used to feed the antenna. Suggested non-resonant lengths include 8.8m (29ft) to cover 40m to 10m, and 16.1m (53ft) to cover 80m to 10m. An ATU is often a prerequisite.

However, in this case, my intention is to use the 9:1 UNUN to help achieve a good VSWR match for a mono-band half-wave antenna for 10m. This opportunity arises when we consider the likely impedance found at various stages of a half-wavelength of wire. **Figure 1** shows the range of impedances typically found at different points along the half-wave vertical antenna. Height above ground is also an influencing factor, but in terms of ball-park figures, a vertical half-wave antenna, fed around a metre above ground, will have the impedance figures in the region of those highlighted. Significantly, at around 12-16% from the lower end of the antenna, we see a typical impedance somewhere around 350Ω to 550Ω. The likely transformation of the feed-point impedance is somewhere around a factor of 9 when using a 9:1 UNUN, so this should provide an opportunity for a good match to 50Ω coaxial cable.

The antenna configuration

Using the formula of 143/f metres (f is the frequency in MHz) for our 10m half-wave (at 28.500MHz), the calculation gives the overall length as 5.018m. As the antenna was to be fed at 14% from the base, an approximate ratio of 6 (longer wire): 1 (shorter wire) was to be employed for their lengths. Therefore, the position of the 9:1 UNUN was to allow for 72cm of wire to be below it, connected to the ground terminal of the UNUN, and 4.28m of wire to run above the 9:1 UNUN connected to its radiator terminal. **Figure 2** shows these dimensions, with the antenna supported by a guyed 7m fibreglass pole, and with the 9:1 UNUN positioned at the top of the lowest section of the pole, negating the possibility of its weight causing a collapse of the pole's sections and thus avoiding any damage to the thin wall of the fibreglass. This meant that the UNUN was approximately a metre above ground and the base of the lower shorter wire was 28cm above ground.

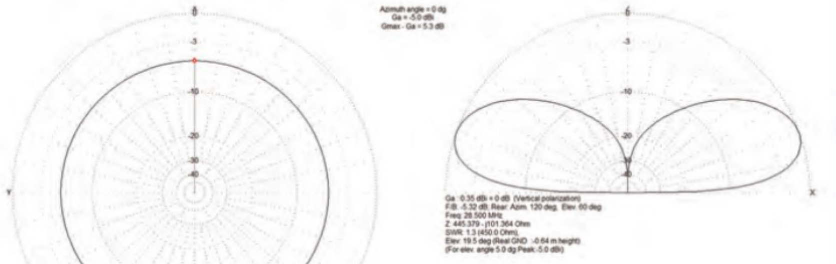


FIGURE 3: Modelled far-field and azimuth patterns, showing useful low-angle gain on 28.500MHz.

FIGURE 4: The 9:1 UNUN and elements.

FIGURE 5: Upper element and guyed pole.

Modelling

Using MMANA-GAL software, the antenna was modelled using the above dimensions. **Figure 3** reveals the approximate far-field and azimuth patterns we could expect from a half-wave vertical antenna, using this off-centre-fed design, at a low height above ground. The gain shown on the left-hand side of the diagram is -5.0dBi at a low take-off angle of 5° (useful for DX). This mirrors what we should also expect from a quarter-wave ground-mounted vertical antenna, with a ground radial system for example. Setting the VSWR parameter at 450Ω (a ball-park figure), modelling predicts a VSWR in the region of 1.3:1 using these dimensions.

Erecting and tuning the antenna

I erected and guyed the 7-metre-long fibreglass pole, and then attached the UNUN to the top of the lowest section of the pole, which does not telescope (see **Figures 4** and **5**). The antenna was fed with 90cm of RG-58 coaxial cable, which in turn connected into a commercially-acquired line isolator (consisting of 8 turns of mini-8 coaxial cable around an FT 240-31 core), acting as a feed-line choke. When operating, this was followed by 7m of RG-58 into the transceiver. To measure VSWR, the antenna analyser was fed with the 90cm of RG-58, and was attached to the radio side of the choke using a double PL-259. Care was taken to ensure that the feed line was positioned away from the lower shorter leg of the dipole (an angle of approximately 45° was achieved using a small garden chair as a support), to minimise the coupling to the antenna, which may have skewed the VSWR reading.

The initial VSWR reading proved to be quite interesting as the antenna produced a very handy VSWR dip of 1.3:1 at 26.01MHz (**Figure 6**), with a sub-2:1 VSWR bandwidth from 24.3MHz to 27.7MHz. At 28.500MHz the VSWR was 3.2:1. Clearly, we had an antenna which was too long. There followed a careful process of pruning the antenna length, taking care to ensure that pruning maintained the 6:1 ratio between the longer and shorter wires.

Eventually, following two rounds of pruning and checking, I arrived at a useful VSWR for 28.500MHz. **Figure 7** shows a VSWR dip of 1.4:1 at 28.500MHz, with some reactance, but we nevertheless had a perfectly-workable match to 50Ω. The 2:1 VSWR curve was similar, if slightly narrower, than our initial measurement, being between 27.0MHz to 29.8MHz. The final lengths for both legs of our off-centre-fed vertical dipole are shown in **Figure 8**. These show a reduction of 7.4% from the originally-calculated half-wave length.

On-air performance

As it was a Sunday morning, there was a reasonable chance of there being some activity on 10m and yes, before you say it, there was indeed a contest. In this instance, the Scandinavian SSB contest was underway. Upon switching on my IC-7300, I was pleased to see a very busy band scope on 10m and decided to hunt and pounce on stations, starting from 28.300MHz and

Table 1: Half-wave antenna dimensions after a 7.4% reduction in length.

Band (m)	Centre frequency (MHz)	Upper wire (m)	Lower wire
20m	14.200	7.98	1.33
17m	18.130	6.25	1.04
15m	21.250	5.33	0.89
12m	24.950	4.54	0.76
10m	28.500	3.98	0.67

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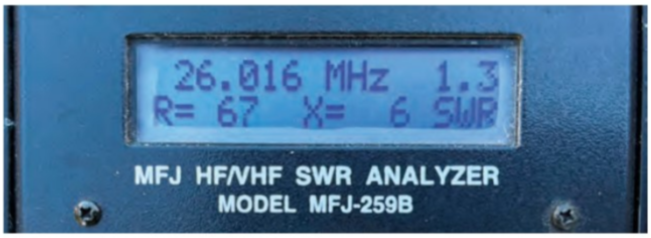

FIGURE 6: VSWR reading before any adjustments, showing the best VSWR below 10m.

FIGURE 7: VSWR reading for 10m after shortening the antenna.

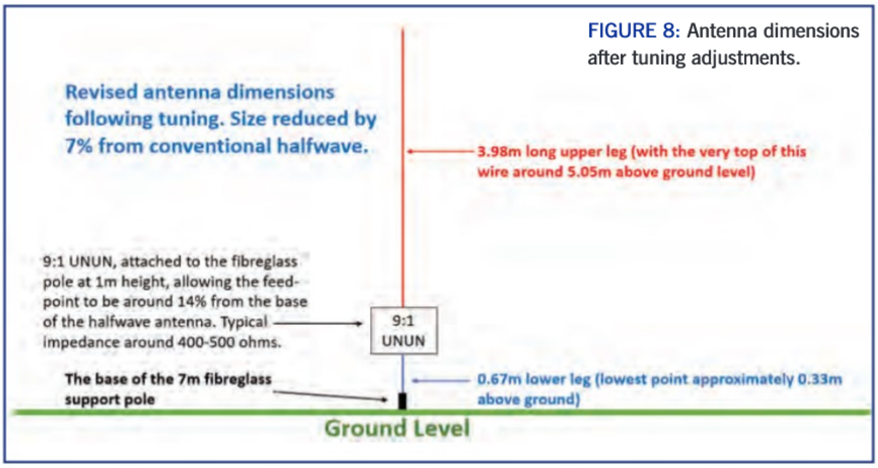

FIGURE 8: Antenna dimensions after tuning adjustments.

going up to 28.570MHz. As expected, the stations heard were indeed contesters. The following 11 contacts were logged, all within a time period of 13 minutes: OH9JS, TF3T, OH8WR, OH7K, OG5B, SB3W, LC5C, OH6RE, OI3V, SM2S and OH7KBF.

Being a contest, everyone was 5 and 9 but received signal strengths were very good (many S9 or above) and this was promising. Many of the contest stations I worked no doubt had some very good antenna systems, but it was pleasing to note that all bar one of these contacts were established on the first time of asking. The antenna therefore fulfilled its brief to be tuneable on the frequency range desired, and it received well and (at least in this instance) transmitted quite well also.

Using this design on other bands

Bearing in mind the important caveat that each installation is affected by its unique environment, especially in busy semi-urban settings such as mine, if we extrapolate the lengths used in this example to other bands, we arrive at the approximate lengths shown in **Table 1**, where dimensions are given after a 7.4% reduction from the usual half-wave formula of 143/f m (f in MHz). Best advice is to cut the lengths without the reduction and then trim. The thing to remember, of course, is to trim the wires using the same approximate ratio of 6:1, thus maintaining a similar feed-point impedance for the 9:1 UNUN to transform to near 50Ω.

Further design possibilities

The temptation (at least for me!) is to see if it is possible to produce a dual-band version of this antenna, eg covering the 10m and 15m bands. Centre-fed dipoles, for example, often use parallel wires both horizontally and vertically to allow use on more than one band (the so-called fan dipole). However, a very real consideration is that a centre-fed dipole, cut for a specific band, is fed at the voltage minimum/current maximum part of the antenna. Therefore, in a traditional centre-fed fan dipole, the non-resonant lengths of wire present a higher impedance and the current flows (mostly) in the appropriate dipole (with lower impedance) cut for the band of operation. If we were to try this fan arrangement with an end-fed half-wave dipole for example, we would have the antenna fed at the voltage maximum/current minimum point (with a very high impedance measuring around 2000Ω to 4,000Ω). This means that the non-resonant half-wave would probably produce a lower impedance, leading to that half-wave taking the current rather than the half-wave we wish to use, and resulting in a high VSWR.

It would be interesting to see whether this arrangement might work with this off-centre-fed design, so that we have a fan off-centre-fed dipole. Whilst the feed-point impedance will be much lower than the end-fed half-wave arrangement, it should still be around 400Ω to 500Ω. Additionally, the feed-point itself is positioned at a point which is much nearer to the voltage maximum, rather than the current maximum, point of the antenna. I have a suspicion that this may be a step too far, but might be worth a half-hour of tinkering nonetheless!

To convert this type of antenna into a multi-band antenna, an option would be to lengthen it slightly to somewhere near the full 7m available from the lightweight fibreglass pole used in this instance, keeping close to the 6:1 ratio between the longer and smaller wires. This would give an antenna of approximately 6.8m in total length, with a longer top wire of 5.83m and a shorter lower wire of 0.97m. This provides useful low-angle gain, using 5° take-off as our benchmark, on 15m, 12m and 10m. As it is only fractionally longer than a half-wave on 15m, a match to 50Ω via the 9:1 UNUN should be straightforward. 10m and 12m will see a much higher VSWR, and positioning a tuner as close as possible to the feed-point would be advantageous to minimise feed-line loss. By using the same 90cm of RG-58 that was used to feed the 10m half-wave version, which we then connect to a remotely-positioned ATU, we would restrict feed-line losses on all the proposed bands (20-10m) to under 1dB.

At this longer length, the antenna is just short of being a 5/8th wave on 12m and between a 5/8th and ¾ wave on 10m. On 17m, this arrangement would be just shy of a half-wave in length and would still be a useful performer. Gain on 20m, at 5° take-off angle is reduced to -6.8dBi according to modelling, but this is not much of a deal-breaker, even when considering that our off-centre-fed dipole is now just over a 1/3rd of a wavelength long on that band.

Finally, whether we use this off-centre-fed arrangement as a mono-band or multi-band option, we do have an antenna which provides a relatively-low visual impact, and negates the need to run coaxial cable or window-line feeder from the much-higher centre point of a vertical dipole/doublet. This can be of great benefit practically when seeking to work portable, or to keep the visual impact to a minimum for family and neighbours.

Overall, as a mono-band or a multi-band antenna, this could be a useful antenna and maybe another option if you possess, perhaps somewhere deep in your shack drawers or cupboard, that forgotten 9:1 UNUN.

Review

Chameleon CHA TD-Lite antenna

The CHA TD-Lite from Chameleon (Figure 1) is an HF dipole that covers all the amateur bands from 1.8-54MHz using your rig's built-in antenna tuner.

Established in 2008, Chameleon is an American company based in Nevada, that specialises in tactical antennas for mobile, portable, base station, marine, EMCOMM, MARS/CAP, ARES, SATERN, RACES, first responders, emergency preparedness, Skywarn, military and government communications. The TD stands for 'tactical dipole' and echoes Chameleon's military background. In fact, the antenna comes with a military-style canvas pouch in which it can be stored (**Figure 2**).

The antenna is designed for portable operation, but is equally at home in a base station. The antenna is 36.58m (120ft) long in total (two dipole legs of 18.29m (60ft, see **Figure 3**). At its centre is the feed point/transformer to which you connect your coax. The entire kit consists of one EMCOMM II transformer (feedpoint), two 18.29m (60ft) copper-clad Kevlar PTFE (Teflon) wires, two tent stakes and a bag in which to store it all. The antenna features stainless steel hardware throughout, and can handle 500W on SSB, 250W on CW and 100W on modes with continuous duty cycle (AM/FM/RTTY and all digital modes). The transformer/feed point has two wing-nut screws to connect the dipole legs, and a hook for connecting to your tower or other support.

And that's it. There is nothing to adjust or tune and no switches to change bands.

The instructions state: "The antenna will work successfully supported by trees, masts, the tops of vehicles or any convenient object or structure. The antenna works most effectively when elevated at a reasonable height, but if no support is available it will also radiate (with limited efficiency) when stretched out on the ground. The radiation pattern of the antenna has a significant vertical component at all frequencies, making it ideal for NVIS (near vertical incidence skywave) applications."

But does it work and how does it perform?

I mounted the feed point at about 7.6m (25ft) and anchored the ends of the dipole to a tree and a fence. The transformer (**Figure 4**) at

FIGURE 1: The Chameleon CHA TD-Lite antenna.

FIGURE 2: The military-style canvas pouch.

the centre weighs 0.42kg (just under one pound). This isn't too weighty, but probably too much for a flimsy fibreglass fishing pole. If you have a suitable tree branch over which you could throw a length of cord to haul it up that would be ideal, which is why it makes such a good portable antenna.

It is very unusual to find an antenna that

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steve@infotechcomms.co.uk

FIGURE 3: One of the dipole arms folded for transport, showing the end fixings.

FIGURE 4: The transformer (feedpoint).

can cover all of the amateur bands with a low VSWR. Chameleon have managed this with a matching device or transformer built into the feed point. Take a look at the charts of measured VSWR values and you will see that it does a pretty good job (**Table 1**). It is certainly within the range of most internal ATUs to bring it down to 1:1, but on some bands (14, 21 and 28MHz for example) you could run it without an ATU with no problems. Quite how Chameleon has managed this is unclear, but my guess is that the feed point contains some non-inductive resistive element to get the impedance down to near 50Ω on all bands, and therefore it is important not to exceed the power limits. This technique is used in the tilted terminated folded dipole (T2FD). It does make for a very versatile antenna that you don't have to worry about tuning each time you change band.

Chameleon doesn't mention 5MHz, but I measured 3.0:1 VSWR across the whole band and it pulled in signals quite well. An internal ATU should be able to pull that down to 1:1. While I was at it, I thought I would look at the VSWR on VHF and UHF as well. This ran from 1.7:1 to 2.0:1 from 144MHz to 146MHz and 1.7:1 on 433MHz. I don't suggest you use it as a VHF/UHF antenna, but thought you might like to know the VSWR results for emergency purposes. On Top Band I did hear an inter-G QSO at reasonable strength, and the fact it offers a VSWR of 1.3:1 in a dipole width of just 36.58m (120ft) is very useful.

I used the antenna on everything from 3.5MHz to 28MHz for a few days, and compared it with my 40.2m (132ft) end-fed half-wave antenna (EFHW), which is mounted at about the same height, but between different trees in the garden. On the whole, the Chameleon performed well with signals within an S-point or two of the EFHW antenna. Sometimes signals were stronger on the Chameleon. In other words, it is not the compromise antenna I expected it to be.

A test using 100W CW on 20m and the reverse beacon network, resulted in me being heard in nine countries across Europe with a maximum signal-to-noise ratio (SNR) of 27dB (OH6BG). Doing the same test with my 40m (132ft) EFHW resulted in 10 spots with an average SNR increase of about 6dB, which corresponds quite well with the on-air reception tests. In other words, it is about an S-point down on average compared with my EFHW, but some signals were similar.

Moving to 40m FT8, I had a pleasant morning working around Europe and the UK using 50W. It was the same on 17m FT8, while 15m and 12m FT8 brought in signals from Japan and China. The added bonus is that it works very well on non-amateur frequencies too. I used the Chameleon on medium wave, and also listened to Gander Volmet on 13.270MHz with good results.

If you want to work HF when operating portable, especially on 7MHz and below, the Chameleon would be a good buy. It also suits home-based use where you might want one antenna to cover all bands, including short-wave listening. The Chameleon CHA TD-Lite antenna costs £149.99 including VAT. My thanks to Martin Lynch and Sons for the loan of the antenna.

**Table 1:
Chameleon VSWR measurements.**

Frequency (MHz)	Measured VSWR
1.810	1.3:1
1.995	1.5:1
3.500	2.8:1
3.800	3.2:1
7.000	3.0:1
7.200	3.0:1
10.100	3.6:1
10.150	3.6:1
14.000	1.3:1
14.350	1.5:1
18.068	2.3:1
18.168	2.3:1
21.000	1.3:1
21.450	1.4:1
24.890	2.0:1
24.980	2.0:1
28.000	1.2:1
29.000	1.0:1
29.700	1.2:1
50.000MHz	1.7:1
51.000MHz	1.7:1
52.000MHz	2.0:1

EMC

This month's EMC Column focuses on EMC standards and how these have been influenced by the International Amateur Radio Union (IARU) with input from national amateur radio societies including the RSGB. Information on applicability of EMC standards and regulations is believed to be correct at the time of writing (October 2023) but it may change in the future, and it should not be taken as a definitive guide.

PHOTO 1: **A typical solar PV installation.**

Solar PV inverters

The article in the October 2023 EMC Column about adding filtering to a solar PV installation without optimisers is relevant to existing installations where the inverter was placed on the market before EN 55011:2016/A11:2020 became a European Harmonised Standard. More recent solar PV inverters that comply with EN 55011:2016/A11:2020 should produce lower levels of RF interference below 30MHz and additional filtering should not be necessary.

Many new Solar Photovoltaic (PV) installations are appearing (**see Photo 1**) and the RSGB EMC Committee is aware that some recently-installed solar inverters cause RF interference below 30MHz, and/or at VHF, while others do not. Some Members have asked which models are 'quiet' at RF and which models are not. The short answer is to find out which EMC standards the inverter complies with and find one that complies with EN 55011:2016/A11:2020 Industrial, scientific, and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement.

Most, if not all, solar PV inverters comply with the Generic EMC Standard EN 61000-6-3:2007/A1:2011/AC:2012 Electromagnetic compatibility (EMC). Generic standards - Emission standard for residential, commercial, and light-industrial environments. It appears that EN61000-6-3 on its own without EN 55011:2016/A11:2020 is no longer sufficient for Europe or the UK.

The manufacturer's literature normally lists the standards that the product complies with, and these include various electrical safety standards and EMC standards. They may not state which edition of the standard the product meets and, in the case of EN 55011, it is important that it is EN 55011:2016/A11:2020, not EN 55011:2009/A1:2010. To find full details of which edition of the standard the product complies with you would need to see the EU Declaration of Conformity (DoC) or UKCA DoC. Manufacturers are not obliged to make the DoC available to anyone other than a competent national authority, but many manufacturers include it with the product documentation or make it available online or on request.

If you come across a solar PV inverter that entered the supply chain after 4 May 2022, then it would appear that it should comply with EN 55011:2016/A11:2020 (see below). If it doesn't, and if it appears to be causing RF interference, then you could report it to Ofcom for possible investigation. If you contact the manufacturer or importer then it is advisable to be diplomatic. If you suggest that their product may be non-compliant with the UK EMC Regulations, then they may refer you to their legal department, so a more cautious approach is recommended. You could ask whether it has been tested to EN 55011:2016/A11:2020 and, if not, how it achieves presumption of conformity with the Essential Requirements of the UK EMC Regulations. I would be interested to hear what they say.

Solar PV standards

There have been major improvements in EMC standards for solar PV since 2010 and more work is in progress. Here is the timeline so far.

2015 - IARU published a News Item on 15 June 2015, category EMC, written by Don Beattie, title "Standard for photovoltaic inverters provides relief." This stated that the CISPR 11 publication Ed.6.0 was about to appear officially and that, in this new version, limits finally apply (74dB(μV) between 500kHz and 30MHz) for the DC terminals, in particular for photovoltaic and other systems with a power up to 20kVA in residential environments (Class B). This had been achieved through intensive work of the IARU in the standardization bodies during the previous 5 years by Thilo Kootz, DL9KCE, EMC Coordinator of IARU and others.

2020 - Official Journal of the European Union (the "OJEU"), pages L 366/17 to L 366/20 dated 4.11.2020 published a list of Harmonised Standards **[1]** These included EN 55011:2016 Industrial, scientific, and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement as amended by EN 55011:2016/A1:2017 and EN 55011:2016/A11:2020. This was a direct result of the work by IARU feeding through international standards organisations to become a European Harmonised Standard with effect from 4 November 2020. It was a major improvement because Table 5 – Disturbance voltage limits for class B group 1 equipment measured on a test site (DC power port) includes Quasi-peak and Average limits 0.15-0.5MHz and 0.5-30MHz. Section 6.2.1.1 states that the limits for the LV DC power port only apply to Grid Connected Power Converters (GCPCs) intended for assembly into photovoltaic power generating systems. In the A11:2020 revision of the standard, the DC power port limits for inverters apply regardless of cable length but these limits do not apply to solar PV optimisers nor for GCPCs used in energy storage systems, such as batteries.

As EN 55011:2016/A1:2017 and EN 55011:2016/A11:2020 became a product standard for solar PV, it appears that the generic standard EN 61000-6-3:2007/A1:2011/AC:2012 may no longer give presumption of conformity with the Essential Requirements of the EMC Directive.

2020 - UK left EU on 31 December 2020. The UK Office for Product Safety and Standards has produced a guide "Product Safety and Metrology What's changed from 1 January 2021 in relation to Great Britain?" Key Fact 2 states that safety and other technical requirements have not changed. Schedule 20 on Pages 25 and 26 relates to EMC. As the EN 55011:2016/A11:2020 standard was published in the OJEU on 04 Nov 2020, it became an EU Harmonised Standard in the UK until the UK left the EU. It was subsequently listed as a UK "designated standard" in The Department for Business, Energy & Industrial Strategy Notice of Proposal to Publish 0047/21 of 23 September 2021.

2021 - EN 55011:2016/A2:2021 published 09/09/2021. Amendment A2:2021 extends EN 55011:2016/A11:2020 so that the limits for DC power ports apply to Semiconductor Power Converters (SPCs) intended for DC-to-DC converters used within photovoltaic power generating systems. These also apply to Grid Connected Power Converters (GCPCs) used in energy storage systems such as batteries in solar PV systems. Amendment A2:2021 also restricts the frequency range over which DC conducted emission limits apply, depending on the length of the cable. There is a BSI Blog post "What's new about the European ISM emission requirements standard?" This states that in the UK Committee there was input from the BBC, BT, EMCTLA, GAMBICA, OFCOM and the RSGB. EN 55011:2016/A2:2021 does not yet appear to be a harmonised European standard but when it does become harmonised, it will apply throughout the EU and also in Northern Ireland. It will not apply in England, Wales or Scotland unless and until it becomes a UK Designated Standard for the purposes of UKCA marking.

2022 - The date of withdrawal of a previous edition EN 55011:2009/A1:2010 which did not contain DC power port limits was 4 May 2022. After that date, it appears that all solar PV inverters placed on the market in the EU and the UK need to comply with EN 55011:2016/A11:2020 if the standards route to compliance is used. For anything that contains radio, eg inverters with Wi-Fi, the Radio Equipment Directive (RED) 2014/53/EU applies. Article 3.1(b) of RED references the EMC Directive 2014/30/EU.

2023 - As of the time of writing (October 2023), it can be expected that all GCPCs such as solar PV inverters that are intended for assembly into photovoltaic power generating systems in the EU, Northern Ireland, England, Wales or Scotland should comply with EN 55011:2016/A11:2020.

Market surveillance

According to the European Commission **[2]**, "Market surveillance is the activity carried out by authorities to ensure that products on the market conform to the applicable laws and regulations and comply with the existing EU health and safety requirements. It is crucial to keep the European market safe and to foster trust among consumers and economic operators. It also helps maintain a level playing field to those companies that comply and thus avoid losing market share to rogue traders.

"Market surveillance covers a full range of actions, including the monitoring and control of the market and, where necessary, the imposition of corrective measures and penalties. It involves close contacts of authorities with economic operators (manufacturers, importers, distributors, online platforms, retail shops) as well as with consumers and consumer organisations."

What is happening in practice with market surveillance in the EU and in the UK? This is of particular interest to radio amateurs because many radio interference problems are caused by equipment that does not comply with the EU or UK EMC Regulations and market surveillance is required to remove such products from the market.

In the EU, the EMC Administrative Co-Operation Working Group (EMC ADCO) publishes a market surveillance campaign each year. In 2019, the 11th cross-border EMC Market Surveillance Campaign looked at solar panel inverters **[3]**. Six European national Market Surveillance Authorities ('MSA') EMC ADCO members participated in the campaign but the report does not say which countries they represented.

Tests were done using harmonised standards applicable at the time and neither of these included DC power port limits, which were only introduced on 4 November 2020. Out of 12 solar panel inverters assessed, the report concludes,

"Compliance to disturbance emissions limits was even worse as it was during 2014 campaign (25% of EUT compliant against 33%)."

It remains to be seen whether EMC compliance of solar PV inverters has improved since the new EMC standards have been introduced but it should be easier to identify potentially non-compliant products if they do not list EN 55011:2016/A11:2020 on their Declaration of Conformity.

In 2019-20, the EMC-ADCO 12th cross-border EMC Market Surveillance Campaign looked at LED lighting **[4]**. The report was published in November 2020 with a revision in April 2021. Participation in the campaign was voluntary and was open to all members of EMC ADCO. The cost of obtaining and testing the Equipment Under Test (EUT) was paid by each MSA. Eleven European countries participated in the campaign: Belgium, Croatia, Cyprus, Finland, Germany, Hungary, Lithuania, Netherlands, Poland, Romania and Switzerland.

Tests were done using harmonised standards applicable at the time, EN 505015:2013 Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment. The more recent EN IEC 55015:2019/A11:2020 was not used as it only became harmonised under the EMC Directive from 4 November 2020. A significant difference is that Amendment A11:2020 tests radiated emission limits up to 1GHz instead of 300MHz.

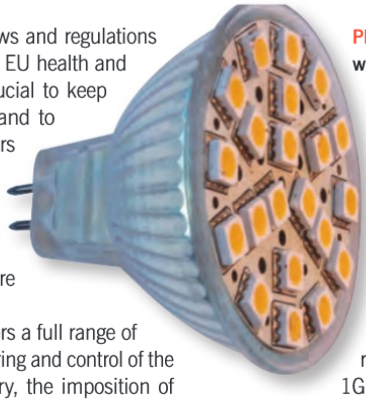

PHOTO 2: A 12V LED spotlight with no CE or UKCA Mark.

The conclusions stated, the 12 EMC MSC showed more than twice better overall compliance results as the fourth EMC MSC of 2011. Compliance to disturbance emissions limits was also better as it was during the 2011 campaign (75% compliant against 62%).

It appears that, although there has been an improvement since 2011, the 25% of non-compliant LED lights is still a major problem from an EMC point of view, particularly as one non-compliant LED light can produce as much RF interference as hundreds of compliant lights. One light tested by EMC-ADCO had no CE mark and we have also come across LED lights with no CE mark (see **Photo 2**).

Since 2020, EMC-ADCO has published two more market surveillance campaigns, microwave ovens and USB hubs, but no more tests of solar PV inverters or LED lighting have been done. Since the UK left the EU, the EMC-ADCO list of market surveillance authorities no longer include a listing for UK. There have also been some changes to market surveillance regulations for England, Wales, and Scotland with significant differences for Northern Ireland.

References

[1] Official Journal of the European Union, pp. L 366/17 to L 366/20
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020D1630
European Commission - The role of market surveillance authorities
[2] https://commission.europa.eu/business-economy-euro/product-safety-and-requirements/product-safety/product-safety-and-market-surveillance_en
[3] Report on the Eleventh joint cross-border EMC market surveillance campaign on Solar panel inverters (2019)
https://ec.europa.eu/docsroom/documents/45506
[4] Report on the twelfth joint cross-border EMC market surveillance campaign on LED lighting equipment - Revision 1 (2019)
https://ec.europa.eu/docsroom/documents/45507

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Design Notes

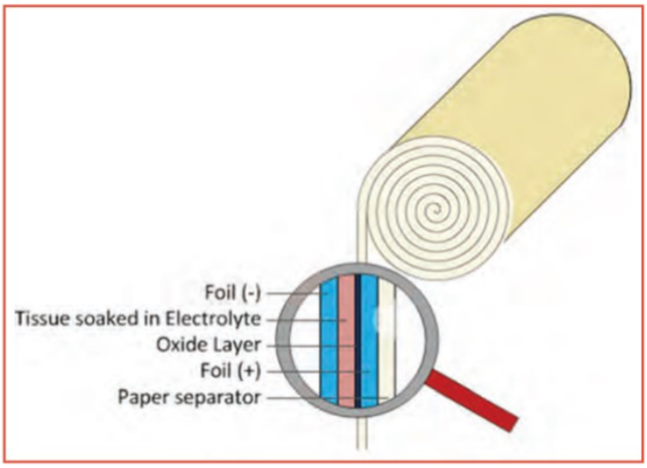

FIGURE 1: The construction of a typical electrolytic capacitor.

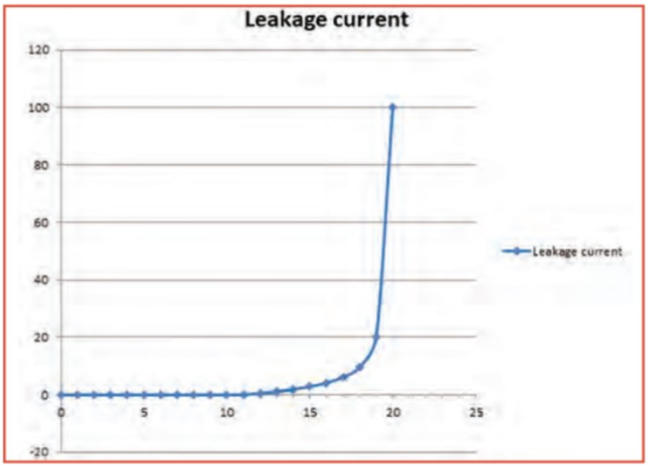

FIGURE 2: Leakage current versus applied voltage for a typical 16V electrolytic capacitor. The vertical current scale should be taken only as relative values.

Steven Bennett, M0YYT sent in this very informative article about choosing electrolytic capacitors.

Identifying good and cheap electrolytic capacitors

"When choosing an aluminium electrolytic capacitor for a new project, we would all like to use a top quality brand (TQB) such as Nichicon, or similar **[1]** but sometimes the cost is prohibitive, so we may turn to little-known brands (LKB) from eBay or AliExpress. We know that the quality of all the operational parameters of TQBs will be high and consistent, but for LKBs it can range from good to very poor! How can we identify if an LKB capacitor is good or not? Looking at published data sheets, even if available, may tell one nothing about the actual quality as some LKBs fail when operating at the voltage marked on the capacitor body.

"The construction of a typical electrolytic capacitor can be seen in **Figure 1**. Capacitance is a function of the dielectric thickness and its area. The dielectric, often aluminium oxide Al_2O_3, is produced when a forming voltage V_f is applied at the factory. Once a capacitor has been created, two other voltages are important, the normal rated operating voltage V_r, and a surge voltage allowable for a short period of time V_s. A fourth voltage not specified and which the capacitor should never experience, is the destruction voltage V_d!

"The scatter chart in **Figure 2** shows the leakage current that might be exhibited by a typical 16V electrolytic capacitor and the potential for disaster, as the applied voltage approaches 20V and the oxide dielectric starts to breakdown. Once the dielectric breaks down, the current increases rapidly, causing the creation of gasses and steam, which quickly leads to the explosive destruction of the capacitor. The onset of dielectric breakdown can be examined safely by applying a high, but current-limited, voltage to a capacitor and observing the terminal voltage. The terminal voltage will increase with time at a speed determined by the capacitance and the current limit, until dielectric breakdown causes an increased leakage current to flow equalling the applied constant current. At this point the terminal voltage will stabilise in an almost Zener diode-like way. Providing that the current injected into the capacitor is small eg 1-5mA then the damage to the oxide layer will be very small and will self-heal once the capacitor is used at its normal rated voltage.

"It is not unreasonable to conclude that the breakdown voltage of an electrolytic capacitor is related to the quality of its dielectric oxide layer, and ultimately its design and manufacturing. As the dielectric is the heart of such a capacitor then its other operating parameters, operational leakage current, lifetime etc may be similarly derived.

"A simple method for measuring breakdown voltage is to connect a capacitor to a voltage source higher than its rated voltage via a high value resistor to limit the current. As I write this, I have a TQB capacitor connected to a 30V power supply via a 10K resistor, limiting the current to a maximum of 3mA. Looking at the DVM connected to the capacitor shows a terminal voltage of 24.85V which, for a device rated at 16V, is very good, and contrasts with my experience with some LKB capacitors which have failed when operating at their rated voltage. However, not all LKB capacitors are of poor quality, and this testing method may be useful in identifying the good ones.

"Higher-voltage capacitors, eg 450V, can be tested in a similar way using a high-voltage source and suitable current-limiting resistor. ALWAYS TAKE PRECAUTIONS WHEN TESTING CAPACITORS AT HIGH VOLTAGE AND ENSURE THEY ARE FULLY DISCHARGED BEFORE TOUCHING THEM!"

Solar power and its quirks

The owners of the Bell Hill set of microwave beacons recently received a very nasty surprise. The price paid for the electricity used, which had previously been supplied at a very generous subsidised rate, would now have to be paid for in full. The six beacons on site consume around 200W and are purely financed by volunteers and donations. Having to pay full price for the power would triple the annual cost of running them and make the whole beacon complex unviable. So thoughts turned to how the costs could be lowered.

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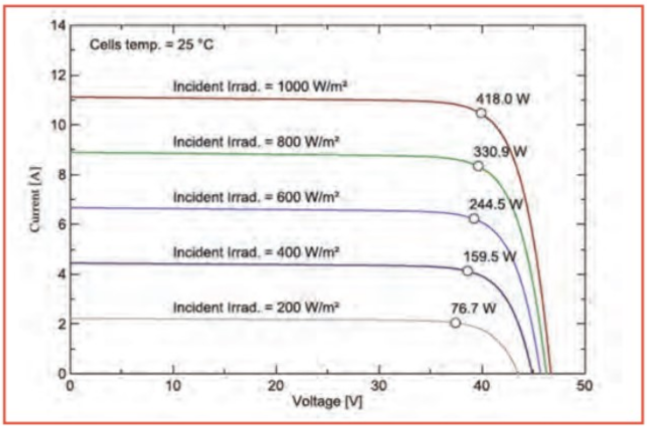

FIGURE 3: **Load I/V curves for varying illumination levels, taken from the Perlight Delta 415W data sheet.**

FIGURE 4: **Grid-tied micro inverter, and the combined current /voltage monitor used to measure the solar panel's input. A fan has been added to keep the unit cool when running at full power in a hot conservatory.**

One of the more feasible routes is to install a solar panel to offset some daytime consumption, but it comes with complications. Solar panels can be relatively cheap these days, and it was suggested we would be offered some second-user ones at zero cost. But the trouble is, at peak output, one solar panel alone will deliver more than the beacons use, so if we had two in operation then, during the summer months, or even on a bright sunny winter's day, more power would be produced that would be consumed. This could just be exported to the grid (and therefore of no benefit to us), or batteries could be used to store the excess energy. But now things get very complicated.

Balancing supplies

The beacons currently run from 12V supplied from a float-charged lead-acid battery. Current consumption is a little over 10A (so the 20A rated PSU is not that efficient). At first sight, the obvious place to connect solar power would be to use a switch-mode converter to drop the voltage to 12V and connect in parallel with the existing DC supply. That would certainly be the easy solution, and possibly the most efficient. But when the Sun is shining and more power is being produced than consumed, the battery could easily be overcharged. And how do we stop the mains PSU trying to supply power and overriding the solar input? And what about that residual mains power wasted in the PSU even when delivering no current. That solution is a non-starter.

The next option is to use a small grid-tied inverter to convert solar power to 230V AC and feed it into the mains, as used in all domestic installations albeit at much higher power levels. Now surplus energy will be dealt with properly, even if it is wasted by feeding into the grid backwards, and we certainly can't negotiate a feed in tariff for this low a power level! 'Micro-power' grid-tied inverters are relatively cheap, but now, even if the PSU is replaced with a more efficient one, we still won't be making maximum use of the solar energy available, especially on dull days when it is not running at over-capacity. To get a feel for the requirements, some thought and experimentation were going to be needed. A modern 400W-rated solar panel was purchased for 'JNT labs to experiment with, and a small 500W-rated grid-tied inverter. Before the inverter arrived, an old home brew step-down switched-mode power supply (SMPS) module described earlier in this column **[2]** was adjusted to deliver 13.8V output and used to charge a 70Ah lead-acid leisure battery. A 12Ω 200W fan-cooled load was also connected to simulate the entire beacon setup. The SMPS was connected directly to the solar panel via an eBay-purchased current/voltage/energy monitor. It was a hot bright summer's day in early September, and the panel propped up to face directly at the Sun during the middle of the day.

Current source and maximum power point

Solar panels do not behave like batteries or power supplies. When open circuit, an output voltage will be measured across the terminals, and for a typical domestic panel this will somewhere around 40V. But the similarity ends there. Solar panels are best described as current sources with a maximum voltage limit and a little bit of series resistance. The current delivered is directly proportional to solar illumination, with the effective resistance varying with both solar energy and load. The net effect is to produce a set of load curves like those shown in **Figure 3** for different illumination levels where it can be seen the output voltage and current can take on a range of values for any given solar flux, depending on how it is loaded **[3]**. For low voltages, the output current is nearly constant, so the power being delivered to a load is higher if, for that current, the voltage can be maximised. But as the upper voltage limit is approached, current drops off, reducing power delivery.

For any given value of illumination, there is one optimum point where maximum power can be extracted. This is close to the knee before maximum voltage, but its exact placing is often unknown, and varies with illumination and panel temperature. This is termed the maximum power point (MPP) and is shown in Figure 3 for each illumination level.

Getting back to the first test, just connecting my step-down converter didn't make good use of the maximum power coming from the panel. Even though the battery was being heavily loaded, and the SMPS capable of delivering more than 10A, it didn't want to, and I could never deliver more than 10A into the supply with the solar panel at maximum illumination where it could ideally be expected to at least deliver well over 300W. At this current supply, equating to some 150W of output, the panel voltage was being dragged down to around 28-30V although, to be fair, in the bright sunlight the maximum power possible wasn't actually being asked for. More importantly, at lower solar levels, the voltage was being dragged down to a level well below the maximum power, and it is in this area on cloudy dull days where maximum power extraction is important.

Tracking the maximum power point

The grid-tied inverter arrived after a few days and was connected up. It is described as a maximum power point tracking (MPPT) unit, and can be seen in **Figure 4**, along with the eBay-purchased DC power-monitoring module. Like all domestic converters, it has an algorithm inside that adjusts the operating point to get as close as possible, in real time, to the MPP. How any individual controller does this is rarely published – it will be a trade secret – but there is much published about how it can be done. The favourite seems to be by jittering. The controller makes a small adjustment to the converter's operating point, in practice changing the pulse width modulator's (PWM) duty cycle, while continuously monitoring

FIGURE 5: The typical innards of a disposable vape, showing the heating element, battery and bottom cap containing the sensor. The top cap/mouthpiece has also been separated.

FIGURE 6: All of the rechargeable lithium cells recovered from a collection of disposable vapes. The two green cells that look like electrolytic capacitors had to be unsoldered, but all the rest just needed wires cutting.

the power being delivered to the load and see if this has gone up or down with the slight adjustment. The PWM duty cycle can then be optimised in real time to place it at the MPP. My micro inverter certainly seemed to be doing something like that. In constant bright sunlight, the voltage, current, and power shown on the display danced round quite a lot initially, with the dancing gradually converging on a more-or-less fixed output (the best I ever saw was 370W). When solar illumination reduced, it danced around a few values and settled at a new point, which we hope was the optimum point. And that's the stage 'JNT labs has reached at the moment.

The next stage is to construct an open-loop buck-mode SMPS, using synchronous switching and a pair of MOSFETs, similar to that in **[4]**, so that the effect of setting an arbitrary PWM duty cycle can be observed. Output voltage and current monitoring can be added to feed those two values back to a PIC processor for a home-brewed MPPT solution. The intention is to design an MPPT 13.8V DC supply to go directly across the Bell Hill beacons DC supply. But even then, some additional control will be needed to make sure solar power is given priority over that supplied from the mains. I did say it was going to be complicated. Progress will be reported in this column as it happens.

Free lithium batteries

We looked at recovering lithium battery cells, and how they can be safely reused, in this column in September 2022. But there is another source of smaller rechargeable lithium batteries that are not only free, but the holders of them are more than delighted to give them away, the more the merrier, in disposable vapes. Sold for a few pounds each, these things give their user a few hundred 'puffs' after which they are discarded. Each vape typically contains a 360mAh lithium battery, a wad of gauze soaked in evil-smelling (your views may differ) oil that is vaporised by a heating element, and a combined sensor/high current switch that responds to airflow. Quite why a rechargeable battery is used in a throw-away product seems a bit of a mystery, but is most likely to be just a cost issue. Rechargeable Li batteries are ubiquitous and hence cheap, so they just use what is already around. The disposal of these vapes is a nightmare. Many users just throw spent ones in wastepaper bins or on the ground. The latter can be a problem as the Li battery can pose a hazard to wildlife in all sorts of ways and, even when disposed of in litter bins, can subsequently cause a fire hazard for waste collectors.

I found one of these discarded on the ground and took it home to dismantle and see if the battery was useable. It was easy to open up just by pulling off the ends. At that stage I didn't know what was inside or the optimum way to dismantle it, got covered in evil-smelling liquid, and managed to trigger the heating element. On seeing the red glow I initially I thought I'd shorted the battery, so quickly moved it to a safe place in case it wanted to catch alight; it didn't, it just emitted some foul-smelling smoke. Eventually the battery was extracted and tested. The terminal voltage was 3.7V and it delivered over an amp on a test load, so it was in good shape. I kept my eyes on the ground after that but never found another one, although apparently they are more commonly to be found dropped in city centres.

There is a vape shop near me, with some very large notices decrying these disposable things, stating that they refuse to sell them but will take old discarded ones for proper disposal. This is a service that ALL sellers are supposed to offer. The owner of the shop was a bit bemused when I went in and asked for a small handful to dismantle. I initially took three away although he'd offered me more. I'd selected three all of more-or-less the same type.

Dismantling process

Those three were quite different from the one I found earlier, but after a bit of practice I discovered the best way to remove the battery and stay free of the oil. Grasp the bottom plastic cap section firmly in a vice, but not tight enough to crush it as it contains the air flow sensor. Gently pull on the casing to remove it. The cap will separate, and will probably be attached to the rest of the bits still inside the casing by three thin wires. At this stage, do not cut any of these, but use them to gently extract the battery and heating element by gentle pulling. Don't poke any metallic elements inside, but something like a ceramic trimming tool or other plastic spike can be used to help ease the innards out if they appear to get stuck. A typical set of innards can be seen in **Figure 5**. To avoid shorting the battery, cut all the wires ONE AT A TIME to separate the heater, battery and sensor. Sticky tape and various bits of gunge are used to hold things together, and the wires need to be eased out of that, but otherwise that's it.

After successfully dismantling those first three batteries, I went back to the shop and walked out with half the contents of the box used to collect them, around twenty in all. There were quite a few different types, but all could be dismantled the same way. Two had a battery soldered directly onto a PCB carrying the sensor and were a bit more involved. These had to be unsoldered, done with care to avoid shorting the terminals. Otherwise, a fruitful morning was spent dismantling them all. I accidently triggered only one other, and that was by blowing into the bottom and triggering the sensor; no batteries were shorted. The resulting battery collection can be seen in **Figure 6**. Most are of the basic cylindrical shape with a few exceptions, like the squashed-looking silver one from the first vape I'd picked up, and the two light green ones that look like electrolytic capacitors. Only one cell had a terminal voltage, when tested, of below 3V, so all were in good condition. A few were charged to full capacity (see **[2]**) and appeared to hold most of the 350mAh they were rated at.

Now all that's required is to work out what to do with them all.

References

[1] Rubycon, United Chemi-Con, Sanyo, Panasonic, and others.

[2] **Special care** needs to be taken when charging Lithium cells. Use either a proper charger module, or very carefully read the advice that can be found by searching the web. Never leave unattended where a fire could cause damage.

[3] westech-solar.co.uk/perlight-delta-415w/

[4] Synchronous buck-mode SMPSU: *Design Notes*, October 2018

A fresh look at broadband wire antennas for HF

Introduction

Radio amateurs have long had an interest in broadband antennas, if only to reduce the number of wires needed to work on all bands between 80m and 10m. 'Top Band', as 160m used to be known, always provided its own challenges in terms of antenna size (and thus the space to accommodate a top-band antenna) and so it was not usually included in that broadband ensemble. Of course, multiband antennas such as trap dipoles, the ubiquitous G5RV, and its more effective variant the ZS6BKW, as well as some others, provide a partial solution to that problem but certainly not a complete one.

The impetus for much of the work on simple broadband wire antennas came from tactical military communications. Armies on the move have always found HF challenging for the simple reason that the necessary antennas are usually too large to be accommodated on vehicles, and even when 'at the halt' neither time nor space allow for the erection of large, and especially complicated, wire structures. These constraints immediately rule out two particularly-effective broadband antennas: the log-periodic array (or Log-P, as it is often called) and the even-larger rhombic and its relative the V-beam, both of them monsters usually beyond the reach of most radio amateurs. Hence much thought was given to increasing the VSWR bandwidth of simpler structures that required only a single conductor or, at worst, a few closely-spaced wires to simulate a much thicker conductor. That last condition gives us a clue to what certainly helps to increase an antenna's bandwidth: use as thick a conductor as is practicable, because that reduces the variation in the antenna's reactance as the frequency is changed. Needless to say, thick poles are ruled out, but a number of closely-spaced wires can emulate a single much thicker conductor at least as far as electromagnetic waves are concerned. These 'vestigial' wire structures are also very much lighter, of course.

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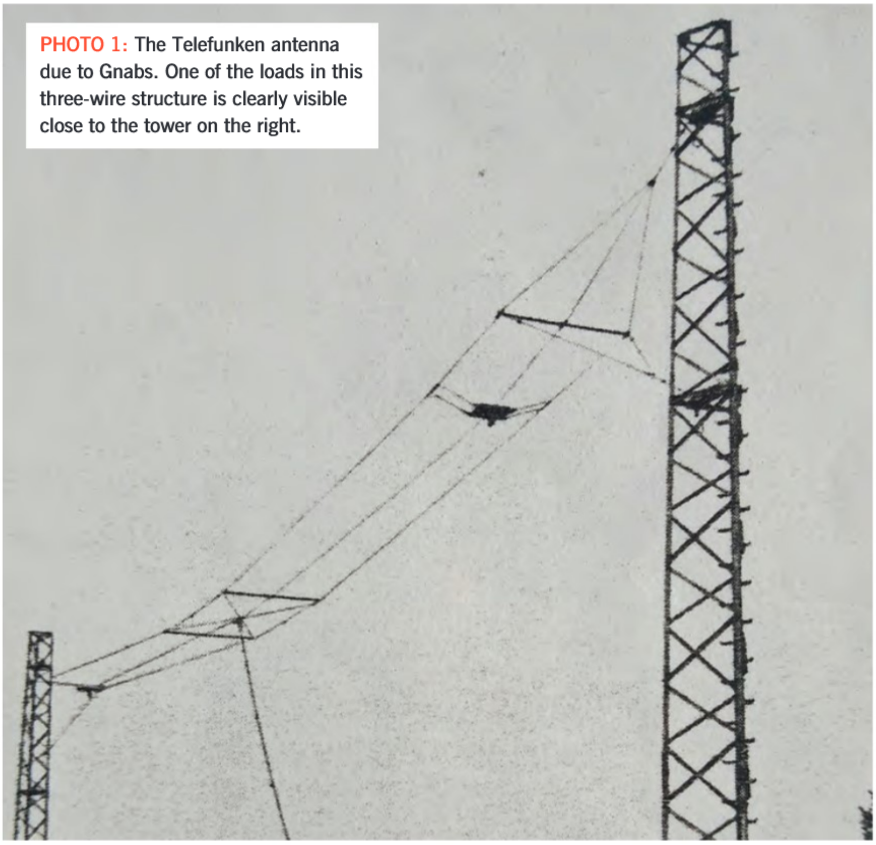

PHOTO 1: The Telefunken antenna due to Gnabs. One of the loads in this three-wire structure is clearly visible close to the tower on the right.

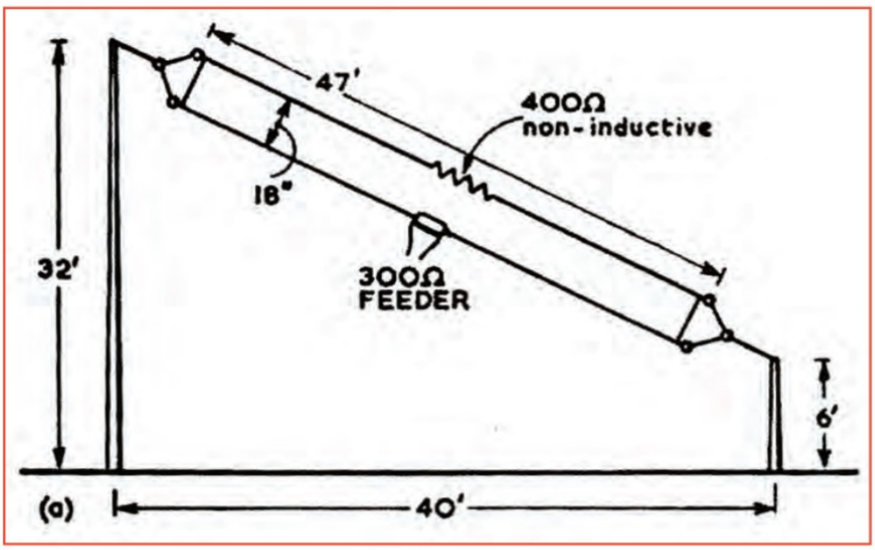

FIGURE 1: The T2FD resistively-loaded antenna.

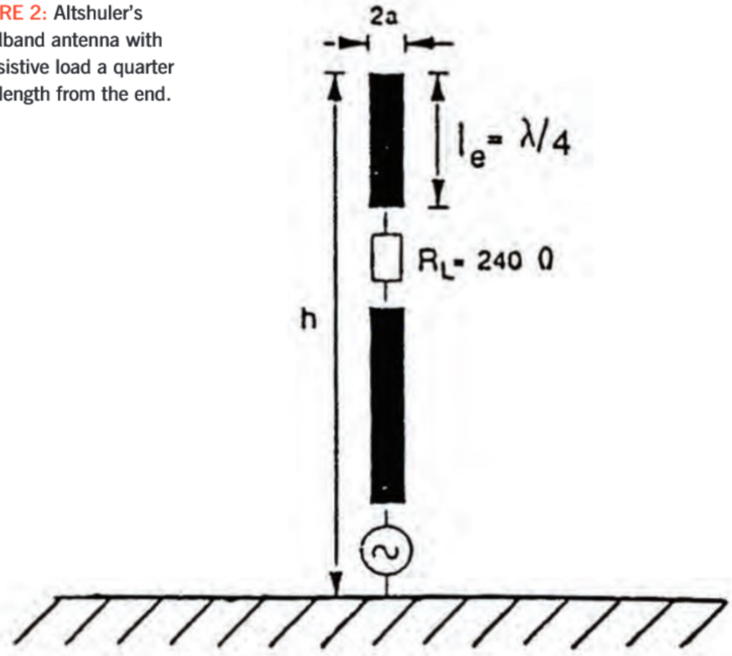

FIGURE 2: Altshuler's broadband antenna with its resistive load a quarter wavelength from the end.

Loading the wire

Perhaps the earliest work on increasing a wire antenna's bandwidth was carried out in the 1950s by the US Navy. The antenna that resulted from their efforts entered the amateur ranks as the T2FD, not a callsign but an acronym for 'terminated tilted folded dipole'. The T2FD is shown in **Figure 1** reproduced from Pat Hawker, G3VA's much-missed monthly Technical Topics column **[1]** that appeared in *RadCom* for over fifty years. The antenna resembles a conventional folded dipole except for the resistor that is inserted opposite the feed point. It's that resistor that increases the antenna's bandwidth but, naturally, it does so at the expense of its radiation efficiency. I won't dwell on the T2FD because it has been well-described in RSGB publications over many years.

The next significant analytical work, up to that time, was done by Edward Altshuler, also in the US, a decade later than the T2FD. Altshuler, though he was described as an avid radio amateur, never revealed his callsign in his professional publications. Anyway, he developed what he called the travelling-wave linear antenna **[2]**. It was a "monopole" driven against a ground plane (but obviously the principle applies equally well to a dipole configuration) consisting of a fairly thick conductor, either solid or one made of vestigial wires, with a resistive load inserted a quarter of a wavelength from its end (see **Figure 2**). By choosing the resistor with a value close to the characteristic impedance of the antenna, the usual standing wave of current that exists along an unloaded conductor would then become a travelling wave and, as is well known, the input impedance is then more or less constant regardless of the antenna's length, and so its bandwidth is considerably increased. Of course, just as in the T2FD, around 50% of the input power is dissipated in that loading resistor (note, however, that losing fifty per cent of your transmitted power results only in a decrease of about half an S point at the receiver). The reason for placing the resistor a quarter of a wavelength from the end of the antenna relies on the fact that the current along that particular length rises from zero at its end to its maximum value (and hence its lowest impedance) at the quarter-wave distance. Current therefore flows through the resistor and this ensures that the rest of the antenna is properly terminated by its characteristic impedance. Altshuler's experiments showed that a resistor of 240Ω was ideal for this purpose. The antenna produced a better than 2:1 VSWR over a frequency range of about 3:1. Once again, of course, this improvement in VSWR bandwidth came at the expense of power loss within the resistor. And so, this pioneering work done sixty years ago indicated that, as ever, one gets nothing for nothing: increasing the bandwidth of simple antennas always comes at a cost of decreased radiation efficiency.

The advent of solid-state transmitters has increased the need for broadband antennas. It is now possible for power amplifiers to cover the complete HF band, between 3 and 30MHz, without the need for any tuning and loading adjustments, just as long as they are presented with a load with a VSWR of less than about 2:1 in the industry-standard 50Ω systems. There has been much work carried out subsequently to improve the performance of resistively-loaded antennas in order to cover the bandwidth from 3 to 30MHz and to achieve as high an efficiency as possible.

An international effort

An important step forward in broadband wire

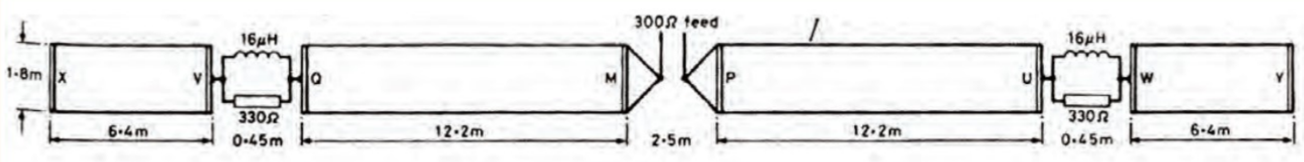

FIGURE 3a: The Guertler-Collyer 'Australian Dipole'.

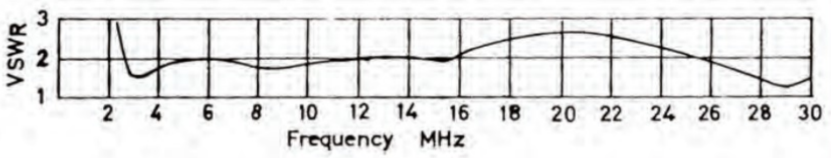

FIGURE 3b: The measured VSWR as a function of frequency.

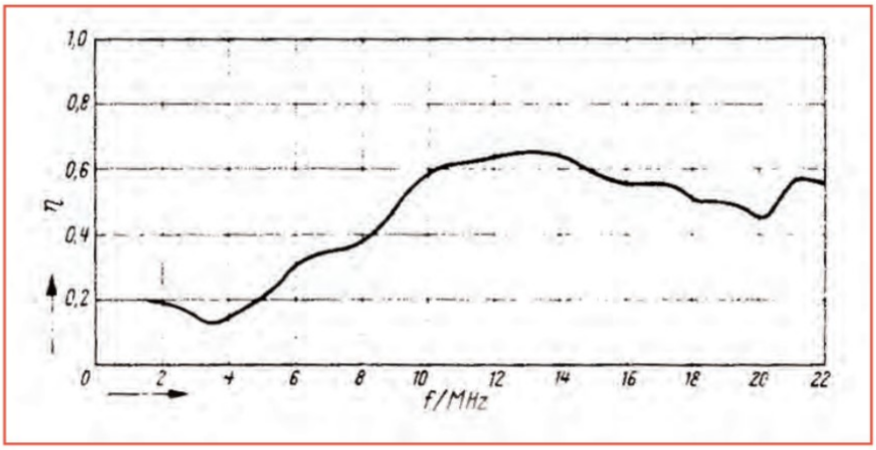

FIGURE 4: **The efficiency of the Gnabs antenna.**

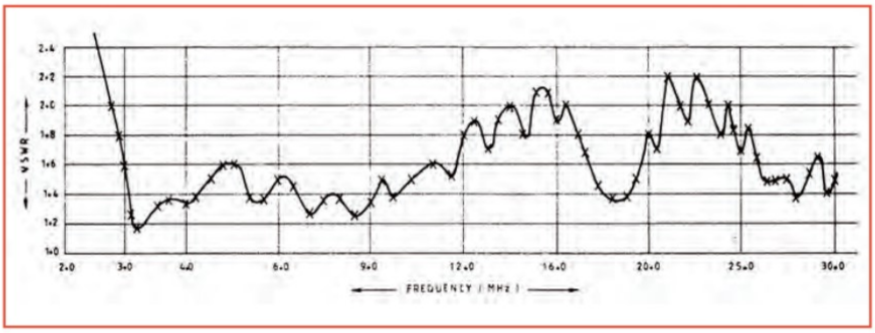

FIGURE 5: **Measured VSWR of the Harris antenna.**

antenna design was made by a Telefunken engineer, V.K. Gnabs, and published in 1966 **[3]**. In it, Gnabs described a parallel-wire dipole configuration clearly intended to simulate a thick solid antenna. Three wires were used with the outer two being spaced about 2m apart. They formed a centre-fed dipole with a total length from end to end of about 36m. Gnabs's measured results showed that the antenna produced a better than 2:1 VSWR between 3 and 24MHz. The key to this significantly-wider bandwidth than that achieved in the Altshuler configuration was the use of two parallel resistor-inductor (RL) loads, one in each arm of the dipole, with each being situated about 14m from the central feed point of the antenna (see **Photo 1**). Presumably, because Gnabs worked for a commercial company, he gave away no secrets about the values of either the resistor or the inductor he had used! But he did disclose some details of the measured results he obtained. In addition to producing better than 2:1 VSWR over a wide bandwidth, the radiation efficiency, though only about 15% at 3MHz, actually reached a little more than 60% at 14MHz before dropping slightly above that. A graph showing those results appears in **Figure 4**. Again there was the inevitable trade-off between bandwidth and efficiency, but there is no doubt that this interesting structure had real potential in many HF situations.

The 'Australian Dipole'

It is perhaps not surprising that Australia, with its vast area but relatively-small and, in places, very sparse population, should have encountered the need for broadband HF antennas. Both the Royal Flying Doctor Service and the Schools of the Air had real needs for 24-hour communications between widely-separated parts of the continent. Before the modern era of satellites and the internet, only HF radio could provide it.

In 1973 a paper titled *Improvements in Travelling Wave Dipoles* was presented at a radio conference held in Melbourne **[4]**. The authors were R.J.F. Guertler and G.E. Collyer, working for a company called Antenna Engineering Australia in that city. As all good researchers do, Guertler and Collyer had familiarised themselves with the international antenna literature and they had come across the article by Gnabs. What they produced was an antenna that soon became known as the 'Australian Dipole'. It owed its existence very much to the ideas first published by Gnabs, though his name has been forgotten over the years. A diagram of the Australian Dipole is shown in **Figure 3a**.

The antenna is somewhat longer than the Gnabs version, being 40.6m from end to end. The two dipole arms, to the left and right of the feed point, are split into sections 12.2 and 6.4m long respectively. Between them, and separated from each by a distance of 0.45m, is a parallel resistor-inductor load whose values were not hidden from the eyes of any commercial competitor. They were given as 330Ω and 16μH, though the designers commented that neither value was overly critical. Clearly, the resistors dissipate some of the input power so their ratings must be adequate for the task. The two wires, making up what became known as tramlines, were 1.8m apart and were joined to their parallel partners at their ends. It should be noted that the feed point is connected to its dipole arms by tapered sections. This was found, experimentally, to improve the quality of the impedance match and hence the VSWR. The balanced transmission line feeding the antenna had a characteristic impedance of 300Ω. **Figure 3b** shows the measured VSWR on that line across the band from 2 to 30MHz. It is less than 2:1 between about 3 and 15MHz, and it then rises to a maximum of about 2.6:1 at 20MHz, before falling again almost to 1:1 at 29MHz and then rising slightly at 30MHz.

Making the measurements

Measurements such as these will obviously have been made at ground-level, hence requiring a suitable length of transmission line between the antenna feed-point and the equipment down below. Whereas one could use 300Ω line all the way to a matching transformer and balun at the transmitter (which requires an unbalanced 50Ω load), it seems sensible to do that impedance transformation at the antenna's feed point and then use 50Ω coaxial cable all the way to the transmitter. This is what Guertler and Collyer did. As I indicate below, the measured VSWR at the input to the coaxial cable will always be lower at that point than it is at the antenna because all feed lines have losses (coaxial cable being considerably more lossy than open-wire line, for example) and the total losses are increased in the presence of standing waves. The effect of that is to cause the VSWR at the transmitter end of the coax to be lower than it is at the antenna feed point, thus somewhat artificially enhancing the apparent performance of the antenna (this was discussed by Peter, G3XJE in his *RadCom* article *SWR and all that*, September 2020; see his **Figure 6** in particular.)

Measuring the radiation efficiency of antennas is a far more difficult task, but it can be deduced in this type of resistively-loaded antenna if one is able to measure the voltage across one of those loading resistors at various frequencies across the band. However, the antenna being at some height above ground can pose significant problems, of course, but it's not impossible to do and, apparently, this is what Gnabs had done because he showed a graph of radiation efficiency across the HF band for his particular antenna (see **Figure 4**).

Out of Africa

Attention now switched to Africa, to Botswana in fact. There, a broadcast engineer by the name of D.W. Harris, with the amateur radio callsign of A22BX, sought a more-practical solution to the news-gathering methods hitherto employed by Radio Botswana. In a large country, with poor roads at that time as well as a somewhat-unreliable telephone service, there were frequently unacceptable delays in getting local news items to the national broadcaster. Harris decided to use HF radio to speed up the communications, and frequencies were allocated for this purpose. Given the well-known variations in the ionosphere over 24 hours, both with the seasons and over the period of the sunspot cycle, it was therefore necessary to be able to change frequency easily. Harris decided that a broadband antenna, rather than multiple dipoles, would better serve his purpose and his quest to find one soon unearthed the Australian Dipole.

Harris's big contribution to the advancement of the broadband antenna art was to add a third wire between the two outer ones in the tramlines of the VK version of the antenna. This simple modification (which, rather intriguingly, Gnabs had used all along!), was reported in 1982 **[5]**. The antenna included a 6:1 impedance transformer and balun at the feed point. **Figure 5** shows the measured VSWR at 250 to 500kHz intervals across the band between 2 and 30MHz. What Harris did mention, unlike previous authors, was that he had used about 25m of RG58 coax between the antenna, at a height of about 13m, and his VSWR meter alongside his transmitter.

Table 1 shows the effect of that length of coax on the VSWR, as measured at the transmitter, compared with its actual value at the antenna feed point of a typical broadband antenna of this type. The additional feed-line losses, which are increased by the standing waves, were computed by using a program developed by Owen Duffy, VK2OMD. In all the versions of the Gnabs and Australian dipoles, the VSWR rises above 2:1 at the higher frequencies, and so the table shows the effects of the coaxial-cable losses from 16 to 30MHz. Clearly, the longer the cable the lower the VSWR seen by the transmitter

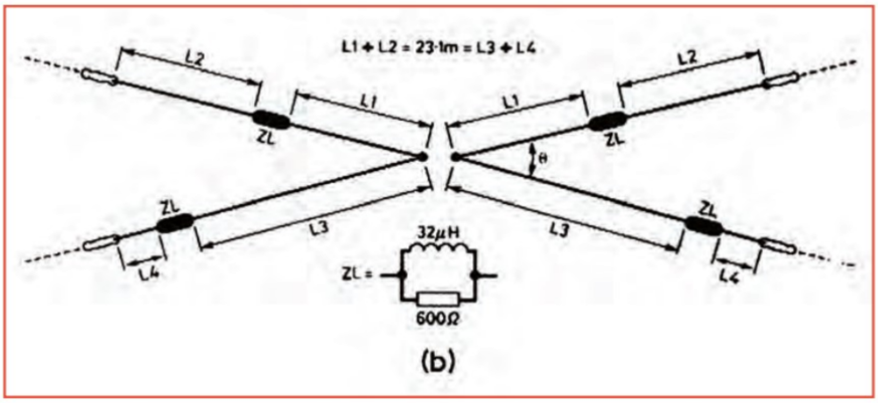

FIGURE 6: The Fourie -Austin loaded dipole antenna.

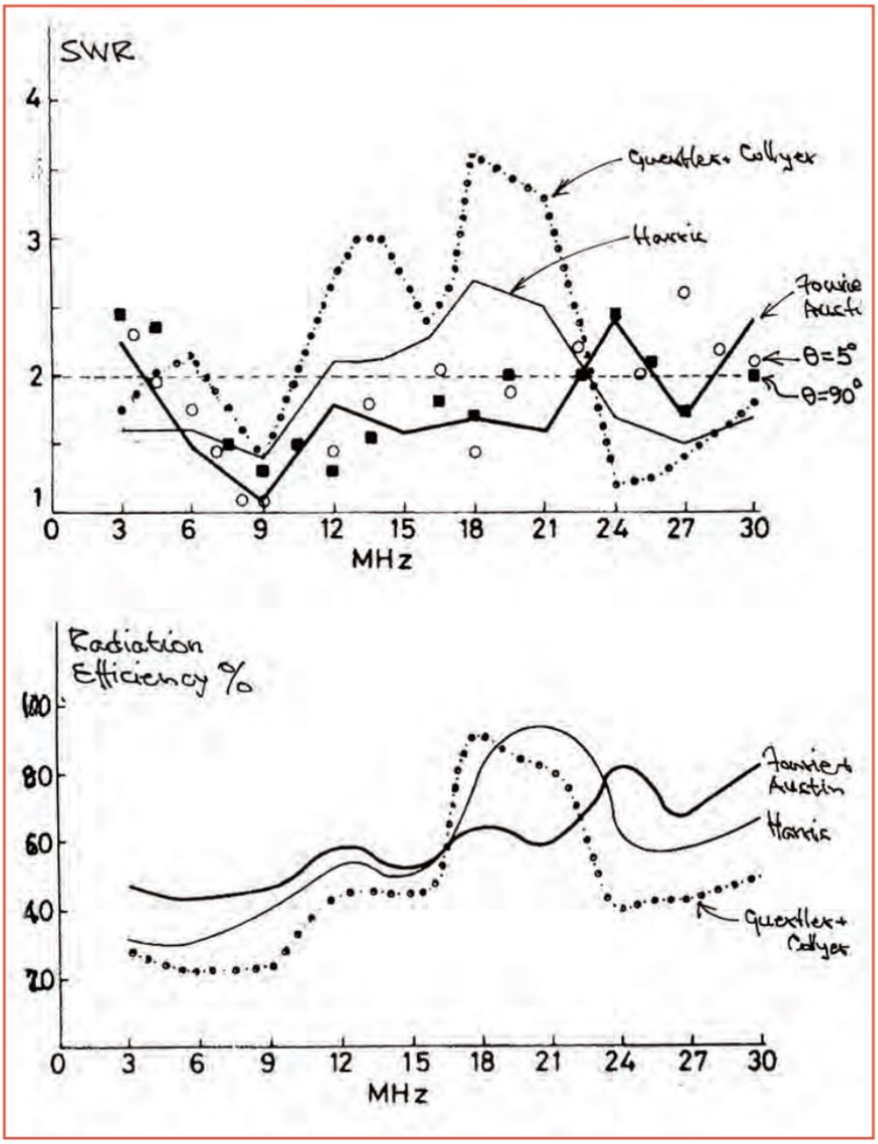

FIGURE 7: Computed VSWR and efficiency of the Fourie-Austin, Guertler-Collyer and Harris antennas and measured VSWR of the Fourie-Austin antenna.

Table 1: Effect of loss on input VSWR in three lengths of RG58 A/U coax cable

Frequency/MHz	VSWR at the antenna	VSWR at the TX with 10m cable	VSWR at the TX with 20m coax	VSWR at the TX with 30m coax
16	1.8	1.7	1.6	1.5
18	5.0	3.7	3.0	2.5
20	4.9	3.6	2.8	2.4
22	2.7	2.3	1.9	1.7
24	1.3	1.2	1.2	1.2
26	3.5	2.8	2.3	1.9
28	4.4	3.1	2.5	2.1
30	4.7	3.3	2.5	2.1

but, of course, at the expense of increased losses in the line. The lower the VSWR at the antenna, to start with, the better the outcome.

The ZS connection

At around about the same time, work commenced in South Africa on trying to optimise the performance of broadband wire antennas at HF. My research group at Witwatersrand University was supported in this by various users of the HF spectrum. Naturally, we also studied the literature from Altshuler to Harris before throwing ourselves into it. Along the way we encountered two fascinating, if somewhat unusual, papers by Ross Treharne, another Australian radio amateur (VK2IQ) and radio engineer, who proposed what he described as 'monocarpic whole-band antennas' **[6]**. For those as bemused as we were by the term monocarpic, the dictionary reveals it is something that bears fruit just once. Another way of putting it is that the energy fed to an antenna is not reflected at the feed point, regardless of the frequency – hence it is a broadband, or as Treharne preferred, a whole-band, antenna. He certainly had some novel ideas.

This was also the time when the 'Method of Moments', as embodied in the Numerical Electromagnetic Code (NEC), became a very powerful tool for the analysis of wire-type antennas. We embraced it in the form of NEC-2 running on state-of-the-art (at the time) IBM-AT personal computers crunching at 8MHz. This was absolutely pedestrian by today's standards but that's how it was. As an example, the Australian Dipole, when set up to run using NEC-2, took about three hours to compute the driving-point impedance of the antenna (and from it the VSWR and efficiency) across the HF band from 3 to 30MHz. This required some thought to improve not only the efficiency of the antenna but ours too, and it led to the development of a much simpler method of attacking the problem that used a lossy transmission-line model of the antenna. This is not the place to go into those details, but the improvement in computing performance was dramatic. Each run of the special-purpose program developed by my research students produced answers in about two minutes. It must be understood that this program was intended to analyse just the particular loaded-wire antenna of interest to us at the time. By contrast, the NEC code was extremely versatile and could be applied to far more complicated wire-grid models, representing not only antennas but even the vehicles, aircraft or ships on which they may have been mounted. Our solution was simply to provide rapid and reasonably-accurate results to determine the direction in which a design should go. Refinement and much-improved accuracy required the use of NEC-2.

Staggering the loads and spreading the wires

A much-improved broadband antenna followed from these simulations **[7]**. It became known as the Austin-Fourie antenna **[8]**, **[9]**, but the order should have been reversed because Andre Fourie had done most of the heavy lifting in developing it. By staggering the positions of the loads within the two dipole arms, it was possible to remove most of the resonance effects which had degraded the VSWR performance of the Australian Dipole while, fortuitously, also improving the radiation efficiency. In addition, the action of spreading those two conductors to form a V or fan dipole proved most beneficial. **Figure 6** shows the antenna with the relevant lengths L1 to L4 marked. It should be noted that L1+L2 = L3+L4 = 23.1m, or each being half the total length of the Australian dipole. With L1 = 13.5m and L3 = 17m, the deleterious resonance effects are avoided. In addition, the parallel resistor-inductor loads have twice the values they had in the Australian Dipole, hence R= 600Ω and L=32μH. As might be expected, the included angle between the two V-sections affects the optimum characteristic impedance of the transmission line, but the effect is small and 450Ω balanced line (or a balun having a 9:1 impedance ratio if 50Ω coaxial cable is used) is close to ideal.

Figure 7 gives the computed performance of the Guertler-Collyer, Harris and Fourie-Austin antennas in terms of both VSWR and radiation efficiency. Measured VSWR results for the V-dipole version are included for 5° and 90° angular separations between the wires. It is clear that the antenna with its staggered loads and spread ends is superior to those others across most of the frequency range. It will also be considerably lighter and possibly a lot easier to erect.

Conclusion

The development of the ideal broadband HF dipole antenna is probably an on-going and never-ending quest. Significant contributions towards achieving that goal began in Germany as far back as the 1960s, if not even earlier in the US Navy. Then the research effort migrated to the southern hemisphere where radio amateurs, functioning in their professional engineering roles, took the process forward over the next two decades. All we can say now is: where to next?

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Contesting

This month we welcome guest columnist John, G4IRN discussing station automation and how he's applied it at his remote station.

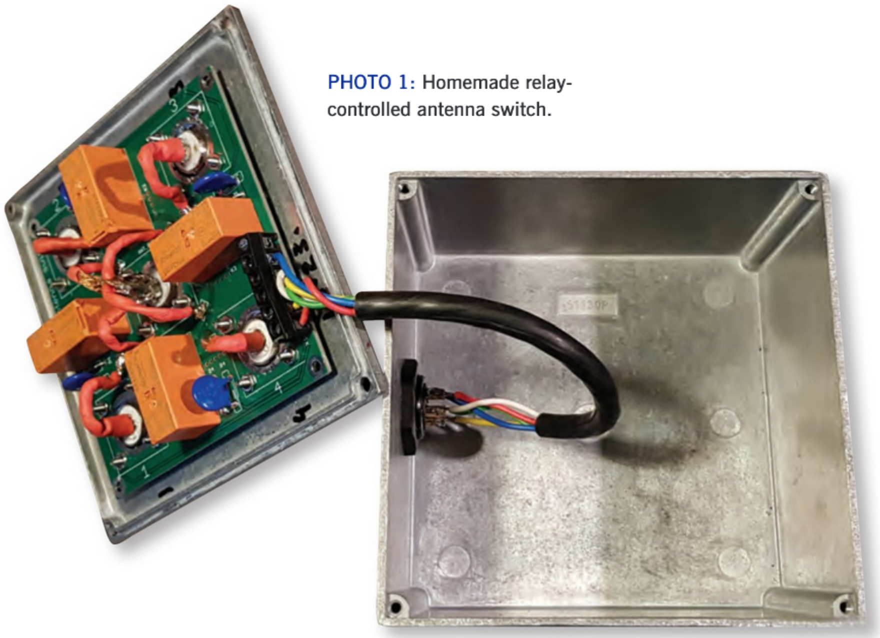

PHOTO 1: Homemade relay-controlled antenna switch.

Station automation for contesting, and more

As the contesting bug bites there is often a desire to become more effective as an operator. However, another dimension to effectiveness and efficiency is station automation ie making your station slicker by needing less manual intervention to do things. Basic aspects of station automation may be simpler than you think and there are several benefits to be gained:

- Reduce operator tiredness
- Reduce the risk of human error and potential damage to the station
- Station operation becomes very predictable – 'same every time'
- Frees the operator's mind to concentrate on working more stations
- Reduces the learning curve for guest operators
- Can improve log accuracy

What's not to like? Furthermore, as another benefit, an automated station becomes more accessible for remote operation, which is the angle I came to this from.

Starting from basics, *computer logging* is a form of automation. It takes away the manual chore of writing callsigns into a log, checking for dupe QSOs, multipliers etc. Chris has covered different contest software products in this column in the past; these products have in-built features that can help control different aspects of the station. Let's look at the possibilities.

Computer Aided Transceiver (CAT) operation (aka 'computer-assisted tuning') is a bedrock of station automation and will work well with your contest software. CAT is the term used by Yaesu, Kenwood, Elecraft and others to provide radio information to external devices but Icom have their own similar protocol called *Computer Interface 5 (CI-V)*. CAT protocols differ between the manufacturers, but they are all similar in that a RS232 (serial) or USB port is made available on the rear of the radio to provide radio information in a format understood by external software. Contest software needs to be set up to communicate with the radio in use, though this is usually a one-time configuration.

CAT and CI-V give control of frequency, VFO, filters, audio gain and many other settings that allow the radio to be operated with mouse clicks or keystroke operations on a computer keyboard. Top contesters do not like moving their hands away from the keyboard; good software supports all the essential radio functions although this, of course, takes some practice. Additionally, stations being logged or spotted have their exact frequency simultaneously recorded, without the operator having to think about it.

A *digital voice keyer (DVK)* allows the operator to record voice messages and play them back on the air eg 'CQ Contest G4IRN', 'Thank you, QRZ G4IRN' and 'five nine one four' for fixed exchange contests such as the CQ World Wide DX Contest. Contest software allows the user to record audio files on the PC and play them back by pressing F-Keys. Suitable audio cables will need to be

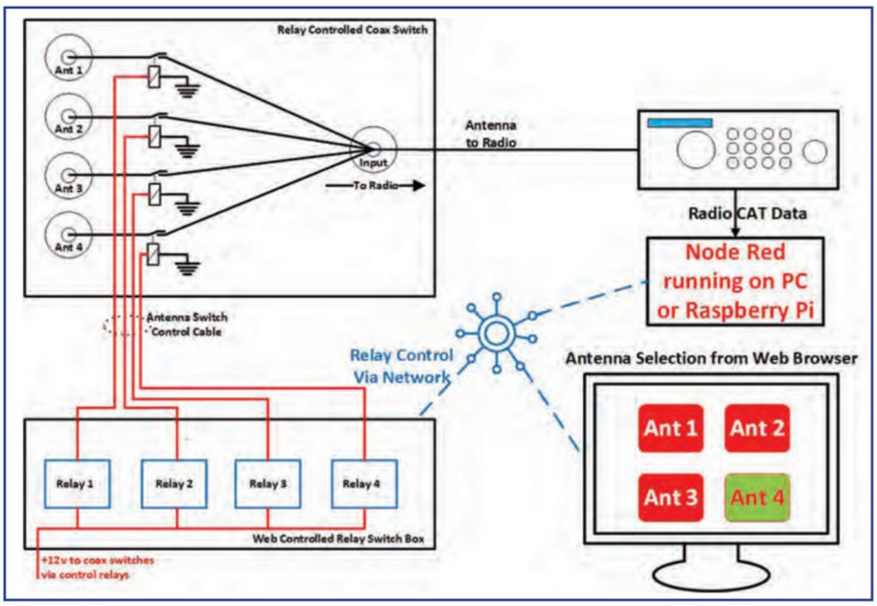

FIGURE 1: Antenna switching schematic.

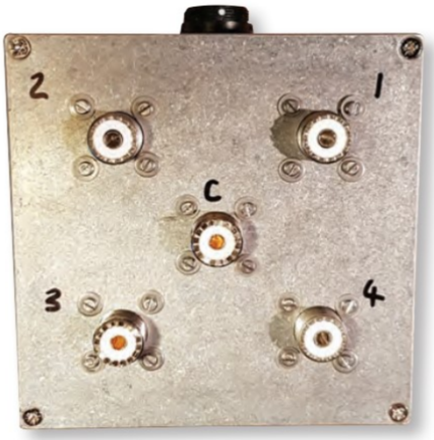

PHOTO 2: Antenna switch box.

set up between the PC and radio but these are often the same ones that are otherwise used for data-mode operation. Many modern radios have a built-in DVK. Even if using one of these, the message can usually be recorded and initiated from F-Keys in the contest software, so there is no need to be interacting with buttons on the radio during the contest. Just a word of caution about DVKs – in multi-operator environments it is best to have each operator record their own messages; a mix of voices during a QSO can lead to confusion at the other end. Also, check the level and profile of the recordings to ensure they sound like the microphone audio. Again, inconsistent audio can lead to confusion.

With suitable configuration, all good contest software will send *Morse code (CW),* initiated from the keyboard's F-Keys and keyed out through a serial port. K1EL's WinKey units (and their clones) are popular devices to ensure well-timed CW characters are sent.

All the above could be considered the basics of station automation however, as the station increases in complexity, further opportunities may exist to de-stress the operator and avoid potentially-damaging mistakes. A limitation of most (if not all) radios is that they do not provide enough outputs to drive the station switching possibilities but there are several commercial products available that provide control for antenna switching, band pass filter switching, rotor control and amplifier band switching. Integrated 'station management' control boxes exist at the high end but solutions for tighter budgets are available. Web-enabled devices and the free programming framework Node-RED **[1]** have been game changers in this area (see *RadCom* articles in July and August 2023 by G4WNC).

Antenna switching

Antenna switching presents an obvious opportunity for automation and can help avoid nasty mishaps such as transmitting into the wrong antenna. The premise is that the correct antenna is automatically selected depending on the transmit frequency of the radio. The approach I have taken is to use relay-controlled coax switches (**Photos 1 and 2**). PCBs for 2-, 4- or 6-way switches can be purchased from eBay or ready-made units are commercially available. Switching from one antenna output to another requires the application of 12V (typically) to the appropriate relay. It's important, of course, to ensure no more than one antenna is selected simultaneously – commercial antenna controllers will manage this for you based on the CAT frequency or 'band data' from the radio. Such logic can be built into Node-RED workflows if going down the homebrew route. Always make sure you have measures in place to avoid switching antennas while the transmitter is enabled.

To select one of six antenna outputs using Node-RED, a web-enabled relay control board (**Photo 3**) with at least six relays is required. Each relay should be connected to a corresponding antenna switch (ie relays to control the relays) so 12V can be switched on/off to that relay. When one of the antennas is switched 'on', the others should be switched 'off' (antenna 'lockout'). This can be initiated manually from the web dashboard or automatically from the radio with appropriate Node-RED programming (**Figure 1**). This approach can support more than one antenna on a band. Once settled on a particular band, antennas can be manually switched without an automated override occurring. The high-level workflow I have employed comprises:

1 – Read the radio's frequency
2 - Convert frequency to band
3 – Switch 'on' the relay for the antenna corresponding to the current band and switch the others 'off'
4 – When the band changes, go to step 3

Using a similar approach, coax switches for *band pass filters* can be controlled automatically from the Node-RED flow or manually from the Node-RED dashboard.

Linear amplifiers

Linear amplifiers may provide another opportunity for automation if they support automatic band changes. Such devices usually support CAT, CI-V or Yaesu format BCD (binary coded band data) straight from the radio. Some newer Ethernet-enabled amplifiers will read UDP (User Datagram Protocol) frequency packets issued from contest logging software or from a Node-RED workflow over a LAN. Personally, I prefer the Node-RED approach since it removes the dependency on the contest software. Node-RED can be programmed to generate the UDP packets from the radio's frequency data.

Antenna rotators

Antenna rotators need to be turned from time to time. Suitable rotor controllers will integrate to contest software to be turned manually from the keyboard or automatically based on the location of the callsign being logged. Look out for rotor controllers with an interface eg a serial, USB or Ethernet port. For older controllers with no such connections, the 'Easy Rotor Controller' kit **[2]** from Germany provides a great way to control the rotor and what's more it can be integrated with Node-RED to give a web dashboard control and view.

PHOTO 3: Web-enabled relay board.

At my remote station, I use Node-RED on a Raspberry Pi to perform station monitoring, antenna and amplifier switching. The same setup also gives me remote power control to the equipment. A benefit of web-enabled devices is that they can be controlled from a 'dashboard' on a web page on multiple device types eg iPad, phone or laptop from anywhere in the world.

What I have described in this article are some basic station functions that can often easily be automated. I have not gone into more complex SO2R (Single Op, 2 Radios) or multi-transmitter scenarios, but with some careful design, the same tools can be used. Node-RED has revolutionised the possibilities, but it comes with a steep learning curve. There are several good learning resources and lots of templates available on the internet and, once confidence to develop workflows is gained, the possibilities are endless.

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HF

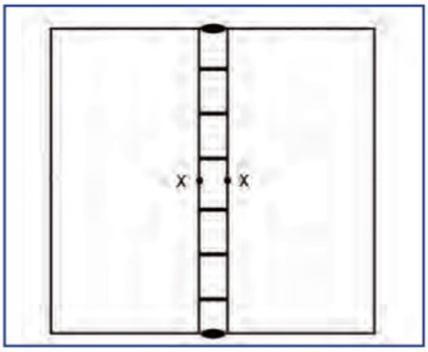

FIGURE 1: DJ4VM quad element.

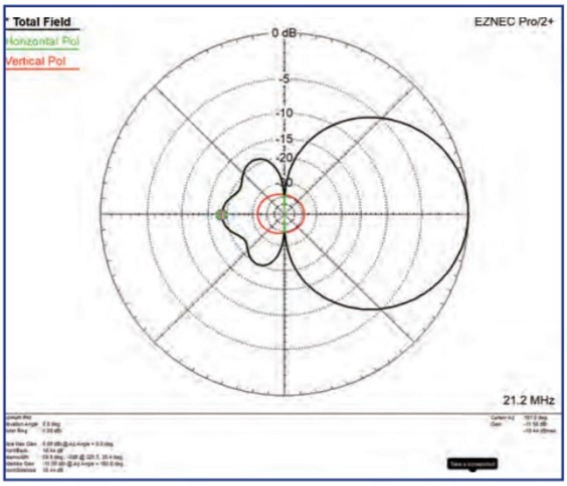

FIGURE 2: G3YPZ's Quad Azimuth Plot at 21.2MHz showing a gain of 6.88dBi and a f/b of 18.44dB, with Test Flexweave Loop.

PHOTO 1: Clamp.

At the time of writing, the HF bands are producing an easily-landed DX catch for even modestly-equipped stations, with the solar flux index (SFI) hitting 166 on 9 October.

At G3YPZ, the HF operations were hampered by a combination of an argument between a horse chestnut tree and my quad. An intermittent feeder connection necessitated lowering the antenna, which promptly entangled itself in some summer growth branches, laden with conkers. It was a no-win situation and one of the fibreglass poles snapped. The quad, a DJ4VM design (**Figure 1**), built by Ron, G8CTZ, who, as well as having a far greater technical knowledge than your scribe in matters electronic, is also a first-class mechanical engineer. Ron managed a quick fix, but we decided that, after 16 years, the poles were at the end of their days and new ones were ordered. The DJ4VM quad uses two 20m loops, with the normal quad spacing. Each loop is split into two rectangles, with ladder line linking them to which the balanced feeder is attached. I use a pair of KW Z matches, one on the driven element, the other on the second twin feeder, which goes to the reflector and is tuned for maximum current. It performs well on all bands, although the 300Ω feeder suffers from damp and needs re-tuning when it rains. I'm planning to run coaxial cable to the base of the tower and use a remote matching unit to simplify matters. The rebuild will follow the DK7ZB design, using tuned reflectors made from Flexweave **[1]**.

When the original antenna was built, we used a combination of jubilee clips and tape to secure the wires on the poles. Ron decided to design proper aluminium clamps (**Photo 1**), which slide over the poles and have drilled holes through which the elements can be threaded and secured. It is hoped that the antenna can be completely refurbished before the onset of winter. Flexweave is convenient. EZNEC provides facilities for modelling insulated wire and we found that velocity factor (Vf) did affect the length required. G8CTZ modelled the quad, which has diamond shaped elements, using MMANA-GAL, because it is easier to input data – but does not provide for insulated wire. He then imported the file into EZNEC Pro v7 and I modelled the insulation on the wires (see **Figure 2**). As expected, they were shorter. We cut a loop for 15m and put it on to the spreaders. The big problem was assessing the front-to-back (f/b) ratio, as we couldn't get far enough away from the antenna on my property to get meaningful readings. Using the KIWI SDR in Ashland, Maine **[2]**, I was able to hear my 25W carrier from the K3 at a signal peak of S5 on the SDR meter. Rotating the quad by 180° caused the signal to drop into the noise. This was repeated on different frequencies in the band and the f/b ratio was observable. QSB is always an issue, but I was able to get an impression over a period of several minutes and repeated turning of the antenna. Checking the f/b ratio on signals received and worked confirmed what the SDR was evidencing. This is a work in progress.

AM: resurrecting a Heathkit DX100

Three years ago, I picked up a vintage DX100 (**Photo 2**), one of the most popular AM/CW transmitters, which were still being produced into the late 1960s, for home construction. This one was quite poorly and needed a driver transformer for the modulator, as well as repairs to the power supply. The wrong coil had been fitted in the 5763 driver for the 10m and 15m bands. G8CTZ had built a DDS VFO based on the PA0KLT design, and I was keen to use this with the transmitter **[3]**. The original VFO sub chassis was removed and the 6AU6 valve was recycled, mounted on the main chassis and configured as an interface/untuned amplifier for the DDS, running at 3.5MHz for the 80m band and 7MHz for all the other bands – multiplication being achieved using the existing circuitry. The transmitter is now working on all the original HF bands, producing 70W of carrier from the two 6146s on 29MHz, modulated by a pair of KT88s. It is still a work in progress. Tim, WA1HLR has published a series of modifications for the DX100, which I intend to complete **[4]**.

GW3TMP

Talking of DX100s, Howarth, GW3TMP, based in Mold in North Wales, has a classic station (**Photo 3**) which he uses for daily contacts with Tom, W0TDH on the 15m and 10m bands. They often start on SSB and switch to AM if conditions allow. Howarth writes, "I began my SWL apprenticeship just as cycle 19 peaked, using a one-valve TRF receiver and a piece of wire around the picture rail in our living room. I thought 10m was always like that, but I learned differently as time went by. I am attaching a photo of my AM station in what I call studio B".

Technical

Line stretchers
and antenna impedance

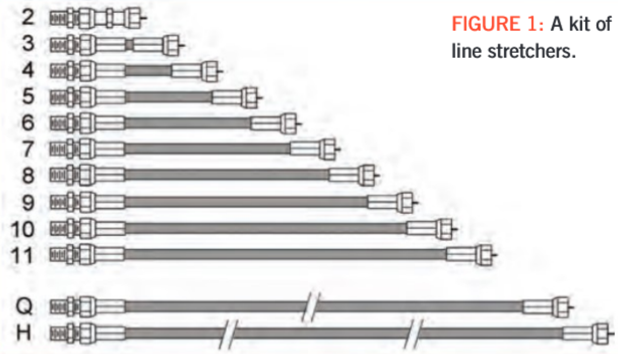

FIGURE 1: A kit of line stretchers.

The antenna experimenter often needs to measure antenna impedance, and a high-end network analyser makes this easy to do.

It can be calibrated to show the impedance at the end of a long run of coaxial cable, internally manipulating Smith chart equations to calculate out the effect of the coax. But even a less-expensive analyser, such as the MFJ antenna analyser, can be used for the same purpose. However, measuring the impedance directly at the antenna terminals is not recommended. Any equipment in the antenna's immediate vicinity can severely disturb those measurements. Here I describe a way to move the antenna terminals to a distant point, where impedance measurements can be made safely.

Impedances and cable length

If an antenna's coaxial feeder is exactly a few half electrical wavelengths long, the measured impedance, Z, at its end will be more-or-less that of the antenna, provided that the feeder has a low loss. Stretching the feeder by an additional quarter of a wavelength changes the measurement to $Z = Z_0^2 / Z_{antenna,}$ where Z_0 is the characteristic impedance of the additional length. So, by being able to stretch the feeder to an integral number of electrical quarter waves in length, one can measure either $Z_{antenna}$ without the extra quarter wavelength, or its admittance, $Y_{antenna} = Z / Z_0^2$, at one spot frequency, by adding in the extra quarter wavelength.

To this end, I've built a kit of 'line stretchers', short pieces of RG-6, 75Ω coaxial cable with type F connectors. You could also use 50Ω cable, although the characteristic impedance of the cable used in the line-stretcher kit doesn't matter provided you know what it is. You could also use a different type of connector if you wished, without changing the principles. The shortest stretcher in my kit is an F barrel coupled to an F double male. Fittings measure ¾in from mating face to mating face. Thus my 'unit' length is set at ¾in, with stretcher number 2 two units long.

The remaining units are pieces of RG-6 with F male fittings, and an F barrel attached at one end. The kit contains stretchers of length 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 unit lengths. I have added two more, cut for 148MHz: a 'Q' unit, close to 23 units, or 17in long, which is an electrical quarter wavelength, and an 'H' unit, close to 45 units, or 34in long, an electrical half wavelength at that frequency. **Figure 1** shows a sketch of the kit. I often design antenna models for 148MHz, the input frequencies of our local repeaters being 147.3MHz and 147.9MHz. UK radio amateurs might want to go for 145MHz instead. Designs can then be put to use when desired. Their coaxial feeder lengths are adjusted to a chosen number of quarter-waves with the stretchers, thus enabling me to measure the antenna impedance (or its admittance).

Using the line stretchers

The first step in doing a measurement is to disconnect the antenna, making the far end of the coaxial feeder an open circuit. The impedance at the near end of the cable is then almost entirely reactive (it would be entirely reactive with perfect loss-less coaxial cable). Add different stretchers until the reactance drops to zero where an odd number of quarter waves has been reached, or to infinity with an even number. Then connect the antenna, and read the antenna's admittance or impedance, respectively. You can then prune and fiddle with the antenna to bring its impedance to a desired reactance-free value when it is then resonant. More fiddling can bring its impedance to a desired resistance, such as 50Ω.

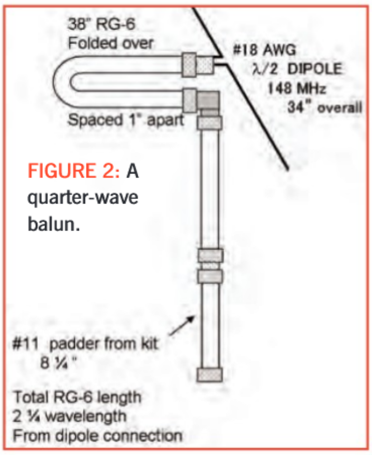

FIGURE 2: A quarter-wave balun.

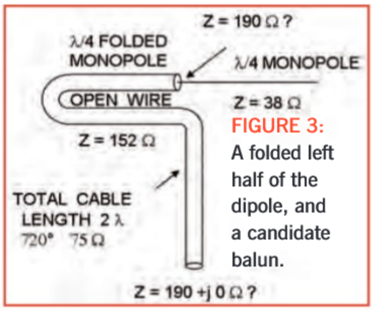

FIGURE 3: A folded left half of the dipole, and a candidate balun.

In practice

As a case study, I explored the possibility of using a quarter-wave, shorted, open-wire line as a balun. In **Figure 2**, a balanced half-wave wire dipole for 148MHz is fed directly from unbalanced coaxial cable. The latter is bent into a skinny 'U' shape with a 1in spacing making the open-wire line and a quarter-wave shorted stub. Its open end inserts a very high impedance in series with the coaxial cable run, attenuating common-mode current along the braid, and hence decoupling the balanced antenna from unbalanced coax, ie it forms a balun. The coaxial cable was adjusted to a length of 2¼ wavelengths. I found $Z = 89 + j0$ ohms, with $Z_0 = 75\Omega$, giving $Z_{antenna} = 63\Omega$, a reasonable result. A proper dipole has an impedance closer to 75Ω.

In a second example, the coaxial part of a 'half-folded' 148MHz dipole, fed with 75Ω coax, was stretched to a length of 2 wavelengths, as shown in **Figure 3**. The coaxial cable itself, bent again into a quarter-wave, skinny 'U', formed both the folded left half of the dipole, and a candidate balun. Z came to $200 \pm j40\Omega$, but the reactive value was unstable and bouncing between zero and that $j40\Omega$. I had obtained a similar result in an initial investigation of such an antenna. It seemed odd at the time and puzzling. However, if one views the antenna as a 38Ω quarter-wave element in series with a quarter-wave folded element at four times 38Ω, the feed impedance would be $Z = 5 \times 38 = 190\Omega$. Hence the 200Ω value is explainable!

Both example antennas easily keyed 2m repeaters a few tens of miles distant, driven with 5W of power. I offer the above, in the hope that you find it useful in your own antenna experimenting.

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