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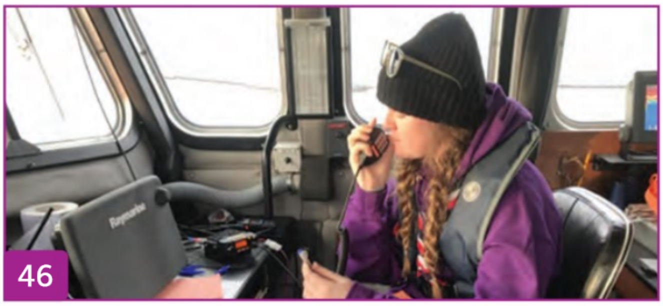

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Cover images: Image of a DMR hot-spot that goes under the name of MMDVM (Multi-Mode Digital Voice Modem) with selected dashboard images in the background. Images courtesy Bob Cowdery, G3UKB. Designed by Kevin Williams, M6CYB

RadCom THE RADIO SOCIETY OF GREAT BRITAIN'S MEMBERS' MAGAZINE

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New Products

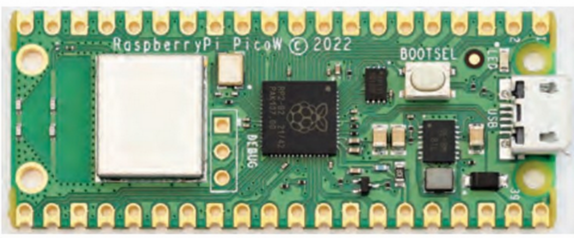
Xiegu G106

The Xiegu G106 is an entry level QRP transceiver that has been designed for outdoor and portable operation. It weighs just 720g and is 120 x 40 x 135mm. With 16 bit sampling SDR architecture and delivering 5W RF output, the transceiver covers the 10 to 80m amateur bands, including the WARC bands. On CW operation there are three filter bandwidths for easy reception of weak signals. The transceiver can also be used for digital modes with the optional DE-19 digital adaptor.

The receiver covers 550kHz – 30MHz and 88 – 108MHz (WFM commercial radio band) and should be available around the end of July. The price is expected to be around £399 and it will be available from Nevada Radio (www.nevadaradio.co.uk) or Waters & Stanton (www.hamradiostore.co.uk).

Raspberry Pi Pico-W

The hugely successful Raspberry Pi Pico now has a 2.4GHz Wi Fi-enabled sibling called the Pico-W. The RP2040 processor chip is an in-house design and employs a dual-core, 133MHz Arm Cortex-M0+ unit with 256kB of SRAM and a unique programmable I/O system. The Pico has seen a boom in adoption during the current chip shortage thanks to the Pi team's foresight in placing advance orders in the millions. The team also have a pipeline of orders for tens of millions more, so supply should continue to be good. The new Pico-W board uses the same form factor as the original Pico so that it will drop into the existing range of expansion and prototyping boards. To provide Wi-Fi, the Pico-W uses an Infineon CYW43439 chip, and all the radio circuitry (except the antenna!) is enclosed in a metal shield. This chip also supports Bluetooth Classic and Low-Energy but is not currently enabled. However, the Pi team say this may be enabled later. The addition of Wi-Fi makes the Pico-W particularly attractive for IoT devices. As with all Pi products, the documentation is excellent, and there's a new 27-page guide dedicated to using the board's Wi-Fi facilities. Despite the advanced technology of the Pico-W, it is priced at £5.99 inclusive of VAT and is available now.



Flex PowerGenius XL

The Power Genius XL amplifier from Flex takes the output from your radio and amplifies its performance exponentially. It's exceptionally clean and delivers full power at 100% ICAS duty cycles. It is the only fully SO2R-capable amplifier on the market with 70dB nominal isolation between transceiver inputs. The amplifier covers the 1.8-54MHz amateur bands. It also includes smart control of cooling – real-time settings of drain voltage, drive and fan speed for best thermal performance. It is expected to retail around £7199.95 and should be available in late July. Find out more at www.hamradio.co.uk.

Hilberling UDL-16

The Hilberling UDL-16 was shown at the recent Ham Radio show in Friedrichshafen, Germany in June. It is a multi-band transverter to expand your transceiver into a QO-100 satellite earth station. You need no computer or software. There are 16 switchable combinations – 4 simplex and 12 duplex via a separate Rx out connector. It supports input on the 6 and 2m bands as well as 70 and 23cm. The output on 23cm is 20W PEP and it requires an input signal or between 25mW and 10W. it is expected to retail at around 2100 Euro. Details are sparse as we go to press but more will be found at www.hilberling.de in due course.

Antennas

The HB9CV beam antenna, continued with examples of HB9CV antennas built for the 2m and 70cm bands.

As described previously, the HB9CV antenna comprises two parallel elements that are separated about 0.125 wavelengths (λ) apart and are supported by a central boom. One element is about 0.5λ in length, while the other is made shorter at around 0.46λ long. In this antenna, both the elements are fed. However, the longer element is fed 180° out of phase compared to the shorter element using gamma matches **[1]**. The elements' gamma matches are connected with a length of insulated conductor, which forms a transmission line with the aluminium boom support. Coaxial (coax) cable is used to feed the antenna towards the shorter element's end of the antenna, with a variable capacitor used to connect the coax cable's inner conductor to the transmission line run between the gamma matches. **Photo 1** shows the 2m band HB9CV antenna that is described this month.

A HB9CV 2m band antenna

This antenna used 12mm and 8mm diameter aluminium tubes for its two elements, which were supported by a boom made from a 20mm diameter aluminium tube. The antenna's design dimensions were calculated using a frequency of 144.25MHz, which corresponds to a wavelength (λ) of 2.08m. Using this wavelength gives the elements' design lengths and the separation between them as:

Longer element ≈ 0.5 x 2.08m, or 1.04m
Shorter element ≈ 0.46 x 2.08m, or 0.957m
The centre-to-centre distance between the elements ≈ 0.125 x 2.08m, or 0.26m.

Figure 1 shows the concept of the antenna and includes the antenna's *actual* dimensions after the antenna had been tuned at 144.25MHz.

Each element was made using a 12mm diameter aluminium tube that was used to support flush-fitting 8mm diameter aluminium tubes at each end. The length of the 12mm diameter tube was 340mm, while the 8mm diameter tubes were 420mm long. The 8mm diameter tubes were held in place using small self-tapping screws, which were passed through suitable holes drilled into the larger 12mm diameter tube's ends.

To keep the smaller diameter tubes firmly in place, two self-tapping screws were used at each end of the 12mm diameter tube as shown in Figure 1. This arrangement allowed the smaller tubes to be equally moved in and out of the larger tube to tune the antenna while testing. A 5.5mm hole was drilled through the centre of each 12mm diameter tube to enable

PHOTO 1: The 2m band HB9CV under test as described in the text.

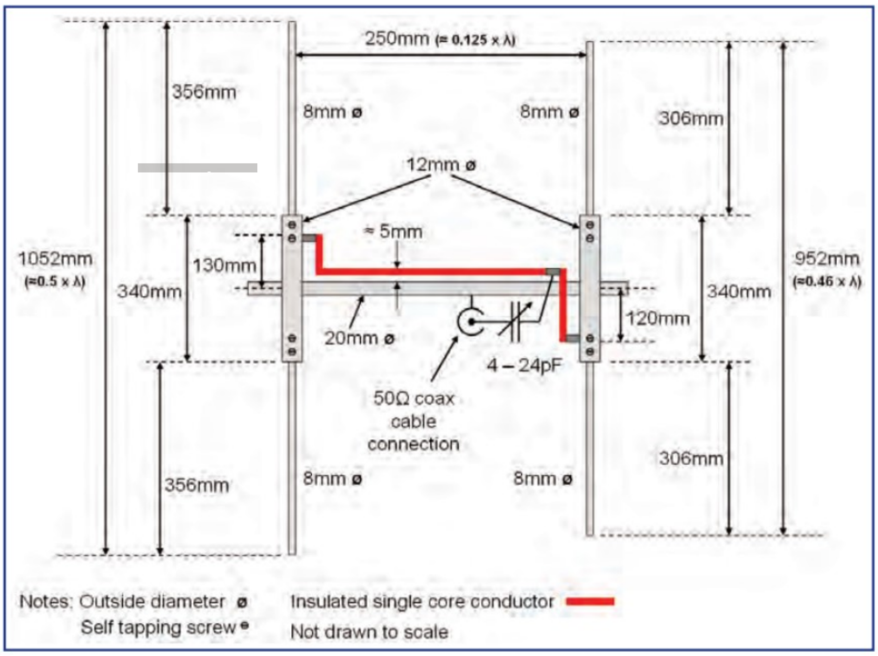


FIGURE 1: The layout and actual dimensions used for the 2m band HB9CV antenna.

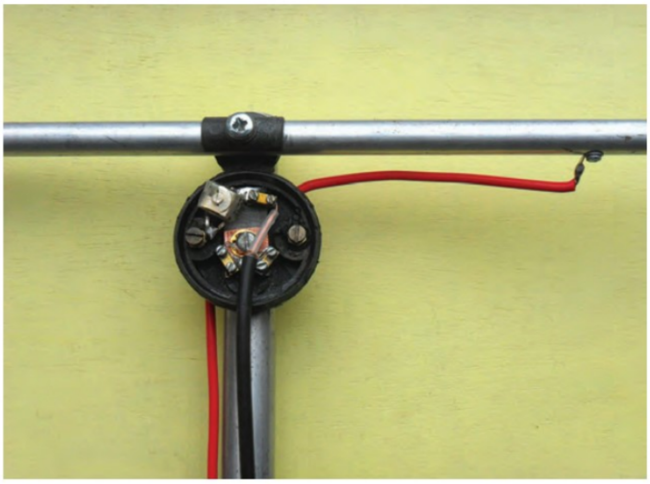


PHOTO 2: The HB9CV antenna's dipole centre and shorter element's gamma-match layout.

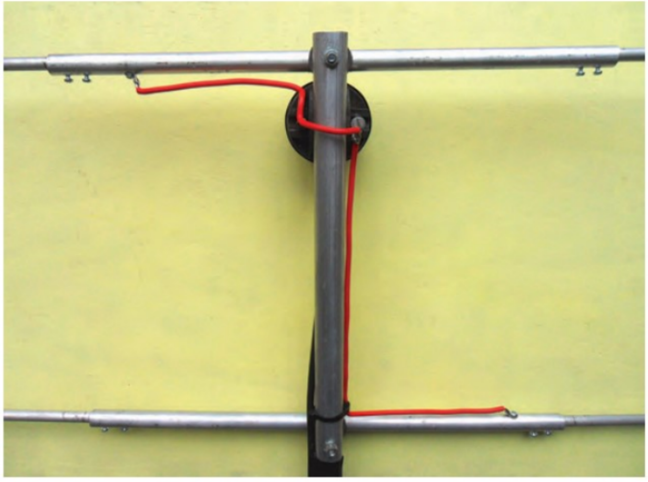


PHOTO 3: The underside of the HB9CV antenna showing the layout of the transmission line and gamma-matches.

it to be attached to the antenna's boom using an element clamp with a M5 nut and bolt. The element clamps used were salvaged from a scrap antenna, although they could be fabricated using L-section aluminium as described in Antennas previously **[2]**.

The antenna's boom was made from a 400mm length of 20mm diameter aluminium tube. Two parallel 5.5mm holes were drilled at distances of 25mm and 275mm (ie 250mm) into this tube from one end to take the antenna's two elements. This left a sufficiently long section of the 20mm diameter tube extending behind the longer element to enable the antenna to be clamped to a mast.

A commercially made dipole centre DPC-A was used to enable the antenna's coax feeder cable to be connected to the antenna. This dipole centre was obtained from an online supplier, although they can often be obtained at radio rallies. A rectangular connection plate was made using single sided PCB with a strip of the copper etched away towards one end leaving two copper surfaces. Two brass terminal connectors were soldered to the larger of the copper surfaces and one brass terminal connector to the other. The larger copper surface was connected to the antenna's boom through the dipole centre's retaining bolt. This arrangement allowed the coax feeder cable's screen to be connected to the larger copper surface using the two terminal connectors. Only one of the dipoles centre's brass terminal pillars was used to connect with the transmission line that was run below the dipole centre. A ceramic air-spaced preset 4 - 24pF variable capacitor was connected to the brass terminal pillar and its other lead soldered to the connection plate's smaller copper surface, where the coax cable's inner conductor was connected to its terminal. The other end of the brass pillar was attached to a connection tab using two nuts, with the transmission line then soldered to this connection tab. **Photo 2** shows the layout used for the dipole centre for reference.

Alternatively, a dipole centre could be made using a small plastic ABS box along with a brass bolt, nuts, washers, connection tabs and self-tapping screws in conjunction with the PCB connection plate described above. Suitable holes being drilled into the box to take the brass bolt, fit the PCB connection plate and to pass the coax feeder cable through.

A length of 2mm diameter insulated single core wire was used to make the transmission line and the gamma matches. This wire was initially cut too long to allow it to reach between the two elements and to form the two gamma matches. The insulated wire was run leaving a gap of about 5mm between the boom and the elements. Referring to Figure 1, the longer element's gamma match was 130mm in length, while the shorter element's gamma match was 120mm long. A section of the wire's insulation was removed to allow it to be soldered to the dipole centre pillar's connection tab. The transmission line's wire was bent under the dipole centre and run beneath the lower section of the antenna's boom and then run towards the shorter element while maintaining a gap of about 5mm (note that the gamma matches are connected 180° out of phase). Each end of the wire was then bent and run parallel with each element to form its gamma match. Each gamma match's end was connected by soldering it to a connection tab attached to the element, which was held in place with a small self-tapping screw. **Photo 3** shows the arrangement used for the gamma matches.

Once the antenna had been constructed the antenna's RG-58 coax feeder cable was attached, which was 9m long.

Testing and tuning

Using a MFJ 269c analyser, the antenna's elements and their spacing were adjusted to minimise the SWR at 144.25MHz, with the antenna at about 1.5m AGL. The preset capacitor was then varied to further reduce the SWR. After completing this process and having signed on in CW, the antenna was tested on 144.25MHz using a transmit power of 10 watts. The antenna was carefully adjusted and an SWR of better than 1.1:1 was obtained. The antenna was attached to a mast and raised to 5m AGL. When tested using 10 watts of power the antenna's SWR continued to remain the same. The power level was increased to 50 watts and the SWR did not increase. The SWR was also measured between 144.05MHz to 145.5MHz and remained under 1.2:1. Once the tests were completed, the transmissions were signed off.

The antenna's directivity was measured by recording the received signal level from a local 2m band beacon. With the antenna at 5m AGL, the signal on the receiver was maximised by directly pointing the antenna at the beacon. The antenna was then turned in steps of 15° and the change in the received signal was recorded. The results obtained were plotted to give the antenna's horizontal plane radiation pattern at 5m AGL and these are shown in **Figure 2**. Using a MMANA-GAL model of the antenna, the antenna's horizontal radiation pattern was also predicted at the same frequency with the antenna at 5m AGL,

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using the application's default ground settings [3]. The antenna's predicted horizontal plane radiation pattern is included in Figure 2 for comparison. As can be seen in Figure 2, the measured and predicted horizontal radiation patterns followed the same form. The antenna's measured beamwidth was 70° and this was close to its predicted beamwidth of 68°. The antenna's measured front/back ratio (F/B) was about 15dB and was better than the 12dB predicted.

On air use

The HB9CV antenna has been used for making local 2m SSB contacts and during RSGB activity contests. For a two element beam, the antenna has enabled many contacts to be made, with some exceeding 200km when using 50 watts.

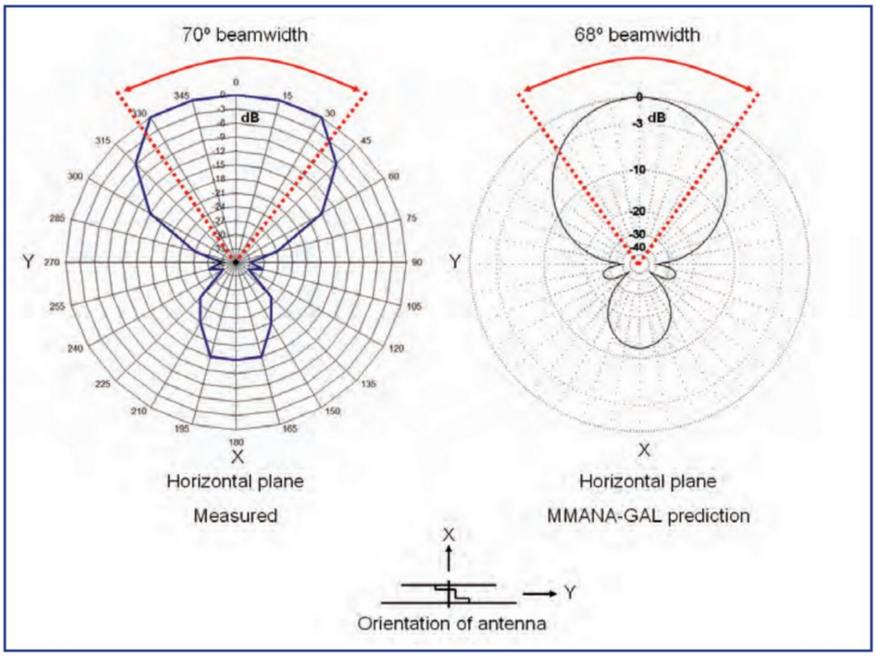

FIGURE 2: A comparison between the HB9CV antenna's measured and predicted horizontal plane radiation patterns at 5m AGL.

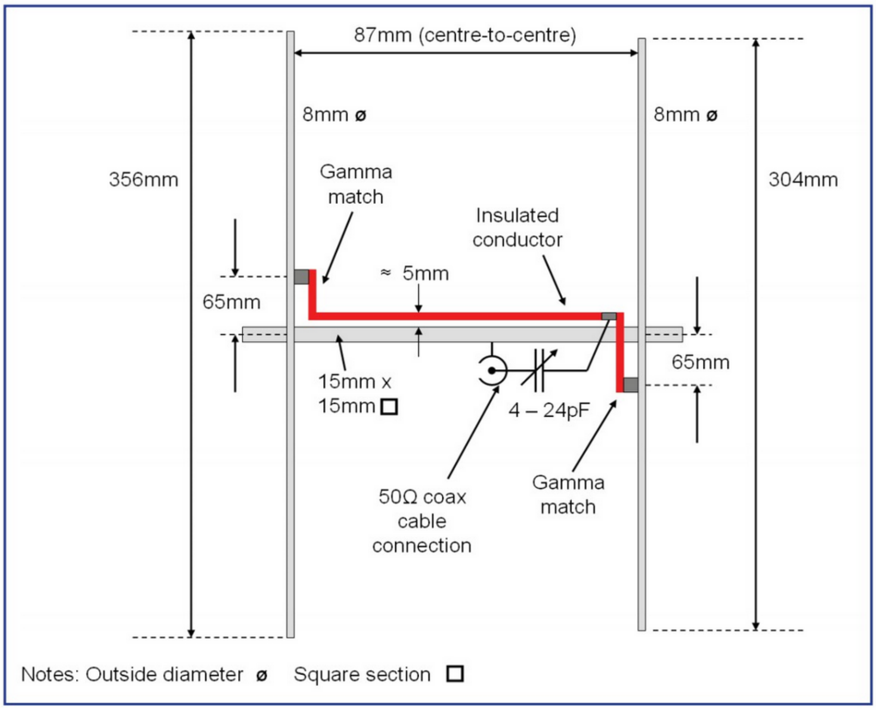

FIGURE 3: Layout and physical dimensions for the 70cm band HB9CV antenna.

A 70cm band HB9CV

The physical dimensions for a 70cm HB9CV antenna centred on 432.5MHz are shown as **Figure 3**. The construction of this antenna was very similar to the 2m band HB9CV antenna, therefore only a summary of the antenna's construction and testing are given.

The antenna's performance was predicted using a MMANA-GAL model at 5m AGL, with the default ground settings selected [3]. This indicated the antenna's gain was about 13dBi with a F/B of about 15dB. The antenna's radiation patterns were very similar to those predicted for the 2m HB9CV antenna modelled.

The antenna's elements were made using 8mm diameter aluminium tubes that were supported by a 300mm long boom made from 15mm x 15mm square aluminium tube.

The antenna's elements were fed using the same transmission line and gamma match technique as described for the 2m band HB9CV antenna. The dimensions of the transmission line and gamma matches are also included in Figure 3. The feeder used was a low-loss 50Ω coax cable.

In a similar way as the 2m HB9CV antenna, a dipole centre DPC-A was used to enable the antenna's coax feeder cable to be connected to the antenna. To tune the antenna, a 4 - 24pF preset capacitor was connected between the 50Ω coax cable's inner conductor and the dipole centre's pillar that was connected to the transmission line.

When tuned to 432.5MHz, the antenna's SWR was 1:1. The antenna's SWR was measured between 431MHz to 435MHz and was better than 1.3:1.

The antenna has been used for making local contacts, during RSGB activity contests and portable use. A photograph of this antenna was included in last month's Antennas for reference.

Websearch

[1] L.B. Cebik, W4RNL. The HB9CV Phased Array and Gain Comparisons. http://www.antentop.org/w4rnl.001/hb.html

[2] RSGB RadCom, Antennas: VHF Element clamps in September 2018 and March 2021. UHF dipole element clamps in September 2021.

[3] MMANA-GAL basic V3.0.0.31, freeware antenna analysing application, by Makoto Mori JE3HHT. MMANA-GAL basic and Pro by Alex Schewelew DL1PBD and Igor Gontcharenko DL2KQ. 1999 onwards. Default ground: Dielectric 13, 5 mS/m, others 0.

Design Notes

I've sometimes been asked for component values that are 'missing' from diagrams published in this column.

Circuit diagrams in published articles usually show values, especially when the component is important for correct operation. But there are many cases where the exact value is not critical or depends on circumstances of use. Coupling and decoupling capacitors are often a prime example of this, where any value covering a power of ten or wider will do.

For example, capacitors across the rails decoupling at VHF can be anything from say 220pF to 10nF. The same spread applies to interstage coupling used for blocking DC. Decoupling of digital circuitry is often done with 100nF – but it doesn't have to be exactly this value, just a nice round value that's 'about right'. Often circuits published in this column will not show component values in such positions, leaving it up to the experimenter to use whatever is to hand.

As a rule of thumb, for RF coupling use a value whose reactance is between a quarter to a tenth of Z_0. Or even lower if you want – but beware of self-resonance effects if going too low a reactance. Using 100nF as a coupling capacitor at 144MHz isn't a good idea, 1nF would do better here.

But what about values of components that do matter to some extent and are given on the diagram. The accepted convention in such diagram is to show the component value the designer *actually used*. This may be a lesser obtainable value that just happened to be sitting in the junk box.

Common sense, experience and intuition are needed in such cases – don't stick to it rigidly if you think it doesn't matter and are trying to find that elusive 49.9Ω resistor. One case in point, I will often specify a resistor used for a Z_0 termination as being 50Ω. A 50Ω resistor doesn't actually exist in the normal set, the nearest popular one is 51Ω, or even 47Ω, either of whose effect when used in this situation isn't serious. In VSWR terms, those result in 1.02:1 and 1.06:1 respectively, equivalent to a return loss of 40dB or 30dB – hardly important. If you want to be really pedantic, use 49.9Ω from the E96 series.

Even semiconductors can fall into this non-specified category. Choose one that meets the voltage or current requirements. If it's critical, the type or the important parameters to look for will be mentioned.

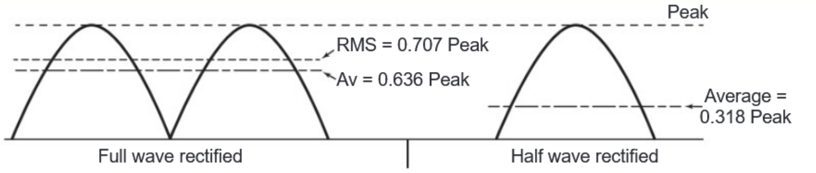

FIGURE 1: The relative levels of half wave and full wave rectified sine waves.

AC voltage measurement

All Digital Multi Meters, DMMs, offer the capability to measure AC voltage and current. It's an unspoken fact that this usually means 50Hz sinusoidal waveforms as the biggest user of AC measurement is, by far, the electrical industry. If such a meter is stuck across the AC mains it happily reads 230 – 240V and everyone is happy. But what is it actually measuring? This is where you need to look at the small print.

Traditional analogue meters of old, as well as the earlier DMMs, used a simple half wave, or perhaps a full wave, rectifier to deliver a DC voltage to be measured. The meter scaling was then scaled to show the RMS value of that sinusoidal voltage as shown in **Figure 1**. The meter is actually measuring the average value of a half-sine waveform (or two successive half-sines in the case of full wave rectification) that is directly related to RMS *for a sine wave only*. The average value of a half-wave rectified sine is given by

$$V_{DC} = \frac{V_{PEAK}}{\pi} = 0.318{*}V$$

For full wave rectification the value is doubled. To obtain the RMS value the answer is scaled by √2, the peak to RMS ratio of a sinewave, so the result becomes

$$V_{DC} = \frac{\sqrt{2}V_{RMS}}{\pi}$$

which is very close to $V_{DC} = 0.45{*}V_{RMS}$ for a half wave rectified signal. All nice and simple. But what if the waveform isn't a sine wave?

Take a square wave as an example. This has a peak value of either plus or minus V, and nothing else. It's RMS or heating value is now exactly equal to that peak. A classic meter scaled for a sine input will measure this peak, then scale it as if the waveform were sinusoidal, resulting in a measurement low of its real RMS value. For waveforms with a higher peak to mean or peak to RMS, like speech, the situation is even worse.

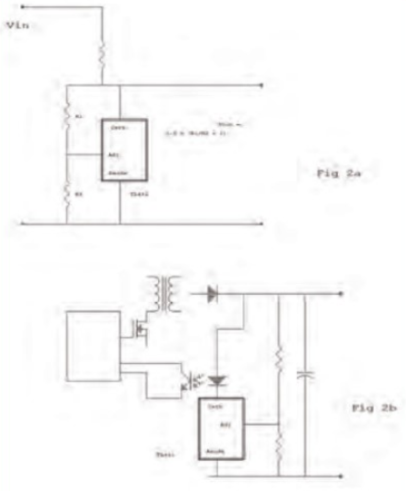

FIGURE 2: Using the TL431 as a straightforward shunt regulator and in the feedback loop of an isolated SMPSU.

For several decades, custom RMS-DC chips like the Analog Devices AD636 have been around. These consist of a simple analogue computer implementing a square, average and square root process, delivering a DC output more-or-less representing the RMS value of the input. Providing it doesn't exceed a certain value of peak-mean ratio, and is within certain frequency limits dictated by chip technology and the averaging time constant used, and various other restrictions that are not often given. Modern DMMs, are often stated to be 'True RMS' and incorporate either a chip of this type to do the conversion, or have the conversion algorithms and hardware inside a custom DMM chip. They are an improvement over average reading types – perhaps – but still give problems. Not least because they often don't respond to any DC component superimposed on the AC. Added DC contributes to the heating or RMS value of any real waveform, but true RMS meters often miss it.

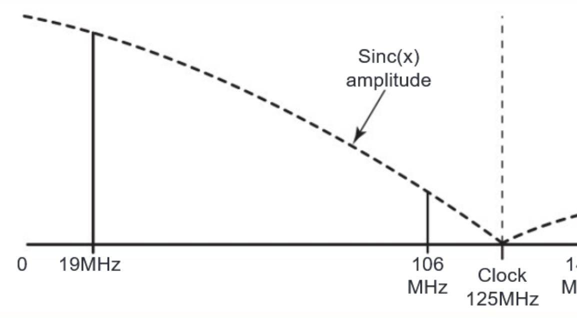

FIGURE 3: Alias products generated from a DDS clocked at 125MHz when delivering a programmed output at 19MHz.

The third option is sampling, using digital signal processing to calculate the RMS, and any other parameter wanted. The input waveform is sampled and measured in a fast analogue to digital (A/D) converter at a suitable rate (think 'Nyquist') and all the successive samples are processed as wanted. This is a good way to properly measure arbitrary waveforms, but has its own limitations. The A/D converter has to run at a significantly faster speed than the other measurement types, and has to have a sufficient resolution for decent accuracy of measurement.

Some practical measurements

I have three digital multi meters, none of which are of any particularly exotic type or even modern, so decided to see what result they showed when used to measure an arbitrary but very predictable waveform. This is a 5V peak-peak pseudo random sequence generated in a PIC at a sampling / clock rate of 29kHz. Taken via a coupling capacitor to remove DC this becomes a square shaped waveform of ±2.5V. The true RMS is therefore 2.5V, since the magnitude of the output is always 2.5V. A PN (pseudo noise) sequence of this type has most of the energy in frequency components that extend from a fraction of a Hz up to 'Nyquist' (close to half the clock rate), with some of the energy in the higher alias frequencies but rolling off with a SINC(X) response.

Two of the DVMs claim to measure 'True RMS', the other older one doesn't make this claim. The 5V peak-peak 29kHz clocked PN sequence gave three different results:

- AVO M806 (quite old, not true RMS) - 1.70V
- METEX M-3660D (True-RMS) - 2.47V
- ISOTECH ICM36R Clamp ammeter + DMM (True-RMS) - 1.74V

The older AVO unit is not true-RMS and probably measures average, assumes a sine and normalises to this. In these circumstances it should show $2.5/\sqrt{2} = 1.77$V. It is also quite old – at least 20 years – so may not have a particularly high frequency response and the higher frequency components may be causing a bit of a roll-off. A reading of 4% low is perhaps not too outrageous in this case

The METEX gives, near enough, the correct real RMS value, which at frequencies going up beyond audio is impressive for what was, a few years ago, a far-Eastern made relatively cheap and unknown bit of test equipment. Further testing will be needed to know for certain if this is correct, or merely a fluke.

The ISOTECH unit is not at all impressive. Either its frequency response lets it down, or it measures peak and is not doing a proper RMS approximation. To be entirely fair I bought this one because I wanted a DC clamp-ammeter, but as it also had AC/DC volts and ohms it had to go in the test bucket.

Discussing this matter on the RSGB Technical Group, a few comments were received: Paul Elliot, G0TXL wrote, "When I was looking at specs for handheld DVMs a while back I found few could handle much above 400Hz with any accuracy. The Fluke True-RMS range seemed to be better than most but only two or three could handle beyond 20kHz. I suspect that may be your issue". From Jim Moritz, M0BMU, "I have an Iso-Tech ICM30R clamp-multimeter, which seems to be quite similar to your ICM36R. I had a peek inside to see what is doing the RMSing – it has an AD737 RMS-DC converter, one of many produced by Analog Devices that are basically a real-time analogue computer implementation of the RMS calculation. The data sheet is quite informative – being a device that uses non-linear elements. Bandwidth depends on signal amplitude, being only about 1kHz with a 1mV RMS input for a few percent error, but increasing to about 100kHz once you get into the 10s of millivolts. The AD737 is quite an old design now, and things move on; I see from the Analog website they are now offering devices operating on similar principles such as the AD8361 that goes up to 2.5GHz! I also have a function generator that does a PRBS output. To replicate your test I set this to 5V pk-pk with 29kHz clock and the ICM30R measured 2.06V RMS; reducing the clock to 1kHz produced a reading of 2.59V. Feeding it with a 2.5V RMS sine wave produced a reading of 2.62V, but it is 3dB down around 7kHz, so definitely Iso-Tech have not achieved optimal bandwidth with this design. I did check the waveforms on my digital 'scope, which showed them to be as close to nominal as it can measure. Older, or cheaper modern DMMs have 'average responding, scaled to RMS for sinusoidal input' AC ranges, that use an op-amp in an active full-wave rectifier circuit, like Fig 21 in the ICL7106 DMM chip data sheet **[1]**. This is only accurate for sine wave inputs, similar to the AC ranges in analogue multimeters like the old AVO 8 and its friends."

TL431 Shunt Regulator

This three-pin device is often forgotten when a small low power voltage regulator is needed. It is a threshold device that switches hard on when the third, adjust, terminal reaches 2.5V, otherwise it is off. Such basic operation hides how it can be used in many ways.

First as a shunt voltage regulator, as shown in **Figure 2a**. The two feedback resistors are selected to give $V_{ADJ} = 2.5$V at the wanted V_{OUT}. The feedback ensures the current drawn through the source resistor is exactly that needed to maintain the wanted output voltage across the device. Although shunt regulation is wasteful of power and only suitable for low current applications, there are times when it really is the only solution to providing a regulated voltage for low power circuitry. Such as powering a microcontroller when the only supply is high voltage rectified mains.

The on-off nature of the output, behaving like a comparator, means it can be used to provide voltage feedback via other non-linear components such as opto-isolators as shown in **Figure 2b**. It is in this application that the use of the TL431 is very widespread and usually unnoticed – in a very large number of switch mode PSUs. The output side of the SMPSU has a voltage divider on the output delivering 2.5V to the ADJ pin of the chip. The output drives an opto-isolator that crosses to the input side with isolation rated up to a few kV. The opto-isolator output controls the pulse width modulator driving the input to the transformer. Thus a control loop is set up across the isolation barrier, using the TL431 as voltage reference. If you have a SMPSU and want to change the output voltage, open it up and look first of all for a TL431 chip in the feedback. Beware though, it may have more than one – they are so cheap and easy to use a second device may be incorporated as a safety overvoltage trip.

There are numerous other uses of this device, and the data sheet suggests many different ideas – some a bit 'unusual'. A final note of caution, the two main terminals are referred to as 'Anode' and 'Cathode' – a harkening back to old valve days. In this case, it is being referred to as if it were behaving as an avalanche, reverse biased, diode. The 'cathode' is connected to the positive and the 'anode' terminal to the negative side. Confusing, yes! it's caught me out more than once.

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andy.g4jnt@gmail.com

Programming a DDS for Alias Products

Deriving the value to programme into the setting register of a Direct Digital Synthesiser is a straightforward calculation when a normal output is wanted. Assuming a 32 bit device like the still ever-popular AD9850,

$$N = \frac{F_{OUT} * 2^{32}}{F_{CLOCK}}$$

If we have a device clocked from a 125MHz oscillator and a wanted output at 19MHz, the value N that has to be programmed into the chip is 19/125 * 4294967296 = 652835029, or in hexadecimal 0x26E978D5. But what if we want a higher alias product? A DDS set to deliver F_{OUT} generates a comb of frequencies of the form $N.F_{CLOCK} \pm F_{OUT}$ as shown in **Figure 3**. These are normally removed by the low pass filter, unless you actually want one of them in which case a bandpass filter can extract the alias.

To calculate the value of N required for a particular alias product is a bit tedious, involving trying various multiples of the clock and subtracting or adding the wanted output until a suitable value for the basic F_{OUT} is found. The problem is made even more complicated if the calculation is to be performed in a small microcontroller on the fly. But quite by chance, at 'JNT labs, a short cut using just basic integer arithmetic showed up.

It came about as a few years ago I'd written a routine that emulated the CAT protocol of Icom radios to set the frequency of an LM2541 Fract-N synthesiser chip from driver software such as WSJT-X **[2]**. I was modifying the routine to control an AD9850 DDS, keeping all the original CAT decoding and frequency setting code, calculating N from the requested frequency in 1Hz steps using a 32 bit x 32 bit multiplication process (64 bit result) in a PIC microcontroller. As part of the testing, I requested a frequency of 144MHz forgetting that a DDS clocked at 125MHz couldn't do this. The PIC went away and blindly calculated a value to send to the DDS chip equivalent to 144/125 * 2^{32}. It didn't know or care that this is a value higher than the DDS could cope with and was nonsense. The way I'd written the PIC code, only the lowest 32 bits of the result were used and sent to the DDS, any higher bytes were thrown away. Looking at my frequency meter it was happily reading 19MHz. 'Oh', thinks I, 'that's the fundamental needed to get an alias product at 144MHz, 125 + 19 = 144MHz. How convenient'. I then asked it to generate 100MHz, and it gave an output at 25MHz. Again correct, with an alias at 125 – 25 = 100MHz. Any frequency requested right up to beyond UHF always gave the correct fundamental that would result in an alias at the requested frequency. Why was this happening, it could be very useful? It turns out that the fortuitous result is all a function of truncating the binary integer arithmetic and works for all the alias products of the form $F_{ALIAS} = F_{CLOCK} \pm F_{OUT}$. The rather surprising finding comes about as follows:

$$N' = \frac{2^{32} * F}{F_{CLOCK}}$$

With N' being the effective value of N for the alias above Nyquist.

If a demanded value of F exactly equal to the clock is requested, N is then equal to 2^{32}, which in binary is five bytes, equal to 01, 00, 00,00, 00. If only the lower four are used to send to the chip, a value of zero is programmed in. That itself is a pointless scenario giving zero frequency output, but it also works for frequencies higher than the clock. The fifth (and higher) bytes represent the alias number which is not used. The remainder of the result in the 32 lowest bits is then the fundamental frequency that needs to be programmed into the chip, the N value, to allow the alias product to be delivered where it was calculated. That seemed clear enough for alias products of the form $F_{ALIAS} = F_{CLOCK} + F_{OUT}$ but what about those of the form $F_{ALIAS} = F_{CLOCK} - F_{OUT+}$ where N' doesn't always overflow four bytes? And this is where the advantage or otherwise of mixing signed and unsigned integer arithmetic, normally a programmer's nightmare, actually helps.

Inside the DDS, the N value is used to increment a counter, at the clock rate, whose count is used as a lookup to a table of SINE values before sending to the D/A converter. When the counter overflows it just starts again, throwing away the bits in the overflow. Equivalent to a sinewave going back to its minimum or maximum every cycle. When a value of N corresponding to a frequency between $F_{CLOCK}/2$ and F_{CLOCK} is programmed in, the counter overflows nearly every time it increments by this value, in effect behaving as if the counter were decrementing by some smaller value instead. This effective decrement works just the same in the DDS, which doesn't care about negative or positive frequency, and is just the value needed to generate the correct F_{OUT} for the requested alias product. An alternative way of looking at this is to consider the 32 bit result of the simple calculation as a signed twos-complement number. If the MSB is set, (which it would be for any requested frequency in this range using simple arithmetic) then it means it's treated as a negative number even though the 'real' calculation does not involve negative numbers.

All very convenient indeed if a DDS device is required to deliver products at its alias frequencies. Just do the calculations using simple 32 bit integer arithmetic and there is no need to actually calculate the fundamental.

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2: http://g4jnt.com/CAT_Controlled_Synth.pdf source code at http://g4jnt.com/CAT_Ctrl_LO.asm

Icom ID-52E VHF/UHF dual band D-Star transceiver

I was excited to have the chance to take a look at the new Icom ID-52E. D-Star was the first digital mode that I tried out, back in 2009, with a purchase of an IC-E92, which is still in my shack and working well. What would one of the newer models of D-Star portables have to offer, I wondered.

As ever, let's take a look at what Icom have to say about the ID-52E.

The ID-52E VHF/UHF dual-band digital transceiver is the latest in a long line of D-Star handportables from Icom and succeeds the popular ID-51EPLUS2. Two versions will be available globally, the ID-52A for the USA and ID-52E for Europe.

The radio features a large transflective colour display that makes it easy to see outdoors, even in bright sunlight. The size of the display has also been increased to 2.3 inches from 1.7 inches which was adopted on the ID-51E. The ID-52E supports Bluetooth communication as standard. You can wirelessly connect to Android devices with the ST-4001A/ST-4001I Picture Utility Software when the RS-MS1A Remote Control Software installed. The optional VS-3 Bluetooth headset is also available, for hands-free operation.

Features

- *Simultaneous reception in V/V, U/U, V/U as well as DV/DV.*
- *Airband reception is expanded from VHF to UHF (225 to 374.995MHz).*
- *Can be charged via a micro USB connector.*
- *Audio output has been increased from 400mW to 750mW.*
- *The latest D-STAR functions allow you to send, receive and view saved photos on an installed microSD card using only the ID-52EE.*
- Accessories for the ID-51E, including battery packs and microphones, can be used.

In addition to the above, the ID-52E has a variety of other features including DR function with easy set-up, built-in GPS receiver, micro SD card slot, IPX7 waterproof construction (1-metre depth of water for 30 minutes), and Terminal/Access Point modes.

First impressions

Unpacking the ID-52E, the first impression is of a more sizable unit than I'd somehow expected. The build construction feels solid and it's well finished. The front of the unit is dominated by the colour display, which is nice and bright even in sunlight. There are six buttons and a menu/rocker control in the centre of the unit. There is a slot for the micro SD card (make sure you insert the card with the connections facing forward). There's a DC input jack (a charger is supplied), micro USB connector as well as microphone/speaker jacks.

Getting started

Although a good quality instruction manual is provided (for a full manual, you need to go online and download it), I found it relatively straightforward to get started with the radio. Because I do not have a local D-Star repeater in range, my first test for the ID-52E was to get it talking to my digital hotspot and try some D-Star QSOs.

This was a simple matter of entering my callsign into the appropriate field in the rig (the manual guides you through this), changing to the frequency of my hotspot and engaging DV (digital) mode. Having done this, I started to hear the D-Star stations coming through from reflector REF030C that I had set up on the hotspot.

When I tried to call stations, I noticed that the hotspot didn't seem to hear me. Then I remembered a quirk that I've seen on other Icom D-Star radios when using a hotspot. You need to enable duplex, but set the repeater offset to 0. I don't know why this works, but it does and I have seen reference to it elsewhere, so I don't think it's just me. Having sorted that out, I was soon making QSOs.

By chance, one of my first QSOs was with Jonathan, M0JSX who was also using an Icom ID-52E and in fact, you might enjoy taking a look at his YouTube video all about the rig that you can find at https://youtu.be/YeexzvS3dQI. Jonathan was enthusiastic about his ID-52EE and mentioned a couple of features that he loved, which as he put it, that he hadn't realised he needed; the auto-answer feature and the scope. I'll make sure to have a look at those later.

The ID-52E has GPS built in, so can determine your position. You can set it up to send your location

The first utility I tried was the ST-4001I Share Pictures utility, transferring pictures from my iPhone and adding my callsign.

periodically. In fact, I noticed receiving these type of beacons when I was 'tuned' to REF030C, with stations sending these locations that are then displayed on the screen of the ID-52E while the rig announces the callsign in speech. I wondered whether I would find this annoying, but decided I liked it, particularly if you were working or not paying attention to the screen of the ID-52E. This digital version of APRS is called DPRS. In addition, there is plenty of GPS functionality. You can save locations to GPS memories and there's even a GPS alarm, so that if a station comes into a particular area, transmitting a DPRS beacon, an alarm will sound!

Over the next few days, I found myself enjoying using the D-Star reflectors and making QSOs around the world. Audio quality both on transmit and receive using D-Star seemed to be excellent. When using the hotspot, I used the Super Low Power setting of 0.1W, which meant that the battery life was very good indeed. High power is 5W, Medium 2.5W, Low2 1W, Low1 0.5W and SLO 0.1W. A useful range of power levels depending on how you want to use the radio.

The battery can be charged using the supplied charger through the DC in jack, or it is possible to charge using the micro USB connector. USB charging is definitely a plus point as most of us carry a USB charger around to supply our phones. Just make sure you have the correct lead.

In use

The ID-52E has the dualwatch feature that allows you to monitor two frequencies at the same time. It's not full duplex (sorry satellite operators!) but even so, you could monitor the 2m FM calling frequency on one side of the radio and your digital hotspot on the other

One of the excellent features of the ID-52E is the built-in repeater directory. Long press the DR button and you'll see the repeater directory displayed. You can page through to find the repeater you want, using the select wheel on top of the radio. You'll go through the D-Star repeaters first, organised by band and then the analogue (FM) repeaters.

A really handy feature uses both the GPS and repeater directory to find your closest repeater. Simply press the Select button, click on Near Repeater and then indicate whether you want to search all repeaters, FM repeaters or D-Star repeaters. You'll then be shown a list of repeaters sorted by distance from where you are.

My only minor criticism was that as far as I could see, the repeater directory only included UK repeaters. If, like me, you're lucky enough to live close to the coast, then your most accessible repeaters may not actually be in the UK! Mine are in the Republic of Ireland and I'm sure there are places on the channel coast where it's easier to work a repeater in France than in the UK. Of course, in this situation, there is nothing to stop you adding your own repeaters into the directory, which is easiest done on the computer. Software is available to do this and in fact, if you look at the latest TX Factor video, Bob, G0FGX shows how to do this. You can also add stations into the repeater list, without a computer, from the keypad.

If you have a D-Star repeater close to you, then you will be able to use the ID-52E to link and unlink different reflectors- it's all quite straightforward once you get used to it.

As Jonathan, M0JSX had mentioned the Auto Reply feature, I thought I'd see how this worked. The idea is that if someone calls you on D-Star and you are not available, then you can configure the ID-52E to either play a recorded voice message of up to 10 seconds (assuming you've put a micro-SD card in the rig) or to send a position report based on your GPS co-ordinates. Clearly, the rig needs to be switched on to do this, but if the rig was on in the shack with the volume turned down because you were busy, this could be a good way of telling people you are around, but they should call back later.

Menu display of the Icom ID-52E.

Jonathan also mentioned the scope function. This is a bit like a simple pan adapter and allows you to take a look at a chunk of the RF spectrum so that you can see where there is activity. There are various modes available that allow you to determine what part of the band you want to look at. It could certainly be useful in areas that you are unfamiliar with.

The ID-52E features both a QSO Recorder and Voice Recorder function. The QSO recorder can be set to record all QSOs onto the Micro SD card. Both outgoing and incoming transmissions are recorded. The files are organised by folder based on date. Once you switch the QSO recorder on, it remains on, even if you switch the ID-52E off and back on again. The Voice Recorder function allows you to use the ID-52E as a Dictaphone (remember those?), you press the PTT to record. As with the QSO Recorder the files are stored on the Micro SD card.

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EMC

Almost all electronic products contain switching power supply units (PSUs). If these are poorly designed or faulty, they can affect users of the MF/HF radio spectrum including radio amateurs and short wave listeners plus wired telecommunications networks such as ADSL and VDSL.

In this month's EMC column we look at some results of testing three small plug-in switching power supply units (PSUs) using the Rohde & Schwarz FPC 1500 spectrum analyser that the RSGB EMC Committee now has for supporting its EMC investigations work (see also Feb 2022 *RadCom* EMC Column).

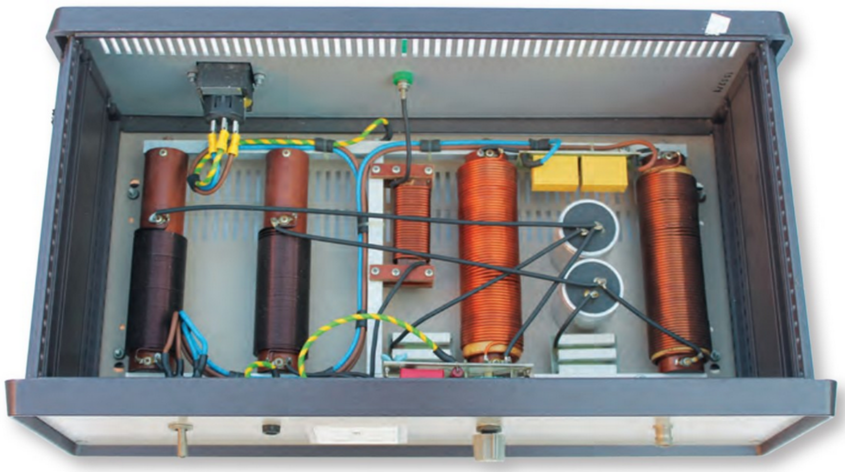

PHOTO 1: **A Line Impedance Stabilisation Network (LISN) used for EMC testing.**

Artificial Mains Network

Below 30MHz, EMC standards measure conducted emissions of interference into the mains using a Line Impedance Stabilisation Network or LISN, also known as an Artificial Mains Network (AMN). This network and other coupling devices are specified in BS EN 55016-1-2:2014. **Photo 1** shows a Chase MN 2050 LISN that was kindly donated by a former EMC Committee member. This model is designed for use by professional EMC testing laboratories and it covers 9kHz - 30MHz with a current rating of up to 15 amps. It contains capacitors that pass a significant reactive mains current to earth, so it would trip a Residual Current Device (RCD). To avoid this, it is being used via a 500VA mains isolating transformer for testing low current devices.

An essential accessory for mains conducted emission testing is an attenuator/transient limiter to protect the measuring receiver or spectrum analyser.

PHOTO 2: **A power supply unit for a Raspberry Pi 4.**

Raspberry Pi PSU

Photo 2 shows the first PSU tested, a 5.1V 3A mains adaptor for a Raspberry Pi 4. **Photo 3** shows the test set-up. The green wire is connected to the shell of a scrap USB plug that is plugged into a spare USB socket, which is connected to the negative side of the DC PSU. This wire can be AC grounded via 150Ω to the ground plane (mains earth) or it can be left 'floating'. The Raspberry Pi 4 PSU was tested with the negative side of the DC PSU AC grounded via 150Ω to give the worst case level of emissions.

The blue trace in **Figure 1** shows the mains conducted emissions from the Raspberry Pi PSU in 9kHz bandwidth using Quasi-peak (QP) detection. The yellow trace shows the measuring system noise floor and a few medium wave broadcast signals, after allowing for the effect of the attenuator/transient limiter and other factors including the LISN. It can be seen that the measuring system noise floor rises by about 35dB from 10MHz down to 100kHz.

Marker M1 shows that the Raspberry Pi 4 PSU switches at a frequency of about 30kHz. This is an advantage as it produces lower levels of RFI than

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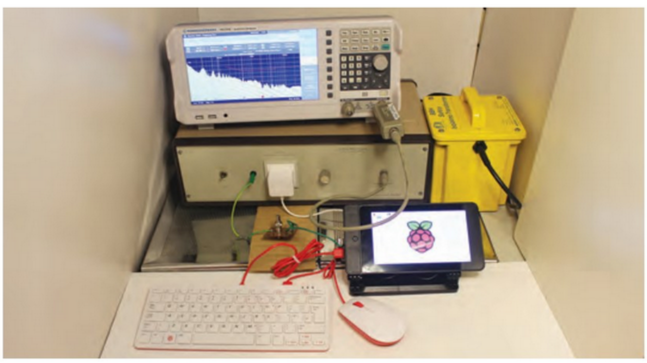


PHOTO 3: **Conducted emission testing of a Raspberry Pi 4.**

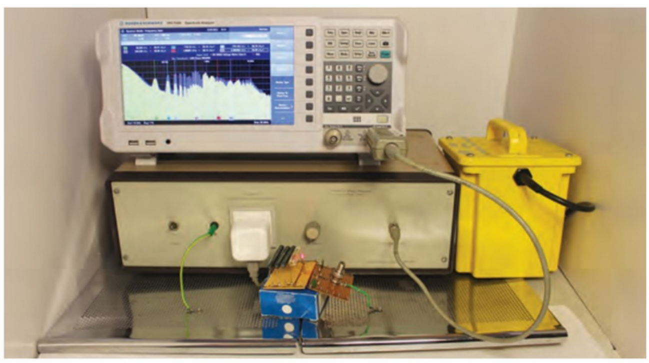


PHOTO 4: **Conducted emission testing of a 5V security camera PSU.**

FIGURE 1: **Mains conducted emissions from Raspberry Pi PSU (blue) and measuring system noise floor (yellow).**

FIGURE 2: **Mains conducted emissions from 5V security camera PSU with load floating (yellow) and load grounded via 150Ω (blue).**

some other types that operate at higher frequencies. Marker M2 shows the 2nd harmonic around 60kHz and Marker M3 shows the 3rd harmonic around 91kHz.

From 150kHz upwards where the EN 55022 and EN 55032 limits start, the level of harmonics is about 20dB below the limit and the harmonic levels fall progressively. Above 500kHz where the limit line flattens off, the harmonics continue to fall. This is what should happen and at 1.8MHz, they are at least 30dB below the limit, 35dB below at 3.5MHz and at least 40dB below at 5MHz and above.

These results show that if a low power PSU is well designed, it can achieve levels of RFI that are well below the EN55022 limits and it is unlikely to cause interference in amateur bands. This sets a standard against which others can be judged. If you need a 5.1V 3A PSU with a USB 'C' output connector and low RFI, this looks like a good choice.

Security camera PSU

Photo 4 shows conducted emission testing of a PSU for an outdoor security camera. The power resistors provide a 2.5A load and the red LED is a hot resistor warning light. The other circuit board with the BNC connector provides 150Ω AC-coupled load to the ground plane which is mains earth. This can be switched in or out by fitting or removing the 50Ω terminator on the BNC socket.

Figure 2 shows the mains conducted emissions from the 5V security camera PSU in 9kHz bandwidth using QP detection. The yellow trace is with the load 'floating' relative ground. The switching frequency is around 60kHz and the harmonics fall progressively with frequency up to the 6th harmonic, as would be expected. Above 400kHz, the harmonics start to rise and at 3.5MHz, the emission is very close to the limit. Due to measurement uncertainties, we can't say whether it would pass or fail if tested on an accredited EMC test site but it appears marginal to say the least. If the load has low enough capacitance to ground, we found that it sometimes passed the test with 0.1dB to spare but at other times it exceeded the limit.

This PSU has a USB output socket that powers the camera via a 7.5m long cable. To simulate the effect of the cable, we tested the PSU with a 150Ω AC-coupled load from the DC output to ground. This causes the emissions to increase as shown by the blue trace in Figure 2. The emission would exceed the limit if tested under these conditions although it is not known whether it was tested with a long cable. Clearly the effect of the cable needs to be taken into account as a 7.5m cable is a quarter wavelength long at 10MHz and this PSU has been reported to cause significant interference on some amateur bands in practice.

12V PSU

Photo 5 shows the underside of a PSU with an output of 12V 0.5A that is used to power some networking equipment. The conducted

FIGURE 3: **Mains conducted emissions from 5V security camera PSU with load grounded via 150Ω (yellow) and DC output conducted emissions (blue).**

emission test setup was similar to Photo 4 except that the power resistors provide a 0.5A load at 12V. A 150Ω AC-coupled load to the ground can be switched in or out.

Figure 3 shows the mains conducted emissions from the 12V 0.5A PSU in 9kHz bandwidth using QP detection. The yellow trace is with the load 'floating' relative ground. The switching frequency is around 60kHz and the harmonics fall progressively with frequency up to the 3rd harmonic, as would be expected. Above 180kHz, the harmonics start to rise although they are still well below the limit.

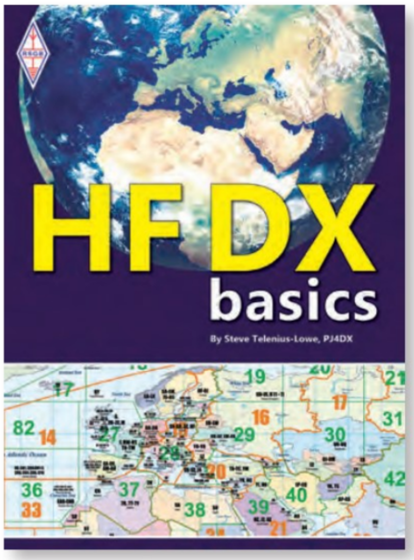
This PSU is designed to power a networking device that may have other cables connected. To simulate the effect of the cable, we tested the PSU with a 150Ω AC coupled load from the DC output to ground. This causes the emissions to increase as shown by the blue trace in Figure 3 although they are still at least 10dB below the limit at 3.5MHz. In practice this PSU has been reported to cause significant interference on amateur bands. There are two possible reasons for this:

- First, the EN 55022 Class B limit is based on interference being injected into the mains, where only part of it is converted to a common-mode signal that radiates but the emission from the DC power cable comes out as common-mode so all of it can radiate.
- Secondly, the RF interference via the output cable gets out via the interwinding capacitance of the transformer. We measured this as 31pF so it has a reactance of 1.47kΩ at 3.5MHz. This is quite a high impedance source so it drives a near constant RF current into the output cable whether its impedance to earth is low or high.

Book Review

HF DX Basics

By Steve Telenius-Lowe, PJ4DX



With sunpot cycle 25 on the rise, the timing of this book is well planned. We are looking at increased propagation and more chances of being able to work DX. Following on from the book *HF SSB DXing,* Steve, PJ4DX has revised and updated the book to include more than just SSB operation - Morse code and datamodes such as FT4 and FT8.

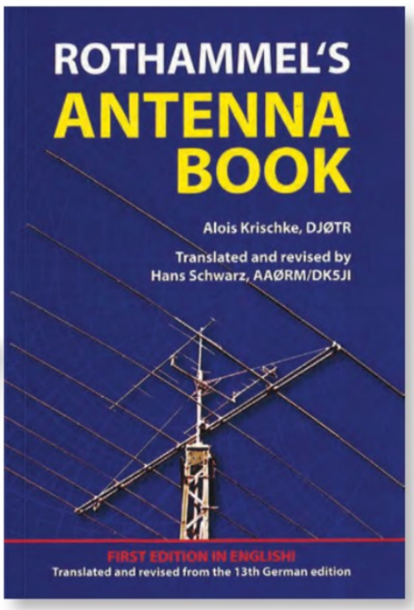
To set the foundation, the book works through the different tools you will find useful when DXing. Understanding the DXCC system, Logbook of The World and Club Log will help keep track of your achievements and see where you can make improvements. The chapters that help you choose which antenna would be best for your station was very helpful. You can actually get good results with a very modest station by choosing the right options. This includes deciding which transceiver would work for you too. Of course, once your station is ready, that's just the start. Where will you find the DX? The author takes you through the propagation on the various HF bands, describing when the band will give the best results. Once you understand that you will have a better chance. But there are also DX newsletters than can point you in the right direction. If you know a station is going to be operating from a certain part of the world, you can then use your propagation knowledge to work out the best time to search out the DX.

The book takes you through the most common modes for DXing - SSB and FT8, describing how the mode works and showing how to make sure your signal is as good as it can be.

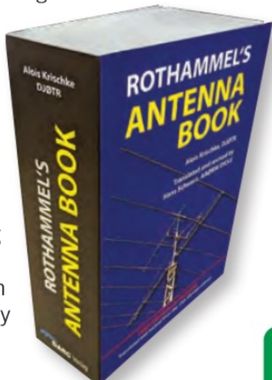
Steve, PJ4DX is a well-known DXer and previous editor of *RadCom*. He has an easy-to-understand style of writing and makes even the technical aspects of DXing very readable. How about challenging yourself in the world of HF DXing? It is possible with an average 100W station and wire antennas. Be careful though, if the 'bug' of DXing bites, your hobby may never be the same!

Size: 174 x 240mm, 144 pages ISBN: 9781 9139 9522 5
Non Members £11.99, RSGB Members £9.99

Rothammel's Antenna Book



This is one of the best antenna books I have read in a very long time. Known in Germany for years as the 'Antenna Bible', this is the first English translation of this 1600 page reference for antenna design covering LF to the microwave bands and it has certainly earned its name. The book begins with comprehensive sections covering the general principles of antennas and electromagnetic waves. This sets a solid foundation for the terms used in the rest of the book making it an excellent reference book. Next is an examination of a broad range of transmission lines and matching systems. The book's main section provides a detailed look at almost every type of antenna you can imagine. The antennas are narrowly grouped by type; for example, there are separate chapters for horizontal HF monoband, horizontal HF multiband, long wire arrays, broadside and end-fed arrays, loop antennas, compact antennas, horizontal directional HF antennas, etc. Each chapter begins with a well-written introduction describing the key features of each antenna type and references to articles that either introduced or refined the designs.



Each antenna design includes the formulae for calculating the dimensions and antenna gain, giving the reader everything you need to understand or re-create each design. The final sections of the book include chapters covering antenna measurement, practical construction techniques, lightning protection, grounding and EMC. *The Antenna Book* has been continually updated, and this edition contains chapters on electromagnetic field exposure and antenna-related computer programs. The book uses extensive referencing throughout, thus making it easy for the reader to dig deeper into any designs.

This book will be a valuable reference for anyone interested in antenna design and would also make an excellent addition to any club's library. Well worth reading.

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Technical

Experiments with 1mW on 1296MHz

I started to explore what could be done with 1mW using homemade equipment on the 1296MHz band.

A lovely Spring day for radio experiments on a nearby hilltop (by the way I am noting transmissions times on a pad while holding the pen lid in my mouth, not smoking a cigar!). The box mounted on the tripod contains the 1mW transmitter and dipole antenna.

In Part 1 last month, I described some experiments using 1mW on 1296MHz. Now we will look at some notes and thoughts about the 1296MHz band, which I hope will be useful for people relatively new to these frequencies and those who enjoy making radio equipment.

What does the 1296MHz band have to offer? It offers low noise, highly sensitive receivers and small yet high gain antennas that are still within the range of what can be made at home.

1296MHz transmit-receive paths are influenced much more than 144MHz paths by large buildings and other objects obstructing the signal path and by the weather. On long paths, water vapour can have an effect. Warm air tends to hold higher concentrations of water moisture than cold air, so winter days are often better than summer days (this is especially so on the higher frequency microwave bands).

A great band to experiment

As the 1296MHz band wavelengths are a tenth of those on the 144MHz band, the antennas are proportionally smaller. 144MHz band antennas that can only ever be the dream to the city dweller, can be realised on 1296MHz! You can see what I mean in Photo 5a and 5b of the two 4 x 5 element arrays for 144MHz and 1296MHz bands: the tiny one I am holding in my hands is the same antenna but for 1296MHz. Note: wooden booms are fine for 144MHz antennas but the moisture in the wood does not make it a good building material for 1296MHz antenna booms.

Although antennas are tiny on 1296MHz, they are not too tiny to hinder making your own designs and experiments – as long as you are careful with your measurements. A fantastic array of different types of antenna can be made on 1296MHz including: short, long and stacked Yagis, Rhombic and V-beams, colinear arrays, helical beams (with circular polarisations), slot antennas, parabolic reflector antennas and many others.

These high gain antennas help overcome the higher path losses at these frequencies, but one has to remember that very high gain antennas require precise alignment with the target. It's possible to miss a contact if you are not pointing correctly!

I worked a station in Normandy recently on the 144MHz, 433MHz and 1296MHz bands. He had different antennas and powers on the three bands and so it's difficult to make direct comparisons, but over this path we had good signal strength on all bands and the signals got stronger as we went up in frequency. It is often said it's worth going as high a frequency as possible to make a contact. This makes 1296MHz a very interesting band to have in addition to 144MHz and the 432MHz bands, without having to delve into the subtleties and complexities of the much higher frequency microwaves.

Feeder loss

A major issue at 1296MHz is feeder loss. A 20cm piece of cable does not look very long but it's about a wavelength (give or take the velocity factor). The equivalent on 3.5MHz would be 60-70m long! A 15m length of RG58 that might be practical (but perhaps not ideal) for a portable set up on 144MHz band, would be a disaster on 1296MHz. The cable would have very high loss (about 18dB for a 30m length at 1000MHz) and would effectively be a lossy noise source plugged into the receiver!

I have a 15m length of Andrew Heliax (approximately 20mm diameter) that has a low loss at 1296MHz but unfortunately, it's very heavy and quite inflexible cable to experiment with. I use a 15m fibreglass mast on my home location that is fixed / supported at the base (no space for guy wires) but running approximately 10kg of Heliax up the mast just does not work – the weight curves the mast.

I currently use a 12m length of CLF-400 coax between antenna and transverter, which is a good compromise between loss, weight and flexibility.

For receiving experiments, my ideal set up is to use a very small 1296MHz to 144MHz converter (see PE1CMO further on), which is so small and lightweight it can be fitted directly onto the antenna (with a very small coax lead). Then I can 'pipe' the converted signal down the mast cable at 144 MHz (where the losses are far less) using RG58 or mini-8.

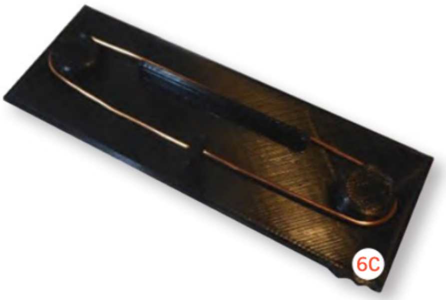
1296MHz gear

The ICR7000 is fairly old now (approximately 1990s) but is a very well made and well regarded receiver that covers all modes (AM, FM, SSB and CW) from approximately 25MHz to 1.999GHz. The radio even has a spare phono socket on the back that you can use to take a signal from the receiver for a particular purpose. I tapped into the S-meter circuit so that I could feed this to a data logger.

The S-meter circuit creates a fairly linear relationship between its voltage (0-2.5V) and the S-scale S0 = 0V, S1 = 0.2V ….. S9 = 1.4V,

PHOTO 5: As the 1296MHz band wavelengths are a tenth of those on the 144MHz band, the antennas are proportionally smaller.

PHOTO 6A-C: I have also used the 3D printer to create jigs for bending just the right amount of wire to create folded dipoles for 23cm band Yagis, as well as a handy cutting jig to help saw semi rigid coax.



to S9 + 30dB = 2.1V, which can be logged by my data logger (0-10V input).

Receive converters

PE1CMO produce some very nice 1296MHz band gear [1]. In particular they produce a tiny state-of-the-art 1296MHz to 144MHz receive converter, perfect for backpack portable experiments with a FT-817 receiver or for putting on the top of a mast.

The PE1CMO converter has good band pass filtering on the input and seems to work very well indeed. It is so small and light it can easily be fitted right at the antenna and the converted signal (144MHz) sent down the coax with far, far less loss and noise.

Transverters – LT23S

This is an old but good SSB Electronics transverter that converts from 144MHz to 1296MHz, which claims receiver noise figure of 1.8dB and 10 watt output power on the 1296MHz band. I use this to convert the 1296MHz signal from the receive antenna down to 144MHz and log the ICR7000 (tuned to 144MHz) S-meter circuit.

AR 8200 MKII v ICR30

Many amateur radio handhelds receive on 1296MHz, for example my TH-F7 covers the band but only for AM or FM modes. I have tried making a BFO, so I can listen to CW (eg beacons) when set to AM, but I could not get this to work well.

A few years ago I brought a second-hand AR8200, which is a wide frequency range handheld receiver that covers 1296MHz and has CW and SSB modes. However, the one I purchased did not receive well on 1296MHz – high noise and instabilities – which was disappointing.

One has to be careful buying second-hand gear.

Recently I purchased an ICR30, which really is a fantastic portable radio that covers all modes from 100kHz to 3GHz. Even though it's quite a recent radio, Icom is no longer producing the radio (one of the main IC manufacturers used for components in the radio has gone bust).

A note on band pass filtering

The pulses from nearby mobile phone masts can cause havoc with UHF equipment and so some sort of input band pass filter is a must (especially if you are going to go portable on hills close to cell phone masts etc.). If you buy a wide band hand-held receiver, such as the amazing ICR30 (which covers 100kHz to 3GHz) bear in mind that there is no room in this tiny marvel to have the required 'stack' of band pass filters that you would need to actually receive reliably over such a large range! So, for ideal reception you either you have to select the attenuator(s) or fit a band pass filter between antenna and receiver (or both preferably).

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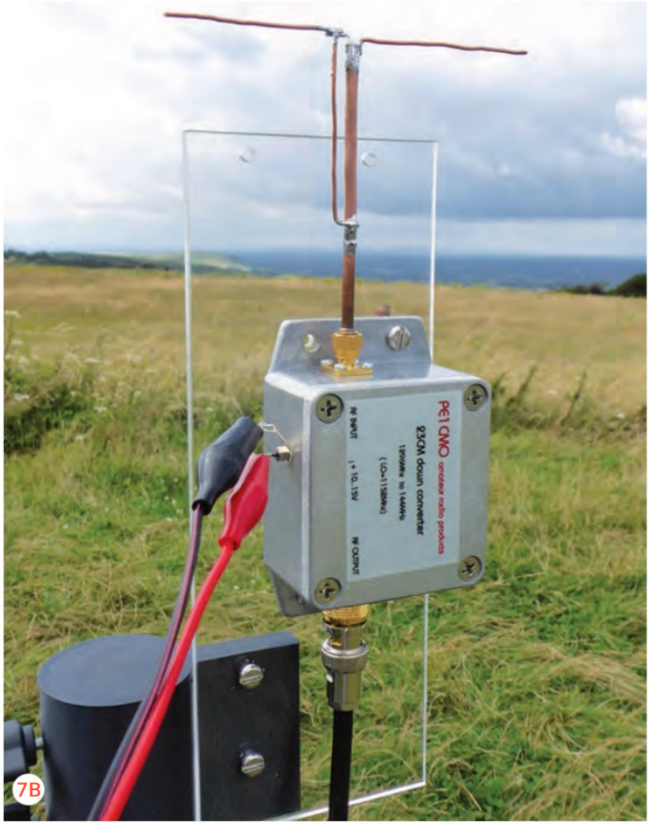

PHOTO 7A-B: **On top of Ditching Beacon receiving the Isle of Wight beacon (1296.800MHz) S8 using a dipole on the PE1CMO receive converter and using a FT-817 (tuned to 144.800MHz).**

SWR and power measurements

SWR meters for 1296MHz are expensive and for most of us not something we might use enough to justify the cost (although a radio club might invest in one for members to use etc.). However, a few years ago DC6ZM wrote a nice article in *RadCom* [2] showing how you can make an economical UHF SWR and power meter using AD8318 demodulating log amplifiers and surplus coax directional couplers. I have built this design and it allows me check my transmitter and receiver antennas and also measure the power output of my low power transmitter [5].

Homemade Yagis

One can make metal boom Yagis at 1296MHz, but I have found insulating booms are preferable. You need to be very accurate when cutting the element lengths (fraction of a mm). It should be noted that water vapour can adversely effect 1296MHz antennas (eg rain water).

Many commercial Yagi designs don't place the elements through the boom, but use small plastic holders to raise the elements above metal boom. Unless you can braze the elements to a brass boom to get a perfect contact each side of the boom it can cause problems. I made a Yagi using a 10mm square cross section aluminium boom (taking care to take into consideration the shortening effect of the boom) and push fitting the elements into snug holes along the boom. I found the SWR was super sensitive to mechanical vibration. It seems that the elements were making and breaking contact either side of the boom effectively randomly adding 5mm or so to the element lengths and rendering the antenna useless. Redesigning the element lengths for a non-conducting Perspex boom solved the problem.

There are useful Yagi simulation web pages that seem to work well for designing 1296MHz antennas and some are listed on the folded dipole jig page on my 3D printing pages **[3]**.

Help from a 3D printer

I have a lovely 16m long fibreglass mast in my backyard that allows me to get antennas high enough to be above most of the houses and chalk hills in the immediate vicinity. However I don't have any space to put up guy wires for this mast, so I rely on the mast being supported from the bottom using TV type brackets. The antennas on this mast need to be very lightweight to avoid problems with the mast flexing. Thankfully, 1296MHz antennas are just this; small and light. However, commercially made rotators are quite heavy, so I 3D printed a very small lightweight rotator for temporary experimental use, which is working out well,

I have also used the 3D printer to create jigs for bending just the right amount of wire to create folded dipoles for 1296MHz band Yagis. There is also a handy cutting jig to help saw semi-rigid coax, **Photo 6a-c**. Details can be found on my 3D printing section of my website [3].

Isle of Wight beacon measurements

The Isle of Wight beacon G8MBU (62m asl, 1296.8000MHz) is located at one of the high spots on the island and is about 80km distant. The beacon runs about 2W into an Alford slot antenna giving about 10W ERP **[4]**. I can rarely hear the beacon from my home location in Brighton (60m asl) as there are too many chalk hills in the path to my west. However, I do occasionally get a signal rising above the noise near sundown on some days. If I walk just a few 100m up my road towards the local high spot (Hollingbury Hill), the G8MBU beacon can easily be heard. It just shows you how very important a high and clear take-off is for 1296MHz work, **Photo 7A** and **7B**.

The highest spot near my location is Ditching Beacon (approximately 248m asl IO90VT) and the Isle of Wight is clearly visible most days. Using the PE1CMO converter with just a horizontal dipole directly on the input I can hear G8MBU very strongly as a S8 signal with the gear sitting onto of the Ditching Beacon trig point (see photo). It's interesting to note that, in the car park, just a few 100m away from the trig point (only a few 10m less height in altitude, but to the East 'behind' the top) you can't even hear the beacon.

It is clear that antenna height and a clear line of sight is key to success on the 1296MHz band.

Acknowledgments

I would like to thank Dave, 2E1EOO, Phil, G4UDU, G8MBU as well as Andy, G4JNT (PLL modules), F1CJN (1296MHz signal source), Sarah Hogben and Geoff Rowland.

Websearch

[1] PE1CMO converter: https://www.hf-electronics.nl/PE1CMO-Converters

[2] Measuring power, return loss and SWR at GHz frequencies, DL6ZM, *RadCom* March 2020, p. 30-32.

[3] G1EXG 3D printing web page: www.creative-science.org.uk/3D.html

[4] Personal communication with G8MBU, April 2022

[5] G1EXG radio web page: www.creative-science.org.uk/g1exg.html

Technical

The less is more guide to DMR

This article will show you only what you need to know to set up and use DMR on a budget.

Digital voice systems are complex. You only have to browse the massive amount of information on the web to blow your mind and decide 'I could never get my head around that' … and not bother. That, and the fact I wasn't sure if it was going to be interesting has kept me away from these modes. However, being ever curious I felt I should give any new(ish) aspect of our hobby a chance, so an inexpensive DMR radio and a hotspot board were duly ordered without giving either much thought. How difficult could it be? Fire it up and it will just work, won't it? Well, no, it took a while and a lot of *think, try again* loops before I got anywhere but it was both interesting and enjoyable with a little frustration thrown in.

There are four main digital voice modes, DMR, D-Star, P25 and C4FM/System Fusion. This article is about DMR (Digital Mobile Radio), which is a commercial standard adopted for Amateur Radio use. The P25 mode is also commercial and is probably of little interest for amateur use. Of the others D-Star is an Icom system although also sold by Kenwood and System Fusion, often called Fusion or C4FM is a Yaesu system. The latter two are no doubt easier to setup and use than DMR but are heavily tied into those radios and can be expensive. If you have a D-Star or Fusion enabled radio you may not want to dive into DMR, but if not this is a cheaper entry point and does have the advantage of more vendors and it's quite a lot of fun to set up for those who still like to play!

When we talk about digital voice modes, we are mainly talking about internet linked radios (often one handy to another). This article concentrates on a handy tethered to a hot spot. The simplest means of getting on-air. There are countless aspects not covered here but the clue is in the title.

This is not a guide in the normal sense of the word, you can't follow it from start to finish and have something working. It's not 'death by configuration'! There is so much of that on the web that there is absolutely no point in repeating it here. The problem I found was not lack of information but so much information that I was drowning in detail (mostly unwanted) before I even understood what it was all about. Use this in conjunction with the dearth of information on the web and other publications.

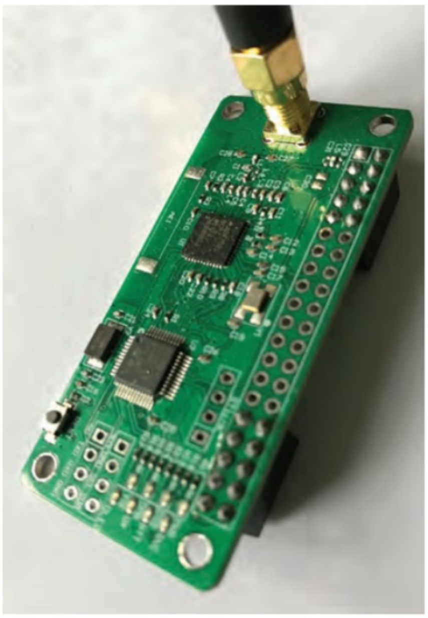

PHOTO 1: If you pick an MMDVM that looks like this, then chances are what I tell you here will work.

You have to consider these modes in the same vein as repeater operation where the two halves of the repeater happen to be connected by a very long piece of wire. It's pretty surreal to be listening to a VK mobile coming in on your handy at 5/9 chatting to European stations and you tend to forget about that long piece of wire. Even if you don't consider it 'real radio' it's worth a look just to appreciate the technology involved.

The big picture

There is no doubt that this is a big subject and the deeper you want to delve the more technical detail and capability unfolds. It can be off-putting, and while people in the know like to show just how complex the system can be, it's not necessary to understand in detail any more than you have to understand 4G to use your mobile phone.

I guess everyone has seen the diagram showing radios, nodes and the internet cloud, see **Figure 1**. This is the simplest possible diagram showing just the bits of interest. Whilst such diagrams are helpful to give an overall picture of how things can connect, it's not particularly helpful in an operational sense. For me, the crux of understanding what it was all about was talk groups and zones and I didn't get to understand those until I had battled through multiple reconfigurations of trying to get something to work.

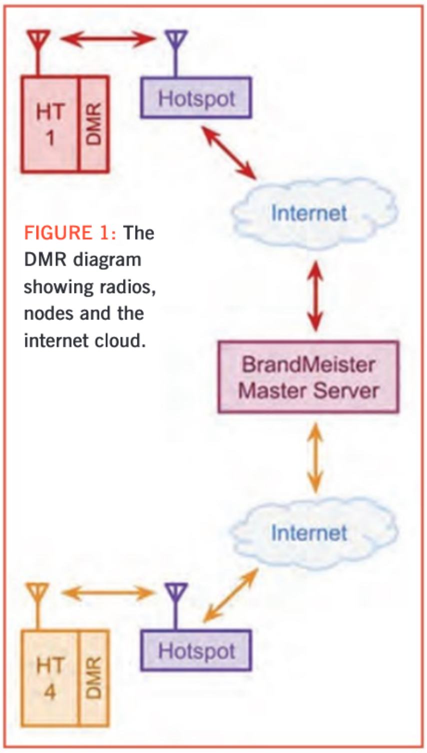

FIGURE 1: The DMR diagram showing radios, nodes and the internet cloud.

Before we get to those there is the basic question of who enables internet linking, where are the servers and what do they do. Again, there are multiple providers of these services but as far as I can tell the most used is the BrandMeister network [1]. When you view the dashboard, see **Figure 2**, it's immediately obvious that this is a world-wide network of some 48 master servers around the globe. There is a real-time display of countries active and the number of voice calls in progress. This is the best place to start and does not require any special hardware, or even an account.

Talk Groups: A talk group is somewhat like a chat-room. There are a lot of these organised from world-wide to countries to regions/states and then special interest groups, local groups etc. There is a great viewer in the Brand-Meister dashboard under 'Services/Hose line', see **Figure 3**. The 'Hose

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PHOTO 2: The MMDVM Hat simply plugs onto the RPi.

FIGURE 2: The BrandMeister network dashboard.

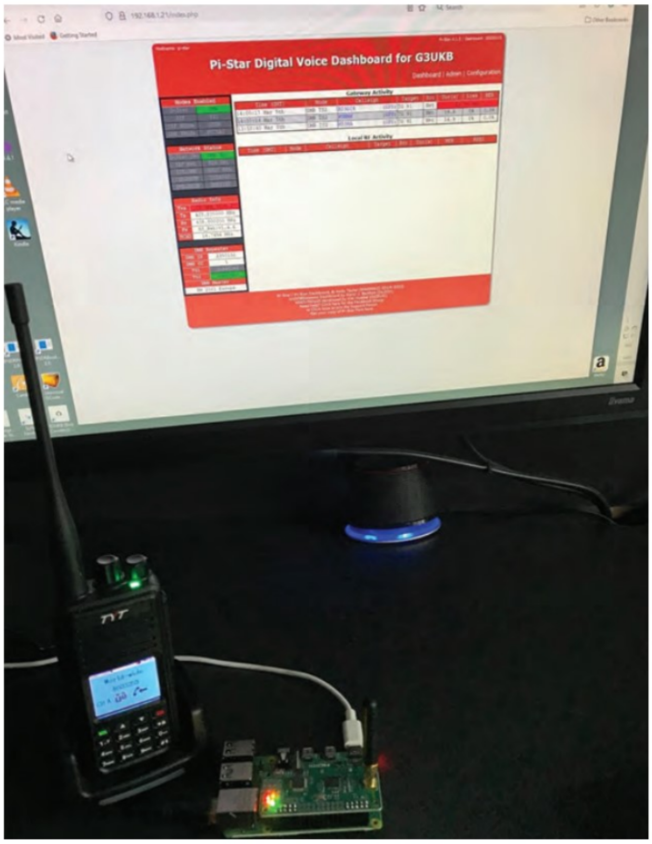

PHOTO 3: The minimal system, up and running.

line' application gives a real-time view of active talk groups with audio. As talk groups become active, they are added to the display and those which have current activity are highlighted with a red border. Click on a highlighted talk group and you will get audio. This is a great way to understand how DMR operational protocols work. It really feels little different from normal QSOs. The world-wide talk group is a good place to listen as there is almost always activity there.

Zones: A Zone is simply a collection of talk groups. How you chose to use zones and which talk groups you decide to assign to them is entirely a personal choice. Just consider it like a folder to which you can add talk groups for different operational environments.

Hardware: When I decided to look into DMR I didn't want to spend much because I didn't know if it would hold any interest. I looked for an entry level DMR handy and came up with the TYT MD-UV380 **[2]** which seemed to get pretty good reviews. Next on the list was a DMR hot-spot that goes under the name of MMDVM (Multi-Mode Digital Voice Modem). Now, you can buy a complete turnkey bit of kit but if you want to keep the price down and happen to have a spare RPi (version 3 or 4) hanging around then it's a much better learning experience to pick one of these off eBay. The handy and MMDVM will set you back around £100. If you pick an MMDVM that looks like **Photo 1**, then chances are what I tell you here will work. The MMDVM Hat simply plugs onto the RPi, see **Photo 2**.

Software: This bit is really easy, trust me, no computer knowledge is required at all as long as you know how to put an image onto an SD card for your RPi. There is an excellent piece of software called Pi-Star **[3]** that can be downloaded as an image file that you can then transfer to your SD card. When this starts up it runs a web server which you can connect to from any browser so the only connection you need to the RPi is power.

The fun starts

I got my hardware up and running pretty quickly, only at this time I had no idea what DMR was all about and started to follow various configuration guides on the internet **[4]**. I got into all sorts of trouble and bit by bit sorted out my mistakes, being convinced for quite some time that the MMDVM must be broken.

You will need to follow these configuration guides as well, but the following notes may help to iron out some of the problems that I met. Of course, your mileage may vary and you may have a completely different set of problems. However, it's worth persevering.

I've written this as just a set of notes in roughly the normal order of progress.

Radio notes

Unlock the radio: I don't know how many radios this applies to, but I went round in circles trying to get the radio to connect. The thing is, when the configuration is set to channel mode you don't see the frequency. It was only when I changed to frequency mode that it was obvious my radio was stuck on 450MHz. For reasons unknown TYT lock their radios at this frequency. To unlock turn the radio off, press and hold the buttons either side of the PTT and switch on. There is

FIGURE 3: A great viewer in the Brand-Meister dashboard under 'Services/Hose line'.

no indication the radio was locked or is now unlocked but it was and that was one major hazard out the way.

Programming the Code Plug: I've never really understood the name. I guess it comes from the point of view that you can plug-in an SD card or a USB drive that contains a file of the operating parameters for the radio. Now, you can get pre-configured code plugs for almost every radio. However, that's not very flexibly and does not give you the tools and know-how to create your own configuration. I can only comment on the TYT radios as I don't have any other handy. There are two options for programming software:

From the TYT site [2]. This is rather a dated Windows MDI (Multiple Document Interface) application. However it does the job and it's free.

RT Systems MD-UV380 Programmer, not free but reasonably priced and a more up-to-date interface.

Drivers (oh my!). Since the advent of Win 10 driver signing, getting Win 10 drivers can be frustrating. At the time TYT did not have any Win 10 drivers. They did point me to a sharing site and said that driver would work but it was a very large zip which didn't seem right. They have now, they tell me, hosted that file on their own site. I had already taken a different approach and bought the RT Systems application which has a Win 10 driver that installed without issue. That same driver also works with the TYT application. The driver I notice can be downloaded without buying the software although that feels a bit sneaky.

Once you have the software of your choice and a working driver and you can connect to your radio and read data from it you are good to go. Follow one of the configuration guides to program your radio. However, you might want to read the rest of the notes first.

Radio ID: You may or may not know that to get on-air you need a radio id programmed into your radio. This is a pretty simple process, go to **[6]**, register and follow the instructions. You will need a scan (or a good quality photo) of your lifetime license. I got my ID through in a matter of hours.

Radio Configuration: A good plan is to read data from the radio, delete the pre-programmed channels and then save that as the default. Set up the general settings first which is your id and other personal data. I think the nomenclature is a little odd, at least in the TYT software. Talk groups are called digital contacts. First off, I would just set up one contact, say world-wide (91). Contacts are then attached to a channel and channels are attached to a zone. That is pretty much radio configuration in a nutshell. There are many other fields but defaults seem to work. Understand them at your leisure.

Once happy with the configuration write the data to the radio and save it with the date as the filename. You will visit the configuration many more times but if you mess up its then easy to fall back to the last good configuration.

MMDVM and Pi-Star software Notes

Go for a board with the following description *MMDVM Hotspot Board DMR P25 YSF DSTAR Board for Raspberry Pi* or similar wording. There are a huge variety of boards and built or partially built systems with an equally large variety of pricing (from around £20 upwards). This should look the same as Photo 1 and is a simplex board. My board had no identifying markings.

Starting at the End: It's always useful to know what you are aiming for before starting. I didn't find that out until I had it working and it would have been very useful to know what the dashboard should look like. **Figure 4** shows the Pi-Star admin page with everything up and running. Note the indicators in green. I keyed the Tx briefly to initially select the world-wide talk group and local RF was then indicated, network activity followed, and audio through the DMR radio. On the MMDVM there is a green power light, a red led that flashes with about 0.5s period. This led indicates all is well with the software as it is driven from two important parts of the software and is part of the watchdog system. There is also another red led and an amber led. These led's mimic the Trx status on the dashboard, so amber when 'Listening DMR', red and amber when 'TX DMR' and both off when 'Listening'. The difference between 'Listening' and 'Listening DMR' is not clear.

The two indicators DMR and DMRNet should stay green. Red is a failed to establish for whatever reason. In this case the live logs may be a help. If the DMRNet indicator is amber that means something is missing. The something is probably a BrandMeister password. At some time in the past this was introduced for better security.

Finally, MMDVMHost should be green indicating that the MMDVM 'might' be properly configured. See later comments to qualify the 'might'.

Getting a BrandMeister DMR password: This is a two-stage thing. You have to get a BrandMeister account first and then you have to set a password. That password then goes into the DMR configuration section. I had trouble with this because for some reason BrandMeister didn't send me a verification email. I tried to log a problem report that also required a logon and a verification email, which also never arrived. At this point I was pretty much stuck. Then I thought, I have another email account so I tried that, which worked and I was able to log the problem. I couldn't do anything with my original registration because it was stuck waiting for me to respond to the verification email that was never going to arrive! Fortunately, after a few days the admin guys set me up. Hopefully you won't have this problem. See **[7]** for instructions on setting your DMR password.

Local Network Connections: This is a slightly confusing area. There are three connectivity options.

The so-called Auto AP.

Local wireless connection to your router.

Wired connection.

Auto AP (Access Point): The Pi-Star software can run its own Wi-Fi access point. This is useful if you don't have a convenient wired connection, you can plug in to when first switching on or when moving your MMDVM to another location, perhaps a mobile connection using your phone to create a Wi-Fi hot spot or a temporary location in another household. If pi-star cannot connect to any network for around two minutes, it will run Auto AP. You can then connect from your laptop, tablet etc. to set up the local Wi-Fi parameters. The Auto AP should show in your network parameters as Pi-Star-Setup with the usual default password.

Local Wireless Connection: Once you have access to the dashboard either via Auto AP or a wired connection you can set up the Wi-Fi parameters in the configuration section. After doing so you may be greeted with an offline message. It may take a minute or two to sort itself out or you can do a restart (only via the power menu, see Issue 2),

Wired Connection: I always prefer a wired connection if you can get to one, but I know most people use Wi-Fi exclusively. If you have a wired connection in the normal location then it will save you having to worry about Auto AP and Wi-Fi parameters.

Selecting the Device Type: This is where I spent a lot of time. When you drop down the device type combo, there are a lot, and I mean a lot of devices listed, so how on earth are you supposed to know which type the MMDVM with

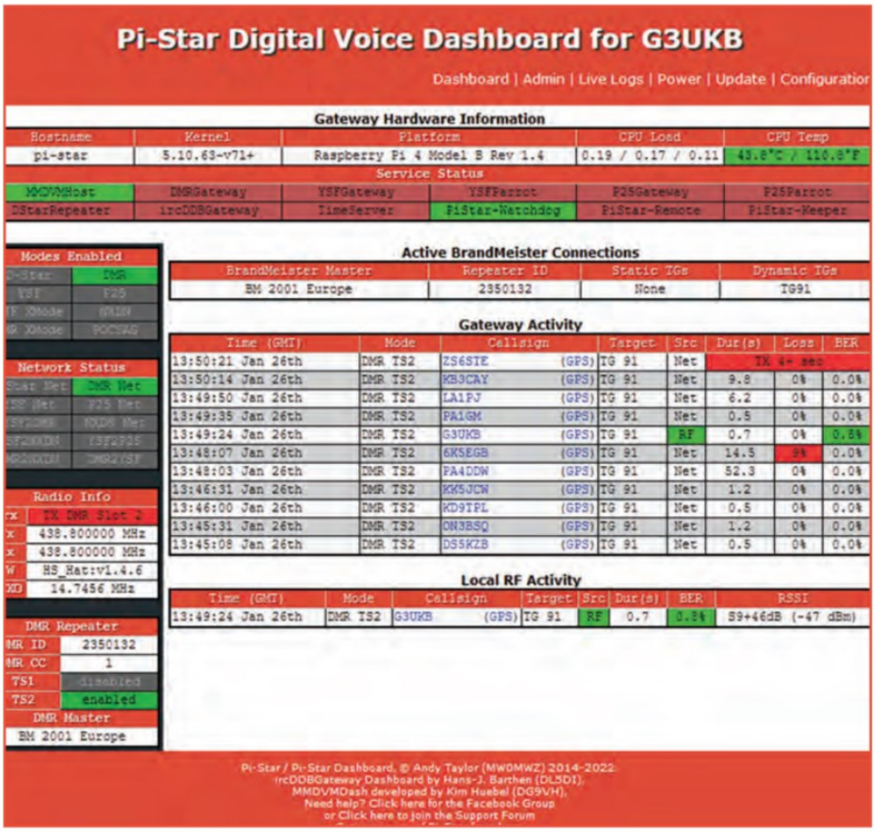

FIGURE 4: **The Pi-Star admin page with everything up and running.**

no identifying markings is? It was pretty much trial and error. Selecting the wrong type gives no errors, just that the DMR indicator stays red. You can go through the ones that say something about being an RPi Hat, but selecting a new type and pressing update didn't always change the type although I didn't realise that until, eventually, I did a reboot and started getting different results. The type for my device turned out to be *DV-Mega Raspberry Pi Hat (GPIO) – Single Band (70cm)* and if you have a similar looking board, it will probably work for you as well. It may even be that you have a green status, but you still can't key up. This also happened and was also down to the wrong device selected although it was obviously partially working.

Getting on-frequency: These MMDVM boards can be off frequency by quite a bit. Initially I thought that I couldn't key up because it was so far off that it was outside the passband and there was some discussion on the web saying that was possible. I then set about tweaking the offsets in the configuration up and down until it was obvious that was not the problem. I even tried the MMDVMCal built-in analyser before realising it needed to see RF to work. It turned out just to be the wrong device selected. Once you have RF the display will show how far off-frequency you are and you can then start playing offsets or use MMDVMCal [6] to find exactly the right offset figures.

Other Hints and Issues

Hint 1: In Pi-Star dashboard always press the update under the configuration section when you make a change. Initially you won't even see additional settings until you do that.

Hint 2: Always use the Dashboard/Power menu to power-down or reboot. See issue 2.

Issue 1: Problem with DNS, sometimes pi-star/admin works sometimes it needs an IP address (look at your router connection page for the current IP address). This may just be an issue with my router or name server but if you can't get the browser to connect then try the IP address.

Issue 2: So, I had just got it working, the dashboard showed I had local RF so I could select the talk group and I was getting audio. Everything looked great… then the next time I power it all up, zilch, both DMR and Net indicators were red and there was no flashing red led. If things don't work or abruptly stop working the first port of call is the 'live logs' accessible from the configuration page. Mine showed -

Failed to read firmware version after 6 attempts

This apparently is the dreaded message that seems to pop up often and there is an equally large range of associated reasons and things to try. I refused to believe that the firmware had suddenly corrupted itself while the system was off or that the hardware had an equally sudden mishap while it was powered off. I was unsure what to do but this worked for me.

I selected update from the configuration menu. Things kicked into life again. Was this because somehow Pi-Star had got into a strange state and the update fixed it? This was the only explanation I could think of. I was now getting audio but could not key the Tx side. This also showed me something else, that Pi-Star remembers the last talk group I selected. This apparently is called pseudo-static, such that the last talk group is automatically restarted without having to key the Tx. I also read that you can set up true static talk groups in BrandMeister, anyway I digress.

Why then was I not able to key the Tx. It turns out that the update somehow reset my device to something other than my selected device. Now this has happened a few times. Sometimes selecting the correct device and pressing update will do the trick and sometimes it needs a reboot.

Rebooting and shutting down: I have a feeling that my habit of just pulling power on an RPi is what probably caused the issue above. Always use the power menu to power-down or reboot. Now, if power loss was due to an outage or a trip going then maybe that accounts for some of the reported problems.

Conclusion

I hope this article will encourage some to have a look at this growing section of the hobby. Radio IDs are being issued at a pretty high rate, which is a good indication of the level of interest. There is an immense amount of information on the web that is both useful and daunting. Certainly there is a lot more to explore than I have outlined here but apply the KISS principle **[8]** initially to get just one channel working to an MMDVM, only then read some of the more complex material to see where to go next.

The minimal system up and running is shown in **Photo 3**.

Websearch

1: BrandMeister: https://brandmeister.network/

2: MD-UV380: https://www.tyt888.com/?mod=product_show&id=127

3: Pi-Star: https://www.pistar.uk/

4: Configuration guides etc: Search, too many to mention.

5: Hotspot calibration: http://www.k9npx.com/2019/02/hotspot-offset-calibration.html

6: Radio ID: https://www.radioid.net

7: BrandMeister password: https://news.brandmeister.network/configure-a-security-password-for-your-hotspots/

8: KISS: https://en.wikipedia.org/wiki/KISS_principle

Coupling the Far-Off Reaches of the Smith Chart— The 'Felix' Coupler

One thing I've learned over the years as both a radio operator as well as short wave listener is that antennas are anything but ideal.

My first antenna was about 25 feet of wire bought at the local gas station (back in the 1950s) and strung along the eaves of our house and driving my Hallicrafters S-120, then my pride and joy. Reading about proper antenna design I knew I needed more wire – a *lot* more wire. Well, in time I got more wire, but by then I'd also gotten my first licence and now worried about impedance matching. Fast forward to today, and now that I have the equipment to measure my antennas' impedances. I've also acquired or built an array of matching networks because, although I have good radios to work with, my antennas have always left a lot to be desired, mostly because of my space limitations. And working with those matching networks I always – *always* – wind up never having enough capacitance or inductance or whatever. All that led me to design a series of receive-only couplers named after another of our cats – Felix. Some of these incorporated an 'Oscar' type of preselector, and were dubbed 'Odd Couplers', since one of our favorite movies features an Oscar and a Felix as *The Odd Couple*. The design shown here is the latest (but probably not the last) iteration, and it does better than any of its predecessors. **Photo 1** shows the current Felix coupler front panel. It looks like there's a lot going on (and there is), but let's back up and look at the basics of the engineering problem.

While there are plenty of different coupling circuits, for wide-ranging impedances two are most common: the Pi network and the T network. **Figure 1** shows the equivalent circuit of the Felix coupler – it's a common T network with tricks added to help the circuit do things it normally doesn't do. As I said, when using a coupler to match to a 'broadband' antenna (often just a long piece of wire), I keep running out of either inductance or capacitance or both.

But first, let me – or rather, let the next graph, **Figure 2** – illustrate why Felix came to be.

PHOTO 1: Felix's Front Panel.

This is data, believe it or not, for a commercially-available 'broadband' QRP or SWL antenna that I'm currently using for my receiver collection. Now whether it's the antenna or how it is installed that has caused all the wild fluctuations is immaterial. Most antennas, when installed in limited-space environments, exhibit a variety of behaviours like this one. One local amateur here in the Silicon Valley was famous for figuring out how to load up her rain gutters, and for that she was rewarded as a well-known DXer. I doubt that any amateur would want to use an antenna as illustrated in Figure 1, but needs must, as they say. Along with that is the need – for some equipment – that a low-SWR source be presented for optimal performance. The 'Oscar Regenerative Preselector' I described in *RadCom* recently **[1]** works far better with a near-50Ω source impedance, and the SDR units that we have come to rely upon are generally even more picky.

There are a few ways around this problem. But let me show you how I chose to attack the issues. Figures 3-7 show screen captures from SimSmith run on my computer. SimSmith **[2]** is another beautiful piece of freeware that I rely upon a lot in my work, and I highly recommend it. And in case you're curious, there's an excellent *RadCom* article on Smith Charts in general **[3]**.

Now as I begin, I'm going to start by analysing matching as I use my T-network as an L-network. I've designed Felix to be able to do just that, and L-networks are inherently going to have lower losses than either T or Pi-networks (more on this later). This matters less when you're transmitting, but when you're trying to dig out weak signals every little bit saved helps. SimSmith, by the way, calculates the losses of a network, and that turns out to be a great value.

So, in the spirit of good engineering, the first thing to do is set design goals. Here are mine:

Employ a T-network format that can be switchable into capacitor-input or capacitor-output L networks to lower overall losses.

Reviewing the spectrum to be covered by

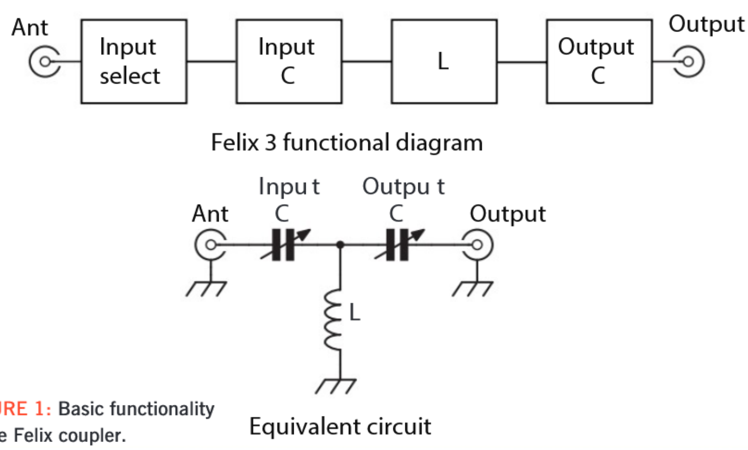

FIGURE 1: Basic functionality of the Felix coupler.

my antenna, I need to account for impedances ≤ 5Ω and ≥ 1.5kΩ, from under 2MHz to at least 30MHz.

Since I won't be using a roller inductor, the inductances should be easily swappable as I gain experience using the unit. A switchable bank of series-additive inductors will be used; maximum number of inductors is 12, limited by the switch I'll use.

As a first pass, capacitance on the input and output should be from a few pF to about 3nF. Keep Q as high as possible.

A means of running the antenna directly into a VNA or bypassing the coupler entirely should be included.

Although designed as receive-only, I want this unit capable of passing a few watts (under 50) of transmitted power as well.

Keep everything as compact as possible (even with all the other goals!) to limit stray inductance and capacitance.

Use a star ground/earth connection, and make the mechanical assemblies robust to avoid long-term problems.

Well, that's quite a list. If I was designing a coupler for a well-behaved antenna with a maximum SWR of 2.5, this would be a snap…and a lot simpler. But this list addresses most of the shortcomings I've experienced in previous designs and in most commercial couplers. And while you might be tempted to say that most amateurs don't need all this, I'd offer that the Felix coupler has been developed to also explore additional tricks and techniques that can help *you* when things aren't quite so perfect. I recall having regular 20m QSOs with ZL2AKH (now SK) in Nelson, New Zealand some years ago when he was running barefoot into 'over 100 feet of wire strung in the trees'. Just the kind of situation that benefits from a 'Felix' type of solution.

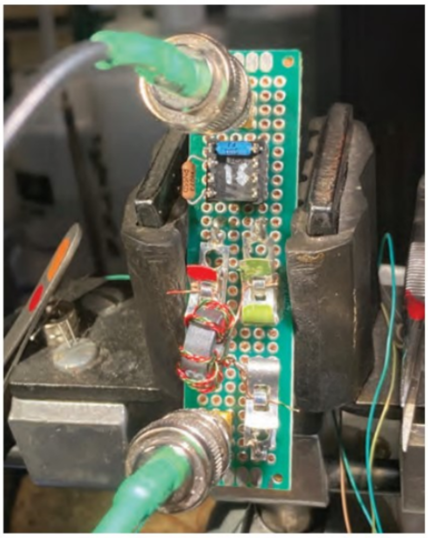

PHOTO 2: Transformer Test Jig.

So let's see where the design leads us at, say, 2MHz and a conveniently insane resistor I use for testing, 2.2Ω. For now I'm not adding additional reactance to the input; that'll add a bit more loss and tuning from the coupler, but for now let's focus on just getting data on the network to see where it leads. **Figure 3** shows the SimSmith output for a typical matching solution.

If I was designing a 160m coupler for a short wire having low impedance, this might be enough. But there are some problems even for that case. SimSmith calculates throughput for a 1 watt input from the 50Ω source, and when you run this in SimSmith this is reflected in the '←W' value at the 2.2Ω input port. I'm employing an L-network to reduces losses, but this network loses about 10% of the signal *just in the coupler*, and the input capacitor is large – about 7.3nF. And then there's the narrow-band nature of this solution. I've decided on a metric and dubbed it 'Match-Q', defining it as the center frequency (here 2MHz) divided by the frequency range over which the SWR remains *below 2* (ie, losses ≤ 10%). The smaller dashed circle in **Figure 3** is the SWR = 2 limit on the Smith Chart. For this case, Match-Q is rather high: about 7. That means you'll be adjusting the coupler a lot, and a Match-Q closer to 1 would be better. There are, of course, other capacitor-inductor pairings that might works as well or even better, but many will still be close to what I'm showing here.

So, to help mitigate these issues, I invoked an old trick that works quite well for this sort of application, and is really easy for receive-only or low power (under 50 watts). I simply use a 1:16 impedance transformer at the input to boost the 2.2Ω to about 35Ω (SWR < 2). **Figure 4** shows the result. For the 20Ω impedance presented to the network input C = 3.4nF (still high but manageable), L = 6μH, and the Match Q is about very low, staying within the SWR = 2 circle over a 1.2 to > 5MHz range. The losses in the coupler are about 1.5% here. As long as the losses in the transformer are low enough, this should work.

As part of this engineering exercise I originally used 1:9 transformers, and they worked reasonably well, but the switch to 1:16 units turned out to have no more losses in the transformers (once I finalised a new design) and do a better job of putting impedances much closer to the SWR = 2 circle and this leads to lower losses and greater bandwidth (lower Match-Q). I'll describe the "transformer problem" in just a bit further along.

At the other end of the Smith Chart, my VNA sometimes shows quite high impedance magnitudes, sometimes about 2kΩ (SWR ~40!), sometimes from wire antennas, sometimes from verticals. Happily, this doesn't happen on my SWL antenna, but since I've had the High-Z impedance more than once, I'm including design data here. That's the situation illustrated in **Figure 5**. Note that the L-network is reversed, with the capacitor as the output element. And for Z = 2kΩ at 2MHz L = 23.9μH, C = 271pF, and the Match Q is 10.5 for a loss within the coupler of ~13%. Turn the transformer around so it's now a 16:1 transformation and Z is now 125Ω hms (SWR ~2.5), and, as **Figure 6** shows, L = 8.1μH, C = 1300pF, and with losses only 2.5% the Match Q is 1.0.

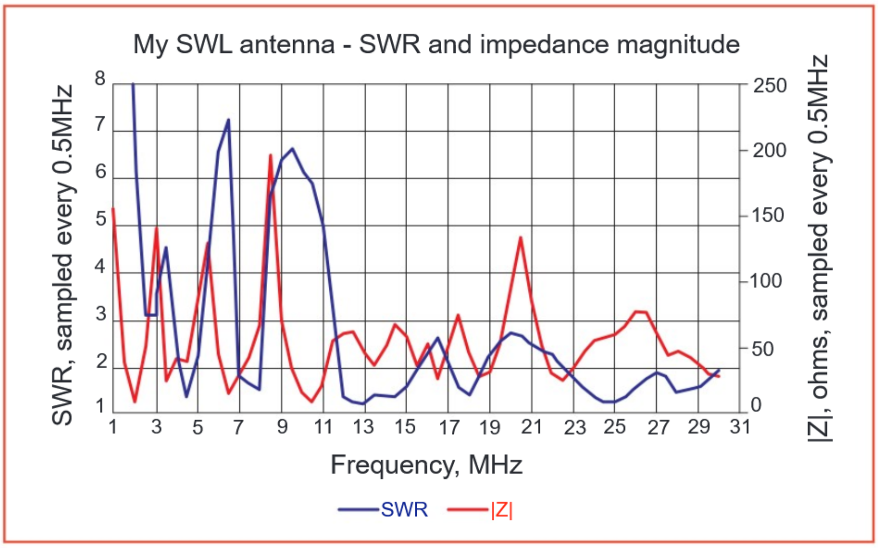

FIGURE 2: My 'typical' SWL end-fed antenna.

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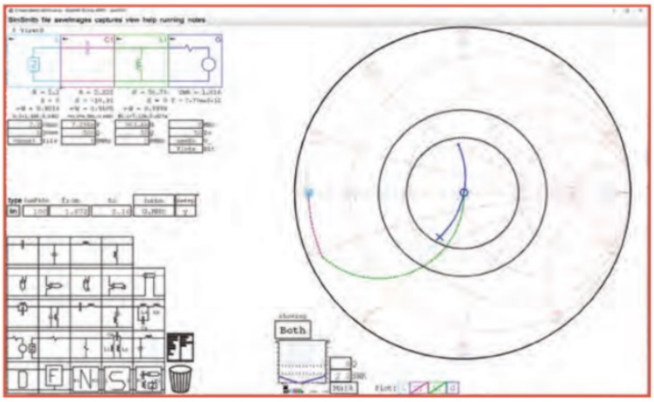

FIGURE 3: L-network solution for Z=2.2Ω at 2MHz.

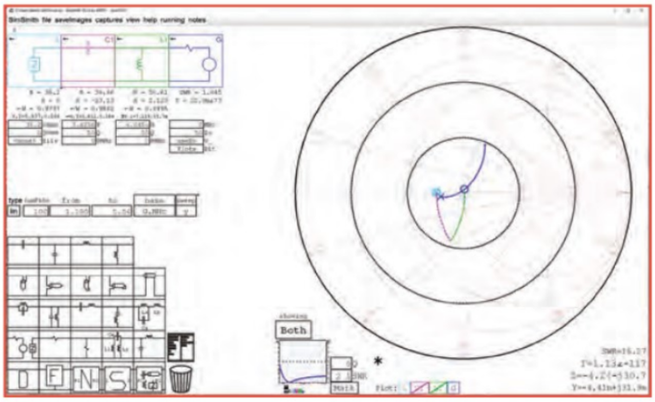

FIGURE 4: L-network solution after invoking the 1:16 transformer on the input.

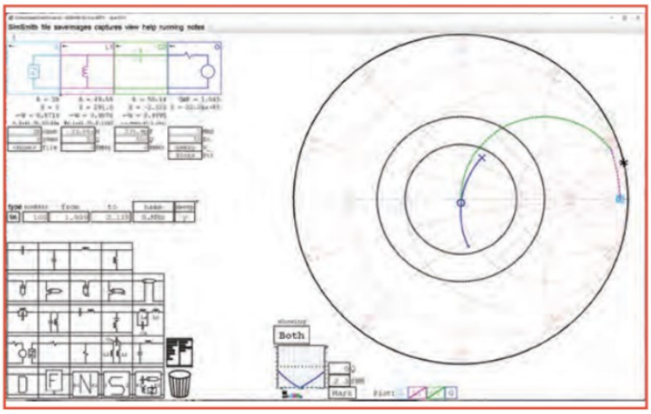

FIGURE 5: L-network solution to handle Z = 2kΩ

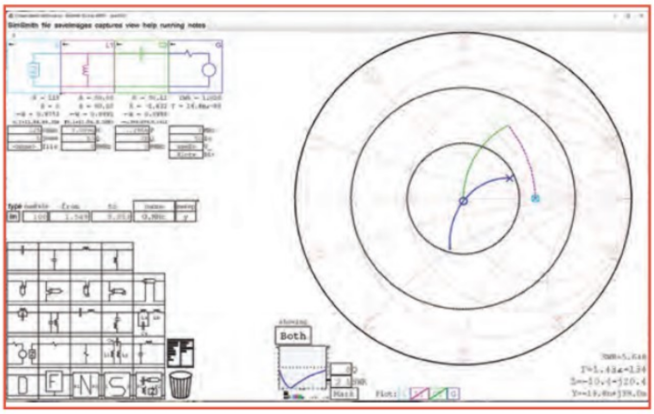

FIGURE 6: 16:1 transformation of 2kΩ to 125Ω.

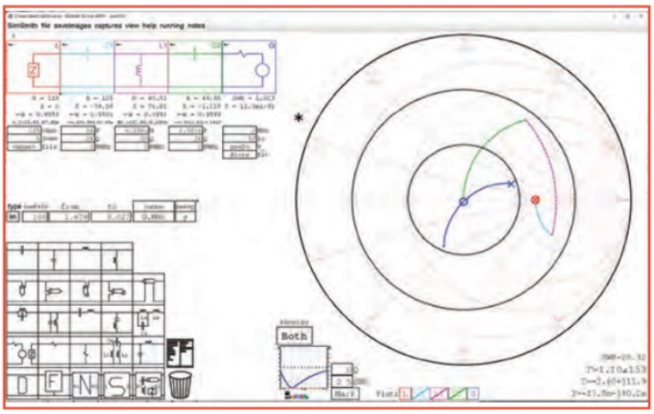

FIGURE 7: Using the full T-network instead of the L-network.

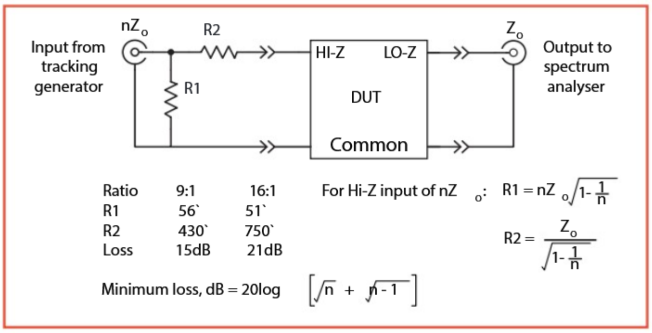

FIGURE 8: Testing the Transformers (DUT = Device Under Test).

But what about the comparison of a T network to an L network you ask? Well, **Figure 7** shows what happens. Nice match, but the Match Q rises from 1 to 1.5, and losses almost double over the L-network solution, though they are still low. There are instances where one is forced to use the T configuration, but most typically exhibit higher Match-Q and often somewhat lower efficiency, especially when the source becomes reactive.

So this now became an engineering assignment to make and measure transformers of, say, ratios of 9 and 16 over the 1.5-30MHz range, and I wanted to explore both ratios, just in case. Of interest will be attenuation flatness over my frequency range and, naturally, overall loss. Twenty years ago, this would have been a more formidable undertaking, but with the proliferation of spectrum analysers with tracking generators this is manageable and productive. And there's a nice procedure and commentary online by WA1ION to help this out **[4]**. The setup and procedure are familiar to anyone trying to make measurements on devices that aren't designed to present a nice 50Ω port to our equipment, and so the document in that link is a good thing to hang on to for future experimentation. Useful and educational.

Figure 8 shows how this is set up. The resistive attenuating 'pads' are able to do a reasonable job of 'matching' the impedances needed, but at the cost of some serious attenuation. It turns out that such pads are limited to a '*minimum* attenuation' depending on the ratio of impedances, and that's what I'm using here. A -3dB, 50Ω pad on the output can be added to the output to provide a measure of

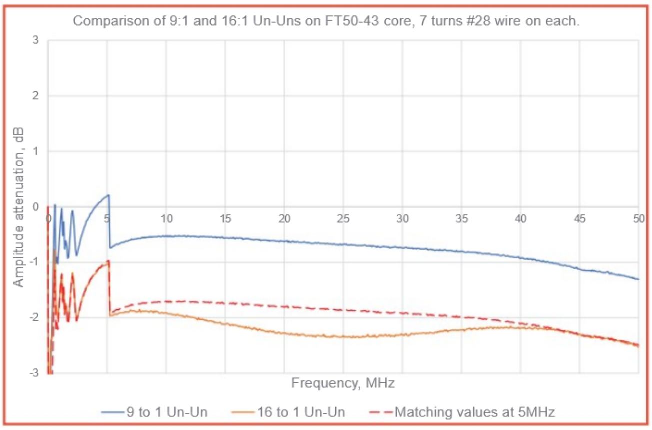

FIGURE 9: First-cut transformers on FT50-43 cores.

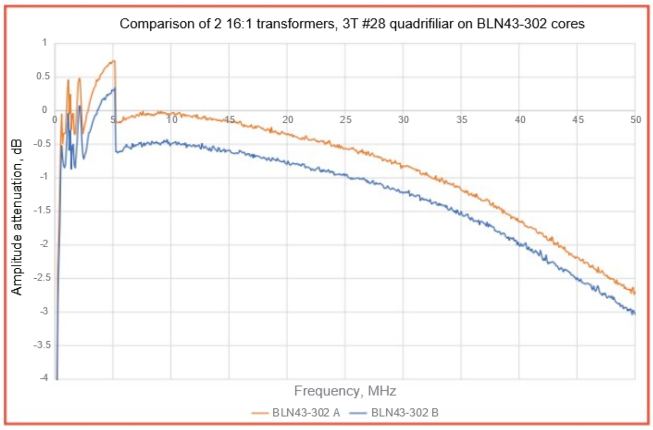

FIGURE 10: Test results for 2 balun-core transformers.

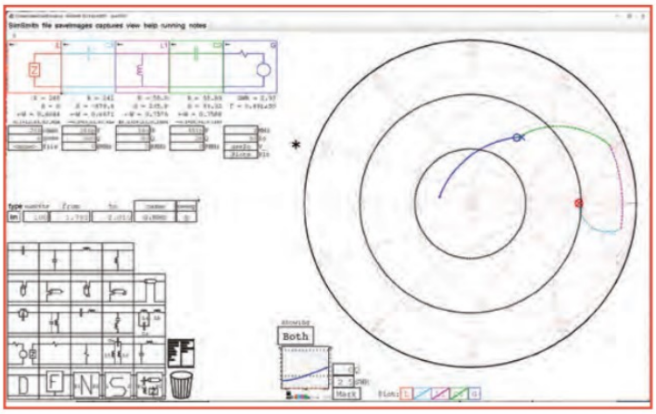

FIGURE 11: 'Handbook' calculated values for Z = 240Ω at 2MHz.

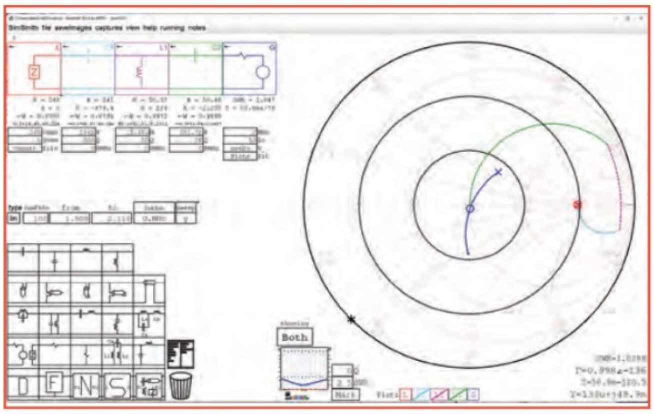

FIGURE 12: Adjusting component values to improve performance of network in Figure 10.

stability if you're using a high-impedance measurement tool like an oscilloscope. If you're operating into a good 50Ω load it's not required. I've included 5% tolerance resistor values for the 2 pads as well as the maths for calculating their exact values. **Photo 2** shows my testing jig at work. The connectors that hold the transformer are old school 'Fahnestock' connectors. Might be hard to find, but I have found the extremely valuable in my work. In Photo 2 the pad is visible beneath the connector at the top of the PCB. I built it on a plug-in header and it's installed on a socket so I can use the same jig for either transformer ratio.

Figure 9 shows the results for the two transformers. I first decided on FT50(A)-43 cores for this design, but, later, after *much* experimentation, changed my mind. Figure 9, however, is still instructive. Also, depending on your design goals, you might want to test out other core sizes and materials, as well as varying the multi-filar twisting rate and number of turns. My tracking generator output is 'produced' by my Rigol DSA815-TG piecewise, so the 1dB excursions are just the internal workings of the Analyser. Discrepancies between theoretical and measured attenuations are a function of the resistors used and the toroid-to-toroid variability we experience. I find that every time I apply wire to ferrite (and do no further tweaking of the turns spacing) the results change slightly. Of course, nothing's perfect; we're just looking for any useful data to help the design. In Figure 9 I overcame the loss offset in order to overlay one curve onto the other; the results are now easier to understand. Both transformers work pretty well over the 1-30MHz range, with only a small loss in the 16:1 design above 10MHz.

But one thing I learned from this week's-long exercise is that, in general, the flatter the response the greater the losses overall. I won't add the details here (maybe enough for another article), but that turned out to lead me to my 'final' (for now) transformer design, the results of which are shown in **Figure 10**.

Two things jump out right away. They're not quite as flat as the standard donut toroid units (about 2.5dB down at 50MHz, compared to 0.5dB down there for the toroids), and their overall losses are less.

As I noted, this is not just fun in my lab but also an engineering exercise from which we can all learn.

For my money, any coupler should be able to take a VSWR = 5 input and land it inside the VSWR ≤ 2 circle. This means that input impedances (neglecting the reactive parts) between 10 and 250Ω should be handled by the simplified schematic in Figure 2. Dividing or multiplying by 16 (the transformer ratio) gives an input from the antenna of 2.2 to 2000Ω. From an engineering point of view this solution was worth building.

One last thing to note along the way in this part of the design has to do with why I'm using SimSmith instead of the 'Handbook' **[5]** values one can easily calculate. Well, let me offer an example of a 'match' tweaked on SimSmith versus calculated values for Q=2 at 2MHz. **Figure 11** is the SimSmith result at an input impedance of 240Ω (15Ω x 16) based solely on 'Handbook' calculations for Q=2. **Figure 12** shows the corrections suggested by SimSmith manipulation.

Figure 11 shows a network that simply does not work well. SWR is too high at the output and efficiency is about 66% (loss of about 33%). Figure 12 is better, but losses are still high, about 14%. **Figure 13** is

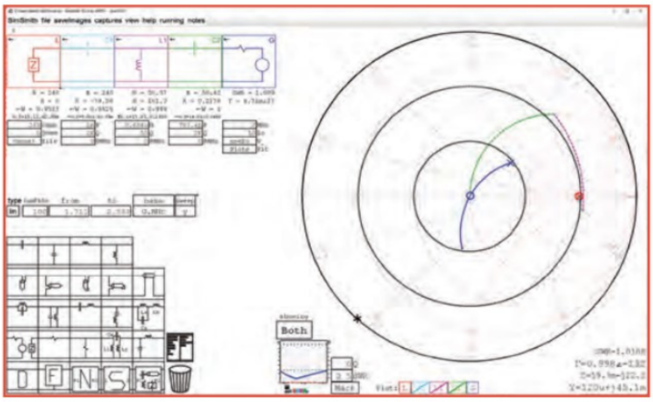

FIGURE 13: Non-Handbook Felix T-network solution.

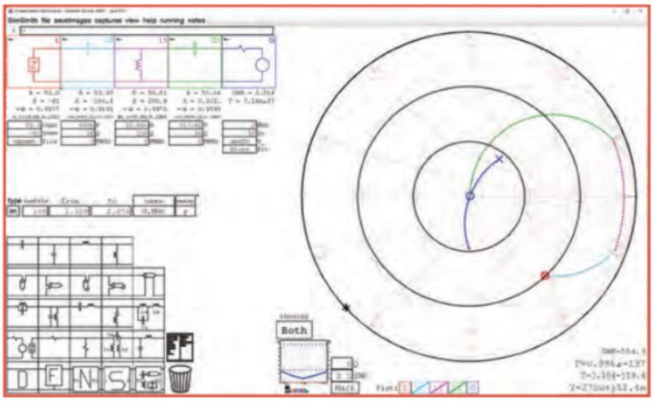

FIGURE 14: An 'awful' real-world antenna connected to T-network Felix through the 16:1 transformer.

the winner, of course, with losses predicted at <5% and a Match-Q of 2.4. Still, I find derived values from the Handbook maths to be an excellent place to start, but acknowledge that tools like SimSmith can help any designer do a better job. There are *many* solutions to each problem; we need to 'engineer' the best solutions that we can.

So back to SimSmith to begin the task of estimating how much capacitance and inductance I'll need. Since I'm not using a variable inductor in this iteration of Felix I'll plan on a wide array of small, high-Q fixed inductors. At the low end I'll be constrained literally by the length of the wires used to hook things together – a few tens of nanohenries. At the high end I've learned that it's good to have well over the more-or-less standard 30μH inductors sold, so I settled – for now – on about 49μH, hoping I won't need that much very often, and mostly at low frequencies. The design will allow individual inductors to be swapped as I learn the limitations of the real coupler as opposed to its ideal cousin. Likewise, I have a couple of old Soviet-era capacitors with a maximum range of about 1000pF. I'll add series or parallel capacitance to take the range from a few pF to about 3nF, again, while designing Felix to try to lessen circuit losses where possible, at about 1-2MHz larger values are often required. I might add more high-end capacitance later on, as I learn how best to use Felix's powers.

Since I've been 'designing' using purely resistive sources, one might wonder what happens when the antenna attached has some significant reactance. Well, it all still works, happily. Let's start with a $|Z| \sim 100$, with a capacitive reactance. I've also added in stray inductance (50nH is a guess on the high side) and "too much" switch/connector resistance (0.5Ω). (My as-built Felix shows about 0.2Ω, maximum.) At 2MHz, **Figure 14** shows the match.

Efficiency is still about 94%, even with the added reactance, and Match-Q is high – 13.5. So now we're in the land of trade-offs: trading efficiency for lowering the Q and making it easier to tune. **Figure 15** is the same 'awful' antenna (not unlike mine), with the stray components in the coupler, but using an L-network.

The L-network has a Match-Q of 3, while the efficiency is now less, about 92%. Hopefully, most antenna impedances will be somewhat less reactive.

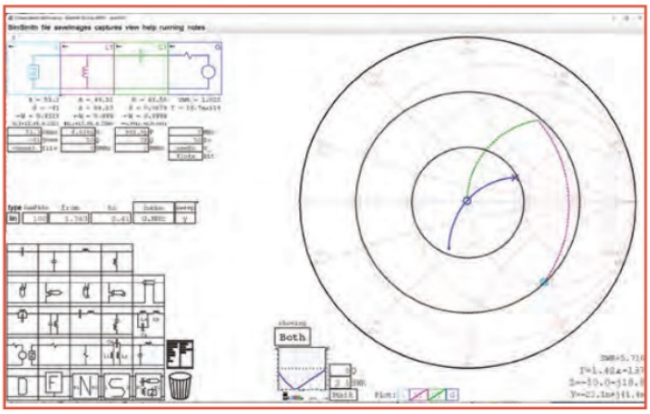

FIGURE 15: Same source impedance, but going to an L-network.

However, it's been instructive to explore how my design choices will react to the real world, and I ran a *lot* of such models to confirm what I built.

That wraps up the first part of Felix's story. In the next installment I'll turn to the task of turning engineering into what you see in Photo 1.

References

[1] *'Oscar': a broadband regenerative preselector, parts 1 and 2*, Sheldon Hutchison, N6JJA, *RadCom* 97(10-11), October-November 2021.

[2] AE6TY.com/Smith_Charts.html#content1-n, and AE6TY.com/assets/files/QRParticle.pdf

[3] *Demystifying the Smith Chart*, Michael J Toia, K3MT, *RadCom* 95(2), February 2019, p.60.

[4] www.qsl.net/wa1ion/bev/bb_antenna_matching.pdf

[5] I rely on the ARRL *Radio Amateur's Handbook*, finding these designs tabulated in the 'RF Design' section of most recent volumes of that publication.

Do you have a project you would like to see published?

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It doesn't matter if you have never written before – we can provide as much or as little editorial support as you require. We'll need good quality photos to accompany your article **[1]** but line drawings (circuits and other diagrams) can be a simple sketch. We re-draw the majority of diagrams to give a consistent style across all articles. There is rarely any time pressure, so you can work at your own pace. Our acceptance procedure for technical articles **[2]** involves an independent review by a member of the Technical Panel, whose members are always willing to work with authors if there's something that needs more explanation or would benefit from clarifying.

[1] www.rsgb.org/radcompix
[2] https://tinyurl.com/RC-guidance

Review

Vero VR-N7500

Dual band radio

What's special about the Vero VR-N7500 dual band mobile radio? As it turns out, it's quite an innovative device and, as far as I know, is unique on the market.

Let's have a quick look at what the manufacturers have to say and follow that up with my impressions of using the radio.

The Vero Telecom VGC VR-N7500 is a brand new 50 watt VHF/40 watt UHF Headless ham transceiver with a solid build quality. It is very different in design compared to any other ham radio you have used in your mobile or base.

The VR-N7500 can implement a smartphone as the control panel. The main radio can be installed in the trunk while the phone/tablet is connected to the radio through Bluetooth.

Multiple Bluetooth Connections

- Connect to optional bluetooth PTT
- Connect to bluetooth headset (eg Cardo, Schuberth, Viper, Sena, Interphone and Vimoto etc.) This is very useful for cycling enthusiasts, omitting the cumbersome wiring.
- Connect to cell phone to programme the radio
- Connect to optional bluetooth speaker microphone
- Connect to other bluetooth 2.0+ accessories
- *Using the APRS feature you can send your updated location in real time to the APRS-IS servers, which will then plot your position on APRS maps such as APRS.FI*

Key Features

- *Output Power: 50 watts VHF 40 watts UHF*
- *App programming*
- *CTCSS/DCS/DTMF/2-Tone, 5-Tone decode and encode.*
- *Supplied with wired mic.*
- *Allows Multi Bluetooth connections*
- *Allows Network radio to RF connection*

The Vero VR-N7500 dual band mobile showing the speaker/microphone.

Out of the box

The most important thing that you notice about the VR-7500 is that it doesn't have a front panel – or more accurately a control panel. It's a headless, 'no-fuss' radio. It has a really nice, robust feel to it.

As I'm sure you will have gathered from the manufacturers' information, your mobile phone, connected via Bluetooth, is the control panel that allows you to adjust the settings of the radio. It's worth pointing out at this early stage, that although you will need a mobile phone to set the VR-7500 up, you don't need the phone to use the rig, which might be a bit of a shortcoming, although without the 'control' phone handy, functionality of the rig is limited.

The other important thing to consider about the VR-7500 is what sort of mobile phone you have. The VR-7500 can be programmed by both Android and iOS devices, however, it's fair to say that there is much more functionality available to Android users than to iOS users. You certainly *can* use an iOS device, but some features will not be accessible. I will cover this in more detail shortly.

Although I have said 'mobile phone', any Bluetooth enabled device capable of running either Android or iOS should be capable of communicating with the VR-7500. Although both I and the RSGB would advise caution in this regard, I understand that some users with Android enabled systems in their cars have 'jailbroken' the systems and can run the VR-7500 control app natively on the car's audio/navigation/control system. I have not tested this, so cannot provide any further details.

The VR-7500 comes with a standard 'fist' type microphone, but if you wanted to mount the radio in the boot, for example, or under the seat, you can purchase an optional Bluetooth speaker/microphone to allow you to do this. Another built-in option is that you can use the microphone/speaker on the Android/iOS device you are using to control the radio. In a mobile context, this would only work if you had a hands-free system to control your phone. When I tried this, in the shack, although transmitted and received audio was received on the Android device, it was not the best quality and was subject to slight delays and jumpiness. So, this would be fine for monitoring and short-term usage, but I feel most people would want better quality than this.

Programming the radio

The first thing you'll want to do, of course, is to program up the radio with the channels that you want to use. To do this, you'll need to get the app installed on your mobile phone/device. Both applications are free of charge. For the Android version search for HT (the icon has green circles). For the iOS version search for BS HT (once again, the icon has green circles)

By the way, only limited documentation comes with the VR-7500, but Min, G0JMS has put together a useful document on getting the most out of your VR-7500, which can be downloaded from the Moonraker website at https://moonrakeronline.com. There is also a Facebook group and a Google group for people interested in the VR-7500 that may help you with support.

As I'm primarily an iOS user, I decided to set up the app on my iPhone. The first thing was to pair the rig, using Bluetooth. Switch the VR-7500 on and then press the power button on the rig twice in fairly quick succession. You'll see the lights flash on the rig to indicate that it is now in pairing mode. Within the HT app on your phone you will now be able to complete the pairing process and within a very short space of time, you will see the radio indicated under 'My Device' showing connected. You can then open this up and will see a graphical display of 16 channels with some frequencies.

It's now time to setup some channels. Simply long press one of the channel 'squares' and you'll be taken into the 'Channel Setup'. You can set up the name of the channel, transmit and receive frequencies, CTCSS, Power Level and Bandwidth. There are some other features, including setting the channel as receive only, or muting.

As soon as you enter the channel data, the channel will be available on the radio.

The radio can be controlled by many Bluetooth enabled devices.

In use

A really nice feature of the VR-7500 is that it has built in APRS (1200 baud) capability. You can setup the APRS channel (144.800MHz) and there's also an APRS settings page that allows you to connect to an APRS iGate (gateway between RF to the APRS-IS service on the internet). For example, this may allow the APRS packets that you receive to be sent to the APRS.FI site (http://aprs.fi). You could also enable APRS packets to come from the Internet and be sent from your radio. I did not enable this as I could not see any benefit, but you can filter this data, so if you only wanted to rebroadcast APRS packets from within 100km you could set this up. You can also opt to receive APRS messages sent from the Internet. You can elect to send an APRS beacon packet at a timed interval that you can select (I opted for 15 minutes – if APRS is very busy where you are, perhaps go less frequently). Within this beacon packet, the VR-7500 will include your location (latitude/longitude) and some text, which you can configure. Should you wish to disable sending your position for reasons of privacy, you can of course do so.

The VR-7500 will operate in dual channel mode, so you can monitor APRS as well as listening to a local repeater or simplex channel. You can also scan through the group of 16 channels. When the scanner finds a busy channel, it will stop there until the transmission ends. As far as I can see, there is no option to modify the scan behaviour. I did not find a way of muting the APRS packet activity from the speaker. There is a mute checkbox for the channel, but it did not save the setting! There's a setting to determine which channel your APRS beacon is sent on. It's well worth checking this otherwise you could be sending APRS packets on your local repeater.

One point I should bring out if you are planning to use an iOS device, the memory capacity is limited to a single group of 16 memories. On Android you can have as many groups of 16 memories as you like!

Pairing with an Android device

It's immediately clear that using an Android device with the VR-7500 is preferable and a considerable number of facilities are available on the Android app that are not present on the iOS version.

The first thing that I absolutely loved was the ability to upgrade the firmware of the VR-7500 through the app. The app indicates whether an upgrade is available and if it is, the firmware is downloaded onto the Android device and then sent and installed onto the radio using Bluetooth. I don't think I have ever seen such a seamless firmware upgrade process. Well done, Vero!

Setup of memories, scanning and frequencies is essentially the same as on the iOS version and seemed to work well. What you can do though is to have multiple memory groups (each memory group contains 16 channels). I cannot see mention of any limit on the number of memory groups that are available on Android.

There is greater APRS functionality on Android than on iOS. As well as the Map, plotting stations that you have heard and showing their distance, you can display a list of the APRS messages that you have received as well as a list of the individual APRS stations seen. The Map can be configured to show stations that you have received over a period of time, ranging from the last 3 hours up to 'ever'.

Perhaps the major difference between the iOS and Android version of the software is that in Android there is some 'network radio' (Voice over IP) capability. The Android app has a built in VoIP client allowing you to connect to the Vero network. You can, if you wish, also bind the VR-7500 to a channel on the Vero network so that it will act as a gateway. Please be mindful of your licencing conditions here.

I hadn't realised until I tried out the network radio functionality, that if you have the app switched on your phone, but you are away from the radio, you can still use the app as a Network Radio client. I put a call through the Vero UK channel to see if Min, G0JMS was around. Indeed, he was out for a walk with his phone, but not in Bluetooth range of his VR-7500 and we were still able to have a quick chat. It's worth stating that the Network Radio interfacing on the VR-7500 only works with the Vero network and you cannot use it in the same way with Zello, for example. G0JMS told me that a US amateur had used a VR-7500 as a gateway between a network radio channel and a repeater. Other amateurs can connect to the network channel using either an Android mobile phone running the HT app, or another Vero VR-7500 and Android app running as a gateway and another FM to access the gateway.

If one or more amateurs in your area have VR-7500 radios, it looks like there is an intriguing 'Teams' feature to play with. It bears some resemblance to Yaesu's Group Monitor feature on Fusion radios. The Vero Teams feature allows you to create a group of users on a particular frequency and once established it appears that you can exchange voice, APRS, Morse code and even SSTV pictures. I wasn't able to test this, which was a shame, but I was particularly intrigued by the possibility of sending SSTV natively! The documentation only mentions sending SSTV, so I am not sure whether you would be able to receive the pictures that were sent. Min, G0JMS says that this feature works on RF and he believes, on a network channel also.

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The Vero VR-N7500 does not have a control panel so can be mounted in the boot of your car.

What about the RF features?

Receive sensitivity of the VR-7500 seemed largely what I would expect from a VHF FM rig and I was able to hear everything that I expected to at the appropriate signal strengths. The VR-7500 has three output power settings; Low, Medium and High (VHF: 50W/UHF: 40W). I measured the power settings on 2m as High: 40W, Medium: 15W and Low: 7W. Measurements on 70cm was a little less on the high power setting at around 35W but 15W and 7W on the medium and low settings respectively. Squelch control didn't seem quite as granular as I might have liked, but this was not a serious problem. Transceive coverage of the rig is between 136-174MHz and 400-480MHz, so please make sure that you type carefully when setting up the transmit frequency! If you wanted to set a receive only channel – perhaps Marine band or PMR446, then you could easily do this, setting 'Disable TX' in the channel settings. To be doubly secure, you could set an obscure Tx frequency in the amateur bands, so that there was no chance of transmitting somewhere that you shouldn't.

The audio quality of the speaker in the supplied speaker/mic was 'average'. I found it a little prone to distortion even at modest levels. It wasn't dreadful, just not quite as sharp as I'd have liked. Tone is generally on the high side, which is probably quite good for listening in the car, but perhaps less pleasant when listening in a quieter shack.

Bluetooth speaker/microphones

The VR-7500 does not come with a Bluetooth microphone as standard. There are two different types of Bluetooth microphone. The first that I tested was an BMH-7500 that looks exactly like a speaker/mic but without a cord.

To use it, of course, you'll need to pair it. Put the rig into pairing mode by pressing the power button twice in quick succession. Then switch on the BMH-7500 and place that into pairing mode by pressing the power button on the microphone twice in quick succession. After a short while there will be a Chinese announcement (there's no option to change to English) and the pattern of the lights on the microphone will change. All being well, the speaker/mic is now paired with the rig.

The two buttons with arrows on the right of the microphone keypad serve as up and down keys. Pressing the OK button on the keypad allows you to toggle between the up/down keys serving as volume or channel controls. When in channel mode, the microphone will announce which channel number (in the group of sixteen) that you are on.

Audio quality of the BMH-7500 seemed broadly similar to the speaker/microphone on the wired microphone, which as they look almost identical is not surprising. However, there seemed a little less distortion on the BMH-7500, which made me wonder if my wired microphone had a minor fault.

The range of the Bluetooth seemed to allow a distance of 10m or so between the rig and speaker/microphone that would certainly be adequate for placing the rig in the boot of your car, or under a seat. If you were using it in the shack, you wouldn't be able to get too far around the house with it, but it would afford some flexibility. The BMH-7500 has a magnet on the back of it, allowing you to secure the microphone to some suitable metallic object.

The second Bluetooth speaker/microphone that I tested was the BHM-78, also from Vero. This is a more sophisticated device and in fact, looks like a miniature handheld. It's a Bluetooth speaker/microphone with GPS and colour display capability. You can either pair it directly with the rig, or with your mobile phone, where it will communicate with the HT application. A word of warning if you are iOS user – this didn't seem to work when I tried it. If you are an Android user, you can use the BHM-78 as a speaker microphone, not only to the Vero VR-N7500 but also for the Network Radio channel.

The BHM-78 also has a nice compass display (which seems quite accurate) as well as indicated your altitude (calculated by GPS) and the current temperature. It will also show a distance and bearing to APRS stations that you have received.

Despite a fairly small speaker, the audio quality from the BHM-78 is quite pleasant to listen to and does not distort unduly at the type of volume that you might need to listen to in a vehicle, although it does not lend itself to handsfree operation.

A Bluetooth PTT is also available, another useful option when mobile.

Overall

I said at the outset that the Vero VR-N7500 is an innovative device. The nice thing is that the facilities are well implemented and did not feel flaky. RF performance of the rig was perfectly respectable and I liked the well-built, chunky feel of the rig itself.

The built in APRS capabilities were enjoyable and well implemented.

You will get the most out of the VR-N7500 if you are an Android user. If you are an iOS user, then, as I've noted, things will be a little more restricted and there is no possibility for you to use the Network Radio capabilities. Vero Teams features, which look interesting, are only available to Android users.

If I had a reservation, it was about the requirement to have a mobile phone as a control panel. Why? After all, most of us carry a phone with us all the time and programming the rig from a quickly connected phone is hardly a problem. It's not that. My only reservation is that in 10 or 15 years time, Android and iOS may have vanished completely – or at least will have (I hope!) evolved massively. Finding a suitable device to program your VR-7500, may, at that time, prove a challenge – a bit like that bit of software than you can only run on a Windows 98 (or worse still, an MS-DOS) PC!

Assuming that you are happy to set that aside, then if you are someone who enjoys both radio and mobile phone technology then the Vero VR-N7500 is well worth a look. The 'headless' radio may also be attractive to those who monitor a limited range of channels – you don't need a display – you can just power on the rig and it will be on whatever channel you left it on. You can navigate the channels, if required, from the microphone, without recourse to your mobile phone, only using that if programming is required.

Thanks

Many thanks to Chris Taylor of Moonraker for the review model and his willingness to answer questions, also many thanks to Min, G0JMS for his insight into the detailed operation of the VR-N7500. The VR-N7500 costs £149.99, the BMH-7500 speaker microphone £39.95, the Bluetooth PTT £12.95 and the N7500 LCD Speaker Microphone BHM-78 unit £59.95 available from Moonraker UK Ltd (https://moonrakeronline.com/) and other retailers.

On the Cusp of a Scientific Revolution?

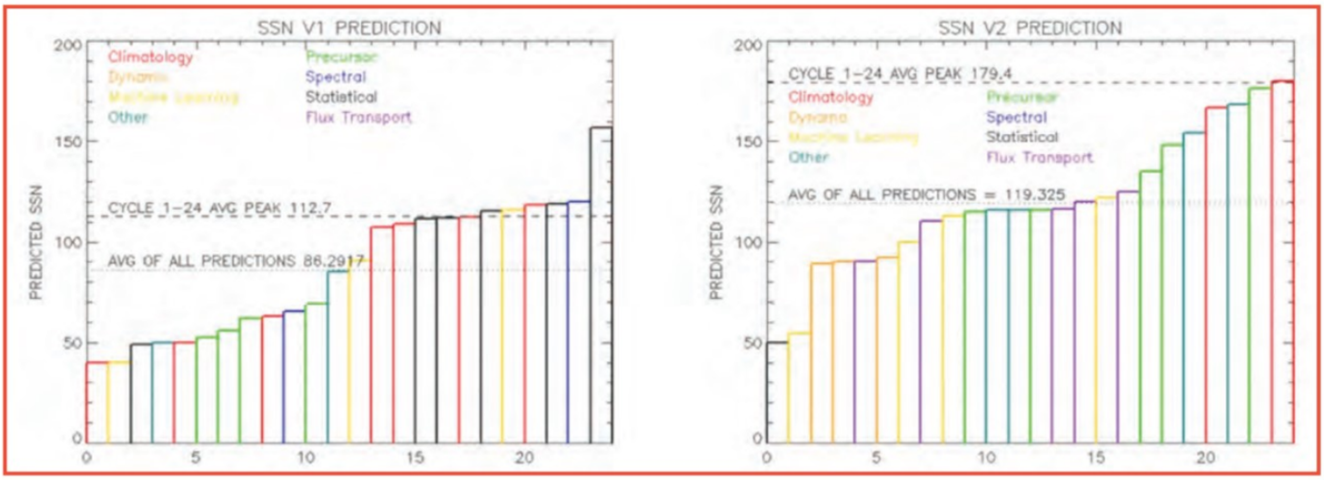

FIGURE 2: **NASA-NOAA Panel Cycle 25 Predication Graph of 61 Empirical Models Considered.**

Part two of this article will examine the predictions for Cycle 25 and what the data may mean.

McIntosh et al. (2020) were pleasantly surprised to see that there was a linear relationship between the terminator separation and the upcoming Sunspot Cycle strength. Indeed, this technique 'nailed' Sunspot Cycle 24, which many at the time failed to do. They also noted the likelihood that the terminator to end Sunspot Cycle 24 was imminent. This indicated that a *very short* terminator separation was likely and thus Sunspot Cycle 25 may have significant amplitude. One more than double the amplitude that had just been presented by a NOAA-NASA Panel of solar activity and dynamo experts. This clear break between the methodologies presented an opportunity.

McIntosh et al. (2020) closed their analysis with a caveat – explicitly acknowledging Yogi Berra in that it "is tough to make predictions, especially about the future" – they would finalise their forecast of Sunspot Cycle 25 when the Sunspot Cycle 24 terminator arrives. Wait they did. Waiting until the last embers of 2021, following a few false starts in November 2020 and June 2021, the terminator arrived mid-December of 2021 (McIntosh et al. 2022). The 10 year, 10 month terminator separation led to a revised forecast of the Sunspot Cycle 25 at 190 [±20] that will peak in mid 2024, an amplitude just above the historical average but still 80 percent larger than the consensus forecast (see **Figure 5**).

With this revised forecast of Sunspot Cycle 25 activity levels, the McIntosh team used it to project the peak monthly solar flux level in the range 200 [±25] at solar maximum. This is based upon the relationship between the smoothed sunspot number and the radio solar flux transition transformation. This is shown in **Figure 6** and is based upon the monthly value.

If the hypotheses from McIntosh et al. (2020, 2022) yield a better forecast of Sunspot Cycle 25 than the Panel's consensus prediction which includes all of the pre-eminent physically motivated dynamo models (see Figure 2 from part 1 of this article, July 2022 *RadCom* and reproduced here), does this put the prevalent paradigm in a crisis state?

Are We in a Revolutionary Period?

A century ago, the world waited while some measurements were taken of the 1919 total solar eclipse. Albert Einstein's General Theory of Relativity had a sub-theorem of the Principle of Equivalence where he postulated in 1911 that light bending was a consequence (Gilmore and Tausch-Pebody 2020). Einstein and Freundlich sought astronomers to search for the light-bending effect.

This was a theoretical paradigm clash between the classical perspective of Newton (current paradigm) and the upstart and revolutionary postulates of Einstein. The prominent British expeditions led by Eddington, Dyson and Davidson, sponsored by the British Royal Society and the Royal Astronomical Society, headed to the tropics of Brazil and to the island of Principe while the literate world waited for the results.

History shows that Einstein's challenging paradigm-shift was supported by the results of the extraordinary experiments. The *London Times* headline stated, "Revolution in science. Newtonian ideas overthrown" (The Times 1919). Questions about the eclipse results that have been proven largely groundless aside (Gilmore and Tausch-Pebody 2020; Kennefleck 2009): *Who now reads Newton for science rather than history?*

We invoke this famous episode in physics to bring to bear how paradigmatic crises in science arise and can play out. **[note 4]** Key elements of extant theory can be challenged

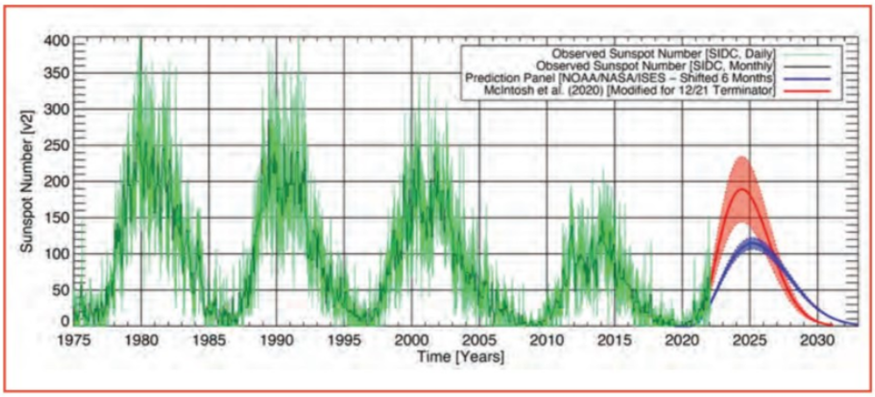

FIGURE 5: Final McIntosh Team and Official Panel Predictions for Cycle 25, Post-Terminator Event in December 2021.

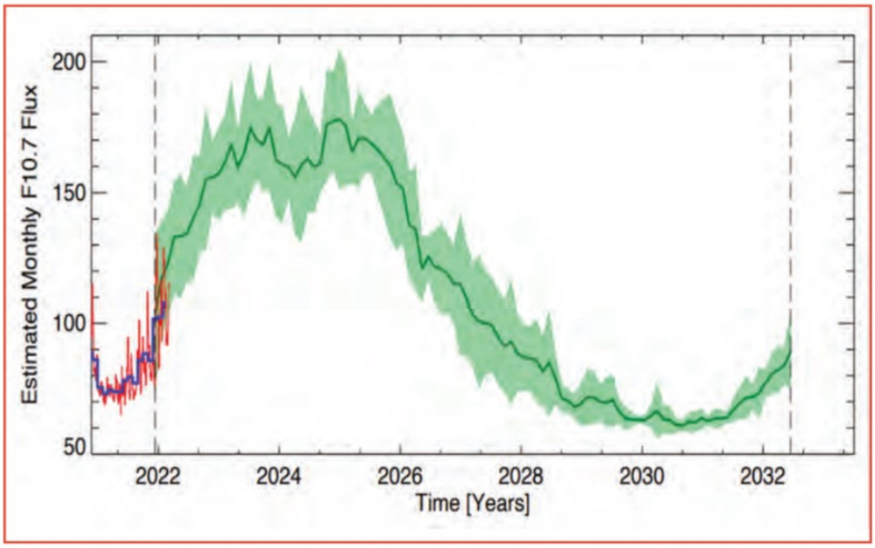

FIGURE 6: Prediction Model for Solar Flux (F10.7) at Solar Maximum for Sunspot Cycle 25.

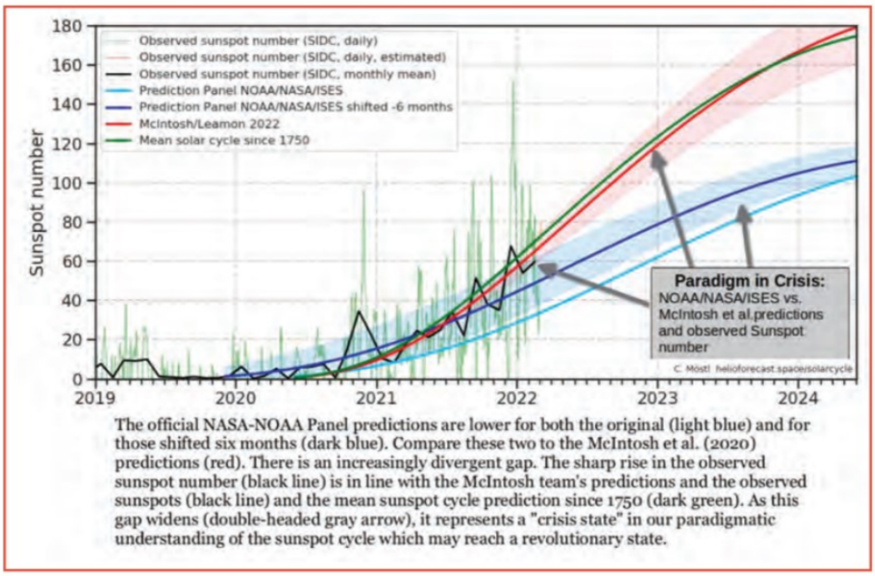

FIGURE 7: Paradigm Crisis State Illustration using McIntosh Team and Official Panel Predictions Compared to Observed Sunspots and Mean Sunspots Since 1750 Projection.

by substantive innovation and, if borne out by critical empirical observations (as in the solar eclipse expeditions of a century ago), the reigning paradigm moves into a *crisis* state as shown in Figure 1. We illustrate this below for the present day regarding the Solar Cycle in general and the cyclic nature of sunspots in particular.

With the NOAA-NASA Panel not providing scientific details underpinning their official prediction for Cycle 25, we are left to make suppositions about them (see also Nandy (2020)). These are legion in the practitioner world of amateur radio as we illustrated above. In the Panel's public documentation, the closest thing to theory-and-methods used are a list of the array of models they considered. **[note 5]** There is simply no public disclosure of how their official predictions were operationally constructed. We characterise the almost complete lack of questioning this omission of standard scientific disclosure by amateur radio operators a result of the 'boundary maintenance' influence that a well-ingrained reigning paradigm holds over its followers and practitioners.

Are we in a paradigm crisis stage for sunspot predictions? We illustrate in **Figure 7** these competing predictions and how they compare to empirical observation. The reader should refer to Figure 1 for the point in the cycle of paradigm change identified as a crisis state by the physicist Thomas Kuhn. It is striking that as each month and year passes, the predicted sunspot number by each source grows further apart.

There is a starkly clearer alignment of the McIntosh team prediction with the actual sunspot number as of this writing (March 2021). The Panel's predictions are much lower than both those of the McIntosh team and the average number of sunspots since 1750 projected over the horizon. More importantly, they are much *lower* than the actual observed sunspot number thus far in Cycle 25.

We ardently note that as time passed, the terminator failed to show up in 2020. However, the Sun did make and attempt to break out in November of that year but the increase in activity surged in the southern hemisphere and fizzled out in a few months (rotations). If we fast forward a year to December 2021, the equatorial bright point density dropped like a stone after fluctuating wildly since May 2021. All the other indicators of the terminator's arrival confirm the date as 13 December 2021, yielding a

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10-year and 10-month terminator separation. This is just below the historical average. The closing caveat of McIntosh et al. (2020) was invoked to finalise the forecast of solar cycle 25 to be above the historical average, at 190 ±30, approaching twice the amplitude of Sunspot Cycle 24 and the consensus forecast (McIntosh et al. 2022).

The central question is at what point, should this divergence continue into Cycle 25, will the translucent paradigm of the official NOAA-NASA Panel be in a crisis state? Should this play out over the next few years in this way, will we be on the cusp of a scientific revolution in our understanding and forecasting of the Sunspot Cycle?

We think that the preponderance of evidence in terms of the philosophy of science, competing theory and concepts, and peer-reviewed empirical data analysis suggest that we will indeed be in such crisis. The stark lack of scientific disclosure by the Panel as to the theoretical underpinnings and methods guiding their official predictions places a clear distinction between the current paradigm and the competing one proposed by the McIntosh team into that state of crisis already. Not unlike those interested in the class of ideas expressed by Newton and Einstein a century ago, amateur radio operators can follow the data at the HelioForecast website (https://helioforecast.space/solarcycle).

Notes

[4] The sad story of what was called "cold fusion" is an example of when new theoretical approaches do *not* cause a sufficient scientific rift in paradigmatic terms to warrant a crisis. See one version of the story by Gary Taubes called *Bad Science: The Short Life and Weird Times of Cold Fusion* (1993). Taubes earlier had examined the role of economics in science in the prominent magazine, *Science* (1990). This is not divorced from the present case of "institutional" official predictions of sunspots. Government appropriations and grants to university and private sector research centers are frequently swayed by the "boundary maintenance" of an existing paradigm (Kuhn 1962; Sinderman 2001). We suspect that Wilson's early work on the Hale Cycle and sunspots was deemed insufficiently "interesting" by the larger community of scientists.

[5] This is not unlike modern-day meteorologists who predict the path of a hurricane by using an average of "spaghetti models" of the hurricane's future path. A spaghetti model is a nickname for computer models visualising the *potential* path of a tropical cyclone. When shown together, the individual model tracks can somewhat resemble strands of spaghetti. They are based upon a range of forecast models and traditions and have been said to be "limited by human imagination and bounded by weather data" (https://weather.com/science/weather-explainers/news/spaghetti-models-tropics-tropical-storm-hurricane). These spaghetti model averages are often subsequently superseded by the National Hurricane Center's 3-7 day advisories (not unlike sunspot predictions being updated as a specific Cycle progresses) (https://apps.sfwmd.gov/sfwmd/common/images/weather/plots.html).

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This is a very controversial theory that goes against the official predictions for Solar Cycle 25. The Solar Cycle Prediction Panel, which comprises scientists representing NOAA, NASA, the International Space Environment Services, and other US and international scientists, predicts that Solar Cycle 25 will be a fairly weak cycle, the same strength as cycle 24.

It says solar maximum is expected in July 2025, with a peak of 115 sunspots. The Howell/Mcintosh paper puts the maximum at around 190 in late 2024.

It will be interesting to see what actually happens, although we will have to wait at least two to three years to find out!

RSGB Propagation Studies Committee