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June 2023

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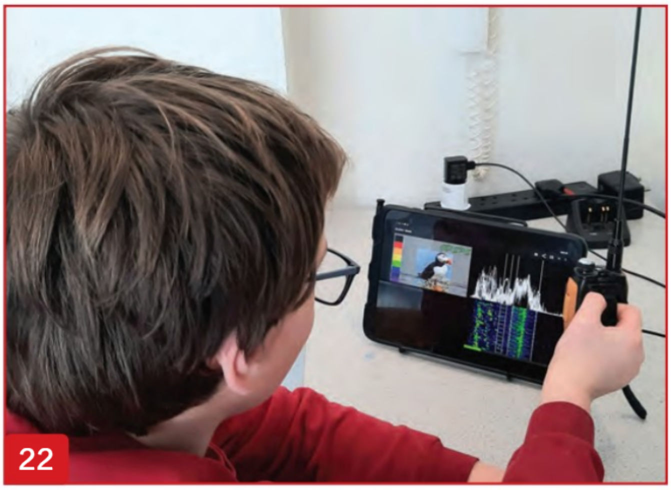

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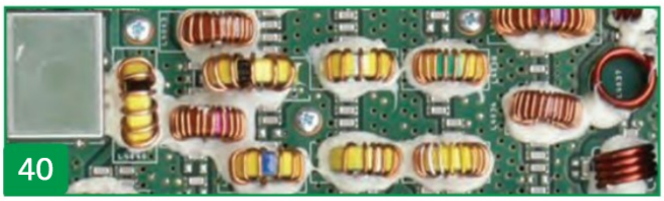

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Yaesu FT-710 review
Design by Kevin Williams, M6CYB

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

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New Products

ACOM 500S Solid State 160-4m Linear Amplifier

ACOM Bulgaria has just released its new 500S Solid State Linear Amplifier. Significantly, this is the first ever model in the range to cover from HF up to 4m (70MHz). Built to the usual high standards the 500S will give 500W or digital modes) for 20W drive and includes two antenna o change or CAT interface. The product is availabl from The DX Shop Limited which is now centre for their products. For m

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pssuspend.exe	30/03/2023 16:58	Application	384 KB
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Pstools.chm	01/10/2012 20:53	Compiled HTML ...	66 KB
psversion.txt	06/11/2007 20:47	Text Document	1 KB
RAMMap.exe	11/05/2022 16:49	Application	662 KB
RAMMap64.exe	11/05/2022 16:49	Application	355 KB
RDCMan.exe	25/01/2023 18:11	Application	1,858 KB
readme.txt	12/04/2023 00:37	Text Document	8 KB

- FM radio/ air band receiving
- VOX (voice-operated transmission)
- NOAA weather forecast
- Built-in torch
- Frequency/ DCS/ CTCSS scan
- Digital signal CTCC/ DCS
- 1600 mAh rechargeable Li-ion battery pack
- USB Type C and desktop cradle charging

Available from Mirfield Electronics for £37.95. For more information visit: www.mirfield-electronics.co.uk

MyDEL Kevlar 50 metres braided antenna wire

This product is made in London, UK to meet military specifications and is the same wire braid used by the Royal Signals, British Army along with NATO and other military users.

With a 2.7mm diameter, the wire is incredibly flexible, strong, and almost indestructible. The tinned copper weave and Kevlar core make it virtually unbreakable, even under a 135Kg or 300lb strain test.

The wire is very easy to solder, making it an ideal choice for radio enthusiasts.

Available from Martin Lynch & Sons for £59.95. See www.hamradio.co.uk for more information

MC-750 100W portable HF antenna

A portable antenna kit that supports the 40-6m bands with maximum power of 100W PEP. With a 65 x 9x 7cm carry bag (1.8kg), it can be easily packed for travel. It operates as 1/4 wavelength antenna on 14MHz-50MHz. For 7MHz operation, the supplied 7MHz coil is needed.

Frequency range: 7MHz-50MHz

Impedance: 50Ω

Radials: 4 x 3.5m

Available from Martin Lynch & sons for £199.99.

See www.hamradio.co.uk for more information.

Data

FIGURE 1: partial screenshot from the oscardata software.

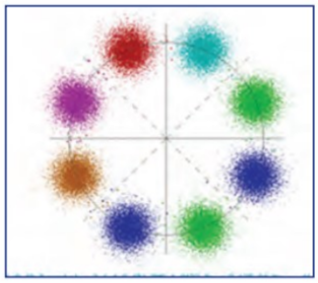

FIGURE 2: simulated standard 8-PSK constellation.

High Speed Mode on QO-100

Users of the QO-100 satellite's narrowband transponder may have noticed a continuous noise-like signal, about the width of a standard SSB filter, just below the upper beacon signal and centred on 10489.995MHz. This is a broadcast using a new high-speed modem, HSMODEM developed by members of Amsat-DL, especially DJ0ABR and DD1US and is listed in the band plan as an "Experimental Multi-Mode Beacon".

The developers wanted as fast a data rate that could be achieved while sticking to the rules, requiring that transmissions through the transponder must be no more than 2.7kHz wide, and must not be stronger than the upper and lower beacons. These two requirements restrain the maximum possible theoretical data, according to Shannon's law **[1]** to an absolute maximum of around 9kBits/s when in a pure Gaussian noise restricted environment like that on the satellite link. The power limits the best S/N ratio that can be achieved and the bandwidth restricts the symbol rate. There is also a requirement from Amsat that all communications via QO-100 use full duplex so transmissions can be monitored in real time.

The developers initially considered one of the many high-speed modem waveforms used at HF to achieve 4800b/s and higher rates but eventually ruled these out. HF waveforms are all designed to cope with the vagaries of HF propagation such as fading and multipath and therefore carry overhead in training and clock recovery signalling that wastes potential capacity. So, they looked for a more customised waveform.

The need was for up to 7200b/s for multi-media transport, pictures, bulletin boards, news and web pages, although lower data rates should be entertained for radios with restricted bandwidth (such as older SSB radios) and those with smaller antennas. The developers eventually settled on a combined amplitude-phase waveform with eight states. This allows three bits per symbol which, at a baud rate of 2400Hz to fit comfortably in the necessary bandwidth, means the data rate is potentially 7200b/s. With the use of file compression, an effective rate of over 9000b/s is theoretically achievable, although this is lowered appreciably in practice. Reed-Solomon error correction is added to strengthen the link. The modem works in full duplex mode with simultaneous encoding and decoding.

The Software

Software, *oscardata*, for using HSMODEM, and receiving the beacon broadcast can be found at **[2]**, which also links to a fuller description of the project, the waveform, and has software download and instructions for installation. It is available for Windows, Linux and R-Pi computers; the Windows version is stated to require Win-10 *but may work with Win-7, although this is untested*. I downloaded the *oscardata* package which installed OK and, after a bit of setting up, ran perfectly on my Win-10 laptop. However, although it installed OK on my quite powerful albeit 15-year-old Win-7 desktop it failed to work, generating a run-time error message from HSMODEM which failed to start.

In use the modem runs in the background – a command prompt screen gives the state of this. The main *oscardata* screen, shown in **Figure 1**, gives access to file, text and picture transmission and receiving. Unfortunately, since I cannot install on my Win-7 shack computer, it is difficult to transmit using this laptop, and at the time of writing only beacon reception has been tested. Not spelled out very well in the manual is the fact that the beacon broadcast carries data that is presented on a webpage. You have to open an html file, *oscardata.html*, supplied in the software installation package. That in turn offers real-time spectrum usage plots of both satellite transponders and various information pages such as CW skimmer, Amsat news and satellite PSK-reporter hits.

The Waveform

We have to mention this as it's somewhat unusual. Normally the eight states needed to send three bits per symbol would be encoded as 8 phases arranged around a circle. An example of this can be seen in the simulated 8-PSK waveform of **Figure 2**. For *HSMODEM* the eight constellation positions are organised, unusually, as seven placed around a circle and one at zero amplitude in the middle. Seven in the circle means the points are 51.4° apart, instead of the standard 45° for 8-PSK, which results in a slightly better use of the constellation space. A greater distance between adjacent points that permits reliable decoding in a slightly lower S/N than 8-PSK can offer. The constellation plot of a real off-air signal using this pattern can be seen in the bottom left of Figure 1. Rather neat, a bit of lateral thinking on the designers' part and a datamode constellation not seen very often. The inclusion of a zero amplitude point, which will occur on average every eight symbols, will help in clock recovery, needing less non-linear processing to extract a clock signal.

For lower power stations with reduced bandwidth there is a fallback mode using 4-QPSK (two bits per symbol), with a constellation using the basic square pattern.

Renaming Serial Ports

Mike, W9MDB, writing in the WSJT Group, provides information on changing the name of your serial COM ports to make them more explicit: "I renamed my serial ports to include info on the hardware connected. I also found that if you put a space in front of the single-digit COM ports you can see them in COM port order in device manager.

"So I now have renamed ports based on details found in the reference **[3]**:

- Open properties of the device in Device Manager
- Under the details tab, select Driver Key and copy the value it shows
- Open regedit and search for the value within HKEY_LOCAL_MACHINE\SYSTEM\ControlSet001\Enum
- Give yourself ownership and full control over the key (folder) that you find it in
- Add/Edit the string value with name *FriendlyName*. Use whatever name you want it to have
- The new name will take effect when you reopen Device Manager"

References

[1] Shannon's Law relating S/N, bandwidth and information carrying capacity: https://en.wikipedia.org/wiki/Shannon%E2%80%93Hartley_theorem

[2] HSMODEM and the QO-100 High Speed Multimedia Beacon: https://amsat-dl.org/en/qo-100-high-speed-multi-media-beacon/

[3] Renaming COM ports: http://www.eightforums.com/customization/15321-tutorial-how-change-device-names-device-manager.html

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Antennas

When it comes to HF antennas, especially those that purport to be 'multi' band, it is easy to follow the maxim that there is no such thing as a free lunch. So, when I discovered information relating to the design of the Rybakov multi-band vertical antenna, I read this with an intrigued, yet cautious mind.

The Rybakov is a 7.6m (around 25 feet) long vertical antenna, designed for quick deployment when operating portable, and is said to be able to cover all bands from 80 to 6m. The antenna's design and name originated from Enrico, IV3SBE. He named the antenna as the 'Rybakov 806' (806 referring to both the lowest and highest bands covered). The name 'Rybakov' derives from the Russian for 'fisherman', perhaps a play on the fibreglass, fishing-style poles often used to help deploy this antenna. Or perhaps, the nature of our hobby, casting our net to try and catch contacts?

The Rybakov design

Semantics aside, the design of the antenna is quite clear and easy to follow. As **figure 1** shows, the radiating wire should be fed via a 4:1 UNUN. This antenna will undoubtedly require the use of an external tuner, and is likely to require the use of a wide ranging ATU owing to the range of impedances presented across different bands. So, why 7.6m?

The first reason is the need to present an impedance that our tuner can match across various bands, this is not an easy thing to achieve. For instance, if we reduced the length to 5m, we would instantly be left with a lower impedance (likely around 30-50Ω) on 14MHz as a quarter-wave, but contrastingly a very high impedance (upwards of 2,000-3,000Ω or more) on 28MHz as a half-wave. 6m of antenna length begins to provide a problem for the 12m band, owing again to its proximity to being a half-wave on that band. Also note that both 5 and 6m of length means that the antenna is still very short for 7MHz and would suffer in terms of having a low radiation resistance and radiation efficiency, as well as possibly presenting a low impedance for the tuner to try and match.

The final length of 7.6m therefore means that the antenna avoids being a quarter-wave on any band from 40 to 10m (although it is close to being one on 30m) and just about swerves away from being a half-wave on 21MHz, and even though

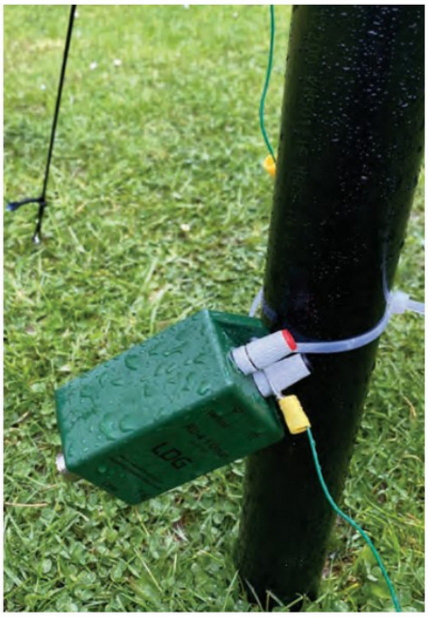


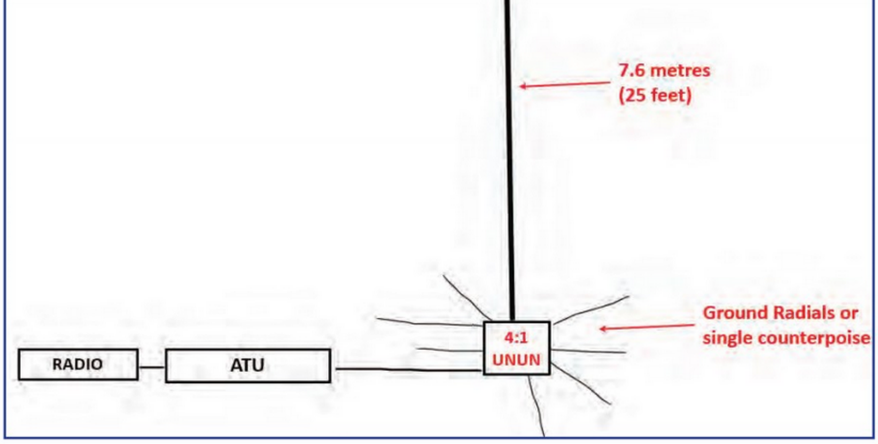
PHOTO 1: 4:1 UNUN attached to fibreglass pole

at 7.6m long the antenna is almost a half-wave at 18MHz, the use of a 4:1 UNUN should help to move impedance down to well below 1,000Ω and within reach of most automatic or manual external tuners (depending on the length and type of feeder used). Moreover, at 7.6m long, it reaches the length of a 3/16th wave for 7MHz and thus improves radiation efficiency by increasing radiation resistance at this length compared with smaller lengths.

On 40m, the antenna will be a compromise, being less than a quarter-wave in length. However, assuming that it is deployed on average ground, conductivity wise, a modest ground radial field of around 40m or more in total and considering additional losses for the ATU/UNUN (a reasonable estimate is a combined 2dB), it should still produce an overall radiation efficiency not much worse than 7-9dB compared with a similarly installed full-sized quarter-wave for the 40m band. Given its already compromised nature for 7MHz, it is my intention to focus on this antenna as a possible option for the 40 to 10m bands, rather than for the 80m band.

Bearing in mind the short nature of the antenna at 7MHz, a good radial ground system is very important to attempt to improve the radiation efficiency to become competitive with a similarly installed quarter-wave. Using ground-loss computations provided by the ARRL Antenna Handbook and based on using ground with average conductivity, improvements on 7MHz can be seen from the intended installation, using a total of 40m of ground radials (1 wavelength), to a maximum of 320m (8 wavelengths). Clearly, the latter we can assume to be a 'permanent' home-based set-up and the former more suited to a portable/semi-permanent installation. As we install more radials, we enhance the overall efficiency of this antenna, from a figure of around 10% using the 40m of radials, up to 27% using 320m (**Table 1**). These figures are based upon the antenna's radiation resistance of just over 14Ω and factoring in a combined ATU and UNUN loss at 2dB and the losses using the type and length of coaxial cable used. As we can see, once we install 160m of radials, the benefits of installing further radials reaches somewhat of a plateau. Note that at 160m of radials, the antenna improves by almost 3dB versus using the same antenna with

FIGURE 1: antenna and shack configuration.



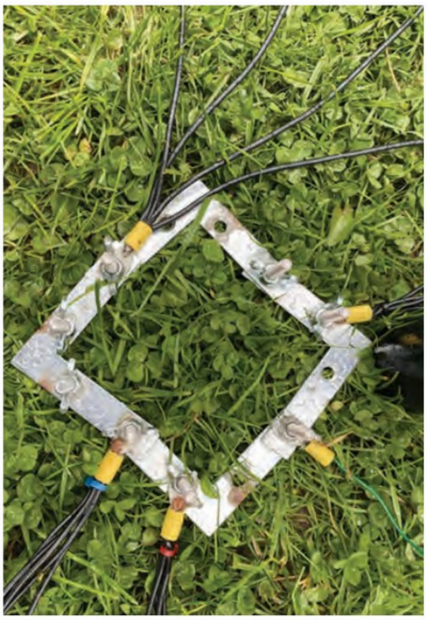


PHOTO 2: Homebrew radial plate.

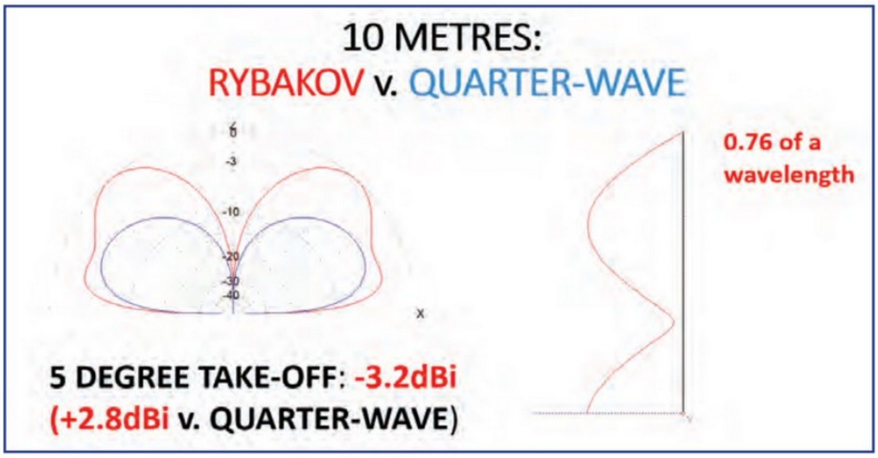


FIGURE 2: Rybakov versus quarter-wave antenna on the 10m band.

40m of radials and is now within 5dB of a quarter-wave (if the quarter-wave has a 1.2:1 feed-point VSWR, also using 40m of radials and with the same coaxial cable feedline used as the Rybakov).

At 10MHz and above, the Rybakov's efficiency becomes increasingly competitive versus a quarter-wave equivalent, again with the same total ground radial system of 40m and assuming a 1.2:1 feed-point VSWR for each quarter-wave. Factoring in radiation resistance, ground-loss, assumed Tuner/UNUN losses (at 2dB) and coax attenuation, each band is no worse than -2.0dB (30m) and, at best, it is -1.0dB (20m), compared with a quarter-wave equivalent for that band.

Before installation, it was also worth examining the potential gain for this vertical antenna, especially at lower angles which are useful for DX. Selecting a 5° take-off angle, it was interesting to use MMANA-gal modelling software to note the antenna's potential performance in comparison with a ground-mounted quarter-wave for each frequency. **Table 2** reveals that on 14MHz and below, this antenna provides gain at 5°, which is almost identical to that of a quarter-wave (around -6dBi). Once the antenna approaches a half-wave and longer (18-29MHz), we see an increase in low angle gain, especially on both the 12 and 10m bands. On 12m, this antenna is fractionally longer than a 5/8th wave and is a 0.76 wave on 10m (**figures 2 and 3**).

The second reason why this antenna is 7.6m long is the tricky conundrum of attempting to use a single vertical element across several bands. Whilst the aim of such an antenna length is to be sufficient to become competitive against a quarter-wave on its lowest frequency, it should also avoid being too long to injure low angle gain on its highest frequency. Therefore on 28MHz, this antenna is a fraction longer than a 3/4 wavelength long at 0.76 of a wavelength. Once any vertical's length surpasses 0.8 of a wavelength, gain at low angles begins to diminish (to a minimum of -9 dBi), as its main lobes occur at higher angles. This begins to reverse itself so that at around 1.25 of a wavelength, gain begins to match, or better, a quarter-wave equivalent. The Rybakov's length, therefore, is carefully chosen to be as efficient as possible on 7MHz, whilst keeping low angle gain characteristics on 28 and 29MHz. All whilst trying to avoid becoming a half-wave on any band, to avoid high impedances which could be tough to match.

40m BAND... IMPROVEMENT BY ADDING RADIALS			
40m GROUND RADIALS (current)	= 10% efficiency		(-7.6dB)
80m GROUND RADIALS	= 14% efficiency	(+1.5dB)	(-6.1dB)
160m GROUND RADIALS	= 19% efficiency	(+2.8dB)	(-4.8dB)
240m GROUND RADIALS	= 22% efficiency	(+3.5dB)	(-4.1dB)
320m GROUND RADIALS	= 27% efficiency	(+4.3dB)	(-3.2dB)

GREEN = v. CURRENT RYBAKOV WITH 40m OF RADIALS
BLUE = v. QUARTER-WAVE WITH 40m OF RADIALS

Note: Same UNUN and coax type/length used

TABLE 1: efficiency improved by adding radials.

5 DEGREE TAKE OFF GAIN 40-10 METRES	
7.150 MHz:	-6.4dBi
10.120 MHz:	-6.7dBi
14.220 MHz:	-6.4dBi
18.130 MHz:	-5.4dBi
21.250 MHz:	-4.2dBi
24.950 MHz:	-2.4dBi
28.500 MHz:	-3.2dBi

TABLE 2: 5° take-off gain, 40-10m bands.

SWR MEASURED AT FEEDPOINT AT 4:1 UNUN	
7.150 MHz:	15:1
10.120 MHz:	9.8:1
14.220 MHz:	2.2:1
18.130 MHz:	11.2:1
21.250 MHz:	15:1
24.950 MHz:	8.3:1
28.500 MHz:	2.9:1

TABLE 3: SWR measurements at feedpoint.

COAX LOSS – 7m ECOFLEX 10 & 2m RG-58 (SWR & TYPE/LENGTH OF COAX USED)	
7.150 MHz:	0.7dB
10.120 MHz:	0.5dB
14.220 MHz:	0.2dB
18.130 MHz:	0.8dB
21.250 MHz:	1.1dB
24.950 MHz:	0.7dB
28.500 MHz:	0.3dB

TABLE 4: coax losses.

Getting on the air

Having investigated its potential, it was time to get this antenna on the air. Selecting a typically wet and windy day, I cut a length of wire measuring 7.6m and attached this using a combination of electrical tape and reusable Velcro ties to an 8m fibreglass pole. The 4:1 UNUN was placed at the bottom of the guyed support pole used to slot the fibreglass pole into, and the antenna itself was attached to the red 'hot' side of the UNUN, with a short, 10cm wire attached to the black 'ground' side of the UNUN and then attached to the home-brew radial plate on the ground (**photos 1 and 2**). Radials were then attached to the homebrew plate. As indicated, I used a total of 40m of ground radials (4 bunches of 4 x 2.5m long wires) to emulate a typical portable set-up.

My first task was to measure the VSWR for each band at the feed-point of the 4:1 UNUN. Utilising a double PL-259 and my Rigexpert analyser, I derived the figures shown in **table 3**. At first glance, these figures seem challenging. On the 40m band, being a short vertical, this antenna

Tim Hier, G5TM.
timhier@icloud.com

PHOTO 3: operating position.

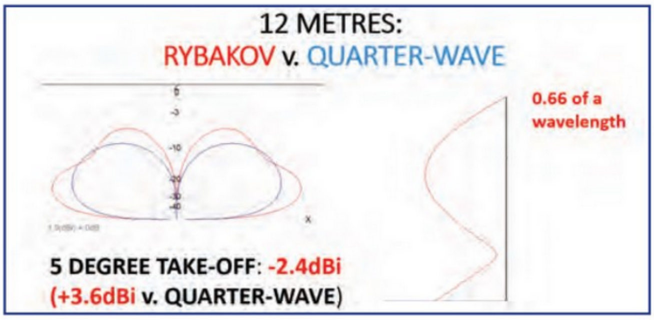


FIGURE 3: Rybakov versus quarter-wave antenna on the 12m band.

is already compromised, although feed-line attenuation will be less on 7MHz compared with higher frequencies. On the 15 and 17m bands, the elevated VSWR can be explained due to the length of this antenna being close to a half-wave for both bands (0.48 on 17m and 0.57 on 15m respectively) and thus producing a high feed-point impedance of more than 2,000Ω, which the 4:1 UNUN will partially reduce. Similarly, on the 12m band, the antenna will produce a slight mismatch owing to it being slightly longer than a 5/8 wave. On 20m, the antenna, as a 3/8 wave, will already produce a relatively close match to 200Ω, thus explaining why we have a decent match to 50Ω on 14MHz when using the 4:1 UNUN.

Bearing in mind the wide range of VSWR readings, the calculated feedline attenuation (using the KV5R coax loss calculator available online) was quite manageable (**table 4**). The combined 7m of Ecoflex-10 (which has almost an identical attenuation on HF as LMR 400) plus the added 2m of RG-58, which was necessary to reach the operating position, produced a respectable set of coax losses from 40 to 10m. Because of these workable losses, I decided to use the installation, shown in **figure 1**, as opposed to using a remote tuner closer to the feed-point, which would have offset any major losses. The shack setup is shown in **photo 3**.

Not only did the day I had available to test the antenna serve to be unsuitable weather-wise, but it also presented a poor day for HF conditions. The A and K indices were 66 and 6 respectively, showing a major solar event and rendering HF both noisy and quite flat.The good news was that all bands were tuneable to a VSWR of 1.5:1 or less. 40m did see the need to retune towards the extreme band edges, as VSWR slipped over 2:1, however this was to be expected with a relatively short antenna. This was not necessary for any of the bands from 30 to 10m. Despite this, I was able to make contacts during the next two days, using SSB. Whilst DX was far from plentiful, I was able to use the antenna to make contacts on 40, 20 and 10m (I have yet to use data modes or CW so 30m was not tested). Some inter-G was worked on 40m with varying signal reports (vertical antennas are usually less proficient for short-skip contacts compared with a low height dipole, for example). On 20, 17, 15 and 12m, several contacts with Eastern Europe were made, with strong Rx and Tx signals in most cases. On 28MHz, I managed to work six stations from Israel during the Holyland contest that afternoon.

Conclusion and future thoughts

The Rybakov antenna shows some promise as a 'Jack-of-all-trades' antenna. It is clearly a compromise on 40m, but caution should always be exercised when measuring the efficiency of antennas purely in terms of percentages. It is sometimes easy to overlook that an antenna with an efficiency of 10%, such as this antenna is likely to be, on 7MHz (mostly governed by its short length and the modest ground system used), less than two S-units down on an antenna with an 85% efficiency (which is pretty good) using the same Tx power. This is why mobile operators often enjoy success on 40m with very short, loaded whip antennas, which typically perform at half the efficiency compared with this version of the Rybakov.

As a vertical which is shorter than a quarter-wave on 7MHz, the Rybakov definitely requires a good ground radial system. Many articles concerning this antenna recommend the use of a single counterpoise wire of around 5m in length. This will serve to assist on the higher HF bands but serves as a wholly inadequate ground system for operation on 40m. Using several short radials of around 2.5m really assists this antenna in terms of reducing ground losses. If this antenna is considered as a permanent or semi-permanent installation, then the amount of 4 wavelengths for 40m (160 metres in total of ground radials) should be considered. In other words, get as many radials on the ground as you can. On the higher HF frequencies, especially at 14MHz and above, with the antenna ranging from 0.38 to 0.76 of a wavelength long, fewer radials are acceptable.

From 14 to 21MHz, the Rybakov, using the configuration described in this article, will provide practically identical real-world performance to a comparable quarter-wave, using the same ground radial system on each band. On the 12 and 10m bands, this antenna provides gain at the low, DX-friendly angle of 5° take off which is between 3 and 4dBi superior to a quarter-wave. Alternative configurations for this antenna are of course possible. A 9:1 UNUN could be used, although this may provide a greater challenge to match frequencies with already low impedances, such as 10 and 7MHz, although this would assist lowering the already high impedance for 18 and 21MHz. A remote, weatherproof ATU (avoiding the use of an UNUN) may well be fruitful as this could, in theory, remove some UNUN losses. Although the higher impedances on 18 and 21MHz may again prove tough for such an ATU to match to 50Ω.

It is important to also note that when deploying this, or any non-resonant antenna system, with the ATU at the radio end of the feedline, care should be taken to select good quality, low-loss coaxial cable to minimise losses. The coaxial cable I used for this installation (Ecoflex-10) has losses equivalent to LMR400, a coaxial cable often used for reasonably long runs on VHF and even UHF. Otherwise, keep the length of the coaxial cable to a minimum.

The final aspect to ponder is that when considering the length of radiator to be used in a single non-resonant vertical HF antenna, it is very difficult to choose a length which provides an acceptable compromise on the lowest frequency, whilst still avoiding the creation of high lobes which would dilute DX performance on the higher HF bands, whilst also treading the fine line of presenting an acceptable range of matchable impedances across several HF bands. The Rybakov comes closer than most to doing this across a band ratio of 4:1 (40-10m).

I look forward to using this antenna in a portable configuration in the future. Living a ten-minute drive to a seaside location will, no doubt, aid the performance of almost all vertical HF antennas. The Rybakov is without doubt a compromise, but with careful planning and deployment, could yet prove to be a happy one.

Feature

Radio blackouts and the severe March storm

On 23 and 24 March 2023 the severity of an ionospheric storm surprised space weather forecasters. Maximum usable frequencies were significantly lower than normal, and auroras spread to mid-latitudes.

A geomagnetic storm **[1]** started at 1200UTC on 23 March and peaked at 0300UTC the following day. The peak value of the planetary K index (Kp) was 8. As shown in **Table 1**, this corresponds to a severe (G4) storm **[2]**. This was the most intense storm in nearly six years. **Figure 1** shows the effect on critical frequencies (foF2) measured using the Fairford, England, ionosonde **[3]**. FoF2 (MHz) is shown vs UT time. FoF2 is the highest frequency that reflects back to the ground during vertical transmissions, and it determines maximum usable frequencies [2]. Green lines show foF2 on 19-23 March. The red line shows a significant drop in foF2 on 24 March when the storm peaked.

On average, geomagnetic storms are more severe near the equinoxes in March and September. In this case, a fast solar wind from a large coronal hole and a difficult-to-track coronal mass ejection combined to produce a severe ionospheric storm **[4]**.

For comparison, **Figure 2** shows scaling factors from the NOAA STORM Time computer model for estimating deviations in foF2 caused by a storm **[5]**. Scaling factors are shown vs UTC time on 24 and 25 March. Red symbols show when foF2 falls more than 25% below the monthly mean foF2 used in the model. These estimates are updated every hour. They show when quiet-day estimates of foF2 should be revised because of a storm.

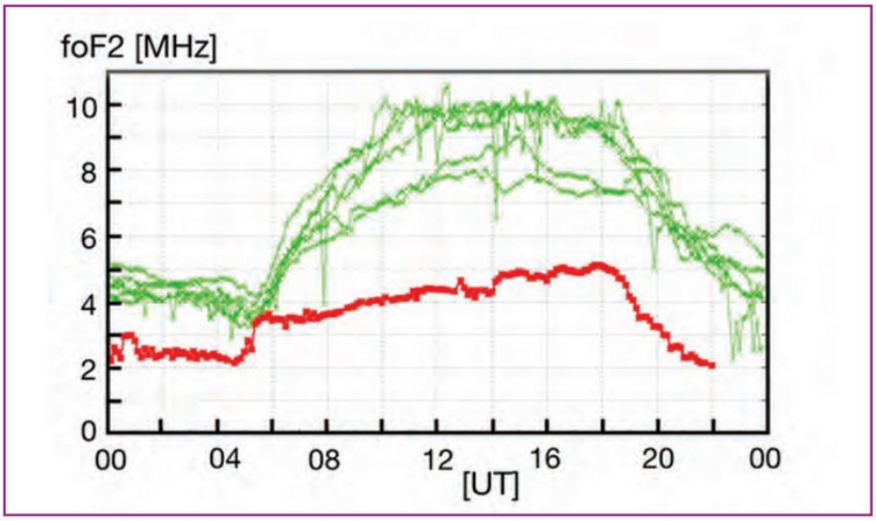


FIGURE 1: **Measurements of critical frequency (foF2) at the Fairford, England, ionosonde show the effect of the 23, 24 March 2023 ionospheric storm. FoF2 (MHz) is shown *vs* UT time for 19, 23 March (green) and 24 March (red) [3].**

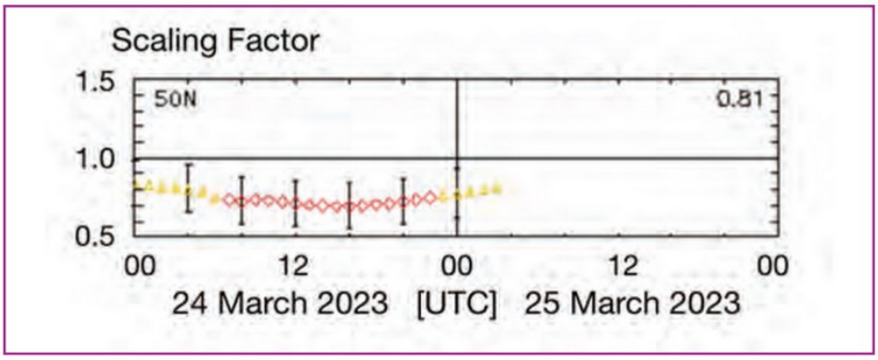


FIGURE 2: **STORM Time Model scaling factors for 50N latitude *vs* UTC time and date. Red symbols show when the critical frequency foF2 falls more than 25% below the monthly mean foF2 used in the model [5].**

Table 1: NOAA Space Weather Scale for Geomagnetic Storms [2].

Level		Propagation	Kp
G5	Extreme	May be impossible	9
G4	Severe	Sporadic	8
G3	Strong	Intermittent	7
G2	Moderate	Fades at higher latitudes	6
G1	Minor	No effect	5

References

[1] Steve Nichols, G0KYA, Radio Propagation Explained, RSGB.

[2] https://www.swpc.noaa.gov/noaa-scales-explanation

[3] https://www.ngdc.noaa.gov/stp/IONO/rt-iono/realtime/RealTime_foF2.html

[4] Tamitha Skov, A Dark Coronal Hole & Stealthy Solar Storm, 23 March 2023.
https://youtu.be/bG0zCbXukm4

[5] https://www.swpc.noaa.gov/products/storm-time-empirical-ionospheric-correction

[5] https://www.swpc.noaa.gov/products/storm-time-empirical-ionospheric-correction

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EMC

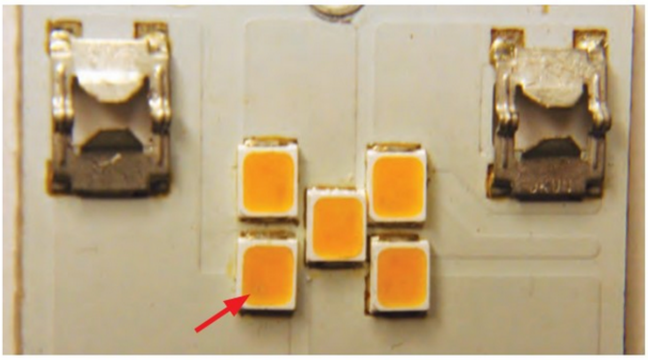

PHOTO 1: **LEDs in a failed GU10 LED lamp. Note small dark spot on failed LED in lower left corner (arrowed).**

Bandwidth and noise

In response to the April 2023 *RadCom* EMC Column, a Member wrote, "Thanks for your continuing efforts in what must at times be a soul-destroying fight against RF noise on behalf of the amateur radio community. I often save reading the EMC column to last because I find it to be the most interesting bit of *RadCom*."

Our Member then asks about how to scale measurements of noise power between different measurement bandwidths. For example, for one measurement the equivalent electric field strength was 28.23dBuV/m at 1.818MHz and the spectrum analyser Resolution Bandwidth (RBW) was set to 300Hz. In the text it was stated that the equivalent field strength in a 9kHz bandwidth would be 43dBuV/m, or an increase of 14.77dB. Where does this figure come from? The answer is 10 x Log(9000/300) which is 14.77dB. The Member's query arises because we are dealing with field strength which is a 'voltage' quantity, not a 'power' quantity, so he asks whether the calculation should be 20 x Log(bandwidth ratio), rather than 10 x Log(bandwidth ratio)?

The answer is that if we scale noise from one bandwidth to another, this is a power ratio. Random thermal noise or any signal or interference that has noise-like properties has a certain amount of noise power in each 1Hz of bandwidth. That means that if we change our measurement bandwidth from 300Hz to 9000Hz the bandwidth is 30 times higher and the noise power is also 30 times higher. 10 x Log(30) comes to 14.77dB.

Why 9kHz?

A Member wonders where the EMC measurement standard based upon 9kHz bandwidth came from. Was it based on the European 9kHz channel spacing for MF broadcasting? Yes, it was. A measurement bandwidth of 9kHz is used for EMC measurements from 150kHz-30MHz because this is considered to be representative of AM broadcast receivers. A measurement bandwidth of 200Hz is used below 150kHz and a bandwidth of 120kHz is used above 30MHz.

Number of devices

CISPR (Comité International Spécial des Perturbations Radioélectriques/International Special Committee on Radio Interference) was founded in 1934 to deal with the subject or radio interference at an international level. CISPR has various subcommittees including CISPR H – Limits for the protection of radio frequencies. The matter of EMC limits is of particular interest to radio amateurs as the CISPR limits below 1000MHz were originally designed to protect reception of broadcast radio and TV signals rather than weak signal amateur radio communications.

In recent years, it has become clear that some of the assumptions that were made when the limits were originally set are no longer valid. For example, it is assumed that the source of disturbance is 10m from the victim receiver, that one single device can emit RFI up to the limit and that devices are not always on so the probability of interference is reduced. Clearly the situation has changed a great deal since some CISPR limits were originally set, some in the 1950s and 1960s. The number of devices in a typical domestic environment has greatly increased, the average separation has decreased and many devices are always on. New developments include the universal use of switching power supplies, LED lighting, inverters in air source heat pumps and optimisers in solar PV systems.

The increasing number of devices is of particular concern. If your house has only one LED light, one mobile phone charger, one TV or one solar PV optimiser (but not all four!), if this one device is 10m from your receiving antenna and if RFI from neighbours' devices is insignificant then the existing EMC limits would protect broadcast signal reception as originally intended but not weak signal amateur radio reception. Clearly this scenario is unrealistic, so something needs to be done. But what needs to be done and who can do it? Typically, EMC standards committees have a majority of industrialists with few radio users. Organisations who represent radio users at an international level include the European Broadcasting Union (EBU) and the International Amateur Radio Union (IARU).

IARU EMC Committee members have done several years of work to make the case to CISPR that EMC limits need to take into account the increasing numbers of devices. This work was initially started by Tore, LA9QL with help from Martin, G8KDF. Since then, Martin, G8KDF has been IARU Global EMC Co-ordinator and he has been leading a CISPR steering committee task force. As of 27 April 2023, the published list of CISPR Working Documents includes CISPR/1497/DC with the title "Increased number of devices". The contents of this document are not publicly available at this stage, but it presents facts and scientifically-based analysis from which conclusions can be drawn. Some excellent work is being done on behalf of the IARU EMC Committee to feed into the international EMC standards making process. This process is inevitably slow, but the IARU work should produce benefits in the longer term. This work has become even more important with the recent news that fluorescent tubes and compact fluorescent lamps will no longer be sold after autumn 2023, so that LED lighting will become the only option for most domestic lighting.

Fluorescent lamps

According to **[1]** "The (European) Commission has adopted a package of rules ending a broad range of existing exemptions for the use of mercury in lamps..." 12 delegated acts have been adopted by the European Commission. These include:

[1] RoHS mercury exemption 1 (a)-(e) – compact fluorescent lamps for general purposes

[4] RoHS mercury exemption 2(a) (1)-(5) - linear fluorescent lamps for general lighting purposes

In the UK, the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2012) (the RoHS regulations) were the implementation into UK law of Directive 2011/65/EU. It appears that in England, Scotland and Wales, powers under the RoHS Directive previously

PHOTO 2: LED driver in a GU10 lamp, component side.

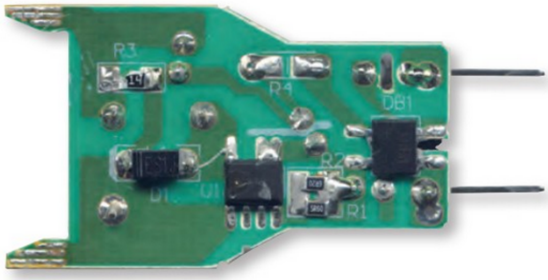

PHOTO 3: LED driver in a GU10 lamp, solder side.

held by the European Commission have been transferred to the Secretary of State. On 1 February 2023, the Department for Environment, Food and Rural Affairs (DEFRA) published decisions on recent determinations on applications for exemptions from the RoHS regulations. The wording appears to be identical to the European Commission delegated acts above.

The effect of the above DEFRA decisions in England, Scotland and Wales and European Commission delegated Acts in the EU and EEA is that exemptions from the RoHS regulations that allow compact fluorescent lamps (CFLs) and linear fluorescent tubes to be sold have been revoked and they expire on 1 February 2024. The exemptions for some types of fluorescent tubes including cold cathode fluorescent tubes used in LCD backlighting expire on 24 Feb 2025.

Consequently, from 1 February 2024, LED lighting will be the only option for most general lighting purposes. This has environmental benefits due to being Mercury-free and due to substantial energy saving. It has only been possible to phase out CFLs due to advances in LED lighting and cost reduction. From an EMC perspective, it is not all good news however. Although well-designed LED lighting should not generate more RF interference than CFLs, not all LED lighting is well designed for EMC. Even if one LED lamp complies with the relevant EMC standard, the cumulative effect of a large number of devices needs to be considered. As we know, not all LED lights do actually comply with the harmonised European standard.

LED 'tubes'

Fluorescent light fittings with linear fluorescent tubes up to 1500mm are widely used in premises such as shops, offices, factories and schools. When replacement fluorescent tubes are no longer available, it will either be necessary to replace the complete light fitting or to fit LED 'tubes'. These are direct replacements for fluorescent tubes, providing the light fitting has an iron cored magnetic 'ballast' choke, not a high frequency ballast. Due to the length of linear tubes, up to 1500mm or more, the potential for the LED 'tube' to act as an antenna that radiates RFI is increased compared to a more compact source such as a small LED lamp. We would be interested to hear of any EMC issues with LED 'tubes' that replaced linear fluorescent tubes.

LED lamp life

Many LED lamps quote an average lifetime of 25,000 or 30,000 hours and some LED luminaires (light fittings) are being sold where the LEDs are non-replaceable, so that if they fail the whole luminaire needs to be replaced. The lifetime quoted is for the LED chips themselves but LEDs need an electronic driver circuit and we have come across cases of premature failure that may be related to the driver rather than the LED chips. One possible cause of LED failure is over-voltage transients on the mains supply. As well as EMC standards for emissions of RFI by electrical lighting equipment, there are also EMC standards for immunity, including immunity to high voltage transients on the mains supply but it is not clear whether LED lights are immune to over-voltage transients on the mains, for example from inductive load switching.

Another possible cause of LED driver failure is inrush current when the LED lamp is switched on. The specification for some LED lamps is an average of 25,000 hours life but a maximum of 15,000 switch-on cycles. If the LED lamp is used in a room where it is frequently switched on and off to save energy, then the number of switch-on cycles could become the limiting factor for the life of the LED rather than the number of hours of operation. Installing a motion sensor to sense whether a room is occupied can produce further energy saving but it would also result in more switch-on cycles.

After a 5W LED GU10 spotlight failed after only about 1000 hours of use, we decided to investigate. **Photo 1** shows the LED board with five LED chips mounted on a metal plate for cooling. These were tested using a low voltage DC bench power supply unit and it was found that each one needs about 9V as each one has three LED chips inside. Four out of five were working but the one in the lower left corner had failed open-circuit and it has a small black spot, possibly where a bond wire to a chip has burned out. This may have been caused by overload.

Photos 2 and **3** show the LED driver. R3 was accidentally damaged when the 'potting' compound was removed. The AC mains comes in via a 10Ω fusible resistor FR1 into the bridge rectifier DB1. The DC output of the bridge rectifier at about 320V DC is fed to a 1uF smoothing capacitor C2 followed by a 3mH inductor L1 and another 1uF capacitor C1. U1 is a switching regulator chip and the yellow component that looks like a ferrite cored transformer is actually an inductor. This drives around 45V DC to the LED board although it is a constant current driver with the output current set by R1 and R2 in parallel. When we tested this particular LED lamp for emissions of RFI, it was relatively 'quiet' but immunity to mains-borne overvoltage 'spikes' is another question.

The failed LED was temporarily bypassed with a 10Ω 1W resistor and the lamp was reassembled. It was tested by increasing the AC voltage slowly using a 'Variac' (variable voltage transformer) as a precaution in case the driver had failed but it was found that the driver was working and four LEDs lit up. This raises the question, why did the LED fail? Did the driver drive too much current, possibly due to an over-voltage transient on the mains? If not, what went wrong? Has anyone else had premature failures with LED lamps? If you have a failed LED lamp, it is interesting to dismantle it and look for a tiny black spot on one of the LEDs that suggests it has been overloaded. Note that the LED driver may not provide any isolation from the mains so do not experiment with 230V AC mains powered LED lamps.

Websearch

[1] Clean and circular electronics: Commission ends use of mercury in lamps as mercury-free alternatives prevail https://environment.ec.europa.eu/news/clean-and-circular-electronics-commission-ends-use-mercury-lamps-mercury-free-alternatives-prevail-2021-12-16_en

[2] DEFRA Decision RoHS exemption applications: Secretary of State determinations https://www.gov.uk/government/publications/restriction-of-hazardous-substances-rohs-determinations-on-exemption-applications/rohs-exemption-applications-secretary-of-state-determinations

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Reciprocity of HF radio waves

To clarify the title, what is meant is that this is a look at whether the quality/strength of signals from the transmitting and receiving stations are the same, do they see the same magnitude of signal? This is a question that has been around for me since my professional telegraphist (radio operator) days, some 55 years ago! It was only recently realised that I now have the resources, and knowledge, to apply tools to answering the reciprocity question.

The tools that will be used during this study are: ITURHFProp **[1]**, HFRAY **[2]** and Proplab Pro 3 **[3]**. ITURHFProp will do the majority of the graft and I will use the other two programs to verify and analyse the results.

Background Data

To get underway some thought was put into which destinations would be chosen for the study. As this is not a mathematics treatise, more one that applies theory to practice, the choice was open to anywhere, globally. In the end, it did come down to some constraints; HFRAY only caters for paths with a maximum of four hops, thus excluding such choices as Melbourne, Australia. The selection now narrowed down, I picked upon Mauritius 3B8 and New York City. Other destinations show the same results so they will not be discussed.

To begin, a simple program was written to output propagation predictions for several different locations. This program showed the frequency and at what time to perform the next step. Another program was written to output data from these destinations, all destinations being used for both transmission and reception ie both ends of the path were predicted with the coordinates being reversed).

Figure 1 shows the predictions that were generated using the circuit G4FKH to New York and vice-versa. The most important information is highlighted, the rest will be utilised later. As can be quickly spotted, there are only two discrepancies in the data of immediate interest (Median received power), those are for 12:00 and 17:00 hours. Only 0.03 of a dB difference and therefore of little consequence. The columns prior to this should be self-explanatory, or can be easily looked up, and the columns following this one will be used later during the analysis and explanation section.

Data analysis and explanation

To corroborate the analysis that was just made, HFRAY was consulted and **Figure 2** was produced. This figure shows the G4FKH to New York circuit at 13:00 hours. For either direction the results are the same. The figure of 147dB is the circuit total loss and is the same in both directions. In **Figure 3**, PropLab Pro 3 shows a similar output to that in Figure 2. There are slight differences because of variances in the parameters due to the outputs being generated at different times. Other circuits show a similar picture and so will not be reproduced.

To make things clear, all the propagation parameters used so far have been identical for both directions, of course the only discrepancy to this is that the coordinates were reversed. Now, what happens when the local noise figure changes from 'RURAL' to 'RESIDENTIAL' at one end of the circuit? **Figure 4** shows such an instance when New York local noise was changed to 'RESIDENTIAL'. Notice that the 'Median received power' remains the same. Looking at the output, this time the SNR is highlighted. Here is an explanation of SNR: "In analogue and digital communications, a signal-to-noise ratio, often written S/N or SNR, is a measure of the strength of the desired signal relative to background noise (undesired signal)." **[4]**. It can be quickly discerned that the New York received SNR is smaller compared to that received at G4FKH. The circuit has lost reciprocity. Therefore, the SNR can be stated as a numerical measure of how well the received signal will be understood (all the other columns shown have the same designation as in Figure 1). This is the same situation when any of the other parameters are changed, ie increasing/decreasing the output power or changing the antenna type etc for either of the stations. The last column in Figure 1 and Figure 4 is the calculated percentage of basic circuit reliability and changes in the same manner as just discussed.

What does this all come down to?

If the setup at each end of a circuit is identical, and radio conditions at each end are identical,

Gwyn Williams, G4FKH
g4fkh@sky.com

FIGURE 1: the calculated data from circuit G4FKH to New York and vice-versa.

Month	Hour (UTC)	Frequency (MHz)	BMUF Path basic MUF (MHz	OPMUF Operation MUF (MHz)	OPMUF90 90% Operation MUF (MHz)	OPMUF10 10% Operation MUF (MHz)	Pr - Median receiver power (dB)	SNR - Median signal-to-noise ratio (dB)	BCR - Basic circuit reliability (%)
Predictions received at G4FKH from New York, March 2023									
03	12	21.025	22.15	25.47	18.71	30.95	-129.21	16.65	67.69
03	13	21.025	23.09	26.56	19.52	32.27	-130.41	15.40	64.48
03	14	21.025	23.28	26.77	20.08	31.60	-131.08	14.68	62.49
03	15	21.025	23.30	26.80	20.51	30.70	-129.48	16.23	66.65
03	16	21.025	23.41	26.93	20.60	30.84	-129.25	16.41	67.09
03	17	21.025	23.34	26.84	20.54	30.75	-128.69	16.99	68.51
Predictions received at New York from G4FKH, March 2023									
03	12	21.025	22.15	25.47	18.71	30.95	-129.18	11.78	52.90
03	13	21.025	23.09	19.52	19.52	32.27	-130.41	10.55	47.33
03	14	21.025	23.28	20.08	20.08	31.60	-131.08	9.88	43.71
03	15	21.025	23.30	20.51	20.51	30.70	-129.48	11.48	51.81
03	16	21.025	23.41	20.60	20.60	30.84	-129.25	11.71	52.64
03	17	21.025	23.34	20.54	20.54	30.75	-128.72	12.24	54.53

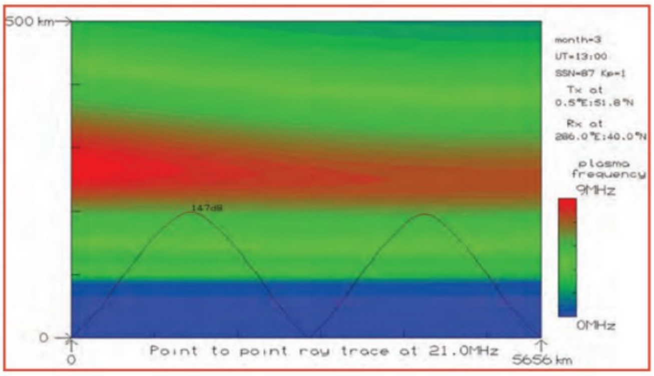

FIGURE 2: output from HFRAY for the G4FKH to New York circuit. Courtesy Chris Coleman, G4HCW's, HFRAY program.

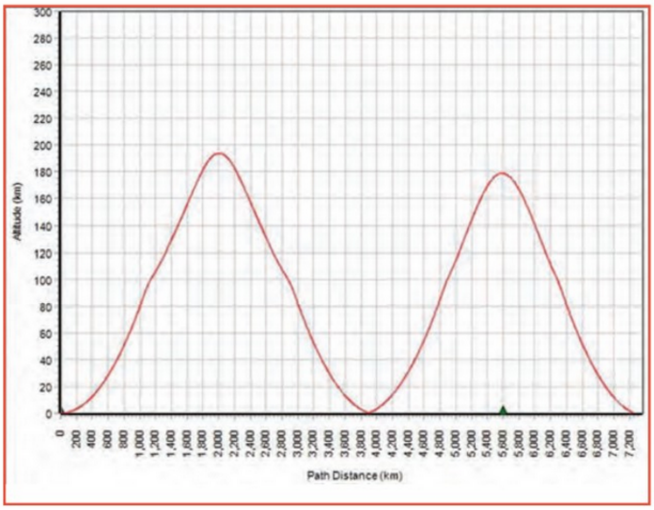

FIGURE 3: the PropLab Pro 3 output for the G4FKH to New York circuit.

then the circuit can be expected to be reciprocal. However, changing any station parameter pulls the circuit out of reciprocity. There are of course exterior influences upon radio transmissions, for example the vagaries of the ionosphere and local conditions. For instance, there could be a radio blackout at one end of the circuit, which will cause total loss of communications. The situations described are not the only ones to effect radio communications, there are a multitude. Changing tack a little, **Figure 5** shows a trans-equatorial path, G4FKH to 3B8. The equatorial anomaly can be seen on the right of the figure. This allows a total of four ground hops from the UK to 3B8 instead of perhaps five or six, with the associated received power losses with extra hops. When a signal fails to reach the ground in the equatorial region, it is known as equatorial ducting. For completeness, in this instance 3B8 receives a stronger signal by 5dB (almost one S-Point) and has a higher basic circuit reliability of 15%.

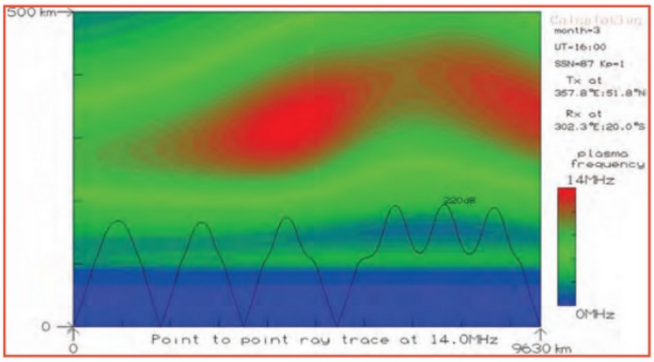

FIGURE 5: this is a HFRAY plot with G4FKH at one end and 3B8 at the other.

Closing statement

This study has answered my questions concerning radio reciprocity and it is hoped it has for the reader. Reading the results of this study, everyone should have perceived that radio circuits are reciprocal when all things are equal. When parameters change, the result is a degree of reciprocity.

References:

[1] ITURHFProp can be obtained from www.itu.int/en/ITU-R/study-groups/rsg3/Pages/iono-tropo-spheric.aspx It's the sixth item down and quite complicated, but I have written a simple Pont-to-Point windows program for those interested (contact the author).

[2] HFRAY is a ray trace program written by Chris Coleman, G4HCW/VK5AHZ, a member of the RSGB PSC. Available from: www.icedrive.net/s/P5SA1BkztRt6WQhhfyjuTRg5ZAiQ

[3] PropLab Pro 3 is a specialist Ray Tracing tool not meant for the uninitiated and is quite expensive. Info can be found here: https://shop.spacew.com/index.php/product/proplab-pro-hf-radio-propagation-laboratory/.

[4] www.techtarget.com/searchnetworking/definition/signal-to-noise-ratio

FIGURE 4: This is a repeat of Fig.1 but with a prediction parameter changed.

Month	Hour (UTC)	Frequency (MHz)	BMUF Path basic MUF (MHz	OPMUF Operation MUF (MHz)	OPMUF90 90% Operation MUF (MHz)	OPMUF10 10% Operation MUF (MHz)	Pr - Median receiver power (dB)	SNR - Median signal-to-noise ratio (dB)	BCR - Basic circuit reliability (%)
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03	14	21.025	23.28	26.77	20.08	31.60	-131.08	14.68	62.49
03	15	21.025	23.30	26.80	20.51	30.70	-129.48	16.23	66.65
03	16	21.025	23.41	26.93	20.60	30.84	-129.25	16.41	67.09
03	17	21.025	23.34	26.84	20.54	30.75	-128.69	16.99	68.51
Predictions received at New York from G4FKH, March 2023									
03	12	21.025	22.15	25.47	18.71	30.95	-129.18	11.78	52.90
03	13	21.025	23.09	26.56	19.52	32.27	-130.41	10.55	47.33
03	14	21.025	23.28	26.77	20.08	31.60	-131.08	9.88	43.71
03	15	21.025	23.30	26.80	20.51	30.70	-129.48	11.48	51.81
03	16	21.025	23.41	26.93	20.60	30.84	-129.25	11.71	52.64
03	17	21.025	23.34	26.84	20.54	30.75	-128.72,	12.24	54.53

Design Notes

PHOTO 1: G4HUP L-C Meter.

Simple coax failure test

A recent communication came from a member who was considering how a Vector Network Analyser could be used to find a faulty connector on a piece of cable. He had a patch lead with a PL259 plug at each end, but at one end or the other the braid had become disconnected – there was no DC continuity on the outer conductor from plug shell to plug shell. He could remove one of the two PL259 plugs to check, but there was then a 50% chance that would be the good one, so a perfectly good connector would have been dismantled only to discover the fault was at the other end. So his suggestion was that if one end was terminated, then a Vector Network Analyser could be connected to the other end, and the resulting plot used to determine the distance to the fault, and if it was on the distant connector or the one on the VNA.

This all seemed a bit over-complicated. If the cable was broken, then any termination at the far end would make little difference to the resulting plot. In fact, with the braid broken but the inner presumably connected, a VNA would give a quite confusing result if the broken end was connected to it. In effect it would be like connecting some sort of long conductor – an antenna - to the inner of the test port. If the 'good' connecter were used on the VNA, it would be just like connecting a length of open circuit feeder. There's a much easier way to determine which end is broken, and doesn't necessarily need a VNA, although one could be used.

Just measure the capacitance of the cable. If you have an L-C meter like the G4HUP one [1] shown in **Photo 1**, then simply measure the capacitance between inner and outer at each end of the cable. Most coaxial cables in use by amateurs have a capacitance somewhere around 70 - 100pF per metre depending on diameter, dielectric and characteristic impedance, so even a short patch cable will have enough 'puffs' between inner and outer to be able to measure. The good end will show the full capacitance of the cable, the broken end just a few stray pico-farads. Instant result!

Quick and simple VNA test

If you do have a VNA but no L/C meter then it is just as easy to use that to find out which end is faulty. Set a frequency span from the lowest the VNA can go up to a frequency no higher than say half the wavelength corresponding to the length of the cable, just so the trace isn't too messy to look at. The plot starts out as a single point close to the right-hand side on a Smith chart plot when nothing is connected to the test port. **Figure 1** shows the S11 plot of an SMA to BNC adapter on this port, behaving as a very short bit of open circuit transmission line.. Without changing anything, or doing any special calibration, just connect one end of the cable to test port 1. If this is the good end of the cable it will immediately show the classic open feeder pattern with the trace circling the Smith chart, but the trace will stay stable as the cable is moved around. **Figure 2** shows the plot of the 320mm piece of UR43 cable seen in Photo 1 over the frequency span 50kHz to 300MHz. Taking into account a velocity factor of 0.7, it would be a wavelength long at around 660MHz.

If the broken connector with the braid open circuit is connected to the VNA the trace will go wild, changing as the cable is moved or placed near objects. Since the inner conductor alone is connected to the test port, and this is capacitively coupled over the length of the cable to the outer, we have just attached a wire antenna to the VNA. Moving the cable, placing your hand near it, or anything else, will move the trace all over the place making it abundantly clear this is the broken connector. **Figure 3** shows the Smith chart plot with just the inner of this same piece of coax connected to the VNA, a contrived broken outer. The small loop in the plot is a resonance of some sort – I didn't measure the exact frequency but it looks to be around 60MHz, which is far too low in frequency to be a function of the short bit of coax alone. The VNA is connected to a laptop PC via a USB cable about 2m long and it is more than likely it is this, in conjunction with the bit of coax, that is forming an asymmetric resonant dipole with the VNA in the middle.

QED. No need for complex calibrated measurements of distance, length of feeder or anything. Just a simple measurement at each end using basic default VNA calibration. A nice clean open-circuit plot is the good connector; a wild one that changes randomly is the connector with the faulty outer.

It's easy to get confused

While on the subject of faulty connections, I have to relate this trivial but initially confusing incident that happened yesterday and left me feeling a bit silly. The GNSS module shown at the top in **Photo 2** was failing to lock up. (This is the transmit source used for the EME chirp generator, described below.) The GNSS module was outputting NMEA data that was indicating no satellites were being received and there was no one

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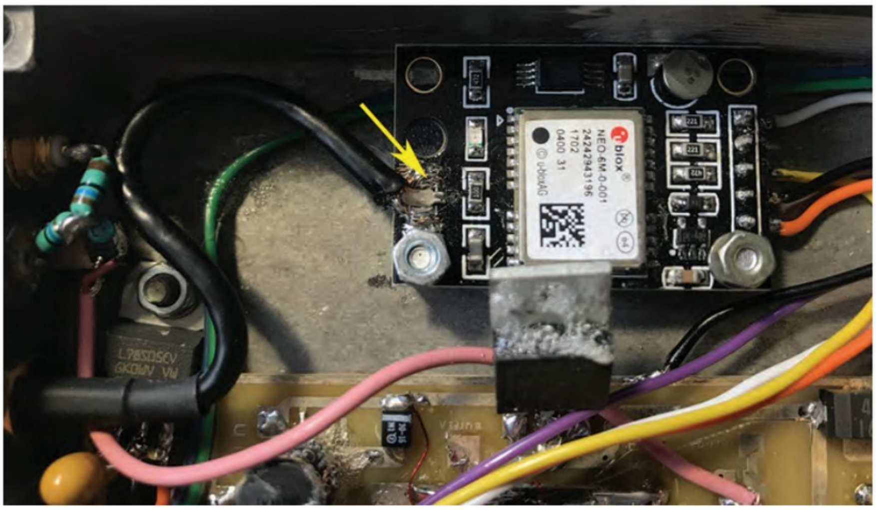

PHOTO 2: the soldering of the inner of the coax connection had failed at the point marked. When tested with a meter probe it was pushed onto the PCB pad showing, apparently, no fault.

pulse-per-second signal. So is looked as if the antenna was faulty or not connected. The first immediate check was to see if the external active antenna was being supplied with DC, so I applied a meter probe to the (somewhat messily soldered) connection where the antenna feed pigtail from the SMA connector attaches to the PCB, marked by the arrow in the photograph. There was 3.2 volts present, exactly as expected, so I removed the antenna from the connector on the outside of the box and measured the voltage there. Nothing, so clearly a broken pigtail from the SMA bulkhead connector to the PCB. I then idly used the continuity tester on my meter, the bleeper, to test from the SMA socket inner to the point marked with the arrow and was more than a bit surprised to see continuity there. How could that be? Volts on the PCB, nothing on the SMA, yet continuity between the two points?

It took a few minutes for light to dawn, and the clue is given in the paragraph above – 'messily soldered'. The coax inner, up until I had disturbed the unit to make some modifications, must have been hanging on by a single strand or whisker of solder to its PCB pad. When I opened it and disturbed the wiring that soldered connection broke and the inner of the cable lifted by a fraction of a millimetre, enough to stop the receiver working. When I applied the test probe from the test meter for the voltage measurement it pressed the inner onto the PCB bringing up the 3.2V. Lift the probe off and it sprang back, breaking the connection again. A bit of resoldering and the unit worked fine.

Frequency multiplication

On the higher frequency bands it is quite common to employ frequency multiplication in a stage that exhibits non-linearity and deliberately generates harmonics of the applied signal. Multipliers can be passive using semiconductors such as Schottky or varactor diodes, or active constructed with bipolar transistors or FETs. Often at the low to middle microwave frequencies, up to perhaps the 10 or 24GHz bands, GaAs FETs were used; above that diodes reign supreme – at the moment. At frequencies up to low VHF, fast logic gates like those in the 74AC and 74VHC families can work very well. But any such non-linear stage doesn't just generate a single wanted harmonic. It generates all multiples of the drive signal, with the amplitude of each gradually reducing as the order of multiplication rises.

An example of this can be seen in the spectrum analyser plot of **Figure 4**. Here a PGA-103 modamp, normally used for linear amplification at frequencies from 50MHz to 2GHz where it gives a gain of around 20dB, is overdriven with a 300MHz input at a level of +7dBm so it runs several dB into saturation. The plot runs from zero Hertz, indicated by the extreme left hand marker, to 1.8GHz and shows the harmonics generated up to the fifth at 1.5GHz. Although in general the level of each harmonic rolls off as the harmonic number increases, there is some bouncing around of relative levels as the input drive power is varied, and it is usually possible to select a drive level that favours one particular harmonic over others. Here the fourth harmonic is enhanced a little to raise it above the third and fifth.

Figure 5 shows the same device driven harder with +11dBm drive at 103MHz showing harmonics up to the 17th. Here the drive was adjusted to make the 5th harmonic as high as possible so although it is still lower than the 4th, not by all that much. It was noticeable that as the peak of the 5th was reached, it was accompanied by a rapid drop in level of the 6th harmonic.

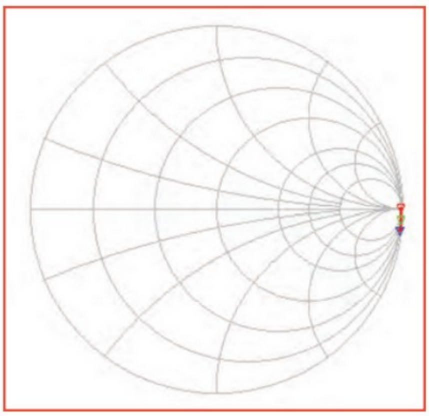

FIGURE 1: 50kHz to 300MHz S11 plot of just an adapter on port 1 of the Nano-VNA.

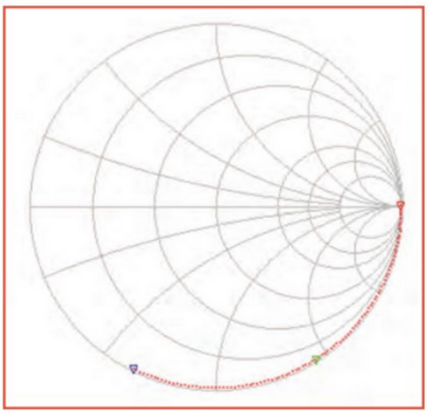

FIGURE 2: 320mm length of UR43 coax, open circuit at the far end. This shows the classic open circuited feeder trace.

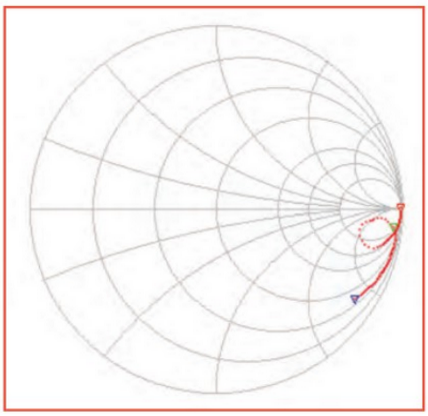

FIGURE 3: plot with just the inner of the coax connected to the VNA. The loop at about 60MHz indicates a resonant structure, likely caused by the coax coupling into the length of the USB cable between VNA and laptop computer, forming an asymmetric dipole.

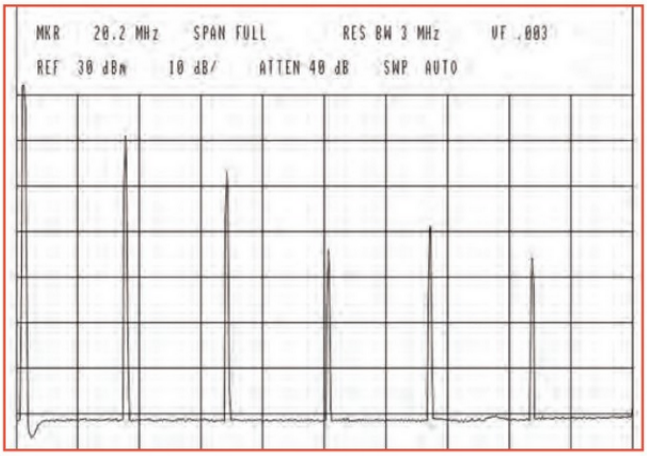

FIGURE 4: **the spectrum from a PGA-103 Modamp overdriven with +7dBm of 300MHz. The plot is from 0 to 1800MHz, with the large spike on the left the 0Hz marker.**

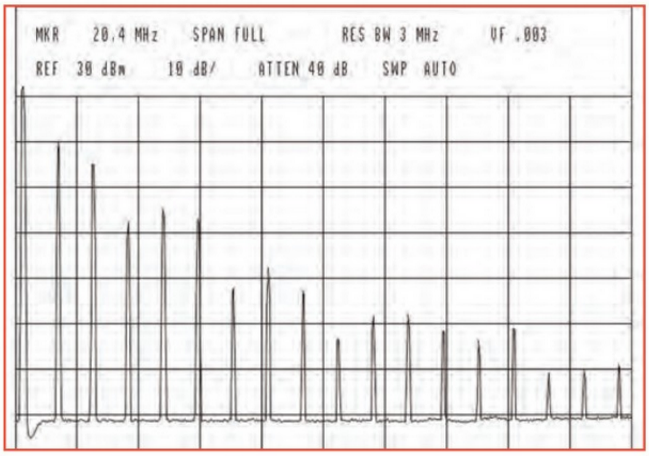

FIGURE 5: **the same modamp as for Figure 4, but driven harder with +11dBm at 103MHz. The drive level was chosen to optimise the 5th harmonic.**

Filtering

The relative levels of the harmonics from a multiplier stage influence the amount of filtering needed to select just the wanted one. If high levels of multiplication are needed, choices have to be made as to how to do that. For example, if we wanted X8 multiplication, do we do that in one stage, and use a tight narrow bandpass filter to reject the 7th and 9th harmonics? Or use a X4 followed by a more modest filter, then X2 and a bit more filtering? It could well be that that the complexity of the filter needed for a single X8 in one hit makes two active stages of X4 and X2 with simpler interstage filtering the better option.

The way the relative levels of the harmonics change with drive means care needs to be taken if the equipment is operated in a scenario where temperature or supply voltage might change. Supply voltage can usually be dealt with by using voltage regulators for a constant V_{DD}, but change of gain and drive with temperature needs to be compensated. Older satellite hardware, before PLL synthesizers became commonplace, was one example where frequency multiplication had to be very carefully controlled and designed to operate over wide temperature excursions. I well remember optimising a X16 multiplier stage (22MHz to 725MHz, built as X4, X4 and X2 using NE645 bipolar multiplier stages) as a 'JNT graduate project back in 1980 for a part of the beacon assembly for a particular satellite. Several months were spent getting it to behave properly over a wide temperature range, and I was pleased to be told my design went into orbit a few years later virtually unchanged.

Fourier and push pull

To complete the discussion on multipliers, we need to look at waveforms and a bit of theory. If the multiplier stage is such that it clips symmetrically, then Mr. Fourier shows that only odd order harmonics will be present. To understand why, consider the spectrum of a perfect square wave. This contains only odd order harmonics, at a level of 1/N (in voltage terms) respectively; so, 1/3 of third harmonic, 1/5 of the fifth, 1/7 of the seventh and so on. The single ended PGA-103 modamp multiplier stage shown above is non-symmetrical when driven just to modest overdrive, giving plenty of even order multiples of the input frequency as shown in **Figure 4**. As drive and saturation increase, the clipping become more symmetrical lowering the even order harmonics – and partially explains the rapid reduction in the 6th as the 5th was optimised.

An alternative circuit topology is push-pull drive into a pair of matched non linear devices. The classic full wave rectifier using a centre tapped transformer and two diodes is exactly this. Full wave rectification of a sinewave gives plenty of second harmonic, and 4th, and 6th an so-on, but next to no odd order components and near complete cancellation of the fundamental. As a straight frequency doubler, the full wave rectifier type of design is hard to beat, with several packaged ready-to-go modules available off the shelf. Mini-Circuits **[2]** have a wide range of units where this concept, as well as single diodes, are used to several tens of GHz.

EME chirp update

In the November 2022 Design Notes we saw how a chirped transmission at 10GHz, correlated with an identically chirped local oscillator was to be used to investigate the EME path, looking at change in the Earth-Moon distance and Doppler as the distance changes. The use of a single chirp for this proved unsatisfactory as a frequency offset on the received signal could be due either to a change in fixed distance, or a change in Doppler shift. The two can't be separated using a single chirp. The solution is to use a dual chirp, up then back down in a dual ramp over a single 2.5 second transmission period. Now, Doppler shift causes both the up and down frequency sweeps to be shifted in the same direction. But a slight increase in time delay causes the upchirp to return later at a higher frequency, but the down chirp, also arriving later will be at reduced frequency. Provided two up and down ramps in frequency are the same speed and just opposite in direction, the resulting frequency shifts from each side of the dual chirp can be compared to separate out those terms due to change of distance, and those due to Doppler shift. This dual chirp is similar in principle to those used on automotive radars that have the same task of separating distance information from Doppler shift due to differing velocities of the radar and the reflecting surface.

The AD9852 DDS chirp source was easy to modify by reprogramming its delta frequency register with the complemented value of chirp step halfway through the Tx interval at 1.25s, set by an accurate timing routine on the PIC controller driven from a GPS locked clock frequency. The same timer routine used on both transmit and LO DDS sources ensures Rx and Tx are precisely locked together as the frequency chirps up and down for each transmission cycle.

References

[1] https://sites.google.com/site/vk3bhr/home/index2-html
The G4HUP meter kit is no longer available, but an updated design by the original author of the project can be found here. G4HUP meters, as well as other designs for LC meters that no doubt work in a similar way can be found on Ebay and other auction sites.
[2] https://www.minicircuits.com/WebStore/Multipliers.html
Mini-Circuits' range of drop-in frequency multipliers.

Review

YAESU FT-710

HF, 50 and 70MHz transceiver

Continuing the approach by Yaesu to upgrade its HF transceiver product range to employ full SDR techniques and touch-screen spectrum displays, the latest member of the family is the FT-710.

PHOTO 1: FT-710 front view.

PHOTO 3: FT-710 Rear view.

It is broadly aimed as a budget class radio but shares most of the same features and functions as its siblings, the top of the range FTDX101 and mid-range FTDX10. As with the FTDX10, it is a 12V operated radio containing a single receiver covering 1.8 to 50MHz at 100W transmit output power and 50W on 70MHz.

Basic functions

The FT-710 measures 239mm(W) x 247mm(D) x 80mm(H) and weighs 4.5kg. This is similar in size to the FT-991A and slightly smaller than the FTDX10. The receiver tunes from 30kHz to 75MHz and the transmitter is enabled on the amateur bands only. Full transmit coverage of the 5MHz band (5.250 – 5.406MHz) as well as 70MHz (70.0 – 70.5MHz) in the UK is provided in firmware version C2(UK) and if not already activated by the dealer is simple to achieve by appropriate button presses. There is no provision for a low-level output to drive transverters or for LF band operation.

The usual modes are provided: SSB, CW, RTTY (FSK), PSK, AM and FM, with wide or narrow operation on AM and FM, reverse sidebands selectable on SSB, CW and RTTY and with AFSK data on SSB and FM. Ideally, operation on the various newer data modes, such as FT8 or FT4, requires many of the parameters such as receive and transmit bandwidth to be set differently to the more traditional modes for optimum results. To avoid having to change these parameters manually by multiple key presses for each mode change, Yaesu introduced the PRESET function. This provides tailoring of some 17 different settings selectable by a single key press and there are five separate stores for different modes that may be name-tagged. Unlike the FTDX10, the FT-710 does not include built-in decoders for CW, RTTY or PSK modes.

There are the usual twin VFOs (A/B) allowing split operation with the ability to check and tune the transmit frequency via TXW. There are 100 easily accessed and name-labelled memory channels that can be ordered into groups if desired. Single button access to 5 or 10 quick access memories is provided, and there are the usual scan functions included. A novel curved LED illumination either side of the tuning knob shows immediately whether VFO or memory is in use, which VFO and whether in split mode or the clarifier is active, all by different colours. This is termed the VFO mode indicator (VMI).

The radio is provided with a separate external matching speaker (SP-40) that can clip on to either side of the main unit. This forward-facing speaker provides much better sound quality and a wider frequency response, and is used together with the built-in speaker in the top of the case to provide the Yaesu Acoustic Enhanced Speaker System (AESS).

The radio is also provided with a power cable and the SSM-75E hand microphone. This microphone is the same as that supplied with the FTDX10 and is fitted with an RJ-45 connector. As well as up/down keys, the microphone has an audio mute button and four function keys that can be assigned to provide alternative access to a number of front panel buttons. The instruction manual is fairly comprehensive and well written and runs to 112 pages but a more comprehensive index would be helpful. No circuit diagrams are included.

Radio design and architecture

The FT-710 uses direct digital sampling in the receiver as used in recent Icom radios and does not employ a down-conversion to an IF with roofing filters as adopted in the hybrid SDR approach used in the FTDX10 and FTDX101. Two A/D converters operating at signal frequency take their input from the front-end unit. The front-end comprises a selection of bandpass filters, similar to the FTDX10, two switchable preamplifiers for 20dB or 10dB gain and three levels of input attenuation, 6/12/18dB.

The output from the A/D converters feeds into the custom FPGA device. This provides three functions. Firstly it generates an IF signal at 18kHz on CW/SSB or 24kHz on AM/FM by a process of decimation to feed the following

PHOTO 2: FT-710 front-top view.

DSP circuit. Secondly it processes the data to provide the spectrum and waterfall displays. Thirdly it generates a dither signal at the A/D converter inputs to reduce or even eliminate low-level intermodulation distortion products that are inherent in the sampling process. The 32-bit DSP following the FPGA provides all further processing – channel filtering, demodulation, noise reduction, audio processing, AGC functions and more. These functions are the same as for the FTDX10, which uses a Texas Instruments DSP. The FT-710 uses a more powerful device from NXP Semiconductors.

The transmit signal is generated directly at final frequency from a D/A converter and then amplified through to the final PA. A high-resolution direct digital synthesiser is used to provide a low-noise clocking source and this operates at 250MHz. This is the same arrangement as is used in the FTDX10. A 0.5ppm TCXO reference ensures high stability.

The radio is solidly constructed in typical Yaesu style using a substantial and well-shielded diecast frame and integral heatsink with a fan on the rear panel. This is quiet and only operates when the temperature rises. A 65mm loudspeaker fits into the case top, and the same speaker is also fitted into the SP-40 external speaker unit. There is no acoustic shrouding used with either speaker. Extensible front feet tilt the front panel to improve visibility and operating ease and a wrap-around case completes the unit. A side-carrying handle and a mounting cradle for mobile or under-shelf mounting are available as accessories.

Front panel and controls

With the display occupying half of the front panel area, the space available for the conventional pushbuttons and rotary controls becomes quite limited and as a consequence many functions are accessed from the touch-screen display and menu. The physical controls are all placed around the tuning drive, including a group of five pushbuttons set into the top face. The main tuning drive is 45mm in diameter with adjustable torque. Two rotary controls, not the usual dual concentrics, provide AF and RF gain/squelch and two click-step rotary controls set other functions. One of these accesses the function menu and the other doubles to provide rapid step tuning and memory scrolling or to set the bandwidth controls, width/shift/notch/APF/contour filtering. Other top-level functions are selected via pushbuttons. Single buttons select the band or mode via the touch-screen display with a triple band-stack allowing three separate combinations of frequency, mode and other settings available for each band. 70MHz is included under the general coverage button and is best stored to memory as it can be overwritten if other general coverage frequencies are later selected.

The main tuning drive has up to 200 steps per revolution with various mode dependant channel step sizes. Tuning in 1MHz or 1kHz steps is achieved by touching the relevant decade digits on the display and the frequency may also be entered directly from a pop-up numeric keypad. A separate button allows fast tuning at x10 speed or fine tuning in 1Hz steps.

Most remaining functions are selected directly from the display or from the function menu using the FUNC selector click-step rotary control. These functions and their selection are largely similar to the FTDX10.

The high resolution TFT colour touch-screen LCD measures 4.3-inch diagonal, somewhat smaller than the FTDX10, and is clear, sharp and bright with a good viewing angle. All areas of the screen are touch-sensitive for setting displayed functions, often showing pop-up menus for choice selection. The upper part of the display shows the receiver set functions including both A and B VFO frequencies, a graphic indication of the channel bandwidth settings and a single analogue-style S meter. The meter indicates one function on transmit, usually power output but SWR, ALC and compression level are also available.

The lower part of the display is devoted to the spectrum scope in its different formats. Six touch buttons along the bottom of the display select the various options. This provides a spectrum scan and waterfall display centred on the receive frequency or between fixed limits, and an audio waveform scope and spectrum display for both the receiver and the transmitter audio. Both scans may be displayed together in normal or expanded formats. The waterfall may be conventional or in pseudo 3-dimensional format (3DSS) and various colours may be selected. These are all similar to the FTDX10. The receiver can be tuned to any frequency on the spectrum display either by touching the screen or with an external mouse connected.

As with all recent radios the set-up menu system is extremely comprehensive with over 200 items split into five categories of every conceivable parameter available for user selection and adjustment. The display makes access very easy, straightforward and unambiguous albeit rather busy.

A headphone jack (3.5mm) and a microphone socket (RJ-45) are provided on the front panel but the key jack is on the rear panel.

Rear panel

There is a single antenna socket on the rear panel but there is no provision for connecting a receive antenna or an additional receiver. A single CW key jack is configurable for paddles, straight keys or external keying and there are 3.5mm jacks for external speaker and FH-2 remote keypad. A 6-pin mini-DIN connector provides audio and interfacing lines for the Data modes. An 8-pin mini-DIN connector is multipurpose. It provides band data and control lines for the FC-40 external

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auto ATU or alternatively interface lines for connecting linear amplifiers. There are no phono jacks to provide alternative methods of connection. The FTDX10 uses a 10-pin mini-DIN for linear amplifier connection and plugs are difficult to obtain so fortunately this has been avoided in the FT-710.

A USB-B connector provides the CAT computer interface for logging programs as well as audio lines for data modes. A single USB-A connector allows the connection of a keyboard or a mouse. The mouse provides an alternative to touching the screen and is more precise and accurate. The keyboard can be used for inputting text into the message stores or for memory labelling. There is no 9-pin D RS-232 jack, it has finally reached the end of the road, but RXD and TXD lines are available on the 8-pin mini-DIN jack. An external display can also be linked via a DVI-D connector

Receive features

The usual receive functions are all provided in a similar fashion to the FTDX10 or indeed in most other radios these days.

Two settings for channel bandwidth are immediately accessible, normal and narrow, by toggling the NAR button. The bandwidth for each can be set independently for each mode over quite wide limits from 4000Hz down to 50Hz on CW and data modes. On AM and FM, two fixed bandwidths are provided. There is no control over the shape or the slope as seen on some radios but the Yaesu contour system provides a rolling peak or cut over the passband and this can be effective in some difficult situations.

An IF notch filter is provided with adjustable centre frequency and width. Operating inside the AGC loop, desensitisation with strong carriers is prevented. Implemented at audio is the auto-notch (DNF), a beat cancellation filter. This automatically locates and removes multiple tones but does not prevent strong carriers from desensitising the receiver and is activated from the menu system. Notches and Contour settings are graphically displayed most effectively on the display together with their effect on the passband spectrum.

The audio bandwidth can be tailored separately for each mode and on CW an audio peak filter can be enabled. This has three selectable bandwidths and is tuneable across the pitch frequency. Also included are a digital noise reduction system and a noise blanker. Both are adjustable.

Three mode-dependant AGC speeds are selectable, programmable over wide limits and AGC can also be switched off. RIT (clarifier) and XIT are both provided and an auto-tune feature that fine-tunes the receiver on clear signals to give the correct CW pitch.

Transmit features

The transmitter power output is variable in 1W steps down to about 5W with different levels on the HF, 50 and 70MHz bands. The radio includes a built-in auto ATU covering bands 1.8 to 50MHz and will tune antennas with VSWR up to 3:1 (2:1 on 50MHz). The tuning settings are stored in memory for rapid recall with a capacity of 100 different settings. For end-fed wire antennas the FC-40 remote auto tuner can be used.

PHOTO 4: Top view with covers removed showing Tx, PA and ATU.

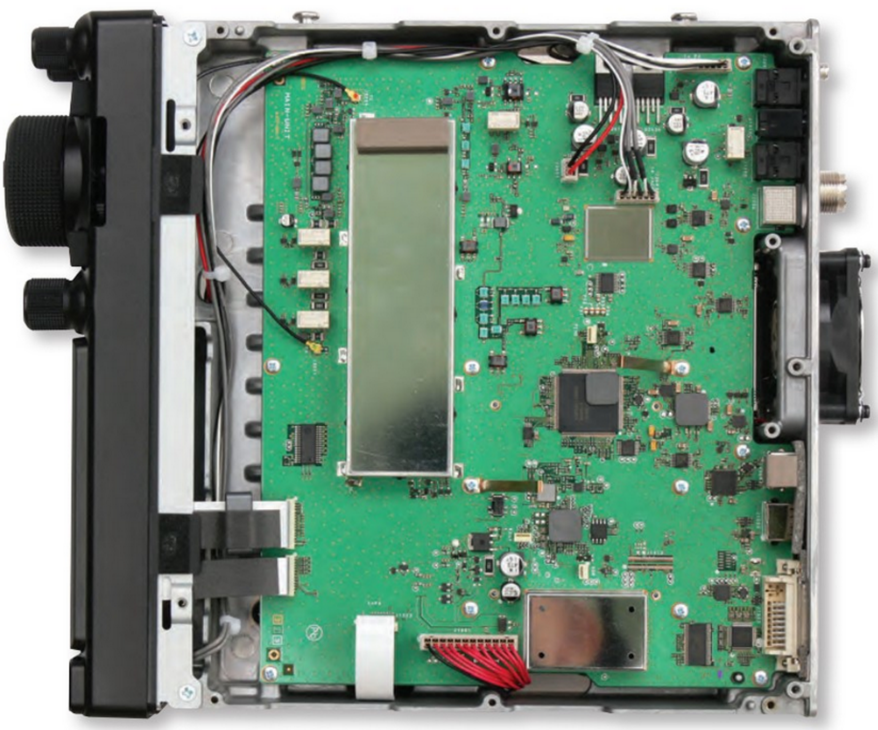

PHOTO 5: Underneath view with covers removed showing small signal circuitry.

PHOTO 6: **FT-710AESS front view.**

On SSB, VOX and a transmission monitor are provided. AMC (Automatic microphone gain control) akin to AGC and also known as VOGAD prevents audio overdrive and a conventional compressor raises the average modulation level. The audio bandwidth may be tailored by one of five bandpass filters in conjunction with a three-stage parametric equaliser with separate settings for the processor on or off. On FM, repeater operation on the 29MHz and 50MHz bands is provided with appropriate shifts and CTCSS tone decoders and encoders.

On CW, the usual break-in modes are provided and a full contest message keyer with all the usual options and settings. Five message stores containing up to 50 characters each can be programmed either from the keying paddle or from text entry using an external keyboard or internal pop-up keypad. Messages can be played back from the front panel or more conveniently using the FH-2 remote keypad accessory.

The radio includes a voice store for use in SSB contests. There are 5 message stores, each capable of storing up to 90 seconds of audio and playback is similar to the CW stores, either from the front panel or using the FH-2 remote keypad. The voice store requires an SD card to be plugged in, unlike the CW stores, which do not need an SD card.

Other features

An SD card slot is fitted into the left-hand side of the case and is used to save various settings, memory contents, receive audio, voice memories, screen capture and updating the firmware. Note that if the SP-40 external speaker unit is clipped onto the left-hand side of the radio, this obscures access to the SD card slot.

The voice store can also be used to record and playback the receiver audio. This is stored as WAV files on the SD card at a rate of 64kB/s. This corresponds to 4.3 hours of recording per GB of storage with a maximum file size of 35GB.

To connect the radio to a computer via the USB-B socket for logging or for data modes such as FT8, it is first necessary to download drivers from the Yaesu website if not already installed on the PC. This will install two virtual COM ports and allows audio transfer as well as data control. I quickly had the radio up and running on FT8.

Full remote control of the radio via the internet or locally via a LAN uses the SCU-LAN10 remote control unit. At the time of this review, the software was not yet available. The LAN unit connects to the radio via the USB-B connector only and does not use the additional multiway connector needed with the FTDX10 or FTDX101.

Measurements

The measured performance of the FT-710 is similar to the FTDX10 in most areas and the full set of measurements is given in the table.

The sensitivity figures were excellent as usual. 8dB attenuation is inserted below 1.7MHz and then sensitivity rolls off further below 500kHz. At 200kHz it is down by over 30dB. The S meter calibration showed about 2.5 to 3dB per S unit and was very linear across the whole range. All modes were broadly the same.

Spurious responses and birdies were very low indeed, none of significance. The AGC attack characteristic was clean with no overshoot but a small hole of about 2 to 3ms was inserted in the attack characteristic, typical of most DSP radios.

The strong signal performance of the receiver is excellent. Direct sampling receivers usually suffer from low-level intermodulation products produced with quite modest signal levels and can be audible on quiet bands. It is caused by the quantisation steps within the A/D conversion process and can be reduced by inserting a noise or dithering signal prior to conversion. With Icom radios, this dither signal is usually switchable but in the FT-710 it is in circuit at all times. It is very effective; there was no trace of intermodulation up until the point at which the overload limit was approached. The intermodulation limited dynamic range measured around 100dB in SSB bandwidths or 105dB in CW bandwidths. These dynamic range figures held at close spacings right down to 1kHz or less and represent a very high performance. Inband linearity was also excellent.

The overload or blocking limit of direct sampling receivers is generally the result of the A/D converter running out of range. In many receivers this point is indicated by an overload display indicator requiring some manual gain reduction by the operator. With the FT-710, overload protection is automatically triggered reducing front-end gain by a subsidiary AGC process so that the A/D converter does not run out of range. This occurs at about +1dBm at the antenna input with the preamp off (IPO) or 10dB/20dB lower with preamplifier 1 or 2 in circuit.

The reciprocal mixing phase noise figures were also excellent, particularly so for radios in this price bracket. The low noise performance allowed the IF filter skirts to be measured down to a level of about –90dB with relative ease and the filters exhibited a clean response with excellent shape factor.

On transmit, the power output was well up to specification and the power reading quite accurate. The two-tone distortion products were generally quite reasonable. The audio was very clean with low distortion and quite tolerant of high ALC levels and overdrive. The processor, similarly, was clean with negligible effect on wideband products.

CW rise and fall shapes were clean with negligible distortion or character shortening at 40wpm even in full break-in mode. Rise and fall times are adjustable and there was no power overshoot at any power level. There is a menu-settable delay on keying (15-30ms) to allow for linear amplifier switching so that the RF is correctly sequenced even for slow linears. This functioned correctly when using the internal keyer, but with external keying this delay time was fixed at 15ms, whatever time is set in the menu. This is a bit too fast

PHOTO 7: Function menu screen view.

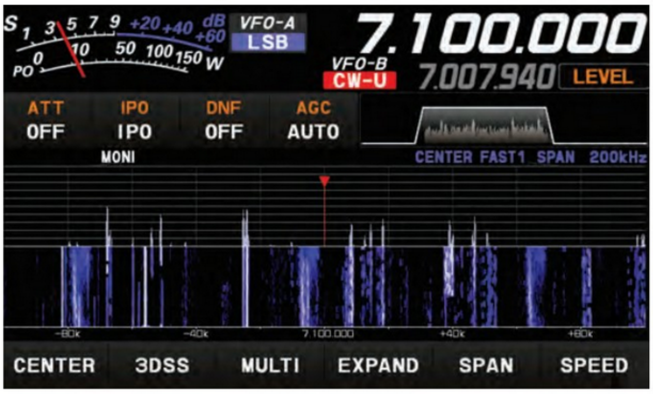

FIGURE 1: Spectrum and waterfall display.

for older style linears, and needs to be resolved, probably a software fix.

AM transmit was clean with fairly low distortion but modulation was predominately in the downward direction. This resulted in overall power reduction with modulation.

The transmit composite noise output at full power is very similar to the FTDX10 and better than most radios on the bands. The noise at lower power and even key-up on CW does not reduce significantly and this is fairly normal with most radios. The key-up noise on CW measured -93dBm/Hz. This noise is largely AM noise which predominates over the phase noise element quoted in brochures.

On-the-air performance

In many ways the operation of the FT-710 is similar to the FTDX10 with similar display functions, similar menu functions and buttons and controls clustered around the tuning knob. The positioning of the controls and how some functions are accessed is somewhat different though. The tuning drive is smooth and positive but with only 200 steps per revolution the trade-off between step size resolution and tuning speed is more of a compromise. The separate click-step control rapidly ensures larger frequency changes are easily made and this also doubles to change channel bandwidth settings. There is no secondary tuning ring as used on the FTDX10, and button timeouts have been improved (lengthened) so rapid selection is less critical. Most functions are in general fairly easy to use.

The display shows the same information as the FTDX10 but as it is somewhat smaller, touch control becomes that much more critical when selecting items on the various menu screens. An external display used with a mouse can be a great help. I used a 24-inch display with very impressive results. The 3D spectrum display gives a good impression of band activity but overall I personally prefer the conventional spectrum with waterfall scans. **Figures 1** and **2** compare the two spectrum scans for the same band activity, one recorded immediately after the other. Tuning the radio from the spectrum display gave reasonably accurate results providing the span was kept fairly low. Using a mouse for this purpose is much more precise than using fingers and of course works on an external display but it is a shame that Yaesu has still not implemented mouse wheel scrolling to fine tune precisely on wanted signals with one hand.

The audio quality using the front facing speaker was very good with much wider frequency response into the bass region than the top-facing speaker alone. This is particularly noticeable on stations who have tailored their transmit audio for a broader bandwidth and, of course, with broadcast stations. The AESS controls did not seem to make much difference to my ears; the improvement was more related to using the external SP-40 speaker.

FIGURE 2: 3DSS display.

As with all modern radios, the performance cannot be faulted. It handled strong signals well and in pileup conditions with clean results, and also with weak signals on the higher bands. The filters and notches were excellent and the DNR digital noise reduction system very effective.

On transmit, the audio quality was good using the supplied SSM-75E hand microphone and if needed there is a huge range of tailoring of the audio response available. The processor was clean and added extra punch. On CW, the keying and the sidetone were clean and it was possible to listen between characters up to around 15wpm. As with the FTDX10 and FTDX101, the process for setting the microphone gain and AMC levels as described in the manual is rather ambiguous, but setting these to give a moderate degree of compression (10dB max) with the ALC in the lower half of the meter display gave good results.

During the period that I had the radio for review, a firmware upgrade became available. I downloaded and installed the upgrade easily with no problems. It addressed a number of improvements and bug fixes.

Conclusions

The FT-710 is another Yaesu radio with a real top class performance at a very attractive price. It has an excellent balance of features and functions with good overall user ergonomics. It is currently priced around £1100 from the usual Yaesu stockists and this represents very good value for money.

Acknowledgements

I would like to express my gratitude to Yaesu UK for the loan of this radio.

Yaesu FT-710 Measured Performance

Receiver measurements

Frequency	Sensitivity SSB 10dBs+n:n IPO	Preamp 1	Preamp 2	Input for S9 IPO	Preamp 1	Preamp 2
1.8MHz	0.7µV (-110dBm)	0.25µV (-119dBm)	0.1µV (-127dBm)	90µV	32µV	9µV
3.5MHz	0.63µV (-111dBm)	0.2µV (-121dBm)	0.1µV (-127dBm)	80µV	28µV	8µV
7MHz	0.63µV (-111dBm)	0.22µV (-120dBm)	0.1µV (-127dBm)	90µV	32µV	8µV
10MHz	0.63µV (-111dBm)	0.22µV (-120dBm)	0.1µV (-127dBm)	90µV	28µV	8µV
14MHz	0.63µV (-111dBm)	0.22µV (-120dBm)	0.1µV (-127dBm)	80µV	28µV	8µV
18MHz	0.7µV (-110dBm)	0.25µV (-119dBm)	0.1µV (-127dBm)	80µV	28µV	8µV
21MHz	0.7µV (-110dBm)	0.25µV (-119dBm)	0.11µV (-126dBm)	80µV	28µV	8µV
24MHz	0.63µV (-111dBm)	0.22µV (-120dBm)	0.1µV (-127dBm)	90µV	28µV	8µV
28MHz	0.63µV (-111dBm)	0.2µV (-121dBm)	0.1µV (-127dBm)	80µV	28µV	8µV
50MHz	0.45µV (-114dBm)	0.14µV (-124dBm)	0.11µV (-126dBm)	80µV	28µV	8µV
70MHz	0.56µV (-112dBm)	0.18µV (-122dBm)	0.13µV (-125dBm)	100µV	32µV	9µV

AGC threshold with preamp1: 2µV
100dB above AGC threshold for <1dB audio output increase
AGC attack time: 2-3ms
AGC decay time: adjustable 20ms to 4s
Max audio at 1% distortion: 1.7W into 8Ω, 2.7W into 4Ω
Inband intermodulation products: better than -60dB

S-Reading (7 MHz)	Input Level USB IPO	Preamp 1	Preamp 2
S1	8µV	2.8µV	0.8µV
S3	13µV	4µV	1.1µV
S5	22µV	8µV	2µV
S7	40µV	14µV	4µV
S9	90µV	32µV	8µV
S9+20	1.1mV	400µV	110µV
S9+40	11mV	4mV	1.1mV
S9+60	110mV	40mV	11mV

Bandwidth Set To	Bandwidth -6dB	-60dB	-70dB	-80dB	-90dB
USB 2.4kHz	2429Hz	3079Hz	3141Hz	3198Hz	3265Hz
CW 500Hz	508Hz	710Hz	730Hz	748Hz	771
CW 100Hz	104Hz	205Hz	215Hz	225Hz	262Hz
AM	8970Hz	10550Hz	10690Hz	10830Hz	10960Hz
AM-N	5970Hz	7630Hz	7790Hz	7930Hz	8060Hz
FM	15830Hz	17470Hz	17610Hz	17750Hz	19970Hz
FM-N	8980Hz	10550Hz	10690Hz	10830Hz	10960Hz

Frequency	Intermodulation Dynamic Range 20kHz spacing, USB 2.4kHz bandwidth IPO	Preamp 1	Preamp 2
1.8MHz	95dB	95dB	91dB
3.5MHz	98dB	99dB	94dB
7MHz	100dB	99dB	95dB
14MHz	101dB	101dB	97dB
21MHz	100dB	99dB	96dB
28MHz	99dB	99dB	95dB
50MHz	95dB	95dB	89dB
70MHz	92dB	92dB	86dB

Frequency Offset	Reciprocal Mixing Dynamic Range 500Hz Bandwidth 7MHz	21MHz	Intermodulation Dynamic Range 500Hz BW 14MHz
1kHz	112dB (-139dBc/Hz)	not measured	105dB
2kHz	114dB (-141dBc/Hz)	not measured	105dB
3kHz	115dB (-142dBc/Hz)	114dB (-141dBc/Hz)	105dB
4kHz	116dB (-143dBc/Hz)	116dB (-143dBc/Hz)	105dB
5kHz	117dB (-144dBc/Hz)	117dB (-144dBc/Hz)	105dB
10kHz	118dB (-145dBc/Hz)	120dB (-147dBc/Hz)	105dB
15kHz	118dB (-145dBc/Hz)	121dB (-148dBc/Hz)	105dB
20kHz	118dB (-145dBc/Hz)	123dB (-150dBc/Hz)	105dB
30kHz	119dB (-146dBc/Hz)	124dB (-151dBc/Hz)	105dB
50kHz	119dB (-146dBc/Hz)	125dB (-152dBc/Hz)	105dB
100kHz	119dB (-146dBc/Hz)	125dB (-152dBc/Hz)	105dB

Transmitter measurements

Frequency	CW Power Output	Harmonics	Intermodulation Products wrt PEP 3rd order	5th order
1.8MHz	106W	-75dB	-30dB	-38dB
3.5MHz	105W	-65dB	-32dB	-38dB
7MHz	103W	-74dB	-36dB	-36dB
10MHz	103W	-60dB	-34dB	-36dB
14MHz	106W	-75dB	-32dB	-36dB
18MHz	108W	-77dB	-32dB	-36dB
21MHz	108W	-72dB	-34dB	-36dB
24MHz	108W	-80dB	-32dB	-36dB
28MHz	108W	-70dB	-32dB	-36dB
50MHz	105W	-82dB	-28dB	-40dB
70MHz	53W	-70dB	-44dB	-40dB

Transmit Frequency Offset	Composite Noise 7MHz 100W O/P
1kHz	-72 dBm/Hz (-122dBc/Hz)
2kHz	-74 dBm/Hz (-124dBc/Hz)
3kHz	-75 dBm/Hz (-125dBc/Hz)
4kHz	-76 dBm/Hz (-126dBc/Hz)
5kHz	-77 dBm/Hz (-127dBc/Hz)
10kHz	-79 dBm/Hz (-129dBc/Hz)
15kHz	-80 dBm/Hz (-130dBc/Hz)
20kHz	-80 dBm/Hz (-130dBc/Hz)
30kHz	-81 dBm/Hz (-131dBc/Hz)
50kHz	-82 dBm/Hz (-132dBc/Hz)
100kHz	-84 dBm/Hz (-134dBc/Hz)

Intermodulation product levels are quoted with respect to PEP.

Microphone input sensitivity: 0.1mV for full output
Transmitter AF distortion: generally less than 0.1%
FM deviation: 2.0kHz narrow / 4.0kHz wide

Note:
All signal input voltages given as PD across antenna terminal. Unless stated otherwise, all measurements made with receiver preamp switched out (IPO), on USB with 2.4kHz bandwidth and on CW with 500Hz bandwidth.

A DIY vertical antenna for the 2, 4, 6 and 10m bands

I have mainly been interested in the VHF bands ever since I passed the Radio Amateur Examination in the early seventies. For a beginner to this wonderful hobby, it's often difficult to know which way your main interest may develop, and even as an old timer your interests continue to change. So, having an antenna that covers multiple bands should prove to be useful.

At no time have I ever come across a vertical radiator for all bands from 10m through to 2m. I have therefore set about designing such an antenna that not only works but is relatively simple and cheap to build. I shall not say much about the actual structural build or the design details. However, I will describe enough so that newcomers to the subject may be inspired to build their own versions.

The description

This antenna is a vertically-mounted dipole for each band, that can be fed with a single 50Ω coaxial cable. The design idea is not new, and is a proven system that works well. The lowest-frequency elements have a dual purpose: they both form the support for the complete antenna system, and constitute the driven vertical dipole antenna for the 10m band. The other bands are added by placing half-wavelength elements close to the 10m band elements. These are not connected to the coaxial feeder, but stand alone.

Matching and resonance

A half-wave dipole antenna has an impedance at its feed point of about 72Ω. I have discovered by experiment with this design that other higher resonant frequencies present have impedances of around 50Ω. Although the lowest resonant frequency may never be a perfect 50Ω match, the bonus is that additional higher resonant frequencies are normally much nearer to 50Ω. This makes the antenna better matched at the additional frequencies used.

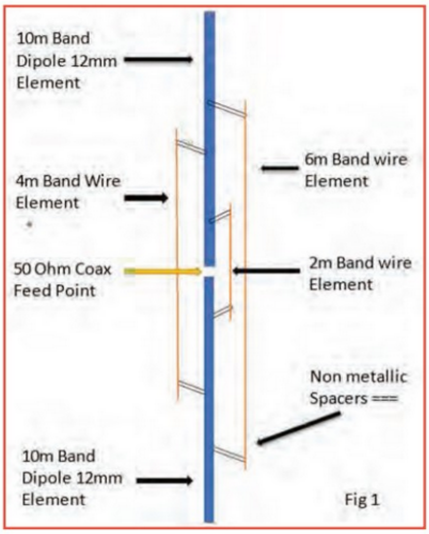

FIGURE 1: Schematic outline of the antenna.

The antenna modelling software I used was ENEC Pro 2+. A few of the ENEC graphs and charts are included for your perusal. I found that only very slight adjustments were needed after building and testing my prototype.

The build

Each of you will have different ideas about how to construct a dipole and there's a huge number of practical designs available on the web. I will describe my own approach.

I originally started this design using a 50mm-diameter scaffold pole for the 10m band thinking it would be better structurally, and adding additional wire elements for higher VHF frequencies. This seemed to be good on paper, and it performed well when tested using computer antenna modelling software, but constructing a dipole centre connector for a heavy 50mm scaffold pole was its downfall. This was a little disappointing, but I wanted to keep things simple and basic.

Most dipole-centre pieces on the market are for antennas made of wire or thin aluminium tubing, so in the final design I used thick-walled aluminium tube for the main support (see **Figure 1**). Such tubing is readily available from numerous suppliers. Using thick-walled tubing (as opposed to thin-walled tubing) reduces flexing, thus retaining the element spacing in windy weather.

For those of you who would prefer to build a more-robust antenna, I have included additional sets of dimensions: see **Table 1 (a), (b) and (c)**. The 10m dipole can be made from 10, 20 or 25mm diameter aluminium tubing, and for the wire elements you can use 1mm copper wire, or 5 or 12mm aluminium tube or rod.

The 10m elements are fixed and held in place by Stauff clamps (**Figure 2**). Stauff clamps may be purchased from **[1]**. This diagram shows just two Stauff clamps being used, but if you use two clamps on each element it will increase the strength of the

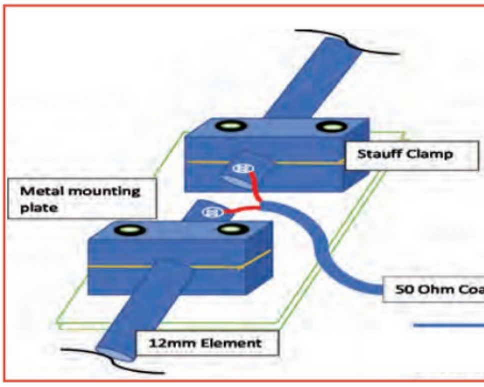

FIGURE 2: Use Stauff clamps to fix the 12m elements in place.

structure. The coaxial cable could be connected directly to each element or you could use a coaxial cable centre connector. I prefer direct connection, which reduces connector losses. The coaxial feeder will distort the antenna's tuning if allowed to hang near the elements. The cable should be brought away at right-angles to the central pole and fixed rigidly in place so that it does not wave about in the breeze. Mounting the whole structure on a horizontal boom, a minimum of about half a metre long, and taping the coax along it, will solve this problem.

The 1mm wire used to create the additional elements in the prototype used copper wire from some old mains cable; it was all held in place by some simple home-made non-metallic spacers (**Figure 3**). You could use additional spacers to prevent any movement in the wind. The centre point of each element should be positioned level with the centre point of the 10m dipole.

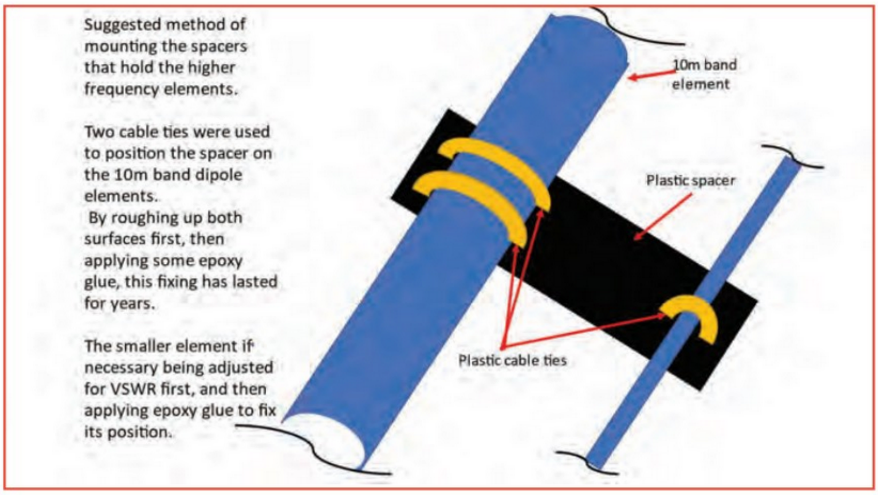

FIGURE 3: A method of fixing the higher-frequency elements.

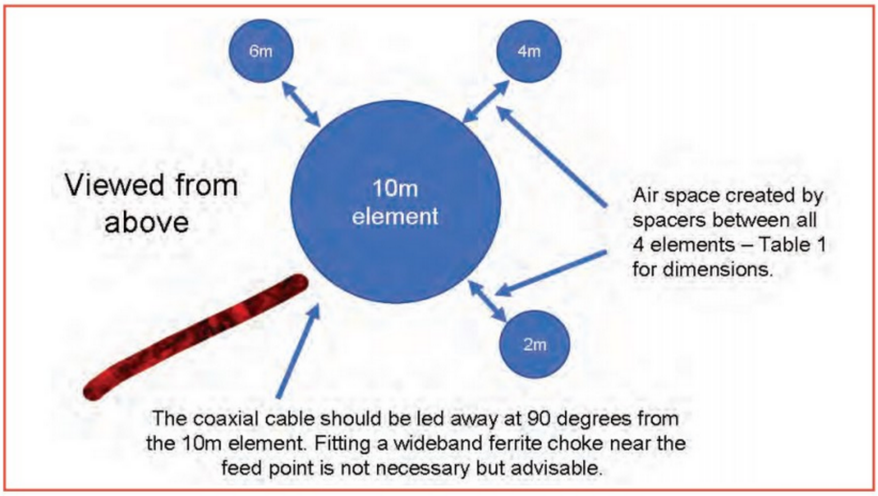

FIGURE 4: Top view showing the arrangement of the elements.

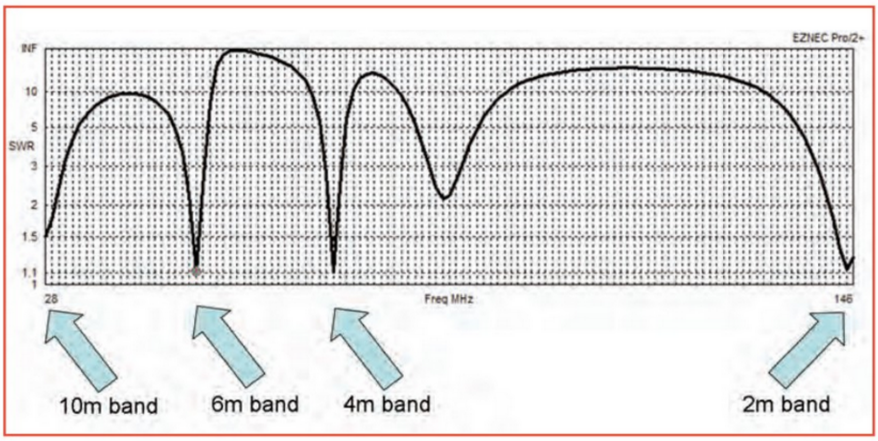

FIGURE 5: Predicted VSWR.

Tuning and fine adjustments

Increasing or decreasing the lengths of each element will move the resonant frequencies up or down. Start by making each element a couple of millimetres longer than my dimensions shown in Table 1 (a), (b) and (c). This should make the resonant frequency a little lower than you require. Shortening each element by a millimetre or so will increase the resonant frequency to that of your choice, each of the ends of the elements being trimmed equally. Remember that cutting them too short is not an option! Remember to block off the element ends to prevent water getting in.

Adjusting the air spacing of the elements in relation to the aluminium 10m element will allow you to alter the VSWR if required. If you should need to do this, do it individually element by element, a single millimetre at a time. Any other adjustments to element lengths or spacing you may need to make should at most only be a single millimetre or so.

If you build the antenna using different diameter tubing than stated in Table 1, much more tuning of element lengths and spacing will be needed. Just remember that changing element lengths will move the resonate frequency, while varying the spacing will affect the VSWR. Have a go and good luck. (See **Figure 4**).

EZNEC predictions

The predicted VSWR for each frequency band is shown in **Figure 5**. In practice it was found that the predictions were accurate and virtually no tuning was necessary. The omni-directional 6m-band radiation pattern shown in **Figure 6** is similar for all the bands.

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In Practice

Over the years I have enjoyed countless contacts using this antenna, particularly during the sporadic-E seasons. Being able to change band without having to change antennas has been a blessing. Using the antenna horizontally for SSB contacts has also proved useful, but the desire for higher gain has led me to use a more directional antenna!

References

[1] Stauff clamps were from www.inovantennas.com

[2] Aluminium tube was from www.aluminiumwarehouse.co.uk

FIGURE 6: Predicted radiation pattern.

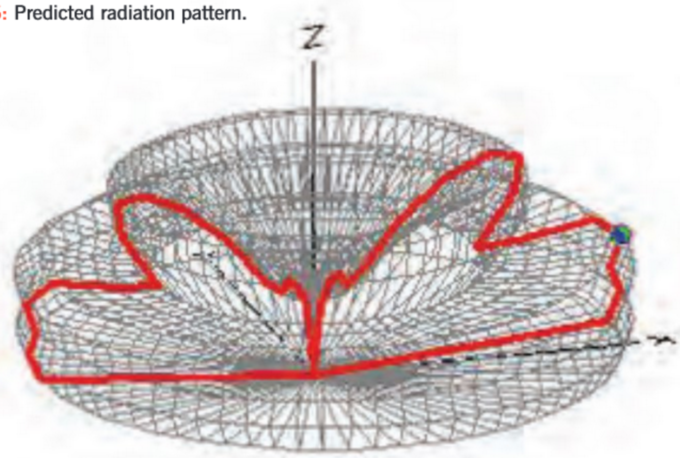

Table 1(a)

Band	Air space from the 12mm element/mm	Element diameter/mm	Element length/mm
2m	54	1	1000
4m	54	1	2090
6m	53	1	2916
10m	-	12	5060

Table 1(b)

Band	Air space from the 12mm element/mm	Element diameter/mm	Element length/mm
2m	82	5	982
4m	82	5	2070
6m	92	5	2880
10m	-	20	5032

Table 1(c)

Band	Air space from the 12mm element/mm	Element diameter/mm	Element length/mm
2m	71.5	12	962
4m	78.5	12	2046
6m	88.5	12	2850
10m	-	25	5035