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Cover images: Spring hat photos by Chris Zajac. Designed by Kevin Williams, M6CYB and *QST* staff. To celebrate the historic first amateur message to successfully cross the Atlantic, *RadCom* and *QST* are sharing a front cover.

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

PA500 portable amplifier has built-in ATU

The PA500 portable amplifier operates from 12 to 16V DC and will deliver up to 60W RF output from 5W RF input. It covers the HF amateur bands from 80 to 10m, with a built in auto tuner for ease of use. The PA500 body is just 30mm thick and very rugged, using a CNC milled durable anodised aluminium body for extreme operation. Although designed to match the Discovery TX-500, the PA500 supports RF-VOX PTT, so no control cable is necessary to the transceiver and accordingly it will work with Icom, Elecraft and many other portable transceivers. Weighing just 900g and sized at 30mm thick by 207mm long and 90mm wide, it is ideal for portable and travel use.

The PA500 will sell for £659.95 and should be available during November from UK distributors Nevada (www.nevadaradio.co.uk) and Waters & Stanton (www.hamradiostore.co.uk).

AR-2300 receiver

AOR in Japan have announced the launch of the AR-2300 Special Edition Black Box receiver. It is an analogue communications receiver that works in conjunction with the AOR software program. The frequency range is 40kHz to 3.15GHz. There is a 15MHz IF output and I/Q output for external display and decoding purposes. The stability is ±0.1ppm and there is provision for an external 10MHz reference source. For commercial applications there is great flexibility for integration into external systems, whilst the unit will also have appeal to the serious hobbyist. Price is £2749 and delivery is expected early 2022. https://hamradiostore.co.uk/

New Alinco transceiver

Nevada are now stocking the new Alinco DR-MD520E, a VHF/UHF DMR transceiver. It has built in GPS with APRS support, a large full colour LCD screen, automatic repeater roaming and 4,000 channels of memory. It's ideal for the amateur DMR user as it allows easy import and export of CSV files and parameters, along with contact databases. The radio automatically detects and switches between analogue and digital modes depending on the signal received. An added bonus is FM broadcast receive with 100 memories and VFO. The radio is packed with many other features and at £299.95 should be a popular radio. It is available from UK distributors Nevada Radio www.nevadaradio.co.uk and other selected UK dealers.

Panadapter interface

ML&S are pleased to announce the new PTRX-9700 panadapter Interface for the Icom IC-9700. Based on the same principle as their best-selling PTRX-7300, Radio Analog have finally released their internally fitted module enabling users of Icom's V/U/SHF transceiver to feed an SDR like the SDRplay RSP-1A without any compromise to the transceivers RF performance. Pre-delivery orders are now being taken at £279.95 and more information is available at HamRadio.co.uk/PTRX9700

SWR/Power meters

Moonraker now have the Sharman Multicom range of SWR/Power meters available. Models such as the Sharman AV-40, a VSWR power meter at £49.99, the Sharman AV-600 a VSWR power meter at £74.99 and the £89.99 Sharman AV-1000 VSWR power meter can all be seen on the website. www.moonraker.eu

Antennas

Antenna tuning unit examples

The T-network and Z-match antenna tuning units (ATU) were recently described. Let's look at two practical homebrewed examples.

T-network ATU built by G4FOY

The T-network ATU can provide an acceptably wide range of impedance transformations without needing to use large-value tuning capacitors. The T-network's input and output ports are both unbalanced, making its use suitable with coaxial feeder cables and unbalanced antennas **[1]**. An example of a T-network ATU circuit is shown in **Figure 1** and was the basis for the ATU built by Ken Scott, G4FOY, covering the bands from 160m to 10m. This ATU was constructed some years ago and has provided a reliable means of matching the transceiver to the coaxial feeder/antenna.

The ATU comprised two 500pF variable capacitors (C1 and C2), a roller-coaster inductor, two SO239 sockets and an integral standing wave ratio (SWR) meter. C1 and C2 were both RF high voltage ceramic insulated capacitors, able to withstand several kilovolts using widely spaced vanes. The roller-coaster inductor was a ceramic insulated type and was driven using gearing to allow it to be finely tuned. Details of the roller-coaster inductor are included in Figure 1. C1 and C2 were separate variable capacitors, however their tuning spindles were mechanically linked using a clamping bush to enable the capacitors to be ganged together. The variable capacitors and the roller-coaster inductor were obtained from radio rallies some years ago.

The ATU's SWR meter circuit was based on the G3TSO design [1] shown in **Figure 2**. To summarise, this circuit uses a current-sampling transformer bridge and is suitable for the 160m to 10m bands. The current transformer (T) used a FT50-43 type ferrite ring of about 12mm diameter. A short length of coaxial cable was passed through the ferrite core forming the primary winding, with a secondary winding of 18 turns wound onto the ferrite ring core. The braid of the cable was earthed at one end to form an electrostatic screen.

However, you must **not** earth both ends of the braid because this will form a shorted turn. D1 and D2 are a matched pair of germanium diodes (OA91 types in this case). The forward F and reverse R power directions are selected using the switch S1, with the reading on the meter adjusted using the 25kΩ variable resistor to suit the transmit power used. A good match is indicated when the F reading is maximum and the R reading is very close to zero.

The ATU was housed in a large aluminium box with the tuning controls and SWR display meter at one end and the transceiver and feeder/antenna connection sockets at the other end, as shown in **Photo 1**.

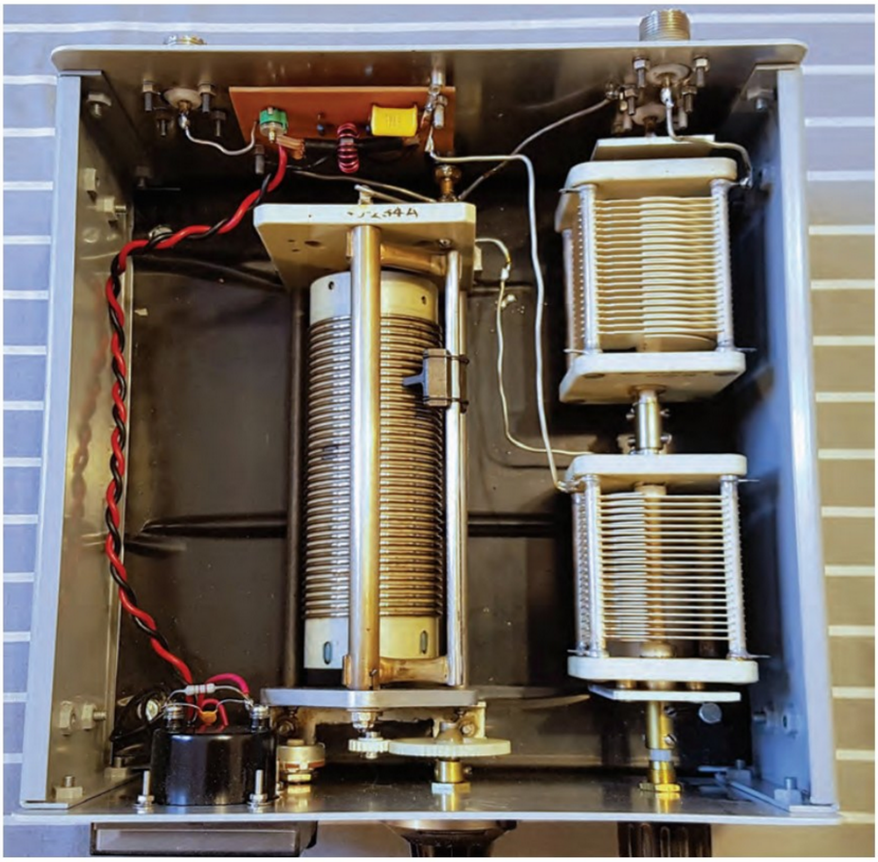

PHOTO 1: Layout of G4FOY's T-network ATU showing the roller-coaster inductor, variable capacitors, connections and controls. Note how the ganged capacitors are arranged so as one increases, the other decreases – maximum value on one corresponds with minimum value on the other.

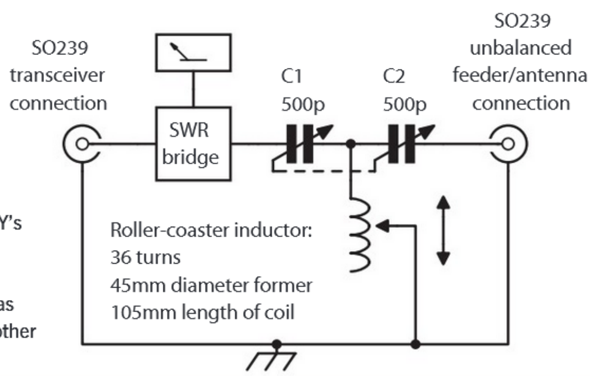

FIGURE 1: Circuit of G4FOY's T-network ATU. C1 and C2 are ganged together but in opposite directions so that as one increases in value the other decreases and vice-versa.

PHOTO 2: Front panel of G4FOY's T-network ATU. Note the use of the calibrated control for adjusting the roller-coaster inductor to indicate the setting for each band.

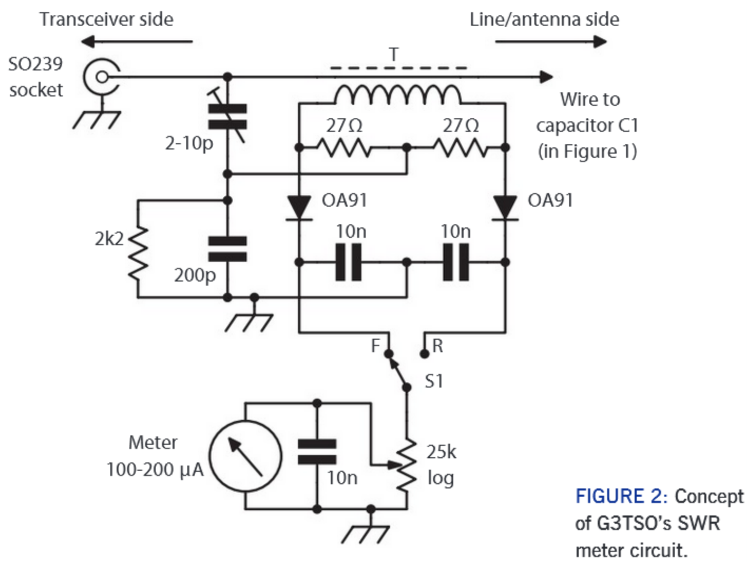

FIGURE 2: Concept of G3TSO's SWR meter circuit.

To tune the ATU, the value of the roller-coaster inductance is adjusted to suit the band to be matched to. This can be done by monitoring the receiver's noise level and varying the inductor until the noise is at a maximum, with the ganged capacitors C1 and C2 set at the mid position. Once the value of the inductance is found, using a low transmit power, ganged capacitors C1 and C2 are varied under load until a decrease in the SWR reading is observed. The SWR may need to be lowered still further by adjusting the value of the inductor slightly up or down depending upon the values of C1 and C2. This is an iterative process with the inductor and ganged capacitors C1 and C2 carefully adjusted until the lowest SWR is found (usually a 1:1 match can be obtained). Once the combination of L1, C1 and C2 has been found for the band in use, the transmit power can be increased. However, good practice is to check that the SWR has not risen when higher transmit powers are used.

Photo 2 shows the front panel of G4FOY's T-network ATU. The calibrated multi-turn control enables a reasonable indication of the inductor's setting to be returned to for each band. Similarly, the variable capacitors' scale provides an indication for their setting for each band.

A Z-match ATU built by G0JMI

Many stations prefer using a balanced antenna (which tends to be fed using a balanced feeder cable, so avoiding problems associated with common mode currents). Therefore, ideally, the ATU used to match the feeder to the transceiver needs to have a balanced feeder/antenna connection. Many ATU designs use a balun between the feeder/antenna and the ATU to provide a balanced interface. However, to avoid using a balun, there is another technique to provide a balanced match by inductively coupling the feeder/antenna to the ATU's main inductor.

An example of a circuit used for a home constructed Z-match balanced ATU **[2]** covering the bands from 80m to 10m is shown in **Figure 3**.

On the bands from 80m to 20m, inductor L1 is connected in parallel with the two sections of C1 (C1 is a double-ganged capacitor comprising C1a and C1b). The smaller inductor, L2, can be thought of as a connecting lead between the top of C1a and the top of C1b. This assumption is valid at lower frequencies because the inductance of L2 is smaller than that of L1. For these bands, the combination of L1, C1a plus C1b can be considered as a simple tuned circuit with one end earthed.

The double-ganged variable capacitor available had a maximum capacitance of 200pF per section. To enable the ATU to operate down to 3.5MHz, two RF high voltage 200pF capacitors are connected in parallel across variable capacitors C1a and C1b using switches S1 and S2 (as shown in Figure 3). This arrangement gave a maximum capacitance for C1a and C1b of 400pF each. With S1 and S2 able to be used independently to switch in the 200pF capacitors across C1a and C1b, this gives flexibility when tuning the ATU on the bands above 80m because often only the 200pF capacitor switched in by S1 was required.

On the 17m to 10m bands the active tuned circuit consists of the two variable capacitors C1a and C1b working as a split-stator capacitor (with the moving vanes earthed) with L2 connected between the two sets of stator vanes. The inductance of L1 is much greater than L2, therefore L1 may be considered as having has no appreciable effect on the performance of the split-stator tuned circuit comprising L2, C1a and C1b.

The antenna used with the Z-match ATU was a doublet that was fed at its centre using a 300Ω ladder line. To enable operation of the bands from 80m to 20m, the feeder/antenna was connected to L3, while for the 17m to 10m bands the feeder/antenna was connected to L4. The connection to either L3 or L4 used banana sockets and plugs.

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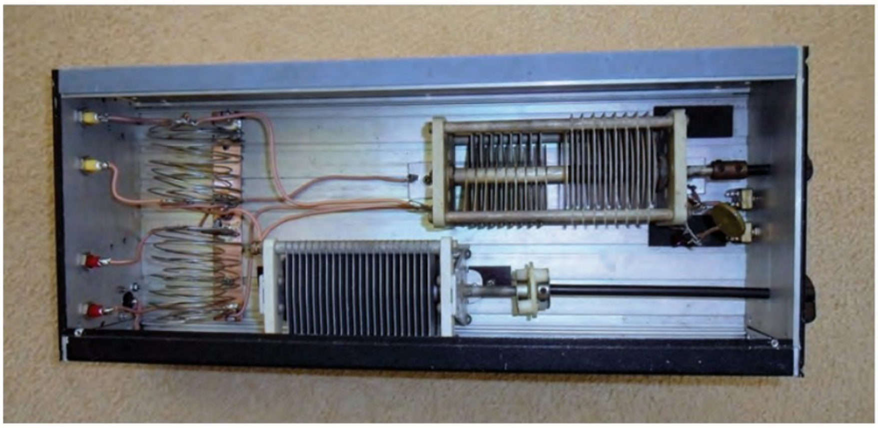

PHOTO 3: Layout of G0JMI's Z-match ATU showing the inductors, variable capacitors, connections and controls.

PHOTO 4: Front panel of G40JMI's Z-match ATU. Note the use of the numbered scales to record the setting for each band.

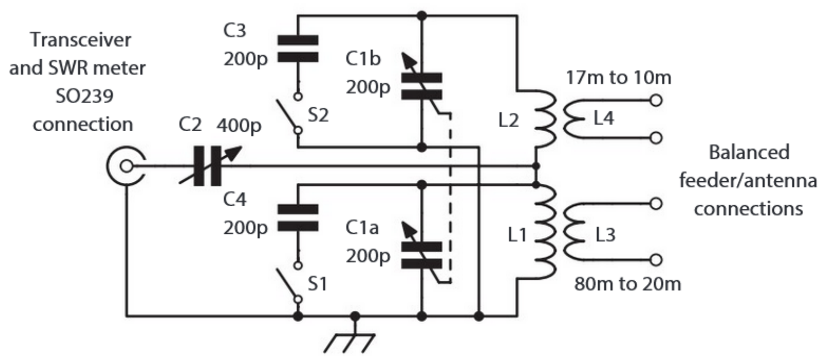

FIGURE 3: Circuit used for a Z-match balanced ATU.

The relatively high impedance LC circuits of L1, C1a, C1b (tuning for 80m to 20m bands) and L2, C1a, C1b (tuning for the 17m to 10m bands) must be detuned slightly off resonance at the frequency in use. The effect of this is to present an impedance with an inductive component (ie R + jX). This impedance, in conjunction with the coupling variable capacitor C2, functions as a series resonant input circuit that, when correctly tuned, presents non-reactive load of close to 50Ω to the transmitter's output.

The Z-match ATU was housed in a panelled aluminium box with its tuning controls at one end and the sockets to connect the transceiver and feeder/antenna at the other end, as shown in **Photo 3**. The coupling variable capacitor C2 needed to be isolated from the aluminium box and so was mounted on insulators.

Table 1 summarises the dimensions for inductors L1 to L4. To enable coupling, L3 surrounds L1 and likewise L4 surrounds L2. Etched strips of single-sided PCB were used to solder each set of inductors in place, as shown in Photo 3.

Tuning

The transceiver was connected through a suitable SWR meter to the Z-match ATU using 50Ω coaxial cable. The feeder/antenna was connected to either L3 or L4, depending upon the desired band. Ganged variable capacitors C1a and C1b were set to the mid position (with S1 or S2 switched in/out as appropriate, depending on the band in use). Capacitor C2 was varied until the received noise level was maximised. Capacitors C1a and C1b were then varied until the received noise level increased still further. Using a low transmit power, capacitors C1a/C1b and C2 were varied under load until a decrease was observed in the SWR reading. This is an iterative process, with variable capacitors C1a/C1b and C2 carefully adjusted until the lowest SWR was found (usually a 1:1 match can be obtained). Once the combination of C1a/C1b and C2 has been found for the band in use, the transmit power was increased, while checking that the SWR has not risen under the higher transmit power.

Photo 4 shows the front panel of the Z-match ATU showing tuning scales used to record an indication of each variable capacitors' setting for the HF band in use. A record was made of the position of S1 or S2 for each band as appropriate.

TABLE 1: Details of the Z-match ATU inductors. All were made with 18SWG (1.22mm) enamelled copper wire.

Inductor	Turns	Outside dia	Length	Note
L1	11	40mm	55mm	L3 surrounds L1
L3	7	50mm	55mm	
L2	7	40mm	45mm	L4 surrounds L2
L4	6	50mm	45mm	

General

Both the ATUs described have been used for SSB/CW contacts, with transmit power levels of up to 100W. The T-network ATU has been used with a loaded dipole on the bands from 160m to 10m, while the Z-match ATU was used with a doublet antenna from 80m to 10m.

References

RSGB *Radio Communication Handbook*, 14th edition edited by Mike Browne, G3DIH: Section 15, Practical HF Antennas,

[1] Pages 15.38 to 15.42.

[2] Pages 15.45 to 15.46.

Ailunce HS-2 1.8MHz to 432MHz SDR Transceiver

Ailunce is a relatively new name in the amateur market. So I looked forward to testing this new transceiver.

I've been aware of the Ailunce HS-2 transceiver for a little while. Ailunce, a Chinese manufacturer, wanted to design an SDR transceiver for the amateur market. In this article I will look at what you can do with the transceiver and how it performs in day-to-day operation.

The review period had a bit of a false start. When the transceiver arrived, I connected it up eagerly but could not receive any signals. I thought perhaps I had missed something, but after an hour or so, trying various parameters, I'd still had no luck. It would transmit fine, but no receive. I contacted Chris Taylor at Moonraker, who'd kindly lent me the review model, to discuss the fault. A replacement unit was quickly on the way, with Chris having diagnosed the original unit as faulty.

The HS-2 arrived well packaged, in a plastic carrying case, along with a microphone and power lead. Taking the rig out of the box, the first impression is of a well-built unit. The aluminium case has a pleasant finish.

The front panel is fairly small and quite 'busy' with a large number of buttons but a nicely sized display. Powering the unit up from 12V (you can use anything from 5 to 32V DC), the set goes through a start-up routine, checking what options and extra units have been installed. I was happy to find that the replacement review rig was receiving just fine as I tuned across some of the HF bands.

Once powered up, the display is quite easy to read although quite small. The waterfall display works well, showing adjacent activity. There's an S-meter as well as power and SWR meters. The power meter did not seem to be calibrated as the readings it gave did not correspond to my shack power meter. The selected filter is indicated along with many other features.

In contrast to the nicely substantial main unit, the microphone is rather lightweight and feels plasticky.

Ailunce is a relatively new name in the amateur market. The HS-2 is an SDR transceiver.

Getting on the air

One of the first things that caught my eye on the HS-2 was the CW decoder. Although I spend a lot of time on digital modes, I enjoy CW too and I'm always looking for ways for newcomers to Morse operating to 'dip a toe in the water'. CW decoders don't do as good a job as a well-trained ear, but if they help a novice CW operator enjoy the mode, it's all good as far as I am concerned. A few experiments tuning across 40m and 20m showed that like many decoders, the HS-2 is very sensitive to how the CW signal is tuned in. As you might expect, it did better with strong signals and machine-sent Morse. Even then, accuracy was maybe around 50-60%. The HS-2's CW decoder might help you decode a call or two, but I don't think you'd want to rely on it. If you want to 'do' Morse-by-ear better, by the way, have a look at CWops CW Academy programme (https://cwops.org/cw-academy/cw-academy-options/).

There's a CW keyer built into the rig and there is a 3.5mm jack plug provided on the back of the rig for you to plug your key or paddle into. To set the keyer up as you wish, long press the Band button and you will find the CW menu. You can adjust sidetone volume, keyer speed and CW delay. There's a training mode, so you can use the HS-2 as a practice oscillator! Curiously, if you are in CW mode and hit the PTT on the microphone, the keyer sends a string of dots.

Data modes

With its low power output (5W or so) the HS-2 lends itself to data modes operation, so I decided to try it out on FT8. This proved to be very simple indeed, although the manual suggests that the HS-2 will only work with computers running the Windows 10 operating system. This sounded rather limiting, so I checked online and quickly found some details of how to use the HS-2 on Linux (https://www.ailunce.com/blog/How-to-configure-WSJTX-for-Ailunce-HS2-on-Linux-System). There is a suggestion that it should work with OS X but I couldn't find much detail when I looked quickly.

The front panel is fairly small with a nicely sized display.

Fortunately, my shack computer runs Windows 10, so it was just a case of running a USB cable from the HS-2 to the computer. No need for separate audio connections. Plugging the USB cable to the computer will set up a virtual COM port. You can then configure WSJT-X (or JTDX). The HS-2 emulates the Yaesu FT-817, so select FT-817 as your transceiver in WSJT-X. You should be able to select the HS-2 in the Sound dialog for both In and Out. You then need to set up the CAT interface, which will point at the virtual COM port set up a moment earlier.

All of this was simpler than it may sound, and I quickly had the HS-2 talking to the computer and decoding FT8. As it happened, the 6m band was open around Europe with a nice Sporadic-E opening and I quickly worked T77C and HB0WR running the 5W from the HS-2 to a vertical aerial, along with several other European stations. Switching to 20m, I quickly made some more European QSOs on FT8 as well as being heard in the USA, not bad with the 5W to a rather ancient Butternut HF6V vertical.

10MHz is a great band for both CW and FT8 if you're running low power, so I switched the HS-2 to 10MHz and had a listen. Everything seemed good, so I decided to call CQ – only to be confronted with a message saying '10M-disable'. I had a quick look in the firmware to see if this was something that could be switched on, but it wasn't. It seemed odd to me that the 10MHz band had been disabled, as I can see the 10MHz band is available in China. I wondered whether the intention had been to provide a facility to disable the 10 *metre* band, but there had been confusion in the implementation of the feature. Assuming that this is a mistake, it would presumably be easy in future of the firmware for 10MHz transmit to be enabled.

SSB/AM

Although I did not spend much time operating on SSB or AM, I thought I would try a CQ call on 3615kHz on AM. Steve, GW1XVC replied straight away to my call and said that the signal was strong enough (which delighted me with 8W), but the audio was very muffled with virtually no high-end. In fact, he said, and I didn't take it amiss, that it sounded like I was talking through a sock! Testing on a monitor receiver, the SSB audio also lacked the clarity I would have liked. I am not sure whether this is down to the microphone supplied with the HS-2 or the signal processing within the rig.

Receive filtering

Receive filtering, although not continuously variable, is relatively flexible and reasonably adequate for the majority of band conditions. I must admit, when I was listening to the 80m AM activity, I enjoyed the ability to widen out the filters and enjoy the quality of the audio.

Built in ATU and VSWR meter

The HS-2 has a built in ATU, which operates between 1.8MHz and 54MHz. It claims to be able to match impedances between 16.7 and 150Ω. Assume then that your antennas are going to need to be a fairly decent match (say around 3:1 or better) and the ATU on the HS-2 will bring that down to 1.5:1 or thereabouts. The HS-2's ATU is not going to be good at matching most long wires, for example. To operate the ATU, you can short press the Tune button. If it is able to tune the antenna you'll see a green T on the top line of the display. If it fails to tune, the T will go grey. Short press Tune again to come out of tuning mode. If you want to use an external tuner, then a nice trick is to press the • button, which sends a carrier, allowing you to tune an antenna manually.

Band change

The facility to change band was rather quirky. Most of the time it would work fine, but occasionally I would select, say, 430MHz and the display would change to 2GHz (which the receiver doesn't cover). I experienced the same effect from time to time on some of the HF bands too. Although this was inconvenient, I could still change band using the Up/Down keys to change the frequency.

Upgrading the firmware…

I thought I'd better see if I could update the firmware to the latest release, as very often there have been developments whilst the rig has been in the supply chain and it's good (usually!) to have the latest and greatest firmware installed. Try as I might (and I spent a lot of time on this), I could not get the HS-2 into the DFU mode required to update the firmware. The instruction manual and a video both said that you need to press the band and power buttons at the same time. I may have been missing some finer point of this instruction, but I could *not* make it work, so I was unable to upgrade the firmware. I tried this on both the original and replacement units, with the same issue. I am perfectly prepared to assume that this was me doing something wrong, but I'm also working on the basis that if *I* have problems with something, some of you might do so as well.

VHF/UHF FM operation

The HS-2 boasts VHF/UHF capability, so I decided to connect up the V-2000 vertical again and try the rig on the local repeaters. My first impression was that the rig was rather insensitive on 2m and 70cm, as signals seemed poorer than expected. That impression was rather false though. I had to go into the RF menu and switch a preamp on (note that you can't just leave it switched on when you are operating on the HF bands, as you will probably find the receiver swamped). Having done that and tweaked the RF Gain setting, the 70cm repeater, GB3SP and the 2m repeater, GB7PD were much more like the signals I would expect.

Setting up the different receive and transmit frequencies for the repeaters and the CTCSS tone was not difficult. The problem came when I looked to save the parameters into a memory. It was a rather fundamental problem: there are no memories on the HS-2! I quickly asked Chris Taylor about this and he tells me that it is planned for a later version of the firmware. As it is, though, you cannot save a repeater's configuration, so you will have to set up the split and CTCSS tones each time you want to use the repeater.

Undaunted, I put a call through the 70cm repeater GB3SP and Martin, GW3XJQ kindly gave me a critical report that the audio was rather thin-sounding. I switched to Wide FM in the hope that it would improve the level of deviation, which it did to some extent. Speaking closer to the microphone improved things further, but the general impression was that the audio was 'OK' but when I switched to my normal shack rig for FM, a Yaesu FTM-400XDE, I think Martin breathed a sigh of relief. The same was true on receive. GB3SP, even with the RF gain control peaked and the preamp on, was noisy. Switching the aerial to the FTM-400XDE, GB3SP was a comfortable S7. I wondered whether these

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The rear panel of the HS-2 has a number of connections, see text.

issues were peculiar to 70cm, but similar tests on GB7PD on 2m showed the same results. So, if you plan to use the HS-2 on 2m or 70cm it's worth bearing in mind that it is usable, but performance is a little disappointing.

Power measurements

Using the tune facility, I made some measurements of the power output. On HF, power varied between 4W on 160m rising to around 8W on 12/15m before dropping back to 6W on 10m. On 6m, output was 5W; on 2m, 8W and on 70cm, 5W. I did not see anything like the 20W mentioned in Ailunce's publicity.

My impression was that power dropped somewhat as the rig warmed up. This is probably a good moment to mention the fan that didn't come on during these tests. Within the firmware, you can adjust the temperature at which the fan comes on – the default is 45°C. Maybe setting it a little lower might lessen the thermal effects on power output.

FM Radio

The HS-2 contains an FM radio (88-108MHz), which is controlled by means of an app in the MENU. It seemed to be fairly sensitive and sounded fine. I couldn't make it automatically search the band and populate the apps memory channels though, although I was able to tune up and down the band manually and select stations to listen to.

Ergonomics

At the beginning of the review, I mentioned that the front panel was busy with a lot of buttons. Those of us with fatter fingers and poorer eyesight than we once had may not find the rig so easy to use. This is particularly the case with the tuning controls, which are the arrow keys on the right side of the front panel. Tuning up and down the band is not the pleasurable experience it would be with a tuning knob, or even a mouse-wheel control! This does affect the use of the rig in 'standalone' mode.

However, all is not lost and one of the benefits of the rig being built with SDR architecture is that it can easily be controlled from your computer. The HS-2 manual gives details of how to set up HDSDR software on your PC to interface with the rig. This certainly gives some options for easier control and a bigger display. The manual also gives directions for interfacing with Ham Radio Deluxe and N1MM software. Controlling the rig from the computer is certainly a much more enjoyable experience.

I was excited to read that the HS-2 included Bluetooth and that an app called QRadioBLE had been developed by BA7JZL for both iOS and Android devices to communicate with the HS-2. The iOS app costs £2.49 on the App Store at the time of writing.

Unfortunately, however, when I went into the Bluetooth menu on the HS-2, I could not activate any of the features to pair with a phone. On looking in the HS-2 manual for further details it says 'Temporarily unavailable'. This is a shame, because the app looks quite well designed and it looks as if you may be able to set up memories in the apps, circumventing the lack of memories on the HS-2 itself. There is, however, some Bluetooth capability in the HS-2 as, when I was checking the Bluetooth settings on my phone, I could see it was present, so I suspect the Master/Slave mode was incorrect and could not be switched.

Ailunce's publicity for the HS-2 mentions the 'HamBox' app to run on a mobile phone, but I could not find this app on either the Apple Store or Play Store so am not sure if it is still available.

Rear panel connections

The rear panel of the HS-2 has a number of connections. There's USB, audio out, a PTT socket to control an amplifier (on a 3.5mm jack); there's also a GPS antenna connection if you have the optional GPS module fitted.

I was curious about the Host USB interface socket. I plugged a USB lead in and a small plume of smoke appeared. 'This doesn't happen to Peter Hart' I thought, and quickly switched off the rig. Removing the lead and switching back on, nervously, I was delighted that it was still functioning. But it shouldn't have done that. The manual says that the port is reserved for charging equipment.

There's a LAN port on the back of the HS-2 that, the manual says, is 'used for remote control and remote firmware upgrade' but I cannot find any details on this so am not convinced whether these features are available now. It's a shame as remote controlling the rig across the internet as would be an interesting feature and the HS-2 might make a useful building block in remotely controlled stations.

Features not tested

Ailunce advertise optional modules for the HS-2: a GPS module and a LORA module. The review model did not come with those modules, so I was not able to test them. It looks like the GPS module should enable APRS functionality within the HS-2 of some sort. It was not clear to me whether the HS-2 could receive APRS messages or data. The LORA module looks interesting too and seemed as if it might feature a chat system sent by the low power LORA protocols.

Conclusions

The HS-2 is a rig whose possibilities had intrigued me for some time. It is full of potential and there are many good features. Equally there are many features that do not quite work as they should or are 'temporarily unavailable'.

I spent some time thinking about who the rig would appeal to. As a low power rig, it might appeal to Foundation licensees, but because of its quirks I think it might be frustrating to people starting their amateur radio journey. It might appeal to more experienced operators who enjoy low power operation. It worked very easily on FT8 using the WSJT-X program, but you could just as easily use FT4, Q65 or WSPR using the same program. Using the N1MM software, you could try some low power RTTY. Similarly, CW operation isn't bad, you can either key it manually or with the built in keyer.

Because the reports of transmitted audio were rather poor, I felt that the rig was probably more at home on either CW or data modes, at least until Ailunce can make some improvements to the transmitted audio quality.

I think the rig might also appeal to people who spend more of their time listening, especially if those people are experienced with using SDR software.

The HS-2 could be great, but that will depend if Ailunce continue to develop and improve the firmware. My concern would be that the development effort would dwindle over time and that it would remain 'middle of the road'. For now, I feel that if you are prepared to work around the shortcomings of the rig, you may well enjoy it, but be prepared that you may feel a little like a 'beta tester' for the rig. Views vary and I spoke to someone who'd used an HS-2 and he felt it represented 'exceptional value for money'. I would be a little more guarded.

My grateful thanks to Chris Taylor of Moonraker for the loan of the HS-2 and for putting up with my questions. The Ailunce HS-2 costs £649.99 including VAT. www.moonraker.eu.

Servicing and improving a KW slow motion drive

Introduction

Spotting a 1960s vintage, valved KW 202 receiver on sale for a very reasonable price, described as 'for spares only', I bought it, sight unseen. However, a brief examination showed that it appeared to be physically complete, so I decided to restore it. The tuning drive felt rough as I roamed the bands. I asked around for information about access to the internals with a view to servicing the mechanicals. I was advised not to attempt it, as it was said to be quite tricky to dismantle and rebuild. As a tyro model engineer, my interest was piqued and I decided to try. The result is this record of my findings and suggestions.

Well-made or at least well-designed mechanical dial drives to operate variable capacitor VFOs are quite uncommon these days, being instead rotary encoders driving digital circuitry. But fine engineering is widely appreciated, especially in the case of the Collins, Drake and National. These manufacturers made very finely engineered VFO drives, although these did not give a direct frequency readout until the HRO 50 appeared in 1950. Until then, users had to look up the dial numbers on a chart to find the frequency in use.

Some mechanical drives still in use suffer from less than perfect 'feel', or 'square bearings' but this as often due to contamination of the reduction gear lubricant by foreign bodies or congealed grease.

Details of the mechanical speed reduction mechanisms used in Eddystone **[1]** **[2]**, Redifon **[3]**, Racal **[4]**, (British) or American receivers are quite well documented, amongst them Drake **[5]**, Swan **[6]**, Collins **[7]**, National **[8]** **[9]**, Hammarlund **[10]** and the generic HBR (Home Brew Receiver) designed by W6TC and K4FX, in blogs by VK5SRP and AA7EE, not to mention the G2DAF, G3RKK and G3PDM projects. Many of these used the Eddystone 898 dial and drive, which is still revered for its silky smooth 'feel' and lack of backlash **[11]** 70 years after its introduction. The Eddystone Users Group has a comprehensive website devoted to the Stratton Company products, including the 1952 International Marine Radio IMR 547 built for them by Eddystone and equivalent to the S700. The Electrovoice RME 4350 appears to suffer badly with seized or slipping reduction drives but the treatment described here should return them to working order, as claimed in various US forums. The KW equipment in question used the now-discontinued Jackson Brothers 4511DR 36 to 1 speed reduction drive, but the current 4511DAF is similar. Details of the Jackson Brothers rotary drives can be found at **[12]**, where some dimensioned drawings can be inspected, and **[13]**. US manufacturers Oren Elliott **[14]** may offer a near equivalent.

PHOTO 1: Overall view of the receiver.

I bought my KW 202 receiver for £20 sight unseen, for spares only. To this end, originality is not paramount. I fitted LEDs as dial lights and added three more in a strip at the top of the meter, hence the Kapton tape protecting the very fine 36g wire used to be inconspicuous and to avoid drilling the panel. These additions do not preclude restoration to the original state if required.

With this procedure there is no need for tricky access with long tools from above, peering down the gap between the front panel and the VFO dial.

I mention also the contemporary Geloso VFO **[15]** and the Electroniques 'front end' RF/VFO/Mixer unit **[16]**, which performed quite well, and Cycloidal speed reduction device **[17]**. Finally, take a look at the Wikipedia entry on 'Backlash' [11], which is relevant in a general sense to this article.

Dismantling and reassembly

You will require angled tweezers, a 5mm flat blade screwdriver x 150mm long, a cocktail stick or crochet hook, and a magnifier (your preference) for reassembly.

KW used BA (British Association) screw sizes. Although now long obsolete, BA fasteners are still made for maintenance purposes. The nearest approximate metric equivalents are 2BA ≈ M5, 4BA ≈ M3.5 and 6BA ≈ M2.8, though it's important to note these are not interchangeable (eg a M5 nut won't properly fit a 2BA screw).

Here are the eight steps to restoring the KW dial drive. As the Buddhists say, the 'Eightfold Path' to Nirvana (in this case, a smooth and gentle tuning drive).

1) Remove the central tuning control, using a 1/16 inch (1.55mm) Allen key (**Photos 1 & 2**). My example was very tight on the shaft and had to be levered off, whilst I tried not to mark the good paintwork or the polished aluminium. After removal I reamed the central hole with a 6.35mm (¼") twist drill. This is the nominal diameter of the reduction gear shaft and it cured the problem, so perhaps something unseen was binding.

2) Unscrew the two very small (1mm-ish) screws. Use a small tray to catch them. At 5mm or so long they are easily lost in the

PHOTO 2: Using the Allen key to remove the inner tuning control.

PHOTO 3: The tray to catch errant screws.

PHOTO 4: Reduction drive as removed.

PHOTO 5: The reduction drive and spacer.

PHOTO 6: The drive and spacer separated.

PHOTO 7: Recessed screws in the spacer showing the clamp behind the panel and the off-centre hole.

PHOTO 8: Tapping the front panel M5.

PHOTO 9: The clutch drive 'up close'.

general debris on most workshop floors. Then remove the outer control (**Photo 3**).

3) Whilst peering down the 8mm/5-16ths hole in the spacer (while simultaneously trying to see, manipulate the screwdriver AND hold a torch), undo the two reduction drive grub screws. These are set at 90 degrees in the boss, only half a turn is required. Remove the long (4BA?) screws holding the drive and spacer to the panel. The clamp behind the panel will fall free but be retained by the VFO shaft. Withdraw the reduction drive (**Photos 4**, **5, 6** & **7**).

4) At this point I travelled up a blind alley, drilling out the aluminium spacer for 5mm bolts, tapping the front panel M5 accordingly (it is thick enough to be so treated) and countersinking or counterboring the spacer, in order to recess the screws. But then I realised that there was a better way (**Photo 8**). Wash the reduction drive mechanism in white spirit or other suitable solvent to remove all old grease. When dry, lubricate with new grease. I used spray-on lithium grease, which seems to work OK. Do not be tempted to adjust the four spring loaded clutch screws; they were set by the KW factory at the time of manufacture and should not need attention (**Photo 9**). Do not strip the slipping clutch mechanism, but re-grease before reassembling the mechanism. The grease, especially if it contains Molyslip (and is therefore black), stains everything nearby so keep it away from your clothes. To reassemble, offer up the reduction drive and tighten the grub screws (**Photo 10**).

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PHOTO 10: The clutch showing the grub screws and the 14mm spacers.

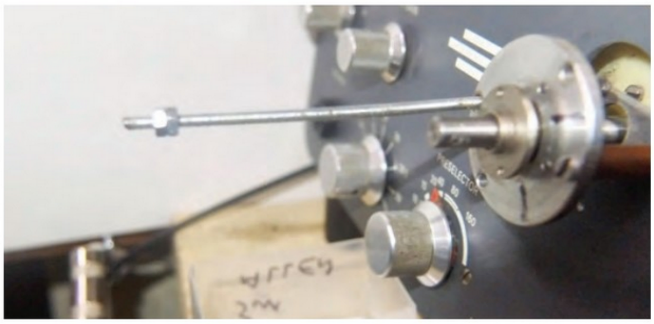

PHOTO 11: The M3 threaded rod used in reassembly.

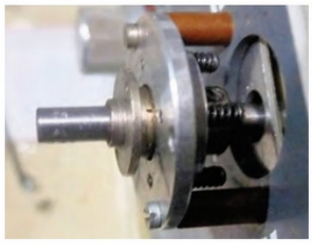

PHOTO 12: Spacers fitted to the receiver.

PHOTO 13: The Allen key supporting the outer control during reassembly.

PHOTO 14: The felt disc between inner and outer controls.

5) Feed the M3 threaded rod through the screw holes and do it up so it is just finger tight. Its purpose is to hold the clamp bar against the rear of the panel whilst a temporary M3 x 10mm screw is inserted in the other position, briefly, to hold the clamp bar steady (**Photo 11**). Returning to the original threaded rod, this can be removed and the proper component inserted with its associated spacer. As an aside, I cannot imagine why this form of assembly was not used in the original design, in view of its advantages for access. Check that the drive operates direct though the clutch to the VFO unit and that the slow-motion mechanism operates without binding or scraping on its companions.

6) Discard the aluminium spacer and replace it with 2 x M3 clearance x 14mm long tubular spacers. This provides much-needed space to reach the grub screws mentioned in 3), and to re-engage with the clamp bar (**Photos** 7 & **12**). Note that the VFO spindle is not central in the front panel hole. The clamp is to hold the reduction drive hard against the front panel on re-assembly.

7) Attach outer control knob, use the tray as in 2) and, whilst the screw is being replaced, insert the Allen key temporarily in the other screw location to hold the knob in place during this delicate operation (or use something like Blu Tack®). Check that it operates smoothly (**Photo 13**) .

8) Make a felt disc to fit over the VFO shaft to add friction and prevent any contact between inner and outer controls (**Photo 14**), then fit the inner control. Fasten the grub screw with the Allen key. Check that the controls operate smoothly. The drive should feel much silkier in operation.

If the drive needs to be removed at a future date, the small changes noted ensure that the entire assembly can be dismantled and rebuilt within five minutes or so.

Additional comments

The vintage Swan 500 and 700 [6] mentioned earlier are more powerful than most desktop transceivers, with outputs of 350W and 700W respectively. Several US amateurs have said that, after attention, the smooth tuning mechanism is 'wonderful'. WQ9E said it was the best tuning mechanism he ever encountered, properly operated and lubricated. I think that this procedure will enable readers to achieve the same level of satisfaction without great expenditure.

As an aside, the Cyclo Harmonic speed reduction drive is discussed in the *Model Engineer* magazine discussion forum in December 2017 [17] and a humorous diversion **[18]** into weird and wonderful dial drives that cause so much frustration to repair technicians will raise an ironic chuckle.

Websearch

[1] http://eddystoneusergroup.org.uk/eddystone-components/
[2] http://eddystoneusergroup.org.uk/Data%20Sheets/imr%2054%20sales%20leaflet.pdf
[3] https://www.m5poo.co.uk/redifon-r551n-receiver/
[4] https://www.radiomuseum.co.uk/racal.html
[5] http://www.zerobeat.net/drakelist/drakemod/drmod33.html
[6] Swan 500/700 https://tinyurl.com/bzbp2ukx (warning: dangerous electrical setups shown)
[7] https://www.antiqueradios.com/forums/viewtopic.php?f−5&t−289311
[8] www.prismnet.com
[9] https://www.radioblvd.com/National%20HRO.htm
[10] www.antiqueradios.com/forums/
[11] https://en.wikipedia.org/wiki/Backlash (engineering)
[12] https://www.royalsignals.org.uk/jackson bros caps/
[13] https://www.mainline-group.com/collections/reduction-drives-classic-6-1
[14] http://www.orenelliottproducts.com/
[15] http://www.g4kfk.co.uk/KW Geloso 4-104 VFO SWM 195808.pdf
[16] https://www.vintage-radio.net/forum/showthread.php?t−151500
also look at http://www.dghwells.clara.net/radio in particular the images IFstrip0001 through 0006 and tuner01 through 06
[17] https://www.model-engineer.co.uk/forums/postings.asp?th−132667
[18] https://www.rfcafe.com/references/radio-electronics/radio-dial-mechanism-radio-electronics-november-1953.htm

EMC

PHOTO 1: QRM on 3571kHz.

PHOTO 2: A telephone pole found to be radiating QRM on 3571kHz.

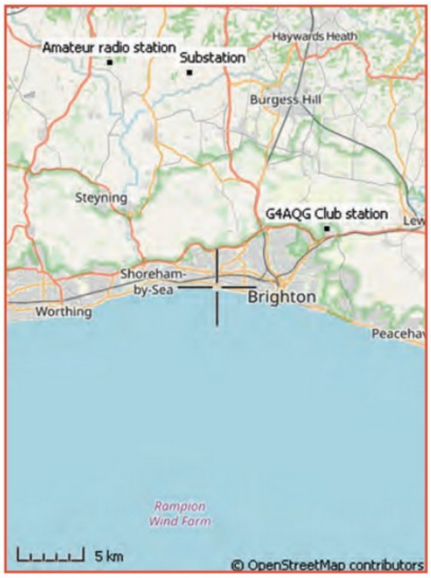

FIGURE: 1 Map showing Rampion offshore wind farm, substation and two amateur radio stations in West Sussex.

Offshore wind farms

The Rampion offshore wind farm **[1]**, off the Sussex coast in the English Channel, consists of 116 turbines on a 70 square kilometre site located between 13 and 20km from the coast. The total installed capacity is 400MW and the amount of renewable electricity generated saves approximately 600,000 tonnes of CO_2 emissions per year. Renewable energy schemes such as offshore and onshore wind farms and solar farms clearly play an important part in developing a power sector that is based largely on renewable sources but in our opinion, a close watch also needs to be kept on the electromagnetic compatibility characteristics of such schemes. There is a need to ensure that they are properly engineered so as to avoid causing significant pollution of the radio frequency spectrum, a finite resource that needs to be protected.

For Rampion 1, the electrical output of each wind turbine is fed via a 33kV cable to an offshore substation that transforms this up to 150kV to feed the offshore export cables. These come ashore near Worthing in West Sussex. From there, an underground onshore cable goes across the South Downs National Park and north to a new addition to the Bolney Substation at Twineham near Hickstead in West Sussex. There it is transformed up to 400kV to feed the National Grid. Transmission from the offshore substation all the way to the onshore substation is high voltage AC (HVAC), unlike some other wind farms and undersea cables that use high voltage DC (HVDC) transmission with converter stations to convert DC to AC. HVDC converter stations are a potential source of radiated RF interference if they are not well engineered so it might be expected that an AC-only system wouldn't cause any significant RFI, but some RFI has been reported from an AC-only substation.

The Rampion offshore wind farm was mentioned in the August 2017 EMC column (p54-55) with a correction in October 2017 (p76-77). In 2018, a member of the RSGB EMC Committee Investigations Group made some measurements outside a substation in West Sussex but on that occasion no significant RF interference was detected. Then, in August 2021, we received a report that University of Sussex ARS G4AQG has also been affected by RFI that was raising the noise floor on the 1.8MHz band. At first they thought it was a fairly substantial solar power installation on campus but direction finding showed that it was elsewhere. The directional bearing was 320° from G4AQG, which points towards a substation 16km away. The operators of G4AQG report that their northwest and west Beverage antennas pick up the RFI very well and the raised noise floor impacts on their reception of USA DX on 1.8MHz. They also provided some recordings of the RFI present and absent at G4AQG on a weak signal from an MW broadcast transmitter on 1521kHz. The RFI can be heard as a 300Hz modulated whine.

The operators of G4AQG made some mobile/portable measurements around the area of the substation using a monopole antenna and an SDRplay RSP1A. One measurement was made near a pub, 1.1km distance from the substation and another was made near the substation gate. As the monopole antenna is not calibrated, it is not possible to relate the measurement to absolute field strength but the measurements did show that the RFI is very 'peaky' around 1250kHz and 1510kHz and that at 1850kHz, the measured level near the substation gate was approximately 20dB higher than near the pub.

Another radio amateur is located at a rural location about 6km west of the substation, see **Figure 1**. He provided the plots in **Figure 2** and **Figure 3**, which were taken using a 1.8MHz EWE type directional antenna set to point east towards the substation. The receiver is an SDRplay RSP1A and the software is SDRconsole v3.0.27.

Figure 2 shows a plot from 1.5-2.5MHz when the RFI is present, which is most of the time. Using the EWE antenna, which is designed for the 1.81-2MHz amateur band, the interference peaks at 2.039MHz, just above the amateur band. At 2.039MHz, the signal strength meter shows 28.1dB(μV), ie 28.1dB above one microvolt (24.4μV) at the input to the RSP1A. The smaller plot in the top left hand corner shows the spectrum of the demodulated audio. There is a peak at 100Hz and another at 200Hz but there is a much larger peak at 300Hz. This is characteristic of a source that is powered by a three-phase electrical supply such as some sort of industrial machine or an electricity substation.

It was noticed that the RFI was not present when there were storm warnings and it seemed to be much reduced when there was very little wind. Observations on 22 and 23 May 2021 (during a severe storm in English Channel) showed that the RFI was not present but it returned on the afternoon of 23 May 2021 and it was at full strength on 24 May 2021. Figure 3 shows a plot from 1.5-2.5MHz when the RFI was not present. The noise would be man-made noise and natural atmospheric noise. There is a broad peak in the noise floor around 1.8MHz because the antenna is resonant in the 1.8MHz amateur band. At 2.039MHz, the signal strength meter shows 0dB(μV), that is 1μV at the input to the RSP1A.

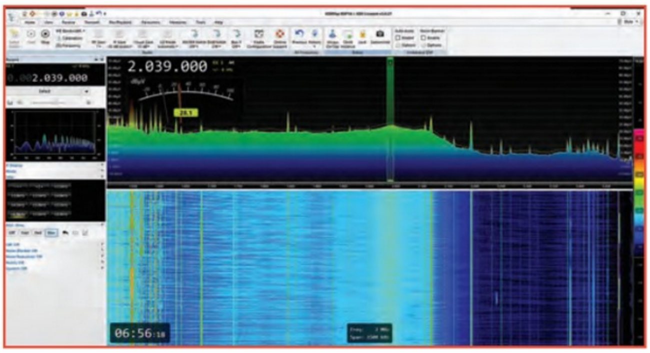

FIGURE 2: 1.5-2.5MHz spectrum plot from substation when the RFI is present.

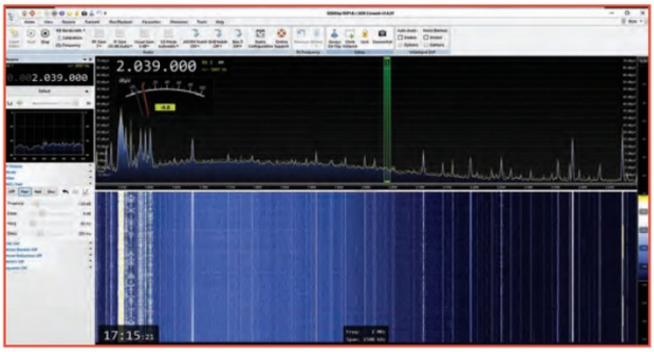

FIGURE 3: 1.5-2.5MHz spectrum plot from substation when the RFI is absent.

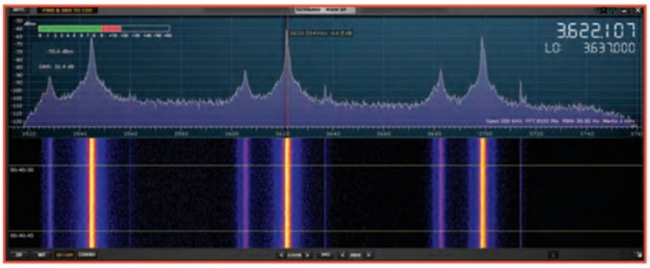

FIGURE 4: Radiated interference from a battery charger with no RF interference filtering in normal (continuous) charging mode.

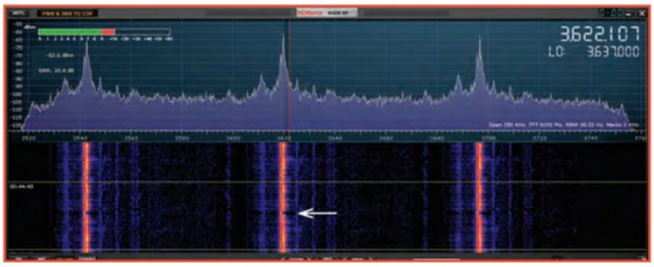

FIGURE 5: Radiated interference from a battery charger with no RF interference filtering in pulse (repair) charging mode.

These two plots clearly show that at this particular rural location 6km from the substation (and using a directional antenna pointing towards the substation), the substation is raising the noise floor on the 1.8MHz amateur band by a substantial amount – up to 28dB. Even at a distance of 16km away, the RFI can still cause very significant interference to weak signal reception.

The RFI disappears during severe storms (when the offshore wind farm does not operate) but the source of the RFI does not appear to be the wind farm itself. It seems to be the substation where the electrical output from the wind farm feeds into the National Grid. The amateurs concerned are in contact with helpful engineers who deal with the substation and it seems that the source may be thyristor switched reactors (TSR) or static compensator (STATCOM) transformers used to stabilise reactive power. A Rampion 2 installation is planned and, as with Rampion 1, this will be required to be compliant with the EMC Directive. The outcome of the Rampion 1 investigation will provide a useful case study, allowing improvements in the design of Rampion 2.

Has anyone else detected RFI, particularly on 1.8MHz or 3.5MHz bands that has a 300Hz whine, indicating a three phase source? Another way to detect such sources is by driving around with a car radio tuned to a weak medium wave station around 1500-1600kHz.

Car battery charger identification

Further to the articles about car battery charger QRM in the April 2021 EMC (p80-81), September 2021 *RadCom* about QRM Finding and Elimination (p58-60), an item in the October 2021 EMC (p76-77) showed how RF interference can be radiated by a car battery charger (or other item with a switching power supply) and its wiring and how it can also be injected into the mains. There is a third possible coupling path from a source of interference to a radio receiver and that is via telephone wiring, whether underground or overhead. Although a car battery charger is not normally connected directly to a telephone line, there may be an indirect RF coupling path from mains wiring to the telephone line via another item such as a DECT cordless phone or DSL router that has both mains power and a telephone line connection. This is what appears to be happening at the QTH of a Member who lives at a very quiet rural location. The QRM is on many different frequencies in the HF bands, at intervals of approximately 80-100kHz. One particular harmonic is at 3571kHz, as shown in **Photo 1**. This frequency was also monitored using a battery powered receiver and it was found to continue even if all the mains power to the house is switched off at the main switch. By walking around with a portable receiver, it was found that the QRM was not being radiated by overhead 11kV power lines but it *does* appear to be radiated by some telephone poles nearby (see **Photo 2**).

The characteristic of the QRM on an SSB receiver is a rapidly fluctuating tone. It was found that this matches the characteristics of the RFI from the Foxsur or Buddygo brand battery chargers when used in 'pulse repair' mode. As the output current pulses on and off, this changes the load on the switching power supply causing the operating frequency to shift slightly. Other types of battery charger such as mobile phone chargers may also pulse on and off, although usually at a much slower rate than 5.2Hz. **Figure 4** and **Figure 5** show radiated interference from a Foxsur brand charger that was donated to RSGB EMC Committee. Figure 4 is in normal continuous charging mode and the characteristic of the RFI is similar to many other devices that use switch mode PSU techniques. Figure 5 shows the 'pulse repair' mode that is claimed to improve the capacity of lead-acid batteries where the plates have become sulphated. Often, these battery chargers are left connected continuously.

The waterfall display shows that there are 26 pulses between the horizontal yellow lines, which are time markers five seconds apart. This makes an average pulse rate of 5.2Hz. From time to time, typically every few minutes, there is a short pause with a couple of missing pulses. This is arrowed in Figure 5. When used in pulse repair mode, these battery chargers effectively transmit a callsign using FSK (J2D) modulation! There may be scope for a new Worked All Battery Chargers (WABC) Award, perhaps commencing next April…

Websearch

[1] https://www.rampionoffshore.com/

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Design Notes

Power amplifier matching

Last month we looked at the design of a 100 watt 50MHz power amplifier that used a relatively simple 1:4 impedance ratio balun on a ferrite core to match the 50Ω output to the optimum load for the push-pull output devices. The comment was made "Some very crafty and weird-looking arrangements are to be found in high power MOSFET amplifiers". So here we'll look at some of those arrangements seen in power amplifiers at various output levels.

To recap, a push-pull PA stage imposes a maximum peak-to-peak voltage equal to a little bit less than twice the supply rail, V_{DD} [1] across a load between the two drains. As rule of thumb we often take a value of 80% of the supply voltage to allow for resistive losses in the device. So $P_{MAX} = 1.6 \times V_{DD}^2 / R_L$ We need to come up with a matching network that turns an unbalanced 50Ω load into a balanced optimum value of R_L and at the same time tune out, or otherwise deal with any reactive term of the device's output impedance. Typically there will be up to a few tens of pF of junction capacitance that, at higher frequencies, affects the optimum load conditions. At HF, and often up to 50MHz, some kind of ferrite cored transformer is often used.

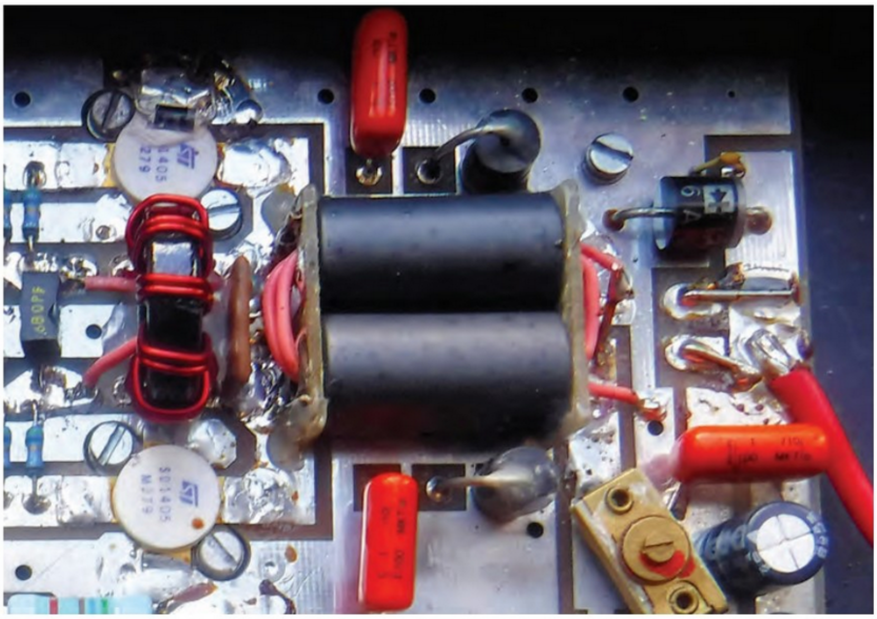

PHOTO 1: The classic transformer used in innumerable HF bipolar power amplifiers running from a 13.5V supply. Photo courtesy G0API.

Transformers

First of all we need to look at the limitations of a classic ferrite-cored transformer. At low frequencies, two independent windings on a continuous ferrite loop will work well. All the flux generated by the primary turns is confined to the core, which in turn couples it into the secondary winding. This works for mains transformers with an iron core, SMPSUs and LF to MF transmitters using ferrite at up to a few hundred kilohertz or even MHz operating frequency.

As the operating frequency rises it becomes more difficult to confine the magnetic flux solely to the core and it begins to leak out into the aether. Our transformer tends to become inductive and less efficient. The properties of the ferrite material become more important as it is carrying all the flux to link the two windings. One solution to this is the transmission line transformer. The primary and secondary windings are no longer separated, but are deliberately very tightly coupled by twisting or laying side by side. That way the flux generated by one winding is nearly completely enveloped in the second winding and there is no longer any need for a core to carry that flux. But now we have a different problem: we can couple flux and hence the current in one piece of wire into the other, but it's still just two pieces of wire. If the primary is connected to a source of power it will present a short circuit. The solution is to wind the twisted or closely-coupled pair onto a ferrite core, as shown in **Figure 1**. The core vastly increases the impedance of primary and secondary windings, but plays only a little part in the transfer of RF power from primary to secondary – that is due solely to the close coupling of the two windings. This is the principle behind most RF transformers. The ferrite core is just there to create a high impedance for the windings.

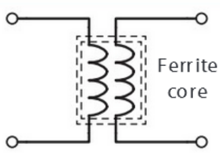

FIGURE 1: Basic 1:1 transmission line transformer using bifilar twisted wire

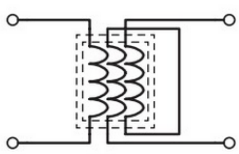

FIGURE 2: Extending the transmission line transformer to give different transformation ratios, using multiple cores of twisted wire.

PHOTO 2: 1:3 turns ratio transformer using lengths of semi rigid coax.

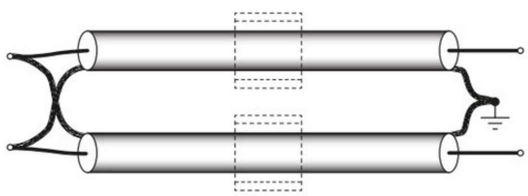

FIGURE 3: Two choked lengths of coax give a 1:4 balanced to balanced impedance transformation by paralleling one end, and connecting the other in series. A design often seen in VHF power amplifiers.

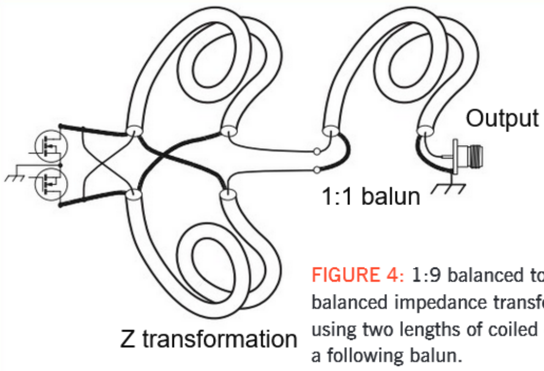

FIGURE 4: 1:9 balanced to balanced impedance transformation using two lengths of coiled coax with a following balun.

The transformation itself can even work without a core That sounds a bit surreal but can allow some quite interesting solutions to the matching problem.

Transformer ratio

If we have a pair of twisted or coupled wires, the lengths of each wire clearly have to be the same and the transformation ratio can only ever be 1:1. The ratio is changed by coupling multiple wires in series and connecting as shown in **Figure 2**. A 1:2 (1:4 impedance ratio) is made with three windings, one primary and two series-connected secondaries. The twisted three-core wire used for this is referred to a trifilar winding. Quadrifilar (four windings) etc is also possible but for practical reasons it's unusual to go beyond three or four wires.

Coaxial solution

Twisting multiple wires is only really practical for thin conductors used at low power. For higher power applications we need a solution that allows a thicker conductor for the low impedance winding **[2]**. The solution to this is to use coax, but we now have to do a certain bit of mental rearrangement. Coax is normally thought of as a single transmission line, with a characteristic impedance for transferring power from A to B and terminated in SMA, BNC, shielded banana plugs or whatever. But don't look at it that way. Think of it instead at three separate conductors with the flux from current flowing in the inner core being intimately coupled to the inner surface of the shield, or outer conductor as its return. Note that term, the inner surface of the outer conductor. It is very important to separate the two. Due to skin-effect at high frequencies, current is confined to only a thin layer on a conductor, so the inside of the shield on a coax cable is **not** connected to the outside except at the two ends. The outside of the shield acts as a single piece of wire that is in parallel with the inner side of the shield, which is intimately coupled with the inner conductor through complete flux linkage.

This gives us another option for a matching transformer. What if we could have a special coax with multiple inner cores and a single outer shield? Connect the multiple inner conductors of a pair in series for the high impedance side and use the outer shield as a single turn low impedance winding. A ferrite core is placed around each side of the assembly to choke off the otherwise short-circuit created by the outer surface of the conductor. Such a design is often fabricated from brass tubing and insulated wire in HF power amplifiers, with impedance ratios from 1:4 up to 1:16. **Photo 1** shows a typical transformer made this way, used in a commercially manufactured PA of several decades ago. The classic 100W HF PA running from a 13.5V supply, often built around bipolar devices, needs an optimum push-pull load of around 3Ω, so a 1:4 transformer like that shown – giving a transformed load of 50/16 = 3.125Ω – usually serves.

Using coax cable

Fabricating transformers with bits of brass tube and PTFE wire isn't always ideal, so another solution using readily available coax cable would be better. For the purpose of flux linking, there is no need to have all the inner windings enclosed in one single outer shield – one core per shield will suffice, using multiple lengths of coax to give the turns ratio. **Photo 2** shows how a 1:3 turns ratio is obtained using short lengths of coax though a ferrite core. All the outers are in parallel and form a single turn primary; the inners are connected in series for the secondary. A 1:2 version of this was used for the 100W PA described last month. As the holes in the ferrite core were big enough to allow this, each 'turn' actually consisted of two lengths of 0.085" semi-rigid coax in parallel, resulting in four lengths of coax passing through each hole in the core. This results in lower loss, as the current in the thinner inner core is shared between two parallel windings.

In all these designs the primary and secondary both have 'floating' ends, in other words neither has any inherent potential to ground, only to each other, and the primary is choked off from the secondary. This is essential in the primary as it has to go to the two balanced drains, but it does mean one end of the secondary can go to ground and the other to an unbalanced feed like coax without affecting any other part of the circuitry. Or if there was a need, it could equally well be used as another balanced output. Perhaps driving an even bigger amplifier stage.

No ferrite

As frequency increases, the need for the choking impedance of a ferrite core reduces. There comes a point where the length of coax, when bent into a circle, forms an air-wound inductor in its own right that can generate enough impedance between the two ends – the task that the ferrite has done before. It then becomes feasible to just use lengths of coax on their own. Note that the common mode impedance (that of the outside of the outer conductor, coiled up) only has to have enough reactance to not significantly matter when shunting the load resistance. Since this load resistance is likely to be 12.5Ω or 5.556Ω, a surprisingly low value of inductance will suffice here at VHF frequencies. **Photo 3** shows a power amplifier for 70MHz capable of over 280 watts output, using an MRF151G device running from a 45V supply rail. The impedance ratio of 1:4 comes from two turns of 0.141" semi rigid coax. The residual shunt inductance is tuned out using a capacitor across the ends, together with the junction capacitance of the FETs themselves.

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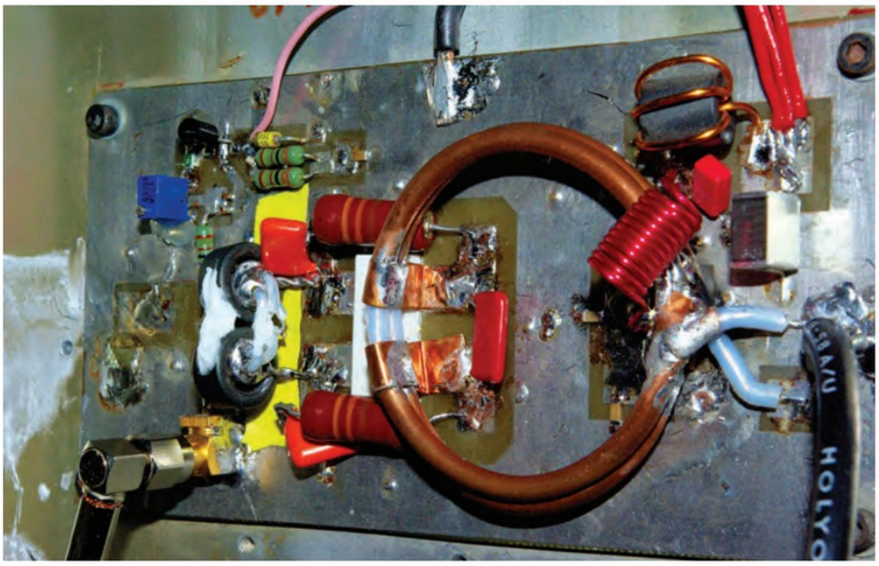

PHOTO 3: 70MHz power amplifier showing the 1:4 air-wound transformer made from semi-rigid coax cable. The residual inductance is tuned out by the capacitor shown across the ends.

There is another way of using lengths of coax that leads to a neater construction. Think just of a short length of coax coiled up. The coiling-up creates enough inductance in the outer conductor to choke-off one end from the other. This common mode choke is often seen on modern VHF antenna designs to give the (incorrectly termed) balun action; minimising current on the outside of the outer conductor when a balanced feed like a dipole is used. We have a, let's say, 50Ω input on one end and the same at the other. But the choking action of the coiling-up means that while the input may well be an unbalanced source with the braid grounded at one end, we can do what we like with the other end of the coax. We can even ground the inner if we wanted to then take the hot RF feed from the outer conductor. Or feed a balanced 50Ω. By definition we've stated a 'short length' of coax and this must be short enough to not start giving transmission line transformations when the impedance at source or load is not equal to its characteristic impedance, but not so very short that the common mode impedance caused by its being formed into a coil becomes significant. As a rule of thumb, that's a length of perhaps no more than a twentieth of a wavelength. The two requirements are mutually exclusive, but a sufficient compromise can often be found; or the residual effects used or tuned out.

Now take two such bits of coiled coax. Connect them as shown in **Figure 3** with one set of ends in parallel and the other in series. The cross-coupled ends means the arrangement is symmetrical so the residual inductance is the same on each side. One end in parallel with the other in series gives a 1:4 impedance transformation, with the braids forming a pair of symmetrical shunt inductances. But there's a catch. With the high impedance ends both having their outers grounded, the inners need to be balanced – grounding one and driving the other gives an unbalanced load on the devices, so we can no longer have a transformer and balun in one assembly. We now a 50Ω balanced to 50Ω unbalanced requirement, which is easily solved with a single bit of coiled coax. Being matched to Z_0 at each end, its length is unimportant, so it can be wound with more than enough turns to create a sufficiently large common mode impedance for full choking. This approach is common in medium power amplifiers at the 100W level on a 28V supply used for amateur and commercial designs. A typical example is that shown at **[3]**. It is common practice to use 25Ω (or even lower Z_0) coax in the first part of the network. This has a thicker inner conductor and thinner dielectric, which helps to reduce heat dissipated in the inner conductor. The lower Z_0 also reduces the effect of transmission line transformer action, being closer to the geometric mean of the two transformed impedances.

Getting more complicated

Higher power and/or a low supply voltage means an impedance ratio of 1:4 is no longer sufficient. A ratio of 1:3 (9:1 impedance transformation) is possible using just coiled bits of coax, but it needs a bit more thinking about. **Figure 4** shows how this is done. A similar serial to parallel transformation is used, but now the output is connected back and in series with the low impedance side so there is, in effect, a 3:1 transformation since the low impedance load now appears in series with the transformed high impedance side, giving a total voltage division of three. Again, the balanced output needs an additional 1:1 balun to complete the network.

This transformation network as used in the W6PQL 1kW 50MHz amplifier can be seen at **[4]**. The photographs on that web site show very clearly the matching arrangement for more than 1kW output from a 50V supply rail.

A puzzle

Now, stop and think. Do a few sums on that W6PQL design: something seems wrong. 1:9 impedance matching gives a load impedance of 5.556Ω. Plugging that into the equation above gives P_{MAX} = 1.6 x 502 / 5.556Ω = 800 watts. Even if the device resistance were to be ignored, a maximum of only 900W is possible. How can this amplifier deliver in excess of 1kW; especially when something like 1.2kW is seen in practice? The secret lies in the bits we glossed over in the above descriptions. Those two arbitrarily 'short' bits of low Z_0 coiled coax really are quite short, so the inductance can't really be ignored any more. Perhaps it's made a precise value – the length and coiling details are specified. When combined with stray capacitance, perhaps there's a small bit of L-matching going on. Does the device capacitance, when converted to a series equivalent then work with the choke common mode L in shunt to give an L-match? Do both work together giving a pi-match? Does the output balun do something?

The article makes no mention of this aspect and it is more than likely some empirical design work went into the design. But the result does seem repeatable. It was while pondering on that puzzle that lead, incidentally, to design shown last month of using a 4:1 coax / ferrite transformer followed by a 30Ω to 50Ω transformation built into the output filter.

References

[1] Throughout this discussion we'll be referring to FET designs, so their connections will be 'gate', 'drain' etc and the supply will be VDD. For bipolar designs, replace these terms with 'collector', 'base', VCC etc.

[2] The term 'winding' is being used in a generic sense as the conductor forming the primary or secondary of a transforming network. It may, or may not, actually be 'wound' round anything.

[3] '100W FM VHF 80Mhz-170MHz RF Power Amplifier Board AMP DIY KITS', at the time of writing listed at https://www.ebay.co.uk/itm/121444676965

[4] https://www.w6pql.com/1kw 6 meter amplifier.htm

A pre-configured automated ATU

Introduction

Most of us have built (or will build) an antenna tuning unit (ATU) at some point in our hobby lifetime, being both fairly simple to do and often cost effective. *[A couple of homebrew examples can be seen in this month's Antennas column – Ed]* Commercial units, of which there are a multitude available, fall into two main groups: manually operated and auto-tuning. The auto-tuning variety almost entirely operate on the same principle, with lots of discrete Cs and Ls relay switched to achieve the lowest SWR at the applied RF frequency. For most operational requirements these two types are perfectly adequate. However, I wanted a unit that could be click tuned to any number of pre-set frequencies and did not require RF while doing so. Furthermore, I wanted it to be remotable and so able to be deployed at the antenna feed point. I also wanted both a manual interface and an application programming interface (API) that could be used from another application for automated tuning. My use-case was mainly weak-signal digital modes with a small unobtrusive multi-band end fed antenna.

ATU design types

There are many ATU designs but the most common are the T-Match, L-Match and various link coupled systems like the Z-Match and derivatives. The T-Match will match a wide range of antenna impedances but is inefficient. The L-Match is efficient but requires a fair amount of L and C, especially at lower frequencies. Link coupled systems and derivatives can be a good choice. All designs have different issues, especially when it comes to automation.

After experimenting with an L-Match arrangement I decided it was too difficult to automate as it not only required large amounts of L and C but the values became critical at higher frequencies; careful design would have been required to switch with small increments and keep stray L and C at very low levels.

A search on the internet revealed the FRI-Match by PA0FRI **[1]**. This looked interesting because it only required a single tapped inductor and two dual gang 500+500pF variable capacitors. After mocking up a few configurations to test (and endlessly playing with different inductors) I had a working design that would tune across all HF bands.

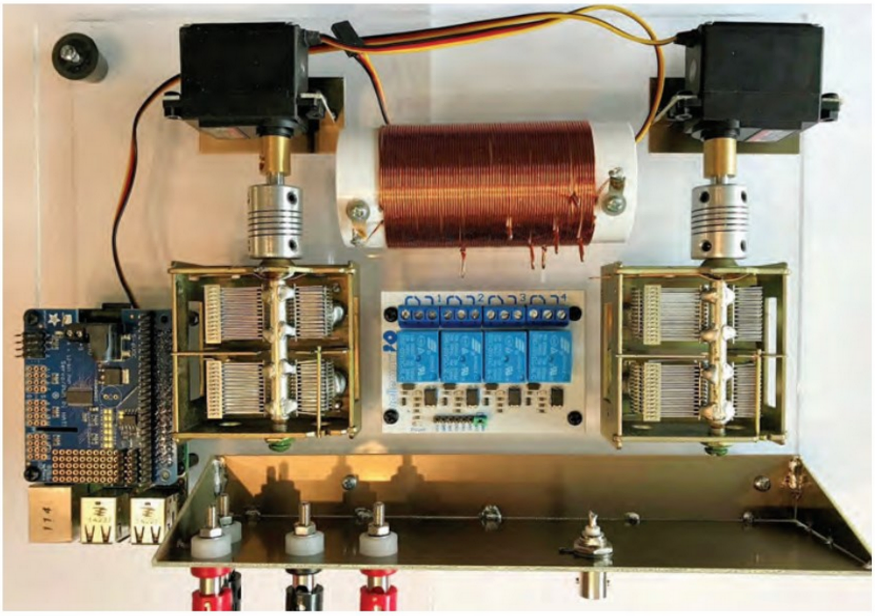

PHOTO 1: General layout of the main items.

Pre-configured?

What does this mean? Whilst it would be possible to implement an SWR bridge into the design and automatically tune for lowest SWR in the same manner as commercial units, that wasn't the aim of my design. What I wanted was the ability to just click tune without providing any RF. The software provides unlimited memories and setting these up for multiple frequencies (as necessary) within each band is quick to do. The principle is that the ATU only needs to be 'tuned' *once* for each memory frequency: after that, it will instantaneously recall the settings on demand.

Antenna

I developed and tested this with an end-fed antenna which is the intended use case. The

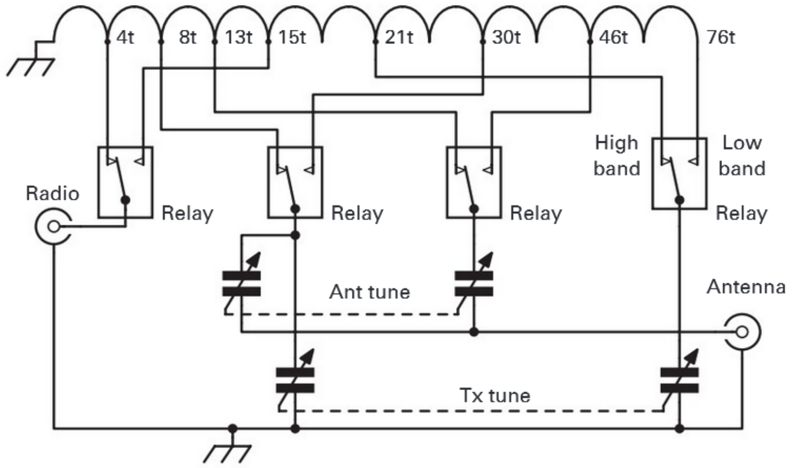

FIGURE 1: The deceptively simple circuit diagram (control system not shown).

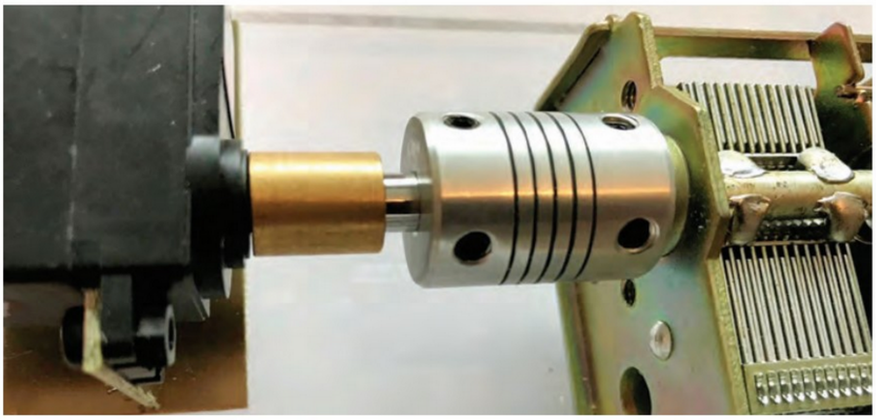

PHOTO 2: Connection between shafts.

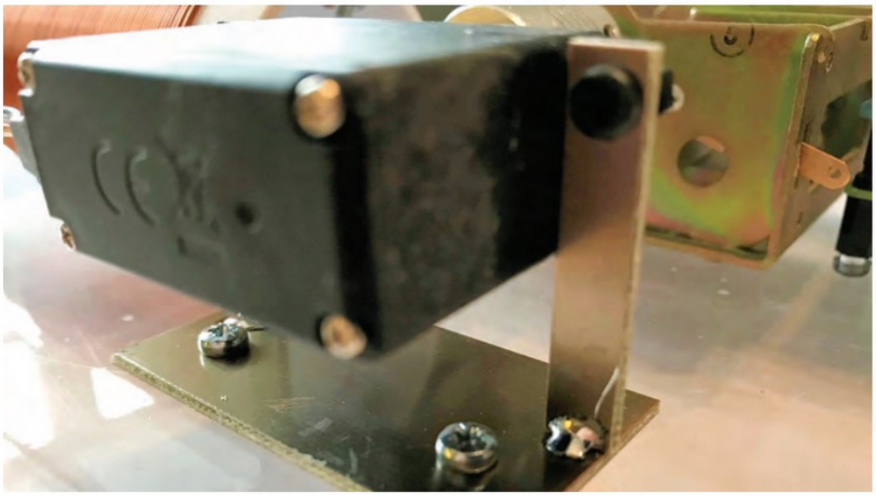

PHOTO 3: The simple servo mount.

possible length values for a multi-band end-fed antenna are calculated to not fall on any multiple of wavelength on any of the required bands. The calculated lengths, according to various net sources (eg **[2]**), are shown in **Table 1**.

I am currently using 25.6m (84ft) for testing, which gives me an acceptable SWR on all bands from 160m to 4m with the exception of 15m (2.6:1) and 17m (2.2:1). All other bands are between 1.1:1 and 2.0:1, with most around 1.3 – 1.5:1. For developing and testing this length of wire was simply strung up out the window with a single counterpoise, as I develop in the house – which is not where my antennas terminate.

Inductor

The inductor was wound on a piece of plastic waste pipe. 76 turns were used, with 7 taps required. This effectively gave two different tapped inductors, one for low bands to 30m and the other for high bands to 4m. The taps are switched with a four-relay unit.

Capacitors

Two dual gang capacitors are required. I used broadcast type dual gang 500pF. A good source for these is eBay. The capacitance seems to be about right. With the test antenna, one or other of the variables was at minimum capacitance at some frequencies but none were close to maximum capacitance for any frequency. This would indicate that a smaller maximum capacitance could be tolerated, whilst a lower minimum capacitance probably wouldn't hurt.

Control system

The controller is a Raspberry Pi (R-Pi) version 2, 3 or 4. These all have multiple I/O pins that can be configured as digital input or outputs. The R-Pi also has an I^2C bus. These are the only I/O lines required, unless you want to incorporate an SWR bridge (which would need additional hardware to provide analogue inputs to the Pi). Four relays are required to switch the inductor taps. Many 4-relay modules are available; I used a Velleman unit **[3]**.

The variable capacitors require a motor to move the vanes, plus a positioning system to 'know' their position. A servo provides these requirements in a small easy to use package. Unless you have a really physically large capacitor that is stiff, a small servo will do the job. I used Hitec Standard servos, which are quite small and have a plastic gear-train. However, they are more than adequate to move the broadcast type capacitors I used.

The capacitors require 180° of rotation, so select a 180° servo. Some servos specify a maximum of 120° and some are free-running (avoid these). When given the correct PWM range, most servos I've seen will achieve 180° even if they specify 120°. The issue appears to be more with the hardware drivers used in models, which may not be able to provide the full PWM range required.

The second thing to note is that servo shafts are very short and are splined, usually around ¼ inch (6.35mm) diameter. You would think there would be a standard for these shafts – but no, different manufacturers may have different splines. Given that we need to connect to a variable capacitor, which may have a ¼ inch, 6 or 8mm shaft, a shaft coupler is required. The only ones I found fit Hitec Standard servos **[4]**. This rather limits your servo selection to Hitec unless you can find alternatives. If your capacitor does not have a ¼" shaft (mine are 6mm) you will also need a ¼" to 6 or 8mm coupler and a small length of ¼" shaft to connect the two couplers.

Although it's possible to control a servo directly from the RPi using the PWM outputs these are not generally considered stable enough, leading to servo 'chatter' and, over the longer term, extra wear on the gear train. The Adafruit 16 Servo Hat for the R-Pi **[5]** is inexpensive and provides good position control. There is also a library available, which makes driving the servo a cinch as you simply need to give it the number of degrees to move to. There is a bit of configuration to do to determine the minimum and maximum pulse width corresponding to 0 and 180° for the selected servo. The software provides a means to configure and test this on the live system.

Mechanical build

The mechanical build is quite straightforward. The only criterion I used was to keep leads as short as practicable, which resulted in the layout shown in **Photo 1**. I used an open chassis build as this gives maximum accessibility for the wiring. The whole unit can then be put into an IP66-rated enclosure with glands for cable entry points. I used a sheet

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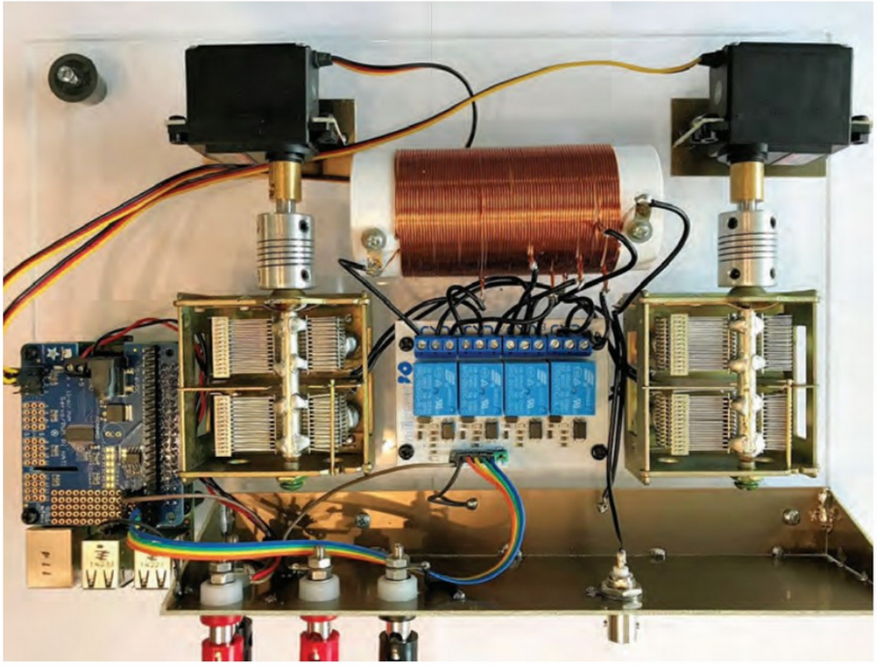

PHOTO 4: Interwiring complete.

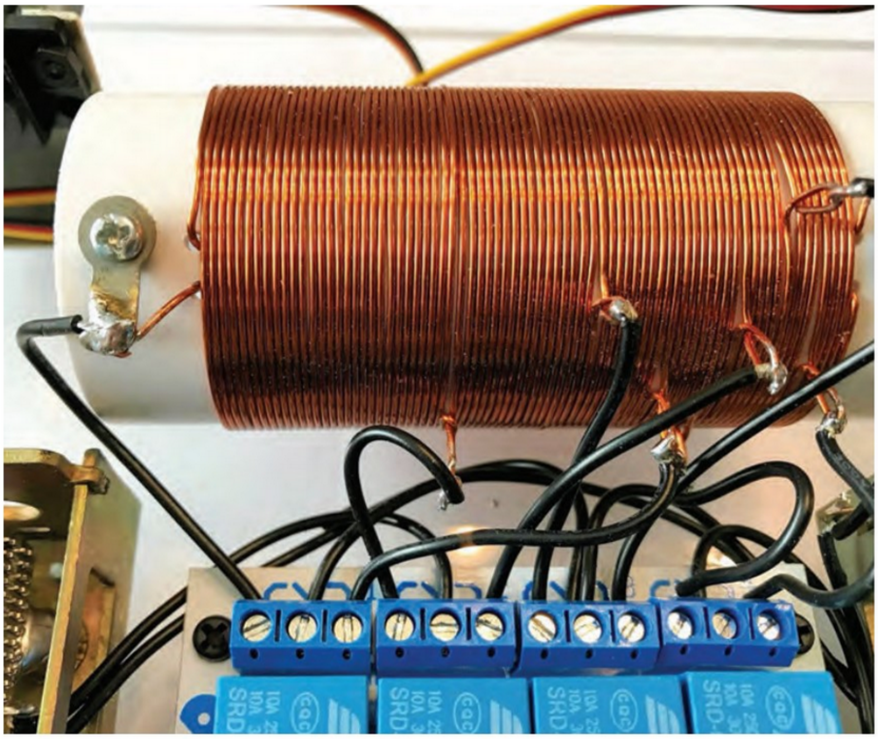

PHOTO 5: Detail of connections between the relay bank and inductor.

TABLE 1: Calculated non-resonant antenna lengths (see text). Metric lengths are rounded to the nearest 10cm.

Metric (m)	8.8	10.8	12.5	17.7	21.7	25.6	32.6	36.3	45.1	61.9	105.8	124.1	129.0
Imperial (ft)	29	35.5	41	58	71	84	107	119	148	203	347	407	423

of 6mm Perspex as the base and fabricated a back panel from pieces of PCB material to hold the connectors and act as a common earth.

The only critical part is the mounting for the servos. The coupling arrangement is shown in **Photo 2**. It is imperative that the servos are properly aligned with the capacitors. I used some PCB material to lock the servos in place, as seen in **Photo 3**. Once everything is fixed, leave the grub screw fixing the shaft to the servo loose for the final configuration (discussed later) and ensure that the capacitor can be rotated without dragging the servo with it and that there are no tight spots.

Electrical build

Figure 1 shows the tuner connections and the coil taps. When the relays are switched to low band all 76 turns are used, with taps at 15, 30 and 46 turns. When switched to high band only the first 21 turns are used, with taps at 4, 8 and 13 turns. The inductor is close wound on a 40mm former with 0.8mm enamelled copper wire. The material I used was 40mm waste pipe, perhaps not as lossless as ideal but it works well enough. If you use a different former, especially a ribbed former where the turn spacing is predetermined, adjust the number of turns to achieve a similar inductance (124μH). The taps should be at approximately 0.2, 0.4 and 0.6 times the number of turns.

The fully connected system is show in **Photo 4** and a close up of the relay connections in **Photo 5**. The R-Pi is to the bottom left of Photo 4 and has the servo HAT on top. This tidies the wiring as the only connections required are to the two servos and 5V. The board can drive up to 16 servos but I've only soldered in headers for four. The relay board is connected to the first four I/O pins, which are brought out on the servo shield. However, you are free to use any pins, as you will see next month. Apart from the I/O and relay connections the R-PI, servo shield and relay board all require 5V. I've brought these out to a connector on the back panel so a single 5V supply can be used.

Next month

I'll conclude next month with the driver software, configuration and operating notes.

Websearch

[1] FRI-Match: https://pa0fri.home.xs4all.nl/ATU/FRImatch/FRImatcheng.htm

[2] Antenna lengths: https://www.hamuniverse.com/randomwireantennalengths.html

[3] MA400 4-relay module: https://cpc.farnell.com/search?st—vellman%20relay

[4] https://www.active-robots.com/24t-hitec-set-screw-servo-shaft-coupler-525134.html

[5] Adafruit 16-Channel PWM / Servo HAT: https://thepihut.com

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A lightweight 46-ele 23cm slot-fed single-boom bi-Yagi

During the lockdown I began to contemplate Yagi antennas. Could one, perhaps, have two Yagis fed by a bi-quad? How about mounted on the same boom?

On its own a bi-quad can have a gain of +7dBi. A 22-element Yagi can be expected to give +13dBi. And if you add a second Yagi, that should get you another +3dB. Hmm, +7dBi plus +13dBi plus 3dB gives a total of +23dBi: that's an awful lot of gain from a 2m-long boom! It seemed almost criminal not to investigate further.

Development

The idea was to create two Yagi arrays either side of a boom, driven by a common feed. There is plenty of precedent for this sort of design and many of the dimensions are well established.

With the aid of the free online CAD program Tinkercad I created drawings for the Bi-Yagi element insulators and developed these into 3D design files, shown in **Figure 1**. Then I used a 3D printer to produce the insulators. I printed them using ABS, which is inexpensive, quite strong and has low RF loss. Although the surfaces must be solid, the insides of the parts only need about 15-25% infill, which helps with losses. It also keeps the weight and cost down. Do make sure that the surfaces are solid and that the parts are waterproof, otherwise water *will* get in and, when it freezes in winter, probably rupture the part.

If you do not have your own 3D printer and don't know a fellow amateur with one, you can order custom-printed parts online. Basically all you need to do is upload the print files and specify the material. It isn't expensive. Alternatively you could improvise element supports using, for instance, 8mm square section plastic tube that you attach to the boom with a single bolt or screw (making sure you don't crush the tube of course).

A major feature of these 3D printed element spacers is that you can easily slide them along the boom to optimize gain before they are fixed in position with a screw. My original design used a short 3D printed stub (the rectangular block in Figure 1) to space the reflector off the back of the boom to facilitate adjustments and swaps. The element dimensions and spacings I used are shown in **Table 1**. Note that these dimensions assume that you don't use the stub arrangement.

You can download my 3D files from **[1]**. I don't claim these dimensions to be optimum; you may well find that you can use an antenna modelling program to make improvements.

The elements are made from readily available cheap lightweight 3.2mm aluminium welding wire. I obtained mine from eBay. Although this wire is soft, it is perfectly suited to producing these short elements. To fit the elements to the supports you will need carefully to drill out the holes in the insulators so that the elements are a tight-ish fit in the holes. Of course, if you haven't got exactly the right size drill bit you can simply drill the holes slightly oversize and glue the elements in place. Hot melt glue will usually work OK but many types of epoxy resin degrade over time when exposed to the ultraviolet in sunlight.

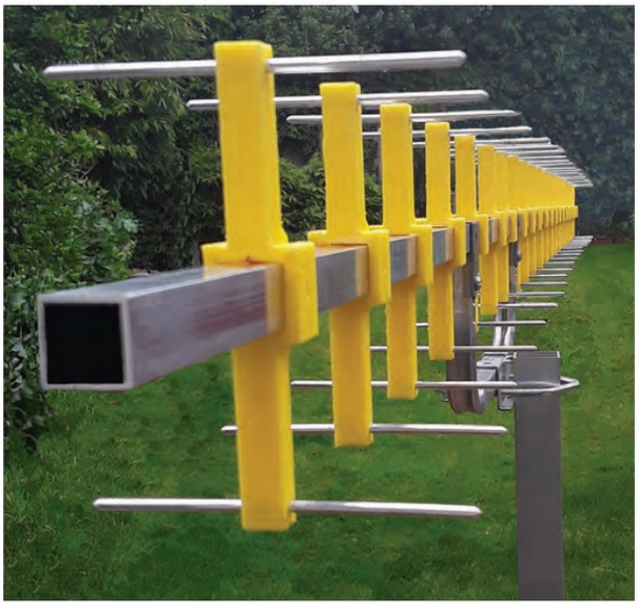

PHOTO 1: General view of the bi-Yagi minus feed.

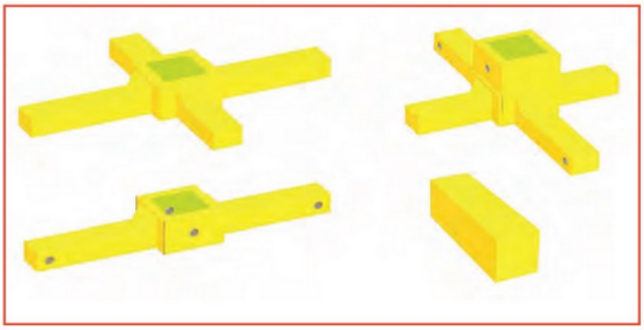

FIGURE 1: The 3D designs. Clockwise from top left: Driven element support, driven element enclosure support, spacer, element support. The reflector support (not shown) is a slightly longer version of the element support.

Feed and driven element

I initially started out using the bi-quad shown in **Photo 2**. My initial tests mating the bi-quad driven element to the bi-Yagi showed good gain but exhibited very critical spacing to get a good match. I strongly believe the bi-quad is the ultimate feed configuration for this bi-Yagi and there is much room for experiment here. However, given the difficulties I encountered in getting a match I decided to change to a more-traditional skeleton slot.

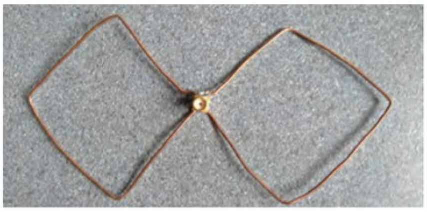
PHOTO 2: Original bi-quad feed.


PHOTO 3: Skeleton slot feed and matching section.

The final version of the feed and driven element are constructed as shown in **Figure 1**. I used 1.75mm diameter copper wire that I got from some mains twin & earth cable after removing all the insulation. The two 30mm pieces between the coax and the driven element are impedance transforming sections. You may need to add or remove the small outside extensions on the centre section to make fine matching adjustments. Instead of soldering the transforming sections to the coax I used a SMA socket so that I could more easily transition to coax with an SMA plug. **Photo 3** shows the prototype feed.


PHOTO 4: Feed mounted inside protective box.

The feed and driven element are mounted in a waterproof box located at the end of the boom. This makes possible presenting the feed to both sets of elements symmetrically on the end of the boom. After some experimentation the skeleton slot feed configuration was wound to provide an easy and symmetrical feed with a good match and excellent gain with the bi-Yagi. **Photo 4** shows how the feed was mounted inside the box and **Photo 5** shows the general arrangement of the feed end of the bi-Yagi.


PHOTO 5: General view of the reflector, driven assembly, boom and bi-Yagi elements.

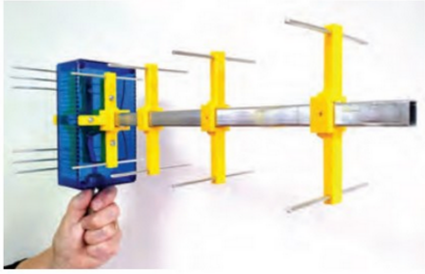
PHOTO 6: Smaller, 10-element version of the bi-Yagi design with a theoretical gain of 12dBi.

The box provides weatherproofing for the feed and connection. The mounting to the boom is with a plastic mount and care should be taken routing the feeder so that there is minimal load on the 3D printed mounts. (Note that in my prototype the boom does not enter the box).

The 3D printed parts are screwed onto the base of the box with the first director elements; the skeleton slot is fixed to the internal mount. A reflector with 6 elements is fitted to the box lid. In my prototype a 3D printed extension was used to position the reflector section.

Performance

My expectations of antenna gains are based on accepted wisdom of two identical Yagis, properly spaced, being +3dB compared to one (especially when driven without a potentially lossy RF splitter). Although I don't have the facility to measure the gain, I found that in practical terms the 46-element bi-Yagi matched or out-performed my longer Tonna.

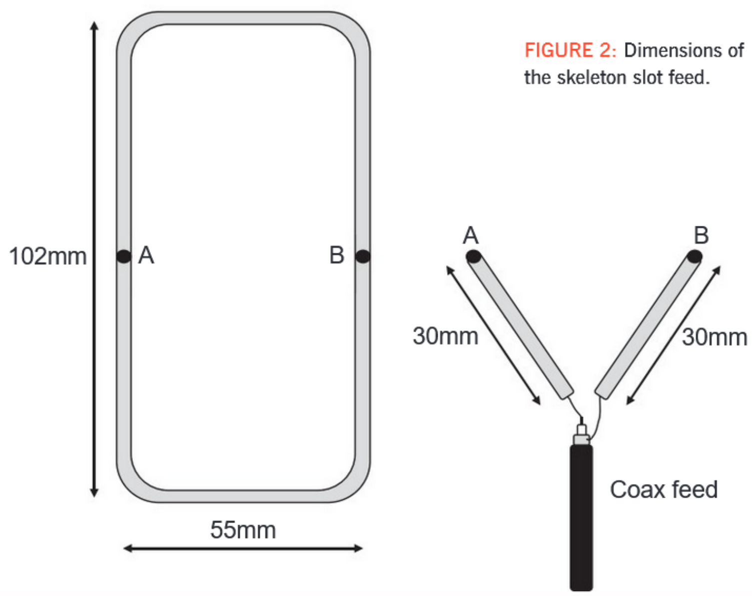

FIGURE 2: Dimensions of the skeleton slot feed.

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6 Junk Sale at Aviation Museum, Foxhall Road, Ipswich. sale starts at 8pm
20 Mince Pies at Aviation Museum, Foxhall Road, Ipswich 7pm

Loughton & Epping Forest ARS
David, M0VID, secretary@lefars.org.uk
1, 8, 15, 22, 29 Net from 8pm on Brandmeister DMR TG23511 and 70.475MHz FM
2, 9, 16, 23, 30 Net 8pm 144.725 MHz FM
3 Meeting at All Saints House Table Top Sale
10 Zoom meeting
17 Meeting at All Saints House Christmas Buffet

Telford & District ARS
John, M0JZH, 0782 473 7716
1 8pm Committee Meeting + 2m ragchew
8 EMF Workshop What the new Ofcom licence conditions mean for us all, and how to calculate it.
15 Practical Topics on a theme - Antennas
22 Mince Pie and Mulled Wine social evening
29 Webex social meeting

REGION 13: EAST MIDLANDS

RR: Mark Burrows, 2E0SBM, RR13@rsgb.org.uk

Bolsover ARS
Alvey, G4KSY, 01246 827135
1, 15 meeting starting at 8pm

Kettering & District ARS
Les, 2E0MNZ, les@moylehousehold.co.uk
2, 9, 16, 23 Net from 7pm on 145.300MHz
5, 12, 19 Breakfast meeting from 10am to 12 noon
7, 14, 21 Meeting from 7pm to 9pm

Lincoln Short-Wave Club
Pam, G4STO, 01427 788 356
1, 22, 29 Club meeting BSA village hall Aisthorpe 7.30pm
2, 16 Repeater net 8pm start on GB3LM (if GB3LM is off air 145.375MHz)
4, 11, 18 Club meeting BSA village hall Aisthorpe 9.30am
8 Christmas social evening BSA village hall Aisthorpe 7.30pm
9, 23, 30 Simplex net 8pm start 145.375MHz

15 Centenary Dinner at the Fox and Hounds Willingham by Stow

Loughborough & District ARC
Chris, G1ETZ, 01509 504 319
7 *Family History,* Andrew, G7SEG
14 *Marconi* Early days
21 Social evening

Nunsfield House ARG
Paul, G1SGZ, pr@nharg.org.uk
2, 9, 16, 23, 30 Club net 145.300MHz 8pm
3, 10, 17 Club meeting, 8pm
6, 13, 20, 27 Monday Morning Derby Net 3.745kHz 9.30am; Shack Night & Club Net 433.450MHz

RAF Waddington ARC
Bob, G3VCA, 0797 116 6250
10 Cub Christmas dinner at the Pyewipe

South Kesteven ARS
Stewart, M0SDM, 0794 408 5113
2 Club night 8pm
10, 24 Net GB3GR 8pm
17 Christmas party and raffle

South Normanton Alfreton & DARC
Alan Jones, M0OLT, secretary@snadarc.com
6, 13, 20 Club meeting from 7pm
7, 14, 21 Club net 7pm +145.450MHz

Bi-Yagi *continued from page 83*

Figure 3 shows the VSWR plot of the final version. I measured it from 1100 to 1400MHz. The VSWR is 2:1 or better over the whole 23cm band (1240-1325MHz) and approaching 1.2:1 in the narrowband segment centred on 1296MHz.

Other configurations

In addition to the version outlined here I also experimented with a much shorter boom version, seen in **Photo 6**. This 10-element implementation has a boom of only 36cm or so yet theoretically has a gain of around 12dBi.

Conclusion

I have found that the bi-Yagi format offers relatively high gains from relatively short boom lengths. The 3D printed element mounts made it easy to experiment with the design and I am pleased with the results achieved. However I suspect the antenna as shown would have relatively high windage (wind resistance) due to the fairly broad cross-sectional area of the element supports. I'm sure though that these could be optimised. Further developments might include integrated spacers between element supports to remove the need to measure everything carefully, or perhaps even a one-piece reflector and drive assembly that includes an enclosure instead of using a bought-in plastic box. There is certainly a lot of scope to explore, adapt and adopt alternative configurations.

All in all, this article just goes to show what can be achieved with a will to experiment, a 3D printer, some inexpensive parts and a little investment of time.

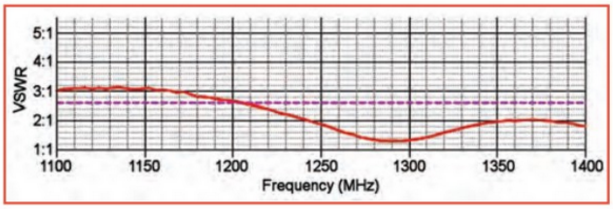

FIGURE 3: Bi-Yagi VSWR plot from 1100 to 1400MHz.

TABLE 1: Element details. Dimensions are in mm.

Element	Distance	Element length	Required
1 (reflector)	0	115	6
2 (feed)	80	102 (see Figure 2)	1
3 (first director)	100	103	2
4 (second dir)	155	98	2
5 (etc)	215	96	2
6	320	94	2
7	435	92	2
8	510	90	2
9	610	90	2
10	700	90	2
11	800	88	2
12	890	88	2
13	980	88	2
14	1080	88	2
15	1180	88	2
16	1280	88	2
17	1370	86	2
18	1470	86	2
19	1560	86	2
20	1660	86	2
21	1750	84	2
22	1840	84	2
23	1940	84	2
24	2040	84	2

Websearch

[1] https://www.thingiverse.com/biyagi/designs