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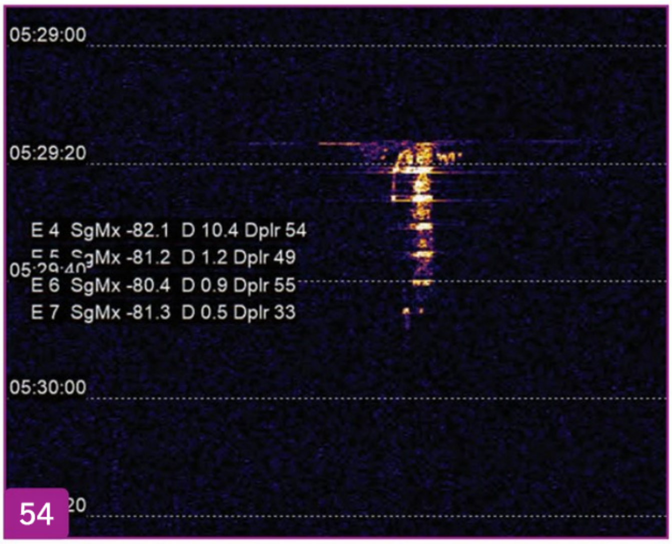

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Features

Technical Features

Cover image, Elecraft K4D HF and 50MHz transceiver. Design by Kevin, M6CYB

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

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New Products

New D-Star handheld from Icom

The ID-52E is a VHF/UHF dual-band digital transceiver, the latest in a long line of D-Star handportables from Icom. Its most striking feature is the large transflective colour display that makes it easy to see outdoors, even in bright sunlight. The size of the display has also been increased to 2.3 inches from 1.7 inches on the ID-51A/E.

Features include simultaneous reception in V/V, U/U, V/U as well as DV/DV, a Waterfall Scope function, a micro USB charging input, audio output nearly doubled to 750mW and the ability to send, receive and view saved photos on an installed microSD card via D-Star with no other equipment. Usefully, accessories for the ID-51E such as battery packs and microphones can be used with the ID-52E.

The ID-52E supports Bluetooth® and can wirelessly connect to Android devices with the ST-4001A/ST-4001I Picture Utility Software, and RS-MS1A Remote Control Software installed. The optional VS-3 Bluetooth® headset is also available, for hands-free operation. One other enhancement is that the airband capability has now been extended to cover the UHF section, 225 to 374.995MHz. The ID-52E has a variety of other features including DR function with easy set-up, a built-in GPS receiver, micro SD card slot, IPX7 waterproof construction (1 metre of water for 30 minutes), and Terminal/Access Point modes.

The ID-52E will appeal to not only beginners but for those experienced operators who want to get even more out of the D-Star network. It will be available from Icom dealers from December 2021 with a suggested retail price of £519.99 (including VAT). Full product details can be found at tinyurl.com/Icom-ID52E and there's an introductory video at https://youtu.be/j4iIzUj8vUo

www.icomuk.co.uk

NanoRanger NR-01 measures down to picoamps

Saelig has announced the NanoRanger® NR-101, an accurate, 3.5 digit, affordable DC ammeter to measure very low currents. With automatic dynamic ranging (9 ranges across 8.5 decades), NanoRanger® measures from 800mA to 1nA, whilst offering a maximum resolution of 10pA. The voltage burden is quoted as 0.05V maximum on all ranges, for minimal effect on the circuit under test. The device is equipped with a fully isolated USB interface for device control and data export. This means attaching a computer to the USB port will not affect your measurements at all. The backlit 11-digit 128 x 64 LCD display provides a wealth of information; for instance, mA, μA, nA, and pA are all on one line. With many more high tech features, the NanoRanger® NR-01 is suitable for professionals and enthusiasts alike. http://www.saelig.com/altonovus/nanoranger.htm

New high-tech Power+SWR Meter from Monitor Sensors

Monitor Sensors has been making professional scientific instruments for more than 25 years. Recently they have turned their expertise to amateur radio. Joining their highly acclaimed 630m and 2200m transverters is a new Power & SWR meter that covers 130kHz to 30MHz. Monitor Sensors say it's a brilliant addition to any LF, MF and HF station and that its accuracy and simplicity will impress the novice and experienced operator alike: it will become a trusted and cherished lifelong feature in any station.

Its auto-ranging facility comes to the fore with a wide power range of 10mW to 2kW. Each meter is individually calibrated using 48 calibration points and the resulting accuracy is quoted as better than 5% over most of the power range. The meter auto detects SSB and displays PEP reading, and has a bargraph display function to make tuning-up easy.

One very useful feature is that the screen changes colour to indicate worsening SWR and the meter has programmable alarm contacts for high SWR, set from the menu system. Operating at 2000 samples per second and temperature compensated, valid VSWR measurements can be obtained with as little as 50mW of input power. It operates from 6-16V DC at about 42mA.

Made in Australia by Monitor Sensors (Aust) Pty Ltd, the cost of the unit is £206 including express delivery worldwide.

To order, visit www.monitorsensors.com/ham/swronly

Senhaix 8800 from Moonraker now has Airband Rx

The Senhaix 8800 is a Bluetooth®-equipped dual band handheld radio that has now been enhanced with the addition of airband receive. It boasts 5W RF power output and a rich array of features including Dual Watch, Dual Standby, a LED Flashlight, DTMF Tone, ANI Code, PTT ID, FM radio, Customisable Channel Names, a 1750Hz Tone and programming via Bluetooth® (the IOS App Store App is SHX8800). It has 128 memories, supports 12.5 and 25kHz channel steps, has ±2.5ppm frequency stability and operates from a nominal 7.4V DC.

Supplied with a battery, antenna, charger, adapter, belt clip and hand strap, the Senhaix 8800 costs £69.95 and is available direct from Moonraker.

www.moonrakeronline.com

Antennas

A Gamma match for HF use

The Gamma Match technique has been previously described for VHF and UHF antennas in the Antennas column **[1]**. This month the theme is a Gamma Match for use with HF band beam arrays.

Gamma Match overview

The length of an HF band beam array's driven element is much longer when compared to a VHF band Yagi array. This can make using a λ/2 dipole as the driven element not always practical because of mechanical issues associated with its length and weight. Taking a 10m band beam array as an example, the dipole's legs are each about 2.5m long and this represents a sizeable torque load being placed on the dipole-centre.

To overcome these problems, often the driven element for an HF band beam array is a single length of aluminium tubing. However, the coaxial feeder cable still needs to be matched to the driven element and the balun techniques used for a dipole tend to become impractical when the driven element is a continuous conductor. One solution that overcomes this problem is to use a Gamma Match **[2]**.

When using this technique the usual practice is to mount the Gamma Match onto the antenna's boom, which provides a convenient means to electrically connect the coaxial cable's shield to the antenna. A short length of conductor, called the gamma rod, is used to connect the centre of the coaxial cable to the correct impedance point on the driven element through a variable capacitor connected in series. This variable capacitor is used to tune out any reactance associated with the driven element and gamma rod. The concept of the Gamma Match is shown in **Figure 1**.

When tuning a Gamma Match to obtain the lowest SWR, several variables may affect the position of the gamma rod's connection to the driven element. These include the:

- Driven-element's length
- Gamma rod's length and diameter
- Value of the variable capacitor
- Spacing between the gamma rod and the driven element (S in Figure 1).

The process to find the correct combination of settings to give the best match can be a time-consuming activity because several iterations of the variables become necessary. One method to improve this procedure is to use an adjustable strap as the connection between the gamma rod and the driven element, allowing its position to be adjusted to find the best match (as shown in Figure 1). With care it is possible to obtain an SWR of 1:1 using this technique.

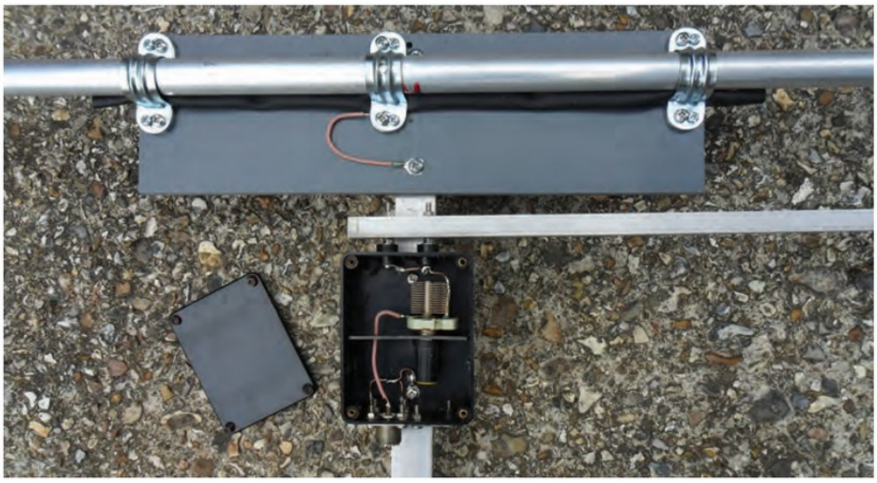

PHOTO 1: The 15m, 12m and 10m band Gamma Match.

The dimensions of the Gamma Match and value of the variable capacitor also depend on the driven element's radiation resistance and whether the driven element is resonant. However, for an HF multi-element beam array using a half wavelength (λ/2) driven element needing to be matched to a 50Ω feeder cable, then the Gamma Match typically consists of a:

- Gamma rod of 0.04 to 0.05 wavelengths (λ) in length with a diameter of around a third to a half of the driven element's diameter
- Centre-to-centre spacing (S) between the gamma rod and the driven element of approximately 0.007λ
- Capacitance value of approximately 7pF/metre of wavelength at the operating frequency.

A Gamma Match for 15m, 12m and 10m

Photo 1 shows an example of a Gamma Match used for multi-element beam antennas covering the 15m, 12m and 10m bands. This Gamma Match used a ceramic variable capacitor whose maximum value was 100pF, a 1m long 12mm by 12mm square profile gamma rod and an adjustable strap, with a space of 80mm used between the gamma rod and the driven element. A suitable plastic box was used to house the variable capacitor, mount a SO239 socket and to support the gamma rod using brass nuts and bolts. The variable capacitor was connected between the SO239 socket's inner terminal and the gamma rod by soldering thick single-core copper wires to its terminals as shown. The SO239 socket's casing was connected to the driven element's centre through the antenna's

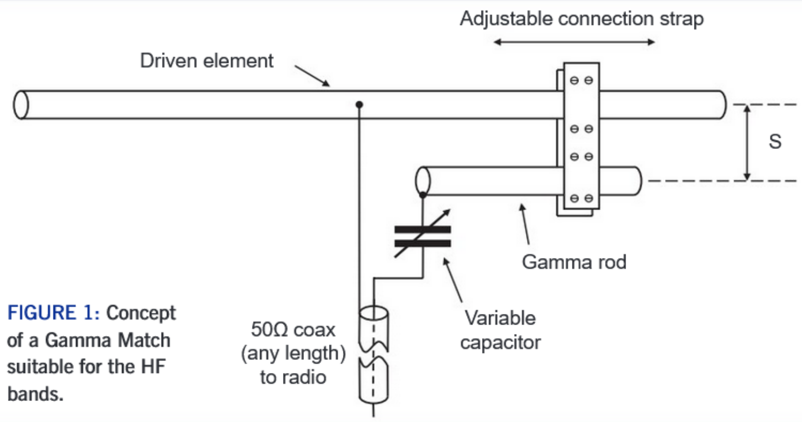

FIGURE 1: Concept of a Gamma Match suitable for the HF bands.

PHOTO 2: The Gamma Match's adjustable strap.

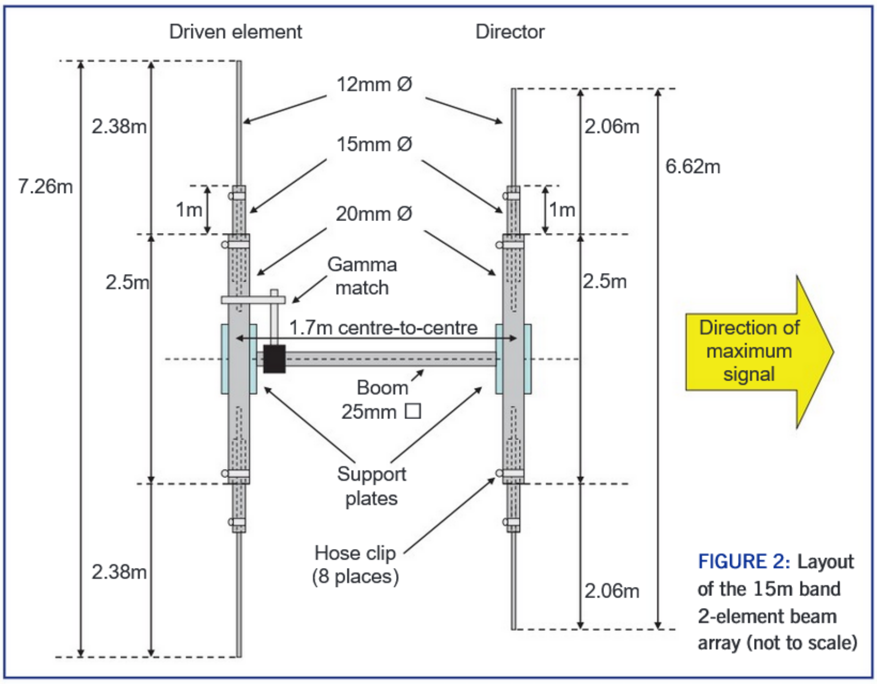

FIGURE 2: Layout of the 15m band 2-element beam array (not to scale)

aluminium boom. To connect the gamma rod to the driven element, an adjustable strap was used as shown in **Photo 2**.

The Gamma Match was intended for use with the antenna when the station was out portable. If the Gamma Match was to be used outside permanently to match an antenna, then it would need to be protected by fully weatherproofing it.

A 15m 2-element beam using a Gamma Match

Figure 2 shows the concept of a 2-element beam array constructed for the 15m band, using the second element as a director. This antenna was intended for temporary or portable use and **Photo 3** shows the antenna in use during an opening on the 15m band.

Either a 2-element beam array using a reflector or a director element could have been constructed. However, the director version of this antenna is slightly smaller, allowing it to be installed where the space is more limited.

Design and predicted performance

The 15m band 2-element beam array was designed using the MMANA-GAL analysis application to predict its dimensions and to model its performance at 21.2MHz when operated at 5m above ground level (AGL). The model was run using the application's default ground option **[3]**.

Figure 3 shows predicted radiation patterns as polar plots for the antenna at 5m AGL. The antenna's predicted vertical radiation pattern shows a single forward lobe with most of the RF signal concentrated between radiation angles of about 16° to 63° (ie about a 47° beamwidth). Such angles of radiation will tend to favour both E and F-layer propagation and should allow shorter and much longer skip stations to be worked when conditions allow. The predicted gain for the antenna was 9dBi (6.9dBd) corresponding with a 35° angle of radiation. The antenna's predicted horizontal radiation pattern indicates significant RF signal concentrated ahead of the director, with a 3dB beamwidth between around 321° to 39° (ie about 78°). The prediction shows no side lobes have formed, however there is a comparatively broad rear lobe predicted giving rise to an F/B of around 10dB.

Construction

The concept of the antenna's layout is shown in Figure 2. To minimise the antenna's weight, its two elements were constructed using 20mm, 15mm and 12mm diameter flush fitting aluminium tubes, allowing assembly as a telescopic arrangement.

To hold each telescopic section in place, an end clamp was made by laterally sawing two cuts at right-angles to each other across the end of the larger tube to a depth of about 20 to 35mm depending on the larger tube's diameter. A portion of the smaller diameter tube was then slid inside the larger tube and a suitable hose clip used to secure the inner tube in place. This technique has the advantage of enabling the element's length to be adjusted during tuning.

A central support was made for the driven element using a sturdy rectangular nylon plate with dimensions of 350mm by 100mm by 12mm. As shown in Photo 1, three 20mm metal saddle-clamps were used to hold the driven element in place on the central support. Additional holes were drilled into each saddle-clamp and through the central support to allow the use of M4 nuts and bolts to hold everything in place.

The director element's construction used a similar telescopic tube arrangement and central support as used for the driven element. Similarly, three 20mm metal saddle-clamps were used to hold the reflector element in place.

Note: the construction of the two elements' central supports was similar to that used for the 10m 2-element beam array described in the February 2021 Antennas.

Both central supports were fixed to the antenna's boom using M5 nuts and bolts, with the boom made from a 1.8m length of 25mm square profile aluminium tube.

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email2mikeparkin@gmail.com

PHOTO 3: The 15m band 2-element beam array in use.

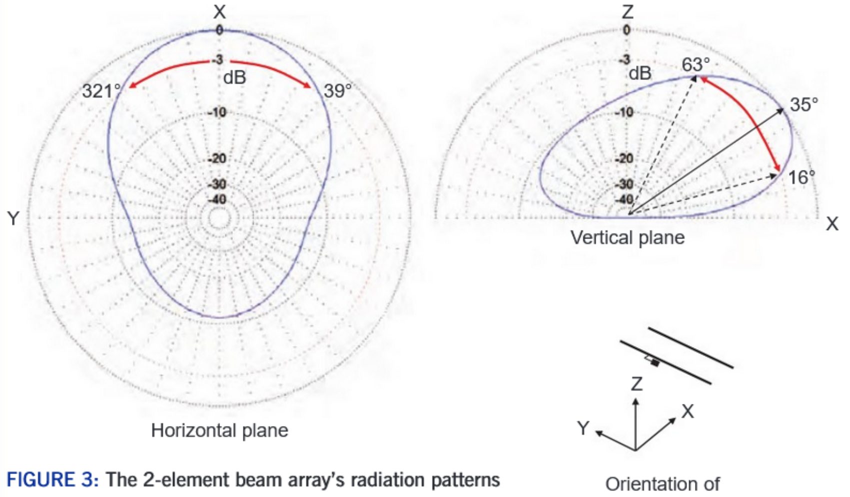


FIGURE 3: The 2-element beam array's radiation patterns as predicted by MMANA-GAL.

Details of the dimensions of the aluminium tubes used to construct the 2-element beam array are summarised in **Table 1**. Construction is as per Figure 2.

Connections

The Gamma Match described previously was used to interface the coaxial feeder cable with the 2-element beam array's driven element. The array was fed using 10m of RG58 coaxial cable run from the radio and connected to the Gamma Match using a PL259 plug.

Tuning and testing

The 2-element beam array was clamped to a 5m extendable mast for testing and tuned to 21.3MHz using an MFJ 269c antenna analyser. The lengths of the driven element and the director were equally varied, along with the space altered between them, to minimise the SWR. The position of the adjustable strap along the gamma rod was altered and the capacitor varied until the minimum SWR was obtained. Eventually, careful adjustment of the array allowed an SWR of 1:1 to be obtained at 21.3MHz, indicating the antenna's feed point impedance was close to 50Ω.

Having signed on in CW, the array was driven at 10W, which was increased to 100W with the SWR remaining at 1:1 at 21.3MHz. The SWR continued to remain low, with 1.15:1 obtained at 21.05MHz and 1.1:1 at 21.4MHz. The directivity of the 2-ele beam array was checked by tuning to a distant beacon and turning the array; the changes on receiver's S-meter were very evident.

On air

During several 15m band openings, the 15m band 2-element beam array has been used to make many SSB and CW contacts within Europe and outside despite the sunspot cycle being at a low point, with some signal reports exceeding S9.

References

[1] *RadCom* May 2017, Antennas, p28-30

[2] *RSGB Radio Communication Handbook*, 14th ed, edited by M Browne, G3DIH: Section 14, Transmission Lines, p14.16-17

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

TABLE 1: Cutting list.

Qty	Description
2	20mm diameter x 2.5m
4	15mm diameter x 1.7m approx
4	12mm diameter x 2m approx
1	Gamma rod 12mm square x 1m
1	25mm square section for boom, 1.8m

MSF shack clock

I was looking for a clock suitable for logging in the shack. It needed to display the time in 24 hour format and UTC. This ruled out all the cheap clocks I could find and all of the radio controlled ones. So I thought it would be a fun project to build my own.

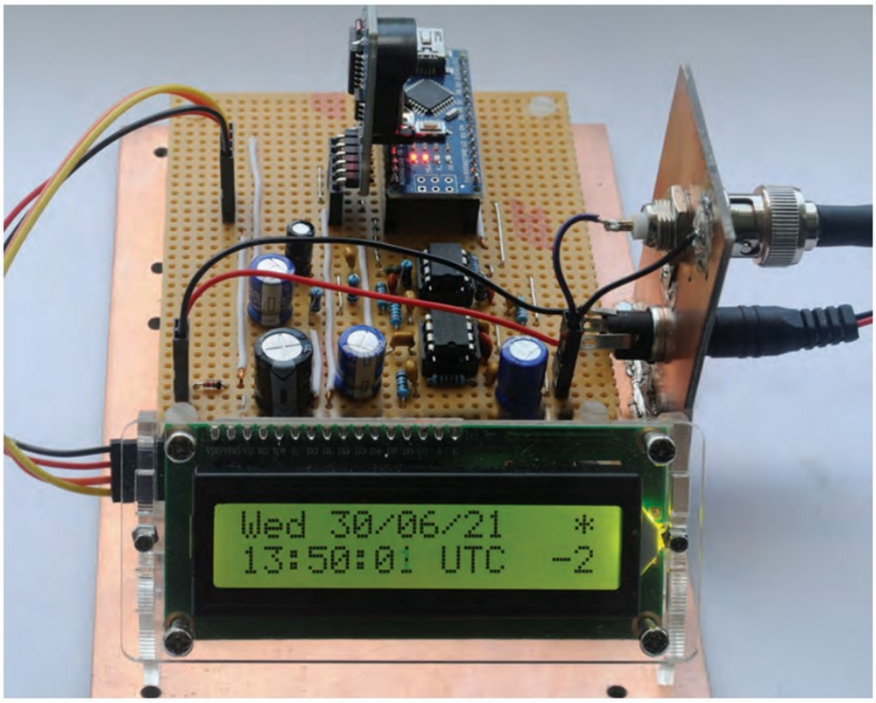


PHOTO 1: General view of the receiver and display section.

Background

The MSF [1] time signal is transmitted at 60kHz from Anthorn in Cumbria on behalf of the National Physical Laboratory. The signal is receivable throughout the British Isles and in many parts of continental Europe. Unfortunately the frequency is very close to that used in many switching power supplies. I had originally planned to build the antenna in the main unit but found that my monitor and oscilloscope produce large amounts of hash and so the clock has a remote active antenna. This only needs to be a couple of metres away to receive a clean signal.

MSF sends a carrier with each second marked by turning the carrier off for 100ms. Minutes are marked by turning the carrier off for 500ms. Each one-second pulse is followed by two data bits; thus, every minute 118 bits of data is sent (ignoring the possibility of a positive or negative leap second). These bits encode the current date and time, although most of the bits are unused.

MSF always sends UK civil time, ie UTC in winter and BST in summer. This is why the radio controlled clocks you can buy never show UTC all year. There is a data bit set to indicate that the time is one hour ahead and this is used to know when to convert (back) to UTC. As well as going back one hour it may also (exceptionally) have to go to the previous day and month.

Overview

The clock consists of two parts: the active antenna and the receiver module, connected by a coax cable.
The active antenna module uses a ferrite rod antenna along with a three transistor amplifier. The coax cable carries its DC supply.

The receiver module is based around an Arduino Nano, which drives a standard 16x2 LCD display over I²C. The receiver itself is a direct conversion design, converting the 60kHz carrier to a 700Hz tone that is amplified and fed into the Arduino's analogue to digital converter (ADC). The tone is detected using the Goertzel Algorithm (see later) and the resulting data is decoded to obtain the current date and time. The module also contains a real time clock (RTC) module to keep the time when the unit is off or if the MSF signal is unavailable.

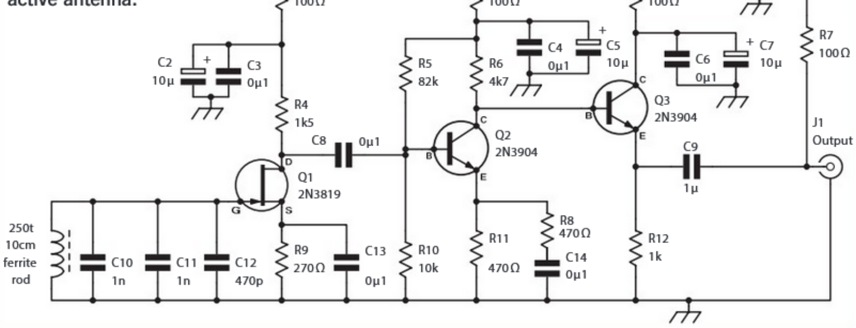
The clock is intended to be connected to the same 13.8V mains power supply as your transceiver – it's not really designed to be run off a battery. The clock comes on and displays the time from the RTC as soon as you power up and, within a couple of minutes, it will have picked up and decoded the accurate time from MSF.

Active antenna

Figure 1 shows the circuit diagram of the active antenna part of the receiver. L1 is a coil on a ferrite rod which is the antenna and forms a resonant circuit with the parallel combination of C10, C11 and C12.

Q1 is a common source JFET amplifier with a very high input impedance so as not to load the tuned circuit. Q2 is a common emitter amplifier to provide additional gain (set by the ratio of R6 to R8). Q3 is an emitter follower with a low output impedance suitable for driving the coax cable. Each transistor is fed via a 100Ω resistor each decoupled by 100nF and 10μF capacitors; this is to ensure stability and to prevent feedback through the power line. The active antenna is powered by 12V through the coax cable via R7. C9 blocks this DC from the amplifier output transistor.

FIGURE 1: Circuit of the active antenna.



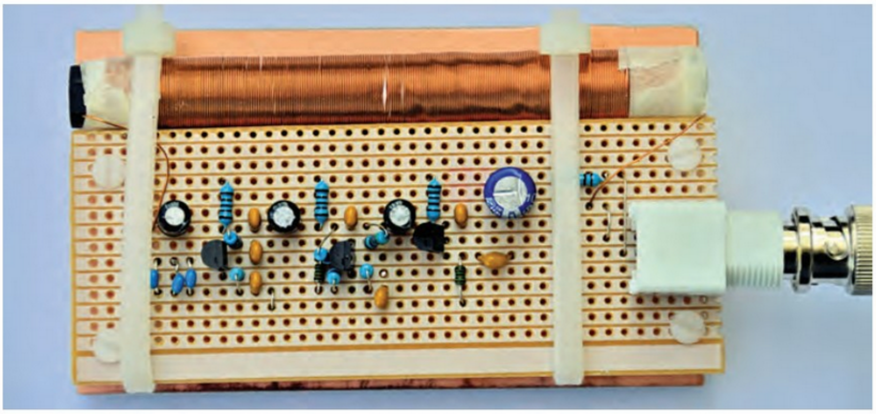


PHOTO 2: The active antenna section.

Depending on the MSF signal strength in your area you may want to adjust the amplifier's gain – a lower value of R8 gives more gain. If there is too much gain then Q3 is likely to clip the signal and the receiver will not decode the signal.

Receiver board

The MSF receiver is a simple direct conversion design and its circuit is shown in **Figure 2**. U1 is an NE602 double balanced mixer with a single-ended input into pin 1 from the coax via DC block C1. R1 feeds 12V down the coax to the active antenna board. The clock for the mixer is generated by the Arduino and is fed into pin 6 via C4. The mixer chip's well-filtered 5V supply is from the Arduino's voltage regulator.

The mixer output is fed into dual opamp U2, which provides two stages of amplification. The output is fed direct into the Arduino's ADC. The first stage has a gain set by the ratio of R5 to R3, ie 100k/4k7 or roughly 21 (26dB, if you prefer). C8 and R5 roll off the gain at higher frequencies to ensure stability. The second stage is identical to the first.

The board requires 12V (nominal) to J2. Diode D1 prevents the board from back powering a PSU (or other circuitry) when the power is off but there is a connection to the Nano's USB connector. The opamps are operated from a single 5V supply (also from the Arduino) with R9 and R10 providing a virtual ground. Again, this and the main power rail are well decoupled. By running the amplifier at 5V we can be sure that strong signals will not produce a signal that exceeds the microcontroller's safe input voltage.

The board has two connectors for external modules. J3 is for the real-time clock module and J4 for the LCD display (operated via I²C).

The Arduino Nano is perhaps overkill for this project but it provides a microcontroller, crystal, voltage regulator and USB connection (for programming). With clones available for just a few pounds it is extremely good value.

Real time clock module

The RTC module, seen in **Photo 3**, contains a Maxim DS3231 RTC chip and a 32K AT24C32 EEPROM (which is not used for this project). These communicate with the microcontroller over the I²C bus. These modules are widely available from online marketplaces. They actually cost much less than the Maxim chip does from authorised distributors so I suspect they are probably clones that don't meet the impressive specification of the genuine article. However, they do actually work well and are perfect in this application.

The module also has provision for a rechargeable 3V coin cell that keeps the RTC clock running when its 5V supply is removed. This is needed so that when the clock is first switched on it can show the current time. Otherwise it can take two minutes to acquire the time. It will also continue to show the time when the signal is not available due to local interference or if the MSF transmitter is switched off for maintenance. The clock will work without the RTC module but it will not be able to set the time if it cannot receive the MSF signal. The RTC keeps better time than the microcontroller's built in timer and so the software reads the current time from the RTC every minute if the MSF signal is not available. There is a diode and resistor from Vcc to the battery to limit the charging current. It's not clear if this is a good way to charge the battery since it does not stop charging when the battery is fully charged. I used a standard non-rechargeable cell and removed the resistor to disable the charging circuit (see Photo 3).

Goertzel Algorithm

The Goertzel Algorithm **[2]** is a simple form of digital signal processing used to detect a tone. It is effectively a single bin Fast Fourier Transform (FFT). To detect a tone of frequency f we need to sample at a rate of at least 2f according to the Nyquist theorem. The number of samples N we need to detect a tone is determined by the sample rate and the desired detection bandwidth.

$$N = \frac{\text{SampleRate}}{\text{Bandwidth}}$$

We need a coefficient to apply to every sample.

$$k = \text{integer}\left(0.5 + \frac{N \times f}{\text{SampleRate}}\right)$$

$$\omega = \frac{2\pi k}{N}$$

$$\text{coeff} = 2\cos\omega \quad \text{(note: } \omega \text{ is in radians)}$$

The algorithm works in blocks of N samples, which starts with $Q_0 = Q_1 = Q_2$

For every sample,

$Q_0 = \text{coeff} \times Q_1 - Q_2 + \text{sample}$

$Q_2 = Q_1$

$Q_1 = Q_0$

After N samples we can calculate the strength of the tone:

$$\text{tone magnitude}^2 = Q_1^2 + Q_2^2 - Q_1 Q_2 \times \text{coeff}$$

We compare this magnitude with a threshold to decide if the tone is present or not.

Every sample requires a multiplication which can be a slow operation on a simple microcontroller. However, we can simplify the calculation if we make the sample frequency exactly four times the tone frequency.

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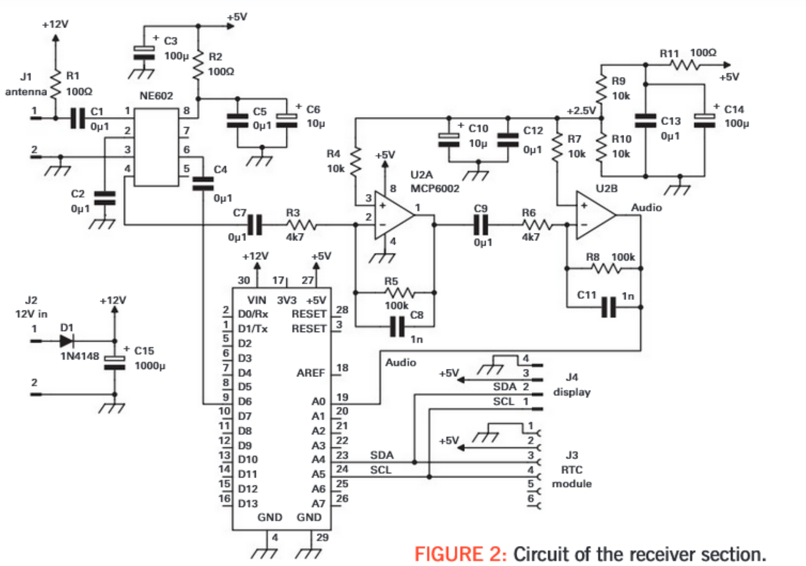

FIGURE 2: Circuit of the receiver section.

PHOTO 3: The RTC module. I removed the resistor from the pads ringed in red (see text).

Now, $k = \frac{N}{4}$ and

$$\cos\omega = \cos\frac{2\pi}{4} = \cos\frac{\pi}{2} = 0$$

and so coeff = 0

This simplifies the calculations to

Q_0 = sample - Q_2

$Q_2 = Q_1$

$Q_1 = Q_0$

tone magnitude^2 = $Q_1^2 + Q_2^2$

Each sample requires one subtraction and every N samples requires two multiplications. We don't need to take the square root as we simply compare magnitude^2 to threshold^2. This is used as the basis of the threshold (with some hysteresis to prevent false detections). The exact mechanism can be seen in the source file `io.c` **[3]**.

To detect 700Hz we use a sample rate of 2800Hz. Let's set a bandwidth of 100Hz so that N=28. These take 10ms so this is the time to detect a tone. The MSF pulses are 100ms so this is fast enough.

Mixer clock

The local oscillator for the NE602 mixer is generated by the Arduino, which has a 16MHz crystal. To get a 700Hz tone from the 60kHz MSF signal we need a clock at either the sum or difference frequency, 60700Hz or 59300Hz. To generate the clock we are using the 8 bit TimerCounter0 in CTC mode. The output frequency is set by the integer value in the OCR register:

$$f_{output} = \frac{16 \times 10^6}{2\,(1 + OCR)}$$

This limits the precision with which we can set the frequency.

- Setting OCR to 134 gives f_{output} = 59259, 41Hz away from our target of 59300Hz.
- Setting OCR to 131 gives f_{output} = 60606, 94Hz away from our target of 60700Hz.

So we choose to use 59300Hz, as the error is smaller.

With the clock at 59259Hz the audio output from the mixer will be at 741Hz so our sample rate should be 4 x 741 = 2964Hz.

The ADC in the microcontroller is set to free running mode so we get an interrupt every conversion. Ideally we want this to happen 2964 times a second. However, the ADC clock is derived from the main clock (16MHz) and its preselector can only divide by powers of 2 up to 128. A conversion takes 13 clock cycles. If we set the preselector to 32 we get a conversion 38461 times a second. We can simply use every 13th conversion, giving a sample rate of about 2959Hz, very close to our target of 2964.

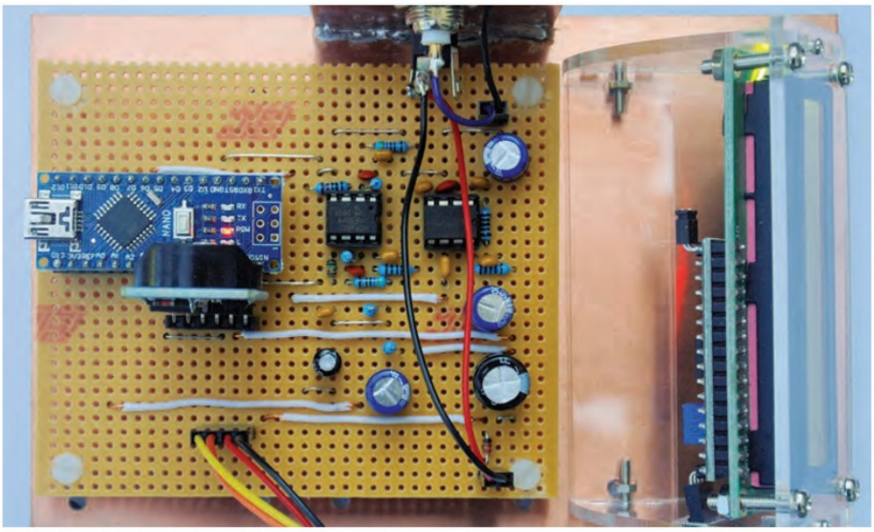
PHOTO 4: Overhead view of the receiver and display section.

Construction

Construction is straightforward. For L1 I had a 10cm ferrite rod of unknown permeability similar to those in old LW/MW radios. I wound on about 250 turns of 30swg enamelled wire. I used my nanoVNA to find its inductance and hence the capacitance required for resonance at 60kHz. Alternatively you could build a simple oscillator and use a scope or general coverage receiver to find the capacitance to resonate at 60kHz. The resonance peak is quite broad.

I built both the receiver board and the active antenna on strip board, mounted on copper clad board using nylon stand-offs. The LCD is housed in a plastic housing that is cheaply available from online marketplaces.

If you are using a non-rechargeable cell in the RTC module then remove the resistor before first power up.

The RTC and Arduino modules are plugged into female pin header sockets. For the other connections on the receiver board I used male header pins but you could of course wire directly to the board. The connections to the LCD require a female header – leads for this are often sold as Dupont leads. However, I now use a crimping tool to make my own leads with 7/0.2mm hook-up wire, as they are much more reliable.

The only connector on the active antenna board is the BNC socket – I used a PCB mounting part as seen in the photos. Obviously, you can wire this however you like and don't have to use BNC connectors.

Photo 4, Photo 1 and Photo 2 show how I laid out the circuits. Precise details can be downloaded from [3].

Software

The software is written in C and built using Atmel Studio 7, which is a free download for Windows. It can also be built using avr-gcc on Linux. The software is open source and is hosted at GitHub [3]. There you will also find ready built hex files that you can program directly without having to build the software yourself. Instructions for programming the Arduino via its USB port and building the software are on the website.

The software makes use of TARL (TGJ AVR Radio Library) **[4]**, a collection of source files that can be used for a number of radio projects.

Display

When the clock is receiving a good MSF signal that it is successfully decoding, it displays an asterisk in the top right corner of the display, as can be seen in Photo 1. Under this is a positive or negative number that indicates the current value of DUT1, which is the difference between astronomical (UT1) and atomic (UTC) time. It is effectively the difference between GMT and UTC. At the time of writing this is showing -2, which means that UTC is 200ms ahead of UT1. This value has no practical relevance to amateur radio that I know of but I display it since it's there.

When the clock is not receiving a good MSF signal the display shows the letters M and S to show whether it has received a minute or second pulse in the last minute or second, respectively. An upper case letter shows it has received the pulse and a lower case letter shows it hasn't. Shortly after turning on the clock you would expect it to show mS to show it is receiving second pulses but hasn't seen a minute pulse yet. Within 60 seconds this should change to MS to show it has now got the minute pulse. After another minute it should have received a full set of MSF data and will show the star and DUT1 value. If it continues to show MS then, although it is receiving a signal, the data is corrupt. In this case experiment with moving the position or orientation of the antenna – or, possibly, reducing the active antenna gain if you're in a particularly good signal area.

The Arduino Nano has 4 LEDs. One indicates power and two show that serial data is being transmitted or received over the USB connection (eg when programming the FLASH memory). The fourth LED is under the control of the software and this is used to indicate when the MSF signal is detected. In normal operation this will be lit and will flash off every second to indicate data is being received. This can be used to help position and orientate the active antenna.

Websearch

[1] https://www.npl.co.uk/msf-signal
[2] https://en.wikipedia.org/wiki/Goertzel_algorithm
[3] Files for this project can be found at https://github.com/G4TGJ/MSFClock
[4] https://github.com/G4TGJ/TARL

Technical

A beginner's guide to 23cm

The 23cm band is the 'gateway band' to microwave frequencies, the lowest frequency allocation in the microwave spectrum available to amateurs.

Whilst 23cm is not available to Foundation licensees, many amateurs have yet to venture onto the band. (Here at G0FVI, despite having a licence since 1985, activity only commenced in 2020 for the first time!). The 23cm band is popular for moonbounce (EME), satellite working and amateur TV amongst others. This article will concentrate on getting setup for simplex operation.

23cm: what to expect?

This band is not a 'plug and play' band like say 2 metres. If you have 23cm capability, and simply put up a collinear you are likely to be disappointed with the results unless you live near a repeater or are in an area of high local FM simplex activity. In order to get the most out of the band an understanding of microwave techniques and propagation is required. Most of the simplex activity is SSB and takes place in contest environments (eg the monthly UK Activity Contests, UKAC). Although when conditions are enhanced, there will be 23cm enthusiasts actively looking for simplex contacts. In general, putting out a blind CQ call on 1296.200MHz (SSB calling channel) will more than likely not be answered. Most enthusiasts use the ON4KST chatroom to see who is about and arrange calls **[1]**. As beams are the norm for 23cm, ON4KST chat makes it much easier to establish beam headings due to the much sharper lobes of beams used on this band. There are forums on social media where you can also arrange a contact such as Facebook **[2]**.

It is often said that for VHF and UHF that 'height is might', this is definitely true for 23cm. Under flat band conditions, a well located hilltop station is likely to be more successful than one in a valley or heavily built-up area without a clear take-off. Signals at 23cm suffer greater attention from surrounding objects than VHF or UHF. For instance, amateurs with nearby trees may find that contacts are easier in the winter when there are no leaves present! For those without the advantage of a good home location, 23cm is the ideal band for portable operation, and many do indeed head for the hills. In the UKAC and other contests there are usually large numbers of portable station entries.

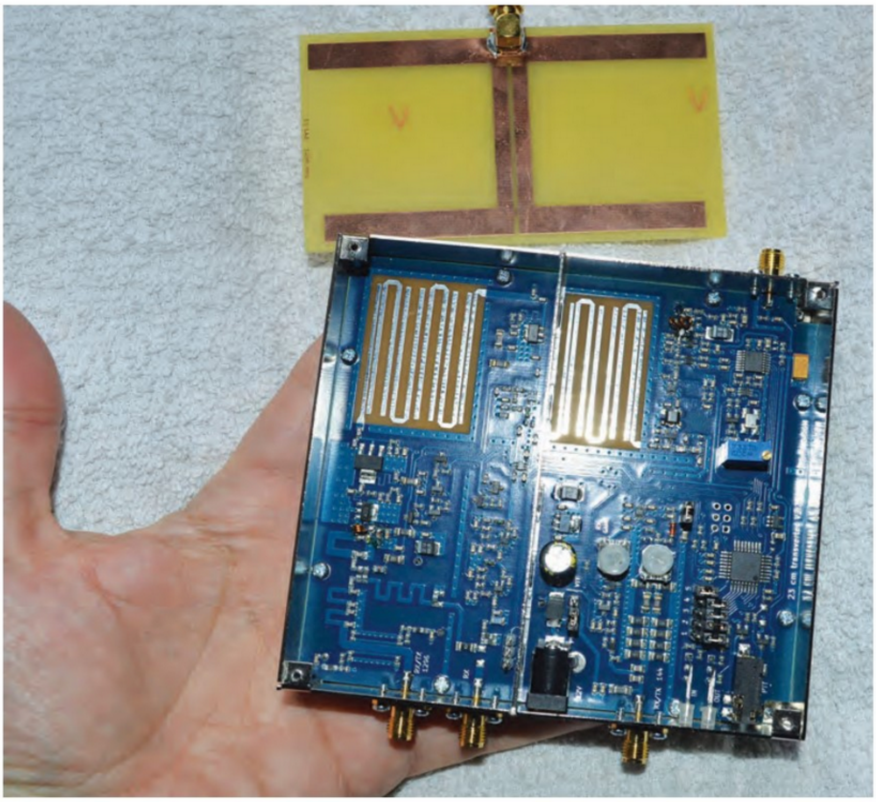

PHOTO 1: **SG lab transverter from Bulgaria.**

Propagation on 23cm

Many amateurs have the mistaken belief that propagation at and indeed above 23cm is 'line of sight' only. This is not the case. Under lift conditions (tropospheric ducting usually associated with high pressure fronts), signals can travel considerable distances, similar to those found on VHF and UHF. During conditions of extreme tropospheric ducting, signals can travel much further than VHF, being comparable to the intense lifts seen on UHF often with high strengths due to the reduced attention than would normally be seen in a 'flat' band. Those living on or near the coast will find that some very stable ducts often form above the sea allowing some considerable distances to be worked. Fading and rapid fading (referred to as QSB) can be seen on 23cm under enhanced tropospheric conditions, in much the same way as seen on 70cm.

Enhanced tropospheric conditions tend to be less frequent on 23cm than VHF and UHF. There are several ways to check for enhanced conditions as well as simply switching on the receiver and scanning around. In the days before the internet, it would be a case of looking at met office pressure charts where high pressures with wide spacings can indicate lift conditions, in conjunction with checking beacons on 23cm. UK

FIGURE 1: **Map of stations worked by G0FVI/P in a UK Activity Contest in 2020.**

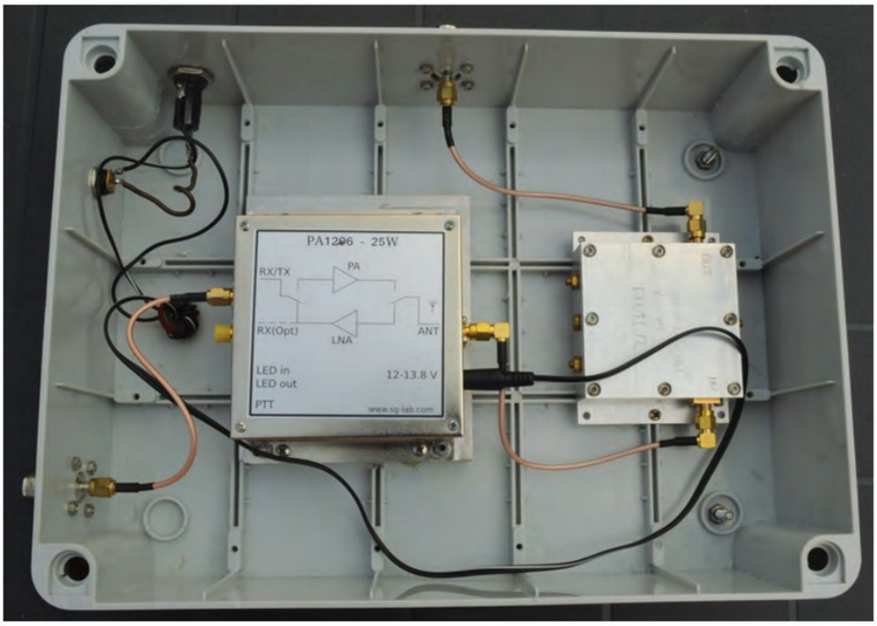

PHOTO 2: SG lab 25W amp/preamp and 23cm bandpass filter for masthead mounting.

and EU beacons are listed in the RSGB yearbook. Today the smart phone will provide you with two other useful tools (amongst others) such as The Hepburn Tropo index **[3]** and DX summit **[4]** that shows DX spots (ON4KST chat will also give you an idea of enhanced conditions by showing who is working who also). **Figure 1** shows contacts for G0FVI/P in a UKAC contest using just 2.5 watts under enhanced tropospheric conditions (no KST chat was used just 'search and pounce' plus CQ).

Another mode of propagation seen on 23cm is scatter that can occur in the troposphere or from aircraft reflections. Tropospheric scattering allows over the horizon contact and usually occurs when signals interact with moisture laden turbulent air in the troposphere and is therefore dependant upon climatic conditions (also terrain). Troposcatter can often give signals a 'rough' sounding edge to them much like auroral scatter seen on the VHF bands. CW is perhaps the mode of choice for tropospheric scatter particularly when signals are 'rough' (anyone who has ever tried to work the lower HF bands during solar storms will attest to this!). Aircraft scatter takes place when signals are reflected from an aircraft that lie in the path between or adjacent to two (or more) stations **[5]**. Considerable distances can be worked using aircraft scatter and signal strengths will normally be higher than those seen in tropospheric scattering. There are numerous programs for tracking aircraft, some requiring hardware, although many amateurs use Airscout by DL2ALF, which is internet based **[6]**. In general, scattering as a mode of propagations requires higher power levels for successful contact (especially with tropospheric scatter) although it is usually possible to achieve contact with lower powers if one of the stations is a 'big gun' type with a high gain antenna array. Reflections from aircraft can sound fairly spectacular to the beginner, a very strong signal can appear out of the noise lasting for several seconds then abruptly disappear, often with no flutter or fading. Rapid exchange of information is the norm for contacts via this form of scatter.

Sometimes it is possible to make contact by reflections off other objects where terrain may obscure the path, for instance two stations in Tenerife recently used a passing cruise ship to establish contact **[7]**. In the 1980s I knew of a station who would 'bounce' signals off a cooling tower of a power station to get around a nearby hill!

Transceivers and transverters for 23cm

At the time of writing, the Icom IC-9700 is the only transceiver in production that includes the 23cm band as standard. There are others that can still be found on the used market including the IC-910H, IC-9100 and the Kenwood TS-2000x. Older radios such as the Yaesu FT-736 and IC-790e with the 23cm option installed crop up occasionally on the market but are a bit long in the tooth now although they are usually more serviceable by the average amateur than more modern rigs, not relying so much on surface mount technology (parts can often be found for older rigs such as the FT-736 on internet auction sites).

Getting on to 23cm has never been easier and there are some fairly cheap alternatives to purchasing a transceiver, in particular the transverter from SG labs of Bulgaria **[8]**. Kuhne of Germany also sell a transverter for 23cm although it is somewhat more expensive than that of SG labs **[9]**. The SG labs transverter (**Photo 1**) has been utilised by a number of beginners (G0FVI included!) and is a highly compact unit with around 2.5 watts output, utilising an IF frequency of 144MHz. The small size is ideal for masthead mounting, which will be discussed shortly. Another route to 23cm could be an Adalm Pluto SDR transceiver or LIME SDR. The latter two only provide a few milliwatts output and require some sort of amplification for transmit. For those of sufficient skill (and) patience a transverter could be constructed from scratch **[10]**. If you decide to attempt the latter option you'll need to ensure your transmitted signal is clean, also some amount of test equipment and prior construction skills will be required.

[It's probably worth noting that the highest performance systems are a good transverter to HF radio – Ed]

Antennas and coax

Beams are the norm for 23cm unless local work is intended on FM or via repeaters. The small size of 23cm beams allows a large number of elements giving fairly substantial gain and a low visual impact with fairly short boom lengths when compared to similar VHF or UHF beams. In general, unless you live in an exceptional VHF/UHF location it is best to avoid the smaller antennas of less than say 36 elements. Many amateurs opt for the 44 element WIMO type antenna (this is in reality a 37 element antenna; the reflector is composed of an 8 element nest). Such an antenna will provide around 18dBd of gain for a boom length of only 3m and can easily be dismantled for portable use. It is, of course, possible to construct a beam for 23cm although the tolerances are somewhat more stringent than say 70cm (for a good write-up on beams for 23cm see **[11]**). The high gain of 23cm beam antennas does in part make up for the increased path losses of the band (under flat conditions) although the beamwidths are narrower, meaning more attention needs to be paid to accuracy of beam headings (use of KST chat and QRZ.com are most useful in this respect!). The parabolic dish is another high gain antenna available for use on 23cm although in practice this is beyond the reach of many amateurs for terrestrial use, the minimum useable diameter being around 1.2-1.4m (a dish feed is also required for a parabolic antenna).

Coax losses are substantially higher at 23cm than those of lower bands, making the use the ubiquitous RG-213 and types of similar loss unwise on this band for all but very short runs. A typical 10 metre length of RG-213 would have a loss approaching 3dB, which equates to around only half of your power reaching the antenna. In the past, amateurs tended to

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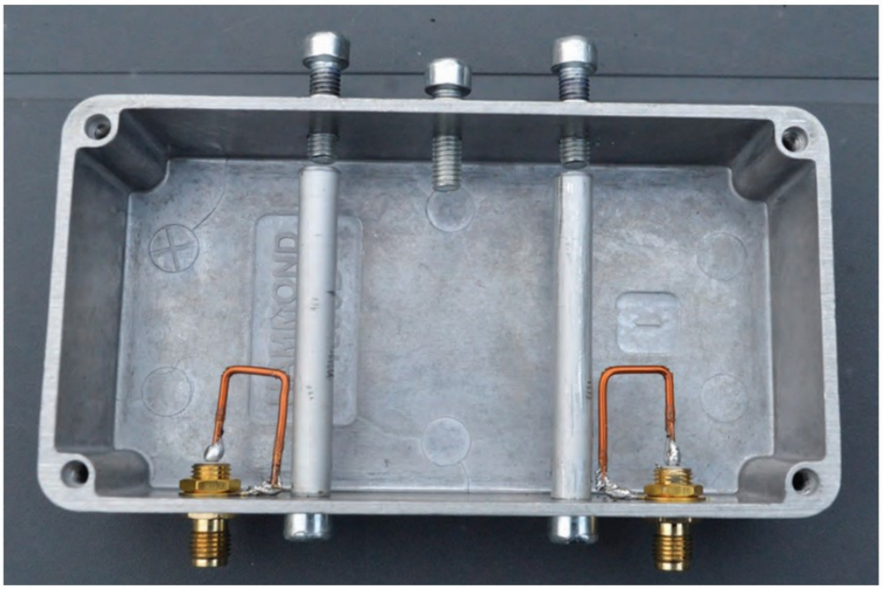

PHOTO 3: Simple 23cm interdigital bandpass filter.

opt for LDF250 and LDF450 coax which was (and still is!) fairly expensive. There are some reasonably priced alternatives to LDF 250/450 today from the likes of Messi and Paoloni of Italy, although fairly long runs (say more than 15m) might still require runs of LDF250/450 or modern equivalents (FSJ 450). The greater losses inherent in coax at 23cm encourage many amateurs to place preamps and transmit amplifiers at the masthead so that such losses are reduced. Coaxial plugs for use at 23cm will normally be high quality N-type or SMA: PL259s are completely useless on this band.

Preamps and amplifiers

Preamps in the form of a masthead mounted type are essential on 23cm unless you have an extremely short coax run (eg hill top SOTA type operation), as even with very high quality coax and high gain antenna there will be loss of received signal by the time that signal reaches the receiver input and without such a preamp you will almost certainly struggle to hear anything other than local traffic or very strong more distant stations. A masthead preamp may be omitted if a transverter is used where this too is mounted at the masthead (the transverter should have receiver gain itself otherwise a separate preamp will still be needed). **Photo 2** shows an SG lab 25W amplifier with built in preamp and a separate 23cm bandpass filter boxed for masthead mounting (note the use of short SMA fly leads for inside box connection).

Commercial masthead preamps are available, although many build the G4DDK kit **[12]** that requires switching/sequencer circuitry **[13]**. Commercial masthead preamps can be operated in RF 'VOX' mode where the preamp senses RF power and bypasses/turns off the receive circuitry (Tx power for RF VOX is generally limited to less than 100 watts), although hard switching options are usually provided in the form of a PTT to ground port.

There are few plug-and-play commercially available 23cm Tx amplifiers, the cheapest being that from SG labs – a 25W amplifier with a preamp built in for Rx. There are numerous designs for self-build amplifiers including several listed in the Microwave Techniques books, perhaps the best known being the design by G4BAO **[14]**. Self-build amplifiers require switching and sequencer circuitry to allow proper operation and avoid damage to any masthead preamp in use. Some amateurs such as PE1RKI offer ready built amps that just require the addition of PSU together with switching/sequencer circuitry **[15]**. Note that many RF devices used at 23cm (in particular that in the G4BAO design and those of PE1RKI) run on supplies of 24V or greater, so you will need power supplies for these or low noise DC-DC up-converters if using 12/13.8V (once again Chinese ready built units can be purchased online although you may need to add RF filtering on the output side).

Noise and filters

The amateur bands today are plagued with noise from a whole range of electronic devices with switch mode power supplies being one of the biggest offenders. Unlike lower bands, 23cm is much less prone to electronic interference. However, if you operate near a mobile phone mast or within range of a high-power TV transmitter you notice an increase in background noise. At G0FVI, the first foray out portable in a UKAC revealed some persistent background noise of 'hash' of around S5 despite being in a country lane a good way from the nearest built-up area. The culprit turned out to be a mobile phone mast half a kilometre away that was introducing undesirable mixing products in the masthead mounted transverter in turn being fed to the IF radio **[16]**. If you operate near a high-powered TV transmitter you may also notice a similar problem. A bandpass filter cures or reduces such problems and is placed immediately after the antenna ahead of any preamp or transverter. Commercially made bandpass filters can be purchased although an effective and easy to build design can be found on the W6QPL site **[17]**. **Photo 3** shows a W6PQL filter constructed by Derek, M0WGD.

In conclusion…

23cm is a fascinating band and the gateway to higher microwave bands. Techniques used at 23cm are a good grounding for venturing onto the other higher bands, in particular 13cm. Hopefully this article has provided an introduction to the band for those thinking of dipping 'their toes in the water' or as an encouragement for progression from Foundation to Intermediate to try the band out. I would recommend that anyone thinking of having a bash at 23cm and above join the microwaver's community **[18]**, a seriously helpful and friendly bunch of people with a vast amount of experience between them! Good luck and happy microwaving!

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Best of 2021

Time to reveal my personal favourite books from 2021

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At this time of the year I reflect on the previous year's books and pick my top three favourites. Sometimes it's easy – there are clear winners – but some years are harder because there's just *so many* good candidates to choose between. Dim the lights please, and cue the drum roll: it's time to reveal my favourites from 2021!

Microcontroller Know How

By Mark Jones, G0MGX

"Amateur radio projects and more" says the subtitle and that's definitely what you get with this book. Mark Jones, G0MGX introduces us to the major families of microcontrollers you are likely to meet in amateur radio including the STM32 and PICmicro series. Along the way we learn of the programming methods (variously assembler, C and so on) and the development environments and ecosystems. There are plenty of projects along the way, ranging from signal generators to a GPS synchronised clock. All of the projects are open-source, meaning the source code is readily available and open to you modifying, extending or otherwise re-using it to your heart's content. All of the microcontroller families mentioned are well supported by their manufacturers with powerful, free tools to help you make them do what you want.

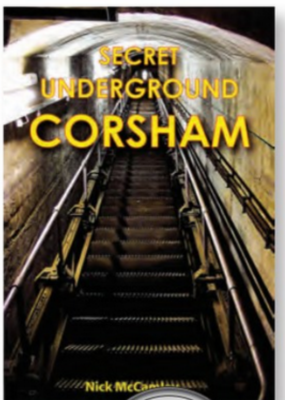
My main microcontroller experience is with the PICmicro series and I was pleased to see that they are well represented in this book. Despite having used them for decades I learned some new wrinkles as I read throuch.

Overall, this is an excellent introduction to today's technology of microcontrollers and shows how you can enter this world without spending a fortune, whilst making some useful gadgets at the same time.

Read the original review: RadCom ***May 2021 page 79***

Secret Underground Corsham

By Nick McCamley



It probably won't surprise anyone that this book was near the top of my favourites list. Documenting what I think is Britain's largest underground secret military establishment isn't a task for the faint-hearted and Nick McCamley has made an excellent job of it.

Beneath Corsham in Wiltshire is a quarry that has been worked for 'Bath' stone for centuries and it is the space left behind after this extraction that has proved so useful to military planners. We learn about everything from the early quarrying history to the hundreds of thousands of tons of explosives stored there when it was a munitions distribution centre in WWII, all the way through to becoming a Cold War protected shelter for Government and Royalty. The size is breath-taking, with the workings stretching for hundreds of acres, and this well-illustrated book magnificently conveys the air and scale of this unbelievable place.

Read the original review: RadCom ***December 2021 page 60***

radiotoday Guide to the Icom IC-7300

By Andrew Barron, ZL3DW

This was a tough, tough choice. Andrew Barron, ZL3DW is an extremely talented writer and he has written many how-to books for the RSGB. They are all uniformly good, which is why it was so tough, but I think the IC-7300 book just pipped the others at the post with the way it describes changes brought about by the radio's major firmware update (technically the book is an update rather than a new title but I'll gloss over that: you can't see the joins).

Andrew writes from the point of view of the amateur. He takes what I'd call a 'task-oriented' approach: if you want to do *this*, you'll need to do *that*, *that* and *this*. Unlike some manuals, Andrew's writing technique joins the the dots to explain how to achieve particular outcome.

His four radiotoday Guide books in 2021 covered the Icom IC-705, Icom IC-7300, Yaesu FTDX10 and Yaesu FTDX101. He has previously written radiotoday Guides to the IC-7610 and to the IC-9700. Not only is ZL3DW good, he's *prolifically* good.

Read the original review: RadCom ***March 2021 page 67***

Design Notes

PICs and programming

Many constructors use the PIC series of microcontrollers from Microchip in projects. In many cases they are asked to perform quite simple tasks like programming a synthesiser chip with a single spot frequency then go to sleep, or form a sequencer to protect masthead equipment during Tx/Rx switching. To get the required functionality, users can either write code for the controller chip in a high level language like C or Basic, or program the device in its native assembler code. At the end of the code writing process the result is converted to binary in a .HEX file and 'blown' (written) into the chip. As an alternative many users may choose to download pre-compiled .HEX code and just blow the device themselves, which removes any need for ability to write software, but allows flexibility and removes the need to purchase pre-programmed chips from a single source for that project.

Ever since the dawn of the PIC controller in the 1990s Microchip has made programmers available. The first ones connected to a Centronics/printer port, or a serial COM port on a PC and needed a separate power supply; later they became USB-controlled and -powered. Initially, chip programmers came with a simple suite of software: an assembler for turning assembly code into .HEX files and software that controlled the programmer. C and Basic language programming suites for PICs was available from several suppliers. As the number of chip types and complexity evolved, so the programmer device had to increase in complexity to cope with them all. Up to around 10 years ago, things stayed reasonably simple, with standalone assembler and programming software packages that were straightforward to drive. By then Microchip, in their infinite wisdom, were trying to move users to a complete package that included code writing, assembler and programmer all within one massive software package – MPLAB: a large, comprehensive, all-in suite sometimes referred to as 'bloatware'. It became really tedious and time-consuming to set up a whole new project with all its associated subsidiary files if all you wanted was a couple of dozen lines of assembly code to set a synth chip on frequency. But, fortunately, for some time afterwards the standalone simple driver packages were still there to be used. Then, around the middle of the last decade, after the PicKit-3 programmer had become established, that stopped. If you look in the catalogues and on the Microchip website you get the PicKit-4 programmer and other more advanced hardware that *has* to be used with the massive MPLAB suite and has no standalone, simple, quick-to-drive route to writing and blowing code. The PicKit-3 was declared obsolete and is no longer supported. This solution to PIC code development may well be what industry wants, but amateurs (and probably more so the 'Hackspace' and 'Maker' communities) wanted the PicKit-3 with its simplicity **[1]**.

PHOTO 1: **Three PicKit-3 programmers. The one in the middle is an original genuine Microchip product. The other two are far-eastern copies, using the same internal controller PIC and firmware, but totally different circuitry with lower levels of protection against overload and mis-connection.**

Pickit-3, clones and short cuts

Fortunately Microchip had always published the circuit diagrams for its controller and the firmware could be downloaded as a .HEX file (chicken, egg…? the PicKit-3 contains quite an advanced PIC device itself). To cope with this need among the home users, various third parties cloned the PicKit-3 programmer, which could then be used with the old driver software. I bought one such clone a few years ago and later, once I realised the Pickit-3 was obsolete, obtained two more clones to keep as backup. Both (Chinese made) clones were purchased from separate eBay sources to reduce the possibility of getting two duds. It turned out that one of the new ones was the same, as far as I could see, as the first clone of a few years ago. **Photo 1** shows my collection – the missing fourth programmer is the same as the one on the left; the genuine original Microchip unit is in the middle.

As you'd expect, when designs are copied and marketed on the cheap, short cuts are taken and construction is rarely as good as the original – in this case USA-made – product. While the basic functionality of the copies is maintained by using the same type of dedicated controller with fixed firmware, the hardware and interfacing only has to keep to the spirit and functionality of the original – and all sort of deviations and short cuts can be made so long as it works more-or-less as the original design does.

After repeated use the mini-USB connector on the two-year-old clone became intermittent. This was cured by opening it up and, rather than trying to replace the connector (which would have been difficult to remove from plated though holes), a tail cut from a surplus USB lead was soldered in. Hot glue and cable ties were used to secure the cable entry. This is the one shown on the left of the photo.

Power rails at war

The second fault that occurred almost immediately on one of the brand new programmers was more invidious, but to see

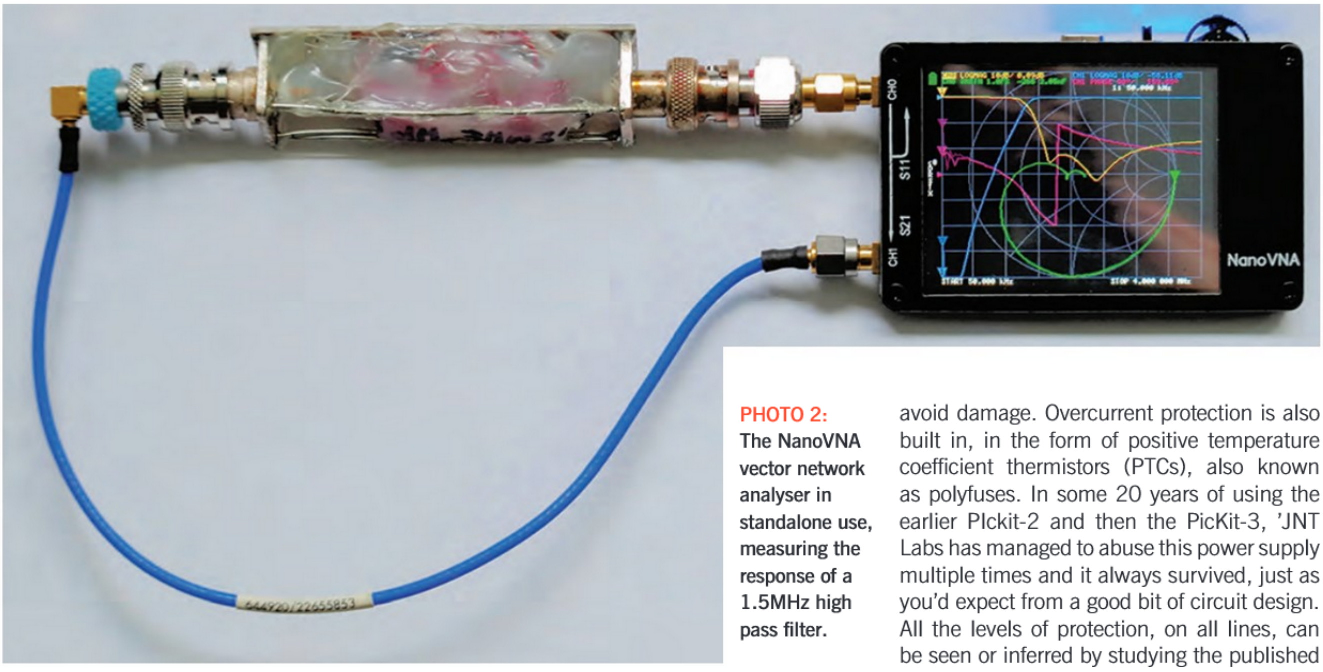


PHOTO 2: **The NanoVNA vector network analyser in standalone use, measuring the response of a 1.5MHz high pass filter.**

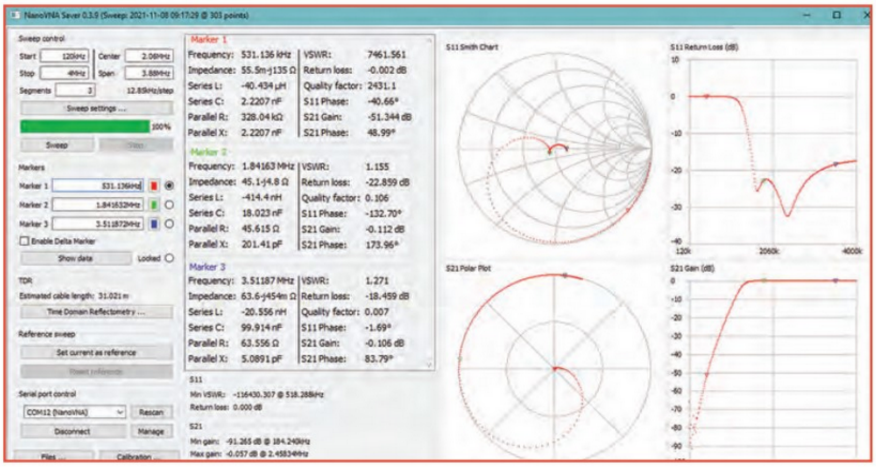


FIGURE 1: **User screen of the PC display for the NanoVNA driver software, showing the response for the filter shown in Photo 2.**

the problem first we need to look at what the programmer hardware has to do. The programming task itself involves sending the codes to the chip on two data and clock lines. But apart from this task, the programmer also has to generate two voltages. One, for putting the target chip into programming mode, is usually +12V at no more than a few microamps. This is generated from a voltage pump inside the unit. The PicKit also has to, optionally, provide a power supply for the target device and it is here that problems can arise. The target device may already be powered from its host equipment, or it may have to be powered from the programmer. The supply voltage is whatever the target chip is designed for, so its source in the programmer is made variable over the range 2.5 – 5V to match all the devices the PicKit may be asked to program. The voltage is set in the programming software and generated in the programmer by a linear regulator driven from a D/A converter in the PicKit's own controller chip. This ability to cope with powering the target from either its own supply or from the programmer at some user-defined voltage setting could be a potential recipe for disaster, with perhaps 5V at many amps being fed back into a programmer set for 2.5V. The proper Microchip designed PicKit has voltage monitoring and switching built in, so any voltage can be detected on the power supply pins and the user warned and power delivery from the programmer blocked to avoid damage. Overcurrent protection is also built in, in the form of positive temperature coefficient thermistors (PTCs), also known as polyfuses. In some 20 years of using the earlier PIckit-2 and then the PicKit-3, 'JNT Labs has managed to abuse this power supply multiple times and it always survived, just as you'd expect from a good bit of circuit design. All the levels of protection, on all lines, can be seen or inferred by studying the published circuit diagram from Microchip.

When using one of the brand new 'clone' programmers that had been set to deliver 5V, I connected the power output in parallel with the output of a voltage regulator on a target board that just happened to be set for 4.9V. The result, even though the target was unpowered, was a high current being sunk from the programmer into that lower voltage regulator. The subsequent demise of the programmer – or at least that part of the circuitry designed to supply power to the target – soon followed. But it could still program devices that were already powered. Clearly, protection components were missing in this new copy unit. So, with Microchip's circuit diagram in front of me, the case was prised apart to see what could be done.

First appearances were that the circuitry inside the clone bore no relationship whatsoever to Microchip's original and the component reference numbers printed on the PCB were best totally ignored. But after much tracing through it was possible to see where cheaper discrete SOT23-packaged FETs replaced dedicated supply drivers – they had kept, sort of, to the spirit of the design if not the actual components. Significantly, although the words polyfuse appeared on the PCB legend where the devices should go to protect against over-current, a thin piece of PCB track shorted the pads where those components should be. During the examination I spotted a small FET with a brown charred appearance that, under a

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Maidenhead Locator System

History

Description of the system

Adoption and use

FIGURE 2: The Wikipedia Maidenhead Locator System article contains some errors…

strong magnifier, showed a small crack. Tracing through, this turned out to be the device that was supposed to safely switch Vdd to power the target from the programmer. Replacing it with a P-channel device from the junk box restored full functionality. I may even fit the polyfuses one day.

NanoVNA

There is no doubt the NanoVNA Vector Network Analyser has taken the amateur radio world by storm. It has even been described as a 'game changer' when it comes to setting up antennas and filters and such. Until recently, although I had a NanoVNA, I had always considered it a bit of a standalone sort of toy, with a flimsy thumbwheel control, low resolution display and no ability to calibrate; the sort of thing you'd take outside to play with on an antenna but not for serious measurements. I never connected it to a PC. All 'serious' measurements were done with the DG8SAQ VNWA. That was until I visited Brian, G4NNS, who was setting up a 50MHz antenna. He had an identical NanoVNA, connected via a USB lead to a PC with a nice, intuitive and easy to use bit of interface software that allowed a simple straightforward calibration procedure – and gave nice plots. Somewhat to my scepticism (having fallen foul of doing this in days gone by of full time employment) the VNWA was connected to a long length of RG-213 and a calibration done at the far end of this run. The CAL procedure involved both two of us, with shouted instructions such as "connect the load" and "now connect the short". I was pleasantly surprised how stable the resulting trace was at 50MHz when this CAL procedure had been completed via fifteen metres of cable. Perhaps if the sun had intermittently come out and warmed the run of cable, that then cooled when clouds appeared, the plots wouldn't have been so stable.

As soon as I got home, a bit of Googling threw up the same driver software for the NanoVNA that Brian was using **[2]** – albeit a later version. In quite short time it was downloaded, installed and running. Operation is near enough immediately intuitive, although to be fair I did spend a bit of time looking for how to connect to the hardware. There is a button to connect at the bottom left of the user screen, labelled 'Serial Port Control', shown in **Figure 1**. It seems to be able to find the connection – a virtual COM port – all by itself by scanning interfaces.

Photo 2 shows the NanoVNA connected to a 1.5MHz high pass filter for measuring its return loss and response. The filter was designed originally for protecting an HF radio when an LF or MF high power transmitter is running in the vicinity. Figure 1 shows the screen for the driver software with the VNWA measuring the response of this filter. This is the default screen layout presented when the software is installed and appears to show just about everything you are likely to want when setting up antenna, filters or other RF systems. It is convenient that the authors of the software appear to have tried to include everything in one go, rather than hiding display setup inside user-setting menus and complex customisations. It really is a nice, well designed bit of software.

Using locators

The IARU, or Maidenhead, locator (abbreviation 'LOC') has been in use within the amateur community since the early 1980s, when it replaced the earlier 'QRA' Locator. The QRA was typically of the form ZM41f (that was my old Birmingham home QTH) and covered just Europe with pseudo-squares of latitude and longitude delivering a positional accuracy of around 4.5km. The Maidenhead Locator scheme that replaced it used codes of the form IO90IV and gave a similar accuracy of positioning. Note the exact format of each. The QRA was always written with a lower case (LC) final letter – it just *did*, no one seems to know why a lower case letter was selected for this character. The designers of the IARU locator specified a pair of UPPER CASE (UC) final letters. But unfortunately, over the years and in spite of UC being clearly called for in the IARU VHF handbook **[3]**, a lot of people just adopted the use of lower case letters for the final two, in the same manner as the old QRA. This incorrect usage has spilled over into a number of popular software packages and even Wikipedia, apart from the introductory paragraph, presently (mid-November 2021) shows the incorrect lower case representation, in spite of referring to the IARU *VHF Handbook* where the use of upper case is clearly spelt out.

As time progressed, additional characters were added to give greater precision when specifying location. Firstly two more numbers were added, such as IO90IV58, which gave positioning to around 450 metre resolution at mid latitudes; this sort of accuracy is often needed by microwavers for calculating bearings for dish pointing and accurate calculation of path distances.

Subsequently, the use of GNSS positioning became ubiquitous and anyone could find their location anywhere on the Earth to within a few metres. The Locator system was extended by adding on alternate pairs of letters and numbers, so I sit here typing this in IO90IV58AK, while the back garden is in IO90IV58AL. Each final letter 'sub-squaroid' in this format gives roughly 18 metres positioning. Since it's possible, with modern GNSS systems available to all, a final pair of numbers can be added for 1.8m positioning, such as IO90IV58AK34. Now think how daft specifying the locator using lower case letters would look: IO0iv58ak34 just does *not* look right! Now, how does one edit Wikipedia pages…?

References

[1] The more advanced DsPIC family of devices has no simple standalone programming facility and still requires the full MPLAB suite and Integrated Programming Environment to be used. Using the PicKit-3 with this setup requires different firmware to be downloaded into the programmer before use. Thus if MPLAB is going to have to be used from time to time as well as the standalone PIckit-3 utility, it is convenient to keep two separate programmers on hand, each loaded with the appropriate firmware.

[2] https://nanovna.com/?page_id=90

[3] https://www.iaru-r1.org/wp-content/uploads/2021/03/VHF_Handbook_V9.01.pdf (Locators – page 118)

Desoldering

Sometimes it's necessary to remove a through-hole component from a PCB. This can be because of failure or – heavens forfend – one has fitted the wrong part. Either way, it can be a pain. But I'd like to share a method that I only recently encountered, which can make some jobs so much easier. Forgive me if you already know about it.

The traditional way of removing solder from component is to use desoldering braid or its more recent alternative, the 'solder sucker'. With that spring-loaded device you press its plunger all the way in until there's a click and movement stops. Then, when you press the release button, the internal spring causes the plunger to move up the tube – just like a syringe in reverse – and thus suck up anything near the opening. The device is made of heat-resistant materials, the nozzle often from PTFE, which is largely unaffected by soldering temperatures – furtunate, as in use you plunge it into molten solder!

The solder sucker works best on single sided boards without plated-through holes. In use, you 'prime' the solder sucker by pressing the plunger in, then bring the end of the nozzle very close to a component lead as you simultaneously heat the joint with your soldering iron. When the solder is nice and runny, pressing the release button more or less instantaneously slurps the liquid solder up the tube. If you're lucky it will have sucked all the solder from around the component wire, but more often than not there will be a small fillet left in a plated-through hole that prevents the wire from being withdrawn, as seen in **Photo 1**. Sometimes another try with the solder sucker is all you need, but other times you have to re-solder the joint and try again from scratch. Multi-pin items such as ICs can be quite challenging to remove cleanly.

By chance I came across another approach. You can get a set of thin-wall stainless steel desoldering tubes with plastic handles, as seen in **Photo 2**. Solder doesn't stick to stainless steel and it's this property that makes these desoldering tubes so useful.

First, you need to choose the right size tube. It must be just small enough to fit in the PCB hole but just large enough internally to accept the component lead. My cheap set goes from 0.8mm to 2.0mm in 0.2mm steps, so it's odds-on that there's a near-enough size. In this particular case it was the 1.6mm tube that suited perfectly.

In use, you just fit the tube over the component lead and heat the joint while applying gentle pressure to the handle. As the solder melts you'll feel a little 'give' as the tube separates the lead from the hole. **Photo 3** shows this in action, next to a joint that had been attacked unsuccessfully with a solder sucker. Using the tube approach you end up with a nice clean gap between the component lead and the solder pad, as seen in **Photo 4**. Then all that remains is the optional step of cleaning off the remaining flux and debris. As seen in **Photo 5** I normally use an old toothbrush and a little isopropyl alcohol or methylated spirit, but there are also proprietary flux cleaners that work well.

This isn't, of course, the only way to desolder something but it's a good technique to have in your arsenal. The stainless steel desoldering tube sets aren't expensive – about the same as a low-end solder sucker – and compared to a solder sucker they come into their own when desoldering multi-legged items such as an IC or (as in this case) a PCB-mounted transformer.

Have a look on the various internet sites: I'm sure you'll be able to find a very similar set. I suggest it's a good thing to keep it in your tool kit because one day it could save you a lot of trouble.

Giles Read, G1MFG
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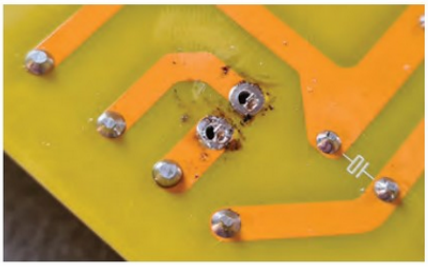

PHOTO 1: A solder sucker often leaves little fillets of solder that cling on to a component leg.

PHOTO 2: An inexpensive set of stainless steel desoldering tubes.

PHOTO 3: Slip the right size tube over the component leg as you heat the joint.

PHOTO 4: The desoldering tube can leave very clean holes and is especially useful when working on double sided boards with plated-through holes.

PHOTO 5: A final clean-up with an old toothbrush and some isopropyl alcohol (or meths) and you're good to go.

A Collaboration of Enthusiasts

Astronomy in the public mind is generally associated with visual observations and the magnificent photographs from the Hubble space telescope.

An amateur radio operator then opened the first window on the nonvisual universe and our perception was fundamentally changed. The first systematic radio observations were made by Grote Reber and amateurs continue to participate in radio astronomy. If you enjoy designing and building equipment, have software skills or an enthusiasm for encouraging others, the UK Radio Astronomy Association (UKRAA) is keen to hear from new volunteers.

The start of radio astronomy

In 1932, Carl Jansky (1905 – 1950) of Bell Telephone Laboratories in New Jersey was tasked with investigating the background noise that was affecting the long distance radio links being developed at that time. He mapped the direction this noise came from and noticed that the strongest source moved across the sky at the same rate as the stars. This was dubbed 'cosmic radio waves' in papers for the Institute of Radio Engineers. At the time, astronomers took little notice and Jansky moved on to other engineering problems. Jansky's name is now used by radio astronomers as the unit used to measure the energy received from a celestial radio source. One Jansky is 10^{-26} watts per square metre per Hertz, a very small amount of radio energy.

Grote Reber, W9GFZ (1911-2002) was the father of radio astronomy. Reber was an engineer, an enthusiastic amateur radio operator who liked to experiment, and was the first person to follow up on Jansky's work. After discovering Jansky's work, he set out to build a radio telescope. The result was a 9m dish aligned north south where the elevation of the dish could be varied to scan the whole sky as it drifted past as the Earth rotated. His observations in 1938 were at 160MHz and he published his first paper in the *Astrophysical Journal* in 1940. He continued his independent work first in Hawaii then Tasmania producing a whole sky map of signal intensity identifying several radio sources such as Cygnus A and Cassiopeia A. Reber's first telescope is now on display at the National Radio Astronomy Observatory's (NRAO) site in Green Bank, West Virginia and the NRAO Amateur Radio Club operates his callsign.

PHOTO 1: Carl Jansky (Photo courtesy NRAO/AUI/NSF).

PHOTO 2: Grote Reber's first radio telescope (Photo courtesy NRAO/AUI/NSF).

Andrew Thomas: I found that my long-standing interest in astronomy was re-energised by a chance encounter at a business conference with a self-declared 'amateur radio astronomer'. Prior to that I had no idea that such things were possible. After consulting "Professor Google" it became clear that there were simple projects which did not require extensive technical knowledge, practical electronic skills or much money. I was hooked especially as it did not involve late nights out in the cold.

My first project was to observe SIDs. I purchased a Receiver from UKRAA and built a 0.8m square loop aerial and recorded the results on an old computer. I have continued these observations and now submit my monthly observations to the BAA. This year I added a two axis Magnetometer to my observatory and record the effect on the Earth's magnetic field of solar events such as coronal mass ejections and flares.

Along the way I re-learnt how to solder and discovered the RaspberryPi and Python programming. While I make no pretence to expertise it's been great fun learning and the results are very rewarding. Radio based astronomy has spurred me on to learn and explore a new world of independent amateur science.

I became a volunteer and Trustee of UKRAA in 2019 and help to assemble and test the equipment ready for sale.

A collaboration of enthusiasts

To generalise slightly there seems to be two approach routes to radio astronomy.

- One path starts with an interest in astronomy and observing. Light pollution and the British weather combine to frustrate optical observers. Radio astronomy provides an alternative way to continue an absorbing hobby. Some astronomical societies have a radio section that helps newcomers get started.
- An alternative path starts with a knowledge of radio technology and an interest in astronomy. Radio amateurs bring an understanding of radio technology and how to build receiving equipment and astronomy is a new way to pursue an established interest.

Radio astronomy, at first sight, looks like a difficult field to enter without technical skills and knowledge. Surely a huge dish, complex radios and powerful computers are needed and it will be expensive?

I arrived with an interest in astronomy, some theoretical electrical engineering knowledge of radio but no practical experience of electronics or programming. The internet has lots of information, receiver designs, reports of completed projects, photos of home-made antennas. All of which was helpful but raised more questions.

What got me started was UKRAA's VLF Receiver and associated accessories. This makes up a complete starter kit that only needs to be connected to a computer to start producing real data and observations.

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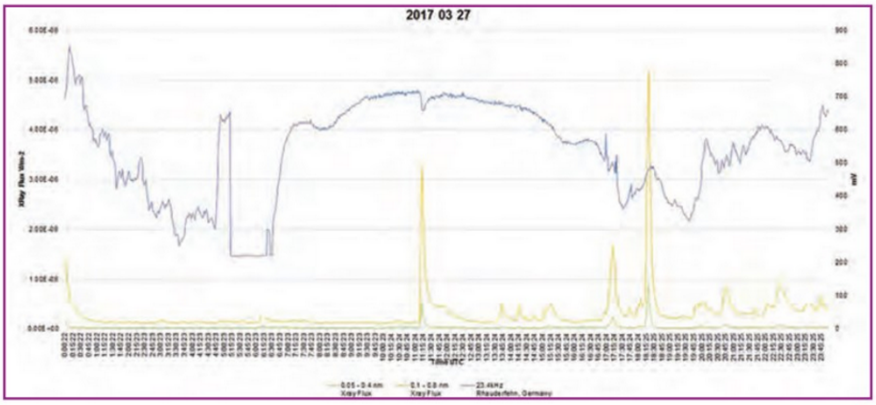

FIGURE 1: **VLF reception over 24 hours showing a Sudden Ionospheric Disturbance (SID) (courtesy of the author).**

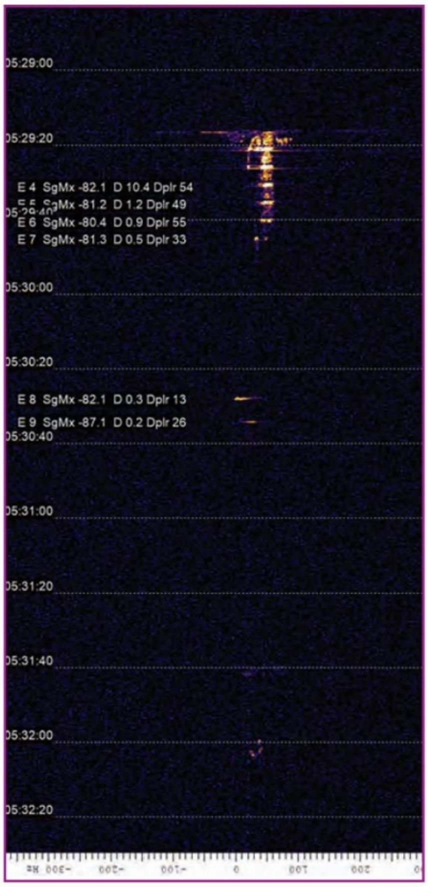

FIGURE 2: **A meteor echo from the GRAVES transmitter showing the signal pulses (courtesy of the author).**

There are many ways the radio amateur can help radio astronomy such as:

- Electronic and practical skills for building equipment, connecting up antennas, and using test equipment.
- Hunting down interference. For example, surveying a site to see if there is too much local interference to carry out specific observations.
- Electrical and mechanical safety. Especially the earthing of aerials and equipment.

These may be everyday things for radio amateurs but to many astronomers they are a mystery.

If I have piqued your interest, do consider getting involved. A good place to start would be to contact your local astronomy society and see what they are doing. When I talk to astronomy societies I often find that they are interested but are uncertain how to start and would appreciate assistance with the technology. There seems to be an opportunity for co-operation between radio and astronomy societies.

The radio sky

Astronomy is one of the sciences where amateur observers can still make contributions to our knowledge. There are a lot of areas of interest and targets to observe: the Sun, Jupiter, mapping the hydrogen in the Milky Way, pulsars and cosmic rays but there is insufficient space to look at all of these in deep technical detail.

The Sun: Observing Sudden Ionospheric Disturbances (SIDs) is a good starting point and can work very well as a school or club project. The equipment is simple, low cost and the antenna can be a simple DIY project. The new 11-year solar cycle has started and I anticipate the number of events to increase significantly after the recent solar minimum.

The chart in **Figure 1** shows the clear signature of a SID 'shark fin', in this instance it is upside down. The orange trace shows the strength of the solar X-rays measured by NASA's GOES satellite. The spike in X-rays emitted by a solar flare can be clearly seen at just after 11:00. There was an even larger spike at approximately 18:30 that did not cause a SID. This is because it occurred after the Sun had set and the X-rays were invisible and had no effect on the ionosphere.

Meteors: Some of the earliest observations made by Lovell at Jodrell Bank were of meteors detected using a military surplus radar set. Meteors can be detected in the same way using the GRAVES space radar operating at 143.05MHz in France or the BRAMS beacon operating at 49.97MHz in Belgium. Observations in the UK are collated by the observing community at radiometeordetection.org. Although the GRAVES signals can be received all over the UK the nature of the pulsed and scanned signal makes it difficult to accurately time events. BRAMS is a continuous carrier wave beacon and allows events to be timed accurately and collated between different observers, unfortunately its low power restricts

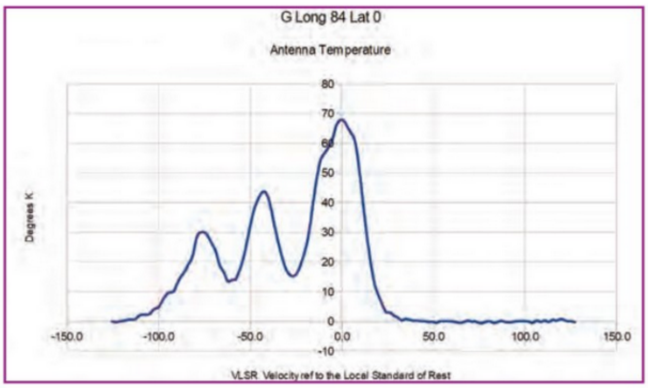

FIGURE 3: **21cm signal at Galactic longitude 84° latitude 0° (courtesy of Brian Coleman).**

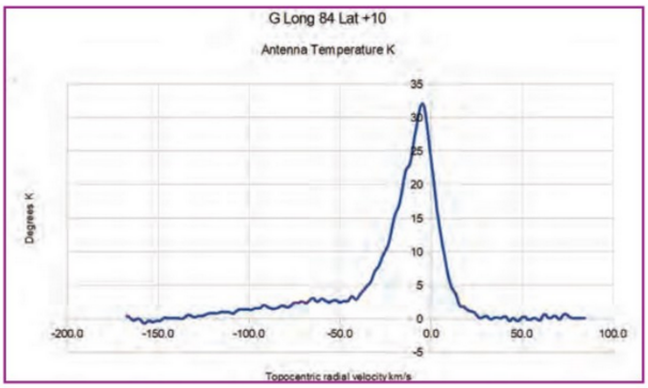

FIGURE 4: **21cm signal at Galactic longitude 84° latitude 10° (courtesy of Brian Coleman).**

Brian Coleman, G4NNS: I've had a lifelong interest in radio, starting with a crystal set. I took my amateur radio exam in 1964. After a chance visit to a junk yard where a supply of waveguide parts was obtained. I became fascinated by microwave radio. Exploits onto 10GHz using Gunn diode transmitters with wideband FM led to carrying equipment to the tops, first of hills then mountains to maximise range.

I made my first parabolic dish with fibreglass and baking foil over a mould formed with plaster of Paris using a wooden template to sculpt the parabolic profile. Years later when a precision 3.7m dish became available and I had the space to put it, I started out on Earth-Moon-Earth communications (EME) where the Moon is used as a passive reflector to extend range far beyond the normal radio horizon. Receiving the very faint echoes from the Moon against the background noise of the Galaxy makes an interest in radio astronomy inevitable. After completing the Introduction to Radio Astronomy distance learning course with the University of Manchester I set about building the hardware to use my antenna to map the hydrogen in the Galaxy.

PHOTO 3: Brian Coleman's current antenna (Photo courtesy of Brian Coleman)

reception to eastern parts of England. Perhaps one day there will be a UK meteor detection beacon?

Galactic observations: Hydrogen is the most abundant element in the Universe and radio astronomy allows us to detect and map the hydrogen clouds in our own Milky Way Galaxy. Hydrogen radiates at 1421MHz (21cm) and these signals can be received with modest equipment using a Yagi or small dish antenna. By pointing the antenna due south over 24 hours the signal strength over a strip of sky can be measured. Adjusting the elevation of the aerial will measure the next strip of sky. Slowly over time a map of the whole sky at 21cm can be created.

A more advanced observation measures the Doppler shift of the 21cm signal and Brian Coleman has provided an example of his observations made with the dish seen in **Photo 3**.

The two plots in **Figure 3 and 4** indicate the amount of hydrogen in the beam of the telescope, measured by the antenna temperature and the distribution of velocity of the hydrogen. In space everything is in motion. When taking measurements we correct for this motion and measure Velocity referenced to our Local Standard of Rest (VLSR on the graphs). For both plots the antenna is pointing at the Milky Way in the direction of the star Deneb.

Figure 3 is looking into the plane of the Milky Way (Galactic Latitude 0°) and shows three peaks corresponding to three 'arms' of our spiral galaxy. By measuring the shift in frequency it can be seen that some of the gas clouds are moving towards the Earth as the Galaxy rotates and others are moving at the same velocity relative to the Earth. The largest peak is from the local hydrogen in our arm of the Galaxy within about 5000 light years, which is not moving towards or away from Earth. In astronomy, objects moving away from us are red shifted with a '+' sign and objects moving towards us are blue shifted with a '-' sign.

Figure 4 is looking above the plane of the Milky Way (Galactic Latitude 10°). Two of the peaks from the other 'arms' have disappeared and just the local hydrogen remains in the beam. The peak is narrower, indicating that there is much less hydrogen as we look even just 10 degrees out of the plane of the Galaxy. This indicates that our Galaxy is very thin. The Wikipedia article about the Milky Way has excellent graphics explaining the spiral arms and co-ordinate system.

John Berman: Head Echo's, never thought I would be using words like that. As an ex Royal Signals Radio Telegraphist I learnt an awful lot about radio communications and spent hours tapping away at the Morse key. Wind forward many years and I was introduced to the world of visual astronomy, which was fascinating. This then progressed to astrophotography and I persevered and obtained reasonable images. Whilst I thoroughly enjoyed this, the combination of light pollution living in South London and clouds really restricted me and short of moving to the Atacama Desert I needed an alternative way to enjoy my astronomy.

Welcome to radio astronomy! Clouds and light pollution, who cares? Here is a way to be involved in astronomy all year round and you don't need to be outdoors in the middle of the night. There are many areas of radio astronomy, hydrogen line, meteor reflections, pulsars, Radio Jove and VLF to name a few, all looking at different areas and more importantly all within reach of the amateur in terms of both cost and knowledge required. There is a huge amateur community whose experiences ranges from the novice to the expert, but all are willing to share their knowledge.

Having successfully captured a Geminid on my camera many years ago, meteor reflection was an obvious choice and some five years later I'm collaborating with a number of like-minded individuals. I continue to learn and in addition I'm now working on a Muon Detection Project but that's a topic for a different time.

About the UK Radio Astronomy Association (UKRAA)

The UK Radio Astronomy Association was established in 2008 as a registered charity (registration no 1123866) by the British Astronomical Association's Radio Astronomy Group (RAG). UKRAA's objectives are to promote the science of radio astronomy and all branches of radio astronomical research.

Prior to UKRAA's formation, RAG members had designed and built working protypes of a VLF Receiver and Magnetometer. The UKRAA was set up to handle the manufacture and sale of these products and the production of technical manuals covering the use and the background science. (Online store at www.ukraa.com. There is an extensive range of VLF receiver equipment, a magnetometer and E-Field active antenna. UKRAA is also an authorised distributor of LabJack's U3-HV multifunction data acquisition module. UKRAA sells books on radio astronomy suitable for all levels.)

To promote radio astronomy to amateur astronomers we give talks to local Astronomical Societies and amateur radio clubs and have provided support to schools and university departments on educational projects. UKRAA is a not-for-profit business. Any surplus income funds the development of new products and our outreach activities. To keep our prices low UKRAA relies on the volunteers and directors giving their time. To date UKRAA has sold in excess of £46,000 of radio astronomy equipment.

Volunteers: This is where we can collaborate. UKRAA needs new volunteers to help develop new projects and to build and test the existing products. If you can contribute in these areas of expertise they would be delighted to hear from you:

- Electronic assembly of through-hole and surface mount components
- Experience with fault finding electronic circuits would be valuable
- Expertise in the design of electronic circuits
- Software development in Python for the Raspberry Pi. This is to assist with the development of data logging software.
- Precision wood working to make up aerial kits and assembled aerials
- Machining and mechanical assembly to make up enclosures.

Further Information

- The British Astronomical Association has a Radio Astronomy Section at www.britastro.org
- The Society of Amateur Radio Astronomers is a US based organisation with international membership. Their website has a wealth of information on projects. See www.radio-astronomy.org
- Cosmoquest, www.cosmoquest.org/ hosts the '365 Days of Astronomy' podcast. There is an episode about Grote Reber at www.cosmoquest.org/x/365daysofastronomy/2009/08/31/august-31st-grote-reber-the-first-radio-astronomer
- Brian Coleman's website www.brcg4nns.org describes his projects and equipment
- John Berman runs the Radio Meteor Detection Collaboration Project at www.radiometeordetection.org

Elecraft K4D

HF & 50MHz transceiver

After an extended period in development, the Elecraft K4 Transceiver is now available .

The Elecraft K4 front view is dominated by the display and this is central to the whole operation of the radio. At 7 inches diagonal in size, it is a full colour high-resolution LCD touch screen.

There are two fans recessed into the rear panel as well as many of the connectors. Those provided are very comprehensive using traditional connector types.

The Elecraft K4 transceiver was first unveiled at the Dayton Hamvention during May 2019. Aimed as a class-leading radio and the successor to the highly acclaimed and long-standing K3 series, it attracted a great amount of interest and many advance orders were placed with a projected release date later that year. However, the arrival of the Covid pandemic and the difficulty in obtaining key semiconductor chips scuppered these plans and delayed the start of deliveries until the spring of 2021. With a significant backlog of orders, radios are now arriving and I was fortunate to gain access to a sample to conduct this review.

It is still early days. The firmware used in the radios is under continuing development and review. Some of the functions and features are not yet fully implemented, as noted in the following paragraphs. As these become available, firmware upgrades are released and these are currently quite frequent. This review relates to the situation in October 2021 mainly with firmware version R19.

The K4 line-up

The K4 radio is available with a number of options. The basic radio is a direct sampling SDR transceiver covering the HF and 50MHz bands with a single 16-bit A-to-D converter and a single set of receiver front end filters. It has dual receive capability but the second receiver is somewhat limited as it shares the same filters and antenna as the main receiver. The K4D, which is the version reviewed, has a second set of front end filters and a second ADC and can provide two totally independent receivers using separate antennas to provide functions such as diversity reception. For the ultimate in signal handling, the K4HD provides a front end superhet module with narrow bandwidth roofing filters at 8MHz in a similar fashion to the hybrid SDR approach adopted in the Yaesu FTDX101 and some other high-end radios. As of October 2021, the K4HD is not yet available. The basic K4 can be upgraded at a later date to the K4D and similarly the K4D to the K4HD by user-installing the appropriate modules.

The K4 series can be provided with 10W transmit output power or with 100W output, and a wide range internal ATU is also an available option. This will match antennas with VSWRs up to 10:1. Space remains inside the cabinet to install a future VHF/UHF transverter module but details of this have yet to be announced.

A microphone is not provided with the K4 but the MH4 hand microphone is available as an accessory. Any microphone used with the earlier K3 and K2 series, such as the MH2, may also be used and pinning is compatible with Kenwood radios. The SP4 external speaker is also available and fully complements the K-line style. Use two speakers for the two receivers for the ultimate in luxury. Other K-line matching accessories include linear amplifiers for 500W or 1500W output and a separate K-Pod desktop controller. The K-Pod provides a high precision rotary controller similar to the main tuning drive and eight dual function programmable buttons.

The K3 series radios were available in a no-soldering kit format at reduced cost. A similar approach is planned for the K4 at a future date.

Basic functions

The K4 operates from a nominal 13.8V supply. It measures 355mm(w) x 132mm(h) x 317mm(d), including projections, with a tilting bail stand and weighs about 4.5kg. This is somewhat wider than the K3 but similar in height and depth. The receivers both tune from 100kHz to 54MHz and transmitter operation is limited to the amateur bands. The transmitter covers the US frequency allocations, ie to 4MHz on 80m and 7.3MHz on 40m and a particularly wide coverage on 60m of 5.0 – 5.6MHz.

Modes provided include USB/LSB, CW/CWreverse, AM and FM. There are four data modes. DATA and AFSK are audio based with AFSK optimised for RTTY. FSK and PSK use direct keying from a computer or a keyboard. PSK31 or PSK63 is accommodated and 45baud or 75baud on RTTY. Excellent facilities for data mode operation include dual-tone filters and display decoders for CW, RTTY and PSK modes. FM operation includes repeater shifts (not yet fully implemented) and CTCSS or DTMF tones.

The radio has the usual twin VFOs with

K4 top view with cover removed showing the PA, ATU and single board computer.

A/B switching and split frequency operations. VFO A controls the main receiver and VFO B controls the sub receiver. Both receivers have separate tuning knobs and independent and separate settings for all filtering and other functions.

Transverters are very well supported with the K4. In addition to the internal transverter when fitted, up to 12 external transverters are supported. Final frequency readout can be up to 99GHz, with 5mw of IF drive power and adjustable error offset. IF drive can be in the range 100kHz to 54MHz and this could also be used as a transmit drive source for the LF bands. The K4D can also provide independent dual receive from two external transverters or one with the HF signal.

The K4 is provided with a printed get-you-started manual. 43 pages in length, each page has a full-size colour panel view with brief instructions on which control to set and this is indicated on the picture. I found this really useful for initial setup. The full manual is shown on the front panel display and is accessed by a dedicated button. It is also available on the Elecraft website. Although largely complete, it is very compactly written and not very easy to find wanted information particularly if this is rather obscure. Word searching is usually needed as there is no index.

Front panel and controls

The radio is contained in a sheet aluminium case with modules and circuit boards accessible via the top or the bottom. The 65mm square built-in speaker fits in the top. It is quite chunky but there is no enclosed surround or acoustic wadding.

The front panel is dominated by the display and this is central to the whole operation of the radio. At 7 inch diagonal in size, it is a full colour high-resolution LCD touch screen and is very eye-catching. The main tuning knob is smooth to operate and is 50mm in diameter with finger ident. The smaller sub tuning knob is 25mm in diameter. Both will allow between 100 and 400 steps per revolution and tuning step sizes from 1Hz to 100kHz by simply touching the appropriate decade digit on the frequency display. Another rotary control sets the offset for RIT and XIT and some other functions. Three smaller rotary controls have multiple functions and set the receiver bandwidth, gain and squelch levels, transmit power and CW keying characteristics. Operation of the rotary controls and some of the pushbuttons is fairly similar to the K3.

Control of the remaining functions is shared between physical pushbuttons and context-sensitive soft keys on the display. Unlike the scrolling keys on the K3, band and mode selection is now accessed via a matrix grid on the display. Band stacking of three settings is available for each band. Eight soft keys along the bottom access many of the functions for the main and sub receivers, transmitter, display, menu and manual. Currently there are 73 selectable settings in the menu list. In addition to the touch screen, it is also possible to select items using a mouse plugged into any of the USB sockets. The mouse wheel can also be used to tune the radio or set any of the adjustable functions and sliders.

The display indicates the frequency of both receivers at all times together with associated bargraph S-meters and a multitude of messages, labels and icons. If not selected, the sub receiver frequency is dimmed. The panadapter is a key feature of the K4. It can display the spectrum and waterfall of one or both receivers simultaneously and has a host of setting possibilities. This includes the span width from 5kHz up to 368kHz, a wide range to the amplitude scaling in dBm or S-units, display averaging, peak hold, and noise blanking. The settings can be different on different bands and it is also possible to have the panadapter display on an external monitor with different settings to the main display. How the panadapter span relates to the VFO frequency can be set in several different ways such as tracking the VFO or how it responds when a span edge is reached.

Another useful feature of the panadapter is the Mini-Pan window. This window is displayed in place of the relevant S-meter and shows a narrow range of spectrum at higher resolution centred on the VFO frequency and is used to aid the fine tuning of signals.

Rear panel

There are two fans recessed into the rear panel with four step speeds increasing as the temperature rises. Apart from the microphone, headphones and a USB-A socket, all remaining connectors are located on the rear panel. The connections provided are very comprehensive using traditional connector types and avoid awkward to use items such as mini-DIN. There is no key jack on the front panel but twin jacks are on the rear for straight keying and for paddles. Headphone and microphone jacks are duplicated on the rear together with external speaker, audio line in and line out, and are stereo for the two receivers. Headphones and speaker can also be used at the same time. Jacks provide linear amplifier switching and PTT control from typically a foot switch.

The RF connections are very comprehensive. There are three SO239 antenna sockets with a fourth that will be used for VHF when the internal transverter is fitted. BNC sockets provide an input for a separate receive antenna and output to a separate receiver or alternatively to insert an inline external filter. Two more BNC sockets provide for external transverter IF input and output

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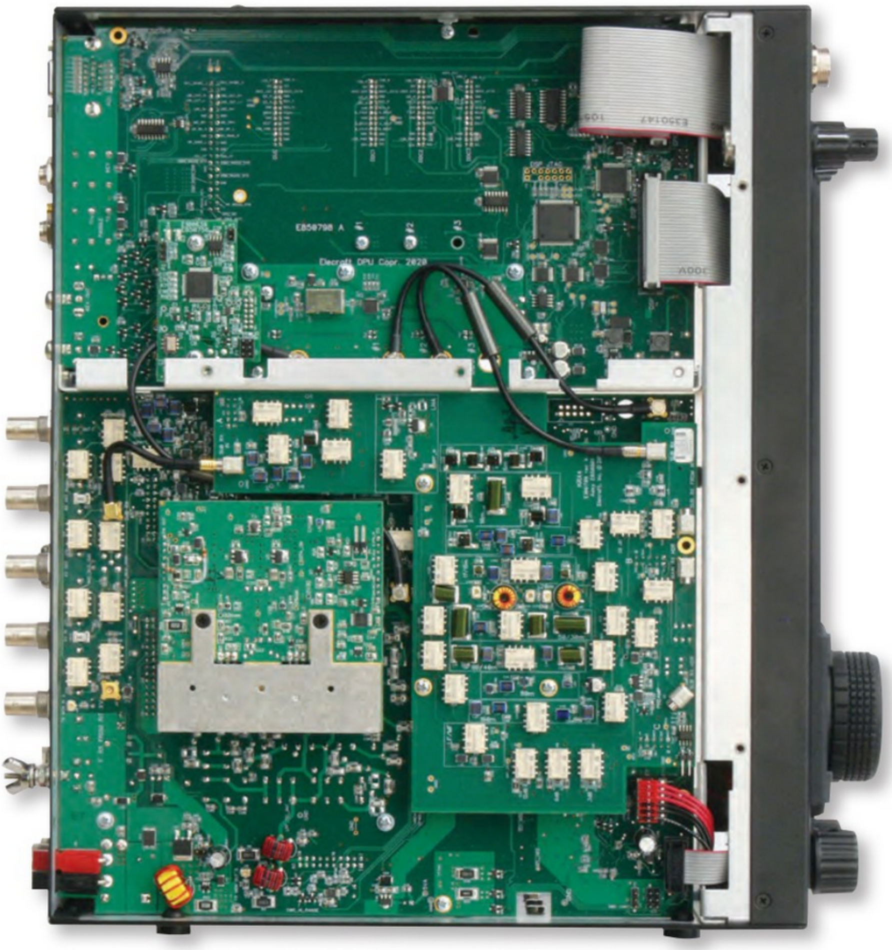


Elecraft K4 bottom view with cover removed showing main processing boards and 2nd receiver filters.

or the input can also be used for another receive-only antenna. The antenna feeds to both receivers can be set independently to any of the antenna inputs with settings stored separately for each band. Similarly the transmitter output can be set to any of the three antenna sockets per band. This really is a very comprehensive arrangement but can take some time initially to set up.

There are a total of three type-A USB jacks to connect a mouse, keyboard, memory stick or the K-Pod and a type-B USB jack to connect to a computer for radio control and soundcard I/O. Two virtual COM ports are automatically created when connected. An Ethernet port connects to a router or modem for full remote operation and firmware updating and an HDMI video connector allows an external monitor to be used. An RS232 connector provides alternative interfacing to a PC for control purposes.

A 15pin D-series accessory connector (as used in PCs for VGA video output) provides a host of I/O lines including band data, transverter control, FSK input, ALC etc. Although the radio includes a high performance TCXO claiming 0.25ppm accuracy, an external 10MHz reference can also be used as an alternative. For linear amplifiers suitably equipped with linearisation feedback, there is a sampling input for this purpose but this is still to be implemented.

Receiver features

The usual receive functions are all provided in a similar fashion to most other recent radios. There are 200 easily accessed and name-labelled memory channels and four quick access memories per band. Name labelling brings up the on-screen keyboard but an external keyboard can also be used. Scanning functions are planned but not yet implemented.

To accommodate different signal levels, the front end has two switchable preamplifiers and a third for the highest sensitivity on 24MHz and above. Also provided is a front end attenuator up to 21dB in 3dB steps, and RF gain and squelch controls. There are two settings for AGC, fast and slow, as well as off and the AGC is fully adjustable for decay rate, threshold, hold time and slope. A noise pulse rejection mode prevents AGC desensitisation on noise pulses. A fully adjustable noise blanker is included as well as a noise reduction system. Auto-tracking and manual notches are also provided and both can be used together on SSB. To improve strong signal intermodulation characteristics, dithering and randomisation is applied to the A-to-D converter. This results in a small reduction in sensitivity but can be switched off if needed.

There are three preset quick-select settings for the channel filtering bandwidth, stored separately for each mode. Each filter can be adjusted for bandwidth and shift or alternatively the upper and lower passband positions and the setting is displayed at all times. The bandwidth on all modes can be set as low as 50Hz and as high as 5kHz. On CW, a narrow bandwidth audio peaking filter is selectable with a bandwidth of 30Hz or 50Hz.

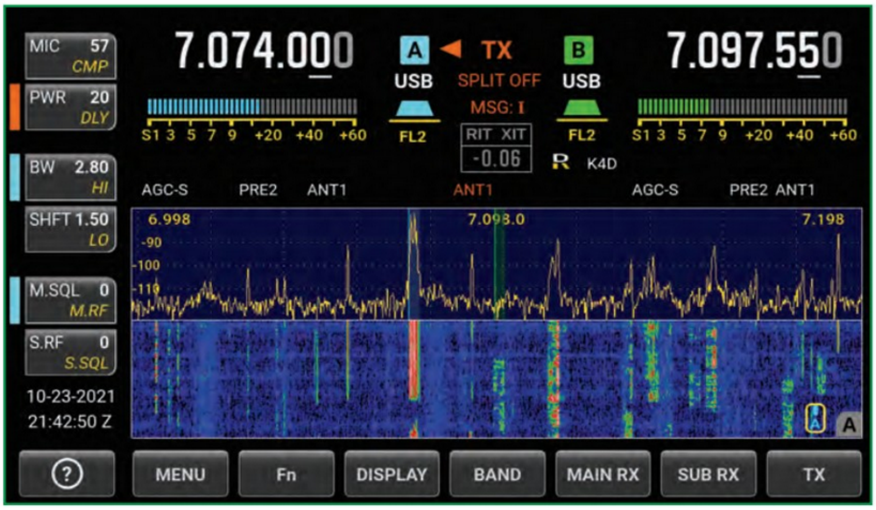
The passband can be tailored to suit using an 8-band graphic equaliser. Special audio effects can also be selected to ease copy in difficult situations when using stereo headphones. This includes simulated stereo and audio pitch mapping. Pitch mapping is particularly helpful on CW, spreading the audio signal from left to right according to pitch and can help with copying signals in pile-ups and reduce fatigue. Diversity reception can also be used with the K4D by using two different receive antennas connected to the two receivers and copying on stereo headphones. Again this can help in difficult situations.

Decoders for CW, RTTY and PSK modes are built-in. This displays either one or three lines of received text and a single line for the transmitted text with 62 characters per line. With an external keyboard connected, keyboard sending on CW, RTTY and PSK is also provided.

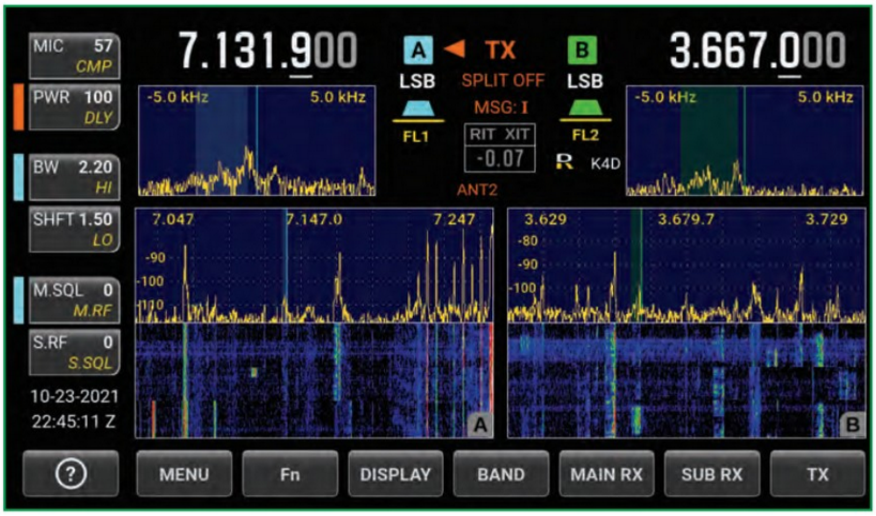
Transmit features

Transmitter power output is variable over the range from 100mW to 100W nominal and below 10W the high power PA is bypassed. The power control is very smooth and has excellent resolution, particularly at the lower levels. Separate power settings per band can be stored and when an Elecraft linear amplifier is also used, separate per band settings with amplifier on and amplifier off are also stored.

VOX, speech processor and a transmission monitor are provided on SSB and an 8-band graphic equaliser similar to that used in the receiver. On CW there is the usual provision for full and semi break-in with a front panel control for drop-back delay. A tune button provides a CW output on any mode at the set level or an alternative lower power level for ATU tuning purposes.



Display with single panadaptor.



Display with dual panadaptors and dual MPAN.

On transmit, the receiver S-meter is replaced by separate bargraphs displaying power output, antenna SWR, ALC and on voice modes, the compression level. Transmit/receive switching uses PIN diodes and hence is totally silent.

A built-in CW keyer operates over the range from 8 to 100wpm with a front panel speed control and adjustable weighting. Eight message stores are provided, each holding up to 60 characters. Messages can be chained and set to auto-repeat. They are programmed either from the on-screen keyboard or an external keyboard. Prosigns (eg "AR") can also be entered. The same message buttons used for the CW stores are also used for RTTY and PSK data modes in a similar fashion but on SSB this feature, the digital voice recorder, has not yet been implemented in the firmware. It will also allow recording of the receiver audio.

Measurements

The full set of measurements is shown in the table. The K4 is a little less sensitive than most radios but still entirely satisfactory for the HF bands. Most modern radios are generally more sensitive than they need to be. On the upper bands, use preamp 3 when band conditions are quiet. The sensitivity figures were measured with the dynamic range optimisation (dithering) enabled, the default option. With this switched out, sensitivity improves by about 2dB. If both receivers are active on the same antenna input the sensitivity reduces by about 3dB. The sensitivity remains flat from 1.8MHz down to 100kHz providing the receiver does not share the same antenna input as the transmitter. It was noticed in measuring sensitivity that there is a downward slope across the audio passband of about 7dB with low-level signals below AGC control.

It is difficult to give a precise figure for S-meter readings as the bargraph dwells for about 3-4dB at each bar level. Results centre around 50μV for S9 on most bands with about 5dB per S-unit and very linear up to 60dB over S9. The S-meter reading was constant, independent of the preamp setting. ADC overload occurred at about +10dBm with preamp off, -1dBm with preamp 1, -8dBm with preamp 2 and –21dBm with preamp 3, suggesting preamplifier gains of 11dB, 18dB and 31dB respectively.

Receiver spurious responses are extremely low: I could find none of significance. The AGC system is highly configurable but the default settings gave a good compromise with minimal overshoot but a small hole on the attack. Decay times were 200-500ms in the fast setting and 1-4s in the slow setting.

As with most direct sampling receivers, low-level intermodulation products appear when input signals are around 40dB below the ADC overload level and remain just a few dB above the noise floor as input levels increase until the overload level is approached. Enabling dither and randomisation in the ADC (dynamic range optimisation) removes these low-level products but degrades sensitivity slightly. In this situation, the intermodulation dynamic range measured 99 to 100dB in 500Hz CW bandwidth at all signal spacings even very close-in below 2kHz. This figure was consistent across all bands. With the dynamic range optimiser switched out, similar figures were measured if the low level products are ignored. In real-life situations and normal antennas, these low level products are masked by band noise except perhaps on the highest bands. These dynamic range figures are similar to other direct sampling radios using 16-bit ADCs and only bettered by the highest performing radios with superhet-based frontends. This is where the K4HD should score when available.

The reciprocal mixing phase noise figures are extremely good, slightly better than the K3S and only bettered close-in by the FTDX101. This allowed the channel filter skirts to be measured down to –80dB. At this level, the filter skirts are widening significantly and prevented measurement of reciprocal mixing at 1kHz offset. On really strong CW signals, bleed through into the opposite sideband can be heard.

The transmitter results are given for the power control set to maximum at 110W. Intermodulation products improve slightly at the 100W level. The speech compressor significantly worsens the third order products but the wideband products remain unchanged. The CW rise and fall times measured about 4ms with minimal distortion but with a slight lengthening of characters more noticeable at higher speeds. There are no first character problems with shortening

On screen keyboard display.

or power overshoot at any level. Full and semi-break-in give the same results. There is a menu-settable delay on keying (5-25ms) to allow for linear amplifier switching and the RF is correctly sequenced. The transmit composite noise output is very good but not quite as low as the K3S.

On-the-air performance

Initial impressions on using the radio for the first time are very positive with its colourful eye-catching display and user-friendly layout. It is a radio that needs some time to fully appreciate all its features and time spent learning how to use and access the various functions is essential. If you are a previous K3 user, the learning phase will be shorter as many of the controls are similar in concept and use. The introductory manual is a good first start but the full operating manual is quite clumsy to use. I found this more convenient to access as a pdf file on a separate PC rather than on the display. Another source of information and user help is to join the K4 Groups.io email group. This is a very active group and a great source of information and help from real experts. Elecraft founders Wayne Burdick, N6KR and Eric Swartz, WA6HHQ actively pursue issues and the Elecraft team address updates to the firmware when needed.

It takes 25 seconds from switching on before the radio is ready to use. Also there is a short delay of 6 seconds when switching off. I also noticed a slight delay responding to some key presses and a 5 second delay when headphones are unplugged before audio returns to the loudspeaker.

Once through the learning phase I found the radio is easy and a delight to use. The controls are well laid out, are of a good size and the tuning drives are excellent. The display is stunning and the panadapter screens are very clear and easy to use. They can show a large and accurate display range of over 100dB and can view signals well down to the noise floor. Although the touch-screen operates well, I generally preferred to use a mouse to access the display functions as it is more accurate to position than a finger. An external display screen can also be very helpful and this can display different information from the display on the radio, in particular different panadapter views.

In terms of performance the receiver was superb, quiet, yet sensitive and clean sounding with no trace of overload on strong signals. The audio quality was good particularly with headphones. The internal speaker was acceptable but somewhat restricted on bass response and I noticed some resonances on CW. Clean sounding results were achieved down through the broadcast bands to 100kHz. The filtering functions, notches, noise blanker and noise reduction all performed well and as expected. The CW filters were excellent; there was minimal ringing right down to 50Hz bandwidth, although skirt width might be an issue.

I was particularly impressed with the audio effects when used with headphones. Pitch mode on CW was very effective at spatially spreading the audio with multiple signals or QRM within the passband. Delay mode on SSB created an interesting presence to the signal. Difficult to describe, it needs to be heard to appreciate.

On transmit, the audio quality was good using an Elecraft MH2 microphone and can be tailored to suit needs. The compressor added some punch but was not particularly effective. CW QSK was very effective, very quiet with no changeover relays and clean in operation. The fans are very quiet, only operating when the heatsink temperature rises and with four speeds. I never experienced the fans operating at the higher speeds.

I connected the radio to my PC using the USB interface with no problems and used it with my main station log, Logger32. It also connected to WSJT-X and I had it running on FT8 with the audio lines connected via USB virtual COM ports.

During the course of this review there were two firmware upgrades released, R26 being the latest. These are very easy to install, simply by connecting the radio by Ethernet to your home router, or as in my case via the Ethernet port on a Wi-Fi range extender, and push the relevant buttons on the radio to install. That's it, no additional software needs to be installed or downloaded. Alternatively the firmware can be upgraded by downloading from the Elecraft website to a memory stick and installing via USB.

Conclusions

The K4 is indeed a very impressive radio. An excellent performer with very well implemented functions and a superb display, it is destined to take over from the K3S as the radio of choice for many DX enthusiasts, DXpeditions and contest stations. With some of the functions and features still to be finalised, it promises a great future. Still with a significant backlog of orders, Waters & Stanton is the UK agent, with prices starting around £4250 inclusive of VAT.

Acknowledgements

I would like to express my gratitude to Waters & Stanton for the loan of the Elecraft K4D for review.

First UK Demonstration

In September 2019, Eric Swartz, WA6HHQ gave the very first UK demonstration of the K4 at the premises of Waters & Stanton Ltd in Portsmouth. He then went on to demonstrate the K4 at the National Hamfest later that month. You can view a video of his talk on the Waters & Stanton YouTube channel, www.youtube.com/watch?v=r-PHL68WIdg&t=590s.

In 2020, Eric was the keynote speaker at the Online RSGB Convention. You can view that talk about the origins of Elecraft and the development of the K4 at www.youtube.com/TheRSGB.

Elecraft K4D Measured Performance

Receiver measurements

Frequency	Sensitivity SSB 10dBs+n:n Preamp Off	Preamp 1	Preamp 2	Preamp 3
1.8MHz	2.0µV (-101dBm)	0.63µV (-111dBm)	0.35µV (-116dBm)	-
3.5MHz	2.0µV (-101dBm)	0.63µV (-111dBm)	0.35µV (-116dBm)	-
7MHz	1.3µV (-105dBm)	0.40µV (-115dBm)	0.22µV (-120dBm)	-
10MHz	1.4µV (-104dBm)	0.40µV (-115dBm)	0.20µV (-121dBm)	-
14MHz	1.3µV (-105dBm)	0.32µV (-117dBm)	0.22µV (-122dBm)	-
18MHz	1.6µV (-103dBm)	0.56µV (-112dBm)	0.82µV (-118dBm)	-
21MHz	1.8µV (-102dBm)	0.70µV (-110dBm)	0.40µV (-115dBm)	-
24MHz	3.2µV (-97dBm)	0.90µV (-108dBm)	0.22µV (-120dBm)	0.09µV (-128dBm)
28MHz	2.2µV (-100dBm)	0.70µV (-110dBm)	0.32µV (-117dBm)	0.10µV (-127dBm)
50MHz	4.0µV (-95dBm)	0.90µV (-108dBm)	0.40µV (-115dBm)	0.13µV (-125dBm)

Max audio at 1% distortion: 1.3W into 4Ω
Inband intermodulation products: better than -60dB

Bandwidth Set To	Bandwidth -6dB	-60dB	-70dB	-80dB
USB 2.4kHz	2434Hz	2759Hz	2786Hz	5922Hz
CW 500Hz	495Hz	813Hz	839Hz	867Hz

Frequency Offset	Reciprocal Mixing Dynamic Range 500Hz Bandwidth 7MHz	21MHz
1kHz	see text	not measured
2kHz	116dB (-143dBc/Hz)	115dB (-141dBc/Hz)
3kHz	117dB (-144dBc/Hz)	116dB (-143dBc/Hz)
4kHz	119dB (-146dBc/Hz)	118dB (-147dBc/Hz)
5kHz	120dB (-147dBc/Hz)	119dB (-149dBc/Hz)
10kHz	125dB (-152dBc/Hz)	122dB (-151dBc/Hz)
15kHz	128dB (-155dBc/Hz)	123dB (-151dBc/Hz)
20kHz	129dB (-156dBc/Hz)	124dB (-151dBc/Hz)
30kHz	ADC overflow	125dB (-151dBc/Hz)
50kHz	ADC overflow	ADC overflow

Transmitter measurements

Frequency	Max CW Power Output	Harmonics	Intermodulation Products wrt PEP 3rd order	5th order
1.8MHz	114W	-55dB	-32dB	-36dB
3.5MHz	122W	-62dB	-34dB	-36dB
7MHz	121W	-70dB	-34dB	-36dB
10MHz	121W	-70dB	-48dB	-35dB
14MHz	120W	-50dB	-32dB	-39dB
18MHz	119W	-75dB	-32dB	-38dB
21MHz	119W	-75dB	-32dB	-42dB
24MHz	121W	-75dB	-32dB	-35dB
28MHz	120W	-80dB	-43dB	-36dB
50MHz	103W	-80dB	-27dB	-38dB

Intermodulation product levels are quoted with respect to PEP

Frequency Offset	Transmit Composite Noise 7MHz 100W O/P	Transmit Composite Noise 21MHz 100W O/P
1kHz	-74dBm/Hz (-124dBc/Hz)	not measured
2kHz	-80dBm/Hz (-130dBc/Hz)	not measured
3kHz	-87dBm/Hz (-137dBc/Hz)	not measured
4kHz	-90dBm/Hz (-140dBc/Hz)	not measured
5kHz	-91dBm/Hz (-141dBc/Hz)	-82dBm/Hz (-132dBc/Hz)
10kHz	-91dBm/Hz (-141dBc/Hz)	-83dBm/Hz (-133dBc/Hz)
15kHz	-91dBm/Hz (-141dBc/Hz)	-83dBm/Hz (-133dBc/Hz)
20kHz	-94dBm/Hz (-144dBc/Hz)	-87dBm/Hz (-137dBc/Hz)
30kHz	-96dBm/Hz (-146dBc/Hz)	-89dBm/Hz (-139dBc/Hz)
50kHz	-98dBm/Hz (-148dBc/Hz)	-91dBm/Hz (-141dBc/Hz)
100kHz	-99dBm/Hz (-149dBc/Hz)	-91dBm/Hz (-141dBc/Hz)

Microphone input sensitivity: 0.7mV for full output
Transmitter AF distortion: generally less than 0.1%
FM deviation: as per menu set
SSB Data T/R switch speed: mute-TX 24ms, TX-mute 5ms, mute-RX 40ms, RX-mute 5ms

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

bhi 5W DSP Noise Cancelling In-Line Module

PHOTO 1A.

PHOTO 1B.

PHOTO 1 A, B, C: **Top view, and side views of the module showing the various controls and input and output ports.**

What is noise and why do you need to cancel it?

Imagine that you are standing in front of Wembley Stadium at the time of the FA Cup Final that is being played. Fans are cheering on their respective teams, but you are interested in hearing a classical guitarist who is sat on a balcony behind the stadium playing your favourite piece of music. If it were not for the crowds cheering, you would be able to hear him, but due to their exuberance (the noise) you cannot hear the music (the signal). This analogy illustrates the problem of noise.

Noise is an increasing problem on the amateur bands and serves to make weak signals unreadable or at best, partially readable. In physics, the concept of noise is broad, but basically describes some form of fluctuation that has an element of randomness; it contrasts with signal which conveys the required information. The ability to distinguish signal from noise is what is required.

The new bhi noise cancelling In-Line Module is designed to clean up noisy signals and is claimed to work with most radios, so that speech quality in radio and voice communications is enhanced by the reduction of noise. The manufacturer suggest that its use will result in 'stress free' listening without all the unwanted noise and interference. It is the latest in a line of products from bhi to come to the market and is aimed at the amateur radio market, CB users, marine radio users but is also suitable for use with scanners, intercoms and similar equipment.

Out of the box

The bhi NES10-2 Mk4 noise reduction speaker was reviewed in *RadCom* in May 2020 and has a number of similarities to this new unit. Both units use digital signal processing (DSP) algorithms to effect noise reduction. Essentially, this works by analysing the incoming audio signal and then uses sophisticated processing that differentiates speech from noise, following which the noise is attenuated with the intention of leaving only speech. It should be appreciated that the algorithm is aimed at speech rather than other modes with the possible exception of Morse (CW).

On opening the box you will find the module itself, which measures 135mm x 65mm x 46mm, 4 self-adhesive rubber feet, a fused DC power lead and a ALD-001 3.5 mm audio lead, as well as the user manual. The manual is comprehensive, 'user friendly' and clearly written.

The controls

The controls are at either end of the box and comprise an on/off/DSP switch, a status and overload LED as well as a rotary filter switch

PHOTO 2: **The unit in action on top of the author's Yaesu FTDX101MP on 3.743MHz.**

at one end. At the other end there are audio input, extension speaker and headphone jacks and a DC power socket.

The grey filter knob permits the user to select 8 different settings ranging between 8 and 40dB of noise cancellation. The power requirements are a DC source between 10 and 16 volts providing a minimum current of 500mA that should provide no problem is obtaining in any station (**Photos 1A, B and C**).

An output level adjustment screw is situated on one of the long side panels. The manufacturer recommends that this is set to ensure that the audio level is the same whether the module is powered on or off; this generally corresponds to a quarter of a turn from the minimum position.

Graham, from bhi, kindly provided me an external speaker and power supply to use with the module to help me evaluate it.

In use

Setting up the module was quick and entirely straightforward. I decided firstly to try it on my Yaesu FTDX101 MP to evaluate its performance on the HF bands and then on VHF and UHF on my Yaesu FT-897D. The 80m band is always noisy and, from my home (QTH), the ambient noise on the band is typically S9 but can be worse (**Photo 2**). I heard a SV9 station in the noise on SSB where only every 10th word was vaguely discernible. On activating the unit, the noise reduced considerably, so much so, that I could copy the station clearly and I then went on to work him for a short QSO without any problem.

I had similar experiences on all the other HF bands. Interestingly, 10 metres that has become increasing active over the last five or six months, presumably due to enhanced sunspot activity, provided me with the opportunity to work a ZS1 station on SSB that was 'pulled out of the noise'. In my view, without the bhi box, this station would have been unworkable.

I went on to try the module on the 2m and 70cm bands. From my QTH, I noted a very useful reduction in noise on 2 metres FM, both on simplex and through my local repeaters, which are GB7RW (Whitby) and GB3HG (Thirsk). Unfortunately, I could not access the Harrogate 70cm repeater GB3HJ from my location, so I am unable to comment on how the unit performed on UHF, although I have no reason to suspect it would not perform as well as on the other bands on which I have tested it.

I have had the unit for a couple of weeks and although I would like to have had it for longer, the deadline for press was such that I needed to report on it sooner rather than later. I have been impressed with its performance and it definitely goes a long way to making signals that are marginal, interpretable and workable. Careful experimentation is required to select the most appropriate setting and do bear in mind that stronger signals may also be associated with considerable noise, which can be improved using this device.

Like Mike Richards, G4WNC (who reviewed the NES10-2 MK4) I found that noise associated with Morse transmissions could be reduced with the unit and, like him, I noted that lower settings proved most effective.

Summary

The bhi DSP noise cancelling in-line module is a useful piece of equipment to help with noise reduction on the amateur bands. It is easy to use and install and 'does what it says on the tin'.

It costs £159.95 including VAT and can be obtained directly from bhi Ltd, 22 Woolven Close, Burgess Hill, West Sussex RH15 9RR who are on +44 (0)1444 870333 or alternatively via email to sales@bhi-ltd.com.

I would like to thank Graham Somerville, Managing Director of bhi for the kind loan of the module.

Paul Marks, G8FVK
pmarks4550@aol.com

Technical

Digimodes interface for the FT-900

Introduction

Having previously made a digimodes interface for my Kenwood TS-850, my friend Tom, EI2ILB, asked if I could make him one for his Yaesu FT-900. I said, yes, sure, no problem. It's worth noting that the resulting interface described here will work with most rigs (and includes a PTT if needed). **Photo 1** shows the result.

There are two distinct parts to a digital interface for a transceiver: the rig control (usually referred to as Computer Aided Transceiver or CAT) and the audio interface to connect the rig's mic and speaker signals to your computer.

A quick look at the interface specs for the Yaesu showed me that the CAT used a 6-pin micro-DIN connector, which looked like it could be a real challenge to wire up reliably. So I decided up front to save some headaches and use a ready made CAT to USB interface cable, available from the usual sources (prices seem to range between £15 and £20). So that part was sorted.

Next was the audio side. Many Yaesu transceivers have a useful interface connector on the back, called a DVS-2, which has both audio in and out and a PTT line. Great. So I built a prototype interface using an audio isolation transformer from my junkbox and connected everything up to the FT-900.

Firing up JTDX software (personally I prefer it to WSJT-X) on my bench Raspberry Pi, I could see received signals from the rig and the CAT was working fine – but nothing was happening when switched over to transmit. Nothing at all going out. Hmm.

PHOTO 1: **The completed interface, plus one of the inexpensive USB sound dongles.**

The Yaesu DVS-2 interface

Luckily (and thanks to Tom) I had access to a service manual for the FT-900 and spent a bit of time studying the circuit diagrams, which provided the explanation: these radios use a couple of control lines to set the state of an analogue switch, or multiplexer, as shown in **Figure 1**. The lines feed into a switching transistor (powered from a 5V rail) and then on to an analogue multiplexer IC, a MC14053. So it seemed fairly clear that switching one or both of these lines to logic high was needed to enable the audio interfaces (and I found out later both lines need to go high for transmit to work). So this project was going to need a bit more thinking and some circuitry to perform this input switching.

The outcome of that thinking is shown in **Figure 2**. Nothing very original here I have to say, and all fairly common components, so should not be too challenging to get working. To simplify matters, I opted to use one of the ubiquitous USB audio adapters that are widely available. The example I used (seen in Photo 4) was bought from Amazon for around £6.

Circuit

The circuit digram is shown in Figure 2. A USB sound dongle (not shown in the diagram) is used to make the connection to the computer. Its Mic and Headphone/speaker ports are connected to the audio isolating transformer, T1. I used a

Ralph Musto, GM4MHE
ralphmusto@icloud.com

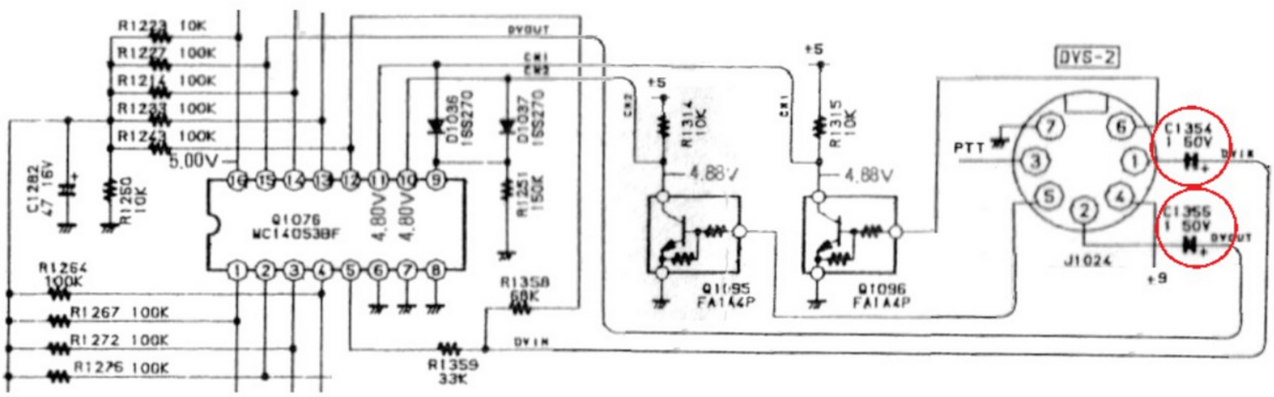


FIGURE 1: **Detail of circuit associated with DVS-2 socket (adapted from circuit in Yaesu FT-900 manual). The two capacitors ringed in red provide DC isolation, see text.**

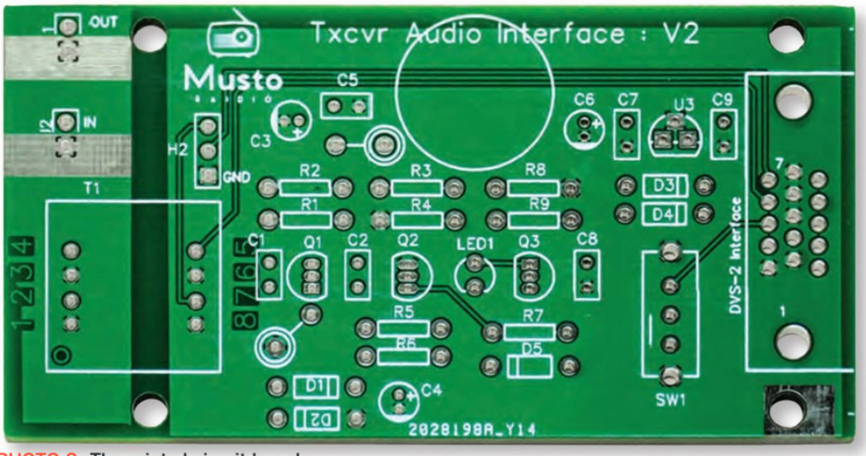


PHOTO 2: The printed circuit board.

PHOTO 3: Completed board in enclosure. Note how 3.5mm plugs are soldered to the PCB to plug into the USB sound dongle.

neat Bourns two channel example available from Mouser, part number 652-LM-NP-1005L. Audio output from the transformer is amplified by Q2 and fed into a detecting network formed by D1, D2, R4 and C4. When audio is present a voltage appears across C4 and turns on Q2, illuminating the LED and providing an active-low PTT signal via D5 to the DVS-2 (via SW1, which can be used to inhibit the PTT). When Q2 turns on Q3 turns off, sending DC control signals via D3 and D4 to CNTL 1 and CNTL 2 on the DVS-2. VR1 sets the Tx audio level (and should rarely need altering; a preset may be used). The DVS-2 interface handily includes a 9V supply connection, which is used by U3 to provide a low current +5V supply for the interface. The rest of the circuit should be fairly self-explanatory. Ferrite beads (FB) are used here and there to damp out any possible RF sensitivity.

Note that the audio connections on the FT-900 DVS-2 interface have 1µF capacitors included internally (circled in red in Figure 1) so no capacitor isolation is fitted on the interface board. If using this with another rig, it would be worth checking that the inputs and outputs are DC coupled – or you could simply add a couple of capacitors to the interface circuit.

PCB

The first prototype was built dead bug style as a proof of concept but since this project was going to be handed over to someone else and not just kept on my shack table I decided it would be best to make a PCB for a more professional and reliable finish.

Over the years I have tried most methods for homebrewing a circuit board – a time consuming and messy business mostly, that had pretty mixed results. So these days the hard work is all done on my computer and I get the boards professionally manufactured by our friends in China. And in any case, I also quite enjoy the process of drawing up the schematic and then laying out the board. I have been using JLCPCB for my boards, but there are many others.

There are a number of design application options, but my go-to these days is easyEDA Designer. I have also used kiCAD in the past, but found that complicated to use and seemed to constantly get stuck due to some missing dependency. EasyEDA Designer on the other hand I find very easy to use for both schematic drawing and PCB creation. It has an extensive component library, but adding your own components is also simple to do if needed. It can be run from a desktop app, but I find it works just fine from a web browser. **Figure 3** shows the board design in progress. This is a fairly simple circuit obviously, so a standard two layer board works just fine. A single sided board would be perfectly feasible but there's no significant cost benefit these days. When your board design is finished it can then be sent directly from easyEDA Designer to JLCPCB for manufacture. **Photo 2** shows the finished board as it arrived from the manufacturer. The total cost for five boards was US$15 – and of that, $11

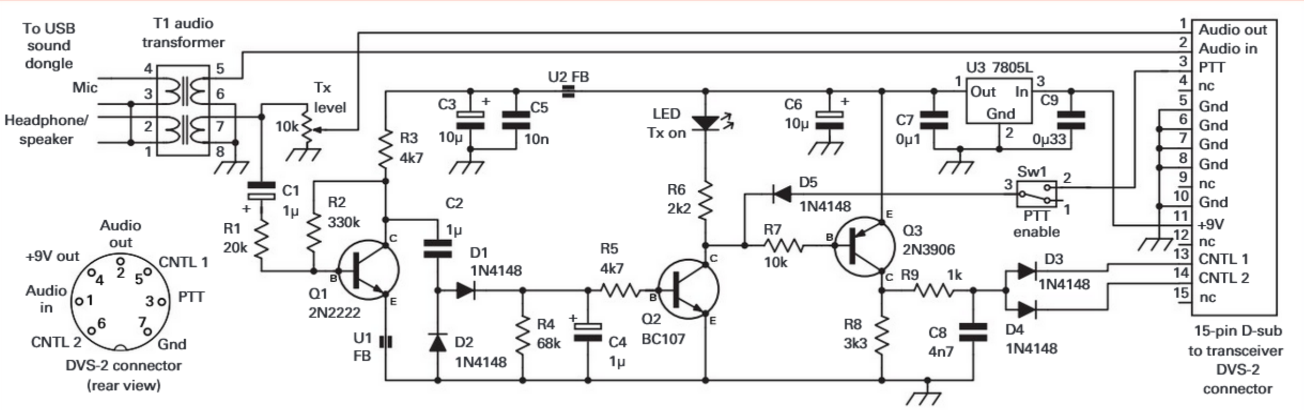


FIGURE 2: Circuit diagram of the interface.

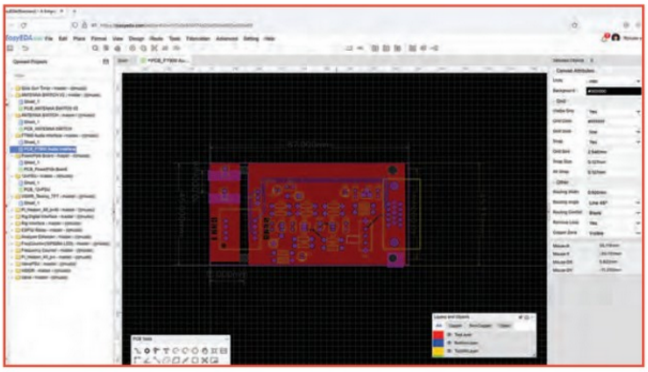


FIGURE 3: PCB being designed using EasyEDA.

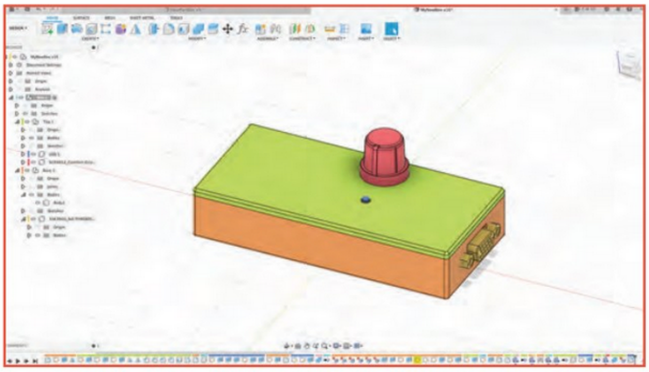


FIGURE 4: Developing the enclosure's 3D print design.

was the DHL Express shipping. It takes about a week for the boards to be manufactured and delivered.

I have uploaded my design files to GitHub and you can download them from **[1]**. You'll find the circuit diagram, bill of materials, Gerber files for the PCB and STL files for the enclosure – more on that later.

The board uses all through hole parts and is simple to assemble. I also arranged the board layout to take two jack plugs that, with the rear shell removed, are soldered directly onto the board. The USB dongle can then be plugged straight in, with no cables needed. The assembled results can be seen in **Photo 3**.

Enclosure

The interface could be put in any box you like, but – as I have a 3D printer – I decided that making a proprietary enclosure would be part of the fun of this project. Anyone who has been involved with 3D printing will know that one of the biggest challenges is actually drawing up what you want to print. Once again, there are many options for this. For most simple stuff I have found Tinkercad to be great. Very easy to learn to use, and only let down by perhaps a lack of more complex functions. Lately though, I have become a big fan of Fusion 360. This is primarily aimed at the professional market and has extensive capabilities, but they also have a free version of the software available for personal use. There are some restrictions on the free version, but for us hobby printers it is still very capable. Give it a try.

Figure 4 shows the box during the design process. It is possible to add in components such as connectors, fixings etc that then help in checking clearances and hole positions. The box design uses a lid that snaps into place (no screws required) but you might need a metal 'spudger' to open it.

When printing something that will be in use permanently, I like to give the finished print a coat of clear lacquer. It gives a smoother finish that is just nicer to touch and handle.

The decal for the pot was printed on a label printer that we usually use for labelling jam pots. You could choose to include labelling information in the 3D design files, so that they become part of the case.

Interface cable

The cable between the interface box and radio should be well screened. One option that I have used several times successfully is to repurpose an old computer VGA cable. These have individually screened connections for the red, green and blue signals, various additional connections, and an overall screen, so ideal for this kind of job. And they are still available at pretty cheap prices (I picked up a 5m one from Amazon for £5). Thus the circuit board has been laid out to take a VGA socket (Mouser part number 523-7HDE15SDH4RHNVGA) and use the screened connections for the audio in, out and the PTT. The only additional task is to make off the other end of the cable with the DIN plug for the transceiver.

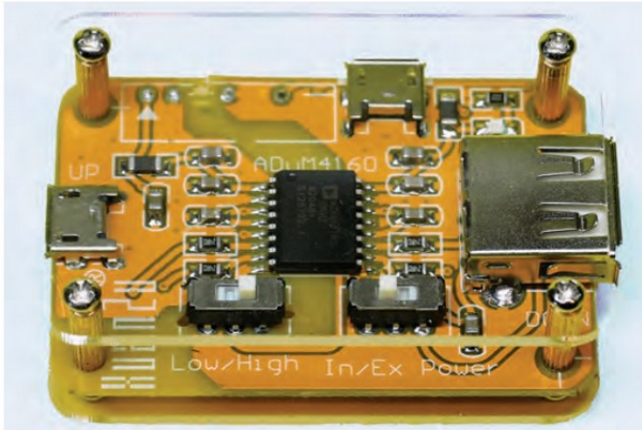


PHOTO 4: Typical USB isolator (see text).

In use

There are two things to be aware of when first setting this up. Firstly, we are only using one channel here on the audio connections (although you could connect them both together through a couple of resistors where the USB dongle connects to the board), so you might need to adjust the settings in the digital software you are using to operate from the left or right channel. There seems to be no consistency between the different programmes as to which channel they default to, so a bit of experimentation may be needed to get the right one selected.

You also may need to increase the audio level coming from your computer to get the switch to operate, which you can check with the TX On LED.

The pot sets the transmit level, so adjust that as needed for your rig to ensure the audio stays at the low end of the rig's ALC range. I have not included a separate pot for the receive audio levels, as I have found this can be done easily enough on the PC and, once set, does not usually need further adjustment.

As mentioned at the beginning, I chose to use a ready made CAT to USB cable. You may wish to maximise the isolation between your PC and the radio by using a USB isolator, such as the one seen in **Photo 4**. These provide ground isolation for the USB interface and are small, cheap and easy to use. They are also readily available from various sources with prices in the range of £5 to £15.

I hope you found this article interesting and will have a go at making the interface.

Websearch

[1] www. github.com/rjmusto/FT900_Digimode/

A pre-configured automated ATU
Part 2

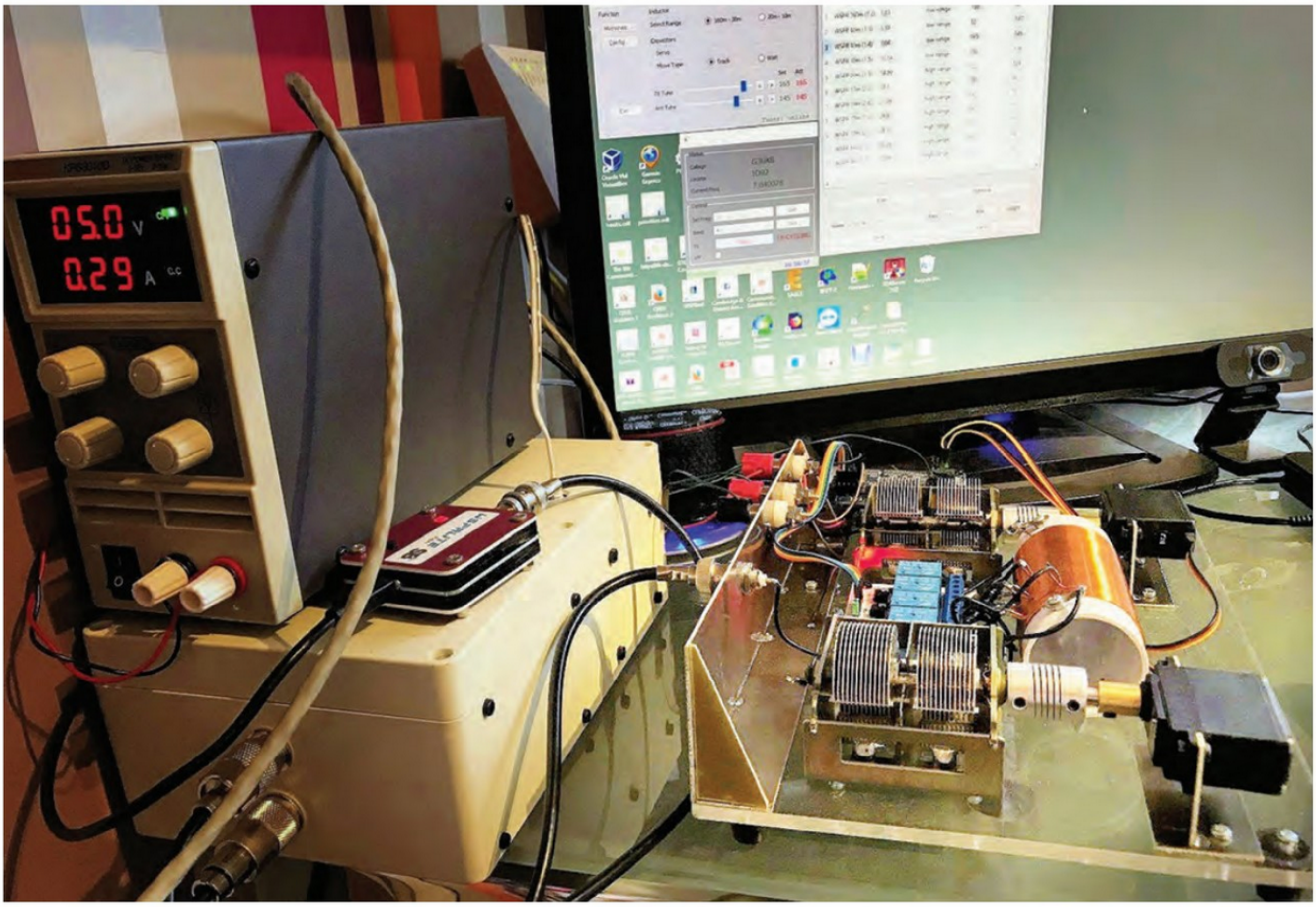


PHOTO 6: Test setup.

Introduction

Last month we looked at the hardware elements of the pre-configured automated ATU. We conclude with the software and usage aspects.

Software

The software consists of the server side running on the RPi and the client side running on any device that can run Python.

The software is hosted on GitHub **[6]**. Download the software using either a git client or download the zip file. On the GitHub page, drop down the green Code button for download options.

There are three directories under FRIMatch. The /server directory contains the files that run on the RPi. The /client directory contains the files that run on the client device. The /lib directory is the API that can be used from automation programs (ignore this unless you plan to experiment with automation). To make life simple, install all files on both the client and server devices.

Server (RPi)

Although you can run your RPi with a monitor, mouse and keyboard attached that's pretty inconvenient. If you enable VNC in the RPi configuration and install a VNC client on your client computer then access becomes very convenient, especially during the testing phase. For final deployment you might want to start the application automatically on power-up. There are several different ways to do this and lots of help on the web.

The server is a command line application and is silent apart from announcing itself, unless there is an error.

The software requires the Adafruit library. Install this on your RPi:

```
> sudo pip3 install adafruit-circuitpython-servokit
```

In the RPi configuration you will need to enable the I^{2}C interface.

Run the server:

```
$ cd <your install directory>/FRIMatch/server
$ python3 main.py
```

NB: use python3 not python (which is v2). Likewise pip3 not pip.

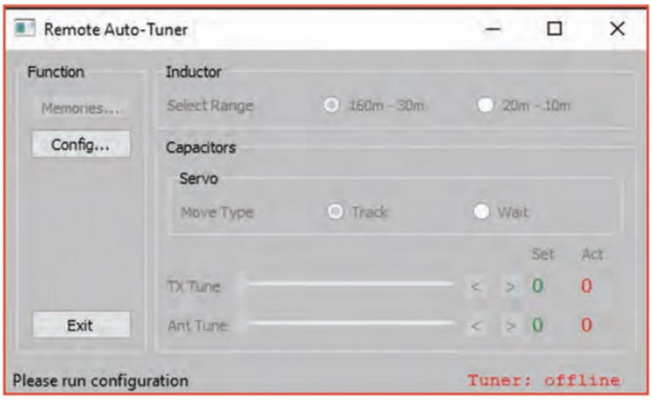


FIGURE 2: **Main window prior to configuration.**

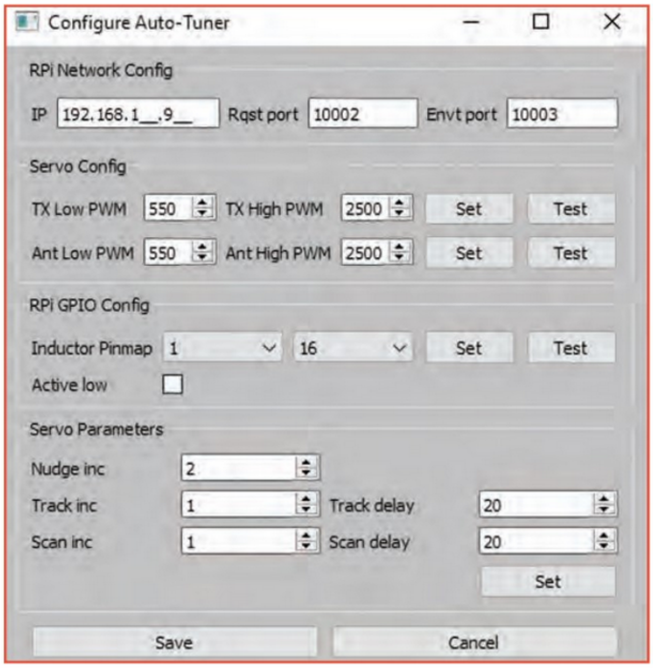


FIGURE 3: **Configuration window.**

The server listens for UDP (User Datagram Protocol) commands from the client over your local network. These commands are elementary as there is little intelligence in the server. We simply tell the server which relays to energise and the rotational degrees for each servo. There are also a number of configuration items that are sent to the server when the client starts and connects. In addition the server sends back position information as a servo moves.

Client

The client side is a GUI application using the PyQt bindings to the Qt5 library.

The software requires Python 3. If on a recent version of Linux, including the RPi as a client the version installed should work fine. If on Windows install the latest version. However, I note that version 3.9+ will no longer work on Windows 7. I'm currently using 3.7.2, which I suggest if you want to be 100% sure there are no backward compatibility issues.

When you have installed Python 3 and pip3, install the PyQt5 libraries:

```
> pip3 install pyqt5
```

Run the client:

```
> cd <your install directory>/FRIMatch/client
> python tuner_client.py ../config/auto_tuner.cfg
```

The configuration file can be any name, any path. If it does not exist (the path must exist) then it will be created using defaults the first time the application is run. If you have several antennas they will require different ATU setting. Having a different configuration file for each antenna is better than cluttering up one file with multiple settings.

The main window of the application is simplistic allowing manual control of the relay switching and the two capacitors. There are two further windows for configuration and memories. When first running the client without the server and if there is no state file the interface will look like **Figure 2**.

The only interaction allowed is to run the configuration. The prompt 'please configure' in the status line is shown only the first time you run the client.

Configuration

The configuration window is shown in **Figure 3**.

First, set the IP address to that of your RPi. Without closing the client windows, start the server application (if not started) and the client should connect as shown in **Figure 4**.

The next task is to set the servo range such that each servo moves 0-180 degrees. As mentioned earlier, leave the grub screw on the servo side loose such that the servo is free to rotate without moving the capacitor.

In the configuration window the low and high PWM corresponding to 0 and 180 degrees need to be set. First try, say, 700 to 1200; click set, which will send these values to the tuner, then click test. The test will move the servo one cycle – low, high, low. Note which direction the servo turns and keep adjusting until a full 180° movement is obtained. The Hitec servos I use require 550 to 2500.

Having obtained the correct range, try moving using the sliders on the main windows and then leave at 0 degrees. Now manually move the capacitors to their 0° position (fully meshed), tighten the grub screws and then ensure the capacitors can be moved through their full 180° from the main window sliders.

Next, configure the GPIO. If your relay module is active low (ie the relays are energised when the I/O pin is driven low) then check the 'Active low' box. Select 1 to 4 in the first dropdown (representing taps 1-4) and for each select the pin its connected to from the second dropdown. Click 'Set' each time. When all four pins have been set click 'Test'. This will cycle the four relays on and off.

The final set of adjustments are for the servos. Servos do not have any speed control. With a DC motor, pulse width modulation (PWM) can be used to control the speed. With a servo, the PWM mark/space ratio controls the position. In order to slow the speed to a reasonable level the technique is to command the servo a few degrees at a time, with a short delay between commands. With small steps and a small delay, movement appears quite smooth. The defaults for the servos should work fine but if you want to explore then try adjusting the step size and delay for each movement type. Click 'Set' to send the values to the tuner and then move the servo to see the effect.

'Save' or 'Cancel' all configuration changes.

Bob Cowdery, G3UKB
bob@bobcowdery.plus.com

FIGURE 4: **Main window post-configuration, allowing access to controls.**

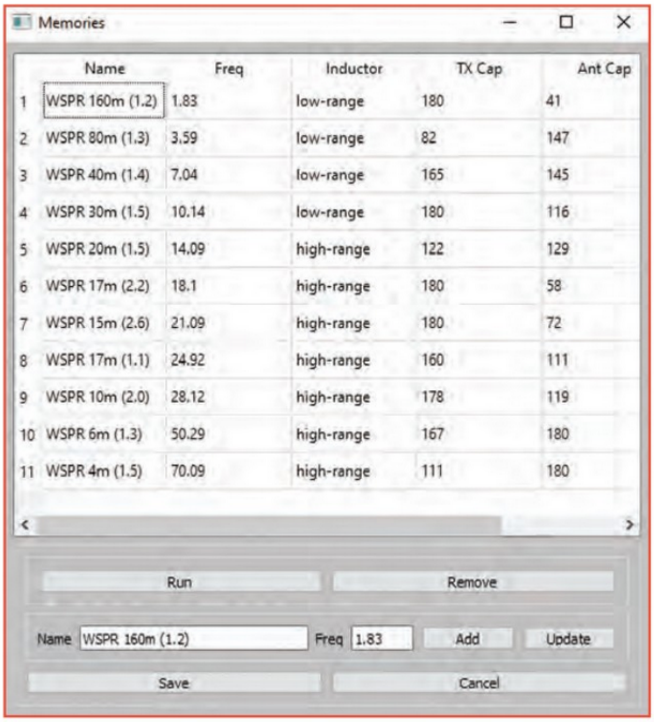


FIGURE 5: **The Memory window.**

Tuning

Once configured, the tuner can be connected up to an antenna and an antenna analyser. Initially, just choose a frequency – say within the 40m band; select the 160m-30m range and tune the capacitors for minimum SWR.

There are two move modes. When set to 'Track', the capacitor will follow the slider value (but if you move fast it will lag behind). In the two fields to the right of the slider the 'Set' value shows the current value of the slider and the 'Act' value is the actual value of the capacitor. When set to 'Wait' the servo will not move until the slider is released. This mode makes it easier to perform a scan.

Once you have the capacitors in roughly the right places, fine adjustment can be done with the increase/decrease buttons < >, which will move the servo a small amount on each press.

Memories

Clearly, adjusting the tuner every time you move frequency is not practical. As a test I set up memories for every WSPR frequency from 160m to 4m. The memory window is shown in **Figure 5**. This allows you to manage as many memories as you need. The software does not impose a limit to the number you can add. This window, like the configuration window is not modal; you can use it and the main window together.

To add a memory, tune for lowest SWR, then enter a name and a frequency. I've usually added the actual SWR after the name for reference. Click 'Add' and the entry will be added and will include the current settings of the band range and rotation degrees for each capacitor.

A memory may be executed either by a double click on the entry or selecting it and clicking 'Run'. The tuner will automatically move to the new settings. A memory can also be removed or edited. To remove click the appropriate memory number and then click 'Remove'. To edit, again click the appropriate memory number and the settings will be brought into the Name and Freq fields. Run the memory to set the range and capacitors to the last setting. Update the fields if required, retune as necessary, then click 'Update' and the new values, including the current band range and rotational degrees, will overwrite the entry.

'Save' or 'Cancel' all memory changes.

Testing

Tests were initially done on every band using another project as the RF source, which was published in two parts in *RadCom Plus* Spring 2021; it is an automation system for the WSPR Lite and a set of remote operated filters for six of the HF bands, 160 – 10m. The test setup is shown in **Photo 6**. The software that drives the WSPR Lite was modified so that it would also drive not only filter selection but operate the tuner to select a memory for automatic execution. In the tuner download there is a /lib directory that contains the necessary files that can be directly imported into any Python program to drive the tuner programmatically.

Bearing in mind the WSPR tests were done using an 25⅔m end fed antenna only 2m high and with a short single counterpoise wire, my expectations were low. I did get some spots on all bands to 15m, although the best performing were 40m and 80m (which was not a surprise).

There is a very short video on YouTube **[7]** that shows the tuner in three clips, each starting off-tune and executing the same memory. The first clip shows the UI, second the tuner and the third clip shows the Antenna Analyser.

In use

The final deployment will be in an IP66 box at the antenna feedpoint. Three leads are required back to the shack: feeder, power and network. You could put a 5V PSU in the box but that would mean bringing mains out to the box; it's safer to stick to 5V. If the feed point is close enough to a wireless access point you could use Wi-Fi and ditch the wired Ethernet cable.

As previously mentioned, auto-starting the application on power-up is pretty much essential for final deployment.

Caveats

Construction of the prototype assumes QRP power levels, both because of the broadcast type variable capacitors and the proximity of the digital signal wiring to the tuner components. If you want to use higher power then ensure the components are adequately rated, screen the electronics and decouple the power lines.

Websearch

[6] https://github.com/G3UKB/AutoTuner
[7] https://youtu.be/y8KFuf4482c