Contents

June 2022

58

News and Reports

Regulars

Reviews

24

Features

Technical Features

Cover image, Images from the Commonwealth Contest. Top image courtesy Colin Smithers, G4CWH. Lower three images courtesy Nigel Cawthorne, G3TXF. Designed by Kevin Williams, M6CYB

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

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New Products

Digital Audio Filter

Nevada has stock of a new Digital Audio Filter from Xiegu.

The XIEGU GNR1 incorporates both audio digital noise reduction and audio digital filtering. It will effectively reduce both background noise, improve signal to noise ratio and make received voice transmissions more clear and intelligible. The unit will work with both HF and VHF/UHF radios to give a big improvement in reception.

The filter has independent adjustments of both input and output levels to work with both headphones or an external speaker, giving up to 3W audio output.

The XIEGU XRN1 sells for £229.95 and is available from UK importers Nevada www.nevadaradio.co.uk or Waters & Stanton www.hamradiostore.co.uk.

Mobile antenna

The Sharman MD-3500 Slider mobile antenna is a complete antenna with simple slide tuning giving all bands from 80 through to 6m. As it can handle up to 1300 watts, this could be a good field day or portable excursion antenna. It uses a PL259 mount and resonance is achieved by sliding the antenna for minimum SWR. The fully constructed length is around 2.6m. It retails for £69.96 and is available from Moonraker, see www.moonraker.eu.

Elad FDM-S3 SDR

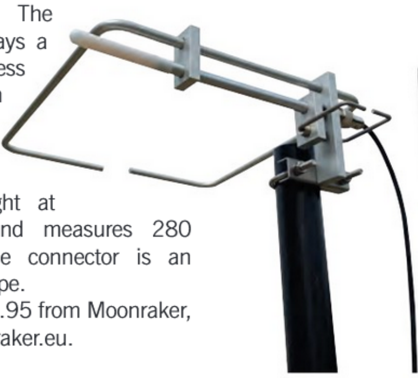
Not a brand new piece of equipment, but ML&S tells us that it is back in stock after a long delay due to component shortages. The receiver covers from 9kHz to 108MHz with a twin antenna input. It boasts eight low and high bandpass filters and a sampling rate of up to 122.8MHz. It has four independent receivers that can be scanned simultaneously. It retails for £968.20 and you can read more about this SDR receiver at HamRadio.co.uk/FDMS3.

Halo Loop Antenna

Moonraker has stock of a new dual band halo antenna, the Sharman HLP-270 2m and 70cm antenna. It covers 140-150 and 400-470MHz with quoted gain figures of 4dB for the VHF band and 5dB for the UHF band. The specifications says a VSWR figure of less than 1.5:1 with a maximum power of 800W.

It is light-weight at just 0.36kg and measures 280 x 280mm. The connector is an SO-239 UHF type.

It retails for £49.95 from Moonraker, see www.moonraker.eu.



DigiRig Mobile

The DigiRig is a tiny digital modes interface that combines audio codec, serial CAT interface and a PTT switch. It supports full featured CAT interface: PTT, bands, tuning etc (not just VOX based PTT), using a single USB connection to computer minimising the cables mess. It uses widely supported CP2102 serial interface & CM108 audio codec

The DigiRig retails for £99.95 and you can find out more details at HamRadio.co.uk/DigiRig.

Antennas

Recently, the column summarised how an HF end-fed wire could be worked against an artificial earth system, using a counterpoise wire as an example [1]. In response, Peter Gavin, M0URL wrote concerning his interesting antenna arrangement.

Counterpoise Wires

Provided ICNIRP regulations **[2]** are fully met, a method to provide an artificial earth system for an antenna is to use an insulated counterpoise wire that the antenna is worked against. The concept of this arrangement is shown in **Figure 1** for an HF bands end-fed wire antenna, which is similar to WR8RW's antenna described in February's Antennas. The advantage of using a counterpoise wire is that an external earth is not required so avoiding any conflict with the mains electricity supply's earth that could result in dangerous conditions occurring. Such conditions can happen as a result of rare mains distribution faults arising **[3]**.

To minimise the effect of common mode currents flowing along the outer surface of the coaxial cable's screen conductor, an RF current choke can be incorporated into the coaxial cable that is run between the radio equipment and the UnUn (unbalanced-to-unbalanced transformer) connected to the wire-span. Ideally the RF current choke should be placed as close as possible to where the coaxial cable is connected to the UnUn as shown in Figure 1. The RF current choke often comprises several turns of the coaxial feeder cable that is wound to form an inductor **[4]**. Without the RF choke to minimise them, any common mode currents flowing along the coaxial feeder cable's outer screen allow the cable's screen to become effectively part of the antenna's radiating system. This can lead to undesirable RF voltages in the shack, the distortion of the antenna's radiation pattern and an increase in the noise level when on receive caused by RF currents induced from close by mains cabling and electrical equipment.

Using an example of an end-fed wire, where a 9:1 UnUn transformer is used to interface the wire-span with the coaxial feeder cable, the counterpoise wire should be connected to where the coaxial feeder cable's outer shield is terminated on the UnUn's common connection. This arrangement is shown conceptually in **Figure 2** for reference. The length of the counterpoise wire is chosen to suit the lowest wavelength (λ) of operation, with this usually being a λ/4 long. This arrangement should also give good results when the wavelength in use is an odd harmonic of the lowest wavelength.

Using a counterpoise wire as an artificial earth is also convenient when the station operates from an upper floor of a building. The counterpoise wire can be run down the wall from an upstairs window and secured to a suitable anchor point. The counterpoise wire can also be run at an angle, or bent around as necessary, to allow it to avoid wiring, metal pipes or guttering.

M0URL's end-fed wire

Peter, M0URL installed a 38m long end-fed wire in a horizontal V-configuration, with each side of the V being 19m in length with an angle of

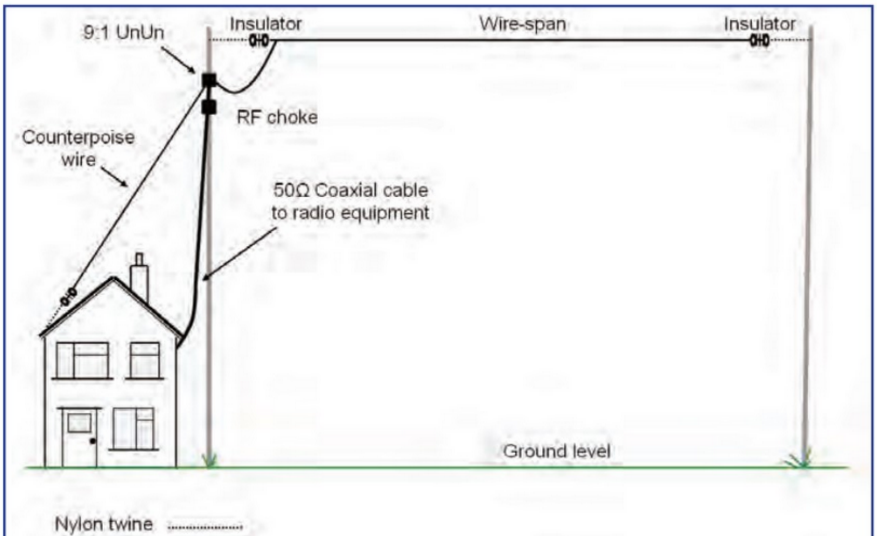


FIGURE 1: The concept of an end-fed wire worked against a counterpoise wire.

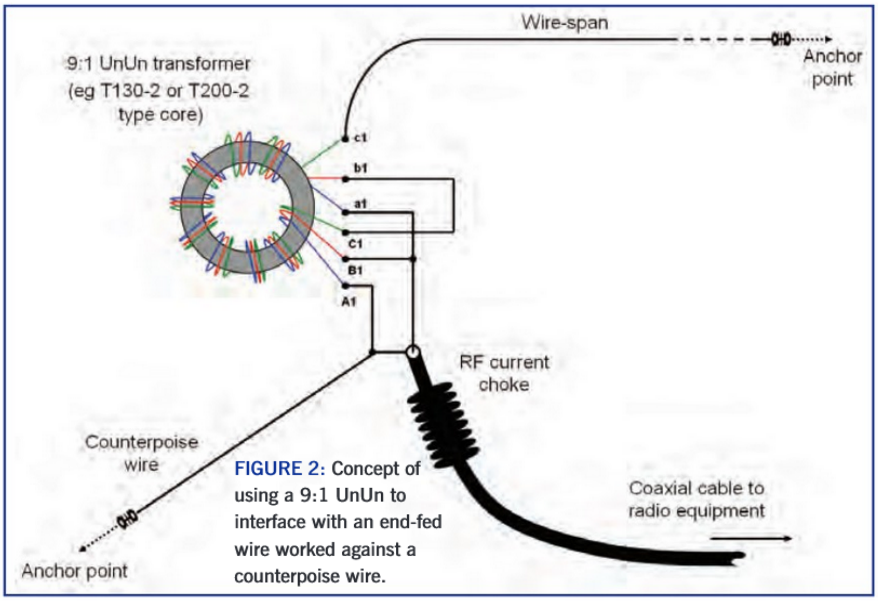


FIGURE 2: Concept of using a 9:1 UnUn to interface with an end-fed wire worked against a counterpoise wire.

Mike Parkin, G0JMI
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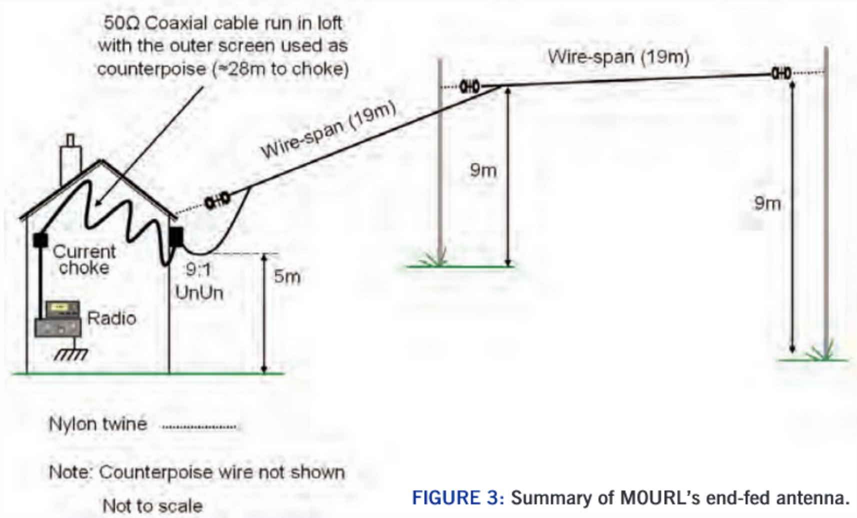

FIGURE 3: Summary of M0URL's end-fed antenna.

about 50° between the two spans. The end-fed wire was originally worked against a counterpoise wire, however the arrangement used to secure the counterpoise wire's end often got severed as a result of bad weather or accidentally when cutting the hedge.

It was not convenient to install an RF current choke at the UnUn end of the coaxial cable. Therefore, the RF current choke was installed within the coaxial cable closer to the radio equipment. This resulted in about 28m of the coaxial cable being run through the loft between the UnUn and the RF current choke, with the advantage that the RF current choke was located inside the house out of the weather. **Figure 3** shows the concept of Peter's end-fed antenna.

Peter participates in many HF contests, where he can often make several hundred contacts during a single contest. As a result, he has built up a good understanding of how the antenna can be expected to perform on the HF bands. When the antenna was used with its counterpoise wire disconnected, the antenna continued to perform surprisingly well.

M0URL antenna model

The antenna was modelled using MMANA-GAL to provide an indication of the antenna's performance, with initially the counterpoise wire and then with the coaxial cable acting as the counterpoise. The application's default ground option was selected for the model **[5]**. The antenna model was run on the 160m, 80m, 40m, 20m and 10m bands, with these bands chosen because they provided a reasonable indication of the radiation pattern as the band of operation was changed.

Figures 4 to **7** provide an indication of the modelled performance of the antenna in the horizontal and vertical planes. In the figures, the red curves represent the antenna using a counterpoise wire and the blue curves using the coaxial cable's outer screen acting as the counterpoise. The coaxial cable was modelled in the same plane as the counterpoise wire but in the opposite direction. The counterpoise wire was set at right angles to the wire-span and run parallel to the ground. However, only the first 15m of the coaxial cable counterpoise was at a right angle to the wire-span and then it contained some bends in the cable to represent it being run in the loft of a house. A 25μH inductor was included at the coaxial cable's end to represent the RF current choke. Both the counterpoise wire and the coaxial cable were 28m in length to give a reasonable comparison.

Referring to Figure 4, on both the 160m and 80m bands the antenna's predicted radiation patterns were similar when either the counterpoise wire or the coaxial cable was used as the counterpoise. However, the vertical plane plot indicates the coaxial cable counterpoise may be slightly more effective.

Figure 5 shows the antenna's predicted performances on 40m, where using either the counterpoise wire or the coaxial cable as the counterpoise indicates similar performances. However, using the coaxial cable as the counterpoise indicates a slightly better performance compared to the counterpoise wire.

Figure 6 illustrates the antenna's predicted performances on 20m, where a difference between using the counterpoise wire and the coaxial cable as the counterpoise are more noticeable. Surprisingly, the coaxial cable counterpoise's blue curve indicates an improvement over using the counterpoise wire.

Figure 7 shows the antenna's predicted performances on 10m. The prediction indicates the shapes of the two curves are similar. However, the counterpoise wire's predicted red curve indicates a slightly better performance compared to the coaxial cable counterpoise's blue curve.

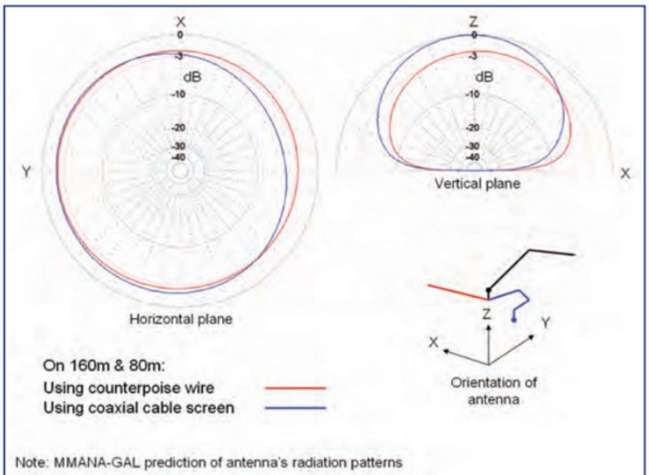

FIGURE 4: Comparison between using a counterpoise wire and the coaxial feeder cable's screen acting as a counterpoise on the 160m and 80m bands (wire and cable lengths were 28m).

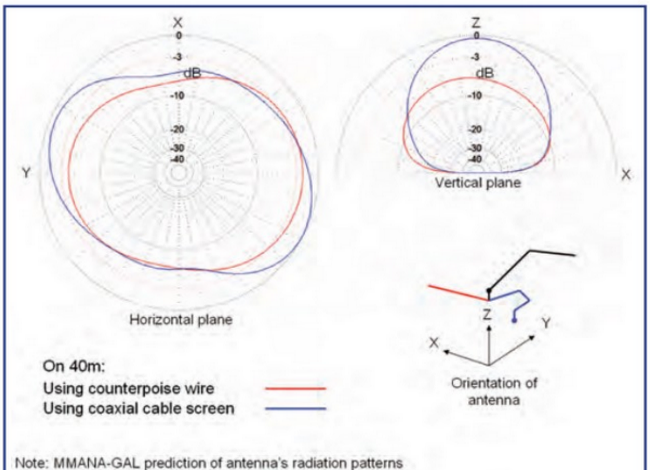

FIGURE 5: The same end-fed antenna's counterpoise arrangements compared on the 40m band.

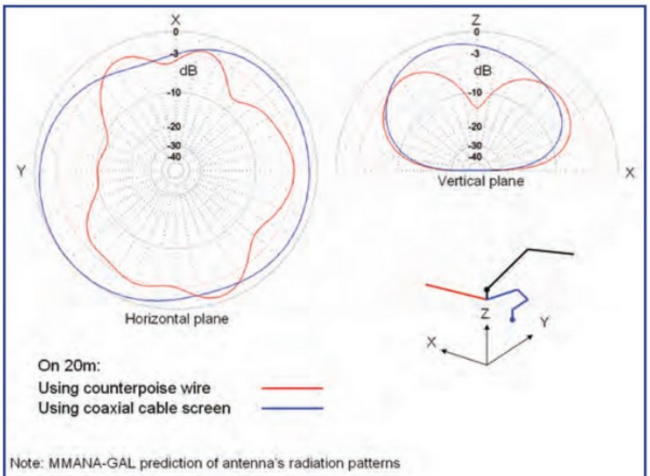

FIGURE 6: **The same end-fed antenna's counterpoise arrangements compared on the 20m band.**

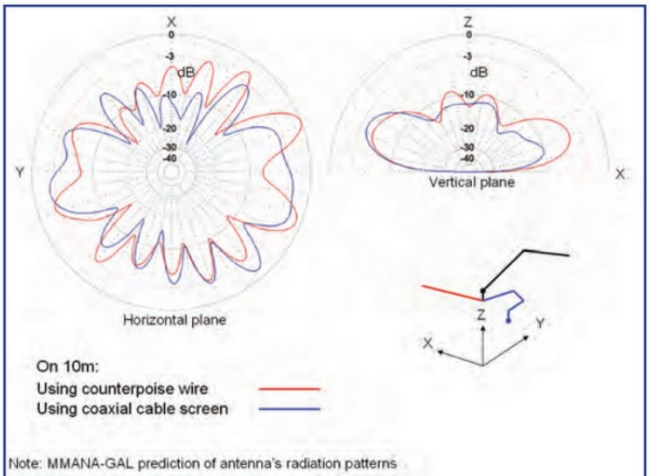

FIGURE 7: **The same end-fed antenna's counterpoise arrangements compared on the 10m band.**

Observations

The predicted radiation patterns shown in Figures 4 to 7 represent two specific scenarios that were modelled for an end-fed wire antenna using:

- A conventional counterpoise wire (shown as the red curves).
- The coaxial feeder cable's outer screen as a counterpoise in conjunction with an inline RF current choke installed towards the radio equipment's end of the cable (blue curves).

For the 38m long wire-span modelled, surprisingly the results obtained indicated use of the coaxial feeder cable's outer screen when used as a 28m long counterpoise gave a similar or slightly better performance when compared to a 28m long counterpoise wire.

The coaxial cable was modelled with some bends included within its length to represent the cable being run the loft of a house to be representative of an actual scenario. If a different configuration and length of coaxial cable was to be modelled, then the predicted radiation patterns obtained may differ. However, the results obtained provide a fair indication of the performance that could be expected for end-fed antenna where the coaxial feeder cable's outer screen is used as a counterpoise in association with an RF choke.

When Peter, M0URL tried using his end-fed antenna where the coaxial feeder cable provided the counterpoise rather then a separate wire, he did not notice any real significant difference in the performance of his antenna.

Provided ICNIRP regulations are followed in full, where it is not physically possible to install a separate counterpoise wire for an end-fed wire to be worked against, the technique described of using the coaxial feeder cable's outer screen as the counterpoise (in association with an RF current choke) might provide a practical solution.

Many thanks for all the information Peter.

Has anyone out there tried using this technique where the coaxial feeder cable acts as a counterpoise, it would be interesting to hear from you?

The controlled feeder dipole

The technique of using the outer screen of the coaxial feeder cable to act as an RF radiator as a result of common mode currents flowing is the basis for the controlled radiation feeder (CFR) dipole, which was summarised in Antennas recently **[6]**. This technique was described by Bill Sykes, G2HCG several years ago **[7]**. John Pegler, G3ENI and Dan Sharpe, G3ZUN used the CFR technique as a basis for a 5MHz portable antenna when conducting near vertical incident skywave (NVIS) experiments. Their dipole antenna comprised an electrical quarter wavelength (λ/4) long wire soldered to the inner conductor of the coaxial feeder cable, with an RF choke situated an electrical λ/4 down the coaxial cable forming the other leg of the dipole. The concept of a CFR dipole is shown in **Figure 8** for reference.

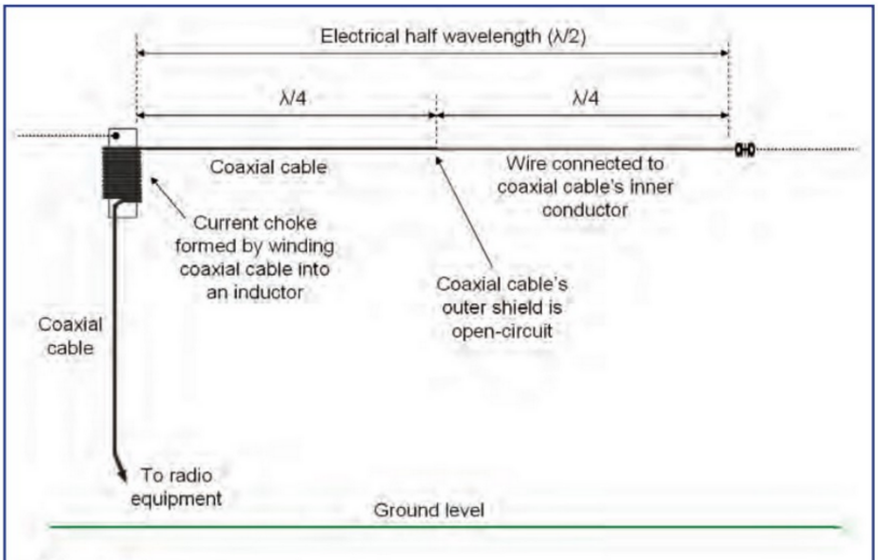

FIGURE 8: **Concept of the CFR dipole technique.**

Websearch

1: *RadCom* Antennas. August 2021, pages 18 - 20.

2: An independent non-profit organisation, the *International Commission on Non-Ionizing Radiation Protection* www.icnirp.org

3: Protective Multiple Earthing (PME) by Russell Tribe, G4SAQ, pages 46 -48. *RadCom* April 2022.

4: RSGB *Radio Communication Handbook*, 14th edition edited by Mike Browne, G3DIH: Section 14, Transmission Lines, pages 14.13 - 14.15.

5: 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, 5 mS/m, others 0.

6: Antennas. *RadCom* February 2019, pages 16 - 20. March 2019, pages 16 - 18.

7: Controlled Feeder Radiation, B. Sykes, G2HCG. *RadCom* May 1990, pages 40 - 41.

RigExpert TI-5000 Interface

Computers have become an essential accessory for most modern shacks, simply because they are so useful. Applications can range from logging your QSOs through to managing your entire station.

The front panel of the RigExpert TI-5000 interface.

This application of your computer can be further extended for those that enjoy datamodes operation. The freedom to make QSOs under virtually any conditions using FT-8 has helped many amateurs during lockdown. However, RF and computing don't necessarily sit well together, and figuring out the interconnections can be daunting. This is where an interface unit such as the RigExpert TI-5000 can help. This neat package provides comprehensive interconnection facilities for a wide range of rigs and operating modes, whilst reducing the PC connections to a single USB cable. Whereas many interface units cater primarily to data mode operators, the TI-5000 also provides phone and CW features. In addition to providing a USB soundcard, it offers four serial ports that cover CAT, hardware PTT, WinKey (emulated) CW keying and squelch detection. There are also two microphone inputs.

PHOTO 1: **TI-5000 rear panel connections.**

Getting started

The RigExpert TI-5000 is supplied with a good quality USB-2 cable that's fitted with a common-mode choke to help tame any RFI problems. In addition to handling all the PC communications, the USB-2 cable also powers the TI-5000, further simplifying the connections. The link to your rig is handled via a dedicated cable that connects to a 25-way D-connector on the rear of the TI-5000, **Photo 1**. Dedicated cables are available for most of the popular rigs. However, I was delighted to see that RigExpert has published complete schematic diagrams of the rig leads so that you can make your own link cable. These diagrams are available from the Downloads section of their website (www.rigexpert.com). I used the TI-5000 with a Yaesu FT-897 rig and a ready-made TI-5000 cable for my review. This cable had connectors for the CAT and ACC sockets on the FT-897, along with a 3.5mm plug for the key jack. I was pleased to see that the TI-5000 uses industry-standard chips to provide the audio and serial ports for the computer interface. This enables the soundcard and COM ports to be recognised and installed using the standard Windows drivers. I initially used the TI-5000 on Windows 10 and 11 based computers, and both recognised the TI-5000 hardware without any issue. While having four serial ports covers all operating requirements, Windows allocates these ports a COM number with no indication of which is which. This potentially confusing situation is solved using a serial port monitor application. This is available as a free download from RigExpert's website (www.rigexpert.com). When I ran the downloaded file, it installed additional drivers for the TI-5000 and the Port Monitor application itself. When executed, the Port Monitor displays an information panel that clearly shows the function of each port along with an option to copy the output to the clipboard, **Figure 1**. This is a helpful addition and makes the subsequent software configuration much easier.

The front panel, **Photo 2**, features four audio level controls providing excellent control of the audio passing to and from your rig. The final control on the front is the CW speed and this sets the speed for both paddle and computer-generated CW. I found the LED indicators on the front panel to be particularly helpful when testing the software configurations.

Another example of how RigExpert supports the operator can be found in the supplied booklet titled Software Sample Setups. This lists all the popular radio software packages and provides illustrated, step-by-step, instructions for configuring the software to work with the TI-5000. This was a big help and made the TI-5000 well suited to those new to linking their rig and computer.

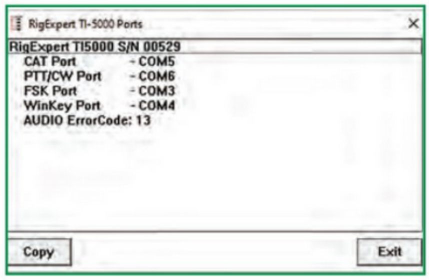

FIGURE 1: **Port monitor displaying TI-5000 COM port allocations.**

Unsigned drivers

The TI-5000 drivers used to annotate the serial ports are currently unsigned and rejected by Windows 10 and 11. This may be resolved sometime in the future, but the drivers can be installed by temporarily disabling the Windows driver signing enforcement. Here's how to do it:

Click the Windows icon, select power, then press and hold the shift button whilst choosing Restart.

When the computer restarts, choose Troubleshooting – Advanced Options

PHOTO 2: TI-5000 front panel.

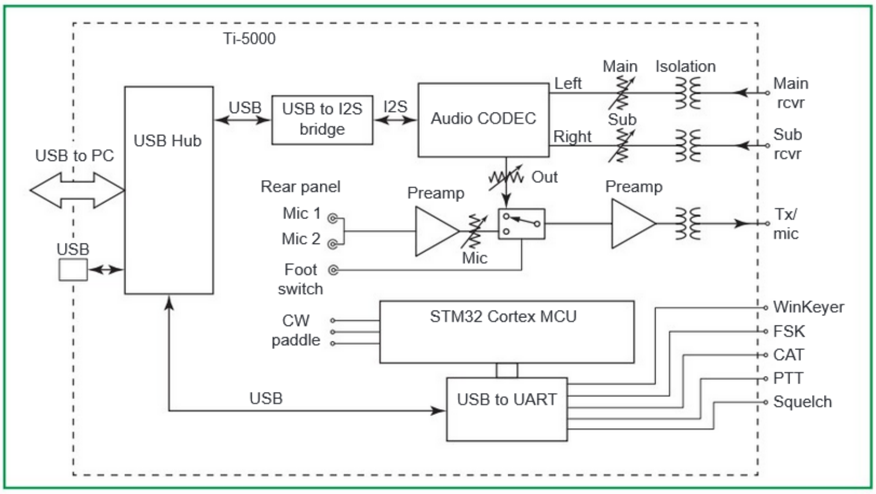

FIGURE 2: Simplified block diagram of the TI-5000.

Click Startup Settings

Click Restart

The PC will restart with the Startup settings menu displayed; press 7 to disable driver signing enforcement.

When the PC reboots, you will be able to install the TI-5000 drivers.

Once installed, restart your PC to return driver signing to normal.

A peek inside

The TI-5000 is housed inside a good quality steel chassis. As you might have gathered from the extensive range of features, a lot is going on inside the TI-5000. The RigExpert team were very helpful and supplied complete circuit diagrams to help with my review. These are commercially sensitive, so I won't be sharing them. However, I have created a simplified block diagram, **Figure 2**, to provide an insight into the inner workings. Starting from the USB port, this is routed to a 4-port USB hub and some protection circuitry that extracts the power supply for the TI-5000. Of the four internal USB ports, one is made available on the rear panel and could be used to connect a mouse or similar peripheral. Two of the remaining ports feed genuine FTDI chips to generate the four serial ports that support CAT, PTT, WinKeyer, FSK and Squelch. The remaining USB port is first converted to I2S digital audio format and then to an audio CODEC (COder/DECoder) chip that provides the audio inputs and outputs. To help tame any stray RF from the rig or antenna, the audio inputs and outputs are DC and RF isolated using audio line transformers. The audio input transformers are followed by a front-panel level control. After the level control is a switchable gain buffer amplifier that allows the interface to run from various audio sources ranging from high-level speaker outputs to the preferred line-out from the rig. The two inputs utilise the left and right channels of the CODEC and are intended to take the audio from the main and sub receivers, where available. The audio output to the rig is similarly isolated, with a level control, gain selectable buffer amplifier and line transformer. The switchable gain adjustment for the audio buffer amplifiers is carried out via a 6-pole DIL slider switch located on the base of the TI-5000. This is very clearly marked, **Photo 3**. To support SSB operation through the same interface, the TI-5000 has two microphone sockets on the rear panel. These are paralleled together and feed a switchable gain buffer amplifier and a common gain control on the front panel. The neat part comes with the switching arrangement between data audio and microphone audio. Next to the microphone inputs is a phono jack for a footswitch, and it is this footswitch that toggles the transmit audio between the microphone and computer. Although it's labelled up as a footswitch, any toggle switch will do the job.

For CW operators, the TI-5000 includes a WinKey emulator that accepts a paddle input via a 3.5mm stereo jack. The emulator can also be used to form the CW from software such as FLDIGI. The Winkey emulation is provided by the onboard STM ARM Cortex CPU and includes a speed control on the front panel. Operating CW from a keyboard can be troublesome if running a multitasking operating system such as Windows. This is because multitasking operating systems are not good at generating precise timings. By using the Winkey emulation, you can be assured of accurate CW spacing.

Despite its comprehensive facilities, the TI-500 current draw from the USB port was very modest at just 100mA. This should be available from just about any USB port.

In Use

For the review, I've been using the TI-5000 with an FT-897 transceiver along with my main Windows 11 PC, a Windows 10 laptop and, of course, a Raspberry Pi or two. I started with FT-8, which is the dominant mode on the HF bands. Before I started, I made a printout of the RigExpert port monitor output, so I had the port allocation to hand.

For datamodes testing, I started with WSJT-X as this is probably the most popular software for FT8/4 and many other modes. The software configuration was fully covered in the supplied example booklet, and I was pleasantly surprised to find that rig control and the audio ins and outs all worked the first time. One common problem with inexperienced FT-8/4 operators is overdriving at the audio input of the rig. This causes inband inter-modulation products that fellow operators will not appreciate. With the TI-5000, this was easy to control as I increased interface Out control to achieve the desired power, then backed off slightly. With the default settings, I found the control range was a bit too compressed around the minimum setting of the Out control. That was easily fixed by moving the gain slider switch on the base of the TI-5000 to the 1:10 position. This reduced the gain of the output buffer amplifier by a factor of 10, which put the full power setting of the control at about ¾ way round the control dial. Following my success with WSJT-X, I moved on to FLDIGI, as this is probably the next most popular software. FLDIGI is included in the setup examples booklet so I followed those instructions. This took me through setting up the audio, PTT and CAT configuration and included screenshots with all the essential boxes highlighted. As with

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ptamike@hotmail.com

PHOTO 3: DIL gain switches on the underside of the TI-5000.

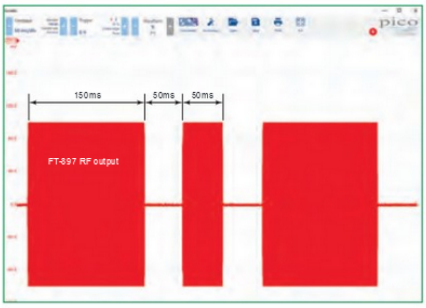

FIGURE 3: CW RF keying waveform measured at transceiver output.

WSJT-X, everything worked, and I had full rig control. One point to watch for FT-897 owners is the mode selection. The TI-5000 uses the rear Data port to inject and receive the audio signals. This port only works when the rig is set to Dig mode. In my case, setting FLDIGI to RTTY automatically put the rig into Dig mode, but this is worth checking if you find you're not transmitting. However, this is not a TI-5000 issue but related to the way FLDIGI and the FT-897 communicate. The only significant feature that wasn't covered in the examples booklet was the WinKeyer, so I've included that in the next section.

CW operation is well-covered thanks to the integrated Winkey emulation that supports computer and hand-keyed paddle operation. To test the TI-5000, I used FLDIGI on my main PC with a modified Spacemark ETM-5C paddle. The paddle connection was via a 3.5mm stereo jack on the rear panel with the paddles connected to the tip, ring and sleeve. When using the FT-897, the interface cable has a 3.5mm plug that fits the Key jack on the rig's rear panel. To use the WinKeyer emulation, I selected the FLDIGI Configuration panel and selected Modem – CW – Winkeyer. Here I could choose the WinKeyer COM port and press the Connect button. This produced a confirmation message in FLDIGI. One point to watch here is that the Connect button acts as a toggle, ie press it once to connect and again to disconnect. Also, don't forget to hit the save button after making changes to the FLDIGI setup. With the configuration completed, I could start operating. When using the Winkey emulation, the speed of the keyboard generated CW was conveniently controlled by the Speed potentiometer on the front panel of the TI-5000. I was interested in seeing the transmitted CW's timing, so I used a 40dB RF tap to sample the Tx output and fed it to my Picoscope. I've shown a screenshot in **Figure 3**. As you can see, the timing was bang on the ideal 3:1:1 ratio. I performed an identical test using the ETM paddle with the same results. For those that like to combine computer and hand sent CW, the TI-5000 worked extremely well. I could take over simply by using the paddle at any point in the QSO. As soon as I touched the paddle the computer output halted and switched to the paddle. If I wanted to continue the computer output, I just had to hit the Tx button in FLDIGI. One excellent point about combining hand and computer CW with the WinKeyer is the speed consistency, as the paddle and computer CW run at the speed set by the front panel knob. With a bit of practice, I could seamlessly switch between the two keying sources.

Slow Scan TV (SSTV) continues to survive and there is usually activity to be found around 14.230MHz. For the review, I installed MMSSTV software and followed the RigExpert guidance to configure the software. This is a mode where the TI-5000 microphone inputs and footswitch proved very useful. When operating SSTV it is common practice to talk and send SSTV on the same USB channel. The TI-5000 made this particularly easy as I could use the footswitch input to swap between SSTV data and my microphone. The provision of separate level controls for the SSTV signal and microphone made it easy to balance the drive levels.

With my continuing interest in using the Raspberry Pi for amateur radio, I connected the TI-5000 with my Pi-4 and loaded one of my datamodes microSD cards. The port monitor program that identified the COM ports on Windows wasn't available for the Pi, but I soon worked out the port allocations and have shown them in **Table 1**.

Summary

The TI-5000 was a pleasure to use during the review and provided a straightforward interface for a wide range of operating modes. The level controls on the front panel made it easy to control the audio levels in both directions between the PC software and the rig. The provision of the port monitor software to identify the port names combined with the excellent documentation make the TI-5000 ideal for those new to interfacing their rigs as well as more experienced operators. The RigExpert TI-5000 costs £154.99 inclusive of VAT at 20% and is available from Moonraker (https://moonrakeronline.com). My thanks to Moonraker for the loan of the review model.

TABLE 1: Raspberry Pi serial port allocations

Function	Pi port name
CAT	/dev/ttyUSB0
PTT	/dev/ttyUSB1 (set to use RTS)
Winkeyer	/dev/ttyACM0
Squelch	/dev/ttyACM1

Specification summary

Interfaces: CAT (Computer Aided Transceiver)
FSK output
PTT & CW output
CW keyer (WinKey emulation)
Footswitch
Microphone input
Computer connection: USB-1/2 or 3 for power (100mA) and communications
Transceiver connection: Single 25-pin D connector
Audio: Maximum input/output is 1V
Audio sampling: Input/output sample rate: 8-48kHz
Audio resolution: True 16-bit DAC/ADC
CAT serial port: 300-115200 baud
Compatibility: RS-232, CI-V, TTL or inverted TTL
PTT output: Open-collector and TTL-level
CW output: Open-collector
Max output current: 50mA
FSK output: Baudrate 45-1200, open-collector
Computer support: MacOS/Linux, Windows 2000/XP/Vista/7/8/10/11 (32 or 64-bit)
Dimensions: 20cm x 10cm x 4cm
Weight: 300g
Warranty: 2 years

Data

PHOTO 1: 2.4GHz Quadrifilar Helix antenna used for QO-100 uplinks tests using the JT9G-Fast and JT9H-Fast modes.

A post to the RSGB-Tech Group **[1]** asked the question, "…are there certain waveforms that are better than others, or some that are simply snake oil…" A question that equates more or less to, *is one datamode better than any other?*

It is impossible, or at least very difficult, to say that 'one waveform is better than others'. You have to take into account whether you are band-limited, or power-limited. On the amateur bands our popular weak signal modes are power limited, but some situations, like amateur TV, can be bandwidth-limited. Do you need coherent or incoherent modulation? In other words, do you need to recover and lock to a carrier. Which mostly boils down to how accurately does tuning have to be maintained and the stability of the link and equipment. How is the clock carried on the waveform, if it is needed at all? What synchronisation overhead is required? And, of course, the data rate you want, whether Forward Error Correction is used, and how strong does it have to be. Do you need 100% perfect copy at all times or an indication of failure; or can the occasional error to be allowed through? Do you want a system that automatically asks for a repeat if the message fails?

The field of information theory and transmission is a huge one, it has taken up many minds for decades and is a post-graduate degree subject in its own right and technology is moving forwards all the time. Some of the modes and concepts that were just dreams in their designers' eyes 50 years ago are now possible with the massive processing power in chips costing pennies.

In our own area of popularity, look how the modes just within the WSJT suite have grown in 20 years, from simple non-FEC ones like JT44, ISCAT and FSK441, through JT4, JT9 and JT65 that use convolutional and Reed Solomon coding not requiring massive processing power to decode and were perfectly OK on the simpler PCs of the early 2000s. Now we can move to the more efficient and better FEC codes like Low Density Parity Check (LDPC) ones like FT8, FST4, MSK144 that rely on a fast and powerful processor to give optimum decoding.

Outside WSJT, there are those lesser known keyboard-keyboard modes that employ heavy correction for reliable paths like THROB, Olivia, MT63 and, of course, STANAG 4285 of which there is an amateur implementation written by G4GUO but only ever used by a few of us for the fun of it once. Or there are the simple keyboard modes with little or no correction, RTTY and PSK31/63 still popular for their ease and simplicity. And now there are the whole family of OFDM modes (Orthogonal Frequency Division Multiplexing) that can be used with abandon, tailoring baud rate, number of tones, bandwidth, number of symbols per tone and FEC to every whim. And then there are the Fuzzy modes like Hellschriber and QRSS/DFCW that rely on the human eye / brain to interpret to computer's output.

But, in spite of all that, it is probably quite safe to say that Morse, when used as a data mode, sent and decoded by computer, is probably one of the most useless, ludicrous non-sensical whims radio amateurs have recently gone down. I once heard of a group doing CW Field Day with computers for both ends of the link – and then wondering why they weren't very successful!

If you want an on-off data mode, and there are perhaps the odd and occasional cases where it may be useful over FSK or PSK or whatever, then something like OPERA will do an excellent job. Not some arbitrary variable symbol length code that needs some clever clock extraction.

Mobile through QO-100

Prompted by remembering a paper at a conference back in the mid 1980s about transmitting mobile data through a geostationary satellite, I tried up-linking on 2.4GHz to the QO-100 spacecraft from a moving car, monitoring the downlink at home. A number of modes and different power levels were tried, but only one mode turned out to be robust enough to withstand the variable Doppler and fast fading and to have a sufficient sensitivity to work with the self-imposed link power budget. I used a Quadrifilar helix antenna, as shown in **Photo 1**, to give omni-directional circular polarisation. A 10 watt PA operated with a low duty cycle allowed an average RF power of just a couple of watts. The only mode that worked well was fast variants of JT9, JT9G-Fast and JT9H-Fast. These do not use GPS timing, and transmissions consist of frames of around 0.85 and 0.42 seconds respectively for the G and H submodes, repeated for as long as the user wants. I used bursts consisting of four frames every 10 seconds, giving a Tx duty cycle of around 34% or 17%.

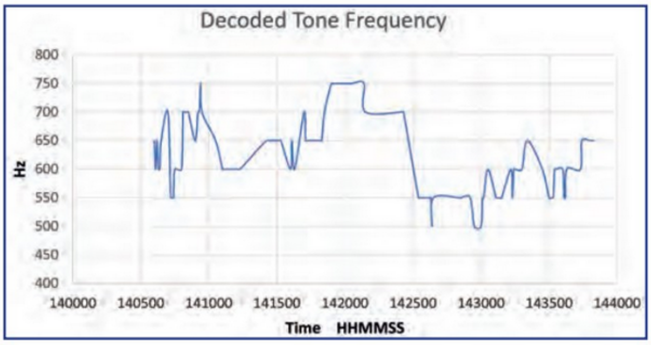

FIGURE 1: Doppler shift from mobile QO-100 uplink transmissions using the JT9G-Fast mode. Transmissions were from a car driven on a circular route over urban and rural roads at speeds of up to 40mph.

The results were very successful. Using JT9G-Fast, on a run over urban and rural roads, approximately 50% of all transmissions were successfully decoded. Using JT9H-Fast, this figure dropped to 39%, but considering the lower duty cycle of this, it can perhaps be said that the wider JT9H-Fast was the better mode. The WSKJT software reports the decoded tone frequency and for mobile operation this depends on Doppler shift due to vehicle movement towards or away from the satellite. The reported DF value and hence Doppler shift was plotted for the duration of the test for all successful decodes. A plot of this appears in **Figure 1**. More details of these mobile tests can be found at **[2]**.

Don't forget JS8Call

From the monthly calling notice: "The JS8 QSO Party is a chance to get on the air with JS8 and make some contacts every month. Whether you like a quick exchange or a long rag-chew, this event is for you. We have a lot of great, patient operators in the group, so the environment should be very welcoming!

"The party is an all-day global event held monthly on the second Saturday of the month (unless the schedule is modified for a particular event). It runs for 24 hours starting at 1900UTC on Saturday and ending at 1900UTC on Sunday using all amateur bands

"Remember, by default, JS8 QSO Party events are not contests, so all amateur bands are open for use and that with JS8 we have the freedom of free-text. So feel free to QSY toward a clear frequency and talk about anything you want."

References

1: RSGBTech https://groups.io/g/RSGBTechnical
2: http://g4jnt.com/MobileDataThroughQO100.pdf

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EMC

G.fast

G.fast is a type of broadband Internet access **[1]**. The 'fast' in G.fast stands for Fast Access to Subscriber Terminals. It is defined in International Telecommunications Union (ITU) Recommendation G.9700/9701. It is similar in many ways to VDSL2 that uses optical fibre to the street cabinet (FTTC) then copper wire to the customer's premises. G.fast is sometimes known as Fibre to the Distribution Point (FTTdp). The distribution point is a fibre node that acts as Digital Subscriber Line Access Multiplexer (DSLAM). This could be mounted on a pole or underground and in the UK, Openreach has used 'side pod' extensions on street cabinets. A G.fast FTTdp fibre node connects to a limited number of customers via existing copper cables at a distances of typically up to 250m. G.fast achieves data rates of up to 300Mbit/sec, which is higher than VDSL2 due to shorter lines. These allow higher frequencies to be used, up to 106MHz or 212MHz.

In 2017 -2018, Openreach announced that it was launching G.fast services to a total of 127 locations in the UK. In 2020, Openreach announced G.fast deployments would officially remain on pause until at least April 2021, as Fibre to the Premises (FTTP) takes priority. See also **[2]**. We understand that G.fast passes about 2.8 million homes but it is not known how many users there are.

G.fast has a number of potential EMC issues. First, the frequencies used extend up to VHF so that compared to VDSL2, G.fast cables are more likely to radiate RF interference or to be susceptible to signals from nearby transmitters. Secondly, the modulation used in G.fast is different from VDSL2. VDSL2 interference sounds similar to continuous random thermal noise and VDSL2 uses Frequency Division Duplexing (FDD) with different frequency bands for upstream and downstream. G.fast uses Time Division Duplexing (TDD) so it switches rapidly between upstream and downstream transmission with a default frame length of 0.75ms. This causes a whine at 1.333kHz. Nevertheless, the G.9700 recommendation specifies 'notching' of international amateur radio bands and some other frequencies.

There have been a few reports of immunity problems where G.fast lines are affected by amateur radio transmissions and one solution in such cases is to change to Fibre to the Premises (FTTP), see below.

Fibre to the Premises (FTTP)

In the April 2022 EMC Column, Figure 1(d) shows Fibre to the Premises (FTTP), sometimes known as Fibre to the Home (FTTH). With FTTP, the optical fibre comes in to an Optical Network Terminator (ONT) similar to the one shown in **Photo 1**. The whole link is optical fibre with no copper wire,

PHOTO 1: A typical Optical Network Terminator (ONT) for Fibre to the Premises (FTTP).

FTTP should avoid any EMC problems because the optical fibre itself does not radiate any RF interference (egress) and it is also completely immune to RF signals from nearby transmitters (ingress). In practice however it has been reported that some ONTs are powered by a 12V switching power supply unit that generates RF interference up to 3.5MHz and above. One Member reports that he has many devices in the house with switching power supplies that do not generate significant RF interference with his particular antenna location. Then he upgraded his broadband from ADSL/ VDSL to FTTP and he reports that got more RF interference instead of less. We are currently testing one of these switching power supply units and we plan to report the results in a future EMC column.

Mobility Scooter Chargers

A Member contacted the RSGB Helpdesk for advice about a new neighbour who had something that was causing "total wipe out on HF". The source was found to be the charger for the neighbour's electric mobility scooter which is left on charge 24/7. The original charger had been dropped and the connector had been broken so the owner bought a new charger of unknown origin online. It was then noticed that the charger was designed for more recent mobility scooters that have Lithium batteries whereas the neighbour's mobility scooter was an older model with 24V sealed lead acid batteries.

It appears that the Member did the owner of the mobility scooter a favour by pointing out that it was the wrong type of charger. A charger designed for a Lithium battery would not give the correct output voltage for a lead-acid battery so it would either not charge properly or it would overcharge if left on continuously. Overcharging would cause gassing and loss of water in a sealed lead acid battery that cannot be topped up, so it would be likely to shorten the life of the battery. The unbranded charger that was causing the RF interference was disposed of and it was replaced with another new charger that is suitable for lead-acid batteries. This also solved the RF interference problem.

Cistern Flush Interference

The following message was sent to the EMC Helpdesk by a Member.

"Dear EMC Helpdesk, Recently, we had our bathroom refurbished. As part of this, the plumber fitted a new toilet that has a Roper Rhodes Contactless Dual Flush Capacitive sensor model TR9014 / CSFK, hidden behind the fascia. The problem is that when I tune on 40m or 80m at 75W, the toilet endlessly flushes. I wonder whether you've come upon this before? We have many other capacitive touchscreens in the house but this is the only one that seems ultra-sensitive to RF. I have attempted to reduce the sensitivity of the device with some success, by covering it in foil as an experiment. Unfortunately, there is no nearby metal to 'earth' the foil. I wonder if you have any other advice? For example, is a 'Faraday blanket' such as https://www.amazon.co.uk/Protection-Faraday-Shielding-Military-Signals/dp/B0895LTG3V/ likely to be successful?

Yours, flushed with perplexity..."

In answer to the above question, this is the first time we have heard of Cistern Flush Interference (CFI) but we would be interested to hear of any other cases. The capacitive sensor is installed behind a panel of timber or laminate and it can detect the wave of a hand through the thickness of the panel. As with any electronic product that is CE Marked, it should comply with The Electromagnetic Compatibility Regulations 2016, UK Statutory Instrument 2016 No. 1091. These include Essential Requirements that cover electromagnetic disturbances generated and also immunity to the electromagnetic disturbance to be expected in its intended use.

The sensor is powered by four AA size alkaline batteries so there are no external wires that could pick up RF. This leaves screening as the only option. We don't think that the 'Faraday blanket' would be any better for screening than aluminium foil and in any case, the blanket is only designed for frequencies above 10MHz whereas the unit

PHOTO 2: **A portable LW/MW/SW radio in a VW California.**

PHOTO 3: **LED light control panel in a VW California.**

is sensitive to transmissions in the 3.5MHz and 7MHz amateur bands. Wrapping the unit in foil has been found to give some improvement but the front of the sensor would need to be left open to allow the capacitive sensor to work. It may be possible to partially screen the front of the sensor leaving a hole. if there is no RF earth such as a copper water pipe nearby then connecting the screening foil to the negative side of the internal battery pack may help.

Camper Vans

A Member reports that his 2021 VW California 'Coast' camper van has a VW 'Discover Media' Infotainment system. This includes FM and DAB radio but there are no long wave or medium wave bands nor any radio aerial suitable for frequencies below 88MHz. The Infotainment System can also play streaming media via the Internet, using data services on a mobile phone network. This works when driving in built-up areas or on main roads but a camp site at a rural location is another matter. There may not be any 3G/4G mobile phone coverage or there may be hundreds of other users all trying to access the Internet via one overloaded 3G/4G mobile phone base station.

Radio 4 long wave on 198kHz provides good coverage of UK mainland and beyond but the only way to receive this is by using a portable radio such as the classic Grundig radio shown in **Photo 2**. This gives good LW reception by the window when the van is parked in day time but after dark, the LED lights in the van cause interference to Long Wave although MW is not too bad. A touch screen camping control panel has various functions including dimming the LED lights individually (see **Photo 3**). The LED lights are driven with Pulse Width Modulated (PWM) waveforms at two different frequencies, 375Hz and 190Hz with many harmonics.

Figure 1 shows a measurement made in the van from 0 - 2MHz using a passive loop antenna. The loop is not calibrated so the measurements cannot be related to field strength but the MW broadcast signals between 909kHz and 1548kHz are very strong at this location at over 300mV/m. The harmonics of the PWM LED drive can be seen up to about 500kHz and beyond and these affect reception of Radio 4 long wave on 198kHz.

FIGURE 1: **Frequency spectrum from 0 - 2MHz in a VW California showing harmonics of LED light drive waveform.**

Articulated HGVs

A Member writes, "Dear EMC team, Being a regular on the Worked All Britain nets, I said to the group that I would write to you on a topic of conversation which comes up regularly. Naturally, WAB includes a significant number of HF mobile operators and it turns out that they report a common interference issue that is actually well-known to mobile amateur operators.

"The engine unit of Volvo articulated vehicles appears to produce a wide-bandwidth and very unstable whine, that affects (at least) both 80m and 40m. It is specific to Volvo vehicles only. When passing Volvo artics on the motorway, this whine can be detected up to 200m either side of the vehicle as you pass it, and close to the vehicle it completely blots out any reception *[on 3.5MHz or 7MHz Ed]*. If one drives past a lorry park or into motorway services parking area, multiple whines are heard and can be easily tracked down to Volvo lorries. Note that this seems to be mostly prevalent with articulated Volvos. Their rigid lorries and the majority of their domestic cars do not seem to exhibit this noise although I have personally heard this from one of their top-end SUVs.

"The unstable whine does not seem to be speed related. If Volvo drivers who are taking their rest periods have their engines running, this generates just as much noise as when on the move. I do not believe the whine is present when the truck is fully turned off. Of course, the interference is generally transitory with vehicles on the move past each other, unless of course you're stuck in a nine-mile queue right next to one of these trucks!

"I wonder whether this has been reported to you before?"

We haven't heard of this before but we would be interested to hear from anyone who knows the reason why these engines radiate RFI on HF radio bands.

References

1: Wikipedia G.fast https://en.wikipedia.org/wiki/G.fast
2: ISP Review article on G.fast https://www.ispreview.co.uk/index.php/2020/06/openreach-confirm-g-fast-broadband-rollout-paused-until-2021.html

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Stereo-code filter

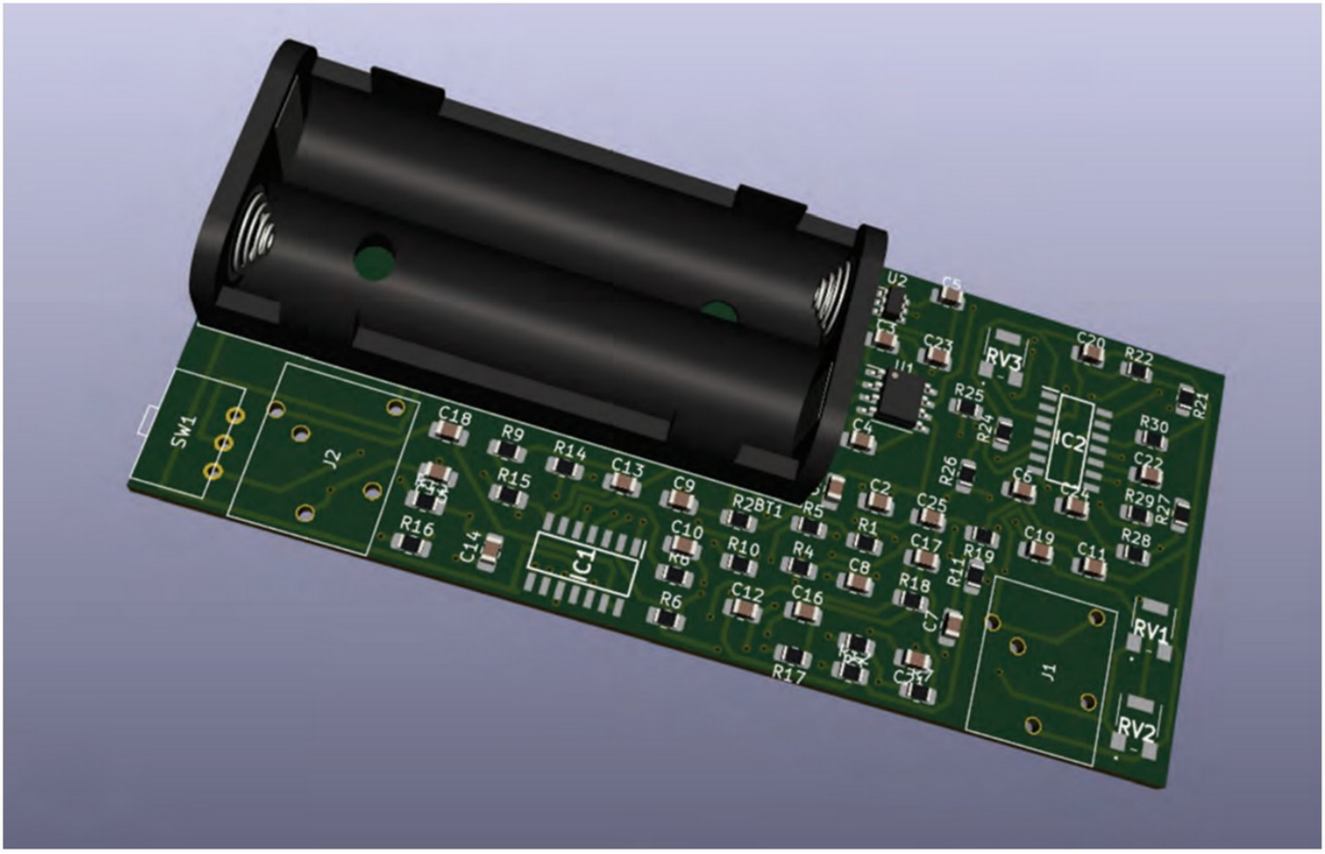

PHOTO 1: The 3D layout of the PCB.

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In the September 1975 edition of *RadCom* magazine **[1]**, the RSGB published an article entitled "Subjective Selectivity and Stereocode" by Dud Charman, G3CJ and R Harris, G3OTK. This article discussed the 'cocktail party' effect where the ears and brain can work to distinguish conversations from different places in the room using the source spacial separation providing small time differences of arrival at each ear. They postulated that this could be used to separate Morse signals of different tone if the spacial time differences could be synthesised in an audio processor. They developed an active filter with a channel for each ear with amplitude shaping and group delay shaping to emulate motion as a source frequency is swept across the audio band and so provides this aural effect.

Some years after publication, having taken out my G4UAZ call (that I now have swapped back to G8CQX!) and become a Morse enthusiast, I built a version of their design on Veroboard. The effect had to be heard to fully appreciate it. It is like the signal you have tuned to the centre of the passband is in the middle of your head and others are off to the sides. Loud signals appear closer so you get a 3D sensation. I stopped using a narrow CW

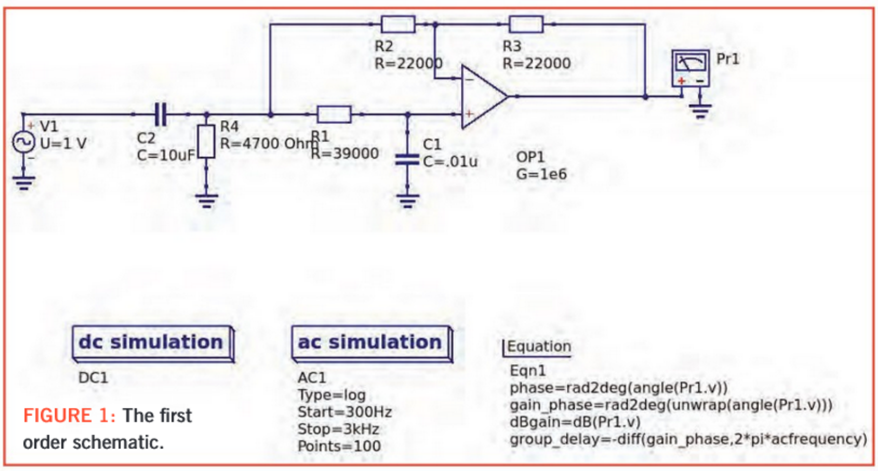


FIGURE 1: The first order schematic.

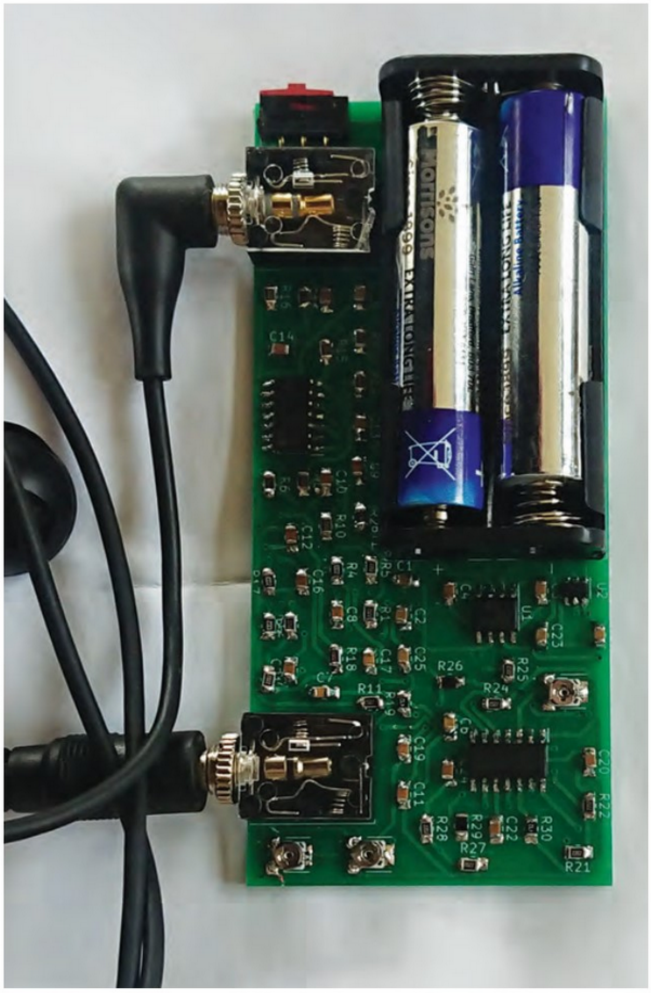


PHOTO 2: The finished project.

filter preferring to experience the full passband whilst concentrating on the wanted signal, which is easy and not at all tiring for long periods of listening when heard through the stereo-code filter. Sadly, I eventually lost it to a power supply issue and have always hankered after a replacement but couldn't bring myself to re-build it in prototype Veroboard form because of the large amount of effort needed. I considered what a digital implementation would require. If one were to take the amplitude and phase responses of this filter's two channels, then Fourier transform to get the impulse responses, one could use them to provide the weighting coefficients needed for the Finite Impulse Response (FIR) digital filters to do the same job. It would probably need quite a lot of processing power as compared to the modest low powered op-amp active analogue filter. That is fine if you want to be able to flexibly tune the response by changing the weights but, in this case, it isn't required.

Digital implementation

For example, we shall see later we need to implement an audio tuned circuit in each channel as well as a number of low pass elements. The FIR filter will need a digital delay line of a fraction of a second, so one could very roughly estimate the minimum processing requirement might be in the order of 100k 16bit or preferably 32bit floating point multiply-accumulate operations per sample. That does seem easily doable on a modern low power DSP device like a TLV320. There are dedicated IIR and FIR blocks in many devices that might be usable. The FIR approach would have a noticeable delay though, which would be a nuisance for slick break-in contest working. Alternatively, one could take the transfer functions in Laplacian operator form from the original article, parametise and perform a bilinear Z transform to get the z domain function. From those, the coefficients for Infinite Impulse Response filter section implementation can be got. It should be easily within the processing capability of such devices. There are then issues of rounding, scaling and not the least, stability to be tackled as they arise, so this is not a trivial exercise and would take me a lot longer to achieve.

This sort of processing is also within reach of devices like the Cirrus Logic CS497014, which has uses in things like ear-bud noise reduction. An evaluation kit to start writing software for either of these devices would be hundreds of pounds to buy though not dissimilar to the Texas Instruments device kits. This dominates my thinking for a

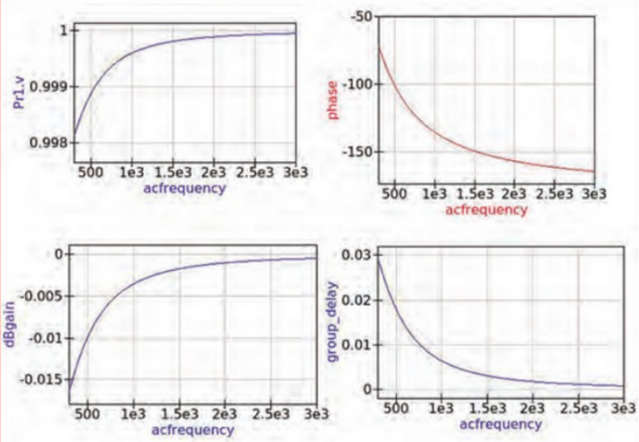
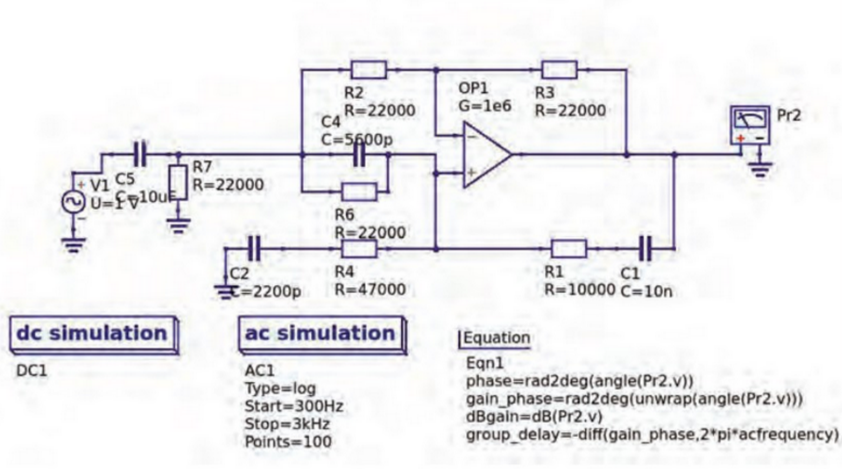


FIGURE 2: First order response graphs.

FIGURE 3: The second order schematic.



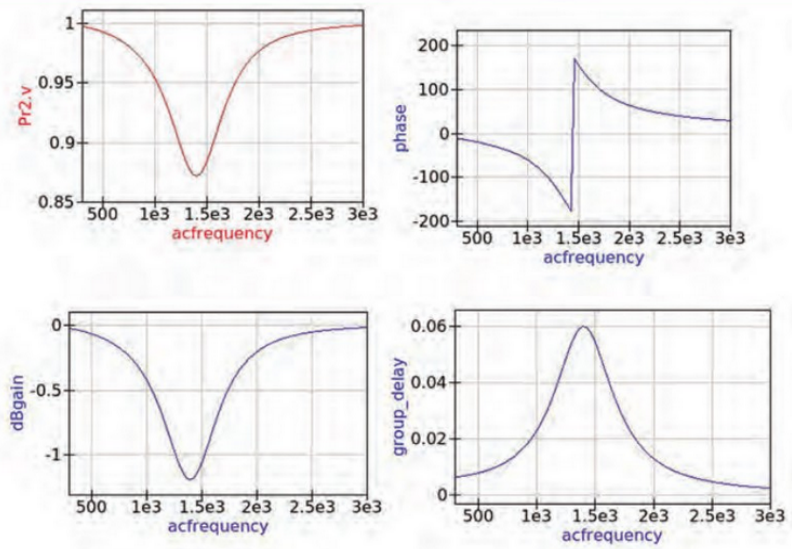


FIGURE 4: **Second order response graphs.**

hobby project rather than the £10(ish) device cost .

The advantage of a digital solution is one can modify the filtering characteristics easily and add other functions. The advantage of the analogue solution is lower power, lower component cost, easy build and no need to program. The fact that one cannot change the filtering characteristic is not an issue if one can design with confidence of getting it right first time given you know exactly what is required. That is where computer simulation of the schematic followed by PC assisted PCB design comes in. It is relatively easy to get it right first time if you check things carefully this way. And the simple binaural stereo-code function is not going to change. So the active analogue filter gives me exactly what I want without the hassle of getting a development system up and running to develop new filter designs for a DSP device.

So, an active analogue filter able to drive a pair of earphones can be small, light and battery powered. And now with more time on my hands, I have eventually decided to have a go at modernising the design. I started by checking the fundamentals using QUCS Spice simulation. The original authors had not the means to do much experimentation with component value sensitivity so had to specify some non-standard ones to be sure of getting the calculated response. I have been able to update the design to be easier to source and build by make using standard values. I experimented around the calculated values with nearest standard E12 values and checking it is still a good response. I had no

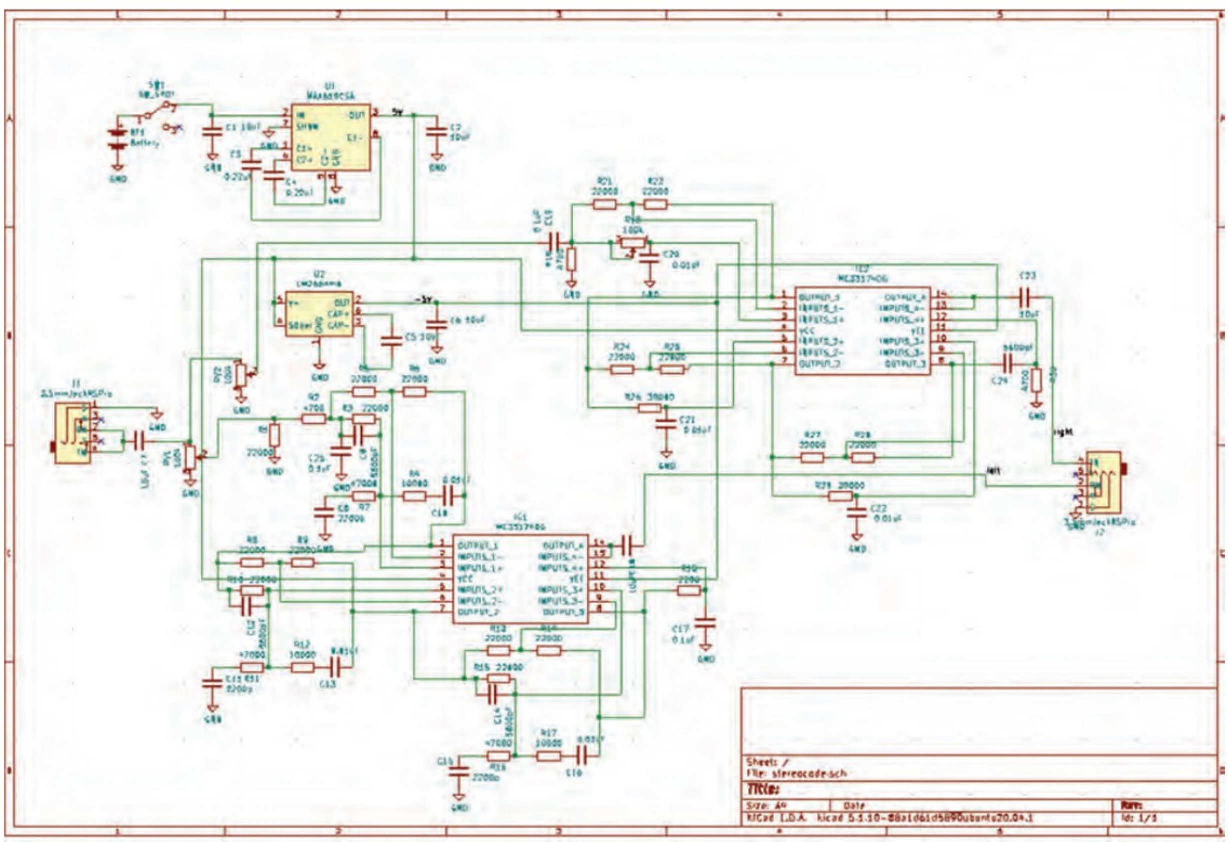


FIGURE 5: **The complete schematic.**

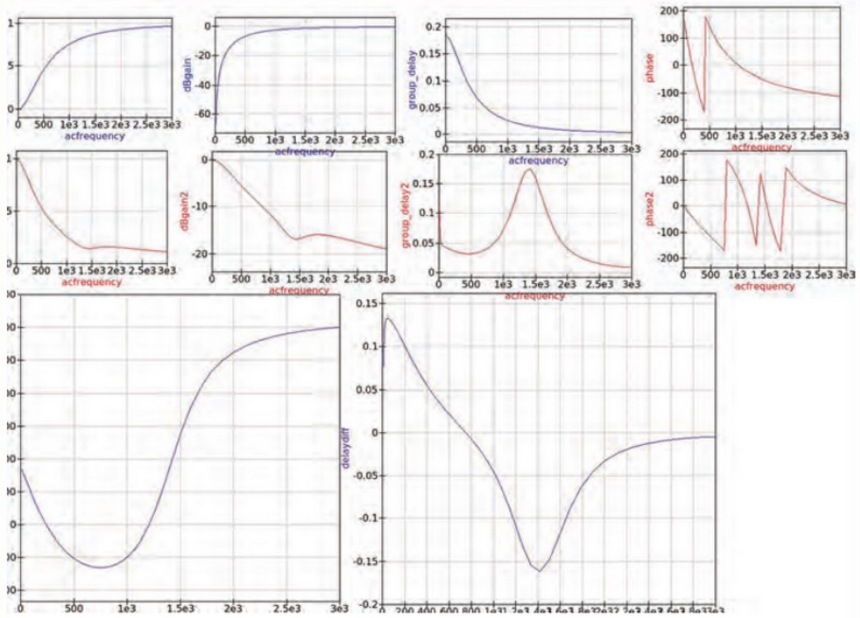


FIGURE 6: The simulated responses.

problem getting as good a response without having to combine components to do it.

Two prototypes

The design uses two prototypes for the shaping of group delay, a first order all pass section and a second order all pass section. One type is used in the left channel and one in the right. They provide a time delay (termed 'group delay' and characterised by the rate of change with frequency) that differs positively or negatively with frequency at the tuning frequency. The remaining amplitude shaping is then achieved with RC filters. The key point is to achieve a relative group delay difference between the two filter channels which alters with frequency in the same way a source delay is presented to a pair of ears as the source transits across in front of the head.

The circuit schematic and the response of the first order prototype filter obtained by simulation in open source QUCS spice are shown in **Figures 1** and **2**.

The point to note is that the amplitude response changes very little over the audio band (note that the scale is suppressed zero) and the delay falls smoothly with frequency, especially around 700Hz, which is the sort of frequency a receiver will be tuned to when receiving CW.

The corresponding figures for a second order prototype are shown in **Figures 3** and **4**.

Again, if you take into account the suppressed zero nature of the gain and amplitude curves, then you can see that there is little amplitude variation over the audio band. Both these circuits are examples of 'all pass networks'. This second order circuit has a resonance whose sharpness is determined by the ratio of values in the feedback to the + input of the op-amp. The resonance gives an opposite characteristic to the delay curve so it rises from the lower audio edge to the resonance just before 1.5kHz. That is because energy is stored in the tuned circuit for longer the nearer you get to the tuning point, so the signal takes longer to get through. The difference between the first and second order characteristics between 300Hz and 1.5kHz has the property we want, namely it moves with frequency as if the source moves in position in front of us when the frequency is changed.

These simulations confirm that the original design was correct in needing 3 sections of each filter to get the delay difference values that corresponds to a delay difference between sounds arriving at ears spaced by a typical head size, nominally about 15cm. A complete

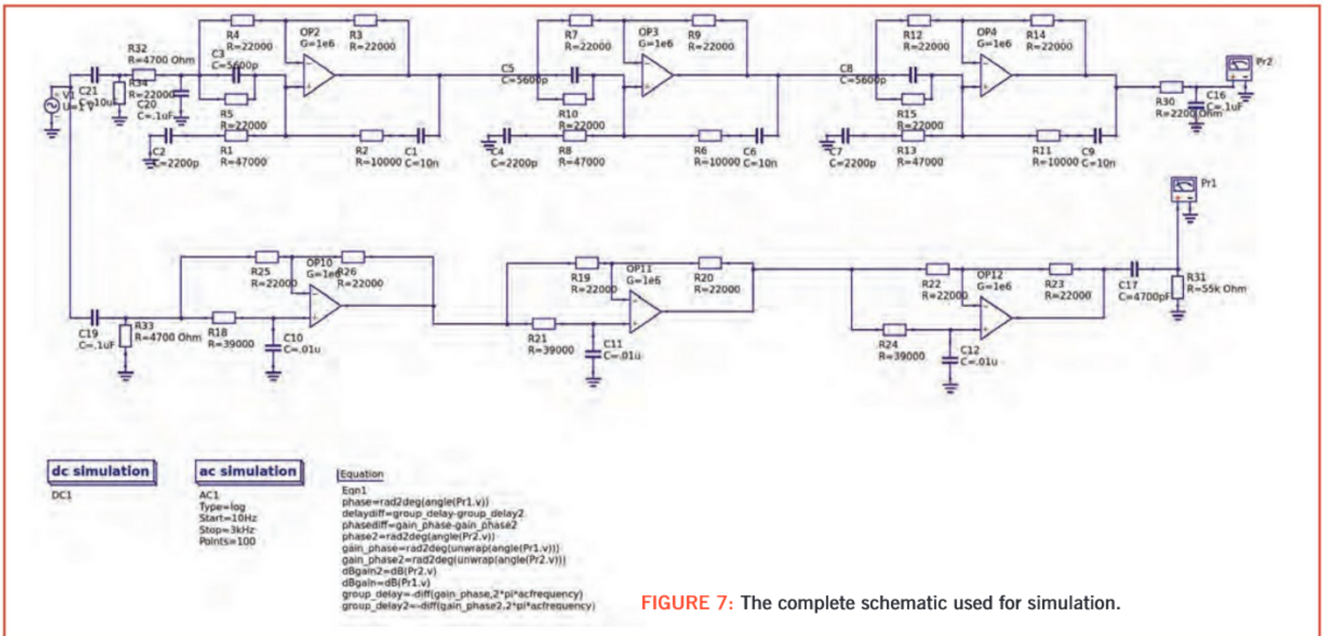


FIGURE 7: The complete schematic used for simulation.

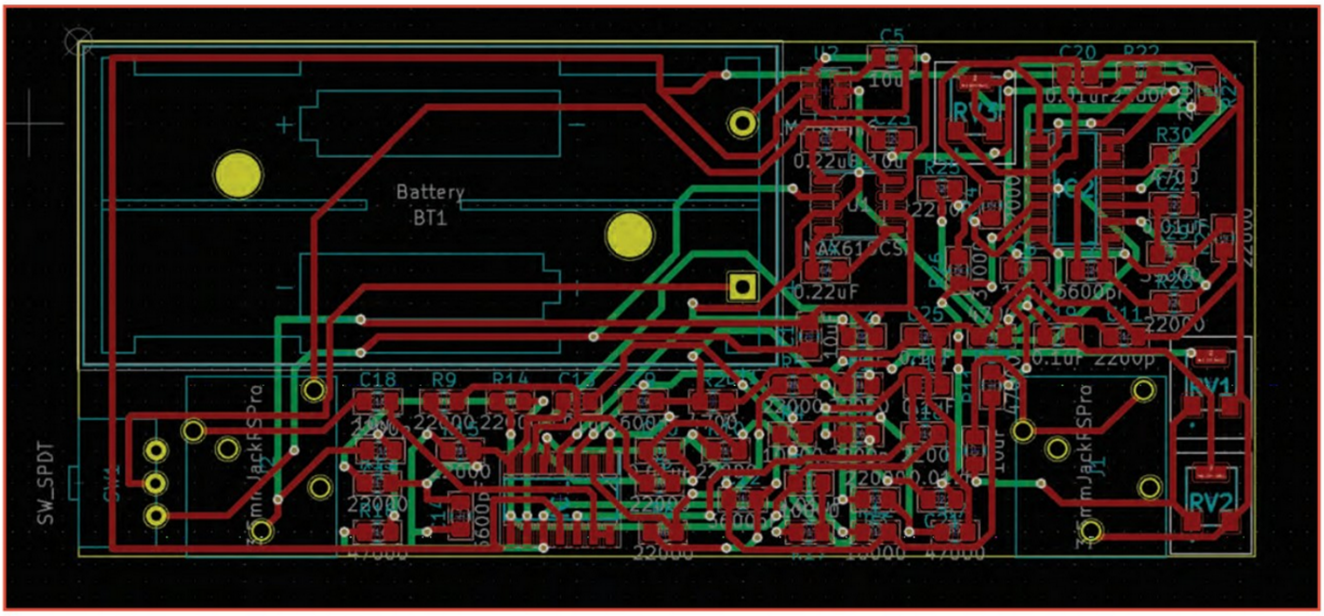


FIGURE 8: The track layout.

stereo-coder has three sections in each of the left and right channel halves to feed each ear and has an appropriate high or low pass amplitude shaping RC section at the input and output of each of left and right channels. The overall simulation schematic to get the required characteristics and simulated responses are as in **Figures 6** and **7**.

The responses show each channel and the differences in phase and delay in the bottom two curves. The rising and falling amplitude responses introduced by the RC filters are clear. Signals at the lowest or highest ends of the audio bandwidth will be mainly heard in the ear listening to the second order filter based or first order filter based channels respectively. What happens in between when the signal is tuned around the intended reception frequency (700Hz) is that the signals in each ear are about the same amplitude but have the differential delay difference in the bottom right curve, which makes it seem like it moves in front of you as you slightly adjust the tuning. Different signals with slightly different tones will sound like they are spread out in front of you. It is a very distinct and natural seeming sensation and makes concentrating on just one signal subjectively much easier. All this is very much in line with the original design so I decided to design a surface mount PCB and build some prototypes. Surface mount components are more readily available these days and I find manual assembly is no problem with very fine tweezers, solder and soldering iron bit and the means to see what you are doing. I use high magnification binocular viewers. Some people advocate other means of assembly such as hot air guns and solder paste or even home based reflow soldering, but I have found direct soldering effective and choose components that are suitable for this. Other methods of assembly will work, this is just the easiest for me. I use open source Kicad for schematic capture, net-list production and layout. The PCB schematic (**Figure 5**) has added an output buffer for earphones, connectors, power switch and a battery holder and charge pump devices to generate plus and minus 5V supply rails from the two AAA size batteries.

It uses two quad op-amps (IC1 and IC2) with a 14-pin dual in line surface mount footprint. The fourth amplifier in each is configured as a voltage follower to drive the earphones. U1 and U2 are the charge pump devices to generate +5V and -5V rail respectively. With a little auto placement help I finally arrived at a compact (90mm x 40mm) 2-layer layout which passed all the design rule checks. **Photo 1** and **Figure 8** show the track layout and simulation of the 3D layout. The finished project can be seen in **Photo 2**.

This then allowed me to order a few prototype printed circuit boards online just by uploading the Gerber files and completing the order and within two weeks they popped through the letter box. So much easier than prototyping my old one with wiring board like Veroboard. Provisioning the remain bill of materials was all next-day delivery so I was quickly able to try it out.

Finished project

The performance was everything that I remembered of the original and entirely confirms the simulation results. The drain from the battery is less than 10mA. The LM324 op amp has just enough ability to drive earphones without too much distortion and the whine from the charge pumps although detectable is not of concern. The two input potentiometers are set to near maximum and adjusted so each channel is equally loud on tune. In my case that is pretty much the same for each. RV3 should allow a small adjustment to the centre frequency. In my case I set it to about 39kΩ and left it there as it was near enough the tuning point for my rigs. You get used to tuning a signal into a 'position' that need not be exactly ahead to be 'netted', but it helps to be close. There is a tremendous sensation of signal motion with small amounts of tuning around this point. With a pile up there is a sense of space, weak signals to the back and strong to the front. In the archive **[2]** is an audio file that is a recording of live reception being tuned up and down and shows the effect if you listen to it on earphones or headphones. It is even more stunning if you are tuning the knob at the same time so you get manual-aural coordination. This URL archive has all the Gerber files needed to get a PCB made and a sample audio file that needs to be heard via earphones or headphones for the proper effect. Although I retain all design rights to these and schematics, I am very happy for people to make the device for their own use or to supply to others at cost.

Websearch

1: September 1975 *RadCom* see www.rsgb.org/radcom under supplementary material to view the original article.

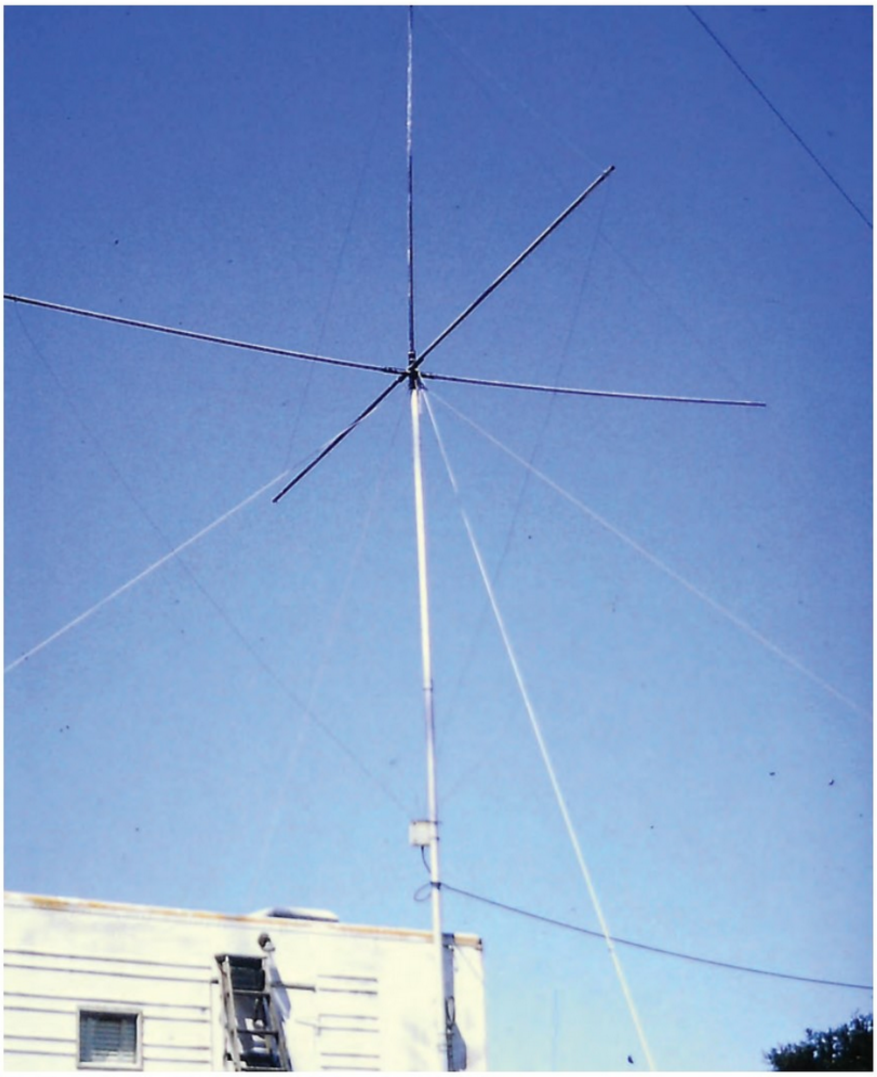
2: Reference URL for Gerber files for PCB manufacture, Bill of materials and for sample MP3 audio demonstration https://github.com/john-g8cqx/Stereocode_2021.

How do I know where the DX reception is?

Or, how do I know where to point my beam?

In essence, these are really the same question. All amateurs want to know which far-off places can hear them. This is one of the aspects of WSPR, PSK Recorder, the Reverse Beacon network and FT8 that make them so popular. For amateurs in the UK working around Europe, it is only challenging when a rare country like Albania is activated. Those interested in DX will know that there has to be propagation to that region. How can you actually tell, in real time, when you are sitting in front of your rig?

Of course, one way is to scan the bands for signals and then try to call the DX station. And that's what amateurs used to do. Or operators could be glued to the Cluster. But that can only show a fraction of stations on the air. Sometimes, whilst working a pileup, my call will not appear: and sometimes only after I've gone off the air (QRT). But there is what appears to be a simple method that has been around for a lot longer than all of these technical wonders. It was revolutionary at its inception and has been the biggest contribution to amateurs that are interested in chasing DX for almost half a century!



The trailer/caravan overlooked Berkeley. The antenna is a ¼ wave for 20m.

The Beacon Network

In 1972, the North Californian DX Foundation board decided they wanted to expand their operation in a scientific way. They wanted to go further than assisting DXpeditions with equipment and support. Man had landed on the Moon but amateurs were still chasing DX the hard way.

They approached their scientific advisor, Dr 'Mike' Villard Jr., W6QYT of Stanford University to help them with their quest. Mike had a friend who was working with floating maritime beacons that gave out radio signals on a project connected to SAR (Search & Rescue). The beacons were going to be used to track currents in Alaskan waters to give emergency services data to enable them to track drifting vessels in difficulty. OK, how is this related to amateur radio?

Mike arranged for one of the beacons that transmitted on 20m, being tested in Washington, DC, to be switched on. A group of NCDXF members listened, as well as being in contact with each other on the 2m band, locally. The 25 watt transmission was heard well, and even the one-watt was copyable! So, the idea was formed. Beacons running on 20m (14.100MHz) around the World would contribute to scientific knowledge and be available for operators to hear. There was one big snag – each beacon cost about US $25,000! (Approximately $160,000, over £130,000 today.) This was well outside any NCDXF budget. So, where did they go from there?

The finer details

The Board turned to the amateurs that had worked on the OSCAR I – IV satellites, including Chuck

The equipment is a TS-120 plus phasing unit designed by Mike, K6MYC.

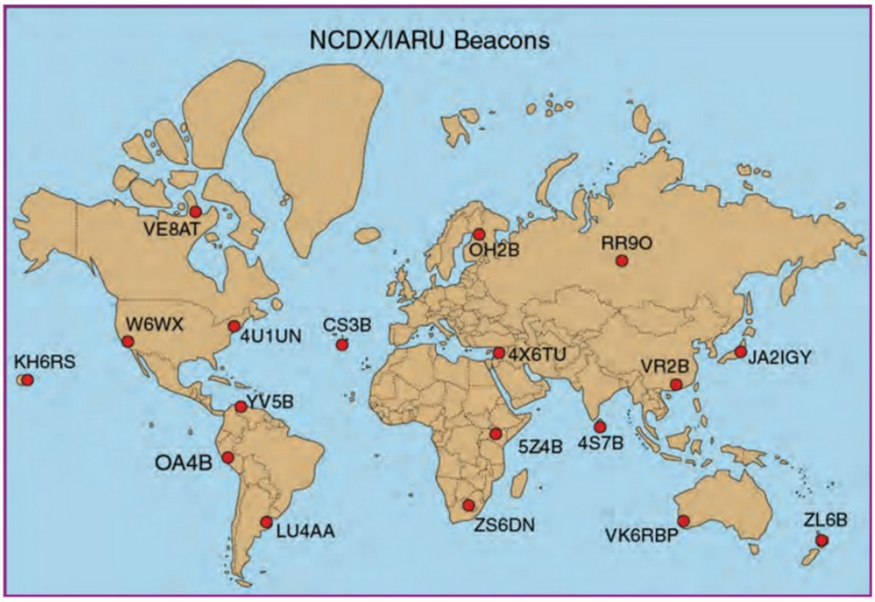


FIGURE 1: When all are operational there are 18 beacon messages over a three-minute period. This shows the locations.

Towns, K6LFH. Surprisingly, after a short series of meetings they came up with a unique but brilliant idea. It would be a worldwide beacon system where each beacon transmitted for one minute in sequence, using the same message format. At W6QYT's suggestion each beacon's transmission sequence could be lowered in 10dB steps in the final stages to check the level of propagation. But then came the reality. Who was going to design and build these beacons? K6LFH brought in Jim Ouimet, K6OPO, a prestigious designer and builder of Project Oscar fame.

It's all very well to have the project mapped out but there was one obvious immediate hurdle placed in the way of operation. They needed a licence from the FCC. Fortunately, Mr. A. Prose Walker, W4BW, Head of the Amateur Section of the FCC encouraged the Foundation and arranged for them to meet with groups that were planning to present papers at WARC-79. The NCDXF have recognised W4BW's encouragement as fundamental. During submissions to the FCC the NCDXF had to give an undertaking that the prototype beacon in California would be monitored 24-hours a day – and they would supply the FCC with the names of amateurs who were detailed to listen! Unattended remote operation was yet to be approved. The prototype became operational in 1979 on a trailer overlooking Stanford University. Calls went out for amateurs to send in reports of the signals heard and the uptake was very good. As this was before Internet, reports were faxed or sent through the good-old postal system. We need to remember this was when using QSL cards was the only method for confirming contacts.

Going worldwide

After two years of operation from California, the NCDXF were ready to look for potential beacon operators in other parts of the World. With the recruitment of Dave Leeson, W6QHS, designs were finalised: and production started on the other nine needed. The design was centred on a TS-120 with a phasing unit designed by Mike Stahl, K6MYC (then of KLM Antennas). As an aside, the TS-120 transceivers operated 24/7 for over 10 years on 20m before replacement!

Very quickly, Dr. Max de Hensler, HB9RS of the United Nations, Martti Laine, OH2BH and other prominent amateur radio operators managed to find locations in their own countries or organisations. And the beacons' messages have gone out on 14.100MHz since the 1980s.

Before the story moves on, I would like to mention that during some RTTY contests operators interfere with the beacon frequency 14.100MHz CW, even though it has been part of the IARU regulations for many years. Non-beacon operation in the beacon band is against every country's regulations! Even regular messages posted on the Cluster to desist are ignored by those who are inconsiderate.

Bigger and better

Back to the plot, in 1984 then Secretary of Region 2 of IARU Alberto Shaio, HK3DEU recognised how successful the 20m-beacon project had been. He proposed a new worldwide beacon system. The WARC bands had been awarded to amateurs at WARC-79. The new name was the NCDXF/IARU International Beacon Project. The big step forward was that beacons would not only operate on a time-sharing, but on a band–orientated schedule!

Of course, the big question was: Who would design and build these new beacons – never mind solve the synchronisation aspect of shorter transmissions to fit in all of the 'new' beacons. NCDXF members threw around ideas until 1988.

This is when Bob Fabry, N6EK, retired Professor of Computer Science at the University of California, Berkeley, got involved with W6QHS and they worked to develop the system as it is today. There was a discussion about time duration when listening to the beacons. Considering the reception period of each signal was quite far-sighted. The NCDXF and the Executive Committee of IARU Region 2 accepted the 12-second version for each CW message. However, N6EK who had investigated

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FIGURE 2: This shows operations on one band, illustrated by LOGGER 32.

FIGURE 3: This shows operations on three bands, illustrated by LOGGER 32.

several possibilities realised the time span of each transmission should be 10 seconds for practical reasons. When all are operational there will be 18 beacon messages over a three-minute period. See above for locations.

Kenwood donated 16 T-50 transceivers to the new multiband project. On each there was a plaque commemorating Jim Rafferty, N6RJ . As you may know, at that time, Jim Rafferty was Mr Radio Shack.

Distribution of the 'new' beacons ran from late-1995 to September 1996 . Basically, each beacon's CW signal is: Callsign (100 watts at 22wpm) followed 4 'dahs' of one second descending in power – 100W, 10W, 1W and 0.1W. Additional frequencies allocated were 18.110MHz, 21.150MHz, 24.930MHz and 28.200MHz. After cycling through the bands (20m – 10m) there is a silence period. It took some time for this easily accessible system to be up and running. It's still the best 'now' system for checking the one aspect that a successful operator cannot do without – propagation.

The reverse beacon network (RBN) might fill that space, eventually. That is, if more operators are prepared to leave equipment running unattended.

Monitoring propagation

Fortunately for present-day amateurs, most computer logging programs have a facility that allows operators to monitor propagation in two ways. The first is concentrating on a particular band. This means changes in azimuth for those with directional antennas – not always a simple requirement. Of course, many operators with directional antennas (like a V-beam) would probably be listening on a particular spread of bearings, unless they have an omni-directional antenna available. And, the second is when concentrating on a specific area (one beacon). Then the transceiver needs to hop from band to band (and possibly antenna to antenna) to follow the transmissions. With CAT this is easily done. (one band) and (one area/beacon) illustrate these facilities in LOGGER 32. The Notes below give URLs for some stand-alone apps.

With the upturn in propagation, this facility enabled me to respond to a recent 17m and 12m request for a QSO from YB4FE. After thinking about it, I asked Freddy, by email, to listen for the ZS beacon on 17m and I agreed to listen for the VR2 beacon. When propagation was good, I heard the beacon. So, I emailed him and we had our sked. The following day listening for the beacons on 12m, with the beam pointing east, I could just hear VR2B when I was called by VO1FOG! Eventually, with him pointing to Europe and me pointing to north, we had a catch-up contact (QSO). By then the VR2 beacon was coming in quite well. When we finished, and after a short email, the 12m QSO with YB4FE was completed, with pleasantries as well as reports.

Many operators have never been through the top end of a sunpot cycle. This brief guide to the NCDXF/IARU beacons may help. Operating from the bottom of Africa, I find transmissions from the beacons are invaluable. Some days, on 12m and 10m I can monitor the propagation as it moves westward.

Propagation goes in cycles and we are at the start of a new one. I would like to leave you with the words of John Troster, W6ISQ. He was actively involved in the NCDXF/IARU project. The following was written in 1994. Some would say, 'it's an echo from the past' that repeats.

"We are grateful to the Universities, National Societies and individuals who have volunteered to operate the beacons in this expanded network. It will be interesting to monitor the beacons during the increase in HF band activity as the sunspot cycle passes through its minimum and begins its climb back to DX glory!"

Of course, there are also long path contacts to be made. But that's another story …

More information, eg which beacons are actually running, can be found at www.ncdxf.org/beacon.

Apps to monitor the beacons can be found at **[4]**. Applications for most computers, Android, iPhone & iPad, as well as Windows mobile are listed.

For monitoring and record keeping FAROS 1.6 by VE3NEA is recommended. This is a dedicated program from Afreet Software. Interfacing a radio with a computer is best done through an active interface, and, an omni-directional multiband antenna. An interesting thesis *Monitoring Station for South Africa*, C. Mudzingwa, Rhodes University 2009 made use of FAROS. It shows observations of the reception of transmissions from NCDXF/IARU beacons closest to South Africa. However, there are a couple of incorrect statements regarding radio equipment, like misunderstanding the purpose of choke baluns.

Thanks to Ross, K6GFJ for the use of his previously unpublished photos that are now on the NCDXF website. He is the keeper of the Foundation's history. Also to Glenn, W0GJ secretary and longest serving director, for his assistance.

References:

1: Ham Radio Outlet owner, SK June 1993
2: Information from the NCDXF website will list beacons that are off air. Also, there is information, like when they are in the process of upgrading to new controllers and ICOM-7200 transceivers. However, there are a few times when there could a lag in this information.
Update: The VE8AT beacon is operating (temporarily) from Inuvik NT, about 1850km from the Eureka site. Regarding 4U1UN, with the panic over security and the excuse of the pandemic, limited access to the site could have ruled out the location for a permanent 24/7 operation of any sort, but the 4U1UN beacon is running. The political aspect has not been considered.
3: 1997 Edition of the CQ Almanac
4: www.ncdxf.org/beacon/beaconprogram.html

Feature

Sporadic-E and HF Bands/ Predictions

In this article I will discuss the effects upon the HF bands caused by Sporadic-E, rather than a treatise of what Sporadic-E is or how it comes into being.

There are plenty of books and articles that describe how Sporadic-E comes into effect. One such article was published in the May 2021 edition of *RadCom Plus* **[1]**. It was an in-depth study by Jim Bacon, G3YLA upon this subject, worth a read to those interested in this phenomenon. Another reason why I do not wish to go into the causes of Sporadic-E is because the phenomenon is not yet fully understood! There is room for individual research here. For this discussion, only occurrences of Sporadic-E in the Northern mid-latitudes will be considered.

Bands under discussion

By HF bands, I refer to the amateur allocation between and including 80m to 10m. Sporadic-E affects these bands in diverse ways. It tends to blanket out the bands, when it is making itself felt. This means that few modes are effective for communications during these periods, ground wave being an example of one and short skip off the E-layer on 80m/40m being another. The signals simply cannot reach the higher F layers because of the Sporadic-E, so long range contacts are not possible. When the bands are blanketed out, the *RadCom* predictions and in fact all current validated HF propagation prediction models become superfluous until such time as the ionosphere returns to normal. Some would say that there are advantages to be gained when Sporadic-E is prevalent. For example, it is possible to work inter-Europe on 10m during this phenomenon. HF propagation prediction models do not predict the occurrence of Sporadic-E and therefore do not forecast these occurrences.

Timing and identifying

Traditionally, Sporadic-E is around and prevalent during June and July, however, for the last couple of years it has lasted well into September. Incidentally it is quite possible to experience this phenomenon outside of this time frame. It really is quite a simple task to ascertain whether there is Sporadic-E or indeed Blanketing Sporadic-E. The method I use is to interrogate the Chilton Ionosondes. **Figure 1** shows a typical display when there was Blanketing Sporadic-E.

For those not used to interpreting such diagrams, I wrote an article for *RadCom* that appeared in the May 2009 edition. A copy of the article can be obtained from the RSGB Propagation Studies Committee page on the RSGB website **[2]**. It can also be seen from Figure 1 that Sporadic-E occurs at the height of about 110km so is quite simple to recognise.

Good luck with DXing during the upward trend and the height of Solar Cycle 25, let's hope that this phenomenon does not spoil things too much for the HF community.

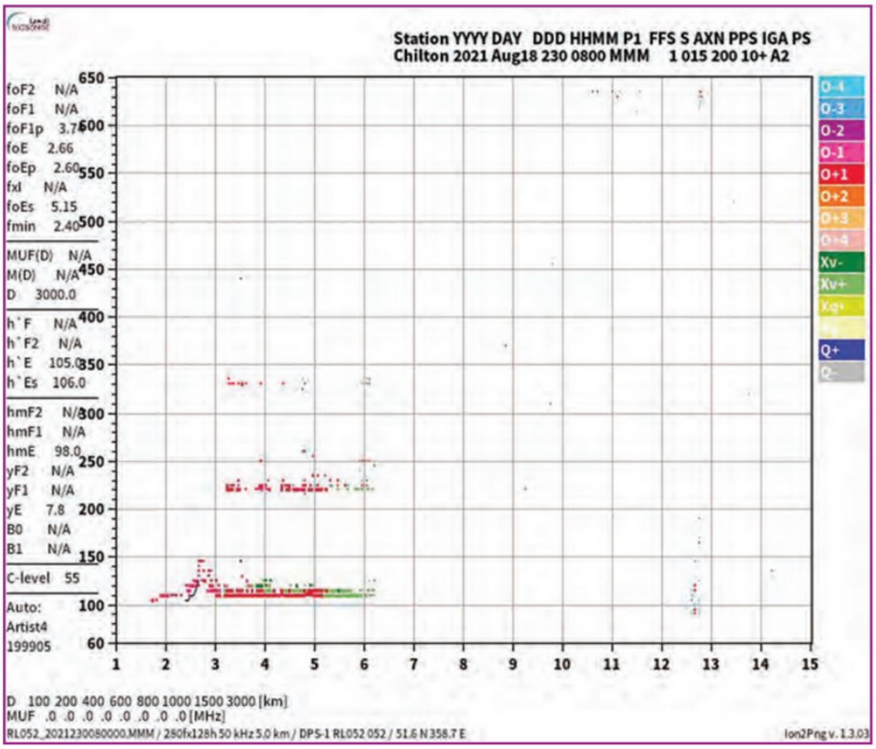

FIGURE 1: **Chilton Ionosonde display showing Blanketing Sporadic-E. Courtesy - UK Solar System Data Centre at the Rutherford Appleton Laboratory, Chilton.**

Websearch

1: www.rsgb.org/radcom-plus

2: www.rsgb.org/psc

Propagation Studies Committee

The Propagation Studies Committee (PSU) promotes interest in radio propagation amongst radio amateurs and short wave listeners, to enable them to make informed use of the amateur bands and develop a research interest into the subject. www.rsgb.org/psc.

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A Guide to Feeding, Choking And Balancing

The obvious way to achieve balanced feed at a balanced dipole or doublet is to drive the antenna via a balanced feeder from a balanced source.

Our radios invariably have unbalanced output sockets, where one side of the feeder is joined to the case of the radio. This in turn is joined to ground, either by an earth conductor or via the electricity supply to the radio. We may, therefore, expect the transmitter to cause a common mode current if we were stupid enough to directly connect our balanced feeder. The consequences are distortion of radiation patterns and a tendency for noise to be introduced by the feeder. We can expect to reduce these effects by installing a unun in the form of a bifilar choke or a balun transformer. This being located in the coax feeder or at the ends of a twin wire feeder. There are several types of balancing device of which examples are shown in **Figure 1**.

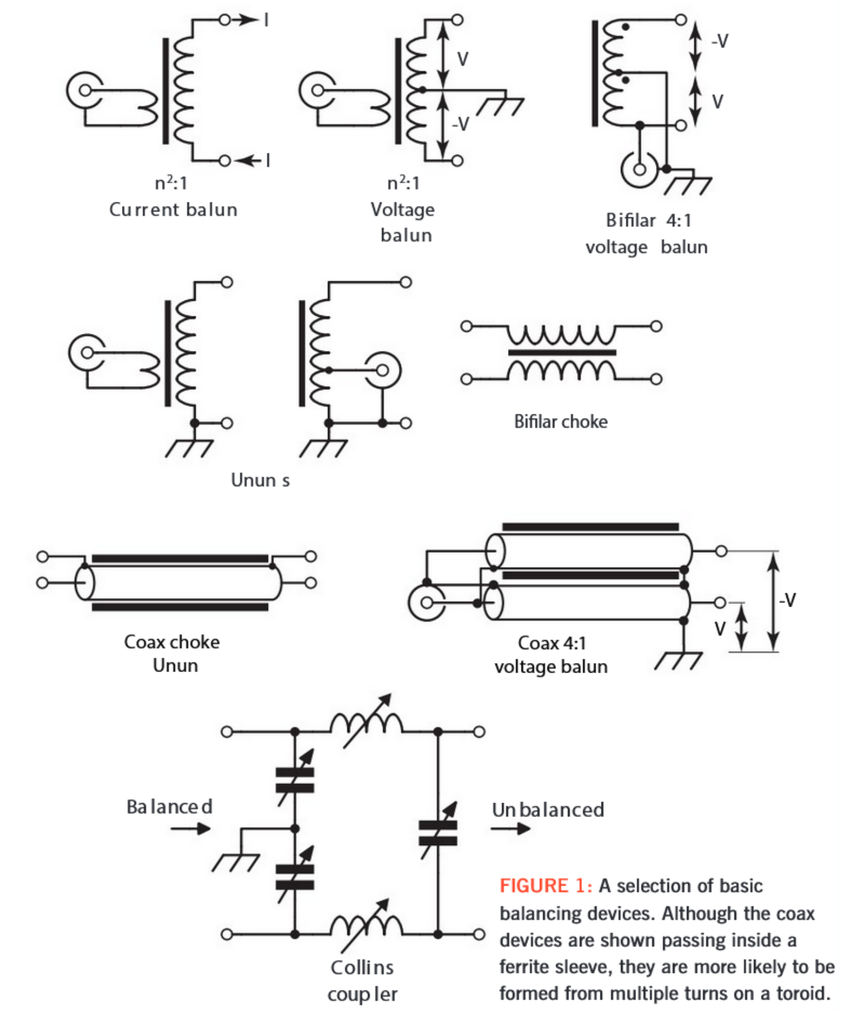

FIGURE 1: A selection of basic balancing devices. Although the coax devices are shown passing inside a ferrite sleeve, they are more likely to be formed from multiple turns on a toroid.

Problems with coax

It is very convenient, though not usually very efficient, to run coax directly from the radio to a dipole. This introduces problems that are not present in a balanced system. Many have done this without any problems due to the current that inevitably flows on the outer surface of the braid. There is no need for a choke at the radio because it cannot put current on the surface of the braid. However, a choke at the dipole is essential, regardless of the degree of balance or unbalance due to the construction or location of the antenna relative to other conductors. A saving grace is that with coax between radio and antenna we only have to worry about the antenna being a source of common mode, or more precisely braid current.

Some have suffered RF feedback or EMC problems that are attributed to braid current. Although this current does not enter the radio via its output socket, the radiation field from the braid *current* or the current returning to a shared ground connection, may impact on wires entering the radio from such items as a data modem, microphone, logging computer or telephone wiring via a router. Those who have not suffered from EMC, may have a fortunate length of coax between their antenna and their radio's ground connection. Simple tests to confirm that you may have a problem at high frequencies is to slide your hand over the feeder as close as practicable to the antenna or otherwise to make additional ground connections to the braid at locations other than the radio and get someone to see if the SWR changes.

Braid current figures

A 14MHz horizontal dipole was modelled with the feeder braid running down to the ground from one side of the feed point as in the model represented by **Figure 2**. The inner surface and inner conductor of the feeder supply power to the antenna and to the outer surface of the braid. The impedance and hence SWR at the radio is, therefore, a function of antenna and braid. Hence the test above. The inner conductor cannot be shown because it is inside the braid but is included by placing a generator that represents the radio at the antenna end. These are the braid to antenna current ratios computed for some different lengths of feeder:

5.2m; -39dB
15m; -32dB
20m; -14dB
43m; -8.8dB

The 5.2m cable is a fortunate choice because it does not require a choke. Now let us introduce a choke at the *radio* end to effectively open-circuit the outer surface of the braid. This should reduce braid current that would otherwise return to the ground near the operator. Here are the new current ratios at the *antenna* end:

5.2m; -2.4dB
15m; -11dB
20m; -29dB
43m; -32dB

The choke has *reduced* the ratio at the 5.2m and 15m feeders. This is because these are near odd multiples of a quarter wave and thus, because of the choke, present a *low* braid impedance at the antenna. The ratios at the 20m and 43m cables have *increased* because these are near multiples of a half-wave and they now present a *high* braid impedance at the antenna.

As shown here and in Figure 2, the choke causes more current on the surface of the braid of the 5.2m cable than there is in that half of the antenna that is connected to the inner conductor! The antenna and 5.2m feeder combination will perform principally as an inverted L radiator. This may be confirmed by plotting the radiation pattern. Instead of the expected figure eight, the HRP is a cardioid. In this case the braid is an efficient receptor of noise. (Vertically polarised noise fields do not have the neutralising component, due to ground reflection that is exhibited by horizontal polarisation). This noise will be fed to the dipole and will return to the radio via the inner conductor of the coax, without any impediment by the choke. The operator without RF feedback could instead have a noise problem!

Although the local choke on its own has minimised the possibility of EMC problems near the radio that are due to braid *current*, it is likely that it has made the feeder braid an EMC and EMF source due to its *electric field*. This is because of the possible high braid impedance and consequent high braid voltage on the feeder side of the choke.

Antenna choke

Now let us see what can be achieved by moving the choke to the *antenna* end of the feeder. Here are the current ratios for chokes that have inductive reactance of; 100Ω and 1000Ω. These represent respectively; chokes using external ferrite loading and multiple turns of coax wound on a ferrite toroid or rod:

Feeder	100Ω	1000Ω
5.2m	-39dB	-48dB
15m	-37dB	-33dB
20m	-9dB	-33dB
43m	-15dB	-47dB

The 1000Ω choke has reduced braid current at the antenna to potentially *increase* noise immunity by the difference between these and the results without a choke. *The quarter wave feeder, or any feeder length that is grounded a quarter wave from the feed point, performs to some extent as a balun and attenuation is potentially good regardless of a choke* (length of braid, not electrical length of the coax). Note that the 100Ω choke and 5.2m feeder combination degrade performance. This is because the feeder and one half of the antenna are performing as an inverted L in which the low inductance choke is tending to resonate the combination. My experience is that -30dB is achievable in practice from a choke of 500Ω reactance at a dipole antenna. This could for example, mean a noise reduction when due to this mechanism from S9 to S4. (S9 to S2 on some Japanese radios.)

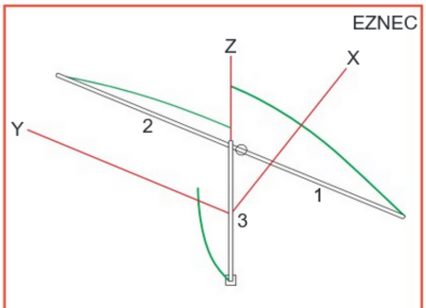

FIGURE 2: The dramatic EZNEC presentation of the 14MHz dipole when driven via coax. This shows the braid and antenna currents when a choke is fitted at the radio end of the feeder.

Braid current with an unbalanced dipole

As an example of an unbalanced antenna, we will slope the dipole at 45° and drop the feeder vertically to the ground. The braid current ratio is different, depending whether it is joined to the upper or lower half of the dipole. The upper half is first:

5.2m; -13/-18.6dB
15m; -31.7/-13dB
20m; -26.4/-16.8dB
43m; -5.2/-13dB

Which half to connect to the braid for minimum common mode current depends on the length of the feeder. However, the current ratios are generally worse than for the horizontal antenna and confirm the greater need for an effective choke.

Belt and braces

To minimise susceptibility to local noise, it is definitely necessary to have a choke at the antenna end of a coax fed balanced or unbalanced antenna. To minimise EMC it may help to have chokes at antenna and radio, especially if the radio's connection to ground is not effective. Alternatively, to further minimise EMC, the feeder braid may be connected to ground before it enters the house. This needs a connection resistance that is an order lower than the approximate 350Ω characteristic impedance of the braid. A few earth rods, or in my case a flattened and buried redundant copper hot water cylinder.

A proper job, the balanced alternative

A balanced feeder connecting to a balanced HF antenna avoids the EMC problems, excessive weight, cost and dissipation losses of coax. It does not require a choke at the antenna. There is no likelihood of a limitation to transmitter power with popular types of balanced feeders. For example, a 600Ω feeder of 1mm copper conductors can comfortably handle PEP of 20,000/√*S* watts. Where *S* is the SWR. It can do this with values of *S* that will cause significant attenuation or failure at the same length of coax. Unlike coax, a balanced feeder is susceptible to common mode current from the radio if the latter does not supply a balanced signal.

A balun transformer at the radio or at the transition from coax to twin feeder helps to ensure that common mode currents do not reach the radio's ground connection or cause the introduction of noise from the feeder to a *balanced* antenna. Another factor to consider, is the requirement for the centre point at a voltage type balun like those in Figure 1 to be connected to ground. They do not work if suspended at an antenna but often cover a much wider frequency range than a choke when connected directly at the output socket of the radio or tuner. (Ask any short wave broadcaster transmitter operator). This is because chokes become progressively less effective with reducing frequency and tend to have spurious resonances at higher frequencies. I have used a Voltage balun with success on many different types of antenna. In most cases a short length of low loss coax ran to an outdoor location for the balun. However, a ground connection, as previously described, is required to replace that provided at the now essential tuner.

More bands

A balanced feeder with tuner does not require the antenna to be resonant and, therefore, it will allow the 14MHz dipole to be used on other bands, 10 to 50MHz. The balun needs to have a conservative power rating because it must

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accept a high SWR. The 600Ω SWR in this case is less than 7 on these bands other than 10MHz where it is much higher.

Typically, the power handling capacity reduces as the inverse route of SWR, as with a feeder. A rating of just over 1kW is required for 400 watts and SWR of 7 if using a 50-600Ω balun. Except for its influence on power rating, transformation ratio is not important because it is unlikely to be working into the feeder's characteristic impedance.

A balun of 4:1 impedance ratio, like those in Figure 1 is quite suitable for feeders of 150 to 750Ω impedance when used with a good tuner. A resonant balun or balanced tuner employing air-wound inductors is most appropriate. This is what our grandfathers used when they worked the world with their 5 watts.

Twin feeder and unbalanced antenna

If we use a balanced feeder to drive an *unbalanced* antenna such as a low vertical or bent doublet, there will inevitably be dissimilarity between the impedances presented to the radio by each leg. The result is different amplitudes between currents in each leg. The consequence is common mode current. The degree of suppression of common mode current is given by;

20 Log [(I1 –I2)/ I1 + I2]

where I1 and I2 are the currents in each leg. It causes the feeder to act like an antenna and thus radiate and receive, like coax braid. Radiation causes the common mode current due to the radio to be reduced as we move away from the antenna. On higher frequencies, where feeders may be many wavelengths, there may be no discernible imbalance at the radio and the loss of useful power due to feeder radiation may go unnoticed. An interesting fact that is unlikely to concern us amateurs, is that at high power, imbalance due to common mode currents produced by a nominally balanced transmitter may cause fault inducing voltages or currents on a short balanced feeder. The VSWR in common mode can be very much higher than the VSWR in balanced mode. This is because the feeder is not terminated in common mode and is not long enough to radiate much power. Longer feeders that are able to radiate, may rely on their radiation resistance to provide a termination in common mode.

There is a myth that says a current balun is more effective than a voltage balun at preventing common mode current in these circumstances. A current balun obviously provides similar currents in each leg of the balanced feeder at the point where it is connected, but is this situation maintained at the unbalanced antenna? Even if equal currents arrive at the antenna they flow in unequal impedances. Consequently, we expect different Voltages on each half of the antenna at the feed-point. There is, therefore, a common mode Voltage on the feeder that cannot exist without a related common mode current. The following exercise is confirmation:

The now off–centre fed 14MHz dipole was modelled by driving it at a point 1/3rd from one end via a 7m length of twin wire feeder. This was formed from 100mm spaced 1mm wires. When equal currents were provided by simulating a *current* balun at the radio end, the ratio of currents into each side of the antenna was 5.3:1. The higher current was in the short side of the antenna. Maximum gain was 1.7dBi. Next, the feeder was driven with equal voltages, provided by a simulated *voltage* balun. The current ratio was only 1.4:1, with the higher current in the long side of the antenna. Maximum gain was 4.8dBi. These current ratios equate to common mode suppression of -3.3dB and -15.5dB respectively. The voltage balun, therefore offers more than 12dB greater protection against feeder noise and makes better use of the antenna as a radiator by providing 3dB more gain. Different lengths of feeder or feeder with a different characteristic impedance will give different results.

Another solution to driving an unbalanced antenna was a device called a Collins coupler, shown in Figure 1. This consists of a pair of nominally 90° π networks, one for each leg. The 90° networks have the characteristic of converting 'currents into voltages'! When adjusted independently they transform the dissimilar currents on each leg of a feeder into the equal voltages, as required by a transmitter or tuner with balanced output. Unfortunately, it needs to be installed at the antenna and adjusted for each band to reduce common mode current on the intervening feeder. A more practical solution is to keep the voltage balun or current balun at the radio/tuner and rely on a choke at the antenna. The snag is that a wideband 600Ω choke is likely to be bulky so we need a choke formed from twin 80 or 100Ω twin cable or as was once popular, a bifilar choke of pairs of well insulated (eg ptfe) wires wound side by side. We must then accept that this will modify the VSWR. But bear in mind that common mode rejection is likely to be more important operationally than low SWR on a high impedance twin wire feeder, providing the associated tuner can cope.

Want to see *your* work published in *RadCom*?

RadCom and *RadCom Plus* are always looking for people with good, previously unpublished projects and features. Many of the technical articles you see in these pages come from people with no previous publishing or writing experience. What they *do* have is enthusiasm and a good, original, unpublished idea.

Big or small, as long as it's something to do with amateur radio, we're interested. There is great demand for constructional projects, ranging from simple to complex. Aerial projects and any sort of buildable electronic widget are favourites. The most complex projects go into *RadCom Plus* but the majority will appear here in *RadCom*.

What to do

The first step is get in touch with the editorial team via email to radcom@rsgb.org.uk and simply tell us what you have in mind.

It doesn't matter if you have never written before – we can provide as much or as little editorial support as you require. We'll need good quality photos to accompany your article **[1]** but line drawings (circuits and other diagrams) can be a simple sketch. We re-draw the majority of diagrams to give a consistent style across all articles. There is rarely any time pressure, so you can work at your own pace.

Acceptance procedure

Our acceptance procedure for technical articles **[2]** involves an independent review by a member of the Technical Forum, whose members are always willing to work with authors if there's something that needs more explanation or would benefit from clarifying.

Feature articles aren't assessed in that way, but most of the info in [2] still applies: it's well worth reading that page before you send any articles to *RadCom*.

Although initial draft and discussion material can be accepted in most common formats, we will need to receive the final material in a suitable form for reproduction. Usually this means text in a Word file with the minimum possible of formatting, and photos as per [1].

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

A Cautionary Tale of Resonance

Shortly after Christmas 2021 I started seeing impulse interference in the 10m band. My home (QTH) is notoriously noisy and, as I was not very active on 10m, I put it on the back burner to investigate. Initially by waving my trusty FT-817 around I located it to the wall of my next-door neighbour's house. I asked if he'd "bought any new electricals recently" and left it at that as there was no obvious interference on the lower bands.

With the upcoming Winter DX period and sunspot cycle 25 starting to build, in February I decided that I wanted to do some serious 10m work so got myself a 'proper 10m antenna' in the form of an excellent Innovantennas Moxon square beam **[1]**. I quickly confirmed that the noise was definitely coming from the neighbour's house, but due to the excellent directional pattern of the Moxon, only if I beamed at it. It was in the direction of Japan and Australia so not optimum! While the IC-7610's noise blanker coped well with it, any strong adjacent CW signal caused me interference on the frequency to which I was tuned, in the form of raspy Morse in the form of the original Impulse noise.

Into action

I contacted my neighbour again, and he was up to doing some investigations. He'd worked alongside engineers at a local aerospace company, so I think he knew what to expect!

We did the usual 'Stage 1'. Namely turn off each section of his house at the main panel until the noise stopped and we quickly isolated it one particular circuit. After a few sessions on the phone of 'Stage 2', "I've turned that off, has it gone?" we narrowed it down to a Samsung television in one of the bedrooms. The one closest to my 10m antenna, of course!

Stage 3 is 'get the clip-on ferrites and mains filters out'. Adding ferrites to the mains and antenna lead didn't do too much, but I could clearly see that the noise was varying as he moved the mains lead about. Progress! I then gave him my GM3SEK mains filter **[2]**, and the interference dropped quite noticeably. At this point he said, "there's an extension lead, shall I try changing that?" On removing the extension, the interference stopped! He replaced it with different one and immediately, no interference even without the SEK filter. Result!

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Problem solved – but why?

Out of curiosity, I got him to give me the offending extension lead. It's shown in **Photo 1**. It's a surge protected 5m long, 4-way, type L4W4S18 branded Logik, sold by (amongst others,) Currys **[3]**.

I initially suspected the LEDs on it but when I plugged it in to my workshop and put a mains load on it, where was no sign of interference on 10m from the extension. Clearly not an issue generated within the extension itself, I then started thinking outside the box. It's a 5m extension lead and I'm operating on 10m. I measured it at just under 5m long. That makes it likely to be resonant as a half wave on 10m: a pretty good radiator for anything that's coming out of the TV. I then connected my Mini VNA between the live and earth of the plug on the extension and plotted the SWR from 28 to 30MHz.

Photo 2 shows the result as a SWR of 2.56 at 29MHz, dropping to below 2:1 at 30MHz.

Yes, it's a pretty good 10m antenna, and anything coming off the TV would be radiated efficiently!

Moral of the story? Buy a 3m extension lead if you're planning to work 10 metres!

Finally, thanks to my neighbour, Frank, who was more helpful than I could ever wish a neighbour to be.

PHOTO 1: **The offending 10m-resonant extension lead.**

Websearch
1: Innovantennas Moxon: https://bit.ly/3ugOrf9
2: GM3SEK Filter: https://gm3sek.com/2019/10/11/clean-up-your-shack-2019/
3: Logik extension lead: https://bit.ly/3NTTbNy

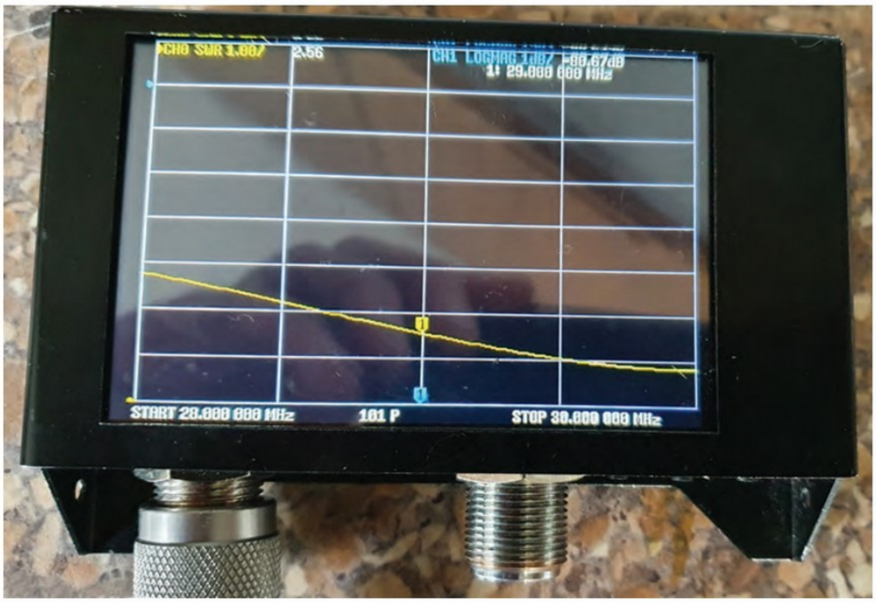


PHOTO 2: **The SWR plot between live and earth of the extension. Courtesy G4BAO.**

Design Notes

This month we are looking at Software Defined Radio, linearity and spuria.

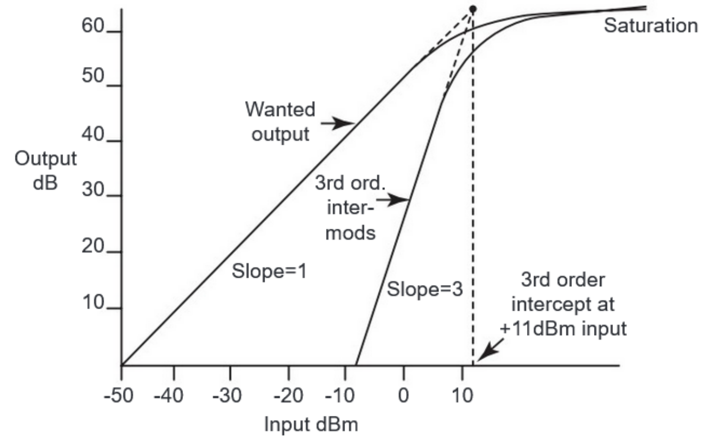


FIGURE 1: **Classic third order intermodulation. The Third order products increase three times as fast (in dB) as the input is raised. The point where the two lines would intersect, if the radio hadn't already saturated, is the Third Order Intercept. The TOIP is often accepted as a 'figure of merit' for the strong signal handing of old style analogue superhet receivers.**

In the old days, when receivers used all analogue technology – amplifiers, mixers and filters – visualising how non-linearity contributed to spurious responses was a relatively straightforward process to understand and test for. Non-linear stages generated intermodulation products, IMPs, whose frequency and amplitude could be predicted then measured. Lower level and fewer IMPs generated from a test signal, the better the radio. The first stage mixer was usually the biggest contribution to receiver performance.

The most popular and well-understood test is the 'two tone test' to deliberately generate and measure third order intermodulation products. Two RF signals are passed into the receiver front end through a variable attenuator, the level of the generated third order intermodulation products then being measured. The nature of IMPs is such that they increase at a faster rate than input amplitude, so if the two test tones are increased in level by 1dB, the 3rd order IMPs go up by 3dB. There comes a point, *theoretically*, where the level of the 3rd order IMPs at the receiver output is equal to that of the test tones. The input power at this level is called the Third Order Intercept Point, TOIP. It can only ever be a theoretical value as the receiver will have reached saturation long before this equal-amplitude point is reached. But nevertheless, by plotting a graph of input power versus output power, the 3rd order IMP can be found by extrapolation as shown in **Figure 1**. The TOIP became a well-understood and accepted measure of receiver linearity for many years.

A/D Conversion

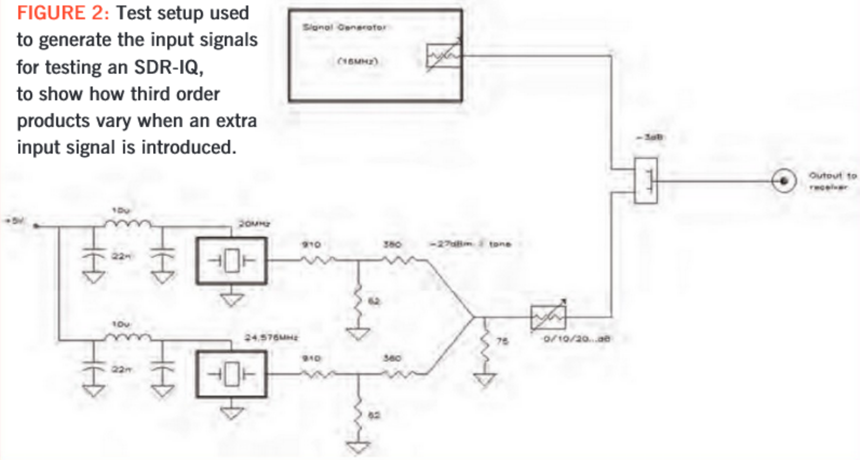
Then everything changed. Receivers nowadays no longer have a front end mixer; after a modest bit of amplification, or none at all, the antenna input is filtered and passed to an Analogue to Digital (A/D) converter where is it turned into a stream of numbers. The sampling is generally at a frequency well over 100MHz and to a resolution of at least 16 bits. The total RF input containing everything coming in from the antenna (albeit tailored in its spectrum by the input filtering) is converted to one of 65536 different discrete levels, more than 100 million times per second. How do we test these direct sampling receivers?

Initially manufacturers and interested parties used the old tried and tested two-tone method but it rapidly became obvious this was meaningless and could give some very surprising results when another signal was included along with the two tones. Not long after the SDR-IQ appeared, possibly the first direct sampling receiver to hit the amateur market (14 bit resolution sampled at 66.7MHz), I was asked to do a two tone test on it while introducing a third frequency at a lower level, and observe what happened. The full details can be found in **[1]**, but are summarised here.

Two / three tone testing the SDR-IQ

A two tone test source at 20 and 24.6MHz was constructed from two TTL oscillator modules and a resistive combiner. The output

FIGURE 2: **Test setup used to generate the input signals for testing an SDR-IQ, to show how third order products vary when an extra input signal is introduced.**



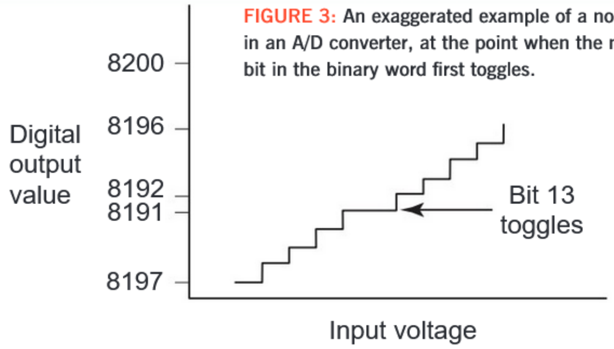


FIGURE 3: An exaggerated example of a non-linear step in an A/D converter, at the point when the next higher bit in the binary word first toggles.

of this, along with a lower and separately adjustable level of a 16MHz signal were fed into the SDR-IQ. **Figure 2** shows a diagram of the test set. The aim was to look at the level of the third order products generated from the two main inputs, while the power of the extra signal was altered. In any analogue radio, this extra signal would not affect the main IMP products; it might be observed generating more low level products at separated frequencies, but not affecting the main IMPs from the 20 and 24MHz inputs. With the SDR-IQ this was not the case.

With the two main carriers at 20 and 24.567MHz generating a fixed and measurable third order product, the introduction of the third frequency at 16MHz caused the third order IMP to change quite dramatically. In fact, as the level of the 16MHz was increased, the TOIMPs actually decreased. All this was well below any levels at which A/D saturation could be blamed. Refer to [1] for the full set of results, but to take just one example: At a fixed level of -50dBm input for the two test tones, the resulting IMPs from these, as the level of the 16MHz input was changed, can be seen in **Table 1**. The values in brackets were nearly in the noise and their exact levels a bit difficult to determine accurately.

The introduction of an increasing amount of 16MHz actually lowered the level of those intermod products being generated from the two 20MHz inputs. The linearity of the radio appeared to be improving as the amplitude of a third signal was increased. This is very definitely not what might be expected of any conventional analogue RF front end! It was clear that introducing more signals appeared to improve linearity, and that a simple two tone test for linearity is worse than meaningless for direct sampling SDRs.

Distortion mechanisms in A/Ds

Fast, high specification A/D converters are complex beasts, doing a complicated conversion process using techniques the manufacturers don't always want to fully reveal for their competitors to see. In any A/D converter there are several mechanisms where the string of resulting numbers may not faithfully represent a sampled version of what goes in. One of these is quantisation regularity. Each of the 65536 levels, or steps, for a 16 bit converter should be of exactly equal amplitude, but they may not be. Depending on converter architecture, some steps, especially around points where a high order bit in the output word toggles, may be bigger than others. An exaggerated example of this is shown in **Figure 3** where the change in input voltage as the output value steps from 8191 to 8192 (where the value of the 13th binary bit changes) is not the same as those either side of this where only lower order bits toggle. Cheaper and older A/D converters can suffer from this problem and the resulting now less-accurate representation of the instantaneous value is just one type of non-linearity.

We can have an interesting situation when it comes to testing. Assume this single step error, when the output count reaches 8192, is the *only* source of error in an otherwise perfect A/D converter. A low level signal, one whose amplitude doesn't result in the A/D output ever going above 8192, will never toggle this bit. The non-linear jump will not appear and at this level of input signal the A/D will measure as ideal. But increase the input amplitude just a tiny bit, enough to start to toggle this bit at the peak of the input waveform and the non-linearity appears. The resulting stream of numbers no longer faithfully represents what is going in, so as we go down the digital processing chain this jump reappears as if it were spurious frequencies in the input, distortion, unwanted products, extra noise – or something. It's nearly impossible to say exactly what, though.

Imperfect build and construction

Now consider a totally different distortion mechanism, one caused by poor PCB layout perhaps. Let's say one of the digital output lines from the A/D converter, that carrying bit number 10 for example, is rather long and unscreened and loops close to the antenna connection. Bad PCB layout, but it could happen. Low level input signals, those that never get above a level to cause bit 10 to toggle, pass the digital conversion unscathed. But let the input rise a little more and bit 10 starts to toggle. It's a high level digital signal, a square wave of perhaps 0 / 3.3V with sharp edges and it's coupling into the antenna port. The A/D converter input is now seeing genuine real extra RF signals coming in, leaking from its own output pins, and these appear in the processed receiver output – somewhere and somehow. As the amplitude of the real wanted input signal is raised further, this RF leakage from bit 10 is now swamped by bigger stuff and its effects further down the chain become less noticeable, especially as there are now more higher order bits toggling. We have a situation where a particular mid-amplitude signal can generate what looks like unwanted products and non-linearity, but whose effect is reduced when the input amplitude either falls or rises. How on earth can that be quantified?

These are just two basic, and perhaps slightly exaggerated, examples of the problems that beset manufacturers, test houses and consumers when it comes to specifying and measuring the performance of modern direct sampling radios. Some will blindly just do a third order IMP test and trust to consumers' blindness and historical view of analogue RF architectures to accept the results as good, bad or indifferent. Other unscrupulous or just naïve manufacturers may carefully, or blindly, select a range of input signals that give good results. I'm not saying this is the case, but it could happen. We need a test method that stresses the A/D converter and straddles all non-linear mechanisms in a standardised way everyone can understand. One such process is notched noise.

Notched noise

A test signal consisting of two or three carriers doesn't give meaningful results when used as an input to SDRs. We need a waveform that includes many frequencies and straddles all amplitudes so the A/D converter is operated over its full range. Noise meets this criteria. It has random but statistically determined amplitude peaks, and has a flat frequency response that can easily cover the entire input range of the receiver under test. But if it covers the whole input range, how do we test for spurious responses? The

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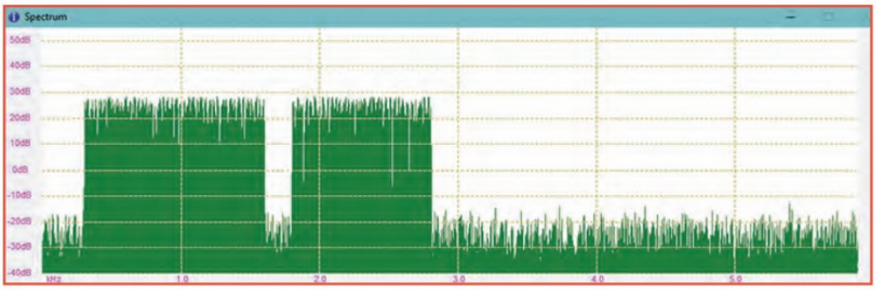

FIGURE 4: **'Notched Noise'. Actually a wall of 500 carriers with a gap in the middle. An approximation to a true noise-like waveform with a hole for measurement of spurious products.**

solution is to use a noise-like signal, but create an artificial hole in its spectrum where we can test for spurious products being generated.

As we saw in Design Notes, October last year, the intermodulation products from a few carriers, four or more, spread right across the spectrum inside and outside of the span of the generators, and rapidly fill up the spaces in between. Any spectral hole in wideband noise will fill up with intermodulation and spurious products. If the level of these can be determined in relation to the input level, then a fairer test of the receiver and A/D process could result.

Generating wideband noises with a hole in it is not a trivial task. The telephone companies have used this technique for years on the analogue network, using wideband noise sources and L/C filters at frequencies up to a few MHz for wideband carrier systems. But it needs a high order complex band-stop filter to give a deep enough notch for testing. Our high performance radios may well require a notch depth of 80dB to see low level spurii. Such attenuation in a band stop filter is possible, but needs a complex filter with very careful design and build, and does not come cheap.

Another solution is to generate the test signal digitally. The test signal does not have to actually be real noise, a bank of multiple carriers will behave in exactly the same way as noise. It is trivial with a DSP algorithm to generate multiple sine waves – thousands of them if necessary – all formed in parallel Numerically Controlled Oscillators and summed. The gap is generated by merely not generating a few carriers in the middle. The sum of all the NCOs is fed to a D/A converter to give the test input to the receiver. An example using 500 carriers at audio, spanning the typical SSB frequency range of 2300 – 2800Hz can be seen in **Figure 4**. A proper receiver test set needs to cover a much wider frequency band than this example and the NCOs plus D/A converter require hardware running at tens of Megahertz. Such hardware would typically be built using an FPGA.

The snag with this system is that the D/A converter needs to be certainly as good as, and ideally a lot better in performance and linearity than the A/D in the receiver under test. It is generally the case, certainly at lower frequencies, that D/A converters may be more linear and easier to do than A/Ds, but at the bandwidths of interest here that is not guaranteed. Whatever; a top spec D/A must be used.

Now we have a test signal that can be completely determined by the user, perhaps SDR testing can be put onto a more uniform and accepted footing. For interest and to see such a signal the .WAV file at **[2]** contains 500 individual tones within a 3kHz bandwidth with a gap a few tens of Hz wide around 1.67kHz. This is the waveform that produced the plot in Figure 4. The sampling rate is 12kHz and the peak of the waveform is only around ±4300, so it doesn't span the maximum possible ±32767 range of a soundcard's D/A converter. Therefore the hole can only be around 70dB below the peak, and significantly less than this when average power is considered, as the diagram shows. But if replayed though a non-linear audio stage it ought to be possible to see intermodulation products raise the floor of this gap when the resultant output is viewed with an audio spectrum analyser like *Spectran* or *Spectrum Lab*. Use a good quality soundcard to get the best possible S/N ratio.

To carry things a stage further, try upconverting this audio waveform to double sideband RF in a simple high level mixer like a bus-switch, and replay through an SSB radio. See if non-linearities can be found by increasing Rx input level.

TABLE 1: Intermodulation Test on an SDR-IQ with an additional signal.

20 + 24.576MHz Level, dBm	16MHz level	15.424MHz TOIP, dBm	29.152MHz TOIP, dBm
-50	-30	(<-135)	(-130)
-50	-35	(-130)	(-125)
-50	-40	(-128)	-120
-50	-45	-125	-112
-50	-50	-124	-110
-50	-55	-113	-96
-50	-60	-108	-94
-50	-65	-106	-93

Timestamp hash

On the higher / microwave bands you may be listening, with no one else on the band to talk to, and you suddenly hear this DX beacon at some fantastic distance, the best DX on that band ever. But you didn't make a recording and no one believes you; you're winding them up! How could you prove you heard it? A while ago, when GPS timing started to be used on beacons for data transmissions and frequency locking, I proposed a scheme where a beacon could transmit a unique time stamp that the keeper could verify had been sent at that time and thus prove reception – acting as a sort of automatic QSL.

The idea is that the time and date delivered every minute by the GPS receiver at the beacon is cryptographically merged with a password that only the beacon keeper or other authorised person knows. The merged time/password is reduced to a simple and unique message, a hash, that the beacon transmits. It changes every minute and becomes impossible for anyone to predict what the next timestamp message will be without knowing the password, even if all previous timestamps are known. A listener records the timestamp message along with the date/time of reception, then reports this to the beacon keeper. Knowing the password, the keeper can regenerate the message for that particular date and time and verify that the beacon signal must have actually been received.

I proposed a scheme that produced a three letter pronounceable pseudo-word consisting of consonant, vowel, consonant to make reception and logging in CW straightforward and intuitive. The full details of the algorithm and hashing can be found at **[3]**. The PIC code and algorithm details have been on the website for download since 2006, but there is no record of who, or what beacons have actually implemented this idea. The only one I know for certain (as I supplied the source hardware!) are the DL0SHF 10GHz and 24GHz EME / moonbounce beacons, where the timestamp hash is sent as part of the Q65 data message.

References

1: http://g4jnt.com/SDRIQ_Linearity.pdf
2: http://g4jnt.com/Download/500TONES_GAP.WAV
3: http://g4jnt.com/BeaconTimestamp.pdf