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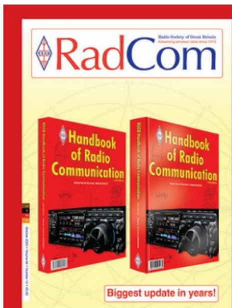


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Design by Kevin Williams, M6CYB


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# New Products

## ID-50E dual-band D-Star digital handheld radio, available now!

**Icom UK is pleased to announce that its latest handheld portable amateur radio, the ID-50E, is now available for sale from authorised Icom amateur radio dealers with a suggested retail price of £449.99 including VAT.**

As well as operating as a normal FM radio, the ID-50E is designed to work on the D-Star (Digital Smart Technology for Amateur Radio) network, a system widely used by amateur radio operators worldwide. With D-Star compatibility users gain access to an extensive network of repeaters, reflectors and linking capabilities greatly expanding communication possibilities. The D-Star DV mode can send not only voice but also image data. Photos from a smart device can be imported into the ID-50E using the ST-ID50A/W picture utility software to exchange photos and QSL cards.

The ID-50E has functions to enhance your radio operating experience. The Band Scope and Waterfall displays can visually show active channels with a wide span and timeline so it is easy to find active channels by sight. The Dualwatch function doubles QSO opportunities to monitor VHF/VHF, VHF/UHF and UHF/UHF bands at the same time.

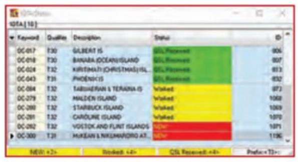
The ID-50E can also receive both the Airband and the FM bands. Moreover, almost all of the optional accessories for the ID-52/ID-51/ID-31 series transceivers can be shared. A large-capacity battery pack, BP-307, for the IC-705, is available as well.

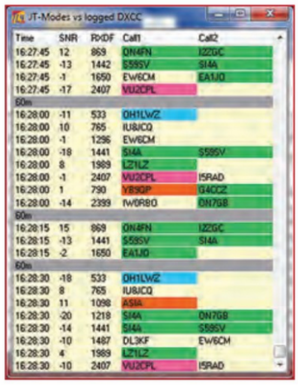
**Main Features**

- Global communication reach using the D-Star network
- Easy D-Star settings help beginners
- Terminal Mode and Access Point Mode
- Share Picture function with the ST-ID50A/W picture utility software
- Band Scope with Waterfall display
- Dualwatch function of VHF/VHF, VHF/UHF and UHF/UHF
- VHF Airband and FM broadcast receiver capability
- Same optional accessories can be shared with the ID-52/ID-51/ID-31 series transceivers

For further information about this new model, visit the 'ID-50E Dual-Band D-STAR Digital Handheld Radio Transceiver' product page' via icomuk.co.uk

## Updated version: Turbolog4.19 now available





The main focus of the new version of the station management programme Turbolog4 is on the keyword facility. Keywords are identifiers of items collected in QSOs and applied at award programs like IOTA, RDA, WAB, DOK, WAS etc. Turbolog4 now processes even multiple instances of the same type of identifiers applied in a QSO. This typically happens while working the RDA award since multiple RDAs from the same location in numbers of up to four or even more are offered quite frequently. Practical experience shows: wherever manual entries are applied, errors occur. Consequently, the new keyword facility includes a check utility for data consistency. If started, the output may be surprising to many a confident user. However, an easy remedy is at hand. Award standings can rapidly be accessed from entering complete keywords or leading parts of it on the CALL field. A special routine is available for the IOTA award. The pitcure shows an IOTA status display upon entering the prefix "T3" and pressing a hotkey. Comfortable usage of FT8/FT4 is again improved. The unique CAT interface to the transceiver can now be toggled to the WSJT-X or JTDX application by means of just one hotkey. Furthermore, the most valuable Turbolog4 adjunct box showing the received spots in a lined-up manner to the left side of the JT-application is upgraded again. Every call in all spot lines received from the particular radio channel at every period is matched to the complete Log in Turbolog4 and a highlighting background colour is applied according to the standings.The powerful proprietary CAT system in Turbolog4 demonstrates flexibility and strength over and over again. A couple of new transceivers were added to its drop-down list of available devices. One of those is APACHE Lab's SDR transceiver ANAN 7000 DLE, for example. Turbolog4's ROTOR control facility is well suited for microham's new ARCO control box. Software maintenance and database services are essential tasks for every new release of Turbolog4.

Turbolog4 is a shareware project.

Visit https://www.turbolog.de/for more information

## ScanKing TXHF-6 Discone 80-6m Antenna

Not only does it cover 3 to 1000MHz on receive, you can also transmit on the 80 to 6m bands using up to 200W.

**Key Features/ specifications:**

- Type: Discone Type TXHF-6 Antenna
- Frequency: Rx 3-1000MHz
- Frequency: Tx 3.5, 7, 14, 21, 29, 50MHz
- Gain: 2.15dBi over standard Discone
- Height: 84cm
- Diameter: 220cm
- Radius: 110cm

The product is available from moonrakeronline.com

# Antennas

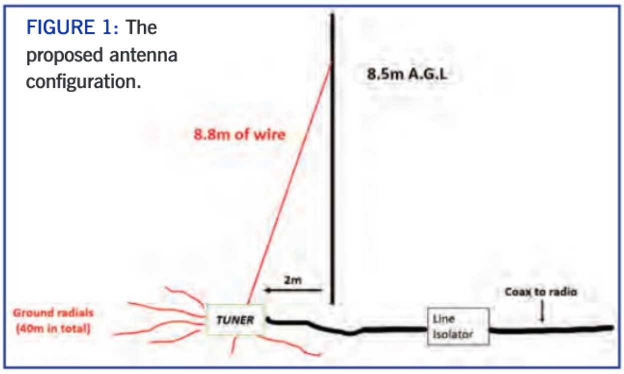



FIGURE 1: The proposed antenna configuration.

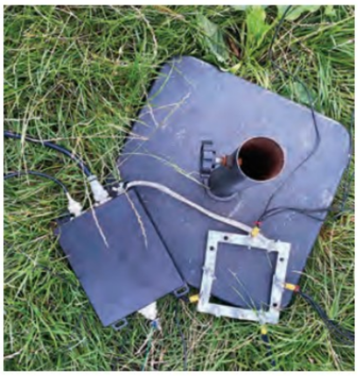


FIGURE 2: The remote ATU sitting on a parasol stand along with a homebrew radial plate.

**I suppose many of us who enjoy the hobby are by nature tinkerers. In my case, this centres around antenna design, and the compulsion to try out the next idea that comes into my head.**

Therefore, my attention is drawn towards a quick-to-deploy (ten minutes maximum), low-fuss multi-band antenna, suitable for portable operating. My main aim is to be able to be frequency-agile from 40m to 10m, with as great a focus on efficiency as I can muster. As well as the desire to be able to get on the air quickly, my focus, especially on the higher-frequency bands, is to work DX stations, especially now that we are looking ahead to sunspot maximum in the current sunspot cycle. The other main consideration is to be able to operate using as a small a footprint as possible. The antenna itself will be deployed in a sloping configuration, albeit as a near-vertical 'sloper'.

## The antenna's design

The desire to use the antenna as a sloper, rather than as a straight vertical, is because I would like to move the antenna slightly away from the car and reduce the interaction with the body of the vehicle. **Figure 1** reveals the antenna configuration. The antenna runs from the 10m fibre-glass support pole, positioned in a drive-on mast support next to the car, down to a remote long wire tuner positioned at ground level, situated approximately 2m from the base of the pole. The tuner is then attached to a home-made radial plate by a short earth strap, with 40m in total of ground radials attached to the plate (see **Figure 2**). I also took the precaution of adding a line isolator/choke to the coaxial cable (**Figure 3**), bearing in mind that, as the coaxial cable from the remote tuner could have some common-mode current, it could well in effect act as another radial. The line isolator was therefore positioned at the end of a 9m run of RG-58 coaxial cable, with a further 5m of RG-58 making its way from the line isolator to the transceiver.

Using a single radiating element across all bands from 40m to 10m will allow me to operate speedily upon arrival at my portable position but will also necessitate having to match a non-resonant end-fed antenna across several bands. The required antenna length ideally needs to avoid being a half, or full wavelength on any desired band of operation. There are many guides available online discussing ideal lengths for the antenna. I have selected 8.8m (29ft) for my radiator, which presents an antenna length which is a fraction of a wavelength on the HF bands, as outlined in **Table 1**.

Therefore, we avoid the high impedance presented at the feed point of half- and full-wavelength end-fed antennas, thus ensuring that the impedance is within the tuning range of the ATU (the ATU I am using can match up to a stated maximum impedance of 1500Ω). The antenna is also long enough to be fractionally shorter than a quarter-wave on 40m, so has a reasonable radiation resistance and thus efficiency. In contrast, on 12m and especially on 10m, the antenna becomes longer than three-quarters of a wavelength, which presents a compromise as the gain at lower take-off angles (useful for DX) is reduced slightly. A single-element vertical, or near-vertical, antenna covering a bandwidth ratio greater than 3:1 (in this case 40m to 10m means a 4:1 ratio), will always present a compromise between the antenna being long enough to be reasonably efficient on the lowest band, yet avoiding it being so long that we dilute our ability to work DX on the higher bands.

## The antenna modelled

Out of curiosity, I decided to use MMANA-gal modelling software to look at the potential performance and nature of the antenna. I examined 40, 20, 17, 15, 12 and 10m, only omitting 30m as I would be operating SSB rather than CW or digital. The gain figures are based on a 5° take-off angle, suited to DX. I also compared the antenna in its sloping configuration with it being used as a vertical. In each case, the antenna has the same number of ground radials (40m) and is modelled as deployed over ground with average conductivity (pastoral in nature). Each diagram shows the gain (in red) at 5° elevation, both in the direction of the slope denoted 'forward' and behind it, denoted 'reverse'. The omni-directional gain for a vertical version of this antenna (in blue) is also shown. **Figure 4** shows that there is a slight bias in the direction of the slope for 40m but not by a significant amount, and these figures are very similar for 20m. On these bands, the antenna acts pretty much like a standard quarter or half-wave vertical antenna. On 17m (**Figure 5**) there is even less difference in gain between the direction towards and away from the slope of the antenna, and both are very similar to the omni-directional gain of this antenna as a vertical antenna.

The antenna seems to perform best on 15m (**Figure 6**). Here, it is a fraction longer than 5/8 of a wavelength and produces some useful low-angle gain. Interestingly, the antenna is now beginning to produce slightly more gain in the opposite direction to the slope. On 12m, and especially 10m, this pattern is accentuated. **Figure 7** shows that, on 12m, there is just under a 4dB difference at 5° elevation in favour of the direction away from the slope, with the vertical somewhat in between the two in terms of gain. Even in its weakest direction, a gain of -5.6dBi is still at the level of a quarter-wave vertical. On 10m (**Figure 8**) the contrast is much greater, with there being almost a 9dB bias in favour of the direction away from the slope. Once again, the vertical's gain at 5° elevation sits in between that of the gain shown in front of and behind the slight slope. In its weakest direction, gain at 5° is 6dB or so down on a typical ground-mounted quarter- or half-wave vertical antenna. To all intents and purposes therefore, this antenna, in the configuration shown, can be regarded in the real world as acting in a way which is like an omni-directional vertical antenna. It provides

**FIGURE 3:** The line isolator attached in line with the RG-58 coaxial cable.

only fractionally worse and sometimes better gain at 5° elevation compared with a quarter-wave or half-wave ground-mounted vertical antenna, on all bands except 10m. Here it has a length of 7/8 of a wavelength and is quite directional, exhibiting a noticeable front-to-back quality. Unsurprisingly, the antenna is dominated by vertical polarisation for each band.

## The antenna deployed

One warm August evening, I loaded up the car and visited a favourite local high spot, which has a nice section in the car park I use which allows for an easily deployed HF antenna. **Figure 9** shows the antenna as it was deployed (the antenna wire is highlighted in red). As you can see, the slope of the antenna was quite mild. Set-up time was just under ten minutes (yes, I timed it!) from switching off the car's ignition to being able to call CQ. In all, I was active from about 1930UTC to 0015UTC. My first task was to ensure that the antenna could be matched to 50Ω across the six bands I intended to use. Having connected everything together, I pressed the tune button on my IC-7300, which activated the remote tuner's control cable, and was delighted to see that my remote MAT-40 tuner matched all bands to a 1.2:1 VSWR or better.

Once this had been established, it was then time to tune around the bands. Given that I had begun operating around thirty minutes before dusk, I thought it prudent to listen to the higher HF bands. It became clear, very quickly, that 10m was closed. However, on 12m the band scope on my IC-7300 showed that there was a reasonable signal on 24.945MHz. It emerged as an opportunity to work DX and, on the first attempt, I established a QSO with PT2AST (Brazil), receiving him 5/2 and obtaining a 5/5 report. It was obvious that this band was also closing rapidly, so I was very happy indeed to work him. I used 100W for this and all subsequent contacts.

I then decided to try out the antenna on 40m. Recently, this band becomes alive with Inter-G contacts in the four hours around dusk. An almost-vertical antenna like this one may not be totally ideal to work contacts from 100-250 miles away in theory (modelling shows that, at 70° take-off angle, the antenna is 12dB weaker than a flat-top dipole at 5m above ground level). However, anyone who has used even a 2m long vertical mobile whip will tell you that when there is reasonable-to-good Inter-G propagation, you can work many stations with ease. So it proved with this antenna, with barely a gap showing anywhere on the band scope, and I made contacts with several UK stations, along with stations in Denmark, Austria, and France. I could have easily remained on 40m and worked many more but tore myself away to look at 15m. Quickly tuned, the antenna helped reveal some nice signals on the band scope, and I was able to work some satisfying DX, notably PY6HD (Brazil), LU1JHD (Argentina), WT0S (USA), and KM4GBM (USA). Then, later in the evening, my attention turned to 17m, and I was delighted to work Japan (JR7AQL) with 5/3 reports both ways. Subsequent DX on 17m took in WP4TZ (a parks on the air (POTA) station in Puerto Rico), CO8LY (Cuba), K4SJR and KD2VBH (both USA). Finally, on 20m, I was pleased to work N4WFU and N1WMN (both USA), V51WW (Namibia), and VE2YI (Canada).

The stations worked that evening are captured in **Figure 10**. A good geographical spread was attained, with contacts made across the Atlantic and to the Far-East. Overall, the antenna met its intended brief. It tuned seamlessly across all the desired bands of operation. It managed to work DX across the higher HF bands (aside from a closed 10m).

**Table 1:** The antenna length expressed as fractions of a wavelength of the HF bands.

| Band | Fraction of wavelength |
|---|---|
| 40m | 0.22 |
| 30m | 0.31 |
| 20m | 0.44 |
| 17m | 0.55 |
| 15m | 0.65 |
| 12m | 0.77 |
| 10m | 0.88 |

## Alternatives and future tweaking

In terms of the antenna's length, it all really depends on which bands you wish to work. If 10m and 12m are not a priority, then an increase to a non-resonant 9.45m (31ft) would allow for an improved performance on 40m, as it would almost be a quarter-wavelength long and three-quarters of a wavelength on 15m, whilst avoiding being a high-impedance end-fed half-wave on other bands. A reduction to a non-resonant length of 7.6m (25ft) would admittedly reduce efficiency on 40m (but not to a deal-breaking amount) but bring back 10m as a three-quarter wavelength antenna, and 12m as fractionally more than 5/8 of a wavelength long. To work quite effectively on 80m as a portable antenna, it is perhaps better for it to be elongated to a non-resonant length of at least 16.1m (53ft), 17.7m (58ft) or 21.9m (72ft). Of course, this would likely mean that the antenna would need to be deployed as an inverted-V or as a shallower sloping antenna.

Why use a remote tuner at the feed point and not rely on an impedance transformer

**Tim Hier, G5TM**
timhier@icloud.com

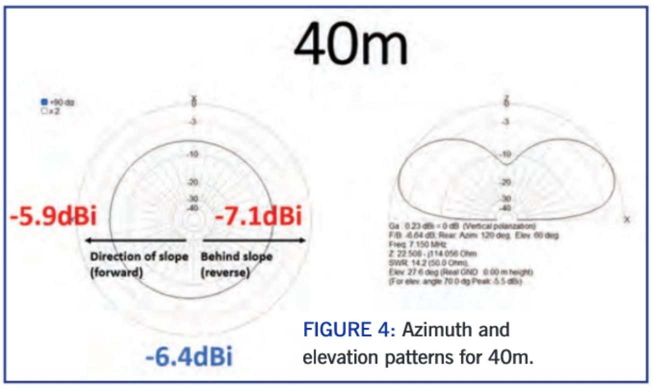



**FIGURE 4:** Azimuth and elevation patterns for 40m.

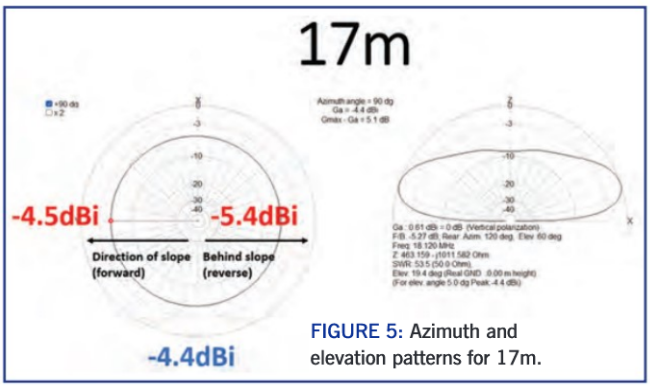



**FIGURE 5:** Azimuth and elevation patterns for 17m.

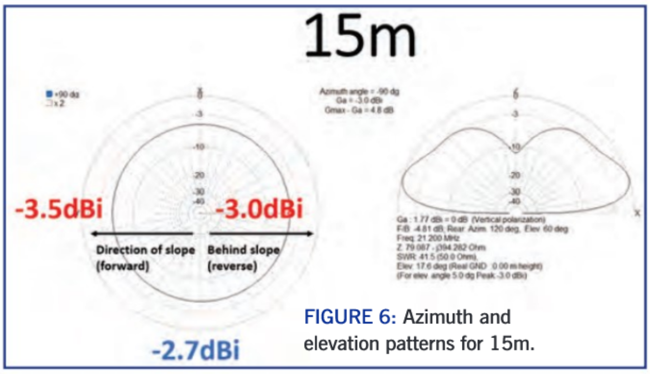



FIGURE 6: Azimuth and elevation patterns for 15m.

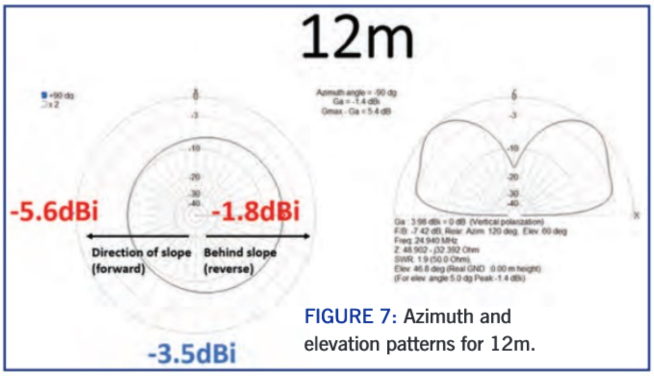



FIGURE 7: Azimuth and elevation patterns for 12m.

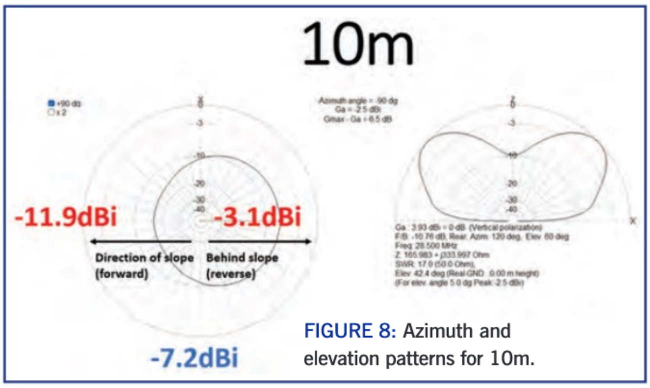



FIGURE 8: Azimuth and elevation patterns for 10m.

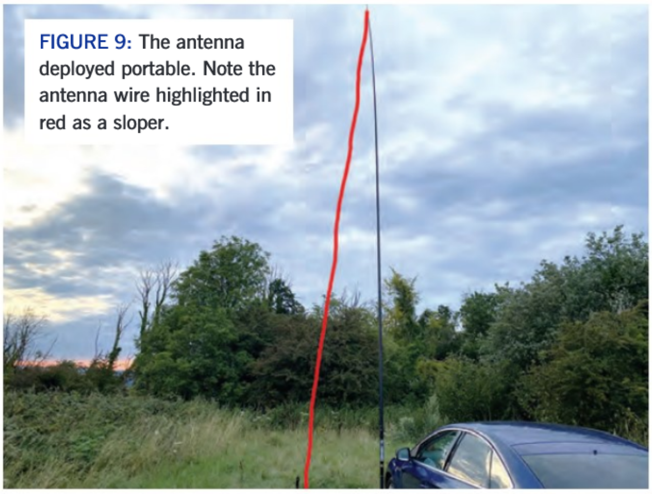


FIGURE 9: The antenna deployed portable. Note the antenna wire highlighted in red as a sloper.

FIGURE 10: The QSO map from the evening working portable, showing a decent return for DX.

such as a 9:1 UNUN perhaps? The 9:1 is an often-used design and can work very well indeed. I examined this as an option, by reconstructing this antenna, using the same length of coaxial cable feeder (with the line isolator positioned in the same location) running from the 9:1 UNUN and connected to an ATU next to the radio. Assuming the same degree of tuner/UNUN losses in both antenna systems, let us examine the feedline/VSWR losses for both systems. **Table 2** compares these configurations. To enable the comparison, I presumed an achieved 1.4:1 VSWR at the feed point following the remote tuner (a pessimistic figure I think on some bands). I also measured the VSWR right at the SO-239 connection at the 9:1 UNUN.

**Table 2: The losses expected using a remote tuner and using an UNUN.**

| Band | With a remote tuner/dB | With a 9:1 UNUN and a tuner at the radio/dB |
|---|---|---|
| 40m | 0.4 | 3.2 |
| 20m | 0.6 | 1.5 |
| 17m | 0.7 | 2.1 |
| 15m | 0.8 | 2.9 |
| 12m | 0.9 | 2.9 |
| 10m | 0.9 | 1.8 |

On most bands there would seem to be between a 1dB to 3dB additional loss in the 9:1 system. This is not a terrible amount, especially when HF conditions are favourable and when you compare that antenna to the use of a shorter HF mono-band mobile whip or screwdriver antenna for example. Of course, I used, by portable standards, an extensive run of coaxial cable, so reducing this to around 5 to 8m would reduce these losses still further. It is also important to recognise that, once the antenna is at 0.4 to 0.6 of a wavelength long, the enhancement provided by an extensive ground radial system diminishes, making it a good antenna on 20, 17 and 15m even without many ground radials. In this case, on 40m however, once the antenna slips below 0.25 of a wavelength long, the need for a good ground radial system becomes much greater as the radiation resistance reduces.

## Conclusions

Overall, I enjoyed thinking about, modelling, and using this antenna. Real-world performance was very encouraging during a period when HF rather languished in the summer doldrums, and when all-too-regular solar flares affected HF propagation. It is my intention to use this antenna, portable, for the CQWW SSB contest in late October, and have some fun band-hopping with ease. The antenna tuned each time seamlessly, and in under three seconds on the various bands, thanks to the remote ATU. Here's to better propagation this Autumn!

# JNC MC-750
## HF antenna

PHOTO 1: The antenna in its nylon case.

**The MC-750 is the latest portable HF antenna available from Martin Lynch and Sons. It covers from 7 to 50MHz and is a quarter-wave, ground-plane antenna with four 3.5m wire radials included. It has a removable loading coil for the 30m and 40m bands, but is otherwise a single radiator with a telescopic whip.**

The whole antenna comes in a neat nylon case with a carrying handle (**Photo 1**) and, at the moment, comes with a free tripod to make the installation easier.

The MC-750 is ideal for portable operations as, apart from adding coaxial cable, it is entirely self-contained. You might want to add a rubber mallet to help with installing the ground spike, but you can always use the tripod instead. However, watch out for high winds which could topple the antenna.

On opening up the carrying case you'll find the MC-750 feed point/ground post (**Photo 2**), which comes affixed to a 10-inch (25.4cm) metal ground spike. It has an SO-239 socket for coaxial cable and plug-in sockets for the four supplied yellow 3.5m wire radials (**Photo 3**).

On the top is a threaded hole into which you fix the 50cm extension. The hole is a different thread size from that on the feed point. This ensures that you don't get them muddled up and also means that the 40m loading coil (**Photo 4**), if used, is elevated a little off the ground.

Once you have knocked the stake into the ground with a suitable mallet (**Photo 5**), added the extension, and the four supplied radials, you can then add the sturdy telescopic whip. When collapsed this is just 52cm long, but it can be extended to a total length of 557cm (**Photo 6**).

### Build quality

A quick word at this point about the quality. I was impressed overall as the parts are all well-made and well-finished. All of the fixings use Allen key-headed bolts and the 40m loading coil has a plastic covering. The four radials are wound on a piece of plastic to keep them neat and tidy.

It is a sturdy antenna that looks like it will last well and take quite a bit of punishment. The fitted nylon case is an added bonus.

### How does it work?

The antenna works as a quarter wave vertical, but the clever bit is that the required resonant lengths for 7, 14, 18, 21, 24 and 28MHz are printed on the side of the telescopic whip. This may save you from having to take a VSWR meter with you. There are no markings for 10MHz or 50MHz, so you will have to either set the antenna by trial and error or use a VSWR meter. For 7MHz you add the supplied 40m loading coil and extend the antenna to the 7MHz mark. Likewise, for 10MHz you keep the 40m coil and shorten the telescopic whip for the lowest VSWR.


PHOTO 2: The feedpoint installed on top of the ground spike.

### VSWR

The overall VSWR results were as follows and roughly matched the markings on the telescopic section:

| | |
|---|---|
| 14.000 - 14.350MHz | 1.4:1 |
| 18.068 - 18.168MHz | 1.2:1 |
| 21.000 - 21.450MHz | 1.4:1 |
| 24.890 - 24.990MHz | 1.5:1 |
| 28.000 - 29.100MHz | 1.6:1 |

Adding the 40m coil resulted in the following:

| | |
|---|---|
| 7.000MHz | 1.0:1 |
| 7.200MHz | 2:1 |

By shortening the antenna slightly, I was able to get the VSWR down to 1.1:1 on 7.200MHz. So, you can tune the antenna for the part of the 40m band that you wish to work.

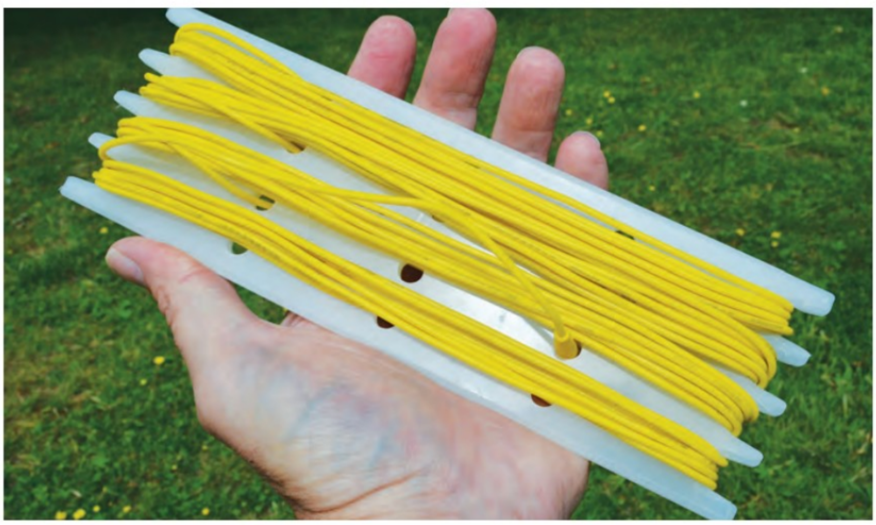


PHOTO 3: The four radials before installation.

**PHOTO 4:** **The loading coil for the 40m band.**

On the 30m band (with the 40m coil included) the lowest VSWR I achieved was of 1.5:1 on 10.115MHz, but again you can fine tune it.

On the 6m band, with the telescopic whip set to 98cm (giving a total length of 148cm), I was able to get a VSWR reading of 1.4:1 across the entire band.

So, do you really need to carry a VSWR meter with you? Probably not. But if you are going to use the 30 or 40m bands, or perhaps even 6m, it is probably a good idea to just check that the VSWR is acceptable before operating.


**PHOTO 5:** **The rubber mallet used to install the ground spike.**


**PHOTO 6:** **The antenna installation complete.**

## Operating

Having set up the antenna in my back garden, I connected it up to my Yaesu FTDX-3000, setting the power to 10W, and started monitoring FT8 on 14.074MHz. My first thought was that the antenna worked very well. Received signals were much better than with my 132ft (40.2m) end-fed half-wave antenna.

Turning to transmit, I quickly put Germany, Finland, Greece, Italy and Austria in the log over a period of about 20 minutes. Stations heard but not worked included Japan and Australia. Switching to FT4, Crete and Greece were quickly added to the log.

I then retuned the antenna for 17m (a 30-second job) and added Madeira, Finland and Bulgaria. Stations heard but not worked included Saudi Arabia and Japan.

After shortening the antenna for 21MHz it was a similar story. Upping the power to 50W, I worked D2UY in Angola, which was a new entity for me!

Having made the antenna even shorter, I tuned up on 28MHz but there was little activity there.

The following weekend was Norfolk Amateur Radio Club's 'Radio by the Seaside' event at West Runton on the North Norfolk coast. I took the MC-750 as my only antenna to see what it could do. Using a QCX 3W 20m CW radio and an original three-band (20m, 30m and 40m) 3W Mountain Topper, both good QRP radios, I was excited to see how the antenna would perform with QRP power.

Luckily, it was the IARU HF World Championship 2023 until 1200UTC and, having set up the antenna for the 20m band and using the QCX, I was soon putting stations in the log (**Photo 7**). I41M, I470, II9HQ (all Italy) were worked on CW, along with S50HQ (Slovenia), Z30HQ (North Macedonia), HG0HQ (Hungary) and HB9HQ (Switzerland).

Despite my low power I commented it was "like shooting fish in a barrel!"

After the contest finished it was tough going, despite being spotted on 20m by the CW Reverse Beacon Network (RBN) in Germany, Poland, Italy, Slovenia and Estonia. On fitting the 40m loading coil and retuning the antenna, there was little to be heard on CW on the 40m band using my Mountain Topper radio, but on calling CQ I was spotted by SE5E in Sweden. After retuning for the 30m band, nothing was worked and no RBN reports were logged. Because of the loading coil, it is a very short antenna for the 30m band.


**PHOTO 7:** **A QCX transceiver in use with the antenna on the 20m band.**

## Conclusions

Overall, I was impressed by the build quality and the ease with which the antenna could be erected. It worked very well on the 20m band and up, and would make a good SOTA antenna. I was less impressed with its performance on 30m and 40m, but by upping your power you could no doubt make contacts, especially on CW and FT8.

The MC-750 costs £229.99, including a free tripod worth £34.99. My thanks to Martin Lynch and Sons for the loan of the antenna.

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Technical

# An introduction to antenna noise cancellers

**Most amateurs who have been licensed for several decades or more will no doubt have fond memories of bands free from the electronic and electrical noise that now plague the spectrum.**

Few amateurs these days are lucky enough to live in a low-noise environment, and most of us will, at some stage, have to deal with locally-generated noise from various sources such as switch-mode power supplies, computer equipment etc.

## Introduction

In general, the HF bands are more prone to interference, although many of us have experienced problems on bands up to 1240MHz (23cm) and higher. In the first instance, it is necessary to determine if the interference is being generated in-house as this will, in almost all cases, be easiest to remove or mitigate **[1]**. Noise sources that emanate from places other than in your own property will clearly need to be identified and tracked to source, which may involve use of a portable spectrum analyser or SDR receiver for nearby devices, or some direction-finding skills for more distant noise sources. An excellent article by Ian, G0CNN, is well worth a read **[2]**.

Often it is not possible to mitigate, or remove, the noise generated by noise sources, perhaps because of uncooperative neighbours. In the case of a 'stealth' amateur radio station, it may not be desirable to approach neighbours at all. Whilst an IF or AF DSP in a modern radio, in conjunction with front-end attenuation and noise blanking, can often provide some reduction in received noise, the most effective way to reduce noise is, of course, to prevent it getting into your receiver in the first place. A very effective way of attenuating or removing noise via the antenna is by use of a noise-cancellation device, often referred to as an 'antenna noise canceller'. This short article will cover the use of such devices, showing what can be achieved by their use and their limitations.

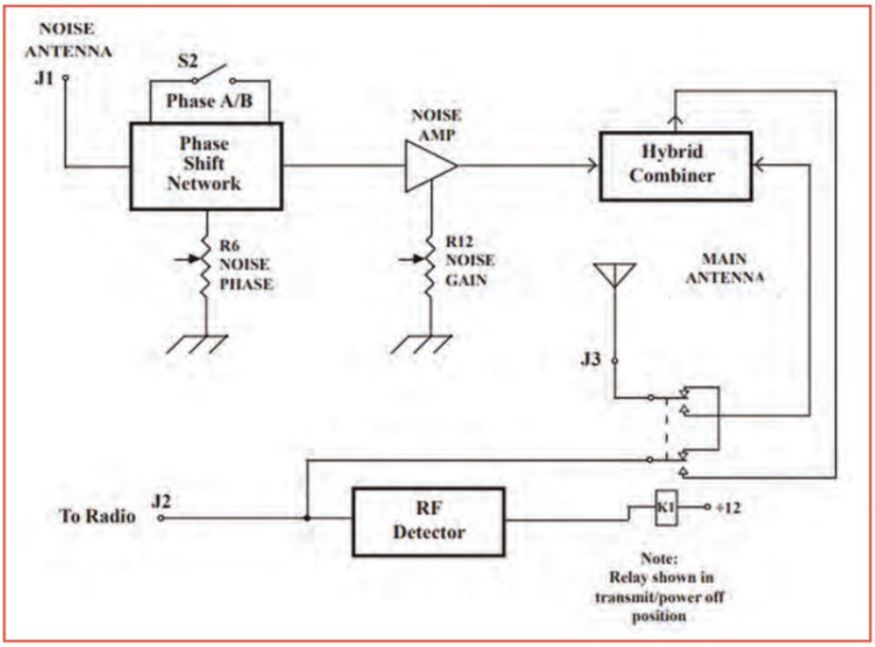


FIGURE 1: A block diagram of the Timewave ANC4 antenna noise canceller.

## Principle operation of the antenna noise canceller

The operation of an antenna noise canceller is straightforward, and is based on the principle that two waveforms of the same shape and amplitude, but 180° out of phase with each other, cancel when added together, known in Physics as 'destructive interference' **[3]**. An antenna noise canceller has two antenna inputs, one for the main station antenna used for receiving, and one for another receive-only antenna referred to as the 'noise antenna'. The main station antenna receives both the wanted signal and the locally-generated noise. The noise antenna picks up the locally-generated noise and, in general, will be shorter and less effective on the band in use so that the wanted signal is completely absent or very much weaker than the locally-generated noise. The signal from the noise antenna is passed through a phase-shift network so that the noise can be made to be 180° out of phase with the noise on the main antenna. The phase-shifted noise signal is then amplified so that it is at same strength as that picked up by the main antenna, and is combined with the signal from the main antenna, thus cancelling the noise and leaving only the wanted signal. **Figure 1** shows the block diagram of a commercially-available antenna noise canceller, the Timewave JPS ANC-4 **[4]**. There are other units available such as the MFJ 1026 **[5]**, and some of Chinese origin such as the X-phase **[6]**. It is of course possible to build your own antenna noise canceller, and there are numerous designs to be found on the internet **[7]**.

The commercially-available units are usually designed to operate on HF and 50MHz only. Keying on transmit is achieved by either RF VOX, or PTT line input. When not switched on, most commercially-available units default to by-pass mode. Linear amplifiers, or any meters such as VSWR meters etc, should be placed after the noise canceller.


FIGURE 2: The ANC4 noise canceller in use (the screw-in telescopic whip is shown at the top far left).

## The noise antenna

The noise antenna in an antenna noise canceller system is perhaps the most critical part of the system and will determine the effectiveness of noise cancellation. The noise antenna needs to be able to pick up enough of the local noise to be cancelled, whilst at the same time receive a much-lower level of the wanted signal (preferably zero). As such, the noise antenna is usually deliberately made to be shorter than a main antenna for the band in use. Both the Timewave and MFJ cancellers come with a short telescopic antenna that may be screwed into the top of the unit (**Figure 2**). In general, use of such a telescopic antenna will only be effective for noise sources close by (up to 5m), such as might be emanating from a neighbouring property. For noise sources that are further away, an external antenna is usually necessary, and this can take the form of a very short dipole, small loop, or a vertical antenna. The noise antenna should be placed as near as possible to the local noise source, and preferably close to ground level to attenuate any distant signals. For example, at my last QTH, my neighbour had a cooker, the electronic clock/timer of which generated a noise of around S5 on most of the HF bands, which they were unwilling to switch off when not in use. I used a short, untuned, horizontal, balanced dipole of total length around 1.2m. This dipole was placed in a ground-floor room next to an external wall and alley, so that the noise antenna was approximately 4.5m away from the cooker. Using this antenna, I was able to eliminate the noise on all bands from 160 to 10 metres. Some degree of patience and experimentation is usually required to determine the optimal position (including the polarisation) for placement of a noise antenna. Occasionally, not enough noise is picked up by a small noise antenna, and it may be necessary to increase the size, hence possibly increasing the level of the wanted signal picked up by the noise antenna which may interact with it.

## Types of noise that can be cancelled

Antenna noise cancellers can eliminate or attenuate a wide range of noises, including power-line noise emanating from a single point (see (e) below), wideband hash-type noise, and carrier signals (eg so-called 'birdies'). The interfering waveform needs be continuous and reasonably stable in its shape

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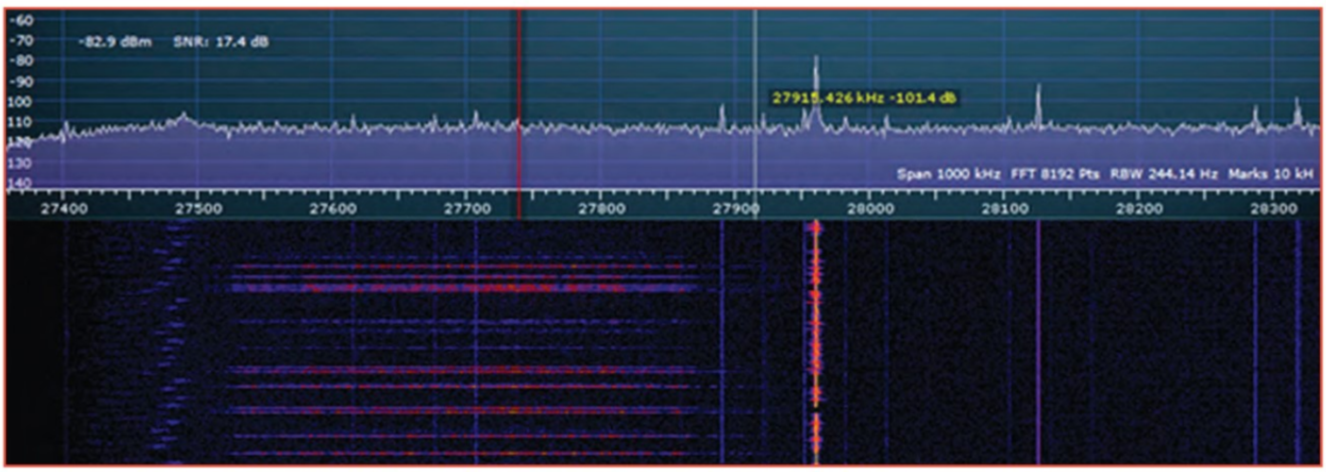


FIGURE 3: Interference below, and in, the 10m band at G0FVI.

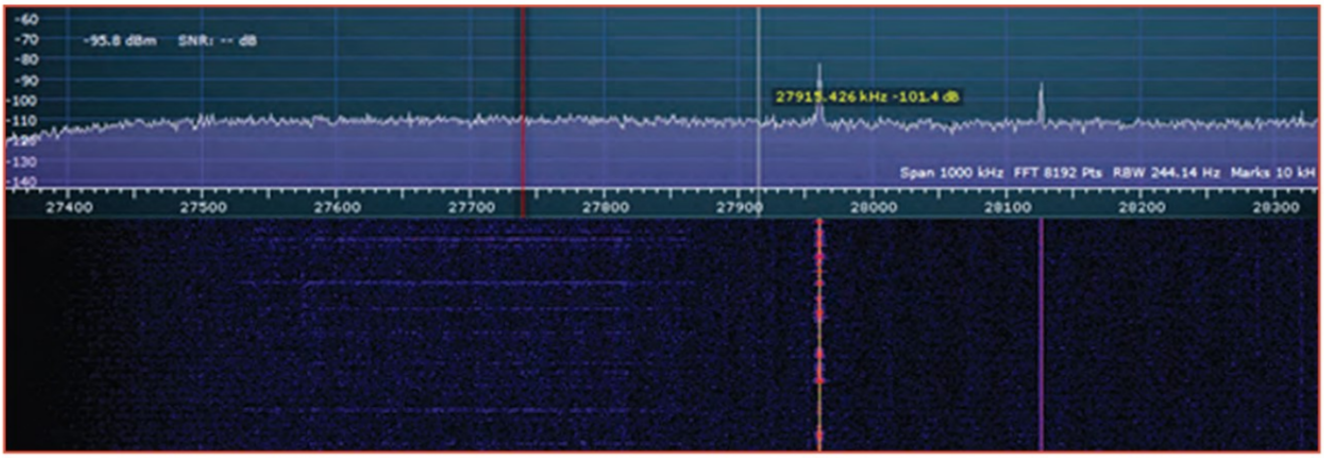


FIGURE 4: The 10m band after removal of a local interfering noise source.

and amplitude for effective cancellation. Unstable (drifting) noises can be eliminated, but will almost certainly require continuous adjustment of the phase and or amplitude controls of the noise canceller which in practice is difficult to achieve.

## Disadvantages of antenna noise cancellers

Whilst antenna noise cancellers can be most effective in removing or reducing noise, there are some caveats to their use listed here:

(a) Adjustment of phase and amplitude controls on these units requires of patience, and the user will almost certainly find that very small adjustments of the controls will be needed to find the required null at which noise is removed or attenuated to an acceptable level.

(b) Some attenuation of the wanted signal may occur when using a noise canceller. The insertion loss of my Timewave unit is around 6dB.

(c) Correct placement of the noise antenna is critical, and on occasions the noise antenna may not be able to receive enough of the noise signal for effective cancellation.

(d) Antenna noise cancellers are usually only able to remove one source of noise at a time. The signals from different noise sources will rarely be of the same phase so, if you have multiple interfering signals, it may be a case of choosing which one to remove.

(e) A noise source that emanates from several different directions (and thus phase) will almost certainly not be removed by an antenna noise canceller, the classic example being power-line noise.

## In practice – an example

There are numerous examples on YouTube of some quite-dramatic noise removal (enter ANC4 or MFJ 1026 into the search bar of YouTube) which can give you some idea as to the effectiveness of these units. Presented here is an example of some noise removal at G0FVI. One of the neighbouring properties appears to be using some kind of power-line data device which uses multiple band segments within the shortwave bands. These devices use the home electrical wiring to distribute internet signals to other parts of a property where WIFI is weaker. The particular device in question appears to be notched for the amateur HF bands, although there remain some rather tiresome low-level carriers and a slightly raised noise floor, most notably on the 10m band, with what appears to be very strong data bursts which wipe out completely most the old CB 27/81 band below 10m (**Figure 3**). Note there is a carrier at 28.125MHz emanating from the home alarm system at G0FVI, the other carriers shown in Figure 3 are 'birdies' from the interfering PLT device. A carrier can also be seen around 27.915MHz from a QSO of some local CB users. Using the in-built telescopic whip for my ANC4, it was possible to remove the interfering data bursts and associated 'birdies' almost completely (see **Figure 4**). Note that the carrier from my home alarm system is still present at 28.125MHz, and is not removed as it is of a different amplitude and phase from the interfering data device. The QSO taking place around 27.915MHz has also not been removed, so this must represent a wanted signal (unfortunately 10m was not open at the time the screenshots were taken!). There is, of course, some reduction in noise level and attenuation of signals arising from the insertion loss of the noise canceller itself.

Note that the noise source given in this example has multiple points of radiation (RF through house wiring), which as mentioned above can often not be removed completely using an antenna noise canceller.

## Will it work for me?

If you have some stubborn interference that you've been unable to remove, you may already be thinking about using an antenna noise canceller. Whilst many radio amateurs have found that antenna noise cancellers have allowed them to continue with their hobby, some will no doubt have experienced less satisfying results. The effectiveness of an antenna noise canceller will (as outlined above) depend very much on the proximity of the noise source and effectiveness of your noise antenna, and so it is advisable to spend some time looking for the source of any noise before buying such a device. For locally-generated noise, say within a 100m or so, you will probably find (as I have) that an antenna noise canceller can be a useful device, although you will need patience and will almost certainly have to experiment with different configurations of the noise antenna. You may need to use a longer noise antenna, which may possibly attenuate the wanted signal somewhat if the phases of the wanted and unwanted signals match, although this may not necessarily be a bad compromise as it may make the difference between having a QSO or not!

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[5] https://mfjenterprises.com/products/mfj-1026

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# EMC

## Solar PV

The environmental benefits of producing energy from renewable sources such as solar photovoltaic (PV) systems are widely accepted and domestic solar photovoltaic (PV) micro-generation systems are being installed in increasing numbers. Such systems should not affect radio communications if they are well engineered for EMC but it appears that not all systems are well engineered and some may cause pollution of a different type of environment, that is the electromagnetic environment. The RSGB EMC Helpdesk is receiving an increasing number of EMC cases related to solar PV installations. See also RSGB EMC Committee page on solar PV **[1]**.

There are several different types of solar PV installation and, if an EMC problem arises, it is important to find out which type you are dealing with because they require a different approach. The first things to find out, if possible, are the make and model of inverter and whether the system has optimisers. An article in the February 2013 *RadCom EMC Column* described broadband VHF noise radiated by a solar PV system with optimisers.

## With optimisers

**Figure 1** shows a solar PV installation with 10 panels and optimisers fitted to each panel. Some domestic installations may have 14 or more panels. Each optimiser contains a DC-to-DC converter that uses switching techniques and these converters may generate RF interference. The red arrows indicate RF current paths in cables that can lead to radiated interference and the red arcs indicate direct radiation. RFI can be radiated directly from the optimiser itself or it can get out via DC input and output cables. In Figure 1 there is another possible source of RFI, the inverter(s). These are known as Grid Connected Power Conditioners (GCPC). These convert the DC output of the panels to AC power that is synchronous to the AC mains. There may be one, two or more inverters in a typical domestic installation depending on the power and in Figure 1 these are in the loft. The inverter could radiate RFI via its AC mains output, via its DC input(s) or directly from the case.

Tacking RFI from a solar PV system with optimisers can be quite complex. An article by K1KP in the April 2016 *QST* **[2]** shows how this was tackled on a 10kW system in the USA. Some solar PV systems do not have optimisers and not all optimisers generate significant amounts of RFI. The optimisers may communicate with the inverter using powerline communications (PLC) techniques via the DC power lines and it may be possible to switch the optimisers on and off remotely using the control and monitoring system of the inverter. This can be used to find out whether or not the optimisers are a significant source of RFI.

**PHOTO 1: Two Schaffner FN2410H-8-44 filters fitted to the DC inputs of a solar PV system.**

## Without optimisers

**Figure 2** shows a solar PV system without optimisers. As with Figure 1, red arrows indicate RF current paths in cables and red arcs indicate direct radiation. In this example there is only one inverter that may be able to handle a power of up to 4.8 kW in a larger system. The inverter may be mounted at or near ground level so that the wires going up to the roof are much longer and the potential to radiate RFI is greater. Some systems use what is known as a hybrid inverter with a storage battery. Without optimisers, the inverter(s) are the only source of RFI so any problems should be easier to tackle, especially if the inverter is at ground level. RFI can get out via the AC mains output but this is usually quite well filtered in order to meet the relevant EMC standards. RFI can also get out via the DC input wiring and this path may not have much RFI filtering. The relevant EMC standard is BS EN IEC 61000-6-3:2021 Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for equipment in residential environments. This supersedes BS EN 61000 6 3:2007+A1:2011 but as mentioned in my August 2023 *EMC Column*, in the case of solar PV systems neither edition requires testing of conducted RF emissions that get out via the DC power port(s).

Another way that RFI may get out is via direct radiation from the inverter itself. This is known as the "enclosure port" in the Generic emission standard. Limits only apply at frequencies above 30MHz however, so direct radiation at HF bands does not need to be tested. It might appear that an inverter in a metal case would be well screened and this is generally true but, in some cases, there could be direct radiation depending on where RF currents flow in the metalwork.

## DC filters

In response to the item in August 2023 *EMC Column*, a Member sent an email saying that he ran a solar PV installation company between 2010 and 2012. The first installation was on his own home. This consisted of 14 x Panasonic/Sanyo 235W panels connected to an SMA SB3000HF string inverter. The panels were configured as two strings of seven, with a string voltage of around 300V. This was before the days of optimisers, so none of those were present. The inverter was located in a garage with around 10m of cable between the inverter and the start of the panel array. He only operated on the 28 and 50MHz bands at that time with a 4-element 28MHz/ 5-element 50MHz interlaced Yagi at a height of 7m above ground. The antenna overhung the solar array and came within two or three metres of it. At peak solar generation, he experienced "raspy spurs", of up to S5 signal strength, throughout the 28MHz band, along with other lower-level noise, and lower-level spurs on 50MHz. He occasionally encouraged the 28MHz Yagi onto 24MHz and the interference level was worse there than on 28MHz. He can't comment about other bands.

At the time, the common 'fix' for such interference seemed to be long strings of ferrite beads and he considered this for a while. Then he spotted an advert in a solar trade magazine, from filter manufacturer Schaffner, which mentioned solar inverters and EMC. He spoke with the Schaffner applications engineer who advised that 30dB RF attenuation would be achieved using their high-voltage DC filters. He purchased a pair of Schaffner FN2410H-8-44 filters, placed those in an enclosure, installed that next to the inverter, connected them up and, sure enough, about 30dB of noise went away… completely gone on 50MHz, almost imperceptible on 28MHz and low enough to be of no inconvenience on 24MHz.

**Photo 1** shows the two Schaffner FN2410H-8-44 filters mounted in an enclosure with the cover removed and the DC input from the solar panels isolated. This enclosure should be mounted as close as possible to the inverter.

These filters are available from distributors such as Farnell, Digikey or Mouser but they may be on a relatively-long lead time from some suppliers. It is also important to get the model with the letter "H" as this is a high voltage type. Clearly installation work must be done by a qualified installer, particularly as the strings of solar panels can output hundreds of volts DC in daylight. The filters shown were mounted in a garage but clearly if they are outdoors then a sufficiently waterproof enclosure is required. If any other type of filter is used then it must be suitable for DC with an adequate voltage rating, which needs to be higher than mains voltage. The filters require an earth wire to be effective but where should this wire be connected? A good earthing/bonding strategy at mains frequencies may not be effective at radio frequencies due to the length of wires and area of loops. One possibility is to run the earth wire from the filter to an earth terminal on the inverter, keeping the earth wire as short as possible and close to the DC power wires to minimise the area of loops that can radiate. Oher arrangements are possible including a metal water/central heating pipe or even an earth spike in the ground if this can be made with a low enough resistance but if an independent earth is used, it would be necessary to consider the effect of protective multiple earthing (PME). See also RSGB EMC Information Leaflet 7: Earthing-and-the-Radio-Amateur **[3]**.

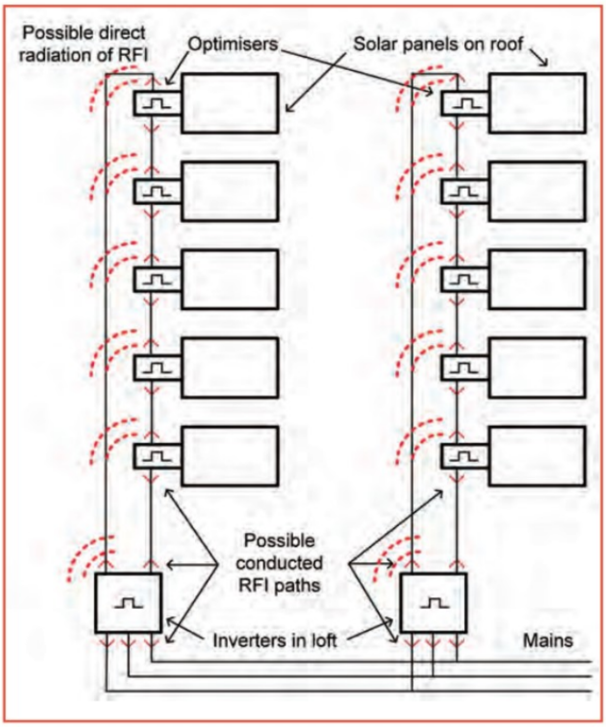


FIGURE 1: A typical solar PV system with optimisers and loft mounted inverters.

## CE or UKCA?

As mentioned in the February 2023 *EMC Column*, an EU Directive (2014/30/EU) on electromagnetic compatibility (commonly called the EMC Directive) was implemented into UK law by The Electromagnetic Compatibility Regulations 2016. The EU Withdrawal Act 2018 preserved the Regulations but made various changes including replacing the CE Mark with the UK Conformity Assessed (UKCA) mark. The following information applies to England, Scotland and Wales. Different rules apply in Northern Ireland.

According to a Department for Energy Security and Net Zero and Department for Business and Trade, last updated 1 August 2023, Manufacturing Guidance UKCA marking: conformity assessment and documentation [3], the Government intends to extend recognition of the CE marking for placing most goods on the market in Great Britain, indefinitely, beyond December 2024. These updates apply to the 18 regulations that fall under the Department for Business and Trade (DBT). Three that relate to electrical and electronic engineering include Electromagnetic Compatibility (EMC), Radio Equipment (RE) and Low Voltage Equipment (LV). In this context, 'Low Voltage' means mains voltage.

The intention of this change appears to be reduction in the cost for manufacturers to comply with UKCA marking requirements but does this mean that goods can continue to be sold in England, Scotland and Wales with a CE mark rather than a UKCA mark? It is not as simple as that. The rules are quite complex and this article summarises the situation in general terms but it should not be taken as an authoritative guide to any legislation. Any manufacturers that are selling electronic products in the UK should consult [3].

In the European Union, "Harmonised Standards" are published in the Official Journal of the European Communities (OJ) whereas in the UK there is a list of "Designated Standards". In the case of EMC, the list is published by the Department for Business, Energy and Industrial Strategy. Many of these standards are identical to EU Harmonised standards but not all are. When Harmonised European standards are updated, UK Designated Standards may lag behind. This could introduce another stage of delay before new European standards become UK Designated Standards.

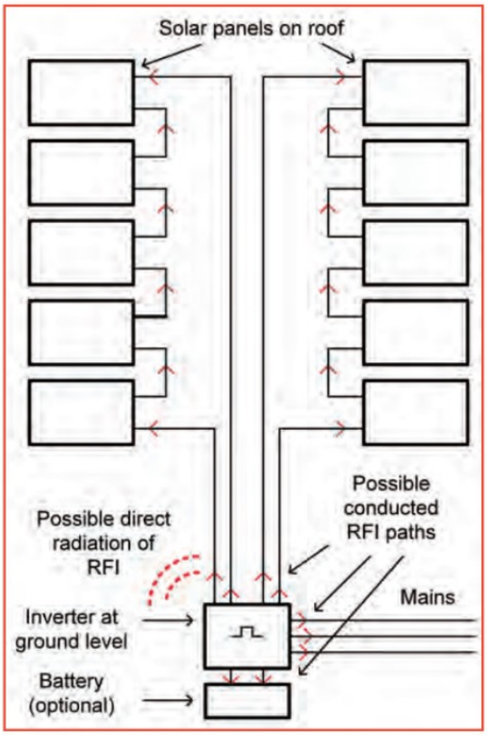


FIGURE 2: A typical solar PV system with ground mounted inverter and no optimisers.

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https://rsgb.org/main/technical/emc/solar-pv-panels/

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[4] EMC Leaflet 7: Earthing-and-the-Radio-Amateur
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# Design Notes

## Corrections

In June's Design Notes, I made a couple of incorrect statements relating to aircraft power supplies. Robert, G8RPI wrote in to say:

"In the August design there is described some information on aircraft 400Hz power supplies. I have to correct one statement in the piece. He says that the supply is 200V phase to phase with no neutral. He calls this a "delta feed". This is not correct. Aircraft 3 phase AC supplies are always from a star connected source and have the star point "neutral" connected to the airframe. There is no separate neutral conductor in the distribution system. While loads above 500VA should, according to the relevant standard, be 3 phase there are many smaller loads (and some larger despite the standard) that are single phase. These connect between one phase and a (typically local) connection to the airframe. The supply is normally referred to as 115V AC (phase to neutral) not 200V. Some military standards eg MIL-STD-704F do refer to 115/200V in the description but all the limits are for the 115V phase to neutral voltage. The civil standard, RTCA DO160G, has standard voltage unbalance limits of 6V between phases and phase error of 4 degrees. The military standard has a tighter voltage limit of 3V. Some loads, particularly motors, are delta connected with no neutral but anything electronic or with a filter must have a neutral and Star connected source. "On methods of driving simple loads like fans I use what is effectively a combination of the methods Andy describes. I use three toroidal mains transformers with the LV windings connected as centre-tapped. All three centre taps connect to the positive DC supply, the "ends" go to the drains of six common source MOSFETS. Sources go to negative DC / Common. The gates are then driven with a PIC while a simple PWM stepped sinewave as shown by Andy produces a nicer wave form, for most applications a fixed single pulse width is good enough. Output voltage can be fine-tuned by adjusting (or PWM) the DC supply. The transformer HV (originally primary) windings are connected for 115V (parallel) at each transformer and the three then connected to Star for the output. This arrangement requires no HV switching and is very efficient. 50/60Hz toroidal transformers run fine at 400Hz. Their cores are oversized for 400Hz. It's the $I^2R$ losses of the windings that stops you using them at much higher power than their 50/60Hz rating. I do like Andy's description of the quadrature to 3 phase transformation. In industry this is often called a Scott-T transformer. It is also used with low-level signals in syncro and servo applications."

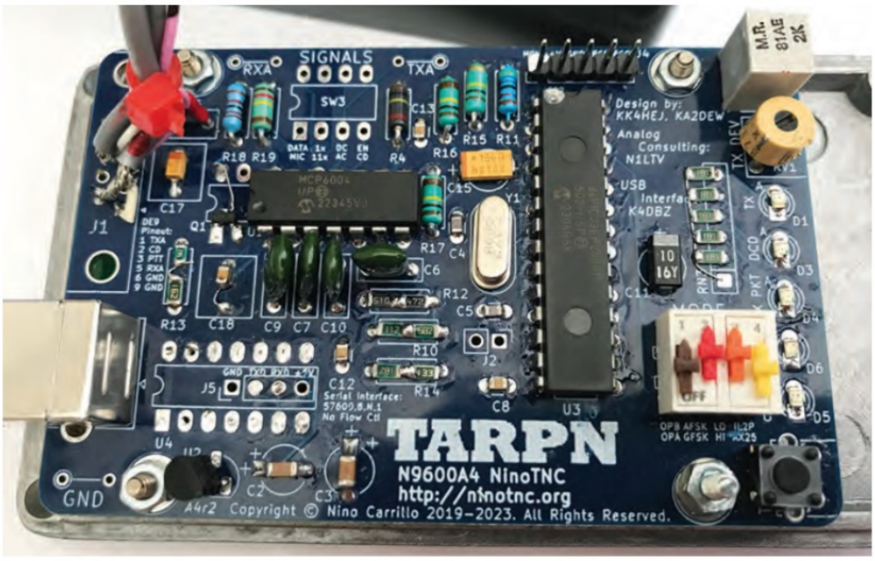


FIGURE 1: **The NinoTNC PCB supplied by TARPN constructed from the 'JNT Junkbox which contains mostly SMT components. An FTDI FT232 USB/COM port bridge module sits under the PCB, replacing the MCP2221 the board was designed for.**

I also stated that the ripple frequency of full-wave rectified 400Hz 3-phase is 1200Hz whereas it is, of course, 2400Hz as pointed out by Bob Richardson, G3XMB.

## Building the NinoTNC

This terminal node controller (TNC) for packet radio is described in this issue's *Data* column, and is supplied as a PCB and programmed dsPic chip, although full kits are now available. Unfortunately for me (though I doubt many readers will agree), is the all through-hole construction. Here at 'JNT labs, stocks of through-hole components in the junk box are getting low – I've been constructing everything using surface-mount (SMT) devices for decades now, and most components here are in that format. Having to continually flip a PCB over to solder wires, then cut them off and flip the board back to insert another component, is just too tedious. So SMT devices, tweezers and a PCB held rigidly is my preferred option. The board was built up using what wire-ended resistors I had, with the rest of the board built using the larger-sized 1206 SMT types and wire links. As the board had plated-though holes and a metal pad both sides for soldering, using SMT components on the top with wire bridges was perfectly feasible. **Figure 1** shows the somewhat unorthodox construction of this PCB; compare with a picture of one built 'properly' on the TARPN website given in *Data*. The missing IC visible in the photograph is an MCP2221 USB-serial COM port bridge that I replaced with an FTDI232 module hidden underneath. There is quite a saga behind this.

## USB / COM port serial bridge woes

The USB interface on the NinoTNC uses an MCP2221 device, a simple USB-serial bridge supplied by Microchip, the PIC people. The instructions stated that drivers for this device were native to Windows 10 and higher, but older Windows operating systems would require a driver to be downloaded from the Microchip web site. I have two PCs and, after building the TNC module, I connected it first to my laptop running Windows 10. It

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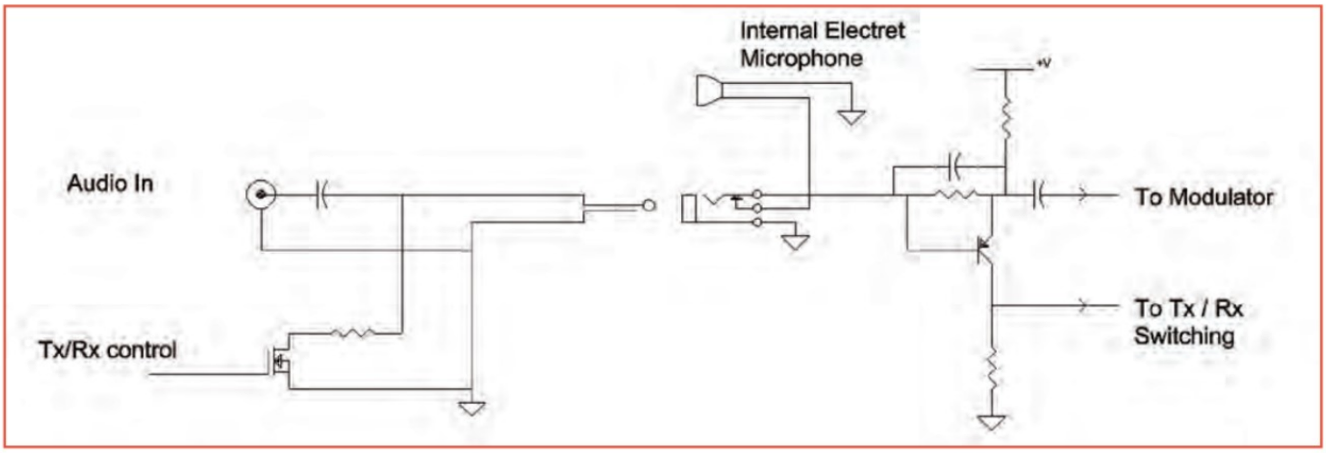


FIGURE 2: PTT and external microphone connection on typical hand-held radios. Circuitry within the radio is speculative, showing the need to power an electret microphone, using the current drawn by this to signal TX operation. The need for CR networks to separate audio from TX/ RX control may well contribute to the long switching times of these radios.

automatically installed the driver and worked straightaway – so the hardware was all OK. My shack PC is an older, but quite potent, HP desktop running a full 64-bit version of Windows 7 Pro that still gets some regular updates from Microsoft. The desktop runs all my amateur-radio software wonderfully, faster and better than the more-modern laptop does, and has multiple USB COM ports, all using the FTDI FT232 device **[1]** for these. Now the saga starts, and needs to be followed in sequence. I switched on the desktop and went to the Microchip website where a bit of searching showed an installation package for the MCP2221 device. I downloaded it and ran the executable. It appeared to install OK, the MCP2221 was recognised, and it worked as a valid COM port. That was it for the day and I was about to turn the PC off but noticed there was a Windows update pending, so I let it get on with that and then turn itself off afterwards. The update appeared to take a lot longer than normal and I ought to have been a little bit suspicious.

Next day, I turned the PC on only to be met with a message from the BIOS saying that it failed to boot Windows, a file was corrupted, or some similar message. It then offered to repair it for me, reverting to an earlier version before the update and also offered to run CHKDSK although I didn't take up that latter offer. After more than 30 minutes of disk churning and a few messages, it rebooted Windows successfully and I breathed a sigh of relief – but that was to be short lived.

The reversion to an earlier version had lost the MCP2221 driver, so I once again installed it using the utility from Microchip and once more it seemed to work. The Windows update was pending and as I assumed it had been that Windows update that had caused to boot problem, I certainly wasn't going to allow it in again, so I switched off without letting the update go ahead. Later that day I switched back on and… you've guessed it! This time I let CHKDSK do its job first where it found and repaired some damaged sectors, then the Windows boot repair, and all was fine again.

It was clearly the MCP2221 driver installation that was doing the damage so it looked like I couldn't use that USB / COM Port interface with the shack desktop. That interface chip was unsoldered from the PCB and replaced with an FT232 module from FTDI fitted on the underside of the TNC's PCB (not visible in Figure 1). This chip is a USB / COM port interface I have used literally hundreds of times and whose driver was firmly established on both PCs. It has never given any problems and is probably the only USB/COM port bridge I would ever use.

And finally, now convinced the MCP221 driver was the culprit, I somewhat nervously allowed the Windows update to go ahead. The restart after the update went perfectly, so it definitely was the installation package for the MCP2221 available from the Microchip website that crashed my somewhat unusual Windows 7 Pro system. That's not to say it won't work with other Windows 7 systems, or that I didn't read the website notes and downloaded the wrong installation package or something, but you have been warned.

## Transmit / receive switching times

As part of packet radio tests using my new TNC, four radios were tried with it. These were two relatively-old 2m/70cm handhelds, the Icom IC-T70E and Alinco DJ-596 models, and two all-mode rigs, the popular FT-817 and my Elad FDM-Duo. The latter two had auxiliary sockets for audio in/out and PTT that were used for connection of the lines from the TNC. Interfacing the two hand-held radios was more complex, and had to be done through the external microphone and headphone connectors. On most handhelds, external PTT control is made via DC on the microphone connection, sharing a single wire and using a resistor / capacitor to separate PTT from microphone audio. **Figure 2** shows a typical connection diagram for interfacing. Also shown is a **speculative** input circuit for the hand-held radio, and is just one of several ways it might be done. Most microphones are electret types, and need a few milliamps of DC to power them. Current is drawn when the external microphone is switched into circuit by the PTT switch. This is detected within the transceiver by the voltage dropped across the series resistor, turning on the PNP device, sending a signal to the TX/ RX circuitry. The need for a capacitor to pass the audio across this series resistor is likely to be one of several reasons RX/TX switching delays are so high.

To check out operations, I tried connecting to a local packet repeater / bulletin-board service (BBS), GB7SOU. The FT-817 and FDM-Duo worked fine, immediately connecting as soon as I issued the 'connect' command. The two handhelds were very unreliable, giving just occasional connection and lots of 'floating reply packets', visible on the traffic-monitor window. Several times, the BBS response packets were seen, but my acknowledgement transmission wasn't being received, so a proper connection was never made. After a bit of pondering, it occurred to me that what must be happening was that the handhelds were taking an excessive time to go to transmit, missing the opening part of a transmitted packet, or perhaps it was the delay before the RX worked properly after coming out of transmit, or both. The TNC can have a value set to compensate for the transmit delay, but nothing can be done about the receive delay. When TX delay setting was put to the maximum of around 1s, the Alinco then worked quite well, but the Icom still wouldn't allow a fully-reliable connection to that BBS. Time to make some measurements.

One input of a dual channel oscilloscope was triggered from the PTT line using the negative-going RX-TX edge. The transmitted RF was passed through an attenuator and went to the second channel. I have a 300MHz oscilloscope so it can show a 144MHz waveform directly but, for one with a lower bandwidth, a diode detector on the TX output can be used, looking at the resulting DC output.

The measured results for RX-TX timing are shown in **Table 1**, where it can be seen that there is a considerable difference between the handhelds and the base-station radios.

Measuring TX-RX delay was a bit more complicated. The receiver has to have a modulated signal already present to be able to respond as soon as it is ready, so a continuous transmission with an FM tone had to be running. The FDM-Duo was used for that, with an audio tone drive and continuous RF from its 1mW output port to a short antenna. Using the FDM-Duo as the test source meant this obviously couldn't then appear in the list of radios measured for TX-RX delay. The oscilloscope trigger this time was on the PTT line's positive-going transition, with channel 2 monitoring audio from the headphone socket. The results showed even longer delays than those for going into transmit mode for the two handhelds (see **Table 2**). The longer delays for both transitions on the Icom show why the Alinco could just about be persuaded to work once TX delay in the TNC had been set to maximum, but the Icom failed to provide reliable working.

Table 1: Measured RX-TX delays.

| Model | Delay (ms) |
|---|---|
| IC-T70 | 170 |
| DJ-596 | 110 |
| FDM-Duo | 15 |
| FT817 | 25 |

Table 2: Measured TX-RX delays.

| Model | Delay (ms) |
|---|---|
| IC-T70 | 300 |
| DJ-596 | 250 |
| FT817 | 60 |

## FM test source

The second test detailed above showed up the fact that here at 'JNT labs there is no test equipment, other than the FDM-Duo transceiver, capable of generating a modulated signal suitable for testing FM radio systems, and especially nothing that is usable as a calibrated source. There are plenty of signal generators on the surplus market that can provide FM signals, but I don't want yet another large rack-mounted piece of equipment for only just one extra task. So what simple bit of homebrew kit might be possible using a direct digital synthesis (DDS) chip, ideally one of the everlasting AD9850 family of which I have quite a few modules? What follows is just a thought process; any hardware build will be later in the year and will be reported here.

I want, as a minimum, a capability of generating FM at 144MHz, ideally also at 432MHz with a known frequency deviation from a precise sinusoidal tone frequency. If it was possible to use a voice input as well, so much the better. The humble AD9850 is a versatile DDS chip capable of being clocked at least to 120MHz, and is usually supplied with a 125MHz clock oscillator. For 'normal' DDS operation, that generally means a maximum output frequency at up to around 35% to 40% of the clock frequency, ie up to 50MHz, before alias products become difficult to separate out. Those alias products occur right up to UHF, at frequencies of $N.F_{CLOCK}$ +/- $F_{PROG}$, where N is a positive integer. So if we want an output at 144.9MHz, the DDS chip is programmed to generate 144.9 - 125 = 19.9MHz and the second alias extracted **[2]**. For an output of 433.7MHz, we'd use a higher alias product, programming the chip for 58.7MHz and extracting the alias product at 3.125 + 58.7 = 433.7MHz. As we're testing receivers, the relatively-low level of the alias products won't matter, nor will the presence of all the other terms that will be ignored and filtered out in the receiver under test.

## FM from a DDS

So how can a DDS chip generate FM? The AD9850 is programmed by sending it a serial word of 40 bits containing the code for the RF output frequency. If this could be repeated fast enough, at a sampling rate sufficient to faithfully reproduce the modulating tone, the DDS could be reprogrammed in real time with samples that set the instantaneous frequency of an FM modulated waveform. Inside the controller, we use a numerically-controlled oscillator at a sampling rate $F_{SAMPLE}$, looking up successive values from a sine table to generate the modulating tone. Each value looked up is then added to a fixed number representing the centre RF frequency, then sent to the DDS generator chip. So we are continually reprogramming the DDS chip at $F_{SAMPLE}$ rate, with values that move it around the required centre frequency at the generated tone. Voila, we have an FM signal and, as the frequency of alias products relies only on multiples of the fixed clock, with no harmonics of the programmed frequency, $N.F_{CLOCK}$ +/- $F_{PROG}$, FM deviation will be the same on all alias products right up to UHF. This is something not possible if RF multiplication were used to get to the higher frequencies.

## Choosing some values

If we assume a maximum desired modulation frequency of, say, 3kHz, then to avoid too many sampling sidebands (we can't filter our modulation), we really need to use a sampling rate up in the tens of kHz, reprogramming the DDS say every 32 microseconds, an $F_{SAMPLE}$ of 31.25kHz. If a PIC processor is used to control the DDS, generating a 40-bit word sent on a serial interface every 32$\mu$s or faster is a bit too much for the baseline devices, although some modern chips, and certainly dsPics, can do it. However, as usual, I want to keep things simple and stick to a workhorse device. These days that is the 16F1827 PIC, which would be able to do serial programming if the internal SPI interface peripheral were used. However, I don't really like this peripheral, and fortunately, the AD9850 has a faster method of programming: a parallel bus.

The 40 bits can be sent as five parallel bytes on an 8-bit bus, and in fact this is the start-up default programming mode for the AD9850. Now there is no timing problem at all. Any basic PIC device, even the antiquated 16F628, the workhorse of the last decade, can send five words on a parallel bus 31250 times a second, complete with sine table lookup and an addition. The 16F1827 contains an A/D converter which could be used with digitised microphone input in place of the sine table lookup for voice modulation

There is the snag that eight input/output (I/O) lines are used for the bus plus a strobe, all of which uses up most of the I/O lines available for other interfacing tasks, not leaving a lot for user input and a display if an 18-pin PIC device is used. But it does appear to be just possible with a simple user interface, perhaps using potentiometer input and an I2C-driven liquid-crystal display (LCD) with a pushbutton. Or we could just use another PIC device with more I/O pins, or a dsPic, which has the advantage of allowing a higher sampling rate and more-complex processing. So there's an autumn project for 'JNT labs: to develop a fully-digital FM test source to provide a signal for FM radio systems.

**References**

[1] FT232 USB / COM port bridge: https://ftdichip.com/products/ft232rl/
[2] More on using alias products from a DDS can be found in *Design Notes* for August 2022.

Feature

# AM revisited, part 2

**In this article I'm going to look at setting up both modern transceivers and vintage transmitters, methods of generating amplitude modulation (AM), as well as surveying what is available to buy or build.**

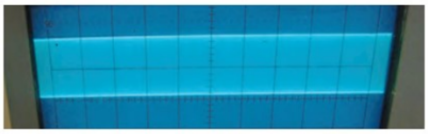

FIGURE 1: Oscilloscope trace of the signal from an Elecraft K3, delivering a 10W CW carrier into a 50W dummy load.

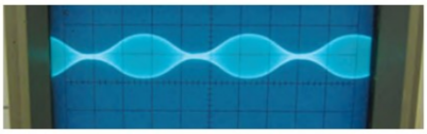

FIGURE 2: Oscilloscope trace of the signal from the K3, with a 1kHz tone applied in the AM mode.

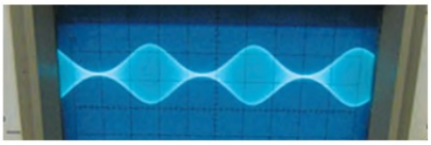

FIGURE 3: Oscilloscope trace of the signal from the IC-7300, set to 10W with a 1kHz tone on AM.

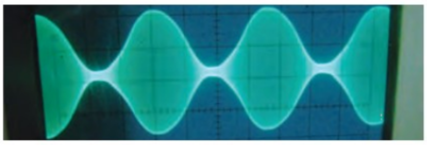

FIGURE 4: Oscilloscope trace of my KW Vanguard fully modulated with a 1kHz tone.

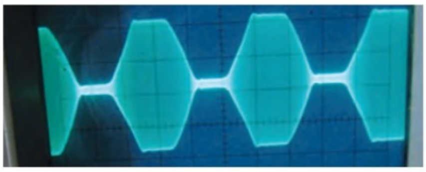

FIGURE 5: A trace from my KW Vanguard when over-modulated.

## Case study: Elecraft K3 and Icom IC-7300, both set to 10W PEP

**Figure 1** shows the 10W carrier from the K3 in CW mode. Applying a 1KHz tone to the K3 in the SSB mode results in the same power and waveform as the CW carrier. **Figure 2** shows the tone on AM. The K3 ALC does affect the power level, so the peak power is held back and it is not quite 100% modulated. When switched to AM, the firmware limits the carrier power to 2.5W. With the tone applied, the envelope peaks approach those seen on SSB and CW. Using the microphone gain and compression controls, I can get an acceptable modulation level. The bottom of the waveform should go down to the base line, nice and smoothly and the peaks should not flatten.

Turning now to the IC-7300, the compressor does not function on AM (**Figure 3**). I find I need nearly full microphone gain with the fist microphone supplied, to achieve 100% modulation. As with the K3, when switched to AM, the carrier power dropped back to about 2.5W. With the tone applied, the oscilloscope shows an almost perfect 100% modulated waveform. With the power level set to 100W, the carrier output on AM is 25W. Never attempt to run a 100W pep rated radio above 25W of carrier power on AM. If you are tempted to use an amplifier, to be compliant you must set it to no more than 100W carrier, which will provide 400W pep, the legal limit for AM in the UK. Make sure your amplifier is rated sufficiently to cope with 100W continuous power.

If the transceiver is not set up correctly, the output power can go down as you speak. This can sometimes be an inherent problem with the ALC in some transceivers. Many Yaesu radios suffer from this. Having set the transceiver up, you are now ready to go. Tune to the centre of the received signal and you will be close enough. On most transceivers, the digital readout should give you the frequency of your carrier. So on 80m, if you want to call CQ, set your frequency to 3.615MHz and call.

## Vintage 'boat anchors'

The urge to get a real AM transmitter often becomes a driving ambition. Because they were mostly valve radios and are now quite old, they are also heavy and often referred to as 'boat anchors'. One of the most popular transmitters in the UK was the KW Vanguard, which was produced as a kit, or ready built, by KW Electronics in the mid 1950s. Most boat anchors will operate in a similar way. Transceivers were not common back then, so you had a separate transmitter and receiver, the latter often WWII surplus, such as the National HRO, RCA AR88, Marconi CR100 or CR300, etc. Muting the receiver when transmitting is an issue, but beyond the scope of this article. For those used to transceivers, a whole new operating experience awaits them!

## Case study: setting up the KW Vanguard

On the back of the chassis (which was modified to include top band) is a power switch. I selected the low-power position. I set the VFO switch to 40m and set the VFO to 7.100MHz. The PA band switch was also set to 40m. Using a dummy load and setting the meter switch to 'PA' (which monitors the anode current drawn by the 6146 PA valve), I keyed the transmitter and, using the 'PA Tune' control, adjusted for a dip in the anode current. Switching to 'Grid', I adjusted the 'Drive' level and the 'Grid Tune' to 2.5mA. Going to high power, I switched back to 'PA' and adjusted the 'PA Tune' and 'A E Coupling' (load) controls to set a dipped anode current of 110mA. I then switched to '% Mod' and adjusted the 'Mod. Gain' to be within the 100% limit. The minutiae of this procedure will be a bit different for each transmitter, but this should be a reasonable guide for anyone unfamiliar with valve equipment.

## Netting the transmitter to the receiver

Tune the station you want to call to the centre of the carrier on the receiver. On the Vanguard, there is a 'Tune' switch, on other transmitters it may be marked 'Net'. This will switch the VFO on. Tune the VFO until you hear it beat with the carrier of the station you are about to call and set to zero beat. You are then ready to go.

Keep an eye on your modulation level. Many of the old transmitters are capable of over-modulation, which results in distortion and splatter. Monitor your frequency, if using a VFO, as it **will** drift. This is good practise and essential on 5.317MHz, where you must remain within the tight frequency allocation. Your transmitted bandwidth must not exceed 6kHz, to remain compliant on this band.

**Figure 4** shows the oscilloscope trace for my KW Vanguard, and **Figure 5** an example of over-modulation. Note that the peaks of the waveform are flattened in Figure 5, and the bottom of the waveform breaks up.

## What 'boat anchors' are available?

There were a few British manufacturers. KW produced a mobile transmitter in addition to

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tjpost@traditional-jazz.com


FIGURE 6: G4AQB's Codar AT5, with the homebrew RATS receiver.

FIGURE 7: G4HTZ's Johnson Viking II, coupled with his RCA AR88 from the 1940s.

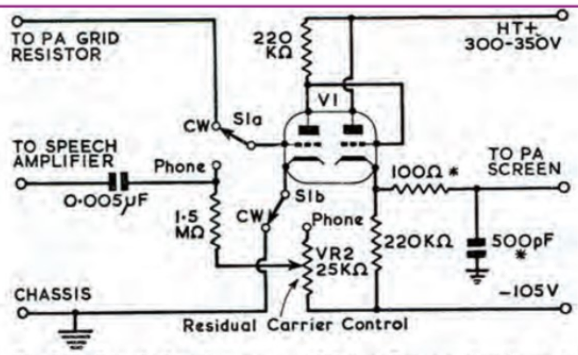



**Fig. 9.15. Practical series gate modulator. For p.a. inputs up to 75 watts, suitable valves are the 6SN7 and 12AU7. For higher inputs, a 12BH7 may be used. Alternatively, two 6J5s or triode connected 6V6s are suggested. The 100 ohm resistor and 500 pF capacitor marked with asterisks are the normal screen decoupling components mounted close to the p.a. valveholder.**

FIGURE 8: Typical series-gate modulator, as published in the *1968 RSGB Radio Communication Handbook*.


FIGURE 9: G4AQB's homebrew 'class E' transceiver.

the Vanguard, which was electrically the same as the Vanguard; this was called the KW Valiant. Maximum output was between 40W and 50W CW on the lower bands, and less on 10m. Some of these were modified to include 160m and, as mentioned earlier, had a power switch on the rear. The PA valve in the Vanguard was a 6146 and it was anode-modulated and screen-modulated by a pair of 6L6s. The big brother was the KW Victor which ran full legal power, using two 6146s in the PA, modulated by a pair of 807s. The KW160 was a top-band only transmitter.

## Other vintage AM transmitters

The Labgear LG50 was another popular transmitter, running 50W with a 6146; its big brother, the LG300, used an 813 valve which required an external modulator.

Heathkit: the DX40 and DX60 used a single 6146 valve, with series-gate or carrier-control, screen-grid modulation. They were crystal-controlled, with an optional VFO. The DX100U was the big brother. The UK version had two 6146s, modulated by two KT88s. This covered 160m to 10m.

The Panda Cub was capable of 25W on AM, with an 807 PA and two 6V6s in the modulator. The Panda PR130V ran 120W AM, using two 807 valves in the PA, modulated by two further 807s.

Minimitter made several transmitters. The Deluxe was the first HF transmitter I used, and it had two 807s, modulated by two other 807s. The Mercury, I believe, came later. They also made the Top 2-7 three-band transmitter.

The Lafayette Starflight was similar to the Heathkit DX 60. These are now as rare as hen's teeth. I had one of them in early '70s. Like the DX60, it used series-gate modulation.

The Codar AT5 was a very popular two-band, small transmitter for top band and 80m. This used a 6BW6 PA and 6BW6 modulator. It could be used mobile as well! There are many of these still in use today, including one at Steve, G4AQB's (**Figure 6**).

Some American equipment has made its way over here, and Johnson Vikings are often heard. Steve, G4HTZ, imported one a few years ago and carried out a very full and professional rebuild (**Figure 7**).

## Types of modulation

W8JI's website gives an in-depth look at the different methods of generating AM **[1]**. The most-common form of modulation in vintage equipment is 'anode and screen' modulation. The modulator needs to provide 50% of the carrier power, ie for a 100W transmitter, 50W of audio power is required and a big modulation transformer. In 'Heising' or 'choke modulation', the high-voltage supplies (HT) to the PA valve and the modulator are passed through a common inductor or choke. A similar system was used in the Codar AT5. The 'series gate' or 'carrier control', screen-grid modulation is an economical way of modulating a transmitter without a huge audio amplifier and transformer. This was used in the Heathkit DX40, DX60, Lafayette Starflight, and some later Drake multimode transceivers. A small double triode, such as a 12AU7, will modulate a 75W transmitter (see **Figure 8**). A relatively-recent way of getting good-quality AM using solid-state equipment is known as 'class E'. Eric, GW8LJJ has an in-depth article on the web detailing a 400W pep transmitter for 80m **[2].**

## SSB with inserted carrier

Older SSB transmitters, such as the KW Viceroy and Vespa, the Yaesu FL50B, FL200B, and early FT200 and FT101 transceivers, all unbalanced the balanced modulator to allow the carrier to get through the transmitter chain, but the SSB filter remained in circuit, so the result was an AM-like signal but with only one sideband. This equipment needs careful adjustment in order to achieve reasonable results. Set up the carrier to no more than 25W. Adjust the microphone gain so that the PA current moves slightly during modulation. It is very

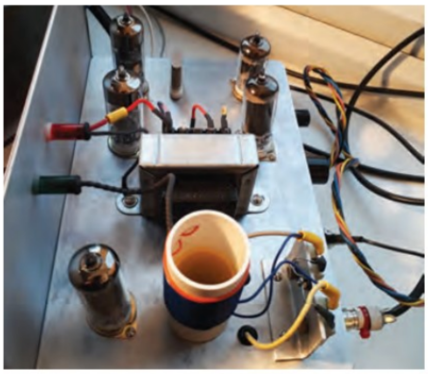


FIGURE 10: G4JQT's homebrew 5MHz copy of the Codar AT5.

easy to get distortion, which sounds like SSB without a BFO in the receiver to resolve it. A speech clipper or compressor would be a good way to ensure that a good modulation level is achieved without distortion.

## Today's homebrew options

Many people use solid-state transmitters exploiting various techniques to obtain their AM signals. Eric, GW8LJJ, and Dave, GW4GTE, run the 'S9 Plus' website, which offers a number of modules in kit form for the assembly of 'class E' transmitters **[3]**.

Steve, G4AQB writes, "My 80m AM transceiver was a project by GW8LJJ. Most of the transmitter and modulator is built on a single board, and the PA tuning is on a separate board. The transmitter uses 'class E', which is very efficient. The VFO is an Arduino Nano with a Si5351 clock generator with a small OLED display. I use a large 100-step CNC rotary encoder which works very well. The receiver is an RAT5 board tuned to 80m. The meter doubles as S-meter and RF output. Although the transceiver is single-band, it is quite easy to make it multi-band. The transmitter puts out about 10W carrier with a supply of 12V" (see **Figure 9**).

The 'Pine Board Project' by Dr Bob Heil, K9EID, is a simple valve transmitter built on a pine board, so there is no requirement for chassis bashing or printed circuit boards. Bob is, of course, highly regarded in audio circles. His Heil microphones produce some of the finest SSB signals on the bands, so it is no surprise that he pays great attention to getting good-quality AM **[4]**.

Ian, G4JQT, has built a 5MHz transmitter based on the Codar AT5. It is crystal-controlled, and produces a good signal on 5.317MHz.

I hope this article may inspire more people to get on the bands and enjoy some really good AM QSOs, especially from September onwards on 15m and 10m, where US and Canadian QSOs should be in abundance. My video on Youtube, 'AM Revisited' **[5]**, covers much more than I have room for in this article, and has many recordings of AM signals on all the HF bands. Other references of interest are to be found at **[6]**, **[7]**, **[8]**, **[9]**, and **[10]**.

**References**


[1] W8JI in-depth article on AM: w8ji.com/amplitude_modulation.htm

[2] GW8LJJ 400 Watt Class E Transmitter: www.radioenthusiast.co.uk/news/80m-am-class-e-400w-transmitter/

[3] S9 Plus website, supplying AM kits: www.s9plus.com

[4] The 'Pine Board AM Transmitter' by Dr Bob Heil K9EID: youtu.be/6mHiFE_n2Zk

[5] 'AM Revisited' talk given to the Dragon Amateur Radio Club: youtu.be/ZvI8UxOSy7s

[6] Vintage & Military Amateur Radio Society: www.vmars.org.uk

[7] Facebook AM Europe Group: www.facebook.com/groups/656582541370211

[8] Facebook Amplitude Modulation Classic Group https://www.facebook.com/groups/1486661551550190

[9] Amplitude Modulation Amateur Radio Society: contact Simon, MW0NWM, at m3set@yahoo.co.uk

[10] AM phone net: amfone.net/amforum/index.php


## Contest Calendar October 2023

Ian Pawson, G0FCT

### RSGB HF Events

| Date | Event | Times (UTC) | Mode(s) | Band(s) | Exchange |
|---|---|---|---|---|---|
| Mon 2 Oct | Autumn Series CW | 1900-2030 | CW | 3.5 | RST + SN |
| Wed 11 Oct | Autumn Series DATA | 1900-2030 | RTTY, PSK63 | 3.5 | RST + SN |
| Mon 16 Oct | RSGB FT4 Contest | 1900-2030 | FT4 | 3.5, 7, 14 | Report |
| Thu 26 Oct | Autumn Series SSB | 1900-2030 | SSB | 3.5 | RS + SN |

### RSGB VHF Events

| Date | Event | Times (UTC) | Mode(s) | Band(s) | Exchange |
|---|---|---|---|---|---|
| Tue 3 Oct | 144MHz UKAC | 1900-2130 | All | 144 | RS(T) + SN + Locator |
| Tue 3 Oct | 144MHz FMAC | 1800-1855 | FM | 144 | RS + SN + Locator |
| Wed 4 Oct | 144MHz FT8 AC (4 hour) | 1700-2100 | FT8 | 144 | Report + 4-character Locator |
| Wed 4 Oct | 144MHz FT8 AC (2 hour) | 1900-2100 | FT8 | 144 | Report + 4-character Locator |
| Sat 7-Sun 8 Oct | Oct 432MHz-245GHz Contest | 1400-1400 | All | 432-245G | RS(T) + SN + Locator |
| Sat 7 Oct | 2.3GHz Trophy | 1400-2200 | All | 2.3G | RS(T) + SN + Locator |
| Sat 7 Oct | 1.2GHz Trophy | 1400-2200 | All | 1.3G | RS(T) + SN + Locator |
| Tue 10 Oct | 432MHz UKAC | 1900-2130 | All | 432 | RS(T) + SN + Locator |
| Tue 10 Oct | 432MHz FMAC | 1800-1855 | FM | 432 | RS + SN + Locator |
| Wed 11 Oct | 432MHz FT8 AC (4 hour) | 1700-2100 | FT8 | 432 | Report + 4-character Locator |
| Wed 11 Oct | 432MHz FT8 AC (2 hour) | 1900-2100 | FT8 | 432 | Report + 4-character Locator |
| Thu 12 Oct | 50MHz UKAC | 1900-2130 | All | 50 | RS(T) + SN + Locator |
| Tue 17 Oct | 1.3GHz UKAC | 1900-2130 | All | 1.3G | RS(T) + SN + Locator |
| Thu 19 Oct | 70MHz UKAC | 1900-2130 | All | 70 | RS(T) + SN + Locator |
| Sun 22 Oct | 50MHz AFS Contest | 0900-1300 | All | 50 | RS(T) + SN + Locator |
| Tue 24 Oct | SHF UKAC | 1830-2130 | All | 2.3-10G | RS(T) + SN + Locator |

### Best of the Rest Events

| Date | Event | Times (UTC) | Mode(s) | Band(s) | Exchange (Info) |
|---|---|---|---|---|---|
| Sun 1 Oct | WAB DX Contest | 0500-2300 | SSB | 3.5-28 | RS + SN + WAB area |
| Tue 3 Oct | IRTS 80m Evening Counties | 1900-2000 | CW, SSB | 3.5 | RS(T) + SN (EI & GI also send County code) |
| Wed 4 Oct | UKEICC 80m | 2000-2100 | SSB | 3.5 | 6-character Locator |
| Sat 7-Sun 8 Oct | IARU 432MHz-245GHz | 1400-1400 | All | 432-245G | RS(T) + SN + Locator |
| Sat 7-Sun 8 Oct | Oceania DX SSB | 0600-0600 | SSB | 1.8-28 | RS + SN |
| Sat 14-Sun 15 Oct | Oceania DX CW | 0600-0600 | CW, SSB | 1.8-28 | RST + SN |
| Sat 21-Sun 22 Oct | Worked All Germany | 1500-1500 | CW, SSB | 3.5-28 | RS(T) + SN (DL also send DOK) |
| Sun 15 Oct | UKuG 24-76GHz | 0900-1700 | All | 24-76G | RS(T) + SN + Locator |
| Wed 25 Oct | UKEICC 80m | 2000-2100 | CW | 3.5 | 6-character Locator |
| Sat 28-Sun 29 Oct | CQ WW DX SSB | 0000-2359 | SSB | 1.8-28 | RS + CQ Zone (UK = 14) |

For all the latest RSGB contest information and results, visit www.rsgbcc.org

Technical

# Pitfalls to avoid for a successful QO-100 satellite project

**QO-100 is a geostationary communications satellite, also known as Es'hail-2 and Qatar-Oscar 100. It was launched in November 2018 and, amongst other communication facilities, it carries amateur radio transponders operating in the 2,400MHz and 10,450MHz bands.**

## Introduction

QO-100 has a number of features useful to the radio amateur. It is geostationary, so a fixed dish can be used. Because of its high altitude, it has significant area coverage. The operating frequencies mean that simple helix antennas can be used for the transmit frequencies, and modified TV LNB (low-noise block) downconverters for the receive frequencies. More details can be found at the QO-100 website **[1]**.

This project was inspired by an article in the February 2022 issue of *RadCom* by John, M5AML. Since my QTH is located in a dip, I struggle with some of the amateur bands on both reception and transmission. My reason for choosing satellite communication was that the dip would not affect my signal quality provided I could get a line of sight with the satellite. Also, satellite dishes are neighbour-friendly as some of my neighbours have them already for TV reception and mine, whilst slightly larger, would not look too out of place.

Whilst there have been many articles in the *RadCom* about setting up a QO-100 station, I would like to share with you the pitfalls I encountered in doing so and thus saving any potential constructor both time and money. I went on a journey, from using individual radios, to a fully-customised transceiver which is a joy to use.

The first issue to confront is: do you build the radio first and test it with a dish and LNB, or do you build the dish and LNB first and then test it with a radio? I chose the latter approach, as the cost of a dish and LNB was significantly less than the cost of building the radio. But with no working dish, LNB or radio, where do you point the dish?

## The LNB

My initial thought was to use my Yaesu FT-817 for the up-link, and my Icom 7100 for the down-link using a transverter, as QO-100 operation requires you to monitor your own transmissions (**Figure 1**). A transverter converts one set of frequencies into another, either up or down depending on the design. The IC7100 cannot accept an input frequency of 10GHz, so a suitable intermediate frequency (IF) needs to be generated. This can be done by modifying the LNB, and providing an external local oscillator (LO). The LNB will take the LO frequency and multiply it up by 390. An external oscillator also has the advantage that it can be extremely stable (see GPSDOs later). Thus, to receive 10,489 MHz, and convert it down to 433MHz for the Icom radio, the LO needs to be:

$$f_{LO} = \frac{f_{signal} - f_{IF}}{390}$$

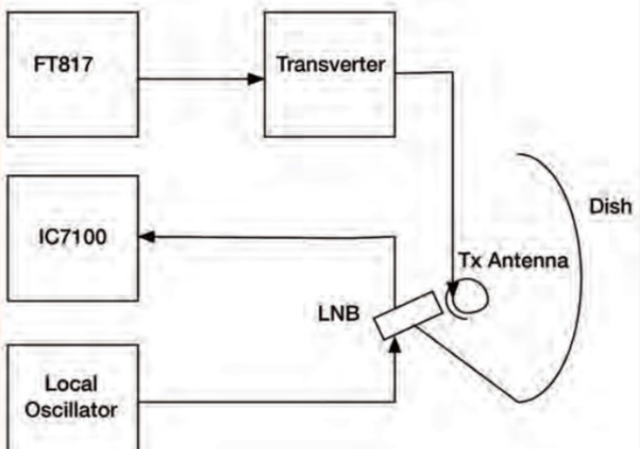
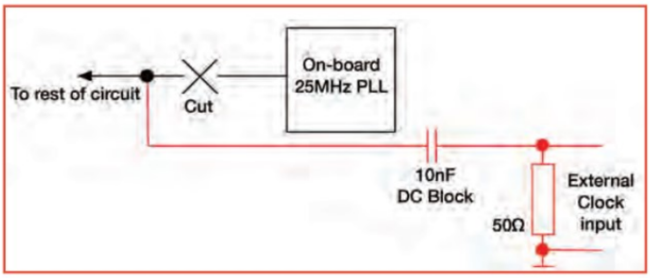



FIGURE 1: The block diagram of my set-up.



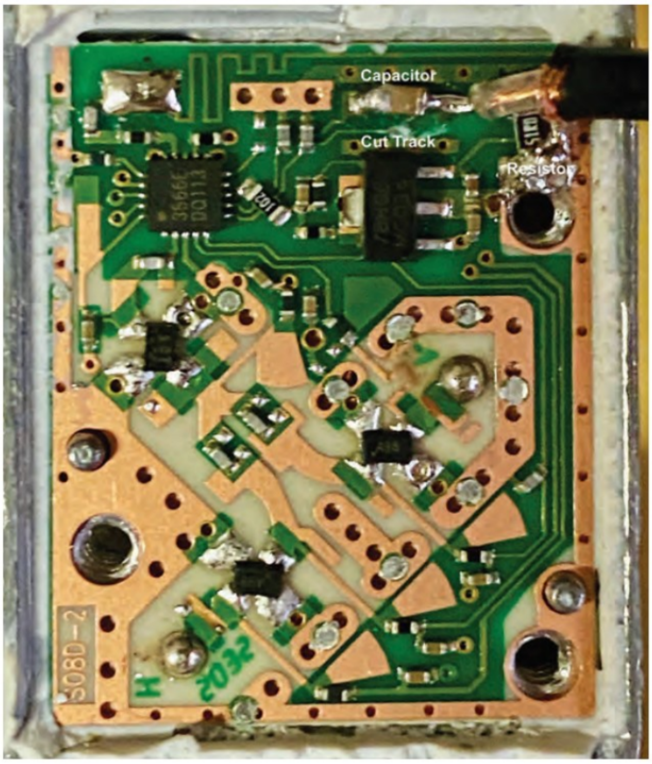




FIGURE 2: Details of the LNB modification, block diagram (a), and photograph (b).

FIGURE 3: An offset-fed parabolic dish.


FIGURE 4: Measuring the elevation angle.

Substituting, (10,489-433) / 390 = 25.7MHz. In order to get a usable IF out of the LNB, I followed G4HSK **[2]**, and added a surface-mount 0805 50Ω resistor, and an 0805 10nF coupling capacitor, to my LNB type Goobay 67269. The on-board 25MHz clock is disconnected and then a DC blocking capacitor and 50Ω load added as per the red mark-up in **Figure 2 (a) and (b)**. Many different sorts of LNB can be used, but it has to have a PLL clock, and not be of the synthesized-frequency design as these cannot accept an external LO. A cable was soldered to the junction of the capacitor and resistor for the clock input. I got through three Goobay LNBs until I got one to work. These LNBs use surface mount devices which are very difficult to work with unless you have the right equipment and some experience; I had neither. I did purchase a tool for soldering surface-mount devices (SMD), but found the hot-air soldering station with syringe-dispensed soldering paste to be superior. Figure 2(b) shows my attempts with a soldering iron. The biggest problem I encountered was anchoring the screen to the aluminium case to make a reliable screen connection. Whilst it did work, I was concerned about making the whole assembly weatherproof and robust. In the end, I purchased a pre-modified LNB (supplied by DX Patrol **[3]**) with an external LO input. This LNB has separate LO input and signal output, and this arrangement has been very reliable and is robust. Power to the LNB is via a Bias-T.

## Dish pointing

With a working LNB and dish, the next question to answer is where to point the dish in the sky? The beam width of the dish is not wide, typically 2.5° for an 86cm dish operating at 10GHz. Randomly pointing the dish at the sky will not be an easy way to find the satellite! If a circular dish is used, pointing the dish is somewhat easier as there is no offset angle to worry about and, providing you know the elevation and azimuth of the QO-100 satellite, simply point the dish in that direction. For my location in IO92, the elevation angle is 24.6° and the azimuth is 147° clockwise from magnetic North. The pointing from your QTH can be found at **[4]**.

If you are using a parabolic dish with an elliptical circumference and offset LNB, you may want to mount your LNB in such a position that the dish 'looks' circular to it. Mount it on the longest diameter (see for example **Figure 3**), and use Russ, G4SAQ's method **[5]** of calculating the dish offset angle for an offset-fed parabolic dish. Measure the larger up-down diameter, *A*, and the smaller side-to-side diameter *B*. The offset angle, $\phi$ from the horizontal is then given by

$$\cos(\phi) = \frac{B}{A}$$

In my case, the dish measures 96cm x 86cm, so my offset angle is 26°. If I were to mount my dish with the circumference in the vertical plane, the LNB would be pointing at an angle of 26° up from the horizontal. However, for my location, QO-100 is at an elevation of 24.6°, so I have to point the dish *down* by 1.4° from vertical. This method will get the dish and LNB pointing in approximately the right direction.

I refined the dish pointing whilst viewing the output of the LNB on an inexpensive software-defined radio (SDR), and the SDR# software **[6]**. Using the waterfall display, I adjusted the dish in both azimuth and elevation for the maximum signal whilst tuned to the upper beacon at 10,490MHz. After doing this, I measured my elevation using a plumb line (see **Figure 4**) and found the actual angle from the formula

$$\sin(\phi_{actual}) = \frac{x}{A}$$

where $x$ is the distance shown on the tape measure. In my case $x$ was 6.5cm and $A$ was 96cm, giving an actual offset angle of 3.8°. Once you have the dish and LNB pointing in the right direction, the securing bolts should be tightened before adjusting the skew.

Skew is the rotation about the pointing direction of the LNB when viewed from the front of the dish. It is used to take account of the effect of the Earth's curvature on the received polarisation, and should be adjusted to ensure that the correctly-polarised signal is aligned with the vertical and horizontal elements within the LNB. Markings on the edge of the LNB give the skew in angles of degrees. You can find the skew from [4], but I found the best way to set it was to tune in to a good signal, slacken the securing bolts holding the LNB, and then rotate the LNB until a null was found (which is easier to locate than a peak). Then rotate the LNB by 90° back for maximum signal strength. Once the skew is determined, the LNB can be secured by tightening the securing bolts.

The dish and LNB are now aligned.

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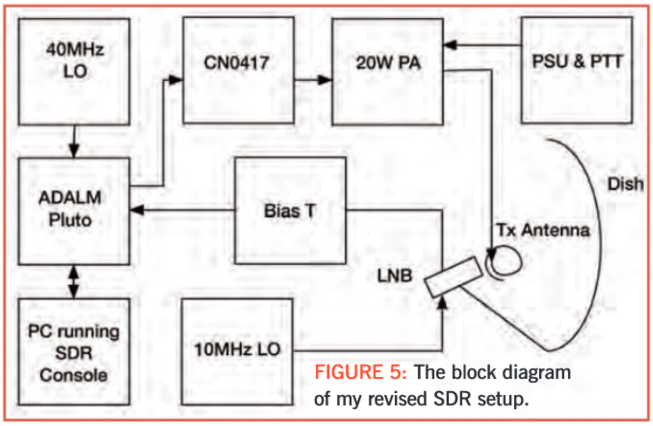


FIGURE 5: The block diagram of my revised SDR setup.

## Operating frequencies

I was concerned about the very precise LO frequencies and frequency stability required to operate with QO-100, so I purchased two mini low-jitter precision GPS-disciplined oscillators (GPSDO). One is used for the downlink and the other for the uplink. This gave me independent control of the IF frequencies. My initial setup was with the two radios and the transverter. However, whilst I got the downlink to work, I still could not make the uplink work. Using separate radios and transverters is a perfectly good route to go, but there would always be the need to make a number of calculations to select the correct frequencies when operating. This is when I discovered SDR Console.

SDR Console provides a software interface to SDRs from a variety of manufacturers. It is available free of charge and can be downloaded from the SDR-Radio website **[7]**. It can do all of the calculations for the required operating frequencies, and can set the transceiver Rx and Tx frequencies via a USB link. I decided to purchase an ADALM-Pluto revision D (see below) as my SDR because of its independent Rx and Tx capabilities. One of the criteria for operating with QO-100 is that you monitor your own transmissions to ensure that the signal does not exceed that of the beacons. If the signal level is exceeded, the LEILA alarm is sounded on your receive frequency, prompting you to reduce power. LEILA is a German term, 'leistungs limit anzeige', which means 'energy limit notification'.

## ADALM-Pluto

This is a versatile piece of hardware which I used to replace the transverter and the two radios; see **Figure 5** for the block diagram of my revised set-up. ADALM stands for 'Analog Devices active learning module', and the Pluto module can be used as a full duplex SDR radio **[8]**. It has undergone several iterations, and is currently available as revision D. This has an external clock input CLK_IN, which is useful because the on-board 40MHz crystal is only stable to ±25ppm (±1,000Hz), and is not stable enough for our purposes when multiplied up to the LO frequencies. An external GPSDO, with programmable frequency and amplitude, can reduce the error to ±1ppb, too small to be a problem, and these are available, for example, from SDR-Kits **[9]**. To select the external clock input, a firmware modification is needed (see below). Thus my setup now consisted of an LNB supplied by DX Patrol feeding directly into the ADALM-Pluto. The output of the Pluto is at very low power, 7dBm, so an external amplifier is needed to boost this to a level suitable for input to an RF power amplifier. An Analog Devices CN0417 **[10]** amplifier is a USB-powered amplifier providing typically 20dB of gain with the input and output matched to 50Ω. It has a band-pass filter to maintain an operating band from 1,800MHz to 2,700MHz, and I used this to feed an SG Labs PA2400 20W RF power amplifier. The CN0417 is readily available from Mouser Electronics as an evaluation board. The power amplifier is available from SG Labs **[11]**. This amplifier operates from 24V to 28V DC providing a maximum of 22W at 28V from 2.38GHz to 2.43 GHz. I

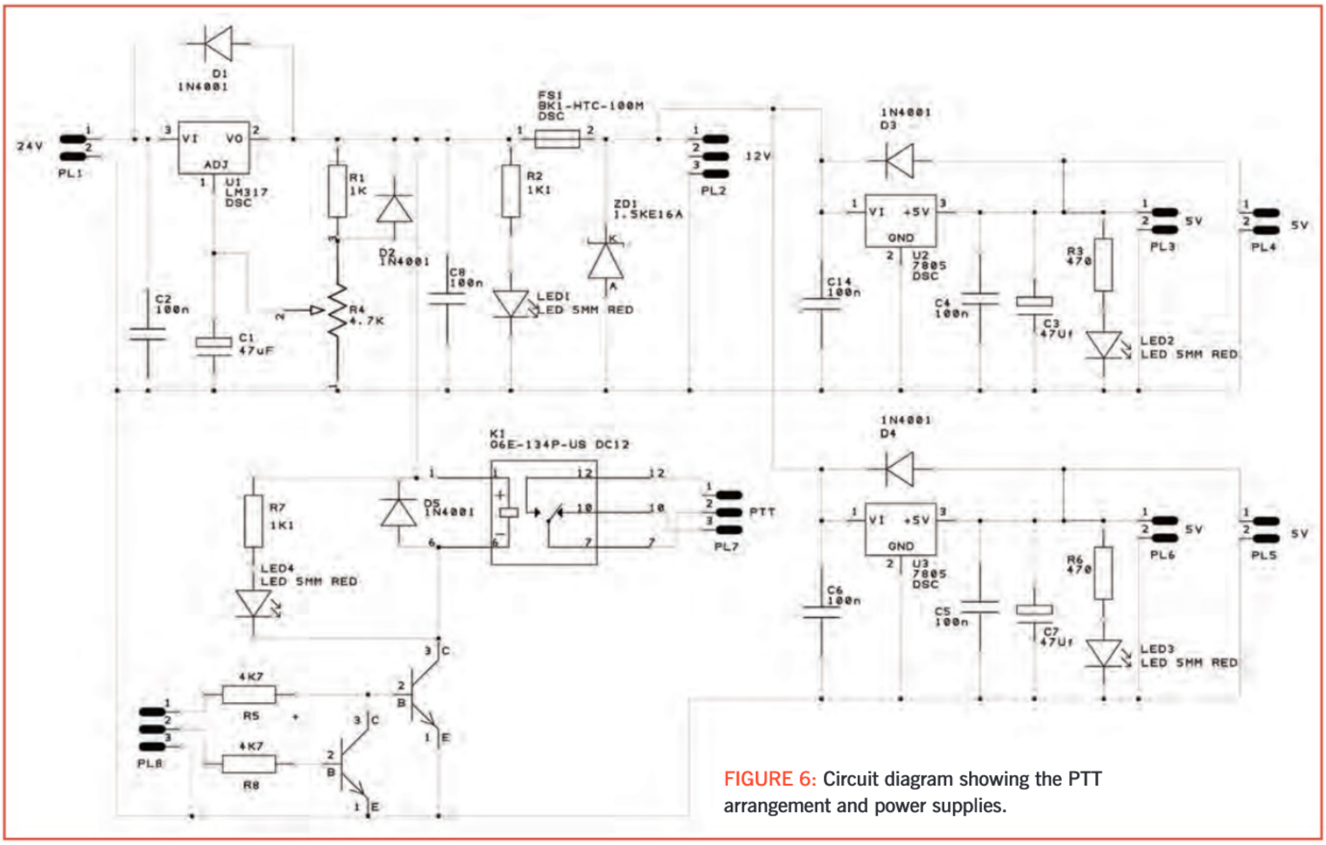


FIGURE 6: Circuit diagram showing the PTT arrangement and power supplies.

FIGURE 7: **The M5AML helix antenna.**

purchased version 2 which has a PTT input (see below). Version 3 does not need the PTT function as it has RF VOX switching.

## Firmware

The Pluto introduces another level of complexity in that it needs upgrades to its firmware. Out of the box, it will show up as a USB device when connected to a Windows PC. By using PuTTY (SSH client interface), the required firmware can be loaded, and external clock sources selected. To select the external clock source, use the following commands in PuTTY when logged in as root:

```
fw_setenv refclk_source external
fw_setenv ad936x_ext_refclk_override "<40000000>"
pluto_reboot reset
```

In my case, I loaded the stock Analog Devices firmware (V0.37 currently) which works with SDR Console, but I needed to select the external frequency source provided by one of the GPSDOs, and provide a push-to-talk (PTT) switch to the SG Labs PA. Using the excellent firmware provided by F5UII **[12]**, I installed version 0303 and the Pluto Rev D (PlutoDVB Patch Detection Hardware Revision Firmware perseverance 0303 -v2022-08-21.zip) patch. This combination (with the PTT hardware below) provided all I needed for remote PTT switching of the PA and external LO operation.

With the addition of a USB-to-Ethernet adapter, I realised that the whole transceiver could be easily located remotely with only a power supply and Ethernet cable needed. Had I continued with the Yaesu/Icom route, I would have needed two *long* good-quality coaxial cables too. Thus my goal of locating the dish, LNB and transceiver on the garage roof became a real proposition.

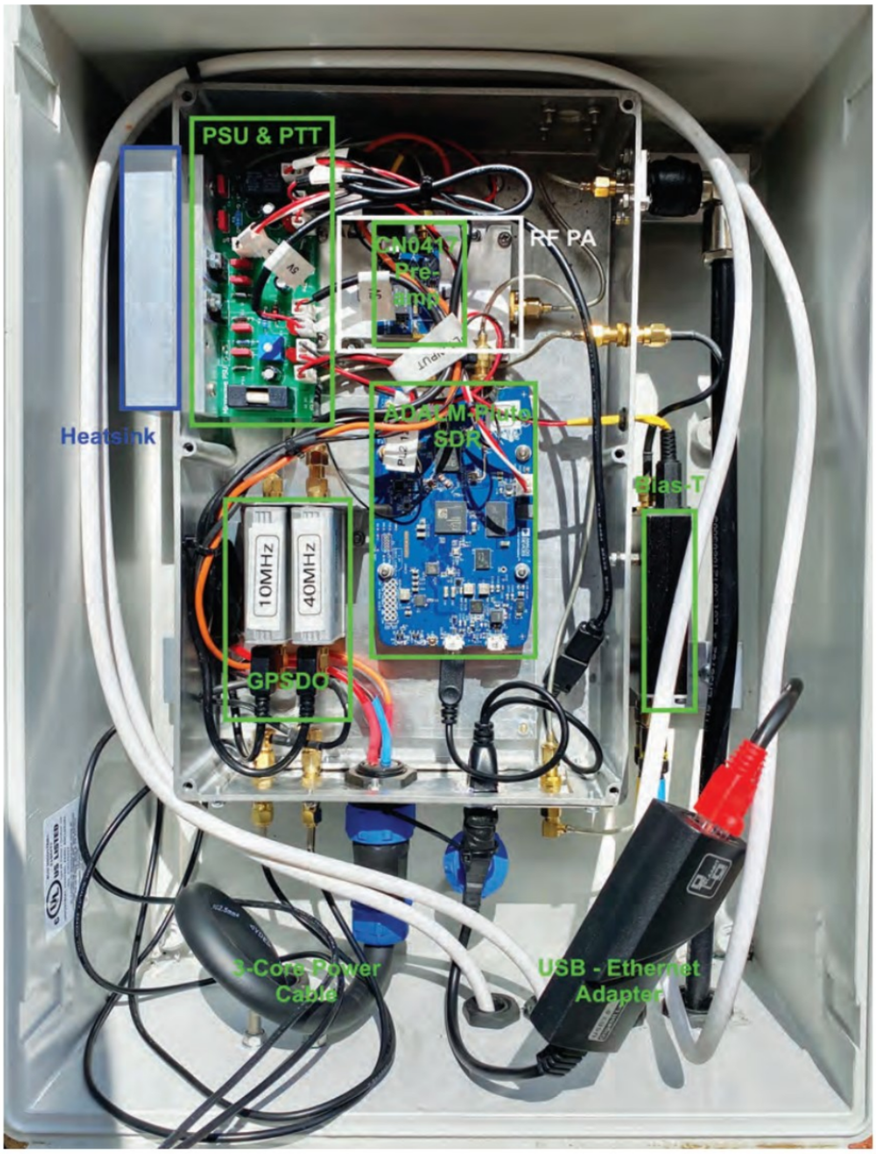


FIGURE 8: **The transceiver is housed in a weatherproof box (shown with the cover removed).**

## PTT

If you use an SG Labs V3, you can skip this bit. Two output pins, GPO0 and GPO1 (PL8 pins 2 and 1), of the Pluto general-purpose outputs (GPO) are used to provide PTT switching. Two outputs are needed to prevent the PTT being activated at start-up when the GPO outputs are set momentarily high. The circuit arrangement, derived from F5UII, prevents PTT at start-up, whilst maintaining PTT functionality from SDR Console (**Figure 6**). PL7 pins 1 and 2 provide the PTT to the PA. PTT can then be achieved using the soft Tx button on SDR Console via Ethernet. I took the opportunity to combine the various power supplies and PTT on a single PCB.

## Power settings

With an output from the ADALM Pluto of 7dBm (5mW) and a 20dB boost by the CN0417, I had about 0.5W of RF which was perfect for feeding into the SG Labs PA. The 16dB amplification of the PA with a power supply voltage of 24V gave a total RF power output of 17W maximum at the input to the feeder. The short feeder ensured low losses to the Tx antenna.

## Transmitter antenna

I used M5AML's helix antenna, and initially this worked very well (**Figure 7**). The return loss was better than 25dB at the required operating frequency. However, I couldn't work out how to make it weatherproof and replaced it with a DX Patrol helix antenna

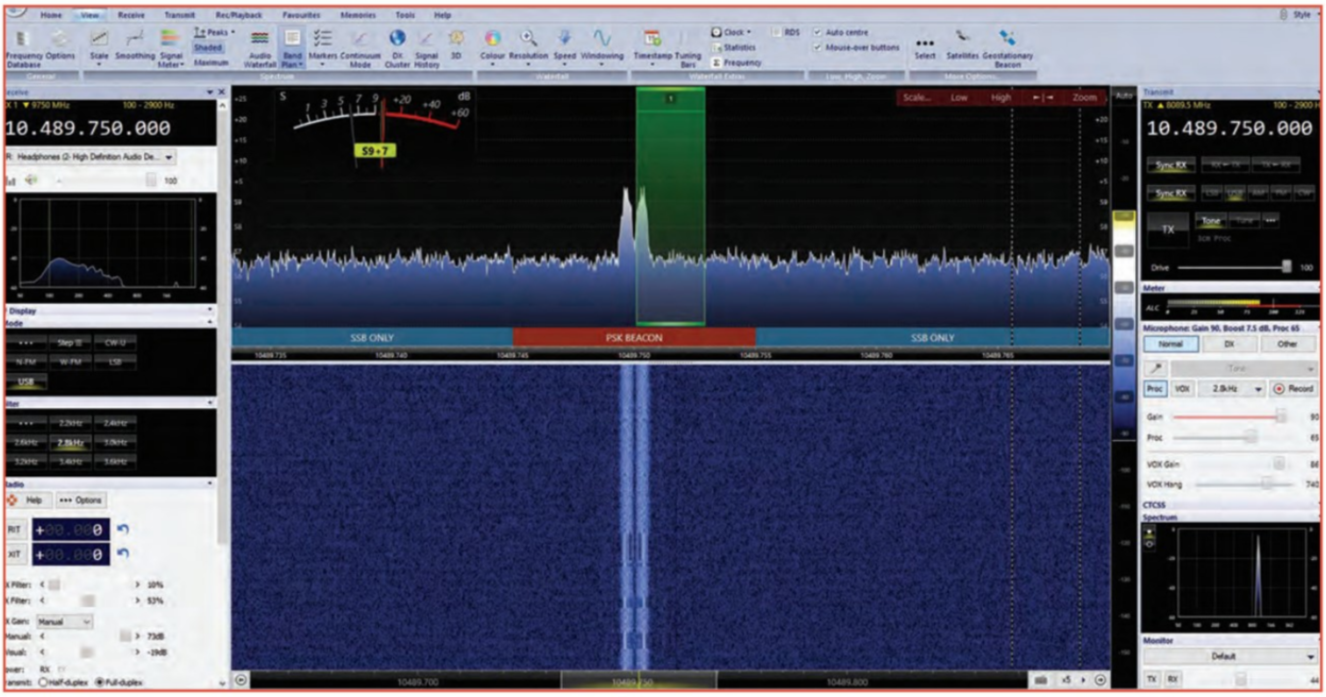


FIGURE 9: A screen capture of SDR Console displaying the PSK beacon.

which mounted nicely onto their LNB. The return loss wasn't as good, but it was more than adequate for my purposes.

## Power supplies

Having decided to locate the whole transceiver remotely, I wanted to provide a single power supply feed, and initially chose 24V DC as this was the highest voltage needed to get a reasonable power out of the PA. When I did the load calculations though, I discovered that the GPSDOs, ADALM-Pluto, and CN0417 drew about 1.5A in their quiescent states. Since I intended to use low-noise linear regulators, with a 24V supply, this would mean that about 18W would be dissipated as heat. A better solution was to provide a 3-core cable to the remotely-located transceiver with separate 24V and 15V supplies fed from a remote PSU. I repurposed a Yaesu FT-707 for the remote PSU by increasing the output to 15V and tapping directly into the raw 24V supply for the PA. The circuit in Figure 6 not only provided the PTT function, but also took the 15V supply and generated two 5V supplies for the GPSDOs, a 5V supply for the ADALM Pluto, a 5V supply for the CN0417, and a 12V supply for the LNB Bias T. The PCB was designed using free DesignSpark **[13]** software and the PCB designs sent to a Chinese manufacturer who turned round five double-sided PCBs to a very high standard in five days at low cost. DesignSpark is a free-to-download PCB / schematic design package. A PCB can be very quickly designed, and the files for manufacture created easily and cheaply.

## Housing

The whole transceiver, power supply board, ADALM Pluto and GPSDOs, are remotely located on the gable end of my house above the garage, with a 1m feeder to both the LNB and Tx antenna. An Ethernet connection to my wired network provides the link to the computer running SDR Console. The GPSDO antennas are mounted with industrial-grade double-sided sticky tape inside the weatherproof box on the door and appear to work well. The whole assembly is housed in a weatherproof box (**Figure 8**) with cable glands used at the bottom of the box located behind the dish. The dish is mounted on a short 20cm bracket to keep it close to the wall to reduce wind resistance (see Figure 3). I have made several QSOs now with reports of 5 and 9. As a finishing touch, I integrated the SDR Console software with Log40M **[14]** to automate the logging process.

## Operating and costs

The proof of this project is in the operating. The output from the completed project can be seen from the SDR Console screen shown in **Figure 9**. Notice how well the PSK beacon is centred at 10.489,750GHz because of the precision and stability of the GPSDO. The total cost of the major components, excluding cables and connectors, nuts and bolts etc, came to just less than £900 (2022).

## Conclusion

This project has been 18 months in the making. I have learned an enormous amount about LNBs, dish alignment, surface-mount devices and soldering, transverters, GPSDOs and frequency drift, GHz antenna design, GHz cable routing, PCB design, ADALM-Pluto and its firmware, SDR Console, and Log40M. I highly recommend using the wonderful QO-100 resource for your hobby.


**References**

[1] https://amsat-uk.org/about/
[2]https://dh1da.darc.de/projekte/Amateurfunk/QO-100_LNB/Goobay_67269_LNB_Mod-DH1DA.pdf
[3] https://dxpatrol.pt/
[4] https://eshail.batc.org.uk/point/
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