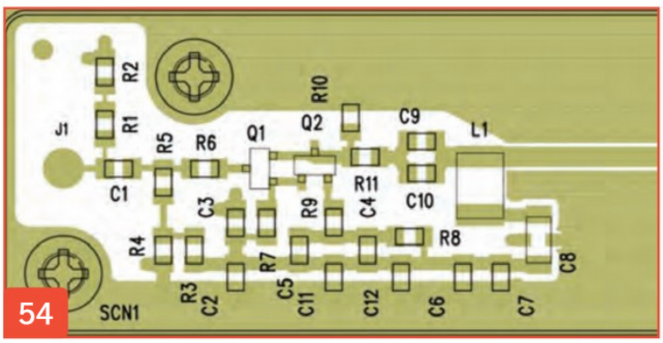
Contents

March 2023

News and Reports

Regulars

Reviews



54

64

Features

Technical Features

YOTA month reports
Design by Kevin, M6CYB

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

Managing Editor: Edward O'Neill, M0TZX, edward.oneill@rsgb.org.uk
Technical Editor: Matthew Smith, M0VWS, matthew.smith@rsgb.org.uk
Layout and Design: Kevin Williams, M6CYB, kevin.williams@rsgb.org.uk

All contributions and correspondence concerning *RadCom* should be emailed to: radcom@rsgb.org.uk. Alternatively by post to *RadCom* Editor, 3 Abbey Court, Fraser Road, Priory Business Park, Bedford MK44 3WH Phone 01234 832 700.

RadCom is published by the Radio Society of Great Britain as its official journal and is sent free and post paid to all Members of the Society. **The April 2023 edition of *RadCom* is expected to arrive with most Members by 17 March 2023** although this can take up to a week longer in some cases; international deliveries can take longer still.

All material in *RadCom* is subject to editing for length, clarity, style, punctuation, grammar, legality & taste. Articles for *RadCom* are accepted on the strict understanding that they are previously unpublished and not currently on offer to any other publication. Unless otherwise indicated the RSGB has purchased all rights to published articles. No responsibility can be assumed for the return of unsolicited material. See www.rsgb.org/radcompix for info on taking photos for publication.

The online *RadCom* is at www.rsgb.org/radcom/
RadCom Plus is available to RSGB Members online at www.rsgb.org/radcom-plus
RadCom Basics for Members new to the hobby can be found at www.rsgb.org/radcom-basics/
Abbreviations and acronyms we use are listed at http://tinyurl.com/RC-acronyms

RADCOM (ISSN No: 1367-1499) is published monthly by the Radio Society of Great Britain and is distributed in the USA by RRD/Spatial, 1250 Valley Brook Ave, Lyndhurst NJ 07071. Periodicals postage pending paid at So Hackensack NJ. POSTMASTER: end address changes to RADCOM c/o RRD, 1250 Valley Brook Ave, Lyndhurst NJ 07071

www.facebook.com/theRSGB
Twitter @theRSGB

British Science Week

We're delighted to be supporting British Science Week 2023. British Science Week, run by the British Science Association, is an annual event celebrating science, technology, engineering and maths. It provides a platform to support teachers, STEM professionals and the public in delivering STEM activities and events across the UK.

The theme this year is 'Connections' which lends itself perfectly to wireless communication and amateur radio-related activities.

Get involved!

We'd love to see radio clubs using this opportunity to get young people involved in 'connecting' through amateur radio. Maybe you could approach your local school, Scout/Guiding group or youth club and organise an activity for that week.

Several radio clubs from across the UK have already planned activities for British Science Week, and we hope our resources will inspire you to get involved too!

Need some ideas?

We've put together a set of activities suitable for Early years, Primary and Secondary aged children. These range from constructing a yogurt pot telephone and using a torch to send Morse code messages, to activities with a BBC Micro:bit V2 and receiving a fitter message from the FunCube satellite.

Build a Morse Tutor at the RSGB National Radio Centre

As part of British Science Week, we are excited to be running our ever popular 'Build a Morse Tutor' workshops at Bletchley Park on Saturday 18 March.

Find out more

For information about the workshop and to see our British Science Week activity pack, visit our website: www.rsgb.org/bsw

Share news of your activities

If you get involved in British Science Week this year, do send short reports and photos to comms@rsgb.org.uk – we'd love to share your stories!

Youth and amateur radio

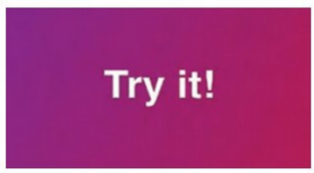
We've been expanding our web information for young people and now have four exciting pages:

Youth – this is the place to start! It draws together the various activities, information and pages that will help you find out more about amateur radio, and how to get involved: www.rsgb.org/youth

School Zone – if you're a school or college with an amateur radio club, or if you'd like to set one up, take a look at this page and see who you can connect with: www.rsgb.org/school-zone

University Corner – this list highlights universities that have either a thriving amateur radio club, or a group of enthusiastic radio amateurs who are trying to start a club! www.rsgb.org/university-corner

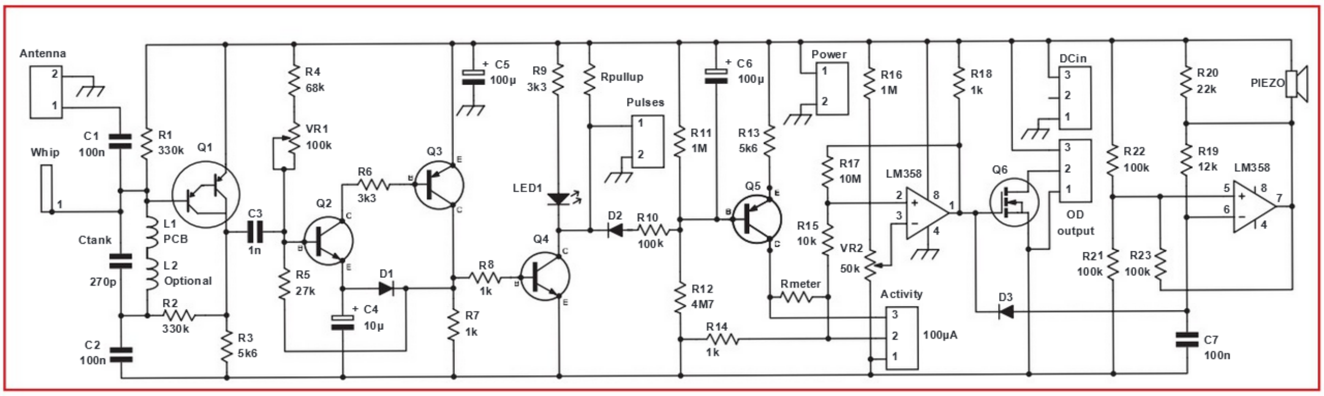
YOTA (Youngsters on the Air) – with camps every summer and a dedicated YOTA Month every December, there are opportunities to meet people both in person and on the air: www.rsgb.org/yota



We've also launched a new video that highlights in under 30 seconds why some young people like amateur radio and the different things you can try. Take a look on our YouTube channel or via the link on our Youth web page.

A lightning detector

Unfortunately, the Lightning Detector Schematic at the top of page 69 of the February issue of *RadCom* was not printed clearly. The *RadCom* team apologies for this. The Schematic has been redrawn and is printed below.



New Products

We are pleased to introduce a new Nevada power supply: PS-1335

A power supply for uncertain times. The Nevada PS-1335 is a power supply with a difference! Not only does it provide a very highly efficient mains regulated supply with overvoltage protection, over-current protection and short protection, but by adding a battery becomes an un-interruptible supply. The PS-1335 will continue to operate equipment via the battery even when the mains supply fails! By adding a suitable 13.8V (nominal 12V) lead-acid or sealed-gel battery, when the mains is on the battery is kept charged with up to 1.8A charging current, keeping the battery ready for use. When the mains fails, a fast relay switches in the battery to keep everything going. The battery is fused with a 30A fuse. The power supply has been designed to be exceptionally RF quiet, ideal for using with a transceiver. It is also immune to RFI at close range. Weighing just 1.52Kg, it's ideal for use both at home and on your travels. The unit sells for just £99.95. http://www.nevadaradio.co.uk/

New portable radios from Mirfield Electronics

This is the KT5000 2m/70cm FM base/mobile transceiver. It has 25/20W output, 200 memories, simplex and repeater operation with DCS and CTCSS. DTMF microphone, detachable front panel for mounting remotely (supplied with a 4m flat RJ45 ribbon cable), loud 2W audio out, supplied with programming cable and all mounting hardware. Easily programable from the DTMF microphone. Available from Mirfield Electronics at £129.95 via www.mirfield-electronics.co.uk

The KTWP12 is probably the smallest 2m/70cm base/mobile transceiver around. The display is part of the microphone assembly and is very easy to use. It features 20W RF out for both VHF and UHF, 200 memories, both simplex and repeater operation using DCS and CTCSS. Supplied with a programming cable. Easy programming from the DTMF microphone as standard. Includes all mounting hardware. Available from Mirfield Electronics at £109.95 via www.mirfield-electronics.co.uk

The ZUMspot USB is a most advanced radio module board. When connected to a Windows/Mac/Linux computer and MMDVM/BlueDV software, they together make a small and efficient multi-mode digital hotspot.

ZUMspot USB features: a high performance 32-bit ARM processor, ZUMspot board fully assembled and tested, supports DMR, P-25, D-Star, System Fusion, NXDN and POCSAG. Onboard LEDs to show status (Tx, Rx, PTT, Mode), up to 10mW RF power, integrated Internal UHF antenna, connects via USB to computers such as Windows, Mac, Linux, and supported by MMDVM and BlueDV software. The firmware is pre-loaded and is easily upgraded via software. Open source firmware (MMDVM) and board design. With a one-year warranty, the ZumSpot USB is available from Martin Lynch and Sons, at www.hamradio.co.uk, priced at £130.00

The ZUMspot USB Package Includes:

- ZUMspot USB UHF Board
- Integrated Internal UHF Antenna

Antennas


PHOTO 1: The antenna as I received it from the seller.

Last month I talked about the repurposing of an antenna that I brought second-hand. The Antenna in question was a Siro 27-4, an 11m CB band antenna, tuned to 27MHz. My plans to convert this into a three-element 10m field day antenna are the subject of February and March's antennas columns.


PHOTO 2: Over tightening of the mast clamps causes tube malformation.

Last month I went into some detail about the theory behind beam antennas, discussing what needs to be changed and adjusted to move a beam antenna up in frequency by around 1.5MHz. In addition to changing the frequency, I also wanted to modify the antenna from four elements to three, making it smaller and lighter to carry. I had not realised just how much work was involved with this project. It would seem that I overestimated the condition of the donor antenna somewhat.

Unfortunately, the previous owner obviously didn't have the skill I do, known as 'torque wrench arm' as almost every clamp was over tightened, crushing the aluminium tube at nearly every joint. The centre clamps were also over-tightened causing the tube to become misshapen. This prevents you from sliding the forged aluminium mounting sections over the malformed areas. This meant I could either cut the main tube to remove the clamps and then replace it with a new tube, or I could use it as it was and accept the locations for the clamps within the range available (this was the chosen option). At some time in the past, additional screws had been placed through the element clamps into the main tube. This caused some issues and is really not required. The original screws through the sides of the element clamps are easily strong enough and, if done correctly and tightened evenly, will prevent any movement from occurring when the antenna is in use. I started by cleaning up the elements one at a time, removing the rusting screws and sanding each element to remove the oxidation and dirt from the joints.

Thankfully, each element can be collapsed with the screws removed, making it around 60cm shorter. This will help for transporting them. They are then easily extended on site and, thanks to the factory swaged ends, they cannot be removed completely.

I cleaned and smoothed all tubes and edges. Using a 120- or 200-grit sanding block, I went over all parts of the antenna. Not only does this clean the surface of the tubes from oxidation, it also helps to remove any sharp burs that may be on the surface. Remember that this will be a field day antenna, and we will hand assemble it each time we use it. We don't want sharp metal burs anywhere that can cause injury.

It is important to use the correct files when working with aluminium. They should be fine grade files for metal use, not wood files, and it is useful to use a set square when cutting the tubes to ensure the cuts are straight. After cutting the tube, I immediately removed the burs from the end of it using a fine grade file. Then I used the 200-grit sanding block to tidy up the end. If you have one, I recommend using a mini half-round file to clean the burs on the inside of the tube.

I ensured to fix the work piece correctly while cutting and used a heavy vice with rubber jaws to hold the tube. It is not sensible to try to cut the tube by hand-holding it. You might end up with a bad cut and risk the saw jumping onto your fingers. It is good advice to let the saw do the work! Don't put a lot of weight on the saw and don't force it. Keep the speed slow and the cut accurate. The better the cut is, the less work is needed afterwards.

PHOTO 3: Not the original screws here.

PHOTO 4: Always remove the burs from the tubes.

PHOTO 5: Always clean the tube joints on the elements.

PHOTO 6: Always tidy the sharp burs from the ends of the tubes.

PHOTO 7: One of the elements collapsed down

When making boom spacing measurements always measure from/to the element diameter centres, or the element clamp ends. The rule of thumb here is to always use the same point of reference for each measurement, or a difference of a few centimetres may result.

Luckily for me, the Gamma match connection point was in good condition with no bent parts or stripped threads. The gamma match fixing point in this case was attached to the underside of the driven element clamp (as you would expect it to be). You will see from the design of the element clamps, the gamma match fixing point can be attached to any clamp. Going from four antenna elements to three, gives me one spare element clamp. If I can find another gamma match assembly, I might be able to add to this antenna in the future.

After cleaning and laying out all the parts of the antenna, it was time to make a draft build and see how it looked. This required placing the main boom of the antenna into the workmate and orienting it so that the elements pointed out to the sides. This was a little tricky to do but, when assembled, the antenna balanced itself on the bench (the boom not being clamped by the workmate), so that was a good sign! As far as speedy assembly and disassembly go, it takes only minutes. The elements are just pushed into the forged clamps. With the weight of the element pulling down, there is enough mechanical grip to hold the element in place. Based on the fact that this is a field day summer antenna, I will simply just use this method of fixing as it requires no tools. It is quick and anyone can do it. There is also the option, for a windy day, to just place the element fixing screws slightly in place, using a non-fast thread locking solution on the screw (or even plumbers' tape). This means the elements

Matthew Smith, M0VWS
matthew.smith@rsgb.org.uk

PHOTO 8: **Hold the work with a good vice.**

would still be a push-fit but held more firmly in place. Remember we don't want anything too permanent here. But we do want the antenna to have good electrical conductivity and stay together on the mast, even in slight to moderate wind.

The final part of this build was to cut the boom to length and add the gamma match to the driven element. The gamma match section, as it came, was not in perfect condition. It also needed to be cleaned and made functional again. This didn't involve much work though. I am looking for a new insulator section for the gamma match. I hope to find a section of rubber pipe or clear plastic tube to use inside the gamma match. This will help to make an even spacing between the inside and outside of the tube. When fitting the gamma match shorting bar, which goes between the gamma match element and the main driven element, it is not necessary to tighten the screws very much. First, I adjusted the gamma match using a VNA. I will point out here though that it is necessary to tighten the screws on the shorting bar enough so as to make

PHOTO 9: **Measurement of the boom section.**

a good connection between the two parts of the antenna. This allows for a nice clean plot on the VNA.

I didn't make large adjustments to the gamma match at this point, only small adjustments were required – not more than a centimetre at a time in either direction. Within a few minutes I was able to get the antenna to around 29MHz. I didn't spend much time adjusting it, as it was only half a metre from the ground, but it was clear that the antenna would work. I was also pleasantly surprised to see such a wide 2.0:1

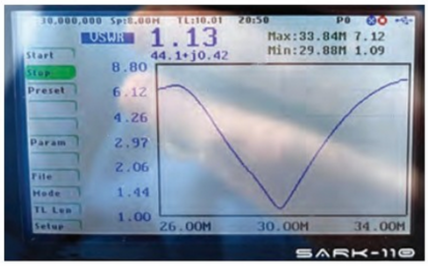


PHOTO 10: **SARK 110 plot of 26.0-34.0MHz showing minimum SWR of 1.09 at 29.8MHz.**

SWR bandwidth of around 600kHz or more. This will mean that the antenna is quite easily useable in all areas of the 10m amateur band. Also, as I saw 1.09:1 at 29.8MHz, I am sure I can, with a little adjustment, get this SWR result for 28.350 to 29.000MHz.

Conclusion

To summarise this task, I would say that I have enjoyed modifying the antenna and, if you can get the original Siro 27-4 at a good price to begin with, then it may well be worth trying it – if you can find a used one in good condition. In my case, the donor antenna was not in great shape. I had to put a lot of work into making good all the individual components before I could use them.

The one thing that I said at the start of this, in part 1, was that I would report on the fact that I might learn something in doing it. This, for sure, has been the case. I have learned a lot more than something. Most importantly though, I have had a lot of fun, and that's what amateur radio is mostly about.

PHOTO 11: **Assembled beam held in the workmate.**

FireSpot Review

Digital radio hotspots are at the core of today's VHF, and UHF voice modes and the FireSpot is a new digital radio hotspot from Moonraker. The FireSpot uses a fast processor with an Ethernet connection to make a rapid-starting hotspot that's quicker and easier to configure, thanks to that Ethernet port.

FIGURE 1: Moonraker FireSpot hotspot.

What do you get?

The Firespot is housed in a 3D-printed enclosure with various colour schemes available. The review model had a textured grey finish **(Figure 1)**. In the box was a compact USB Wi-Fi dongle and a Micro-B USB power cable, but no paperwork. The instructions come in the form of a single-page A4 document that you can download from the Moonraker website. This assumes the user is familiar with their digital radio and can program operating frequency and talkgroups, reflectors, etc.

I've shown internal views of the Firespot in **Figure 2**. Here you can see that it has two PCBs with the top board connected using a 10-pin GPIO connector. The complete assembly drops into a neat 3D-printed, two-part case. This has integrated supports for both the main board and RF board. With the lid fitted, the boards are clamped securely in place. The top RF board appears to be a standard MMDVM board with an STM32F103 ARM-Cortex processor. I could not see the RF chip as it was hidden below the hard-soldered OLED display daughter board. The main processor board is an Orange Pi Zero version 1.5 that uses the All Winner H3 SoC. This features a powerful ARM-Cortex-A7 quad-core processor with onboard graphics support. The graphics output is not populated nor required for hotspot use. The main board also has 256MB of RAM, a single USB port and the Ethernet RJ-45 connector. This latter port simplifies the setup process and is a welcome addition. The hotspot uses the Pi-Star software and matching MMDVM firmware which is supplied preinstalled on a MicroSD card. This card slots into the holder located underneath the processor board. This FireSpot's hardware combination has two main benefits compared to a typical setup using a Pi-Zero. The first is the provision of an Ethernet port, which means you can access and configure the hotspot without setting up a Wi-Fi connection first. This shortens and simplifies the setup process. The other benefit comes from the more powerful processor, as the quad-core AllWinner SoC will boot quickly and be generally more responsive than a HotSpot using a basic Pi Zero. A micro-B USB connector is supplied to link to your own power source. The FireSpot required 5 volts at a nominal 1 amp. I measured the review model and it was very economical at around 300mA. Most phone charger power supplies should be able to meet this with ease. One word of warning: beware of the replacing the power cable with a super flexible type. These often use very thin conductors with a surprisingly high resistance that can cause a significant voltage drop. I've traced several Raspberry Pi stability problems back to this and the same could happen with a hotspot!

Why use a hotspot?

FM phone activity on the VHF and UHF bands has declined over recent years, and anyone trying to make a phone QSO (digital or analogue) in many areas of the UK may struggle to find a contact. This is because much of the general chatter and news that used to keep the bands alive has migrated to Internet-based channels. Another factor is the heightened caution when driving, which has deterred many mobile operators. To crown it all, we have three similar but incompatible digital voice modes to choose from DMR, D-STAR and Yaesu Fusion. Despite these obstacles, digital voice has continued to grow, so what's happening? The simple answer is that the hotspot has arrived! To understand the role of the hotspot, we first need to look at how digital voice systems use the Internet.

Digital voice signals are relatively easy to package for sending over the Internet, so one obvious application is to link a few local repeaters to increase their coverage area. However, Internet linking can be taken a step further, where we use an Internet-based server to provide the linking. These server links have their own identity or address and have the potential to provide a global reach. This technique of server-based linking is used to create the Yaesu Wires-X rooms, D-STAR reflectors and DMR talkgroups. These are all just server-based links that join connected parties together. These links have become the foundation of modern digital radio and there are currently thousands of them. Some can provide global coverage, such as the DMR BrandMeister Talkgroup 91, while others may be local or dedicated to specialist interest groups. We also have cross-mode links available where DMR users can talk to D-STAR or Yaesu Fusion and vice versa. Whilst this has been a much simplified look at digital voice and the Internet, I hope you can appreciate the basic principles and the potential. To use these internet links, you need to first access a repeater, which can be a problem for many, especially with the limited range on 70cms. The solution is to use a private repeater. That is precisely the role of the hotspot. It is a low-power, Internet-connected private repeater that gives you access to the digital voice network. You locate the hotspot conveniently and use your rig anywhere in your home to access the world!

The FireSpot

The FireSpot uses the well-established MMDVM (Multi-Mode Digital Voice Modem) firmware for the transceiver and Pi-Star software for the OrangePi Zero processor. Using Pi-Star is helpful because it is the most popular hotspot software, so there is plenty of help available on the Internet if you have problems. The Pi-Star software is preconfigured by Moonraker for the FireSpot hardware, so there is minimal configuration required to get started. The provision of the Ethernet port simplified the configuration as I could plug the FireSpot into my local network and access the hotspot by entering pi-star local into a web browser on any computer or tablet. After the sign-in using the default pi-star/raspberry login, the standard Pi-Star dashboard screen was returned **(Figure 3)**. This is particularly helpful for those new to hotspots as you don't need to configure a Wi-Fi connection before you can begin the configuration. If you do prefer to use a Wi-Fi connection, as I did, it was quicker to enter the Wi-Fi details directly into Pi-Star whilst connected by Ethernet, and then remove the cable. This worked well for me. I also have a decent mesh Wi-Fi system at home so I had no problems with Wi-Fi speed.

The FireSpot is a simplex hotspot, which means you transmit to, and receive on the same frequency. In my case, I altered the default operating frequency to 438.8MHz as I had some strong local interference on the default channel. For this review, I used a DMR rig, so I began by entering my DMR ID, callsign and other station details. The FireSpot works with DMR, D-STAR and Yaesu Fusion rigs, so you just configure the settings to match your rig. Whilst the boot-up (30 seconds) and access to the Pi-Star dashboard were fast, configuration changes still seemed quite slow. On investigation, this was due to the way Pi-Star applies the updates. Because the software uses background services, these must be stopped and restarted for the changes to take effect. The starting and stopping of the services cause the apparent slow response. With the configuration complete and the FireSpot rebooted, I was ready to start operating. As with all hotspots,

Mike Richards, G4WNC
ptamike@photobyte.org

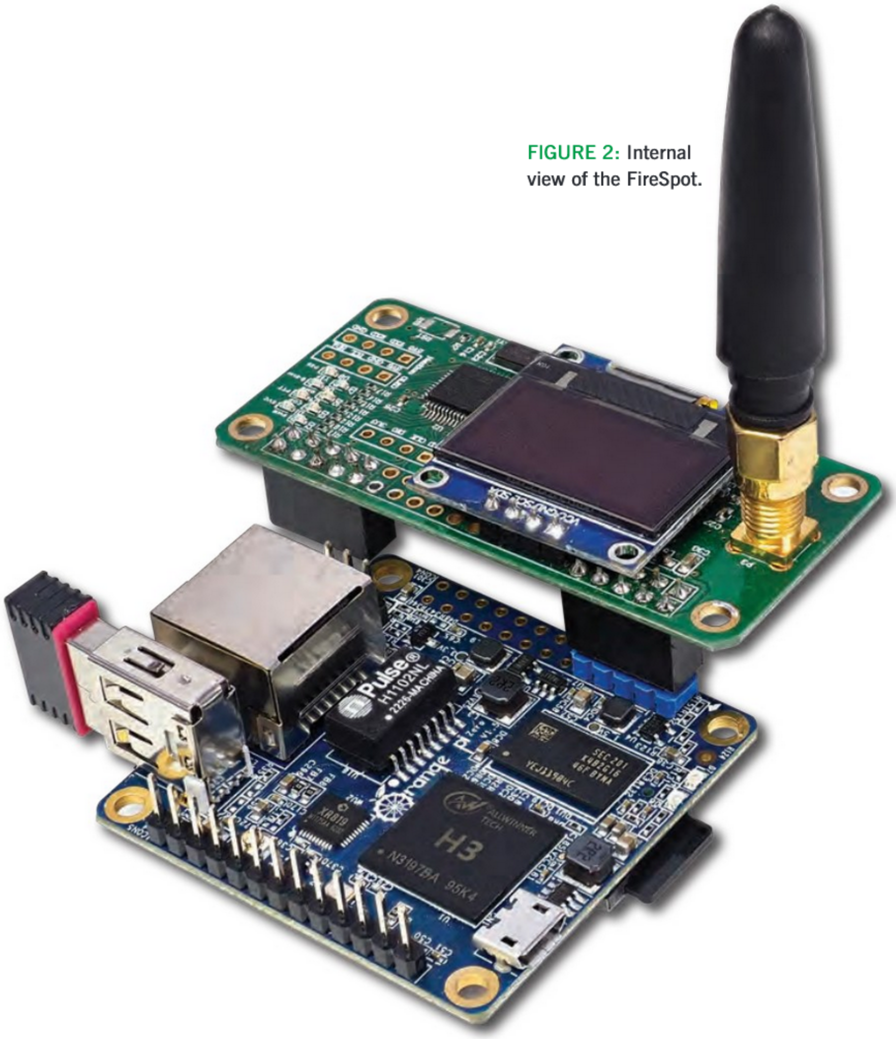
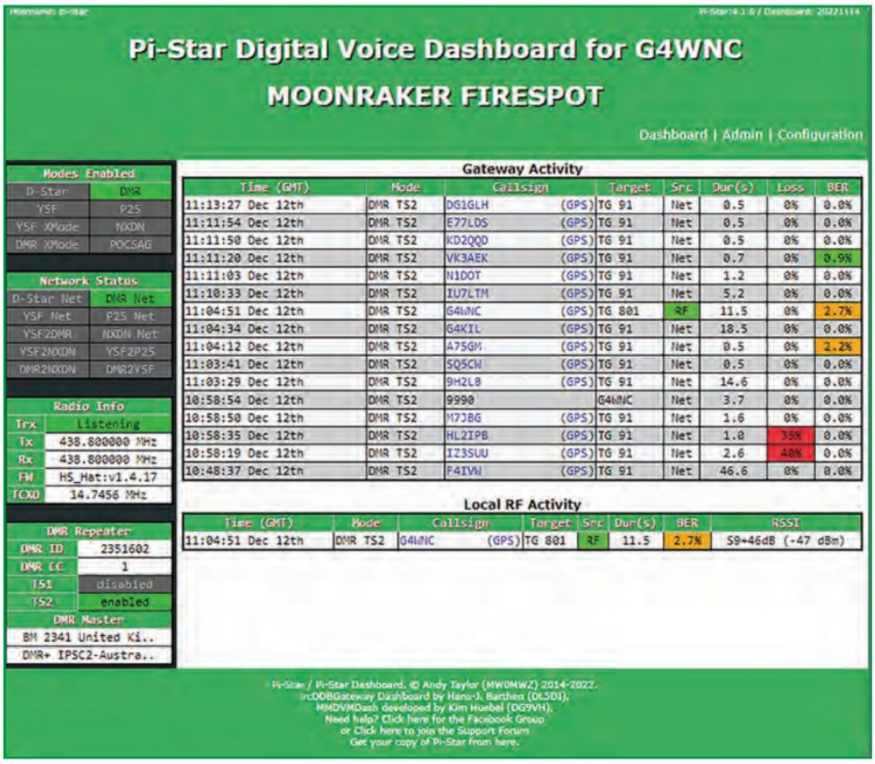


FIGURE 2: Internal view of the FireSpot.



Pi-Star Digital Voice Dashboard for G4WNC
MOONRAKER FIRESPOT

Dashboard | Admin | Configuration

Modes Enabled	
D-Star	DMR
YSF	P25
YSF XMode	NXDN
DMR XMode	POCSAG

Network Status	
D-Star Net	DMR Net
YSF Net	P25 Net
YSF2DMR	NXDN Net
YSF2NXDN	YSF2P25
DMR2NXDN	DMR2YSF

Radio Info	
Trx	Listening
Tx	438.800000 MHz
Rx	438.800000 MHz
FW	HS_Hat:v1.4.17
TCXO	14.7456 MHz

DMR Repeater	
DMR ID	2351602
DMR CC	1
TS1	disabled
TS2	enabled
DMR Master	
BM 2341 United Ki..	
DMR+ IPSC2-Austra..	

Gateway Activity

Time (GMT)	Mode	Callsign	Target	Src	Dur(s)	Loss	BER
11:13:27 Dec 12th	DMR TS2	DG1GLH (GPS)	TG 91	Net	0.5	0%	0.0%
11:11:54 Dec 12th	DMR TS2	E77LDS (GPS)	TG 91	Net	0.5	0%	0.0%
11:11:50 Dec 12th	DMR TS2	KD2QQD (GPS)	TG 91	Net	0.5	0%	0.0%
11:11:20 Dec 12th	DMR TS2	VK3AEK (GPS)	TG 91	Net	0.7	0%	0.9%
11:11:03 Dec 12th	DMR TS2	N1DOT (GPS)	TG 91	Net	1.2	0%	0.0%
11:10:33 Dec 12th	DMR TS2	IU7LTM (GPS)	TG 91	Net	5.2	0%	0.0%
11:04:51 Dec 12th	DMR TS2	G4WNC (GPS)	TG 801	RF	11.5	0%	2.7%
11:04:34 Dec 12th	DMR TS2	G4KIL (GPS)	TG 91	Net	18.5	0%	0.0%
11:04:12 Dec 12th	DMR TS2	A75GM (GPS)	TG 91	Net	0.5	0%	2.2%
11:03:41 Dec 12th	DMR TS2	SQ5CW (GPS)	TG 91	Net	0.5	0%	0.0%
11:03:29 Dec 12th	DMR TS2	9H2LB (GPS)	TG 91	Net	14.6	0%	0.0%
10:58:54 Dec 12th	DMR TS2	9990	G4WNC	Net	3.7	0%	0.0%
10:58:50 Dec 12th	DMR TS2	M7JBG (GPS)	TG 91	Net	1.6	0%	0.0%
10:58:35 Dec 12th	DMR TS2	HL2IPB (GPS)	TG 91	Net	1.0	35%	0.0%
10:58:19 Dec 12th	DMR TS2	IZ3SUU (GPS)	TG 91	Net	2.6	40%	0.0%
10:48:37 Dec 12th	DMR TS2	F4IVW (GPS)	TG 91	Net	46.6	0%	0.0%

Local RF Activity

Time (GMT)	Mode	Callsign	Target	Src	Dur(s)	BER	RSSI
11:04:51 Dec 12th	DMR TS2	G4WNC (GPS)	TG 801	RF	11.5	2.7%	S9+46dB (-47 dBm)

Pi-Star / Pi-Star Dashboard, © Andy Taylor (MW0MWZ) 2014-2022.
ircDDBGateway Dashboard by Hans-J. Barthen (DL5DI).
MMDVMDash developed by Kim Huebel (DG9VH).
Need help? Click here for the Facebook Group
or Click here to join the Support Forum
Get your copy of Pi-Star from here.

FIGURE 3: Pi-Star dashboard.

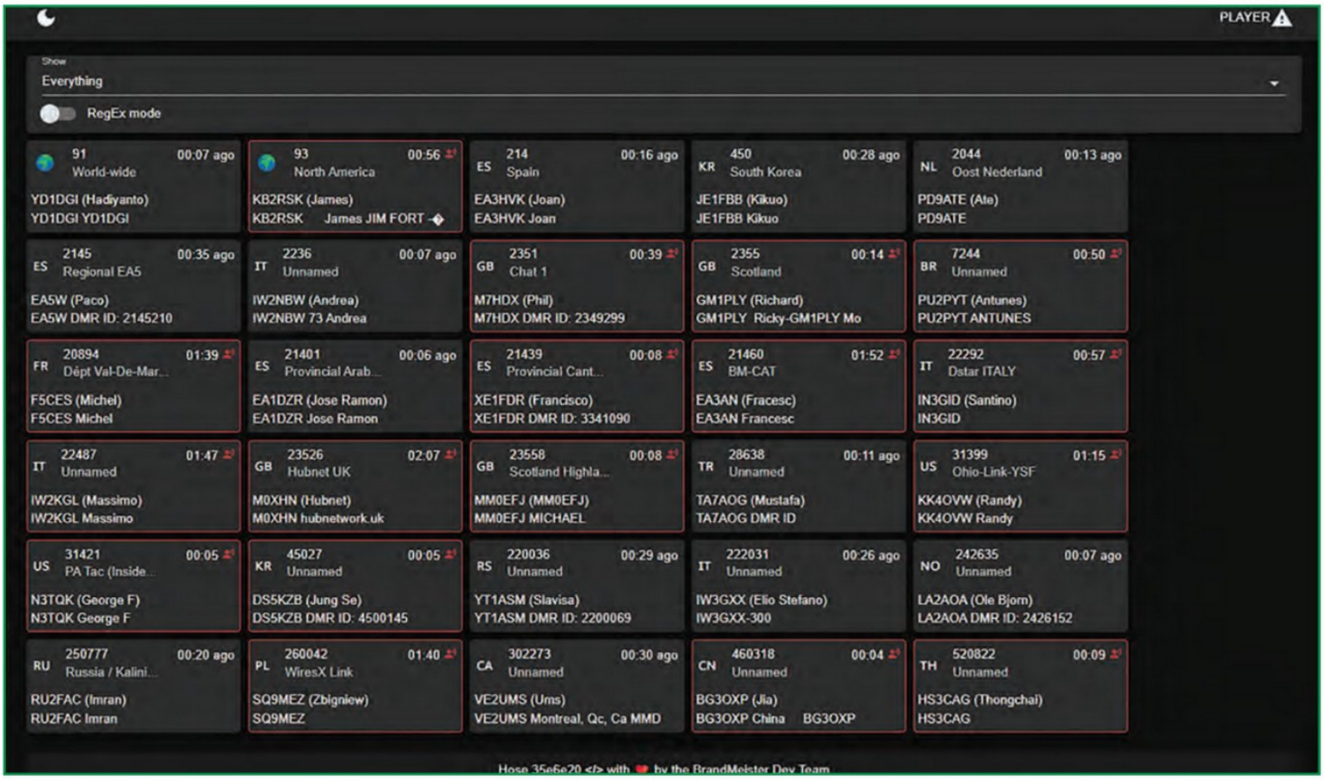


FIGURE 4: BrandMeister Hoseline.

you direct the FireSpot to the desired repeater, talkgroup, reflector, etc, by keying your rig with the appropriate destination selected. Being a simplex hotspot, this can only be done when the FireSpot is in receive mode. If you've previously been monitoring a busy channel such as a worldwide talkgroup, you must wait for a break before making the switch. I used a DMR rig (TyT MD-UV380) for the review, so I decided to use the popular BrandMeister network. I initially had a problem accessing this network, but this turned out to be a password problem. BrandMeister recommends setting a hotspot password when using their network. I duly did this, but I used a complex password. It seems that this can be problematic with the current MMDVM firmware. I changed to a simpler password, and all was well. I was soon able to use the Parrot (9990) talkgroup to prove everything was working before starting a few QSOs. For those new to DMR, the Parrot talkgroup repeats whatever you transmit. It's a private connection between your rig and an Internet-based server, so provides a valuable check that your system is working correctly and that your voice quality is good. If you have problems, you can use the BrandMeister hoseline **(Figure 4)** to check your signal is triggering the desired talkgroup. When everything was running, I started looking around for QSOs. There is plenty of activity around, and an interesting place to start is the World Wide talkgroup 91 on the BrandMeister network. I was soon in QSO with Louis, 9H2LB on the island of Malta. This is one of the great benefits of operating with a hotspot, as you can work the world from your armchair! There are thousands of talkgroups out there so it's worth seeking out interesting topics. I did have a couple of lockups with the FireSpot, but these were easily recovered with a reboot. The small OLED display provided helpful confirmation of the operating mode and talkgroup **(Figure 5)**. One of the many great features of the excellent Pi-Star software is the update service. This manages the update process and requires just a single click from the operator. For this review I was using Pi-Star 4.1.6.

Summary

The FireSpot is a very compact and capable simplex hotspot with the advantage of an Ethernet connection for quicker configuration. The choice of Pi-Star software brings with it a huge feature set and plenty of support. The Moonraker FireSpot costs £129.95 inclusive of VAT and is available from Moonraker (moonrakeronline.com). My thanks to Moonraker for the loan of the review model.

FIGURE 5: FireSpot OLED display.

Design Notes

Everything this month comes from comments sent in by you, the readers. So many thanks for your comments and work, keep it coming in.

Inrush current limiter

Peter, G8EZE sent in this protection circuitry he designed for a 2.4/3.0kW inrush current conditioning switch. "This project started after a couple of 13A / 3kW wireless remote controlled switches failed with contacts welded closed after a few hundred cycles of switching the mains supply to two personal computers. The relay contacts were rated 13A for resistive loads, and on investigation, the inrush currents easily exceeded 40A per PC during the first current cycle. As relay contacts can bounce for several milliseconds after initial closure, it is not surprising that they welded after a few hundred operations.

"A circuit was developed shown in **Figure 1** using a TRIAC and a relay to make a stand-alone external surge conditioner that would protect both the wireless switch and its own contacts with modest computer loads or with resistive loads up to 2.4 or 3kW dependent on the relay. By delaying load turn-on and using zero voltage switching, the 40A inrush current was reduced to less than 12A and the wireless switch contacts are protected. R1 and C1 limit the current applied to bridge rectifier B1 and smoothed by C2, which delays LED turn-on in opto-coupler OK1 by around 100ms after initial application of power. As the AC supply voltage next passes through zero, the TRIAC is triggered to pass full power to the load. Zener diode D1 and R4 stabilise the output of the rectifier at around 27V before the relay pulls in, delayed by R7/ C4 to around 250ms after power application. The relay's normally open contacts short out the TRIAC, reducing its dissipation to virtually nothing. The BTA16-800CW TRIAC has a low dynamic resistance and does not need a heatsink as it only carries the full load current for a few cycles, see its data sheet and **[1]**. The current drawn by the relay pulls the bridge rectifier output down to about 14V, reducing the dissipation of the whole circuit to around 0.5W once switching is complete. The relay shown is designed to pull in at 19V and release around 2.4V. The electronic circuits are protected by a thermal and overcurrent non-resettable fuse rated at 2A/130ºC cable-tied to the relay body in case of an overheating fault. R2 discharges C1 if the circuit is unplugged from the mains supply at a voltage crest to prevent potential shock from the exposed connector pins. **Figure 2** shows the approximate timing sequence, which is dependent on the voltage phase angle at start-up and component tolerances."

Critical components and construction

"This is a 240VAC mains-powered circuit capable of carrying significant current and should be treated with respect for the potentially lethal voltages involved. It should have a conventional 13A fuse in the plug connecting it to the wall socket or wireless switch. The entire circuit is floating and must be enclosed so that it is impossible to come into contact with live components when the cover is fitted. If a metal enclosure is used, it must be properly earthed.

None of the resistors dissipates more than 250mW, but R1, R2 and R9 (if fitted) must have a continuous rating of at least 350V, ie 1/2W carbon film CR series or 1W metal oxide. Capacitor C1 must be at least 275 VAC X2 rated, capacitor C3 should have a 375V AC X2 rating, if used. Thermal fuse F1 is an AUPO A4-F rated for 250 VAC, 2A 130C opening current / temperature. The relay is a 24V, 21 x 16 x 22mm PCB mounted device with 1280Ω coil resistance and a low hold-in voltage. Single pole change-over models with a 10A contact rating are readily available. The 16A normally open type is harder to obtain, which may explain why some wireless remote switches on sale are now rated for only 2.4kW (resistive) load. The circuit can be constructed on single-sided glass-fibre printed circuit board. Construction is not critical other than to ensure adequate separation between traces for the high voltages involved. The relay contact traces could carry up to 13A continuously at full load with the right type of relay. A 1oz/35μm thick copper trace of 7mm width can safely do this on 1.6mm FR4 PCB with a 25°C temperature rise over ambient. A copper wire soldered to the surface can be used to increase the current carrying capacity and reduce the temperature rise of the PCB trace. The TRIAC circuit trace width is not as critical as it only carries the full current for a few hundred milliseconds. Reference **[1]** gives more details on thermal management and mounting."

Phase shifting

Bran Searle, M0UVU wrote in to say "I saw your call for topics in this month's *RadCom*. Something I've been interested recently are methods for VHF phase shifting, ideally at PCB-scale rather than with wound ferrites etc. This is part of a quest to find a very lightweight balun for a 2m SOTA Yagi; copper bazooka baluns weigh too much and air-core wound coax baluns aren't that effective at this frequency. For 1GHz and above the answer is to use rat-race coupler or delay lines to get a 180° shift, but these are pretty large at VHF.

"Potential solutions I've considered are designing a rat race coupler, but with the transmission lines between ports replaced with emulated longer transmission lines using LC networks. Alternatively, perhaps use the 3-stage RC phase shifters you'd use for an oscillator. I recognise this is a topic of perhaps limited interest, but would be good to see some in-depth analysis of the options.

"An L/C Pi network acts as a transmission line and by suitable choice of values any phase shift can be generated. To get the widest bandwidth, albeit with more components, switching between a high-pass and a low-pass network can give up to an octave bandwidth with 90 degrees of phase shift. This configuration was actually built, back in my full-time working days in the early 1980s, as part of a breadboard beamforming matrix for a phased array intended for spacecraft use. Lumped element L/C networks gave binary weighted phase shifts of 11° / 22°/ 45° and 90° over the frequency range of 25 to 40MHz – which was the Intermediate Frequency band for the final transponder. It was all a very long time ago, but I seem to recall a mean phase setting accuracy of 3° was achieved over all phase settings and all 18 RF paths. The LC networks were all three section high-pass / low-pass Pi, using TO5 can latching relays to switch between low-pass and high-pass sections. The 180° switchable phase shift section was generated in a differential amplifier.

Back then, computer circuit analysis software didn't exist – or at least not for the masses – and spreadsheets were unheard of, so the L/C values had to be worked out by hand. I still have the transfer equations written in ink in a very old notebook from that era, but they are a little too complex to include here. If anyone is interested, drop me an email. These days any circuit analysis package such as Spice will allow such networks to be designed from scratch."

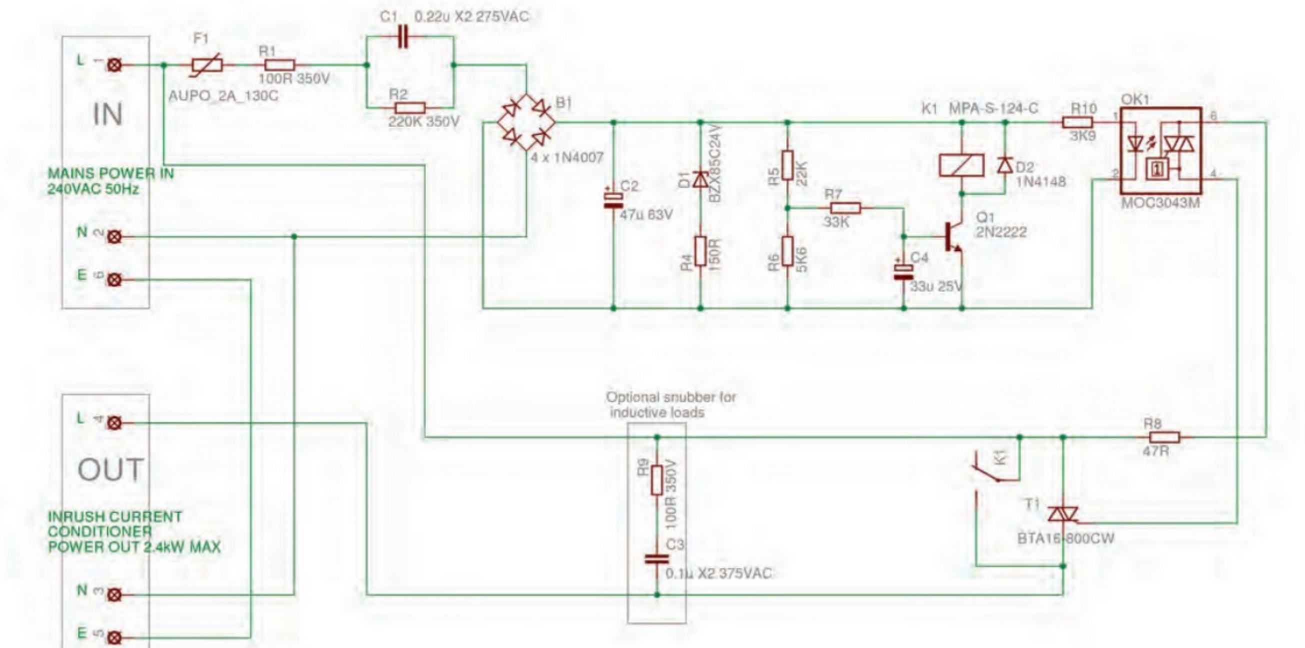


FIGURE 1: **Circuit Diagram of G8EZE's inrush current limiter.**

Power reduction in high power amps

John, G4SWX, drew my attention to a long discussion / thread that has been ongoing on one of the many technical forums related to VHF and power amplifiers. A discussion that, it appears, became quite heated (pun intended!). He noted that a number of amateurs had purchased high power LDMOS linear amplifiers, some rated at over one kilowatt, and were merely under-driving them by reducing the input drive power to ensure the output power did not exceed the legal maximum of 400W. Several operators had commented that the reliability of such amplifiers when underdriven was sometimes poor, with devices failing and overheating.

This is to be expected. Any PA stage designed for a given power output will be a lot less efficient when backed off just by reducing the drive power. To see the very basic reasons behind this, along with a few sums, look back at my design of a 100W PA for the GB3MBA beacon in the November and December 2021 *Design Notes*. That PA used an old MOSFET device designed for 300W but being used at only 100W output. Exactly the same sort of problem, even if the old devices like the MRF141 are a bit different from the more modern LDMOS devices. It makes the point that to use high power devices at lower power, while keeping efficiency up, requires either that the matching network is changed to *present the active devices with the optimum impedance for that power output*, or *the supply voltage is lowered*. Modern LDMOS PAs are designed with proper matching networks, designed to reflect back harmonics and optimise efficiency at the rated power, so changing the network may not be that straightforward. Reducing the supply volts is probably the simplest option, and will certainly increase reliability and reduce thermal dissipation.

John stated: "The device which convinced me that I could not do better than the data sheet reference circuit was the MRF100AN. Nominal 100W output at 144MHz but when I used Ansoft Designer and just matched the fundamental component I ended up with a 65-70W amplifier that got very hot! When backed off, the reduced efficiency can be bad enough to raise dissipation to beyond the safe limits and lower device reliability. And even doing it by other routes will lead to diminished linearity. The problem of excessive device temperature is common and not realised by those running digital modes where the heatsink temperature might remain within reasonable limits."

Prompted by comments (underlined) made in the review of a high power 2m filter **[2]**, he subsequently went on to add: "Changing the harmonic impedance, external to a finished amplifier, by adding a filter can change the device efficiency by changing the way/phase in which harmonics are reflected. This was my issue with the band-pass filter review that started this [the email chat] off! As somebody who 'might' know a little about VHF and UHF technology and something about high power on 144MHz, I have a number of comments concerning the review:

"I will make comments on a number of quotes from the article and point to places where such misconceptions have ended up in amateur technical folklore: It's good practice to prevent unwanted signals (harmonics) leaving your shack in the first place, which a bandpass filter can help you minimise. Whilst the reduction of harmonics is meritorious, the use of a bandpass filter to do this at VHF/UHF is a highly flawed proposal. The author is not alone in getting this wrong, as Peter, G3RZP knows well, this view was regularly propagated by George Jessup G6JP(SK). Any amateur who has done much filter design will tell you that at these frequencies a low-pass or harmonic 'suck-out' filter can be easily built and will usually measure close to a prediction given by a computer design package. A VHF/UHF band-pass filter on the other hand will usually have far greater stray capacitance issues and will result in lower harmonic suppression than a low-pass or 'suck-out' filter. Whilst I would agree that at far higher microwave frequencies a band-pass filter is easier to implement this is not the case, nor cost of a purchased item, at VHF. As most amateurs use commercial high power VHF/UHF amplifiers that already contain good low-pass filters further filtering (except rarely at 50MHz) is not required.

Andy Talbot, G4JNT
andy.g4jnt@gmail.com

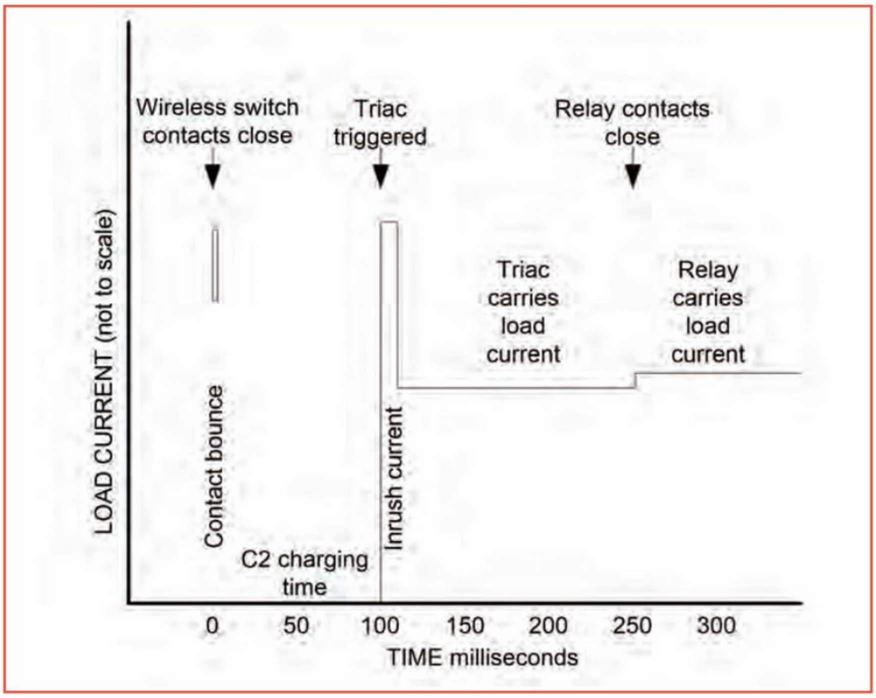


FIGURE 2: **Timing diagram of the inrush current limiter.**

Of course, the usual linear amplifier rules of minimising the drive and operating well within the maximum output of the amplifier still apply, which will minimise non-linearity and harmonics in the first place. An amplifier rated at 1kW will work away all day at 400W without being driven anywhere near its limit… "I would agree if the linear amplifier uses bipolar transistors or even a valve(s) in the final stage but NOT LDMOS devices. The majority of high power VHF amplifiers currently sold and home-built use LDMOS devices which are not understood by most amateurs.

"LDMOS devices are sold with a maximum output specification at a given supply voltage, often 50V for high power devices. This maximum output specification is generated at a given drive level in the manufacturer's test circuit. This specification is usually with the device driven into a near-switching mode with output circuitry to deliberately reflect the 3rd harmonic (and sometimes the 5th) back into the device. This reflection of the harmonic energy back into the device is critical in achieving high output stage efficiency so that very high output powers can be achieved.

"Simply reducing the drive power to achieve less output often results in higher final device dissipation which often leads to shorter lifetime and destroyed output devices. There are huge numbers of VHF DXers that have blown up commercial high power LDMOS amplifiers by driving them to produce output power lower than the maximum specification!

"The first graph in the excellent article by John, G3XDY **[3]** gives you some idea of the problem. John used a BLF188XR which is rated at >1200W output at 144MHz. John reduced the supply voltage from the manufacturer's suggested 50V to 28V and halved the device dissipation for 400W output. How many amateurs consider reducing the supply voltage rather than the drive level to achieve a lower output? Indeed, in the 144MHz DX community many people destroy many devices by under-running them. It has been found by some that the length of coaxial cable between home-brew SSPAs and associated filters was critical to lower dissipation producing long LDMOS device life. This was discussed in depth within the EME community, one such thread can be found at **[4]**.

"I also asked somebody who I considered an expert on the subject who replied: 'I've been reading the posts on the (2m, or so it seems!) EME list about the magic length of cable seemingly required between the PA and its companion LPF. A lot of [incorrect comments] have been written over the last few days. To understand the reason why, it's necessary to come to a rather fundamental understanding of power amplifier operation. Most people's mental model is deficient. A pity, as conceptually it's quite simple. I've no wish to get directly involved in the discussions and posturing on that list, but this may help with clear thinking.

"Simplifying things very greatly: any power amplifier device operating outside class-A can be considered to be a voltage-controlled switch, turning the current supplied to the load on and off. The phase angle over which that switch is on, and the complex load impedance presented to the active device has great influence on the efficiency of the amplifier: hence the many amplifier classifications – I think I saw a reference to class-G in a recent publication, but being retired, I ignored it! Fundamentally the 'classes' beyond A are all trying to square a circle.

"To get the greatest efficiency the drain/collector/anode waveform has to be a good approximation to a square-wave. You can get that by reflecting harmonic energy back into the amplifier in the right phase(s) by means of a suitably designed output matching network/LPF. However, that needs an LPF specifically designed for the job, not one of those designed using look-up tables usually seen in amateur practice. Varying the phase of the load presented to the amplifier by means of cable length can help a bit, but it's not the answer! Optimising the PA/LPF network isn't straightforward. The amplifier and output filter should be designed holistically. Absorptive filters are NOT the answer to efficiency problems, although I do see a new amateur radio fashion emerging!"

"This is not a trivial subject, where 'old-school' radio amateur writings are giving a completely wrong answer. Putting a band-pass filter on the end of an LDMOS SSPA could well end up with destruction of the final device(s) with limited increase in output spectral purity. This is a significant issue with modern designed and built amateur 'linear' amplifiers where external output filters must not be added! Sadly this is not understood by many of the designers and none of the vendors."

Sign off

All the comments above were made by several people, to others, so apologies for confusions over quotes and the positions of inverted commas – some of which should really be nested.

There's no more space left to detail 'JNT Lab's work in recent months but details of a driver for older AC-motor driven rotators, running from a 12V battery, will hopefully appear next month.

References

[1] AN533 SCRs TRIACs and AC switches thermal management precautions for handling and mounting (ST Microelectronics)
[2] 2m Band pass Filter from Antennas-Amplifiers' RadCom Review, January 2023
[3]https://www.qsl.net/g3xdy/144MHz%20SSPA%20with%20LDMOS%20protection%20circuit.htm
[4] http://mailman.pe1itr.com/pipermail/moon-net/2020-December/044433.html

Regulars

QRP Matters

Revisiting an 80m QRP Transceiver

Being the Chairman of the G-QRP Club brings with it a range of duties. One that crops up every few years is to maintain the QRP chapter in the RSGB's Radio Communications Handbook.

This time around, when I was asked to review the text and update it, I thought it would be sensible to revisit the project that is included in the Chapter; I was conscious that a number of the original components had become obsolete and at least one supplier quoted no longer existed, at least not on the high street.

The project is a QRP (low power) CW transceiver for the 3.5MHz band. It comprises of a conventional VFO, a direct conversion receiver module, a two transistor transmitter module, and a few other circuits providing transmit/receive switching, RIT and sidetone. It is ideal for someone with a little bit of soldering experience and, with care, could make an excellent first transceiver project; I recall starting to build a similar 7MHz transceiver before I was even licensed.

My 'junk box' has grown over the last 40 years such that I had all of the parts needed to build the project as described, but I remember not being so well stocked, and having to buy parts for projects as I needed them. I therefore went through the project parts list to see how easy it would be for a newcomer to find the required components in 2023.

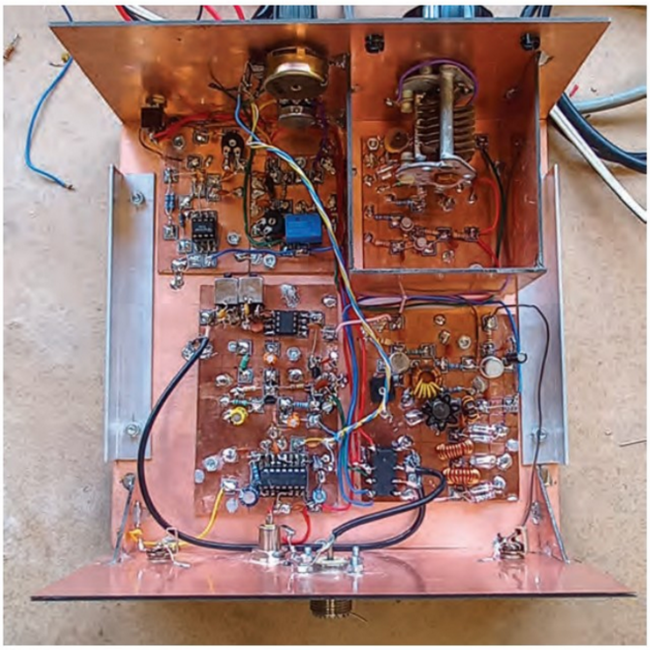


FIGURE 1: the completed transceiver.

Construction techniques

Many QRP projects only provide details on building the electronic circuits. This one includes information on how to construct an enclosure using double-sided printed circuit board material. I followed the design instructions and found them to be perfectly adequate, although I needed to make a few small changes to suit the parts I used.

I did not follow all of the construction techniques described in the original article but used what has become my 'go to' method for experimental circuits; using MeSquares. These are small squares of thin PCB material that are supplied in sheets so you can break off as many as you need.

You need to spend a little time thinking about layout (I use pencil on graph paper to plan how it might work).

Once you have the layout sorted, the MeSquares are glued to a piece of copper-clad PCB material to act as isolated islands to solder component leads to. Any grounded components are soldered to the main copper board, which provides a good ground. It works very well. It is neater than 'dead bug' or 'ugly' style, and it allows for the easy swapping out of parts. You should be able to see what I mean from the photos of the modules in this article.

There are also MePads, which are laid out for Integrated Circuits, surface mount devices, and even valve bases. I used the MePads for the ICs in the receiver module.

The MeSquares and MePads come from QRPMe, in the USA, but members of the G-QRP Club can purchase them through Club Sales. If you have the time and patience, you can make your own.

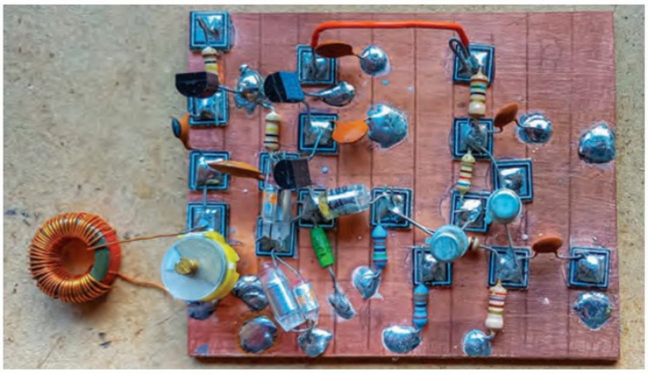


FIGURE 2: the completed VFO board.

The VFO

In any radio of this type, the VFO is the 'beating heart', enabling the receiver to demodulate the incoming signals, and generating the RF that will be amplified and transmitted. This seemed like the best place to start.

Most of the parts are still readily available, although the once common BC108 small signal transistors are becoming less common. They can be replaced by 2N3904s, which are widely available at low cost, and perform very well.

The BB409 variable capacitance diode used to provide Receiver Incremental Tuning (RIT), is obsolete. There were some being offered on eBay at silly prices. The MV209 is still available and has an almost identical specification. I tried one and it worked exactly as it should. Several of the suppliers listed below have a range of both wire-ended and surface mount diodes that would be suitable if you cannot source a BB409 or MV209.

Steve Hartley, G0FUW
g0fuw@tiscali.co.uk

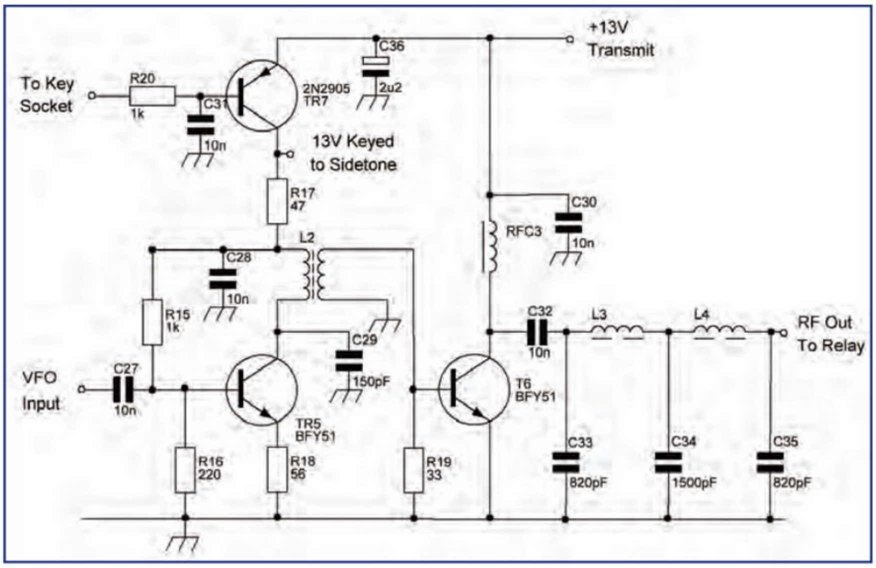


FIGURE 3: revised transmitter wiring.

Probably the hardest part to find will be the 10pF air-spaced variable capacitor. The old Jackson Brothers units once featured in many component catalogues but, alas, no longer. I was able to find some similar 20pF units sold by an EU supplier, and many were being offered on eBay. It is not an immediate supply solution, but keeping an eye out for nice air-spaced variable capacitors is something to do at rallies and Hamfests; there are quite often some old units sitting there waiting to be rejuvenated and reused. I used one from my 'junk' stock that had been waiting for a suitable project, just like this one.

One alternative to an expensive air-spaced cap is to use the more readily available polyvaricon capacitors. These often have a 60pF section which can be used in series with a 15 or 22pF fixed capacitor to give the desired range. I tried one I had to hand and found it worked reasonably well, but as I had an air-spaced unit, that is what I stuck with.

The 'nuclear' option is to replace the VFO with a digital oscillator based on an Arduino Nano, or similar microcontroller, with an SI5351, or similar, frequency generator. However, that takes the project in a rather different direction, and is maybe more suitable for a future upgrade article. Watch this space…

There is a 65pF trimmer in the VFO circuit to provide some frequency adjustment. The trimmer is listed as a Maplin part. As most reading this will know, the Maplin chain closed all of its high street shops in 2018. However, all is not lost; similar trimmers are available from other on-line suppliers. You might be limited to 40pF maximum, but that should give enough variation to get the VFO on frequency. A list of suggested suppliers is included at the end of this article.

My test VFO was found to be very stable and produced a good few volts of RF ranging from 3.500 to 3.650MHz.

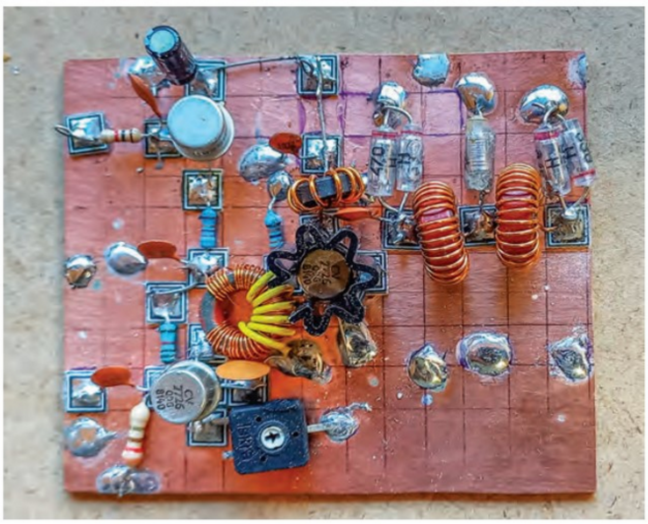


FIGURE 4: the completed transmitter board.

The transmitter

The circuit specifies two BFY51 transistors. These are also obsolete but small quantities can be had from a few smaller suppliers, and eBay sellers. Be prepared to pay a good few pounds, especially if you want a spare, or two. I bought five CV7726, BFY51 equivalents, for £2.75 from a UK eBay seller. They performed exactly as expected, producing almost three watts of RF output.

I don't recall where I first saw them used, but I have used BD139 transistors in simple QRP transmitters for a good number of years. They are sold as audio devices but they seem to be very happy up to 14MHz, at least. I tried a couple in this project and they proved to be more than capable, providing the same three watts output. You can nudge that up to four watts if you reduce the emitter resistor in the driver to 47 ohms. Several UK suppliers have BD139s at less than a pound for five.

The original 2N2905 keying transistor can also be costly but is easily replaced by a 2N3906, which is widely available for a few pennies.

I did not have any ferrite beads to hand for the RFC but had a number of wee FT-37-43 ferrite toroids. I find these easier to wind than the ferrite beads, which require very thin wire. Somewhere between 5 and 10 turns of 27 SWG enamelled copper wire does a good job on the toroidal former. Both ferrite beads and toroids are still available from the suppliers listed.

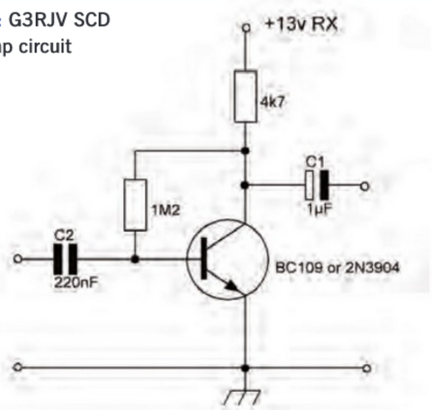
The Low Pass Filter capacitors are specified as polystyrene. I could not find the values quoted for sale anywhere, but it is not difficult to parallel other values, that *are* available, to get the correct capacitance, or something that is 'within tolerance':

820pF = 470pF + 330pF = 2.5% low
1500pF = 1nF + 560pF = 4% high

To see if the capacitor pairings had any detrimental effect on performance, I ran my hacked filter through a nanoVNA and it was just fine; less than 1dB loss in the passband, -26dB on 7MHz and -65dB on 10.5MHz.

If you want better attenuation of the second harmonic, there are some improved filter designs

FIGURE 5: G3RJV SCD AF Pre-Amp circuit



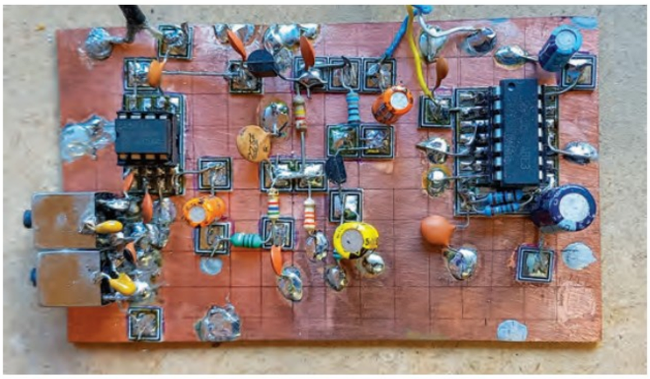


FIGURE 6: the completed receiver board.

by Ed Wetherhold, W3NQN, on the G-QRP Club website. These have a few extra parts but drop all harmonics to -60dB, or better.

On testing the transmitter I noticed some carrier leakage; in transmit mode there was still some RF showing on the power meter when the key was up. The leakage was around 100mW, and probably not an issue for DX contacts, However, as I found out with one of my early transceivers, a low level signal between the dits and dahs can be annoying and makes copying the Morse more difficult during more local contacts.

Luckily, I remembered how I fixed it, and it is quite easy to implement on this project. All that is required is to rewire the transmitter module so the driver is keyed, rather than the power amplifier. I tried it on my test build and it was 100% successful. A revised schematic is provided above.

The receiver

The front end of the receiver has a double tuned circuit band pass filter; the original circuit used TOKO KANK3333 coils. The TOKO coils disappeared several years ago but Spectrum Communications of Dorset commissioned replacement coils to be made. Their 45u0L coil is the direct replacement for the KANK3333 and I can confirm that they perform every bit as well as the original TOKO coils in this project. I tuned mine using the nanoVNA, but doing it by ear works equally well.

The 'ubiquitous' NE602 mixer used for the product detector is still available, at least the G-QRP Club have plenty in stock, and there are plenty of SA612 surface mount versions available. The SMD versions can be soldered without too much trouble or specialist equipment to the MePads mentioned earlier.

I had some real issues with feedback/oscillation with the audio section; it worked OK at low volume settings but there was a constant 'frying eggs' sound and an almighty squeal when the volume went above half-way. Cutting a very long fault-finding story short, I found that removing the audio filter parts RFC2, C17, R9 and C18, and changing the biasing of the transistor cured the problem completely. The 'new' AF pre-amp came from an old G3RJV project and not only did it tame the instability, it gave more output (see **figure 5** above). I am in the process of revisiting this section to see if a little audio filtering can be added by replacing the transistor with an op-amp.

An original BC109 was tried in the audio amplifier and it was replaced by a 2N3904 transistor with no discernible impact on performance; both squealed equally badly before the modification! There are some metal can BC109s around but their little plastic cousins are much easier to find and will not trouble the bank balance.

The LM380 audio amplifier is still readily available. There are two versions; the one specified has 14 pins, the other has just 8 pins. Both will work in this project but the layout would need to be tweaked for an 8-pin version. This is not difficult if you compare the two pin-outs on the datasheets.

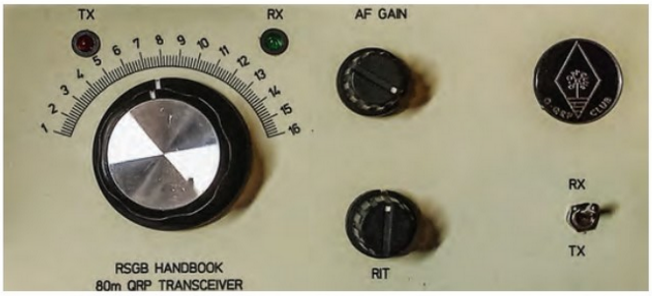


FIGURE 7: the finished project front panel.

'Bells and whistles'

George, G3RJV, the founder of the G-QRP Club and prolific author, often referred to ancillary circuits like the RIT, Sidetone and Changeover Relay as the 'Bells and Whistles' that make a transceiver more pleasurable to use.

The only thing in these circuits that could cause any supply issues is the variable capacitance diode referred to earlier; all other parts were found to be readily available and the circuits performed as expected.

I did make a small change to the Sidetone oscillator; I found the tone a little low for my liking so R26 was changed from 22k to 9k. To find the right value, I replaced the 22k fixed resistor with a 22k pre-set variable resistor and found 9k gave a tone that I was happy with. It is not the most musical sidetone, but it does its job, allowing you to hear what you are sending.

On-air tests

Due to the horrendous levels of QRM from VDSL and other city centre 'electronic fog', it has been a while since I operated on 80m, so I don't normally have an antenna for that band. However, on first connecting the 20-10m Cobweb it wasn't long before some Morse was heard; several German stations and one from Belgium.

With a 'bit of end-fed wire' and a matching unit I put the transmitter on the air but had zero luck in making a contact. I therefore set up a sked with my good friend Lewis, G4YTN, and he gave me a cross-town report of 599. Playing my rusty CW back via 2m FM gave me full confidence that the radio was indeed transmitting and was capable of QSOs.

Summary

The main purpose of this exercise was to check that a project that was originally put together a good few years ago was still buildable in 2023. Whilst a few component substitutions may be needed, the circuits are still viable and work pretty much as the original article suggests. Some minor circuit changes can improve performance by removing carrier leakage on transmit, and removing audio feedback/oscillation on receive.

You can find all the circuits and construction details in the RSGB book *50 Projects for the Radio Amateur,* and a slightly abridged version in the 14th edition of the RSGB *Radio Communications Handbook*. Having confirmed it is still buildable, it will feature in the next edition too.

Web Links

[1] G-QRP Club: https://www.gqrp.com/
[2] Spectrum Communications: http://www.spectrumcomms.co.uk/Components.htm
[3] Bowood Electronics: https://www.bowood-electronics.co.uk/
[4] Kanga UK: https://www.kanga-products.co.uk/components.html
[5] CPC: https://cpc.farnell.com/
[6] Rapid Electronics: https://www.rapidonline.com/
[7] RF-Microwave: https://www.rf-microwave.com/en/home/
[8] Cricklewood Electronics: https://www.cricklewoodelectronics.com/
[9] Mouser UK: https://www.mouser.co.uk/
[10] Digi-Key: https://www.digikey.co.uk/

Wideband high input impedance unity gain HF/VHF RF amplifier

The original circuit dates to the mid 1970s using leaded components. An updated version by Andy Talbot, G4JNT was published in *RadCom* in May and June of 2021.

This version used surface mount technology (SMT) components but Q2 was a 2N2907. I found this to be obsolete and difficult to obtain. I replaced this with an MMBTH81, which has a much higher transition frequency (fT). The RF coupling / decoupling I have modified to improve the bandwidth and provision for a screening can has also enhanced the design. The full schematic is shown in **Figure 1**. This has been laid out on a professional PCB to build the project.

The output trace shown on the assembly drawing in **Figure 2** is a coplanar waveguide above a bottom ground plane that allows attachment of a side mounted PCB SMA connector. With the addition of a screening can, the RF circuits are fully enclosed.

Photo 2 shows the SMD assembled board before fitting the screening can.

Being high impedance (Z), you can connect the RF input to a short wire or small metal plate about the size of a QSL card. The mounting holes are to facilitate holding the probe in place, but these are grounded so insulators must be used if connected direct to the probe head. **QR 1** links to the materials used (Bill of Materials, BOM). The RF gain is unity and the maximum input is 6V pk/pk before any noticeable distortion occurs (a supply voltage of 24V for distortion free unity gain).

PHOTO 1: **Cased probe assembly.**

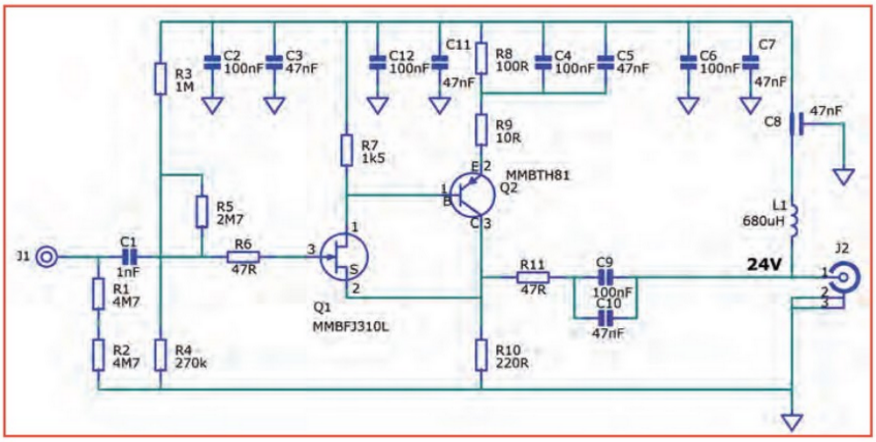


FIGURE 1: **Probe schematic.**

Test results

The test results were obtained using a VNA calibrated between 100kHz to 200MHz. To measure the performance of the unity gain amplifier first we need a bias T that is sufficiently wideband to cover 100kHz to 200MHz. A lot of bias Ts advertised as wideband fall noticeably short of the mark and drop off in performance at the low frequency end. Therefore, I cannibalised the very circuit used in the probe output as shown in **Figure 3**. The results are shown in **Table 1**.

Satisfied that the losses are negligible, let us look at the actual probe under bias conditions. The input of the probe was coupled to a vector network analyser via a test interface jig shown in **Photo 3**. This uses a Coda-pin sprung contact arranged as the centre pin of a coaxial interface. This was calibrated from 100kHz to 200MHz. The gain shown in **Table 2** was almost unity and found to be within half a dB across the HF bands and usefully extends to cover the 6, 4 and 2m bands.

Ignoring the bias T for the moment, let us think about what we have measured. The VNA output is 50Ω. The nearfield probe is high Z, 0dBm at the input delivers 0dBm at the output. Yes, it does, but this is misleading. Voltage gain is unity, but the impedances are very different. Consider the setup in **Figure 4**. Let us assume the VNA output is 0dBm and is connected to the nearfield probe. Zin at 'A' is much greater than 50Ω so the VNA delivers an output voltage 6dB higher than if it were terminated into 50Ω. The voltage at 'B' is the same as 'A', unity gain. But now consider when the probe is terminated into 50Ω. Vout at 'C' will be 6dB lower than input 'A'.

A table with nearfield probe output in dBm as a function of Power Flux density and E field with this correction is shown in **Table 3** (onine at QR 2).

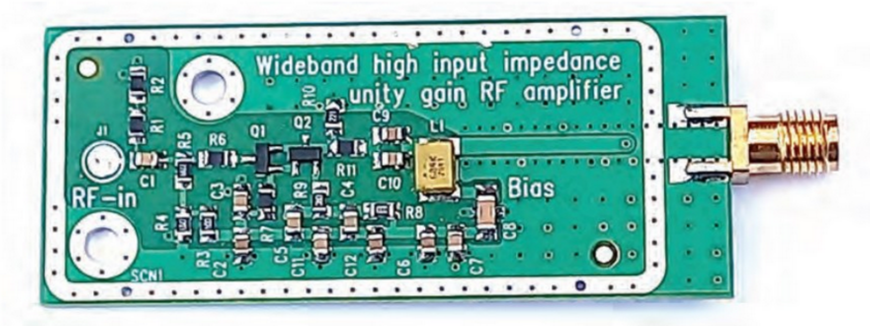


PHOTO 2: SMD assembled board.

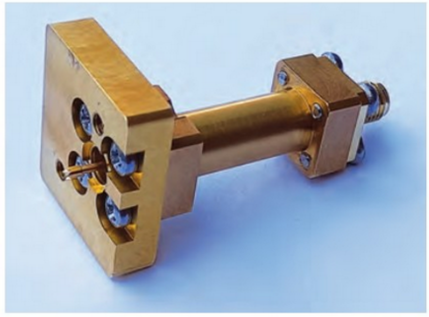


PHOTO 3: Test interface.

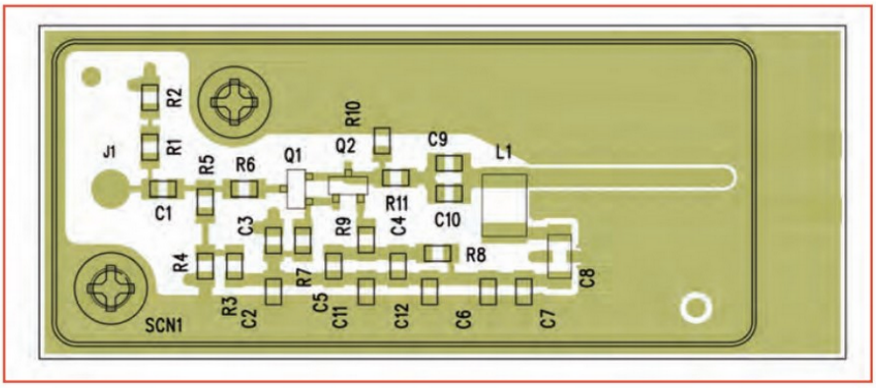


FIGURE 2: Assembly drawing.

Maths behind measurements and antenna gains

These equations have been published before but just for clarity are repeated here. An idealised antenna is a point radiation source in all directions covering the surface of a sphere. The area of the sphere is $4\pi r^2$

Power Density [S] is a measure of the radiated power on the surface of this sphere.

$$S = \frac{P}{(4\pi r^2)} \rightarrow = \frac{E^2}{\eta_0} \rightarrow = \eta_0 \times H^2 \rightarrow = E \times H \quad \text{W/m}^2$$

Where P is transmitter power in watts.
E is EMF in V/m RMS
H is amps/m

η_0 is resistance of free space = 120π or 377Ω

r is the radius of the sphere in metres.
If an antenna has gain, then Power Density 'S' is a function of

$$\frac{G \times P}{(4\pi r^2)} \rightarrow \text{units W/m}^2$$

Where:
G is the linear gain (isotropic) of the antenna under evaluation.
To calculate G, antennas are frequently quoted as having gains in terms relative to a halfwave dipole dBd. To calculate gain we must convert the log specification into a linear term and derive gain relative to an isotropic radiator.
Therefore, for an antenna quoted in dBd we have:

$$G = 1.64 \times \text{Antilog}\left(\frac{dBd}{10}\right)$$

1.64 is the gain of a half wave dipole eg 2.14dB isotropic. The explanation here is energy is concentrated, radiating two side lobes from a dipole, the maximum radiation is in front and back but little is measured at the ends as you can see in **Figure 5** depicting the 3D far field radiation of a halfwave dipole. Because the energy distribution is focused, it has gain relative to an idealised isotropic radiator where all the energy would be evenly distributed over the surface of the sphere.
For antennass quoted in gains of dBi the above equation becomes:

$$G = \text{Antilog}\left(\frac{dBd}{10}\right)$$

So now we can calculate Power Density in watts/m² for any antenna with gains quoted in dBd or dBi.
To calculate EMF in V/m then we apply Ohms law:

$$E = \sqrt{(S \times \eta_0)}$$

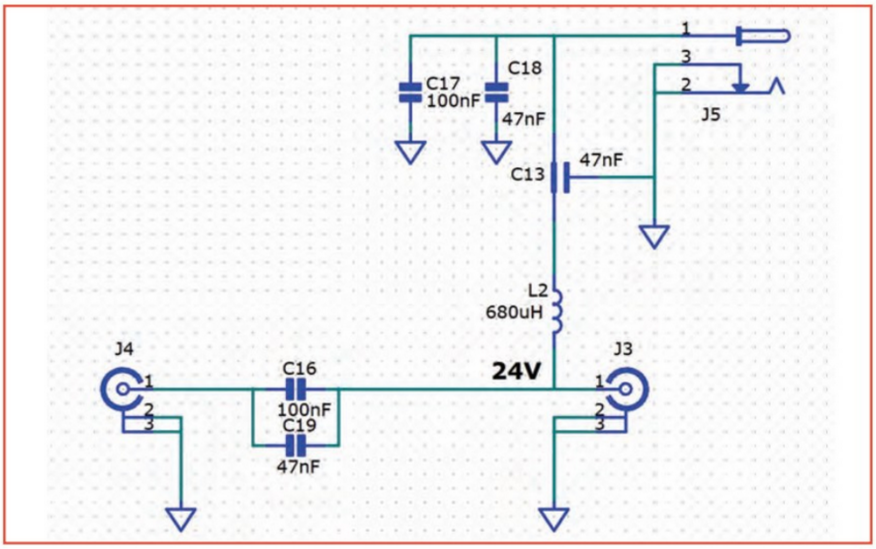


FIGURE 3: Bias T Circuit.

David Allen G8LHD
david.camtech@outlook.com

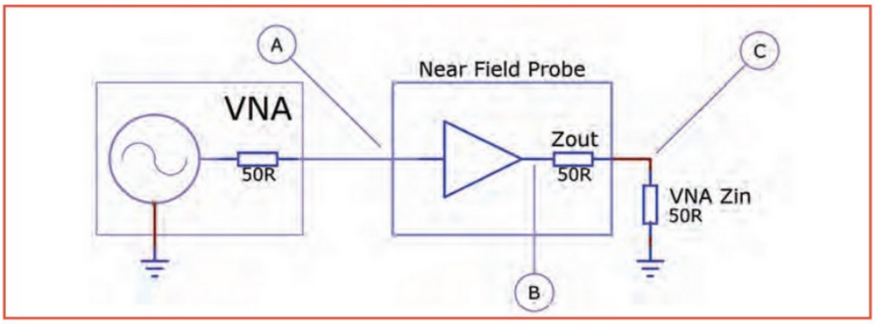


FIGURE 4: Test setup.

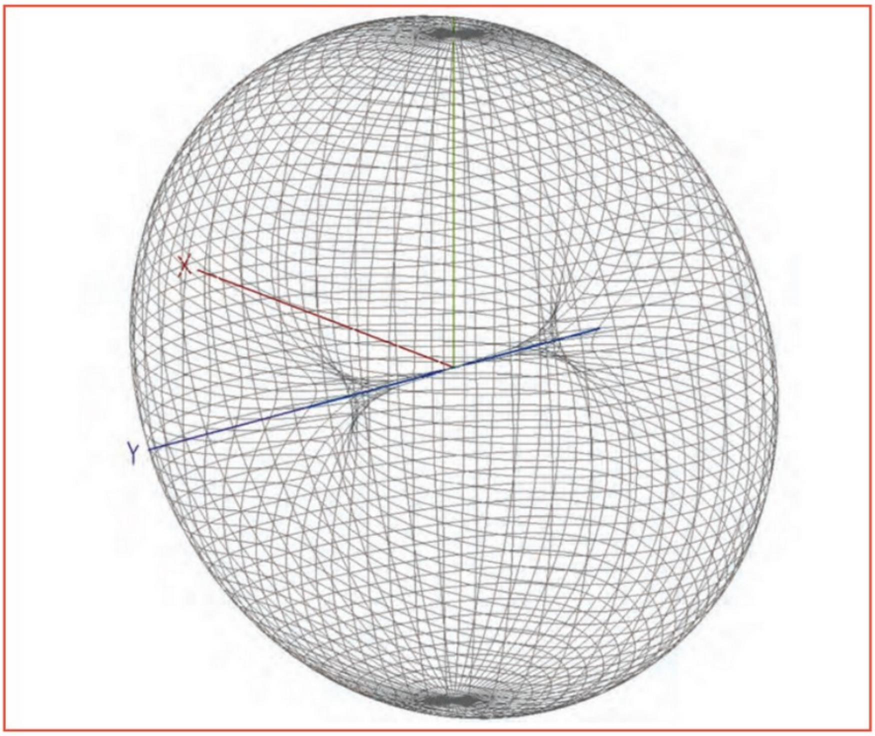


FIGURE 5: A λ/2 dipole radiation pattern.

Where η_0 is the resistance of free space 377Ω.

Example:
A halfwave dipole has a gain of 2.14dBi. Our transmitter output power is 100W, power density *S* is:

$$\frac{1.64 \times 100}{\left(4\pi r^2\right)}$$

If '*r*' is 3 metres then Power Flux Density is:

$$S = \frac{1.64}{\left(4\pi 3^2\right)} = 1.45 \text{ W/m}^2$$

$$EMF = \sqrt{\left(S \times \eta_0\right)} = 23.38 \text{ V/m}$$

Our probe upper measurement limit is ~2.25V/m, clearly, we need to turn the Tx power down or increase '*r*' to reduce the field strength.

Interestingly, if one plots PFD (*S*) and calculates the probe output with correction factor for the measured ~0.3dB loss over the HF bands, plus taking into account the further -6dB due to the open / 50Ω termination we get this:

10mW PFD produces +2.5dBm output. Now if we insert a 2.5dB pad between our measuring instrument [spectrum analyser] we get parity where 10mW PFD gives us 10mW on the spectrum analyser. Now this is useful to us as we can directly interpret PFD by just reading the power level on a Spectrum analyser.

A 2.5dB pad can be constructed as a Pi (p) attenuator with 390Ω and 15Ω series resistor. You could however get away with a commercial -3dB pad and accept an accuracy of 1dB. Adding an external pad also has an added benefit explained below.

A word of caution: The nearfield probe is capable of driving >10mW into a 50R load in strong field conditions. The tinySA instrument I use has a maximum input of +10dBm with 0dB internal attenuation and +20dBm with 30dB internal attenuation. Take care not to exceed the manufacturers maximum recommendations.

Near field verses far-field

The radiation field from an antenna can be considered as two regions. The far field or Fresnel zone boundary is at a distance from an antenna under test equal to $2L^2 \div \lambda$ metres. L = the largest aperture or element of the antenna. λ = wavelength in m. Near field radiation boundary is $\lambda \div 2\pi$ metres. For reliable antenna measurements it's recommended to use the far field boundary. Radiation pattern after this boundary region is nearly identical in the very far field.

Limits for safe exposure

Refer to the RSGB website and search 'EMC exposure'. There are several documents available including the ITU-T Telecommunication Standardisation K.52 (06/2021) reference document and the ICNIRP guidelines March 2020. ITU-T; Power density '*S*' limit is published for 100MHz to 400MHz at 2W/m² public exposure.

ICNIRP; E field public exposure levels for 100kHz -30MHz = $300/(f^{0.7})$ V/m [f in MHz]
ICNIRP; E field public exposure levels for 30-400MHz = 27.7V/m [2W/m²].

Expect more guidance on safe level exposure to be published in the near future.

Table 3 (online) is in 1dB increments so looking up Power Flux Density (*S*) in W/m² shows the corresponding EMF V/m and near field output in dBm. The results printed in blue show the probe output upper operational region. Result printed in red are just for clarity.

QR 1: BOM
(thersgb.org/go/rfprobe)

QR 2: Table 3
(thersgb.org/go/rfprobe)

TABLE 1:
Bias T losses.

Frequency	Loss dB
100kHz	-0.07
1MHz	-0.00
5MHz	-0.01
10MHz	-0.01
20MHz	-0.02
30MHz	-0.03
50MHz	-0.04
70MHz	-0.12
145MHz	-0.14
200MHz	-0.32

TABLE 2:
RF probe gain

Frequency	Loss dB
100kHz	-0.7
1MHz	-0.38
5MHz	-0.37
10MHz	-0.36
20MHz	-0.33
30MHz	-0.27
50MHz	-0.1
70MHz	0.08
145MHz	0.8
150MHz	0.8