A transverter for 2.4 GHz

Andrew Davis VK1DA

A transverter for the 2.4 GHz band was built in the week prior to the 2008 Spring VHF/UHF Field Day. Its design was based on separate modules for the functions of mixers, filters and amplifiers, standard kit modules and surplus coaxial cables and connectors.

Introduction

This article describes how I came to build a transverter for 2.4 GHz in the week prior to the 2008 VHF/UHF Field Day contest. It uses a design approach that could be adapted for any microwave band.

Why did I even consider this project? The increasing interest in microwave bands in the VK1 area and the high scoring rate for microwave bands meant that if I added 2.4 GHz to my Field Day station, I would gain an extra band, earn extra points in my field day log and, I hoped, inch closer to Doug VK4OE's score.

I did not expect to work long distances with a one to two watt signal, I just wanted to make a handful of contacts on an extra band.

Components and modules

Some useful components for this type of project had been purchased previously, some found via the advertising and auction website eBay.com.au. Items purchased included two bandpass filters centred on about 2.3 GHz and a 10 MHz oven-controlled crystal oscillator. These oscillators can be used as a frequency reference for a microwave Phase Locked Oscillator (PLO).

I had also purchased from *MiniKits* a kit for a transverter sequencer for controlling a multistage transverter and a kit for a microwave Transmit/Receive (T/R) antenna relay using a small surface mount relay, suitable for power levels up to 10 watts at 2.4 GHz.

Ted Garnett VK1BL had built some amplifiers using the *MiniKits* experimenter boards and low cost Monolithic Microwave Integrated Circuits (MMICs), for the receiver RF amplifier and low level transmitter amplifiers.

While researching PLOs Ted had also found on eBay a Phase Locked Oscillator (PLO) that could be ordered for a variety of frequencies including 2256 MHz. This frequency is required for the Local Oscillator (LO) in a transverter giving a 2400-2404 MHz range when used with a 144-148 MHz transceiver as the intermediate frequency (IF).

He had also experimented with the one to two watt output stages of Comwave mixer/amp/power amp modules also being sold via eBay. These components had proven to work well and were ready for use in a project.

Between us we had the main components needed for a 2.4 GHz transverter. The question was whether those components could be transformed into a working unit and when it would be done. Ideally it should be completed in time for the coming summer Field Days, the first being the Spring VHF/UHF Field Day in mid November 2008.

In August 2008 there seemed to be plenty of time and other things took priority. However early in November the imminent VHF/UHF Field Day focussed my attention more closely and I decided to try to build something for use during that event.

The design

Figure 1 shows the block diagram of the transverter.

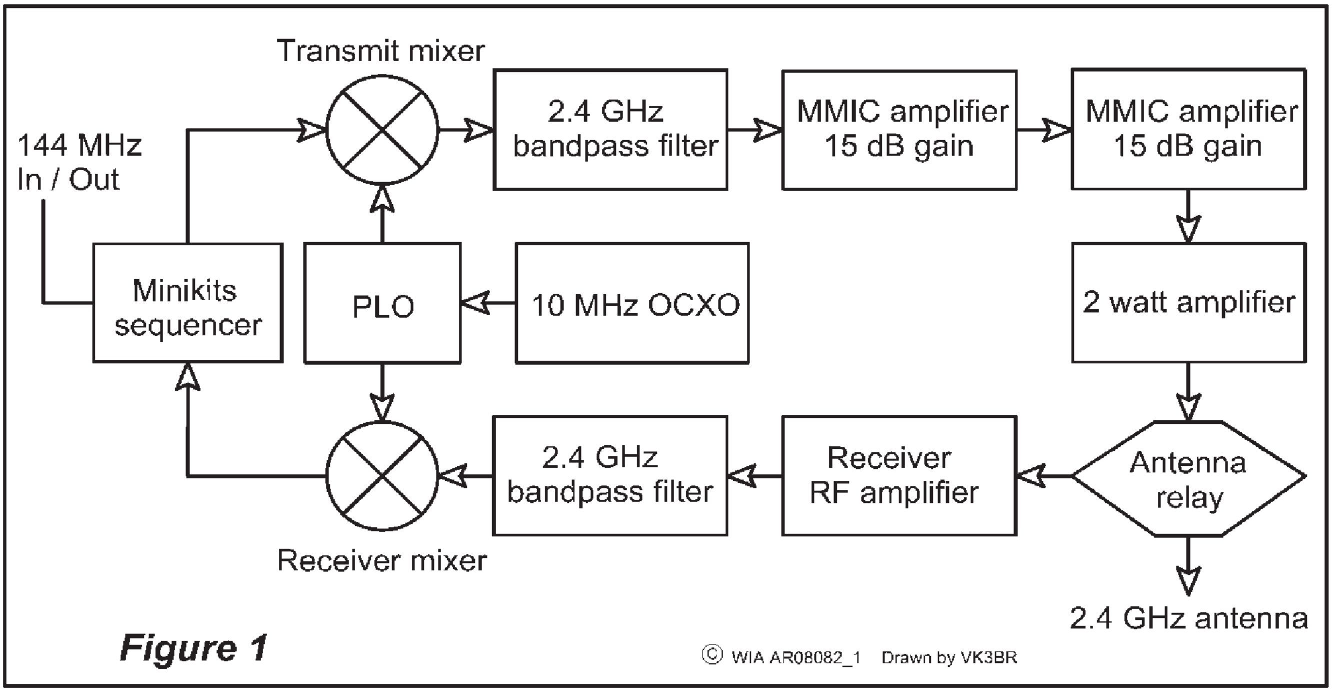

Figure 1: The 2.4 GHz transverter block diagram.

The key to the frequency conversion is the local oscillator signal, provided by a PLO producing a 2256 MHz signal for both mixers. This device is quite small, measuring about 25 mm by 15 mm and produces a signal that is proportionally as stable as the 10 MHz reference signal from the OCXO.

This method of producing the LO signal is significantly simpler than using a crystal oscillator and multiplying it many times to the final desired frequency, with accompanying filters and amplifiers.

As can be seen from the photos at Photos 1 and 2, using a preassembled PLO makes the LO part of the project physically very simple with only a small PCB to install in a shielded box and connect input, output and DC supply.

The LO signal of 2256 MHz combined with the FT-290R IF radio to provide a 4 MHz range, from 2400 to 2404 MHz. The frequency used for local contacts was 2403.1 MHz, which was obtained by tuning the FT-290R to 147.1 MHz. This is in the FM part of the 2 m band, but there are no FM repeaters on that frequency in my normal operating areas.

The output of the 10 MHz OCXO was higher than the rated input level of the PLO, so an attenuator was built from ordinary carbon film resistors and added to the output pins on the OCXO. The output of the PLO was a bit higher than desired for the mixers (+7 dBm), so the splitter providing the LO to the two mixers was designed to attenuate the PLO output by about 5 dB.

The transmit driver amplifiers were built by Ted using two *MiniKits* experimenter boards.

The output level from the mixer, with +7 dBm LO and about 0 dBm IF drive on 144 MHz, was about -7 dBm and a further 4 to 5 dB was lost in the filter. The +15 dBm available for the power amplifier was higher than needed. The drive level could have been reduced by inserting 6 to 10 dB of attenuation between the driver and power amplifiers.

An alternative was to reduce the IF drive to the mixer using the level control on the sequencer, which was the approach I took. I adjusted the 144 MHz drive level to the point where output did not increase, took that as the compression point and backed the drive off a smidgeon.

The FT-290R was set to low power which is rated at 300 mW output. This is still far more than the transverter requires and some simplification could be achieved by changing the 300 mW setting to about 10 mW.

The receiver RF amplifier stage was also built by Ted using the MGA86576 MMIC. On the test bench a -120 dBm signal produced good audible signals in the FT-290R and this was considered adequate sensitivity given that the output power of the transmitter was only one to two watts. There was no need to have a moonbounce level of receiver performance with a low power transmitter.

The low level amplifiers and the receiver RF amplifier all worked best at nine volts so the sequencer was supplied nine volts from a subregulator. Precision voltage regulation was not really required for either the sequencer or the RF amplifier but is readily provided by a three terminal regulator. I decided to use a Jaycar general purpose adjustable regulator board (purchased as a kit consisting of a PCB and about 10 components).

As the relay board was very light it was not mounted separately onto the case but merely connected to the three semi-rigid cables and left floating in mid air. The board did not appear to move at all when mounted on the cables and bolting it to a panel would have complicated and lengthened the connections. The cables are stiff enough to provide more than enough strength and stability for this application.

Transmit/Receive changeover switching is triggered by the FT-290R, which puts a +5 V DC voltage onto the antenna output when in transmit mode, as well as the RF.

This DC voltage triggers the sequencer to change from receive to transmit mode, first turning off the receiver RF amplifier, then changing the antenna relay, then enabling the final amplifier, then switching power to the transmitter amplifier stages and switching the IF signal over to the transmit mixer.

The *MiniKits* sequencer also caters for the DC voltage switching used by the Icom IC-202 series, which work the opposite way, the DC voltage appearing on receive and going to zero on transmit. The sequencer also has an RF actuated input which operates whichever of the DC methods is in use.

A sequencer is probably overkill for a low powered transverter but I wanted, in the future, to cater for increased output power from a different final amplifier.

The filters were originally tuned for about 2.3 GHz but were readily re-tuned with the aid of a microwave sweeper, tuning first for an acceptable waveform on a sweep display and then fine tuning for maximum return loss (or minimum SWR) with a 50 ohm load. After this tuning no further adjustments were made to them.

The final layout of the transverter can be seen in Photo 2, showing the remaining components other than the OCXO and PLO shown in Photo 1. Most of the RF connections are made using semirigid coaxial cables with SMA male connectors, which are available in various lengths as surplus items.

Timing

The project was started on the Saturday a week before the Field Day. Ted checked the PLO and mixer, looking for the optimum IF drive level into the mixer and checking on the OCXO drive level into the PLO. A test of the receiver mixer was also made.

Assembly of the sequencer commenced on the next afternoon and was completed after several sessions of about one hour each. Early in the week I visited Jaycar and purchased a cabinet, some hardware and the sub-regulator kit.

By Thursday night prior to the Field Day I had assembled the sequencer and regulator, mounted all modules into the cabinet and had installed the RF sockets and a DC connector. I had not yet tested the sequencer, which caused concern the next day.

I took the partly assembled box back to Ted's place on Thursday night and by 12:30 am all remaining modules (OCXO, PLO, power amplifier, bias supply board) were mounted and ready for testing. We were able to check out the receiver sensitivity but the DC switching for the transmitter stages had not yet been completed.

The next morning I spent an hour completing DC wiring from the sequencer to relays and the power amplifier bias supply. Finally it was transmitter test time and I first tested the sequencer to check that all DC switching was working correctly. At that point I found the sequencer was not responding to the incoming DC voltage from the FT-290R. I had to stop and get ready for the day's work, but having reached this point I did not want to drop the project just because of a few components or soldered connections on the sequencer.

At lunch time I went home for an hour and commenced tracing DC voltages on the sequencer board. After fixing two non-soldered joints, the sequencer was operating correctly and I could measure

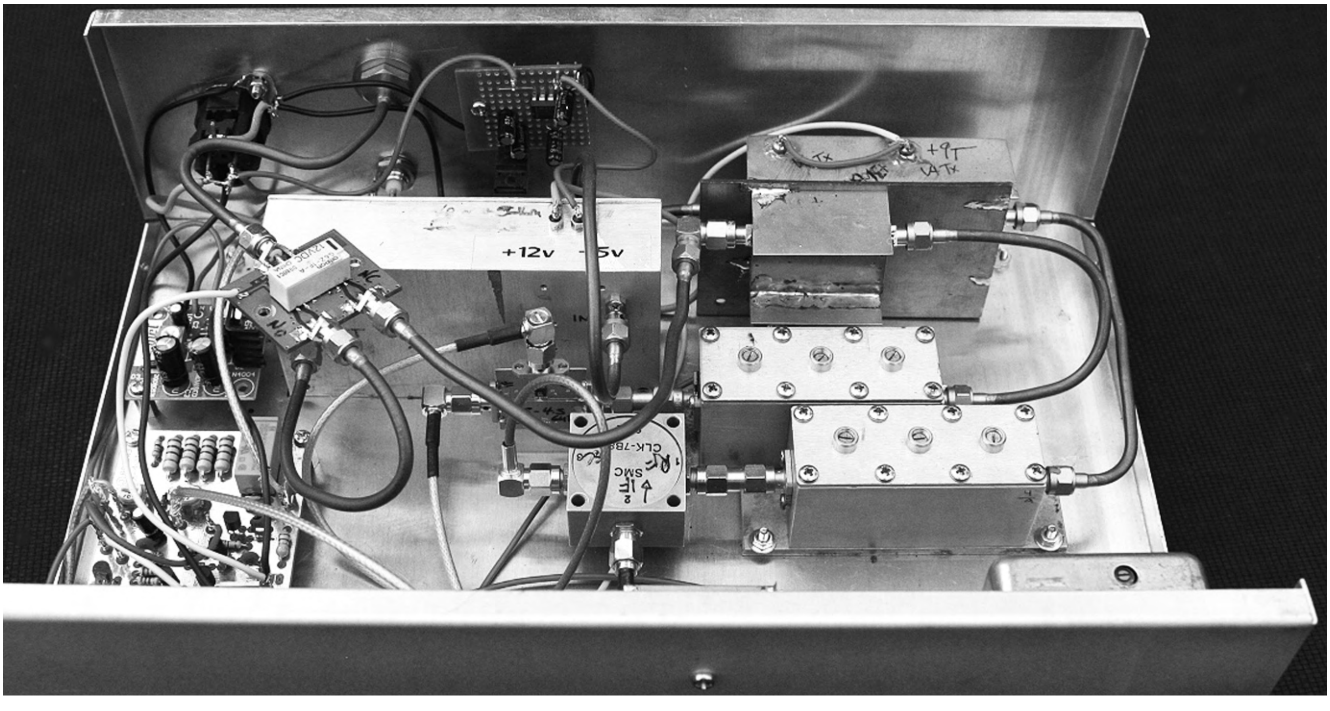

Photo 1: The main components of the transverter. The sequencer and subregulator are on the far left, the two mixers are shown attached to the 2.4 GHz filters and the low level amplifiers to the rear on the right. The transmitter power amplifier is in the aluminium box just under the small circuit board suspended on the coaxial cables, which contains only the antenna relay. The -5 V supply is on a veroboard mounted on the rear panel. The connectors on the rear panel are the DC input, the 2.4 GHz antenna connector and the 144 MHz input.

all the output voltages being enabled by the sequencer when the FT-290 was keyed up.

I connected a HP432A power meter (another recent acquisition) to the antenna socket of the transverter via 30 dB of attenuators. The 144 MHz input from the FT-290R was connected via a 5 metre length of RG-58 coax, the intended configuration for the Field Day.

With the FT-290R in SSB mode, I pressed the TX button and heard all relays switch over, then spoke a word or two into the mike and saw the power meter move. This looked good, so I switched the FT-290R to a constant carrier and adjusted the drive level from the sequencer to the TX mixer.

Due to the excessive gain in the TX amplifier chain the output from the sequencer could be set at just above minimum for an indicated +4 dBm on the power meter. Adding the 30 dB of the attenuator this indicated an output power of +34 dBm or about 2.5 watts.

I knew that the 20 dB attenuator was not necessarily accurate at 2.4 GHz. It had BNC connectors and was unlikely to be accurate at that frequency. However I knew there was RF power coming out of the box and I was then able to continue preparations for the Field Day.

The outcome

The transverter performed well and gave me some valuable points during the Field Day. I have published some photos from the field day, at *http://www.flickr.com/photos/exposite/*

Configuration

The transverter was deliberately designed to be operated remotely and supplied with only 13.8 V DC and the 144 MHz drive signal from the FT-290R IF radio. This permits a short feedline from the antenna to the transverter, minimising losses in the feedline.

Although only 4 metres of LDF440 cable was used, even good quality cable has measurable losses at these frequencies so it is important to minimise losses on both transmit and receive.

The feedline from the IF radio was operating at a much lower frequency of 144 MHz so could be much longer, even in relatively lossy cable like RG-58, as any losses are readily made up for in the transverter. In future Field Days I plan to mount the transverter on the mast just below the antenna, to reduce losses further.

Future development

There are a few potential alternatives and changes to the design of this transverter.

Reduce the module and connector count by sharing one mixer and filter between the transmit and receive signal paths. This would require a diplexer for the IF and 2.4 GHz signals. An article by Paul Wade W1GHZ (Reference 2) showed how this can be simply achieved using resistors to isolate the signal paths sufficiently. The 3 dB loss is easily made up by the gain available from MMICs, the “BC108s of microwaves”. This would make the transverter even simpler, with only one mixer and one filter required.

The power amplifier uses a MOSFET that will be damaged if the drain supply is connected in the absence of the gate bias supply. The sequencer has a suitable input that could lock the transverter in receive mode if the bias is not present.

As noted above, the multi stage sequencer is probably not necessary for a low power transverter. A two relay system such as the simple sequencer design by G3SEK would be adequate. The only really important delay is to the IF drive on transmit, to ensure no relay

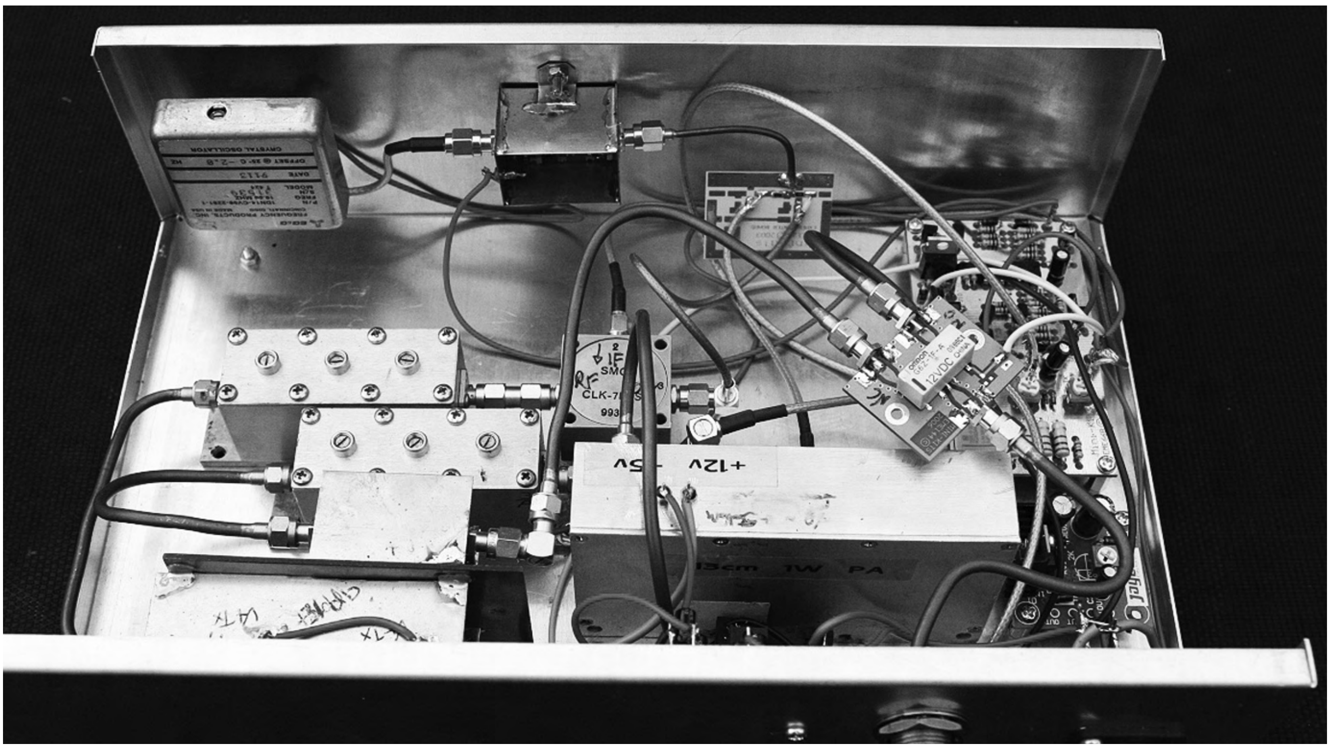

Photo 2: A view of the transverter from the rear, showing the 10 MHz reference oscillator on the far left and the phase locked oscillator board in its small brass enclosure. The PCB next to the PLO is simply a splitter with some attenuation, with outputs to both mixers.

other than the low level input relay is ever hot-switching.

No polarity protection was installed in the original transverter. The 9 V regulator board does have a series diode, so the only components at risk are those not switched by the sequencer and running from the 13.8 V supply. However this is not a sensible risk to take with equipment that will be assembled and connected in the field. With a fuse in the power lead, a reversed diode across the DC input connector is all that is required. This avoids the loss of voltage (typically 0.6 V) across a series diode. For low power equipment the simplest protection method is a bridge rectifier on the DC input.

With a stable 10 MHz oscillator in this transverter, it is feasible to use the same signal to stabilise other similar transverters. The relative frequency error would be predictable. For more demanding accuracy and stability, the OCXO can be replaced by a GPS-stabilised 10 MHz source. There is enough room in this transverter box for a GPS receiver.

The sequencer could also be shared between multiple transverters with outputs switched appropriately.

Alternatives

Alternatives for the transmitter power amplifier include other surplus amplifiers ranging from 10 watt to 25 watt levels. Some are being offered by Australian sellers on eBay.au.

Pyrojoseph on US eBay offers a range of modules including 25 watt amplifiers. If you want to start at the 2 watt power level, *MiniKits* offers a kit for a 2 watt amplifier for this band.

For the PLO there are alternatives becoming available. Andy Sayers VK2AES described a design for a series of PLO boards at GippsTech in July 2008, for a variety of frequencies between one and 10 GHz. I plan to use those boards for future microwave projects. Watch for an announcement about those boards. The PLO with acceptable phase noise seems to be the critical part of any microwave transverter and finding a suitable source solves the majority of the technical problems for the higher bands.

The bandpass filters I used were disposals items from multimedia distribution systems equipment or similar. However experimentation by Ted VK1BL with home made interdigital filters has shown that quite acceptable results can be obtained provided they are assembled with care and they are tuned correctly.

For higher power levels it would probably be advisable to use additional filtering before the power amplifier stage to ensure spurious outputs are kept to an acceptable level.

The amplifiers are "linear" so harmonic output and intermodulation distortion should be very low. (In addition, the second and higher harmonics may be out of the amplifying device's operating range so its ability to generate harmonics is presumably limited.) Nevertheless most commercial equipment on these bands have filters everywhere because microwave gear is typically co-located with other equipment and clean outputs are essential.

If the same filtering is applied to the receiver then the receiver will be equally well protected from image responses and intermodulation products in its mixer.

Parts sources

10 MHz OCXO. Various types are on *eBay*. I bought a Trimble OCXO from China for about AU$70 posted.

PLO with output on 2256 MHz. Source: *eBay.com*.

Mixers. One of the mixers was built on a simple board using a standard microwave double-balanced mixer rated for this frequency, with SMA connectors soldered to the board. The mixer has several tiny transformers and a matched set of microwave diodes on a chip. The other mixer was a commercial microwave mixer which Ted loaned for this project.

Filters. I bought these surplus filters from *Garry Nosworthy* at Nowra, via eBay. I do not know if he has more.

MMICs and experimenter boards for receiver and transmitter amplifiers: – *MiniKits*.

RF amp for receiver: MGA86576 – *MiniKits*

Connectors: panel mount N socket with semi-rigid cable and SMA plug: I purchased a few of these from *RF Resale* (Alan Devlin, VK3XPD) at GippsTech.

Semi-rigid cables with SMA connectors: purchased from Alan Devlin.

Sequencer board and microwave relay kits – *MiniKits*.

9 V adjustable regulator board: *Jaycar*, (this could be built using any suitable regulator chip mounted on perf board, veroboard, blank PCB, "paddyboard" style or even tagstrips. Only required if the amplifiers cannot be run from the (typically) 13.8 V DC supply.

Hardware: case, standoffs, nuts and bolts: *Jaycar*.

Building gear for the microwave bands

A key to success in projects like this is being able to get components and modules checked and measured so that you know that outputs are on the right frequency, levels are correct, and so on. Getting access to good test equipment makes this project much easier and results come quicker.

I had never built any equipment for microwave bands before so this was a new experience for me. However this project showed me that it was quite feasible once I had the right components and some help with testing and alignment. I plan to build similar equipment for other microwave bands.

Summary

The 2.4 GHz transverter presented here was designed and built using proven available modules, using surplus components where possible. No circuit diagram is included, as the components available to other builders may be different. Hopefully, publishing the project in this way will encourage others to have a go at getting some equipment running on the microwave bands. My professional work is in computing and I have no training in RF or microwaves, so if I can do it, so can you.

The transverter did what I wanted it to do. I made about 12 contacts with two local stations during the Field Day, with the pleasure of using equipment I had largely built myself. This was very satisfying.

This was a typical amateur radio project, thrown together at the last minute, with a very rewarding outcome.

Acknowledgements

This project succeeded only due to the support I received from Ted Garnett VK1BL. Thank you very much, Ted!

References

1. *MiniKits* is run by Mark Kilmier VK5EME in Adelaide. Mark publishes a catalogue of kits and components at affordable prices and provides an excellent mail order service. See *www.minikits.com.au*

2. Paul Wade W1GHZ, 2008, *Microwave Multiband Transverters for the Rover*, see *http://www.w1ghz.org/*

3. *eBay.au*, see *www.ebay.com.au* on the web.

ar