23cm / 1296 MHz Transverter

July 2009

The time has come for me to get 23cm gear going mainly for activities for VHF/UHF Field Days and since I now have a bit more time on my hands, I decided that the approach would be "hands-on" style. By that statement, nothing would be bought outright (i.e. a black box device) and, wherever possible, made here in my workshop.

The first step was to decide on a transverter design and a lot of time was spent researching on the world wide web using the key words "23cm transverter" and "1296 transverter". In brief, the best / most relevant results were attributed to W1GHZ's (http://www.w1ghz.org/MBT/Multiband_Four_Microwave_Transverters.pdf)rover designs for UHF/microwave (http://www.w1ghz.org/MBT/Multiband_Four_Microwave_Transverters.pdf). Would I build one from the ideas presented there ? - or would I just take the easy path and buy something similar ? The main thing about the rover design transverter was that it was high-side injection and for the published crystal/oscillator frequency, 1296.1 was going to be derived from an I.F. (intermediate frequency) of 143.900 MHz - which wasn't going to work for me as the proposed transceiver will NOT go below 144.000 Mhz. Maybe I could have chased up a slightly lower crystal but then it wasn't going to be s simple solution. I couldn't just use a standard low side injection on the same W1GHZ 1296 PCB as the tuned L.O. (local oscillator) PCB filters were for 1440 MHz - rather than about 1150 MHz. No, that was not a good solution. Actually I found out later that there was a solution by W1GHZ but by then it was too late - my mind had been made up! His solution : NEW- 1296 MHz Transverter - Right Side Up (Low-side LO injection) Paper (http://www.w1ghz.org/MBT/1296MHz_Transverter-Right_Side_Up.pdf) - which I still didn't like because the 64MHz oscillator had no frequency correction adjustment !

In short, I decided that while I felt I was capable of laying out a suitable PCB, my experience at 1.3GHz was in relatively short supply so I considered that, initially at least, the probable "most-successful track" was to buy a "kit of bits" from Minikits (http://www.minikits.com.au) in South Australia. Mark VK5EME despatched the ordered goods within a day of ordering and so my 23cm journey / saga begins.....

The following is a bit blog-ish but best describes the due process and findings.

Step one : 2nd July 2009 - Build up the Local Oscillator PCB - the Minikits EME-65B (http://www.minikits.com.au/eme65b.htm) - the recently revised version.

This PCB uses a couple of surface mount transistors but the rest of the components are standard leaded styles (eg conventional capacitors and resistors..). I decided that I would use the 95.91666 MHz crystal so that my I.F. would be 145 MHz rather than 144 MHz. The main reason was that since I would be operating on, for example, 144.150 MHz USB during a field day, the last thing I would need to do is to have to jump and find the 2 metre radio's volume control when I fired up on 1296.150 USB. By selecting the 95.9xx MHz option, the frequency on 2 metres would be 145.150 MHz USB for an output frequency of 1296.150 USB. Hopefully, the 1.0 MHz separation would be enough, when coupled with the few milliwatts of power at that frequency, not to cause significant interference to the 2 metre radio.

The board was built up and finally powered up. Hint : when mounting the 10 ohm resistor supplying the collector of the BFR93A via L4 (near the LHS black electrolytic capacitor in the photo above), mount it a little above the PCB for 2 reasons : (1) you need to be able to measure the voltage across it as you tune the trimmers; and (2) it does get warm under normal operation.

Checking the crystal was oscillating and then monitoring the output at 575.500 MHz on my 1GHz spectrum analyser plus on wideband AM on my Icom IC-R7100 receiver made it easy to find the nominally correct tuning points - but more about this below.

Info from Minikits about the tuning sequence was as follows :

The free-running frequency of the coil L1 & C1 needs to be determined first. Please follow the following alignment notes.

Disconnect the wire link near the crystal & connect the supplied 47 ohm resistor between the two BFR92A transistors emitter connections. This effectively will allow the oscillator to free run at the resonant frequency of L1/C1 without the crystal. Monitoring the signal on a either a wavemeter or a scanner tuned to the crystal frequency, e.g. 94MHz, 96MHz, or (67.333MHz with 432/28MHz Transverter), adjust the oscillator coil L1, (Toko Coil) until you hear the signal. It will not be all that stable or easy to tune exactly, but you should try & tune it within a few kHz.

You need to get this right first before connecting the crystal into circuit. When you are happy that it is correct then reconnect the crystal into the circuit.

Do alignment section 3 (of the supplied kit notes) for maximum output power.

Then you can get the frequency of the oscillator onto frequency as in section 4 (of the supplied kit notes).

L1 is not normally used to adjust the frequency of the oscillator but can be used to trim it slightly if the crystal is only off a few hundred Hz. The EME.DOC changes should only be tried without crystal fitted So don't use L1 to move the frequncy very far else the crystal will become rubbery. I recommend leaving L1 where it free-runs on frequency & doing the above steps.

My initial problems were that the tuning of the first trimmer (TC1), the collector tuned circuit of the second BFR92A tuned to 200MHz, made the oscillator "squegg" (low frequency oscillate). The squegging noise was plainly evident in the R7100 receiver so I knew there were some problems to be addressed. Tuning L1 caused the squegg-rate to vary as did adjusting TC1. The oscillator was off frequency - about 10KHz low at 575.5 MHz. A couple of spurious were noted on the spec analyser at about +/- 15MHz on either side of the true LO output. Tuning these two adjustments, but primarily L1, caused the frequency to shift - something was not quite correct... The tuning slug of L1 was a fair way out of it's former and seeking info on the Minikits web site for this project revealed a document that indicated for an operating frequency around 96MHz, the capacitor across L1 should be more like 15pF - rather than the original 22pF. I changed C1 to 15pF and the slug was now almost mid-way down the former - so the best value was probably actually 18pF. Even so, I left it at 15pF. The oscillator still squegged as L1 and TC1 were tuned but the output at 575.5 MHz rose and I was able to tune the rest of the trimmer capacitors for maximum output. Having optimised the rest of the trimmers, it was time to get down to find the cause of the instability in the oscillator itself.

My experience with well-designed crystal oscillators over the past 40 years is that they usually oscillate at/around the marked crystal frequency - or they don't oscillate at all. If an oscillator squeggs then there is a fundamental design or construction flaw. If you tune the "tank circuit" within range of resonance at the oscillator frequency, it will "pull" the frequency low or high a little - but squegging - not on !

The oscillator style is a well-known Butler format, two transistors that use a crystal between the emitters, the base of the first transistor at RF ground. I could probably have reduced the 27pF coupling capacitor between them to something lower, like 6.8pF, but I started using another ceramic disc capacitor (with short pigtails/leads) and placing it across various points on the PCB while watching the output on the spectrum analyser and listening to the LO at 575.5 on the R7100. There were two points that dramatically changed the spurious and the squegging - the supposedly RF-earthed base connection of the first BFR92A, and the top of its collector tuned circuit (i.e. 'cold end' of L1 & C1). Both of these are bypassed by 1nF capacitors to ground but maybe the particular style supplied are not quite a low enough impedance at RF - I don't really know - however by placing additional ceramic capacitor bypasses on the bottom of the PCB, all of the spurious noted disappeared and so did the squegging ! Tuning L1 too far in stopped any oscillation, too far out - the same. Around mid-way between the 'stop points', the oscillator started each time power was applied, varied the output frequency by a KHz or so, but the required signal purity (i.e. freedom from spurious) was now there.

The capacitors I used were simply picked up out of a "mixed pile" and provided the capacitance was more than about 200pF, it should be an adequate value to be a low impedance at 100+ MHz. The final values were 470pF across the base to ground of the 1st BFR92A and 1000pF across the "cold end" of the oscillator tank (L1/C1) to ground - but they could just have easily been almost anything between 220pF and 47nF. The physical / electrical structure (ie. good ceramic disc) was more important than final value.

I also have to go on record that I consider that the supplied "tuning technique" for L1 seems to be unusually complex. I am not saying it doesn't work - or shouldn't be followed - just that it shouldn't be required in a suitably-designed & fundamentally-stable oscillator.

See also a document by as suggested by Kevin Murphy ZL1UJG about using this oscillator kit in building a 1296 MHz beacon (/~vk4adc/web/images/UserFiles/File/23cminfo/Developing%20a%201296%20MHz%20Beacon.pdf)

Make sure you read the KIT FAULTS & MODIFICATIONS part on the EME65B page... (http://www.minikits.com.au/eme65b.htm)

The two extra disc capacitors on the bottom of the PCB.
Realistically I should have removed the original "as-supplied" capacitors and fitted these in the original holes but that doesn't make the "proving it's stable" process any easier.
Maybe I will do that before I finally mount the LO PCB into the box !

That solved one problem but not the other : the LO was still low of 575.500 by nearly 10KHz. The supplied info suggests that you use a series capacitor in lieu of wire link "Option 2" for low of frequency, a series inductor for high of frequency. Obviously I needed a series capacitor to bring it up. I tried a 22pF disc in series and the frequency rose by all of a KHz or so. I was going to need a lot less series C. My parts box revealed some new miniature ceramic 5-30pF trimmers and checking it against the PCB hole spacing for the Option 2 link, it would fit if I enlarged the hole diameters. See photo below for how it was accomplished.

Adjusting the trimmer while noting the LO frequency on the counter shifted it to about 575.500 +2.8KHz before it ran out of range. Looking good. Over a period of adjustments, it became obvious that the best adjustment process was to adjust the extra trimmer capacitor to approximate frequency and then fine tune with L1 for absolute.

From the photo below, you will notice that I have fitted the 50 degree PTC thermistor to the TS07S (50 degree rated) crystal and then used the supplied thick heatshrink to encapsulate the assembly. My initial observations indicate that the output frequency is drifting - but given the warning from Mark at Minikits that the unit needs to be run continuously for at least a week to "age" the crystal, I won't worry about that "fine frequency stability" yet.

P.S. : info from Mark on 5 July :
"OK on the oscillator. We have been working with a number of Hams in other countries for over 12 months to redesign the EME65 Kit. It has needed an update for some time & I am now at the stage of finishing the circuit board artwork ready for a prototype panel to be made soon & sent off to the Hams involved for testing. The EME65 Kit is very old & goes way back to the early 1990s but has had very minor changes along the way, as it basically worked well & was reasonably successful to build. The crystals are causing many of the issues in recent times as HY-Q products are a bit variable even in batches. The new design does address many of your issues & there is much more RF bypassing around the oscillator & multiplier.

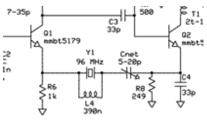
I expect that the additional ceramic leaded caps may be adding more bypassing & also some inductance which is fixing the stability issues. This problem does change with different HY-Q crystals so it's a real pain. The coil L1 should not be used to move the frequency more than a couple hundred Hz as the tank circuit needs to resonate at the crystal's frequency. Using L1 to move more than this will reduce the stability of the oscillator & increase the phase noise. Best to try & tune with your trimmer cap in series. I would also suggest using a 10pF NPO trimmer & use a NPO ceramic across make up the capacitance & reduce any drift. "

Update 21st Nov 2009

The transverter is all up and running but this note has been added here (rather than at the bottom) as this information is specific to the L.O. PCB.
The LO would still not come up on frequency with it's highest frequency per the trimmer capacitor adjustment falling about 2KHz short of the 1151.000 MHz target. If I adjusted L1 to try to move it the last little bit then the oscillator would drop out. The tuning range of the trimmer moved the frequency from 1150.976 to 1150.998 but just didn't quite make it to the 1151.000 mark.

A few minutes on the web confirmed that the Butler oscillator uses a series resonant crystal - which is what Hy-Q produces under their TS-07S code. A few more minutes showed that the EME65 circuit was essentially the same schematic as created by G4DDK and had no easy fine-trimming. I then chanced across the Butler circuit from W6PQL (/~vk4adc/web/images/UserFiles/Image/23cminfo/butler-osc-v3_1.GIF) which showed a series trimmer capacitor PLUS a shunt inductor across the 96MHz crystal.

Extract of the important segment of the W6PQL schematic :



The Minikits info suggests using either a series inductance or series capacitance to trim the crystal to frequency - but it doesn't suggest both. I didn't have any ~400nH inductors so I tried a 1uH in parallel with the crystal and it still would not reach the desired frequency. I then tried 2 in parallel = 0.5uH = 500nH and still no joy. I suspected that the Q was probably not high enough so then jumped on the web to find a calculator for a single layer coil. The philips #2 screwdriver on my bench was about 5mm diameter so I played with some dimensions for turns and length to aim for 300nH to 400nH of inductance. The final version was 10 turns of 0.8mm enamelled wire wound on the 5mm screwdriver former and occupying about 10mm length. This coil was soldered across the crystal pads underneath the PCB.

 (/~vk4adc/web/../23cminfo/100_4398mid.JPG)

Underside view showing the air-wound coil across the crystal.
Yes, it got crushed a bit pushing it down to provide good clearance but still does the job.

Note that the PCB is now surrounded by a tinplate shield - an addition since the earlier photos. The PCB is mounted on 10mm tapped standoffs and the 30mm wide tinplate strip was soldered to the top of the pcb while being pushed down against the bottom plate. The corners were made by just pushing it around a piece of 42 x 19 pine so are not really good squares. Nevertheless, it still functions as desired.

 (/~vk4adc/web/../23cminfo/100_4401mid.JPG)

(/~vk4adc/web/../23cminfo/100_4401mid.JPG)
Top view showing the 2-10pF trimmer soldered to the top of the PCB pins.
The last photo above these shows the ceramic one used previously.

The red wire through the hole will eventually be replaced by a feed-through ceramic...

While I was at it with the soldering iron, I removed the on-board ceramic frequency adjustment trimmer, placed PCB pins in the holes then added an 810 series plastic-style 2-10pF trimmer to these on the top of the PCB. When I powered up the PCB, voila - it was about 1151.003 MHz. A quick adjustment on the 2-10pF trimmer and it was on frequency. The adjustment of L1 became much broader too - and the oscillator no longer seemed to drop out.

The moral is that if you can't get the EME65 to net to frequency, add the series trimmer and the shunt inductor in one hit. If you have 390nH SMT inductors then they will most likely work. If you don't have any, wind up an air-wound coil to add.

Frequency stability comment : The EME65 with the crystal heater moves about 1KHz from cold to hot but in my case the majority of this shift happens within 2-3 minutes of switch-on. After that the frequency shift is minimal (< 100Hz at 1151) so the injection frequency has been set up at least half an hour after that - and there it stays. The crystal heater has been on enough over the recent months for the ageing process to happen almost completely - but remember that newly built LO's with crystal heaters will drift.......

Just another comment : with the transverter running towards full power on SSB, there was an obvious frequency shift due DC power supply voltage "wobble" even though the actual oscillator is fed from a 78L08 regulator on board. If you listen to the LO signal on a receiver set to a SSB mode, you will hear the frequency shift as you adjust the multiplier stage trimmers - and this is the cause of the warble. My fix was to include a 7809 positive 9 volt regulator in power line to the whole L.O. PCB - and the warble disappeared.

Step 2 : 3rd July 2009 : Build up the EME72B transverter (http://www.minikits.com.au/eme72b.htm)PCB.

Actually the construction of this PCB was relatively simple given the way the surface mount components were supplied - individually separated and stuck onto a partial- A4 back-page and all clearly identified as to marking/value. I congratulate Mark on this idea.

The first step in the instructions was to check for swarf (unwanted / leftover PCB material) around the MMIC amplifer holes. On my PCB, there was a short circuit on 3 of the 4 holes due to a nearly-invisible track of PCB copper cladding grounding one of the tracks/pads. A sharp knife readily removed the material and an ohm-meter (DMM) check then showed open circuit on each one. While talking about swarf, I found a short circuit due to a fleck of swarf (/tinning) on the top of the PCB along the 12V supply rail - identifiable in the full photo below as the long sideways-T track. It is a good idea to use the ohm-meter test as each component is soldered to the PCB remembering that capacitors will read open-circuit (O/C) so if you have a bypass capacitor reading short-circuit, then it is either the positioning of the surface mount capacitor on the mounting point - or you still have a trace of swarf there somewhere.

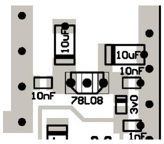
Apart from that the rest was relatively straight-forward.... until I got to the 78L08 voltage regulator orientation.

Now thr 78L08 mounts on the "top" of the PCB, the same side as the Toko helical filters but the photo on Minikits transverter page shows the regulator mounted like this (flat up) :

And if you look at the photo excerted from my assembled PCB, you will note that I mounted it the other way around (flat down) :

Before I soldered it in, I cross-checked the PCB layout supplied in the instructions, even going so far as to find a data sheet for the 78L08 (/~vk4adc/web/images/UserFiles/File/23cminfo/78L08.pdf) to check the lead-out configuration, and checking the tracks on the PCB to see which was the input voltage pad etc... I came to the conclusion that the photo on the Minikits web page was in error (P.S. - which Mark tells me is not wrong..).

The response email from Mark on 5 July provided an answer :

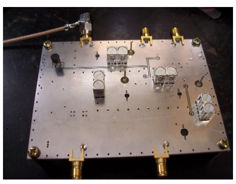


... he said that the orientation on the PCB layout documentation - as supplied with the kit - was in error !
Why others haven't found this before now is something you need to wonder about !!!
This image is an partial extract from the complete new layout document ART72B.PDF with the 78L08 orientation changed over.

Strange though, I still wonder if Mark is correct on this ?? NO, he wasn't - see below

The only construction difficulty I encountered otherwise was that the holes for the 3 PCB power pins were slightly small - I had to drill them out before the pins could be pushed in for soldering.

Now you will note that in my full size photo of the top of the transverter, only a part of each leg of the SMA PCB mount coax connectors has been soldered - so far. This is so that I can remove them when I finally find a local source of tinplate to make up the shields for all of the 23cm PCBs, then re-solder them on the outside of the tinplate once the shields are fitted.



Due to "grandfather's chores" (due to school holidays etc.), I wasn't able to get to the point of powering up the transverter PCB.. but that will be coming shortly (next week ?) when the story continues.....

P.S. I went out today (3rd July) to visit Apple Aluminium (here in Brisbane) and bought some 6mm aluminium rod (2 x 4m lengths) plus some 6m metre lengths of SQUARE boom tube to start on some yagis - as time permits - or - as required once the transverter is finished and needs an actual antenna. Thought about making loop yagis but I consider aluminium rod is easier to work with and you don't have to worry about de-forming loops in transit to field day sites...

Continuing : 7 July 2009 : The LO PCB finally seems to have more-or-less stabilised at 575.502180 MHz so it is time to move on with the transverter testing.

Keeping in mind my contemplations about the correct orientation of the 78L08 regulator - as above - and after re-checking a PDF of the regulator lead orientation, I left the 78L08 as I had soldered it onto the PCB and carefully applied voltage though a 390 ohm resistor to the receive supply pin, measured the voltage on the regulator output pin - pheww - about +5v out with +6.8v input. Feeling happy that I expected around that, I dropped the 390 ohm resistor out of line. The input voltage to the regulator was +12.8V, the output +7.96V. So I did have the regulator in the correct way in my photo & Mark's photo and new layout details were wrong.

After doing that, the test setup was quite simple - a couple of wires soldered to the +12V Rx and +12V Tx pins and on to opposite sides of a DPDT mini-toggle switch, common centre going to +12V as well as to the LO buffer pin on the transverter PCB and the LO PCB supply as well. Apply the Marconi sig gen at 1296.1 / 3 = 432.0333MHz, 10% AM, at about -50dBm into the 1296 receive input SMA connector, receive output SMA across to the R7100 receiver tuned to 145.100. Couldn't be simpler - or so I thought.

Hearing nothing but white noise at around S8 on the R7100, maybe the LO is off frequency. No, no sign of the sig gen signal found when tuning right up and down +/1 MHz. Somehow I hadn't expected that much noise in the receiver and wondered why. I started tuning the injection helical filters (1151MHz) and the noise level altered. Ok, we have LO injection. I thought I had better start checking some voltages and all started to look more-or-less ok until I got to the MGF1302 RF preamplifier. It was showing +0.08V on the base instead of -0.67V. Checking the drain revealed it was +0.8V. The ICL7660 negative voltage generator was running but the BC857 voltages were weird. The BC857 is used to control the MGF1302 but it certainly wasn't acting correctly. There was about -3.6V at the bottom of the 47K bias resistor for the MGF1302. I thought I might have soldered the MGF1302 onto the PCB incorrectly - no, it is as per the details supplied in the layout and correctly orientated - probably "stuffed" - but correctly orientated.. No spare available so I just dropped off the hairpins from their joints and used a ceramic disc capacitor directly onto the drain PCB track from the input SMA connector, bypassing that stage. Turned the power back on : still noise - lots of it - too much.

I went back to the LO helicals and at one point in tuning the second adjuster, the noise dropped right off and I could hear a little bit of the sig gen's modulation in the noise of the R7100. I fine-tuned the R7100 and centred the signal : +5 KHz. It was something to do with LO - that was for sure. Please note that I hadn't touched the LO PCB since I did the last adjustments a few days ago - when it seemed stable. Maybe the ERA3 in the LO was being overdriven and if I de-tuned the last trimmer on the LO PCB, it should reduce that somewhat. The difference it made was radical. The white noise in the R7100 dropped right down, the signal to noise jumped up. Guess what ?? The LO PCB is the major part of that problem. I detuned the first trimmer (BFR92A collector, tuned to about 192 MHz), and was greeted with burps, whistles and white noise. Not happy Jan !

I was going to set the sig gen to put about -20dBm at 145.1 into the transmit port but it's not worth even trying it until the LO instability story is resolved.

Thoroughly discouraged by my findings, I will have to order more MGF1302 devices and at least one BC857 transistor. Turn off the power and walk away in disgust about sums up today's transverter testing activities.

On the basis that I would eventually get it all functioning, I started the construction of a 26 element 1296 MHz yagi (http://www.vk4adc.com/web/index.php/vhfuhf-projects/22-1296-antennas/53-23cm-fd-yagi.html) so that I wasn't at least completely stagnant on the project.

Continuing : 8 July 2009 : Ordered more parts from Minikits, should arrive within a couple of days. Includes a couple of MGF1302's, ERA3 and MAV11 MMICS plus some SMD NPO capacitors for general use/experimentation.
Following the saga yesterday, I decided that I would re-check the LO PCB for stability. Terminated in 50 ohms and visible on the spec analyser and monitoring frequency on the counter, it powered up ok. I re-peaked the 4 trimmers (TC1 to TC4) for max output on the analyser on 575.500 MHz and it all seems stable. Following up a comment by Kevin ZL1UJG on VKLogger, I powered it off, soldered the sides of the L1 coil shielding can to the PCB - no obvious change. My consideration was that for the thing to be unstable, the first thing to evaluate was the bypassing on the supply points since the majority of the rest of the design has its earthing/shielding taken care of by the double sided PCB.

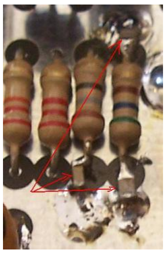
I didn't like the track lengths from the supply feed to the top of L1 or to the top of L2. Similarly the track to base of the first BFR92A from the 1nF disc capacitor seemed a trifle long to be super-effective so I soldered in 5 x 1nF SMD caps on the top of the PCB as per the photo. The ceramic discs added to the underneath of the PCB earlier were left in place - if for no other reason, the extra bypassing wouldn't hurt.

The positions are : 1 & 2 : each end of the 560 ohm, 3 : 'hot' (trimmer) end of the 18 ohm, 4 : 'top' end of the 820 ohm (towards the crystal), 5 : across the 1nF ceramic disc pigtail ('cold' end of L2).

Everything was more stable - even putting my hand near the PCB was causing less frequency shift than before. By no means is this an exhaustive test but I tuned all of the trimmers in turn and none caused anything other than a shift off the peak output point except for TC1 and TC2 which also caused a minor frequency change. TC3 & TC4 - no frequency change, just a peak in output. Maybe it is now stable (????).

 (/~vk4adc/web/../23cminfo/100_3772mid.JPG).

The 5 x 1nF SMD capacitors soldered to the top layer of the PCB and to the pigtails of the relevant components, angled slightly upward to prevent short-circuiting to the PCB.
(Note : check each position with a ohm-meter that there is no S/C before continuing)
Click for a larger image.



Closer view of 3 of the SMD 1nF cap positions - showing part of how it was done.
Sorry but the camera doesn't focus really well on close-ups.

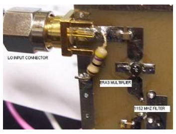
Continuing : 8 July 2009 - 8PM - receive & transmit side tests.

Seeing as how the LO seems to be stable now, it was worthwhile to try and re-test the (pre-amp-less) receive side.

Test configuration : EME72B LO input from LO PCB, sig gen at -50dBm at 432.0333 into the 1296 RX input port, RX IF output to the R7100.

Procedure : Powered on the LO and the Tvtr PCBs with +12V power supply in the receive mode. Could hear the sig gen but displayed R7100 signal level poor - made sure that the receiver was on-frequency - yes.

Adjusted the 1151 MHz LO helical filter - noise, burps, whistles yet again. Finger near the input of the ERA3 LO amplifier - goes crazy. Finger near the output - stable. Obviously with the high gain of the ERA3, the LO chain is unstable yet with a 50 ohm load on the LO PCB all is ok. The ERA3 must not be providing close enough to a 50 ohm load to the LO so it was time to get vicious about this instability. I soldered a conventional 47 ohm 1/4w resistor directly across the LO input socket (at 575MHz, this type of resistor is ok with ultra-short leads) and before the 10pf coupling capacitor to the ERA3, knowing that it was going to reduce the LO input to the mixer by around 6dB. Powered the assembly back up and it was stable regardless of where I tuned the 1151 MHz helical filter adjusters - so tried the output trimmer on the LO PCB - still stable. Well worth the drop in LO injection if you have complete stability ! When I get a bit further along, I will increase the resistor value to reduce the LO injection level drop - but not at the price of any sign of instability.....



The 1151 MHz LO helical filter was peaked by using a diode probe directly at the ADE11X mixer pin, tuned normally. The 1296 helical filter between the mixer and the 1296 T/R switch diodes was peaked using the reduced signal level from the sig gen and then the 1296 helical filter between the ERA receive amp and the (if it was connected) MGF1302 stage was peaked. The sig gen level was about -70dBm at 432 MHz so the 3rd harmonic would have been somewhat lower level (sorry haven't measured its level WRT 432). Just remember, this is without the RF preamp in circuit.

Given all, it looked like it was going to work once the preamp was functioning.

It was time to set up the transmit side of the EME72B transverter.

Test configuration : EME72B LO input from LO PCB, 0dBm at 145.100 into the TX IF input, RF load / power meter etc on the 1296 TX output port. Spec analyser still on 575.5 & R7100 on 1296.1 MHz.

Procedure : power on the LO & Tvtr PCBs, +12V power in the transmit mode. Diode probe on the 1296 output SMA connector centre pin.

RF output Reading : bugger all ! Multimeter time again. Measure the voltage on the ERA3 transmit amplifier output pin - about 3.5V - ok. Measure the voltage on the MAV11 output pin - 0V - wrong. The 220 / 270 ohm parallel SMD resistors were hot enough to burn the end of my finger. DMM : zero ohms on the MAV11 output pin to ground. Unsoldered the 68nH supply RFC. Still zero ohms on the MAV11 output pin. Unsoldered the MAV11 - now open circuit. Measured the MAV11 output to common pins as > 200 ohms so not short circuit. Checked the PCB for swarf around the output pin and there was a ultra-fine hair-like strand of swarf poking up in the air near the output pin. OBVIOUSLY I HAD DISLODGED IT - BUT NOT REMOVED IT ENTIRELY when I de-swarfed the PCB at the beginning of the construction. With the MAV11 soldered to the PCB, it must have been contacting the output pin hence the short circuit and zero volts. Resoldered the MAV11 back to the PCB - still measured O/C on the output track. Resoldered the 68nH RFC, still no short circuits evident. Bravely re-applied the +12V power - yes, positive volts on the output pin, RF power meter just reading above zero on a 1 watt scale and diode probe about 0.17V. Repeaked the transmit side helical - RF power meter now reading higher (around 25mW / +14dBm) and diode probe about 0.34V.

Varied the input level from the sig gen at 145.1 in 1dB steps down to about -20dBm and the RF output at 1296 varied in sympathy. Listened to the receiver with its internal 20db attenuator on and 0dBm I.F. drive, initially at 1296 - S8, for the 1151 MHz LO - < S1, for the mixer image at 1005.9 - not detectable. More conclusive tests and actual level measurements to be carried out later.

Hot damn - this thing is going to work !!!!
Time to give it up for the night & with the positive outcomes, I will probably sleep better !

Continuing : 8 July 2009 - checking the sig gen - a Marconi 2019 - Freq range - 80KHz to 1040MHz, RF level from +13dBm to -127dBm, AM & FM.

Time to see what the 3rd harmonic of the sig gen measures with respect to on-frequency. Note - top freq of the generator is 1040 MHz so can't do it at 1296....

Marconi generator in to R7100 tuned to 990.000 MHz, internal attenuator on - S5 = -64dBm
Marconi re-tuned to 330.000 - to achieve S5 again, the generator output had to be raised to -20dBm
Therefore 3rd harmonic attenuation is 44dB.

So if the sig gen is set to -70dBm and tuned to 432.0333, the actual 1296.1 level is -114dBm.

Just to confirm the 44dB, I retuned the receiver to 1020.000 MHz, again -64dBm to give S5, sig gen to 340.000 MHz, attenuator changed up to give -20dB before S5 was again displayed. Consistent....

As such, the receive side of the EME72B is hearing -114 dBm with the MGF1302 preamp bypassed. This low noise GaAsfet device has a gain rating of 11dB at 4GHz so should provide a similar value at 1.3GHz, maybe a little more. Just from that, the finished device should hear in the order of -127dB - the lower extremity of the Marconi sig gen !

Now if only I could find the place I "safely" stored the RF power block after I bought it a few months ago. After looking through multiple boxes in the workshop over about 3 hours, it just doesn't want to be found.

Continuing : 12 July 2009 - Replaced MGF1302 rf preamp FET

The bits arrived on Friday but have been busy trying to get a Trimble Thunderbolt GPSDO (http://www.vk4adc.com/web/index.php/general-projects/34-frequency-stabilisation/78-gpsdo-project.html) running so the transverter was put aside for a couple of days. { See separate web page }

Duly unsoldered the old MGF1302 and the temporary BC557 and cleaned up the PCB pads today. Installed these new parts - and yes - the original MGF1302 was oriented exactly the same way. Powered up the PCB and about +2.7V on the drain (in lieu of +0.8) and the gate now had a small negative voltage.

Set the sig gen to 432.0333 MHz again, output level to -70dBm and connected the transverter IF out to the R7100. The signal was quite strong in the receiver so the sig gen output was reduced to around -85dBm and the signal was still quite audible. { -85 + -44 (3rd harm attenuation) = -139 dBm (less generator leakage). }

I subsequently did a few tests comparing the basic R7100 and the transverter receive performance :

Basic R7100 @ 1296.1 requires -64dBm for S1 (USB mode, 1KHz tone) { -64 + -44 = -108dBm }

Transverter + R7100 @ 145.1 requires -74dBm @ 1296.1 for S1 (USB mode, 1KHz tone) { -74 + -44 = -118dBm }
Side note : Basic R7100 requires -103dBm for S1 @ 145.1 (USB mode, 1KHz tone)

The R7100 starts to hear the rising sig gen signal at about -85dBm (ie -85+-44 = -129 dBm)
The transverter/R7100 starts to hear the rising sig gen signal at about -94dBm (ie -94+-44 = -138dBm)
This test was based on when the received signal was actually starting to rise in the background noise level as the generator level was increased and while I don't necessarily believe that the transverter/R7100 combination is going to hear signals at -138dBm, it is just another comparison point. At some stage, I should do an actual Signal/Noise measurement (SINAD).

Noted that without a coax connected to the RX input (1296), the MGF1302 was somewhat unstable (unterminated input).

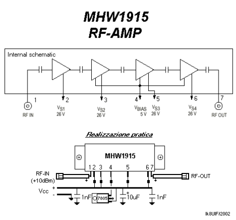
From VKLogger dated 18/7/09 - http://www.vklogger.com/forum/viewtopic.php?f=40&t=8472&start=0 (http://www.vklogger.com/forum/viewtopic.php?f=40&t=8472&start=0) :

Doug - Incredible detail and a very good read upon visiting your site. I will retrieve my project from the corner where I threw it in disgust many months ago and check the regulator orientation, and solder dags etc.
Many thanks,
Dan VK2GG

It seems that I am not the only one who has had "issues".....

Continuing : 19 July 2009 - Finally located the MHW1815 RF power block (http://f5ad.free.fr/Docs_Composants/MHW1915.pdf) tonight whilst looking for circuit/paperwork for the shack 1GHz frequency counter - so this week will see the mod's from http://www.geocities.com/vk3rtv/ampmod.html (http://www.geocities.com/vk3rtv/ampmod.html)applied to the module - then hopefully powering it up on 1296 !
{ Note : when I tried to save & print their page it was not entirely successful. I have extracted the page details and placed a local copy - without their weird formatting - on the VK4ADC web site, with some extra notes added about the extra SMD caps found on the MHW1815.

In essence, the values of various capacitors within the power amplifier block have to be increased to lower the operating frequency from 1800/1900 MHz down to 1300 MHz....



(/~vk4adc/web/../MHW1915.php)

"Use a 13.8V supply initially for testing. Use an input signal of approximately 10dbm (10mW) and a maximum of 17dbm (50mW) at 1240MHz. The output should be 5W - 7W if all is well. A supply of up to 24V can be used with an increase in output power to approximately 15W - 20W."
I will be running it on 13.8V so hope to see about 5W+ out of it.

20 July 2009 : Did the initial mods within the module, mounted it on a heatsink with the 5V regulator, bypasses and coax in/out, got about 300mW out of it - instead of 5 watts - before I killed it with a slip of the tweezers... Now waiting on getting another one before I can continue with the project...

Visit my MHW1815 page to see my final comments regarding these conversions at the bottom.

Update 21st Nov 2009

The transverter is all up and running and there are notes further up this web page regarding extra mods I made to the EME65 L.O. PCB.

There have been a few changes in direction along the track as available time became less and success with the MHW1815 mods seemed to evade me.

In the end, I took the easy way out and bought an EME162 1 watt 1296 driver PCB kit and the 1296 PA PCB kit (http://www.minikits.com.au/kits2.html) from Minikits (http://www.minikits.com.au/)so that I could make the 2009 VK Spring Field Day deadline I had set for myself. My greatest issue was locating a Mitsubishi RA18H1213G power amp module in time - Minikits had none, nor did any other suppliers around the world....

I created a PICAXE-base sequencer with some simple delayed pin activations for inclusion in the box - visit the project web page on this site for more details. (http://www.vk4adc.com/web/index.php/vhfuhf-projects/24-v-u-transverters/60-picaxe-tvtr-sequencer.html)

The photos of the completed transverter will be added shortly, probably after the field day. As they say, a picture is worth a thousand words.....

Update 11 Dec 2009

The field day has come and gone and the 23cm transverter worked well. I did have an issue with the RF gain control on the old Kenwood TR751A but given that it has had virtually no use for well over 5 years, that is not really surprising to me. One thing I did note was that when using what was supposedly our "field day calling frequency " of 1296.150MHz, stations who were supposedly on 1296.150 just simply "weren't". I noted frequency variations of up to around 2 KHz...... I did have a minor "FM-ing" of the frequency reported whilst transmitting and have yet to investigate that properly and maybe insert a low dropout voltage regulator into the supply line to the LO PCB. Alternatively, it could actually be within the TR751A !! The top heatsink became warm - but not overly hot - during the field day but given that it was a hot day in the first place, the actual temperature rise might only have been around 10 degrees centigrade. During the set-up of the transmit side in the shack, using FM as a carrier source to do adjustments & measurements, the heatsink became warm - but then again, it WAS *key-down for quite a few minutes at a time !*

UPDATE 2010 : See the new page about the PLL synthesiser project to fix the crystal frequency drift issues.. (http://www.vk4adc.com/web/index.php/general-projects/34-frequency-stabilisation/82-vhfpll.html)

The transverter was built into a 220 x 145 x 55mm diecast box and utilises a heatsink 225mm long (the extra 5mm was NOT trimmed off, it resides at the front to provide a level of physical protection for the LED indicators), 105mm wide and with a rated thermal resistance of 0.9° C/Watt, This has been affixed to the "top" of the diecast box using thermal transfer compound as well as screws. The only connections into the box are 12V DC power in (hard-wired), a BNC socket for the I.F. connection to the transceiver, an N female for connection to the 23cm antenna and a 3.5mm socket/jack which supplies the PTT and ALC plus ground connections, again back to the transceiver's remote control port. To set up for operation on 1296 SSB, simply add 12Volts and the 23cm antenna !!

At this stage, the box has not been painted but should receive a coat of paint after I create the new "companion" 70cm/432MHz transverter using the same size diecast box & heatsink (hopefully) early in 2010. That way both will actually be the same colour, probably matt black or hammertone grey.

The photos below illustrate how it all went together.. { click on each photo to view larger scale in a separate window }

(/~vk4adc/web/../23cminfo/100_4462mid.jpg)

(/~vk4adc/web/../23cminfo/100_4460mid.jpg)

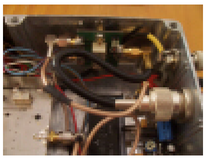
This is the overall inside view of the completed transverter . Sequencer at top LHS, ant c/o relay at top RHS, LO at centre left, main transverter PCB at centre, 1 watt tx driver at lower RHS, PA PCB at RHS.

No real apologies for the lack of nylon ties to neaten it up as it was finished only a week before the field day and working on other equipment had priorities too !

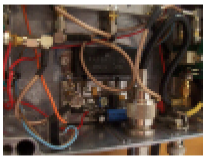
(/~vk4adc/web/../23cminfo/100_4462mid.jpg)

(/~vk4adc/web/../23cminfo/100_4462mid.jpg)

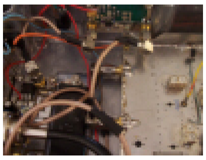
(/~vk4adc/web/../23cminfo/100_4462mid.jpg)

(/~vk4adc/web/../23cminfo/100_4462mid.jpg)

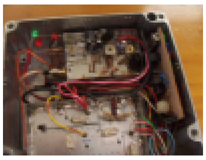
The antenna changeover relay assembly has SMA connections and uses RG316 minature coax to the PA & RX inputs and a Cellfoil 9006 lead back to the bulkhead N antenna connector.

(/~vk4adc/web/../23cminfo/100_4461mid.jpg)

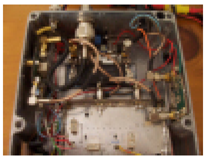
The PA PCB is actually mounted on the back flange of the box with the RA18H1213G mounted through a rectangular slot cut in the diecast box directly onto the heatsink extrusion.

(/~vk4adc/web/../23cminfo/100_4463mid.jpg)

This view shows the 1 watt TX driver PCB mounted on the side flange of the diecast box (again using thermal compound) and also provides another view of the slot in the diecast for the PA RF power block.

(/~vk4adc/web/../23cminfo/100_4464mid.jpg)

The sequencer is at RHS, LO surrounded by tinplate shield and the upper edge of the transverter PCB. The quick mid-air 20dB 3-resistor-attenuator was included at the TX IF port feed at the last minute to further reduce the drive from the TR751 IF source with it set for about 100mW output.

(/~vk4adc/web/../23cminfo/100_4465mid.jpg)

The "far end" view from a different angle.

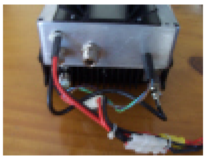
(/~vk4adc/web/../23cminfo/100_4466mid.jpg)

Upside-down with the "lid" on.

The adhesive rubber feet act as spacers off the top of the TR751A.

 (/~vk4adc/web/../23cminfo/100_4467mid.jpg)

Top view of the transverter shows the heatsink structure a little better. All screws used in the assembly were countersunk into the diecast material.

 (/~vk4adc/web/../23cminfo/100_4468mid.jpg)

External rear panel view.
3.5mm plug/socket to RHS for PTT and ALC,
centre N connector to antenna,
12V power in at top LHS and BNC below it for connection of the IF at 145 MHz.

 (/~vk4adc/web/../23cminfo/100_4469mid.jpg)

Front view of the transverter mounted atop the TR751A.
Red LED at top LHS is TX, green below it is just power on, red to their right flashes if the 3.5mm plug is not inserted into the rear panel socket. In other words, there is no RF power reduction through ALC in place - DON'T TRANSMIT !!!!

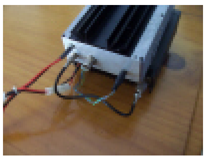
 (/~vk4adc/web/../23cminfo/100_4471mid.jpg)

RHS side view showing the 2 mounting flanges that hold the transverter onto the TR751A. In practice the transverter is a snug fit into the flanges so only one screw on each side is required, one front & one back.

Note - the flanges are just 90 degree angle pieces of aluminium stock and are screwed to the top of the TR751A via the original 4 top cover screws. No extra holes were drilled...

 (/~vk4adc/web/../23cminfo/100_4472mid.jpg)

LHS side view showing the flanges and, again, a single retaining screw in the front flange.

 (/~vk4adc/web/../23cminfo/100_4473mid.jpg)

Angled view of the rear shows the connections a little clearer. The transverter is fused separately to the TR751A before the power leads are joined to become a single overall lead to the power plug

That concludes this web page about the development of a working 23cm / 1296 MHz transverter. I hope my trials and tribulations have helped you work out your own methodology towards getting equipment built and working on this band. I also have to mention that being able to use equipment that you have built, even from a kit of parts, gives you some level of extra satisfaction and sense of achievement. It certainly has for me.

THE END