76 GHz and 122 GHz in a single Transverter.

After reading an Article (1) written by Kerry Banke – N6IZW, I became enthused with building gear for 47 GHz. It was not long however before I realised I had all the parts needed to build a 76/78 GHz Transverter instead.
This homebrew, Prototype Transverter is with just one exception - ALL Coaxial.

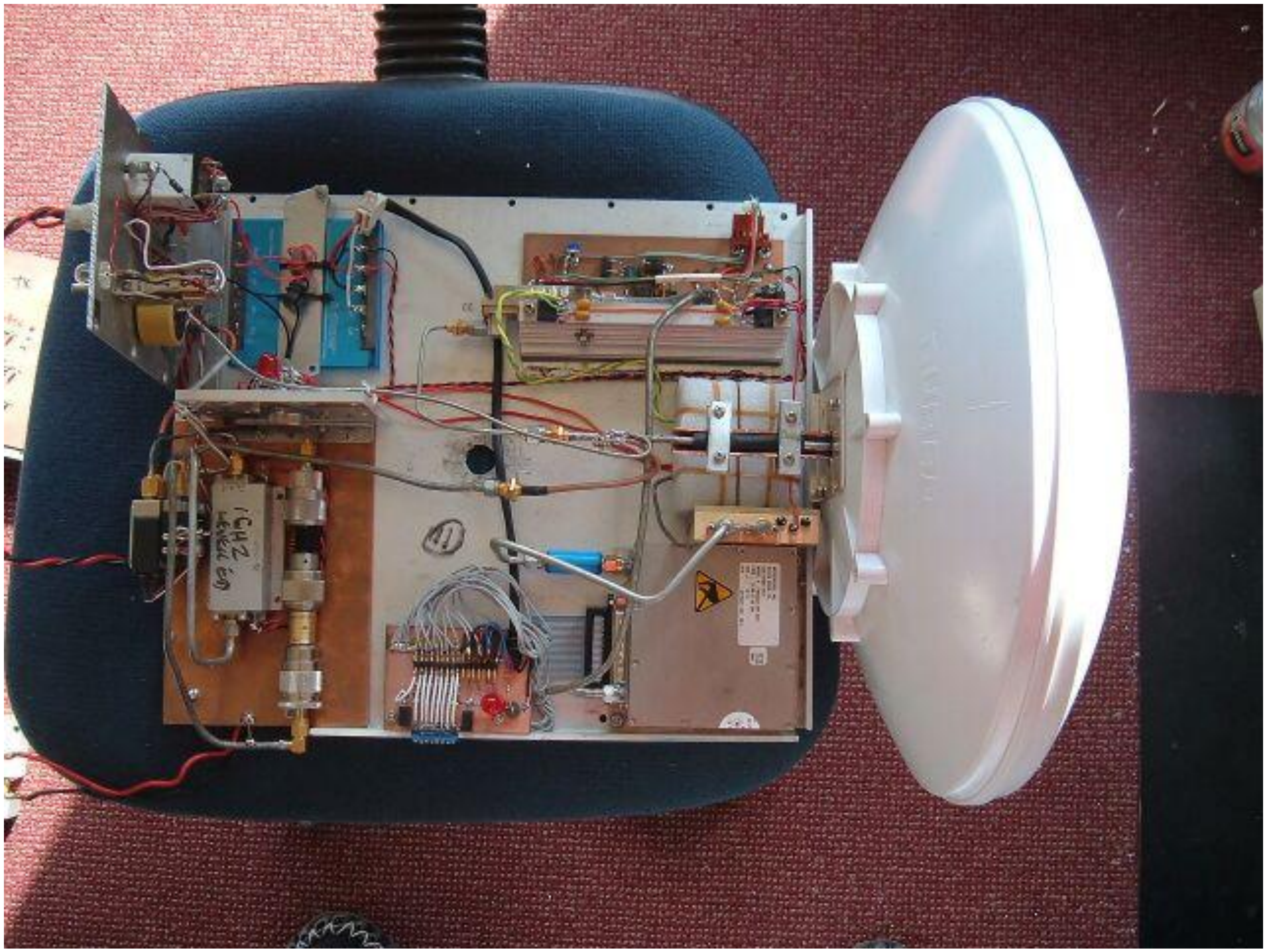
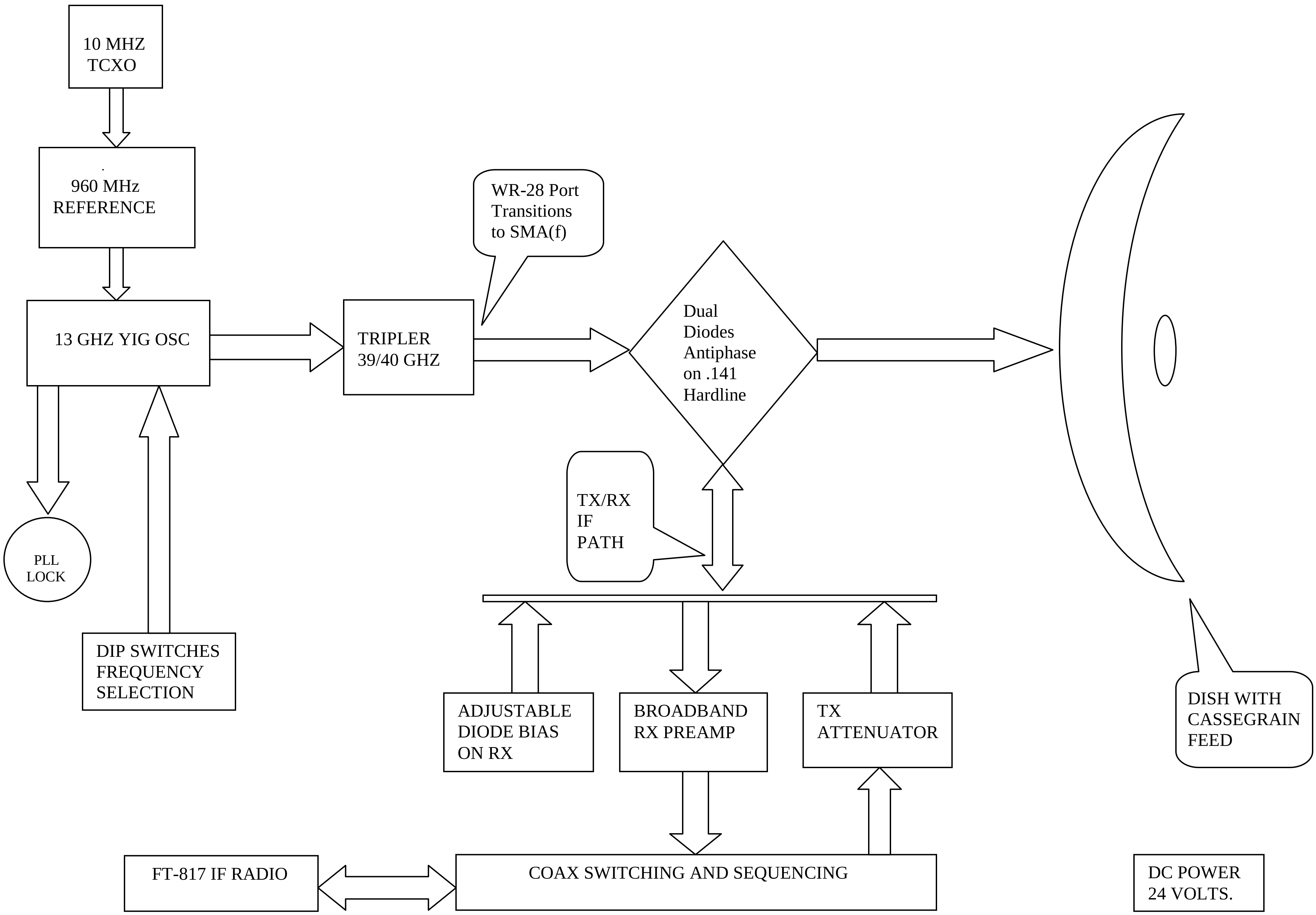


Figure 1

76 GHZ 122 GHZ TRANSVERTER BLOCK DIAGRAM



Two Prototype Transverters in Figure 1 were designed and built all within the space of 4 weeks. They still look a bit rough but of greater importance to me is that they “work” amazing well !

Referring to the Block Diagram, each Transverter consists of a DIP settable, Microsource 26 GHz YIG Oscillator. This Brick requires a 960 MHz Reference which is then TCXO Locked back to 10 MHz. By removing the internal passive Doubler, this now 13 GHz Brick delivers up to +16 dBm to drive a X3 or X4, 39/40 GHz Multiplier (CMA382400AUP) delivering circa 100 Milliwatts or +20 dBm.
This Multiplier with it’s WR-28 Transition is mounted upper right on the heatsink.
Some of you will recognise this Part Number as the same as Philipp – DL2AM has used in his 76/122/241 GHz hardware.

After Tripling, this 39/40 GHz signal exits through a WR-28 to SMA(m) Transition on the Output Port. Aside from this WR-28 Transition, on the CMA 39/40 GHz Multiplier, I have NOT used any Waveguide in my design. The RF is then fed coaxially to Pump a pair of Antiphase Diodes (surplus 14 GHz Mixers) mounted/soldered on the end of a piece of .141 Hardline. A photo of some prototype Mixers can be found later in this document.
A small flared Horn is fitted over these Diodes and this “Feed” is then slide through a rear dish mount and aimed at an integrated Cassegrain Reflector in the Radome of a 300 mm dish. The positioning of this Horn relative to the Diodes is VERY critical. Correctly positioned, a performance improvement of more than 15-20 dB can be expected. Signal Polarisation is still an issue, so rotating one “Feed” for optimum performance is necessary.
I have no idea what Polarisation I set my Feeds for. Horizontal or Vertical or Offset ? I would welcome comments on how can I determine this ?
Figure 2 shows the Cassegrain dishes during my early testing.

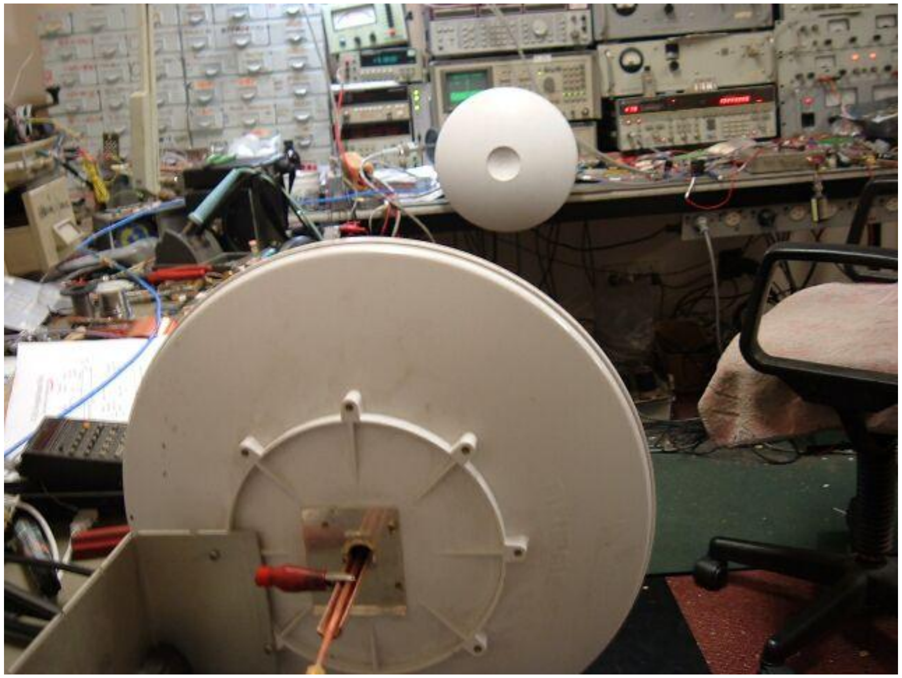


Figure 2

The Second Harmonic of 39 GHz is of course 78 GHz ! Figure 3 shows the unfiltered, Double Sideband signal. So, the 78 GHz Centre frequency with its 2 Sidebands, 144 MHz either side. The other signals to the right of the 78 GHz centre are “Mixer” products. They are NOT real !!
There are no constraints on the choice of IF Frequency or Operating Mode. HF through to UHF IF frequencies can be used within the constraints of the Mixing processes to create our LSB or USB. So, Oscillator plus IF when “mixed” must still be within our Band Allocation.

NOTE : I deliberately chose to use our VK 78 GHz segment because although the Microsource Brick will function (Lock) down to 12.65 GHz, I found the Output of the X3 CMA382400AUP Multiplier block was dropping away because it is operating towards it’s lower frequency limit.

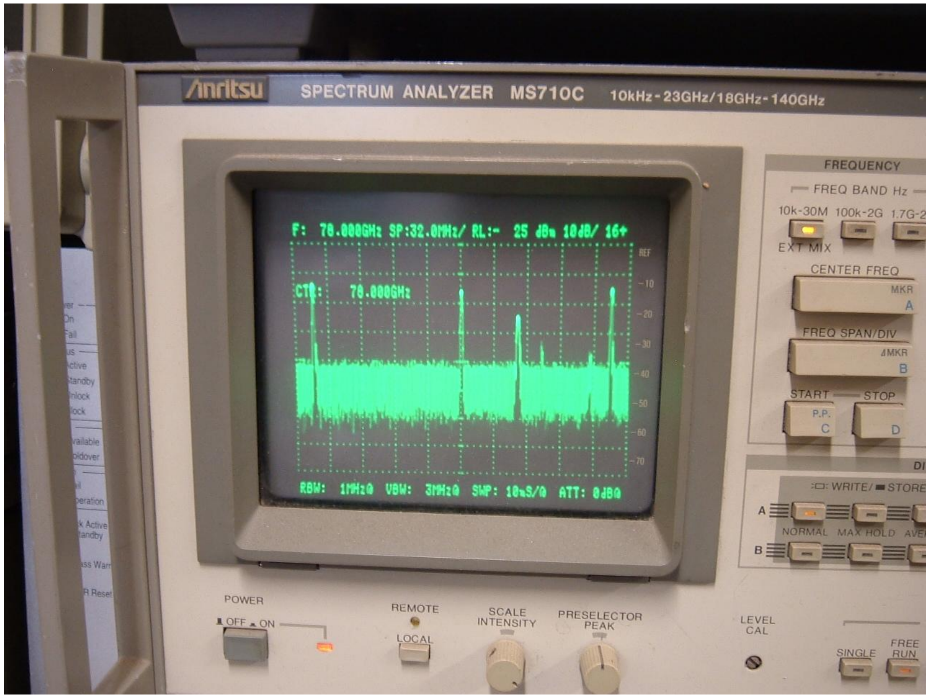


Figure 3

The IF connection for TX and RX is quite simple.
Referring to Fig 4, I cut a small hole in the .141 Hardline to expose the inner conductor near the SMA connector that couples to the X3 Multiplier.
I then soldered the braid of a thin flexible Teflon Coax (RG-174 or similar) along the side of the .141 copper jacket with the inner conductor in line/near this “hole”. This is the IF Cable. I then solder a short but very fine piece of wire from the centre conductor of the .141 to the junction of a 1nF capacitor and a 470 Ohm. The 1nF connects to the inner of the IF cable. DC isolation is necessary because the RX DC Bias (see below) via the 470 Ohm would be shunted. This thin IF connection forms an RF Choke @ 39 GHz but it allows 144 or 432 MHz to pass with minimal attenuation. For picture clarity, I’ve unsoldered the 470 Ohm and the bypass capacitor from the .085 Semi rigid Hardline supplying the RX DC Bias.

Figure 4

RX DC Bias for the Diodes.
The Multiplier diodes I have used to date are ordinary "leaded" Schottky units. Transverter RX sensitivity can be optimised considerably by setting/adjusting some nominal DC Bias to these Diodes. In my testing, I noticed that the optimum bias voltage is somewhat temperature dependent and the Diodes may also give greater efficiency (less loss) with either + or – Biasing. To achieve this, I used a 5K Ohm potentiometer with both +/- 5 volts WRT to earth on either end. The Lever with the series current limiting resistor (470 Ohms) connects to the centre of the Antiphase Diodes. Varying the Pot varies the voltage plus and minus. I also found a small value decoupling capacitor on this Bias Line at the IF connection point to earth improves the RX signal to Noise performance.

Standard Coaxial Relay switching is necessary.
On TX, the SSB Modulation from the FT-817 is switched and attenuated down to a few milliwatts. Between 0 dBm and +7 dBm works fine. I found if too much IF injection is applied, sensitivity (Diode response ?) is degraded giving reduced output.
On RX, a broadband RF amplifier is fitted in the RX path to improve the overall sensitivity. Figure 5 refers.

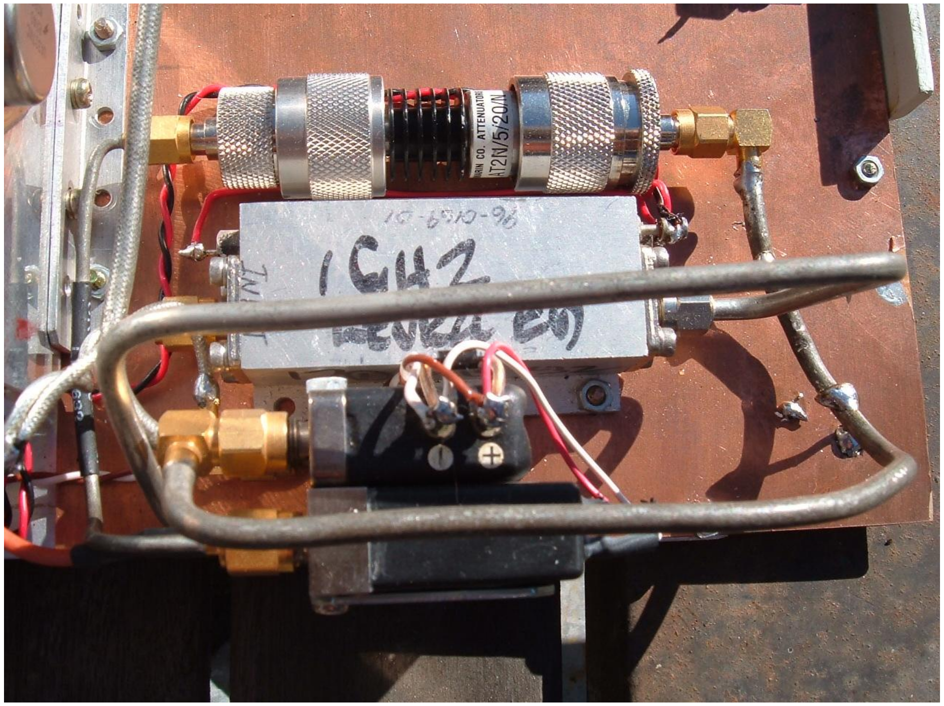


Figure 5

Output Power on 78 GHz.
The absolute Power level on 78 GHz is difficult to quantify. I don't think it can be measured easily. The "pumped" Antiphase Diodes are mounted on the end of the .141 Hardline and pushed into the dish at/near the Focal Point. Therefore, there are no coaxial or waveguide connections available. However, with both dishes pointing at each other and separated by 2 metres, using my homebrew uncalibrated Harmonic Mixers; I have measured at best on the Spectrum Analyser a level of -25 dBm on 78 GHz. Suffice to say that it is a whole lot less than ONE Milliwatt.

The first ever VK, 78 GHz QSO was conducted over a 1.5 Kilometre suburban path on August 3rd, 2011. The Operators were Alan – VK3XPD and Michael – VK3KH. This Record was extended a few days later to circa 12 Kilometres. Signal Reports over this longer path were 5+1 both ways.
One significant observation was quickly identified. The "pointing" of our small 300mm Dishes is extremely sharp on these higher frequencies.
As an investigative exercise, on the shorter path, we tuned up the Band to the 3rd Harmonic of 117 GHz signal. Although it was a very weak signal, it was quite audible. This clearly showed good prospects for operation on 122 GHz.

Now, being the "Devil's Advocate" perhaps some of you may be thinking that this could have been a 39 GHz QSO and not 78 GHz ?

In the course of developing this simple Transverter, I built up multiple sets/versions of homebrew Harmonic Mixers to test on my Spectrum Analyser.
A sample of my Prototypes can be seen in below. All these units worked well/OK with some variability.
I found the "leaded" Antiphase Diodes in the lower photo make excellent Harmonic Mixers.
For many of us, the likelihood of owning the rather expensive HP 1197X series of Waveguide Harmonic Mixers for V, E or W Bands is a "dream".
The techniques I have described here make it VERY easy for almost anyone to build their own Harmonic Mixers that are usable well beyond 100 GHz.
With my homebrew Mixers, I can now easily see these 78 and 122 GHz signals. In Bench testing, I have actually seen signals up to 140 GHz, the upper Frequency limit of my Anritsu MS710E Spectrum Analyser. Not bad for 14 GHz diodes !!

The absolute Conversion Loss may be unknown - but who cares !!
It's the ability to actually "see" and quantify these Frequencies. And best of all, these 100+ GHz Harmonic Mixers only cost a few $$$ to make.

Frequency determination.
There is another method of determining the Transverter operating Frequency.
I'm using 10 MHz TCXO's to "Lock" the 13 GHz Oscillators. There are however slight frequency differences in the TCXO frequencies. Therefore, the "Locked" 13 GHz sources are not identical in their output frequencies. Consequently, the Transverters have a frequency "Offset" or difference due to these very small TCXO frequency differences. The result, my Transverters have a circa 22 KHz difference between each 13 GHz Oscillator.
After the X3 multiplication of these "circa" 13 GHz signals, the frequency difference between the Transverters now equates to 66 KHz for the 39 GHz signal, 132 KHz for the doubled 78 GHz signal and finally 198 KHz for the 3rd Harmonic on 117 GHz.

For our 78 GHz QSO, one of our FT-817 IF's on 2 Metres was simply tuned 132 KHz higher (or lower for LSB) in frequency. So, with one IF Rig running a CW "Ident" on 144.150 MHz, the other IF Rig was tuned up to 144.282 MHz where the 2nd Harmonic 78 GHz signal should be.
Controversially, this also means that an IF to IF contact is NOT possible !
Interestingly, this frequency difference is an advantageous situation because if I had used GPS Locking on both Transverters... there would have been zero Frequency Offset/error. For this scenario, a 39 GHz contact (strongest signal) or worse, an IF to IF contact would have been unavoidable.

The "multiplication" technique I have used means that the fundamental 39/40 GHz "pump" signal is also radiated because RF filtering is not possible.
There is however an obvious benefit with this situation.
Being much louder than the desirable 2nd Harmonic, this 39/40 GHz signal can be used for initial Dish alignment/sighting and then we tune up the Band to the desired 2nd or 3rd Harmonic for 78/122 GHz, defined by the TCXO differences between the Transverters.
For shorter close in distances when initially testing the gear in the Field, using the 39/40 GHz signal is not really necessary because the 78/122 GHz signals are so much stronger closer in. However, over the longer distances, this technique of initially optimising our Dish Pointing using the stronger 39/40 GHz Injection signal worked VERY well for us.

After the success we had on 78 GHz, I started looking at the possibilities for 122 GHz.
Since there is no frequency limiting Waveguide used in my Transverter design, both Bands - 78 GHz (39.0 GHz x2) and 122 GHz (40.6 GHz x3) are potentially achievable with ONE Transverter by simply changing the 13 GHz Oscillator frequency. This is easily done by setting the Dip Switches.
There was one proviso – would the 14 GHz Antiphase Diodes generate enough 3rd Harmonic RF on circa 122 GHz ?

In VK, the 122 GHz allocation has a lower Band edge of 122.250 GHz. Using a 144 MHz IF, the Multiplier needs to deliver circa 40.75 GHz to the Antiphase Diodes. This frequency is towards the upper performance limit of the CMA382400AUP Multiplier. So, I decided to use a 435.15 MHz IF which pulls the "drive" frequency down to a more efficient operating point of 40.605 GHz. This equates to 13.535 GHz from the Brick.

Bench testing with my homebrew Harmonic Mixers on the Spectrum Analyser showed I had a 122.25015 GHz signal but it was quite weak.
I had also found the CTR960459102R01 X3 Multiplier performed better delivering more RF @ the higher end at 40.6 GHz than the CMA382400AUP Multiplier. It also needs less RF Drive than the CMA unit. Swapping the CTR unit in, I found a noticeable improvement in the 122 GHz signal strength.

In further testing on 122 GHz, I found that altering the RX DC Bias on the TX Unit (normally used for RX optimisation), delivered a slight improvement in the RX signal strength on the other unit. I'm not entirely sure why this Bias adjustment was beneficial/necessary. It would seem to indicate that I'm suffering from insufficient RF Drive at 40.6 GHz. This still needs further investigation.

My initial observation on 122 GHz was the faster frequency drift due thermal changes affecting the TCXO's.
IF Signal "wobbling" (quiver) on the audible tone was also much more noticeable on this 3rd Harmonic Signal. I was able to reduce the frequency drift somewhat by fitting a "heater" and more Insulation around the TCXO's.
The Signal "wobbling" is an interesting phenomenon.
On the Test Bench, once the TCXO's are up to "internal" temperature and therefore relatively stable, the "wobbling" of a GPS Locked IF signal (435.15 MHz CW Carrier) from the TX unit is quite noticeable on the 3rd Harmonic of 122 GHz.
It get's even more noticeable when I tuned up to the 4th Harmonic of 162 GHz.
Not surprisingly, I could not find a Signal at the 5th Harmonic of 203 GHz.

The first ever VK, 122 GHz QSO was conducted over a 1.5 Kilometre suburban path. Signal Reports were 5+1 both ways with some QSB.

So there you have it – a description of the techniques I used to develop ONE Transverter that will cover BOTH 78 GHz and the 122 GHz Bands.

In concluding this article - I hope the contents inspire a few of you to have a go at building homebrew 78/122 GHz gear !!!

Cheers,

Alan – VK3XPD

My Thank you's.

1. Kerry Banke - N6IZW, San Diego Microwave Group for his Technical article -
   A Simple Harmonic Mixer/Antenna Feed for 47 and 76 GHz Experiments.
   For more information, check out this Website... http://www.ham-radio.com/sbms/sd

2. Will Jensby - W0EOM for supplying the 39/40 GHz Multipliers.