Transverter Concept for 134GHz

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In the *Scatterpoint* January 2007 issue Sam, G4DDK, discussed a possible concept for a 134GHz transverter that based on the hope that the cheap multiplier CMA 382400AUP or S004079 (discontinued!) might also work on the frequency 33.7GHz. Philipp, DL2AM, checked this possibility, but found by measurements that the CMA 382400AUP is usable only for the output frequency range 37.8 to 40.8GHz. Thus it was not possible to realise the proposal from G4DDK. This is also the reason why 122GHz became the favourite band in Germany, and many construction articles were published by DL2AM and myself. Then the next project for DL2AM was the 241GHz band. But cancellation of the 145GHz band gave us *two* new bands, both 122 and 134GHz, so we really should try to use the 134GHz band also.

1. Frequency concepts

For the RX mixer two options are possible:

Option 1 — 22.3GHz (x 2) = 44.6GHz, (x 3) = 134GHz
Harmonic mixer, 3rd harmonic

Option 2 — 22.3GHz (x 3) = 67GHz, (x 2) = 134GHz
Harmonic mixer, 2nd harmonic
Subharmonic mixer

For the CW transmitter there is only one possibility:

22.3GHz (x 6) = 134GHz

With the usual diodes and the available power it is not possible to achieve sufficient power levels on 44GHz and 67GHz for further tripling and doubling, respectively. Thus it makes sense to use a different transverter concept.

2. Technologies

In my opinion in the near future there will be no cheap multiplier modules available on the surplus market for 44GHz or 67GHz which have the necessary output power of about 100mW. Thus there are only two possibilities at the moment:

1. There are chips available for the range from 38 to 44GHz which allow construction of amplifiers in wire bonding technique. For SSB and CW, they would give performance on TX like we have been able to reach on 122GHz. However, this possibility is probably an option only for few Microwave amateurs. See also the paper from DB6NT: (http://www.kuhne-electronic.de/de/shop/147_Transverter/article:134_MKU_47_G)
2. At 22GHz it is possible to realise output power levels of 100mW and more. On the RX side this allows the same sensitivity on 134GHz as we have on 122GHz. But on the TX side the construction of an SSB mixer for 134GHz is not an option due to the low power levels. Even for CW a loss of up to 16 dB vs. the 122GHz band has to be accepted.

I have chosen the second option and made intensive experiments, as this way can be followed by all interested microwave amateurs without any problem.

3. Examination of different modules

In total I built and tested 13 modules. The former experiences on 122GHz were very helpful here. As we are using 122.250GHz for narrow mode operation, we chose 134.250GHz accordingly.

3.1. The oscillator module

For the first experiments we did not use OCXOs but crystals which were heated to 40°C with the precision

crystal heater QH40A from DB6NT. For cooling the oscillator modules were screwed to a heatsink. One oscillator module was built with the LO PCB No.10 (PCB 12GHz LO MK4) and another with LO PCB No.24 (PCB 24GHz LO), both from DB6NT (Source 1). I made tests to see if the existing etched stripline filters for 12GHz and 24GHz could be used directly for 11.2GHz and 22.4GHz respectively. On the first board I also changed the 1520MHz Neosid helical filter to one for 1396MHz (this filter is available separately from DB6NT). The result was that both PCBs can be used without any changes. On 11.2GHz, 60mW output was instantly obtained using the parts as shown in the usual parts list. As this power is too high for many applications, the drain resistors from T10, T11 and T12 can be increased (by trial). For the 22.4GHz LO the doubler stage was a bit critical at the output, and here an optimisation was necessary with small flags. For the adjustment I used a tuned commercial WG filter with a flat top bandwidth of 100MHz (22.320 to 22.450GHz, insertion loss < 1dB). See Figure 1 and Figure 2. This filter has 5 chambers and 11 tunings screws and SMA input and output. I want to thank Francois, LX1DU who supplied this filter.

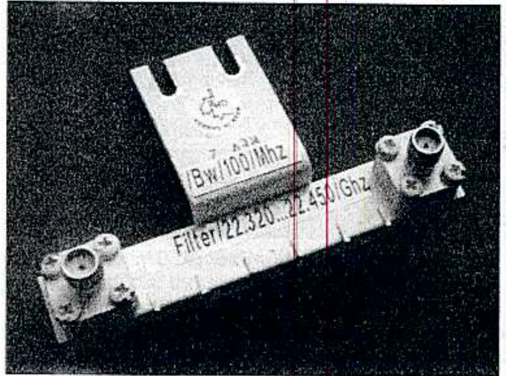


Fig. 1: Adjustment tool WG chamber filter for 22GHz

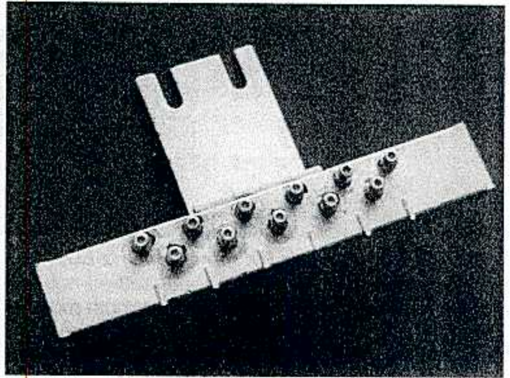


Fig. 2: Adjustment side of the WG filter

An output of 6.5mW output was achieved at 22GHz. This can drive a PA with 4 x NE 32584 C (PCB No. 13 – PCB 24GHz PA Ampl. Koax. from DB6NT) and gives over 100mW. If an 11.2GHz LO is used for the signal chain, a long doubler strip can be built with the two PCB No. 02 (PCB 12 / 24GHz Doppler) and No. 17 (PCB 24GHz PA Amp. HL in – koax out > Bake), also using 4 x NE 32584 C on the PA board. The assembled unit is listed as MKU X2 1224 in the catalogue from DB6NT and intended for 11 to 12GHz.

With 1mW input on 11.2GHz, 120mW output was obtained on 22.4GHz (Psat = 122mW). This was measured in the lab from DL2AM. I prefer this version of signal processing on 22GHz with > 100mW. Also this module was screwed to a heatsink.

3.2. Usability of available PCBs

In total there are currently 47 PCBs available from DB6NT. The next step was to check if there were any suitable for a 134GHz concept. At first version 1 was checked:

Doubler from 22 to 44GHz
PCB No. 33 - PCB 23 / 47GHz Doubler
Standard casing DB6NT (34 x 30 x 17 mm)
Varactor diode MA 46H146
Tuning element Tekelec 4.05 mm Ø (output)
Circular WG 4.5 mm Ø
Optimal tuning with additional flags
(Input stripline, stub extensions)

Harmonic mixer 44 to 134GHz
PCB No. 31 - PCB 120GHz Multiplier by 3
Special casing with short circuit slider for WR 28 (1)
(44 x 30 x 20 mm)
Mixer diode MA 1317

Tuning element Tekelec 1.8 mm Ø (output)
Circular WG 1.8 mm Ø
Optimal tuning with additional flags
(Input stripline)

Figure 3 shows the open 134GHz RX mixer for the 44GHz LO frequency. At the top left one can see the short circuit slider for the WR28 input next to the feedthrough capacitor and the IF jack.

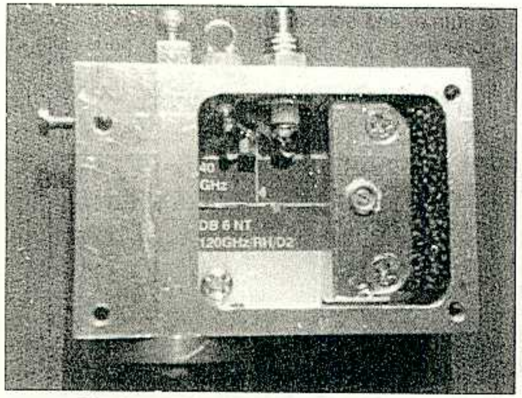


Fig. 3: 134GHz RX mixer (44GHz LO)

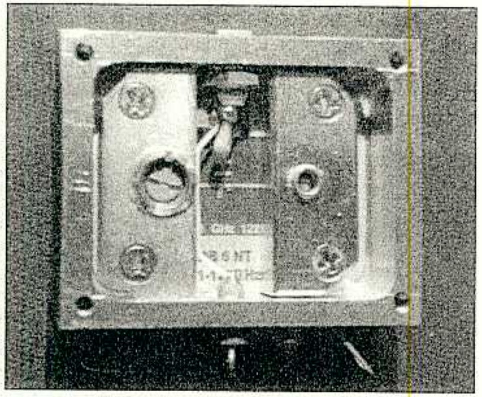


Fig. 4: 134GHz RX mixer (67GHz LO)

For more detailed examinations at first both modules should not be directly screwed together in sandwich structure. Thus for the preliminary connection a short piece of rectangular WG WR19 with flanges was used. The diameter of the circular WG was chosen for a good transfer from table data as follows:

43.0 – 50.0GHz = 4.78mm Ø
110.0 – 140.0GHz = 1.85mm Ø

The power on 44GHz has to be reduced a lot for best signal to noise ratio. This is possible very sensitively with the input short circuit slider of the mixer.

Now version 2 was checked:

Tripler from 22 to 67GHz
PCB No. 30 – PCB 25.3 / 76GHz Tripler
Standard casing DB6NT (34 x 30 x 17 mm)
Tripler diode MA 1310
Tuning element Tekelec 3.2 mm Ø (output)
Circular WG 3 mm Ø
Optimal tuning with additional flags
(Input stripline, output choke line)

(Table value circular WG: 66.0 – 88.0GHz = 3.18mm Ø)

Harmonic mixer 67 to 134GHz
PCB No. 40 – PCB 120GHz SHM-Mixer
Standard casing DB6NT (38 x 30 x 17 mm)
Mixer diode zero bias HSCH 9161
Tuning element Tekelec 4.05 mm Ø (input)
Circular WG 3 mm Ø
Tuning element Tekelec 1.8 mm Ø (output)
Circular WG 1.8 mm Ø
Optimal tuning with additional flags
(input stripline)

Figure 4 shows the opened 134GHz RX mixer for the LO frequency of 67GHz. For space reasons the feedthrough capacitor had to be placed on the opposite side. Also here a sandwich connection was not made at first, but the tripler and mixer were connected by a short piece of rectangular WG WR12 with

flanges. A significantly improved RX sensitivity was found here compared with version 1.

For both variants, separate IF preamplifiers were used with BFP 182 optimised for low noise. For adjusting the 22 to 67GHz tripler I have used a modified two stage resonator filter for 76GHz according to an OE9PMJ design. In order to get it in resonance on 67GHz, the volume of both chambers had to be reduced slightly by inserting M 2.5 brass screws from the bottom, and the drillings were enlarged to 1.5mm diameter. LX1DU measured the filter and the insertion loss was 5dB on 67.150GHz, the 3dB bandwidth was 600MHz. See Figure 5.

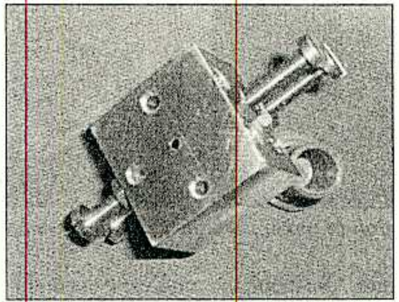


Fig. 5: Modified resonator filter for 67GHz

Intermediate result for the PCB usability
I concluded that the selected PCBs from the DB6NT list can be used for the realisation of both variants. Only the tripler PCB No. 30 is a bit problematic. DL2AM measured 12 dB suppression of the unwanted 44GHz signal for my module.

4. Comparison of the mixers of variants 1 and 2

For this test a controllable signal generator is necessary. Experiences from 122 and 241GHz showed DL2AM and me that an optimal adjustment of the mixer is only possible if a strongly attenuated signal on the final frequency is fed directly by a suiting piece of WG into the mixer and the received signal is being analysed properly on the IF side. This method is called also "IF tuning method".

4.1. My IF method

If possible the ALC of the driver transceiver should be switched off and the AF voltage should be displayed through a diode on a µA meter. For setting to zero the AF control of the driver is used.
When comparing different mixers the mixer input signal has to be always the same level, also the amplification of the driver has to be always the same. This can be done by simply inserting a 100Ω potentiometer into the IF line for compensation of different gains. One should start with the mixer that is assumed to be the worse one and adjust to best signal to noise ratio with the oscillator power level and the working resistance of the mixer diode. Experience shows that the mixer noise should only be slightly above the additional noise of the IF preamplifier. The signal from the generator is attenuated until it is just still audible in the noise of the transceiver. Then the better mixer is taken and at the same signal generator output level one will hear a significantly stronger signal and a see a larger readout on the µA meter. By inserting defined attenuator elements on the IF side the received signal is reduced until it is again just audible in the noise. One will notice that one S unit on the S meter of the transceiver will be in most cases not equivalent to 6 dB! If a measuring transmitter is available, the S meter could be checked properly and calibrated).

Thus with simple means and without a noise source for 134GHz we can make an approximate statement about the sensitivity difference between the different mixer systems. This method is really laborious and takes much time, but delivers quite reliable results.

4.2. The signal generator

The 22GHz LO module was connected directly to an infinitely variable 0 to 20dB attenuator from Narda (Type 26410, 7 to 18GHz). Then follows an old x6 multiplier (24 / 145GHz) with a HSCH 9191 from my former 145GHz station. From the x6 multiplier the signal is fed to the mixer through about 70mm of rectangular WG WR7 with flanges. Figure 6 shows the lab assembly for the mixer version 1. Figure 7 shows the same assembly for the RX mixer version 2.

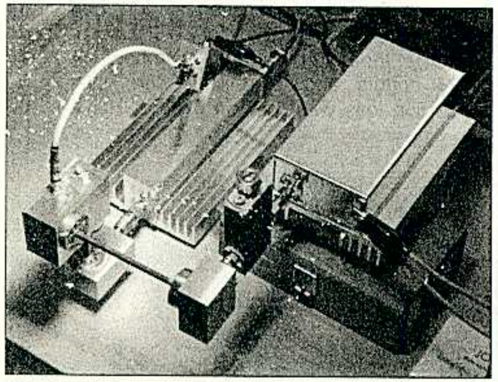


Fig. 6: Lab assembly examination of mixer version 1

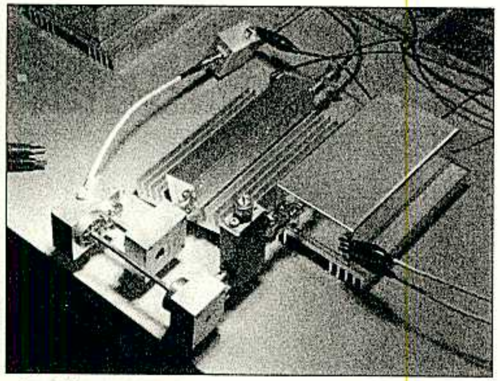


Fig. 7: Same for mixer version 2

On the right sides of Figures 6 and 7 one can see the signal generator consisting of the LO, attenuator and x6 multiplier. On the left side one can see the corresponding RX mixer with separate IF preamplifier.

5. Result and comparison of both mixer versions

The signal processing for version 1 is more simple regarding the adjustment, but is significantly less sensitive than version 2. The differences are very similar to the results I got from my comparisons on 122GHz (2). Using the "IF method" I found for version 2 an improvement of about 8dB for the S/N ratio. Thus this version will be preferred for a later transverter construction into a casing.

Values of the operating point adjustment for best S/N ratio with the zero bias detector diode HSCH 9161 were: Ra = 330Ω, U = 0.07V and Iq = 215µA. These values are just an indication, and may alter depending on the LO power level, frequency and diode variations. According to my experiments with this diode used as a mixer the working resistance Ra may be even below 100Ω and the diode current may be even below 100µA. For any assembly the optimal values have to be determined again experimentally.

Figure 8 shows both input sides of the mixer version 2 with the flange mounts. Due to the fixed distance on the glued PCB between the 67GHz LO input and the 134GHz input, one of the flanges had to be cut a bit. I chose the LO input.

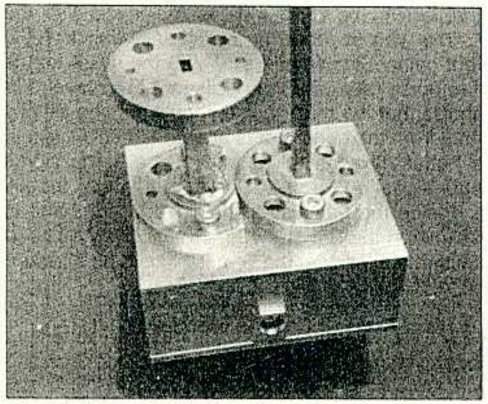


Fig. 8: Mixer version 2 with LO port and RF port

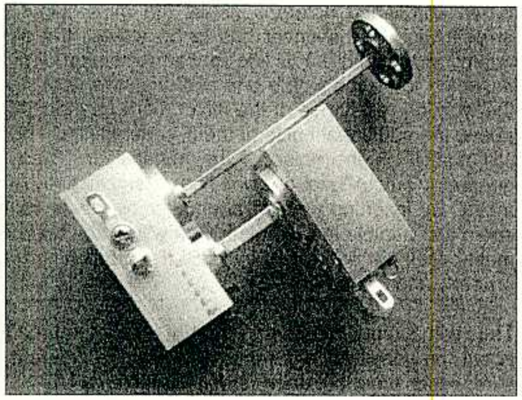


Fig. 9: Complete RX mixer head with tripler

The complete RX mixer head with tripler, prepared for mount in a casing, is shown in Figure 9. The IF preamplifier is fixed separately in the transverter casing and connected with a short Teflon cable.

As all parameters are determined now, I plan a second assembly in sandwich structure with an intermediate flange with circular WG drilling. This way was realised already for my last RX mixer on 122GHz (2).

6. The CW transmitter

6 times multiplier 22 to 134GHz
PCB No. 32 – PCB 120GHz Multiplier by 5
Standard casing DB6NT (34 x 30 x 17mm)
Multiplier diode MA 1310
Tuning element Tekelec 1.8mm Ø
Circular WG 1.8mm Ø
Optimal tuning with additional flags
(Input stripline)

The x6 multiplier is driven by a long doubler strip as shown in Figure 6 and Figure 7. With 120mW input DL2AM has measured the following values:

Pout 134GHz	19.0µW
Suppression of 5 x 22.4GHz (112GHz)	6dB
With additional flange with 1.6mm drilling as filter:	
Pout 134GHz	14.3µW

The additional flange suppresses the unwanted 112GHz signal significantly better but also the wanted 134GHz signal is getting attenuated as the diameter of 1.6mm is not optimal for 134GHz. As the 112GHz signal is not received from the other station due to the RX mixer concept, the additional flange is not necessary.

Figure 10 shows the open x6 multiplier from 22 to 134GHz. Optimal working point adjustment for this unit were: Ra = 10Ω, U = 0.35V, Iq = 35mA. Also for the x6 multiplier the PCB from DB6NT can be used.

Although at first glance the obtained power level may seem very small, one should not compare this with the possibilities on 122GHz (see fundamentals in section 2). This should not be any reason not to undertake any attempts on the 134GHz band! The power level here is the same as we had on 145GHz before this band was lost, and under these circumstances DB6NT achieved in 1997 a long-standing world record of 53km.

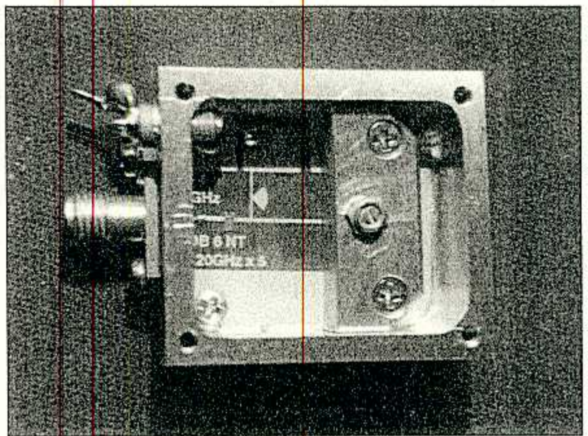
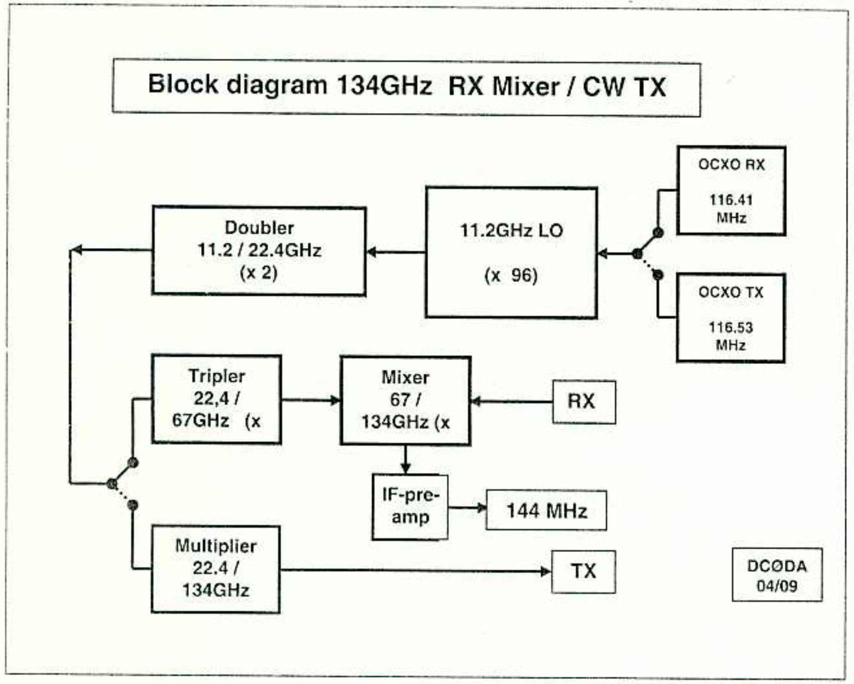


Fig. 10: 6 times multiplier from 22 to 134GHz

7. Suggestion for a transverter assembly with separate RX mixer and CW transmitter

A simple block diagram explains the concept:



When using 144MHz IF the following crystal frequencies result:

OCXO RX	OCXO TX
Q 116,41145MHz	Q 116,53645MHz
Pout 1mW	Pout 1mW

Both OCXOs are switched via a small card relay to the input of a 12GHz LO (DB6NT, version for 11.2GHz). The LO module is broadband enough and delivers on RX the frequency 11.1755GHz and on TX the frequency 11.1875GHz. The output power should not exceed 10mW, as the FETs in the following doubler strip from 11.2 to 22.4GHz show significantly more gain than on 24GHz. Also this frequency doubler is broadband enough (RX 22.351GHz, TX 22.375GHz). Always output power levels of more than 100mW were obtained at 22GHz. At the output of the frequency doubler an SMA relay is directly screwed on. This relay should have less than 1dB insertion loss on 22GHz. On RX the SMA relay switches the output from the doubler into the tripler from 22.351GHz to 67.053GHz, which directly drives the RX harmonic mixer to 134.106GHz. On TX the SMA relay switches the 22GHz drive to the 6 times multiplier from 22.375GHz to 134.250GHz. Both final modules are attached directly on the back cover of the transverter box. For RX and TX the parabolic dish is changed manually. This is no problem with a dish diameter of 25cm (PROCOM dish). This is also the way I work on 122 and 241GHz. Due to the solution with the two relays, only a minimum of single components is necessary. For sure there are also other ways.

8. Results

Two almost identical transverters were built. For the second one I used modules from my old 145GHz transverter which were slightly modified in the frequency processing. Unfortunately the old mixer was much worse on 134GHz than the new one, but was used for first tests. Figure 11 shows the new first transverter built according to the above block diagram. One can spot the different modules easily.
Using a power FET one can key the long 11/22GHz doubler strip without clicks for driving the 6 times multiplier. A switch on the front enables a permanent signal for adjusting the antenna. A tiny push button on the front may be used for CW in case they key was forgotten at home! A µA meter shows the current of the mixer diode or the diode current of the 6 times multiplier on TX. Figure 12 shows both 134GHz transverters ready before the first test.

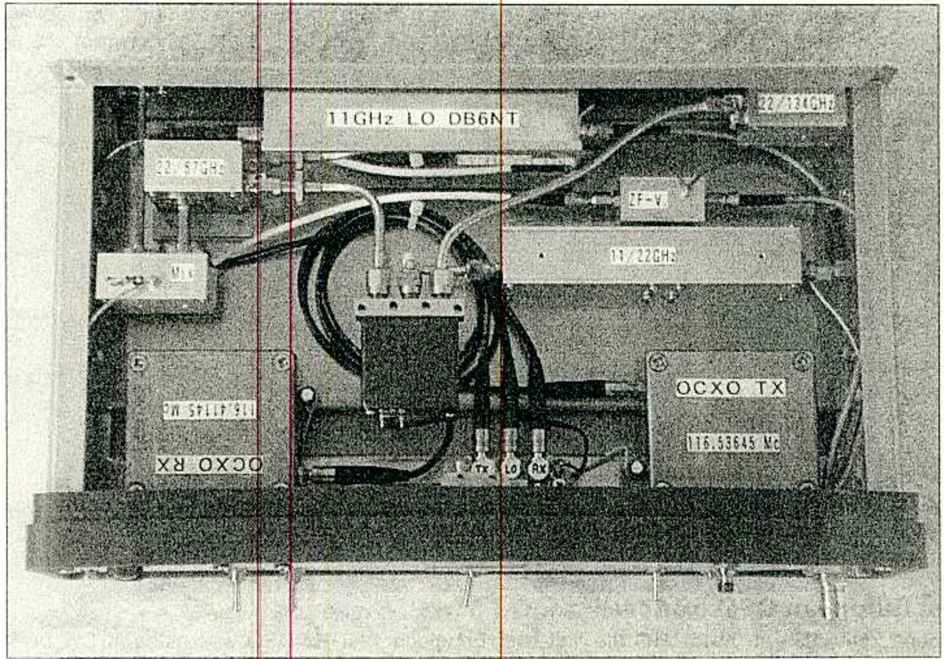


Fig. 11: Ready 134GHz transverter

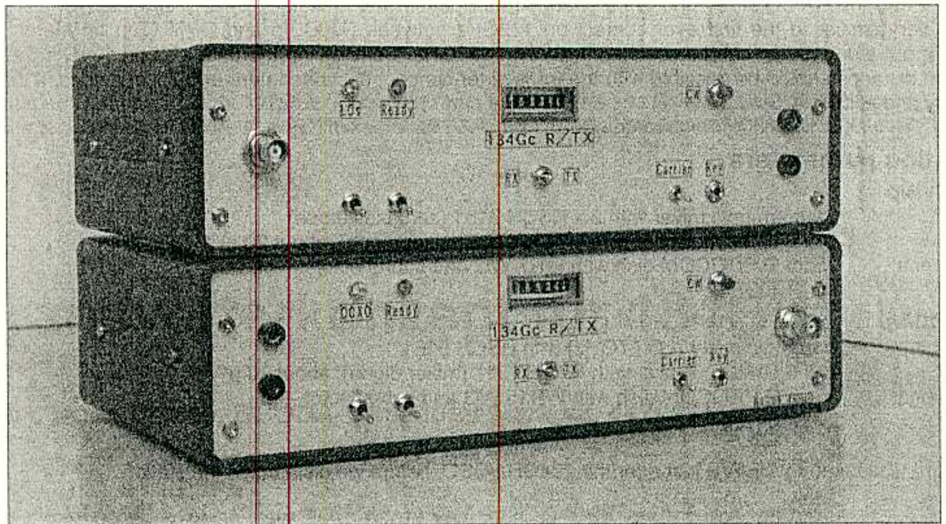


Fig. 12: Both 134GHz transverters

It is well known that for QSOs on these extremely high frequencies the path should be tested first, and the antennas should be aligned on a lower band. I always make these tests on the 76GHz band using an aluminium bar on which two transverters are mounted. Figure 13 shows both transverters, for 76GHz and 134GHz, mounted on the head of my tripod.

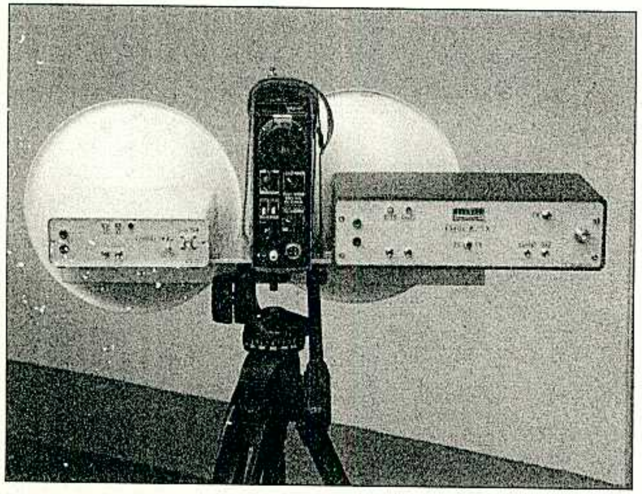


Fig. 13: 76GHz transverter (right) and 134GHz transverter (left) on the mounting bar of the tripod. Both dishes are 25cm Ø. In the middle is the 144MHz driver, an IC202.

First European QSO on 134GHz

On June 26th 2009 at 09:15 UTC the first ever European 134GHz QSO was made in CW between DF6VB/p and DCØDA/p over a flat 1km path distance in JO31RQ. Humidity was 78% and temperature 28° C, so not quite optimal conditions. The small distance was chosen because we wanted to get familiar with the new rigs first. We found that the second transverter with the old modified modules was much worse and the RX mixer needed to be changed to a better one. This first 134GHz contact over just 1km was very similar to the first ever contact on 122GHz between DJ6BU/p and DH6FAE/p on March 28th 2005; but today, 50km can be reached in CW on 122GHz. Considering the path loss on 134GHz, about 20km distance should be possible with the transverter concept described here and 25cm dishes, if the air is dry and cold.

Station parameters

DF6VB/p

RX:	Subharmonic mixer with 2 x HSCH 9161 (zero bias diode)
TX:	CW 6 times multiplier with HSCH 9101 (mixer diode), about 20 µW
Antenna:	25cm Ø PROCOM dish with WR7 WG and subreflector
RST	for DCØDA/p 5 3 9

DCØDA/p

RX:	Harmonic mixer (LO 67GHz) with HSCH 9161
TX:	CW 6 times multiplier with MA4E 1317 (mixer diode), about 20 µW
Antenna:	25cm Ø PROCOM dish with WR15 WG and subreflector
RST:	for DF6VB/p 5 6 9

Fig. 14 was taken by DF6VB just after the 134GHz QSO, before we dismantled the station.

Remark

Unfortunately I only had a 145GHz dish with WR7 WG available, so on my station I used a dish with WR15 WG which is normally my 'combi' dish for 47GHz and 76GHz. I had already discovered on 122GHz that the over-sized WG also lets pass higher frequencies without any losses that I could measure.

Conclusions

I need to find diodes with a better efficiency for the 6 times multiplier. Also the next tests should be made when the air is cold and dry. According to all my experiences on 122GHz I do not think that it is possible to improve the RX mixer any more.

I hope this article will inspire others to make experiments on our barely 134GHz amateur band. I want to thank the following amateurs for their help realising this concept: Karl Ochs, DJ6BU, for milling the casings; Philipp Prinz, DL2AM, for detailed measurements; Francois Cronauer, LX1DU, for providing and measuring the adjustment tools; and Michael Kuhne, DB6NT, for providing the special helical filters.
Vy 73 + 55 de DCØDA.

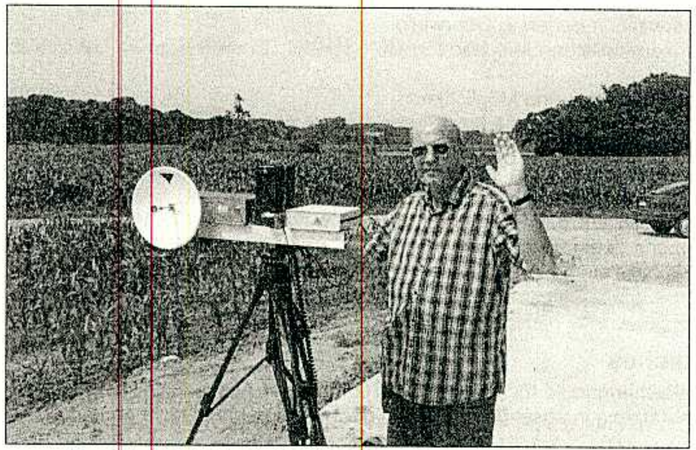


Fig. 14: DCØDA/p in JO31RQ just after the 134GHz QSO

Sources

(1) Kuhne Electronic GmbH, Scheibenacker 3, 95180 Berg / Oberfranken, Tel. (0 92 93) 80 09 39, Fax (0 92 93) 80 09 38, www.kuhne-electronic.de, www.db6nt.de, info@kuhne-electronic.de

Literature

(1) Jürgen Dahms, DCØDA: 122GHz Transverter with separate TX and RX part, DUBUS 1/07, p.48
(2) Jürgen Dahms, DCØDA: New RX mixer for 122GHz with 10dB improvement, DUBUS 2/08, p.47

Transverterkonzept für 134GHz

von Jürgen Dahms, DCØDA, Vinklöther Mark 48, 44265 Dortmund

In der Info Scatterpoint January 2007 wurde von Sam, G4DDK ein mögliches Konzept für 134GHz diskutiert, welches auf der Hoffnung basierte, dass der preiswerte Multiplier CMA 382400AUP oder S004079 (nicht mehr lieferbar!) auch noch im Frequenzbereich von 33,7GHz arbeitet. Sehr bald stand durch Messungen von Philipp, DL2AM, fest, dass der Multiplier CMA 382400AUP nur für einen Ausgangsfrequenzbereich zwischen 37,8 und 40,8GHz einsetzbar ist. Damit war der Vorschlag von G4DDK so nicht umsetzbar. In DL wurde deshalb von Anfang an das 122GHz Band mit Erfolg favorisiert und etliche Bauvorschläge von DL2AM und mir veröffentlicht. Danach widmete sich DL2AM dem 241GHz Band. Bewusst wurde das 134GHz Band vorerst ignoriert. Da wir durch den Wegfall des 145GHz Bandes die Frequenzbänder 122 und 134GHz neu bekommen haben, sollten wir aber dennoch experimentell auch das 134GHz Band nutzen.