Techniques for 47 GHz & up

Updates and additions to the 47 GHz transverter from DUBUS 3/2015: RF and NF measurements, a homemade attenuator and feed matching.

by Philipp Prinz, DL2AM

I want to report some findings and additions to the 47 GHz transverter that I described in Dubus 3/2015. This consists of a mixer with two MA4E1318 antiparallel diodes and an amplifier from DB6NT with a mechanical changeover (see Fig. 1). With this setup a lot more experiments and measurements can be made.

The noise figure of this mixer alone, with its IF amplifier, but without a 47 GHz filter, is about 18 dB (DSB) for an LO power of 110 mW on 23.472 GHz. With 90mW of LO the NF is about 15dB and with 50mW just about 11dB (DSB). The 18dB NF does not need to be taken into account if an amplifier with 23dB gain is used. In this case the NF is almost the same as for the amplifier, measured at the input of the amplifier on receive. See Fig. 2.

It is not good to use the mixer and not lower the LO power on RX, as then the poorer NF would be in effect. The same scenario is known from the setups for 76, 122 and 241 GHz that I described in my previous articles. There is an easy solution, lowering the 5-6 V DC for the CMA 382400 AUP multiplier to 3.2-3.5 V on RX with a small additional circuit. Unfortunately there are no such multipliers for 47 GHz.

Note: If the WGs from an amplifier with mechanical changeover do not fit totally parallel to each other, or there is a small gap of about 0.1mm between the amplifier and turning plate, there is hardly any deterioration measurable. Possibly thermal transfer from the amplifier to the rotary plate might suffer a bit.

I wanted to make some measurements of the maximum RF output, but both my HP Q8486 and Anritsu MP715 measuring heads have a maximum power input of 100 mW. A 20 dB coupler like a HP U752 (WR19) would be needed, or a suitable attenuator could be used. I chose to construct the latter myself. I disassembled some WR15 and WR42 variable attenuators and discovered that the attenuating sheet had the shape of a slowly rising curve, perhaps to enable fine adjustment of the attenuation. I constructed a similar assembly into a WR 19 waveguide by milling a 0.2 mm wide slot into the E plane of the WG. I soldered a tiny copper sheet to both sides of the slot, having first put two razor blades in the milled slot in order to prevent solder entering the slot. See fig. 4.
When I calibrated this homemade attenuator, I noticed that inserting the sheet further into the waveguide led to a significantly lower displayed power level. It was an easy task to adjust to 6 dB attenuation. The sheet was secured between the two clips with a locking screw. So, I was finally able to measure the output power of the 47 GHz transverter with the 100mW measuring head.

Good quality mica sheet could also be used as the attenuation element. Mica is able to dissipate the heat that is generated by the RF, which is very important. The two clips that are soldered to the WR19 waveguide transfer the heat away from the attenuator element. It is important that the attenuation sheet has good thermal conductivity, as this determines for the most part how much RF can be applied to the attenuator.

I took the opportunity to compare three different measuring heads: an Anritsu MP 715 A (40-60 GHz), a Hughes (40-60 GHz, WR 19) and an HP 8486 A with a WR 22 to WR 19 taper. I used my HP 83650L as a signal source. I was surprised to find only small differences in the measured power between the three heads, even at different power levels.

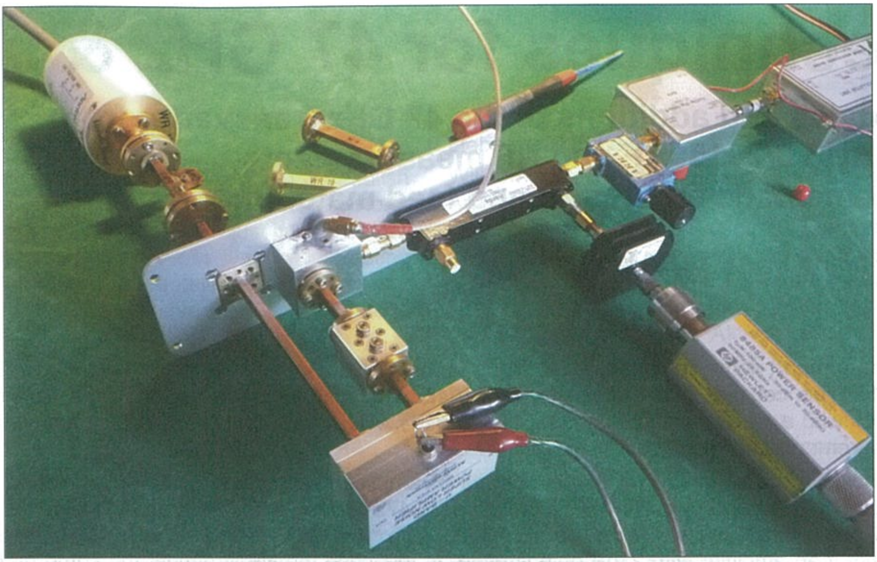

Fig. 1: 47 GHz transverter with amplifier and mechanical changeover

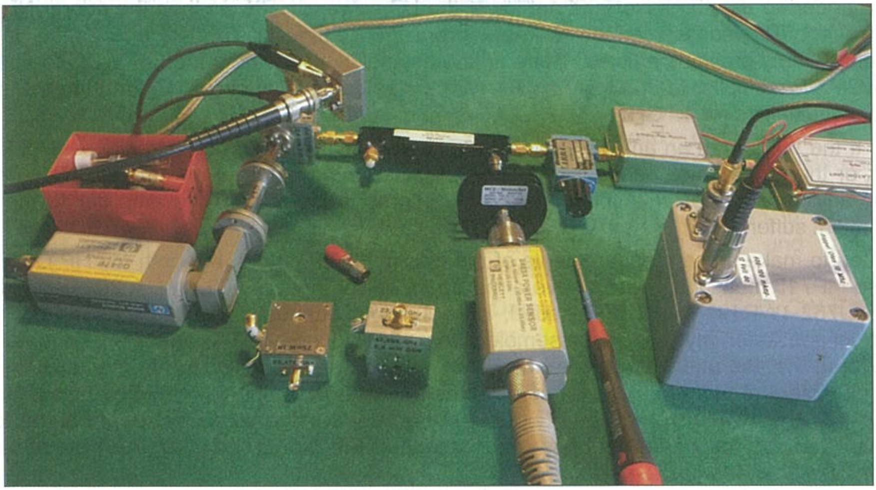

Fig. 2: NF measurement of the 47 GHz mixer from DL2AM

Here are some measurements of the 47 GHz transverter, as described in , DUBUS 3/2015, with a steep-sided 47 GHz filter attached):

144 MHz IF power		set to	16 mW
Mixer output power DSB		set to	3 mW
IN	changeover amp	set to	1.1 mW USB
OUT	changeover amp		250 mW USB (see figure 6)

A NF of 5.95 dB was measured using a narrow-band filter, HPQ 347B noise source and a WR22 to WR19 taper.

The suppression of all sidebands was measured as better than 40 dB.

Fig. 3: 47 GHz coupler and homemade 6 dB WR19 attenuator

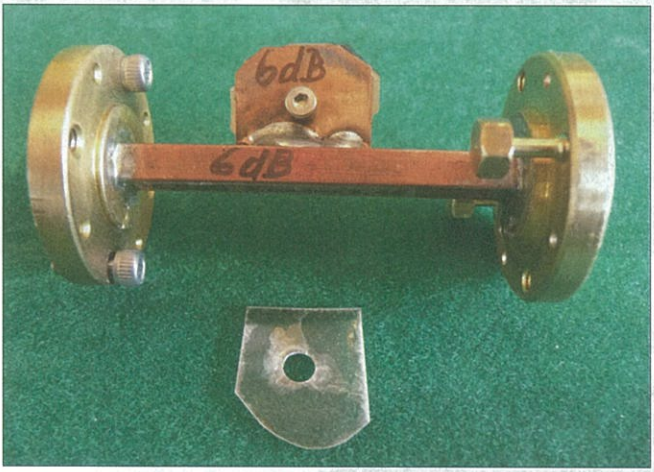

Fig. 4: Homemade 6 dB attenuator, close-up view

I also built three more 47 GHz mixers, each using one MA4E1318 diode and measured them. The results for all of them were very similar. The LO input on 23.472 GHz was 75 mW, IF power on 144 MHz was 20 mW and the output on 47.088 GHz was 2.6 mW DSB. These results indicate that the conversion losses are not too bad. See fig. 7. The results of noise measurements were similar for all three mixers. With an IF amplifier and a high LO power of 70 mW, I measured 13.5 dB NF. I also wanted to determine the sensitivity limit of these mixers, so I fed a signal of -128 dBm at 47.088 GHz to the input. I found that a CW QSO would be easily possible with a FT-290R and a 2.4 kHz bandwidth under these conditions. See fig. 8.

I made some matching tests with a 25 cm Procom dish using simple Cassegrain and shepherd's crook feeds without a front flare, on both 47 and 76 GHz. For this purpose I used an HP U752 WR19 -20 dB directional coupler and an isolator on 47 GHz. On 76 GHz I used two -10 dB WR12 couplers in series and a suitable isolator. See fig. 9. Waveguide couplers have a high directivity greater than 40 dB. This helps to reduce measurement errors. As a signal source I used my transverter, which delivered enough power on 47 GHz and a HPQ8486 power head with a WR22 to WR19 taper. For a simple Cassegrain system, I found that on 47 GHz the best match occurred at a distance of 7.2 mm between the waveguide and the sub-reflector disk. Unfortunately this is not close to the value for best illumination - that is 6.6 mm. Moving the reflector has big effects: A change of 1/10 mm may change the matching by about 10 dB. At optimum (about 7.2 mm) the return loss is about 31 dB. See fig. 10. When using a WR19 shepherd's crook feed with a non-flared aperture, the return loss is about 13.1 dB, regardless of if the feed is at the focus or not. See fig. 11. I made the same tests on 76 GHz. I used two 10 dB WR12 directional couplers together, one in forward the other in reverse direction. See fig. 12. An Anritsu MP717A display was used. The signal source was a 76 GHz mechanical changeover transverter. First, a simple WR12 Cassegrain system was examined. Again, I moved the reflector disk back and forth. The best match was a return loss of 32 dB at a distance of 6.62 mm between waveguide and disk. This also means an optimal illumination of the dish. Finally, a WR12 shepherd's crook feed, without a flared aperture, was tested. The values were similar to those on 47 GHz: a return loss of 13.3 dB was measured. This was predicatable.

Fig. 5: Comparison of 3 different measuring heads on 47 GHz

Fig. 6: Output power measurement of the 47 GHz transverter using ahomemade 6 dB attenuator

Finally, I want to remind you that that the MA46H146 varactor diode can cope with a high LO input power of up to 140 mW. I would also like to pass on the hint not to forget good old colophony (rosin) when soldering small parts. It is of great help and the residue can be easily washed away.

Such experiments are quite time-consuming and my fingers got tired from all the screwing and unscrewing. However, it was important to me to determine all these figures. There is always something new to learn that is interesting, both for me and I think o for other microwave enthusiasts as well.

Literature

Philipp Prinz, DL2AM: A 47GHz Transverter – with mechanical changeover, DUBUS 1/2010, pp. 32 and DUBUS Technik 10, pp. 257

Philipp Prinz, DL2AM: Doubler from 23.5 GHz to 47 GHz, DUBUS 4/2013, pp.9 and DUBUS Technik 13, pp. 207

Philipp Prinz, DL2AM: 47 GHz Transverter, DUBUS 3/2015, pp. 9.

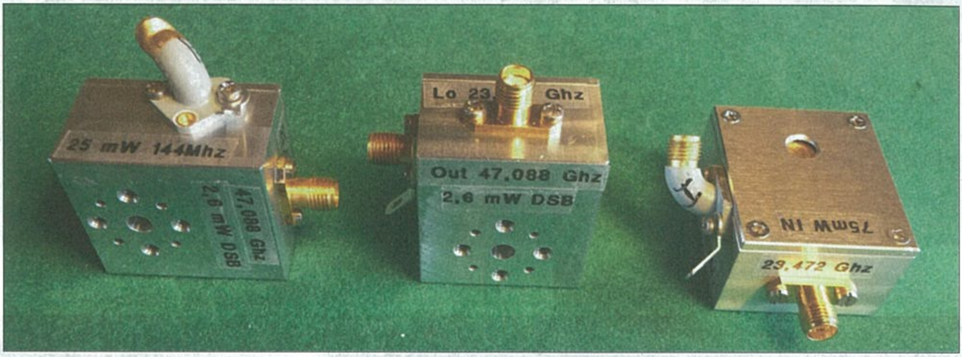

Fig. 7: Three 47 GHz mixers, ready for measurements

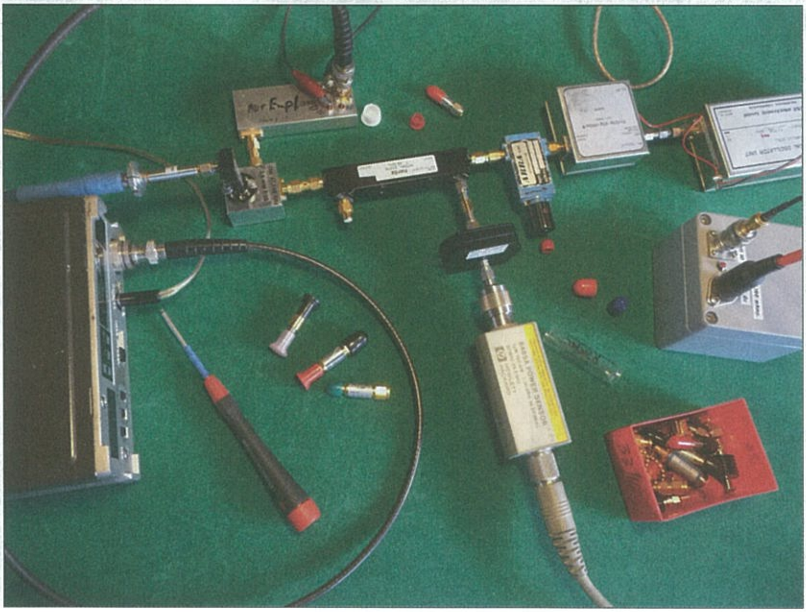

Fig. 8: Setup for measuring the sensitivity limit of the 47 GHz mixer

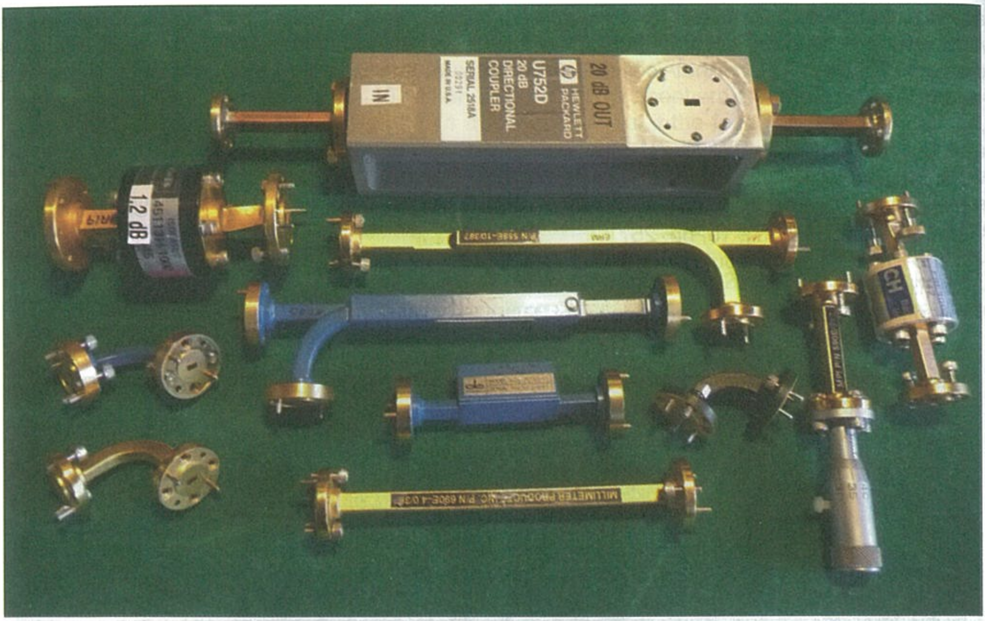

Fig. 9: Couplers for 47 GHz and 76 GHz and measuring equipment

Fig. 10: 25 cm parabolic dish from Procom with WR19 Cassegrain feed for 47 GHz

Fig. 11: Procom 25 cm dish with WR19 shepherd's crook feed

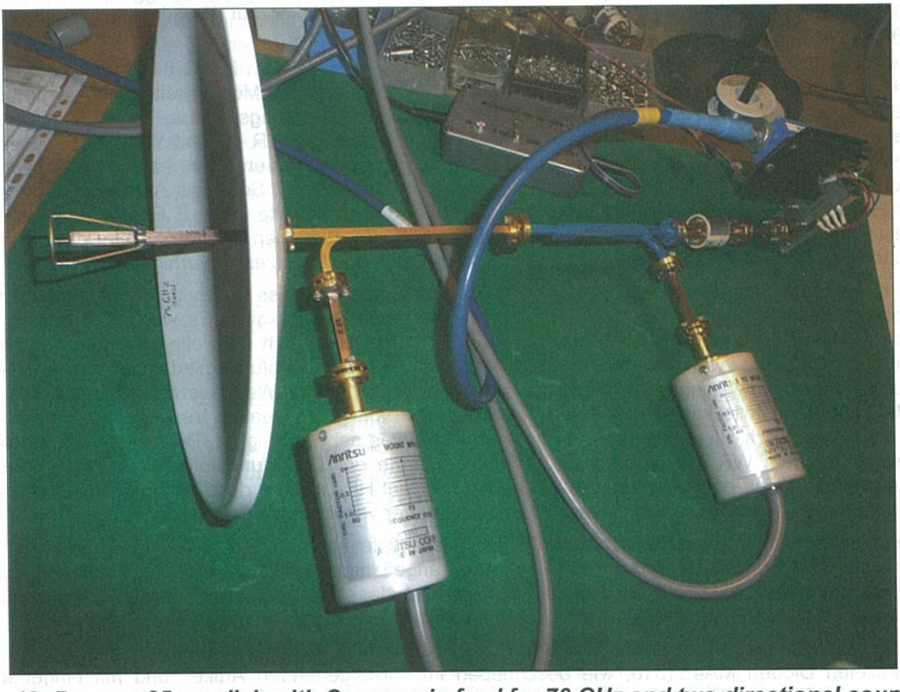

Fig. 12: Procom 25 cm dish with Cassegrain feed for 76 GHz and two directional couplers