"My attempt to build a 5W SSPA 76GHz"

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Swedish EME Meeting

Örebro 2019

Why SSPA?

- The first successful EME echo test and the first one-way EME test on 4mm band were done in 2013.
- Why is there still no two-way EME QSO?
- No high power TWT's or Klystrons are available on this band.
- The only way is to build SSPA.

How much power we need?

Successful EME echo test was done 25 February 2013 with transmitted power 60W.

Libration rate was 0.002 degrees per minute.

After this test antenna was improved by about 2 dB.

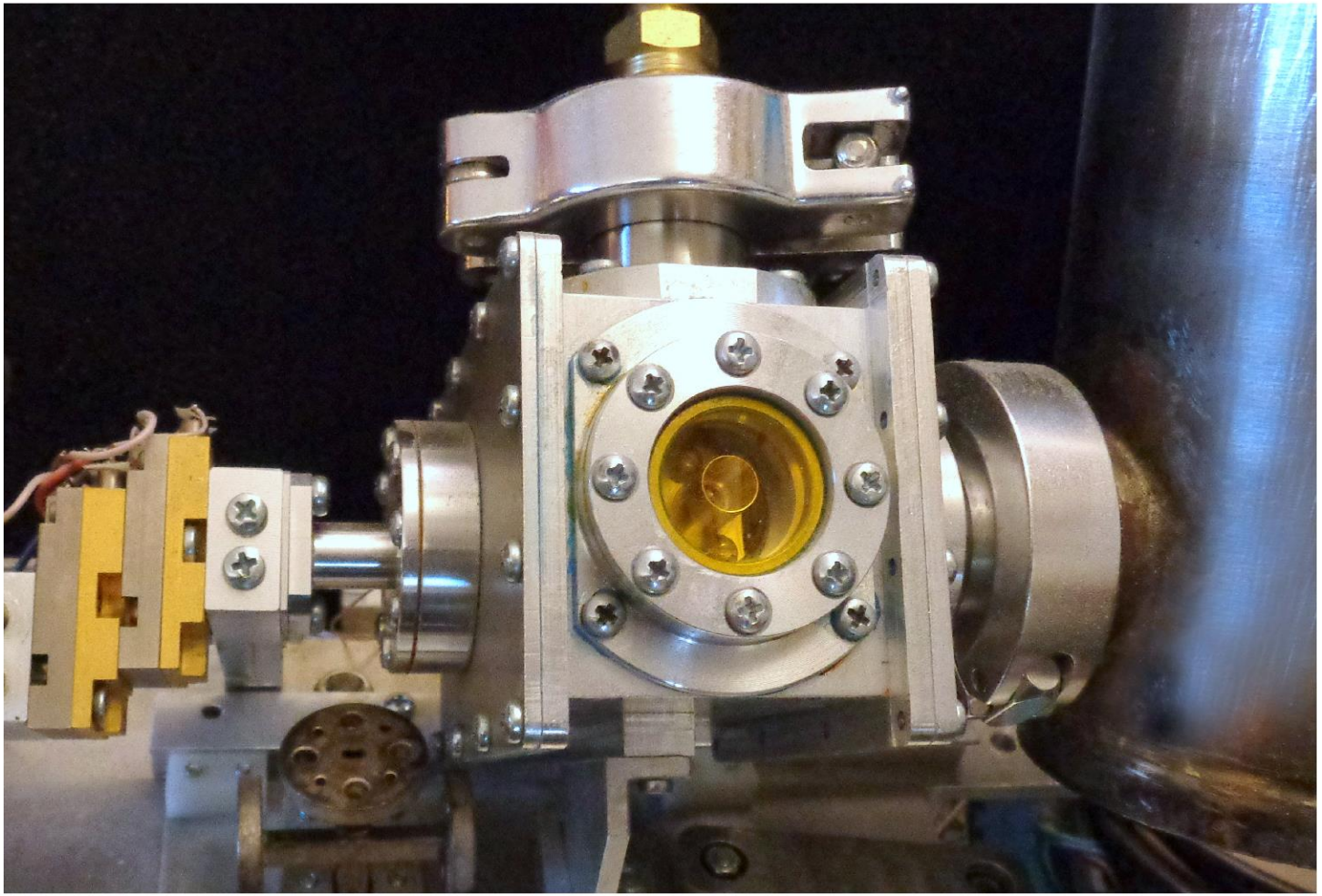
Liquid Nitrogen cooling of the LNA give up to 8 dB of improvement.

The total improvement of about 10 dB allows to reduce power from 60W to 6W.

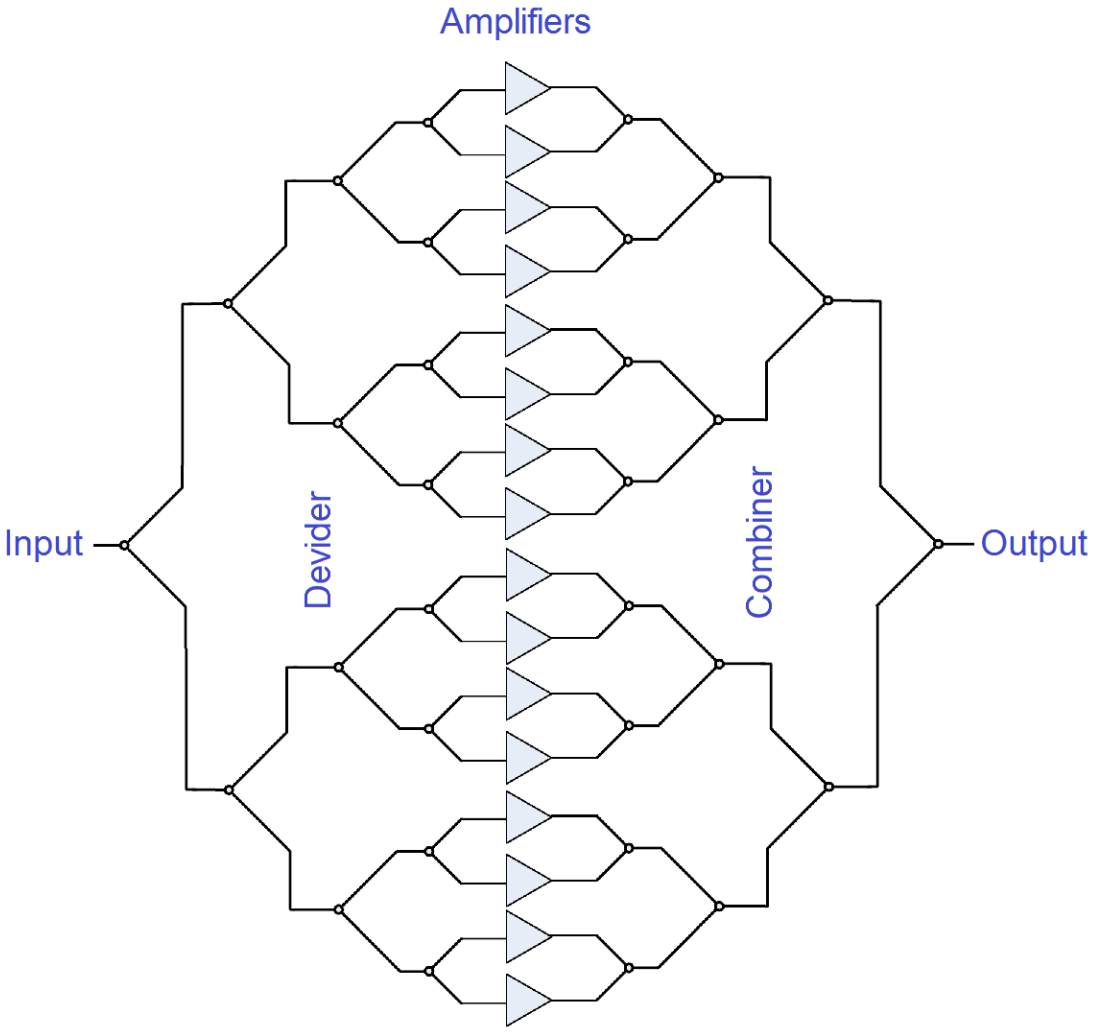
If to choose optimum time it is easy to reduce Libration rate and to get 2...3 times S/N additional improvement.

Based on this, the power of the transmitter 5 W can be sufficient for EME on 76 GHz.

Liquid Nitrogen cooled LNA allow to reduce Tx power



Binary combining



To get 5W we need to combine 16 amplifiers

For total combining losses -1 dB we need 400 mW amplifiers or 500 mW for - 2 dB losses.

N-way combining strategy.

Allow to combine N amplifiers directly in one step.

No multiplying losses in several stages.

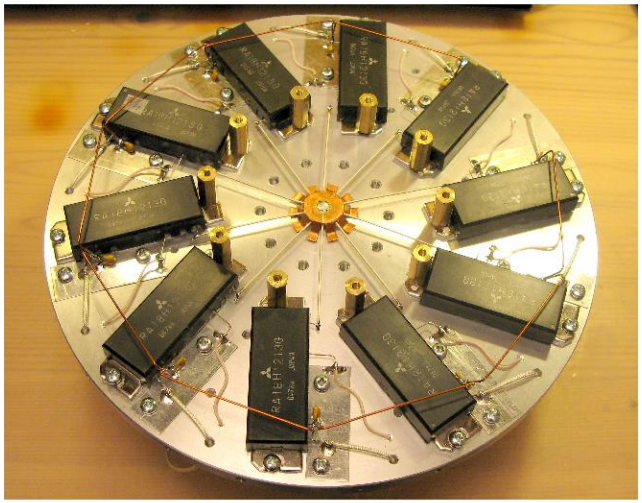
You can combine any quantity of amps you have. No only 2, 4, 8, 16... .

On millimeter waves the loss in transmission lines is high.

Better to use spatial combining by cavity or by non-resonant structures.

I decided to left spatial combining for the future.

The example of N-way combining



Combining of 10 Mitsubishi modules RA181213G.

My water cooled 23 cm PA from 2007.

Output power 700 W in CW mode
(Vdd = 16V; I = 124A)

No one module has been lost.

MMIC Amplifier

gAPZ0041A

gotMiC

Göteborg Microwave Integrated Circuits

Doc. Rev. A02-16

gAPZ0041 A
E-band PA MMIC
71-76 GHz

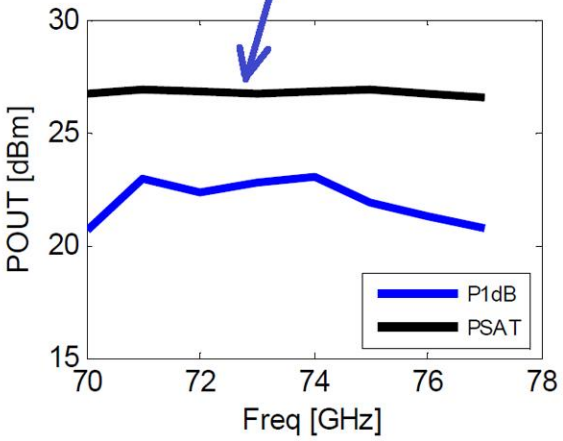
Features

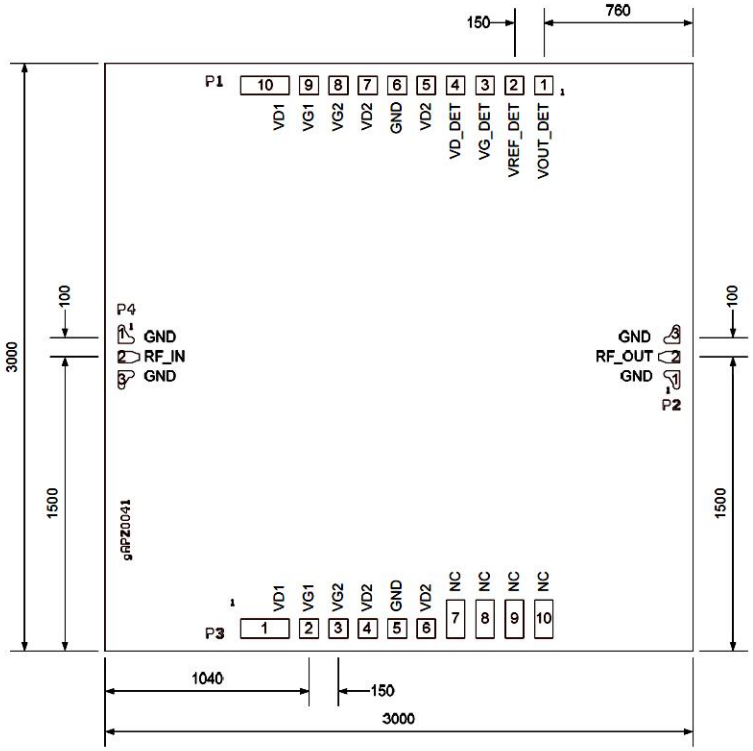
- 23/27 dBm P1dB/PSAT
- E1-band coverage
- 32 dBm OIP3
- 25 dB gain

Typical Applications

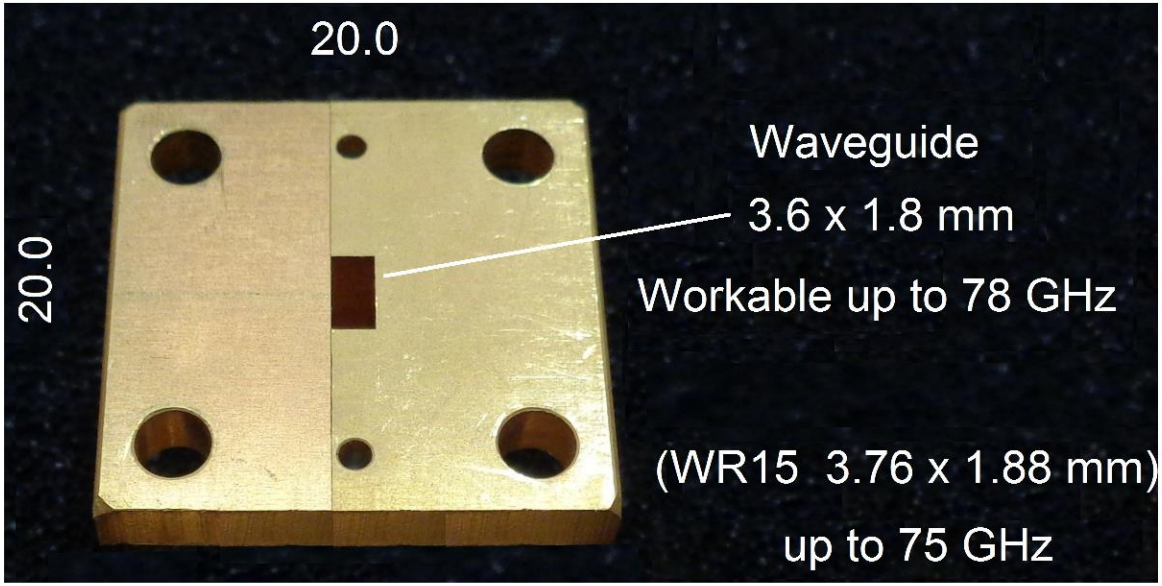
- Point-to-point communication
- Instrumentation
- Fiber over radio
- 77 GHz automotive radar

23/27 dBm P1dB/PSAT





The choice of the size of the waveguide



An old USSR standard.

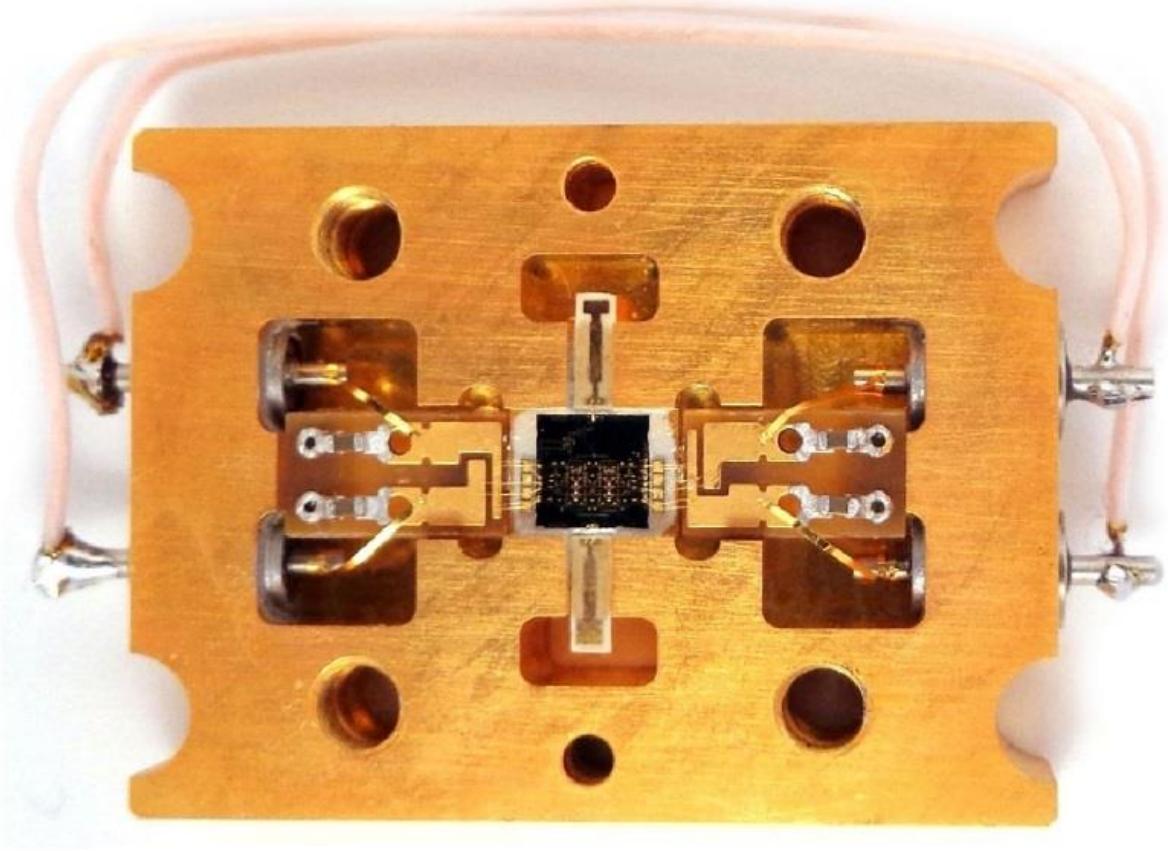
Advantage:

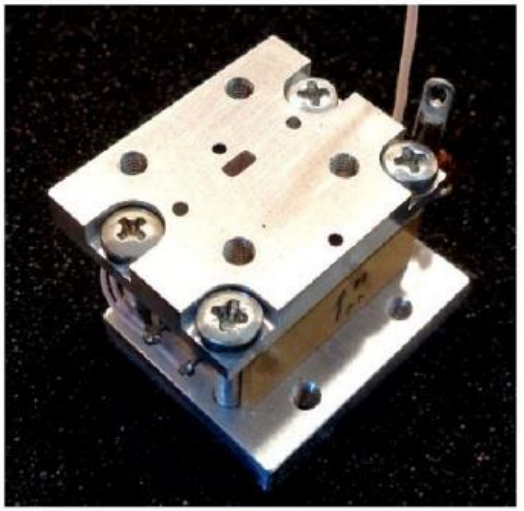
- Lower losses compared to WR12.

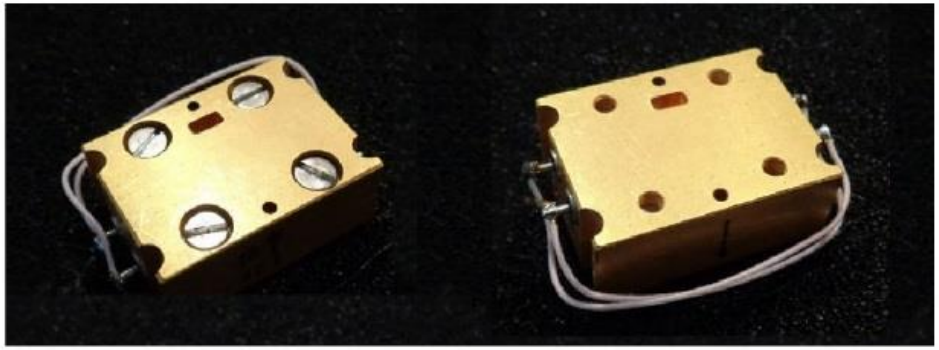
- The presence of the test equipment with this size of the waveguide (Scalar Network analyzer and Power meter from 1980s).

- The availability of waveguide units with a waveguide of this size.

Amplifier



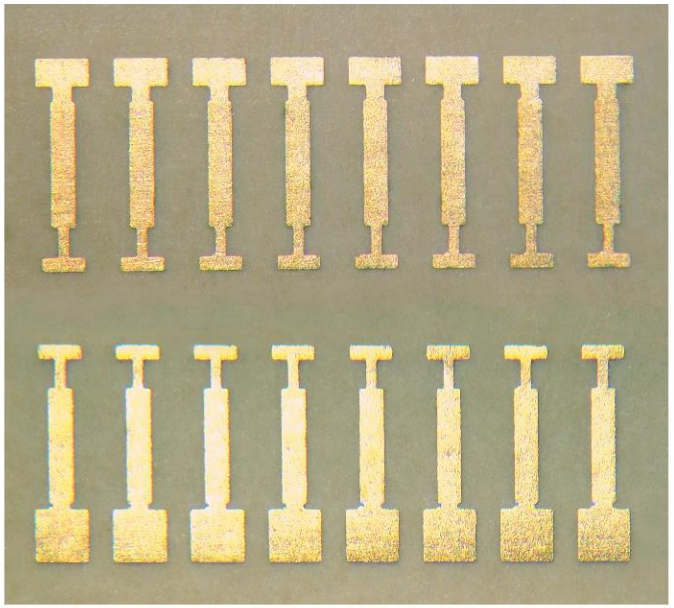




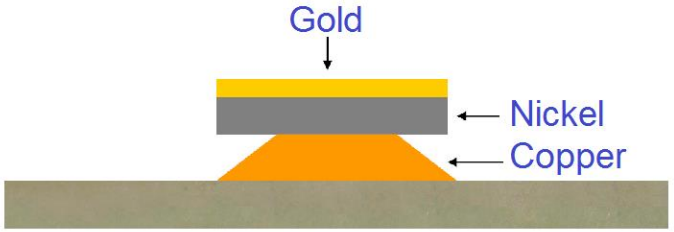
Amplifier with adapter to standard flange.
(for measurements)

RF Boards

RO3003, 0.13 mm thickness, 9um copper cladding.



Ordered in China



"Gold as Etch Resist" technology

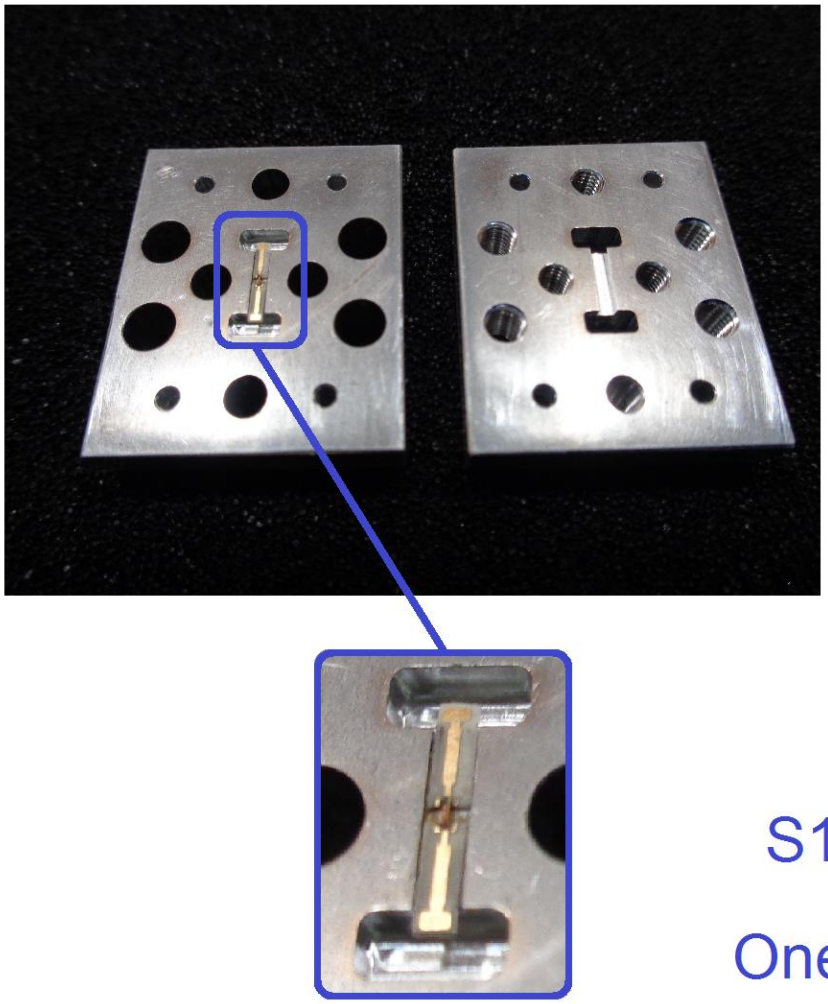
High Overetched

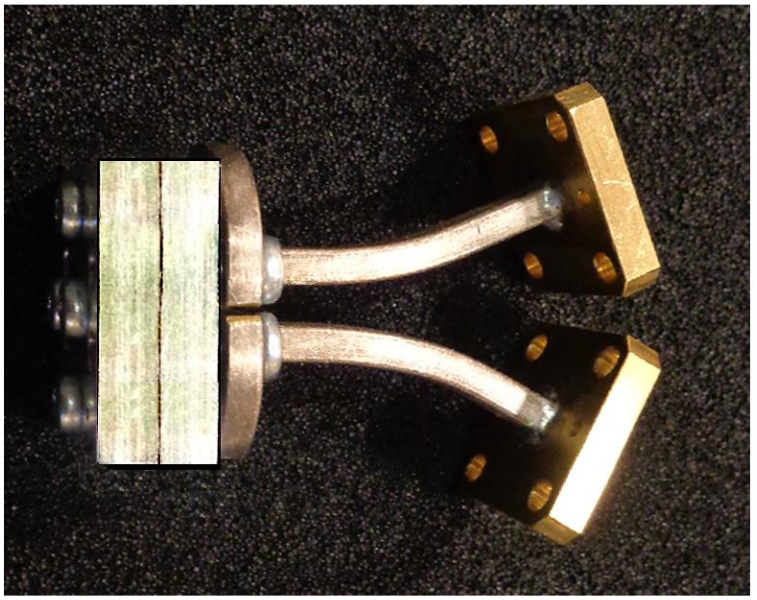
Better

Problems:

- 17 um copper foil (ordered 9 um). High etch "undercut" as a result.
- "Hard Gold" finishing (ordered "Soft Gold"). Problems with wire bonding.

RF Boards Testing



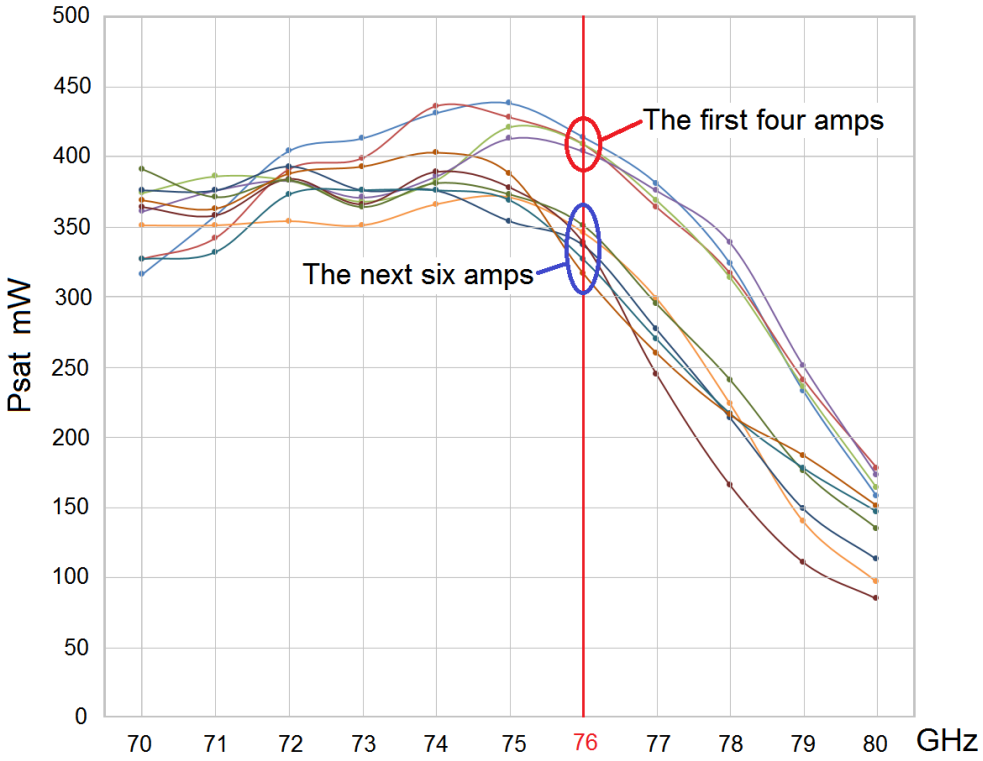


On 76 GHz:

S11 = -25 dB Loss = 0.7 dB

One transition loss 0.35 dB (8%)

Amplifiers testing in saturation mode



Input Power 15 mW

Vd = +3.3 V

Vg = -0.4 V

Few month to try to understand what was happened after the first four amplifiers.

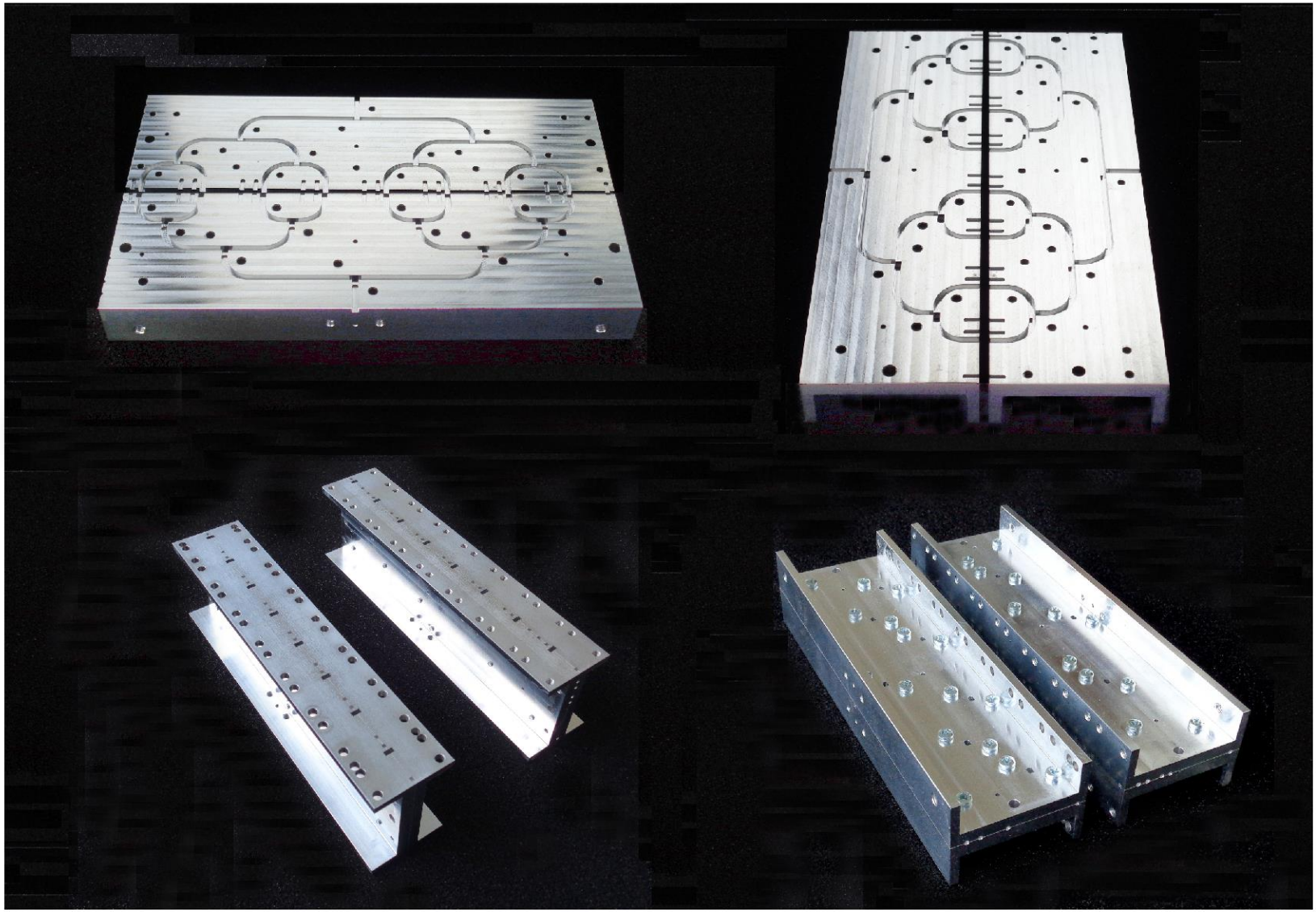
About 20% loss of output power.

Tested numerous hypotheses, but it is still not clear why.

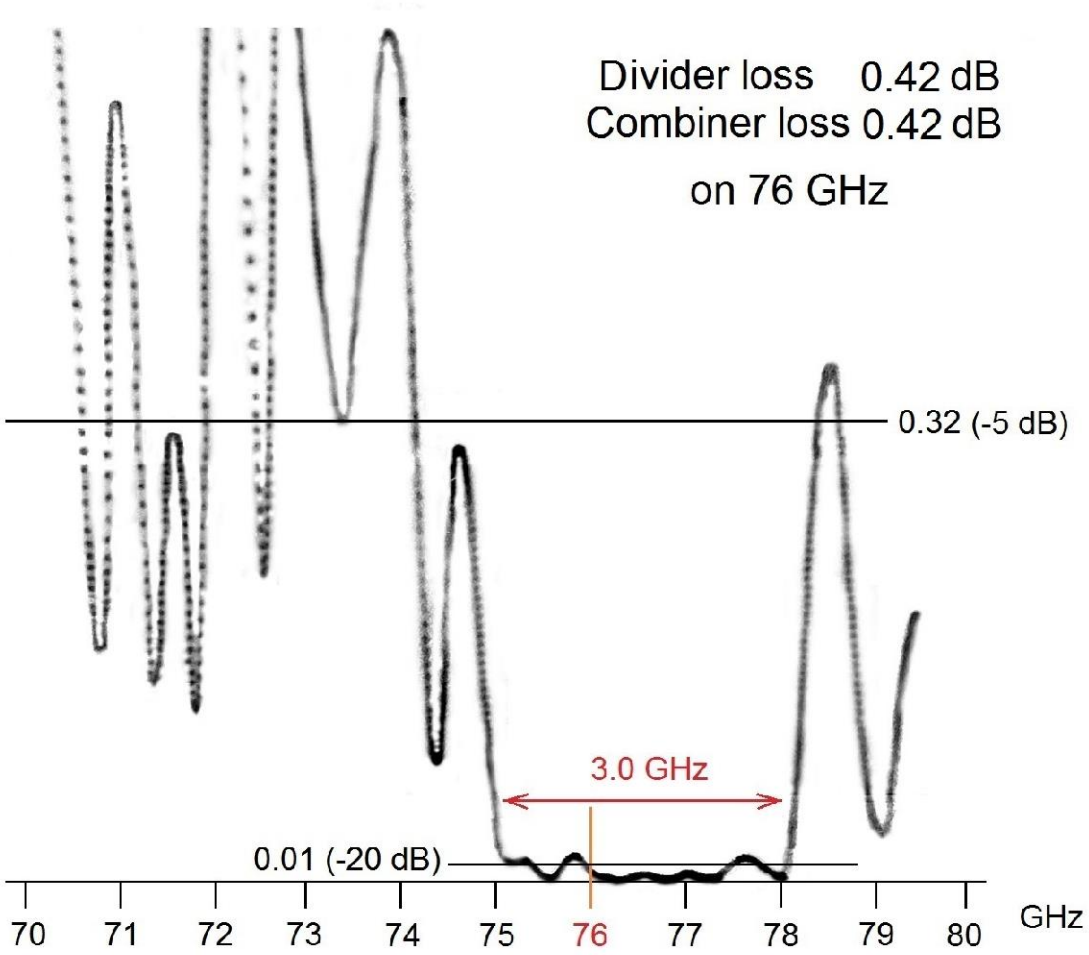
Further assembly of amplifiers was stopped.

Before the conference, I decided to combine the eight best amplifiers.

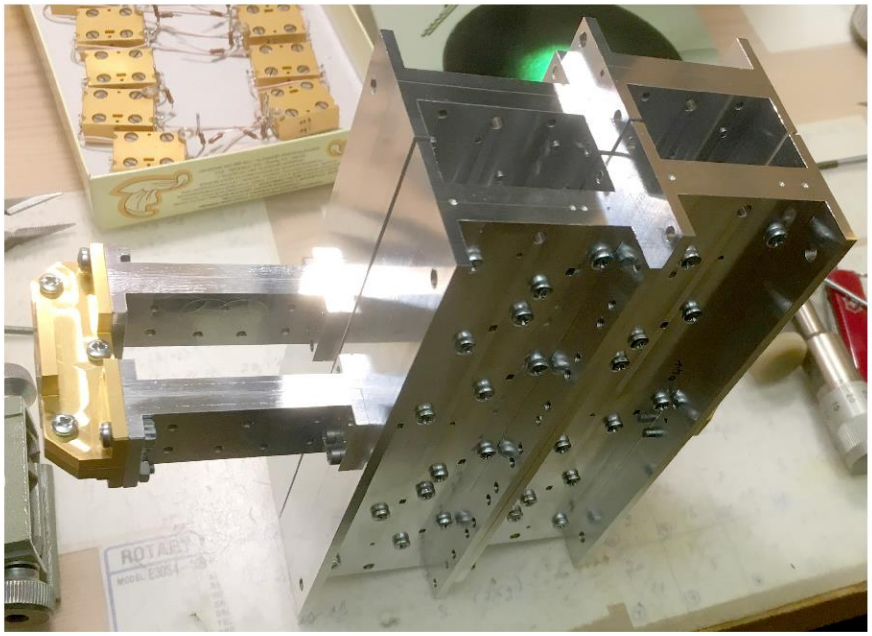
8-way divider/combiner

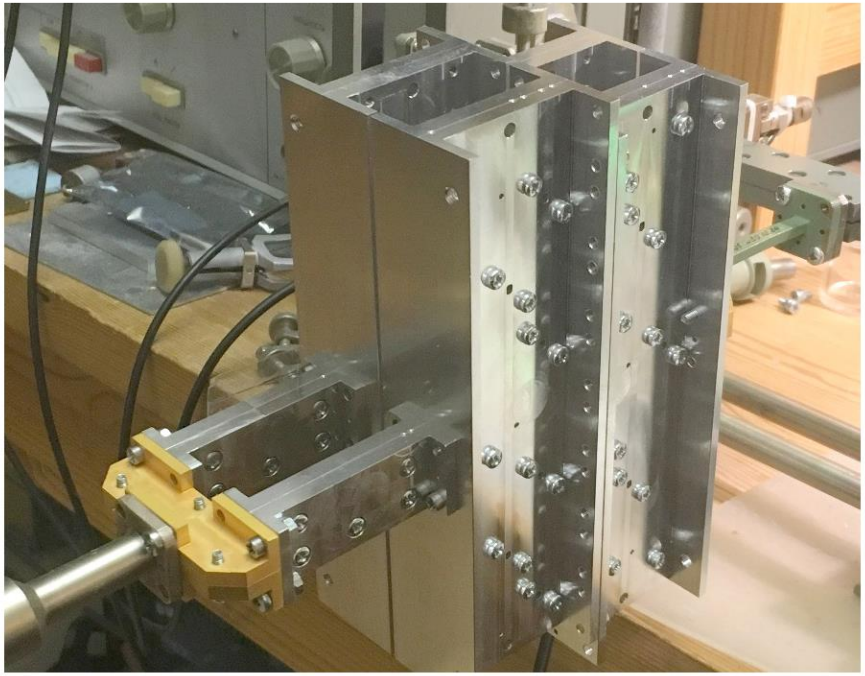


S11 for 8-way Divider plus 8-way Combiner

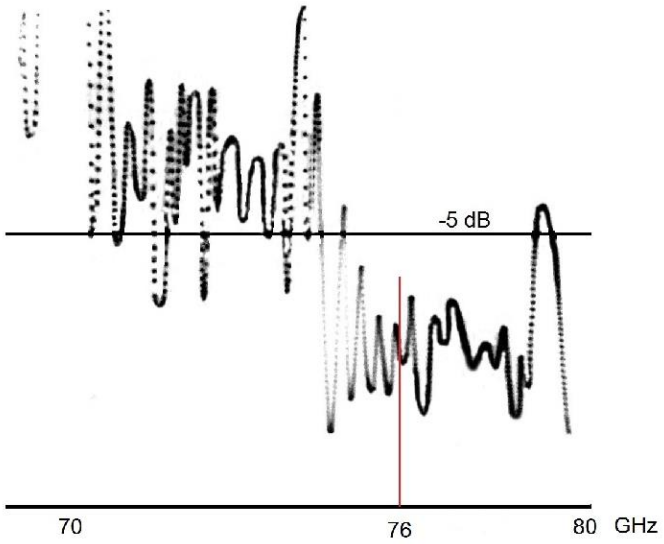


16-way divider/combiner



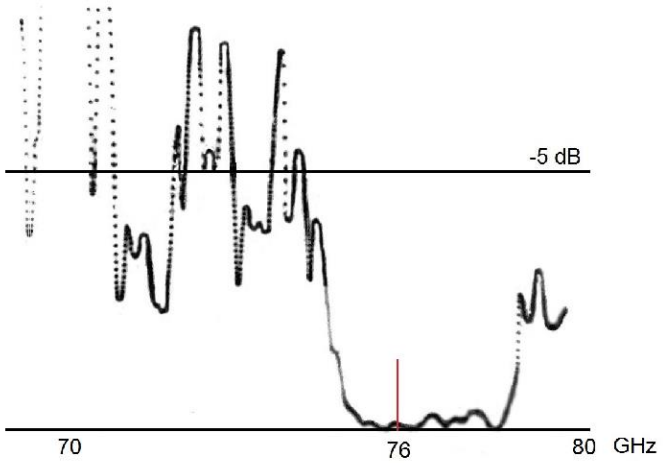


S11 for 16-way Divider plus 16-way Combiner



Without phase shifter

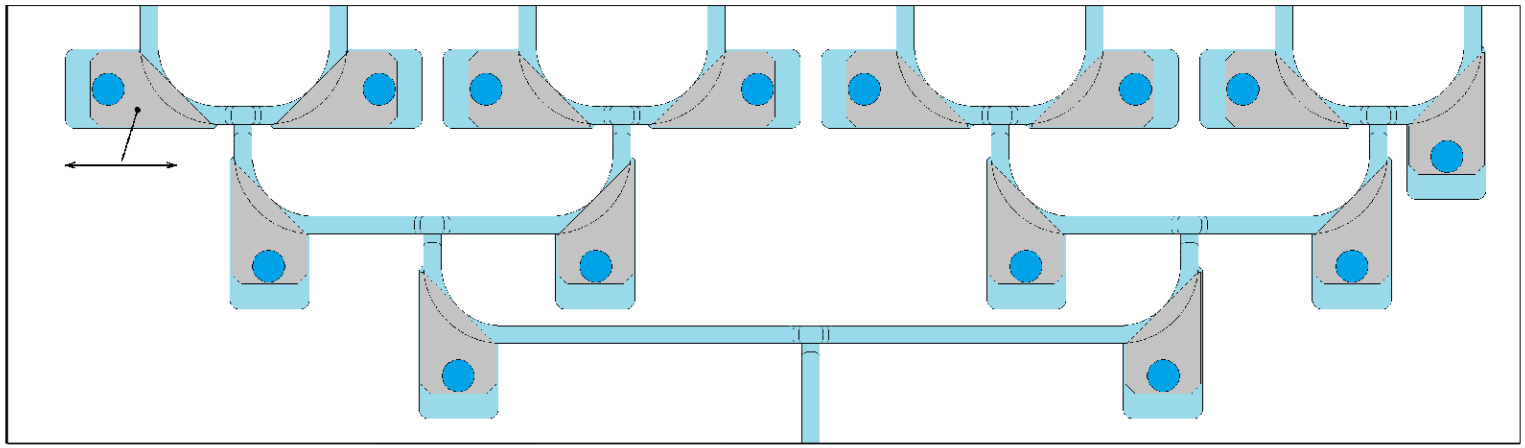
0.75 dB 16-way Combiner loss

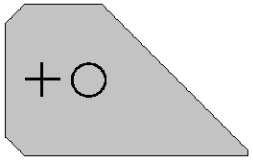


Phase shift correction

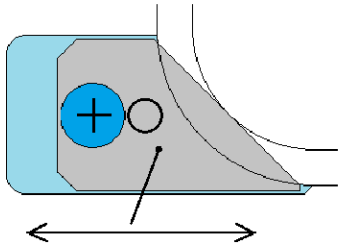
Improvement of Divider and Combiner (1)

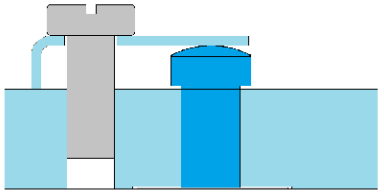
Was added phase shifters for correcting variations of parameters of the amplifiers.



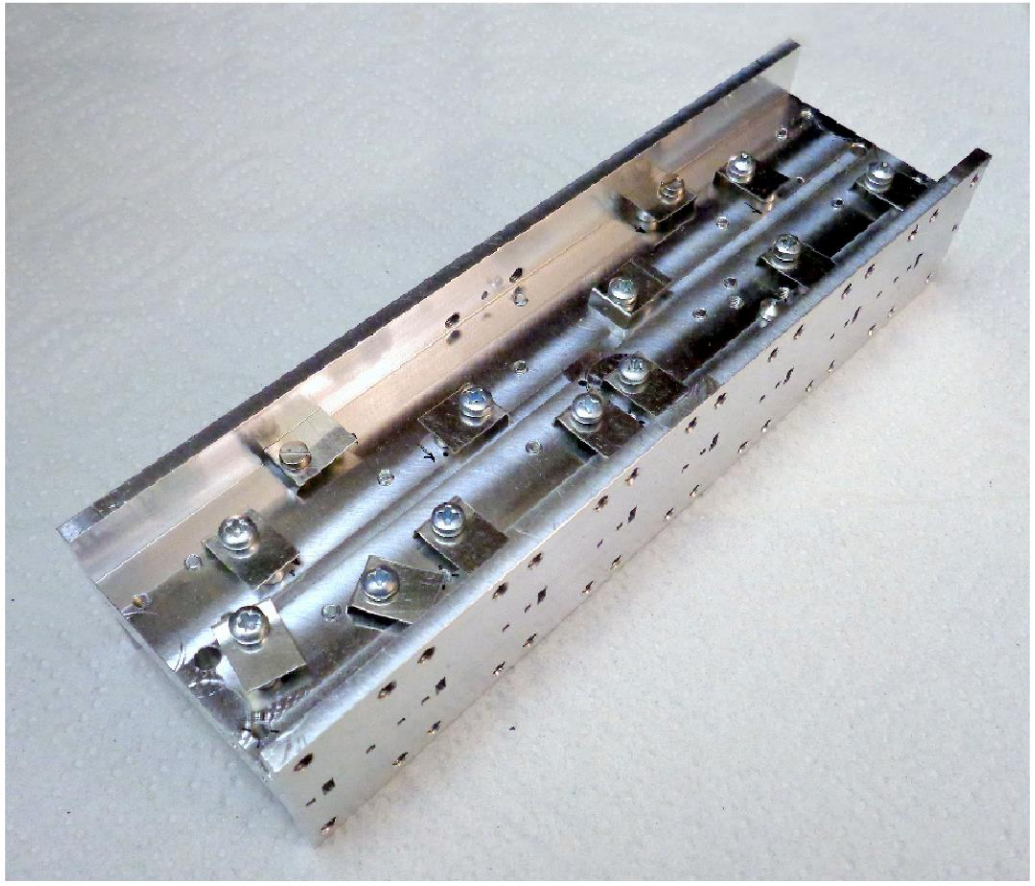


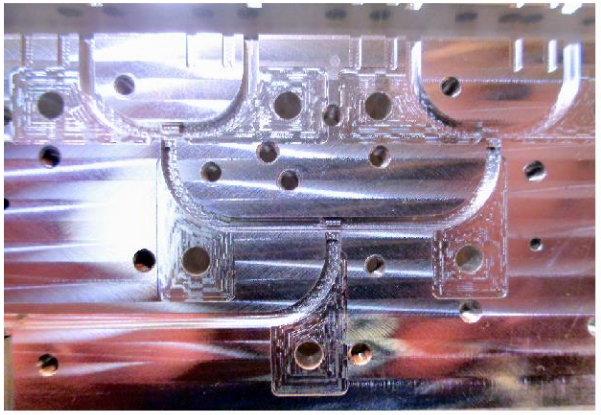
Mica 0.05 mm

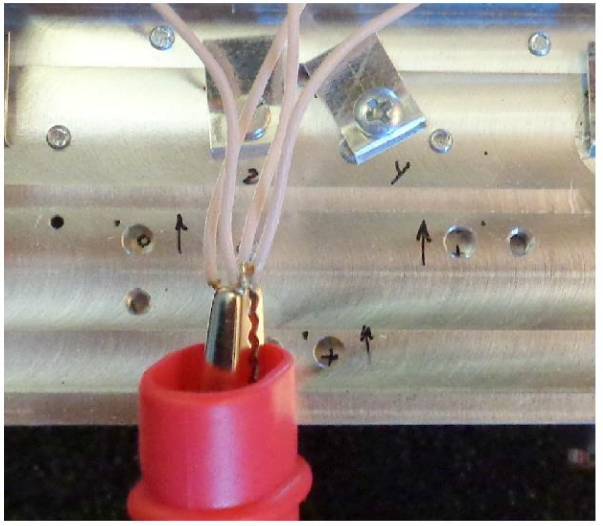




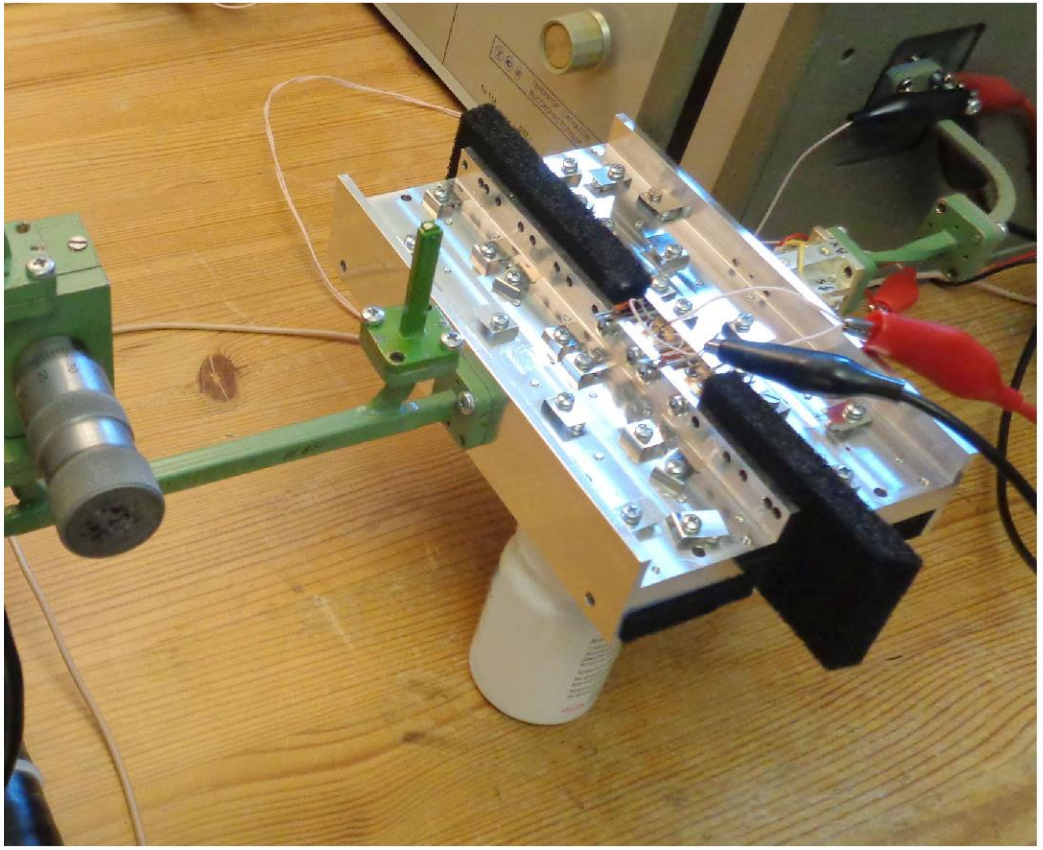
Improvement of Divider and Combiner (2)



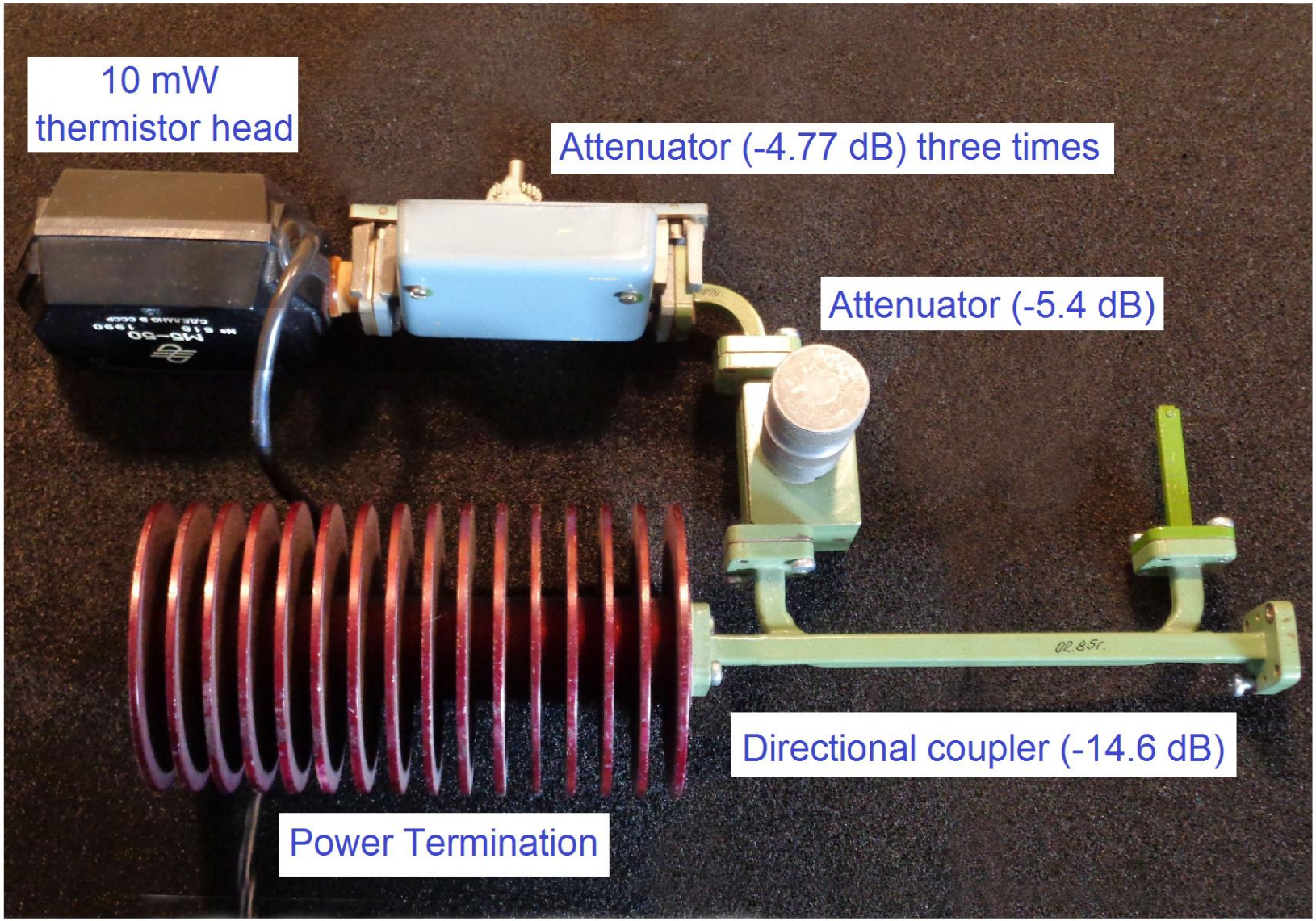




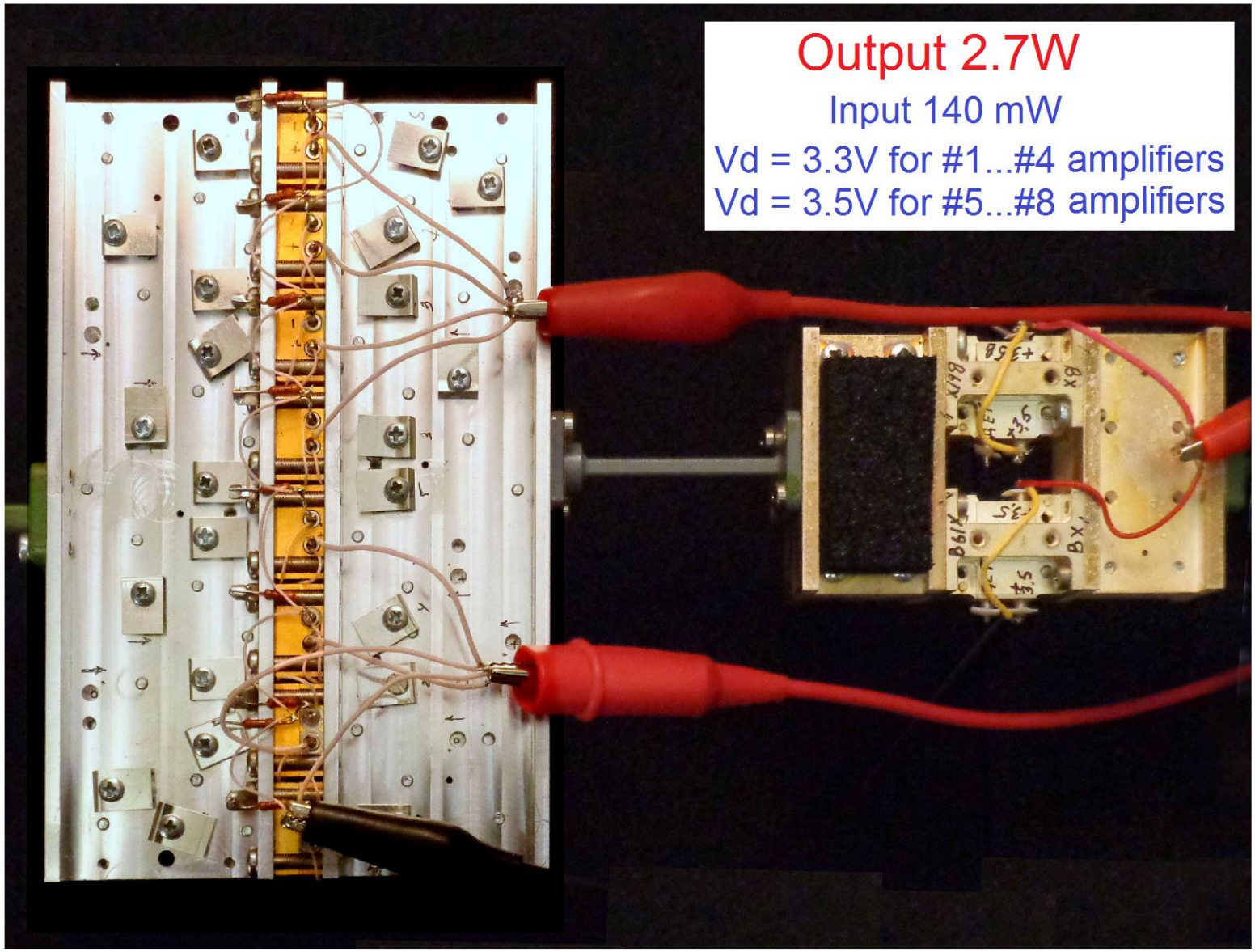
Phase tuning for #3 and #4 amplifiers



Power measurement unit (3W full scale)



Final phase tuning and Power measurement.



CONCLUSION

5 W on the 4 mm band is a difficult, but solvable problem.

THANK YOU FOR ATTENTION!

Many thanks to Dmitry RA3AQ for the great help.

Many thanks to Georgy, my grand-nephew, for milled components.