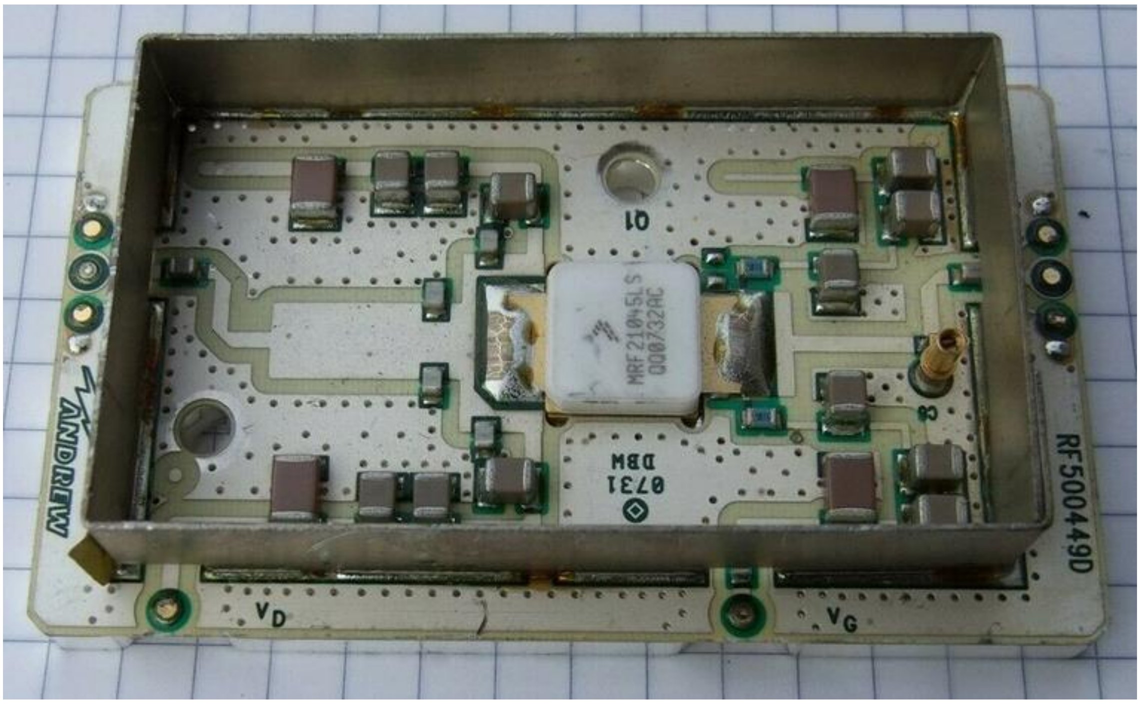
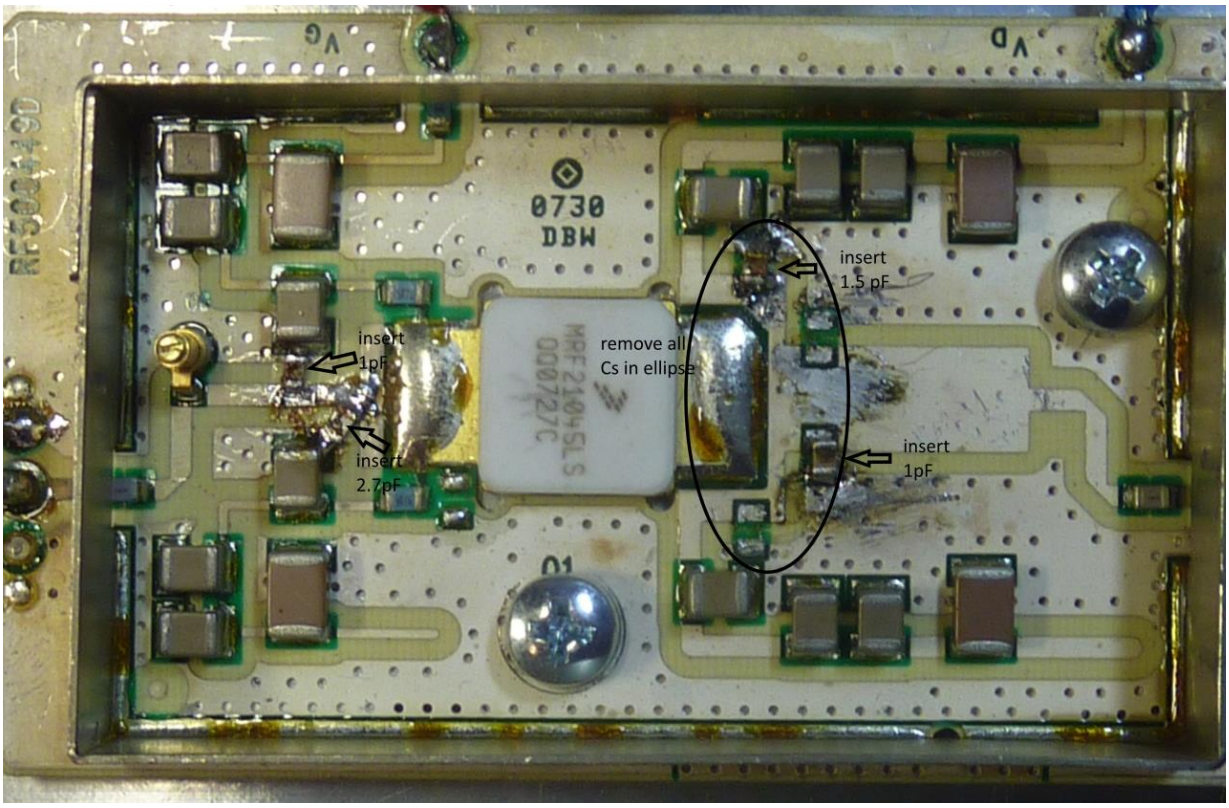
2.4 GHz 27W power amplifier with MRF21045

Matthias, DD1US, February 23rd 2020, rev 1.1

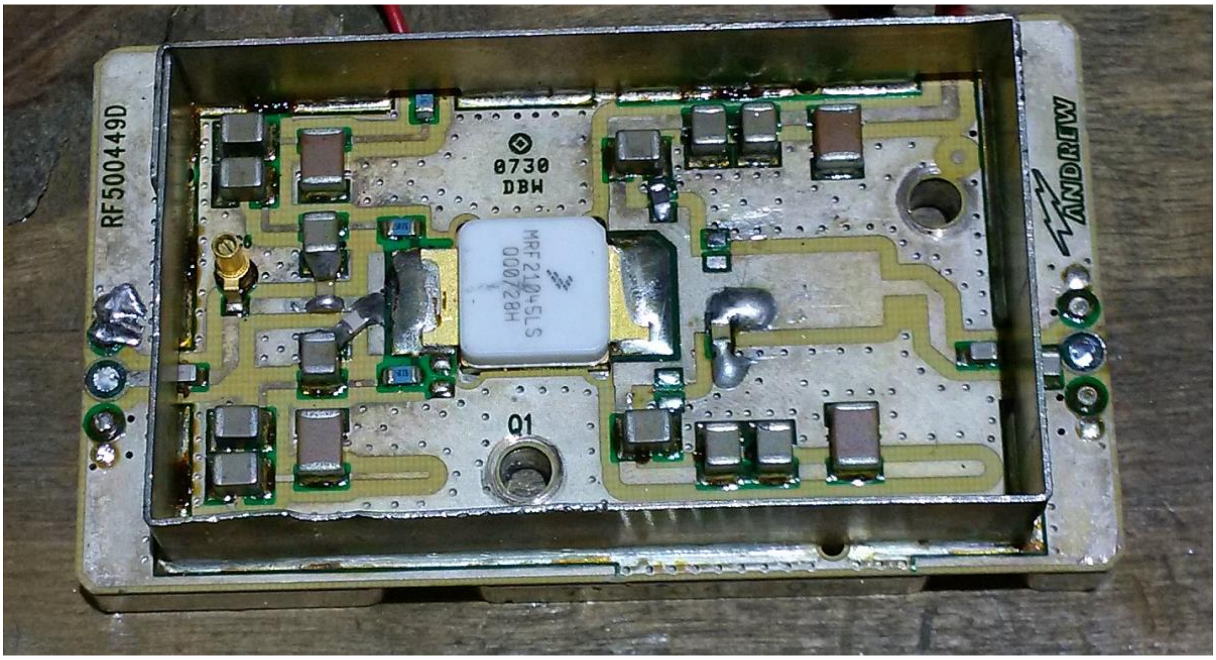
I am presently working on my portable setup for QO-100. As I will be using a small parabolic dish, I will need more power than I am presently using. I had an old small PA module from Andrews marked as RF500449D. It is based on an MRF21045 transistor and I decided to give it a try. Here is a picture of the unmodified unit:



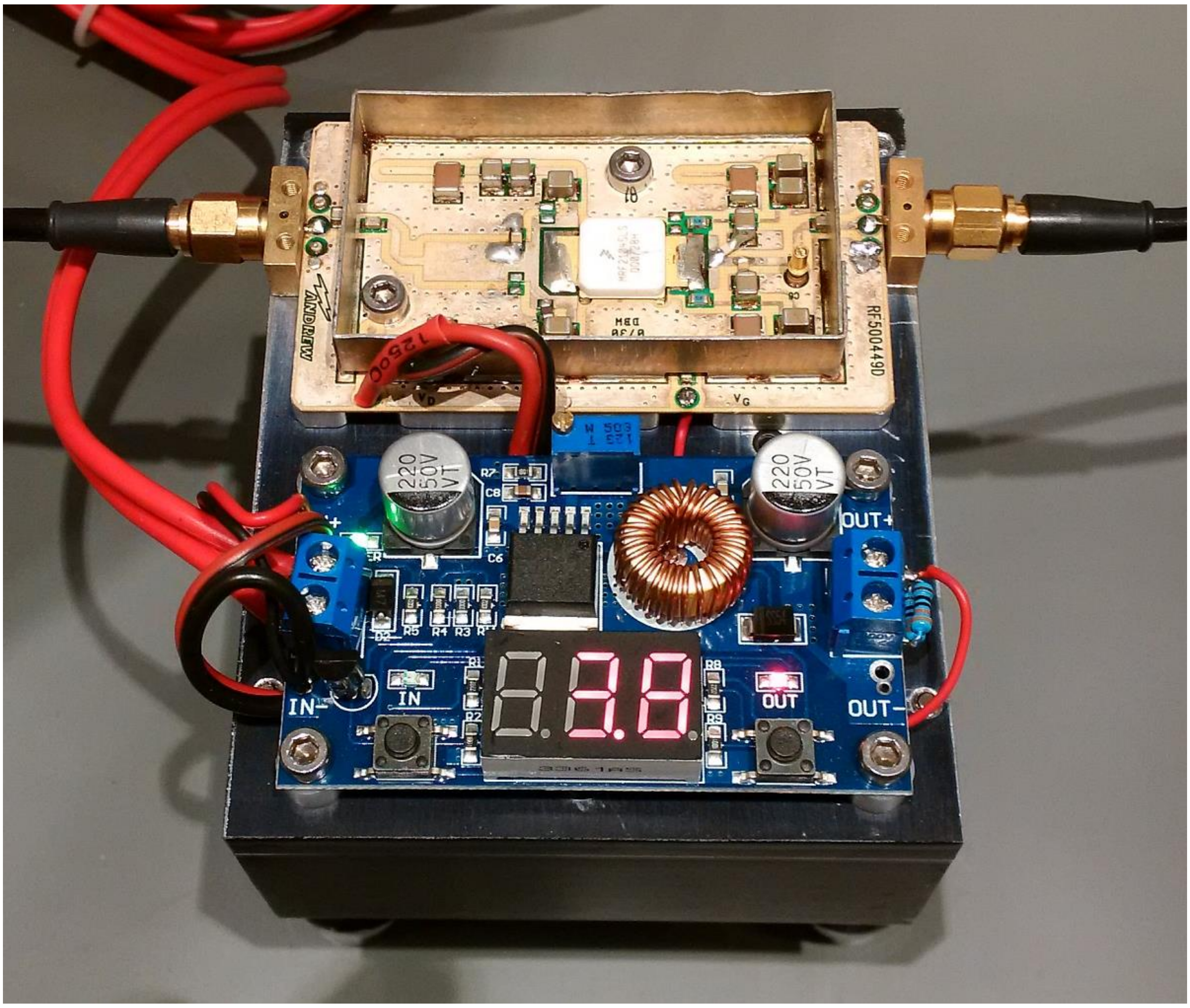
Ernst-Guenter DK5DN had kindly posted a description in the AMSAT-DL Forum about the necessary modifications to operate it at 2.4 GHz. Here is a picture from DK5DN showing his modifications:



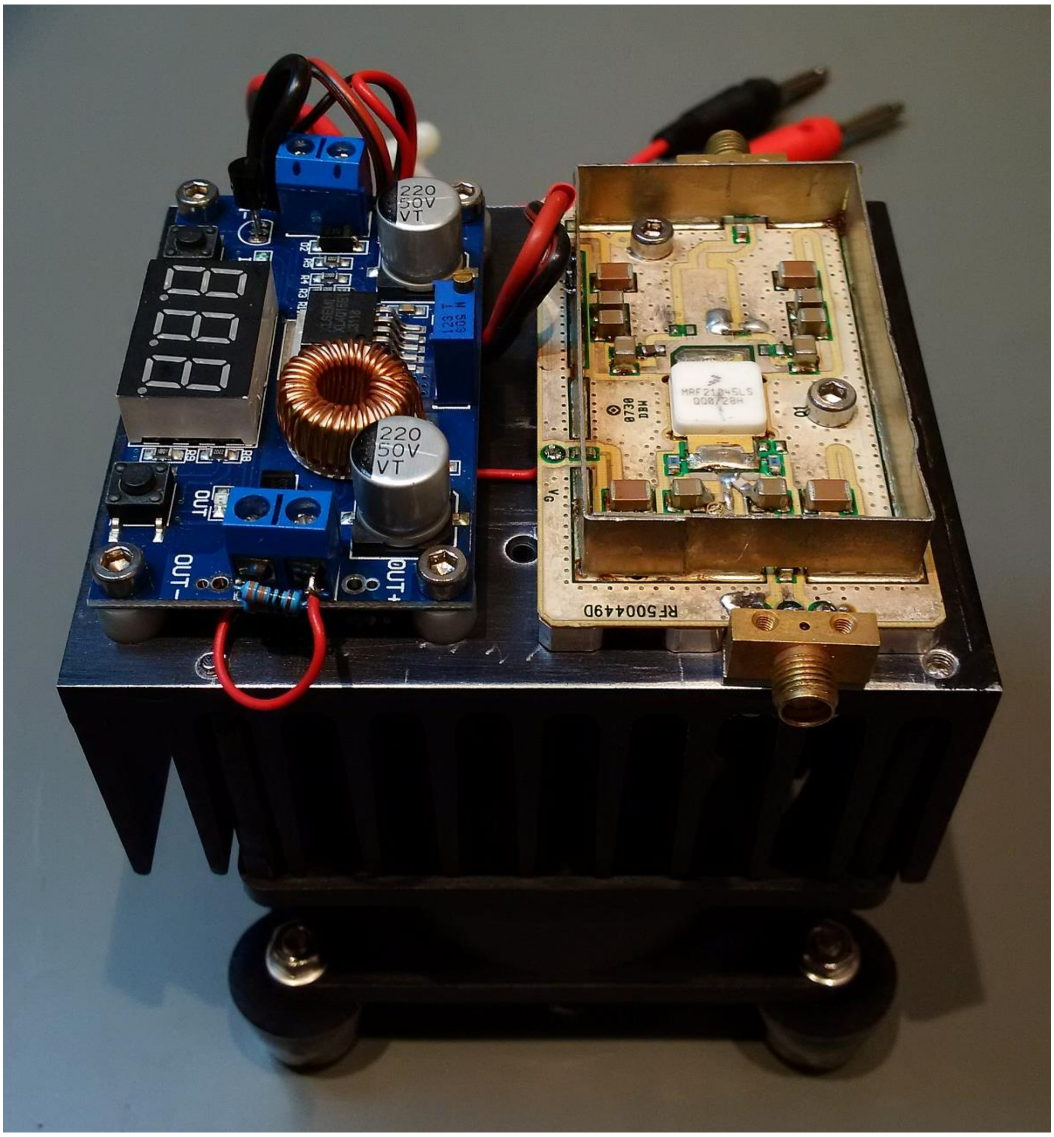
I followed exactly his advice without any further modifications. The only tuning point is a trimmer capacitor at the input of the amplifier. Here is a picture of my modified module:



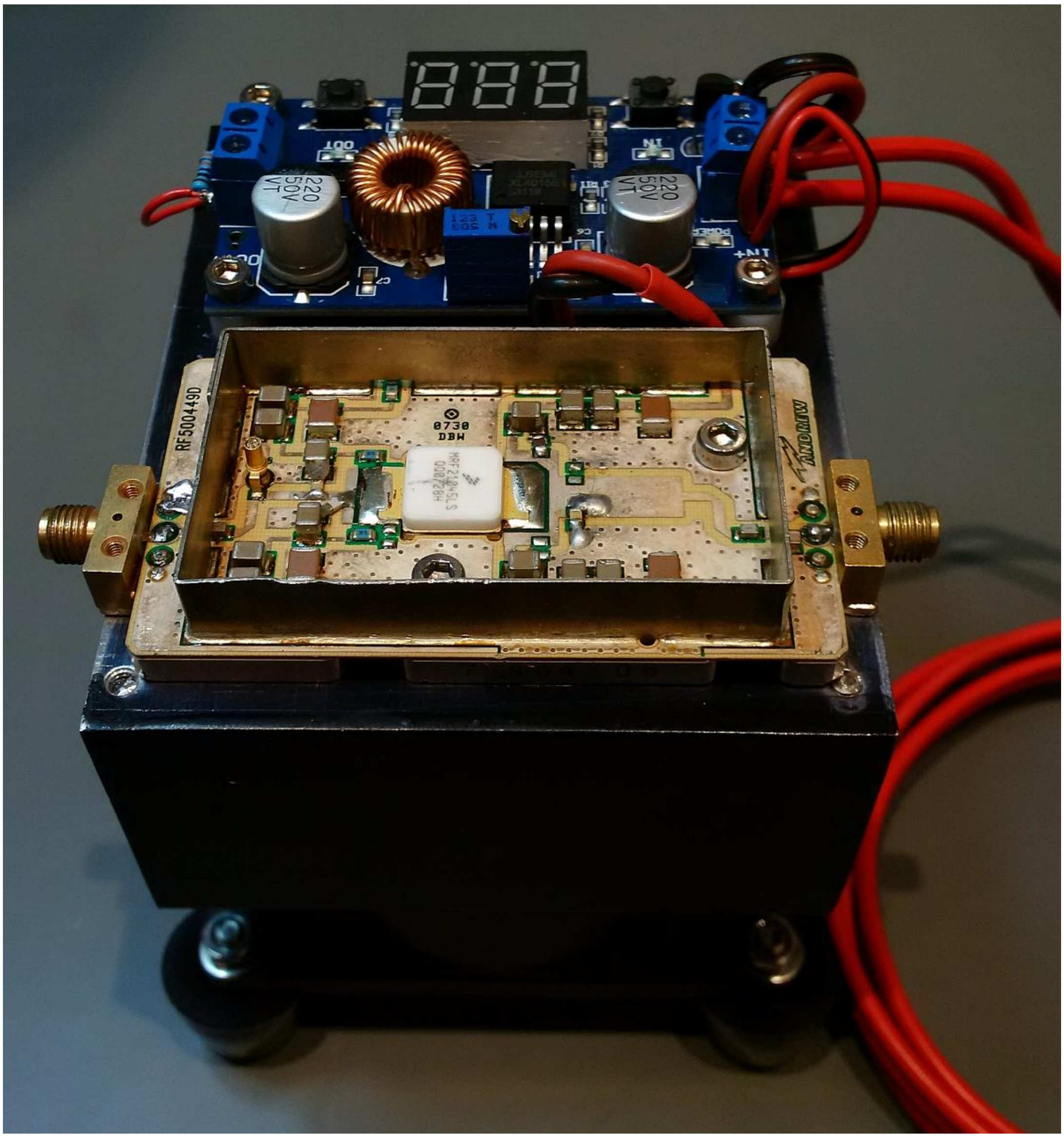
On the next pages you will find some pictures of my complete setup:



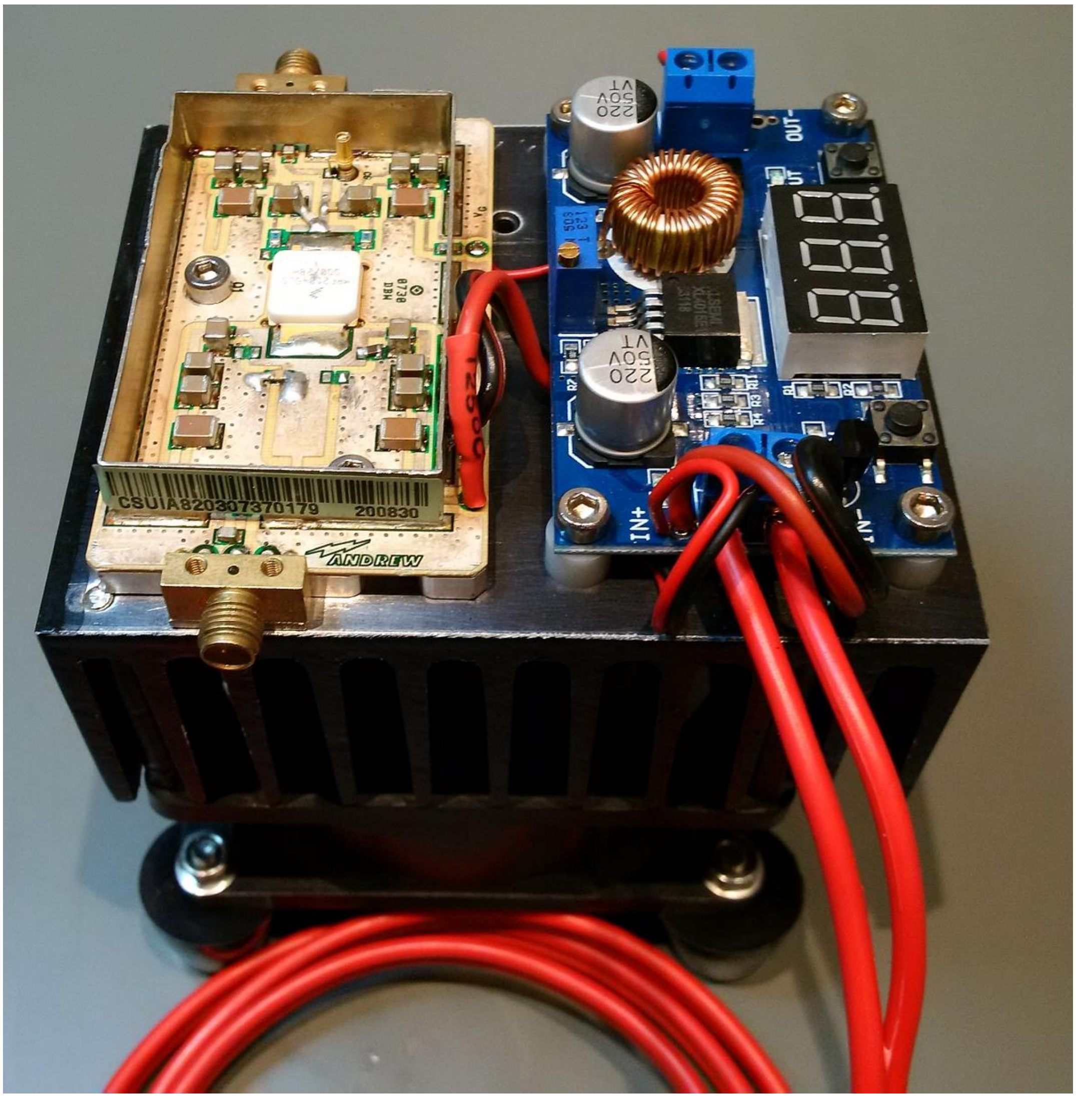
The PA module is mounted together with an adjustable DC-DC converter for the gate bias voltage on a heatsink. The DC-DC converter is oversized but I had it here in my storage and it features the capability to measure its input voltage (i.e. the drain voltage of the MRF21045) and its output voltage (i.e. the gate voltage of the MRF21045).



A fan is mandatory to cool the heatsink. I had a Pabst Multifan available which runs from 12-18V DC. During the tests I did run it with 28V but might add a temperature sensor to the heatsink and make the speed variable.



All pictures show the PA module without a lid. During the tests it turned out, that the performance of the amplifier is the same with and without lid. Of course it is recommended to mount a lid during operation to assure a proper shielding.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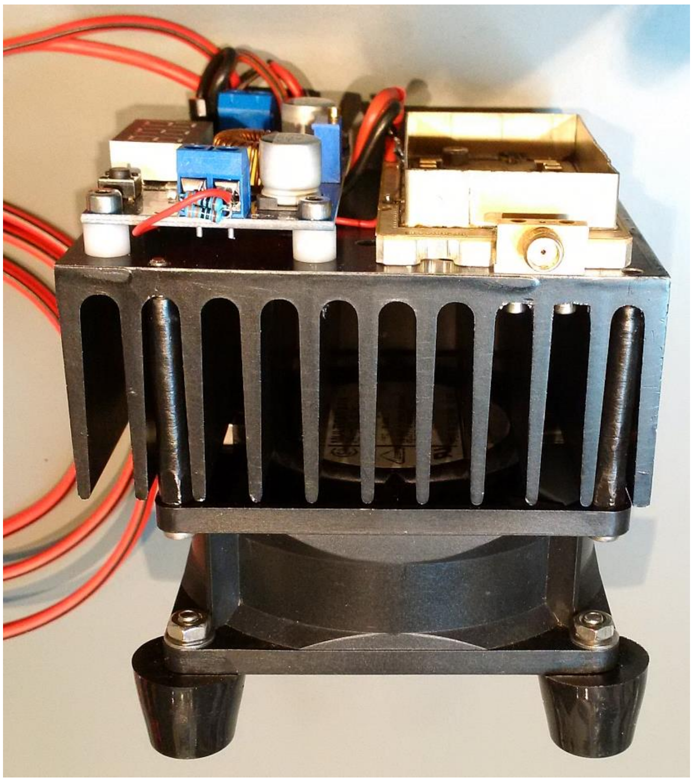
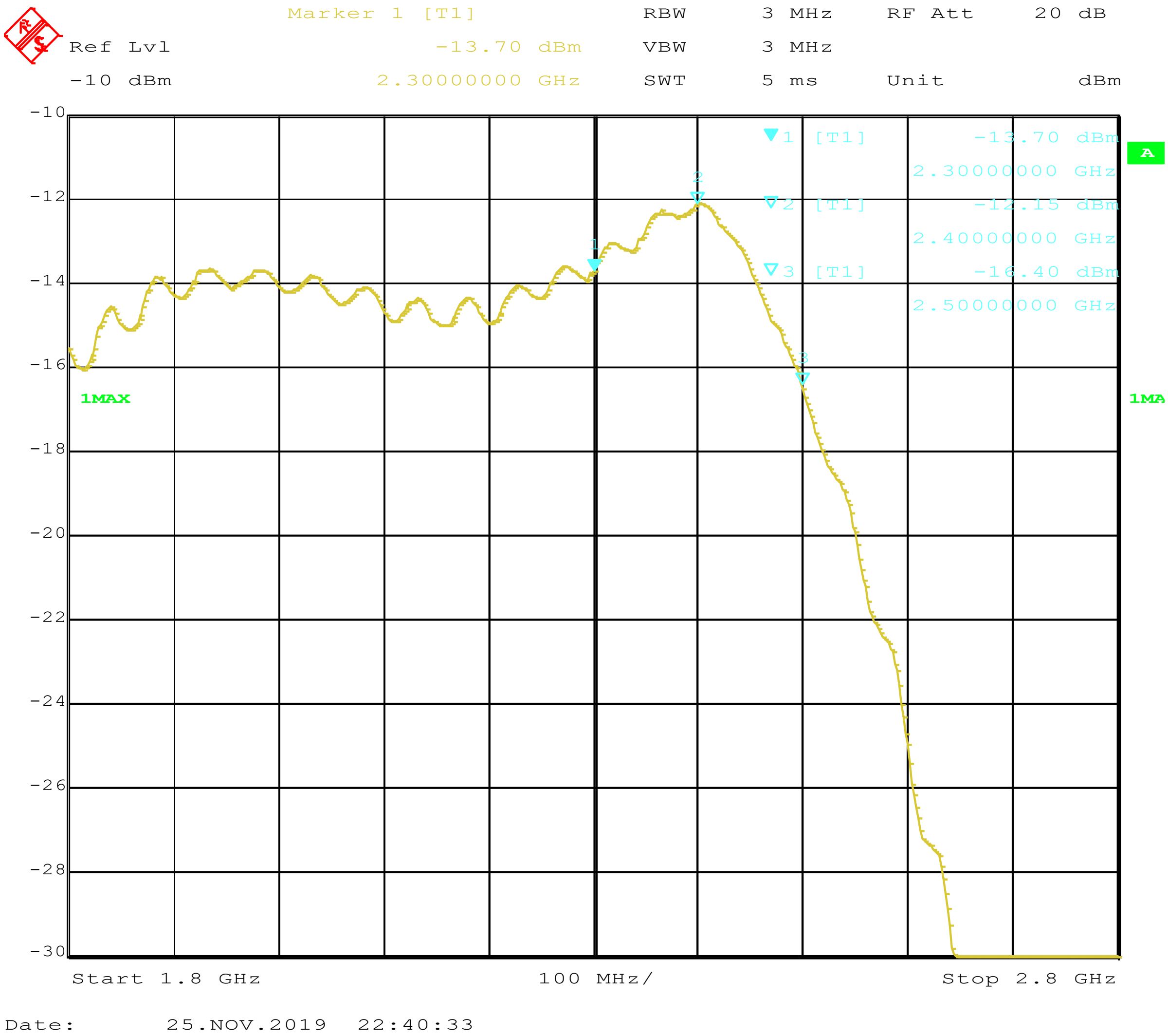


Time to move to the measurement results …

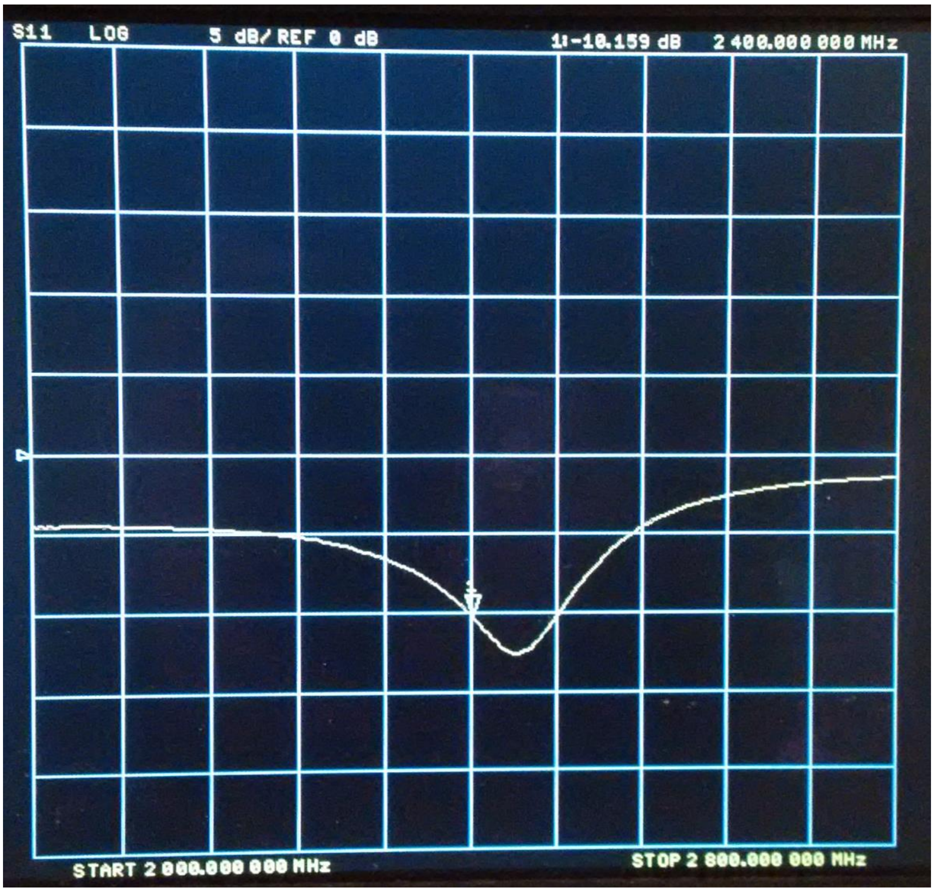
All measurements were done at 2.4 GHz unless otherwise stated. The supply voltage was 28V.

This is the frequency response of the modified amplifier. It was measured with a drive level of 20mW in the frequency range 1.8 … 2,8 GHz. At the output of the amplifier a 40dB attenuator loss was inserted before the signal was fed to the spectrum analyzer. Together with the cable losses at the input and output of the amplifier the total losses to be added to the values in the diagram below are 41.5dB.

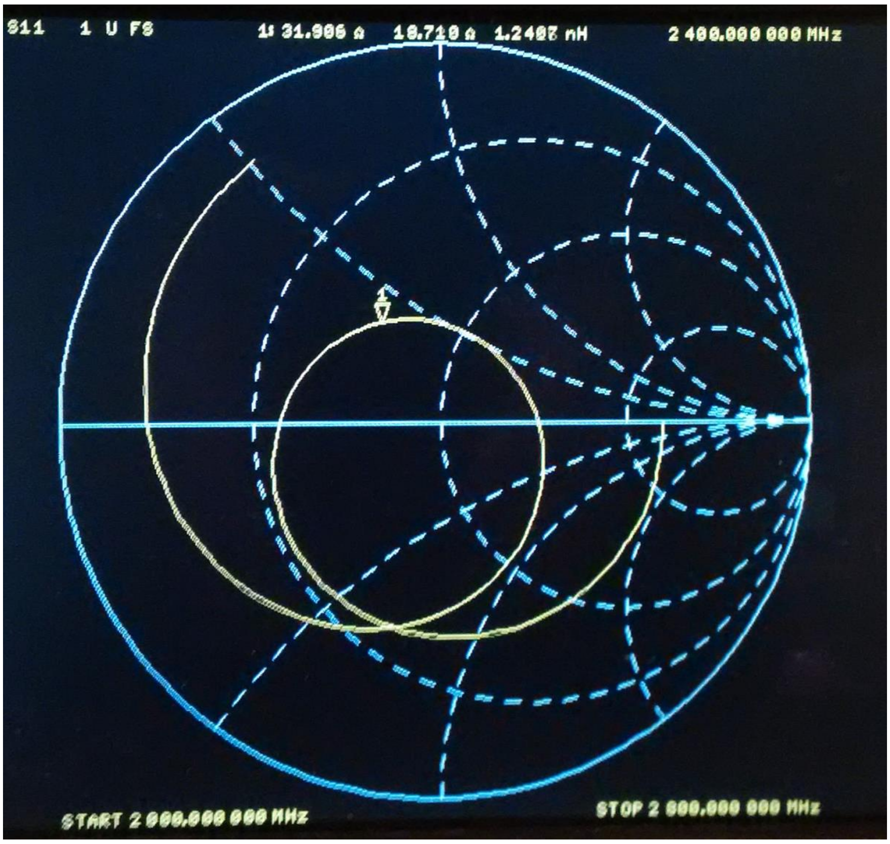


The frequency response peaks nicely at 2.4 GHz with a gain of 16.3dB. The ripple in the frequency response is probably due to my measurement setup.

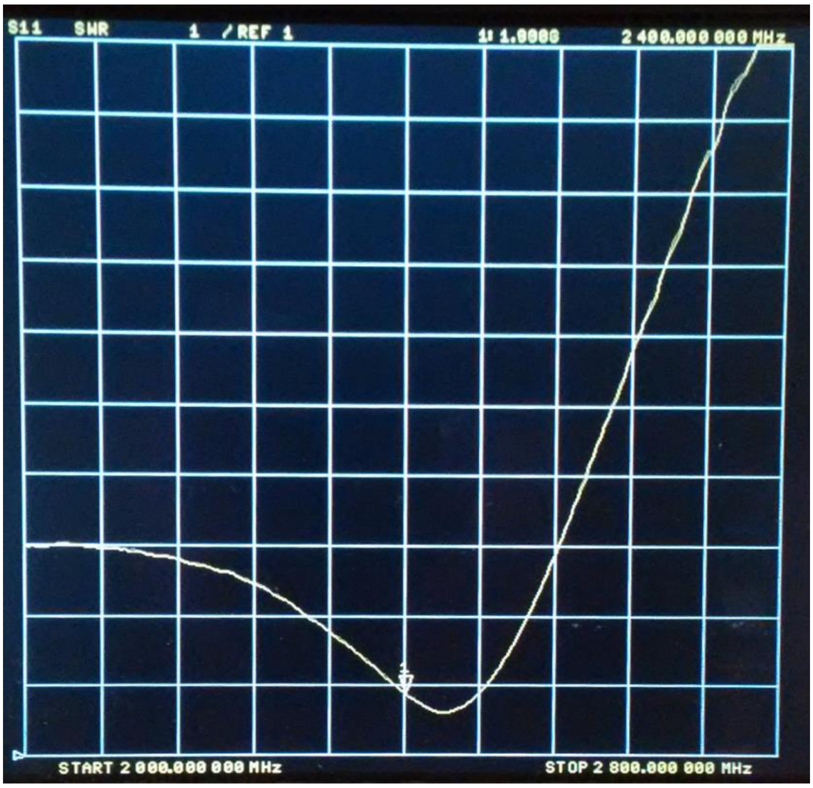
Next you can find the measured input matching of the amplifier in the frequency range 2.0 … 2.8 GHz.



S11 return loss at 2.4 GHz is 10dB



S11 Smith diagram looks ok though not perfect



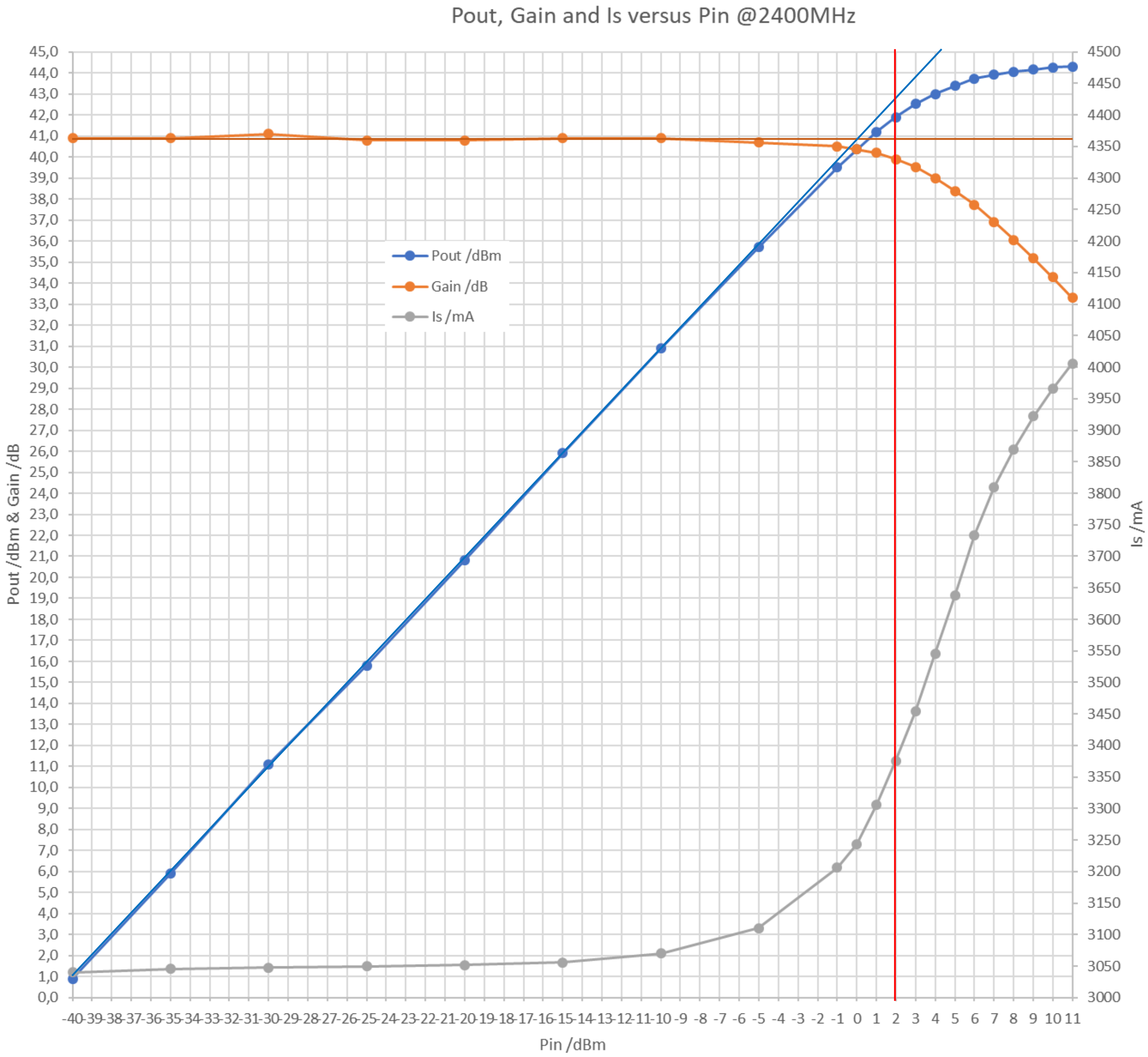
S11 VSWR at 2.4 GHz is 1:1.9

In summary the input matching should be good enough in order to not run in problems when cascading the amplifier with a driver amplifier.

Next I measured the gain, output power and the current consumption as a function of the drive level. In order to have enough drive power I added a medium power amplifier based on a MHL21336 module between the signal generator and the power amplifier. Both PAs were operated at a supply voltage of 28V and a combined quiescent current of 3.05A.

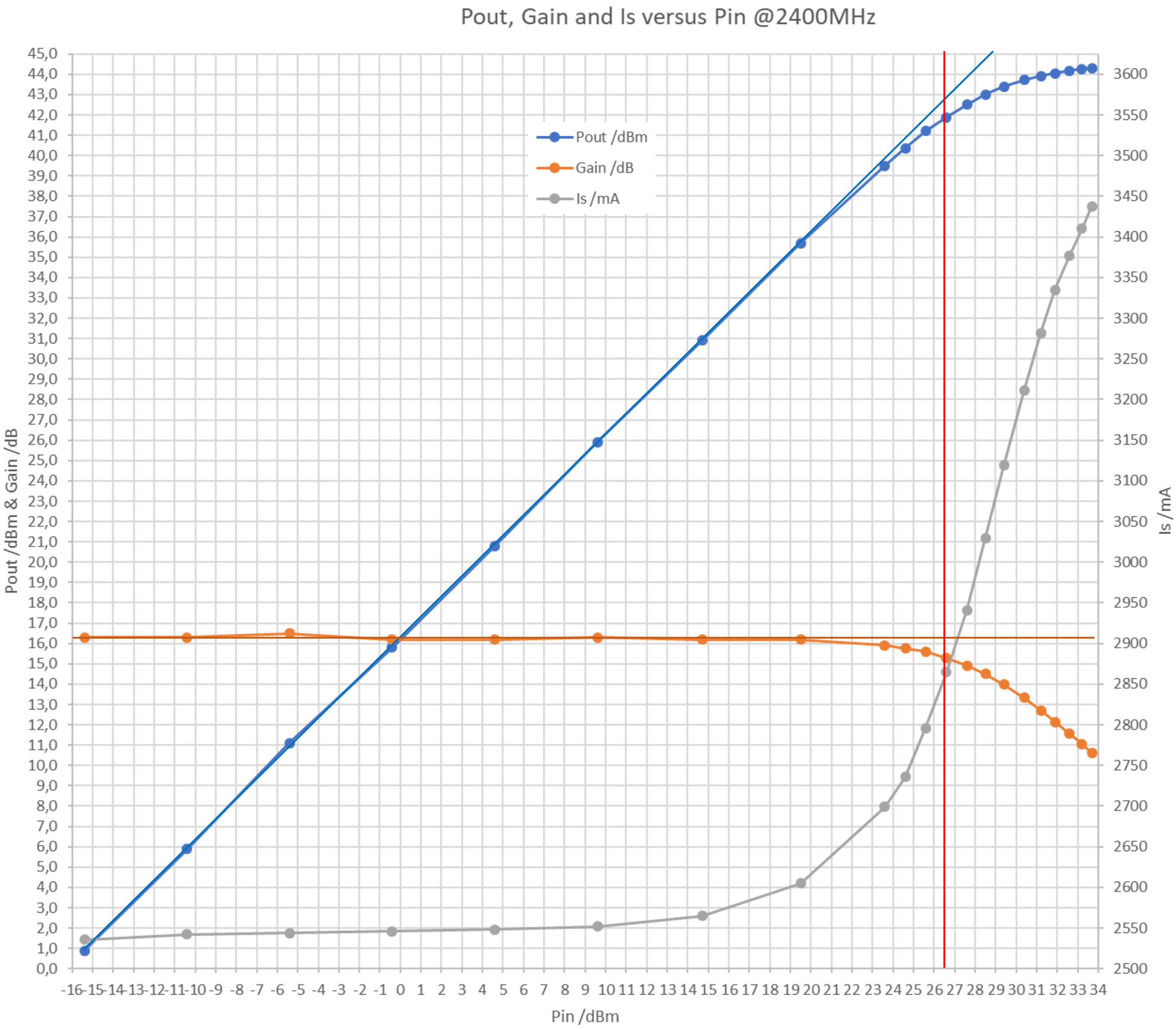
You can find a decription of the medium power amplifier on my website www.dd1us.de. The title is “2.4 Ghz 1.3W power amplifier MHL21336”.

Here is the measurement result of the 2 cascaded amplifiers:



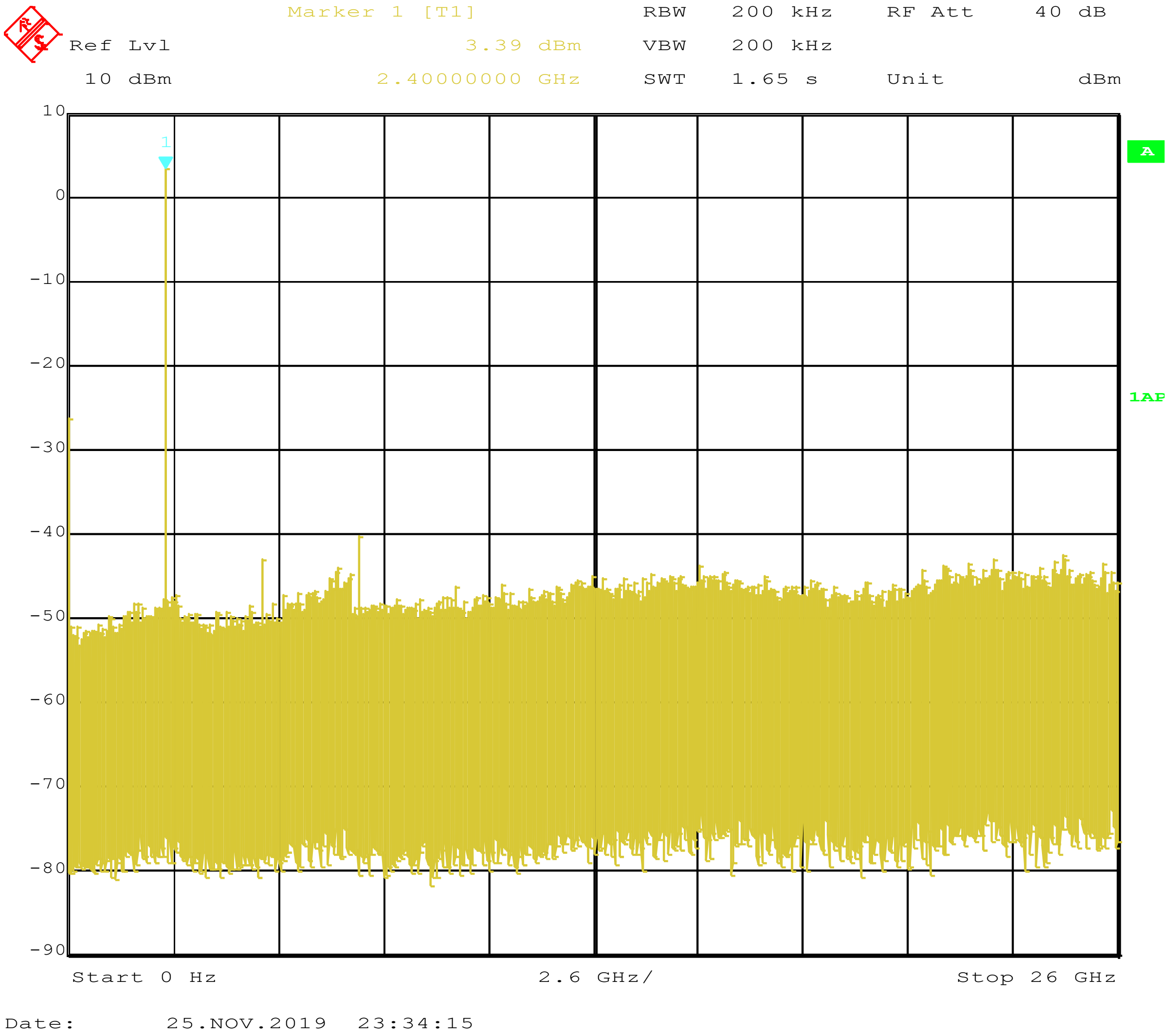
The combined gain is 41dB, the 1 dB compression point P1dB is 41.9dBm = 15W, the saturated output power Psat is 44.3dBm = 27W. In full compression the total current consumption (of both amplifiers) is 4A and the power added efficiency is 24%.

Next I subtracted the gain of the driver amplifier and thus extracted the parameters of the MRF21045 based PA itself.



The gain of the power amplfier is 16.3dB, the 1 dB compression point P1dB is 41.9dBm = 15W, the saturated output power Psat is 44.3dBm = 27W. In full compression the total current consumption is 3.4A and the drain efficiency is 28%.

Finally I measured the harmonic content of the power amplifier when operated in full saturation.



The second harmonic at 4.8 GHz is suppressed by about 48dB, the third harmonic at 7.2 GHz is suppressed by 43dB. Higher harmonics are lower than -50dBc. This are very good values. A simple harmonic filter is appropriate to suppress both by 60dB.

In order to get the maximum gain and full output power the gate voltage was adjusted to 4.4V in all previous measurements, which resulted in a quiescent current of 2.55A. When reducing the quiescent current of the PA from 2.55A down to 600mA the small signal gain drops from 16.3dB to 14.5dB. The associated gate voltage is 3.8V. The maximum output power Psat and harmonic suppression stay almost the same. Especially for portable operation in SSB where power consumption is important, I will reduce the quiescent current accordingly.

In summary the PA is working as expected. Please bear in mind that the LD-MOSFET transistor is intended to be used as a 45W amplifier in the frequency range 2110 .. 2170 MHz with a gain of 15dB.

I would like to thank Ernst-Guenter DK5DN for kindly providing his description of the modification of the PA.

I am always grateful to get feedback and will be happy to answer questions.

Please direct them to the Email address which you will find below.

Best regards

Matthias DD1US

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