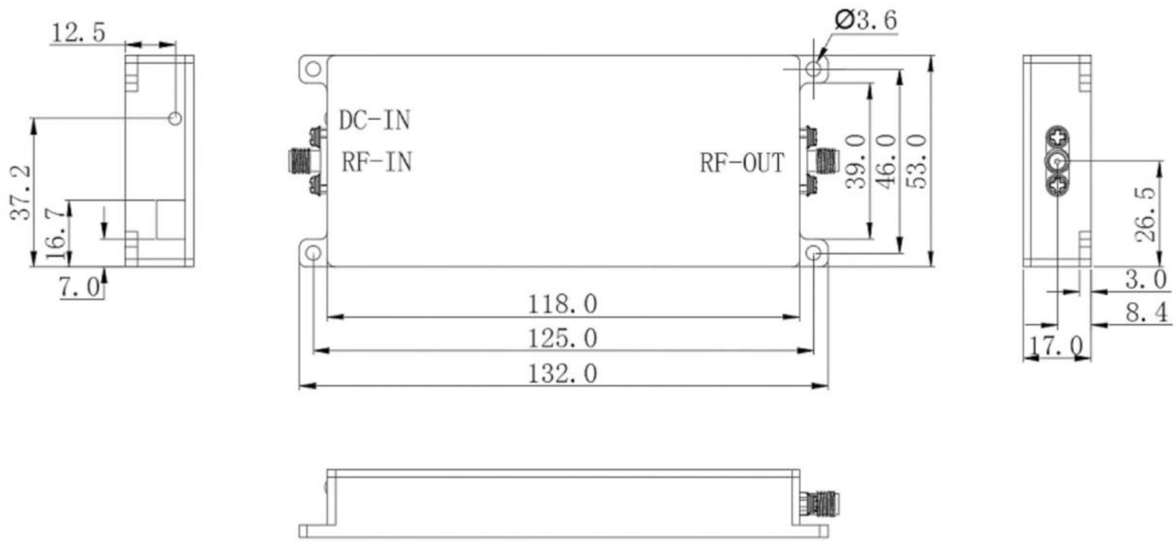
A 90W power amplifier for the 6cm band

Matthias, DD1US, April 22nd 2025, rev 1.1

Recently there have shown up GaN based power amplifier modules from a Chinese source called Szhuashi. I was most interested in the 50W module YPM5880B for the 6cm band and decided to give it a try.

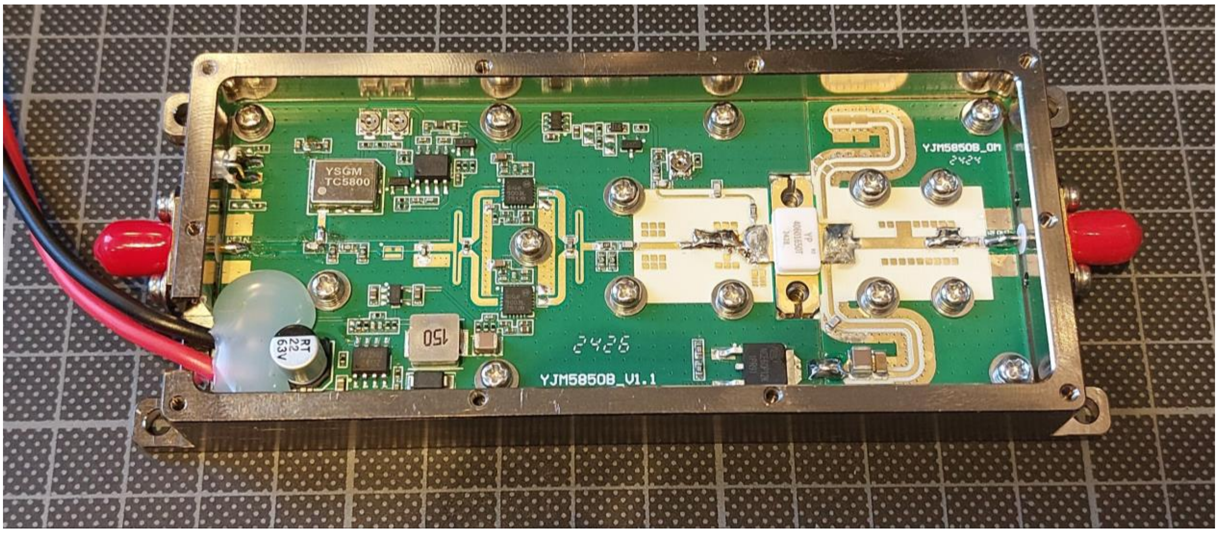
The seller provides the following specifications:

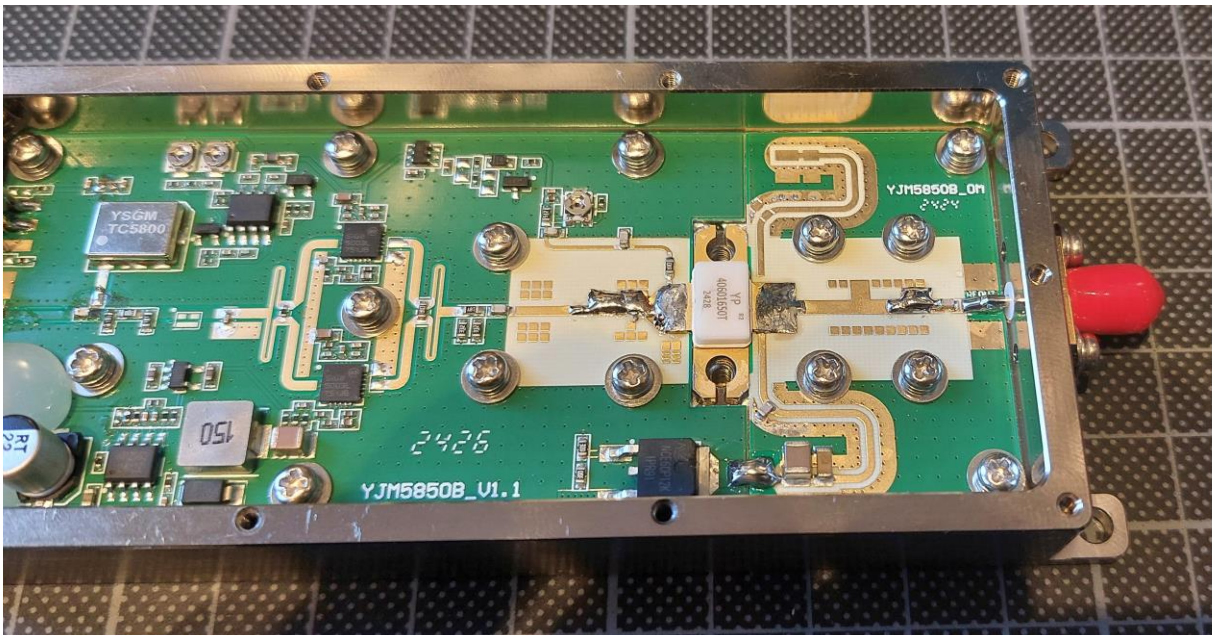
Testing environment: DC=32V, Tamb=25°C
Frequency Range: 5700 … 5900MHz
Signal Gain: 42dB
Output power: 47-48dBm
Band Fluctuation: <1dB
Maximum input power: +6dBm
Operating Current: 3.6A
Operating temperature range: -30°C … +85°C
Storage tempereature range: -40°C … +150°C
Relative humidity: <80% RH
Dimensions:

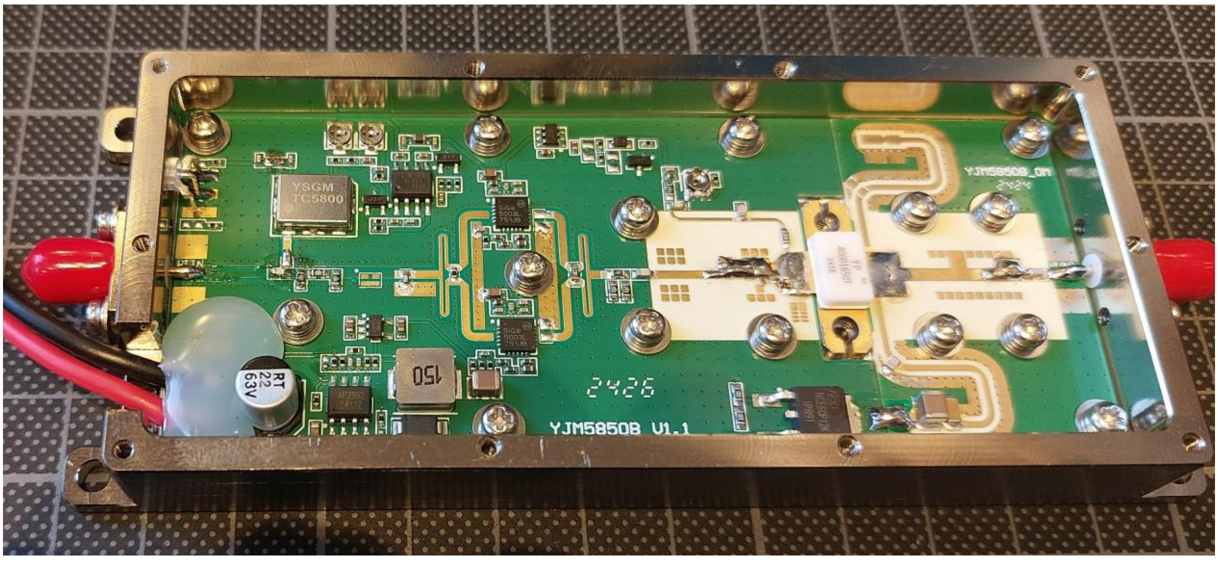


I bought the module on Ebay and a few weeks later it arrived.

The PA is housed in a compact aluminium encasing and is a two-stage amplifier with the first stage comprised of two MMIC amplifiers SiGe SE5003L operating in parallel and the second stage based on a GaN HEMT transistor with the part number YP40601650T from Innotion. Here are some pictures of the opened PA module:



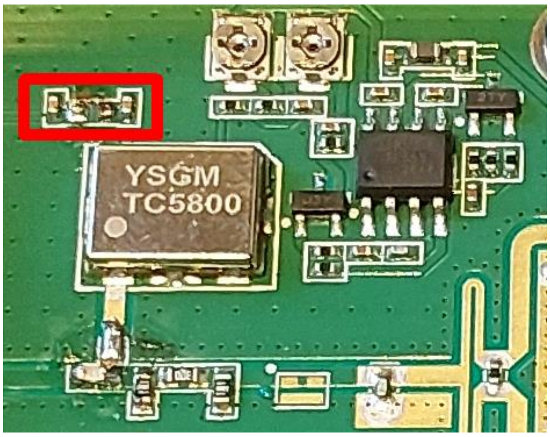




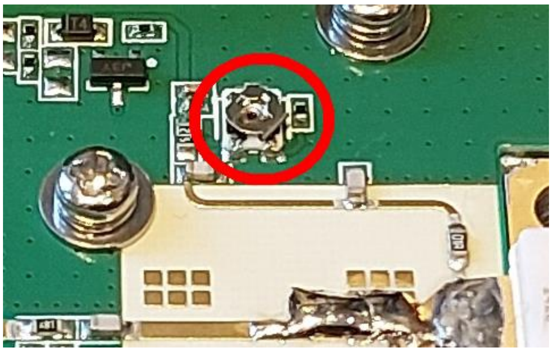
Each SiGe SE5003L MMIC is operated with a single supply voltage of +5V and provides a gain of 32dB and maximum output power of +23dBm. The current consumption is typically 340mA.

The Innotion YP40601650T is a 50W internally matched GaN HEMT transistor for the frequency range 4400 to 6000MHz. Its specified saturated output power at 5700MHz is 48.6dBm with an efficiency of 50.4% and an input drive power of 37.4dBm.

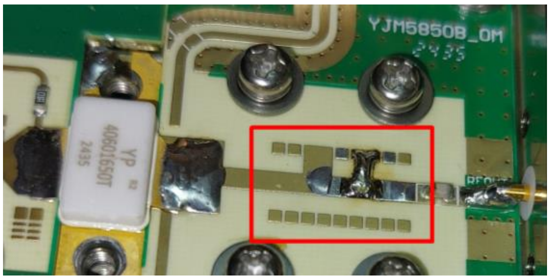
Besides the amplifier chain there is an additional oscillator marked with YSGM TC5800 in the encasing. Apparently, this amplifier can also be used as a drone jammer when the oscillator is enabled. In my module the oscillator was disabled but I heard from other users that they had to disable the oscillator in their units. Make sure to check this when you receive the unit otherwise the module might already provide full power output without any input signal. You can simply remove the SMD device marked in red in the following picture:



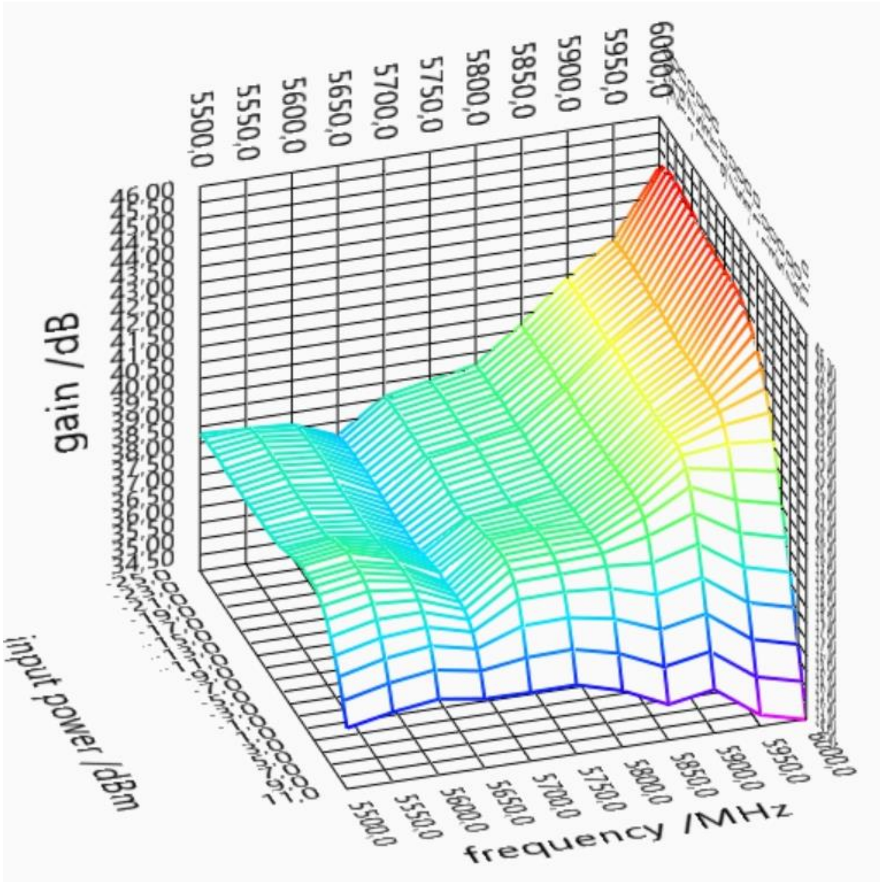
The quiescent current of the PA was originally set to approx. 2.2A. I found that setting a quiescent current of 0.7A resulted in the same maximum output power and a more linear gain versus input power without excessive gain peaking around the P1dB. The quiescent current can be set b with a small trimmer on the board:



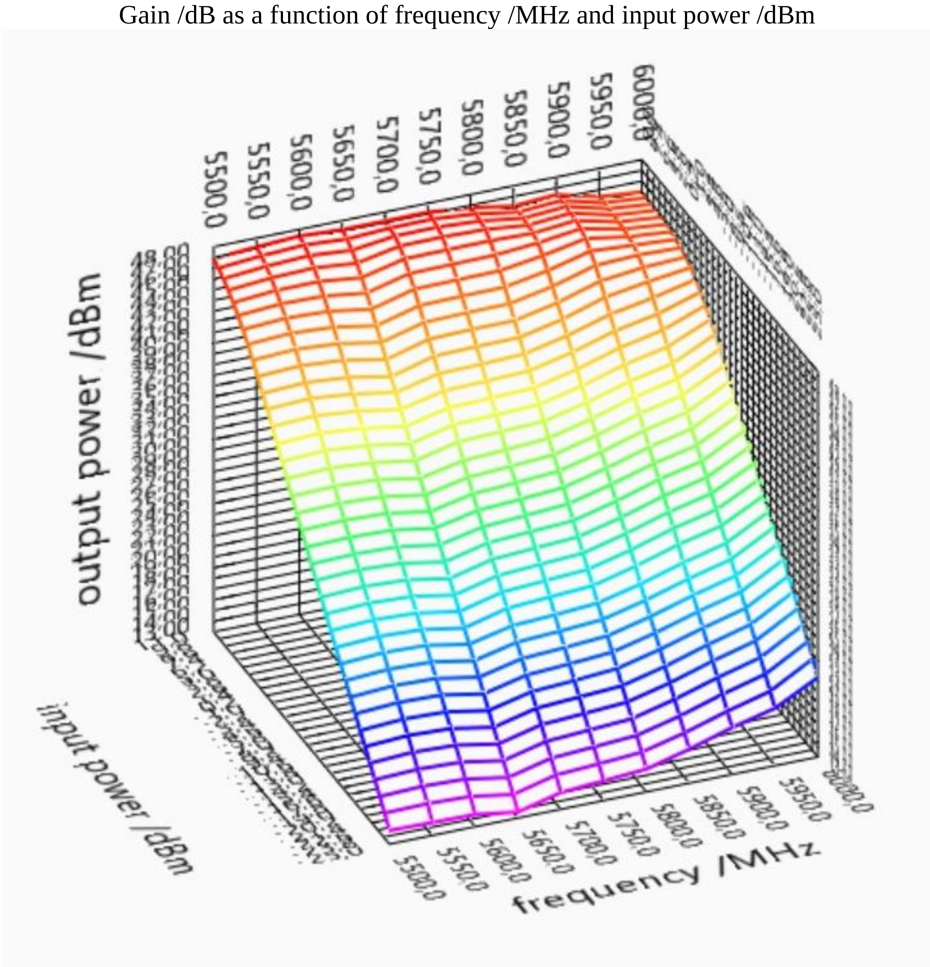
In addition, I slightly tuned the output match of the final transistor for optimum output power and efficiency. This resulted in a slight improvement of output power (ca. +0.2dB) and efficiency (ca. +5%). I tuned some more modules and the tuning was slightly different for each module. Even without tuning the modules works quite well.



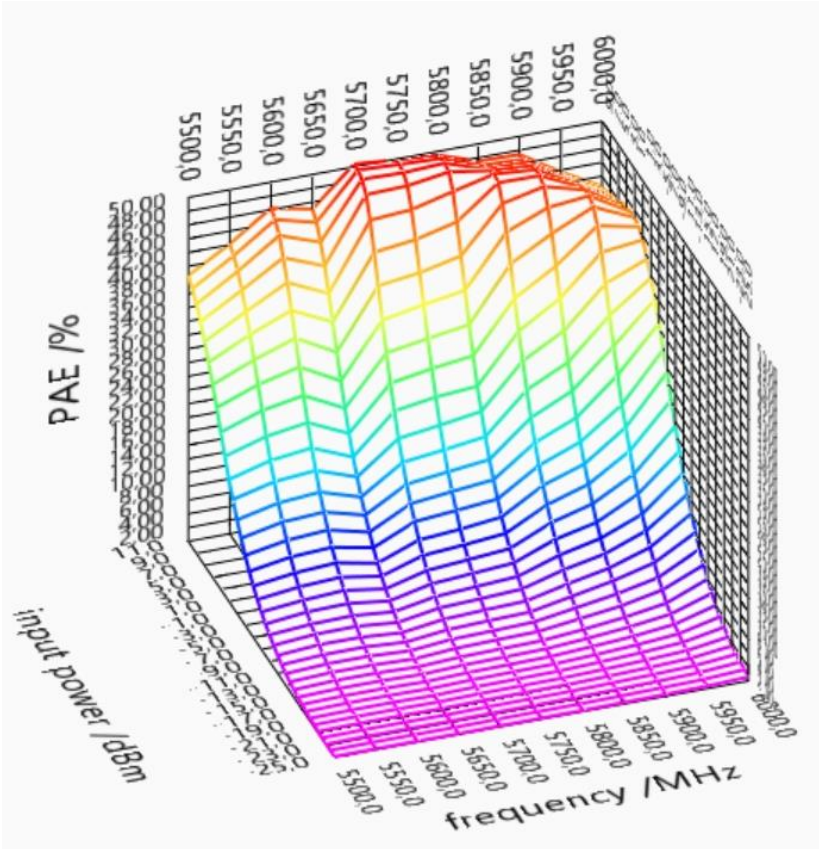
Below please find measurement results after tuning setting the quiescent current of the PA of 700mA. I characterized the PA using my automated measurement setup. Below find graphs of gain (Gp), output power (Pout) and power added efficiency (PAE) as a function of input power (Pin) and frequency (f). The frequency range is 5500MHz to 6000MHz in 50MHz steps. The input power range is -25dBm to +11dBm in 1dB steps.



Gain /dB as a function of frequency /MHz and input power /dBm

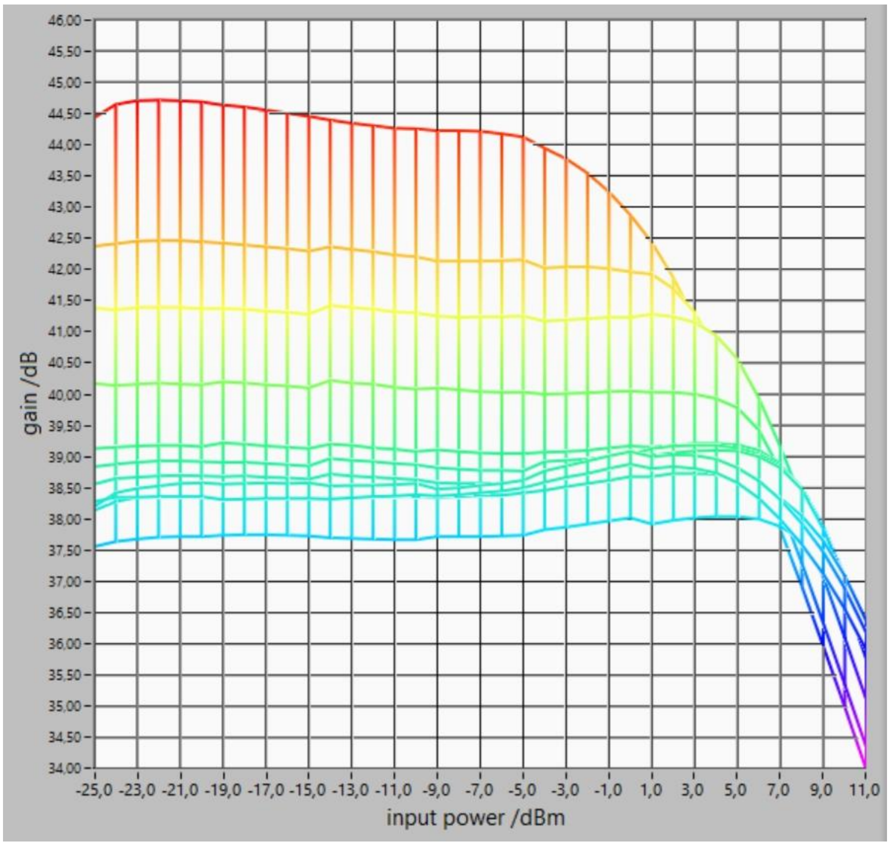


Output power /dBm as a function of frequency /MHz and input power /dBm

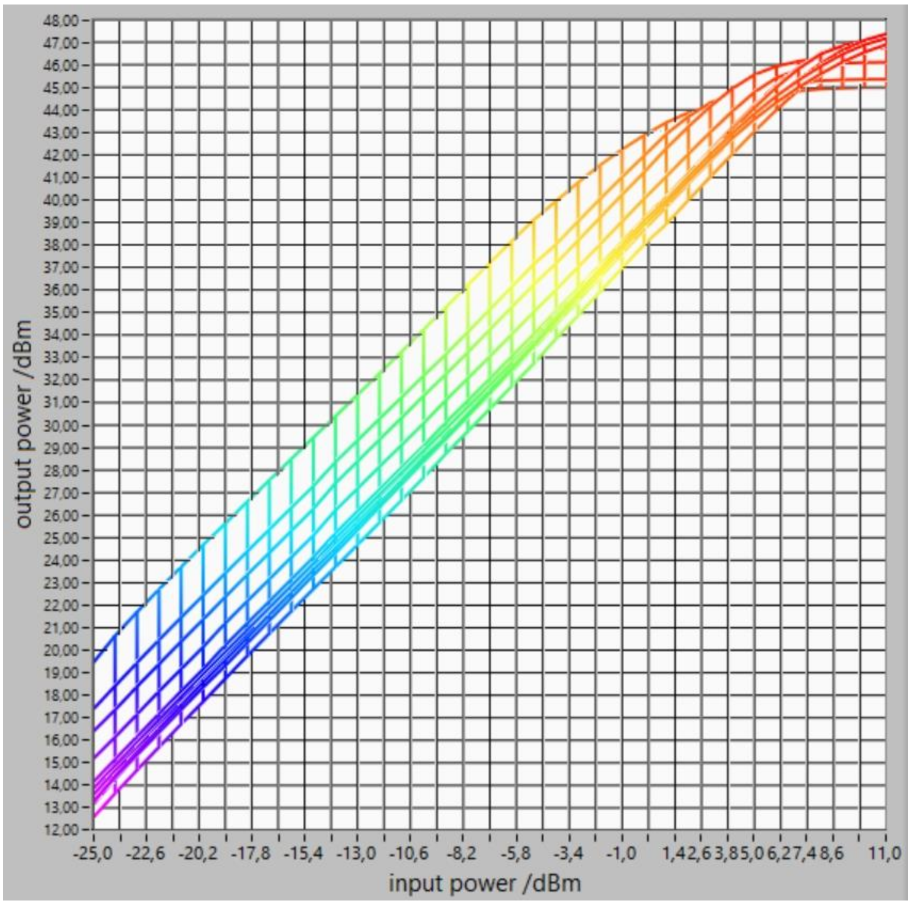


Power added efficiency /% as a function of frequency /MHz and input power /dBm

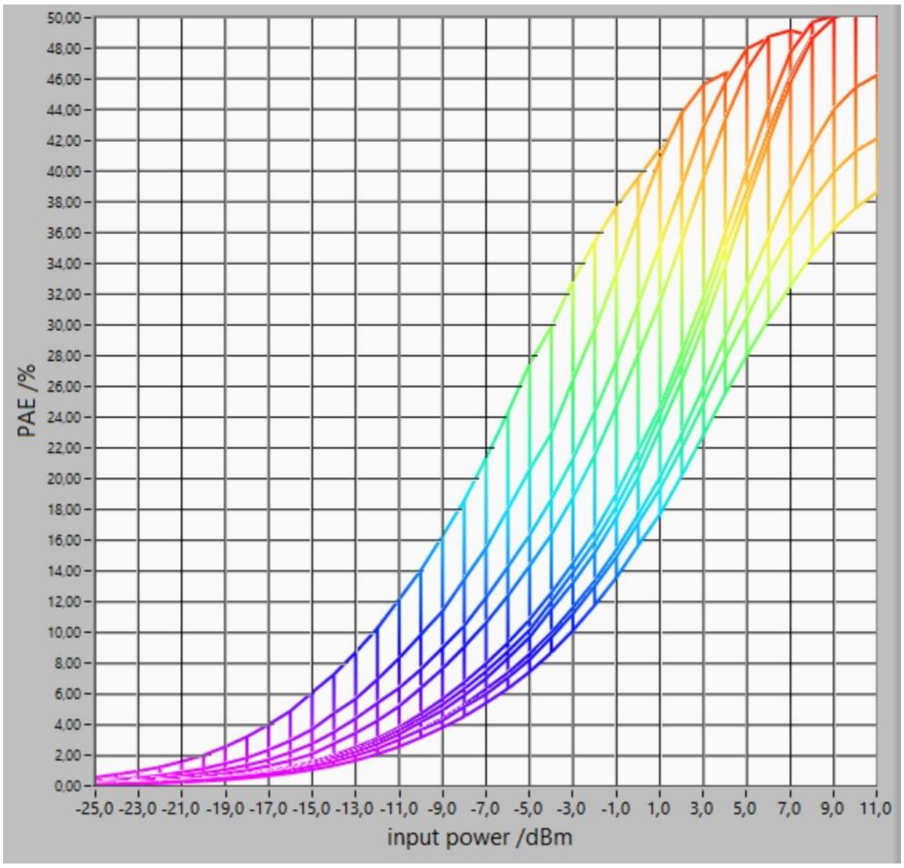
In the next three graphs you can see gain, output powe and power added efficiency plotted versus input power (from -25dBm to +11dBm). The various measurement curves represent different frequencies.



Gain /dB as a function of input power /dBm

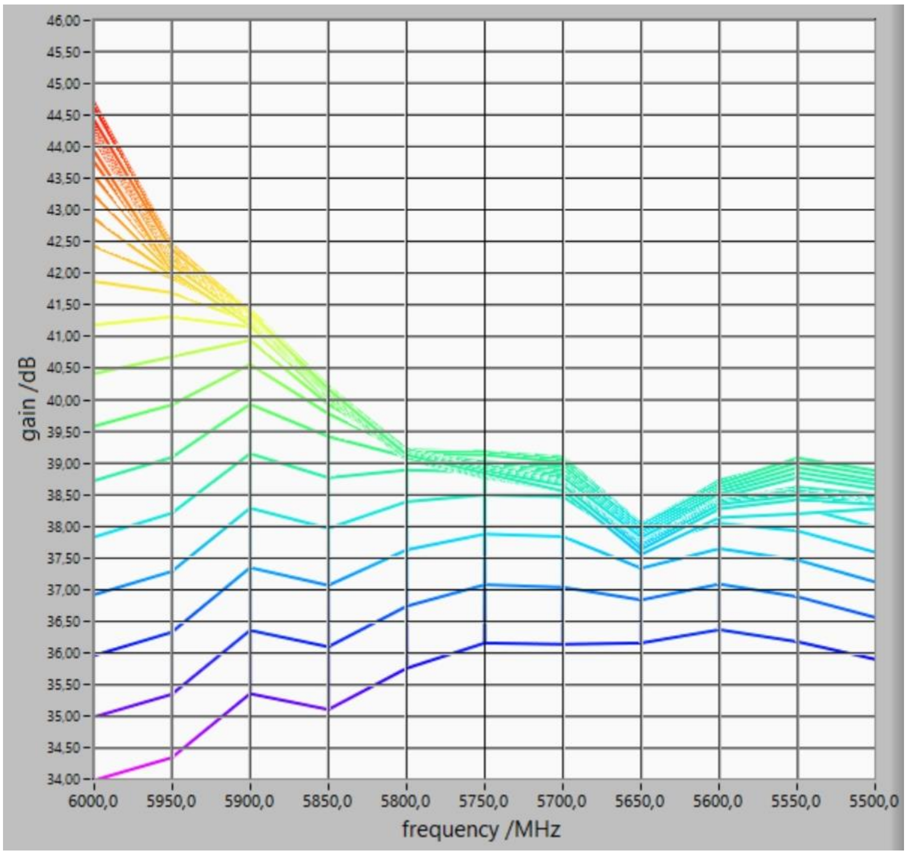


Output power /dBm as a function of input power /dBm

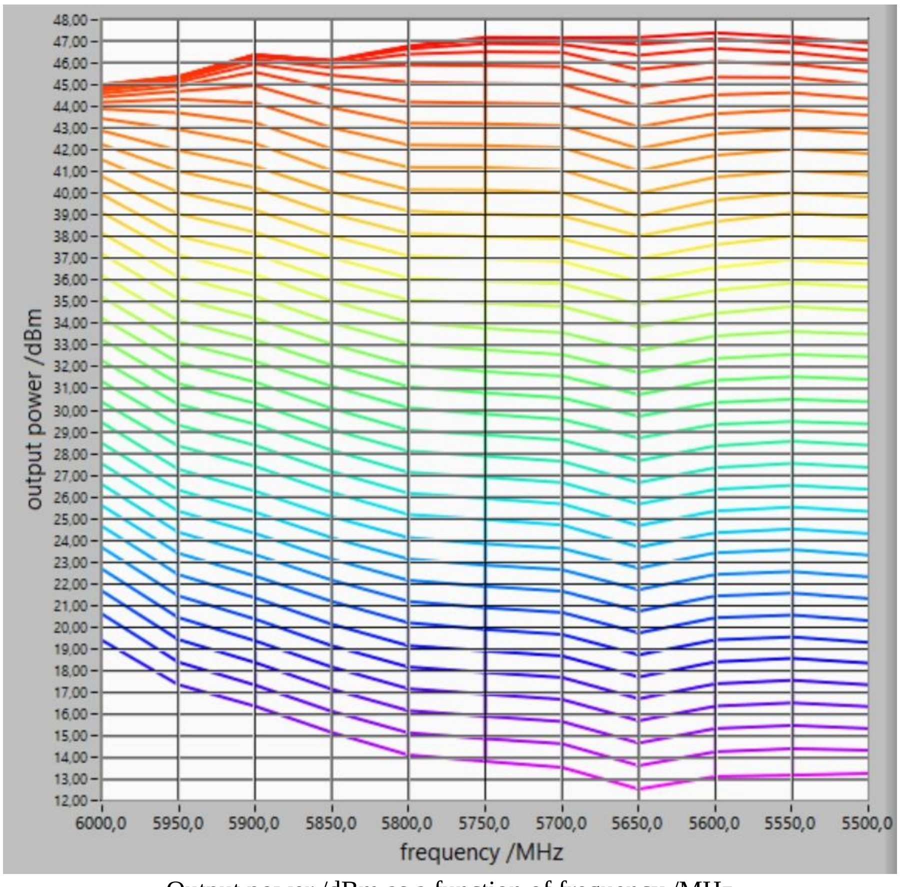


Power added efficiency /% as a function of input power /dBm

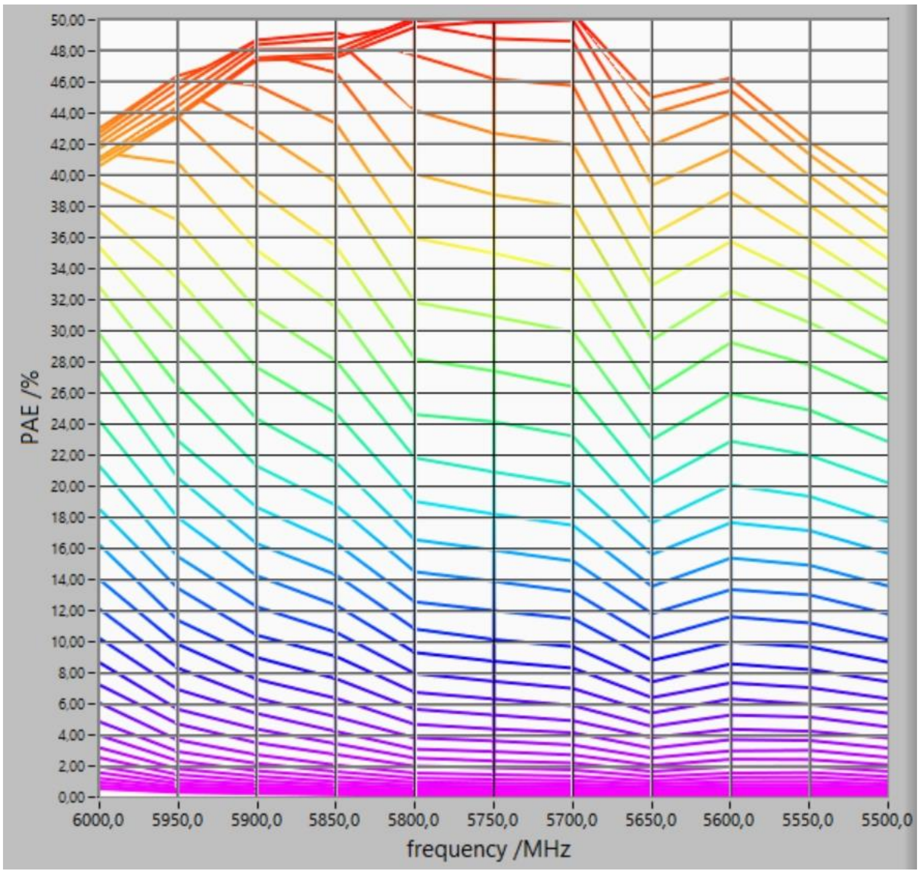
In the final three graphs you can see gain, output power and power added efficiency plotted versus frequency. (from 5500 to 6000MHz). The various measurement curves represent different input power levels.



Gain /dB as a function of frequency /MHz and input power /dBm



Output power /dBm as a function of frequency /MHz



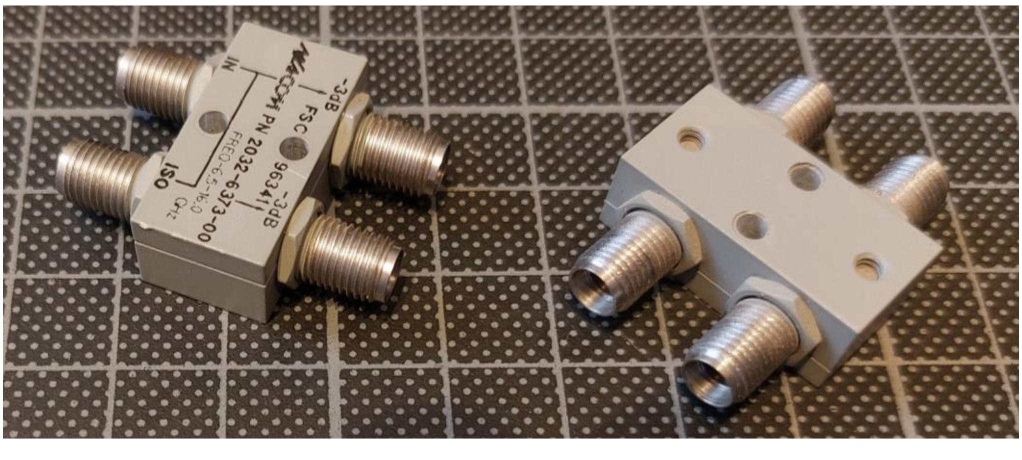
Power added efficiency /% as a function of frequency /MHz

The PA module performance is quite close to the specified values. With a little tuning a maximum output power at 5700MHz of 50W and a PAE of 50% can be achieved. I measured 3 different modules and their performance varies only slightly. Tuning the output matching for maximum PAE and power was slightly different for each.

Please note that in all the measurements above there is a slight dip in gain, power and efficiency at 5650MHz. This is a problem in my measurement setup and was the same for all devices I measured. Please ignore this.

After achieving such excellent results with the modules, I decided to build a PA unit based on two of such modules combined with 90° hybrid coupler.

For the input I used a hybrid splitter / combiner from M/A-COM with the part number 2032-6373-00. Event though it is specified for higher frequencies (6.5 to 12.3GHz) I verified that it performs well at 5700MHz.

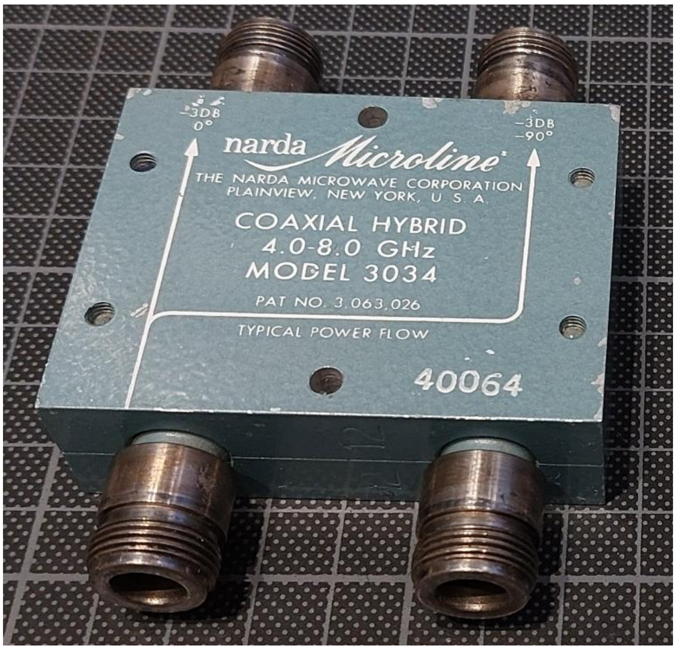


Over the full frequency range this coupler is specified to have a maximum amplitude imbalance of ±0.5dB, maximum insertion loss of 0.5dB and a minimum isolation of 18dB. The maximum VSWR at all ports is 1.35 which corresponds to a return loss of 16.5dB. It can handle a maximum continuous power of 30W.

I verified the performance of the coupler at 5.7GHz and measured its parameters for the intended usecase as a splitter (port numbering clockwise with In=port1, -3dB=port2, -3dB=port3, ISO=port4):

S11 = -24.5dB (VSWR=1.13)
S22 = -19.2dB (VSWR=1.25)
S33 = -22.8dB (VSWR=1.16)
S21 = -3.13dB
S31 = -3.18dB
Phase difference between the two -3dB output ports 92.2°. Corresponding phase error 2.2°.

For combining the outputs of the two amplifier modules I used a 90° hybrid combiner from NARDA with the model number 3034. It is specified for the frequency range 4.0 to 8.0GHz with a maximum continuous power of 200W. The nominal coupling factor from the common input port to each output port is 3.0 to 3.3dB. The maximum amplitude imbalance between the output ports is ±0.5dB. The minimum isolation is 18dB. The maximum VSWR at all ports is 1.3 which corresponds to a return loss of 17.8dB.

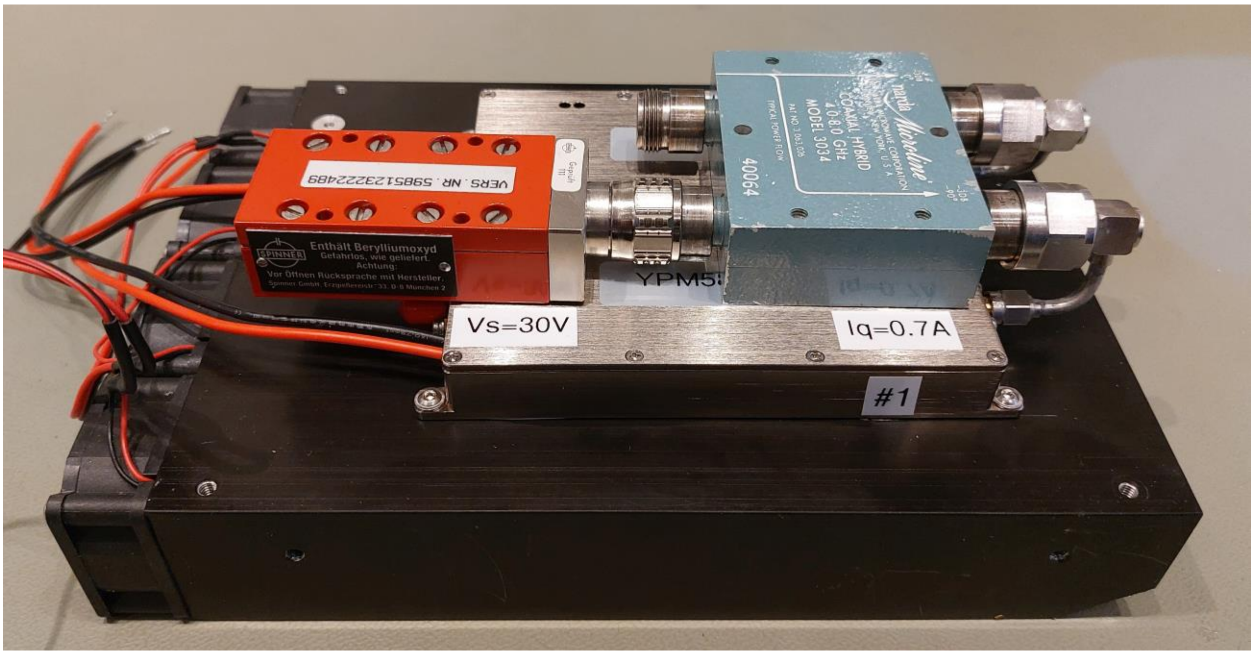


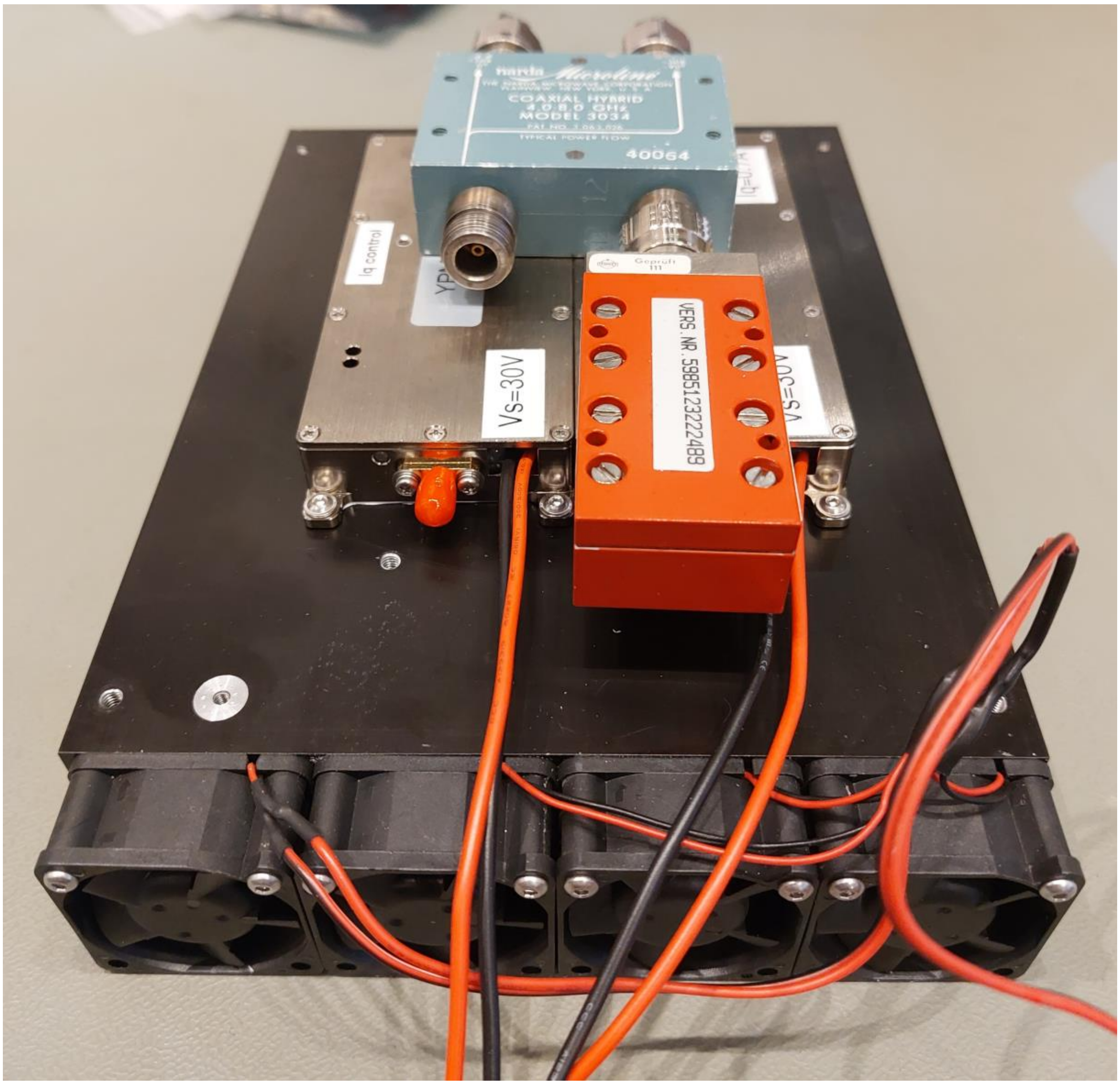
I measured the performance of the coupler at 5.75GHz (port numbering clockwise with In=port1, -3dB/0°=port2, -3dB/-90°=port3, ISO=port4):

S11 = -19.6dB (VSWR=1.23)
S22 = -12.9dB (VSWR=1.59)
S33 = -16.7dB (VSWR=1.34)
S21 = -2.94dB
S31 = -3.32dB
Phase difference between the two -3dB ports when used as a splitter 87.6°. Corresponding phase error 2.4°.
Phase difference between the two -3dB ports when used as a combiner 88.3°. Corresponding phase error 1.7°.

To tune the phase of the two amplifier branches I used a variable phase shifter JYE BAO PTS-A3A8-18-15*f. It is specified for a frequency range up to 18GHz. At 6GHz the specified phase shift range is 90°.

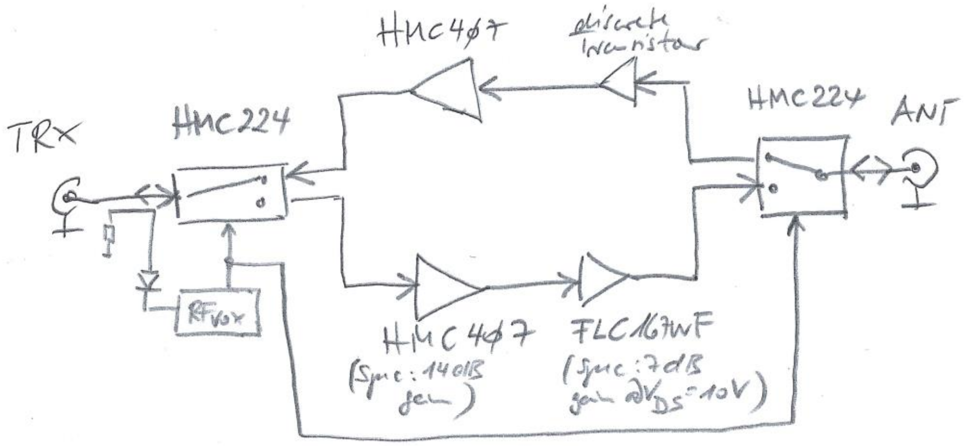
I mounted the two PA modules on a heatsink and added four 40mm fan, which turned out to be a sufficient cooling solution also when operating the PA at maximum power for transmit times of more than 10 minutes.



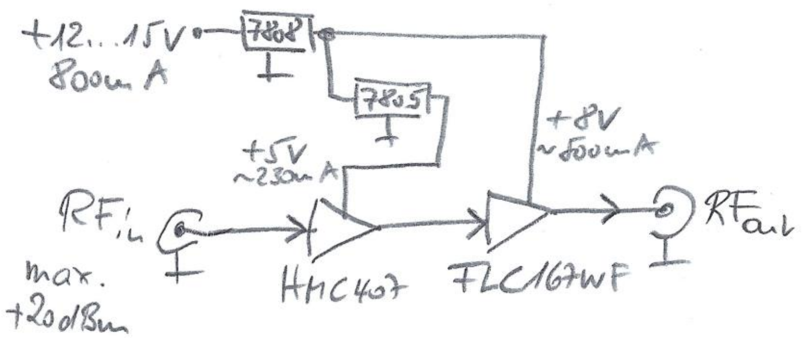


The short jumper connections from SMA male to N-male turned out to be not good for 5700MHz. I assume it is due to the right angle N-connectors and I replaced them with straight connections. The isolation port of the output combiner is terminated by a Spinner BN-527711 50Ohm dummy load with a maximum power of 25W. If needed it can be mounted on a heatsink which will increase the maximum power to 80W. This dummy load turned out to have an excellent return loss at 5.7GHz of more than 30dB.

As I wanted to be able to drive the PA with a SDR transceiver I decided to add a driver amplifier. I had a PCB of an old bidirectional RF-LINX WIFI amplifier (Antennafier MN-5080SX)) in my drawers and modified it. This is a sketch of the original block diagram of this amplifier:



This modules provided a TX gain of 14dB and a RX gain of 17dB, The measured maximum output power was 24.65dBm with an input power of 11.4dBm.
The transmit gain was originally 14dB which was a bit low for my application. I decided to disable the receive amplifier path and remove the HMC407 T/R-switches. I also disabled the RF-VOX function which was switching from RX to TX at an input power of about +2dBm and enable the transmit amplifier chain as soon as the supply voltage is applied. This is a sketch of the block diagram of the modified amplifier:

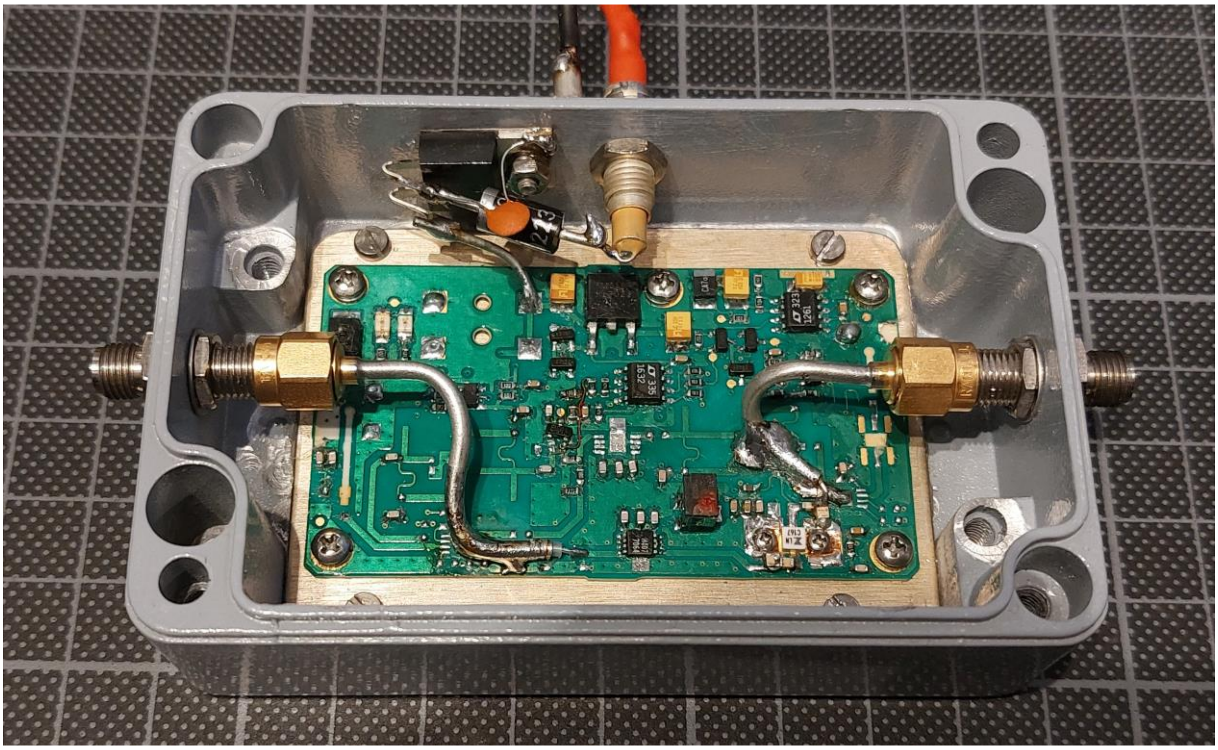


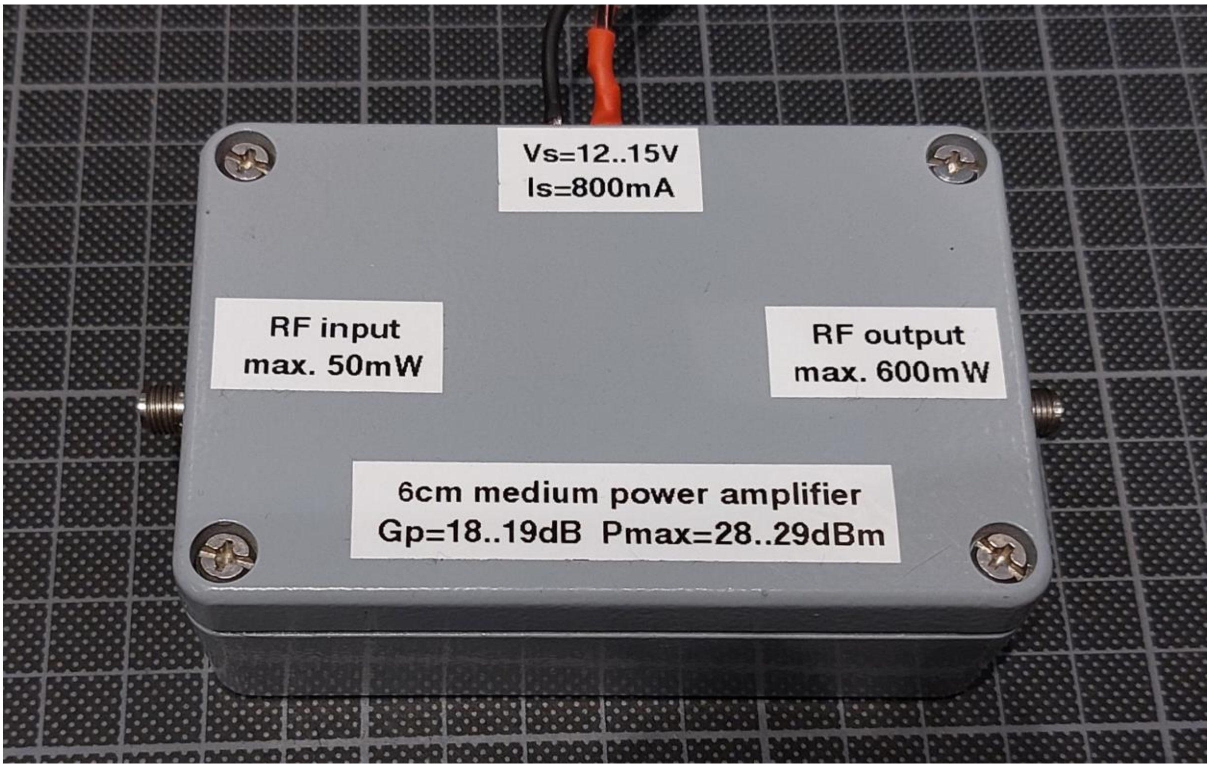
In order to be able to use the 12V power supply I added a second voltage regulator reducing the voltage from 12V to 8V. Here are the measured parameters of the modified amplifier:

Pin /dBm	Pout /dBm	Gain /dB
0	19	19
5	24.3	19.3
10	27.8	17.8
13	28.8	15.8

The PA gives a linear gain of about 19dB at 5700MHz with a P1dB of about 27dBm. If needed the maximum output power could be increased to +30dBm if the supply voltage of the final stage is increased from 8V to 10V. This is not needed in my setup.

I mounted the PCB in a aluminum encasing which was screwed to a sidewall of the PA encasing.



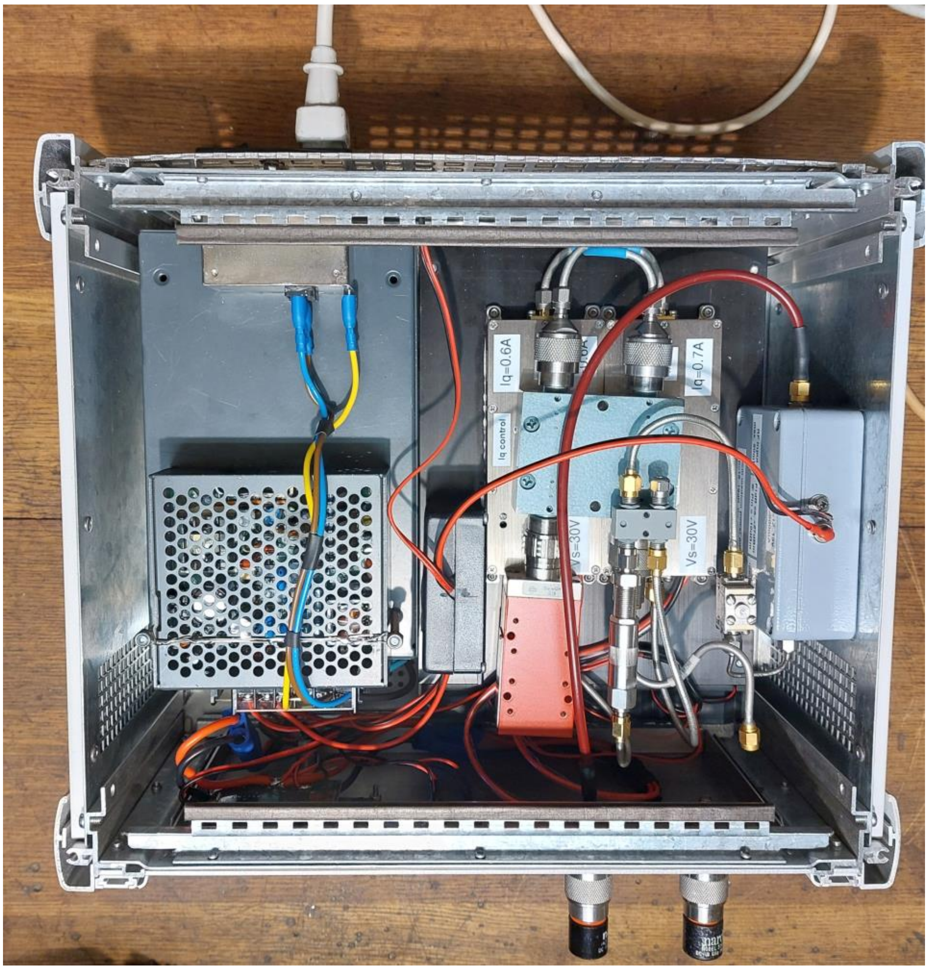


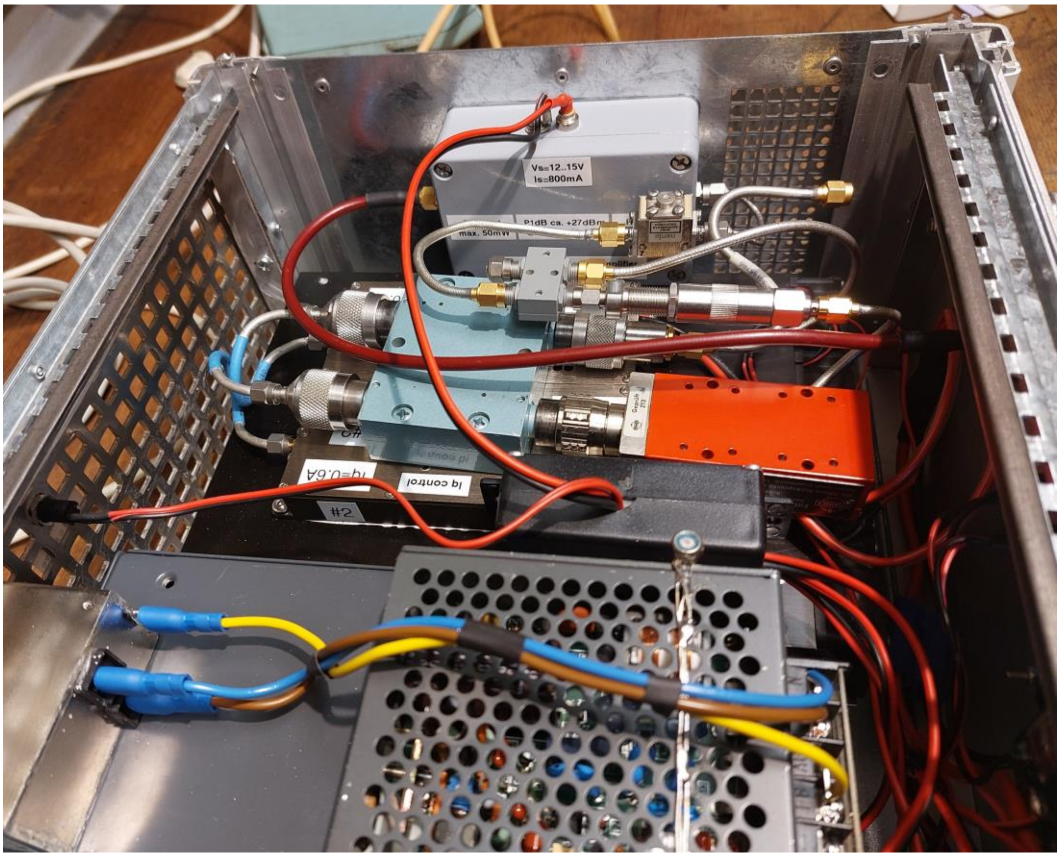
I am using two power supplies units from DENSEI Lambda.

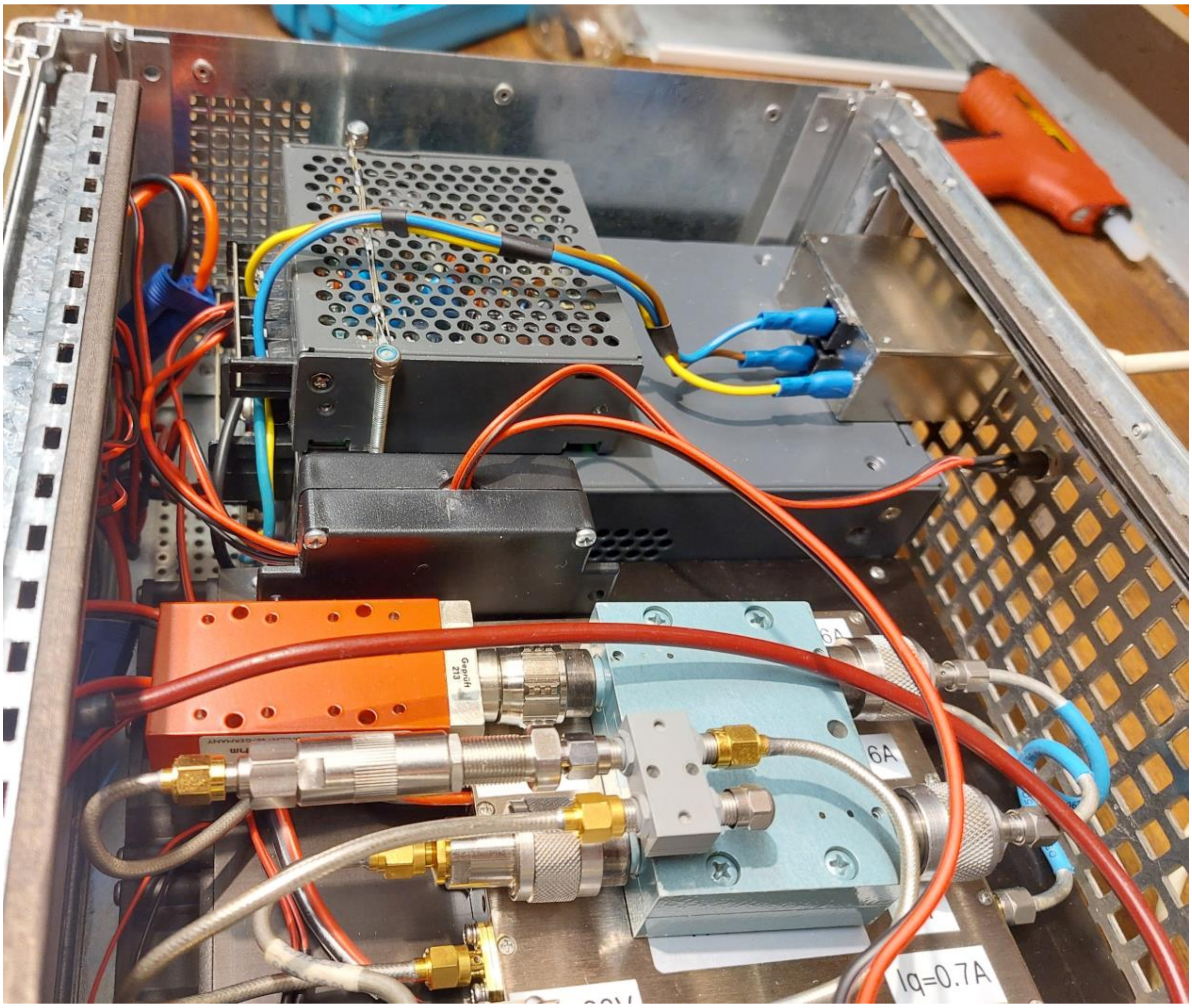
A 24V EWS300 24V/14A unit with the output voltage adjusted to 30V. The nice thing about this power supply is that the output voltage can be enabled by connecting two pins TOG and CNT and this is used by the PTT input. Thus the two PA modules are only powered on when the PTT is activated.

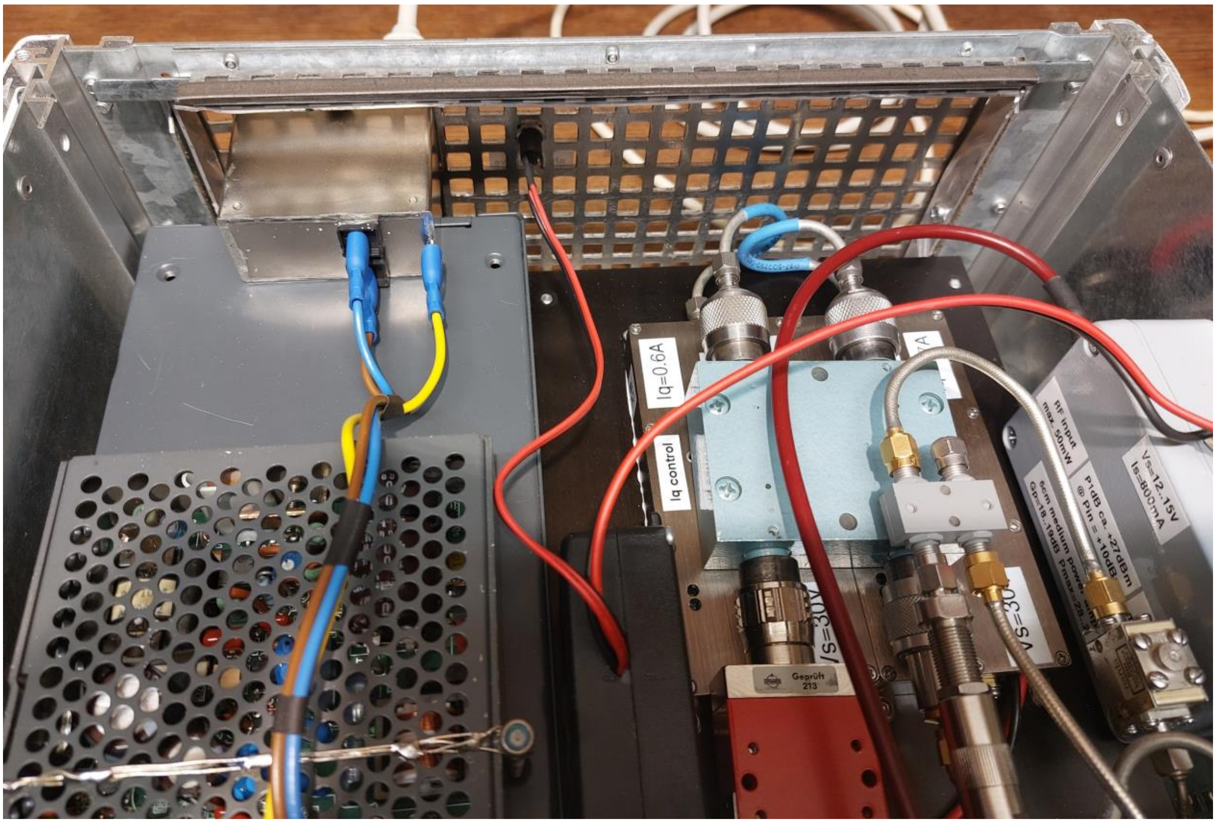
The second power supply is a Lambda EWS-15-15 15V/1.1A which I adjusted to an output voltage of 12V. This powers the driver amplifier and the fans for cooling the heatsink. The 12V is always on as soon as 230V mains switch of the complete PA is switched on.

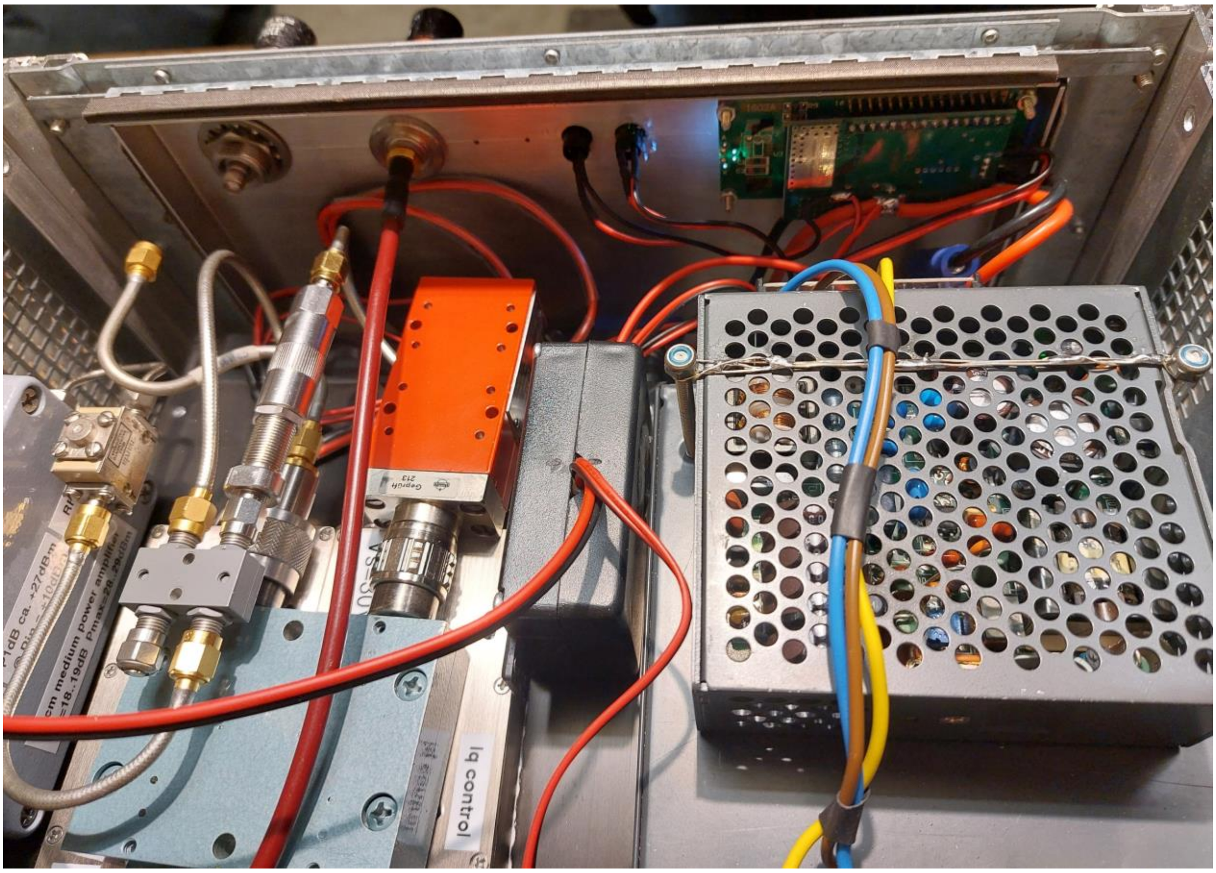
Here are some pictures of the integration of the varous modules in the encasing.

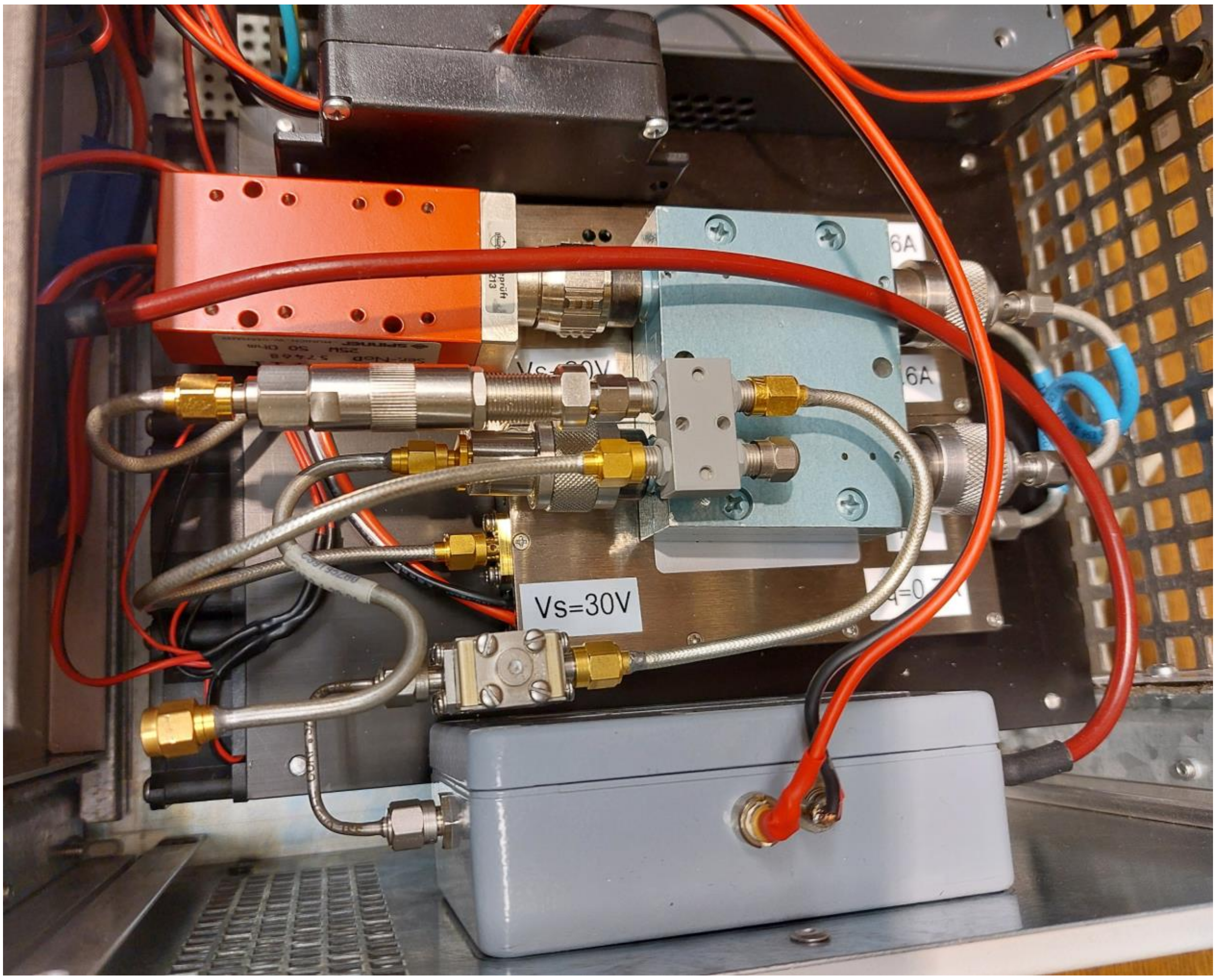





Iq=0.7A


Iq=0.6A
Iq control

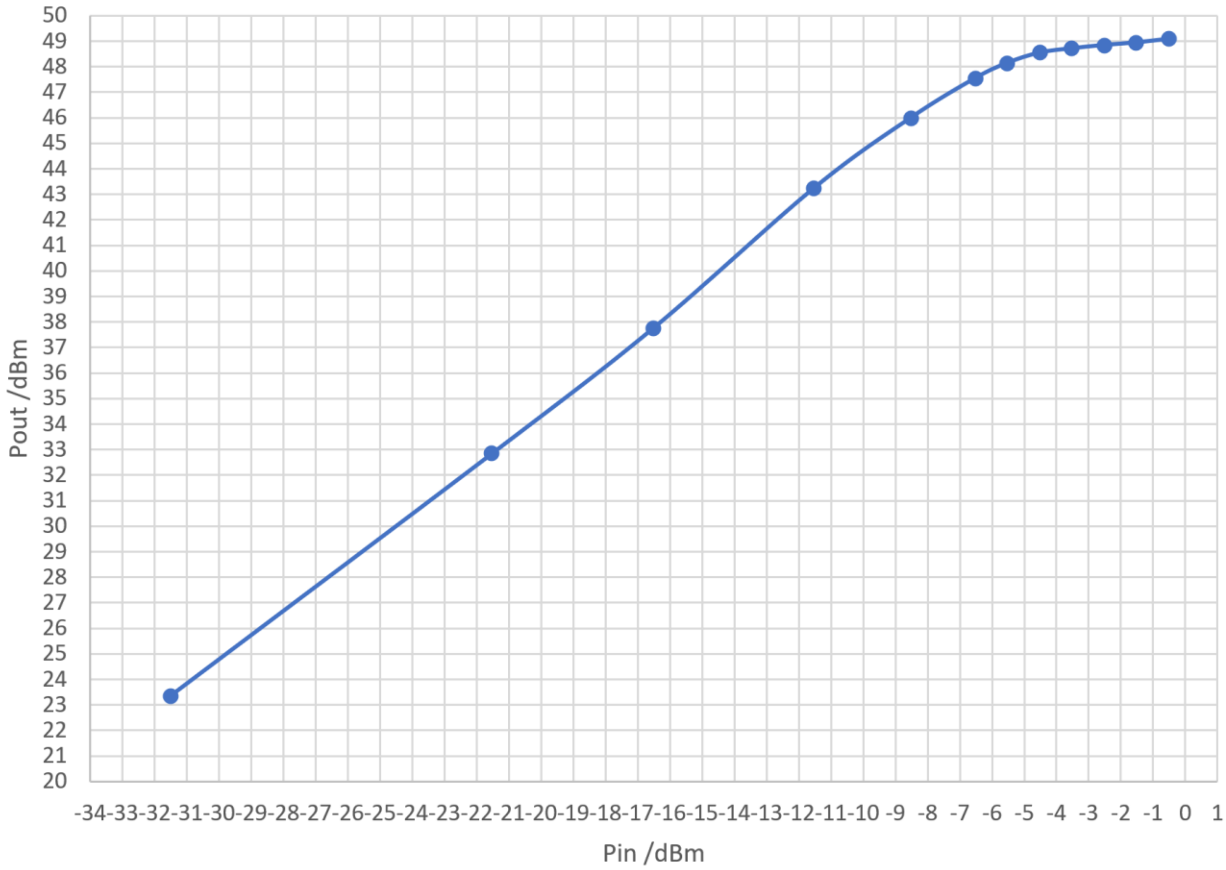

Iq control


Vs=30V

I mounted a DC voltage and current meter for the 30V power supply and two LEDs as indicators for the 12V voltage (green) and the activated PTT (blue) in the front plate. In addition, I added a push button switch to be able to activate the PTT / switch the PA module on for testing.

The back side features on the left an AC power jack, AC fuse and an AC power switch. The 3.5mm jack is used for activating the PTT / switch the PA module on remotely. Here are some pictures of the finished PA.

Finally, I measured the performance of the complete PA. I had it running for some time and it was warm.
I measured an output power of 82W. Below find the measurement:



After this measurement I found out that the patch cable at the output from the coupler to the front plate was getting hot. Apparently, the losses were too significant.

After replacing this patch cable with a solid cable, I measured an output power of 93W when the PA was cold and 88W when it was operating for some time.

By the way, I checked the phase adjustment using the phase shifter for different input powers and also when the PA was cold and hot. I had expected to some phase shift but this was negligible. I did not find a difference of the optimum phase setting.

I will repeat the measurements with my automated measurement setup again when I find time in the next weeks.

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

Please direct them to my Email address, which you find on my website.

Best regards

Matthias DD1US

Homepage: http://www.dd1us.de