AMSAT-DL 2.4 GHz 6W PA for operation via QO-100 especially with an SDR

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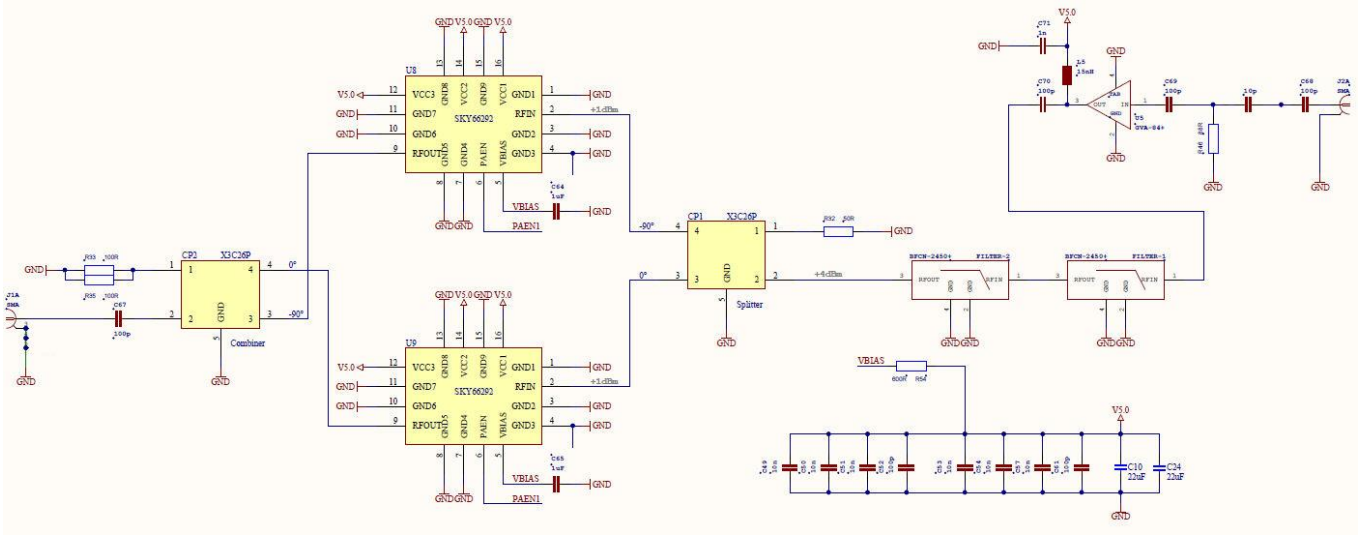
There are various concepts for power amplifiers for the geostationary satellite QO-100. Unfortunately, many concepts are based on a supply voltage of 28V with a very low efficiency. In addition, many amplifiers have too low a gain to drive them directly with an SDR such as the ADALM-Pluto, a LimeSDR-USB or LimeSDR-mini.

The following design was developed by Stefan DG8FAC for operation with an SDR via the narrowband transponder. It is optimised for a wide voltage supply range from 6 to 15V and a high overall efficiency. This makes it particularly suitable for portable applications. The amplifier can also be used very well as a driver between an ADALM-Pluto and a High Power PA for DATV. You will find some measurement results later in this documentation.

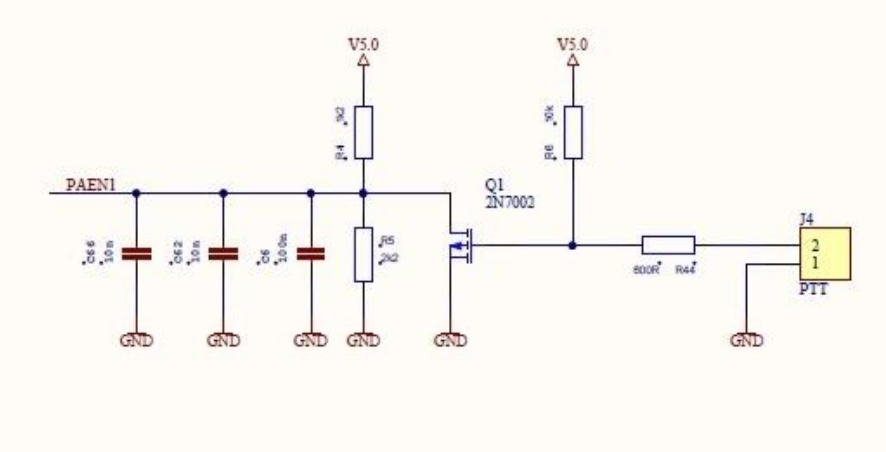
This PA delivers a saturated output power of more than 6W. For SSB operation via QO-100, the PA should not be driven above approx. 3W to ensure sufficient linearity. Due to the two-stage design with a high linear gain of approx. 46dB, already approx. 120uW are sufficient to generate an output power of 3W.

In the following you will find a detailed description of the circuit before you find measurement results and a summary.



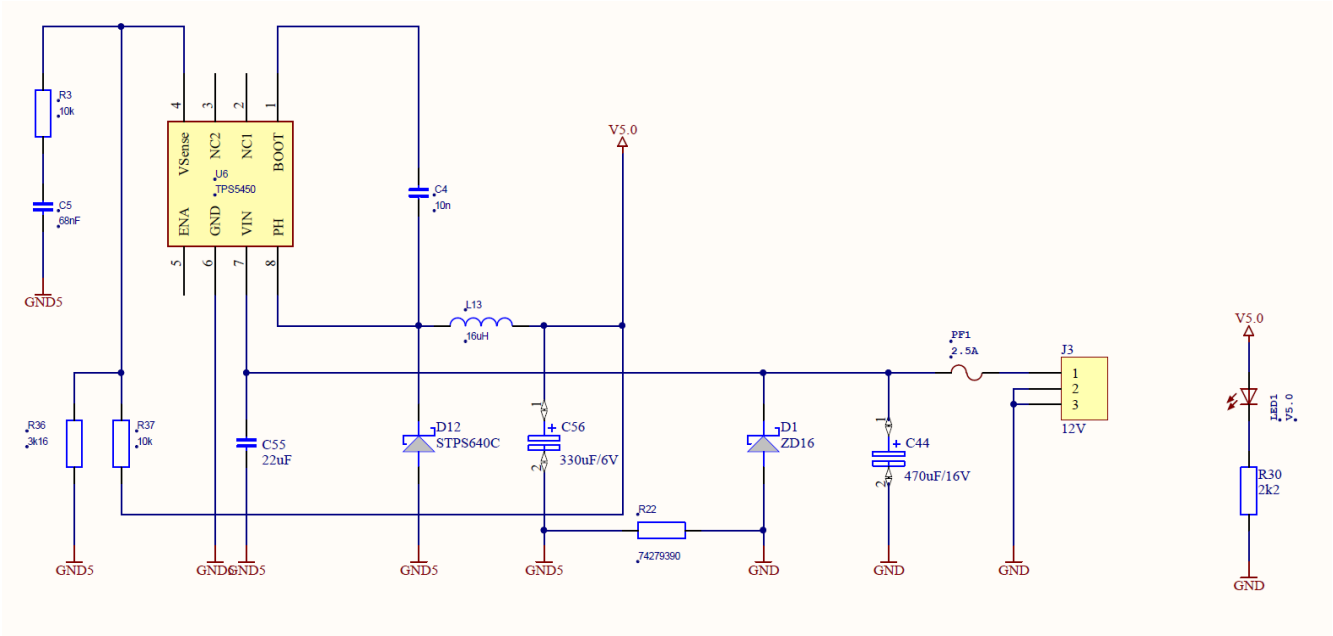
Circuit diagram RF section

The input signal (in the circuit diagram on the right) is first matched to the input of the driver amplifier and then amplified by this MMIC of the type Minicircuits GVA-84+ by approx. 16dB. Unwanted spurious emissions, for example from a local oscillator not optimally suppressed in the transmitter, are then suppressed by 2 cascaded LTCC bandpass filters of the Mini-Circuits company type BFCN-2450+. Subsequently, the signal is split by a 90 degree hybrid coupler to 2 low power amplifiers of the company Skyworks of the type SKY66292. After both partial signals have been amplified by approx. 35dB, they are combined in another identical 90 degree hybrid coupler and the sum signal is made available at the output socket (in the circuit diagram on the left). Both hybrid couplers of the type GSC356-HYB2500 from Soshin offer sufficient margin with a nominal maximum power of 100W.



Circuit diagram PTT input

The PA offers a PTT switch input with which the two Skyworks amplifiers can be switched on or off. This ensures that no output signal leaves the PA during reception. It also reduces the quiescent current during reception to approx. 62mA. When the PTT is pressed (active low), the quiescent current of the power amplifier is approx. 130mA at a supply voltage of 12V.

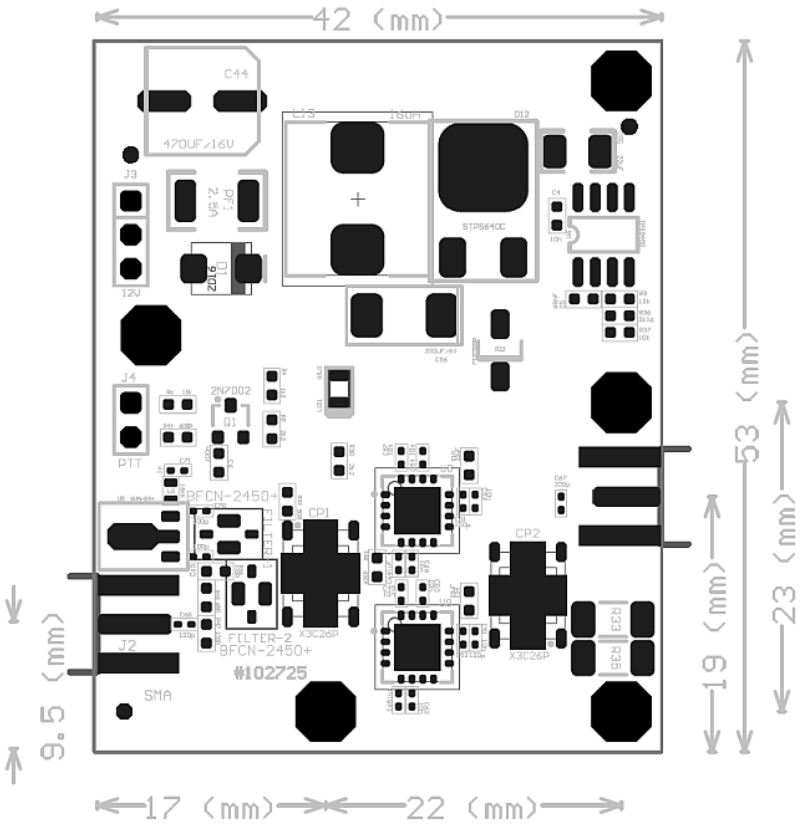


Circuit diagram power supply section

In order to guarantee a constant output power with a high efficiency over a wide supply voltage range from 6V to 15V, a small, highly efficient switching power supply based on a TPS5450 from Texas Instrument is integrated into the PA. All 3 amplifier stages are operated with a regulated supply voltage of +5V.

The PA is realized on a very compact PCB with the dimensions 42mm x 53mm. A combination of FR4 and Teflon is used as PCB material to minimize RF losses and at the same time optimize manufacturing costs.

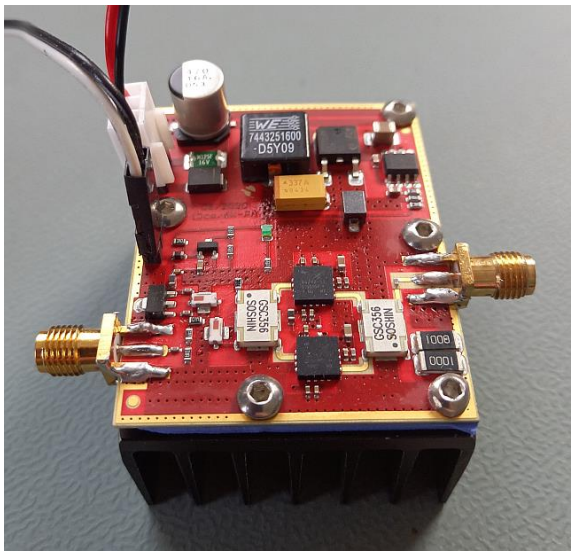
All SMD components are assembled using a professional assembly and soldering system.

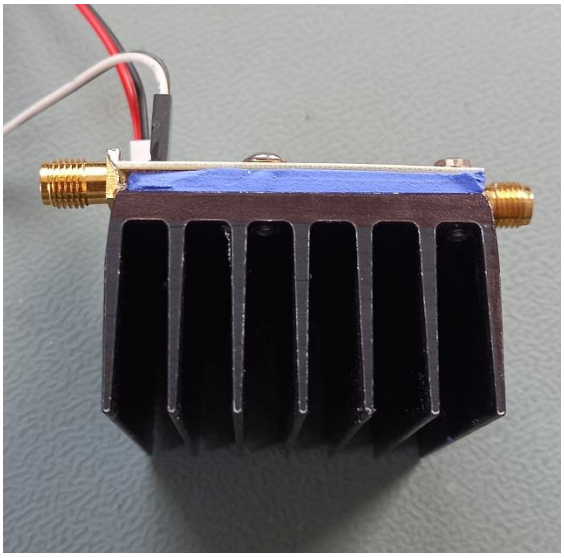


Layout

Heat dissipation with simultaneous electrical insulation is ensured by a 3mm thick thermal pad of the type EC360BLUE from ExtremeCool. This heat conduction pad has a thermal conductivity of 5W/mK and is applied over the entire surface between the PCB and the heat sink. First, remove the thicker protective film and position the PAD on the bottom of the PCB and press it on lightly. Then peel off the thinner protective film and position the PCB with PAD on the heat sink. The kit comes with 2 PADs of 2mm and 3mm thickness. If you mount the PA board on a larger plate or heat sink, you will have problems screwing on the SMA connectors when using the 3mm PAD. In this case it is better to stack the two PADs. With the resulting approx. 5mm thickness, the distance between the SMA socket and the heat sink is then sufficient. It is sufficient to compress the PADs only slightly.

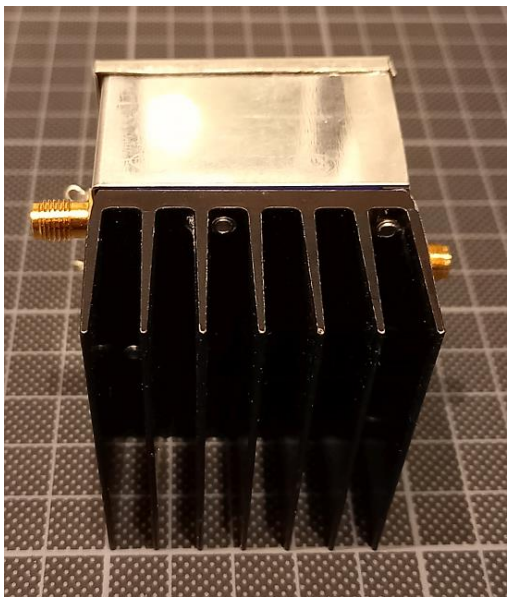
Here are some pictures of the test setup. The heat sink should be dimensioned somewhat larger for long continuous transmissions, e.g. for digital data transmissions with the AMSAT-DL high-speed modem or when used as a driver for DATV.

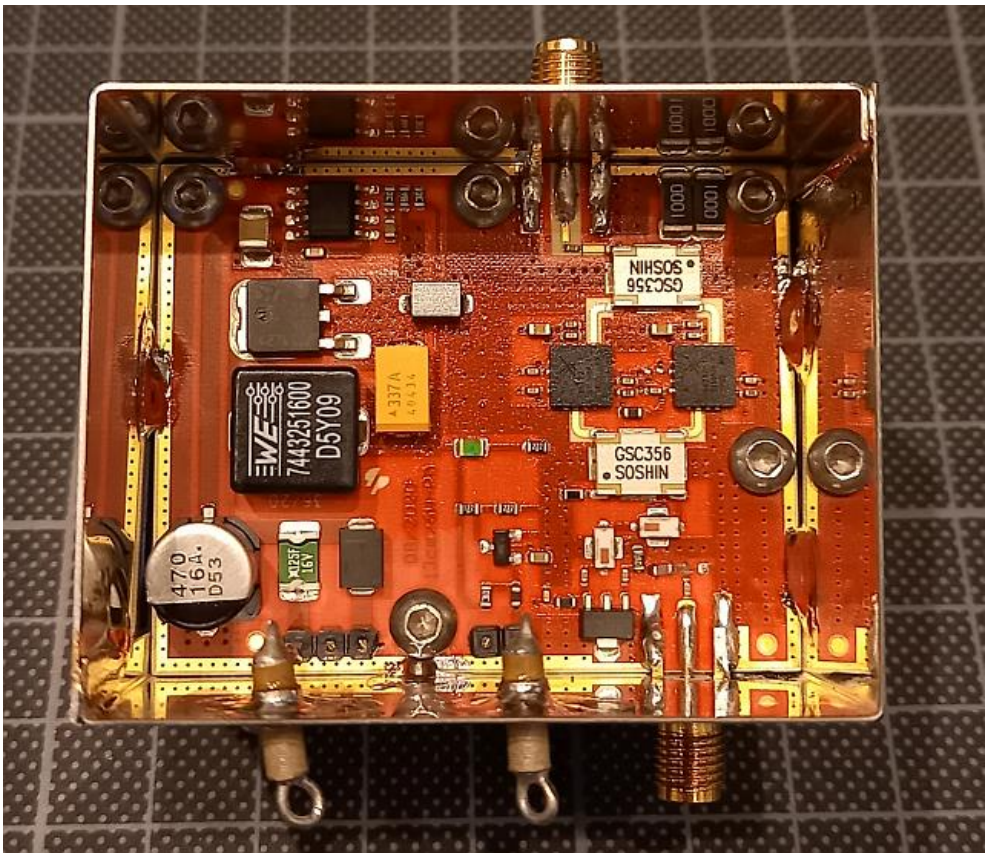

Test setup without housing


Sandwich construction with blue thermal pad

If the PA is not mounted in a metal housing as a whole, it should be installed in a tinplate housing for sufficient shielding. Feed-through capacitors for the supply voltage feed and the PTT switching signal avoid conducted interference.

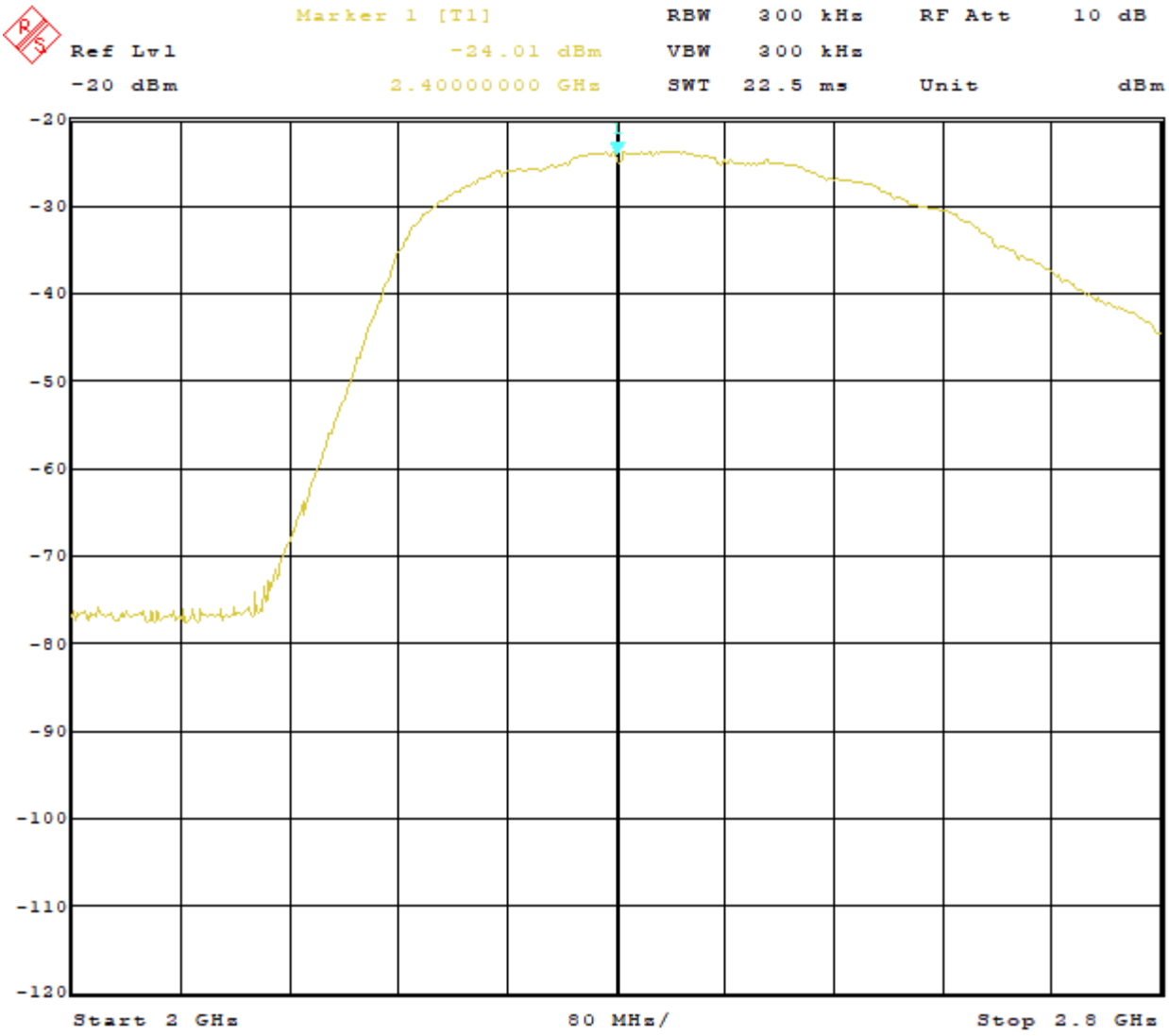
Test setup in tinplate housing


Test setup with heatsink



Test setup in the opened tinplate housing

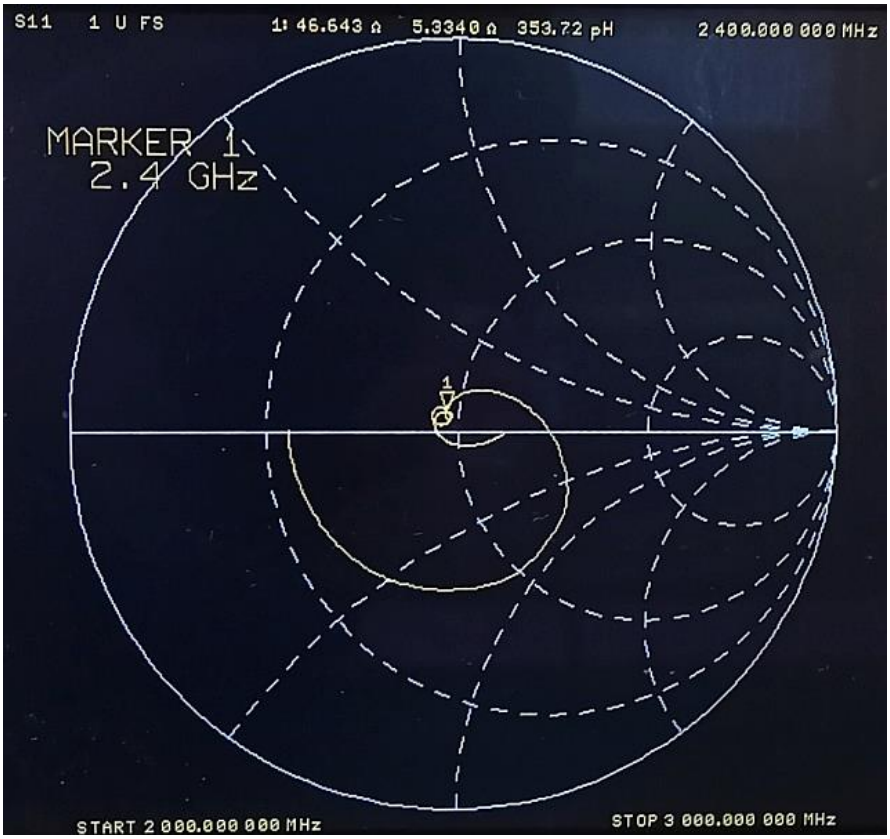
The frequency response of the amplifier was measured in the frequency range 2.0 to 2.8 GHz. The measurement was made with a spectrum analyser in "peak hold" mode and the signal generator was tuned by hand. The following picture shows the measured output level, whereby an attenuation of 40.8 dB was inserted between the amplifier output and the spectrum analyser input.



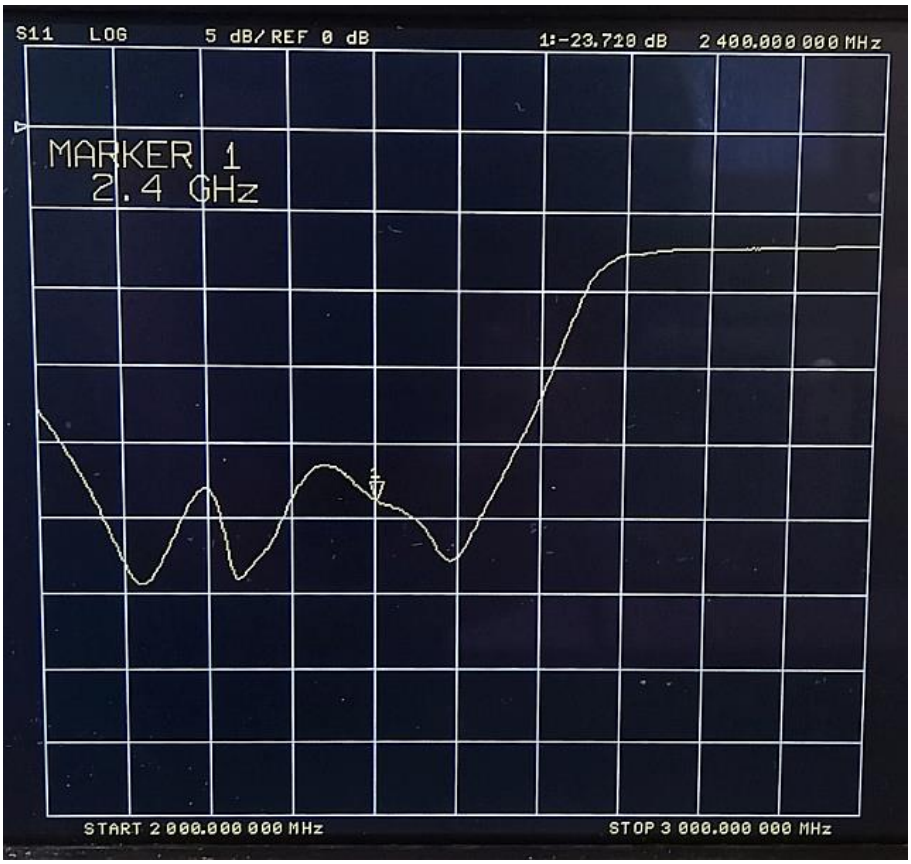
Gemessener Frequenzgang

The two cascaded bandpass filters attenuate signals below 2120MHz by more than 55dB. In fact, the suppression is even higher, but the measurement was limited by the dynamic range of the measurement setup. If an upconverter with an intermediate frequency of 435MHz is used, the local oscillator is usually at 1965MHz and the mirror frequency at 1530MHz. If the upconverter does not suppress these signals well, they will be lowered sufficiently in this PA at the latest.

During the development of the amplifier, emphasis was placed on good input matching in order to minimise possible feedback effects on the transmitter. The input matching is approx. 23 dB.

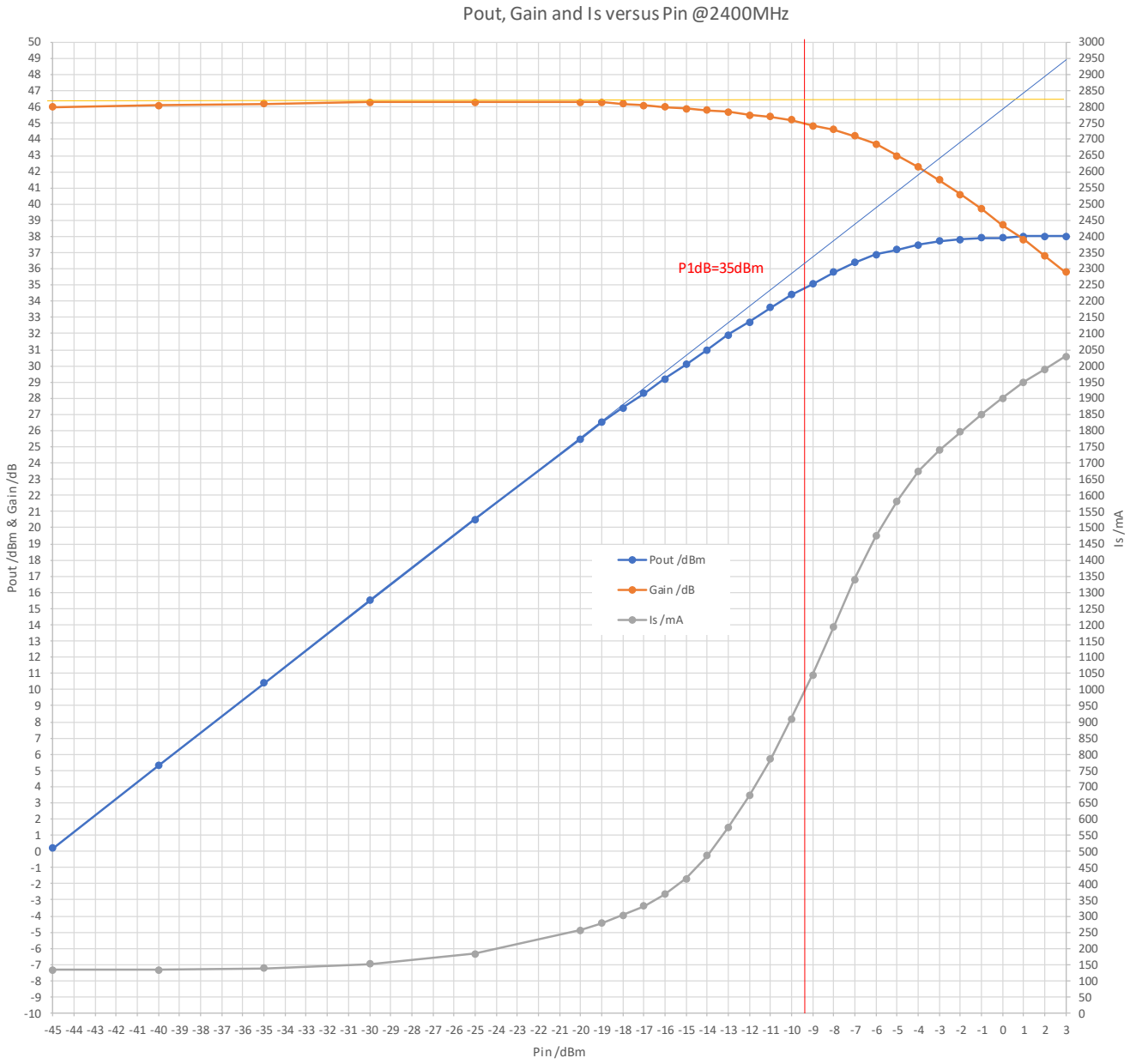


Input matching S11: Smith-Chart



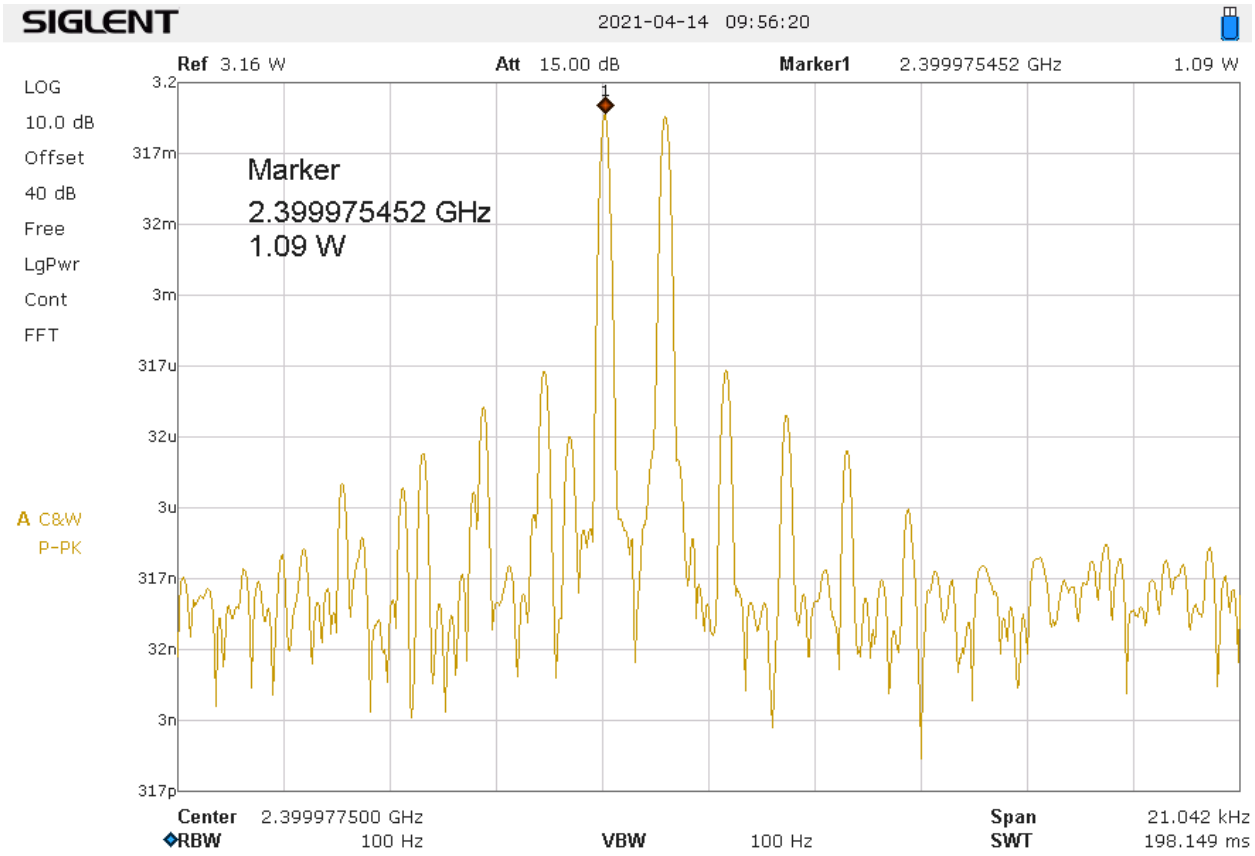
Input matching S11: LogMag 10dB per div

Here is the measurement of gain, output power and current consumption of the test setup as a function of input power.



The complete amplifier has a total gain of 46dB. The 1dB compression point is approx. 35dBm corresponding to 3.2W. The saturated output power is more than 6W and is already reached with a drive power of -1dBm. A maximum input power of +3dBm should not be exceeded in order to not destroy the amplifier. With an input power of -10dBm, an output power of approx. 3W is generated. This low drive power should be able to be delivered with a sufficiently clean signal by all common SDRs such as ADALM-Pluto, LimeSDR-USB and LimeSDR-mini.

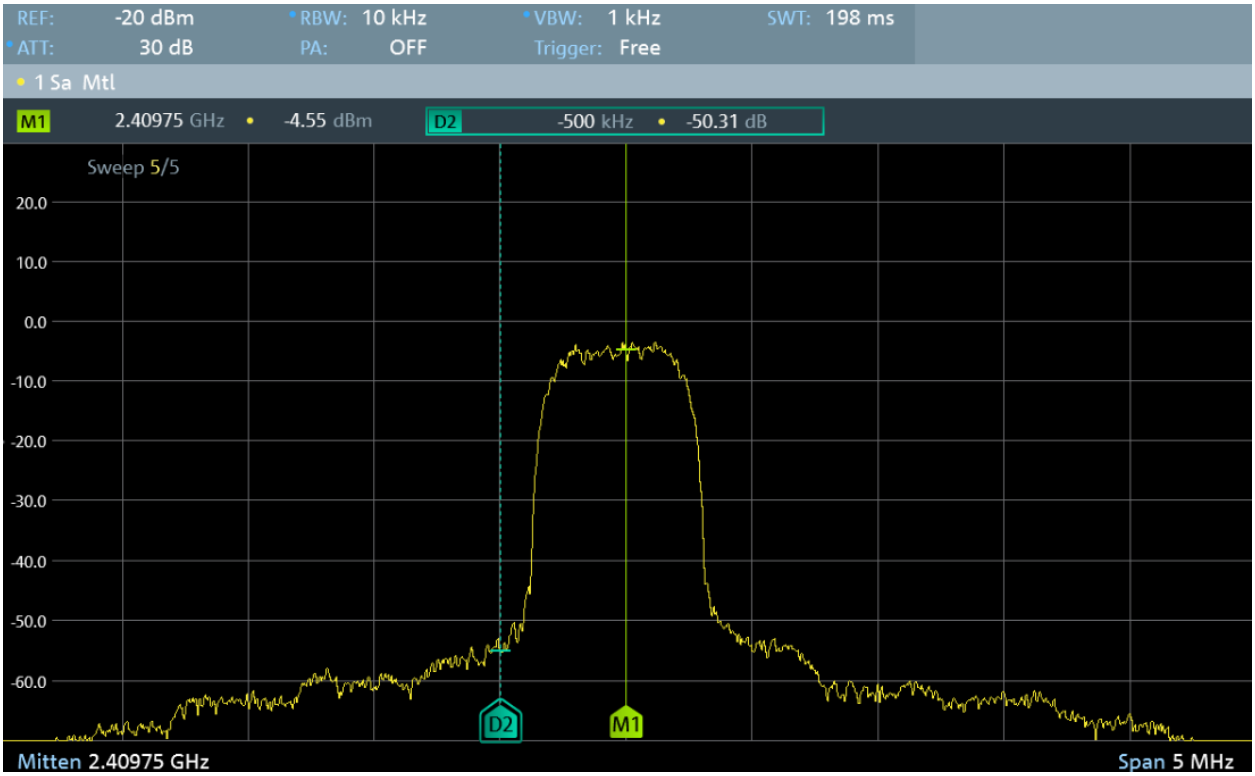
Andreas DL5CN characterized his amplifier and measured a 3rd order intermodulation products being down at about 40dBc at a output power level of 4W PEP. For this measurement he drove the amplifier with his ADALM Pluto (drive level set to 84%).



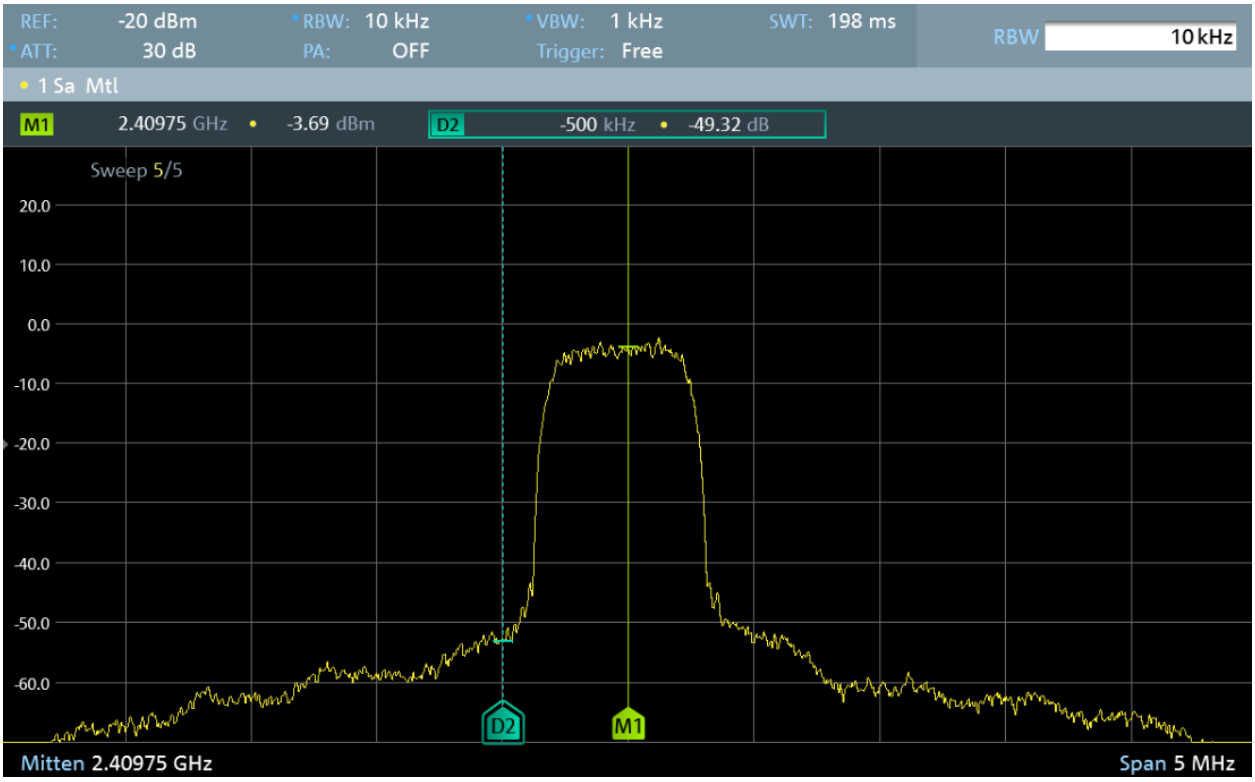
Andreas makes a point of pointing out that his measurement results might have been slightly influenced by tolerances of cables, adaptors, etc.

Kurt DJ0ABR made measurements of the output spectrum when using an ADALM-Pluto as a DVB-S2 DATV transmitter. The modulation was QPSK, the symbol rate was 500kS/s. The following screenshots were made with a measurement setup with a 20dB attenuator in front of the Spectrumanalyzer. Therefore, 20dB must be added to each of the displayed values.

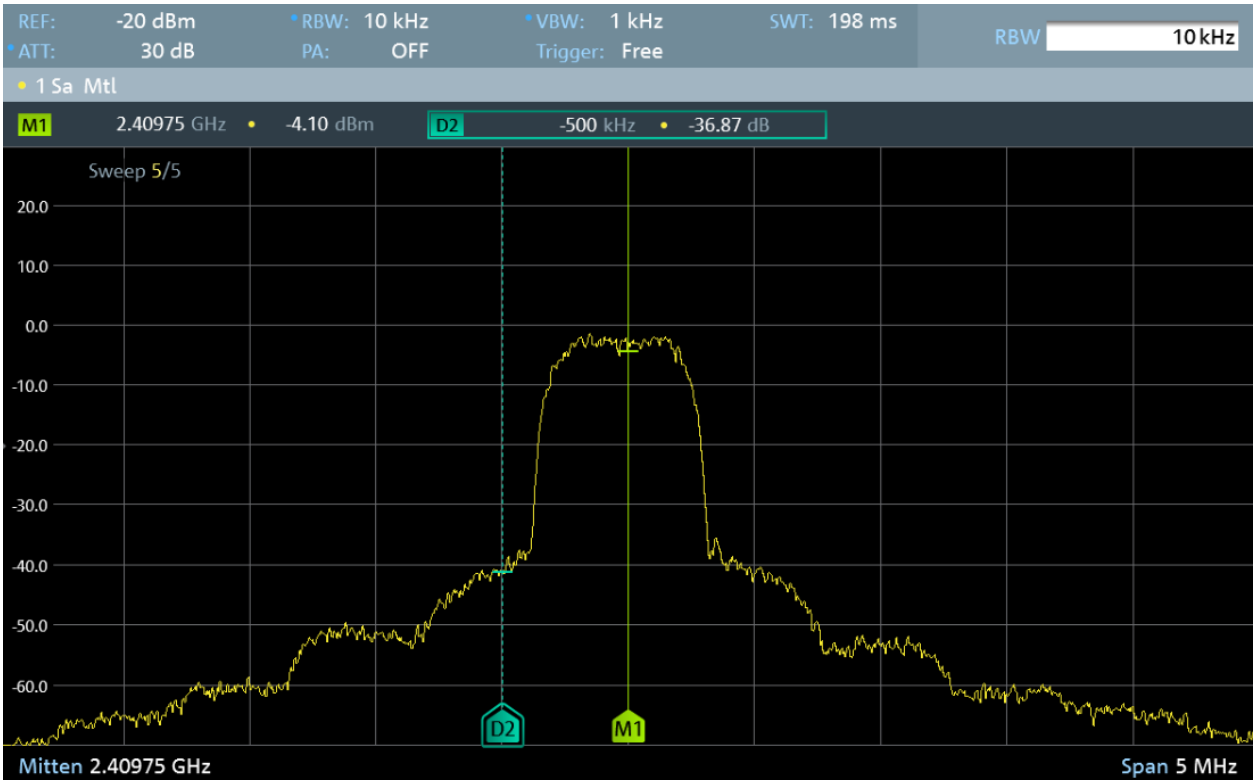
Up to an output level of approx. 33dBm corresponding to 2W, the output spectrum is very good. The shoulders (spectrum regrowth) are down by more than 50dB:



At an output power of approx. 33.9dBm corresponding to approx. 2.5W, the shoulders can be seen to some extent.



If the output level is increased further to 35.3dBm corresponding to 3.3W, the shoulders are only down by approx. 37dB. The output power should not be increased any further. Since another power amplifier is usually connected downstream, the 6W PA for DATV with QPSK modulation described here should be operated at a maximum output power of 2W.



If it is not possible to ensure good matching of the transmitting antenna at all times, it is advisable to insert an isolator at the output of the amplifier.

We wish you much fun and success with the new amplifier.

Kind regards

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