6.7 GHz methanol maser line receiver project

The line 6.7 GHz (6668.5192 MHz) of methanol corresponds to the transition $5_1 \rightarrow 6_0$, A^+ type molecule, II class of maser excitations; it is expected stronger than 12 GHz line, therefore, a list objects could be detected at 6.7 GHz by amateur means is expected wider. RFI at nearby frequencies are not too strong in comparison with 12 GHz band. Here are some pictures from the receiver project with my short comments. Hope the project is far from final, but this is a first version of receiver working today.

The receiver consist of indoor and outdoor parts. Outdoor part is just downconverter from 6668 MHz to IF less 1 GHz (968 MHz in my project). USRP B200mini controlled by LabVIEW software was used as the indoor part, see a detailed description in SARA journal 2022, September-October issue, p. 71. Indoor and outdoor parts are connected by 20 m coax with additional amplifier compensating the coax losses.

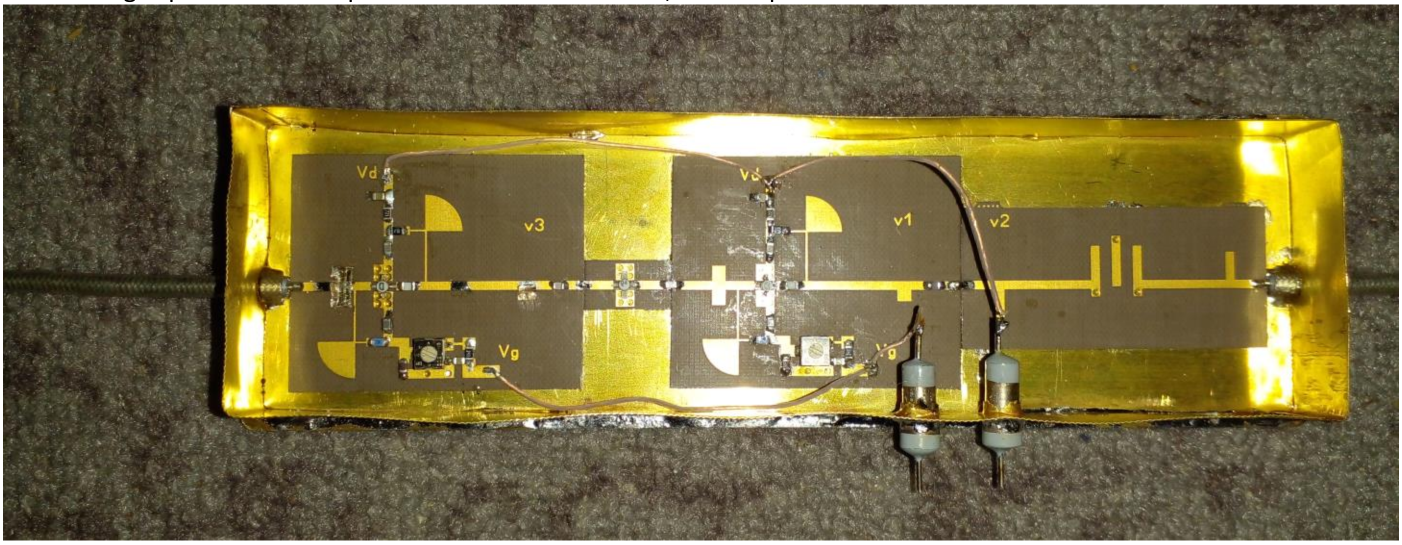
About downconverter in the outdoor part:

Any attempts to modify an equipment for 5.7 GHz amateur band gave poor results; the gap with needed frequency 6.668 GHz is too large, and no accepted Noise Figure was obtained. I applied RX module from Terrasat outdoor 6 GHz link purchased at eBay several years ago. It can be applied as downconverter with external LO, but the inner filter was removed (bypassed). Unfortunately, the filter rejected at 6668 MHz already. The module was intended initially for lower frequencies; its nominal frequencies was 5.85–6.45 GHz. I think its brother, the Terrasat RX downconverter https://www.ebay.com/itm/144887655689 will work at 6668 MHz without modifying (and will not require the filtering in LNA, see below). Terrasat modules require about several dBm at LO input; the Noise Figure at their RF input can be expected about 2-2.5 dB, conversion gain is about 25 dB. The module works with single rail power supply +5 V (nominal + 5.5 V).

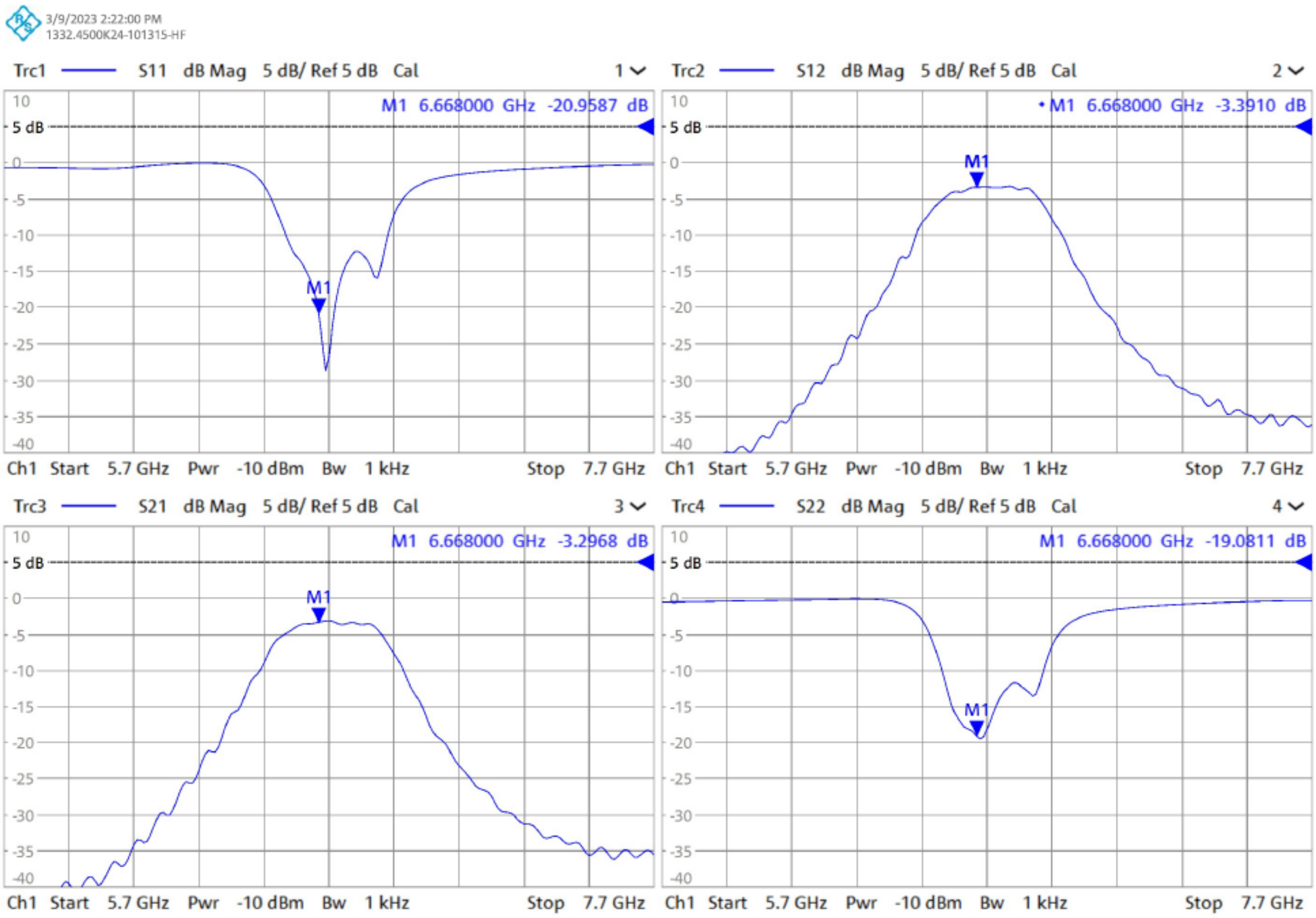
My LO frequency was 5.7 GHz. As LO I used Chinese RF source from AliExpress based, as declared by seller, on PLL HMC833, https://aliexpress.ru/item/10000201112020.html. The source's output at this frequency was too low; an amplifier with ADL5611 was applied to enhance the level. The PLL uses 25 MHz TCXO inside RF source as a reference. I didn't find a good available 25 MHz OCXO as an external reference instead; unfortunately, bought at AliExpress Chinese reference https://aliexpress.ru/item/1005004601387265.html spoils the spectrum of PLL output significantly.

The TCXO frequency error is checked and taken into account in VLSR calculations.

The downconverter module requires a LNA in any case. My LNA includes two stages of amplifying and an output filter for 6668 MHz. GaAs FETs NE32584c were applied in amplifiers. The LNA was composed from several PCB (amplifiers itself, attenuator between stages, output filter, each projected separately) in enclosure with semirigid coax connections without DC blocking capacitor in the input for the sake of lower NF, see the picture below:



Output 3-order interdigital filter characteristics (measured with VNA R&S ZNA and specially designed fixtures):



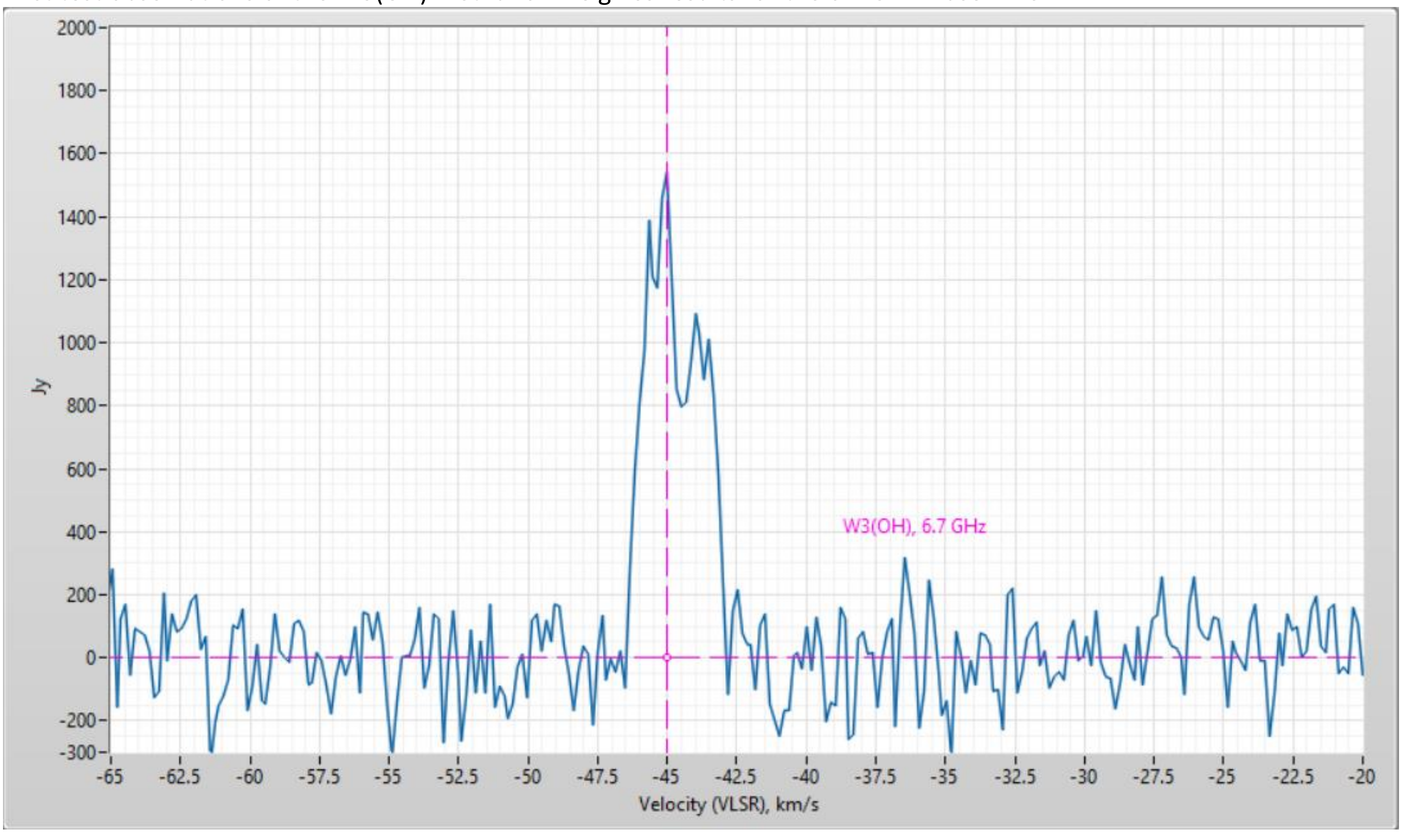
Transfer characteristic slopes are not too steep, but the stopband attenuation is acceptable for the receiver.

The FETs for amplifiers were extracted from old sat LNB and, as it seems, already degraded. I spent many days in attempts to get expected NF (less 0.7-0.8 dB), but the best I have squeezed from the LNA is about 1.6 dB. Not too good, but acceptable for first tests. One can see on the LNA picture that some projected tuning stubs were removed and new ones are soldered.

The foto of the outdoor part under Noise Figure tests (noise head – Noisecom NC346A Precision with DC blocking adapter):

The feed was initially intended for 5.7 GHz amateur band (for terrestrial links, not for EME), and modified for our frequency just shortening the probe inside. This circular horn was modelled in Comsol, 2D axisymmetric RF module; calculated far field pattern shows the feed provides a good illumination of the dish with aperture efficiency about 0.68.

First test observations of the W3(OH) methanol line gives results for the 6.7 GHz maser line:



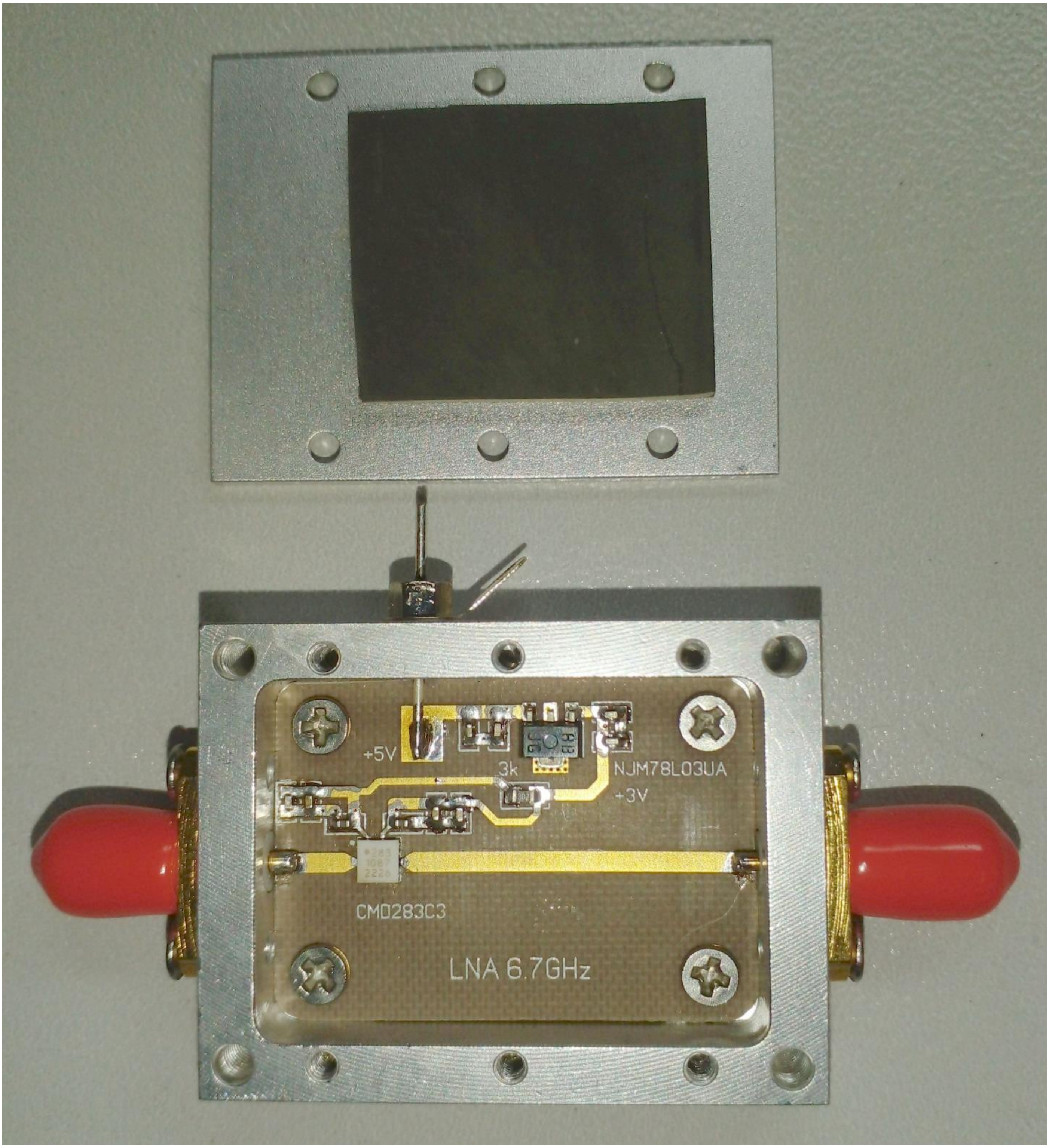
Integration time was about 40 min, receiver resolution – about 5 kHz (0.2 km/s in the VLSR scale), the dish position was controlled by automatic tracking of the source. Expected line width and peak velocity are reproduced well, but received peak level is somewhat lower than expected >3000 Jy. There was a real snowfall during measurements; the atmospheric absorption was taken 1 dB, but higher absorption values were also probable.

The last foto is the view of my dish (1.8 m) in action:

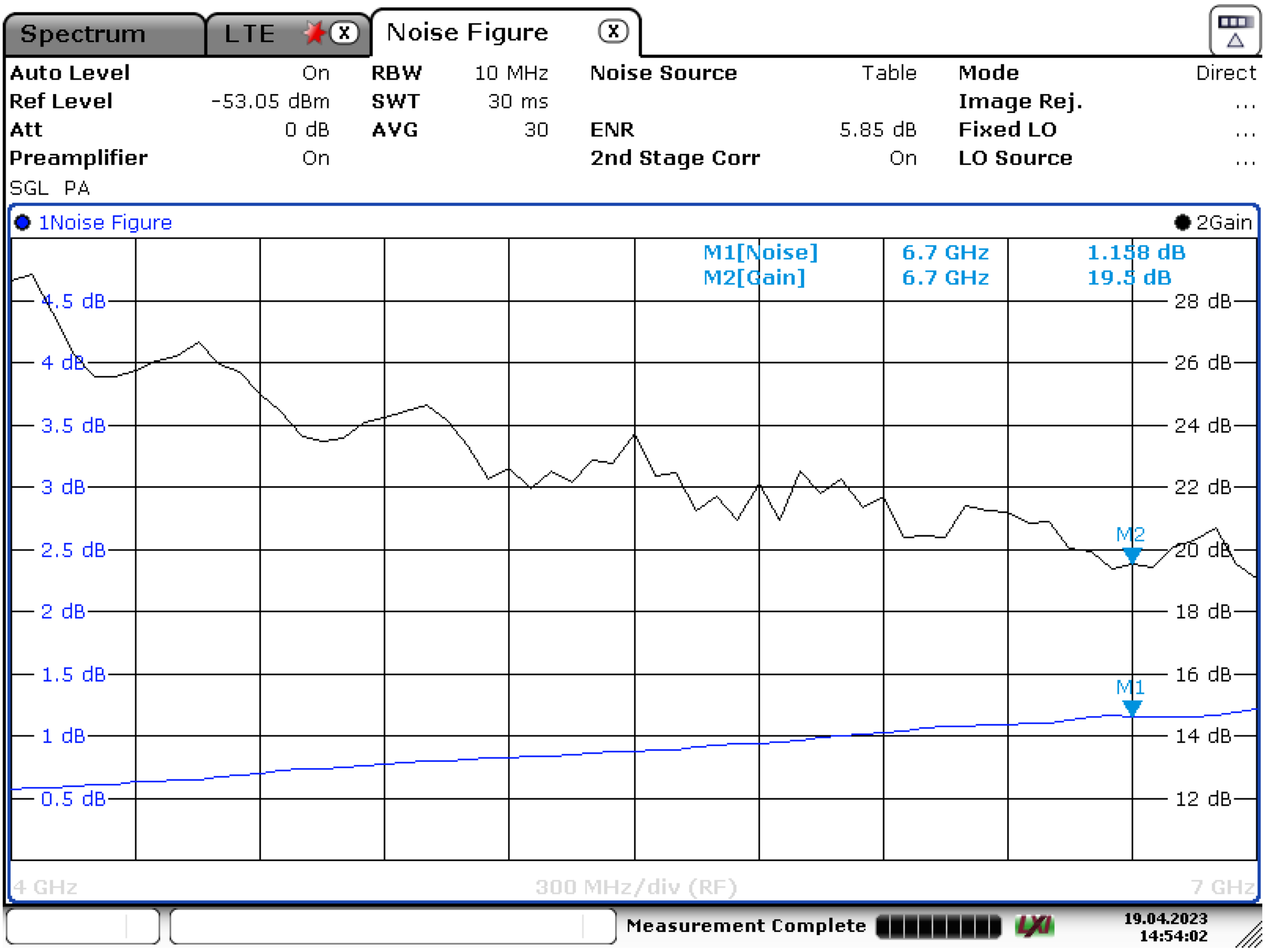
Dish telescope characteristics: Antenna Sensitivity (Forward Gain) – 0.63 mK/Jy, T_{sys} was 200 K or higher this day (including the atmospheric thermal noise).

LNA 6.7 GHz

Foto with assembled LNA are shown below. Main parts are specified in the silkscreen at the PCB (nominal of decoupling capacitors can be taken from corresponding datasheets). PCB was manufactured on Rogers AD250 0.02" laminate.



Noise Figure and insertion Gain are at the plot next (measured by R&S FSV with noise head NC346A Precision). A better Noise Figure was expected at 6.7 GHz according the plots in the CMD283C3 datasheet (about 0.8-0.9 dB), but just 1.16 dB was received. Nevertheless, it is better than in available LNA from Mini-Circuts https://www.minicircuits.com/WebStore/dashboard.html?model=ZX60-83LN-S%2B. The RF abrorber at the lid is desirable because of the used enclosure is resonant at nearby frequencies. The enclosure was taken from chinnese bias-tee devices https://aliexpress.ru/item/32910023861.html. Noise figure was measured with the absorber at the lid inside. Measured S-paremetrs for LNA assembled with and without RF absorber are shown at the below pictures too.



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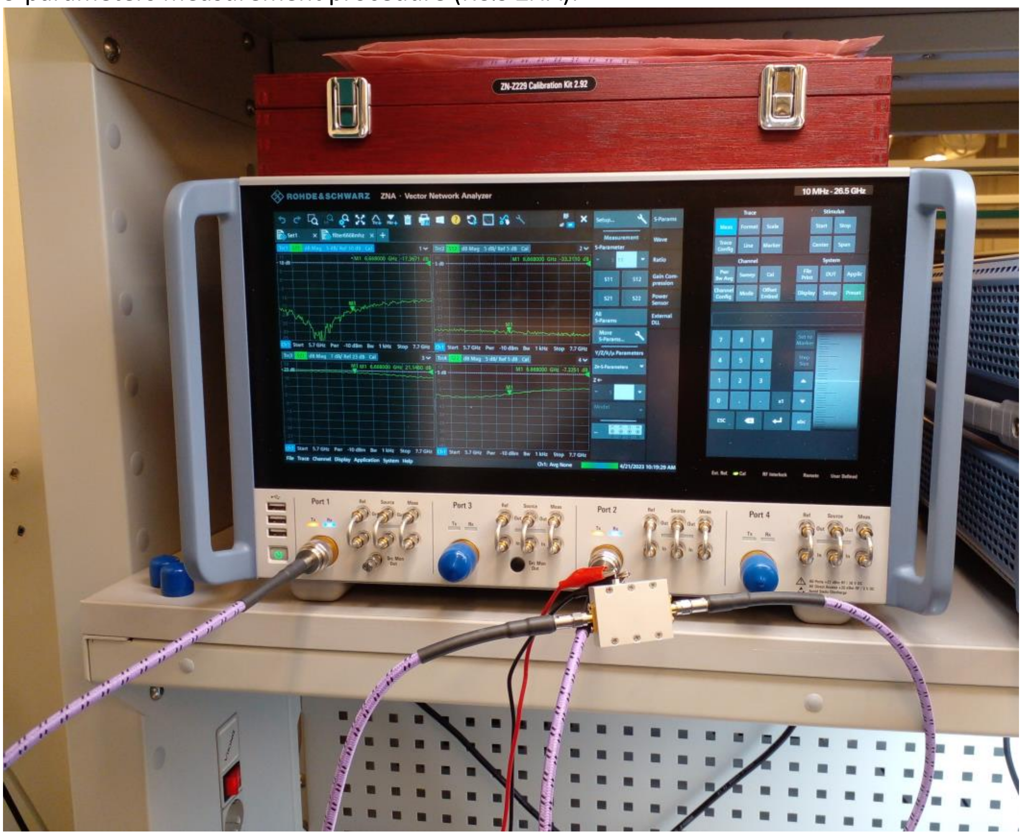
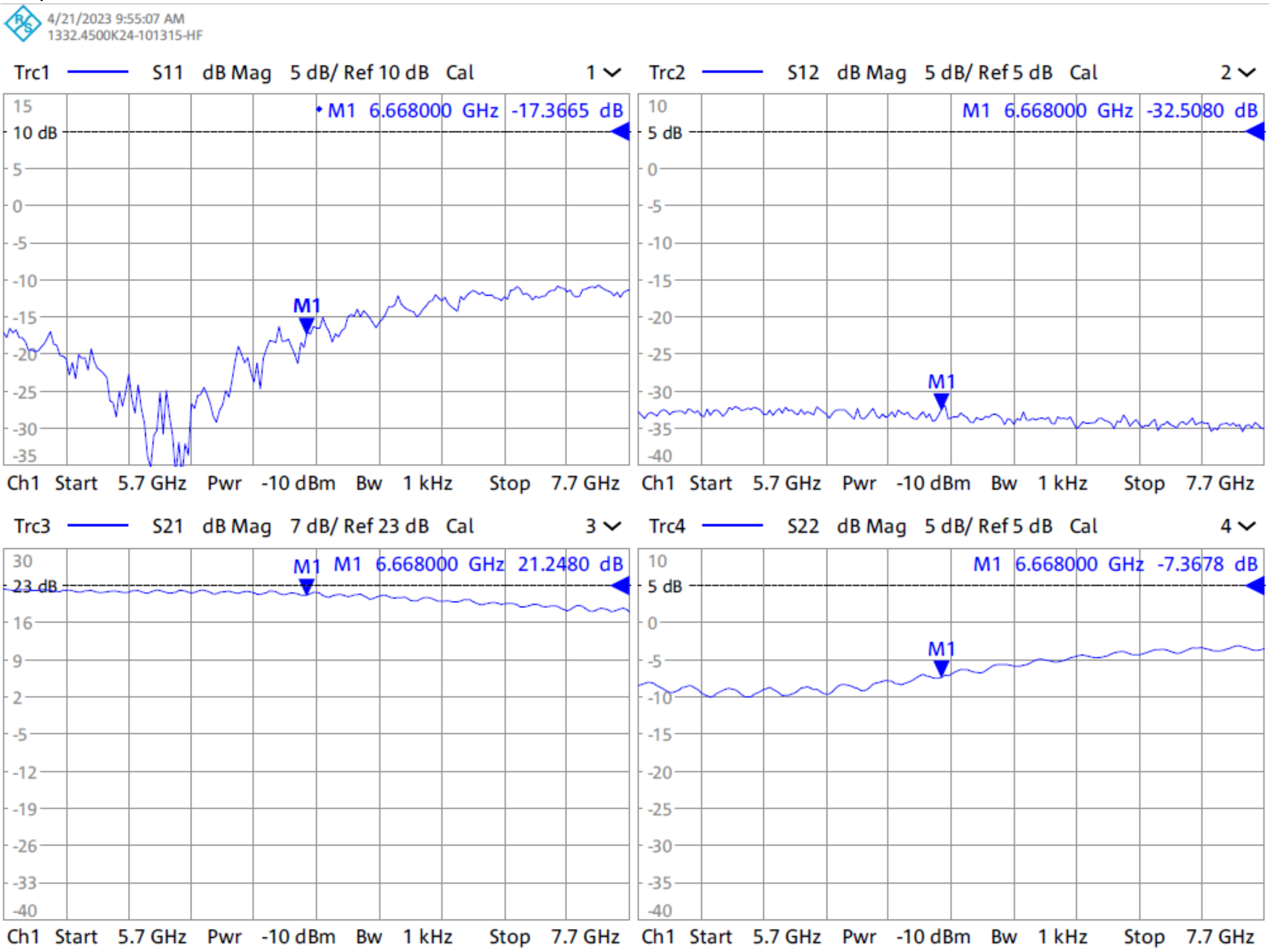
S-parameters measurement procedure (R&S ZNA):



Fully asssembled LNA with RF absorber at the lid inside:



LNA without RF absorber inside with the enclosure resonsnce: