# A 35MHz-4400MHz RF Signal Generator based on an ADF4351 synthesizer and a PE43702 digital step attenuator

Matthias DD1US, January 8th 2022, rev 1.3

Recently I found a programmable RF synthesizer module on Ebay, which covers the frequency range 35 MHz up to 4400 MHz and is based on an ADF4351 IC from Analog Devices. The cost including shipping was 30 US$. The module has a size of 88mm * 67mm and includes a little OLED display and 5 push buttons as a user interface. Thus, it provides a stand-alone solution for a tiny RF synthesizer. In addition, the module features a USB-C connector which should provide a host USB and serial port. However, I have not yet tested this function.

Here is a picture of the module:
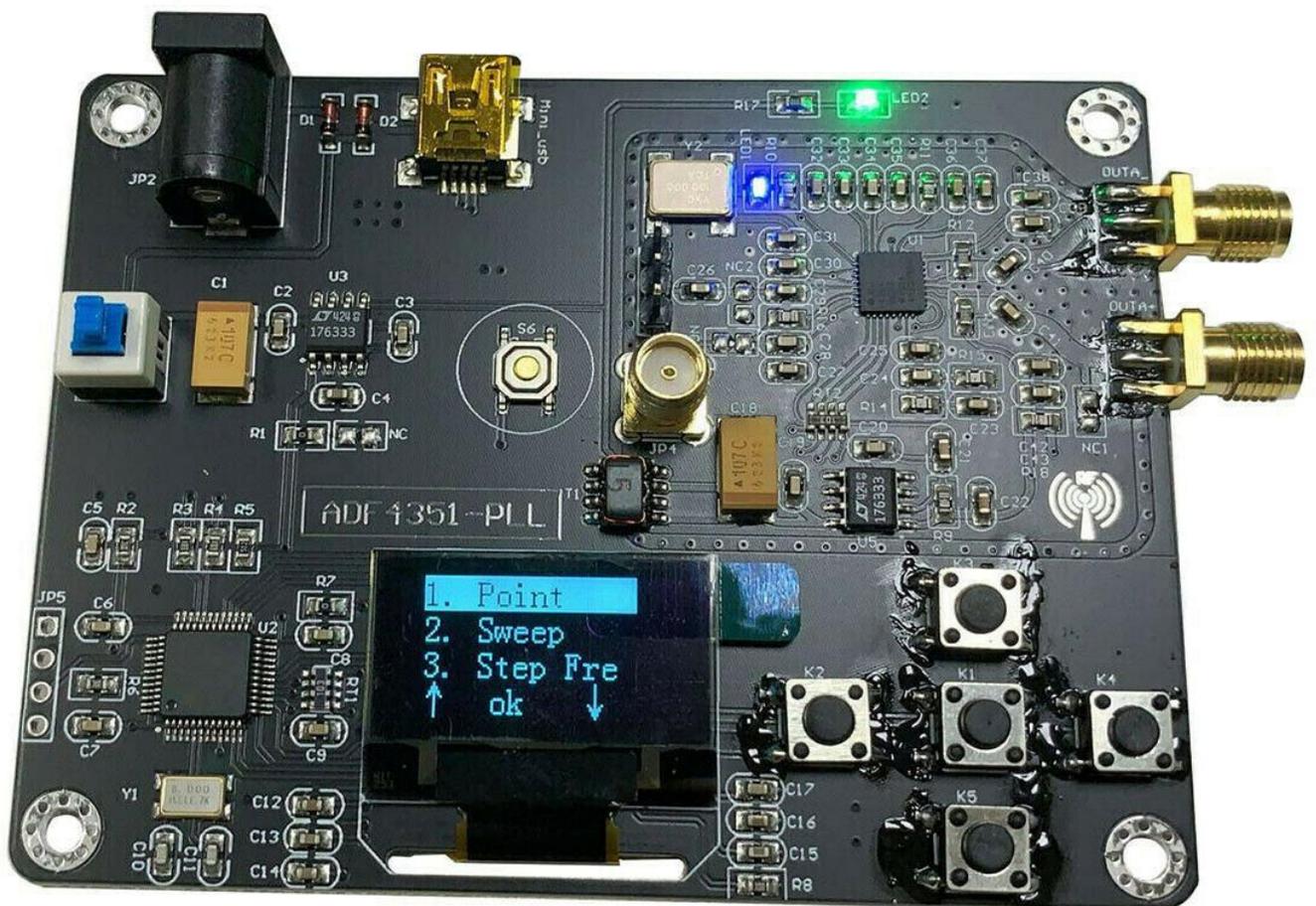
The module is supposed to provide a wide supply voltage range of 5 to 15V however a test with 12V supply voltage quickly killed one of the electrolytic capacitors. The two low noise voltage regulators LT1763 which are used on the board should support a wide supply voltage range but apparently the electrolytic capacitors are not chosen for higher supply voltages. After substituting the defective capacitor, I decided to operate the board with a stable 5V supply.

The module features 2 RF outputs (at 2 SMA connectors) providing signals in the frequency range 35MHz to 4.4GHz. The output frequency can be either a fixed frequency or a swept frequency output. The start frequency, stop frequency, step size and hold time per frequency step can be

defined by the user interface. The minimum step frequency is defined as 100kHz though the user interface also allows lower entries. I will check this out in the future.
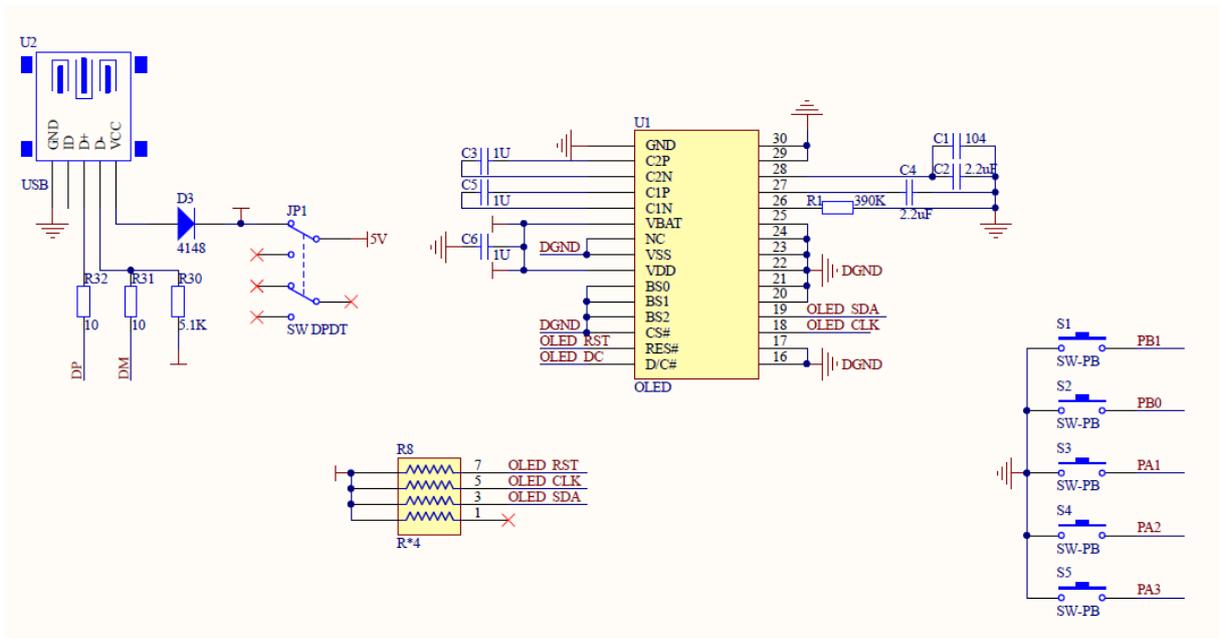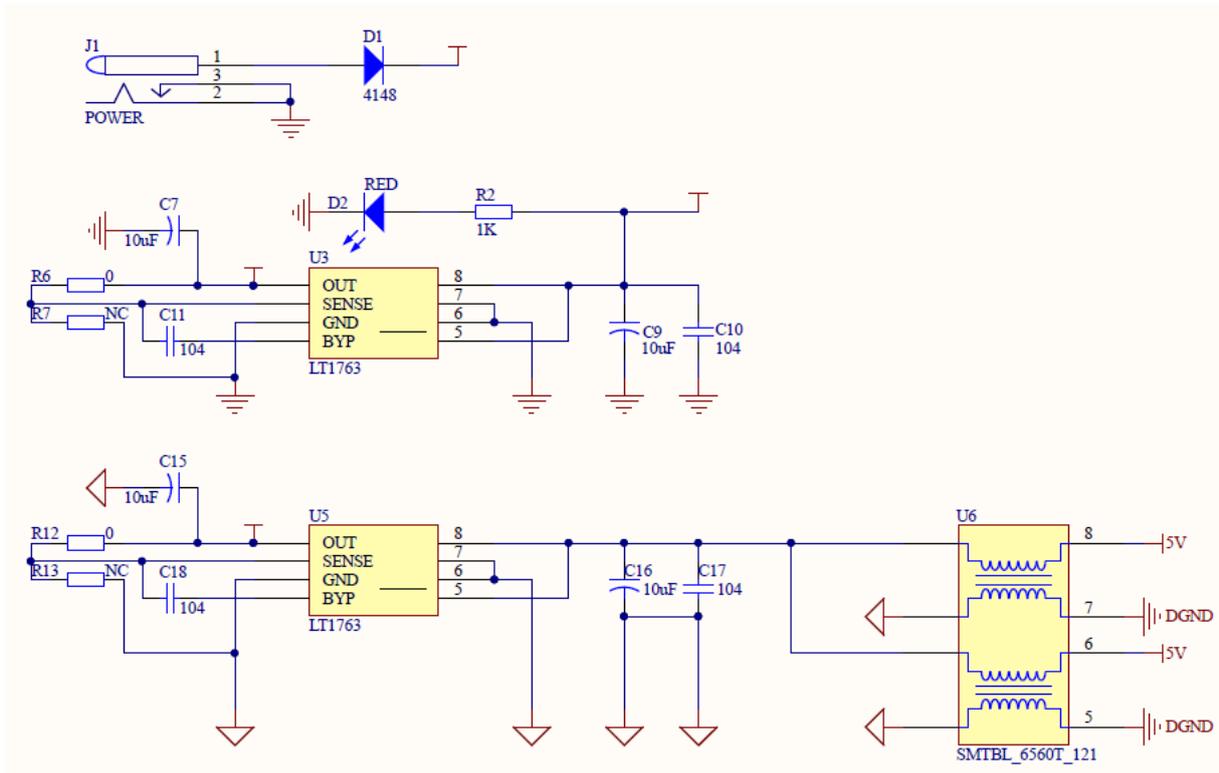
The user can select by a jumper, whether he wants to use the on-board 100MHz crystal oscillator or an external reference frequency signal injected through a SMA connector.
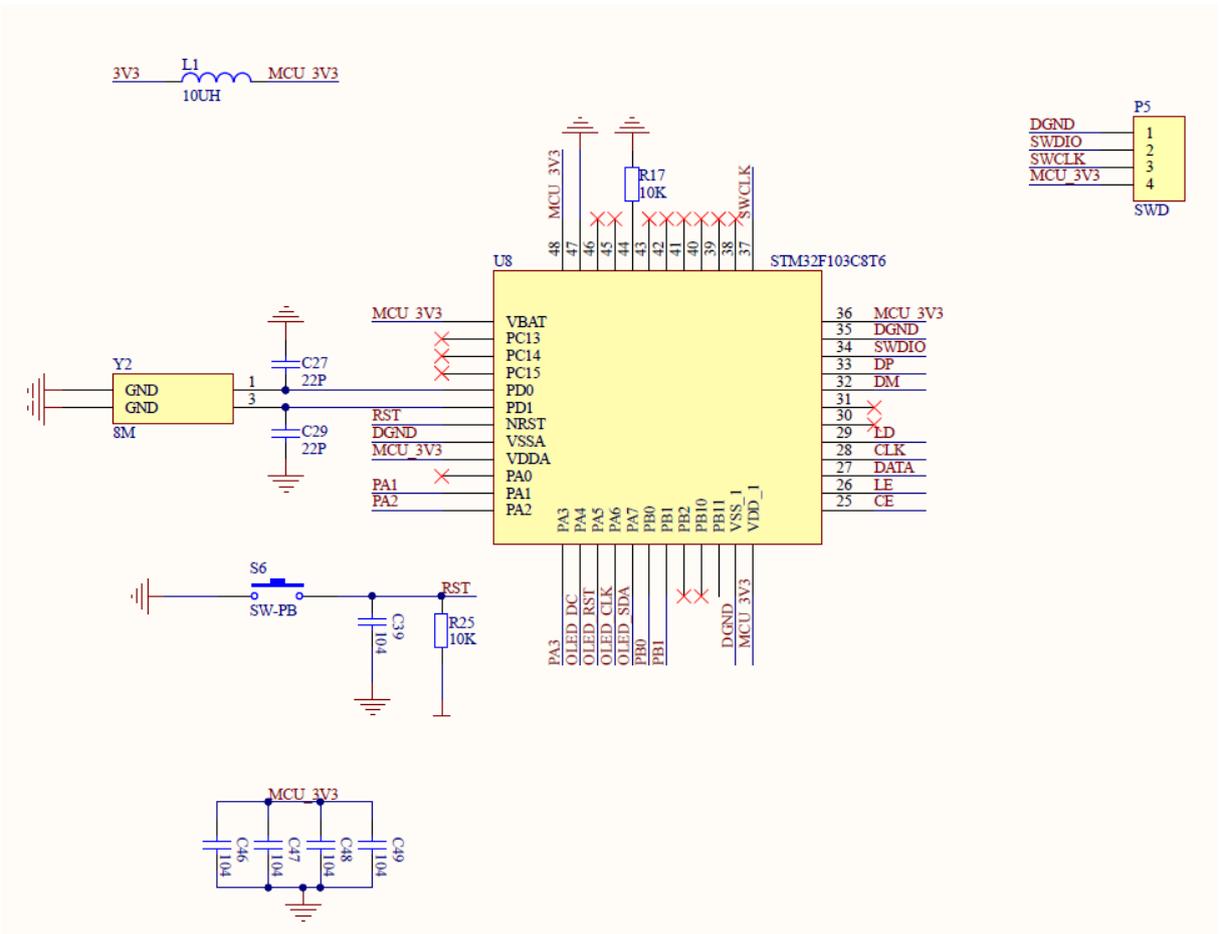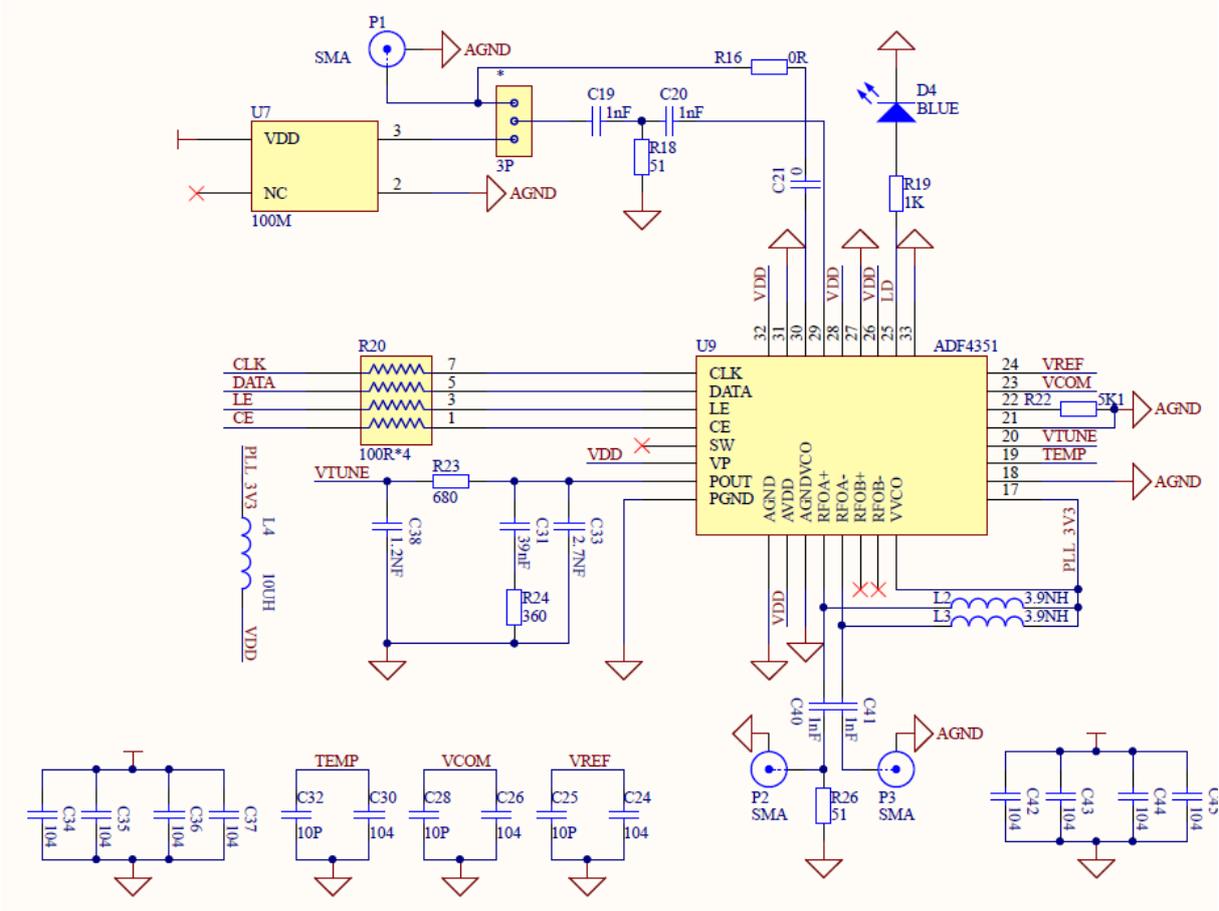

Here are some RF parameters which I also have not yet verified:

     - Frequency error: ±1KHz

     - Module phase noise: better than -100dBc at 10KHz (noise varies with the frequency band)

     - Module output power: 7dBm (maximum)

     - The output power can be varied in the following steps: -4, -1, +2, +5dB

Here are some schematics which I found in the internet. On a first glance they seem to match the board yet I have not yet checked it out completely.

P1
SMA
AGND
U7
VDD 3
NC 2
AGND
100M

*
3P

C19 1nF   C20 1nF
R16 0R
R18 51
C21 0

D4 BLUE
R19 1K

VDD 32 31 30 29 28 27 26 25 33
CLK U9 ADF4351 VREF 24
DATA VCOM 23
LE R22 5K1 AGND 22
CE 21
SW VTUNE 20
VP TEMP 19
POUT 18
PGND AGND 17

R20 7 5 3 1
CLK
DATA
LE
CE
100R*4

VDD

VTUNE
R23 680
C38 1.2NF   C31 39nF   C33 2.7NF
R24 360

PLL_3V3
L4 10UH
VDD

AGND AVDD AGNDVCO RFOA+ RFOA- RFOB+ RFOB- VVCO

PLL_3V3
L2 3.9NH
L3 3.9NH

VDD

C40 1nF   C41 1nF
AGND

P2 SMA   R26 51   P3 SMA

C34 104 C35 104 C36 104 C37 104
TEMP C32 10P C30 104 VCOM C28 10P C26 104 VREF C25 10P C24 104
C42 104 C43 104 C44 104 C45 104

3V3 L1 10UH MCU_3V3

MCU_3V3
R17 10K
SWCLK
48 47 46 45 44 43 42 41 40 39 38 37

U8 STM32F103C8T6

VBAT 36 MCU_3V3
PC13 35 DGND
PC14 34 SWDIO
PC15 33 DP
PD0 32 DM
PD1 31
NRST 30
VSSA 29 LD
VDDA 28 CLK
PA0 27 DATA
PA1 26 LE
PA2 25 CE

MCU_3V3
Y2
GND
GND
8M
C27 22P
C29 22P
RST
DGND
MCU_3V3

PA0 PA1 PA2

PA3 PA4 PA5 PA6 PA7 PB0 PB1 PB2 PB10 PB11 VSS_1 VDD_1

S6
SW-PB
C39 104
RST
R25 10K

OLED_DC OLED_RST OLED_CLK OLED_SDA PB0 PB1   DGND MCU_3V3
PA3

P5
DGND 1
SWDIO 2
SWCLK 3
MCU_3V3 4
SWD

MCU_3V3
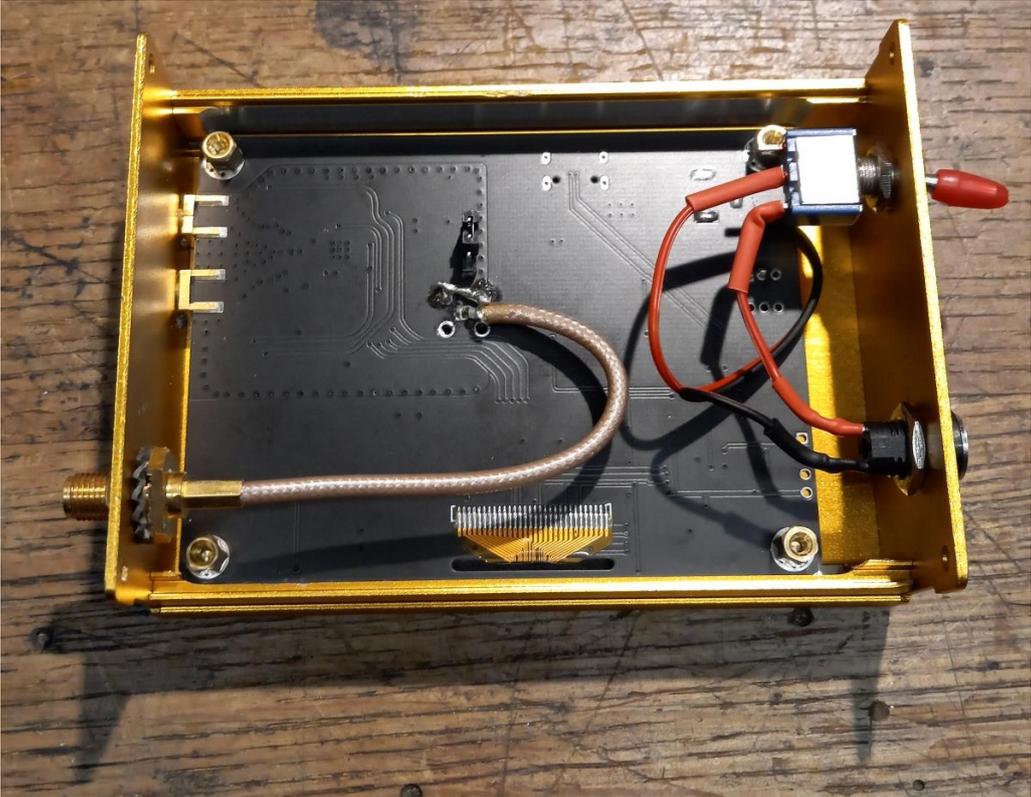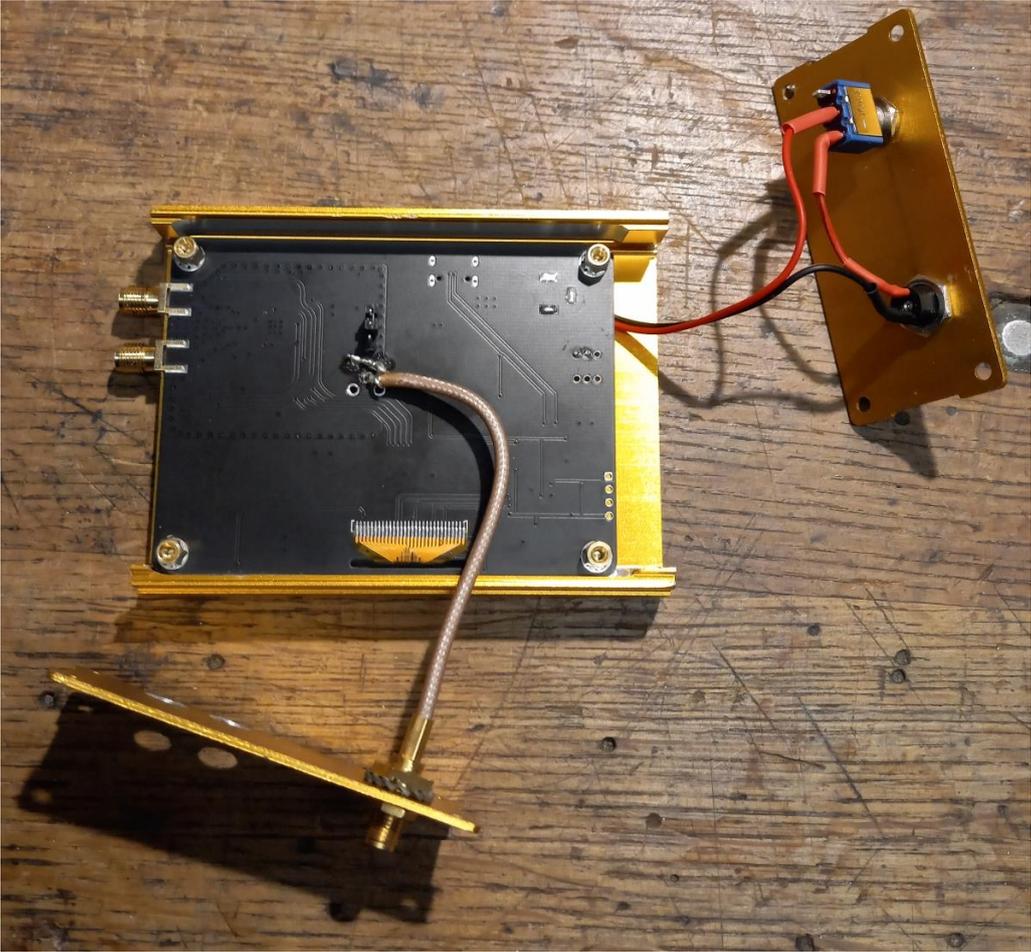C46 104 C47 104 C48 104 C49 104

4

As I really dislike operating such a module without a proper encasing which protects the electronics but also shields the RF circuitry, I looked in my drawers for a suitable encasing. Finally, I found an aluminum encasing which I had bought some time ago from an online shop in China. The module fits almost perfectly in this encasing which needed only a little bit of grinding at its inside.
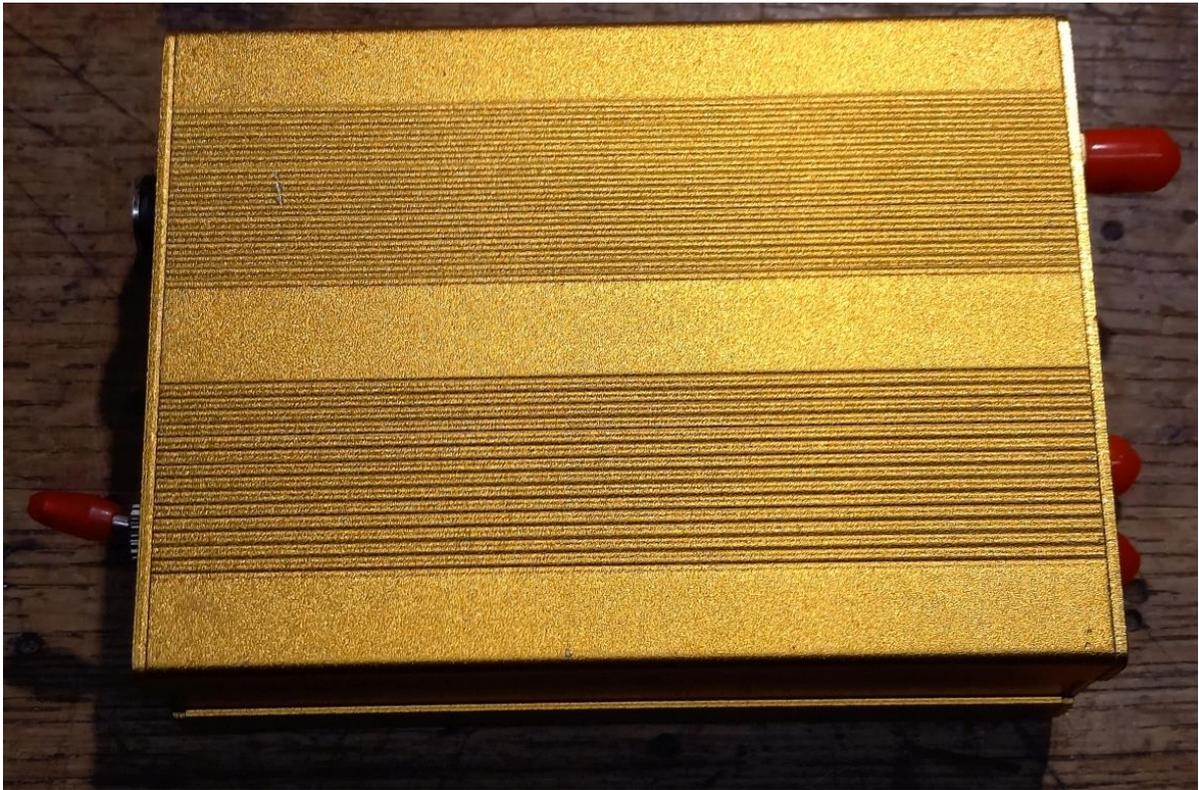
I removed the following components from the module: the on/off switch, the SMA connector for the external reference input and the DC jack. I also removed the jumper pins and soldered them to the backside of the PCB. In addition, I replaced all 5 push buttons by a version with slightly higher plastic buttons. For the DC supply I mounted a corresponding jack in the encasing and routed the positive supply line via an on/off switch next to the jack. Finally, I soldered a thin 50 Ohms coaxial cable to the reference input line on the PCB. I mounted a SMA jack on the other end of the coaxial cable.
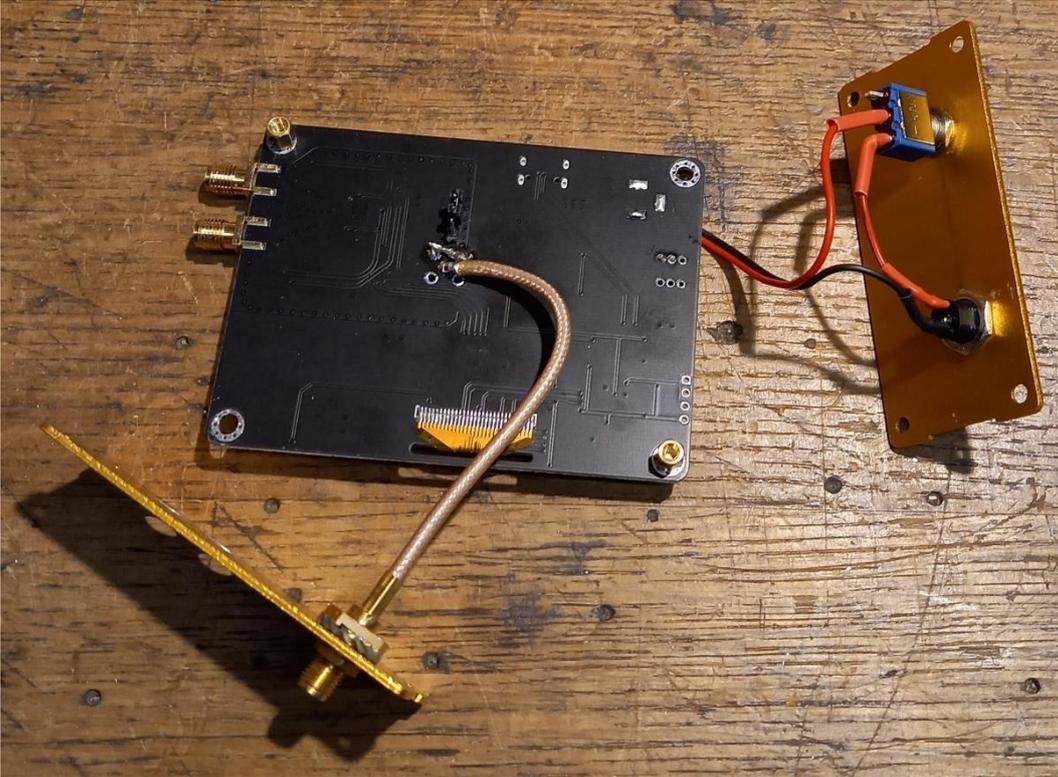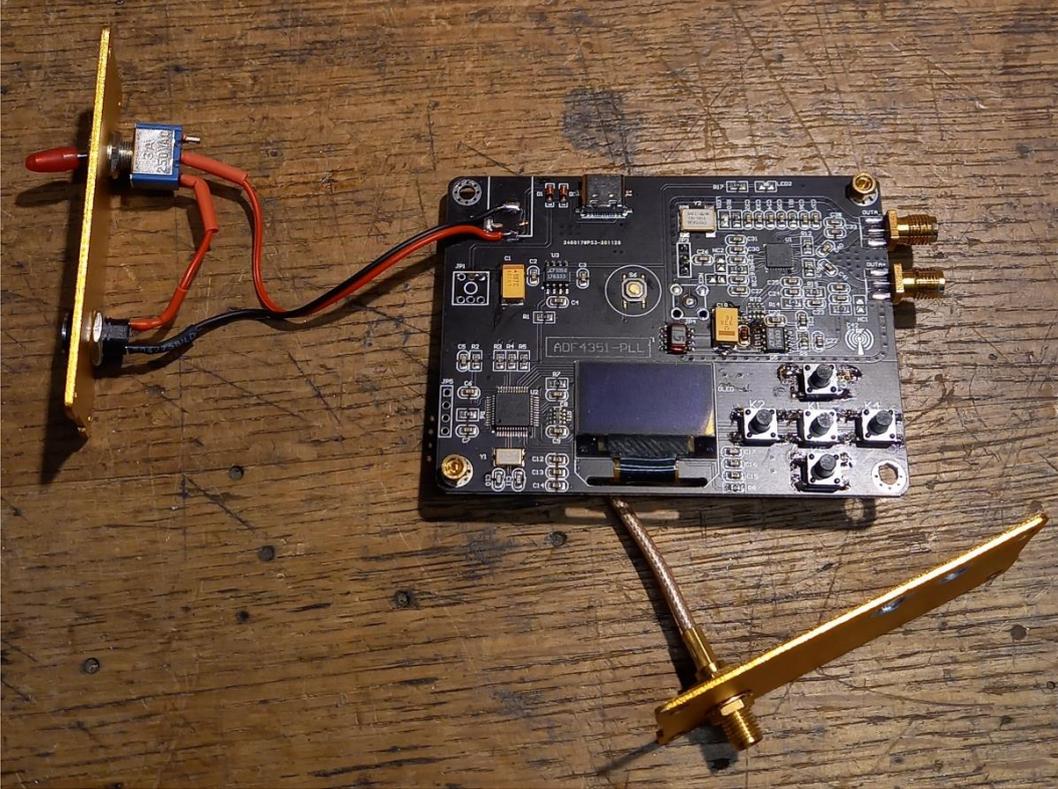
With those modifications the front of the module can now be attached to encasing as shown in the next pictures:

ADF4351 Synthesizer 35 ... 4400 MHz

1. Point
2. Sweep
3. Step Fre

REF INPUT
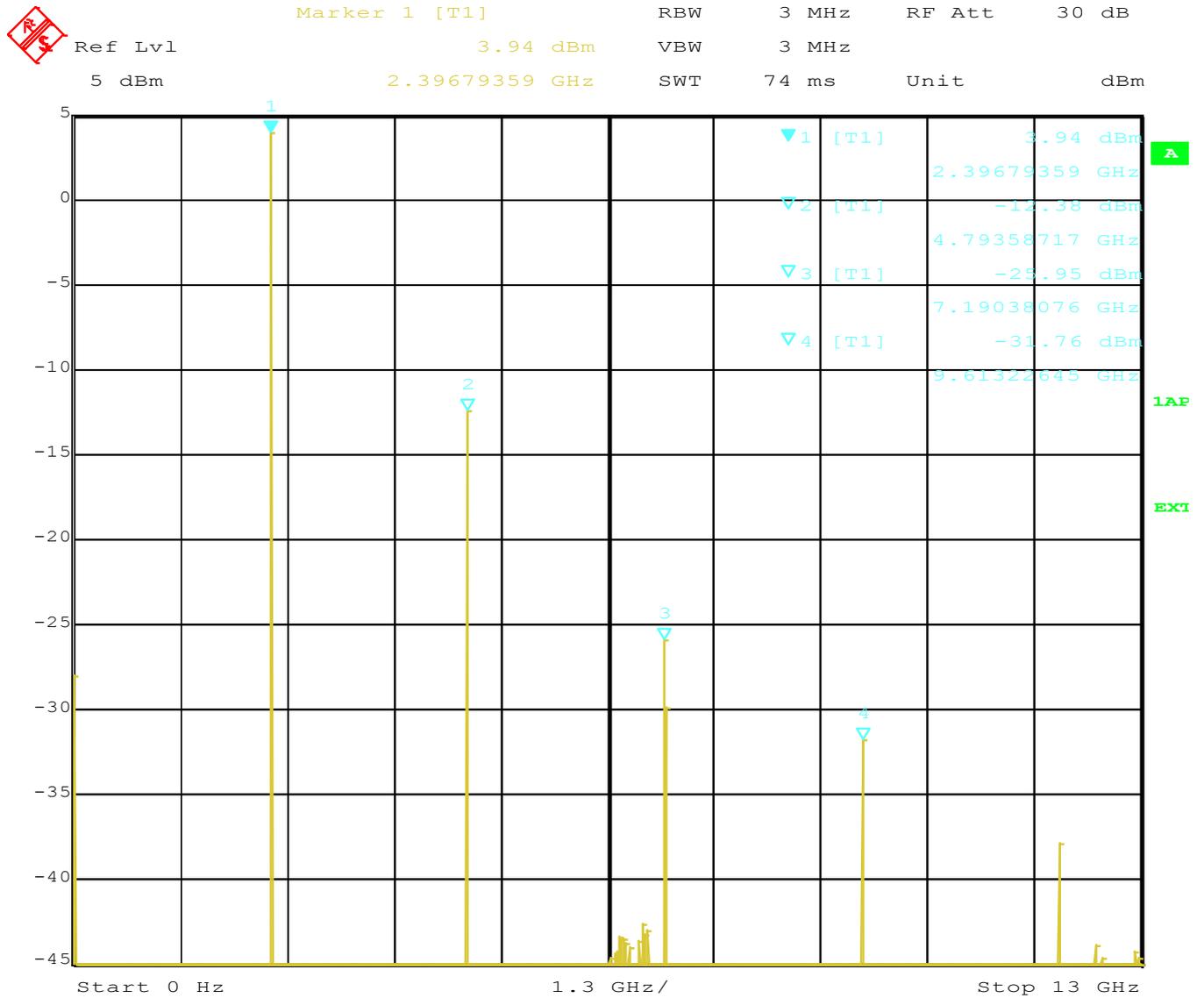100 MHz

OUT OCT A
35 ... 4400 MHz

ON / OFF

5V 200mA

Next, I made some measurements of the output signal of the synthesizer module.

First please see the output signal of Output A when Output B is terminated with 50 Ohms:

			Marker 1 [T1]			RBW	3 MHz	RF Att	30 dB

Ref Lvl

3.94 dBm   VBW   3 MHz

5 dBm   2.39679359 GHz   SWT   74 ms   Unit   dBm

	Marker					
▼1 [T1]	3.94 dBm	2.39679359 GHz
▽2 [T1]	-12.38 dBm	4.79358717 GHz
▽3 [T1]	-25.95 dBm	7.19038076 GHz
▽4 [T1]	-31.76 dBm	9.61322645 GHz

A

1AP

EXT

Start 0 Hz   1.3 GHz/   Stop 13 GHz

Date: 1.NOV.2021   20:30:27

We can see the fundamental signal at 2.4 GHz with a level of 4dBm and the harmonics at -12dBm, -26dBm, -32dBm and -38dBm.
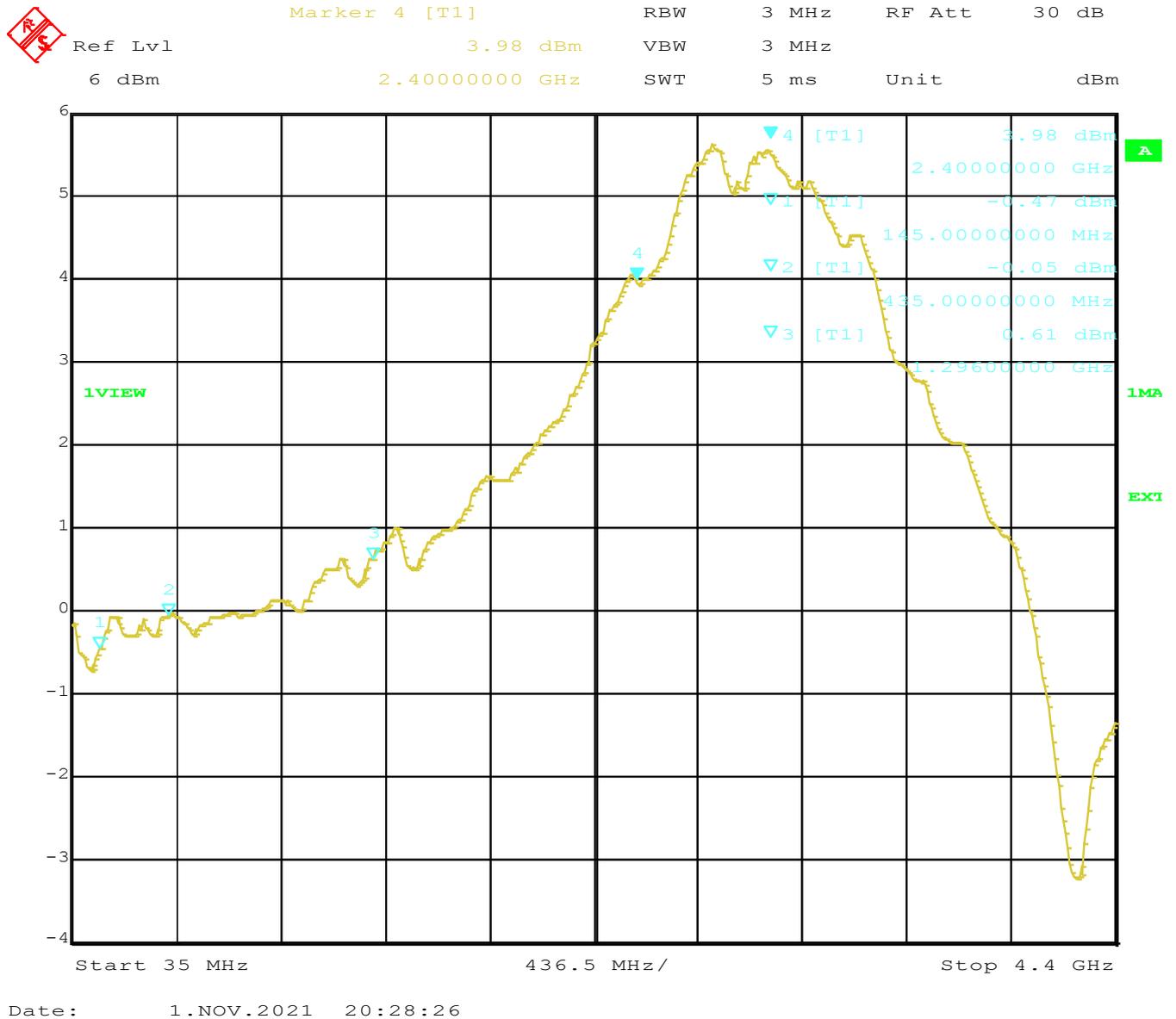
If we do not terminate Output B properly the signal at Output gets distorted. Here is the same measurement with Output B left open:

		Marker 1 [T1]		RBW	3 MHz	RF Att	30 dB
Ref Lvl			0.45 dBm	VBW	3 MHz		
5 dBm			2.39679359 GHz	SWT	74 ms	Unit	dBm

▼1 [T1] 0.45 dBm 2.39679359 GHz
▽2 [T1] -10.21 dBm 4.79358717 GHz
▽3 [T1] -21.97 dBm 7.19038076 GHz
▽4 [T1] -31.28 dBm 9.61322645 GHz

Start 0 Hz   1.3 GHz/   Stop 13 GHz

Date: 1.NOV.2021   20:30:52
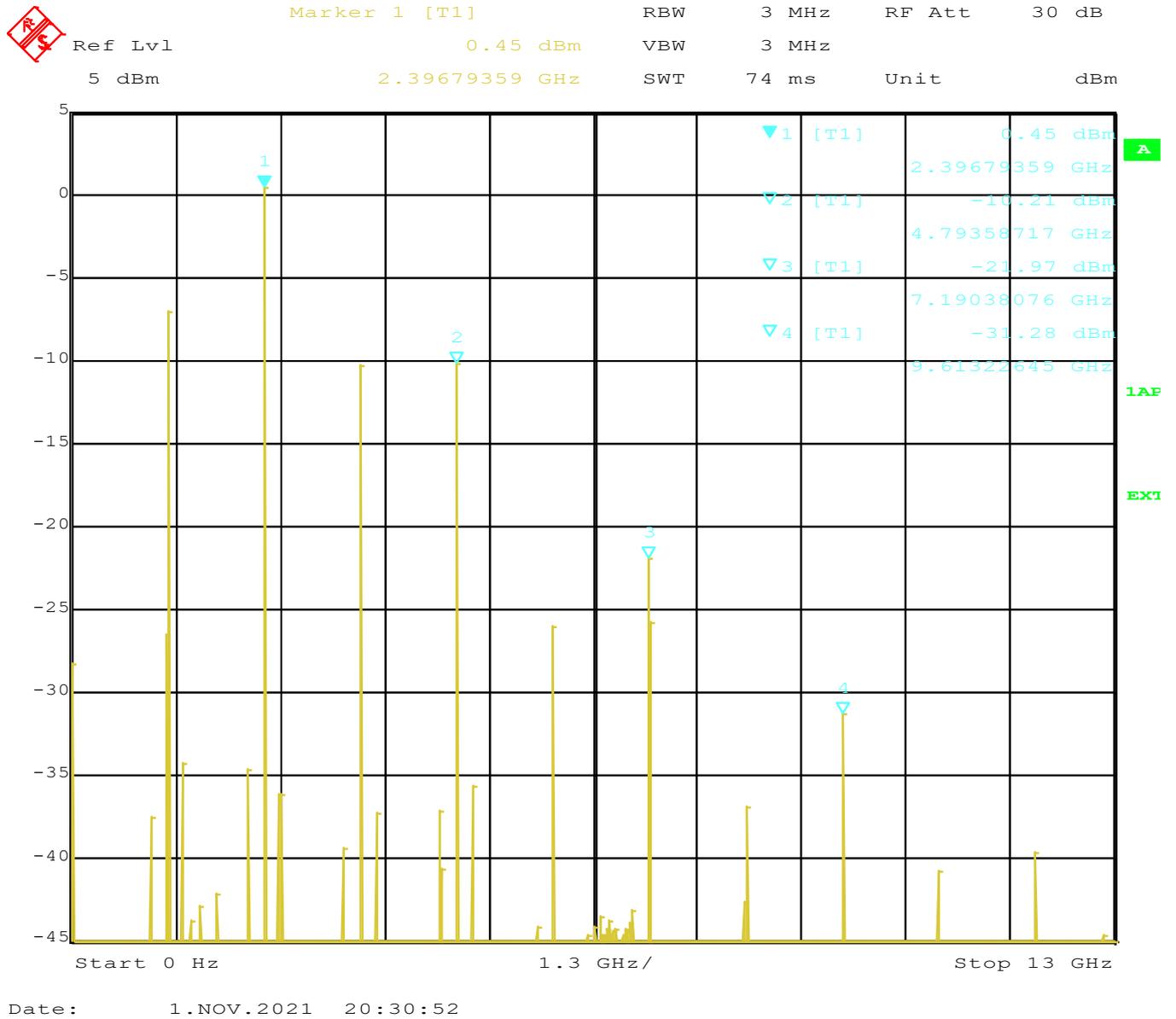
We see spurious signals at ½ the target frequency and many harmonics thereof.

As we can see it is very important to terminate the unused the output ports properly with 50 Ohms.

In the next diagram you can see the output signal level versus frequency when setting the output level to max (which is +5dB in the menu). Please note the scale which is only 10dB for the complete vertical axis. The frequency was swept from 35MHz to 4400MHz.

Marker 4 [T1]   RBW   3 MHz   RF Att   30 dB
Ref Lvl   3.98 dBm   VBW   3 MHz
6 dBm   2.40000000 GHz   SWT   5 ms   Unit   dBm

▼4 [T1]   3.98 dBm
                 2.40000000 GHz
▽1 [T1]   -0.47 dBm
                 145.00000000 MHz
▽2 [T1]   -0.05 dBm
                 435.00000000 MHz
▽3 [T1]   0.61 dBm
                 1.29600000 GHz

1VIEW

Start 35 MHz   436.5 MHz/   Stop 4.4 GHz
Date: 1.NOV.2021   20:28:26

The output power varies by about 9dB over that wide frequency range with the output power peaking at more than +4dBm in the frequency range 2400MHz to 3420MHz.

In the Ham radio bands 2m, 70cm and 23cm the output power level is -0,5dBm, 0dBm and +0,6dBm respectively. In the 13cm band the maximum output level is +4dBm and in the 9cm band it is +3dBm.

In comparison I repeated the measurement using Output B while having Output A terminated with 50 Ohms.
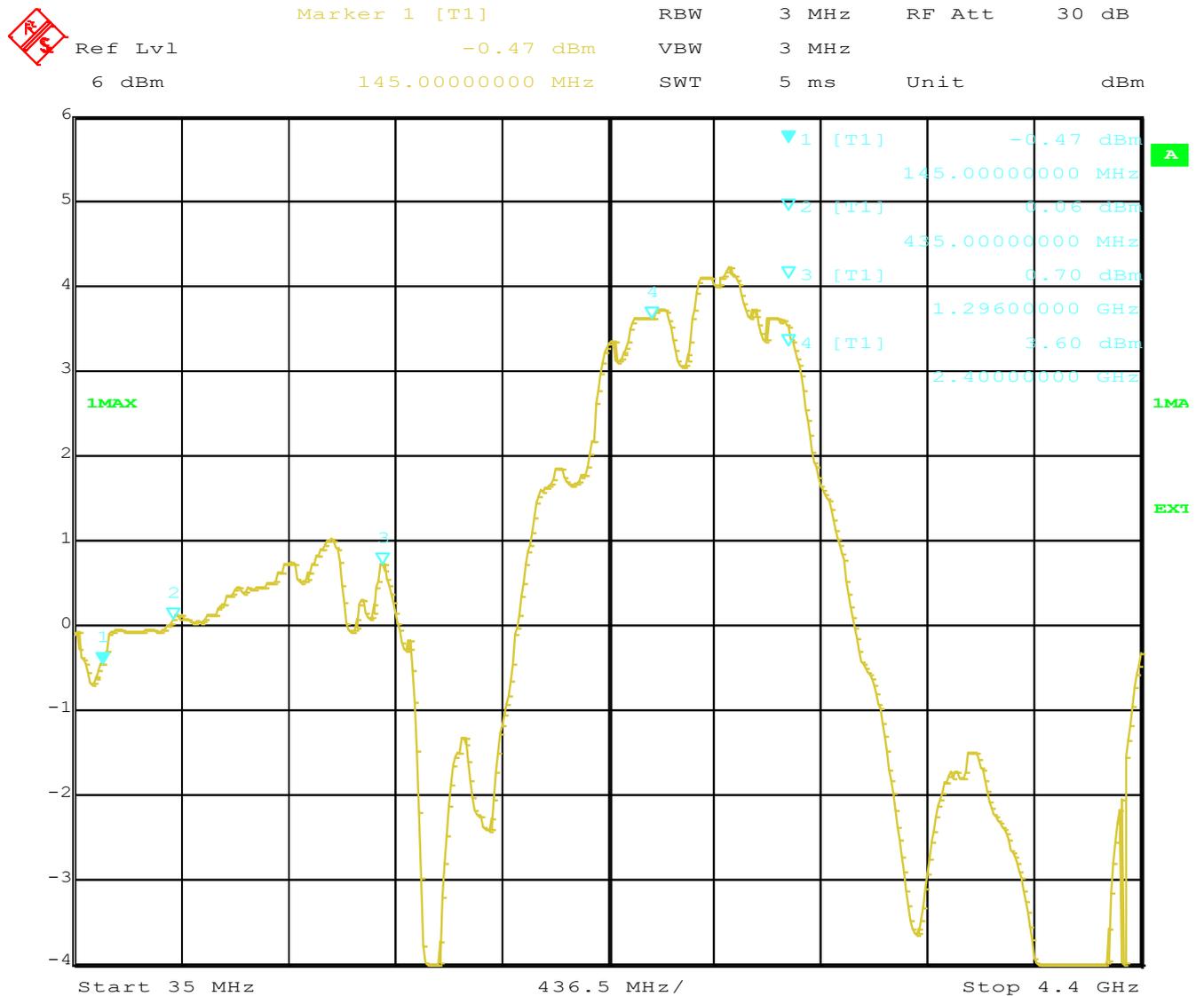
The curve shows some differences especially two dips in the frequency range 1350-1750MHz and 3200-4300MHz. Interestingly the output power levels in the Ham bands 2m, 70cm, 23cm and 13cm are almost the same as of Output A: -0,5dBm, 0dBm, +0,7dBm and +3,6dBm. However, in the 9cm band the output power level is -3dBm and thus 6dB lower than at Output A.

As the synthesizer module can vary the output level only in four steps: -4, -1, +2, +5dB and in many applications it is very helpful to be able to adjust the output level of a signal source in a wider range, I decided to add a digital RF attenuator to the synthesizer. I bought a ready-made module which is based on a PE43702 7bit digital attenuator from Peregrine Semiconductor. This attenuator is specified for the frequency range 9kHz to 4 GHz and thus fits very well to the synthesizer module. The attenuation can be adjusted in very fine steps of 0.25dB in the range 0 to 31.75dB. The supply voltage range of 3.3 to 5.0V matches well the supply voltage of the synthesizer. Here are some pictures of the module which includes an OLED display and 5 buttons to control it.

Please note that I replaced the original push buttons by higher ones in order to be able to integrate it into the same incasing as the synthesizer module and to be still able to push the buttons.
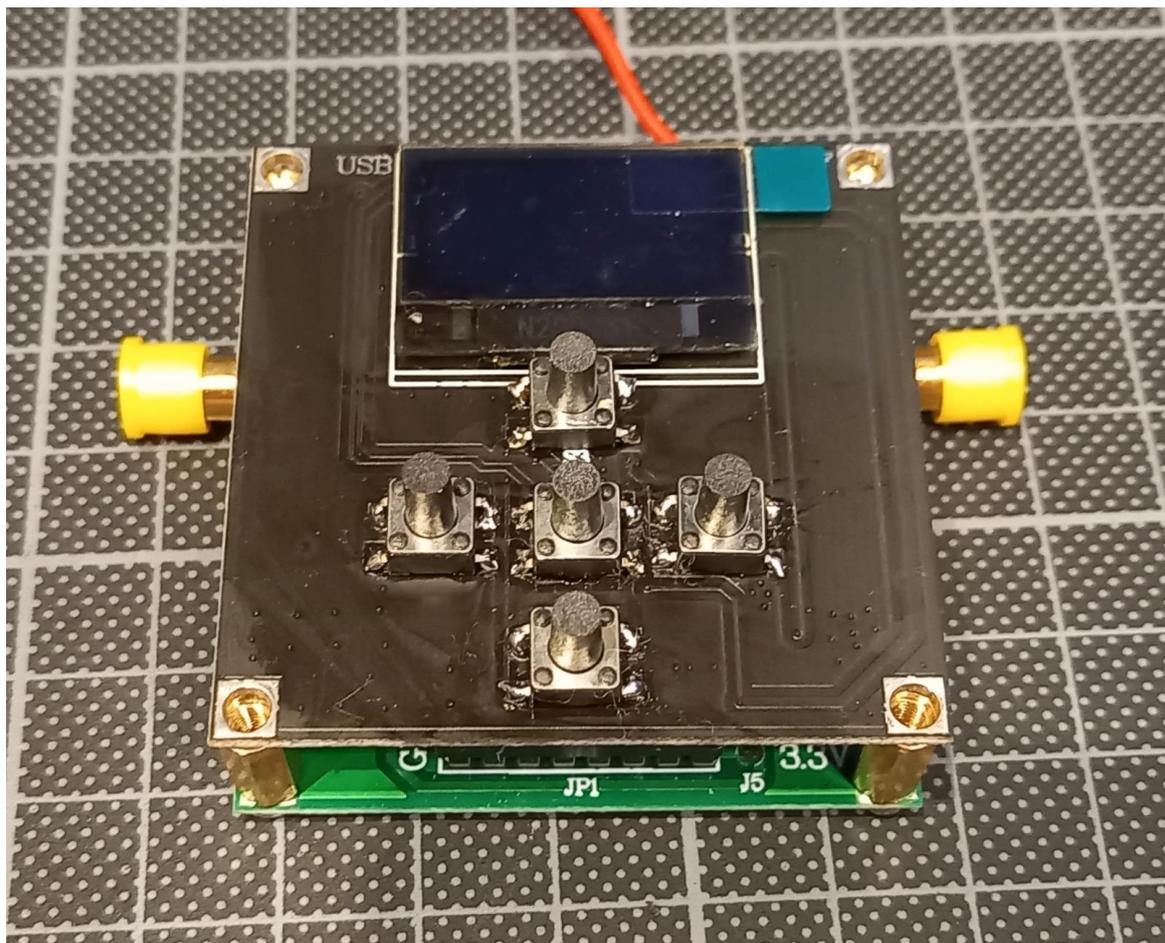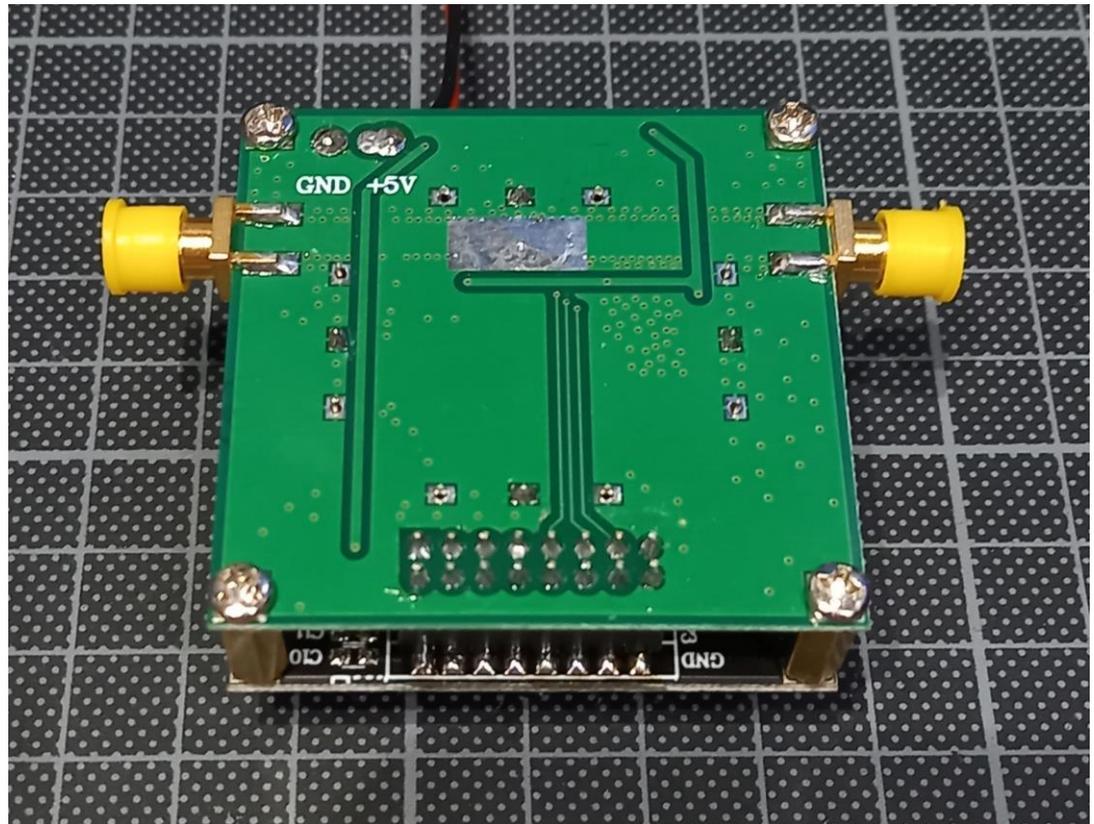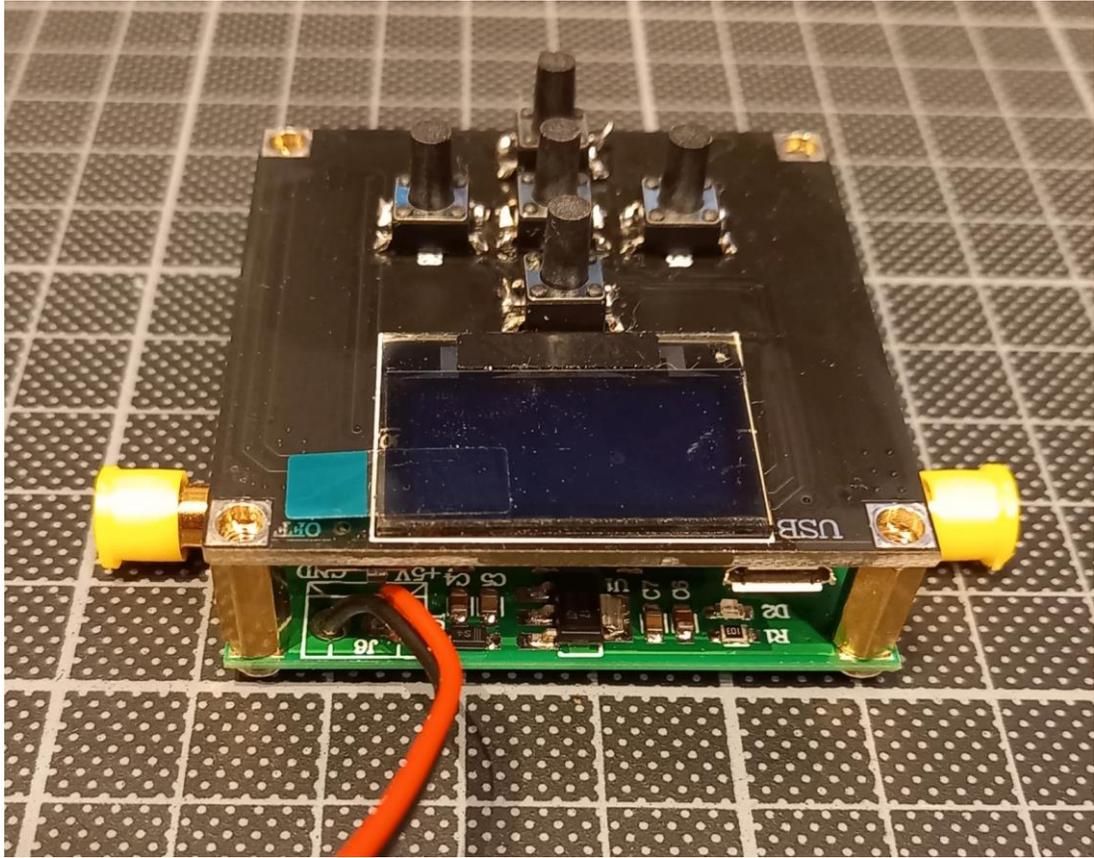
I integrated this module in the same encasing as the synthesizer module. I decided to not interconnect the synthesizer module and the attenuator module internally but to have all ports available outside. This way I can use the attenuator module also independent from the synthesizer module and vice versa. All RF connectors are SMA type. As you can see on the lower right picture, one of the two outputs of the synthesizer is connected with a semi rigid cable to the input of the step attenuator. In case the attenuator is to be used independently of the synthesizer this jumper cable can be simply removed.

The user interfaces of the synthesizer module and the attenuator are on two opposite sides of the encasing as I assume that in typical applications the frequency is swept at constant power or the power is swept at a constant frequency. Therefore, always only one of the user interfaces is actually needed.

If you do not want to spend the effort modify a metal encasing in order to integrate the synthesizer module, there is now a very simple solution: Andi DL3RCG has designed a 3D printable encasing for the synthesizer module and published the complete design data at thingiverse. You can find it at https://www.thingiverse.com/thing:5188465
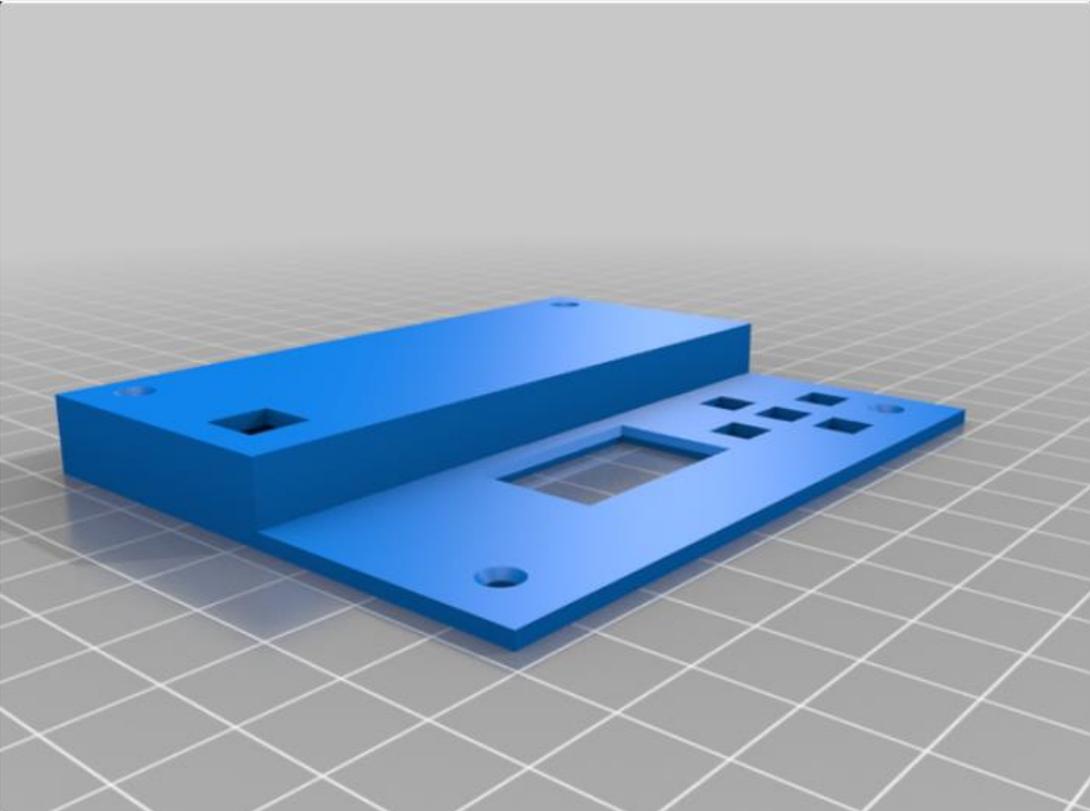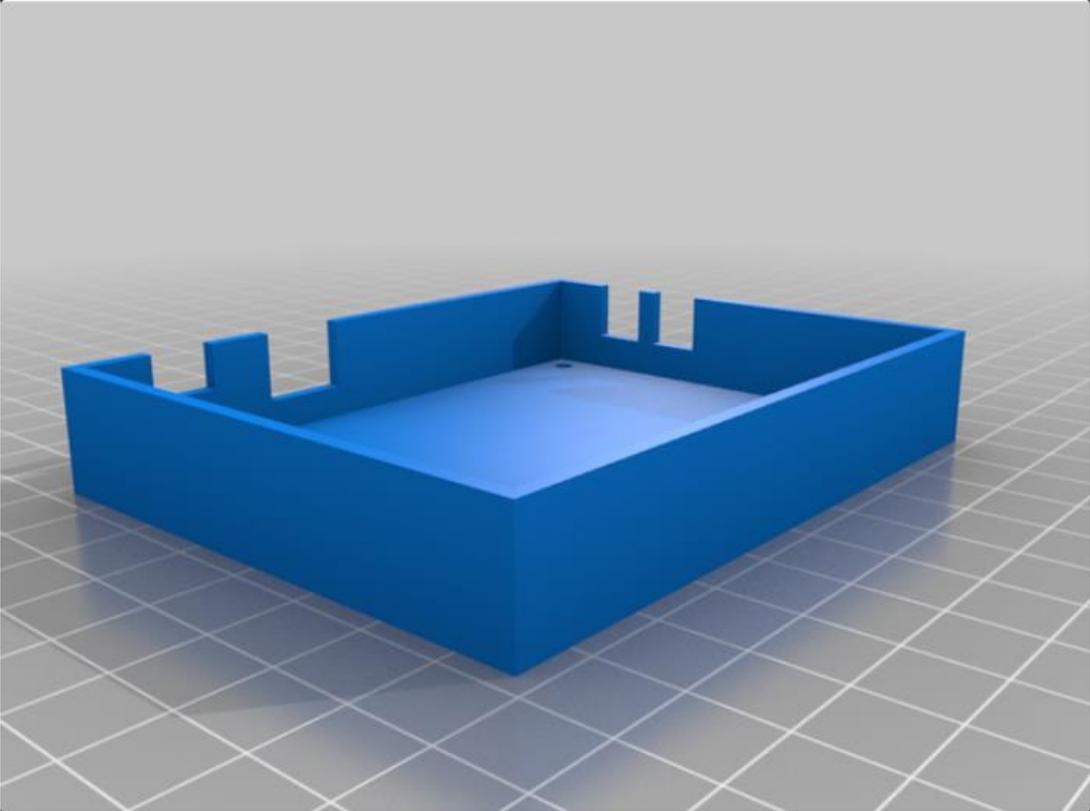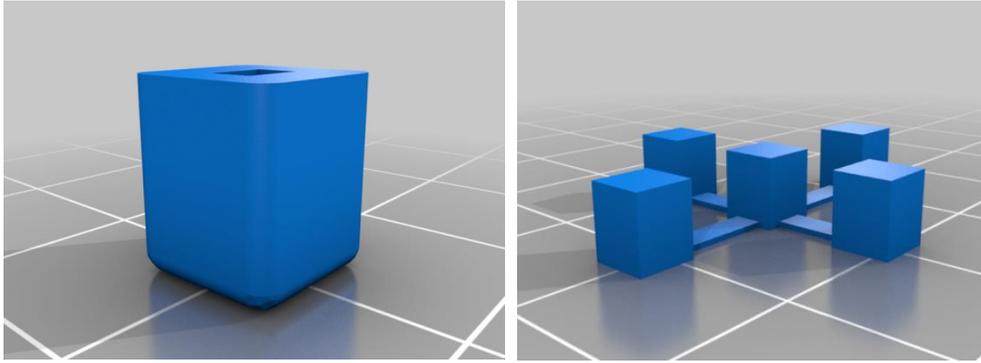
Andi was kind enough to also print one encasing for me as I had a second synthesizer board. In order to have a shielding for the synthesizer module we decided to spray coat the outside of the encasing with a highly conductive shielding lacquer on metal basis "EMV 35" and then add a protective layer using black paint. Here are some pictures:
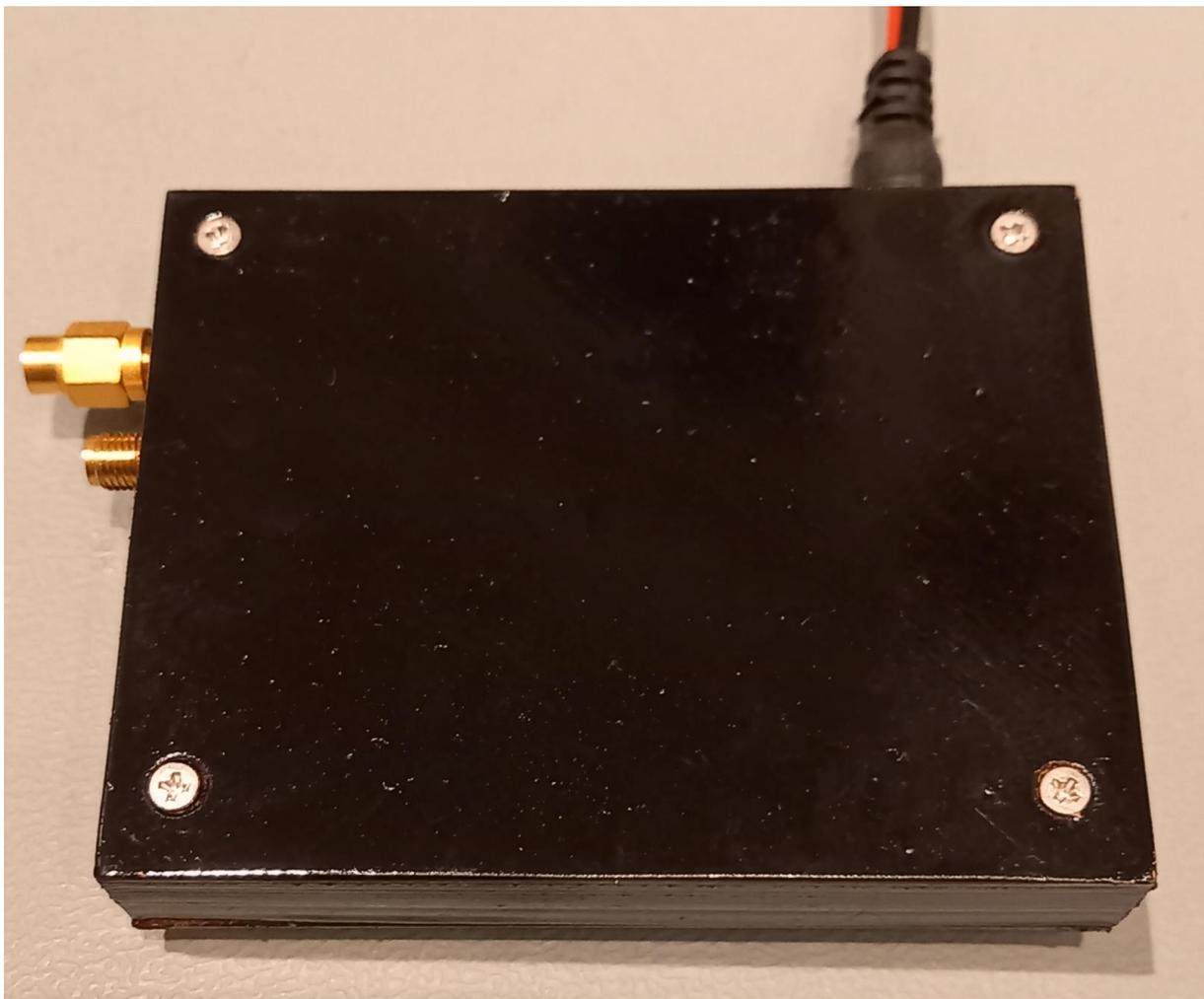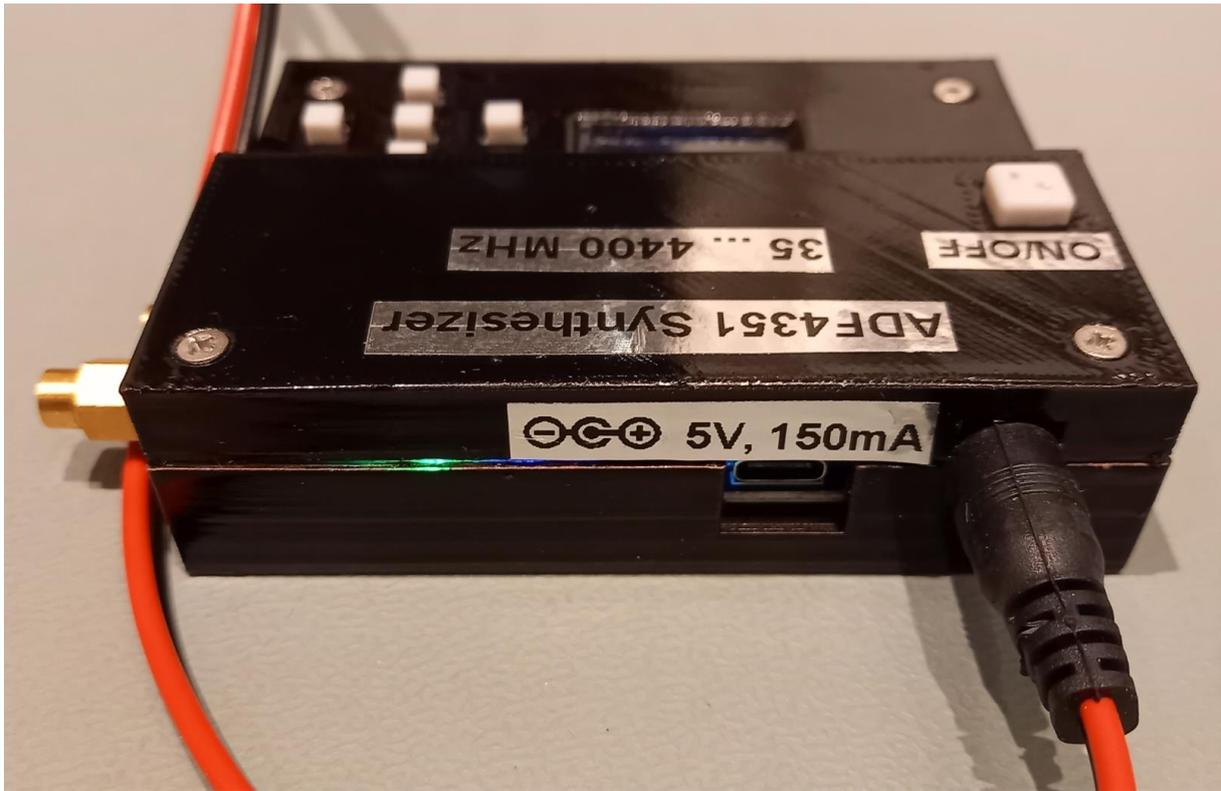
Questions and remarks are always very welcome. Please send them to the Email address given below.

Kind regards

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