EME The Hard Way -

Why Make It Simple When You Can Make It Complicated.

EME2026 Tenerife – By Carsten Grøn OZ9AAR

The PDF version of this presentation has several links in it; they will take you to the relevant web pages

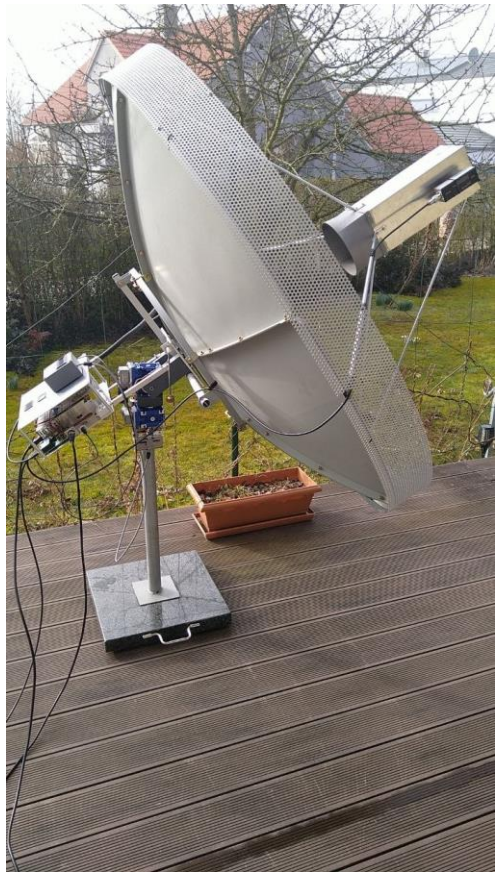
More information: www.moonbounce.dk

WARNING!

The following presentation is NOT what is <u>needed</u> to get on 23cm EME !!!

You can do it with simpler means.

“Much is too much”



Robert DC1RDB

Example of how compact and efficient you can get on 23cm EME,
”USD$ 80,- Cooker dish”
setup with 130W at feed.
Optimized feedhorn and fence.

Agenda

01	History and background of OZ9AAR
02	The new project, 4.8m dish for EME
03	“Yak Shaving” – “Do B so you can do C so you can do A..”
04	First results
05	Questions?

01 History and background of OZ9AAR

- Born 1966, married to Henriette, two boys, three grandkids, two cats
- Working as a software and hardware developer for 42+ years so far.
- Got licensed in 1992, started on satellite and HF same year
- Got on 2m EME with four Yagi's and 1KW (3 x 4CX350) in 1993
- Built a 5-meter dish for 23cm in 1994, dual water cooled 2C39's tubes in PA
- Moved QTH in 1995, started building 8 x 15 element X Yagi for 2m EME
- Gave up on 2m after a few years, got help from a massive storm and heavy QRM
- Built an 8m dish for 23cm EME in 2000
- In 2003 I stopped with Ham Radio, busy with new job and life in general

- In 2022 I could no longer stay away
- Back on satellites, 9000+ QSO in 2 ½ years, WAS, 175 DXCC/1300 VUCC conf., 36 WAZ zones
- The EME dream was still very much alive!
  - Rebuilt my satellite antennas in 2024 to 4 x 23 element Yagi's for 70cm, currently QRV
  - Started designing my current 4.8m dish system December 2024
  - Decided to develop as much as possible (for me) of the subsystems myself, and share with others
  - Installation started summer 2025

01 History and background of OZ9AAR

4 x 15, 2m, 1993

8 x 15 xpol, 2m, 1997

01 History and background of OZ9AAR

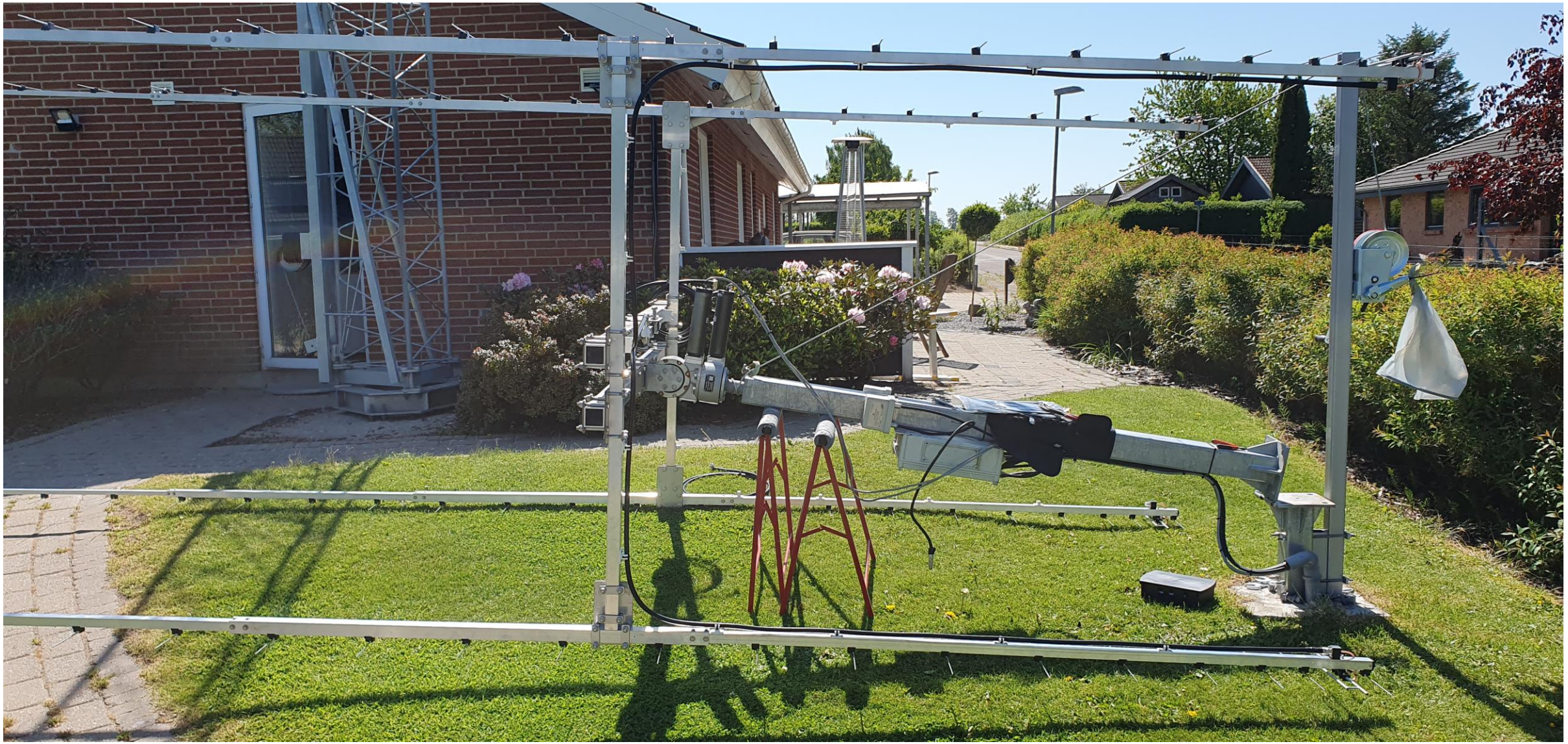
5m dish, 1994 (now at OZ6OL)

8m dish, 23cm, 2000 (now at SM7GVF)

01 History and background of OZ9AAR

4 x 23 elements for 70cm/400W since 2024

01 History and background of OZ9AAR



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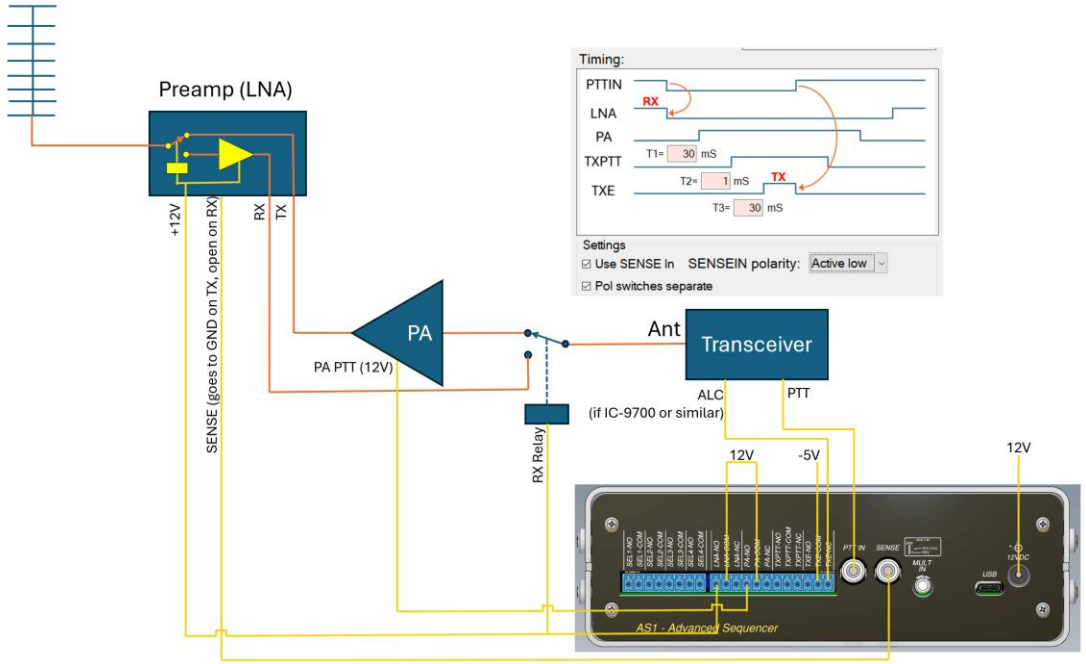


Remote controlled PA
Using REPAM module
and Dual RF Head

01 History and background of OZ9AAR

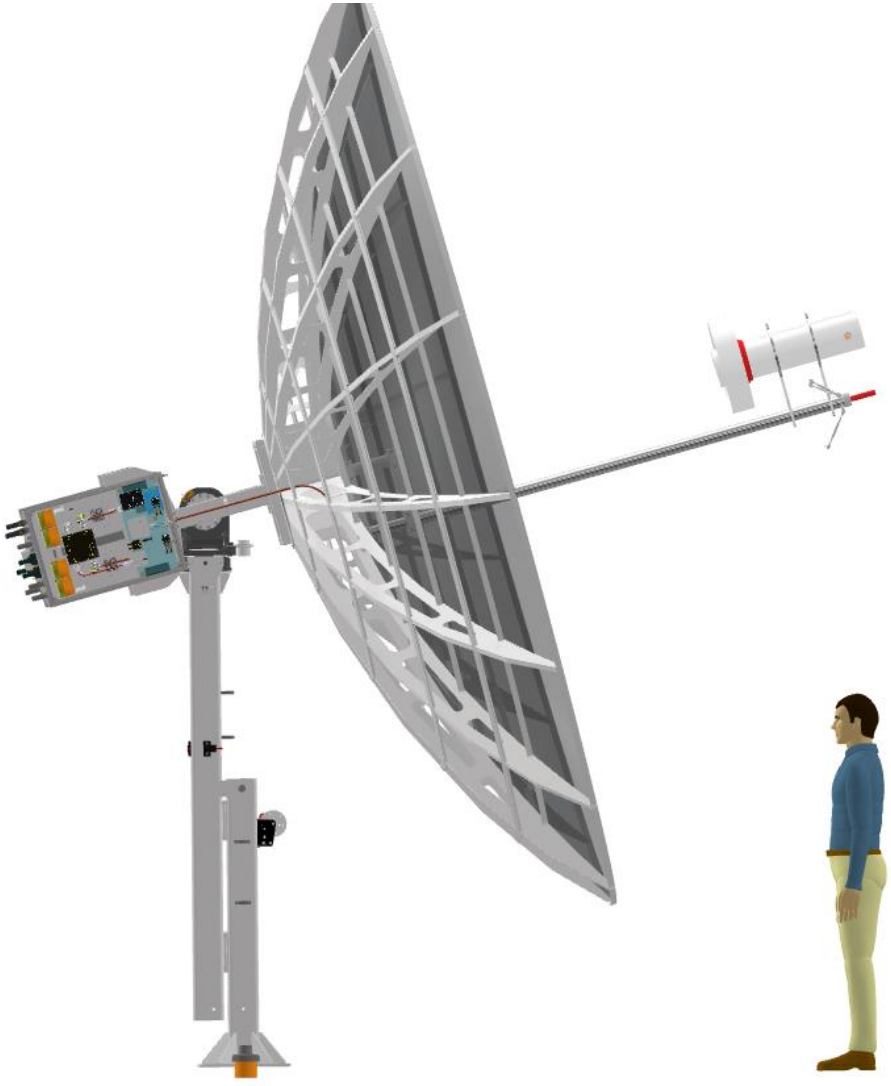
G0JDL John, 2 x 14 elements from Antennas-Amplifiers, 160W at feed. Worked 14 times so far

Callsign: G0JDL Band: All bands Clear

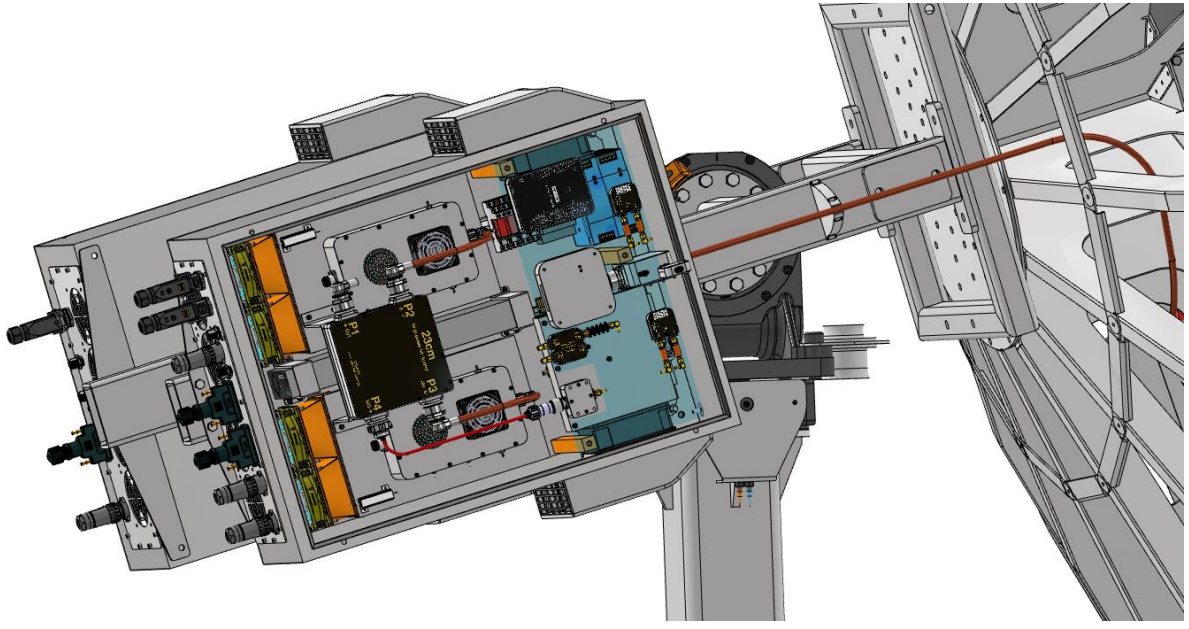
Total QSOs	Sessions	Avg best SNR	Avg my SNR from DX
14	14	-25,5 dB	-26,1 dB

Date	Time (UTC)	Frequency	Band	Best SNR	His SNR	My SNR
2024-12-11	21:20	432,088 MHz	70cm	-24 dB	-24 dB	-28 dB
2024-12-12	20:16	432,088 MHz	70cm	-25 dB	-26 dB	-22 dB
2024-12-13	21:46	432,088 MHz	70cm	-25 dB	-31 dB	-24 dB
2025-02-06	16:08	432,088 MHz	70cm	-26 dB	-26 dB	-24 dB
2025-02-10	21:42	432,087 MHz	70cm	-27 dB	-26 dB	-32 dB
2025-03-02	16:05	432,068 MHz	70cm	-22 dB	-23 dB	-32 dB
2025-04-01	17:42	432,083 MHz	70cm	-25 dB	-25 dB	-21 dB
2025-04-03	18:01	432,068 MHz	70cm	-25 dB	-25 dB	-24 dB
2025-04-29	13:25	432,068 MHz	70cm	-28 dB	-28 dB	-26 dB
2025-04-30	18:03	432,068 MHz	70cm	-25 dB	-25 dB	-25 dB
2025-08-18	11:00	432,088 MHz	70cm	-26 dB	-24 dB	-27 dB
2025-12-28	19:31	432,070 MHz	70cm	-28 dB	-28 dB	-26 dB
2025-12-30	21:15	432,070 MHz	70cm	-24 dB	-24 dB	-28 dB
2026-01-27	19:47	432,068 MHz	70cm	-27 dB	-27 dB	-26 dB

02 The new project, 4.8m dish for EME



- Small(er) dish (4.8m)
- Back of garden hard to reach, no machines
- Able to “man handle” everything – foldable tower
- Own development of most/all subsystems
- **Making most of these available for others to build**
- The dish acquired thru Zdenek OK1DFC
- Everything (EVERYTHING!) done in CAD
- The project was an excellent exercise in mechanical, electronics, RF and software design



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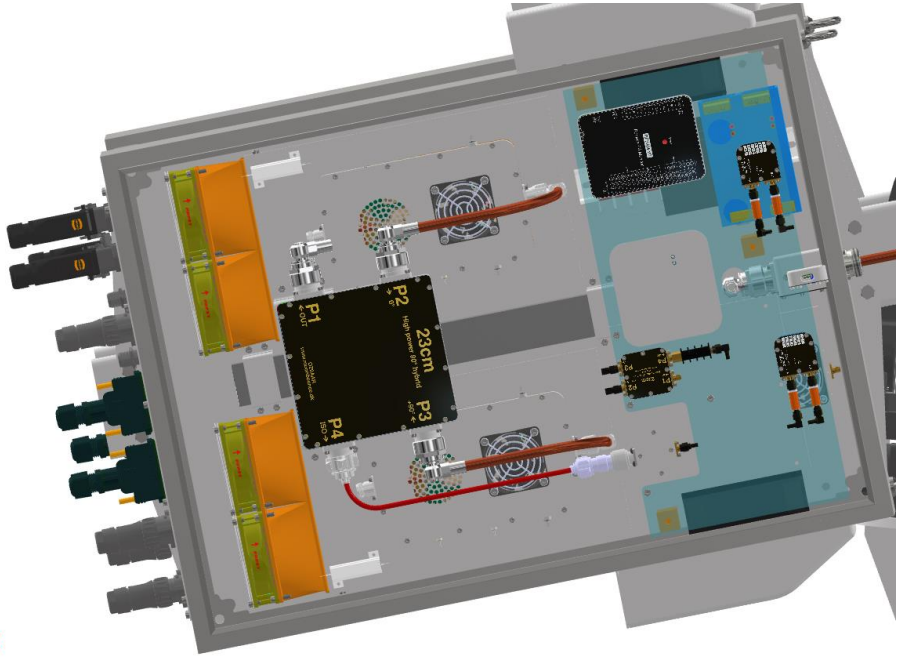

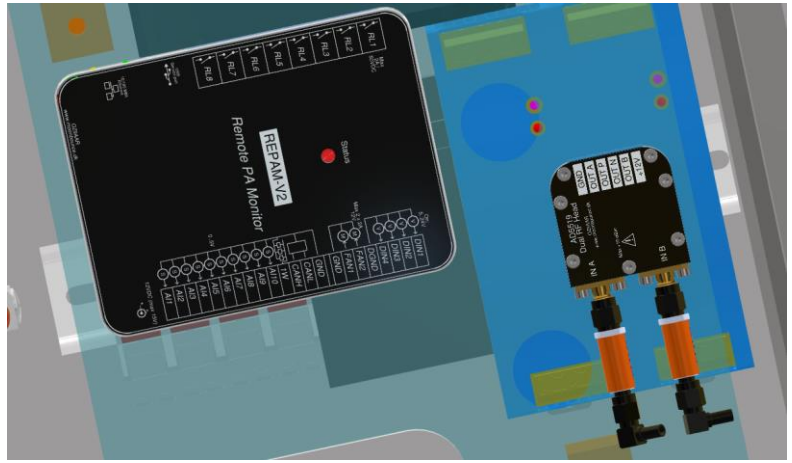

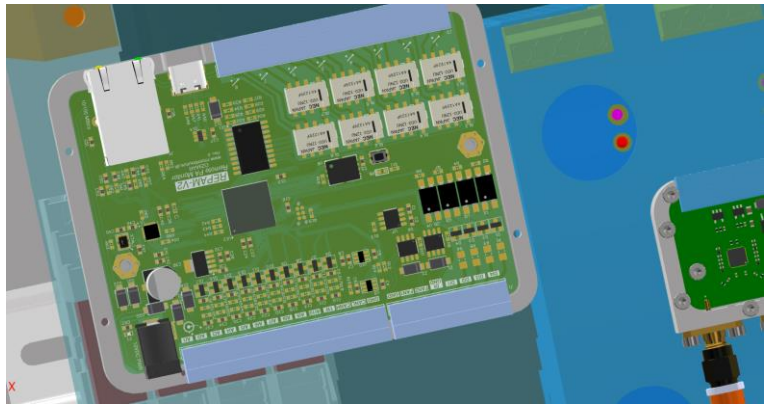

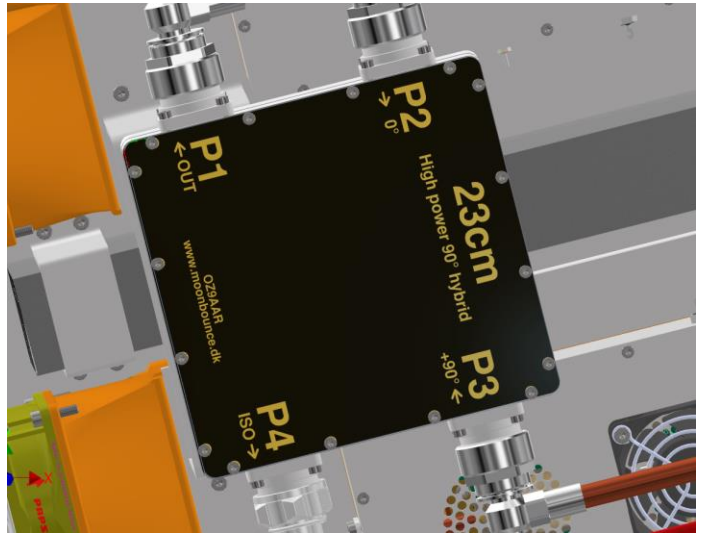

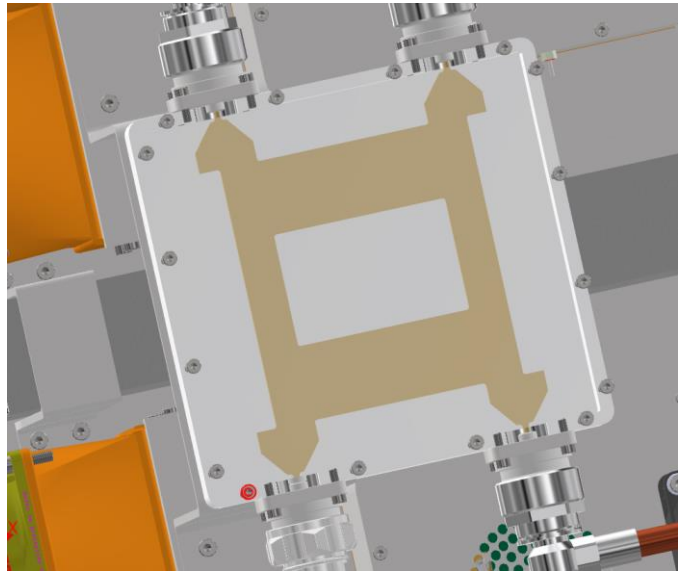

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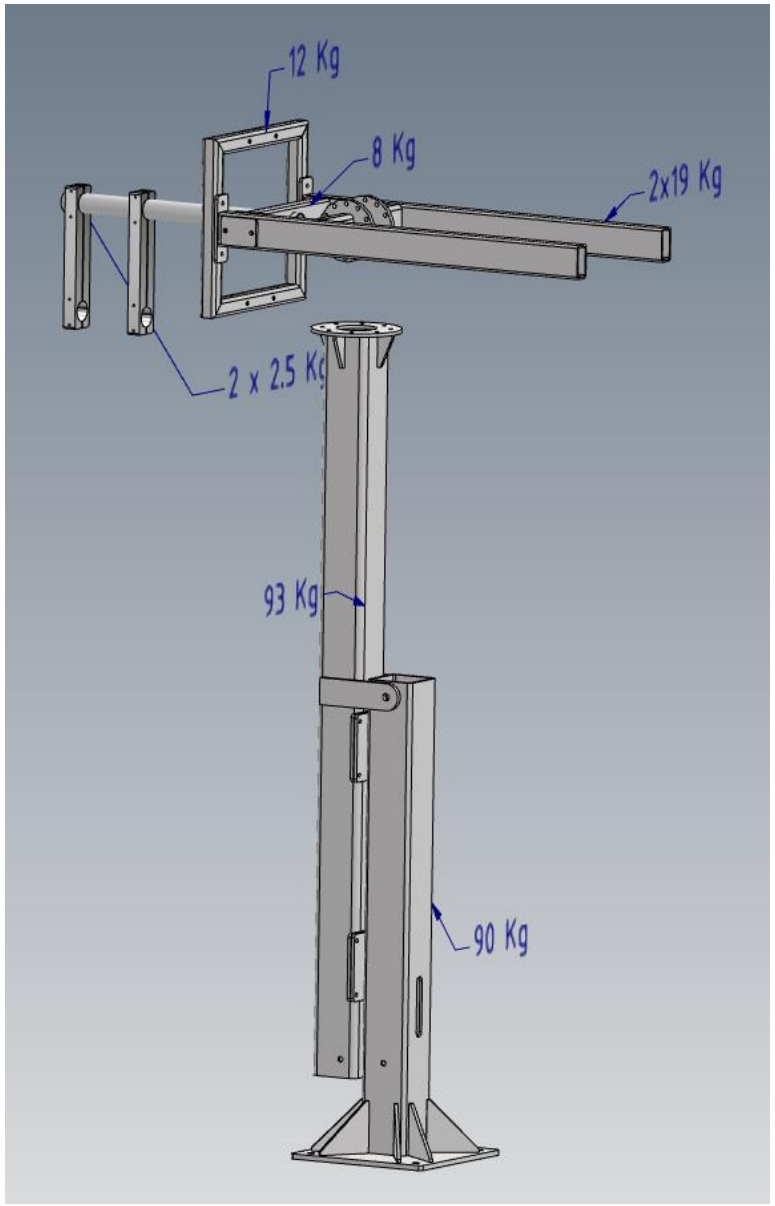
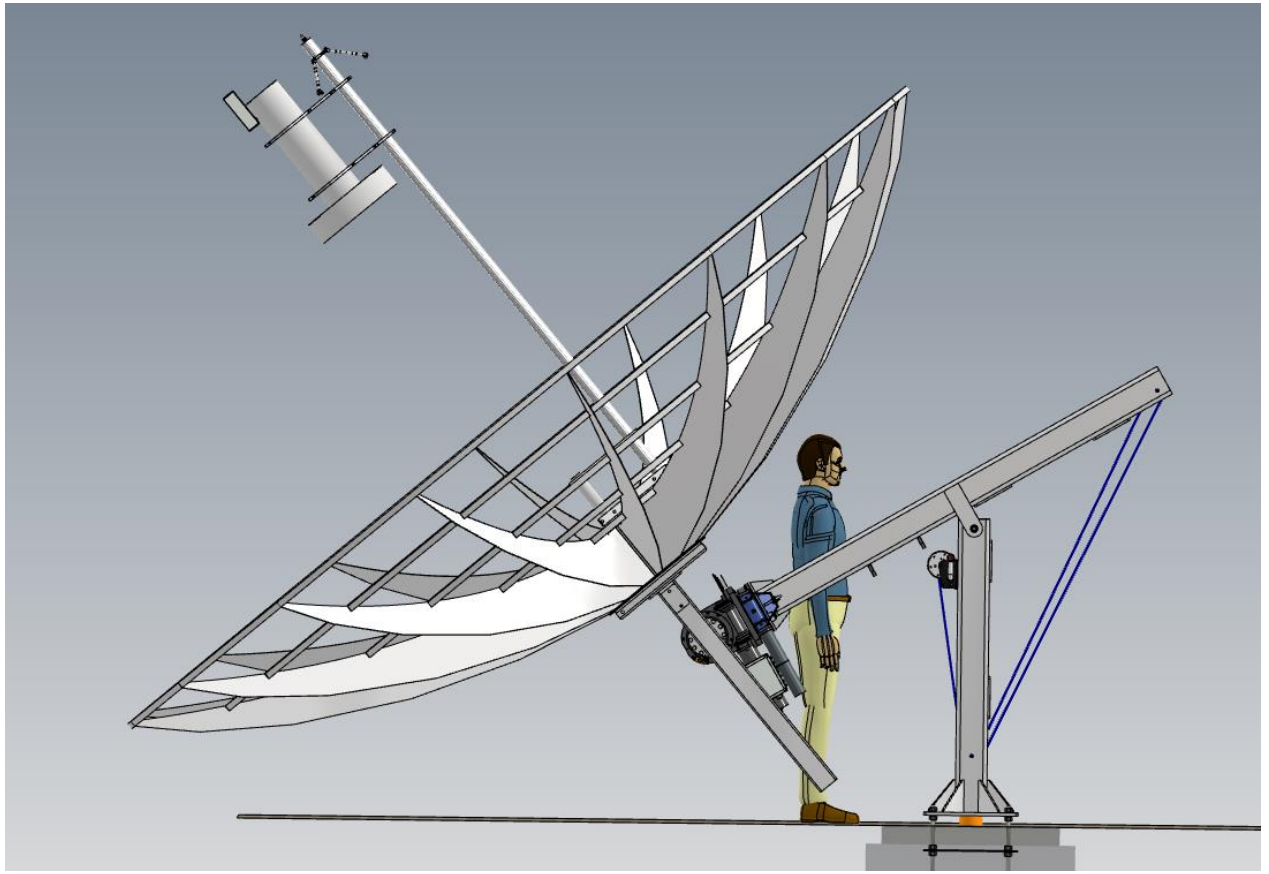
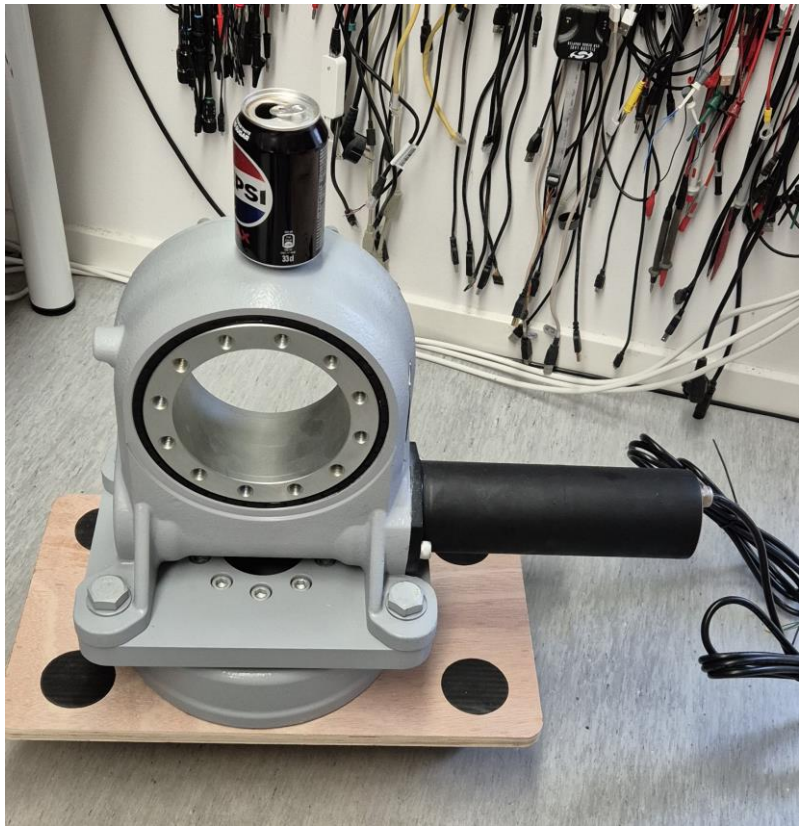


- Complete solution for tower and Az/El mount
  - Everything designed in Autodesk Inventor
  - I got the parts fabricated thru Zdenek OK1DFC (OK3VM)
  - All files available, make your own (except the dish)
  - Link to project files



02 The new project, 4.8m dish for EME

- Using SVH7 slewdrive from Coresun/China
- Tilting tower, lowered using a winch
- Square galvanized steel tubing, 150x150x8mm
- Elevation point 260 cm above ground
- Weight of tower + slewdrive (85 Kg) is around 340 Kg
- Total system ~550 Kg



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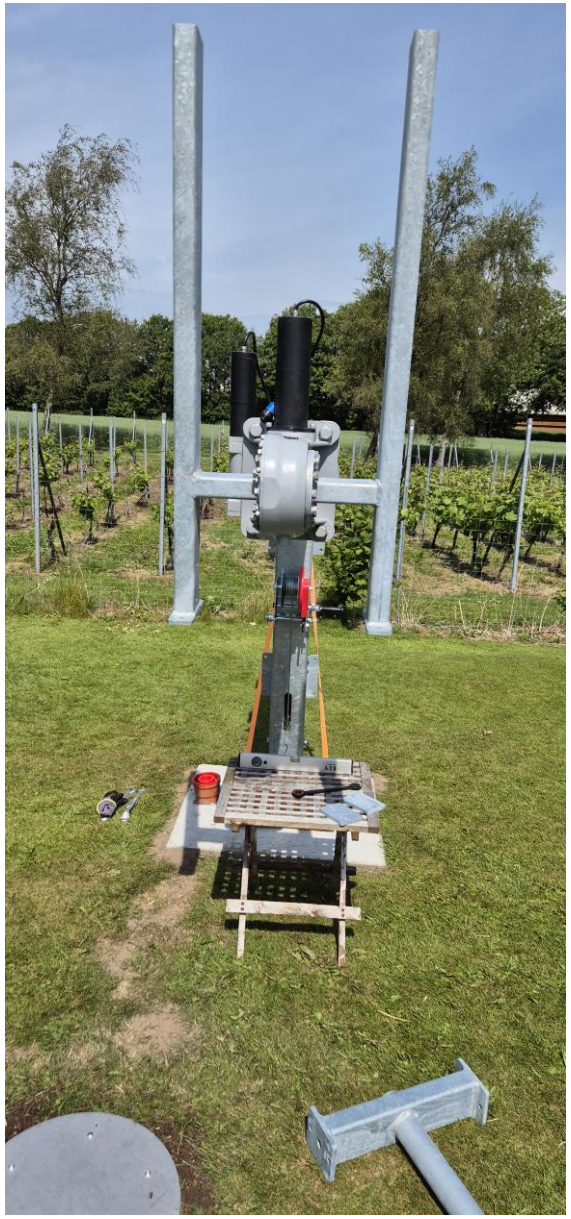

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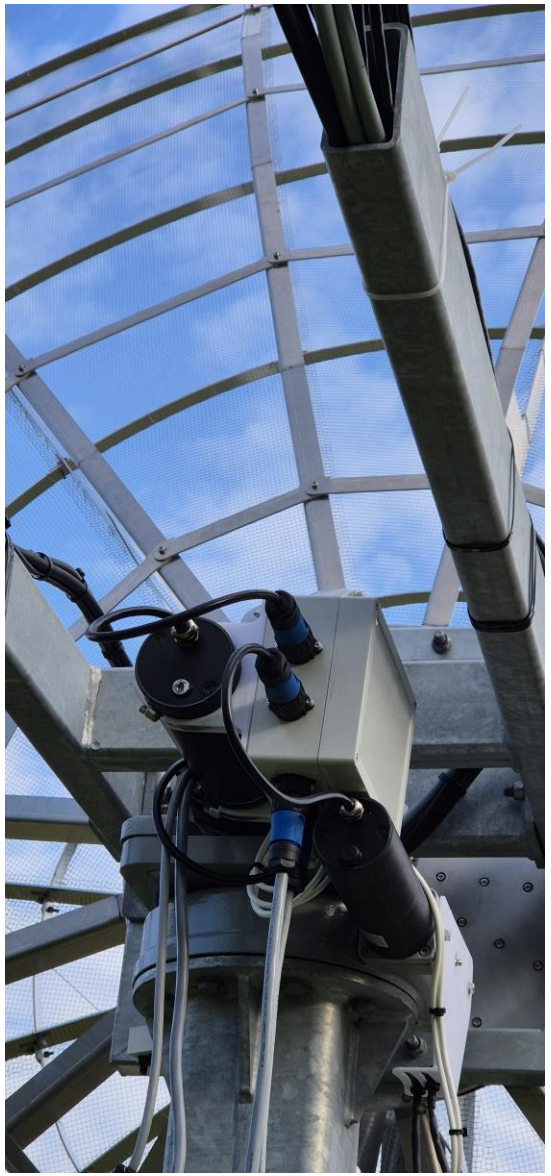
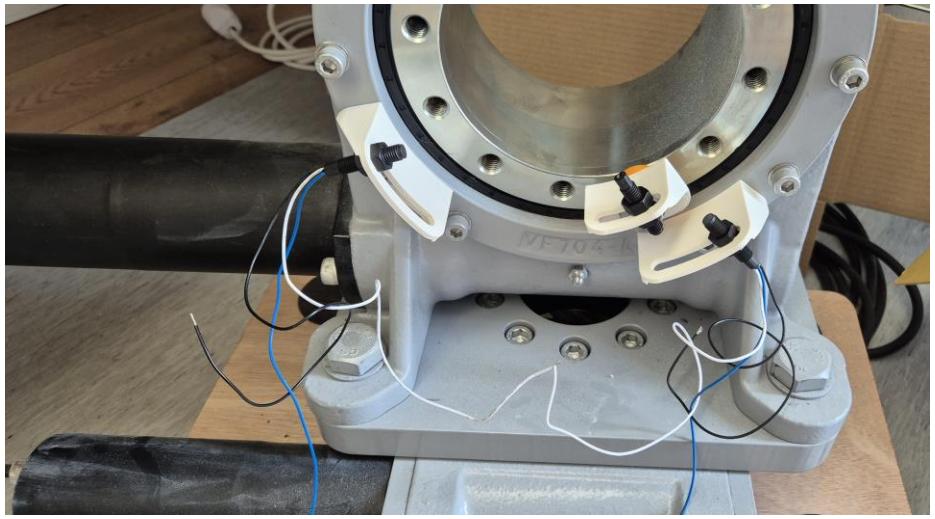
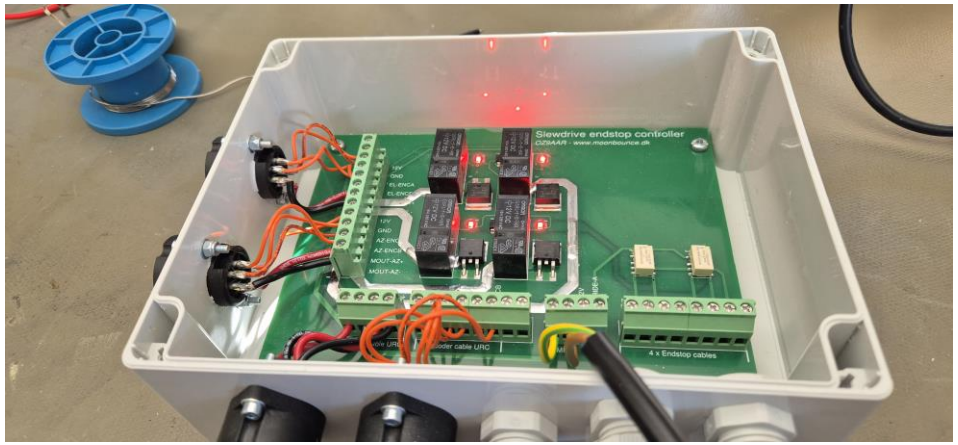


End stop interface box.
The slewdrive have “infinite power”, needed end-stops that would not be dependent on software/rotor controller.
All files available, make your own.
[Link to files/project]





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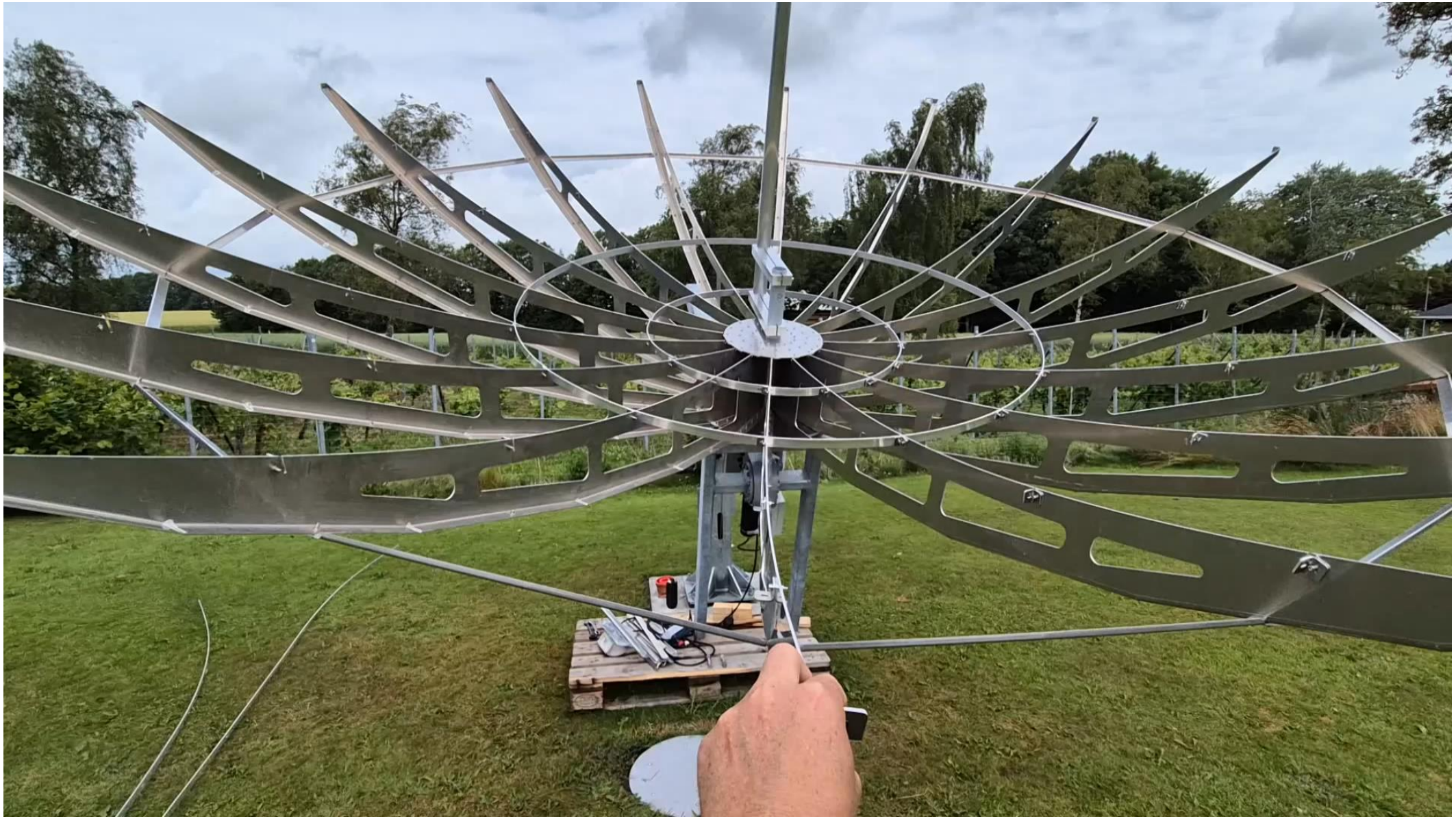

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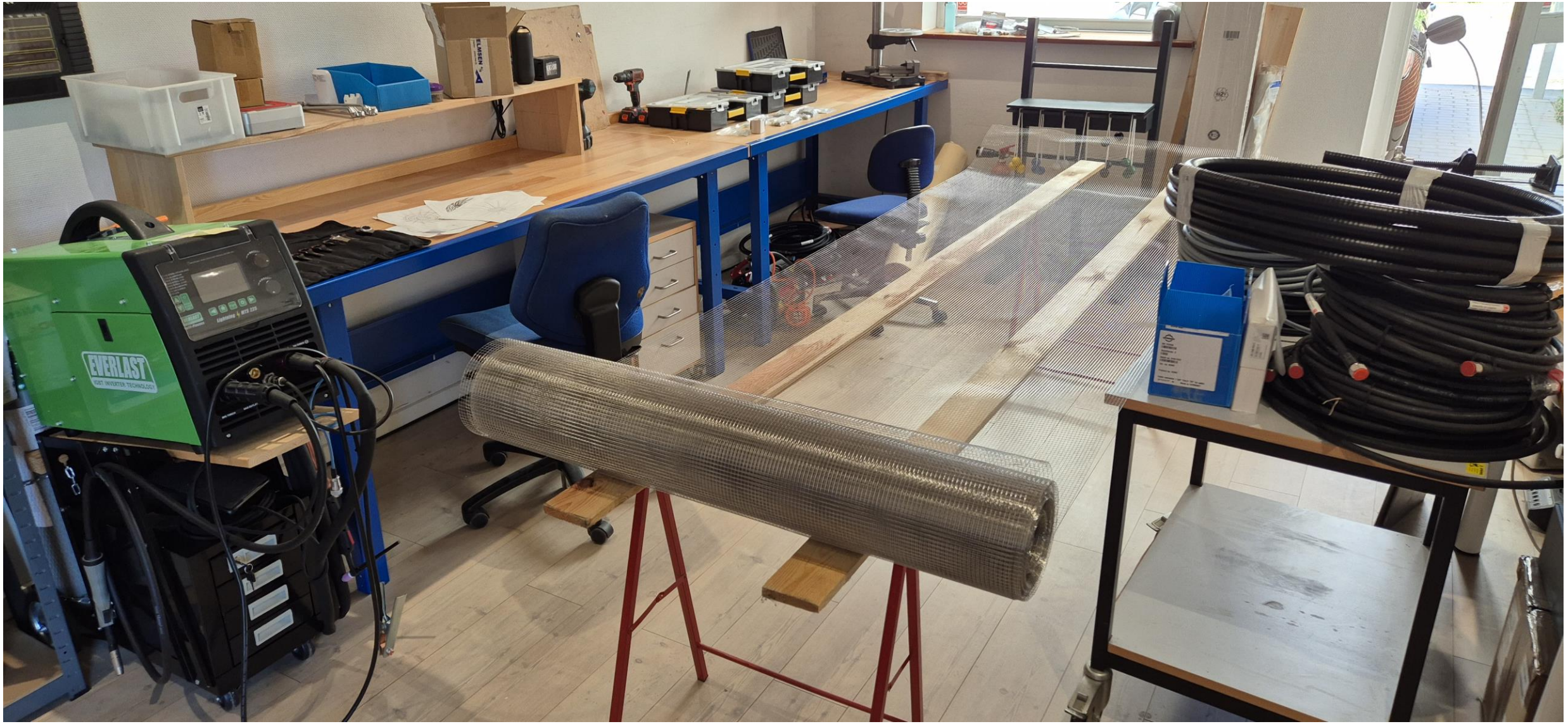
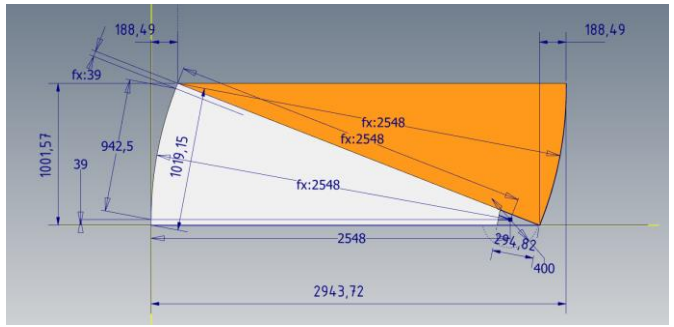


02 The new project, 4.8m dish for EME

Cut 3 layers of pie shaped mesh at a time, using angle grinder (careful!)



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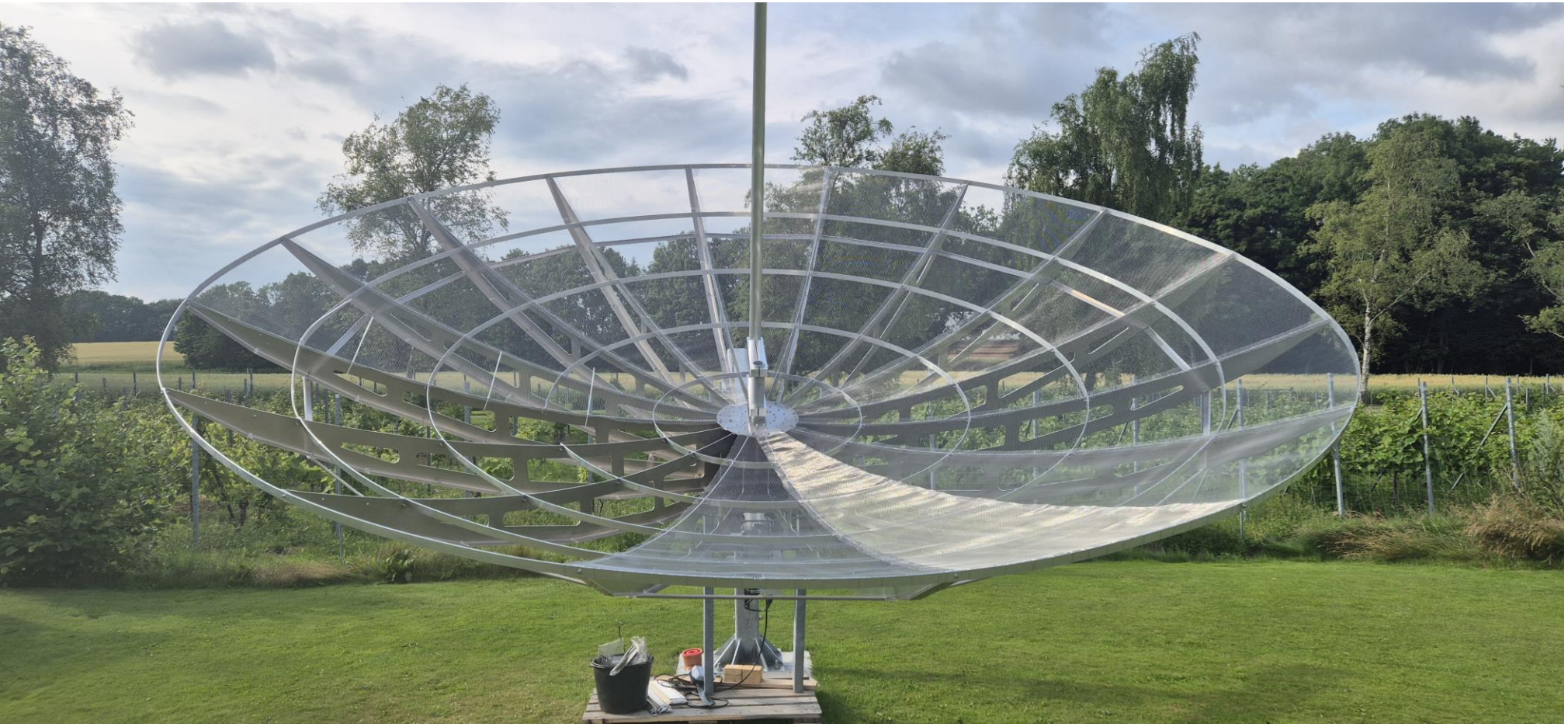


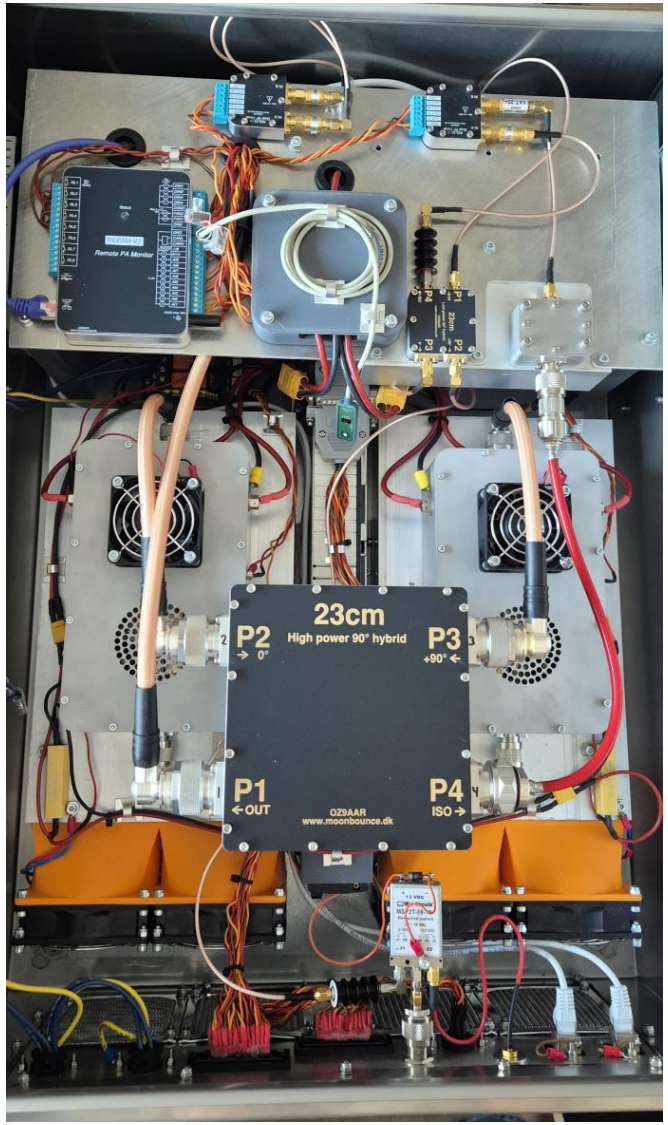
The battle is almost over...

02 The new project, 4.8m dish for EME

Routed all cables in flexible hose. Lined with steel spiral.

02 The new project, 4.8m dish for EME

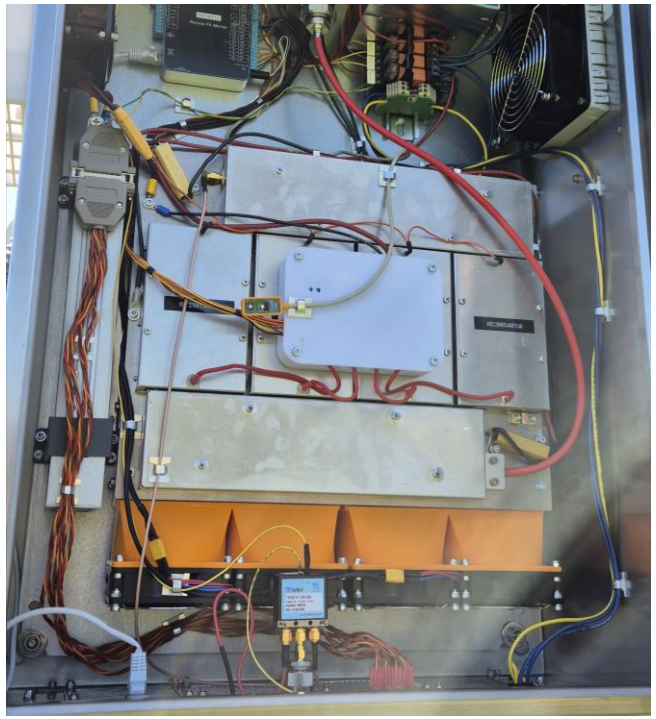
Dual W6PQL PA for 23cm



PA systems installed on dish (elevation arms):
+ Low cable loss, less clutter in shack, no noise ☺
- More complicated, remote control and operation
- Control humidity
REPAM handles the negatives.

PA systems installed at dish

4 x DVB modules for 70cm



Helping hands and paws during the process

02 The new project, 4.8m dish for EME

03

“Yak Shaving” – “Do B so you can do C so you can do A..”

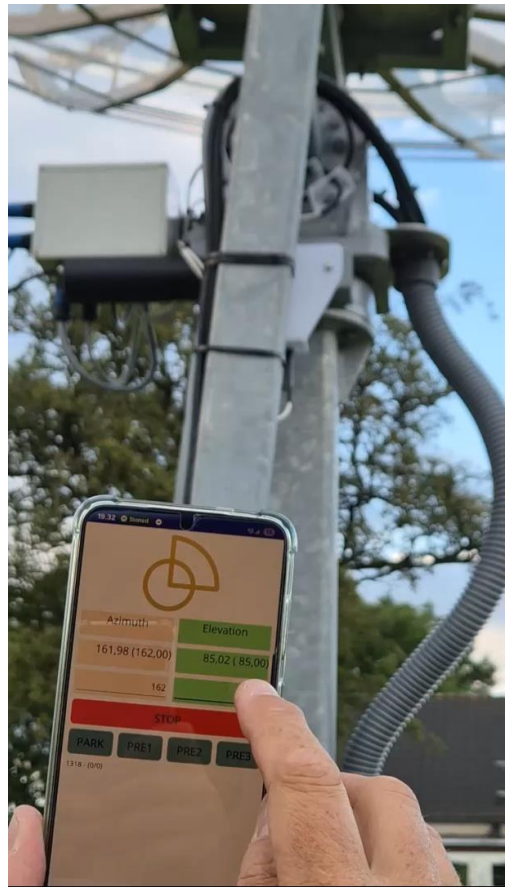
03 “Yak Shaving” – “Do B so you can do C so you can do A..”

- I decided from the start to develop most of the components of the system myself
- Spent around 2 years developing all the different components/devices used:
  - URC – Ultimate Rotor Controller
  - Mobile application for controlling URC
  - REPAM - REmote PA Monitoring device, via network/Ethernet
  - Configuration and monitoring applications for REPAM (one is available as source code)
  - Dual RF Head (analog/USB/M5/Ethernet) - power measurement devices.
  - High power 144-2300 MHz directional coupler
  - 23cm high power and low power hybrid combiners (+ QRO for 70cm, QRP for 2M/70cm).
  - Flatpack2 HE PSU interface board.
  - High power (400W and 1500W) attenuators.
  - Sequencer (now sold by Antennas-Amplifiers)
  - Heatsink/fan ducting module for PA modules/systems.
  - 150W+ 23cm PA module (design by BG3MDO/BG0AUB) used as driver.
  - Designed mechanics (boxes, heat spreaders) for dual W6PQL PA modules.
  - Overcurrent protection switch/current monitor (single, dual and quad channels).
  - Feedhorn for 23cm, based on OM6AA design.
  - A couple of “extras”, Windows applications: SimpleCalc, SkyScanner and SatTrack
- All information/files are available on my webpage: www.moonbounce.dk

03

“Yak Shaving” – “Do B so you can do C so you can do A..”

- URC - Ultimate Rotor Controller
  - With Quadrature inputs, CAN Bus, RS-485, RS232 and Ethernet/LAN
  - Monitors motor currents, does PWM ramps, various watchdog features. Webserver, socket interface, UDP status etc.
  - Cortex M7, 600 MHz, 32 Mbyte RAM, 128 Mbyte Flash drive
  - Capacitive color touchscreen, 4.3 inch, 480x272 pixels
  - Track sun and moon autonomously, Web server built-in
  - Android mobile application
  - For now, only my “internal project”. Will change soon.
  - Link to project



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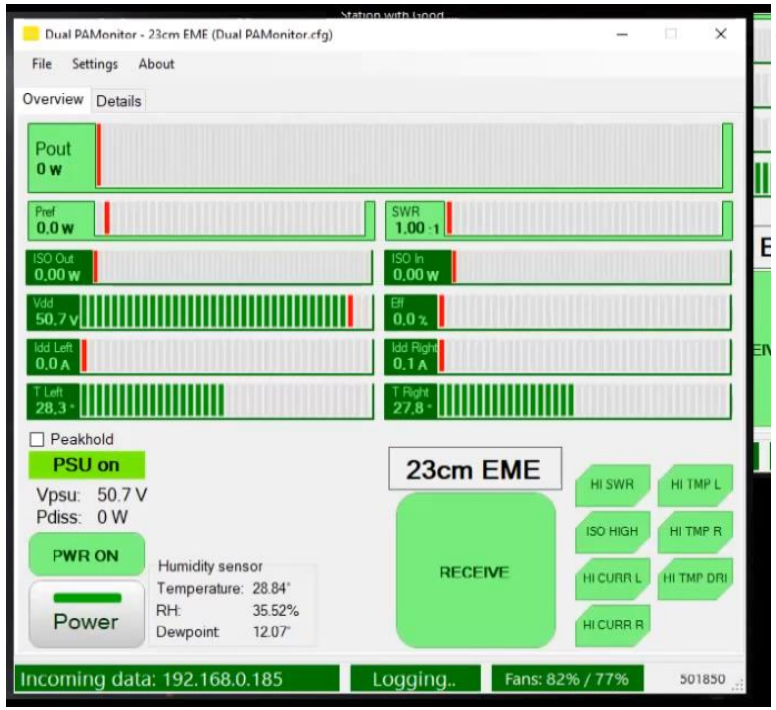
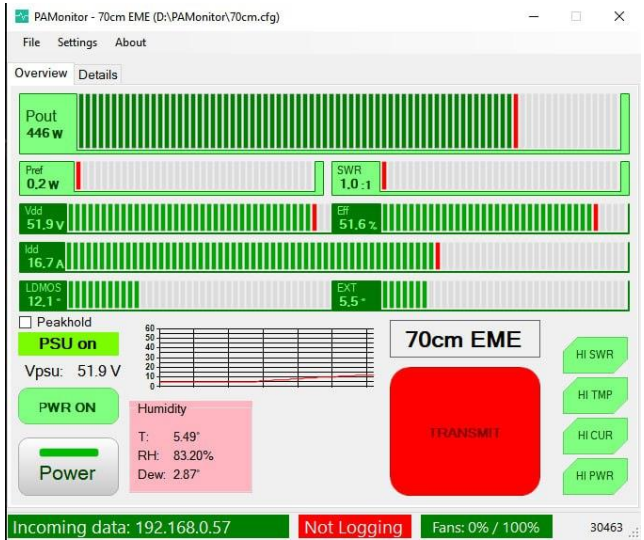
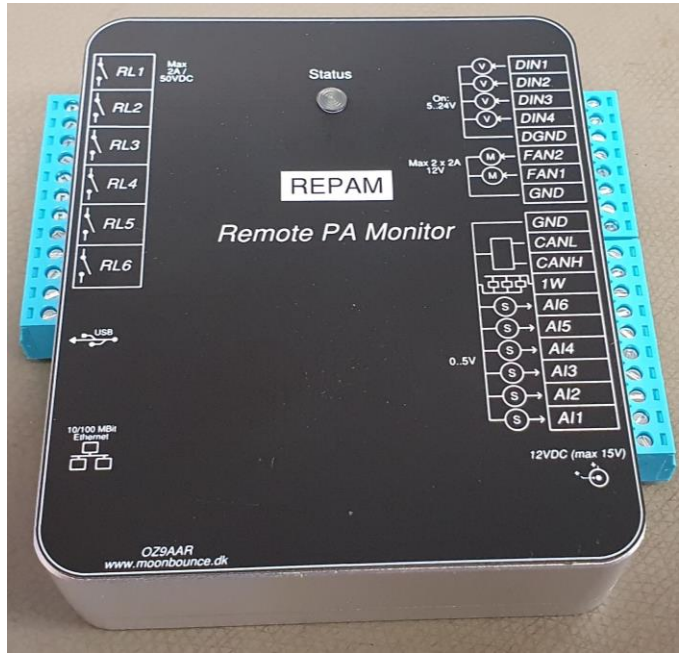


- REPAM – REmote PA Monitor
  - 4 x DI, 6 x AI, 6 x DO, CAN Bus, 1-Wire, 2 x 12V (2A total) PWM, Ethernet
  - Supports 8 temperature sensors and one RH sensor, using 1wire bus
  - Up to 12 triggers/alarms (ex. max current, max SWR, max temp. etc.)
  - Triggers are working autonomously, no PC required
  - Fan controller controls up to two fans (each 2A, max total 2A)
  - Humidity/dewpoint controller controls heat and fans
  - Calculates FWD/REF/SWR if connected to Dual RF Head – Analog
  - Four individual “PowerCalc” channels using two Dual RF Head - Analog
  - Monitor and configuration of Flatpack2 HE PSU using CAN Bus
  - V2 version coming (10 x AI, 8 x DO)
  - Link to product





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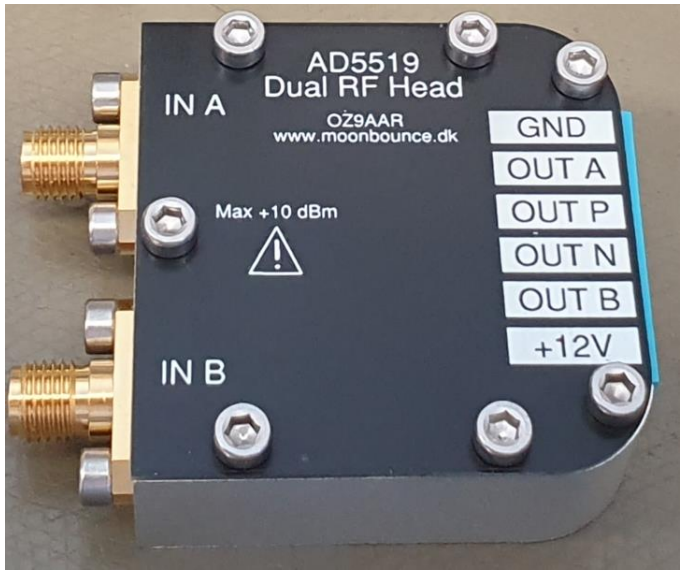
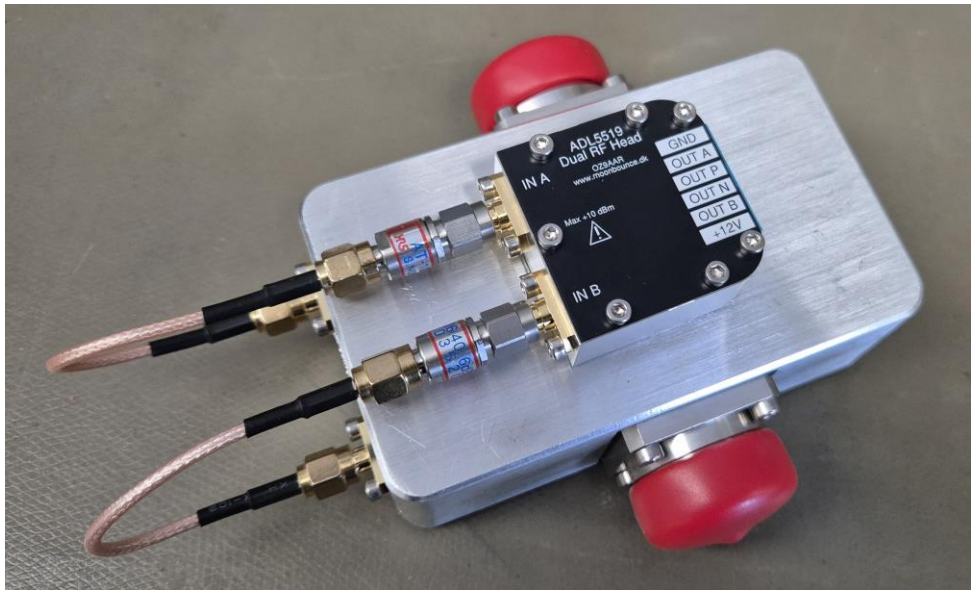
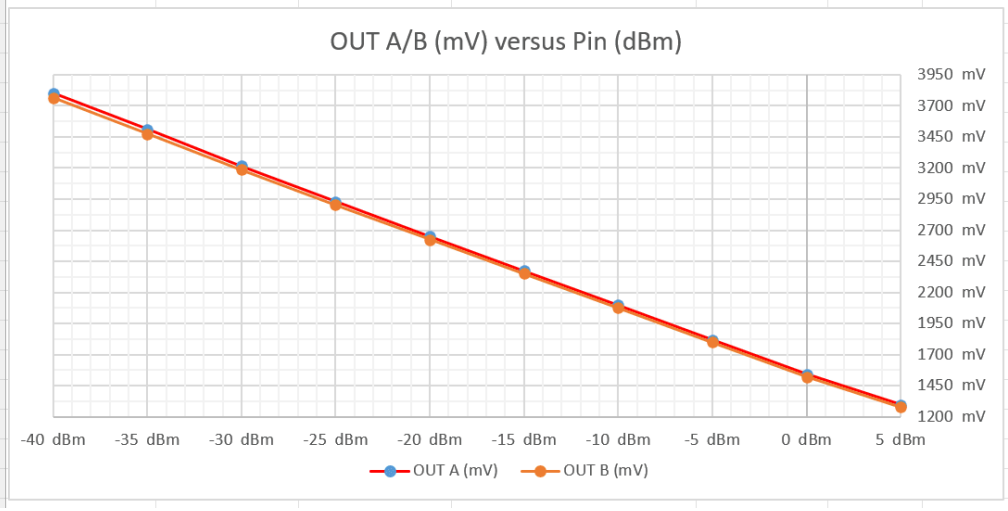




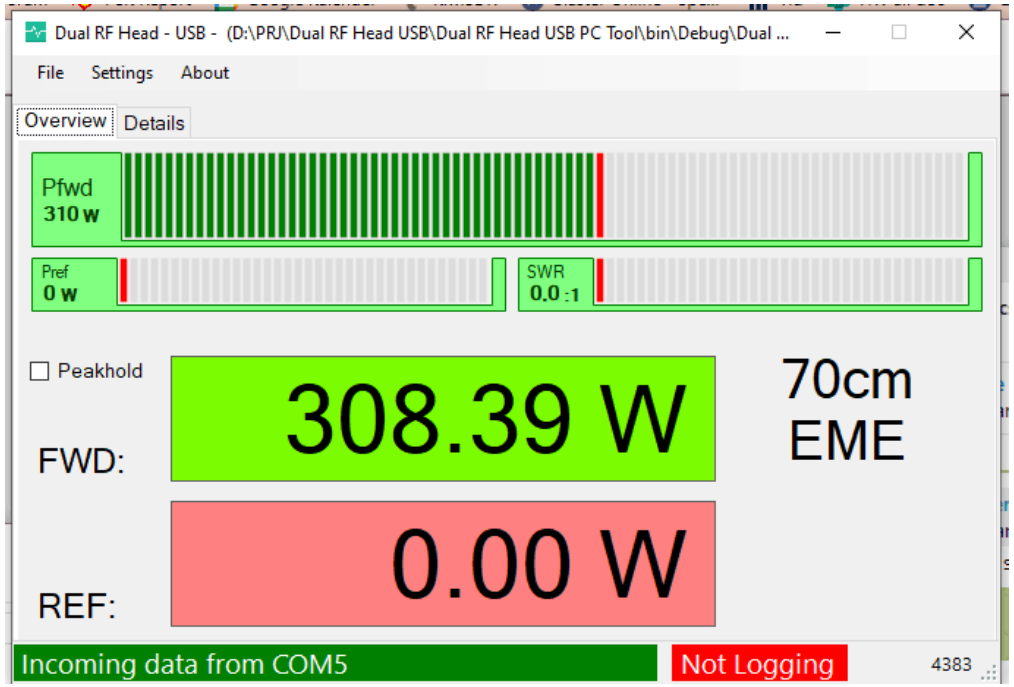
- Dual RF Head - Analog
  - Measures from 1 MHz to 8 GHz (useable to 10 GHz)
  - >50 dB dynamic range (+/- 1 dB) up to 8 GHz
  - Max input +10 dBm, two channels (A/B – Forward/Reflected)
  - Analog output, -55 mV/dB (~4.4V to ~1V)
  - All files available, make your own
  - Link to project

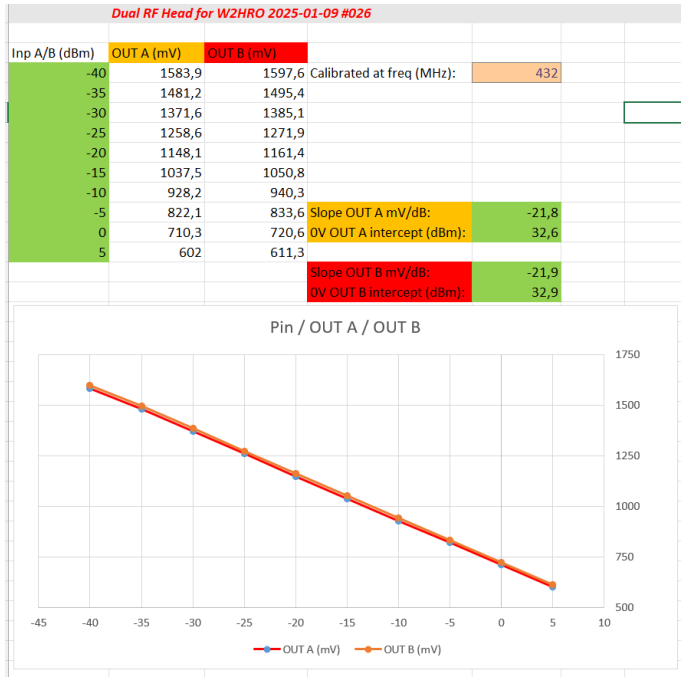
Inp A/B (dBm)	OUT A (mV)	OUT B (mV)		
-40	3803	3763	Calibrated at freq (MHz):	3000
-35	3511	3475		
-30	3215	3186		
-25	2930	2904	*Slope OUT A mV/dB:*	-55,7
-20	2650	2625	*0V OUT A intercept (dBm):*	28,3
-15	2374	2350		
-10	2097	2076	*Slope OUT B mV/dB:*	-55,3
-5	1819	1800	*0V OUT B intercept (dBm):*	28,1
0	1541	1521		
5	1297	1276		



03 “Yak Shaving” – “Do B so you can do C so you can do A..”

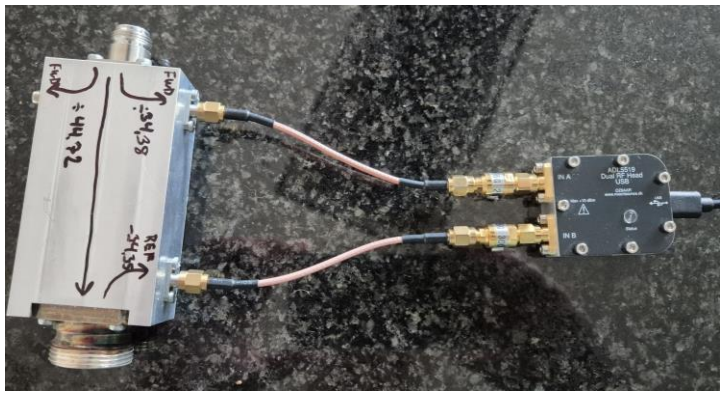
- Dual RF Head - USB
  - Measures from 1 MHz to 8 GHz (useable to 10 GHz)
  - >50 dB dynamic range (+/- 1 dB) up to 8 GHz
  - Max input +10 dBm, two channels (A/B – Forward/Reflected)
  - USB serial (ASCII) output, W, dBm, SWR, peak
  - Source code for PC application freely available
  - All files available, make your own
  - Link to project





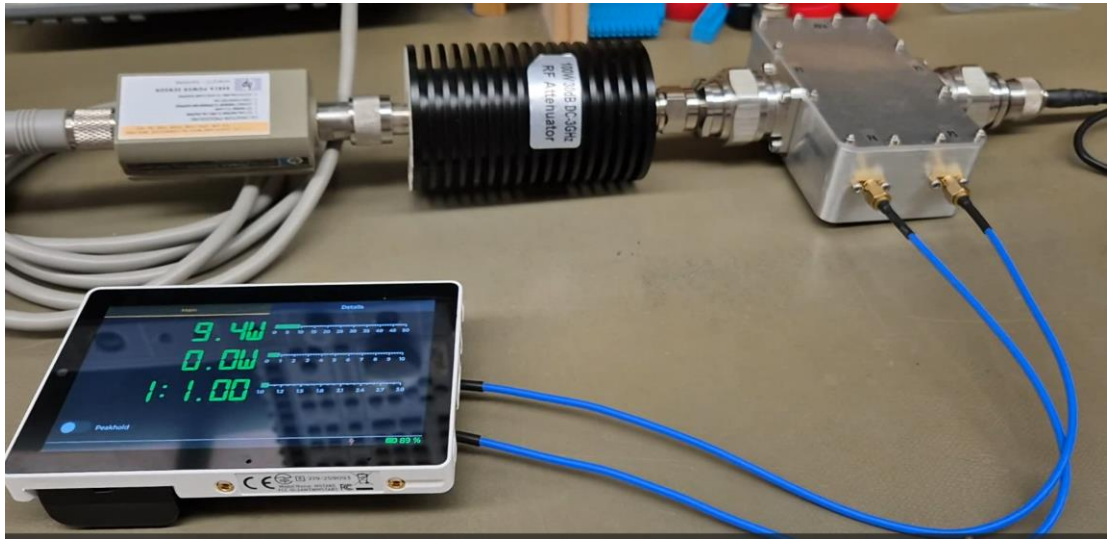
Dual RF Head for W2HRO 2025-01-09 #026

Inp A/B (dBm)	OUT A (mV)	OUT B (mV)		
-40	1583,9	1597,6	Calibrated at freq (MHz):	432
-35	1481,2	1495,4		
-30	1371,6	1385,1		
-25	1258,6	1271,9		
-20	1148,1	1161,4		
-15	1037,5	1050,8		
-10	928,2	940,3		
-5	822,1	833,6	Slope OUT A mV/dB:	-21,8
0	710,3	720,6	0V OUT A intercept (dBm):	32,6
5	602	611,3		
			Slope OUT B mV/dB:	-21,9
			0V OUT B intercept (dBm):	32,9

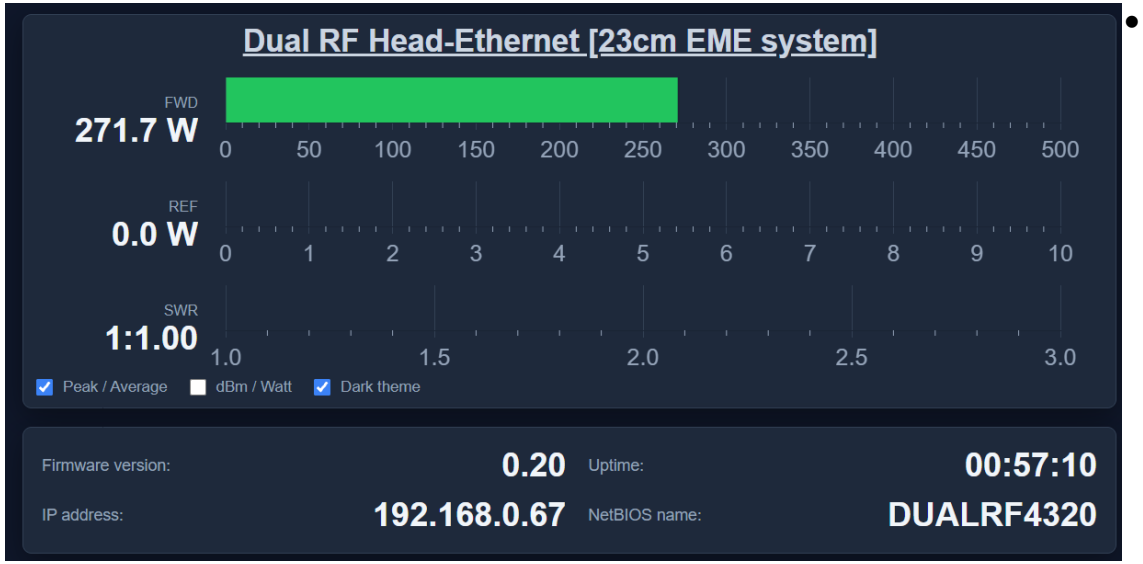


03 “Yak Shaving” – “Do B so you can do C so you can do A..”

- Dual RF Head – M5
  - Standalone power meter / mW meter using a Tab5 or CoreS3
  - Measures from 1 MHz to 8 GHz (useable to at least 10 GHz)
  - >50 dB dynamic range (+/- 1 dB) up to 8 GHz (“0.1W to 4KW”)
  - Max input +10 dBm, two channels (A/B – Forward/Reflected)
  - USB serial (ASCII) output, W, dBm, SWR, peak (same as Dual RF Head – USB)
  - Source code for Tab5/CoreS3 applications freely available
  - All files available, make your own
  - Link to project



03 “Yak Shaving” – “Do B so you can do C so you can do A..”

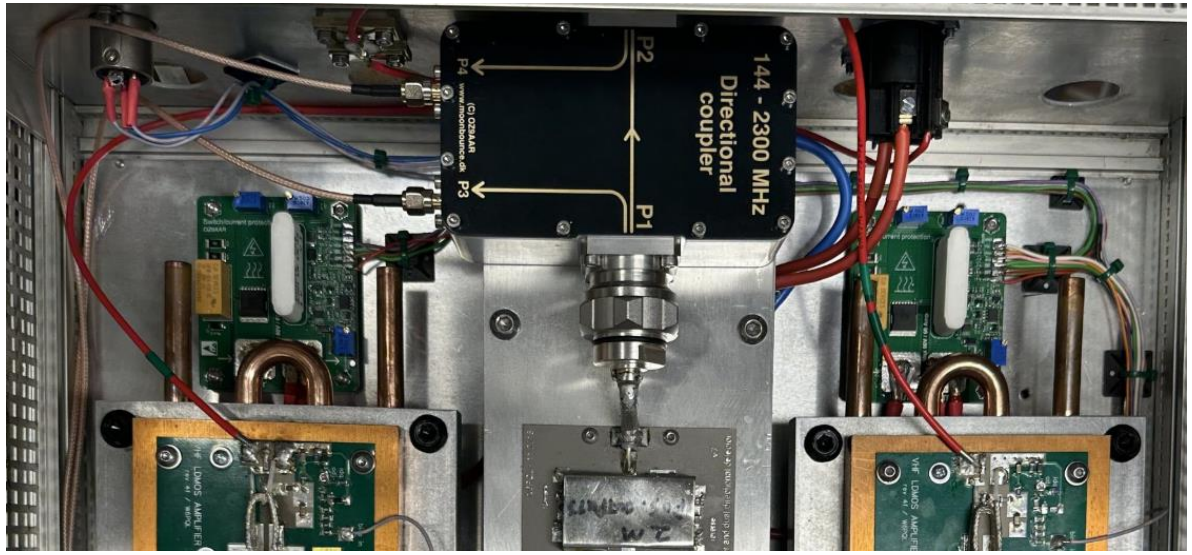


- Dual RF Head – Ethernet
  - Network (LAN) connected power meter / mW meter
  - Measures from 1 MHz to 8 GHz (useable to 10 GHz)
  - >50 dB dyn. range (+/- 1 dB) to 8 GHz (“0.1W to 4KW”)
  - Max input +10 dBm, two channels (A/B – FWD/REF)
  - TCP/IP socket (ASCII) output, W, dBm, SWR, peak
  - **Built-in webserver, view data from a browser!**
  - 10/100 Mbps, DHCP or static IP address
  - Source code for PC application freely available
  - Link to product

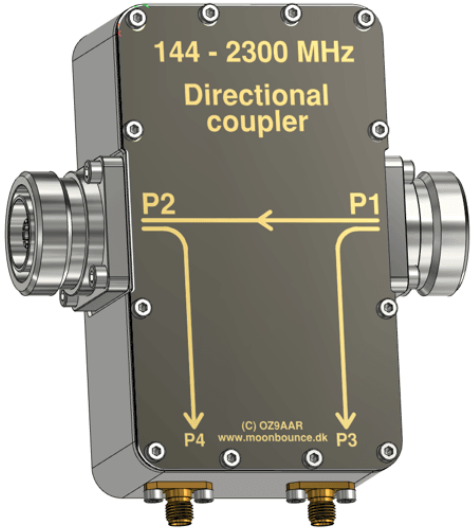
03 “Yak Shaving” – “Do B so you can do C so you can do A..”

- High power directional coupler for 144-2300 MHz
  - Based on excellent notes from Paul W1GHZ
  - Using DIN 7/16 female connectors on in- and output
  - Handles easily 2+ KW on most bands
  - RL “–50”/”-44”/-34/-23 dB on 2/70/23/13
  - Coupling -61/-52/-42/-37 dB on 2/70/23/13
  - Directivity 24/25/30/21 dB on 2/70/23/13
  - Link to product

OE3NFC VHF amplifier



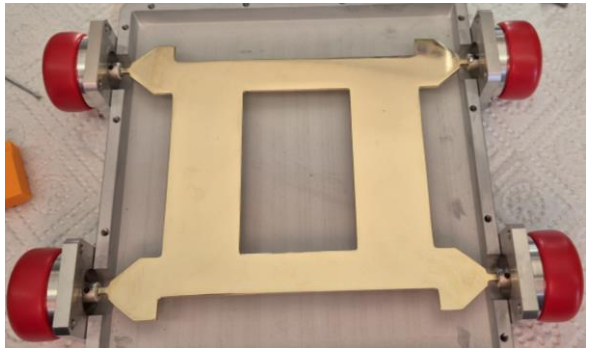
Results for directional coupler #024 2026-01-08



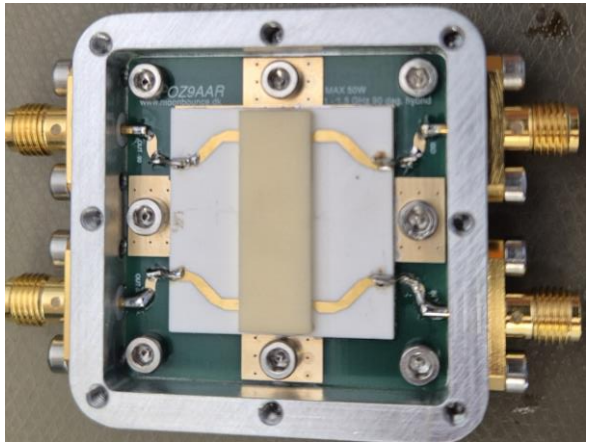
Return loss (dB)	144 MHz	432 MHz	1296 MHz	2300 MHz
P1	-50,8	-44	-34,8	-23,3
P2	-49,8	-45,7	-37,7	-23,1
P3	-37,3	-29,1	-24,2	-31
P4	-36,1	-28,1	-26,5	-29,3
Coupling (dB)				
P31	-61,3	-51,9	-42,4	-37,7
P42	-61,3	-51,9	-42,4	-37,6
Isolation (dB)				
P41	-85,5	-77,5	-73,4	-59,1
P32	-85,3	-76,8	-72,2	-59,8
Directivity (dB)				
P31-P41 (FWD)	24,2	25,6	31	21,4
P42-P32 (REF)	24	24,9	29,8	22,2
Loss (dB)				
P21	<= 0.01	<= 0.01	<= 0.03	<= 0.07

03 “Yak Shaving” – “Do B so you can do C so you can do A..”

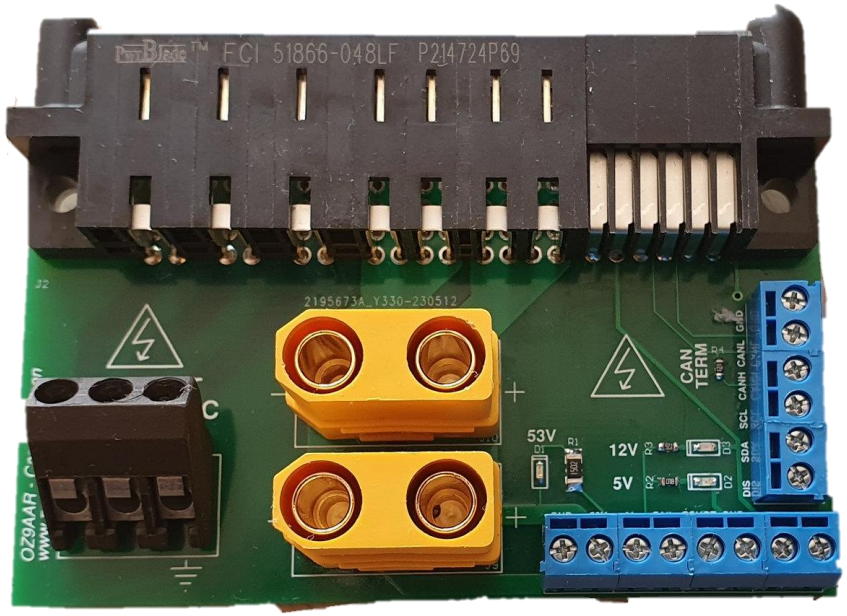
- High power 90° hybrid for 23cm
  - Based on a design from Rainer Bertelsmeier DJ9BV (SK)
  - DIN 7/16 female connectors on all ports
  - Handles 1.5+ KW
  - Return loss > 22/24 dB on all ports
  - Phase error < 1.5°
  - (also have a QRO version for 70cm)
  - All files available, make your own
  - Link to project



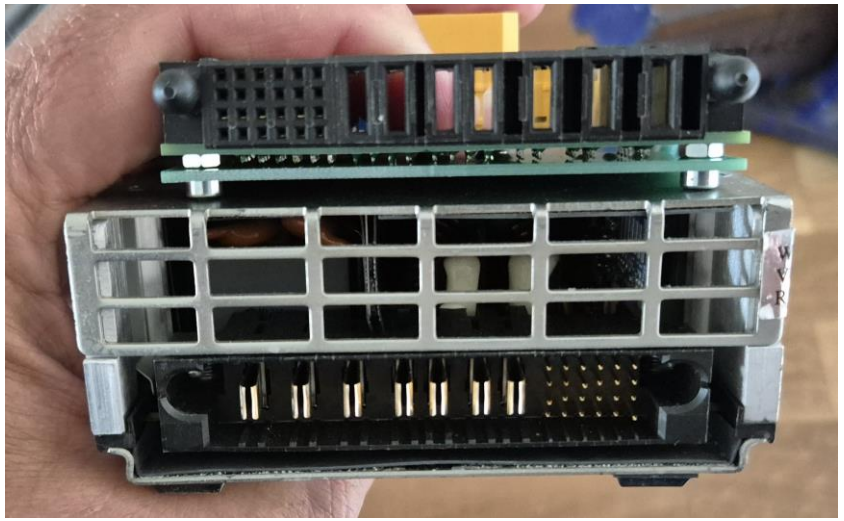
- Low power 90° hybrid for 23cm
  - SMA female connectors on all ports
  - Handles max 50W
  - Return loss > 21 dB on all ports
  - Phase error < 1.5°
  - (Also available for 2m and 70cm)
  - All files available, make your own
  - Link to project

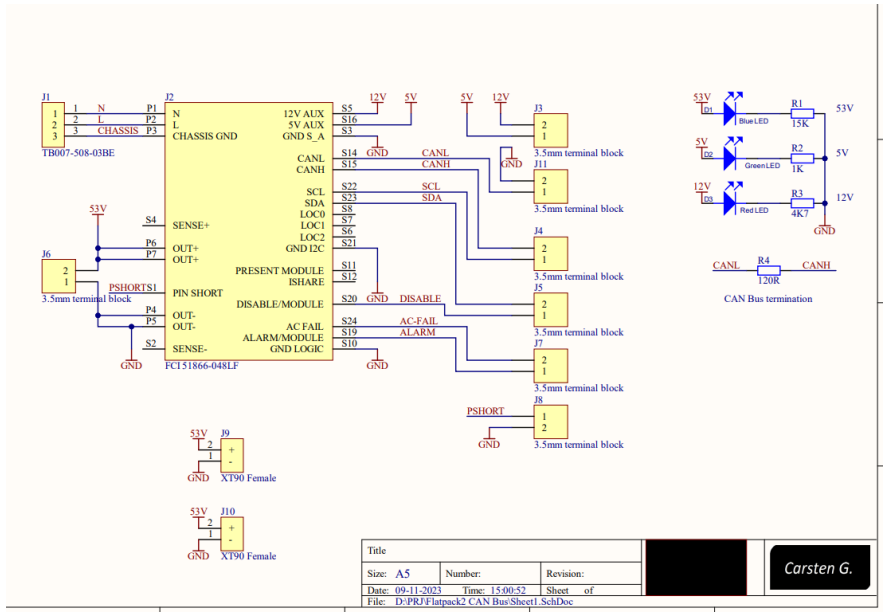


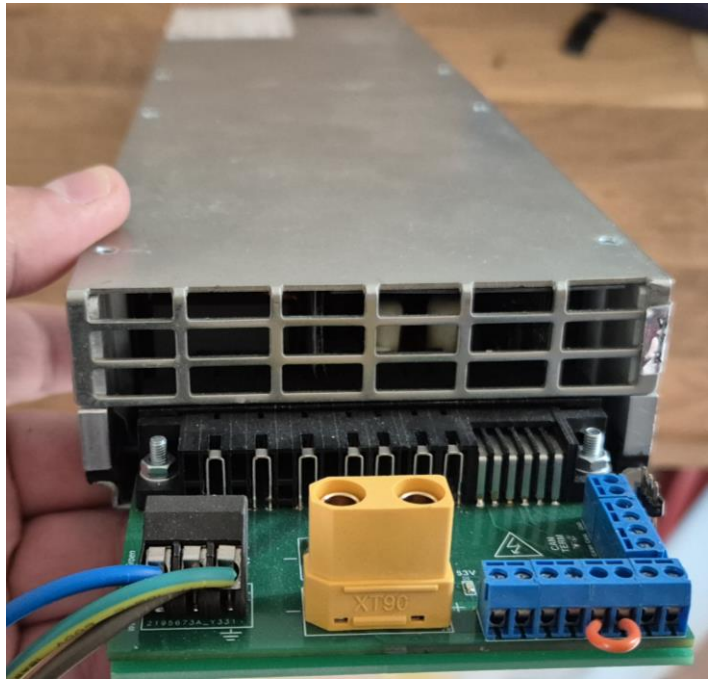
03 “Yak Shaving” – “Do B so you can do C so you can do A..”



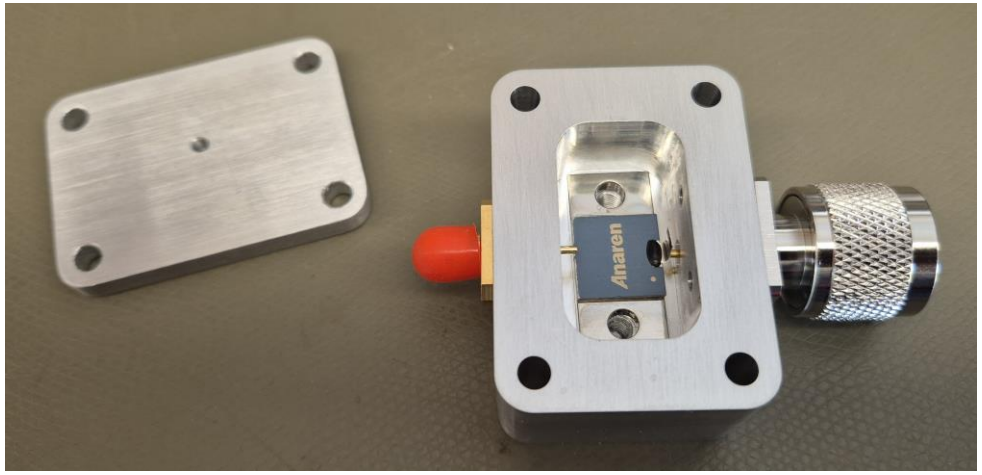
- Flatpack2 HE 3KW PSU interface board
  - Dual XT90 connectors for high voltage output (50V)
  - 5V and 12V brought out
  - CAN bus connection (connects to REPAM for config/monitor)
  - Alarm output
  - I2C bus
  - Disable input
  - All files available, make your own
  - [Link to project]



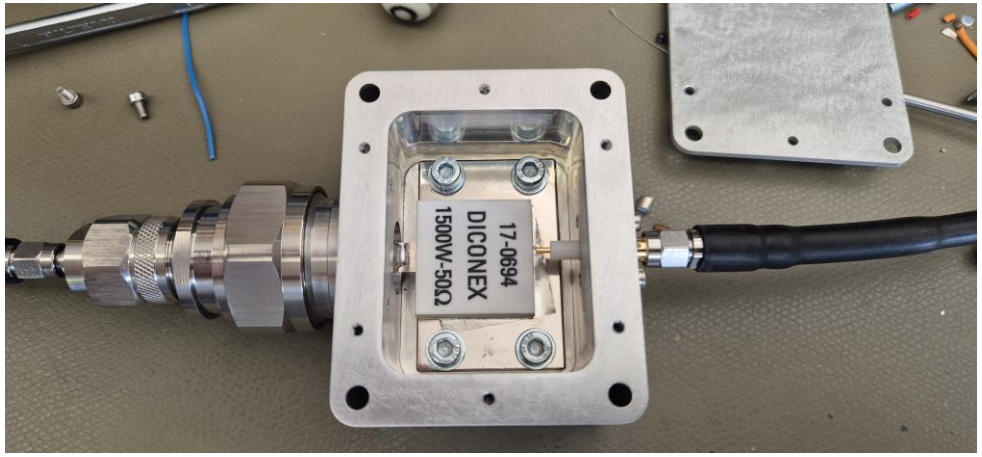




03 “Yak Shaving” – “Do B so you can do C so you can do A..”

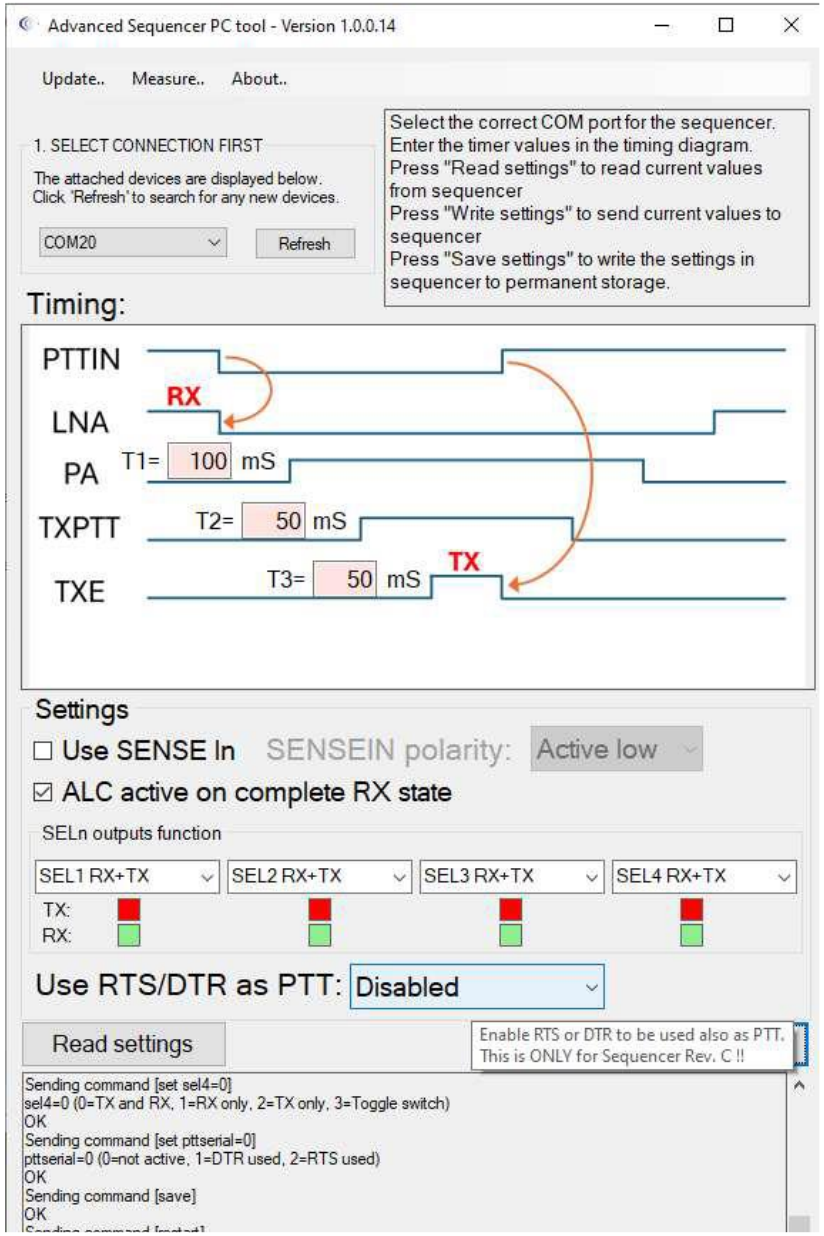


- 400W attenuator (mounts to suitable heatsink)
  - Using N male connector on input
  - RL -39/-21/-18/-14 dB on 2/70/23/13
  - Coupling -47/-38/-33/-55 dB on 2/70/23/13
  - All files available, make your own
  - Link to project



- 1500W attenuator (mounts to suitable heatsink)
  - Using DIN 7/16 female connector on input
  - RL -26/-26/-18 dB on 70/23/13
  - Coupling -59/-57/-51 dB on 70/23/13
  - All files available, make your own
  - Link to project

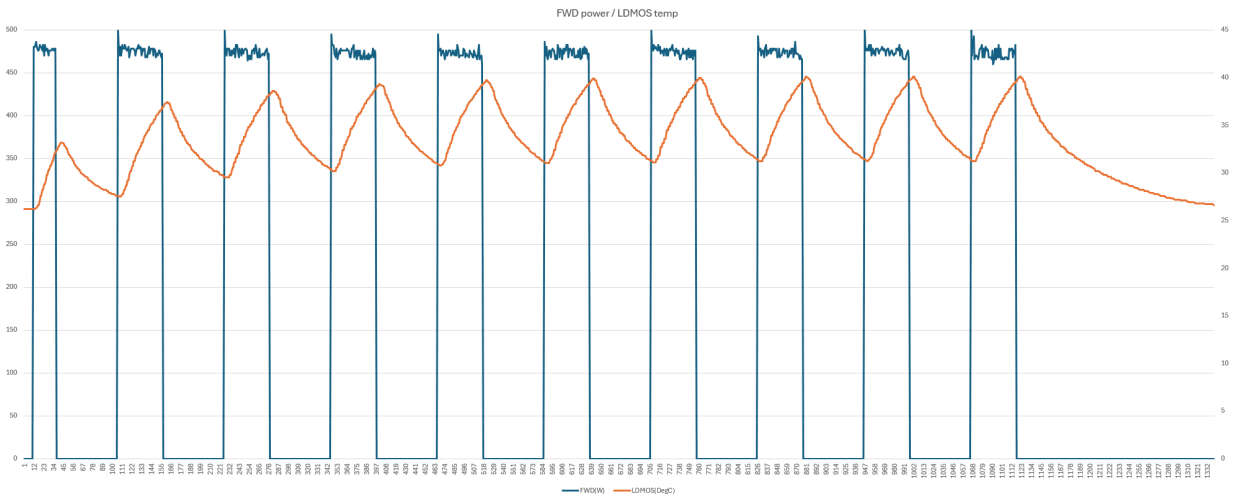
03 “Yak Shaving” – “Do B so you can do C so you can do A..”

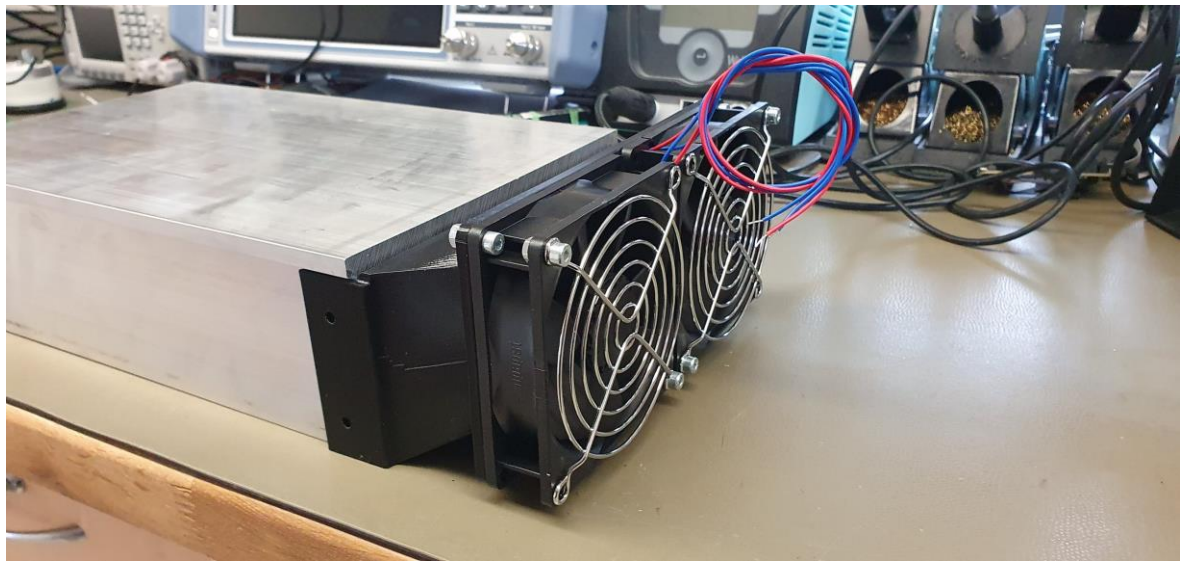


- Programmable sequencer
  - 4 relay outputs, three programmable timers
  - Internal ALC generator (-4V, adjustable)
  - 4 relays, toggle switches or polarization outputs
  - PTT input, Sense input, daisy chain
  - PTT using RTS/DTR from USB-C serial port
  - Can measure relay activation timing
  - Configured using PC application / simple serial terminal
  - Can be controlled using USB-C connector, serial port
  - Available from [Antennas-Amplifiers]

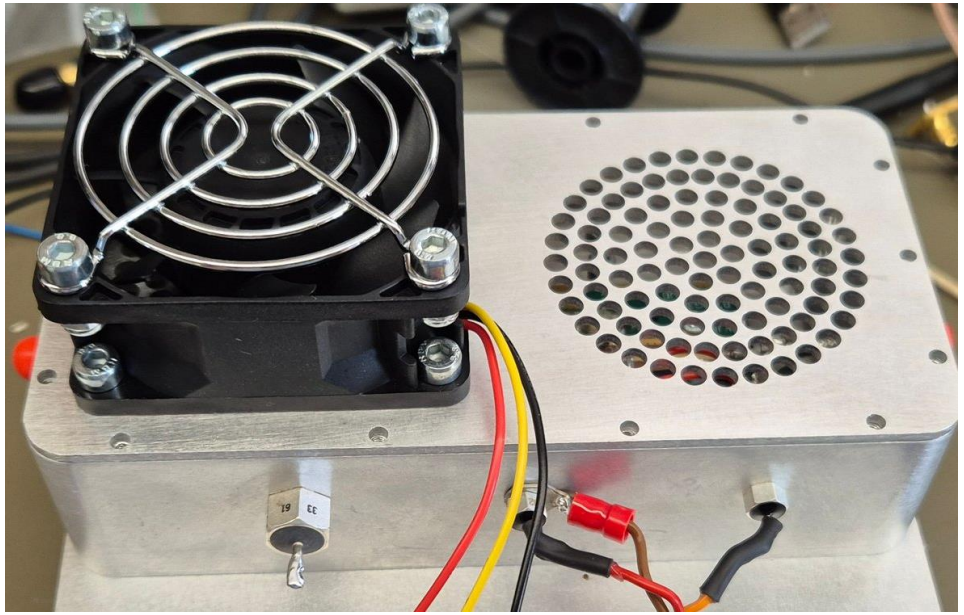
03 “Yak Shaving” – “Do B so you can do C so you can do A..”

- Heatsink and ducting for fans
  - Uses two 12V fans (92 x 92 x 25mm, Pabst 3412NG)
  - Heatsink is 0.05 K/W at 30 m^3/h (500 LFM)
  - 500W dissipation => 25° temperature rise above ambient
  - Used in my 70cm 500W, 70cm 1KW and 23cm PA
  - All files available, make your own
  - Link to project

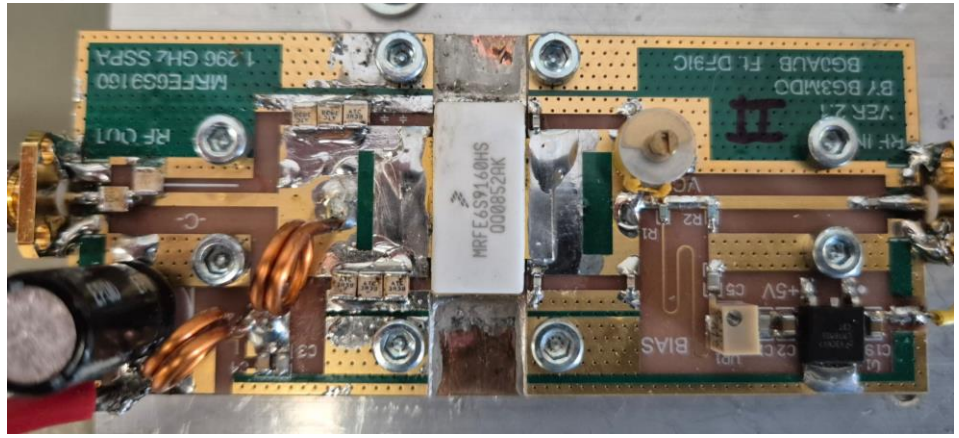




03 “Yak Shaving” – “Do B so you can do C so you can do A..”

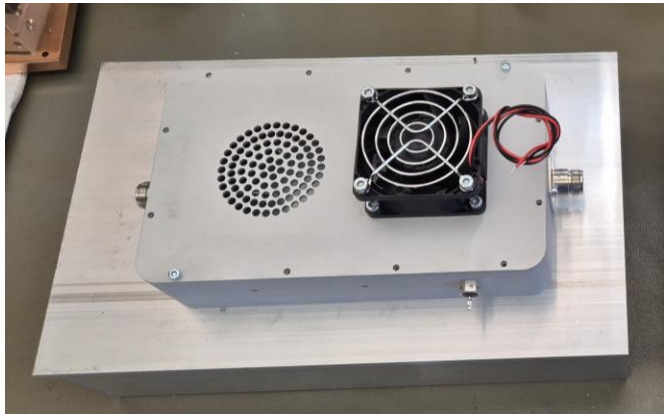


- 150W+ 23cm PA module (used as low power driver in 23cm PA)
  - Used at 14V supply voltage as driver
  - Uses cheap LDMOS (€19 at UTSOURCE) CAREFUL with eBay!
  - Designed copper heat spreader and CNC alu box
  - All files available, make your own
  - Link to project

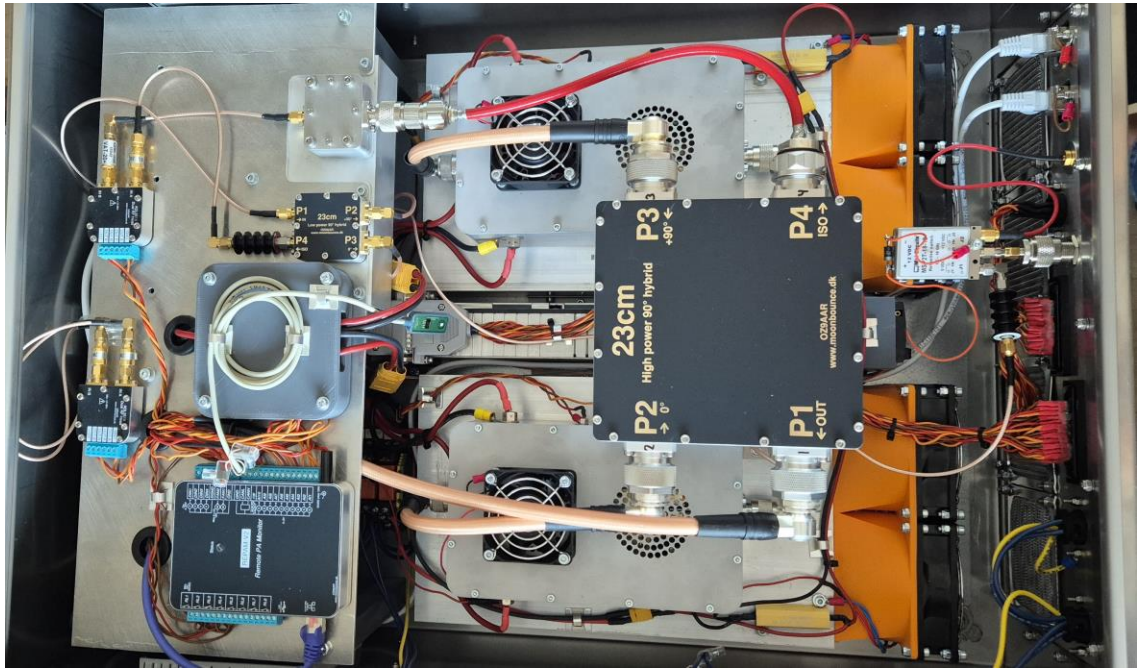


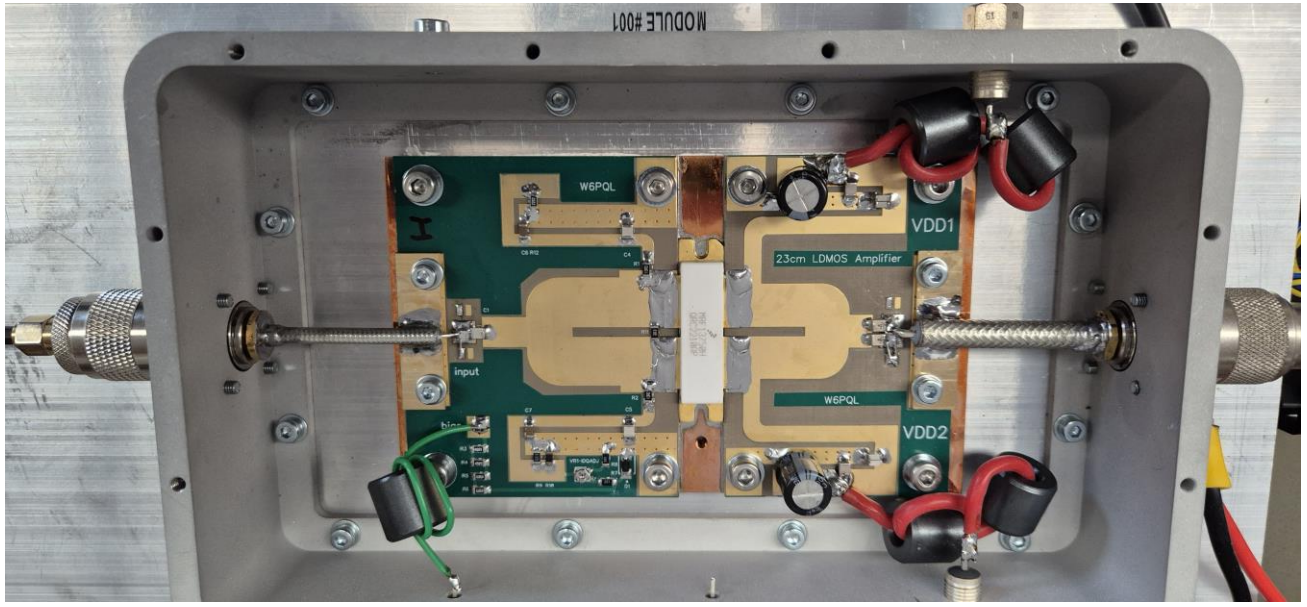
IC-9700 pwr setting %	Pin at 1M RG316 dBm	Pin W (inkl extra B16RG316 0 dB)	Measured mW/attn W	Pout W (inkl RG142 0 dB)	Idd mA @ 28 V		Eff %	Gain dB	P dissipation W
0	17,63	0,06	7,10	7,1	2,47		10,3	20,9	62,1
5	24,62	0,29	27,10	27,1	4,44		21,8	19,7	97,2
6	25,74	0,37	35,80	35,8	5		25,6	19,8	104,2
7	26,54	0,45	42,70	42,7	5,47		27,9	19,8	110,5
8	27,44	0,55	50,40	50,4	6,03		29,9	19,6	118,4
9	28,1	0,65	58,40	58,4	6,48		32,2	19,6	123,0
10	28,99	0,79	71,20	71,2	7,12		35,7	19,5	128,2
15	30,31	1,07	95,00	95,0	8,18		41,5	19,5	134,0
20	31,33	1,36	117,40	117,4	9,05		46,3	19,4	136,0
25	32,32	1,71	140,30	140,3	9,86		50,8	19,2	135,8
30	33,21	2,09	156,10	156,1	10,45		53,3	18,7	136,5
35	34,02	2,52	166,00	166,0	10,86		54,6	18,2	138,1
40	34,68	2,94	171,40	171,4	11,13		55,0	17,7	140,2
50	36,05	4,03	179,80	179,8	11,7		54,9	16,5	147,8

03 “Yak Shaving” – “Do B so you can do C so you can do A..”



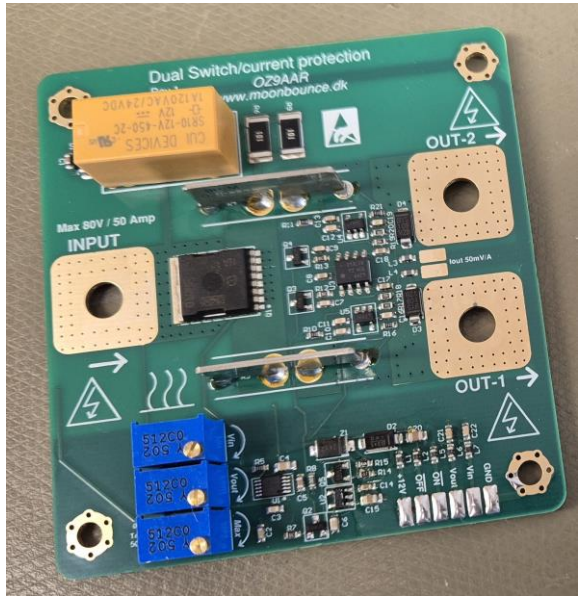
- Enclosing box for W6PQL 23cm PA
  - CNC milled aluminum (and CU heat-spreader)
  - N female on in- and output
  - Two Feedthrough capacitors for power
  - Feedthrough cap. for bias
  - Feedthrough cap. 1wire temperature sensor
  - Integrated fan in cover for output circuit
  - All files available, make your own
  - Link to project (used in my dual PA for EME)



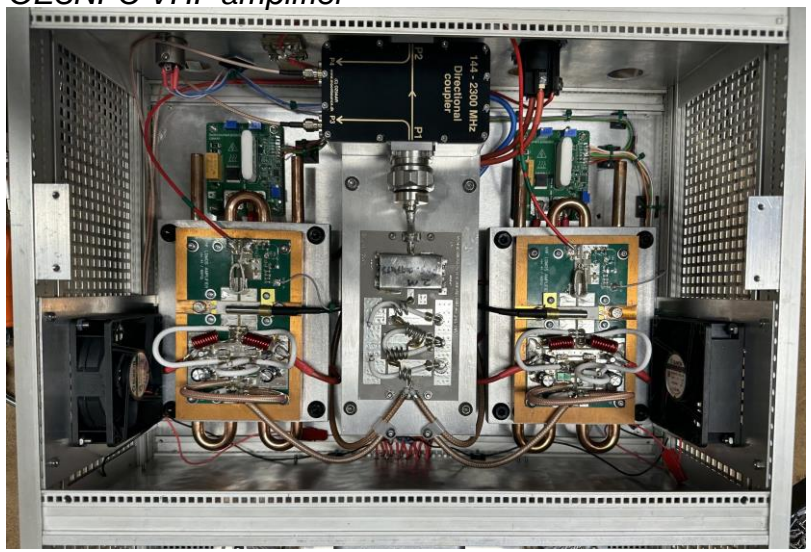


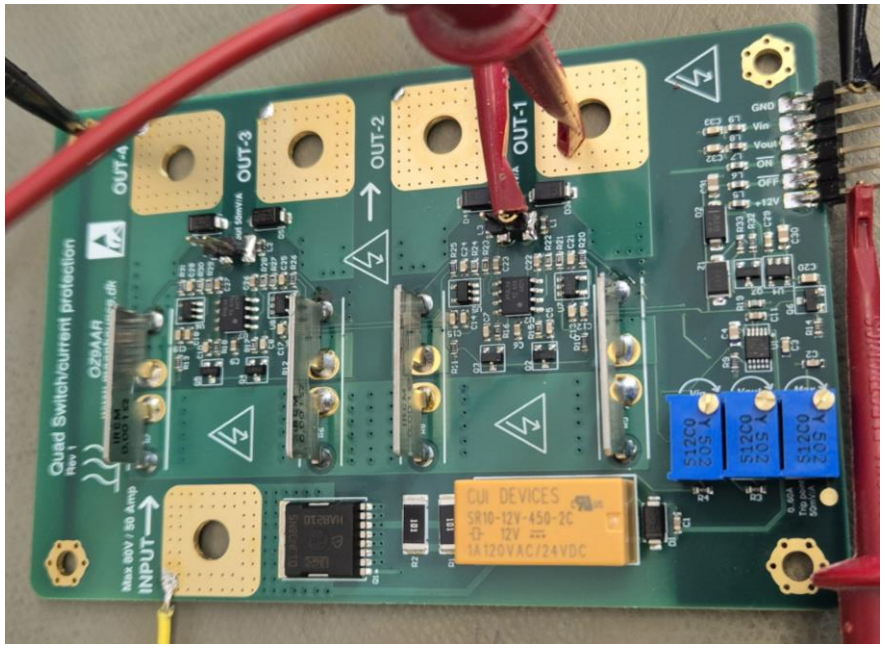
03 “Yak Shaving” – “Do B so you can do C so you can do A..”

- Overcurrent protection, single, dual and quad version
  - Overcurrent protection, adjustable from 0 to 60 Amp
  - On/off switch using two inputs
  - Scales Vin and Vout voltages (ex. 60V => 4V)
  - Current monitor output, 50 mV/Amp (ex. 1V => 20Amp)
  - Reacts in less than 0.5 mS (can be changed with capacitor)
  - Works excellent together with REPAM module
  - Multiple single (and dual/quad) can be connected together
  - All files available, make your own
  - Link to project



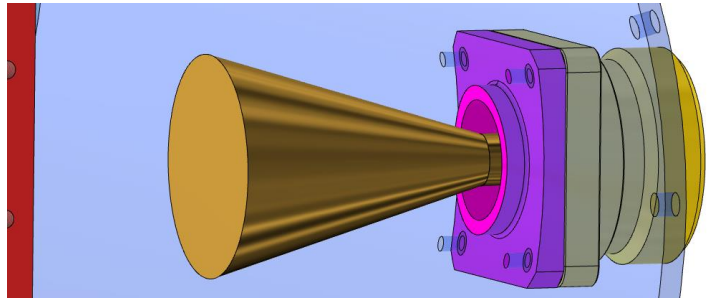
OE3NFC VHF amplifier

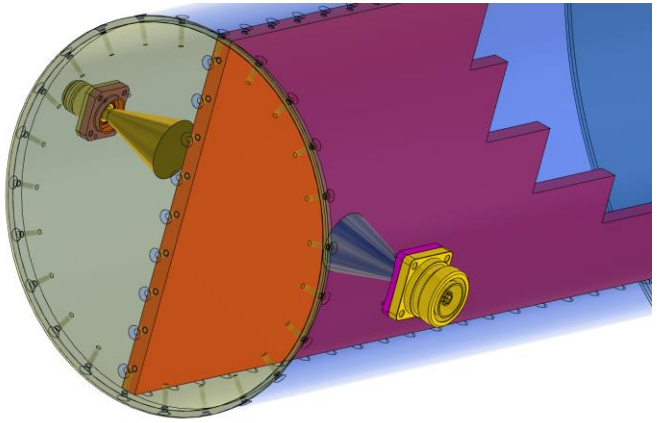


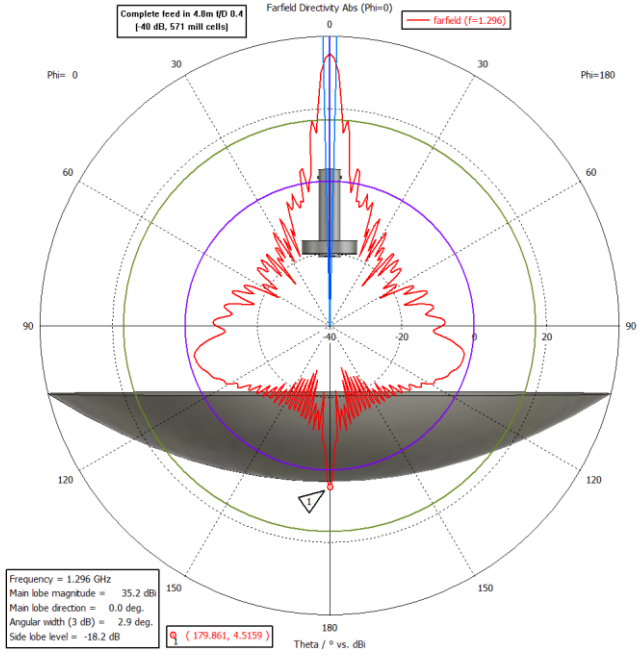


03 “Yak Shaving” – “Do B so you can do C so you can do A..”

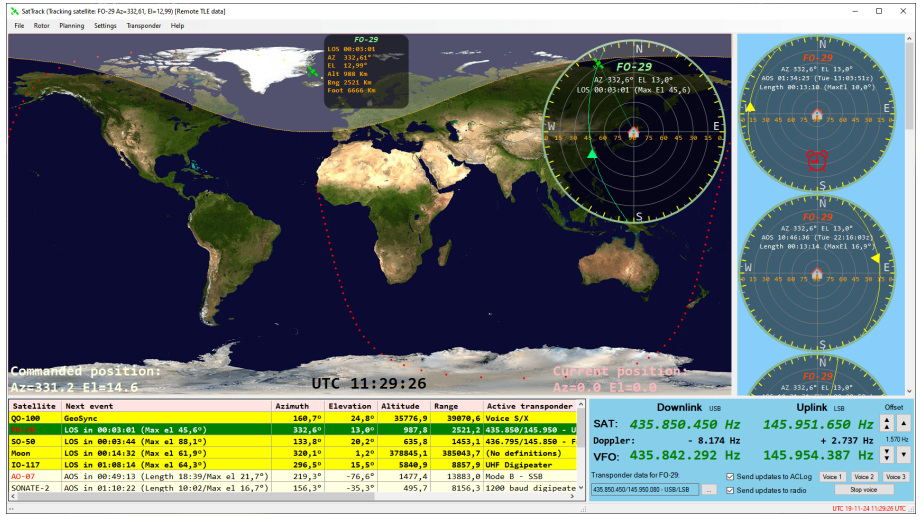
- 23cm feedhorn
  - Based on the original excellent design by Rasto OM6AA
  - All critical parts CNC produced, only need to drill main tube using drill jig
  - Return loss on prototype, TX > -29 dB, TX/RX isolation > 25.8 dB
  - Still experimenting (Chapparal etc.)
  - Files/parts available or make your own
  - Link to project



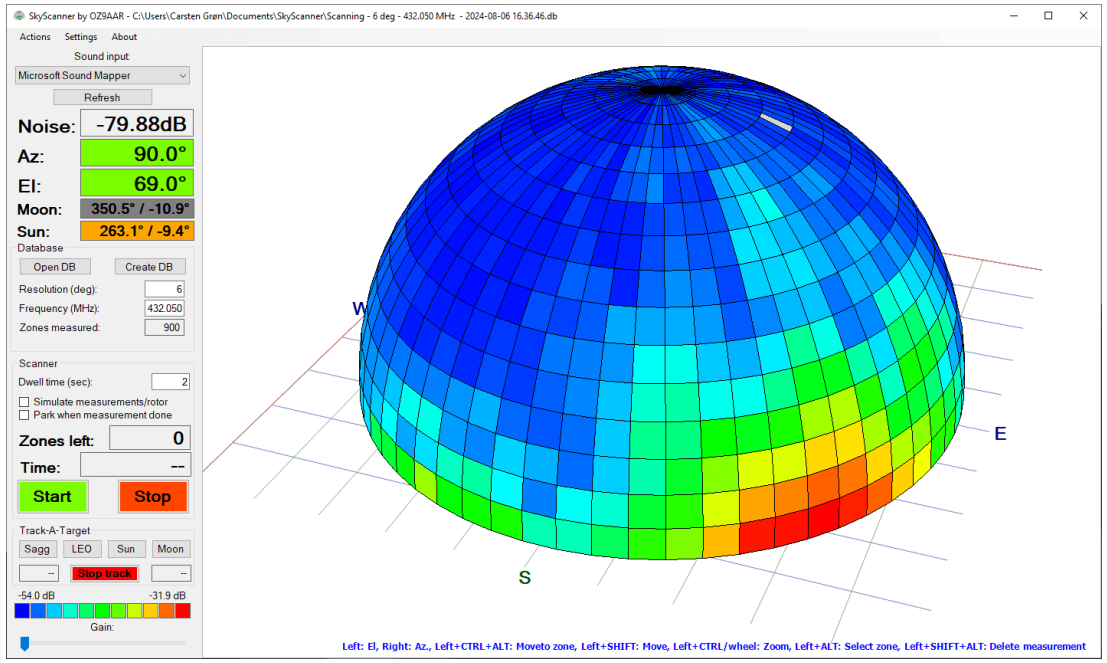


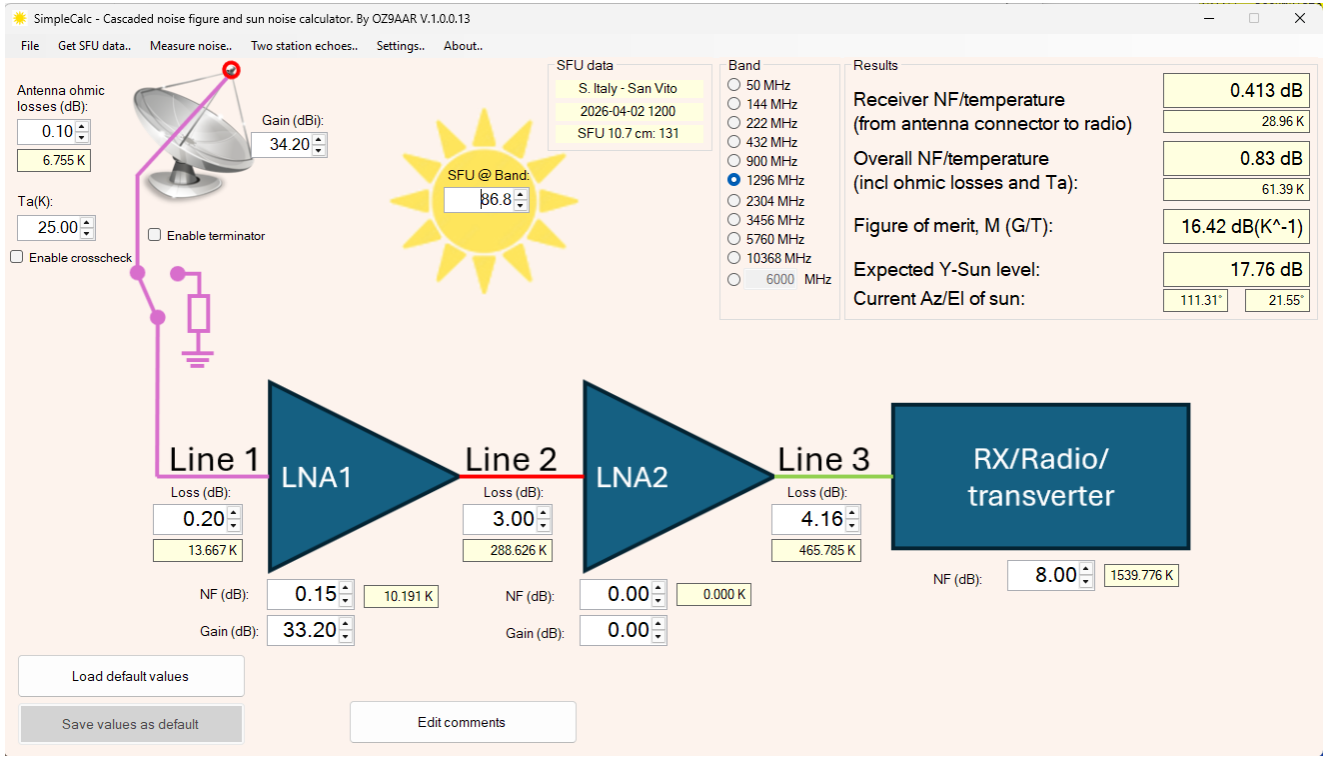


03 “Yak Shaving” – “Do B so you can do C so you can do A..”



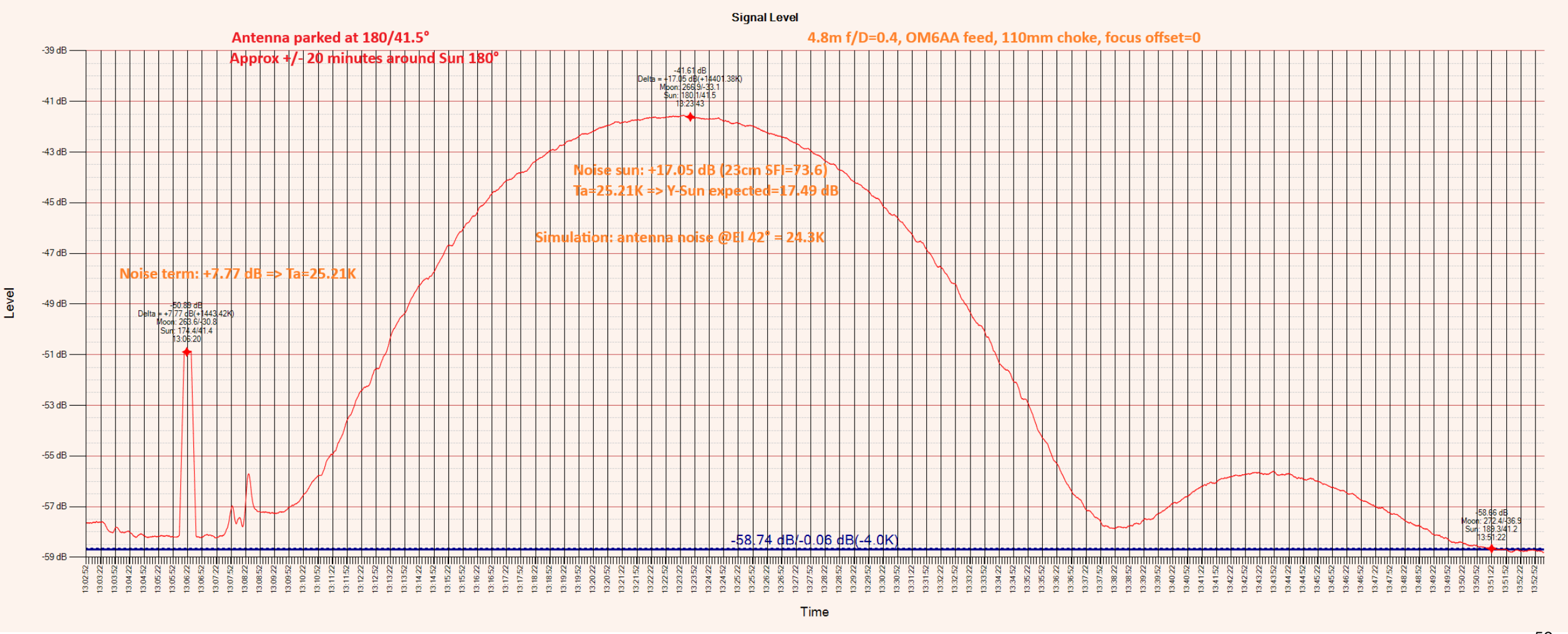
- Various software applications
  - SatTrack – Satellite tracking (rotor and radio control)
  - SimpleCalc – Sun noise/measurement and EME echo prediction
  - SkyScanner – 3D scan for noise sources



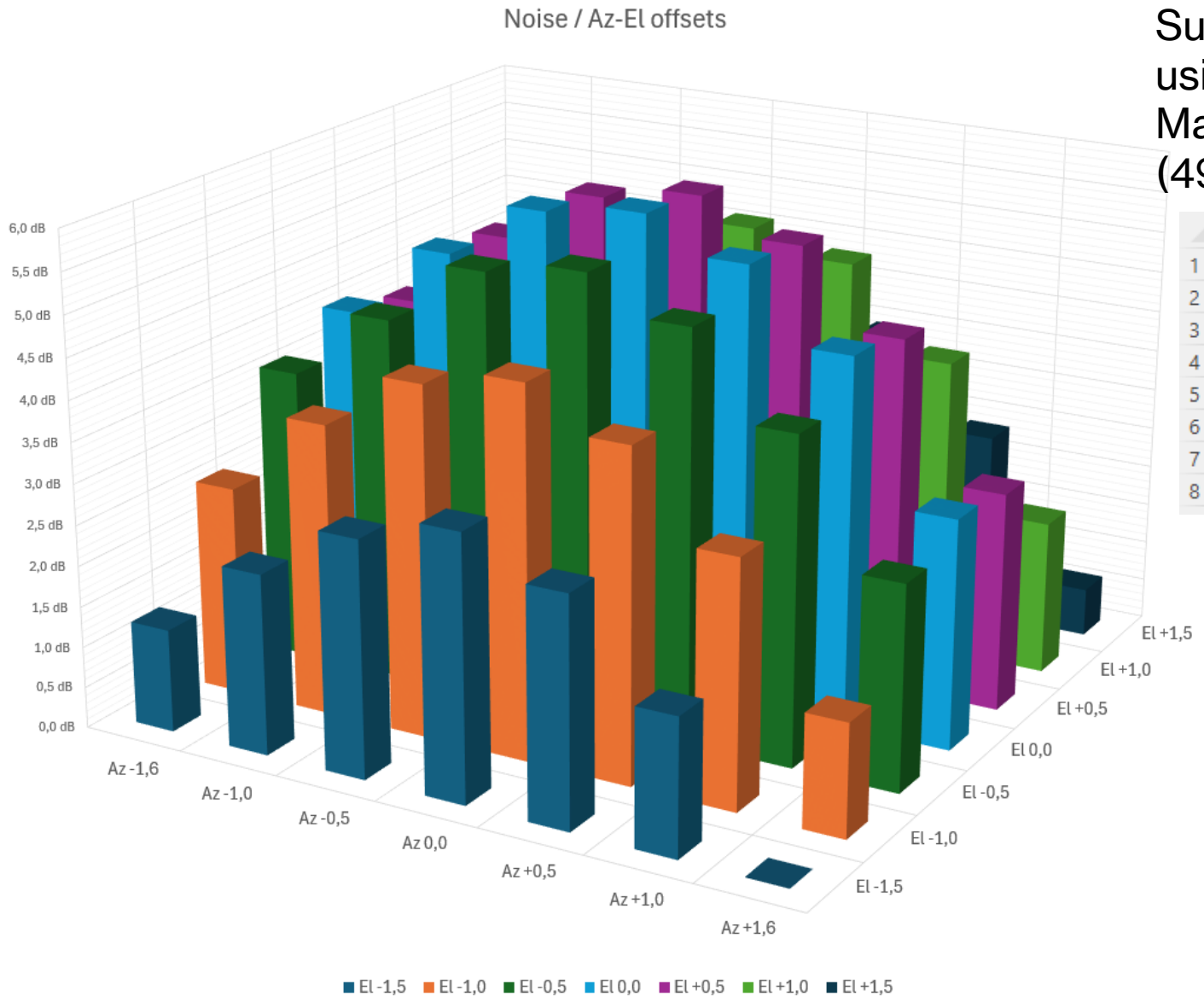


03 “Yak Shaving” – “Do B so you can do C so you can do A..”

First tests of sun noise and terminator noise (before optimization)
Noise window from SimpleCalc application.

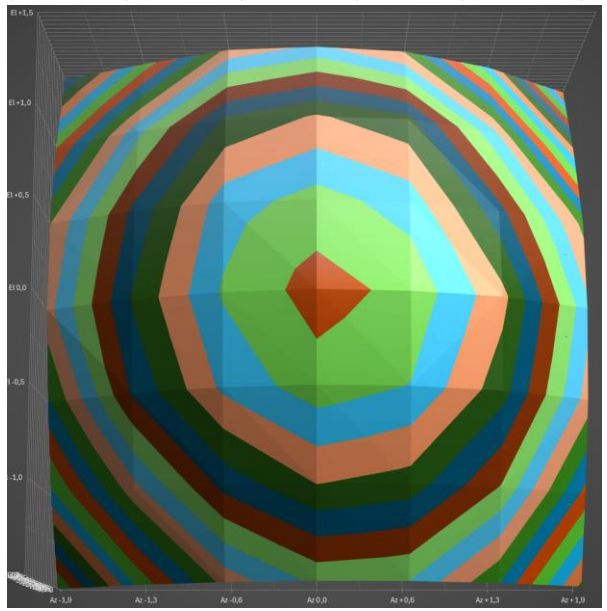


03 “Yak Shaving” – “Do B so you can do C so you can do A..”



Sun sweep (can also do moon sweep using SkyScanner application.
Made a 3° sweep in Az and El with 0.5° steps. (49 measurements taken)

	A	B	C	D	E	F	G	H
1	El offset	El -1,5	El -1,0	El -0,5	El 0,0	El +0,5	El +1,0	El +1,5
2	Az -1,6	1,26	2,56	3,6	4	3,79	3,1	1,74
3	Az -1,0	2,21	3,58	4,47	4,94	4,81	4,04	2,75
4	Az -0,5	2,89	4,29	5,25	5,64	5,5	4,9	3,65
5	Az 0,0	3,23	4,53	5,44	5,8	5,7	4,98	3,85
6	Az +0,5	2,79	4,04	5,01	5,39	5,28	4,72	3,43
7	Az +1,0	1,67	3,01	4	4,52	4,35	3,68	2,34
8	Az +1,6	0	1,38	2,51	2,82	2,69	1,89	0,59

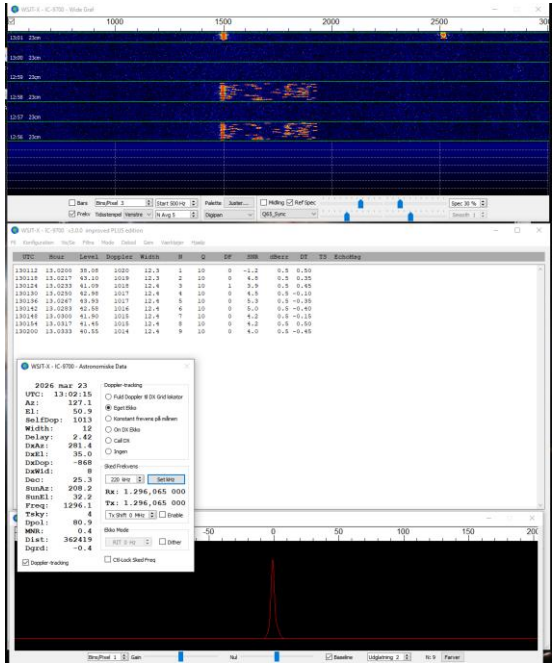


04 First results

Around noon Sunday March 22nd, 2026, I fastened the last screw and cable in the feedhorn at the dish.
40 minutes later, I had my first QSO on 23cm EME, an excellent SSB QSO with Walter ON4BCB.
Walter uses the same feedhorn (OM6AA) as I do, Walter was in the group that made the prototypes “back then”.
The following 5 hours, I worked 57 QSO’s, a couple on CW and the rest on Q65.
6 days later, a total of 110 QSO’s (11 x SSB, 3 x CW and 96 x Q65) were completed (ZL, T7, 9J, CY0 etc.)

Smallest station worked so far, Peter PA2V, 36 ele., 2.9 meter long, 200W at feed, preamp in shack, no elevation.
Sun noise within 0 to -0.3 dB from predicted, own echoes, WSJT, +5.3 dB (predicted +5.3 dB), -14.2 dB with 6..8W at feed.

Good solid SSB echoes.



Peter, PA2V

My own SSB echoes

05 Questions?

Thanks to my lovely wife Henriette for support and encouragement!
Many thanks to my very good friend, Lars Robert Nielsen for brainstorming and practical help
Thanks to Ingebrigt LB6B for brainstorming, review and suggestions.

More information: www.moonbounce.dk

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