

Mikrobølgeteknik

**7-800 km QSOer dagligt på
mikrobølgebåndene**

**Eller sagt på en anden måde:
Hvordan får man
mikrobølgesignaler ud over
horisonten?**

Foredrag 17. januar 2019
hos
OZ3EDR i Struer

Det vil jeg fortælle om

- ◆ Et opgør med myter om mikrobølge
- ◆ Lidt teori om udbredelsesforhold på V-U-SHF
- ◆ 7-800 km QSOer dagligt på mikrobølgebåndene
- ◆ Stationsopbygning
- ◆ Operationsteknik og hjælpemidler
- ◆ Amatørradioens ekstremsport: QSO-er over 750.000 km via månen

Hvad er mikrobølger?

- ◆ Frekvenser over 1.000 MHz = 1 GHz, hvor kondensatorer bliver til spoler
- ◆ Mulige frekvensbånd/bølgelængder:
 - 1296-1298 MHz = 23 cm
 - **2320-2322 MHz = 13 cm - indtil 31.12.2018**
 - 3400-3402 MHz = 9 cm
 - 5760-5762 MHz = 6 cm
 - 10368-10370 MHz = 3 cm
 - 24048-24050 MHz = 1,2 cm
 - +47/76/122/134/241 GHz

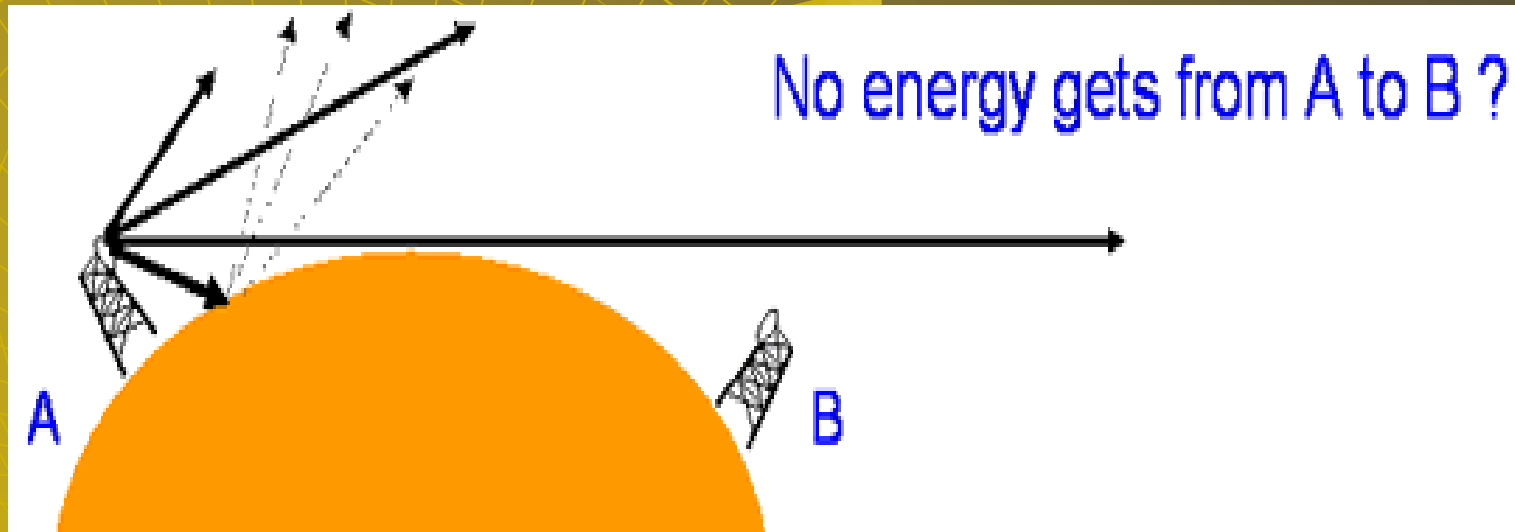
Myter

- ◆ Der kommer kun støj ud af højttaleren på mikrobølgebåndene
- ◆ Der er ingen stationer QRV på disse bånd
- ◆ Kun for selvbyggere
- ◆ Blikkenslagerarbejde

- ◆ Disse myter vil jeg forsøge at aflive!

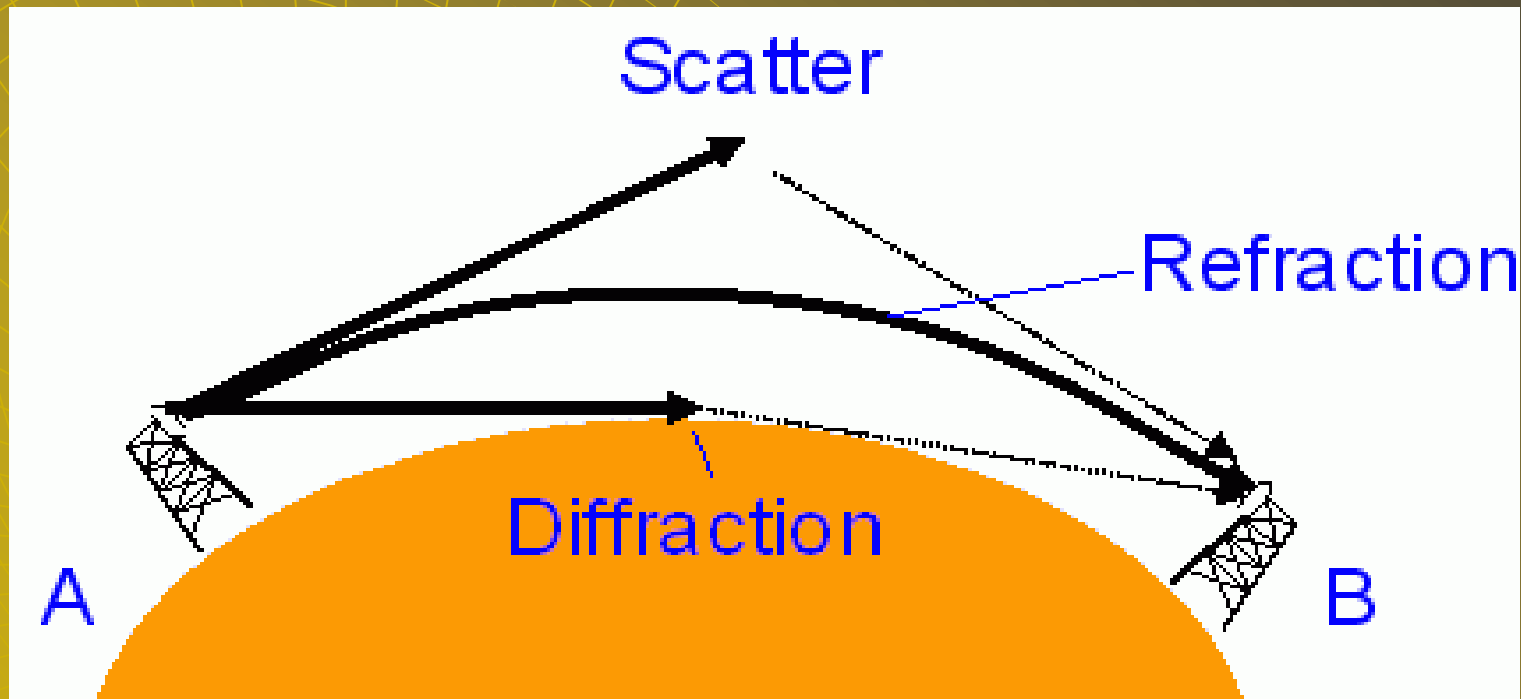
Mikrobølgesignalers udbredelse

- ◆ Mikrobølgesignaler udbredes som lys



- ◆ Men er det nu også helt rigtigt?

Mikrobølgesignalers udbredelse



+ Reflektion

Udbredelsesformer VUSHF

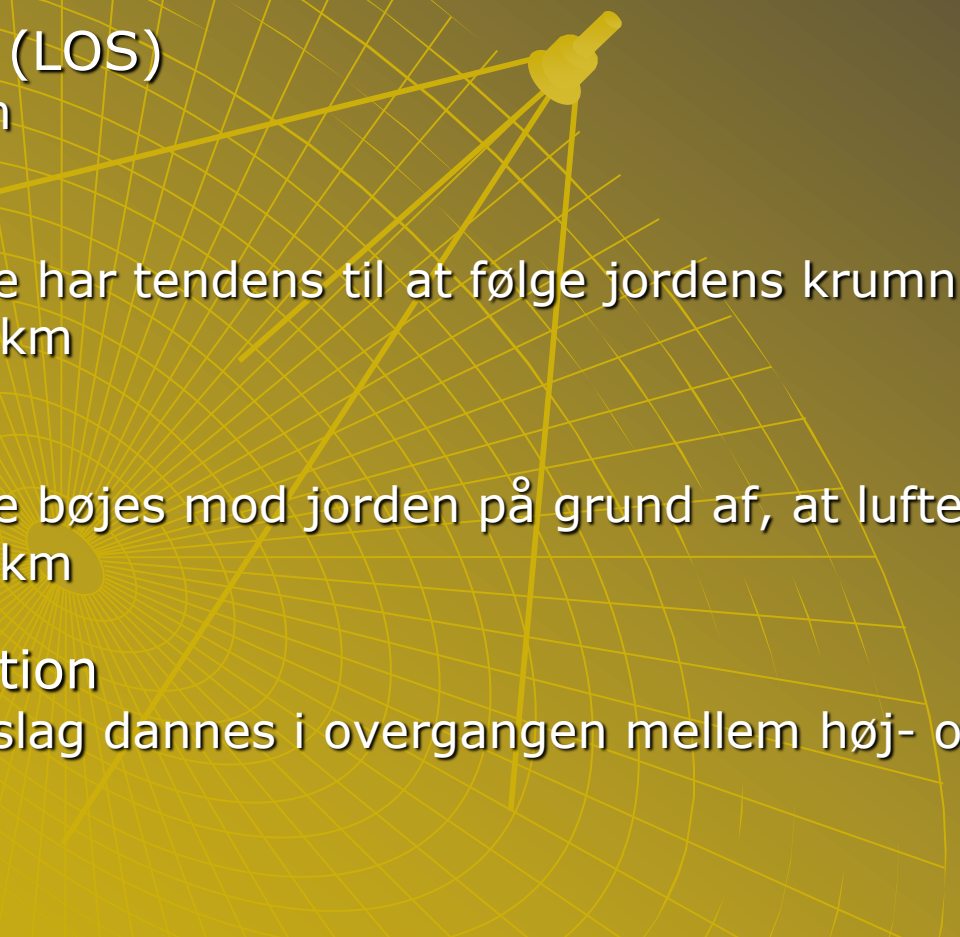
De vigtigste:

Type		2 m	70 cm	23cm	13cm+
Tropo	TR	✓	✓	✓	✓
E-refleksion	ES	✓			
Aurora	AU	✓	✓	✓	
Meteorscatter	MS	✓	✓		
Regnscatter	RS				✓
Flyreflektion	AR	✓	✓	✓	✓
Månereflektion	EME	✓	✓	✓	✓

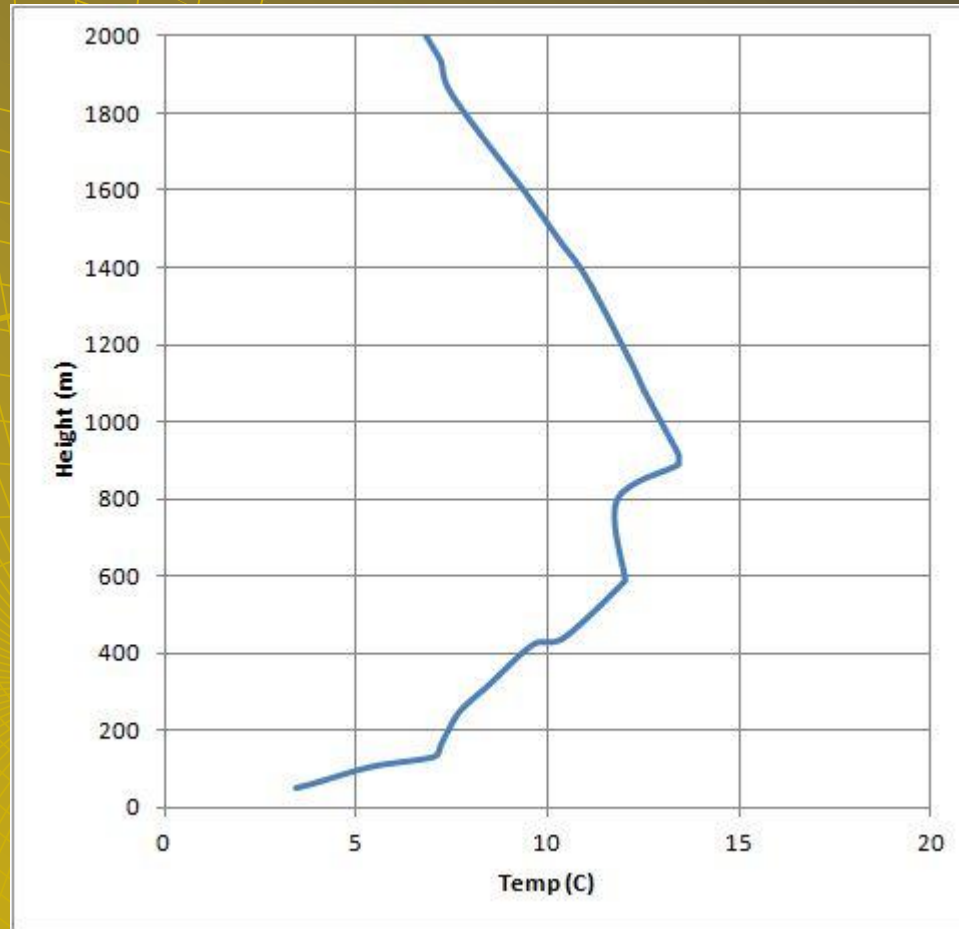
Hvor langt kan man række på de forskellige udbredelsesarter?

- ◆ Troposfærisk udbredelse
 - >2000 km
- ◆ Regnscatter
 - >1000 km - bedste bånd 3/6 cm
- ◆ Flyreflektion
 - 400 - >800 km
- ◆ Månereflektion
 - >19000 km

Troposfærisk udbredelse

- ◆ Udbredelse i jordatmosfærens nederste lag – op til ca. 16 km
 - ◆ Direkte sigt (LOS)
 - 0 – 30 km
 - ◆ Diffraktion
 - Signalerne har tendens til at følge jordens krumning
 - 30 – 100 km
 - ◆ Refraktion
 - Signalerne bøjes mod jorden på grund af, at luften bliver tyndere
 - 30 – 100 km
 - ◆ Superrefraktion
 - Inversionslag dannes i overgangen mellem høj- og lavtryksområder
 - >200 km
- 
- A diagram illustrating tropospheric propagation. It shows a yellow antenna on a tower emitting a signal. The signal path is shown as a yellow line that curves downwards towards the Earth's surface, following the curvature of the planet. The background features a grid of latitude and longitude lines on a globe, with a yellow sun-like symbol at the top center.

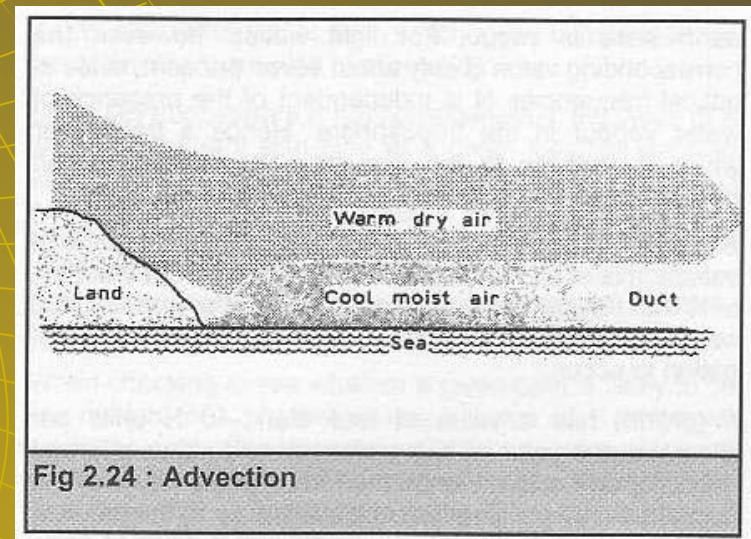
Temperaturinversion



Sydengland 2012-03-14

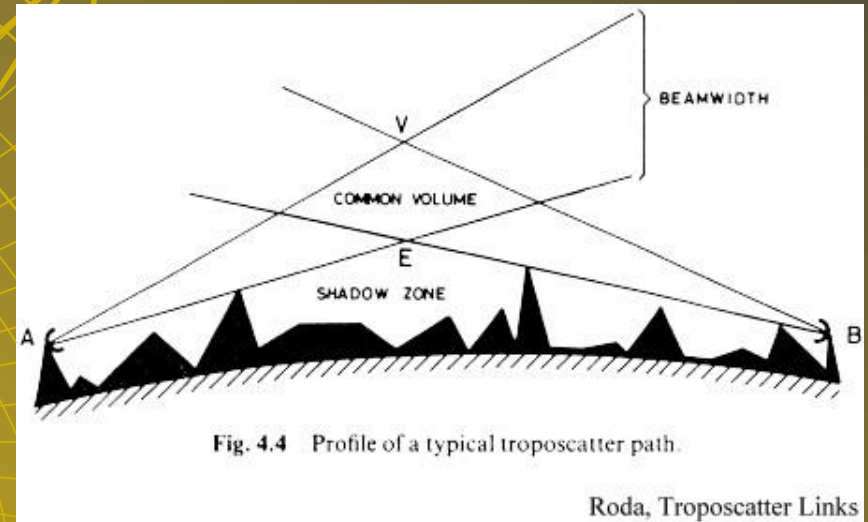
Troposfærisk udbredelse

- ◆ Ducting
 - Kanaler mellem inversionslag og jorden eller mellem inversionslag
 - >1000 km
- ◆ Seaducting
 - Dannes over vand, når varm og tør luft blæser hen over køligere og fugtig luft
 - Optræder typisk i perioden maj - juni
 - Kan kun udnyttes af kystnære stationer
 - Ekstremt kraftige signaler

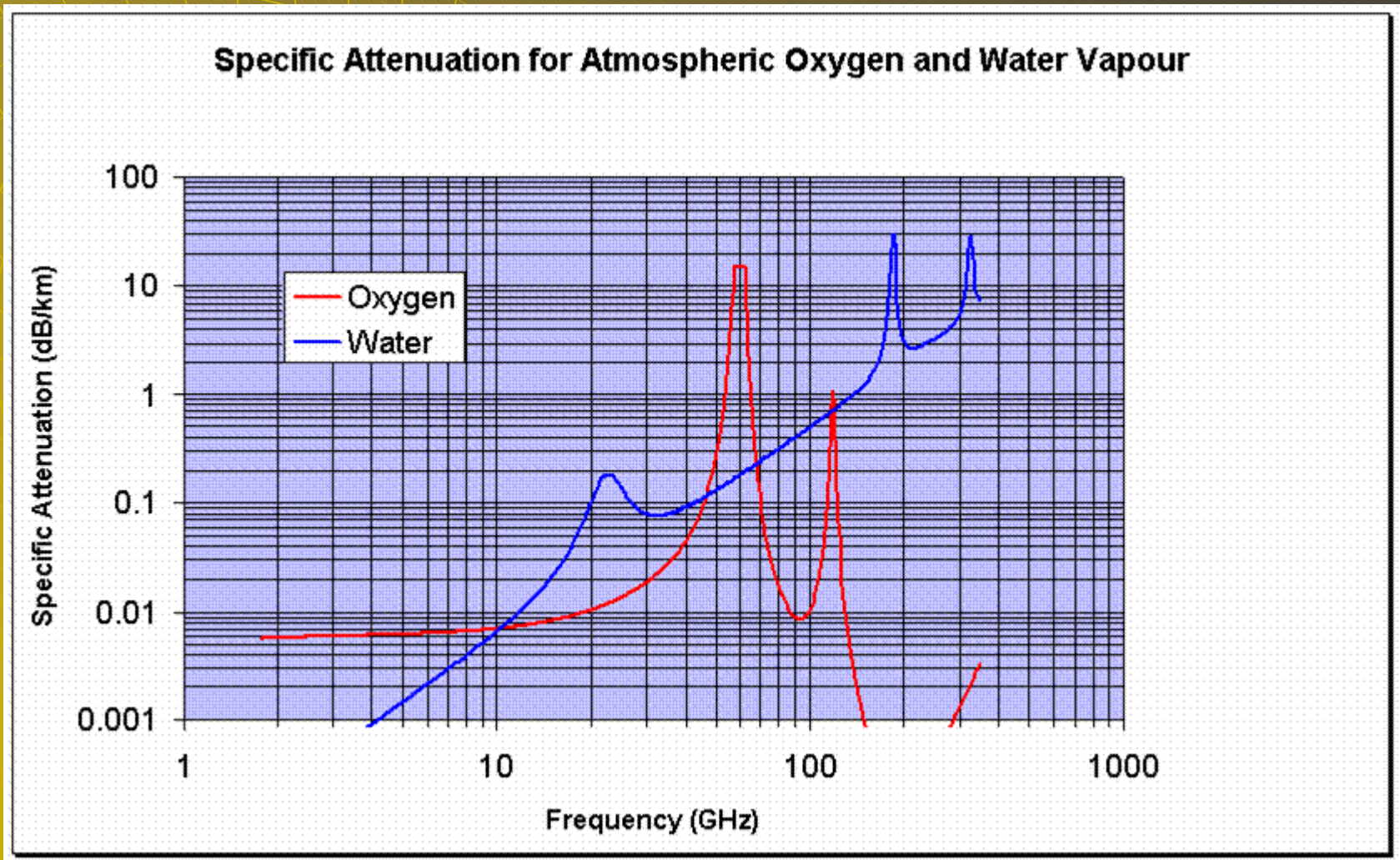


Troposfærisk udbredelse

- ◆ Troposcatter
(scatter=spredning)
 - Forurening i den nederste del af troposfæren
 - 100 – 800 km



Vanddamps og ilt's indflydelse



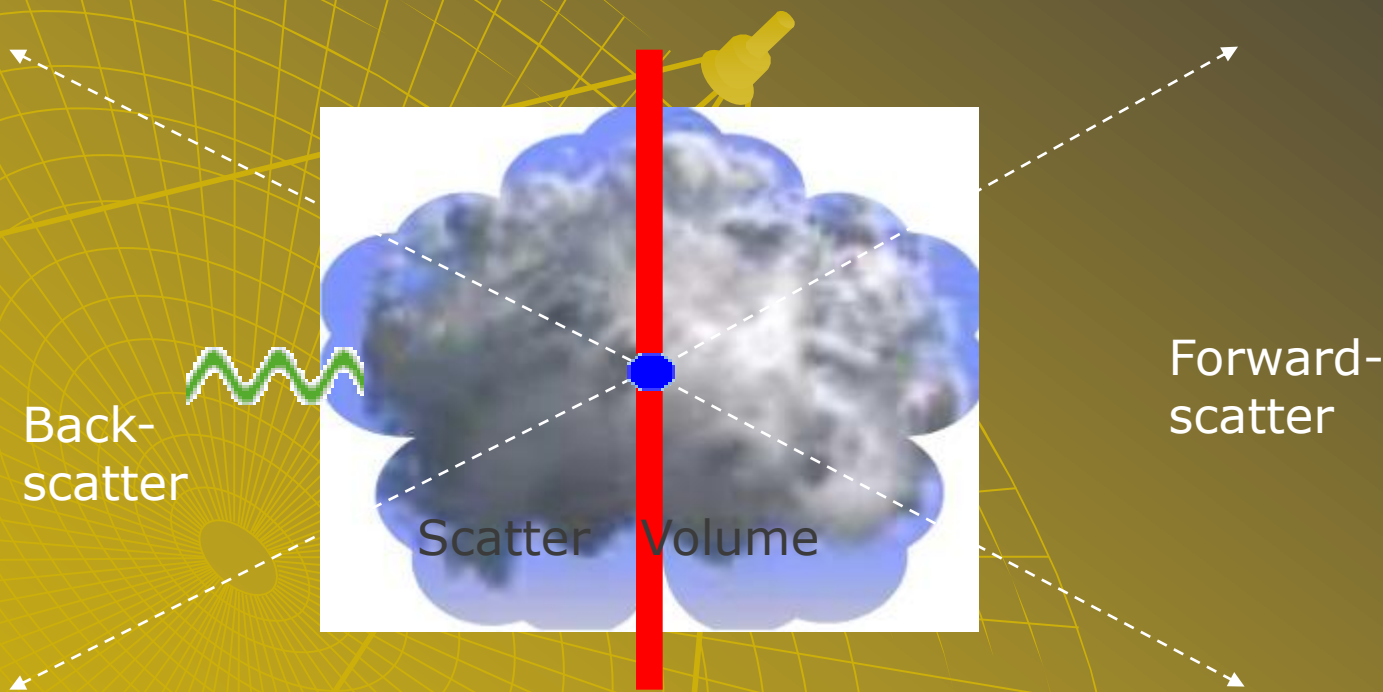
Vanddamps og ilts indflydelse

Band	Total (dB/100km)	Oxygen (dB/100km)	Water (dB/100km)
13cms	0.7	0.7	0.03
9cms	0.8	0.7	0.07
6cms	0.9	0.7	0.2
3cms	1.5	0.8	0.7
24GHz	18	1.4	16.5
47GHz	24	13	11
76GHz	36	9	27

- ◆ 1013 mB
- ◆ 15 °C
- ◆ 7,5 g/m³ vanddamp

Regnscatter

Horizontal polarisation



Back-scatter

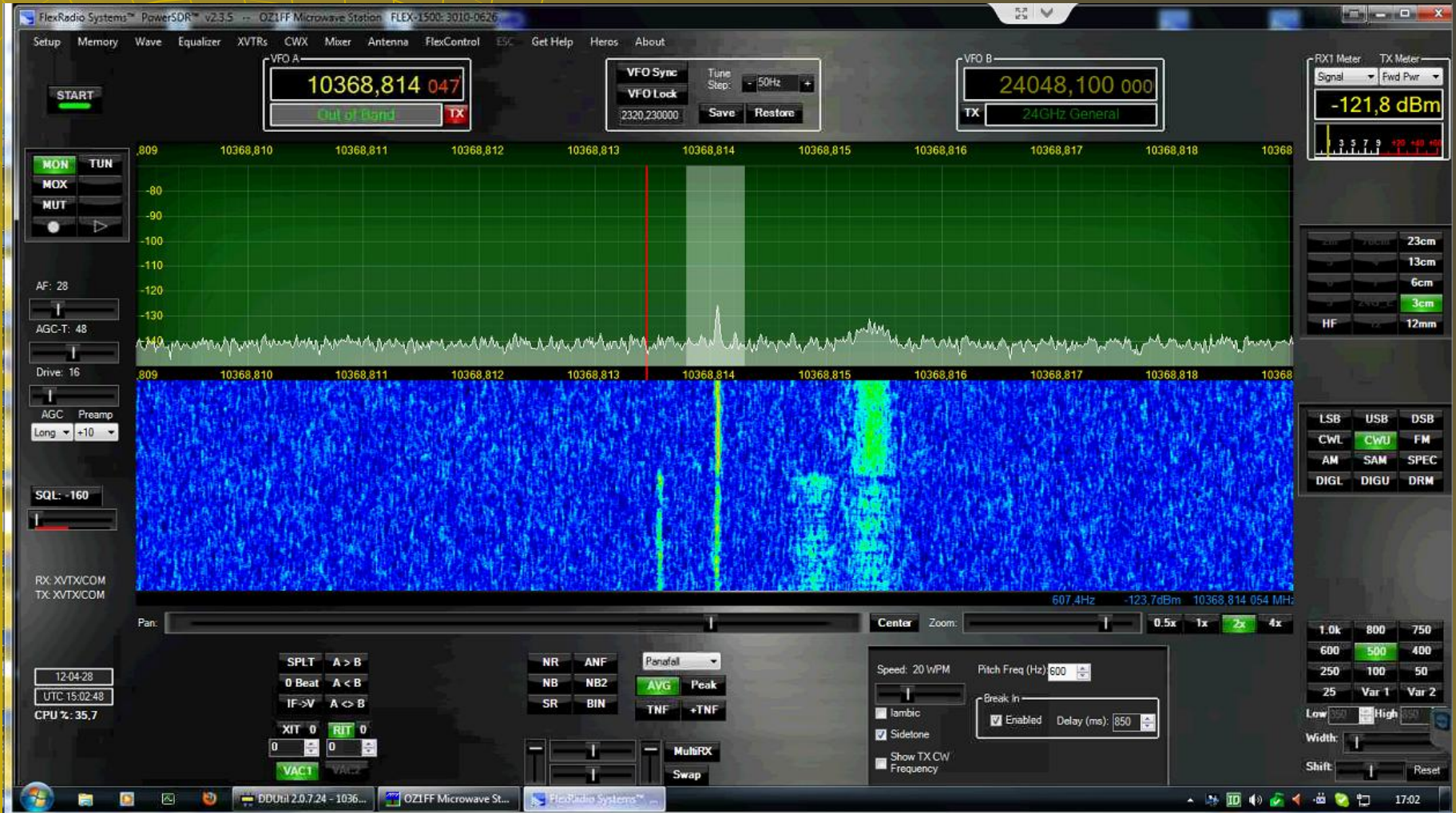
Forward-scatter

Scatter Volume

Regnscatter

- ◆ 10 GHz er det optimale bånd
 - Dråbestørrelse $1/10 \lambda$
- ◆ Dopplerskift/Smear
- ◆ Kraftig forvrængning på back/side scatter (CW/FM)
- ◆ Ringe forvrængning på forward scatter (SSB)
- ◆ Op til >1000 km
- ◆ Sommerfænomen
 - Typisk fra sidst på eftermiddagen

Regnscatter



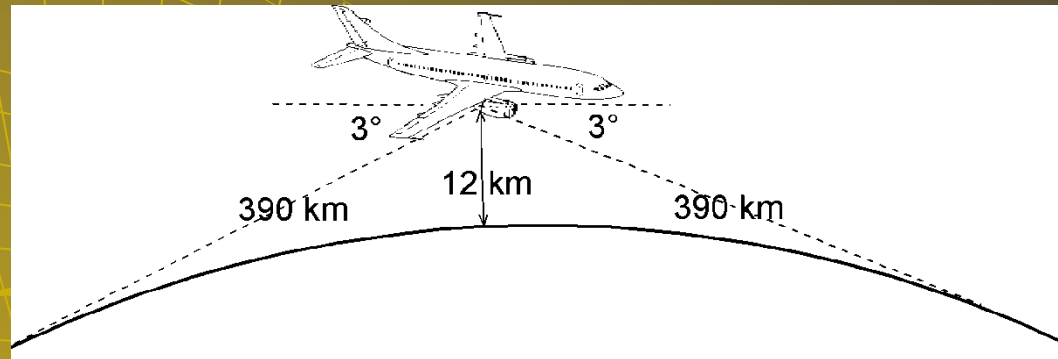
Rækkevidde



Flyreflektion

- ◆ Refleksion på trafikfly
 - Kan vare fra 10 sekunder til flere minutter afhængig af flyets størrelse, højde, hastighed og kurs
 - Dopplerskift
 - Tålmodighed
 - Op til 8-900 km

Flyreflektion



- ◆ Maksimum rækkevidde ved fly i FL400 i den rette position, direkte sigt (LOS) på strækningen og inkluderet refraktion i atmosfæren, er 1040 km



Kan det så bruges til noget?

- ◆ Ja, men afhængigt af mange faktorer
 - Vejret – årstiden
 - ◆ Morgen/aftentropo om sommeren
 - ◆ Dårlige forhold om vinteren
 - ◆ Vinterhøjtryk kan give højtliggende ducts
 - QTH – free take off
 - Antenner
 - Station
 - Flytrafikken
 - Operatør 😊

Resultater OZ1FF

Bånd	WWL	DXCC	ODX [km]
23cm	122	23	TR:1256
13cm	77	15	TR:1256
6cm	37	9	TR:1100, RS:804
3cm	114	34	TR:1194, RS:1099, EME:11813
1,2cm	22	9	TR:360, RS:418, EME:7882
0,6cm	5	3	TR:123

10 GHz QSO-er

- ◆ TR ODX 1099 km
- ◆ 290 RS QSOs siden 2001-01-01
 - ◆ Heraf 1 på 24 GHz
- ◆ Totalt >2.178 QSOs på 10 GHz

Mikrobølgestation

- ◆ Hovedkomponenter
 - HF/VHF/UHF-radio
 - Transverter(ere)
 - Low Noise Amplifier (LNA)
 - Power Amplifier (PA)
 - Kabler og konnektorer
 - Antennerelæ
 - Antenne
 - Computer(e)/Internet

Station OZ1FF

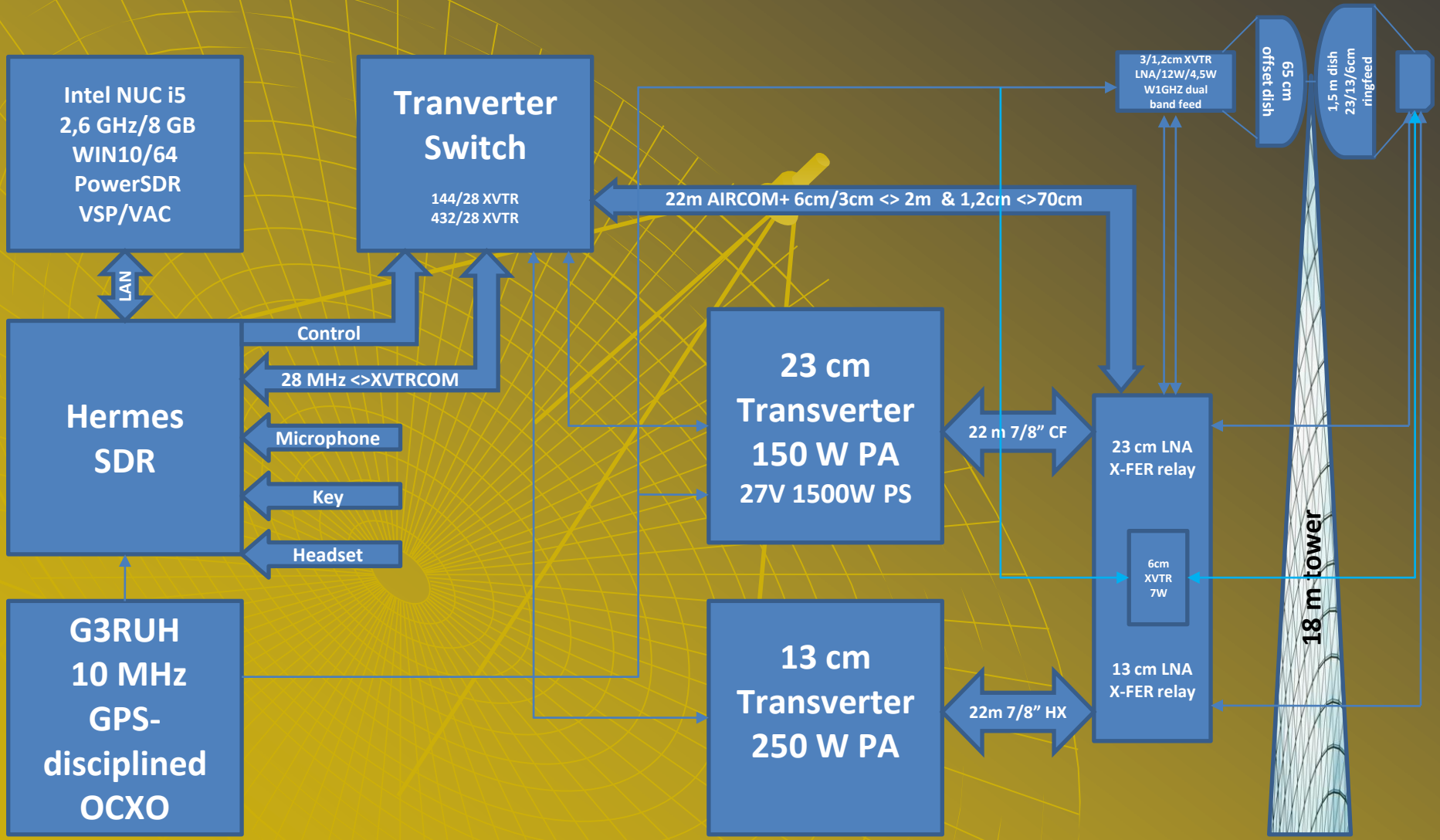
Opbygget og optimeret siden 1998

Band	TRX	PreAmp	PA	Antenne
23cm	Hermes/ MKU13G2*	LNA131AH-HEMT	145 W	1,5m parabol*
13cm	Hermes/MKU144G2/ MKU23G2*	LNA231AH-HEMT	250 W*	1,5m parabol*
6cm	Hermes/MKU144G2/ MKU57G2*	N/A	7 W*	1,5m parabol*
3cm	Hermes/MKU144G2/ MKU10G3	LNA101AS-HEMT	12/50 W	65/240 cm parabol*
1,2cm	Hermes/MKU432G2/ MKU24GA	MKU243RX2	4,5/10 W	65/240 cm parabol*
0,6cm	MKU47G2/FT-817	N/A	80 mW	30 cm parabol*

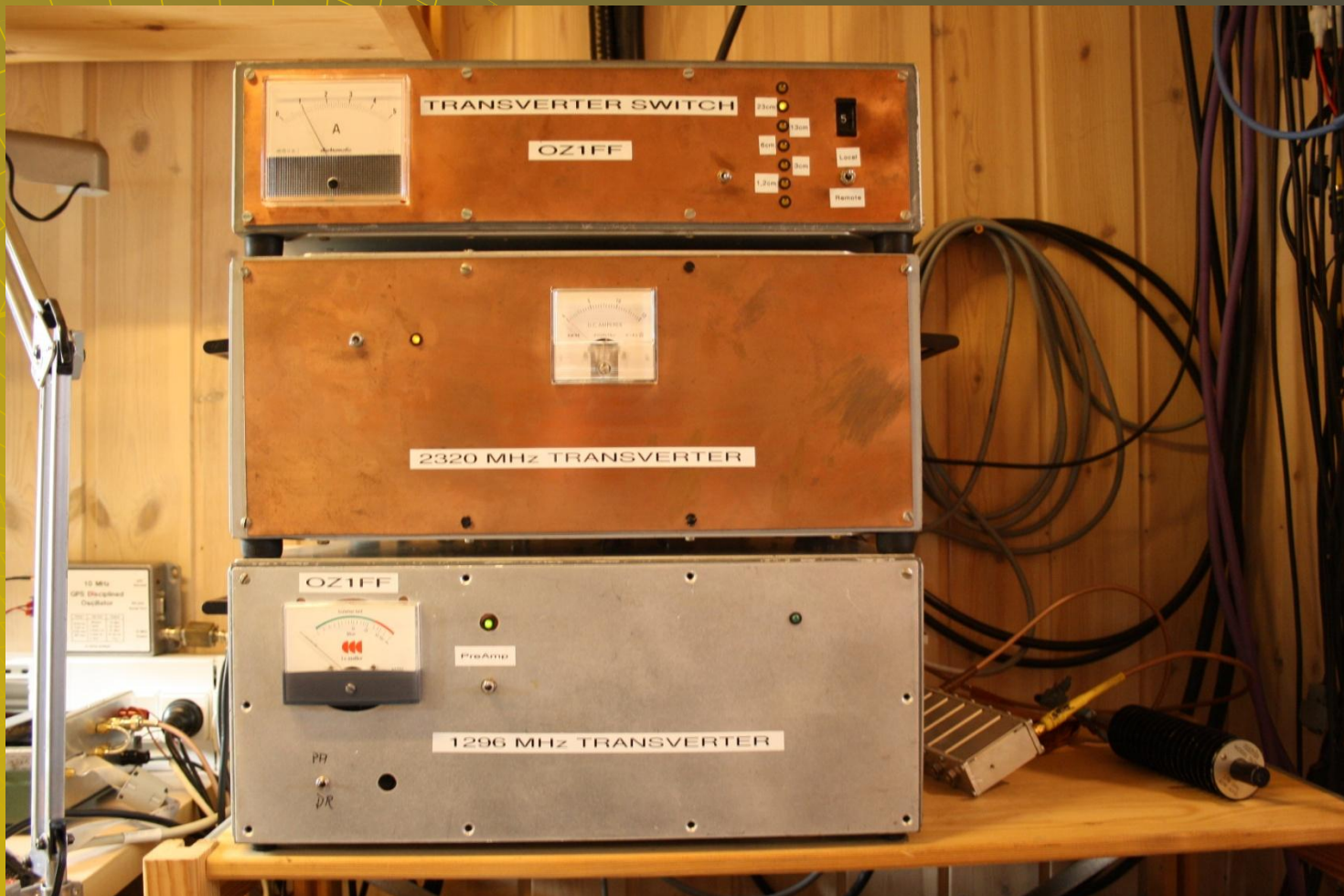
* Byggesæt

* Surplus

OZ1FF Microwave Station



Transvertere



Antenner

- ◆ QTH JO45BO58 5 mASL
- ◆ Antennemast 18 m
- ◆ 1,5 m parabol
 - Ringfeed 23/13/6 cm
- ◆ 65 cm parabol
 - 3/1,2 cm
- ◆ Rotor uden for meget slør



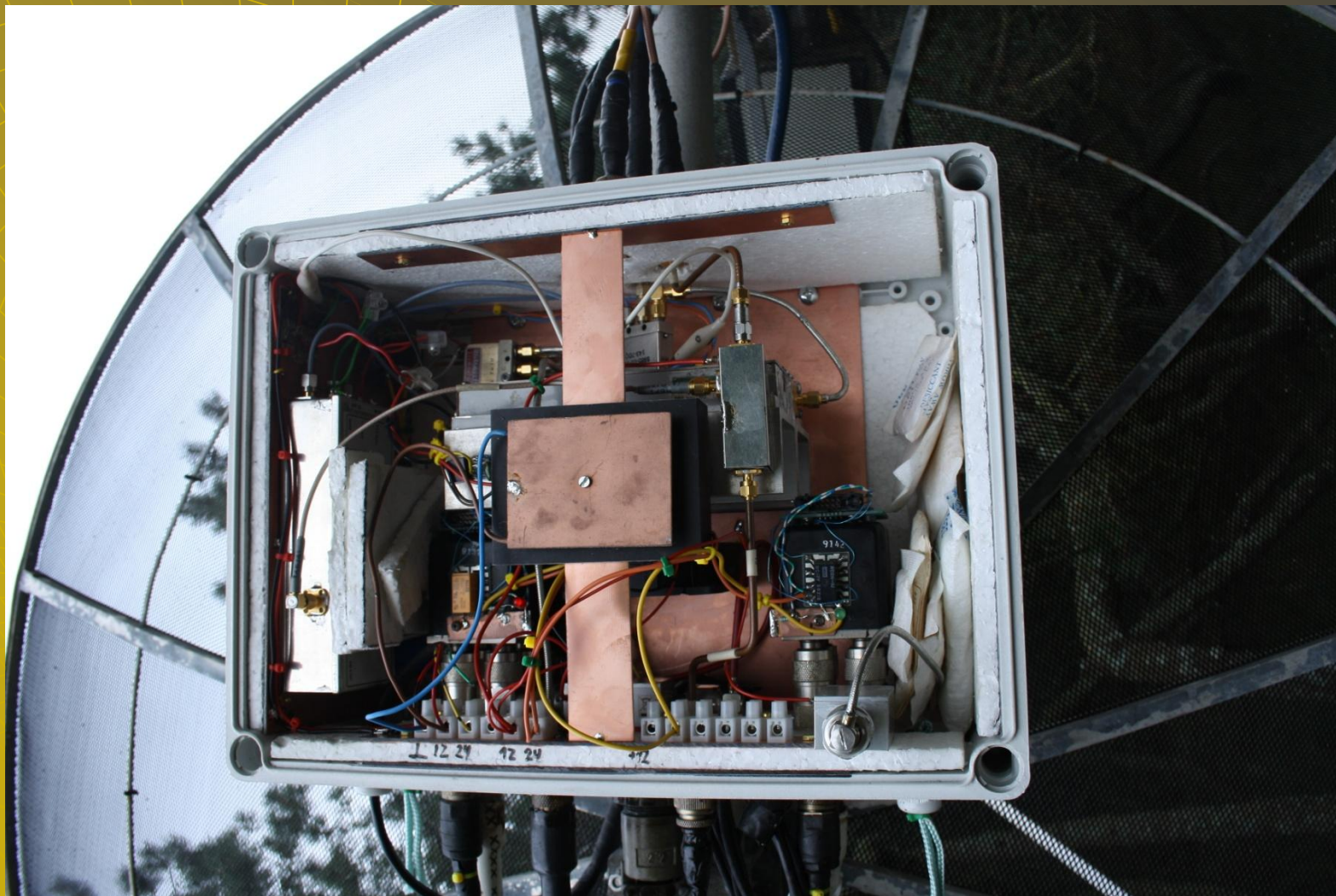
Anntenner



Ringfeeds 1,3 – 10 GHz



Masteboks



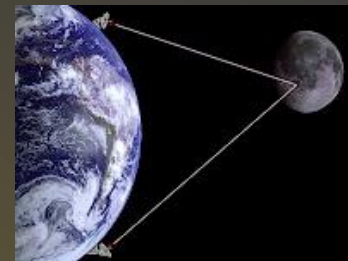
10/24 GHz transverterboks



Kigge efter beacons



Earth-Moon-Earth



- ◆ Den ultimative radioforbindelse
 - 750.000 km
- ◆ 289/297 dB strækingsdæmpning på 10/24 GHz
- ◆ Store antenner
 - Tracking
- ◆ Store sendere - følsomme modtagere

- ◆ Men – mindre kan også gøre det

Hvorfor EME?

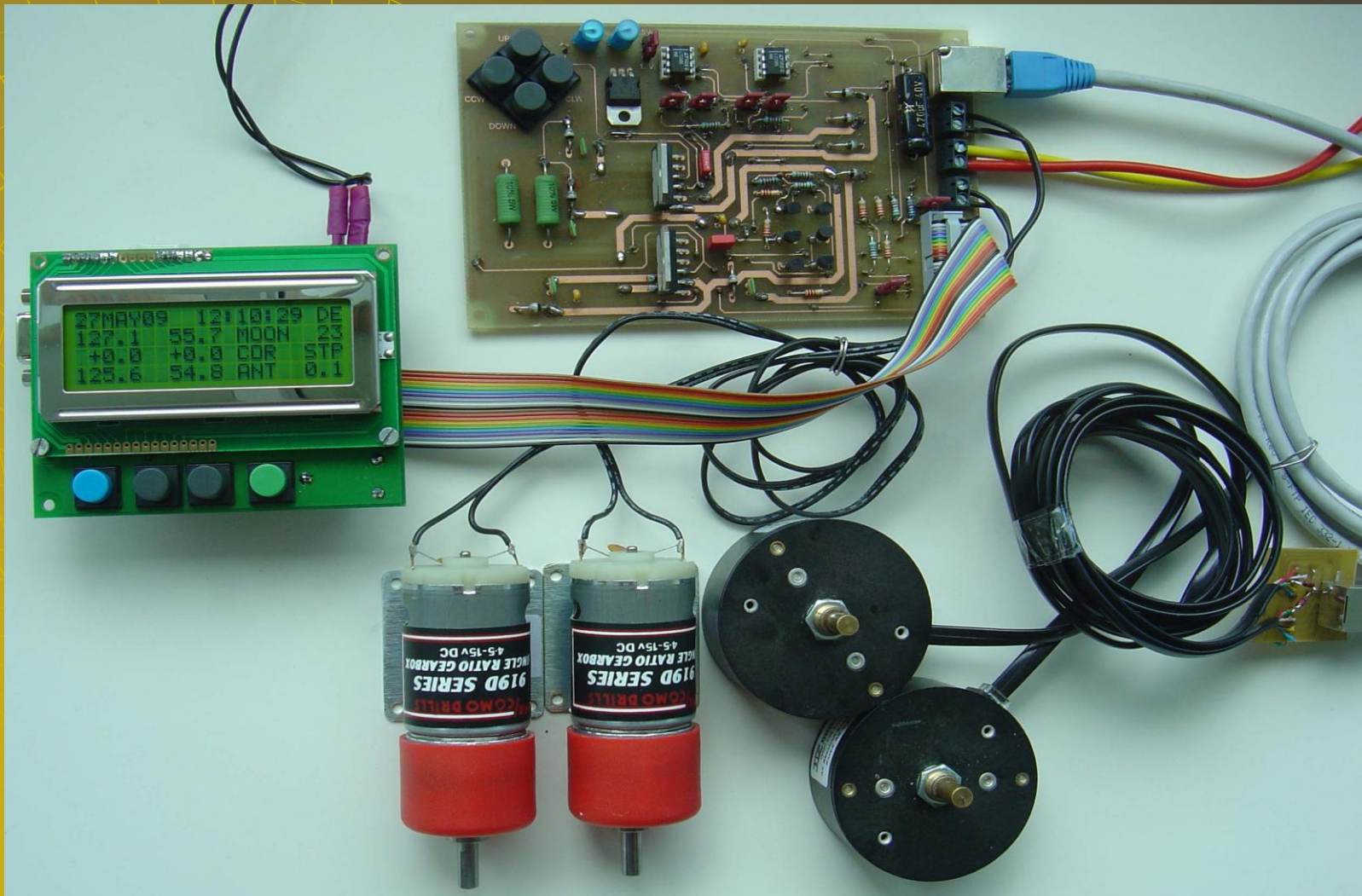
“EME opens up the bands at VHF and above to a new frontier of worldwide DX”

Joe Taylor – K1JT

Az/EI rotor



OE5JFL-controller



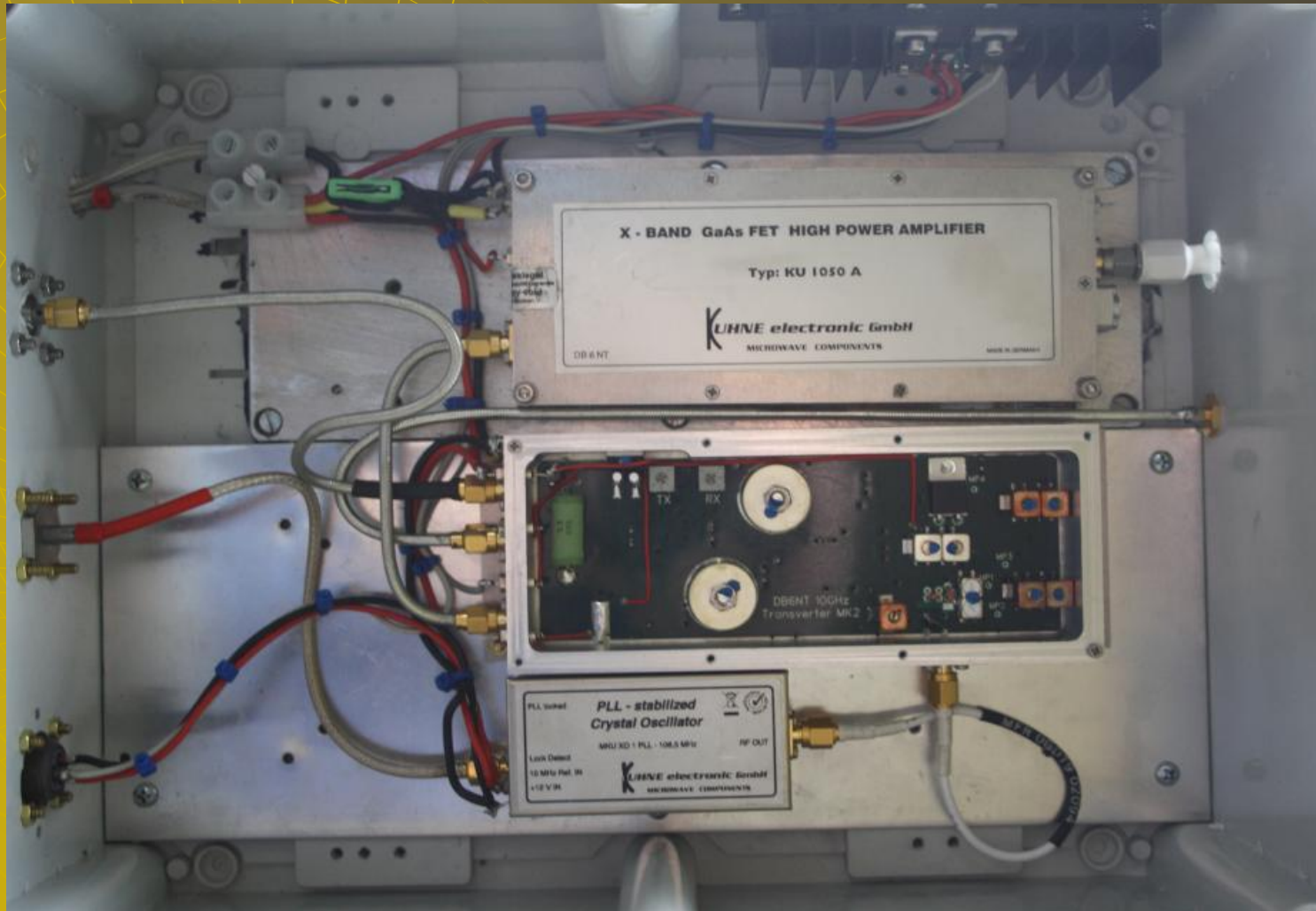
Feed, LNA, WG-switch



Feed, LNA, WG-switch



Transverter + SSPA



Referenceoscillator



QRO



Operationsprocedurer

- ◆ Hvornår er der nogen QRV?
 - DL0SHF Beacon
 - Ekkotest
 - Planlægningsprogram Moon Sked
 - HB9Q EME-logger
- ◆ Mode
 - CW
 - "De store drenge" kører også SSB
 - MGM med WSJT-X

DLOSHF

PowerSDR™ OpenHPSDR mRX PS v3.4.2 (7/5/17) -- OZ1FF Microwave Station

Setup Memory Wave Equalizer XVTRs CWX Diversity Collapse Linearity RA

VFO A: 144,015 584
2M CW TX

VFO Sync Tune Step: -25Hz +
VFO Lock 1296,230000 Save Restore

VFO B: 144,021
2M CW TX

MON TUN
MOX TUN
DUP PS-A

Master AF: 10

WSJT-X - Astronomical Data

2018 nov 06
UTC: 11:26:49
Az: 198.5
El: 25.6
SelfDop: -8034
Width: 134
Delay: 2.51
DxAz: 200.9
DxEI: 26.4
DxDop: -8416
DxWid: 135
Dec: -7.3
SunAz: 184.0
SunEl: 18.3
Freq: 10368
Tsky: 3
Dpol: -1.7
MNR: 0.0
Dgrd: -1.1

Doppler tracking
 Full Doppler to DX Grid
 Own Echo
 Constant frequency on Moon
 On DX Echo
 Call DX
 None

Sked frequency
 Rx: 10.368,024 000
 Tx: 10.368,018 052

Press and hold the CTRL key to adjust the sked frequency manually with the rig's VFO dial or enter frequency directly into the band entry field on the main window.

Doppler tracking

WSJT-X v1.9.1 by K1JT

File Configurations View Mode Decode Save Tools Help

Single-Period Decodes					Average Decodes				
UTC	dB	DT	Freq	Message	UTC	dB	DT	Freq	Message
1122	-7	2.8	1002	* CQ DLOSHF JO54	1120	-11	3.0	993	* CQ DLOSHF JO54
1123	-21	3.4	995	*	1121	-22	4.0	998	*
1124	-8	3.0	1000	* CQ DLOSHF JO54	1122	-7	2.8	1002	* CQ DLOSHF JO54
1123	-21	3.4	995	*	1123	-21	3.4	995	*
1124	-8	3.0	1000	* CQ DLOSHF JO54	1124	-8	3.0	1000	* CQ DLOSHF JO54
1125	-22	4.0	1005	*	1125	-22	4.0	1005	*

Log QSO Stop Monitor Erase Decode Enable Tx Halt Tx Tune Menus

3cm 10.368,015 584 Tx even/1st

DX Call: DLOSHF DX Grid: JO54bh
Az: 137 193 km

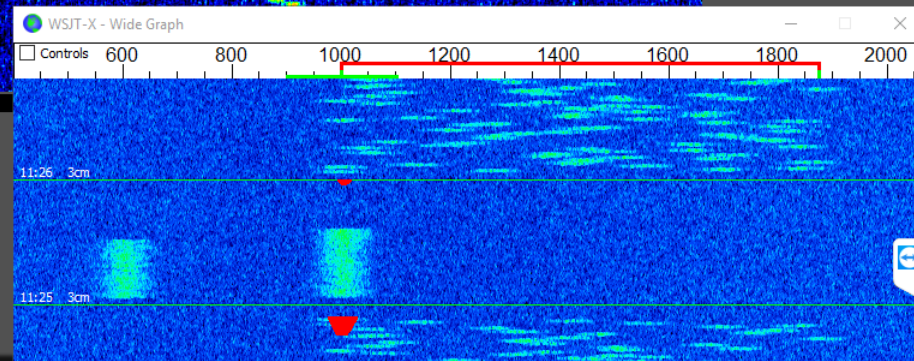
10.368,015 584
2018 nov 06
11:26:49

Generate Std Msgs Next Now Pwr

OZ7Z OZ1FF JO45	<input type="radio"/> Tx 1
OZ7Z OZ1FF -15	<input type="radio"/> Tx 2
OZ7Z OZ1FF R-15	<input type="radio"/> Tx 3
OZ7Z OZ1FF RRR	<input type="radio"/> Tx 4
OZ7Z OZ1FF 73	<input type="radio"/> Tx 5
CQ OZ1FF JO45	<input checked="" type="radio"/> Tx 6

Receiving QRA64D Last Tx: CQ OZ1FF JO45 49/60 WD:0m

LSB USB DSB
CWL CWU FM
AM SAM SPEC
DIGL DIGU DRM



Windows taskbar with various icons and system tray showing DAN 12:26

Ekkotest



HB9Q Logger

HB9Q | LOGGER - Mozilla Firefox

https://logger.hb9q.ch

1296 23xx 5760 10xxx 24000

@call write your message here...

UTC search...

01:17	GD All QRV 24GHz good echoes	JA1WQF	Mitsuo
01:18	Hi Larry Are you planning for 24 GHz?	JA1WQF	Mitsuo
21:44	Hello Kjeld What time can you see the moon? My window is up to 0000Z on the 30th	JA1WQF	Mitsuo
22:22	RRR TNX fr info	DL6ABC	Matthias
22:20	ok want only to tell that the new Preamp do not like deep temperatures	DC7KY	Klaus
22:19	Hello Cluas no activity on 10GHZ go to bed	DL6ABC	Matthias
22:17	hallo Matthias	DC7KY	Klaus
22:14	ok, thanks was very good evening, sleep well	DC7KY	Klaus
22:11	OK Klaus, tnx for fb qso, park ant. 73 & gn	DF1OI	Johannes
22:10	no, have to stop TX, my other antennas are in this direction	DC7KY	Klaus
22:09	Klaus quick check with qra64d?	DF1OI	Johannes
22:07	rr Mitsuo, will keep 24g installed, tnx & 73	DF1OI	Johannes
22:01	very good signals from both today, because +4degreeC	DF1OI	Johannes
22:00	this is 3-5 dB over noise	DC7KY	Klaus
21:59	rrr tnx again 73	JA1WQF	Mitsuo
21:58	@1000 is me	JA1WQF	Mitsuo
21:58	i have the same Dish and 25 W	DC7KY	Klaus
21:57	camera helps a lot	DF1OI	Johannes
21:57	Great!	JA1WQF	Mitsuo

Who is online

OZ1FF (ME)

Remove all highlight Hide all Show all

CW

- ◆ Procedure ved sked
 - 2,5/1 min sekvens samt QRG aftalt på forhånd
 - QRS med god tegnafstand
- ◆ Random QSO
 - Køres som normale QSO-er
 - Køres på ekkofrekvensen med manuel dopplerkorrektion

MGM

- ◆ WSJT-X
 - Muligheder
 - Timing
 - ◆ Synkronisere PC med tidsserver
 - Frekvensstabilitet -nøjagtighed
 - Dopplerkompensation via CAT
 - ◆ Fuld kompensation, både RX og TX
 - ◆ CFOM – Constant Frequency On Moon
 - JT4A-F
 - QRA64A-E

OZ7Z

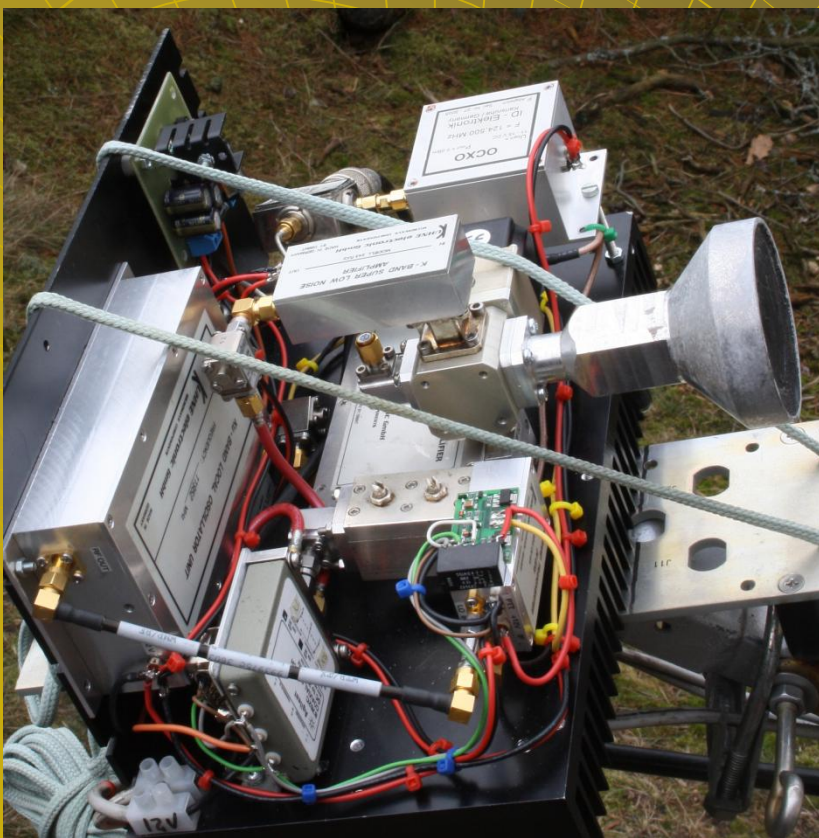
- ◆ 90 cm parabol
- ◆ 15W
- ◆ 1,8 dB NF
- ◆ 4 QSO-er
- ◆ Hørt mange stationer



EME 24 GHz

Transverter

W5LUA ekkotest



EME 24 GHz

- ◆ 10 initials
- ◆ LX/OK/DL/W/G/F/PA0
- ◆ ODX 7882 km
- ◆ Mindste effekt/parabol
 - Kun muligt under optimale betingelser
 - ◆ Månen i perigæum og højt på himlen
 - ◆ Lavt vanddampindhold i atmosfæren
- ◆ Tracking & dopplerkorrektion



W5LUA Ekkotest

The screenshot displays the FlexRadio Systems PowerSDR v2.3.5 software interface. The main window shows a spectrum analyzer with a frequency range from 24048,1155 to 24048,1195 MHz. The VFO A is set to 24048,117 650 MHz (24GHz General TX) and VFO B is set to 24048,100 000 MHz (24GHz General TX). The signal strength is -124,1 dBm. The interface includes various control panels for tuning, AGC, and signal processing. A small window in the foreground shows the call sign W5LUA and the frequency 599 kHz. The system tray at the bottom shows the date and time as 04:00.

OZ1FF Ekkotest

The screenshot displays the PowerSDR v2.3.5 software interface for an OZ1FF Microwave Station (FLEX-1500; 2810-0382). The main window features a central spectrum plot with a frequency range from 24048,114 to 24048,118 MHz. The plot shows a signal at 24048,116 MHz. The interface includes several control panels:

- Top Left:** START button, MON/TUN buttons, and a frequency display showing 24048,116 450 MHz (24GHz General TX).
- Top Center:** VFO Sync and VFO Lock controls, with a Tune Step set to 50Hz and a VFO Lock value of 10368,100000. Save and Restore buttons are also present.
- Top Right:** RX/TX Meter showing a signal level of -128,2 dBm.
- Left Panel:** AGC-T: 45, Drive: 30, AGC Presamp (Long +30), and SQL: -160.
- Right Panel:** RX/TX Meter, Sig Avg, and a table of signal levels for different frequencies (23cm, 13cm, 6cm, 3cm).
- Bottom Center:** A large control panel with buttons for NR, ANF, NBZ, SR, BIN, and various filter settings. It also includes a Speed control (20 WPM) and a Pitch Freq (Hz) control (600 Hz).
- Bottom Left:** A small window showing the station name "OZ1FF Microwave Station" and a digital display showing "Az 70 69".

The taskbar at the bottom shows several open applications, including PowerSDR v2.3.5, DOUtil v2.0, CwType, and Microsoft PowerPoint.

OZ1FF @ W5LUA

The screenshot shows the WSJT 9.5 software interface. At the top, the title bar reads "WSJT 9.5 r3033 by K1JT". The menu bar includes "File", "Setup", "View", "Mode", "Decode", "Save", "Band", and "Help".

The main display area features a waterfall plot with a frequency range from 135000 to 145000 Hz. A prominent signal is visible at 140500 Hz. To the right of the plot, a cyan box displays the following data:

Moon
Az: 106.21
El: 21.21
Dop: 6883
Dgrd: -1.3

Below the plot, a table lists decoded messages. The table has columns for FileID, Sync, dB, DT, DF, W, and other parameters. The messages are:

FileID	Sync	dB	DT	DF	W	Message	Other
135700	1	-19	-0.9	-545	9 *		
135900	6	-15	4.9	-13	79 *	W5LUA OZ1FF	1 0 E
140100	2	-18	-0.8	-315	9 *		
140100	0	-21	-1.3	-155	4		
140300	0	-21	-1.2	-101	4		
140500	4	-16	4.3	-74	28 *	W5LUA OZ1FF	1 0 E

Below the table, there are buttons for "Log QSO", "Stop", "Monitor" (highlighted in green), "Decode", "Erase", "Clear Avg", "Include", "Exclude", and "TxStop".

The bottom section contains a "To radio:" field with "OZ1FF" and a "Grid:" field with "JO45bo". A digital clock displays "2013 Mar 11 14:07:13". Other controls include "Az: 35", "4898 mi", "Dsec 0.0", "Sync 1", "Zap", "Tol 50", "AFC", "MinW A", "Efreeze", "Tx First", "Rpt: -15", "Gen Msgs", and "Auto is ON".

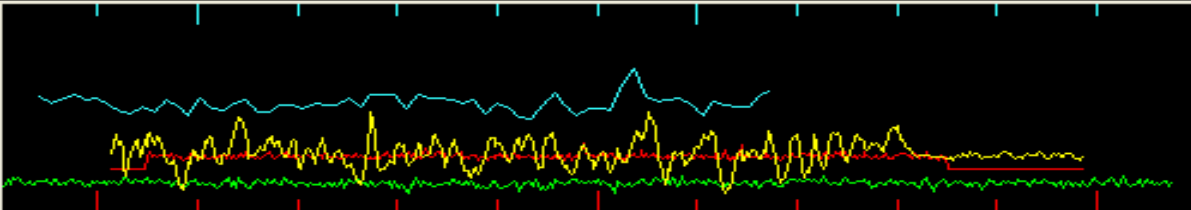
The status bar at the bottom shows "1.0000 1.0001", "JT4F", "Freeze DF: -104", "Rx noise: 0 dB", "T/R Period: 60 s", and a green "Receiving" indicator.

W5LUA med automatisk dopplerkorrektion

OZ1FF @ W5LUA

WSJT 9.5 r3033 by K1JT

File Setup View Mode Decode Save Band Help



Moon

Az: 86.05

E1: 22.73

Dop: 10526

Dgrd: -2.0

8.4 Time (s) OZ1FF_130315_163700

FileID	Sync	dB	DT	DF	WV	
163300	0	-21	4.7	-94	4	
163300	0	-21	2.3	-182	4	
163300	0	-21	2.3	-182	4 #	
163300	0	-20	0.1	-24	4 #	
163500	5	-16	4.3	-24	77 #	W5LUA OZ1FF -11 1 20 F
163700	1	-19	4.4	-15	4 #	

163700 1 7/7
163700 2 11/11

Log QSO Stop **Monitor** Decode Erase Clear Avg Include Exclude TxStop

To radio:

Grid:

Az: 35 4898 mi

2013 Mar 15

16:39:16

Dsec 0.0

Sync -2 Zap

Tol 400 AFC

MinW A Efreeze

Tx First

Rpt:

OZ1FF W5LUA EM13 Tx1

OZ1FF W5LUA -16 Tx2

OZ1FF W5LUA R-16 Tx3

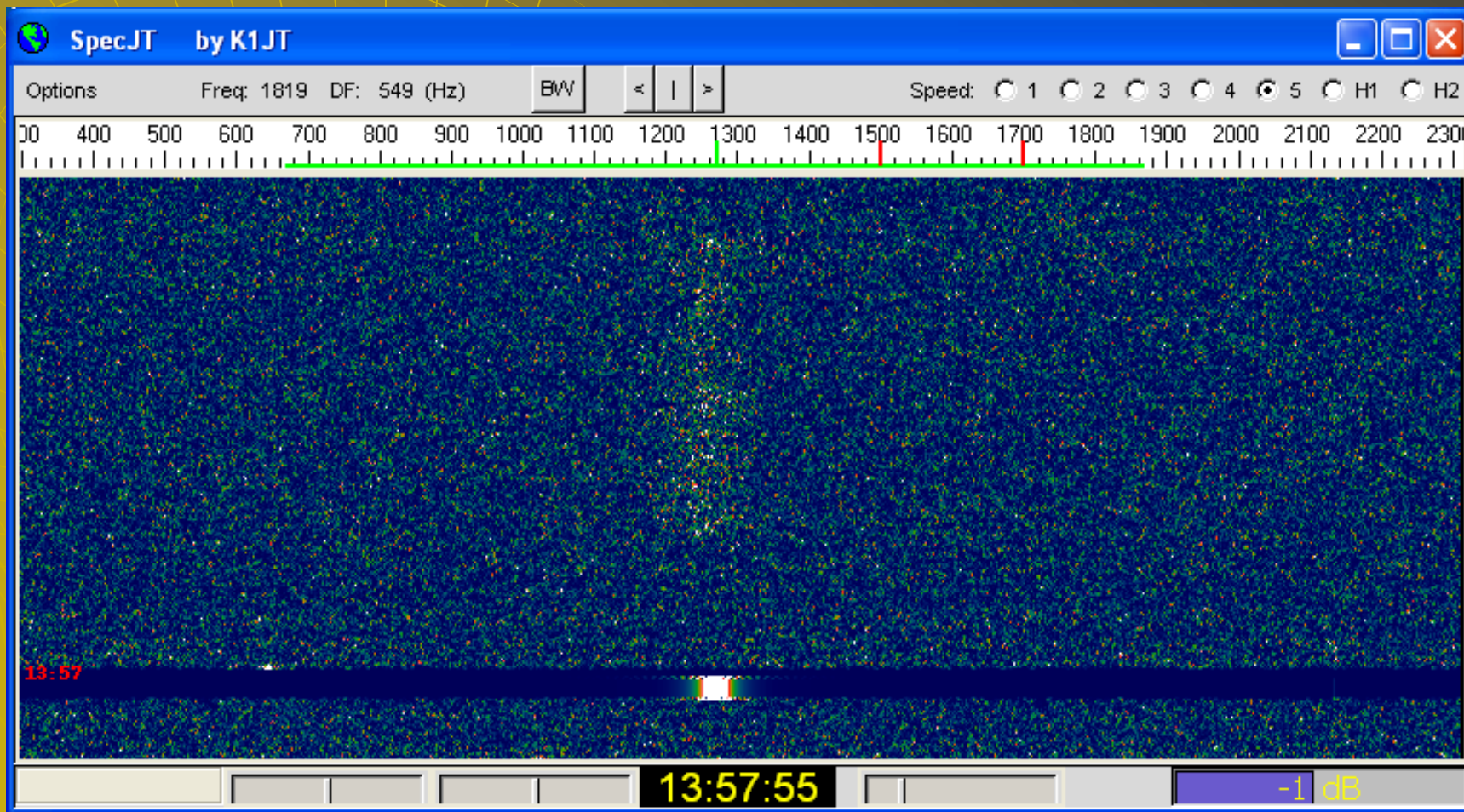
@1500 (RRR) Tx4

@1700 (73) Tx5

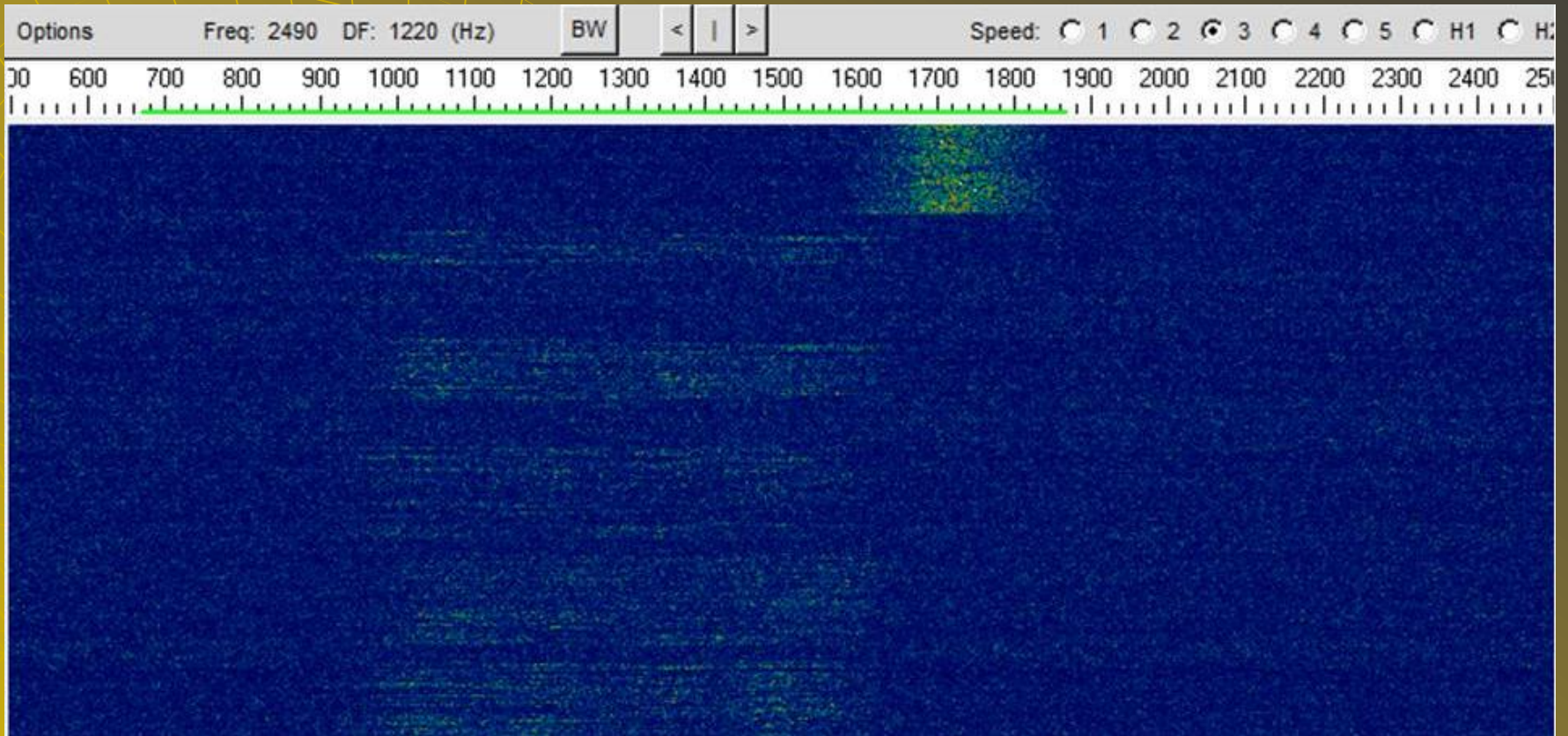
CQ W5LUA EM13 Tx6

1.0000 1.0001 **JT4F** Freeze DF: -51 Rx noise: 0 dB T/R Period: 60 s **Receiving**

OZ1FF 1270 Hz Sync. tone



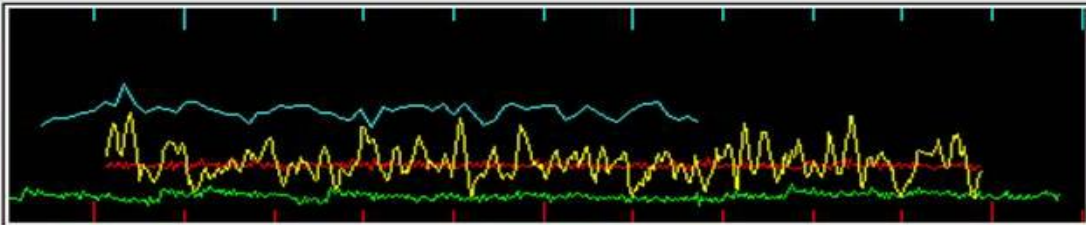
W5LUA 73



W5LUA @ OZ1FF

WSJT 9.5 r3033 by K1JT

File Setup View Mode Decode Save Band Help



Moon
Az: 229.41
El: 40.82
Dop: 9058
Dgrd: -2.0

47.1 Time (s) Mon_130315_164900

FileID	Sync	dB	DT	DF	W				
163000	9	-11	3.5	-4	96	*	OZ1FF W5LUA EM13	1	36 B
163200	8	-13	3.5	37	96	*	OZ1FF W5LUA EM13	1	24 C
163400	6	-14	3.3	-13	92	*	OZ1FF W5LUA EM13	1	25 C
163600	6	-14	3.1	22	90	#	OZ1FF W5LUA R-16	1	17 C
163800	5	-16	3.4	28	90	#	OZ1FF W5LUA R-16	0	16 F
164000	0	-21	4.8	182	7	#			
164200	6	-14	3.5	9	92	*	TNXQSOKJELD	1	0 C
164900	1	31/31							
164900	2	20/20							

Log QSO Stop Monitor Decode Erase Clear Avg Include Exclude TxStp

To radio: W5LUA Lookup
Grid: EM13qc Add
Az: 301 7882 km
2013 Mar 15 16:52:46 Dsec 0.0
Sync -1 Zap
Tol 400 AFC
MinW A Freeze
Tx First
Rpt: -11
Gen Msgs Auto is OFF

- W5LUA OZ1FF Tx1
- W5LUA OZ1FF -11 Tx2
- W5LUA OZ1FF R-11 Tx3
- @1500 (RRR) Tx4
- @1700 (73) Tx5
- @127d Tx6

1.0000 1.0000 JT4F Freeze DF: 3 Rx noise: 0 dB T/R Period: 60 s Receiving

Værktøjer

- ◆ Beaconspot.eu
- ◆ ON4KST/KST2me
- ◆ DX-Cluster
- ◆ [PA5DD regnradar](http://PA5DD)
- ◆ [Wetteronline – Profikarten](http://Wetteronline)
- ◆ [Hepburns Tropoindex](http://Hepburns)
- ◆ VHF-udvalget
- ◆ MMMVHF