The EISCAT Heating Facility

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Outline

- Description of the hardware
- Antenna beams
- Practical details- power levels etc.
- Controlling the heater from eros (new)
- Radar mode (new)
- Dynasonde (HF sounder)

World overview

- 1970: **Platteville**, Colorado
- 1975: **SURA** (Nizhni Novgorod), Russia
- ~1980: **Arecibo** (Puerto Rico), **Tromsø** (Norway), **HIPAS** (Alaska)
- 1995: **HAARP** (Alaska)
- 2003: **SPEAR** (Svalbard)

A comparison

( ) means planned	Plateville Colorado USA	Arecibo Puerto Rico	**HIPAS Alaska USA**	**HAARP Alaska USA**	**EISCAT Tromsø Norway**	**SURA Russia**	**SPEAR Spitsbergen Norway**
Geographic Coordinates	40.18 N 104.73 E	18.3 N 66.8 W	**65.0 N 147.0 W**	**62.39 N 145.15W**	**69.6 N 19.2 E**	**59.13N 46.1 E**	**78.9 N 78.15 W**
Magnetic Latitude	49.1 N	32 N	**76 N**	**63.09 N**	**67 N**	**50 N**	
Frequency [MHz]	2.8-10	3-12	**2.8-5**	**2.8-10**	**3.9-5.5 5.5-8.0**	**4.5-9**	**4-6 (2-3)**
Radiated Power [MW]	2	0.8	**1.6**	**3.6**	**1.0**	**0.75**	**0.19**
Antenna Gain [dB]	19	23-26	**18-19**	**20-31**	**22-25 28-31**	**23-26**	**22 (16)**
Effective Radiated Power [MW]	100	160	**130**	**400-3000**	**180-340 630-1260**	**150-280**	**32 (8)**

Why do we need the HEATING facility?

Why?: HF facilities are the only *true* active experiments in the ionosphere because the plasma may be temporarily modified under user control.

Experiments can be divided into 2 groups:

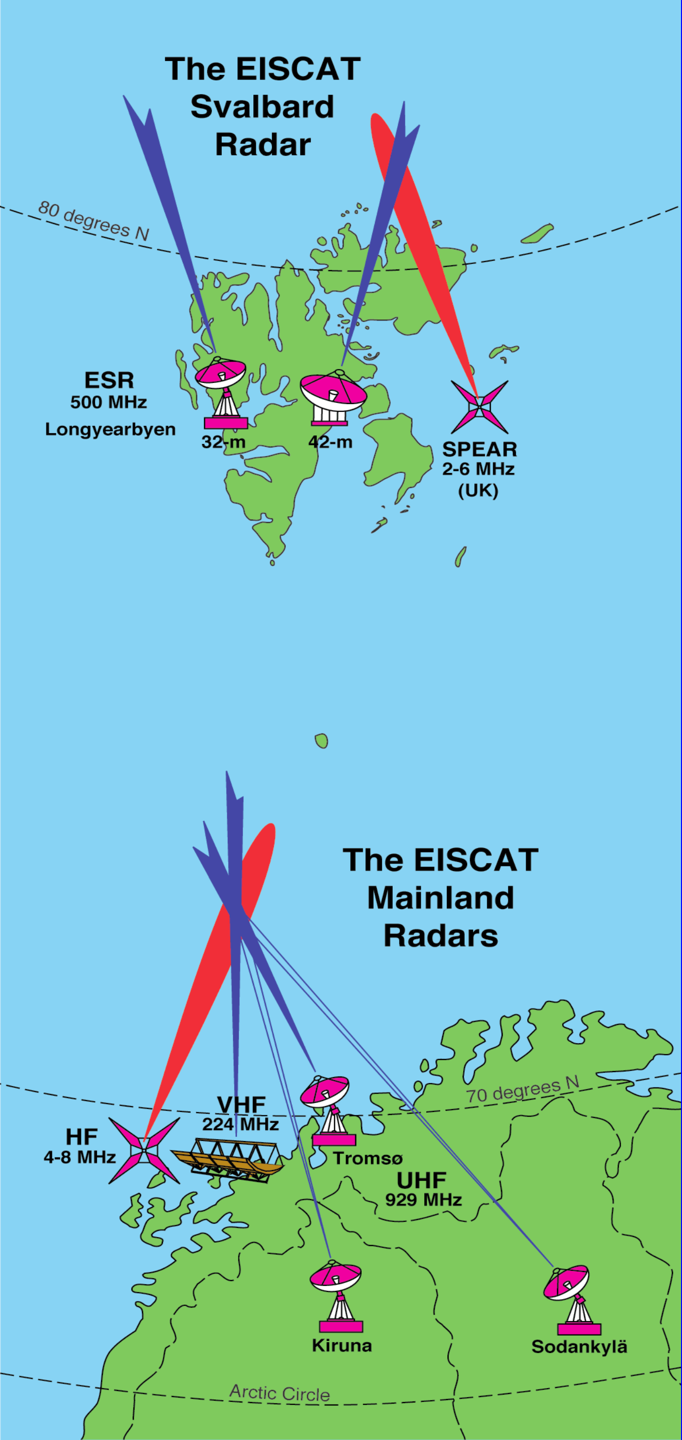
Plasma physics investigations:

the ionosphere is used as a laboratory to study wave-plasma turbulence and instabilities.

- **Geophysical investigations:**

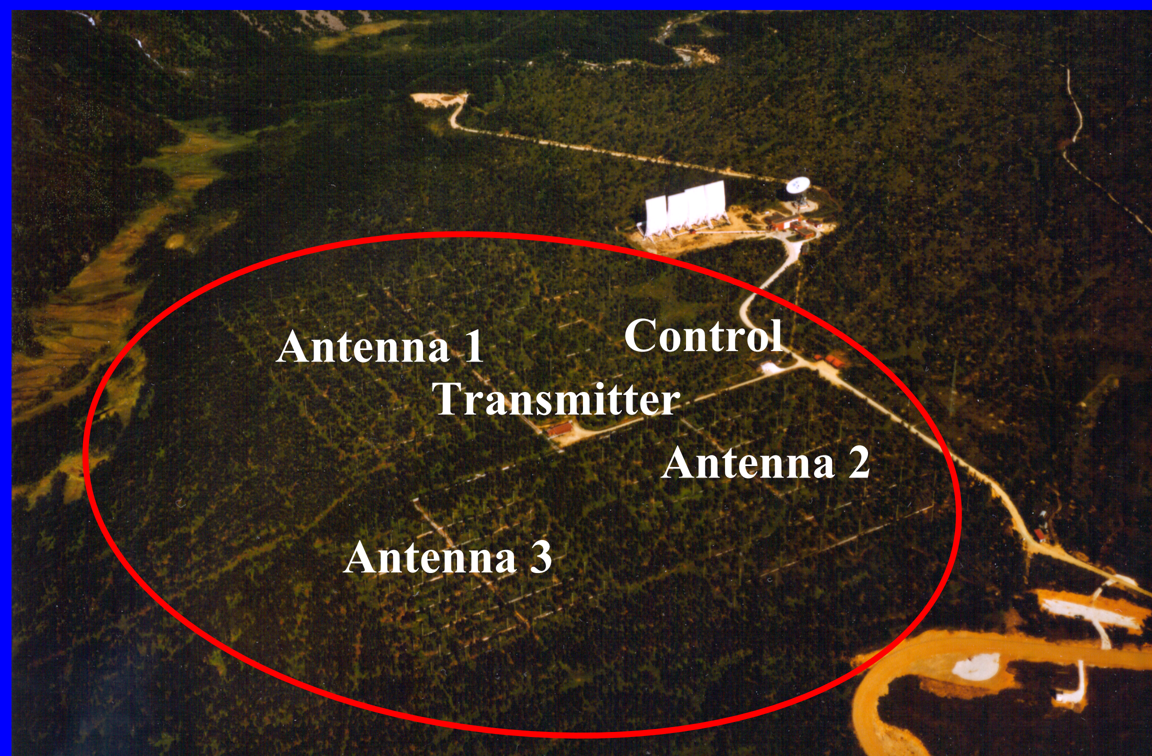
  ionospheric, atmospheric or magnetospheric research is undertaken.

Operations: ~200 hours per year (1 year=8760 hours), mostly in user-defined campaign mode.

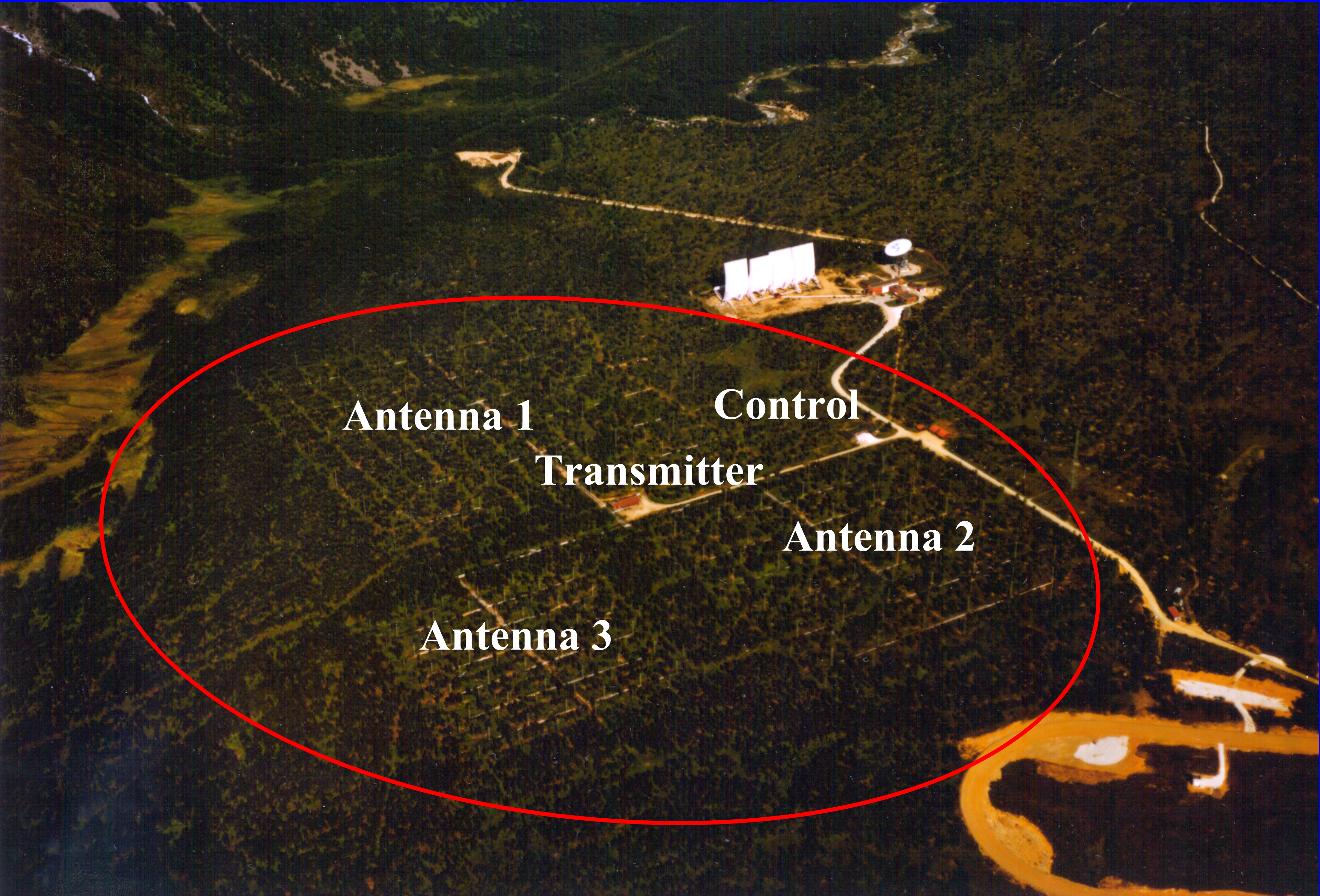


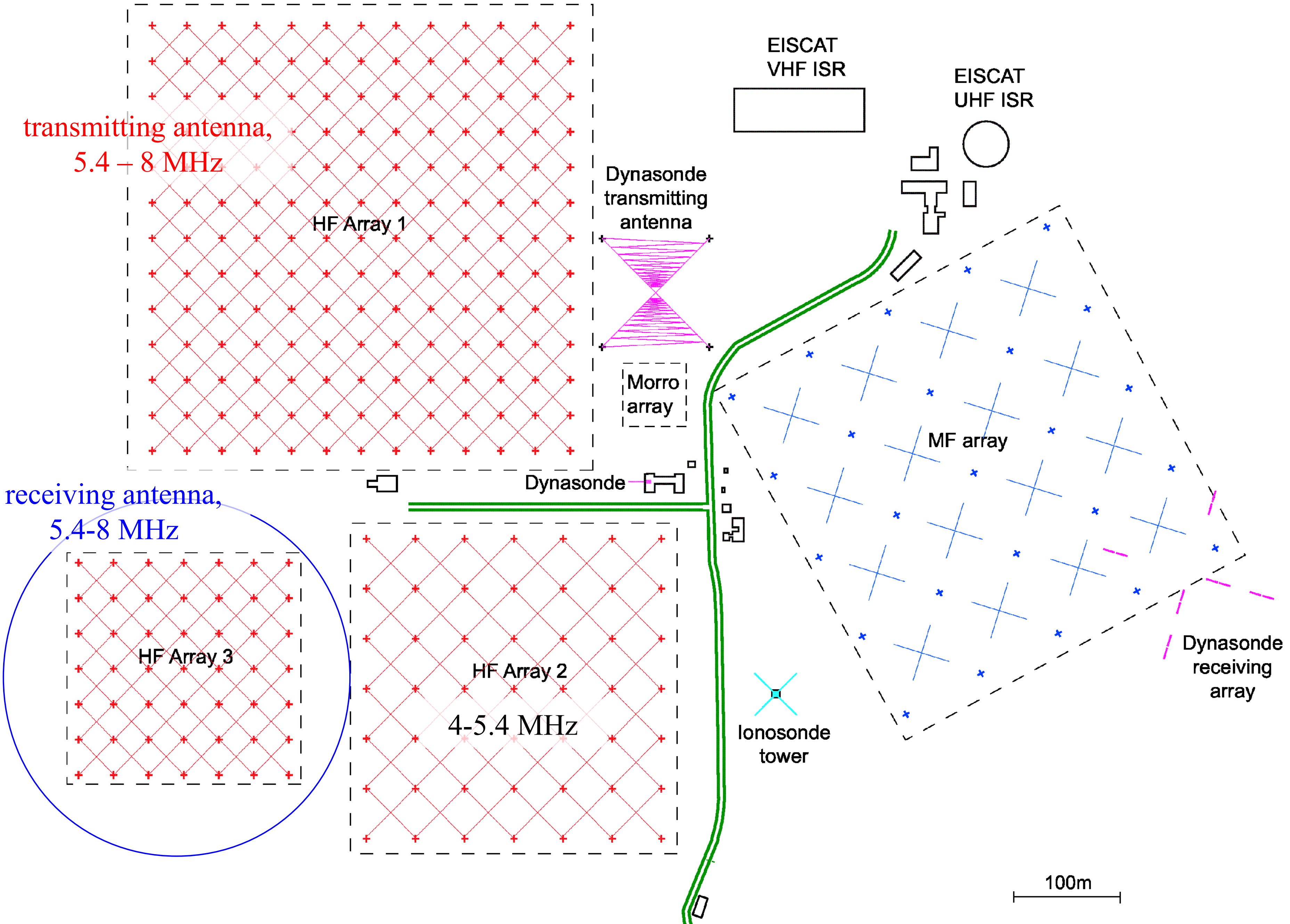
SPEAR

HEATING



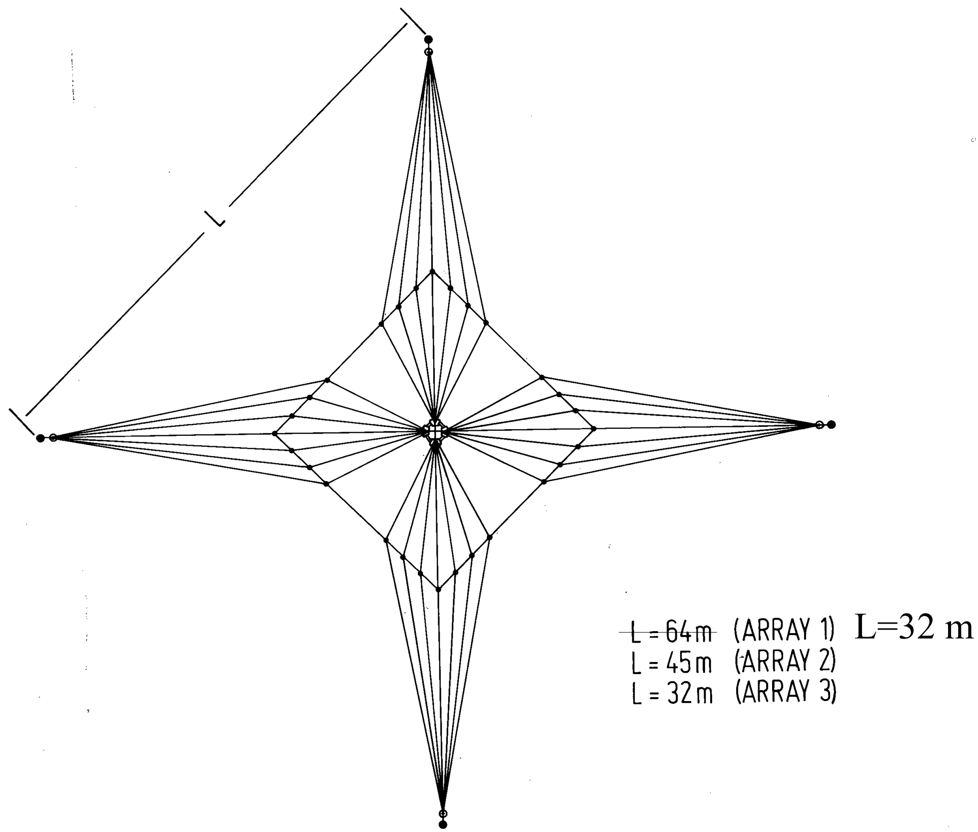
The Heating facility at Tromsø



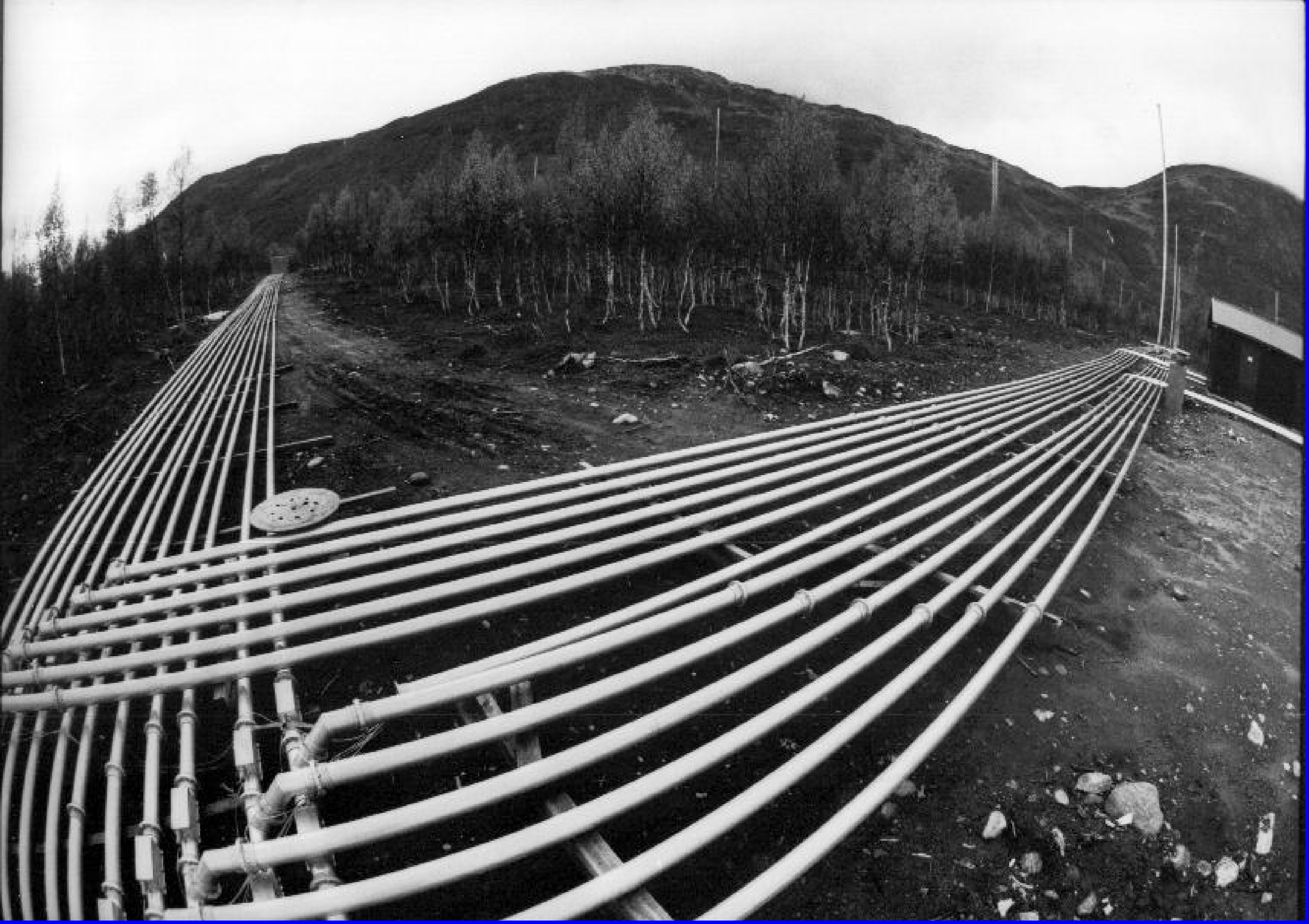


transmitting antenna,
5.4 – 8 MHz
HF Array 1
EISCAT
VHF ISR
EISCAT
UHF ISR
Dynasonde
transmitting
antenna
Morro
array
MF array
Dynasonde
receiving antenna,
5.4-8 MHz
HF Array 3
HF Array 2
4-5.4 MHz
Ionosonde
tower
Dynasonde
receiving
array
100m

A single HEATING antenna


L
~~L = 64m~~ (ARRAY 1) L=32 m
L = 45m (ARRAY 2)
L = 32m (ARRAY 3)

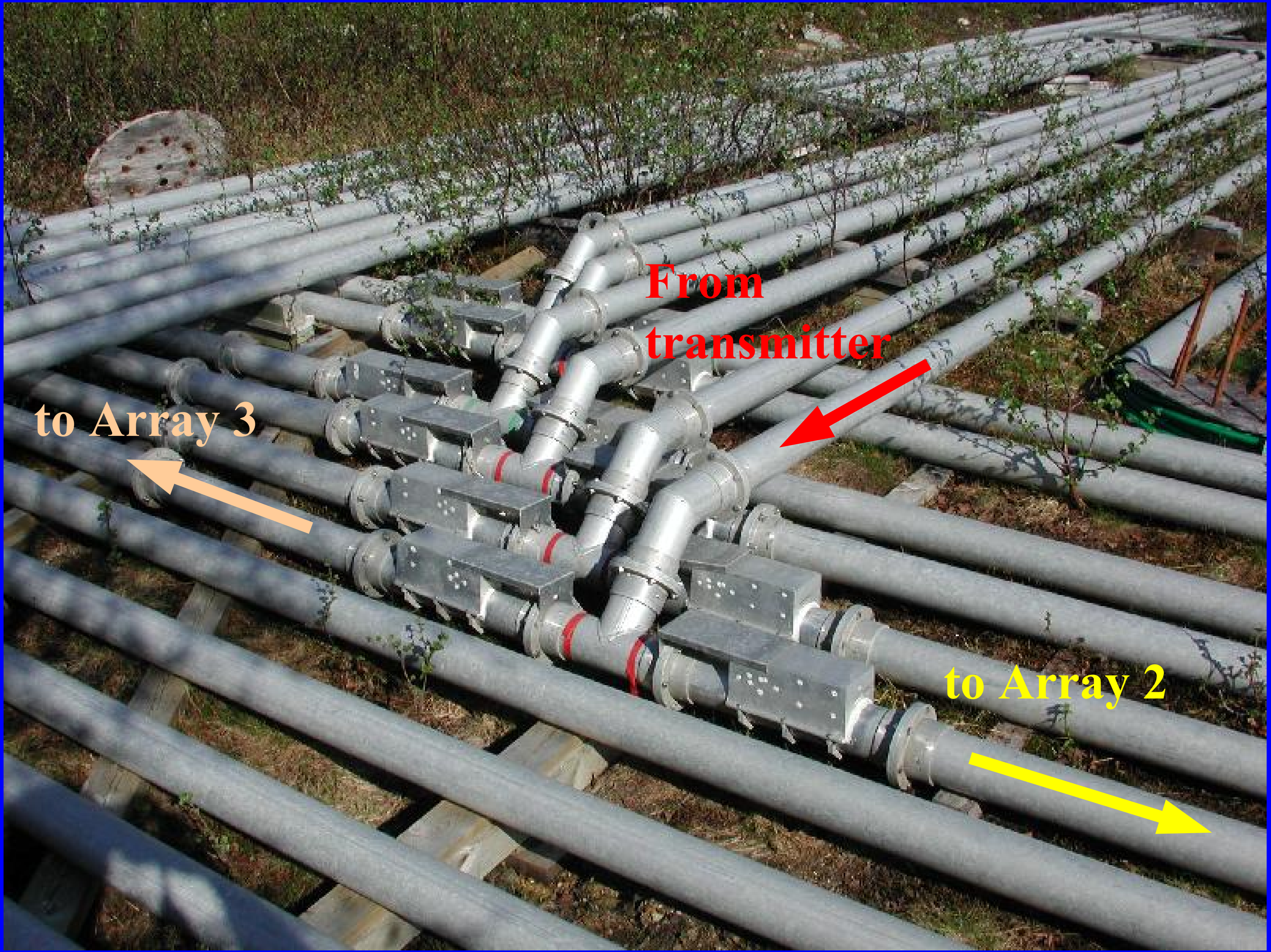
An antenna array



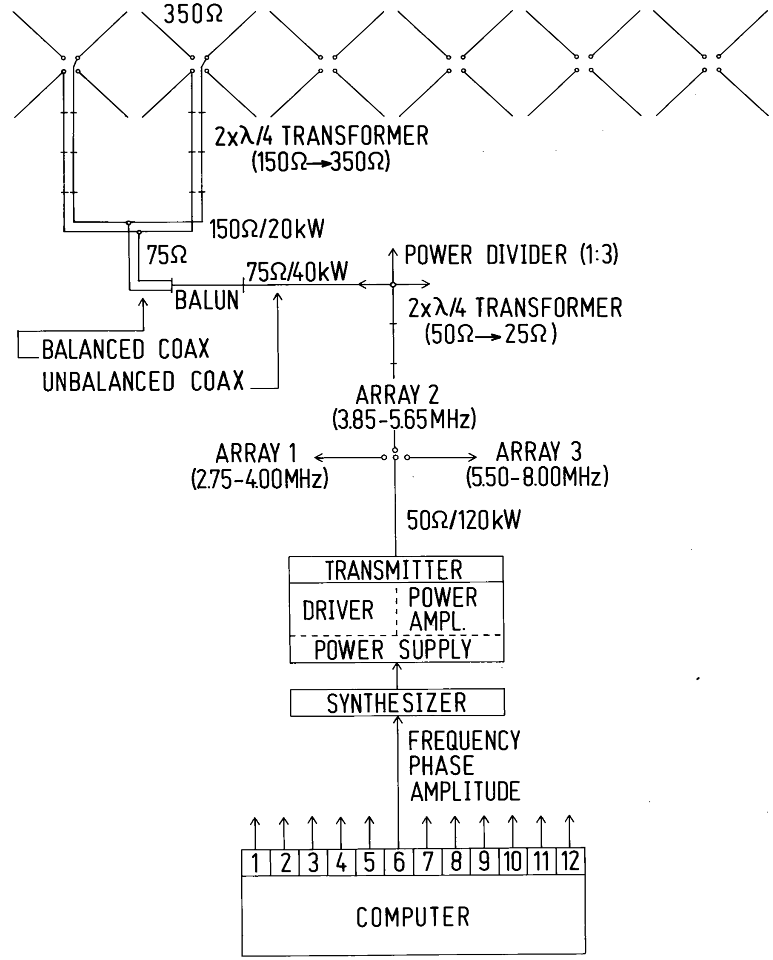
Coax

Only **50 km of home-made aluminium RF coaxial transmission lines with mechanical switches**

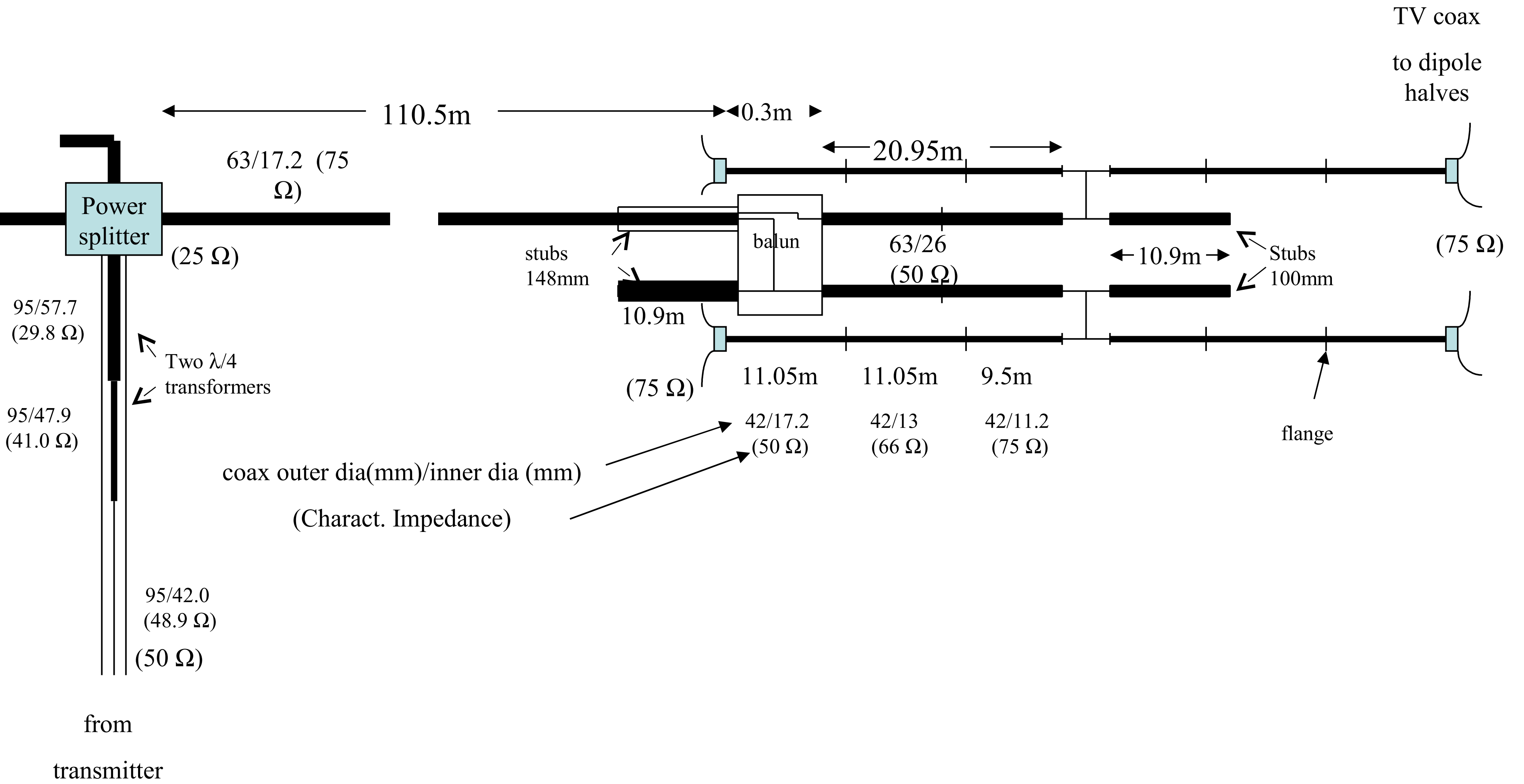
Coaxial switches



Thermal expansion: One of many detours


350Ω
2xλ/4 TRANSFORMER
(150Ω→350Ω)
150Ω/20kW
75Ω
75Ω/40kW
BALUN
POWER DIVIDER (1:3)
2xλ/4 TRANSFORMER
(50Ω→25Ω)
BALANCED COAX
UNBALANCED COAX
ARRAY 2
(3.85-5.65MHz)
ARRAY 1
(2.75-4.00MHz)
ARRAY 3
(5.50-8.00MHz)
50Ω/120kW
TRANSMITTER
DRIVER
POWER
AMPL.
POWER SUPPLY
SYNTHESIZER
FREQUENCY
PHASE
AMPLITUDE
1 2 3 4 5 6 7 8 9 10 11 12
COMPUTER

HF Array-1



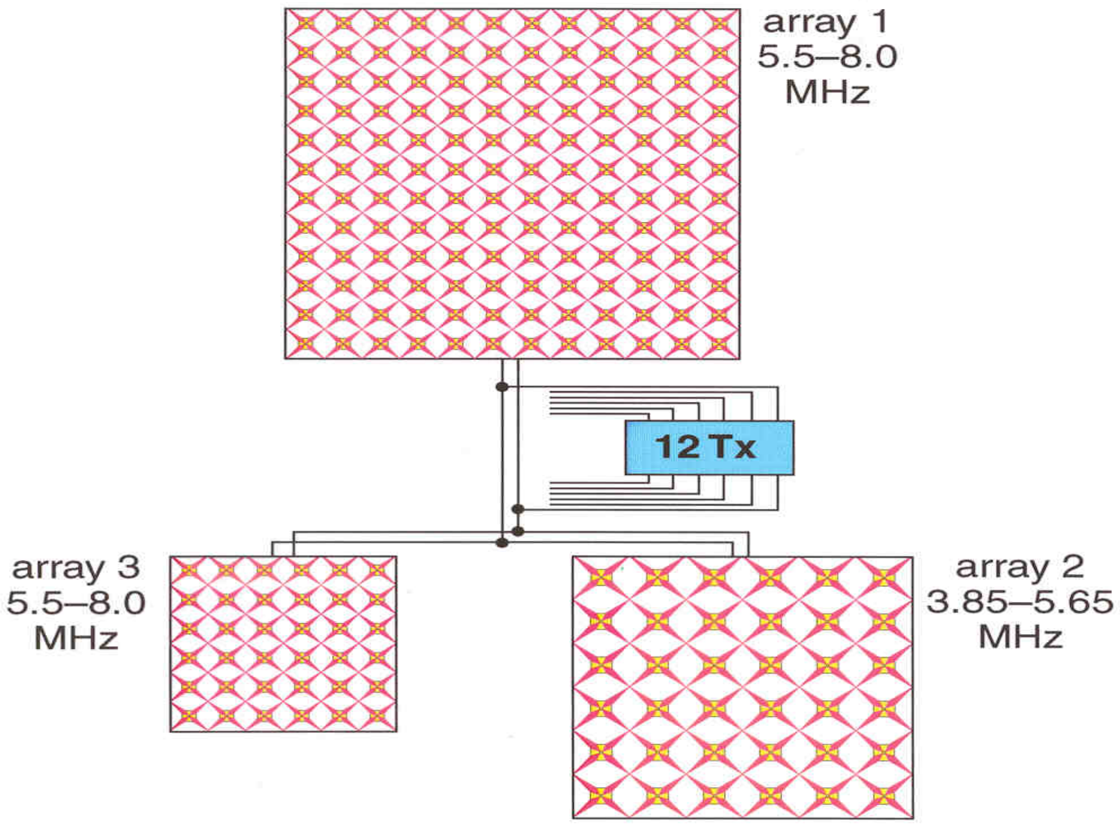
notes:

lengths were measured to the flanges. (MTR, Nov 2007)

coax diameters are from design drawings

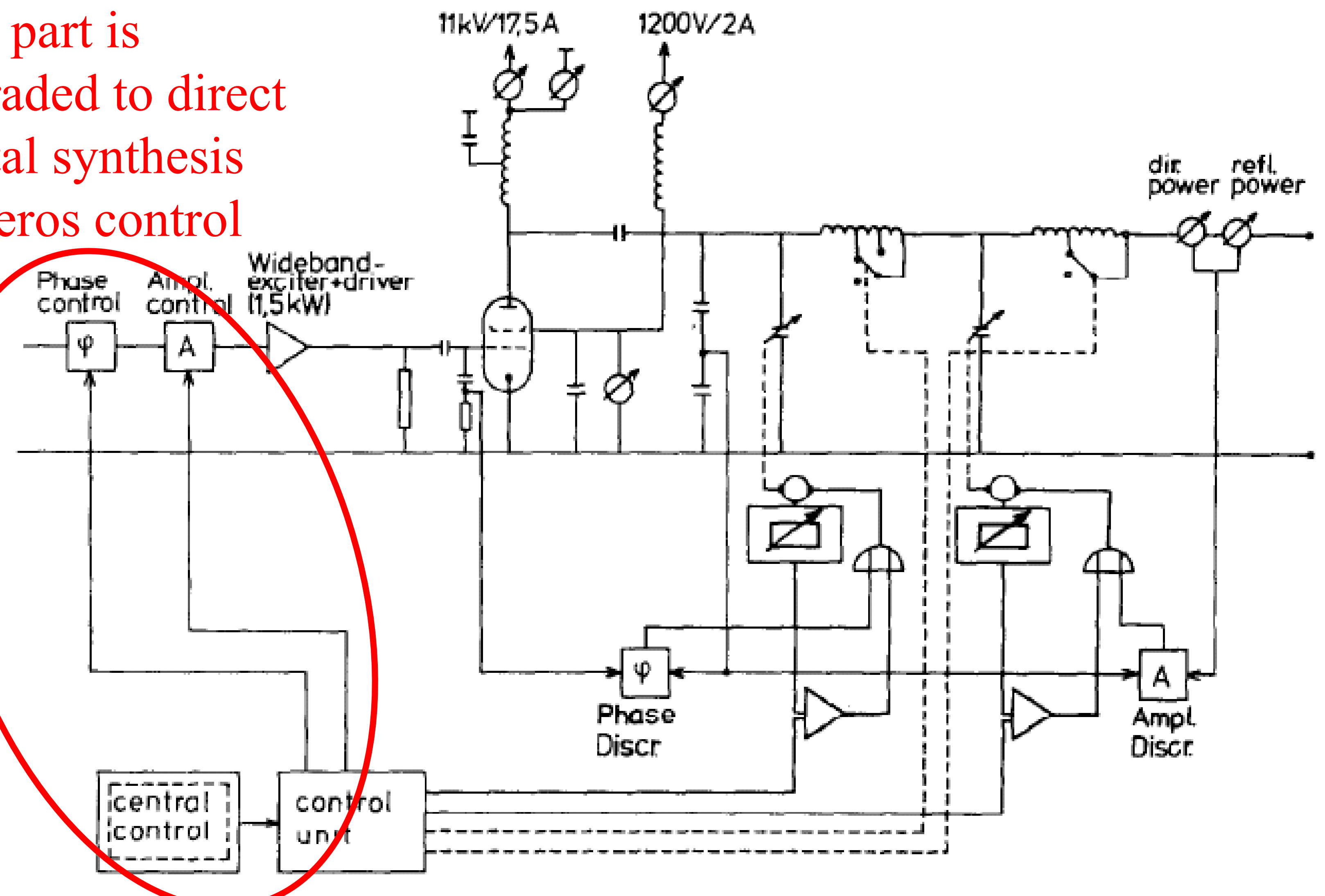
Tromsø Heating Facility

Parameter	Trans.	Array 1	Array 2	Array 3
Frequency (MHz)	$2.7 - 8.0$	$5.5 - 8.0$	$4.0 - 5.5$	$5.5 - 8.0$
Power (kW)	12×100			
ERP (MW)		1200	300	300
Antenna gain (dB)		30	24	24
3-dB Beam width		7.5°	14.5°	14.5°
$\mathbf{E}$ at 250 km (Vm^{-1})		1	0.5	0.5
Power at 250 km (mWm^{-2})		1.6	0.4	0.4



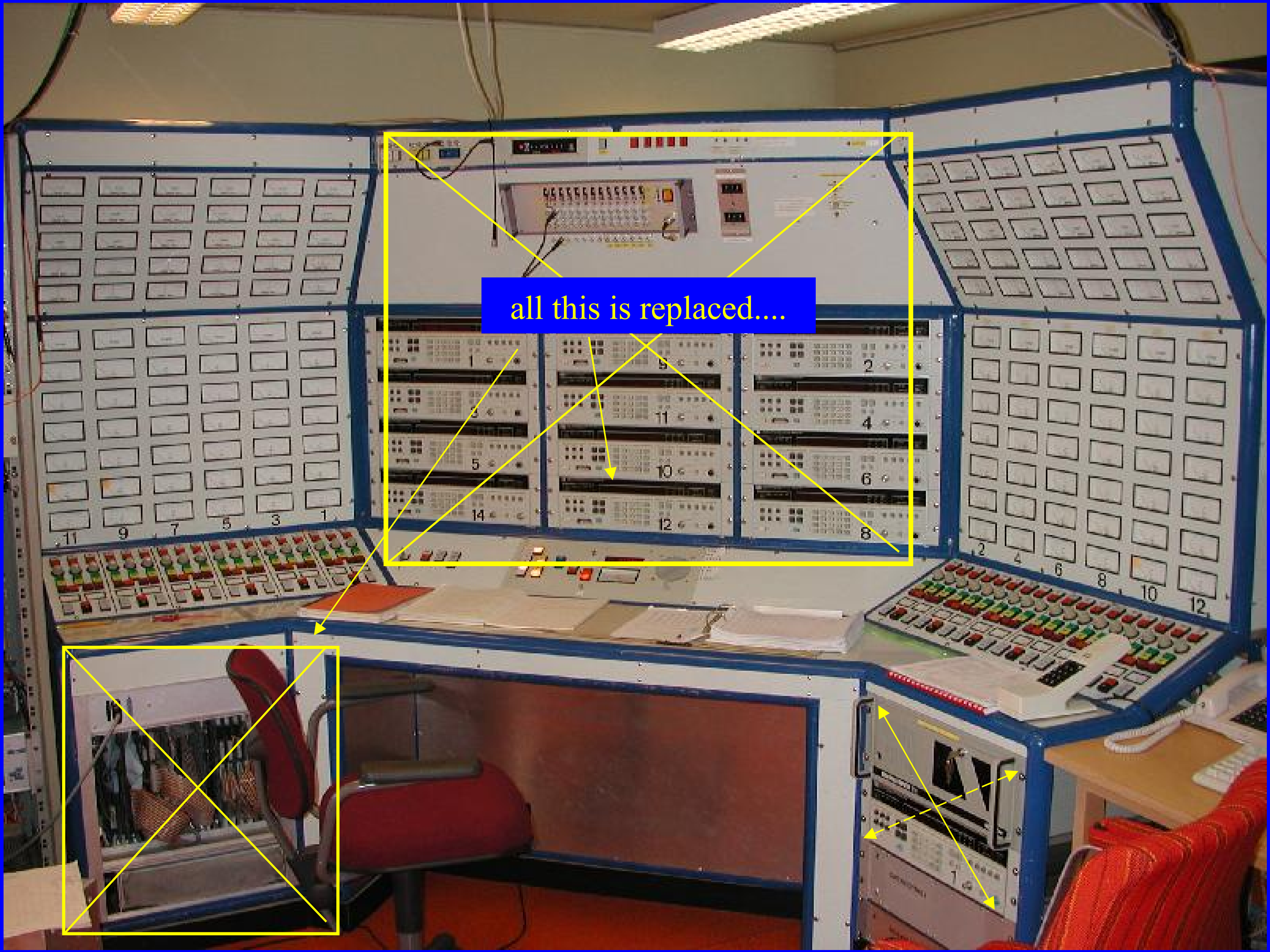
Inside one transmitter

This part is upgraded to direct digital synthesis and eros control



Schematic of one of the 12 transmitters.

Heater control room



EROS as the new control software

- Allows a unified approach to EISCAT's major instruments,
- especially when it comes to the HF radar data (see later)
- Is used to load and control the direct digital synthesizers, radar controllers, transmitter interface, and local oscillator for the radar mode.
- This is the first time that EROS actually controls the high power transmitters, so its use may be limited to EISCAT staff, or at least scientists will have to use it together with EISCAT staff.
- Software is easily changeable and expandable.

File Edit View Bookmarks Widgets Feeds Tools Help

http://www.sgo.fi/~jussi/eiscat/erosdoc/eros_comman

Search with Goog

Heating Command List

See also Heatig Command Reference

A --
- ampgen
- autotuning

B --
- beam

C --
- changehamplitude
- changehphase

D --
- dds
- deselectddsboard

H --
- heating
- ~~hfcommand~~

L --
- loaddds

M --
- mpvwrite

P --
- ~~petclearcommandqueue~~
- ~~petgetfile~~
- ~~petls~~
- ~~petpwd~~
- ~~petputfile~~
- printbeam
- printdds
- printtx

S --
- selectddsboard
- setcapacitor
- sethamplitude
- sethfrequency
- sethphase
- startddsboard
- syncdds

EROS HF commands

(still under development)

File Edit View Bookmarks Widgets Feeds Tools Help

http://www.sgo.fi/~jussi/eiscat/erosdoc/cmds_hot.html#sethfrequency

Search with Google

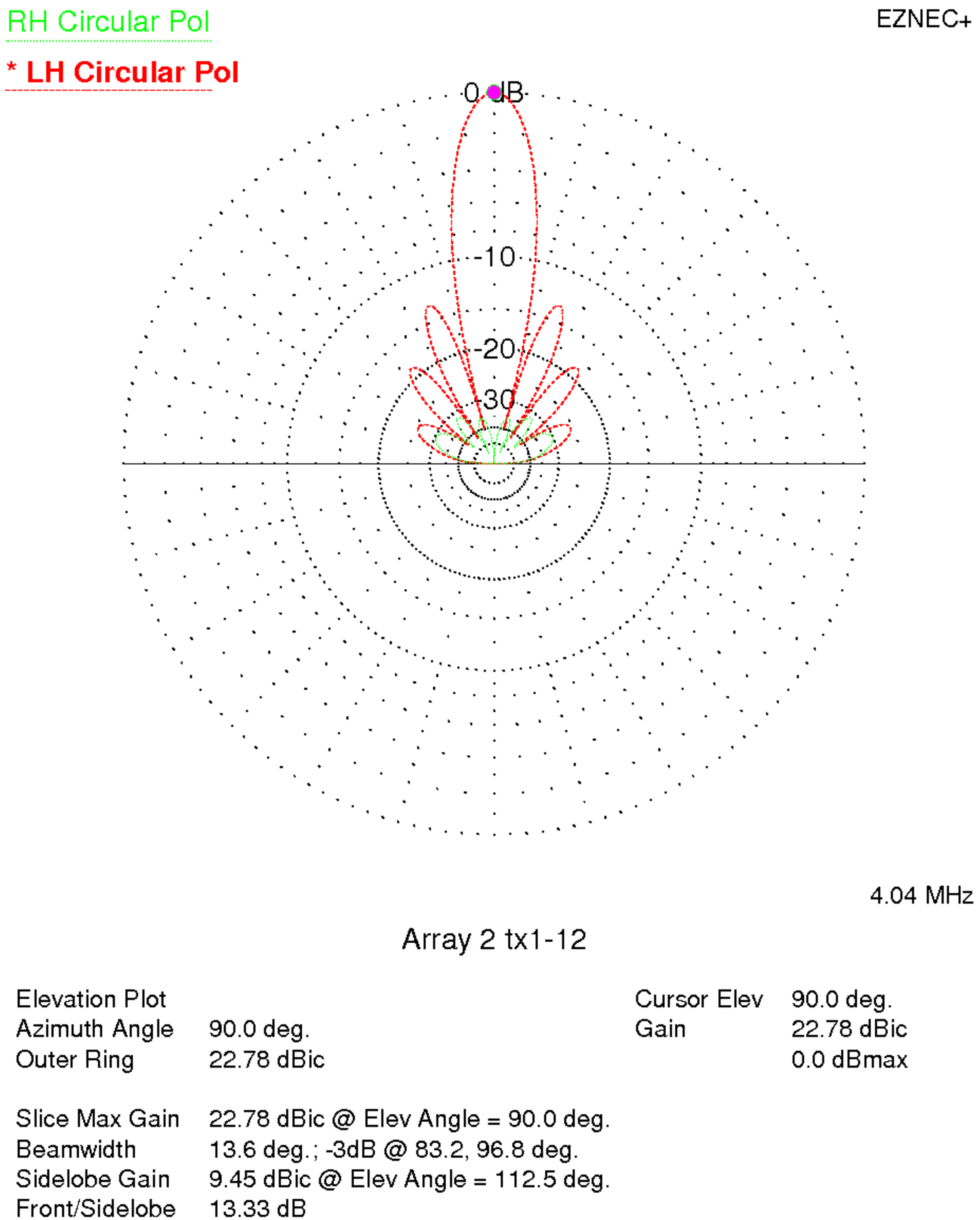
sethfrequency

```
    Set carrier frequency on one or more of the Heating exciter DDS units.
Synopsis
    sethfrequency ?-nowait? ?-chec? ?-verbose? ?TXLIST? FREQVALUE ?FREQUNIT?
    sethfrequency ?-nowait? ?-chec? ?-verbose? ?TXLIST? -raw INTEGER
Description
    Set the frequency turning word (FTW) on the specified DDS units.
    -> TXLIST is of the form
            spec ?spec ...?
       where
            spec = tN | mK | tN,N,... | mK,K | all
       The DDS unit number N is 1-12, or is "*" to imply "t1 ... t12".
       The number K of the "master" DDS is 1 or 2, or is "*"
       to imply "m1 m2".
       The spec "all" is equivalent to "m* t*".
       If TXLIST is missing, "all" is assumed.
    -> FREQUNIT can be either MHz, kHz or Hz. Default is "MHz".
    -> If the flag -raw is used, the given INTEGER is used as the FTW
       without modifications. The INTEGER can be input as any of the
       standard C-language integer strings.
    -> If the flag -check is used, input is checked and a normalized
       ddslist and ampvalue is returned, but no amplitude setting is done.
    -> Note that after setting frequencies, normally a syncdds should
       also be given.
    -> If the flag -nowait is used, the command does not check whether
       the DDS is really free to use (not being used by R/C). By default,
       the command waits for the DDS to be free.
Examples
    sethfrequency 4.04 ;# all DDS (including m1 and m2).
    sethfrequency t1 5.4
    sethfrequency m1 5400 kHz
    sethfrequency m1,2 t1,2,3,4 4.04 MHz
    sethfrequency m1 m2 t1 t2 t3 4.04
    sethfrequency m2 t* 4.04   ;# all DDSs except m1
See also
    dds sethamplitude sethphase syncdds
```

---

sethphase

```
    Set phase offset on one or more Heating exciter DDS units.
```



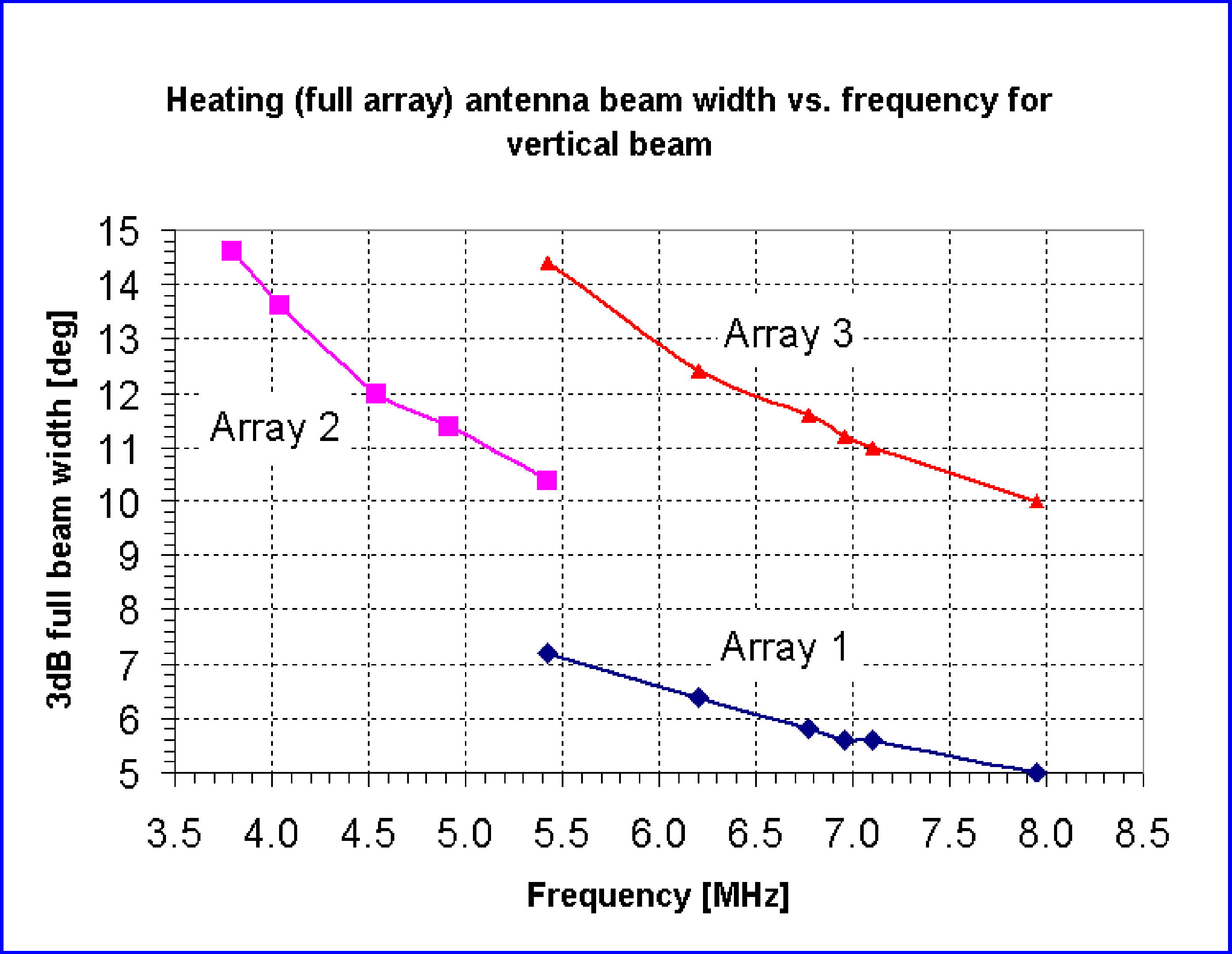
Model radiation pattern using EZNEC

Assuming a perfect ground, the modelled gain is 22.78 dB at the lowest frequency of the array (#2)

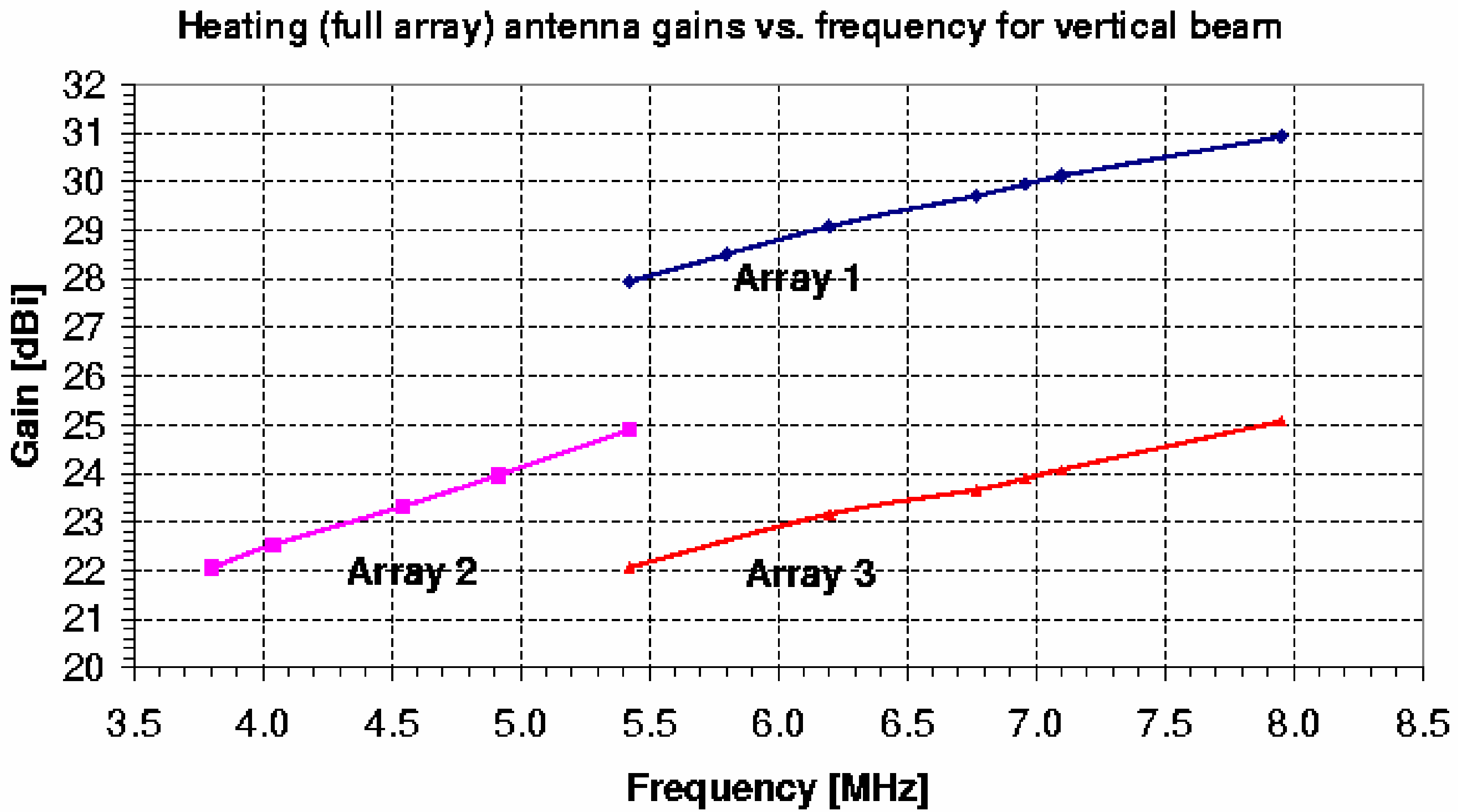
BUT, putting in more realistic ground conductivity and dielectric constant gives us about 1.1 dB less gain ! (= 0.77)

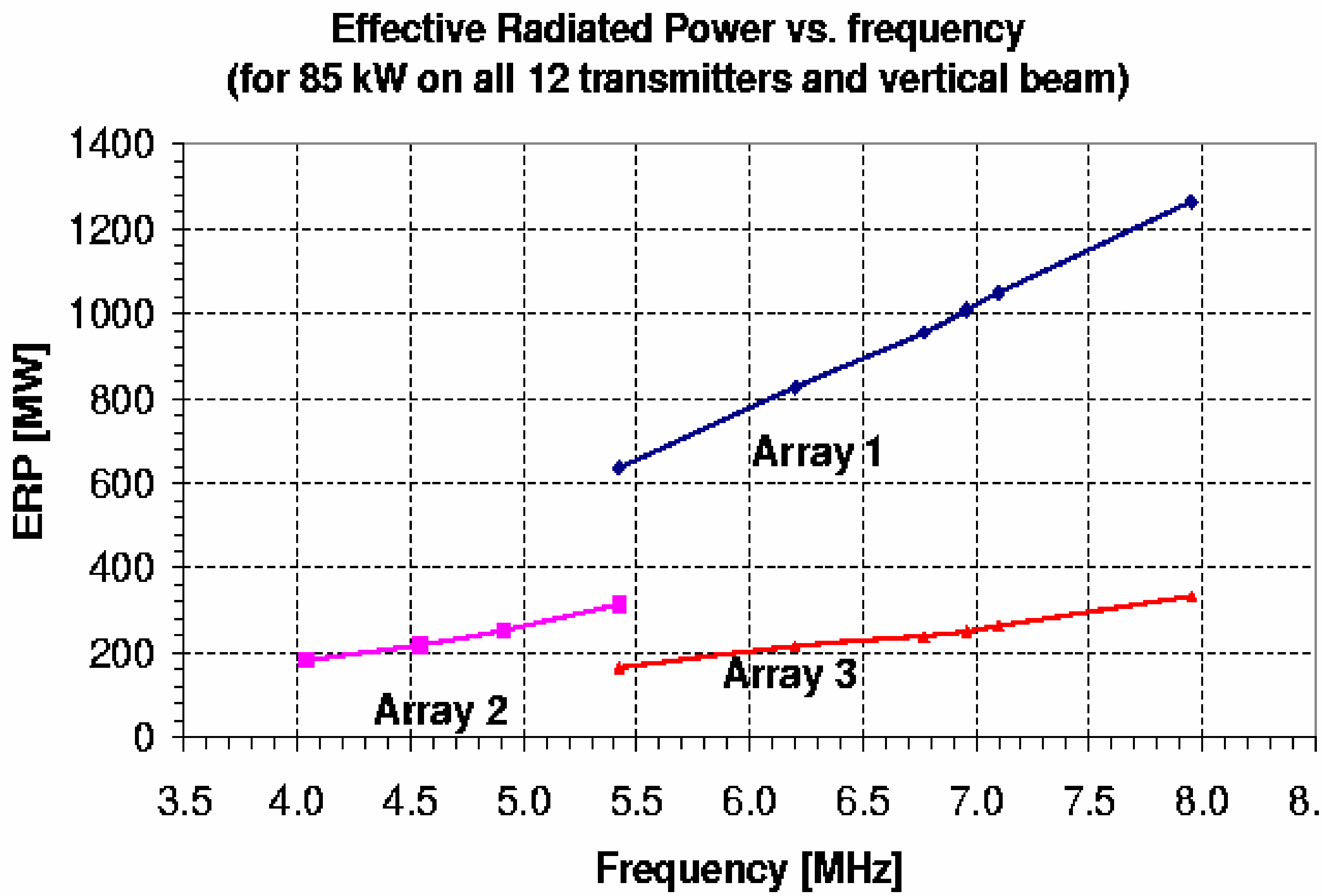
Gain=21.68 dB

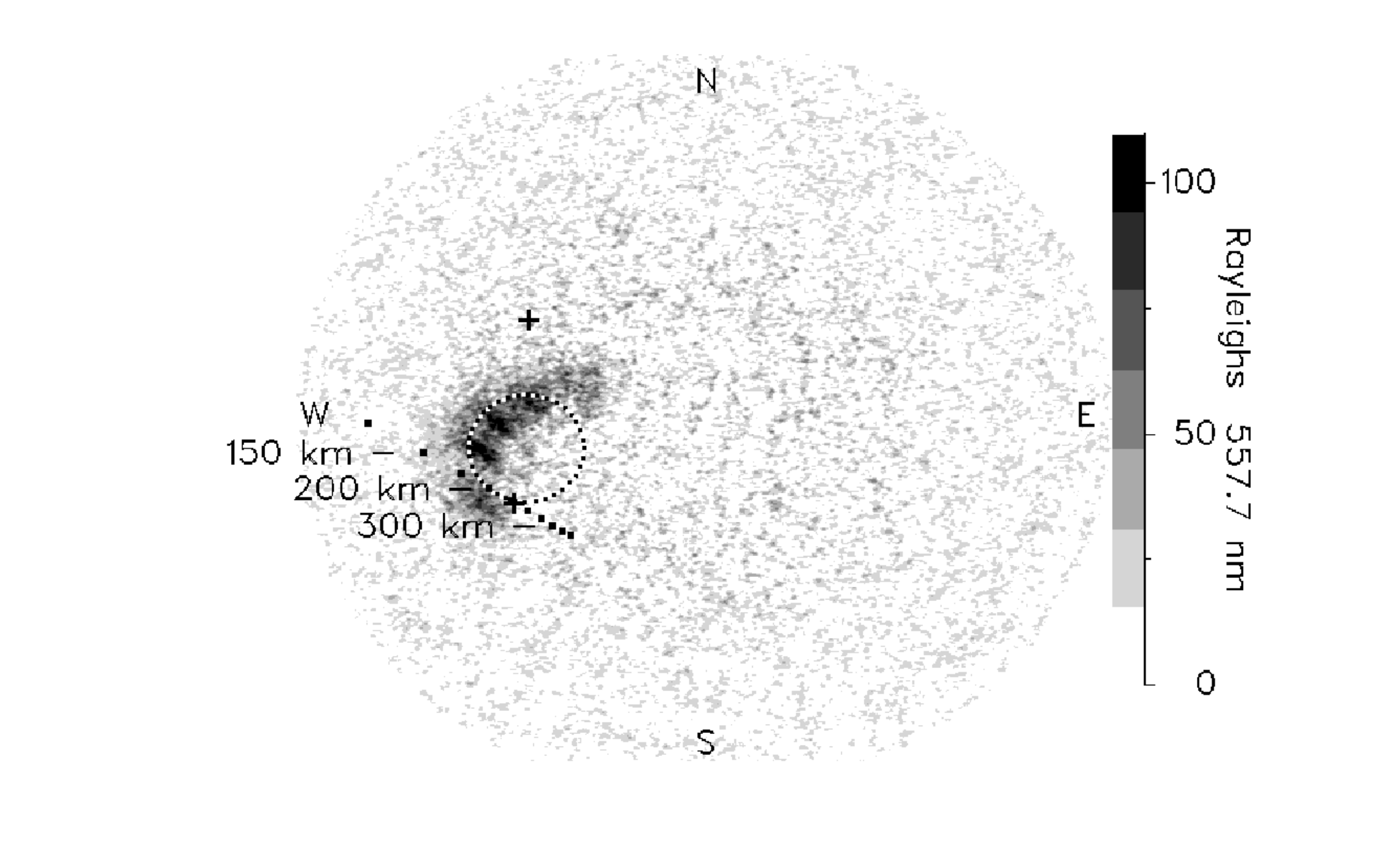
Array beam widths as function of frequency



Antenna array gain as function of frequency




Effective Radiated Power vs. frequency
(for 85 kW on all 12 transmitters and vertical beam)
ERP [MW]
1400
1200
1000
800
600
400
200
0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Frequency [MHz]
Array 1
Array 2
Array 3



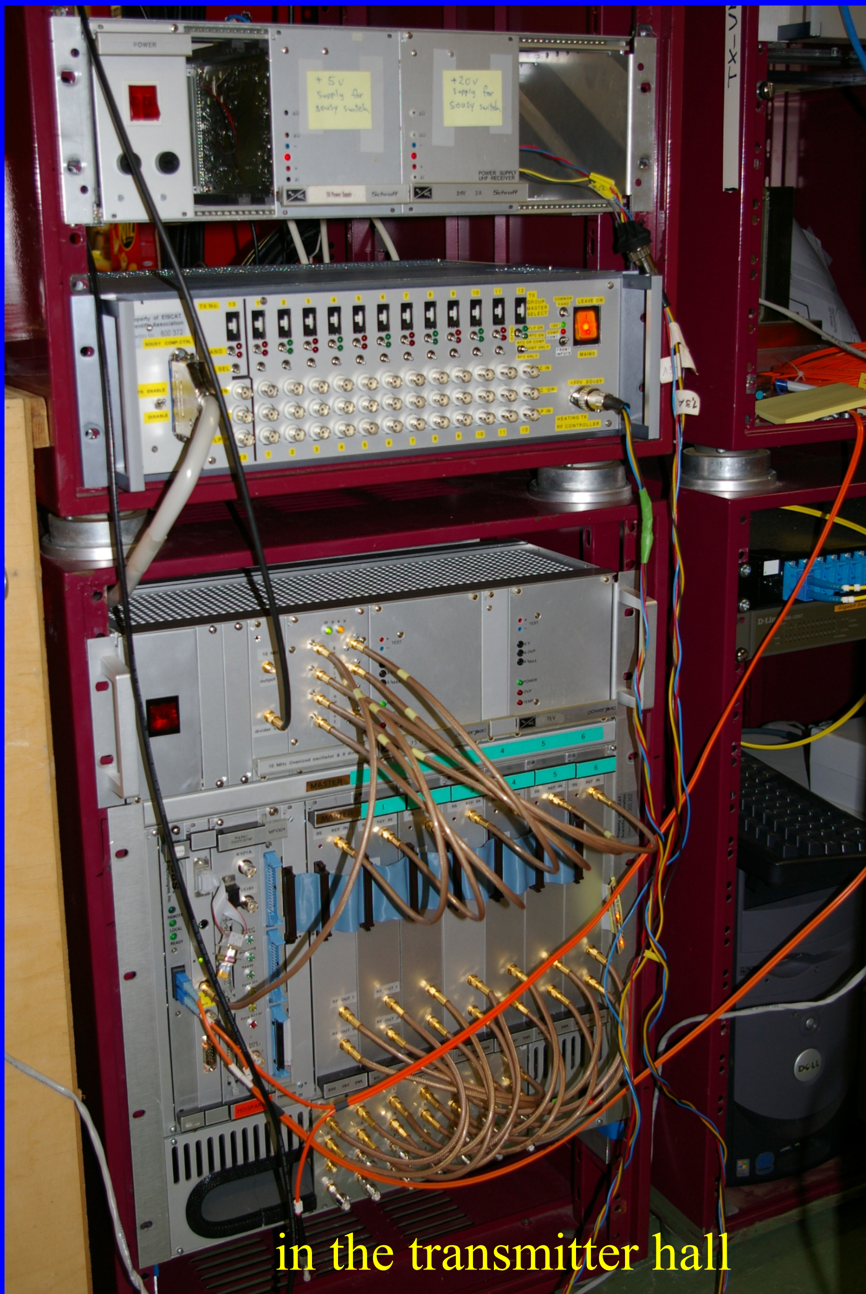
The artificial auroral structure at 16:37:05 UT on12 November 2001, 5 s after HF pump turn on. Integration time =5 s. The image is taken in the zenith from Skibotn and has a 50º field of view (large circle). The -3 dB locus of the pump beam assuming free space propagation is shown as a small circle (beamwidth = 7.4º), projected at 230 km altitude and tilted 9º south of the HF facility at Ramfjordmoen. The upper cross shows the location of the HF transmitter whilst the lower cross shows the magnetic field line direction (12.8º S), both projected at 230 km. The dotted line represents the magnetic field line connected to Ramfjordmoen and the labels give altitude. (from Kosch et al., GRL, 2004)

Heating transmitter log sheet — Page: 1059

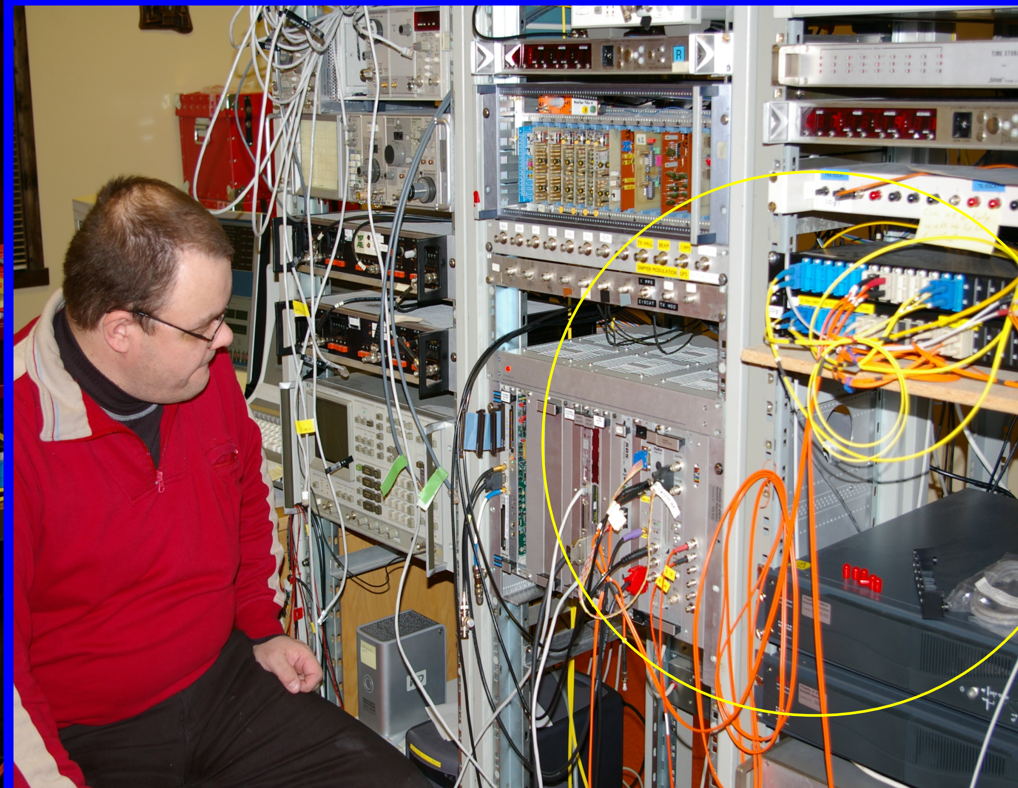
Date	Time (UT) ON	Time (UT) OFF	Freq (MHz)	Power (kW)	Transmitters	Array	Polzn	Directn	Description of Modulation	Associate, and Comments
30.10.02	04:00	04:55	"	"	"	2	0	-12°	55min CW.]	[NO/GE]
	09:00		7.100717	85	1-6	3	0	-12°	CW (tune 09:00-09:02:46 UT)	
		09:55	7.100898	85	7-12	3	0	-12°		
	10:00		7.953717	85	1-6	3	0	-12°	CW (tune 10:00 - 10:04:37 UT, Tx10 dropped out)	
		10:55	7.953898		7-12	3	0	-12°		

Two halves of array going through one phase cycle

7.953 MHz, Array 3



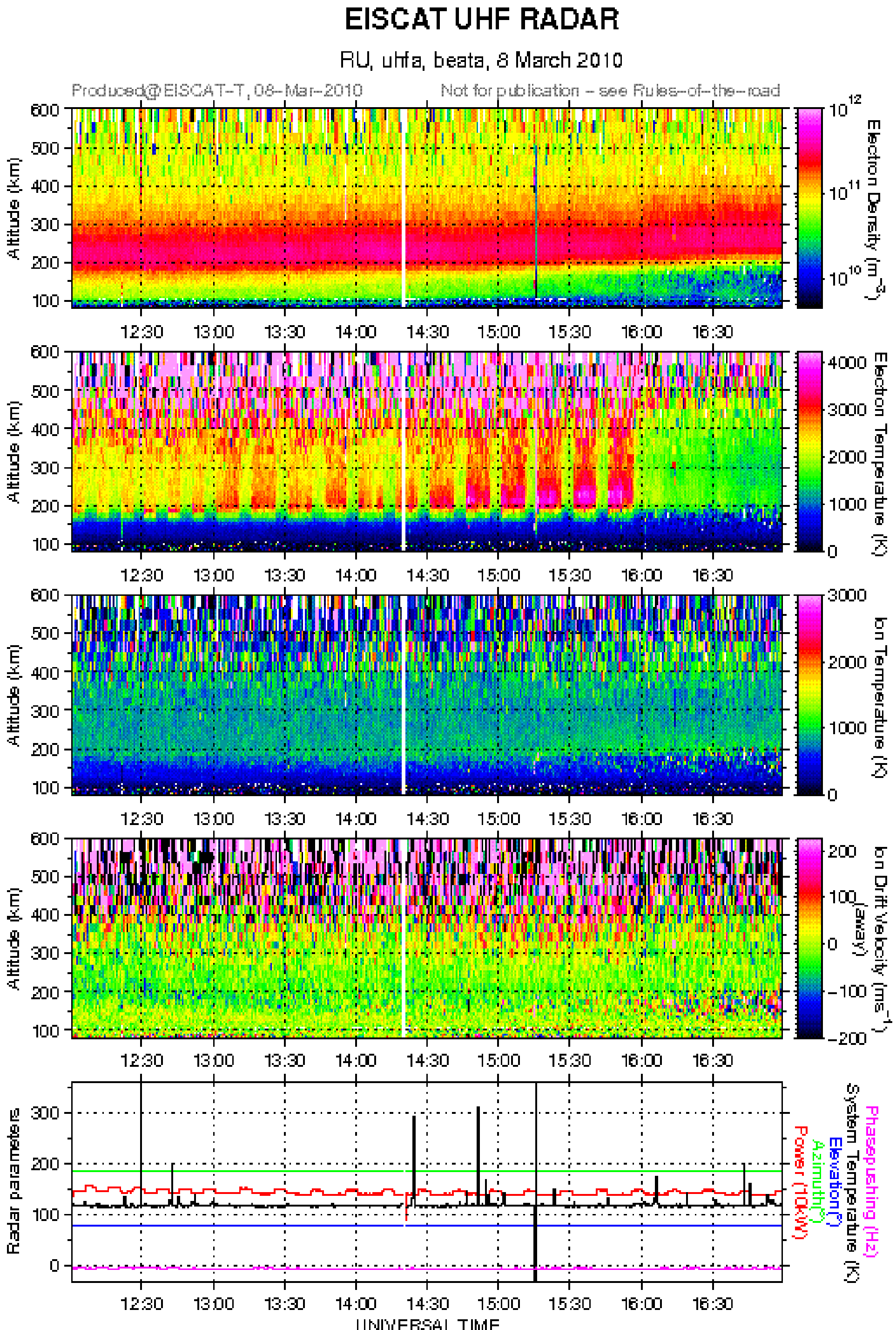
in the transmitter hall



in the control room

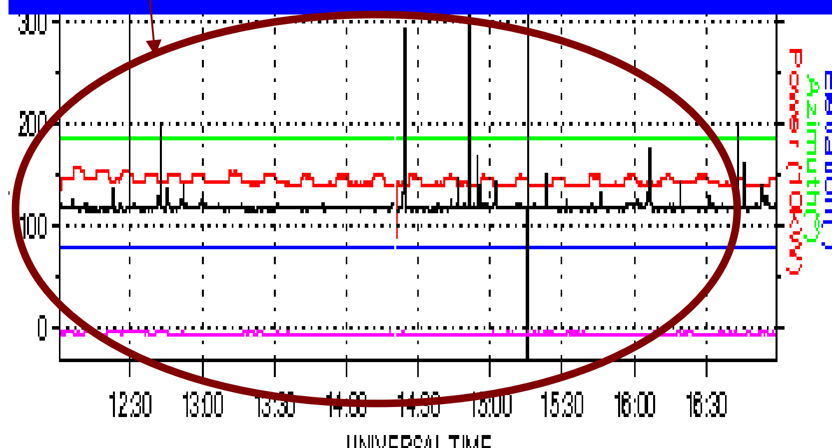
Practical things about heater operation

Heater on/off modulates the power line voltage to the EISCAT radars.



Turning the heater on and off changes the line voltage and the radar power.

The radars do have a servo system to keep the power constant but it has a time constant.



Practical things about heater operation

Heater on/off modulates the power line voltage to the EISCAT radars.

High power consumption by Heating is expensive - low duty cycles (<50%) are encouraged.

Sometimes faults or poor connectors in the coaxial feed system may cause broad-band arcing and interference on the VHF radar.

Time scales and modulations

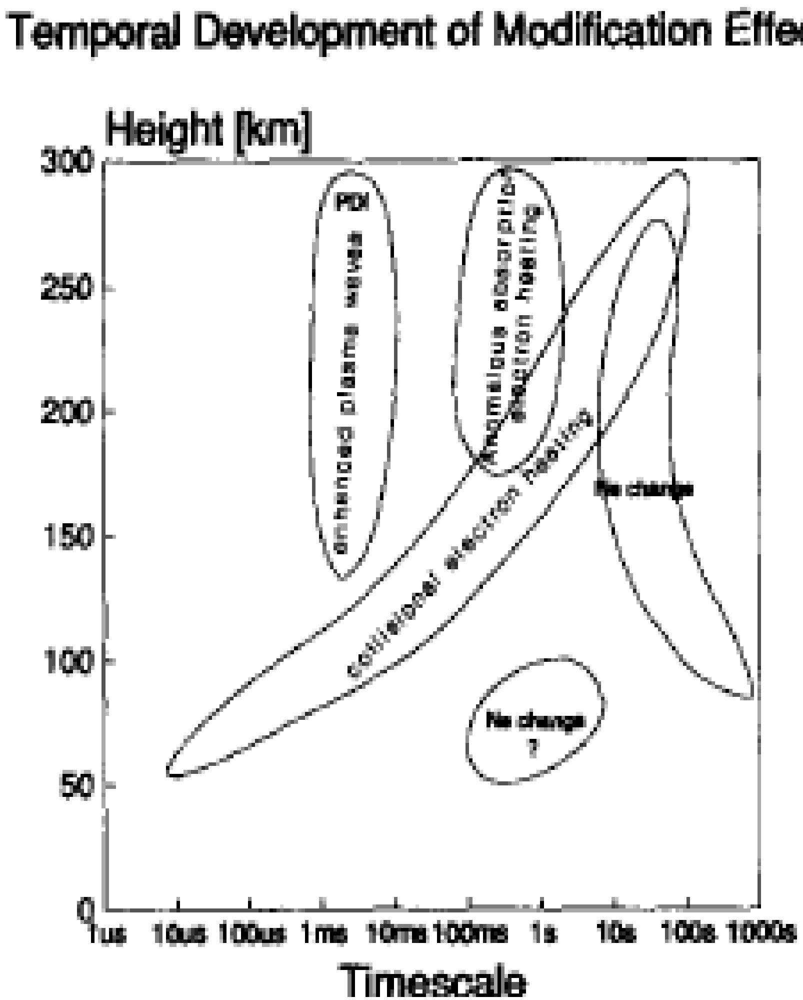


Fig. 6. Timescales of heating-induced phenomena as a function of height.

<u>Typical modulations</u>

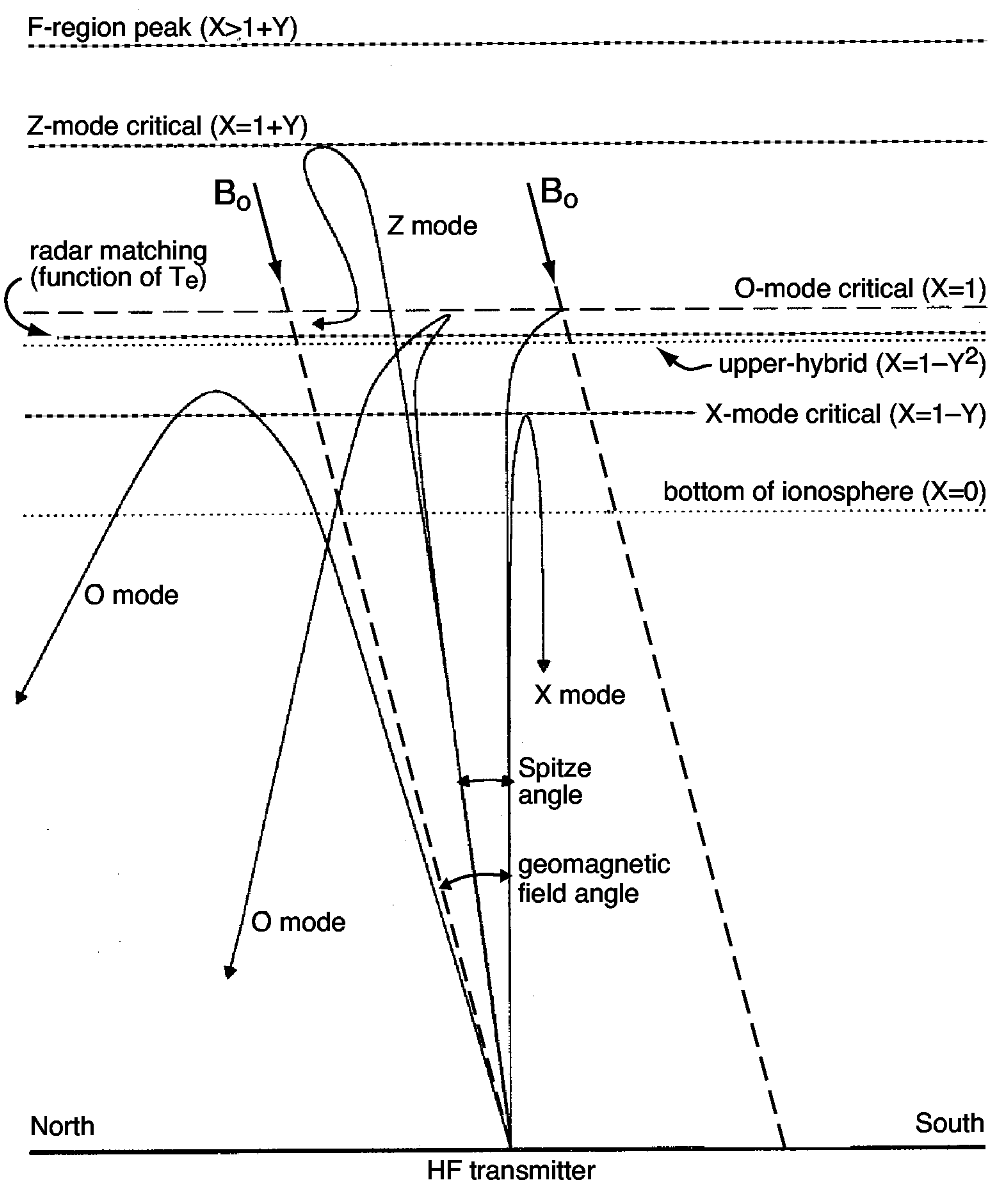
100 ms on every 10s

10 min on, 6 min off

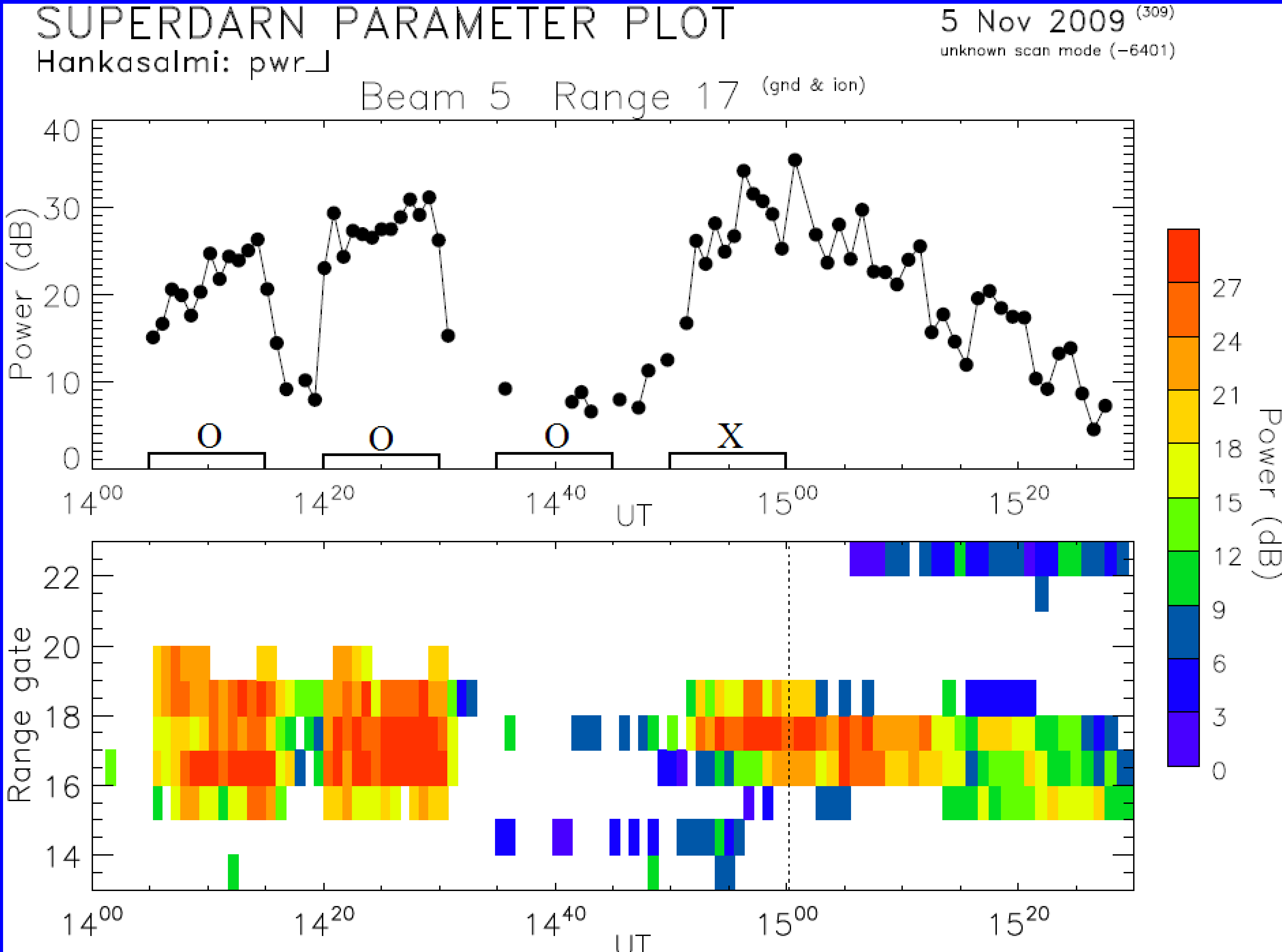
20 s on, 160 s off

2.4 kHz AM for 10s
0.7 kHz AM for 10s
and repeat

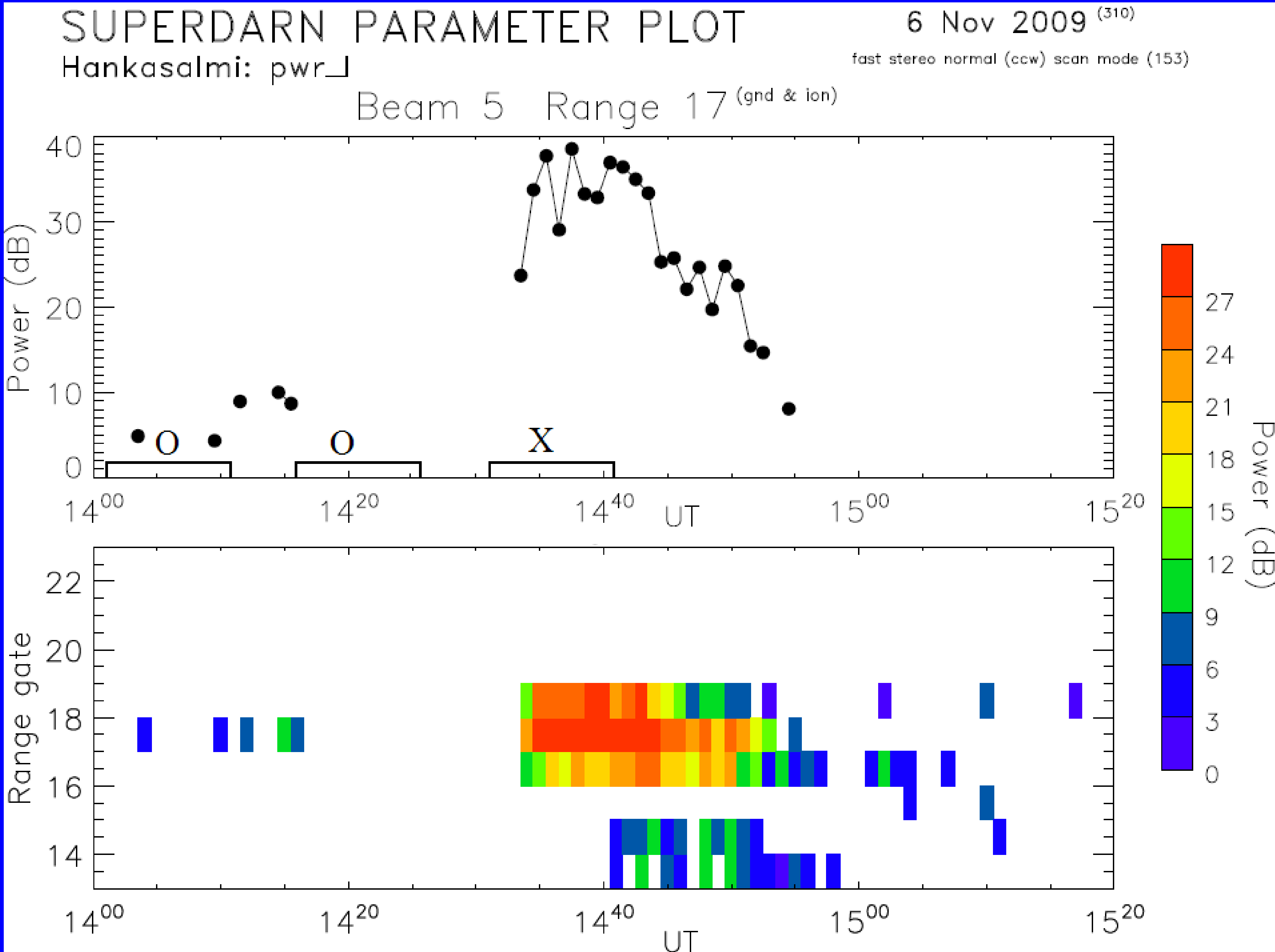
30 us on every 10 ms



Schematic view of HF ray paths in the bottomside F region for $f_oF2>f_{hf}+f_{ce}$ where f_oF2 is the peak F-region plasma frequency (the maximum O-mode reflection frequency), f_{hf} is the HF, or RF, pump frequency, and f_{ce} is the electron cyclotron, or gyro-, frequency.
Adapted from *Rietveld et al.* [1993] figure 4.



SUPERDARN PARAMETER PLOT
Hankasalmi: pwr_l
5 Nov 2009 (309)
unknown scan mode (-6401)
Beam 5 Range 17 (gnd & ion)
Power (dB)
O
O
O
X
UT
Range gate
Power (dB)


SUPERDARN PARAMETER PLOT
Hankasalmi: pwr_l
6 Nov 2009 (310)
fast stereo normal (ccw) scan mode (153)
Beam 5 Range 17 (gnd & ion)
Power (dB)
O
O
X
UT
Range gate
Power (dB)
14 00
14 20
14 40
15 00
15 20

Heating as a radar

Heating is normally a transmitter connected to one of three antennas, actually arrays.

Two of the antenna arrays (1 & 3) have the same frequency range but different gains and beamwidths.

So by disconnecting one of the arrays from the transmitter and combining the signals from the rows of antennas we could use one array as a receiving antenna without having a transmit/receive switch.

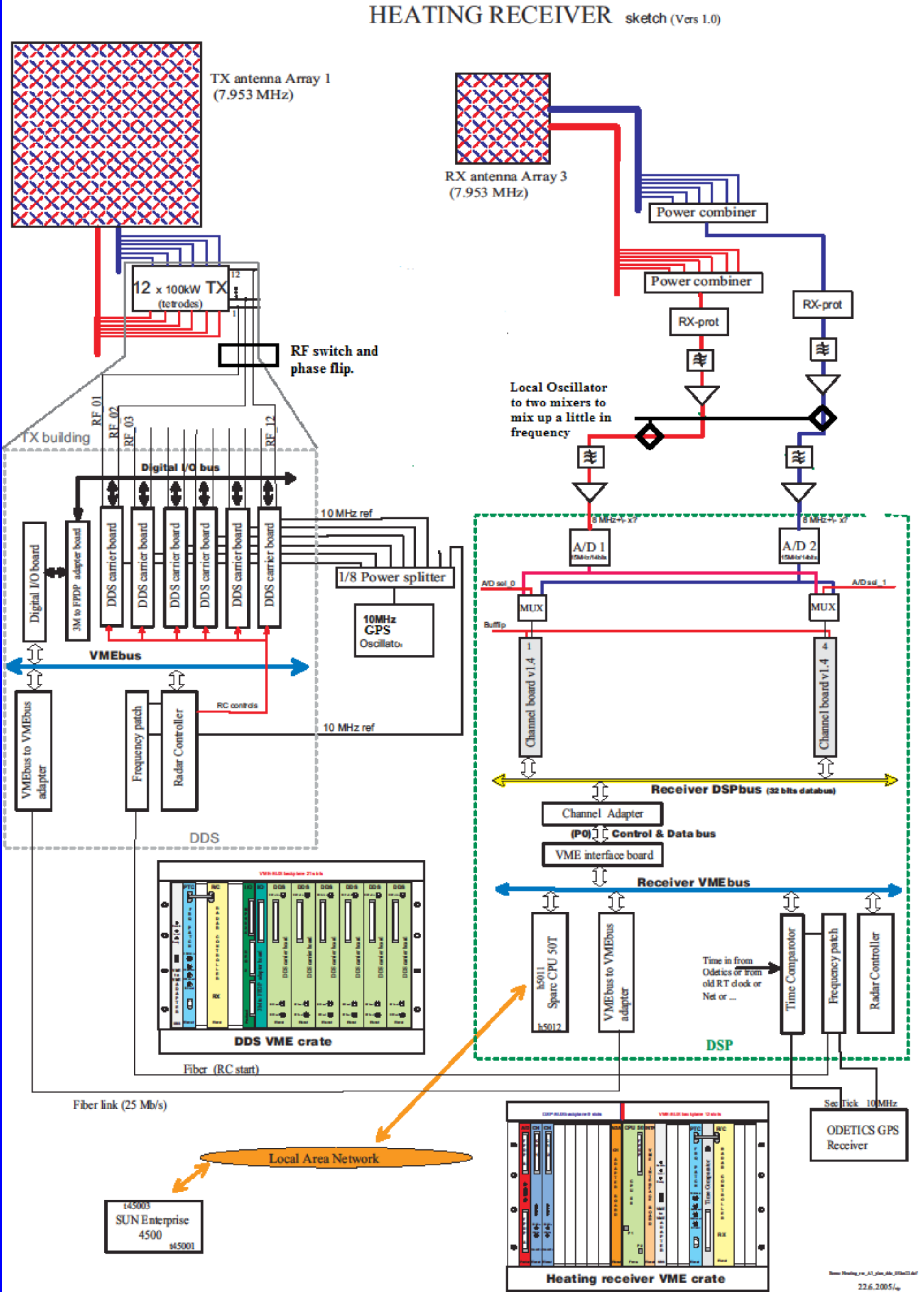
Magnetospheric Radar

UHF and VHF radars sometimes see enhanced ion-acoustic echoes associated with the aurora (NEIALs)

They are more common at 224 MHz than at 930 MHz. I hear that also at 150 MHz in Kharkov they have seen such echoes.

Can we see them at HF (e.g. 8 MHz, the highest heater frequency) i.e. at 19m Bragg scale ?

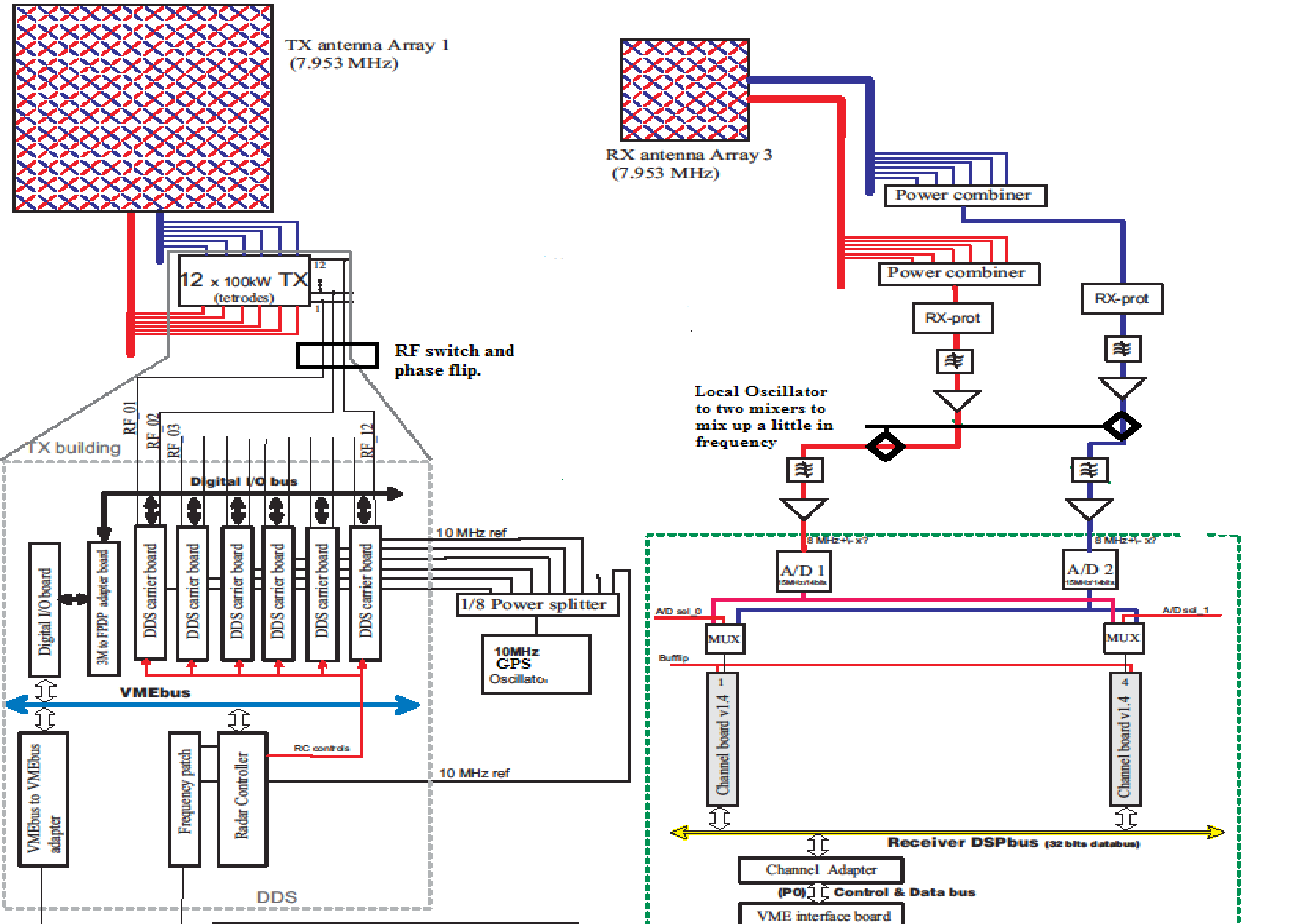
We have two antenna arrays covering 5.5-8 MHz. Disconnect one from the transmitter and use as a receiving antenna, avoiding the need for transmit/receive switches.



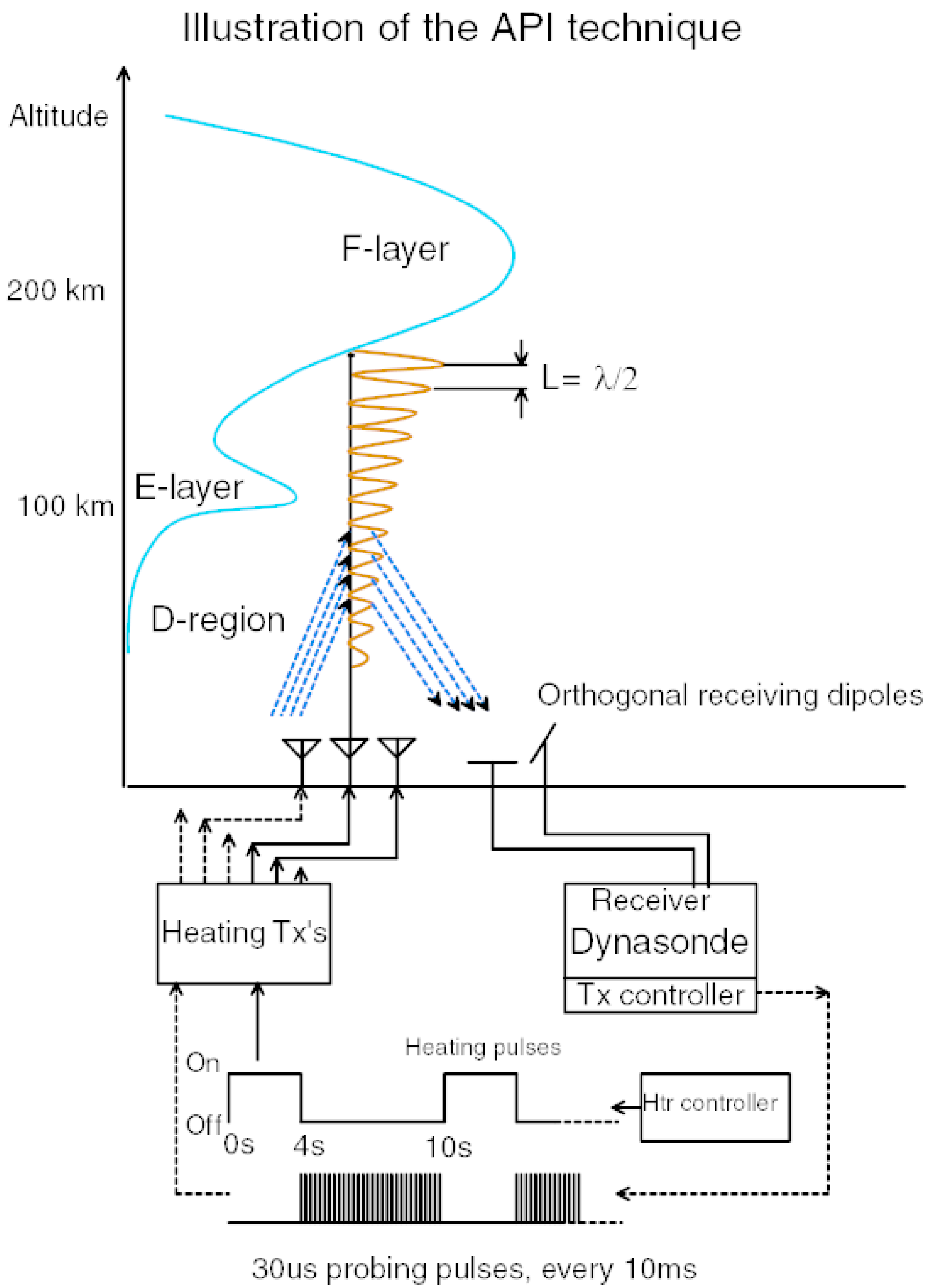
Using antenna array-3 as a receiver

Array-3 feed lines, power combiners

HEATING RECEIVER sketch (Vers 1.0)



Artificial Periodic Irregularities (API)

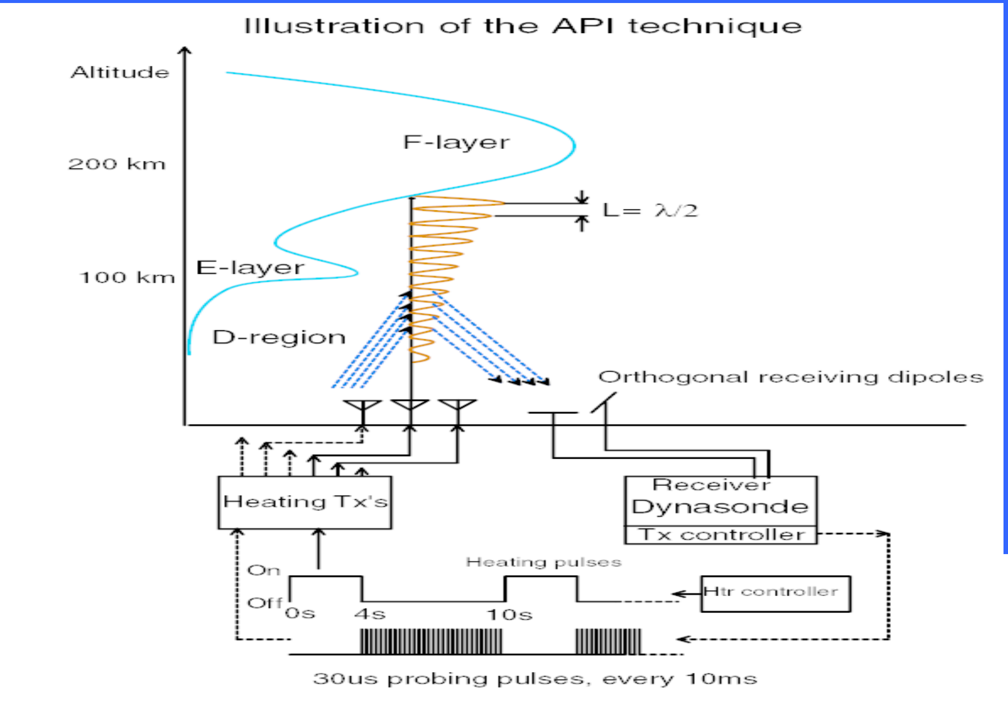


The API technique was invented at SURA and allows any HF pump and ionosonde to probe the ionosphere. API are formed by a standing wave due to interference between the upward radiated wave and its own reflection from the ionosphere.

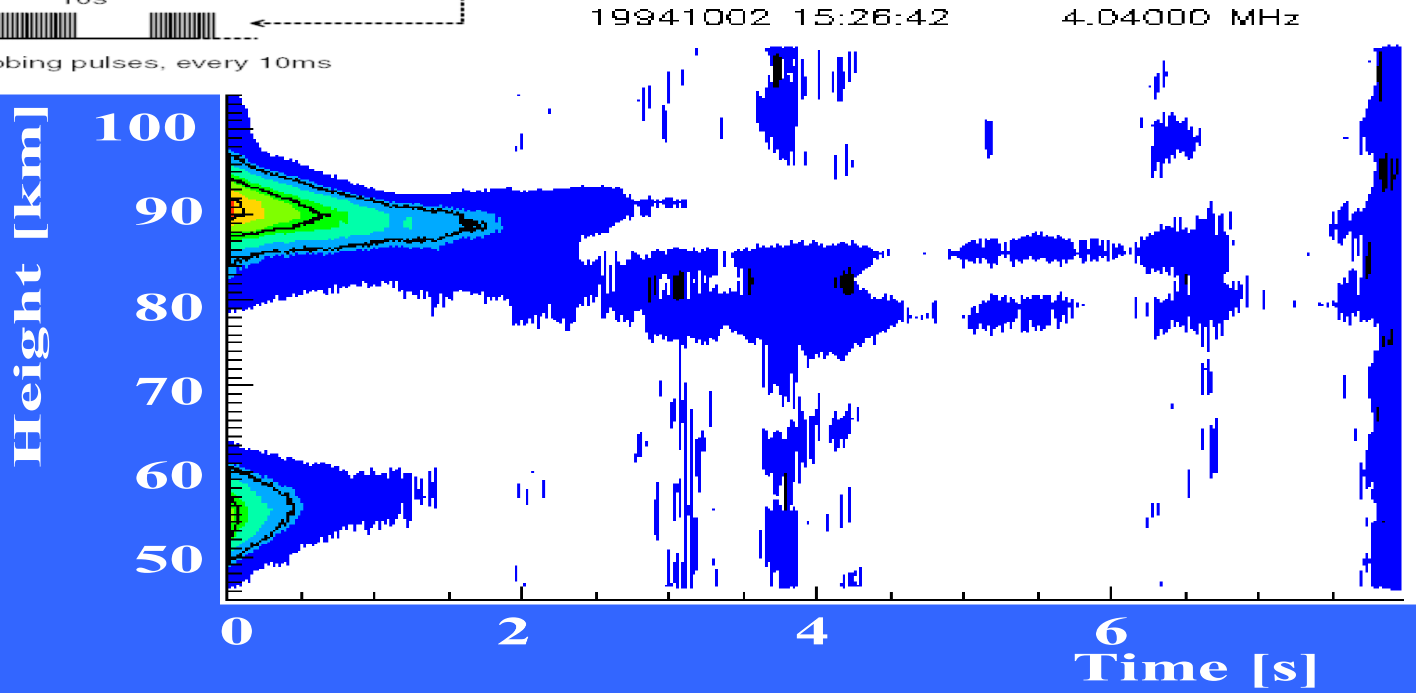
Measured parameters include: N(n), N(e), N(O-), vertical V(i), T(n), T(i) & T(e)

Use HF to explore unknown regions

with Artificial Periodic Irregularities (API)



The decay of API as a function of height and time in the D-region and mesosphere gives information on electron density, ion chemistry, winds etc.



Dynasonde (HF sounder)

For HF experiments an ionosonde is rather essential.

At Tromsø we have two in fact, EISCAT's dynasonde and UiT Digisonde. (We also have a dynasonde on Svalbard)

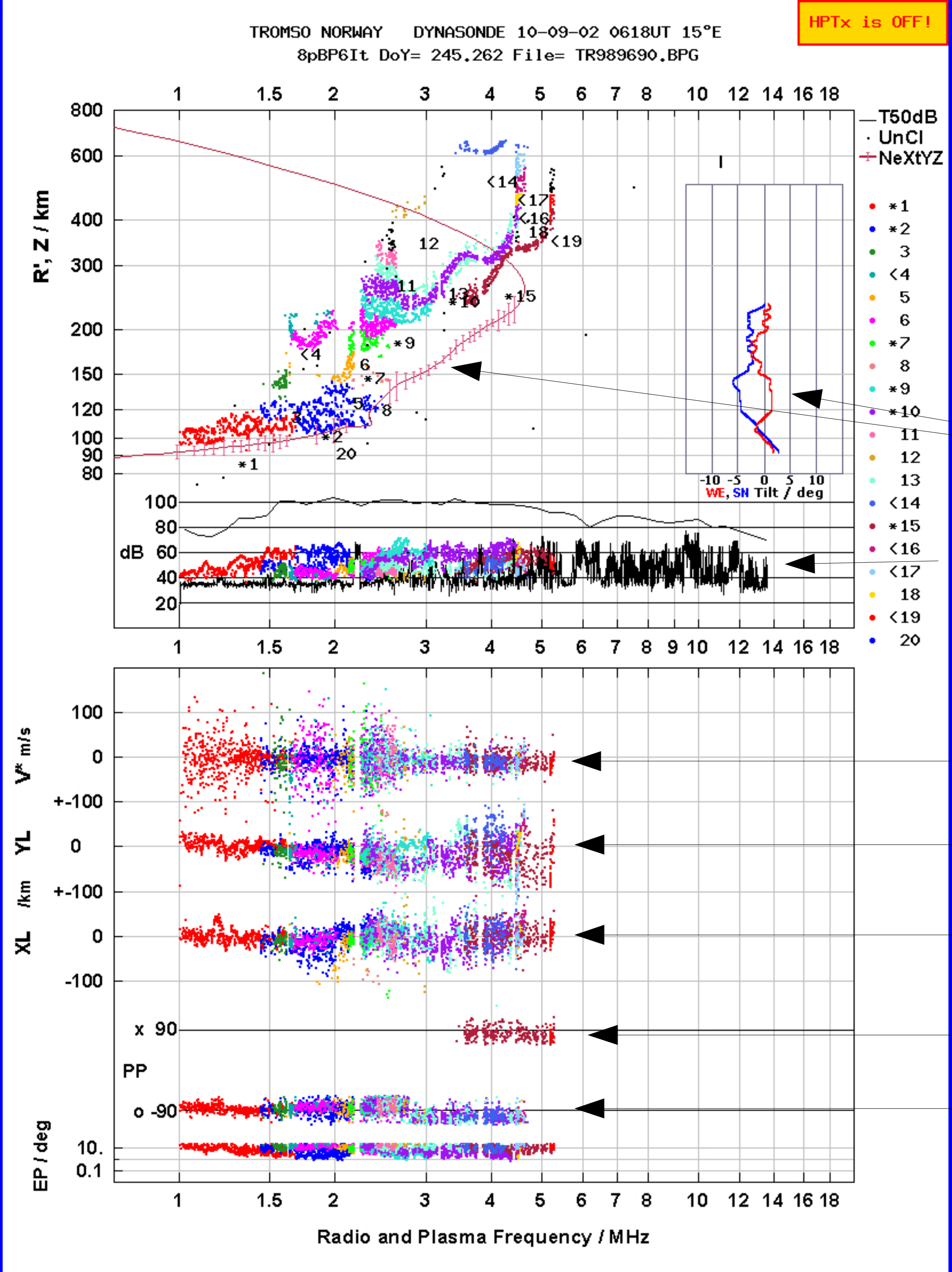
The dynasonde runs at least every 6 mins, but can go down to 1 or 2 minutes.

The latest advanced analysis displays are at:

http://dynserv.eiscat.uit.no/

Details of the Tromsø dynasonde in:

Rietveld, M.T., J. W. Wright, N. Zabotin, M. L.V. Pitteway, The Tromsø Dynasonde, Polar Science, 2, 1, 55-71, doi:10.1016/j.polar.2008.02.001, 2008.



The colours are traces of echoes with similar characteristics in all parameters.

NextYZ 2-D Ne profile

Echo (colour) and noise(black) amplitudes

Doppler velocity

north-south echo direction

east-west echo direction

X-mode

O-mode