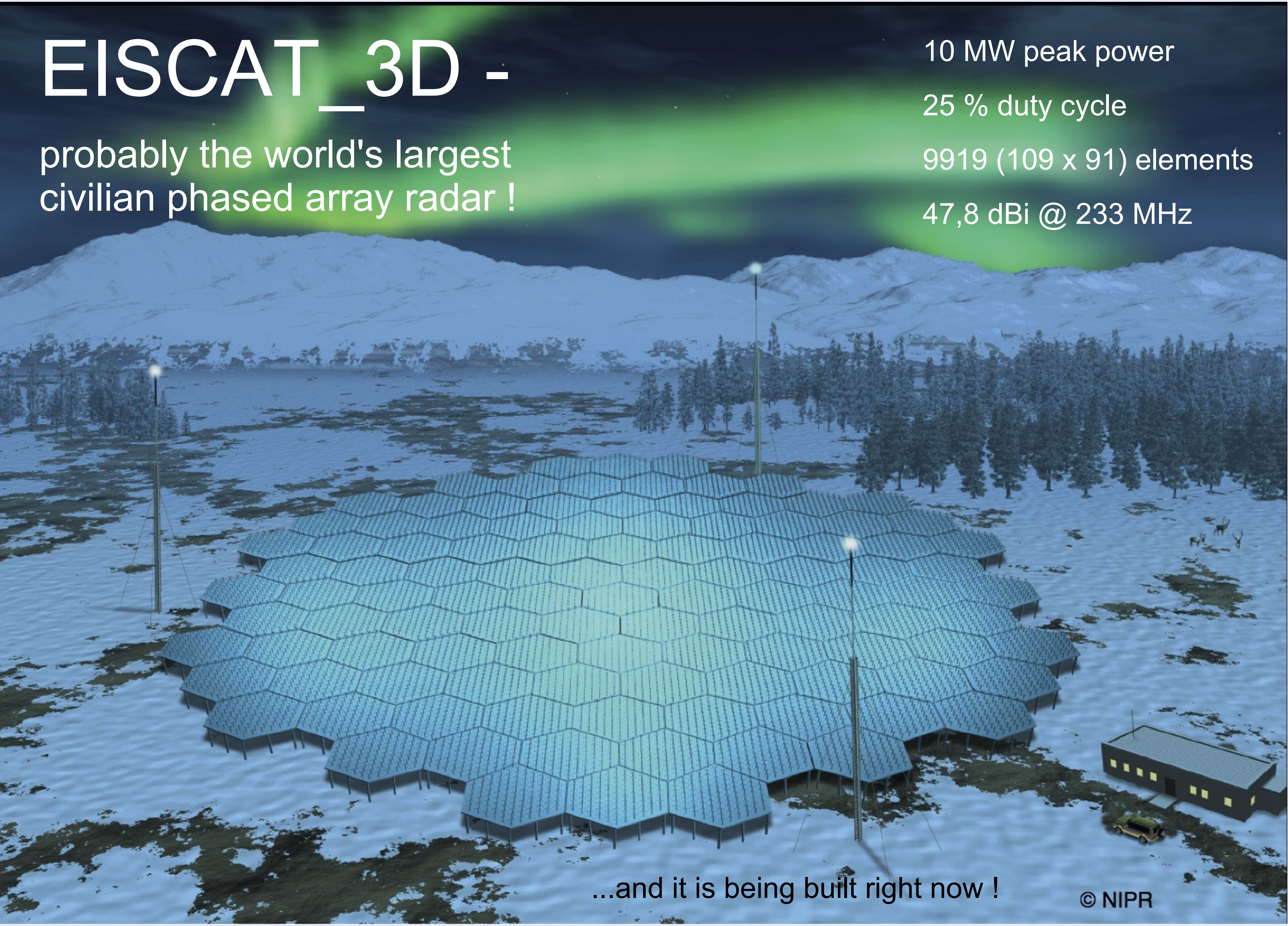
Quite a bit off topic at a 432+ MHz meeting -

but since it is about a weak signal type system,
we thought it might still be interesting...



EISCAT_3D -

probably the world's largest
civilian phased array radar !

- 10 MW peak power
- 25 % duty cycle
- 9919 (109 x 91) elements
- 47,8 dBi @ 233 MHz

...and it is being built right now !

© NIPR

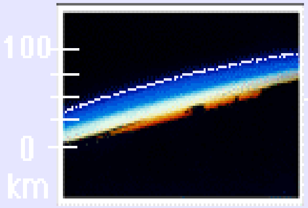
What, and why, is EISCAT_3D ?

- 3rd (or 4th?) generation *incoherent scatter* radar
- Successor to the EISCAT KST and ESR systems
- Located in the auroral zone in northern Scandinavia
- **Why:** to do quasi-real time(<1s) 3D mapping of the physical state of the atmosphere and ionosphere, over an area of more than 300 by 300 km and all the way from the tropopause to well beyond 1000 km
- **How:**
  - Fully digital phased array technology
  - Several arrays => triangulation => vector velocities
  - Very high peak and average transmitter power

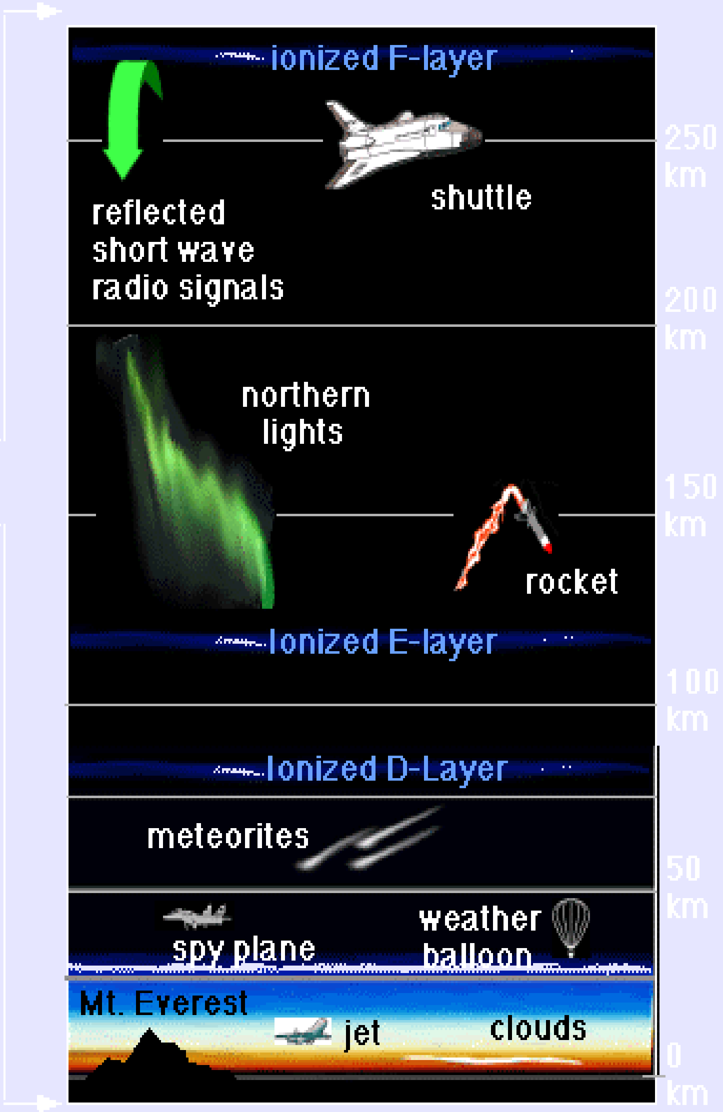
Scandinavian space research started with optical studies of aurora 100+ years ago...

But today, we can remote-sense the ionosphere

The Atmosphere and the Earth-Space Interface



View of the entire atmospheric layer from the space shuttle (courtesy of NASA)



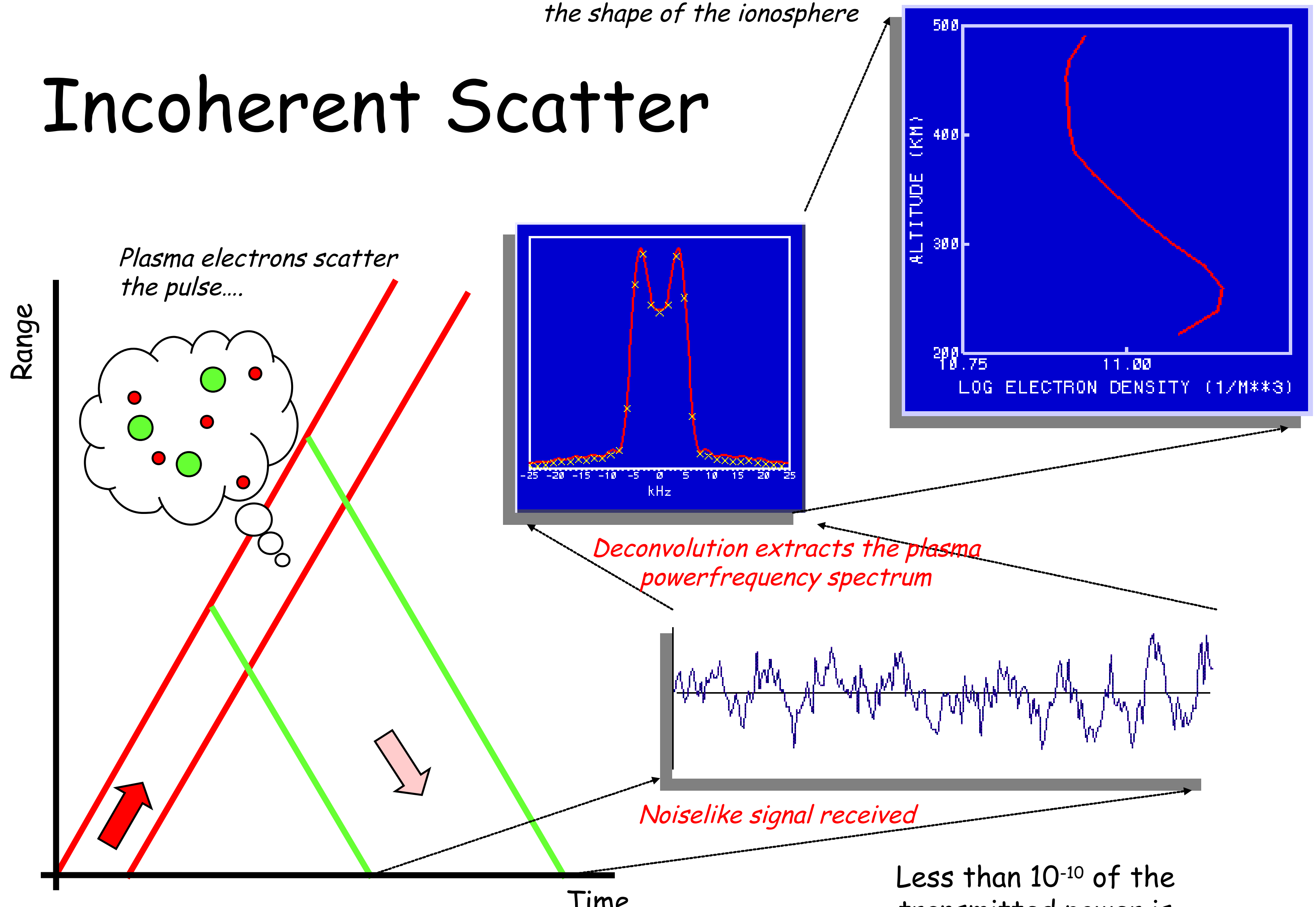
by illuminating it with extremely powerful radar pulses (many GW ERP !) and then analyse the very weak radar echoes off the free electrons in the ionospheric plasma.

The spectral shape of the echo carries information about the physical state of the plasma:

- drift velocity (”winds”)
- electrical fields and currents
- electron- and ion temperatures
- electron density
- ion mass

The technique is known as **incoherent scatter radar (ISR)**.

Incoherent Scatter



Iterative fitting reproduces the shape of the ionosphere

Plasma electrons scatter the pulse….

Deconvolution extracts the plasma powerfrequency spectrum

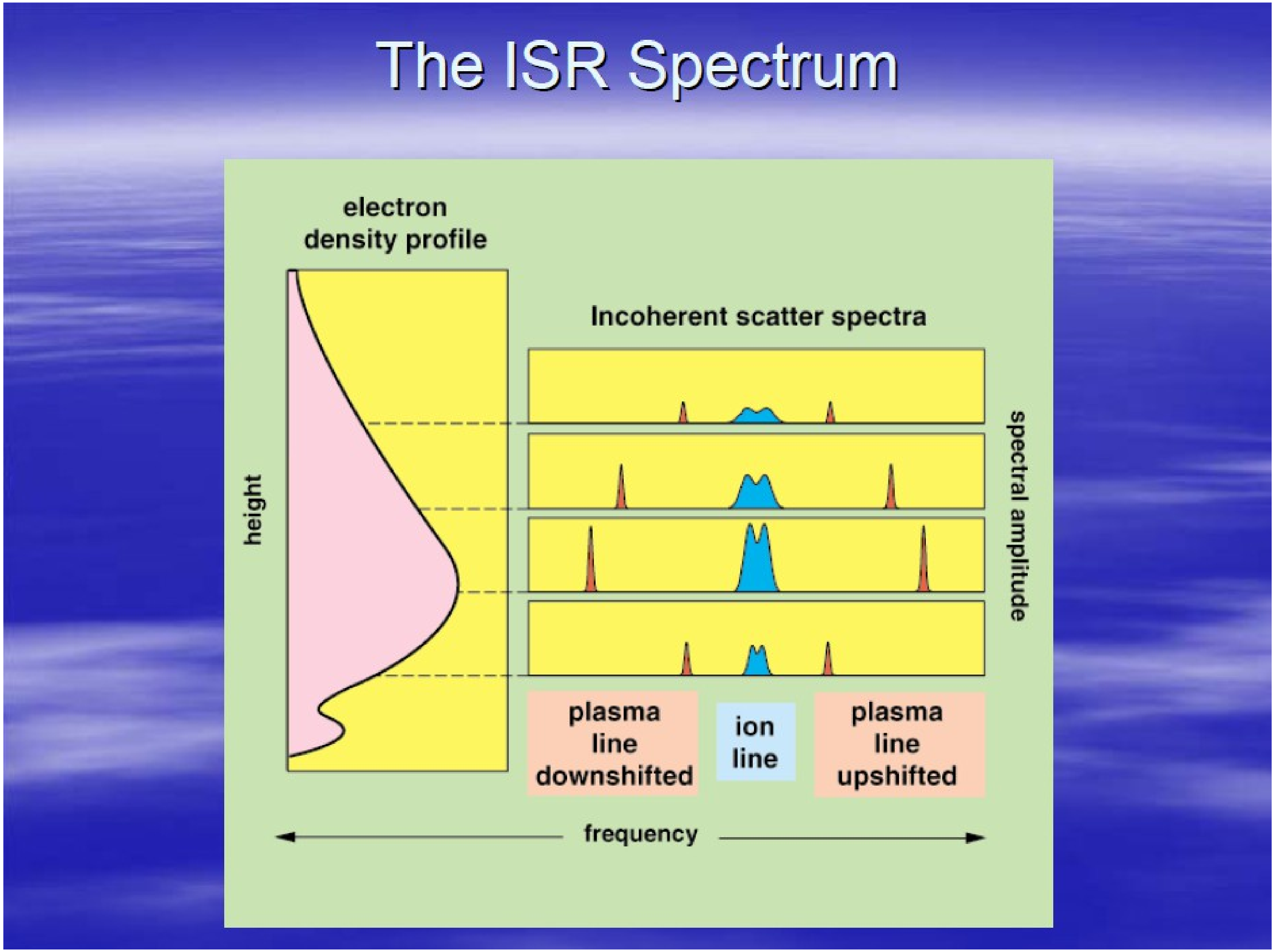
Noiselike signal received

High power VHF/UHF pulse
(f ›› f_p)

Very sensitive receiver

Less than 10^{-10} of the transmitted power is scattered by the ionosphere !

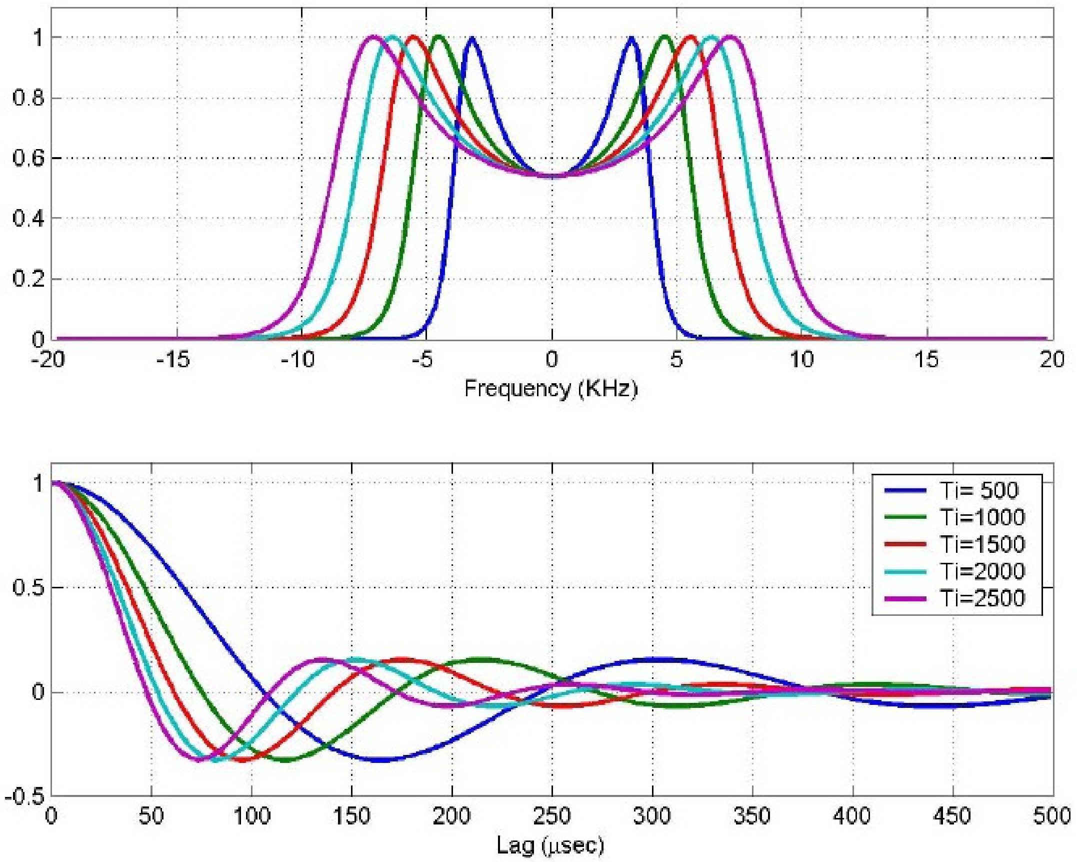
The very weak scattering means that the TX pulse propagates practically undisturbed through the ionosphere (first Born approximation !) and so all altitudes will be illuminated and measured…



The ISR Spectrum

The plasma electrons are not free, they are coupled to the positive ions through electrostatic forces. The resulting spectrum is dominated by the ion motions...

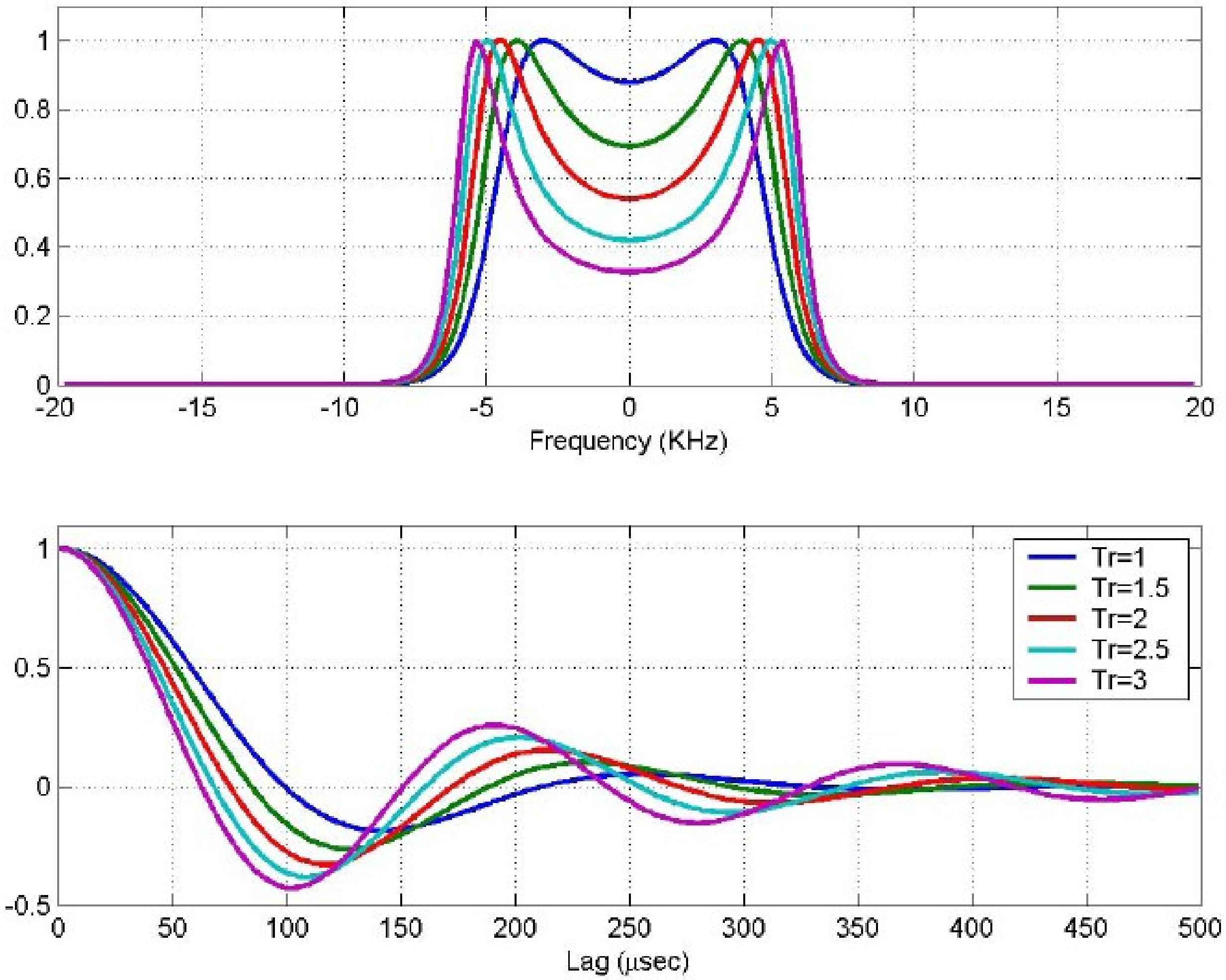
Ion Temperature



Parameters
Freq: 449 MHz
Ne: 10^{12} m^{-3}
Te: 2*Ti
Comp: 100% O^+
ν_{in}: 10^{-6} KHz

Hotter ions => greater mean ion speed => wider scatter spectrum...

Electron/Ion Temperature Ratio



Parameters
Freq: 449 MHz
Ne: 10^{12} m^{-3}
Ti: 1000 K
Comp: 100% O^+
ν_{in}: 10^{-6} KHz

Hotter electrons => greater mean electron speed => stronger decoupling from ions

Some model IS ion line spectra from different ionospheric regions

LEGEND:

Red – F region (300 km)

$n_e = 3 .10^{11}$ $T_e = 2000$
K O^+ $T_i = 1000$
K

Green - F region (300 km)

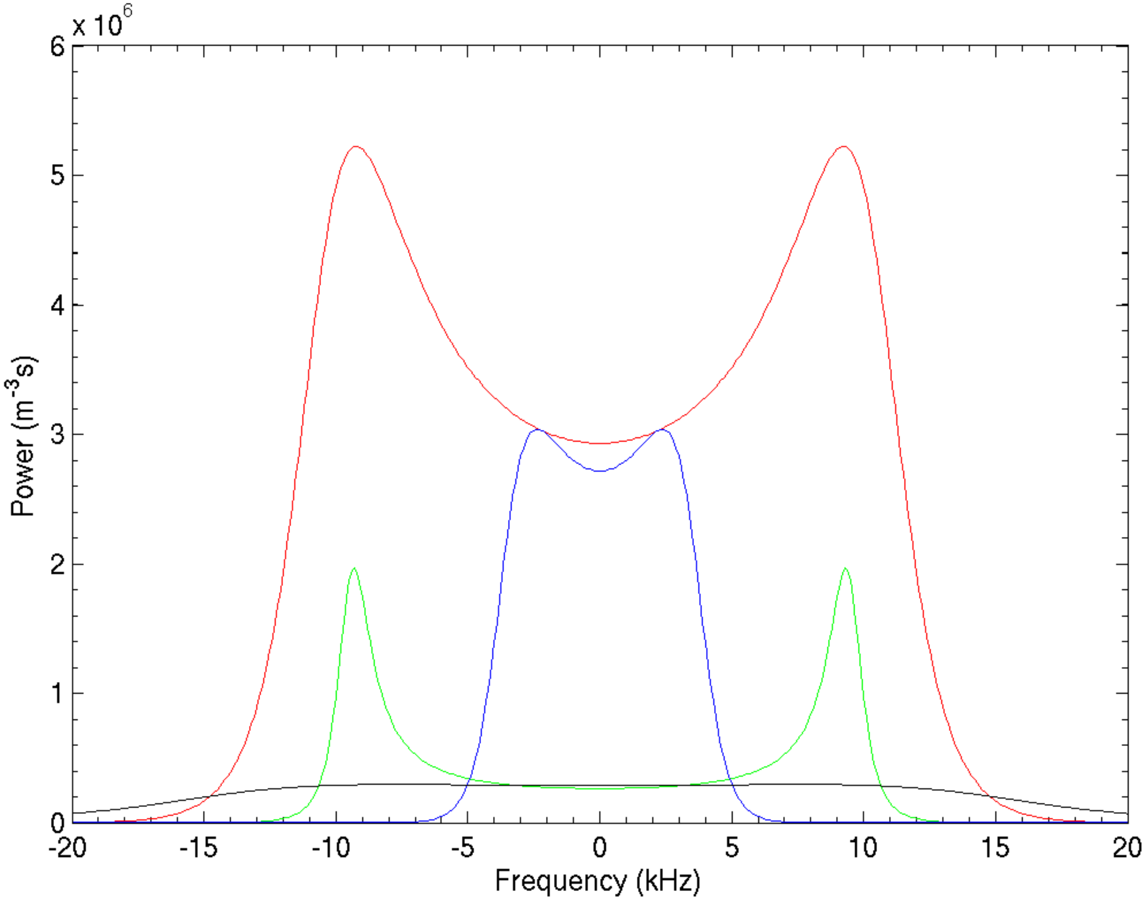
$n_e = 1 .10^{11}$ $T_e = 3000$
K O^+ $T_i = 500$ K

Blue – E region (120 km)

$n_e = 5 .10^{10}$ $T_e = 300$
K NO^+ / O_2^+ $T_i =$
300 K

Black – topside (1000 km)

$n_e = 5 .10^{10}$ $T_e = 4000$
K 90%O^+ 10% H^+ $T_i =$
3000 K

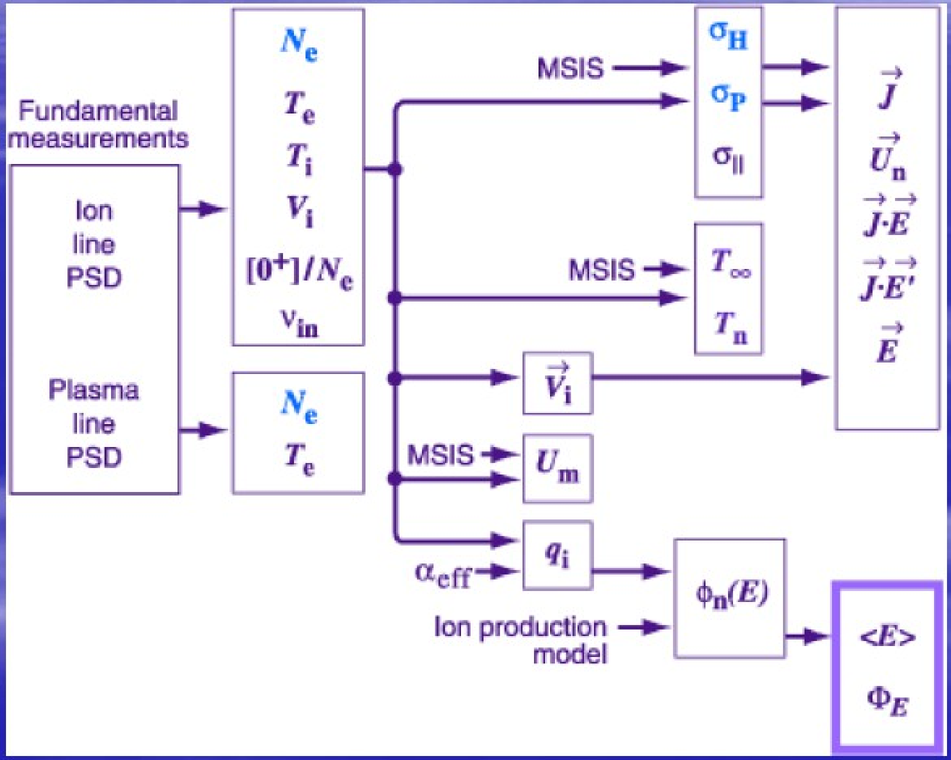


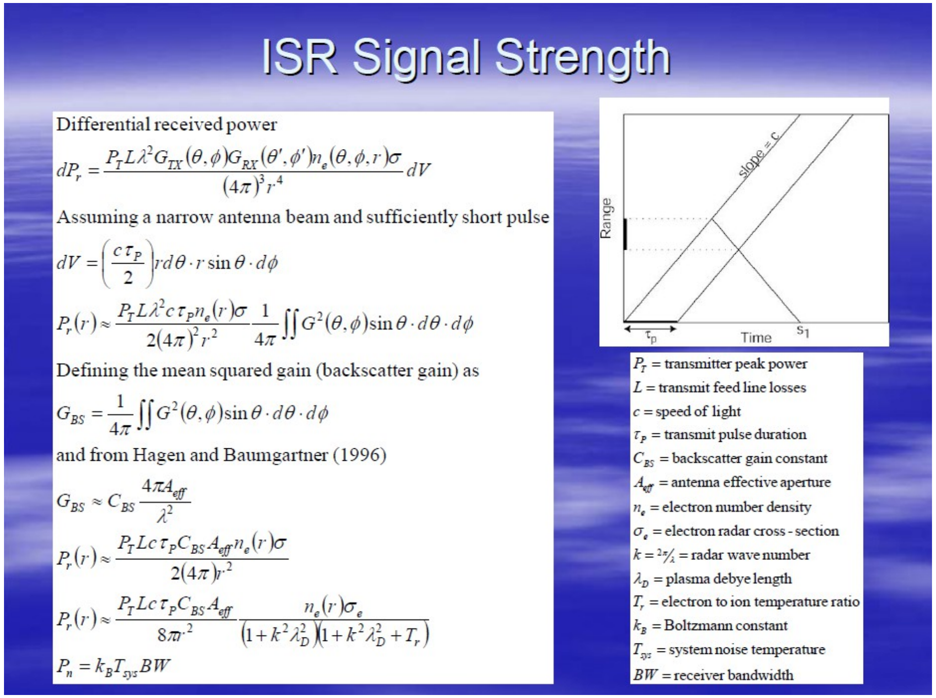
Spectra computed for the EISCAT UHF radar,

$\lambda = 0.33$ m (930 MHz).

Power spectral density (y-axis) plotted to linear scale

ISR Measurable Parameters





ISR Signal Strength

Differential received power

$$dP_r = \frac{P_T L \lambda^2 G_{TX}(\theta,\phi) G_{RX}(\theta',\phi') n_e(\theta,\phi,r)\sigma}{(4\pi)^3 r^4} dV$$

Assuming a narrow antenna beam and sufficiently short pulse

$$dV = \left(\frac{c\tau_P}{2}\right) r d\theta \cdot r \sin\theta \cdot d\phi$$

$$P_r(r) \approx \frac{P_T L \lambda^2 c \tau_P n_e(r)\sigma}{2(4\pi)^2 r^2} \frac{1}{4\pi} \iint G^2(\theta,\phi) \sin\theta \cdot d\theta \cdot d\phi$$

Defining the mean squared gain (backscatter gain) as

$$G_{BS} = \frac{1}{4\pi} \iint G^2(\theta,\phi) \sin\theta \cdot d\theta \cdot d\phi$$

and from Hagen and Baumgartner (1996)

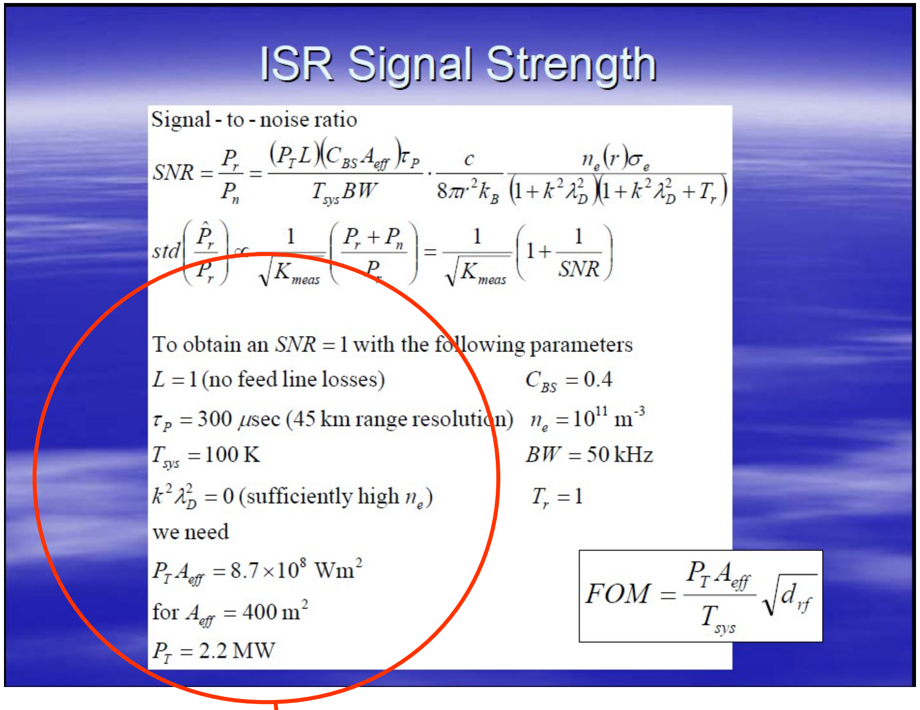
$$G_{BS} \approx C_{BS} \frac{4\pi A_{eff}}{\lambda^2}$$

$$P_r(r) \approx \frac{P_T L c \tau_P C_{BS} A_{eff} n_e(r)\sigma}{2(4\pi) r^2}$$

$$P_r(r) \approx \frac{P_T L c \tau_P C_{BS} A_{eff}}{8\pi r^2} \frac{n_e(r)\sigma_e}{(1+k^2\lambda_D^2)(1+k^2\lambda_D^2+T_r)}$$

$$P_n = k_B T_{sys} BW$$

P_T = transmitter peak power
L = transmit feed line losses
c = speed of light
τ_P = transmit pulse duration
C_{BS} = backscatter gain constant
A_{eff} = antenna effective aperture
n_e = electron number density
σ_e = electron radar cross - section
$k = 2\pi/\lambda$ = radar wave number
λ_D = plasma debye length
T_r = electron to ion temperature ratio
k_B = Boltzmann constant
T_{sys} = system noise temperature
BW = receiver bandwidth



ISR Signal Strength

Signal - to - noise ratio

$$SNR = \frac{P_r}{P_n} = \frac{(P_T L)(C_{BS} A_{eff})\tau_P}{T_{sys} BW} \cdot \frac{c}{8\pi r^2 k_B} \frac{n_e(r)\sigma_e}{(1+k^2\lambda_D^2)(1+k^2\lambda_D^2+T_r)}$$

$$std\left(\frac{\hat{P}_r}{P_r}\right) \propto \frac{1}{\sqrt{K_{meas}}}\left(\frac{P_r+P_n}{P_r}\right) = \frac{1}{\sqrt{K_{meas}}}\left(1+\frac{1}{SNR}\right)$$

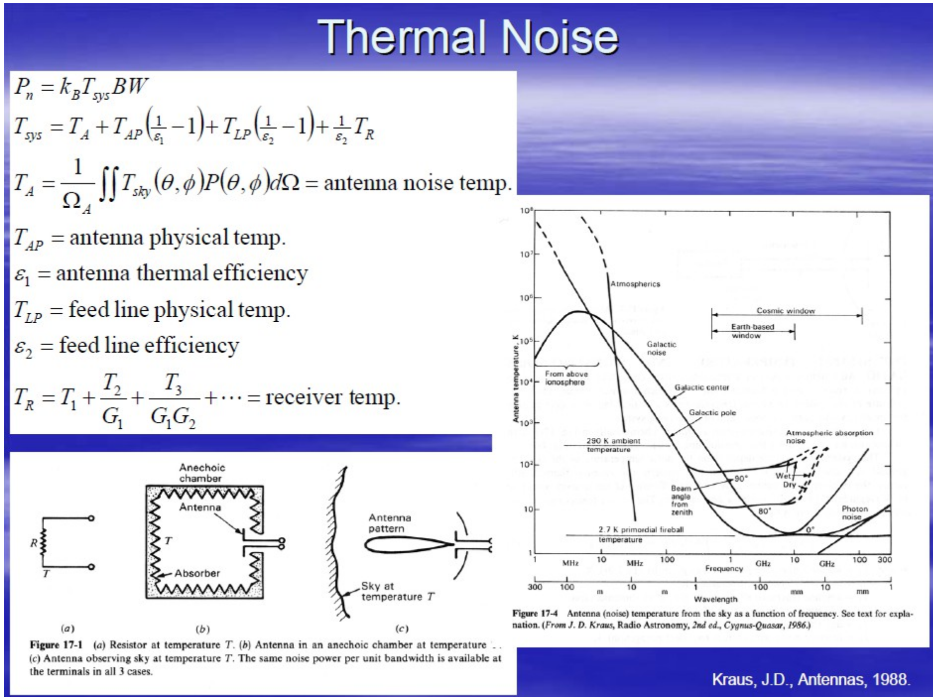
To obtain an $SNR = 1$ with the following parameters

$L = 1$ (no feed line losses) $\quad C_{BS} = 0.4$
$\tau_P = 300\ \mu\text{sec}$ (45 km range resolution) $\quad n_e = 10^{11}\ \text{m}^{-3}$
$T_{sys} = 100\ \text{K}$ $\quad BW = 50\ \text{kHz}$
$k^2\lambda_D^2 = 0$ (sufficiently high n_e) $\quad T_r = 1$

we need

$P_T A_{eff} = 8.7 \times 10^8\ \text{Wm}^2$
for $A_{eff} = 400\ \text{m}^2$
$P_T = 2.2\ \text{MW}$

$$FOM = \frac{P_T A_{eff}}{T_{sys}} \sqrt{d_{rf}}$$



Thermal Noise

$$P_n = k_B T_{sys} BW$$

$$T_{sys} = T_A + T_{AP}\left(\tfrac{1}{\varepsilon_1}-1\right) + T_{LP}\left(\tfrac{1}{\varepsilon_2}-1\right) + \tfrac{1}{\varepsilon_2} T_R$$

$$T_A = \frac{1}{\Omega_A} \iint T_{sky}(\theta,\phi) P(\theta,\phi) d\Omega = \text{antenna noise temp.}$$

T_{AP} = antenna physical temp.
ε_1 = antenna thermal efficiency
T_{LP} = feed line physical temp.
ε_2 = feed line efficiency

$$T_R = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \cdots = \text{receiver temp.}$$

Figure 17-1 (*a*) Resistor at temperature T. (*b*) Antenna in an anechoic chamber at temperature [illegible] (*c*) Antenna observing sky at temperature T. The same noise power per unit bandwidth is available at the terminals in all 3 cases.

Figure 17-4 Antenna (noise) temperature from the sky as a function of frequency. See text for explanation. (*From J. D. Kraus,* Radio Astronomy, *2nd ed., Cygnus-Quasar, 1986.*)

Kraus, J.D., Antennas, 1988.

The construction of a scientifically relevant ISR system is a very costly “acres and megawatts” business – not something easily done by an individual group or institute -

(unless 3^{rd} parties come up with funding...)

Early ISR and EISCAT history

- 1958: William Gordon (Cornell U) shows that an incoherent scatter radar capable of profiling the ionosphere is technically possible
- 1960s: ISR systems built at Arecibo (PR), Jicamarca (Peru), Chatanika (AK), Malvern (UK), St. Santin (FR)
- 1968: Hultqvist (SE), Holt (NO) and Oksman (FI) formulate first EISCAT proposal
- 1969: URSI GA adopts a resolution supporting the construction of an incoherent-scatter radar in the European auroral zone
- 1970 – 1973: Technical planning, forming the Association
- 1975: Formal creation of the EISCAT Scientific Association
- 1976 – 1981: Construction of the UHF and VHF systems
- Aug. 26, 1981: Official inauguration of EISCAT by HM King Carl XVI Gustaf of Sweden

EISCAT, the European Incoherent SCATter Association –

International research organisation, formed 1975

Swedish non-profit association, head offices in Kiruna, Director is ex-N6MCD / OX3EO


Tromso, Norway: VHF and UHF


Sodankylä, FI: UHF RX


Kiruna, Sweden: UHF RX


Spitsbergen: UHF (500 MHz)

Present EISCAT systems:

UHF 927 MHz (Tromso)
ESR 500 MHz (Svalbard)
VHF 224 MHz (T/K/S)

1st generation: Kiruna receiver site. 32-m dish and 224 MHz test array for EISCAT 3D

SK2GJ QRV 1296 MHz EME autumn 1980...

2nd generation, 1992-1998: EISCAT Svalbard Radar (ESR)

Photo: Ingemar Wolf

/Users/ugw/ham_radio/föredrag_lindesberg/esr_receiver_a3_blockd.pdf

ESR 32-meter RX

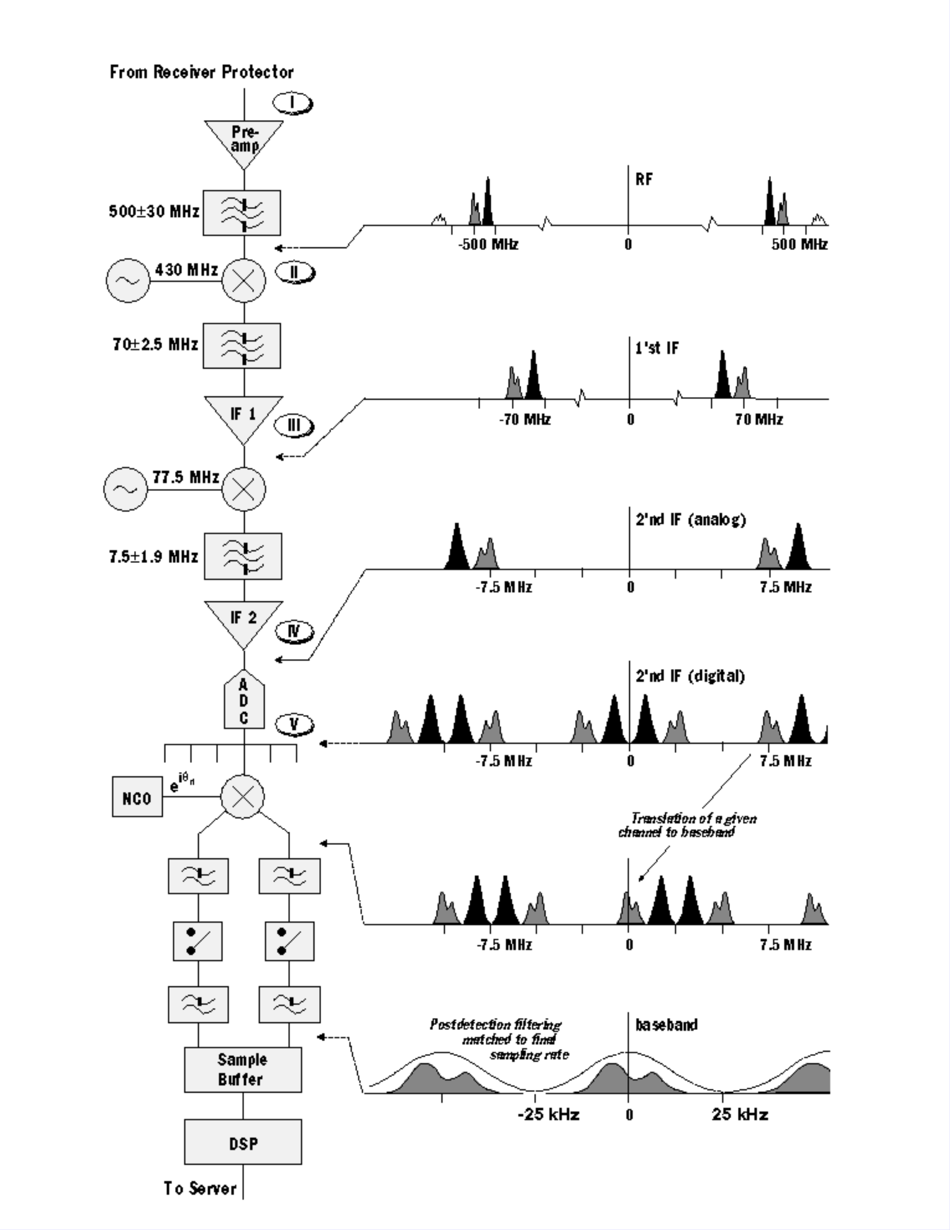
500 MHz signals are down-converted in two steps, first to ≈ 70 MHz and then to a second IF at 5.6 - 9.4 MHz.

The 2ns IF band is then digitized by a 5 Ms/s, 12 bit ADC (constructive undersampling).

Further signal processing is done in 8 parallel hardware channels. Each channel comprises a NCO, a digital mixer (that also does real=> complex-conversion) and two parallel, programmable FIR-filter/decimators (I and Q).

The decimator output data streams are routed to double-banked buffer memories, which are then read by a SUN Sparc MPU server -

and from there onwards, ”SDR” takes over !



October 2003: JW/SM2BYA QRV 432 MHz in ARRL EME contest...

Status 2007:

Fair latitudinal coverage (63-80 N)

4 possible lines of sight

Time resolution ≈ s

Spatial resolution ≈ km

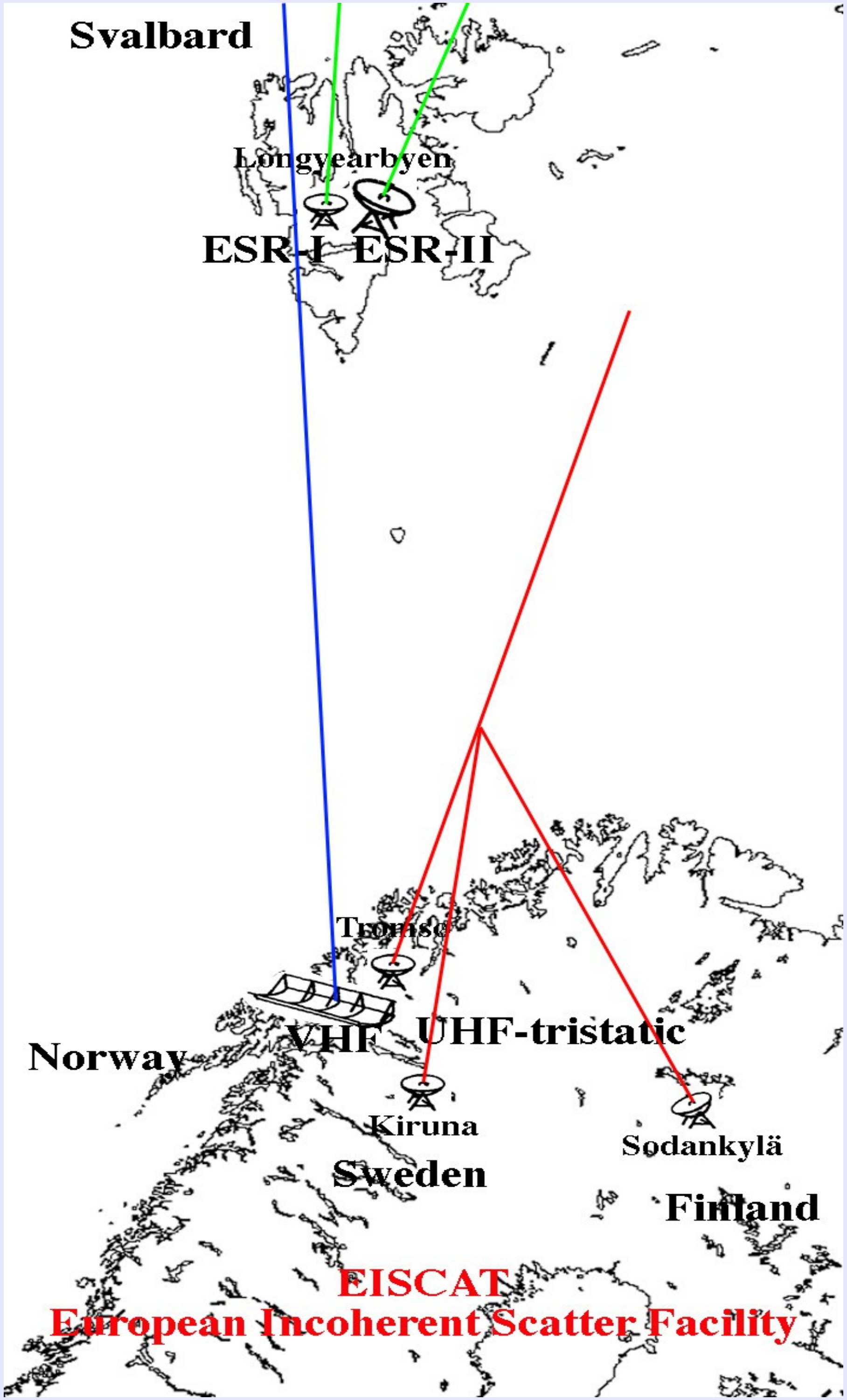
3D measurements possible, using UHF -

but only at one point at a time -

and only until 2010 -

So a new, better radar was needed!

=> ……



Tromsö	69°35' N, 19°14' E
Kiruna	67°52' N, 20°26' E
Sodankylä	67°22' N, 26°38' E
ESR	78°09' N, 16°03' E

VHF 222.8 – 225.4 MHz

UHF 926.6 – 930.5 MHz

ESR 498.0 – 502.0 MHz

Scientists' wish list *circa* 2004

Optical measurements had shown that the fine structure in dynamic aurora was often of order < 100m, but the existing radars (KST och ESR) could only provide a resolution of the order of 1 km, both vertically and horizontally.

So at least a *tenfold* improvement of both time and space resolution was needed:

A new radar system should be able to measure

- *electron density, n_e, with < 100 m altitude resolution, < 1 s time resolution and 10% accuracy from 100 to 300 km altitude,*
- *3D electric fields ($\underline{E}$) at more than five altitudes between 100 and 300 km, simultaneously,*
- *< 150 m horizontal resolution at 100 km altitude,*

and

- *cover a 100 x 100 km part of the ionosphere with 3D - measurements in a few seconds,*

and also

- *record and save raw data at microsecond time resolution as required.*

Q: Was this possible with Y 2007 technology ?

If yes, at what cost ?

To find out, EISCAT started a study with support from the EU:

EISCAT_3D Feasibility Study

This ran from 2005 to 2009

...and its conclusion was -

YES, IT CAN BE DONE -

and at a manageable cost to boot !

The study, as published in RSB 2010, comprised a worked-out proposal for a system architecture -

/Users/ugw/ham_radio/föredrag_lindesberg/RSB_332_2010_03.pdf

The scientists waxed lyrical...

/Users/ugw/ham_radio/föredrag_lindesberg/EISCAT_2010.mov

Proposed system geometry

- Three (eventually five) stations:
  - Roughly the same geometry as EISCAT KST, i.e.
  - one station (the northernmost one, somewhere in Troms) fitted with both transmitter and receiver,
  - other stations receive-only, 150 - 300 km distant from the transmitter on two nearly orthogonal baselines (N-S and E-W),

Present idea of the EISCAT 3D system geometry – vector E field capability retained and improved:

The central core (denoted by a green filled circle) is assumed to be located near the present Norwegian EISCAT site at Ramfjordmoen. The dashed circle with a radius of approximately 250 km indicates the approximate extent of the central core FOW at 300 km altitude. Receiving sites located near Porjus (Sweden) and Kaamanen (Finland) provide 3D coverage over the (250-800) km height range, while two additional sites near Abisko (Sweden) and Masi (Norway) cover the (70-300) km height range. All these sites have been surveyed for RFI/EMC and found to be “clean”.

Proposed antenna technology

The demands from the scientific user community could be met only by:

- a system of very large *phased arrays*

- beam steering through combination of *time delay* and *phase shifting*

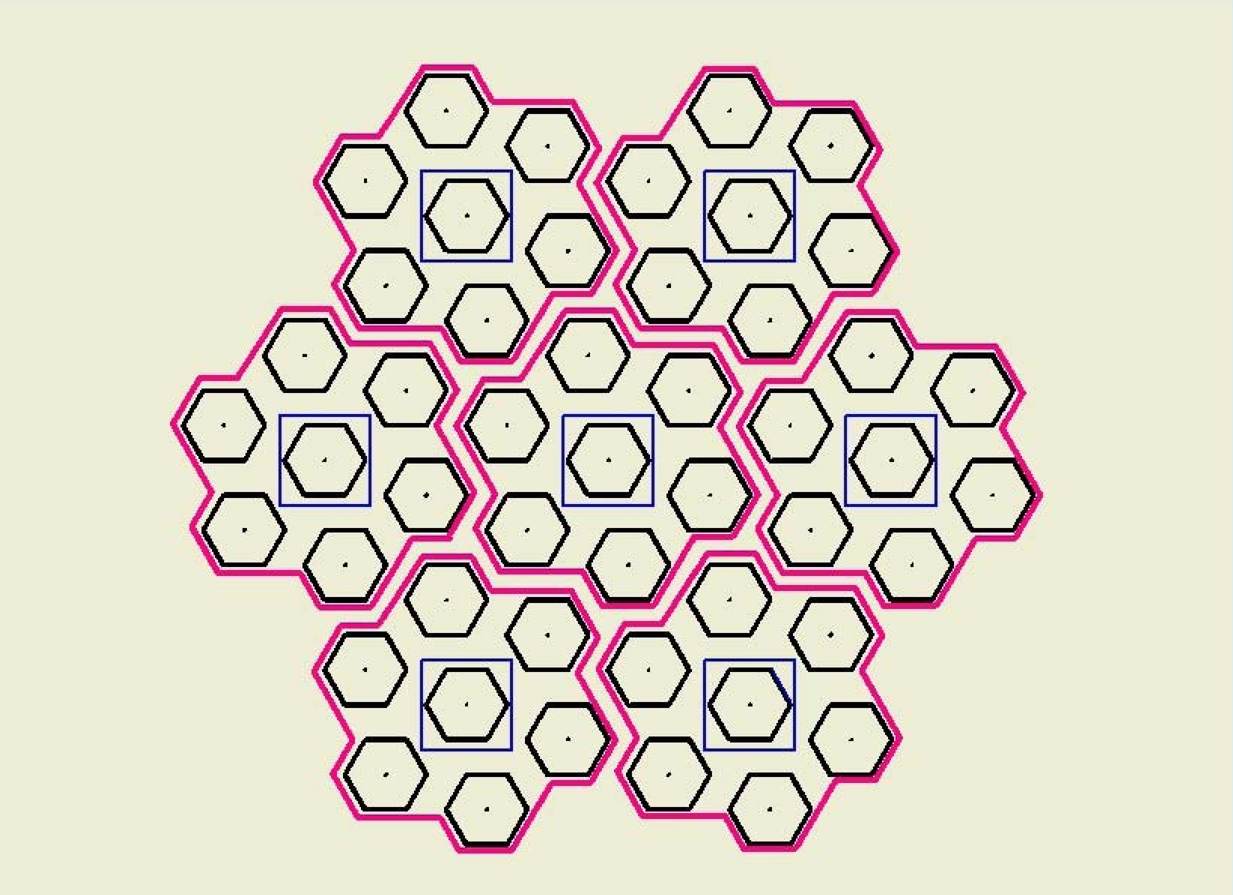
In turn, this would imply

- *individual direct-digitizing receivers* for each antenna element (tens of thousands!),

- *individual transmitters* for each element, and

- *massive digital signal processing* in real-time...

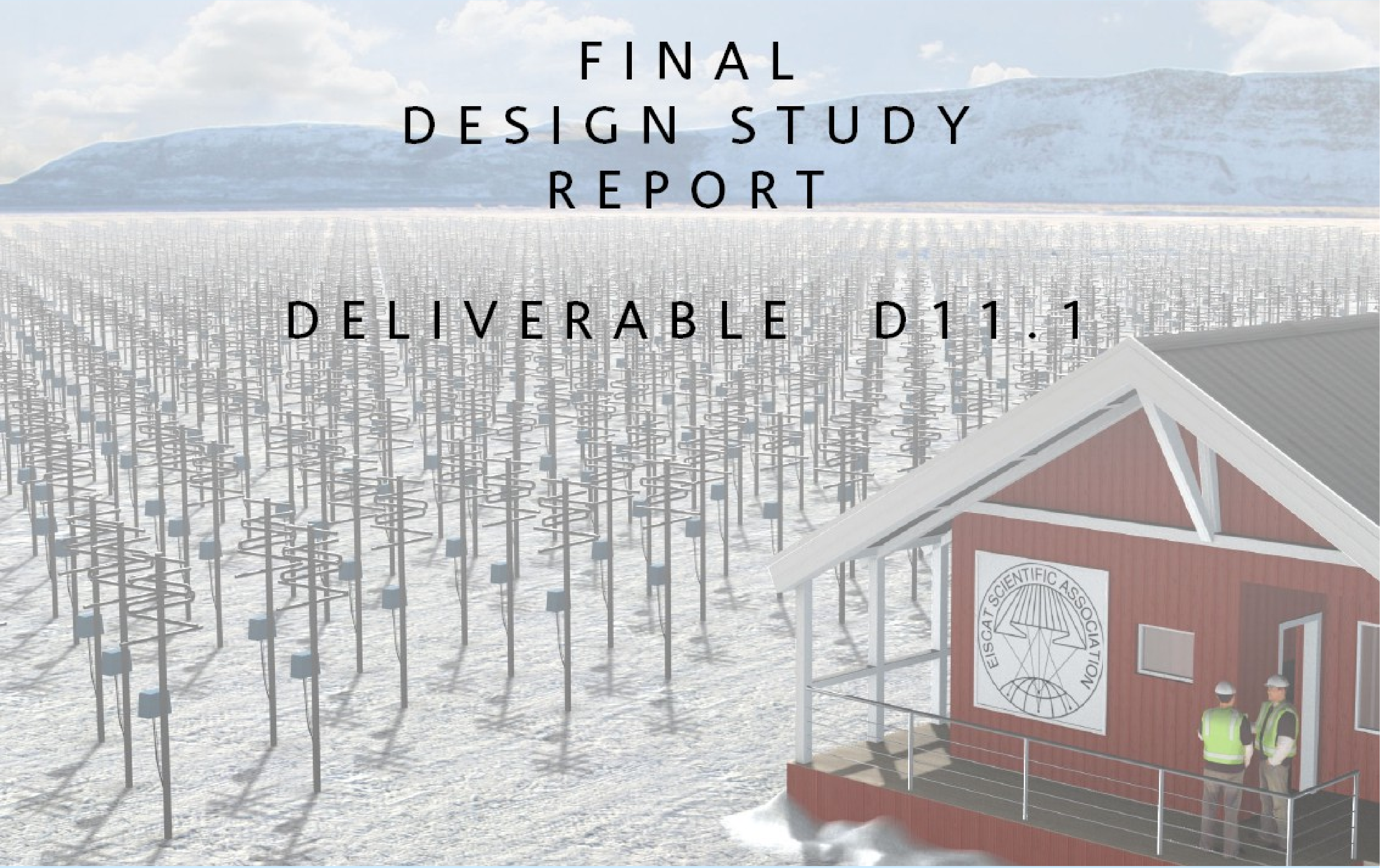
Proposed EI_3D Core Array Structure



The 3D core array will be built up from close-packed 49-element sub-groups, each of which can be regarded as composed of seven 7-element hexagonal cells. The figure shows a top view of a 343-element, approximately 18-m diameter array group, formed from seven sub-groups (outlined in red); the full Core will comprise approx. 49 343-element groups.

Each sub-group is served by a common, approx. 2-m by 2-m equipment container (indicated by a blue square at the centre of each sub-group) containing all RF, signal processing and control and monitoring electronics.

An artist’s view of the 16000-element Core array…

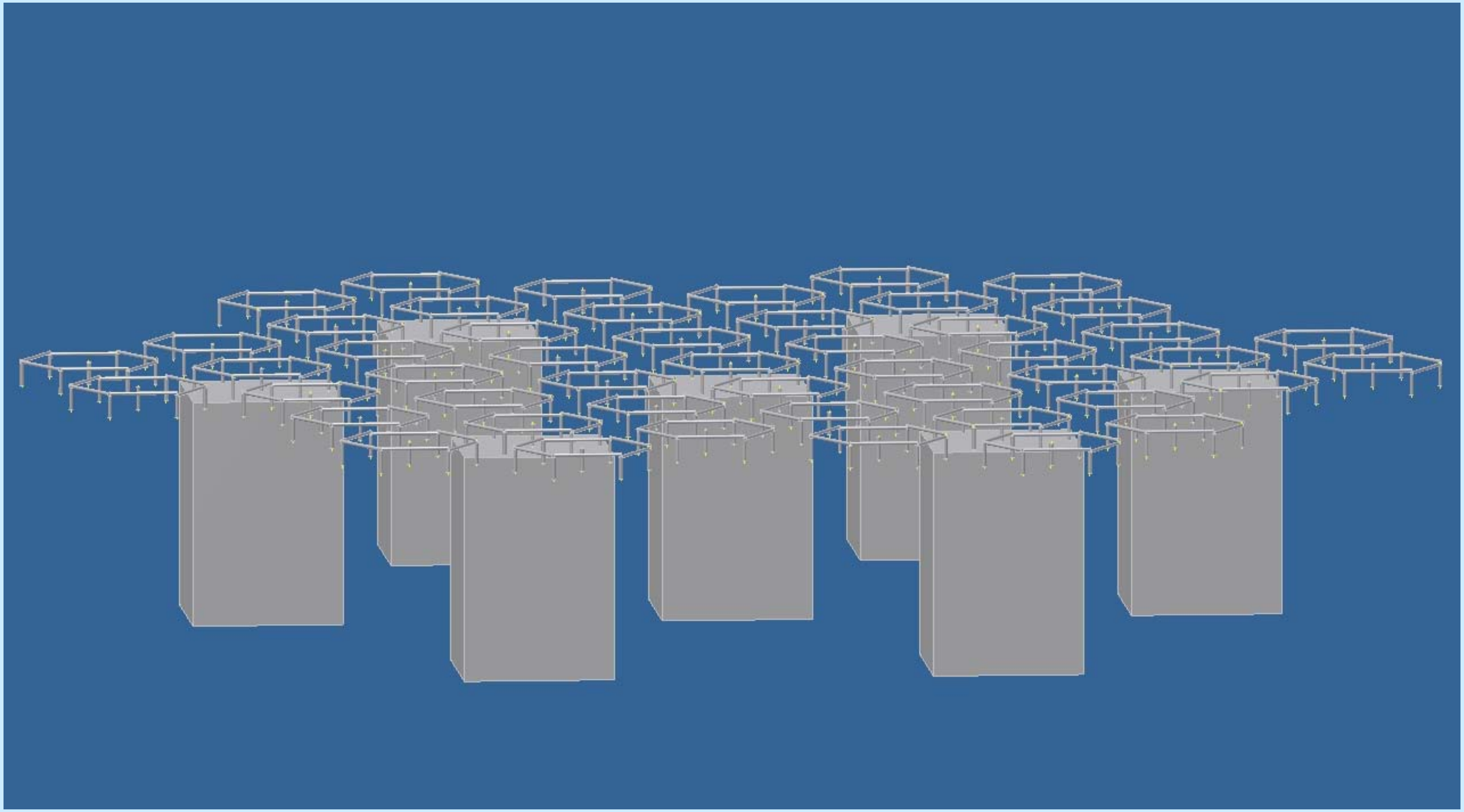


FINAL
DESIGN STUDY
REPORT

DELIVERABLE D11.1

…but it will probably look more like this…

EI_3D Core Array Side View

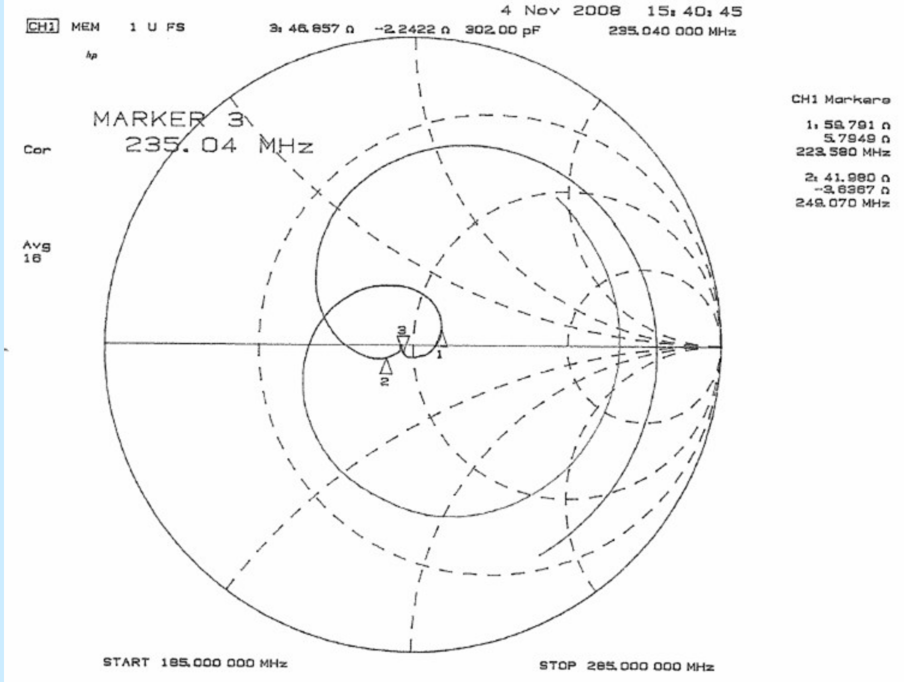


A side view of the 343-element array group. Each hexagon denotes a seven-element cell, comprising six element radiators at its corners and one at its centre. The array is assumed to be elevated at least 3 m above average ground; the actual element radiators and the array support structure are suppressed for clarity. Seven 2 x 2 x 2.8 m equipment containers, each serving 49 radiators, are situated under the array.

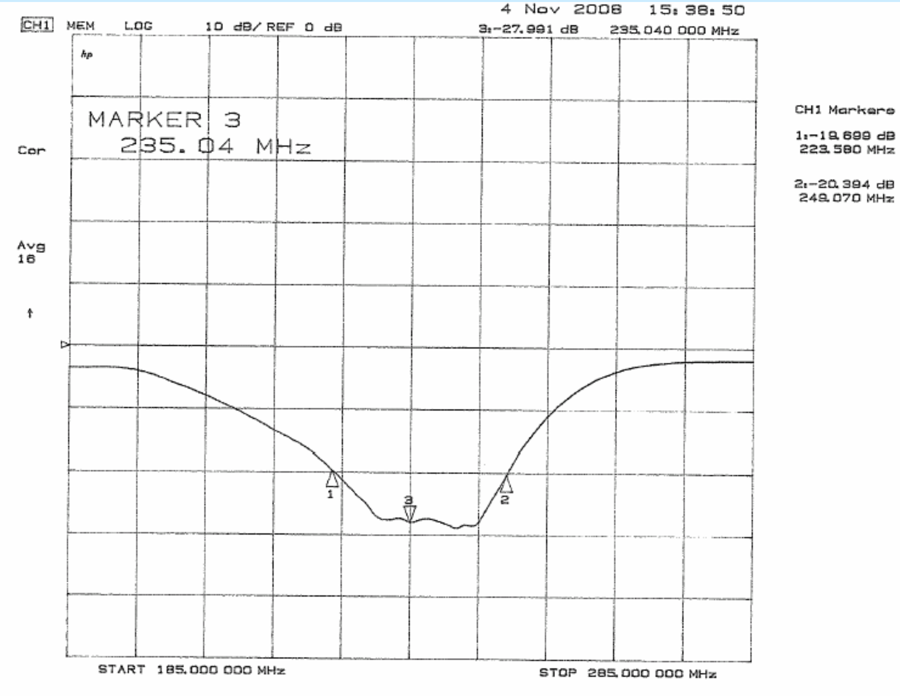
First physical build of the “Renkwitz Yagi”

Kiruna, December 2008

Design DJ8MS



Measured reflection coefficient s_{11}



Proposed TX system

- Center frequency 233 MHz (T-DAB block 13A - 13D)
- Instantaneous power bandwidth 6 MHz
- Individual power amplifiers for each array element (≈ 20000 units !)
- Total peak power approaching 10 MW (500 W per PA),
- PAs linear over > 20 dB => arbitrary modulation (CW …. white noise)
- Individual (NCO + digital mixer) - AWGs for each PA
- Pulse-to-pulse beam re-pointing and modulating code change
- Pulse-to-pulse polarization modulation
- Beam steering through combination of time delay and phase shift
-

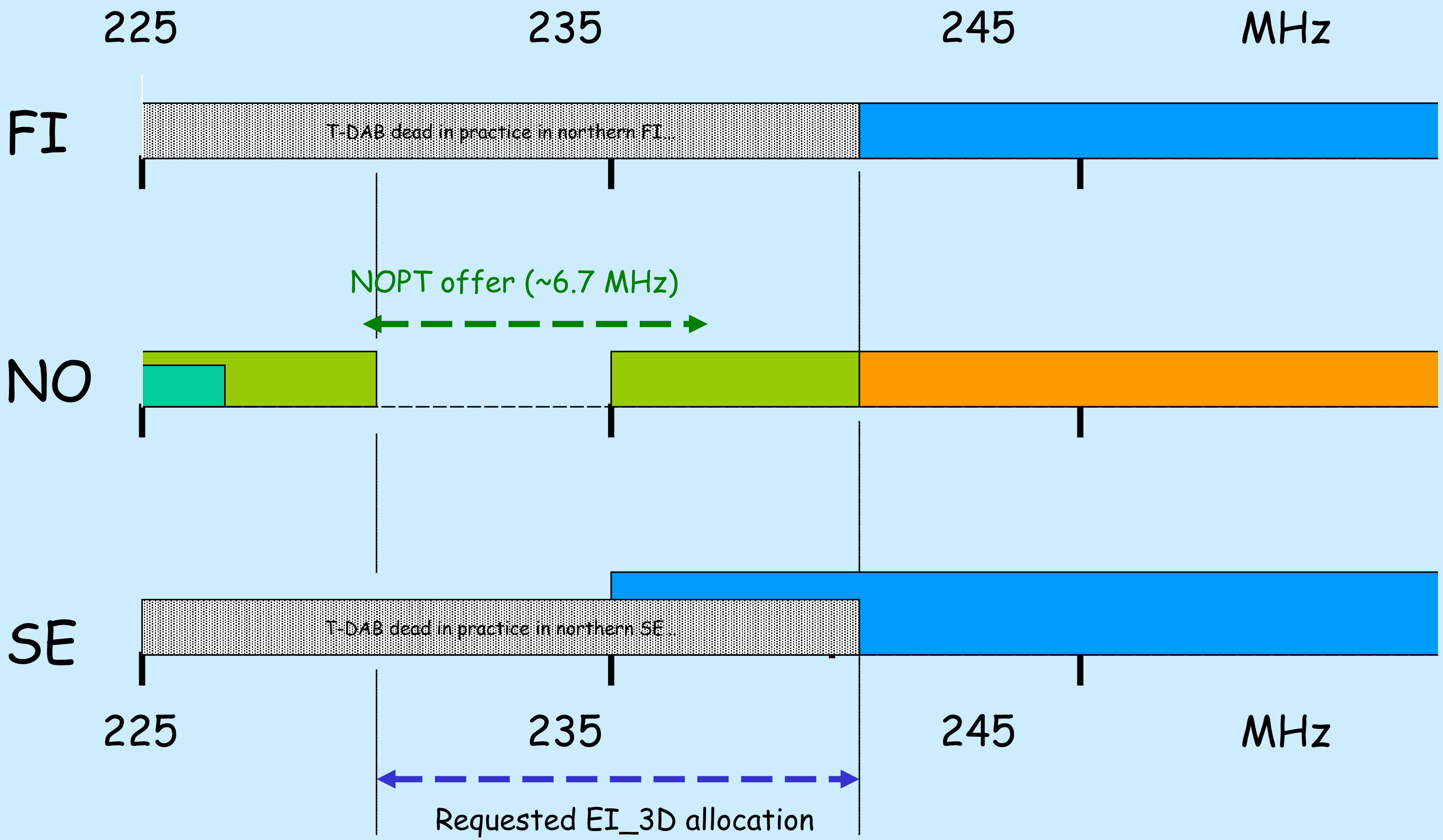
High VHF Spectrum Usage in FI, NO, SE as of 2008-10

🟩 Space Research (EI VHF)

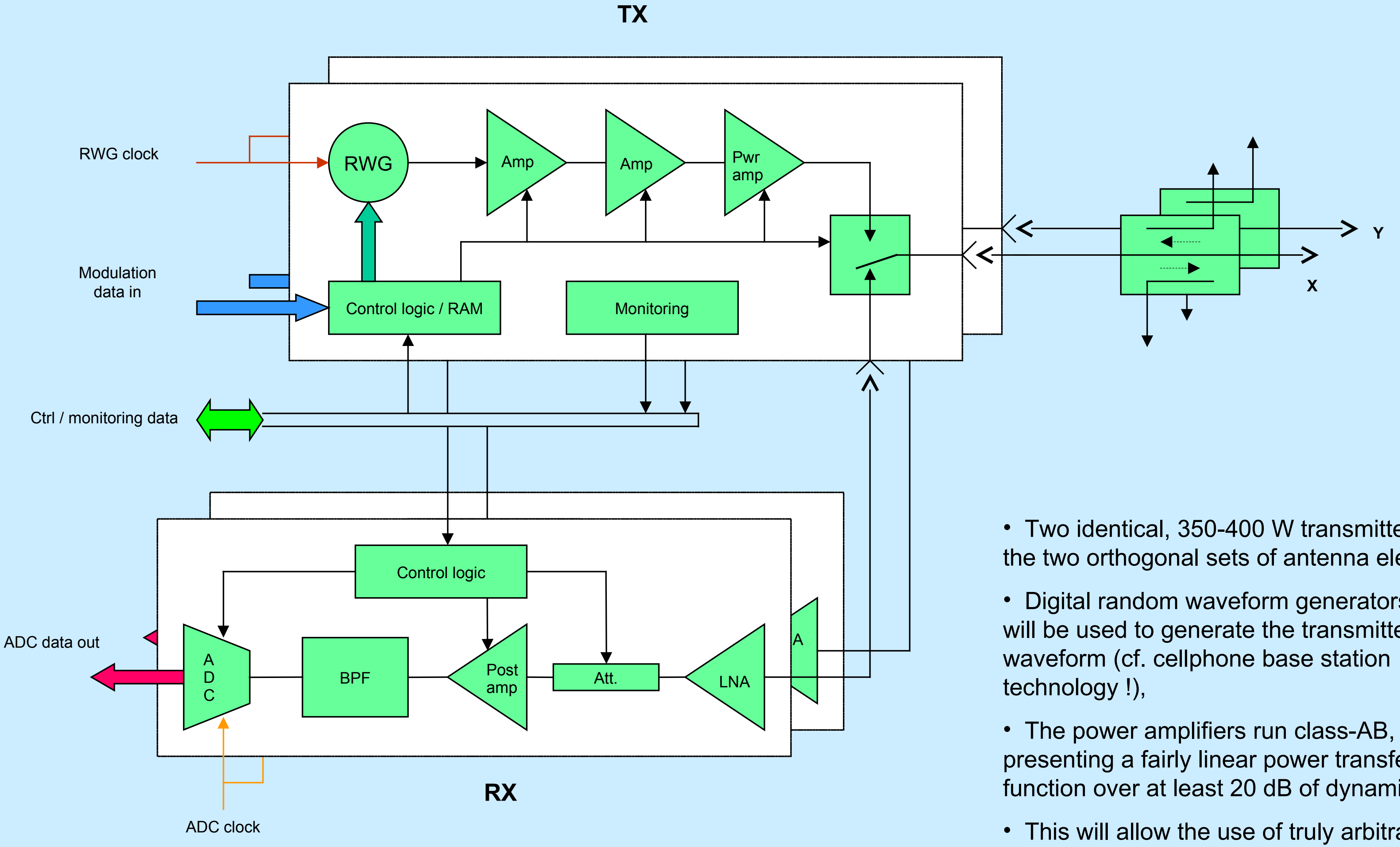
🟩 Terrestrial digital broadcasting (T-DAB)

🟦 Defence

🟧 Mobile

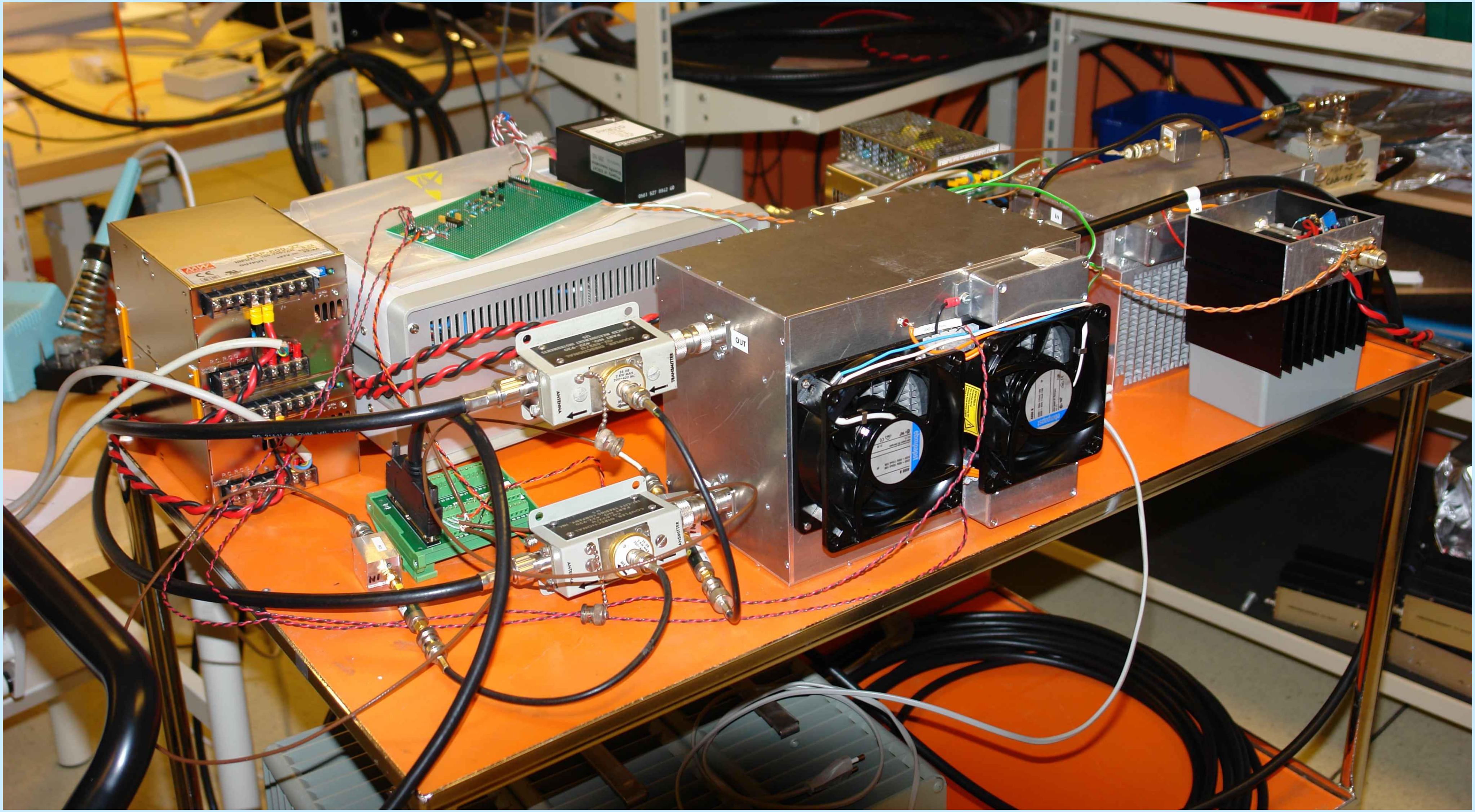


The basic *Radio Frequency Unit* (RFU)



- The two receiver units (one for each polarisation) are essentially the same as those used in the remote receive-only arrays, thus physically separate from the transmitter modules.

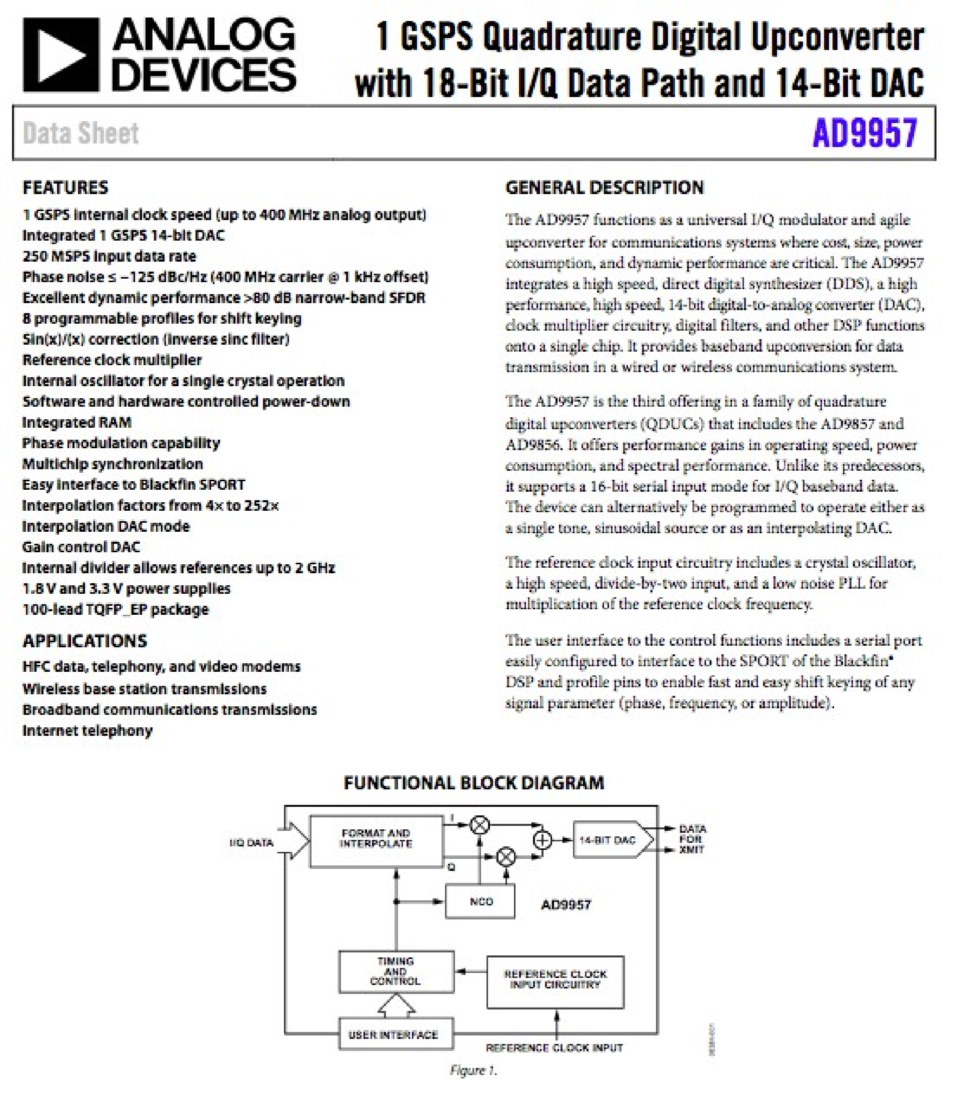
- Two identical, 350-400 W transmitters drive the two orthogonal sets of antenna elements,
- Digital random waveform generators (RWG) will be used to generate the transmitted waveform (cf. cellphone base station technology !),
- The power amplifiers run class-AB, thus presenting a fairly linear power transfer function over at least 20 dB of dynamic range,
- This will allow the use of truly arbitrary radar waveforms (including pseudo-noise).



Photograph of the complete (2 x 300W) test setup. The aluminium box with ventilators at front centre contains two independent BLF 248 amplifiers. On its right is the driver chain, composed of a Mitsubishi power module followed by a single BLF 248 amplifier (partly hidden). A four-port hybrid (hidden) splits the drive power into two 30-watt signals driving one amplifier each. Final amplifier output power is sampled and monitored through two -35 dB directional coupler line samplers. The 28 V PSUs for the final amplifiers are located at the left rear; the grey instrument to their right is the EPROM-based sequencer.

This setup was run continuously at full power and 25% duty cycle for over 700 hours without any failures.

A proof-of-concept AWG / beam steering system was built around the AD9957 QDUC and a Virtex 5 FPGA; a 3-channel version was successfully tested at the Jicamarca (Peru) radar in 2012...



ANALOG DEVICES

1 GSPS Quadrature Digital Upconverter with 18-Bit I/Q Data Path and 14-Bit DAC

Data Sheet **AD9957**

FEATURES

- 1 GSPS internal clock speed (up to 400 MHz analog output)
- Integrated 1 GSPS 14-bit DAC
- 250 MSPS input data rate
- Phase noise ≤ −125 dBc/Hz (400 MHz carrier @ 1 kHz offset)
- Excellent dynamic performance >80 dB narrow-band SFDR
- 8 programmable profiles for shift keying
- Sin(x)/(x) correction (inverse sinc filter)
- Reference clock multiplier
- Internal oscillator for a single crystal operation
- Software and hardware controlled power-down
- Integrated RAM
- Phase modulation capability
- Multichip synchronization
- Easy interface to Blackfin SPORT
- Interpolation factors from 4× to 252×
- Interpolation DAC mode
- Gain control DAC
- Internal divider allows references up to 2 GHz
- 1.8 V and 3.3 V power supplies
- 100-lead TQFP_EP package

APPLICATIONS

- HFC data, telephony, and video modems
- Wireless base station transmissions
- Broadband communications transmissions
- Internet telephony

GENERAL DESCRIPTION

The AD9957 functions as a universal I/Q modulator and agile upconverter for communications systems where cost, size, power consumption, and dynamic performance are critical. The AD9957 integrates a high speed, direct digital synthesizer (DDS), a high performance, high speed, 14-bit digital-to-analog converter (DAC), clock multiplier circuitry, digital filters, and other DSP functions onto a single chip. It provides baseband upconversion for data transmission in a wired or wireless communications system.

The AD9957 is the third offering in a family of quadrature digital upconverters (QDUCs) that includes the AD9857 and AD9856. It offers performance gains in operating speed, power consumption, and spectral performance. Unlike its predecessors, it supports a 16-bit serial input mode for I/Q baseband data. The device can alternatively be programmed to operate either as a single tone, sinusoidal source or as an interpolating DAC.

The reference clock input circuitry includes a crystal oscillator, a high speed, divide-by-two input, and a low noise PLL for multiplication of the reference clock frequency.

The user interface to the control functions includes a serial port easily configured to interface to the SPORT of the Blackfin® DSP and profile pins to enable fast and easy shift keying of any signal parameter (phase, frequency, or amplitude).

FUNCTIONAL BLOCK DIAGRAM

Figure 1.

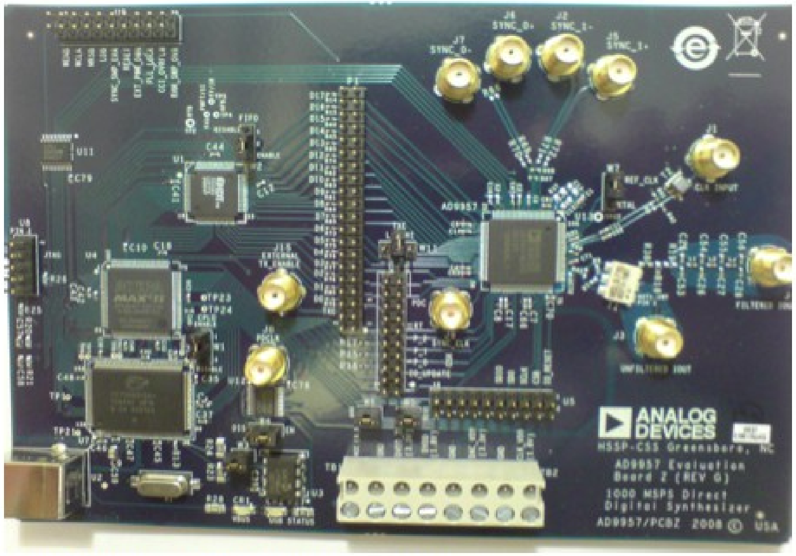


Figure 3.1: Photograph of the EVAL-AD9957 evaluation board.

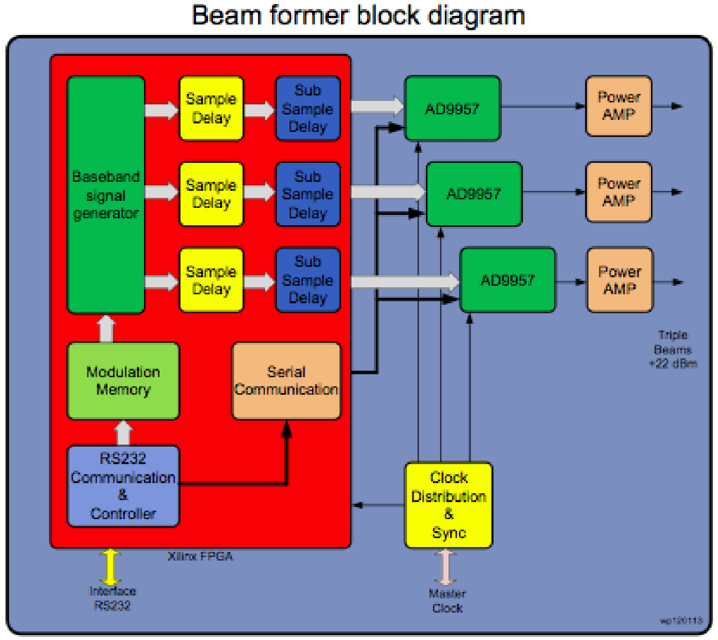


Figure 5.5: Showing the main functional blocks of the FPGA beam-former (red box) and the signal flow through the 3-channel arbitrary-waveform exciter. All modulation data paths (white) are 8 bits wide. The yellow blocks labelled "Sample Delay" are implemented as digital pipelines, while the blue blocks labelled "Sub Sample Delay" are 36-tap all-pass FIR filters with filter coefficients selected to produce an output signal delayed by a fraction of a sample interval relative to the input signal over and above the constant integer sample filter delay. In the present prototype realisation, baseband data flows from the modulation memory through the delay system and on to the AD9957s at 15 Msamples (complex) / second.

Then things moved slowly for several years (politics), but in 2017 the project finally went into construction...

- 1st phase finacing (685 MSEK) secured,
- System specifications frozen,
- Construction plan laid down:
  - Approx. same geometry as proposed by design study, but antenna sites slightly relocated,
  - Construction in four stages:

    1) Three antennas, TX 5 MW
    2) TX => 10 MW
    3) A fourth antenna (RX, NO)
    4) A fifth antenna (RX, SE)

EISCAT 3D

EISCAT SCIENTIFIC ASSOCIATION

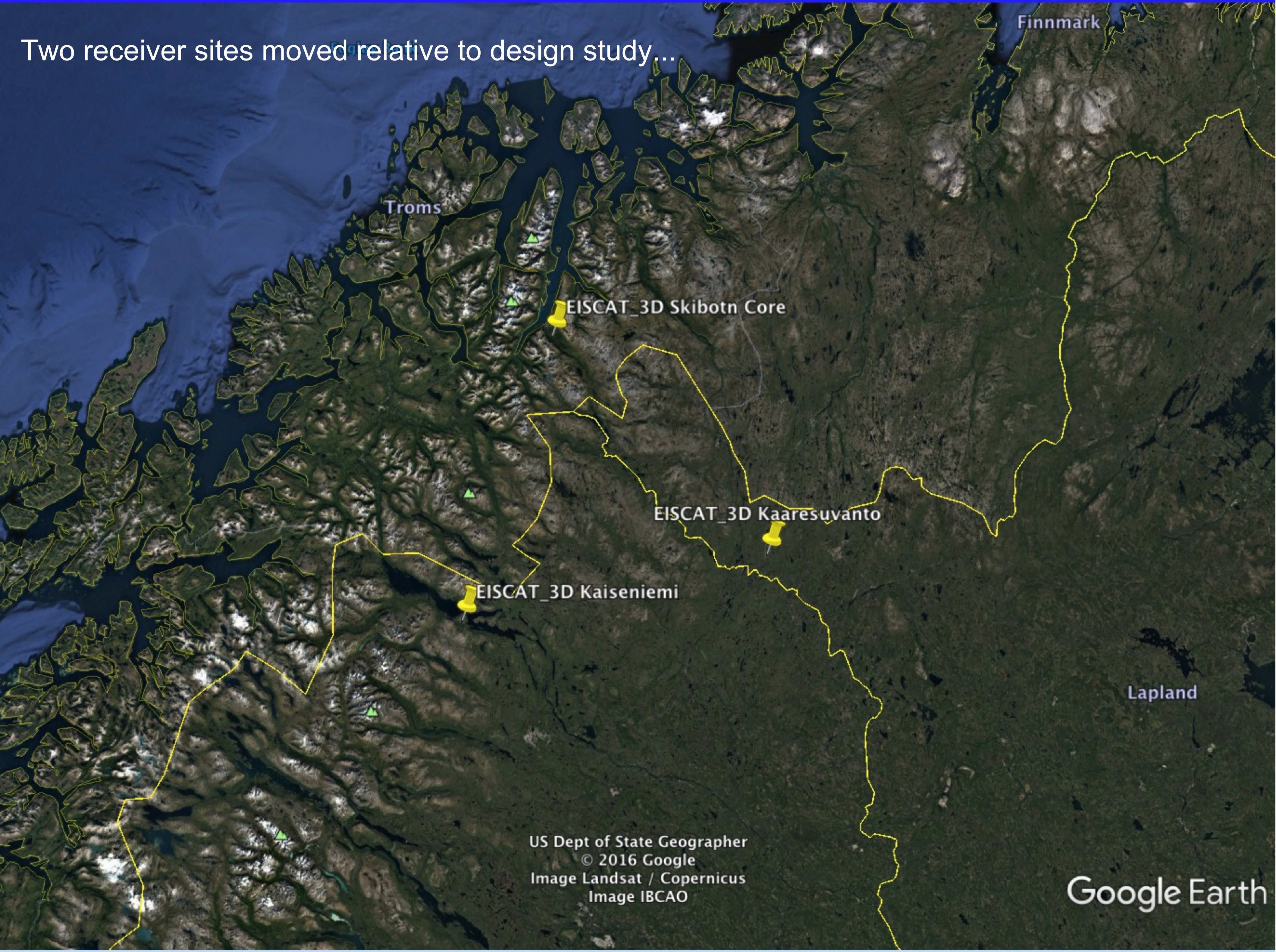
This plaque was unveiled on
7 September 2017
to mark the beginning of the construction of the

Denne plaketten ble avduket den
7. september 2017
i anledning starten på arbeidet med

EISCAT_3D Core Site Facility

Official Kick-Off in Tromsø
2017-09-07

Two receiver sites moved relative to design study...



US Dept of State Geographer
© 2016 Google
Image Landsat / Copernicus
Image IBCAO

”Core Site”, Skibotn / Troms, Norge

The first prototype array module, Tromsø Sept 07, 2017
Element antennas now sloping X dipoles rather than Yagis

Mass production of 91-elements array modules

contracted to *East China Research Institute of Electronic Engineering* (ECRIEE)), Hefei, PRC. The EISCAT_3D project group paid a visit there in January 2019 to check the first module, which will now be tested and then shipped to EISCAT. More than 500 of these modules will be built !

The antenna proper, as lifted off the container

The target design uses ≈ 2 x more elements per module than proposed in the Feasibility Study, combined with denser packning (0,5 λ between elements)

This increases the grating-lobe-free steering range from 40^o to 60^o off zenith, but at a cost...

Container interior

19 inch racks for TX/RX

Cabling from
antennas installed

The receivers will produce ”astronomical” amounts of raw data, that must be handled in real-time...

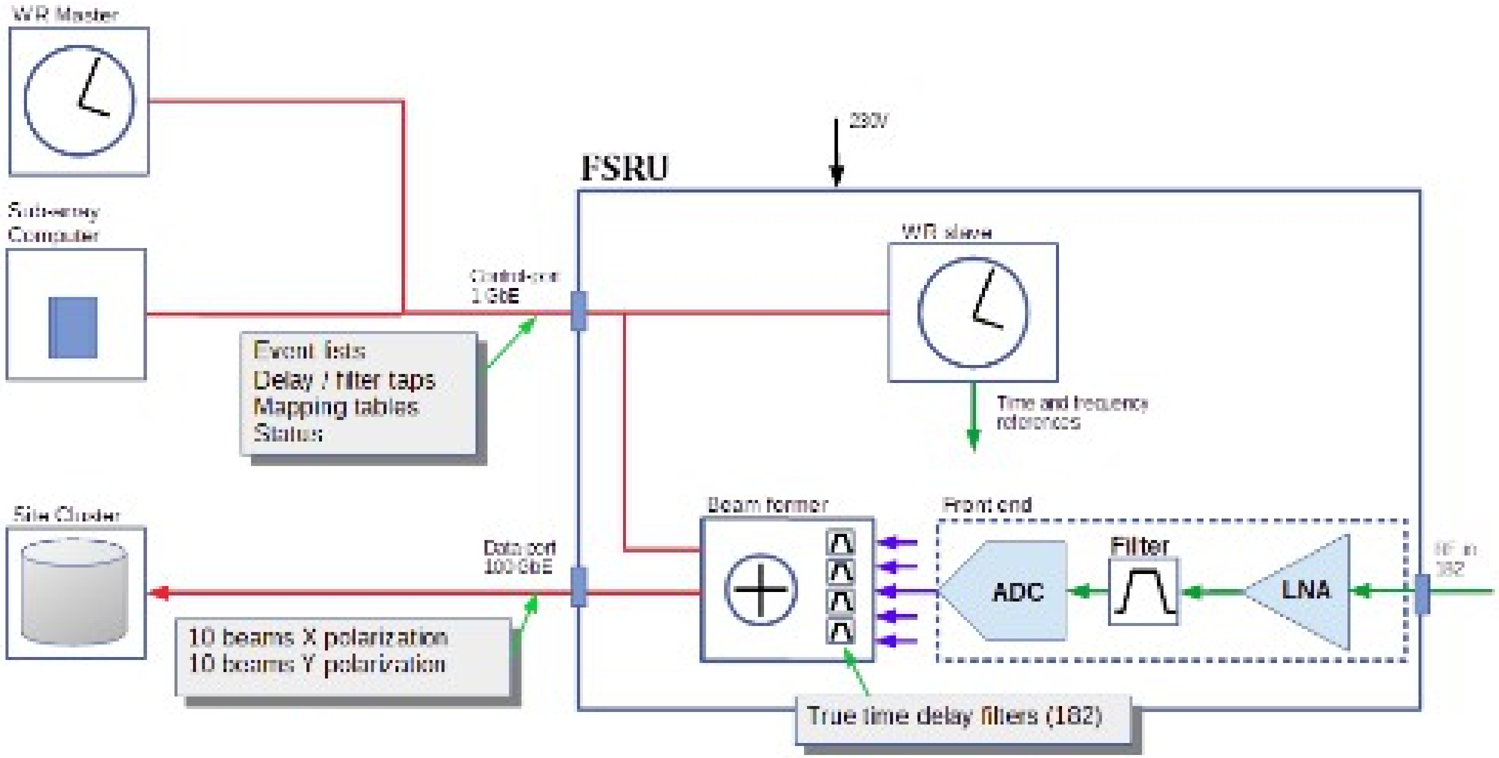


Diagram 5.First Stage Receiver Unit.

≈ 50 Ms/s (complex) /ADC

x 182 ADC / antenna module

= 9,2 Gs/s per module !

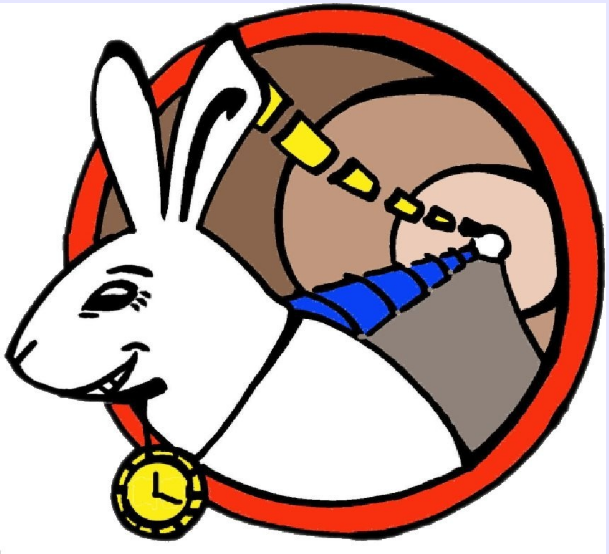
Method: local *”beamformers”* in FPGA-

Raw samples merged into 10+10 ”wide” beams,

so reducing data rate to ≈ 1 Gs/s per antenna module

Challenge # 1: timekeeping

- All ≈ 20000 ADCs and DACs in an array must be time-synchronized to better than a tenth of a period at 233 MHz, i.e.
- **Δt << 0,4 ns !**
- In 2007, this was one of the outstanding design challenges; no good solution had been found. How to solve it in practice today ?
- **Well, with the help of a bunny -**



- In 2008, CERN and GSI began developing a new system for precision timekeeping over Ethernet, called ”*White Rabbit*” after the eponymous character in ”Alice in Wonderland” that checks his watch again and again...
- WR has now been standardized by IEEE -

White Rabbit

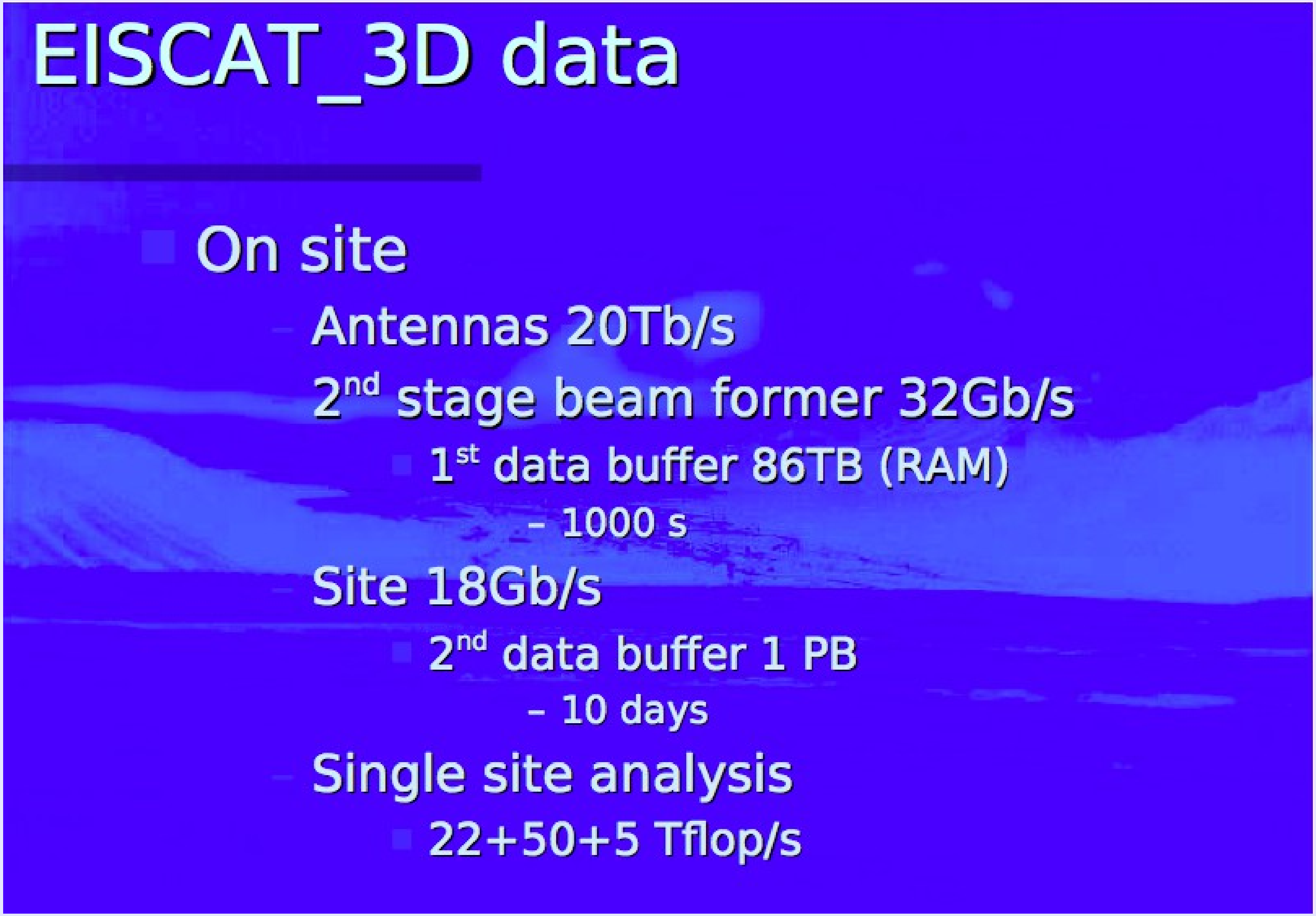
- Operates over normal Gigabit Ethernet, IEEE 802.3
- Network topology following IEEE 802.1Q (Bridged LAN...)
- At the bottom: The 2008 version of Precision Time Protocol,

  PTP/IEEE 1588-2008
- Special routers - but open HW and SW !
- Hierarchical timekeeping, based on a master clock + a strictly defined request/reply protocol that queries every node in the LAN and measures the delay between request and reply

  => sub-nanosecond absolute accuracy

  => synchronization to < few tens of picoseconds within LAN !
- In successful routine operation at the CERN LHC...
- Will now also be used for EISCAT_3D timekeeping !

Challenge # 2: handle the data flow



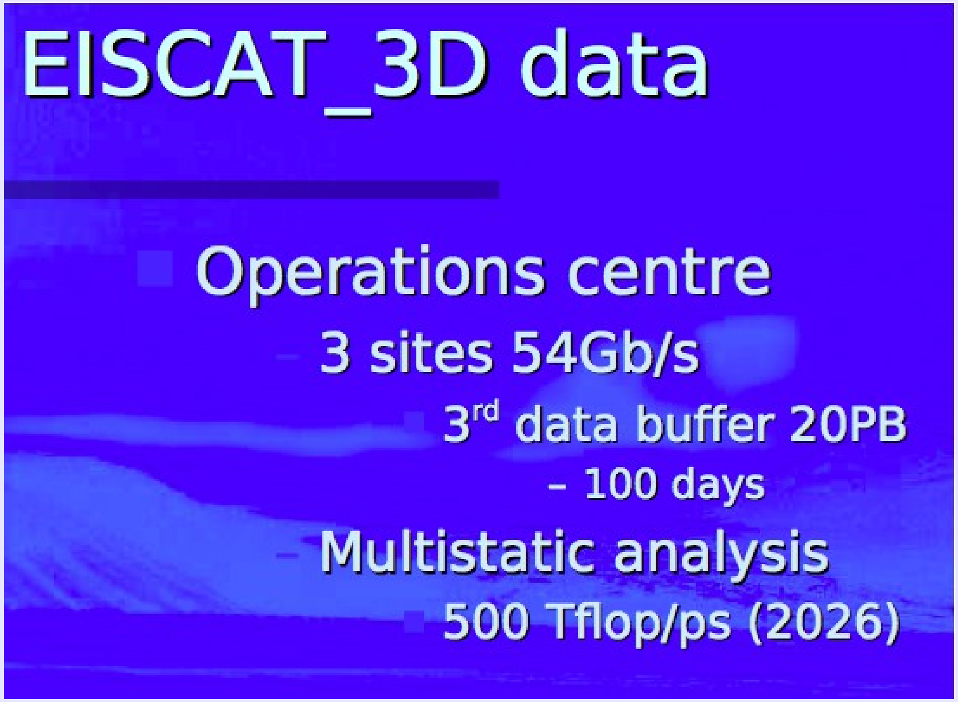
EISCAT_3D data

- On site
  - Antennas 20Tb/s
  - 2nd stage beam former 32Gb/s
    - 1st data buffer 86TB (RAM)
      - 1000 s
  - Site 18Gb/s
    - 2nd data buffer 1 PB
      - 10 days
  - Single site analysis
    - 22+50+5 Tflop/s

It has been necessary to define five levels of data products at different time resolutions...

Data levels

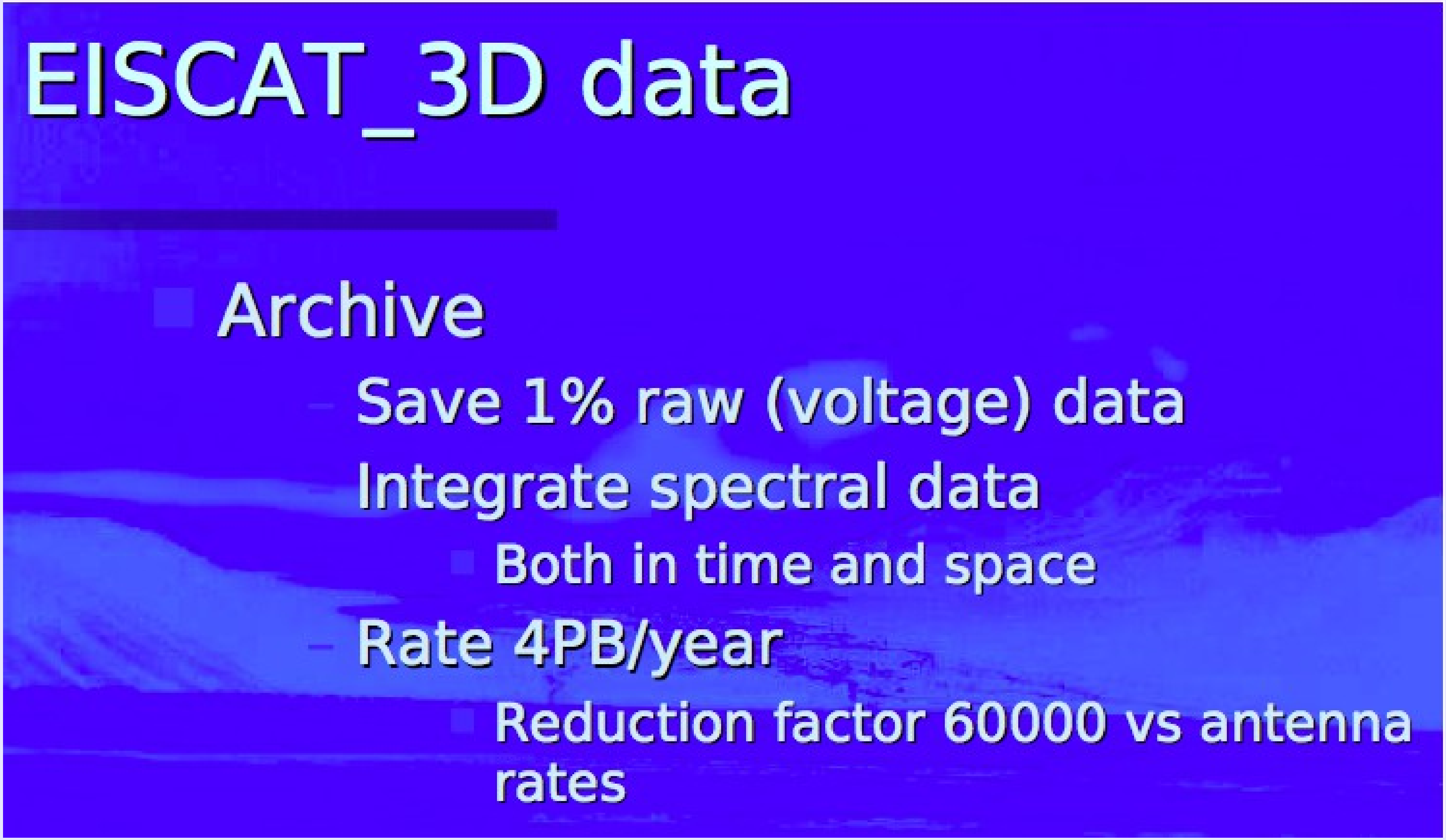
- Level 0
  - From ADC, never store
- Level 1, Voltage (sensitive)
  - Reduced BW (filtered, resampled)
  - Sample interval, microseconds
  - Profile interval, milliseconds
- Level 2, Spectral data
  - Correlated and integrated time/space)
  - File interval, second
- Level 3
  - Ionospheric parameters (volume scatter)
  - Atmospheric parameters (sheet scatter)
    - Tropo, Strato, Meso, Thermosphere
  - Hard target parameters (line/point scater)
    - Space Debris, Meteors
- Level 4
  - User data, reports (filtered, resampled)
    - Climate...



EISCAT_3D data

- Operations centre
  - 3 sites 54Gb/s
    - 3rd data buffer 20PB
      - 100 days
  - Multistatic analysis
    - 500 Tflop/ps (2026)

For long-time archiving, the data volume must be drastically reduced...



EISCAT_3D data

- Archive
  - Save 1% raw (voltage) data
  - Integrate spectral data
    - Both in time and space
  - Rate 4PB/year
    - Reduction factor 60000 vs antenna rates

Simulations of some scan patterns

The old UHF system	/Users/ugw/ham_radio/föredrag_lindesberg/movie_legacy.html
EISCAT_3D, one viewing direction	/Users/ugw/ham_radio/föredrag_lindesberg/test_40.html
EISCAT_3D, five viewing directions	/Users/ugw/ham_radio/föredrag_lindesberg/test_41.html
EISCAT_3D, two users (changing between two scan patterns)	/Users/ugw/ham_radio/föredrag_lindesberg/test_42.html
Program interrupt / program change (for instance to follow a meteor echo)	/Users/ugw/ham_radio/föredrag_lindesberg/test_43.html
Raster scan (3D-sampling of ionosphere)	/Users/ugw/ham_radio/föredrag_lindesberg/test_44.html

Photo: Torbjörn Lövgren

Mer info: www.eiscat.se

EISCAT

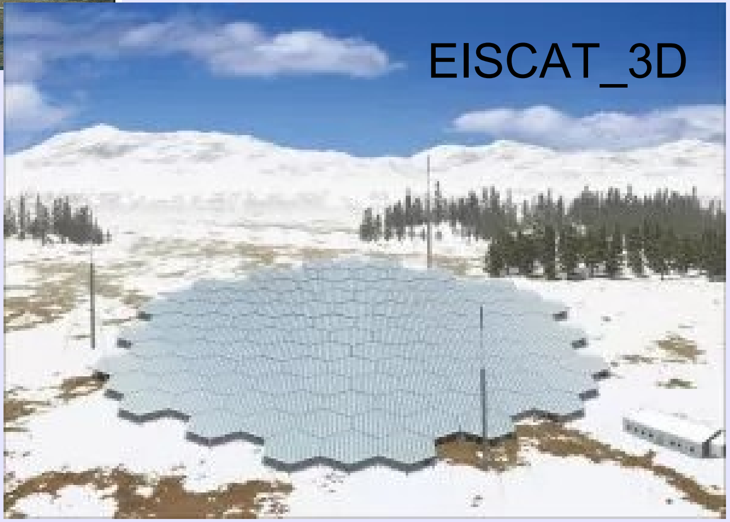
Yesterday


KST

Today


ESR

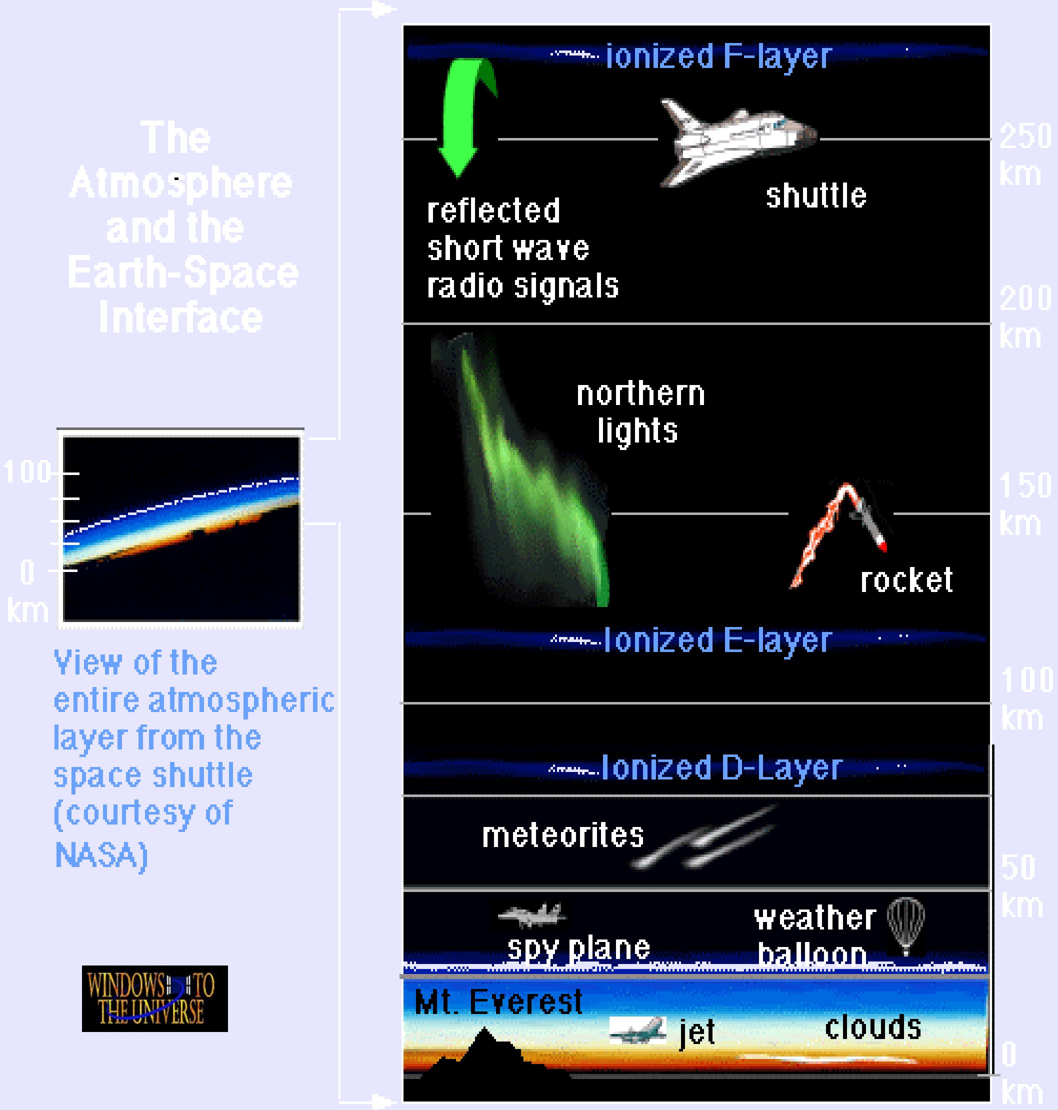
Tomorrow


EISCAT_3D

Gudmund Wannberg SM3BYA

EME Meeting 2019 Örebro

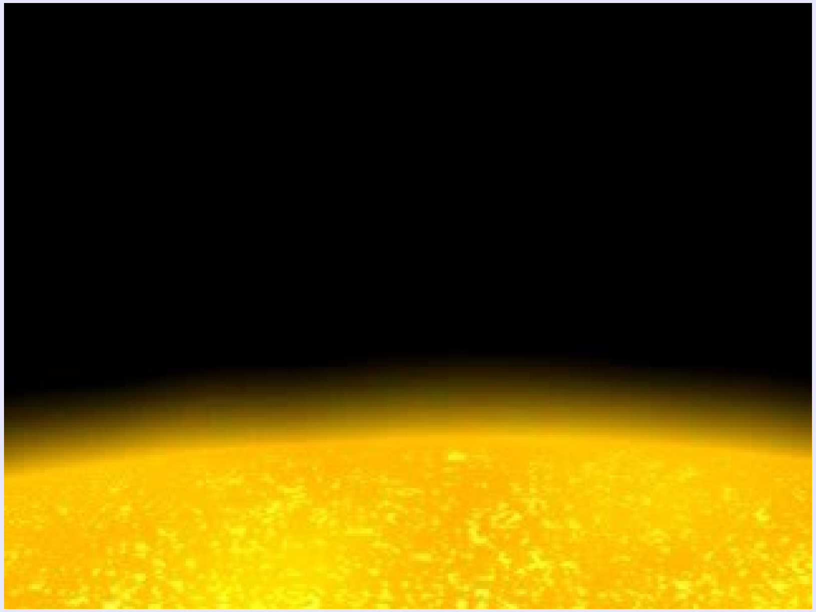
Jonosfären börjar vid c:a 80 km höjd. Norrskenet ligger oftast mellan 90 och 120 km.

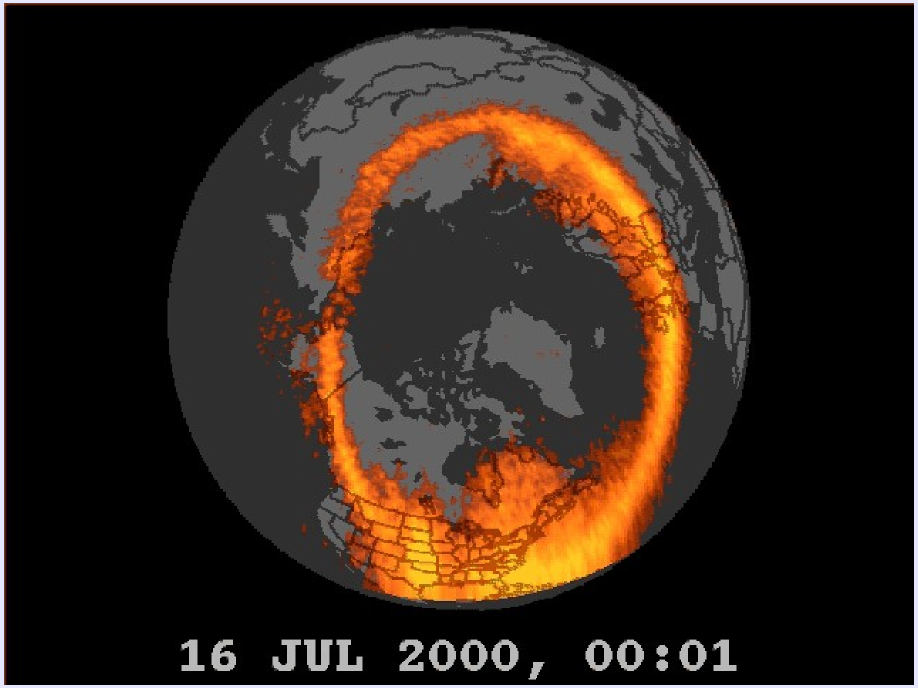


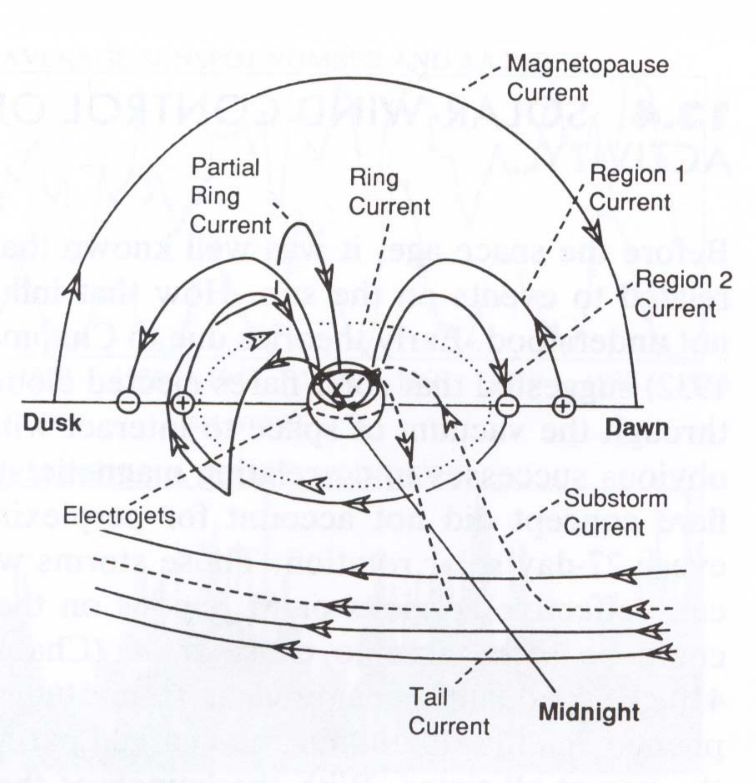
Man kan naturligtvis observera norrsken från marken

med hjälp av kameror och magnetfältsmätningar. Det var uppdraget för Sveriges första forskningsetablering i Kiruna (numera IRF)...

- **...men idag vill forskarna studera hela det kopplade sol-jordsystemet:**
- **Solvinden** transporterar energi och elektriska laddningsbärare till jorden. Där stöter laddningsbärarna på **jordens magnetfält** och avlänkas; **magnetosfären** deformeras. En stor del av solvindspartiklarna hamnar till slut i **jonosfärens norrskenszoner.** **D**är skapar de norrsken - men de dumpar även enorma mängder energi där - följdeffekterna kallar vi **rymdväder** **!**
- **Norrskenszonen är som en bildskärm som avbildar en stor del av magnetosfären...**

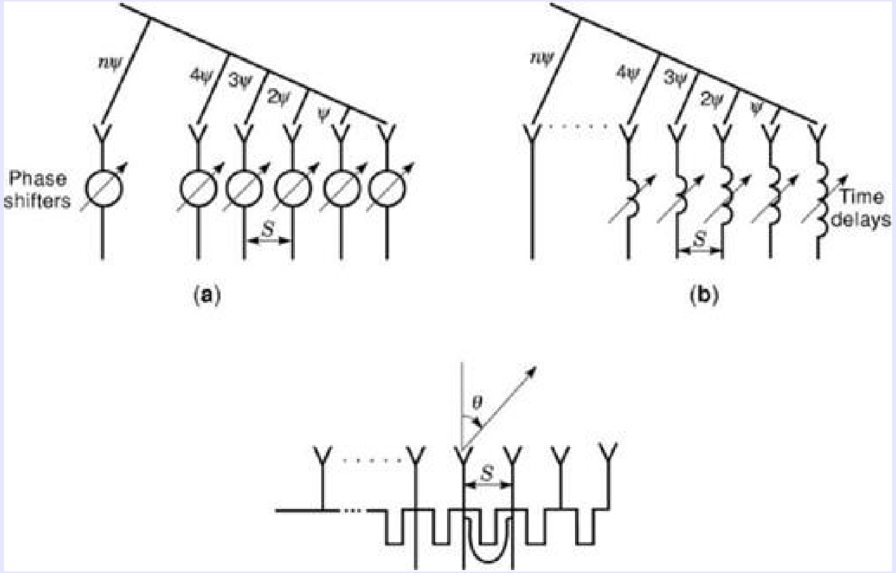



16 JUL 2000, 00:01

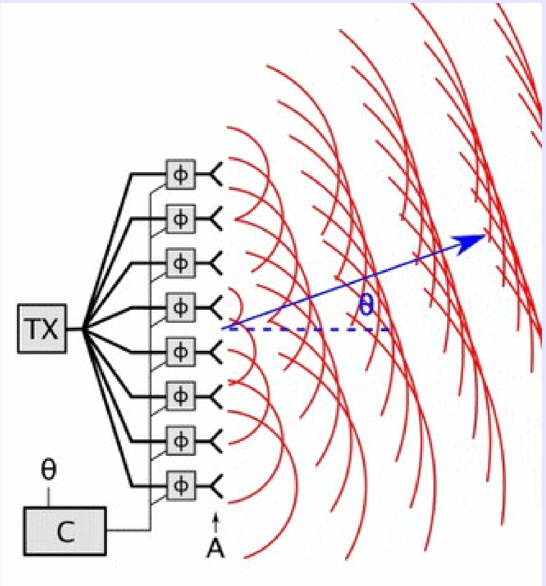


Så här fungerar en ”phased array”

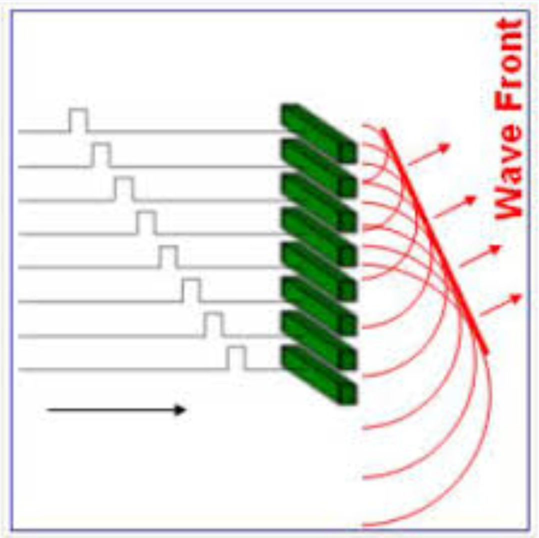
Ett stort antal element med låg antenn-vinst (t.ex.dipol-reflektor) och följaktligen stor öppningsvinkel, placeras ut med ≈ 0,5 - 1,0 våglängder inbördes avstånd.



Man kan då skapa en smal lob var som helst inom det enskilda elementets huvudlob, genom att *fasskifta* eller *fördröja* signalerna från de enskilda elementen och sedan summera dem. Om man direktsamplar kan man använda samma data flera gånger för att skapa flera samtidiga lober...



Fasskift - OK om smalband



Tidsfördröjning - *nödvändigt vid puls*