Introduction to EISCAT

What you need to know to run an experiment

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EISCAT Scientific Association

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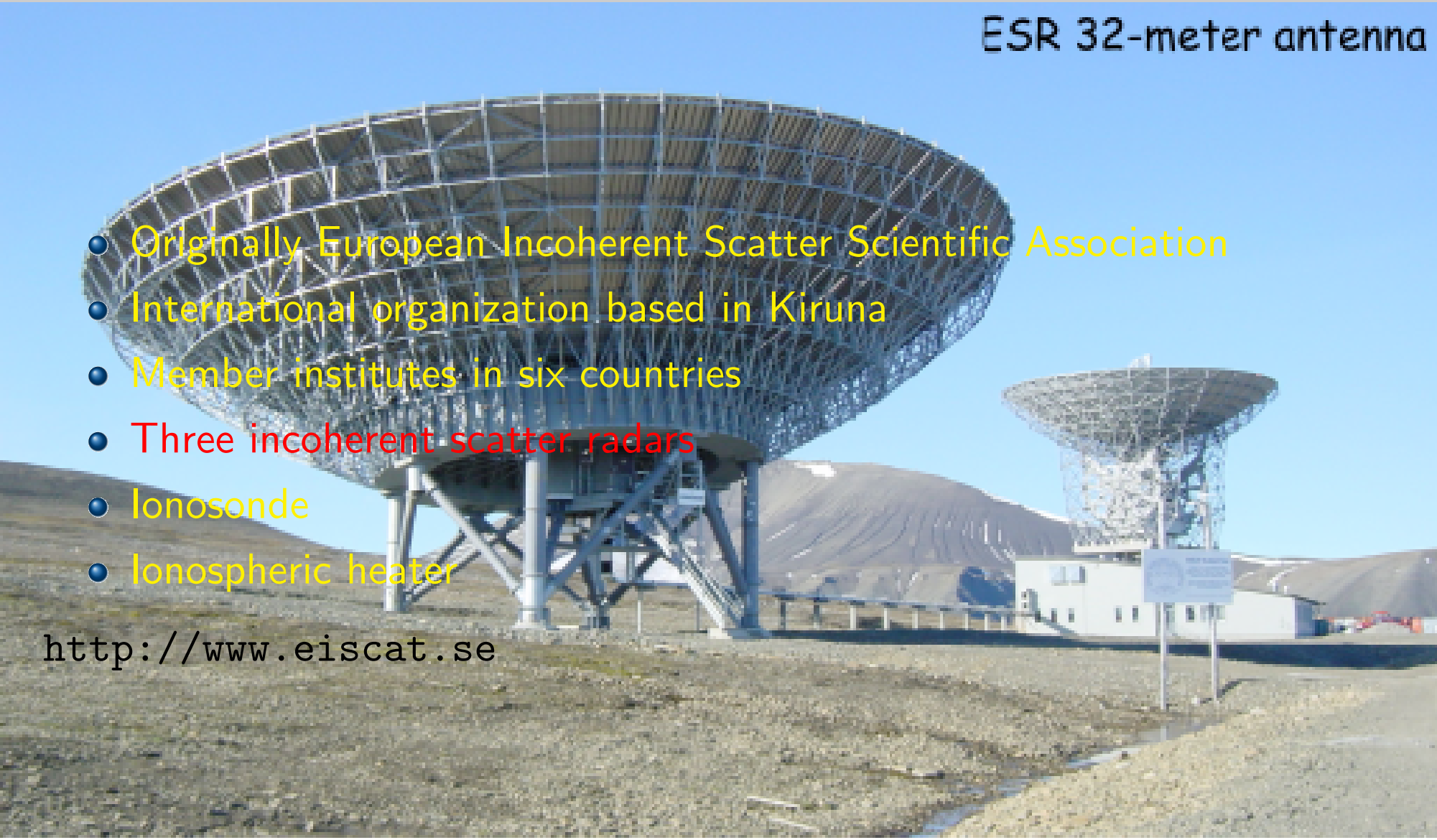
1. Overview of EISCAT
2. Overview of EISCAT hardware and signal processing
3. EISCAT experiment configuration: EROS, ELAN, TARLAN and so on
4. Running EISCAT: EROS command line, real time graph and real time analysis

Outline

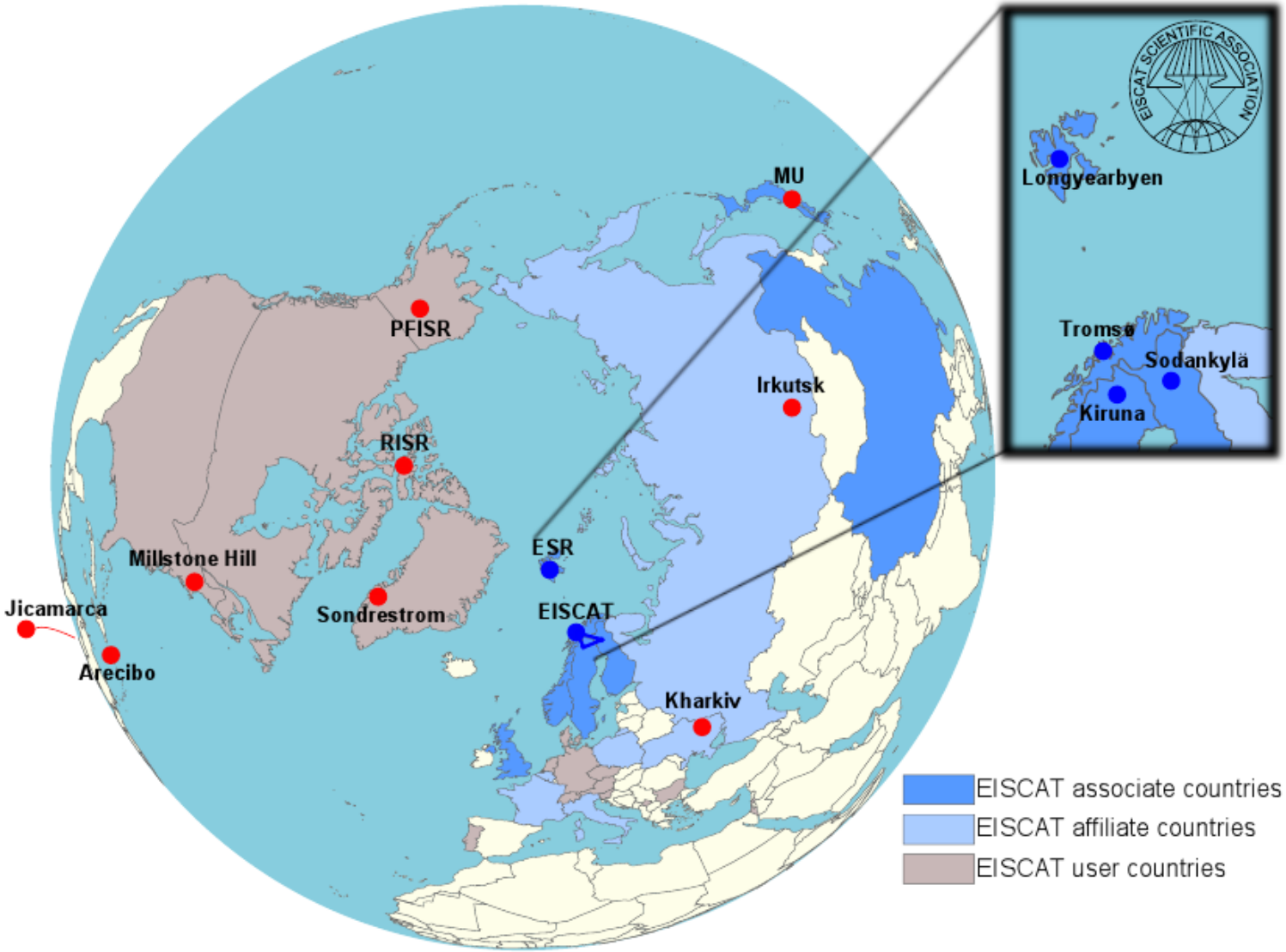
What is EISCAT?



- Orlginally European Incoherent Scatter Scientific Association
- International organization based in Kiruna
- Member institutes in six countries
- Three incoherent scatter radars
- Ionosonde
- Ionospheric heater

`http://www.eiscat.se`

EISCAT in the world



Map Anders Tjulin

EISCAT Svalbard radar (ESR)

- 500 MHz band
- Longyearbyen, Svalbard, 78°09'11" N, 16°01'44" E
- Cusp and dayside auroral oval

From slides by Assar Westman

EISCAT mainland radars

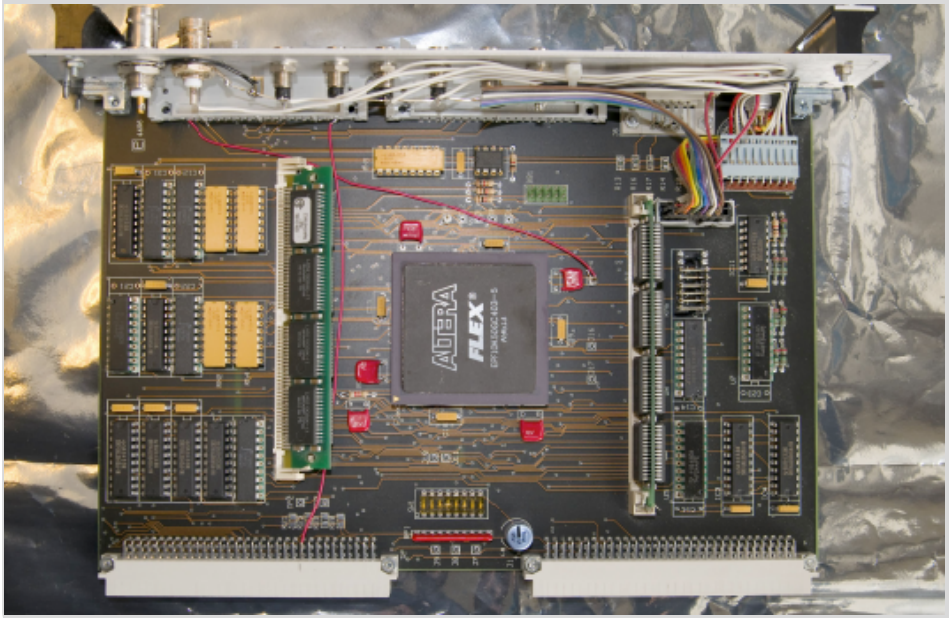
- UHF, 930 MHz
- VHF, 224 MHz, tristatic

Nightside auroral oval, atmospheric dynamics, active heating. . .

Outline

Transmitting a signal

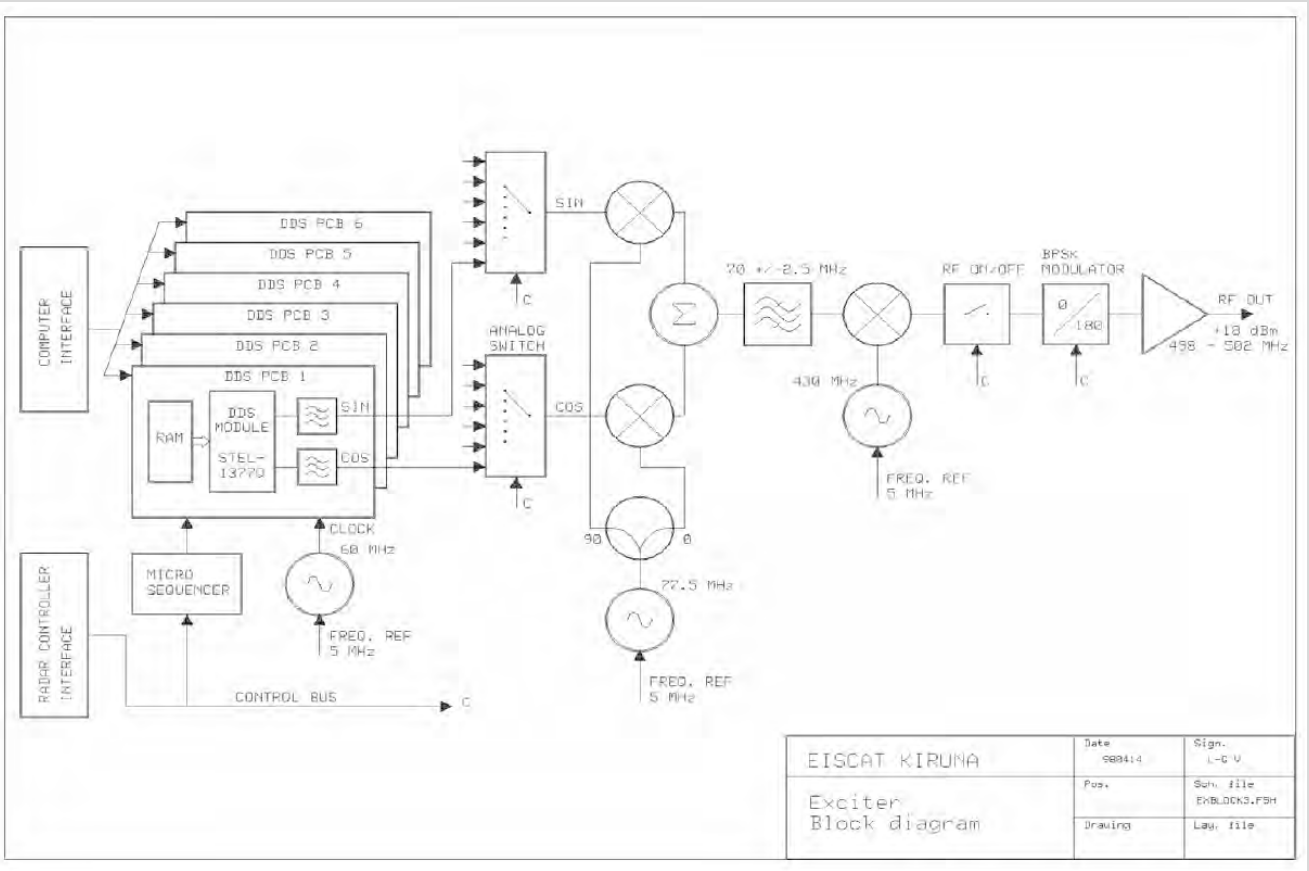
Radar controllers



- The hearts of the system
- Handle fast synchronizations
- Memory banks containing sequences of bits
- 10 MHz resolution
- One for Tx and one for each Rx

Transmitting a signal

Exciter

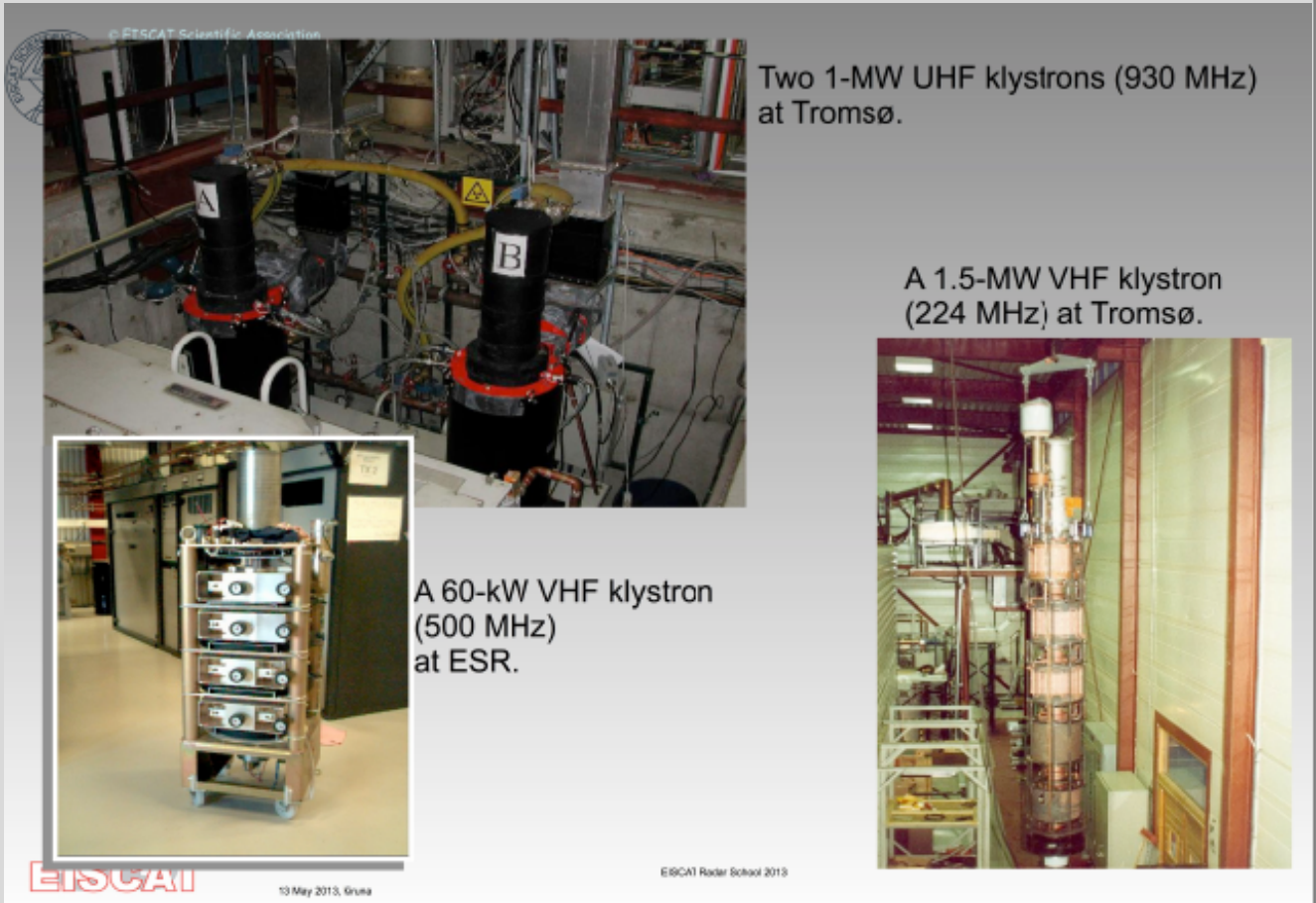


- Generates the signal
- 0 and 180 degree phase flips

Transmitting a signal

Power amplifiers

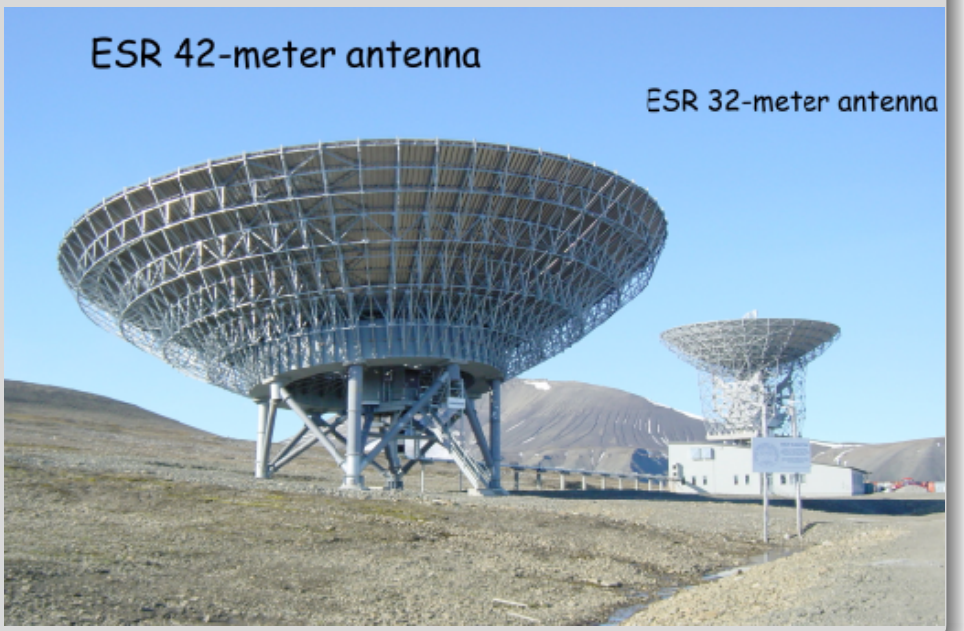
- Raise the output power
- ESR peak output 1 MW (average 250 kW)
- Waveguides to the antennas



Transmitting a signal

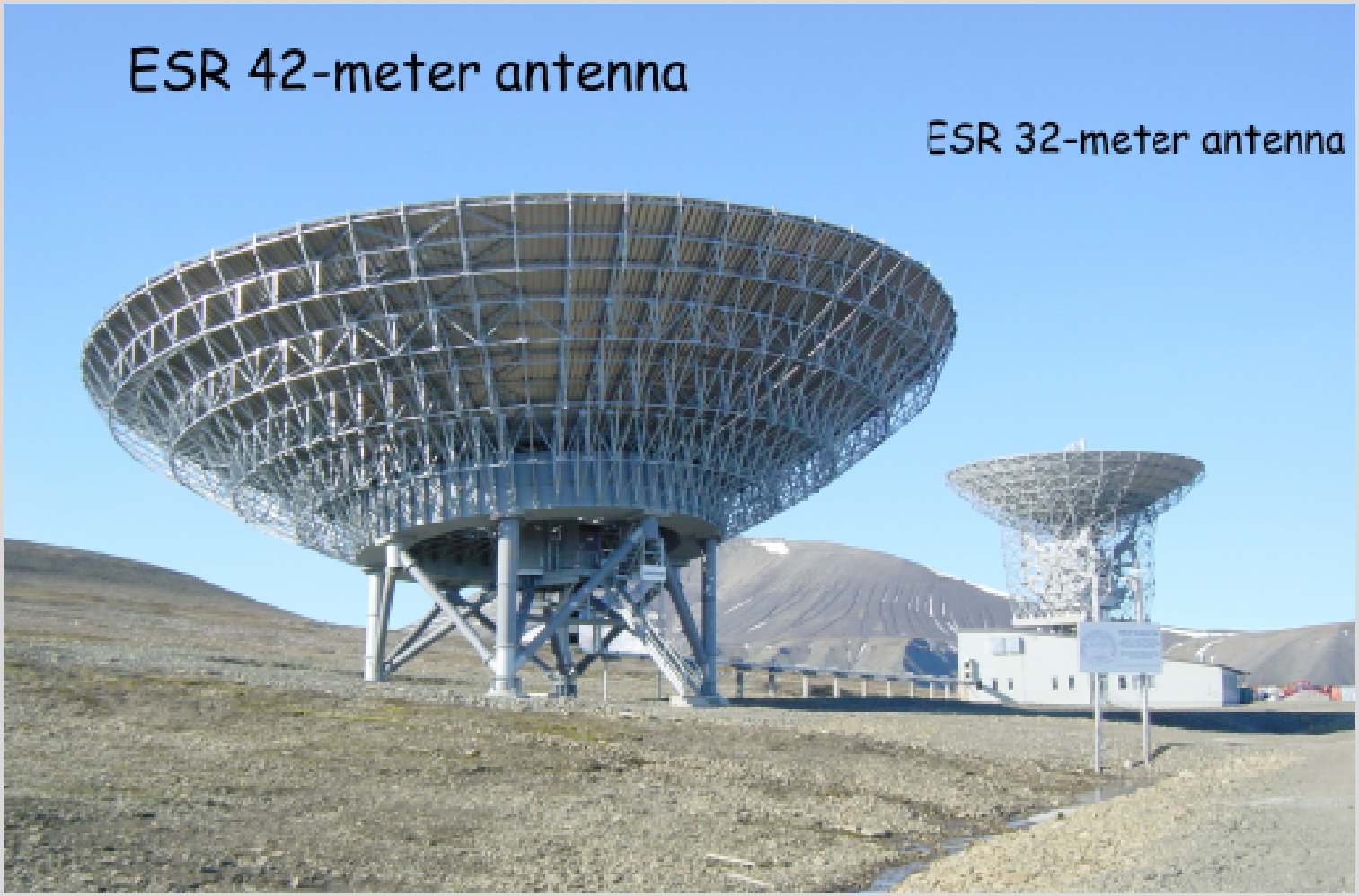
Antennas

- Waveguide from amplifiers
- ESR has antenna switch
- Polarizer, mode converter
- Receiver protection



Receiving the scattered signal

Antennas



Receiving the scattered signal

Analogue receiver chain

1. Polarizer
2. Receiver protector
3. Noise injection
4. Low noise amplifier
5. 2 local oscillators and mixers downconvert the signal
6. A/D conversion and digital processing

Receiving the scattered signal

Basics of the digital processing

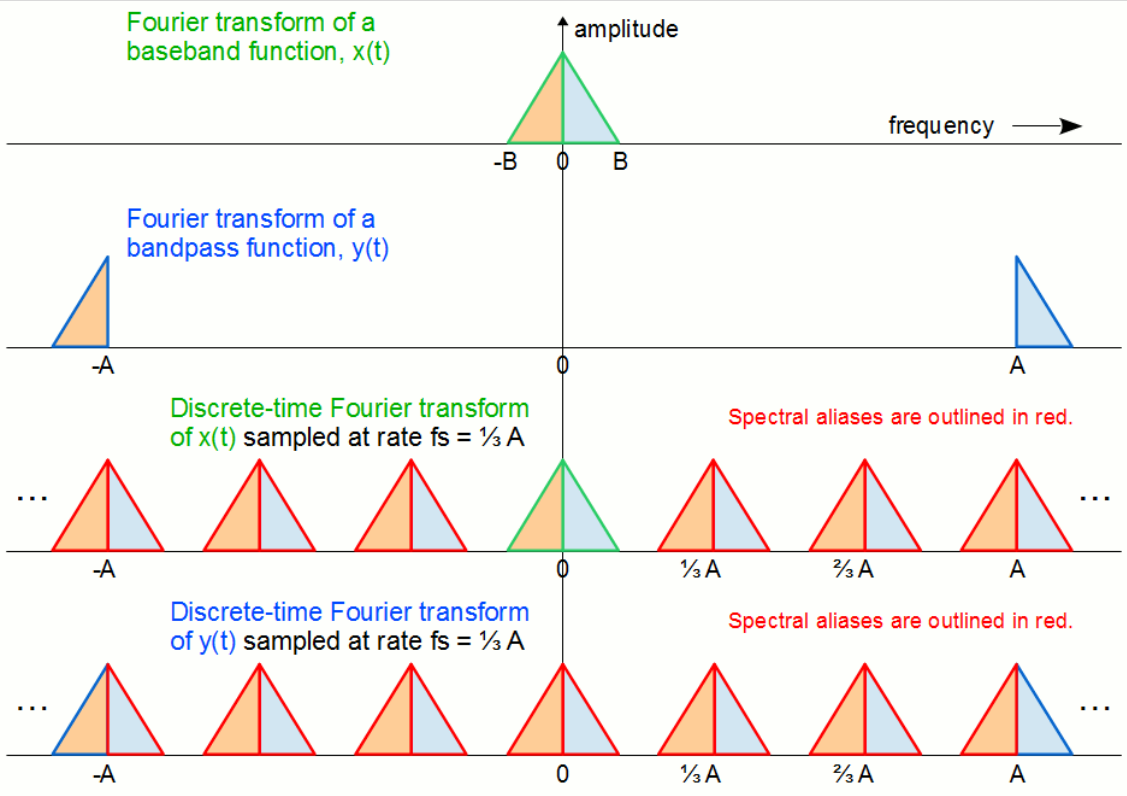


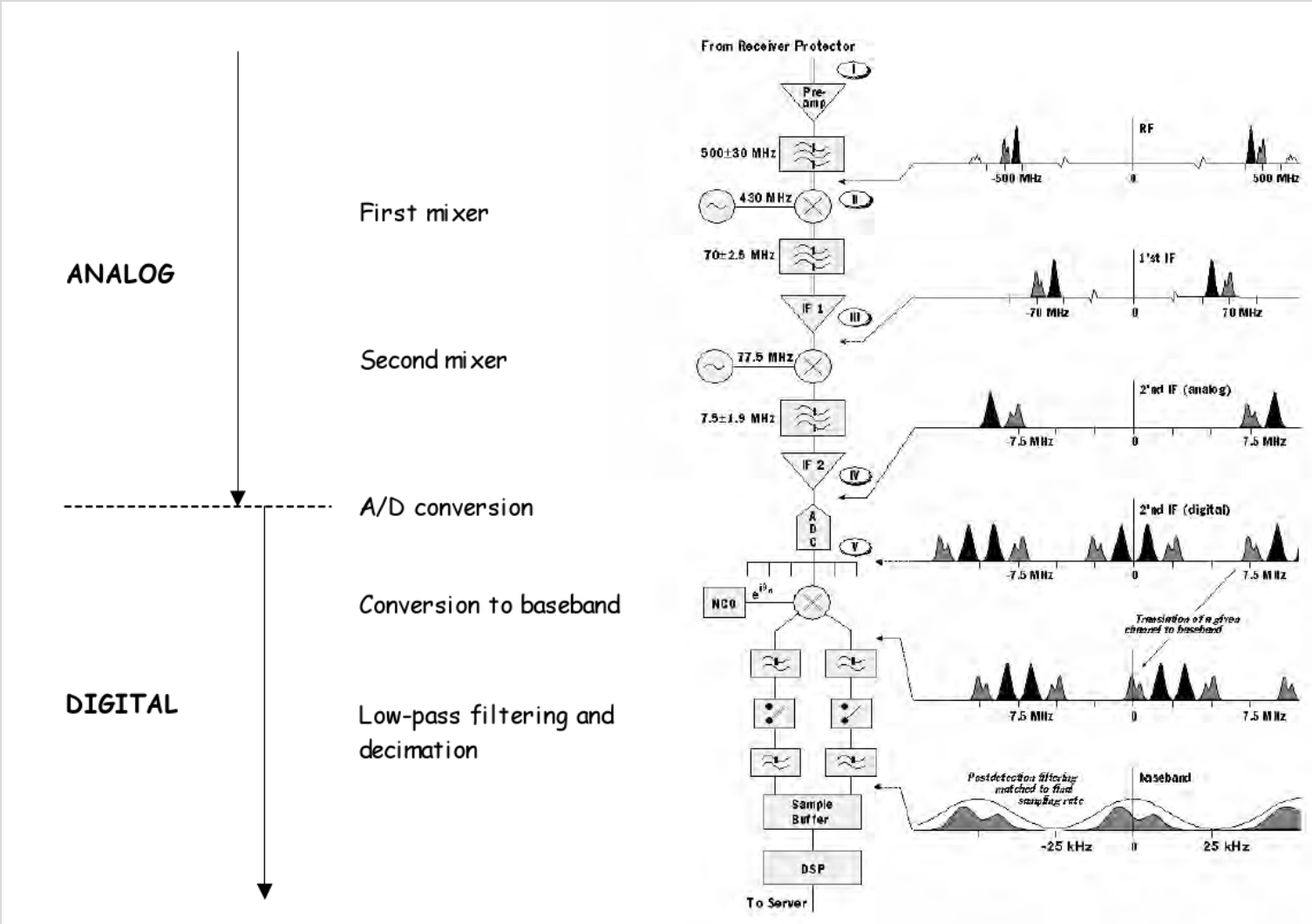
Figure from Wikipedia

A closer look at the sampling theorem

- ISR spectrum after downmixing: like y(t) here
- Sampling at a rate f_s lower than the signal frequencies
- Aliasing does not matter if signal is within one Nyquist zone ($-f_s/2$ to $f_s/2$ around center frequency)

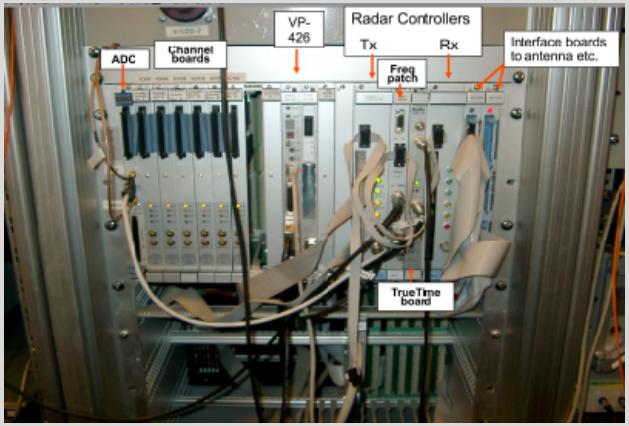
Receiving the scattered signal

Overview of EISCAT signal processing

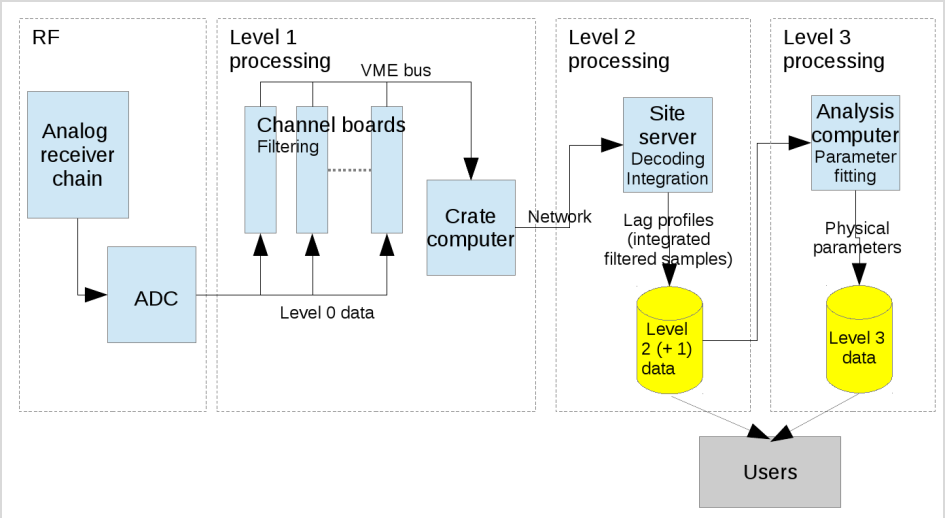


Receiving the scattered signal

Digital receiver (and radar controllers): the VME crate



Schematic summary



Outline

Experiment considerations

https://www.eiscat.se/groups/Documentation/UserGuides/eiscat-experiments/at_download/file

1. Radar and antenna
   - location
   - frequency
2. Pulse code program
   Usually alternating codes
   - Altitude interval
   - Range resolution
   - Time resolution
   - Plasma lines or not
   - ESR: antenna switching
3. Antenna scan pattern

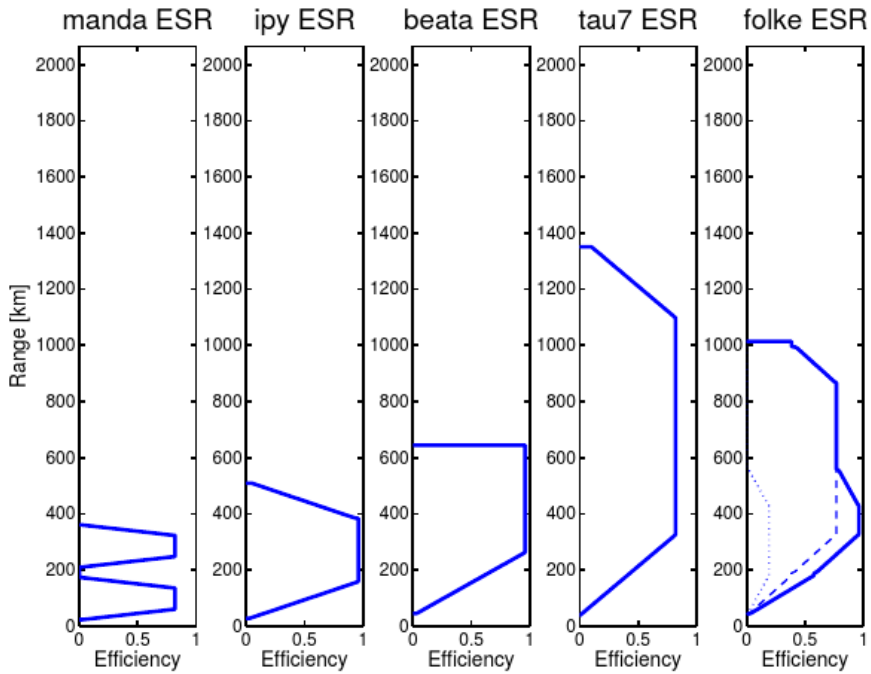


Figure 3: Overview of the ranges covered at the EISCAT ESR radar by the experiments used in the common programmes.

EISCAT Realtime Operating System (EROS)

http://sgo.fi/~jussi/eiscat

- Handles all "slow" configurations
- Consists of several UNIX processes
- Based on **Tcl** script language
- Loads all configurations; VME crate computer talks to
  - antenna control unit
  - VME boards
  - ESR exciters

EROS files

Defining an experiment in EROS: several files needed

Experiment Language ELAN (.elan) Extended Tcl/Tk, loads other files, synchronization to 1 second

Transmit and Receive Language TARLAN (.tlan) Radar controller program, compiled to binary code, 10 MHz synchronization

.frq ESR exciter settings

.nco Channel board frequency settings

.fil Channel board filter configurations etc

.DECO Decoder settings

`exp_site.txt`, .ac, `t_to_ps.txt` Descriptions of alternating code

.rtg_def.m Describes data format for real time graph

Principle of experiment design: write one Python program that generates most of the above

EROS files

ELAN file example (just a short part)

```
BLOCK beata {{scan cp1} {owner CP} {height 240.0}} {
   --- skip many settings
   # Stop receiver --
   SYNC -10
   stopradar -rec
   if {[ISUHF]||[ISVHF]||[ISESR]} {
       stopradar -trans
   }
   if {[ISESR]} {
       stopradar -pla
       stopdata pla
   }
   stopdata
   # Load radar controller --
   if {[ISESR]} {
    if { $ant=="42p" } {
        loadradar rec -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-42p_ionesr.rbin -prog1 0
        loadradar pla -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-42p_plasmaesr.rbin -prog1 0
        loadradar trans -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-42p_esr.tbin -prog1 0
    } else {
        loadradar rec -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-42m_ionesr.rbin -prog1 0
        loadradar rec -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-32m_ionesr.rbin -prog2 16384
        loadradar pla -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-32m_plasmaesr.rbin -prog1 0
        loadradar trans -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-42m_esr.tbin -prog1 0
        loadradar trans -loopc $Loopc -sync $Sync -file $XDIR/${Expname}-32m_esr.tbin -prog2 16384
    }
    loadexciter $TXFRQ
    --- skip ---
```

EROS files

Antenna scan example

```
# cp2_pattern.elan
#
...
block cp2_pattern { Iper {Flag "normal"} } {

    set N42 10
    set N32 10
    set Npos 3

    if { $Flag == "normal" } {
        set AZ(1) 144.00; set  EL(1) 66.66
        set AZ(2) 171.60; set  EL(2) 90.00
        set AZ(3) 171.60; set  EL(3) 63.20
    } else {
        set AZ(1) -36.00; set  EL(1) 113.34
        set AZ(2)  -8.40; set  EL(2)  90.00
        set AZ(3)  -8.40; set  EL(3) 116.80
    }

    set Title "cp2 scan"

    source /kst/exp/scans/esr/esrrantenna.tcl
    DiscreteScan AZ EL $Npos $Iper $Flag $Title $N42 $N32

};#cp2_pattern
```

EROS files

TARLAN file example

```
SETTCR 0
%%%% SUBCYCLE 1 %%%%
AT 1.1 NCOSEL0,NCOSEL0P,ANTENNA0,AD1R,AD1L,STFIR,AD2LP,AD1RP,STFIRP
AT 3 WREG UNIT0,FSEL0,OPERA
AT 4 FLOAD UNIT0,FSEL0,OPERA
AT 5 RXPROT,RXSYNCON,TXSYNCON
AT 6 PREAMPOFF
AT 10 RXSYNCOFF,TXSYNCOFF
AT 20 MOSEL UNIT0
AT 40 BEAMON
%%%% RF TRANSMISSION %%%%
AT 50 CH1,RFDRON,PHA180 %++
AT 150 PHA0 %--
AT 250 PHA180 %+
AT 300 PHA0 %-
AT 350 PHA180 %++++
AT 550 PHA0 %--
AT 650 PHA180 %+
AT 700 PHA0 %----
AT 900 PHA180 %+
AT 950 PHA0 %--
AT 1050 PHA180 %+
AT 1100 PHA0 %-
AT 1150 PHA180 %+++
AT 1300 PHA0 %---
AT 1450 PHA180 %+
AT 1500 PHA0 %-
AT 1550 RFDROFF,PHA0
AT 1555 BEAMOFF
AT 1650 CH1OFF
```

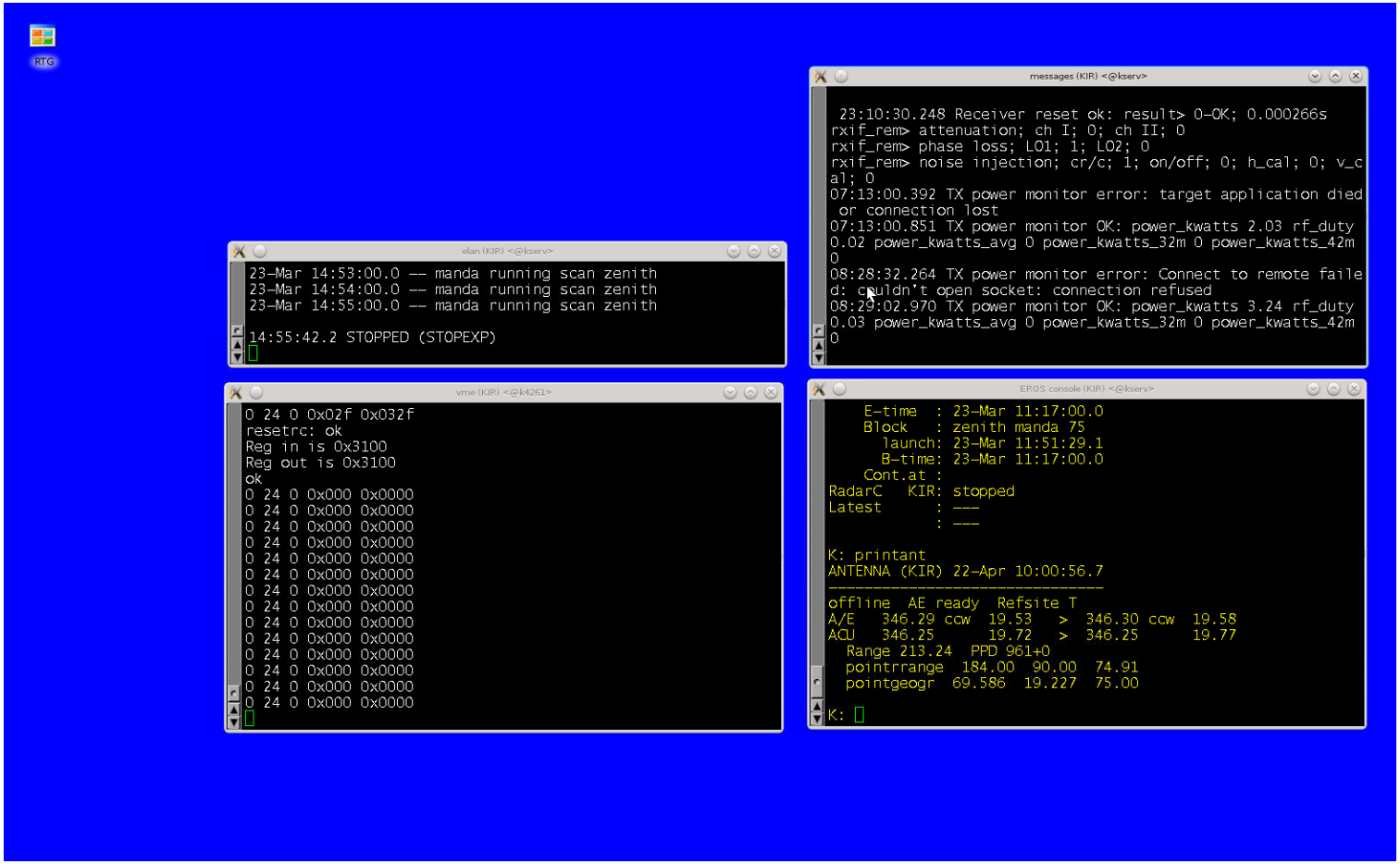
Data processing in software

Data correlation (voltage to ACF domain)

- VME crate computer: **lag_wrap**
  - Configuration: `.fil` file
  - Reads out data from channel boards
  - Sorting, preformatting, cross products
  - Reads transmitter power
- Main computer: **decodump**
  - Decoding: configuration `.DECO` file
  - Other processing also possible
  - Final time integration
  - Adds parameter block
  - Stores to files compatible with Matlab

Outline

The EROS console (Kiruna site)



The window titled **EROS console** is a command line interface where you run all EROS commands.

Important EROS commands (see http://sgo.fi/~jussi/eiscat/erosdoc/eros_commands.html)

runexperiment Load and execute experiment ELAN file at specified time with specified parameters

Example

```
runexp /kst/exp/beata/beata fm ip2 CP
```

enablerecording Important: enable data storage

printexperiment Show experiment status

pointdir (and other similar commands) Change antenna pointing

printantenna Show antenna pointing

stopexperiment Stop the experiment

Note: all commands can be abbreviated!

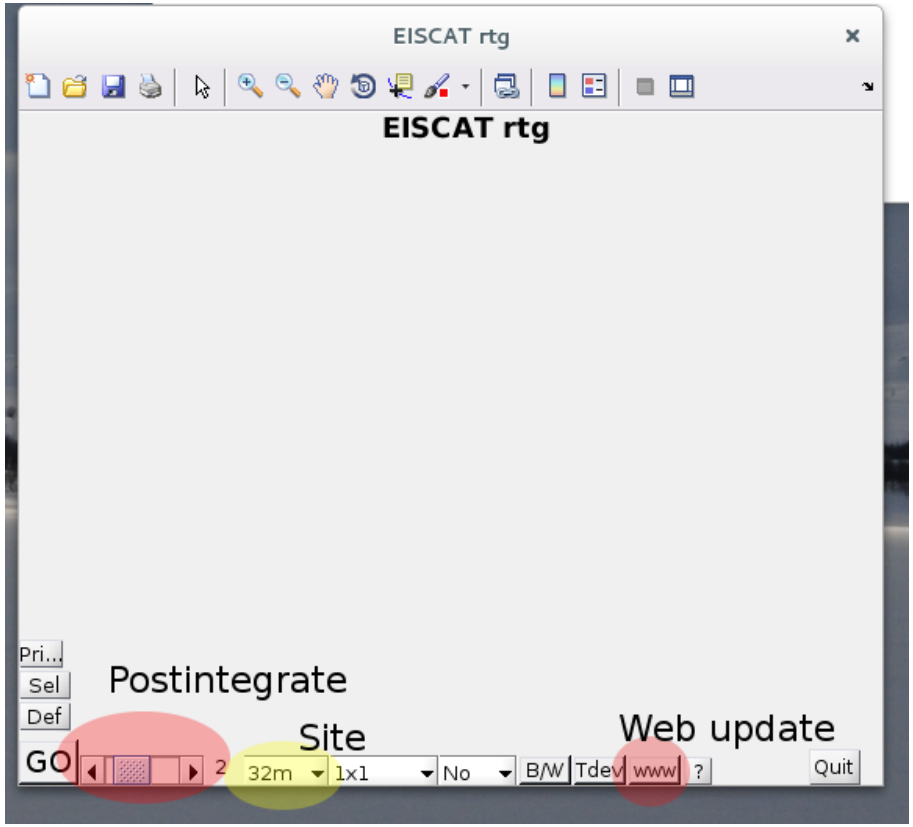
Real-time graph

RTG overview

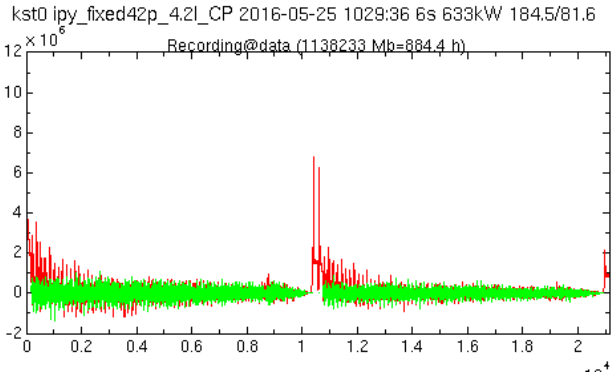
- Matlab software
- Reads data files
- Plots spectra and overviews
  - Selected in experiment's **rtg_def.m**
- Can update web page

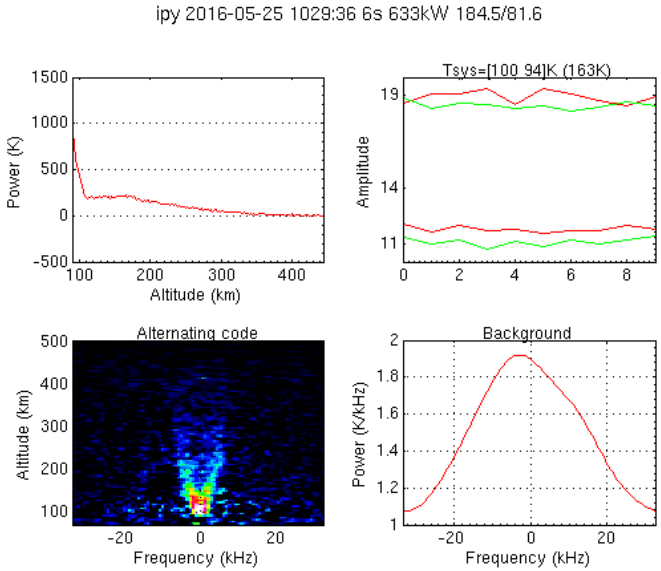
RTG user interface

- Post-integration of data
- Site and other settings
- Plot geometry
- Enable WWW update



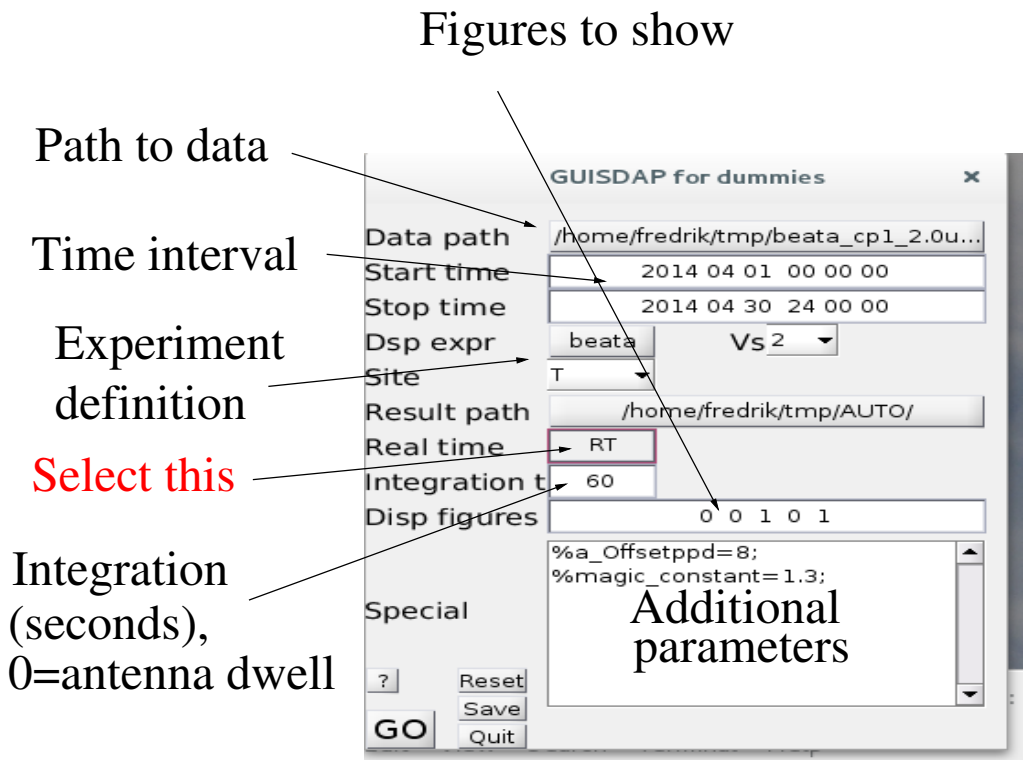
Example of RTG output



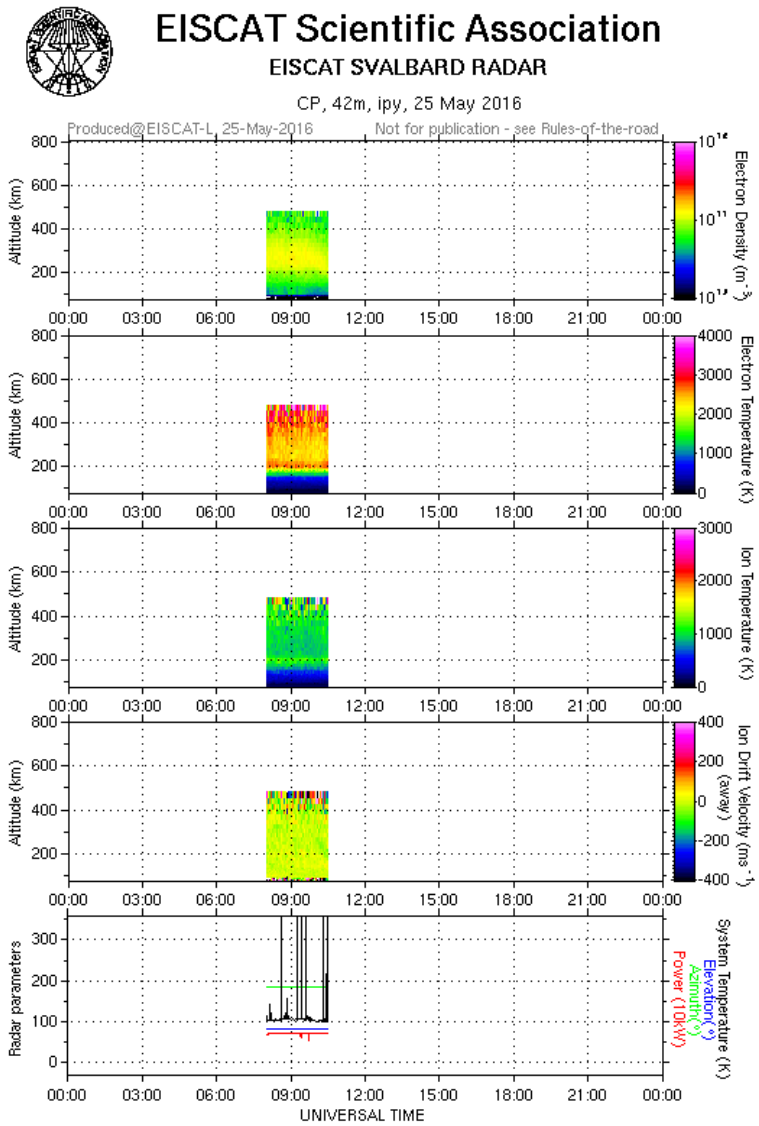


Real-time analysis

- GUISDAP: Matlab software package
- `guisdap -a`
- Set parameters and go



GUISDAP output (vizu)



More information

- http://www.eiscat.se
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- http://sgo.fi/~jussi/eiscat/erosdoc/eros_commands.html)