

Introduction to EISCAT

What you need to know to run an experiment

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EISCAT Scientific Association

Incoherent scatter radar school 2016, Sodankylä

- 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

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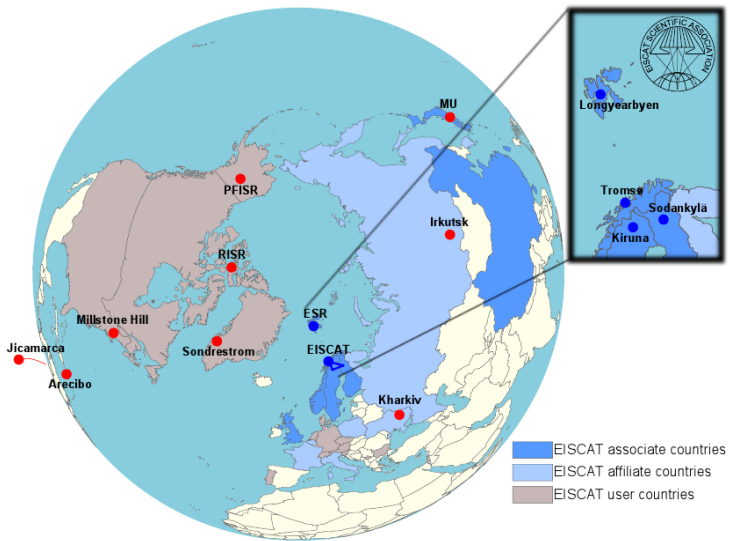
What is EISCAT?

ESR 32-meter antenna

- Originally 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, $78^{\circ}09'11''$ N, $16^{\circ}01'44''$ E
- Cusp and dayside auroral oval



From slides by Assar Westman

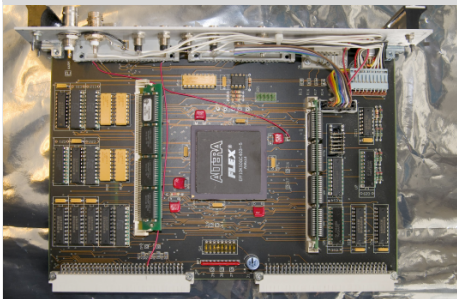
- UHF, 930 MHz
- VHF, 224 MHz, tristatic

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

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Transmitting a signal

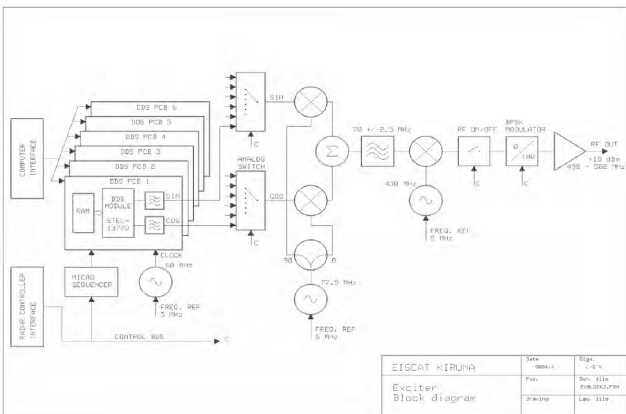
Radar controllers



- 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

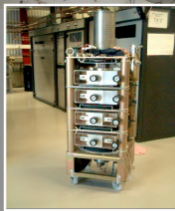
Transmitting a signal

Power amplifiers

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



Two 1-MW UHF klystrons (930 MHz) at Tromsø.



A 60-kW VHF klystron (500 MHz) at ESR.



A 1.5-MW VHF klystron (224 MHz) at Tromsø.

EISCAT

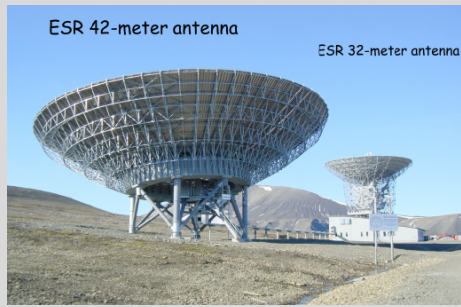
13 May 2013, Grana

EISCAT Radar School 2013

Transmitting a signal

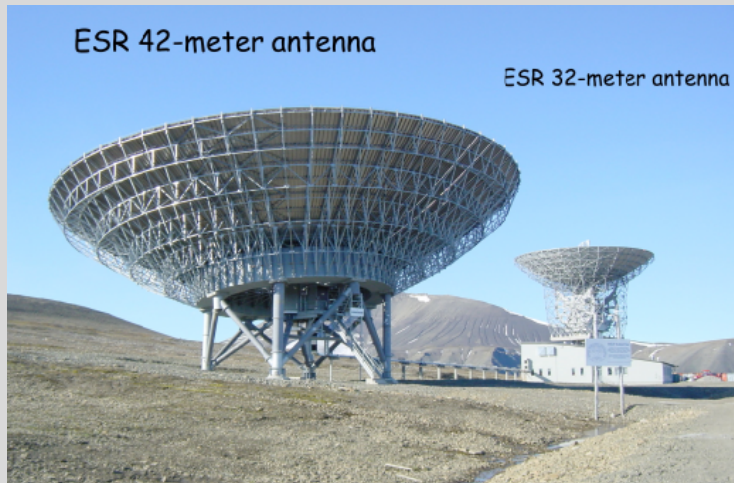
Antennas

- 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

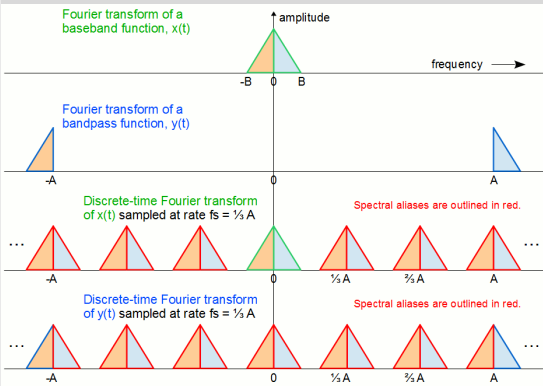


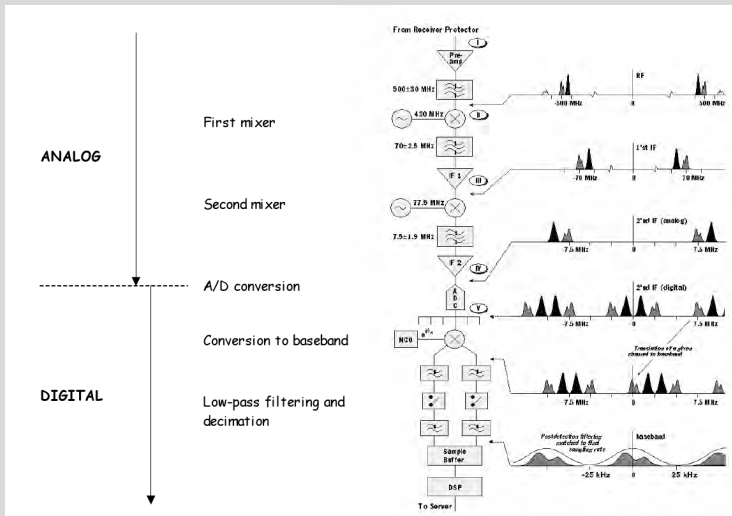
Figure from Wikipedia

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)

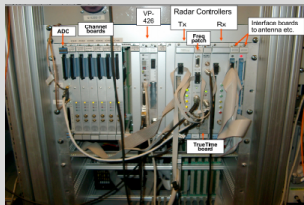
Receiving the scattered signal

Overview of EISCAT signal processing

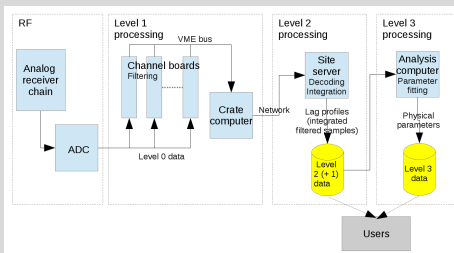


Receiving the scattered signal

Digital receiver (and radar controllers): the VME crate



Schematic summary



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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

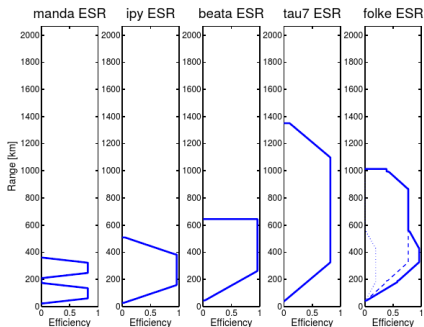


Figure 3: Overview of the ranges covered at the EISCAT ESR radar by the experiments used in the common programmes.

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

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

.ncf 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

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 ---

```

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
```

TARLAN file example

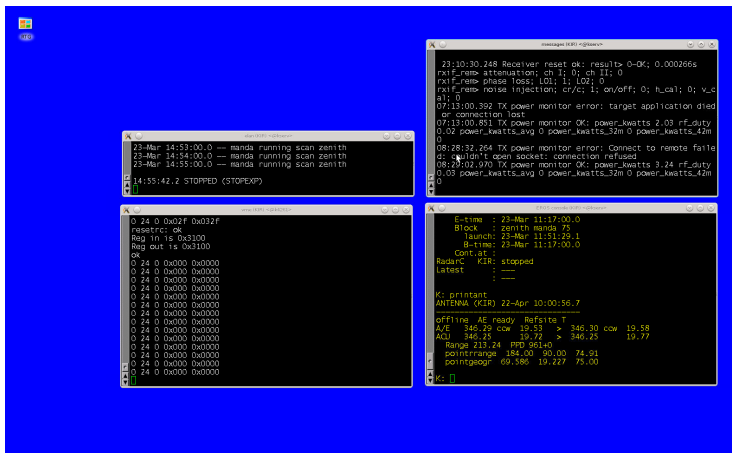
```
SETTCR 0
%%-% SUBCYCLE 1 %%%
AT 1.1 NCOSELO,NCOSELOP,ANTENNAO,AD1R,AD1L,STFIR,AD2LP,AD1RP,STFIRP
AT 3 WREG UNITO,FSELO,OPERA
AT 4 FLOAD UNITO,FSELO,OPERA
AT 5 RXPROT,RXSYNCON,TXSYNCON
AT 6 PREAMPOFF
AT 10 RXSYNCOFF,TXSYNCOFF
AT 20 MOSEL UNITO
AT 40 BEAMON
%%-% RF TRANSMISSION %%%
AT 50 CH1,RFDRON,PHA180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


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

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The EROS console (Kiruna site)



```
message (EROS) @blaserw
23:10:30.248 Receiver reset ok: result> 0-OK; 0.000266s
rx1F_ramp-attenuation: ch 1; 0; ch 11; 0
rx1F_ramp-phase loss; LO1; 1; LO2; 0
rx1F_ramp-noise injection; cr/c; 1; on/off; 0; h_cal; 0; v_c
a1; 0
07:15:00.392 TX power monitor error: target application died
or connection lost
07:13:00.851 TX power monitor OK: power_kwatts 2.03 rF_duty
0.02 power_kwatts_avg 0 power_kwatts_32m 0 power_kwatts_42m
0
08:28:32.264 TX power monitor error: Connect to remote fail
e: couldn't open socket: connection refused
08:28:02.970 TX power monitor OK: power_kwatts 3.24 rF_duty
0.03 power_kwatts_avg 0 power_kwatts_32m 0 power_kwatts_42m
0

mandascan @blaserw
23-Mar 14:53:00.0 --- manda running scan zenith
23-Mar 14:54:00.0 --- manda running scan zenith
23-Mar 14:55:00.0 --- manda running scan zenith
14:55:42.2 STOPPED (STOPEXP)

mandascan @blaserw
0 24 0 0x02f 0x032f
resetrc; ok
Reg in 1s 0x3100
Reg out 1s 0x3100
ok
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
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0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000
0 24 0 0x000 0x0000

23-Mar 11:17:00.0
Block : zenith manda 75
Taunch: 23-Mar 11:51:29.1
B-time: 23-Mar 11:17:00.0
Contstat :
RadarC_KIR: stopped
Latest : ---

K: printant
ANTENNA (KIR) 22-Apr 10:00:56.7

offline AE ready RefSite T
A/E 346.29 cow 19.53 > 346.30 cow 19.58
ACU 346.25 19.72 > 346.25 19.77
Range 213.24 RPD 961.0
pointrrange 184.00 90.00 74.91
pointgeogr 69.586 19.227 75.00

K: [ ]
```

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

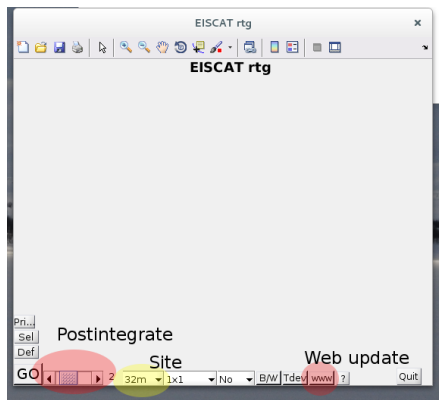
Note: all commands can be abbreviated!

RTG overview

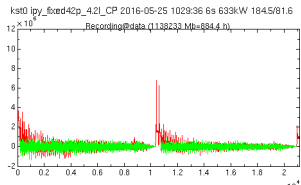
- Matlab software
- Reads data files
- Plots spectra and overviews
 - ▶ Selected in experiment's **rtg_def.m**
- Can update web page

RTG user interface

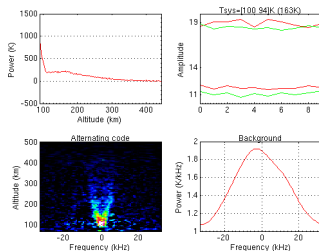
- Post-integration of data
- Site and other settings
- Plot geometry
- Enable WWW update



Example of RTG output



ipy 2016-05-25 1029:36 6s 633k/W 1845/81.6



Real-time analysis

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

Figures to show

Path to data

Time interval

Experiment definition

Select this

Integration (seconds), 0=antenna dwell

The screenshot shows the GUISDAP for dummies interface. The window title is "GUISDAP for dummies". The interface includes several input fields and buttons. Annotations with arrows point to specific elements: "Path to data" points to the "Data path" field containing "/home/fredrik/tmp/beata_cp1_2.0u..."; "Time interval" points to the "Start time" and "Stop time" fields, which are set to "2014 04 01 00 00 00" and "2014 04 30 24 00 00" respectively; "Experiment definition" points to the "Dsp expr" field containing "beata" and the "Vs 2" dropdown menu; "Select this" points to the "Real time" dropdown menu, which is set to "RT" and is highlighted with a red box; "Integration (seconds), 0=antenna dwell" points to the "Integration t" field containing "60". Other visible elements include the "Result path" field set to "/home/fredrik/tmp/AUTO/", the "Disp figures" field set to "0 0 1 0 1", and a "Special" section with a text area containing "%a_Offsetppd=8;" and "%magic_constant=1.3;". The text "Additional parameters" is overlaid on this section. At the bottom, there are buttons for "?", "Reset", "Save", "GO", and "Quit".

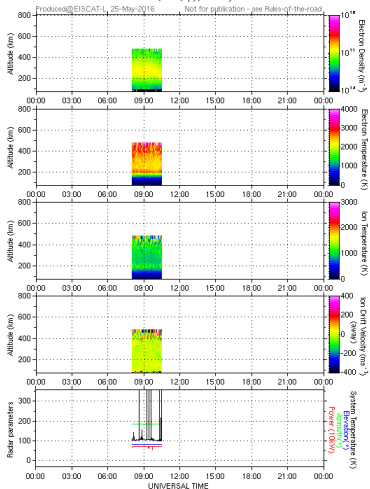
Additional parameters



EISCAT Scientific Association

EISCAT SVALBARD RADAR

CP, 42m, ipy, 25 May 2016



ESR 42-meter antenna

ESR 32-meter antenna

Questions?

More information

- <http://www.eiscat.se>
- https://www.eiscat.se/groups/Documentation/UserGuides/eiscat-experiments/at_download/file
- http://sgo.fi/~jussi/eiscat/erosdoc/eros_commands.html