Introduction to EISCAT

Hardware, control and signal processing

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Outline

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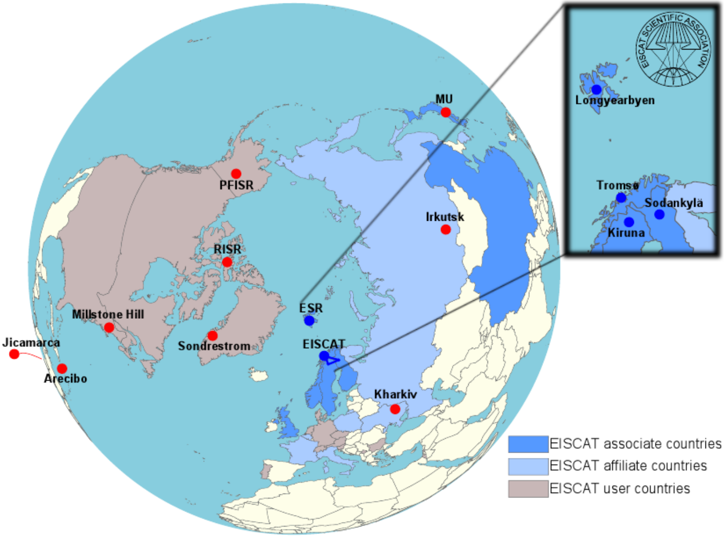
1. Overview of EISCAT
2. EISCAT hardware and signal processing basics
3. EISCAT operation basics

What is EISCAT?

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

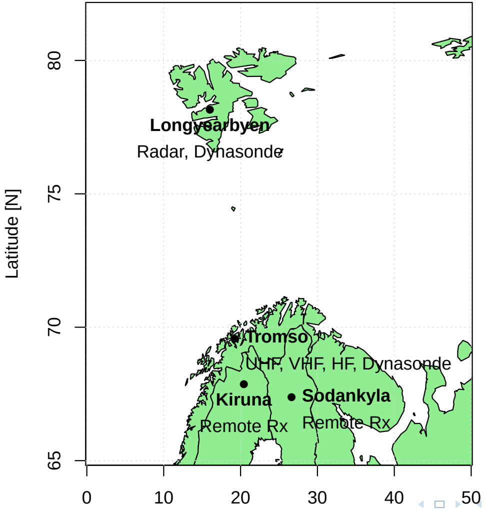
http://www.eiscat.se

EISCAT in the world



Map Anders Tjulin

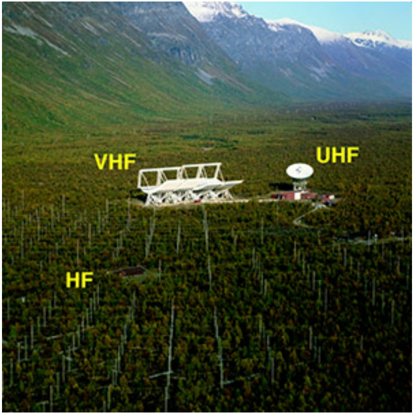
What we have and where



EISCAT Headquarters, Kiruna

- Director
- Financial office
- Development
- Scheduling of operations
- Project management

EISCAT radar site, Ramfjordmoen near Tromsø

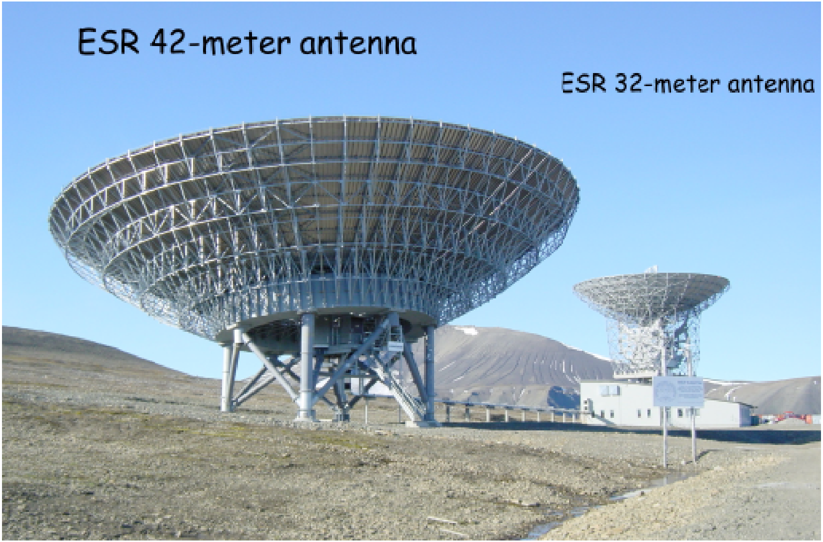


EISCAT remote receiver site, Sodankylä

EISCAT remote receiver site, Kiruna

- Close to IRF
- Visit tomorrow — take your own pictures ☺

EISCAT Svalbard radar site near Longyearbyen 78° N



Outline

A generic radar system

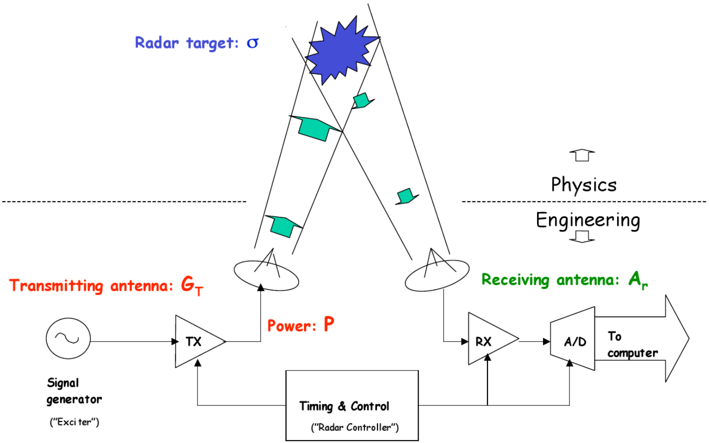
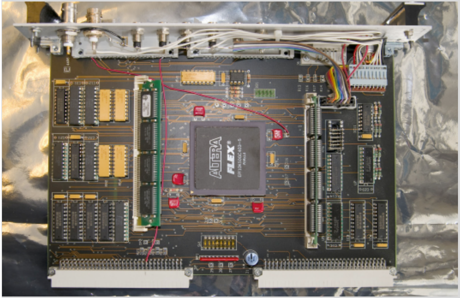


Figure from G. Wannberg

Transmitting a signal

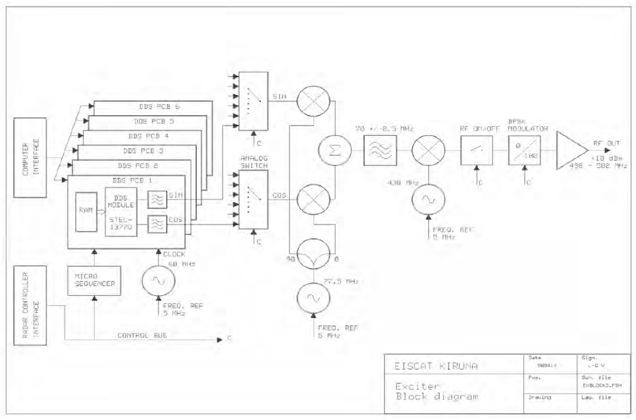
Radar controllers



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

Transmitting a signal

Exciter

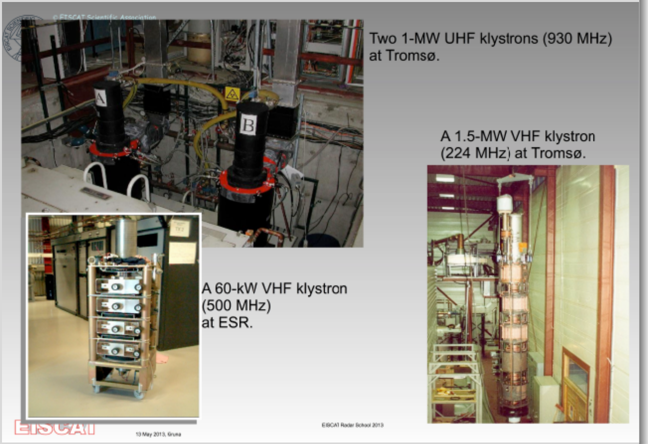


- Generates the signal
- 0 and 180 degree phase flips

Transmitting a signal

Power amplifiers

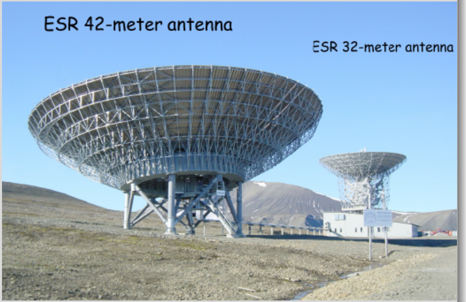
- Raise the output power
- ESR peak output 1 MW (average 250 kW)
- Waveguides to the antennas



Transmitting a signal

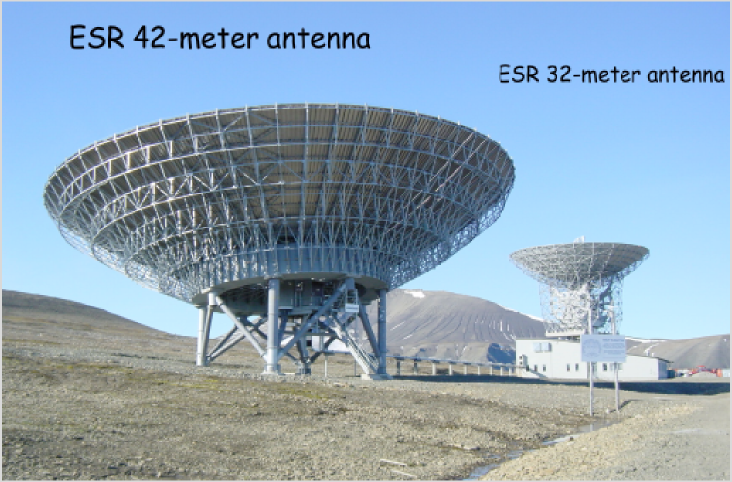
Antennas

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



Receiving the scattered signal

Antennas



Receiving the scattered signal

Analogue receiver chain

1. Polariser
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

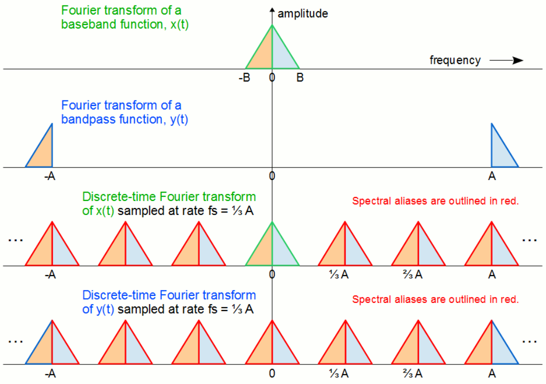
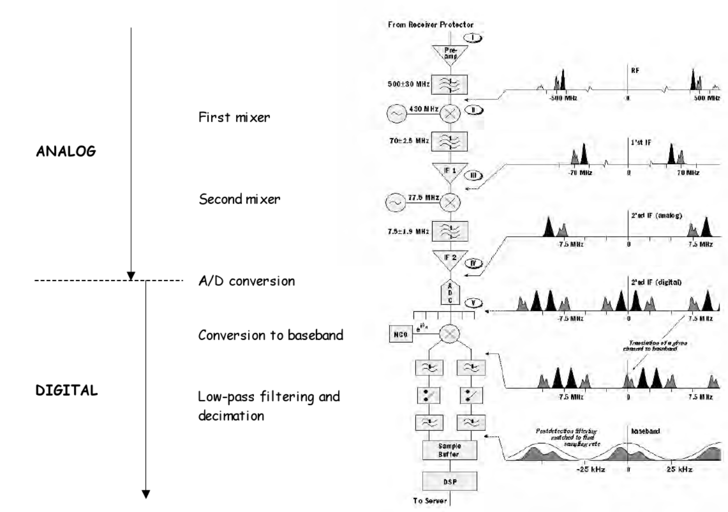


Figure from Wikipedia

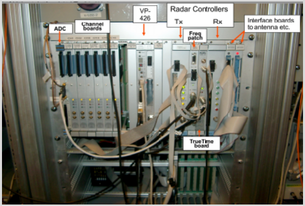
A closer look at the sampling theorem

- 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 centre frequency)

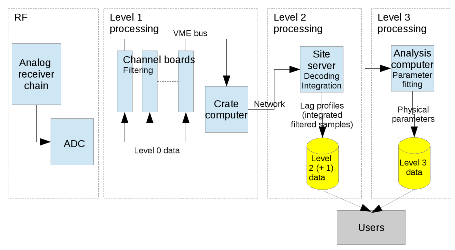
Overview of EISCAT signal processing



Digital receiver (and radar controllers): the VME crate



Schematic summary



Receiving the scattered signal

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

EISCAT experiments

Pulse code experiments

- Range coverage and resolution
- Time resolution
- Spectral resolution
- Plasma lines ot not
- Names are acronyms like *beata*, *ipy*, *manda*...

See `https://www.eiscat.se/wp-content/uploads/2017/04/Experiments.pdf`

EISCAT experiments

Antenna scan programs

- Common Programme scans (CP1, CP2...): standard, the same for every CP run
- Special scans (e.g. satellites, moon and asteroids, space debris...)

EISCAT experiments

Svalbard: Two modes of antenna switching

1. Pulse to pulse switching (as if both antennas would have their own transmitter): part of pulse code
2. Normal experiments: single or slow switching, part of scan program

EISCAT experiments

To think about when you look at results

- Where was the antenna pointing?
- What range coverage and resolution does the pulse code have?
- What time resolution does the pulse code have?
- What is the spectral resolution — suitable for incoherent scatter, meteors, middle atmosphere. . . ?

Defining an experiment

A few concepts which you will encounter when you become an EISCAT user

Files needed to set up an experiment

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

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

.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

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 ---
```

Defining an experiment

A few concepts which you will encounter when you become an EISCAT user

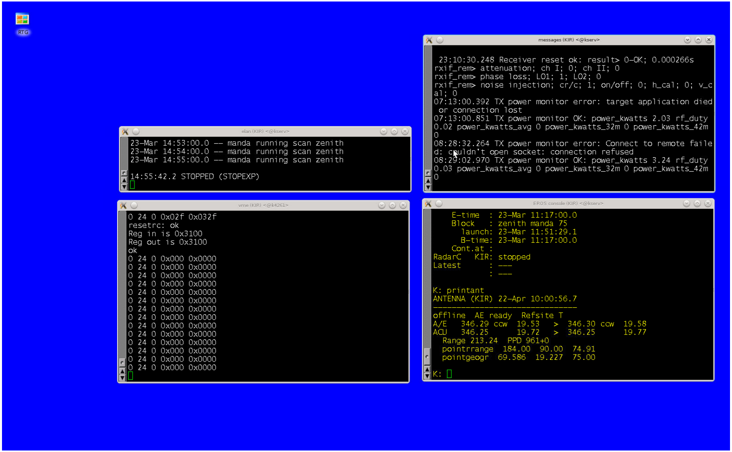
Antenna scan example

```
# 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 (just the first few lines)

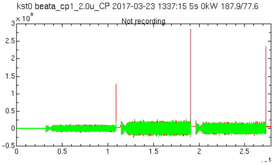
```
SETTCR 0
%%%% SUBCYCLE 1 %%%%
AT 1.1 NCOSEL0,NCOSEL0P,ANTENNA0,AD1R,AD1L,STFIR,AD2LP,AD1RP,STFIRP
AT 3 WREG UNIT0,FSEL0,OPERA
AT 4 FLOAD UNIT0,FSEL0,OPERA
AT 5 RXPROT,RXSYNCON,TXSYNCON
AT 6 PREAMPOFF
AT 10 RXSYNCOFF,TXSYNCOFF
AT 20 MOSEL UNIT0
AT 40 BEAMON
%%%% RF TRANSMISSION %%%%
AT 50 CH1,RFDRON,PHA180 %++
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
```

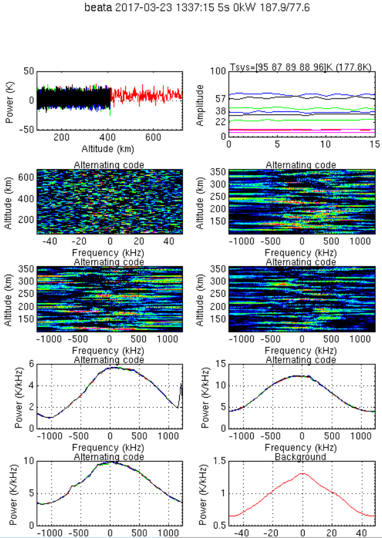
The EISCAT Realtime Operating System (EROS) console at Kiruna site



Controls everything. This is where you run commands to control EISCAT.

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





Next...

1. Right now: Introduction to analysis software (GUISDAP on Matlab)
2. Tomorrow: Kiruna EISCAT receiver site visit
3. Thursday and Friday: Analysis, group work in D2