# A possible fix for Heating and E3D

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## Status of existing facilities:

1. HAARP is owned & operated by U. of Alaska and regular campaigns are made (?). For how long ?
2. The ‘new’ Arecibo heater has major problems after the collapse of towers etc. Will it be resurected ??
3. SURA- is still operating but is also getting old.
4. Heating (EISCAT) is 40 years old and operational.

## Status of Tromsø site:

- Mike Rietveld is about to retire as site leader (31 Dec.)
- Arild Stenberg will be acting site leader.

- Erik Varberg is responsible for the Heating facility

- UHF & VHF radars are working well. The UHF antenna can be used for scanning after much repair work the last year.

Heater:

- Tx-tubes: We have two Chinese tubes in the system with a third transmitter planned to be modified & one more as spare (4 Chinese tubes).
- Arrays-1 and 2 working, Array-3 still damaged after last winter's snow.

# Heating use:

| | |
|---|---|
| 2015 | 183 hrs |
| 2016 | 123 hrs |
| 2017 | 147 hrs |
| 2018 | 99 hrs |
| 2019 | 97 hrs |
| 2020 | ca. 90 hrs |

Decreasing hours are partly due to solar minimum, where foF2 is too low for many experiments.
But we also have fewer users: Russia (AARI) has no funding for buying hours, UK has fewer users.

China is an increasingly important user, but Covid-19 has prevented them (and a group from Russia) from visiting this year.

On the other hand publications remain at a good level with about 10 papers per year which is about 30% of the total EISCAT publications.

# Science being done

ELF/VLF waves excitation (e.g. beat frequency heating) (China, RU)
SEE imaging (NO)
Suomi-100, Picasso satellite conjunctions (FI, NO)
Topside plasma wave excitation (NO, SW)
L-mode effects (SW)
Attempts at artificial optical emissions (SW, NO)
X-mode heating effects (RU, SW, NO, CN)
PMSE modulation (multiple wavelength radars, UHF, VHF, HF)

# From 2018: Keeping the present heater running

## Challenges

- Keeping the HF hardware working
  1. transmitter tubes √
  2. Array-1 antenna feeds √
  3. coaxial line maintenance ×
- Getting new staff to run the HF √ as MTR heads for retirement
- Some field-aligned E_3D radar × experiments will not be possible with present heater location

## Opportunities

- Hire new young staff for the HF operation.
- Plan, design and fund a new HF facility near Skibotn.
- Use the HF-radar mode to investigate long-range and possibly magnetospheric echoes.
- Use the UHF to do field-aligned research on WAILES while we still can (but difficult now at solar minimum with low foF2 values).

# The future

1. There are serious limitations on the science that can be done using E3D with the present location of the heater: e.g. One cannot measure along the heated field-line. We cannot operate at the 2nd gyroharmonic.

2. Moving the present heater is not an option due to age, design of feedlines and antennas etc.

3. Build a new modern heater: distributed transmitters near antennas, probably solid state, air-cooled, wide frequency coverage from 2nd gyroharmonic (ca. 2.7 MHz to about 8-10 MHz)

For option 3: First a science case is needed.

Working group: Antti Kero, Wu Jun, Cesar La Hoz, Juha Vierinen, Thomas Leyser, Mike Rietveld
So far this group has not done much

Funding will be difficult. Need to fund E3D first ?

Relevant paper:

**PAST, PRESENT AND FUTURE OF ACTIVE EXPERIMENTS IN SPACE**

A. V. Streltsov, J.-J. Berthelier, A. A. Chernyshov, V. L. Frolov, F. Honary, M. J. Kosch, R. P. McCoy, E. V. Mishin, M. T. Rietveld

*Space Science Reviews, 214:118, https://doi.org/10.1007/s11214-018-0549-7 2018*

Can we tilt the heater beam towards the east, towards E3D ?

In the 1980s Array-2 (4-5.6 MHz) had the option to tilt about 10 west for flying rockets through the heated region. This capability was largely removed about 1990 for ease of maintenance.

The modification of the antenna array and the determination of the heating frequency for the realization of Heating rocket experiments
*Rose, G.,* Report MPAE-W-46-79-11,
Max-Planck-Institut für Aeronomie, Katlenburg-Lindau, Germany, 1979

First results of the in situ measurements of the HERO Heating Campaign
*Rose, G., B. Grandal, E. Neske, W. Ott, K. Spenner,*
Spec. Publ. Eur. Space Agency, ESA SP-183, 263-267, 1983

Preliminary results from the HERO project: In situ measurements of ionospheric modifications using sounding rockets,
*Grandal, B., G. Rose, J. Holtet, K. Måseide, E. Neske,*
Spec. Publ. Eur. Space Agency, ESA SP-195, 75-80, 1983

Experimental Results From the HERO Project: In Situ Measurements of Ionospheric Modifications Using Sounding Rockets,
*Rose, G., B. Grandal, E. Neske, W. Ott, K. Spenner, J. Holtet, K. Måseide, J. Trøim,*
J. Geophys. Res., 90, A3, 2851-2860, 1985.

Experimental Results From the HERO Project: In Situ Measurements of Ionospheric Modifications Using Sounding Rockets,

*Rose, G., B. Grandal, E. Neske, W. Ott, K. Spenner, J. Holtet, K. Måseide, J. Trøim,* J. Geophys. Res., 90, A3, 2851-2860, 1985.

**"For the HERO project the heating frequency could be chosen from a set of 10 frequencies 3.8, 4.0, 4.2 up to 5.6 MHz in order to have available a heating frequency which was close to the actual critical frequency of the F layer at the time of interest. The antenna array covering this range was modified in order to transmit into the westerly direction towards the prospective rocket apogee. The antenna beam width corresponds to a diameter of 65 km at an altitude (range) of 250 km."**

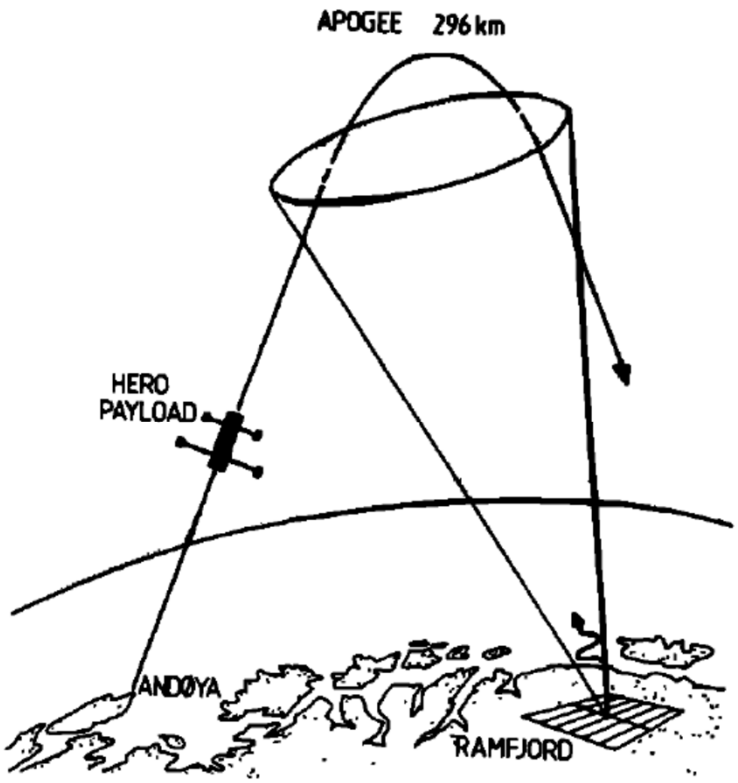


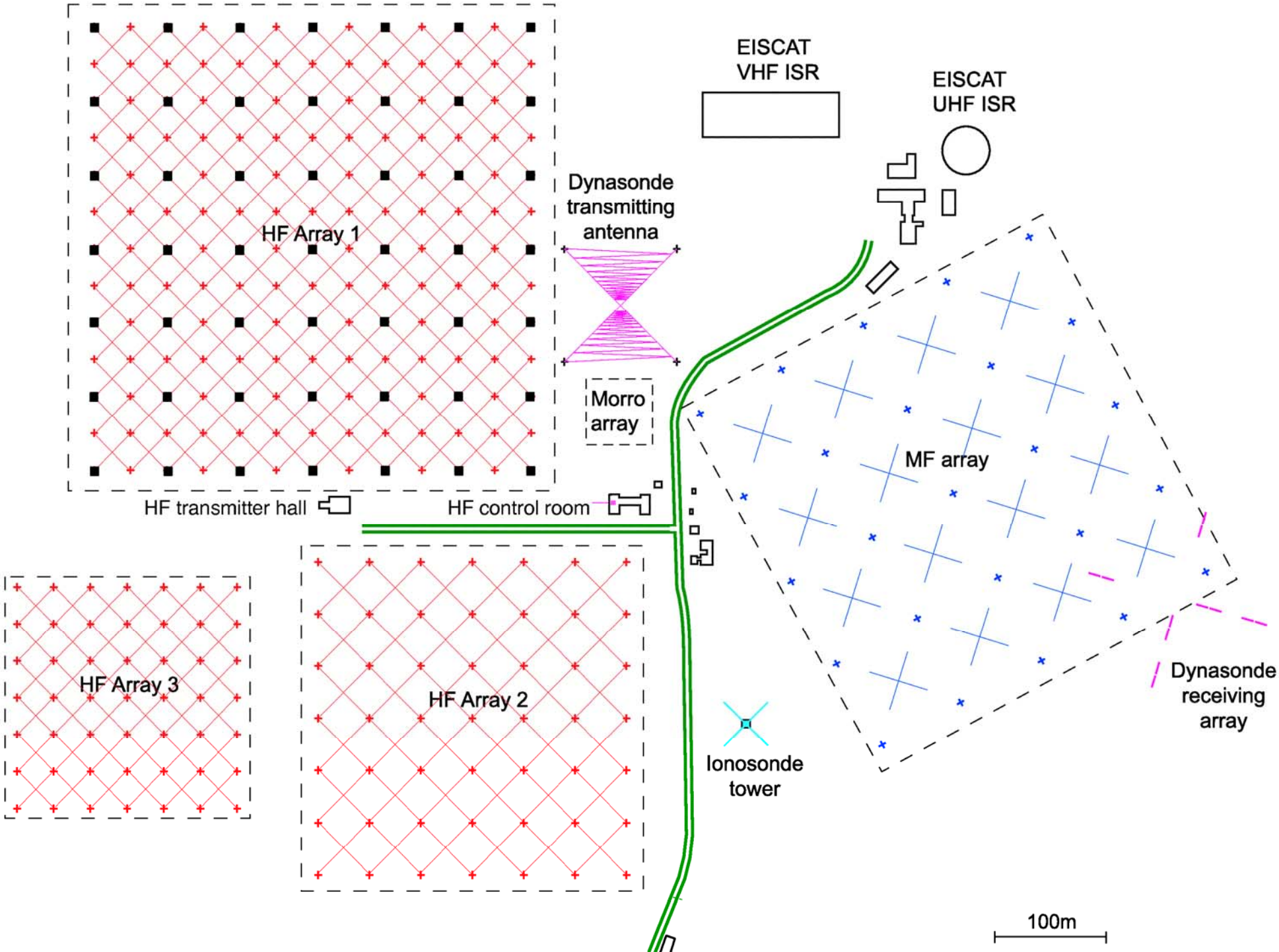

Fig. 1. The geometry of the HERO trajectory and the beam of the heating wave.

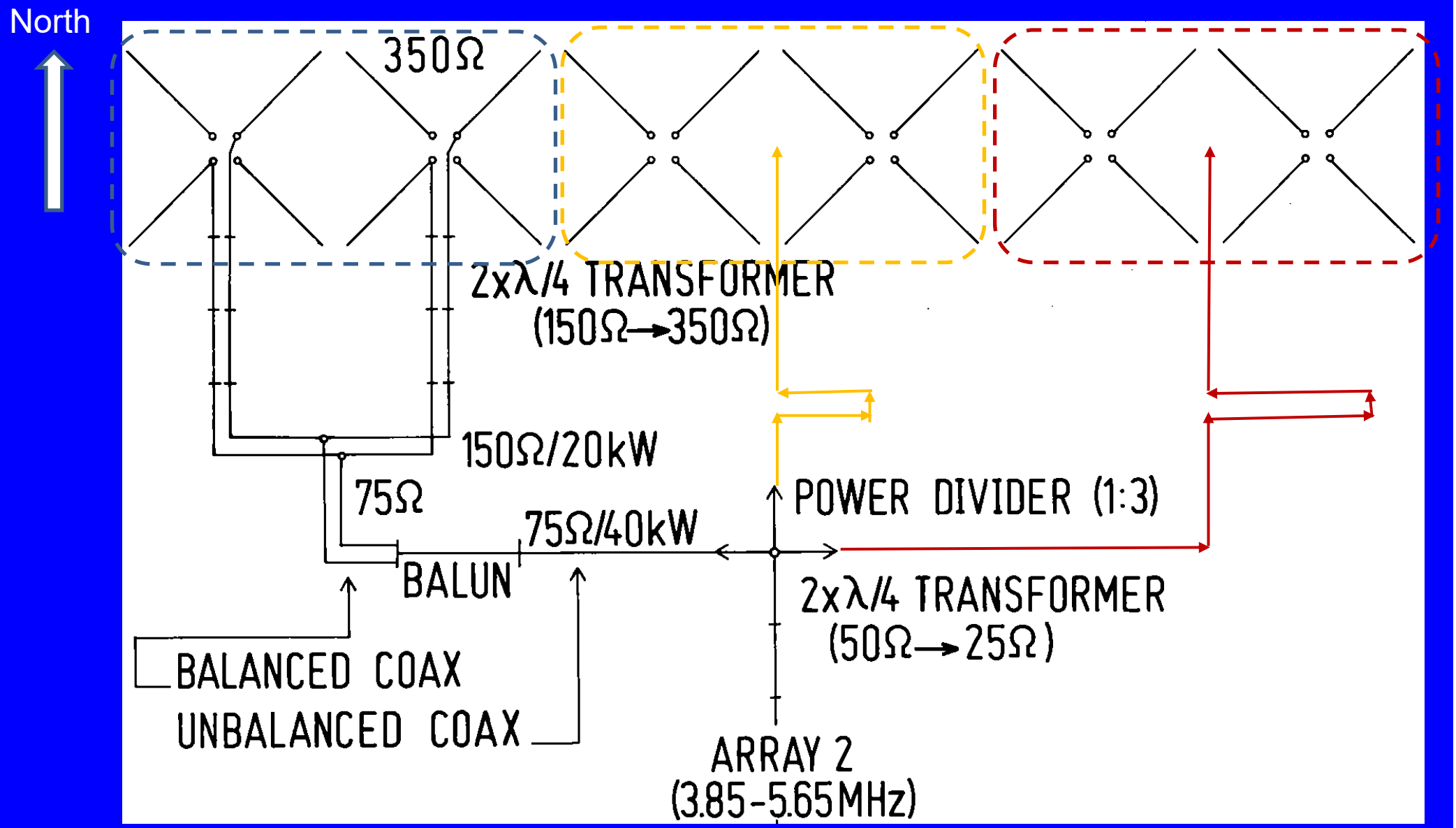
To point to the F region, zenith to the EISCAT-3D transmitter in Skibotn, we need to point the HF beam approximately 12º east and 4º south (needs more detailed calculation).

The southward pointing can be achieved by the usual phase change between transmitters, but the eastward pointing needs a hardware phase change between antennas, or more practically between pairs of antennas.

The exact phase change needs to be made for the most likely wavelength to be used, probably the highest frequency (5.423 MHz, or 55.3m wavelength)

# HF facility layout



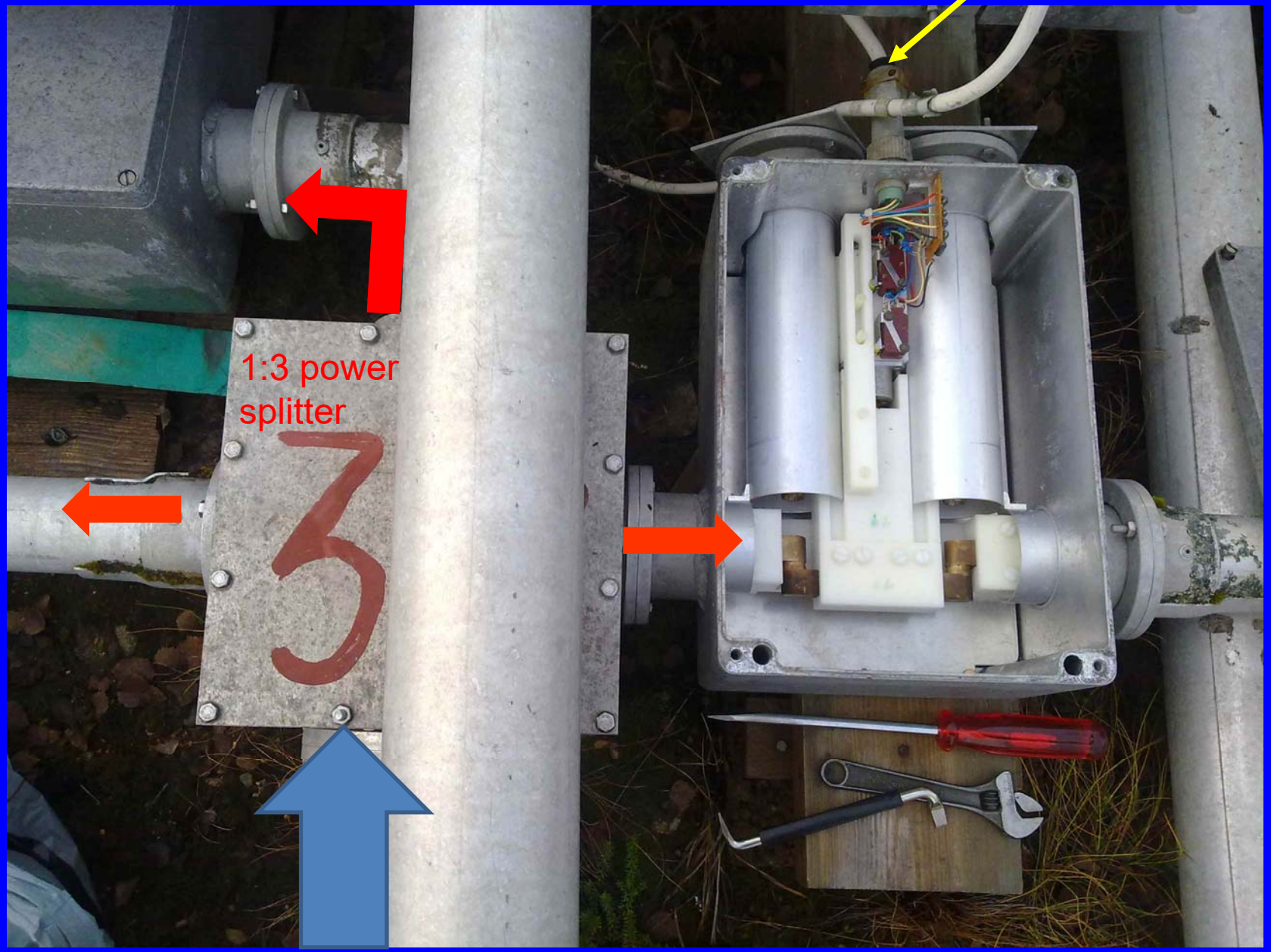



Add phase-length to two coax lines to two pairs of antennas to tilt beam eastwards


To modify the whole array
(12 transmitters), we need to make
24 coaxial delay lines ……

Photo from October 2013, showing excellent condition of the coax-switch

Control & power cable from heater control room



# Summary

One needs to check that we have enough aluminium tubes, spacers, flanges for the required 24 phase-delay coaxial lines. I suspect that we do have enough.
If necessary one could cannibalise another array.

The extra phase-delay cables need wooden supports.

The control cables to the coaxial switches still exist, but they have not been used for nearly 30 years so they need to be checked.

The controller unit with power supplies still exists in the control room (no photo) and has not been used for nearly 30 years so needs to be checked.

So field-aligned measurements with E3D may be possible, and maybe even In-situ rocket measurements from ESRANGE

So there is quite a lot of work involved, but probably little new hardware investments.

# Second gyroharmonic antenna

**Second gyroharmonic antenna:**
For solar minimum conditions like we are reaching now,
wishes have been expressed for a low frequency second gyro-harmonic capability.
We would like to put up a prototype half-wave dipole antenna using the 22m wooden masts in Array-1 to measure its impedance characteristics around the second gyroharmonic of 2.71 MHz (for this we need, and now have, a 22m lift).

The challenge is to devise a power distribution and impedance matching scheme between the transmitter and the antennas.
The idea is to initially evaluate the feasibility and resources required to resurrect a limited Narrow-band of the low frequency capability using a small number of antennas in Array-1.
A scientific justification case exists.