Test and calibration procedure for the hardware of RNO-G

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RNO-G calibration overview

The RNO-G calibration concept is work in progress, but the following aspects are planned (building on previous results and experiences):

—Station surveying with differential GPS after deployment for initial antenna positions

—Local calibration pulsers (see RNO-G station figure) for local antenna positions (like in ARA, see talk by **Kaeli Hughes**) and snow accumulation (like ARIANNA, see talk by **Jakob Beise**)

— Calibration from the DISC borehole for full station calibration and ice properties (see talk by **Dave Besson** about SPUNK and South Pole SPICE measurements)

— Local density measurement: the Big RAID drill will (likely) provide density measurements for every hole drilled, providing a map of firn densities throughout the array.

RNO-G calibration overview

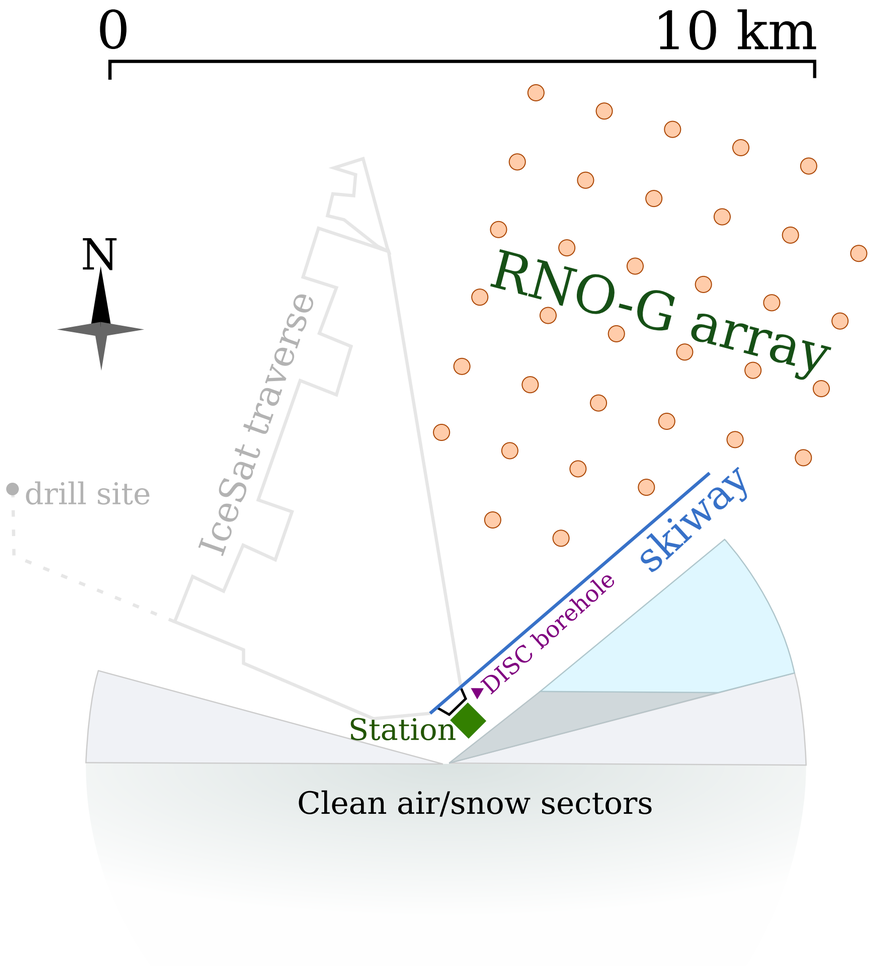
— Lab calibration of all devices (**this talk**)

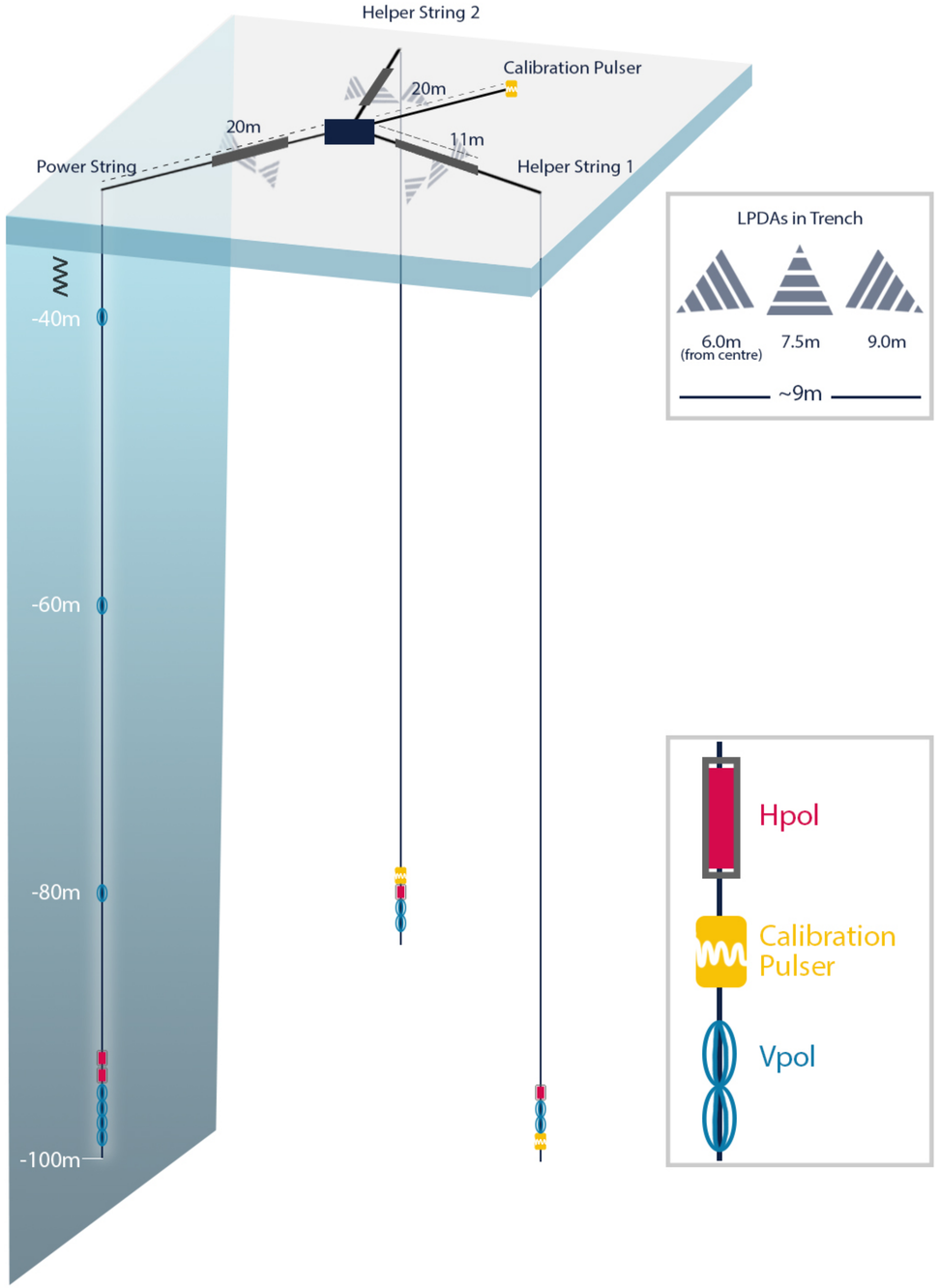
— Cosmic ray flux measurements with surface antennas (confirmation of amplitude scale and system operation, see talk by **Christian Glaser** and **Simon De Kockere**)

— Vertical scan of antennas response: plans to turn the station pulser on while dropping the last string, providing data to improve antenna simulations.

— Other calibration sources: CW sources like the twice-daily radiosonde and satellites, and airplanes (see **Jakob Beise, Christian Glaser, Cosmin Deaconu** talks)

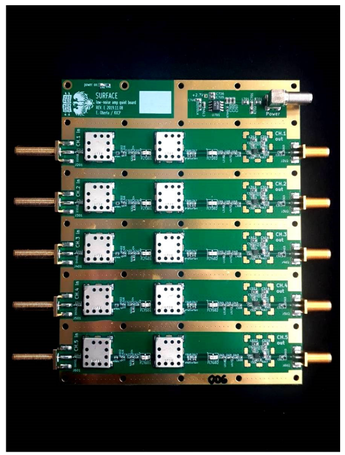
RNO-G station





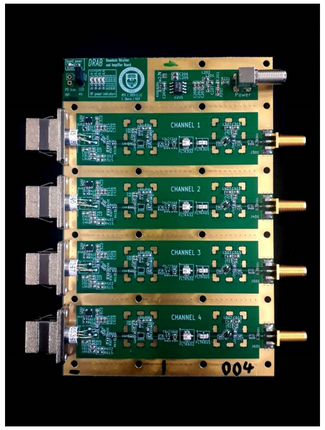
Three types of Amplifiers:

Surface board



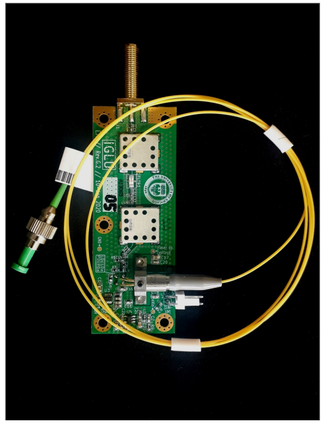
DRAB

Downhole Receiver and Amplifier Board



IGLU

In-ice Gain with Low-power Unit



- **DRABs** and **Surface boards** will be sitting in the DAQ box at the surface, will experience temperatures between -20°C and 20°C, and go through many temperature changes.
- **IGLUs** : will be inside the ice at colder, but more static T between -40°C and -30°C.

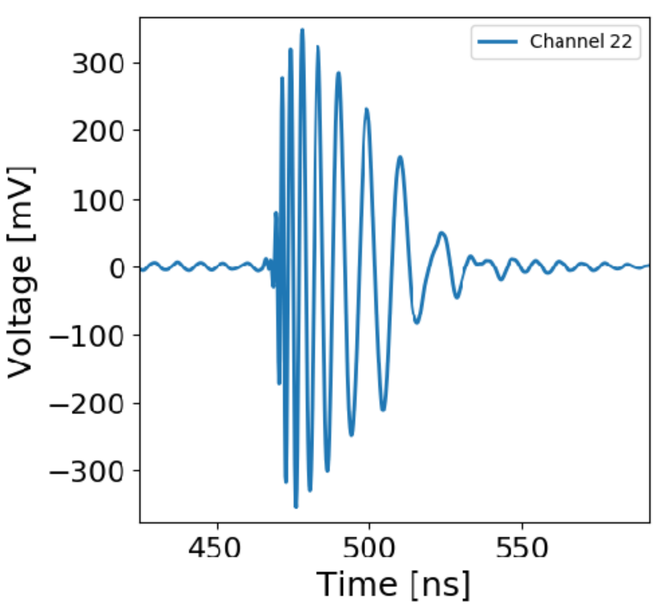
Instrument response

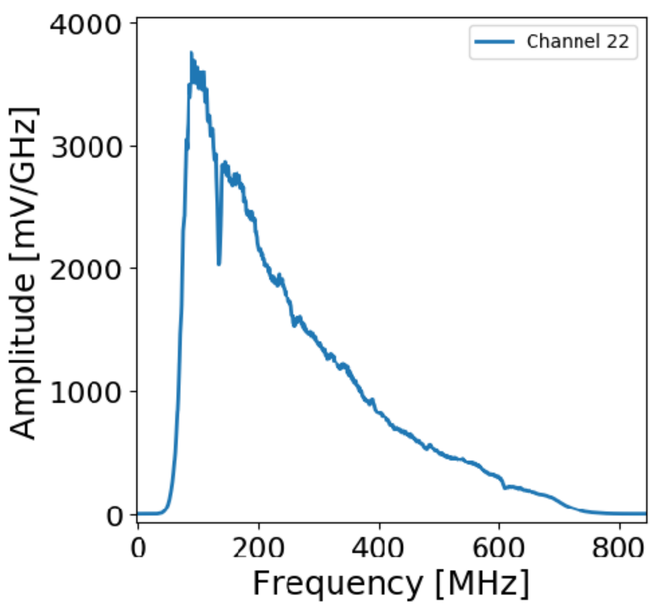
from

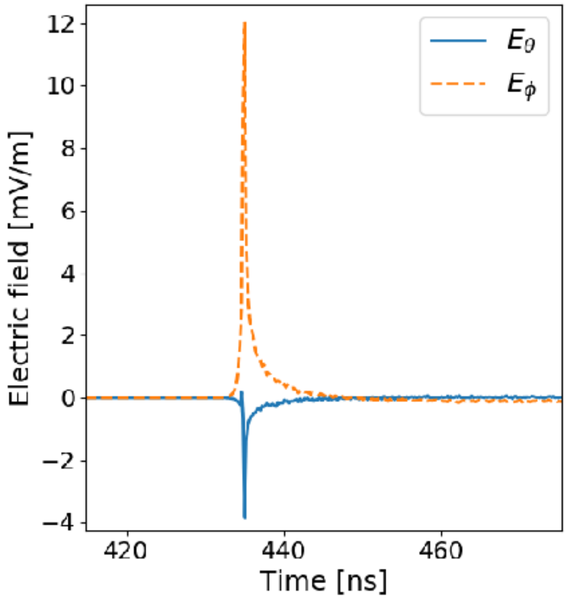
Recorded waveform

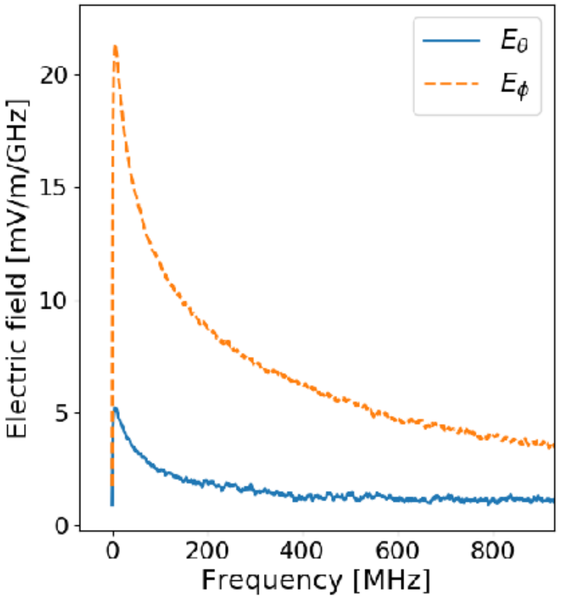
we want

Electric field









So we need to study very well the hardware response

All boards were tested using a **Vector Network Analyzer (VNA):** 4 S-parameters were measured to examine the transmitted and the reflected signals at the input and the output.

4-phase Test Procedure:

Was planned to test the survival and response of the boards at very low temperatures:

1. **Function test**
2. **Stress test**
3. **Parameter influence**
4. **Temperature dependence**

1. Function test:

First function test was performed to look for broken boards or non perfectly functioning boards. It was checked if all channels of all boards worked.

S-parameters:

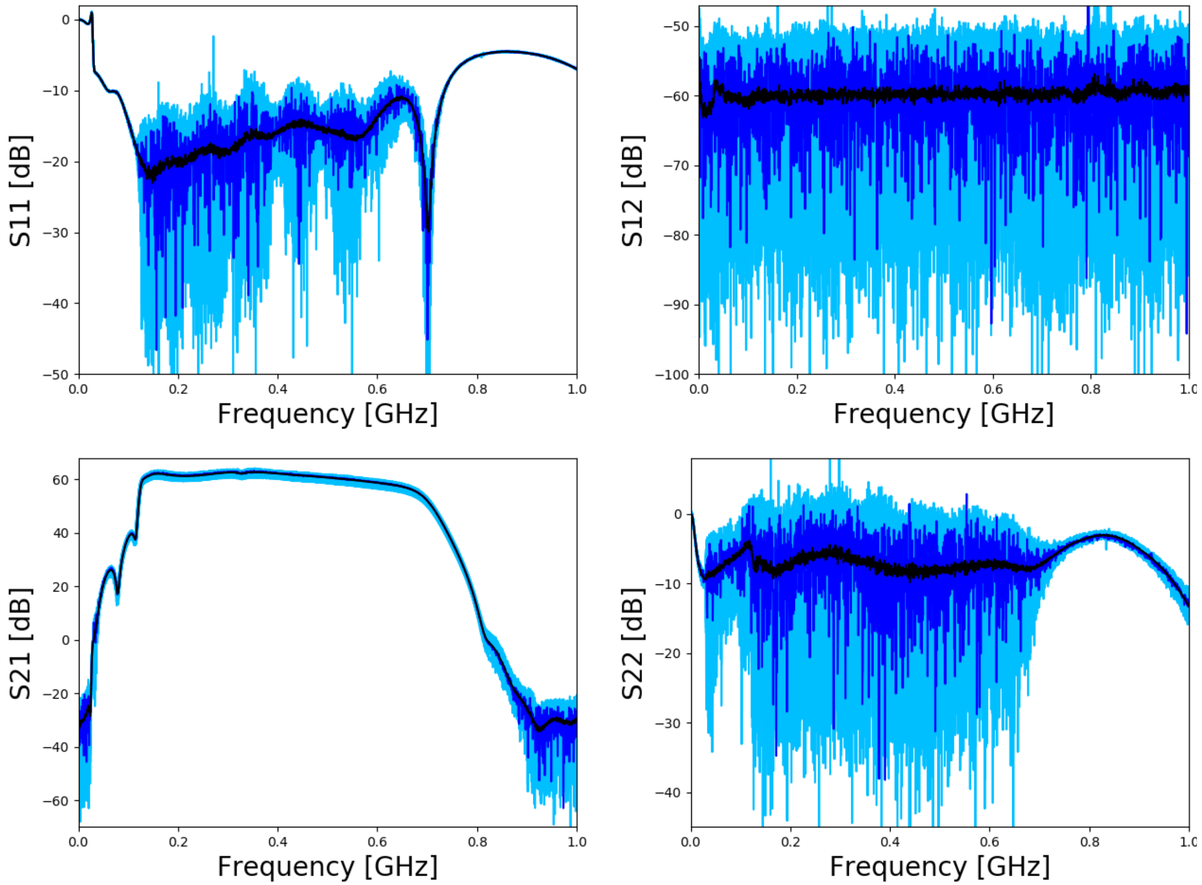


Figure 4.5: S-parameters of the DRABs [dB]. The same measurements in logarithmic form. The gain of the DRABs (bottom left) features a small characteristic drop at 326 MHz.

Plot by Nora Feigl

2. Stress test:

2.1 In order to test the survival of the boards at very low temperatures: **Temperature Cycles** in the temperature chamber: 5 cycles from 0° to -50° for all amplifiers

2.2 Second S-parameters measurement at room temperature for all amplifiers

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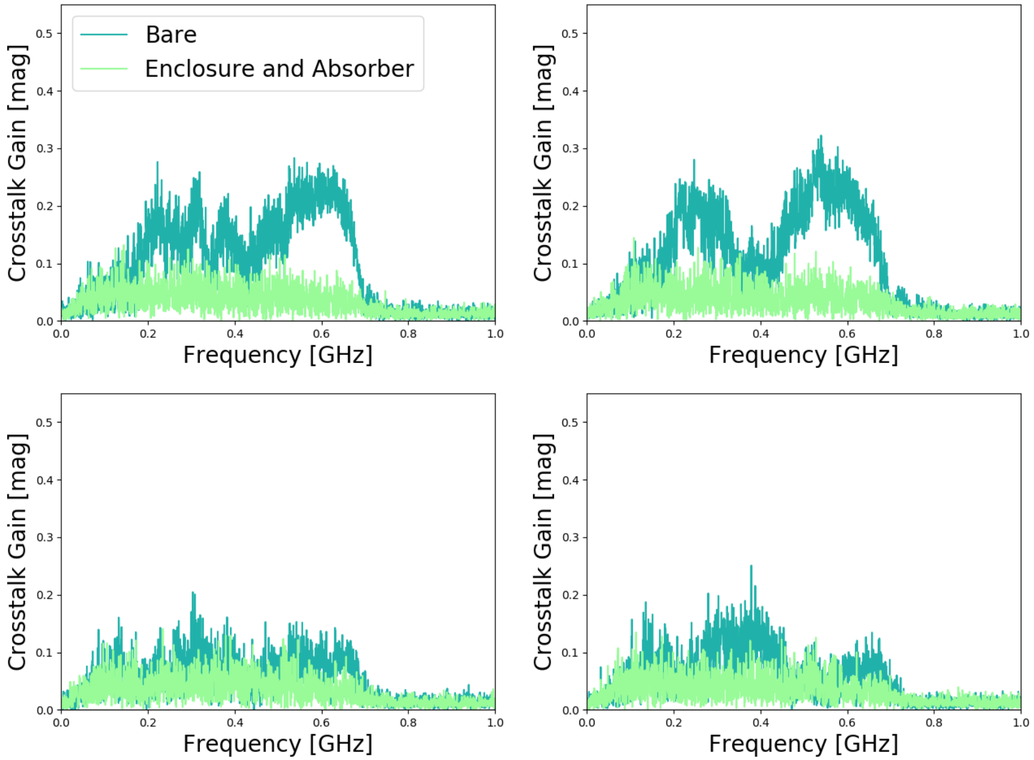
Result: All boards survived the stress tests: they worked before and after the temperature drop.

3. Parameter influence + other tests:

(Surface board)

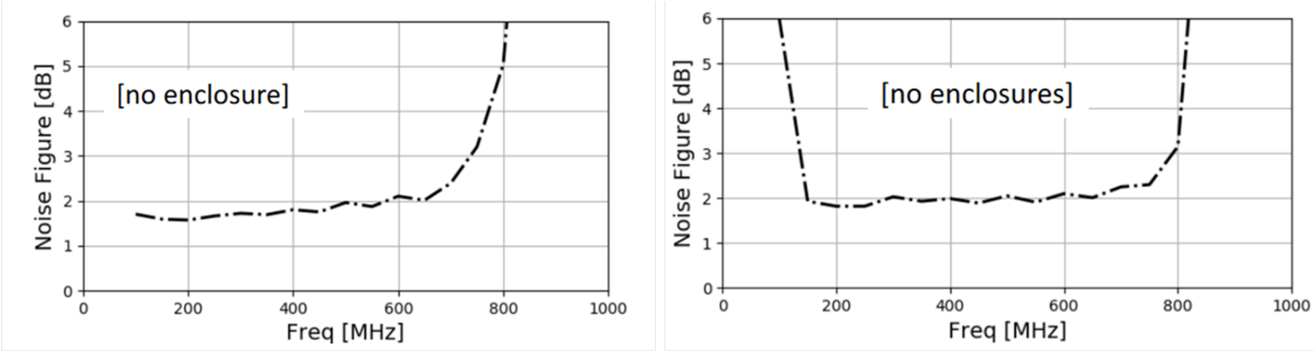
Crosstalk:

Crosstalk determines the disturbance due to other channels.



Noise figure:

Describes the amount of noise the amplifier board adds to the signal transmitted through the board.



Measurements were done with a noise figure meter of a SURFACE board (left) and a DRAB (right).

Plot by Nora Feigl

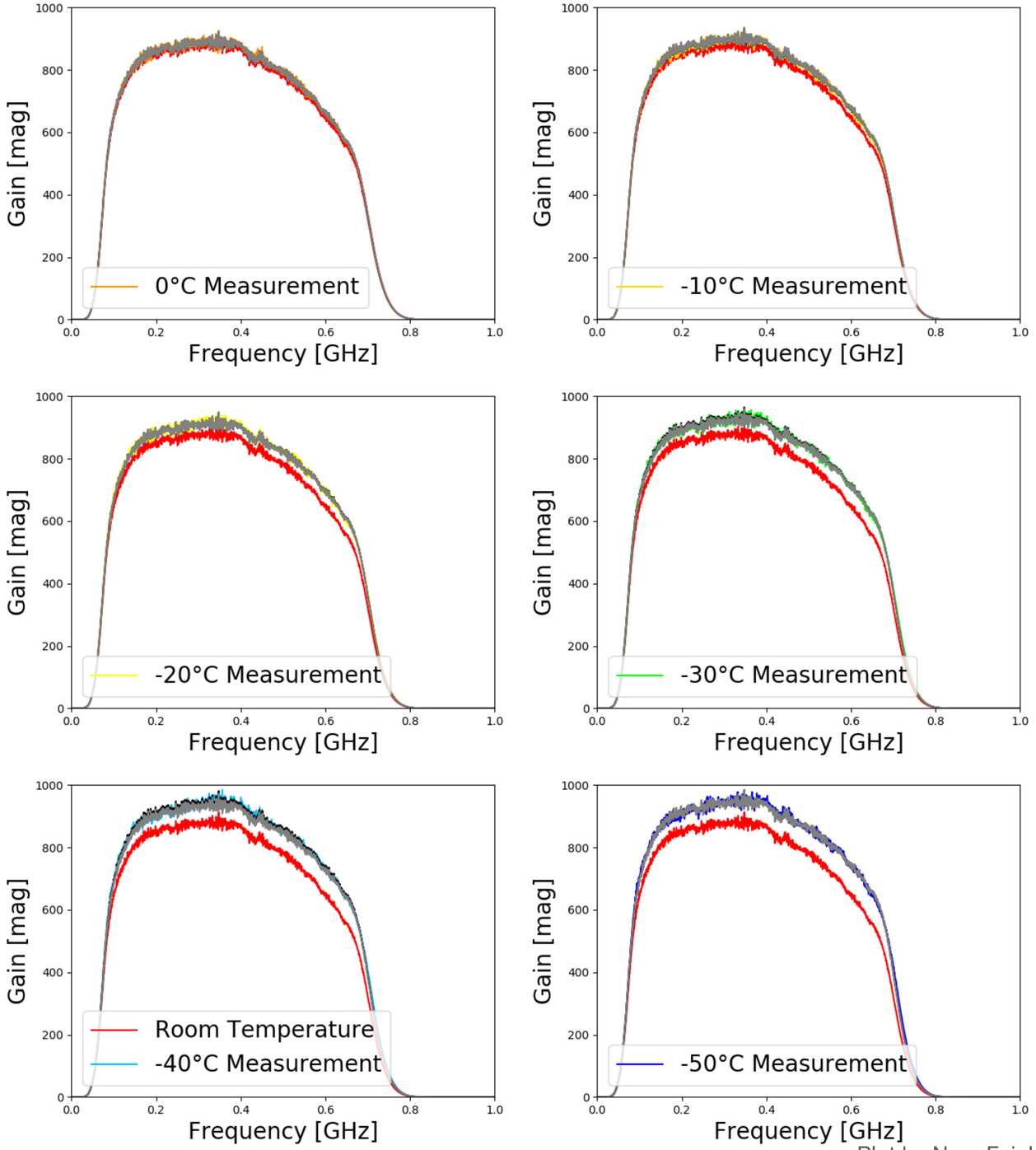
4. Temperature dependence: Surface boards

[All RNO-G stations have a temperature sensor for continuous monitoring and correction]

—The gain increases with the decreasing temperature.

— Instead of measuring every board at multiple temperatures, the T_{room} gain measurement was multiplied with a **fit function G(f, T)** in order to calculate the gain at other temperatures.

— **The fit function G(f, T)** is obtained fitting the measurements of the temperature dependence of one board at T: 0°, -10°, -20°, -30°, -40°, -50° C



Plot by Nora Feigl

4. Temperature dependence:
DRAB + IGLU

Testing **DRABs** and **IGLU** has to study the influence of the temperature of different components:

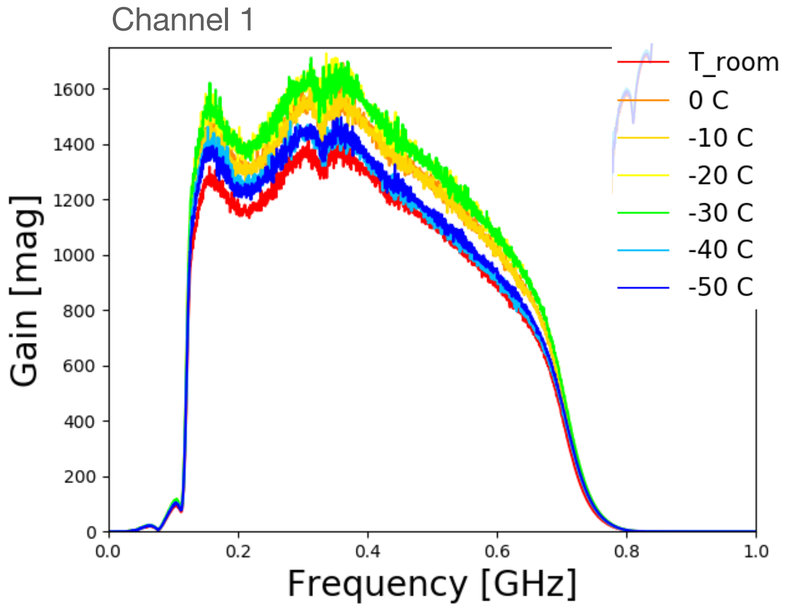
Test: One board inside the T-chamber while the other at room temperature. The fiber was either inside or outside the chamber.

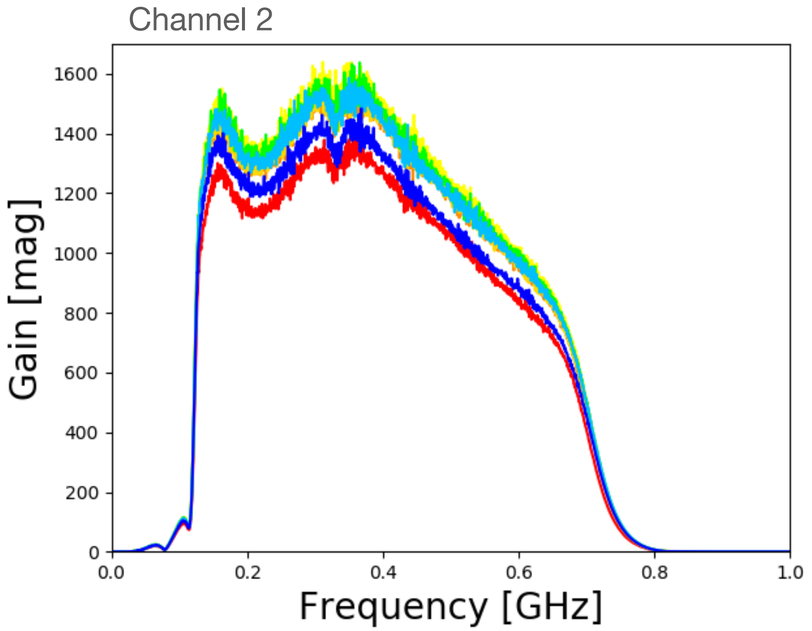
Results:

- On the total down-hole chain measurements the IGLU temperature has the most influence.
- For T in -30°C — -40°C the gain behavior is most uncertain: some channels showed an increased, some a decreased gain compared to the measurements at higher temperatures.

However, applying the corrections we obtain a maximum deviation of ~7% (at -40°) !

(IGLU inside the chamber, DRAB and fiber outside)





Plot by Nora Feigl

Database

- Centralized database of calibration values for all components
- Scaleable, controlled upload via limited web interface:
http://radio.zeuthen.desy.de
- Will in the future integrate with our software for fully custom and time dependent detector descriptions

Summary

RNO-G Calibration Plan:

- Extensive Lab testing of cables, amplifiers, etc.
- Field survey (GPS positions, local densities, local pulser drop)
- Calibration campaign (DISC borehole)
- Continuous monitoring (temperature sensors, local calibration pulsers, cosmic rays, CW, …)