

REACH Receiver

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Cavendish Astrophysics

Structure of the talk



- Intro and receiver team
- Radiometer system
 - Receiver design
 - Modelling directions
- 2nd Receiver
- Future directions

The receiver team



Current team

- The references for this talk
- [1]: N. Razavi-Ghods, I. Roque et al: Radiometer Design for the REACH global 21-cm experiment ([arxiv:2307.00099v2.pdf](https://arxiv.org/abs/2307.00099v2) (arxiv.org))
- [2]: I.L.V. Roque et al: Bayesian Noise wave calibration for 21-cm global experiments



Rohan Patel:
RA



Kaan Artuc:
PhD student



John Ely:
Engineer



Paul Scott-
Emeritus

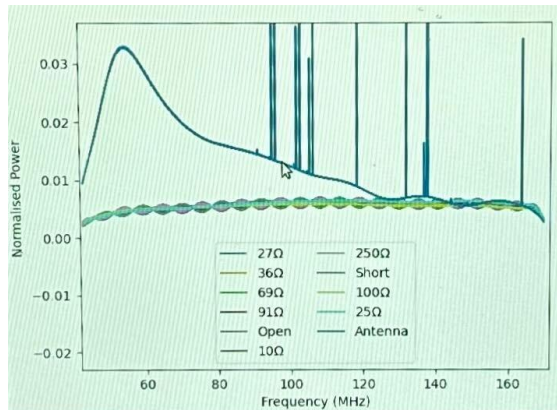
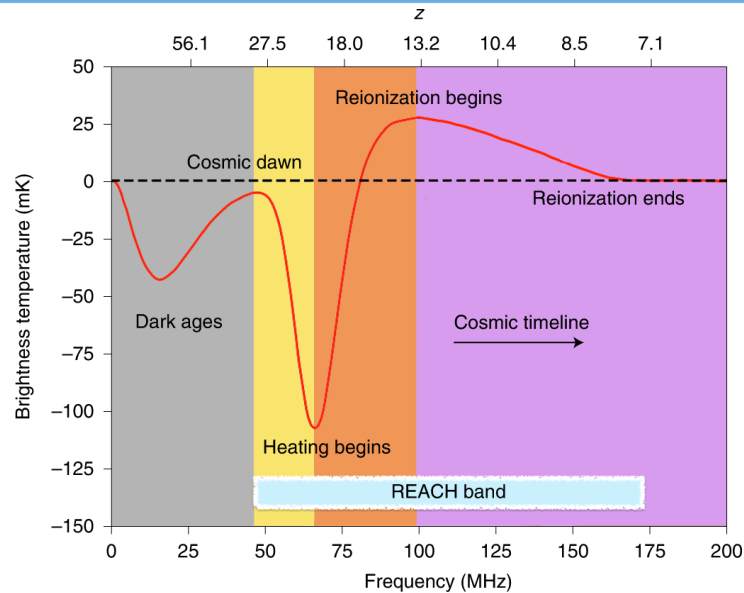


Steve Carey-
Engineer (ret)

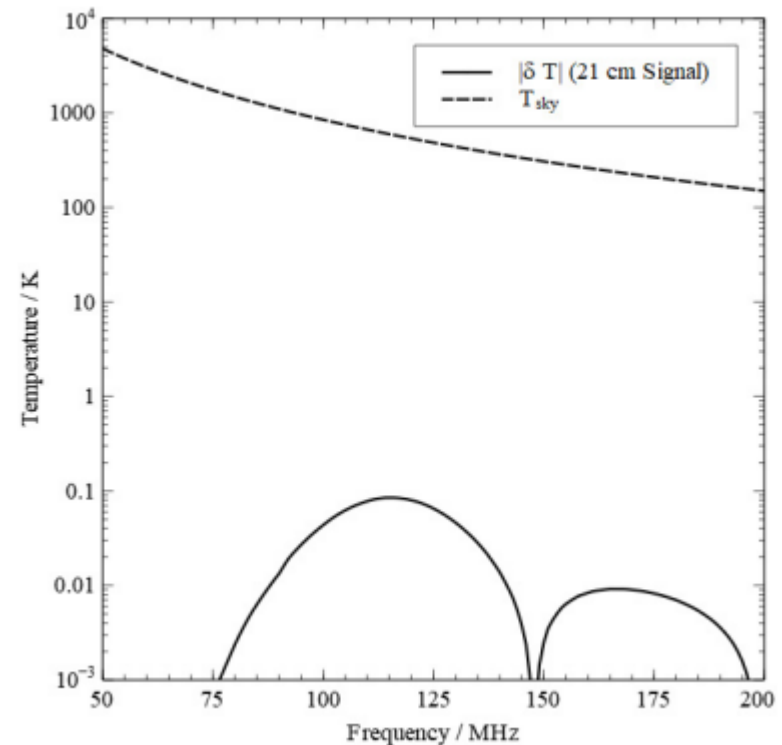


Ian Roque:
PhD student

The task: detect the first light

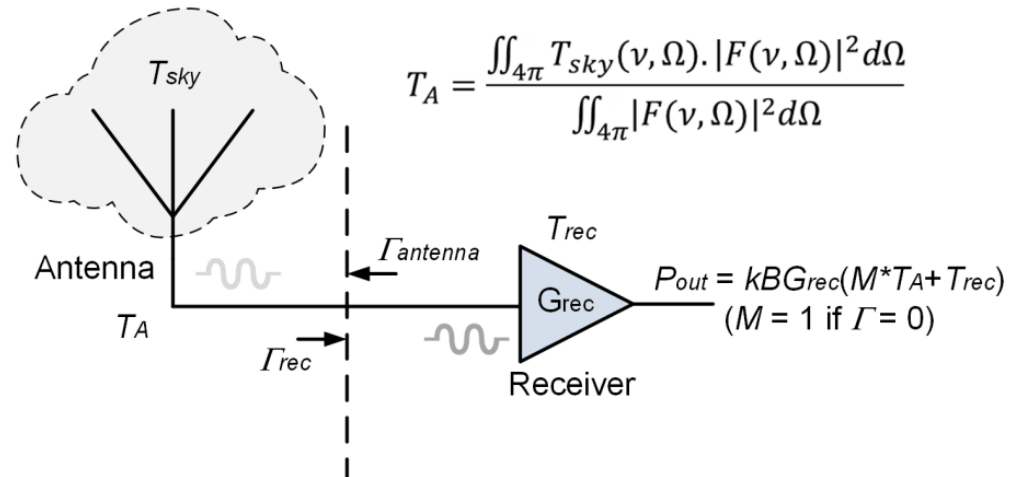


First
light
August
2023



From J.Cumner et al: Radio Antenna
Design for Sky-Averaged 21 cm
Cosmology Experiments: The REACH
Case

- The radiometer is based on the 3-way Dicke switching
- Calibration is based on EDGES (noise waves, more from Harry) formalism

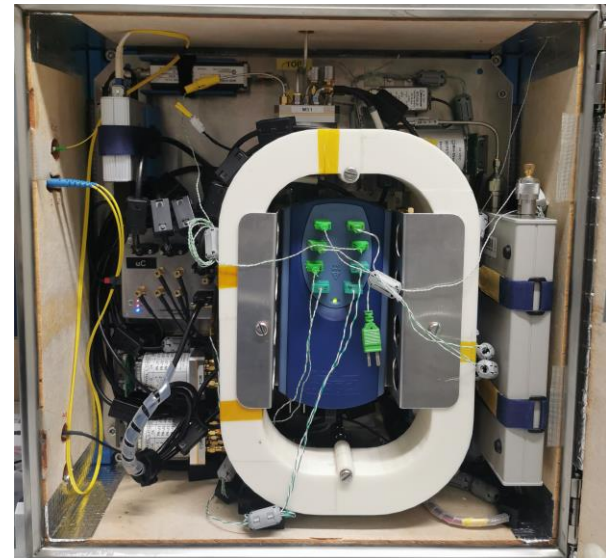
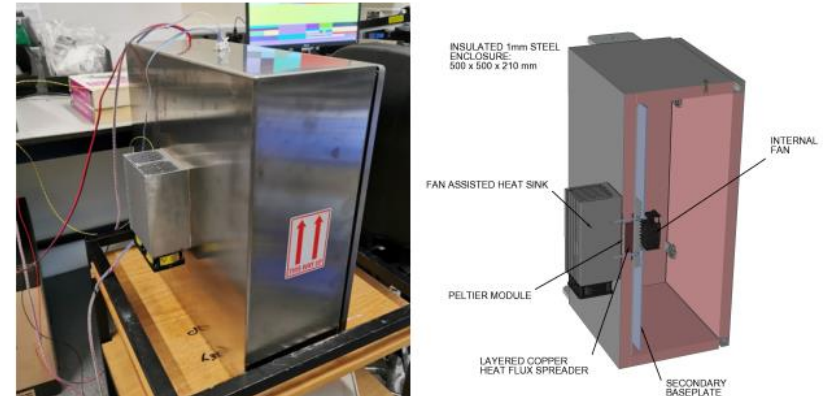


$$T_{NS} \left(\frac{P_{source} - P_L}{P_{NS} - P_L} \right) + T_L = T_{source} \left[\frac{1 - |\Gamma_{source}|^2}{|1 - \Gamma_{source}\Gamma_{rec}|^2} \right] + T_{unc} \left[\frac{|\Gamma_{source}|^2}{|1 - \Gamma_{source}\Gamma_{rec}|^2} \right] + T_{cos} \left[\frac{\text{Re}(\frac{\Gamma_{source}}{1 - \Gamma_{source}\Gamma_{rec}})}{\sqrt{1 - |\Gamma_{rec}|^2}} \right] + T_{sin} \left[\frac{\text{Im}(\frac{\Gamma_{source}}{1 - \Gamma_{source}\Gamma_{rec}})}{\sqrt{1 - |\Gamma_{rec}|^2}} \right]$$

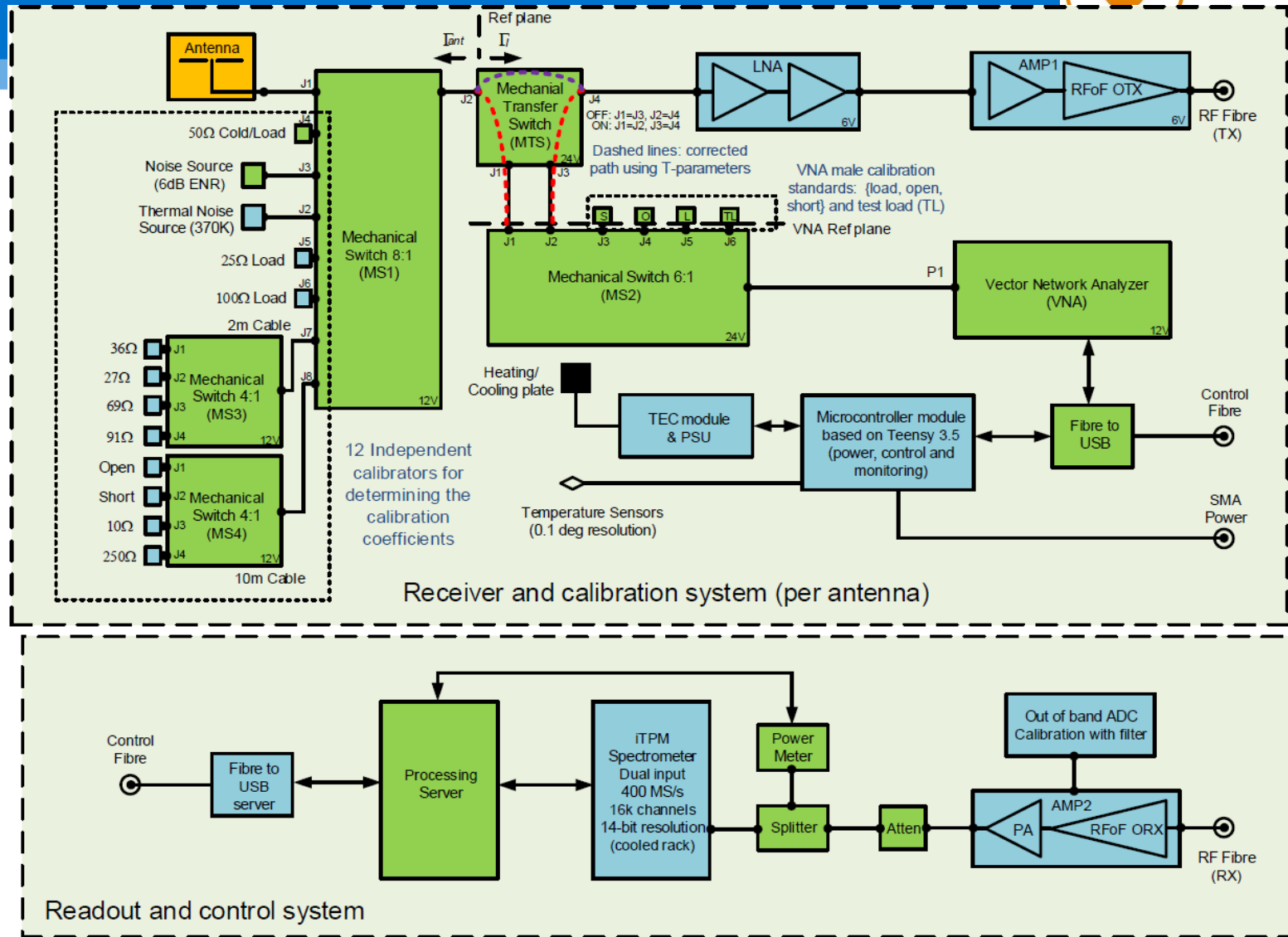
Receiver design



- Components and sensitivity was designed for 20mK sensitivity
- The different sources trying to cover the Smith chart
- The entire receiver is in a steel box with an RFI gasket and is also thermally isolated under the antenna and ground plane

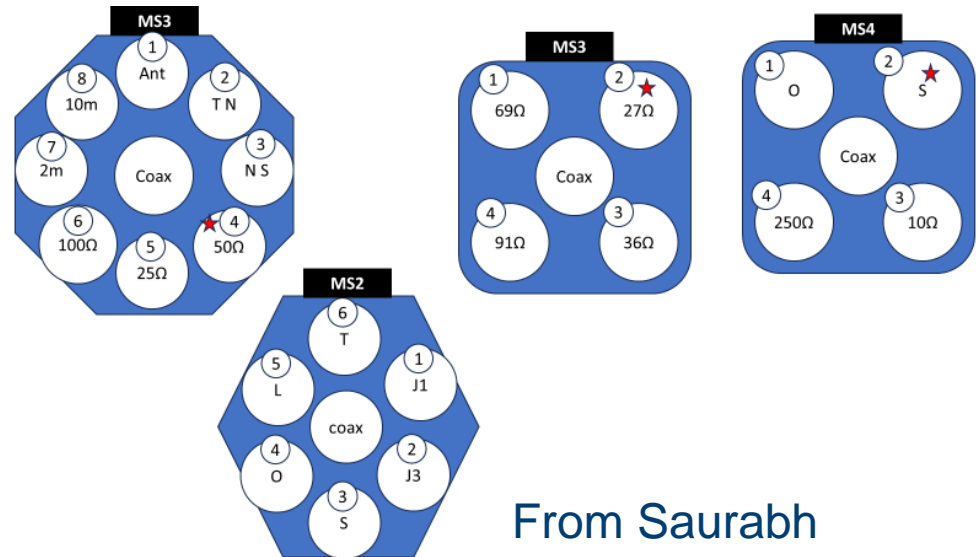


Schematic of the Receiver



Thermal managements and measurements

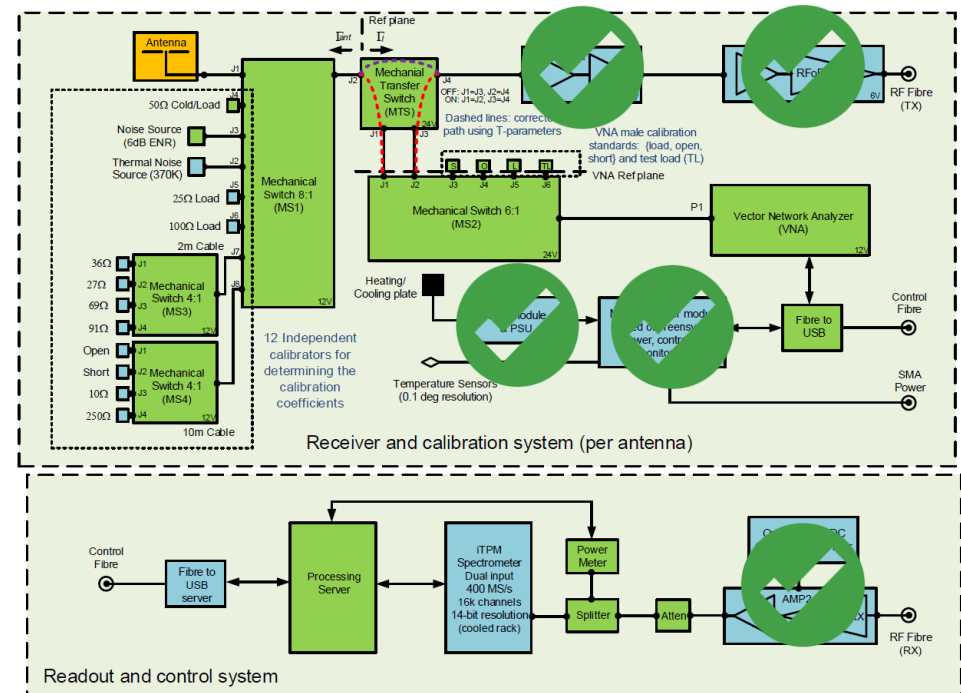
- 8 thermocouple measurements
- MS1, MS3, MS4, hot load, 2m, 10m cable, LNA and antenna feeding cable to 0.1K accuracy
- Plan: Switch the LNA to sensor to internal antenna (further temp sensors)
- FEM models can inform decisions on temp sensor placements



2nd Receiver



- We will have an identical one to the first one (blue: custom made, green: commercial) (for now)
- We can test new features and calibration on a complete system-
> at Lord's Bridge with a dipole
- Can be used to debug (moon vehicle principle)
- Eventually a 2nd antenna will be used on site
- Observations can inform where to change

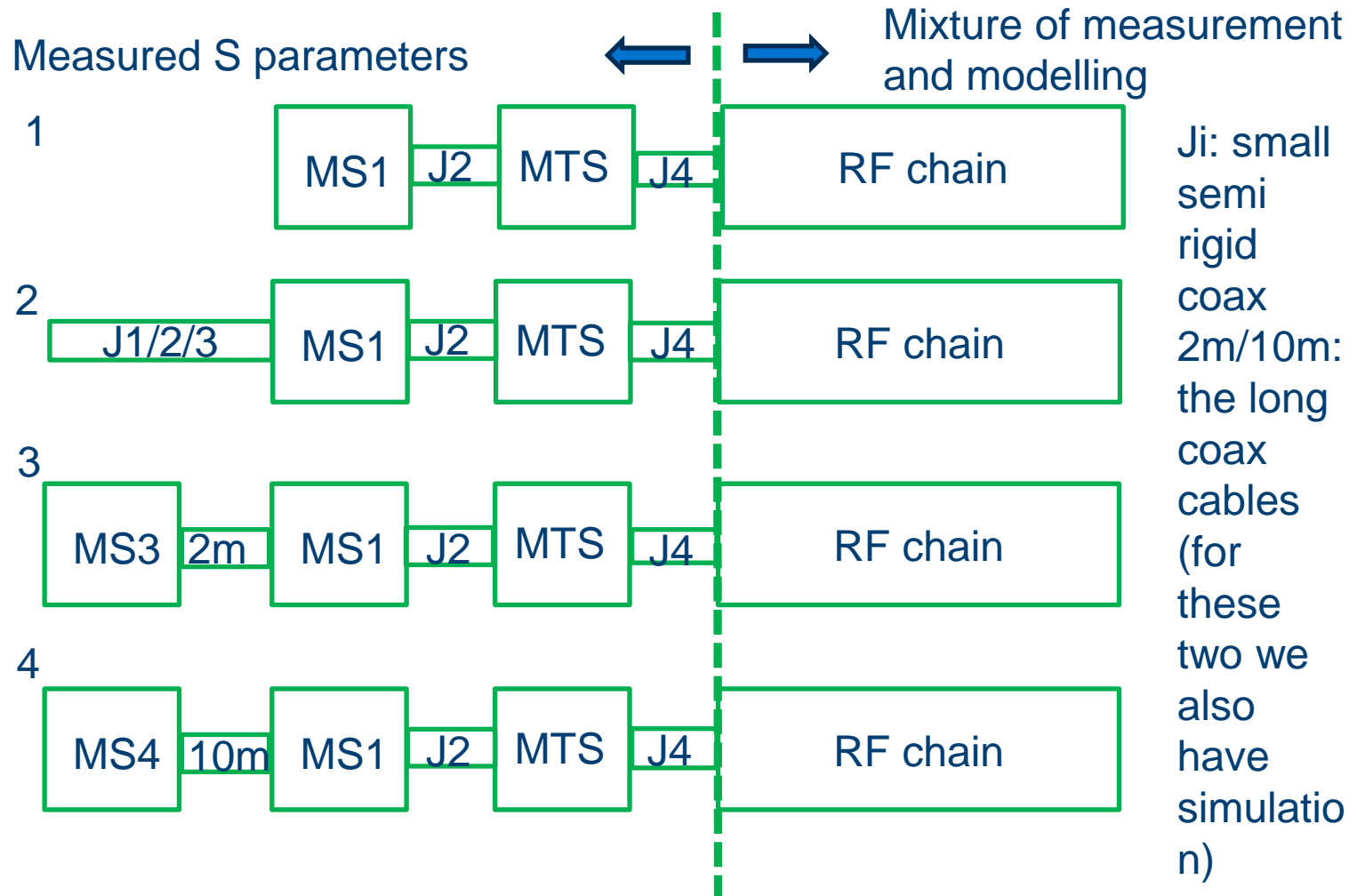


S-parameters for simulations

Current efforts:
building models
for mock data
generation

Each
configuration(1-
4) meant to
represent a
possible RF path

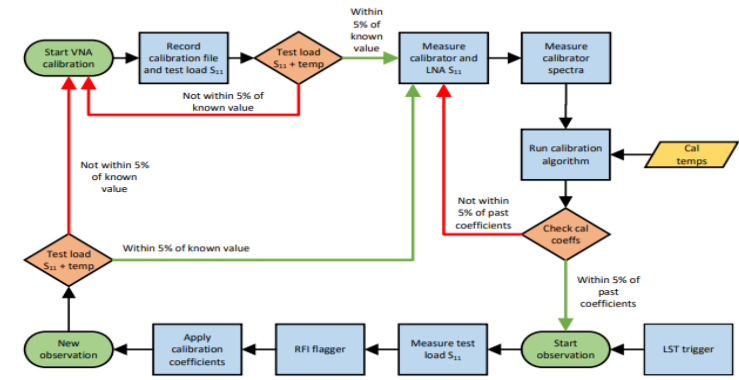
For each block
we have S
parameters



Future directions



- Improvements on the current design: fewer switches, better SOL standards for the VNA (a more powerful peltier element)
- Longer integration time for the data set
- Running observations will also inform us on the receiver
- 2nd Receiver building
- Current effort: building models of the receiver to aide mock data generation for calibration
- Observation strategy update

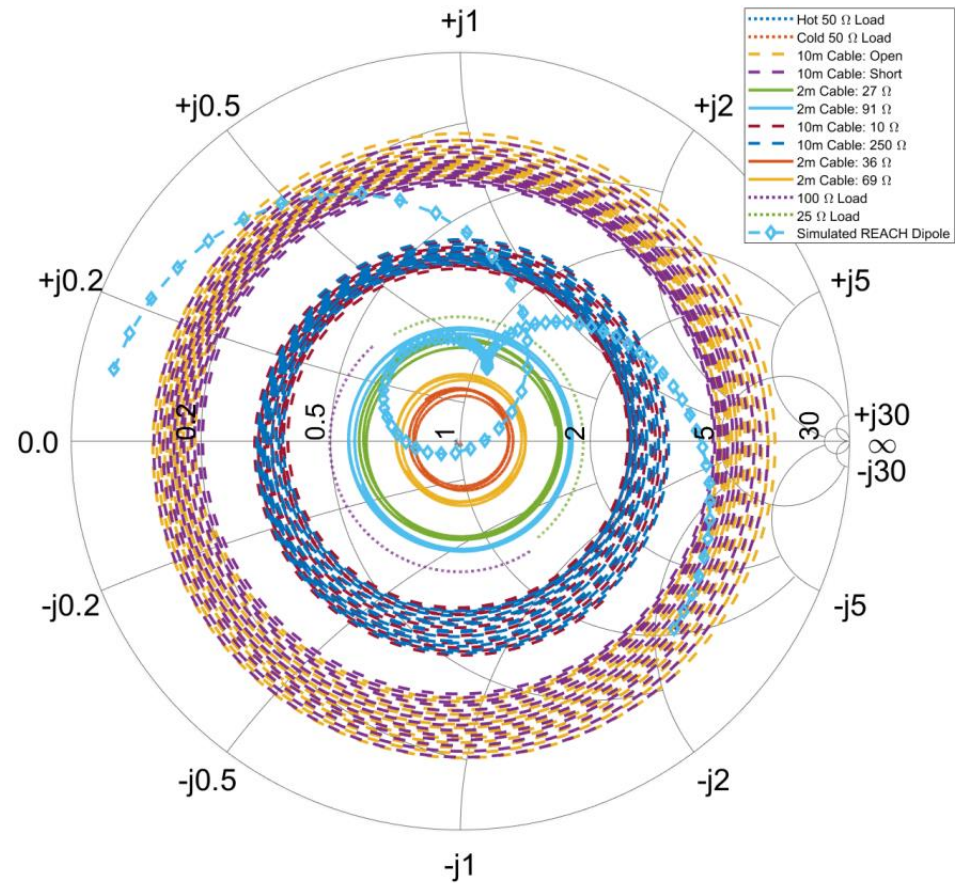


Thanks

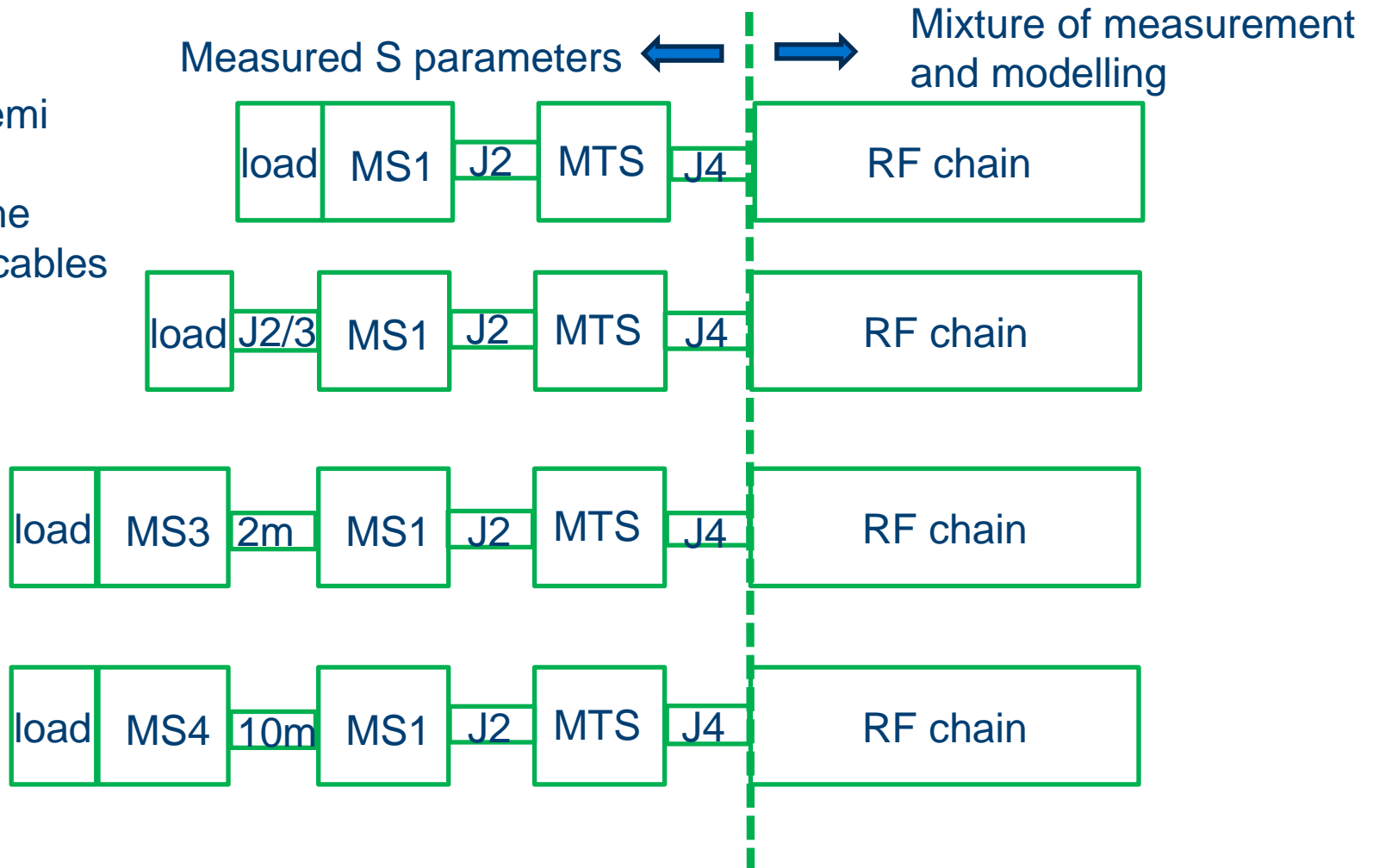
Antenna and calibrator impedances

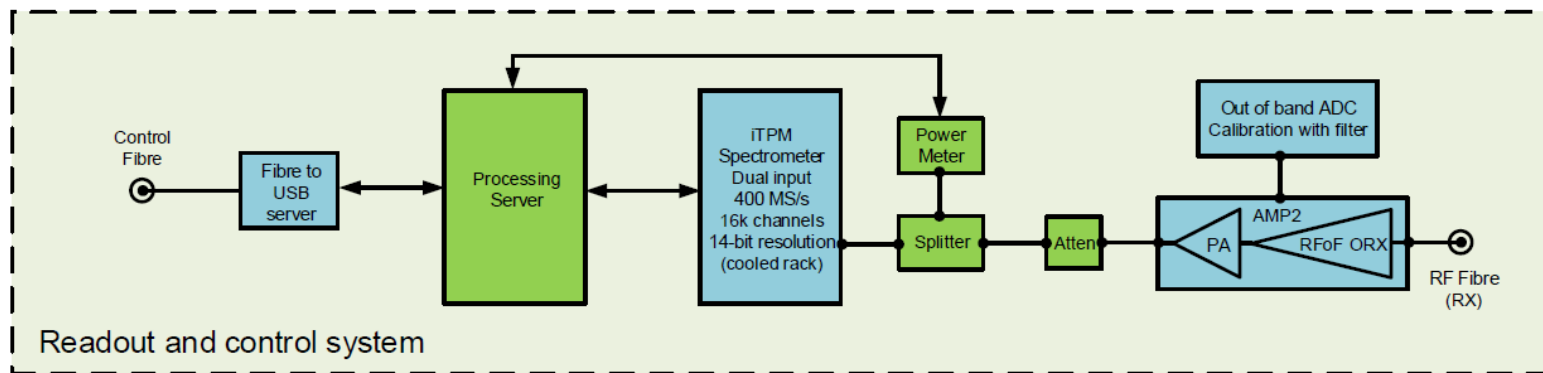
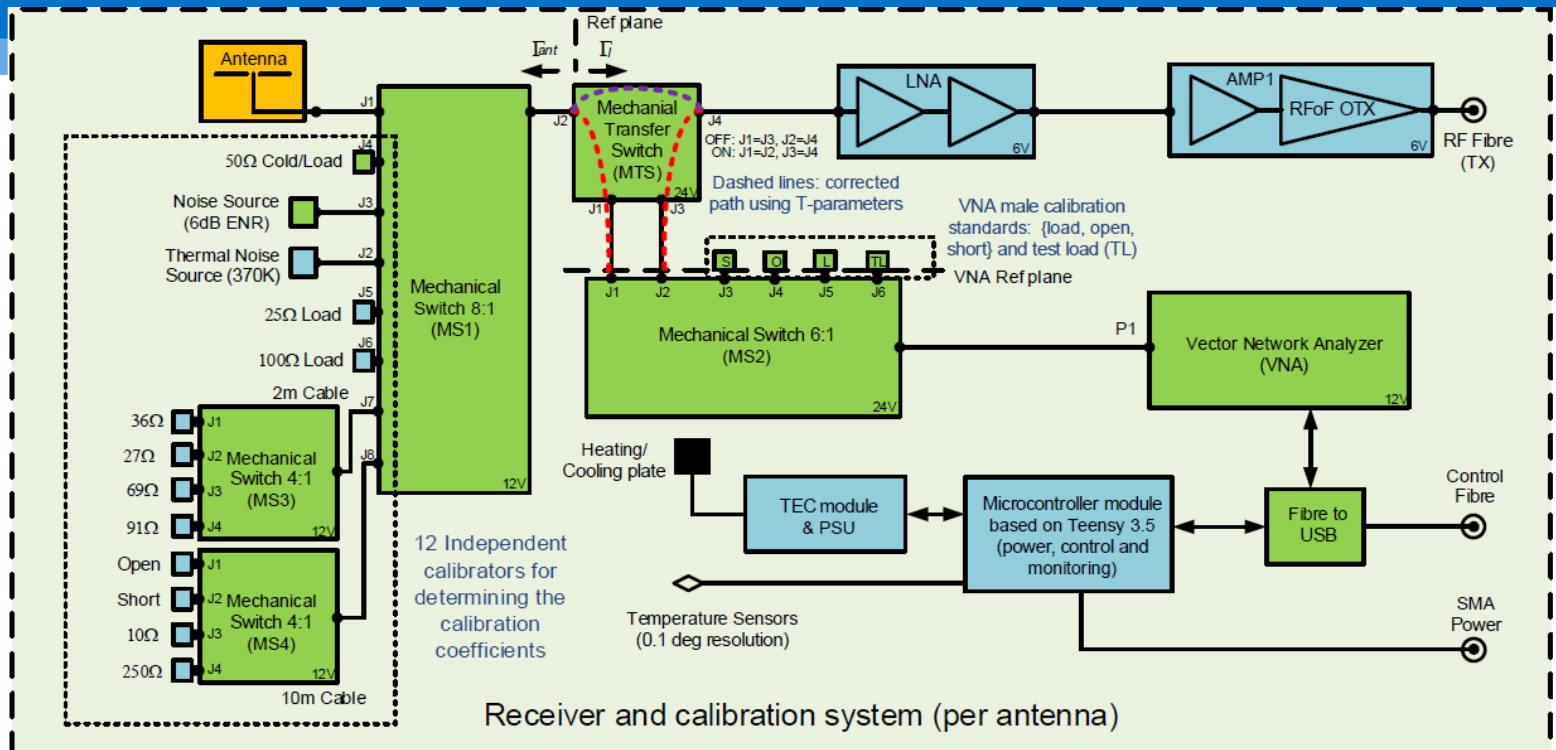


- Smith Chart showing the simulated dipole antenna impedance and the sources
- Antenna impedance shown is between 50-150MHz

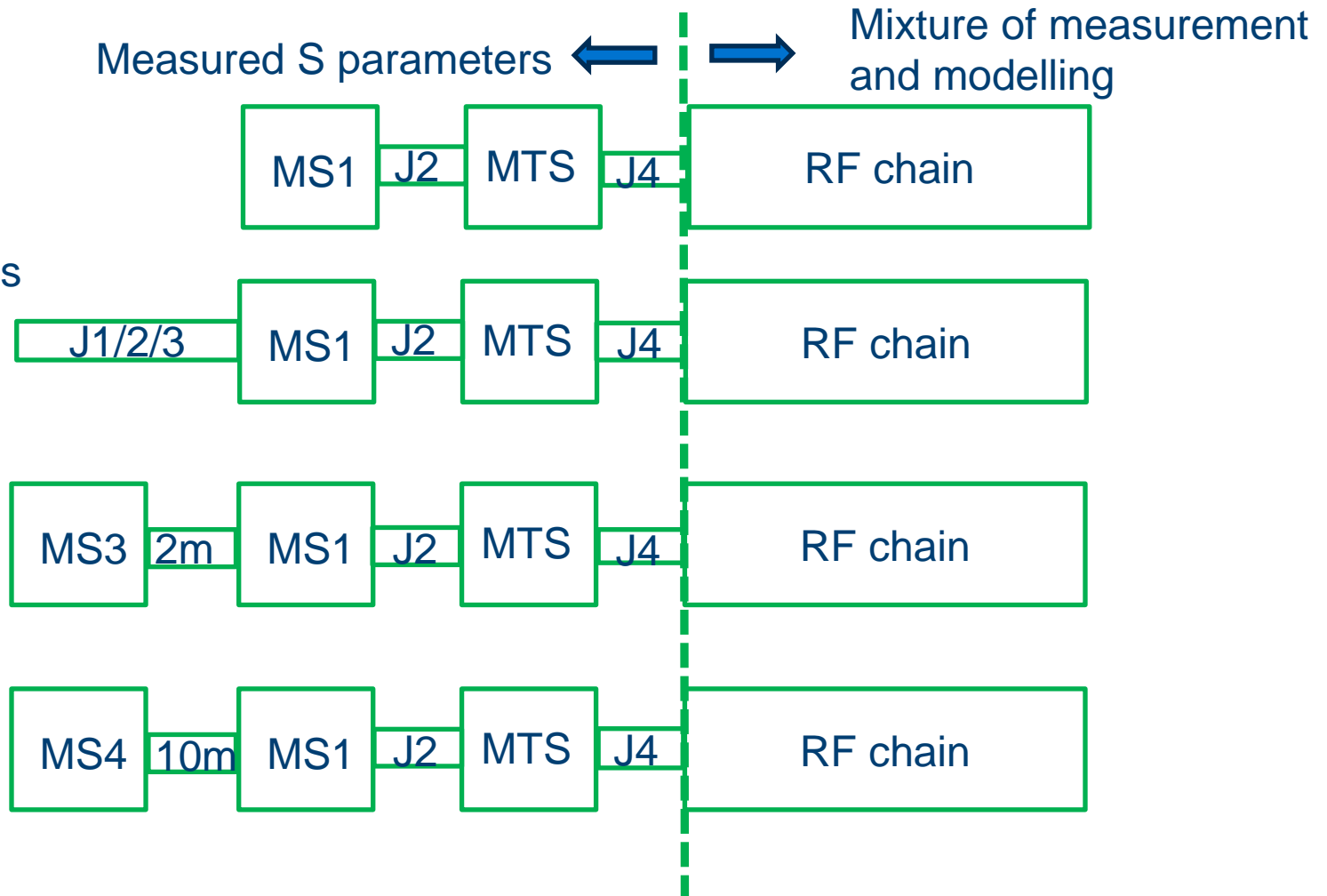


Ji: small semi
rigid coax
2m/10m: the
long coax cables

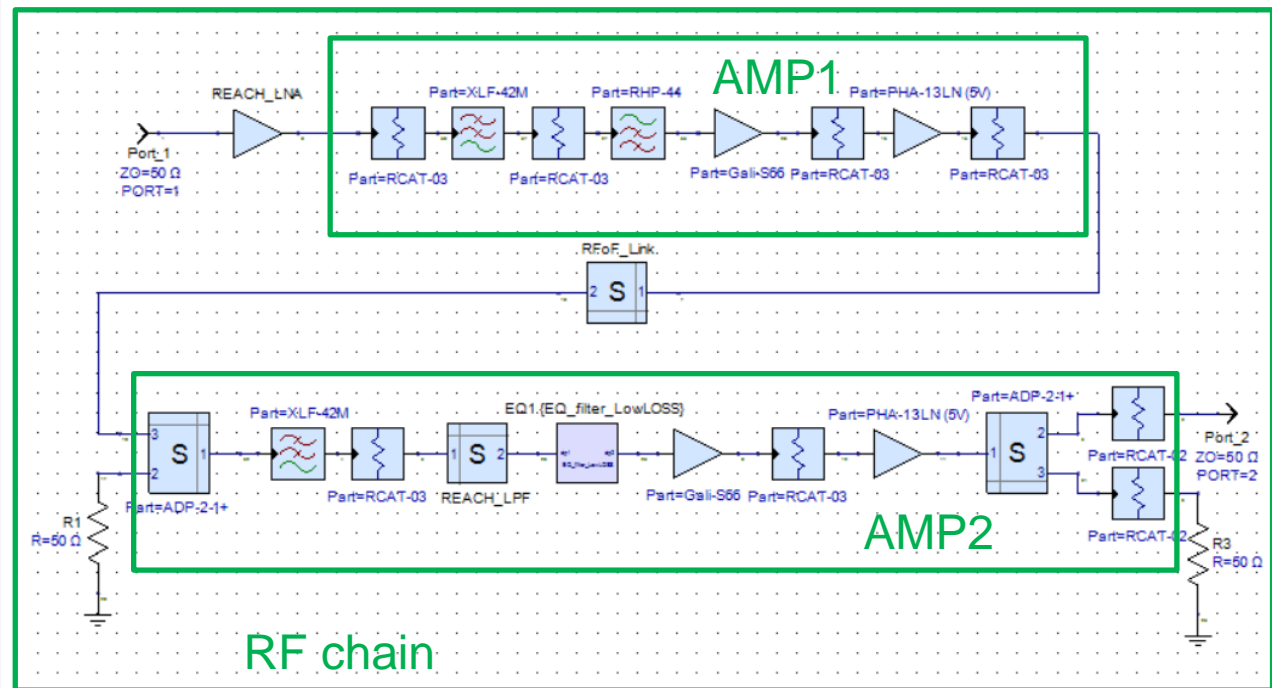




Ji: small semi
rigid coax
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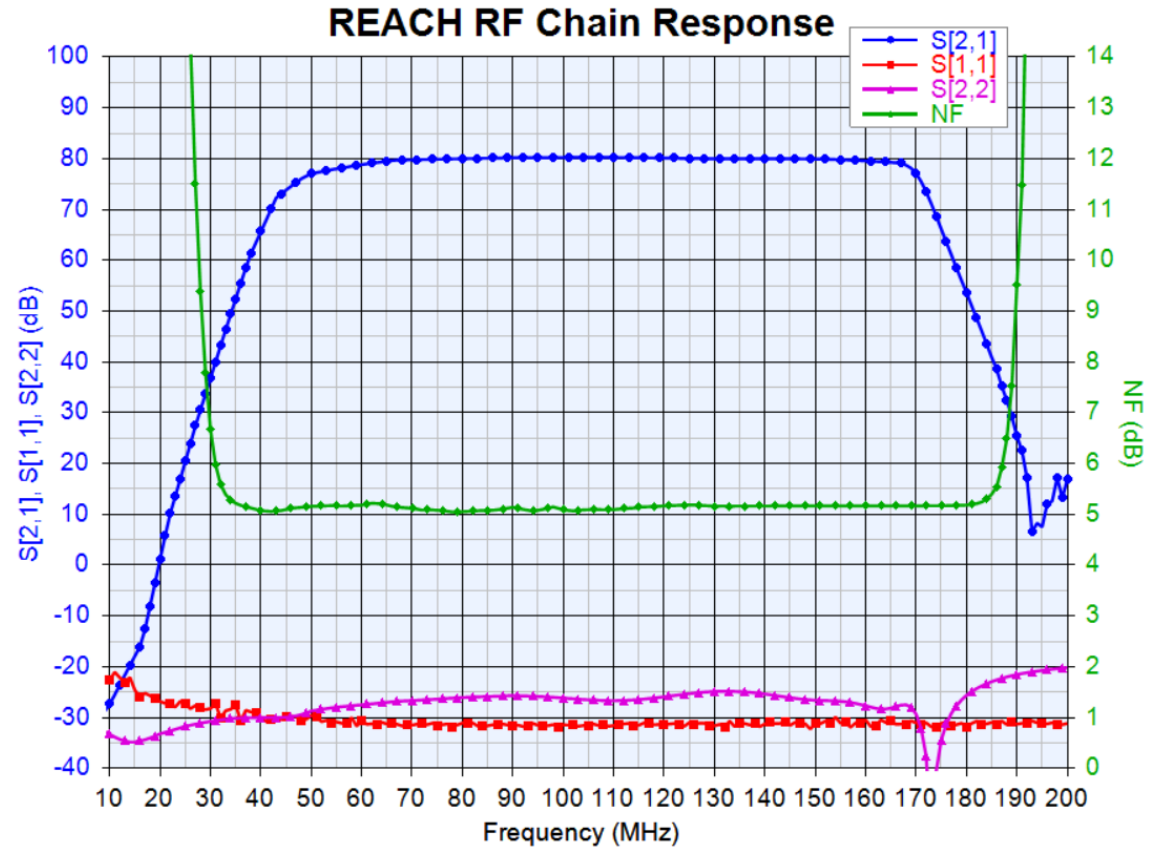


- Block diagram of RF chain (analogue part)
- Note that the LNA is based on S parameter measurement done in Cambridge



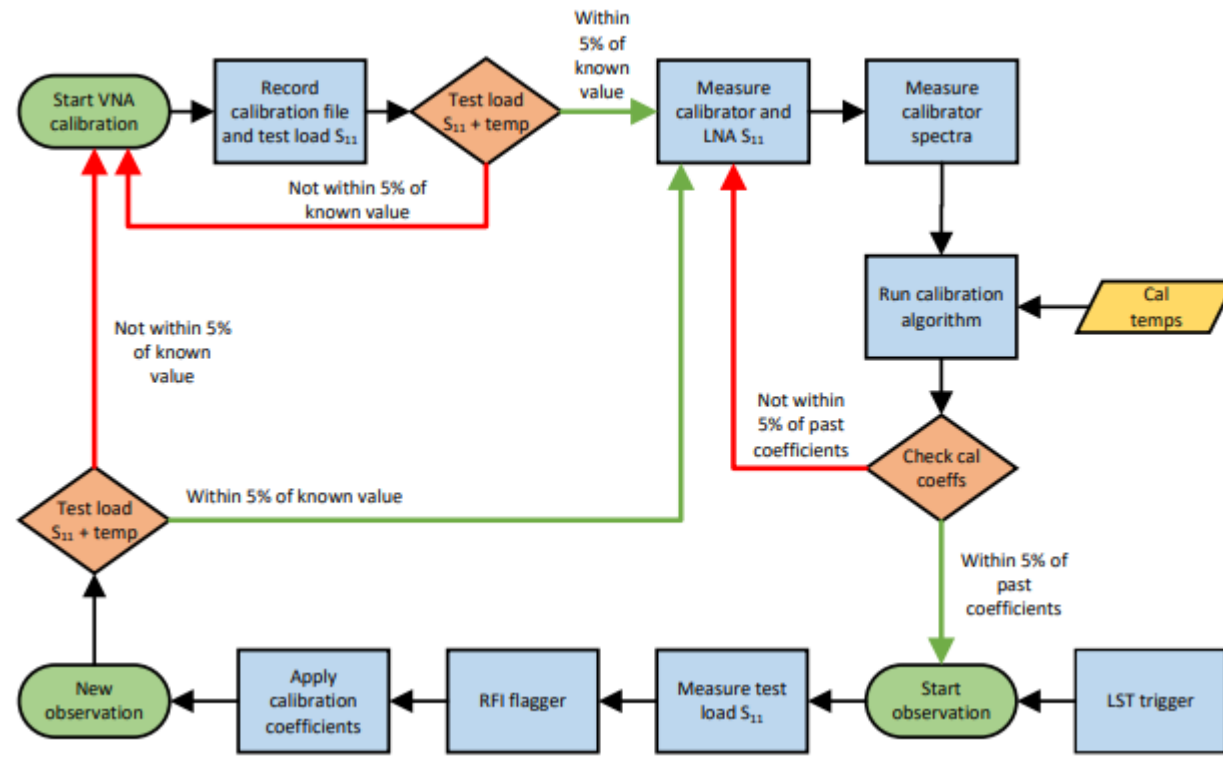
RF chain response

- Simulation by Nima
- LNA: measured, the other components are simulation based

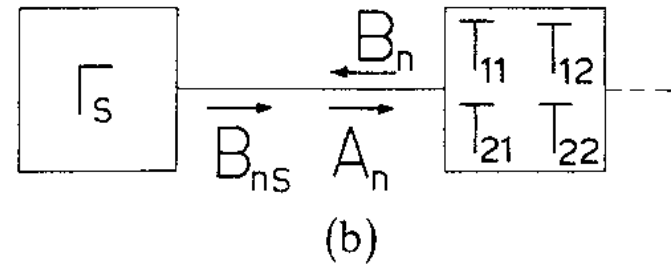


Cable current

- 10m cable is 10.1m; **model LBC195**
2m cable is 2.02m; **model: not sure could be LMC195 or LBC195**
- **New cables: 2m and 10m LCOM200**



- Noise waves from Meys paper
- Supposed to have a uncorrelated noise from receiver Tunc and describing the correlated part by Tsin and Tcos



Additional temp sensors

- There's a possibility to extend the 8



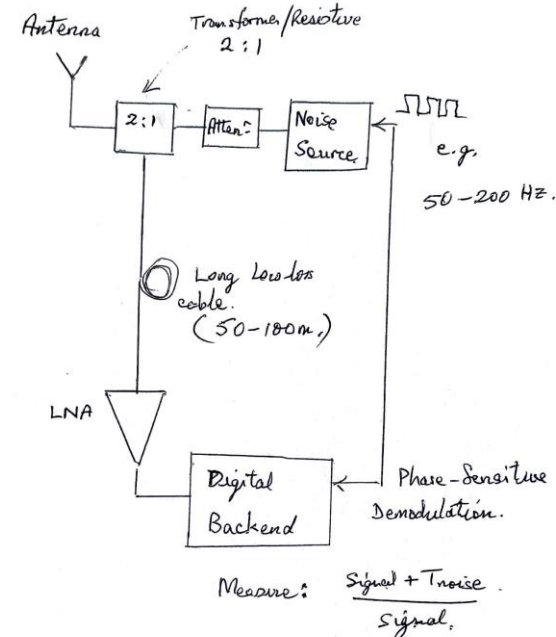
Fig. 0: The bottom and top layers of the stacked

Pros

1. Direct comparison of Antenna Power with a Noise source, using calibrated, passive components.
2. Using a long cable between the antenna and the LNA, the period of any standing waves (SWs) can be put outside the range of structure expected in the HI spectrum.
3. The SWs can either be fitted to a model or the spectrum convolved with a narrow bandstop filter. [Because the amplitude of the SWs will vary across the spectrum, fitting to a constant amplitude sine-wave is not appropriate.] Note that it is NOT necessary to know the phase of the SWs.
4. Measurements can be repeated with the 2:1 inputs interchanged if thought necessary.
5. Test measurements can easily be made with the Antenna replaced by alternative Noise sources for diagnostic purposes.

Cons

1. The effective system temperature is increased due to the loss in the 2:1 and the long cable. However the sky temperature is likely to be a significant factor in *any* receiving system.
2. The long cable will be bulky! However, it does mean that the active part of the receiving system can be a long way from the antenna (and the cable could also carry the drive signal for the noise source, if required).
3. There do not appear to be any requirements for temperature control anywhere in the system.
4. Because the calibration signal is relatively small e.g. ~10 to 20 K, a longer integration time will be required to reduce the noise level in the chosen spectral resolution bandwidth. These numbers need to be quantified!



Radically new ideas are also being looked at too, an idea by Paul Scott- > advantage very simple, but perhaps too simple