“SARAS”

(Shaped Antenna measurement of the background RAdio Spectrum)

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Team "SARAS"

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Plan of the talk.

- System specifications.
- System configurations.
- Data acquisition strategy.
- Understanding SARAS data set.
- Observing strategies.
- Algorithms for interference rejection.
- Analysis.

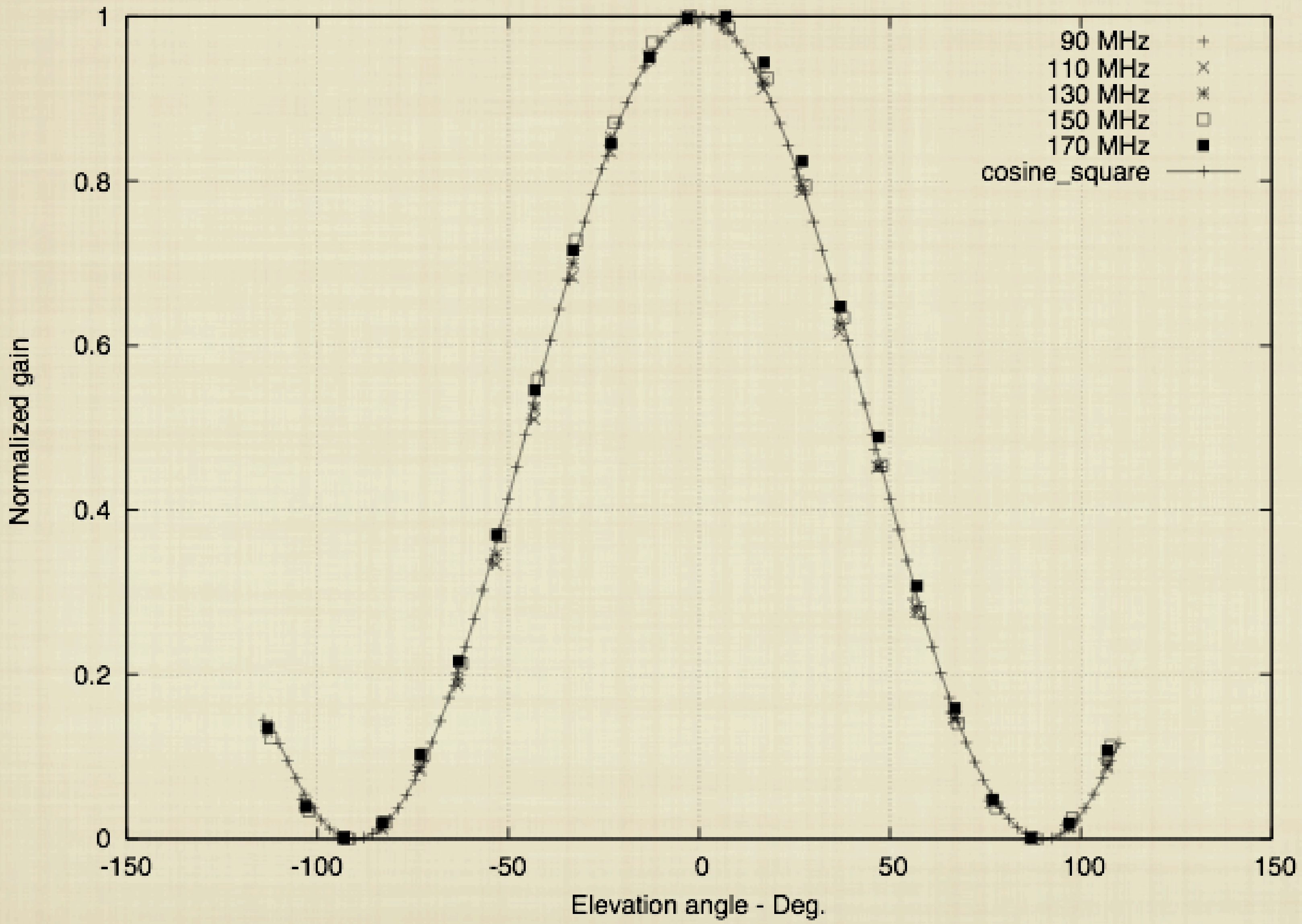
SARAS: system specification

- A correlation spectrometer with a single antenna.
- Frequency range: 87.5 to 175 MHz.
  (Presently operating between 110 to 175 MHz.)
- Redshift range z=15.1 to 7.1 .
- Number of frequency channel 1024.
- Sampling rate 175 Mhz.
- Spectra are recorded every 0.7 sec.

System configuration part 1: The Antenna

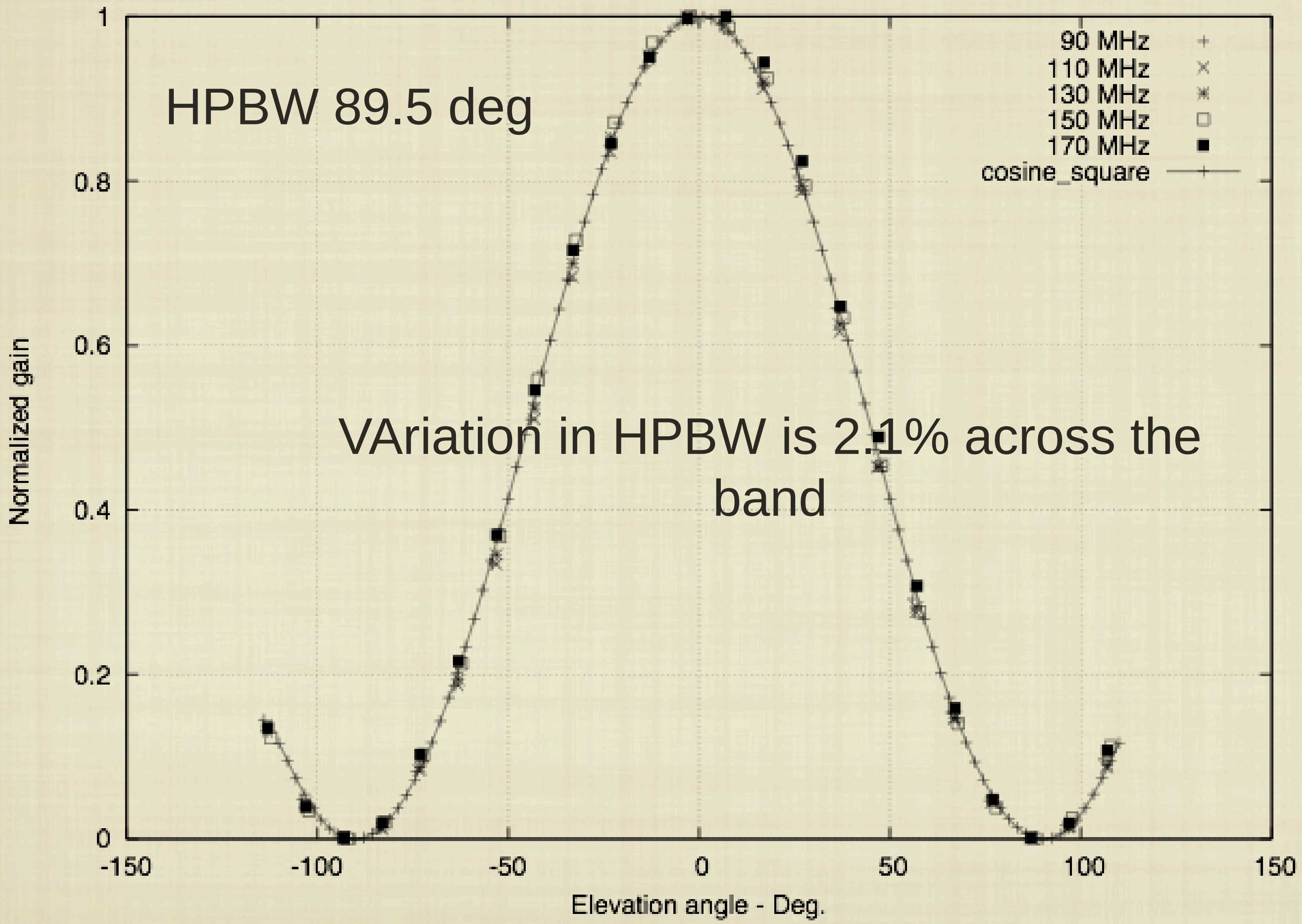
Antenna : A frequency independent (fat) Shaped Dipole antenna, Raghunathan et al. 2012,(Submitted to IEEE)

System configuration part 1: The Antenna.



Measured Radiation Pattern, Raghunathan et al. 2012

System configuration part 1: The Antenna.



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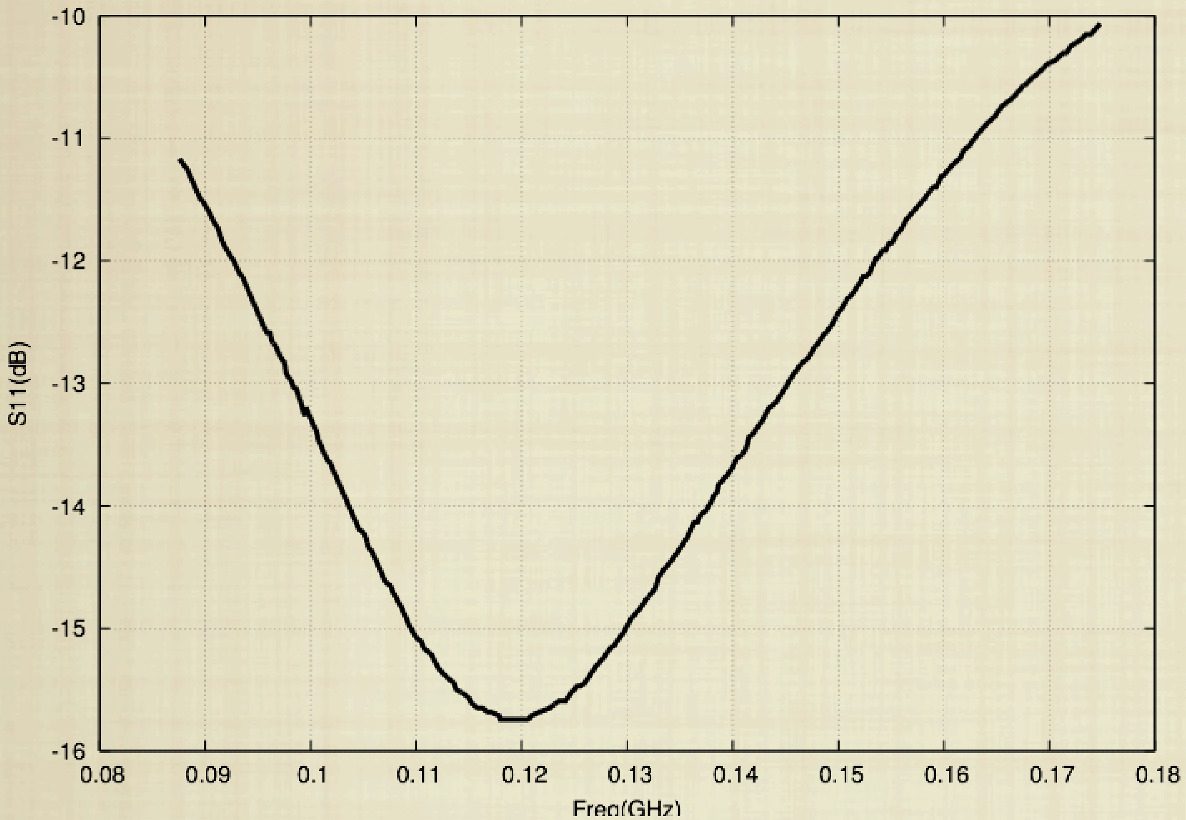
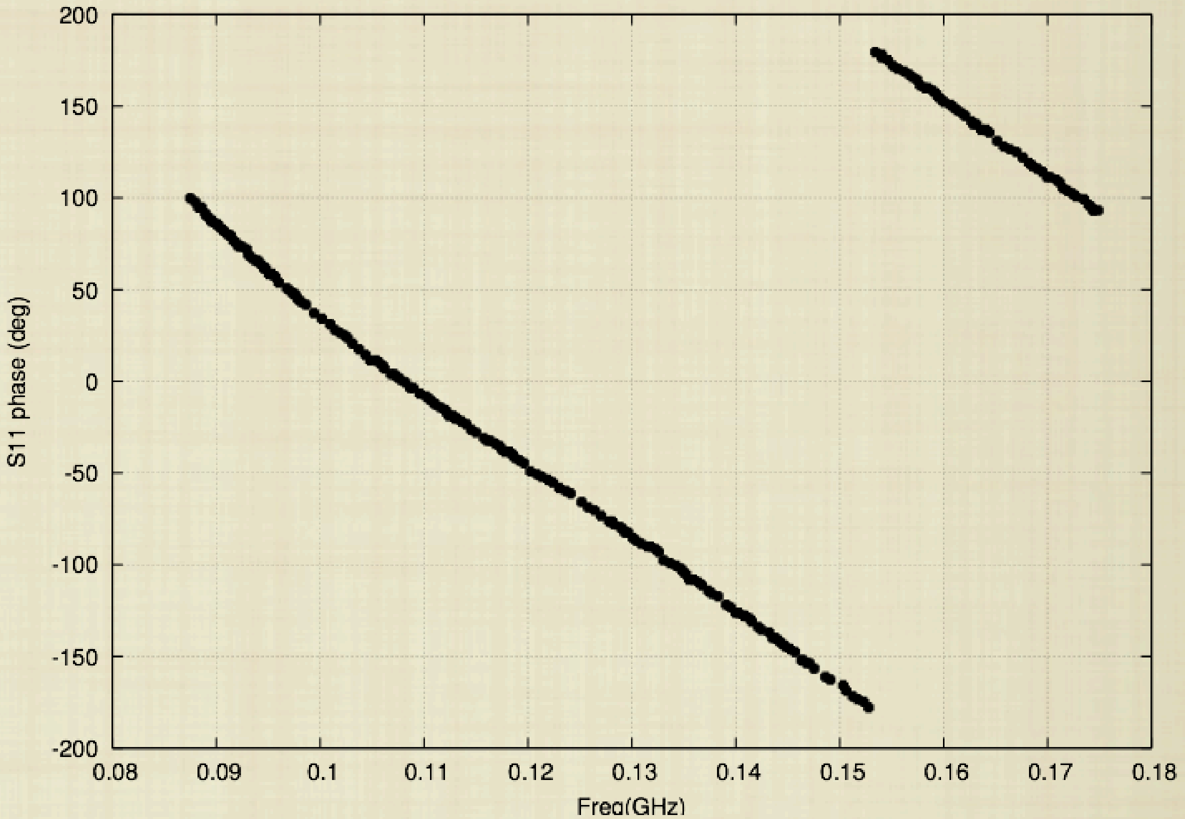
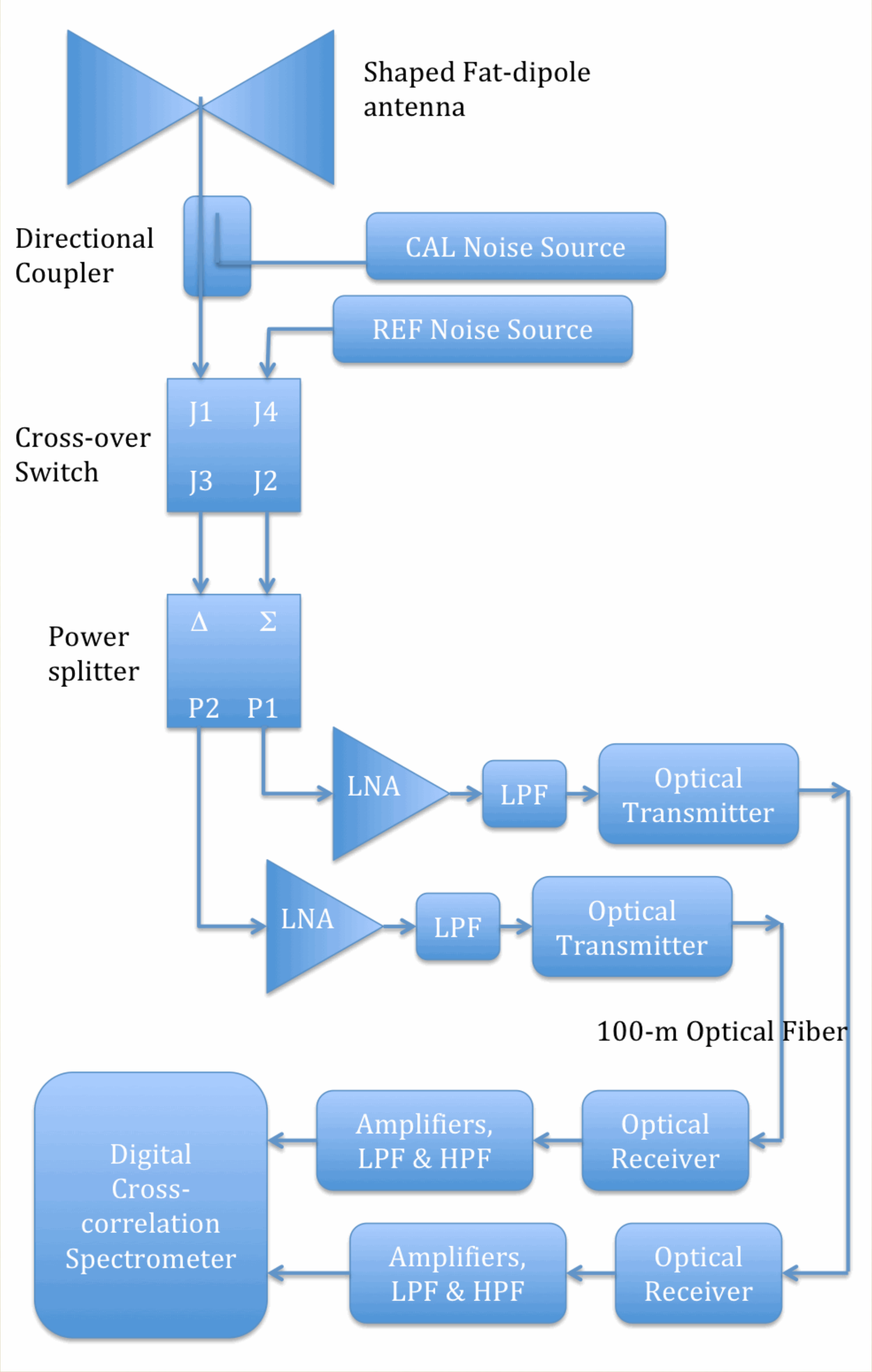




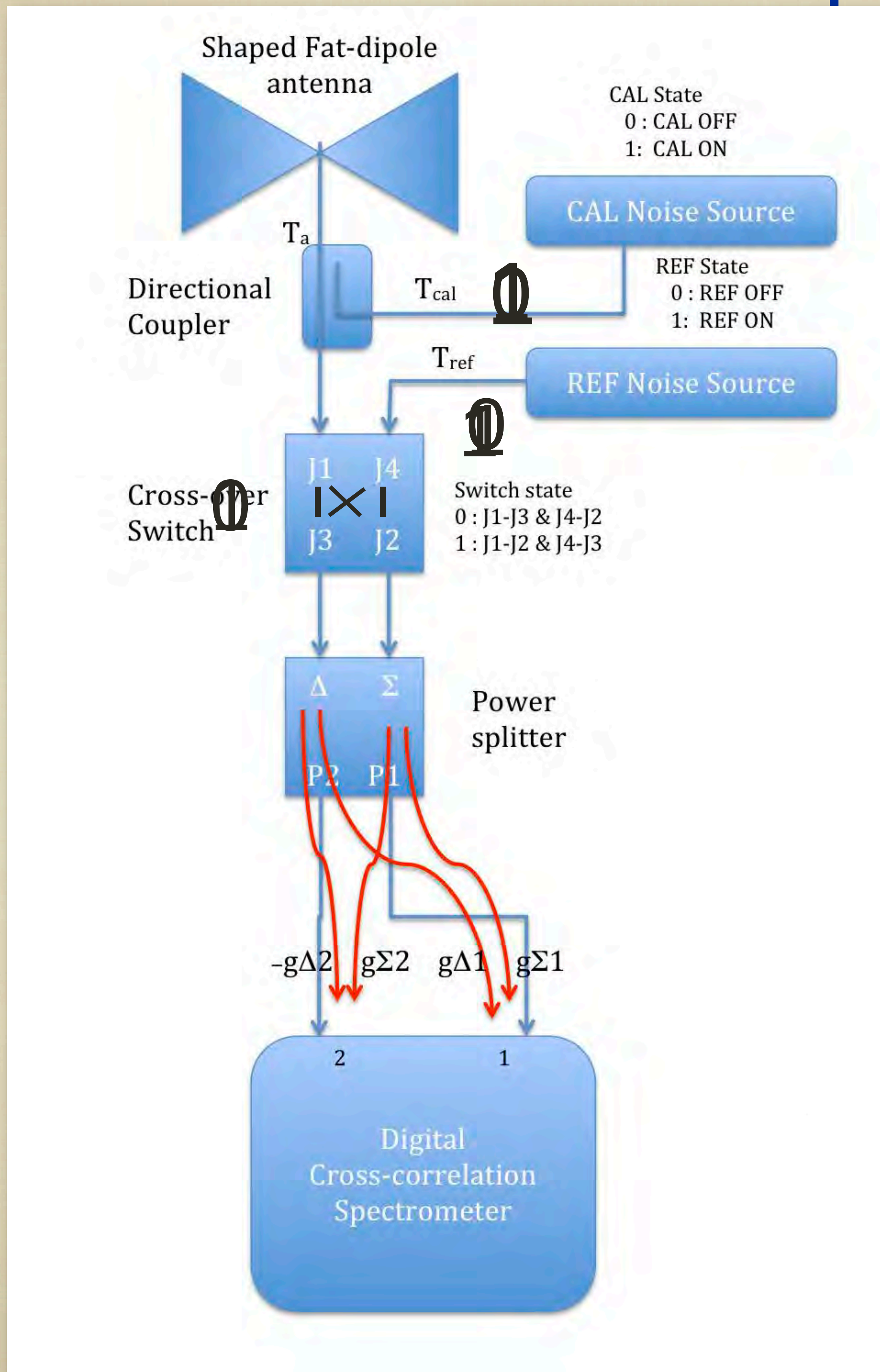
We will discuss more on return loss during analysis

Measured Return Loss

System configuration part 2: The Receiver.



SARAS data calibration strategy ::



Switch State	Cal Noise State	Ref Noise State
0	0	0
0	1	0
0	0	1
1	0	0
1	1	0
1	0	1

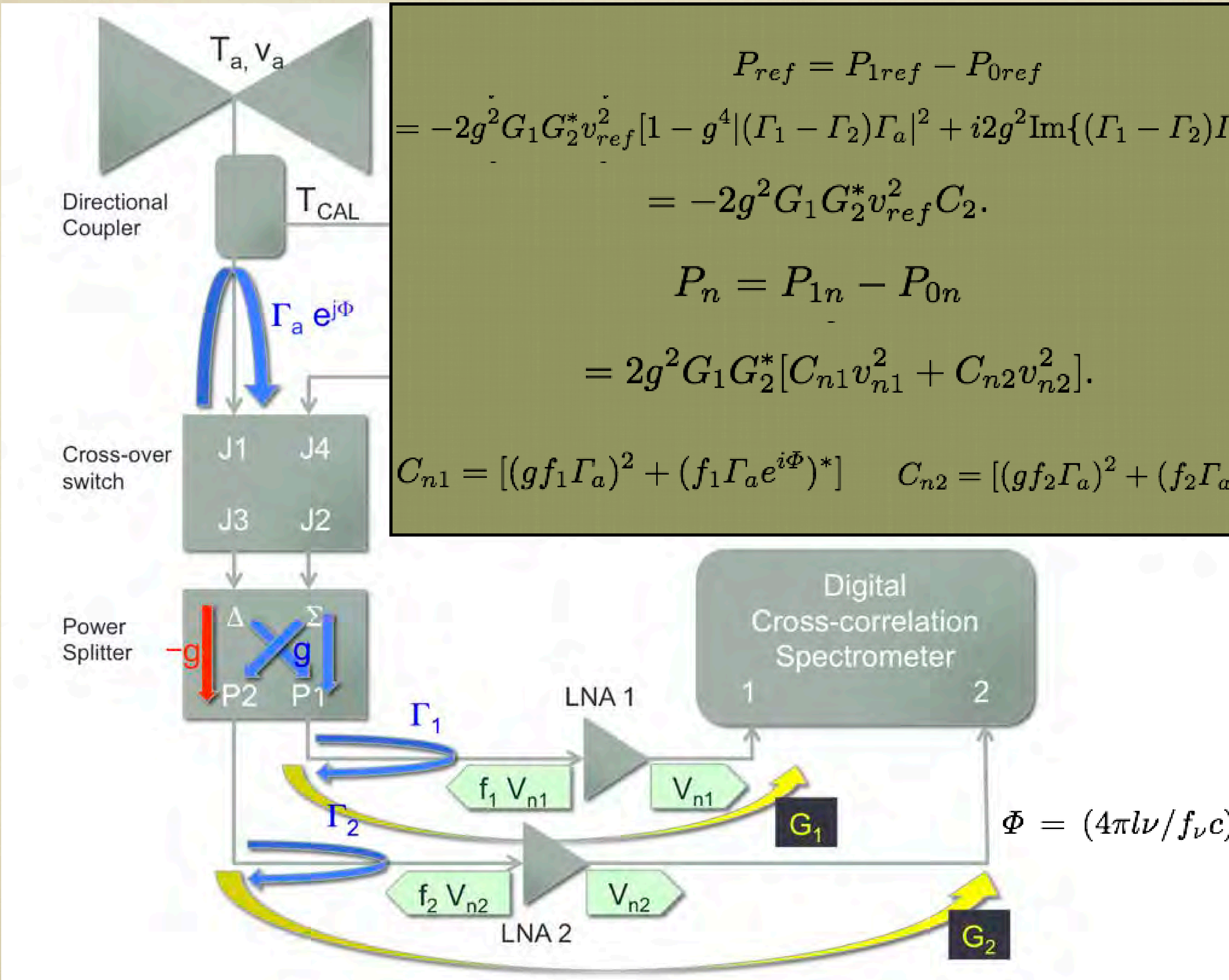
$$= (g_{\Sigma 1} g_{\Sigma 2} + g_{\Delta 1} g_{\Delta 2})(T_a - T_{ref0}),$$

$$P_{cal} = P_{1cal} - P_{0cal}$$
$$= (g_{\Sigma 1} g_{\Sigma 2} + g_{\Delta 1} g_{\Delta 2})(T_a + T_{cal} - T_{ref0})$$

$$P_{cal} - P_{off} = (g_{\Sigma 1} g_{\Sigma 2} + g_{\Delta 1} g_{\Delta 2}) T_{cal}.$$

$$T_a - T_{ref0} = \frac{P_{off}}{(P_{cal} - P_{off})} \times T_{cal}.$$

Non-idealities in the SARAS system.



$$P_{ref} = P_{1ref} - P_{0ref}$$

$$= -2g^2 G_1 G_2^* v_{ref}^2 [1 - g^4 |(\Gamma_1 - \Gamma_2)\Gamma_a|^2 + i2g^2 \mathrm{Im}\{(\Gamma_1 - \Gamma_2)\Gamma_a e^{i\Phi}\}]$$

$$= -2g^2 G_1 G_2^* v_{ref}^2 C_2.$$

$$P_n = P_{1n} - P_{0n}$$

$$= 2g^2 G_1 G_2^* [C_{n1} v_{n1}^2 + C_{n2} v_{n2}^2].$$

$$C_{n1} = [(g f_1 \Gamma_a)^2 + (f_1 \Gamma_a e^{i\Phi})^*] \qquad C_{n2} = [(g f_2 \Gamma_a)^2 + (f_2 \Gamma_a e^{i\Phi})].$$

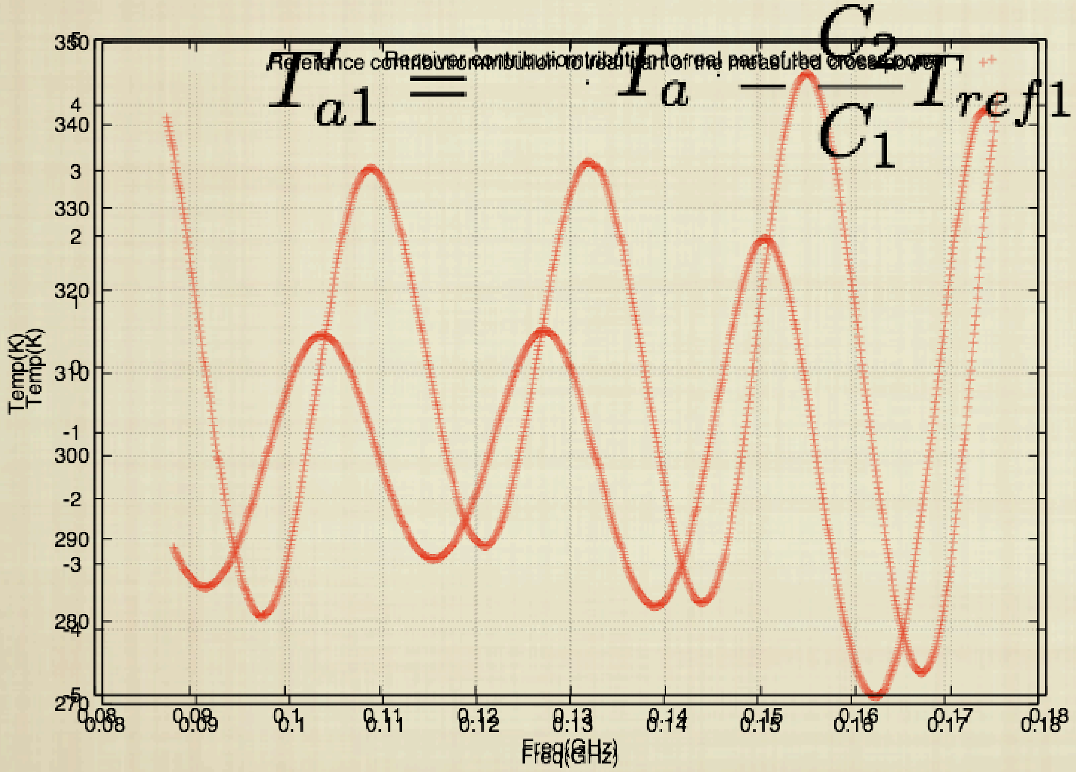
$$\Phi = (4\pi l \nu / f_\nu c),$$

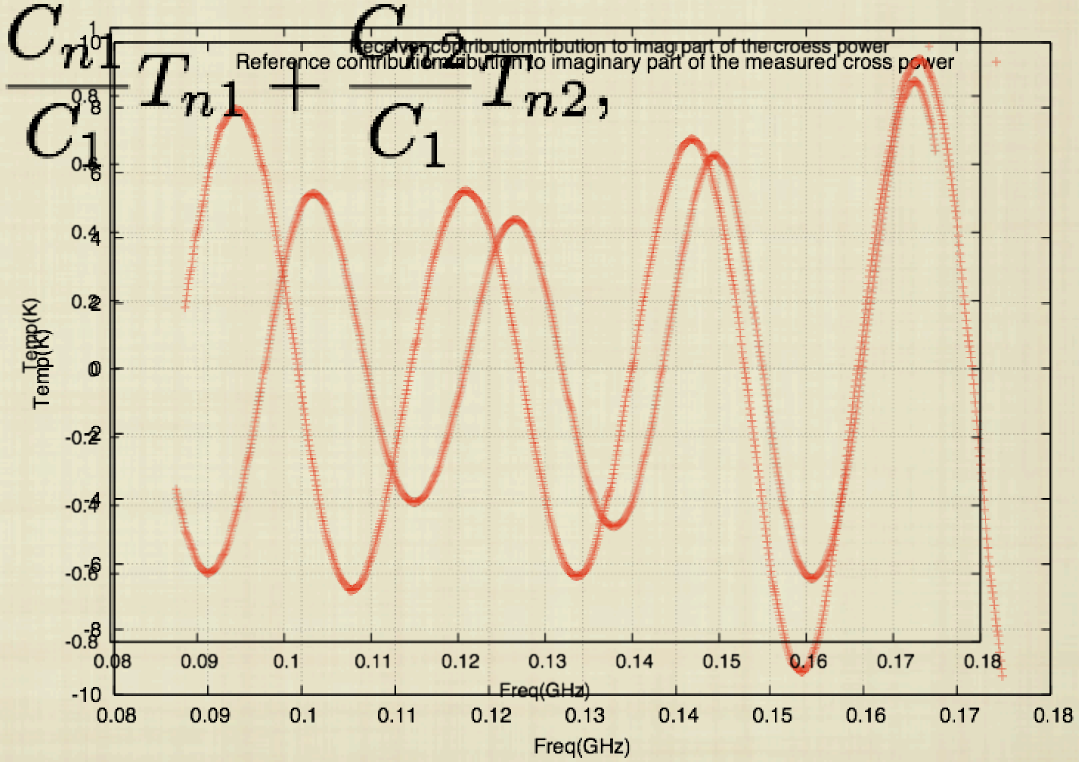
Understanding the SARAS Data set.

One calibrated spectrum is,

$$T'_{a0} = T_a - \frac{C_2}{C_1} T_{ref0} + \frac{C_{n1}}{C_1} T_{n1} + \frac{C_{n2}}{C_1} T_{n2}$$

$$T'_{a1} = T_a - \frac{C_2}{C_1} T_{ref1} + \frac{C_{n1}}{C_1} T_{n1} + \frac{C_{n2}}{C_1} T_{n2},$$





Understanding the SARAS Data set.

One calibrated spectrum is,

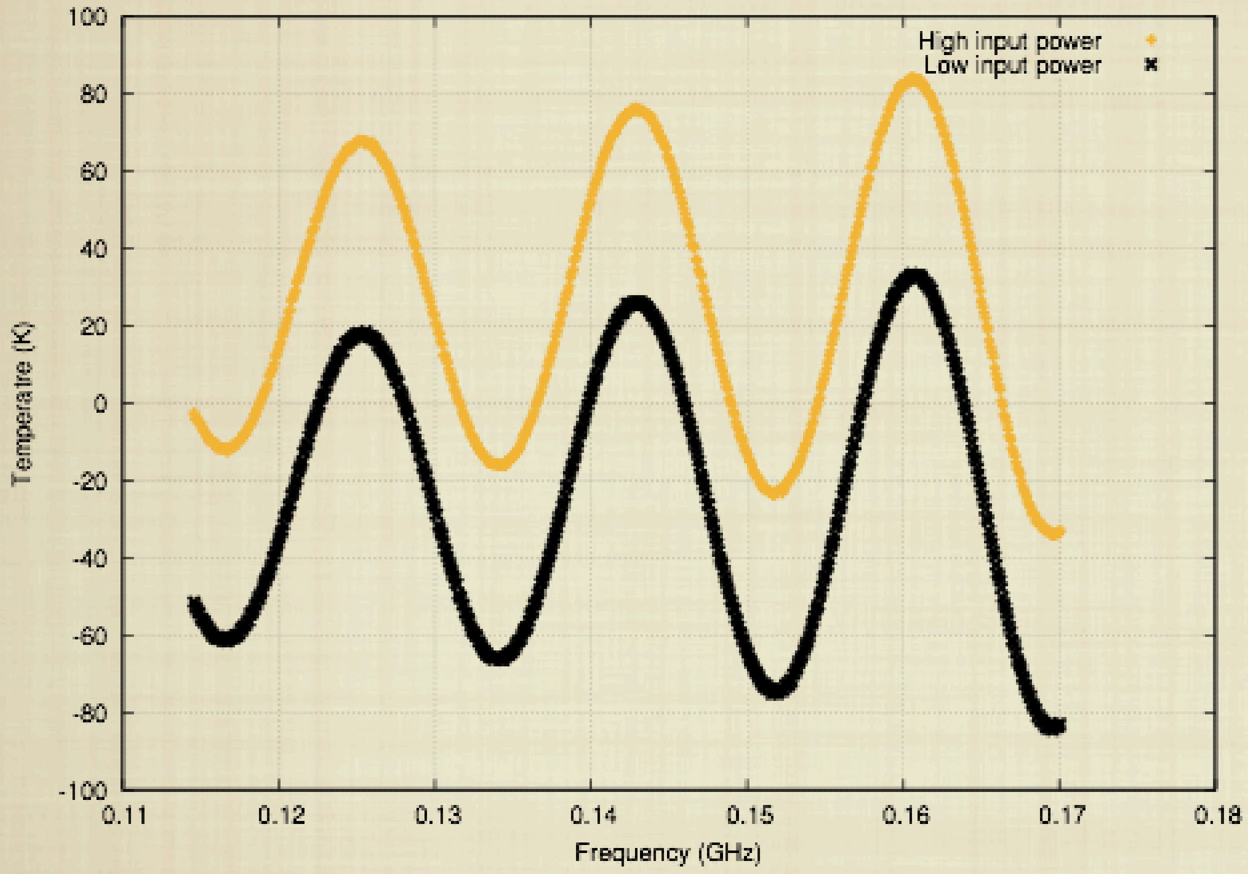
$$T'_{a0} = T_a - \frac{C_2}{C_1}T_{ref0} + \frac{C_{n1}}{C_1}T_{n1} + \frac{C_{n2}}{C_1}T_{n2}$$

$$T'_{a1} = T_a - \frac{C_2}{C_1}T_{ref1} + \frac{C_{n1}}{C_1}T_{n1} + \frac{C_{n2}}{C_1}T_{n2},$$

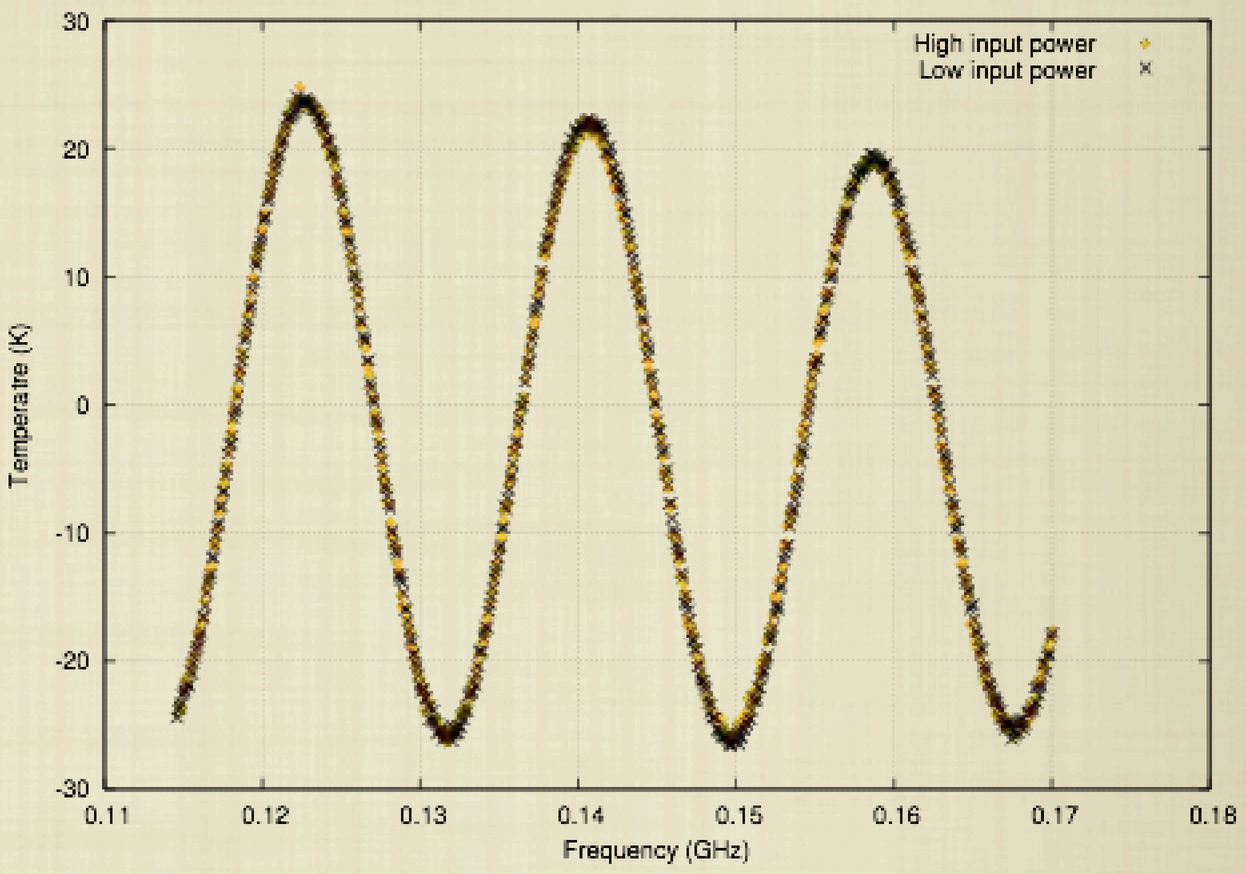
Difference Spectrum 1 : $T^{'}_{a0} - T^{'}_{a1} = \frac{C_2}{C_1}(T_{ref1} - T_{ref0}).$

Difference Spectrum 2 : $T^{'}_{ah} - T^{'}_{ac} = T_{ah} - T_{ac} = G_a(T_{hot\ sky} - T_{cold\ sky}).$

SARAS test data confirming the system performance.



Real



Imag

Foundation of our data analysis lies on developing a method where based on the knowledge of the imaginary part of the measured cross-power and also the derived data product, we can model the systematic effects in the real part which contains the sky.

Observing Strategies.

Two modes of observation :

Mode 1: Long delay mode. For
Cosmic Radio Background : CRB

Mode 2: Shortest delay mode.
For Epoch of Reionization : EoR

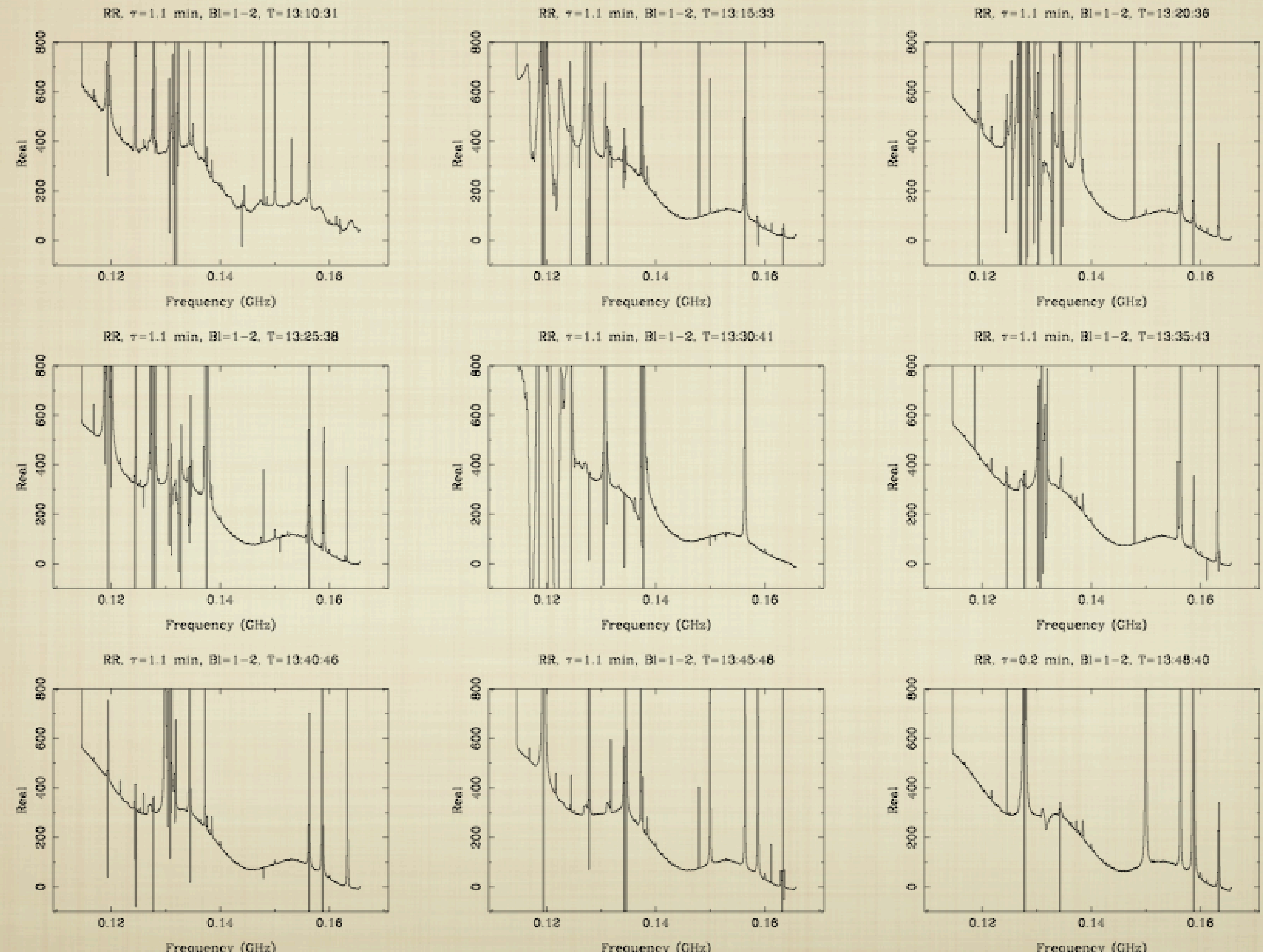
Observing Strategies.

- Mode 1 : Maximize the delay between the reflected component and the direct component to have a few cycles of the ripple. Establish the analysis pipeline using all the measured and the derived spectrum and derive the prior on the sky foreground parameters. Do a joint modeling for the sky foreground and the reflections.
  Don’t care about EoR !!

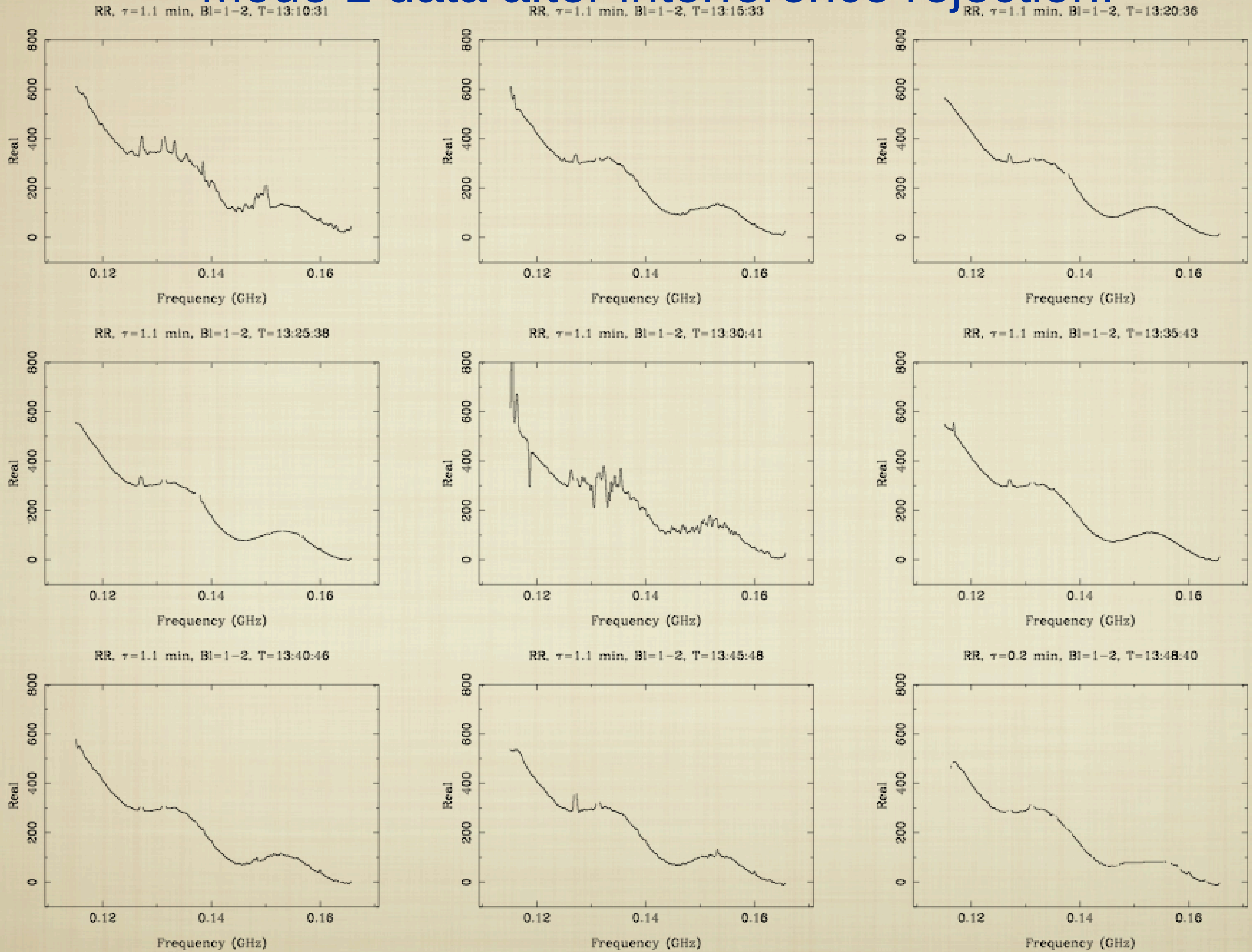
Observing Strategies.

- Mode 2 : Minimize the delay between the reflected component and the direct component so as to have just a fraction of the ripple in the measured data. Using the prior from the CRB measurement for the sky model and do a joint modeling for the sky foreground and the reflections.
  Now go for EoR!

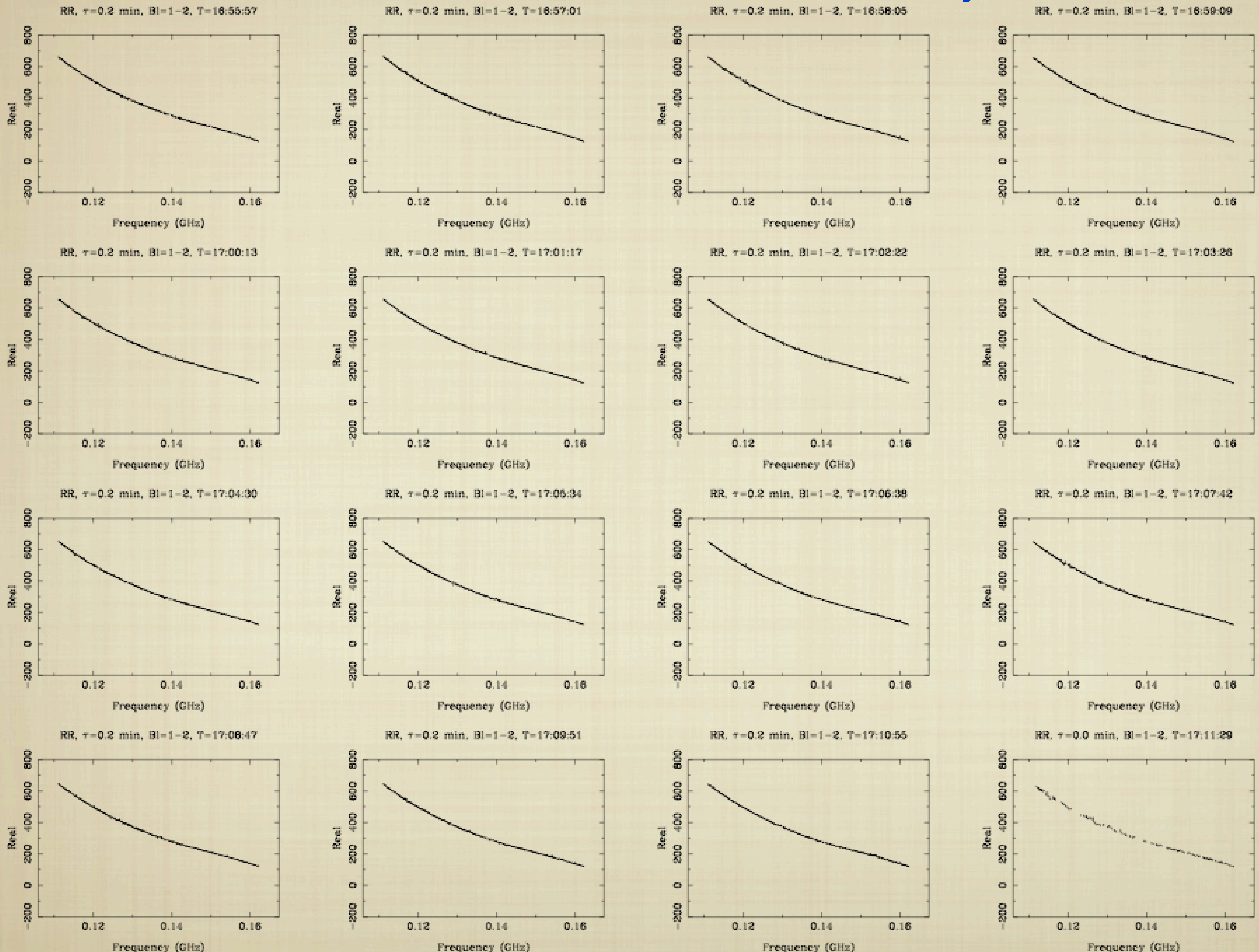
Mode 1 data showing interference condition at Gouribidanur



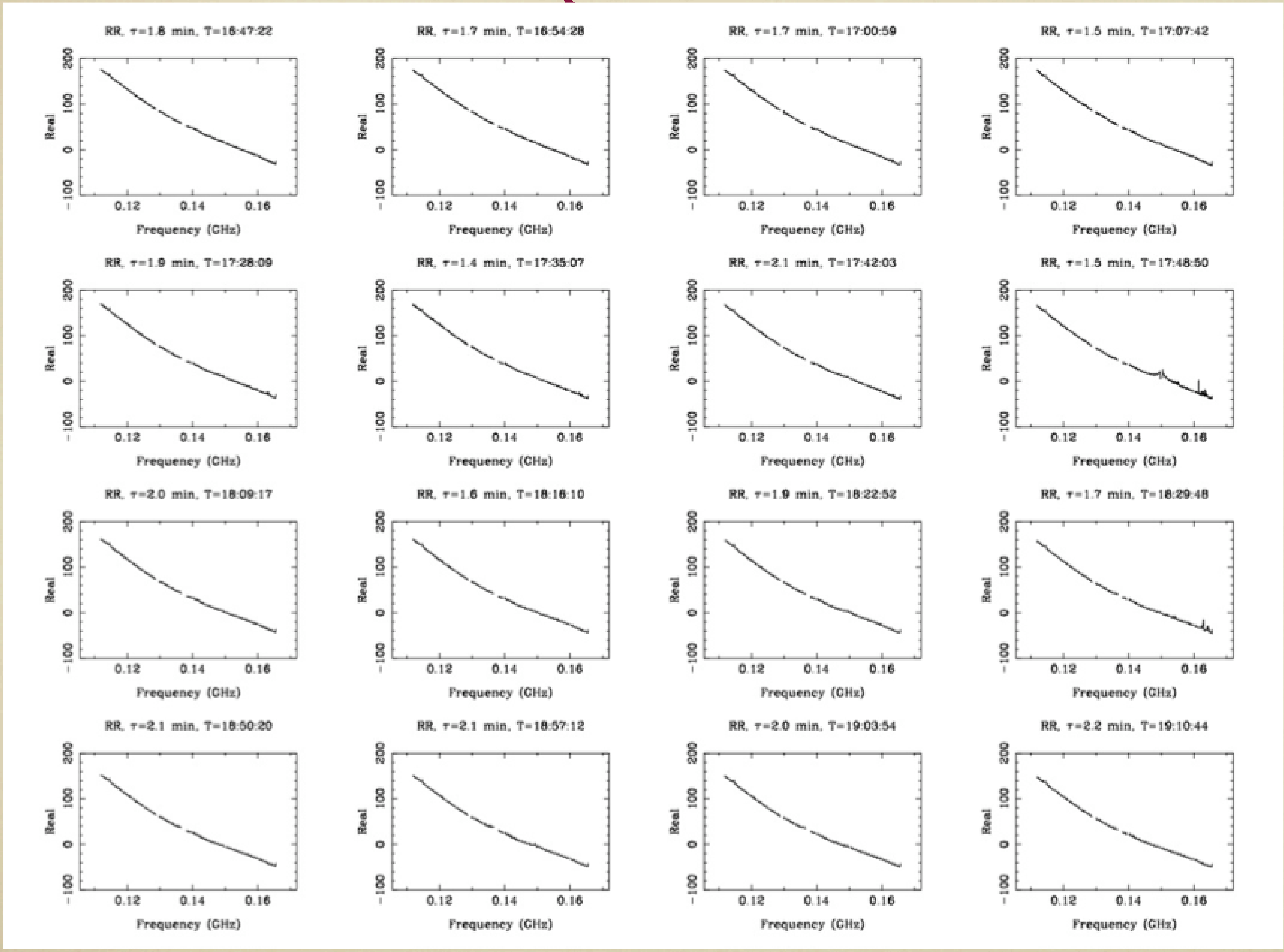
Mode 1 data after interference rejection.



Mode 2 data after interference rejection.



A Question!



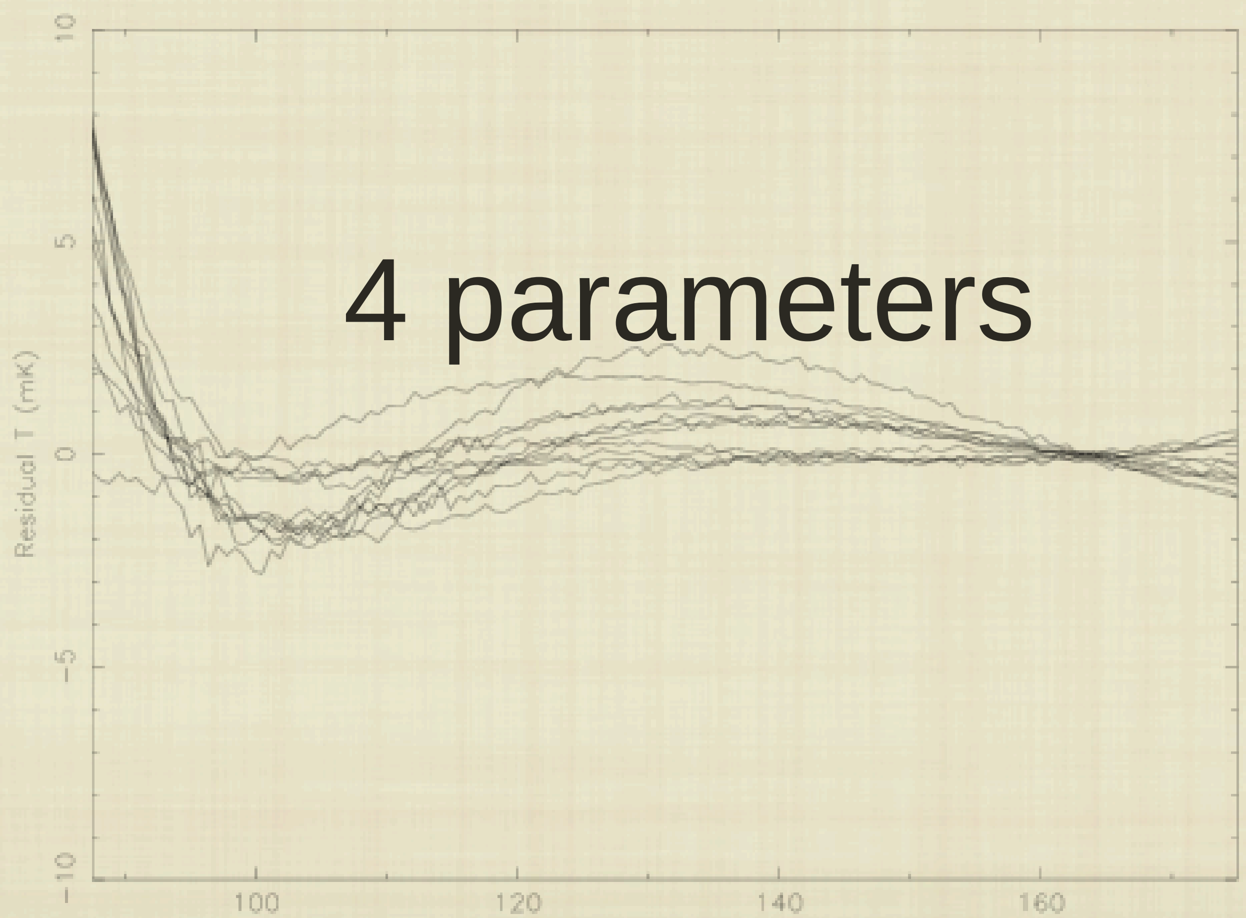
RR, τ=1.8 min, T=16:47:22
RR, τ=1.7 min, T=16:54:28
RR, τ=1.7 min, T=17:00:59
RR, τ=1.5 min, T=17:07:42
RR, τ=1.9 min, T=17:28:09
RR, τ=1.4 min, T=17:35:07
RR, τ=2.1 min, T=17:42:03
RR, τ=1.5 min, T=17:48:50
RR, τ=2.0 min, T=18:09:17
RR, τ=1.6 min, T=18:16:10
RR, τ=1.9 min, T=18:22:52
RR, τ=1.7 min, T=18:29:48
RR, τ=2.1 min, T=18:50:20
RR, τ=2.1 min, T=18:57:12
RR, τ=2.0 min, T=19:03:54
RR, τ=2.2 min, T=19:10:44
Real
Frequency (GHz)

SARAS Analysis : SARAS parameter space

- Sky : Tsky, EoR.
- Complex reflection coefficients : Gamma_a, Gamma1, Gamma2.
- Antenna and the power splitter gain Ga, g.
- Round trip delay : Phi.
- Receiver noise fraction : f1, f2.

SARAS Analysis : parameter space : Sky model

$$\log_{10}T = a_0 + a_1(log_{10}f) + a_2(log_{10}f)^2 + a_3(log_{10}f)^3$$



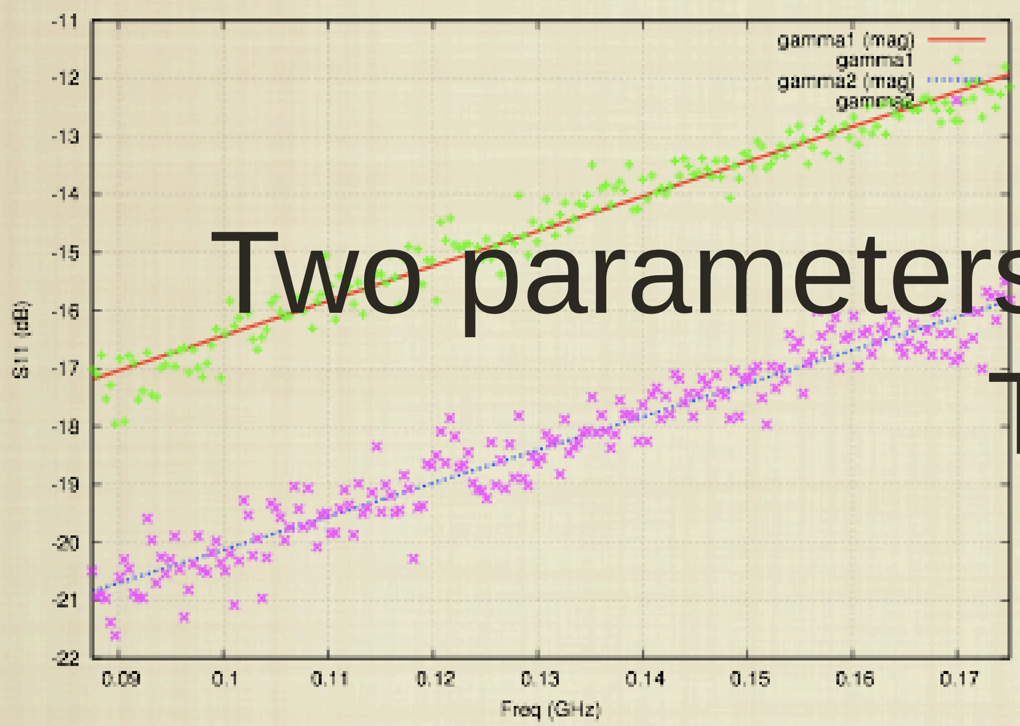
4 parameters

Number of EoR parameters will depend on the model of reionization. From the simplest model: a minimum of 2.

Analysis : parameter space : Reflection Coefficients

Two parameters for each of the lines

Total 8



ig. 5 Reflection coefficients of the two LNAs Magnitude)

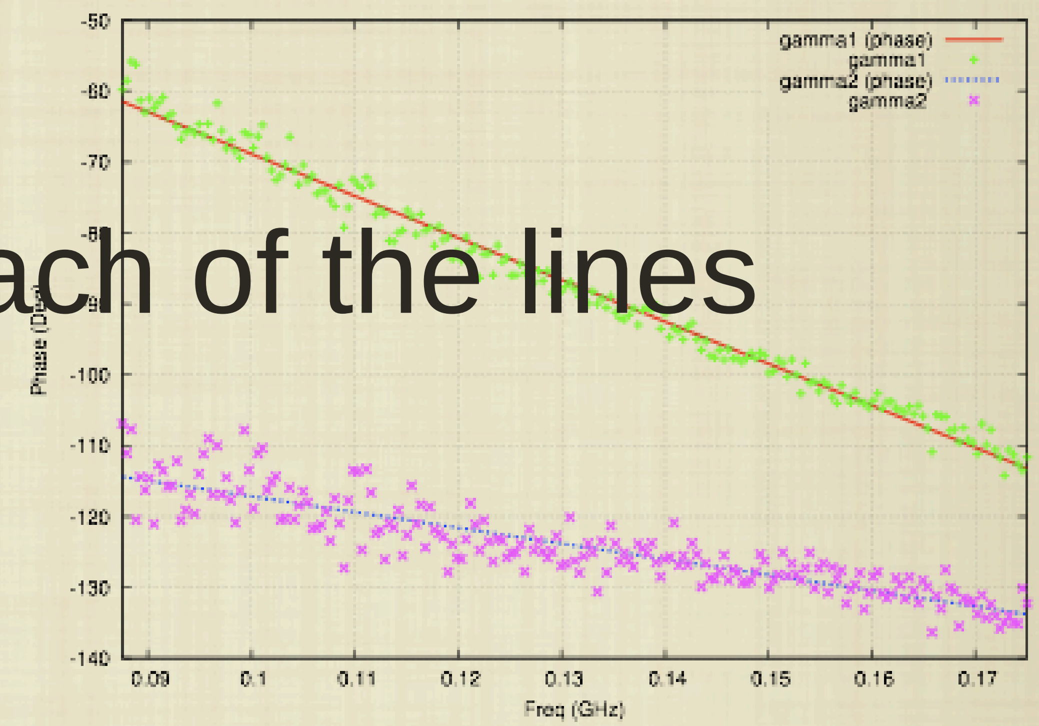
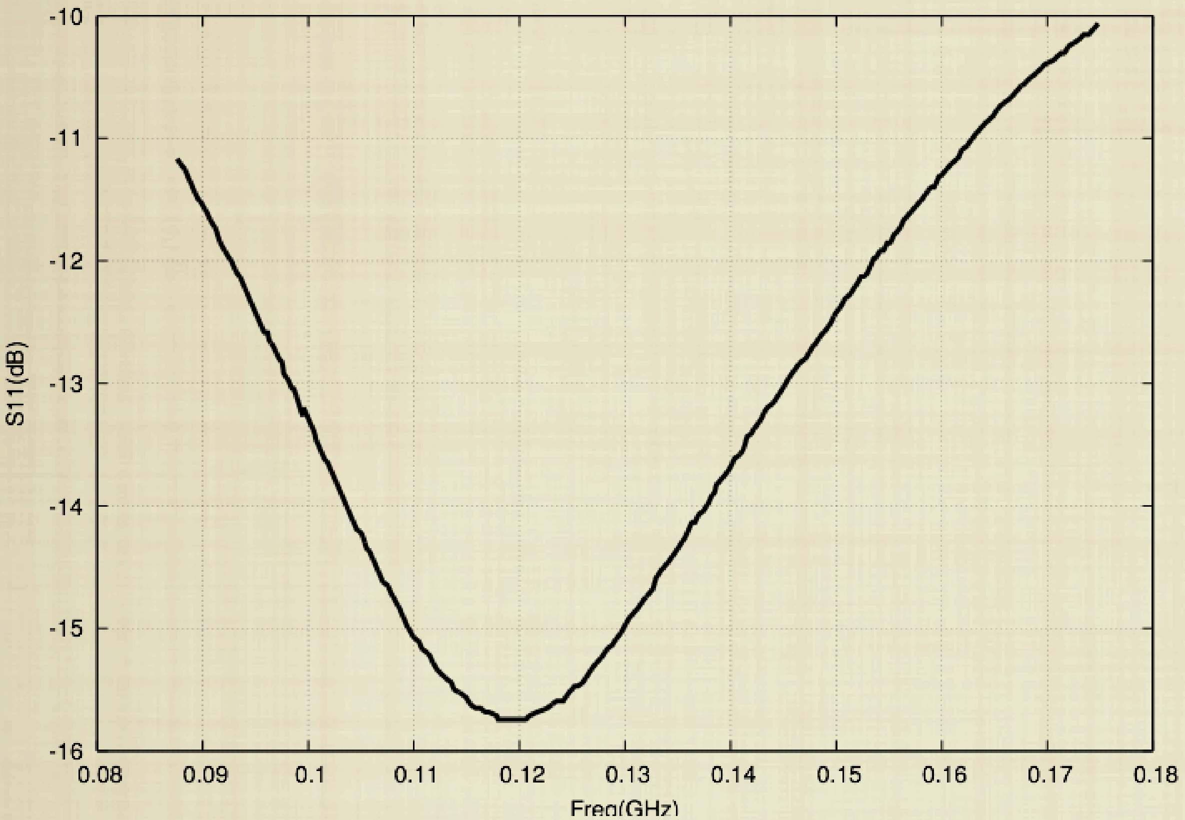
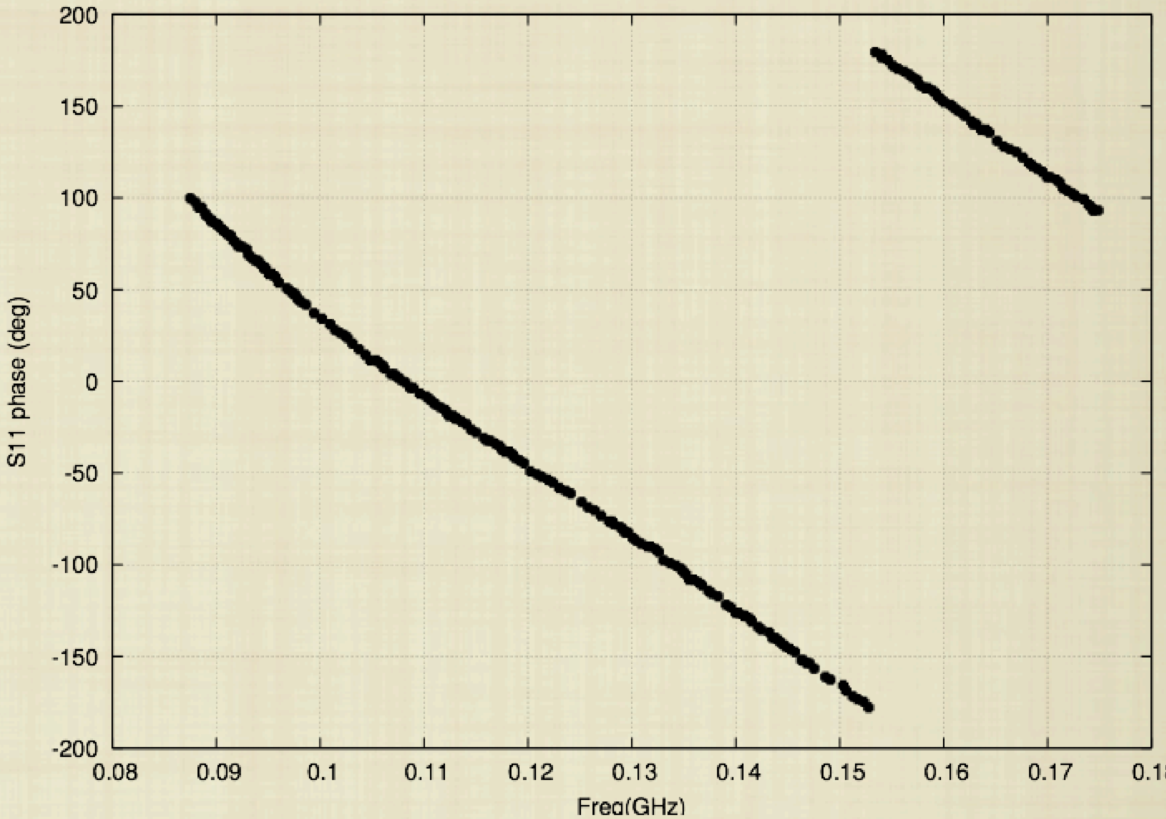


Fig. 6 Reflection coefficients of the two LNAs (Phase)

SARAS Analysis : parameter space : Antenna Return loss





If using the measurements, then filter out the high frequency components

SARAS Analysis : parameter space : All others

- Antenna gain Ga : A third order polynomial(simulations.)
  High hopes for antenna gain calibration using nano-second pulse injection!

- f1, f2, phi, g : 1 parameter each, and frequency independent. So total 4.

All that SARAS have in store now,

- parameter space as large as 15 to 20 dimensions. Possibly minimum amongst all the ongoing experiments.
- 5 measurement equations, 2 having sky, rest having systematics.
- 12 hrs observation => 10000 calibrated spectra.
- 84 hrs observation in CRB mode .
- 84 Hrs observation is EoR mode.

And some really high hopes....

Reference:

- SARAS : a precesion system for measurement of EoR signatures in the spectrum of the Cosmic Badio Background. Patra et al. 2012, Submitted to Experimental Astronomy.


Thank you..