A Transit Dish Design for High-Redshift 21cm Intensity Mapping Experiments

ABSTRACT

1. Introduction

- importance of frequency smoothness
- collecting area

2. Background

- τ-modes, wedge, EoR window
- geometric interpretation of τ-modes

3. Geometric Constraints

- first principles of EoR window, how that maps to a specification for design
- cost analysis
- critically constrained design
- symmetric on-axis parabaloid, for reasons of symmetry in polarization response

4. Design and Construction

4.1. bent pipes as approximation to parabola

4.2. faceting (rms deviation from parabaloid)

- bent pipes as approximation to parabola
- faceting (rms deviation from parabaloid)
- shielding (screens)

- splash cone
- hub –¿ see technical doc
- feed suspension (feed with mast, back screen by kevlar wire)

- materials, PVC selection -¿ construction¡$ournal.texdesignlifetime(wood, PVC)$

5. Simulated Performance

- beam pattern
- delay performance (E-M modeling)

6. Fabrication and Deployment

- lessons/principles
- process to precision to specifications on precision

7. Reflectometry Test Setup

One of the popular uses of reflectometry (TDR) is to tell fault locations and magnitudes in a damaged camble by viewing the discontinuity in response in time domain which is physical distance. Our use:

impedance mismatch, return loss, feed impedance mismatch of the feed electronics (50 Ω to free space $120\pi\Omega$)

What is a network analyzer?

...its an instrument that provides a frequency-swept signal to a 2-port network and measures the resulting S-parameters (caveat: more expensive network analyzers can measure networks which have more than 2 ports). S-parameters imply that a 50 ohm load is built into each network analyzers port. 50 ohm port impedance makes high-frequency measurements viable. Network analyzers are designed to accurately measure the ratios of the reflected signal to the incident signal and the transmitted signal to the incident signal.

f = 4.5m for 2 reflections, i.e. 4 crossing attenuation - ¿ 59.0ns -¿ ahow up as 118.11 ns in S11 and S22 plots

1. Change the power from manual to +10dB

2. Number of points 401
3. Frequency: 50MHz to 1000 MHz
4. Channels S11, S21, S12, S22
5. average on 16 measusrements
6. end sequence on calibration option

7.1. Choice of Hardware

The dipole feed element consists of the PAPER feed, a mating board, two 4:1 baluns one for each polarization (for TDR), 50Ω cables with SMA connectors. LMR400 spec (LMR400dataspec.pdf) 50Ω 10m length, singal attenuation over 10m is 0.5dB @ 150MHz.

Use of Agilent ES8753 as the VNA.

Later replaced the mating board with another design, swap out the balun with the 75Ω PAPER balun and receiver.

7.2. Calibration of VNA

2-port calibration is done prior to all measurements taken, SLOT is performed at the setup of...... see NA Calibration.ppt

Why do we need to calibrate the network analyzer?

... because it has errors, and because we are usually adding cables to the ports on the analyzer. We dont want the effects of the cables to contaminate the measurements of our circuit under test. To calibrate means to move the reference plane for the measurements (the position of zero phase, zero loss, zero mismatch) to the tips of the cables.

What is calibration?

... its the process of setting up the network analyzer so it knows how to correct for its own errors and for the effects of any cables. To do a calibration you have to use calibration standards. Calibration standards come in sets for different types of connectors. Calibration standards are basically pre-measured precisely-known devices. Along with those hardware calibration standards, there also has to be a software cal kit loaded into the analyzer which contains their parameters. You calibrate by attaching the various Short, Open, Load, Thru standards to your cables and then pressing a bunch of buttons on the Calibrate menu. When you push Done, the analyzer calculates the correction coefficients it will apply to all subsequent measurements. Youll take a bunch of measurements of calibration standards that youll attach to the ends of your test cables, in order to acquire the necessary correction coefficients that will subsequently get applied to your measurements of your device under test.

After you do the calibration, the network analyzer comes up with correction coefficients which it uses to correct any subsequent measurements. All of the network analyzers errors will then be exactly calibrated out at 3 impedances: the impedances of the Short, Open and Load standard you just applied during the calibration (whose pre-measured model values were stored in their software cal kit on the analyzer). There will be small residual errors at all other impedances you try to measure.

7.3. Feed Height Test

S11 S22 taken at heights:

$$m,$$

m,

$$m..plotsssss$$

7.4. Configurations

May 5th stuff @ height 14' 6" mountain bumps 60' - 80'

Dish without cone, with screen set1- set2: measurements without cone, 2 metal sheets covering the entrace to the dish, covering panel A, B set5- set6: measurements with cone, 2 metal sheets covering the entrance to the dish, covering panel A, B

April 16 @ 14'3" no$_{c}one1 = containingdatatakenwithoutconewith1metalsheet@14'6"set3 - set4 : measuremnetswithcone, 1metalsheetcoveringtheentrancetothedish, coveringpanelA$

dish different heights Mar 28 h1 = 67" h2 = 10'3.5" h3 = 14'0.5"

7.5. Window Functions

For our measurements, the data sampled are limited by the frequency range to be trancated at the start and end, hence cause sinc(x) ringing effect in time domain. A windowing function can be applied which gradually reduces the frequency response and controls the sidelobes created during the truncation process.

The IFT is calculated only on the data points measured, rather than taking the negative frequency response to be the conjugate of the measured data. This calculation gives a complex (real and imaginary parts) time domain responses. In the bandpass mode, the window is centered between the start and stop frequencies. The IFT is applied from minus one-half of the frequency span to plus one-half of the span.

Agilent VNA time domain option uses Kaiser-Bassel window (see TimeDomainGatingWindowFunc.pdf and FFTWindow.pdf) shows some plots using different window functions window$_test.py$

- reflectometry
- hardware
- calibration of the good
- feed height test
- configurations
- window function used in delay transform

8. Results

8.1. Delay Spectrum for Configurations

Using TDR

May 5th stuff @ height 14' 6" mountain bumps 60' - 80'

Dish without cone, with screen set1- set2: measurements without cone, 2 metal sheets covering the entrace to the dish, covering panel A, B set5- set6: measurements with cone, 2 metal sheets covering the entrance to the dish, covering panel A, B

=====

April 16 @ 14'3" no$_cone1 = containingdatatakenwithoutconewith1metalsheet@14'6"set3 - set4 : measuremnetswithcone, 1metalsheetcoveringtheentrancetothedish, coveringpanelA$

======== dish different heights Mar 28 h1 = 67" h2 = 10'3.5" h3 = 14'0.5"

8.2. Cone test

¿ show May 5th cone helped on reduce backlobe, see section **??**

8.3. How well did we place everything

¿See contruction¡*journal*

- delay spectrum for configurations
- cost
- photos of constructed element
- XXX hook up receiver and to a sky test?
- measured parabolicity
- why were we right in the antenuation per reflection?
- does the cone help?
- how well did we place everything?
- ways to ensure spec in field
- mention extender as unnecessary in flat deployments

9. Conclusion

- relevance to HERA, project cost
- link Pober et al. (2014) sensitivity/science
- polarization matching
- frequency coverage, need for a feed re-design.

10. Acknowledgment

We would like to thank SKA-SA for the site infrastructure, maintenance, and observing support that has made this work possible, as well as the significant efforts of the staff at NRAO's Green Bank and Charlottesville sites. AP would like to thank M. McQuinn and A. Lidz for helpful discussions and ionization models. The PAPER project is supported by the National Science Foundation (awards 0804508, 1129258, and 1125558), and a generous grant from the Mt. Cuba Astronomical Association.

Fig. 1.— THIS FIGURE SHOWS THE ANALYSIS ON PARABOLA

Fig. 2.— THIS FIGURE SHOWS THE PHOTGRAMMRY ANALYSIS

Fig. 3.— PUT FIGURE SHOW WINDOW

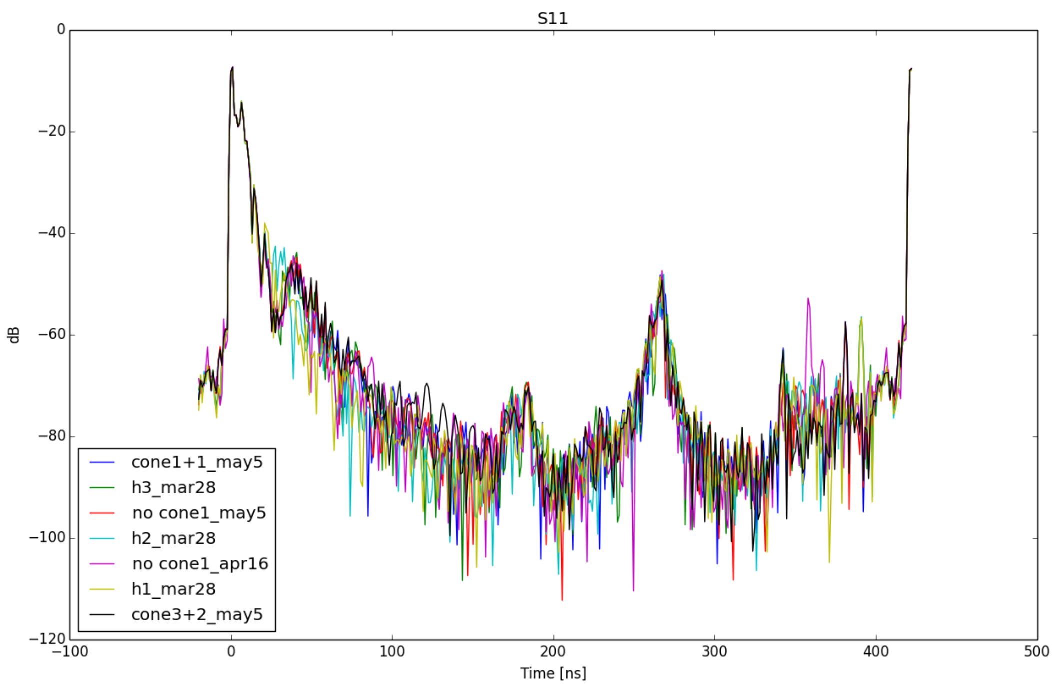

Fig. 4.— Shows mar28 height tests, apr16, may5 cone test

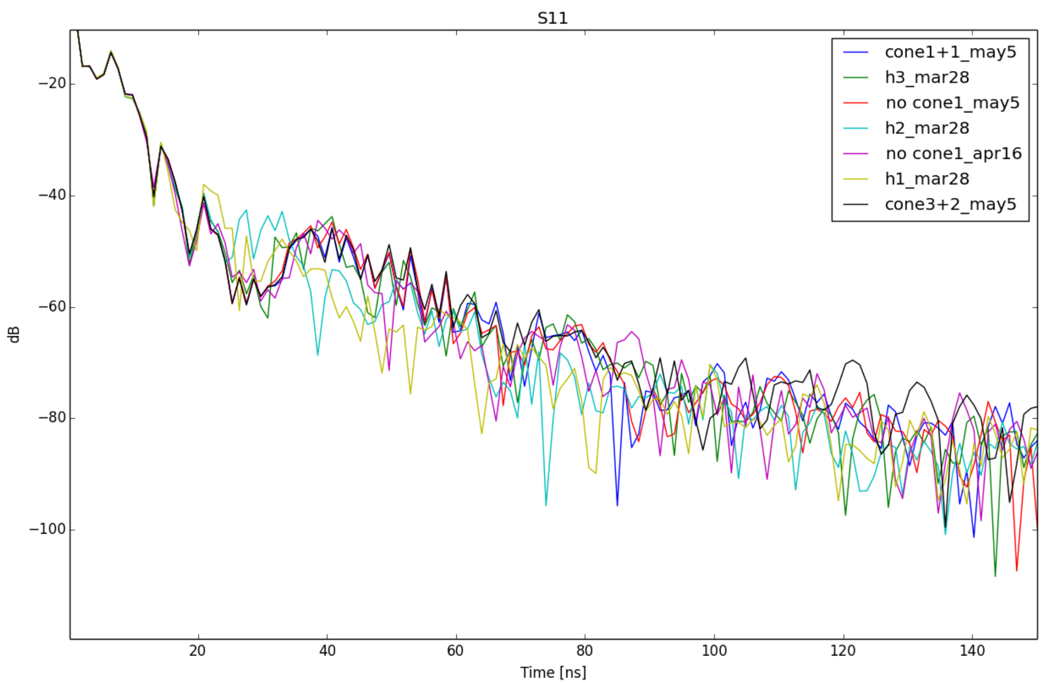

Fig. 5.— Shows mar28 height tests, apr16, may5 cone test zoomed on 10-150ns, can see height test changed the delay

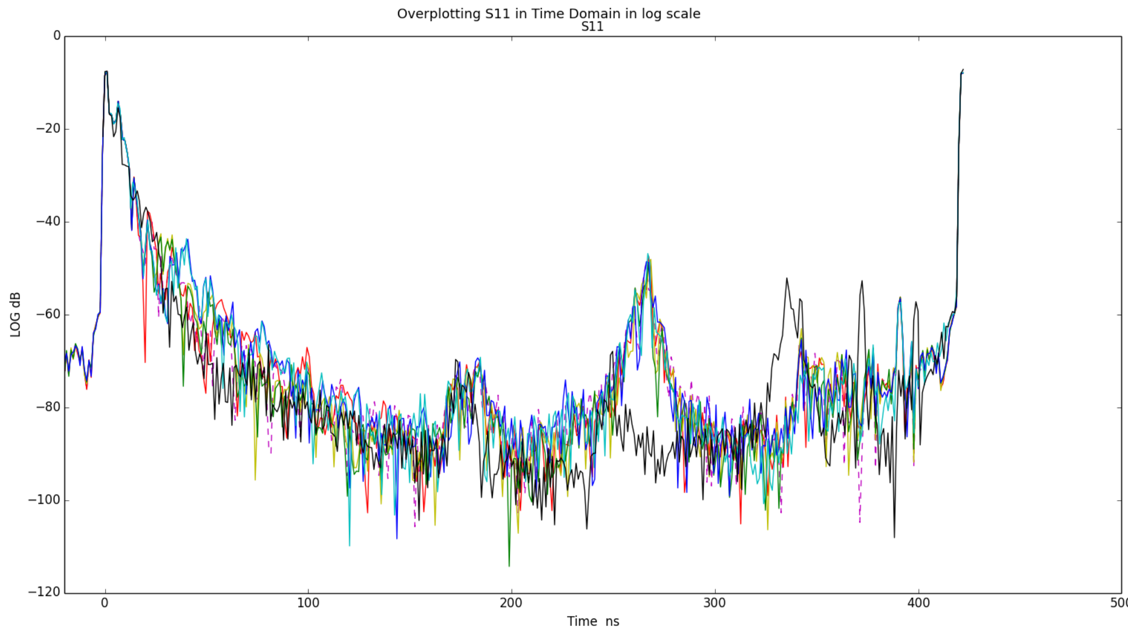

Fig. 6.— Shows mar28 height tests, apr16, may5 cone test and test not on dish, shows bump is reflection due to surroundings.

Fig. 7.— CONFIG 1

Fig. 9.— Shows cone VS no cone, combine 2 plots above, apparent difference cone make, but needs redesign for better backlobe minimization as seen from 48ns.

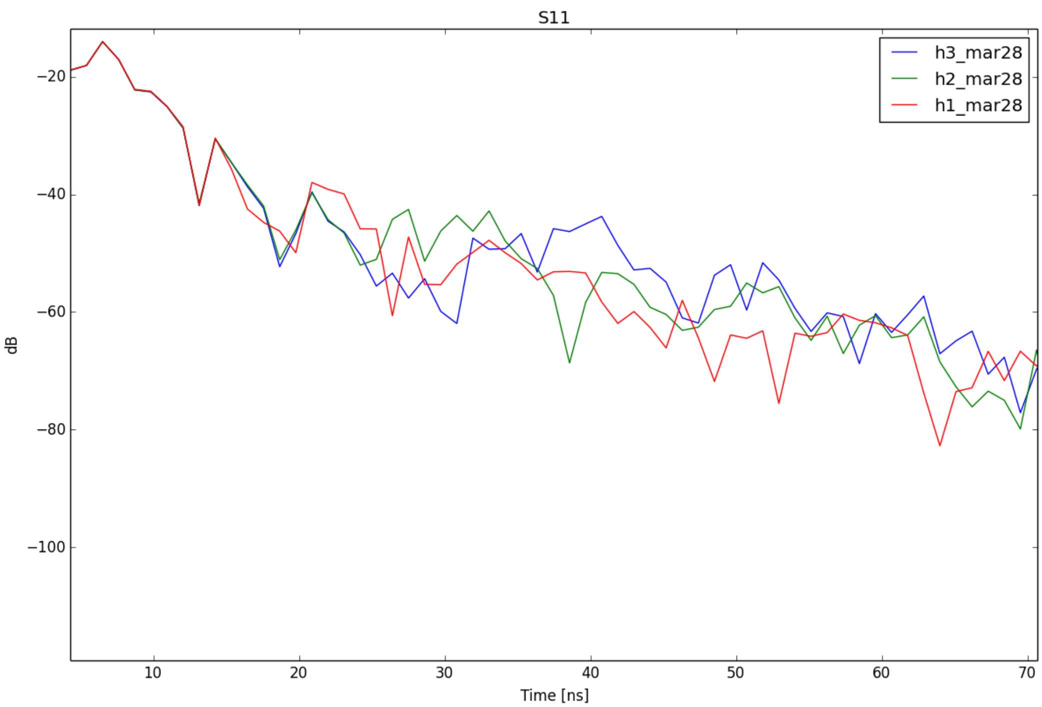

Fig. 10.— height test zoomed