Calibration Instrumentation for the Hydrogen Intensity Real-time Analysis experiment

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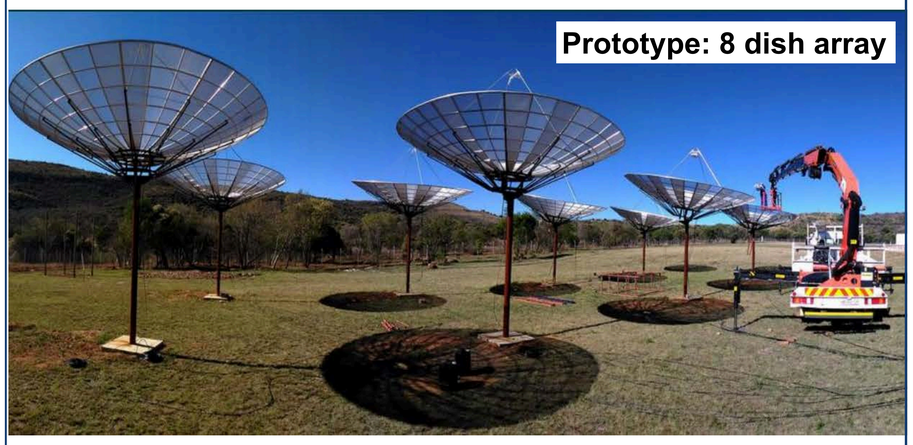
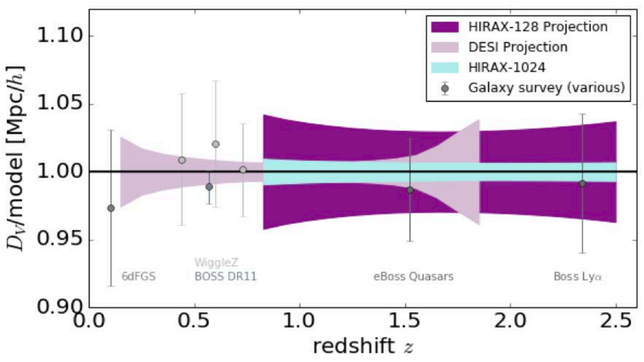
Abstract

The Hydrogen Intensity Real-time Analysis eXperiment (HIRAX) is a 21cm intensity mapping experiment to be deployed in South Africa. It will consist of 1024 six meter parabolic dishes, and will map much of the southern sky over the course of four years. HIRAX will be revolutionary: it will look near when the universe shifted from matter to energy dominated, a redshift range that is relatively unexplored; it will provide a new probe to better understand BAOs, at different redshifts and with different tracers than prior optical surveys; and it will dramatically expand the detection and understanding of fast radio bursts (FRBs). For HIRAX to achieve its bold science goals, it will need to overcome bright foregrounds, which requires precise characterization of the instrument. Here, I focus on two aspects of the HIRAX instrument characterization: (1) optimizing the signal/noise of feeds by developing a test chamber, and (2) mapping the antenna beam patterns.

HIRAX Array

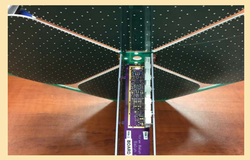


HIRAX

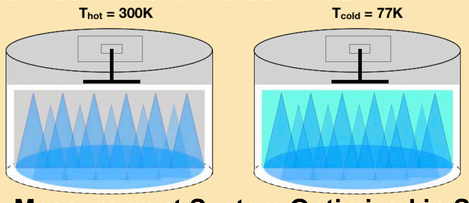


(1) Antenna Noise Temperature Testing

Challenge: Amplifier is directly in balun we cannot directly measure the noise temperature.



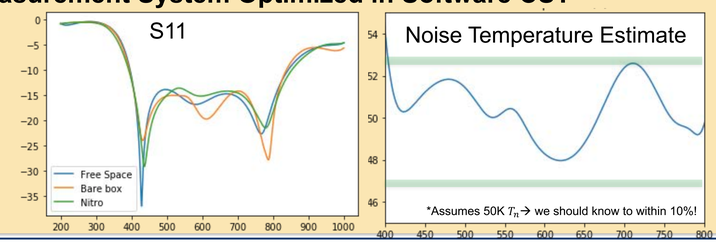
Solution: Y-Factor Measurement!



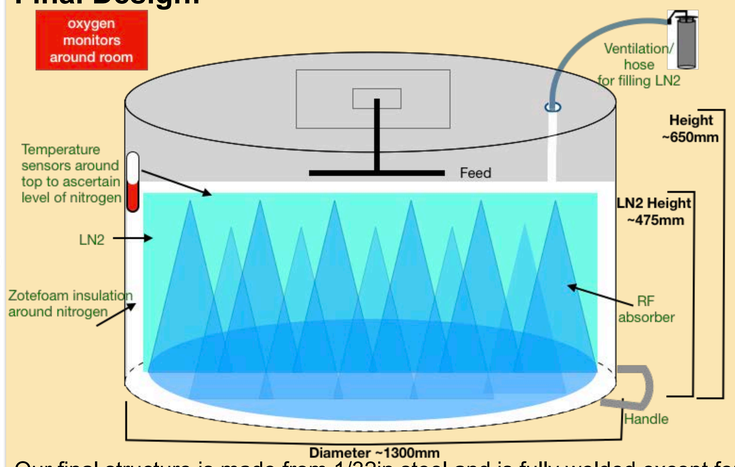
$$Y = \frac{P_h}{P_c} \qquad T_{noise} = \frac{T_h - YT_c}{Y - 1}$$

Th = 300K (room temperature)
Tc = 77K (liquid nitrogen)

Measurement System Optimized in Software CST



Final Design:



Our final structure is made from 1/32in steel and is fully welded except for the top, which bolts on. We use AEP-18 series RF absorber, and a zotefoam layer for insulation. It will be able to safely hold the >500L LN2 boiling off over ~24 hours!

(2) Drone Beam Calibration

Why drones?

- Cannot calibrate in the traditional way of pointing at a source, because instrument is not steerable.

What are we doing?

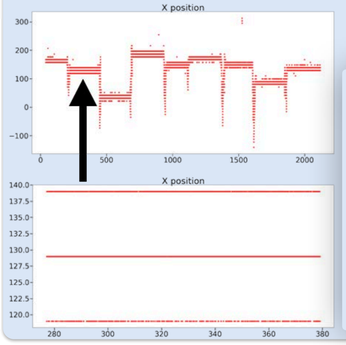
-Flying over sections of the instrument in a pre-determined grid pattern, making amplitude measurements for each polarization

-Eventually, we will use drone pointing and data sets to analyze and generate beam maps.

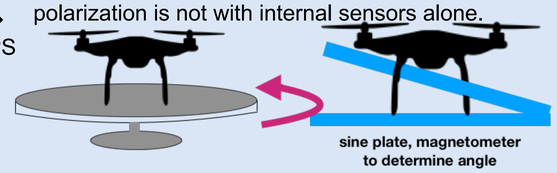
Our Drone: DJI Matrice 600 Pro

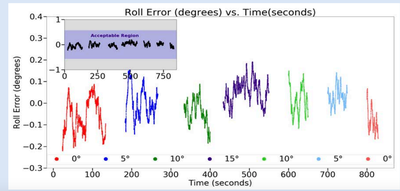
Accuracy Tests:

XY Position (16mm tolerance) : Drone doesn't meet requirements → we will need to add a differential GPS



Angle (0.8° tolerance): Tilt angle is reasonable, polarization is not with internal sensors alone.





Other Instrumentation:

Antenna: BicoLog 5070→Lightweight, broadband (30-1000MHz)

Noise Source:

•Designed by Laura Newburgh and Thomas Barker

•400-800 MHz HIRAX/CHIME, and 1-1.5 GHz BMX at BNL

•Switchable with TTL.

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