MIT HAYSTACK OBSERVATORY

NSF

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ANTENNA AND AMPLIFIER MODELING FOR HIGH-ACCURACY CALIBRATION OF RADIO DATA

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Overview

- Epoch of Reionization
- EDGES Project
- Measurements and Calibrations
- West Forks Trip
- Data Analysis
- Conclusion / Future Work

Epoch of Reionization

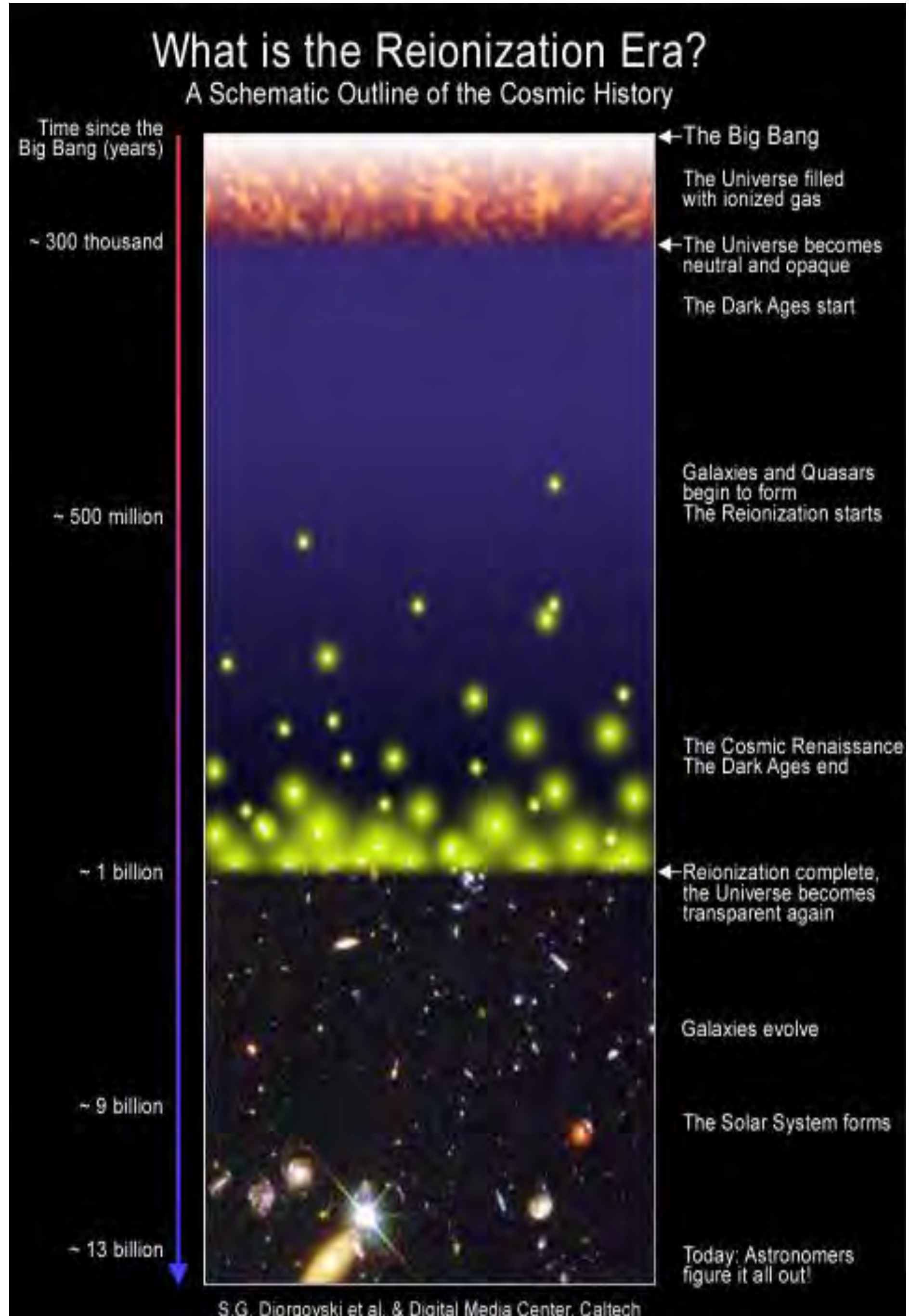
-The Big Bang occurs

-300,000 years later neutral hydrogen forms.

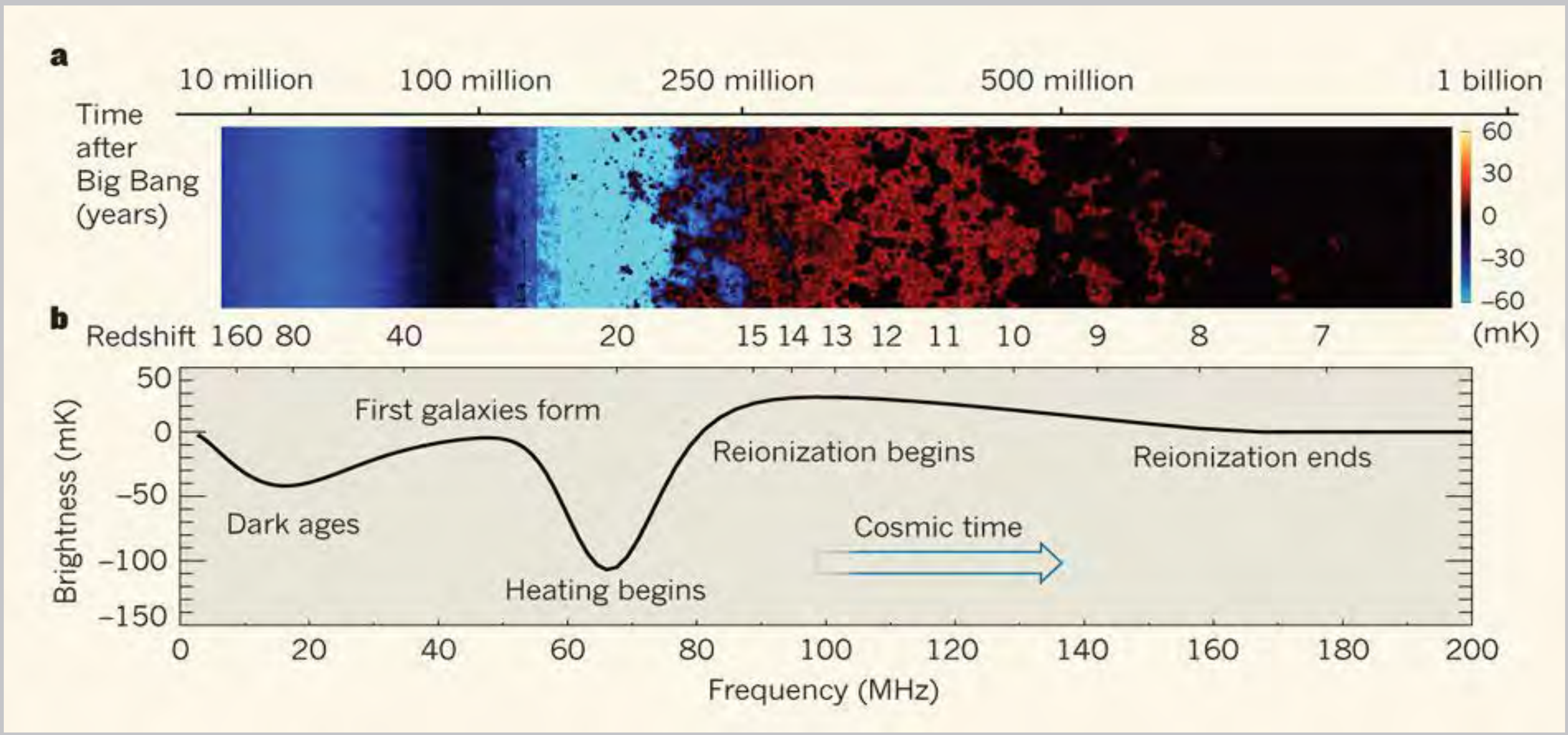
-About 500 million years after the Big Bang, the stars and galaxies began to form, emitting ultra-violet radiation.

-This period is known as the Epoch of Reionization (EoR)

- Redshifted 21cm emission line of neutral hydrogen

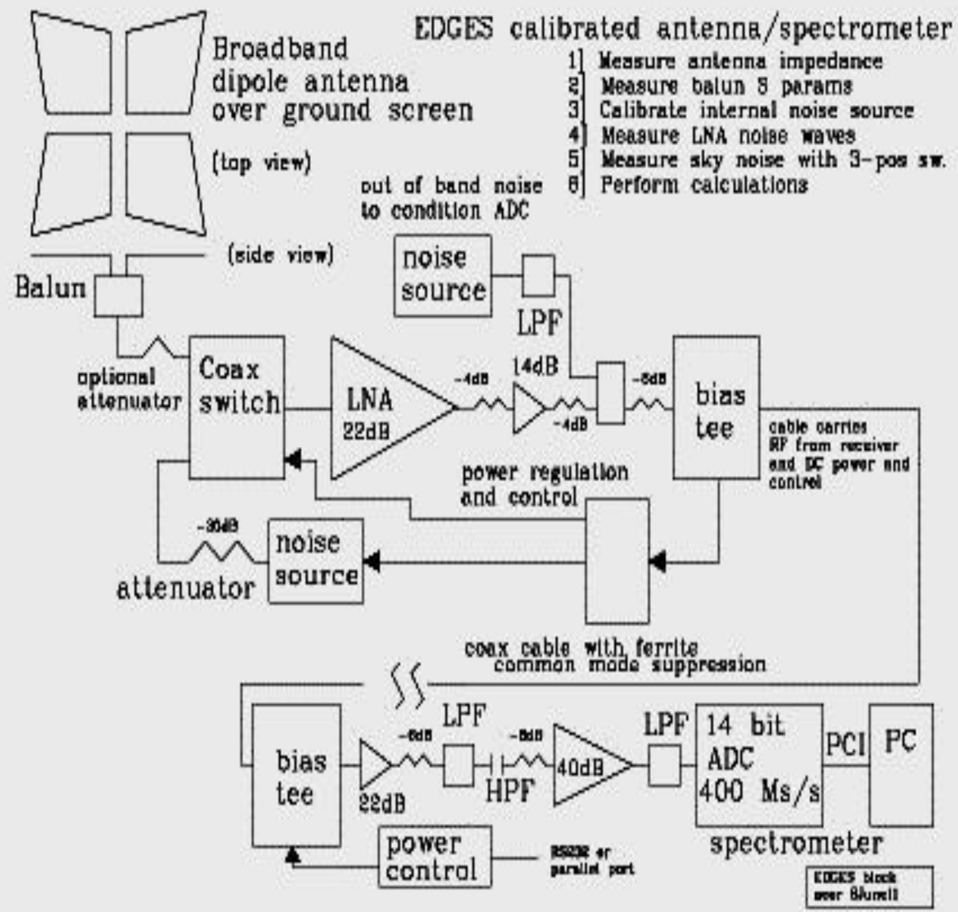


Redshifted 21cm Hydrogen Line



EDGES Project

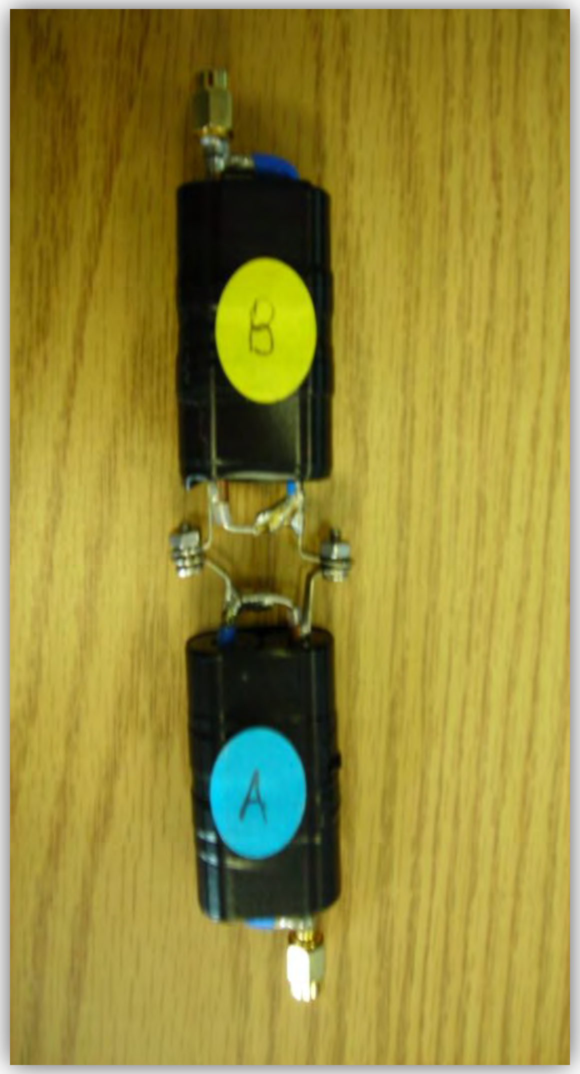
- The **E**xperiment to **D**etect the **G**lobal **E**oR **S**tep (EDGES)
- The Approach
  - radio antenna and spectrometer



Required Measurements for a Calibration of the Sky Noise Spectrum

- Measurement of balun loss.
- Accurate measurements of balun s-parameters.
- Accurate measurements of antenna reflection coefficient.
- Flat Spectrum noise source.

Measurements and Calibrations



<u>Measurements of Balun S–Parameters</u>

-What is a balun?

-Use of balun

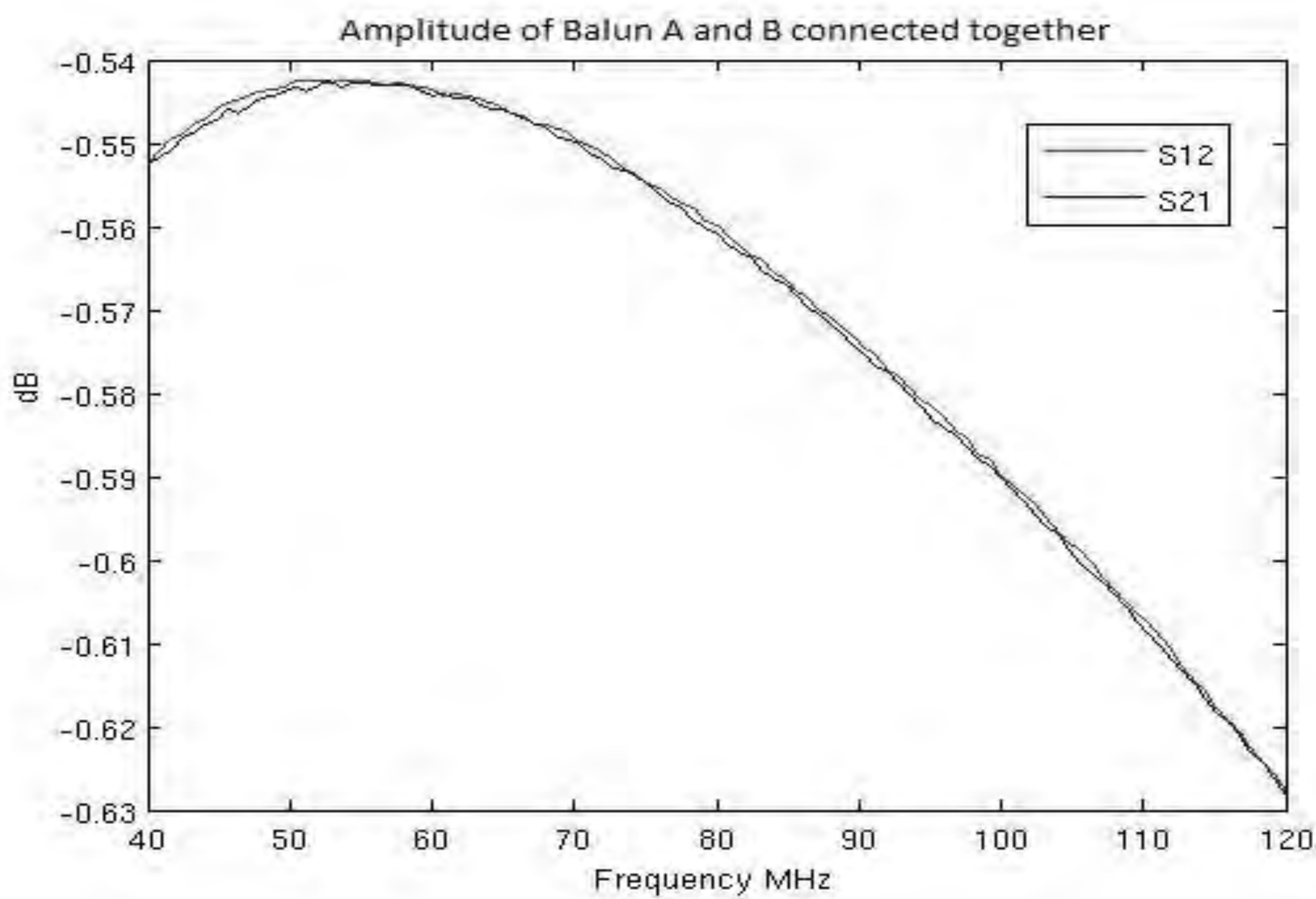
-What is a s-parameter?

-2-port Vector Network Analyzer (VNA). Model: N9923A FieldFox Handheld RF Vector Network Analyzer made by Agilent Technologies

-Low loss balun a back-to-back measurement for good estimate.

$$\mathrm{dB} \approx 20\log_{10}|S_{21}|$$

Measurements of Balun S-Parameters



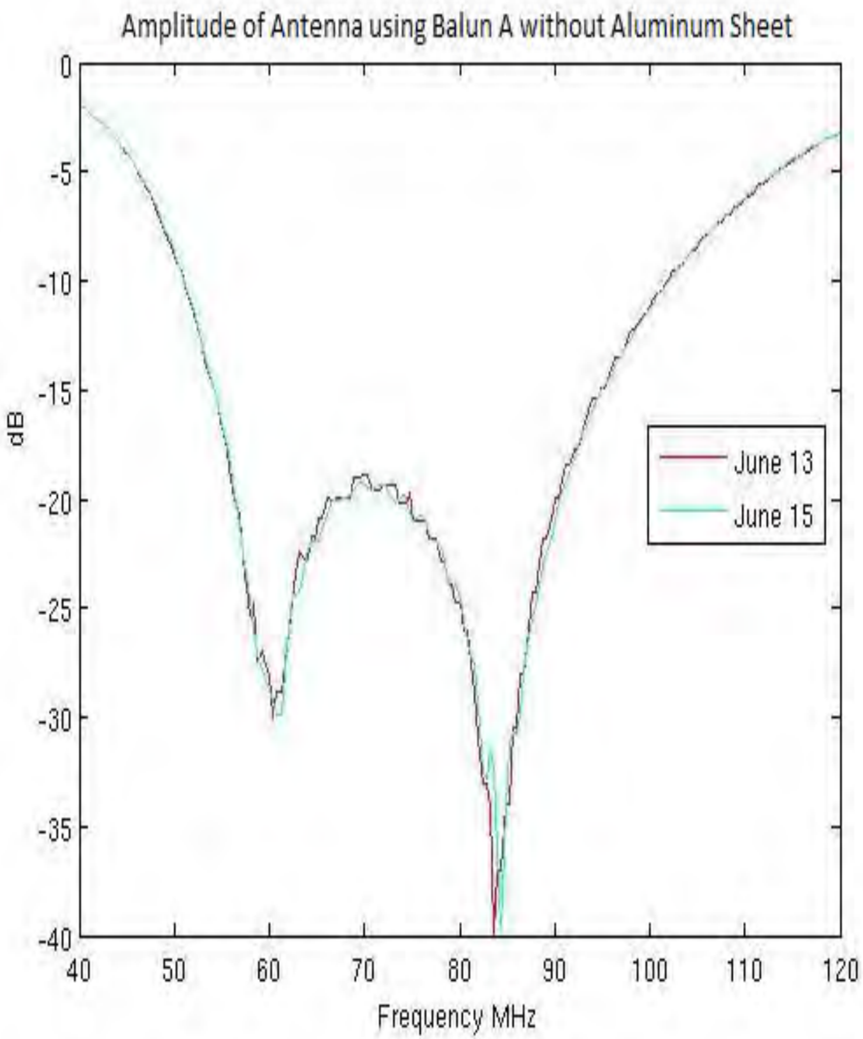
-Show loss for back-to-back measurment

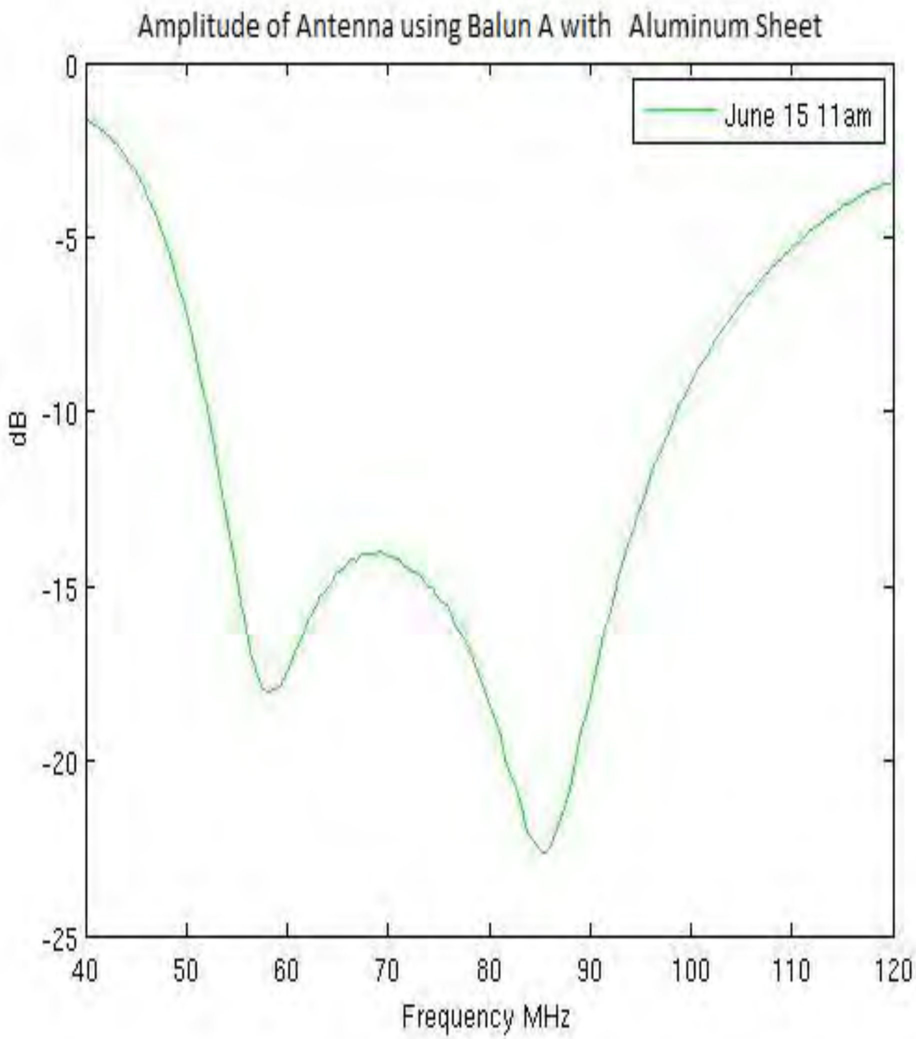
-Loss for one balun is half the amplitude

Antenna Impedance

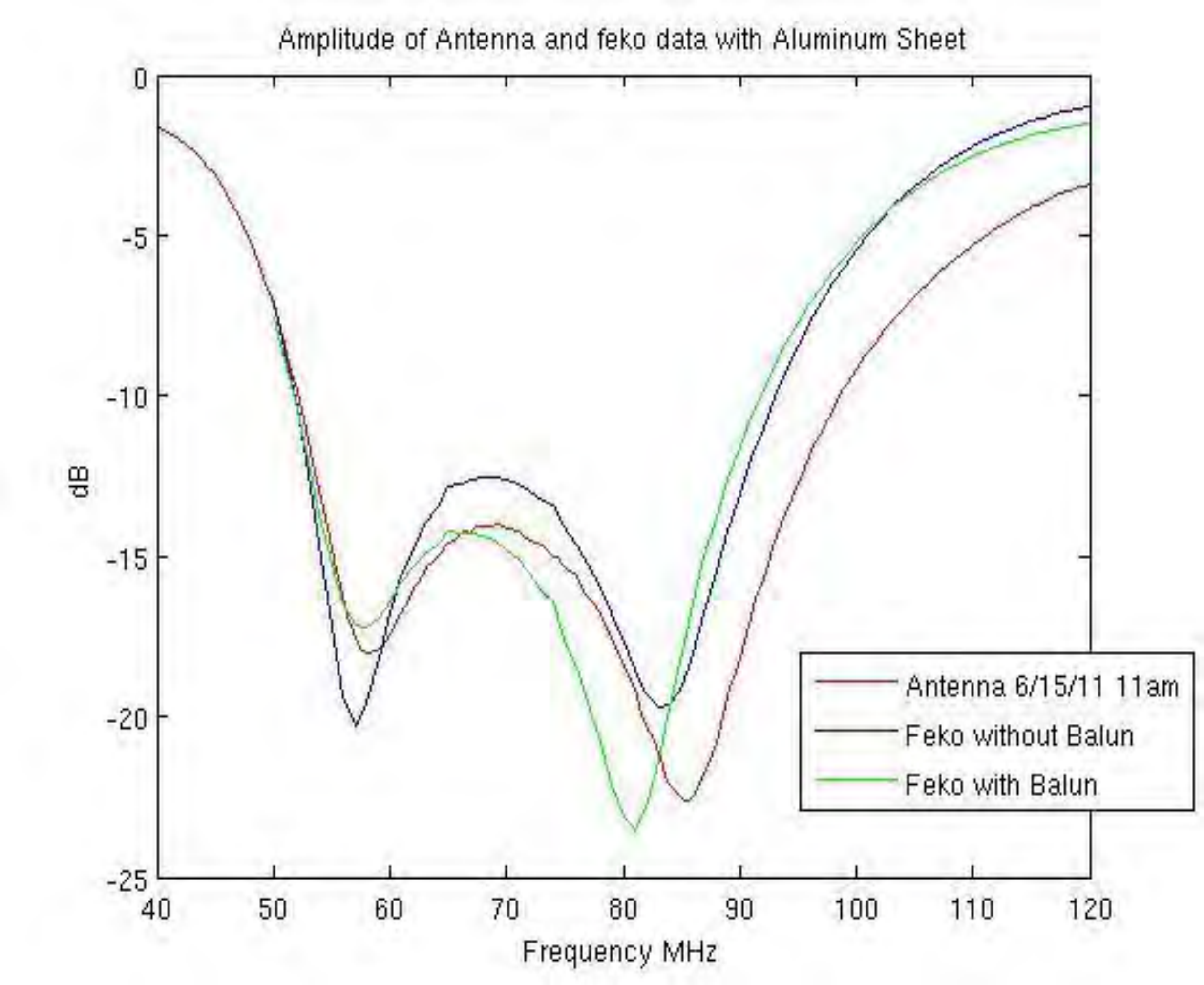
- Location
  - MIT Haystack
  - Not optimal location
- Problems
  - Ground Plane (cement vs. Aluminum)
- Comparisons
  - Types of ground planes

Effect of Ground Plane





Antenna Impedance

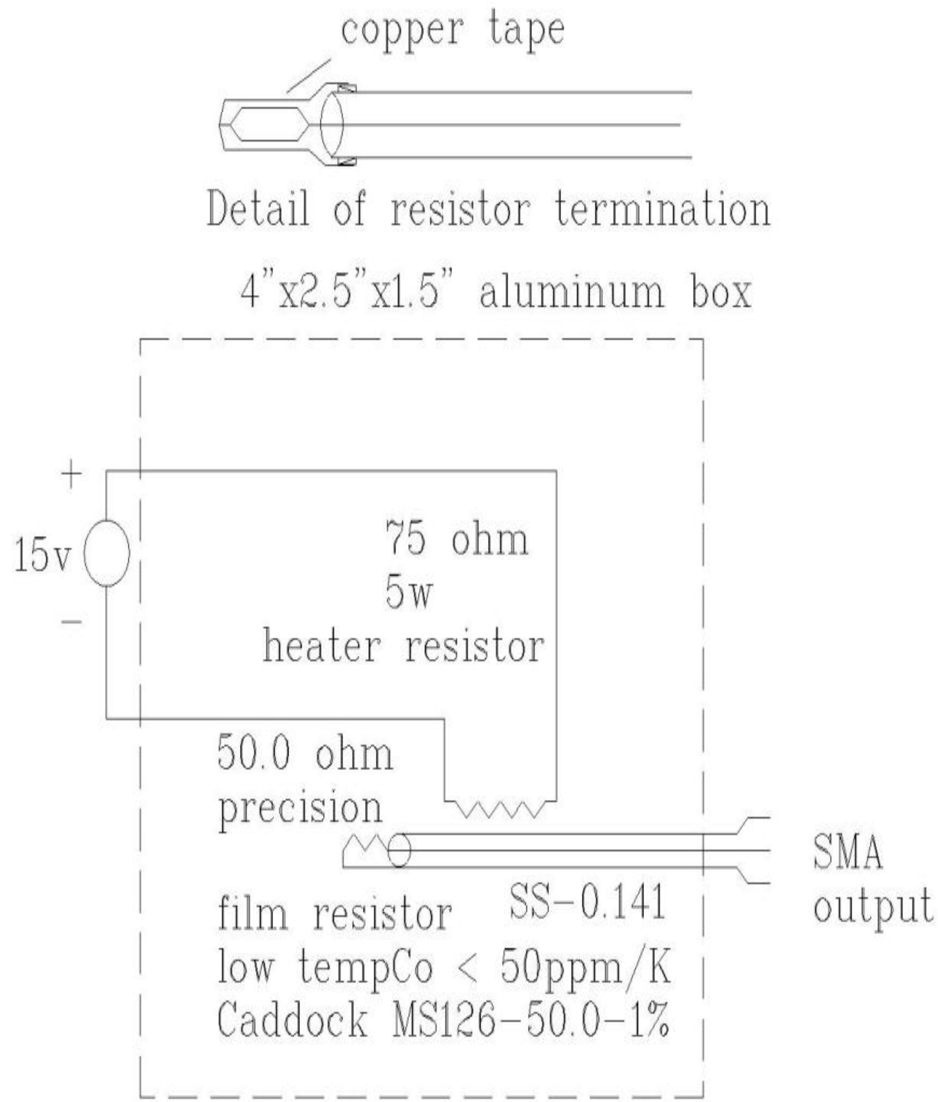


Balun Corrections

$\Gamma_{ant} = \frac{z_{ant}-50}{z_{ant}+50}$ -Feko provides us with the impedance z_{ant}

$\Gamma_{ant+bal} = S_{11} + \frac{S_{12}S_{21}\Gamma_{ant}}{1-S_{22}\Gamma_{ant}}$ -S-parameters from balun

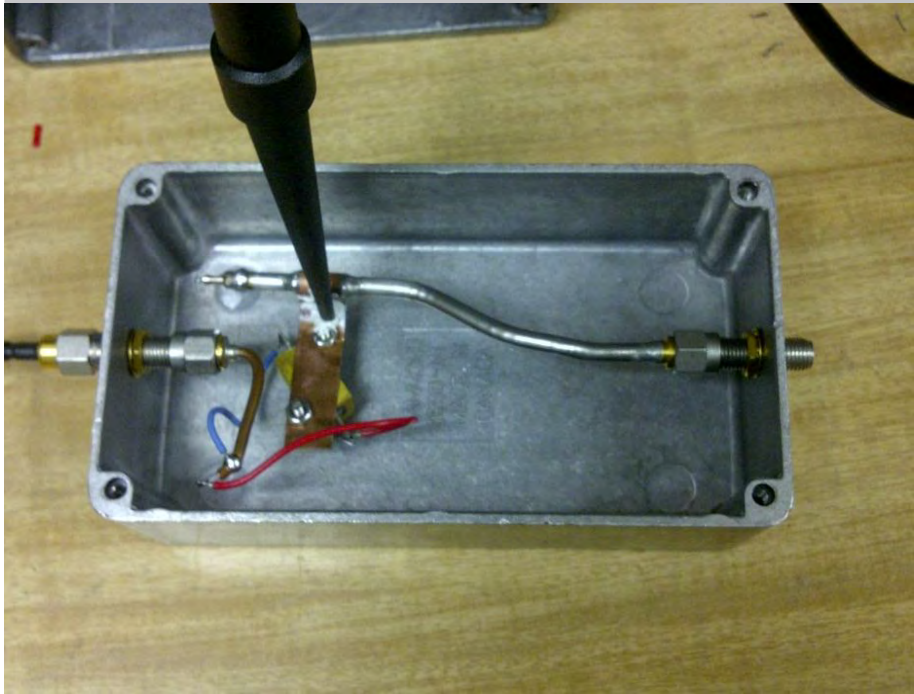
Hot Thermal Noise for Calibration



- Internal noise diode
- HP246C noise source flatness variance
- Hot noise source

HP346C Flatness Variance

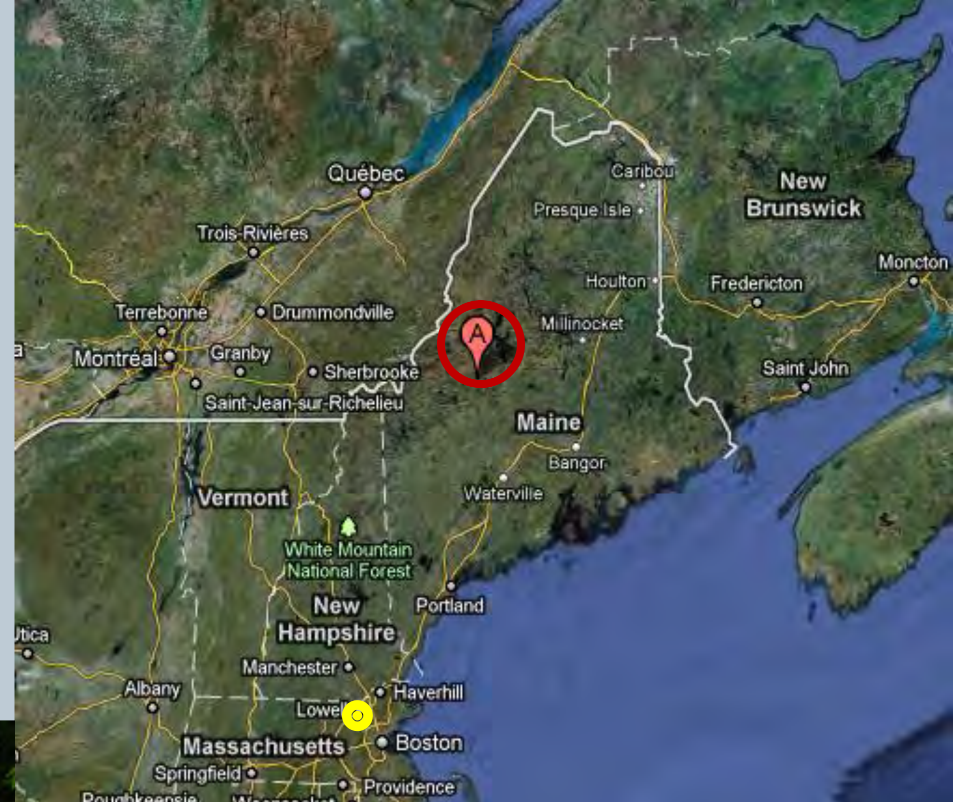
Freq MHz	ENR dB
10	12.70
100	12.82
1000	12.73




West Forks Plt.
Established 1893
Welcome Bienvenue

West Forks Trip

- -Difficulties finding radio quiet zone
- -West Forks, ME
- -Hopes for Trip



A / red = West Forks, ME
Yellow = MIT Haystack

Ground Plane Placement

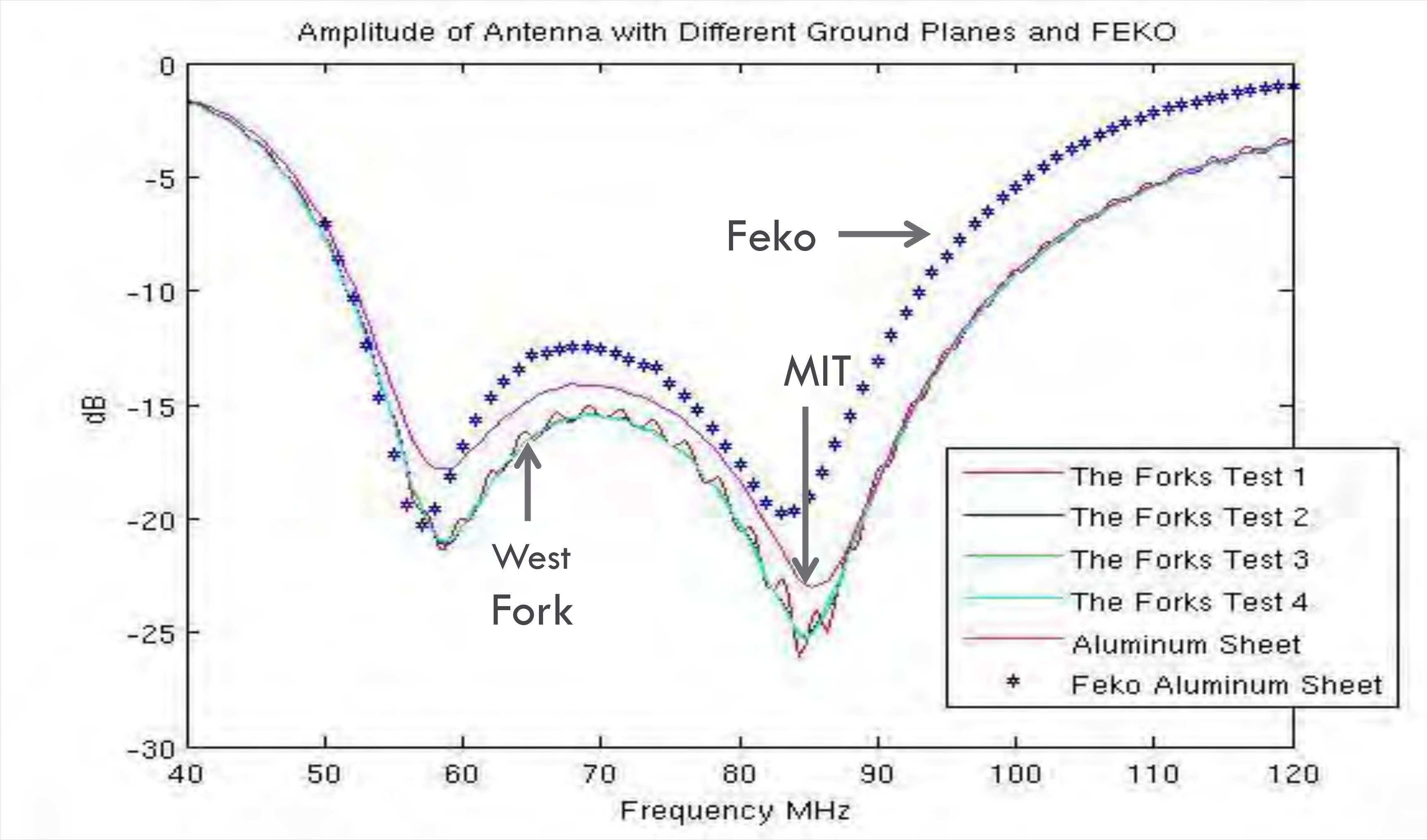
Antenna and ground plane

-Map of field where data was taken.

-Black = ground plane, white = antenna. not to scale

Ground plane wire

Antenna S_{11} Return Loss



-West Forks vs. Haystack
-Difference in Ground Planes
-West Forks return loss test

Data Anaylsis

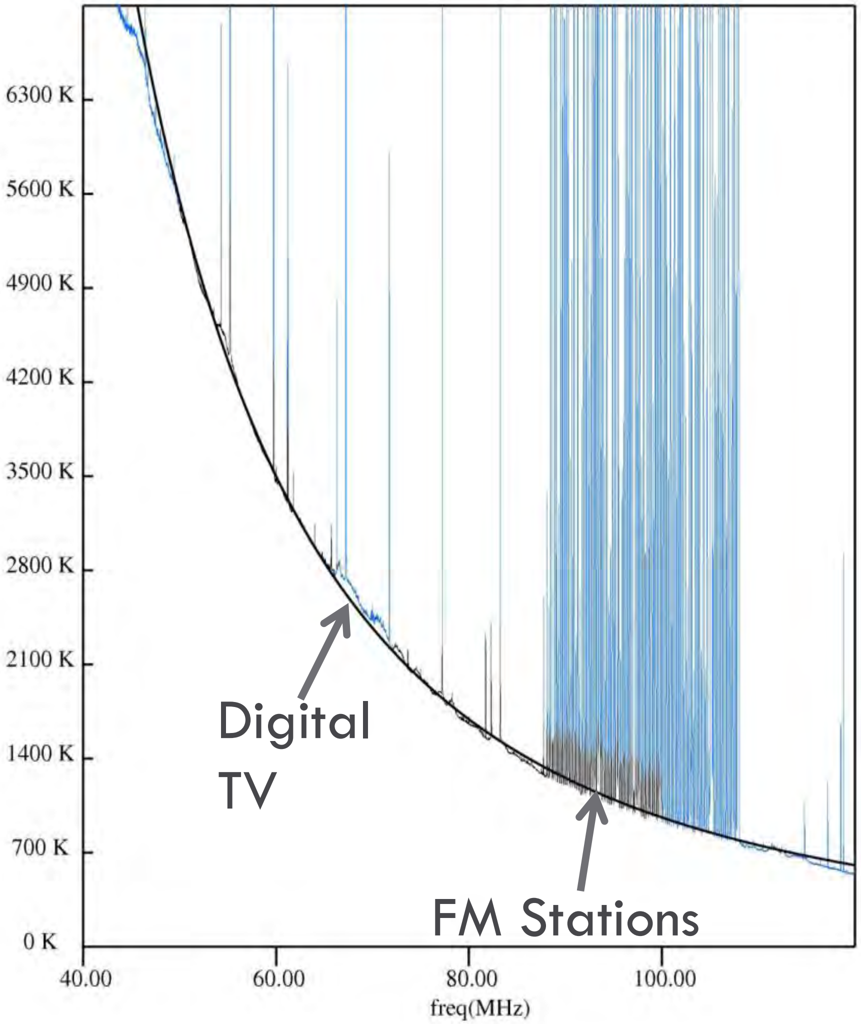
- Brightness temperature power law $T_{sky} \propto v^{-\beta}$

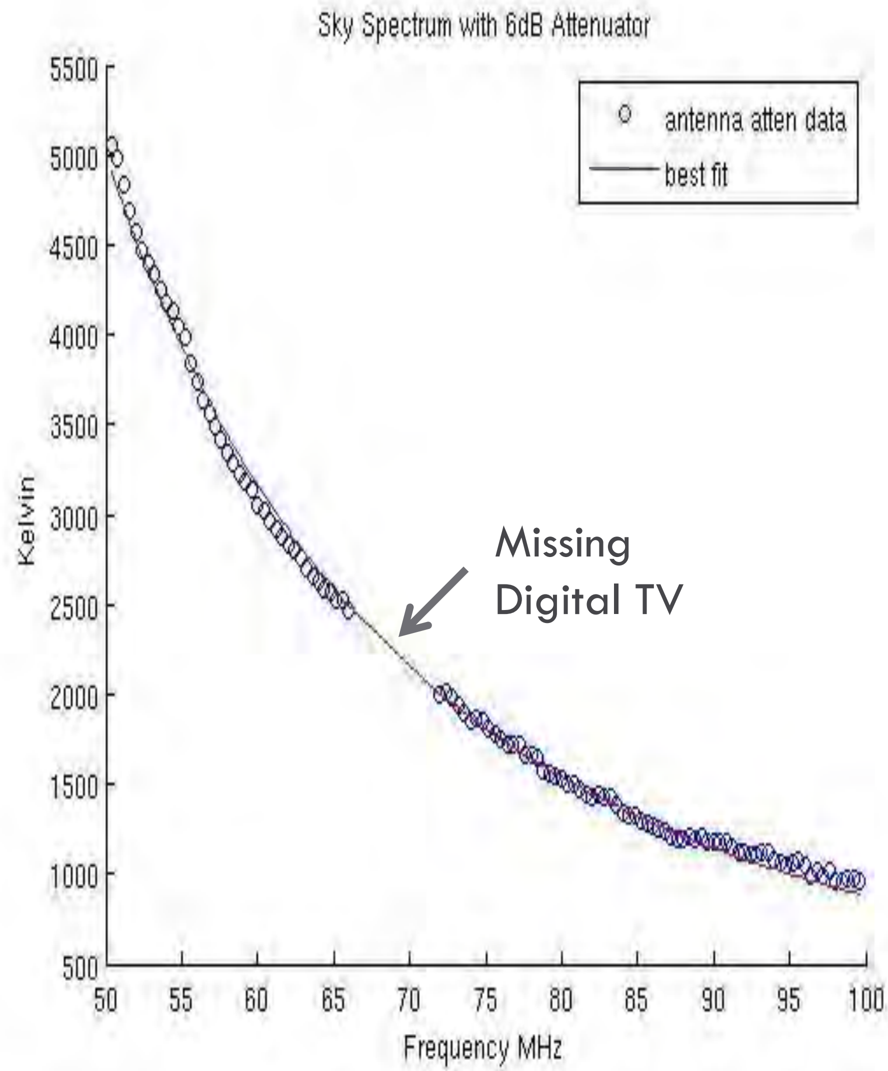
- Model for brightness temperature

$$T_{sky}(v) = T_{50}\left(\frac{v}{v_{50}}\right)^{-\beta}$$

T_{50} is the temperature at $v_{50} = 50MHz$.

Data Analysis





Best fit lines results

$T_{50} = 5060\ K, \beta = 2.51 \pm 0.05$

Conclusion / Future Work

- Better balun measurements
  - Mutli-port balun measurements
  - Mutli-port VNA
- Calibration of hot noise source
- Better radio quiet zones
- Test antenna in Mileura Station in Western Australia

Acknowledgements

- Alan E.E. Rogers
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- Everyone at MIT Haystack

Sky Spectrum Calculations

- $T_u(f) = \left[\frac{P_{sky}(f)-P_{load}(f)}{P_{cal}(f)-P_{load}(f)}\right] T_{cal} + T_{load}$
- P_{sky} Power spectrum on the sky
- P_{load} Power spectrum on the load
- P_{cal} Power spectrum on the load and calibration
- T_{cal} Internal calibration spectrum in K
- T_{load} Ambient temperature of the load
- T_u Uncorrected sky temperature
- $T_{sky} = \frac{T_u - T_{amb}(1-L) - T_{amb}(1-L)|\Gamma|^2 L}{(1-|\Gamma|^2)L}$
- $L = 10^{-\frac{(L_g + L_a + L_b)}{10}}$
- $|\Gamma|^2 = 10^{-\frac{(L_b - L_r)}{10}}$
- L_g ground loss ≈ 0.2 dB
- L_a attenuator = 6.0 dB
- L_b balun loss ≈ 0.3 dB
- L_r antenna return loss measured through balun in dB positive for loss
- T_{amb} ambient temperature