

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

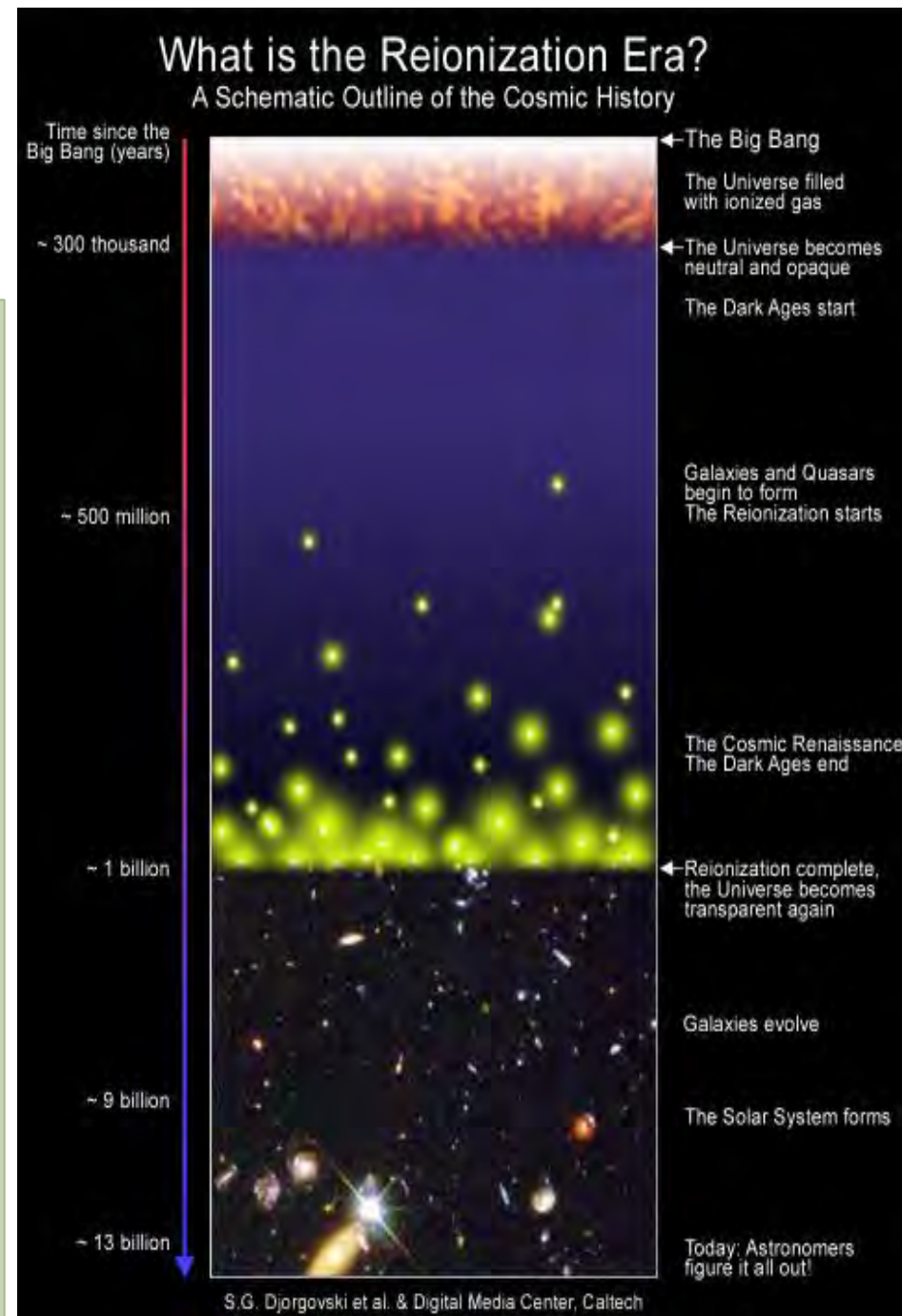
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Overview

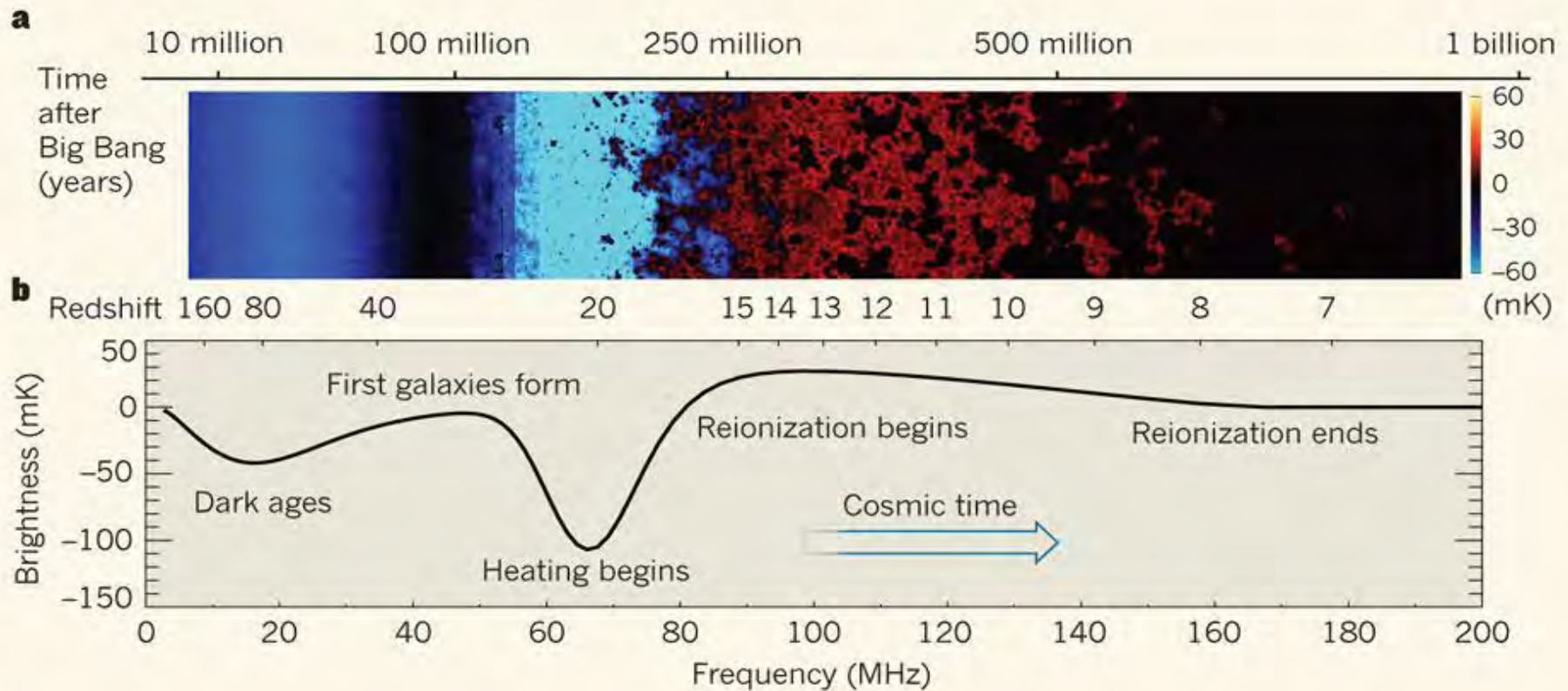
- Epoch of Reionization
- EDGES Project
- Measurements and Calibrations
- West Forks Trip
- Data Analysis
- Conclusion / Future Work

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 21 cm emission line of neutral hydrogen



Redshifted 21 cm Hydrogen Line

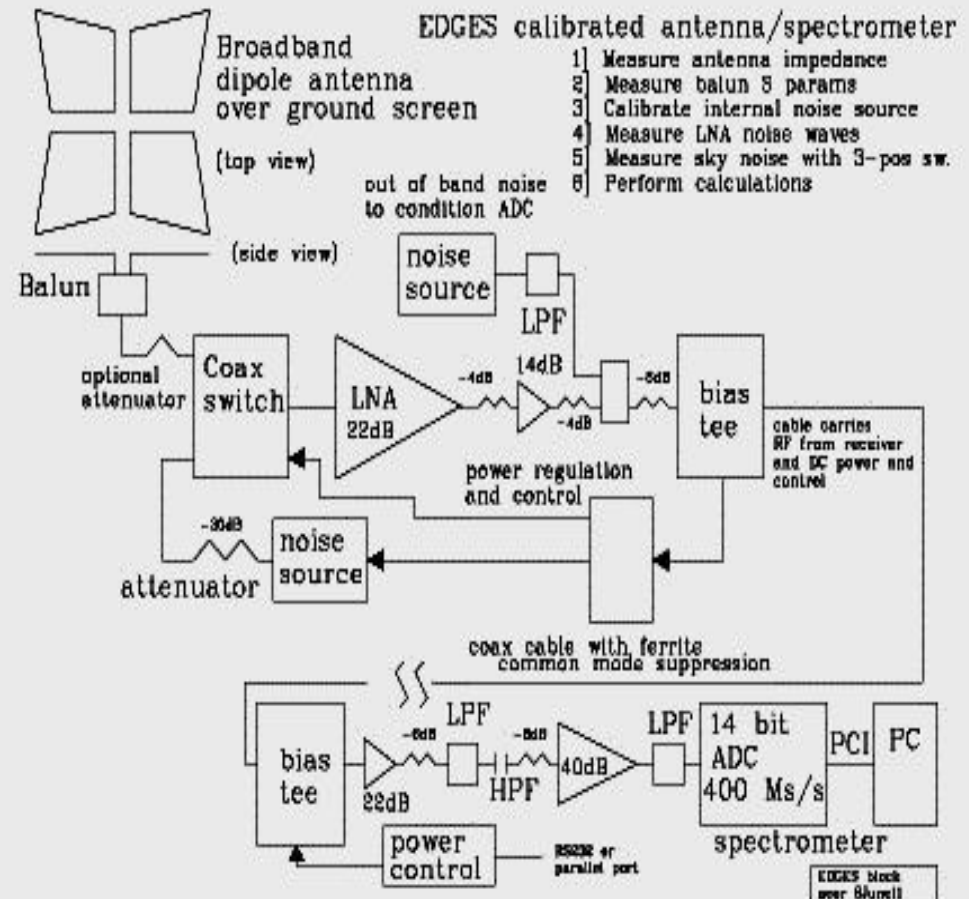


EDGES Project

□ The Experiment to Detect the Global EoR Step (EDGES)

□ The Approach

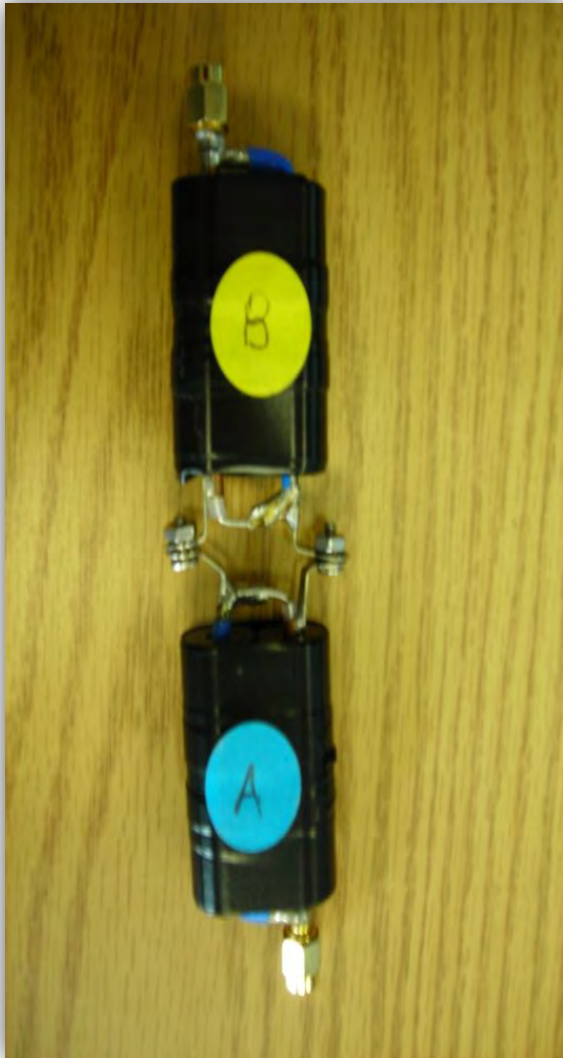
- radio antenna and spectrometer



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



Measurements of Balun S-Parameters

-What is a balun?

-Use of balun

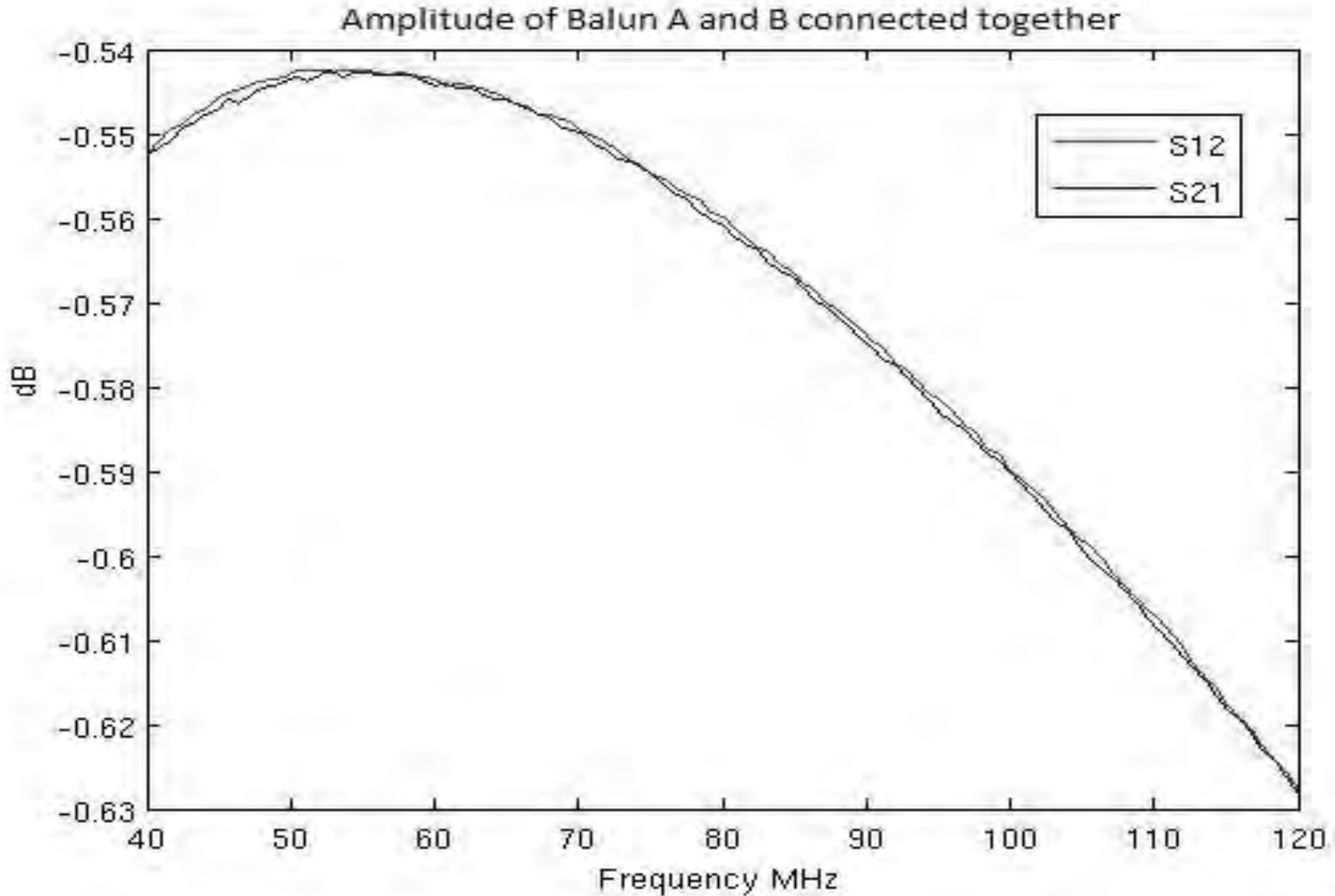
-What is a s-parameter?

-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.

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

Measurements of Balun S-Parameters



- Show loss for back-to-back measurement
- Loss for one balun is half the amplitude

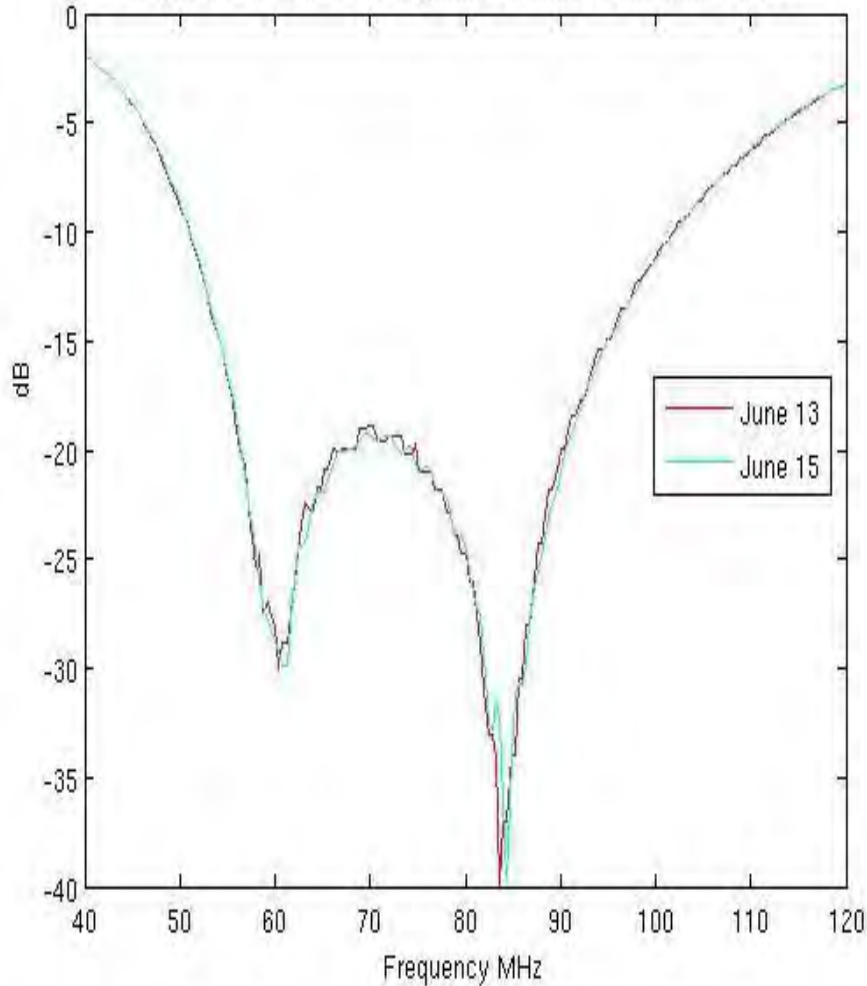
Antenna Impedance

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

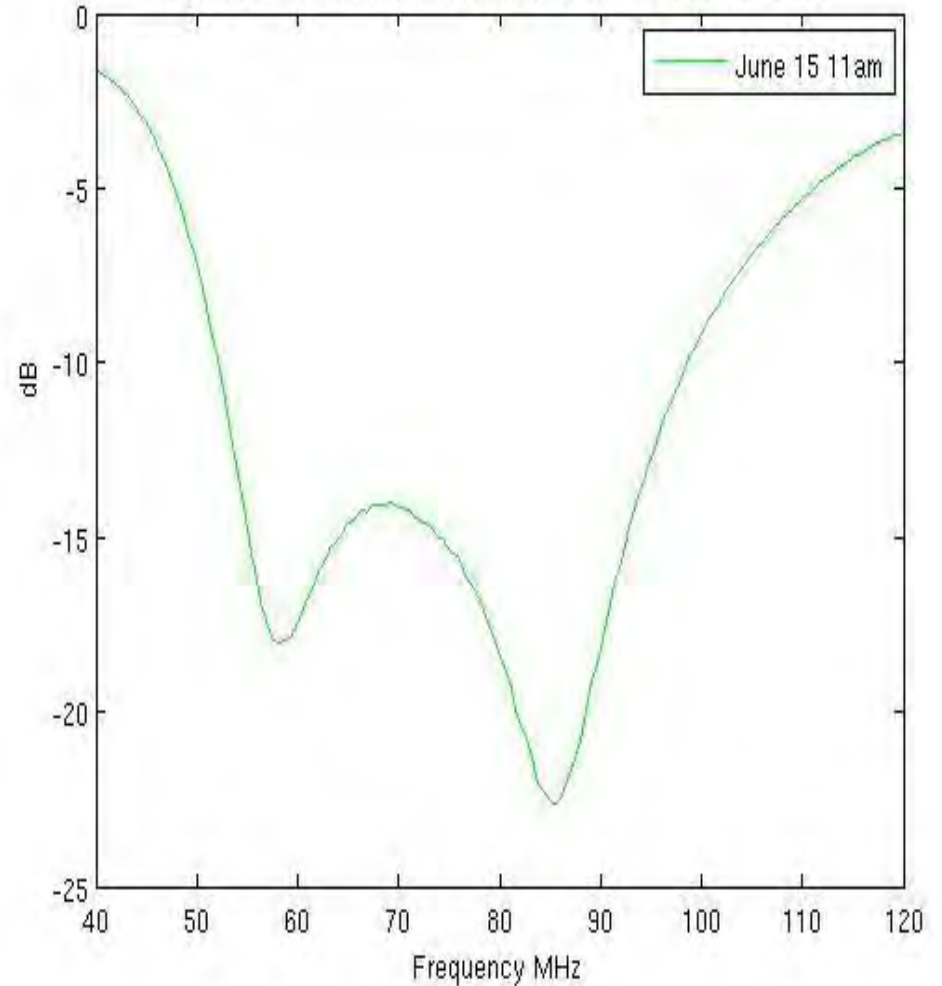


Effect of Ground Plane

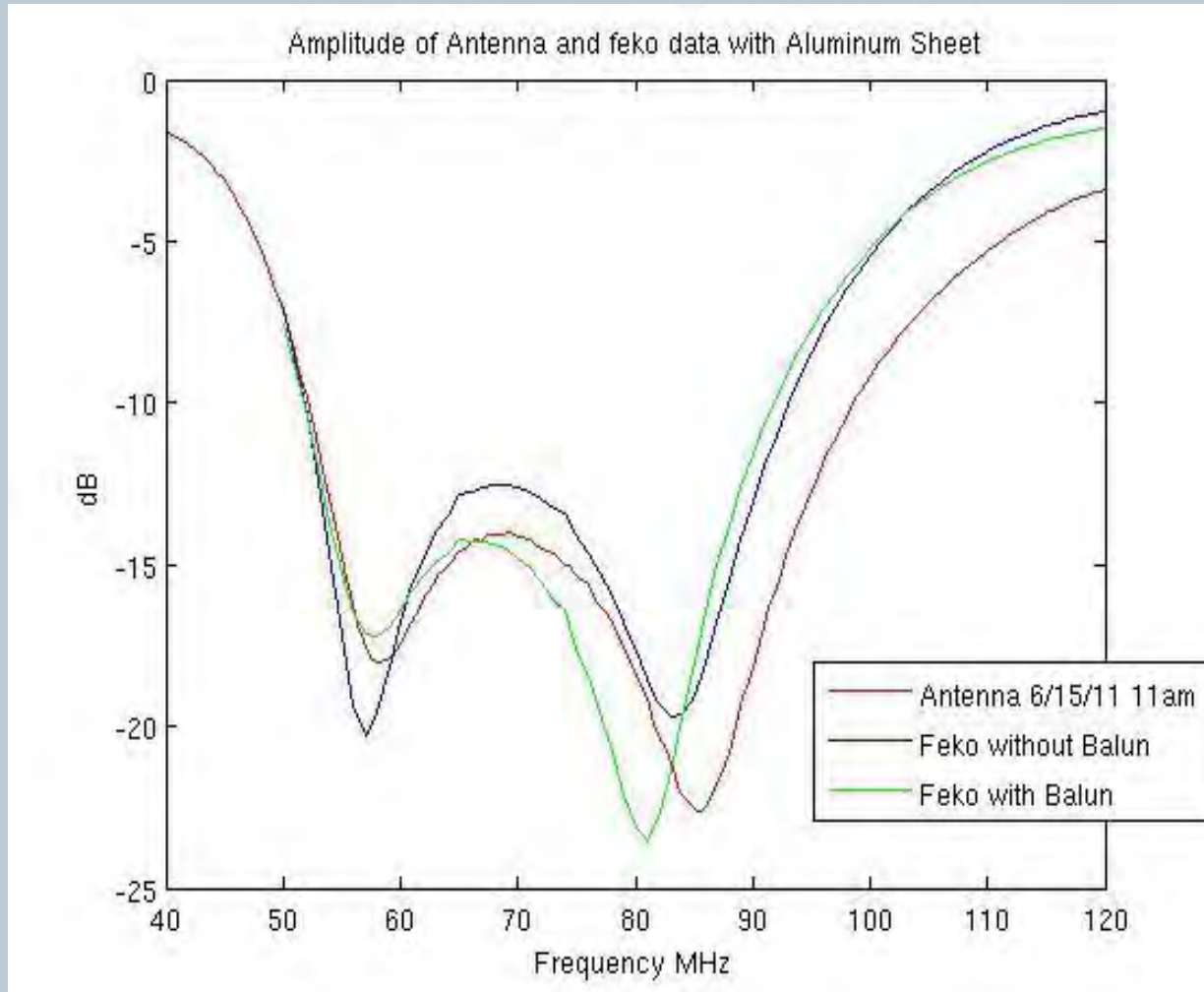
Amplitude of Antenna using Balun A without Aluminum Sheet



Amplitude of Antenna using Balun A with Aluminum Sheet



Antenna Impedance



Balun Corrections

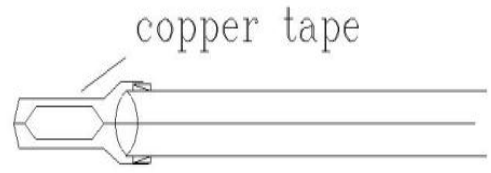
$$\Gamma_{ant} = \frac{z_{ant} - 50}{z_{ant} + 50}$$

-Feko provides us with the impedance Z_{ant}

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

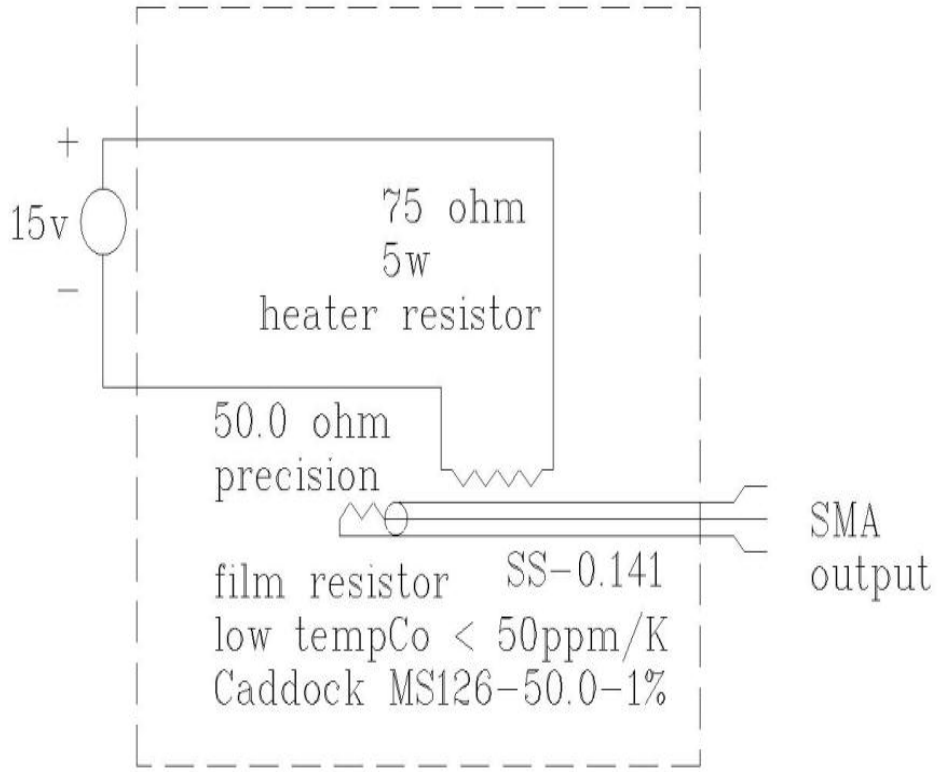
-S-parameters from balun

Hot Thermal Noise for Calibration



Detail of resistor termination

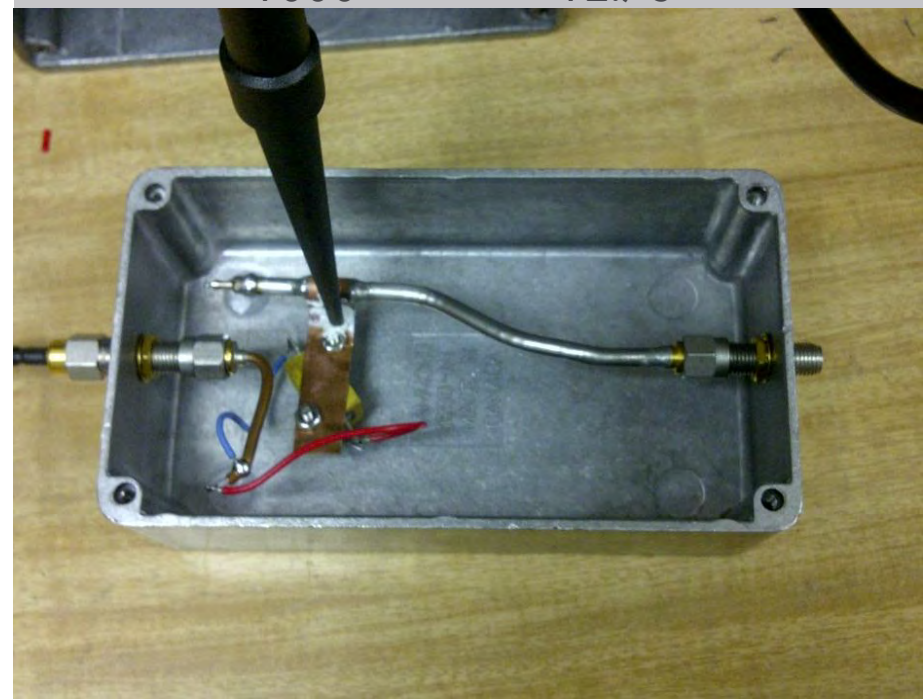
4"x2.5"x1.5" aluminum box



- 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



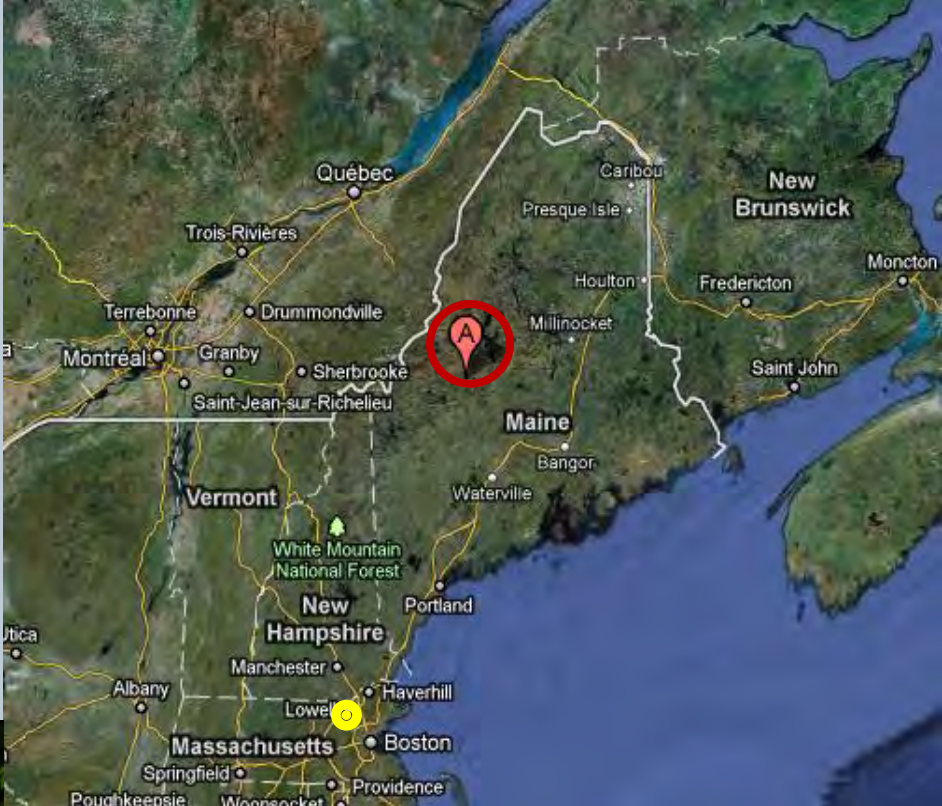


West Forks Plt.

Established 1893

Welcome  Bienvenue

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



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

West Forks Trip



The last log drive / La fin du flottage du bois

Using the river as a highway

In the early 1800s, numerous logging operators began using the Kennebec River for transportation purposes. In 1835, the Kennebec Log Driving Company was formed to coordinate river driving activity for 64 different logging contractors.

At the peak of its operation (1893), the KLD handled a record 188 million board feet



La rivière, une autoroute

Au début des années 1800, de nombreuses exploitations forestières ont commencé à se servir de la rivière Kennebec comme moyen de transport. En 1835, on a constitué la Kennebec Log Driving Company (KLD) pour coordonner les activités de flottage, ou drave, auprès de 64 entrepreneurs.

Au plus fort de ses activités (1893), la KLD a établi un record quant à la quantité de billes de bois transportées : 188 millions de pieds-planche



Originally, log drive sawlogs (ABOVE) downstream lumber

Ground Plane Placement



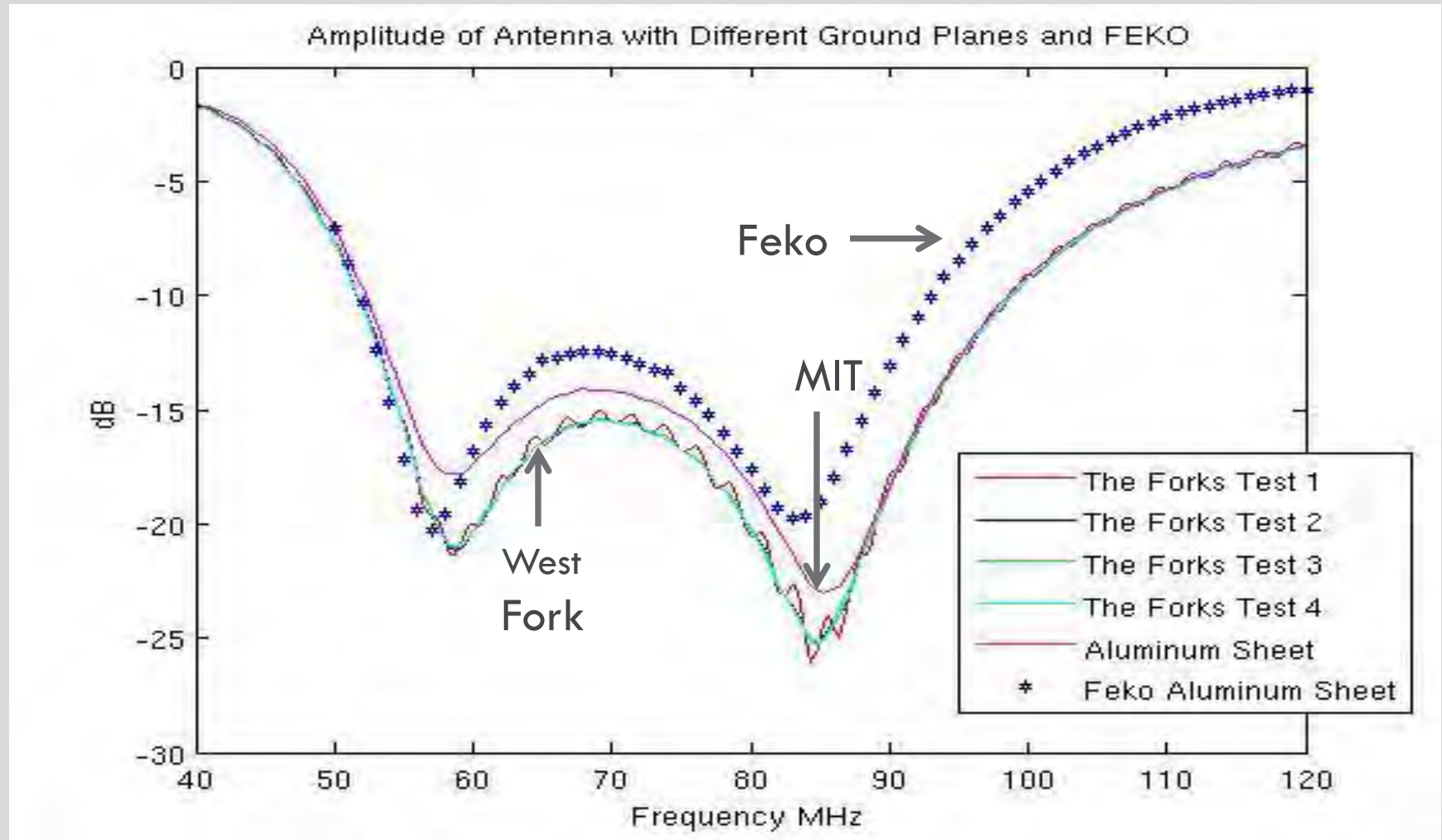
Antenna and ground plane

- 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 Analysis

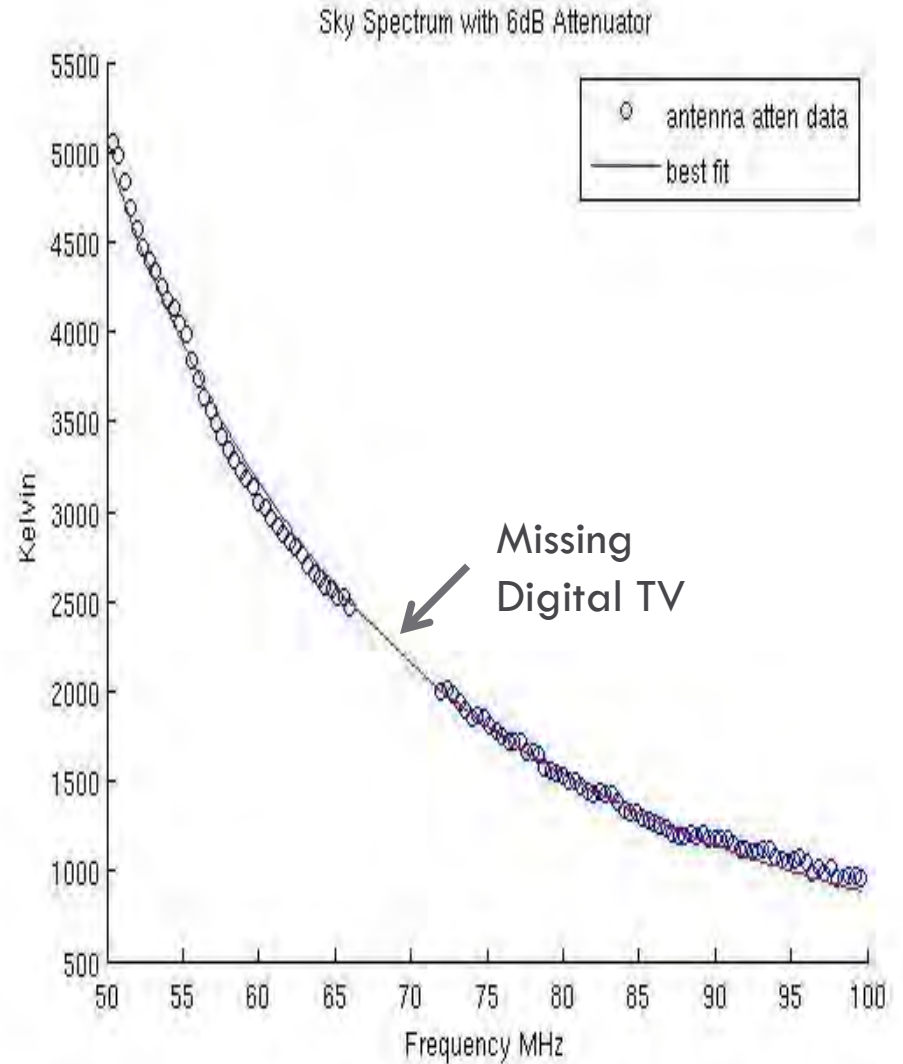
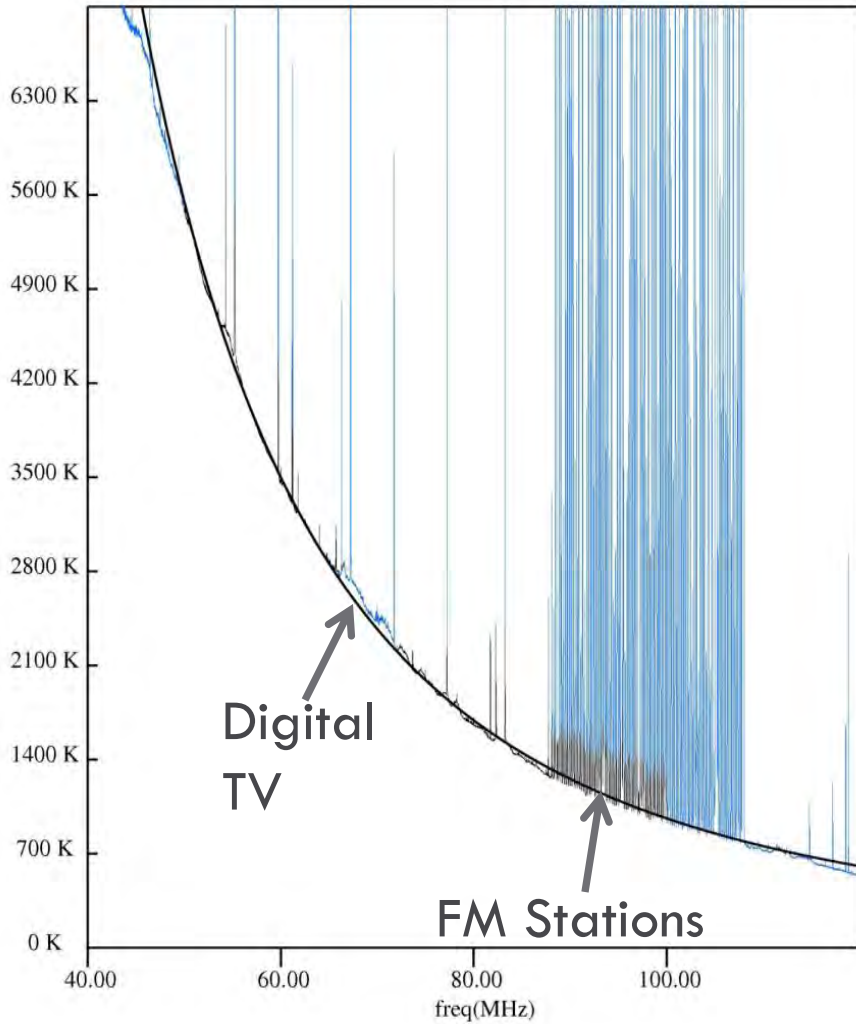
□ Brightness temperature power law $T_{sky} \propto \nu^{-\beta}$

□ Model for brightness temperature

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

T_{50} is the temperature at $\nu_{50} = 50\text{MHz}$.

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
- Judd Bowman, professor at Arizona State University
- Hamdi Mani, undergraduate at Arizona State University
- Everyone at MIT Haystack

Sky Spectrum Calculations

$$\square T_u(f) = \left[\frac{P_{sky}(f) - P_{load}(f)}{P_{cal}(f) - P_{load}(f)} \right] T_{cal} + T_{load}$$

$\square P_{sky}$ Power spectrum on the sky

$\square P_{load}$ Power spectrum on the load

$\square P_{cal}$ Power spectrum on the load and calibration

$\square T_{cal}$ Internal calibration spectrum in K

$\square T_{load}$ Ambient temperature of the load

$\square T_u$ Uncorrected sky temperature

$$\square T_{sky} = \frac{T_u - T_{amb}(1-L) - T_{amb}(1-L)|\Gamma|^2 L}{(1-|\Gamma|^2)L}$$

$$\square L = 10^{-\frac{(L_g + L_a + L_b)}{10}}$$

$$\square |\Gamma|^2 = 10^{-\frac{(L_b - L_r)}{10}}$$

$\square L_g$ ground loss ≈ 0.2 dB

$\square L_a$ attenuator = 6.0 dB

$\square L_b$ balun loss ≈ 0.3 dB

$\square L_r$ antenna return loss measured through balun in dB positive for loss

$\square T_{amb}$ ambient temperature