HYPERION
Absorber Testings

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Introduction

The 'Why'

Because we are using a low-frequency interferometer to detect a global or monopole signal, we must implement absorber baffles to impose an artificial horizon on the sky. An interferometer itself cannot help us directly measure the monopole term, as it works by imposing spatial frequencies across the sky. The 21cm global signal of reionization, a monopole signal, would integrate to zero for a perfect interferometer. Introducing the absorber baffles allows us to create an artificial horizon, forcing the monopole term into higher-order Fourier modes.

This memo documents the setup and procedure of testing antenna response to absorptive and reflective materials using a FieldFox RF Analyzer.

Setup

Before testing begins, a 4 feet by 4 feet box and a 4.5 feet by 4.5 feet box are required to set up the absorptive and reflective material.

The reflector box acts as a Faraday cage (chicken wire lines the inside of the box and acts as a reflective surface). Copper mesh is used to fill holes or cracks when closing the box to the Faraday cage. The figures below are the following setups for some absorber tests.[1]

[1] More figures are being generated to provide a visual setup for each of the tests taken.

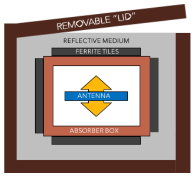

Figure 1: Ferrite Tile Setup with Absorber Box

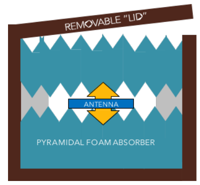

Figure 2: Pyramidal foam testing with minimal spacing between the dipole and the absorbers.

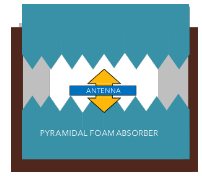

Figure 3: Pyramidal foam testing with greater spacing between the dipole and the absorbers (causing the lid of the Faraday cage to be left open).

Testings

The setup for each type of absorber tested thus far is noted below, where the frequency range and output power level for S11 measurements remains the same.

Items of Importance:
'Lid On' Case: The opening, or 'lid' of the Faraday cage has been closed to test absorptive properties of materials in a fully reflective environment.
'Lid Off' Case: The opening/'lid' of the Faraday cage is opened to test absorptive properties of materials in a partially reflective environment.
Frequency range: 30-120Mhz with a $\Delta\nu = 10MHz$
Output Power Level: -15dBm

Testing the Faraday Cage (sans absorber material, for baseline measurements):

For S11 measurements (using Network Analyzer):

- Dipole antenna placed center inside Faraday cage with no absorber material in/around Faraday cage
- These baseline measurements are required for both ''lid on' and 'lid off' cases

Testing (Pyramidal) Foam Absorber

When testing the foam absorber, it is sufficient to place it in the reflector box so that the foam covers as much of the chicken wire as possible. Several configurations were made for the pyramidal foam absorber, as it works best at higher frequencies, but was used for low-frequency measurements.
For S11 measurements (using Network Analyzer):

- Dipole antenna placed center inside Faraday cage with various configurations of pyramidal foam absorbers surrounding the antenna:
  - pyramidal foam placed around antenna with minimal spacing between antenna and absorbers (allowing for a ''lid' on case)

  - pyramidal foam placed around antenna with greater spacing between dipole and absorbers (causing a 'lid' off case)

- Pyramidal foam measurements are required for both 'lid on' and 'lid off' cases

Testing Ferrite Tiles

The various configurations used thus far with ferrite tiles (all tests required 'lid' on and 'lid' off cases):

- Dense Tests:
  - Absorber Box (4ft by 4ft) surrounded by ferrite tiles (121 tiles on each side of the 6-sided box) with the dipole placed in the center of the absorber box at a 45° angle.
  - Ferrite tiles surrounding the inside of the Faraday cage (by use of drill) with 81 tiles on each side of the 6-sided Faraday cage

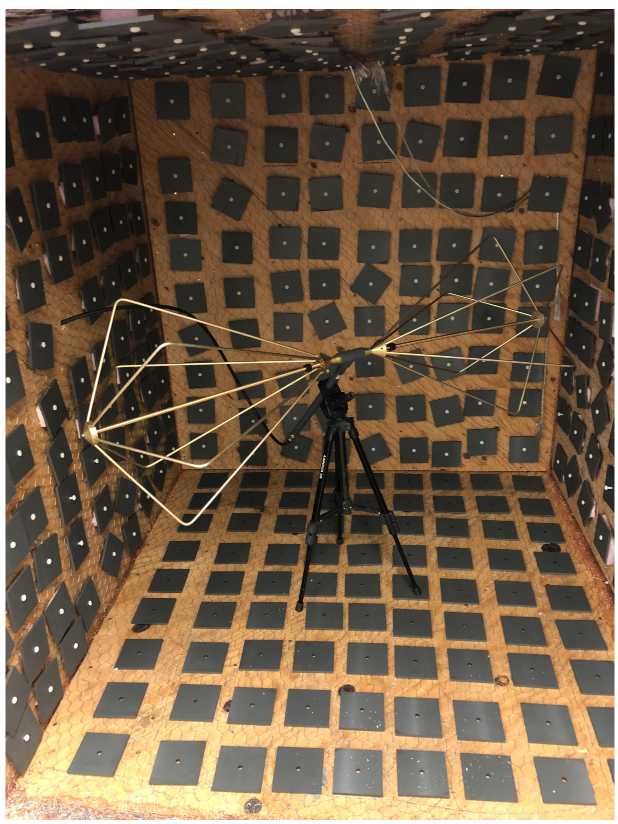

Figure 4: Ferrite tile setup with the tiles drilled into the reflector box. This is the case for 9x9 ferrite setup, with the dipole oriented at 45°. This dipole is always oriented at 45° inside the Faraday cage for ferrite tile tests because the ends of the dipole touch the tiles in any other orientation.

- Sparse Tests
  - Ferrite tiles surrounding inside of Faraday cage (by use of drill) with 25 tiles on each side of the 6-sided Faraday cage
  - A trial sparse test was conducted with a heavy-duty tarp that covered the opening of the Faraday cage when the 'lid' was removed
    * the tarp carried ∼60 ferrite tiles and only covered the opening - the dipole was not fully surrounded by absorber material

The (4ft by 4ft) Absorber Box

For an ideal dense test of ferrite tiles, the absorber box was key for supporting the absorbers' weight. The tiles were placed along the sides of the box to cover as much of the outside surface of the absorber box as possible. Once covered, this box was placed center inside the Faraday cage. We used styrofoam to maintain the right position of the dipole with respect to the absorber box, and with respect to the Faraday cage (thick pieces of styrofoam were placed between the Faraday cage and bottom of the absorber box, and rope was used to properly position the dipole).

Testing Zotefoam Absorber

- Dipole placed center in rectangular box built out of Zotefoam placed inside Faraday cage
- Zotefoam box dimensions: 52 inches wide, 41 inches long
- Various configurations were made with this setup
  - One test of the entire 6-sided Zotefoam box enclosing the antenna
  - Two tests where one side of the Zotefoam box was removed to determine any change in measurements
- Measurements using Zotefoam required both 'lid' on and 'lid' off cases.

Experimental Controls for All Absorber Tests:

For Measurements using Spectrum Analyzer:

- Position of transmitter
- Position of receiver
- Distance in between transmitter and receiver

For Measurements using Network Analyzer (S11 Measurements):

- Dipole position
  - For ferrite tests (inside absorber box and inside Faraday cage): 45° orientation
  - For other tests: 180° orientation

Variables:

- Absorber material (foam, ferrite tile, etc.)
- Absorber Setup - various configurations for the same absorber
- Lid (open Faraday cage vs closed)

Results

Spectrum Analyzer Testing

All tests here were conducted with the FCC-1 and FCC-2 baluns. The amplitude on the signal generator was set to **15dBm**.

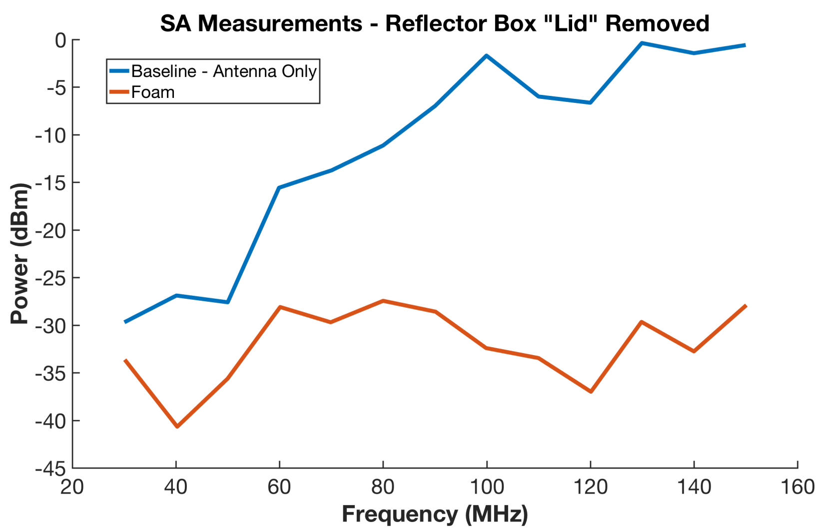

Figure 5: Even with the reflector box 'lid' removed, the foam absorbers decrease the power returned back in comparison to the baseline testing for the 'lid' off. The dipole-dipole distance for baseline test is **136.5 inches**. The dipole-dipole distance for the foam test is **139 inches**.

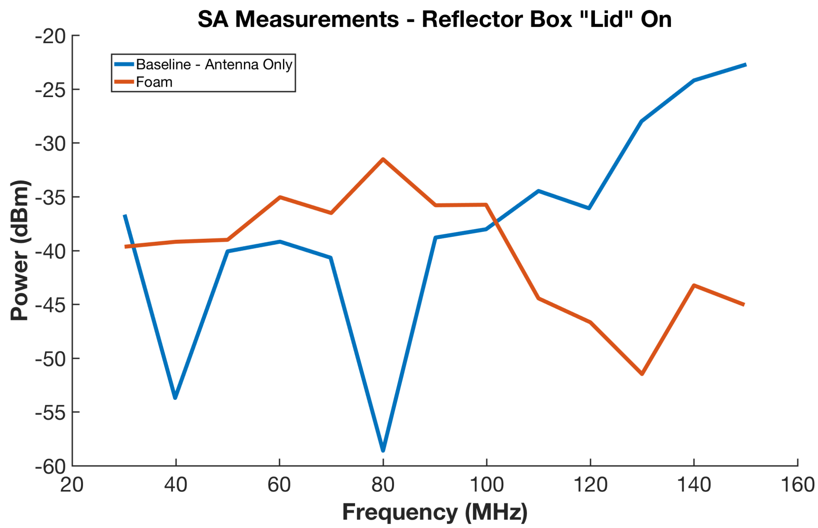

Figure 6: With the ‘lid’ on, the baseline testing has dips in power returned back - **reflections??** The foam absorbers here are placed as close to the dipole as possible. The foam absorbers seem to absorb well at higher frequencies; however, at lower frequencies, the foam absorbers do not absorb as well. The dipole-dipole distance for the baseline test is **136.5 inches**. The dipole-dipole distance for the foam testing here is **139 inches**.

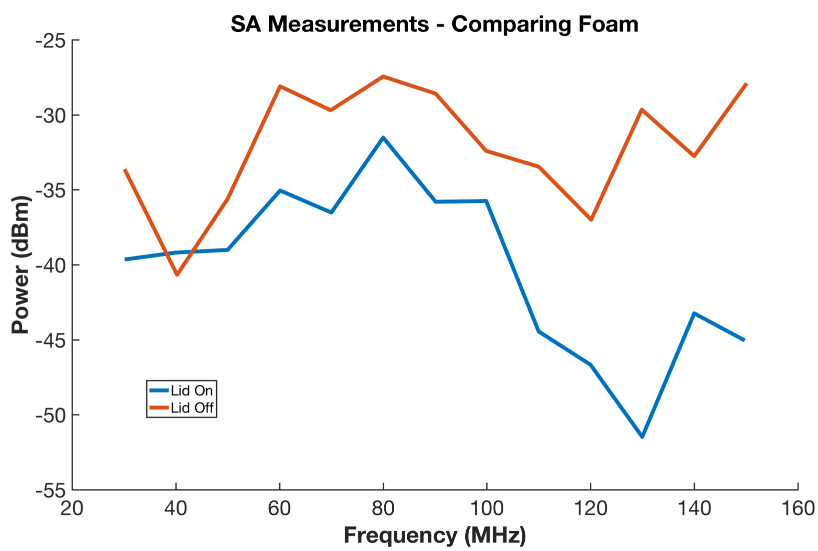

Figure 7: As expected, the foam absorbers behave best with the ‘lid’ on in a fully reflective environment.

Return Loss Measurements

Faraday Cage ‘Lid’ On

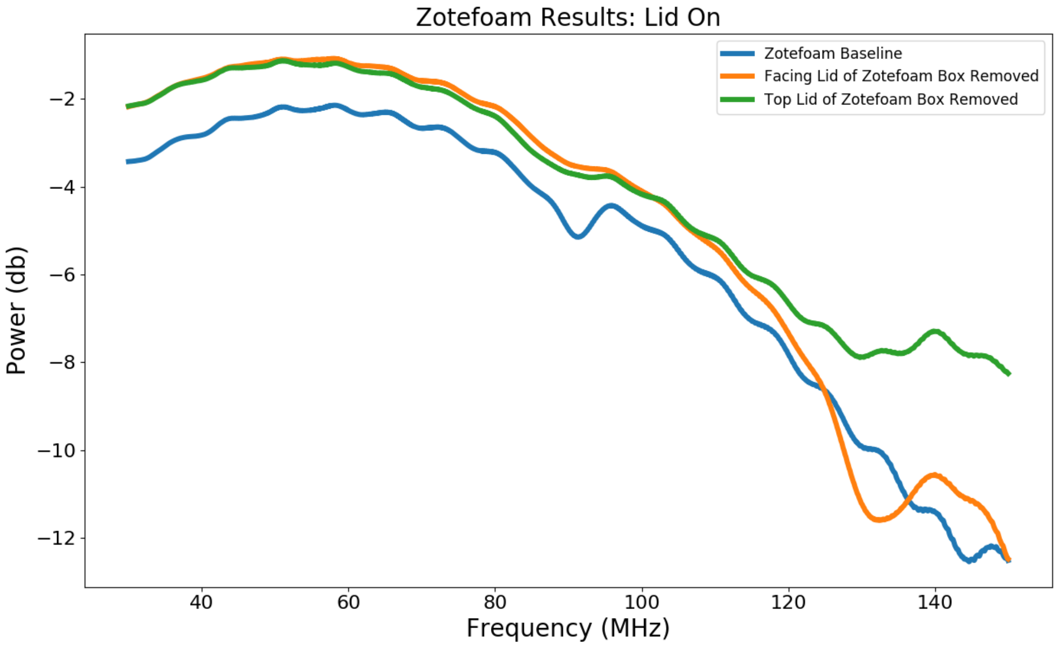

Figure 8: S11 measurements using Zotefoam absorber. The results from the Zotefoam absorber are when the antenna is completely surrounded by a 6-sided Zotefoam ‘box’ rather than certain faces of the box removed.

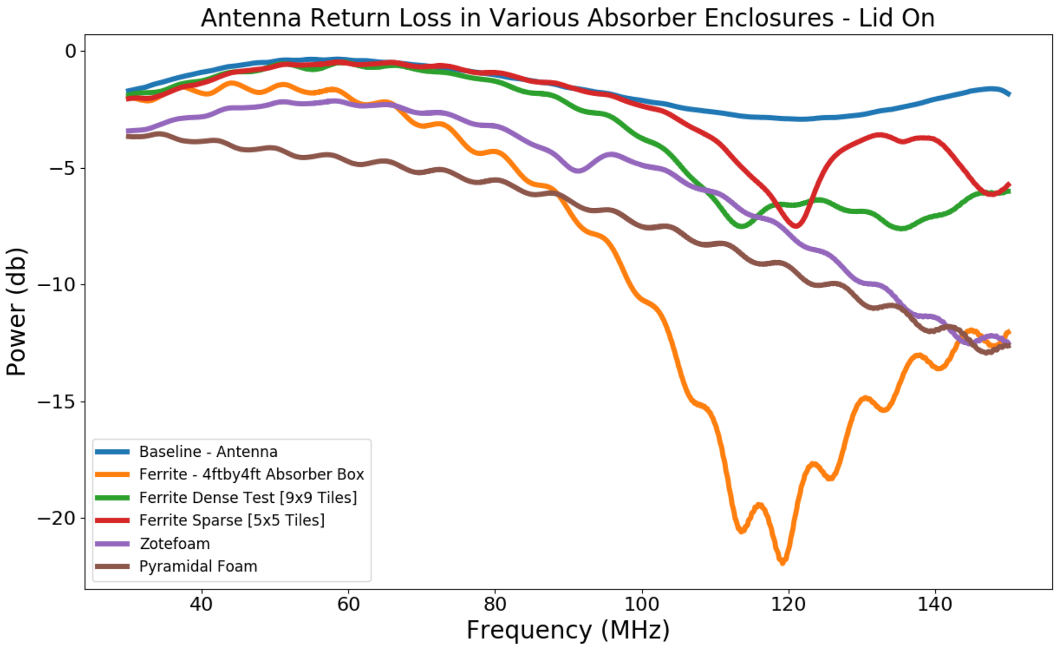

Figure 9: Return loss measurements for all absorbers used thus far with the reflector box 'lid' on.

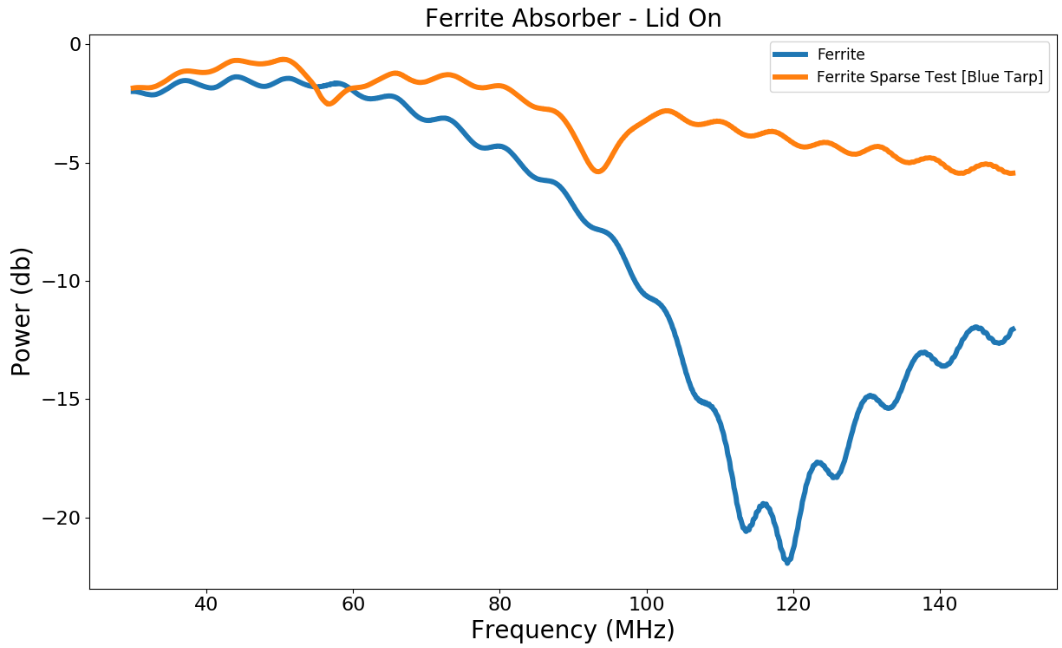

Figure 10: S11 measurements comparing dense ferrite tiles (the absorber box with 11x11 tiles on each side of the 6-sided box) and the ferrite 'sparse' test using the blue tarp. Though this is not a correct comparison by any means, it is notable to see absorptive properties of ferrite tiles in various configurations.

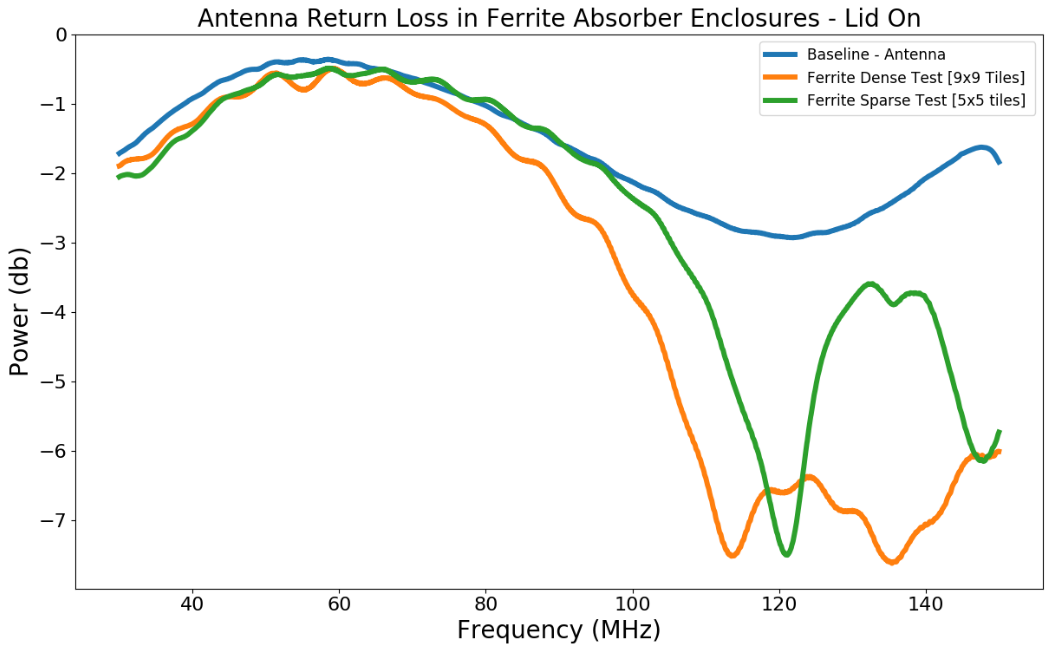

Figure 11: The most recent S11 measurements with ferrite tiles drilled (February 2018).

Faraday Cage 'Lid' Off

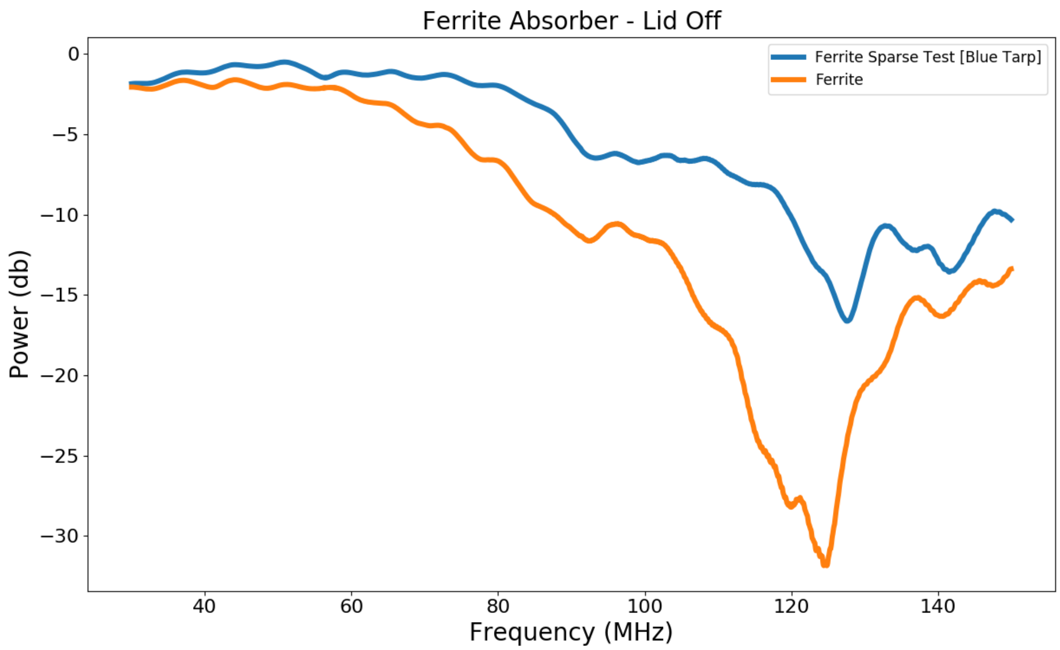

Figure 12: S11 measurements comparing the 'lid' off case of the dense ferrite test (using absorber box of 11x11 tiles on each side) with the first 'sparse' test (using blue tarp only covering the opening of the Faraday cage with ~ 60 tiles)

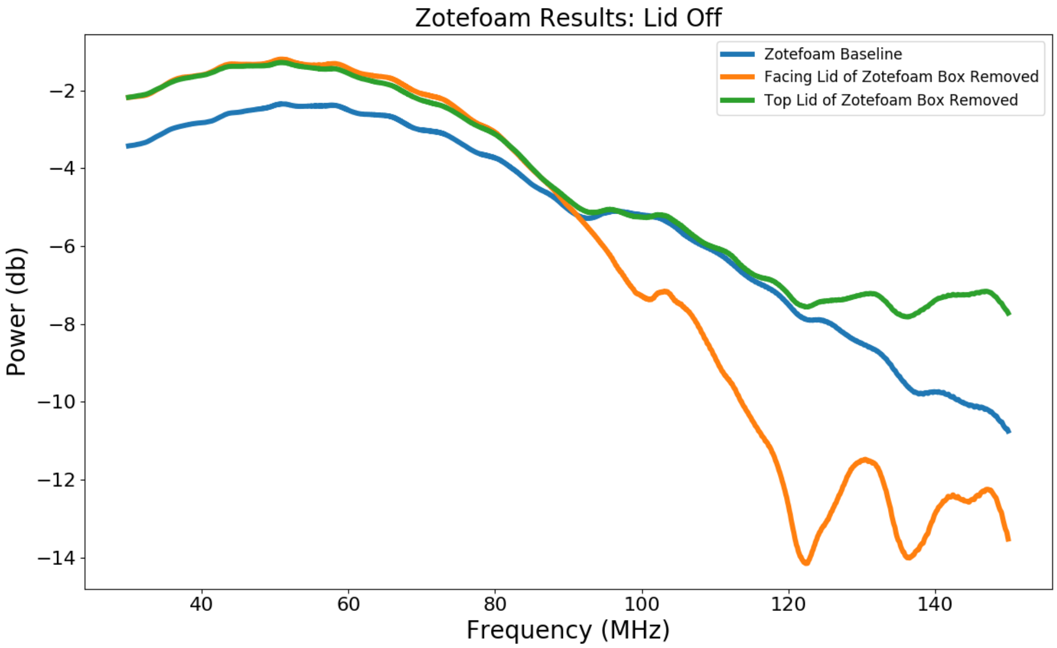

Figure 13: S11 measurements for Zotefoam absorbers for the 'lid' off case.

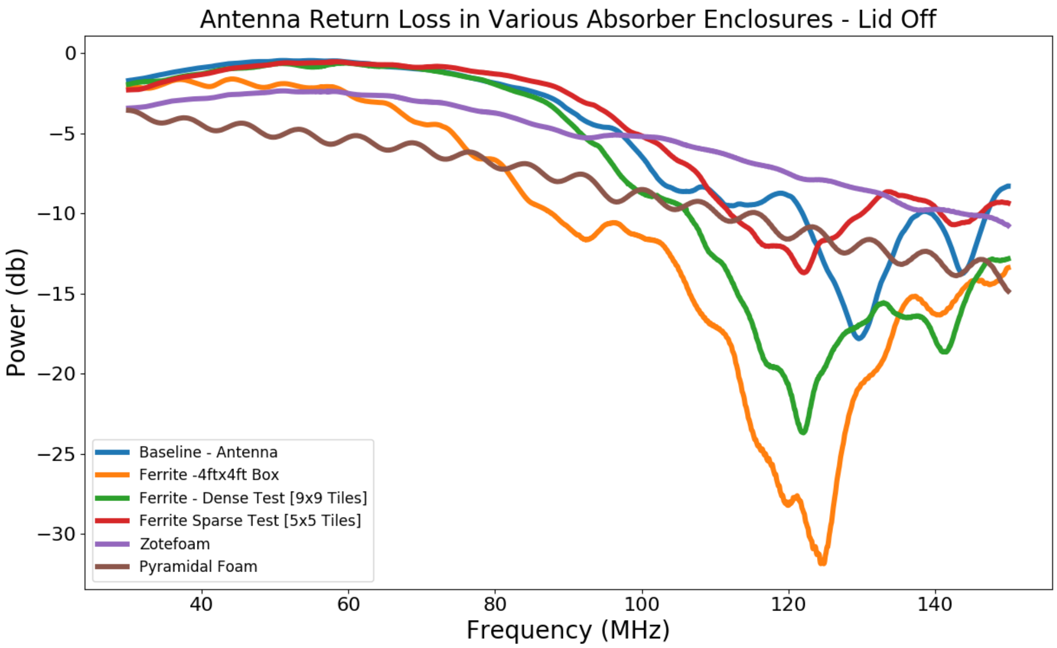

Figure 14: S11 measurements for all absorbers in the 'lid' off case.

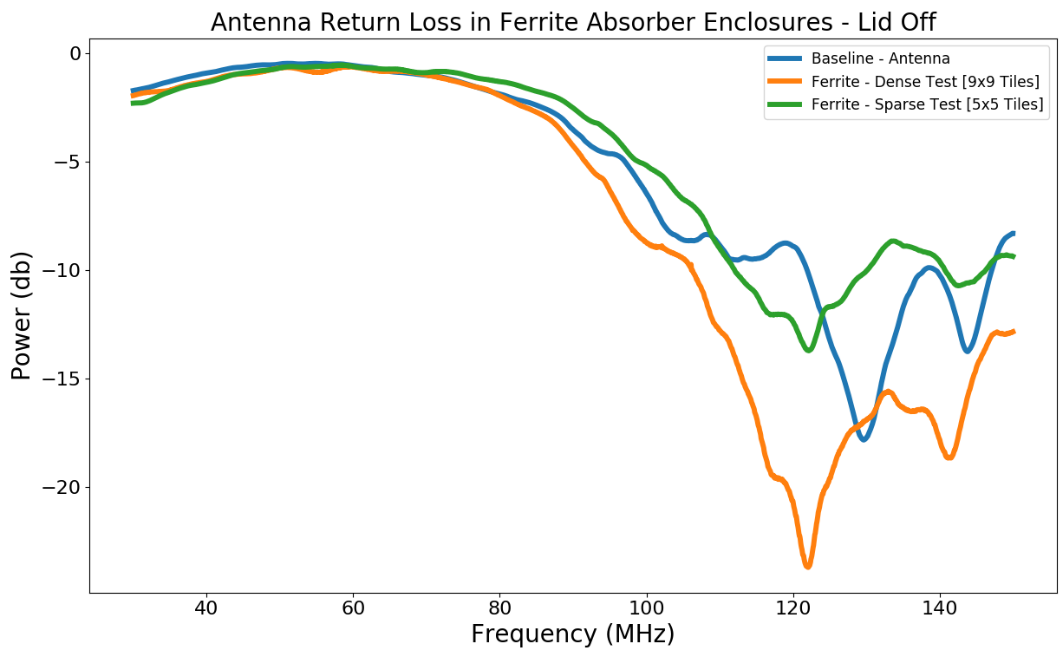

Figure 15: The most recent S11 measurements with ferrite tiles (February 2018).

Return Loss Analysis/Conclusion

As expected, the baseline test shows no change in power in a fully reflective environment ('lid' on). In a partially reflective environment ('lid' off), the baseline test shows a loss in power ? some energy has dissipated away. The pyramidal foam shows reflection regardless of its spacing from the antenna; however, it still behaves better than the Zotefoam. Pyramidal foam absorbers are known for performing optimally at higher frequencies; however, in the field at the Owens Valley Radio Observatory (OVRO), they eliminated cross-talk between 2 fat dipoles placed 1 wavelength apart. When the cross-talk was eliminated, some of the wave was reflected back (Figure 2). It is evident that the ferrite tiles return the least amount of power in both cases. Notice that the ferrite tiles absorb the most near 120MHz.

1 Random Notes Along the Way - From Various HYPERION Meetings/Lessons

For return loss measurements, the DUT will be analyzed under isolation. For spectrum analyzer tests, a basic dipole antenna will be used as the transmitting antenna and the DUT will act as the receiving antenna. The length of the dipole antenna arms will be adjusted as different frequencies are tested.

When looking at absorber testings - when the lid is on, the difference in the curve, or the change in the power level that you see in the plots is precisely the ratio between 'escaped' radiation and radiation that bounced back.

Calibration Notes

Calibration with the FieldFox (using the Network Analyzer mode) will give a baseline noise level that can be subtracted when doing testing. It will also show the return loss of the cable being used to measure the response of the antenna so that it can be subtracted out as well.

The testing done on the reflector box with no absorber material will be used as a baseline measurement source for establishing the attenuation of the antenna itself. This is because, ideally, all of the signal radiated should be reflected back to the antenna. After this basis is established, absorber testings should proceed. For any absorptive material, ideally, there should be no signal response or a minute signal response.

The lid open versus closed testing is necessary to test the structural integrity of the boxes. If the boxes are made correctly with no significant cracks and holes, there should be a large difference in antenna response on the FieldFox when comparing the two cases for each box. It is important to establish electrical contact inside the reflector box, so any cracks and holes should be filled with copper mesh (or an alternative conducting material) in order to ensure continuity. This is important in making sure that the box behaves as similarly to a Faraday cage as possible.

During foam absorber testing, a certain distance should be kept between opposing foam structures (i.e. the foam structures on one side of the DUT in relation to the foam structures on the other side of the DUT). This ensures that the wavelengths are allowed a chance to be absorbed into the foam instead of simply bouncing off of the surface back into the DUT due to minimal spacing between the structures.