# Reducing the RFI problems at GGAO

## Science and Engineering


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## Abstract


The Space Geodesy Project (SGP) has been dedicating a lot of their time and resources to the vision of co-locating various geodetic techniques at one site, with the goal of bringing the International Terrestrial Reference Frame (ITRF) within a spatial resolution uncertainty of 1mm. The VLBI (Very Long Baseline Interferometry) broadband development system was conceived to address the worsening radio frequency interference (RFI) issues while providing additional bandwidth that is required to meet this ITRF precision requirement. Broadband mean 2-14 GHz, but there are avoidable conflicts that are being addressed through masking, filtering and absorbing/shielding.

There are spectrum sharing challenges associated with having four geodetic techniques coexisting are the same site. The 9.41 GHz Laser Hazard Ranging System (LHRS) radar and a 2036 MHz DORIS beacon power levels affect the VLBI broadband system. The cryogenic receivers are highly susceptible to RFI. To attenuate the RFI that the VLBI picks up on, material that is designed to absorb X-band frequency, in conjunction with a reflector material will be positioned near the LHRS radar. With Network Analyzer tests, we identify which absorber/reflector material combination will be the most effective for building an RFI barrier deployed between the LHRS radar and the VLBI antenna.


## Introduction

**Objective**

The objective of this project is to determine the best combination of absorber material and reflector material to attenuate RFI from a DORIS beacon and LHRS radars. The materials examined were Eccosorb SF-9.5, Eccosorb DSF-9.5, Eccosorb SF-2.0, Eccosorb ANW-75, AL100 reflector, Laminated MW Absorber. The main focus of these tests are on the X-band materials

**Background**

Very Long Baseline Interferometry (VLBI) is a geodetic technique that has the ability to define an inertial reference frame and to measure the Earth's orientation in this frame. It is measures the time difference between the arrival at two Earth-based antennas of a radio wave emitted by a distant quasar. Simple geometry can then be used to determine how far apart the telescopes that received the radio wave from the quasar actually are.

By taking numerous measurements from various VLBI antennas one will be able to tell how the ground beneath the telescopes moves around and how the Earth rotates about its axis in a given day. The VLBI makes direct measurements of the Earth's orientation in space. These measurements allow geoscientists to study phenomena such as atmospheric angular momentum, ocean tides and currents, and the elastic response of the solid Earth [1].

The VLBI broadband (2-14 GHz) development system was conceived to address the worsening radio frequency interference (RFI) issues while providing additional bandwidth that is required to meet this ITRF precision requirement. There are avoidable conflicts that are being addressed through masking, filtering and absorbing/shielding [1]. The main focus is on the filtering and absorbing/shielding aspect of reducing RFI.

An Agilent Network Analyzer has been used to determine the Scattering Parameters (S-parameters) of 6 different materials as well as several different combinations of those materials. The S-parameters describe the electrical behavior of linear electrical networks when undergoing various steady state stimuli by electrical signals [2]. These parameters are particularly useful in applications such as microwave engineering. The materials have been tapped and loaded in between two waveguide launchers and tested under X-band and S-band frequency ranges.

## Methods

***Materials***

The materials being tested with an Agilent Network Analyzer are:

1. **Eccosorb SF-9.5 (Dark Gray)** – Frequency range from 1 - 18 GHz [3].
2. **Eccosorb DSF-9.5 (Gray)** – Frequency range from 3 - 17 GHz [4].
3. **AL100 reflector (Silver)** – Frequency range from 100 MHz to 18 GHz [5].
4. **Laminated MW Absorber (Black)** – Offers protection for frequencies up to, and over, 10GHz [6].
5. **Eccosorb SF-2.0 (Sgray)** – Frequency range from 1 - 18 GHz, [3].
6. **Eccosorb ANW-75 (ANW)** - Frequency range greater than 2.4GHz [7].

***Equipment***

1.) Agilent Network Analyzer
2.) WR75 waveguide kit
3.) WR430 waveguide kit

***Process***

1. Turn on Agilent Network Analyzer and make sure coaxial cables are securely connected to Port 1 and Port 2.
2. Connect waveguide launchers to Port 1 and Port 2. A torque wrench may be required to tighten the connector between the coax cable and the waveguide launchers. Ensure that the correct waveguides are being used for the material tests. The WR75 waveguide kit is used for X-band frequency measurements (9-15 GHz).
3. Select Cal Wizard and follow the process to calibrate the Network Analyzer to the kit that is being used. The calibration wizard will go through several steps where the user will be required to select the type of connectors being used (in this case, X-band and S-band waveguides) and the specific calibration kit being used.
4. The calibration process will then go through a process in which a series of tests will be implemented. The first step will be to attach a "Short" to the Port 1 launcher. Once connected, the user will need to click measure. The second step of the process is to connect the "Short" to the Port 2 launcher and click measure. The third step of the process is to connect Port 1 directly to Port 2. The fourth, and final, step of the process is to insert the ¼ line between Port 1 and Port 2. Each of these steps requires the user to bolt the apparatuses together during the calibration measurements for optimum results.
5. Select the frequency range that is relevant to the analysis. Again, X-band's frequency range is 9-15 GHz.
6. The materials had holes tapped into it so it could interface with the waveguide launchers.
7. Select the material(s) to be analyzed and bolt the material to the waveguide launchers.
8. Place markers on the Network Analyzer's screen at the frequencies of interest, e.g. 9.41 GHz.
9. Repeat steps 5-8 for all of the material combinations.

## Test Results

- The data obtained from the network analyzer was used to create graphs of power ratio (in the form of a decibel) as a function of frequency for each X-band material tested. Figure 1 shows the reflective properties for the combination of Dark Gray and Silver which were found to have a null around -10.2772 dB at 10.2 GHz for its reflective S11 parameter. As the frequency rose, the attenuation of the material decreased. The S22 parameter remained close to zero. Figure 1 also shows the reflective properties of Dark Gray and the Black materials. This graph shows that there is a null of -9.5991 dB at 10.2 GHz in the parameter S11's dataset. The S22 parameter was close to zero. Both of these plots were compared to a "standard" defined by no material being in between the launchers. Figure 2 shows the transfer function properties, S12 and S21, for both of the Dark Gray combinations. The Dark Gray/Silver combination's transfer function properties fell below the noise floor (-80 dB) which equates to a short being on either of the ports used in testing. The Dark Gray/Black combination's transfer coefficients were greater than 40 dB. Again, both of these plots were compared to a "standard" defined by no material being in between the launchers. The standard is approximately 0 dB.
- Figure 3 provides a graph for the parameters measured for the combination of Gray/Silver and Gray/Black materials. The Gray/Silver combination has a null of -6.7129 dB at 9.48 GHz. The S22 parameter for this combination was close to zero. The Gray/Black combination shows that there is a null of -7.532 dB at 9.99 GHz in the parameter S11's dataset. The S22 parameter was close to zero. Both of these plots were compared to a "standard" defined by no material being in between the launchers. Figure 4 shows the transfer function properties, S12 and S21, for both of the Gray combinations. The Gray/Silver combination's transfer function properties fell below the noise floor (-80 dB) which equates to a short being on either of the ports used in testing. The Gray/Black combination's transfer coefficients were greater than 40 dB. It can also be seen that the Gray/Black combination attenuates as the frequency increases. Again, both of these plots were compared to a "standard" defined by no material being in between the launchers. The standard is approximately 0 dB.
- Figure 5 shows the reflective properties for the combination of Eccosorb ANW-75 and AL100 reflector materials, which was found to have three nulls in its reflective parameters. The first null of -17.9 dB was at 10.32 GHz, the second null of -14.301 dB was at 12.75 GHz and the final null of -10.24 dB was at 14.76 GHz. The S22 parameter remained close to zero. Figure 6 shows the transfer function properties of this combination of materials. Like the last two combinations, the parameters, S12 and S21, fell below the noise floor (-85 dB).

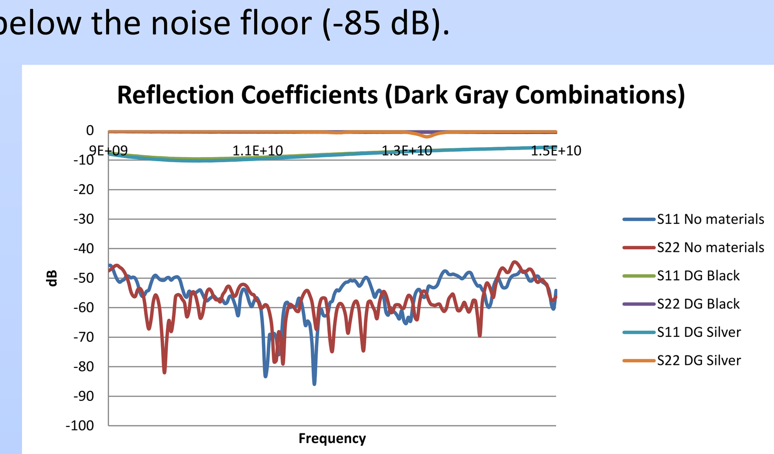


Figure 1: Reflection Coefficients for the Dark Gray Combinations

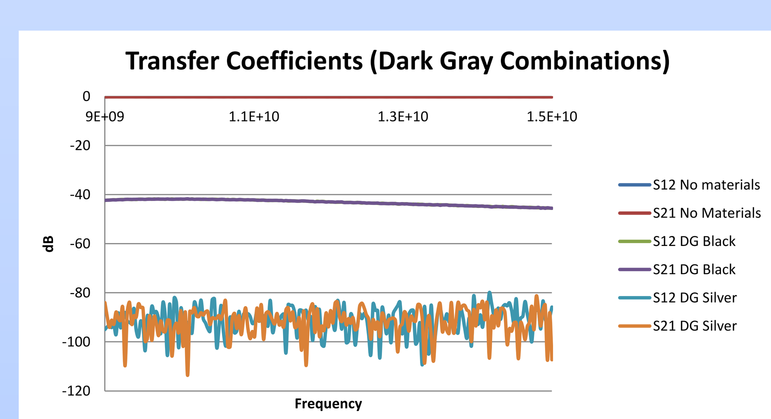


Figure 2: Transfer Coefficients for the Dark Gray Combinations

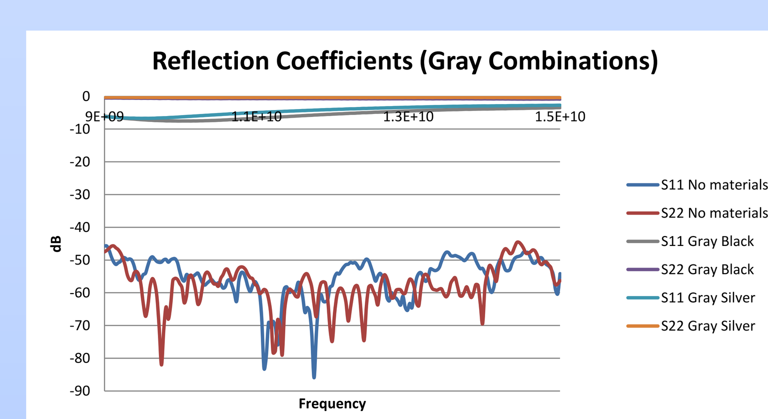


Figure 3: Reflection Coefficients for the Gray Combinations

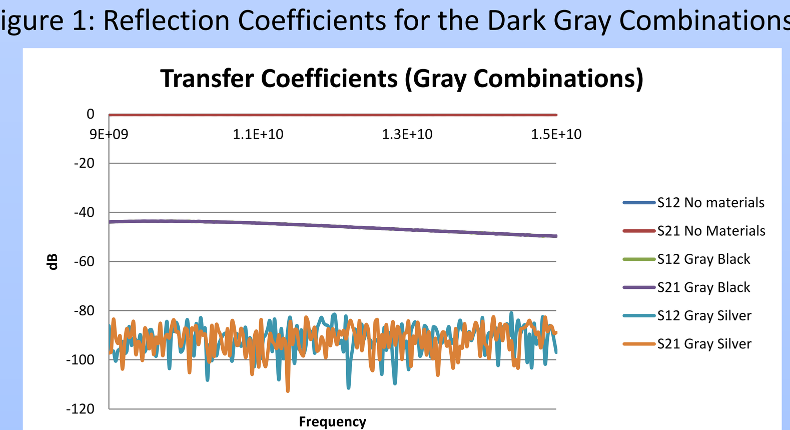


Figure 4: Transfer Coefficients for the Gray Combinations

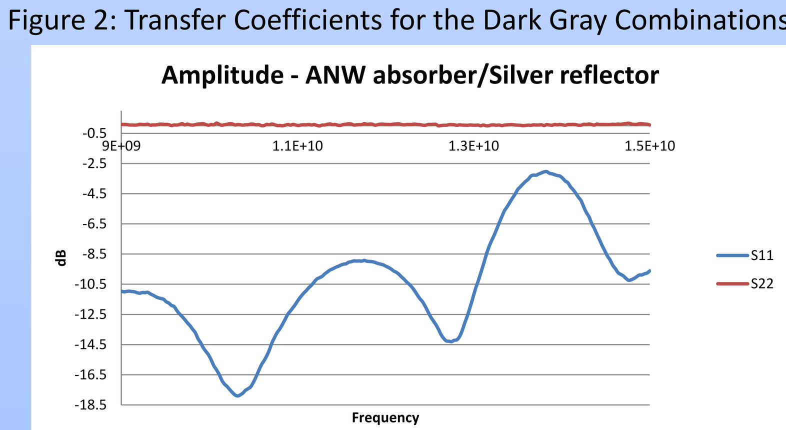


Figure 5:Reflection Coefficients for the ANW/Silver Combination

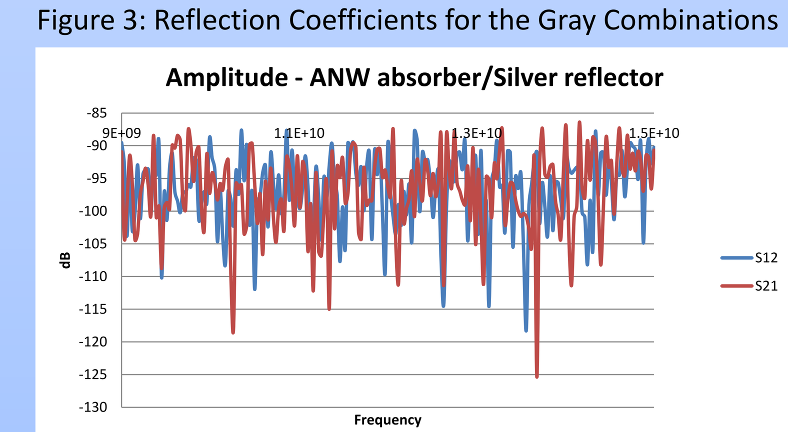


Figure 5: Transfer Coefficients for the ANW/Silver Combination

## Discussion

From initial observations of the data, it appears that the experimental data follows the manufacturer's specs with the exception that the frequency is phased slightly. This discrepancy can be explained by the fact that we only used two bolts, as opposed to four, to fixate the material in between the waveguide launchers. For the calibration, everything had to be bolted to the launchers and tightened and the data would be skewed if the bolts weren't tightened. Only one reading was taken for each measurement, while an average of several measurements for each parameter would have been a more accurate and comprehensive choice for calculations. Tapping the materials would also inhibit the accuracy of the placement of the material as it may have introduced defects that could cause a leakage during the tests.

The materials used in the Network Analyzer test experienced similar trends in terms of the attenuation of its reflective and transfer coefficients. As the frequency increases, the attenuation of the signal decreases. The null for the Eccosorb SF materials was said to occur at 9.4 GHz in the distributor's spec sheet. The power level is clearly affected by the frequency range as seen in Figures 1 through 4 but exhibits desired effects in the range that we're interested in (9-10 GHz). The combinations of Dark Gray/Black, Dark Gray/Silver, Gray/Black, and Gray/Silver showed a null in the desired frequency range. Outside of this range, the frequency is fairly consistent but doesn't attenuate as well. The first null for the Eccosorb ANW-75's reflective parameters was attenuated within the frequency range of the LHRS. The attenuation is also the most pronounced of the materials tested at X-band frequency. As a result, this is the material that is being selected for future tests at the GGAO site.

In general, the attenuation of the absorber materials, when combined with the AL100 Reflector material, was found to be very good at the frequency that the LHRS radar transmits in. The AL100 Reflector material exhibits the ability to drop the S12 and S21 transfer parameters below the noise floor. It also exhibits the ability to attenuate the frequency that the LHRS radars operate in. To better understand the effects of the absorber/reflector combinations, the Eccosorb-ANW and AL100 Reflector material will be used at the Goddard Geophysical and Astronomical Observatory (GGAO) to attenuate the signal of the LHRS radar.

## Conclusion

Several materials were tested for their attenuations at X-band frequency using an Agilent Network Analyzer. The data from the spec sheet was compared to the experimental data obtained from the Network Analyzer. It was found that the experimental data did not deviate in terms of frequency but the reflectivity (dB) differed by less than what was predicted.

All the materials tested exhibited the same type of behavior in their reflective properties, with the exception of the Eccosorb ANW-75 absorber that displayed a different type of trend. Nevertheless, the attenuations that were obtained from the Agilent Network Analyzer hold great importance for design considerations. There is a clear null in all of the S11 parameters and all of the transfer coefficients were attenuated. At the end of the day, the combination that we're going to use for field testing at the LHRS radar is the Eccosorb ANW-75 in conjunction with the AL100 reflector wall shield.

## References


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## Acknowledgements


1) Lawrence Hilliard
2) Wendy Avelar
3) SGP Interns