Microwave and Millimeter-wave Systems: Propagation studies at 5G Wireless Bands

By: Lizette Rodriguez and Emiliano Novas

Introduction

- Wireless technology has made leaps and bounds.
- Internet speeds are faster than ever.
- 5G technology is a major engineering milestone.
- Communications technology is becoming ever more advanced.

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Objective

Our goal is to understand the effects of radio frequency interference on a signal of interest through:

- Measuring signal path loss at 5G bands (1.9GHz, 3.7GHz, 28GHz and 39GHz.
- Assess interference on an FM radio station using an SDR.
- Supporting the implementation of an antenna measurement system.

Motivation

- Advances in communications and radar systems require increased bandwidth and spectrum usage.
- This spectrum occupancy can contaminate critical scientific observations where the receivers are extremely sensitive.

Background

- What even is 5G?
- What exactly is interference?
- What is path loss?
- What makes 5G better than 4G?

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Path Loss and the Friis Equation

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2}$$

Where,

P_r = Power at the receiving antenna

P_t = Output power of transmitting antenna

G_t = Gain of the transmitting antenna

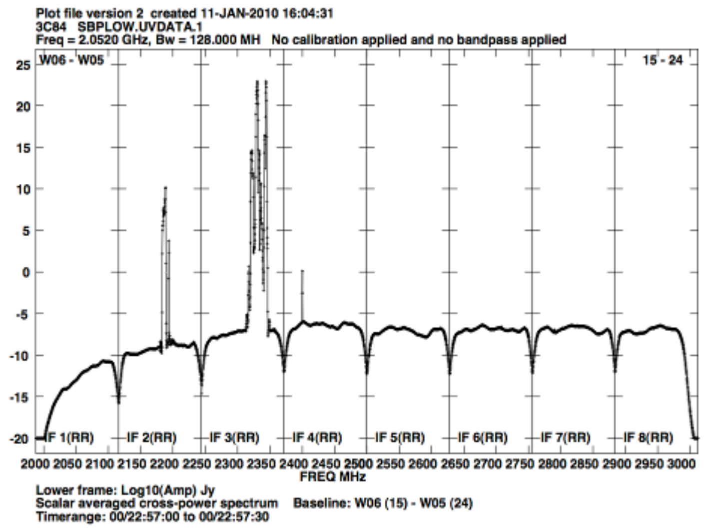
G_r= Gain of the receiving antenna

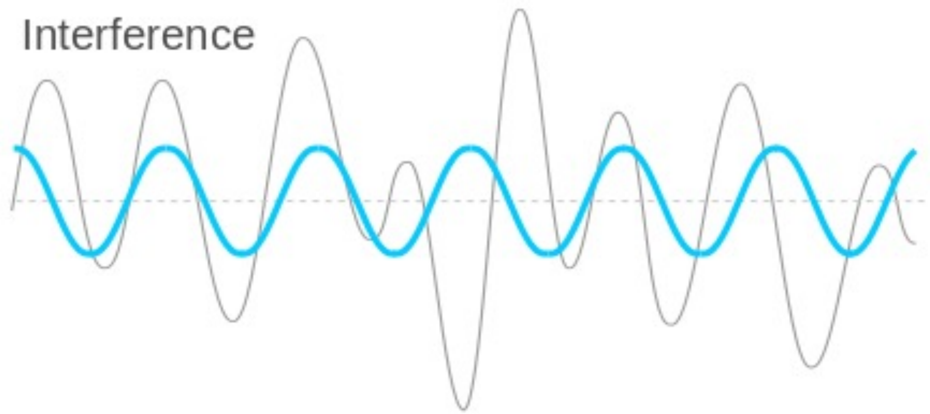
λ = Wavelength

R = Distance between the antennas

Interference

- A signal undergoes interference when another signal(s) interrupts or distorts it.
- The interfering signal can be in the same frequency or near it.





Antenna Radiation Patterns

- An antenna's radiation pattern is a graphical representation of its radiation properties.
- Radiation patterns are graphed in polar coordinates.

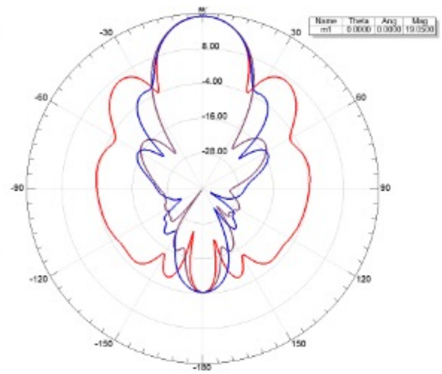


Fig. 2: Type Horn Antenna 22240 at 28 GHz

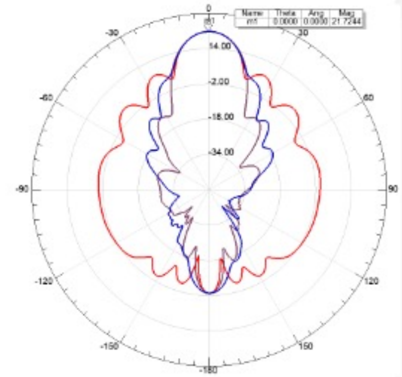


Fig. 3: Type Horn Antenna 22240 at 39 GHz

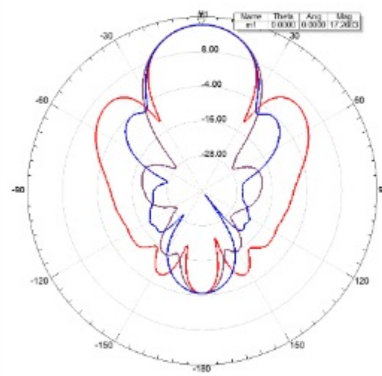


Fig. 4: Type Horn Antenna 23240 at 28 GHz

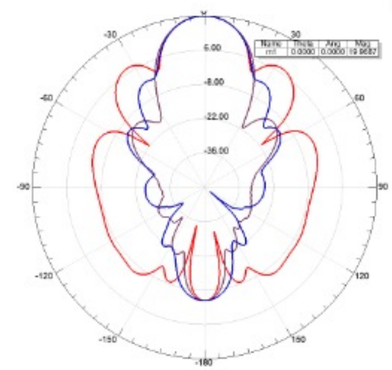
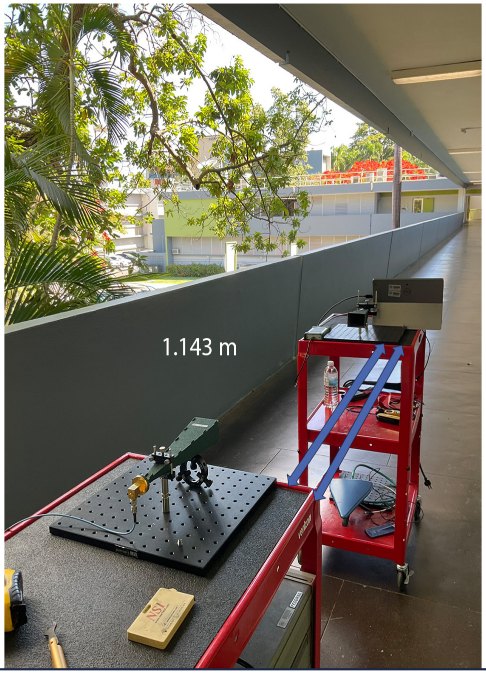


Fig. 5: Type Horn Antenna 23240 at 39 GHz

Methodology



Environment Two or (ENV 2) is seen in the figure above

Environment One or (ENV 1) is seen in the figure above

1 dB Compression Point

1dB Compression Analysis (Phase 1)

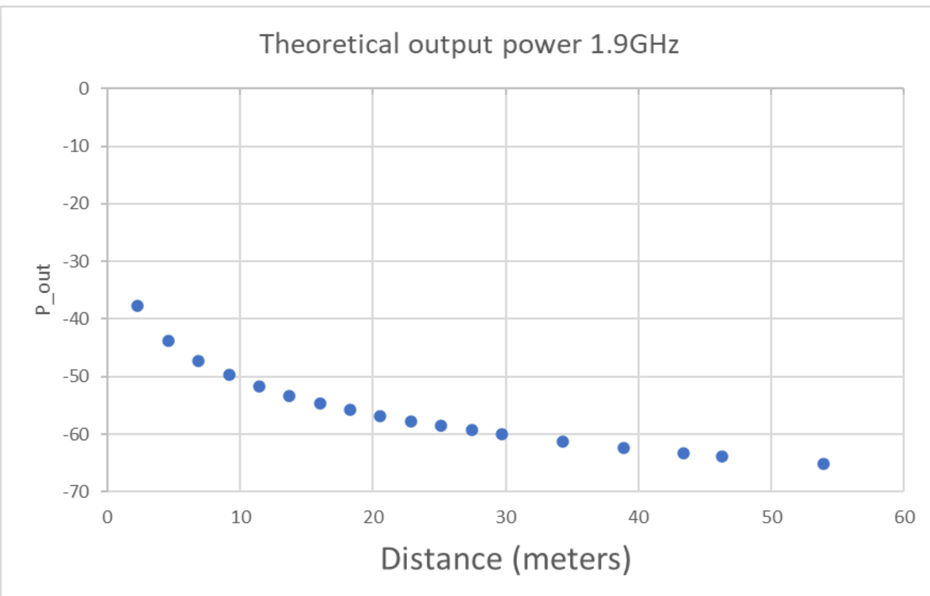
- Signal Generator and amplifier were used to transmit signals at frequencies 1.9 GHz, 3.7 GHz, 28 GHz, and 39 GHz.
- 1dB compression points were found across all 4 frequencies to determine the maximum transmit power.

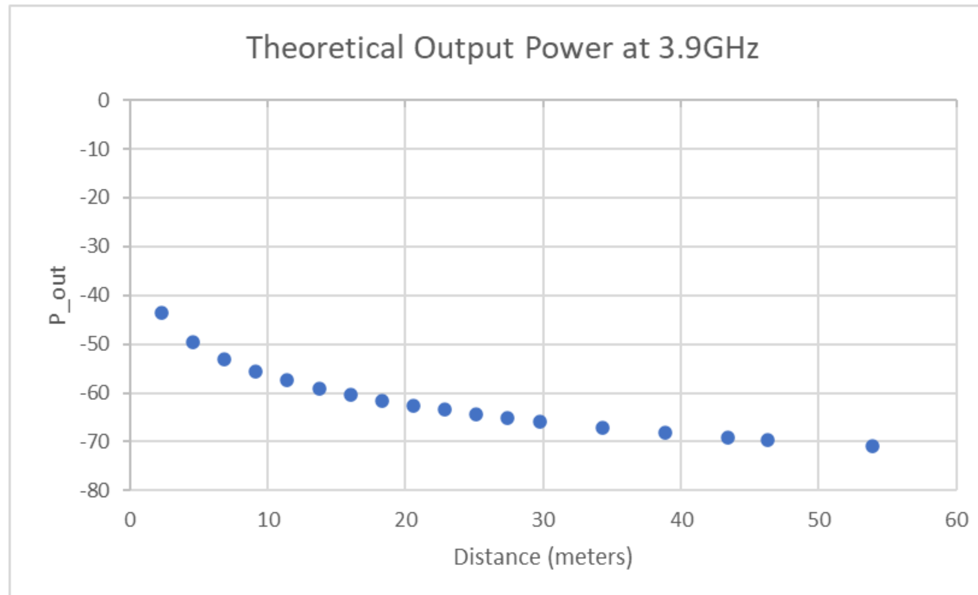
Linear Path Loss Analysis

Linear Analysis or Point to Point Antenna Set-up (PTP)

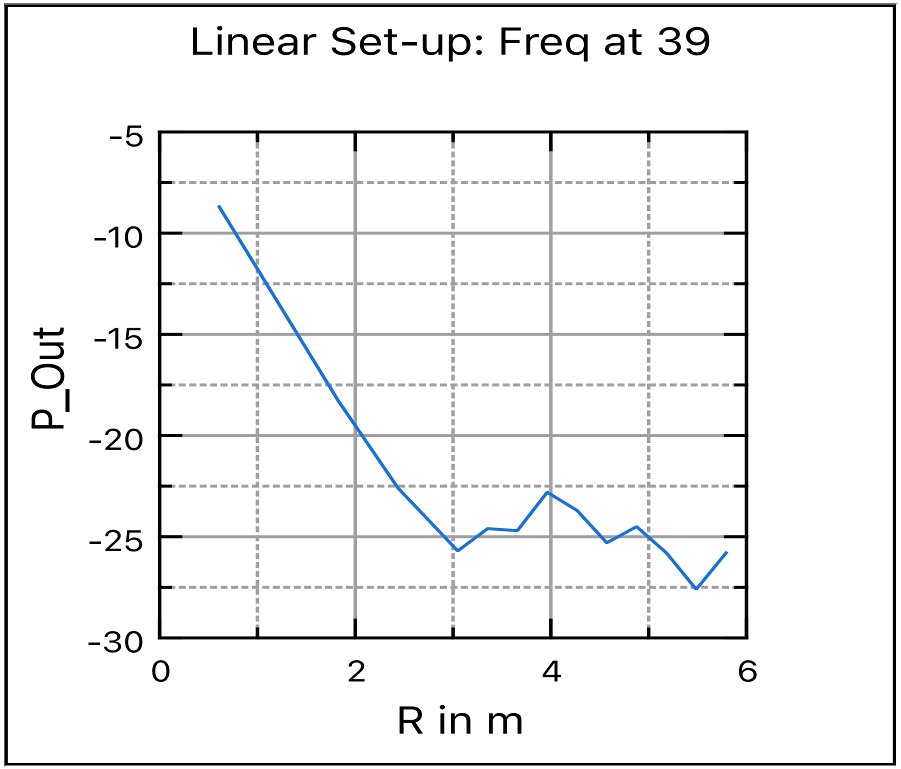
- The signal generators position lies at the transmitting signal in reference to the connected Gain Horn 22240.
- PTP data collection was done by denoting portable Kestrel thermostat the ENV1 humidity and temperature levels. During the data collection phase, the researcher on the receiving end would look at the ANSYS® software and collect peak Output power values
- Collecting peak values at various incremented values of 0.6096 m then at 3.048 m the increments decrease to 0.3048 m.

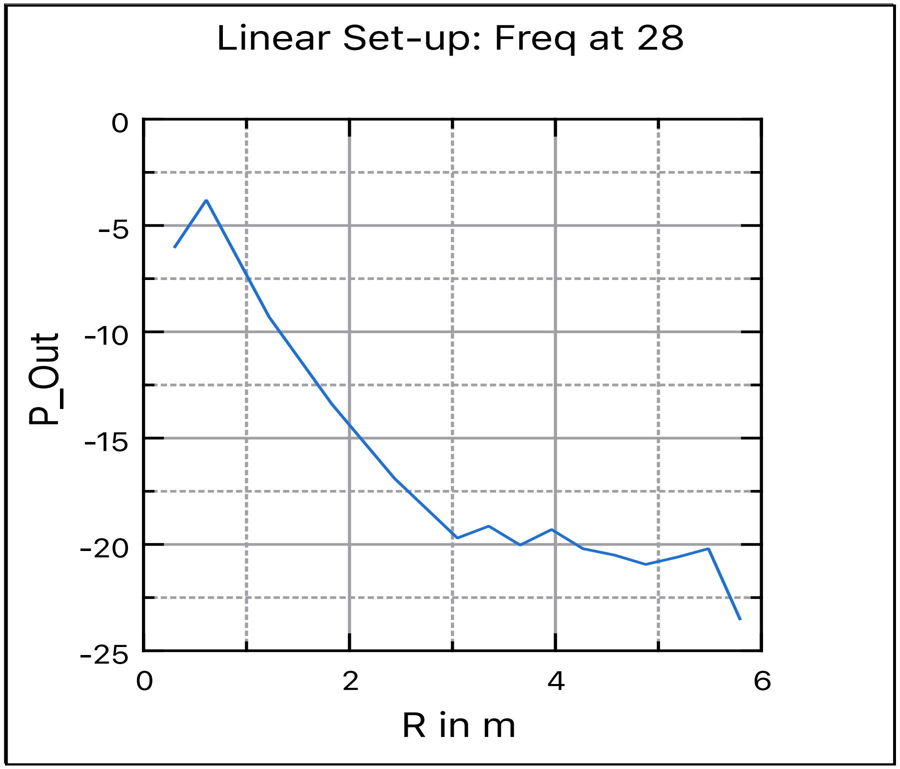
Theoretical output power at 1.9GHz and 3.7GHz





Discussion Graphs





Lateral Displacement Analysis

Point to Point Lateral Analysis (PTPL)

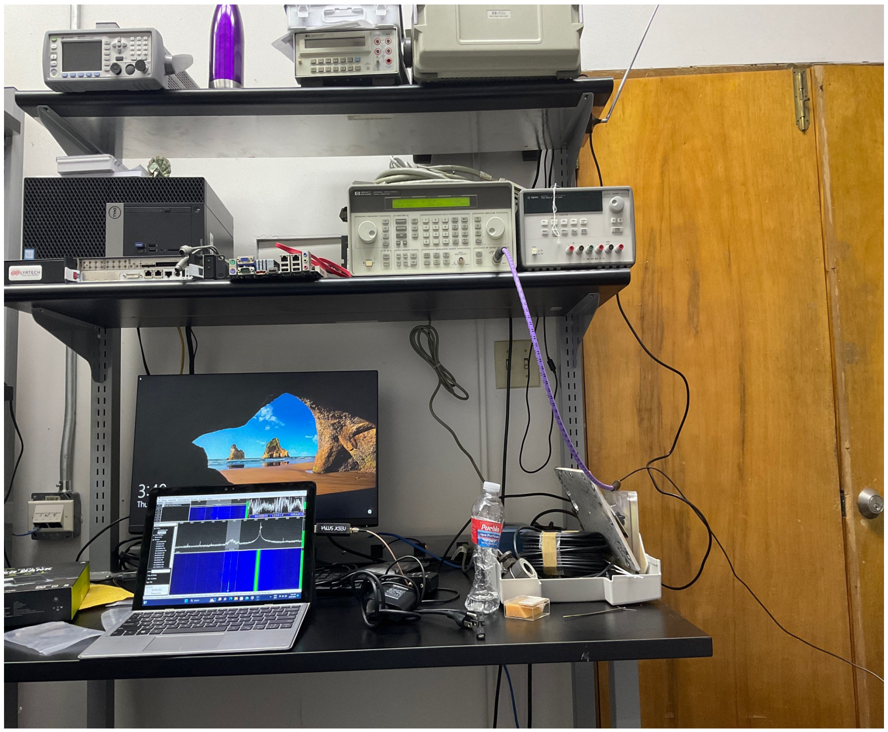
- Researchers used PTP set-up to then add a lateral element of in-field testing in ENV 1.
- Incrementally the researchers distanced themselves from the point of origination after accounting for the output powers values at increments in the negative direction.
- The receiving Gain horn antenna was 3.048 m apart. From this distance linear increments of 3.048 were implemented. At the 18.288 m mark increments of 6.096 were implemented At every incremental PTP distance mark a negative displacement increments of 0.3048, 0.6096, 0.9144 meters was taken to measure the power output peaks.

Angular Displacement Analysis

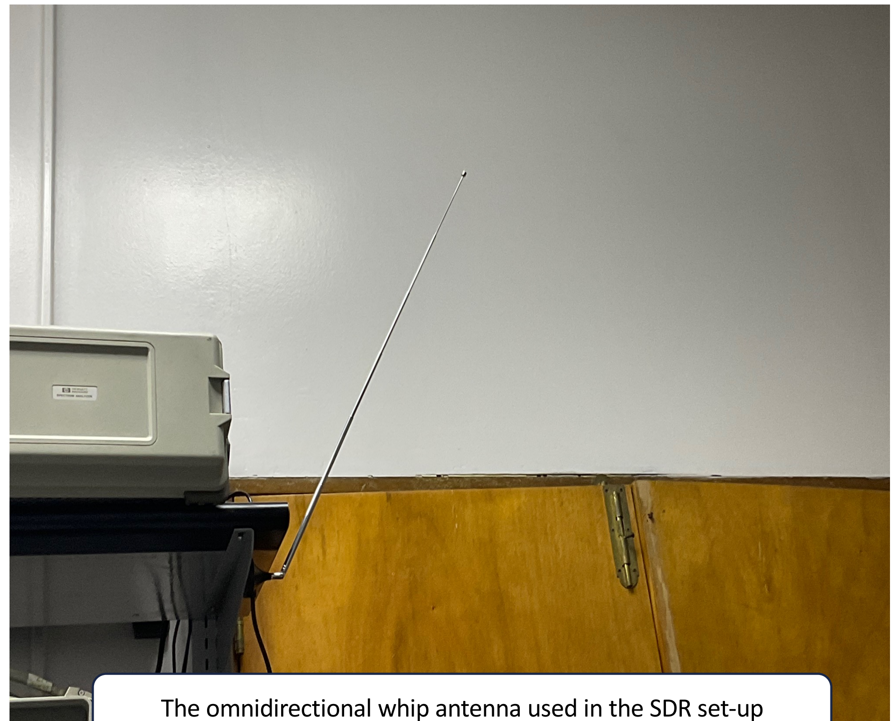
Point to Point Angular Analysis (PTPA)

- Environment 2 or (ENV2) had moderate hallway exposure. The only thing different about the set-up for the angular analysis is the HyperLog's® position (this being at the point of origination were the transmitting gain horn antenna used to be).
- On the receiving end is the OmniLOG39000®, is an omnidirectional receiver.
- Linear displacement increments of 2.286 m were implemented until the value 43.434 m. After that measurement of displacement 1.7399 m was used to cover more ground towards the end of the hallway in ENV2.
- Researchers were only able to environmentally accomplish 0.3048 and 0.6096 m in the negative directionAngularly the researcher that was transmitting would displace the angular antenna in both positive and negative directions in increments of 30° and 90°.

Methodology Phase: 2



Windows laptop, signal generator, spectrum analyzer used in the SDR set-up



The omnidirectional whip antenna used in the SDR set-up

Software-defined Radio (SDR)

Software-defined Radio Studies (SDR) (Phase 2)

- After the installation of the SDR software the researchers were able to use a spectrum analyzer, signal generator, and omnidirectional whip antenna to review transmitted radio signals across multiple frequencies. The spectrum analyzer had multiple ports in the set-up for the in-lab testing two of the four ports were used in the in-lab set-up. This set-up was made so that the spectrum analyzer would connect to the windows PC and the signal generator that was used to interfere with the SDR alongside the omnidirectional whip antenna.
- During the study a list of observations were compiled in a table via excel to analyze the effects of the interference on the radio station 90.2 MHz.

Software-defined Radio (SDR)

- Skirt width is interference seen in adjacent/nearing frequencies to the center frequency of the oscillator signal.
- Skirt width increases as power increases.
- The better the oscillator, the smaller the skirt width.
- Severe enough skirt width can ruin the signal you are measuring.

Omni-Antenna Purposeful Interfrence Data			
		Center Freq (mHz)	
Amp (dBm)	Skirt width (kHz)	Start:	Stop:
-30	70	90.2	90.42
-27	78	90.15	90.45
-24	88	90.2	90.48
-21	100	90.05	90.65
-18	108	90.03	91.54
-15	140	89.4	91.17

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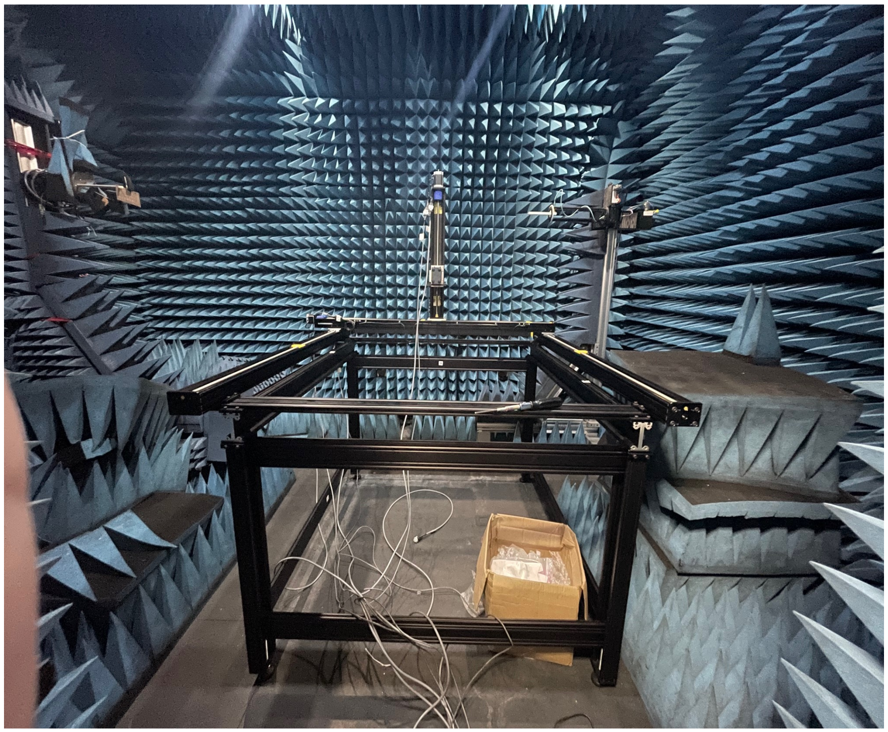
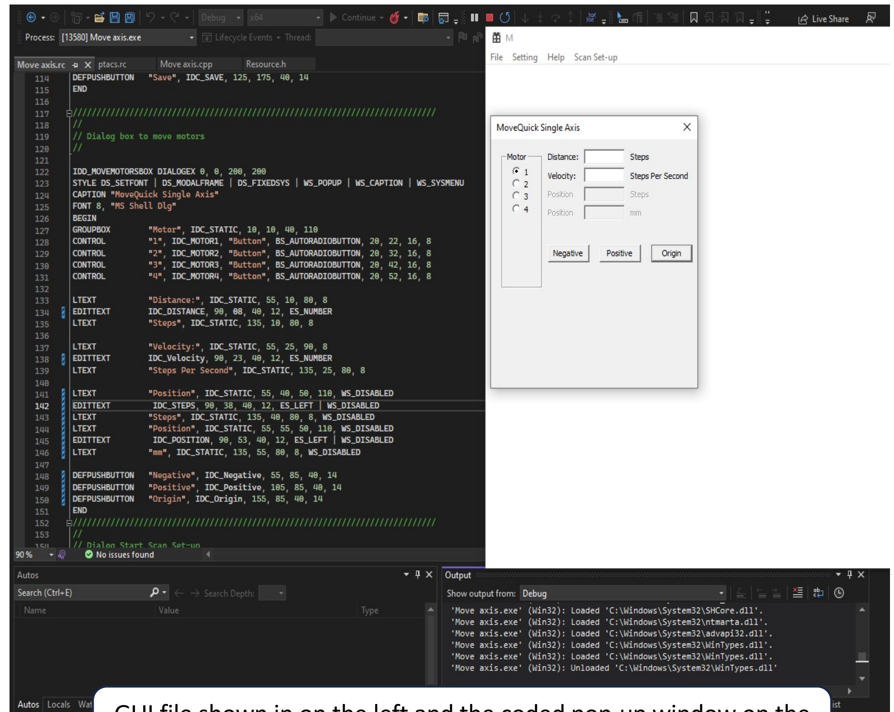
Methodology Phase: 3



The Bi-slide system along with the VXM motor set-up



GUI file shown in on the left and the coded pop-up window on the right

Graphical User Interphase (GUI)

Graphical User Interphase (GUI) for Radiative Prints (Phase: 3)

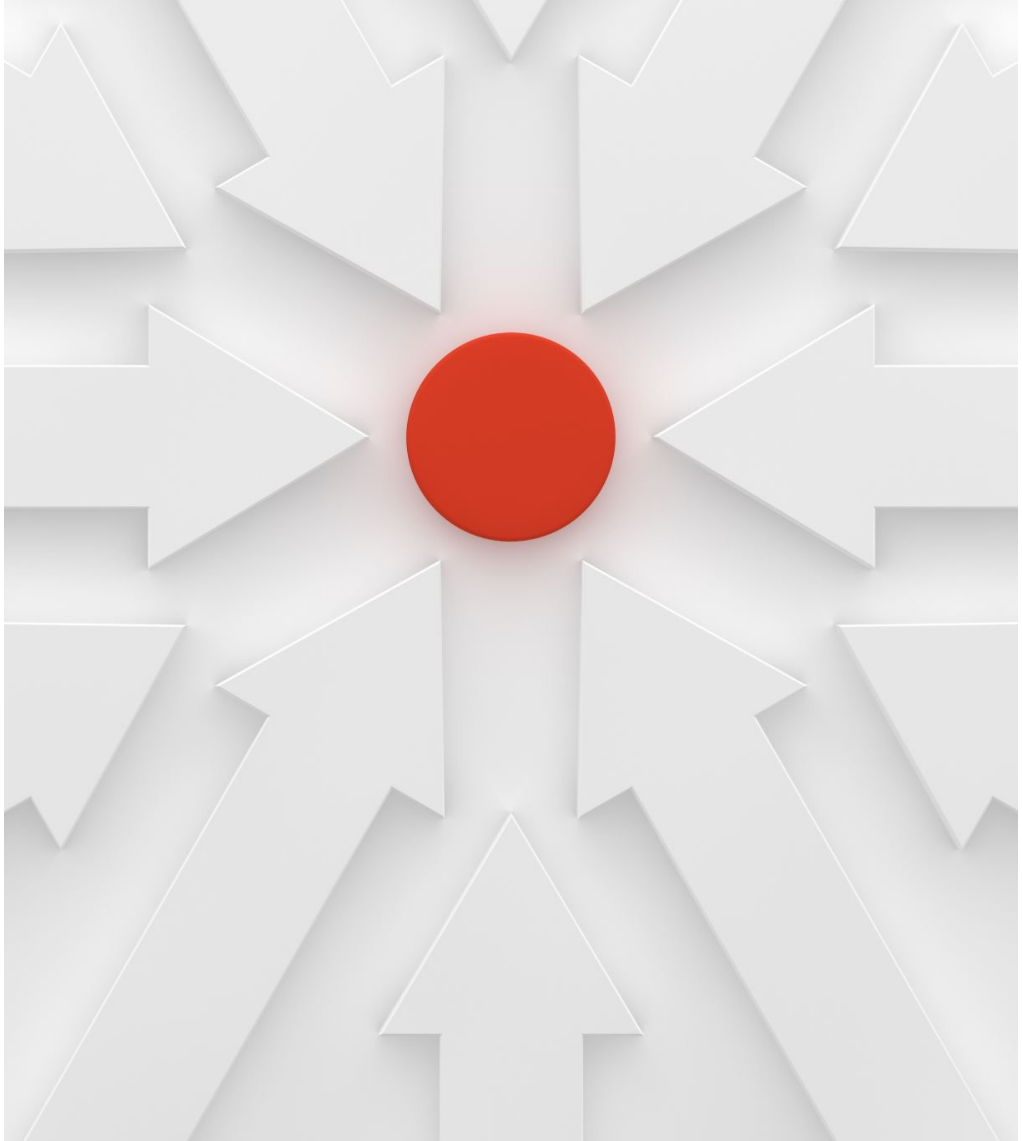
- The Bi-slide system is an arc frame that must be perfectly aligned with its counterpart directly across from it. To accomplish this both researchers used a serve of screwdrivers and Allen wrenches to unscrew items pf the Bi-side system that were not properly aligned about measurements cucullated previously.
- All the readings were leveled and conclusively stated that the bi-slide bars were equidistant to each other a series of test runs including the COSMOS® software was used to test the bas functionality.
- This provided the limits of velocity that must be set for the VXM motors to move and the steps per second that can experimentally and theoretically be accomplished in a certain period.
- While coding the GUI first file was a markdown. The second file is a file that was used was a .h file that served as a file that defined basic outlining variables for the .rc file and .cpp file (the markdown and C coded files). The third file used was the coded C file were both researchers used recourses such as the VXM user manual to encode movements that the VXM motors and the Bi-slide system could recognize to easily interpret data faster for future uses. These sets of movements were connected to the GUI user interface that was designed by both researchers during the pre- liminary makings of the graphical interphase.

Discussion

- Environment played a key role in the path loss experiment.
- Location was important to consider in the interference experiment.
- Radiation pattern mostly falls under future work due to its challenges.

Conclusions

- Path loss is greatly diminished when you have an environment full of reflective surfaces.
- Signal interference and noise are greater at lower frequencies.



Future Work

Phase 1: Antenna Analysis

A tape measure of 25 ft to ascertain distances between the receiving and transmitting antennas to deduct things such as signal threshold. Controls in ENV1 and ENV2 could have been more accurate if measurements were done with things such as an automated measurement system. Both researchers during the phase one experiments could have used levelers to combat the possibility of the terrain of both environments being uneven. A tertiary environment should have been considered were the sets of in-field data lay completely open with extreme airway exposure in a public pathway.

Phase 2: SDR Studies

the omnidirectional whip antenna did not reach smaller frequencies in SDR trials. This range which could have provided observations insight into how interference behaves at lower frequencies. Things like inductors and more omnidirectional whip antennas could have made this possible due to the whip antenna could only servile so many frequency values using the SDR software.

Phase 3: GUI Construction

Construction of GUI did not provide any data as intended because of the constraints of time both researchers faced during the actual alignment of the Bi-slides the initial days of working in the anechoic chamber. This meaning that the graphical interphase provided thought the viewable git-hub server is viably unfinished due to these constraints. Further improvement to the interface can be done to make the options more user-friendly such as helpful description and allocation of objects within the options in the main menu provided in the GUI.

References

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- [2] A. Strickland, "'game changer' satellite will measure most of the water on the planet," CNN, https://edition.cnn.com/2022/12/16/world/nasa-swot-launch-scn/ (accessed Aug. 4, 2023).
- [3] "Radio Frequency Interference," Science Website, https://science.nrao.edu/facilities/vla/docs/manuals/obsguide/rfi (accessed Aug. 4, 2023).
- [4] C. Ramos, C. Padilla-Diffoot, L. Sostre, and S. Vargas, UPRM, Mayaguez, PR, rep., 2018
- [5] L. Rodriguez and E. Novas, "Lizetterod/uprm_summer_2023," GitHub, https://github.com/lizetterod/uprm_summer_2023 (accessed Aug. 4, 2023).