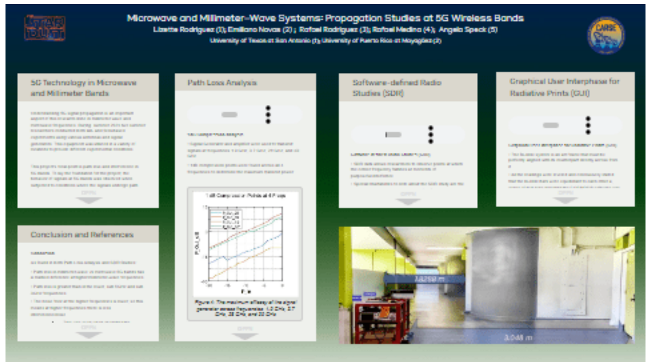
# Microwave and Millimeter-Wave Systems: Propagation Studies at 5G Wireless Bands

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## 5G TECHNOLOGY IN MICROWAVE AND MILLIMETER BANDS

Understanding 5G signal propagation is an important aspect of this research done in millimeter wave and microwave frequencies. During summer 2023 tw field-based experiments using various antennas and signal generators. This equipment was utilized in a variety of locations to provide different experimenta

This project's focal point is path loss and interference in 5G bands. To lay the foundation for the project, the behavior of signals at 5G bands was observed v undergo path loss due to environmental factors, such as wind, humidity, rain, angle and lateral displacement of the signal source/transmitter with respect to the transmitter and receptor, and when subjected to interference at nearing and equal frequencies from other signals. The goal is to find a way to mitigate sa sent and received more efficiently, with less path loss, and lower adverse effects due to noise and direct interference. The results of the listed objectives abo behavior in different bands in the frequencies of 1.9, 3.7, 28,39 GHz. The direct effects of interference were observed for a multitude of instruments includi Horn antennas, HyperLog® antennas.

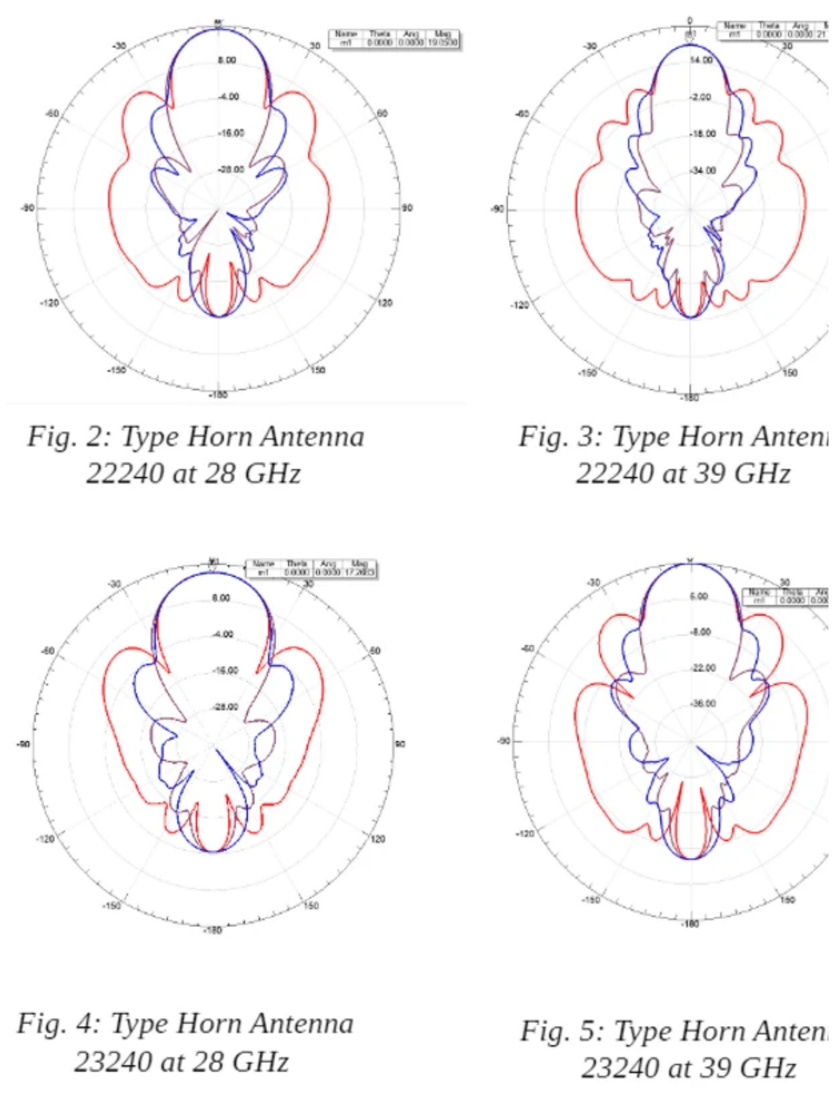


*Figure 1: Horn antenna radiation patterns at 28GHz and 39GHz*

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

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

$\lambda$ = Wavelength

$R$ = Distance between the antennas

*Figure 2: The theoretical power of the receiving antenna equation used in pathloss analysis*

In order to automate and expedite the process of taking antenna pattern measurements in a planar near-field system we have begun development of a user-fi radiation patterns of transmitting antennas at 5G bands in an anechoic chamber using a vector network analyzer controlled by said GUI.

## CONCLUSION AND REFERENCES

**Conclusion**

As found in both Path Loss Analysis and SDR Studies:

• Path loss in millimeter-wave vs microwave 5G bands has a marked difference at higher/millimeter-wave frequencies.

• Path loss is greater than in the lower, sub 5GHz and sub 3GHz frequencies.

• The noise floor at the higher frequencies is lower, so this means at higher frequencies there is less interference/noise.

- This was seen when operating the SDR at AM and FM frequencies. When the machine is tuned to the higher frequencies, well past the 88MHz to 10ℓ could visibly observe the noise floor progressively getting lower.

• Path loss is required to measure antenna radiation patterns at 5G bands, so that the physical behavior of the signals can be better described and modeled.

**Refrences**

• [1] “What is Wifi?,” What Is WiFi? – Spectrum Resources, https://www.spectrum.com/resources/internet-wifi/what-is-wifi (accessed Aug. 3, 2023).

• [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-laur

• [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).

PATH LOSS ANALYSIS

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**1dB Compression analysis**

• 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.

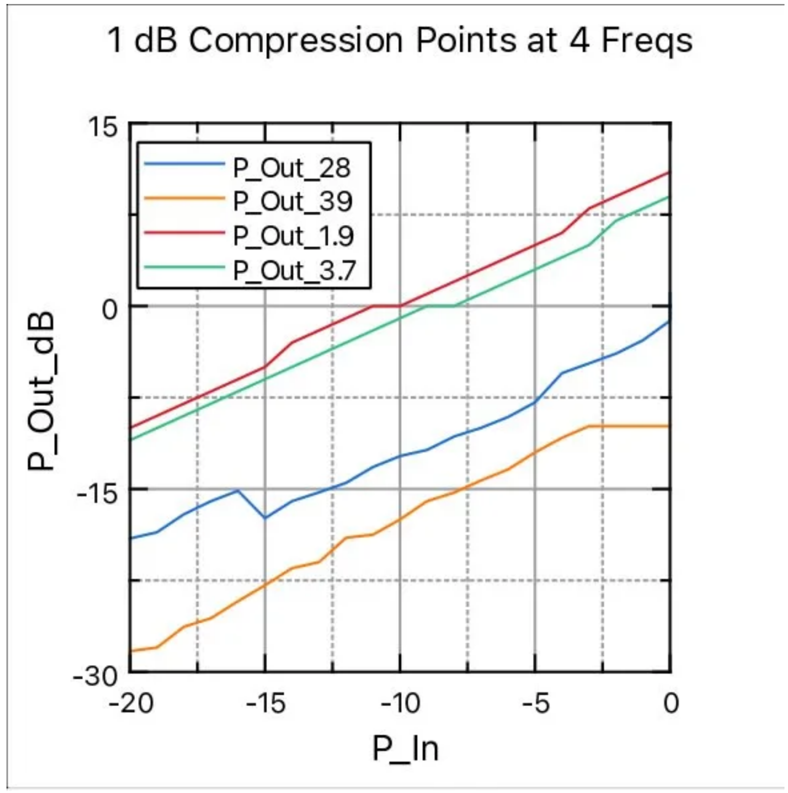


*Figure 4: The maximum efficacy of the signal generator across frequencies: 1.9 GHz, 3.7 GHz, 28 GHz, and 39*

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

• PTP data collection was done in ENV1

• Collecting peak values at various incremented values of 0.6096 m then at 3.048 m the increments decrease to 0.3048 m.

**Experimental:**

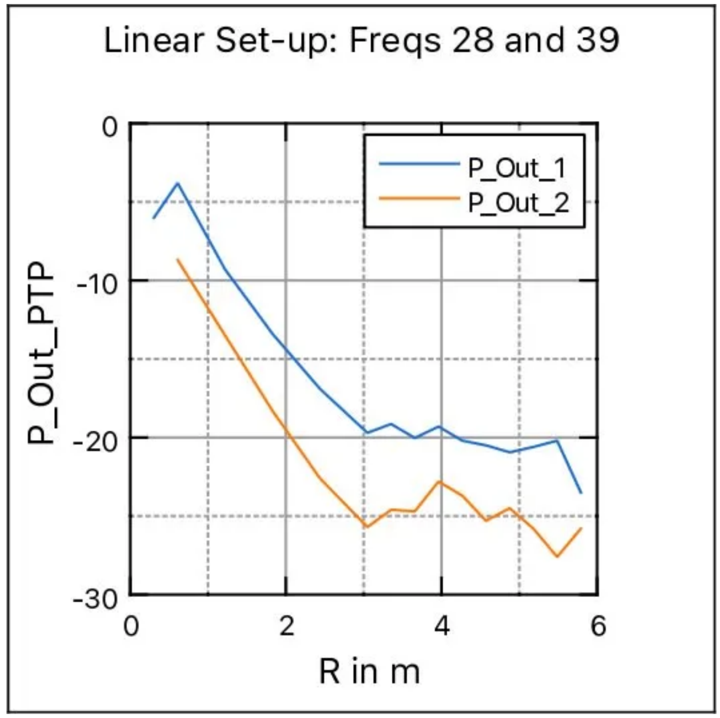


*Figure 5: Linear experimental graph set-up for 28 and 39 GHz*

**Theoretical:**

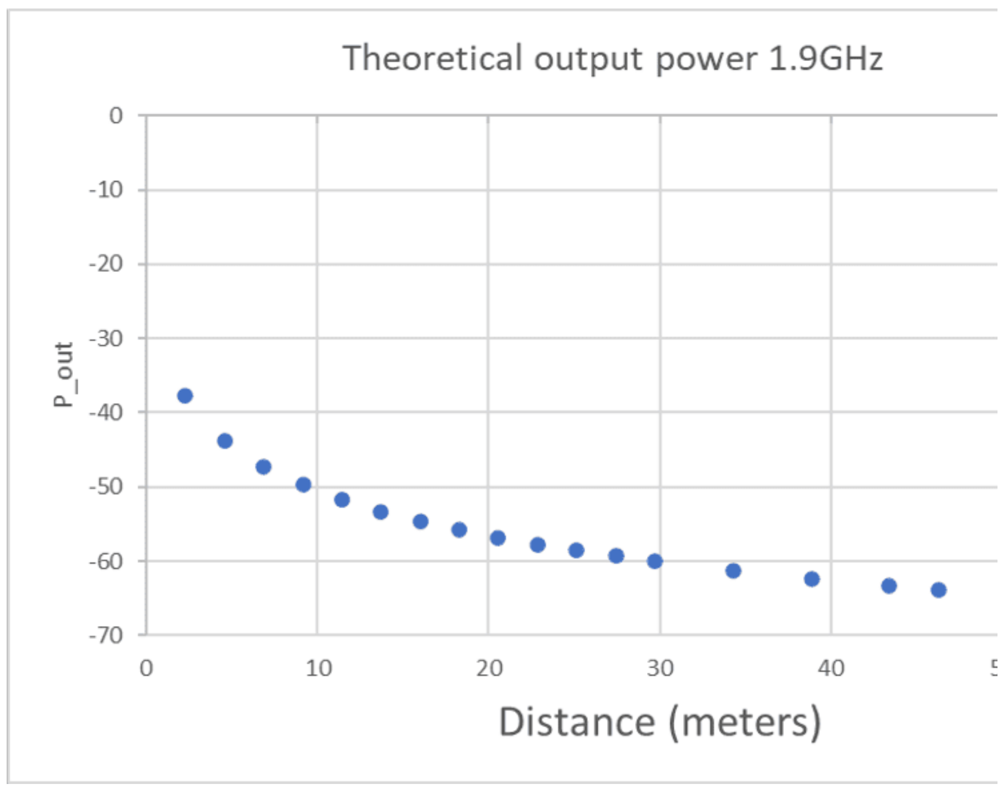


*Figure 6: Calculated output power of the receving gain horn antenna at 1.9 GHz*

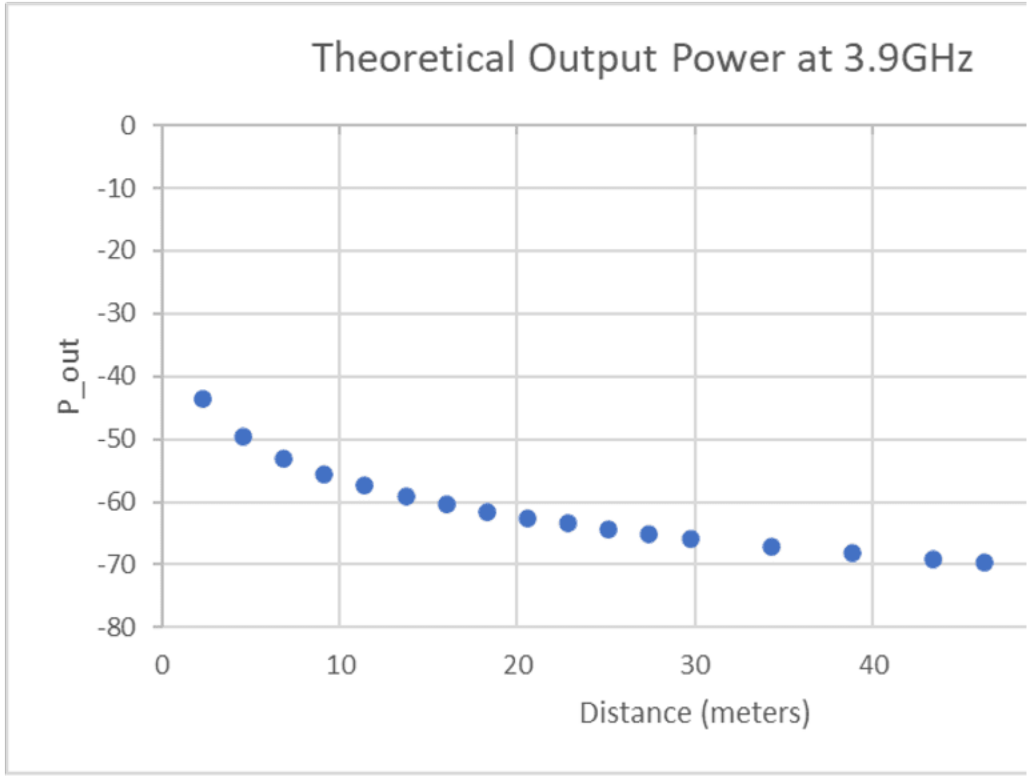


*Figure 7: Calculated output power of the receving gain horn antenna at 3.9 GHz*

**Point to Point Lateral Analysis (PTPL)**

• Researchers used PTP set-up to then add a lateral element of in-field testing in ENV 1.

• 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 c PTP distance mark a negative displacement increments of 0.3048, 0.6096, 0.9144 meters was taken to measure the power output peaks.

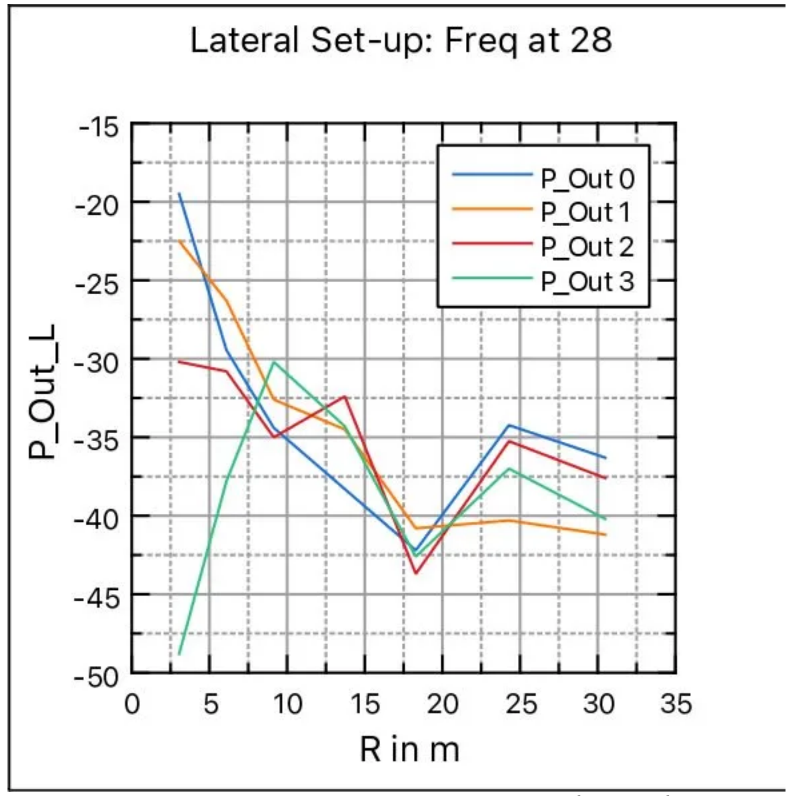

*Figure 8: Out-put power at a linear and added lateral set-up at the frequency of 28 GHz*

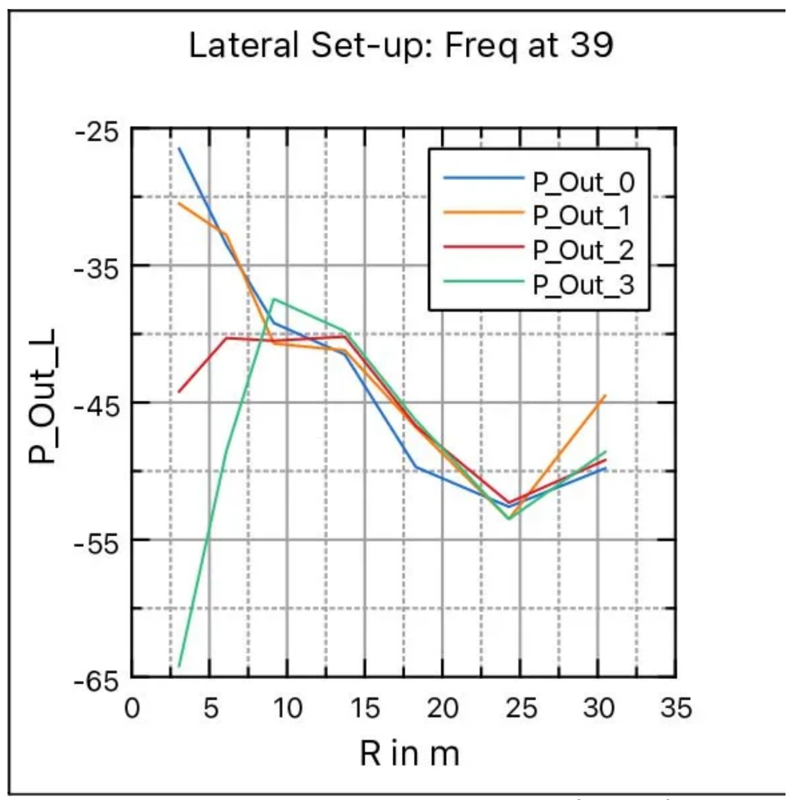

*Figure 9: Out-put power at a linear and added lateral set-up at the frequency of 39 GHz*

**Point to Point Angular (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 ( 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 cc in ENV2.

• Researchers were only able to environmentally accomplish 0.3048 and 0.6096 m in the negative direction.

**Output Powers LAT:**

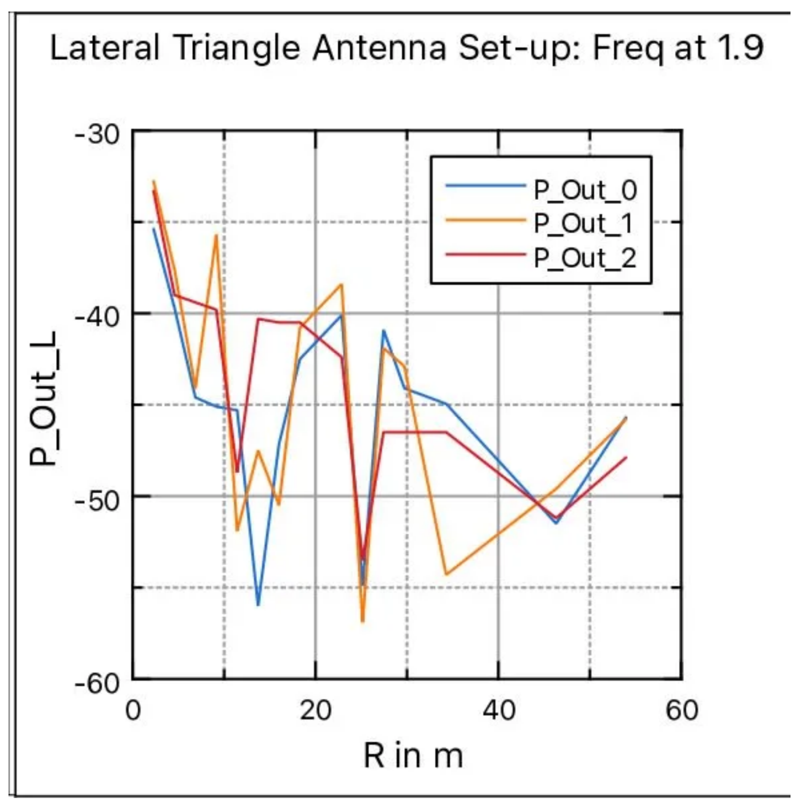


*Figure 10: Out-put power at a linear and added lateral set-up at the frequency of 1.9 GHz*

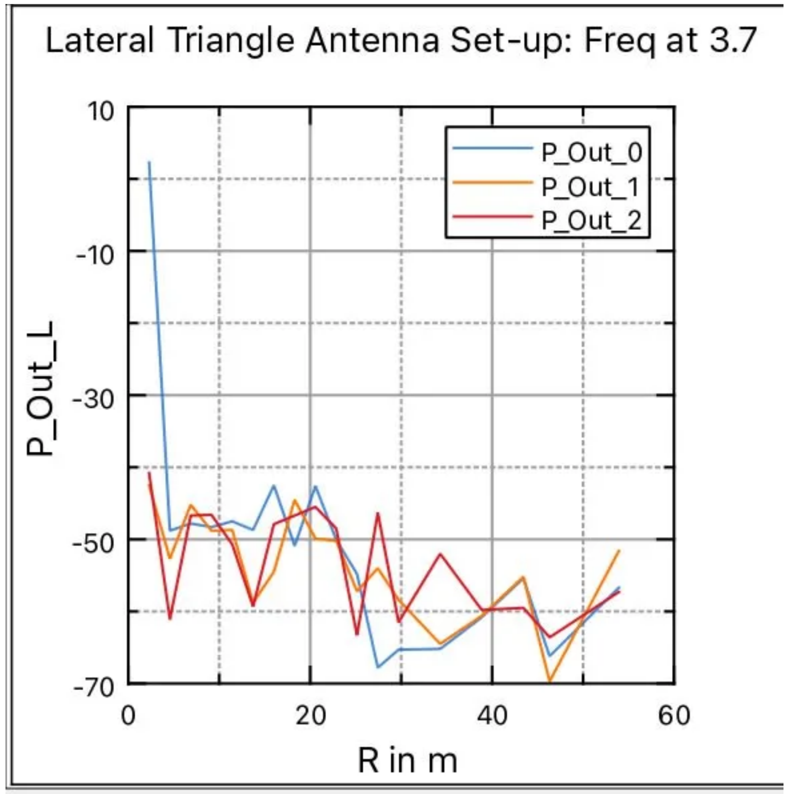


*Figure 11: Out-put power at a linear and added lateral set-up at the frequency of 3.7 GHz*

**Output Powers ANG:**

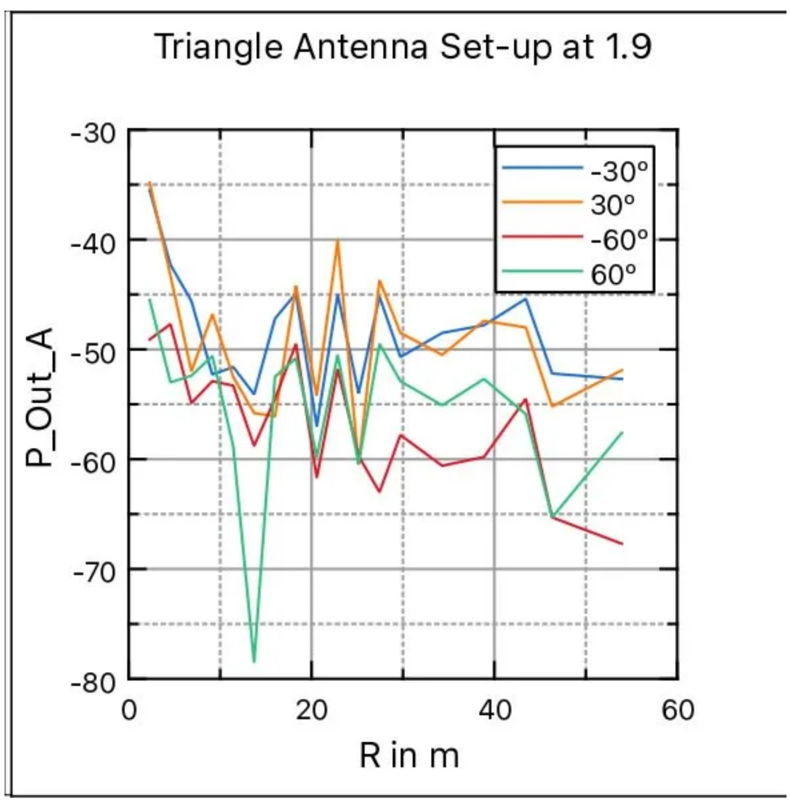


*Figure 12: Out-put power at an angular displacement set-up at the frequency value of 1.9 GHz*

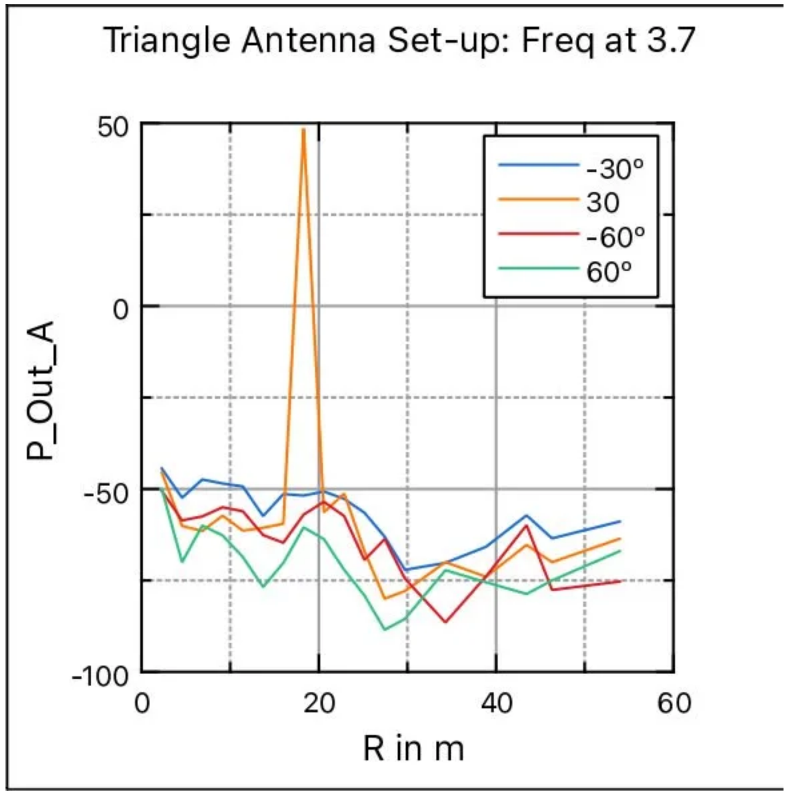


*Figure 13: Out-put power at an angular displacement set-up at the frequency value of 1.9 GHz*

SOFTWARE-DEFINED RADIO STUDIES (SDR)

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**Software-defined Radio Studies (SDR)**

• SDR data allows researchers to observe points at which the cetner frequency flatlines at moments of purposeful interfernce

• Special chartaristics to note about the SDR study are the prominent charteristics noted at the -21 dBm mark which describe as the oscillating signal

| Omni-Antenna Purposeful Interfrence Data | | | |
|---|---|---|---|
| | | Center Freq ( | |
| Amp (dBm) | Skirt width (kHz) | Start: | Sto |
| -30 | 70 | 90.2 | |
| -27 | 78 | 90.15 | |
| -24 | 88 | 90.2 | |
| -21 | 100 | 90.05 | |
| -18 | 108 | 90.03 | |
| -15 | 140 | 89.4 | |

*Figure 3: A table of observations from the purposeful interfernce study done in the FM station*

**Data Analysis**

•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.

GRAPHICAL USER INTERPHASE FOR RADIATIVE PRINTS (GUI)

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**Graphical User Interphase for Radiative Prints (GUI)**

• The Bi-slide system is an arc frame that must be perfectly aligned with its counterpart directly across from it.

• 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® so

• 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 ac

**Coding:**

• 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 an

• 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 a interpret data faster for future uses.

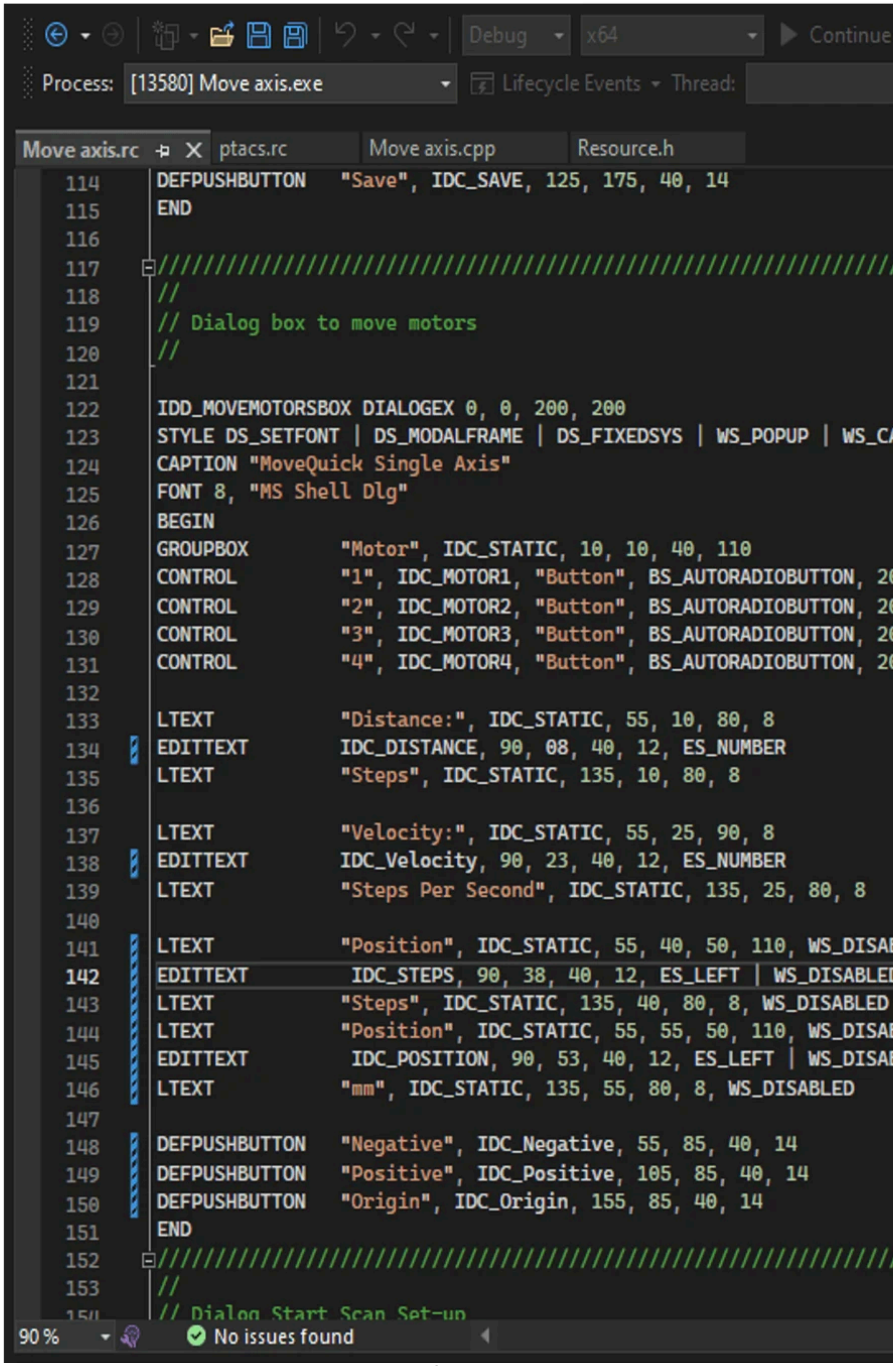



*Figure 14: The GUI markdown that is the ground work for the interavive diplay that works along side Move axis.cpp to control the bi*

uprm_summer_2023 / Move axis / **Move axis.cpp**

**S120 and S120** Update: New Commit.. 8/3/23

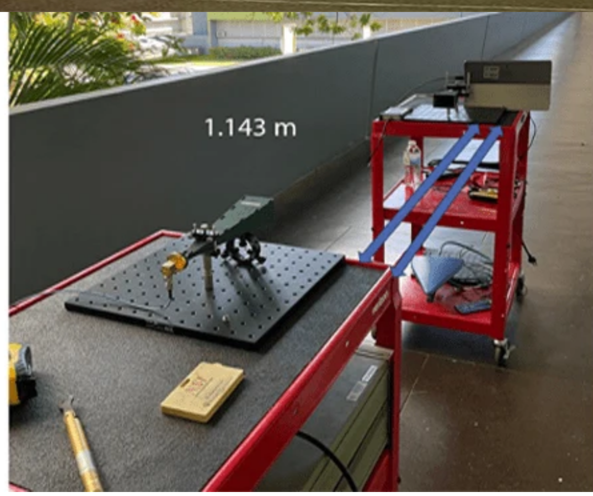
Code Blame 1053 lines (913 loc) · 34 KB

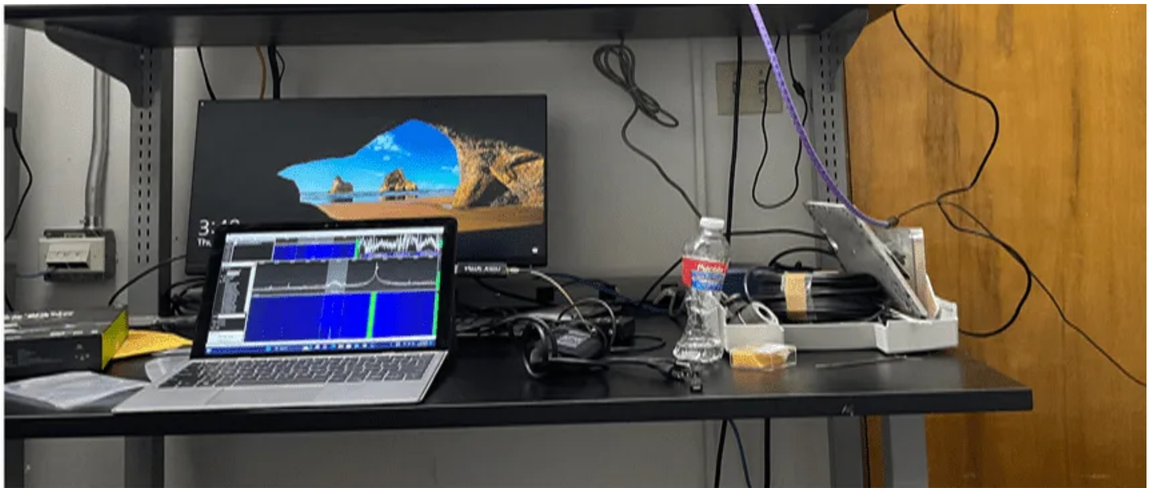
```
// Move axis.cpp : Defines the entry point for the application.
//

#include "framework.h"
#include "Move axis.h"
#include <stdio.h>
#include <math.h>
//include <winuser.h>

#define MAX_LOADSTRING 100

// Global Variables:
HINSTANCE hInst;                                // current instance
WCHAR szTitle[MAX_LOADSTRING];                  // The title bar te
WCHAR szWindowClass[MAX_LOADSTRING];            // the main window
HANDLE hCom;

static struct HardwareInfo {
    char IPaddress[16];
    char rsrcName[64];
    char AntennaPort[6];
    char PositionerPort[6];
}g_Hardware = { "0", "0", "0", "0" };

// structure to control the COM Ports
struct ComStrc {
    char* ComName;
    int BaudRate;
    int ByteSize;
    int Parity;
    int StopBits;
}PosComPort;

// Forward declarations of functions included in this code module:
ATOM                MyRegisterClass(HINSTANCE hInstance);
BOOL                InitInstance(HINSTANCE, int);
```

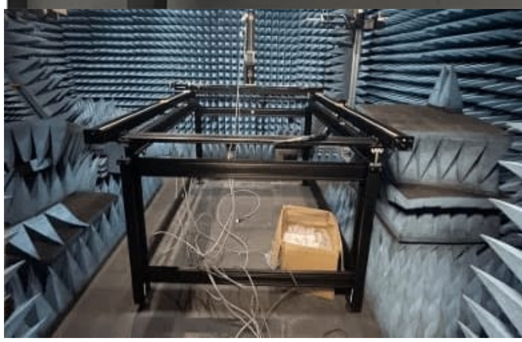
*Figure 15: A picture from github displaying the Move axis.cpp code that shows the many motor fucntions the bislide may have under diff*

• These sets of movements were connected to the GUI user interface that was designed by both researchers during the pre- liminary makings of the graphic:


1.8288 m
0.5334 m
0.5334 m
3.048 m


1.143 m





## DISCLOSURES

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TRANSCRIPT

## ABSTRACT

5G technology has made wireless communication effortless. Researchers have accrued knowledge to make 5G technology reliable and determine how its properties can further progress research in electronics and astronomy alike. Understanding 5G signal propagation is an important aspect of this research done in millimeter wave and microwave frequencies.

During summer 2023 two summer researchers conducted both lab- and field-based experiments using various antennas and signal generators. This equipment was utilized in a variety of locations to provide different experimental conditions. The location selection took into account various parameters including temperature, topography, and accessibility. The main goal was to accurately measure and predict the effects of path loss (drop in signal amplitude with distance) and interference. Following data collection, the results were analyzed to compare propagation behavior in different bands in the frequencies of 1.9, 3.7, 28,39 GHz. The direct effects of interference were observed for a multitude of instruments including signal generators, spectrum analyzers, Gain Horn antennas, HyperLog® antennas. It was found that the effects of path loss are more severe on higher frequencies, while lower frequencies tend to undergo more interference.

In order to automate and expedite the process of taking antenna pattern measurements in a planar near-field system we have begun development of a user-friendly GUI. Future plans include measuring the radiation patterns of transmitting antennas at 5G bands in an anechoic chamber using a vector network analyzer controlled by said GUI.

## REFERENCES


• [1] “What is Wifi?,” What Is WiFi? – Spectrum Resources, https://www.spectrum.com/resources/internet-wifi/what-is-wifi (accessed Aug. 3, 2023).

• [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).

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