Field and Lab Analysis of Radio Frequency Antenna Systems across Multiple Spectrum Bands

R1 – RF, Microwaves and Millimeter-wave Systems

Yamil Guzman, Emiliano Novas, Isaac Rivera, Bryan Busby – Department of Electrical Engineering
Advisor Dr. Rafael Rodriguez Solis – Department of Electrical Engineering

Abstract

Radio frequency propagation measurements across wireless commercial bands (39 GHz, 28 GHz, Sub 6 GHz, Sub 3 GHz, and Sub 1 GHz) play a critical role when designing wireless networks. Understanding propagation characteristics allows more efficient communication networks design, through base station placing for optimum coverage. Path loss and link quality measurements are both necessary to understand the system performance under different propagation environments.

Through this project we propose to investigate the propagation characteristics at 1.9, 3.7, 28 and 39 GHz in different indoor and outdoor locations across campus, using Software Defined Radios (SDRs), signal generators and spectrum analyzers to measure the path loss and link quality.

Problem and Hypothesis

5G systems operating at millimeter-wave frequencies suffer from attenuation and fading due to different environmental factors, such as precipitation, fog and humidity. In addition, natural and man-made materials like concrete, metal, and wood, limit the communication range. These effects are less pronounced at lower microwave frequencies, and it is important to compare these effects at different frequencies. Path loss (received power) measurements can be useful for this purpose, but they do not necessarily indicate their effects in link quality or data transmission rates. Software Defined Radio Systems provide an alternative for transmitting and receiving modulated signals and testing link quality.

Through propagation measurements across the different bands, it is possible to optimize network design, with the appropriate mix of frequency bands, to ensure coverage, availability and reliability at the data rates expected from 5G systems.

Objectives

- Analyze and compare the propagation characteristics at 28, 39, 3.7 and 1.9 GHz using directional antennas as the transmitter and receiver to measure the power received in different architectural environments.
- Analyze the effects of reflection, diffraction, and penetration with different materials at different frequencies in a laboratory setup and in the field.
- Develop a SDR based transmission and reception system for the propagation measurements at 3.7 and 1.9 GHz.
- Develop a Vivaldi antenna array for the transmission and reception system at 28 and 39 GHz.

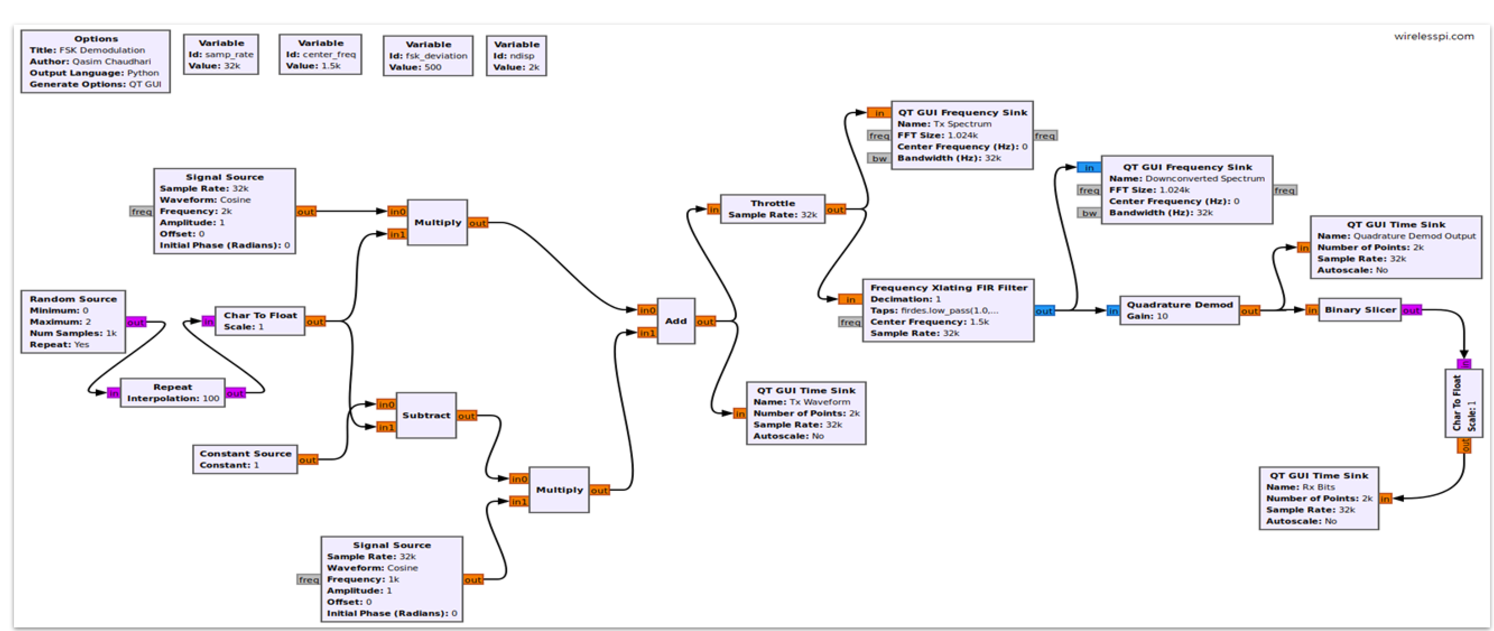
Methodology

During this year we will concentrate in three areas: (1) Programming of the USRP B205 mini-i using gnuradio as a transmitter and a receiver for the frequencies of 1.9 and 3.7 GHz; (2) Diffraction experiments at 1.9, 3.7, 28 and 39 GHz using the existing signal generator and spectrum analyzer, and (3) the design of compact Vivaldi antennas for measurements at 28 and 39 GHz.

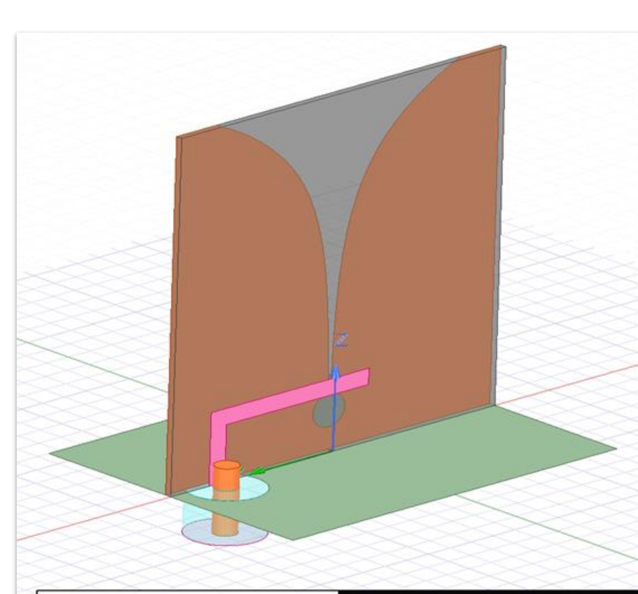
For (1) we will use gnuradio to initially program simple waveforms for transmit, and the receiver to capture the waveforms, and build on the experience gained to program digital modulated signals for transmit and the appropriate receiver. The end goal is to calculate the bit error rate at the receiver, knowing the transmitted sequence.

For (2) we will select different areas on campus, and set up different experiments in the laboratory, to measure diffraction effects when energy hits corners at different angles. We will start with line-of-sight path loss measurements to gain experience in the use of the instrumentation and obtain benchmark values to compare to when the diffraction studies are performed. We will use the existing antennas, signal generator, and spectrum analyzer to perform the propagation measurements.

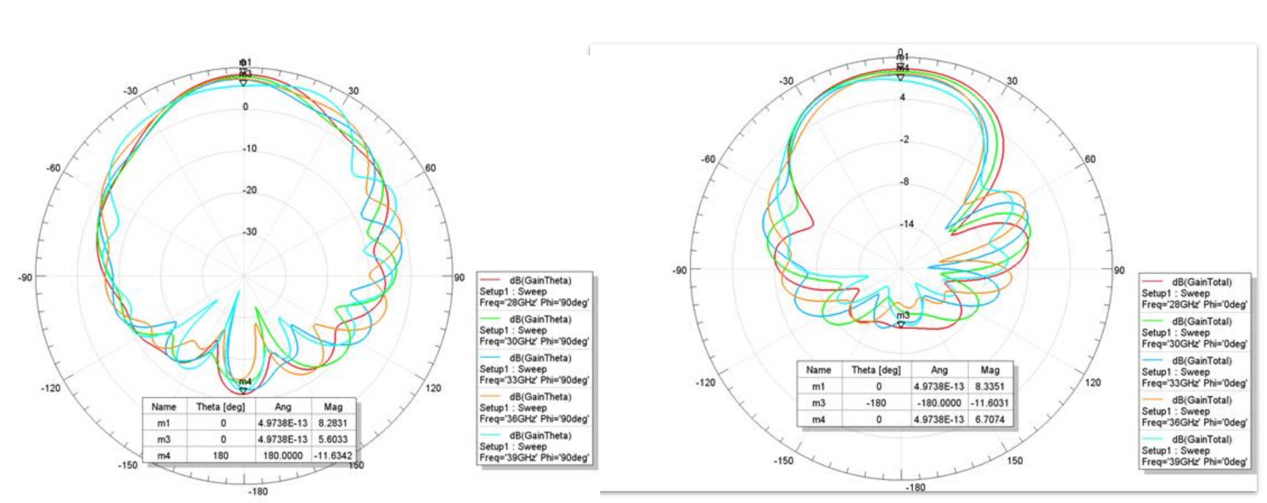
For (3), using existing data from research done during the summer of 2023, in which power measurements were taken using standard gain horn antennas in order to observe physical behavior and the effect of path loss on signals at 5G bands, we will design a Vivaldi antenna using Ansys HFSS, prototype the antenna, and measure the fabricated antenna impedance using a vector network analyzer in the laboratory.




Example setup in gnuradio, and USRP B205i mini being used in the project



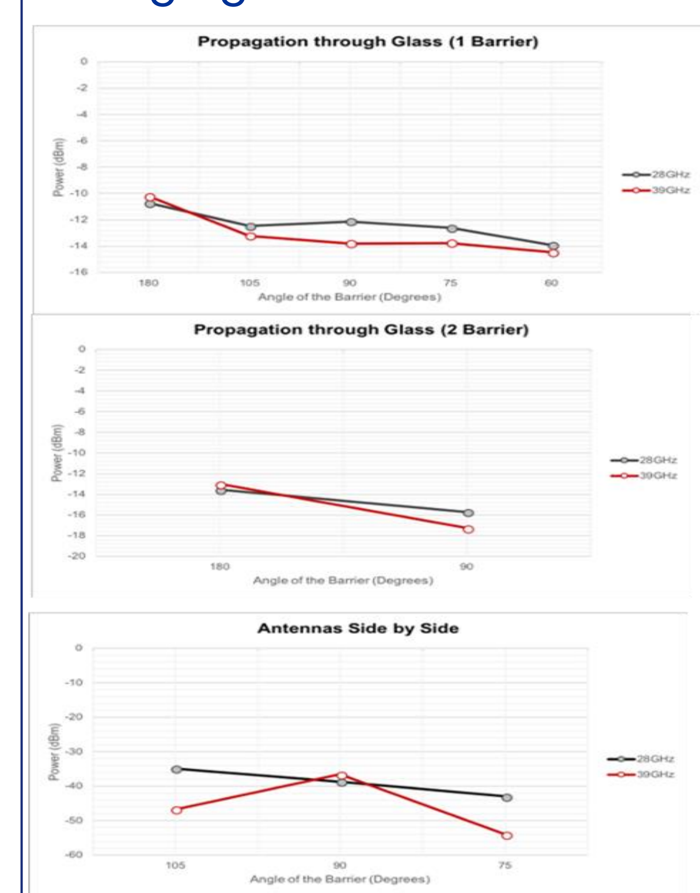
Ansys HFSS model of the proposed Vivaldi slot antenna



Simulated H-plane (left) and E-plane (right) gain patterns for the Vivaldi antenna

Preliminary Results

We have started the design process for the Vivaldi antenna and the initial gain patterns are shown. In previous activities with Verizon we performed propagation measurements at 28 and 39 GHz. An example of the setup measuring propagation through glass is shown below.



Timeline

1. Organization (September)
2. Introduction to 5G systems and ANSYS Electronics HFSS simulation program. (Sept-Oct)
3. Familiarize with gnuradio. (Oct-Dec)
4. Antenna simulation and design. (Oct-Dec)
5. Diffraction measurements (Oct-May)
6. Programming of signals in SDR, and Antenna fabrication and measurements. (Jan-Mar)
7. Propagation measurements with SDR (Mar-May)

References

Verizon 5G Technical Forum: http://www.5gtf.org/

USRP Guide
http://kb.ettus.com/B200/B210/B200mini/B205mini_Getting_Started_Guides

3GPP
http://www.3gpp.org/news-events/3gpp-news/1674-timeline_5g Tentative

Acknowledgements

This work is performed as part of the ECE Industry Affiilates Program, with the support of Verizon.This work was supported in part by the NSF Center for Advanced Radio Sciences and Engineering, under Cooperative Agreement Award AST-2132229.