Senior Design Proposal

1 Introduction

Current beamforming technologies require a large array of antennas and are subsequently very expensive. The antennas are active elements and must be individually tweaked to change directions. Using Nico and Dr. Chisum's novel lens antenna prototype, a simple, linear feed antenna can be used in series with GRIN lenses to beam form inexpensively without sacrificing performance.

2 Problem Description

Low Earth Orbit (LEO) satellites orbit 1000 km above the Earth, delivering cheaper high-speed internet capability to rural communities. 5G mmWave transmission is difficult through modern windows because they are composed of low-emissivity glass to minimize the amount of infrared and ultraviolet light that can pass through glass. Therefore, there is a need for a 5G WIFI repeater mounted on the inside of a window to bridge services from a 5G base station into a user's home.

3 Proposed Solution

Subsystems

- **Feed Translation Mechanism**
  - Provides the electronic control of the feed antenna position to allow for beam control on the antenna. A proposed solution is to attach the feed antenna to a threaded bushing and the DC/servo motor to the rod to enable lateral shifting
- **Mounting Hardware**
  - Designing and fabricating the mount to attach the lens antenna and translation hardware to the window (i.e Suction Cups)
- **Casing and Design**
  - Inexpensive, 3D printed structure with metal-layering
  - Modularize the major subsystems and iterate on the build
- **Microcontroller and Associated Functions**
  - Power reading/indicator
    - Responsible for displaying the current feed antenna position and the current strength relative to the optimal position
    - A power sensor will be used to determine the current strength
  - Translation control (DC Motor)
    - Allow the user to adjust the position of the feed antenna with a simple UI/buttons. Auto-adjustment feature as well to ensure maximum power.
  - Board Design

        - A PCB board will be designed to accommodate the serial communications between the sensors and the microcontroller
- **Parallel Plate Waveguide**
    - Designing and constructing the parallel plates to guide the propagation wave from the GRIN lens to the feed antenna
        - 3D-print the PPWG and add metal layering in the desired spots
- **Indoor Antenna**
    - Used to propagate the amplified outdoor mmWave signal in an indoor environment
    - Ideally a wideband antenna but either 28 or 39 GHz would work as well
- **Gain Block**
    - Allows for transmit and receive signals to/from the indoor antenna

4 Demonstrated Features

Feed Translation Mechanism

- The lens antenna can be moved across the desired range with no issues
- The feed mechanism is able to move at the desired sensitivity

Mounting Hardware

- The casing containing the system is able to be securely attached to a window

Casing and Design

- An inexpensive, sleek, 3D printed design should be ready for demonstration
- The design holds the GRIN lenses, feed antenna, MCU, Motor, and LED indicator
- The power level linked to the LED is prominently displayed on the casing

Microcontroller and Associated Functions

- The available power relative to the optimal configuration is correctly displayed on the LED interface
- The feed mechanism has an automated feature that can keep the antenna in the optimal position at all times
- The MCU is able to determine where the feed antenna is at all times
- The serial communication lines correctly receive and transmit data to/from the sensors

Parallel Plate Waveguide

- The propagation wave is correctly routed from the GRIN lenses to the feed antenna

- Minimal loss due to the waveguide

Indoor Antenna

- The signal is correctly propagated in the indoor environment and can be identified

5 Available Technologies

- Feed translation with electronic control: Linear rail composed of stepper motor and rail.

  https://amzn.to/3CdVTGz

- Power Supply: Many power supplies can be found online for less than $15 such as

  https://amzn.to/3kEjMBh

- Microcontroller: PIC32MX174F2

  https://bit.ly/2YOqAEQ

- Parallel Plate Waveguide: We will consult with Nico Garcia more on this part, but we plan to construct our own.
- Indoor Omnidirectional Antenna: This area we are not sure on yet, we are going to discuss the topic more with Nico.
- Gain Block comprising x4 amps: provided by Nico
- Suction Cups:

  https://www.amazon.com/CONBOLA-Suction-Upgraded-Accessory-Securing/dp/B08N13T8X2/

- Motor and threaded rod:

  https://www.amazon.com/Motor-M355MM-Thread-Output-500RPM/dp/B07556CZL1

6 Engineering Content

Subsystems

- **Feed Translation Mechanism**
  - This system will require our group to integrate a power sensor with the GRIN lens technology, microcontroller, and a linear rail stepper or threaded rod/servo motor. The purpose of this system will be to determine

the optimal position of the Lens in order to provide the optimal gain for receiving data.

- **Mounting Hardware and Enclosure**
  - In order for our prototype to be completed, it needs to be able to be mounted to a window. This will require the design and/or purchase of an enclosure for electronic components and the mounting hardware to ensure the device remains connected to a window. This system will require 3D printing and CAD work.
- **Microcontroller and Related Functions**
  - This subsystem will require coding and debugging in addition to the control of our feed translation mechanism and LED readouts.
- **Board Design**
  - The board design will need to accommodate serial communication lines between our power reading device and our microcontroller. Additionally, the board will need to connect our microcontroller to our feed translation mechanism and provide LED status updates to the user.
- **Parallel Plate WaveGuide(PPWG)**
  - In order to direct our desired signals between GRIN Lenses we will need to design a low cost simple fabrication PPWG. This will most likely be a 3D printed project with metal layerings in order to form the necessary waveguide.
- **Indoor Antenna**
  - Ideally a wideband antenna to transmit and receive in indoor space

7 Conclusions

Using our solution, an inexpensive application of the lens antenna can be demonstrated, performing beamforming without the use of a large array of antennas. Our design will produce a secure, sleek device that can be attached to any window in order to amplify mmWave signals from nearby base stations. The adjustable feed translation mechanism will allow for maximum power transfer regardless of the orientation of the incoming mmWaves and be correctly amplified indoors for all mmWave needs. Further, the power level of the feed relative to the optimal position will be prominently displayed, allowing for visual confirmation of the system working properly.