Wi-Fi Mapping

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Abstract: Devices like computers, mobile phones, and other wireless equipment can be interfaced with the Internet by Wi-Fi, a wireless networking technology. Through a wireless router, internet connectivity is established. When Wi-Fi is accessed by devices, they are being connected to a wireless router that allows the devices to interface with the internet in a compatible manner. The Radiation from Wi-Fi module does not spread equally in space. This work deals with mapping the radiation in space and to track the positions where the maximum radiation is obtained for a wireless device. A highly directive receiving antenna is used to measures the power dissipated by the router at each location in a building/office. This power reading is converted into a 2D image and overlaid on top of a real-life image which can help consumers easily identify the distribution of Wi-Fi signals in their building.
Keywords: Antenna, Wi-Fi, Directivity, Heatmap

I.   INTRODUCTION

The state-of-the-art wireless technologies has led to a tremendous increase in the preferences for wireless devices. In the indoor scenario, the wireless devices connect to internet through the router which is a hardware device that enables users to link multiple computers and other devices to a single internet connection. When Wi-Fi is accessed from other devices, they get linked to a wireless router allowing the Wi-Fi compatible devices to connect to the internet. The signal radiation does not equally spread in space.

A consumer mounts the router in a random place without knowing which place will result in maximum usage of signal strength of the Wi-Fi signal. If the router is in a remote corner of the house, then the router covers unnecessarily a great deal of the outside world. Shifting the router to a more centralized location is a viable option. The closer the router is to the middle of the coverage area, the better the reception in the house will be. The chances for neighboring routers to interfere with each other is high in an apartment building. The strength of Wi-Fi signals inside a building is primarily determined by the size of the building and the obstacles that impede signals from reaching their intended destination. Positioning the router in the optimum location will enable to improve the signal strength and thereby provides a better user quality.

A 2.4GHz tuned helical antenna is designed with materials in the form of the pipe, copper wire, connectors and wireless adapters and various other components. A highly directive receiving antenna that measures the power dissipated by the router at each location in a building/office is designed. The power reading is further converted into a 2D image and overlaid on top of a real-life image which helps the consumers easily identify the distribution of Wi-Fi signals in their building.

This solution will enable the users to place the router in the optimum location and properly using the available strength of the router rather than buying alternatives to boost the signal reach.

II.   METHODOLOGY

2.1   Hardware Implementation

2.1.1   Software Defined Radio

The signal acquisition and signal processing parts work hand in hand as we use the help of an SDR for acquiring and processing the Wi-fi Signal.

Software Defined Radio (SDR) is a most commonly used radio communication device where in mostly used hardware implemented components are instead implemented via software. They are systems on a computer or through other embedded systems. After radio frequency signals are reduced, the auditory frequency band is sampled with a high-performance audio frequency ADC.

All demodulation, filtering (both audio and video frequency), and signal amplification settings are controlled by the SDR (equivalent and binaural presentation).The application of digital signals to radio waves is known as SDR.

SDR intended for this project is HackRF One

HackRF one is an SDR peripheral capable of receiving and transmitting radio signals ranging from 1MHz to 6GHz. HackRF one is an open-source hardware platform that may be used as a USB peripheral or programmed for stand-alone operation. It was created to aid in the creation and testing of new and next generation radio technologies. The HackRF One is an all-in-one SDR in a small, lightweight shell.

Fig.1: HackRF One SDR

2.1.2   Arduino Microcontroller

Arduino is a free and open-source platform for creating electronic projects. Arduino is made up of a hardware programmable circuit board (also known as a microcontroller) and software (IDE) that runs on a computer and to the physical board, computer code is written and uploaded. We are using Arduino Nano for this project. The Arduino Nano is a small, comprehensive, and breadboard-friendly microcontroller based on the ATmega328P. In a smaller form, it delivers the same connections and characteristics as the Arduino Uno board.

The Arduino Nano contains thirty male input and output headers arranged in a dip-30 style that can be programmed using the Arduino Software integrated programming environment (IDE), that is present in all Arduino boards and can be used both offline and online. A 9V battery can be used to power the board or a type-b micro-USB cable. It includes a more powerful ATmega4809 processor as well as double the RAM.

Fig.2: Arduino Nano

2.1.3   Stepper Motor

A stepper motor, is a brushless DC electric motor which is also called as stepping motor or step motor divides a whole rotation into a sequence of equal steps. The position of the motor can be instructed without any position sensor for feedback to move and hold at one of these steps as long as the motor is suitably sized for the application in terms of speed and torque.

For this project, we are using the Nema17 stepper motor. The Nema 17 is used as the stepper motor because it has enough torque to keep the antenna in place. A hybrid stepping motor with a holding torque of 3.2 kg-cm, the NEMA 17 is a hybrid stepping motor. CNC machines, hard drives, printers, CNC machines, laser cutters, and linear actuators are all examples of NEMA17 stepper motors in use. The motor comes with six lead wires and a 12-volt rated voltage. It can run on a lower voltage source. These motors have a step angle of 1.8 degrees, which means they have 200 steps each revolution and each step covers 1.8 degrees, resulting in a high level of control. These motors run on 12 volts and can produce a lot of torque.

Fig.3: Nema17 Stepper Motor

2.2   System Design
         A highly directive antenna tuned to 2.4 GHz frequency for detecting the Wi-fi signal is constructed and mounted on top of an Arduino controlled platform and moves the antenna both the horizontal and vertical plane. It receives signal radiation from the Wi-fi module. The antenna is connected to the SDR (Software Defined Radio) that captures the power from signals obtained from the antenna at a defined interval. This SDR is accompanied by a software companion like GNU Radio which helps in acquiring the power readings. This reading is stored in a data file (.txt) and is imported to MATLAB for image processing. The spatial coordinate for plotting the image is predefined in the code and the final heatmap image is derived. Further the heatmap image is overlaid on top of a real-life panoramic image for easy visualization of the signal power distribution.
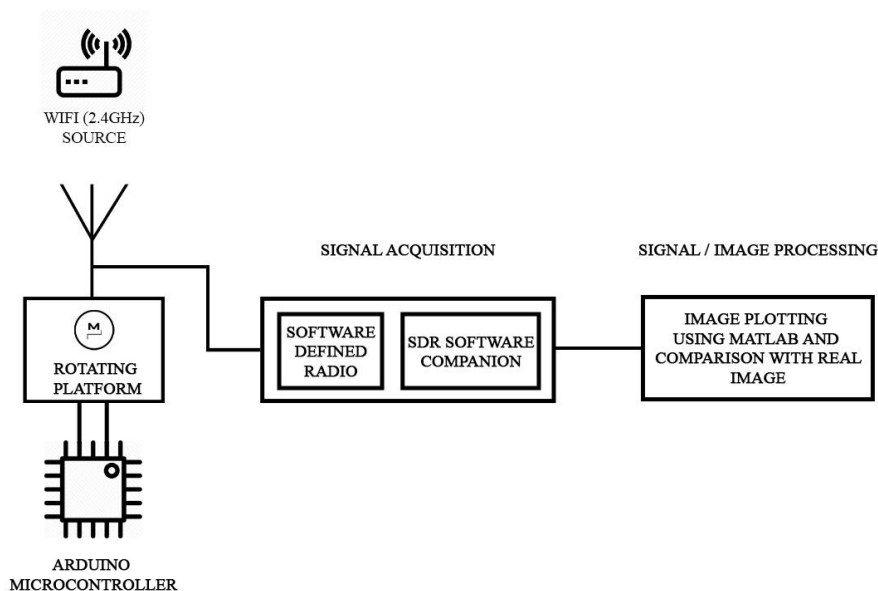
Fig.4: System Block Diagram

2.3   Simulation System Model
2.3.1   MATLAB SIMULINK
         MATLAB is a high-level programming language for scientific computation. It interfaces with problems and solutions written in standard mathematical symbols and blends visualization, computation, and programming in a user-friendly manner. Simulink is a graphical interface for modelling, simulation, and analysis of dynamic systems. It is a MATLAB add-on product. It allows for the quick creation of virtual prototypes that may be used to go through design concepts at any level of minimum effort.

Antenna Designer Toolbox - Antenna toolbox is a collection of functions and tools that are created for the purpose of designing, analyzing and visualizing antenna elements and arrays. It can create freestanding antennas and antenna arrays using preset elements with parameterized geometry, arbitrary planar structures and bespoke three-dimensional structures described in STL files.

RF Block Set Toolbox - For building RF communications and radar systems, the RF block set includes a Simulink model library and simulation engine. Simulating RF transceivers and front ends is possible with the RF Blockset. Non-linear RF amplifiers can be used to estimate properties like as odd order and even order intermodulation distortion, gain, memory effects and noise. At the command line, use the rfantenna object to create an RF antenna element. You can also use the Antenna Designer app in the Antenna ToolboxTM to import your antenna design.

2.3.2   Circuit Diagram

RF front end system is referred to the analog front end of wireless communication system. Due to properties of electromagnetic waves, digital signals cannot directly pass-through wireless channels. Thus, it must be converted to analog signals of high frequency and then transmitted through the channel. Filtering, amplification and mixing are processes undergone by signal.
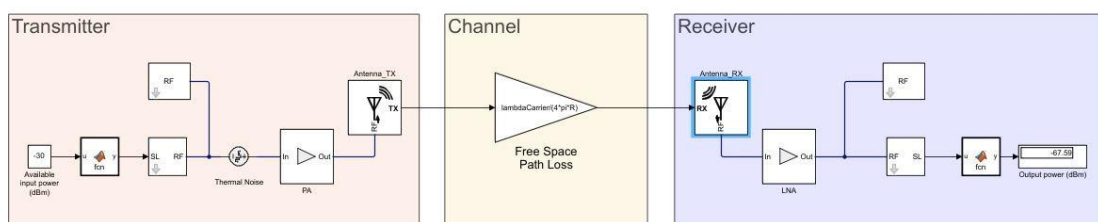

Fig.5: RF Circuit Diagram

RF Transmitter- This part includes signal source, input port, Configuration block, power amplifier (PA) and transmitting antenna. Input signal generation uses Simulink signal source that generates signal which represent the modulation of RF signal.

• Input block: It shifts ideal frequency of input signal in an optimal way around carrier frequency. It converts Simulink signal to RF Block set Circuit Envelope voltage or current.

• Configuration block: It is where circuit envelop simulation time step is set. RF Block set software handles carrier analytically and simulates modulating signal based on time steps. Circuit envelop is a time domain simulation superimposed on a harmonic balance analysis. This technique is used to increase the speed of RF system simulation. So, this block is mainly used to model RF signal that include properties such as envelope bandwidth, harmonic order, simulation frequencies etc.

• Power amplifier: It is mainly present and designed in the transmitter to increase the signal's power level before transmitting to the antenna. This power boost is necessary to attain desired signal to noise ratio in the receiver. Transmitting antenna receives this signal and radiates.

RF Receiver- This includes low noise amplifier, the outport and receiving antenna. Receiving antenna is Helical antenna designed.

• Low noise amplifier: It introduces noise and nonlinearity. Without reducing its signal to noise ratio, it increases amplitude of a very low power signal. This amplifier increases the power of both signal and noise. For RF receivers the noise factor F is another important performance figure which is denoted SNRin/SNRout. It is a measure of amount of noise added to the receiver.

• Outport: Outport block is return gateway from circuit envelop to Simulink Environment. It converts RF Block set Circuit Envelop voltage or current to Simulink signal.

Thermal Noise - It is the most prevalent type of noise introduced in an RF system. This noise is produced either externally by channel interference or antenna or internally by active components.

Channel - In wireless communication systems, radio frequency channels play an important role. The RF spectrum utilized for wireless communication is referred to as a channel. The channel band that can be used are specified by each IEEE wireless standard. Radio frequency bands between 5.15 and 5.87GHz are specified in the 802.11a standard.

III. RESULTS

3.1 Hardware Implementation

The Partial Results that were obtained in the hardware phase are:

Design of a 2.4GHz Helical Antenna was completed by referencing [2].

The helix antenna can be thought of as an N-turn spring with a reflector attached. The distance 'd' between the turns is about 0.25C, and a turn's circumference 'C' is around one wavelength 'l'. The reflector's size, 'R,' is equal to either 'C' or 'l,' and can be a square or a circle. Both ends of the antenna must have the same polarization to achieve maximum energy transfer.

The gain G of the antenna, relative to an isotropic antenna [dBi], can be calculated by;

➢ $G = 11.8 + 10 * log \{Cl2 * N * d\}$ dBi

The diameter D of 1 turn = $(l\pi)$ = 39.3 mm.

Length of wire With D = 42 mm, C = 42*pi = 132 mm (which is 1.07 l).

Turns of 12 (N = 12) are sufficient for distances ranging from 100m to 3km with a line of sight. As a result, the PVC pipe will be 40 cm long (3.24 l). The wire is wrapped and bonded around the PVC pipe.

The impedance of the antenna, which is;

➢ Z = 10 * (C/l) = 140*{(42*pi)/123.4} = 150 Ohm

A helical antenna of frequency 2.4GHz was built according to the design parameters.
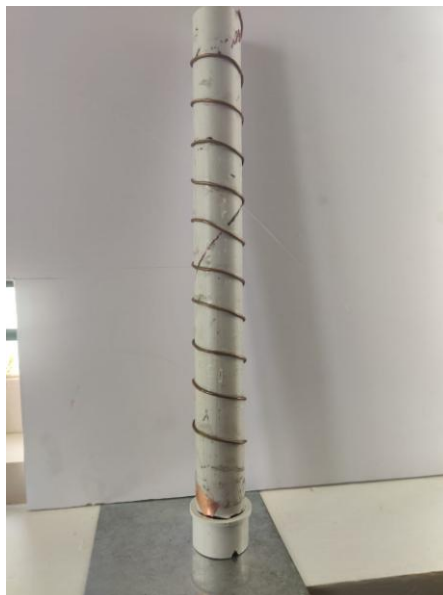

Fig.6: Built Helical Antenna

Arduino controlled Stepper motor connections were established for the mounting platform.
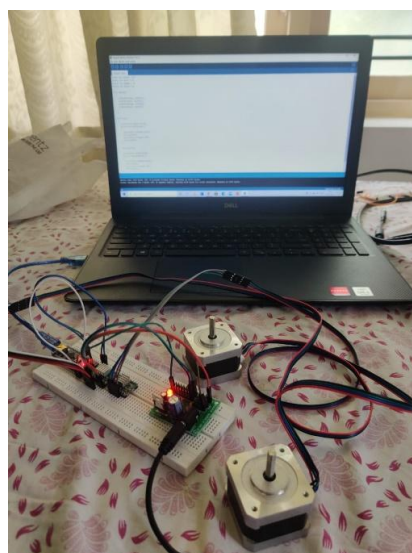

Fig.7: Arduino Controlled Stepper Motor Connections

3.2   Simulation System

The multiple values taken from the output power block in the model within Simulink is used to construct a 2D distribution image of the Wi-Fi power distribution. The size of the image can vary with the number of output readings taken for plotting it.

The receiver of the circuit displays the output power readings in dBm (decibel milliwatts). It is expressed as negative values. Several readings were taken on varying certain parameters. Heatmap is plotted based on values that were obtained by varying tilt axis of receiving antenna. The heatmap in figure 4 shows the output power values in negative logarithmic scale. Right top area of this heatmap denotes area with maximum signal readings. Left bottom area of above heatmap shows area with minimum signal readings.
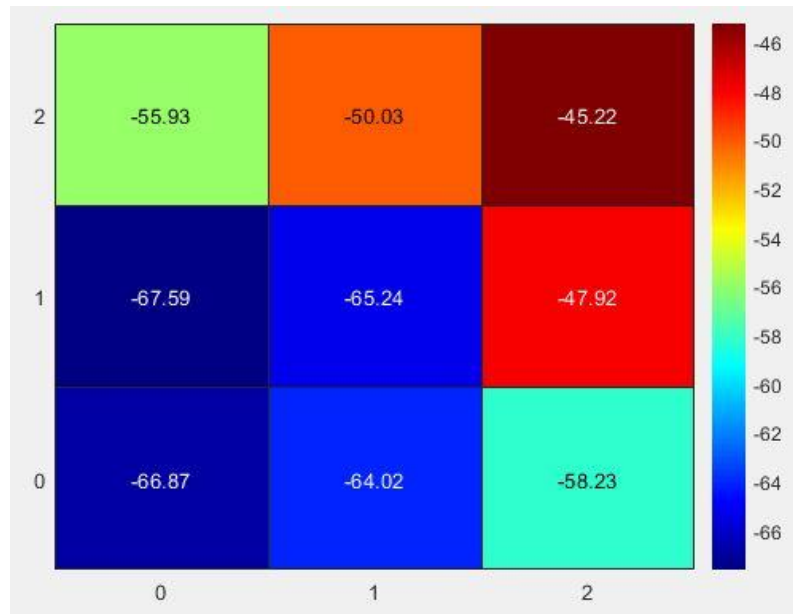

Fig.8: Final Heatmap

Other readings of output power were taken by varying the distance between transmitting antenna and receiving antenna. Graph plotted indicates the relationship between distance between antennas and output power values.
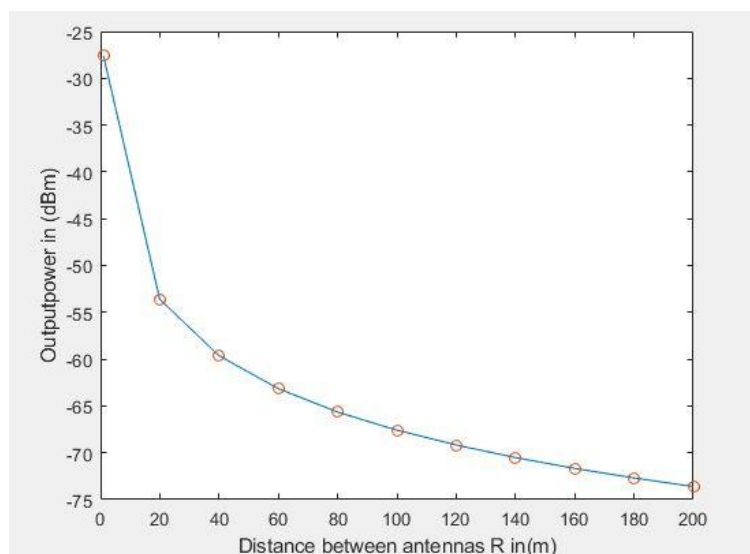

Fig.9: Output Power v/s Distance between antennas

IV.   CONCLUSION

This project can be used in real life by constructing a helical antenna using the appropriate parameters for receiving the power output of a Wi-Fi router with the help of an SDR (Software Defined Radio receiver) and plotting its distribution image from the output values and later overlapping it with a real-life image of the scanned space. This overlayed image helps in the permanent installation of a Wi-Fi router as its signal

distribution can be seen if placed in a particular location. This method can be used for finding a permanent location for installing a Wi-Fi Source. Apart from Wi-Fi this method can be used in real life to detect cellular devices in a building or office. This is achieved by using another antenna tuned to the cellular frequency ranges. This is very helpful in rescue operations at times of a calamity when a building collapses and people are stuck inside the rubble. Hence this method shows many uses in detecting radio waves precisely in real time.

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