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Reimagining Wireless Connectivity: Crafting An Innovative 4x4 Fractal Mimo Antenna For Enhanced Wifi Performance

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ABSTRACT

With the emergence of practical implementations of Multiple Input Multiple Output (MIMO) technology, several challenges have surfaced, and one of these challenges involves devising strategies for the optimal placement of multiple antennas on both the transmitter and receiver sides to minimize interference. The physical locations where these antennas need to be positioned are not always ideal for accommodating multiple antennas in desired positions. To address this issue, MIMO antennas with a narrow vertical beamwidth have been engineered and strategically positioned within a single radome. This innovative approach significantly mitigates the challenges associated with antenna placement. Within the scope of this thesis, the design process for such antennas begins with the creation of a dual-band microstrip antenna that effectively radiates in both WLAN frequency bands. This particular antenna is crafted using a 0.5mm thick copper sheet, and its dual-band capabilities are achieved by introducing two slots in the sheet, forming two dipoles, each catering to a distinct frequency band. This type of antenna effectively alleviates the constraints related to antenna placement, especially when striving to ensure minimal interference between antennas on the transmitter and receiver sides. The physical locations where these antennas are intended to be installed are not always conducive to accommodating multiple antennas in desired configurations. To overcome this challenge, high-gain MIMO antennas can be employed, capable of receiving input from multiple sources without causing mutual interference. This approach provides an effective solution to the complex issue of antenna placement. The overarching goal of the research conducted in this thesis is to develop high-gain fractal antennas that can meet the demands of future communication standards, which prioritize high data rates and reliable performance simultaneously. These developed antennas effectively address the challenges associated with the placement of multiple antennas within a MIMO system, ultimately enhancing the overall performance and effectiveness of the communication system.

Antenna Design

The dual-band antenna is crafted from a slender copper sheet, fashioned into a dipole antenna design. To create a functional dipole antenna, symmetry is crucial, ensuring that both sides from the center exhibit balance. It's imperative that the combined length and width of each radiating arm corresponds to a quarter or half wavelength of the operating frequency. To adhere to this principle, two dissimilar arms serve as the radiating components in the dual-band dipole antenna. The antenna is fashioned from a copper strip with specific dimensions of 39.5 mm in length, 9.75 mm in width, and 0.5 mm in thickness, as illustrated in Figure 1. The central section of the strip is short-circuited with another strip. Two L-shaped slots are precisely carved into each arm to form two radiating dipole arms. The dimensions of these dipole arms are carefully adjusted for optimal performance, measuring 15.25 mm in length and 1.85 mm in width for one arm, and 13.25 mm in length and 4.25 mm in width for the other. The antenna is powered through an SMA connector, connected to a 50Ω coaxial cable.

User Interface

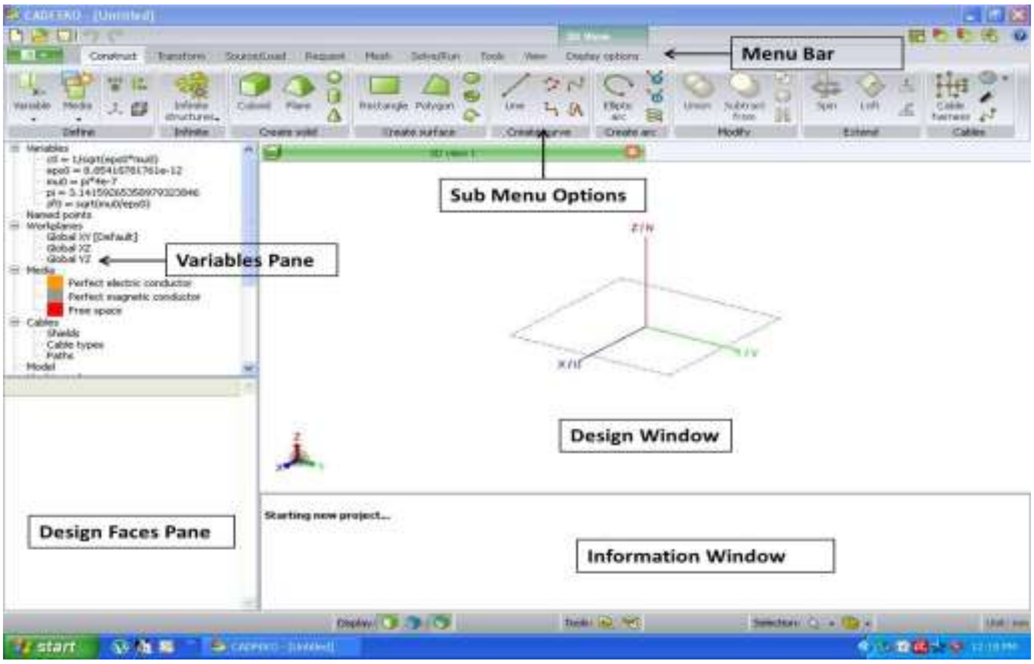


Fig. 1: Screenshot of EMSS CADFEKO with various interface units

Fig.1 shows the screenshot of EMSS CADFEKO. The CADFEKO v6.1 Window can be divided into following parts

a) Menu Bar: Located at the top of the interface, the Menu Bar houses a range of menu options. When selected, these options trigger the appearance of subsequent submenu choices.

b) Sub Menu Options: Just beneath the Menu Bar, the Sub Menu Options are accessible. This area facilitates the selection of options for generating, meshing, and resolving antenna designs.

c) Variables Pane: Within this section, you'll find definitions for all the variables within a design, encompassing parameters such as voltage, frequency, and other design-specific variables.

d) Design Faces Pane: The Design Faces Pane is dedicated to presenting the edges and surfaces of the antenna being created in the design workspace. This pane serves as a gateway to access properties related to these faces and edges.

e) Information Window: The Information Window offers valuable insights into the ongoing design and simulation processes, including the display of processing updates and error messages.

f) Design Window: Serving as the primary workspace, the Design Window is where you can craft your desired design. It offers three-dimensional rotation capabilities and includes scaling features for precise adjustments.

Design steps

Following are the design steps for creating the metal strip dipole antenna on CADFEKO v 6.1

1. Change the model unit

From the ‘Construct’ tab, select the model unit option and change the units to ‘Millimeters (mm)’.

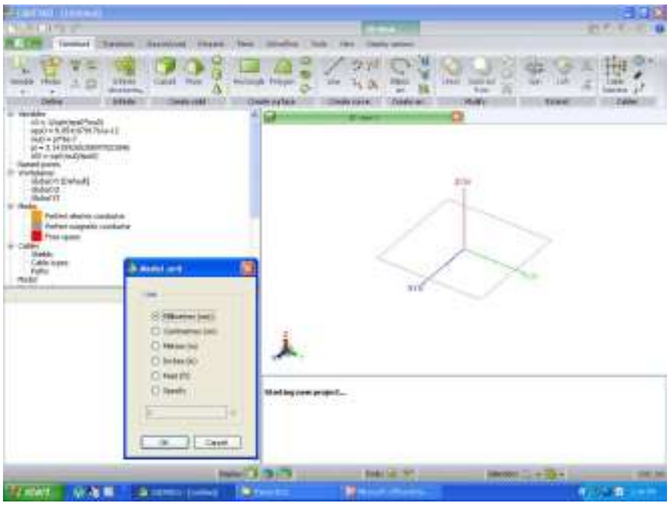


Fig. 2: Screenshot of EMSS FEKO with model unit options

2. Select material

From the media library, select the required medium and add it to the model

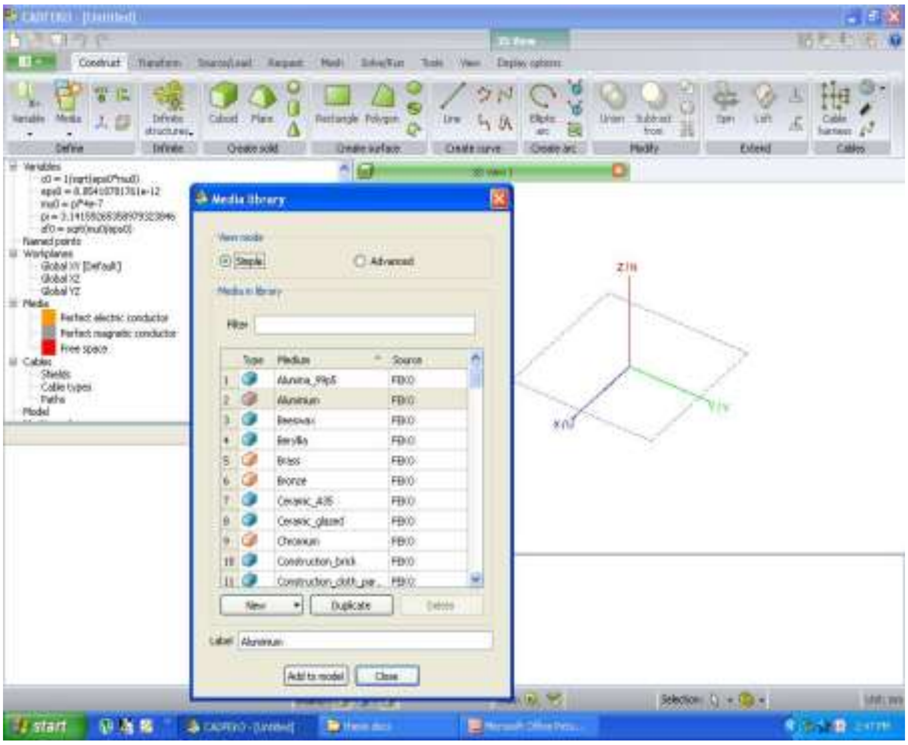


Fig. 3: Screenshot of EMSS FEKO with Media library

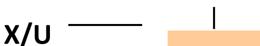
3. Create design

The antenna is then designed using various surface blocks available in the 'Construct' tab.

Fig. 4: Screenshot of EMSS FEKO with surface creation option.

4. Select frequency

In the left pane, right click on the Frequency option under the Solution option and Assign frequency to the model.



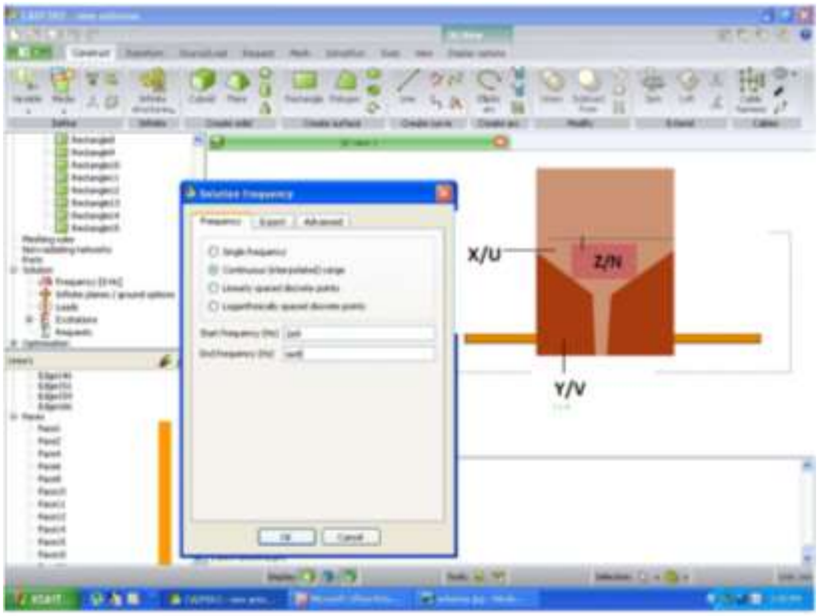


Fig. 5: Screenshot of EMSS FEKO with solution frequency selection window

5. Solve

Click on FEKO solver button under 'Solve/Run' tab.

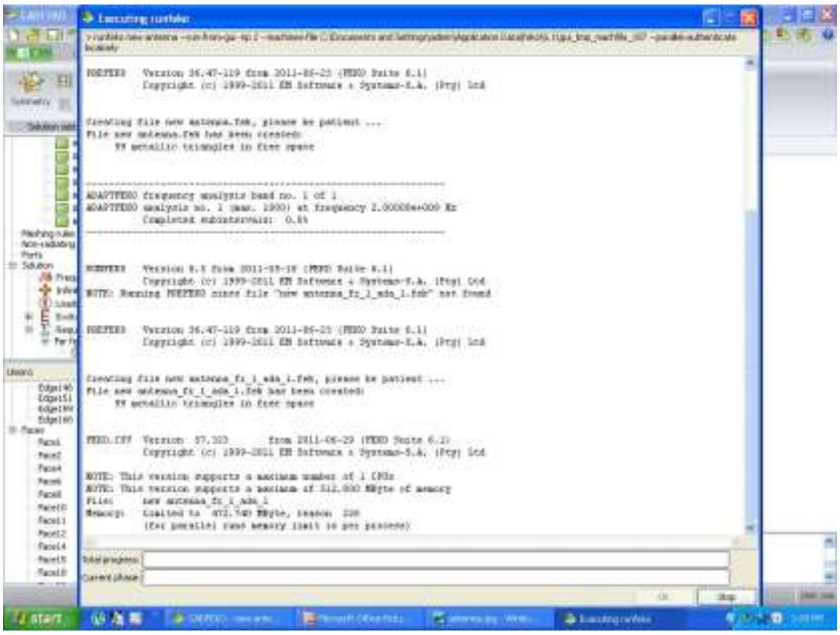


Fig. 6: Screenshot of EMSS FEKO with FEKO solver.

The antenna design is solved by CADFEKO using Method of Moments (MoM) numerical method. The module which solves the antenna design is called FEKO solver. After the FEKO solver has completed its processing. POSTFEKO is used to view the results.

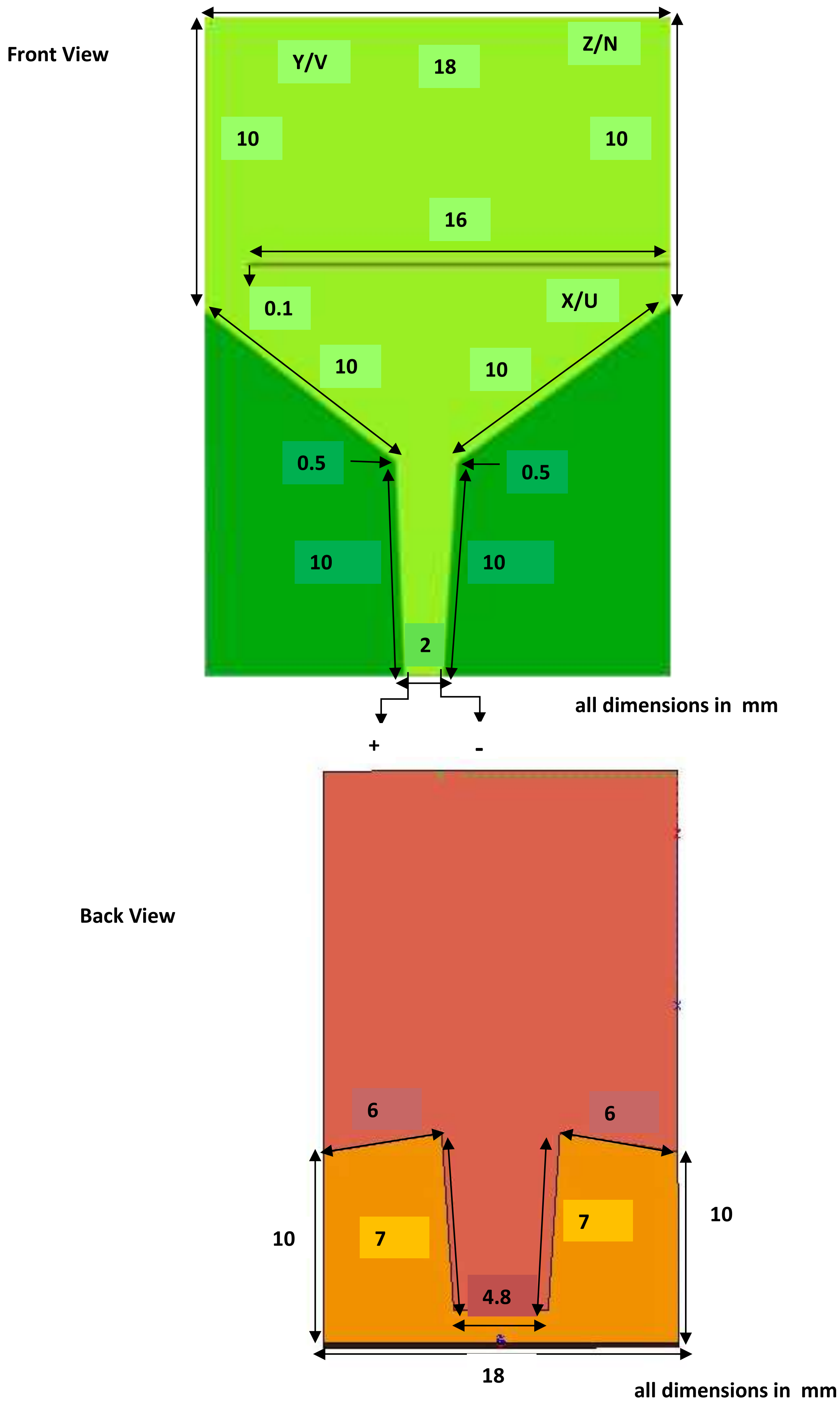

Front View
Y/V
18
Z/N
10
10
16
0.1
X/U
10
10
0.5
0.5
10
10
2
all dimensions in mm
+
-
Back View
6
6
10
7
7
10
4.8
18
all dimensions in mm

Fig . 7 : Proposed Antenna Design

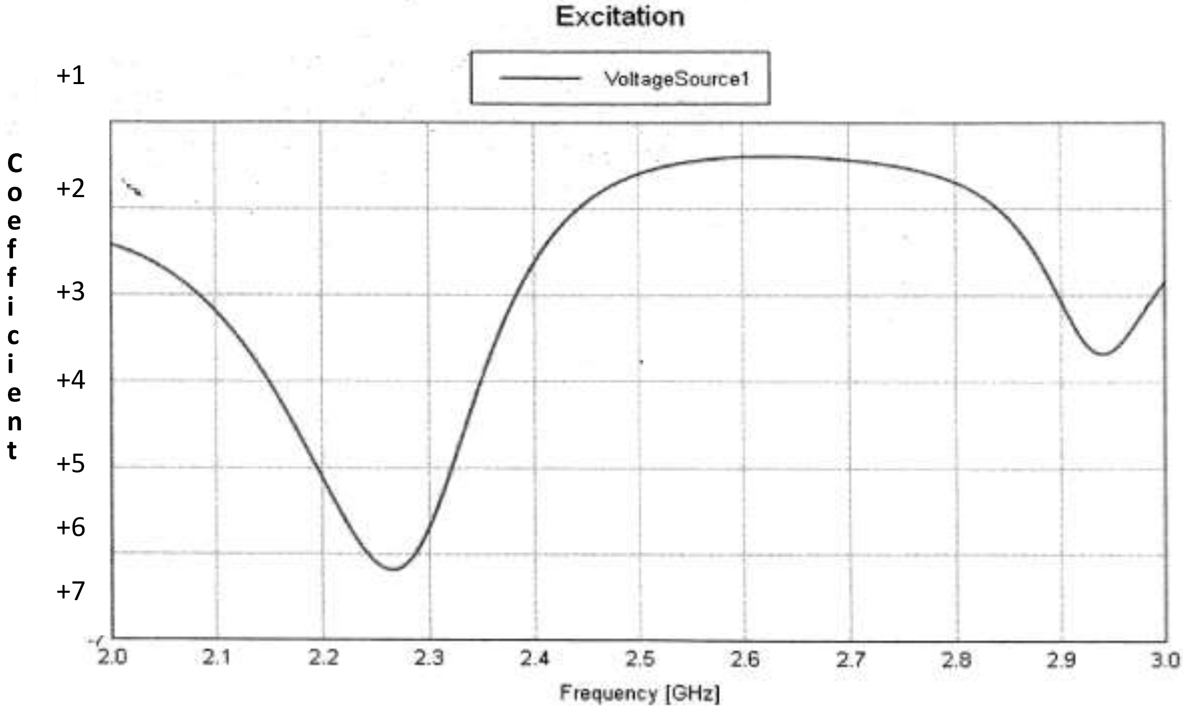


Fig. 8 :Return Loss vs. Frequency

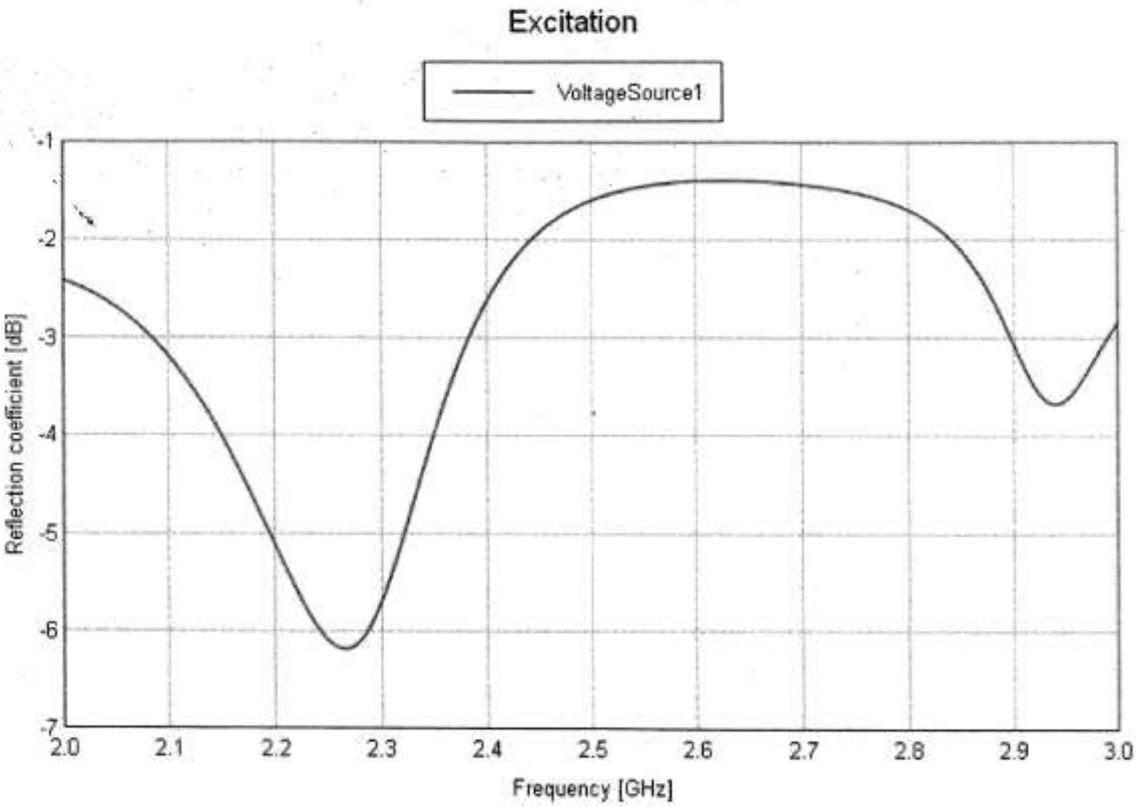


Fig. 9 : Reflection coefficient vs. frequency

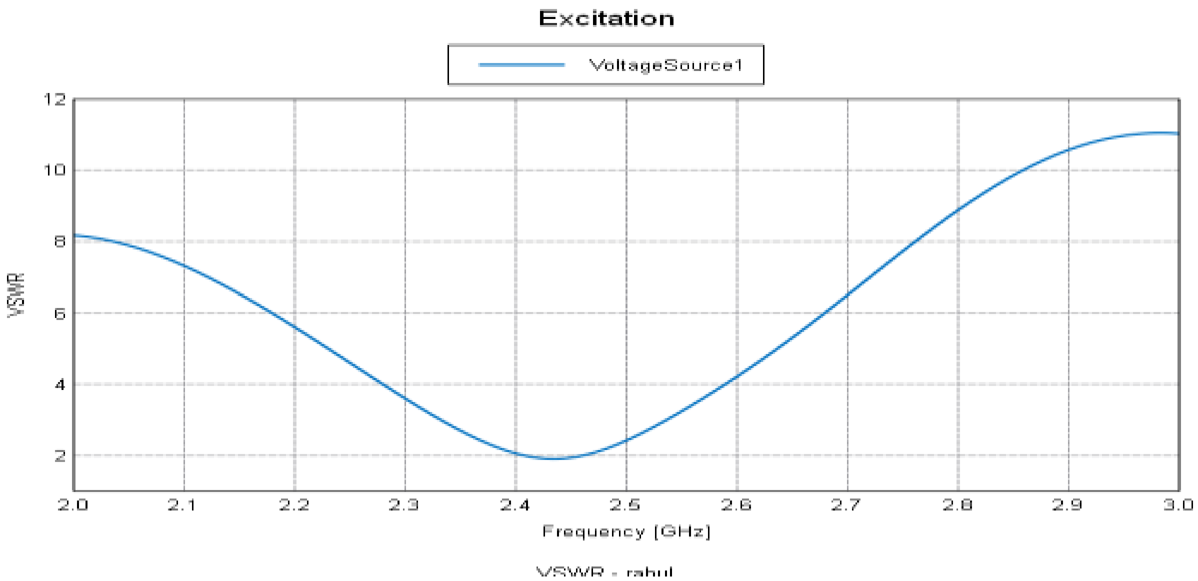


Fig. 10: VSWR vs. Frequency

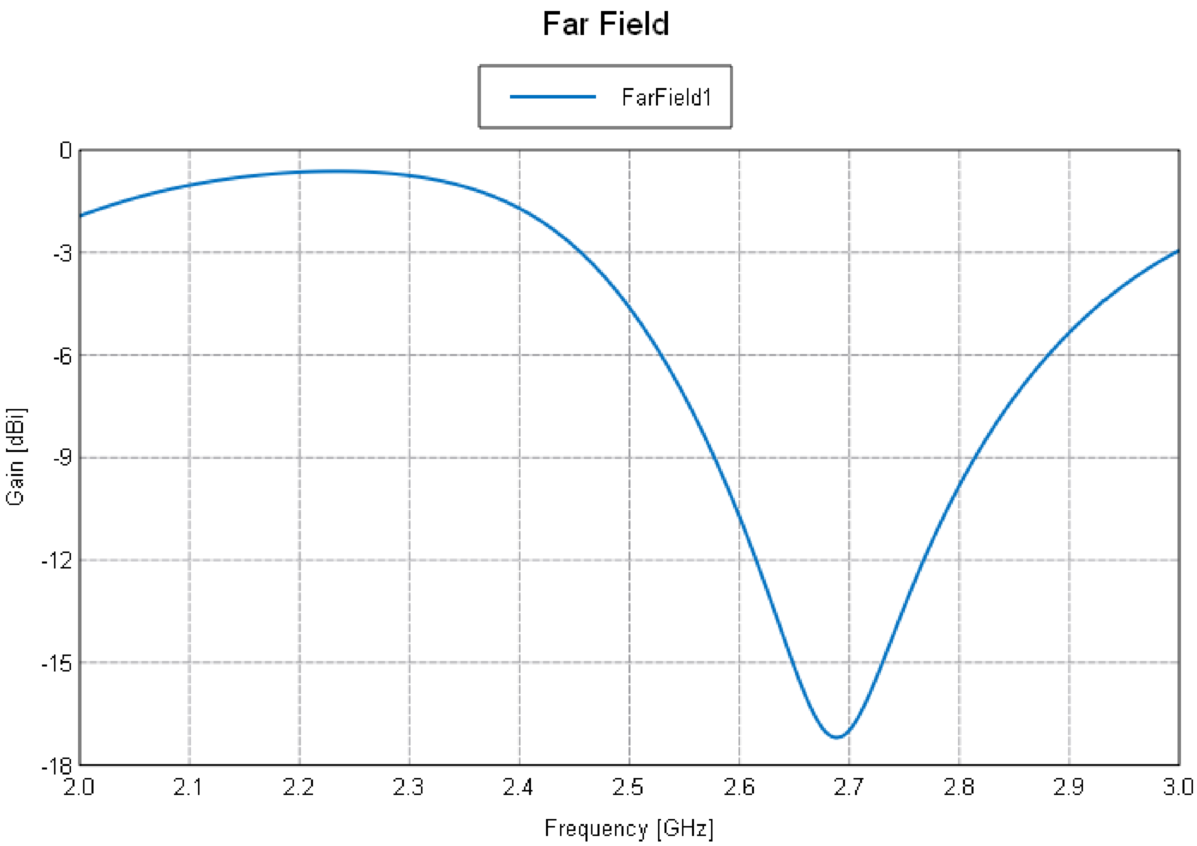


Fig. 11: Total directivity vs. frquency

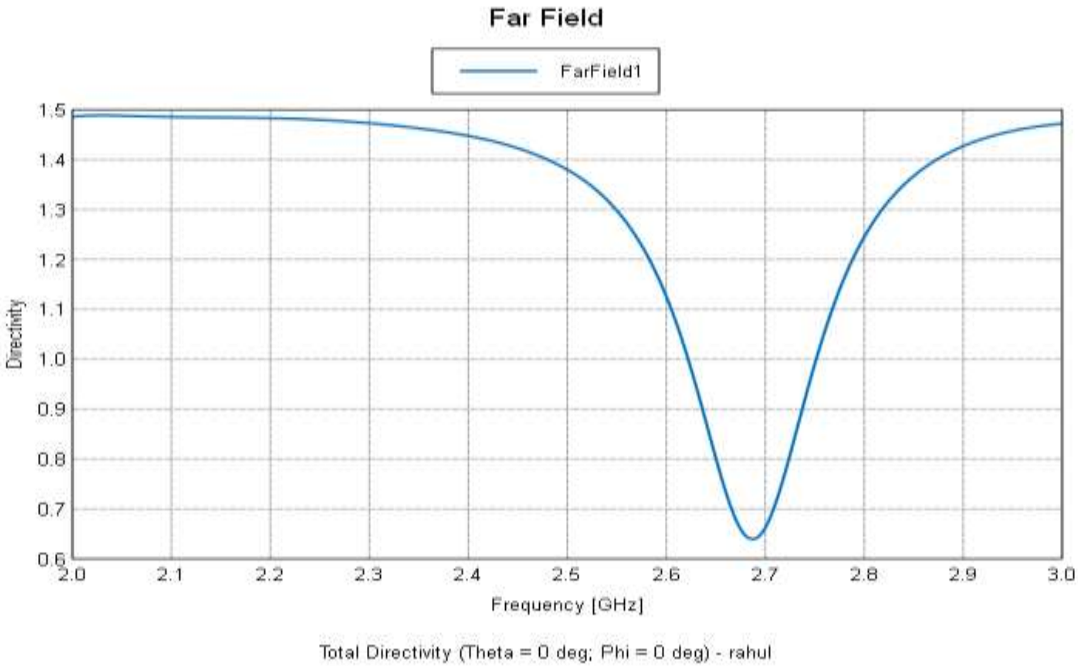


Fig. 11: Total directivity vs. frquency

Antenna Fabrication

Front View **Back View**

Fig. 12: Proposed Antenna

Fig. 13: VNA Testing of Proposed Antenna

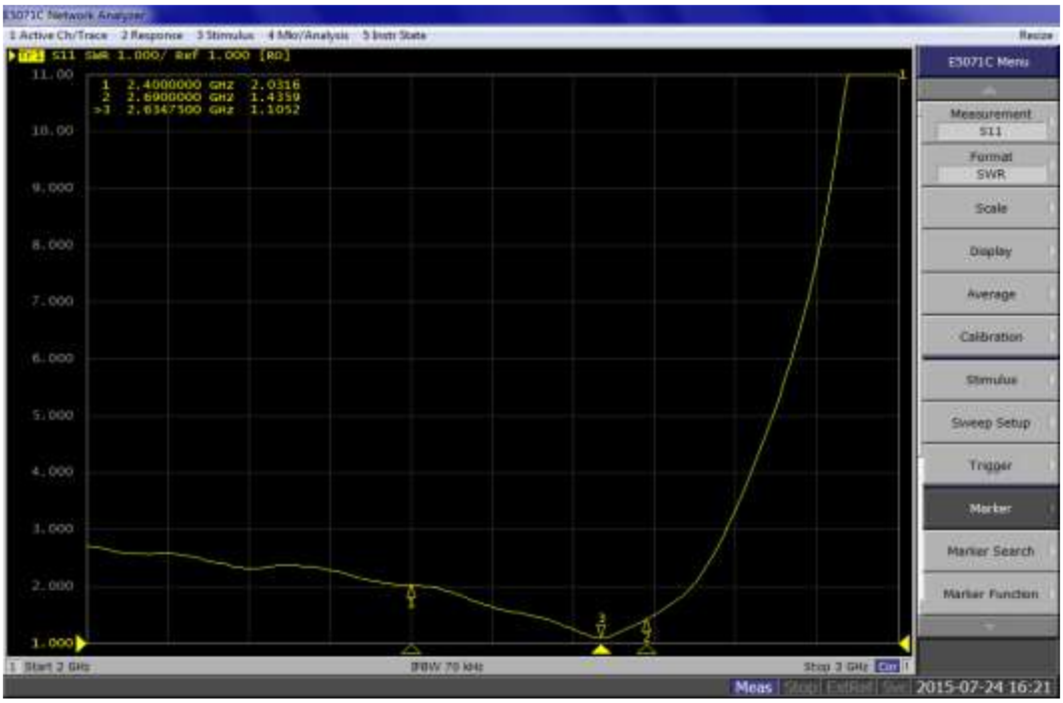


Fig. 14: Measured VSWR vs. frequency curve on VNA

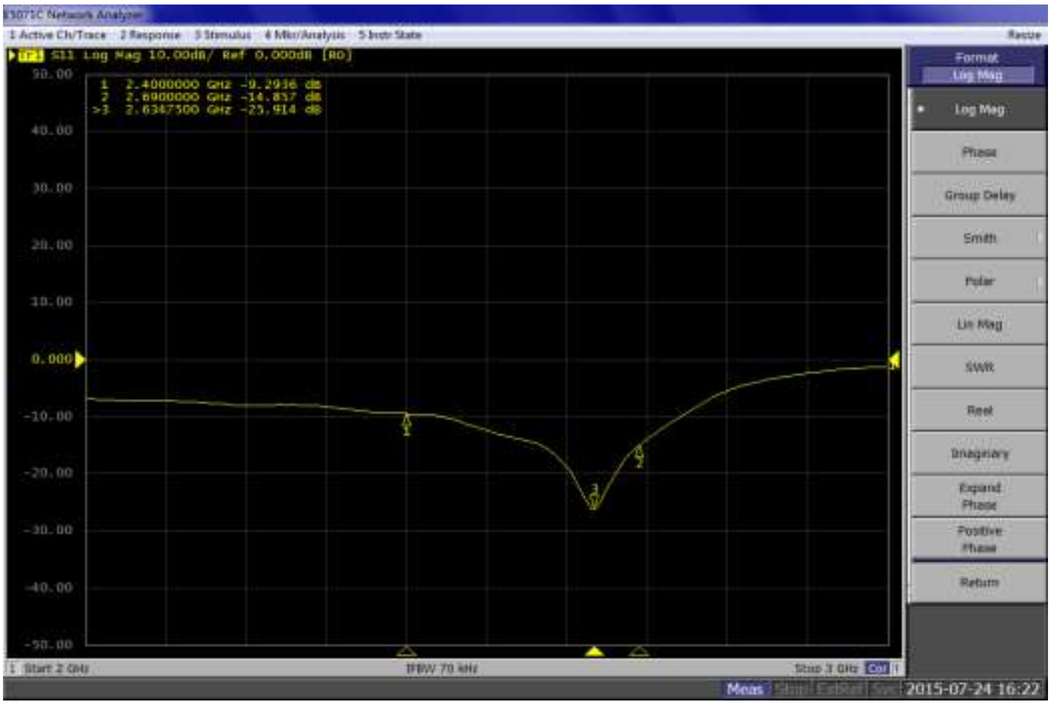


Fig. 15: Measured return loss vs. frequency curve on VNA

Figures 15 and 16 present the radiation pattern measurements of the antenna conducted using a Virtual Network Analyzer. The measurements were carried out with an Anritsu VNA Master MS2025B, which operates within a frequency range of 500 KHz to 6 GHz. The depicted figures illustrate a close alignment between the measured radiation pattern and the simulated radiation pattern. Notably, a return loss of -10 dB was achieved for both frequency bands. Within the lower frequency band, the minimum return loss was -9.2936 dB at 2.400 GHz, while in the upper band, it reached -25.914 dB at 2.488 GHz.

To create the necessary MIMO sector antenna, the initial step involves fabricating a basic dual-band metal plate antenna optimized for efficient radiation at the required WLAN standard frequency bands. This antenna serves as the foundation for the subsequent design of two fractal antenna configurations. These fractal antenna designs consist of four sections each, and they are ultimately enclosed within a single radome to form the desired 4-port MIMO fractal antenna.

CONCLUSION

In this thesis, a 4-port MIMO antenna operating on the IEEE 802.11a/b/g/n frequency bands is designed. These frequency bands are designated for WLAN applications and encompass the range of 2400MHz to 2488MHz. The design process begins with the creation of a dual-band microstrip antenna, optimized for efficient radiation in both WLAN bands. This antenna is fashioned from a 0.5mm thick copper sheet, featuring two slots that form separate dipoles for each frequency band.

To construct the microstrip antenna, these elements are strategically positioned in front of a reflector to generate the desired radiation pattern. Discrepancies in the Voltage Standing Wave Ratio (VSWR) values between theoretical and practical measurements for the microstrip antenna may stem from calibration differences between the Vector Network Analyzer (VNA) and the antenna.

The desired 4-port MIMO microstrip antenna can be achieved by housing four units of these individual antenna sections within a single radome. Given the compact size of both sector antennas, they can be accommodated within the radome with sufficient spacing. Additionally, the narrow vertical beamwidth mitigates interference between the radiations from the individual antennas.

This antenna design addresses the challenge of accommodating multiple antennas at transmitter and receiver locations while minimizing interference. Often, the available positions for antenna placement do not align with the desired locations. To circumvent this issue, high-gain MIMO antennas are employed, capable of accepting input from multiple sources without introducing interference. This effectively resolves the problem of antenna placement.

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