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OPTIMIZING DUAL-BAND ANTENNA EFFICIENCY: RIDGE WIDTH PARAMETRIC STUDY OF QUAD RIDGE HORN ANTENNAS

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ABSTRACT

The purpose of this project was to develop a quad ridged horn antenna for a GSM and mid band 5G application, capable of dual frequency range operation at 1.8 GHz and 3.5 GHz. The antenna was constructed using 3D printing technology and Polylactic Acid (PLA), a thermoplastic polymer known for its high strength and compatibility with 3D printing processes. The impact of varying ridge width dimensions on the antenna's performance was evaluated using a range of parametric techniques. Ridge widths of 10 mm, 13.5 mm, and 17 mm were analysed to assess the effects of dimension alterations. Results demonstrated that the antenna is capable of dual band frequency operation with signal reflections of -16.89 dB and -28.60 dB at 1.8 GHz and 3.5 GHz, respectively. This research contributes to the development of efficient and cost-effective antennas for wireless communication applications in the GSM and mid band 5G spectrum.

Keywords: quad ridge, horn antennas, 3D printed antenna, global system for mobile communications, mid band 5G.

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1. INTRODUCTION

The evolution of humanity has always been influenced by connectivity. In history, the cellular wireless technology began to develop and revolutionize in the 1970s [1]. Wideband spectrum and higher frequency are the most crucial criteria to perform the best performance by the user. Nowadays, the fifth generation (5G) of mobile wireless communication has already arrived, and several consortiums are continuously working to build 5G standards. Future high data-rate communications will be made possible by fifth-generation (5G) communication, which has received a lot of attention. The comprehension of the propagation channels is crucial for the design and testing of the 5G communication system, necessitating a substantial body of channel measurements [2]. Third generation (3G) is developed to fourth generation (4G) with the advent of high-speed packet access (HSPA) and long-term evolution (LTE) technology (4G). 5G is chosen over the fourth generation (4G) because it has extensive bandwidth availability, which improves network performance [3]. Cellular technology advances significantly from the first generation to the fourth generation thanks to serialized generation progression and revolutions [4].

Some of these features show the new services of 5G such as low power to reduce energy consumption, enhanced network coverage area, high-speed data connection with massive, internet of Things (IoT), downlink speed up to 10 Gbps in stationary users, and low latency [5].

Horn antennas offer practical solutions for communications networks in an era where the world is preparing for 5G cellular wireless communications [6]. In 1897, Bengali Indian radio scientist Jagadish Chandra Bose created one of the earliest horn antennas [7]. Horn antennas have attracted attention on a global scale since they were first developed in the 1950s due to their extraordinarily wide impedance bandwidth, ease of manufacturing, and high-power capabilities.

Broadband antennas with horns offer several advantages. Horn antennas are typically used as the active component of the dish antenna to feed the dish. The waveguide antenna uses a corrugated horn to provide a broad beam width and is meant to be compact enough to comply [8]. It is also simple to make and compact enough to combine with 5G communication gear.

A specific form of antenna that can be easily enhanced by changing the way it is built is a horn antenna. The horn antenna's better antenna gain and stronger directivity also contribute to its reduced VSWR, wider bandwidth, and less weight [9]. The ridge structure is applied to the waveguide section and the horn segment of the horn antenna based on the ridge waveguide's broadening capabilities. As a consequence, it is possible to create a quad-ridge horn antenna with a narrow band.

The quad ridge horn antenna had been the subject of numerous prior studies. Barapatre's [10] quad ridged horn antenna for high gain application is another example The antenna is used in his work at frequencies ranging from 0.7 GHz to 2 GHz. Al-Zuhairi [11] has suggested a portable dual-polarization, ultra-wideband quad-ridged horn antenna. The whole frequency range of the antenna exhibits a 40 dB isolation between the two linear polarization signals. For port 1, it covers the range of 3.72 GHz to 10.52 GHz, while for port 2; it covers the range of 3.63 GHz to 10.74 GHz. In these publications [12-17],

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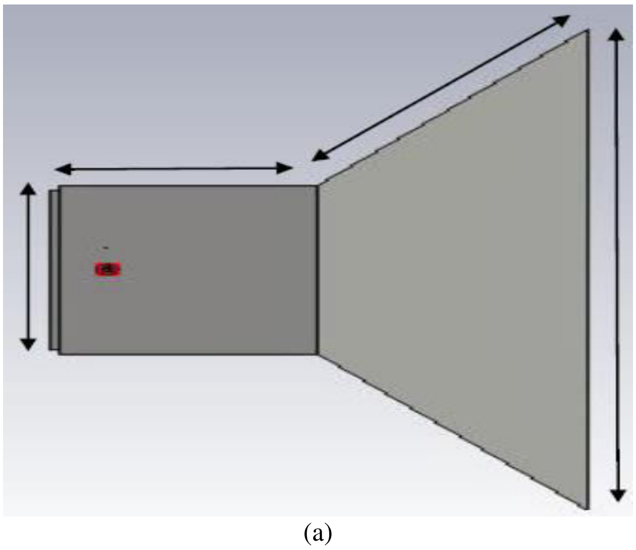
more work on quad ridge horn antenna on 5G technology application is also discussed.

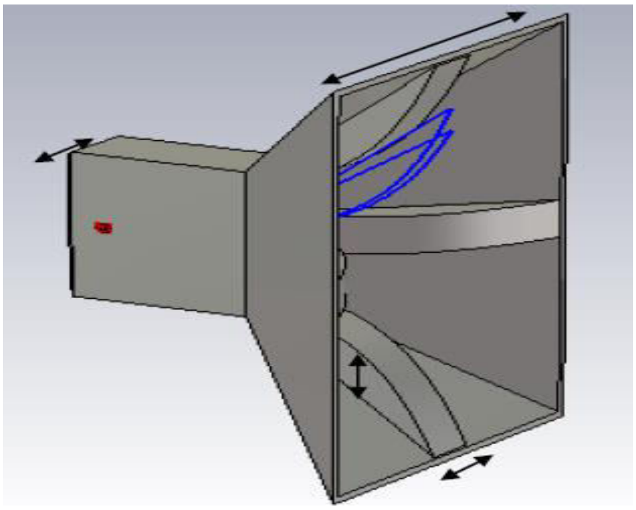
In this work, for GSM and mid band applications, a dual-band quad ridged horn antenna operating at frequencies of 1.8 GHz and 3.5 GHz is developed. The impact of changes in antenna diameter is defined by several parametric studies. The waveguide part receives the ridge component, and the horn antenna's horn component relies on the ridge waveguide's ability to expand the signal. A narrow band quad-ridge horn antenna might be the outcome. The creation of a quad ridged horn antenna is a good example of the potential of 3D printing, especially PLA-based technology.

2. ANTENNA DESIGN AND ANALYSIS

As the technology grows more in demand, the designers must be aware of the fundamentals of ultra-wideband to confirm that the antenna developed performs ideally at 1.8 GHz and 3.5 GHz frequencies in a GSM and 5G application (UWB). CST (Computer Simulation Technology) Microwave Studio is used to simulate this design. In this case, the impedance is modified to 50 to match the impedance of the coaxial line. Since they can be simulated more efficiently than waveguide ports, discrete ports are favoured, especially when the design has a very tiny mesh. Figure-1 displays the horn antenna's schematic design.



(a)



(b)

Figure-1. Schematic diagram of the horn antenna, (a) Side view of horn antenna, (b) Perspective view of horn antenna.

At this phase, it is anticipated that the antenna's bandwidth in this design will be reduced to 3.5 GHz to support mid-band 5G applications. Since 3D printing has such a significant impact on so many other industries and has the potential to change the game in the future, it was chosen as the method for making antennas.

Additionally, it has become more affordable, accessible, and effective. The simulated and built antennas were created using the solid, non-printed polylactic acid (PLA) material's dielectric constant.

3. RESULTS AND DISCUSSIONS

This section discusses the antenna result parameters of return loss, resonant frequency, and gain. Besides that, the parametric study performance is also stated. It is comprised of three crucial components: a ridge, a horn, and a waveguide transducer. A squared-off rectangular waveguide of type WR284 is employed as a waveguide transducer, and its operating frequency ranges from 2.6 GHz to 3.95 GHz. The bandwidth is listed as ranging from 1.74 GHz to 1.83 GHz in another part.

The gain, return loss, bandwidth, and radiation pattern of the proposed antenna are all listed in this section. Figure-2 displays the outcomes of the return loss graph of the antenna design following the simulation in CST Microwave Studio. The resonance frequency therefore drops by -28.60 dB at 3.5 GHz.

The antenna has a gain of 9.327 dB at 3.5 GHz, a total efficiency of -0.0577 dB, and a radiation efficiency of 0.01357 dB, according to the simulation's data. The diagram below shows the radiation pattern of a horn antenna, which has a primary lobe, a side lobe, and a rear lobe. The resulting main lobe has an amplitude of -2.49 dB and a magnitude of -3.8 dB in the side lobe. It demonstrates how much bigger the major lobe is about the side and rear lobes. This demonstrates that compared to other directions, the major lobe emits greater energy. As

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radiation intensity rises, the main lobe becomes more confined.

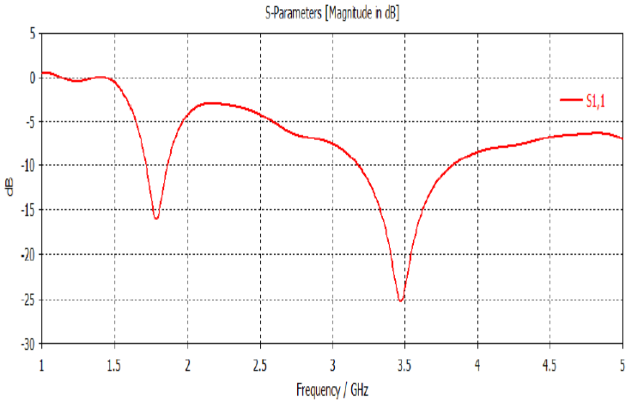
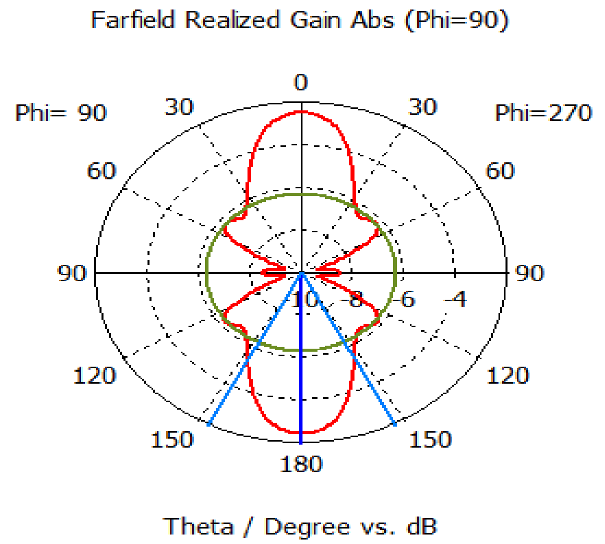
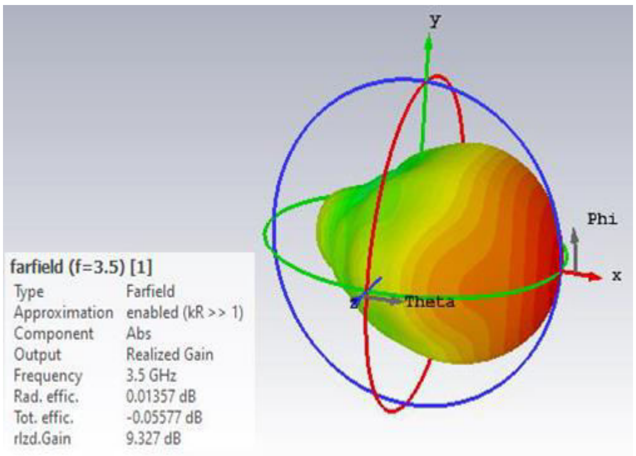


Figure-2. Return loss of the proposed horn antenna.



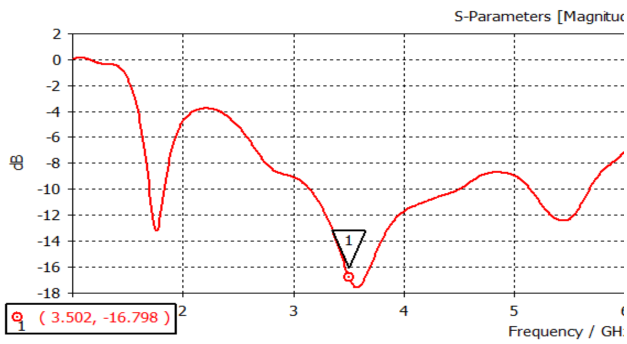
(a)



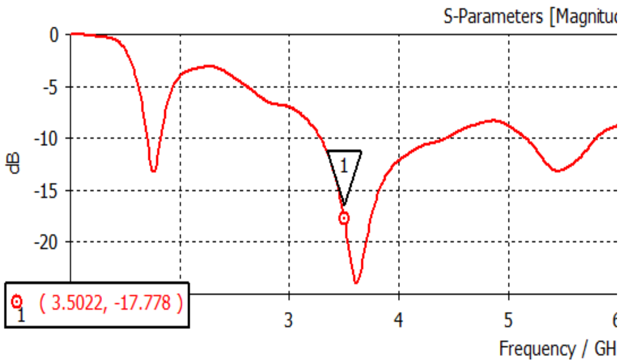
(b)

Figure-3. Radiation pattern of the proposed horn antenna, (a) 2D view, (b) 3D view with gain.

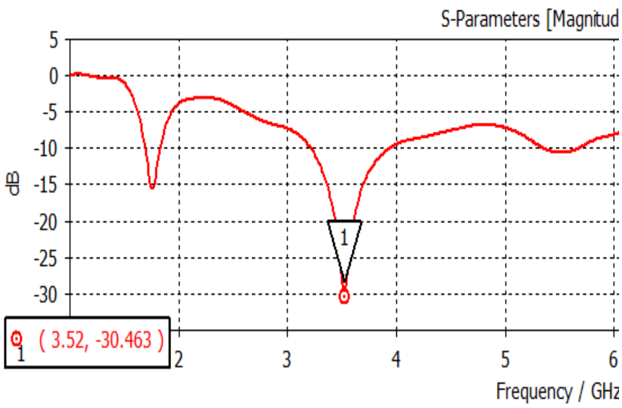
On the other hand, the comparison between the simulation quad ridge horn antennas with varying ridge widths of 10 mm, 13.5 mm, and 17 mm is shown in Table-2. The resonance frequency of the S11 parameter will move to the left if the ridge height is increased, according to the comparison between the two proposed antennas. If it is set to 3.5 GHz, but ridge height increases, the s11 parameter will shift to 3.5 GHz and below. This simulation was done following several optimizations. Table-1 shows the result simulation of the difference value of ridge width. Figure-4 shows the result simulation performance of the difference value of ridge width of 10 mm, 13.5 mm, and 17 mm.



(a)



(b)



(c)

Figure-4. Result simulation of the difference value of ridge width, (a) 10 mm, (b) 13.5 mm, (c) 17 mm.

Table-1. Result simulation of the difference value of ridge width.

Ridge Width	Return loss at 3.5 GHz of frequency	Return loss better than - 10 dB at resonant frequency
10 mm	16.798 dB	-17.809 dB at 3.67 GHz
13.5 mm	17.778 dB	-24.56 dB at 3.69 GHz
17 mm	29.963 dB	-30.463 dB at 3.52 GHz

4. CONCLUSIONS

A design for a quad ridge horn antenna that can be produced using 3D printers and PLA is the first completed project in this thesis. This dual band quad ridged horn antenna is better than the standard antenna and performs at 1.8 GHz and 3.5 GHz for GSM and mid band applications. The antenna radiates more fiercely in that direction, as seen by the bigger gain indicated. It has a gain of 9.327 dB at 3.5 GHz. nearly all of the simulation process design's parameters have produced the desired results.

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