

## DESIGN DIFFERENT DIMENSIONAL PATCH RECTANGULAR DIELECTRIC RESONATOR ANTENNA FOR 5G APPLICATION

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### ABSTRACT

The rectangular-shaped dielectric resonator antenna (DRA) working on higher order mode is proposed in this research for fifth generation (5G) communication applications. The Ku band was considered a possible carrier frequency that was important enough to be included in 5G technology. DRAs were created to increase the capacity and bandwidth of transmission. Because of the lossy silicon substrate materials used in DRA, it has a lower radiation efficiency and a lower bandwidth impedance. To compare the performance of this antenna, it was designed, simulated, and analyzed with the antenna already in the market. CST Microwave Studio Software (CST) was used to simulate the antennas. The design aims to achieve a minimum of -10 dB Return Loss (RL), ensuring that at least 90% of power is transferred at a frequency of 15 GHz, as well as a bandwidth of up to 1 GHz to meet 5G requirements. The suggested rectangular dielectric resonator antenna has a return loss of -46.17 dB and a bandwidth of 1.1 GHz and is tuned to 15 GHz. The proposed antenna can work in a 5G environment.

**Keywords:** 5G communication, Microwave Band, Transmission capacity, Radiation efficiency, Return Loss (RL),

### INTRODUCTION

Wireless communication started to grow rapidly in nowadays technology. This transformation is accelerating as a result of the introduction of a new generation of data networks, known as 5G [1]. Starting with analogue (1G), moving to digital (2G), then to 3G, which provides a fast data rate, and finally to 4G, which is a cellular wireless communication technology that is generally deployed in every country [2]. Aside from that, there are certain issues with 4G, such as high energy consumption, limited bandwidth, and spectrum shortages [2]. To address these issues, the spectrum above 6 GHz was allocated for 5G technology, which will require far larger bandwidths than ever before. Only higher frequency bands (over 6 GHz) will be capable of delivering such huge data rates [3].

Among the antennas, the Dielectric Resonator Antenna (DRA) has the best properties. Because of the lossy silicon substrate materials, it has a lower radiation efficiency and a lower bandwidth impedance, among other advantages. This antenna is often compact in size, light in weight, and inexpensive [4]. When compared to microstrip patch antennas, dielectric resonator antennas (DRA) span a wider bandwidth and have fewer losses, making them ideal for use in the high spectrum [5]. Miniaturized antennas are available in a variety of shapes, including rectangular, hemispherical, cylindrical, and hybrid antennas. Cylindrical and rectangular dielectric resonator antennas are the two most popular shapes. However, the advantage of using a rectangular form is that it contains three geometrical dimensions that are independent of one another (a: length x b:

width x d: height). Rectangular constructions are thought to be more versatile than other shapes since two of the three dimensions can be freely adjusted for given resonance frequencies and have a low degree of importance of differences [4]. High frequency and high gain are primarily supported by higher order mode. One of the strategies for increasing or optimizing the value of gain and bandwidth for the DRA is to employ the higher order mode. When compared to other gain enhancement techniques, higher order mode excitation is the easiest [6].

Microstrip patch antennas (MPAs) are a type of planar antenna that has undergone substantial research and development over the last four decades. They have been a popular among antenna designers, and they have been employed in a variety of military and commercial applications in wireless communication systems [7]. The patch can be rectangular, round, triangular, U-shaped, E-shaped, or any other shape you like. Microstrip patch antennas can be combined with microwave circuitry and are inexpensive, small, and easy to construct [8]. It is made with a traditional microstrip fabrication technique. A microstrip antenna features a radiating patch on one side and a ground plane on the other side of a dielectric substrate [9].

This research is about to design and simulate rectangular dielectric resonator antenna attached on it microstrip patch to make an analysis on the results obtained for application in 5G Technology. There were two types of designs consist in this research which the benchmark design and proposed design. The benchmark design was obtained from the current research while proposed design was optimized from the benchmark design to increase the performance for operating in 5G application.

## **LITERATURE REVIEW**

The literature review is one of the most important steps in the research process. This is a strategy for verifying and identifying the data and procedures utilized in earlier projects. The goal of the literature review is to give the reader a broad overview of the relevant methods utilized to get the best results. This part covered a review of several research papers authored by a variety of authors.

### ***Shape of Dielectric Resonator Antenna***

Dielectric Resonator Antenna (DRA) can be designed in a variety of geometries, including rectangular, cylindrical, hemispheric, and circular cross-predominate. For various characteristics like as permittivity, impedance, resonant frequency, and coupling mechanism, the various forms produce diverse results. There will be a variety of analytical models to examine its configuration based on the numerous parameter measurements [10]. The cylindrical and rectangular shapes are the most prevalent. Other complex shapes, such as spherical, hemispherical, cross-shaped, and super-shaped antennas, are rarely employed in antenna design due to their difficulties in designing or constructing. [4].

### ***Shape of Microstrip Patch Antenna***

Microstrip antennas are divided into three categories: patch antennas, slot/traveling antennas, and printed dipole antennas. Microstrip patch antennas can take any shape from the three varieties listed above. The majority of microstrip slot/traveling antennas are rectangular or circular in form[8]. Any shape is possible for a microstrip patch antenna. The patch antenna's form variations aid

compactness in applications such as impedance, resonant frequency, and coupling mechanism. Usually dimension used for microstrip patch was (WP: width of the patch x LP: Length of the patch)[8]. Microstrip patch antennas are one type of microstrip antenna, and they are the most popular among them due to their various shapes. The patch in a microstrip patch antenna (MSPA) is usually made of a conducting material like copper or gold. Microstrip patch antennas come in a variety of shapes, including rectangular, circular, triangular, and elliptical. On the dielectric substrate, the radiating patch and feed lines are normally photo-etched[9]. The two most common shape are the circular and rectangular ones. However, there are some other complex shapes such as H-shape, E-shape, S-shape, and U-shape that rarely used in designing an antenna.

### ***Type of Feeder***

Feeding mechanisms are the method of excitation utilized to get the desired antenna performance. Designing Dielectric Resonator Antennas (DRAs) and microstrip patch systems necessitates a variety of feeding mechanisms. This feeding method is critical for antenna society, as the antenna has a wide range of applications. A good technique for determining the appropriate feeding is required due to the multiple feeds necessary to excite DRA and microstrip patch. Microstrip line feeding, coaxial probe feeding, slot/aperture couple feeding, and Co-Planar Waveguide (CPW) feeding are the four most common feeding systems[11]. However, because it is the simplest technique to excite the DRA and microstrip patch, this study used microstrip line fed.

### ***Basic Antenna Parameters***

The Dielectric Resonator Antenna is distinguished by several characteristics, including high efficiency, small size, and wide operational bandwidth. It must relate to numerous parameters to meet the qualities or specifications. Polarization, directivity/gain, relative permittivity, bandwidth, return loss, and VSWR are all basic antenna properties.

### ***Polarization***

Polarization is defined as the direction of electrical fields when the antenna's attitude is equal. There are three types of polarization: linear, circular, and elliptic[12].

### ***Directivity/Gain***

The ratio of radiation to the intensity that would be obtained if the antenna recognized the power is referred to as directivity. Antenna gain is a metric that describes how well an antenna performs. Both, however, have a close relationship[13].

### ***Relative permittivity of the Material***

The dielectric constant, also known as relative permittivity, describes how well an insulator can polarize a substance by applying an electric field. Furthermore, it demonstrates the ability to store energy when a voltage is applied to it[11].

### ***Bandwidth***

The term bandwidth is classified as the frequency range in which the outcomes of the antenna according to certain characteristics [13]. It is typically measured in unit of hertz (Hz).

### ***Return Loss***

Return loss is the power which signifies the total power that lost to the load and reflect from insertion of a device in transmission line. Therefore, the value of Return Loss is equal to VSWR where the function is to represent the communication between the transmitter and an antenna[13] .

### ***VSWR***

Highest power transfer between the transmitter and the antenna must carry out for the antenna to perform effectively. When, the impedance of the antenna ( $Z_{in}$ ) matches with the transmitter ( $Z_S$ ), it will transfer maximum power. According to the maximum power transfer theorem, it can only be transmitted if the transmitter impedance is a complex conjugate of the antenna impedance being considered, and likewise[13]. If the matching criterion is not met, some power may have been reflected, resulting in the generate of standing waves, which can be defined by VSWR.

## **PROBLEM STATEMENT**

The majority of current research on Rectangular Dielectric Resonator Antenna (RDRA) focuses on feeding strategies, arrays, and various antenna shapes to maximize bandwidth, gain, radiation pattern, and other factors [14]. However, the combination of microstrip patch antenna and Rectangular Dielectric Resonator Antenna (RDRA) still not widely study yet. This is because new fields of research, such as increased gain techniques, multiband, and wideband antenna design, are more appealing to researchers[10].

Next, when using feeding approaches, the antenna design is critical since the stimulated modes are sensitive to the antenna size [10]. Because reshaping the Dielectric Resonator Antenna (DRA) in fabrication is difficult due to the hardness of its material, it is critical to have a suitable design to avoid an error [10].

Furthermore, the dielectric resonator's impedance bandwidth is determined by the volume (V) to surface (S) ratio; as the antenna's height increases, the bandwidth decreases [5]. The antenna should have a bandwidth of more than 1 GHz, which is one of the most important parameters to consider while meeting 5G specifications [1]. Larger order mode is used to maximize the value of bandwidth and create higher data rates to meet the needs.

## **SIGNIFICANCE OF RESEARCH**

DRA is so crucial in today's wireless communication technology; the outcomes of the research will assist society. The antenna design criteria are continually evolving according to diverse usage nowadays, in response to market demand. Electronic gadgets must be highly efficient, have a large bandwidth, and have a low equipment capacity, according to today's consumer market. To meet this need, this research will aid in the development of antennas for usage in 5G applications.

Furthermore, the research contribution focuses more on the designer because they may simultaneously design the appropriate antenna to meet 5G criteria based on their own design concept. As a result, this study will instruct the designer on how to adjust the antenna's dimension for the greatest results.

## RESEARCH METHODOLOGY

The methodology of the project was explained in this chapter. It goes into detail about the research tool, as well as the system and hardware development. This project's process is discussed, which includes the use of a software tool, design specifications, simulation design, and prototype design.

### *CST Microwave Studio Software*

CST Microwave Studio (2016), sometimes known as CST MWS, is a tool for designing 3D electromagnetic devices with higher frequencies, such as antennas, filters, planar, and other functions. CST can also model and solve any low-frequency electromagnetic problems, as well as some mechanical problems [15]. As a result, CST software is well suited for electromagnetic field simulation across all frequency bands. CST Microwave Studio is the major software used in this study to design the antenna (2019).

### *Antenna Geometry*

Figure 1 shows the benchmark and proposed antenna geometry created in CST Microwave Studio. The proposed design specifications were derived from a benchmark design in which the antenna's length, width, and height were optimized [16]. These three geometrical parameters were adjusted to improve the antenna's performance in terms of return loss, VSWR, and bandwidth. The resonant frequency is a critical parameter in RDRA design because it determines the antenna's performance. The antenna will be able to work at its best if the appropriate frequency is chosen. Using the formula in equation, the resonant frequency may be predicted [1]. Table 1 shows the design specifications for the benchmark and proposed designs.

Table 1: Design specification of the benchmark and proposed DR antenna

Parameters		Benchmark Design[16]	Proposed Design
(a)	Length of DRA, a (mm)	13.5	12
(b)	Width of DRA, b (mm)	9	11
(c)	Height of DRA, d (mm)	7.62	20.5
(d)	Width of patch, WP (mm)	42	5.98
(e)	Length of patch, LP (mm)	18	7.95
(f)	Substrate Length, SL (mm)	50	50
(g)	Substrate Width, SW (mm)	50	50
(h)	Substrate Height, SH (mm)	1.6	1.6
(i)	Thickness Conductor, Mt (mm)	0.035	0.035
(j)	Width Feed, WF (mm)	1.5	1.5
(k)	Resonant Frequency Estimation (GHz)	15	15

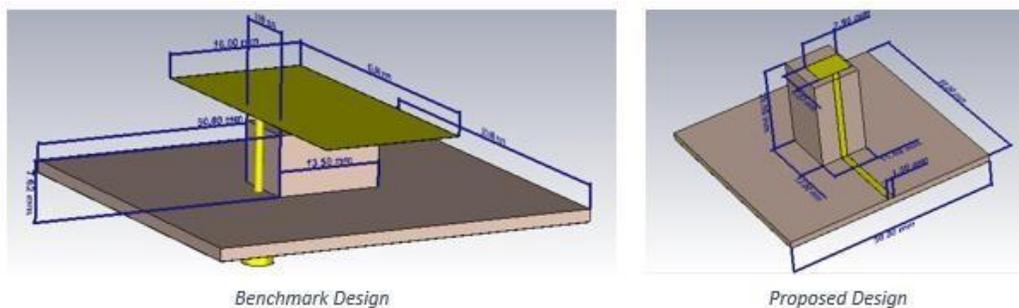


Figure 1: Benchmark Design (left) and Proposed Design Antenna (right)

## RESULTS AND DISCUSSION

The simulation and measurement findings of the design of a Dielectric Resonator antenna are explained and discussed in this chapter. CST Microwave Studio 2019 software was used to simulate the results.

### Simulation

Designing and simulating the benchmark and proposed designs with the CST Microwave Studio Software. Both designs had various dimensions in terms of DRA's length, breadth, and height, as well as the patch's measurements, as indicated in Table 1. The most significant parameters that assess the performance of an antenna in a 5G application are return loss, bandwidth, VSWR, gain, and efficiency. Table 2 below shows the findings of the simulated antennas.

Table 2: Summarize Simulated Results Obtained

Parameters	Benchmark Design	Proposed Design
Resonant Frequency (GHz)	15	15
Return Loss (dB)	-23.59	-46.85
Bandwidth (GHz)	0.25	0.50
VSWR	1.15	1.4
Gain	5.17	6.82
Efficiency (%)	1.25	0.83

The simulated S-parameter of RDRA is presented in Figure 3. Referring to the Table 2, the return loss for the proposed design is -46.17 dB at 15 GHz. The simulated -10dB impedance bandwidth  $S_{11} < -10\text{dB}$  of the antenna is 6.6% (15.3 GHz – 14.8 GHz = 0.5 GHz). The return loss for the benchmark design is -23.59 dB at 15 GHz. Then, the simulated -10dB impedance bandwidth  $S_{11} < -10\text{dB}$  of the antenna is 4.4% (14.6 GHz – 14.4 GHz = 0.2 GHz). The result obtains in proposed design has greater value in term of its bandwidth compared to benchmark design.

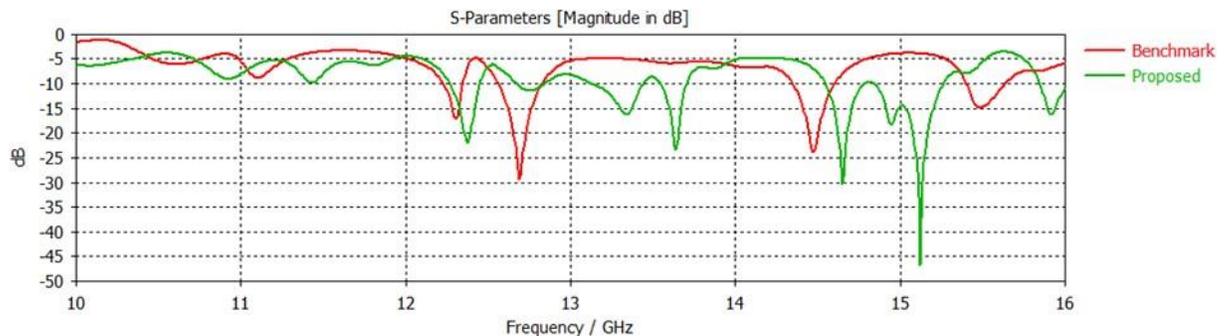


Figure 2: S-Parameter graph Result

The simulated VSWR curve as a function of frequency is shown in Figure 4. The VSWR for the entire impedance bandwidth is 1.4 and 4.4 for the proposed and benchmark designs, respectively. The number should be in the range of 1.0 to 2.0. Thus, proposed designs have attained the necessary VSWR value and benchmark design does not meet the requirement; however, for an excellent VSWR outcome, the value should range from 1.5 to 2.0. However, values between 1.0 and 2.0 are deemed acceptable, whereas values greater than 2.0 are regarded unsatisfactory.

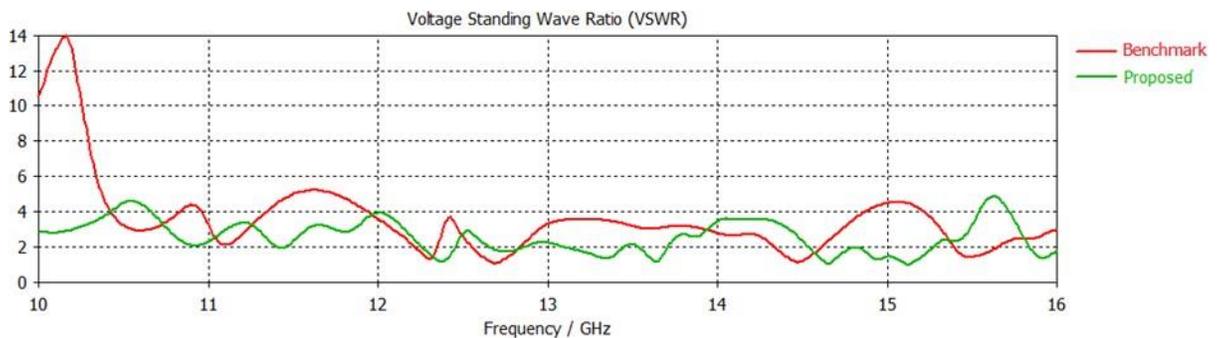
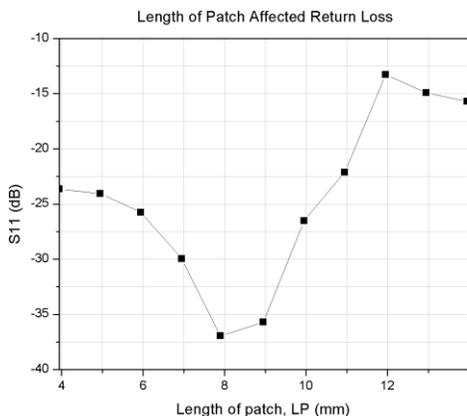
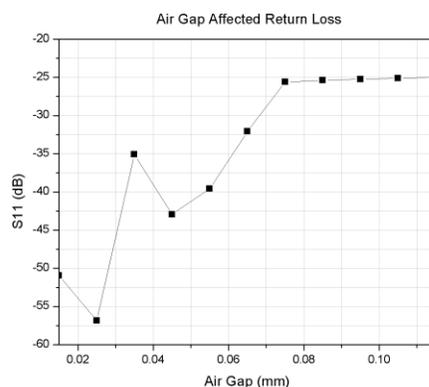


Figure 3: VSWR graph Result

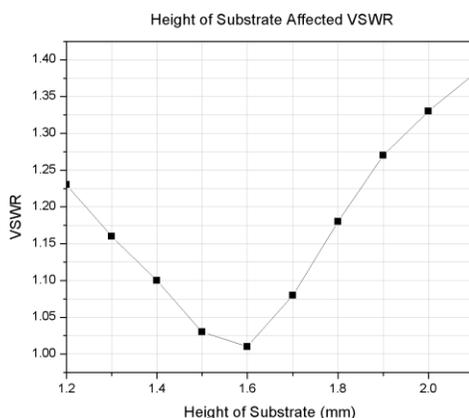
*Analyzing on Parameter Variation*



*Figure 4: Length of patch against S11*



*Figure 5: Gap DRA between substrate against S11*



*Figure 6: Height of substrate against VSWR*

There are three comparisons in this analysis between antenna parameter change and antenna output parameter. Figure 4 depicts how the length of the patch, LP, affects the value of the antenna's return loss. Return loss was measured at -46.85dB for the relevant frequency, with a patch length of 7.95mm. Due to those adjustments, the return loss recorded a diminishing pattern after lengthening the patch length. The longer the patch, the greater the return loss of antenna gain at the needed frequency [17]. Figure 5 depicts the influence of the air gap between the DRA and the substrate on the antenna's return loss value. Because of the resonance frequency, the bigger the air gap, the higher the return loss, which makes the antenna less effective for the 5G need. The air gap was measured at 0.025 mm, and the return loss was -57.89 dB. In terms of use in 5G applications, this is such a fantastic value return loss for the antenna. Following the appropriate degree of air gap, the return loss increases to the point where the antenna becomes ineffective. The influence of substrate height on the VSWR value is seen in Figure 6. Because of the resonance frequency, the thicker the substrate, the higher the VSWR, making the antenna less effective for 5G. VSWR should be between 1 and 2, with 1.5 being the most effective. The VSWR was observed at 1.38 with a substrate thickness of 2.1 mm. In terms of use in 5G applications, this is such a fantastic value VSWR for the antenna. The VSWR increases as the height of the substrate rises, making the antenna more frequency effective. Following that, the antenna's value became more stable because of the combination of parameter variations

## CONCLUSION AND RECOMMENDATION

This research was performed successfully, and a 15 GHz rectangular dielectric resonator antenna with microstrip patch load on it feed by microstrip feeding technique was designed and produced as a result. The goal of this project is to contribute to the development of 5G technology by concentrating on the Ku band spectrum. Satellite communications, broadband communications, radars, space communications, and amateur radio signals all employ these waves.

The benchmark antenna gave the bandwidth of 0.2 GHz over the frequency of 15 GHz while 0.5 GHz for proposed result. This means that the antennas had not many losses while conducting this type of antenna. The benchmark results gave the Return Loss of -23.59 dB and -46.17 dB for proposed result. There was the parameter of patch affected the return loss of the antenna, which is length of patch, LP. The VSWR result obtained from the test showed a good result with 1.4 for the proposed result but fall on 4.4 for benchmark result. As a conclusion, the proposed RDRA loaded with microstrip patch was tested and found that it was capable to operates in 5G application since the requirement for 5G technology was achieved.

A few recommendations from this research need to be improved in the future to contribute to 5G technology. The research on the sort of feeding approach utilized should be continued in the future, as different feeding techniques have resulted in varying performances. Furthermore, different types of substrates, such as RT/Duroid, and other types of dielectric materials can be employed to improve S-parameter and VSWR performance. Aside from that, due to limited capabilities at the university, the method chosen to create the dielectric material was not the correct methodology. Furthermore, the S-parameter and VSWR were measured as antenna performance parameters in this study. As a result, other characteristics such as gain, directivity, radiation pattern, and so on should be investigated in future research to learn more about the antenna's performance. Finally, to model and analyze the suggested Rectangular Dielectric Resonator Antenna design, various simulation software such as HFSS, Sonnet light, and Keysight ADS should be investigated.

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