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IMPLICATIONS OF THE REDUCTION OF PATCH LENGTH IN RECTANGULAR MICROSTRIP PATCH ANTENNA DESIGN

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ABSTRACT

This paper investigates the implications of the reduction of patch length in Rectangular Microstrip Patch Antenna (RMPA) design. In order to determine the implications of the patch length reduction, two (2) rectangular microstrip patch antennae which were designed, modelled and simulated using the same procedures, the same software, the same feeding method, the same materials and the same dimensions of all the antenna parameters, with the exception of the length of the

Introduction

Antenna is an inevitable part of any wireless communication system. It is a manufactured radiating device or "an electric inducer which is used to transform electrical waves into electromagnetic waves and electromagnetic waves into electrical waves" (Bhoot A. A, 2019). Despite the fact that there are different types of antenna that can be designed and constructed for wireless communication, most people prefer a micro-strip patch antenna. This is due to its low-cost, ease of construction and flexibility in terms of usage (Alkharusi, 2020). Other advantages are the antenna's small volume and performance. However, micro-strip antenna has a number of set-backs such as numerous losses, (Al-dawi, 2022). A micro-strip patch antenna has different shapes with a rectangular shape being the most popular. A rectangular micro-strip patch antenna is widely used due to its simplicity in fabrication and handling, and its robust design (Subrahmanya, 2009). The design of micro-strip patch antenna consists of three major components i.e. patch, substrate and ground plane. The patch is a radiating part which is made of a conductive material like copper. The ground plane is a

patch, were analysed. One of the antennae was adopted while the other was a newly designed antenna whose patch length was reduced by about 2% when compared with the length of the adopted antenna. The two (2) antennae were designed at 3.5 GHz resonant frequency and simulated using CST Microwave Studio Suite 2019 for 5G applications. Transmission line method was used as the feeding method of the antennae. Based on the results, it was found that the reduction in dimension of the patch length significantly affects the performance of the RMPA negatively. This implies that increment of the dimension of the patch length to certain level, enhances the performance of the RMPA.

Key Words: Dimension, Implications, Parameters, Patch, Reduction.

flat conductive material which acts as part of the antenna to reflect the radio waves emitted from the other components of the mechanical support to the antenna (Hegazy, 2018). Different methods and techniques were used by researchers to enhance the performance of microstrip patch antenna. Researches are still on-going in search of other means of improving the MPA's performance. One of the qualities that make MPA attractive in modern/wireless communication system is its small size (Firoz Ahmed, 2021). It is therefore essential to find means of designing smaller size antennae without compromising its performance (Nurulazlina Ramli, 2020). The implications of the reduction of the patch length in designing a RMPA will provide us vital information concerning the design of the MPA. This paper therefore investigates the implications of the reduction of patch length in Rectangular Microstrip Patch Antenna (RMPA) design.

In order to determine the implications of the patch length reduction, two (2) rectangular microstrip patch antennae will be designed, modelled and simulated using the same procedures, the same software, the same feeding method, the same materials and the same dimensions of all the antenna parameters, with the exception of the length of the patch, and analysed. One of the antennae will be adopted while the other will be a newly designed antenna whose patch length will be reduced by about 2% when compared with the length of the adopted antenna. The two (2) antennae will be designed at 3.5 GHz resonant frequency and simulated using CST Microwave Studio Suite 2019 for 5G applications. Transmission line method will be used as the feeding method of the antennae.

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LITERATURE REVIEW

In (Sohel Rana, n.d), it was reported that a multiband microstrip patch antenna for wireless applications in the L, S, and C frequency bands was investigated using FR-4 substrate material. Radars, cell phones, satellite communication, and Wi-Fi can all use the antenna. For design and simulation, CST software produces precise results and numerous optimizations. For multiband wireless applications, the objective was to determine the proper return loss, standard VSWR, and bandwidth. It was a good contender for wireless applications because the simulation findings were better than those of earlier studies. The optimization of MPA was done by changing the dimensions of some of its parameters such as the length of the patch. A rectangular microstrip patch antenna with inset feed for Industrial-Scientific-and-Medical (ISM) band applications was designed, implemented, and the process is described in (Sagne, 2020). In order to create an antenna model with good performance, parametric variations which involve changing the proportions of several antenna parameters were employed. When the antenna was developed with a 28.3x37.5 mm2 patch, FR4 substrate, and inset feeding approach, the best results were obtained. With a gain and return loss of 1.977dBi and -19.25dB, respectively, the results demonstrate a good return loss at a desired frequency. The performance parameters of a microstrip rectangular patch antenna were examined in (Malik, 2020), with particular attention paid to how frequency was affected by antenna length, width, and dielectric constant. Critical aspects like antenna feed width and effective wavelength are taken into consideration as it explains and simulates these characteristics using MATLAB software. The findings indicated that while the effective dielectric constant was unaffected, antenna design necessitates more length and width at lower frequencies. The antenna was designed using 3D printing technology and tested in an antenna laboratory. The results showed that a suitable and reliable microstrip antenna optimized for microwave frequencies had been developed, potentially contributing to wireless communication technology. The study (Kaustubh K. Shukla, 2023) explores the design of a rectangular microstrip patch antenna to improve its gain and bandwidth, with experiments demonstrating that increasing substrate height and patch length can enhance bandwidth and gain.

METHODOLOGY

A Rectangular Microstrip Patch Antenna (RMPA) was adopted from (Abbas Adamu, 2024) and another RMPA was designed, modelled and simulated using the same procedure, the same feeding method, the same materials and the same dimensions of all the antenna parameters with the adopted RMPA except for the dimension of the patch length. The variation in the length of the patch was to determine the implications of the reduction of the patch length. The antennae were modelled and simulated in CST Microwave Studio Suite 2019. The results of the two (2) antennae were finally analysed.

Design Calculations of the Parameters of Microstrip Patch Antenna

The following equations were used for the designs of the antennae (Septiany, 2021):

Step I: Calculate the width of the micro-strip patch

$$W = \frac{C}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad 1$$

Step II: Determine the effective dielectric constant, ε_{eff}

$$\varepsilon_{eff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\ 1+\left[\frac{1}{\sqrt{1+12\left(\frac{w}{h}\right)}}\right] \quad 2$$

Step III: Calculate the height of the substrate which is given as:

$$\frac{h}{\lambda} \le \frac{0.3}{2\pi\sqrt{\epsilon_r}} = h = \frac{0.3c}{2\pi f\sqrt{\varepsilon_r}} \quad 3$$

Step IV: Determine the effective length, L_{eff}.

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{eff}}} \quad 4$$

Step V: Find the extension length, ΔL.

$$\Delta L = 0.412h\left[\frac{\varepsilon_{eff}+0.3)\ (\frac{w}{h}+0.264}{\varepsilon_{eff}-0.258)\ (\frac{w}{h}+0.8)}\right] \quad 5$$

Step VI: Calculate the actual length of the micro-strip patch.

$$L = L_{eff} - 2\Delta L \quad 6$$

Step VII: Find the ground plane dimensions. The ground plane dimensions (Length and Width) are given as:

$$L_g = L + 6h \quad 7$$

$$W_g = W + 6h \quad 8$$

Where L and W are the length and the width of the patch antenna.

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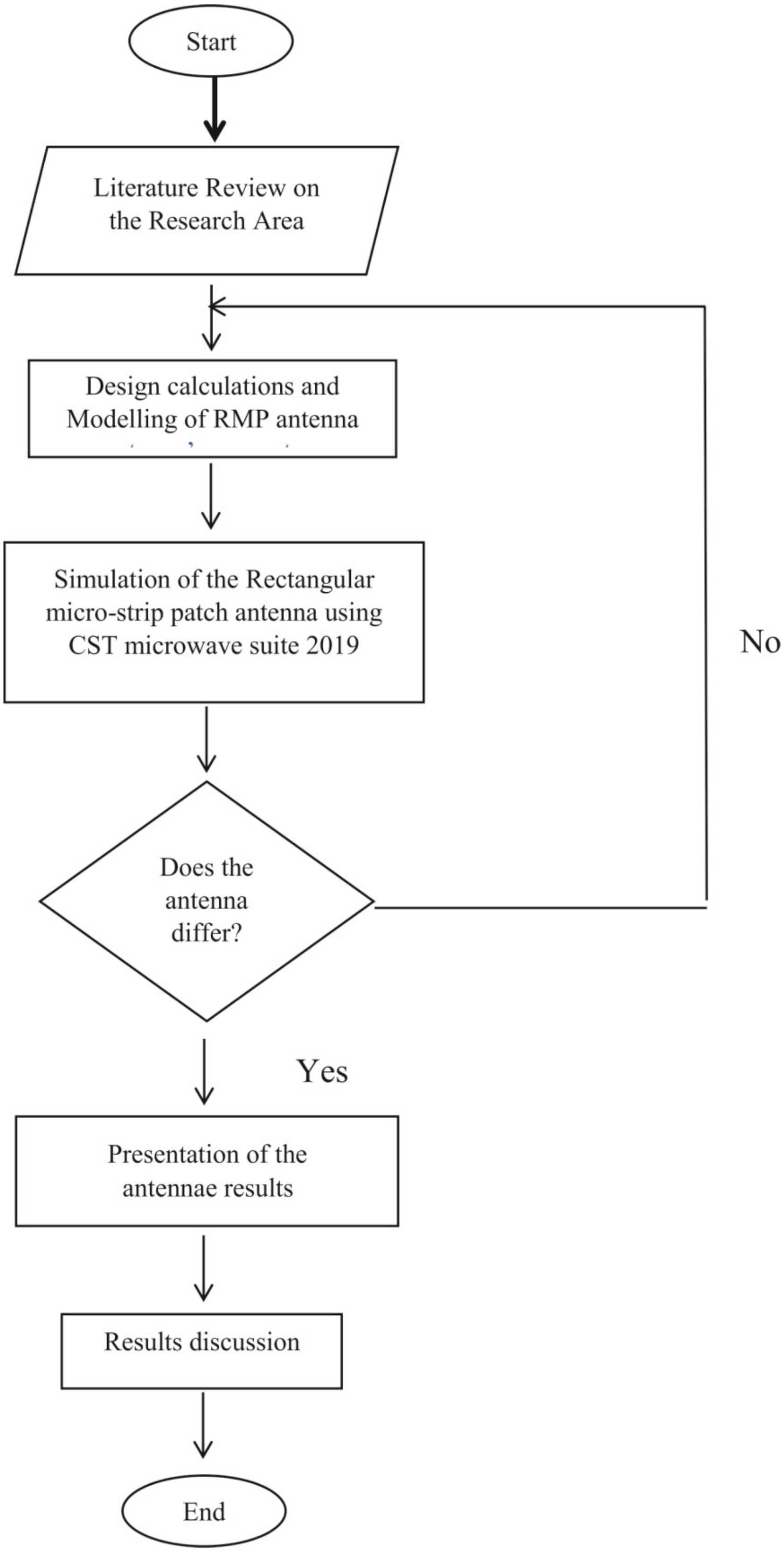

Figure 1: A Flow-chart of the Steps Followed in the Research

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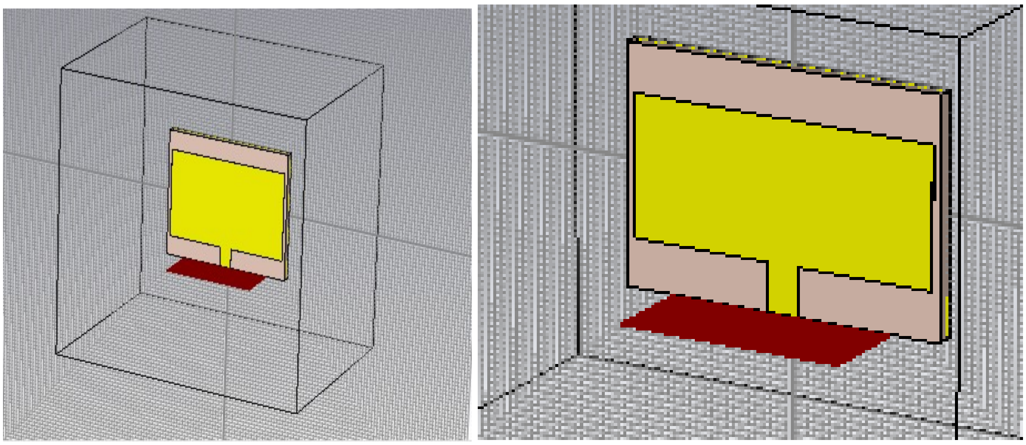
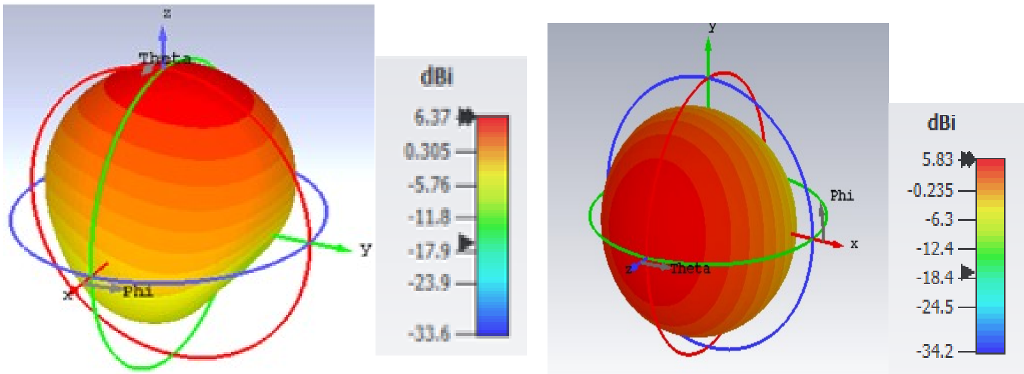
RESULTS AND DISCUSSIONS



(a) Adopted Model of RMPA *(b) A New Model of RMPA with Reduced Length of the Patch*

Figure 2: Models of RMPA (Source: CST Microwave Studio Suite, 2019)

Figure 2 'a' and 'b' show the models of the RMPA's used in this research paper. Each of the two (2) antennae has three (3) major parts, namely ground, substrate and patch. The two (2) antennae were designed in the same way, using the same materials and the same feeding technique, only that the patch length of the first model (2 'a') is greater than the patch length of the second model (2 'b') with 0.36 mm. This is done to determine the implication of the reduction in the length of the patch.



(a) 3D View of the Radiation Pattern of the Adopted RMPA *(b) 3D View of the Radiation Pattern of the Newly Designed RMPA*

Figure 3: The 3D Radiation Patterns of RMPA: (Source: CST Microwave Studio Suite, 2019)

Figure 3 ('a' and 'b') show the 3D radiation patterns of the two antennae under study. The red portions on the figures show the areas with higher amount of radiation. The antennae can therefore be used as directional antennae. It is also clear from the figures that the adopted model (2'a') has higher gain of 6.37 dB than the newly designed model (2 'b') which has the gain of 5.83. It is therefore obvious that about 8.5 % of gain is reduced in the second RMPA design. This implies that the variation in the gain is attributed to the reduction in the length of the antenna's patch.

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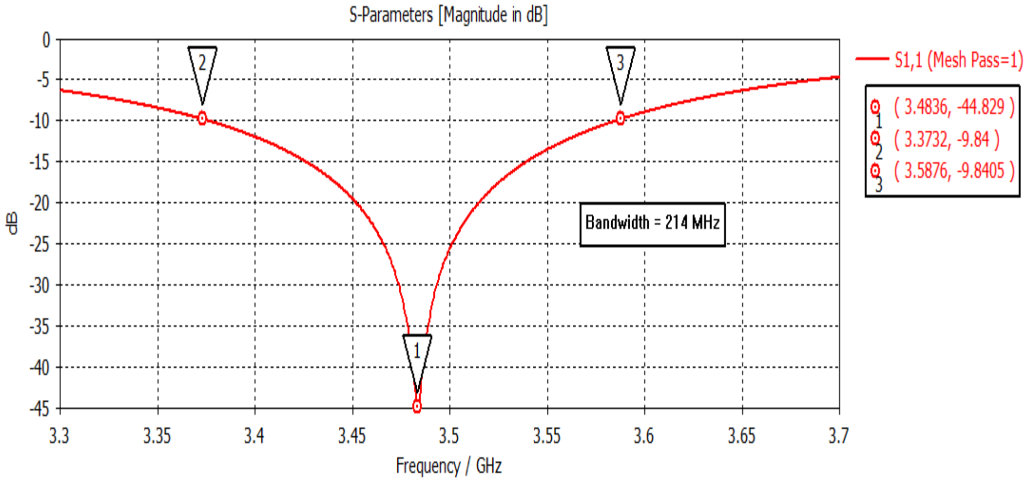
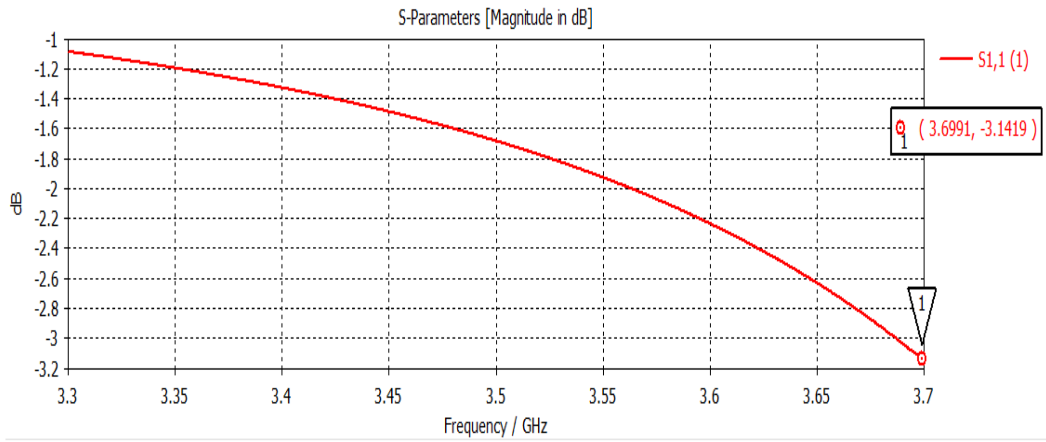


(a) Reflection Coefficient of the Adopted RMPA Model



(b) Reflection Coefficient of the Newly Designed RMPA Model

Figure 4: The Reflection Coefficients (S_{11}) of RMPA Models (Source: CST Microwave Studio Suite, 2019).

Figure 3 'a' and 'b' show the reflection coefficient graphs of the RMPA models. From the graph, the adopted model 'a' has a reflection coefficient of -44.829 dB which is a very good result for 5G applications because the ITU recommended a reflection coefficient of less than -10 dB. It also has a bandwidth of 214 MHz which is also commendable.

On the other hand, the newly designed model (1 'b') has a poor reflection coefficient value of -3.142 dB. Consequently, the graph is not in a curve form and so the bandwidth of the design cannot be predicted. These two (2) things show that the design is weak and cannot be used in 5G applications. The variation is solely attributed to the reduction of the patch length in the second design.

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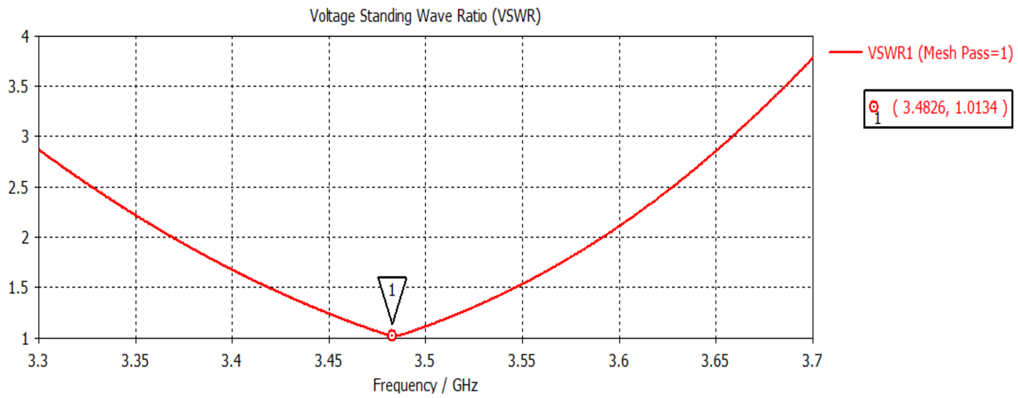
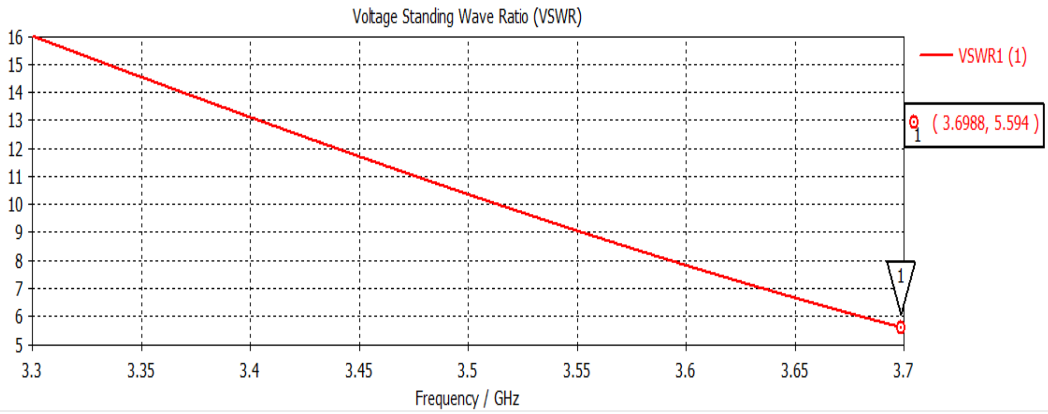


(a) *VSWR of the Adopted Model of the RMPA*



(b) *VSWR of the Newly Designed Model of the RMPA*

Figure 5: The VSWR's of RMPA Models: (Source: CST Microwave Studio Suite, 2019)

Figure 5 'a' and 'b' show the Voltage Standing Wave Ratio (VSWR) of the RMPA's. Figure 'a' shows the VSWR of the adopted antenna design which is a quite good result as it stands at 1.013. The threshold is put by ITU at < 2 for 5G applications.
On the other hand, the 'b' model has a VSWR of 5.594 which is too far behind the threshold. It can be concluded that the 'b' model cannot be used in 5G applications and the deficiency in its design is attributed to the reduction of the patch length of the RMPA.

CONCLUSION

This work aimed at finding the implications of the reduction of patch length in Rectangular Microstrip Patch Antenna (RMPA) design. An RMPA was adopted while another was newly designed and simulated using the same procedures, materials, dimensions and software. The only difference between the two (2) antennae was that the patch length of the newly designed antenna was reduced by about 2% as compared by the adopted RMPA. In conclusion, the results of the two (2) antennae analysed showed that the reduction of the patch length significantly affects the performance of the antenna negatively. This can be clearly seen from the results of the antenna's

Voltage Standing Wave Ratio and Reflection Coefficient. It can also be deduced from the results that the length of the patch can be increased to certain level in order to enhance the performance of RMPA during its design and modelling.

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