HP
JIETR2023
Hummingbird Publications
Journal of Innovations in Engineering & Tech. Res.
www.hummingbirdjournals.com
© May, 2025
Vol. 8 No. 5

Role of Proper Selection of a Conducting Material in Microstrip Patch Antenna Design

[1]Abbas Adamu; [2]Paul Thomas Muge; [3]Bilyaminu Usman; [4]Na'im Garba Yusuf; & [5]Mbonu Oyebuchi Ebulu
[1-5]Department of Electrical and Electronics Engineering Technology, Federal Polytechnic N'yak-Shendam. Plateau State
Corresponding Author: abbasawa85@gmail.com
DOI: **https://doi.org/10.70382/hujcer.v8i5.004**

Key Words:
Aluminium, Conducting Material, Copper Annealed, Iron, Resonant Frequency.

Abstract
This paper examines the role of a proper selection of a conducting material in the design of microstrip patch antenna. A microstrip patch antenna has three (3) main parts of ground, substrate and patch. The patch and the ground are made up of a conducting material. In this work, three (3) Rectangular Microstrip Patch Antennae (RMPA) were considered at 3.5 GHz resonant frequency for 5G applications with different conducting materials in order to determine the role of conducting material in designing a microstrip patch antenna. The antennae were designed, modelled and simulated using the same feeding methods, the same dimensions and the same materials with the exception of the conducting material. Copper annealed, iron and aluminium were used for the models of the antennae. It was found that the best conducting material was copper annealed, followed by aluminium then iron. Hence, the performance of a microstrip patch antenna depends on the type of conducting material used in its design among other factors. It is recommended that other conducting materials be explored to determine their role in ensuring effective design of the microstrip patch antenna.

Introduction

In designing a microstrip patch antenna (MPA), the proper selection of a dielectric material and its thickness is essential in ensuring the effectiveness of the antenna in terms of performance (Rafi'a Nishat Toma, 2019; A., 2024). Apart from the substrate of the antenna, the other two main parts of the MPA are made up of conducting material. Most researches on MPA design in the literature used copper annealed as conducting material. It is therefore important to determine the role of a proper selection of a conducting material in designing MPA and the individual capability of the different conducting materials when used for MPA design. Some of the conducting materials include iron and aluminium. The performance of three (3) similar antennae modelled with different conducting materials were analysed to determine their roles in the MPA designs. One of the three (3) antennae which was modelled using copper annealed was adopted from (Abbas Adamu, 2024).

LITERATURE REVIEW

Researches were carried out to determine the contributions of substrates in enhancing the performance of MPA. For instance, in (Maruf Ahamed, 2012), results for different dielectric constant values were presented, with the best results achieved at a thickness of 2.88mm and a resonance frequency of 2GHz. The proposed antenna design on Duroid substrate with a dielectric constant of 2.32 provides high performance at 2GHz, with a radiation efficiency of 91.99%. It was reported in (Tiara Septiany Persada, 2021) that the rectangular patch antenna, a compact device for mobile communication, has limitations due to its limited bandwidth. A natural dielectric can enhance this by replacing the artificial dielectric, resulting in a 13.82% increase in bandwidth and a 14.12% reduction in size. This method can be used for miniaturizing patch antenna size. The study in (Rafi'a Nishat Toma, 2019) optimizes the performance parameters of microstrip patch antennas using Roger RT Duroid substrates. The antennas are designed with resonant frequencies of 10 GHz, 28 GHz, and 2.5 GHz. The study demonstrates that employing higher dielectric constant substrate material affects antenna performance but enhances bandwidth. The proposed antenna can operate at 10 GHz with 85% efficiency. At 29.46 GHz, the modified square patch antenna provides directivity and a gain of 6.97dB. The paper (Sagne, 2020) discusses the design, implementation, and procedure of a rectangular microstrip patch antenna with inset feed for Industrial-Scientific-and Medical (ISM) band applications. The antenna is designed with a FR4 substrate and fed with an inset feeding technique.

The results show a significant match between simulated and fabricated antenna results, with gain and return loss achieved at 1.977dBi and -19.25dB respectively. It was reported in (Varalakshmi, 2023) that microstrip patch antennas (MPA) have become more prominent in wireless communication due to their tiny size and versatility. However, precise alignment and line feeding might be hard. Using CST studio software 2019, the suggested radiator was examined for three geometries and various substrates with a dielectric layer height of 1.6 mm. In another study (Nuralazlinz Ramli, 2020), a 3.5 GHz microstrip patch antenna using three different substrates materials with varying relative permittivity have been designed. However, the thickness of the substrates are slightly different from each other which is 1.6 mm for FR-4, 1.575 mm for RT-5880 and 1.58 mm for TLC-30 have been chosen to carry out this work. The three substrates materials are FR-4 (Design-1), RT-5880 (Design-2), and TLC-30 (Design-3) with the relative permittivity of 4.3, 2.2, and 3, respectively. The antennas' performances in terms of reflection coefficient, voltage standing wave ratio (VSWR), bandwidth, gain, and efficiency performance is simulated, analyzed and compared using CST Microwave studio (CST 2019). The findings reveal that there is a significant change in gain and bandwidth due to different relative permittivity. The paper (Alam, 2018) investigates the resonance and radiation characteristics of patch antennas using two different dielectric substrates at the GSM 1800 MHz band. The researchers used a high permittivity dielectric material (barium titanate) to reduce antenna size and compare its performance with a low permittivity substrate. The antenna volume decreased by 2.5 dB. On the other hand, there are limited researches or almost no researches carried out on the contributions of the conducting material in enhancing the overall performance of the MPA. It is therefore important to determine the role of the conducting material in the overall performance of the MPA.

METHODOLOGY

A RMPA at 3.5 GHz resonant frequency for 5G applications which was designed using copper annealed was adopted (Abbas Adamu, 2024). Other two (2) RMPA's were modelled using the same specifications with the adopted antenna with a difference of the conducting materials that were used. While the adopted material was made up of a copper annealed, the other two (2) were modelled using iron and aluminium. The two (2) new designs were simulated in CST Microwave Studio Suite 2019 just like the adopted antenna. The results of the three (3) antennae were analysed in order to determine the role of each conducting material in enhancing the performance of the MPA.

Design Equations of RMPA

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

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

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

1

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

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

2

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

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

3

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

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

4

Step V: Find the extension length, ΔL.

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

5

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

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

6

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

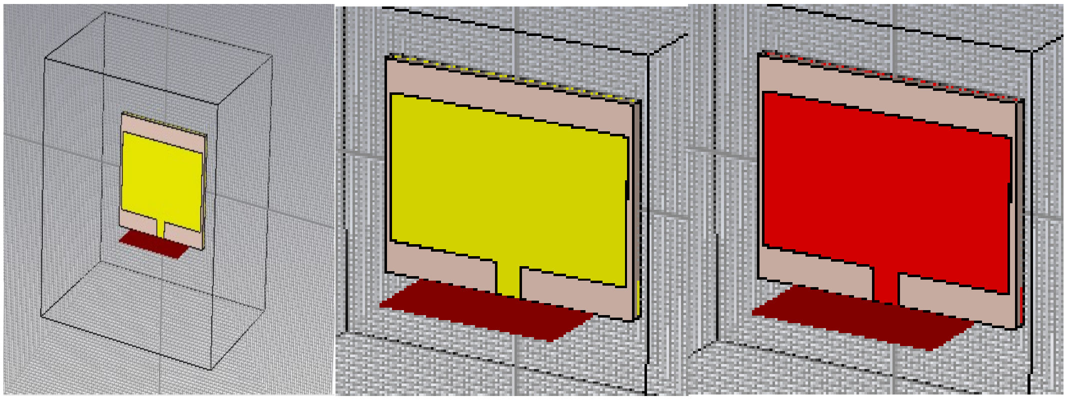
$$L_g = L + 6h$$ 7

$$W_g = W + 6h$$

8

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

RESULTS AND DISCUSSIONS

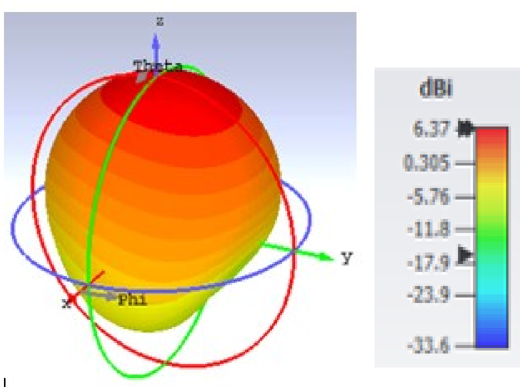


(a) *(b)* *(c)*

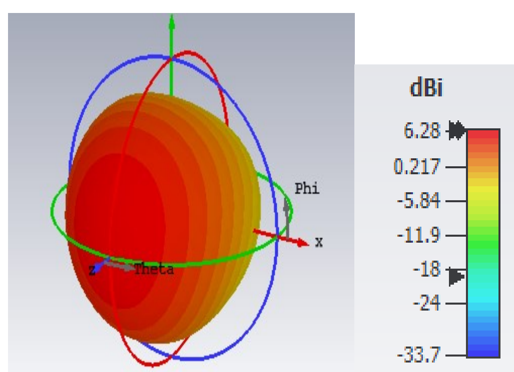
(a)The Adopted Model of RMPA with Copper Annealed (b) The Newly Designed Model of RMPA using Aluminium (c) The Newly Designed Model of RMPA using Iron

Figure 1: Models of RMPA with Different Conducting Materials

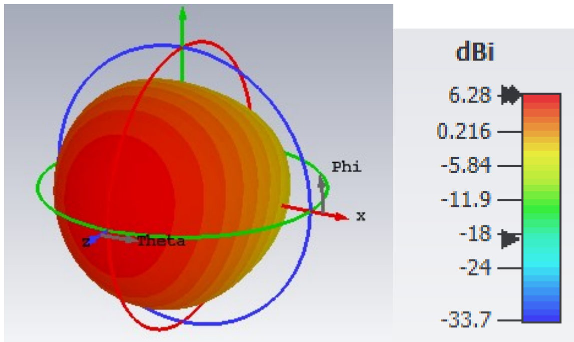
Figure 1 'a' to 'c' show the models of the three (3) antennae which were modelled with three (3) different conducting materials. The antennae were designed with copper annealed, aluminum and iron respectively. The MPA has three (3) main parts, namely: ground, substrate and patch. The three (3) models were designed using the same feeding methods, the same dimensions of the parameters and the same materials, with the exception of the conducting materials. It is therefore assumed that all variations in the antennae's performance were attributed to the different conducting materials used in the designs.



(a) The 3D View of the Radiation Pattern Of the Adopted RMPA (with Copper Annealed);

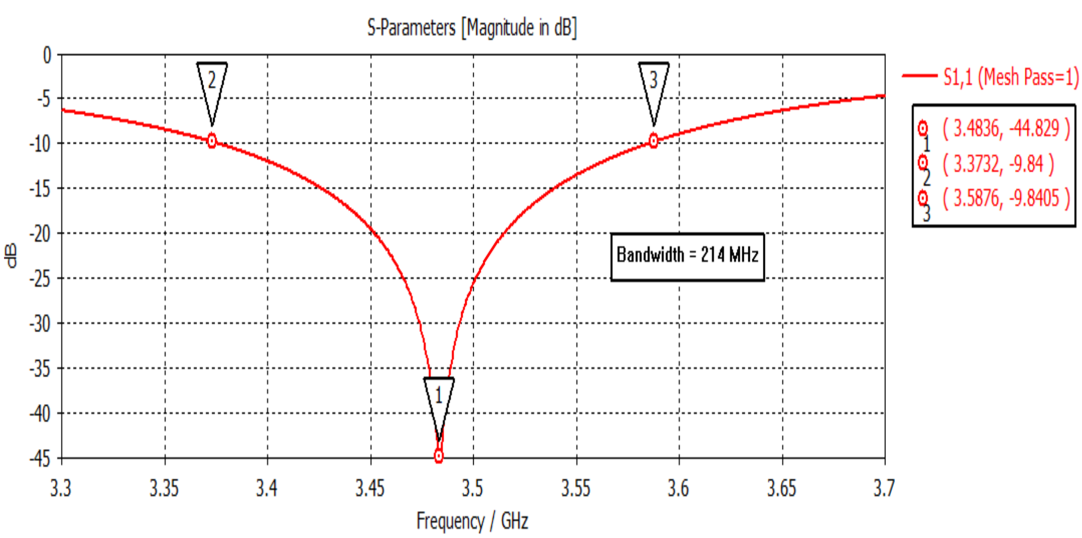


(b) The 3D View of the Radiation Pattern of the newly designed RMPA (with Aluminium)

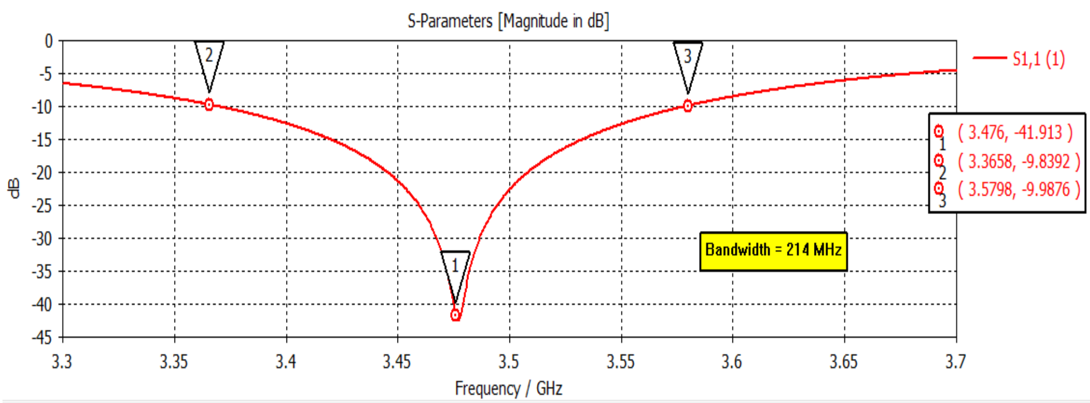


(c)The 3D View of the Radiation Pattern of the newly designed RMPA (with Iron)
Figure 2: The 3D Views of the Radiation Pattern of the RMPA's

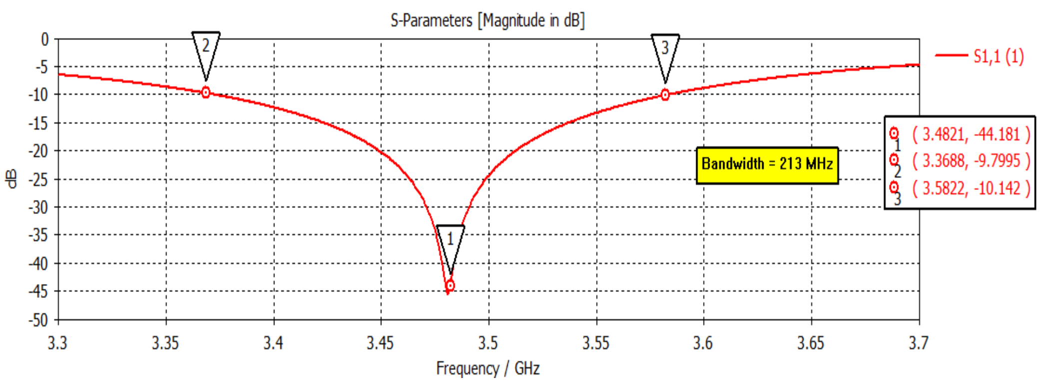
Figure 2 'a' to 'c' show the radiation pattern of three (3) antennae which were designed using different conducting materials. The antennae were modelled using copper annealed, aluminum and iron respectively. The red portions of the radiation patterns show the area that has high amount of radiation. This indicates that the antennae are good candidates in use as directional antenna. Based on the results, the 'a' antenna which was made with copper annealed, has the highest gain of 6.37 dB. The other two (2) antennae have the same amount of gain which is 6.28 dB. The three (3) antennae can all be used for the same applications because there is no significant difference in the amount of their gains. However, we can deduce that copper annealed is the best conducting material out of these three (3) in terms of gain. Again, the other two (2) antennae (b and c) are the same in this regard.



(a) The Reflection Coefficient of the adopted antenna (with Copper Annealed)



The Reflection Coefficient of the antenna designed with Aluminum

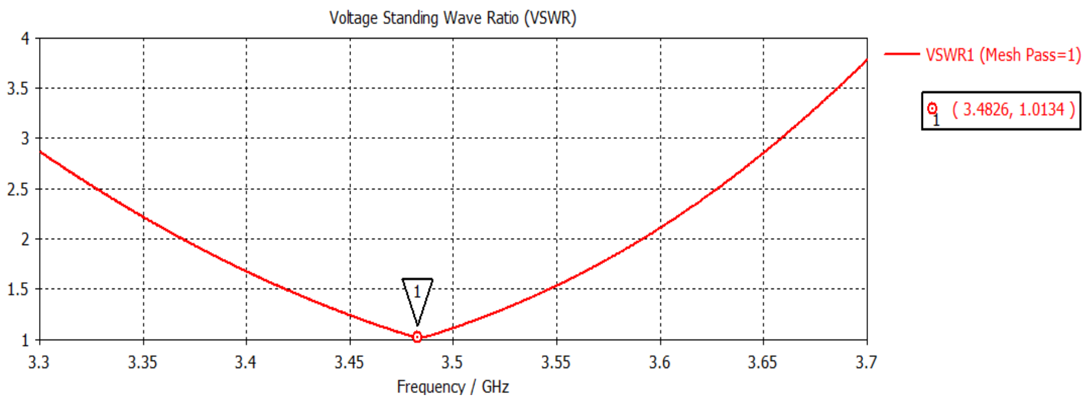


(b) The Reflection Coefficient of the antenna designed with Iron

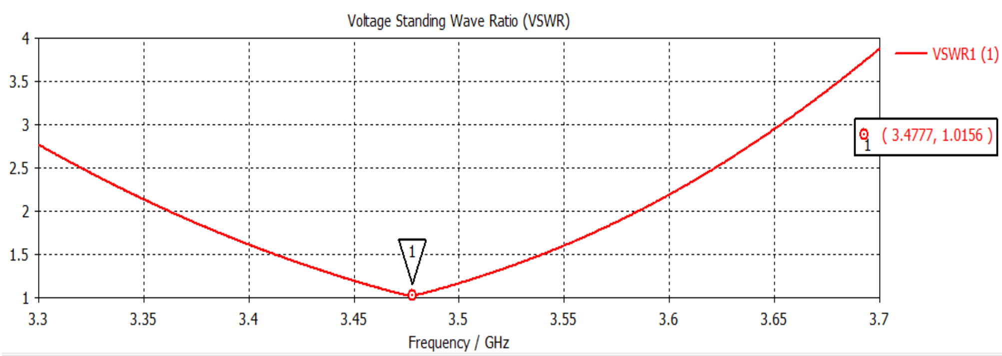
Figure 3: The Reflection Coefficients of MPA's designs using different Conducting Materials

Figure 3 'a' to 'c' show the reflection coefficient graphs of the three (3) antennae. The threshold value of the reflection coefficient value for 5G applications is less than -10 dB, as recommended by ITU. Therefore, all the designs can be used for 5G applications because they have good values of reflection coefficient. The lower the value of the reflection coefficient, the better the antenna. The results show that the antennae have reflection coefficient values of -44.829 dB, -41.913 dB and -44. 181 dB for copper annealed, aluminum and iron respectively. Although there is no significant difference in terms of the reflection coefficient values of the antennae, the antenna which was designed with copper annealed has the lowest value followed by the antenna with iron, then the antenna with aluminum.

With regard to the bandwidths of the antennae, the antennae have bandwidths within the same range. While the antenna with copper annealed has the widest bandwidth of 214 MHz, the other two (2) antennae have the same bandwidths of 213MHz each. It is therefore apparent that the antennae have almost the same value of bandwidths.

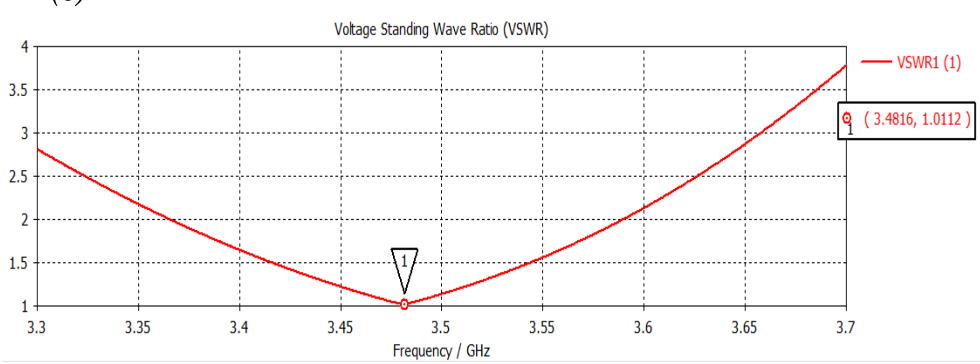


(a) The VSWR of the adopted RMPA (with Copper Annealed)



(b) The VSWR of the antenna designed with Aluminum

(c)



(d) The VSWR of the antenna designed with Iron

Figure 4: The VSWR's of the RMPA's

Figure 4 'a' to 'c' show the Voltage Standing Wave Ratio (VSWR) of the three (3) antennae. All the antennae achieved good values of the VSWR. The ITU recommended less than 2 as the requirement for a MPA to be used in 5G applications. The lower the VSWR of an antenna, the better the antenna. The VSWR of the three (3) antennae are 1.0156, 1.0156 and 1.0112 for antenna designed with copper annealed, aluminum and iron respectively. It is clear from the results that there is no significant difference among the antennae in terms of their VSWR's.

CONCLUSION

Base on the findings of this research paper, we can conclude that the conducting material used in designing a MPA plays a vital role in ensuring the overall performance of a MPA. Again, it is clear that the three (3) conducting materials used in designing the antennae have almost the same qualities as there is no significant difference in their performance. It can also be deduced that one conducting material may be better than another or may be the same with another in terms of a particular parameter while the latter may be better than the former in terms of another parameter. Hence, in using any of the three (3) conducting materials used in designing the MPA's of this paper for fabrication, other factors, such as economic factors and availability of the conducting material, should be prioritized. It is recommended that other conducting materials be explored to determine their role in ensuring effective design of the microstrip patch antenna.

REFERENCES

A., M. M. (2024). Design of Microstrip Patch Antenna. *International Journal of Advanced Computer Sience and Applications, 11*(8), 77-83.

Abbas Adamu, A. A. (2024). Performance enhancement of a rectangular microstrip patch antenna using TLC-30 substrates for 5G applications: Design and simulation. *2nd National Conference/Exhibition of Academic Staff Union of Polytechnics Federal Polytechnic Bauchi Chapter: Prospects of Technopreneurship as a Catalyst for Sustainable Industrialization in Nigeria.*

Alam, M. A. (2018). Performance evaluation of rectangular microstrip patch antennas loaded with plastic and Barium-Titanate substrates at GSM 1800 MHz band. *Open Journal of Antennas and Propagation, 6*(3), 36-42.

Maruf Ahamed, K. B. (2012). Rectangular Microstrip Patch Antenna at 2 GHz on different dielectric constant for pervasive wireless communication. *International Journal of Electrical and Computer Engineering, 2*(3), 417-424.

Nuralazlinz Ramli, S. K. (2020). Besign and performancevanalysis of different dielectric substrate based microstrip patch antenna for 5G applications. *International Journal of Advanced Computer Science and Applications, 11*(8), 77-83.

Rafi'a Nishat Toma, I. A. (2019). Analysis of the effect of changing height of the substrate of square shaped microstrip patch antenna on the performance for 5G applications. *International Journal of Wireless and Microwave Technologies, 9*(3), 33-45. doi:10.5815/ijwmt.2019.03.04

Sagne, A. T. (2020). Parametric variations of rectangular microstrip patch antenna designed for WLAN application. *Helix, 13*(14), 15-19.

Tiara Septiany Persada, H. L. (2021). Bandwidth Enhancement of the Rectangular Patch Antenna Using Artificial Dielectric and Proximity Coupled Line Feed. *Advances in Engineering Research, Proceedings of the 2nd International Seminar of Science and Applied Technology (ISSAT 2021). 207.* ATLANTIS PRESS.

Varalakshmi, P. V. (2023). Analysis of substrate and shapes of microstrip antenna for 5G witreless communicatyions. *Research Square*. doi:https://doi.org/10.21203/rs.3.rs-2560928