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Design and Analysis of a Ku Band Rectangular Microstrip Patch Antenna

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ABSTRACT

The aim of this work was to design a rectangular microstrip patch antenna that will operate at a Ku band. The design was done using mathematical or computation method. The frequency of operation of the rectangular microstrip patch antenna designed is 16 GHz (16 x 10^9 Hz). It was observed from the result that as the values of the dielectric constant is increasing, the dimensions- height, length and width of the antenna decrease. For instance, when the value of the dielectric constant increased from 2.0 to 2.5, the patch antenna height decreased from 0.633 mm to 0.566; the width decreased from 7.65 mm to 7.09 mm, and length changed from 6.48 mm to 5.82 mm. It was concluded that the higher values of dielectric constant will result in the decrease in the size of a rectangular microstrip patch antenna. It was recommended that further work involving the varying of frequency with or without the varying of the value of dielectric constant be done since this one involved a constant frequency of operation with varying values of the dielectric constant, εr.

KEYWORDS: Antenna, Dielectric, Microstrip, Satellite, Width

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1. INTRODUCTION

An antenna is a device that transmits and/or receives electromagnetic waves. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band (Ahmed, 2011). Microstrip antennas consists of patch, substrate, ground plane and feeding point. It is simple to construct and are mostly used in the microwave frequency range (Atser *et al.,* 2013).

The microstrip Ultra Wideband antennas is one of the most commonly used antennas in radar applications. It has attracted a lot of attention because of their advantages such as ease of fabrication simple structure, easy integration with microwave integrated circuits (Houda, 2016). In Wireless transmission technology, a microstrip patch antenna is the most popular, especially in microwave systems because of their attractive features such as small in size, light weight and easy to fabricate (Mahmud, et al., 2018). The basic antenna geometry comprises of a dielectric substrate sandwiched between the ground and radiating patch. The substrate, besides providing mechanical strength to the overall antenna design, also allows surface waves to propagate through it (Suvadeep, 2014).

The microstrip patch antenna is an essential component of wireless communication and consists of a ground plane, dielectric substrate, and a thin copper metallic patch. The rectangular and circular shapes are the most frequently employed shapes for microstrip patch antennas (*Rishitha, 2023*). The design carried out in this work is different from the previous works reviewed so fr in the course of the work.

2. BASIC COMPONENTS OF MICROSTRIP PATCH ANTENNA DESIGN

2.1. Dielectric substrate: A substrate is a semiconductor used as basis for an integrated circuit or electronic component. A dielectric substrate is a substrate that does not conduct direct current and therefore used as insulator. The value of dielectric constant reduces with the height of the patch antenna. the dielectric constant ε_r is defined as the ratio of permittivity of a substance to the permittivity of free space. This design makes use of a substrate; RT DUROID 5880 with dielectric constant of 2.6

2.2. Frequency of operation: This is the frequency at which the antenna receives and/or transmits signals. It can be calculated when the height of the patch is known or can be selected before the design. The operating frequency used in this design is 4.5GHz which is within the C-Band frequency range. Operating frequency is represented by the symbol F_c or F_o.

2.3. Height of the patch antenna: The height can be selected before calculating the operating frequency of the antenna, or the operating frequency can be used to find the height, or both can be selected before the design but must meet the condition given as (Huang and Kevin, 2008);

$$\frac{h}{\lambda} \leq \frac{0.3}{2\pi\sqrt{\varepsilon_r}} \qquad (1)$$

3. Antenna Design Method

The method used for the design is mathematical method. Various parameters of the antenna are determined using mathematical equations as shown below.

3.1. Determination of the height (H) of the patch: The height of the patch is calculated using the formula (Huang and Kevin, 2008);

$$H = \frac{0.3C}{2\Pi F_o\sqrt{\varepsilon_r}} \qquad (2)$$

Where C = Speed of light, given as 3.0 x 10^8m/s, ε_r = The dielectric substrate, which varies from 2.0 to 4.0 in this design and analysis.

The height, H is in millimetres (mm)

3.2. Determination of the width (W) of the patch: The width of the patch is calculated using the formula give as (Huang and Kevin, 2008);

$$W = \frac{C}{2F_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad (3)$$

The width, W is in millimetres (mm)

3.3. Determination of the effective dielectric constant (ε_{eff}): It is calculated using the mathematical relation given as (Huang and Kevin, 2008);

$$\varepsilon_{eff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1 + \frac{1}{\sqrt{1+12\left(\frac{H}{W}\right)}}\right) \qquad (4)$$

Or, equivalently,

$$\varepsilon_{eff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1+12\left(\frac{H}{W}\right)\right)^{-0.5} \qquad (5)$$

H and W are the height and the width of the patch in that other.

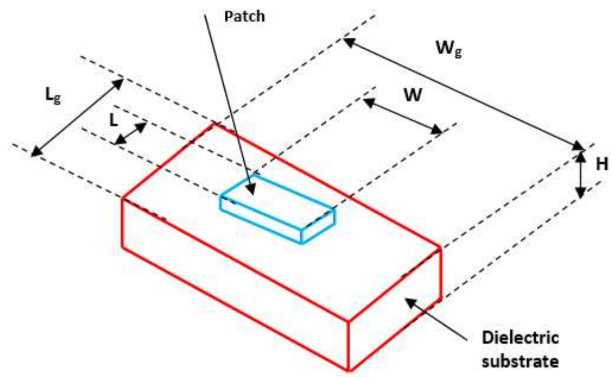

Fig. 1: Schematic diagram of a rectangular microstrip patch antenna

3.4. Determination of the effective length of the patch (L_{eff}): The effective length of the patch is given by the formula (Huang and Kevin, 2008);

$$L_{eff} = \frac{C}{2F_o\sqrt{\varepsilon_{eff}}} \qquad (6)$$

3.5. Determination of the length extension (ΔL): Length extension is the additional length at the end of the patch as a result of the fringing field along its width. It is calculated using the formula given as (Huang and Kevin, 2008);

$$\Delta L = 0.412H\left[\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{H}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{H}+0.8\right)}\right] \qquad (7)$$

Where ΔL is the patch length extension in millimetre, H and W are the height and width of the patch respectively, and ε_{eff} is the effective dielectric constant of the substrate, and is dimensionless.

3.6. Determination of the actual length (*L*) of the patch: The actual length of the patch, L is the difference between the effective length and twice of the length extension of the patch. It is represented mathematically as (Huang and Kevin, 2008);

$$L = L_{eff} - 2\Delta L \quad (8)$$

3.7. Determination of the ground plane dimensions: The ground plane dimensions are calculated for the length and the width. The ground plane length and width dimensions are more than the length and width in that order by six times thickness or height of the patch. They are calculated using the formula given as (Huang and Kevin, 2008);

$$L_g = L + 6H \quad (9)$$

$$W_g = W + 6H \quad (10)$$

L and W, are the length and the width of the patch antenna accordingly.

3.8. Determination of feed point: The point of location of feed to the patch antenna can be located in x-y coordinates as X_f, Y_f. The formulas for calculating the feed point locations are given as (Huang and Kevin, 2008);

$$X_f = \frac{L}{2\sqrt{\varepsilon_{eff}}} \quad (11)$$

$$y_f = \frac{w}{2} \quad (12)$$

Where X_F and Y_f are the feed point location along X-Y coordinates.

4. Results and discussions

Table 1.0 shows the parameters of the designed Ku band rectangular microstrip patch antenna at a frequency of 16 GHz. The design of the antenna was carried out in such a way that the operating frequency was kept constant while the value of the dialectic constant of substrate was varied. While the operating frequency was kept at 16 GHz throughout the design, the dielectric constant values were varied from 2.0, 2.2, 2.4, 2.6, to 2.8 respectively.

F (GHz)	εr	h (mm)	W (mm)	L (mm)	Lg (mm)	Wg (mm)	Xf (mm)	Yf (mm)
16	2.0	0.633	7.65	6.48	10.28	11.45	2.38	3.83
16	2.5	0.566	7.09	5.82	9.22	10.48	1.92	3.54
16	3.0	0.517	6.63	5.32	8.43	9.73	1.61	3.31
16	3.5	0.478	6.25	4.94	7.81	9.12	1.39	3.13
16	4.0	0.448	5.93	4.62	7.31	8.61	1.22	2.96

From the table (table 1.0), it can be observed that at the frequency of 16 GHz and dielectric constant of 2.0, the patch antenna height is 0.633 mm, the width is 7.65 mm, Length is 6.48 mm. As the dielectric constant value was varied to 2.5, the height of the patch was 0.566 mm, the width was 7.09 mm, the length was 5.82 mm; as the dielectric constant value was varied to 3, the height of the patch 0.517 , the width was 6.63 mm and the length was 5.32 mm; as the dielectric constant value was varied to 3.5, the height of the patch 0.478 , the width was 6.25 mm and the length was 4.94 mm; as the dielectric constant value was varied to 4.0, the height of the patch 0.448, the width was 5.93 mm and the length was 4.62 mm.

Also, the ground plane dimensions are ground distance of the length and the width of the substrate. At the dielectric value of 2.0, the ground plane length and width are 10.28 mm and 11.45 mm, at the dielectric value of 2.5, the ground plane length and width are 9.22 mm and 10.48 mm, at the dielectric value of 3.0, the ground plane length and width are 8.43 mm and 9.73 mm, at the dielectric value of 3.5, the ground plane length and width are 7.81 mm and 9.12 mm, and at the dielectric value of 4.0, the ground plane length and width are 7.31 mm and 8.61 respectively. Furthermore, the location or coordinate of the point of connection of the cable on the antenna is very important. It is given as Xf and Yf, which are the distance from the centre to the x-axis and Y- axis of the antenna. From the table, at the dielectric value of 2.0, the coordinate distances; Xf and Yf are 2.38 mm and 3.83 mm; at the dielectric value of 2.5, the coordinate distances; Xf and Yf are 1.92 mm and 3.54, and so on.

From the results, it can be observed that as the value of the dielectric constant increases from 2.0 to 2.5, ... 4.0, the height, length and width of the antenna decrease accordingly. In other words, as the frequency was kept constant at 16 GHz, and the dielectric constant increases in values, there was a reduction in the height, length and width of the antenna. This implies that at higher dielectric constant values, the size of the size of the rectangular microstrip antenna reduces.

5. Conclusion

The design of a Ku frequency band rectangular microstrip patch antenna has been done using computation or mathematical method. From the results, it was observed that as the values of the dielectric substrate or material increase, the dimensions- height, length and width of the antenna decrease. For instance, when the value of the dielectric constant increased from 2.0 to 2.5, the patch antenna height decreased from 0.633 mm to 0.566; the width decreased from 7.65 mm to 7.09 mm, and length changed from 6.48 mm to 5.82 mm. It can be concluded that the higher values of dielectric constant will lead to reduction in the size of a rectangular microstrip patch antenna.

6. Recommendation

This work was done on a fixed frequency of operation while the dielectric constants values were made to vary, further work involving the varying of frequency with or without the varying of the value of dielectric constant is recommended.

References

[1] Ahmed Fatthi Alsager (2011): Design and Analysis of Microstrip Patch Antenna Arrays, Master thesis, University College of Borås,

[2] Atser A. Roy, Joseph M. Môm and Douglas T. Kureve (2013): *Effect of Dielectric Constant on the Design of Rectangular Microstrip Antenna,* https://www.researchgate.net/publication/271466716

[3] Houda Werfelli, Khaoula Tayari, Mondher Chaoui, Mongi Lahiani, Hamadi Ghariani (2016): Design of Rectangular Microstrip Patch Antenna. 2nd International Conference on Advanced Technologies for Signal and Image Processing. Pp 1 – 7

[4] Huang Yi and Kevin Boyle 2008 *Antennas: From Theory to Practice* Jhon Wiley & Sons United Kingdom.

[5] Rishitha Kyama, Sree Dharani Sanapureddy, Jeevan Gyadapaka, and Khasim K N (2023): Design and Analysis of Microstrip Rectangular Patch Antenna for 5G Applications. E3S Web of Conferences 391, 01113, pp 1 – 9. https://doi.org/10.1051/e3sconf/202339101113

[6] S N S Mahmud, M A Jusoh, S E Jasim, A H Zamani and M H Abdullah (2018): Design, simulation and analysis a microstrip antenna using PU-EFB substrate. IOP Conf. Series: Materials Science and Engineering 342, 012021. Pp 1 – 8, doi:10.1088/1757-899X/342/1/012021.

[7] Suvadeep Choudhury (2014): Effect of Dielectric Permittivity and Height on a Microstrip-Fed Rectangular Patch Antenna. International Journal of Engineering and Computer technology, Vol 5(2), pp 129 – 130.