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Design of an S-Band Rectangular Microstrip Patch Antenna

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***Abstract*— An S-band antenna is to operate within the frequency range of 2-4 GHz. This frequency is designed to operate at the frequency of 2.2 GHz using the dielectric substrate, FR4dielectric material of dielectric constant of 2.6.**

The design employed the transmission line model and parameters of the rectangular microstrip patch antenna were obtained using Microsoft excel worksheet.

The result shows that the antenna has the length of 40.23 mm, width of 50.82 mm and the high of the substrate as 4.04 mm. Also, the substrate has the length or Ground plane length, Lg, of 64.45 mm and Ground plane width, Wg, of 75.04mm. From this design dimensions, the antenna can be used for devices that have limited space for antenna, or its communication unit.

***Index Terms*— Microstrip, Dielectric constant, S band, transmission line, Length**

I. INTRODUCTION

An antenna is a device used for receiving and/or transmitting electromagnetic waves signals. A microstrip patch antenna consists of a conducting patch of any planar or non- planar geometry on one side of a dielectric substrate with a ground plane on other side.

The field of Antennas is vigorous and dynamic and planar oriented antennas such as Microstrip Patch have attracted significant attention primarily for space borne applications. A microstrip antenna is characterized by its Length, Width, Input impedance, and Gain and radiation patterns [Rita, and Vijay, 2014].

It is used to send and/or receive signals in communication devices. Additionally the simplicity of the structures makes this type of antennas suitable for low cost manufacturing and this is also one key feature of micro strip patch antennas are used in mobile communications applications [Kazi, *et al., 2011*].

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. The radiation increases with frequency increase and using thicker substrates with lower permittivity, and originates mostly at discontinuities [Rop,*et al.,* 2012]

As a result of the daily improvement in technology especially in the area of communication devices used in various fields- broadcasting, telecommunication, medical services, telemetry, etc, there is need to assess how the change in a dielectric constant of a mictrostrip patch antenna affects its bandwidth and the overall size.

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1.1 Uses or application S- band

S band is a part of the microwave band of the electromagnetic spectrum that has the range between 2 -4 GHz. S band is used for weather radar, communication satellite, ship radar, wireless network, and amateur radio and television.

1.2. Basic parameters of microstrip patch antenna design

1.2.1 Dielectric substrate: A dielectric substrate is a substrate that does not conduct direct current and therefore used as insulator. The dielectric constant ε_r is defined as the ratio of permittivity of a substance to the permittivity of free space.

1.2.2 Operating frequency: This is the frequency at which the antenna receives and/or transmits signals. Frequency of operation of a microstrip antenna can be calculated when the height of the patch is known or can be selected before the design.

1.2.3 Height of the substrate: The height of the substrate to be used in the design can be selected before calculating the operating frequency of the antenna if there is a prior knowledge of the size of the equipment in which the antenna will be used it, or the operating frequency can be used to find the height, or both can be selected before the design. For any given height, the condition in equation (1.0) must be fulfilled.

$$\frac{h}{\lambda} \leq \frac{0.3}{2\pi\sqrt{\varepsilon_r}} \quad \text{------------ 1.1}$$

h = height of the dielectric substrate, ε_r is the dielectric constant of the substrate, and λ is the wave length.

II. DESIGN PROCEDURES

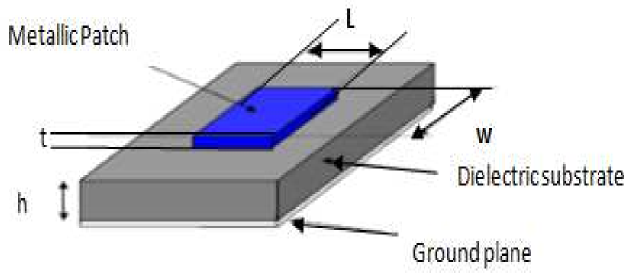

Fig. 2.1: Schematic diagram of a rectangular microstrip patch antenna

2.1 Calculation of the height (h): This is the height of the dielectric substrate upon which the metallic patch is mounted or placed. The height of the dielectric substrate of a microstrip antenna in calculated using the formula given as;

$$h = \frac{0.3C}{2\pi f\sqrt{\varepsilon_r}} \quad \text{------------ 2.1}$$

Where C = speed of light, given as 3.0 x 10^8m/s, ε_r = the dielectric substrate

2.2 Calculation of the width (W) of the patch: The width of the patch is calculated using the formula give as;

$$w = \frac{C}{2F_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad \text{------------ 2.2}$$

2.3 Calculation of the effective dielectric constant (ε_{eff}):

The effective dielectric constant is calculated using the formula given as;

$$\varepsilon_{eff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1+\frac{1}{\sqrt{1+12\left(\frac{h}{w}\right)}}\right) \quad \text{------ 2.3}$$

Where *h* and *w* are the height and the width of the patch in that order. The effective dielectric constant is always less than the dielectric constant itself because of fringe effect.

2.4 Calculation of the effective length of the patch (L_{eff}): The effective length of the patch antenna is the sum of the actual length of the antenna and its extension or the fringe effects. $L_{eff} = \frac{C}{2f\sqrt{\varepsilon_{eff}}}$ ------------- 2.4

2.5 Calculation 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;

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.8\right)}\right] \quad \text{------- 2.5}$$

Where ΔL is the patch length extension, *h* and *w* are the height and width of the patch respectively, and ε_{eff} is the effective dielectric constant of the substrate.

2.6 Calculation 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;

$$L = L_{eff} - 2\Delta L \quad \text{-------- 2.6}$$

2.7 Calculation 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;

$$L_g = L + 6h \quad \text{------------------- 2.7}$$

$$W_g = w + 6h \quad \text{------------------ 2.8}$$

Where *L* and *w*, are the length and the width of the patch antenna

III. Computations

3.1 Calculation of the height (h): The height of the dielectric substrate of a microstrip antenna in calculated using the formula given as;

$$h = \frac{0.3C}{2\pi f\sqrt{\varepsilon_r}} \quad 2$$

Where C = speed of light, given as 3.0 x 10^8m/s, ε_r = 2.6, and frequency, f = 2.2GHz. When these values of these parameters are substituted accordingly,
h = 4.04 mm

3.2 Calculation of the width (W) of the patch: The width of the patch is calculated using the formula give as;

$$w = \frac{C}{2f\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Where C = speed of light, given as 3.0 x 10^8m/s, ε_r = 2.6, and frequency, f = 2.2GHz. When these values of these parameters are substituted accordingly,
w = 50.82 mm

3.3 Calculation of the effective dielectric constant (ε_{eff}):

The effective dielectric constant is calculated using the formula given as;

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

Where *h* and *w* are the height and the width of the patch which are 4.04 mm and 50.82 mm respectively. When these values are substituted into the equation,
ε_{eff} = 2.37 mm

3.4 Calculation of the effective length of the patch (L_{eff}): The effective length of the patch antenna is calculated using the formula;

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

When the value of C, *f* and ε_{eff} are substituted accordingly,

L_{eff} = 42.25 mm

3.5 Calculation 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;

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

When values of ε_{eff}, *h* and *w* are substituted accordingly,

$\Delta L = 2.02$ mm

3.6 Calculation 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;

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

Therefore, when 2.02mm is substituted for ΔL and 42.25 mm is substituted for L_{eff},
L = 40.23 mm

3.7. Calculation 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;

$$L_g = L + 6h \quad \text{and} \quad W_g = w + 6h$$

Where *L* and *w*, are the length and the width of the patch antenna, and when their values are substituted accordingly, *Lg* = 64.45mm and *Wg* = 75.04mm.

IV. SUMMARY OF RESULTS AND DISCUSSION

Dielectric substrate = FR4dielectric material
Table 4.1: Designed antenna parameters

S/N	Parameters	Values
1	Frequency, f	2.2 GHz
2	Dielectric substrate constant, ε_r	2.6
3	Speed of light, c	3.0 x 10^8m/s
4	Height, *h*	4.04 mm
5	Patch Width, *w*	50.82 mm
6	Patch Length, L	40.23 mm
7	Ground plane length, *Lg*	64.45 mm
8	Ground plane width, *Wg*	75.04mm

Table 4.1 shows the parameters of the rectangular microstrip patch antenna using the dielectric substrate material-FR4dielectric material of dielectric constant, εr, 2.6. The antenna was designed to operate at the frequency of 2.2 GHz, which is within the S- band frequency spectrum. The various parameters were gotten using mathematical computations of transmission line model. From the result, it was observed the designed rectangular microstrip patch antenna has the length of 40.23 mm, width of 50.82 mm and the high of the substrate as 4.04 mm. in addition, the substrate has the length or Ground plane length, *Lg,* of 64.45 mm and Ground plane width, *Wg,* of 75.04mm.
From this design dimensions, this antenna can be used for devices that have limited space for antenna, or its communication unit.

V. Conclusion

The parameters for an S-band rectangular microstrip patch antenna have been calculated using transmission line model. From the result, length of 40.23 mm, width of 50.82 mm and the high of the substrate as 4.04 mm. In addition, the substrate has the length or Ground plane length, *Lg,* of 64.45 mm and Ground plane width, *Wg,* of 75.04mm were obtained for an antenna which will of 2.2 GHz operational frequency using the dielectric constant of 2.6.

VI. Recommendation

In this design, the frequency of 2.2 GHz was used, other frequency of operation using the same dielectric constant can be used for future work.

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