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Investigation of 15-7.5cm Wavelength Single Patch Micro strip Antenna.

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ABSTRACT

In the world today, the relevance of antennas is crucial as they are utilized in various sectors. Thus, this paper focuses on the design and analysis by simulation of a rectangular microstrip patch antenna at a wavelength of 15-7.5cm. The software used for analysis by simulation is known as CST Microwave studio. Furthermore, design calculations were performed and the parameters obtained were used for the simulation. The results obtained revealed that the size of the designed antenna can operate within 2.3256GHz and 2.3923GHz with a maximum return loss of -36.46dB at 2.3582GHz. The value of the voltage standing wave ratio obtained after the simulation was 1.029 at a resonant frequency of 2.358GHz, which is within the accepted range for communication systems operating in the S-band. The radiation pattern of the antenna was also investigated which revealed the directivity of the antenna to be 6.750dB, with a gain of 1.28dB at a frequency of 2.4GHz.

Keywords: Bandwidth, Antenna, Microstrip, Radiation, Gain, Directivity

I. INTRODUCTION

Antennas are components whose primary function is to receive, decode, and convert the physical signal into electric current or vice-versa [9]. They play a critical position inside the field of Wi-Fi communications, and as of today, technology antennas have shown that they are the most important thing in all wireless communications. They are used in industries, academic institutes, and even at home. As nanotechnology is in the process of being introduced in all sectors of technology, then the wireless communication (Wi-Fi) takes interest, and this phase off the wires because they are cumbersome, thus, Wi-Fi is widely used in many electronic gadgets. In all modes of communication, whether civilian or military, there is need for an antenna which is easy to manufacture and also has compatibility in such a way that it can fit into anything, and this antenna is known as the microstrip patch antenna. Using a standard microstrip production technique, microstrip antennas are incredibly simple to construct [8]. The patch can be made of different configurations, but the best are the rectangular and circular ones.

Microstrip patch antennas are made up of a metallic patch of metal on top of a grounded dielectric substrate, with relative permeability and permeability. The metallic patch may be of different shapes however, this paper focuses on the rectangular shape. Microstrip patch antennas have a low profile and can operate at dual and triple frequencies. As a result, they are best suited for aircraft and mobile applications. They are also increasingly being used in the commercial sector of the industry, particularly in GPS (Global Positioning System), SDARS (Satellite Digital Audio Radio Services), and WLAN (Wireless Local Area Network).

Rectangular microstrip antenna are among the most commonly used type of antennas in the microwave frequency range, and they are frequently used in the millimeter-wave frequency range (below about 1GHz, the size of a microstrip antenna is usually too large to be practical, and other types of antennas such as wire antennas dominate). This patch is of any planar or non-planar geometry on one side of dielectric substrate and a ground plane on the other side. The patch used is made up of conducting materials such as gold, tin, and nickel. The rectangular microstrip patch can easily be analyzed using the transmission line model and the cavity model.

The transmission line model essentially describes the microstrip antenna as two slots separated by a low impedance transmission line, and it measures the input performance of a rectangular patch antenna. The microstrip is essentially a non-homogenous line made up of two dielectrics, usually the substrate and air. In cavity model, the interior region of dielectric substrate is modelled as a cavity bounded by electric walls on top and bottom. In this paper, the transmission line method was used to investigate the characteristics of a rectangular microstrip patch antenna for 15-7.5 wavelength (S-band wireless communication). Furthermore, CST studio was utilized for the design and simulation of the rectangular microstrip patch antenna.

The objectives of the study are:
i. To review microstrip patch antenna characteristics.
ii. To review rectangular microstrip patch antenna design techniques.
iii. To design a rectangular microstrip patch antenna using the transmission line model in conjunction with CST studio.
iv. To simulate and analyze the characteristics of the designed rectangular microstrip patch antenna.

II. LITERATURE REVIEW

[4] Proposed that a H-U-E slotted microstrip antenna is suitable for wireless communications. The antenna resonates in the frequency range of (2.0-6.3) GHz with the center frequency of 4.2GHz. The proposed antenna provides return loss of approximately -30dB. The antenna is fed with coaxial feeding which yields an impedance bandwidth of 103.6% and VSWR of less than 1.07. The proposed antenna was simulated using Ansoft's HFSS software.

[2] Stated that the rapid development of electronics and wireless communications led to great demand for wireless devices that can operate at different standards. In modern communication devices over conventional antenna, microstrip patch antenna is commonly used due to their low profile and low volume. This paper presented a review upon the most recent research efforts associated with those techniques to design a microstrip patch antenna and enhance the overall performance.

[11] Stated that microstrip patch antennas have been widely used for many years due to their inherent advantages such as low cost, small size, easy integration, and low-profile characteristics. In this paper, the bandwidth was enhanced by using dimensionally invariance resonance frequency (DIResF) method, and using different techniques like utilizing slots in the patch by changing the height, dielectric constant, and feed point.

[7] Describes a method for improving isolation in microstrip patch antenna arrays. By introducing a flaw known as band notch function, a meander line resonation is introduced. The resonator is intended to prevent surface current from flowing at the resonance frequency of two patch antennas. With a reduced edge-to-edge spacing of 7mm, this antenna improved isolation by 16dbB.

[6] Describes a high-gain linear 14 antenna array built with a circular slotted patch for usage in 5G communication applications. When tuned to resonance, the antenna was capable of supporting TM_{11} as a fundamental mode at a frequency of 28GHz. To characterize the antenna prototype, the concept of the antenna was tested using vector network analyzers (VNA) and an anechoic chamber.

[5] Describes an examination into the design of patch antennas for usage in 5G wireless communication systems. The results obtained revealed the microstrip resonated at 27.97GHz with a directivity of 7.6dB, a bandwidth of 1.06GHz, and areflection coefficient of -20.95dB.

[1] Built and simulated an antenna to operate at 3.5GHz. CST software was used to simulate four different types of antennas ranging from single elements to 18 arrays, and a microstrip feed line was used in the 18-array antenna. Its directed radiation contributes to the base station's ability to provide high-quality, high-capacity network connectivity. This antenna was designed for long distance point-to-point communication, and at 3.5GHz the gain obtained was 6.938dB.

3.1 METHOD

This section examines the design characteristics of a rectangular microstrip patch antenna using the transmission line model method in conjunction with a software known as CST studio for simulations. Furthermore, the substrate material should be low in insertion loss with a loss tangent of less than 0.005.

3.1.1 Transmission Line Model Method

In the transmission line model method, we assume that the patch is a transmission line or part of a transmission line. The transmission line model represents the microstrip patch antenna by two slots, separated by a low-impedance transmission line of length L.

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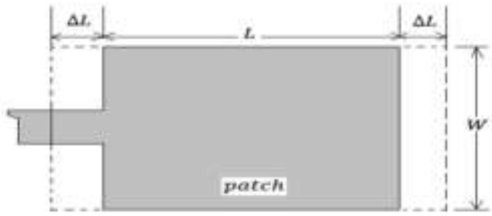

Figure 1: A Physical and Effective Length of a Microstrip Patch

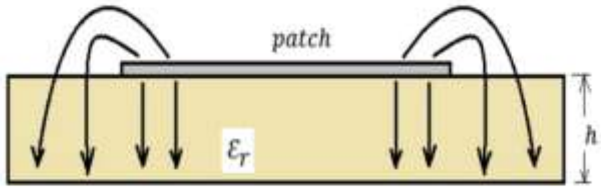

Figure 2: Electric Field Lines due to Fringing

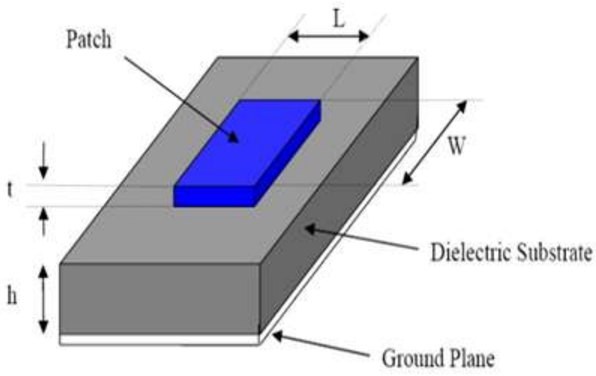

Figure 3: Microstrip Antenna Parameters

The most important parameters considered when designing a microstrip patch antenna are; the frequency of operation (f_o), dielectric constant of the substrate (ε_r), and height of dielectric substrate (h). The antenna was designed between the range of 2.4GHz and 3.0GHz is the default resonant frequency exclusive for this research work, the dielectric substrate used is FR4 with a dielectric constant of 4.3, and the dielectric height chosen was 1.6mm. Furthermore, we assume that the thickness of the conductor, t, that forms the line, has no effect on our calculations. Thus, we use empirical formulas that depend only on the line dimensions; the width W, the length L, the height h, and the dielectric constant ε_r of the substrate [10].

The width of the microstrip line is given by:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{\upsilon_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Substituting the values of C = $3x10^8$m/s, f_0 = 2.4GHz and ε_r = 4.3;

Width W = 38.39mm

Wavelength (λ) = C/F (2)

Thus, λ = 0.125mm

For patch antennas, air is above the substrate and this will lead to $1<\varepsilon_{reff}<\varepsilon_r$. For $\varepsilon>>1$, ε_{reff} is closer to the actual value of the dielectric constant ε_r of the substrate.

[Edwards et. al., 2000]The effective dielectric constant can be calculated using:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+\frac{12h}{W}}} \qquad (3)$$

Substituting the values of W = 38.39mm, h = 1.6mm and ε_r = 4.3;

$\varepsilon_{reff} = 4.67$

The extension of the length of the patch can be calculated by:

$$\frac{\Delta L_{eff}}{h} = 0.412 \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (4)$$

To calculate the effective length, we add the length L to the extension of the length ΔL.

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (5)$$

With the values ε_{reff} = 3.99, C = 3x10^8m/s, f_0 = 2.4GHz

L_{eff} = 31.3mm

Calculation of the length extension (ΔL) with h = 1.6mm;

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (6)$$

Substituting the values from h, w, and ε_{reff}, ΔL = 1.10mm

[Shanmugapriya, 2015] Calculation of the length of the patch (L) is obtained using:

$$L = L_{eff} - 2\Delta L \quad (7)$$

Thus, L = 26.72mm

Furthermore, the length and width of the ground plane can be obtained using:

$$L_g = 6h + L \quad (8)$$

Thus, L_g = 36.32mm

$$W_g = 6h + W \quad (9)$$

Thus W_g = 47.99mm

The length of the insert-feed is given as:

$$f_i = 10^{-4}(0.001699 * \varepsilon_r^7 + 0.13761 * \varepsilon_r^6 - 6.1783*\varepsilon r5+93.187*\varepsilon r4-682.69*\varepsilon r3+2561.9*\varepsilon r2-4043*\varepsilon r+6697*L2 \quad (10)$$

Thus, f_i = 8.85mm

3.1.2 Bandwidth

The bandwidth of a broadband antenna can be defined as the ratio of the upper to lower frequencies of acceptable operation, while the bandwidth of a narrowband antenna can be defined as the percentage of the frequency difference over the center frequency [Constantine 2005]. Furthermore, these definitions can be written in terms of equation as follows:

$$BW_{broadband} = \frac{f_H}{f_L} \quad (11)$$

f_H = 2.4361
f_L = 2.3716
Thus, BW = 1.027dB

$$BW_{narrowband}\ (\%) = \left[\frac{f_H - f_L}{f_C}\right] 100 \quad (12)$$

Thus, BW = 2.69%
Where;
f_H = Upper frequency.
f_L = Lower frequency.
f_C = Center frequency.
An antenna is said to be broadband if f_H/f_L = 2.

3.1.3 Voltage Standing Wave Ratio (VSWR)

There should be a maximum power supply between the transmitter and the antenna for the antenna to perform efficiently. This happens only when the impedance Z_{in} is matched to the transmitter impedance, Z_s. In the process of achieving this configuration, there is always a reflection of the power which leads to the standing waves, which is characterized by the Voltage Standing Wave Ratio (VSWR).

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+S_{11}}{1-S_{11}} \quad (13)$$

As the reflection coefficient ranges from 0 to 1, the VSWR ranges from 1 to ∞. One method of judging the efficiency of an antenna is by measuring its VSWR.

3.1.4 Return Loss

The return loss is an important parameter when testing an antenna. It is related to impedance matching and the maximum transfer of power theory. It is also a measure of the effectiveness of an antenna to deliver power from source to antenna. The return loss (RL) is defined by the ratio of the incident power of the antenna P_{in} to the power reflected back from the antenna of the source P_{ref}. Mathematically;

$$RL = 10 \log_{10} \frac{P_{in}}{P_{ref}} (dB) \quad (14)$$

3.2 Simulation Software

As earlier stated, the software used for the analysis by simulation of the rectangular microstrip patch antenna is known as CST microwave studio. Furthermore, the table below gives the parameters

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for the design of the microstrip patch antenna which will be used in the software.

Table 1: Calculated Design Parameters

Parameters	Rating (mm)
Width of Patch (W)	38.39
Length of Patch (L)	26.72
Feedline Length (Fi)	8.85
Feedline Width (Wf)	3.137
Space between Patch and Feedline (Gpf)	1
Ground Length (Lg)	36.32
Ground Width (Wg)	47.99
Height of Patch (Ht)	0.035
Substrate-Height (Hs)	1.6

III. RESULTS

This section includes the output of the mathematical computation and simulation work done on the microstrip patch antenna. The results displayed includes the physical and electrical properties of the microstrip patch antenna which was analyzed. The results of the microstrip patch antenna design such as the return loss, VSWR, and radiation pattern can be obtained by using the CST Microwave studio as displayed in the respective figures below.

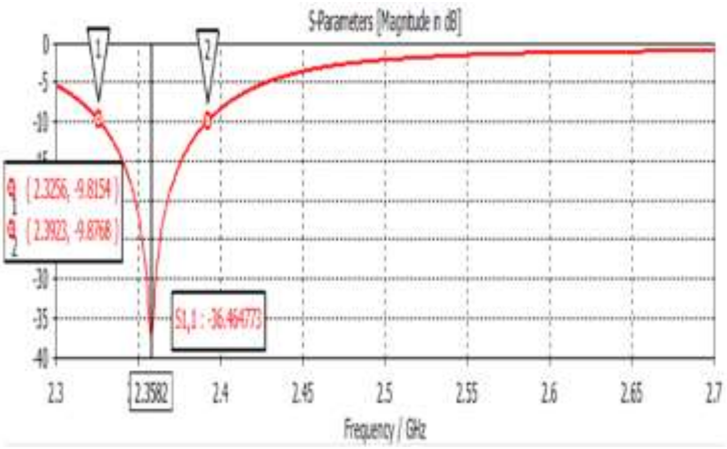

Figure 4: Chart of Return Loss against Frequency

Based on the operating frequency of the antenna, the simulated results obtained were good. However, there was a slight shift in frequency from the designed 2.4GHz to 2.3582GHz as displayed above in Figure 4. Furthermore, at a resonant frequency of 2.3582GHz with a return loss of -36.46dB within a frequency range of 2.3GHz to 2.7GHz. The minimum and maximum operational frequencies of the antenna are 2.3256GHz and 2.3923GHz respectively, measured at a return loss value of -9.8145dB to -9.8768dB. The bandwidth is about 1.029dB and 2.78%.

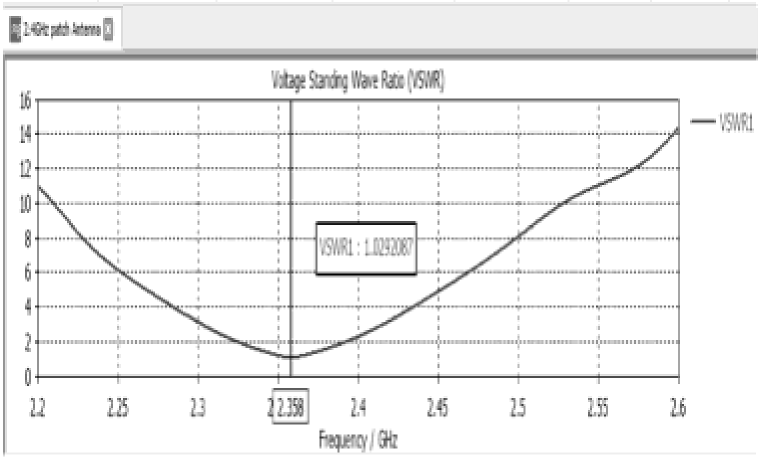

Figure 5: Chart of Voltage Standing Wave Ratio against Frequency

Figure 5 displays the VSWR of the microstrip patch antenna designed. To achieve effect impedance matching and minimal reflected power, the value of VSWR should be low (not more than 2.0db and near to 1.0db) for communication systems operating in the S-band. From the simulation result obtained, the VSWR has a magnitude of 1.029 at a resonant frequency of 2.358GHz. Thus, the magnitude of VSWR falls within the accepted range.

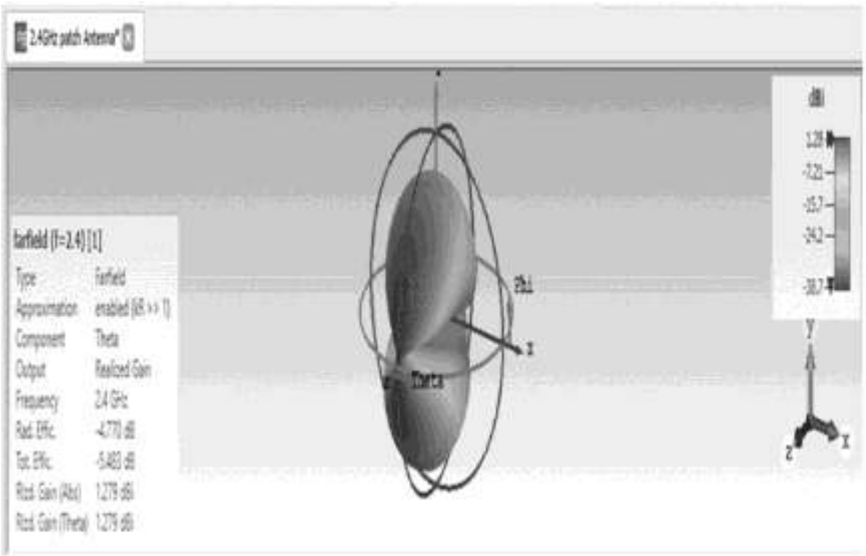

Figure 6. Radiation Pattern of Antenna

Figure 6 displays the 3D far-field radiation pattern for the gain and directivity of an antenna, usually expressed in dB, which refers to the direction and gain of maximum radiation. In this study, the directivity of the antenna at the frequency of 2.4GHz is 6.750dB, while having a gain of 1.28dB.

IV. CONCLUSION

This research work focused on the design and analysis by simulation of a rectangular microstrip patch antenna. From the results obtained, the size of the designed antenna can operate within 2.3256GHz and 2.3923GHz, and its maximum return loss value is -36.46dB at 2.3582GHz. The bandwidth can be increased when the resonance frequency is greater than the working frequency, and this can be easily obtained by altering the substrate parameters; width and height of the patch with rectangular microstrip antenna, and this will generally enhance the return loss. To further increase the return loss, the length of the patch can be compromised, hence increasing the frequency. However, there will be a corresponding reduction in bandwidth.

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