Design of Double Band Slotted Patch Microstrip Antenna for Increasing Efficiency

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***Abstract*—** Microstrip patch antenna is very popular in communication applications for its compact size and low cost. The efficiency and bandwidth of these antennas are limited regardless of how they are used, and they must be enhanced. The simulation and design of a revolutionary miniaturized microstrip patch antenna with radiating double slotted patch and a perfect value of voltage standing wave ratio (VSWR). This proposed antenna has a double band with operating frequency 2.41GHz and 3.27GHz, respectively, making it ideal for Satellite, RADAR, Wi-Fi, and ISM band applications. The ISM band 2.4–2.483GHz is also included in the S-band. This band is used for industrial, scientific, and medical applications. Using Computer Simulation Technology (CST), this research tries to improve the efficiency of a rectangular-double patch antenna. To achieve ideal antenna characteristics, various patch sizes and substrate materials are explored. After that, slot designs and double patches are included to improve the antenna performance even further.

***Keywords*—** Voltage Standing Wave Ratio, Double Patch, ISM Band, Microstrip.

I. INTRODUCTION

The microstrip patch antenna is currently the most extensively used antenna structure since it is simple to install (due to its small size, weight, and cost) and can be built on a printed circuit board [1], [2]. A microstrip patch antenna is just a metallic patch supported by a ground plane placed on a dielectric substance. Rectangular, square, circular, triangular, semicircular, elliptical, diamond, hexagonal, and bowtie are among the shapes utilized for the patch [3]. The rectangular patch is the most common antenna geometry and has been widely studied [4]. Due to its simplicity and other advantages, the proposed antenna is utilized in many applications, including aircraft, spacecraft, missiles, satellites and mobile phones [5], [6]. The antenna is usually fed in two ways: contacting or non-contacting. The contact technique is more appealing because it is straightforward to model and construct and match impedance. Inset or probe feeding techniques are used. The probe feeding used a coaxial cable attached to the extended up to the patch and ground, whereas the inset feeding used a microstrip line directly connected to the patch. The contracting method's main disadvantage is that it produces a narrow frequency spectrum. In the non-contacting approach, an electromagnetic field is connected between the patch and the microstrip line. It is less appealing due to its high cost and difficulties of modeling and manufacture despite its superior bandwidth [7].

The microstrip patch antenna still has low gain efficiency and a limited bandwidth. By single patch, the bandwidth usually is approximately 2-5 percent, and the gain is 5-7dB. Because electromagnetic fringing only happens on both sides of the patch, the antenna only radiates in half-plane. To improve antenna performance, this fringing must be increased. Increasing the height (thickness) of the dielectric substrate is one method that can be used to accomplish this. However, the thickness must not exceed 0.05, or the antenna will stop radiating since the power will be delivered in surface waves rather than transverse waves. Other solutions include lowering the dielectric constant or expanding the patch width where fringing occurs [8]. In reality, the patch width is inversely proportional to the input impedance and directly proportional to the bandwidth; it ultimately affects the radiation pattern.

On the other hand, the patch length has no substantial impact on the radiation and is usually set at $\lambda/2$. However, its ideal value is determined by the patch width and substrate properties. Because antenna patch design is crucial in antenna radiation, various patch shapes have been considered to improve antenna bandwidth and efficiency. However, incorporating it is considerably more practical to cut a slot into a simple patch shape because it is simple and can significantly improve antenna fringing [9]-[12].

This research aims to improve the rectangular patch antenna's performance and Voltage Standing Wave Ratio (VSWR). Various design alternatives and simulation results for the full S-band are illustrated utilizing 2.41GHz and 3.27GHz. Initially, a parametric study introduces a preliminary design that includes various feeding methods, patch sizes, and substrate materials. After that, two patches with slot designs are used to improve antenna performance.

By carving a slit in the ground and applying a Microstrip antenna patch with the right length and breadth values, the antenna may be miniaturized, and bandwidth can be increased.

The following sections make up the proposed paper: The suggested antenna's design, geometry, and optimization are presented in Section II. The simulation results and analysis acquired using CST Studio Suite are discussed in Section III. An overview of this research endeavor is offered in Section IV.

II. ANTENNA AND GEOMETRY

In the Table 1, the values of effective length and width of ground, substrate, patch, and length and width of the junction, feeding pin are shown to analyze the effect of the radiating surface.

Table 1: *Antenna Parameter*

Parameter Name	Length (mm)
Patch width (w)	37
Patch length (L)	28
Ground length (Lg)	70
Ground width (Wg)	100
Feed length (Lf)	14.12
Feed width (Wf)	4
Width junction (Wf2)	1.81
Distance (r)	14.12
Substrate thickness (h)	1.6
Conductor thickness (t)	0.0335

The 3D view, the PIFA (3D) design are shown in Fig. 1, and Fig. 2.

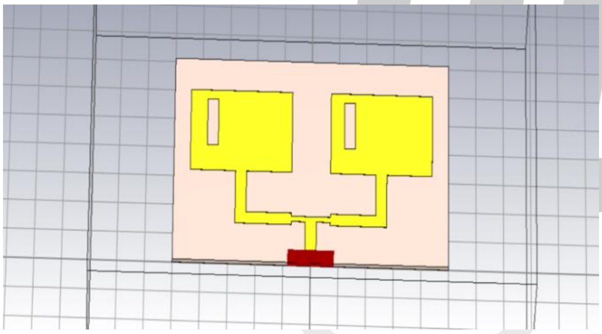

Figure 1: *3D view of Proposed Microstrip Patch Antenna*

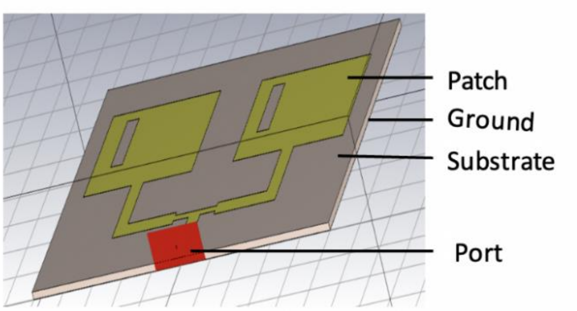

Figure 2: *Geometrical view of proposed Antenna (3D)*

This antenna is simulated by a commercial chip FR-4 substrate with a relative permittivity of 4.4 and thermal conductivity 0.3[W/K/m].

The patch is located on the top of substrate. Patches are rectangular-shaped; both have the rectangular slot. The simulation of this proposed antenna is performed using CST STUDIO SUITE software.

III. SIMULATION AND RESULT ANALYSIS

CST is used to simulate the intended antenna to identify the parameters and determine the cover bands. After the simulation, the return loss is calculated, which is shown in Fig. 3 and Fig. 4.

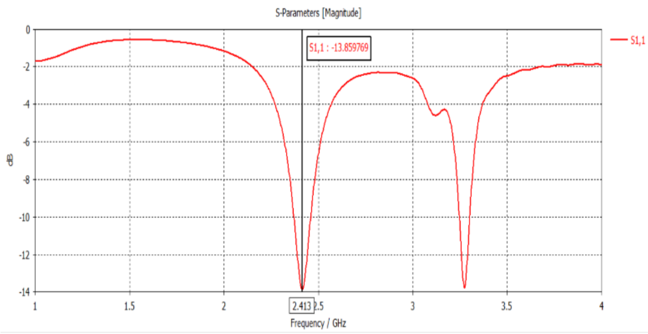

Figure 3: *Simulated return loss of the antenna for 2.41GHz*

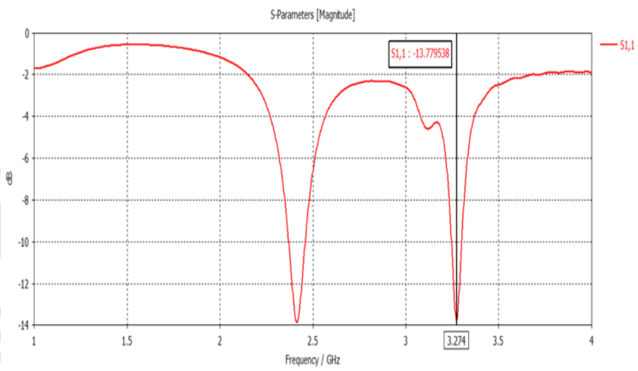

Figure 4: *Simulated return loss of the antenna for 3.27GHz*

Fig. 3 and Fig. 4 show that the antenna can operate at 2.41GHz and 3.27GHz covering S band for commercial use. This antenna can be used in surface ship radar, weather radar, navigation aids, ship identification and tracking, air traffic control, in-flight Wi-Fi, spacecraft telemetry. For this proposed antenna, the return losses -13.86dB and -13.78dB are used as a reference acceptable for satellite and radar communication applications. Voltage Standing Wave Ratio (VSWR) determines the impedance mismatch between the transmission line and antenna. This VSWR should be less than two always.

From the simulated data, we can see that the VSWR values of the two bands are 1.50 and 1.51 at the operating frequency of 2.41GHz and 3.27GHz, respectively. The graphical representations of VSWR for the two bands are shown in Fig. 5 and Fig. 6.

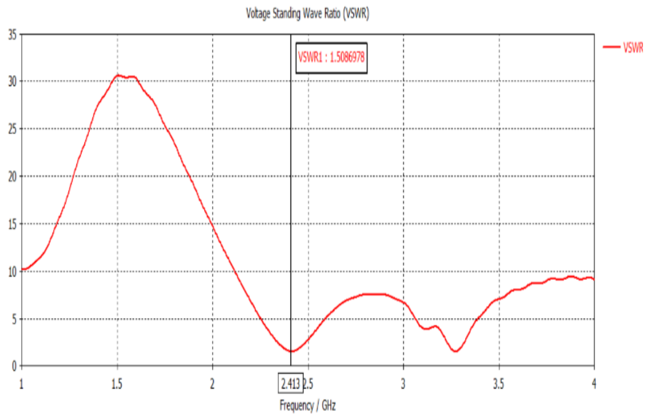

Figure 5: *Simulated VSWR plot for 2.41GHz*

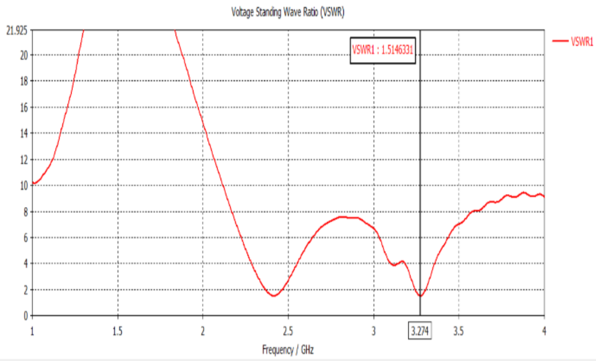

Figure 6: *Simulated VSWR plot for 3.27GHz*

Some 3D radiation patterns observed from the simulation result with directivity are determined from the simulated result for farfield, f=1GHz, f=2.45GHz, and f=4GHz, shown in Fig. 7, Fig. 8, and Fig. 9, respectively.

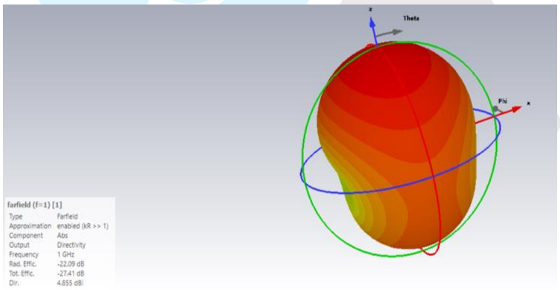

Figure 7: *3D radiation pattern for f=1GHz*

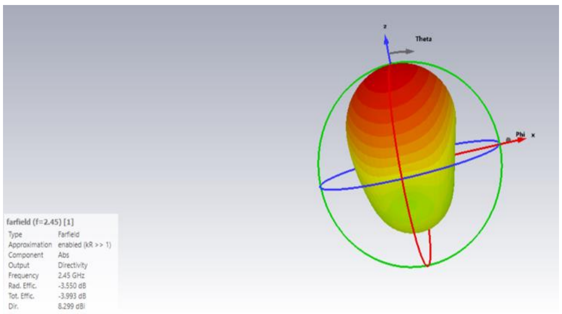

Figure 8: *3D radiation pattern for f=2.45GHz*

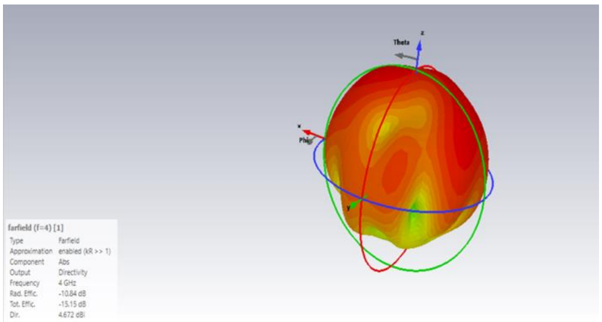

Figure 9: *3D radiation pattern for f=4GHz*

An antenna's directivity is defined as "the ratio of the antenna's radiation intensity in a particular direction to the averaged radiation intensity in all directions." The total antenna power radiated and divided by four equals the average radiation intensity. The greatest radiation intensity direction is assumed if the direction is not given. Several methods for reducing the patch's size include shorting the wall, shorting the pin, and slot cutting. Although the shorting microstrip antenna is small, it has weak gain and a degraded radiation pattern. Cutting slots in the radiating patch can reduce the resonance frequency of the antenna by increasing the route length of the surface current.

Directivity measures the degree of the radiation with a single direction of the antenna. Directivity is an element of gain of the antenna. For an actual antenna, directivity varies from 1.76dBi. The maximum value of directivity for a dish antenna is 50dBi. The strength of radio wave's angular dependence from the antenna is known as the radiation pattern. Farfield and near field is created from field radiation pattern of the antenna. The near field pattern is always placed in front of the source of the cylindrical surface enclosing it. From the following figures, we can see that effective radiating efficiency and directivity are determined. The directivity values are 4.86dBi, 8.29dBi, and 4.67dBi for farfield 1GHz, 2.45GHz, and 4GHz, respectively.

The efficiency of this slotted patch antenna is better, which is determined by Fig. 10.

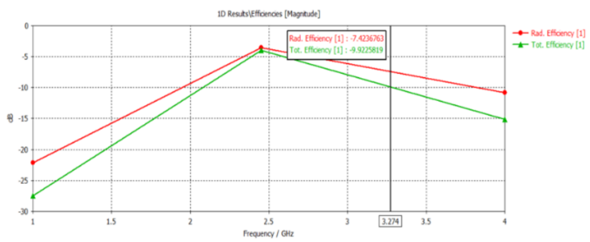

Figure 10: *1D result of efficiency*

Farfield is classified as follows: (I) electric farfield and (II) magnetic farfield. The strength of farfield is inversely proportional to the distance from the source. An excitation figure of farfield is shown in Fig. 11.

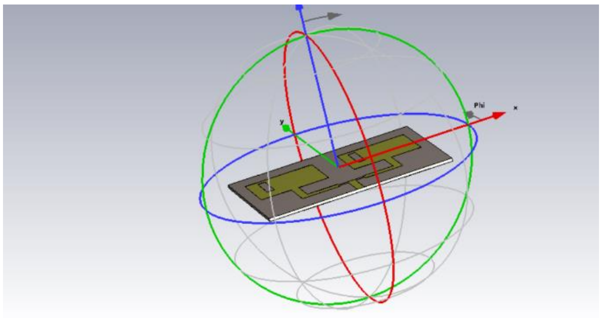

Figure 11: *Farfield excitation.*

IV. CONCLUSION

The proposed paper presents an excellent antenna for satellite and radar applications and essential networking purposes. The effects of double patch slot's width variation for responding frequency, different material substrate, and ground are also analyzed. The frequency response is shifted for the variation of the dual patch and FR4 substrate slots. So, the performance of the designed antenna is outstanding with dual-band and better value of VSWR of 1.50, 1.51 and effective directivity with excellent radiating efficiency. As the width of the slots varies, the frequency response shifts. Natural cork, Wood Plastic, Plastic, and FR4 can all be substituted for one another with minor dimension changes. Though the antenna's performance is satisfactory, more study is needed to improve frequency response, gain, and miniaturize the antenna. From the comparison of many researcher's works of antenna, some advantages are determined such as smaller size, larger bandwidth with multi band and better value of VSWR (1). In addition, within the antenna's operational bandwidth, more steady gain and greater radiation efficiency were found. Furthermore, it has been discovered that the gain at the higher operating band is significantly greater than the gain at the lower operating band. The measured and simulated outcomes are in good agreement. It is very promising to operate because to its simple structure, small size, and high gain.

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