DESIGN OF A MINIATURE RECTANGULAR PATCH ANTENNA FOR KU BAND APPLICATIONS

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ABSTRACT

A significant portion of communication devices employs microstrip antennas because of their compact size, low profile, and ability to conform to both planar and non-planar surfaces. To achieve this, we present a miniature inset-fed rectangular patch antenna using partial ground plane for Ku band applications. The proposed antenna design used an operating frequency of 15.5 GHz, a FR4 substrate with a dielectric constant of 4.3, and a thickness of 1.4 mm. It is fed by a 50 Ω inset feedline. Computer simulation technology (CST) software is used to design, simulate, and analyze. The simulation yields the antenna performance parameters, including return loss (S_{11}), bandwidth, VSWR, gain, directivity, and radiation efficiency. The simulation findings revealed that the proposed antenna resonated at 15.5 GHz, with a return loss of -22.312 dB, a bandwidth of 2.73 GHz (2730 MHz), VSWR of 1.17, a gain of 3.843 dBi, a directivity of 5.926 dBi, and an antenna efficiency of -2.083 dB (61.901%).

KEYWORDS

Rectangular Patch antenna, CST, FR4, Inset-feedline, Ku band

1. INTRODUCTION

An antenna is used to convert radio waves into electrical power and vice versa. Modern wireless communication technology depends heavily on the theory and design of antennas. Microstrip patch antennas (MPAs) are the most basic of the several types of antennas. New antennas are created with microstrip technology to maintain their small size. The simplicity with which they may be mounted on a circuit board is the main advantage of these antennas. The design of patch antennas is simple and cheap. MPAs have a number of benefits due to their low cost of construction, simplicity of manufacture, lightweight, and ease of installation. MPAs are used in many different contexts, including wireless communication, medical applications, and military applications like radar, spacecraft, etc. [1]. So, satellite communication is a possible application for this type of antenna. MPAs have some benefits, but they also have some drawbacks such as limited bandwidth, low gain and low power capacity etc [2].

Several studies are being carried out to solve these difficulties in order to completely maximize advantages including ease of design, ease of fabrication, and low cost in the fabrication of these miniature microstrip antennas. The physical construction of these antennas affects their performance. The researchers offer several strategies for improving antenna performance based on the physical configuration of the antennas. There are numerous different contacting and non-contacting methods for feeding microstrip patch antennas. In contacting methods, RF power is given directly to the radiating patch through the connecting link, which is a microstrip line [3]. Electromagnetic field coupling is achieved by transmitting electricity from a microstrip line to a radiating patch while remaining non-contact. The microstrip line, coaxial probe (both contacting schemes), aperture coupling, and proximity coupling (both non-contacting methods) are the four most commonly utilized feed techniques [4]. Patch antennas have the advantage of being able to be employed in a number of communication links with a variety of needs. The bandwidth of an antenna can be enhanced using several approaches such as increasing the thickness of a substrate with a low dielectric constant, slit carving, and changing patch shapes. An enhancement in the bandwidth of up to 13.7 percent was suggested for a small L-shaped patch by the author [5]. In [6,] a patch antenna array with enhanced bandwidth is demonstrated. A 23 percent increase in antenna bandwidth could be explained by Z. M. Chen's theory [7]. K.F. Lee [8] achieved a 42% increase in bandwidth by employing a small strip antenna with a U-shaped slit. A large bandwidth enhancement was accomplished in [9] by increasing the height of the dielectric layer. The bandgap design of a uniplanar photonic device was used by S. C. Gao [10] to improve the bandwidth and gain. M. Khodier [11] was capable of increasing bandwidth by stacking patch antennas. A ring made of several conducting layers that were kept distinct by laminating dielectric was developed by [12] to boost the gain and bandwidth.

The primary goal of this study is to assess the effectiveness of a compact inset-fed rectangular microstrip patch antenna for Ku band applications using a partial ground plane that operates in the frequency range of 12 GHz to 18 GHz.

2. PROPOSED ANTENNA STRUCTURE

Figure 1 shows the structure of an inset-fed microstrip rectangular patch antenna applying a partial ground plane strategy. The antenna is constructed on a FR4 substrate with a thickness (h) of 1.4 mm and a dielectric constant (ε_r) of 4.3. The patch with a typical impedance of 50 Ω is excited using an inset microstrip feedline. Table 1 summarizes the various characteristics of a microstrip rectangular patch antenna.

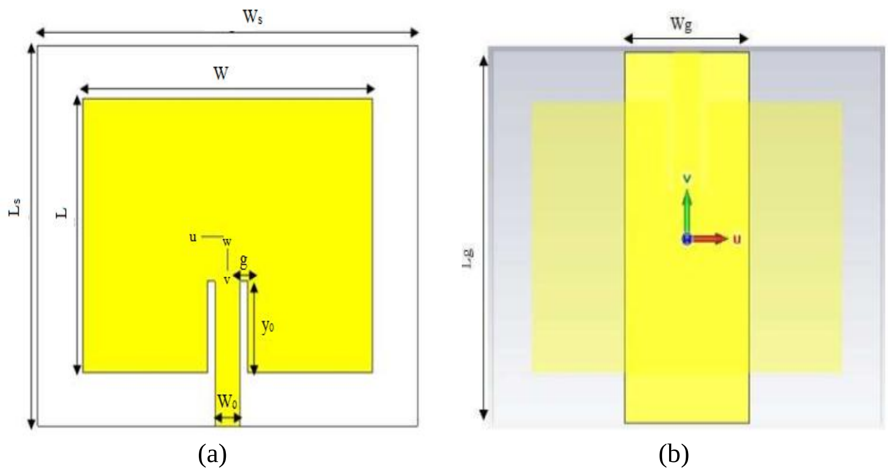

Figure 1. Geometry of the proposed antenna with partial ground plane (a) Front view and (b) Back view

Table 1. Geometrical parameters of microstrip rectangular patch antenna

Parameters	Value (mm)	Parameters	Value (mm)	Parameters	Value (mm)
Substrate Length, L_S	11	Partial ground width, W_g	7.5	Patch width, W	9
Substrate width, W_S	15	Partial ground length, L_g	11	Width of the feed, W_0	2.137
Substrate dielectric constant, ε_r	4.3	Copper thickness, t	0.035	Inset length, y_0	3
Substrate thickness, h	1.4	Patch length, L	7	Inset gap, g	1

3. Simulation Results and Discussion

Figures 2 to 5 show the single-element rectangular patch antenna simulation results produced by CST software. The CST software has been used to model the antenna design, may present the antenna characteristics return loss (S_{11}), bandwidth, VSWR, gain, directivity, and efficiency. To assure investigation and assessment of the recommended antenna's performance using these antenna parameters, the results of the simulated antenna design are summarized and presented below.

3.1. Return Loss (S_{11})

The amount of energy the antenna reflects is determined by return loss (S_{11}). The antenna reflects rather than radiates the entire quantity of power when S_{11}=0 dB. It also provides a measure of how well an impedance-matched device is. A device is said to be appropriately matched when the return loss is small. This shows that the antenna receives the most energy, which enhances performance and results in less power being lost in the antenna. The return loss (S_{11}) for the suggested antenna is shown in Figure 2. At the resonance frequency of 15.5 GHz, the proposed antenna has a low S_{11} of -22.312 dB and good impedance matching between the feed line and antenna. The antenna transmits the most energy and returns the least power at this resonance frequency. A S_{11} of -22.312 dB indicates that approximately 99.7% of the input power is transmitted into the antenna. The bandwidth is calculated using S_{11} plot (< -10 dB). Figure 2 reveals that the planned antenna's impedance bandwidth is 2.73 GHz (2730 MHz), which is higher than that seen in references [13 – 15].

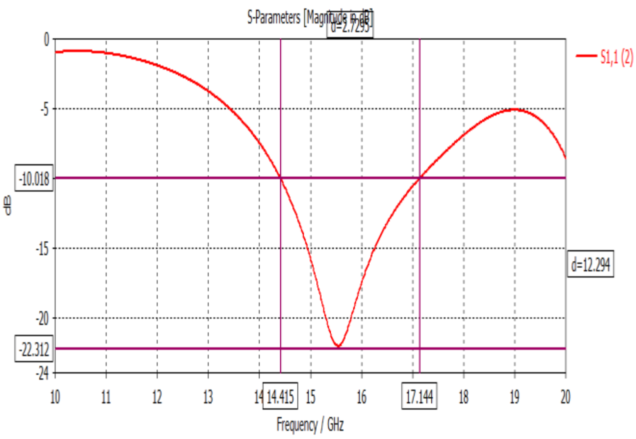

Figure 2. Return loss of the proposed antenna

3.2. Voltage Standing Wave Ratio (VSWR)

The ratio of the greatest to smallest amplitude (or the voltage or current) of the corresponding field elements present on a line feeding an antenna is known as VSWR, and it describes how effectively RF power is transferred. For a good antenna function of any designed antenna, the optimum VSWR range of 1<VSWR< 2 is required. Figure 3 presents the VSWR graph for the suggested antenna. The designed antenna achieved a VSWR value of 1.17 at the resonant frequency of 15.54 GHz. Additionally, it shows that the feed line and antenna have good impedance matching, which is important for the effective operation of the antenna.

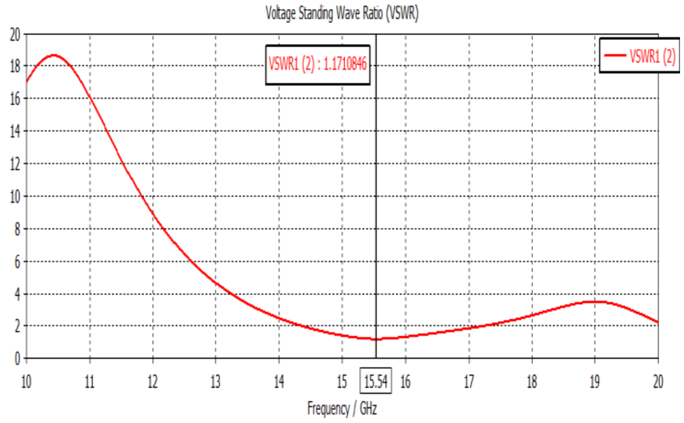

Figure 3. VSWR of the proposed antenna

3.3. Directivity

The directivity of an antenna should also be taken into consideration when designing it. The maximum direction of radiation is measured by the directivity. An antenna of a suitable quality needs to have high directivity. Figure 4 illustrates how the antenna's far-field directivity works. It can be demonstrated that the proposed antenna has a directivity of 5.926 dBi at 15.5 GHz.

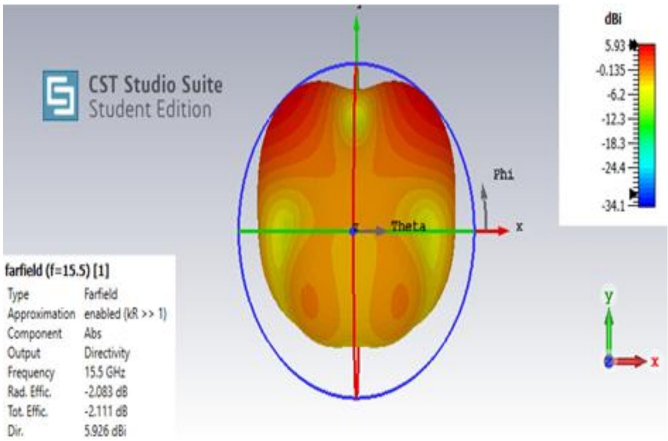

Figure 4. Directivity of the proposed antenna

3.4. Gain

The amount of power supplied from an isotropic source in the direction of the highest radiation is measured by the antenna gain. Figure 5 depicts the gain of the antenna. At 15.5 GHz, the designed antenna has a gain of 3.843 dBi, which shows that this frequency is where the antenna performs best.

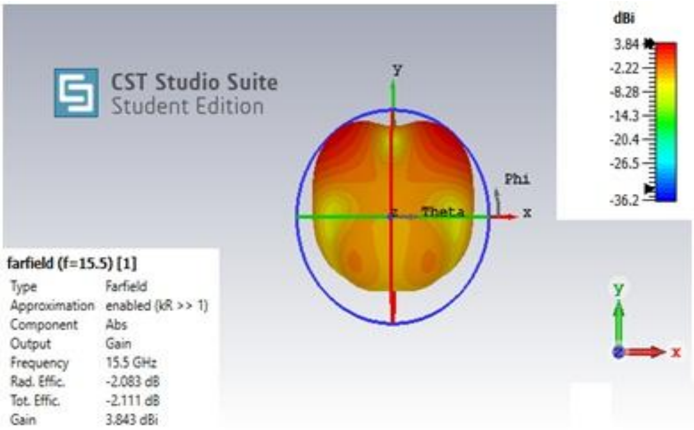

Figure 5. Gain of the proposed antenna

3.5. Efficiency

The parameter used to calculate the relationship between input and output power is antenna efficiency. With just a little portion lost due to conductor and dielectric losses in the materials, the majority of the input power is converted into radiated power and surface wave power. Surface waves are directed waves that are constrained within the substrate and partially radiated and reflected back at its edges. The antenna efficiency needs to be as high as feasible to operate well. The efficiency can be calculated using Figures 4 and 5. Efficiency is determined by considering the maximum gain and directivity parameters. The estimated efficiency is about 64.85%.

4. COMPARISON WITH RECENTLY DEVELOPED WORKS

Table 3 compares the performance of the recommended antenna with a few newly constructed antennas in terms of the return loss, bandwidth, VSWR, and gain. A 2730 MHz bandwidth and VSWR of 1.17 characterize the suggested antenna. In comparison to the reference antenna [13 – 15], the planned antenna is substantially smaller and has a larger bandwidth. The VSWR of the proposed antenna is higher than that given in references [13, 15], but it is lower than that in reference [14]. The desired antenna has a lower return loss than the references [14] but a higher return loss than those [13, 15]. The lower return loss shows that the antenna is capable of perfectly converting all incoming signals into electromagnetic waves.

Table 2. Comparisons of the preceding and present designed inset-fed microstrip rectangular patch antennas

Refs.	Patch size (mm^2)	Return Loss (dB)	VSWR	Bandwidth (MHz)	Gain (dBi/dB)
[13]	17 × 17	-25	<= 1.1	1240	4.45
[14]	13× 11	-19.20	1.246	528	4.80
[15]	10 ×7 .6	-24.61	1.084	382	4.808
Proposed Antenna	9 × 7	-22.312	1.17	2730	3.843

5. CONCLUSION

In this paper, a compact inset-fed rectangular patch antenna with a partial ground plane has been successfully designed for Ku band applications. CST Microwave Studio has been used to assess and study the proposed antenna's performance. The antenna attains a return loss of - 22.312 dB and a 2.73 GHz (2730 MHz) impedance bandwidth between 14.415 GHz and 17.144 GHz. Also, the gain, directivity, and efficiency of this antenna are 3.843 dBi, 5.926 dBi, and -2.083 dB (61.901%). Therefore, the designed antenna may be a good choice for Ku band satellite communication applications.

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