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Design of a microstrip patch antenna for the Ku band applications

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A B S T R A C T

This paper presents a new high gain and highly efficient Microstrip Patch Antenna for Ku band application. The proposed antenna uses a copper (annealed) patch imposed over the FR-4 substrate. The constructed design offers Return loss = –26.5578 dB, Gain = 6.31 dBi at resonant frequency 12.54 GHz, Voltage Standing Wave Ratio = 1.0986392, Bandwidth = 4.1553 GHz (33.14%) and Efficiency = 98.99%, all results are shown in simulation results. This proposed antenna is aimed to increase the capability for Ku band application also employed for wireless application. Computer Simulation Technology software (CST) has been used to execute this design, simulation, and perform analysis. The simulated results represent that this patch antenna achieves better performance in terms of gain, directivity, and return loss.

1. Introduction

An antenna can convert radio frequency to electrical energy or vice versa. In modern times, antenna theory and design become one of the significant subjects for the wireless communication system. Among the various type of antennas, Microstrip Patch Antenna (MPA) is the modest form of the antenna arrangement. Modern antennas use the microstrip technique for the fabrication purpose to keep the antenna size small. Moreover, the most significant advantage of this type of antennas are- they can be simply imposed on a circuit board. Patch antennas are little in cost and are simply made-up. MPA has various compensations because of its inexpensive design, easy manufacturing procedure, very light in weight, the installation process. MPA is applied in numerous areas like – medical uses, wireless communication, and also in military operations like – radar, spacecraft, etcetera [1]. Hence, this type of antenna can be applied for Satellite Communication. Though MPA has advantages, it suffers from several shortcomings too. Usually, MPA has a narrow bandwidth, poor gain, low power capacity, etcetera [2]. To overcome its shortcomings many techniques have been proposed, like– choosing a good conductor and better-quality substrates. An MPA is constructed with a thin metal patch that is mounted on a dielectric substrate [3]. Four feeding methods are employed for feeding power to MPA. They are - microstrip line feed, coaxial line feed, aperture couple feed, and proximity couple feed [4].

2. Literature review

To improve the efficiency and gain of MPA, various techniques are implemented by researchers, like using numerous feeding mechanism and impedance matching, use of different types of slots above the patch, using a thick the substrate of low dielectric constant [5–8]. Two joined patches have been installed on the upper [9] or the lower [10] surface of the substrate to enhance the gain. For improving the gain an air layer has used in three-layer electromagnetically coupled structures [11].

A high gain MPA is recommended with the patch size of $40 \times 40\ mm^2$ is designed for Ku-band applications [12]. Although this antenna provides high gain its fabrication process is complicated. For improving the parameters, a W the shaped antenna is presented with the dimension of $50 \times 72\ mm^2$ [13]. Due to large, it's not suitable for satellite communication. Another W shaped MPA is presented without the ground plane for better bandwidth

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[14]. Here the size of the patch is 5.55×3.5 mm^2. Although it has a small size, gain & radiation efficiency is comparatively low.

In this paper, I shape slot loaded MPA are analysed according to some performance parameters such as - return loss, efficiency, directivity, and Voltage Standing Wave Ratio (VSWR). This proposed antenna achieves an efficiency of 98.5% and it's absolute for Ku-band satellite communications.

3. Methodology

Different shapes of Microstrip Patch Antennas are available. However, this antenna uses a rectangular shape. There are several methods of modeling an antenna, but the proposed antenna is designed by using Transmission Line Model (TEM).

This model is used because of its simplicity and its comparatively the most comfortable model to design an MPA. Hence, this proposed antenna is designed by applying these traditional equations [12]. The equations are,

Step 1: Size of the Width, W: for designing this proposed antenna, the primary step is to determine the width of the patch. This value is determined by this following equation:

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

Where, W = patch width, €r = substrate's relative permittivity, fr = desired resonant frequency, c = speed of light.

Step 2: Estimate of Effective dielectric constant, ε_{reff}: This content is determined by using this equation below:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{2}$$

Where, h = width of the dielectric substrate.

Step 3: Estimate of Effective length, L_{eff} : This parameter is determined by using this equation below:

$$L_{eff} = \frac{c}{2fr\sqrt{\in_{reff}}} \tag{3}$$

Step 4: Estimate of the extent in length, ΔL: As there is an impact of the fringing field is available throughout the patch, it seems bigger comparatively than its initial size. So, for finding the extended length of the proposed antenna, this following equation is used:

$$\Delta L = 0.412h\frac{\in_{reff} + 0.3\left(\frac{W}{h} + 0.264\right)}{\in_{reff} - 0.258\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

Step 5: Estimate of actual length of patch, L: This parameter is determined by using this following equation:

$$L = L_{eff} - 2\Delta L \tag{5}$$

4. Antenna design and measurement

The composition of the proposed antenna is depictured in Fig. 1. This antenna is 'H' in shape. It uses copper (annealed) patch imposed over FR-4 substrate. Table 1 illustrates the proposed antenna dimensions.

The proposed microstrip patch antenna at designed frequency 14 GHz on FR4 substrate simulated with Computer Simulation Technology software (CST). Here, we are going to investigate only about the bandwidth enhancement of H shape patch antenna by creating slot. The design parameters of length (L), width (W) and resonant frequency are optimized for the better return loss.

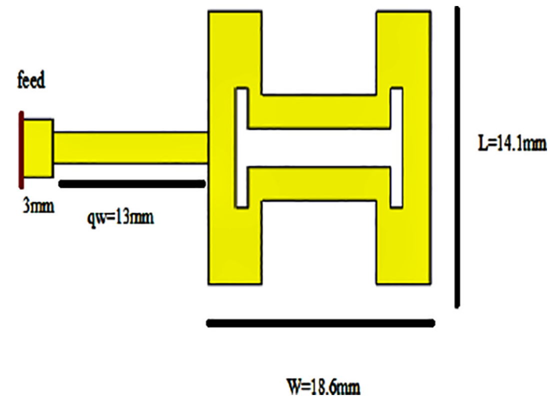

Fig. 1. Structure of proposed antenna.

Table 1
Antenna dimensions.

Height of substrate	1.6 mm
Dielectric constant	4.3
Substrate	FR4
Thickness of the conductor	0.035 mm
Design frequency	14 GHz
Conducting material	Copper

For providing the power to antenna, there is a microstrip feed line which impedance is 50 Ω. This impedance is equal to the proposed antenna.

5. Result

The performance of proposed antenna is discerned by using CST Microwave Studio simulation tool. The proposed antenna provides return loss (S_{11}) which is depictured in Figs. 2 and 3.

This shows the maximal return loss is −26.5578 dB at the resonant frequency 12.54 GHz. The graph also depicts that below −10 dB the antenna attained the bandwidth of 4.1553 GHz (33.14%).

Fig. 4 depict far field radiation directivity and far field radiation gain of proposed antenna respectively. Directivity and Gain is 6.31 dBi.

The voltage standing wave ratio (VSWR) of the proposed antenna is shown in Fig. 5. It can be observed from the result that the VSWR value is 1.14, which is less than 2 for whole operating band, which considered as suitable for the antenna.

Table 2 shows the summary of results of the microstrip patch antenna.

6. Conclusion

In this study, a compact 'H' shaped microstrip patch antenna is presented for Ku band application. The result shows that this antenna provides resonant frequency at 12.54 GHz with return loss −26.5578 dB. The high gain is 6.31dBi. All results are shown in simulation results. Very thin slit or slot in the patch cause Bandwidth and Return loss (S_{11}) is improved. Parasitic patch because wide bandwidth is achieved. Also 13% more bandwidth achieved than bandwidth achieved in previous researches.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

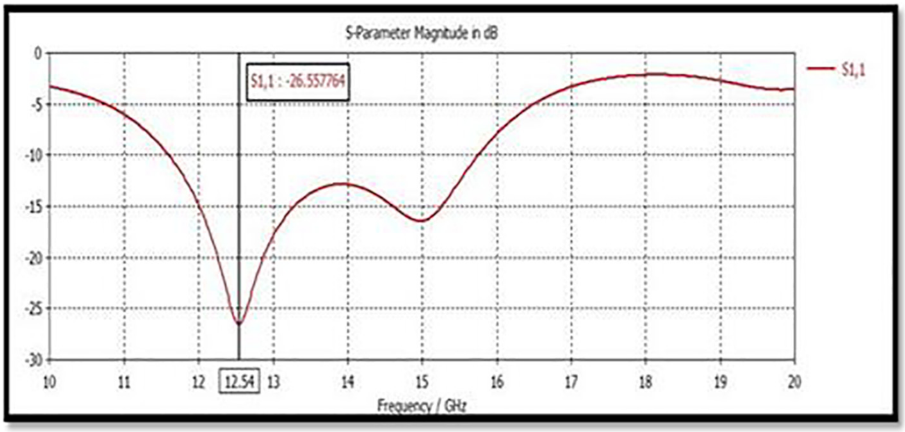

Fig. 2. Return loss vs. frequency.

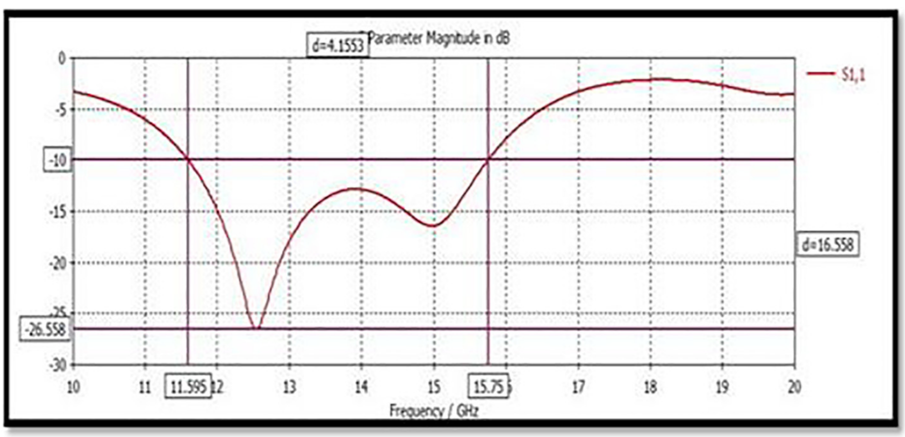

Fig. 3. Return loss vs. frequency.

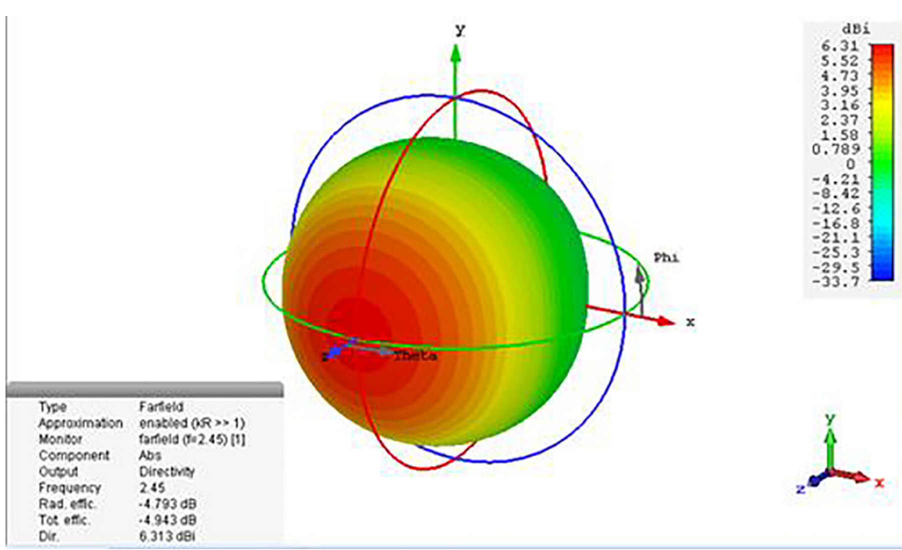

Fig. 4. far-field at 12.54 GHz.

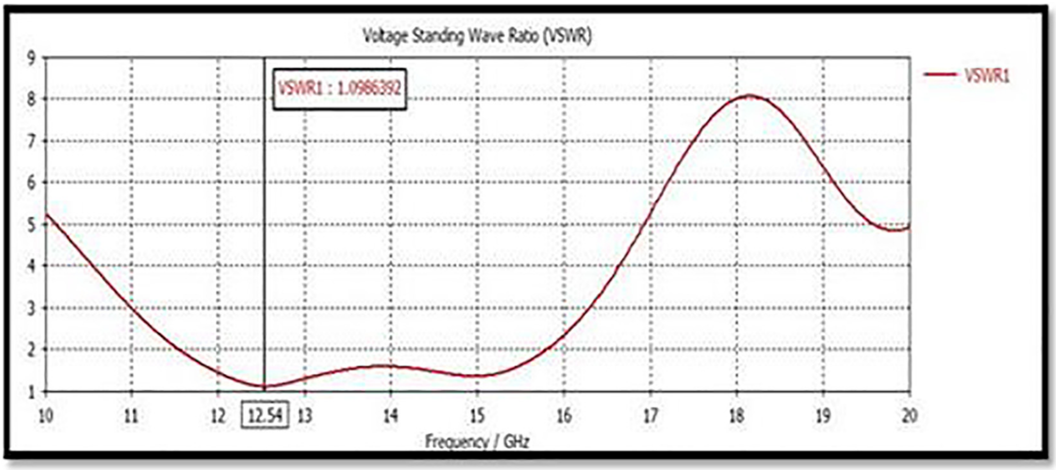

Fig. 5. VSWR vs. Frequency.

Table 2
Outcomes of the proposed MPA.

Return Loss (S_{11})	−26.5578 dB
Directivity	6.31 dBi
VSWR	1.09863

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