International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 13, Issue 5, May 2024)

Design and Performance of Rectangular Microstrip Patch Antenna for Ku-Band Wireless Communication

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***Abstract*— A microstrip antenna needed for wideband transmission must be small, light, and easy to make. The present idea is to create a microstrip antenna that would offer reasonable bandwidth and have a simple geometrical shape. The article presents the design research of a rectangular or square-shaped microstrip antenna. Both antennas used microstrip line for feeding. A larger bandwidth and sufficient return loss are offered by the square microstrip antenna in contrast to the rectangular microstrip. The tiny antenna is intended to operate in the Ku frequency range. With a substantial -1.6 dB return loss and a broad 500 MHz bandwidth, the recommended microstrip antenna is highly effective. This enormous bandwidth is used by several Ku-band wideband utilities.**

Keywords*— Broadband, Microstrip Antenna, VSWR, Gain, Directivity.

I. INTRODUCTION

Microstrip antennas are successfully used in wireless communication systems to fulfil the demands of the latest generation of wireless communication technology while also keeping up with new innovations. Microstrip antennas are used in all of these devices because of their many advantages, which include their high efficiency, low cost, and straightforward design [1]. However, its narrow operating bandwidth limits its use in wireless systems [2]. This is its drawback. Numerous-tasking wireless gadgets and broadband apps have become indispensable parts of our everyday communication life. Low profile wideband is hence no longer as necessary [3]. Many corporate standards and most requirements for mobile and satellite equipment are satisfied by the use of a microstrip antenna. It is evident that fewer electrical circuits are required for wireless applications, and the microstrip is a perfect fit for this. The bulk of applications are using antennas that are getting smaller and smaller. The microstrip antenna fix design meets these specifications. After examining several approaches, it was shown that the microstrip antenna's appropriate impedance bandwidth might be one area for development [4-6]. The carving impact of notches [7,8] and the presence of slots [9–11] in its broadening have been demonstrated by several experiments.

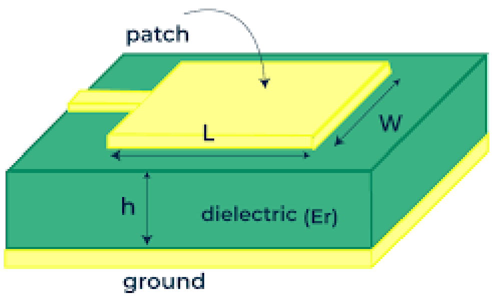

Fig 1: Microstrip Patch Antenna

A very basic form of the microstrip antenna may be constructed by using a dielectric substrate as the base and an arrangement of radiating conducting material on the top side of the substrate. The radiating conducting material might have any simple geometric shape in order to simplify the research and forecast performance.

II. ANTENNA DESIGN AND ANALYSIS

The initial steps in designing the microstrip antenna are accurately identifying the substrate and choosing the operating frequency. It's important to choose the antenna's operating frequency carefully. The planned antenna needs to function within the selected frequency range. In our design, we have selected 15GHz as the operational frequency, which falls inside the Ku-band area. The next stage in the antenna shaping process is to choose a suitable substrate. The height and dielectric of the substrate are steadily affected by the electromagnetic properties of the antenna [12]. For the design, duroid was selected as the dielectric material. Because the dimensions of the antenna are inversely correlated with the dielectric constant, a high dielectric substrate results in a decrease in those dimensions [13]. The feeding method used nowadays is the microstrip feedline.

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Step 1: Estimate of dimension in term of width (W)

Practical width for an effective radiator that results in good radiation efficiency is:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where, μ_0 = free permeability, ε_0 = free space permittivity and ε_r = relative permittivity.

Step 2: Assuming a dielectric constant of, the second step is to calculate the effective dielectric coefficient.

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

Step 3: Calculation of the Effective Length (L_{eff})

The effective length is $$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

Step 4: Calculation of the Length Extension (ΔL)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{rff}-0.258)(\frac{W}{h}+0.8)}$$

Step 5: Calculation of the actual Length of Patch (L)

The actual length of radiating patch is obtained by

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

Step 6: Calculation of the Ground Dimensions (Lg, Wg)

The transmission line model can only work with infinite ground planes. For pragmatic reasons, however, reducing the carbon impact is imperative. Results similar to those for a finite ground plane may be obtained if the ground plane is bigger than the patch dimensions by a factor of many times the substrate thickness across the perimeter, as shown by:

$$L_g = 6h + L\ ,\ W_g = 6h + W$$

The simulation results are obtained by treating the ground plane as infinite.

$$Z_{in} = j\omega L_p + \frac{R}{1+jQ(f_R-\frac{1}{f_R})}$$

With a little knowledge of circuit theory, you can calculate the patch's input impedance as follows: j The frequency ratio is defined as fR= f/f0, where f0 is the patch hole resonance frequency (the resonance frequency of the RLC circuit).

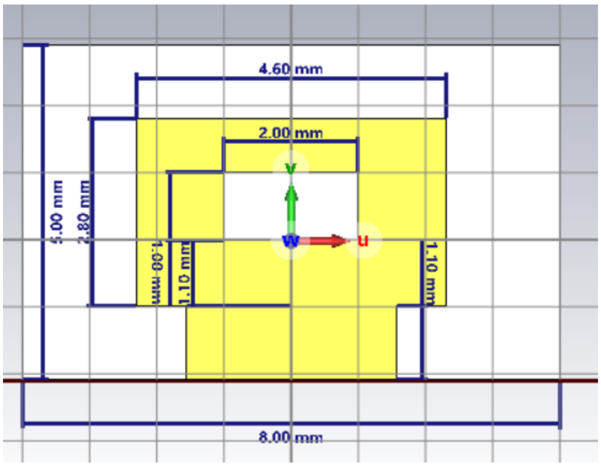

Figure 2: Antenna Design Top view

Figure 2 depicts the design for the suggested microstip patch antenna. The substrate is made of the FR4 substance, which has a dielectric steady worth of 4.4, while the top and bottom layers are made of the lossy copper material.

III. SIMULATION AND RESULTS

Figure 3 illustrates the suggested square microstrip patch form for Ku-band applications. The structure is etched on fire resistant 4 (FR4), measures 8 mm by 5 mm by 1.6 mm overall, has an overall permittivity of 4.4, and a loss digression of 0.024. The antenna parts utilised in this proposal are listed in Table 1. A simple connection or a 50 Ω and 0.5W micro thin link takes care of the antenna.

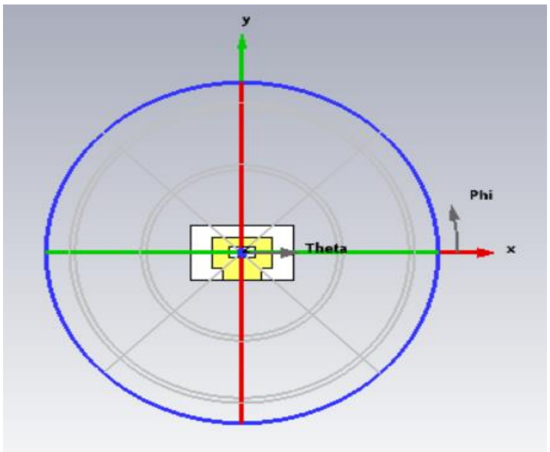

Figure 3: Simulation and fields of proposed antenna

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CST microwave studio simulation and suggested antenna fields utilised to reproduce the design. Figure 3 depicts a circularly organised electric and attractive field simulation.

Table 1: Design parameters for proposed Antenna

Sr No.	Parameter	Value
1	Substrate & Ground Length	5mm
2	Substrate & Ground Width	8mm
3	Tangent Loss	0.06
4	Feed patch length	4mm
5	Feed patch width	3.13mm
6	Feed patch height	0.035mm
7	Frequency (f_r)	15 GHz
8	Dielectric constant(ε_r)	4.4 / FR4
9	Ground Height	0.035mm
10	Substrate Height(Hs)	1.6 mm
11	Line Impedance	50 Ω
12	Patch Length	2.80mm
13	Patch Width	4.60mm

Return loss

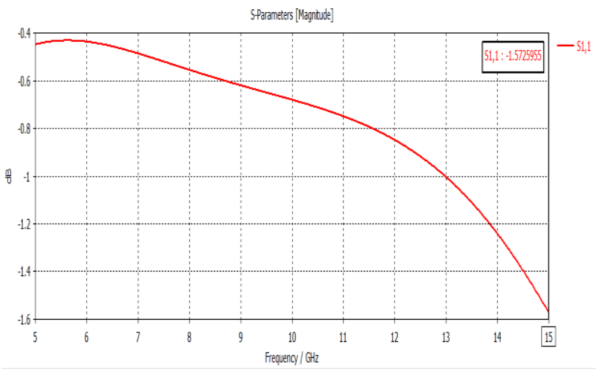

Figure 4: Return loss

The suggested structure's return loss is shown in Figure 4. By looking at this graph, we can easily deduce that the suggested antenna's return loss estimate is -1.6 dB at a resonant frequency of 15 GHz.

Bandwidth

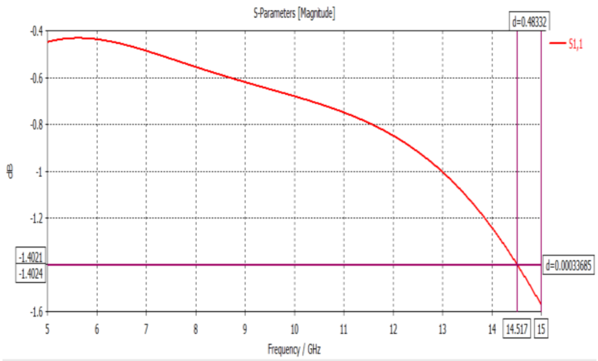

Figure 5: Bandwidth

The bandwidth of a broadband antenna is often represented as a fraction of the difference between the highest and lowest frequencies relative to the bandwidth's fundamental frequency. In this case, 0.5 GHz is the bandwidth of the proposed antenna (14.5GHz – 15GHz).

Voltage Standing Wave Ratio (VSWR)

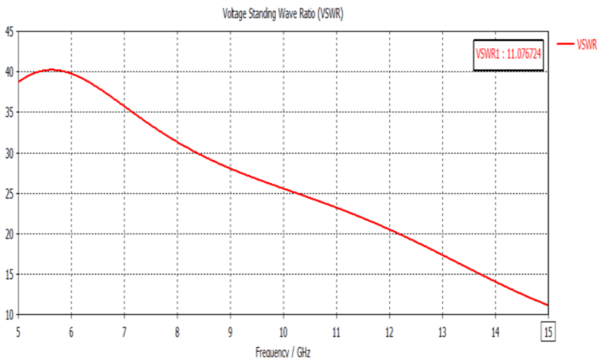

Figure 6: VSWR

The VSWR respect shown in Figure 6 has been attained at 15 GHz, The VSWR value is 11.07.

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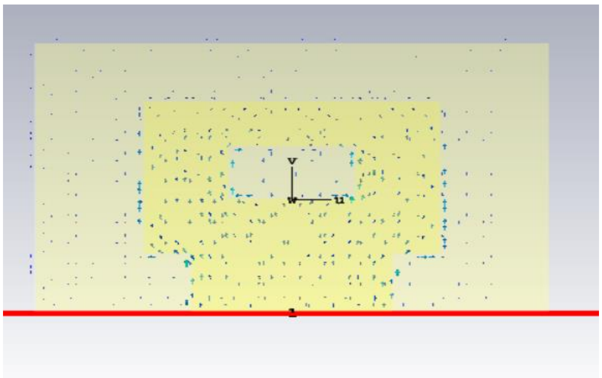

Figure 7: Surface current of proposed antenna

Surface current of the proposed antenna is shown in Figure 7. The proposed antenna's electric and magnetic fields are also shown, with electric field shown by blue dots and magnetic field shown by green dots.

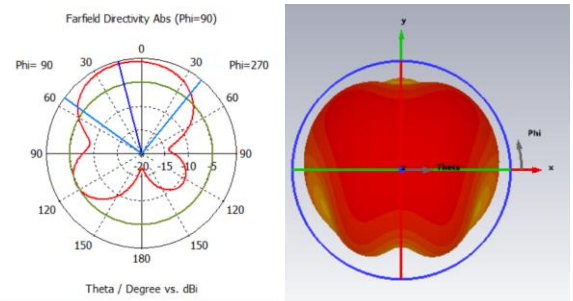

Figure 8: Radiation pattern

As can be seen in Figure 8, the suggested antenna bands have a certain radiation pattern. It's a twist on the force an antenna always sends out as part of the direction of the signal it receives.

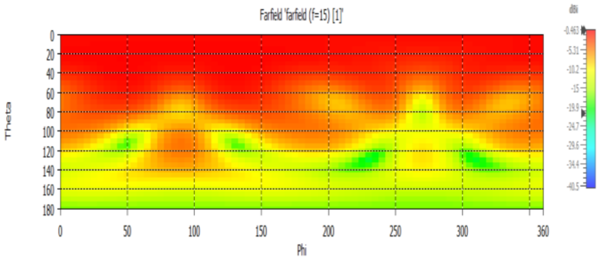

Figure 9: Directivity Analysis

An illustration of the proposed antenna's directional characteristics is shown in Figure 9. Value of directivity is -0.46 dBi.

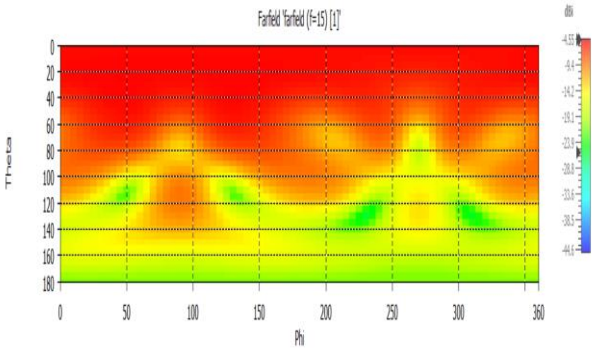

Figure 10: Gain Analysis

An illustration of the proposed antenna's directional characteristics is shown in Figure 10. Value of Gain is -4.55 dBi.

Table 2: Simulated Results of Proposed Antenna

Sr No.	Parameter	Value
1	Dimension	8 X 5 X 1.6 mm3
2	No of band	1
3	Directivity	-0.46 dBi
4	Gain	-4.55 dBi
5	S11 or Return loss	-1.6 dB
6	Band Width	0.5 GHz
7	VSWR	11.07
8	Resonant Frequency	15 GHz
9	Design type	Rectangular

Parameters such as return loss, bandwidth, VSWR, and resounding recurrence are summarised in Table 2. Table 2's recalculated data show that the proposed antenna produces a significant improvement over the status quo.

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IV. CONCLUSION

The proposed microstrip square antenna features a stub feedline and a much wider bandwidth of 500 MHz. It also exhibits a high reflection coefficient of -1.6 dB with a substrate height of 1.6 mm. This validates every aspect of the different antenna structures' designs. The antenna can be expanded broader by appropriately impedance matching a narrow microstrip feedline at the source point. This high return loss and good bandwidth might be useful for a number of wireless applications. Wide-band wireless applications might benefit from a simple antenna.

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