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Design and Analysis of A Ka Band Microstrip Slotted Patch Antenna with 5G Communication Technology Using CST

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Abstract— **Microstrip slotted patch antennas are drawing antenna designers' attention due to appealing features such as less weight and low profile, but they also have certain downsides such as low gain, narrow bandwidth and higher VSWR (Voltage Standing Wave Ratio). These disadvantages can be mitigated to some extent by careful antenna design. This research offers a novel design for microstrip patch antenna bandwidth augmentation, efficiency and reduction of VSWR using a slotted patch adjacent to the radiating patch. A microstrip slotted patch antenna is also proposed for 5G communication in this study. The designed structure operates at 29.416 GHz. The proposed design is simulated using the CST studio suite (Computer Simulation Technology) software. The return loss is -44.78 dB, the bandwidth is 900 MHz and the VSWR is 1.0115. The findings demonstrate that the proposed design has favorable properties for Ka-band applications.**

Keywords— VSWR, Microstrip Slotted Patch Antenna, Ka Band, Return Loss, 5G Communication.

I. INTRODUCTION

In general, the microstrip patch antenna is an important component of communication systems that demand properties such as small size, light weight, simple construction, and wide bandwidth. Geometries include circular, rectangular, triangular, elliptical, square, ring, cone, and other shapes. Nonetheless, rectangular and circular shapes are the most prevalent. The patch antenna's size is determined by the substrate's dielectric constant dielectric material (r) [1], [2]. Faster data rates, higher density connections, and low latency are all features of the 1G/2G/3G/4G and 5G generations [3]. Microstrip patch antennas have various advantages despite inherent limitations such as restricted bandwidth and low strength. However, several strategies for increasing bandwidth and gain have been investigated [4].

The ability to modify the radiation pattern by tuning the patch size of an antenna has the potential to increase the performance and efficiency of a communication system. Manipulation of radiation pattern of an antenna can be used to minimize noise sources or electrical interference, improve signal direction toward targeted users [5], and, most importantly, improve communications security in specific situations. In the realms of satellite, radar, wireless communication, and other applications, pattern reconfigurable antennas are in high demand.

A MPA (Microstrip Patch Antenna), as usually consists of radiating patch, dielectric substrate and a ground plane, as shown in Fig. 1.

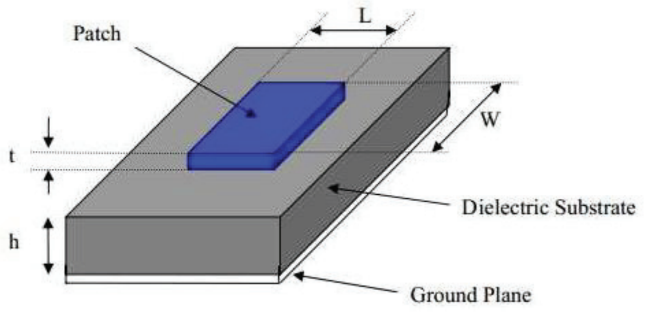

Fig. 1. Image of microstrip patch antenna

Typically, the patch is made of conductive material. On the top of the dielectric substrate, the radiating patch and feed lines are normally set. The patch may be circular, rectangular, square, elliptical, triangular, or different types of shape to simplify performance prediction and analysis. The L (length) of a rectangular patch is typically $0.3333 < < 0.5 \lambda o$, here λo denotes the wavelength of free space. The patch is chosen to be very thin so that it may be easily applied. The dielectric constant of substrate (r ε) should be in the range of $2.2 \leq \leq 12$ r ε.

Microstrip antennas are in square, rectangular, circular, and elliptical configurations, and can be used for different types of secure communication using an antenna system. However, any continuous shape can be created. Due to the advancement of sensor systems and other technology, an antenna plays an important role in wireless communication by receiving or transmitting electromagnetic waves in free space [6].

For antennas, the Voltage Standing Wave Ratio (VSWR) is always a positive and real number. For lower VSWR, the antenna is perfectly matched to the transmission line and it receives more power. The minimum value of VSWR is 1.0. In this situation no power is reflected from the antenna, which is optimal. When an antenna is not matched to the receiver then power is reflected. Standing waves are created along the transmission line as a result of the reflected voltage wave. There is no reflected power and the voltage is a constant magnitude if the VSWR was set to 1.0. So, many researchers are working on reducing VSWR of microstrip patch antenna. For making an efficient antenna, better VSWR is must needed.

In this paper, a software CST STUDIO SUITE 2019 is utilized for simulation and design. This software is a widely used simulation program. The designed antenna operates at 29.416 GHz. The aim of this research is to improve the efficiency and reduce VSWR (Voltage Standing Wave Ratio) by determining different parametric value, feeding method, no. of slots and sizes of patch, materials of patch and substrate. The proposed antenna is covered Ka band applications with 5G communication technology which is very much important for space telescopes, wireless microwave communication systems, military aircraft, vehicle speed detection systems, close-range targeting radars and satellite communications.

The structure of this paper is as follows: the "Antenna System Design" section details the work's implementation, the "Simulation and Result Analysis" section summarizes the study's findings, and the "Conclusion" section summarizes the paper's conclusion.

II. ANTENNA SYSTEM DESIGN

A microstrip patch Antenna has a metal patch which is installed at ground section with a dielectric substrate. These are incredibly small antennas that emit very little radiation. A micro strip antenna is made up of a dielectric substance sandwiched between a very thin metallic strip (t<<λ) and a short height of ground plane (h<<λ). Photo-etching is for establishing the radiating element and feed lines are on the dielectric substrate material. The patch of the antenna is λ/2 in length. When the antenna is activated, the waves formed within the dielectric are reflected, and the energy is radiated from the metal patch's borders, which is a very tiny amount of energy.

The operating frequency is inversely proportional to the physical size of the antenna. To increase the frequency band, the length and width of the slotted microstrip antenna's radiating patch are tuned and slotted during modeling. The equations that are utilized to create this antenna are given below:

$$W = \frac{c}{2f0}\sqrt{\frac{2}{1+\varepsilon\pi}} \tag{1}$$

where, W = width of patch
f_o = resonance frequency
c = light speed

$$L = L_{eff} - 2 \vartriangle \mathrm{L} \tag{2}$$

where, L = patch length
L_{eff} = effective length
$\vartriangle$ L = extension of length

$$L_{eff} = \frac{c}{2f0}\sqrt{\frac{2}{\mathcal{E}\mathrm{eff}}} \tag{3}$$

where $\mathcal{E}_{eff}$ = effective dielectric constant of substrate

$$X_f = \sqrt{\frac{L}{\mathcal{E}\mathrm{eff}}} \quad \text{and} \quad Y_f = \frac{W}{2} \tag{4}$$

where X_f = input position along with X axis.
Y_f = input location along with Y axis.

$$\vartriangle \mathrm{L} = 0.412\mathrm{h}\,\frac{(\varepsilon\mathrm{eff}+0.3)(\frac{w}{h}+2.64)}{\mathcal{E}\mathrm{eff}(\varepsilon\mathrm{eff}-0.258)(\frac{w}{h}+.8)} \tag{5}$$

$$\mathcal{E}_{eff} = \frac{(\mathcal{E}\mathrm{r}+1)}{2} + \frac{(\mathcal{E}\mathrm{r}-1)}{2}\,[1+12\,\frac{\mathrm{h}}{\mathrm{w}}]^{1/2} \tag{6}$$

$$L_g = 6h + \mathrm{L} \tag{7}$$

$$W_g = 6h + \mathrm{W} \tag{8}$$

The equations are calculated and determined the best feed point placement using the parameter values listed below in Table 1. The width of values (mm) 6 is used in our patch design, along with a patch length of 4 mm and a patch thickness of 0.4 mm. Other values from the Table 1, can also be used and a good performance can be acquired as well as the best feed point of the designed microstrip patch antenna.

TABLE I. PARAMETERS OF THE DESIGNED ANTENNA

Parameter Name	Value in mm
Ground Length (Lg)	6
Ground Width (Wg)	6
Substrate Length (Ls)	6
Width of substrate (Ws)	6
Patch Length (Lp)	4
Width of patch (Wp)	6
Ground Thickness (Tg)	0.2
Substrate Thickness (Tsub)	0.4
Thickness of Patch (Tp)	0.4

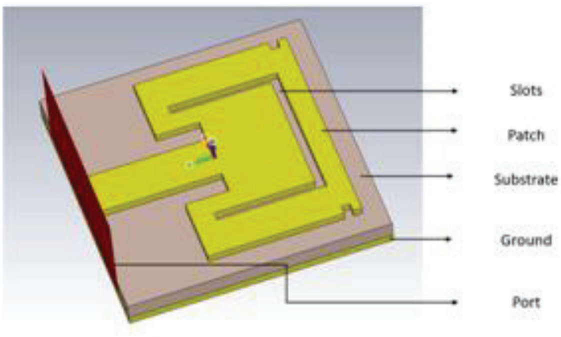

Fig. 2. 3D view of proposed microstrip slotted patch antenna.

In Fig. 2, the designed microstrip slotted patch antenna's substrate material is FR4. It's simple to make, has a low profile, inexpensive, and outperforms other antennas. The dielectric constant of FR4 is much better. Between the ground plane and patch of the designed antenna, we inserted the substrate material. The relative permittivity of FR4 substrate is 4.4 and the thickness is 0.4 mm. The antenna is fed using a microstrip line model. CST STUDIO SUITE 2019 software is used to design the antenna structure.

III. Simulation And Result Analysis

The output of the simulation shows that the designed antenna is operating at 29.416 GHz. The 24.25–29.5 GHz spectrum band is the most licensed and deployed 5G mm wave frequency range in the world. So, the proposed antenna is also a 5G technology antenna. The return loss and bandwidth of the designed microstrip antenna are -44.78 dB and 900 MHz respectively. It covers Ka band with a very impressive value of VSWR 1.0115.

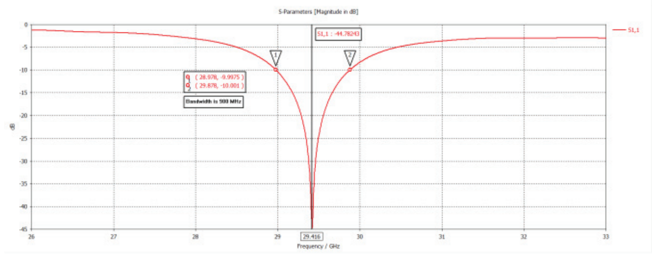

Fig. 3. S-Parameters of proposed Microstrip Patch Antenna.

The value of the S-parameter is shown in Fig. 3. At frequency 29.416 GHz, a large return loss is determined which is -44.78 dB and it has also a better bandwidth of 900 MHz. S parameters link the incident and reflected waves through the device's ports. Analytical techniques can be used to determine or quantify S parameters of particular circuits or components. These S parameters are quite useful when designing antennas.

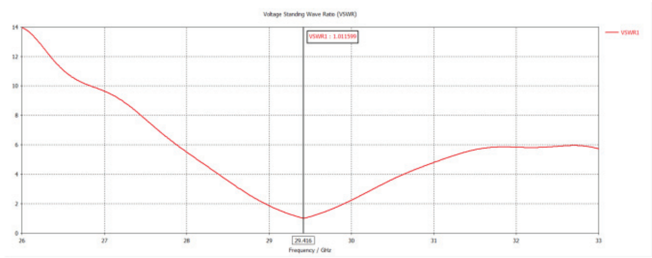

Fig. 4. VSWR of proposed Microstrip Patch Antenna

VSWR of the proposed antenna is shown in Fig. 4 from the CST simulation. At 29.416 GHz frequency, the value of VSWR is also determined, which is 1.0115. The VSWR is a measurement of how efficiently radio-frequency power is transmitted from a power source to a load through a transmission line. The VSWR comparison with previous work is given in the Table 2.

TABLE II. VSWR Comparison With Previous Work

Reference	VSWR
[8]	1.95
[9]	1.0172
[10]	1.5376
[11]	1.4, 1.1, 1.3,
[12]	1.8113, 1.3814, 1.2180
Proposed Work	1.0115

From this table, we can see that our designed antenna is much efficient because it is very nearly to the ideal value 1. So, this proposed antenna has very less reflected power and it is also match to the transmission line.

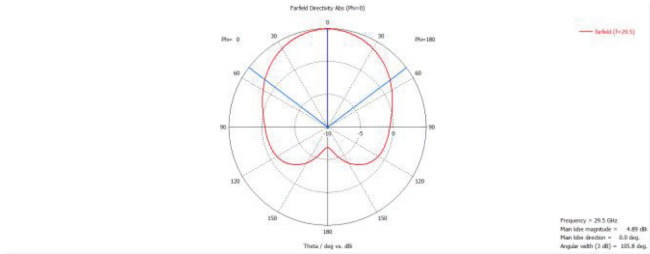

Fig. 5. Far field Directivity at 29.5 GHz for Phi=0

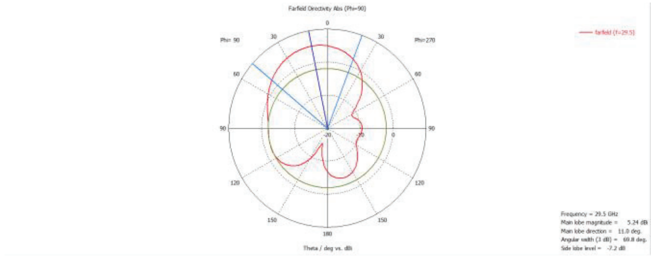

Fig. 6. Far field Directivity at 29.5 GHz for Phi=90

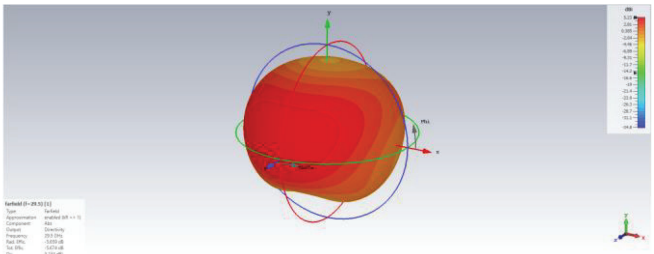

Fig. 7. 3D Far field Directivity at 29.5 GHz

The electromagnetic field's region around an item, a transmitting antenna, or radiation scattering result off an object, are referred to as the far field. The degree to which the radiation emitted is concentrated in a single direction is measured by directivity, which is a parameter of an antenna. Far field directivity at 29.5 GHz for Phi=0 and Phi=90 are shown in Fig. 5 and Fig. 6 respectively. 3D Far field Directivity at 29.5 GHz is also shown in Fig. 7 in which directivity is 5.234 dBi, total efficiency is -5.674 dB and radiation efficiency is -5.659 dB. For the value of directivity, total efficiency, total radiation efficiency and better VSWR, the proposed antenna performance is much better.

IV. Conclusion

The design of Ka band microstrip slotted patch antenna with 5G communication technology has been proposed in this research which is very much efficient antenna. The operating frequency of the designed antenna is 29.416 GHz and this frequency is used for 5G communication technology. The proposed antenna covers the Ka band which bandwidth is 900 MHz. FR4 materials for substrate and slotted patch are used for improving the performance of the designed antenna. The directivity, total efficiency and total radiation efficiency of the proposed antenna are 5.234 dBi, 5.674 dB and -5.659 dB respectively with better VSWR 1.0115. The results show that better substrate material and slotted patches into the design technique can result in a significant inclination of the radiation beam and reduction of VSWR, making the method useful for microstrip antennas. Some performance comparison based on VSWR is described in introduction section. However, this designed antenna can be used for military aircraft, satellite communication, space telescopes, vehicle speed detection system and commercial wireless point-to-point microwave communication systems.

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