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Design of Microstrip Patch Antenna for 5g Applications

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Abstract: *This paper is embedded with microstrip patch antenna that is constructed for future 5G wireless communications. The antenna has a compressed structure of 11mm x 8 mm x 0.5mm, including the ground plane. This antenna is designed using Rogers RT/duroid 5880 substrate used as dielectric material with a miniaturized size of 4.4mm x 3.3mm. Its dielectric constant is 2.2 and has thickness of 0.5 mm. This microstrip patch antenna resonates at frequencies of 28 GHz and 50 GHz. The antenna is simulated by using high frequency structure simulator. The antenna provides a gain of 2.6dB. The structure of antenna and various specifications such as return loss, vswr, gain plot and radiation pattern are discussed.*

Keywords:*Feed, HFSS, Microstrip Patch, Slot, 5G.*

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I. Introduction

Present wireless communication technology is expanding rapidly due to the increase in the numbers of users in terms of internet usage. We have come across 1G, 2G, 3G and recently 4G LTE technologies. One of the provoking factors that affect the today's wireless communication is lack of feasible frequency resources. So to solve this problem, research has been started in 5G wireless communication at millimeter frequency band, which ranges between 20 GHz to 300 GHz. Mostly the frequency range used for 5G research are in range of 24 GHz to 60 GHz [1]. Numerous fields have adopted the 5G technology with Internet of things (IOT). One of the goals of 5G technology is to connect millions of devices together. This future 5G technology can be used in smart cities, smart transportation and robotics.

The agile decrease in size of mobile devices prone to develop miniature antennas that could fit in those devices without affecting the function [2]. This caused to the raise of microstrip patch antennas in 20^{th} century. Microstrip patch antenna consists of a thin metal foil mounted on a substrate, beneath the substrate there is a presence of ground[3]. This microstrip patch antenna can be integrated very easily on the surface of PCB, which can be used in mobile devices as well. Mostly these antennas are used in microwave and millimeter frequency bands.

II. Design Equations For Patch Antennas

The blue print of microstrip patch antenna that is developed at 28 GHz and 50 GHz shown in figure 1. This uses an inset line feeding technique. The measurements of patch are 4.4 mm x 3.3 mm. The thickness of substrate is 0.5 mm with a rectangular slot cut on it. Distinct parameters are considered for developing the antenna such as dielectric constant, thickness of substrate (t_s = 0.5 mm) and resonant frequency (r_f = 28.3 GHz). The complete dimensions are shown in table below. The impedance of feed is 50 ohms. In HFSS the lumped port is used to excitethe antenna. Since the antenna is of very small size to match the impedance of patch and feed line, inset type feeding is chosen for maximum transfer of power.

The analysis of microstrip antenna is done using cavity and transmission line model[4]. The design methodology and equations are portrayed under:

$$m = \frac{C}{2r_f\sqrt{\frac{(e_r+1)}{2}}} \quad ...(1)$$

Where M is the width of patch, C is speed of light that is 3 x 10^8, $r_f$is the resonant frequency that is 28 GHz for future 5G applications and e_r is dielectric constant that is 2.2

$$e_{eff} = \frac{(e_r+1)}{2} + \frac{(e_r-1)}{2}\left[1+12\frac{k}{m}\right]^{\frac{-1}{2}} \quad ...(2)$$

Here k is height of substrate that is 0.5 mm.

$$n_{eff} = \frac{C}{2r_f\sqrt{e_{eff}}} \quad ... (3)$$

Where n is the length of patch

$$\Delta n = 0.412k\frac{(e_{eff}+0.3)(\frac{m}{k}+0.264)}{(e_{eff}-0.258)(\frac{m}{k}+0.8)} \quad \dots (4)$$

$$n = n_{eff} - 2\Delta n \quad \dots (5)$$

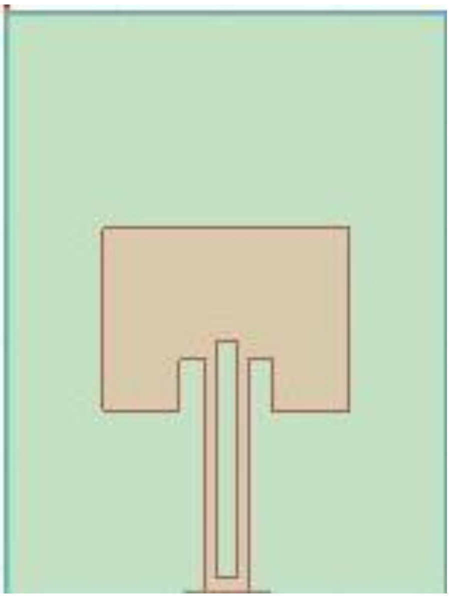

Fig-1. Designed Microstrip Patch Antenna

The size of Substrate is 11 mm x8 mm which is made up of Rogers RT 5880 with a thickness of 0.5 mm. The length and width of patch are 4.4 mm, 3.3 mm respectively. The depth of inset feed is 0.94 mm and width is 0.445 mm. The length and width of slot are 0.385 mm, 4.24 mm respectively. The width of microstrip line is 0.77 mm.

The entire blue print is built using HFSS [5], the substrate is made like a box as per dimensions and perfect E1 boundary is assigned. Now Patch is made on the surface of substrate as per dimensions. An inset slot is made on the both sides of feed to maintain impedance matching. The patch and feed are united and boundary perfect E2 is assigned. Now ground plane is carved at bottom of substrate that is assigned with perfect E3 boundary. Now lumped feed is given to microstrip line with impedance of 50 ohm. The radiation box is drawn with the antenna inside the radiation box which is made of vacuum.

III. Figures And Tables

The parameters used in designing the microstrip patch antenna are shown in the table-1

TABLE-1. Rectangular Patch Antenna

S.No	Parameter	Dimension (mm)
1	n_s	11
2	m_s	8
3	n_p	4.4
4	m_p	3.3
5	n_f	3.3
6	m_f	0.77
7	m_g	11
8	n_g	8
9	n_{gs}	4.24
10	m_{gs}	0.385
11	n_{is}	0.94
12	m_{is}	0.445
13	K	0.5

Table-2.Output Parameters

Parameter	Patch Antenna
Resonant Frequency	28.3 GHz
VSWR	1.58
Gain	2.6 dB

IV. Simulation Results

Return Loss Plot

The S_{11} parameters are considered as antenna return loss parameters. Considering -10 dB to be the base value, the return loss obtained at 28 GHz is 21 dB and return loss obtained at 50 GHz is 31 dB respectively. Fig shows the plot of return loss.

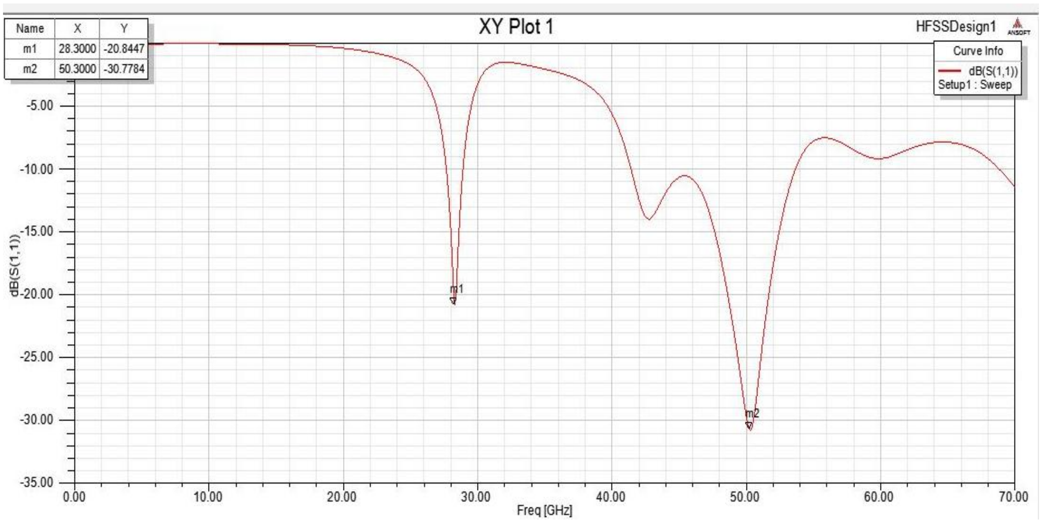

Fig-2. S-Parameters

VSWR Plot

The Voltage Standing Wave Ration (VSWR) is shown In Fig . The ideal value of VSWR is 1 dB and practically it should not be more than 2.5 dB. This antenna has VSWR of 1.58 dB at 1.58 GHz.

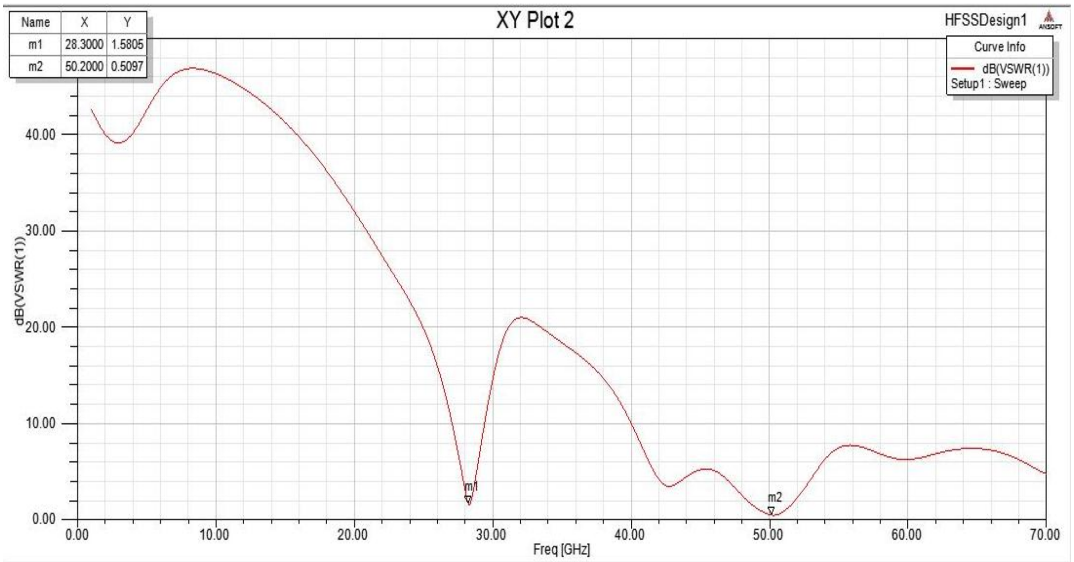

Fig-3. VSWR

Gain Plot

The 3D plot shows the gain of antenna. The antenna has a gain of 2.6 dB. Fig shows the gain of patch.

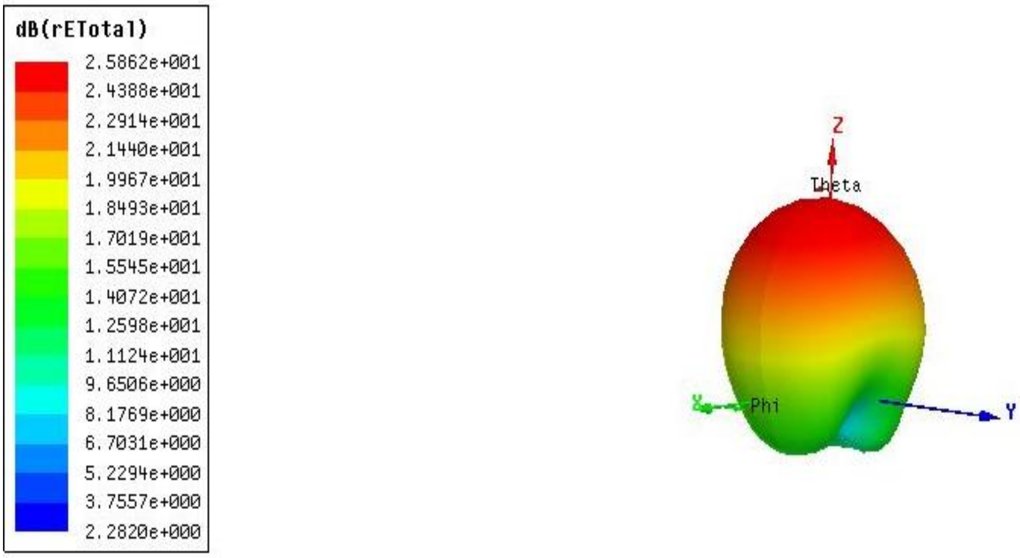

Fig-4. Gain

Radiation Pattern

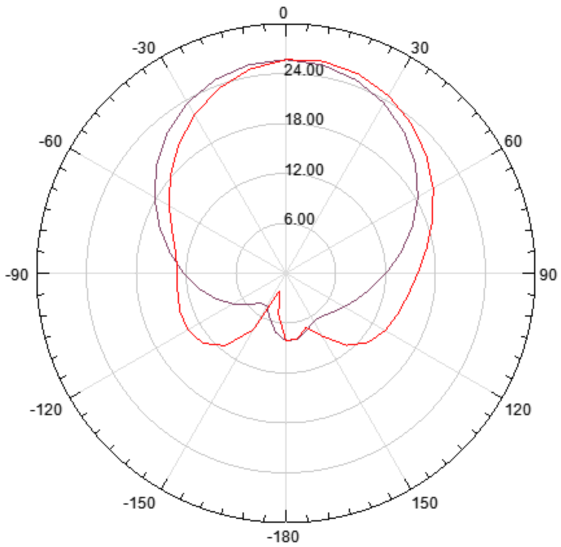

Fig-5. Radiation Pattern

V. Conclusion

In this paper the microstrip patch antenna is designed for future 5G communications. The antenna resonates at frequencies of 28.3 GHz and 50.3 GHz with a return loss of 21 dB and 31 dB respectively. The antenna is best suitable for devices that have a space constraint and can be easily integrated. The Structure of antenna is compressed to 11 mm x 8 mm x 0.5 mm.

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