High Directive Wideband Microstrip Patch Antenna for 5G Mobile Phone Application

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***Abstract*— A compact micro strip patch antenna has been investigated for 5G mobile application. The antenna is especially designed for 5G mobile communication. The antenna is excited by inset feeding technique. The antenna resonates at 38.256 GHz. Proposed patch configuration shows improved bandwidth of 10 GHz with the offset transmission line feed. The antenna was fabricated using a single FR4 substrate of dimension 2.69×4.55×1.6 mm^3.**

***Index Terms*—Microstrip, 5G, Mobile Antenna, Wideband.**

I. Introduction

NOWADAYS because of quick change in communication field to strength of mobile speed there is an increase in data rate. Most of challenges are rising day by day [1,2]. To overcome this challenge technological advancement has taken place in the field of new mobile communication network and subscribers increased up to 150 million and more [3]. 4G network did not fulfill the need of customer. To resolve this problem many researchers have worked on millimeter wave, i.e., high frequency band spectrum. Millimeter wave band called as 5th generation mobile network that provides gigabit communication services [4]. The designed micro strip patch antenna has a compact size with dimensions 6 mm × 6 mm × 1.6 mm. The substrate material used for patch antenna also affects the result efficiency and gain, i.e., FR4 is one of them. It is used for millimeter wave band and gives good result [3, 5]. In Sect. 2, we discussed the literature survey of the previous work. In Sect. 3, the designed antenna is discussed. Section 4 consists of simulation result such as Return Loss, VSWR, Directivity, Gain etc.

The emerging 5G technology is demanding antennas with features previously unseen on a user terminal, such as the beamforming capability of the radiation pattern to perform spatial scanning. This requirement raises numerous design challenges to achieve a reasonable trade-off between technological design issues and commercial criteria - low cost, small size, radiation efficiency, antenna gain, broadband performance, and so on – mainly at millimetric wave bands

Among other options, microstrip antennas with coplanar placement of radiation elements and feeding network seem a good choice to achieve a functional element with a proper balance of performance and manufacturing complexity for 5G applications. Microstrip antennas printed on Duroid substrate have been demonstrated good performance when compared to traditional designs in LTCC technology.

This paper discusses on the problems related to the design of a basic microstrip structure: a patch antenna. Even when this antenna geometry shows less restrictive fabrication needs of resolution and accuracy with respect to other microstrip structures, fabrication restrictions can significantly influence this antenna features, such as resonant frequency and radiation efficiency.

II. Literature Review

5G networks provide number of services for the user by improving bandwidth and data rate [6]. But the main reason is to increase the need of 5G technology as it reduces the size of the antenna, it is light in weight so it reduces size of antenna [7, 8]. Verme et al. [1] proposed a micro strip patch antenna has a compact size of 20 mm × 20 mm × 1.6 mm resonate at 10.15 with 4.46 dBi gain. Jandi et al. [9] proposed micro strip patch antenna has a compact size of 19 mm × 19 mm × 0.787 mm and provide a gain of 5.51 dB at 10.15 GHz and 8.03 dB at 28 GHz. Rafique et al. [10] presented an antenna has compact structure of 16 mm × 16 mm resonate at 28 and 38 GHz. Adedotun et al. [11] This paper presents a simple antenna having square –shaped port patch. Antenna performance is carried out from CST simulation software and proposed antenna resonate at 38.256 GHz frequency.

III. Antenna Design Formulation

A small micro strip patch antenna has inset feeding techniques. The parameter of this antenna is 6 mm × 6 mm with substrate thickness 1.6 mm and FR4-material is used for substrate whose dielectric constant is 4.4. A proposed antenna has rectangular radiating patch i.e. 2.69 mm × 4.55 mm. And one slot is etched on ground plane. These are the steps for antenna design: [12]

Calculate Width (a practical width that lead to good radiation, efficiency is)

$$w = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad \text{-------------------------------------} (1)$$

Manuscript received February 9, 2019.

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Doi: 10.5281/zenodo.3108111

v_0 = The velocity of light.

ε_r = Dielectric constant of substrate.

Effective dielectric constant of the rectangular micro strip patch ant

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right) \quad (2)$$

Patch Length

$$L = L_{eff} - 2\Delta L \quad (3)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (4)$$

Calculation of length extension

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{w}{h}+0.8)} \quad (5)$$

Inset Feed

$$50 = R_{in}\left(\cos\left(\frac{\pi}{L}y_0\right)\right)^2 \quad (6)$$

R_{in}= The input impendence at the leading radiating edge of the patch. While $50\ (\Omega)$ is the desired impendence.

$$R_{in} = 90\frac{\varepsilon_r^2}{\varepsilon_r-1}\left(\frac{L}{W}\right)^2 \quad (7)$$

The width of the Quarter wave line is given by

$$Z_T = \frac{60}{\sqrt{\varepsilon_r}}\ln\left(\frac{8d}{w_T}+\frac{w_T}{4d}\right) \quad (8)$$

Where Z_T is calculated as:

$$z_T = \sqrt{50 \times Z_a} \quad (9)$$

The length of Quarter line

$$L_{T=}\frac{\lambda}{4} = \frac{\lambda_0}{4\sqrt{\varepsilon_{eff}}} \quad (10)$$

The width of 50Ω line is given by:

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_r}\left[1.393+\frac{2}{3}\ln\left(\frac{w}{h}+1.444\right)+\frac{w}{h}\right]} \quad (11)$$

The dimension of proposed antenna is substrate length = 6 mm, substrate width = 6 mm, substrate thickness 1.6 mm, ground length and width is 6 mm × 6 mm, patch length = 2.69 mm, patch width = 4.55 mm, inset feed line = 0.78 mm.

IV. PRACTICAL DESIGN CASES

In Fig. 1 we show a rectangular patch designed at a center frequency of 28GHz. The geometry parameters of this antenna are (in mm): L1=3.46, L2=7.88, L3=1.60, L4=1, L5=0.49, W1=4.22, W2=1.19, WS1=1.05, Ls1=0.65, s1=0.375, s2=0.07. The dimensions L1 and W1 determine the center frequency, and for a regular rectangular patch the edge impedance is 144Ω.

However, a feed line with such impedance implied physical dimensions out of range of our fabrication capabilities, mainly a milling machine with 150µm of resolution. Due to this circumstance, we firstly designed a feed line of 50 Ω and the feeding was not done on the patch edge but in an interior point by using a rectangular notch. The pieces of the feed line with dimensions L3 and L4 constitute a cascade quarter wavelength impedance adapter. The notch dimensions condition the fine tuning of the impedance matching.

A prototype of the built antenna is shown in Fig. 2 (left). In Fig. 3 we show a comparison between the theoretical scattering parameter s11(f) of the antenna designed with ideal port feeding and considering a 1.8mm connector later used for measurements. We observe that having excluded the presence of the connector and even the soldering point used to attach the feeding line and the connector, sharply modified the antenna performance in terms of s11(f).

In Fig. 2 (right) we show a second patch built at a center frequency of 60GHz that follows the same geometry described in Fig. 1. The geometry parameters of this second antenna are (in mm): L1=1.49, L2=9.97, L3=0.77, L4=0.7, L5=0.49, W1=1.9, W2=1.41, WS1=0.88, Ls1=0.33, s1=0.34, s2=0.02. For this frequency, each issue design becomes even more critical. We found that the soldering point must be carefully modelled in the theoretical design given that it represents a non-negligible transition between two different materials that strongly effects the antenna performance, as seen in terms of s11(f) in Fig. 4.

In Fig. 4 we show a comparison of the theoretical and the measured s11(f). We observe a resonant frequency shift that can be explained by different causes: a deviation of the substrate dielectric permittivity value, inaccuracy in the connector modelling, and problems with soldering the connector pin to the feeding line. The dielectric permittivity εr was measured using a DAK setup and theoretical value was also determined by optimization in CST. Finally, a value of 2.43 was used for the design of the 28GHz and 60GHz patches.

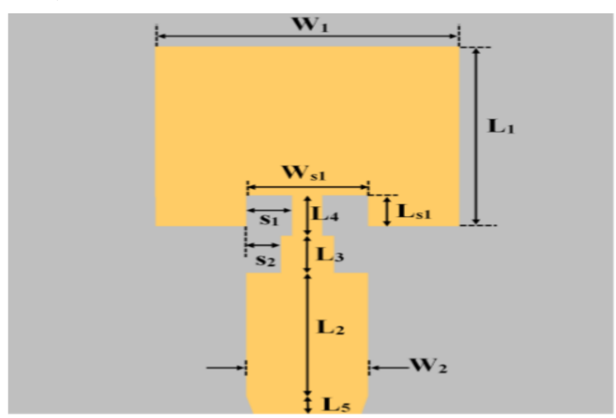

Fig. 1. Geometry of the patch antennas.

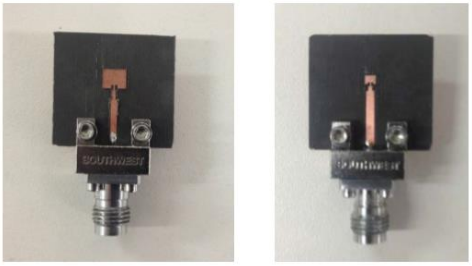

Fig. 2. Photo of the prototypes fabricated at 28 and 60GHz.

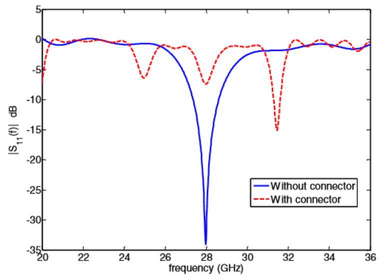

Fig. 3. Comparison of theoretical $s_{11}(f)$ between design optimized without and with connector for the patch at 28GHz.

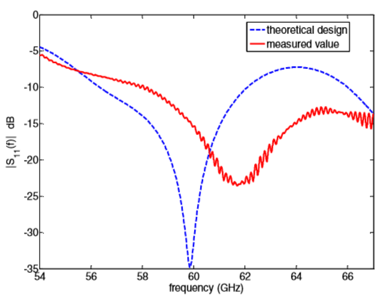

Fig. 4. Comparison of theoretical and experimental parameter $s_{11}(f)$ for the prototype fabricated at 60GHz.

V. Simulation and Results

To check the performance of proposed antenna with CST simulation software (Fig. 3). The return loss and VSWR of this proposed antenna is -21.16 and 1.19 dB respectively. This proposed antenna work at resonating frequency is 38.256 GHz with 5.48 dB gain and 7.716 dB directivity as shown in Fig. 4

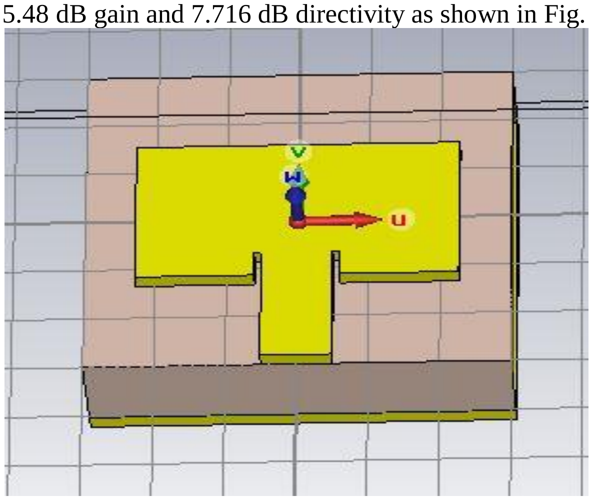

Fig.5. 3D view of proposed antenna

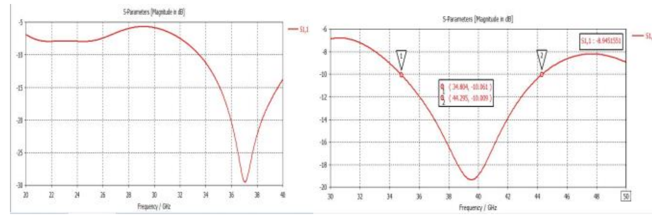

Fig.6. Return loss. (a)-29.48 dB at Notch length 0.08 mm (b) -21.16 dB at Notch length 0.1 mm

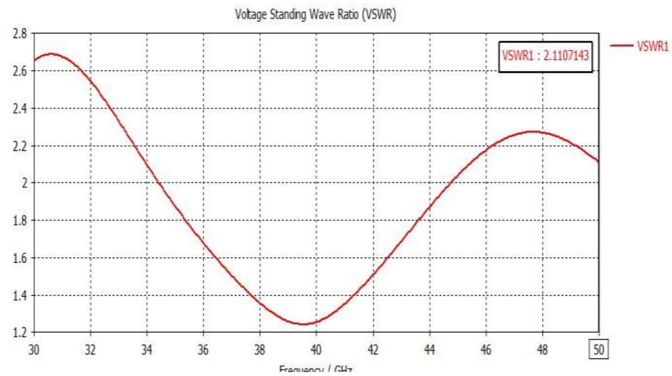

Fig.7. VSWR of the proposed antenna

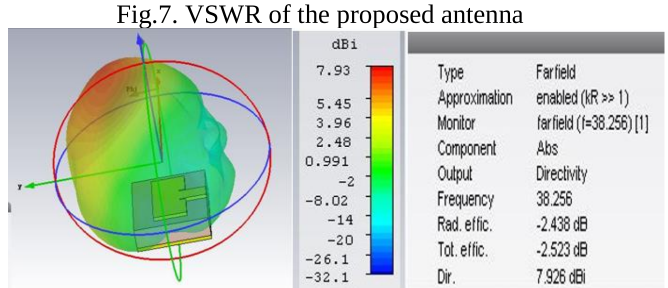

Fig.8. 3-D Directivity plot of the proposed antenna

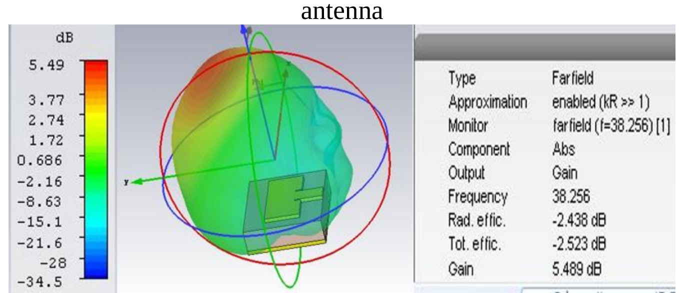

Fig.9. 3-D gain plot for the antenna

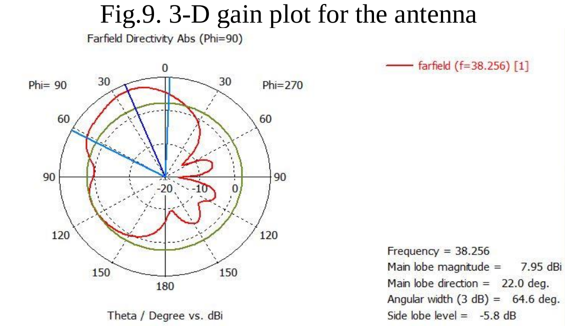

Fig.10: Radiation pattern of the proposed antenna

VI. Analysis

The antenna is fed by inset feeding technique. The return loss is varied with the length of the notch in the inset feeding. At .08 mm the return loss is -29.48 dB & in .1mm that is -

21.16. Initially at .08 mm the result is better. But the gain & directivity at .1mm is far better than that of .08 mm. We observe that VSWR of the proposed antenna is 1.2 which is acceptable for proper transmission & reception. The gain & directivity of the proposed antenna is 5.489 dB & 7.926 dBi respectively which is better than the four-reference antenna. Also, we have a huge bandwidth like 10 GHz is obtained.

Antenna	*Fr* (GHz)	Loss (dB)	VSWR	Directivity (dBi)	Gain (dB)	Efficiency (dB)	Bandwidth
Proposed	38.256	-21.16	1.2	7.926	5.489	-2.438	10 GHz
Reference [1]	10.15	-18.276	2.13	-	4.46	-	-
Reference [13]	31.90	-42.96	.12	5.55	5.2	-	-

VII. Conclusion

Design of antennas for 5G communications brings new challenges to designers. The reduced dimensions imposed by the large frequencies can lead to non-implementable prototypes. This constraint can be faced by fitting the antenna model dimensions to the resolution and accuracy of the fabrication capabilities. We present two design cases of a patch antenna adapted to our assembly restrictions that also consider both the connector and soldering presence. In this paper, a compact size antenna has been simulated for 5 G wireless communication. The proposed patch antenna resonates at 38.256 GHz with a return loss of -21.16 dB. From the results the gain & directivity of antenna with slightly larger length of the notch improved over same antenna. Also, it has a large bandwidth which is very important for high speed communication. Because of compact size (6 mm ×6 mm ×1.6 mm) it can be used where space is most important issue.

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