CHARACTERISTICS OF BEAM STEERING PHASED ARRAY ANTENNA FOR 5G APPLICATIONS

R.Thandaiah Prabu[1], Dr.V.Thulasi Bai[2]

[1]Ph.D Scholar, Anna University, Chennai, Jeppiaar Institute of Technology, Sriperumbudur.

[2]Professor, KCG College of Technology, Chennai.

[1]thandaiah@gmail.com,[2]thulasi_bai@yahoo.com.

Abstract— **In this contribution, Beam steering phased array antenna for the fifth generation (5G) applications were designed and implemented using CST MICROWAVE STUDIO 2014. The proposed Microstrip Patch Antenna (MPA) is designed to operate at the frequency of 28/38 GHz that has the dimensions of 6x5.5 mm^2, using FR-4substrate. The shape of the MPA design is planar Inverted F – Antenna (PIFA) which is desired for its space saving property in wireless devices. Better Omni directional radiation pattern is obtained for the Waveguide port feeding technique. The Phased array antenna elements consisting of 1, 2, 4, 6, 8, and 10 are designed to obtain a maximum gain of 16.2 dB designed at a frequency of 38 GHz with a return loss of -21.02 dB. It exhibits both narrow and wider bandwidth consists of a number of antenna elements that is able to cover mm wave wireless communication bands.**

***Keywords*—Beam steering, Phased array, 5G, 28/38GHz, FR4, Microstrip Patch Antenna (MPA)**

I. INTRODUCTION

Due to enormous increase in mobile data growth and deployment of 4G telecommunication systems, eyes are looking towards the development of 5th generation. Although the deployment of wireless services takes many years, development of 5G technology is being investigated. Using frequencies much higher in the frequency spectrum opens up more spectrums and also provides the possibility of having much wide channel bandwidth. The standard bodies have not yet defined the parameters that are needed to meet a 5G performance. Typical parameters for a 5g standard may include [1]:

Table.1 Typical Parameters for 5G Standard

PARAMETER	PERFORMANCE
Network Capacity	10000 times capacity of current network
Peak Data Rate	10 Gbps
Cell edge data rate	100 Mbps
Latency	< 1 ms
Frequency Band	3 – 300 GHz
Multiple Access	CDMA & BDMA
Core Network	Flatter IP network & 5G Network Interfacing
Connection	support simultaneous connection of massive number of devices and for IoT
Frequency Band Availability	23 GHz, LMDS 28 GHz, 38 GHz, 40 GHz, 46 GHz, 47 GHz, 49 GHz, 60 GHz and E band

In Micro-Strip Patch Antenna, Planar Inverted F antenna is preferred mostly for wireless communication. For this proposed design due to the following advantages like its low-profile structure, less fabrication cost, also it supports both linear and circular polarization. PIFA reduces the backward radiation towards the user's body and head i.e., it minimizes the SAR. In wireless communication low – profile antennas supports multiband and wideband operations that are compact in size. PIFA has a self-resonating structure as shown in Fig.1.

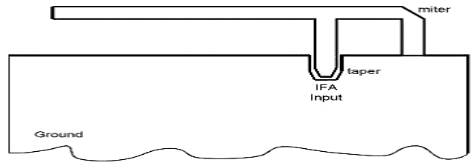


Fig.1. Inverted F Antenna

II. ANTENNA DESIGN

The proposed antenna is designed using an FR-4 substrate having a dielectric constant of 4.4. The PIFA consists of two printed arms, one arm placed on top of the substrate and the other at the bottom of the substrate respectively [2]. Both the arms are joined using microstrip feed line with the ground plane at the bottom. The geometry size of the substrate is 6*5.5 mm^2. The resonant frequency of the designed antenna is measured at 28 GHz and 38 GHz respectively [3, 4]. Rain attenuation and atmospheric absorption characteristics for mm wave propagation is less at these particular frequencies ranges that are most suitable for 5G applications [5].

Operating frequency of the antenna can be calculated from equation $f_0 = \frac{f_l + f_h}{2}$ ----- (1)

Where, fl is the lower frequency and fh is the higher frequency of operating band.

The guided wavelength in the substrate of the antenna is given by the equation $\lambda_0 = \frac{v_0}{f_0}$ ----- (2)

The width & length of the patch are calculated by [6]

$$W = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}} \quad \text{----- (3)}$$

$$h \geq 0.06(\lambda_0 / \sqrt{\varepsilon_r}) \quad \text{----- (4)}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{-1}{2}} \quad \text{----- (5)}$$

$$\Delta l = 0.412h\left[\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)}\right. \quad \text{----- (6)}$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad \text{----- (7)}$$

$$L = L_{eff} \quad 2\Delta l \quad \text{----- (8)}$$

$$W_g = 6h + W \quad \text{----- (9)}$$

$$L_g - 6h + L \quad \text{----- (10)}$$

In this paper we have designed various antenna array elements consisting of 2, 4, 6, 8 and 10 for 5G applications that have a better gain and directivity in comparison with single MPA [7, 8]. The parametric analysis such as Gain, Directivity, Return loss and VSWR for all antenna array elements is discussed. Industrial standard requirements are return loss should be – 10 dB, VSWR values must be less than 2 and gain value above positive 3 dB.

The following section shows the pictorial representation of the various antenna array elements consisting of 2, 4, 6, 8 and 10 for 5G applications. All dimensions in table.2 are in mm.

A. ***Single Element Phased Array Antenna***

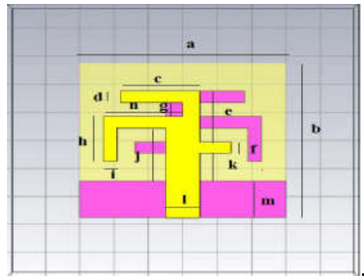
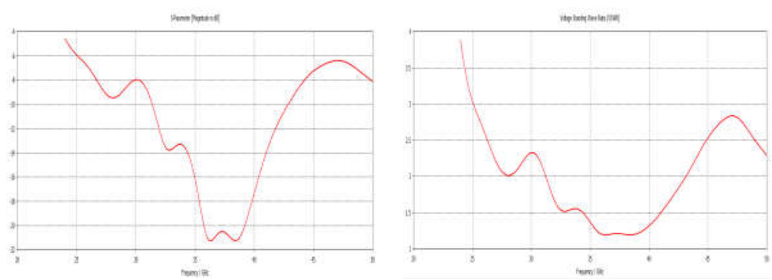


Fig.2 Layout Design of Single Element Phased Array

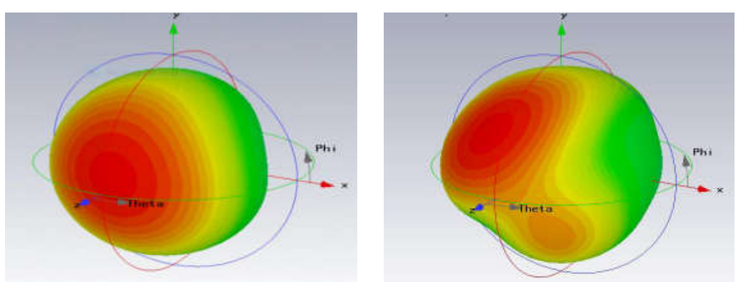
Table.2 Dimensions of Single Element Phased Array

a	b	c	d	e	f	g
6	5.5	2.3	0.4	1.9	0.4	0.2
h	**I**	**j**	**k**	**l**	**m**	**N**
1.6	1.6	1.6	0.8	1	1.3	2.3



(a) (b)

Fig.3 Single Element Phased Array a) Return Loss S11 Parameter b) VSWR



(a) (b)

Fig.4 Single Element Phased Array Radiation Pattern for a) 28 GHz, b) 38 GHz

Based on waveguide feeding technique the proposed antenna satisfies the industrial standard for 38 GHz rather than 28 GHz. To further improve the Gain and Directivity more numbers of elements are added to it.

B. ***Two Elements Phased Array Antenna***

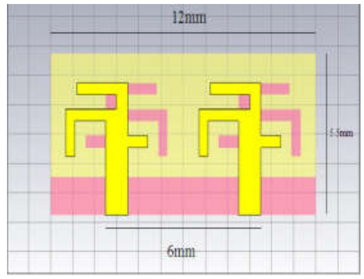
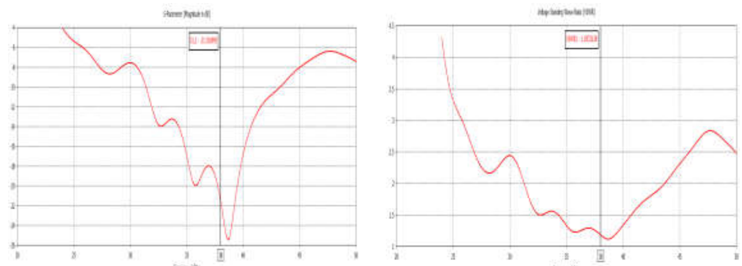
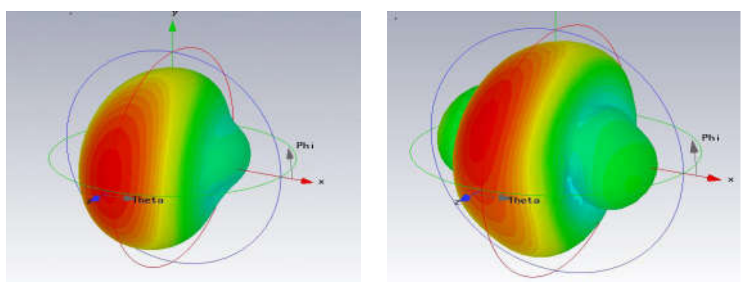


Fig.5 Layout Design of Two Elements Phased Array



(a) (b)

Fig.6 Two Elements Phased Array a) Return Loss S11 Parameter b) VSWR



(a) (b)

Fig.7 Two Elements Phased Array Radiation Pattern for a) 28 GHz b) 38 GHz

C. ***Four Elements Phased Array Antenna***

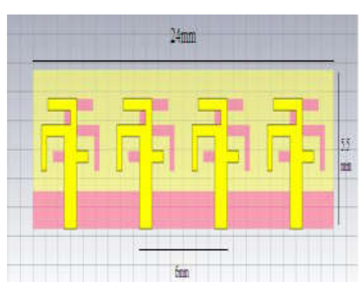
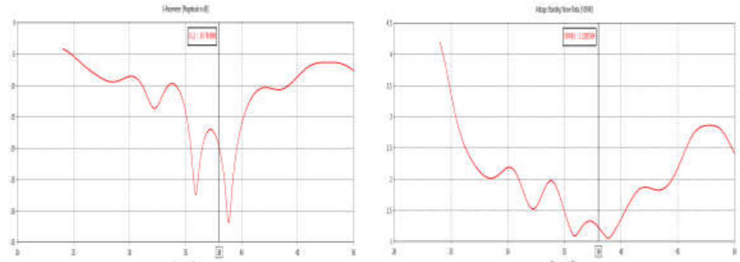


Fig.8 Layout Design of Four Elements Phased Array



(a) (b)

Fig.9 Four Elements Phased Array a) Return Loss S11 Parameter, b) VSWR

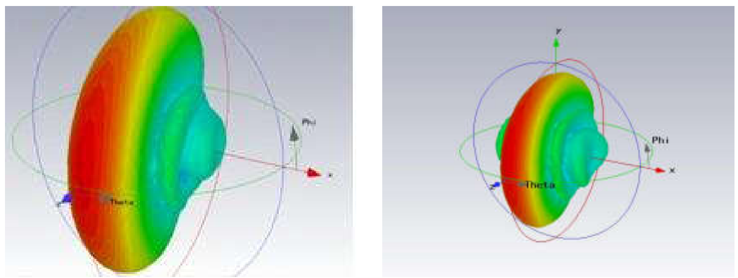
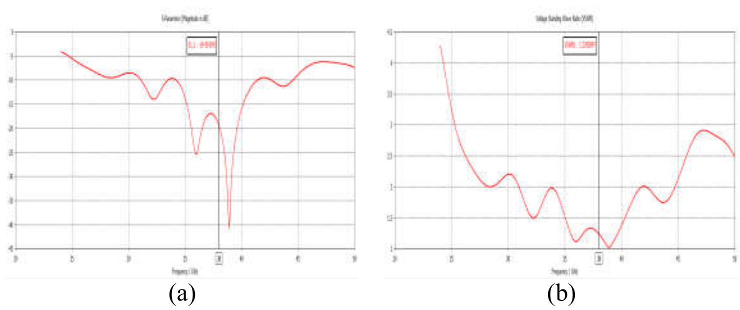


Fig.10 Four Element Phased Array Radiation Pattern for a) 28 GHz b) 38 GHz

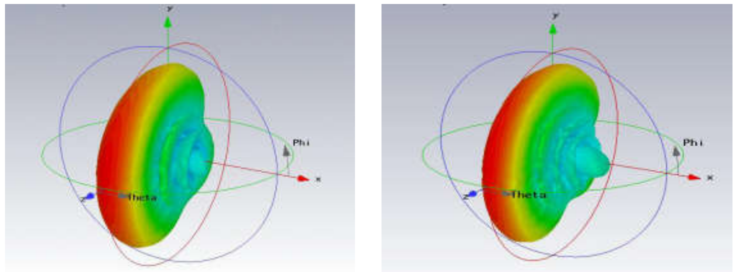
D. ***Six Elements Phased Array Antenna***

Fig.11. Layout Design of Six Elements Phased Array



(a) (b)

Fig.12 Six Elements Phased Array a) Return Loss S11 Parameter b) VSWR



(a) (b)

Fig.13 Six Elements Phased Array Radiation Pattern for a) 28 GHz b) 38 GHz

E. ***Eight Elements Phased Array Antenna***

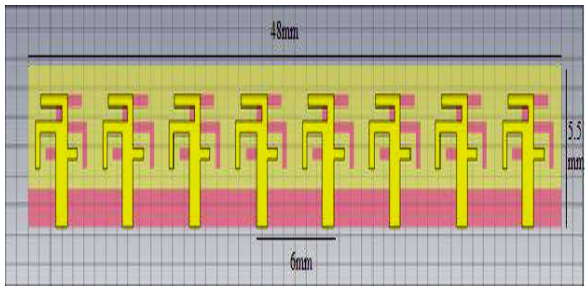
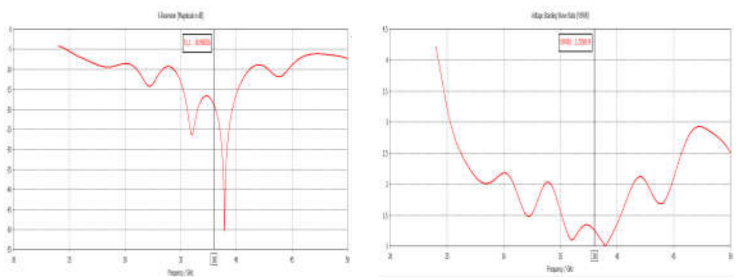
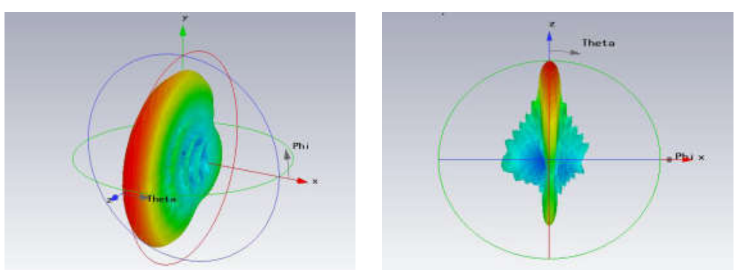


Fig. 14. Layout Design of Eight Elements Phased Array



(a) (b)

Fig.15 Eight Elements Phased Array a) Return Loss S11 Parameter b) VSWR



(a) (b)

Fig.16 Eight Elements Phased Array Radiation Pattern for a) 28 GHz b) 38 GHz

F. TEN ELEMENTS PHASED ARRAY ANTENNA

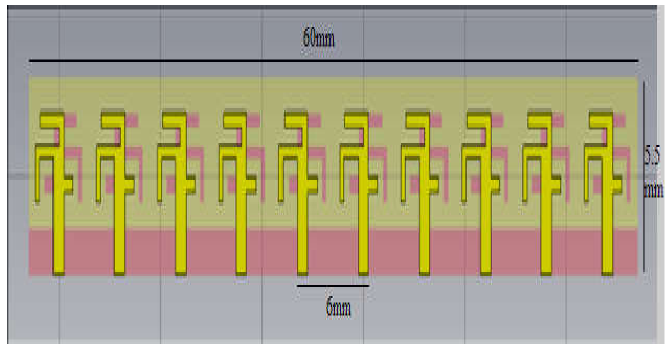
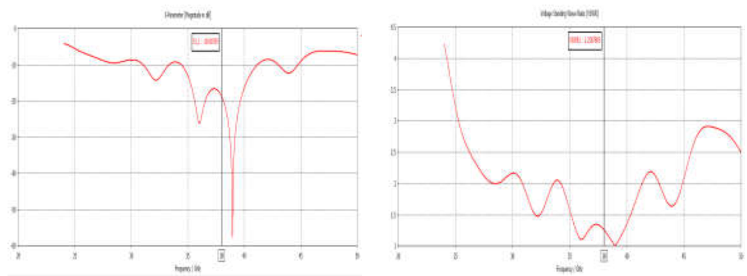
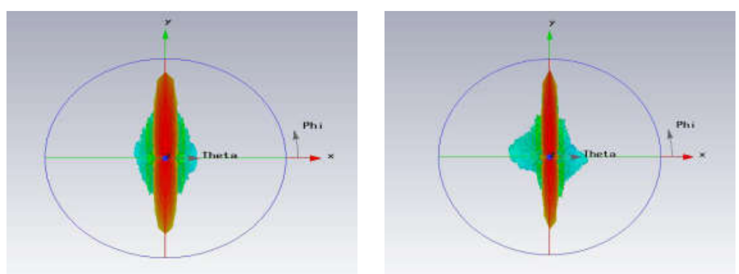


Fig.17. Layout Design of Ten Elements Phased Array



(a) (b)

Fig.18 Ten Elements Phased Array a) Return Loss S11 Parameter b) VSWR



(a) (b)

Fig.19 Ten Elements Phased Array Radiation Pattern for a) 28 GHz b) 38 GHz

Table.3 Comparison of Various Parameters for different Number of Array Elements

Parameters	**Array Elements**					
	1	**2**	**4**	**6**	**8**	**10**
Return loss (38GHz)	-21.2 dB	-21.5 dB	-19.7dB	-19.4dB	-18.9dB	-18.8dB
VSWR (38GHz)	1.19	1.18	1.22	1.23	1.25	1.25
Directivity (28GHz)	6.16dBi	8.58dBi	11.6dBi	13.2dBi	14.4dBi	15.3dBi
Directivity (38GHz)	5.50dBi	8.78dBi	11.9dBi	13.8dBi	15.1dBi	16.1dBi
Gain (28GHz)	6.1	8.5	11.6	13.2	14.4	15.4
Gain (38GHz)	5.5	8.7	11.9	13.8	15.2	16.2

Table.3 shows that for increased number of phased array elements the proposed antenna is appropriate for industrial standards at 38 GHz frequency. The gain, directivity, return loss and VSWR are enhanced for phased array antennas, in which antenna arrays with 10 numbers of elements have better yield for beam steering characteristics.

III. CONCLUSION

The mm-wave frequency range is around 3 – 300 GHz were the prime focus of research is on limited frequency ranges such as 28 GHz, 38 GHz and 60 GHz with much narrower bandwidth. Here we have mainly focused on 28 GHz and 38 GHz frequencies in which a better yield is obtained at 38 GHz based on the feeding methodology. In future we can operate at dual frequency ranges with improved directivity, gain return loss and VSWR.

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