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Design of Eight Element Phased Array Microstrip Patch Antennas for 5G Application

R.Thandaiah Prabu, V.Thulasi Bai

Abstract*: In this paper 4 element and 8 element patch phase array antennas are proposed and their radiation pattern, return loss and gain were measured and investigated for mm-wave 5G applications. From the results, it is found that the proposed antenna can be operated beyond 28GHz for effective 5G applications. The simulation has been carried out in Advanced Design System 2009 (ADS) simulator and Computer Simulation Technology Microwave Studio 2014 (CST) simulator and results show that the eight-element phased array antenna is providing a very good gain of the order of 12.4 dB and 14.2 dB with ADS and CST respectively.

***Index Terms*: 5G, ADS, CST, 28 GHz**

I. INTRODUCTION

Development of 5G technology is growing fast because of the huge growth of mobile users and the data requirements. Even though 5G mm-wave covers a wide frequency range of 3-300 GHz, The first phase of research is carried out on only limited frequencies like 28 GHz, 38 GHz and 60 GHz [1]. Studies have already shown that 28 GHz and 38GHz have low rainfall attenuation & atmospheric attenuations and these are the current frequencies prevalently used for research purposes [2]. The available frequency spectrum over 1 GHz bandwidth in the frequency range of 27.50 – 28.35, 29.10 – 29.25, 31.075 – 31.225 in LMDS 28 GHz and 38.6 – 40.0 in 38 GHz [3]. Microstrip patch antenna is a significant low profile, low cost, antenna and which allows more expansions in it with the introduction of a number of elements called array antenna can be a suitable one for this technology [4].

The Phased array antenna is a collection of a number of radiating elements designed with a phase shifter. Thereby the radiation from each element is shifted by appropriate phase and forming a different beam and increasing antenna gain and direct the radiation in the desired direction. A patch phase array antenna with inset feed line proposed in [5] is suitable for 28GHz operation and provide beam shifting between 660 and 940. A rectangular microstrip 4 * 1 patch array antennas with gain 11.2 dBi and good impedance matching is proposed in [6]. A 1*8 phased array antenna suitable for finding locations of tumors in the breast is investigated in [7].

In this paper, a patch phased array antenna with single, two, four and eight element antennas are proposed and their analytical parameters such as Gain, Directivity, radiation pattern, VSWR, and return loss are calculated and compared. The design and Simulation results are presented in following sections.

II. MICOSTRIP PATCH ANTENNA WITH INSERT FEED LINE

The geometry of rectangular microstrip patch antenna with inset feed given at yo is given in Fig.1 and the dimensions of the antenna are tabulated in Table.1. The Antenna is designed with Flame Retardant 4 (FR4) substrate material with a relative permittivity of 4.4 and with the suitable dimensions of substrate thickness of 1.5 mm, layout layer thickness of 70 µm. The dimensions like length and width of the antenna are calculated from [8].

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

$$h > 0.06\,(\lambda_0 / \sqrt{\epsilon_r}) \quad (2)$$

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

$$\Delta l = 0.412h\left[\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}\right] \quad (3)$$

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

$$L = L_{eff} - 2\Delta l \quad (5)$$

$$W_g = 6h + W \quad (6)$$

$$L_g = 6h + L \quad (7)$$

(8)

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* Correspondence Author

R.Thandaiah Prabu*, Ph.D Scholar, Anna University, Jeppiaar Institute of Technology, Sriperumbudur, India.

Dr.V.Thulasi Bai, Professor, KCG College of Technology, Chennai, India.

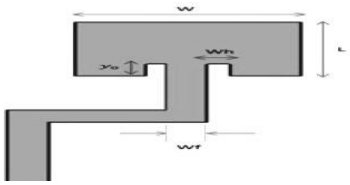

Fig. 1 Geometry of the Patch

Table.1 Parameters of the Single Patch

Parameters	Dimensions(mm)
W	4.2
Lf	3
Wh	0.4
y	0.8
Wf	0.8
Spacing Between Each Element	0.2

The geometry parameters of the patch array antenna with multiple elements are given in Table.2.

Table.2 Parameters of the Array Elements

Patch of Array Antenna	Geometry Parameters	Dimension (mm)
1 X 1	Width	4.2
	Length	9
1 X 2	Width	8.8
	Length	9
1 X 4	Width	17.4
	Length	9

Here we proposed patch phased array antenna with single, two, four and eight elements for 5G mm-wave applications. And these are having better parameters for the desired application compared to the single element antenna given in [9, 10]

III. SIMULATION RESULTS USING ADS 2009

In this section, we presented the simulation results of the proposed antenna with the ADS 2009 Simulator.

A. Single Element Antenna

The single element antenna operating at 28.96 GHz, is given in Fig. 2, its current distribution is shown in Fig.3 and Return Loss in Fig. 4. This antenna is providing Gain of 6.05dB.

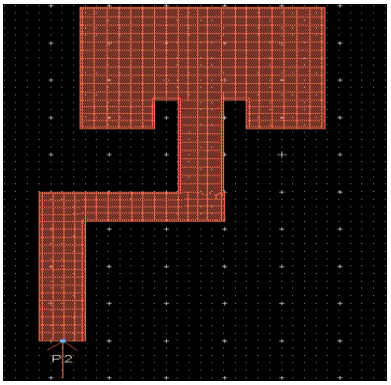

Fig.2 Single Element MPA using ADS

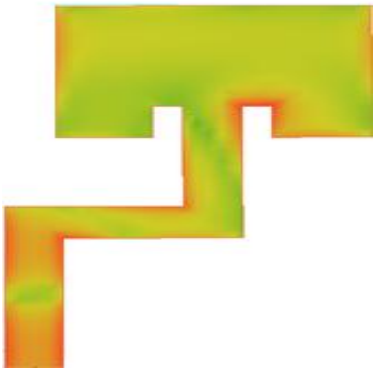

Fig.3 Current Distribution of Single Element MPA

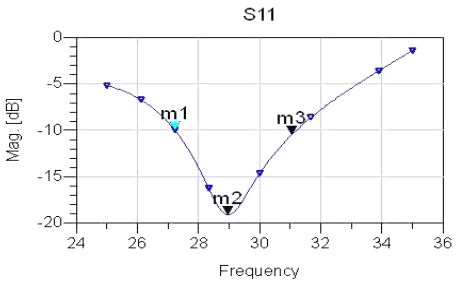

Fig.4 Return Loss of Single Element MPA

B. Two Elements Antenna

The two-element array antenna operating at 29.06 GHz, is shown in Fig. 5, its current distribution is presented in Fig.6 and Return Loss in Fig. 7. This antenna Gain is 7.15dB.

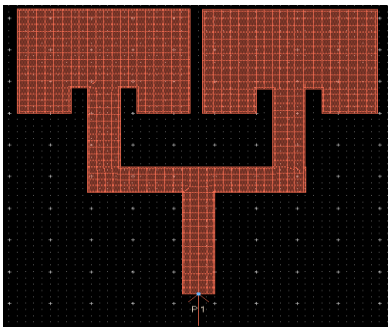

Fig.5 1x2 Elements MPA using ADS

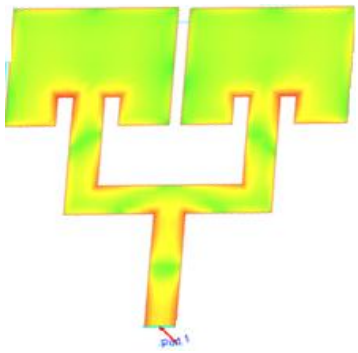

Fig.6 Current Distribution of 1x2 Elements MPA

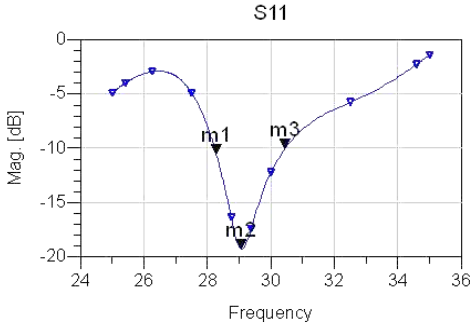

Fig.7 Return Loss of 1x2 Elements MPA

C. Four Elements Antenna

The Four-element array antenna operating at 28.85 GHz, is presented in Fig. 8, its current distribution is and Return Loss is given in Fig.9 and Fig. 10. This antenna Gain is 10.27dB.

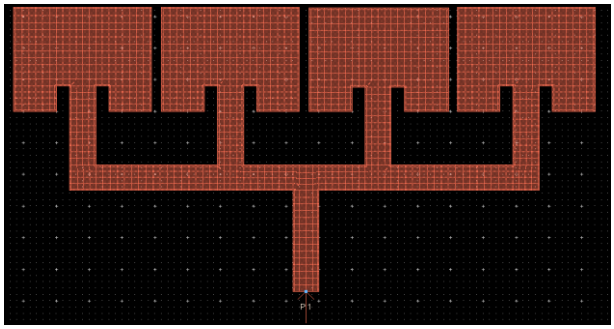

Fig.8 1x4 Elements MPA using ADS

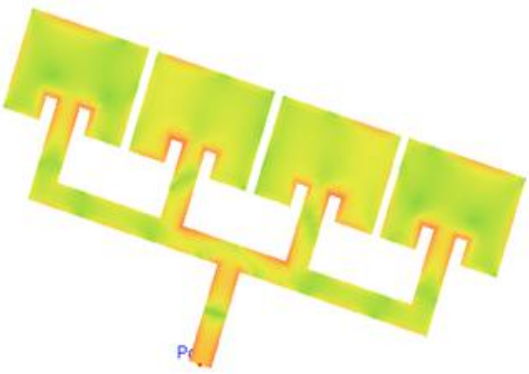

Fig.9 Current Distribution of 1x4 Elements MPA

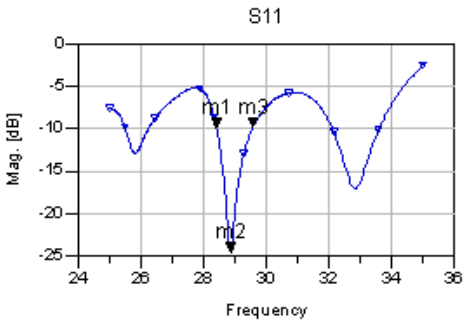

Fig.10 Return Loss of 1x4 Elements MPA

D. Four Elements Antenna

The Eight-element array antenna operating at 29.38 GHz, is shown in Fig. 11, its current distribution is and Return Loss is given in Fig.12 and Fig.13. This antenna Gain is 12.40dB.

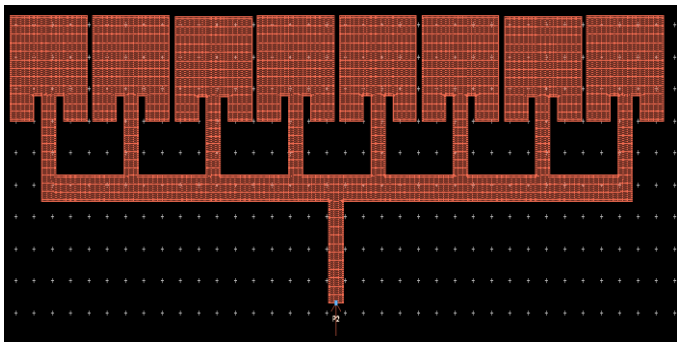

Fig.11 1x8 Elements MPA using ADS

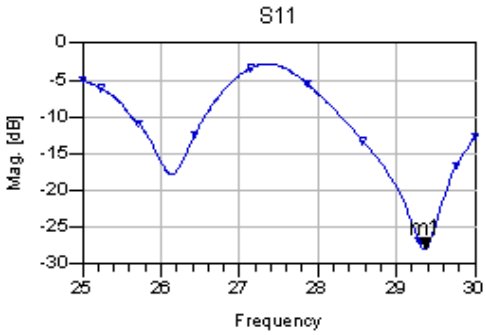

Fig.12 Return Loss of 1x8 Elements MPA

Table.3 Comparison results of Array Elements using ADS

Antenna Elements	Resonant Frequency in GHz	Return Loss	Gain	Bandwidth in GHz
1	28.96	-19.12	6.05	27.22 – 31.15
2	29.06	-19.31	7.15	28.46 – 30.82
4	28.85	-24.56	10.27	28.41 – 29.58
8	29.38	-27.94	12.40	28.42 – 30.60

In table.3, the proposed antennas simulated with ADS 2009 parameters are compared. Industrial standard requirements are return loss should be less than – 10 dB, VSWR values must be less than 2 and gain value should above positive 3 dB. When we use the high frequency range gain value must be higher than 3 dB. All the antenna elements proposed in this paper satisfy the industrial requirements minimum 1 GHz bandwidth. The same analysis for proposed antenna was simulated with CST 2014 which is working in Finite Integration in Technique (FIT) where ADS working in Method of Moment (MOM).

IV. SIMULATION RESULTS USING CST 2014

Here we have presented the proposed antenna model simulated in CST 2014 tool, and the results are plotted. Better results were obtained for the waveguide port.

A. Single Element Antenna

The single element antenna operating at 28.305 GHz, is given in Fig. 13, its Return loss and VSWR are shown in Fig.14 and Fig.15. The antenna radiation pattern and gain are plotted in Fig.16 and is providing Gain of 6.04dB.

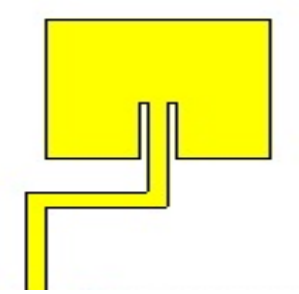

Fig.13 Single Element MPA using CST

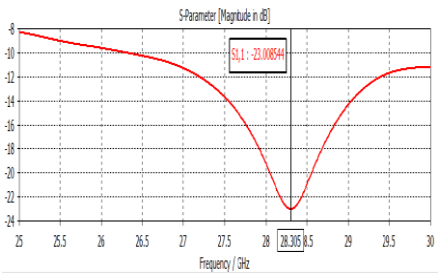

Fig.14 Return Loss of Single Element MPA

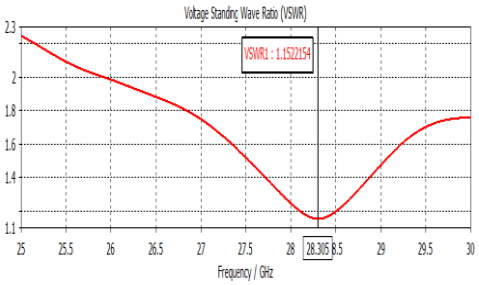

Fig.15 VSWR Output of Single Element MPA

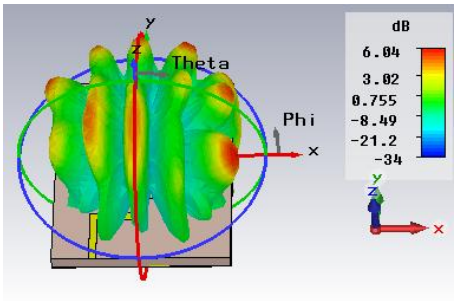

Fig.16 Radiation Pattern and Gain of Single Element MPA

B. Two Elements Antenna

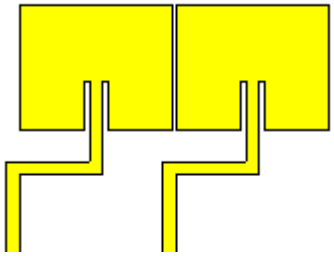

Fig.17 1x2 Elements MPA using CST

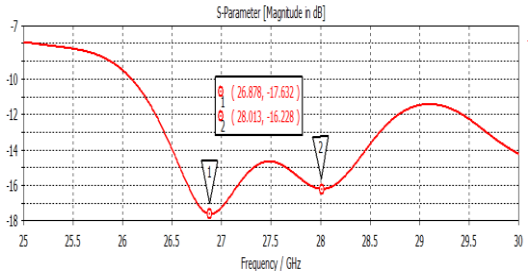

Fig.18 Return Loss of 1x2 Elements MPA

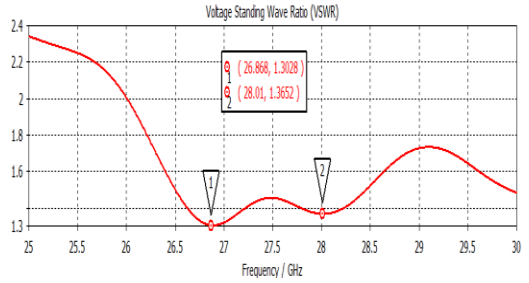

Fig.19 VSWR Output of 1x2 Elements MPA

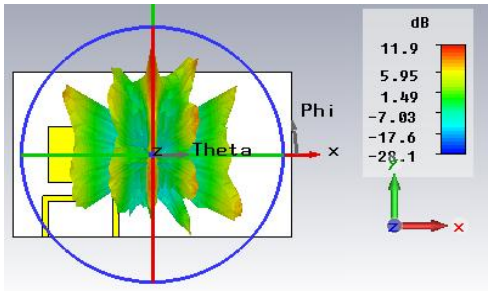

Fig.20 Radiation Pattern and Gain of 1x2Elements MPA

The two-element antenna operating at 28.01 GHz, is given in Fig. 17, its Return loss and VSWR are shown in Fig.18 and Fig.19. The antenna radiation pattern and gain is plotted in Fig.20 and is providing Gain of 11.9 dB.

C. Four Elements Antenna

The Four-element antenna operating at 28.008 GHz, is given in Fig. 21, its Return loss and VSWR are shown in Fig.22 and Fig.23. The antenna radiation pattern and gain is plotted in Fig.24 and is providing Gain of 12.7 dB.

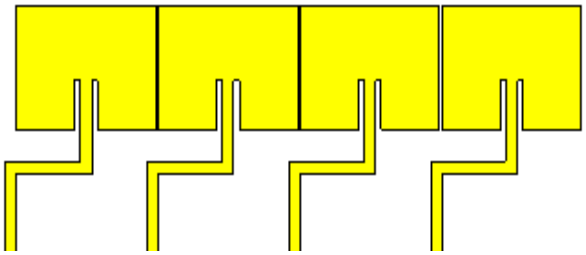

Fig.21 1x4 Elements MPA using CST

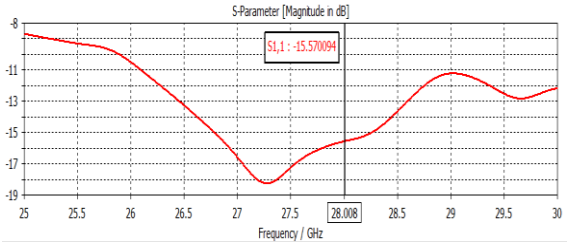

Fig.22 Return Loss of 1x4 Elements MPA

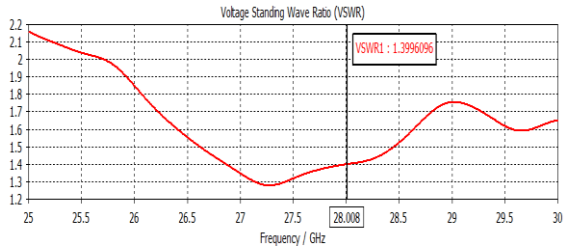

Fig.23 VSWR Output of 1x4 Elements MPA

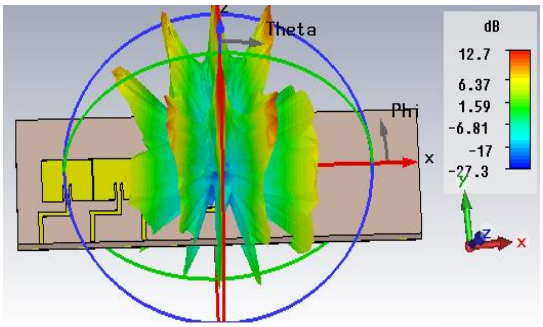

Fig.24 Radiation Pattern and Gain of 1x4 Elements MPA

D. Four Elements Antenna

The Eight-element antenna operating at 28.005 GHz, is given in Fig. 25, its Return loss and VSWR are shown in Fig.26 and Fig.27. The antenna radiation pattern and gain is plotted in Fig.28 and is providing Gain of 14.2 dB.

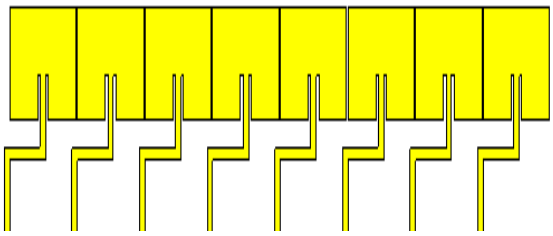

Fig.25 1x8 Elements MPA using CST

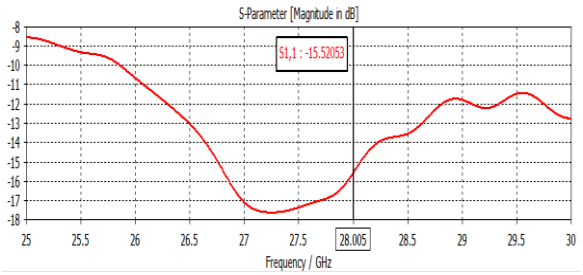

Fig.26 Return Loss of 1x8 Elements MPA

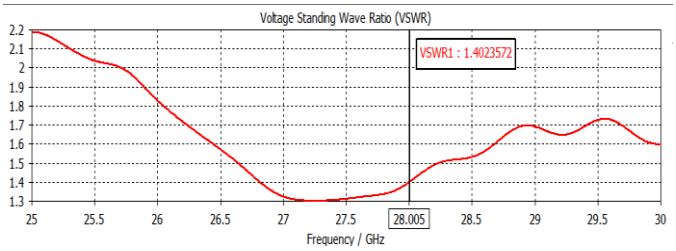

Fig.27 VSWR Output of 1x8 Elements MPA

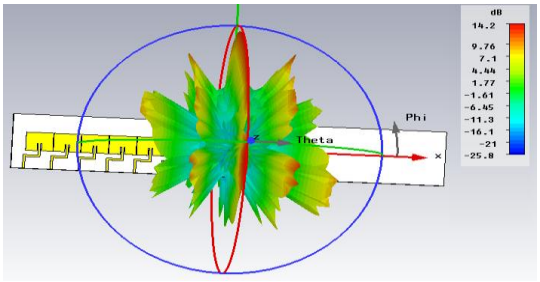

Fig.28 Radiation Pattern and Gain of 1x8 Elements MPA

Table.4 Comparison results of Array Elements using CST

Antenna Elements	Resonant Frequency in GHz	Return Loss	Gain	VSWR	Directivity
1	28.305	-23.00	6.04	1.15	8.27
2	28.01	-16.22	11.9	1.36	14.9
4	28.008	-15.57	12.7	1.39	15.5
8	28.005	-15.52	14.2	1.40	17.1

In table.4, the proposed antennas simulated with CST 2014 parameters are compared. From table 3 and 4, more the number of phased array elements more the antenna Gain, Directivity etc. which can be the best suited for the industrial 5G applications.

V. CONCLUSION

This paper presents a design and investigation of Patch phased array antenna with Single, Two, Four and Eight elements simulated with ADS 2009 and CST 2014 for 5G mm-wave communications.

The proposed antenna array with 8- element is satisfying the industrial requirements of the 5G antenna with high gain and Directivity yield which can be a best suited antenna for 5G applications.

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AUTHORS PROFILE

Mr. R.Thandaiah Prabu was graduated in Electronics and Communication Engineering in 2007 from Paavai Engineering College, affiliated to Anna University, Chennai. He obtained his M.E degree from Alagappa Chettiar College of Engineering and Technology, affiliated to Anna University, Trichy in 2009, specializing in Optical Communication and currently pursuing his Ph.D., in Anna University, Chennai under the specialization of Millimeter Wave Antenna Design for 5 G Applications. He is in teaching profession for the past Nine years. Currently, he is working as an Assistant Professor in Electronics and Communication Engineering Department at Jeppiaar Institute of Technology, Kunnam, Sriperumbudur, Chennai. His area of interest is 5G Antennas, mm – wave, Microstrip Patch Antennas, UWB Antennas, Optical Networks, Wireless Communication. Email Id: thandaiah@gmail.com.

Dr. V. Thulasi Bai received her B.E., degree in Electronics and Communication Engineering from Madurai Kamaraj University, Madurai in 1990, M.S., degree in Electronics control, from BITS , Pilani university in 1997, M.E., degree in Instrumentation Engineering from St.Peter's University, Chennai in 2013 and Ph.D degree from Sathyabama University, Chennai in 2009. She received young women in engineering 2016 from IETE. Presently, she is working as a Professor, HOD in KCG College of Technology, Chennai. Her area of interest includes High-Performance Network, Telemedicine, Embedded System, Wireless Communication and Mobile Adhoc Network. She is having more than 25 years of teaching and Research Experience. Email Id: thulasi_bai@yahoo.com.