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Next Generation Mobile phone antenna and its SAR investigation

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Abstract-This work presents the design and Specific Absorption Rate (SAR) investigation of Fifth Generation (5G) antenna for future mobile communication networks. The radiating patch is made up of copper material backed by a 0.254 mm thicker Roggers-5880 substrate (N9000 PTFE) having relative permittivity and loss tangent of $22x10^{-1}$ and $9x10^{-4}$, correspondingly. The antenna resonates at 23 GHz frequency band. The major lobe gain of the single component 5G antenna is 7.16 dB.To meet the gain requirements of 5G mobile communication systems, 1 x 4 element array antenna has been proposed which increases the bore side gain up to 12.6 dB at the desired frequency. The proposed antennas efficiency is 91-94 % with a sufficient amount of driving point impedance bandwidth (S_{11}<- 10 dB), i.e. 600-620 MHz;The SAR of the proposed antenna is analyzed at two different parts of human body, i.e. belly and hand. The SAR is averaged over 10g of tissue. The proposed 1 x 4 element antenna gives lower values of SAR (<2 W/kg) on all parts of human body. The proposed array antenna can be used in 5G mobile handheld devices. All the simulations are carried out using CST MWS. The proposed antenna is suitable contender for 5G mobile communication systems.

Keywords: Fifth Generation (5G), Antenna Array, SAR, CST MWS

1. INTRODUCTION

From the early stage of wireless communication, higher bandwidth and data rate are the very basic requirements (Rappaport *et. al.* 2013). Until now 1G, 2G, 3G, and 4G wireless technologies for mobile communication has been completely evolved and deployed in almost all parts of the world (Vigj *et. al.* 2016). Bandwidth of 30KHz, 200KHz, 20MHz and 100MHz are offered byFirst-Generation (1G), 2G, 3G and 4G wireless technologies respectively (Neto *et. al.* 2017). According to prominent literature, as the data traffic increase beyond the limit of voice data, it increases the need of speed of internet and in turns the cost and performance are related to it (Famorijii*et. al. 2016;* Khan *et. al. 2015;*).With the extensive use of wireless equipment, devices and mobile resources and services, there are still some issues that must be resolved, such as spectrum crises, low bandwidth and high energy consumption (Haraz. 2016). All these deficiencies forced to move towards Fifth Generation (5G) technology that has resolved this problem by providing very wide bandwidth up to 1GHz for wireless communication, very highdata rate up to 1Gbps and low energy consumption (Giordani *et. al.*2016, Khan *et. al. 2015*). Most probably, 5G technology will be implemented in 2020 (Dave *et. al.* 2015).

The millimeter waves spectrum ranges from (30-300 GHz), but having such a wide range, it's a lotof proportion is unused and can be utilized for 5G (Thomas *et. al.* 2015). Some of the candidate bands for 5G communications in the frequency of 20-50 GHz (Ojaroudiparchin *et. al.* 2015) are specified in **(Fig. 1)**.

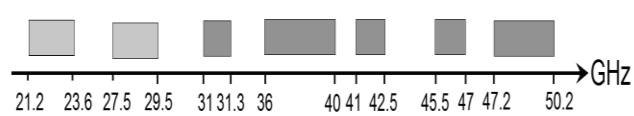

Fig. 1. The frequency bands for the future 5G systems in 20-50 GHz.

With the rapid development of wireless fields, micro strip patch antennas have become more important in antenna community, because of its features like low profile, low cost and lightweight (Jegan *et. al.* 2010). Thus, due to their properties, they are also used for 5G antenna designing.

Being the most vigorous and promising device in this time of remote communication, antennas need to guarantee some security of human body from its electromagnetic radiation (Khan *et. al.* 2016). The maximum exposure of human tissues to electromagnetic radiations has been defined in terms of SARwhich is the energy absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field. The federal communications commission (FCC) and European International Electro Technical Commission(IEC) has

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set the limit of 1.6 W/Kg absorbed per 1g of tissue and 2 W/Kg absorbed per 10g of tissue respectively (Ali *et. al.* 2016).

This remaining of the work demonstrates the design and analysis of a single element and 1x 4-element array antennas in the 23 GHz band for 5G mobile devices. The rest of the paper is organized as follows:

The design methodology of the proposed antennas is explained in **Section 2**. The results and discussion has been presented in **Section 3**. The SAR analysis has been portrayed in **Section 4**, while **Section 5.** conclude the paper and gives recommendation for future.

2. DESIGN APPROACH

a) *Conventional Patch Antenna*

In this section, the geometry of proposed micro strip patch antenna is presented in Fig. 2. The geometry of the nominated antenna consists of a 0.254 mm thicker low loss dielectric substrate material (RT 5880) having relative permittivity and loss tangent of 22×10^{-1} and 9×10^{-4} respectively. A finite ground plane having length *L* and width *W* backs the substrate i.e. 24mm x 20mm respectively. The total volume of the antenna is 24x20x0.254 mm^3. The dimensions of the antenna **(Fig. 2)** listed in Table 1 have been calculated from the well-known transmission line theory (Balanis. 2005). The design formulae to calculate the width (W) and length (L) of the patch antenna are given below.

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

$$L = \frac{c}{2f_o\sqrt{\varepsilon_r}} - 0.824h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \quad (2)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (3)$$

Where, ϵ_{eff} is the effective relative permittivity of the substrate, c is velocity of light, h is thickness of the substrate and f_0 is the resonant frequency of an antenna.

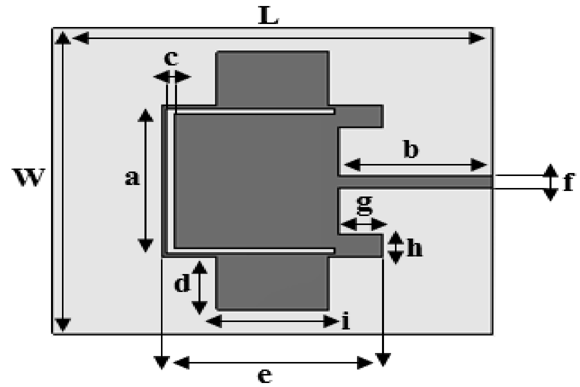


Fig. 2. Geometry of the proposed 5G antenna

The summary of the designed parameters of the proposed antenna is presented in **(Table 1).**

Table 1.Summary of the dimensions of 5G antenna

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
L	24	c	0.4	g	2.5
W	20	d	3.5	h	1.5
a	9.9	e	11.8	i	6
b	5.9	f	0.78	-	-

b) Multiple-elements antenna array

As 5G mobile phone antenna requires a minimum gain of 12dB. One of the simplest way to increase the gain is by making the multiple element array of the antenna (Rani and Mehta. 2016). **(Fig.3)** illustrates the geometry of the proposed 1x4 array.

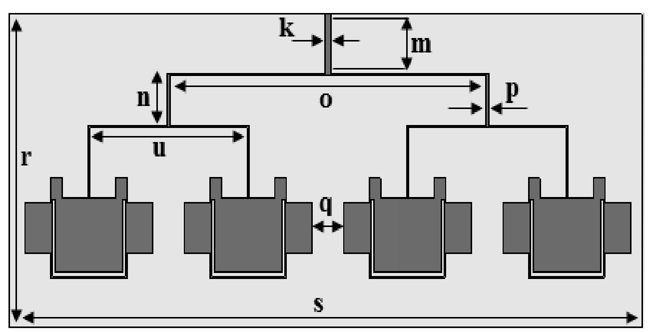


Fig. 3. Proposed multiple-element array antenna (1 x 4 array)

Table 2 summarize the dimensions of the four elements antenna array.

Table2. Design parameters of the array antenna

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
k	0.5	p	0.3	u	20.5
m	7	q	4	-	-
n	6.3	r	37.5	-	-
o	41.2	s	82	-	-

3. RESULTS AND DISCUSSION

a) Return Loss

This section presents detailed study of return loss, (Voltage Standing Wave Ratio) VSWR, efficiency and gain of the proposed antennas.

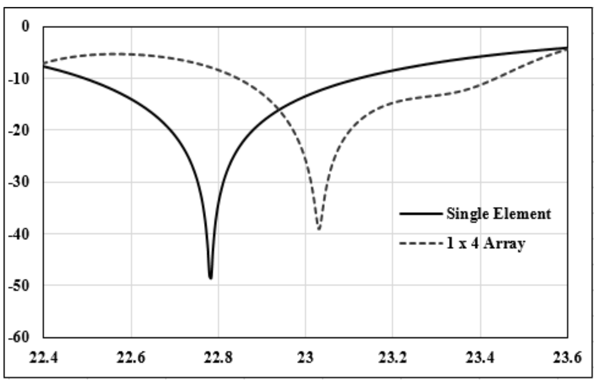


Fig. 4. S-Parameters

(Fig. 4) shows the return loss of the proposed single element and 1 x 4 antenna array. At resonant frequency (23 GHz) the return loss of single element and 1x4 element array is -48.688 and -39.006 dB with a -10dB bandwidth of 620 MHz and 600 MHz, respectively which is adequate for 5G mobile communication.

b) Voltage Standing Wave Ratio (VSWR)

The VSWR of all the two designs has been portrayed in **(Fig. 5)**. The VSWR can be calculated from the following equation:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \quad (6)$$

Where Γ is the reflection coefficient of the antennas. The single element and 1x4 elements array antennas give a VSWR of 1.02 and 1.022, respectively.

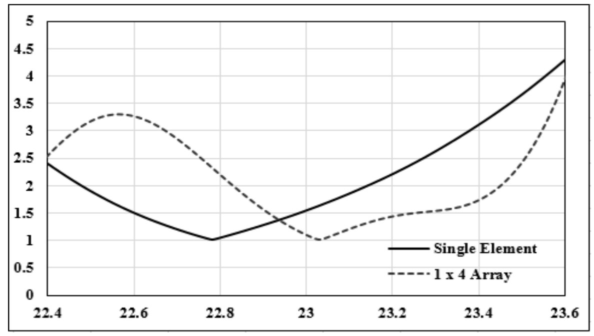
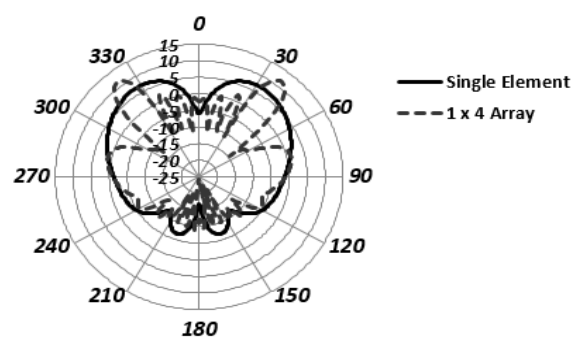


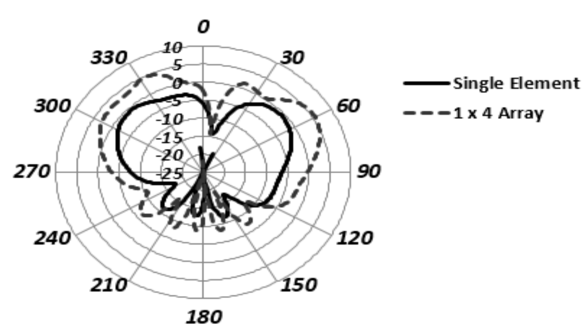
Fig. 5. Voltage Standing Wave Ratio (VSWR)

c) Farfield pattern (2D Plots)

In **(Fig. 6),** the gain patterns of the antennas are compared in the two principal planes, i.e. E-Plane (XZ, $\phi=90^0$) and H-plane (YZ, $\phi=0^0$) at 23 GHz. Thesingle element and 4-element array antenna gives a boresight gain of 7.16 dB and 12.6 dB respectively. The back and side lobe radiations are very low in both principal planes.



(a)

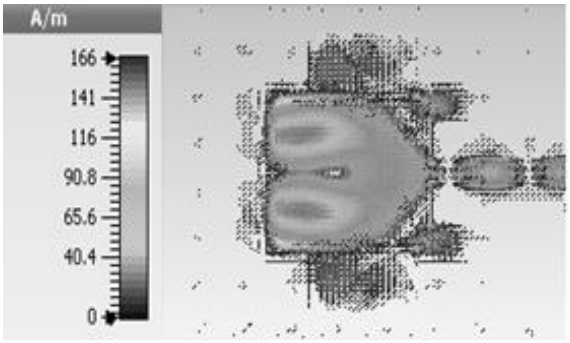


(b)

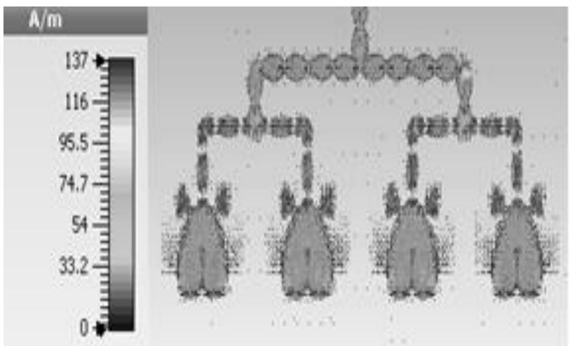
Fig. 6. Far field radiation pattern gain comparison of (single element, 1x4 array) (a) E-Plane (b) H-plane

d) Surface Current Pattern

In **(Fig. 7),** the surface current plots are shown.



(a)

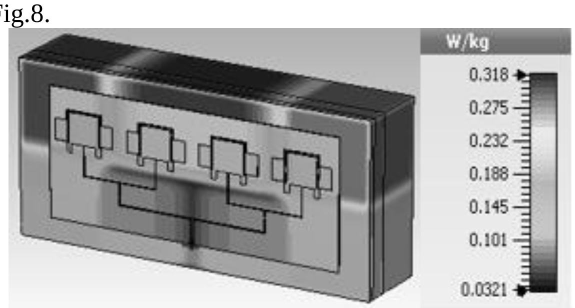


(b)

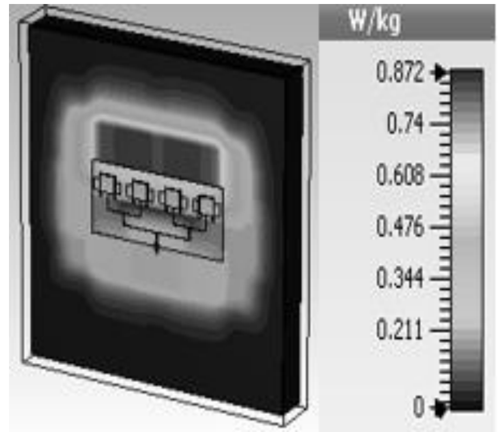
Fig. 7. Surface current distribution at 23 GHz of (a) Single Element (b) 1 x 4 Array

4. SPECIFIC ABSORBTION RATE ANALYSIS (SAR)

SAR analysis of the 23 GHz antenna on various part of the human body i.e. belly and hand has been presented in this section. The SAR analysis is carried out in CST Studio using the IEEE C95.3 averaging method. The European International Electro Technical Commission (IEC) is considered, the safer limit for this standard is 2 W/kg for any 10 g of biological tissue volume. The snapshot of the proposed antenna at two different types of human body parts is illustrated in Fig.8.



(a)



(b)

Fig. 8. Simulated SAR of the proposed antenna with the maximum input power of 0.5 watt, on various parts of human body (a) belly, (b) hand

It is clearly shown in **(Fig. 8)** that for all the two configurations, i) belly and ii) hand small amount of power 0.318 and 0.872 W/kg <2 W/kg, respectively is absorbed in human body tissue. Therefore, the SAR of the proposed antenna lies in the safer limit of IEC standard and thus it is applicable for use in future mobile communication.

5. CONCLUSION

In this paper, a micro strip patch antenna array was proposed for 5G mobile communication. The proposed antenna was designed for the 23 GHz operating frequency with four elements in array structure. The single and four element arrays have been analyzed using CST Microwave Studio. The bore sight gain of single element is 7.16 dB, which is less than the required gain for the 5G mobile phone and other devices. In order to achieve the desired gain, a four-element array has been designed and analyzed. The results show that a 12.6 dB gain with a wider bandwidth of 600 MHz have achieved. Additionally, the SAR analysis at different parts of human body i.e. belly and hand has been carried out, using the IEC SAR averaging method. It has been observed that small amount of the electromagnetic waves is absorbed in human body tissue resulting an SAR of 0.318 and 0.872 W/kg respectively for any 10 g of tissue < 2W/kg. Hence, the SAR lies in the safer limit of the IEC standard, and the antenna can be considered as a potential candidate for the future mobile communication. The prototype of the proposed antenna will be fabricated in future to confirm the simulated results.

REFERENCES:

Ali, U., S. Ullah, J. Khan, M. Shafi, B. Kamal, A. Basir, J. A. Flint, and R. D. Seager. (2016). Design and SAR Analysis of Wearable Antenna on Various Parts of Human Body, Using Conventional and Artificial Ground Planes. *Journal of Electrical Engineering and Technology*: 317-328.

Balanis, C. A. (2005). Antenna Theory, Analysis and Design, 3rd Ed: John Wiley & Sons.

Dave, S., A. Dubey, S. Macwan, and H. Modi. (2015). 5G Cellular Communication System with millimeter waves: Study of Requirements, Hardware and Biological Effects. *IEEE International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN)*: 285-289.

Famoriji, O. J., R. Kashif, and F. Lin. (2016). Millimeter-wave massive-MIMO channel sounding for future mobile broadband. *InIEEE International Conference on Ubiquitous Wireless Broadband (ICUWB, 2016)*: 1-4. IEEE.

Giordani, M., M. Mezzavilla, C. N. Barati, S. Rangan, and M. Zorzi. (2016). Comparative Analysis of Initial Access Techniques in 5G mmWave Cellular Networks. *IEEE Annual Conference on Information Science and Systems (CISS)*: 268-273.

Haraz, O. M. (2016). Broadband and 28/38-GHz Dual-Band Printed Monopole/Elliptical Slot Ring Antennas for the Future 5G Cellular Communications. *Journal of Infrared, Millimeter, and Terahertz Waves*, vol. 37: 308-317.

Jegan, G., A. V. juliet, and G. A. kumar. (2010). Multi Band Microstrip Patch Antenna for Satellite Communication. *Recent Advances in Space Technology Services and Climate Change (RSTS & CC)*: 153-156.

Khan, W. S. M. Umar, F. Ahmad, and S. Ullah. (2016). Specific Absorption Rate Analysis of a WLAN Antenna Using Slotted I-Type Electromagnetic Bandgap (EBG) Structure. In *IEEE International Conference on Intelligent Systems Engineering (ICISE)*: 152-156.

Khan, S., A. Rehman, N. Ahmad, and M. Naeem. (2015). The Reduction of Specific Absorption Rate at Different Frequencies. *Journal of Engineering and Applied Sciences (JEAS), Peshawar*, vol. 34(2):71-75.

Khan, S., N. Ahmad, M. Wahid and B. Baloch (2015). Design of Circular Stud Antenna and Parametric Analysis. *Sindh University Research Journal-SURJ (Science Series)*,vol. 47(2): 231-236.

Neto, A. S., T. D. Oliveira, S. B. Espinola, and J. R. F. Melo. (2017). Dual Band Patch Antenna for 5G Applications with EBG Structure in the Ground Plane and Substrate. *Recent Advances in Information Systems and Technologies. WorldCIST. Advances in Intelligent Systems and Computing*, vol. 570: 1044-1049.

Ojaroudiparchin, N., M. Shen, and G. F. Pedersen. (2015). Multi-Layer 5G Mobile Phone Antenna for Multi-User MIMO Communications. *IEEE23rd Telecommunications Forum Telfor (TELFOR)*: 559-562

Rappaport, T. S., F. Gutierrez, E. Ben-Dor, J. N. Murdock, Q. Yijun, and J. I. Tamir. (2013). Broadband millimeter-wave propagation measurements and models using adaptive-beam antennas for outdoor urban cellular communications. *IEEE Transactions on Antennas and Propagation*, vol. 61 (4): 1850-1859.

Rani, N., and M. Mehta. (2016). Enhancement the Gain of Micro Strip Patch Antenna Using Array Configuration Technique. *International Journal of Innovative Research and Development*, vol. 5 (9): 2278 - 0211.

Thomas, T., K. Veeraswamy,and G. Charishma. (2015). 5G Mobile Handset Multi, Wideband Antenna with Inductor Operating at mm Wave: Design and Analysis. *IEEE1st International Conference on Next Generation Computing Technologies (NGCT)*: 551-554.

Varma, R. and J. Ghosh.(2018). Multi-band proximity coupled microstrip antenna for wireless applications. *Microwave and Optical Technology Letters,*vol. 60(2): 424-428.

Vigj, S., and A. Jain. (2016). 5G: Evolution of a Secure Mobile Technology. *IEEE 3rd International Conference on Computing for Sustainable Global Development (INDIACom)*: 2192-2196.