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Research paper

Antenna for 5G mobile Communications Systems at 10 GHz

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Abstract

The design of compact dual band grid array antenna (GAA) designed on FR-4 substrate for future Fifth Generation (5G) Mobile Communications at 10 GHz is reported. The proposed antenna uses coaxial technique of feeding and has a dimension of 48 mm × 55 mm × 1.6 mm. Simulation results using CST microwave studio illustrates that the antenna has a band from 10.03 GHz to 10.68 GHz and another band from 10.7 GHz to 12.23 GHz. This excludes the 10.68 – 10.7 GHz band in which emissions were forbidden by the Radio Regulations in the sense that it has been allocated for the Radio Astronomy, Space Research and Earth Exploration Satellite (passive). The antenna has a maximum gain of 8.03 dBi at 10 GHz, thus a good candidate for the future 5G mobile communications.

Keywords: *5G; Coaxial probe; grid array antenna; mobile communications.*

1. Introduction

With the incessant explosion of more mobile wireless devices, applications and services, the prevailing fourth generation (4G) wireless communication systems recently deployed by most countries across the world cannot accommodate the problem of spectrum limitations and high energy requirement by these devices and services [1-3]. Nowadays, users that subscribed to mobile broadband systems annually dramatically increases. These users craved for faster Internet access in order to have instant communication [1].

New wireless devices and applications would demand for high speed data transfer and mobility. That is why wireless system designers have since started their research on 5G to explore many areas of applications that were not realizable efficiently in the past such as internet of things (IoT), virtual and augmented realities etc. [2, 4]. The 5G is anticipated to be evolved by 2020 [4, 5] and is expected to provide the best wireless world devoid of limitations of the previous generations thereby changing the manner by which most high bandwidth users connect with mobile radio communication [6, 7].

Forthcoming networks for 5G wireless communication systems will presumably employ the application of millimeter-wave spectrum. Hence, the future 5G Systems and beyond will require design of antenna mainly made up of arrays to provide large bandwidth and high gain unlike the previous generations [5, 8]. Several types of array antenna are widely being used in order to achieve high gain. Microstrip patch and Slot array antenna require somewhat complex technique of feeding in order to achieve a design capable of providing broad bandwidth and high performance. Conversely, designing GAA reduces the difficulty associated with the excitation of array antenna hence provide large bandwidth and high gain [9].

J. D. Kraus proposed the first wire-grid antenna [9]. Variant of wire-grid antenna using microstrip technology used for different applications were reported over the years [2]. However, for 5G mobile applications, fewer designs were reported.

This paper reports a millimeter-wave antenna designed for 5G mobile communication systems at 10 GHz. To the best of our knowledge, no antenna was reported for 5G mobile communications systems at 10 GHz.

2. Methodology

The designed antenna uses FR-4 as substrate with permittivity $\varepsilon_r = 4.4$, $tan\delta = 0.019$ and a thickness $t_s = 1.6mm$. The ground of the antenna is made up of copper with a thickness of 0.035 mm.

In the first place, a single grid cell antenna was designed as shown in Fig. 1.

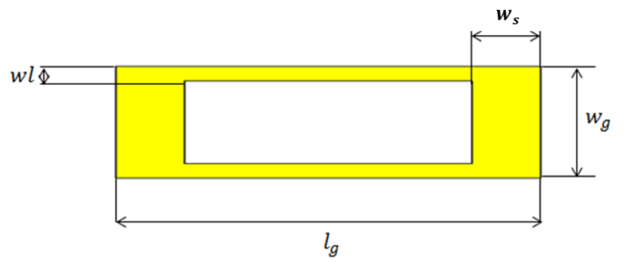

Fig. 1: Single grid cell

The long side l_g of the rectangular mesh with thickness w_l act as the transmission line whereas the short side W_g having a thickness w_s act as both radiating and transmission line [5]. In order to have an efficient resonance, the long side l_g must be approximately equal to λ_g while the short side $W_g = \frac{\lambda_g}{2}$. λ_g is the wavelength (guided) at 10 GHz [5] given by equation 1.

$$\lambda_g = \frac{300}{f\sqrt{\varepsilon_r}} \quad (1)$$

In order to have a comparatively higher gain than the conventional microstrip antennas, the single grid cell in Fig. 1 was then transformed and integrated to form a microstrip grid array antenna with 16 rectangular meshes as shown in Fig. 2.

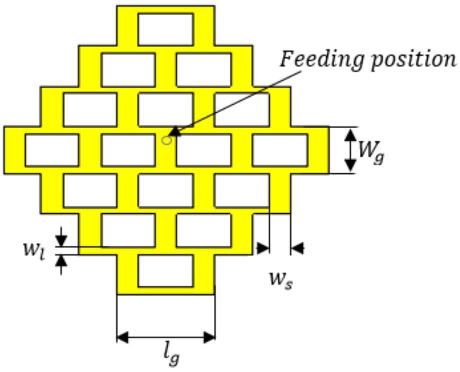

Fig. 2: Geometry of the Grid Array Antenna

Coaxial probe of 50 Ω was used to excite the antenna. The pin of the probe projects from the ground of the antenna to the patch as shown in Fig. 2. The designed antenna was then simulated using CST microwave studio software.
Table 1 presents the calculated values of the antenna.

Table 1: The Calculated values of the proposed antenna

Length l_g (mm)	Width W_g (mm)
13.99	6.99

3. Optimization

In a grid array antenna, both the long and short sides of the rectangular mesh provide the radiation emitted by the antenna. Therefore, by carrying out parametric studies on the widths of these lengths, optimized values that increased the impedance bandwidth and gain of the antenna were obtained. Fig. 3 and 4 presents the results of the optimization of w_l and w_s respectively. Table 2 presents the optimized parameters of the antenna.

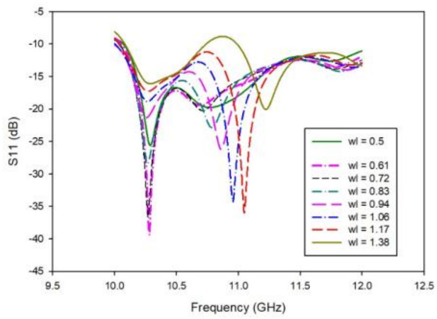

Fig. 3: Parametric Sweep on the width of the long side w_l

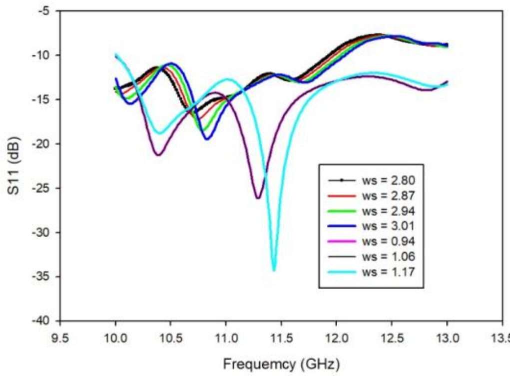

Fig. 4: Parametric Sweep on the width of the short side w_s

Table 2: The Optimized values of the proposed antenna

l_g (mm)	W_g (mm)	w_l (mm)	w_s (mm)
14.8	7.2	3.3	1.1

4. Results and discussion

The return loss of the antenna with the optimized values is shown in Fig. 5. The antenna has a dual band one from **10.03 GHz to 10.68 GHz** with a return loss of -16.33 dB and the second band from **10.7 GHz to 12.23 GHz** with a return loss of -31.90 dB. It should be noted that **10.68 - 10.7 GHz band** was excluded in the sense that emissions are forbidden by the Radio Regulations in this band (ITU Table of Frequency Allocations and the UKFAT).

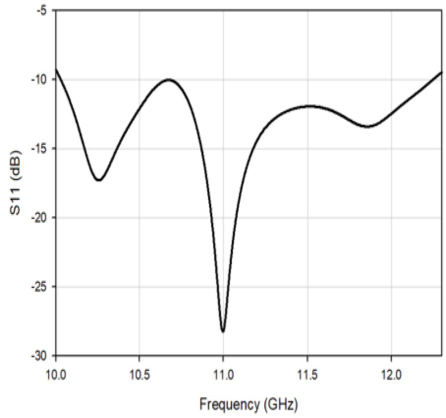

Fig. 5: S_{11} of the antenna with optimized values

The E and H-Plane radiation patterns of the proposed antenna at 10 GHz are presented in Fig. 6 and 7 respectively. It can be seen that the antenna is directional with its main lobe along the boresight direction.

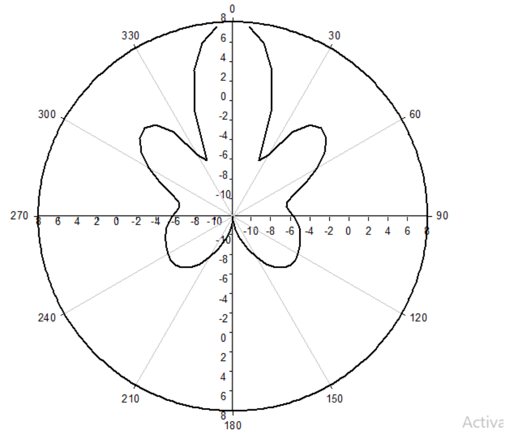

Fig. 6: E-Plane Radiation Pattern

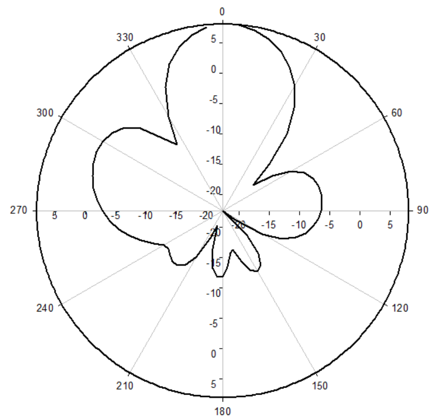

Fig. 7: H-Plane Radiation Pattern

A plot of antenna's gain is presented in Fig. 8. The plot illustrates that antenna has a gain of 8.03 dBi at 10 GHz. Similarly, Fig. 9 depicts the plot of the radiation efficiency of the antenna. It can be seen that the antenna has an efficiency of about 50% at 10.99 GHz.

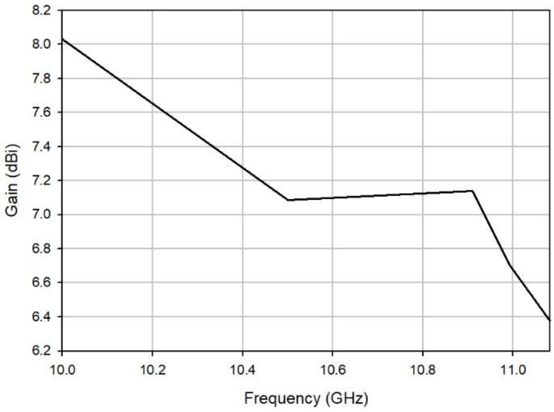

Fig. 8: Gain versus frequency

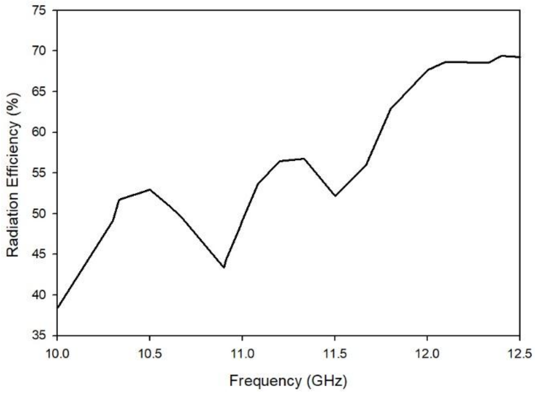

Fig. 9: Radiation Efficiency as a function of frequency

5. Conclusion

A compact directional microstrip Grid Array Antenna at 10 GHz for 5G mobile communication was designed and simulated using CST microwave studio. The antenna was designed on a cheap FR4 substrate and has achieved a dual band from 10.03 GHz to 10.68 GHz and 10.7 GHz to 12.23 GHz. This excludes the 10.68 - 10.7 GHz band in which emissions are forbidden by the Radio Regulations. At 10 GHz, the antenna has achieved a gain of 8.03 dBi. The antenna can be used for the future 5G mobile communications systems.

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