

## Compact Circular Ring Antenna for 5G Mobile Communication Applications

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This paper presents another alternative design of monopole microstrip patch antenna for millimeter wave (MMW) short range wireless communications applications. The purpose of this paper is to discuss a new design of antenna that operates in the MMW frequency range at 60 GHz. The design is based on single element with full size of  $9 \times 11 \text{ mm}^2$  that contains two elliptical loops monopole antenna and a line feed of 50 ohm on the top layer of substate with a partial ground plane on the opposite side. Microstrip-patch antenna has been designed and implemented for 5G wireless communication technology at 60 GHz with low-cost and small size substrate that makes it suitable for small devices. In the proposed design, the used substrate material is Roger RT6035htc lossy with relative dielectric 3.5 and loss tangent 0.0013 with partial ground plane to improve the impedance characteristics. The designed antenna provides a uniform current distribution over the surface of antenna at the resonance frequency with an acceptable realized gain of 4.8 dBi in the far-zone with a return loss reaches up to  $-33 \text{ dB}$ . The simulation results are carried out using high frequency structure simulator (HFSS), FEM is based on full 3D wave electromagnetic solver simulator from Analysis and the obtained results confirm the suitability of the proposed MMW antenna to be a good candidate for 5G applications.

**Keywords:** MMW, Monopole antenna, 5G mobile application, 60 GHz, Circular ring antenna, High frequency structure simulator (HFSS).

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### 1. INTRODUCTION

To adapt the fast development in wireless mobile communication field, monopole antennas such as circular, square, triangular, rectangular, and rhombic are designed to improve and enhance the performance to reach the best radiation and gain characteristics and they are usually used as linearly polarized antennas [1]. There are several designs have been implemented at MM-wave applications, such as aperture-coupled patch antenna, slot patch antennas, multilayer antenna, multiple feed points, helical antenna and patch antenna incorporating an air cavity [2-4].

Nowadays, the millimeter wave radio frequency can provide the basic ground for the new generation (5G). It has operating frequencies spectrum ranges starting from 3 GHz up to 300 GHz to fulfill the needs of the new generation requirements. The frequency spectrum of 5G application is from 20 GHz up to 90 GHz [2]. The frequencies of 5G antennas are designed at 28 GHz, 38 GHz, and 60 GHz. The antennas of 5G applications have a bandwidth of 500 MHz, 1 GHz, and 2 GHz. Hence, they are all suitable and compatible for high data rate and low latency systems [3]. Also, all antennas are preferred to be directional. In addition, they are sensitive to obstacles due to the narrow of the beam width [4]. Now, many substrates are available, and their dielectric constants are always working below 10 GHz except Rogers substrate, which

makes it suitable for ultrahigh frequencies because of low dielectric loss and low dispersion [5, 6].

This paper presents a dual circular rings monopole antenna which is implemented in MM-wave applications with a centered frequency at 60 GHz and this makes it suitable for small devices. The used substrate material is Roger RT6035htc lossy with relative dielectric 3.5 and loss tangent 0.0013.

The remaining sections of this paper are organized as follows: Section two describes the design of antenna parameters. The geometry and simulation results of the proposed antenna design are discussed in section three. The last section concludes the paper and highlights the performance features of the achieved design.

### 2. ANTENNA DESIGN

In recent years, it has been founded that monopole antennas are lightweight, low profile, and easy to be integrated with MMICs [7, 8]. Omnidirectional antennas are widely used in wireless communications system and very desirable for 60 GHz antennas and they have been proposed for MMW applications [9]. These designs are either implemented in multilayer, LTCC technology or fused silica substrate [10]; some of these are not suitable for the high-volume consumer electronic market. Using the MMW antenna this problem can be mitigated while allowing for reduction in interference from multipath reflections.

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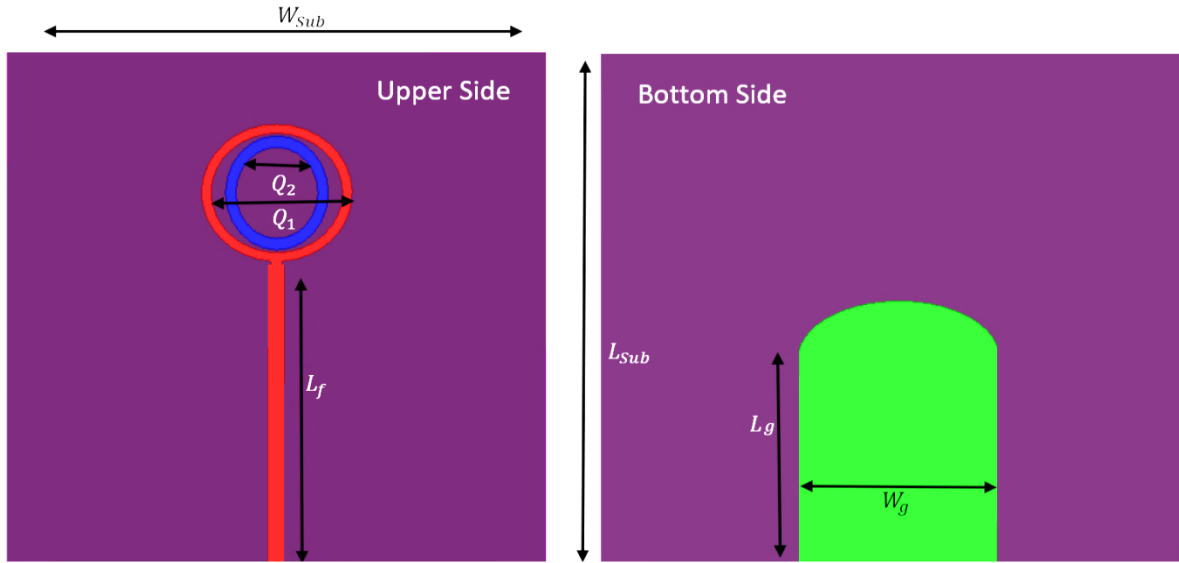


Fig. 1 – Single element patch antenna

2.1 Circular-ring Antenna Design

In 5G Mobile communication's applications, the operated frequency works at frequency range of 60 GHz and monopole antenna in this paper is designed to work at the same frequency. Fig. 1 illustrates the dimensions of substrate width  $W_{sub} = 9$  mm, length  $L_{sub} = 10$  mm and thickness 0.25 mm with Rogers 6035 material having dielectric constant of 2.2 mm, loss tangent of 0.0013 and relative permittivity 3.5. The patch dimensions are line feed  $L_f = 2.07 \lambda_g$ , with two circular rings of radii  $Q_1 = 0.48 \lambda_g$  and  $Q_2 = 0.4 \lambda_g$ , where  $\lambda_g = \frac{\lambda_r}{\sqrt{\epsilon_{eff}}}$ .

The partial ground plane of dimensions  $W_g = 3.4$  mm and  $L_g = 3.5$  mm. In that design the partial ground plane is used to enhance the impedance characteristics by obtaining a deeper return loss at the resonance frequency and this is evident by the achieved results of Fig. 2.

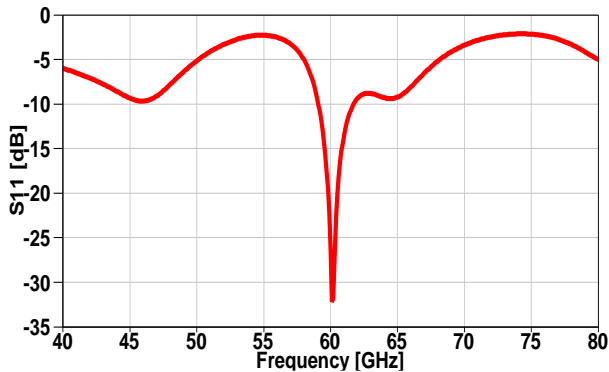


Fig. 2 –  $S_{11}$  of a circular ring monopole antenna

3. SIMULATION AND RESULTS

This section presents simulation results such as return loss, current distribution, radiation pattern and gain of the monopole of 5G monopole antenna at 60 GHz. We start by studying the performance of the

proposed monopole antenna shown in Fig. 1. It is evident from Fig. 2 that the return loss is  $-33$  dB at the resonance frequency of 60 GHz. The patch and the ground plane led the proposed single antenna to have a wider bandwidth than the one achieved in [1] by an increase in 5.24 % in the same band.

For further explanation of the performance of monopole antenna, Fig. 3 shows the simulated surface current distribution for the proposed antenna design which is implemented at 60 GHz [11]. The current distribution is mainly concentrated in the feed line and adjacent to both elliptic parasitic strips beside the feed line. The current is primarily distributed underneath the feed line.

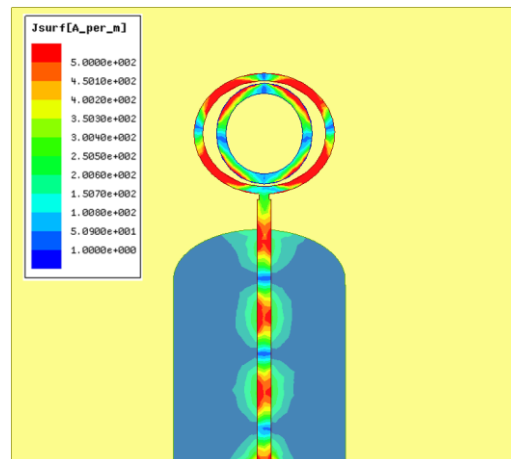


Fig. 3 – Current distribution of 5G monopole antenna at 60 GHz

Fig. 4 and Fig. 5 show the radiation characteristics of the dual rings patch antenna for 5G operation. The 2D and 3D radiation patterns are carried out at a frequency of 60 GHz. Fig. 4 claims that the antenna has a nearly omnidirectional normalized radiation pattern, and it achieves a high realized gain of 4.8 dBi as shown in Fig. 5. It is worth noting that the obtained peak realized gain from this design is 4.8 dBi confirming the suitability of the proposed design for 5G applications.

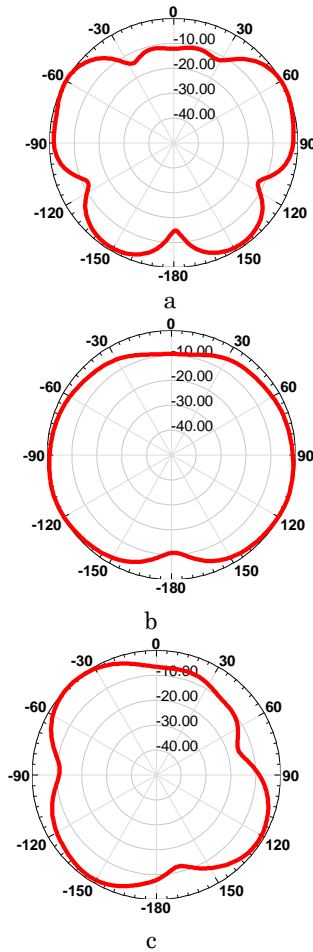


Fig. 4 – Normalized  $E$ -field radiation pattern of 5G monopole antenna at 60 GHz: (a)  $x$ - $y$  plane ( $E$ ), (b)  $y$ - $z$  plane ( $H$ ), and (c)  $x$ - $z$  plane

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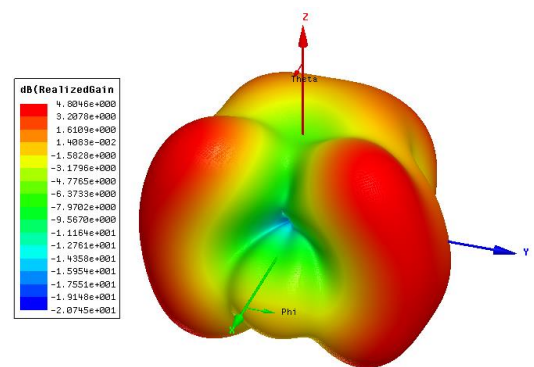


Fig. 5 – Realized gain of 5G monopole antenna at 60 GHz

4. CONCLUSIONS

This paper presents the 5G mobile application by implementing single element of monopole microstrip patch antenna which produce acceptable results at 60GHz. The gain performance has reached 4.8 dBi with uniform current distribution. The impedance and radiation characteristics explained that the proposed monopole antenna allows a high data transmission rate for 5G mobile applications. The proposed antenna achieved the requirements of MMW to operate at the 60 GHz band, in addition to its simple design and easy to be fabricated with a low cost. The achieved results of the proposed antennas made it highly desirable for MMW applications and 5G technology systems and this model is suitable for 5G mobile applications with high performance and low cost of fabrication.

Компактна кільцева антена для додатків мобільного зв'язку 5G

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У роботі представлена альтернативна конструкція несиметричної мікросмугової патч-антени для застосувань бездротового зв'язку у міліметровому (MMW) діапазоні. Метою роботи є обговорення нової конструкції антени, яка працює у MMW діапазоні на частоті 60 ГГц. Конструкція заснована на одному елементі із загальним розміром  $9 \times 11$  мм<sup>2</sup>, який містить дві еліптичні петлі несиметричної антени та лінію подачі з опором 50 Ом на верхній шар підкладки з частковим заземлювачем на протилежній стороні. Мікросмугова патч-антена розроблена та впроваджена для технології бездротового зв'язку 5G на частоті 60 ГГц з недорогою та малою за розміром підкладкою, що робить її придатною для невеликих пристроїв. У запропонованій конструкції використано матеріал підкладки Roger RT6035htc з відносною діелектричною проникністю 3,5 та тангенсом кута втрат 0,0013 і частковий заземлювач для поліпшення імпедансних характеристик. Спроектвана антена забезпечує рівномірний розподіл струму по поверхні антени на резонансній частоті з прийнятним реалізованим коефіцієнтом підсилення 4,8 дБі в далекій зоні та зі зворотними втратами, що сягають – 33 дБ. Результати моделювання отримують з використанням симулятора високочастотних структур (HFSS), а FEM базується на 3D повнохвильовому електромагнітному симуляторі Ansys. Отримані результати підтверджують придатність запропонованої MMW антени як прийнятного кандидата для додатків 5G.

**Ключові слова:** MMW, Несиметрична антена, Мобільний додаток 5G, 60 ГГц, Кільцева антена, Симулятор високочастотних структур (HFSS).