Compact Hexagonal Monopole Antenna for Lower 5G Bands

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***Abstract*—This paper presents a compact planar antenna with extreme wide band. The antenna is designed to cover the entire lower 5th generation operating bands ranging from 2.32GHz to more than 12GHz. This band also covers the IEEE 802.11 a/b/g/n/ac. The patch geometry has been simulated using an industrial standard simulation software called CST MWS. The monopole is miniaturized with a total size of 23x24x1.2mm^3. The radiator and the ground plane are printed on a substrate of Rogers Duriod RT 5880 with relative permittivity of 2.2 and loss tangent of 0.00009. The simulated reflection coefficient and radiation pattern results are presented. S11 parameter for the designed antenna is less that -10dB over the operating band, with lowest value of -32.5dB at 2.85GHz. The radiation pattern is presented at the two orthogonal planes, elevation (E plane) and azimuth (H plane). Simulated results show that the antenna is appropriate of lower 5G bands application and several other wireless systems.**

Keywords-5G; ultra-wide band; planar antenna

I. INTRODUCTION

In the near future, the global mobile data traffic is expected to yearly increase by a rate of 160% [1]. This massive growth is mostly caused by the implementation of Internet of Things (IoT) and mobile video streaming. There will be about 18 billion devices using the IoT out of a total of 29 billion devices [2]. Therefore, the next wireless generation networks will need to overcome enormous demands of wider bandwidth at high frequency bands. The crucial constraint to deploy 5G networks in two years from now is the availability of frequency spectrum. Both lower and higher frequency bands are required for that. For early implementation of 5G, lower bands are perfect because of their properties such as wave propagation and spectrum availability. The major frequency bands located between 2GHz and 6GHz are from 3.3GHz to 4.2GHz and from 4.4GHz to 4.990GHz. Those bands are currently being targeted for early trials of 5G systems in several countries. Table I demonstrations the country regions and the lower 5G bands [3].

To overcome such challenges and the in progress needs, an ultra-wide band (UWB) antenna has been designed. The monopole operates over a frequency band ranging from 2.32GHz to more than 12GHz, which include all the frequency bands allocated for lower 5G systems. It is a model candidate for new generation devices such as tablets and mobile phones etc. Additionally, this band also fulfills the regulations of the UWB technology set by the Federal Communication Commission (FCC) [4]. Moreover, the designed patch covers several spectrum bands such as the IEEE 802.11 a/b/g/n/ac standards for Wi-Fi. Different new ultra-wideband antennas with various designs (rectangular, circular, Vivaldi, elliptical, etc.) have been designed [5-13]. The designs differ in terms of main parameters such as frequency bands, radiation, gain, and physical size. Some of these designs have shortages in their operating frequencies which do not include UWB set by FCC (3.1 to 10.6GHz). The suggested planar antenna in this paper is competitive with many of the previously published designs and has reduced size.

TABLE I. REGIONS WITH EXPECTED LOWER 5G SPECTRUM BANDS

Region	Frequency bands (GHz)
Europe	3.4-3.8
China	3.6, 4.4-4.5, 4.8-4.99
Japan	3.6-4.2, 4.4-4.9
Korea	3.4-3.7
USA	3.1-3.55, 3.7-4.2

II. ANTENNA DESIGN CONFIGURATION

Figure 1 reveals the geometric shape labeled with parameters of the proposed monopole antenna and its parameters after optimization are shown in Table II. The patch has a miniaturized size with 25mm width and 23.5mm length and printed on a thick 1.2mm substrate of Rogers Duroid RT5880Lz that has relative permittivity εr=2.2 and loss tangent δ=0.0009. As shown in Figure 1, the patch is consisting of a main hexagonal shape radiator attached to thirteen smaller two sizes hexagonal radiators at the edges. The radiator is fed using coplanar waveguide (CPW) through a characteristic impedance of 50Ω. The microstrip line has 9.5mm length, 2.2mm width with 0.4mm as a separation gap from the ground plane at each side. The ground is containing two slots which improve the impedance matching. These slots are 5mm long and 0.5mm wide.

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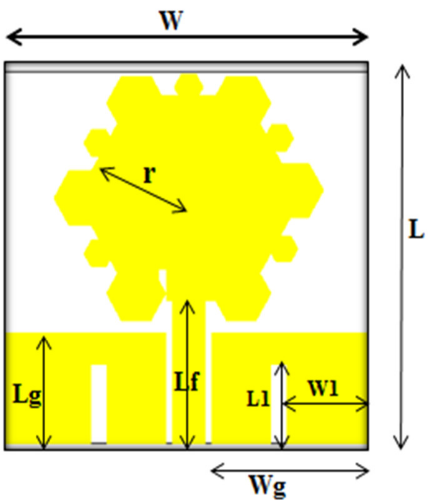

Fig. 1. Design of monopole antenna configuration with labeled parameters

TABLE II. DESIGNED ANTENNA PARAMETERS AFTER OPTIMIZATION

Variables	**L**	**W**	**H**
Dimensions (mm)	23.5	25	1.2
Variables	W_f	L_f	W_1
Dimensions (mm)	2.2	9.5	6
Variables	W_g	L_g	L_1
Dimensions (mm)	11	7	5

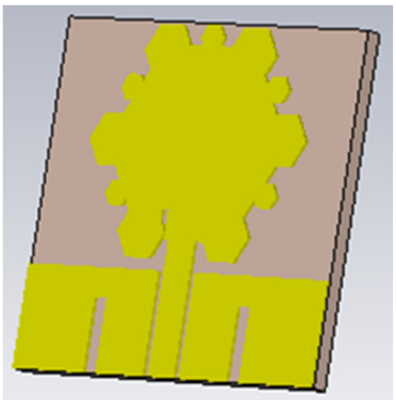

Fig. 2. The proposed antenna from simulation software CST Microwave studio

III. RESULTS AND DISCUSSION

The optimized reflection coefficient (S11) in dB as a function of frequency in GHz is plotted in Figure 3. It displays the extreme-wide bandwidth by which the design is characterized, from 2.32GHz until more than 12GHz which covers the whole FCC UWB set for such wireless applications as well as all for lower 5G bands in regions like Europe, China, Korea, Japan, and United States of America (Table I). The reflection coefficient or S11 has three resonant frequencies which are 2.82GHz, 6.1GHz, and 9.3GHz. As part of the parametric study for the proposed monopole antenna, several substrate materials have been tested and studied such as Rogers RT 5880 (εr=2.2), Rogers RT 5880Lz (εr=1.9), FR-4 (εr=4.3), and Polymide (εr=3.5).

The tested materials are popular for such types of antenna designs. All reflection coefficients which represent the impedance matching for these materials are plotted in Figure 4. It can be observed that Rogers Duroid RT 5880, with 2.2 relative permittivity provides the best impedance matching and covers wider operating frequency. In addition, its reflection coefficient is lower than the common -10dB standard along the entire bandwidth, from 3.1GHz to 10.6GHz. Figure 5 reveals the monopole power gain over the operating frequency in GHz versus the gain in dB. The design is characterized by high power gain that reaches more than 5dBi. Figure 6 demonstrates the normalized radiation pattern at the two main orthogonal planes in polar form at 2.82GHz, 6.1GHz, and 9.3 GHz. Generally, the radiation pattern has an omnidirectional shape with minor distortions at high frequencies due to the increase in power gain. Thus, the proposed antenna design can be placed in a wireless system at any position.

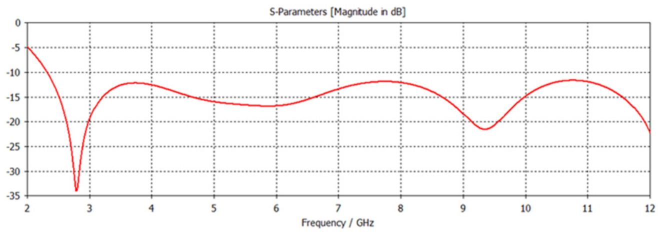

Fig. 3. Simulated reflection coefficient S11 vs operating frequency

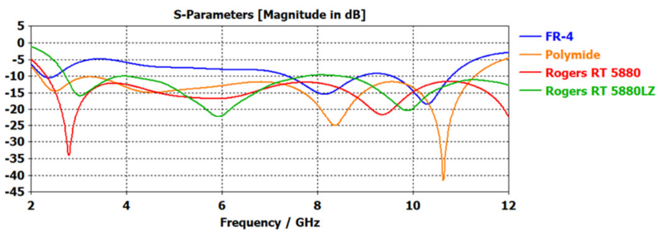

Fig. 4. Reflection coeffecientS11 vs operating frequency for several substrate materials: Rogers RT 5880 (εr=2.2), Rogers RT 5880Lz (εr=1.9), FR-4 (εr=4.3), and Polymide (3.5)

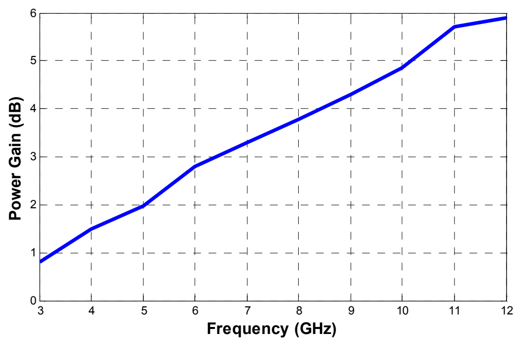

Fig. 5. Simulated power gain of the proposed antenna

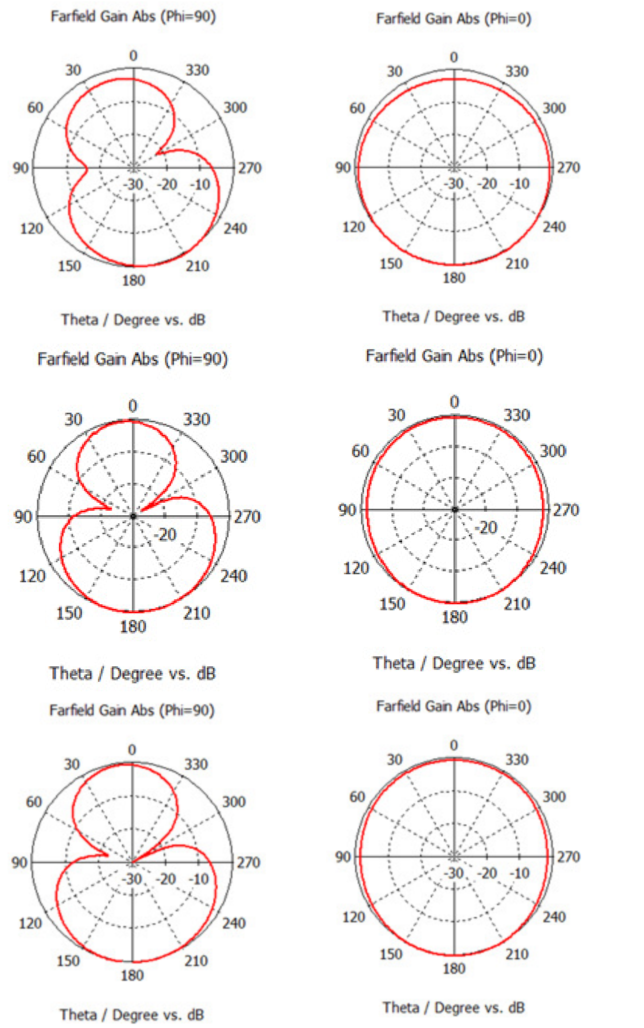

Fig. 6. Normalized radiation pattern for E and H planes in polar form at the resonant frequencies

IV. CONCLUSION

A new compact extreme wide antenna has been presented in this paper. The patch has a very compact structure size, the overall volume is $23\times24\times1.2mm^3$ printed on a substrate of Rogers Duroid RT5880 with 2.2 relative permittivity and 0.00009 loss tangent. The proposed monopole has the ability to operate over a bandwidth from 2.32GHz to more than 12GHz. The maximum obtained power gain is 5.89dB with an omni-directional radiation pattern which is the optimum possible pattern for such antenna type. Thus, the design is appropriate for lower 5G wireless system applications at many countries. Also, the design is appropriate for ultra wide band wireless systems since the bandwidth covers the entire FCC band allocated for such systems. Design and simulation have been conducted using the industrial standard simulation software called CST Microwave studio. More miniaturizing strategies can be applied for further structure size reduction in the future. In addition, the design can be fabricated and experimentally measured.

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