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New Compact Ship-Shape Antenna for the Fifth Generation Bands

Abstract. *This research presents a new ship-shape planar monopole antenna. The design has an extreme operating frequency covering the full lower fifth generation bands varying from 2.95 GHz to more than 19.85 GHz. This bandwidth furthemore includes other bands such as the IEEE 802.11 a/b/g/n/ac. The antenna has been designed and simulated via an industrial standard simulation software called CST microwave studio. The proposed design has a reduced structure with total size of 20x24x1.6 mm. The patch is printed on a substrate of Rogers Duriod RT 5880LZ which has relative permittivity of 1.96 and loss tangent of 0.00009. The reflection coefficient (S11) and normalized radiation pattern have been simulated. The design has a bandwidth of 17 GHz over which the radiation patrern is omnidirectional pattern. The ship-shape patch is suitable for the fifth generation systems and many other wireless applications.*

Straszczenie. W artykule zaprezentowano projekt anteny przeznaczonej do pasam czestotliwp0ści piątej generacji. To jest od 2.95 GHz do 19.85 GHz. Wymiary anteny są 20x24x1.6 mm. Właściwości anteny aymulowano wykorzystując oprogramowanie CST microwave studio. Antenę naniesiono na podłoże Duriod RT 5880LZ. ***Nowy typ anteny do pasma piątej generacji***

Keywords: 5G; Ultra-wide Band; Planar antenna.
Słowa kluczowe: ultra-szerokopasmowa antena, pasmo 5G

Introduction

In the next few years, it is expected to have an increment by a percentage of 160 % in the mobile data traffic globally [1]. This is due to the deployment of internet (IoT) of things and its applications. Thus, the world will have 18 billion devices out of 29 billion internet of things devices [2]. Hence, the world of the 5th G wireless networks need to overawed the massive demand of frequency bands. The vital restriction in the implementation of the new generation is the shortage in the frequency bands. Thus, the lower fifth bands are suitable for the new generation in the early deployment.

The importance of the new generation is due to its outstanding features in terms of super-fast data rates systems. The expected bands for these applications are between 2 GHz and 6 GHz, and varies from region to others. For instance, the lower 5G bands in the united states are 3.1-3.55 and 3.7-4.2, from 3.6-4.2 and 4.4-4.9 in Japan, and from 3.4-3.8 in Europe. Table 1 illustrates the lower next generation frequency bands in many regions. Ultra wide band bands antennas (UWB) are appropriate to fulfil the lower 5th G systems because of their wide bandwidth which covers the entire bands allocated for these systems.

table 1. regions with the fifth generation frequency bands

District	*Operational Frequency*
China	3.6-3.6, 4.4-4.5, 4.8-4.99
Korea	3.4-3.7
Japan	3.6-4.2, 4.4-4.9
USA	3.1-3.55, 3.7-4.2
Europe	3.4-3.8

Various ultra-wideband monopole antennas with different shapes for example, circular, rectangular, elliptical, Vivaldi, and many others have been designed previously [5-15]. The designs vary from one to another by the main parameters such as operating bandwidth, radiation, power gain, and structure size. Some of the antennas have drawbacks in their operating frequencies which do not contain the UWB allocated by the Federal Communication Commission (FCC) (from 3.1 GHz to 10.6 GHz). The proposed ship-shape antenna in this article is competitive with multi of the formerly published designs and has smaller structure size. In the following section, the proposed new antenna design and the simulation results are described in details. The antenna has been designed and simulated using an industrial simulation software (CST Microwave Studio). Next section demonstrates the schematic of the proposed antenna after optimization.

Antenna Design

Figure 1 shows the schematic diagram labeled with parameters of suggested monopole and its parameters after being optimized are revealed in table 2. The patch has a simple miniaturized structure size, that is 20 mm wide and 24 long mm printed on a 1.6 mm thick substrate of Rogers Duroid RT5880Lz with relative permittivity εr=1.96 and loss tangent δ of 0.0009. As displayed in figure 1, the patch is composed of a main ship-shape radiator with trimmed edges this is in order to enhance the impedance matching in the design and to improve the bandwidth (from 2.95 GHz to 19.85 GHz [16]. The radiator is fed by a coplanar waveguide (CPW) technique with 5.5 mm long, and 2.7 mm wide a microstrip line with characteristics impedance of 50 Ω. The following section presents the simulated reflection coefficient S11 in dB with effective parametric studies, power radiation pattern, as well as gain in details.

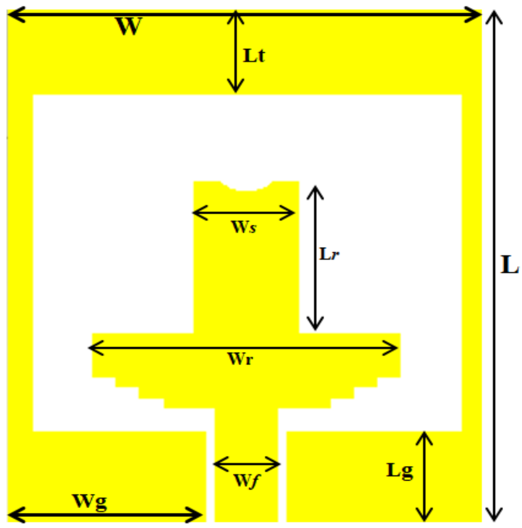


Fig.1. the proposed monopole antenna configuration with labeled parameters

Table 2. Designed antenna parameters in mm. After optimization

Dimension	L	W	H	Wf	Wr
Value in mm	24	20	1.6	2.7	13
Dimension	Wg	Ws	Lf	Lg	Lr
Value in mm	8.3	4.5	5.5	4.5	7

Results and Discussion

Parametric optimization has been performed in order to find out inspiration of the main parameters and to enhance the antenna performance in terms of bandwidth, radiation pattern, and power gain. Figure 2 reveals the optimized reflection coefficient in dB as a function of operating frequency in GHz. It shows the extremely ultra-wide bandwidth which varies from 2.95 GHz till more than 19 GHz that covers the entire FCC bandwidth allocated for wireless systems as well as all lower fifth generation bands illustrated in table 1. This wide bandwidth contains all bands in Europe, China, Japan, Korea, and USA. The S11 has four resonant frequencies which are 3.56 GHz, 7.28 GHz, 9.95 GHz and 17.55 GHz. As part of the parametric optimization for the suggested monopole antenna, several values of the feeding microstripline width have been examined as displayed in figure3. It has noticed that the best impedance matching is obtained at a feeding line width of 2.7 mm. Several substrate materials have studied for instance Rogers RT 5880 (εr=2.2), FR-4 (εr=4.3), Rogers RT 5880Lz (εr=1.96), and Polymide (εr=3.5). The examined materials are common for patch antennas and the reflection coefficient for them are plotted in figure 4. it can be observed that the bandwidth is maximized using Rogers Duroid RT 5880lz material with relative permativity 1.96. over this bandwidth the reflection coeffecient is below than the common standard -10 dB.. Figure 5 shows the normalized power radiation pattern at three resonant frequencies 3.56 GHz, 7.28 GHz, and 9.95 GHz for the main orthogonal planes (elevation plane and azimuth plane) in polar form. In general, the proposed antenna has an omnidirectional radiation pattern with slight minor distortion at high frequencies due to the increment in the power gain. Accordingly, the presented monopole antenna can be located inside the wireless devices at any position because of such radiation feature. Figure 5 illustrates the patch gain in dB over the bandwidth in GHz. The antenna is characterized by its high power gain which reaches around 5.72 dBi.

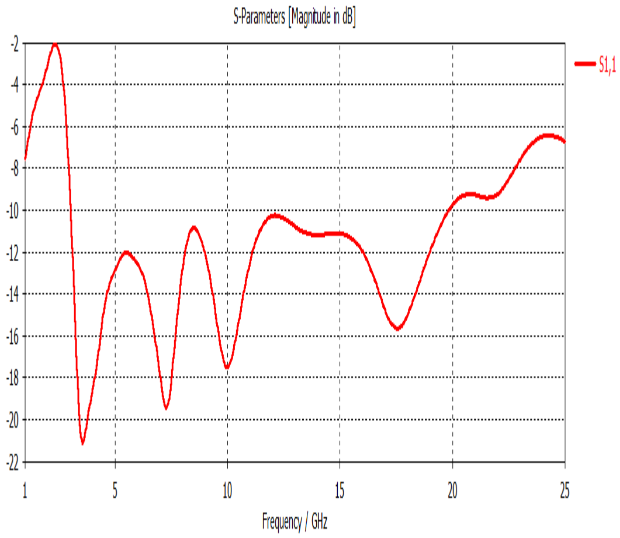


Fig. 2 Simulated reflection coefficient S11 vs the operating frequency

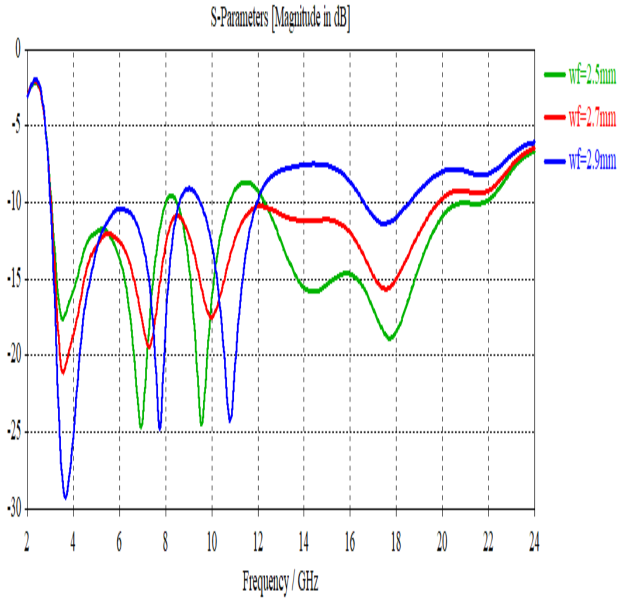


Fig. 3 the simulated reflection coeffecient S11 versus frequency in GHz for multiple feeding line widths

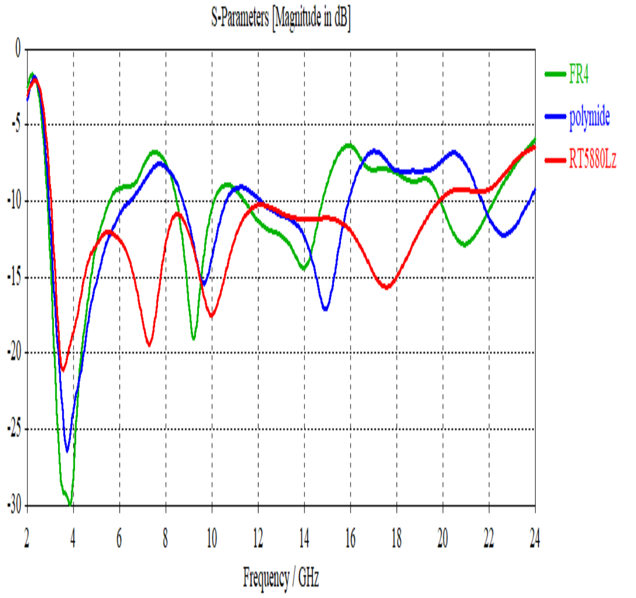
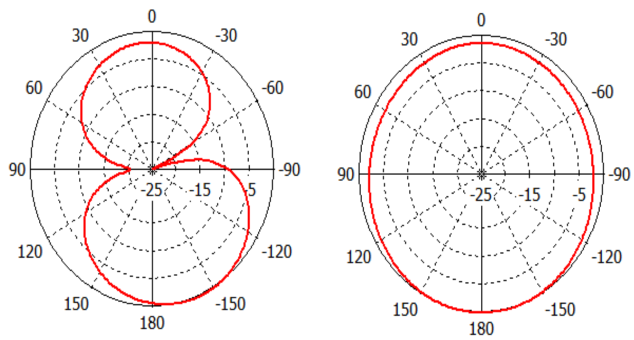


Fig. 4 the reflection coeffecient S11 verus frequency in GHz for multiple common substrate materials Rogers RT 5880 (εr=2.2), Rogers RT 5880 Lz(εr=1.96, FR-4 (εr=4.3), and Polymide (εr=3.5)



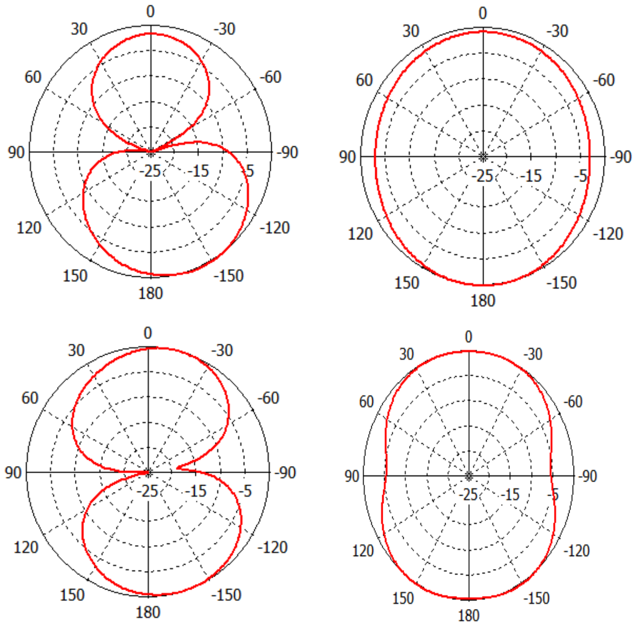


Fig. 5 the normalized radiation pattern for E and H planes in polar form at three resonant frequencies

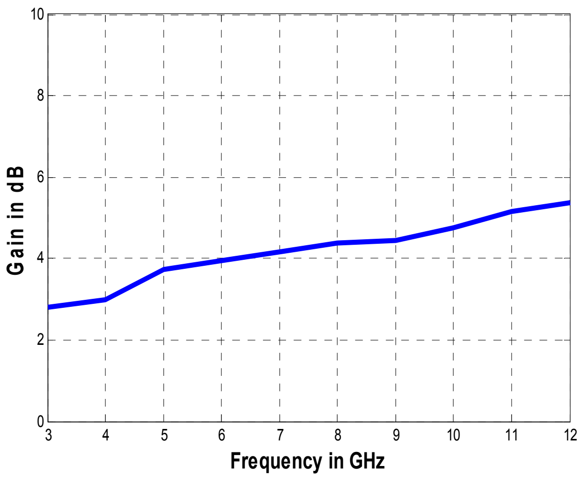


Fig. 6 simulated power gain of the proposed antenna

Conclusion

A new planar ship-shape monopole antenna has been proposed in this paper. The patch is characterized by its extremely wide operating frequency that ranges from 2.95 GHz to more than 19.85 GHz. The design has a single layer compact structure size which is 20 x 24 x 1.6 mm3 and it is printed on a substrate of Rogers Duroid RT5880Lz with relative permittivity of εr= 1.96 and loss tangent of 0.00009. The suggested monopole has high power gain is 5.72 dB with an omni directional radiation pattern that is the optimal possible shape for this type of monopole antennas. Hence, the design is suitable for the initial 5th generation wireless applications at several regions such as Korea, China, Japan, United states of America, as well as several European countries. Furthermore, the antenna is good candidate for short range wireless systems due to the extreme wide bandwidth covers the full Federal Communication Commission (FCC) band allocated for these systems.

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