

A Modified Polygon Shaped Microstrip Patch Antenna Array for Ultra-Wideband Applications

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Abstract— A single element and two elements array polygon shape microstrip antenna is proposed and analyzed in this paper for ultra-wideband (UWB) applications. There are several techniques can be used to optimize antenna performance such as etching rectangular slots on the patch of the antenna with different dimensions and positions. In this paper a two Polygon Shape antenna patches are introduced to enhance the antenna parameters. Also, multi-slots are reached to improve the antenna gain, impedance matching sweep parameter optimization technique is used to all antenna parameters to enhance antenna properties. The dimensions of single element antenna are 30 x 33 mm² and consist of a slotted polygon patch printed on FR-4 substrate. The proposed antenna has a resonant frequency of 6.2 GHz, while the dimensions of two elements antenna array are 60 x 33 mm² and the resonance frequency is 9.8 GHz. A technique of inset feed transmission line was utilized to match the 50 Ω microstrip feed line and the radiating patch. These considerations make the structure is suitable for fifth-generation generation (5G) mobile wireless applications. The proposed antenna was simulated by use Computer Simulation Technology (CST-2020) software.

Keywords—Polygon Antenna, Microstrip Patch Antenna, Ultrawideband (UWB), Slotted Antenna

I. INTRODUCTION

The rapid increase of development of wireless communication systems in recent years led to requirements of compact high efficiency multifunctional antenna that serve many communication systems at the same time. Using Broadband antenna serve multi-device at the same time and has low cost. The microstrip patch antenna (MPA) meets these requirements, but the MPA suffer from low bandwidth and low radiation efficiency. Microstrip patch antennae are widely used in communication systems such as X and Ku, C band, mobile phones, navigation systems, and many other wireless communication systems due to their low cost, low profile, and ease of fabrication and can be integrated in microwave systems [1]-[2].

MPA is also used in nanoscale for biomedical applications to treat skin diseases [3]-[4], and microwave communications band [5]. Bandwidth enhancement is done by using novel hybrid optimization method [6]. Another method used for bandwidth enhanced by using hybrid metal-graphene materials [7]-[8]. Also, the bandwidth of the antenna and other antenna properties can be enhanced by using artificial magnetic conductor (AMC) or frequency selective service (FCC) [9]-[11]. MPA used in plasmonic antenna design [12]. Also, meta-material can be used to increase MPA bandwidth [13]. Other technique for bandwidth enhancement for reconfigurable antenna

properties at tera-hertz can be achieved by using graphene material instead of the conductor in MPA [14]-[18]. A modification in patch by adding stubs used to increase antenna bandwidth [19]. One of the important applications of MPA is energy harvesting [20]-[21]. MPA can be also used to design antennas in photonic frequencies [22].

In recent years, wireless mobile communication systems have become an area of interest due to their wide range of applications in the fields of medical, industries, entertainment, and remote sensing systems. The advantages of ultra-wideband (UWB) antenna systems are simultaneous multi-channel connectivity, high data rate, and low power spectral density moreover having the capacity to deliver high-resolution images. Unfortunately, there are many disadvantages in microstrip antennae such as narrow band and low gain. UWB is an unlicensed frequency band, according to the Federal Communications Commission (FCC), UWB systems are permitted to operate in the frequency band (3.1-10.6 GHz) for commercial purposes [23].

The development of FCC UWB antennas for wideband applications such as: wearable devices, remote sensing, IoT applications, microwave imaging for medical detection, and cognitive radio for high-speed data rate mobile communication. Due to the limited power transmission authorized by the FCC, the main issue with UWB systems is their suitability for short-range communication. Additionally, multipath fading results in environmental scattering, which lowers the transmission quality [24].

The antenna is a major part of any wireless communication systems and it operate at microwave region or in the terahertz frequency band. Many researchers have provided different designs, but these designs suffer for many disadvantages such as low gain, low efficiency and complexity. The design in this paper is different and provides a small antenna size with high bandwidth and good gain that is allocated in the UWB. In [24] by using two circles a compact structure circular geometry microstrip patch antenna for fifth generation (5G) communication systems to obtain large bandwidth, compact requirements, high-data rates. In [25] a faulty ground structure in a wideband circularly polarized microstrip antenna array (DGS) was designed for excellent performances includes: good input impedance matching, return loss, bandwidth, gain and radiation pattern. In [25] a rectangular-shaped microstrip patch antenna with a rectangular shaped slot was designed for 5G wireless applications, using the microstrip line technique for feeding. MPA design procedure presented in [26] The objective of this slot is to contribute to improve antenna performance unit cell

zeroth-order resonator is introduced by composite right/left-handed transmission line method and fed by coplanar waveguide to provide a compact structure of zeroth-order resonator antenna. enhance bandwidth by using the metamaterial inclusion. In [27] a wideband deltoid leaf fractal microstrip patch antennas are designed for scientific and medical (ISM) and wireless local area networks (WLAN) applications.

In this article, we aim to investigate the proposed design characteristics of a polygon configuration with coplanar fading for ultra-wideband applications. The design consists of a polygonal shape, where one long side, denoted as r , provides a coplanar dimension. The antenna is fed by the coplanar feed. The spacing between polygons and coplanarity is sufficient to accommodate UWB frequencies, denoted as t . There is a slight spatial separation in the coplanar feed between the feed and the blades. We utilize Microwave Studio Suite TM 2020 from Computer Simulation Technology (CST 2020) for simulation and optimization to achieve ultra-wideband frequency response and match the input impedance. The CST suite is based on the finite time domain method in three dimensions. The displayed results provide insight into the radiation pattern, impedance, gain, and electromagnetic characteristics of the surface current distribution.

II. MICROSTRIP PATCH ANTENNA

For a large number of wireless communication applications, the rectangular MPA layout is by far the most often used one. In general, the MPA can be fed via a variety of methods, including conducting and non-conducting ones. The microstrip line approach is the most popular of them. As shown in Fig. 1, the rectangular MPA consists of a radiating patch printed on the face of a dielectric substance known as a substrate and a ground plane printed on the bottom of the substrate. The ground plane, feed line, and radiating patch are usually constructed of highly conductive metal. (Typically, copper) [26]-[27]. The Eqs (1-7) Are used to design microstrip patch antenna [28]-[30]:

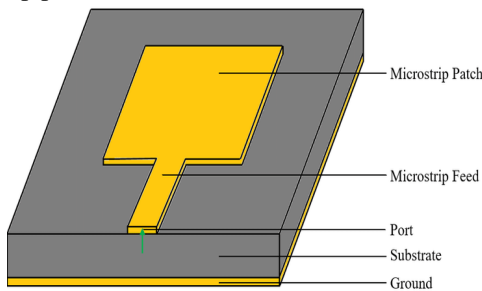


Fig. 1. Microstrip patch antenna

$$W_p = \frac{c}{2f_r \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (1)$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1} \quad (2)$$

$$\Delta L = 0.412h \frac{(\epsilon_{reff} + 0.3) \left[\frac{W_p}{h} + 0.264 \right]}{(\epsilon_{reff} - 0.258) \left[\frac{W_p}{h} + 0.8 \right]} \quad (3)$$

$$L_{eff} = \frac{c}{2f_r \sqrt{\epsilon_{reff}}} \quad (4)$$

$$L_p = L_{eff} - 2\Delta L \quad (5)$$

$$W_s = 2 \times W_p \quad (6)$$

$$L_s = 2 \times L_p \quad (7)$$

where ϵ_{reff} is referred to the effective dielectric constant of the substrate, ϵ_r is represents the dielectric constant of the substrate, h is the thickness of the substrate, W_p is the width of the conducting antenna patch, L_{eff} is effective length, L_p is the actual patch length, ΔL is extension protraction caused by fringing effect.

III. SINGLE ELEMENT POLYGON SHAPE ANTENNA DESIGN

Fig. 2 shows the single-element polygon shape. there are many slots on the patch of the antenna as shown in Fig. 2 a. a 50-ohm transmission line used to feed the patch. The substrate of the antenna is from FR-4 material with a dielectric constant of 4.3. the ground shape and dimensions are shown in Fig. 2 b. the ground plane is not completed along the substrate surface but it is defective and there is a slot in the middle of the upper limit as shown in the figure all dimensions of the antenna are shown in Fig. 2 and also in Table 1.

Table 1. Dimensions of dimensions of single patch polygon antenna

Parameter	Value (mm)
Ls	30
ws	33
wf	2.7
lf	11.3
wg	20
Lg	11
h	1.6
Wp	21.2
Lp	21.2

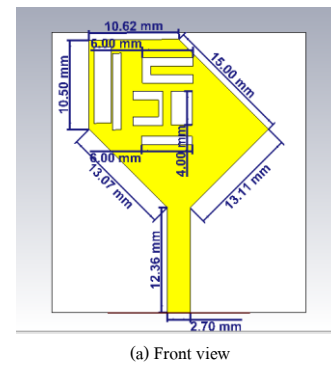


Fig. 2. Single element microstrip patch antenna

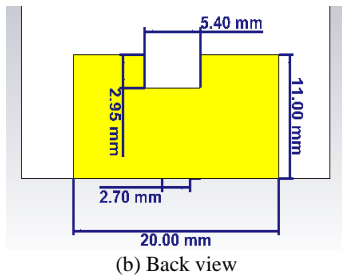


Fig. 3. Single element microstrip patch antenna

The antenna's return losses are depicted in Fig. 3. Except for the frequency band (7-8 GHz), where the return loss is equal to -8Db, the antenna has minimal return loss, less than -10 db. The antenna's return losses are depicted in Fig. 3. Except for the frequency band (7-8 GHz), where the return loss is equal to -8dB, the antenna has minimal return loss, less than -10 dB.

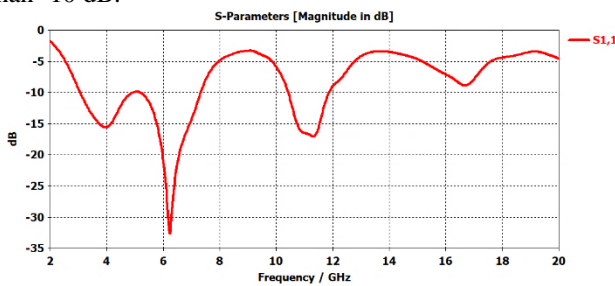


Fig. 4. The return loss of the proposed antenna.

Fig. 4 (a-d) shows the radiation pattern of the antenna at frequencies (4,6,8 and 10 GHz) respectively. It is clear from Fig. 4 that the antenna has good directivity.

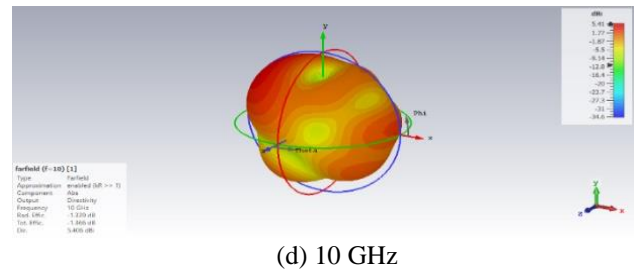
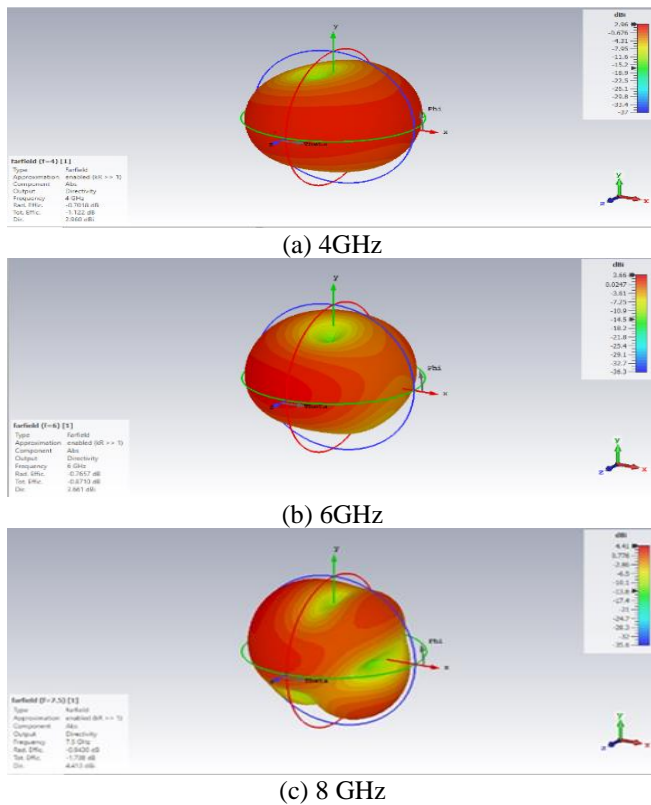


Fig. 5. Far-field of the single antenna at frequency

Fig. 5 shows the that the antenna has a good gain varied in the range of (2.3 - 4.1 dBi) at the designed frequency band.

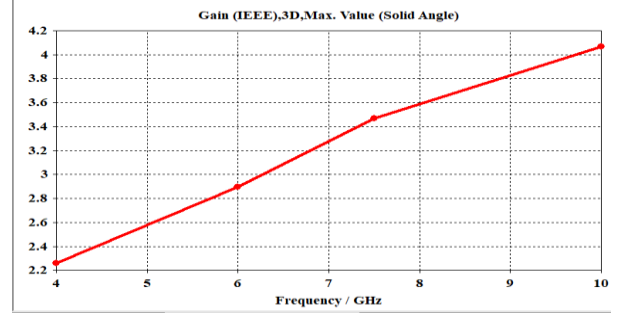


Fig. 6. Gain of the proposed antenna

IV. POLYGON POLARIZED ANTENNA ARRAY DESIGN FOR WIRELESS COMMUNICATION

In this section an antenna array of 2x1 elements with the same shape and dimension as the antenna in section 3. The proposed antenna is shown in Fig. 6. FR4 is used as a substrate, having a dielectric constant of 4.4, thickness $h = 1.6$ mm, and loss tangent of 0.025, the dimensions of the proposed antenna are listed in Table 2. The proposed antenna consists of two identical polygon patches etched with seven slots as shown in Fig. 6, and a 50-ohm transmission line feeds two patches. the patches and transmission line mounted on the FR-4 substrate.

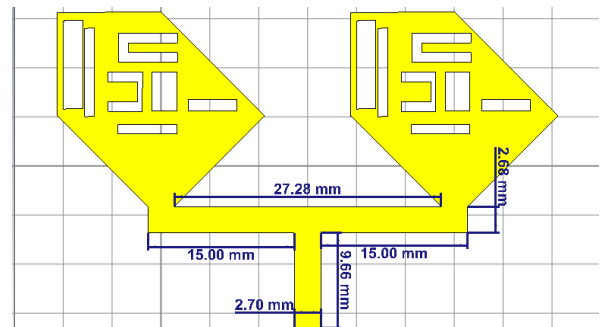


Fig. 7. Simulated 2x1 array antenna

Table 2. Dimensions of two patch antenna array

Parameter	Value (rpm)
Lp	19.7
wp	21.2
L1	15
L2	32.7
L3	9.7
Wf	2.7

V. RESULTS AND DISCUSSION

Fig. 7 shows the return loss of the proposed antenna. the simulation of the proposed antenna is done by using CST software. Usually, the bandwidth of the antenna is measured at frequency bands at which the return loss is less than -10 dB i.e., the reflected power to the antenna is less than 10 %. it is clear from Fig. 7 the antenna has a low return loss of less than -10 Db except at the frequency band (8-10) GHz. The resonance frequency of the proposed antenna is 6 GHz. The effect of slots is to increase antenna bandwidth and gain.

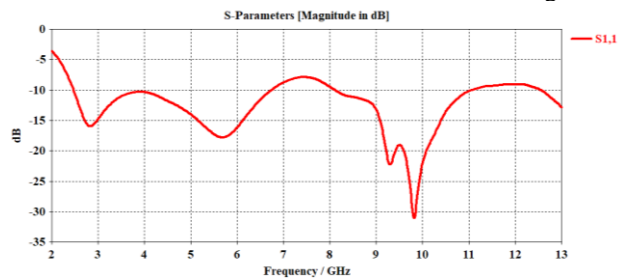


Fig. 8. The return loss of the proposed antenna array

Fig. 8 shows the radiation pattern of the proposed antenna at frequencies 4,6,8,10,12,14 GHz respectively.

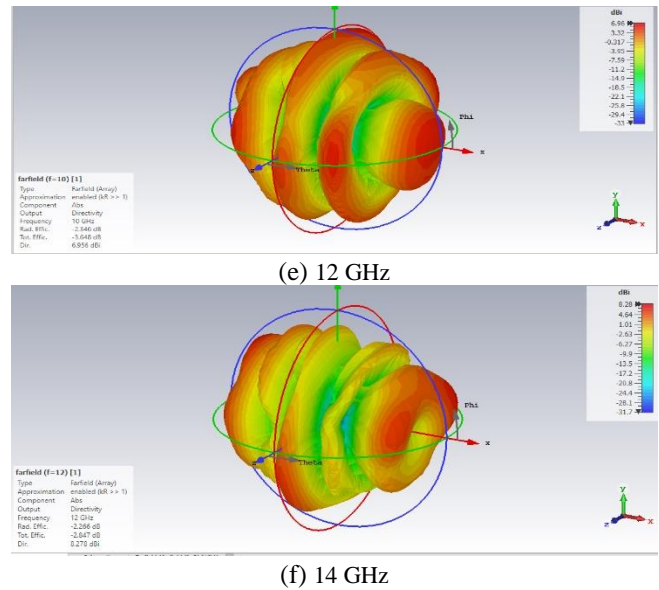
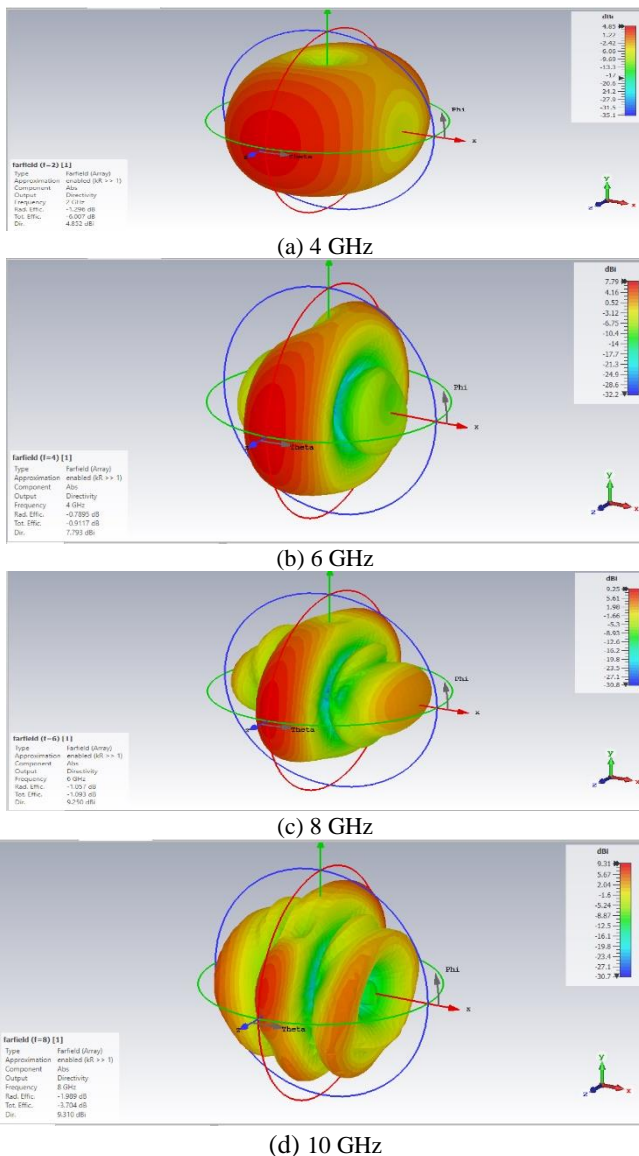


Fig. 9. Directivity of the proposed antenna array

Fig. 8 shows the gain of the proposed antenna at the frequency range (2-14GHz). The antenna has a good gain of up to 5.5 at a frequency of 6 GHz.

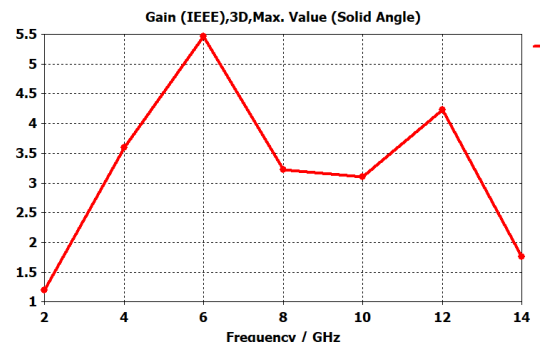


Fig. 10. Gain of 2x1 antenna array

VI. CONCLUSION

A novel slotted patch-based slotted polygon microstrip antenna has been proposed in this article as a potential solution for real-world fifth-generation (5G) mobile wireless applications. Compared to the traditional patch, the proposed antenna provides a size reduction of about 63.33%. Additionally, the suggested antenna offers reasonable performance. It offers a -10dB return loss over a bandwidth of about 12 GHz with a resonance frequency of 6GHz and peak power IEEE gain of 5.5 dB to meet mobile wireless applications.

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