5.8 GHz MPA with High Gain for Wireless Point-to-Point Applications

Lect.Dr. Anwer Sabah Mekki
Department of Medical Devices Techniques Engineering, Al-Turath University College
Lect.Dr. Siba Monther Yousif
Department of Electronic and Communications Engineering, College of Engineering, Al-Nahrain University
Asst.Lect. Noor Kamil Abdalhameed
Department of Medical Devices Techniques Engineering, Al-Turath University College

ABSTRACT
A Microstrip Patch Antenna is proposed to resonate at ISM band of 5.8GHz, with low profile, small size, high gain, and high front to back ratio. The proposed antenna is designed to work on WiMAX for point-to-point applications. The proposed antenna is designed using Computer simulation Technology-Microwave Studio software and optimized. The design is adopted the fractal parasitic elements to enhance the parameters regarding the desired application. The overall dimensions of the suggested antenna are 25 mm × 25 mm × 1.6 mm as (Hight × Width × Thickness) which lead to get small antenna size and low profile. The proposed design achieved low Voltage Standing Wave Ratio of 1.01, which is an approximately semi-ideal value, a very good matching impedance of -44.98 dB, and gain of 10.58 dB with 15.05 F/B with a bandwidth of 2.05 GHz at the center frequency. The simulation design is fabricated using an FR-4 layer of 1.53 mm thickness covered by annealed copper of 0.35 mm thickness. The measurements achieved good agreement with the simulated results. The measured gain is 10.2 dB, matching impedance is -37.6 dB at the center frequency of 5.78 GHz, and bandwidth of 30% from the center frequency. The proposed design is compared with the circular polarized microstrip feeding antenna and 2x1 Simulated Circularly Polarized
Rectangular Microstrip. The comparison highlighted that the proposed design overcomes the circular polarized microstrip feeding antenna in terms of gain and bandwidth while the proposed design overcomes the 2x1 Simulated Circularly Polarized Rectangular Microstrip Patch Array in terms of matching impedance, size, and operating bandwidth.

1- INTRODUCTION

In wireless communications, the antenna is the most vital part. Especially, when resonating within the Industrial, Scientific, and Medical band (ISM); the free licensed frequency [1] and [2]. According to the application, the researcher should focus on specific parameters [3]. In point-to-point applications, the high directivity, high gain, wide bandwidth, and high front to back ratio (F/B) are the most important parameters with the resonant frequency [4-8] .

One of the most used antennas is the Microstrip Patch Antenna (MPA). The MPA has good specifications which makes it the best choice among antenna types in many applications due to its low weight, easy fabrication, low profile, and low cost [9-12].

In transmitting (TX) or receiving (RX) signals, the data rate is so important, the higher data rate the better performance circuit. The antenna is considered as one of the most important parts of the TX/RX system. Therefore, MPA with good parameters is the best choice to be used [13-15].

In [16], the Defected Ground Structured (DGS) is used to design an MPA with a small size of 34 mm × 34 mm× 1.6 mm. In [17], two hybrid layers are used to minimize the antenna size which leads to 32.54 mm × 30.47 mm × 4.6 mm antenna. Moreover, in [18], a T and F shapes are used to resonate at 2.45 GHz and 5.8 GHz. The antenna is designed to be compact in which the dimensions are 40 mm × 30 mm × 0.8 mm.

Reducing the size of MPA is a good achievement while the high gain is also an important goal. The gain in [16-18] are less than 6 dB. High gain MPA means high F/B which comes from redirection of the propagation from back lobe and side lobes to the main lobe and gets high gain as well as high directivity. One of the common methods to enhance the gain is the use of a reflector layer. In [19], an isolated reflected layer is used to enhance the gain. In [20], an artificial magnetic conductor (AMC) is used to get a gain of 6.49 dB. A gain of 13.7 dB is achieved through a Quasi Cassegrain based on metasurfaces [21]. The smallest size from [16-20] can be found in [20] which is 45 mm × 60 mm × 12.9 mm. The enhancement of all the antenna’s parameters is unreachable due to the complicated relations among these parameters. In [22-24] the End-Fire design is used to enhance the directivity, gain F/B ration and reduce the size.

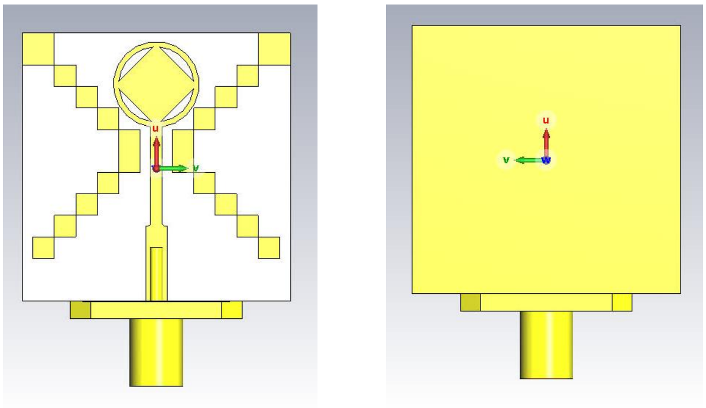
In this work, an MPA with fractal parasitic elements resonates at 5.8 GHz with a measured matching impedance of -37.6 dB, size of 25 mm × 25 mm × 1.6 mm, and gain of 10.2 dB is achieved with a 2.05 GHz bandwidth. The proposed work is compared with the Circular Polarized Microstrip Feeding Antenna [13] and with the 2x1 Simulated Circularly Polarized Rectangular Microstrip Patch Array [25].

2- ANTENNA DESIGN

The proposed antenna is designed theoretically using the MPA design equations [3]. From theoretical equations, the dimensions of the proposed design are estimated regarding to the desired resonant frequency. Then, by using Computer Simulation Technology - Microwave Studio which employs finite element calculations, the design is completed and optimized. In the proposed design, the substrate is FR-4 of 4.3+j 0.025 as an epsilon (ε_r) of 1.53 mm thickness coated with annealed copper from both sides of 0.035 mm thickness. Therefore, the final dimensions of the proposed antenna are 25 mm × 25 mm × 1.6 mm.

The design employs two important concepts; the circular shape of the patch antenna which leads to enhance bandwidth and the fractal parasitic elements which makes the proposed antenna works as end fire antenna with reducing the area and enhances the gain as well as the

F/B ratio. The proposed design is shown in Fig. 1. More details of the patch layer dimensions are illustrated in Fig. 2. The antenna is connected to the port via SMA-50Ω connector.



(a) (b)

Fig.1: The proposed antenna (a) face, (b) GND

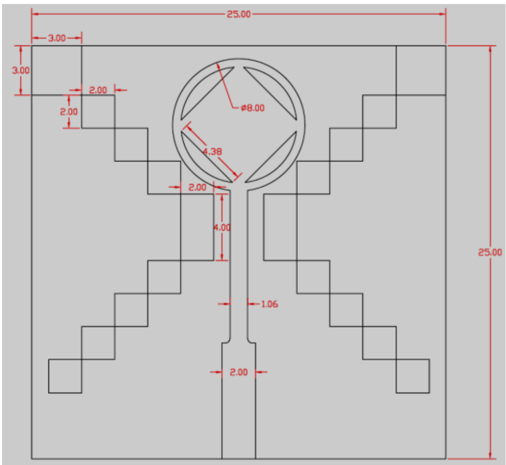


Fig.2: The dimensions of patch layer

3- SIMULATIONS

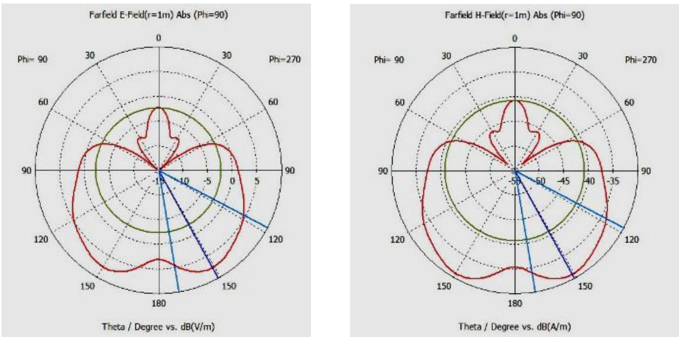
Using CST-MW, the proposed antenna is simulated and the results are listed in Table 1.

Table 1: The simulated results of the proposed antenna

Parameter	Value	Unit
Dimensions	(25×25×1.6)	mm^3 (L × W × T)
Center Frequency	5.83	GHz
Bandwidth	2.01	GHz
S_{11}	-44.986	dB
Impedance	50.565 + j 0.0257	Ω

VSWR	1.011	N/L
Directivity	10.8	dBi
Gain	10.588	dB
Total linear efficiency	0.9443	N/L
F/B	15.051	N/L
Side lobe level	-10.7	dB

The H field and E-Field of the suggested antenna is shown in Fig. 2, which indicates that the suggested antenna works as an End-Fire antenna. The 3D view of the propagation of the directivity is shown in Fig.3.



(a) (b)

Fig.2: Fairfield (a) H- Field, (b) E field

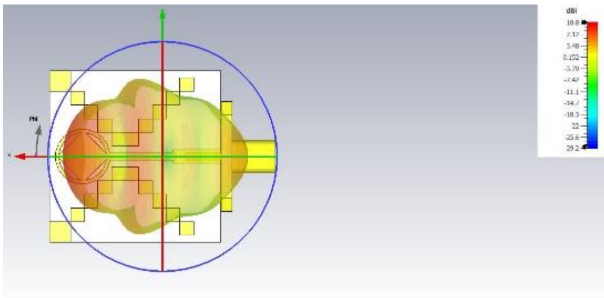


Fig.3: The 3D view of the proposed antenna directivity

The 3D view of directivity indicates that the end-fire proposed antenna is suitable to work on Point to Point (P2P) wireless communications. In Fig. 4, the current density distribution in the proposed antenna is shown.

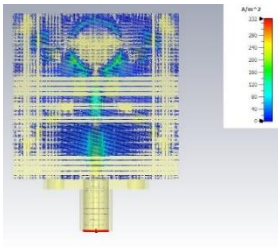
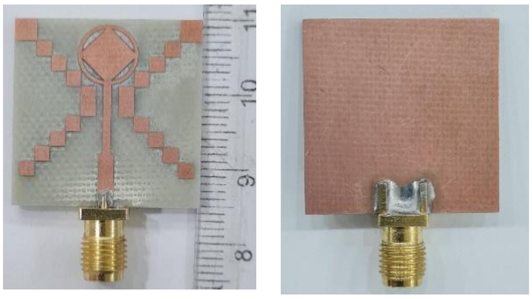


Fig.4: The current distribution in the proposed antenna

4- MEASUREMENTS

The proposed antenna is fabricated on an FR-4 layer of thickness 1.6 mm using the photo etching technique. the fabricated antenna is examined by Vector Network Analyzer (VNA), Spectrum Analyzer, Function Generator, and two horn antennas. The fabricated antenna is shown in Fig.5.



(a) (b)

Fig.5: The fabricated antenna (a) Patch layer, (b) GND layer

The fabricated Antenna is measured in free space using the mentioned setup. Table 2 illustrates the measured parameters of the proposed antenna.

Table 2: The measured parameters of the proposed antenna

Parameter	Value	Unit
Center Frequency	5.78	GHz
Bandwidth	2.02	GHz
S_{11}	-40.51	dB
Gain	10.11	dB

From Table 2, the measured results have good matching with the simulated results. This means that the proposed antenna has a good specification according to the desired application which is P2P antenna in wireless communications.

5- COMPARISON

The comparison between simulated and measured results of the center frequency, S_{11}, and bandwidth is shown in Fig. 6. The measured results are compared with two recently works as shown in Table.3.

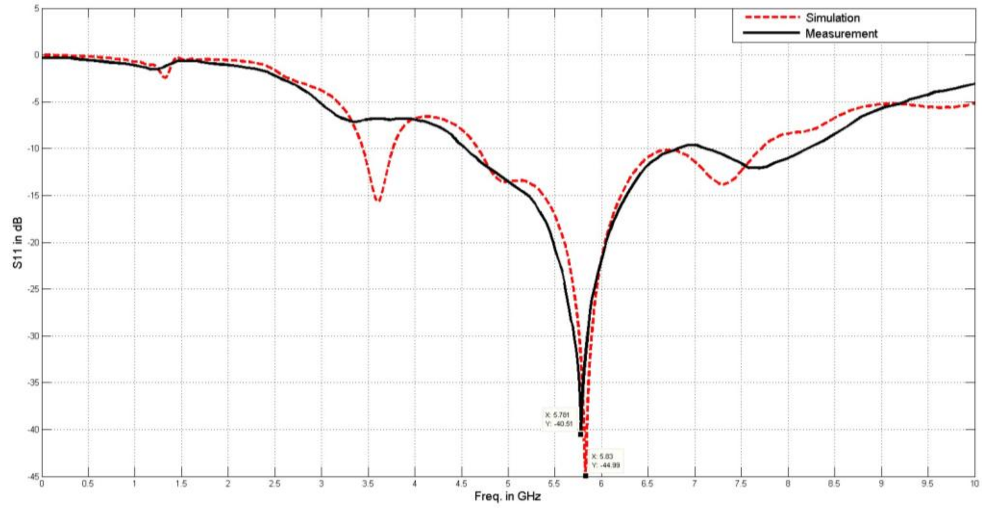


Fig.6: The comparison between simulated and measured S_{11} vs. frequency of the proposed antenna

Table. 3 The comparison of the measured parameters with [13] and [25]

Parameter	**Reference** [13]	**Reference** [25]	**This work**
Center Frequency in GHz	5.8	5.8	5.78
S_{11} in dB	-14	-24.63	-37.6
Bandwidth in GHz	.2	0.175	2.02
Gain in dB	2.34	10.77	10.11
Size in mm^3	379.5	15,912	1000
Technique	circular polarized microstrip feeding	2x1Simulated Circularly Polarized Rectangular Microstrip Patch Array	End-Fire

The comparison shows that the proposed antenna overcomes the circular polarized microstrip feeding antenna in terms of S_{11}, gain and bandwidth and overcomes the 2x1 Simulated Circularly Polarized Rectangular Microstrip Patch Array in terms of size, S_{11}, and operating bandwidth.

6- CONCLUSION

Due to the small size, high gain, and center frequency which is located in the ISM band, the proposed antenna presented in this work has good specifications to be used for wireless P2P. The shape of the MPA accompanied with fractal parasitic elements gives the proposed antenna good parameters values with a small size. Finally, the proposed antenna is compared with the circular polarized microstrip feeding antenna and 2x1 Simulated Circularly Polarized Rectangular Microstrip Patch Array. The proposed design overcomes the circular polarized microstrip feeding antenna in terms of size, gain, and bandwidth. Moreover, the proposed design overcomes the 2x1 Simulated Circularly Polarized Rectangular Microstrip Patch Array in terms of size and operating bandwidth. Therefore, the comparisons show that the proposed antenna can be used in the desired application with high performance. The main contribution of this paper is the use of fractal shapes which change the propagation direction from Z to X and convert the antenna into End-Fire antenna. Consequently, the End-Fire antenna achieve high gain, low size, and high F/B ratio and these specifications can be considered as the optimum specifications for point-to-point wireless transmission.

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