Defected Ground–Structured Symmetric Circular Ring Antenna for Near-Field Scanning Plasmonic Applications

Article *in* Plasmonics · January 2023

DOI: 10.1007/s11468-022-01784-8

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Plasmonics
https://doi.org/10.1007/s11468-022-01784-8

RESEARCH

Defected Ground–Structured Symmetric Circular Ring Antenna for Near-Field Scanning Plasmonic Applications

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Received: 20 November 2022 / Accepted: 30 December 2022

Abstract

The study presents the defected ground structure (DGS) monopole circular ring patch antenna to utilize in wireless applications. Moreover, the design that has been proposed was configured on the FR4 substrate. Initially, the proposed antenna achieves limited gain and bandwidth. The gain and bandwidth can be increased based on the defective ground structures implemented on the ground with symmetric meander line slots presented on the lower and bottom surfaces of the antenna. The feed is integrated with four uniform circular rings on either side of the antenna. Implementing circular rings on the top surface of the antenna and meander line etched slots on the defected ground enhances antenna performance to operate at desired operating bands with the figure of merits. The proposed antenna resonates at 5.6 GHz and 8.5 GHz operating frequencies with a return loss (RL) of − 22 dB and − 33 dB, respectively, obtaining 400 MHz and 700 MHz impedance bandwidth with the reference line at the concerning 10 dB RL. The gains of the proposed antenna are 4.05 dB and 5.43 dB at two resonant bands and achieve bidirectional and semi-Omni directional radiation patterns. The surface currents are also analyzed for the proposed circular patch DGS antenna. The proposed antenna is used for the WiMAX application.

Keywords Return loss · Circula patch DGS antenna · Reflection coefficient · VSWR

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Published online: 17 January 2023

Introduction

The selection of microstrip antenna is appropriate for use in various industries that include the applications associated with medical purposes, telecommunication, satellite broadcasting, and soldierly structures. Microstrip patch antennas are highly useful compared to conventional antennas and have superior possibilities. Nevertheless, the antennas oriented with the patch developed in microstrip attain the flaws restricted to intrinsic characteristics that include minimal bandwidth range, approximated at the frequency centered at 4% under the mid-level radiation under spatial distribution. Further, the strategies downsizing with the implementation of the antennas developed under the patch of the combinational sequence with the employed substrate having the characteristics of dielectric medium set for the fabrication with the ground surface attaining for the DGS integrated equally. Alongside, the antennas developed under the medium of microstrip substrate can be explored with the provision created for variation in the dimensions, weight, cost, and complexity. Upon setting for the ideal case in the embedded systems useful for the household handled profile of antennas in the applications being developed within the developed case of the designs attributed to MMIC. Later certain respective circumstances have been met for the techniques merged to implement the applications associated with the aerodynamic profile under the installation of ground-level surfaces irrespective of the complex traditional means of the supply given by the manufacturing substrates [1].

Microstrip antennas are utilized in various applications, including biological diagnosis and wireless communications. Significant scientific efforts on enhancing the gain and bandwidth of microstrip antennas have been reported to date, including structures that create the probe stacked constructed antennas into the precisely moved microstrip patch worked for the operation into the shorted distance path set within the ground being reduced for the dimensionless reach of the slots that are parasitic to the resonance occurred through the gain reached the minimal cause of the length obtained in the whole province of the constant wavelength utilized for the TMo1o distribution to the band holding sampled frequency that includes the division into the inverted means of the planar-based structure known as planar inverted F antenna (PIFA) within the sequence of the substrate holding the specific characteristics of dielectrics.

DGS is a ground plane–based etched lattice form. DGS can be accomplished by creating a flaw on the backside of a metallic ground plane. This approach gets its name because we generate a defect on the ground plane. Numerous DGS slot shapes have been researched in antenna designs, providing many favourable performances such as size reduction and bandwidth can be enhanced within the impedance count for the attainment of qualitative reach with the increment of gain approximation. With the small distance of the networking system associated with the designed antenna for the microstrip substrate, the faulty situation can be reached with the realization of the planar surface at the stage of grounded boundaries.

Furthermore, the antenna proposed gained the bandwidth at 5 times the typical impedance range. Moreover, the slots have been inserted into the ground surface, which might diminish the dimension of the substrate obtained with the suggested antenna directivity and gain. The resonant frequency with the sampling ratio of the distribution attained in the antennas that are defective to the planar region decremental to the developed performance analyzed to the improved device for the several ranges of microwave structures associated mechanized for the configuration. This theory allows us to increase bandwidth by using a defective ground structure to improve antenna characteristics in applications such as Wi-Fi/WiMax, Bluetooth, and others. Numerous ways can be employed to get improved bandwidth improvement. The enhancements of bandwidth with the previous approaches are discussed in this section. The primary method for increasing bandwidth is to use an I-shaped antenna with a defective ground structure (DGS), which results in a 118% increase in bandwidth. The antenna was intended for S-band applications at frequencies ranging from 2.5 to 4.5 GHz, which enhances the antenna's gain and RL. With the DGS strategies, the reduction in the dimensions can be attained within the functionality of the multiple patches achieved with the design in comparison to the surfaces of the surfaces configured with photonic oriented band-gap (PBG) exterior means of samples.

Nonetheless, DGS has further gained superior knowledge in the design construction of the frequency-sampled bands for the rejection of specific reasons associated with the structures attributed to the classic case of electromagnetic band-gap (EBG) assemblies, which seems as the entire case of configuration constructed within the circuit developed for the microwave applications that include oscillators, amplifiers, and filters. With the published studies associated with the DGS, the antennas proposed have possessed the capability of the DGS in the geometric mean of the dimensioned shapes for several structures. Oriented DGS with the cells that are multiple reaches for implementation of the antennas constructed to the patch of the design developed with the microstrip set to help meet some of the more complex design requirements [2]. With the use in many applications operated under the developed design of antennas in the field of conformal antennas oriented to microstrip set for the superior range of sampled frequencies that include the beam structure, radial design associated under the system of cylindrical antenna micro-stripped case that attains in minimizing the dimension and elongates the beam structure through which the field can be associated for the wide range spread of frequency within the antenna designed. Further, the surfaces of structures within the domain of EBG or PBG set a path in minimizing the waves under the surface, leading to the character development of the band-gap. EBG is utilized for the antenna design in enhancing the performance being suppressed through the propagation of the wave theory subjected to boosting the gain within the antenna. They led to the improved case of patterned radiation developed in the suggested case of periodic signals through the large, possessed area certainly, within the comparative to the elemental analysis of structure associated to the EBG substrate. Though the pattern developed elements of EBG can be qualitative to the DGS guided the etched configuration for the accomplished means to the flow of current for the property built in the filtering of high-pass, low-pass through the impedance mapped to the influencing frequency to distributed phenomenon [3–5]. Besides, the photonic oriented band-gap (PBG) exterior means of samples.

Nonetheless, DGS has gained superior knowledge in designing the frequency sampled bands for the rejection of specific reasons associated with the structures attributed [6]. Within installation of the surfaces of ground level irrespective of the complicated traditional means of the supply given by the manufacturing substrates. Microstrip patch antennas are highly useful compared to other conventional antennas and have superior possibilities. Furthermore, microstrip patch antennas can offer frequency agility, wide bandwidth, and feed [7–12]. Nevertheless, the antennas oriented with the patch developed in microstrip attain the flaws restricted to intrinsic characteristics that include minimal bandwidth range, approximated at the frequency centered at 4% under the mid-level radiation under spatial distribution [13–15].

Nevertheless, applying the periodic patterns, a big area is required for the difficulty in specifying a particular element for the EBG unit. Indeed, the qualities associated with DGS can build the influencing factor, compared to the property filtering with the adjustment of the guided characteristics specified for the reach in the more straightforward design of the etched configurations [16]. Generally, the structures affected the impact of the shielded reach in the planar base flow designs methods to the investigated impedance matched to the bandwidth developed [17, 18], manipulating the slot's designed flow of electricity. Several reach in the distribution for the spacious development for the mapping of the structure associated with the boosting of the antenna in the fundamental frequency [19–21] that assists in the performance analysis in reduction to the frequency sampling. DGS has further gained superior knowledge in designing the frequency-tested bands for the rejection of specific reasons associated with the structures attributed to the classic case of electromagnetic band-gap (EBG) assemblies. It seems as if the entire case of configuration is constructed within the circuit developed for microwave applications that include oscillators, amplifiers, and filters [21]. With the published studies associated with the DGS, the antennas proposed have possessed the capability of the DGS in the geometric mean of the dimensioned shapes for several structures. Oriented DGS with the cells that are multiple reaches of implementation of the antennas constructed to the patch of the design developed with the microstrip set to help meet some of the more complex design requirements [10, 22, 23].

The antenna is one of the most crucial components in the field of RF that ensures the operation of various communication protocols in multiple applications. The antenna is essential for sending signals from one location to another. The need for a single antenna that can cover many wireless communication channels is increasing due to the rapid development of WLAN and WiMAX technologies. A simple structure, many bands, small size, and affordable antennas

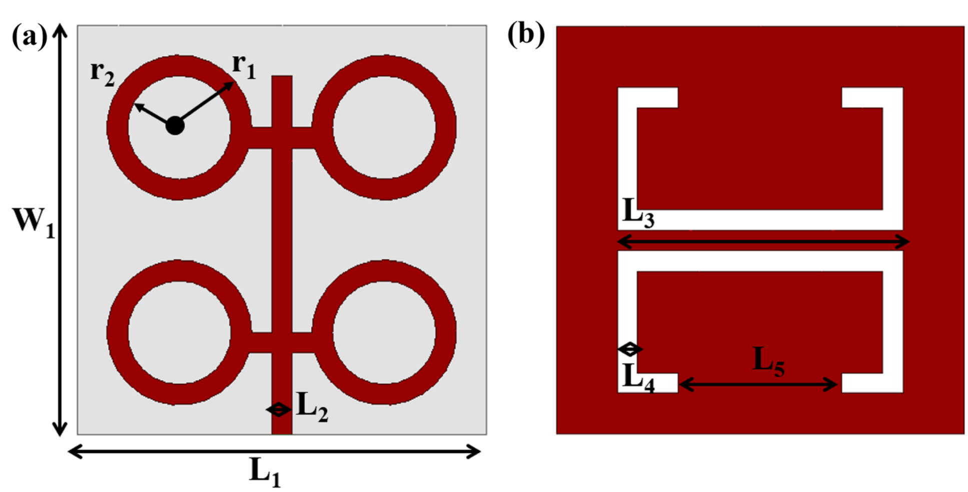

Fig. 1 Geometry view of the suggested antenna. (**a**) Radiating patch and (**b**) Ground plane

Table 1 Dimension of the antenna

Parameters	Dimension(mm)
L_1	40
L_2	2
W_1	40
r_1	12
r_2	8
L_3	18
L_4	2
L_5	9

are widely desired for such communication standards. Various antenna designs are available and performing exceptionally well in the literature. However, many have significant disadvantages, particularly for portable devices, such as their enormous size. Various microstrip antennas with various geometries have been developed to scale down and increase bandwidth for WLAN/WiMAX applications [24–33].

Antenna Design

The antenna configured with the substrate of the built-in design associated with the parametric variation of the substrate meant for the sampled frequency given within the characteristics of electrical field that include the FR-4 patch substrate attributing the approximated relative permittivity (r) having 4.3 with 1.6 mm thickness. The antenna is stimulated by a microstrip feed with a characteristic matching of the impedance mapped to the correlated approximation of 50 Ω with the feedback associated to the dimension holing with 3 mm diameter, with height (hf) of 1.6 mm. Moreover, the patch has been developed with the equivalence of 40 mm × 40 mm under a measured distance calculated within 0.04 mm height, elongated to the measurements taken under the ground surface of the exact dimensions mentioned above.

Figure 1 depicts the complete geometry of a primary antenna that has gained superior knowledge in the design construction of the frequency sampled bands for the rejection of specific reasons associated with the structures attributed to the classic case of EBG assemblies suppressed through the propagation of the wave theory subjected to boosting the gain within the antenna—leading to the improved case of patterned radiation.

Table 1 states the suggested antenna with the dimensional optimization, where L1 and W1 state the antenna substrate length and width. Secondly, L2 state the width of the feedline. L3, L4, and L5 state the size of the defective ground structure. They are employed to get improved bandwidth improvement. The enhancements of bandwidth with the previous approaches are discussed in this section. The primary method for increasing bandwidth is to use an I-shaped antenna with a defective ground structure (DGS), which results in a 118% increase in bandwidth. The antenna was intended for S-band applications at frequencies of several Hz.

Results and Discussion

The suggested antenna simulations are performed using the HFSS tool considering the finite element method. With DGS, the simulated return loss occupies a bandwidth of 400 MHz with a reflection loss of less than 10 dB. Meandering slots placed on the ground plane (GP) to gain bandwidth can be enhanced. The curved-shaped emanating patch can improve the antenna bandwidth with slotted portions and lines. The periodic mender line slots are implemented in the ground plane to enhance the overall

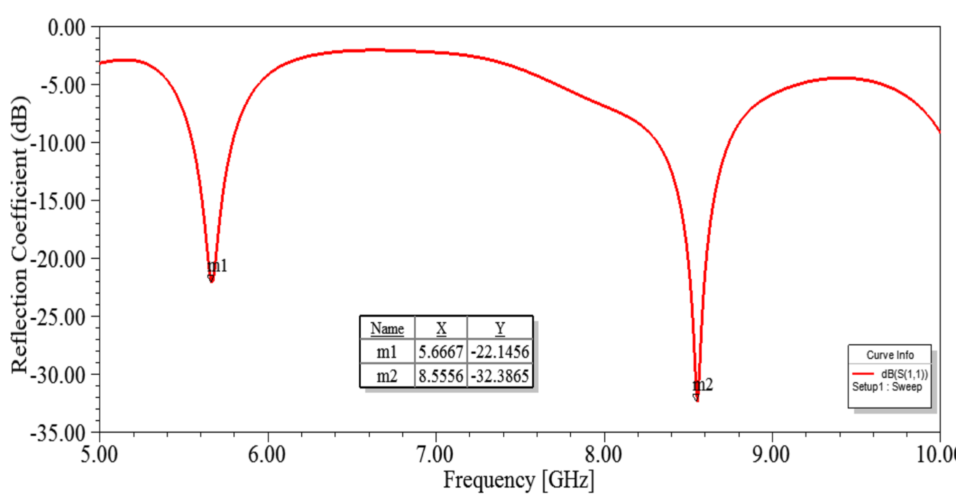

Fig. 2 Suggested antenna reflection coefficient with frequency

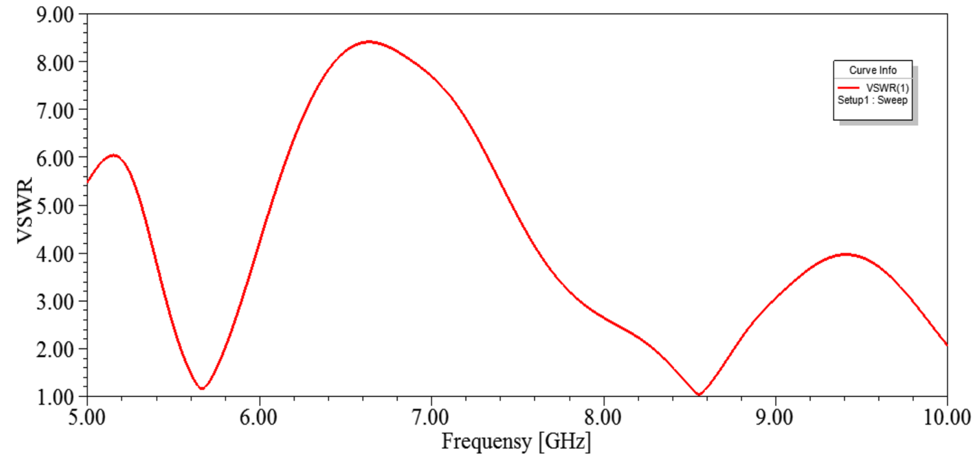

Fig. 3 VSWR to frequency for the suggested antenna

performance of the antenna without altering the physical parameters. The meander slots are presented down the feed line to improve antenna inductance and capacitance. Although, when incorporating this type of antenna with the printed circuit board, it is better to place the RF circuit a small distance away from the ground to keep away from emissions. A periodic imperfection in the patch antenna's ground plane undergoes changes in the transmission line. Therefore, creating a prominent disturbance in current fields. The DGS concept is utilized in many antenna structures to enhance the parameters and characteristics of the antenna. The circular ring patch antenna design achieves miniaturization with DGS. The RL of the suggested circular patch DGS realizes a good reflection coefficient of 22.1 dB and 32.3 dB at 5.6 GHz and 8.5 GHz frequencies. The reflection coefficients obtained are lower at attained frequencies. The parameters of the antenna with DGS accomplish good gain and bandwidth. The patterns and current fields are also observed in this section. The VSWR value should be less than 2 to enhance the antenna's performance. The values of VSWR are as follows 1.08 and 1.32 at corresponding frequencies.

Figure 2 demonstrates the coefficient of reflection associated with antenna development. The structure formed for under-reflection coefficients obtained is lower at attained frequencies. The parameters of the suggested antenna with DGS accomplish good gain and bandwidth.

Figure 3 clarifies the VSWR with the frequency for the suggested antenna. Within, simulations of the proposed antenna are performed utilizing the HFSS tool considering the finite element method. With DGS, the simulated return loss is less than 10 dB. Meandering slots placed on the GP enhance the antenna gain bandwidth. The curved-shaped emanating patch can improve the antenna's bandwidth with slotted portions and lines. The periodic mender line slots are implemented in the GP to enhance the overall performance of the antenna without altering the physical parameters. The RL of the suggested circular patch DGS realizes a good reflection coefficient of 22.1 dB and 32.3 dB at 5.6 GHz and 8.5 GHz frequencies. The reflection coefficients obtained are lower at attained frequencies. The VSWR value should be less than 2 to enhance the antenna's performance. The

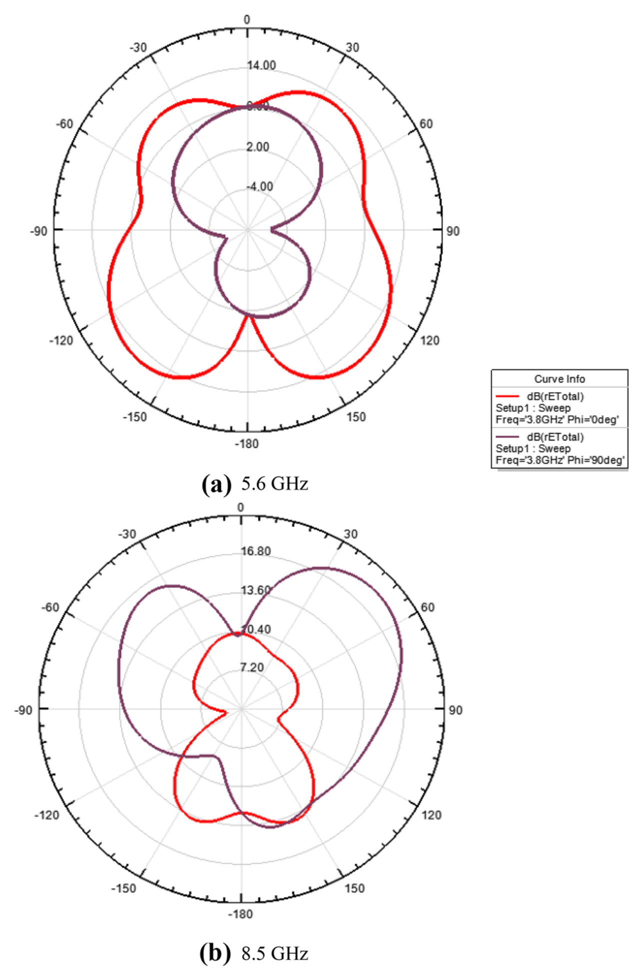

Fig. 4 Suggested Antenna radiation patterns at (**a**) 5.6 GHz, (**b**)8.5 GHz

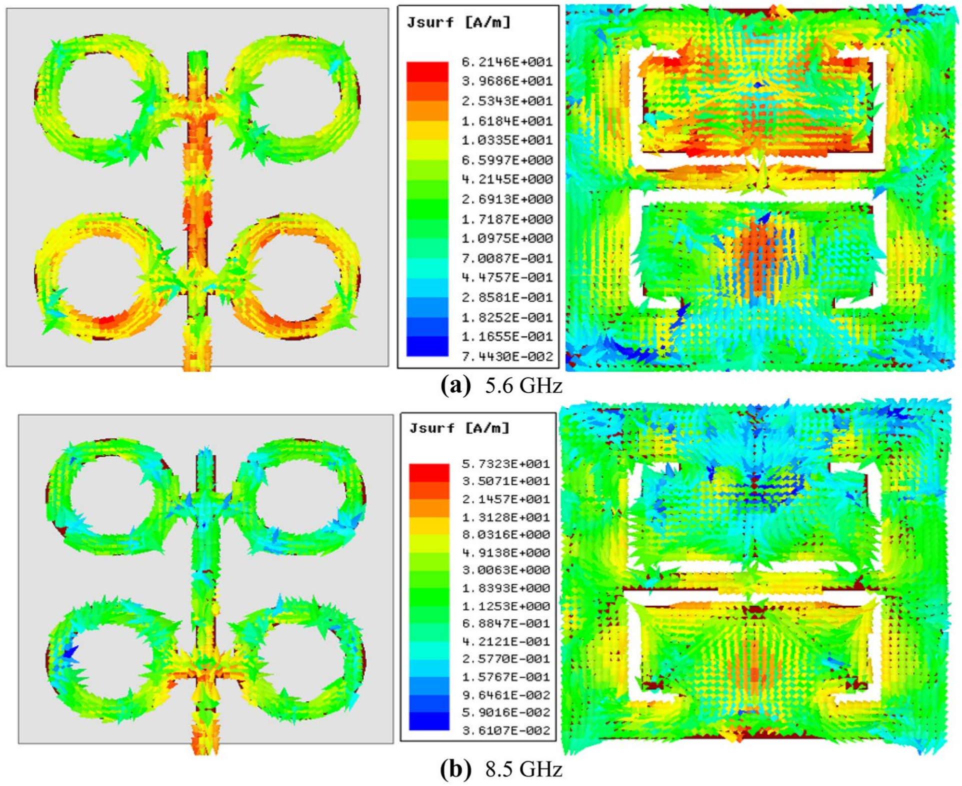

Fig. 5 Current fields of the antenna at (**a**) 5.6 GHz and (**b**) 8.5 GHz

values of VSWR are as follows 1.08 and 1.32 at corresponding frequencies.

The DGS concept is utilized in many antenna structures to enhance the parameters and characteristics of the antenna. The meander slots are presented down the feed line to improvise the inductance and capacitance of the antenna. A periodic imperfection in the patch antenna's GP changes the transmission line. Therefore, creating a prominent disturbance in current fields. Although, when incorporating this type of antenna with the printed circuit board, placing the RF circuit a small distance away from the ground is better to prevent emissions.

Figure 4 depicts the patterns associated with the radiation impact that led to the antenna proposed with the circular ring patch antenna design achieving miniaturization with DGS. The radiation patterns are validated in the far-field region. The E-plane ($\phi = 0$) and the H-plane ($\phi = 90$) are observed. With the lower frequency, the radiation patterns are bidirectional. At the 8.5 GHz frequency, the radiation pattern is still semi–Omni directional. Observing the radiation patterns denotes that the designs are radiated with reasonable magnitude. At that point, the electric field is generated. On the DGS, currents are majorly distributed over the slotted lines. The current areas are observed at 360° phase angles.

Installation of ground-level surfaces irrespective of the complicated traditional means of the supply given by the manufacturing substrates. Figure 5 represents the surface currents of the circular ring patch antenna at 5.6 GHz and 8.5 GHz frequencies. It is observed that the feed line employs large currents compared to the top end of the antenna surface.

Figures 6 and 7 depicts the simulated gains of the suggested circular ring patch antenna. The 3d normalized gain is presented for the proposed circular ring patch antenna. At some portions of the antenna, gain value in a circular shape. And they are noticed at 4.05 dBi and 5.43 dBi for the 2 operating bands. A higher operating frequency causes the gain to be obtained with nulls.

The proposed antenna shows radiation efficiency values of 85% and 91% across the operating frequencies of 5.6 and 8.5 GHz.

Table 2 illustrates the comparison of the suggested antenna with previous studies. The proposed antenna shows a compact size of $40 \times 40 \times 1.6$ mm^3, with a high gain and radiation efficiency of > 80% compared to prior studies.

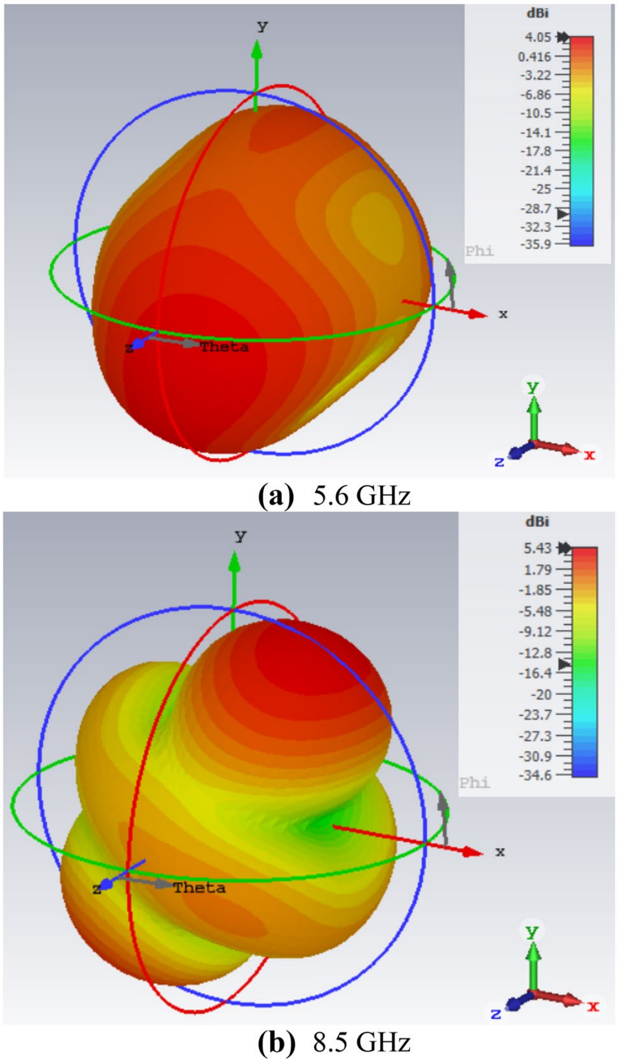

Fig. 6 3D gains of the suggested circular patch antenna at (**a**) 5.6 GHz, (**b**) 8.5 GHz

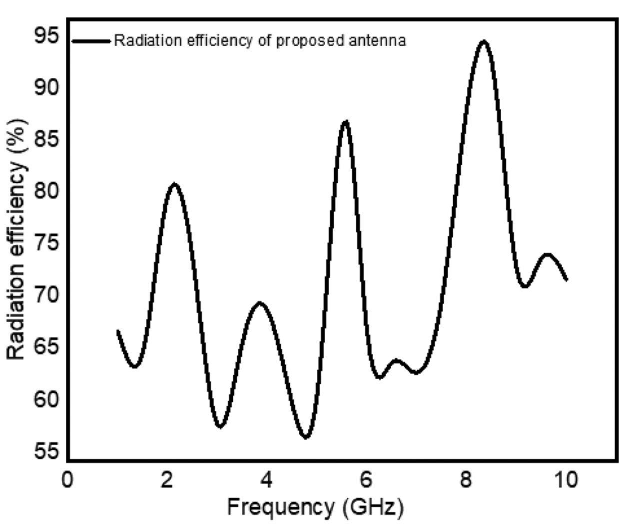

Fig. 7 Radiation efficiency of the proposed antenna

Table 2 Comparison of the suggested antenna with previous antennas

Antenna	Frequency bands covered	Antenna size (mm^3)	Substrate thickness (mm)	Gain of the designed antenna (dBi)	Radiation efficiency (%)
Ref [22]	GSM900/UMTS/GPS/ PCS//WiMAX/Bluetooth/WLAN/ DCS/ Wi-Fi	50 × 35 × 1.6	1.6	4.01	69.45
Ref [23]	GSM850/ LTE750/ GSM900/ UMTS-2110DCS/ /Bluetooth/ WLAN/ UW/ WiMAX	55 × 55 × 0.305	0.305	3.085	82.3
Ref [10]	GSM900/GSM850/ DCS1800/ UMTS2100/PCS1900/ /ISM2450/WiMAX/ WLAN/ With bands of LTE	33 × 25 × 0.8	0.8	2.03	78.2
Proposed Work	**WiMAX**	**40 × 40 × 1.6**	**1.6**	4.05 and 5.43	80 and 91

Conclusion

This work presents a circular ring antenna with DGS for dual-band wireless applications. The obtained frequency bands are popular for wireless applications. Additionally, the dimension of the proposed antenna is 40×40 mm^2. Commercially available software is utilized to design and analyze the proposed antenna. The offered antenna yields bandwidth of 400 MHz and 900 MHz at respective operating frequencies. Gain at obtained operating frequencies are 4.05 dB and 5.43 dB, respectively. The corresponding VSWR values are 1.08 and 1.32 at 5.6 GHz and 8.5 GHz frequencies. The proposed antenna is implemented with a 50 Ω impedance transmission line that will resonate at 2 operating bands. DGS is considered to enhance the gain and bandwidth of the proposed circular patch antenna. To accomplish improved antenna performance, two slots are regarded on the GP. DGS enhances the inductance and capacitance of the antenna design.

Acknowledgements The authors would like to thank the Deanship of Scientific Research at Umm Al-Qura University for supporting this work by Grant Code: (22UQU4340560DSR15). The authors also extend their appreciation and gratitude to Al-Mustaqbal University College in Iraq for funding this project.

Author contribution Authors contributed equally to this work.

Funding This work is funded by the Deanship of Scientific Research at Umm Al-Qura University for supporting this work by Grant Code: (22UQU4340560DSR15).

Data Availability Not applicable.

Declarations

Ethics approval Not applicable.

Consent to Participate Not applicable.

Consent for Publication Not applicable.

Competing interests The authors declare no competing interests.

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