International Journal of Communication Systems and Network Technologies
ISSN-2053-6283

Ring Shaped DGS Patch Antenna for Wireless Communication

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***Abstract* - A orbicular microstrip patch antenna (MPA) conceptualizes with negative ground formation defected ground structure (DGS) feed for narrowband (NB) is assigned. The antenna is conceptualized using CST Studio executing in the Frequency spectrum of operation from 2 GHz to 2.8 GHz. The antenna has a condensed structure with measurements of 60 × 60 × 1.6mm³, transformed as a ring hole and grounded defected ground structure. The assigned antenna can achieve a gain of 5.53 dBi at a frequency of 2.4 GHz and a maximum of 6.57 dB. The power efficiency of the antenna is superior, reaching 97%, and the voltage standing wave ratio (VSWR) is about 1.26 in the narrowband frequency range. The bandwidth, size and robust electrical peculiarities of this antenna make it accomplish for narrow-band implementations.**

Index Terms – Rectangular patch antenna, Ring shaped, DGS, Wireless communication, 2.4 GHz frequency band.

I. INTRODUCTION

In the modern era, the demand for Wireless Communication (WC) has grown substantially due to the widespread use of portable technology and the Internet of Things (IoT). A system's proficiency is greatly influenced by the quality of its antenna in WC. Amongst the abundant antenna varieties, MPA's are often preferred because of their ability to provide functionality in a small package low height and easiness of unification with abundant communication frameworks [1]. WC has changed the way we communicate with each other, allowing us to communicate and send data without a physical connection. The 2.4 GHz frequency band has become a widely used frequency in WC due to their cheaper cost, superior holding power, and synchronization with most of the electronic equipment's. 2.4 GHz WC has grown in space in the past time, giving many WC technologies like Wi-Fi, Bluetooth and Zigbee. This frequency spectrum is also mostly utilized for IoT equipment's due to its ability to broadcast data wirelessly over minimum required distances [2].It will provide an in-depth interpretation of WC in 2.4 GHz distinctive characteristics its perks, limitations and modern era prospects. The advice assigned in this article are useful to practitioners, engineers, and business professionals' involvement in the modernization and implementation of WC studies in the 2.4 GHz frequency coverage. An MPA with a Ring-shaped DGS is assigned for WC implications executing at 2.4 GHz frequency.

The assigned antenna's main objective is to achieve a wide bandwidth, superior gain, and low cross-polarization levels to ensure dependable WC. The DGS assimilated into the ground plane of the antenna effectively suppresses the surface wave propagation and improves the antenna's radiation proficiency. The assigned antenna's layout is analyzed using the finite element method-based electromagnetic artificial replication CST Studio. The artificial replication results establish that the assigned antenna declarations a huge bandwidth of 245 MHz and a superior gain of 5.53dBi, which are suitable for abundant WC implications.[3] The antenna which is performed proficiency is contrasted with conventional rectangular MPA, and the results establish the superiority of the assigned project in form of cross-polarization levels, gain, bandwidth and other related specifications.

This study presents a comprehensive inspection of the antenna, which is performed, its scheme and proficiency peculiarities for WC implications. The assigned antenna's compressed in size, huge bandwidth, and gain is superior which make it a suitable candidate for abundant WC frameworks. The rectangular MPA with Ring shaped DGS has gained substantial attention in the past times due to its unique draft and improved proficiency examined to conventional MPA. The Ring shaped with integrated with DGS composition mostly used to amplify the antenna's proficiency by restraining its surface wave propagation and build up the radiation peculiarities.

The current work antenna's MPA composition is made of a copper-clad dielectric substrate, which is supported by a Ring-shaped DGS assimilated into the base of the antenna i.e., ground. The Ring-shaped DGS contains concentric rings that are connected by slots to form a Ring shape. The Ring shape of the DGS composition helps to redundant of the size of the ground and help to get on peak position of the antenna's radiation proficiency by diminishing its surface wave propagation.

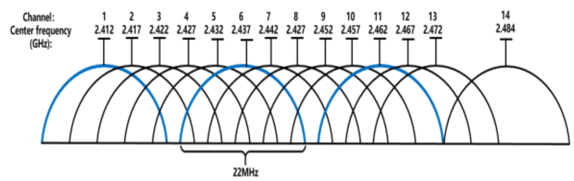

Fig.1 2.4GHz Frequency Domain [4]

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The assigned antenna's proficiency is analyzed on the basis of abundant parameters such as antenna lobe, impedance matching. The artificial replication results establish that the assigned antenna declarations of a huge range of bandwidth of 240 GHz, which takes control of the entire 2.4 GHz frequency spectrum. The antenna also declares a superior gain of 5.5 dBi and low cross-polarization levels, which are necessary peculiarities for dependable WC.

TABLE 1. 2.4GHz Frequency spectrum [5]

Frequency spectrum of operation (GHz)	Wavelength (cm)	Usage
2.4000 - 2.4765	12.5 - 12.0	Bluetooth, Wi-Fi, ZigBee, Cordless Phones, RFID
2.4040 - 2		IEEE 802.11 protocol
2.4000 - 2.4765	12.5 - 12.0	ISM Spectrum
2.4000 - 2.4765	12.5 - 12.0	Microwave Ovens
2.4000 - 2.4765	12.5 - 12.0	RC equipment's
2.4500	12.2	Wireless Charging

A. Defected Ground Structure (DGS)

DGS is a contemporary method utilized to peak the proficiency of microwave equipment, which includes MPA and separators. The formation is created by arranging slots or holes periodically on the ML's ground as its base, altering the electromagnetic characteristics of the ground in order to attain the intended improvement in efficiency. DGS is accessible for abundant applications like upgrading the bandwidth, redundant the volume of microwave separators, and suppressing spurious harmonics. In this current time, the interest is built in DGS due to cost efficiency, easy to manufacture, and Efficacy in amplifying the proficiency of microstrip parts and components. The objective of this research paper is to furnish a comprehensive overview of the present condition of DGS technology, encompassing its design, execution, and utilization in numerous areas.

B. Microstrip Patch Antenna (MPA)

Most of the time, MPA is used antenna in modern communication with the perks of low profile, light weight and easy unification with the network. It works on the principle of the electrical power of the antenna for patching. When electromagnetic waves occur on the surface, some of it is refracted and the remaining is reflected. The perks of MPA includes cost efficient, Portable and unification with project plans. They are commonly used in practices such as handheld phones, satellite broadcast, WLAN and RFID.

II. LITERATURE SURVEY

In the past time, there have been amplifications in the advancement of creative and invocation in antennas for WC. But evenly, some of these antennas still have shortcomings in terms of superior directivity and gain. In the literature, several practitioners have contributed to the field of antenna layout and interpretation. For instance, Ali et al. (2010) assigned the draft and inspection of an MPA with a DGS for WLAN application. Alam et al. (2014) assigned a compressed dual-band MPA with a DGS for 2.4 GHz and 5.8 GHz WLAN implications. [6-7] Chia et al. (2008) conceptualized a DGS for an MPA to improve RP and diminish back radiation. Kumar and Sarin (2018) developed a compressed square MPA with a DHS for Wi-Fi, WLAN implications. [8-9] Hosseini et al. (2015) conceptualized dual-band MPA with a DGS for WC implications at 2.4 GHz and 5.2 GHz.[7] These studies have established the effectiveness of using DGS to improve the proficiency of PA in abundant WC practices.

III. ANTENNA MODELING AND GEOMETRICAL FACTORS

First, the MPA is conceptualized with a length of approximately 60mm and width of 60mm on a FR-4 (attenuative) substrate with a relative permittivity of 4.4 and thickness of 1.6mm. The radiator is energized via a 50Ω coplanar waveguide. Subsequently, a circular shaped DGS is formed on the ground plane of the microstrip line. The DGS is comprised of a circular ring with an external radius of 8mm and internal radius of 4mm. Copper was chosen for its excellent conductivity and superior reactivity, which allows it to effectively distribute electrical energy. Additionally, copper is harder than materials such as silver or gold and is relatively affordable.FR-4 material is chosen as the substrate for drafting antennas because it is more cost-effective and has a higher tolerance for fabrication. The dimensions and location DGS are fine-tuned by use of the artificial replication software CST software. The ring DGS is found to substantially diminish surface wave generation and improve the antenna proficiency by increasing the NB band-width decreasing the S-parameters.

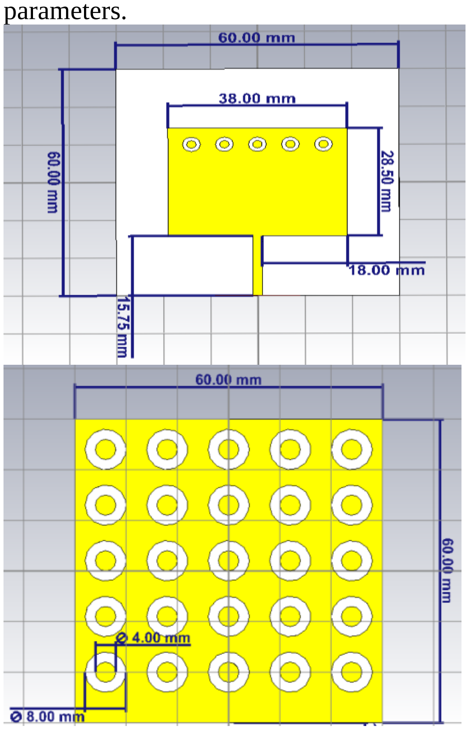

Fig 2. (a) slotted ring-shaped MPA
(b) assigned antenna with DGS composition at ground

The proportions of an MPA can be concluded using the below equations.
the breadth of the antenna is computed by [2]

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

Where,
ε_r = substrate dielectric constant
c = Light Speed
f_0 = fundamental frequency

Also,

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

h = depth
ε_{re} =effective relative permittivity

The effective length is estimated by using this formula

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Since, ΔL = length extension

Also,

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

Since, L = original length
The calculated dimensions of the antenna being considered are 60 x 60 x 1.6mm³.

TABLE 2 Measurements for the designated undertaking.

Expression	Proportions
x	60
y	60
t	0.035
h	1.6
x_1	38
y_1	28.5
xf	2
yf	-25
k	5
r_1	1.9
r_2	1
yl	0

IV. RESULT AND DISCUSSION

A. Return Loss (S11)

International Journal of Communication Systems and Network Technologies
ISSN-2053-6283

S11 is an important metric used in antenna layout to measure the efficiency of an antenna. It refers to the ratio of the power of the reflected signal to the power of the incident signal. Fig. 3 displays the virtualized S11 graphical representation of the outcome antenna formation using CST artificial replication. The output results indicate that the projected antenna establishes resonance at mainly three various frequencies, which are 2.34 GHz, 2.38 GHz, and 2.43 GHz, as shown in the resultant plot. The corresponding S11 values for these frequencies are -10.01 dB, -29.80 dB, and -10.12 dB. The bandwidth of the fundamental frequency spans from 2 GHz to 2.8 GHz. All these specifications are showed in the S11 graphical representation.

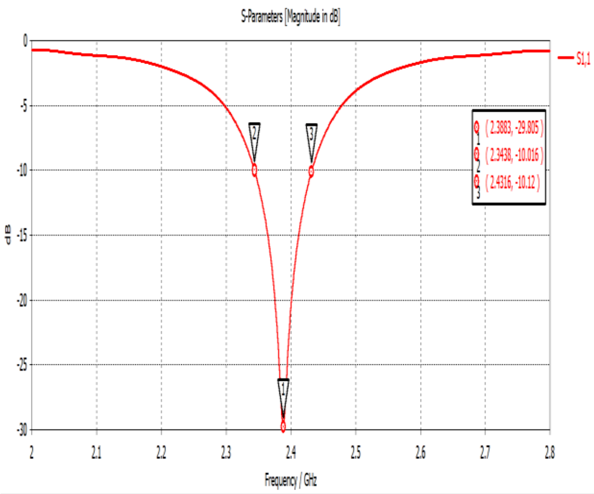

Fig. 3. S11 parameters of the projected study

B. Voltage Standing Wave Ratio (VSWR)

VSWR is determined by dividing the highest voltage by the lowest voltage of the standing wave arrangement that takes place on a transmission line. A higher VSWR value indicates a greater degree of signal reflection, which can result in diminished efficiency and proficiency of the system. Its spectrum should be between 1-2 Based on the interpretation conducted on the conceptualized antenna, it was found that the VSWR for 2.4 GHz frequency is 1.26.

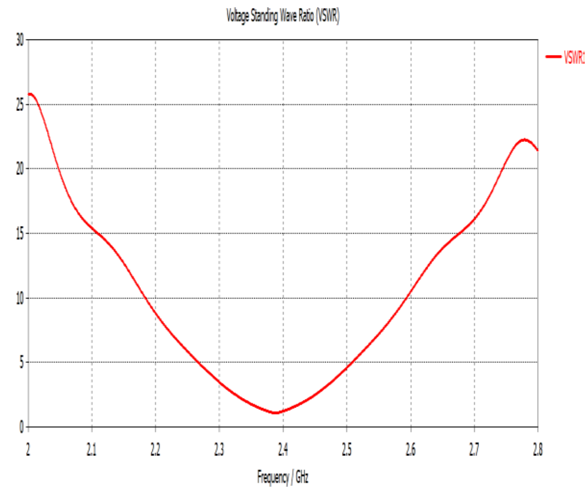

Fig. 4. VSWR graphical representation of current study

C. Directivity and Gain

Directivity is a measure of how well an antenna focuses energy in a particular direction. It is the ratio of the radiation intensity of an antenna in a particular direction to the average radiation intensity of the antenna. Directivity is a dimensionless quantity, often expressed in dB. Gain can be described as the measure of the effectiveness of an antenna in transmitting or receiving electromagnetic radiation in a specific direction, when compared to the radiation transmitted or received by a theoretical isotropic antenna. Based on the artificial replication results, the assigned scheme declarations a gain of 5.53 dBi and directivity of 6.57 dB at 2.4 GHz frequency.

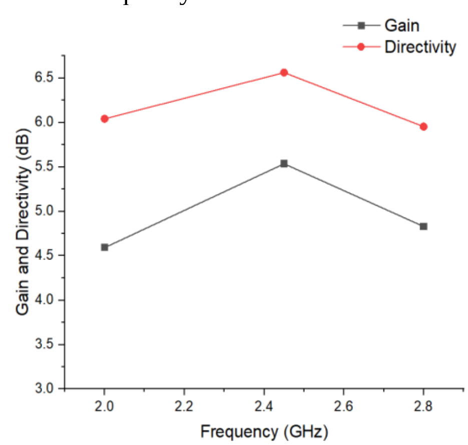

Fig. 5. directivity, gain graphical plot representation projected study

D. Total Efficiency (TE) and Radiation Efficiency (RE)

RE can be described as the ratio of the power radiated by the antenna to the total input power supplied to the antenna. A higher RE value indicates that a greater

proportion of the energy supplied to the antenna is converted into useful radiation. TE can be described as the ratio of the power radiated by the antenna to the total input power, including the power loss in the resistive and reactive components of the antenna thread.
After analyzing the artificial replication outputs, it can be concluded that at a frequency of 2.4 GHz, the RE is 97% and the TE is 96%.

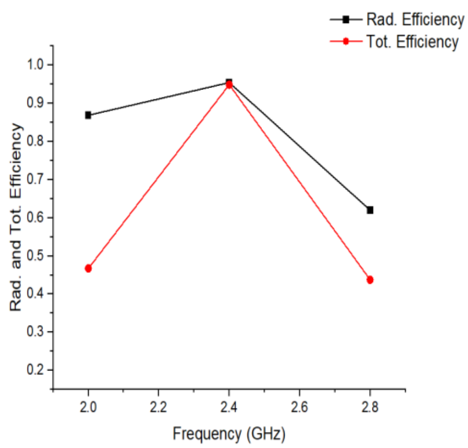

Fig. 6. RE and TE graphical plot representation current study

E. Radiation Pattern (RP)

The RP of an antenna is a graphical representation of the directional properties of the antenna's radiation. It explains how the radiated energy is divided in space as a function of direction. The virtualized far-field RP of the assigned antenna at the fundamental frequencies is assigned in Fig.7, phi equals to 90°. The RP declaration robust and omnidirectional properties, denoting that the antenna is capable of radiating in all directions with equal efficiency.

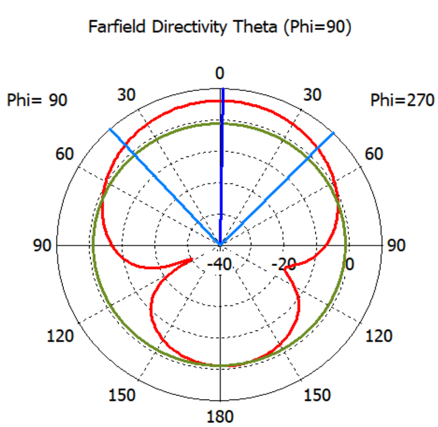

Fig.7. Far-field RP Diagram

E. Analysis of current study with prior research

Evaluated to a normal MPA, ring-shaped MPAs gives several merits. The orbicular geometry with a orbicular slot in the middle introduces extra produced resonances, allowing for multiband and wideband use. The slot also helps decrease the size of the antenna and boosts its conducting bandwidth. The ring-shaped MPA are also less sensitive to the stoutness of the substrate, making them easier to manufacture and more permissive to manufacturing failures. Their low profile and small size make them acceptable for unification into abundant equipment's and frameworks. However, analyzed to MPA, ring-shaped MPA can be more challenging to plan and optimize due to their complex geometry and abundant resonances. Given below table presents a inspection of the proficiency of the basic Ring shaped MPA in proceeding works with the consequence draft.

TABLE 3 proficiency Analysis of current study with prior research

S.No.	**Antenna Structure**	**Feeding Apparatus**	**Gain/TE**	**Rfr.**
1.	Slotted Square MPA	Coaxial probe feed	4.2dBi/85%	[2]
2.	orbicular MPA	Microstrip feed	4.9dBi/88%	[5]
3.	Triangular MPA with DGS	Microstrip feed	5.2dBi/92%	[7]
4.	Hollow curved Elliptical MPA	Coaxial probe feed	5dBi/90%	[11]
5.	Cross-shaped MPA DGS	Coaxial probe feed	4.8dBi/83%	[13]
6.	**Ring-shaped MPA with DGS**	**Microstrip feed**	**5.53dBi/97 %**	**Prpsd.**

V. CONCLUSION

Assigned conceptualized of ring-shaped MPA with DGS manages at a fundamental frequency of 2.4 GHz with a bandwidth of 8 GHz. It declares a gain of 5.53 dBi, directivity of 6.57 dB, and a superior RE of 97%. The RP is omnidirectional and robust. This antenna model has abundant practices in WC frameworks such as WLAN, WiMAX, RFID, and satellite communication frameworks. It can also be used in handheld and portable equipment's, wireless sensor networks, and radar frameworks.

ACKNOWLEDGMENT

The first author wishes to express their gratitude to the Rajasthan Technical University in Kota, India, for their assistance during the research project and the drafting of the paper.

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