Study on Defected Ground Structure Models with Miniaturized Patches for Broadband Communication

by Yus Natali

Study on Defected Ground Structure Models with Miniaturized Patches for Broadband Communication

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***Abstract*— This study proposes the defected ground structure mechanism and improves the antenna properties. Three DGS models are discussed: two models of a single antenna and one model of an array microstrip antenna design. The microstrips are designed for broadband communication frequencies: 2.1 GHz (5G Technology) of a single antenna, and 5.8 GHz (Wireless Local Area Network) of an array antenna. These frequencies are achieved using three shapes of DGS in the simulations and the results are convenient for broadband criteria. The antenna patches are rectangular with two types of DGS, and an array circular with one type of DGS. The results show the DGS gives better bandwidth and gain for a single antenna. Nevertheless, DGS performs gain enhancement for an array antenna and this design gives the miniaturized array antenna of 69.92% and 73.47% in width and length. The three shapes of DGS have different designs, nonetheless, the slot on the DGS with the front side of the patch provides enhancements in antenna performance than other design. Rectangular patch antenna with frame-shaped DGS and array circular antenna with rectangular slots of DGS give bandwidth of 533 MHz and 327 MHz. The single antenna improves the fractional bandwidth of 25.38% with miniaturized patch. Nonetheless, the array circular antenna with DGS obtains a gain enhancement of 16 dB than the initial array without DGS.**

***Keywords*— microstrips antenna, defected ground structure, resonant frequency, impedance bandwidth, gain, miniaturized patch**

I. Introduction

Engineered ground planes is eminent as defected ground structures (DGS), and have evolved from (electromagnetic band-gap) EBG structures [1]–[3]. DGS alters the electrical characteristics of a microstrip transmission line or any other similar structure, affecting the behavior of microstrip antennas [4]. Moreover, DGS is widely used in designing antenna, filter, integrated circuits, and so on. DGS for filter design are discussed in [5]–[10]. A CMOS with DGS for low-phase noise is discussed in [11].

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In paper [12] presents a design approach for transforming an L-shaped stub into a U-shaped stub antenna using DGS. The models give fractional bandwidth of 5.7% and 1.7% for resonant frequencies of 3.5 GHz and 5.8 GHz. A fractional bandwidth of 7 % is discussed in [7] and the DGS model can cancel the harmonics frequencies. A modified antenna using DGS and diodes are performed in [13] and gives a fractional bandwidth of 20.1%. A bow-tie antenna using DGS gives a fractional bandwidth of 13.37% is discussed in [14]. A model of DGS design to reduce cross-polarized is performed in [15]. A super fractional bandwidth of 183.17% is achieved in [16] using DGS. In [17], a monopole circular patch is investigated, exhibiting an impedance bandwidth of 8.1%. Furthermore, at frequencies of 2.9 GHz and 9.1 GHz, the antenna demonstrates enhanced gains of 8.4 dBi and 8.2 dBi, respectively. These findings emphasize the antenna's improved performance characteristics across a wide frequency range. The study in [18] investigates the integration of an Edge-Located Electromagnetic Bandgap (EL-EBG) structure with a DGS, emphasizing their combined effects on noise. However, the specific characterization of fractional bandwidth is not explicitly addressed in this context. The research described in [19] focuses on the implementation of multiple gradual semicircle-shaped DGS incorporated into the rear end of the antipodal Vivaldi antenna. The utilization of these DGSs resulted in a fractional bandwidth of 15.63% and an enhancement in gain, specifically an increase of approximately 2 dB.

A Multiple-Input Multiple-Output (MIMO) antenna is proposed in [20] and minimized the mutual coupling effect between antenna pairs. A symmetrical pyramidal antenna design employing MIMO techniques and incorporating DGS is introduced in [21]. The antenna is optimized for operation at 7.5 GHz, demonstrating a fractional bandwidth of 116%. The study in [22] presents a comprehensive examination of innovative techniques employed in the design of omnidirectional patch antenna, focusing on achieving omnidirectionality in the H-plane through the incorporation of a DGS. The investigation reveals the results, including a fractional bandwidth of 5.51% and a gain of 2.3 dB, demonstrating the effectiveness of the proposed design. The MIMO antenna design incorporating DGS is discussed in [23]. The antenna design exhibits favorable characteristics, including isolation and circular polarization gain across the entire frequency band of 3.4 GHz to 3.8 GHz, with a gain of 5 dB. Additionally, the MIMO antenna achieves a fractional bandwidth of 11.43%, indicating its suitability for broadband communication applications.

An impedance bandwidth of 33.85% is discussed in [24] for an array antenna with DGS. To validate the efficacy of a surrogate-assisted DGS in [25], a 2×2 array of microstrip antennas is employed as a test case. The investigation confirms the utility of the surrogate-assisted DGS approach, yielding a minimum fractional bandwidth of 28.57%.

These references [7], [12], [23]–[25], [14]–[16], [18]–[22] do not discuss the miniaturize or enlargement of the patches or substrates after the DGS implement on the antenna. In this study, a DGS impact on the antenna dimension point of view is discussed. The essential objective of this study is to provide insight for designing single and array microstrip antennas using DGS.

DGS design will affect the antenna properties, distinctively the resonant frequency. This paper discussed the DGS impact on resonant frequency and the solution to obtain the target of the resonant frequency. To obtain the resonant frequency of the antenna, there must be a dimension changing on substrate or patch or feedline. The single antenna is designed by adding the substrate dimension to obtain 2.1 GHz. While the array antenna is miniaturized in patches and substrates to obtain 5.8 GHz. The results are convenient the resonant frequencies and broadband antenna properties.

II. The Single and Array Antenna Design

The use of a substrate composed of a four-level epoxy resin and glass fabric compound reinforced with a flame retardant (FR) material is a commonly implemented solution in the industry.

Commonly substrate is an FR (flame retardant) with four levels of epoxy resin and glass fabric compound. The detailed characteristics of this material are shown in Table 1. The antennas are designed using FR-4 in the simulations. The process of this study is shown in Fig. 4. The first initial antenna design is a rectangular patch antenna for a resonant frequency of 2.1 GHz. The second is an array 2x1 circular patch antenna for 5.8 GHz. The detailed substrate characteristics are performed in Table 1.

The process of this study is shown in Fig 1. LTE has several frequencies for its networks, and the resonant frequencies of 2.1 GHz for downlink communication in LTE networks and unlicensed LTE of 5.8 GHz are chosen. The first step is designing each antenna mathematically based on the resonant frequency requirement and material characteristics. This step gives the initial antenna dimensions. Furthermore, the antenna designs are simulated using CST software and the modified ground plane to obtain optimized antenna requirements. For a single antenna, a rectangular is modified using two types of DGS. The first shape is a frame of DGS, and the second is a rectangular of DGS. While for the array antenna, the antenna characteristic is optimized using one shape of DGS. The circular array antenna is designed using two rectangular slots-shaped of DGS.

TABLE I. Antenna Substrate Specifications

Antenna Parameter	Unit
Substrate Type	FR-4 epoxy
Relative Dielectric Constant, ε_r	4.3
Loss Tangent Dielectric, δ	0.0265
Substrate Height, h	1.6 mm

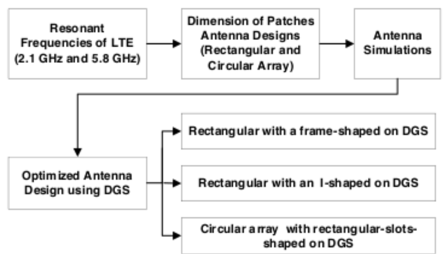

Fig. 1. Study process of DGS

A. Rectangular Patches Antenna Design

The rectangular microstrip is designed for a resonant frequency of 2.1 GHz. A rectangular microstrip has a width, W and length, L and can be designed using (1) and (2) [2].

$$W = \frac{v_o}{2f_r\sqrt{\frac{2}{\varepsilon_r+1}}} \quad (1)$$

$$L = \frac{v_o}{2f_r\sqrt{\mu_o\varepsilon_o}\sqrt{\varepsilon_{reff}}} \quad (2)$$

The effective dielectric constant of the patch, ε_{reff} is calculated using (3).

$$\varepsilon_{reff} = \left(\frac{1}{\sqrt{1+\frac{12d}{w}}}\right)\frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2} \quad (3)$$

The front and the rear view of rectangular antenna are shown in Fig. 2 and Fig. 3. The rectangular patch has a width (w) of 44 mm and length (l) of 33 mm, inclusive a width of feedline of 3mm and length of 16.61 mm. The detail patch rectangular antenna design is performed in Fig 2.

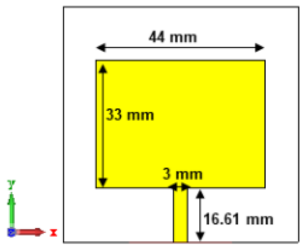

Fig. 2. Front view of a rectangular antenna

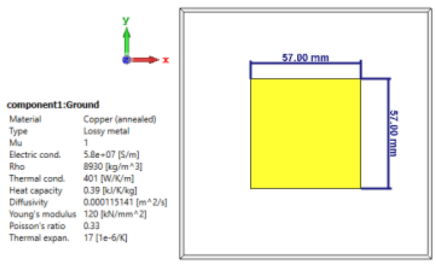

Fig. 3. Rear view of the rectangular antenna without DGS

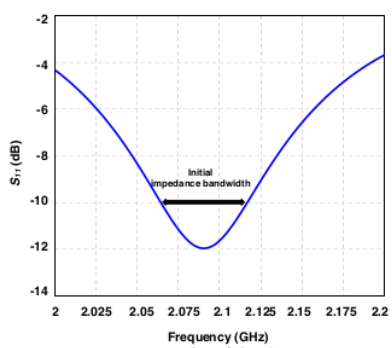

Figure 4. The initial impedance bandwidth of rectangular antenna

Fig. 3 is the initial ground plane design with its dimension of 57 mm for width and length and the same size of its substrate. Thus far, the antenna is not optimized at initial design, nevertheless the resonant frequency is achieved.

The initial rectangular antenna, depicted in Fig. 4, has an impedance bandwidth of 52 MHz. However, this bandwidth does not meet the requirements of LTE applications. Consequently, this study endeavors to optimize the antenna design using software simulations to obtain a suitable impedance bandwidth for LTE.

Array Patches Antenna Designs

The 2x1 array microstrip antenna design consists of two circular patches. The antenna are designed for 5.8 GHz with the circular patches radius, a are calculated using (4).

The F parameter is design using (5) so the circular patch radius, a is 58.59 mm.

$$a = \frac{F}{\left\{1+\frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad (4)$$

$$F = \frac{8{,}794\, x\, 10^9}{f_r \cdot \sqrt{\varepsilon_r}} \quad (5)$$

The array element has a distance of d, and can be calculated using (6).

$$d = \frac{\lambda}{2} \quad (6)$$

The front view of rectangular antenna is shown in Fig. 5 and the ground plane without DGS. The substrate has dimension width of 250 mm and length of 205 mm. Each circular patch has a diameter of 58.59 mm and an inner circular slot of 40 mm diameter. A feedline is connected to the circular patches at the middle point of the patches. The feedline separates the antenna in 131.65 mm for the inner feedline and it has a width of 5.8 mm.

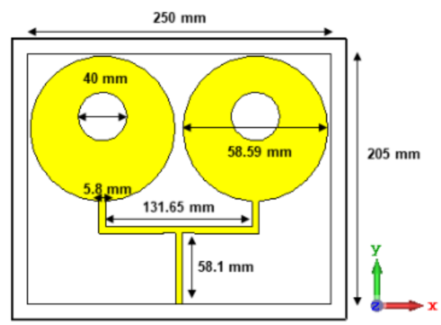

Figure 5. Front view of a circular array antenna

III. DGS Design

The results of DGS design could be found in this section, nevertheless, the ground structure designs change the antenna characteristics. In order to achieve the resonant frequencies, the patches or feeds or substrate dimensions are changed.

The rectangular patch antenna is designed using two shapes of DGS. The first rectangular antenna is design for frame-shaped, and subsequently rectangular-shaped DGS. While the circular array antenna is design using one shaped DGS: two rectangular slot shaped designs.

A. Rectangular Patch Antenna with frame-shaped of DGS

The substrates of this design are widened of 0.47 mm from the initial design. The outer of frame-shaped of DGS has the same width of its substrate, 57.47 mm, whereas the inner boundary of 41.57 mm and 31.1 mm. Nevertheless, the rectangular patch is constantly the same as the initial design. Detail of frame-shaped is shown in Fig. 6. The frame-shaped DGS provide a resonant frequency of 2.1 GHz. The magnitude of the reflection coefficient, S_{11} is -23 dB at the resonant frequency. It has an impedance bandwidth of 533 MHz, which is shown in Fig.7.

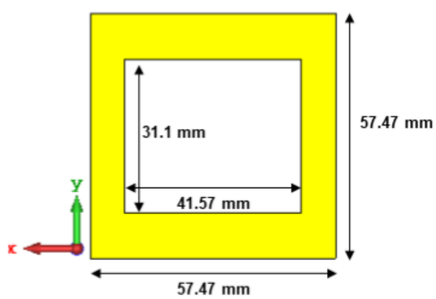

Fig.6. Frame-shaped DGS design

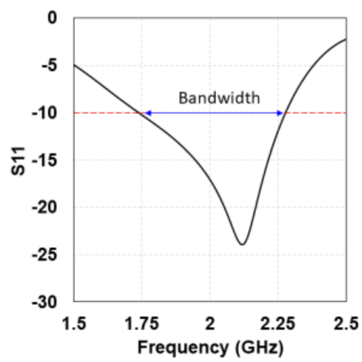

Fig.7. S_{11} of frame-shaped DGS

B. Rectangular Antenna with Rectangular Slot-Shaped DGS

The second DGS design is two slots on edge side of the ground. The ground plane is exactly behind the patch in rear view. This detail design is shown in Fig.8. Generally, the size of this design is enlarged of 22[illegible]% from the initial design, in order to obtain the resonant frequency of 2.1 GHz. The ground plane has a width of 34 mm and a length of 70 mm. The rectangular slot-shaped of DGS gives impedance bandwidth of 118 MHz. It is shown in Fig.9.

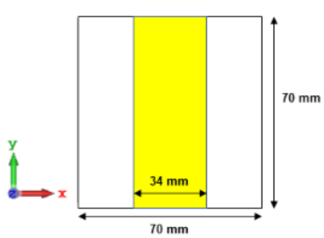

Fig.8. Rectangular-shaped DGS design

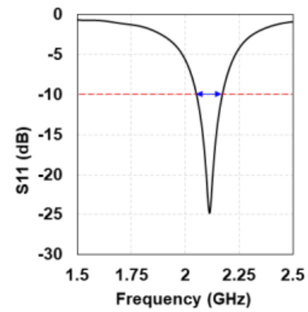

Fig.9. S_{11} rectangular-shaped DGS

C. Array Circular Antenna with Rectangular Slots of DGS

The initial design of ground plane has a width of 250 mm and a length of 205 mm. The ground plane is modified using two rectangular slots of DGS. In order to obtain the resonant frequency of 5.8 GHz, the size of the antenna is minimized. The miniaturized antenna has a dimension of 75.20 mm x 54.93 mm, detail of DGS is shown in Fig. 10. Two slot of DGS is at the back side of the patches. The front view of array circular antenna is shown in Fig.11. The circular slots on the patches are shifted towards the top edge of patches. The result of this modified antenna gives a suitable antenna performance for LTE. The impedance bandwidth is obtained of 327 MHz and shown in Fig.12.

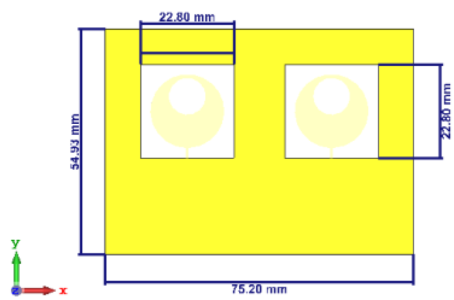

Fig.10. Rectangular slots-shaped DGS design

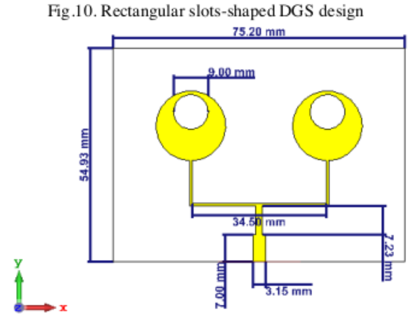

Fig.11. The Front view of array circular antenna

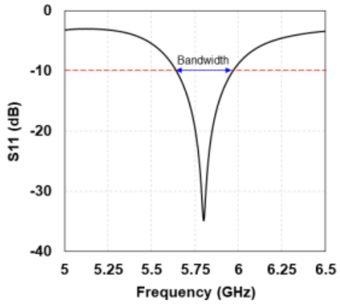

Fig.12. S_{11} rectangular slots-shaped DGS

IV. Result and Discussion

This section discusses the antenna performance former and after using DGS.

A. Antenna with DGS

The results of rectangular DGS models are performed in Table 1. Table 1 shows the rectangular antenna properties in detail. The rectangular with frame-shaped DGS is the better than the rectangular-shaped DGS. The impedance bandwidth of frame-shaped DGS obtains 533 MHz, this is 9.25 times wider than the initial rectangular antenna without DGS. The fractional bandwidth of this model achieves 25.38% and its gain reaches 3.24 dB. These properties are improved from the initial rectangular antenna without DGS. The rectangular patch design is minimized from the initial. Nevertheless, the minimized rectangular patch obtains gain enhancement about 1.2 dB from the initial design. The rectangular with frame-shaped DGS is shown in Fig. 13.

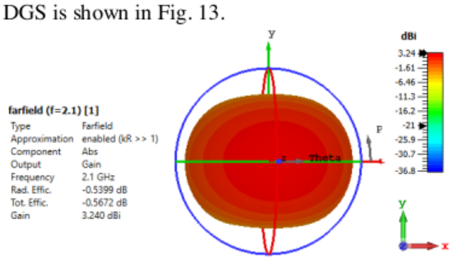

Fig.13. Gain of Rectangular with frame-shaped DGS

TABLE 3. Rectangular Antenna

Antenna Properties	Design		
	Rectangular	***Rectangular with frame-shaped DGS***	***Rectangular with rectangular-shaped DGS***
Impedance Bandwidth	52 MHz	533 MHz	118 MHz
Gain	2.44 dB	3.24 dB	3.3 dB
Fractional Bandwidth	2.48%	25.38%	5.62%
Antenna dimension	57 x 57 mm	57.47 x 57.47 mm	70 x 70 mm
Patch design	44 x 33 mm	41.57 x 31.1 mm (miniaturize)	44 x 30 mm (miniaturize)

The antenna properties of circular array antenna are performed in Table 2. Circular array with rectangular slots of DGS gives better gain than the initial design. Moreover, this model is miniaturized in width and length of 69.92% and 73.47%, nonetheless the antenna gain is improved up to 16 dB. The gain of circular array with rectangular slots of DGS antenna is shown in Fig. 14.

TABLE 2. Circular Array Antenna

Antenna Properties	Design	
	Circular Array	***Circular Array with Rectangular Slots of DGS***
Resonant Frequency	5.85 GHz	5.8 GHz
Impedance Bandwidth	497 MHz	327 MHz
Fractional Bandwidth	8.57 %	5.64%
Gain	-11.14 dB	5.34 dB
Gain improvement	-	16.48 dB
Antenna dimension	250 x 205 mm	75.2 x 54.39 mm (miniaturize)
Patch design	58.59 mm circle diameter	18 mm circle diameter (miniaturize)

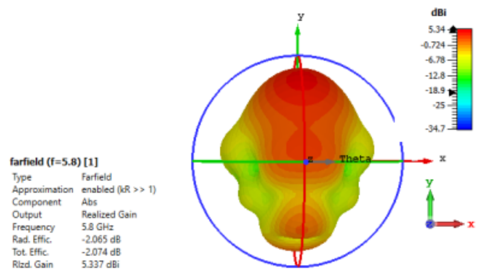

Fig.14. Gain of circular array with rectangular slots of DGS

According to the antenna properties with DGS, for better performance in impedance bandwidth or gain can be achieved using slot of DGS on the back side of patches. The rectangular with frame-shaped DGS is model using rectangular slot at the back side of its patch and gives more widen impedance bandwidth. Meanwhile, the circular array with rectangular slots of DGS gives a gain improvement in miniaturized antenna. These two models of DGS have the same concept of DGS design, to put a slot at the back side of its patches.

B. Feasibility DGS Models with Others

The rectangular with frame-shaped DGS reaches the fractional bandwidth of 25.38% and this value is better than the fractional bandwidth in [7], [12]–[14], [20]. For a resonant frequency of 5.8 GHz, the circular array with rectangular slots of DGS is better than [12] in the fractional bandwidth.

V. Conclusion

A point of view in designing a DGS models are performed in this study. The ground plane at the back side of the patches should be with slot of DGS to perform more widen bandwidth or gain than the full ground plane. The rectangular antenna with frame-shaped of DGS improves almost ten times of the fractional bandwidth. The array antenna enhances the antenna gain of 16 dB using DGS. The miniaturized patch antenna with DGS can achieve the broadband criteria.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All the authors have contributed to this work. Riva, Yosi and Yus designed the antenna. Riva and Yosi simulated the program and optimized the antennas' parameters. Yus analysed the simulation and wrote the paper. Dian, and Dwi analysed the data and reviewed the paper. Yudi and Catur reviewed the paper to final version. All the authors approved the final version of paper.

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References

[1] B. Dwivedy, "Consideration of Engineered Ground Planes for Planar Antennas: Their Effects and Applications, a Review," *IEEE Access*, vol. 10, no. July, pp. 84317–84329, 2022.
[2] C. A. Balanis, *Antenna Theory Analysis and Design*. 2016.
[3] R. S. Elliott, *Antenna theory & design*. 2003.
[4] M. K. Khandelwal, B. K. Kanaujia, and S. Kumar, "Defected ground structure: Fundamentals, analysis, and applications in modern wireless trends," *Int. J. Antennas Propag.*, vol. 2017, 2017.
[5] Y. H. Chen and C. N. Chiu, "An Ultrawideband Bidirectional Absorptive Common-Mode Filter With All-Pass Signal Transmission," *IEEE Access*, vol. 10, pp. 50000–50007, 2022.
[6] X. Luo, J. G. Ma, and E. P. Li, "Hybrid microstrip/DGS cell for filter design," *IEEE Microw. Wirel. Components Lett.*, vol. 21, no. 10, pp. 528–530, 2011.
[7] T. Huang, H. Liu, C. Guo, L. Feng, and L. Geng, "3-D Printed mm-Wave Filter Using Increased-Height DGS Resonator for Spurious Suppression," *IEEE Trans. Circuits Syst. II Express Briefs*, vol. 69, no. 11, pp. 4293–4297, 2022.
[8] K. Z. Hu, B. C. Guo, S. Y. Pan, D. Yan, M. C. Tang, and P. Wang, "Low-Profile Single-Layer Half-Mode SIW Filtering Antenna With Shorted Parasitic Patch and Defected Ground Structure," *IEEE Trans. Circuits Syst. II Express Briefs*, vol. 70, no. 1, pp. 91–95, 2023.
[9] D. Tang and X. Luo, "Compact Filtering Balun with Wide Stopband and Low Radiation Loss Using Hybrid Microstrip and Substrate-Integrated Defected Ground Structure," *IEEE Microw. Wirel. Components Lett.*, vol. 31, no. 6, pp. 549–552, 2021.
[10] S. K. Tseng, C. N. Chiu, Y. C. Tsao, and Y. P. Chiou, "A Novel Ultrawideband Absorptive Common-Mode Filter Design Using a Miniaturized and Resistive Defected Ground Structure," *IEEE Trans. Electromagn. Compat.*, vol. 63, no. 1, pp. 66–73, 2021.
[11] B. Chen, R. K. Pokharel, S. K. Thapa, N. Jahan, and A. Barakat, "Design of 50-GHz Low Phase Noise VCO Employing Two-Branches DGS Resonator in 0.18-µm CMOS Technology," *IEEE Microw. Wirel. Components Lett.*, vol. 32, no. 10, pp. 1203–1206, 2022.
[12] C. Chen, Yifan Mao ; Songtao, Guo ; Menggang, "Compact dual-band monopole antenna with defected ground plane for Internet of things," *IET Microwaves, Antennas Propag.*, vol. 12, no. 8, pp. 1332 – 1338, 2018.
[13] Y. Liu *et al.*, "A Pattern-Reversal Wideband Antenna Integrating Metal Rings, Diodes-Loaded Stubs and Defective Ground," *IEEE Open J. Antennas Propag.*, vol. 3, no. July, pp. 722–731, 2022.
[14] D. W. Astuti, R. Fadilah, Muslim, D. Rusdiyanto, S. Alam, and Y. Wahyu, "Bandwidth Enhancement of Bow-tie Microstrip Patch Antenna Using Defected Ground Structure for 5G," *J. Commun.*, vol. 17, no. 12, pp. 995–1002, 2022.
[15] D. Kumar, Candrakanta; Guha, "Communications Asymmetric Geometry of Defected Ground Structure for Rectangular Microstrip : A New Approach," *IEEE Trans. Antenna Propag.*, vol. 64, no. 6, pp. 2503–2506, 2016.
[16] M. Ayyappan and P. Patel, "On Design of a Triple Elliptical Super Wideband Antenna for 5G Applications," *IEEE Access*, vol. 10, no. July, pp. 76031–76043, 2022.
[17] D. Gopi, A. R. Vadaboyina, and J. R. K. K. Dabbakuti, "DGS based monopole circular-shaped patch antenna for UWB applications," *SN Appl. Sci.*, vol. 3, no. 2, pp. 1–12, 2021.
[18] Y. Chang, N. Li, J. Zhao, Y. Wang, and Z. Yang, "A Novel Ultrasonic Guided Wave-Based Method for Railway Contact Wire Defect Detection," *IEEE Trans. Instrum. Meas.*, vol. 71, 2022.
[19] S. Zhu, H. Liu, P. Wen, Z. Chen, and H. Xu, "Vivaldi Antenna Array Using Defected Ground Structure for Edge Effect Restraint and Back Radiation Suppression," *IEEE Antennas Wirel. Propag. Lett.*, vol. 19, no. 1, pp. 84–88, 2020.
[20] S. Nej, A. Ghosh, S. Ahmad, J. Kumar, A. Ghaffar, and M. I. Hussein, "Design and Characterization of 10-Elements MIMO Antenna With Improved Isolation and Radiation Characteristics for mm-Wave 5G Applications," *IEEE Access*, vol. 10, no. October, pp. 125086–125101, 2022.
[21] P. Kumar *et al.*, "Design of a Six-Port Compact UWB MIMO Antenna with a Distinctive DGS for Improved Isolation," *IEEE Access*, vol. 10, no. October, pp. 112964–112974, 2022.
[22] M. Kim and S. Ahn, "Analytical Approaches for Effects of Edge-Located EBG Structure With Defected Ground Structure on Cavity-Mode Resonances of Power/Ground Planes," *IEEE Trans. Microw. Theory Tech.*, vol. 70, no. 12, pp. 5405–5417, 2022.
[23] S. Chakraborty, M. A. Rahman, M. A. Hossain, A. T. Mobashsher, E. Nishiyama, and I. Toyoda, "A 4-element MIMO antenna with orthogonal circular polarization for sub-6 GHz 5G cellular applications," *SN Applied Sciences*, vol. 2, no. 7. 2020.
[24] B. Maity and S. K. Nayak, "Compact Quad-Band CP Series-Fed Circular Slit Microstrip Array Antenna Using Machine Learning," *IEEE Access*, vol. 10, no. June, pp. 116650–116661, 2022.
[25] B. Qian, X. Huang, X. Chen, M. Abdullah, L. Zhao, and A. Kishk, "Surrogate-Assisted Defected Ground Structure Design for Reducing Mutual Coupling in 2 × 2 Microstrip Antenna Array," *IEEE Antennas Wirel. Propag. Lett.*, vol. 21, no. 2, pp. 351–355, 2022.

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Dian Widi Astuti was born in Jakarta, Indonesia. She received the B. Eng and M. Eng from Universitas Mercu Buana, Jakarta-Indonesia, while her Ph. D degree from Universitas Indonesia in 2022. Since 2012, she has been a lecturer and joint electromagnetic and telecommunication Laboratory in the Universitas Mercu Buana, Jakarta. Her current research interest include microwave, millimeter-wave passive components design. She has involved in the 2019 IEEE International Conference on Antenna Measurement Applications (CAMA), Bali, in October 2019 as Secretary.

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