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Improving the Performances of Microstrip Antenna Array using Defected Ground Structure

Pratistha Brahma, Banani Basu

Abstract: ***In this paper, a two elements antenna array with defective ground structure (DGS) has been designed to achieve significant gain, polarization purity and reduced mutual coupling. A 3 port Wilkinson power divider has been designed at 4.5 GHz frequency to obtain equal power distribution at the output ports. Two Rectangular microstrip patch antennas with DGS at the corners yield improved gain, impedance matching and polarization purity in both E and H plane. The reduction of mutual coupling and side lobe level (SLL) have been achieved by placing the dumbbell shaped DGS bellow the feed line of the power divider. The radiation performances obtained using the fabricated prototype agrees well with that of the simulated one. This array has been designed for C-band application.***

Keywords : Wilkinson Power Divider (Wpd), Defective Ground Structure (Dgs), Gain, Mutual Coupling, Sll.

I. INTRODUCTION

Antenna arrays have an important role in communication system. It is an arrangement of multiple antennas electronically interconnected with each other. Numerous advantages of microstrip antenna such as low cost, light weight, compatibility in MMIC circuits, it is widely implemented in antenna array design for wireless communication system. In an array system, power dividers are commonly used for equal or unequal power distribution from a single external power supply to all the antennas of the system. Wilkinson Power Divider (WPD) is the mostly used power divider for a microwave circuit. Apart from being low cost, WPD has two additional important characteristics: isolated output ports and matched all ports. A broadband WPD has been reported by Tiku Yu in [1]. In article [2], authors have proposed an N-port WPD with physical output separation. Miniaturization of unequal WPD has been reported in [3-4]. Miniaturization of WPD using Defective Ground Structure (DGS) in [5]. DGS are basically geometrical slots imposed on the ground surface of an antenna. A triple band circularly polarized compact antenna with DGS has designed in [6].

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Articles [7-9] have presented microstrip patch antennas with DGS to improve polarization purity. Rashmi A. Pandhare *et al*. have proposed miniaturized microstrip antenna array with DGS to enhance gain [10].

Article [11] has presented a Novel Stacked Patch Array Antenna with DGS for S band and C band applications. A compact multiband MIMO antenna design has been approached in [12] with high isolation using DGS for C and X band applications. [13] has proposed an antenna array with DGS to reduce mutual coupling (MC) between elements . [14] has proposed antenna arrays with DGS to achieve improved gain and CP-XP isolation. In [15], hexagonal DGS has been applied in a three elements antenna array to minimize the higher order modes. To improve the rejection characteristics of the DGS, the shape of the DGS has been optimized using Genetic algorithm.

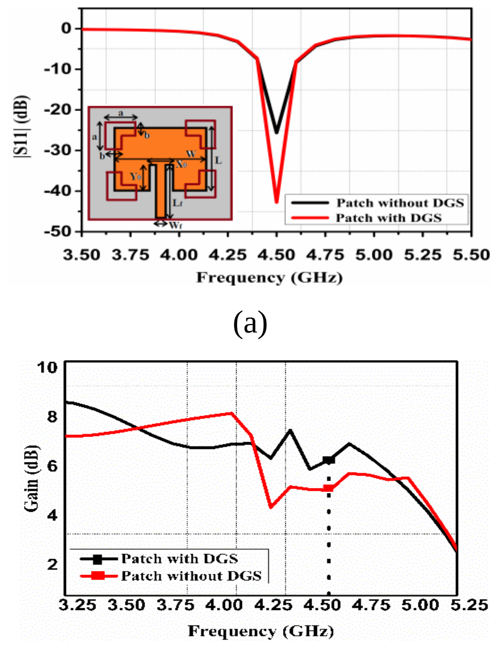
The article proposes a 2 elements rectangular patch antenna array at 4.5 GHz. A three port Wilkinson power divider has been designed to feed the patches with DGS to increase the gain and minimize X-polarized radiation. Two dumbbell shape DGS have been placed along the microstrip line of the power divider to reduce the mutual coupling. The performance of the array has been studied without and with the placement of DGS and the reflection coefficient, gain, mutual coupling (MC), co polarization and cross polarization and sidelobe level (SLL) results have been evaluated Performance of the fabricated prototype of the array closely follow the simulated one.

II. SIMULATION ENVIRONMENT

A. *Rectangular microstrip patch antenna with DGS*

In this work, we have considered a two-element antenna array. First, we have designed a single patch with dimension of the substrate 60 mm × 50 mm × 1.52mm. Square shape DGS has been placed at four corners of the patch as shown in Fig.1 (a). The optimized dimensions of the patch with DGS are shown in Table 1.

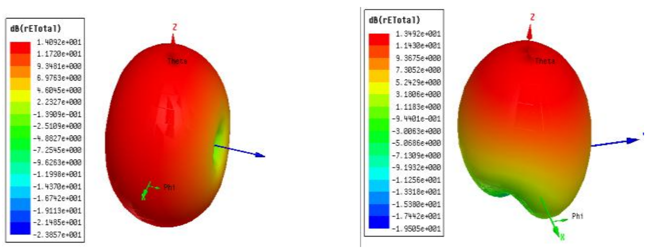
Fig.1 (a) represents S11 for conventional patch and patch with DGS at 4.5 GHz operating frequency. S11 for conventional patch with and without DGS is found at -22 dB and -42.5 dB respectively. As in Fig.1. (b) the gain of conventional patch offers 5.62 dB gain and the proposed patch with DGS offers 6.08 dB gain, both at 4.5 GHz. The square shape DGSs are placed at the radiating edges of the patch as it disturbs the current concentration on the ground and concentrates the total current at the center of the patch which provides significantly increases the gain of the antenna [10-11].



(a)

(b)

Fig.1 (a) S11 (b) Gain of RMPA with DGS and conventional patch without DGS



(a) (b)

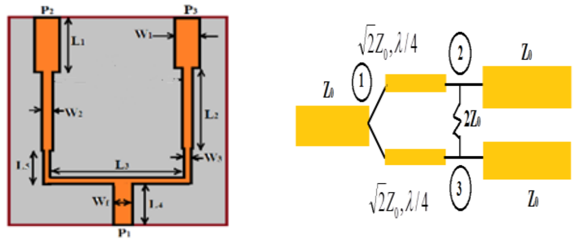
Fig.2 Radiation pattern of single patch (a) without DGS (b) with DGS

Fig. 2 (a) and (b) show the radiation pattern of single miocrostrip patch without DGS and with DGS respectively. Without DGS, the pattern indicates an non- directional pattern of the patch whereas with DGS, the pattern is significantly directional

B. *2:1 Wilkinson Power Divider*

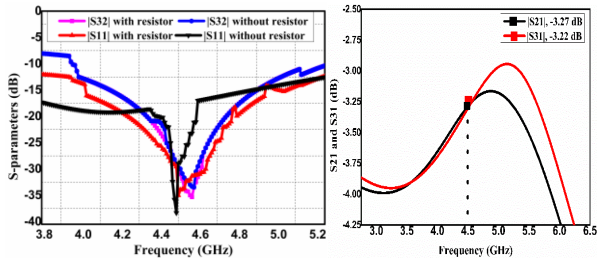
Fig. 3 (a) shows the top view of the proposed 2:1 Wilkinson power having substrate dimension equals to 15mm×23.33 mm×1.52mm. Table 1 shows the measurement of the WPD structure as in Fig.3 (a). Fig.3 (b) represents the schematic diagram of WPD. For simplification, all the impedances are normalized with respect to the characteristic's impedance Z_0. The quarter wavelength has a normalized characteristics impedance $Z = \sqrt{2Z_0}$ and the resistor has a normalized value of R. If power appearing at port 2 and 3 is P_2 and P_3 and $P_2 \neq P_3$, the design will provide a new constant K where $K^2 = \frac{P_3}{P_2}$ [13].

Fig.4. (a) shows S11 and isolation parameter S32 with their minima at -38.02 dB and -35.87dB respectively without isolation resistor R. Fig.4. (b) represents the transmission coefficients (S21 and S31) of the power divider. At 4.5 GHz, S21 is -3.30dB and S31 is -3.28dB. The range of the bandwidth of the power divider is 3.85-5.25 GHz so that it is suitable to feed the proposed patch with DGS to form an array.



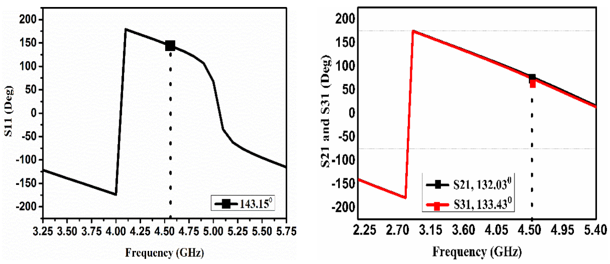
(a) (b)

Fig.3 (a) Dimension of Wilkinson Power Divider (top surface) (b) Schematic diagram of WPD



(a) (b)

Fig.4 S-parameters (a) Reflection Co-efficient and isolation (b) Transmission Co-efficient



(a) (b)

Fig.5 Phase of (a) S11 and (b) S21 and S31

Fig.5 (a) shows phase of S11 and at 4.5 GHz it is 143.15^0. Fig.5. (b) shows the phase of transmission coefficients. At 4.5 GHz, the phase of S21 and S31 are 132.03^0 and 133.43^0 respectively. Fig. 4(b) and Fig.5 (b) ensure the equal power distribution between port 2 (P2) and port 3 (P3) from port 1 (P1).

C. *Antenna array with Defective ground Structure*

A 2 elements DGS integrated array has been investigated with element spacing 0.98λ_0 from the patch boundary shown in Fig.6 (a). The optimized structure has been derived using parametric analysis of the structure in HFSS 13. If we want to include more designing parameters, the conventional optimization techniques may be used to derive the optimized dimension. The size of the substrate is 110 mm×100 mm× 1.52mm. Table 2 represents the dimensions of the parameters mentioned in Fig 6(a) of the proposed array. Investigations were performed with the square shaped DGS placed below the corners of the patch and dumbbell shape DGS below the transmission line. The prototype of the array is depicted in Fig 6 (b) Vector network analyser has been used to measure the data.

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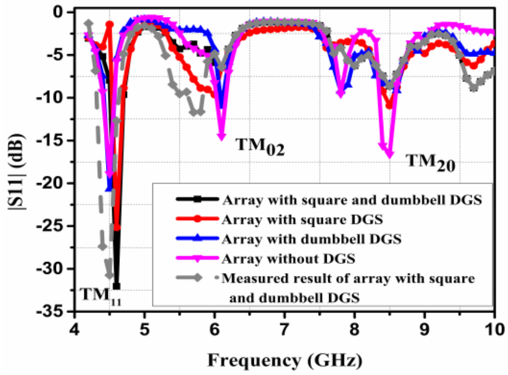
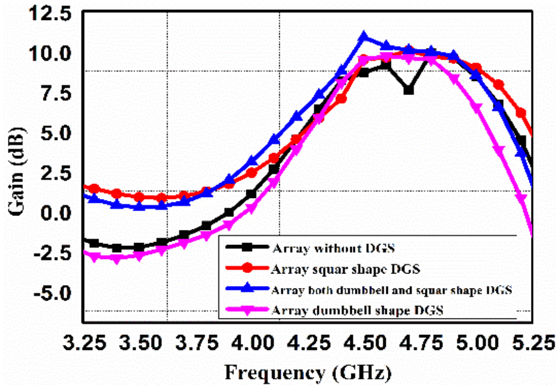
Fig. 7 (a) shows the simulated and measured return loss curve of the proposed array. It is seen that the S11 attains its minima at 4.5 GHz and offers -30.19dB value for the array with both dumbbell and square shape DGS. However, the array without DGS, with only square DGS and with only dumbbell DGS offer S11 minima of -15 dB, -18.25 dB and -25.5 dB respectively at the same frequency.



(a)



(b)

Fig.7 (a) S11 (b) Gain of Array with and without DGS

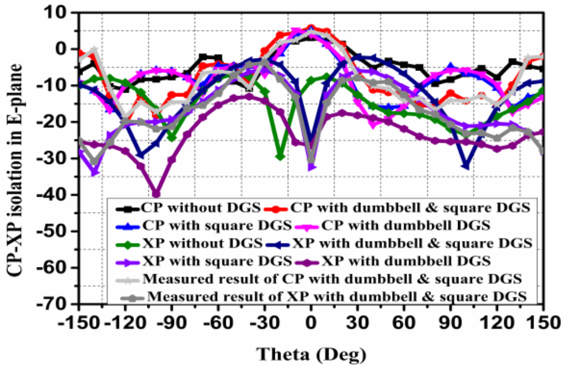
It is seen from Fig. 7 (a) that the higher order mode has been suppressed in array with both dumbbell and square shape DGS whereas it is predominantly present in the array without DGS.

The gain of the array is shown in Fig.7 (b). The proposed array has achieved an excellent gain of 10.15 dB. Using periodic DGS, higher slow wave rate with greater degree of miniaturization has been be achieved.

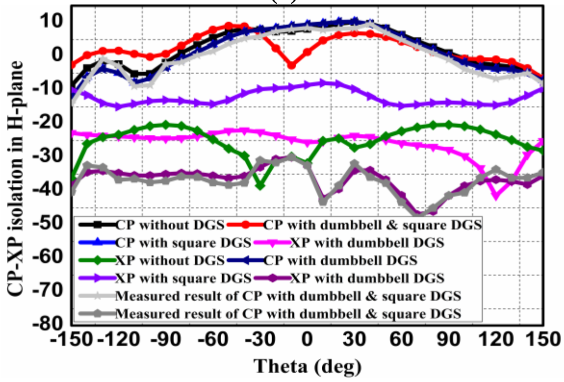
The reflection co efficient has been improved by cascading the defects on the ground plane. Shape of the DGS cells, distance between two units and the placing of the units are the main phenomena which are rigorously studied to improve the radiation performance of the array [11-13].

The work has investigated the co-polarization and cross polarization radiation of the E and H plane of the proposed array carefully.

CP is when both the transmitting and receiving antennas have the same polarization and cross polarization is when both the transmitting and receiving antennas have different polarization. So, XP should be kept minimum to obtain more polarization purity. The CP-XP isolation in E plane and H-plane have shown in Fig.8 (a) and Fig.8 (b) for four different arrays with DGS.



(a)

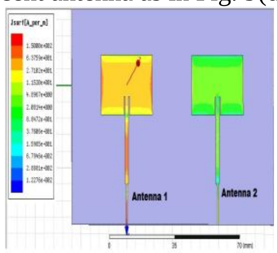


(b)

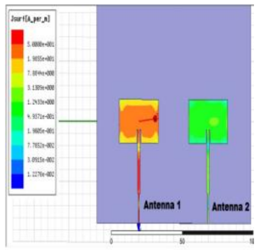
Fig.8 CP-XP isolation in (a) E-plane and (b) H plane of array It is significant to note a consistent CP-XP isolation of 30-40 dB has been achieved over an wide range of θ (-150^0 to $+150^0$) in H plane and a CP-XP isolation of 25-30 dB has been achieved over a range of θ (-60^0 to 150^0) in E plane which is significantly better than that of the paper reported in article [13].

Mutual coupling between two radiating elements of the antenna array has also been studied. It is the electromagnetic interaction between the elements of the array and quantified in terms of the current concentration in one antenna when another antenna is operating. This phenomenon is typically undesirable, as the excitation fed in one antenna, which is supposed to be radiated, is absorbed by the nearby antenna. Hence, mutual coupling reduces the performance and efficiency of antenna array so, it should be kept as minimum as possible.

Fig.9 shows the mutual coupling for four different designing examples. It is found that the minimum current concentration in antenna 2 has been achieved in Fig. 9(d) with both square and dumbbell shape DGS. The microstrip antenna elements without DGS induce large amount of current on the adjacent antenna as in Fig. 9(d).



(a)



(b)

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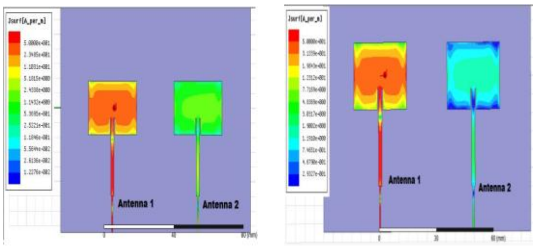


(c) (d)

Fig.9 Mutual coupling between the elements (a) without DGS, (b) DGS with dumbbell shape, (c) DGS with square shape (d) DGS with dumbbell and square shape

A high mutual coupling is produced between the radiating elements. As the DGS of different shapes are placed at the ground plane, the current coupling on the passive antenna 2 has been significantly reduced. Thus, DGS is used to reduce the mutual coupling between the elements in an array so that the gain can be improved [16]. For the proposed structure S21 has been found as -40 dB with square and dumbbell shape DGS which is far better that the -35dB reduction of mutual coupling reported in [16] where antenna 1 is only excited and another element is 50Ω loaded. Fig. 9 and 10 are obtained assuming the feeding points of the two radiating elements are isolated.

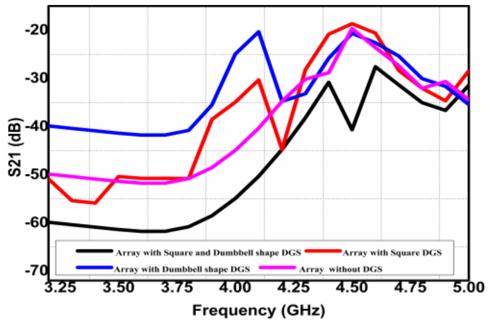
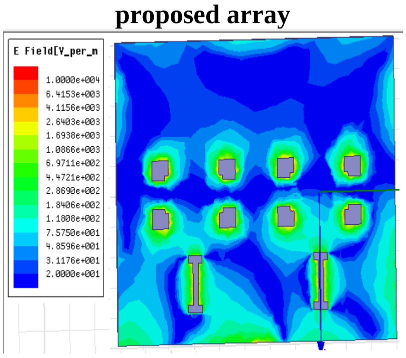
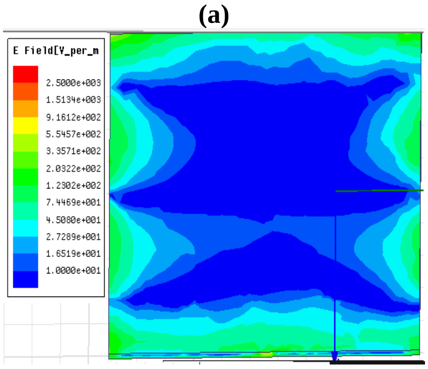


Fig.10 Mutual coupling between the elements of the proposed array



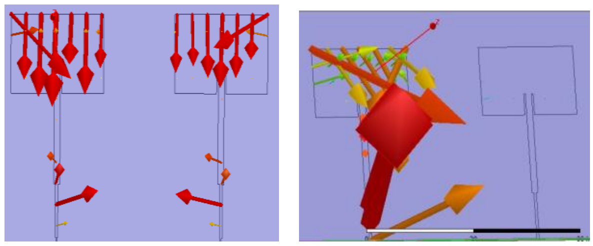
(a)



(b)

Fig. 11 E-filed distribution of the array in ground (a) with DGS (b) without DGS

Fig.11 (a) and Fig.11 (b) represent the E filed distribution of the ground plane of the proposed array with and without DGS respectively.



(a) (b)

Fig.12 E-field vector distribution of array (a) without DGS (b) with DGS

The E filed vector distribution has been shown in Fig 12 (a) and (b) without DGS and with DGS. It is seen that with DGS, the higher amount of electric field vector concentrates toward the radiating edge compared to that obtained without DGS. Thus, the defects minimize the XP level of the array without distressing the dominant mode input impedance and CP radiation . The fact is also corroborated in Fig 7(a) which shows the suppression of the higher order TM_{02} mode with the dumbbell and square shaped DGS. The addition of the DGS confirms the possible suppression or further attenuation of the higher order modes and simultaneously enhanced the fundamental mode TM_{11} as referred in [15].

The placement of the dumbbell shape DGS at the transmission line ensures higher E filed vectors in transmission line. It intensifications the E field vectors in vertical direction as in [16] using periodic DGS. The DGS helps to reduce E filed vector distribution in passive antenna element when both the elements are separately excited and reduces mutual coupling in passive element.

The measured radiation pattern of the antenna array without DGS and with square and dumbbell shape DGS have been shown in Fig.8 (a) and (b). Normalized SLL (Side lobe level) difference for four different array designs has been shown in Fig.13. Minimum SLL has been found for array with dumbbell and square shape DGS as -6 dB compared with other three structures.

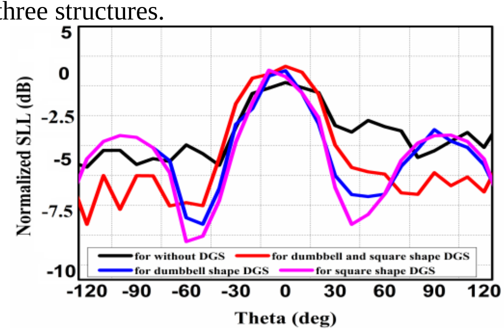


Fig.13 Side Lobe Level (SLL) for proposed array

Table 3 has summarized the radiation performances of array structure with and without DGS. Table 4 has represented a comparative study with the previous references and the proposed array. Fig. 14 shows the fabricated prototype of the array.

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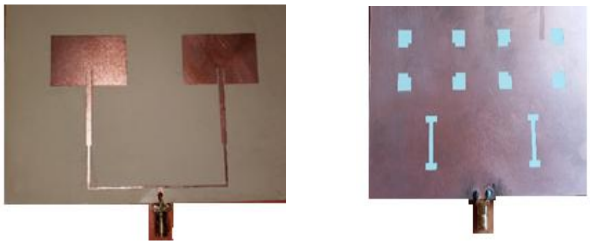

(a) (b)

Fig.14 Fabricated antenna array (a) Top (b) Bottom

Table I: Dimension of parameters of optimized patch and WPD

	Single patch with DGS								Wilkinson Power Divider							
Parameter	**W**	**L**	**W_f**	**L_f**	**X_0**	**Y_0**	**a**	**b**	**W_1**	**W_2**	**W_3**	**L_1**	**L_2**	**L_3**	**L_4**	**L_5**
Value (mm)	28	18.2	1.8	28.1	2.85	9.35	6.5	5	1.8	0.25	0.15	3	9.3	10	5	2

Table II. Dimensions of the parameters of the optimized array

Parameters	**W, L**	**W_f, W_1**	**L_f**	**d**	**X_0, Y_0**	**W_2, W_3**	**L_4, W_4**	**L_1, L_2**	**a, b**	**c, d**	**e, f**
Parameter Value (mm)	28, 18.2	1.8	15	65.5	2.85, 9.35	0.25, 0.15	5, 31.75	9.33, 66.5	6.5, 5	5.5, 13.8	2, 2.5

Table III. . Performance of the antenna array with and without DGS

Parameter	**Conventional array**	**Array with square DGS**	**Array with dumbbell shape DGS**	**Array with square & dumbbell shape DGS**
S11	-15 dB	-17 dB	-25 dB	-30. 19 dB
Gain	7.5 dB	9.88 dB	9.75 dB	10.5 dB
CP-XP in H plane	16 dB	30 dB	26 dB	40 dB
CP-XP in E plane	5 dB	8 dB	15 dB	22 dB
SLL	-3 dB	-4.8 dB	-5 dB	-6 dB

Table IV. Comparison of various parameters of proposed array and others previous designs

Ref No	**Size of the antenna**	**f-low (GHz)**	**Number of elements in array**	**Gain (dB)**	**SLL (dB)**	**Mutual Coupling (dB)**	**CP-XP isolation (dB)**
[11]	$0.49\lambda_0 \times 0.20\lambda_0$	7.4	2	4.2	-10.2	13	-
[12]	$0.28\lambda_0 \times 0.45\lambda_0$	10	4	12.2	-	-	30
[13]	$0.30\lambda_0 \times 0.23\lambda_0$	5	2	10	-	-	20
[14]	$0.22\lambda_0 \times 0.30\lambda_0$	5.8	3	4	-	-	-
[15]	$3.89\lambda_0 \times 3.89\ \lambda_0$	2.75	2	-	-	35	-
[16]	$3.77\lambda_0 \times 3.77\ \lambda_0$	2.27	2	-	-	15	-
Proposed	$\mathbf{0.41\lambda_0 \times 0.27\lambda_0}$	**4.5**	**2**	**10.5**	**-7**	**40.7**	**40**

III. CONCLUSION

In this paper, two elements antenna array with DGS has been presented. A 3 port WPD has been designed at 4.5 GHz to split the power equally between the two output ports. Same magnitude and phase of the transmission coefficients of the two ports at 4.5 GHz confirm the equal power division at the two output ports of the WPD. Two rectangular patch antennas have been connected to the WPD and DGS has been placed at the corners of each element to improve the impedance matching, gain and CP-XP isolation. Further dumbbell shaped DGS is applied bellow the feed line to reduce the mutual coupling between two elements significantly. The S11, gain and the SLL of the radiation pattern of the array have been found as -30.19 dB and 10.5 dB and -7dB respectively where the isolation in E plane and H plane are 22 dB and 40 dB respectively due to the use of two types of DGS.

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REFERENCES

1. T. Yu., "Broadband Wilkinson Power Divider Based on the Segmented Structure", *IEEE Trans. Microw. Theory Tech.*, 2018, vol. 66, no. 4, p. 1902 – 1911. DOI: 10.1109/TMTT.2018.2799579
2. W. Choe , J. Jeong, "N-Way Unequal Wilkinson Power Divider with Physical Output Port Separation"; *IEEE Microwave and Wireless Components Letters*, 2016, vol. 26, no. 4, p. 243-245. DOI: 10.1109/LMWC.2016.2537043
3. M. Heydari, S. Roshani, "Miniaturised unequal Wilkinson power divider using lumped component elements", *Electronics Letters*,2017, vol. 53, no. 16, p. 1117-1119. doi:10.1049/el.2017.2118
4. , T. Zhang, W. Che, , H. Chen, "Miniaturized Multiway Unequal Power Divider with Controllable Characteristic Impedances", *Microwave and Wireless Components Letters IEEE*, 2017, vol. 27, no. 12, p. 1062-1064. doi: 10.1109/LMWC.2017.2750421
5. M.A. Antoniades, G.V. Eleftheriades, " A compact multiband monopole antenna with a defected ground plane", *IEEE Antennas and Wireless Prop. Letters*, 2008, vol. 7, p. 652–655. doi: 10.1109/LAWP.2008.2007813
6. M.K. Khandelwal, B.K. Kanaujia, S. Dwari,S. Kumar, A.K Gautam , "Triple band circularly polarized compact microstrip antenna with defected ground structure for wireless applications", *Int. Journal of Microwave and Wireless Technologies*, 2015, vol. 8, no. 6, p. 943–953. doi:10.1017/S1759078715000288
7. A. Ghosh, S. Chattopadhyay, S. Chakraborty, B. Basu, " Cross type defected ground structure integrated microstrip antenna: a novel perspective for broad banding and augmenting polarization purity", *Journal of Electromagnetic Waves and Applications*,2017, vol 361, no 5, p. 461-476. DOI: 10.1080/09205071.2017.1284610
8. A. Ghosh, S.K. Ghosh, D. Ghosh, "Improved polarization purity for circular microstrip antenna with defected patch surface", *International Journal of Microwave Wireless and Technologies*, 2016, vol.8, p.89–94. doi:10.1017/S1759078714001305
9. S. Chakraborty, A. Ghosh, S. Chattopadhyay, et al., " Improved cross-polarized radiation and wide impedance bandwidth from rectangular microstrip antenna with dumbbell-shaped defected patch surface", *IEEE Antennas Wireless Prop. Letters*, 2016, vol. 15, p.84–88. doi: 10.1109/LAWP.2015.2430881
10. A. Rashmi, A. Pandhare, L. Prasanna, et al., " Miniaturized microstrip antenna array using defected ground structure with enhanced performance", *Engineering Science and Technology, an International Journal* ,2016, vol. 19, p.1360–1367.
11. N. Kishore, G. Upadhyay, V. S. Tripathi, A. Prakash, "Dual band rectangular patch antenna array with defected ground structure for ITS application", *International Journal of Electronics and Communications (AEU)*, 2018, vol. 96, p. 228-237, DOI: https://doi.org/10.1016/j.aeue.2018.09.039
12. F.C.B.D. Sena, J.P.D. Silva, "Harmonic suppression using optimised hexagonal defected ground structure by genetic algorithm", *IET Microwaves, Antennas & Prop.* , 2018, vol. 12, no. 10, p. 1645 – 1648. DOI: 10.1049/iet-map.2017.0733
13. D.M. Pozar, "Microwave engineering", JOHN Wiley & SONS, INC, 2nd Edition, 1998.
14. M.K. Khandelwal, B.K. Kanaujia, S. Kumar, "Defected Ground Structure: Fundamentals, Analysis, and Applications in Modern Wireless Trends", *International Journal of Antennas and Prop., Hindawi*, vol. 2017, Article ID 2018527, DOI: https://doi.org/10.1155/2017/2018527
15. K.Wei, J.Li, L.Wang, R. Xu , "S-shaped periodic defected ground structures to reduce microstrip antenna array mutual coupling", Electronics Letters, 2016, vol. 52, no. 15, p. 1288-1290. DOI: 10.1049/el.2016.0667
16. K.Wei, J.Li, L.Wang, R. Xu, "Microstrip antenna array mutual coupling suppression using coupled polarisation transformer", IET Microwaves, Antennas & Prop., 2017, vol. 11, no. 13, p. 1836-1840. DOI: 10.1049/iet-map.2016.1154

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