A Rectangular Microstrip Patch Antenna (RMPA) with Defected Ground Structure for Bandwidth Enhancement

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Abstract – In this paper, a rectangular microstrip patch antenna with defected ground structure (DGS) for wireless application is proposed. A rectangular shaped DGS is simulated using the Computer Simulation Technology (CST) Microwave Studio software to enhance the antenna bandwidth.
The simulation results is compared and analyzed. The antennas with Rectangular DGS could improve approximately 64% of bandwidth and miniaturize the antenna about 25%.

Keywords- Defected Ground Structure(DGS), Microstrip Patch Antenna, Computer Simulation Technology (CST) software

I. INTRODUCTION

Wireless revolution has become an essential in connecting everyday devices through embedded wireless technology. Embedded wireless communication technology such as WiMAX (IEEE 802.16), WLAN (IEEE 802.11), and WPAN (IEEE 802.15) such as Bluetooth, Zigbee, IrDa and RFID has widely use in today's application, from personal electronics and medical devices, to the transportation infrastructure and manufacturing. These devices require wider band and good radiation performance. It has lead the study and development in antenna field to improve antenna performance.

Microstrip patch antenna (MPA) has widely used in embedded wireless communication and microwave devices because of its characteristics: such as light weight, thin, low volume, low cost and easy manufacturability. MPA provide great advantages over the traditional antenna as it can be easily fabricated and integrated in solid-state devices.

However, the conventional antenna has a narrow bandwidth and low efficiency. Antenna bandwidth can be increased by increasing the height of the substrate, unfortunately this increment will larger the size of antenna and decrease the antenna efficiency.

DGS is used to enhance the MPA performances. DGS is realized by etching off a portion of the ground plan of antenna mostly in form of rectangular[1][2], triangle[3], dumbbell[4][5], circular[6-8], split ring[9], hexagonal[10] or spiral[8][11][12]. The defected ground will disturbs the shield current distribution in the ground plane, which influences the input impendence and current flow of the antenna [9][14-15]. The shape and dimension of the defect will give different effects such as size reduction [11][16], bandwidth enhancement[14][17][18] and gain increasing[18-20].

The purpose of this work is to use rectangular shaped defected ground structure to improve return loss, VSWR and provides higher bandwidth over conventional Rectangular Microstrip Patch Antenna (RMPA) operating at 2.4GHz frequency band for WLAN(IEEE802.11) application.

II. ANTENNA DESIGN AND GEOMETRY

The substrate FR4 with thickness 1.6 mm and dielectric constant of 4.3 has been used. Patch length, width and substrate height are given as *L*, *W* and *h* respectively. The coordinate axis is selected such that the length is along y, width is along x direction.

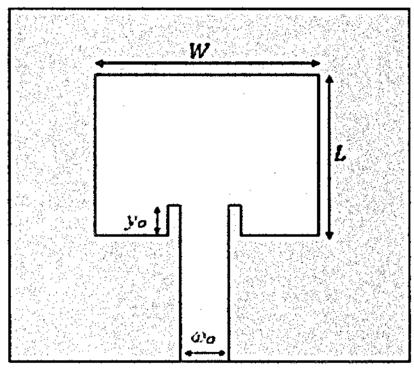


Fig. 1: Rectangular microstrip patch antenna

In order to operate in the fundamental TM_{10} mode, the length of the patch must be slightly less than $\lambda_g/2$ where λ_g is the wavelength in the dielectric medium and is equal to $\lambda_o/\sqrt{\varepsilon_{reff}}$ where λ_o is the free space wavelength.

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} \qquad (1)$$

The width of antenna patch must be kept small enough to avoid excitation of transverse resonance. Typically width must be less than λ_g. The width is calculated by transmission line model equation:

$$W = \frac{c}{2f\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad (2)$$

where c is the speed of light ($3 \times 10^8 \mathrm{ms}^{-1}$).

Reducing the width will increase the resonant frequency, while, increasing the width will reduce the resonance frequecy.

Effective dielectric constant, ε_{eff} is given by the equation:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{\frac{1}{2}} \qquad (3)$$

For a given resonance frequency f_0, the effective length is given as:

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}} \qquad (4)$$

Calculation of Length extention, ΔL is as follows:

$$\Delta L = 0.412\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)}h \qquad (5)$$

The actual length of patch, L is given as:

$$L = L_{eff} - 2\Delta L \qquad (6)$$

Reducing the length of patch will increase the antenna resonance frequency, while increasing the length will reduce the resonance frequency.

The ground plane dimension is given as:

$$L_g = 6h + L \qquad (7)$$

$$W_g = 6h + W \qquad (8)$$

The width of feed line, w_o is given as :

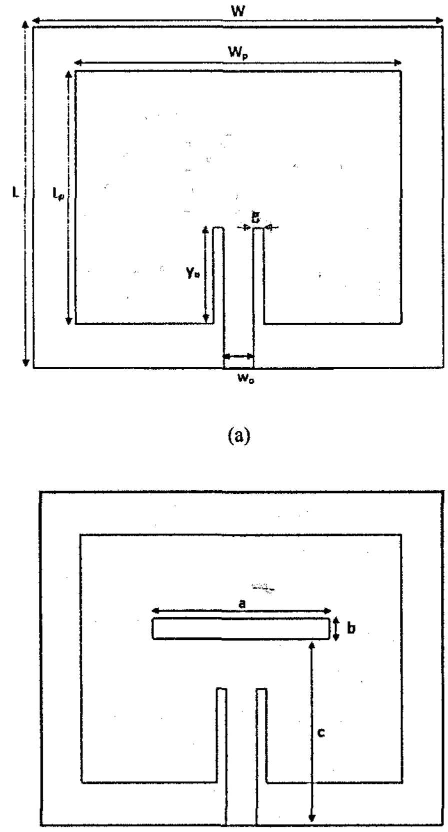
$$Z_c = \frac{87}{\sqrt{\varepsilon_r+1.41}}\ln\left[\frac{5.98h}{0.8\omega_0}\right] \qquad (9)$$

The size of feed line will influence the impedance of antenna. The increments of feed size decrease the input impedance.

TABLE I: PARAMETERS AND DIMENSIONS

Parameters	Dimensions	
	Calculated	Conventional Antenna
Patch width, W_p	38.39	31.00
Patch Length L_p	29.96	25.00

In this work, the effect of DGS position has been investigated.



(a)

(b)

Fig. 2: Rectangular Patch Antenna with Rectangular Shaped DGS (a) Front view, (b) Ground view

III. RESULT AND DISCUSSIONS

The antennas are modelled and simulated using CST Microwave Studio software. The simulation results of conventional antenna are shown in Table III. The RMPA resonates at frequency 2.4GHz and return loss is -25.75 dB.

The rectangular shaped DGS was etched in the ground plane. The position of DGS was put in several different positions along y-axis. The results are shown in Fig.3. From the graph below, it can be concluded that the position of DGS has affected the antenna performance. The DGS at c = 23.25 mm has the best antenna performance in term of return loss and bandwidth. DGS at c = 20.25 mm has the lowest resonance frequency. From Fig. 4, it can be concluded that the resonance frequency reduced when the DGS is put at the area with high H-field

higher frequency.

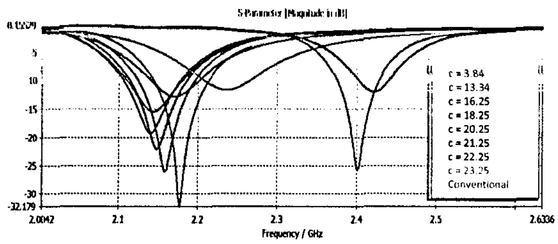
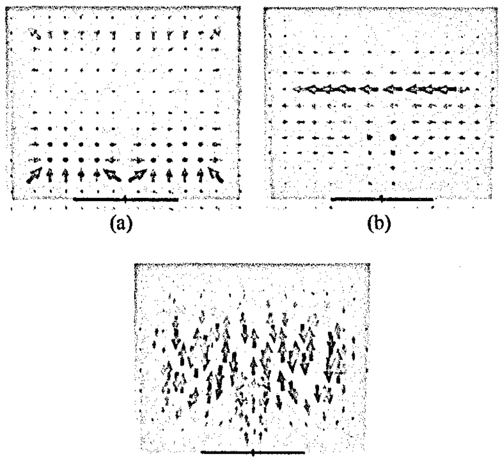


Fig. 3: Return loss for RMPA with DGS at various positions



(a) (b) (c)

Fig. 4: (a) E-field (b) H-field wave propagation and (c) surface current

The DGS at point c = 20.25 mm was then optimized so that it resonates at center frequency of 2.4 GHz. The final design of antenna's parameters is shown in Table II. The antenna size is found to be reduced by 25.4%. Fig. 4 and Table III show the comparison of return loss and bandwidth of conventional RMPA and RMPA with DGS. It is found that the return loss reduced to -39.42 dB and bandwidth enhanced to 86.457 MHz.

TABLE II: PARAMETERS OF PROPOSED ANTENNA

Parameters	Dimensions	
	Conventional RMPA	**Proposed RMPA with Rectangular DGS**
Ground Width, W	47	40.9
Ground Length, L	38.5	33
Patch width, W_p	31	32.5
Patch Length, L_p	25	24.667
Insert cut Length, w_0	9.5	10
Feed Line Width, w_0	3.055	3.055

	Conventional RMPA	**Proposed RMPA with Rectangular DGS**
Return Loss, S1,1 (dB)	-25.75	-39.417
VSWR	1.183	1.022
Bandwidth (MHz)	52.617	86.457
Gain (dB)	3.061	1.348

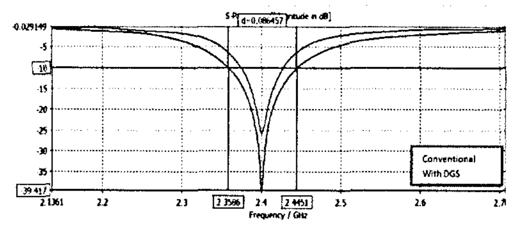
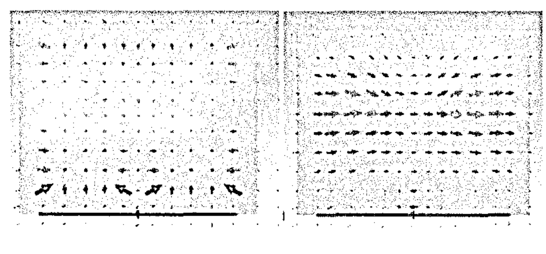


Fig. 5: Comparison between Conventional RMPA and RMPA with DGS



(a) (b)

Fig. 6: E-filed and H-Field for RMPA with DGS

IV. CONCLUSION

In this work it is found that the implementation of Rectangular Shaped DGS on a Rectangular Microstrip Patch Antenna (RMPA) significantly improves the antenna bandwidth by 64.3%, reducing the return loss by 53%, thus improved the impedance matching. Overall, the objective of this work to design a low cost and compact antenna with wider bandwidth is achieved, even though the performance of designed antenna does not show improvement. A future work recommendation is focusing on various shapes of DGSs to increase more bandwidth as well as gain and directivity suitable for WLAN and

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REFERENCES

[1] Wang, L.-T. and J.-S. Sun, "The compact, broadband microstnp antenna with defective ground plane," *IEE International Conference on Antenna and Propagation*, Vol. 2, 622-624, Apr. 2003

[2] Mouloud Challal, Arab Azrar and Mokrane Dehmas, "Rectangular Patch Antenna Performances Improvement Employing Slotted Rectangular shaped for WLAN Applications", *IJCSI International of Computer Science* Issues, Vol. 8, Issue 3, No. 1, May 2011

[3] C. Kumar, and D. Guha, "Defected Ground Structure (DGS)-Integrated Rectangular Microstrip Patch For Improved Polarization Purity With Wide Impedance Bandwidth," *IET Microwaves, Antennas & Propagation*, (in press)

[4] Kim. J.P. and Park. W.S., "Microstrip Low Pass Filter With Multi Slots on Ground Plane," *Electronics Letters*, Vol. 37, No. 25, pp.1525–1526, Dec.2001.

[5] Fitri Yuli Zulkifli, Eko Tjipto Rahardjo, "Mutual Coupling Reduction Of Multiband Microstrip Antenna Array Using Defected Ground Structure", *The 2009 International Symposium on Antennas and Propagation (ISAP 2009)*, October 20-23, 2009, Bangkok, THAILAND

[6] C. Kumar, and D. Guha, "New Defected Ground Structures (DGSs) to reduce cross-polarized radiation of circular microstrip antennas," *IEEE Applied Electromagnetic Conference*, Kolkata, India, 14-16 Dec 2009.

[7] A. Mahmoudian and J. Rashed-Mohassel, "Reduction of EMI and Mutual Coupling in Array Antennas by Using DGS and AMC Structures", *PIERS Proceedings*, Hangzhou, China, 2008

[8] H. Liu, Z.Li, X. Sun, and J.Mao, "Harmonic suppression with photonic bandgap and defected ground structure for a microstrip patch antenna," IEEE *Microw. and Wireless Components Letter*, Vol. 15,55-56, 2005

[9] Jigar M. Patel, Shobhir K. Patel and Falgun N. Thakkar, " Defected Ground Structure Multiband Microstrip Antenna using Complementar Split Ring Resonator", *International Journal of Emerging Trends in Electrical and Electronics*, Vol. 3, Issue 2, May 2013

[10] F. Y. Zulkifli, E. T. Raharjo and D. Hartanto, " Radiation Properties Enhancement of Triangular Patch Microstrip Antenna Array Using Hexagonal Defected Ground Structure", *Progress In Electromagnetics Research M*, Vol. 5, 101-109, 2008

[11] Kumar, P. Kishor, J.; Shrivastav, A.K., "Formulation of Size Reduction Technique In Microstrip Circuits by using DGS and DMS," *Recent Advances in Microwave Theory and Applications, 2008. Microwave 2008. International Conference*, pg 861 -864

[12] Nashaat, D. Elsadek, H.A. ; Abdallah, E. ; Elhenawy, H. ; Iskander, M.F. , "Multiband and miniaturized inset feed microstrip patch antenna using multiple spiral-shaped defect ground structure (DGS)", *Antennas and Propagation Society International Symposium*, 2009. APSURSI '09. IEEE

[13] Jigar M. Patel, Shobhir K. Patel and Falgun N. Thakkar, " Defected Ground Structure Multiband Microstrip Antenna using Complementary Split Ring Resonator", *International Journal of Emerging Trends in Electrical and Electronics*, Vol. 3, Issue 2, May 2013

[14] Gurpreet Singh, Rajni, Ranjit Singh Momi, "Microstrip Patch Antenna with Defected Dround Structure for Bandwidth Enhancement," *International Journal of Computer Application*, Volume 73 – No.9, July 2013.

[15] Arya, A. K., M. V. Kartikeyan, and A. Patnaik. " Efficiency enhancement of microstrip patch antenna with defected ground structure." *Recent Advances in Microwaves Theory and Applications, 2008. MICROWAVES 2008. Pp 729-731. IEEE 2008.*

[16] Kumar, P., Gr. Noida, India ; Mahmood, R. , Kishor, J. , Shrivastav, A.K. , "Designing of a Compact Microstrip Antenna Resonating at 4.8GHz by Using Size Reduction Technique," *Emerging Trends in Electronic and Photonic Devices & Systems*, 2009. ELECTRO '09. International Conference, pg. 370 - 373

[17] Ashwini K. Arya, M. V. Kartikeyan, A. Patnaik, "Efficiency Enhancement of Microstrip Patch Antenna with Defected Ground Structure," *Proceedings of International aconference on Microwave*, 2008

[18] Neeraj Rao and Dinesh Kumar V., "Gain and Bandwidth Enhancement of a Microstrip Antenna Using Partial Substrate Removal in Multiple-layer Dielectric Substrate," *Progress in Electromagnetics Research Symposium Proceedings*, Suzhou, China, Sept. 12-16, 201, pp 1285 – 1289.

[19] Mr. Pokharkar Sagar Babanrao, Mr. Bhasale Sudhir P, Mr. Kazi Aslam Y. "Enhancement of Return Loss and Effeciency of Microstrip Slotted Patch Antenna Using Line Shape Defected Ground Structure." *International Journal on Recent and Innovation Trends in Computing and Communication* . Volume 2 Issue 2. Pp 343-346,February 2014

[20] Debatosh Guha, Sujoy Biswas, and Chandrakanta Kumar, "Printed Antenna Design Using Defected Ground Structures: A review of Fundamentals and State-of-the-Art Developments," *Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)*

[21] P.V. Lokhande and B.T. Salokhe, "Design & Simulation of Circular Microstrip Antenna with Defected Ground Structure (DGS) for WLAN Applications," *IOSR Journal of Electronics and Communication Engineering* (I)SR-JECE), PP 46-50