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Design and Simulation of a Novel Dual Band Microstrip Patch Antenna with Defected Ground Structure for WLAN/WiMAX

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Abstract

In this paper, we present a novel planar rectangular microstrip-fed patch antenna for 2.4 GHz and 5.5 GHz. This configuration radiates at 2.43GHZ (2.27‑2.55 GHz) and 5.52 GHz (5.14‑5.90 GHz) for 2.4, 5.2 and 5.8GHz WLAN bands adopting IEEE 802.11b, IEEE 802.11e and IEEE 802.11a WLAN standards, respectively. The proposed antenna is designed and simulated using CST Microwave Studio 2012 electromagnetic solver based on Finite Integration Technique. The antenna utilizes an H‑shaped defected ground structure (HSDGS) cell on the ground plane which has a triangular cut on one side for dual-band properties. The effect of different dimensions of HSDGS on return loss is also studied. The condensed size, low cost, ease of fabrication, large bandwidth and excellent radiation parameters in comparison with earlier reported designs are the advantages of the proposed antenna. Further the simulated parameters like gain, bandwidth, VSWR, and return loss are in good conformity with ISM (Industrial Scientific and Medical) and industry standards.

Keywords: Bandwidth, CST 2012, DGS, Patch Antenna.

1. Introduction

Modern era especially in the field of communication is considered to be the age of technology, a plethora of systems like the one for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) demand antennas that are compact and robust in performing dual and multi-band operations. Due to the advancement in technology, these systems become smaller in size and hence the antennas in effect have also to be smaller in size to transmit and receive signals [1]. Microstrip patch antennas are prominent and pleasing prospects for this purpose owing to their features like compactness, durability, conformability, low- profile, low cost for fabrication, and compatibility with planar monolithic microwave integrated circuit (MMIC) devices. However, these also suffer from serious disadvantages such as low-efficiency, narrow bandwidth, spurious radiations etc. [2].

Defected ground structure (DGS) have been widely used in microstrip antennas for size reduction, reducing harmonics, bandwidth improvement, diminution of cross polarization and mutual coupling in antenna arrays etc. DGS is an etched off portion in ground plane of a microstrip, coplanar or conductor backed coplanar waveguide that perturbs the current and results in a restricted excitation of electromagnetic waves through the substrate. The most commonly used defected ground structure is dumbbell shaped, its inductance ‘L’ and capacitance ‘C’ is given by equations (1) and (2) respectively [3].

$$L = \frac{1}{4\pi^2 f_0^2 C} \tag{1}$$

$$C = \frac{f_c}{2Z_0} \frac{1}{2\pi(f_0^2 - f_c^2)} \tag{2}$$

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Where f_0, f_c and Z_0 represent resonant frequency, cut-off frequency and characteristic impedance of transmission line above DGS.

2. Applications

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A number of dual band antennas [4]-[10] operating at 2.4/5.2 GHZ have been reported by researchers using different techniques and topologies to obtain the characteristic resonances. A monopole printed antenna for dual-band applications at 2.4/5.2 and 5.8 GHz WLAN bands was proposed by [4]. A dual band dipole antenna for WLAN that used an internal matching circuit to cover entire WLAN bands was presented in [5]. Dual wide-band CPW-fed modified Koch fractal Printed antenna was presented for the same applications [6]. A dual-band antenna for WLAN operation was fabricated on a halogen-free single side adhesive Flexible Copper Clad Laminate (FCCL) [7] used a meandered monopole style top loaded by a thin inverted L-shaped strip to attain acceptable bandwidths to cover the 2.4/5.2 WLAN operating bands. Dual band antenna for WiMAX applications at 5.2GHz and 5.8GHz with ground plane loaded with CSSRR (Complementary Single Split Ring Resonator) was proposed [8] providing a fine elasticity on choice of dual frequency by changing dimensions of CSSRR. A novel dual band antenna was proposed by Debdeep and co-workers [9] for WLAN and WiMAX applications with partially defected ground structure used two complementary split ring resonators (CSRRs) of appropriate dimensions to excite a low order resonating mode supported by the patch lying in the middle WiMAX band to ensure dual band characteristics. A bow-tie microstrip antenna that has an L-shaped defect on its ground is proposed for 2.4/5.8 GHz [10]. The resonances at 2.4 and 5.8 GHz can be altered by varying the dimensions of patch and defect. A dual band patch antenna, relatively simpler to design than existing procedures based on defected ground plane structure has been presented in this paper. The proposed antenna radiates at 2.43 GHz (2.27-2.55 GHz) and 5.52 GHz (5.14-5.90 GHz) suitable for WLAN, Bluetooth, and WiMAX. HSDGS together with triangular cut along one arm of H – shape is used to excite resonances at 2.4 GHz and 5.52 GHz. By properly adjusting the dimensions of arms of HSDGS a good dual band broad impedance bandwidths and radiation characteristics accurate for WLAN 2.4/5.2/5.8 GHz and WiMAX 5.5GHz are achieved.

$$L = \frac{1}{4\pi^2 f_0^2 C} \tag{1}$$

$$C = \frac{f_c}{2Z_0}\frac{1}{2\pi(f_0^2 - f_c^2)} \tag{2}$$

Where f_0, f_c and Z_0 represent resonant frequency, cut-off frequency and characteristic impedance of transmission line above DGS.

The geometry of the proposed dual band rectangular microstrip patch antenna with H-shaped defected ground structure in its ground plane is shown inFig.1. The antenna is fed by a microstrip center lined technique. The radiator and ground plane are on the two opposite faces of flame retardant (FR-4) substrate having thickness of 1.6mm with relative permittivity and loss tangent 4.4 and 0.02 respectively. For a particular target frequency 'f_r' and dielectric constant of substrate 'ε_r' with height 'h', Eq.1 to Eq.8 are used to calculate the width 'w', length 'L' and other parameters related to patch antenna design [2].

$$w = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{3}$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{4}$$

Where 'c' represents speed of light in vacuum. The effective permittivity of dielectric substrate 'ε_{reff}' and

extension in patch length 'ΔL' due to fringing effects is expressed as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \tag{5}$$

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$$\Delta L = h \times 0.421\frac{(\varepsilon_{reff}+0.3)\,(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)\,(\frac{w}{h}+0.8)} \tag{6}$$

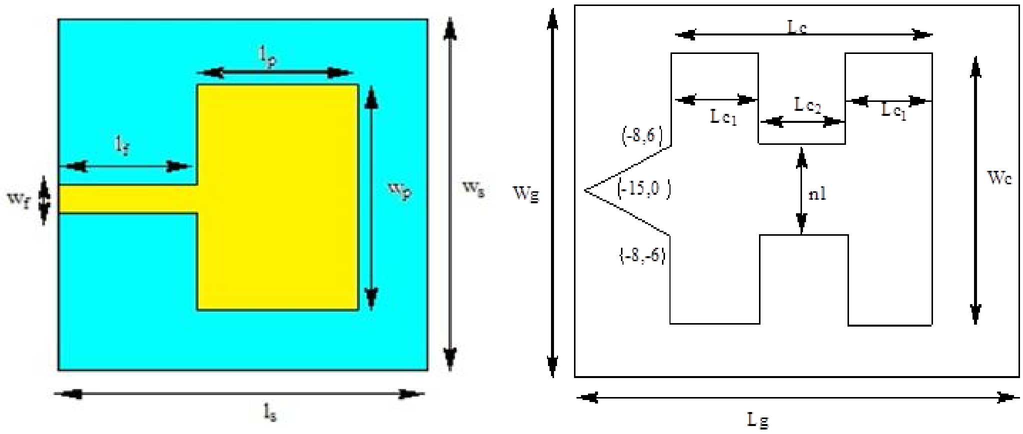


Fig. 1: Geometry of Proposed Dual –Band Antenna (a) Front-View (b) Back –View

The ground plane dimensions are approximately six times the substrate thickness all around the periphery [11]. Hence for this design the ground plane dimensions would be given as:

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

$$W_g = 6h+w \quad (8)$$

A microstrip feed line of width 'w_f' and length 'l_f' is used for feeding the main radiating element of width 'w_p', length 'l_p', and thickness 't_p'. As for the ground plane, unlike the general use of a regular ground plane, it is defected by an H – shape which is placed appropriately at the center. A triangular cut is integrated with one of the parallel arms of H-shaped defect to obtain simultaneous two resonances with good impedance matching. The geometrical parameters of the proposed antenna after optimization are listed in Table 1.

Table 1: Optimized parameters of proposed antenna.

Parameter	W_g	L_g	w_p	l_p	w_f	l_f
Unit [mm]	34	32	22.5	14	3	20
Parameter	l_{c1}	l_{c2}	t_p	n_1	W_c	L_c
Unit [mm]	7	2	0.01	13	29	16

3. Results and Discussions

The simulated return loss of presented structure is shown in Fig.2. Two resonant peaks achieved at 2.43 GHz and 5.52 GHz demonstrate that the antenna is showing a dual–band character. The bandwidth defined for -10 dB return loss is about 275 MHz (2.2775-2.553GHz) and 756 MHz (5.144-5.90) GHz at 2.43 and 5.52 GHz respectively corresponding to an impedance bandwidth of 11.35% and 13.69 % with respect to appropriate resonant frequencies over two operating bands. In fact, the achieved bandwidths all together cover WLAN standards in the 2.4/5.2/5.8 GHz bands, Bluetooth standard in the 2.4 GHz band, and WiMAX standard in the 5.5 GHz band.

The radiation pattern of the proposed antenna that shows both the E and H-plane patterns for both frequencies is represented in Fig. 3. Simulated parameters of interest of described antenna are listed in Table 2. The return loss of antenna with HSDGS and HSDGS integrated with a triangular cut is also shown in Fig. 2. With HSDGS a dual band characteristic was obtained. Further, by the use of triangular defect along one of the parallel arms of HSDGS, the desired frequencies were obtained with wide impedance bandwidth. This signifies that with HSDGS two resonances were excited and the triangular cut considerably improved the matching conditions for lowest (2.2775GHz-2.553 GHz) and highest (5.144GHz-5.90 GHz) bands. To further examine the excitation mechanism, average surface current distributions obtained from CST simulation on both patch and ground plane for optimized antenna were studied. A large surface current was observed over the patch and along the microstrip line at both the resonant frequencies. At lower frequency the current was more concentrated along one of the parallel arms of HSDGS that is not connected to triangular cut as shown in Fig.4 which displays current distribution on ground plane at 2.43 GHz and 5.52 GHz, whereas at higher frequency current was more distributed along the periphery of other arm of HSDGS and triangular cut.

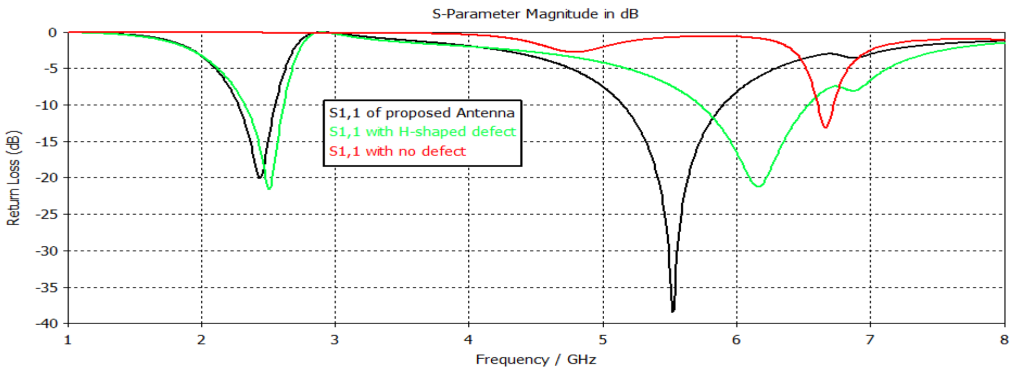
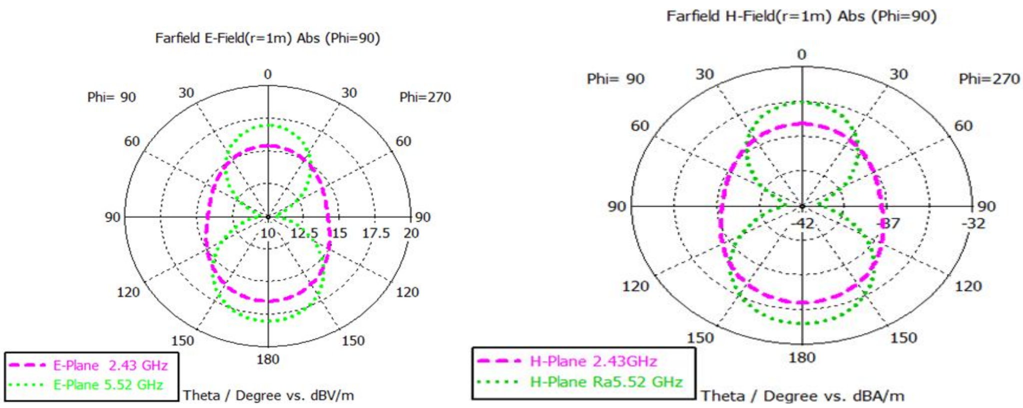


Fig. 2: Simulated Return Loss (dB) against Frequency for Proposed Antenna, with H-shaped and with no Defect



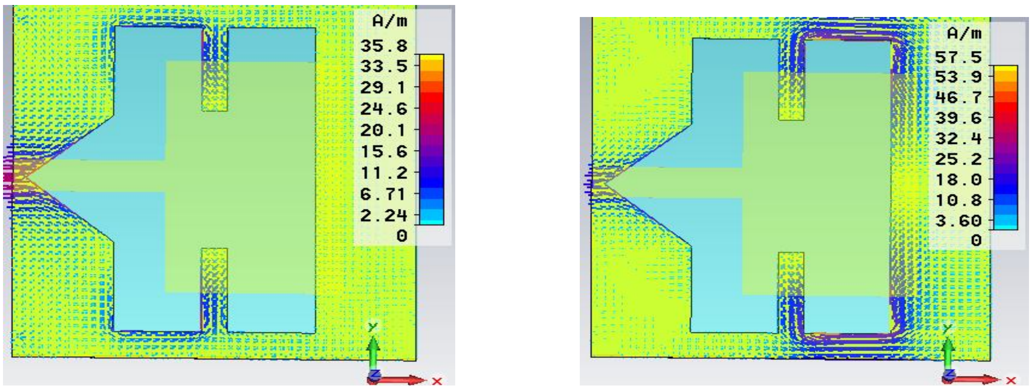
(a) **(b)**

Fig. 3: Simulated Radiation pattern of Proposed Antenna
(a) E-Plane Pattern (b) H-Plane Pattern

The effect of various dimensions of HSDGS on return loss was also examined. The return loss of the proposed antenna when l_{c1}, l_{c2}, and n_1 were varied is shown in Fig. 5. Variables c1, r1, and d1were used to control the size of HSDGS. c1 controls the length l_c whereas d1 controls the extent of w_c and r1 controls the length n_1. When l_{c1} was decreased, the resonant peaks moved towards lower frequencies with a slight increase in return loss at lower resonant band, and vice-versa. Hence, optimum value of l_{c1}=7 was selected. Same trend was observed for n_1. Decrease in l_c further decreased the return loss at lower frequency with increase in it at higher frequency as depicted in Fig. 5(b).

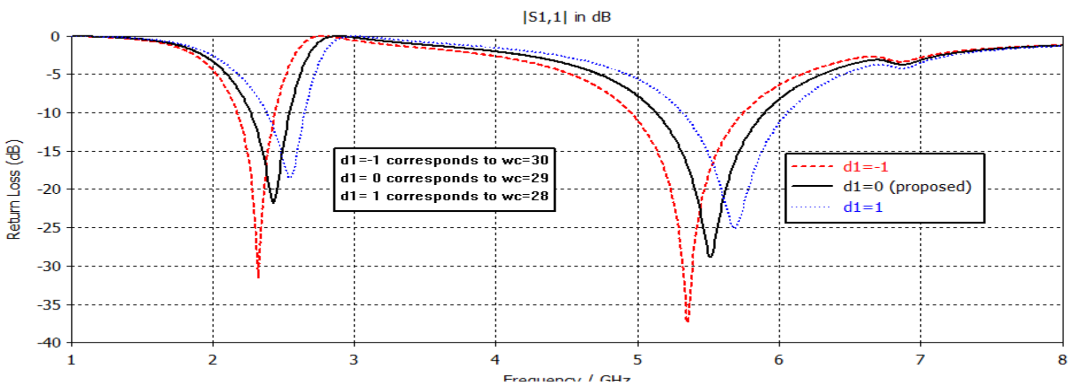
Table 2: Simulated Parameters of Proposed Dual-Band Antenna.

Resonant frequency	Directivity	Antenna efficiency	Gain	Return Loss(dB)	VSWR
2.43GHz	3.207dBi	64.1%	2.053dB	-20.10	1.21
5.52GHz	5.13 dBi	88.15%	4.52dB	-38.44	1.02

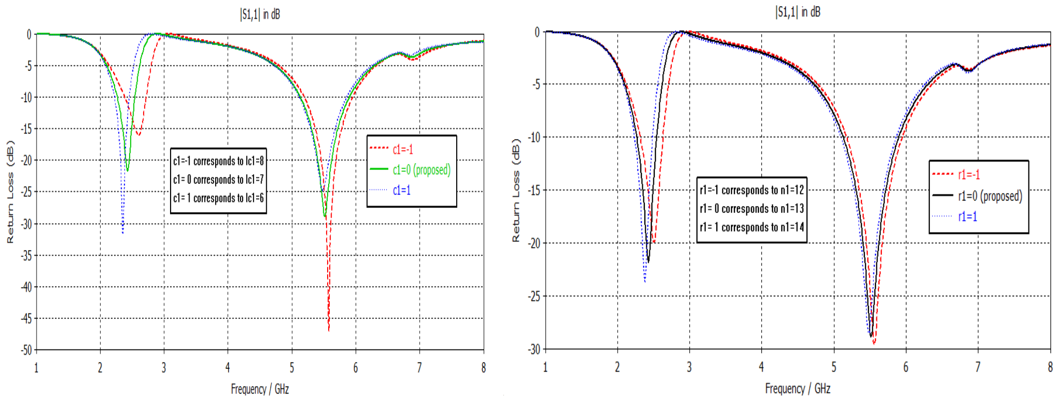


(a) **(b)**

Fig. 4: Surface Current distribution (a) Ground at 2.43 GHz (b) Ground at 5.52 GHz



(a)



(b) **(c)**

Fig. 5: Simulated Return Loss against Frequency for (a) Different values of d1 (b) Different values of c1 (c) Different values of r1

References

[1] S. Maci and G. BifJi Gentili, "*Dual-Frequency Patch Antennas,*" IEEE Antennas and Propagation Magazine, Vol. 39, No. 6, pp.13‐20,December. 1997.

[2] C. A. Balanis, "*Antenna Theory Analysis And Design,*" John Wiley & Sons, 3rd Edition, 2005.

[3] A. K. Arya, A. Patnaik, and M. V. Kartikeyan, "*Microstrip Patch Antenna with Skew-F Shaped DGS for Dual Band Operation,* "Progress In Electromagnetics Research M, Vol. 19, 147-160, 2011

[4] Y L Kuo, and K L Wong, "*Printed double‐T monopole antenna for 2.4/5.2 GHz dual band WLAN operations,*" IEEE Transactions on Antennas Propagat.,Vol. 51, no. 9, pp. 2187‐92, Sep. 2003.

[5] Z Zhang, M F Iskander, J C Langer, and J Mathews, "*Dual‐band WLAN dipole antenna using an internal matching circuit,*" IEEE Trans. Antennas Propagat.,Vol. 53, no. 5, pp. 1813‐18, May. 2005.

[6] D D Krishna, M Gopikrishna, C K Anandan, P Mohananand, and K Vasudevan, "*CPW‐Fed Koch Fractal Slot Antenna for WLAN/WiMAX Applications,*" IEEE Antennas and Wireless Propagation Letters,Vol. 7, pp. 389‐92, 2008.

[7] Hsuan-Yu Chien , Chow-Yen-Desmond Sim , Ching-Her Lee, "*Compact Size Dual-band Antenna Printed on Flexible Substrate for WLAN Operation,*" Proceedings of ISAP2012, Nagoya, Japan.

[8] Kumar Goodwill, Parth C Kalaria, Ramesh Patel, Jagannath Malik, A. Patnaik, M.V.Kartikeyan,"*Dual Band Microstrip Patch Antenna for Wireless Applications at 5.2GHz and 5.8GHz using CSSRR,*" 2012 International Conference on Communications, Devices and Intelligent Systems (CODIS).

[9] Debdeep Sarkar, Kushmanda Saurav, and Kumar Vaibhav Srivastava, *"Design of a Novel Dual-band Microstrip Patch Antenna for WLAN/WiMAX Applications Using Complementary Split Ring Resonators and Partially Defected Ground Structure Progress,"* Electromagnetics Research Symposium Proceedings, Taipei, March 25-28, 2013.

[10] Mehdi Abioghli and Ramazan Ali Sadeghzadeh, "*A New Compact Dual‐Band Bow‐tie Microstrip Antenna for WLAN Applications,*" IETE Journal of Research, Vol. 59, Issue 6, Nov-Dec 2013.

[11] Qian, Yongxi, Dan Sievenpiper,VesnaRadisic, Eli Yablonovitch and Tatsuo Itoh *"A novel approach for gain and bandwidth enhancement of patch antennas,"* In radio and wireless conference, RAWCON 98.1998 IEEE, pp221-224.