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Efficient Proximity Coupled Feed Rectangular Microstrip Patch Antenna with Reduced Harmonic Radiation

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Abstract

This paper presents an efficient proximity coupled feed rectangular microstrip patch antenna with reduced harmonic radiation. The proposed antenna resonates in S-band at frequency of 2.45 GHz with bandwidth of 88.5 MHz. A very good return loss of -47.0546 dB is obtained for the Microstrip patch antenna. The antenna matching can be achieved with an appropriate line-patch overlap, but with a careful design consideration. Not only the good matching of the fundamental mode, but also the effect on the harmonic radiation from the other patch modes has been considered. Varying the length & location of the microstrip feed line and introducing a defect in the ground plane- the harmonic radiation from the other patch mode is reduced to minimum.

Keywords: *Defected Ground Structure, Harmonic radiation, Microstrip Feed line, Microstrip patch antenna, Proximity coupling*

1. Introduction

The development in communication systems requires the development of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequency. The Microstrip antenna is very good for wireless communication due to their planar structure, light weight, low volume, low profile planer configuration which can be easily made conformal to host surface, and ease of integration with active devices. Additionally, some of its characteristics like low fabrication cost, supportive nature for both linear and circular polarization, and low sensitivity to manufacturing tolerance make this antenna very important for next generation [1].

The proposed antenna uses proximity coupled feeding because of its advantages, such as high bandwidth, less spurious radiations, good suppression of higher order modes and ease of impedance matching. In this technique, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The power from the feed network is coupled to the patch electromagnetically [2]. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth compared to other feeding mechanisms, due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances [3].

Active patch antennas have non linear devices inside the antenna and they exhibit high level of harmonic radiations [4]. Sometimes the patch antenna itself is used to filter these harmonics [5]. There are several methods which can be used for suppressing the harmonics [6]-[10]. A photonic bandgap structure on the feeding line of a slot coupled Microstrip patch antenna was introduced by Itoh et al. [6]. Defected ground structures (DGS) [11] and compact resonant cell structure (CMRC) [8] have been used to accomplish the mentioned aim. The second harmonic can be controlled by varying the feed line length and the third harmonics by using a compact resonator [12].

Defected Ground Structure (DGS) is realized by etching off a simple shape in the ground plane, depending on the shape and dimensions of the defect, the shielded current

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distribution in the ground plane is disturbed, resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer. The impedance and surface current of the antenna is affected by DGS. The shape of the defect may be changed from the simple shape to the complicated shape for the better performance. Different shapes of DGS structures, such as rectangular, square, circular, dumbbell, spiral, L-shaped, concentric ring, U-shaped and V-shaped, hairpin DGS, hexagonal DGS, cross shaped DGS and combined structures have appeared in literatures [13].

DGS is used in the Microstrip antenna design for different applications such as radiation properties enhancement, antenna size reduction, harmonic suppression, cross polarization reduction, mutual coupling reduction in antenna arrays, design approach for circular polarization, etc., [13].

DGS was initially invented by Park et al. in the year 1999 retaining the notion of Photonic Band-Gap Structure (PBG). Defected Ground structures (DGS) have two main characteristics-Slow Wave propagation in Pass-band & Band-Stop characteristics in microwave circuits. The DGS is considered as an equivalent circuit consisting of capacitance and inductance. The equivalent inductive part increases due to the defect and produces equivalently the high effective dielectric constant, that is slow wave property-due to this fact the DGS line has the longer electrical length than the standard Microstrip line-for the same physical length. By varying the various dimensions of the defect the desired resonance frequency can be achieved [13]. An 'inverted SHA' shaped DGS for bandwidth enhancement of rectangular microstrip patch antenna was presented by Dawit F. et al. [14]

In this paper an efficient proximity coupled feed Rectangular Microstrip Patch Antenna (RMPA) with reduced harmonic radiation dedicated to different wireless applications in the S-band, like WLAN, ISM and RFID applications is presented. Varying the length & location of the microstrip feed line and Defected Ground structure techniques are used to reduce the harmonic radiation from the other patch mode to minimum.

2. Antenna Design

The Microstrip Patch Antenna (MPA) is made up of rectangular radiating patch printed on the first substrate. The microstrip feed line is placed on the upper side of the second substrate. The geometry of a Proximity Coupled Feed Rectangular Microstrip Patch Antenna (PRMPA) is shown in Figure 1.

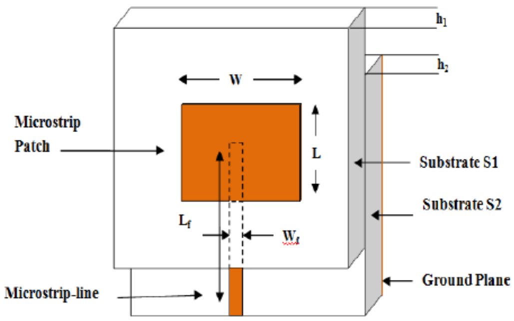


Figure 1. Geometry of Proximity Coupled Feed Rectangular Microstrip Patch Antenna

The antennas are designed using Rogers TMM-3 substrate material with dielectric constant, $\varepsilon_r = 3.27$ and dissipation factor, $\tan\delta = 0.0020$. The two substrates used for this design are of different thickness, $h_1 = 1.27\ mm$ and $h_2 = 0.762\ mm$. When using proximity coupled feed method, the substrate parameters of the two layers can be selected to increase the bandwidth of the patch and to reduce spurious radiation from the microstrip feed line, for this the lower layer should be thin. The radiating patch being placed on the double layer gives a larger bandwidth [15]. The length and width of the patch are 32 mm and 34.68 mm respectively which are dimensioned to resonate at 2.45 GHz. The length and width of the ground plane are 57.9 mm and 70.5 mm respectively.

The microstrip feed line is dimensioned for 50 Ω characteristic impedance; the width of the feed line is 2.6 mm. In this section the effect of varying the microstrip feed line length & location and implementing a defect in the ground plane is investigated. The antenna matching can be achieved with an appropriate line-patch overlap, but with a careful design consideration. Not only the good matching of the fundamental mode, but also the effect on the harmonic radiation from the other patch modes has to be considered. Hence the length & location of the feed line is varied and the ground plane is defected with 'Rectangular' shaped slot for best impedance matching and reduced harmonic radiation from the other patch modes. The slot in the ground plane, which is shown with its dimensions in Figure 2, is centered below the microstrip feed line with respect to x-axis. An efficient proximity coupled feed rectangular microstrip patch antenna with reduced harmonic radiation is achieved by varying the length & location of the feed line and implementing defect in the ground plane. A high return loss at the resonant frequency with harmonic radiation from other patch modes reduced to minimum can be achieved with the length of feed line 25 mm, and the location of the feed line set at (-2.6, -0.5, -1.27). The designed geometry of the Proximity Coupled Feed Rectangular Microstrip Patch Antenna with Defected Ground Structure is shown in Figure 3.

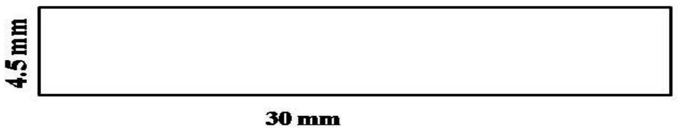
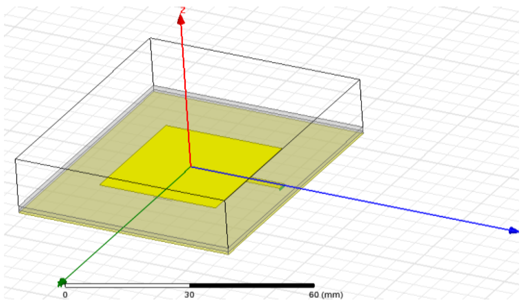
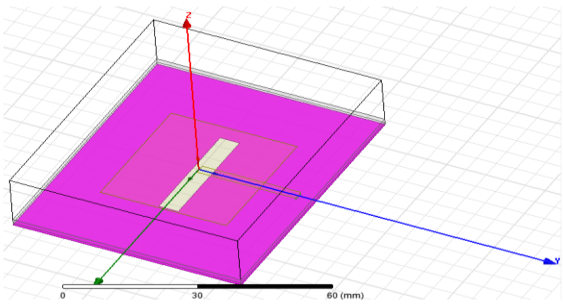


Figure 2. The 'Rectangular' shaped defect introduced in the ground plane with its dimensions



(a) Top view



(b) Bottom view

Figure 3. Deigned structure of the proposed PRMPA with 'Rectangular' shaped slot in the ground plane

The proposed antenna resonates at frequency (f_r) of 2.45 GHz. The resonant frequency, also called the center frequency, is the one at which the return loss is minimum. For a specific resonant frequency (f_r), dielectric constant of the substrate (ε_r) and height of the substrate (h); the design procedure of a rectangular microstrip patch antenna using transmission-line model is as follows:

1) The Patch Width (W): for efficient radiation is given as;

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

Where,

W, is the patch width.

c, is the free space velocity of light,

f_r, is the resonant frequency, and

ε_r, is the dielectric constant of the substrate.

2) The Effective Dielectric Constant $(\boldsymbol{\varepsilon_{reff}})$ **-** Due to the fringing and the wave propagation in the field line, an effective dielectric constant (ε_{reff}) must be obtained.

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

Where,
ε_{reff} , is the effective dielectric constant
h, is the height of the dielectric substrate

3) The Effective Length $(\boldsymbol{L_{eff}})$: for a given resonance frequency (f_r) is given as;

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

4) The Length Extension $(\Delta\boldsymbol{L})$: is given as;

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

5) The Patch Length $(\boldsymbol{L})$**:** The actual patch length now becomes;

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

6) Calculation of Ground Dimen***sions*** $(\boldsymbol{L_g}\ \textbf{and}\ \boldsymbol{W_g})$

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown that similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, the ground plane dimensions would be given as [16]:

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

$$W_g = 6h + W \quad (7)$$

3. Results and Discussions

The proposed Proximity Coupled Feed Rectangular Microstrip Patch Antenna with Defected Ground Structure is evaluated against different parameters to study its performance. Full-wave Electromagnetic (EM) Field Simulator, High Frequency Structure Simulator (HFSS) software package –Version 13.0 (HFSS V.13.0) is used to obtain the performance parameters of the proposed antenna.

3.1. Return Loss and Bandwidth

The proposed PRMPA with Defected Ground Structure shows good return loss of -47.0546 dB at the resonant frequency of 2.45 GHz with the harmonic radiation from other patch modes reduced to minimum as shown in Figure 4. At this resonant frequency, it gives a bandwidth of 88.5 MHz.

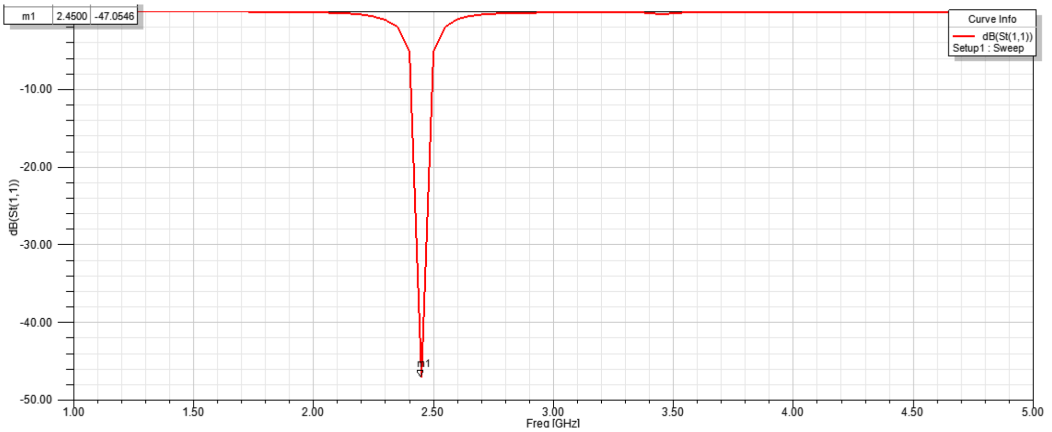


Figure 4. Return Loss of the PRMPA with Defected Ground Structure resonating at 2.45GHz

3.2. VSWR

Figure 5 shows VSWR plot of the proposed PRMPA with Defected Ground Structure. At the resonant frequency of 2.45 GHz, the VSWR is found to be 1.0089. As the value of VSWR is approximately equal to 1 at the resonant frequency; the proposed antenna results in perfect impedance matching.

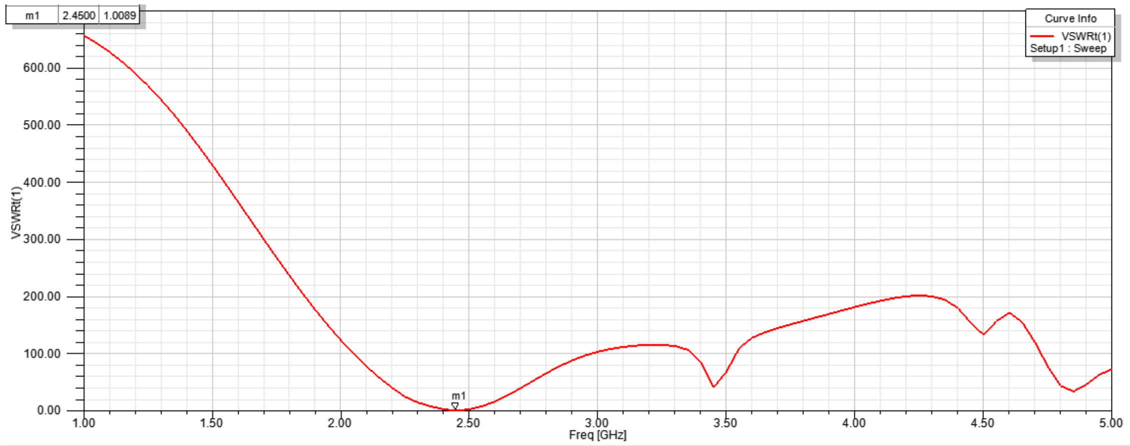


Figure 5. VSWR of the PRMPA with Defected Ground Structure resonating at 2.45GHz

3.3. Directivity

Figure 6 shows the 3D polar plot of total directivity obtained for the proposed PRMPA with Defected Ground Structure. As shown in this figure, the Total Directivity of the proposed antenna at resonant frequency of 2.45 GHz is 4.5799 dB.

Figure 6. 3D polar plot of Total Directivity of the PRMPA with Defected Ground Structure resonating at 2.45 GHz

3.4. Total Gain

Figure 7 shows the polar plot of total gain obtained for the proposed PRMPA with Defected Ground Structure. As shown in this figure, the Total Gain of the proposed antenna at resonant frequency of 2.45 GHz is 4.2797 dB.

Figure 7. 3D polar plot of Total Gain of the PRMPA with Defected Ground Structure resonating at 2.45 GHz

The table below, i.e., Table 1 summarizes the simulation results of the different antenna parameters of the proposed Proximity Coupled Feed Rectangular Microstrip Patch Antenna with Defected Ground Structure.

Table 1. Simulation results of the different antenna parameters of the proposed Proximity Coupled Feed Rectangular Microstrip Patch Antenna with Defected Ground Structure resonating at 2.45 GHz

Antenna parameter	Value
Return loss	-47.0546 dB
Bandwidth	88.5 MHz
VSWR	1.0089
Impedance	49.5889
Directivity	4.5799 dB
Gain	4.2797 dB
Radiation efficiency	93.322%

4. Conclusion

The design of an efficient proximity coupled feed rectangular microstrip patch antenna with Defected Ground Structure which results in reduced harmonic radiation from the other patch modes working in S-band has been successfully accomplished in this paper. By varying the length & location of the microstrip feed line and introducing a defect in the ground plane - a high return loss at the resonant frequency with harmonic radiation from other patch modes reduced to minimum is achieved. The bandwidth of the microstrip patch antenna is found to be 88.5 MHz at resonant frequency of 2.45 GHz with return loss of -47.0546 dB. The proposed antenna is useful for different wireless applications in the S-band, like WLAN, ISM and RFID applications.

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References

[1] Constantine A. Balanis. Antenna Theory: Analysis and Design. 3rd ed. John Wiley & Sons, Inc. 2005.
[2] LC Godara and R Waterhouse. Handbook of Antenna in Wireless Communication. Florida, USA: CRC Press LLC. 2002.
[3] Amit Kumar, Jaspreet Kaur and Rajinder Singh. Performance Analysis of Different Feeding Techniques. *International Journal of Emerging Technology and Advanced Engineering*. 2013; 3(3): 884-890.
[4] M Cryan and P Hall. *Spectral control of integrated active antennas*. Proc. 10th Int. Conf. Antennas Propag. 1997; 1: 518–521, (Conf. Publ. No. 436).
[5] D Segovia, V Gonzalez, JL Vazquez, E Rajo, L Inclan and C Martin. An active broadband-transmitting patch antenna for GSM- 1800 and UMTS. *Microw. Opt. Technol. Lett.* 2004; 41: 350–354.
[6] V Radisic, Y Qian and T Itoh. Broadband power amplifier integrated with slot antenna and novel harmonic tuning structure. *IEEE MTT-S Digest*. 1998.
[7] Y Horii and M Tsutsumi. Harmonic control by photonic bandgap on microstrip patch antenna. *IEEE Microw. GuidedWave Lett.* 1999; 9: 13– 15.
[8] YJ Sung and YS Kim. An improved design of microstrip patch antennas using photonic bandgap structure. *IEEE Trans. Antennas Propag.* 2005; 53: 1799–1804.
[9] S Lin, K Huang and JS Chen. Harmonic control for an integrated microstrip antenna with loaded transmission line. *Microw. Opt. Technol. Lett.* 2005; 44: 379–383.
[10] R Dehbashi, Z Atlasbaf and K Forooraghi. New compact size microstrip antennas with harmonic rejection. *IEEE Antennas Wireless Propag. Lett.* 2006; 5: 395–398.
[11] Y Sung, M Kim and Y Kim. Harmonics reduction with defected ground structure for a microstrip patch antenna. *IEEE Antennas Wireless Propag. Lett.* 2003; 2: 111–113.
[12] Deepti, Amanpreet Kaur, Rajesh Khanna. Multiband Proximity Coupled Microstrip Patch Antenna with EBG and DGS Leading to Reduced Harmonic Radiation. *International Journal of Advanced Research in Computer and Communication Engineering.* 2013; 2(6).
[13] Ashwini K Arya, MV Kartikeyan, A Patnaik. Defected Ground Structure in the perspective of Microstrip Antennas: A Review. *Article in Frequenz Berlin.* 2010; 79-84.
[14] Dawit Fistum, Dilip Mali, Mohammed Ismail. Bandwidth Enhancement of Rectangular Microstrip Patch Antenna using Defected Ground Structure. *Indonesian Journal of Electrical Engineering and Computer Science.* 2016; 3(2): 428 ~ 434.
[15] Jinal R Patel and Jigar B. Chaudhari. Optimization and Return loss Reduction of Microstrip Patch Antenna. *International Journal of Innovative Research in Computer and Communication Engineering.* 2015; 3(6): 4996- 5003.
[16] Preet kaur, Rajiv Nehra, Manjeet Kadian, Dr Asok De and Dr SK Agarwal. Design of improved performance of rectangular microstrip patch antenna using peacock and star shaped DGS. *International Journal of Electronics Signals and Systems (IJESS).* 2013; 3(2): 33-37.