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Multiband Proximity Coupled Microstrip Patch Antenna with EBG and DGS Leading to Reduced Harmonic Radiation

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Abstract: The purpose of this work is to propose a method for suppression of harmonic radiations in a multilayer substrate proximity coupled fed Microstrip patch antenna. The 2nd and 3rd harmonics are suppressed to reduce spurious radiation from any of the corresponding patch modes. The second harmonic is controlled by varying the feed line length and the third harmonics by using a compact resonator. This multilevel resonator has printed metallization with a via connected to the ground plane. The ground plane is a Defected Ground Plane structure. With DGS, a triple band operation is achieved.

Keywords: Compact electromagnetic bandgap (EBG) resonator, Defected Ground Structure (DGS), patch antenna, proximity coupled, harmonic suppression, multibanding.

I. INTRODUCTION

Microwave devices have active elements which generate harmonic frequencies. Since in radio frequency front ends, the microwave devices and antenna are very closely placed, hence if an antenna is not well isolated at these frequencies, those signals can be radiated and part of the power at resonant frequency is lost. Also it results in interference with other radio systems. With a Microstrip patch antenna, active device integration is used to meet the requirements of modern wireless communication. Active patch antennas have non linear devices inside the antenna and they exhibit high level of harmonic radiations [1]. Sometimes the patch antenna itself is used to filter these harmonics [2].

There are several methods which can be used for suppressing the harmonics [3]-[7]. A photonic bandgap structure on the feeding line of a slot coupled Microstrip patch antenna was introduced by Itoh *et al* [3]. Defected ground structures (DGS) [8] and compact resonant cell structure (CMRC) [5] have been used to accomplish the mentioned aim. The disadvantage in using these techniques is that the resonant cells and the periodic elements coplanarly load the feed line of the antenna or they are etched into the ground plane. This results in degradation of the antenna radiation characteristics. All these methods also suffer from spurious back radiation problems due to feeding line radiation related to discontinuities.

In this work, multibanding with reduction of harmonics using two different techniques is investigated:

- Second harmonics is reduced with Feed line-patch overlap length (L)
- Third Harmonics is eliminated using a compact EBG resonator (mushroom type) which consists of a patch with a grounded via [9] [10].
- Triple band is achieved using Defected Ground Structure with order of harmonics reduced to at least one.

The benefits of using proximity coupling feeding technique are the ease in manufacturing and matching. Also, it has a high bandwidth as compared to other feeding mechanisms. Radiation from line-patch discontinuities is reduced as compared to coplanar feeding [11]. Also, selection of an optimum substrate for the line is possible since patch and the line are not printed in the same substrate layer. With an appropriate line-patch overlap, matching to the fundamental patch mode is achieved.

In the section II, mathematical model for EBG and DGS is shown. In III, antenna design parameters using a compact resonator and DGS are obtained. In IV, simulation results for triple band antenna are shown.

II. MATHEMATICAL MODEL

A. *Mushroom EBG*

A mushroom EBG is used as a compact resonator. It consists of two layer substrate with patch on the lower layer and a via connected to the ground. It is characterized by having high

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Vol. 2, Issue 6, June 2013

surface impedance. Although it is made of continuous metal, and conducts dc currents, it does not conduct ac currents within a forbidden frequency band. By incorporating a special texture on a conducting surface, it is possible to alter its radio-frequency electromagnetic properties. In the limit where the period of the surface texture is much smaller than the wavelength, the structure can be described using an effective medium model, and its qualities can be summarized into a single parameter: the surface impedance. A smooth conducting sheet has low surface impedance, but with a specially designed geometry, a textured surface can have high surface impedance. The surface impedance is modeled as a parallel resonant circuit, which can be tuned to exhibit high impedance over a predetermined frequency band. The high-impedance surface can be considered as a kind of two-dimensional photonic crystal that prevents the propagation of radio-frequency surface currents within the bandgap.

We assign to the surface a sheet impedance equal to the impedance of a parallel resonant circuit, consisting of the sheet capacitance and the sheet inductance:

$$Z = j\omega L/(1-\omega^2 LC) \qquad (1)$$

The surface is inductive at low frequencies, and capacitive at high frequencies. The impedance is very high near the resonance frequency, so a high impedence is obtained and the EBG does not support any surface waves, resulting in a frequency band gap.

$$\omega_o = 1/\sqrt{LC} \qquad (2)$$

The high impedence surface also ensures that a plane wave will be reflected without the phase reversal that occurs on a perfect electric conductor (PEC).

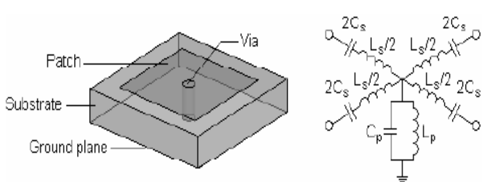

Fig.1 Equivalent circuit representation of metallodielectric structure.

The value of the capacitance is obtained by the fringing capacitance between neighboring co-planar metal plates. This can be done by conformal mapping.

$$C = \frac{W\varepsilon_o(1+\varepsilon_r)}{\pi}\cosh^{-1}\left(\frac{W+g}{g}\right) \qquad (3)$$

Where *W* is the patch width and *g*, gap width.The inductance depends only on the thickness of the structure and the permeability:

$$L = \mu h \qquad (4)$$

h- Substrate thickness

B. Defected Ground Structure (DGS)

Recently, there has been an increasing interest in the use of DGSs for performance enhancement of microstrip antennas and arrays. They are realized by etching of a simple shape defect from the ground plane of the microstrip antenna. The shape may vary from a simple geometry to a complicated one. Due to its resonant behaviour, the DGS may be compared to the LC parallel resonator, i.e., the equivalent circuit of the DGS consists of an inductance and a capacitance in parallel to itself [12, 13].

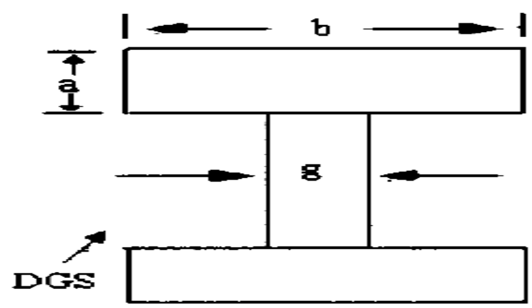

Fig.2 Dumbbell shaped DGS

It is the simple and mostly used dumbbell shaped DGS which is etched in the ground plane below the microstrip line, in which both the areas (*a&b*) and slot gap (*g*) play very important roles for finding the resonance behavior of the DGS.

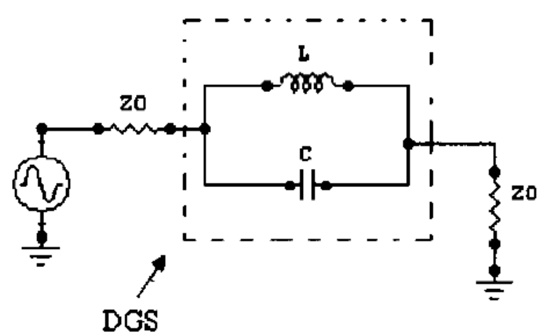

Fig.3 The equivalent circuit of the DGS as a parallel combination of Inductance (*L*) and Capacitance (*C*)

The head areas (*a & b*) are very useful for the variation in the inductance (*L*), and slot (*g*) produces the capacitance (*C*).

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Vol. 2, Issue 6, June 2013

The L and C may be calculated from the formulae given below [15].

$$L = 1/4\pi^2 f_0^2 C \quad (5)$$

$$C = \frac{f_c}{2Z_o} \cdot \frac{1}{2\pi\sqrt{f_o^2 - f_c^2}} \quad (6)$$

III. Antenna Design

The proximity coupled printed antenna configuration is shown in Fig. 4. A squared patch (mm) is used and the substrate multilayer is described in Table I. The dimensions of the substrate are 100×100 mm and patch is 50 ×50mm. The microstrip line feed for proximity feeding is designed as a 50Ω line and is symmetrically located under the metallization of the patch on top of substrate layer 2. CST Microwave Studio 2010 software [14] is used for the full wave simulations in this paper.

A. Parametric study of feedline length

In this section the effect of the variation of the microstrip feed line length is investigated. The antenna matching can be achieved with an appropriate line-patch overlap however with a careful design consideration, not only the good matching of the fundamental mode but also the effect on the harmonic frequencies matching can

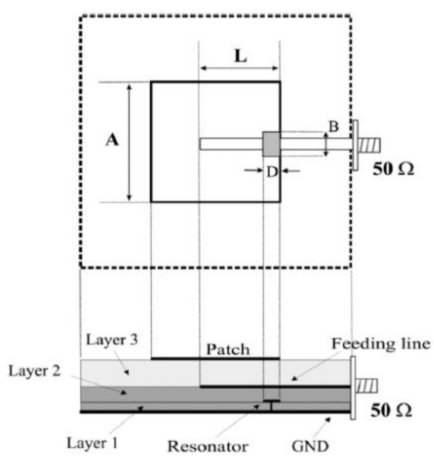

Fig.4 Sketch of Printed Antenna

TABLE I
CHARACTERISTICS OF MULTILAYER SUBSTRATE

Layer	Thickness (mm)	ϵ_r	Material	$\tan\delta$
1	0.5	4.5	FR4	0.015 (1 GHz)
2	1.5	4.5	FR4	0.015 (1 GHz)
3	2	1.05	Rohacell 51	0.0002 (2.5 GHz)

significantly reduce the harmonic radiation. Coupling between the patch and the microstrip line is capacitive in nature. A typical equivalent circuit for this feed is a coupling capacitor that is in series with the parallel resonant circuit representing the patch [15]. This capacitor can be adjusted for matching the antenna. Carrying out a parametric study of this overlap (related to the capacitance in the equivalent circuit) to control the mismatching of the second and third harmonic resonances of the antenna is done. To obtain a good return loss at the fundamental frequency, a length for the overlapping greater than 0.55 L/A is necessary.

B. Resonator Design

In our multilayer design we propose to use a resonator based in the geometry introduced by Sievenpiper *et al.* [9] and firstly applied to implement a compact filter by Horii [10], [15]. The cell consists of a printed small patch (located under the line in a centred position) with a via connected to the ground plane (mushroom type). Substrates are the ones defined in Table I, i.e., the mushroom is printed on the 0.5 mm substrate, then there is an upper layer with the same material and a 1.5 mm thickness, on top of which the line is printed. This mushroom type element works as a resonator, which makes a short circuit between the transmission line and the ground plane at resonance.

The increase in the resonator metallization size causes a reduction in the resonant frequency. Resonator with patch size D=9 mm and B=6 mm is used.

A detailed numerical characterization of the stopband position and bandwidth with the geometrical parameters of the resonator has been presented in [16].

C. Parametric study of DGS

A dumbbell shaped DGS is made, etching the shape from the ground. The parameters of DGS are depicted in Table II.

TABLE II
DGS PARAMETERS

a	*B*	*c*
7mm	36mm	18mm

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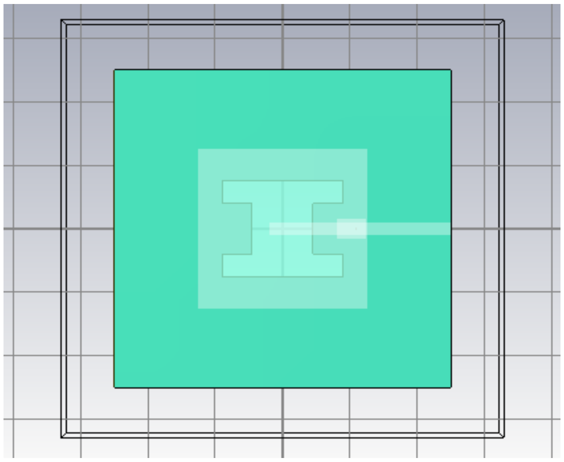

Fig.5 Designed antenna

IV. Simulation Results

A. Return Loss

The simulated return loss of the antenna with EBG and DGS is as shown in figure 6.

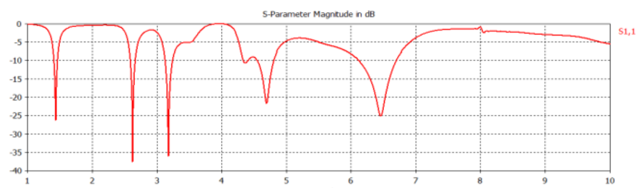

Fig.6 S11 parameter of antenna

With simple proximity coupled antenna, there is a single band operation. Using DGS, multiband operation is obtained but return loss at desired frequencies is higher. Using an EBG in the structure improves the return loss at desired frequencies up to 25dB. It also reduces the harmonic radiations with order of harmonics reduced to at least one. The RL is defined as $RL=20\log_{10}|\Gamma|$

For the perfect matching between the transmitter and antenna $\acute{\Gamma} = 0$ and RL is infinity which means no power is reflected back, while $\acute{\Gamma} = 1$ has an RL = 0, which implies that all the incident power is reflected. In practical applications, the applicable VSWR of 2 is acceptable corresponds to an RL of -9.5 dB or 11% power reflection.

The return loss at 1.43GHz is -26dB, at 2.61GHz is -38dB and at 3.17GHz is -36dB with a bandwidth of 80MHz at all frequencies.

B. VSWR at desired frequencies

The VSWR range at all the desired frequencies is between 1 and 1.30.

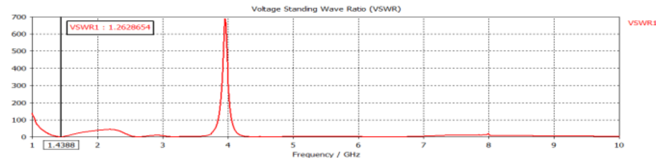

Fig.7 VSWR at 1.43GHz

VSWR at 1.43GHz is found to be 1.26.

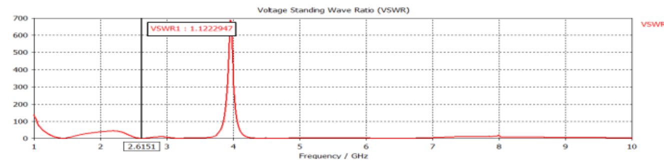

Fig. 8 VSWR at 2.61GHz

VSWR at 2.61GHz is found to be 1.12.

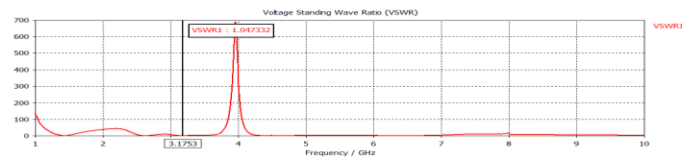

Fig. 9 VSWR at 3.17GHz

VSWR at 3.17 GHz is found to be 1.04.

C. Gain

The polar plots for farfield characteristics at triple band frequencies is shown as below:

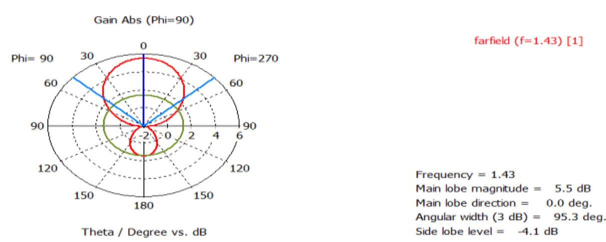

Fig.10 Farfield at 1.43GHz

Highest gain is found to be 5.476dB in the direction of theta equal to zero with an angular width of 95.3 degrees and a side lobe level of -4.1dB.

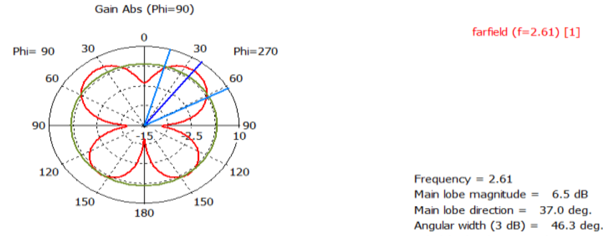

Fig.11 Farfield at 2.61GHz

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International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 6, June 2013

Highest gain is 6.464dB in the direction of theta 37 degrees and Phi=90 and 270 degrees with an angular width of 46.3 degrees. Another front lobe is there which is diametrically opposite and identical to the main lobe. There are two back lobes each having an angular width of 20 degrees. Hence, the antenna radiation pattern is identical to that of omnidirectional antenna.

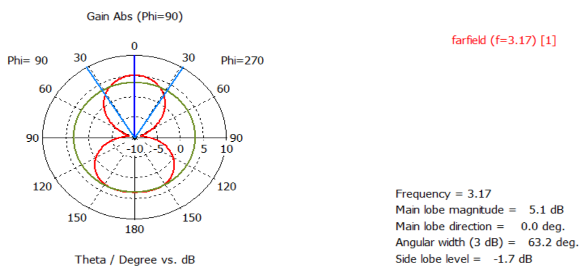

Fig.12 Farfield at 3.17 GHz

Highest gain is found to be 5.121dB in the direction of theta equal to zero with an angular with of 63.2 degrees. There is back lobe in the direction of theta equal to 180 degrees, with an angular width of 120 degrees. These two side lobes allow bidirectional communication.

V. CONCLUSION

Using an EBG and DGS with simple proximity coupled antenna, a compact triple band antenna with reduced harmonics is obtained. The designed triple band antenna can be used for satellite applications. The 1.4GHz band is used to provide supplementary mobile downlink, 2.6GHz band is used for mobile broadcasting and 3.1 GHz band for mobile WiMax applications. With a gain of 5.476dB at 1.43, 6.464dB at 2.61 and 5.121dB at 3.17, this antenna can be used in MIMO applications.

REFERENCES

[1] M. Cryan and P. Hall, "Spectral control of integrated active antennas," in *Proc. 10th Int. Conf. Antennas Propag.*, Apr. 1997, vol. 1, pp. 518–521, (Conf. Publ. No. 436).

[2] D. Segovia, V. Gonzalez, J. L. Vazquez, E. Rajo, L. Inclan, and C. Martin, "An active broadband-transmitting patch antenna for GSM- 1800 and UMTS," *Microw. Opt. Technol. Lett.*, vol. 41, pp. 350–354, Jun. 2004.

[3] V. Radisic, Y. Qian, and T. Itoh, "Broadband power amplifier integrated with slot antenna and novel harmonic tuning structure," *IEEE MTT-S Digest*, 1998.

[4] Y. Horii and M. Tsutsumi, "Harmonic control by photonic bandgap on microstrip patch antenna," *IEEE Microw. GuidedWave Lett.*, vol. 9, pp. 13–15, Jan. 1999.

[5] Y. J. Sung and Y. S. Kim, "An improved design of microstrip patch antennas using photonic bandgap structure," *IEEE Trans. Antennas Propag.*, vol. 53, pp. 1799–1804, May 2005.

[6] S. Lin, K. Huang, and J. S. Chen, "Harmonic control for an integrated microstrip antenna with loaded transmission line," *Microw. Opt. Technol. Lett.*, vol. 44, pp. 379–383, Feb. 2005.

[7] R. Dehbashi, Z. Atlasbaf, and K. Forooraghi, "New compact size microstrip antennas with harmonic rejection," *IEEE Antennas Wireless Propag. Lett.*, vol. 5, pp. 395–398, Dec. 2006.

[8] Y. Sung, M. Kim, and Y. Kim, "Harmonics reduction with defected ground structure for a microstrip patch antenna," *IEEE Antennas Wireless Propag. Lett.*, vol. 2, pp. 111–113, 2003.

[9] D. Sievenpiper, L. Zhang, R. Broas, N. G. Alexopolus, and E. Yablonovitch, "High impedance electromagnetic surfaces with a forbidden frequency band," *IEEE Trans. Microw. Theory Tech.*, vol. 47, pp. 2059–2074, Nov. 1999.

[10] Y. Horii, "Filtering effects of a grounded patches embedded in a microstrip line substrate," Tech. Rep. lEICE, Japan, MWPO2-3, Jul. 2002, pp. 15–22.

[11] G. Splitt and M. Davidovitz, "Guidelines for for design of electromagnetically coupled microstrip patch antennas on two layer substrates," *IEEE Trans. Antennas Propag.*, vol. 38, pp. 1136–1140, Jul. 1990.

[12] Liu, H., Z. Li, and X. Sun, \Compact defected ground structure in microstrip technology," *Electronics Letters*, Vol. 41, No. 3, 132-134, 2005.

[13] Li, G. H., X. H. Jiang, and X. M. Zhong, "A novel defected ground structure and its application to a low pass filter," *Microwave and Optical Technology Letters*, Vol. 48, No. 9, 453{456, 2006.

[14] Computer Simulation Technology, CST Microwave Studio 2010 [Online]. Available: www.cst.com

[15] R. Garg, P. Barthia, I. Bahl, and A. Ittipiboon, *Microstrip Antenna Design sHandbook*. Boston, MA: Artech House, 2000.

[16] L. Inclan-Sanchez, J. L. Vazquez-Roy, and E. Rajo-Iglesias, "Characterization of new compact filter based on EBG resonators," *Proc. Metamaterials*, vol. 1, pp. 681–684, Oct. 2007.