ISSN 2321 – 2004
ISSN 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 1, Issue 6, September 2013

Size Reduction and Bandwidth Enhancement of Microstrip Patch Antenna by Proper Positioning of Patch above the Defected Ground Plane

Madan Mohan[1], Sudipta Das[2], Shambhu Mahato[3],Ashwani Kumar Chaudhary[4]

Student, Department of Electronics and Communication Engineering, IMPS College of Engineering and Technology, Malda, W.B, India[1]

Assistant Professor, Department of Electronics and Communication Engineering, IMPS College of Engineering and Technology, Malda, W.B, India[2]

Student, Department of Electronics and Communication Engineering, IMPS College of Engineering and Technology, Malda, W.B, India[3]

Student, Department of Electronics and Communication Engineering, IMPS College of Engineering and Technology, Malda, W.B, India[4]

Abstract: article, a single layer reduced size broadband microstrip antenna with properly positioned In this patch placed above defected ground plane has been successfully implemented. The size of the antenna is reduced with large enhancement in bandwidth by defecting the ground plane and proper positioning of the patch with respect to the defected ground plane. With theproposed design, a maximum size reduction of 75% in the antenna is obtained with respect to the conventional microstrip patch antenna on an infinite ground plane. The measuredresult shows -10dB return loss bandwidth of about 3.02 GHz (2.85-5.87GHz) and 1.4 GHz(7.10-8.5GHz) which are 69% and 18% respectively around their center frequencies. The overall dimensions of the proposed antenna ($24x20x1.5875mm^3$) can be easily applied for WLAN, HiPERLAN, HisWaNa and WiMAX applications

Keywords: Bandwidth Enhancement, Defected Ground Plane, Microstrip Patch Antenna, Size Reduction, Wireless Communication

INTRODUCTION

The popularity of wireless communication systems has increased remarkably during the last decade and the market demand still continues to increase. As a fundamental part of these systems, antenna is one of the most important design issues in modern wireless communication units. Conventionally, because a single antenna cannot operate at all the frequency bands of wireless communication, multiple different antennas covering the required bands separately should be used. However, usage of many antennas is usually limited by the volume and cost constraints of the applications. Therefore, low cost, small size and wideband antennas are essential to provide multifunctional operations for wireless communication. With the development of MIC and high frequency semiconductor devices, microstrip has drawn the maximum attention of the antenna community in recent years for wireless communication applications. In spite of its various attractive features like, light weight, low cost, easy fabrication, conformability on curved surface and so on, the microstrip element suffers from an inherent limitation of narrow impedance bandwidth typically of about 2-4%. So, along with other developments, widening the bandwidth of microstrip antenna, in general, has become a major branch of activities in the field of printed antennas [1-26]. Researchers have offered numerous methods like aperture coupling [1], use of shorting pins [2-4], stacked patch [5-8], modifications in the feed [9-10], use of coupled parasites [11-12], staggering effect [13] and introducing slots on the radiating patch [14-20] to enhance the bandwidth of microstrip antennas.Many combinations of radiating patch and the ground plane slots were also analyzed to achieve compact and broadband antennas [21-24].Maximum bandwidth of 16% has been achieved ranging from 2.25-2.65GHz using aperture coupled feeding [1] which is not suitable for 3.5GHz/5GHz WiMAX and WLAN systems. The antenna structure proposed in [2] has achieved a bandwidth of 75% but the shape of the antenna is complex to fabricate. Wenquan Cao et. al. [4] has proposed a broadband microstrip antenna loaded with shorting pin and

9.5% bandwidth at 2GHz has been achieved. The microstrip antenna proposed in [7] provides bandwidth of 47% but it uses thick substrate. Stacked notch rectangular microstrip antenna proposed in [8] provides bandwidth of only 23.6%.The L probe feed microstrip patch antenna proposed in [10] has achieved bandwidth of only 11% which not sufficient to cover the bandwidth requirement of modern wireless communication systems. Recently K.Mandal et.al.,[13] has increased the bandwidth of microstrip antenna up to 27% using staggered effect but the size of the antenna is a major problem. The frequency reconfigurable U slot microstrip antenna proposed in [15] has achieved bandwidth of 750MHz ranging from 2.6-3.35GHz but the antenna is not suitable for high speed 5GHz WLAN band. The snowflake fractal antenna [16] provides a bandwidth of 49% with a reduction of 70% in the size of the antenna. The small patch antenna proposed in [17] achieves a size reduction of 50% and bandwidth of 53%. The microstrip line fed microstrip antenna proposed in [19] has increased the bandwidth upto 25% but the large size ($40\times60\times1.6mm^3$) of the antenna is still a major problem. The CPW fed monopole antenna [20] has low gain (2.0-3.8dBi) at the operating bands and also large dimension($32\times51.5mm^2$).Some microstrip antennas with simple radiating patch and slotted ground plane were also proposed by researchers [21-24] to provide compact broadband performance. It was reported by Kuo and Wong [21] that by embedding three meandering slots in the ground plane of the rectangular microstrip patch antenna, the size of the antenna can be reduced by 56% but the narrow bandwidth is a major problem. The microstrip antenna proposed in [22] has increased the operating bandwidth upto 50% by embedding two parallel open end slots on the ground plane. The microstrip line fed rectangular microstrip antenna with open end meandering slots in the ground plane for compact broadband operation has been reported in [23].The bandwidth obtained in that article was 0.43GHz i.e. 40% with 82.9% reduction in antenna size. Recently S.Sarkaret al., [24] proposed an antenna using optimized single slotted ground plane which provides 90% size reduction with only 12.8% BW which radiates in a single frequency. Yikai Chen et al.,[25] proposed an antenna with bandwidth of about 9% of the center frequency. Recently M.A.Martin et.al.,[26] has reported a new design of a U-slot microstrip antenna with an E shaped stacked patch that achieves an impedance bandwidth of 59.7%. In this paper, we have proposed a single layer coaxially fed microstrip patch antenna with defected ground plane for extreme compact and broadband operation. The dual broad impedance bandwidth is achieved without any modifications in the radiating patch and without application of thick substrate. The novelty of our work is that extreme size reduction and wide impedance bandwidth is achieved only by defecting the ground plane with an open ended T shaped slot and proper positioning of the radiating patch with respect to the defected ground plane. This work clearly represents a new design technique to improve the bandwidth of microstrip patch antenna by shifting the position of radiating patch above the defected ground plane. With the proposed design, dual broad bandwidth of 3.02 GHz and 1.40 GHz which are 69% and 18% around their center frequencies are achieved and a reduction of 75% in antenna size is also achieved. The overall size ($24x20x1.5875mm^3$) of the proposed antenna3 is much smaller in comparison with the previously reported antenna structures. The proposed antenna is suitable for IEEE802.11.a (5.15-5.35GHz, 5.725-5.825GHz), WiMAX (3.3-3.7GHz, 5.25-5.85GHz), HiperLAN2 (5.47-5.725 GHz) and HiSWaNa (5.15-5.25 GHz) wireless application bands.

ANTENNA DESIGN

The Width (W) and Length (L) of Antenna1 is calculated from Conventional equations [27].The length and Width of the Conventional Rectangular microstrip patch antenna operating at frequency 5.5GHz are 12mm and 16mm respectively with substrate thickness h=1.5875mm and dielectric constant ε_r=4.4(FR-4).Figure1 shows the structure of the conventional microstrip antenna with L=12mm and W=16mm on an infinite ground plane (3 to 4 times of the size of the patch). Coaxial probe-feed (radius=0.5mm) is located at W/2 and L/3.Figure2 shows the configuration of antenna2 designed with a finite non defected ground plane with properly positioned patch.Figure3 shows the configuration of antenna 3 designed with properly positioned patch above the finite defected ground plane. For proposed antenna structure3 broad operating bandwidth is achieved when the defected ground plane is realized by etching off a simple open ended T shape (defect) from the ground plane. The surface current distribution of the proposed antenna3 at 4.43GHz is shown in figure4.The current distribution of the radiating patch is shown in figure4 (a) and current distribution at ground plane is shown in figure4 (b). Depending on the shape and dimensions of the defect, the shielded current distribution in the ground plane is disturbed, resulting in a controlled excitation and propagation of the electromagnetic waves through the substrate layer and from figure4,it is clear that surface current density is more strong around the slots which creates extra resonance path and varies the resonant frequency of the antenna. The bandwidth enhancement process is realized by obtaining more than one resonant frequency that radiates under -10dB level. Due to the resonant behavior of defected ground structure (DGS), it may be compared with the LC parallel resonator that means the equivalent circuit of DGS consists of an inductance and capacitance in parallel. For the proposed antenna structure, due to the defected ground plane, the equivalent inductive part increases and produces equivalently a high effective dielectric constant, thereby decreasing the resonant frequency. For both antenna2 and antenna3, the centre of the radiating patch is placed 2mm upward with respect to the centre of the ground plane. The optimum result for antenna structure3 is achieved for a particular location of the feed point (X=5mm, Y=9mm considering the centre as the origin). Alteration of location of the feed point results in narrower 10dB bandwidth and less sharp resonances at the respective frequencies. All the three antennas are designed on a FR-4 substrate with dimension 50mm×50mm. The ground plane size was optimized to achieve broad impedance bandwidth. The optimum result is achieved for ground plane of width W_g=24mm and Length L_g=20mm.To achieve wideband operation, all the parameters such as dimension of the ground plane, length and width of the slot, position of the slot on the ground plane, position of patch above the ground plane, position of the feed point were optimized using a parametric study by using IE3D [28], a full-wave commercial EM software capable of simulating finite substrate and a finite ground structure and the prototype of the proposed antenna with optimal geometrical parameters was constructed and measured.

The optimal dimensions of the proposed antenna3 are given in Table1

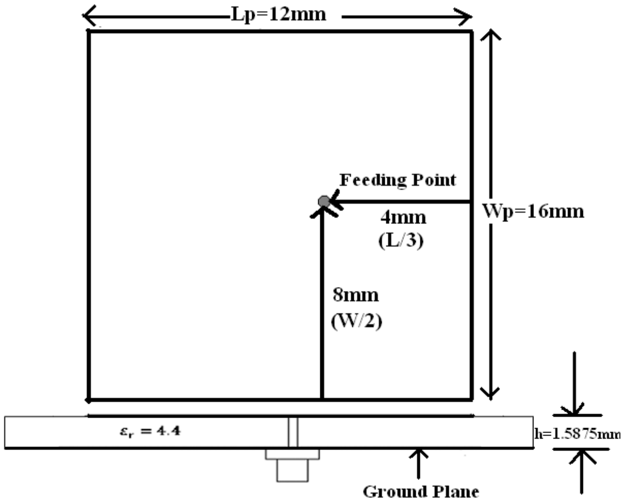

Figure1: Configuration of Antenna1 (Conventional antenna)

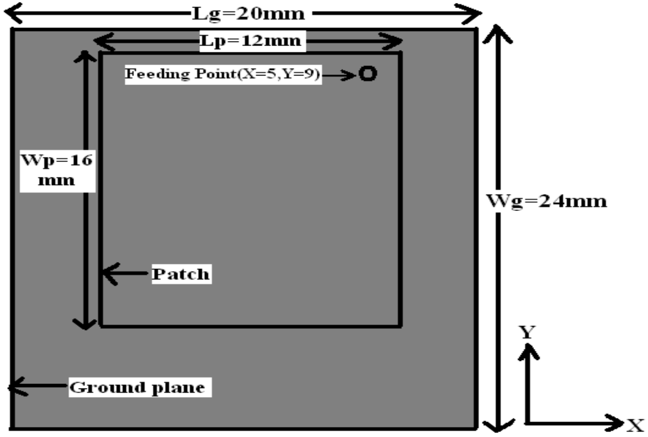

Figure2: Configuration of Antenna2 with properly positioned patch placed above finite non defected ground plane

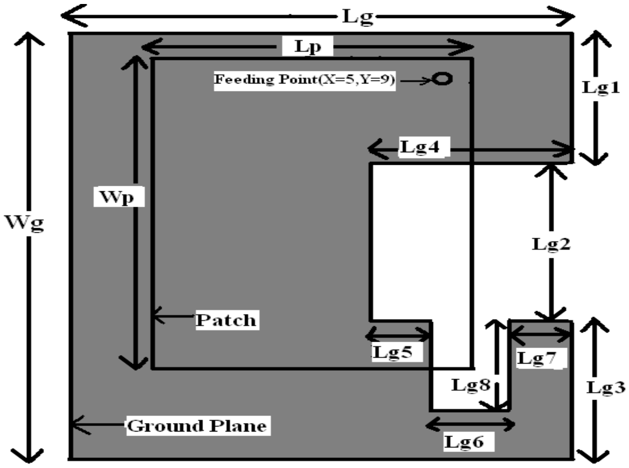

Figure3: Configuration of Proposed Antenna3 with properly positioned patch placed above finite defected ground plane

Table1 Final optimal dimensions of proposed antenna3

Parameter	Value(mm)	Parameter	Value(mm)
Wg	24	Lg3	7.5
Lg	20	Lg4	9
Wp	16	Lg5	2.25
Lp	12	Lg6	4.5
Lg1	7.5	Lg7	2.25
Lg2	9	Lg8	2.7

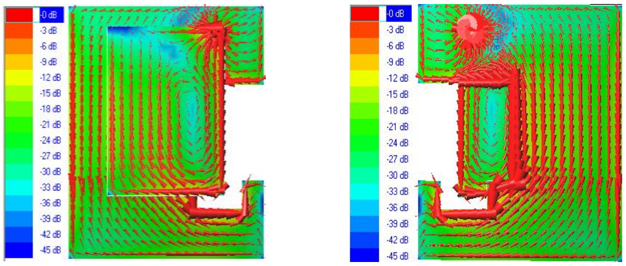

Figure4(a) Figure4 (b)

Figure4: Surface current distribution at 4.43GHz (a) Top View (patch) (b) Bottom View (ground plane)

PARAMETRIC STUDY

To take insight into the physical behavior of the proposed antenna, the impact of varying the design parameters on the antenna return loss versus frequency is studied.Figure5 shows the return loss curves for different shifted positions of the radiating patch above the defected ground plane. As shown in figure 5 by shifting the centre of the patch 2 mm upward with respect to the centre of defected ground plane, the operating bandwidth is enhanced with significantly large

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 1, Issue 6, September 2013

improvement at the upper bands. The effect of probe feeding location of the patch on the variations of bandwidth and return loss is also investigated and it is shown in figures6-7.The optimum result in terms of both improvement of bandwidth and return loss is achieved when the probe is fed at X=5,Y=9.5, considering centre as the origin. Alteration of location of the feeding points result in narrower 10 dB bandwidth and less sharp resonances. The impact of varying the design parameter Lg2 on the return loss of the antenna is demonstrated in figure8.It is clear from figure8 that with increasing Lg2, the bandwidth of the lower band increases and a new resonance mode is produced at the upper band. The optimum bandwidth in both lower band and upper band is achieved when Lg2 is chosen as 9mm. The effect of varying the design parameter Lg4 is depicted in figure9.From the figure it is clear that the bandwidth of the antenna depends upon the design parameter Lg4.The bandwidth of the antenna increases with increasing value of Lg4.The optimum bandwidth is achieved when Lg4 is 9mm. By increasing both the design parameters Lg2 and Lg4, the bandwidth of the antenna is remarkably enhanced at the upper band. The impact of design parameter Lg6 is depicted in figure10.The bandwidth improvement is nearly equal for all the values of Lg6:3.5mm, 4.5mm, 5.5mm but maximum return loss is achieved when Lg6 is chosen as 4.5mm.Figure11demonstrates the impact of varying design parameter Lg8 on the performance of the proposed antenna. When the design parameter Lg8 of the slot is 1.7mm, the return loss of the antenna much better than other values of Lg8 but the achieved bandwidth is (2.8GHz-5.1GHz) which is not covering the upper band WiMAX (5.25-5.85GHz) and HiperLAN2 (5.47-5.725GHz) band but when Lg8 is chosen as 2.7 mm the achieved bandwidth is 2.81-5.87GHz and it covers the bandwidth requirement of upper band WiMAX and HiperLAN2 band.

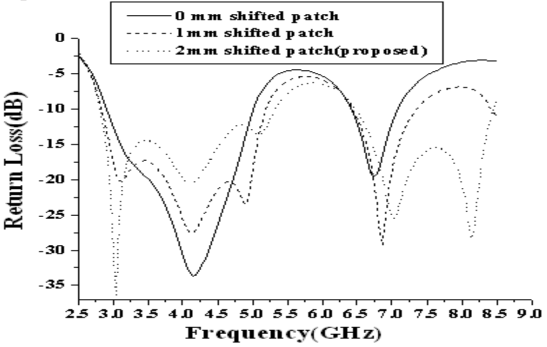

Figure5: Simulated return loss as a function of position of the patch above the defected ground plane

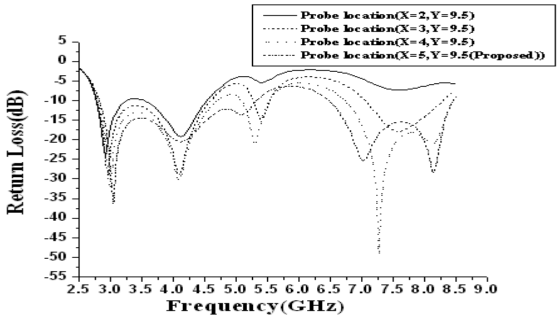

Figure6: Simulated return loss as a function of location of feed point

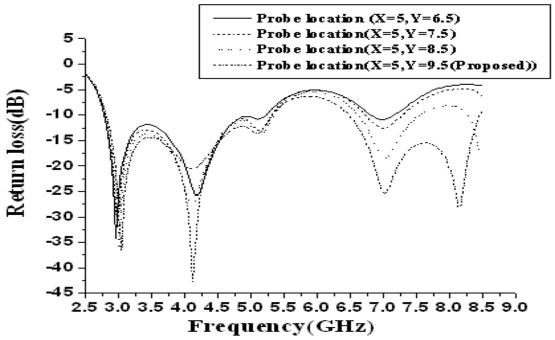

Figure7: Simulated return loss as a function of location of feed point

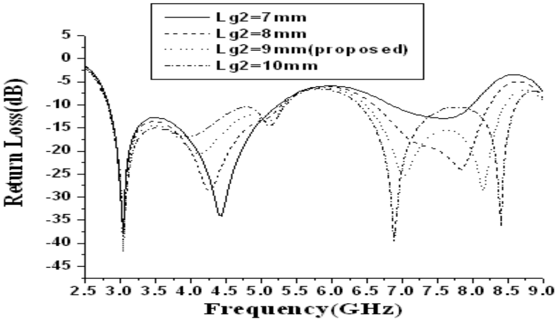

Figure8: Simulated return loss as a function of Lg2

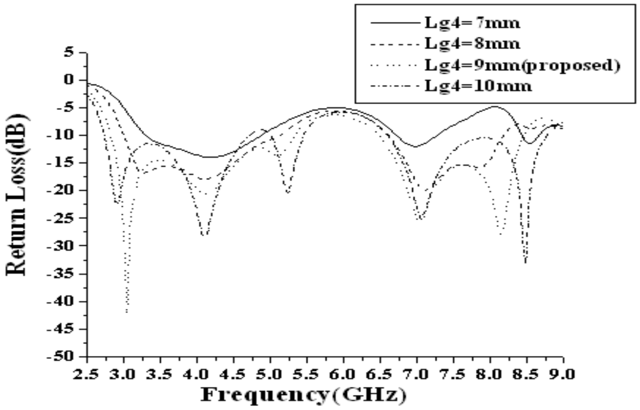

Figure9: Simulated return loss as a function of Lg4

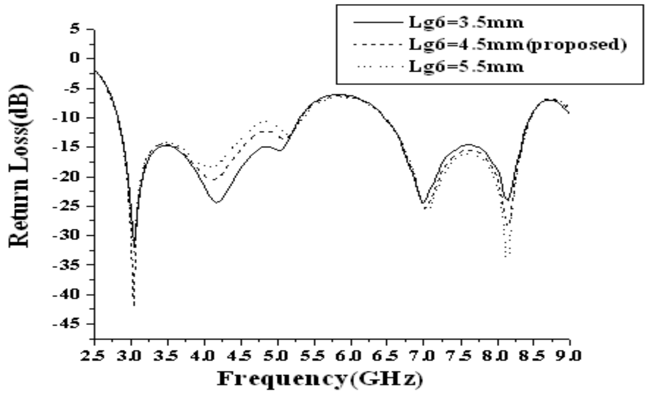

Figure10: Simulated return loss as a function of Lg6

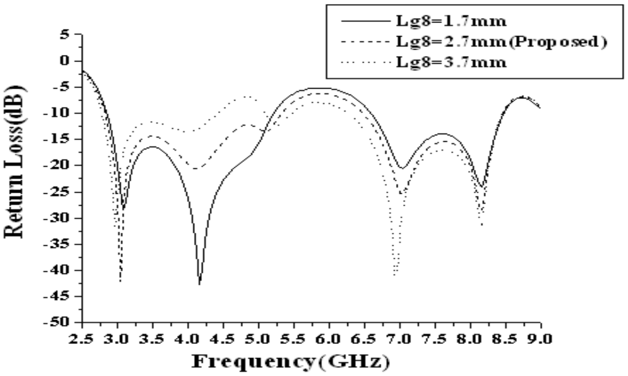

Figure11: Simulated return loss as a function of Lg8

RESULTS AND DISCUSSION

The proposed antenna structures are simulated using Method of Moment based IE3D software. The return loss of the fabricated antenna structures are measured using Agilent vector network analyzer E5071B. The agreement between the simulated and measured data is reasonably good. The slight discrepancy between the measured and simulated results is due to the effect of substrate parameter (thickness), improper soldering of SMA connector or fabrication tolerance. Figure12 shows the simulated and measured return loss versus frequency of the conventional rectangular microstrip patch antenna (antenna1). Both the simulated and measured value shows that the obtained resonant frequency in both simulation and measurement is 5.45GHz.The simulated return loss is -35dB and measured return loss is -20dB for 5.45GHz.Figure 13 shows the simulated and measured return loss versus frequency of antenna2 which is designed with a properly positioned patch placed above finite non defected ground plane. The simulated result shows that the antenna resonates at a frequency of 8.04GHz with -21dB return loss. The simulated result of antenna2 is verified with the measured value of the fabricated antenna structure.The measured result shows that the antenna resonates at 6.97GHz with return loss -18.5dB.The plot of return loss versus resonant frequency of the proposed antenna3 with properly positioned patch above the defected ground plane is shown in figure14.The simulated result shows that with the defection in the ground plane, there exists dual band of broad bandwidth. A -10dB bandwidth of 2.51GHz is obtained from 2.81 to 5.32GHz. Another wide operating bandwidth of 1.98 GHz is obtained from6.47 to8.45GHz. The measured result also shows that there exits dual band of wide operating impedance bandwidth. A -10dB bandwidth of 3.02 GHz is obtained from 2.85 to 5.87GHz which is 69% bandwidth around the center frequency of 4.36GHz. Minimum return loss obtained in the same frequency range is about-23.8dB at4.43GHz.Another wide operating bandwidth of 1.40 GHz is obtained from7.10 to8.5GHz, which is 18% bandwidth around the center frequency of 7.80 GHz. In the same frequency range, minimum return loss of -13dB is obtained at7.31GHz. The Simulated and measured E-plane radiation patterns of the proposed antennas at different resonant frequencies are shown in figures15-17.From the radiation patterns it can be observed that there is a stable response throughout different frequency bands. The measured 3dB beam width of conventional antenna (antenna1) at resonant frequency 5.45GHz is about 64^0.For proposed antenna3 the measured 3dB beam width is about 70^0at resonant frequency 4.43GHz and 73^0 at 7.31GHz. The measured peak gain of the proposed antenna3 is about 4.5dBi at 5.56GHz.

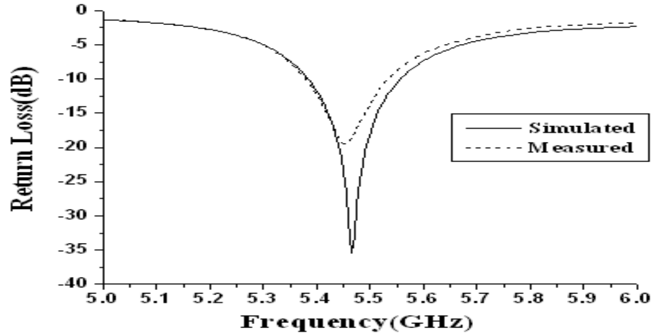

Figure12: Simulated and Measured Return loss Vs. Frequency of Antenna1

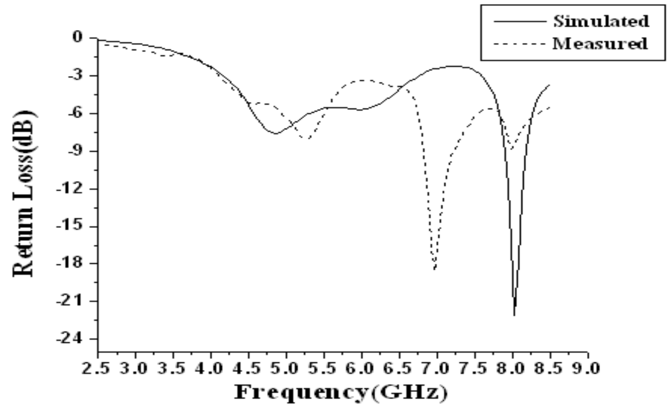

Figure13: Simulated and Measured Return loss Vs. Frequency of Antenna2

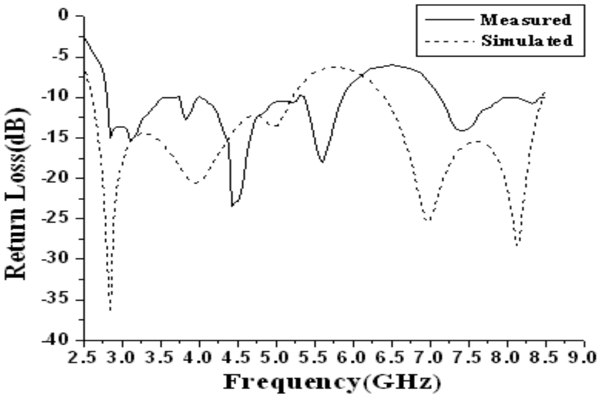

Figure14: Simulated and Measured Return loss Vs. Frequency of Antenna3

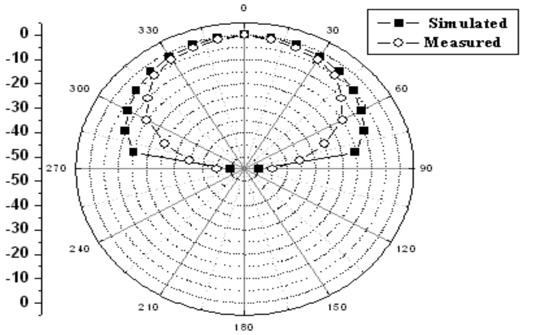

Figure15: Simulated and Measured Radiation pattern of antenna1 at 5.45GHz

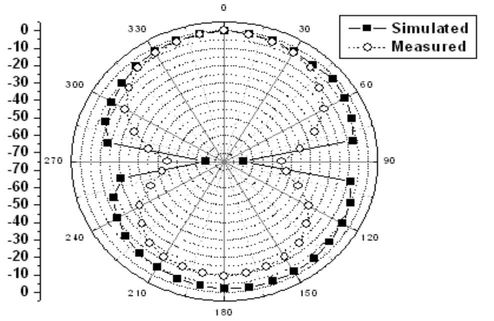

Figure16: Simulated and Measured Radiation pattern of antenna3 at 4.43GHz

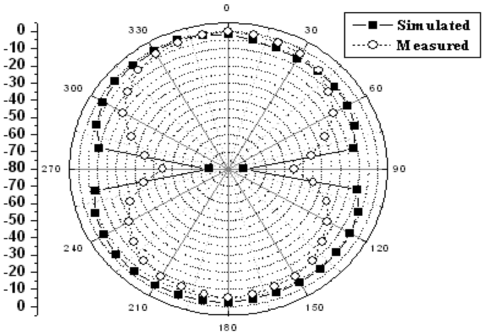

Figure17: Simulated and Measured Radiation pattern of antenna3 at 7.31GHz

CONCLUSION

A single layer reduced size microstrip patch antenna with enhanced bandwidth is presented in this research article. With properly positioned patch placed above defected ground plane, a size reduction of 75% is achieved with dual broad bandwidth of about 3.02 GHz (2.85-5.87GHz) and 1.4 GHz(7.10-8.5GHz) which are 69% and 18% respectively around their center frequencies. Good radiation pattern characteristics with acceptable amount of 3dB beam width for frequencies over the WLAN/WiMAX/HiperLAN/HisWaNa bands are also obtained for the proposed antenna with peak gain of 4.5dBi. Because of low cost, light weight and compact size the proposed antenna structure3 can be used for a number of modern wireless communication systems such as WLAN (5.15-5.35GHz, 5.725-5.825GHz), WiMAX (3.3-3.7GHz, 5.25-5.85GHz), HiperLAN2 (5.47-5.725 GHz) and HiSWaNa (5.15-5.25 GHz) wireless application bands.

REFERENCES

[1] Lai, C.-H., T.-Y. Han, and T.-R. Chen, Broadband aperture- coupled microstrip antennas with low cross polarization and back radiation, Progress In Electromagnetic Research Letters, 5(2008),187-197.

[2] Abbaspour, M. and H. R. Hassani, “Wideband star-shaped microstrip patch antenna,”Progress In Electromagnetic Research Letters,1(2008),61-68.

[3] Osman, H. A., E. A. Aballah, and A. A. Abdel Rhim, “A novel broadband compact circular disk microstrip antenna for wireless applications,” PIERS Online,4(2008),761-766.

[4] Wenquan Cao, Bangning Zhang, Hongbin Li, Tongbin Yi, Aijun Liu, “A Broadband Microstrip Dipole Antenna Loaded with Shorted Pin”, International Conference on Microwave and Millimeter Wave Technology (ICMMT), 2010, pp 1035-1037.

[5] Ansari, J. A. and R. B. Ram, “Broadband stacked U-slot microstrip patch antenna,”Progress In Electromagnetic Research Letters,4(2008),17-24.

[6] Ansari, J. A., P. Singh, S. K. Dubey, R. U. Khan, and B. R. Vishwakarma, “Analysis of stacked V-slot loaded patch antenna for wideband application,” Microwave and Optical Technology Letters,51(2009),324-330.

[7] Nasimuddin and Z.N.Chen, Wideband microstrip antennas with sandwich substrate, IET Microwave Antennas propagation 2(2008), 538-546.

[8] K.Ushakiran,Ravi.M.Yadahalli,R.M.Vani,P.V.Hunagund,Compact broadband stacked dual wide slit loaded rectangular microstrip antenna, Indian journal of Radio and Space physics 37(2008),366-369.

[9] Rafi. G. and L. Shafai, “Broadband microstrip patch antenna with V-slot,”IEEE Proc. Microwave Antennas and Propagation,15(2004), 435-440.

[10] M.T.Ali,N.Nordin,N.Ya’acob,M.N.M.Tan “Design of wideband microstrip patch antenna using L probe fed at 2.6GHz” ICCCE,2012,961-965.

[11] Chai.W., X. Zhang, and J. Liu, “Broadband microstrip antenna fed by a novel coupling device,”PIERS Online,3(2007),1064-1066.

[12] Wi.S.-H, Y.-S. Lee, and J.-G. Yook, “Wideband microstrip patch antenna with U- shaped parasitic elements,” IEEE Transactions on Antennas and Propagation,55(2008), 1196-1199.

[13] K.Mandal, S.Sarkar.P.P.Sarkar, Bandwidth enhancement of Microstrip antenna by staggering effect, Microwave and Optical technology letters53 (2011), 2446-2447.

[14] G.F.Khodaei, J.Nourinia, C.Ghobadi, A Practical Miniaturized U slot patch antenna with enhanced Bandwidth,Progress in Electromagnetic ResearchB 3(2008), 47-62.

[15] 15.Yang.S.-L.S,Kishk. A.A,Kai-Fong Lee,"Frequency recongigurable U slot microstrip patch antenna",IEEE Antennas and Wireless Propagation Letters,vol.7,page-127-129,2008.

[16] 16.B.Mizapour,H.R.Hassani,"Size reduction and bandwidth enhancement of snowflake fractal antenna",IET Microwaves Antennas and Propagation,vol2,issue-2,pages-180-187,2008.

[17] 17.X.L.Bao,M.J.Ammann,"Small patch/slot antenna with 53% Input impedance bandwidth",Electronics Letters,vol.43,issue-3,pages-146-147,2007.

[18] 18.Y.Sung,"Bandwidth enhancement of a microstrip line fed printed wide slot antenna with a parasitic center patch ",IEEE Transanction on Antennas and Propagation ,vol60,issue4,pages-1712-1716,2012.

[19] 19.R.S.Kushwaha,D.K.Srivastava,J.P.Saini,S.dhupkariya,"Bandwidth enhancement for microstrip patch antenna with microstrip line feed,"ICCCT,Pages-183-185,2012.

[20] 20.R.Ghatak,C.Goswami,R.K.Mishra,D.R.Poddar,"A CPW Fed lanar monopole antenna with modified H shaped slot for WLAN/WiMAX application,"Microwave and optical technology letters,vol.54,issue5,pages-1296-1301,2012.

[21] 21. T.W.Chiou, K.L.Wong, Design of Compact microstrip antennas with a slotted ground plane, IEEEAPS Int.Symp Dig (2001),732-735.

[22] 22.R.Hossa,A.Byndas,M.F.Bialkowski,Improvement of Compact terminal antenna performance by incorporating open end slots in the ground plane, IEEE Microwave Wireless Components letters 14(2004),283-285.

[23] 23.Usha Kiran,Vani R.M,Ravi.M.Yadahalli,P.V.Hunagund,SaraF.Farida Microstrip line feed Rectangular microstrip antenna with open end meandering slots in the ground plane for Compact Broadband operation, Microwave and Optical technology letters 49(2007),824-827.

[24] 24.S. Sarkar, A. Das Majumdar, S. Mondal, S. Biswas, D. Sarkar, P. P. Sarkar, "Miniaturization of Rectangular Microstrip Patch Antenna using Optimized Single-Slotted Ground Plane", *Microwave and Optical Technology Letters*, Vol. 53, No. 1 January 2011, pp 111-115.

[25] 25.Yikai Chen, Shiwen Yang, and Zaiping Nie, "Bandwidth Enhancement Method for Low Profile E-Shaped Microstrip Patch Antennas", *IEEE Transactions on Antennas and Propagation, vol. 58, no. 7,July 2010, pp 2442-2447.*

[26] 26.M.A.Martin,B.S.Sharif,C.C.Tsimendis,"Probe feed stacked patch for wideband applications,"IEEE Transanction on antennas and propagation vol.55,no.8,pages-2385-2388,2007.

[27] Antenna Theory, Analysis and Design, Constantine A.Balanis, Wiley, 3rd Edition.

[28] Zeland Software Inc. IE3D: MoM-based EM simulator.