World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:2, No:5, 2008

Compact Slotted Broadband Antenna for Wireless Applications

M. M. Sharma, Swati Gupta, Deepak Bhatnagar, and R. P. Yadav

Abstract**—**This paper presents the theoretical investigation of a slotted patch antenna. The main objective of proposed work is to obtain a large bandwidth antenna with reduced size. The antenna has a compact size of 21.1mm x 20.25mm x 8.5mm. Two designs with minor variation are studied which provide wide impedance bandwidths of 24.056% and 25.63% respectively with the use of parasitic elements when excited by a probe feed. The advantages of this configuration are its compact size and the wide range of frequencies covered. A parametric study is also conducted to investigate the characteristics of the antenna under different conditions. The measured return loss and radiation pattern indicate the suitability of this design for WLAN applications, namely, Wi-Max, 802.11a/b/g and ISM bands.

Keywords**—**Inset feed, microstrip antenna, parasitic patch, shorting wall, slot, wi-max.

I. INTRODUCTION

EXTENSIVE research has been done on microstrip antennas in recent years to exploit their small size and low cost. Although these antennas have proved to be excellent radiators for various applications; they have an inherently narrow bandwidth and low gain. The bandwidth, typically 1-2% is a major limiting factor for the widespread application of these antennas. Various techniques have been implemented in the past to overcome these shortcomings including the use of parasitic elements and multilayer configurations [1]-[5]. Thick, low permittivity substrates have also been used [5] - [6], which further increase the size and inductivity of the antenna. Size reduction is obtained by shorting the patch with the ground plane using a wall or a pin at the point of minimum voltage [1, 3, 5]. These advancements have witnessed a corresponding progress in the fields where microstrip antennas are used. Recent years have witnessed tremendous advancements in wireless communications technologies. Technologies such as UWB [4] have been identified as potentially revolutionary in the coming years.

In this paper, the radiation performance of a compact slotted broadband antenna is obtained by electromagnetic coupling with a parasitic element and by designing it on a thick low permittivity substrate. The design is simulated using 'Microstripes 7.5^{TM} [7] based on the TLM technique of analysis. The present structure is intended for use with the existing and upcoming wireless communication systems.

Manuscript received April 22, 2008. This work was supported by the R&D project "Design and development of W-CDMA for 3G mobile network, funded be MHRD, Govt. of India.

M.M. Sharma is with the Department of Electronics and Communications, Malaviya National Institute of Technology, Jaipur, India (phone: +91-9413346999; E-mail: mmsjpr@ gmail.com).

Swati Gupta is with the Department of Electronics and Communications, Birla Institute of Technology, Mesra, Ranchi, India (E-mail: swatiguptaa@gmail.com)

Deepak Bhatnagar is with the Department of Physics, University of Rajasthan, Jaipur, India (E-mail: dbhatnagar_2000@ rediffmail.com)

R.P. Yadav is with the Department of Electronics and Communications, Malaviya National Institute of Technology, Jaipur, India (E-mail: rp_yadav@ yahoo.com).

II. ANTENNA DESIGN

In this paper, we have proposed a compact slotted antenna having dimensions *L1* x *W1* and designed on a thick foam substrate having relative permittivity equal to 1.04 and a loss tangent equal to 0.0016. A shorting wall having dimensions 3mm x1mmx7mm is used as shown in Fig. 1. The ground plane of antenna has a size of 40mm x 40 mm. Adjacent to the radiating patch, a parasitic patch of dimensions L2 x W2 is placed as shown in Fig. 1. For the present investigations, two sets of parameters with small variations in slot size and dimensions of the parasitic element are considered. These are:
For Design – 1: *L1* = 15mm, *W1* = 9mm, *L2* = 20.25mm, *W2* = 9.6mm
For Design – 2: *L1* = 15mm, *W1* = 9mm, *L2* = 16.4mm, *W2* = 8.2mm

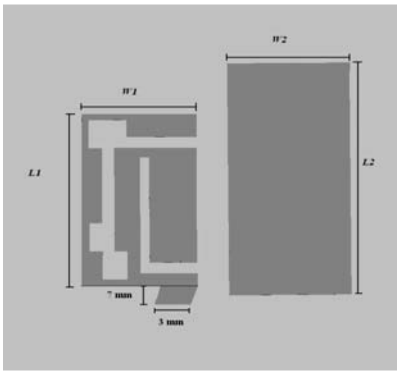

Fig. 1 Antenna geometry with dimensions of the radiating patch and the parasitic patch

Through top view of these antenna geometries in Fig. 2a and Fig. 2b, internal dimension corresponding to Design-1 and Design-2 are shown. Fig. 2c shows a 3-dimensional view of this geometry. Both these geometries have inset feed as shown in Fig. 2a and Fig. 2b.

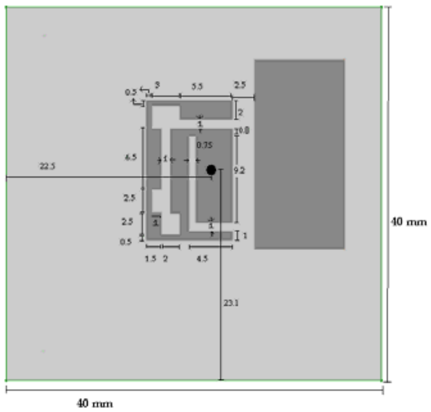

Fig. 2 (a) Top view of antenna structure named 'Design-1'

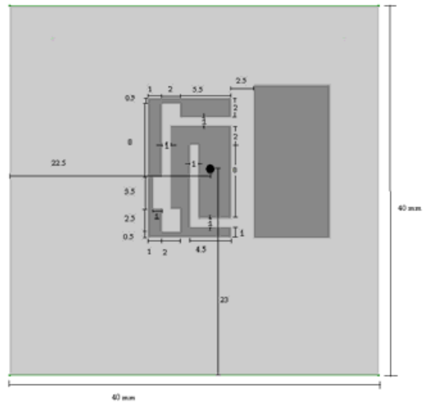

Fig. 2 (b) Top view of antenna structure named 'Design-2'

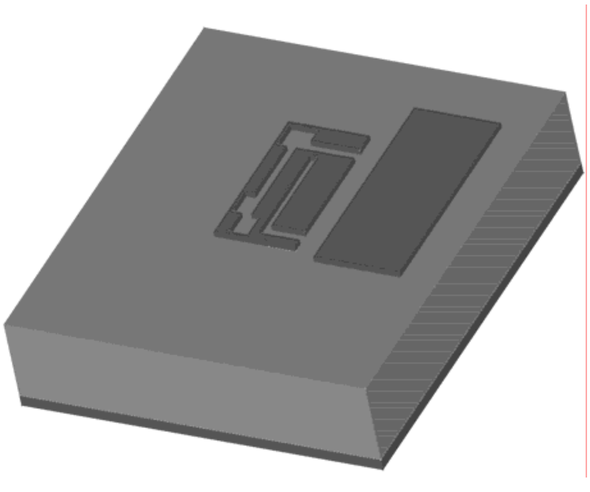

Fig. 2 (c) 3-D view of antenna under consideration

The analysis of these antenna geometries is carried out by applying the following features in the structure:

i) Effect of slots

Slots of appropriate shape and size are made on the radiating element as shown in the figures above, which divides the radiating geometry effectively into three resonant patches. The dimensions of different parts of these slots are shown in these figures. The meander structure thus formed facilitates the attainment of lower resonant frequencies due to cancellation of current.

ii) Effect of substrate material and thickness

The fringing field increases with increase in substrate thickness and decrease in substrate permittivity. The bandwidth of a microstrip antenna also varies directly with the substrate thickness and inversely with the permittivity of the substrate. Therefore in the present communication, a thick dielectric substrate (h = 7 mm) with low permittivity (ϵ_r = 1.04) is chosen to maximize the bandwidth and efficiency of the radiating structure.

iii) Effect of shorting wall

A shorting wall having dimensions 3mm x 1mm x 7mm is utilized for realization of the small size of the antenna. The width of the shorting wall can be used to control the resonant frequencies. An increase in the width of the wall increases the path for average currents thus decreasing the resonant frequencies.

iv) Effect of parasitic patch

A parasitic patch is placed close to the fed patch and excited by capacitive coupling between the two patches. The bandwidth is increased when the resonant frequencies of the two patches are close enough to form a common band. The overall input VSWR will be a superposition of the responses of the two resonators. A parasitic patch with appropriate dimensions has been used to obtain the desired results.

v) Choice of feed

An inset probe feed at 50Ω is used as shown in the figure. This feeding technique is chosen for its ease of fabrication and low spurious radiation.

III. Simulation and Results

The above-mentioned geometries are simulated by the TLM technique of analysis. The return losses of both antenna structures are plotted as a function of frequency in Fig. 3a and Fig. 3b. Two distinct bands are observed at frequencies 2.435 GHz and 5.487 GHz for Design-1 and at 2.468 GHz and 6.020 GHz for Design-2. The impedance bandwidth is defined as the range of frequencies over which the return loss is better than -10db and the VSWR less than two. The maximum bandwidths of the proposed antennas are 24.056% at 5.487 GHz for Design-1 and 25.63% at 6.020 GHz for Design-2.

The narrow bands have bandwidths of 1.889 % at 2.435 GHz for Design-1 and 2.188% at 2.468 GHz for Design-2. The VSWR is less than 2 throughout the bandwidth at the higher resonant frequency for Design-1 and at both resonant frequencies for Design-2. The lower resonant frequency for Design-1 has a VSWR less than 2.2 throughout its bandwidth.

Design-1 has maximum radiation normal to the patch geometry (broadside direction). The 3dB beamwidth for the radiation patterns of both these antenna designs in two cuts (45^o and 135^o) are given in Fig. 4 and Fig. 5. For Design-1, 3dB beam widths in 45^o and 135^o cuts are 166.395^o and 114.09^o respectively. For Design-2 maximum radiation in 45^o

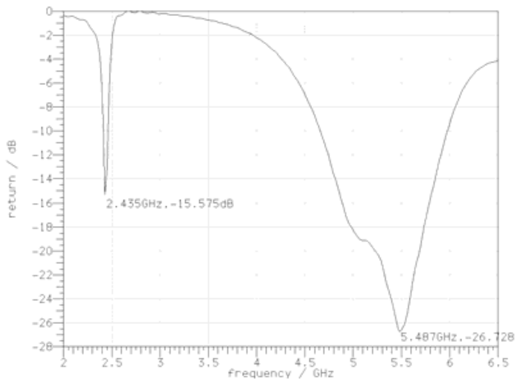

Fig. 3 (a) Variation of return loss with frequency (Design-1)

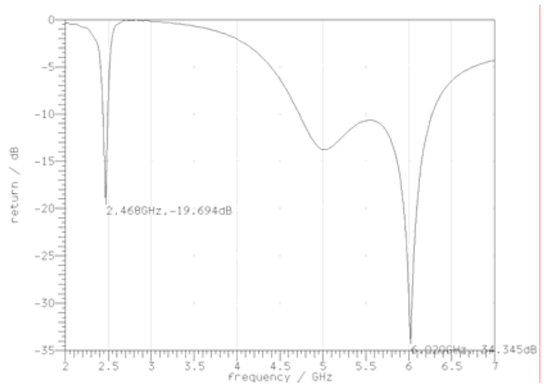

Fig. 3 (b) Variation of return loss with frequency (Design-2)

cut are still in broadside direction ($\theta = 0^o$) but for 135^o cut maximum radiation is obtained in $\theta = 255^o$. The 3dB beamwidth for Design-2 in these two cuts are 165.782^o and 52.09^o respectively.

The gain, directivity and antenna efficiency of Design-1 for the 5.487 GHz frequency band are 4.633 dBi, 4.657dBi and 99.433% respectively are obtained while for 2.435GHz band, these are 0.978 dBi, 1.889 dBi and 91.542% respectively. For Design-2, corresponding to 6.020 GHz band, gain, directivity and antenna efficiency are 5.640 dBi, 5.642 dBi, 99.96% respectively while the 2.468 GHz band these are 1.294 dBi, 1.337 dBi and 99.007% respectively. It is noticed that the parasitic patch enhances the bandwidth of the antenna. Design-1 without a parasitic patch yields a lower gain (0.618 dBi less at the higher resonant frequency of the geometry) and a bandwidth 2.76% less than that of the proposed design. The shorting wall and the slots on the parasitic patch also enhance the response remarkably. Design-1 without a parasitic patch and a shorting wall has a return loss greater than -10dB. The return loss falls to below -10dB with the introduction of a shorting wall and a bandwidth of 8.38% is obtained. Further introduction of slots increases the bandwidth to 24.056%.

A parametric study of the antenna is also conducted to investigate its response to the parasitic patch as well as the substrate thickness. The parameters *L2, W2,* substrate thickness *h*, and the distance between the radiating and parasitic patches *d* for design1 are selected for parametric study. All the other parameters are kept invariant. The results are shown in Table I. Some interesting results are obtained from this study. On increasing the separation, between the radiating and parasitic patches, F2/F1 ratio increases almost linearly.

The bandwidth corresponding to frequency F1 decreases marginally then increases till separation is made d = 2.5 mm and finally it decreases. Similarly gain and antenna efficiency corresponding to frequency F1 decreases on increasing separation, between the radiating and parasitic patches but corresponding to frequency F2, both these parameters increases marginally.

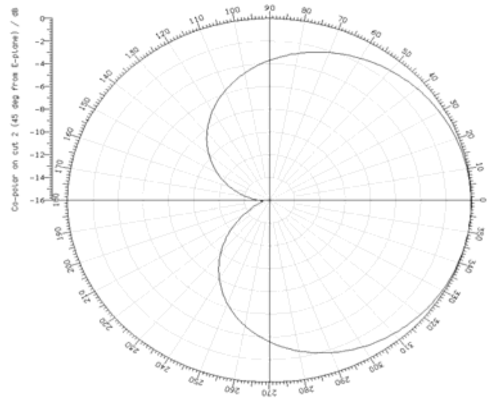

Fig. 4 (a) Co-polar radiation pattern at 45 degrees cut from the E-plane (Design-1) at 2.435 GHz

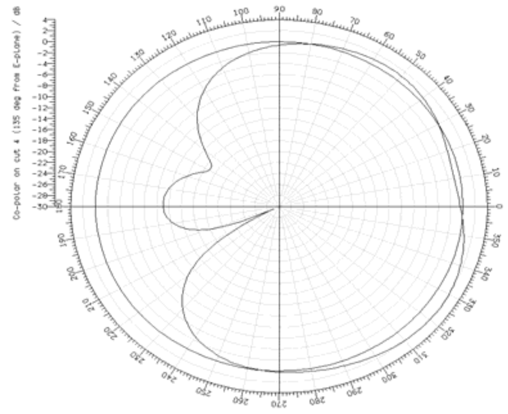

Fig. 4 (b) Co-polar radiation pattern at 135 degrees cut from the E-plane (Design-1) at 5.487 GHz

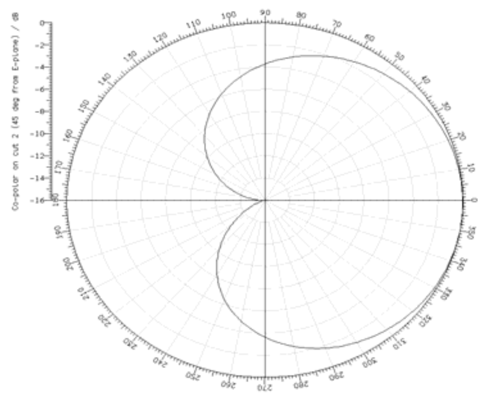

Fig. 5 (a) Co-polar radiation pattern at 45 degrees cut from the E-plane (Design -2) at 2.468 GHz

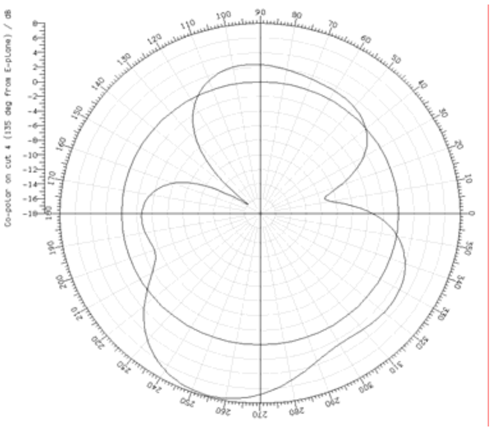

Fig. 5 (b) Co-polar radiation pattern at 135 degrees cut from the E-plane (Design-2) at 6.020 GHz

On increasing substrate height, bandwidth of antenna corresponding to frequency F2 increases. Similarly on increasing parameters L2 and W2, bandwidth of antenna increases significantly. In this communication, more emphasis is given to the enhancement of bandwidth of antenna. One must keep in mind that the gain-bandwidth product for an antenna remains almost constant therefore improved bandwidth values at the cost of reduced gain values are accepted in this communication. The antenna geometries proposed in this communication are suitable for applications in various wireless systems applicable for Wi-Max-802.16, 802.11a/b/g and ISM bands. These may also be used for ultrawideband signals.

IV. Conclusion

A compact slotted broadband antenna is proposed. It is observed that with appropriate substrate height, separation between radiating and parasitic patch and dimensions of parasitic patch, a higher bandwidth and antenna efficiency may be achieved which are the main requirements for an antenna applicable for modern communication systems including wireless systems.

References

[1] Girish Kumar and K.P. Ray, *Broadband Microstrip antennas*, Norwood: Artech House 2003.

[2] Ramesh Garg, P. Bhartia, Inder Bahl, A. Ittipiboon, *Microstip Antenna Design Handbook*, Artech House, 2000.

[3] Tae-Hyun Kim, Dong-Chul Park, "Compact Dual-Band Antenna with Double L-Slits for WLAN Applications" IEEE vol.4, 2005, pp.249-252.

[4] Yashar Zehforoosh, Changiz Ghobadi and Javed Nourinia,"Antenna Design for Ultra Wideband Application Using a New Multilayer Structure" PIERS Online, vol.2, No.6, pp.544-549, 2006

[5] Kin–Lu Wong, *Compact and Broadband Microstrip Antennas* New York: John Wiley & sons, Inc, 2002.

[6] Daniel H. Schaubert, David M. Pozar, and Andrew Adrian, "Effect of Microstrip Antenna Substrate Thickness and Permittivity: Comparison of Theories with Experiment" *IEEE Transactions on antenna and propagation,* vol. 37,no 6,pp.677-682, June 1989.

[7] Microstripes 7.5™. Available: http://www.flomerics.com

TABLE I
Parametric Study of Antenna Geometries under Different Conditions

PARAMETER	VALUE (mm)	OTHER PARAMETER VALUES (mm)	F_1 (GHz)	F_2 (GHz)	F_2/F_1	BW (%)		GAIN (dBi)		ANTENNA EFFICIENCY (%)	
						F_1	F_2	F_1	F_2	F_1	F_2
d	0.5	*h* = 7 *W2* = 9.6 *L2* = 20.25	2.358	5.078	2.153	2.078	14.021	1.097	4.958	91.894	97.209
	1.5		2.422	5.312	2.193	2.023	22.816	1.020	4.607	91.816	99.256
	2.5		2.435	5.487	2.253	1.889	24.056	0.978	4.633	91.542	99.433
	3.5		2.444	5.689	2.327	1.882	22.99	0.948	5.969	91.120	99.547
h	5	*d* = 2.5 *W2* = 9.6 *L2* = 20.25	2.456	5.565	2.265	1.87	14.86	0.781	4.705	88.919	93.255
	6		2.441	5.425	2.222	1.925	20.921	0.906	4.821	90.591	99.076
	7		2.435	5.487	2.253	1.889	24.075	0.978	4.633	91.542	99.433
	8		2.422	5.510	2.274	1.857	26.297	1.011	4.521	91.32	98.762
W2	7.6	*d* = 2.5 *h* = 7 *L 2*= 20.25	2.436	5.493	2.254	1.88	23.903	0.956	4.688	91.233	99.565
	8.6		2.436	5.485	2.251	1.847	23.956	0.967	4.668	91.380	99.603
	9.6		2.435	5.487	2.253	1.889	24.056	0.978	4.633	91.542	99.433
	10.6		2.434	5.488	2.254	1.93	24.125	0.990	4.591	91.705	99.045
	11.6		2.434	5.581	2.292	1.93	23.99	1.003	4.571	91.854	98.437
L2	18.25	*d* = 2.5 *h* = 7 *W2* =9.6	2.433	5.586	2.295	1.849	21.876	0.980	5.160	91.577	99.521
	19.25		2.433	5.559	2.284	1.89	23.007	0.985	4.886	91.616	99.515
	20.25		2.435	5.487	2.253	1.889	24.075	0.978	4.633	91.542	99.433
	21.25		2.435	5.338	2.192	1.889	25.327	0.980	4.395	91.587	99.437