Bandwidth Enhancement of a Micro strip Line Fed Hexagonal Wide-Slot Antenna using Fork-like Tuning Stub

Krishnendu Chattopadhyay, Santanu Das, Sekhar Ranjan Bhadra Chaudhuri

Abstract— In this paper, a printed hexagonal wide slot antenna, fed by a microstrip line with fork like tuning stub for bandwidth enhancement is proposed and experimentally investigated. The impedance, radiation and gain characteristics of this antenna are studied. Simulation and experimental results indicate that a 1.5:1 VSWR bandwidth, of about 1 GHz and 2:1 VSWR bandwidth of 1.34 GHz is achieved at operating frequency around 2.5 GHz, which is about three times larger than a microstrip line fed hexagonal wide slot antenna, with normal tuning stub, considered as reference antenna.

Index Terms—Fork-like tuning stub, Hexagonal wide-slot, and Microstrip line fed, Method of moment, wide band.

I. INTRODUCTION

Printed wide slot antennas are attractive because their operating bands usually have wide impedance bandwidth. In addition, they are completely planar and easily integrable with active devices or microwave monolithic integrated circuits. In recent years, there has been growing research activities on many microstrip line fed printed wide slot antennas [1-11]. In the reported literature [2], a rhombus like slot antenna, exhibits an improvement in bandwidth of 3150 MHz, using offset microstrip line feed. In another paper, a good design of microstrip line fed printed wide slot antenna with a rotated square slot is proposed, where the impedance bandwidth defined by 10dB returnloss, can reach upto 2200 MHz for rotation angle of 50 degree, with respect to centre frequency of 4496.5 MHz [3]. There is another important study on three-offset microstrip line fed slot antenna, which incorporates suitable tuning of three resonance frequencies that lead to the impedance matching over a wide frequency band of about 4255 MHz, for a VSWR less than 2.0[4]. Another most relevant publication on printed wide band rhombus slot antenna excited by a pair of parasitic strips along with microstrip feed line, results in a wide operating bandwidth of 4262 MHz to 4290 MHz, when the length of parasitic strip is selected from 15 to 17mm[5]. An wide slot is a slot with aspect ratio significantly smaller than that of usual narrow slots. For wide band operation, other resonant mode operating for bandwidth enhancement can also be obtained. So within operating bandwidth, two resonant modes with similar radiation patterns and having same polarizations can be possible for wideband operation. In a recent publication, a printed square wide slot with a modified L-shaped microstrip feed for wideband application has been reported [6]. The feed of the proposed wide slot is having a horizontal section, a square patch and a vertical section. It has been found that suitable selection of dimensions of different parts of feed structure will exhibit a very wide 10dB impedance bandwidth of 3510MHz (1210-4720 MHz) or about 118.4% with respect to centre frequency of 2965 MHz.

In this paper, the study is carried-out over a hexagonal wide slot, fed by a microstrip line with fork-like tuning stub, with a grooved fork head. By employing that tuning stub, wideband operation has been obtained. It is found in simulation study, that the impedance bandwidth is about four times larger than a hexagonal slot antenna with a simple straight tuning stub, considered as reference antenna. The simulation study has been carried out by MoM based IE3D simulation software. Both for simulation and experimental study, the impedance bandwidth is defined by 1.5:1 and 2:1 VSWR for most satisfactory antenna matching performance over a wide bandwidth. Detail of the proposed antenna, simulation and experimental results are presented and discussed.

II. ANTENNA CONFIGURATION

The geometry of the hexagonal wide slot proposed antenna is shown in Fig.1(a). The proposed antenna is printed on an FR4 substrate of thickness 1.6mm, with relative permittivity 4.4. The hexagonal wide slot is having a diameter (D) of 53.7mm. The wide slot is fed by a 50Ω microstrip line, having width(Wf) of 3mm, with a fork-like tuning stub, which is printed on opposite of the FR4 substrate.

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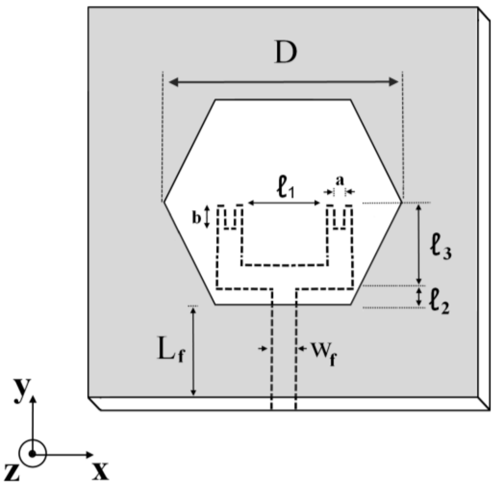
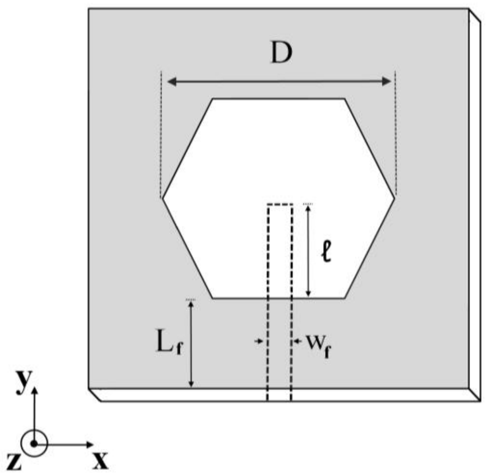


(a)



(b)

Fig.1 Configurations of microstrip line fed wide slot antenna With (a) fork-like tuning stub and (b) a simple tuning stub.

The tuning stub is placed symmetrically with respect to the centre line along y-axis of the wide slot. The fork-like tuning stub is having a straight section of length ℓ_2 and two branch sections of equal lengths ℓ_3. The spacing between the edges of two branches is ℓ_1. For simplicity the widths of these sections are kept same and equal to the width of 50Ω microstrip feed line.

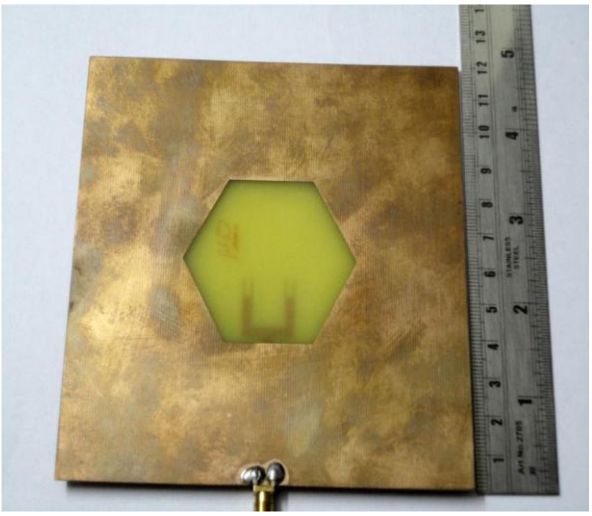


Fig. 2(a) Slot side view of the prototype.

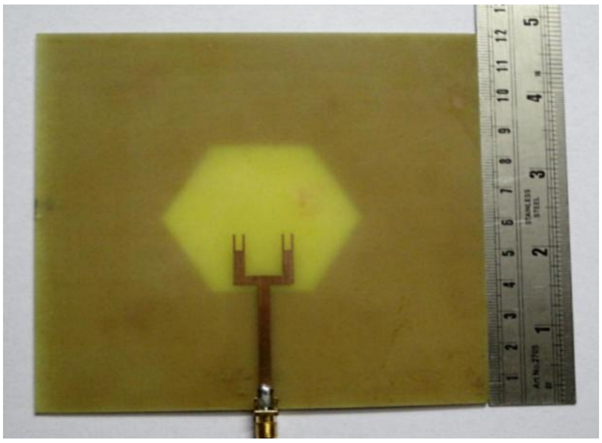


Fig. 2(b) Feed side view of the prototype.

By selecting proper dimensions (ℓ_1,ℓ_2,ℓ_3) of fork-like tuning stub, good impedance matching over an enhanced bandwidth can be exhibited. Antenna1, Antenna2, Antenna3 and Antenna4 are conceived for studies on different dimensions of ℓ_1, ℓ_2 and ℓ_3. The Table I shows the different dimensions of the above antenna configurations. The reference antenna is shown in Fig.1b. The parameters of reference hexagonal slot are same as proposed antenna, except the tuning stub configuration, which is a straight extension of feed line having length (ℓ) of 20mm. The photographic view of slot side and feed side of the prototype is shown in Fig.2.

III. RESULTS AND DISCUSSION

In this section, impedance, radiation and gain characteristics of the proposed antenna are presented. The simulated VSWR responses of the different configurations denoted as Antenna1, Antenna2, Antenna3, Antenna4 are compared with respect to the reference antenna as shown in Fig.3.

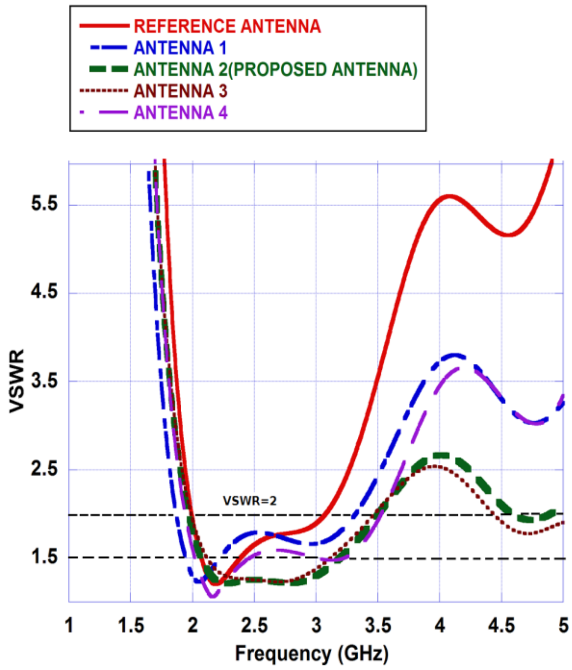


Fig.3 Simulated VSWR response of different configurations.

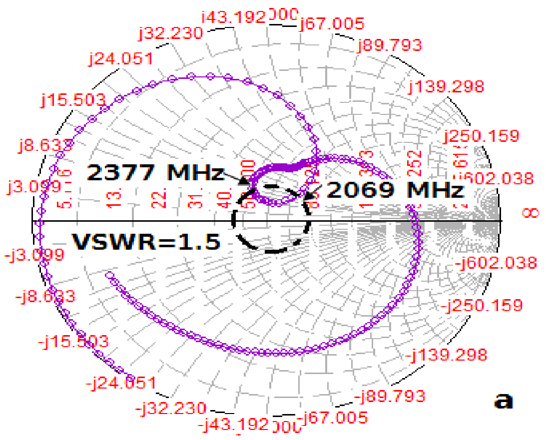
The design parameters of the different antennas along with proposed antenna (Antenna2) are shown in the Table I. The simulated results for 1.5:1 and 2:1 VSWR bandwidth along with corresponding higher (f_H) and lower frequency (f_L) values are shown in Table II.

Table I. Design parameters of different Antennas including proposed antenna (Antenna2).

	ℓ_1 (mm)	ℓ_2 (mm)	ℓ_3 (mm)
Antenna1	4	2	18
Antenna2 (Proposed)	10	2	16
Antenna3	12	2	16
Antenna4	10	0	19
D=53.7mm, a=2mm, b=5mm, W_f=3mm, L_f=36.7mm			

TableII. Comparison between Proposed Antenna (Antenna2) and Reference Antenna defined by 1.5:1 and 2:1 VSWR Bandwidth and f_L and f_H.

	f_L (MHz)	f_H (MHz)	VSWR Bandwidth (MHz) for VSWR=1.5
Reference Antenna	2069	2377	308
Antenna1	1938	2225	287
Antenna2 (Proposed)	2068	3206	1138
Antenna3	2105	3149	1044
Antenna4	2021	2465	444
			VSWR Bandwidth (MHz) for VSWR=2
Reference Antenna	1995	3075	1080
Antenna1	1868	3303	1435
Antenna2 (Proposed)	1959	3516	1557
Antenna3	1983	3463	1480
Antenna4	1955	3522	1567



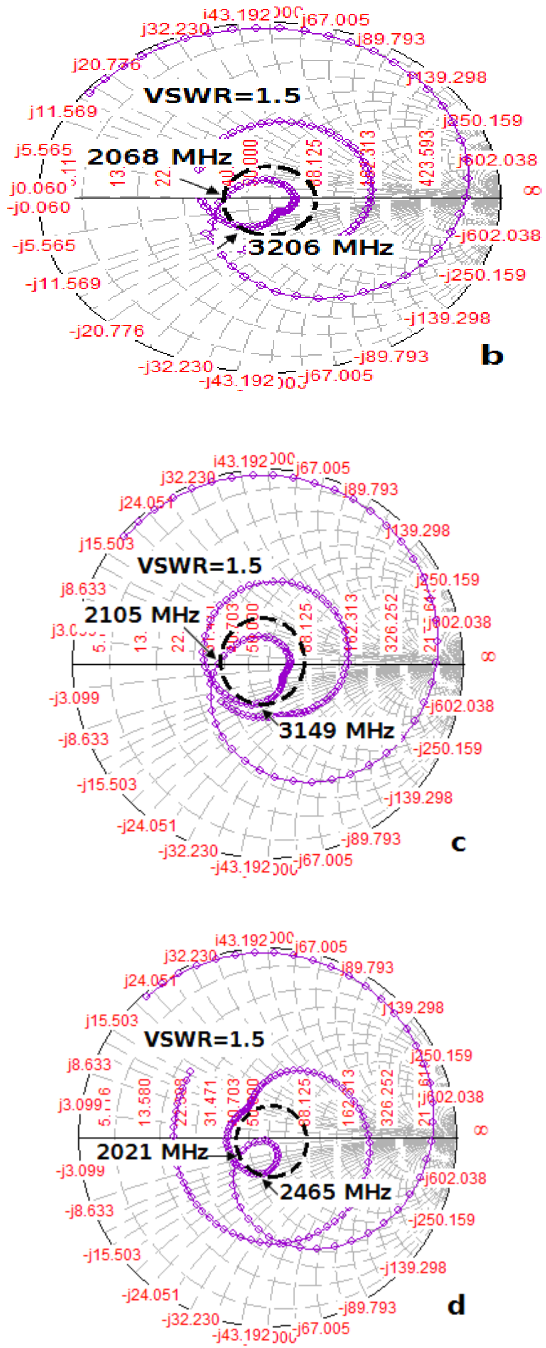


Fig. 4 Input impedance on smith chart (a) Reference antenna. (b) Antenna2. (c) Antenna3. (d) Antenna4.

From the obtained simulation results it is observed that Antenna1, Antenna2, Antenna3 and Antenna4 are exhibiting larger bandwidth than reference antenna with respect to 2:1 VSWR. From the point of view of 1.5:1 VSWR bandwidth, the Antenna2, Antenna3 and Antenna4 are having larger bandwidth than the reference antenna. In view of comparison between antenna2 and Antenna4, it is observed that Antenna2 is exhibiting much larger 1.5:1 VSWR bandwidth i.e 1138 MHz than Antenna4 having 1.5:1 VSWR bandwidth of 444MHz. But with reference to 2:1 VSWR bandwidth, they are exhibiting almost similar performances.

We have considered Antenna2 as proposed antenna comparing both 1.5:1 and 2:1 VSWR bandwidth as it will be useful to radiate more power over a wider band than Antenna4 defined by 1.5:1 VSWR bandwidth. So Antenna2 will be more flexible for wideband operation with high power. It is observed that for 2:1 VSWR bandwidth the conceived design also exhibits a fabrication tolerance.

To explain the phenomena of bandwidth enhancement, the impedance plots on smith chart and magnetic current distribution of the proposed antenna are presented in Fig.4 and Fig.5 respectively. With reference to Fig.4 when the dimension of the fork-like tuning stub varies, the size of coupling loop also varies. For Antenna2 tightest coupling loop with in VSWR=1.5 circle is observed around the centre of the smith chart, which leads to a largely enhanced impedance bandwidth. The magnetic current distribution shown in Fig.5 exhibits the excitation of different coupled resonant modes, corresponding to different path lengths, excited by the geometry of fork-like tuning stub and hexagonal nature of wide slot. The proper tuning between different excited modes is also responsible for large impedance bandwidth. By comparing the results of Antenna1 to Antenna4, it may be concluded that there is an optimal spacing (ℓ_1) between two branch sections of fork-like tuning stub. For Antenna2, the selected spacing is about one fifth of slot diameter (D). The comparison between Antenna2 and Antenna4 indicates that wider 1.5:1 VSWR bandwidth can be obtained by placing a straight section ℓ_2 of the fork-like tuning stub, under the slot at opposite side of substrate. The length ℓ_3 of two branch sections along with grooved top edge is effective for easy fine tuning of the imaginary part of input impedance.

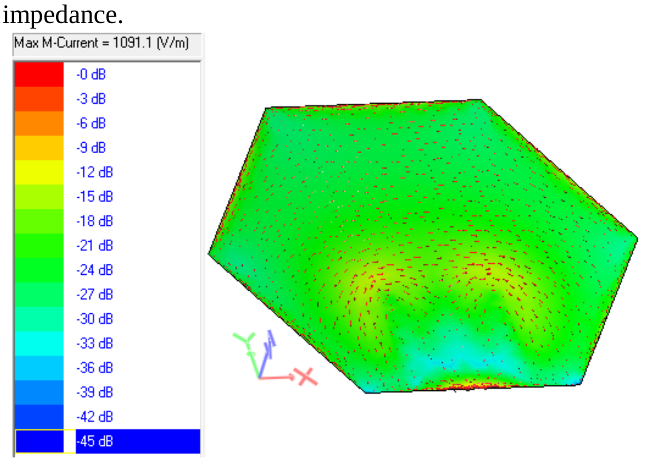


Fig. 5 Magnetic current distribution of proposed antenna.

The prototyping of the proposed antenna (Antenna2) has been done. The VSWR response of the fabricated antenna has been measured by Agilent technology PNA-L Network Analyzer (Model No.N5230A, 10MHz-20GHz).

The simulated and measured VSWR responses of the proposed antenna for 1.5:1 and 2:1 VSWR bandwidth are shown in Fig.6. From the VSWR response of the measured result the bandwidth available is 900MHz (2.095GHz-2.995 GHz) for 1.5:1 VSWR and 1340MHz (2.010GHz-3.350 GHz) for 2:1 VSWR, which is smaller than simulated result. It is probably due to substrate material losses, finite size of ground plane and fabrication tolerances.

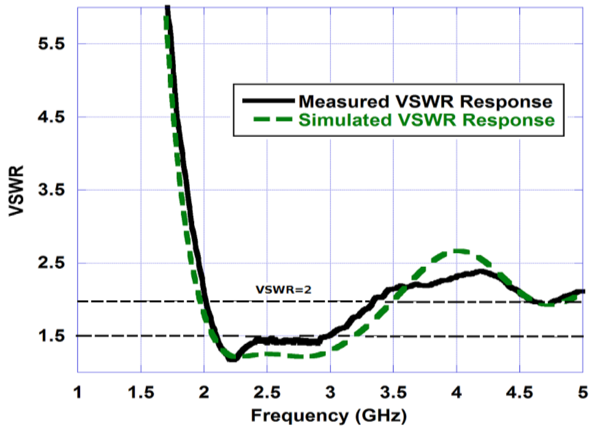
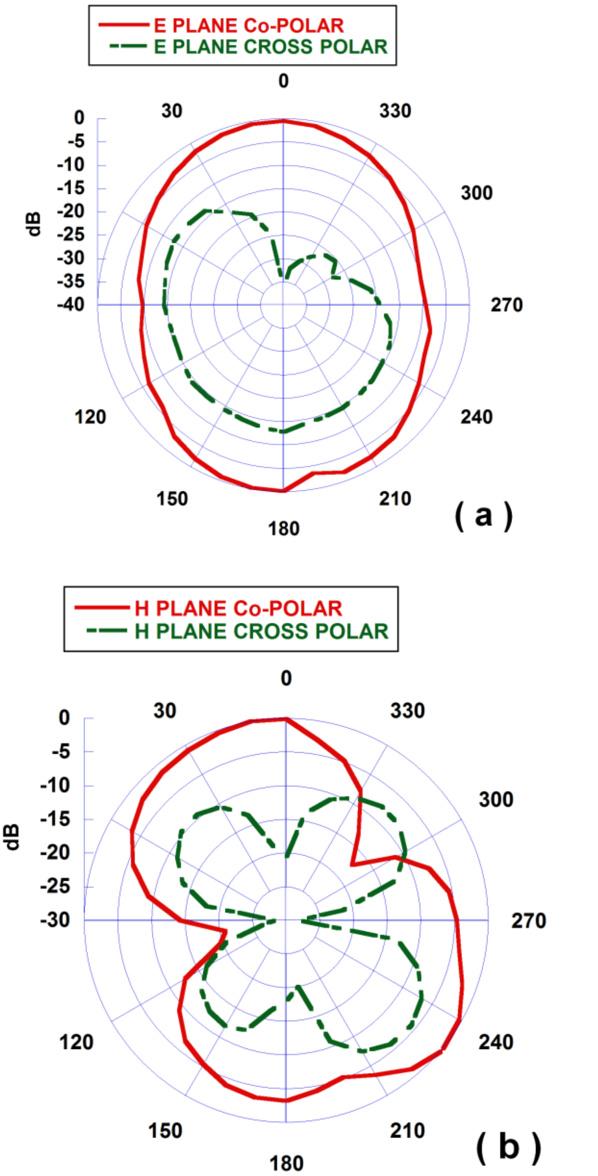
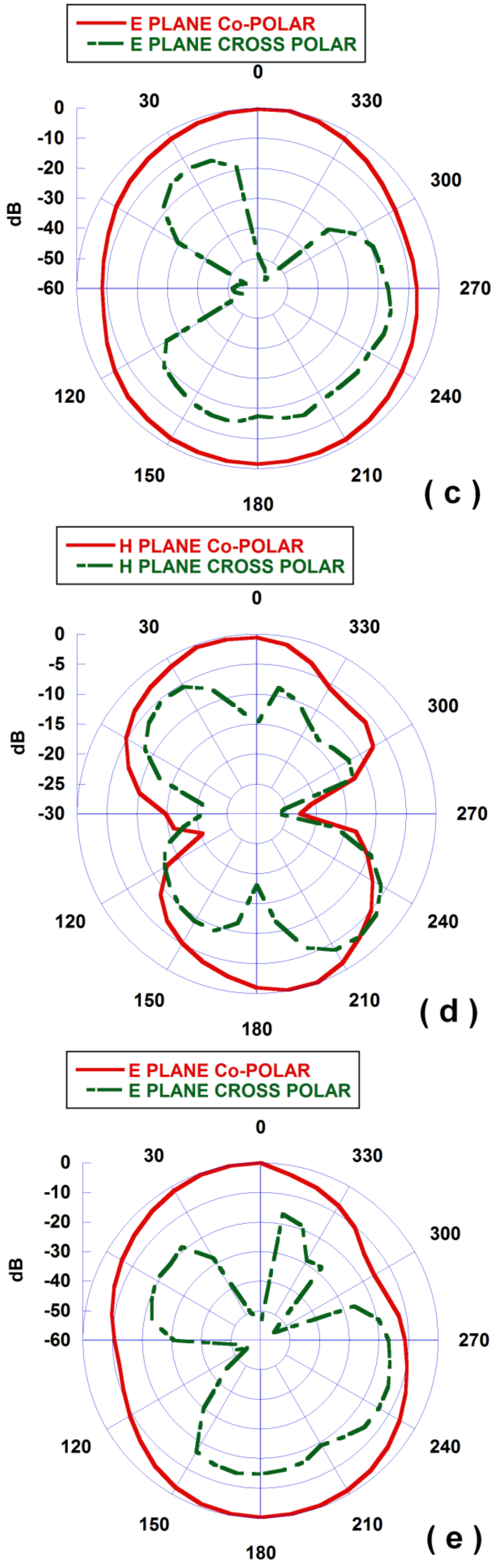


Fig. 6 Comparison between simulated and measured VSWR response of proposed antenna (Antenna2).

Measured radiation patterns of the proposed antenna are plotted in Fig.7 for frequencies 2230MHz, 2500MHz and 2900MHz.





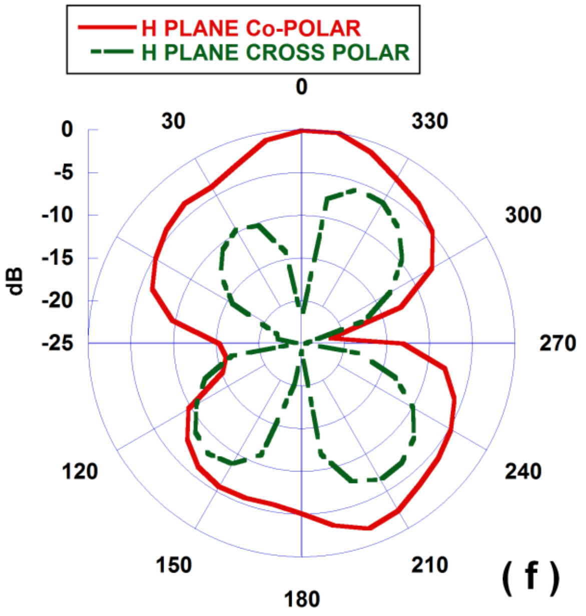


Fig.7 E-plane co-polar & cross-polar radiation patterns(a),(c),(e) and H-plane co-polar & cross-polar radiation patterns(b),(d),(f) at 2230MHz(a,b),2500MHz(c.d) and 2900MHz(e,f) of proposed antenna(Antenna2).

The printed wide slot is a bi-directional radiator and the radiation patterns are almost same in both sides. From the depicted patterns it is observed that throughout the 1.5:1 VSWR bandwidth, the radiation patterns of the proposed antenna have same polarization planes and similar broadside radiation patterns. It is observed that the cross-polarization levels are higher in H-plane(x-z plane) rather than E-plane(y-z plane). With the increase in frequency, the cross-polarization level is also increasing. Beyond 3000MHz the radiation patterns are tilted to a large angle and the maximum radiation is no longer in broadside direction.

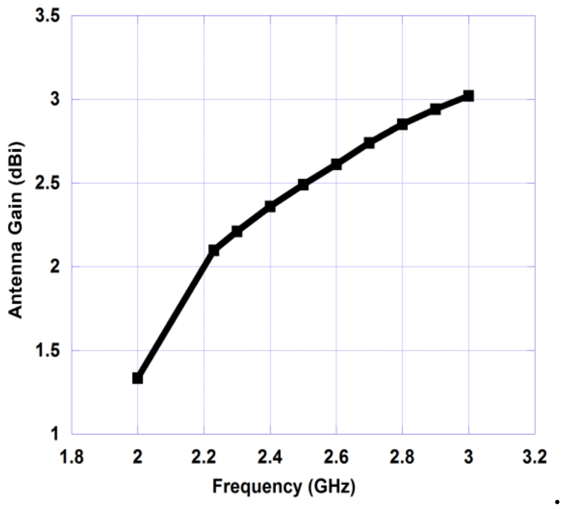


Fig. 8 Peak antenna gain against frequency for proposed antenna (Antenna2).

The peak gain variation of the proposed antenna is shown in Fig.8, within the range where available radiation pattern is broadside.

The variation in peak gain is observed to be about 1.6dBi. So the acceptable broadside radiation pattern is available between 2010-3000MHz (990MHz). The peak antenna gain available is 3.025 dBi.

IV. CONCLUSION

A hexagonal wide slot antenna fed by a 50Ω microstrip line with fork-like tuning stub has been demonstrated. The measured VSWR bandwidth of the proposed antenna, with optimal design parameters is found to be 900MHz for 1.5:1 VSWR . The VSWR bandwidth is about three times larger than the hexagonal wide slot reference antenna, with reference to experimental result. The VSWR 1.5 level is promoting more high power operation in the range 2.095GHz to 2.995GHz. Beyond 3.0GHz (3000MHz) the radiation pattern is also found to be tilted and no longer in broadside direction. So the selection of 1.5:1 VSWR level is justified as compared to VSWR 2 level operation of proposed antenna, when optimum performance in view of both impedance bandwidth and broadside radiation pattern is desirable. However more wide measured impedance bandwidth of about 1340 MHz (2.010GHz-3.350GHz) is available if a compromise in broadside nature of radiation pattern is accepted beyond 3.0GHz. Within this wide impedance bandwidth the acceptable broadside radiation patterns are available over 990MHz.

REFERENCES

1. M. Kahrizi, T.K. Sarkar and Z.A. Maricevic , "Analysis of a wide radiating slot in the ground plane of a microstrip line" *IEEE Trans. Microwave Theory and Techniques*, vol.41,No. 1, pp. 29-37.Jan.1993.
2. J.Y. Jan, J.C. Kao, "Novel printed Wide-band Rhombus-Like slot antenna with an offset microstrip-fed line", *IEEE Antennas and Wireless Propagation Lett*. Vol.6, pp.249-251, 2007.
3. J.Y. Jan, J.W. Su, "Bandwidth Enhancement of a printed wide slot Antenna with a rotated slot" *IEEE Trans. Antennas and Propagation*.vol.53, No.6, pp.2111-2114,2005.
4. Y.W. Jang, "Experimental study of large bandwidth Three-offset microstripline-fed slot antenna" *IEEE Microwave and wireless components Lett.* Vol.11,No.10,pp.425-427,oct.2001.
5. J.Y. Jan, L.C. Wang, "Printed wideband Rhombus slot antenna with a pair of parasitic strips for Multiband applications" *IEEE Trans. Antennas and Propagation*, vol.57, No.4, pp.1267-1270, 2009.
6. Y. Sung, "A printed wide slot antenna with a modified L-shaped microstrip line for wideband applications" *IEEE Trans. Antennas and Propagation*,vol.59,No.10,pp. 3918-3922,2011.
7. J.Y. Sze, K.L. Wong, "Bandwidth enhancement of a microstrip-line-fed printed wide-slot antenna" *IEEE Trans. Antennas and Propagation*, vol.49, No.7, pp.1020-1024, 2001.
8. L. Zhu, R. Fu, K.L. Wu, "A novel broadband microstrip-fed wide slot antenna with double rejection zeros" *IEEE Antennas and Wireless Propagation Lett*., vol.2,pp.194-196,2003.
9. Y.F .Liu, K.L. Lau, Q. Xue, C.H. Chan, "Experimental studies of printed wide slot antennas for wideband applications" *IEEE Antennas and wireless Propagation Lett*., vol.3,pp.273-275,2004.
10. H. Kim, Y. J. Yoon, "Microstrip-fed slot antennas with suppressed harmonics" *IEEE Trans. Antennas and Propagation*,vol.53,No.9, pp. 2809-2817,2005.
11. P.H. Rao, V.F. Fusco,R. Cahill, "Linearly polarized radial stub fed high performance wideband slot antenna" *Electronics Lett*., vol.37,No.6,pp.335-337,March 2001.

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