ROMANIAN JOURNAL OF INFORMATION SCIENCE AND TECHNOLOGY
Volume **14**, Number 2, 2011, 123–130

Radiation Performance of an Elliptical Patch Antenna with Three Orthogonal Sector Slots

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Abstract. The paper presents design and radiation performance of an elliptical patch antenna with three orthogonal sector slots and its performance is compared with that of a conventional elliptical microstrip patch antenna (EMPA) operating under similar test conditions. The proposed elliptical microstrip patch antenna has two sector slots along the major axes aligned opposite to each other and a sector slot orthogonal to these two slots and aligned along the minor axis. The location and dimensions of these sector slots are optimized to obtain improved bandwidth close to 10.96% which is nearly four times higher than that of a conventional EMPA tested under identical test conditions. The gain of antenna is marginally improved still it needs further improvement. The measured E and H plane co and cross polar patterns of modified antenna are also present for better understanding. The modified antenna meets the bandwidth requirements for the IEEE 802.11 a5 wireless local area network (WLAN) applications.

Key-words: elliptical patch antenna, bandwidth, sector slot and wireless local area network.

1. Introduction

The recent growth of wireless communication systems has produced a great demand for compact antennas which may fit inside the handset without protruding out. The most admired structure among the miniature antennas is the microstrip patch antenna. Microstrip patch antennas provide significant advantages such as low profile, low weight, relatively low manufacturing cost and polarization diversity [1]. However, the bandwidth of microstrip antennas is inherently narrow (of order of a few percent) and gain is poor. Therefore, researchers are exploring methods and techniques to design wideband patch antennas with improved performance [2–4]. With the application of slot feeds and thick and air-filled dielectric substrates of very low permittivity, the bandwidth of patch antennas can significantly be improved [5–6]. Further improvements can be made by using parasitic patch and larger slot [7–10]. The proposed antenna is a compact structure, having effective patch area less than that of a conventional elliptical microstrip patch antenna but has much improved performance than that of conventional elliptical microstrip patch antenna. Such an antenna may find application in the IEEE 802.11 a5 communication standard applicable for WLAN communication systems. The antenna geometry is simulated by applying method of moments based IE3D simulation software [11].

2. Conventional elliptical patch antenna

In this communication, first the performance of an elliptical microstrip patch antenna shown in Fig. 1(a) and 1(b) having major and minor axes dimension $a = 1.5$ cm and $b = 1.0$ cm respectively is simulated with IE3D simulation software.

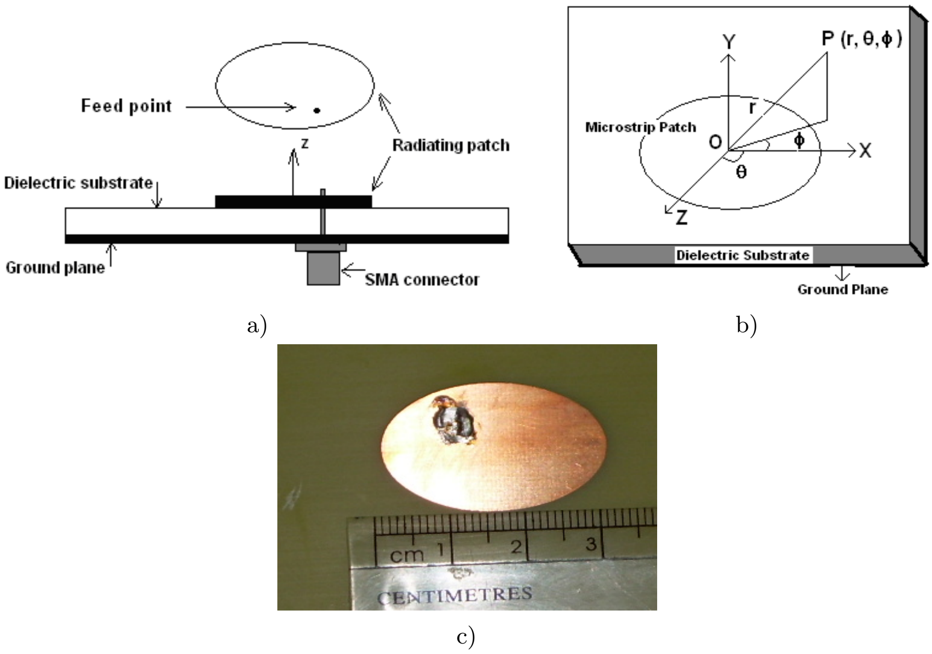

Fig. 1. a) Side view of antenna geometry; b) considered antenna with coordinate system; c) top view of elliptical microstrip patch antenna.

Later this antenna as shown in Fig. 1(c) is printed on epoxy/ glass (FR-4) substrate having substrate relative permittivity $\varepsilon_r = 4.4$, substrate thickness $h = 0.159$ cm, substrate loss tangent $\tan\delta = 0.025$ with infinite metallic copper ground plane. Antenna is feed through inset probe feed arrangement (SMA connector) with 50 ohm feed line.

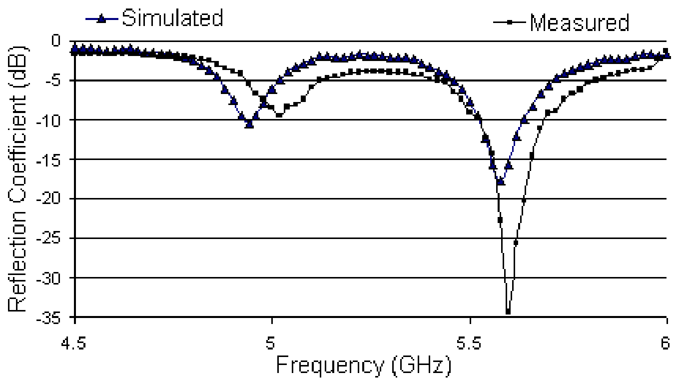

Fig. 2. Simulated and measured variation of reflection coefficient with frequency for elliptical microstrip patch antenna without sector slots.

The simulated and measured variation of reflection coefficient (S_{11}) with frequency is shown in Fig. 2 which indicates that antenna shows to resonance. At first dip the simulated and measured frequencies are 5.01 GHz and 4.94 GHz whereas for second dip the simulated and measured frequencies are 5.61 GHz and 5.574 GHz which are in good agreement. However the first dip corresponding to frequency 5.01 GHz may be considered as non-resonating frequency since the reflection coefficient value is very low and the gain of antenna at this frequency is also very poor. The simulated impedance bandwidth corresponding to second frequency 5.61 GHz is 3.2% which is close to the measured impedance bandwidth of antenna 2.26% with respect to resonance frequency 5.574 GHz. The measured value of VSWR of antenna at second resonance frequency 5.574 GHz is 1.3 which is close to unity and indicates good matching of antenna and feed network. The VSWR is better than desired 2:1 value at frequency of interest.

The input impedance presented at the resonance frequency is (39.17 +j 4.30) ohm which also indicates fair matching between antenna and feed network. The measured gain values of antenna at two frequencies are around 0.15 dBi and 2.69 dBi respectively which are much lower than desired gain of antennas for modern communication systems. These results suggest that conventional elliptical patch antenna in its present form is not suitable for application in modern communication system hence this antenna is modified by introducing three sector slots in this patch and the performance of modified elliptical patch antenna is presented in next section.

3. Modified elliptical patch antenna

The simulation and measured results from a conventional elliptical patch antenna reported in previous section indicates that it has narrow bandwidth and low gain. This antenna geometry is modified by introducing sector slots on the radiating patch. The proposed elliptical microstrip patch antenna has two sector slots along the major axes aligned opposite to each other and one sector slot orthogonal to these two slots and aligned along the minor axis as shown in Fig. 3. The radius, sector angle and location of center of these slots are optimized to obtain best performance. It is realized that on making radius and sector angle of each sector slot 8.0 mm and 20° respectively, the performance of antenna improves to a great extent. Under this condition, center of each slot is 4.0 mm away from the center of the elliptical patch.

The simulated and measured variation of reflection coefficient (s_{11}) with frequency for elliptical microstrip patch antenna with sector slots is shown in Fig. 4 indicates that with the loading of sector slots, both lower (5.01 GHz) and upper frequencies (5.61 GHz) shift to the lower frequency side (4.93 GHz and 5.31 GHz) respectively. The simulated S_{11} curves corresponding to these two frequencies approach to each other and partially overlaps to provide improved impedance bandwidth close to 690 MHz or 13.15% with respect to the central frequency 5.12 GHz. The measured resonance frequencies are 5.012 GHz and 5.236 GHz while measured impedance bandwidth is 560 MHz or 10.96% with respect to central frequency 5.11 GHz.

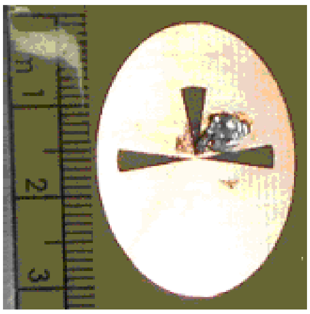

Fig. 3. Geometry of elliptical microstrip patch antenna with sector slots.

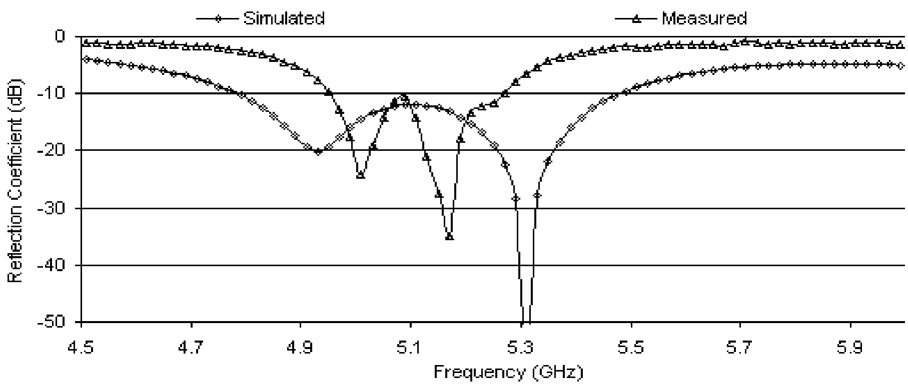

Fig. 4. Simulated and measured variation of reflection coefficient (s_{11}) with frequency for elliptical microstrip patch antenna with sector slots.

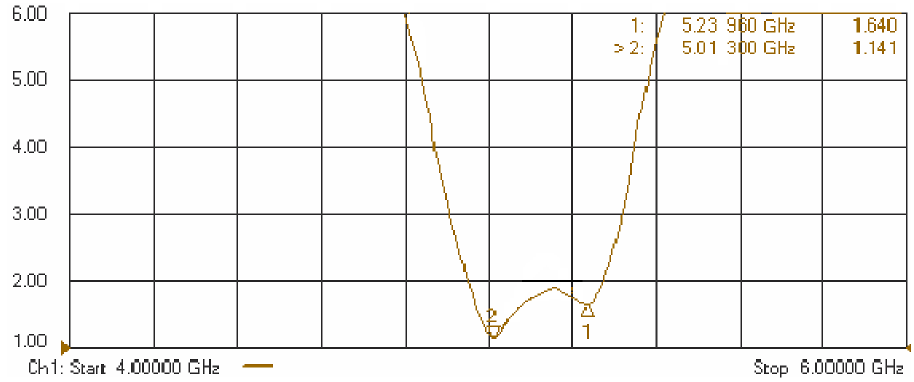

Fig. 5. Measured variation of VSWR with frequency for modified elliptical microstrip patch antenna.

The measured VSWR and input impedance variations of modified elliptical patch antenna with frequency are shown in Figs. 5 and 6 respectively. The VSWR at both frequencies is better than desired 2:1 value (1.64 and 1.14). The input impedance presented at two measured frequencies 5.01 GHz and 5.23 GHz are (56.51 +j 2.067) ohm and (33.63 − j12.28) ohm respectively which again indicates fair matching between antenna and feed network. The measured gain of antenna at the two resonance frequencies are presented in Table 1 and are compared with that of a conventional elliptical patch antenna tested under similar test conditions. The gain of modified elliptical patch antenna is improved in comparison to that of conventional elliptical patch antenna reported in the previous section.

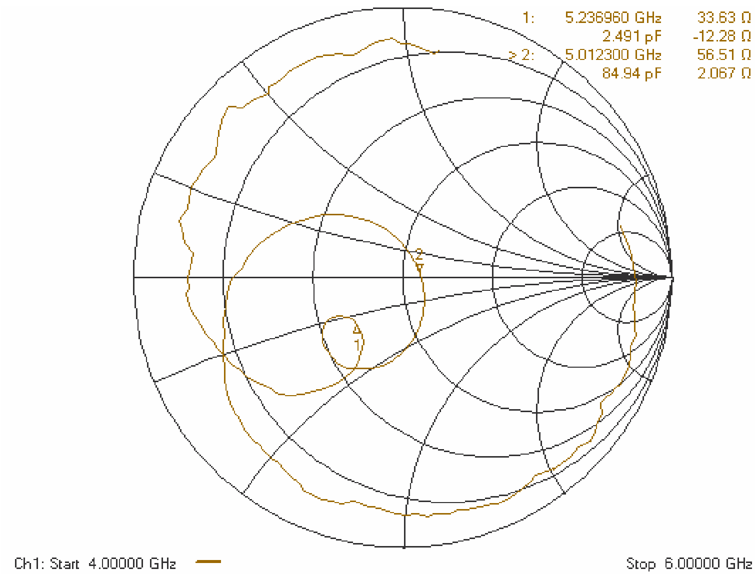

Fig. 6. Measured variation of input impedance with frequency for modified elliptical microstrip patch antenna.

Table 1. Comparison of radiation performances of elliptical microstrip antenna with and without slots

Name of antenna	Resonance frequency (GHz)	Gain in dBi		Radiation Efficiency	Directivity (dBi)
		f_{r1}	f_{r2} ($f_{r2} > f_{r1}$)		
Conventional elliptical patch antenna	5.01 5.61	0.15 dBi	2.69 dBi	22.24% 23.74%	7.42 7.66
Modified elliptical patch antenna with slots	4.94 5.238	0.81 dBi	4.03 dBi	30.92% 36.22%	6.44 7.76

The simulated E and H plane elevation patterns of antenna at four frequencies covering impedance bandwidth region are shown Fig. 7. The patch antenna produces cardoid patterns at all the indicated frequencies, with good gain along on boresight and dropping to 0 dB. The measured E and H plane co and cross polar radiation patterns of antenna at frequency 5.23GHz are shown in Fig. 8. In both E and H plane, co polar patterns are nearly 6dB higher than corresponding cross polar pattern. The direction of maximum radiations in each case is directed normal to the patch geometry and the patterns are more or less symmetrical in nature.

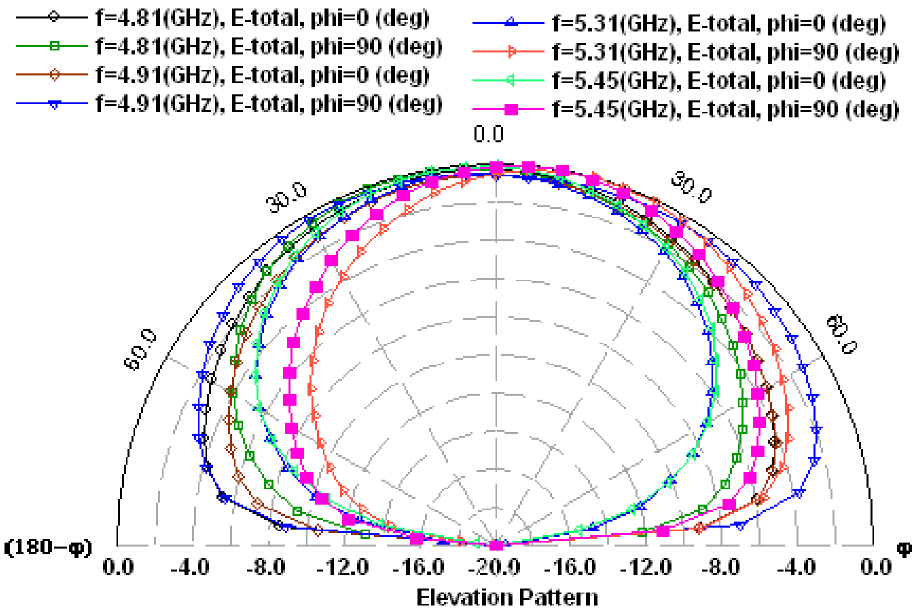

Fig. 7. Simulated E and H plane elevation pattern gain display at four frequencies.

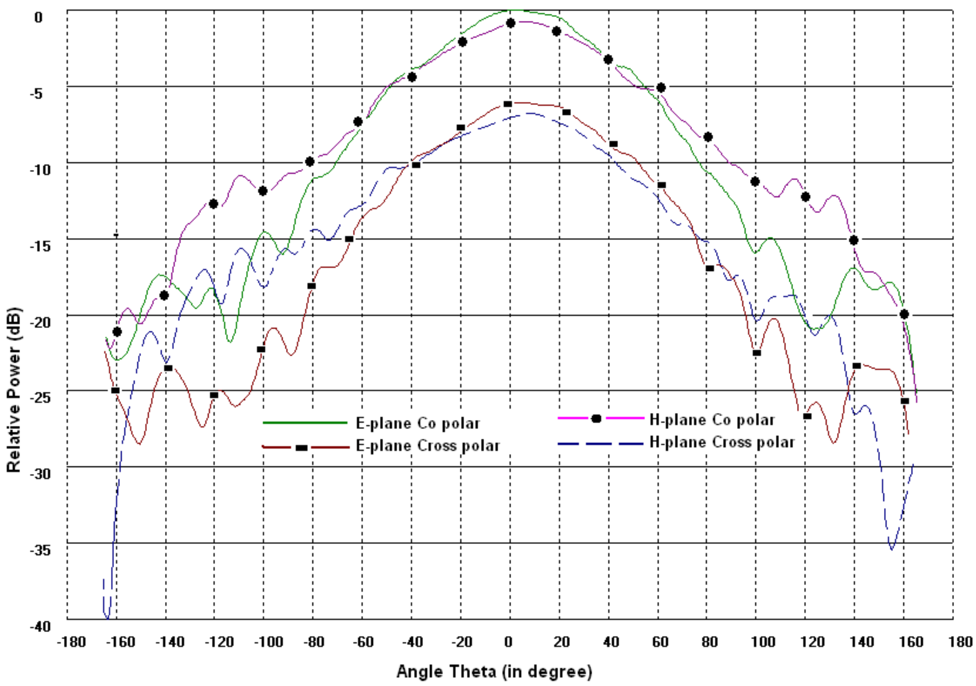

Fig. 8. Measured E and H plane co and cross polar patterns 5.23 GHz.

3. Conclusions

This paper presents the radiation performance of a modified elliptical patch antenna having three orthogonal sector slots. Experimental results are compared with simulation performance for better understanding. It is realized that with the introduction of these sector slots, the effective patch size is marginally reduced but the performance of antenna is significantly improved. Improvement in both impedance bandwidth and gain is realized though gain results need further improvement. The radiation patterns are still stable and the direction of maximum radiations is directed normal to patch geometry. With little more improvement, this antenna may be proved a useful structure for wireless local area networks (WLAN) communications covering the 5.15 to 5.85 GHz frequency bands adopted by IEEE 802.11a5. However there is a slight deviation in simulated and measured values of resonance frequencies and gain of antenna which might be due to the limitations of applied simulation software, fabrication tolerances of antenna and possibility of misalignment of sector slot and feed point during fabrication of prototype antenna for experimentation.

Acknowledgements. Authors like to acknowledge Department of Information and Technology, New Delhi for providing financial support during this work. Authors are also thankful to Dr. S. Pal and Mr. V.V. Srinivasan, ISRO Bangalore for permitting us to use the measurement facilities available at their center.

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