Reduced-Size Microstrip Antenna for Wi-MAX and WLAN

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Abstract – **A dual frequency, compact single probe-feed rectangular microstrip patch antenna with reduced size has been proposed in this paper. The single layered antenna has been designed to resonate in dual frequency mode. The novel design is achieved by cutting rectangular slits at two sides of the patch. Compared to the conventional rectangular patch antenna, this antenna can achieve reduction in patch size up to 73.07%. This antenna has been simulated in ANSOFT designer (based on MOM) software and measured using standard microwave test bench and vector network analyzer. Satisfactory return loss for each resonant frequency has been found. This antenna can be used for Wi-MAX and WLAN applications.**

Keywords – **Microstrip patch antenna, Size reduction, Dual frequency band.**

I. INTRODUCTION

In modern wireless communication systems, the multiband antenna has become one of the most important circuit elements and attracted much interest. To satisfy the IEEE 802.11 WLAN standards in the 2.4/5.2/5.8 GHz operating bands or the worldwide interoperability for microwave access (WiMAX) 2.5/3.5/5.5 GHz bands, multiple bands antenna with low cost, compact size, easy fabrication technique, and higher performance are required. In recent years, demand for small antennas on wireless communication has increased the interest of research work on compact microstrip patch antenna design among microwaves and wireless engineers. The microstrip patch antenna [1-8] is one of the most preferred antenna structures for wireless communication devices and handheld communication devices due to its small size, light weight, low profile and easy integration with other components. One of the physical characteristics of these handheld and wireless communication devices are their small size. To reduce the size of these devices, the size of the components used inside these devices has to be reduced. As microstrip antenna is one of the components being used, the size of these devices depends on this antenna to a large extent. Therefore, one of the techniques of reducing the size of the wireless and handheld communication devices is to reduce the size of the microstrip antenna.

Many techniques have been reported to reduce the size of microstrip antennas for fixed operating frequency. The inverse proportionality of the relative permittivity can be exploited to reduce the physical antenna length at a fixed operating frequency. A higher permittivity substrate can significantly reduce the antenna size by as much as about 90%.

A number of techniques have been reported to reduce the size of a Microstrip antenna. The simplest of them is by modifying the radiating patch or by modifying the ground plane [9-15]. It was reported by Kuo and Wong [9] that by embedding three meandering slots in the ground plane of rectangular microstrip patch antenna, the size of the antenna can be reduced by 56%. Rezvani reported that antenna size reduction of 34% can be achieved by using slotted microstrip patch antenna with defected ground plane [10]. A maximum antenna size reduction of 41% with multifrequency operation was achieved in [12] by varying the positions and dimensions of the rectangular slots on the patch. Antenna size reduction of 64% with multifrequency operation was reported by Sarkar [13] by embedding three narrow rectangular and two circular slots on the patch. It was also reported by Singh [14] that by using cross slot on the rectangular and trapezoidal patch, the size of the antenna can be reduced by 34% and 41%, respectively.

Other most adopted miniaturization methods include use of Koch and Sierpinski fractal-shapes and use of shorting post technique. The Koch patch is fractal shaped and characterized by space-filling and self-similarity properties. Due to the space-filling properties of fractal geometry, the proposed antenna [16, 17] performances have been enhanced in terms of size, gain and multi-frequency behaviour and provide overall antenna size reduction of about 77.1%. Size reduction of a patch antenna by combining two techniques such as inserting slots as inductive loading and using shorting post in the middle of a patch [18] was reported by L. Desclos et al. in the year 2001. The antenna provides a size reduction of around 75 %. The use of edge-shorted patch for size reduction is also a well-known technique and makes a microstrip antenna act as a quarter-wavelength structure and thus can reduce the antenna's physical length by half for a fixed operating frequency. When shorting pins is used instead of a shorting wall, the antenna's fundamental resonant frequency can be further lowered and further size reduction can be obtained. An antenna size reduction of about 89% can be obtained using these methods, and when used with an equilateral triangular microstrip antenna, the size reduction can be made even larger, as much as 94% [19].

The work presented in this article relates to compact microstrip patch antenna with multi-frequency operation obtained by cutting identical finger like narrow slits parallel to the radiating edges. The aim is to reduce the antenna size at an extreme and also to achieve multiple resonant frequencies only by modifying the patch with unmodified ground plane. Single layer, dual frequency microstrip antenna is proposed in this article with a size reduction up to 73.07% and also with a capability to operate at dual bands with sufficient gain. This antenna can be used for Wi-MAX and WLAN applications.

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II. ANTENNA GEOMETRY

The geometry of the proposed compact-dual frequency antenna is shown in Fig. 1. The rectangular patch of dimension 16 mm x 12 mm is printed on a FR 4 substrate of thickness 1.6 mm (h), relative permittivity 4.4 (ε_r), and dimensions of 50 mm x 40 mm. Six identical finger like slits of dimension 1 mm x 5 mm are cut out one by one from the patch as shown in the Fig. 1.

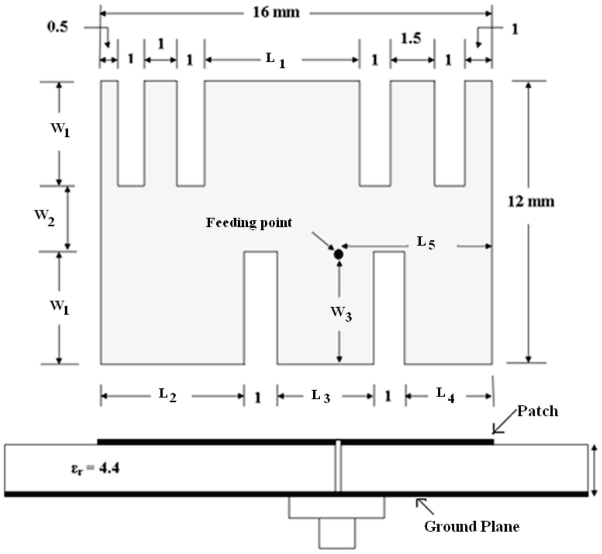

Fig. 1. Geometry of the proposed antenna

Table 1 presents detailed dimensions of the proposed antenna. These dimensions are finalized after a good number of simulations. The patch was fed by a 50Ω coaxial probe (radius = 0.5 mm). The feed location was optimized at (L_5, W_3) to provide good impedance matching.

TABLE 1
ANTENNA DIMENSIONS

L_1	**L_2**	**L_3**	**L_4**	**L_5**	**W_1**	**W_2**	**W_3**
8	6	5.5	2.5	5.8	5	2	4.85

The photograph of the fabricated antenna is shown in the Fig. 2. The proposed design starts with a conventional rectangular patch of dimension 16 mm x 12 mm and is referred as a reference antenna. The width and length of the patch has been calculated using standard equations [20]. Slits of same dimensions are introduced serially and their effects are studied with the help of simulated results only.

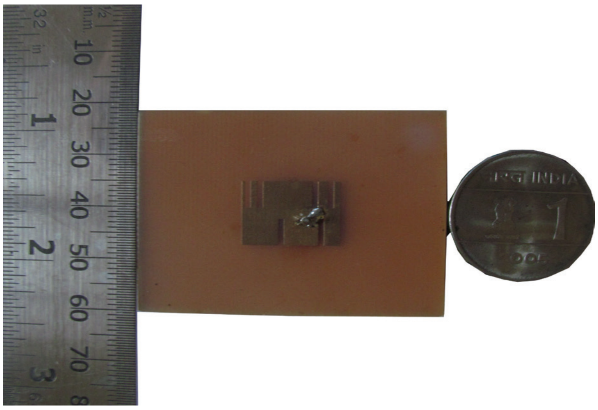

Fig. 2. Photographs of the fabricated antenna

III. RESULTS AND DISCUSSIONS

In order to compare the performances of proposed antenna we consider a reference antenna without any slit. The size and feeding point of the reference antenna is same as that of the proposed antenna. The performance of the proposed antenna is explored using ANSOFT designer software based on Method of Moment (MOM). Fig. 3 shows the simulated input impedance (S_{11}) plot for the reference and proposed antenna. According to the known equation, patch antenna with dimension (16 x 12) mm^2 fabricated on FR-4 substrate (ε_r = 4.4, h=1.6 mm) will resonates at f_r = 4.44 GHz. The reference antenna resonates only at a single frequency of 4.3 GHz. whereas the proposed antenna resonates at two different frequencies 3.1 GHz and 5.5 GHz. So the insertion of slits reasonably reduces the resonant frequency that yields to size reduction.

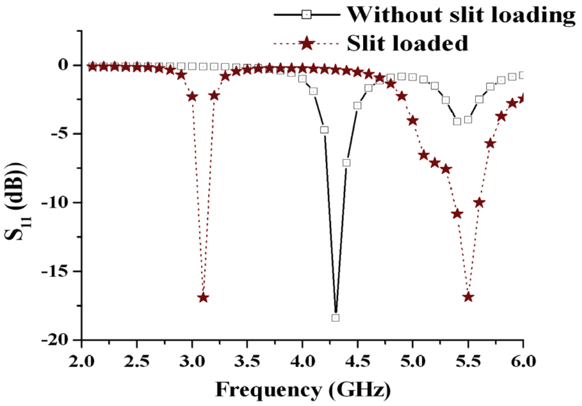

Fig. 3. Simulated S_{11} characteristic for the reference and proposed antenna

The proposed antenna is prototyped and the input impedance is measured using Agilent Vector Network Analyzer. The simulated and measured S_{11} versus frequency plot for the proposed antenna is illustrated in Fig. 4. Proposed antenna resonates at two different frequencies 3.1 GHz and 5.5 GHz (simulated), 3.0 GHz and 5.4 GHz (measured) with satisfactory input impedance. So a reasonable size reduction of around 71% from simulated result and 73.07% from the measured result is achieved. With the slit loaded proposed antenna along with first frequency band 3.05 GHz to 3.15 GHz another useful frequency band of 5.37 GHz to 5.5 GHz is also obtained. These two frequency bands are widely used in Wi-MAX (3.1 to 3.6 GHz) and WLAN (4.9 to 5.9 GHz) respectively.

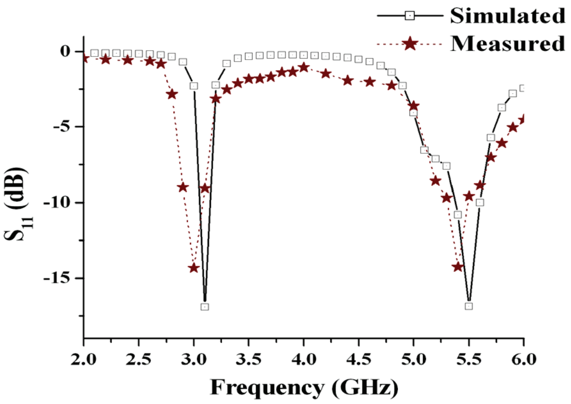

Fig. 4. Simulated and measured S_{11} characteristics for the proposed antenna

The simulated and measured E- and H-plane radiation patterns at 3.1 GHz and 5.5 GHz are shown in Fig. 5(a) and Fig. 5(b), respectively. The radiation patterns are measured using standard microwave test bench. The co and cross polarized components of the field are different in the x–z (H-plane) and y–z (E-plane) plane. In the H-plane, the co-polarized component is E_φ; the cross-polarized component is E_θ. It is contrary in the E-plane.

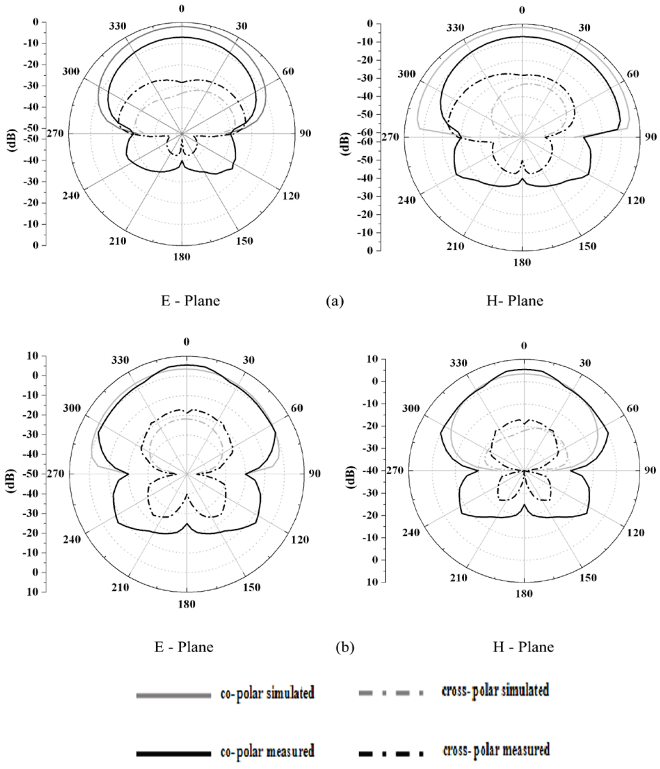

Fig. 5. Simulated and measured radiation patterns of the proposed antenna at different frequencies. (a) 3.1 GHz and (b) 5.5 GHz

The little disagreement between simulated and measured radiation patterns may be due to the loss of the connectors and the measurement process. The results of Fig. 5 show that the radiation patterns are remarkably stable and isolation between co and cross is quite high. Another important point has been noticed that at both frequencies the E-plane and H-Plane radiation patterns are almost similar.

The simulated gain of the proposed antenna is shown in Fig. 6. It reveals that the antenna gain ranges from 0.114 dBi to 2.256 dBi within 2 GHz to 6 GHz frequency band. It is seen that the proposed antenna has an average peak gain of 0.895 dBi. The peak gain at two operating frequencies 3.1 GHz and 5.5 GHz are 0.838 dBi and 2.256 dBi respectively.

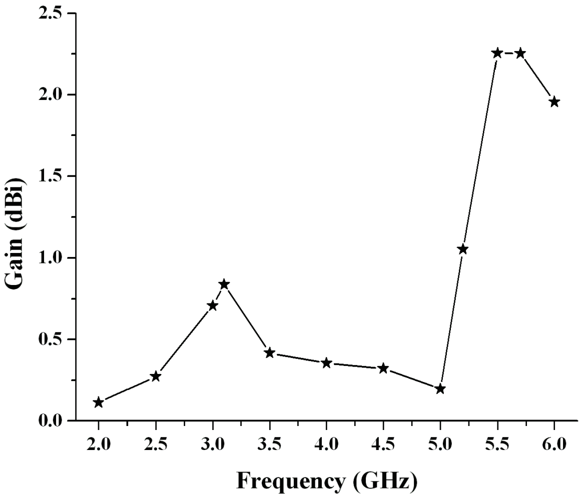

Fig. 6. Simulated peak gain characteristic for the proposed antenna

IV. CONCLUSION

Theoretical and practical investigations of a single layer, single feed, compact multifrequency microstrip patch antenna has been presented in this article. The fabricated antenna has been experimentally studied. Introducing identical finger like narrow slits on the patch, size reduction of about 73.07% has been achieved with multifrequency operation. The proposed antenna is coaxially fed at optimized locations. Alteration of location of feed points results in narrower 10 dB bandwidth. Furthermore, the proposed antennas show considerably good radiation characteristics. Thus, the proposed antenna could be promising for a number of modern wireless communication standards such as Wi-MAX and WLAN.

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