A Novel Design of Slotted Rectangular Microstrip Patch Antenna with Finite Ground for Wi-MAX Application

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Abstract-In this paper small suspended rectangular patch antenna geometry is proposed. The antenna is designed to perform efficiently from 3.28 GHz. to 3.74 GHz, at the resonant frequency of 3.49 GHz having a return loss of -45.54dB. The given range is suitable for median band of IEEE 802.16 Wi-MAX (Worldwide Interoperability for Microwave Access) application. The proposed antenna is designed on simple glass epoxy FR4 dielectric material and fed by simple 50W coaxial probe feed. Finite ground truncation technique is adapted to achieve the best result in bandwidth, impedance matching and directivity. After introduction of a cut in a conventional rectangular patch the antenna is operating at a gain of 3.45dB which is quite acceptable in such application. Effects of the truncation of ground plane on bandwidth, gain, efficiency and radiation characteristics are discussed in this paper.

Index Terms- microstrip patch antenna (MSA), surface wave modes (SWMs), Wi-MAX (Worldwide Interoperability for Microwave Access), finite ground

1. INTRODUCTION

Now days in modern communication systems we need to develop small size, lightweight, low profile, broad band antenna design for compact communication equipments. Worldwide Interoperability for Microwave Access (Wi-MAX) is the most advanced wireless communication having a high data rate. Microstrip patch antennas are used in various wireless applications. These antennas have many desirable features such as: low profile, lightweight, and are easily fabricated by lithographic etching process or a mechanical milling process. But the narrow bandwidth, low gain, polarization impurity and impedance mismatching are become main drawbacks in the application of communication system. Many methods, such as addition of slots, parasitic elements to the basic structure, ground truncation are adapted to improve those drawbacks [1-3]. In previous study A.K. Bhattacharyya shows that the grounded dielectric supports a finite number of surface wave modes (SWMs) which propagate in a direction parallel to the air-dielectric interface. The magnitude of a SWM, in general, increases with the electrical thickness of the substrate. For a truncated ground plane, these surface wave fields partially reflect back and react with the main radiator. This effect alters the input impedance and the radiation patterns of a patch antenna considerably.

In this communication rectangular patch is chosen for better response and ease of analysis rather than any other shapes. The ground plane truncation and addition of a cut at 45 degree elevation with infinite length in the rectangle patch resulting a wide bandwidth and good gain which can be acceptable in modern Wi-MAX application. Effects of the truncation of ground plane on bandwidth, gain efficiency and radiation characteristics are also discussed in this paper. The proposed design is simulated on 1.59 mm thick FR4 substrate.

2. ANTENNA DESIGN

The geometrical representation of the proposed design is shown in Figure 1. The basic parameters are also shown in Figure 1. The antenna is mounted on FR4 substrate with a thickness of 1.59 mm. The antenna is fed by a simple coaxial transmission line. Synthesis and analysis of this proposed design was performed using IE3D v 15.1 commercial software [4]. The simulated resonance frequency corresponding to dominant mode (TM_{11} mode) of conventional rectangular patch antenna without any ground reducing and addition of cut in the patch is 4.29 GHz. Previously discussed that linear polarization can easily be obtained by exciting a simple rectangular patch. For achieving purely linear polarization, a cut of 4.95 mm length at 45 degree elevation has been introduced in the rectangular patch. After introducing the cut of 4.95 mm the proposed antenna gain has increased to 3.45 dB which is quite acceptable. For this design a finite ground of W_1= 100 mm and L_1= 50 mm is taken. The dimension of the proposed patch is W_2= 30 mm, L_2= 20 mm. After selection of a suitable feed location the finite ground has truncated gradually. When the ground area reduced 54% the antenna efficiently perform with a gain of 3.45 dBi and 2:1 VSWR.

cut makes the patch defected one. The ground truncation along the width of proposed design makes the patch suspended type. The resulted geometry of the proposed antenna is shown in Figure 2 where W=46 mm and L=50 mm. Suspended type patch improves the radiation property as it acts as the main radiator as well as it also reduces the parasitic effects of the antenna.

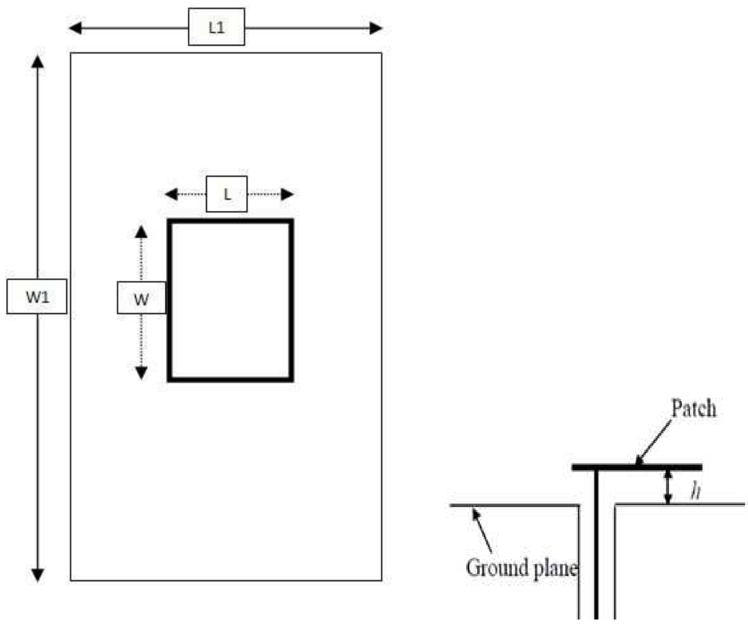


Fig. 1. Antenna geometrical configuration. The parameters are the finite ground of W1=100mm, L1=50mm, and the patch of W= 30 mm, L= 20 mm, h=1.6 mm.

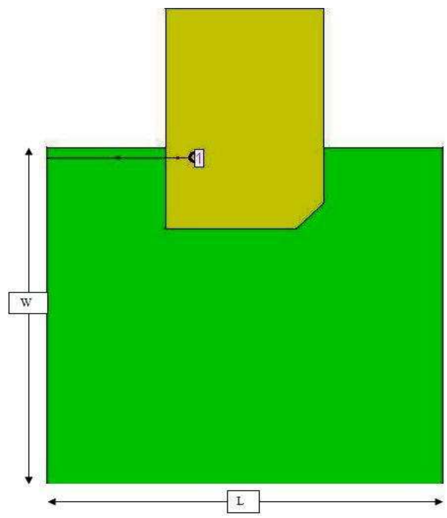


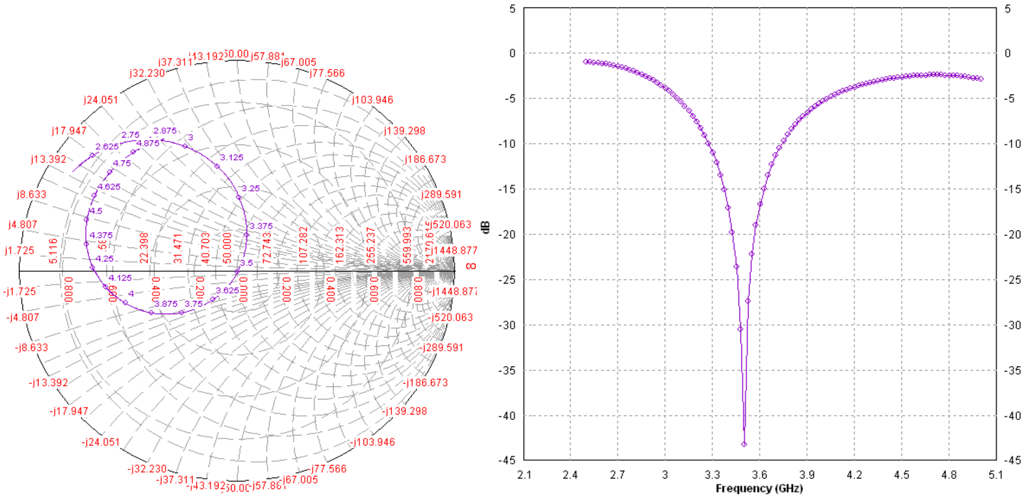
Fig. 2. Antenna geometrical representation after slotting the patch and truncating the ground.

3. RESULT ANALYSIS

Initially started with a finite ground of W1= 100 mm and L_1= 50 mm without any cut in the patch. At that time it's resonating with a narrow bandwidth (2-4%). In order to get proper impedance band width and gain a cut of 4.95 mm has introduced and reducing the finite ground need to be adjusted accordingly. This

Simulated input impedance matching data of the design is shown in Figure 3(a). The concentric circle which passes through the centre of the smith chart implies a wide impedance bandwidth. The antenna band width is extending from 3276 MHz to3744 MHz or 13.4% bandwidth with 2:1 VSWR. The return loss of the proposed design is -44.04 dB at 3.498 GHz is shown in Figure 3(b). Computed current distributions are concentrated at the edge of the slot. The peak gain is about to 3.45dB at the resonant frequency 3.498 GHz is shown in Figure 4.

maximum power from the radiator radiates at the resonant frequency 3.498 GHz. and the patch acts like the main radiator. The wide bandwidth of 13.4% with a good impedance matching is achieved by ground truncation. The current distribution pattern on the



(a) (b)

Fig. 3. (a) Smith chart shows the input impedance matching, (b) Reflection coefficient vs. frequency.

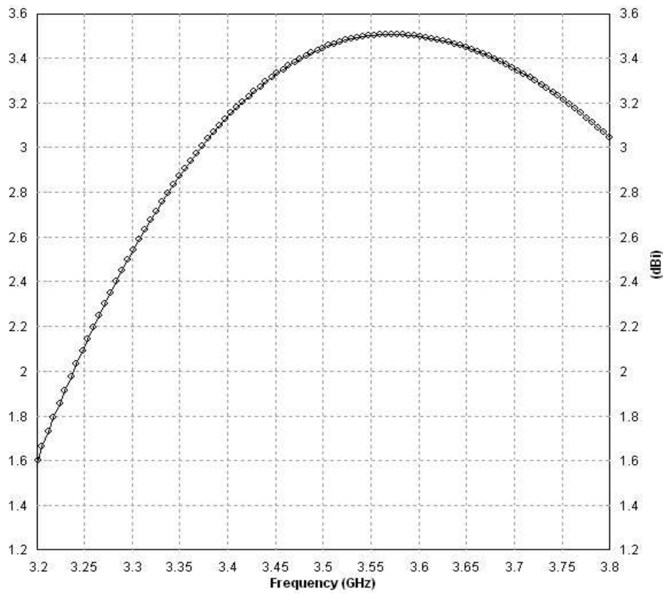


Fig. 4. Total gain with respect to Frequency.

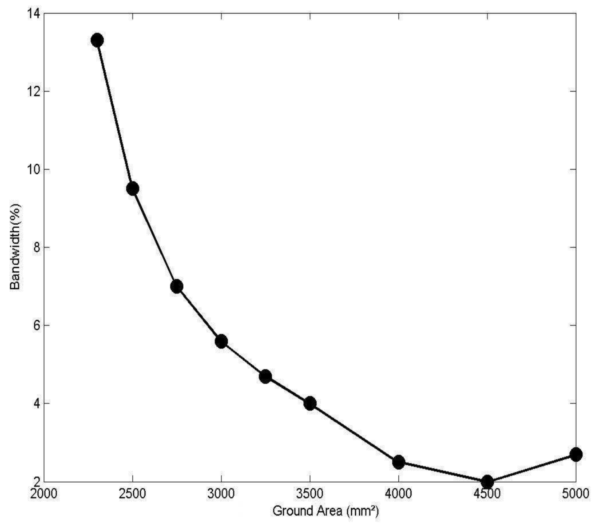
Figure 2 shows that the finite ground truncation makes the antenna suspended type and reduce the size W= 46mm and L= 50mm, gives it's the compactness for miniature application.

In Figure3 (a), the smith chart, the concentric circle shows the perfectly input impedance match with the co-axial transmission line. In Figure3 (b), reflection coefficient vs. frequency (GHz.) shows that the proposed design perfectly resonating at 3.498 GHz with a excellent return loss of -44.04 dB i.e.

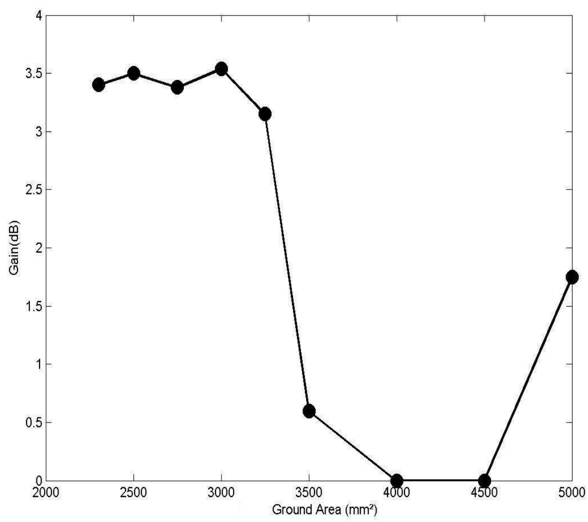
patch concentrates at the edge for this to excite another mode and enhance the bandwidth we introduced a cut and also it makes the patch a defected one.

Figure 4 gain (dB) vs. frequency (GHz) shows that the gain is 3.45 dB at 3.498 GHz. It is also observed that all over the frequency range the proposed design provides average 3 dB gain. The gain of the proposed design is achieved by ground truncating.

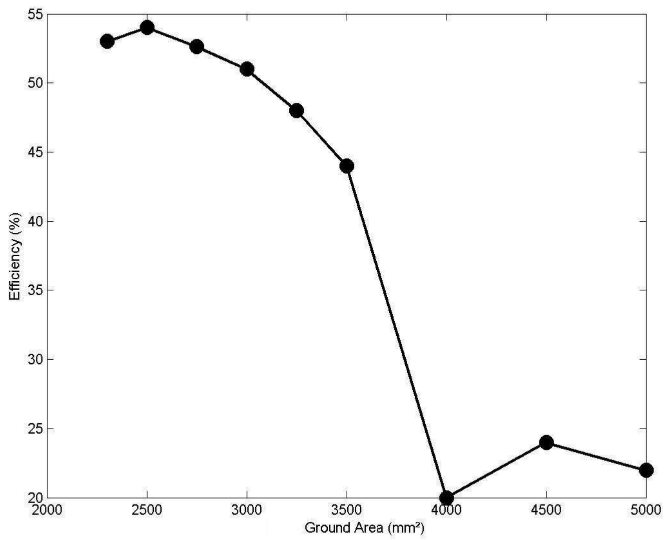
Figure 5 (a) shows that how bandwidth of the proposed design varies with ground truncation. The ground of the antenna is reduced along width, when the width W=46 mm then the proposed design bandwidth is extending from 3276 MHz to3744 MHz the ground plane will significantly affect the resonant frequency, the input resistance and directivity of a rectangular microstrip antenna. Figure 5 (c) shows the increasing manner of efficiency during the changes of ground area.



(a)



(b)



(c)

Fig. 5. (a) Ground area (mm^2) vs. bandwidth (%), (b) Ground area (mm^2) vs. Gain (dB), (c) Ground area (mm^2) vs. Efficiency.

i.e. 13.4% bandwidth. Figure 5 (b) shows the changes in gain due to ground truncation. In previous study we found, there are strong effects on antenna parameters by the ground plane of traditional patch antenna [4-5]. Tavakkol-Hamcdani etc [4] has shown that the size of

4. CONCLUSIONS

In this communication a novel design of a wide band rectangular microstrip antenna has reported where the design provides the frequency range suitable for median band of IEEE 802.16 Wi-MAX (Worldwide Interoperability for Microwave Access) application. In this paper two techniques are described to enhance bandwidth and reduce the antenna size. The techniques are depending on exciting the mode (TM01) with close resonant frequency. The first technique depends on the cut at 45 degree elevation in the patch to meander the current path whereas the second technique is truncating the finite ground. We could reach size reduction along the width and double the bandwidth by using the first technique. Also after truncating the ground the resonant frequency also shifted back from 4.34 GHz to 3.498 GHz. By using the second technique, the size of the antenna was reduced by 54% and enhances the bandwidth by three times its value as compare to the conventional rectangular patch antenna.

(A.1)

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