COMPACT OMNI-DIRECTIONAL PATCH ANTENNA FOR S-BAND FREQUENCY SPECTRA

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ABSTRACT

This paper presents a novel design of a microstrip patch antenna with compact nature and the study of various antenna parameters to suit the applications such as WiMax operating in the frequency range of 3.3 – 3.5 GHz and in other applications like fixed satellite services, maritime mobile services etc. covering 2 - 4 GHz of S-band frequency spectra. It is experimental observed that by placing stubs on the patch with air filled dielectric medium, the resonant frequency of the antenna can be lowered by a considerable amount resulting in compactness. Proposed antenna can be used as a compact antenna system where limited size is a requirement. Measurement results showed the satisfactory performance over S-band frequency spectra with the improved antenna parameters. Details of the antenna design procedure and results are discussed and presented.

KEYWORDS

Co-axially fed, slots, WiMax, frequency, fixed satellite services.

I. INTRODUCTION

Wireless applications have undergone quick progress in recent years. One such particular wireless application that has experienced this trend is WiMax. According to the guideline by Telecom Regulatory Authority of India (TRAI) – Draft Recommendation on Growth of Broadband [1] on the provision of WiMax service, the allocated spectrum band in India is 3.3 - 3.5 GHz. The proposed antenna operates in the frequency range of 3.3 – 3.5 GHz and is useful in WiMax application.

WiMax antenna requires low profile, light weight and broad bandwidth with moderate gain. The microstrip antenna suits these features very well except for its narrow bandwidth. The conventional microstrip antenna couldn't fulfill these requirements as its bandwidth usually ranges from 1 - 2 % [2]. Although the required operating frequency range is from 3.3 – 3.5 GHz, atleast double the bandwidth is required to avoid the expensive tuning operation and not to cause any uncritical during manufacturing. Therefore, there is a need to enhance the bandwidth, gain and to achieve compactness for applications mentioned above.

In the early studies conducted and surveyed, a compact circular microstrip patch antenna with a switchable circular polarization (CP) is designed for 2.4 GHz, the impedance bandwidth and CP bandwidth of the antenna are up to 150 MHz and 35 MHz [3] respectively. The stacked rectangular microstrip antenna (SRMSA) using a co-axial probe feed method achieved a bandwidth of 1.63 % by embedding T-slots in the lower patch of the SRMSA [4]. A design of a coplanar waveguide (CPW) feed square microstrip antenna with circular polarization (CP) is described in [5] and has achieved 2.4% bandwidth. A compact single layer monopulse microstrip patch antenna array [6] for the application of monopulse radar has been designed, manufactured and tested and the design achieved a bandwidth of 5.6%. A novel, low profile compact microstrip antenna which achieved gain of - 4 dBi and bandwidth of 30 MHz is presented in [7]. A planar compact inverted U-shaped patch antenna with high-gain operation for Wi-Fi system has been proposed and investigated and provided relatively wider impedance bandwidth of 162 MHz covering the 2.45 GHz band (2400–2484 MHz) [8]. A dual-resonant patch antenna applicable to active radio frequency identification (RFID) tags is designed. The measurement results reveal that the antenna has the return loss less than –10 dB within the bandwidth of 42 MHz (from 911 to 953 MHz), which totally covers the 5 MHz bandwidth from 920 to 925 MHz [9]. A V-shaped microstrip patch antenna for 2.4 GHz is designed, fabricated, and experimentally measured and this design provided 50 MHz impedance bandwidth determined from 10 dB return loss for 2.4 GHz frequency band [10]. This paper examines a study of novel design of patch for improving the impedance bandwidth, gain and achieving compactness of the microstrip patch antenna on FR4 material for S-band frequency spectra applications.

II. ANTENNA DESIGN AND PATCH STRUCTURE

Figure.1 depicts the front view of the designed antenna. A FR4 dielectric superstrate having dielectric permittivity ϵ_r = 4.4 having thickness h = 1.66 mm with air filled dielectric substrate $\epsilon_o \approx 1$ of thickness Δ = 8.5 mm is sandwiched between the superstrate and ground plane. A copper plate with the dimension $L_g = W_g$ = 40 mm with thickness of h_1 = 1.6 mm is used as a ground plane. The fabricated patch and the ground plane were fixed firmly together with plastic spacers along the four corners of the antenna. The geometry of the patch antenna 1 and 2 (PA 1 and PA 2) is as shown in figure 2 (a) and (b). The patch dimensions are, width W = 23.28 mm and length L = 17.76 mm. Stubs are placed on the patch with dimensions c = 2 mm, d = 1 mm, e = 2 mm, f = 1 mm, g = 2 mm, h = 2 mm, i = 1 mm, j = 2 mm, k = 1 mm, l = 1 mm so as to obtain the improvement in bandwidth, gain and to achieve compactness. The patch along with stub dimensions are taken in terms $\lambda_{0,}$ where λ_0 is the operating wavelength. The patch antenna incorporated with the short stub along the radiating and non radiating edges introduces a capacitance that suppresses some of the inductance introduced by the feed due to the thick substrate, and a resonance of stub can be obtained. In this work, co-axial or probe feed method is used as its main advantage is that, the feed pin can be placed at any place on the patch to have impedance match with its input impedance (50 ohms) and hence the feed pin is placed along the center line of Y-axis at a distance f_p from the top edge of the patch as shown in Figure. 1.

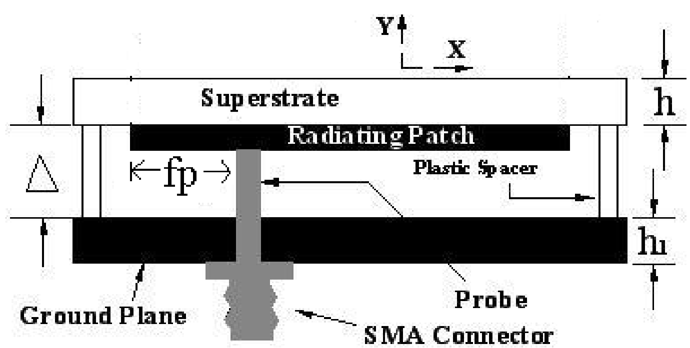
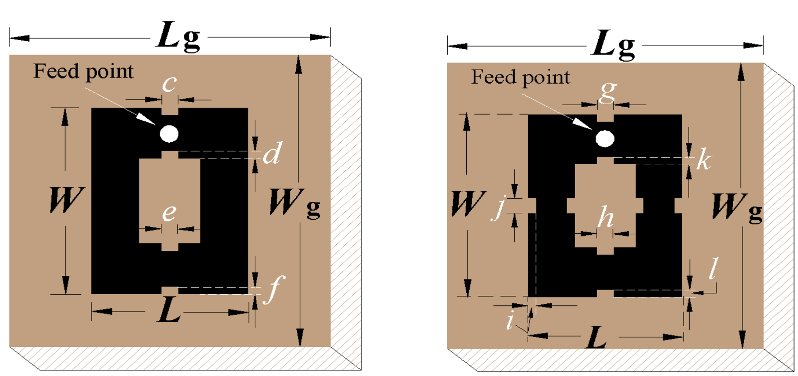


Figure 1. Front view of the designed antenna



(a) (b)

Figure 2. Patch structure. a) PA 1 and b) PA 2

III. RESULTS AND DISCUSSION

The designed patch antennas have been experimentally studied using Vector Network Analyzer (Rohde and Schwarz, Germany make ZVK model 1127.8651). Figure 3 shows the measured return loss (RL) versus frequency characteristics for PA 1 and PA 2 at their respective resonant frequencies. Plot result shows that patch antenna (PA 1) resonates at 3.63 GHz with the total available impedance bandwidth 210 MHz that is 5.77 % covering the frequency range 3.53 GHz to 3.74 GHz and 250 MHz (7.02 %) impedance bandwidth resonating at 3.57 GHz covering 3.43 GHz to 3.68 GHz of S-band for patch antenna 2 (PA 2). It is also noted that minimum of -12.80 dB and -13.34 dB return loss is available at respective resonant frequencies for PA 1 and PA 2. Hence, the resonating frequencies are significantly lowered due to the use of stubs on the patch in comparison to the designed frequency 3.85 GHz for the simple microstrip patch antenna. The designed antennas also achieved a compactness of 11 % and 15 % for PA 1 and PA 2. A gain of 2.75 dB and 3.60 dB at resonant frequencies of 3.63 GHz and 3.57 GHz for PA 1 and PA 2 is also significant.

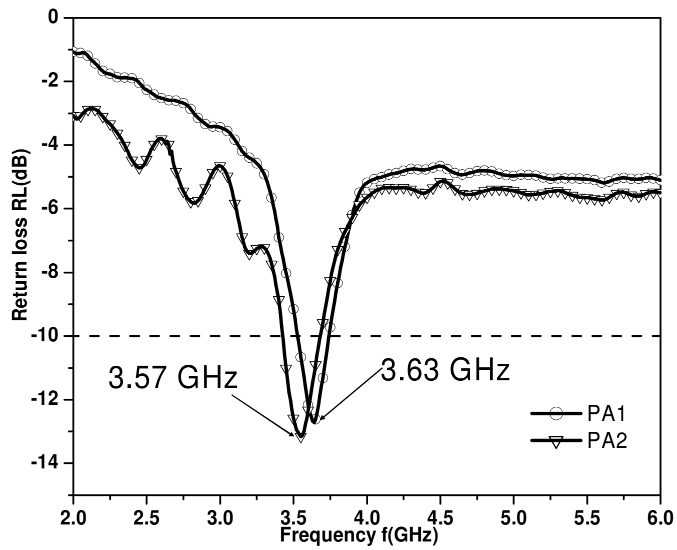
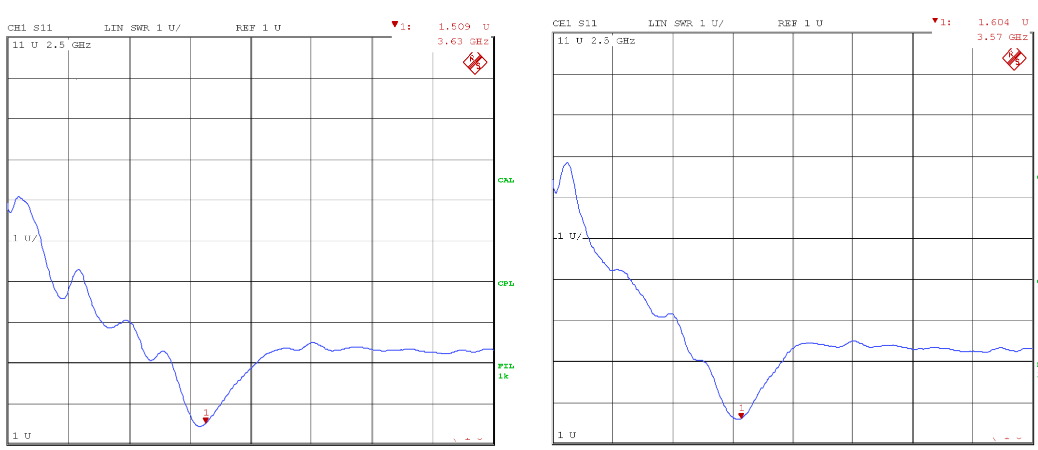


Figure 3. Measured return loss (RL) versus frequency (f) characteristics

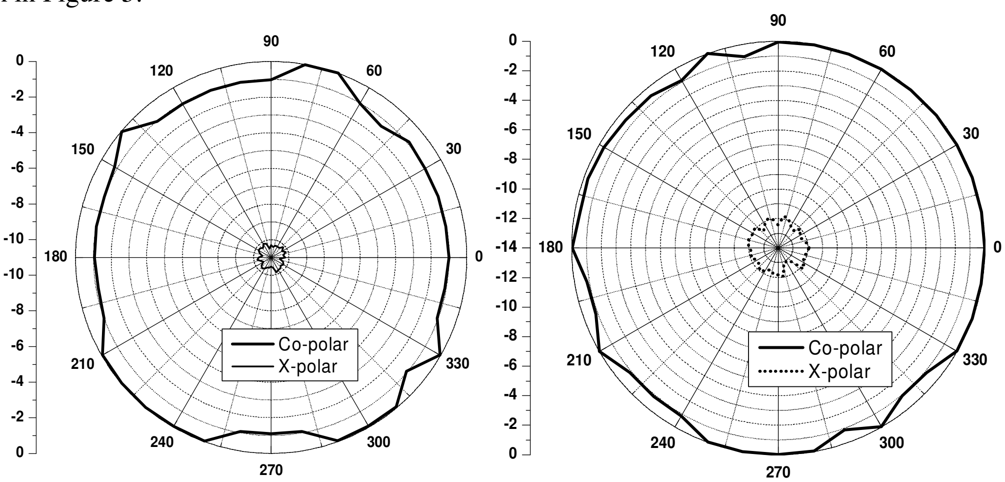
The voltage standing wave ratio (VSWR) is a measure of impedance mismatch between the transmission line and its load. Figure 4 shows the VSWR characteristics of the designed antennas (PA 1 and PA 2) showing the values 1.509 and 1.604 that are less than 2 also justifying less reflected power at the respective resonant frequencies 3.63 GHz and 3.57 GHz.



(a) (b)

Figure 4. VSWR characteristics. a) PA 1 and b) PA 2

The radiation patterns of the designed antennas at the resonant frequencies are also measured and plotted. For the measurement of radiation pattern, the antenna under test (AUT), i.e., the designed antennas and standard pyramidal horn antenna are kept in the far field region. The AUT, which is the receiving antenna, is kept in phase with respect to transmitting pyramidal horn antenna. The received power by AUT is measured from 0^o to 180^o with the rotational motion at steps of 10^o each. Notably, it is seen that the antennas display good omni-directional radiation patterns at resonating frequencies as shown in Figure 5.



(a) (b)

Figure 5. Measured radiation patterns. a) PA 1 and b) PA 2

IV. CONCLUSION

The study has demonstrated that, the designed antennas having air filled substrate, patch with stubs achieved compactness of about 11 % and 15 % with 210 MHz and 250 MHz impedance bandwidth. It is also found that the designed microstrip patch antennas (PA 1 and PA 2) attained a gain of 2.75 dB and 3.60 dB at resonating frequencies with omni directional radiation patterns that can be suitably used for WiMax services, as it utilizes the 3.3 – 3.5 GHz band and also it can be used for applications like fixed satellite services, maritime mobile services etc covering 2 - 4 GHz for S-band frequency.

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Author's biography

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