Design of a micro strip patch antenna to minimize return loss for WI-MAX application

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Abstract: This Worldwide Interoperability for Microwave Access (Wi-MAX) is a technology which maintains group of telecommunications protocols that enables final prop of delivering connectivity from a communication provider to customer and facilitates broadband access. Though broadband Internet access is not available in the inhabited and rural blackout areas, Wi-MAX can potentially eradicate this problem by using an antenna with reasonable bandwidth and high gain. Microstrip patch antenna is one of the most suitable candidates for this purpose and it is very popular among Local Area Network (LAN), Wide Area Network (WAN) and Metropolitan Area Network (MAN), technologies due to their advantages such as low cost, light weight, compatibility with integrated circuits, low volume and easy to install on rigid surface. This paper presents the design of a rectangular microstrip patch antenna operating at 3.5 GHz to achieve maximum bandwidth and the performance of the antenna at different operating frequencies is analyzed using Ansoft software to obtain minimum return loss for Wi-MAX application and is found to be -8.16 dB. The transmission line model is used for analysis.

Keywords: Wi-MAX, Microstrip Patch Antenna, Antenna Design, Ansoft Software, Return Loss

I. INTRODUCTION

Transmission of signals for the purpose of communication over long distances is assisted by telecommunication. In the modern age, telecommunication typically involves the use of different electronic transmitters such as television, telephone, radio or computer [1]. In satellite and wireless mobile communication applications, microstrip antennas have attracted much interest due to their light weight, small size, low cost on mass production, low profile and easy integration with other components [2-3]. With the recent advancements in mobile and wireless communication systems particularly for data communication, the demand for broad band, multi frequency and multiband patch antenna is realized. In applications where increased bandwidth in needed for operation of two or more separate sub-bands, a valid alternative to the broadening of total bandwidth is the use of multi-frequency microstrip antennas [4-5]. Operation in two or more discrete bands with an arbitrary separation of bands is desired in many applications, such as Worldwide Interoperability for Microwave Access (Wi-MAX), Global Positioning system (GPS) and so on. Especially use of microstrip antenna in Wi-MAX application is a great concern. Wi-MAX is a technique to afford wireless data over a long distance in diversity of ways. Wi-MAX is a standard based on IEEE 802.16 which is also called the wireless metropolitan area network. It is enabling delivery of last mile and acting as an alternative to Digital Subscriber Line (DSL) and wired broadband like cable [6]. IEEE 802.16 has adopted three frequency bands namely lower band (2.495- 2.695GHz), median band (3.25 - 3.85 GHz) and upper band (5.25-5.85 GHz) for Wi-Max communication systems [7]. Concerning this standard, a rectangular patch antenna having a thin metallic strip placed above the ground surface with coaxial patch system is designed, determined its various parameters and analysed its return loss at various operating frequencies.

II. ANTENNA DESIGN PROCEDURE

The applications such as satellite, spacecraft and missile where high performance is a necessary and weight, size, cost, ease of installation and aerodynamic profile are constraint; the low profile antennas may be used [3]. Microstrip patch antenna is also a suitable candidate in the field of aerospace applications and mobile communications. Patch antennas are usually operated within the frequency range of 2-11 GHz.

In our proposed design, the microstrip antenna consists of radiating rectangular patch, dielectric substrate, feed and ground plane. Patch and ground plane are connected to each other by thin metal wire and made of copper. In our design we have focused on linear polarization of the antenna. As the designed antenna is used for Wi-MAX application, one procedure is to change the substrate height up to certain threshold for minimizing return loss. In the design procedure, copper is chosen on one side as a ground plane and plastic on the other and air is in between as a substrate with dielectric constant 1.0 (regarding with standard atmospheric pressure 1 atm). But the problem is waves are introduced with the increase of the surface height. Surface waves flow through the substrate and cause scattering at bends of the radiating patch; which corresponds degradation of the antenna performance.

However to accommodate this factor and by using air dielectric substrate, surface waves are not excited easily. Hence it is decisive to justify the height where larger bandwidth with reasonable amount of gain can be achieved. We have chosen the operating frequency at 3.5 GHz and also analysed the return loss at different frequencies chosen from IEEE 802.16 span of 2-11GHz. The structure of a rectangular microstrip patch antenna is shown in Fig. 1.
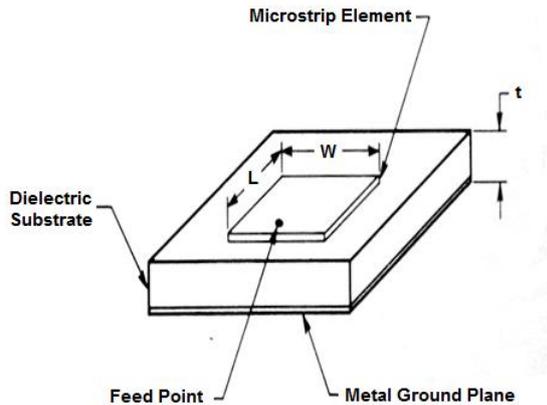
Fig. 1. Structure of a rectangular microstrip patch antenna

A. Calculation of Patch Dimension

In rectangular patch antenna the height (h) of the dielectric constant is usually defined between the free space wavelength ranges of $0.003\lambda_0 \leq h \geq 0.05\lambda_0$. The length (L) of the patch is chosen in the range of $\lambda_{0/3} < L < \lambda_{0/2}$ and the width (W) is taken in between the range of $\lambda_{0/2} < L < \lambda_0$. Patch is selected to be very thin compared to free space wavelength that is $t << \lambda_0$ (where 't' is the patch thickness). We are using transmission line model for the calculation of patch dimension [8]. As input parameters we choose resonant frequency (f_0) of 3.5 GHz, dielectric constant (ε_r) of 1.05 in order to get better efficiency and height (h) of the patch above ground plane of 4 mm. For the necessity of calculation of different parameters the velocity of light (c) is taken to 3×10^8 ms^{-1}. The effective patch width is given by:

$$W = \frac{c}{2f_0} \times \frac{\sqrt{2}}{\sqrt{(\varepsilon_r + 1)}} \qquad (1)$$

The calculated width is, W = 42 mm
Effective dielectric constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \qquad (2)$$

The Calculated value of the effective dielectric constant is, $\varepsilon_{reff} = 1.042$.
Fringes factor (ΔL):

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)(W/h + 0.264)}{(\varepsilon_{reff} - 0.258)(W/h + 0.8)} \qquad (3)$$

The calculation gives the fringes effect as, ΔL = 2.11
Effective length (L_{eff}):

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (4)$$

Calculated effective length is, Leff = 42 mm
Total length (L):

$$L = L_{eff} - 2\Delta L \qquad (5)$$

After subtraction the total length is, L = 38 mm

B. Calculation of Ground plane

When calculating ground plane the size should be greater than the patch. Theoretically the size can be infinite but this is not possible because of physical constrains. The ground plane to the base of any printed circuit will increase the gain of this antenna [9] and we choose copper with dielectric constant 4.4. But on the other hand this may affect the overall bandwidth of the antenna. For this design we determine a substantial large ground plane consisting of square pattern of 100 mm.

C. Patch Model and Feed Point Location

The patch is selected according to the calculated value (L×W×H) that is 38×42×4mm. Then a feed point is located on the patch which is given by 50Ω impedance matching to minimize reflections which is achieved by making the load impedance equal to the source impedance. According to theory impedance varies with its peak value at the edges of the patch and reduces to 0Ω at the centre of the patch. So it is slightly complex to locate a feed point with 50Ω impedance on the patch. Hence the positioning of the feed point occurs at about one third way along the radiator. The proposed model of the microstrip patch antenna is shown in Fig. 2.
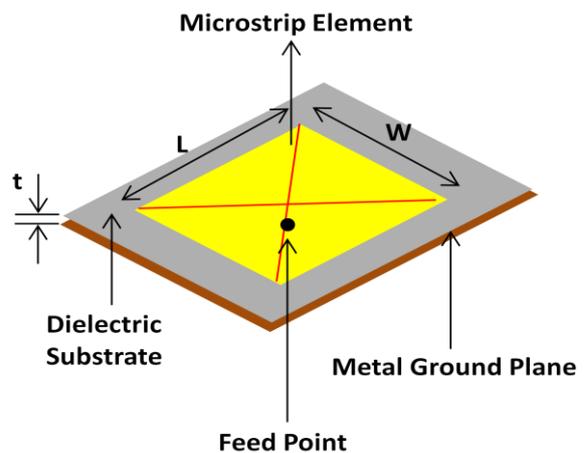
Fig. 2. Structure of proposed microstrip patch antenna

D. Calculation of Return Loss

Return loss is a measure of power reflected from load such as an antenna due to imperfection or mismatch in the communication link. If P_{in} is the incident power on the antenna and P_{ref} is the reflected power back to the source, then return loss is given by the ratio P_{in} / P_{ref}. The load and line are matched better if the power ratio gets higher [10]. The return loss (in dB) is calculated as follows:

$$RL = 10log_{10}\left(\frac{P_{in}}{P_{ref}}\right) dB \qquad (6)$$

For the proposed antenna the microstrip transmission line model is given in Fig. 3.
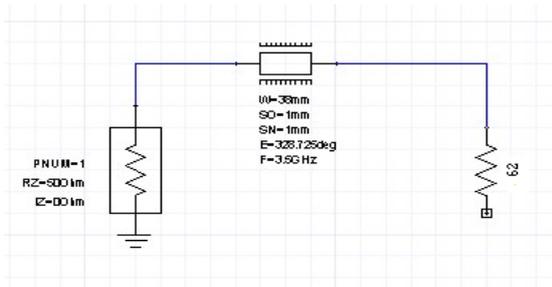
Fig. 3. Microstrip transmission line model

III. RESULT AND DISCUSSION

To evaluate the performance of the designed antenna the return loss is calculated from the transmission line model at different resonant frequencies (Fig. 4.) and observed the minimum return loss.
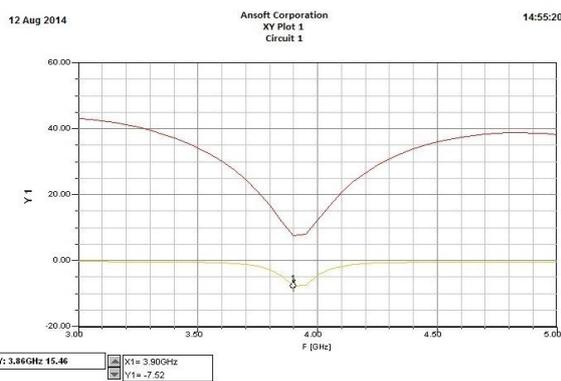
Fig. 4(a). Frequency vs. return loss showing the return loss of -7.52dB at 3.90 GHz
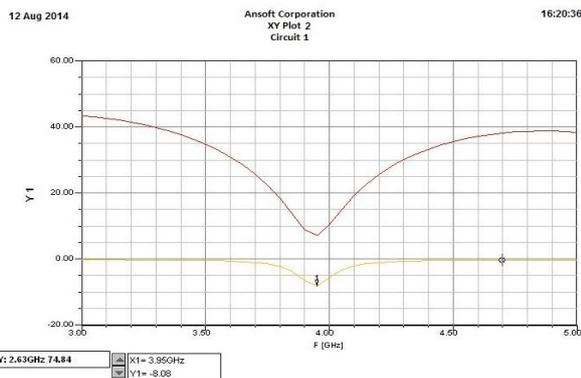
Fig. 4(b). Frequency vs. return loss showing the return loss of -8.08dB at 3.95 GHz
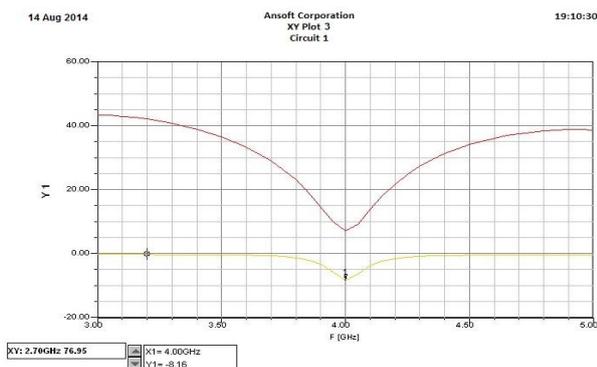
Fig. 4(b). Frequency vs. return loss showing the return loss of -8.16dB at 4.00 GHz

Theoretically the ideal return loss should be RL ≥ -9.5 dB. From the graphs, it is found the minimum return loss of -8.16 dB at frequency 4.0 GHz which is expected and with that a reasonable bandwidth can be achieved. The red curve shows the nature of the return loss with copper material.

IV. CONCLUSION

This work presents the design of a microstrip patch antenna to achieve minimum return loss and maximum bandwidth for Wi-MAX application. The return loss is minimized by designing moderate substrate height between the ground plane and radiating patch about 4 mm. A simple coaxial feeding technique is used to design the antenna. Finally a finite large enough ground plane is design to support the patch.

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