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# METAMATERIAL INSPIRED PATCH ANTENNA WITH L-SHAPE SLOT LOADED GROUND PLANE FOR DUAL BAND (WIMAX/WLAN) APPLICATIONS

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**Abstract**—Due to the integration of different wireless applications at different bands on a single device, multi-band microstrip patch antenna is the best solution keeping the overall size of the device small. In the present work, a metamaterial-inspired antenna is proposed for WiMAX/WLAN applications. Design studies, parametric analysis, simulation results along with measurements for a L-shape slotted ground microstrip patch antenna with CSRR (Complementary Split Ring Resonator) embedded on patch structure operating simultaneously at WiMAX (3.5 GHz) and WLAN (5.8 GHz) are presented. The metamaterial-inspired loading is exploited to create resonance for upper WLAN band while an L-shape slot on the ground plane resonates at the WiMAX band, maintaining the antenna's overall small form-factor. The measured $S$-parameter and radiation patterns of fabricated prototype show that the proposed design is suitable for emerging WiMAX/WLAN applications.

## 1. INTRODUCTION

With the rapid development of wireless communication, the demand for mobile devices that can operate in different frequency bands is on the increase. In recent years, the dualband or multi-band antennas have received much attention for applications to multimode communication systems [1]. The currently popular antenna designs suitable for the applications of wireless local area network (WLAN) and world-wide interoperability for microwave access (WiMAX) have been reported [2–5]. The challenge in designing a WiMAX system is to design a compact, low-cost and low profile antennas. The planar microstrip antenna is

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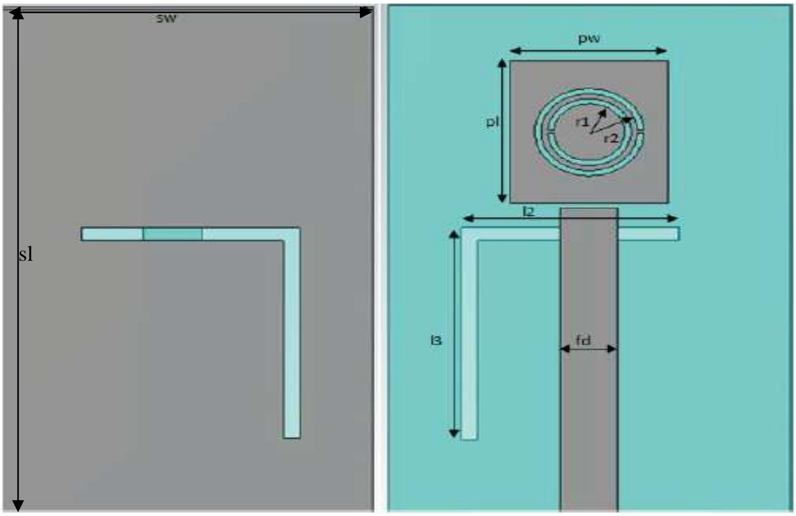
considered a good candidate for WiMAX applications because it is low profile, etched on a single substrate and can provide the feature of multi-band operation. In order to achieve multi-band operation, the traditional approach is to use multi-resonator elements [1], which generally leads to a large volume [6–8] or requires a large ground-plane [9]. In [2], Kuo et al. proposed a dual-band double T-monopole antenna, which achieves a certain miniaturization factor but with a narrow bandwidth at the upper WLAN band. Metamaterials (MTM), on the other hand, provide a conceptual route for implementing small resonant antennas [3, 4]. In this work, a dualband microstrip patch antenna is proposed that employs metamaterial inspired reactive loading and slot loaded ground plane. The MTM-based CSRR loading creates a resonance covering the upper WLAN band of 5.8 GHz, in addition to the resonance over the 3.5 GHz WiMAX band due to L-shape slot on ground plane. Parametric analysis of the design parameters of proposed structure has been done and optimized. A prototype of the proposed antenna has been fabricated and tested for its performance in terms of bandwidth, gain and radiation pattern. The measured reflection coefficient and the radiation patterns are given and discussed.

## 2. ANTENNA GEOMETRY AND PARAMETRIC ANALYSIS

The antenna configuration of the proposed resonator structure is shown in Fig. 1. The CSRR structure being excoriated from the rectangular patch is responsible for the resonance at 5.8 GHz band. The width of CSRR slot is 0.4 mm and the gap is being 0.3 mm. The radius of concentric rings of CSRR are $r1 = 2.2$ mm and $r2 = 3.0$ mm. Length of patch ($pl$) is 11.1 mm and width ($pw$) is 9.8 mm. An L-shaped slot is cut out from the ground plane below the feed line to get resonance at 3.5 GHz band. A substrate of dimension 40 mm × 25 mm is used. Simulated return loss and surface current distribution is shown in Fig. 2 and Fig. 3 respectively which confirms dual band operations at desire bands with reasonable bandwidth. During the simulation a dip in the return loss pattern around 4.1 GHz was observed. This may be due to numerical convergence problem. Observing the surface current distribution at that particular point, a hot spot was observed at the gap of outer ring. During the entire parametric analysis, it is observed that the position of dip does not change.

A gap coupled feeding is used for the patch. A 50 Ω line is used to feed the patch and a gap ($yo$) of 0.4 mm maintained for impedance matching. This gap is varied to have proper impedance




(a) (b)

**Figure 1.** Dual band antenna operating at WiMAX (3.5 GHz) and WLAN (5.8 GHz). (a) Back view. (b) Front view

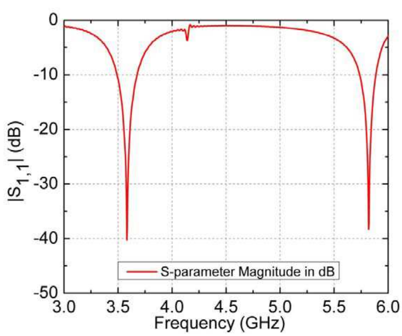
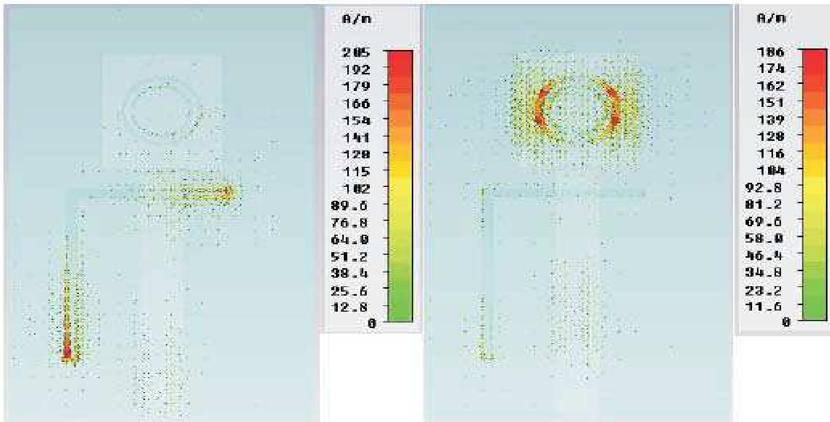



**Figure 2.** The simulated reflection coefficient of the antenna.

matching, hence power coupling between the patch and the feed Fig. 4. The calculated width of the feed line ($fd$) is 3.6 mm for to achieve 50 Ω line impedance. The effect of varying two sections of slot changes the overall length of slot which shifts the resonant frequency according to the inverse relation between electrical length and resonant frequency. The variation in length of section $l3$, affects the level of input impedance matching to some extent at the particular resonance without changing the relative position of slot about its tuned position,




(a) (b)

**Figure 3.** Current distribution at (a) 3.5 GHz (b) 5.8 GHz bands.

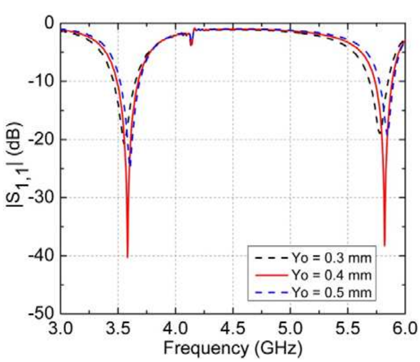



**Figure 4.** Effect of varying *Yo* *on the return loss.*

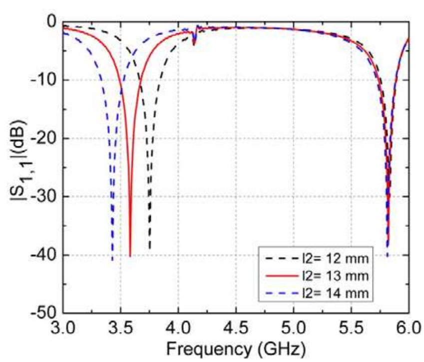



**Figure 5.** Effect of varying $l2$ on the return loss.

as well shifting of resonance. Fig. 5 and Fig. 6 shows effect of varying lengths of slot sections $l2$ and $l3$ respectively. It shows little effect on the 5.8 GHz band. The relative position of slot beneath the feed line affects level of input impedance matching hence the reflection coefficient and shifting at 3.5 GHz resonance band to some extent. Fig. 7 and Fig. 8 show the effect of moving slot about its tuned position along $X$-axis and $Y$-axis directions respectively. This has no effect on the upper WLAN band.

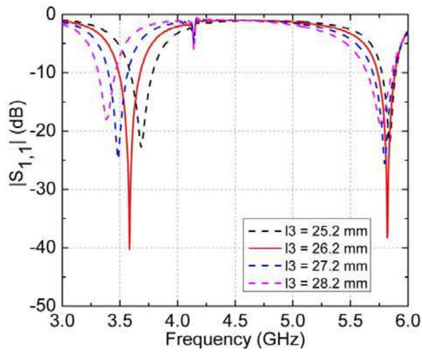



**Figure 6.** Effect of varying $l3$ on the return loss.

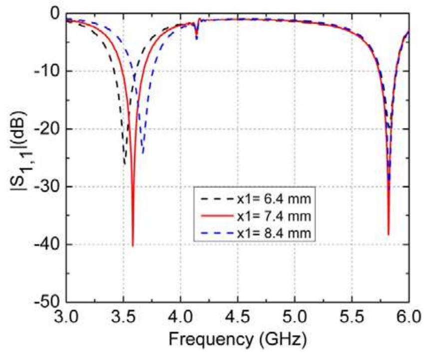



**Figure 7.** Effect of moving slot along $X$-direction On the return loss pattern.

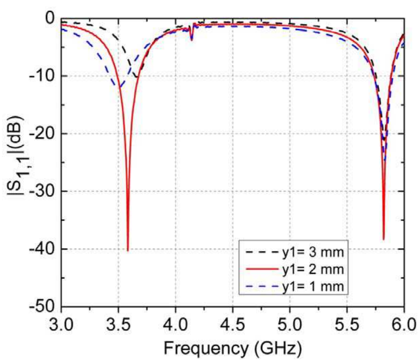



**Figure 8.** Effect of moving slot along $Y$-direction on the return loss pattern.

## 3. FABRICATION AND MEASUREMENT RESULTS

The proposed antenna was designed and simulated in finite integration technique based CST MWS V9. To simulate the antenna Transient solver was chosen. During simulation Hexahedral mesh cell with 20 Lines per lambda was set up. The simulated antenna after detail parametric analysis and optimization was fabricated on a dielectric substrate Neltec NH9332 ($\varepsilon_r = 3.2$, $\tan\delta = 0.0024$, $h = 1.524\,\text{mm}$). Available Photolithography method with wet etching facility was adopted for fabrication of the prototype antenna. The return loss was measured with HP network analyzer (HP 8720B). The radiation performance has been measured in the anechoic chamber keeping the fabricated prototype at receiver end. About 15 dBm power was given to the transmitter antenna from the RF power generator, and the distance between the transmitter and the receiver was kept at 1.5 meter. The gain is calculated using substitution method with the help of the Standard Gain Horn antenna (reference antenna) working in the range 0.9 to 8 GHz.

The fabricated antenna was test for its farfield radiation properties. Measurement were done for pattern in its both the planes ($E$-plane and $H$-plane power pattern). Fig. 9 and Fig. 10 show the fabricated antenna and measured reflection coefficient being tested on the network analyzer respectively. A little shift at the WiMAX resonance was observed during the measurement which may be due to the fabrication error.

**Figure 9.** The fabricated antenna for dual band (WIMAX/WLAN) applications.

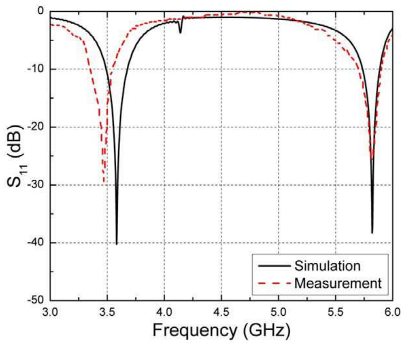



**Figure 10.** The fabricated antenna being tested on a network analyzer.

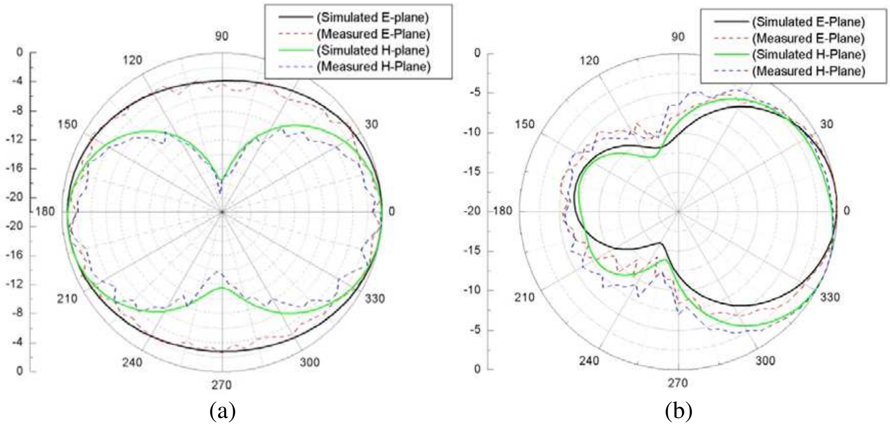



**Figure 11.** Simulated and measured $E$-plane and $H$-plane radiation pattern at (a) 3.5 GHz, (b) 5.8 GHz.

Figure 11 show the simulated and measured radiation patterns of the antenna in both the $E$-plane and the $H$-plane at the respective frequency bands of 3.5 GHz and 5.8 GHz. These plots confirm the broadside directive radiation properties of the antenna. The simulated and measured radiation patterns are in close agreement except some ripples at the measured results. The measured radiation pattern in both $E$-plane and $H$-plane are somewhat distorted compared to that of simulated patterns. This may be due to the fact that low power levels are received by the antenna. Possible reasons for these disagreements between simulated and measured results may due to the possible presence of interference and noise. The achieved impedance bandwidth (measured at $-10$ dB refection coefficient) is around 200 MHz for both the 3.5 GHz and 5.8 GHz band.

The simulated and measured gain curves are given for the 3.5 GHz and 5.8 GHz bands in Fig. 12. At both 3.5 GHz and 5.8 GHz bands the maximum power was received by the antenna at the broadside direction. Consequently, gain measurements are done for the two frequency bands in the directions of their respective maxima using the substitution/gain-transfer technique with the help of a standard horn antenna with calibrated gain. About 1–1.2 dB of difference in the simulated and measured gains is observed which can be attributed to the tolerance in fabrication and measurement errors due to possible presence of environment noise and interferences.

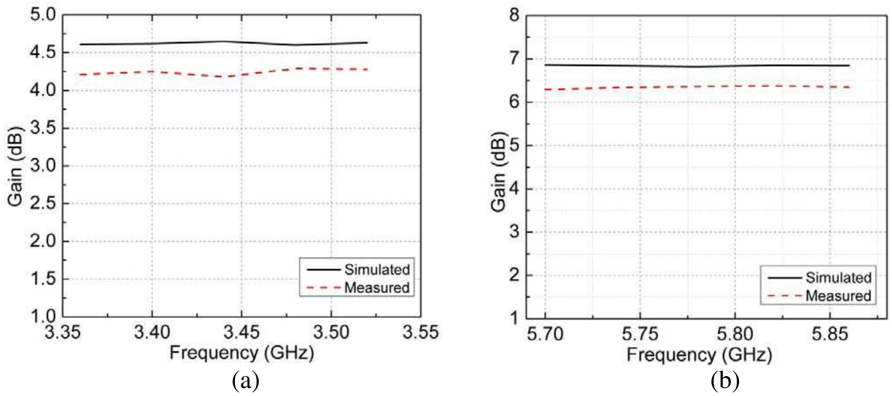



**Figure 12.** Simulated and Measured Gains at (a) 3.5 GHz and (b) 5.8 GHz band.

## 4. CONCLUSIONS

A dual-band metamaterial-inspired microstrip patch antenna is proposed for WiMAX/WLAN applications. The metamaterial inspired CSRR loading on the patch enables a resonance at the upper WLAN band in addition to the resonance at WiMAX due to L-shape slot loaded ground. The CSRR loading reduces the physical size of the patch to operate at upper WLAN band significantly compared to the conventional one. The gap couple feeding method enables direct feeding of the structure without using complicated impedance transformer or microstrip taper. The fabricated prototype upon measurement shows reasonable impedance bandwidth of around 200 MHz, radiation pattern and realized gain for both the operating bands. The proposed design can be easily integrated to microwave circuits and compatible with MMIC technology for practical application. This is also suitable for simultaneous dualband WiMAX/WLAN applications.

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