Metamaterial Enhanced Patch Antenna for WiMAX applications

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1. Introduction

In the past decade, methods to improve antenna performance by using metamaterial super-strate can be approximately differentiated into three categories according to the height. The first is half-wavelength height that can raise the single patch antenna directivity significantly by the research of [1]-[2]. The second is quarter-wavelength height with an artificial ground plane which can provide 90 degree phase reflection and bring almost the same performance as the first one by using the research of [3]-[5]. The last one is the lowest height profile (below 0.1 wavelength) which can also provides approximate 90% aperture efficiency according to the study of [6]. Recently, an ordinary air-layered patch antenna widely applied in consumer fixed access point or similar products and enhanced by metamaterial super-strate structure is successful constructed and simulated. According to the measured result, the proposed metamaterial antenna radome can improve the antenna gain to about 2.0 dB.

2. Antenna design and simulation result

Figure 1(a) shows an ordinary patch antenna covered with the proposed metamaterial super-strate whose size is about 110 × 55 mm^2 (11 × 10 periodic unit-cell elements totally), and the antenna ground plane is chosen to be 100 × 85 mm^2 in this study. The side view of the proposed antenna is as figure 1(b). The height of the metamaterial super-state is impedance sensitive and carefully tuned to 5.0 mm above the PIFA which having a height of 3.5 mm ground plane. The unit-cell of metamaterial super-strate consists of 3 layers (0.3, 0.5, 0.3 mm respectively) of FR4 substrates which having a dielectric constant of 4.4 in simulation sandwiched by 4 layers of S-shaped metallic rings at the upper surface and inverted-S-shaped metallic rings at the lower surface symmetrically, as shown in figure 1(c). In order to operate at WiMAX 3.5 GHz band, the dimensions of the unit-cell including its substrate is about 10 × 5.5 mm^2 and the metallic ring is chosen to be 9.8 mm length and 5.3 mm width. It should be noted that the approximate length of each S-shaped metallic ring is about 26.5 mm or $0.3\lambda_0$ at 3.5 GHz.

In order to compare an ordinary patch with a proposed antenna, antenna prototypes were constructed and studied. The return loss and antenna gain variation across 3.4 – 3.6 GHz band of ordinary patch and proposed antenna are shown in figure 2 and figure 3. Both antennas have resonant mode centered at about 3.5 GHz and are excited with a good impedance matching. By using 10 dB return loss definition, the obtained impedance bandwidth of the proposed antenna reaches about 520 MHz (3.38 – 3.90 GHz) or about 14.2%, which is acceptable for WiMAX operation in the 3.5 GHz band. In figure 3, it clearly shows that the performance of peak antenna gain has great differences between proposed antenna and ordinary patch not only in the measured (solid line) result, but also in the simulated (dotted line) one. More specifically, the maximum antenna of the ordinary patch is about 9.4 dBi at 3.50 GHz and the proposed antenna is about 11.6 dBi at 3.56 GHz. The simulated results obtained by using Ansoft high frequency structure simulator (HFSS) are generally agreed with the measured data. More details of gain improvement properties can emphasize that the result of simulation is almost the same with that of measured data in figure 4 again. It is observed that with the metamaterial superstrate, the antenna gain can effectively improve 1.9 – 2.6 dB in whole operation band of measured result and 1.6 – 3.0 dB in simulated result. Note that the high gain improvement in the band edge is because the gain bandwidth of proposed antenna is wider than referred ordinary patch.

The radiation characteristics of the constructed prototype are also studied. The measured radiation pattern at 3600 MHz plotted in figure 5. Other operating frequencies across WiMAX 3.5 GHz band are also measured, the results shows radiation patterns are similar to those plotted present here. Form the measured E-plane (x-z plane) and H-plane (y-z plane) patterns, good broadside radiation property are observed and are similar to the ordinary patch. However, it is interesting to see that the 3 dB beamwidth of co-polarization in E-plane is 51 degree only and in H-plane is 37 degree only. Moreover, it is quite obvious that the back-radiation both in E-plane and H-plane are smaller than an ordinary patch.

3. Conclusions

The rectangular air-layered patch antenna with a metamaterial superstrate which enhances antenna gain has been successfully constructed and discussed. The height of the constructed meta-material antenna radome, including the patch is only about 6.6 mm, which is equal to about $0.08\lambda_0$ referred to 3.5 GHz. With such thin meta-material antenna radome, the antenna gain can be improved up to 2.0 dB in WiMAX 3.5 GHz band by comparing the ordinary air-layered substrate patch antenna. The impedance bandwidth of the proposed antenna is about 520 MHz. In addition, the proposed antenna is more suitable for consumer market because its size is only $100 \times 85 \times 5.5$ mm^3 (46800 mm^3), that is, almost 50% antenna size is reduced by comparing with the estimated specification of an 1×2 antenna array. Moreover, the meta-material antenna super-strate can be produced by PCB process with low cost, which makes it very promising for industrial manufacturing.

4. Figures and Tables

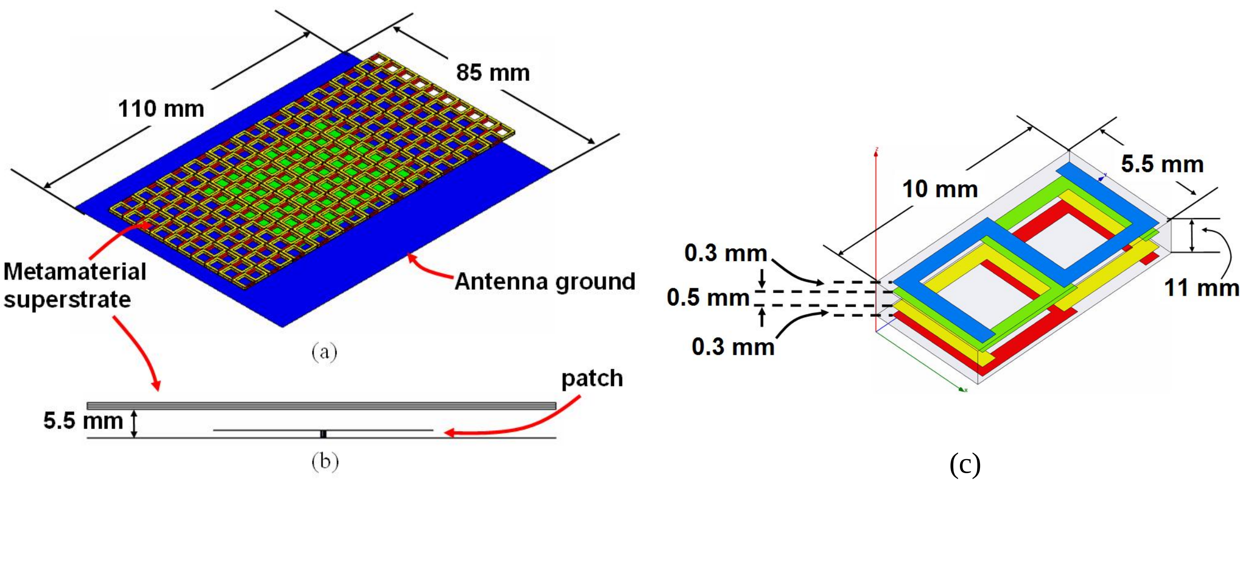

Figure 1: Proposed antenna structre in 3D view (a), side view (b)
, and the unit-cell of metamaterial super-strate (c)

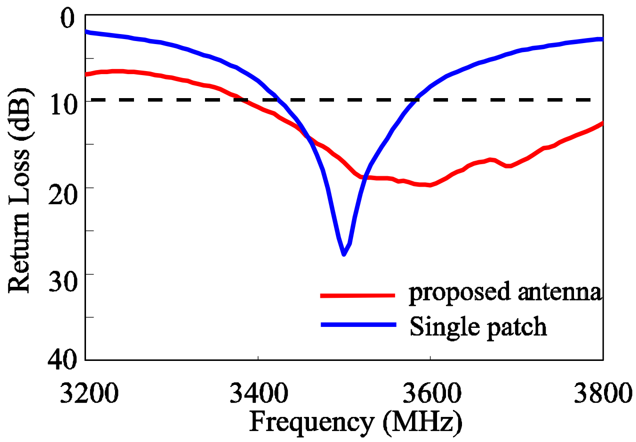

Figure 2: Measured return loss for an ordinary patch (blue line) and proposed antenna (red line)

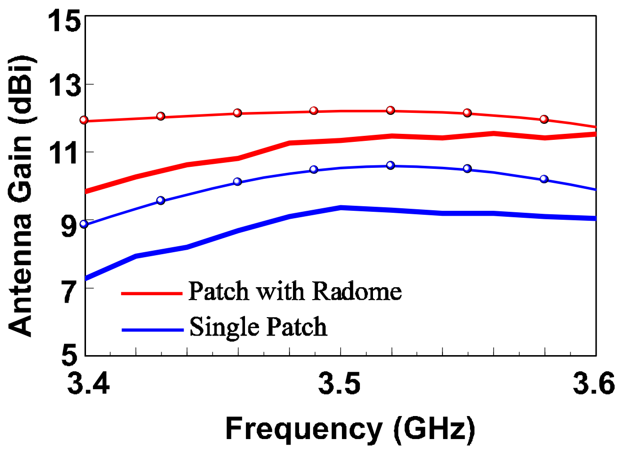

Figure 3: Measured (solid line) and simulated (dotted line) peak antenna gain across WiMAX 3.5 GHz band

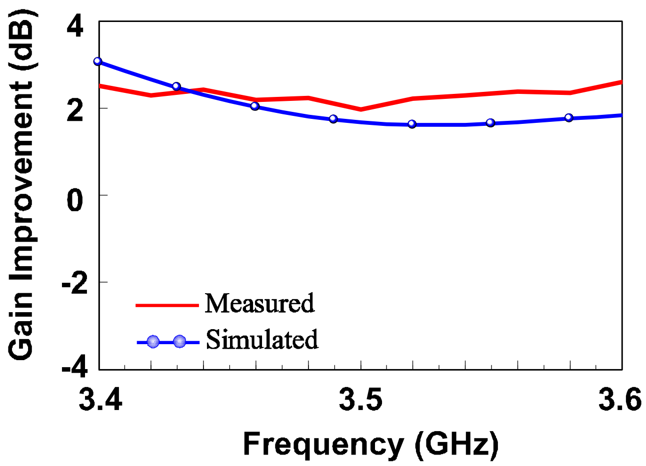

Figure 4: Measured (solid line) and simulated (dotted line) antenna gain improvement characteristic across WiMAX 3.5 GHz band

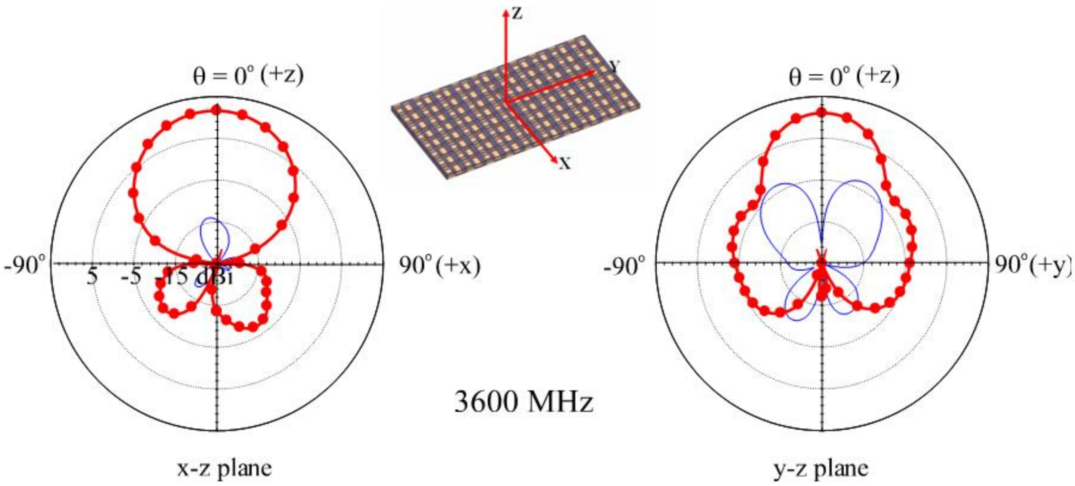

Figure 5: Measured radiation patterns for E-plane (y-z plane) and H-plane (x-z plane)

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