

# Circularly-Polarized Array Antenna using MSA with Asymmetric T-shaped Slit Loads

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## 1. Introduction

At present, the advance of wireless systems require an increase in bandwidth and sharing in limited frequency bands, particularly in PDC (Personal Digital Cellular Telecommunication System), PHS (Personal Handy-Phone System), IMT-2000 (International Mobile Telecommunication-2000), and WLAN (Wireless Local Area Network) [1]. The popular antennas for WLAN access point are linear dipole, slot array, and microstrip antenna. These antennas will be usually placed at the wall of rooms or buildings. Several designs of the single feed dual-band Microstrip Antennas (MSAs) have recently been reported. For example, a dual-band circularly polarized aperture-coupled stacked microstrip patches [2], a spur-line filter-embedded nearly square microstrip patch [3], a circular microstrip patch with two pairs of arc-shaped slots [4], a broad-band U-Shaped PLFA with dual band capability for Bluetooth and WLAN [5], and a square MSA inserted with four T-shaped slits at the patch edges or four Y-shaped slits at the patch corners [6]. The lattermost one proposed a reactively-load technique using four T-shaped slit loads on each patch edge symmetrically. It is small size, low cost, low profile, and light weight compared to the work which are presented in [2]-[4]. Nevertheless, its dual bandwidths of 1.17% and 1.05% are not sufficient to be implemented and was not suggested for utilization in any application. Therefore, Wongsan *et al.* [7] reported an alternative technique providing dual-frequency wider bandwidth MSA using a rectangular patch and modifying the dimensions of four T-shaped slit loads asymmetrically. Moreover, the thickness of FR4 substrate was increased from 1.6 mm to 3.2 mm in order to enlarge the lower and higher bands of this antenna. However, the antenna has low directive gain and asymmetric radiation pattern. To solve their problem, the high directive gain is presented along with a parametric study based on numerical and experimental results [8]. In addition, the radiation patterns are presented for a modification by alternating the slit loads positions on each side of rectangular patches array configuration. In this paper, we present circularly-polarized array antenna using the rectangular patches with asymmetric T-shaped slit loads. The measured results of the input impedance, return loss, and VSWR are also conducted for verification of the simulated results.

## 2. Array Antenna Configuration

Fig.1 illustrates the dual-frequency of single-feed slit-loaded rectangular microstrip antenna. The antenna consists of four T-shaped slits inserted at the patch edges. The rectangular patch has a side length  $L$  and width  $W$ , printed on a substrate of thickness  $h$  and relative permittivity  $\epsilon_r$ . A narrow center slot of dimensions  $l_s \times w_s$  ( $l_s > w_s$ ) is embedded in the  $x$ -axis near the patch center of the rectangular patch. A single probe feeds at point  $(x_p, y_p)$  along the diagonal of the patch. For the designed dimensions of four T-shaped slit, the left and right arms have the same dimensions of a narrow width  $s1$  and a length  $l_1$ . The dimension of each center arm is indicated by  $d_1 \times w_1$  with the different arm width  $d_1 > d_2$ . The dimensions of upper and center arms are of  $s_2 \times l_2$  and  $w_2 \times d_2$ , respectively. The dimensions of lower and center arms are of  $s_3 \times l_2$  and  $w_3 \times d_2$ , respectively. Using those dimensions, the operating frequency is higher.

Moreover, it is found that both shifting a narrow slot out of the patch center along the negative  $x$ -axis and increasing the height of substrate can increase bandwidths to cover the required ISM (Industrial Sciences Medicine) bands. An asymmetric T-shaped slit loaded antenna has the following parameters:  $\epsilon_r = 4.4$ , ground-plane size =  $7.5 \times 7.5 \text{ mm}^2$ ,  $h = 1.6$ ,  $L = 36.87$ ,  $(x_p, y_p) = (-8.25, 6.275)$ ,  $W = 31.232$ ,  $d_1 = 2.14$ ,  $d_2 = 0.067$ ,  $w_1 = 1.511$ ,  $w_2 = 2.015$ ,  $w_3 = 3.525$ ,  $w_s = 1.007$ ,  $l_s = 15.830$ ,  $l_1 = 19.948$ ,  $l_2 = 28.603$ ,  $s_1 = 2.015$ ,  $s_2 = 1.41$  and  $s_3 = 2.017$ . All dimension units are millimeter. By using parameter above, Wongsan *et al.* [8] shown that the resonant frequencies of the asymmetric T-shaped slit loads are 2.45 GHz, 5.25 GHz, and 5.8 GHz, respectively. However, this antenna has low directive gain and asymmetric radiation pattern.

### 3. Experimental and Numerical Results

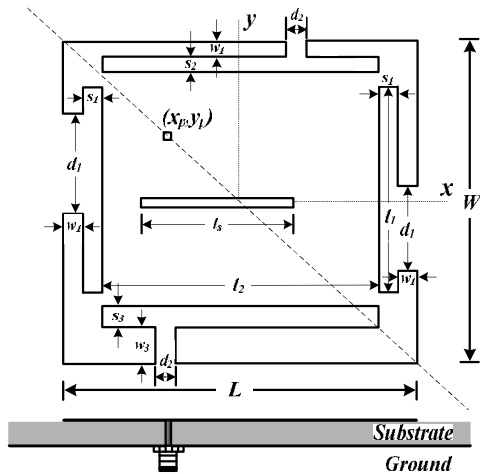


Figure 1: Dual-frequency Rectangular Microstrip Antenna with Asymmetric T-shaped Slit Loads

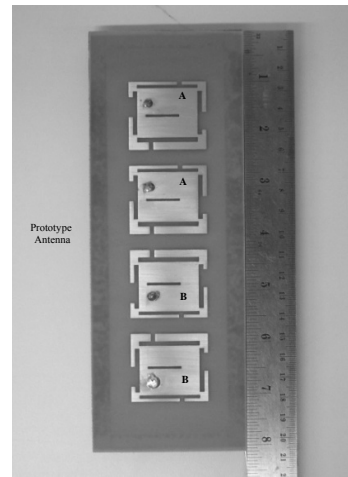


Figure 2: Proposed Rectangular Microstrip Array Antenna by Changing Slit Loads Position on Each Side of Patches

The performance improvement of an array antenna using  $1 \times 4$  rectangular MSAs with asymmetric T-shaped slit loads is proposed for directive gain increment and pattern shaping [8]. The simulated and measured results have been shown that when the array element spacing is adjusted from  $\lambda/2$  down to  $\lambda/3$ , the covering required area will be increased. The modification by alternating the slit loads positions on each side of patches as shown in Fig.2 can improve the radiation patterns to be symmetric shape. In addition, the important parameters which are consisted of the return loss and VSWR have been simulated and measured for validation as shown in Figs.3 and 4. The measured results are in good agreement with the simulated results. For the polarization measurement, the partial method (polarization-pattern method) [9] has been used for polarization measurement of antenna as shown in Fig.6 (a) through (c). In Figs.6 (a) and (c), it is obvious that the proposed antenna is nearly circularly polarized along its axis at  $0^\circ$ . And greater observation angles, its polarization becomes elliptical. For the polarization measurement at 5.25 GHz as shown in Fig.6 (b), the proposed antenna is nearly circularly polarized around its axis. For the difference of polarization measurement, due to the slit loads positions on each side of patches, it has an effect on resonant frequency.

## 4. Conclusion

From this paper, the performance improvement an array antenna using 1×4 rectangular MSA with asymmetric T-shaped slit loads is proposed for measured results polarization. The measured results show that the polarized at the lower, and higher frequency bands, are nearly circularly polarized along its axis at 0°. and circularly polarized at middle frequency band. Finally, this proposed antenna as panel antenna can be realized and applied for wireless applications.

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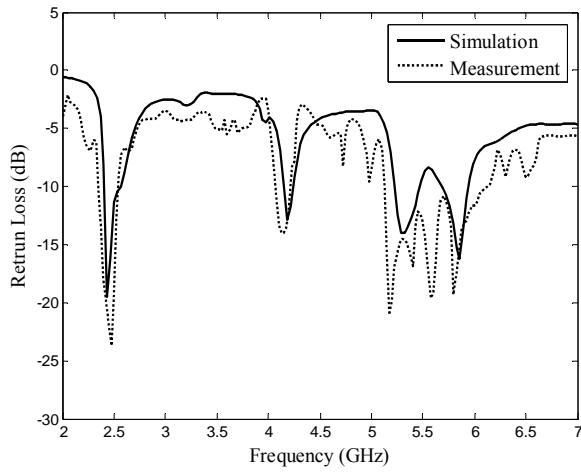


Figure 3: Simulated and Measured Return Loss

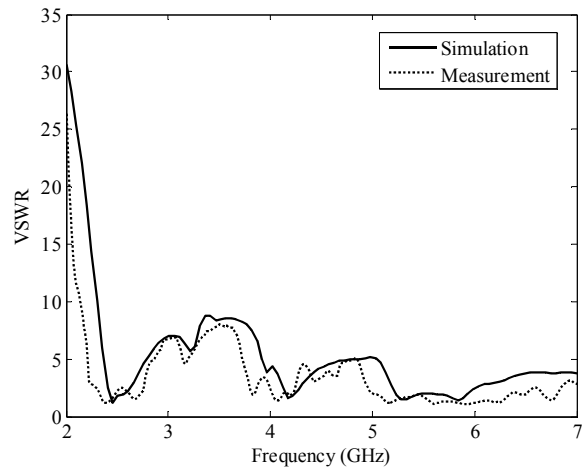
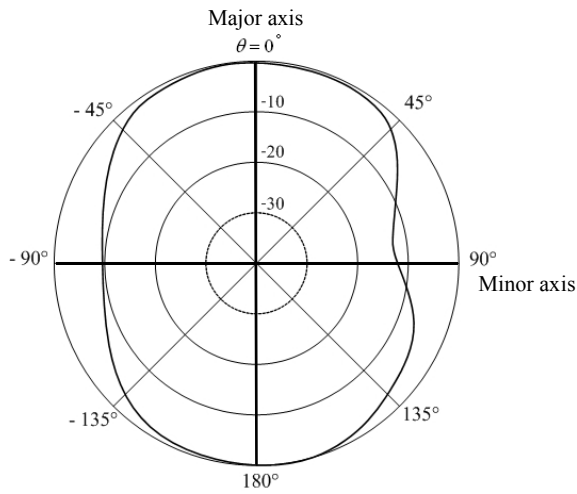
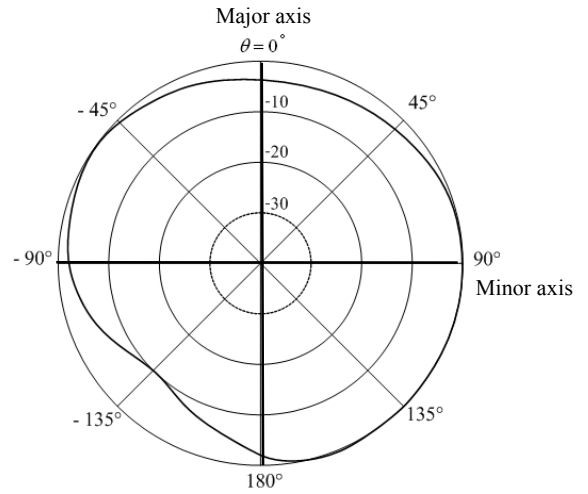


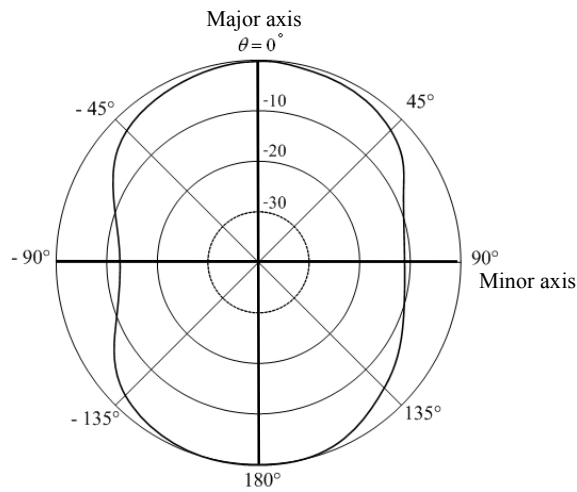
Figure 4: Simulated and Measured VSWR



(a) 2.45 GHz



(b) 5.25 GHz



(c) 5.8 GHz

Figure 6: Polarization Measurement at 2.45 GHz, 5.25 GHz, and 5.8 GHz