Directive Gain Array Antenna using MSA with Asymmetric T-shaped Slit Loads

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Abstract: - This paper presents a 1×4 array antenna using asymmetric T-shaped slit loaded microstrip antenna (MSA). The antenna consists of a dialectic substrate which is used for the antenna panel and a reflector. A modified array configuration is proposed to further enhance the antenna radiation characteristics and usable bandwidth. The IE3D-based simulation results agree with the experimental results. This proposed panel antenna can be applied to wireless communications.

Key-Words: - Array, Directive Gain, Microstrip Antenna, Radiation Patterns

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 wireless LAN (Local Area Network) [1]. Several designs of the single feed dual-band microstrip antennas (MSAs) have recently been reported, for example, a dual-band circularly polarized (CP) 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], and a square MSA inserted with four T-shaped slits at the patch edges or four Y-shaped slits at the patch corners [5]. The lattermost one proposed a reactively-load technique using four T-shaped slit loads on each patch edge symmetrically. It is small of size, low of cost, low of profile, and light of weight compared to the work presented in [2]-[4]. Nevertheless, its dual bandwidths of 1.17% and 1.05% are not sufficient to be implemented as well as it is not suggested to be used 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, this antenna has low gain and asymmetric radiation pattern.

In this paper, we present an array antenna using the rectangular patch array with asymmetric T-shaped slit loaded MSA. The high gain is presented along with a parametric study based on numerical and experimental results. In addition, the radiation patterns are presented for a modified mirror rectangular patch array configuration. The simulation and analysis for the proposed antennas are performed using the IE3D-based simulations. The measurement results of the gain, the magnitude of S_{11}, and radiation patterns are also conducted for verification of the simulation results.

Section 2 describes the synthesis of antenna configuration as a rectangular patch with asymmetric T-shaped slit loaded MSA and array antenna configuration. In addition, we present details of pattern improvement which are adjusted by element patch spacing and modified by mirror patches. The measured results for the 1×4 arrays are reported and compared with the simulated results in section 3. Finally, this paper are concluded in section 4

2 Array Antenna Configuration and Numerical Results

Fig. 1 shows 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, is printed on a substrate of thickness h and relative permittivity ε_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 s_1 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.

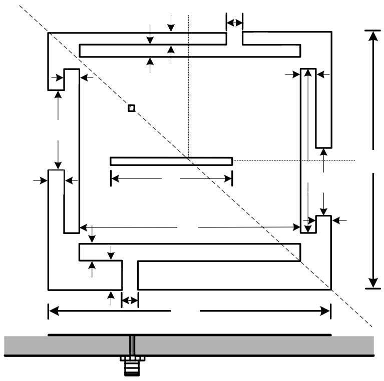


Fig.1 Dual-frequency rectangular microstrip antenna with asymmetric T-shaped slit loads.

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: ε_r =4.4, ground-plane size =7.5×7.5 mm^2, h=1.6, (x_p,y_p)=(-8.25,6.275), L=36.87, 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.* [7] 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 gain and asymmetric radiation pattern.

2.1 1×4 Array Elements

To improve radiation characteristics, a rectangular patch with asymmetric T-shaped slit loaded MSA was arrayed with element spacing of λ/2 to increase the gain as shown in Fig.2. This work proposes the design of asymmetric T-shaped slit loaded MSA which is modeling 1×4 array. As reported in Table1, the simulation results show that gains of array antenna are increased up to 7 dBi, 9 dBi, and 12 dBi for the first, the second and the third frequency bands, respectively. The simulated radiation patterns of the array antenna at the center of three ISM bands are shown in Fig.3.

From the results, the azimuth patterns (H-plane) were wide. On the other hand, the elevation patterns (E-plane) were narrow which reduce propagation losses in undesired areas. Such microstrip antenna is therefore suitable for wall installation.

Table1 Gain for one and four elements

No. element	2.45 GHz	5.25 GHz	5.8 GHz
One-element [7]	3.98 dBi	3.7 dBi	6.14 dBi
Four-elements	7 dBi	9 dBi	12 dBi

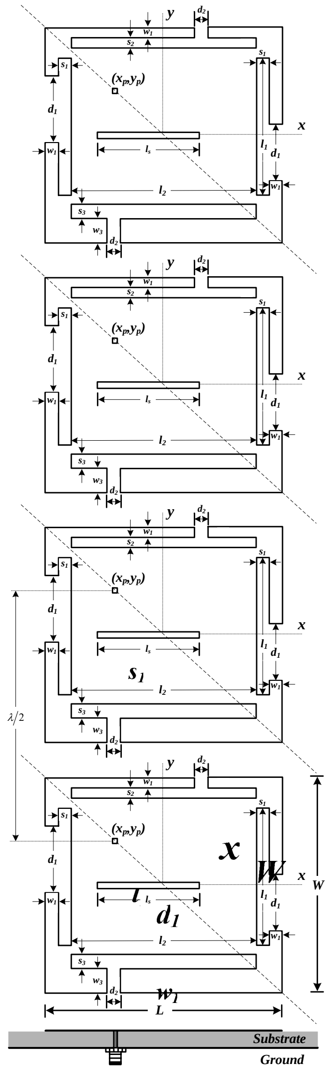
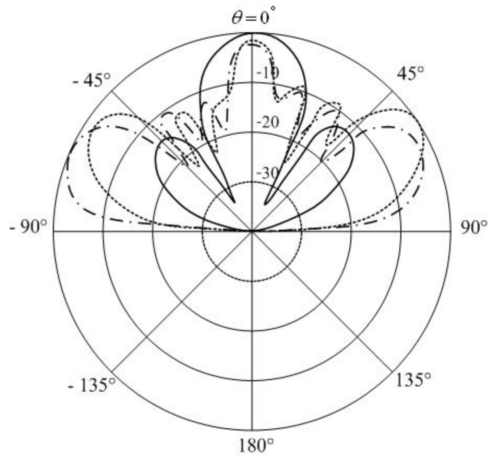
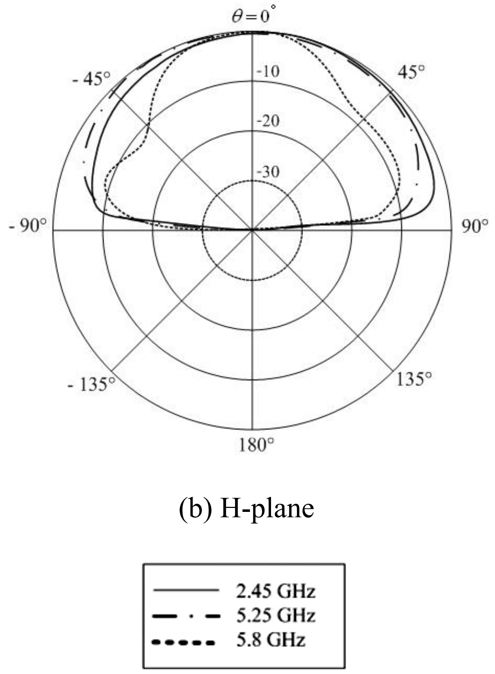


Fig.2 A 1×4 array antenna using rectangular patch with asymmetric T-shaped slit loaded MSA at element spacing of λ/2.



(a) E-plane



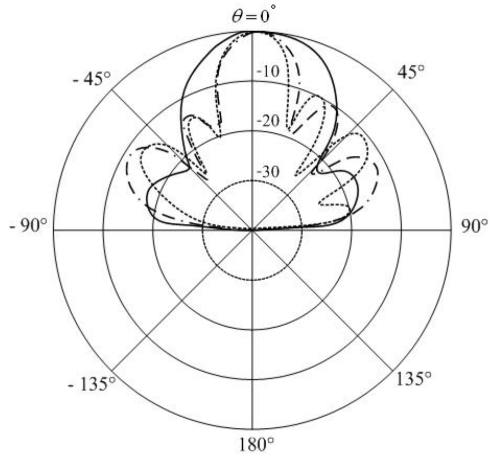
(b) H-plane

Fig.3 Simulated radiation patterns at 2.45 GHz, 5.25 GHz, and 5.8 GHz for element spacing of λ/2.

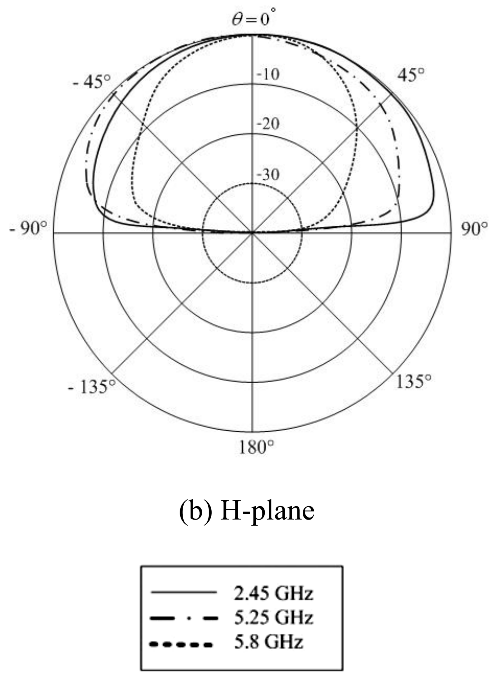
2.2 Radiation Patterns Improvement by adjustment of Patch Spacing

Although array element spacing of λ/2 can increase gain, radiation pattern in E-plane is very narrow beamwide. Therefore, this array antenna can not cover the required area. In addition, if its spacing is shorter than λ/3, patch antennas are overlapped and if its spacing wider than λ/2, the radiation patterns is higher sidelobe level. Thus, the appropriate space between the patch considered here is decreased from λ/2 to λ/3 (40.816 mm).

Fig.4 shows the radiation patterns of the array antenna at distance λ/3 by using the IE3D-based simulations. We found that adjustment of patch spacing to λ/3 can provide the compared with the case of better radiation pattern λ/2.



(a) E-plane



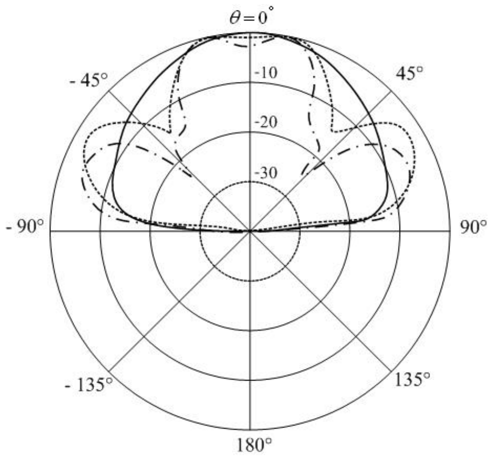
(b) H-plane

Fig. 4 Simulated radiation pattern at 2.45 GHz, 5.25 GHz, and 5.8 GHz for element spacing of λ/3.

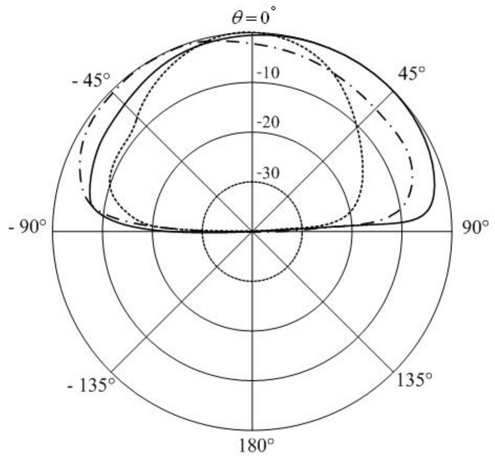
2.3 Radiation Patterns Modification by Mirror of Patches

Since arrayed with λ/3, the radiation patterns are asymmetric. Then modification array antenna using mirror of patch improves the radiation patterns to symmetric as shown in Fig 5, moreover, its radiation patterns cover the required area.

This paper proposes two methods of radiation patterns improvement. First, we propose an adjustment of patch spacing to λ/3 which can decrease sidelobe levels. We then propose a modification of array antennas using mirror of patch to achieve symmetric radiation patterns.



(a) E-plane



(b) H-plane

Fig. 5 Radiation Patterns Modification by Mirror of Patches

3 Experimental Results

In order to implement this concept, the rectangular microstrip array antenna with asymmetric T-shaped slit loads is designed and fabricated as show in Fig.6. The thickness of FR4 substrate is 3.2 mm which is fabricated using two layer of 1.6 mm FR4 PCB which can result in a gap. The proposed antenna is fed with a 50 Ω SMA connector and connected to an HP8722D network analyzer in order to test the reflection coefficients. From Fig.7, it can be clearly seen that the measured reflection coefficients are superimposed with the simulated ones and the good agreement. The simulation results show that at the lower frequency band (2.403-2.57 GHz), its bandwidth is equal to 167 MHz, at the middle and higher frequency band (5.221-5.456 GHz), its bandwidth is equal to 235 MHz, (5.658-5.96 GHz), its bandwidth is equal to 302 MHz, respectively. Also, the measured result show that at the lower frequency band (2.38-2.536 GHz), its bandwidth is equal to 156 MHz, the middle and higher frequency band (4.979-6.308 GHz), its bandwidth is equal to 1.33 GHz. Both of them can cover the required three ISM bands. The measured and simulated far-field radiation patterns of the proposed antenna at the center of three ISM bands are 2.45 GHz, 5.25 GHz, and 5.8 GHz shown in Fig.8. It can be seen that similar radiation patterns for three operating frequency bands are in good agreement.

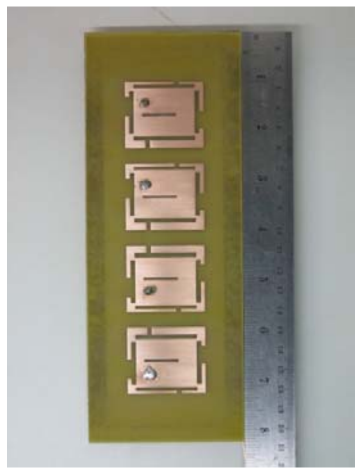


Fig.6 Proposed rectangular microstrip array antenna with asymmetric T-shaped slit loads.

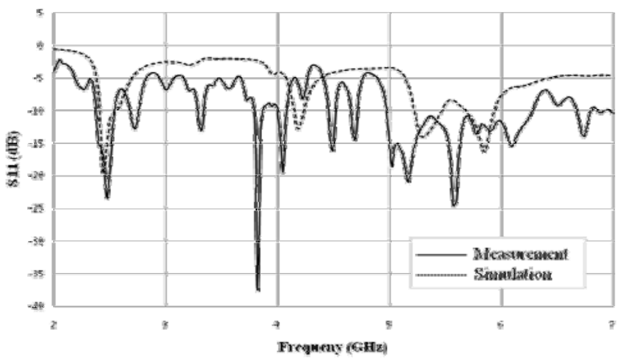
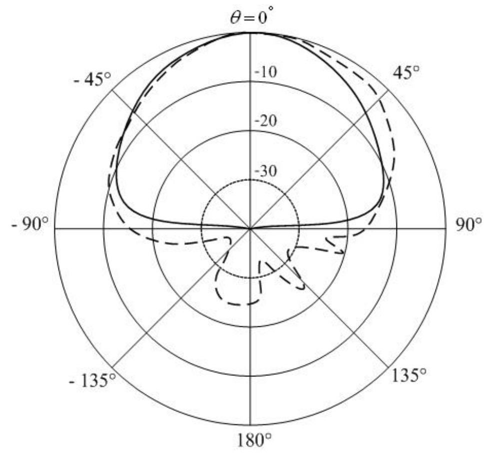
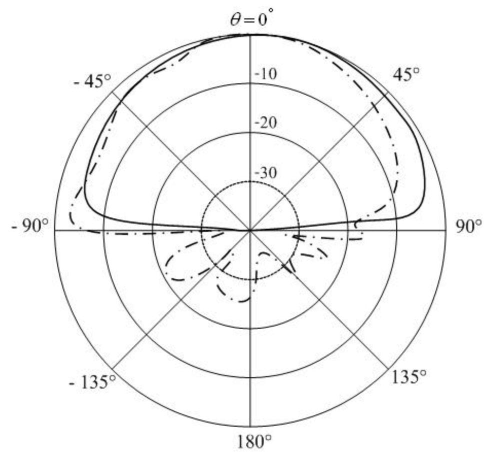


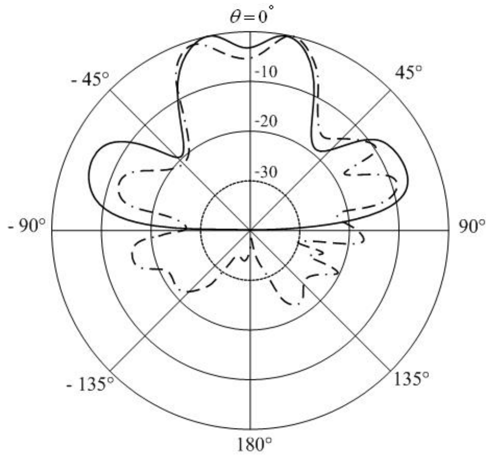
Fig.7 Measured and simulated reflection coefficients.



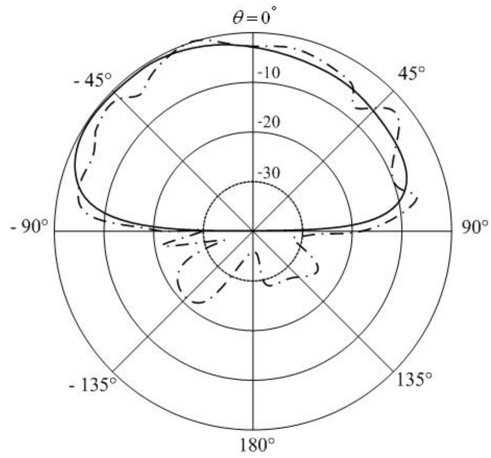
(a) E-plane at 2.45 GHz



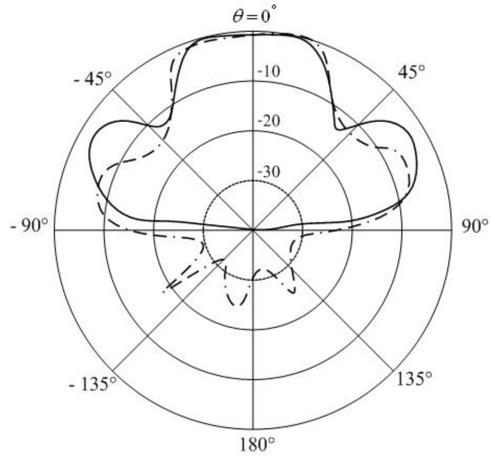
(b) H-plane at 2.45 GHz



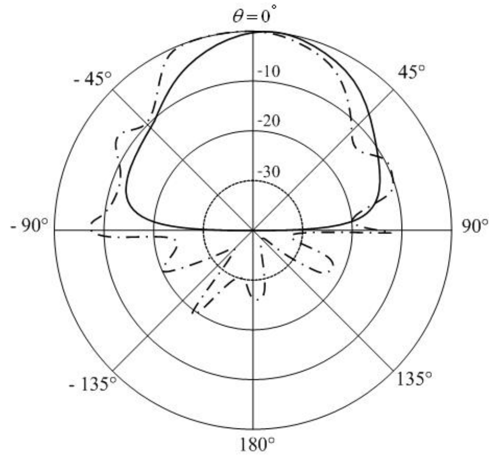
(c) E-plane at 5.25 GHz



(d) H-plane at 5.25 GHz



(e) E-plane at 5.8 GHz



(f) H-plane at 5.8 GHz

—— Simulation –·– Measurement

Fig.8 Measured and simulated far-field radiation pattern at 2.45 GHz, 5.25 GHz, and 5.8 GHz.

From the results of patterns modification by mirror of patches, we found that at the lower frequency band, its gain and radiation patterns are better, furthermore, sidelobe is reduced, at middle frequency band and at the higher frequency band, its radiation patterns have higher sidelobe level that causes of gain decreased.

4 Conclusion

In this paper, a array antenna using rectangular MSA with asymmetric T-shaped slit loaded is proposed for increasing gain. From the simulation results shows that, then, the array element spacing are adjusted from λ/2 to λ/3, covering the required area is increased. In addition, the modification by mirror of patches can improve the radiation patterns to symmetric. The experimental results are in good agreement with the simulation results. Finally, this proposed antenna as panel antenna which can be applied to wireless communications.

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