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Bandwidth Analysis of Dual-band Asymmetric T-shaped Slit-Loaded MSA Using FDTD

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1. Introduction

Wireless communications have been developed widely and rapidly in the modern world and they have already dramatic impact in our life. Wireless local area network (WLAN) is one of the most important applications of wireless communication. WLAN takes advantage of license free frequency bands, industrial, scientific and medical (ISM) bands. At present, its operation frequency bands are spanned from 2.412 GHz to 2.482 GHz (IEEE 802.11b/g), 5.152 GHz to 5.725 GHz (HIPERLAN/2) and 5.15 GHz to 5.825 GHz (IEEE 802.11a). The integration of both bands into one device using a dual-band antenna design becomes critical, which leads to a great demand in designing compact, low-profile, and dual-band antennas for WLAN terminals. To meet these requirements, compact high-performance dual-band planar antennas with good radiation characteristics are needed. Several designs of the single feed dual-band microstrip antennas (MSA) have recently been reported, for example, a dual-band circularly polarized (CP) aperture-coupled stacked microstrip patches [1], a circular microstrip patch with two pairs of arc-shaped slots [2], and a square MSA inserted with four T-shaped slits at the patch edges or Y-shaped slits at the patch corners [3]. The lattermost one proposed a reactively-load technique by using T-shaped slit loads on each edge symmetrically. It is small size, low profile, low cost, and light weight compared to [1]-[2]. Nevertheless, its dual bandwidths of 1.17% and 1.05% are not enough for implementation in WLAN application as well as it is not suggested for utilization in any applications.

In this paper, we have proposed the dual-band MSA, which is both compact in size and dual-band operation suitable for WLAN standards by using a rectangular patch inserted with four asymmetric T-shaped slit loads at the patch edges. This proposed technique is so called Asymmetrically T-shaped Slit-loaded MSA. Furthermore, a center slot is shifted out of the center point of patch and the thickness of FR4 substrate is twice increased from 1.6 mm to 3.2 mm to enlarge the lower and upper bands of this antenna. Finally, the computational results by FDTD method are presented and compared to the measurement results.

2. Design of Rectangular MSA with Asymmetric T-shaped Slit Loads

The single-feed asymmetric T-shaped slit-loaded rectangular MSA is shown in Fig.1. The antenna consists of four asymmetric T-shaped slits inserted at the rectangular patch edges. The rectangular patch has a side length *L* and width *W* that is printed on the substrate of thickness *h* and relative permittivity ε_r. A narrow slot of dimension $l_s \times w_s$ is embedded in the *x*-axis and near the patch center. An exciting probe is fed at point (x_p, y_p) along the diagonal of patch. For the dimension of four T-shaped slits, the right and left arms have the same dimensions of the width S_1 and the length l_1. The dimension of each center arm is represented by $d_1 \times w_1$ ($d_1 > d_2$), the upper and center arms are of $s_2 \times l_2$ and $w_2 \times d_2$, and the lower and center arms are of $s_3 \times l_2$ and $w_3 \times d_2$, respectively. Using those dimensions, the higher operating frequency mode will be

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perturbed and shifted to the required frequency [4]. Moreover, it is found that both shifting a narrow slot out of the patch center along the negative x-axis and increasing the thickness of substrate can enlarge bandwidth to cover the required ISM band as shown in Section 4.

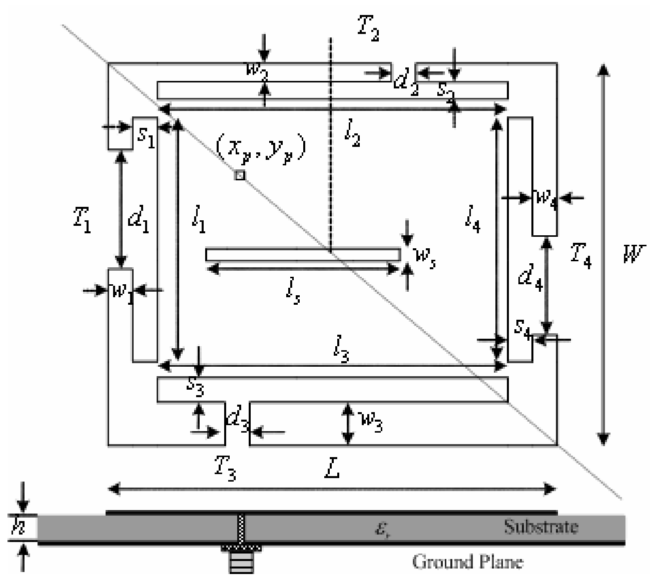
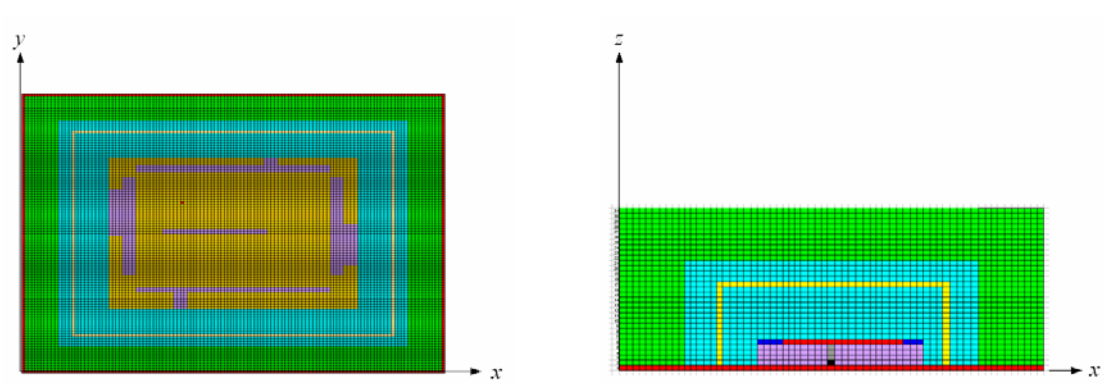


Figure 1: Geometry of Dual-band Asymmetric T-shaped Slit-loaded MSA

3. FDTD Implementation

In this investigation the bandwidth of this proposed MSA are analyzed by FDTD method. This antenna is fed electromagnetically by a 50-Ω coaxial line via SMA-connector. The relative dielectric constant of the FR-4 substrate is 4.4, and dielectric loss and conductor loss are assumed to be zero. For the modelling technique in the FDTD domain, the actual dimension of the rectangular MSA with asymmetric T-shaped slit loads have been specified as follow: ground-plane size $= 75 \times 75\ mm^2$, $h = 1.60$, $L = 36.850$, $W = 31.232$, $d_1 = 2.140$, $d_2 = 0.067$, $w_1 = 1.511$, $w_2 = 2.015$, $w_3 = 3.525$, $w_s = 1.007$, $l_s = 15.830$, $l_1 = 19.948$, $l_2 = 28.603$, $s_1 = 2.015$, $s_2 = 1.410$, $s_3 = 2.017$, and feed position $(x_p, y_p) = -8.20, 6.275$. All dimension units are millimetres. The dimensions of this antenna have been modelled in the x-y plane and z-x plane of the FDTD domain as shown in Fig.2 (a) and (b), respectively.



(a) x-y plane

(b) z-x plane

Figure 2: Asymmetric T-shaped Slit-loaded MSA Modelling in two planes of the FDTD Domain

In order to ensure the accuracy of the computed results, here, the FDTD cell size ($\Delta x = \Delta y = 0.53075\ mm$, $\Delta z = 0.8\ mm$) is smaller than 1/20 wavelength of 2.45 GHz. The computational volume is $173\Delta x \times 162\Delta y \times 69\Delta z$. The time discrete step is $\Delta t \le \Delta x / 2c = 0.8395\ ps$, here, c is the free-space velocity of light. The number of the time steps is 20,000, and this is enough number to converge the amplitude of feed current less than 10^{-5}. The PML 10-layer is adopted as the absorbing boundary condition.

4. Results and Discussions

Initially all the fields on the whole computation domain are set to zero. Absorbing boundary conditions are assumed several cells from the computation domain. The transient responses are recorded at the reference plane until the fields in the computation domain decay to a negligible steady-state value. Then the Fourier transformation is used to obtain the return loss of an asymmetric T-shaped slit-loaded MSA as solid line in Fig.4. The simulated impedance bandwidth for $S_{11} = -10$ dB are 4.08% at 2.45 GHz and 16.81% near 5.8 GHz, respectively. To verify the computed results, the prototype of this antenna is realized by using the FR-4 PCB with the dimension in Section 3 as shown in Fig.5. The return loss was measured by using an HP8720C Network Analyzer. The measured results are superimposed as dash line in Fig.5. It should be pointed out that the good agreement between the computed and measured results can be observed in the impedance bandwidths, which are 4.88% near 2.45 GHz and 18.98% near 5.8 GHz, respectively. Some errors take place because the 3.2 mm. substrate thickness of antenna is fabricated by using two layers of 1.6 mm. FR-4 PCB that can result in gab.

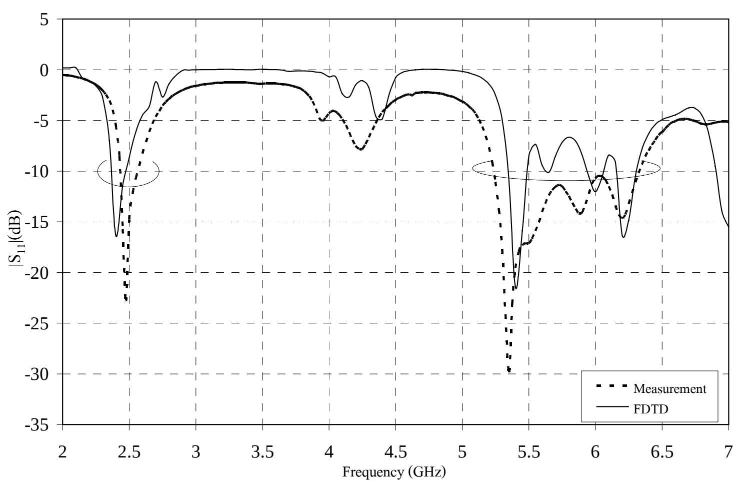


Figure 4: Measured input return loss of the proposed antenna

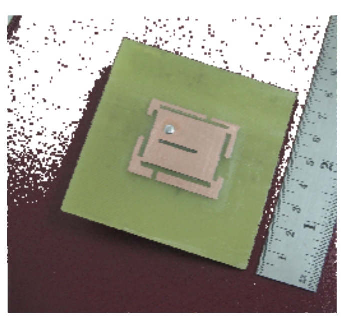


Figure 5: Photograph of The Prototype of Antenna.

5. Conclusions

In conclusion, both computational result by FDTD method and experimental results are given to illustrate that the bandwidth performance of the dual-band rectangular microstrip antenna can be improved using asymmetric T-shaped slits inserted at the rectangular patch edges, off-center slot and double substrate thickness. The prototype of antenna has been realized and measured to verify the computed result. The design is compact, robust and compatible with the IEEE standard, especially for applications at WLAN frequencies.

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