Analysis of Electromagnetic Field in Triangular Slot Antenna

A. Pomsathit*, N. Anantrasirichai * and T. Wakabayashi**
* ReCCIT, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang (KMITL)Ladkrabang, Bangkok, 10520, Thailand
E-mail : kanoppin@kmitl.ac.th
Tel. +66-2737-3000 Ext.50 , Fax. +66-2326-4176
** Department of Communications Engineering, Tokai University
Hiratsuka, Kanagawa, 259-1292, Japan
E-mail : wakaba@et.u.tokai.ac.jp

Abstract: Microstrip antennas have many applications in wireless communication system. This paper propose a analytical far-field pattern of radiation for application of the wireless communication. The triangular slot antenna fed by micorstrip line is proposed at resonance frequency 10 GHz. The simulation results of the electromagnetic field radiation pattern, S parameter, characteristic of input impedance are obtain by using the finite difference time domain (FDTD) method. The analytical space in FDTD analysis are 50x171x120 cells with the cell dimension $\Delta x = 0.152$ mm, $\Delta y = \Delta z = 0.15$ mm.

Keywords: triangular slot, electromagnetic field, current density, microstrip

1. INTRODUCTION

Microstrip antennas have many important applications e.g. in wireless communication devices. Since these devices are becoming smaller and the operation frequencies are becoming higher, traditional methods based on circuit modeling are not accurate any more and new more advanced methods based on solutions of Maxwell's equations are required. Propagation and interaction of electromagnetic waves have a great amount of applications in many areas of technology. Some examples are wireless communication, microwave engineering. Modeling of complex electromagnetic phenomena are both theoretically and computationally demanding, requiring advanced mathematical and numerical methods and combination of mathematics, physics and computer science.

The Finite Difference Time Domain (FDTD) method is introduced to solved the complicate problem in electromagnetic field theory. The equations of electromagnetic field in FDTD method is analyzed in the boundary condition that calculate by central difference expressions base on Maxell's equations and derive by Yee's famous "leap-frog" algorithm for updating the six electromagnetic field components with respect to a certain type of source excitation. For example, x-component of magnetic field and electric field are calculated by equation (1) and (2) respectively.

$$H_X^{n+1/2}(i,j,k) = \frac{1-\rho^*\Delta t/2\mu}{1+\rho^*\Delta t/2\mu} H_X^{n-1/2}(i,j,k) - \frac{\Delta t/\mu}{1+\rho^*\Delta t/2\mu} \left\{ \frac{E_Z^n(i,j,k)-E_Z^n(i,j-1,k)}{\Delta y} - \frac{E_Y^n(i,j,k)-E_Y^n(i,j,k-1)}{\Delta Z} \right\} \quad (1).$$

$$E_X^{n+1}(i,j,k) = \frac{1-\sigma\Delta t/2\varepsilon}{1+\sigma\Delta t/2\varepsilon} E_X^n(i,j,k) + \frac{\Delta t/\varepsilon}{1+\sigma\Delta t/2\varepsilon} \left\{ \frac{H_X^{n+1/2}(i,j+1,k)-H_Z^{n+1/2}(i,j,k)}{\Delta y} - \frac{H_Y^{n+1/2}(i,j,k+1)-E_Y^{n+1/2}(i,j,k)}{\Delta Z} \right\} \quad (2)$$

In this paper, we will consider double triangular shape on the ground plane fed by microstrip line. From the simulation results the electromagnetic filed at resonance frequency 10 GHz are shown.

2. DOUBLE TRIANGULAR SLOT ANTENNA STRUCTURE

The structure of double triangular slot antenna is shown in Fig. 1. Double triangular slot antenna on the ground plane is fed by a microstrip line at the center among its.

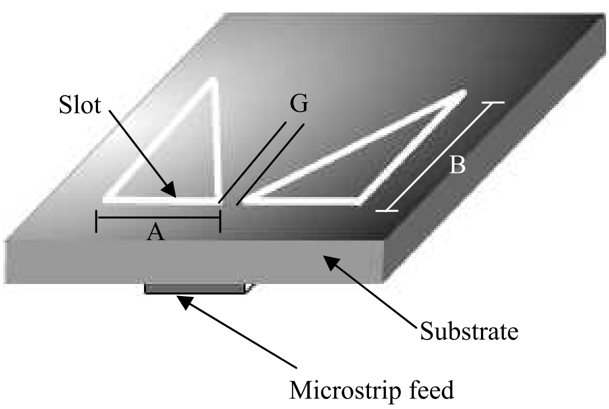


Fig. 1 The triangular slot antenna structure

slot antenna. These triangular slot antennas have the same geometry and size. The microstrip line is designed to be 50 ohms in order to match the measurement system, it has the substrate of the thickness h = 1.52 mm and the dielectric constant = 2.17.

The adjustment in some parameters for match impedance are as follows:

- length of slot side A and B = 8.1 mm.
- gap between triangular slot (G) = 0.45 mm.
- The distance between edge of micorstrip line and adjacent side of triangular slot is about 10.5 mm.

3. FDTD ALGORITHM

The algorithm of FDTD electromagnetic field analysis was introduced by Kane Yee. FDTD technique can be treats in transients conditions such as pulse in the time domain, and computational electromagnetic modeling which can predict and analysis of the electromagnetic responses of complex problems. The starting point of the FDTD algorithm is the two Maxwell's equations in derivative forms in the time domain.

$$\nabla \times \overline{E} = -\mu \frac{\partial \overline{H}}{\partial t} - \rho^* \overline{H} \qquad (3)$$

$$\nabla \times \overline{H} = \varepsilon \frac{\partial \overline{E}}{\partial t} + \sigma \overline{E} \qquad (4)$$

where ε and σ , μ and ρ* are the electric permittivity and conductivity, and magnetic permeability and resistivity of the medium, respectively. In a rectangular coordinate system, equation (1) and (2) can be expanded into the partial differential equations. We also need to descretize the time domain using a properly chosen time step. The maximum time step that may be used is limited by the stability restriction of the finite difference equation,

$$\Delta t \le \frac{1}{v_{\max}} \sqrt{\frac{1}{(\Delta x)^2} + \frac{1}{(\Delta y)^2} + \frac{1}{(\Delta z)^2}} \qquad (5)$$

where v_{max} is the highest velocity of wave propagation within the problem space, and can usually be replaced by c = 2.997925 x 10^8 m/s, the speed of light in free space. For the case of antennas, it is usually safe to make Δt to be largest value allowed by the above stability condition, so that the number of FDTD iteration steps can be minimized.

4. SIMULATION RESULTS

To simulate this triangular slot antenna by using FDTD analysis and design of microwave circuit and antenna software. This software is a full wave electromagnetic simulation code for general three dimension (3D) passive structures, particularly planar - oriented microwave circuit and antennas which base on the FDTD algorithm. It can get the results such as input impedance, S parameter and radiation pattern. For this reason, it can get the good results by simulation.

4.1 Reflected loss

The reflected loss or return loss S_{11} which is a parameter of antenna given as follows.

$$S_{11} = \frac{\Im\left[V_{ref}(t)\right]}{\Im\left[V_{inc}(t)\right]} e^{2\gamma L} \qquad (6)$$

Where $\Im$ shows a Fourier Transform and L is the length between an observing point and a reference point. The propagation constant can be define by

$$\gamma = \alpha + j\beta \qquad (7)$$

where α and ß are attenuation and phase constants, respectively. The input impedance is the complex number. By using an S_{11} parameter and characteristic impedance Z_o of a microstrip line, the input impedance can be find out as follows.

$$Z_{IN} = \left[\frac{(1 + S_{11})}{(1 - S_{11})}\right] Z_O \qquad (8)$$

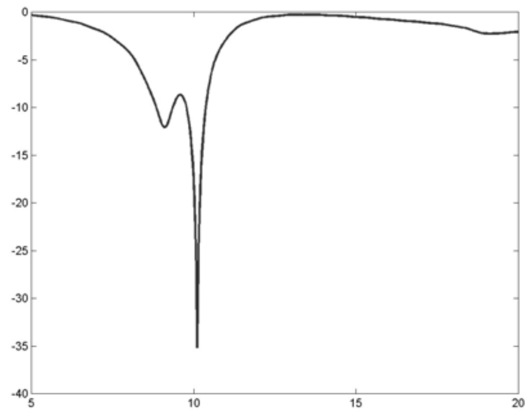


Fig. 2 Characteristics of the return loss at 10.09 GHz.

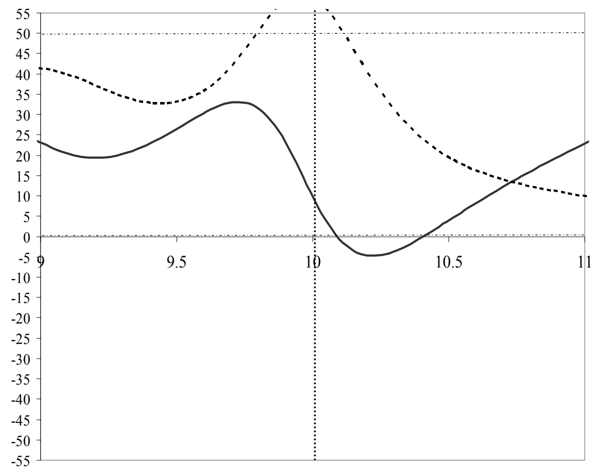


Fig.3 Characteristics of input impedance at 10.09 GHz.

By adjusting technique, S11 is nearly –35.2 dB at resonance frequency 10.09 GHz as shown in Fig.2. Similarly, Fig.3

shown the input impedance in real and imaginary at 51.67 ohms and -0.55 ohms, respectively. For perfect impedance matching, the length of microstrip line is adjusted to cancel the imaginary part. The results of good matching can be obtained at resonance frequency.

4.2 Characteristic of electric field

The wave propagation along a microstrip line through substrate and aperture of triangular slot antenna. It clearly in electric field at 10.09 GHz, figure4 shows the field intensity is maximal at the two corner of both triangular slot. The radiation in one side of triangular slot in accordance with the resonance one-wavelength at 10.09 GHz.

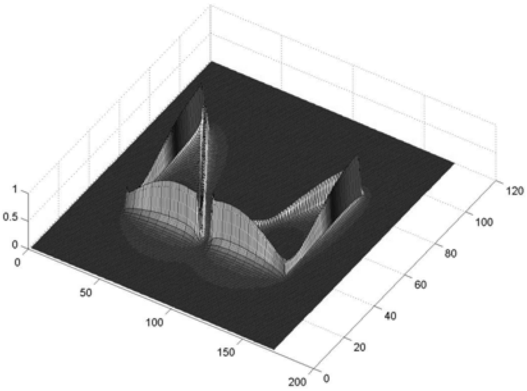


Fig. 4 Electric field of triangular slot antenna.

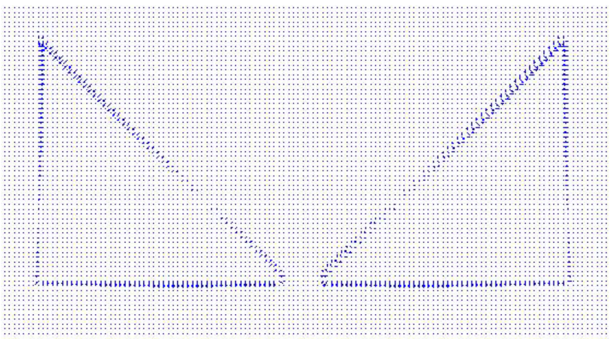


Fig. 5 The overview of transverse electric field vector in across section of triangular slot antenna.

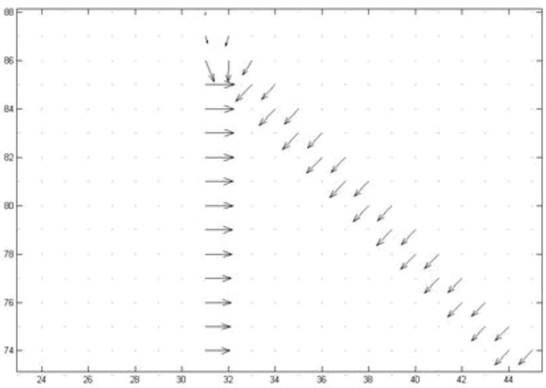


Fig. 6. Extension at the vertex of left triangular slot in transverse electric field vector

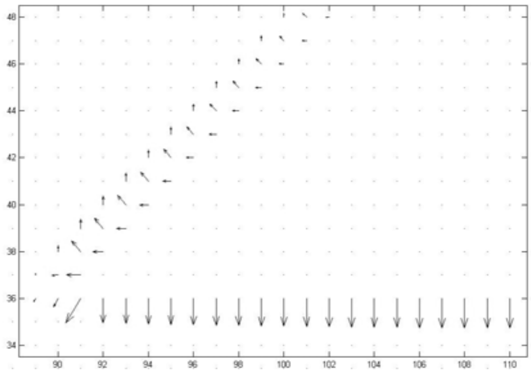


Fig. 7. Extension at the left corner of right triangular slot in transverse electric field vector

4.3 Characteristic of magnetic field

The field distribution in this structure can be demonstrate the steady state profile of magnetic field as shown in figure 8 at resonance frequency 10.09 GHz. The peak of magnetic field will be occur at the position in degradation of electric field.

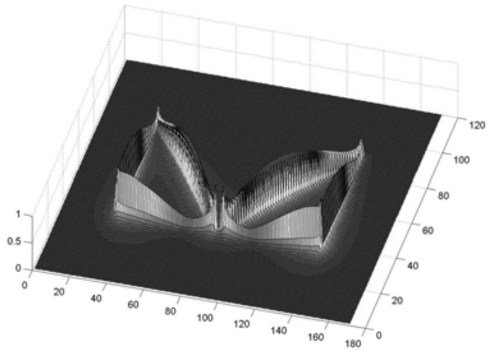


Fig. 8 Magnetic field of triangular slot antenna.

4.4 Characteristic of current density

The equivalent electric current density are related to the magnetic field component.

$$\vec{J}_s = \hat{\eta} \times \vec{H} \qquad (9)$$

Figure 9 shown current density depending on the magnetic field.

4.5 Far field patterns

Far field patterns are obtained by converting near fields to far fields in the frequency domain. Herein, We can obtain radiating field at the far field point as shown by equation (10) and (11). Far fields patterns of the xy and xz planes are simulated as shown in Figure 8 and 9.

$$E_\theta = \eta H_\phi = -j\frac{e^{-jkr}}{2\lambda r}(\eta N_\theta + L_\phi) \qquad (10)$$

$$E_\phi = \eta H_\theta = j\frac{e^{-jkr}}{2\lambda r}(-\eta N_\theta + L_\theta) \qquad (11)$$

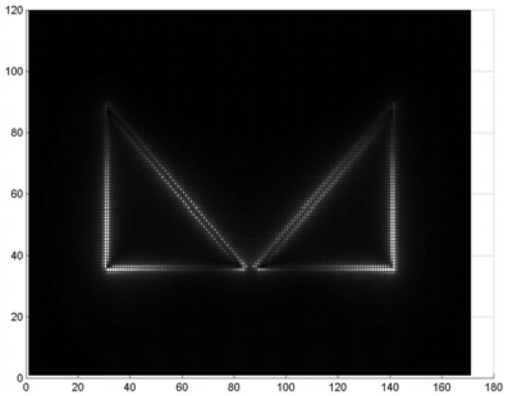


Fig. 9 Current Density of triangular slot antenna.

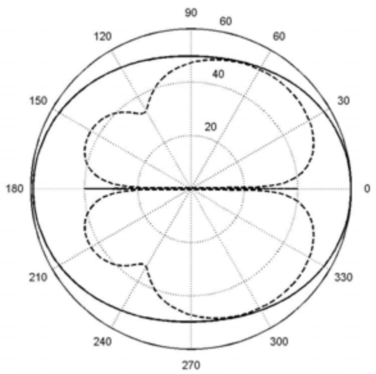
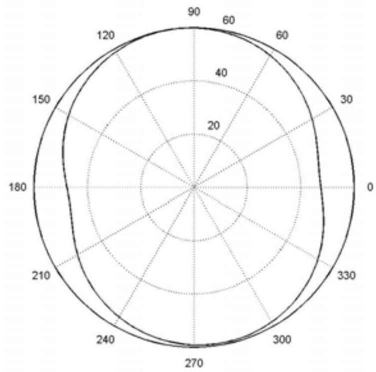


Fig.10 Far field pattern on the xy-plane

5. CONCLUSION

The electromagnetic field in slot antenna can be considered from the wave propagation along the microstrip line through the aperture of triangle slot antenna. The magnetic field will be maximum at the two point of each triangular slot antenna side which course the one side triangular slot antenna is one wave – length of resonance frequency. The triangular slot antenna obtain radiation pattern on xy and xz plane that to show omni-directional of antenna's radiation pattern. Therefore, the FDTD method was used to analyze the electromagnetic field of triangular slot antenna. Herein, simulation results of triangular slot antenna coupled by a microstrip line is shown. From the results the proposed antenna described here is useful for wireless communications.



* Cross polarization is not display since it is a much a lower level compared to the other patterns.

Fig.11 Far field pattern on the xz-plane

REFERENCES

[1] Yongxi Qian and Tatsuo Itoh, FDTD Analysis and Design of Microwave Circuits and Antennas Software and Application, Realize Inc., 1999

[2] A. Santamaria and F.J.Lopez-Hernandez, Wireless LAN Systems, Artech House,Boston London, 1993

[3] Allen Taflove, Computational Electrodynamics The Finite-Difference Time-Domain Method, Artech House, Inc., 1995.

[5] N. Anantrasirichai, A. Pomsathit and C. Benjangkaprasert, Microstrp Line Coupled Triangular Slot Antenna, International Symposium on Electromagnetic Compatibility, Beiging China, 2002