

Wideband Microstrip Slot Array Antenna for Radar Applications

P. Rakluea^{*}, N. Anantrasirichai^{**} and T. Wakabayashi^{***}

^{*}Department of Electronic and Telecommunication Engineering,
Faculty of Engineering, Rajamangala Institute of Technology (RIT),
Klong 6, Thanyaburi, Pathumthanee, Thailand

E-mail : p_ruglure@hotmail.com

^{**}ReCCIT, Faculty of Engineering

King Mongkut's Institute of Technology Ladkrabang (KMITL)

Ladkrabang, Bangkok, 10520, Thailand

E-mail : kanoppin@kmitl.ac.th

^{***}School of Information Technology and Electronics, Tokai University

Hiratsuka, Kanagawa, 259-1292, Japan

E-mail : wakaba@et_u.tokai.ac.jp

Abstract: Microstrip slot array antenna fed by microstrip line is introduced. Slot antenna is designed to operate at 10 GHz for using in radar systems. Antenna have dielectric constant of the substrate is 2.17 (PTFE). In fact, it is study to analyze slot array antenna including feeding line with wide bandwidth. The characteristics of antenna is proposed and analyzed for instance input impedance, S_{11} parameter and far field radiation patterns which these characteristics can also be calculated efficiently and accurately by using FDTD Method.

Keywords: wideband, slot array, FDTD

1. INTRODUCTION

In present day radar systems, the need for antennas of small size and high efficiency has generated much attention in the study of compact microstrip antenna. Microstrip antennas have several advantages compared to conventional microwave antenna and therefore many applications cover the broad frequency range from 100 MHz – 100 GHz. Some of the principal advantages of microstrip antennas compared to conventional microwave antennas are small size, light weight, low volume and thin profile configurations. Nowadays, the development of printed broad technology in the dielectric substrate material can make good printing antenna with low loss. However, microstrip antennas inherently have narrow bandwidths and in general are half-wavelength structures operating at the fundamental resonant mode. Their antennas have feeders such as microstrip-fed patch antenna, slot-fed patch antenna, slot antenna with CPW feed, microstrip-fed slot antenna etc. Furthermore, their characteristics of antenna are affected by feeders, substrates and frames. Therefore, it is practice to analyze antennas with them.

The slot antenna has been investigated since at least the 1940s [1], and is treated in many electromagnetic textbooks [2], but the major drawback of microstrip antenna in its basic form is its inherently narrow bandwidth. The narrow bandwidth of these antenna is a major obstacle that restricts wider applications. In general, transverse or slanted slots are cut in the ground plane of a microstrip line and present series impedance to the feed line. Y. Yoshimura [3], D. M. Pozar [4], and Sarrio *et al.* [5] demonstrated simple techniques of narrow band (a few percent of the bandwidth [5], [6]) matching of the slot radiator. In order to overcome this difficulty, Y. Yoshimura shifted the feed point from the center of the slot and short-circuited the feed microstrip through the dielectric substrate with the slot side, which is located further from the feed input. A similar technique of feed-point shifting close to

the slot end was used by D. M. Pozar. In both cases, the offset of the feed point leads to perfect impedance matching in a narrow frequency band. Therefore, techniques for wide bandwidth the microstrip antenna have been proposed. Recently, microstrip line-fed slot antennas with wide bandwidth have been investigated [7], [8].

In this paper, we will consider microstrip slot array antenna fed by microstrip line. This antenna have been designed at 10 GHz with wide bandwidth for radar systems. The analysis are performed using the simulation which is based on the FDTD method.

2. FDTD METHOD

Simulation this antenna by using FDTD method [9]. This software is a full wave electromagnetic simulation code for general three dimensional (3D) passive structures, particularly planar-oriented microwave circuits and antennas which are based on the FDTD algorithm [10]. The algorithm of FDTD electromagnetic field analysis was introduced by Kane Yee. FDTD technique treats transients such as pulse in the time domain, and computational electromagnetic modeling which can predict and analysis of the electromagnetic responses of complex problems.

For FDTD simulation of general three-dimensional microwave structures, it is more effective to use pulsed signal sources for excitation in the circuit. Gaussian pulse has been preferred source signal. The equations of electromagnetic field in FDTD method is analyzed in the boundary condition that calculate by central difference expressions base on Maxwell's equations and can easily derive Yee's famous "leap-frog" algorithm for updating the six electromagnetic field components with respect to a certain type of source excitation.

For source excitation of the antenna is input voltage $V(t)$ base on Gaussian pulse and express as

$$V(t) = e^{-\left(\frac{t-t_0}{T}\right)^2} \quad (1)$$

The input impedance is the complex number. To find out the input impedance can be done by using an parameter S_{11} and characteristic impedance Z_0 of a microstrip line as follows

$$Z_{IN} = \left[\frac{(1 + S_{11})}{(1 - S_{11})} \right] Z_0 \quad (2)$$

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

$$S_{11} = \frac{\Im[V_{ref}(t)]}{\Im[V_{inc}(t)]} e^{2\gamma L} \quad (3)$$

where \Im shows a Fourier Transform and L is the distance between an observing point and a reference point. The propagation constant γ can be defined by

$$\gamma = \alpha + j\beta \quad (4)$$

where α and β are attenuation and phase constants, respectively.

The time step satisfies the following courant condition.

$$\Delta t \leq \frac{1}{c} \sqrt{\frac{1}{(\Delta x)^2} + \frac{1}{(\Delta y)^2} + \frac{1}{(\Delta z)^2}} \quad (5)$$

Where c is a light velocity in free space.

For example, x-component of magnetic field for updating the six electromagnetic field is calculated by

$$H_X^{n+1/2}(i,j,k) = \frac{1 - \rho^* \Delta t / 2\mu}{1 + \rho^* \Delta t / 2\mu} H_X^{n-1/2}(i,j,k) - \frac{\Delta t / \mu}{1 + \rho^* \Delta t / 2\mu} \left\{ \frac{E_Z^n(i,j,k) - E_Z^n(i,j-1,k)}{\Delta y} - \frac{E_Y^n(i,j,k) - E_Y^n(i,j,k-1)}{\Delta z} \right\} \quad (6)$$

For example, x-component of electric field for updating the six electromagnetic field is calculated by

$$E_X^{n+1}(i,j,k) = \frac{1 - \sigma \Delta t / 2\epsilon}{1 + \sigma \Delta t / 2\epsilon} E_X^n(i,j,k) + \frac{\Delta t / \epsilon}{1 + \sigma \Delta t / 2\epsilon} \left\{ \frac{H_Z^{n+1/2}(i,j+1,k) - H_Z^{n+1/2}(i,j,k)}{\Delta y} - \frac{H_Y^{n+1/2}(i,j,k+1) - H_Y^{n+1/2}(i,j,k)}{\Delta z} \right\} \quad (7)$$

where ϵ , σ , μ and ρ^* are the electric permittivity (F/m) and conductivity (S/m), and magnetic permeability (H/m) and resistivity (Ω/m) of the medium, respectively.

3. ANTENNA STRUCTURE AND SIMULATION RESULTS

The geometry of the slot array antenna are shown in Fig 1. Furthermore, parameter of this antenna consist of two slot array on ground plane. The slot array fed by microstrip line that is designed for match impedance 50 ohms at resonance frequency, where thickness of substrate is 1.52 mm, width of microstrip line is 4.8 mm. with dielectric constant 2.17 (PTFE). The parameters of antenna are also showed, where L_s are the length of slots, D_s is distance between two slots array, W_s are width of slots and L_m is distance between center of lower slot to edge of microstrip line. The antenna have been designed for band of the radar systems at 10 GHz.

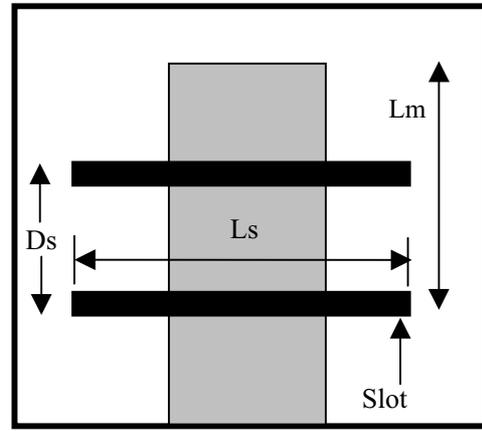


Fig 1. The geometry and parameters for slot array antenna

Table 1. The dimentions and simulation results of the slot array antenna

Ws (mm)	0.9	0.9	0.9
Lm (mm)	9.6	9.6	9.6
Ls (mm)	24	24	24
Ds (mm)	3.6	5.4	7.2
Frequency (GHz)	10.01	10.05	10.02
S_{11} (dB)	-34	-30	-25
Zin real	48.91	51.29	53.32
Zin Imag	1.345	-2.006	-5.032
VSWR	1.036	1.048	1.124
Bandwidth (%)	18.3	21.1	16.5

Table 1 show dimentions and simulations of the slot array antenna that it has obtained for good matching impedance and wide bandwidth. The microstrip slot array antenna is analyzed in order to for wide bandwidth at resonance frequency about 10 GHz. The antenna is compared in distance between two slots array (D_s). For bandwidth is measured in VSWR less than 2.

By simulation results is analyzed and demonstrated as follows:

1. It is clear that L_s is about λ_g at resonance frequency
2. L_m is designed in order to matching impedance about $0.5 \lambda_g$.
3. D_s and W_s control wide bandwidth that D_s is about $0.25 \lambda_g$ and W_s about $0.045 \lambda_g$. But L_s and D_s affect with matching impedance as well

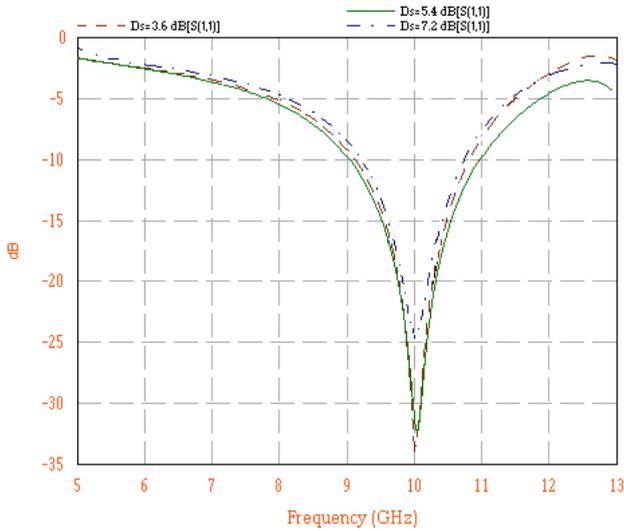


Fig 2. Return loss of microstrip slot array antenna

Fig 2. shows return loss of microstrip slot array antenna that is compared in distance between two slots array (D_s). By distance between two slots array is 5.4 mm. to obtain highest wide bandwidth

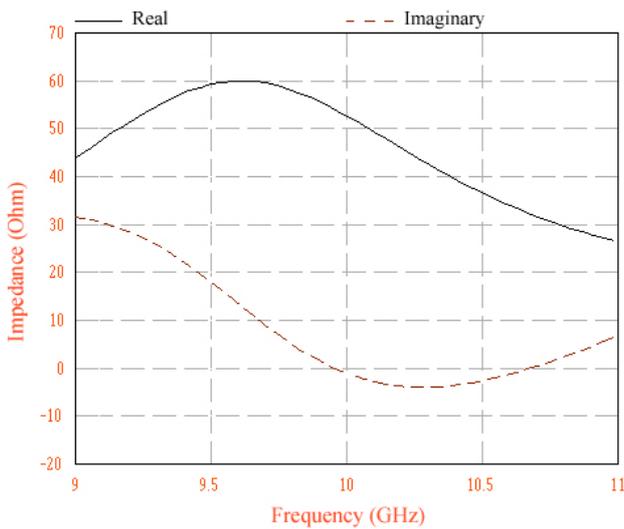


Fig 3. Input impedance of microstrip slot array antenna for $D_s = 5.4$ mm.

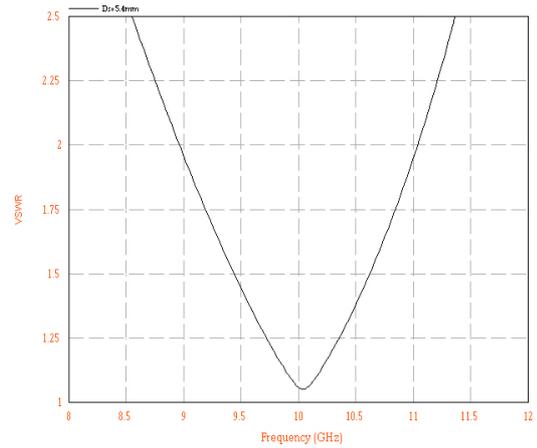


Fig 4. VSWR of microstrip slot array antenna for $D_s = 5.4$ mm.

Fig 3. shows Input impedance and Fig 4. Shows VSWR of microstrip slot array antenna for $D_s = 5.4$ mm. that it has obtained for good matching impedance and wide bandwidth.

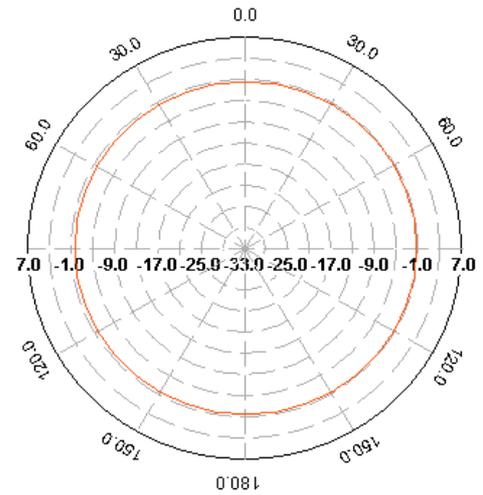


Fig 5. Far Fields patterns on the xy plane

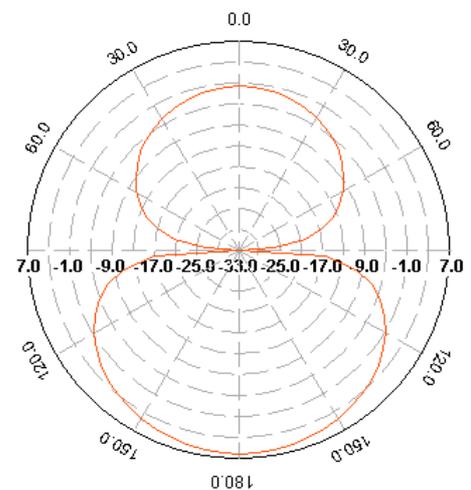


Fig 6. Far Fields patterns on the xz plane

By using FDTD method. It is possible to transform the near field to far field by discrete Fourier transform to carry out for equivalent electric and magnetic current densities during the FDTD iteration. Hence, far fields are obtained by converting near fields to far fields in the frequency domain.

Fig 5. shows far fields patterns on the xy plane and Fig 6. shows far fields patterns of the xz plane. Hence, the microstrip array antenna is demonstrated in uni-radiation pattern

4. CONCLUSION

The microstrip slot array antenna are analyzed in this paper. The antenna have obtained good matching impedance and wide bandwidth for radar systems. Length of slots control resonance frequency. Furthermore, width of slots and distance between two slots array control wide bandwidth. Finally, in this antenna have shown uni-radiation pattern.

REFERENCES

- [1] H. G. Booker, "Slot aeriels and their relation to complementary wire aeriels," *J. IEE (London)*, pt. IIIA, vol. 93, pp. 620–626, 1946.
- [2] R. E. Collin, *Antenna and Radiowave Propagation*, New York: Mc-Graw-Hill, 1985.
- [3] Y. Yoshimura, "A microstrip slot antenna," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-20, pp. 760–762, Nov. 1972.
- [4] D. M. Pozar, "Reciprocity method of analysis for printed slot and slotcoupled microstrip antennas," *IEEE Trans. Antennas Propagat.*, vol. AP-34, pp. 1439–1446, Dec. 1986.
- [5] S. Sarrio, Y. Qian, and E. Yamashita, "Theoretical and experimental study of optimum feeding structures for printed slot antennas," in *Asia Pacific Microwave Conf.*, Oct. 1994, pp. 1129–1132.
- [6] M. Kahrizi, T. K. Sarkar, and Z. H. Maricevic, "Analysis of a wide radiating slot in the ground plane of a microstrip line," *IEEE Trans. Microwave Theory Tech.*, vol. 41, pp. 29–37, Jan. 1993.
- [7] W. R. Deal, V. Radisic, Y. Qian, and T. Itoh, "A broadband microstrip-fed slot antenna," in *IEEE MTT-Symp. Technol. Wireless Applicat. Dig.*, Feb. 1999, pp. 209–212.
- [8] Yong - Woong Jang, "Experimental Study of Large Bandwidth Three-Offset Microstripline-Fed Slot Antenna" *Ieee microwave and wireless components letters*, vol 11, no 10, october 2001, pp. 425-427
- [9] Yongxi Qian and Tatsuo Itoh, "FDTD Analysis and Design of Microwave Circuits and Antennas Software and Applications", Realize Inc., 1999.
- [10] Allen Taflove, "Computational Electrodynamics The Finite-Difference Time-Domain Method", Artech House, INC., 1995.