The Characteristic Analysis of the Cross-shaped Microstrip Slot Antenna with the Reflector for Permittivity and Height of Dielectrics

Yong-Woong Jang*, Ho-Sub Shin**, Dong-Jin Oh***

* Dept. Of Elec. Communication, Keuckdong College

** Dept. of Computer and Communication Engineering, Chungbuk Nat'l Univ.

*** Dept. of Electronics Engineering, Hongik Univ.

38 Danpyung-Ree, Kamgok-Myun, Eumsung-Kun, Chungcheongbuk-Do, 369-850, Republic of Korea

Tel:+82-446-881-3317, Fax:+82-446-881-3310

E-mail: ywchang@telecom.kdc.ac.kr

Abstract: We analyzed the cross-shaped microstripline-fed slot antenna with the reflector using FDTD(Finite-Difference Time-Domain) method in this paper. The proposed antenna uses R/T Duroid-5880 substrate(relative permittivity 2.2 and height(1.578 mm) of dielectrics), and compares the optimized results of other kind substrates. The maximum bandwidth of the proposed antenna is from 1.91 GHz to 5.21 GHz, which is approximately 1.437 octave for the VSWR ≤ 2. It was found that the bandwidth of the antenna depend highly on the length of the horizontal and vertical feedline as well as the offset position of the feedline. The experimented data for the VSWR and the radiation pattern of the antenna are also represented.

1. Introduction

The most microstripline-fed structures of the printed slot antenna has been used by the method of making the microstrip-fed structures across the center of slot [1]. The conventional center-fed transverse slot antennas have a large value of radiation impedance so that it is very difficult to match in practice. For solving these problems, the short tunning stub and open tunning stub were proposed offset from the center of a slot to the end of it by Yoshmura [2] and Posar [3], respectively. When these cases is narrow slot width only, these are good for the impedance matching. But when the slot width is wide, these need a special matching circuit at the feeding port for good impedance matching.

In this paper, we analyzed the cross-shaped microstripline-fed slot antenna with the reflector using FDTD (Finite-Difference Time-Domain) method. The proposed antenna using R/T Duroid-5880 substrate (relative permittivity 2.2 and height(1.578 mm) of dielectrics) is analyzed by using FDTD method that enhances the bandwidth wider than the used one without a special matching. And the Ez-component of electric field in the time domain is computed. We also computed return loss, VSWR, and radiation pattern in the frequency domain by Fourier transforming the time domain results. From these results, the antenna having maximum bandwidth was tested, after being designed and fabricated it.

2. Antenna structure and analysis method

The printed slot antenna with cross-shaped feedline(Fig. 1) is better than the used feedline structures for design. l_s represents the length of a slot, W_s is the width of a slot, and l_d is the length of the horizontal feedline, and l_u is the length of top vertical feedline, and offset represents the gap from a slot center to the center of horizontal feedline,

W_f is the width of microstrip feedline. Fig 1. represents a structure of the antenna, it consists of the slot radiator and cross-shaped feedline. The analysis using the method of FDTD is based on Yee's unit cell and Mur's ABC [5].

3. Simulation and results

This antenna (Fig. 1) is analyzed on the three-dimensions by FDTD method. The sizes of space cell are Δx=0.333 mm, Δy=0.25 mm, Δz=0.5 mm. The total analysis space is composed of 272 x 360 x 203 cells in respective x, y, z direction. The sizes of antenna by using FDTD method are set to the followings ; l_s=150 Δx, W_s=128Δy, l_d = 87 Δx, l_u =40Δy, offset=40Δy, W_f=14Δx. Fig. 2 represents the 3-dimensional E_z-component of the electric field as the time-varying pulse is reached the steady state of the antenna.

The characteristics of antenna is sensitive to the the antenna design parameters(l_s, W_s, l_d, l_u, offset, W_f). The VSWR, return loss, and radiation pattern in the frequency domain are calculated by Fourier transforming the time domain results. With fixing the other parameters, when the slot widths(W_s) is 28 mm, 32 mm, 36 mm which are 16Δy(4mm) of a minimum cell Δy=0.25 respectively, the calculated VSWR results represents in Fig. 3. When W_s is 28 mm, the bandwidth is about 2.1 GHz, and when W_s is 32 mm, it increases the bandwidth to 3.3 GHz, and when W_s is 36 mm, it decreases the bandwidth to 3.0 GHz again.

Fig. 4 represents the comparision between the bandwidth of FR-4(ε_{r1}= 4.3, h_1=1.0 mm) and R/T Duroid-5880(ε_{r1}= 2.2, h_1=1.578 mm) for the $S_{11} \leq$-10 dB, there were the available frequency large from 1.975 GHz to 4.7625 GHz, three-resonances at S11 less than -10 dB. R/T Duroid-5880 substrate obtained bandwidth 0.537 octave(1.77 GHz) more than FR-4 substrate.

Table 1 represents the comparision values of optimized design parameters and bandwidth for the various kind substrates.

4. Experiment and results

Fig. 5 represents the comparision between the theory and the experiment for the center frequency 3.3 GHz, there were the available frequency large from 1.93 GHz to 5.30 GHz, broad bandwidth 3,370 MHz, three-resonances at S11 less than -10 dB. The antenna dimensions are

(a) Feed : ε_{r1} =2.2; h_1=1.5 mm; W_f =4.796mm; l_d=23mm; l_u=9mm; offset=10 mm

(b) Slot : l_s=50mm; W_s=32mm

Fig.6 represents the comparision between the theory and the experiment for a E-plane radiation pattern. After the calibration using a horn antenna, we has been measured the radiation pattern at the far field, and the measured results are in good agreement with the calculated results.

5. Conclusion

In this paper, we analyzed the cross-shaped microstripline-fed slot antenna with the reflector using FDTD(Finite-Difference Time-Domain) method. There were represent the optimized design parameters and maximum bandwidth of the proposed antenna, and compared the results for the relative permittivity and height of substrate. The maximum bandwidth of the proposed antenna is from 1.91 GHz to 5.21 GHz, which is approximately 1.437 octave for the VSWR $\leq$ 2.

The measured values are in good agreement with FDTD results. This antenna may be useful or powerful broadband array antenna.

References

1. M. Kahrizi, T.K.Sarkar and Z.H.Maricevic, " Analsis of a wide radiating slot in the ground plane of a microstrip line," IEEE Trans. Microwave Theory Tech., vol. MTT-41, MTT-41, pp.29-37, Jan. 1993.
2. Y. Yoshimura, "A microstrip slot antenna," IEEE Trans. Microwave Theory Tech., vol. MTT-20, pp. 760-762,

Nov. 1972.

3. D. M. Pozar, "Reciprocity method of analysis for printed slot and slot-coupled microstrip antennas, " IEEE Trans. Antennas and Propagat., vol. AP-34, pp. 1439-1446, Dec. 1986.
4. K. S. Yee, "Numerical solution of initial boundary-value problems involving Maxwell's equations in isotropic media," IEEE Trans. Antennas and Propagat., vol. AP-14, pp.302-307, May 1966.
5. G. Mur, "Absorbing boundary conditions for the finite-difference approximation of the time-domain electromagnetic-field equation," IEEE Trans., Electromag. Compat., vol. EMC-23, no.4, pp. 377-382, Nov. 1981.

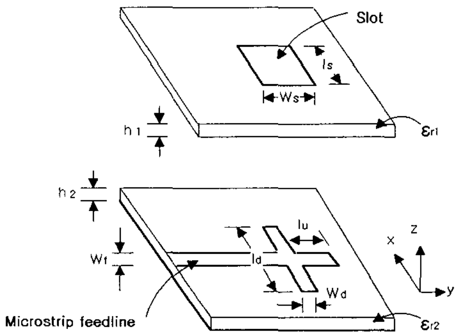

Fig.1 Structure and design parameters of antenna

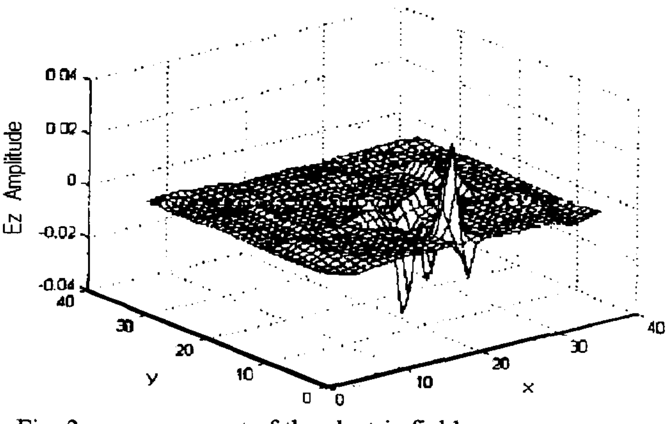

Fig. 2 z-component of the electric field

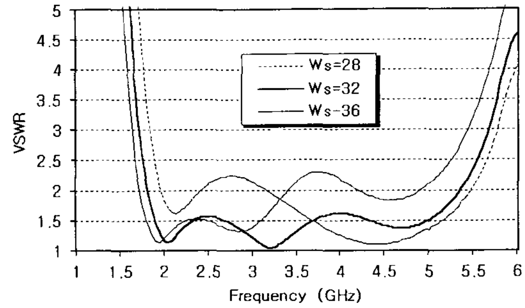

Fig.3 Calculated VSWR as a function of the slot width(W_s); l_s=50mm, l_d =29mm, l_u=8 mm, offset=10 mm, W_f=4.796 mm, ε_{r1}= 2.2, h_1=1.578mm, ε_{r2}=1.0, h_2=40mm

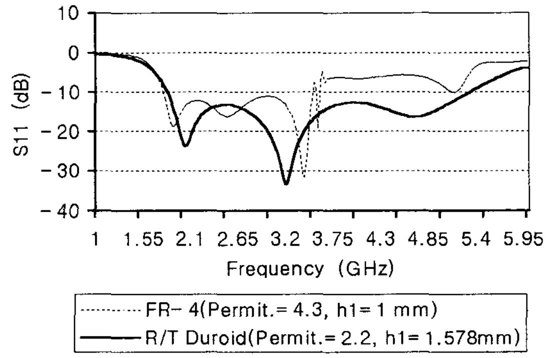

Fig. 4 Comparision of return loss values

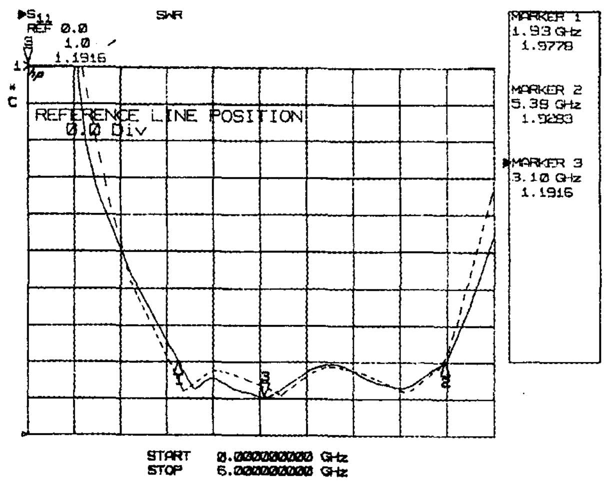

Fig. 5 VSWR
(- - - : Calculated values,
-----: Measured values)

Table 1. Represents the comparision values of optimized design parameters and bandwidth for the various kind substrates.

Substrate type	Relative Permittivity	h_1 (mm)	l_d (mm)	l_u (mm)	Offset (mm)	Offset $/W_s$	B/W (GHz)
R/T Duroid	2.2	1.578	29	8	10	0.313	3.30
R/T Duroid	2.5	0.528	24	8.5	11	0.344	1.30
Taconic	2.6	1.578	28	9	9.5	0.297	2.30
FR-4	4.3	1.0	20	10	10	0.313	1.75

(l_s=50 mm, W_s=32 mm)

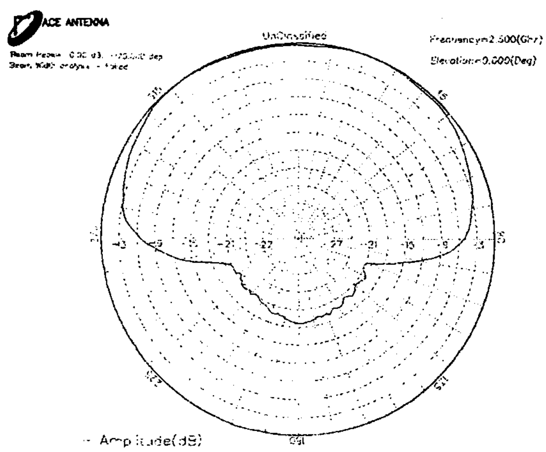

Fig. 6 Measured E-plane radiation pattern