원편파용 광대역 마이크로스트립 크로스 슬롯 어레이 안테나의 설계에 관한 연구

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A Study on the Design of Wideband Microstrip Cross Slot Array Antennas with Circular Polarization

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요 약

원편파용 마이크로스트립 안테나 소자들은 많은 형태가 있는데, 이것은 훌륭한 단위 방사기로 사용되었다. 원편파용 안테나의 이점은 송·수신시스템 사이에 엄격한 설정을 요구하지 않기 때문에 원편파용 프린트 안테나는 많은 위성과 이동무선시스템에 자주 사용되었다. 원편파용 마이크로스트립 안테나의 3 dB 축비와 임피던스의 광대역을 실현하기 위해서 복잡한 급전구조와 3층의 패치 소자가 연구되었다. 본 논문은 원편파용 광대역 마이크로스트립 크로스 슬롯 어레이 안테나의 설계를 나타낸다. 제안한 안테나는 급전부인 마이크로스트립 라인과 원편파 발생을 위한 방사부인 크로스 슬롯으로 구성되어 있다. 광대역을 위해서 3층 구조가 고려되었고, 크로스 슬롯은 급전선과 전자기적 결합을 한다. 1소자 크로스 슬롯 안테나의 최적 파라미터가 모멘트 법에 의해 해석 및 설계되었다. 이러한 파라미터들은 방사소자들 사이의 상호결합을 고려한 어레이 안테나 설계에도 적용되었다. 제안한 안테나의 우현편파와 좌현편파는 비대칭 크로스 슬롯 구조와 슬롯 위치에 의해 쉽게 제어된다. 1소자와 15소자 크로스 슬롯 안테나에서 1 dB 이하의 축비와 안테나의 광대역 특성을 얻었다.

ABSTRACT

There are many types of circularly polarized(CP) microstrip antenna elements, which are used as a good unit radiator. Since an advantage of CP antenna is no strict alignment requirements between Rx and Tx system, the printed antennas with circular polarization are very often used in numerous satellite and mobile radio systems. In order to realize the broad bandwidth of 3 dB axial ratio and impedance of CP microstrip antenna, complex feed structure and tri-plate patch element have been researched. This paper describes a design of wideband microstrip cross slot array antennas with circular polarization. The proposed antenna is composed of an open-ended microstrip feed line as a feeder and a cross slot as a radiator for circular polarization. To realize the wide bandwidth, tri-plate structure are considered and cross slot is electromagnetically coupled with feed line. Optimum parameters of 1-element cross slot antenna are analyzed and designed by method of moments. These parameters are also applied to array antennas design considered the mutual coupling between radiating elements. Right hand circular polarization(RHCP) and left hand circular polarization(LHCP) of the proposed antenna are easily controlled by asymmetrical cross slot structure and slot position. In 1-element and 15-element cross slot array antenna, the good axial ratio of 1 dB below and the broad bandwidth characteristics of antenna are obtained.

키워드

Microstrip, Circular Polarization, Cross Slot, RHCP, LHCP

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Ⅰ. Introduction

With increasing the mobile and satellite broadcastings system, the researches of novel circularly polarized elements are progressing. One of the most interesting antenna applications is the development of mobile direct broadcasting satellite(DBS) reception antenna with circular polarization. There are many types of the circularly polarized antennas such as the parabolic reflector, the waveguide array antennas, and the microstrip antennas. Some merit of the microstrip array antennas are simple fabrication, low cost in production, and the planar structure with low profile[1]. However, one of the most serious problems of microstrip antenna is the considerable narrow bandwidth compared to planar microwave antenna in high frequency. Circularly polarized wave is realized by analysis of asymmetrical cross slot structure. To realize the wide bandwidth antenna, the electromagnetically coupled tri-plate structure are considered. Design parameters of the proposed antenna are discussed in this paper[2][3].

Ⅱ. 1-element design

1. Antenna structure

Fig. 1 shows the analysis model of 1-element cross slot antenna structure for RHCP and LHCP. The proposed antenna is composed of multi-layered structure with relative permittivity 2.6 and air. This antenna is also composed of the open-ended microstrip line as a feeder and the cross slot as a circularly polarized radiator. To design the microstrip cross slot antenna with RHCP and LHCP at 11.85 GHz, the height(DH2) between the cross slot and the microstrip feed line, the angle(A) between a pair of slot, the rotation angle(B) of cross slot, the various slot(SL1, SL2, SL3 and SL4) length and the offset(D0) between the center of feed line and the center of cross slot are calculated.

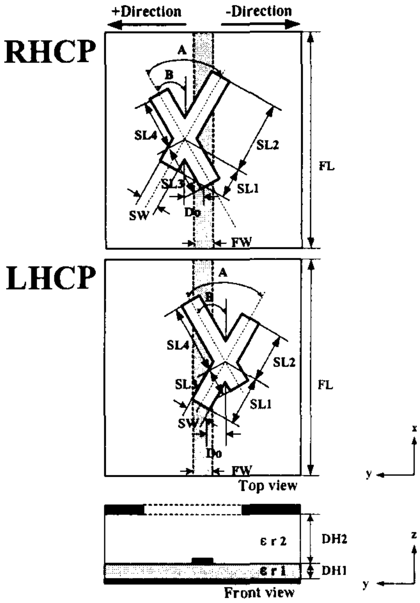


Fig. 1 Structure of 1-element cross slot antenna

2. Numerical results

Fig. 2 shows the axial ratio for the variation of DH2 at 11.85 GHz. DH2 is the height between the cross slot and the microstrip line. The scope of DH2 with 3 dB axial ratio is 3.0 mm to 6.5 mm. When the DH2 is 4.2 mm, the calculated minimum axial ratio is about 0.4 dB. The DH2 of 4.2 mm is used hereafter.

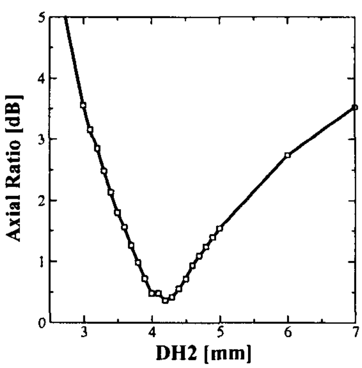


Fig. 2 Axial ratio for the variation of DH2

Fig. 3 shows the axial ratio for the variation of A at 11.85 GHz. A is the angle between a fair of slot. Angle B is a half of A. When the A is 60 degrees, as shown in Fig. 3, the calculated minimum axial ratio is about 0.2 dB. The A of 60 degrees is used hereafter.

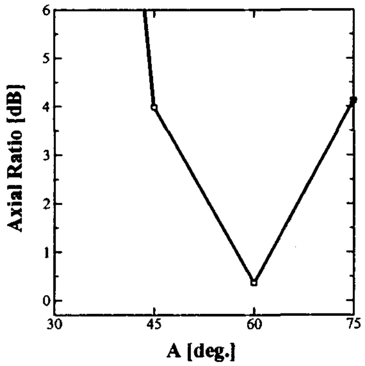


Fig. 3 Axial ratio for the variation of A

Fig. 4 shows the axial ratio for the variation of SL1 and SL3 at 11.85 GHz. The solid line and the dotted line indicate RHCP and LHCP obtained by variation length of SL1 and SL3, respectively. For example, when the SL1 and SL2 are 2 mm and 10 mm, the calculated minimum axial ratio are about 0.2 dB. When the slot is asymmetry structure for the center feed line, the axial ratio is more excellent. Therefore, the asymmetry structures have high-probability for the circular polarization.

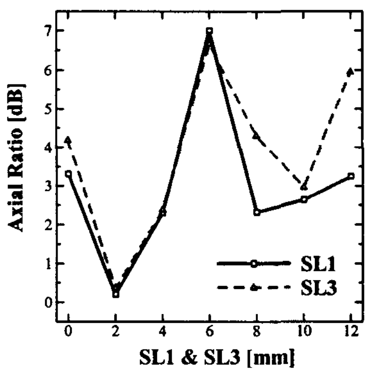
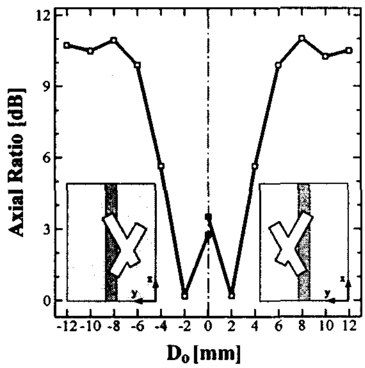
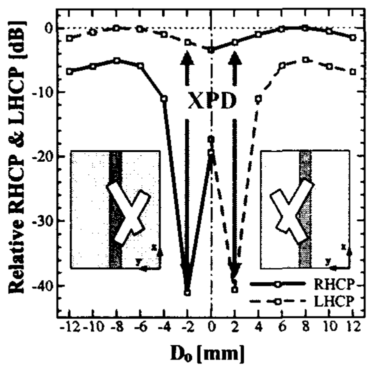


Fig. 4 Axial ratio for the variation of SL1 & SL3

Fig. 5 (a) shows the axial ratio for the variation of D0 at 11.85 GHz. D0 is the offset between the center of feed line and the center of cross slot. When the slot is moved +y and -y direction on the center feed line, the axial ratio improved. And the axial ratios have symmetrical values for the center feed line. At this time, two slots of the y direction have the symmetrical structure for the center feed line. When the D0 is 2 mm, the calculated minimum axial ratio are about 0.2 dB.



(a) Axial ratio



(b) RHCP & LHCP

Fig. 5 AR, RHCP & LHCP for the variation of D0

Fig. 5 (b) shows RHCP and LHCP for the variation of D0. When the slot is move +y direction on the center feed line, RHCP is larger than LHCP and the slot is move -y direction on the center feed line, LHCP is larger than RHCP.

Therefore, the discrimination of RHCP and LHCP depend on the cross slot position. When the D0 is 2 mm, the calculated maximum cross polarization discrimination(XPD) are about 39 dB.

Table 1 shows the calculated optimum parameters of model antenna for RHCP and LHCP.

Table. 1 Design parameters of model antenna

Parameters	RHCP	LHCP
Design Frequency	11.85 GHz	11.85 GHz
DH1	0.8 mm	0.8 mm
DH2	4.2 mm	4.2 mm
$\varepsilon_r 1$	2.6	2.6
$\varepsilon_r 2$	Air	Air
FW	2.4 mm	2.4 mm
SW	3.5 mm	3.5 mm
SL1	2.0 mm	6.0 mm
SL2	10.0 mm	6.0 mm
SL3	6.0 mm	2.0 mm
SL4	6.0 mm	10.0 mm
D_0	2.0 mm	2.0 mm
A	60°	60°

3. Experimental results

Fig. 6 shows the photograph of the fabricated 1-element microstrip cross slot antenna constructed with 0.8 mm thick microstrip substrate(εr=2.6) and metal plate of aluminum.

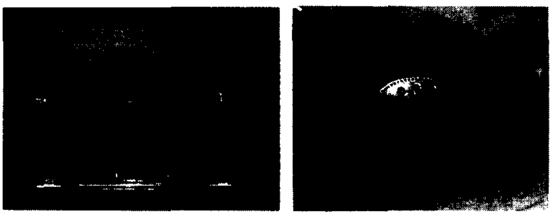


Fig. 6 The fabricated microstrip cross slot antenna

Fig. 7 shows the S11 and S21 of the 1-element microstrip cross slot antenna. In the experiment, the resonant frequency is about 11.9 GHz. The differences of experiment and calculation values are due to the manufacturing error.

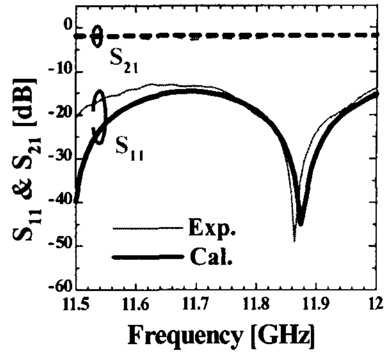


Fig. 7 Comparison between calculation and experiment

Fig. 8 shows the calculated axial ratio for the variation of frequency using the parameters of table 1. The bandwidth with the axial ratio of 3 dB below is 3.35 GHz from 10.6 to 13.95 GHz.

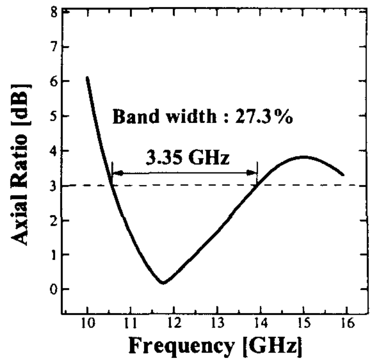


Fig. 8 Axial ratio for the variation of frequency

Fig. 9 shows the radiation patterns for the experiment and calculation. E_θ and E_ϕ components of x-z plane are calculated and measured at 11.85 GHz. The bandwidth with the axial ratio of 3 dB below is about 105 degrees in experiment and the radiation patterns are well agree with calculation. In experiment, ripple is dependent on ground plane size.

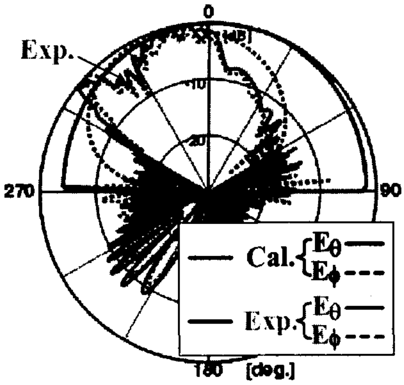


Fig. 9 Radiation patterns observed by the experiment and calculation

III. 15-element design

Fig. 10 shows the structure of 15-element microstrip cross slot array antenna for RHCP. To realize the circular polarization, the height(DH2) between the cross slot and the microstrip feed line and the offset(D0) between the center of feed line and the center of cross slot are calculated. To realize the beam tilting effects, the distance(D) between each slot is calculated.

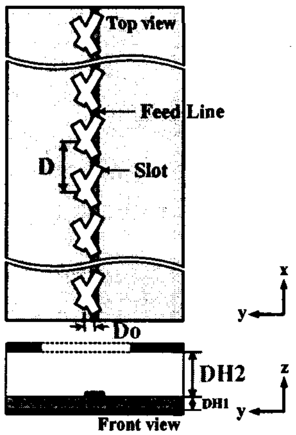


Fig. 10 Structure of 15-element cross slot array antenna

Fig. 11 shows the axial ratio for the variation of D0 at 11.85 GHz. When the D0 is 2.3 mm, the calculated minimum axial ratio is about 0.3 dB.

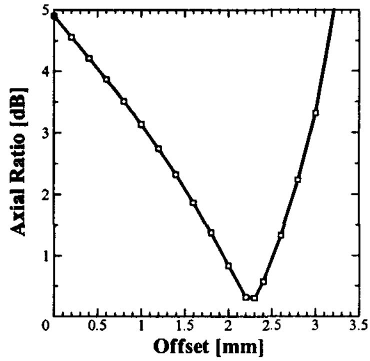


Fig. 11 Axial ratio for the variation of D0

Fig. 12 shows the axial ratio for the variation of DH2 at 11.85 GHz. When the DH2 is 4.1 mm, the calculated minimum axial ratio is about 0.1 dB.

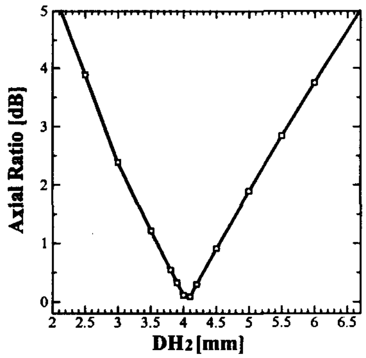


Fig. 12 Axial ratio for the variation of DH2

Fig. 13 shows the E-plane radiation patterns for the variation of D at 11.85 GHz. When the D are 17.0 mm, 16.0 mm and 14.5 mm, the beam tilting angle of 0, 354 and 346 degrees are obtained, respectively. When the D is 14.5 mm, the beam tilting angle of 14 degrees from the 0 degree is obtained. Beam tilting angle depends on variation of D. The calculated axial ratio and the side lobe level are about 0.8 dB and -13 dB below for the main beam level, respectively.

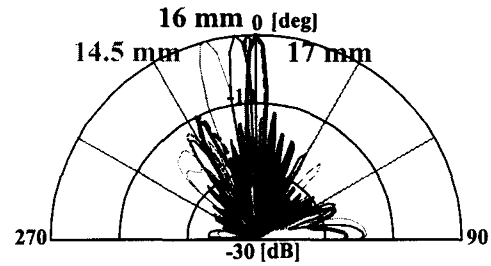


Fig. 13 E-plane radiation patterns for the variation of D at 11.85 GHz

Fig. 14 shows the photograph of the fabricated 15-element microstrip cross slot array antenna.

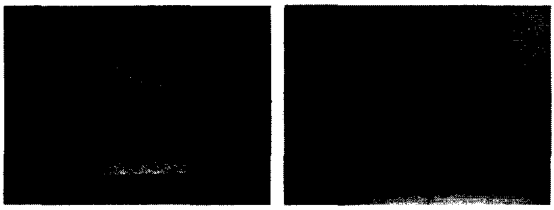


Fig. 14 The fabricated 15-element cross slot array antenna

Fig. 15 shows the reflection coefficients of the 15-element microstrip cross slot array antenna. The measured reflection coefficients of 15-element microstrip cross slot array antenna is about -10 below and shows the wide bandwidth characteristics.

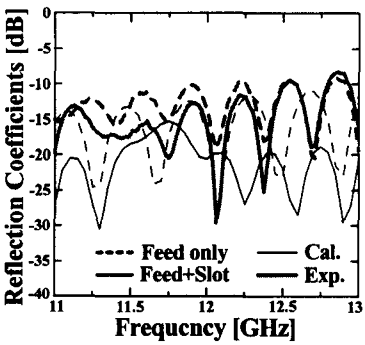


Fig. 15 Comparison between calculation and experiment

Ⅳ. Conclusion

The microstrip slot antenna composed of feed line and X-shaped electromagnetic coupled(EMC) slot is presented for the wide bandwidth and circular polarization in this paper. To analyze and design the microstrip cross slot antenna, method of moments is used and compared with experiment results. In 1-element and 15-element cross slot antenna, RHCP and LHCP are easily controlled by asymmetrical cross slot structure and slot position. The calculated and the measured bandwidth with the axial ratio of 3 dB below are about 3.35 GHz from 10.6 to 13.95 GHz and about 105 degrees in 1-element experiment, respectively. In 15-element array, the calculated axial ratio in the main beam direction and the relative side lobe level are about 0.8 dB and -13 dB below for the main beam level, respectively.

Reference

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