Simulation and Analysis of a Circularly Polarized waveguide slot Radiator

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Abstract. This paper simulated and analyzed a circularly polarized (CP) waveguide composite slot radiator at X -band in this paper. According to the radiation principle of the waveguide slot, a composite slot located at the broad wall of a rectangular waveguide, which included a cross-slot and a circular slot, was designed and the specific structure and dimensions were provided. The circularly polarized waveguide cross-slot radiator discussed in this paper was simulated by using the full wave electromagnetic simulation software. The voltage standing wave ratio (VSWR) was lower than 1.2 within the frequency range of from 7.5GHz to 8.5GHz. The simulated axial ratio (AR) at the boresight direction within the discussed frequency range was lower than 3dB. The design and simulation results of circularly polarized waveguide cross-slot radiator in this paper can provide a reference for the practical engineering application.

Introduction

In many radar and communication systems, the circularly polarized (CP) antennas are usually employed due to their good performances [1-5]. In satellite and ground station, CP can avoid the Faraday rotation effect. What's more, the CP antenna has the advantages of restraining interference from rain and fog, suppressing multipath effect. By now, a lot of kinds of CP antennas have been invented and applied the practical engineering. Because the circularly polarized slotted waveguide antennas have high efficiency in high gain and high frequency range, they are widely used for small earth stations in satellite communications and direct broadcasting from satellite (DBS) and so on. The radiation principle of waveguide slot radiator has been researched for many years and a lot of waveguide slot antennas have been designed. In the reference [5], a new design-ideal a type of composite antenna of waveguide cross-slot array is proposed and used as data transmission antenna on remote sensing satellites at low earth orbit, instead of the shaped reflector. The outstanding advantage is to leaves more space on the plane toward the earth for other remote sensing devices due to its compact structure and small size. In the reference [6], the design of a novel Ku-band circular-polarized and beam-shaped planer antenna array was presented, the open quadr-ridged waveguide fed by straight slots cutting in broad wall of rectangular waveguide was used to attain circular-polarization. In the reference [7], a design procedure for circularly polarized waveguide slot linear arrays is presented. The array element, a circularly polarized radiator, consists of two closely spaced inclined radiating slots. In the reference [8], a new waveguide slot configuration able to radiate a circular polarization with a very low axial ratio was presented, and the proposed configuration consists of two very closely spaced radiating slots. Both left-hand and right-hand circular polarization can be independently obtained. In this paper, a circularly polarized waveguide slot radiator was simulated and its radiation performances were analyzed. The discussed frequency range was from 7.5GHz to 8GHz. The structure and radiation performances of the proposed composite waveguide slot radiator were provided.

Radiation principle and structure of the waveguide cross slot radiator

According to the principle of waveguide slot antenna, a pair of crossed slots cut into the broad wall of a rectangular waveguide at the proper spot can radiate circularly polarized electromagnetic wave. The equations for the transverse and longitudinal magnetic fields of the dominant mode (TE_{10} mode) in the rectangular waveguide can be expressed by:

$$H_z = H_0 \cos\left(\frac{\pi x}{a}\right) \tag{1}$$

$$H_x = jH_0\left[\sqrt{\left(\frac{2a}{\lambda}\right)^2 - 1}\right]\sin\left(\frac{\pi x}{a}\right) \tag{2}$$

Where H_x is the transverse magnetic-field intensity, H_z is the longitudinal magnetic field intensity, H_0 is a constant, λ is the free-space wavelength, a is tthe waveguide width, and x is the transverse coordinate. There are two values of x which satisfy $|H_z| = |H_x|$.These points can be expressed by

$$x = \frac{a}{\pi} c\tan^{-1}\left(\pm\sqrt{\left(\frac{2a}{\lambda}\right)^2 - 1}\right) \tag{3}$$

The cross-slot located the above positions can radiate circularly polarized electromagnetic wave. In this paper, a composite slot located at the broad wall of a rectangular waveguide was discussed. The composite slot consisted of a cross slot and a circular slot at the center of the cross slot. The discussed frequency range was 7.5GHz to 8.5 GHz. The slot dimension was calculated and optimized in order to realize circular polarized radiation. Fig.1 showed the simulation model of designed composite slot radiator. The width and height of rectangular waveguide were 25.9 millimeters and 12.95 millimeters, respectively. The width and length of the cross slot were 4 millimeters and 14 millimeters. The radius R2 was 2 millimeters. The diameter of circular slot at the center of cross slot was 8 millimeters. The dimension of designed composite waveguide slot radiator was shown in Fig.2.

Fig.1 The model of designed composite waveguide slot radiator

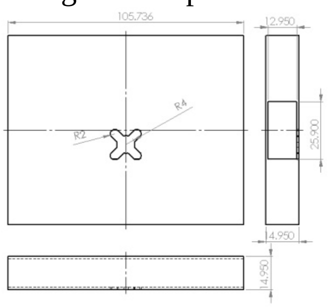


Fig.2: The dimension of designed composite waveguide slot radiator

Performance Simulation and Analysis

The discussed composite waveguide slot with circular polarization was simulated and optimized by using electromagnetic simulation software CST. The specific simulation results were provided in this section. Fig.3 showed the simulated VSWR of the composite waveguide slot radiator. The simulated VSWR was lower than 1.2 within the frequency range between 7.5GHz and 8. 5GHz, so good patching performance was achieved.

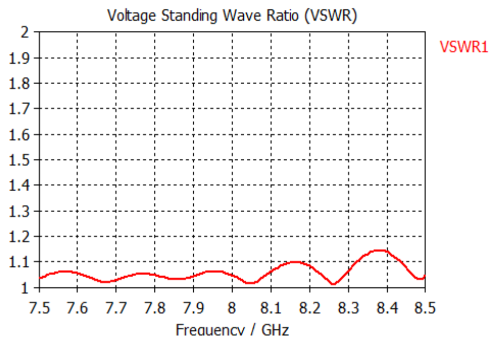
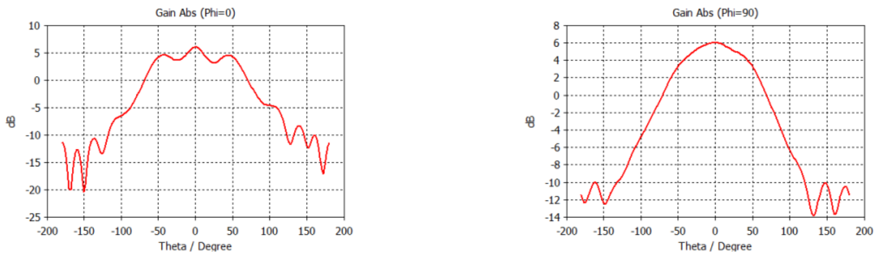


Fig.3: The simulated VSWR of the composite waveguide slot radiator

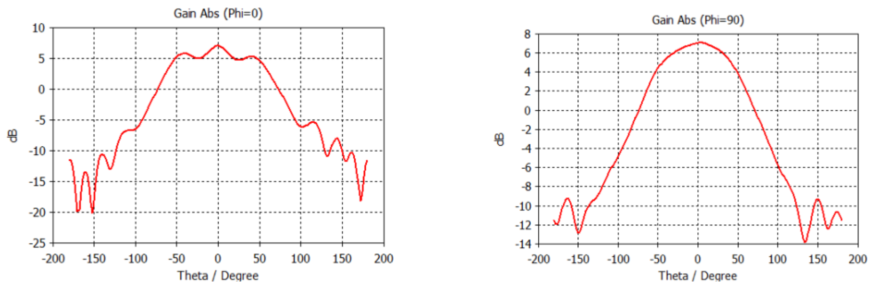
In this section, the radiation patterns of the composite waveguide slot radiator were given and discussed. The discussed frequency range was from 7.5GHz to 8.5GHz. The simulated results of radiation patterns at 7.5GHz were shown in Fig.4. Fig.4 (a) and Fig.4 (b) were the Gain patterns at *xoz* plane and *yoz* plane, respectively. The Gain of the composite waveguide slot radiator was about 6.0dBi, and the half power beam widths at *xoz* plane and *yoz* plane were 115 degree and 103.7 degree, respectively. The side lobe levels of the composite waveguide slot radiator at *xoz* plane and *yoz* plane were about -14.3dB and -16dB, respectively. The observed AR at the boresight direction for the frequency of 7.5GHz was about 2.08dB, so the circularly polarized radiation performance was realized.



(a)Pattern at *xoz* plane (b) Pattern at *yoz* plane

Fig.5 The simulated results of radiation patterns at 7.5GHz

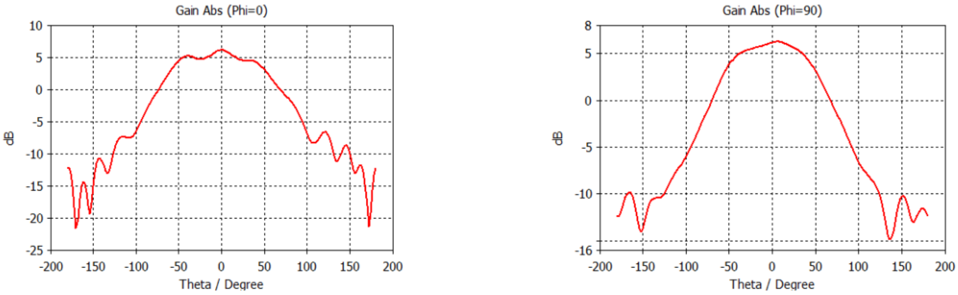
The simulated results of radiation patterns at 8GHz were shown in Fig.6. The Gain of the composite waveguide slot radiator at 8GHz was about 7.0dBi, and the half power beam widths at *xoz* plane and *yoz* plane were 110.8 degree and 101 degree, respectively. For this frequency, the side lobe levels of the composite waveguide slot radiator at *xoz* plane and *yoz* plane were about -12.4dB and -16.3dB, respectively. The observed AR at the boresight direction for the frequency of 8GHz was about 2.59dB, which indicated the circularly polarized radiation performance was also achieved at the center frequency.



(a)Pattern at *xoz* plane (b) Pattern at *yoz* plane

Fig.6 The simulated results of radiation patterns at 8GHz

The simulated results of radiation patterns at 8.5GHz were shown in Fig.7. The Gain of the composite waveguide slot radiator at 8.5GHz was about 6.8dBi, and the half power beam widths at *xoz* plane and *yoz* plane were 107.7 degree and 102.8 degree, respectively. For this frequency, the side lobe levels of the composite waveguide slot radiator at *xoz* plane and *yoz* plane were about -12.8dB and -16dB, respectively. The observed AR at the boresight direction for the frequency of 8.5GHz was about 2.68dB, and it can be seen that the AR satisfied the circularly polarized requirement. According to simulation results, the observed gains and radiation patterns were basically constant for the frequency range from 7.5GHz to 8.5GHz.



(a)Pattern at *xoz* plane (b) Pattern at *yoz* plane

Fig.7 The simulated results of radiation patterns at 8.5GHz

Conclusions

A circularly polarized waveguide cross-slot radiator was simulated and analyzed by using the electromagnetic simulation software in this paper. Based on the radiation principle of traditional waveguide cross-slot radiator, this paper introduced a circular slot at the center of traditional cross-slot, which was a composite cross-slot radiator. The specific structure of composite waveguide slot radiator was simulated and its parameters were determined by optimization. The simulation results indicated that the composite waveguide slot radiator can radiate circularly polarized electromagnetic wave within the discussed frequency range from 7.5GHz to 8.5GHz. At the same time, the wide beam width and low AR were observed for the discussed waveguide slot radiator in this paper, so it is suitable for several practical applications.

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