Post-Wall Waveguide Circuit Consisting of π-junctions for a Center-Feed Parallel Plate Slot Array

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Abstract

The center-feed structure is applied to the post-wall waveguide fed parallel plate slot array to widen the frequency bandwidth. The center-feed antenna has a blocking area at its center. This blocking makes the sidelobe level high in the E-plane, therefore the width of the blocking area should be reduced. The authors propose a novel center-feed waveguide consisting of π-junctions for this reduction. This structure can make the blocking width reduced from 2.6 λ_0 *to 2.1* λ_0*. The measured sidelobe level in the E-plane of the novel feed using π-junctions is suppressed down to –9.4 dB while that of the conventional feed using cross-junctions is –7.8 dB in uniformly excited antennas.*

1. INTRODUCTION

A post-wall waveguide-fed parallel plate slot array shown in Fig.1 is one of attractive candidates for high efficiency and mass producible planar array antennas in millimeter wave applications [1]-[3]. The frequency bandwidth becomes narrow due to the long line effect when the number of slots increases, as is often the case with a series-fed array antenna. The main beam direction is squinted when the frequency is shifted from a design one. The authors apply a center-feed structure developed for a single layer waveguide slot array [4] for reducing the long line effect to the post-wall waveguide-fed parallel plate slot array as well, as shown in Fig.2. Two subarrays of slots are arranged on both sides of the feed waveguide. A quasi-TEM wave is excited in each subarray through the coupling windows. The length of the radiating waveguide in the center-feed antenna is halved in comparison with that of the end-feed one. The symmetrical structure of the array can keep the main beam at the boresight against frequency change. The center-feed antenna has a blocking area without slots at its center. This blocking area makes the sidelobe level high in the E-plane, therefore the width of the blocking area should be reduced for suppressing the sidelobe.
We proposed a center-feed structure using cross-junctions. The measured sidelobe level in the E-plane of the uniformly excited antenna with feed using cross-junctions is –7.8 dB. In this paper, the authors propose a novel post-wall center-feed circuit consisting of π-junctions for reducing the width of the blocking. This circuit can make the blocking width reduced from 2.6 λ_0 to 2.1 λ_0. The measured sidelobe level in the E-plane of the proposed feed is suppressed down to –9.4 dB

2. STRUCTURE

Fig.3 shows the structure of a conventional center-feed waveguide consisting of cross-junctions. Coupling windows are placed with a spacing of the guide wavelength in the feed waveguide to be excited in phase. One subarray of slots should have a longer distance by half wavelength from the feed waveguide than the other in order to have the same direction of polarization between the two subarrays for boresight radiation. This makes the blocking large. We propose a novel center-feed waveguide consisting of π-junctions for reduction of a blocking width. The feed waveguide is a cascade of the π-junctions as shown in Fig.4. The spacing of the coupling windows is a half guide wavelength in the feed waveguide. The upper and lower coupling windows are excited in alternating phase. Both subarrays of slots can be placed at equal distances from the feed waveguide for boresight radiation. The width of the blocking area is reduced from 2.6 λ_0 to 2.1 λ_0, and lower sidelobe level in the E-plane than the cross-junction type is expected. The upper sub-array of slots is shifted from the lower one in the horizontal direction by a half guide wavelength of the feed waveguide as shown in Fig.4.

3. ANALYSIS MODEL AND DESIGN

Fig.5 shows an analysis model of the π-junction. Taking into account the periodicity of the structure and the field in the parallel plate waveguide, we adopt a unit junction model for design which consists of two periodic boundary walls as shown in Fig.5. The waveguide posts are replaced by perfect electric conductor walls with thickness of the post diameter. A TE_{10} mode is incident from Port 1. The divided power to Port 3 is controlled by the width w of the coupling window, while the reflection to Port 1 is minimized by the position (p,

q) of the reflection canceling post. Fig.6 shows the parameters designed for a cascade of 16 junctions at 61.25 GHz. The junctions are numbered from the termination to the input port. When the junction gets closer to the termination, the width w of the coupling window increases and the transverse position p of the reflection canceling post shifts the center of the feed waveguide so that the divided power to Port 3 becomes larger.

4. MODEL ANTENNA AND EXPERIMENTAL RESULTS

Fig.7 shows the picture of the fabricated antenna. The feed waveguide and the slot array are designed to get uniform aperture distribution at 61.25 GHz. The substrate is made of PTFE. The dielectric constant is 2.17. The height of the substrate is 1.2 mm. The aperture size is 81 mm × 85 mm ($16.5\ \lambda_0 \times 17.4\ \lambda_0$). The antenna has a blocking area at its center. The width of the blocking area of the π-junction type is 10.6 mm ($2.1\ \lambda_0$), while that of the cross-junction type is 13.0 mm ($2.6\ \lambda_0$). Fig.8 shows the frequency dependence of the overall reflection at the input port. The reflection is −7.1 dB (20 %) at 61.25 GHz. This reflection loss for the gain is estimated to be about −1.0 dB (100 %–20 %=80 %). The measured aperture distribution at 61.25GHz is shown in Fig.9. The amplitude is weak over the blocking area, because there are no slots. 60-deg. phase error is observed in the direction parallel to the feed waveguide, while the amplitude is almost uniform in this direction. Fig.10 shows the frequency characteristics of the gain. The result of the conventional end-feed type is included for the comparison. The aperture size of the conventional end-feed antenna is 80 mm × 80 mm ($16.3\ \lambda_0 \times 16.3\ \lambda_0$) as shown in Fig.11. The peak of the measured antenna gain is 31.9 dBi at 61.5 GHz. The efficiency is 42.3 % for the aperture size including the blocking area. The bandwidth for 1 dB gain reduction is 1.3 times as wide as that of the conventional end-feed type due to the reduction of a long line effect. The measured radiation pattern in the E-plane of the π-junction type antenna is shown in Fig.12. The result of the cross-junction type is also included for the comparison. The sidelobe level in the E-plane of the π-junction type is −9.4 dB while that of the cross-junction type is −7.8 dB.

5. CONCLUSION

We have proposed a post-wall waveguide circuit consisting of π-junctions for center-feed of a parallel plate slot array antenna for reduction of the blocking area. The width of the blocking area of the π-junction type is less than that of the cross-junction type by $0.5\ \lambda_0$. We have designed and fabricated an antenna with uniform distribution at 61.25 GHz. The bandwidth with gain reduction of 1 dB is 1.3 times as wide as that of conventional end-feed type. The sidelobe level in the E-plane of the π-junction type is suppressed down to −9.4 dB while that of the cross-junction type is −7.8 dB.

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[4] S.H. Park, J. Hirokawa and M. Ando, “A planer cross-junction power divider for the center feed in single-layer slotted waveguide arrays,” IEICE Trans. Commun., vol.E85, no.11, pp.2476-2481, Nov. 2002.

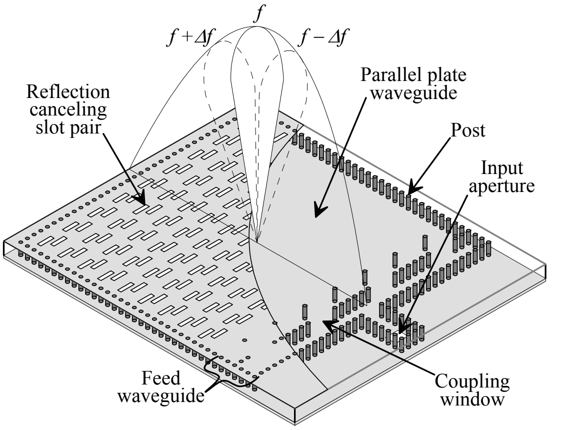


Fig.1: Post-wall waveguide-fed parallel plate slot array

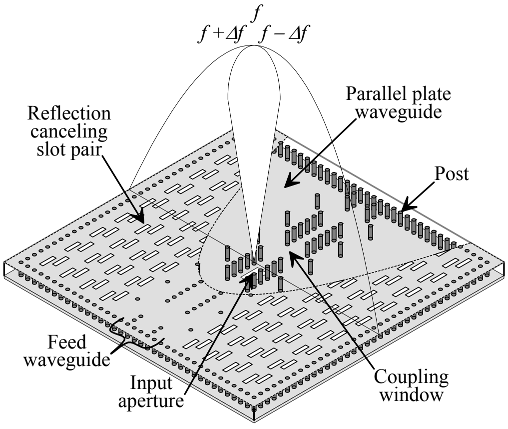


Fig.2: Post-wall waveguide center-fed parallel plate slot array

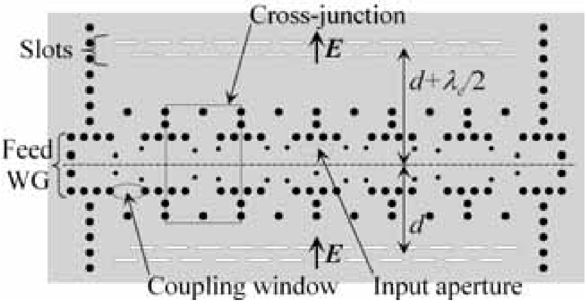


Fig.3: Post-wall center-feed waveguide consisting of cross-junctions

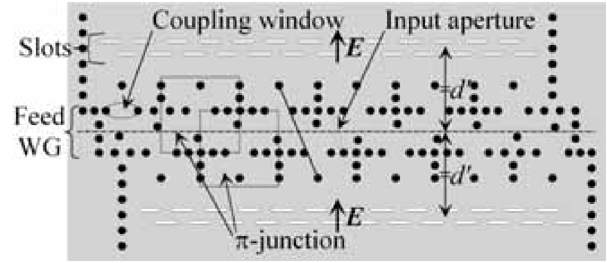


Fig.4: Post-wall center-feed waveguide consisting of π-junctions

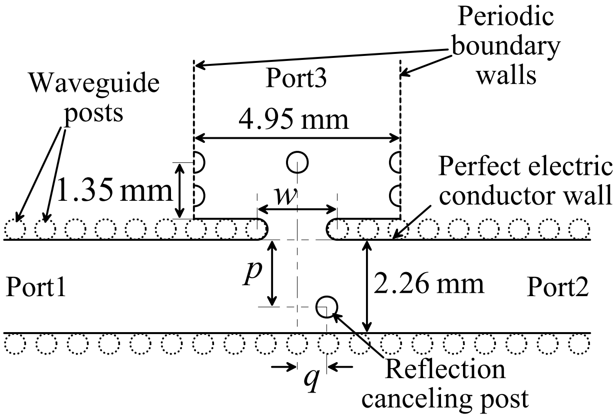


Fig.5: Analysis model of a π-junction

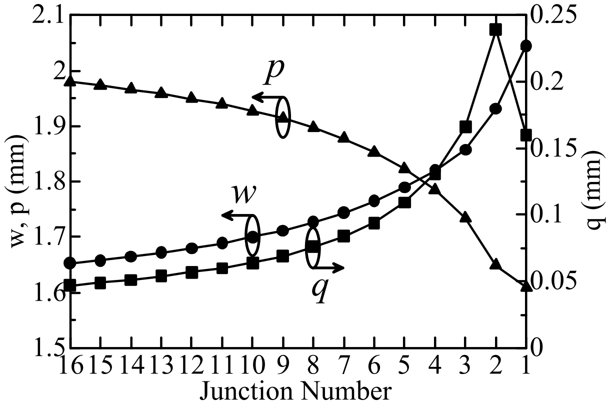


Fig.6: Design result of the π-junctions

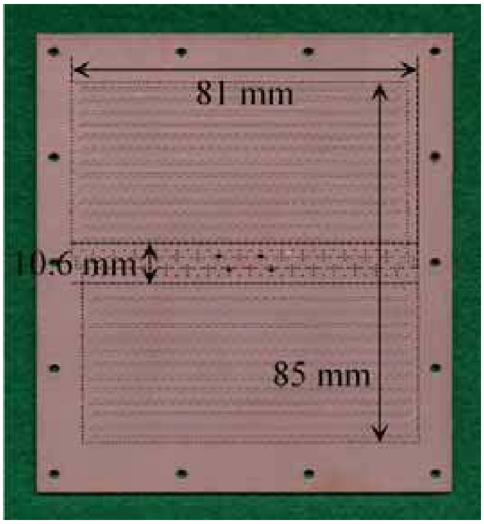


Fig.7: Photo of the center-feed antenna (π-junction type)

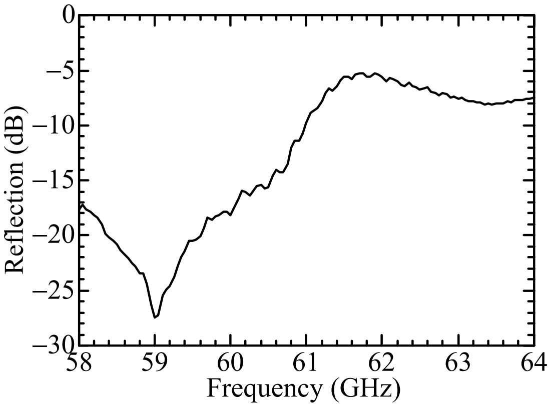
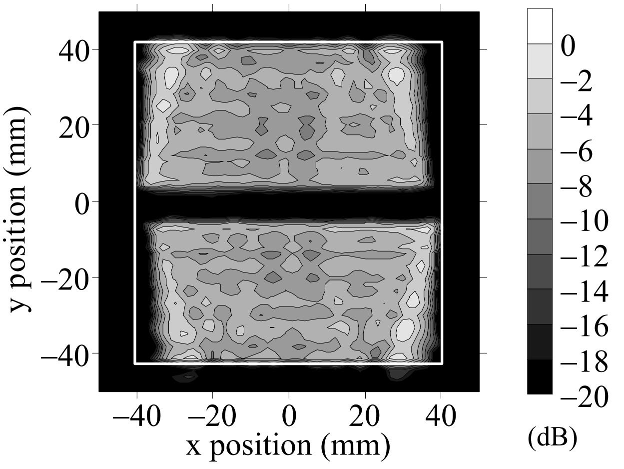
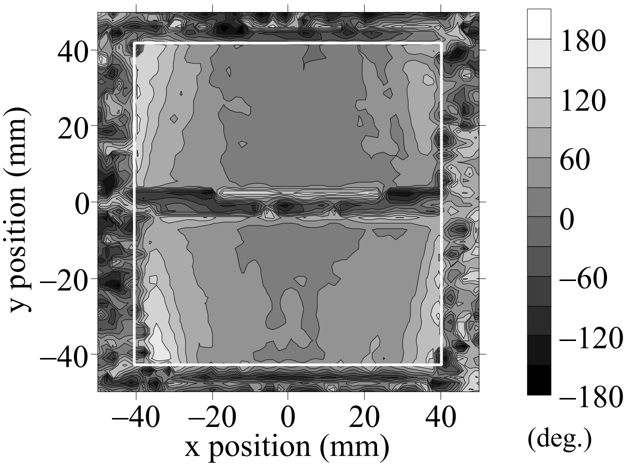


Fig.8: Frequency dependence of reflection



(a) Amplitude



(b) Phase

Fig.9: Aperture distribution (61.25 GHz)

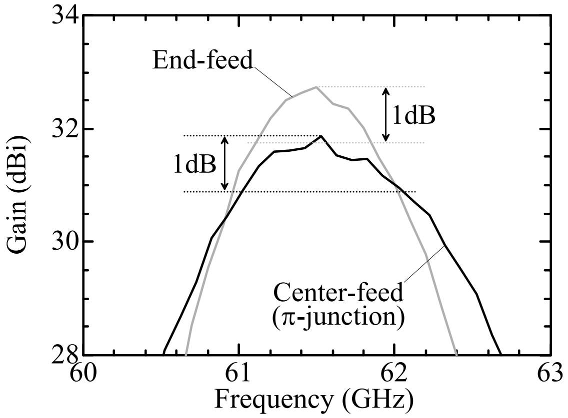


Fig.10: Frequency characteristics of gain

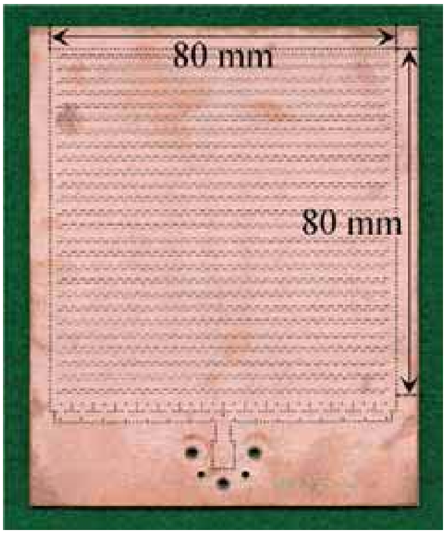


Fig.11: Photo of the conventional end-feed antenna

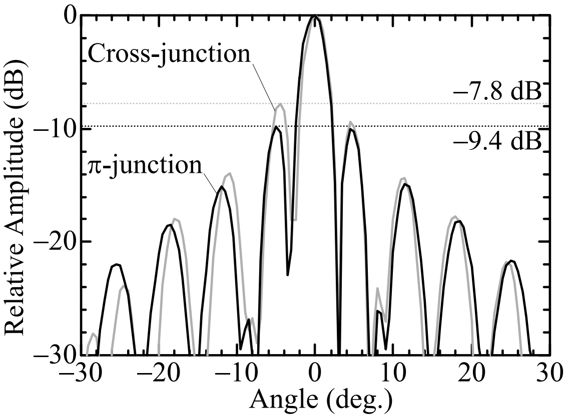


Fig.12: Radiation pattern in the E-plane (61.25 GHz)