# Ridged Cross-Junction Power Divider for the Center Feed in a Single-Layer Slotted Waveguide Array


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**Abstract**

The center feed in a single-layer slotted waveguide array [1,2] is the one of the key component of dual polarization fixed wireless access system. Two center feed single layer slotted waveguide arrays with orthogonal polarization in exactly the same frequency are used for transmission and reception, respectively. Each array has bore sight beam. This antenna has extremely high XPD (almost 50dB in measurement) and high isolation (over 80dB in measurement) between two arrays orthogonally arranged side-by-side. On the other hands, the blocking area at the center of the antenna causes the high sidelobe level. The reducing blocking area is required. The ridged cross-junction power divider is proposed to solve above problem.


## 1. INTRODUCTION

Fixed Wireless Access (FWA) systems in the 26 GHz band have been commercialized in Japan for high-speed Internet connections between subscribers and base stations [3]. Compact and low-cost user terminals are realized by adopting alternating-phase fed single-layer waveguide slot arrays [4].As the unique structure of alternating phase fed arrays, it consists of two parts, a slot plate and a base plate with corrugations screwed to each other as shown in fig.1, which dispenses with electrical contact in the strict sense [5].

To double the frequency efficiency, we have proposed a dual polarization system that utilizes high XPD of slotted waveguide arrays [6]. A single layer slotted waveguide array has been one of the key components in this system, since it has high efficiency and a mass producible structure. This array, in its original form, has the cascaded feed at one end of the aperture with travelling wave operation. It suffers the frequency dependent beam shift as is usual the case with the travelling wave arrays and brings about the fatal difficulty in dual-polarization FWA systems where a terminal consists of two linearly-polarized arrays arranged orthogonally. To solve this problem, authors have developed H-plane cross-junction multiple way power divider [7] and E- to H-plane cross-junction multiple way power divider [8,9] for feeding the array from the center of the aperture, which still lie in the same layer as the radiating waveguides. The E- to H-plane cross-junction power divider is solved the problem of the blocking area as shown in fig.2. The distance d is the spacing of between the center of the first slots across the cross-junction. But this feed waveguide can not be the axis of symmetry of slot array. So the isolation is almost (60dB) in the case of two array arranged orthogonally side-by side. This system is required higher isolation and the reducing blocking area to decrease sidelobe.

This paper demonstrates the predicted characteristics of a ridged cross-junction and a linear array with this cross-junction. The reflection and the divided power can be designed. The sidelobe is confirmed as the advantage of the feed with ridged cross-junction.

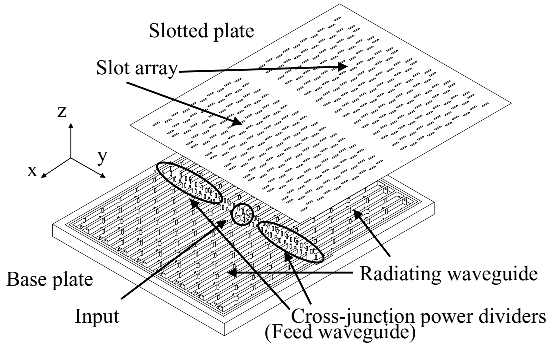
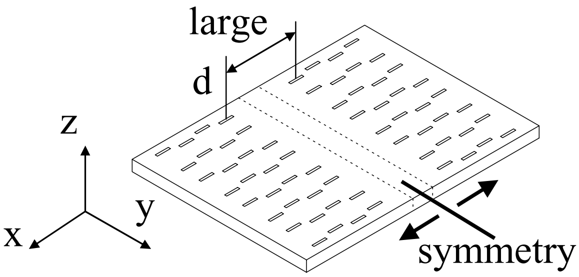
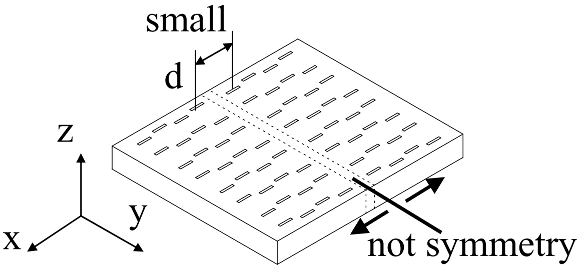


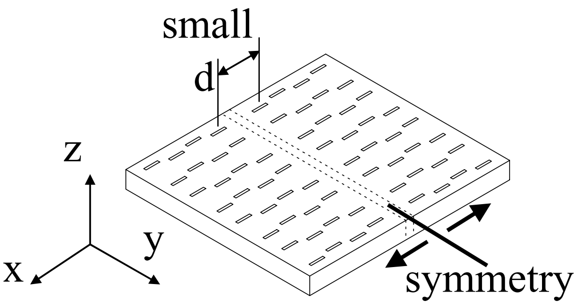

Fig. 1: The structure of the center-feed in a single-layer slotted waveguide array.




(a) The array with H-plane cross-junction power divider.

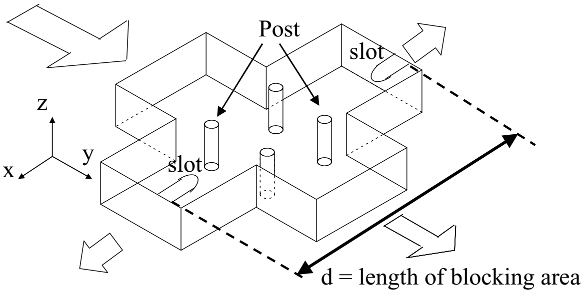



(b) The array with E- to H-plane cross-junction power divider.

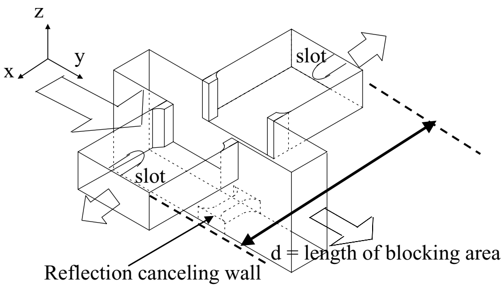



(c) The array with ridged cross-junction power divider.

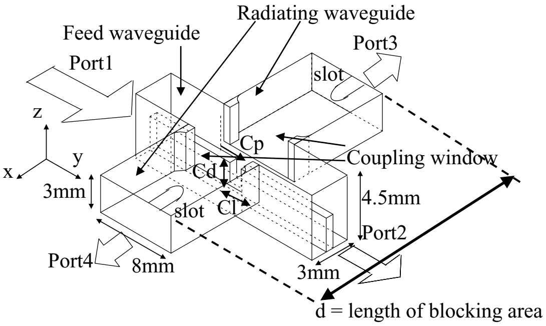
Fig. 2: The difference of the blocking area and symmetry of the slot arrays.




(a) A H-plane cross-junction (conventional)




(b) A E- to H-plane cross-junction (conventional)




(c) A ridged cross-junction (proposed)

Fig. 3: Structure of a cross-junction

## 2. STRUCTURE

Three types of a cross-junction are shown in Fig.3. Fig.3 (a) is a H-plane cross-junction. The cross-junction has four inductive posts to control division to two radiating waveguides and to suppress the reflection. The broad wall of the feed waveguide is set 9.0mm so that the spacing of the radiating waveguide is an half of the guided wavelength of the feed waveguide. This model realizes the center-feed in a single-layer slotted waveguide array. Though, the blocking area of the antenna aperture is relatively large ($2.1\lambda$). This space causes the high sidelobe in H-plane radiation pattern and the aperture efficiency degradation.

To suppress a blockage in the antenna aperture, a novel unit structure of the E- to H-plane cross-junction is proposed in Fig.3 (b). The narrow wall of the feed waveguide is embedded on the top instead of the broad wall in the conventional H-plane cross-junction, in order to reduce the blocking area of the slot array in Fig.2 (b). A unit cross-junction has a wall at the bottom of the feed waveguide to suppress the reflection and two windows to control division to two radiating waveguides. The division is controlled by the width of the coupling windows. The reflection is controlled by the height of the wall and its position from the center of the cross-junction. The wall and the windows can be fabricated with the grooved feed waveguide simultaneously. It is suppressed below -30dB at 25.3GHz in the design. The broad wall of the feed waveguide is set 7.2mm so that the spacing of the radiating waveguide is an half of the guided wavelength of the feed waveguide. The narrow–wall width of the feed waveguide is chosen 3.6mm, which is an half of the broad–wall width. This model can reduce the blocking area. The sidelobe is achieved less than -13dB and improved antenna efficiency. But the slot array does not symmetry in the center line on the feed waveguide. So this structure cannot obtain high isolation in the case of arranged orthogonally side-by-side. The measured isolation is almost 60dB.

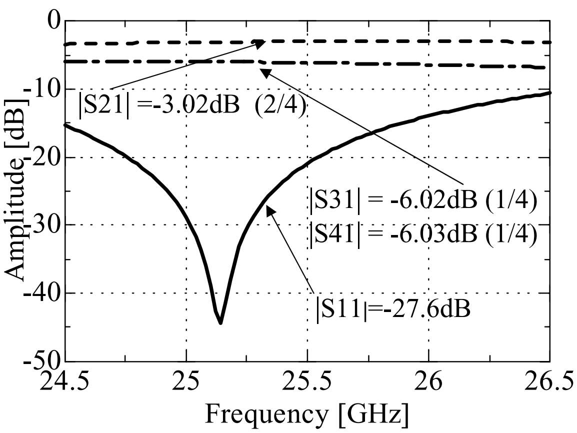
To obtain the high isolation (over 80dB) must need symmetry of slot arrays. So cross-junction is required to distribute the electric field of Ez component in same phase to each radiating waveguides. From this point of view, ridged cross-junction is proposed as shown in fig.3 (c). A unit cross-junction has a ridged structure to reduce the area of the broad wall on the antenna aperture. The structure of the cutting ridge can produce a wave to suppress the reflection from the coupling windows. Two coupling windows control the division to two radiating waveguides. The reflection is controlled by the length Cl of the cutting ridge, the depth Cd of cutting ridge, and its position Cp from the center of the cross-junction. It is suppressed below -30dB at 25.3GHz in the design. The broad wall depth of the feed waveguide is set 4.5mm and height of the ridged structure is set 2.5mm. This model can reduce the blocking area. The symmetry slot array on the axis of feed waveguide is obtained using this cross-junction. And reduce the blocking broad wall area from 9.0mm to 3.0mm compare with conventional H-plane cross-junction.

The distance between first slot and coupling window of cross-junction is also important to reduce blocking area on the aperture. Next we discuss the each power divider distribution characteristics and evaluate the reducing blocking area using the radiation pattern with 10 slots array each radiating waveguides.

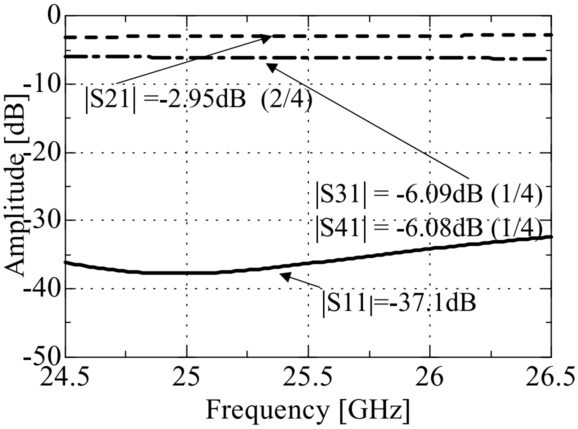
## 3. ANALYSIS

### *A. Characteristics of each Cross-junctions*

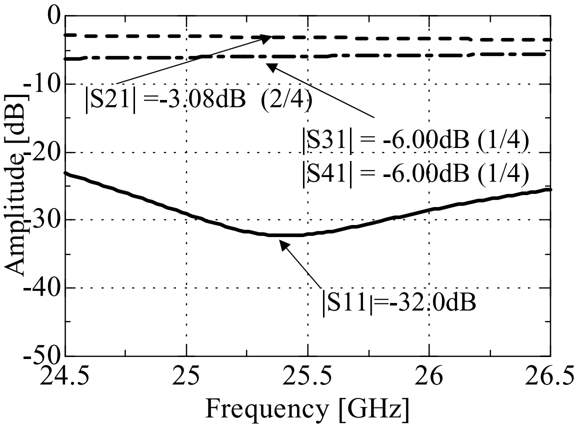
First, we compare the characteristics of each cross-junction . The amplitude of reflection and distribution in each model are shown in Fig.4. Reflection (|S11|), transmission (|S21|, |S31|, |S41|) characteristics are evaluated by the commercial Finite Element Method (FEM) software Ansoft HFSS™ (High-Frequency Structure Simulator). Fig.4 shows the reflection and divided amplitude of the junctions in Fig.3 where the total coupled power to the two radiating waveguides is 50% as an example. The design frequency is 25.3GHz. The reflection cancelling using 4 posts is relatively narrow band in H-plane cross-junction power divider as shown in fig.4 (a). On the other hand, E- to H-plane cross-junction and ridged cross-junction have more wide band characteristics (|S11| is less than -20dB range)




(a) H-plane cross-junction (conventional).




(b) E- to H-plane cross-junction (conventional)




(c) Ridged cross-junction (proposed).
Cl=1.2mm, Cd=1.5mm, Cp=0.8mm.

Fig. 4: The amplitude of reflection and divided power.

*B. Radiation pattern in H-plane (including blocking area)*

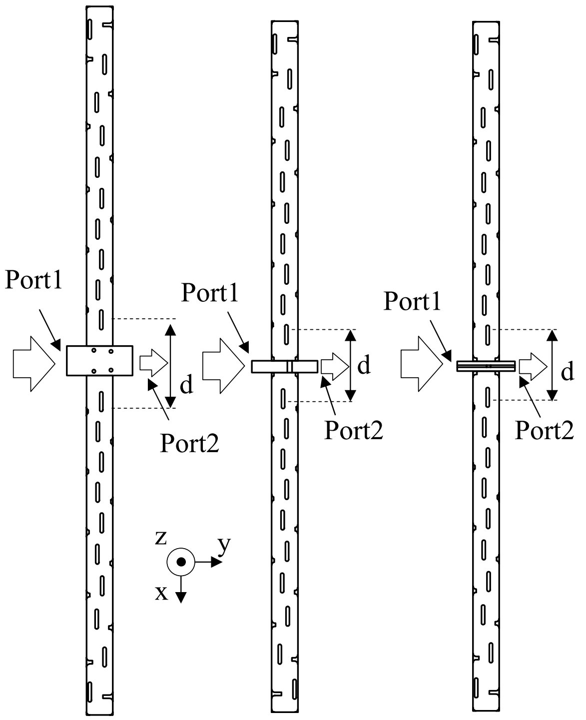
Next, we discuss the effect of reducing the blocking area using proposed model. Each radiating waveguide has 10 slots, each of which with a reflection-canceling side wall as shown in Fig.5. The total number of the slots in the array is 20 (10x2). The slot array is designed to excite uniformly. The design frequency is 25.3GHz.

Fig.6 shows the results of predicted radiation pattern of the H-plane which has blocking area in the center. The predicted radiation pattern, this slot array uses H-plane model, E- to H-plane model, and ridged model, has the first side-lobe level is almost -11dB(d=2.1 $\lambda$ ) as shown in Fig.6(a), -12dB(d=1.7 $\lambda$ ) as shown in Fig.6 (b), and -13dB (d=1.6 $\lambda$ ) as shown in Fig.6 (c) respectively. In first design, each first slot edge is positioned 5.0mm from cross-junction's coupling windows to neglect mutual coupling inner field. The distance between each first slots is important. So, next step the slot array move toward to cross-junction's coupling windows. The H-plane model and ridged model is need 2mm between slot and cross-junction for maintain slot's excitation phase. If the distance is less than 2mm, each first slots is excited different phase. So the first sidelobe is increased. H-plane cross-junction model is achieved only -12dB (d=1.6 $\lambda$ ) as shown in Fig.6 (a). Ridged cross-junction model can be obtained almost -13dB (d=1.1 $\lambda$ ) of uniform amplitude array as shown in fig.6 (c). So this slot array is symmetry in cross-junction, the high isolation will be obtain in the case of orthogonally arranged two slot arrays side-by side. This was improved at a point of the first side-lobe level in comparison with the antenna which uses conventional H-plane cross-junction. E- to H-plane cross-junction model can be obtained less than -13dB (d=1.1 $\lambda$ ) as shown in Fig.6 (b).

This time, slot array only move to cross-junction power divider, in future study the first slot can be revised for exciting phase and amplitude.

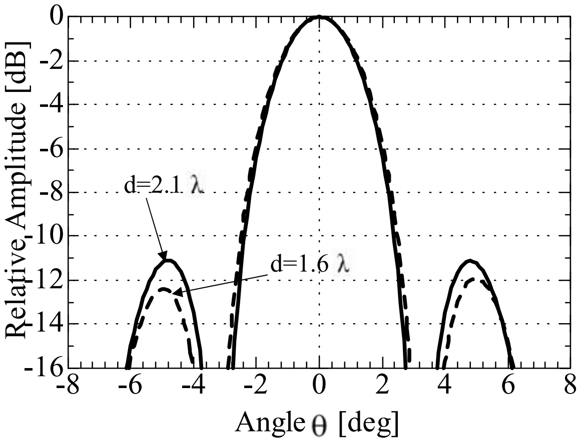
## 4. Conclusion

We have proposed the ridged cross-junction for the feed waveguide in a center-feed single-layer waveguide. This feed waveguide is advantageous in terms of reducing blocking area and symmetry slot array to obtain high isolation. The calculated sidelobe level of the proposed cross-junction is almost -13dB in H-plane at 25.3GHz. Our future study is to array cross-junctions to use planar antenna feed structure.

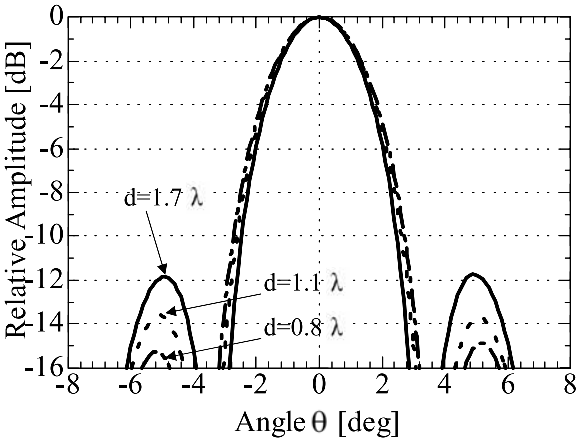



(a) H-plane model (b) E- to H-plane model (c) Ridged model

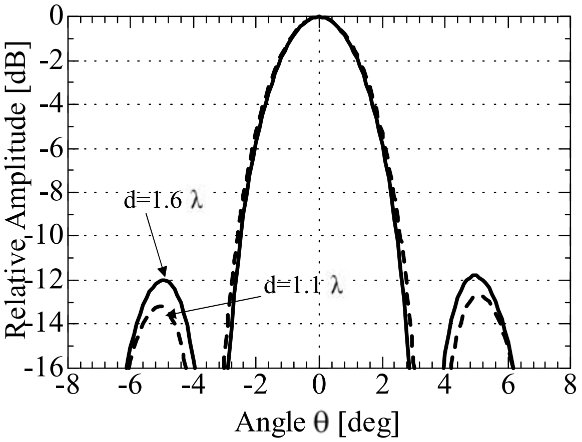
Fig.5 A cross-junction power divider with slot array. The distance d is the spacing of between the center of the first slots across the cross-junction.




(a) Linear array with a H-plane cross-junction




(b) Linear array with an E- to H-plane cross-junction




(c) Linear array with a ridged cross-junction

Fig.6 Radiation pattern in H-plane (ZX-plane).

## ACKNOWLEDGEMENT

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