A Wideband Single-layer Slotted Waveguide Array with an Embedded Partially Corporate Feed

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1. Introduction

Various wireless communication systems for millimetre wave band such as Fixed Wireless Access (FWA) have been developed. An alternating phase fed single-layer slotted waveguide array [1] as shown in Fig.1 consists of only two components, that is the slot plate and the base plate and they can be screwed together. It is one of the strong candidates for these systems because it has high gain, high efficiency and very low cost due to the simple structure. It works in travelling wave operation and the bandwidth is inversely proportional to the length of waveguide. Therefore, there is trade-off between directivity and bandwidth; the system specification can not always be met.

Long line effects should be suppressed in two directions (2D) in the aperture; that is along the directions of the feed waveguide and the radiation waveguide. Partially corporate feeds for 1D suppression introduced in the end feed waveguide have already been reported [2][3]. Our objective is to realize broadband single-layer slotted waveguide arrays by two-dimensionally embedding partially corporate feed in the aperture [4]. Fig.2 (b) shows the structure of partially corporate feed embedded in the aperture. Whole the aperture is divided into 4 units. The number of cascaded cross junctions [5] and the length of radiation waveguide in each unit are reduced to 1/2 and the long line effect is suppressed two-dimensionally.

In this paper, the bandwidth enhancement of the partially corporate feed is assessed in terms of array factor, by using the simplified model of the small dipole element, where the change of guide wavelength is taken into account. No slots are allocated over the embedded partially corporate feed and the blocking effects become notable as the corporate feed become widespread in comparison to the center feed as shown in Fig.2 (a). Large blocking area results in high side-lobe level and gain/efficiency reduction of the array. The basic design critelia for this unique array is proposed taking the blocking effects into account. E-plane coupler with acceptably small blocking width is proposed and the electromagnetic design is conducted [6]. A small array with embedded partially corporate feed is fabricated and the basic operation is verified. The feasibility of partially corporate feed is confirmed [4]. It is our future work to demonstrate the drastic bandwidth enhancement by testing a larger and higher gain arrays.

2. Bandwidth Enhancement of Array Directivity

2.1 Small Dipole Model

Fig.3 shows the approximation models where slots are replaced with small dipole elements. The spacing between small dipoles is set to be d_x=d_y=0.75λ_0. The total number of elements is N^2. The phase error of each element at shifted frequency, which is the long line effects, is given according to the distance from in-phase port of the corporate feed by taking the change of wave length in waveguide into account. The blocking area is defined by additional width Δd along the partially corporate feed as is indicated in the figure.

2.2 Numerical Results

As the first step, the additional distance *Δd* is set to zero the effect of blocking is neglected. The bandwidth enhancement by introducing the partially corporate feed is evaluated. The frequency characteristics of directivity are calculated in Fig.4 for various size of the aperture or the number of elements N^2. For the center feed array, the bandwidth becomes narrower as the gain becomes higher. Therefore, they can not be specified arbitrarily for the center feed single-layer array. For example, 5% bandwidth at 40dBi can never been realized by optimizing the aperture size. Fig.4 also shows the envelope curves which are drawn from sets of directivity curves for various number of element, which indicate the upper limit of the designability. By introducing the partially corporate feed, we can enhance this limit and realize high directivity and wide bandwidth at the same time. For example, the 40dBi-bandwidth of about 2% for the center feed is enhanced to 4% for partially corporate feed.

3. Design of a Partially Corporate Feed and Reduction of Aperture Blocking Effects

In practical implementation, embedding the corporate feed in the aperture of single-layer slotted waveguide array causes the blocking area due to the physical width of the feed structure. The junction between the feed and the radiation waveguide also affects the blocking width [6][7]. We evaluate the degradation due to the additional distance *Δd* by the simplified dipole models. As shown in Fig.5, The efficiency of array with partially corporate feed rapidly decreases as the additional distance *Δd* is larger. Fig.6 summarizes the efficiency degradation as functions of *Δd.* In the conventional H-plane coupler center feed single-layer slotted waveguide array, the additional distance *Δd* is about 0.9 to 1.3 λ_0 [6]. The radiation pattern in H-plane for $\Delta d= 0.9\lambda_0$ is shown in Fig.7 for Corp4. The far sidelobes are growing up and the H-plane coupler can not be used for the partially corporate feed. The degradation of directivity and the increasing sidelobe are confirmed. From Fig.6, we could use the best of the benefit from partially corporate feed if the blocking *Δd* can be less than about $0.3\lambda_0$, which is realized by introducing the E-plane coupler. The narrow wall of the E-plane feed waveguide is embedded on antenna surface and $\Delta d= 0.3\lambda_0$. As shown Fig.8, E-plane T-junction and E to H-plane cross junction are designed by the FEM analysis to this end. It is predicted that the reflection are below -20dB [4][6].

4. Measurement of an Array with an Embedded Partially Corporate Feed

For the confirmation of the basic operation of the array with embedded partially corporate feed, a model antenna is fabricated at 25.0GHz. Because of the easiness for the fabrication, it is relatively small sized and the large bandwidth enhancement is not aimed. The aperture consists of four units. In each unit, the number of the radiating waveguides is 12 and the number of the slots is 4 for each radiation waveguide. The prediction by HFSS and measurement results are compared in Fig.10, 11 and 12. We have good agreements between the measurements and the prediction. The design as well as the concepts in previous sections is confirmed; the partially corporate feed has potentially superior to the center feed for the large and high gain array.

5. Conclusion

A wideband single-layer slotted waveguide array with an embedded partially corporate feed is proposed. The frequency characteristic of directivity of the array using partially corporate feed is calculated by taking the change of the guide wavelength into account. The degradation associated with the increasing aperture blockage over embedded feed is also evaluated. The design criterion of this unique array is established. The feasibility and the reality of the concept are verified by the measurement using a small test array. The partially corporate feed brings the new design freedom for the single layer waveguide arrays in principle, where the antenna gain and the bandwidth can be independently specified.

Acknowledgments

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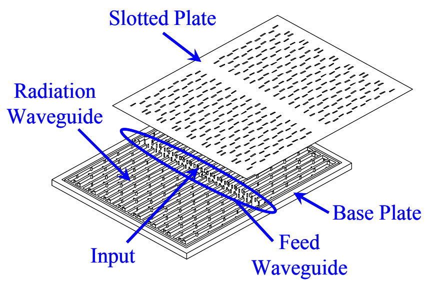
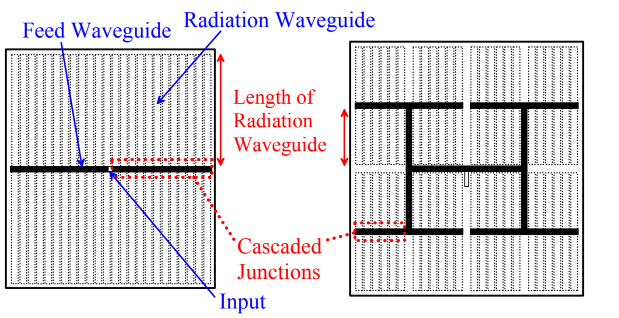
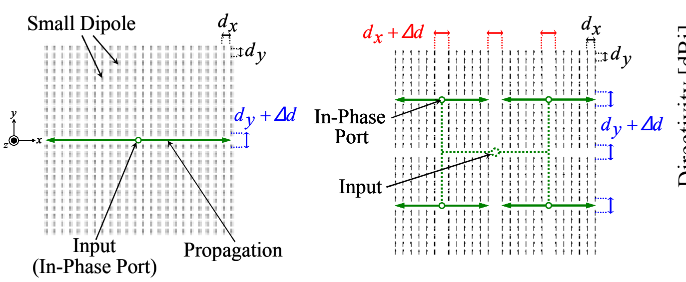


Fig.1 An Alternating Phase Fed Single-layer Slotted Waveguide Array



(a) Center Feed (b) Partially Coporate Feed

Fig.2 Center Feed and Partially Corporate Feed



(a) Center Feed (b) Partially Corporate Feed

Fig.3 Approximation Models for Simplified Calculation

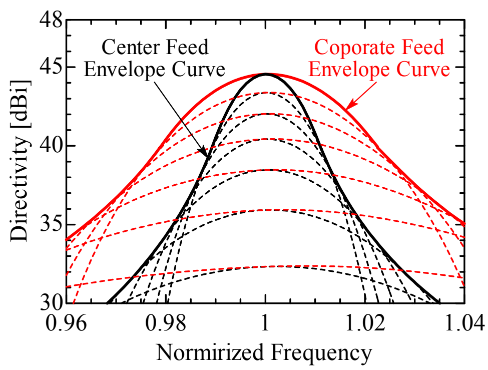


Fig.4 Antenna Directivity vs. Frequency Bandwidth

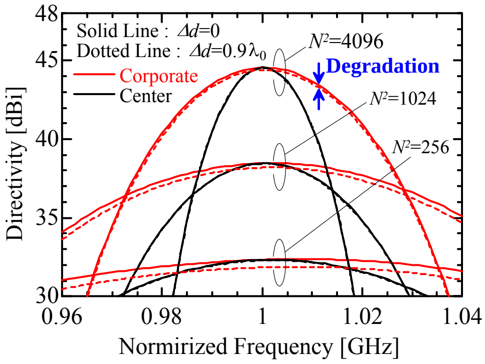


Fig.5 Directivity and Frequecncy Bandwidth

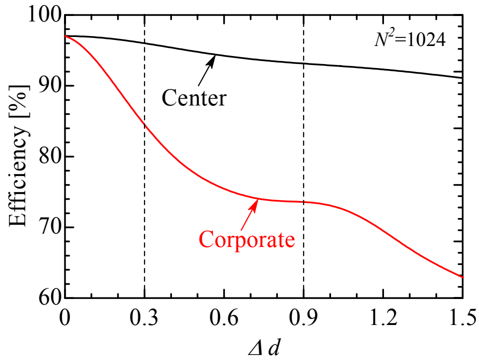


Fig.6 Aperture Efficiency vs. Blocking Width

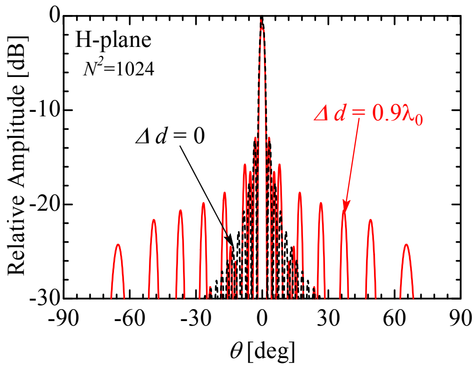


Fig.7 Radiation Pattern (H-plane)

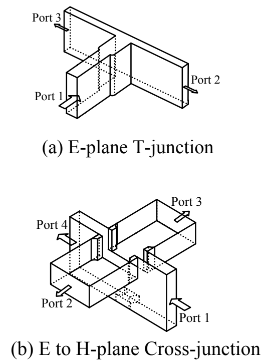
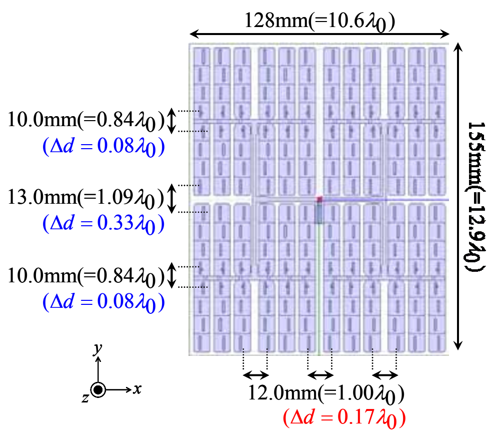


Fig.8 E-to-H plane Coupler and E-Plane Divide



Center Freq. 25.0GHz

Fig.9 Test Antenna

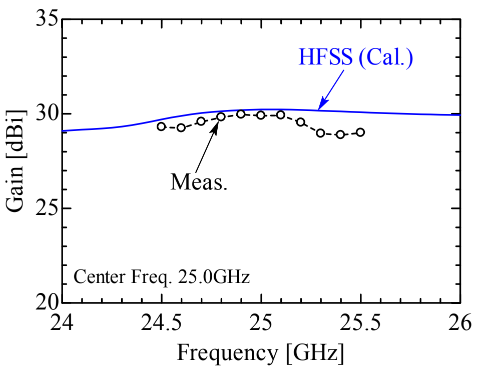


Fig.10 Measured and Predicted Gain

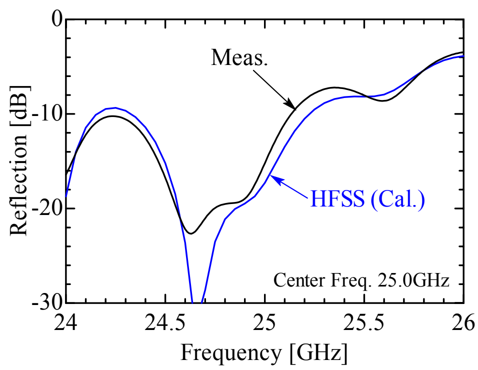


Fig.11 Reflection at Antenna Input

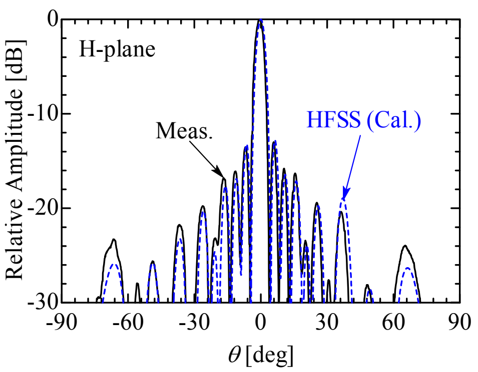


Fig.12 Radiation Pattern (H-plane)