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Reflection Characteristics of Center-Feed Single-Layer Waveguide Arrays

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1. Introduction

Fixed Wireless Access (FWA) system in 26GHz band has been commercialized in Japan. Compact and low cost user terminals are realized by adopting single layer waveguide slots arrays [1]. This unique antenna consists of two parts, that is a slot plate and a base plate with corrugations, which dispenses with electrical contact in strict sense and are simply screwed. Basically, it works in traveling wave operation where all the components such as power dividers and slots, are designed so that the reflection is suppressed in each component. To reduce the inherent beam tilting with frequency change in single layer slotted waveguide arrays, center-feed arrays was proposed recently [2]. Challenges for frequency reuse based upon high polarization purity which is inherent to planar slotted waveguide arrays [2] are now underway using this array. One difficulty in these types of array is the increase of reflection at the input port as the size of the array increases.

In this paper, we discuss the reflection characteristics of large center-feed single-layer waveguide arrays. The FEM analysis by using HFSS is conducted for the whole structure of center-feed waveguide. The predicted reflection shows remarkable agreement with the experiments, though the structure is very large in terms of the wavelength. The reflection from each components, the power divider, the slot waveguide and the aperture at the antenna input, is evaluated and the mechanism of reflection accumulation is discussed. As the number of cross junctions increase, the reflection besides the design frequency grows while the external mutual coupling between slots in adjacent radiation waveguides results in increasing reflection at the design frequency.

2. Reflection in Center-Feed Single-Layer Waveguide Arrays

Fig.1 shows a structure of a center-feed single-layer waveguide arrays. It has 32(=16x2) radiation waveguides. The 32-way power divider at the center of the antenna aperture consists of 16 cross-junctions; 8cross junctions are arrayed in series on each side of the antenna input. One cross-junction has 4 inductive posts and two output port to radiation waveguides [3][4]. One radiation waveguide has 10 slots, each with reflection canceling sidewalls; total slots in the array is 320(10x32). Each antenna element is analyzed and designed by method of moment [5][6]. The test antenna is fabricated at 26GHz band for FWA system as shown in Fig.2, with the center frequency at 25.3GHz. This large scale structure is drawn in detail in FEM. A quarter of the structure is modeled taking the symmetry into account. The size of the mesh is 66951 tetrahedra. The measured and simulated reflection, defined at the input waveguide connected to the array via input aperture, is compared in Fig. 3. The reflection is suppressed at a little bit higher frequency of 25.6GHz. The reflection at the design frequency is about –10dB and is not sufficiently low. The agreement of the prediction and the measurement is noteworthy for such an electrically large structure. It assures the high accuracy in fabrication and the stable operation with the simple contact by screws.

Anyway, for reduction of antenna overall reflection at the input, we have to identify the locations which cause reflection. A large variety of models such as the antenna input aperture, a set of cross junctions, a power divider and radiating waveguides with different number of slots etc., are simulated.

At first, we investigated the reflection from the antenna input aperture as the interface to the standard waveguide. Local structure including the antenna input aperture on the backside of the base plate is three-dimensional as is shown in Fig.4(a). The simulation shows that the reflection from the aperture (length=5.9mm) is negligible in Fig.5 at the design frequency. Then as the remaining two parts are also investigated, that is the series of cross-junction (power divider) as in Fig.4 (b) and linear slot array as in Fig.4 (c). In Fig.5, the predicted reflection is well suppressed for 16-way power divider and a 10-slot linear array in isolated environment, at design frequency. The accumulation of reflection, as the number of waveguides increases, is demonstrated for various length of series of cross junction in Fig.6. Fig.7 shows that the reflection of –20dB for 3-way (one cross junction) is accumulated up to –10dB for 15-way (7 cross Junctions), except at the design frequency where all junctions are designed to be almost reflection-free. These confirm the successful MoM design of these components for reflection suppression at the design frequency, though they are a bit narrow banded.

Now, we discuss the degradation of reflection at the design frequency as is shown in Fig.3, when these parts are combined.

3. Reflection due to mutual coupling

The degradation of reflection at the design frequency from that in Fig.5 to that in Fig.3 remains unidentified thus far. The mutual coupling between slots via external region is discussed. Since the mutual coupling in a linear array was already assessed, the coupling between adjacent radiation waveguide is focused upon. In order to evaluate accumulation of reflection due to external mutual coupling, we analyzed the models (a), (b) and (c) for 1, 5 and 10(full) slots per waveguide respectively, as are shown in Fig.8. The end of radiation waveguides are terminated by matched load in case of the models (a) and (b) in Fig.8. The antenna overall reflection is given in Fig.9 as a function of a number of slot and radiation waveguide. To extract the coupling from slots in neighboring waveguides, we impose the absorbing boundary above each radiation waveguide as is shown in Fig.8 (d). Reflection of analysis model Fig.8 (d) which excludes mutual coupling is well suppressed at design frequency 25.3 GHz. On the other hand, reflection for the model Fig.8 (a), (b) and (c) are suffering from the increase of reflection as the number of slots increases. It is observed that the mutual coupling in the first few slots in the radiation waveguides are dominant and that in the slots near the waveguide terminal are not so important. If we compare these results with the reflection of a linear array in Fig.5, the accumulation of reflection with the number of radiation waveguide is observed but the reflection at the design frequency remain excellent. So, we may conclude that the reflection from external mutual coupling between adjacent waveguide causes the high reflection especially at the design frequency. It should be taken into account in slot array design in the future.

4. Antenna Gain

The antenna directive gain derived from the near field measurement data are presented in Fig. 10. As is usual the case with the narrow band antennas, the overall reflection at the design frequency may be improved by the modification of parts at the antenna input. So we modify length of antenna input aperture from 5.9mm to 5.0mm. The test antenna with modified length of antenna input aperture is fabricated. Fig.11 shows a comparison between experimental result and FEM analysis for overall structure. Two results have reasonable agreement and the reflection characteristics are slightly improved, though the overall revel of reflection is around –10dB and the reflection at 25.3GHz is not sufficiently low. The amplitude distribution of E-field over a two dimensional aperture is measured for this improved model. The antenna directive gain is calculated as well by using the near field measurement data. The change of the input aperture slightly affects the aperture illumination and the gain is also increased about 0.5 dBi as shown in Fig.10. For wider band width, this method is not effective and each component of reflection should be suppressed, which includes the mutual effects of slots.

5. Conclusion

We discussed reflection characteristics of center-feed single-layer waveguide arrays. Key components for narrow banded reflection are identified as (1) the cumulative reflection from multiple-way power divider beside the design frequency, and (2) the external mutual coupling of slots near the feed waveguide. The way out of these difficulties must be developed in the future design of wideband waveguide antenna.

Reference

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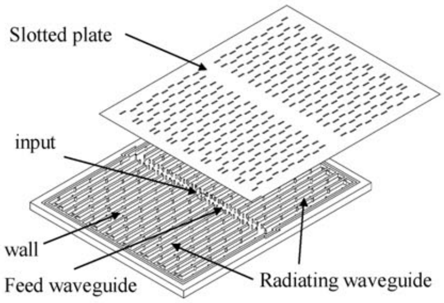


Fig.1: Structure of center-feed single-layer waveguide arrays.

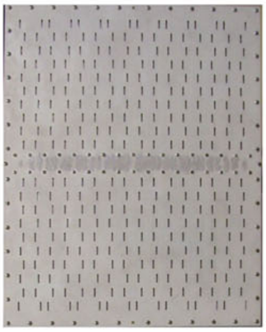


Fig.2: Photograph of fabricated antenna.

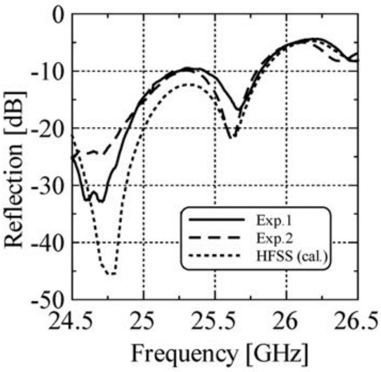
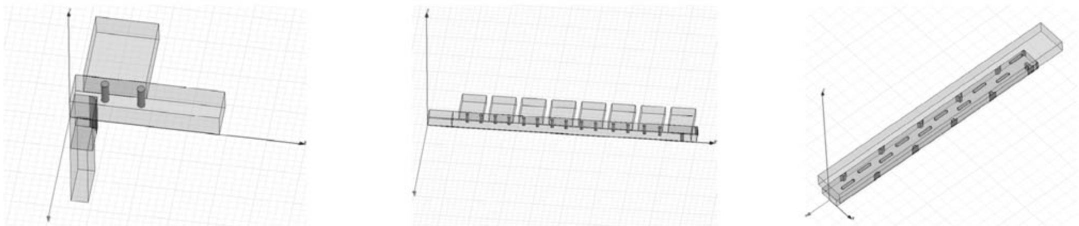


Fig.3: Overall reflection (length of antenna input aperture:5.9mm)



(a) antenna input aperture.

(b) 16-way power divider.

(c) slots array.

Fig.4: Various models for simulation.

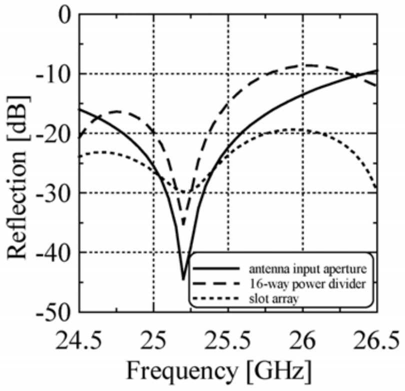


Fig.5: Reflection
for various models.

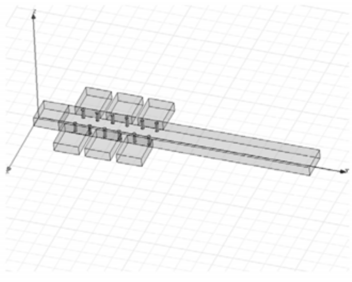


Fig.6: 7-way power divider model

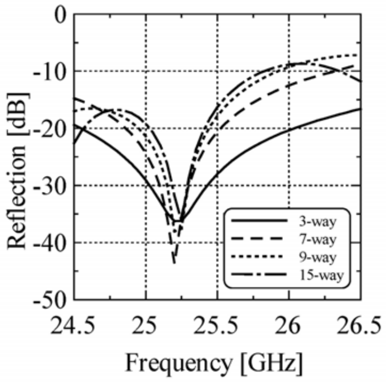
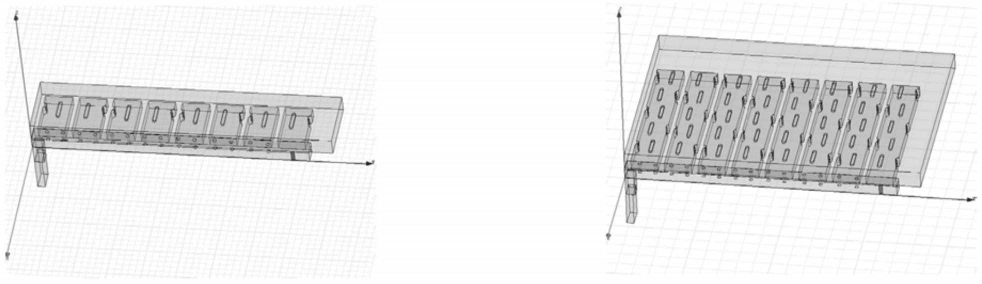


Fig.7: Accumulation of reflection
with the number of division. (cal.)



(a) Slot array with one slot for radiation waveguide. (total number of slots 8 x 4)

(b) Slot array with five slots for radiation waveguide. (total number of slots 40 x 4)

(c) Slot array with ten slots for radiation waveguide. (total number of slots 80 x 4)

(d) Slot array with ten slots for radiation waveguide. (without mutual coupling)

Fig.8: Various models for external slot coupling simulation.

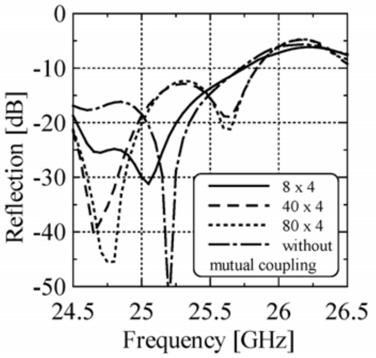


Fig.9: Reflection
as function of number of slot. (cal.)

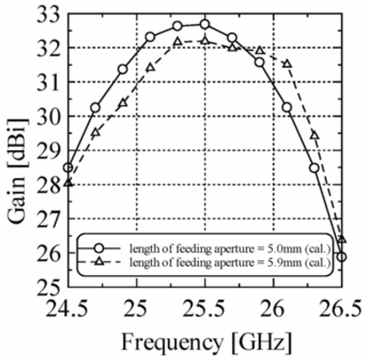


Fig.10: Directive Gain. (cal.)

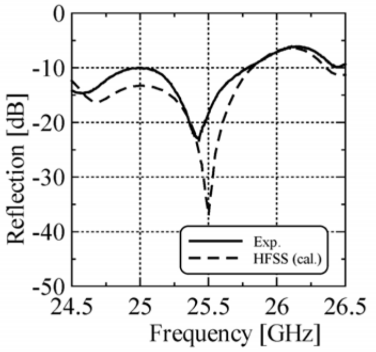


Fig.11: Overall reflection.
(length of antenna input aperture:5.0mm)