Feeding Structure to Widen Bandwidth for Dual-polarization Corporate-feed Waveguide Slot Array Antenna

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Abstract

We introduce a new feeding structure having wide bandwidth for the dual-polarization operation in the corporate-feed waveguide slot array antenna in the 60GHz band. The reflections at the two input ports have about 7% at VSWR 1.5:1. The isolation between the two ports shows -30 dB.

Keywords : Dual polarization, Full-corporate Feeding, Multi-Layer Waveguide

1. Introduction

In the area of milli-meter wave antennas, the waveguide slot array antenna, which has advantages of low profile, low cross-polarization level and very low transmission loss, is widely employed. However, the waveguide slot array antenna has disadvantages of narrow bandwidth and beam squint in series feeding of the elements. A double-layer corporate-feed waveguide slot array antenna [1], where the feeding circuit is located in the bottom layer underneath the radiating waveguides in the top layer, has been developed for wideband operation and to avoid the beam squint. To realize the double-layer structure, we have introduce a new fabrication method called 'diffusion bonding of laminated thin metal plates' [1, 2]. The diffusion bonding method provides a high degree of accuracy and mass productivity with low cost. In addition, we can easily realize multi-layer structure using this method. A 16x16 element array designed and fabricated in 60 GHz band achieves a high gain of 32 dBi as well as a wide bandwidth of 8 % for the high antenna efficiency of more than 80 %.

On the other hand, the waveguide slot array antenna is also characterized as less flexibility in the dual-polarization operation. There are only a few previous researches on the dual-polarization of the waveguide slot array antenna. In most previous works [3, 4], the sub-arrays with orthogonal linear polarizations are interlaced side by side. The development of dual-polarized radiating elements in common as well as corresponding exciting networks is awaited to enhance the aperture efficiency by twice. Moreover, a wider bandwidth in the feeding circuit rather than the simple series feed also deserves more expectations. We already proposed a multi-layer full-corporate waveguide feeding structure to excite a slot array in dual-polarization operation sharing common radiating units [5]. It shows a high isolation of more than -50 dB as well as a high XPD of more than 37 dBi in 60 GHz. However, the previous structure which we proposed has a seriously narrow bandwidth of less than 1% in the reflection.

In this paper, we propose a modified feeding structure for the dual-polarization operating with broad bandwidth. The newly proposed feeding structure shows broad bandwidth over 7% for each port to excite the dual-polarization.

2. Multi-Layer Structure for Antenna and Feeding Structure

Fig. 1 shows the 16x16-element double-layer waveguide slot array for the 60 GHz band [1]. As mentioned above, the feeding network is located on the bottom layer while the radiating part is located in the upper layer. A 2x2-element slot array in the upper layer is designed as the radiating unit, which is fed in-phase and in parallel by the full-corporate waveguide feeding structure placed in the lower layer through the coupling slot. Fig. 2 shows the exploded perspective view of the radiating unit with periodic boundary walls. Fig. 3 shows the operation mechanism of the 2x2-

element radiating unit for single polarization antenna. Four radiating slots are excited in the same single linear polarization through the coupling slot located underneath the cavity. For the dual-polarization operation, the radiating slots must be changed into square shapes. The coupling slots and the cavity also must be changed into a cross-slot and symmetrical structure in both of the longitudinal and transverse directions as illustrated in Fig. 4.

To realize the feeding structure for the dual-polarization, we had composed a three-layer feeding structure [5]. Fig. 5 shows the specific structure we had proposed. Note that the design of the radiating part is not included which will be located in the first layer. The longitudinal magnetic field is to be excited by the corporate feeding circuit placed in the fourth layer, which is same with that of the double layer antenna [1]. On the other hand, the transverse magnetic field is to be excited by applying the transverse slot in the second layer. The third layer was introduced to excite in-phase for the transverse slots on the second layer. We can expect a high isolation as well as a high XPD because the longitudinal slot locates at the center of waveguide in the second layer. The extension and the array of the feeding unit in Fig. 5, we can realize a full-corporate feeding network for the slot array antenna.

Fig. 6 shows the frequency characteristics of reflection and transmission coefficients by assuming that an infinite ground plane is embedded around the four cross slots in Fig.5 to show the feasibility of the dual-polarization operation of the feed circuit. In future, a cavity with four radiating slots shown in Fig.4 will be placed over each cross slot. Even though S_{11} and S_{22} are well matched in the operating frequency, the bandwidth of S_{11} is very narrow. Meanwhile, the isolation between the two ports is sufficiently suppressed below -50 dB. It can be explained at same time, the reasons for the narrow bandwidth of S_{11} and good isolation between the two ports. The longitudinal coupling slot between the second and the fourth layer must be very high because the third layer is located between those two layers. Fig. 7 shows the frequency characteristics of the bandwidth of S_{11} and the isolation between the two ports according to the height of the longitudinal coupling slot between the second and the fourth layer. As seen in Fig. 7, the bandwidth of S_{11} and the isolation between the two ports have the trade-off relationship according to the height of the coupling slot. In the view of the bandwidth improvement of the S_{11}, the height of the longitudinal coupling slot should be lower even though the isolation will be worse.

3. Bandwidth Improvement with a Modified Structure

Fig 8 shows the modified structure for the bandwidth improvement of S_{11}. The order of the second layer and the third layer in the previous structure are changed each other in the new structure. Thus the height of the longitudinal coupling slot became very low automatically. Because the height of the longitudinal coupling slot is the key parameter of the bandwidth of the S_{11}, the broad bandwidth is realized with this new structure. In this new structure, the transverse magnetic field and the longitudinal magnetic field are excited by the second layer and forth layer, respectively. However, the operation principle of the new structure is not changed at all compared with the previous structure. Only, the height of the cross slot on the second layer became high for the transverse exciting of the second layer.

Fig. 9 shows the frequency characteristic of the newly proposed structure by assuming similarly for the results in Fig.6. The bandwidth of the S_{11} shows 7 % at VSWR 1.5:1. It is remarkable improvement comparing with the previous result. Only changing the order of the layers, it can be realized a broad bandwidth feeding structure for the dual-polarization operation. Even though the height of the cross slot became high instead of the longitudinal coupling slot, it does not effect on the bandwidth of this feeding structure. Fig.10 shows the directivity of the cross-slot in the principle E-plane. It shows 23 dB of the XPD between the two orthogonal linear polarizations. The XPD of this feeding structure will be improved in later.

4. Conclusions

We have proposed a new structure for dual-polarization operation of a slot array for broad bandwidth. As the simulation results by the HFSS, the reflection is suppressed below VSWR 1.5:1

over 7 % bandwidth. The Isolation and XPD show -30 dB and 20 dB at the operating frequency, respectively. The radiating part on the first layer will be designed in later.

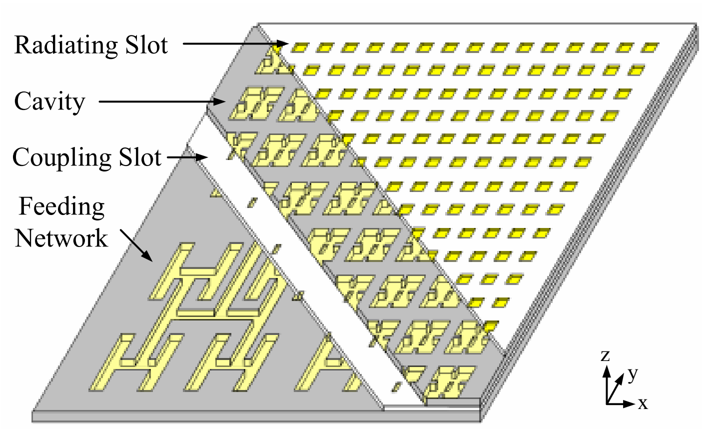

Figure 1: 16x16-Element Double-layer Corporate Array.

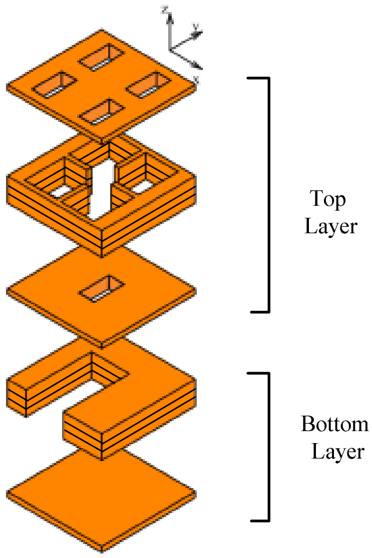

Figure 2: Radiating Unit of 2x2 Slots.

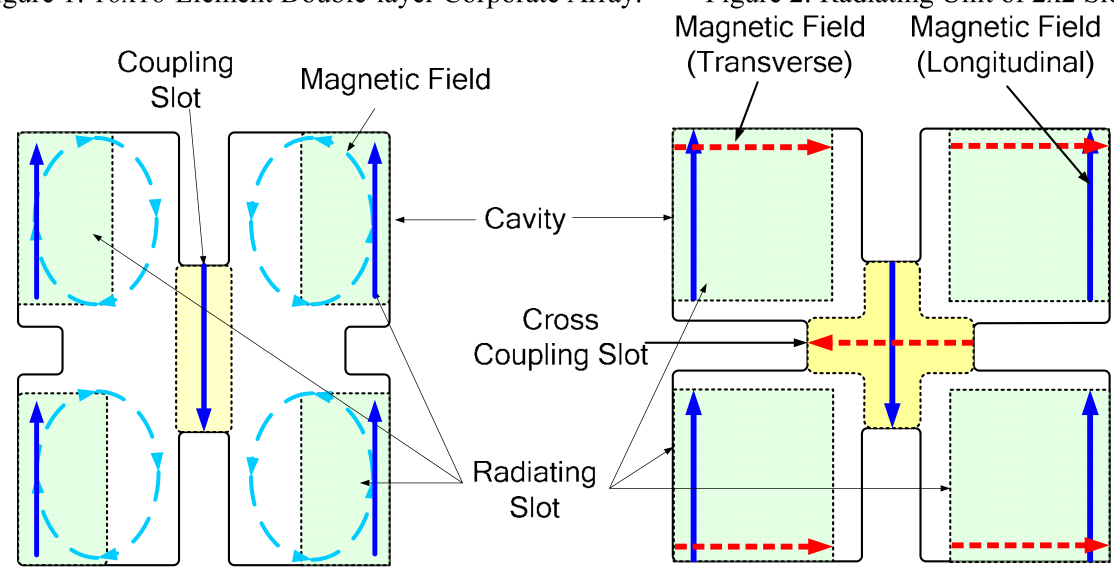

Figure 3: Magnetic Field of Single Polarization.

Figure 4: Magnetic Field of Dual Polarization.

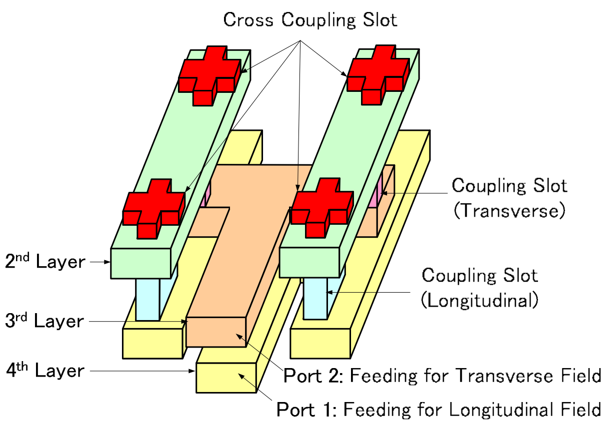

Figure 5: Corporate Feed of 4x4 Slots to Excite both Longitudinal and Transverse Components.

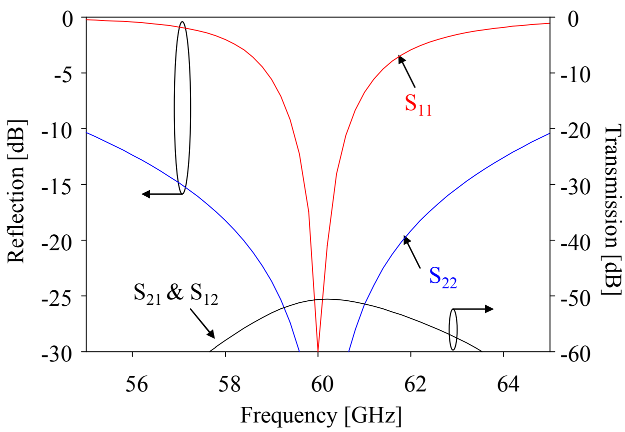

Figure 6: Frequency Characteristic of S-parameters.

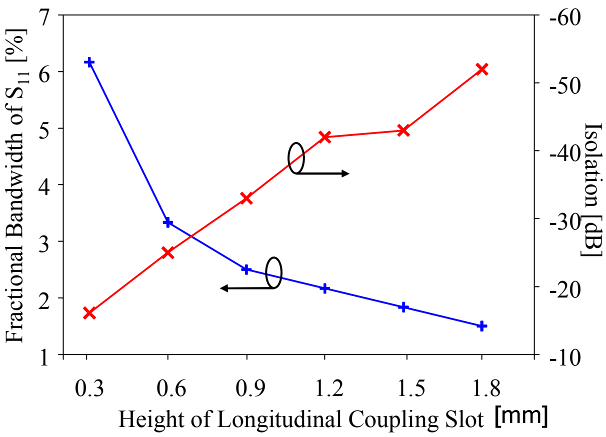

Figure 7: Bandwidth and Isolation according to the Height of the Longitudinal Coupling Slot.

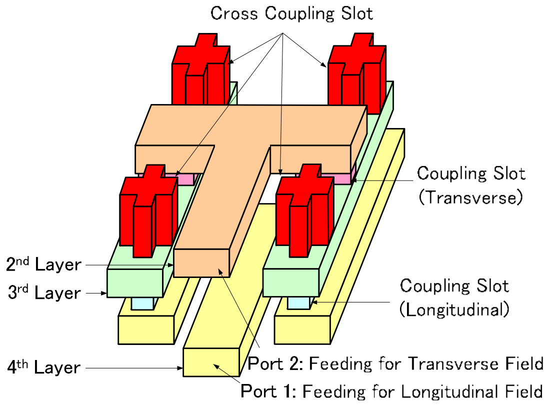

Figure 8: New Feeding Structure for the Broad Bandwidth Operation.

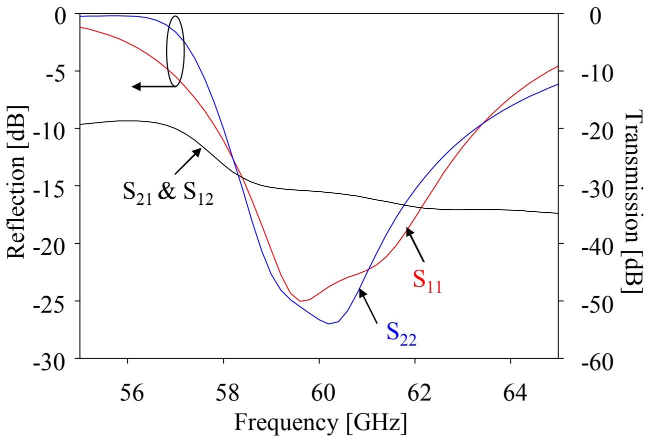

Figure 9: Frequency Characteristic of S-parameters.

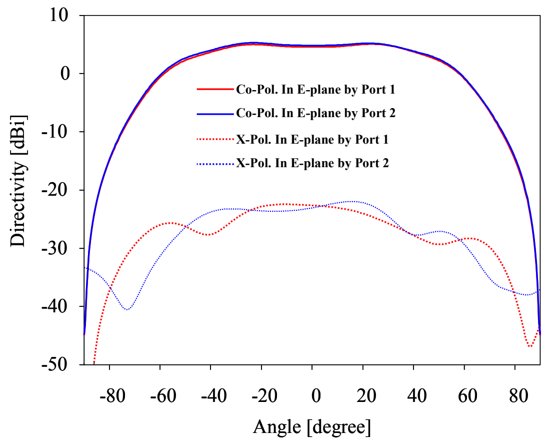

Figure 10: Directivity of Cross-Slot in E-plane

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