# Polarization Isolation Characteristics Between Two Center-Feed Single-Layer Waveguide Arrays Arranged Side-by-Side

*(Invited Paper)*

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***Abstract*** - The near field coupling between two large alternating-phase fed single-layer waveguide arrays arranged side-by-side is analyzed by the Finite Element Method (FEM) (HFSS). First, the overall reflection as well as the radiation pattern from the array (320 slots and 18.4 $\lambda$ x 14.9 $\lambda$) is analyzed, and excellent agreement with measurements is observed. Next, the isolation between two arrays is computed, and remarkable polarization isolations of more than 80 dB are predicted. The isolation is verified by measurements. The influence of the relative arrangement of the arrays upon the isolation is discussed.

## I. INTRODUCTION

Millimeter-wave applications [1] have been highlighted and intensively developed for high-speed and broadband communication due to their extensive frequency resources. To overcome serious attenuations due to rain, snow, etc., relatively short-range FWA (Fixed Wireless Access) systems in the 26GHz band are in commercial use in Japan [2] where extremely small size and low-cost wireless terminals have been realized. Single-layer slotted waveguide arrays [3] are one of the key components in this system since they have a high gain of about 32dBi, high efficiency of more than 70%, and mass producible structures. One difficulty, however, of this antenna is the relatively narrow bandwidth due to its traveling wave operation. Polarization re-use is attractive and effective for mitigating this difficulty since linear polarized slot arrays have inherently high XPD and the polarization purity does not deteriorate greatly in short range propagation.

This paper demonstrates the feasibility of a challenging system where frequency is fully re-used by the use of polarization isolation only [4]. An FWA system with this concept is presented in Figure 1. Figure 2 presents two center-feed single-layer slotted waveguide arrays with orthogonal polarization in exactly the same frequency band for transmission and reception. In order to completely reuse the frequency two times [5, 6], approximately 100dB of transmission-reception isolation is required. A preliminary scenario is to realize this isolation by the combination of an antenna isolation of 50dB and a cross-polarization compensating algorithm circuit of 50dB. The latter dispenses with the diplexer, and the use of Microwave Integrated Circuits realizes the miniaturization and economization of equipment. This paper assesses and verifies the isolation between two pairs of arrays in orthogonal polarization by simulation using Ansoft HFSS™ (High-Frequency Structure Simulator) and measurement.

We prepared two center-feed single-layer waveguide arrays [7] which have boresight beams as shown in Figure 2. The arrays are arranged side-by-side in the same plane: one is for transmitting and the other is for receiving in the FWA system. Isolation of about 80 dB is observed in both measurement and simulation.

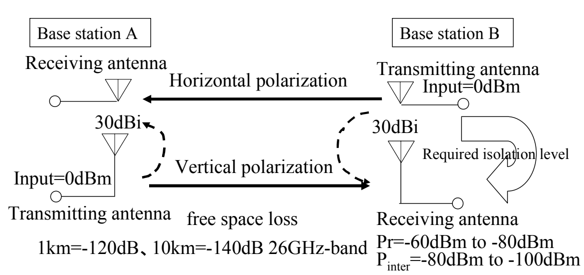
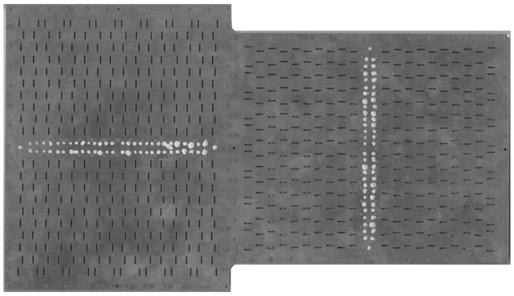



Figure 1. Dual polarization wireless system for two-times frequency reuse.



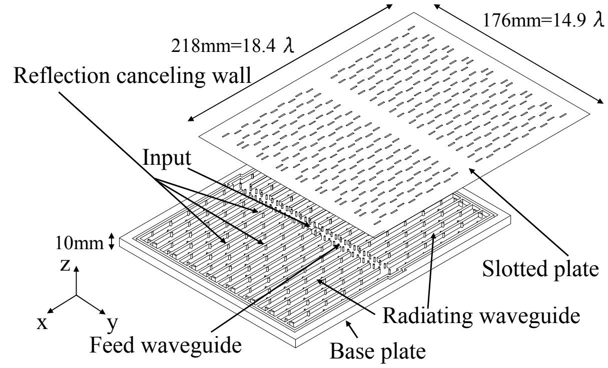
(a) Transmitting antenna (b) Receiving antenna

Figure 2. Orthogonally polarized slot arrays in side-by-side arrangement.

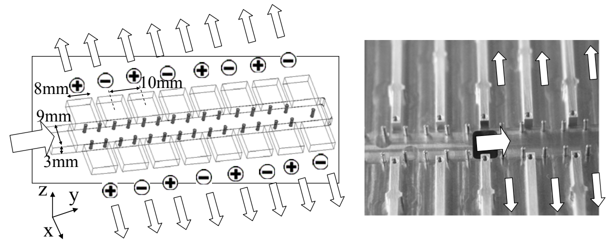
## II. CONFIGURATION AND SIMULATION MODEL FOR AN ARRAY

Figure 3(a) shows the structure of a center-feed single-layer waveguide array. The unique structure of the alternating-phase fed array consists of two parts: a slotted plate and a base plate with corrugations screwed to each other, which dispenses with the need for perfect electrical contact. Slots are cut in the broad wall of the rectangular waveguide [8-10]. This structure has a cross-junction power divider [11-16] at the center of the array as shown in Figure 3(b) and has a stable boresight main beam. Heretofore, a beam tilting technique was used for suppression of reflection from the slot array at the antenna input [17]. This time, reflection canceling walls are introduced to suppress reflections from each radiating slot [18-20] as shown in Figure 3(c). In the FWA system, two center-feed single-layer waveguide arrays with the same structure are placed orthogonally as shown in Figure 2. Since the main beams of both antennas radiate in the same boresight direction, transmitting and receiving antennas can be installed in the same plane, and, hence, be unified.

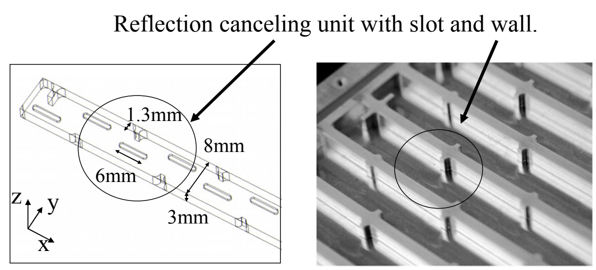
This structure has the manufacturing advantage that it can be dug from only one side of the slotted aperture. Figure 4 shows the simulated model of this antenna. The antenna size is 14.9 $\lambda$ (176mm) x 18.4 $\lambda$ (218mm) at the design frequency 25.3GHz. We simulated this model using HFSS. The simulation computer's specifications are given in Table 1, and the parameters used in the HFSS simulation are presented in Table 2. HFSS's adaptive mesh generation is used [21].




(a) Full array




(b) A multiple-way power divider consisting of series of cross-junctions.




(c) Reflection canceling unit consisting of slot and wall.

Figure 3. A center-feed alternating-phase fed single-layer waveguide array.

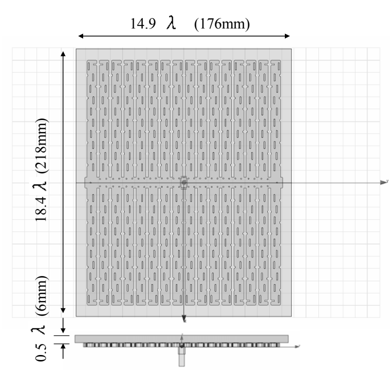



Figure 4. Full model of center–feed single layer waveguide array (10*32=320slots) for simulation.

Table 1. Personal computer specification.

| | |
|---|---|
| CPU | Xeon 3.6GHz |
| Memory | 16GB |
| HDD | 500GB × 2 |
| OS | Windows XP 64bit Edition |
| HFSS | Version 10 |

Table 2. Parameters used in HFSS simulation.

| Model | Figure 4 | Figure 9 h=0, d=0 | Figure 9 h=1, d=0 |
|---|---|---|---|
| Pass Number | 12 | 10 | 10 |
| Tetrahedra | 829154 | 1104685 | 1084560 |
| Delta S | 0.0024275 | 0.0070885 | 0.0088132 |
| Real Time | 28h20m03s | 37h23m31s | 33h06m39s |
| Memory | 14GB | 14GB | 14GB |
| Matrix | 4953196 | 6541060 | 6421842 |

## III. REFLECTION AND RADIATION PATTERNS OF AN ARRAY

In order to evaluate and understand the slot coupling in the array, the analysis model of an external half space is discussed. In the design of the slots of the prototype array, a linear array model with an infinite ground plane, called "isolated waveguide model", is considered and the mutual coupling effects between slots in adjacent radiating waveguides are neglected. The full structure simulation adopts the more realistic model as shown in Figure 5 (a) where the actual mutual coupling between slots in the adjacent waveguides via the half space is considered. The alternating-phase fed array is unique in that the adjacent waveguide is fed 180 degrees out-of-phase, and, if it is large enough, the external half space is well approximated by conducting metal walls that extend from the narrow walls as shown in Figure 5 (b). Figure 6 shows the calculated and measured overall reflection characteristics of this antenna. The measurements are predicted well by the simulation for model (a), though the array structure is very large and computationally heavy. As is expected from the principle of the design, the simulated result for model (b) with the metal walls also agrees with the measurements as well as the full model in (a). From the practical design point of view, the results suggest that the slot design for the reflection and the illumination control in a single radiating waveguide may be conducted by use of the linear array model with the conducting walls in (b) instead of the full array model in (a) [22]. In Figures 7 and 8 are presented the radiation patterns. The calculated and measured radiation patterns are almost identical.

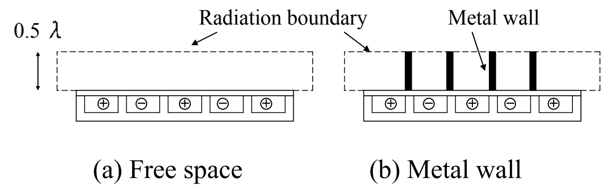



Figure 5. Simplified design/analysis model of external half-space above the array aperture.

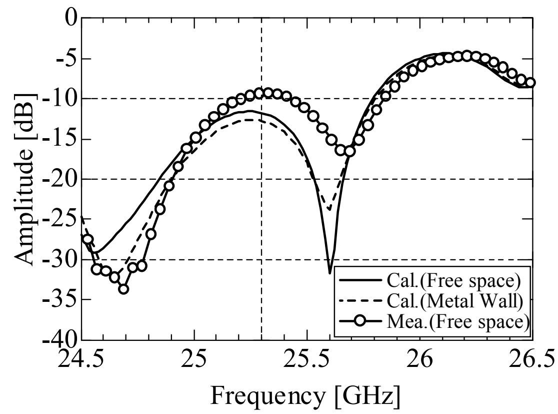



Figure 6. Overall reflection characteristics.

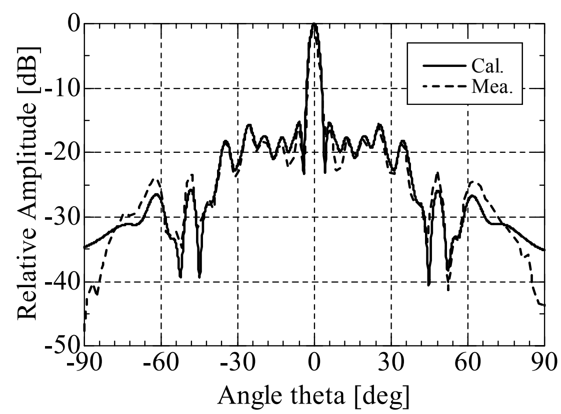



Figure 7. H-plane radiation pattern at 25.3GHz.

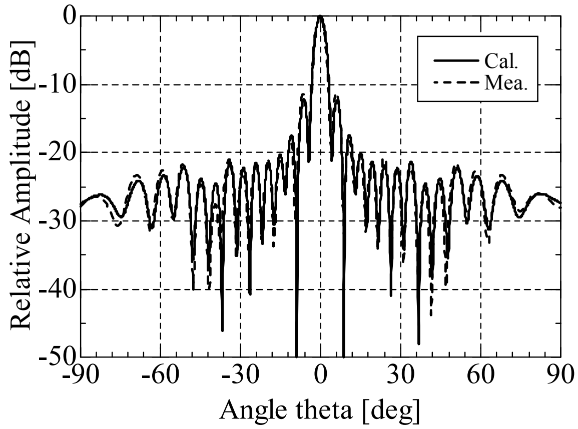



Figure 8. E-plane radiation pattern at 25.3GHz.

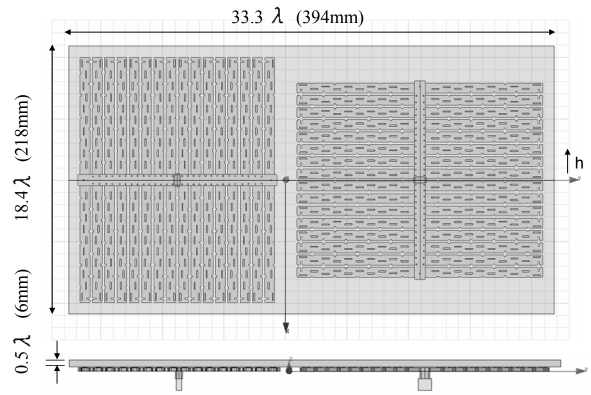
## IV. ISOLATION CHARACTERISTICS OF ORTHOGONALLY POLARIZED PAIR ARRAYS ARRANGED SIDE-BY-SIDE

Two center-feed waveguide arrays are combined side-by-side as shown in Figure 2. This antenna has a gain of more than 30 dBi. Figure 9 shows the simulated model of this antenna. The antenna size is 18.4 $\lambda$ (218mm) x 33.3 $\lambda$ (394mm) at the design frequency 25.3GHz. We simulated this model using HFSS, and the parameters used in the HFSS simulation are presented in Table 2. Figure 10 shows the mesh on the slotted plate, and Figure 11 presents the calculated S-parameters. Isolation (S21 and S12) between the ports of the two antennas is more than 80dB at 25.3GHz. This value is very promising for the dual polarization wireless systems proposed in Fig. 1. Figure 12 compares the measured data with the simulated data and the results support the above proposal.

Next, the degradation of polarization isolation due to the offset in the arrangement in the pair is discussed. The second array is offset with the distance h as shown in Figure 9. The simulated and measured isolations for h=1 $\lambda$ is also included in Fig.12 and are in reasonable agreement with each other. The polarization isolation is about 60-70dB and is degraded by about 10-20 dB.

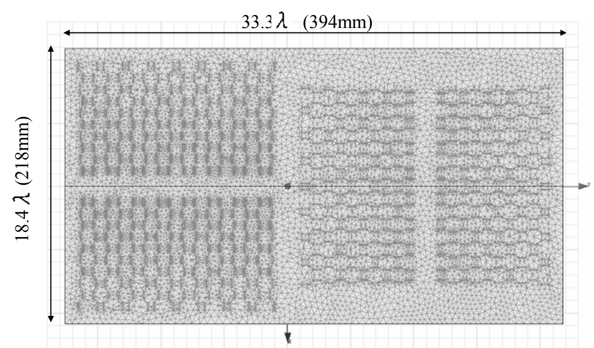
The effects of arrangement are now discussed in more detail. We prepared two center-feed single-layer waveguide arrays which have the same structure. We measured the isolation for different values of distance d ( = 0, 1, 2, 3 $\lambda$ ) and position h ( = 0, 1, 2, 3 $\lambda$ ) as shown in Fig.13. In Figure 14, the measured isolation results are summarized as functions of d and h. The results indicate a serious degradation of isolation due to increasing h but an improvement in isolation due to increasing d. In order to confirm these general results qualitatively, we conducted a series of simulations. Figure 15 shows the full size arrays used in the simulation; isolation is evaluated for variety of distances d ( = 0, 1, 2, 3 $\lambda$ ) and positions h ( = 0, 1, 2, 3 $\lambda$ ).

Figure 16 shows the results of isolation between two arrays at 25.3GHz. If the distance d is increased, the isolation improves, but, if the position h is increased, isolation degrades. Almost the same tendency as in Figure 14 is observed. This phenomenon can be summarized as follows. The residual cross polarization coupling between two arrays is effectively cancelled out at the receiving antenna output resulting in remarkably high isolation, due to the symmetrical structure and arrangement of the paired arrays.




(a) Transmitting antenna (b) Receiving antenna

Figure 9. Simulation model of orthogonally polarized pair arrays in symmetrical arrangement.




(a) Transmitting antenna (b) Receiving antenna

Figure 10. Mesh on the slotted plate (HFSS).

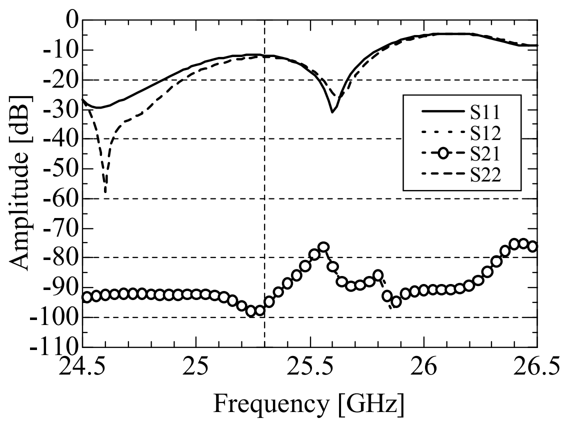



Figure 11. Simulation results of reflection and isolation characteristics between two center-feed waveguide arrays.

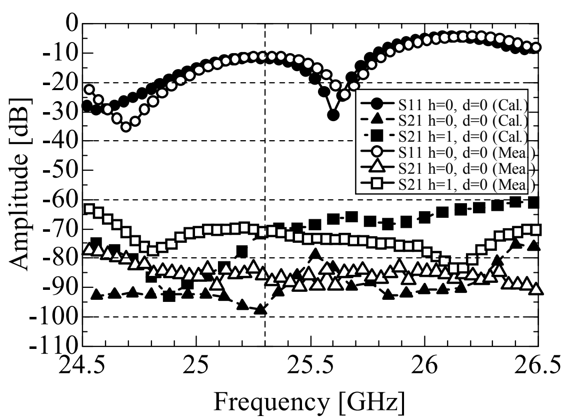
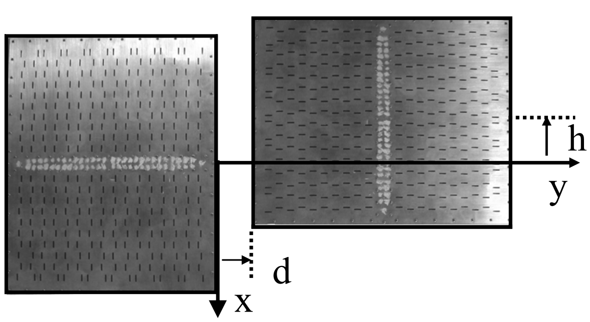



Figure 12. Measured results of reflection and isolation characteristics between two center-feed waveguide arrays.




(a) Transmitting antenna (b) Receiving antenna

Figure 13. Isolation between two trial manufactured antennas arranged with distance d and position h.

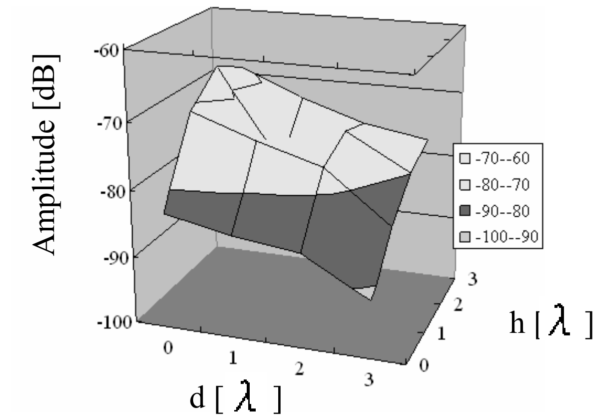
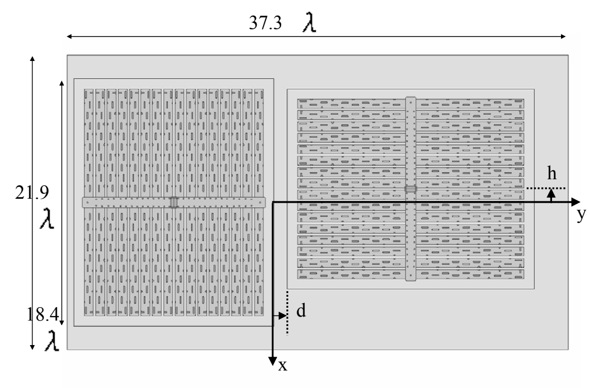



Figure 14. Position dependence of isolation at 25.3GHz (Measured).




(a) Transmitting antenna (b) Receiving antenna

Figure 15. Full array model for simulation of position dependence of isolation.

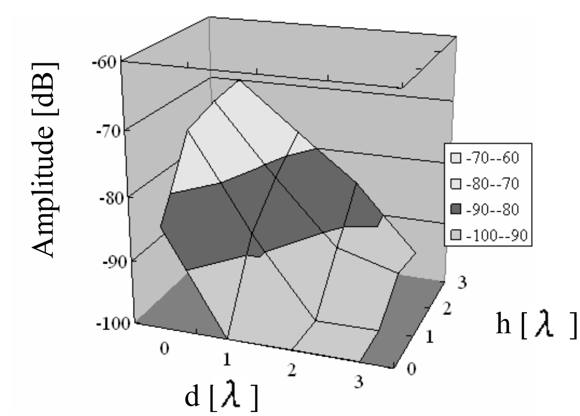



Figure 16. Position dependence of isolation between two arrays at 25.3GHz (Calculated).

## V. CONCLUSION

We discussed the coupling characteristics of two center-feed alternating-phase fed single-layer waveguide arrays. Large-size arrays were analyzed by using HFSS. The total size of the problem is 320 x 2 = 640 slots and 37.3 $\lambda$ x21,9 $\lambda$ .Results of simulation and measurements exhibit good agreement. More than 80 dB of isolation is achieved by the symmetrical and tight arrangement. The symmetry of the arrangement as well as the structure is the key for high isolation. These results provide the basis for the application of slot arrays to dual polarization wireless systems. Also, the effectiveness of performance simulation of large scale arrays in terms of polarization isolation and reflection indicates a promising design tool in antenna engineering.

## ACKNOWLEDGMENT

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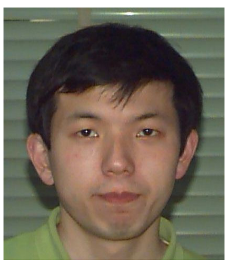

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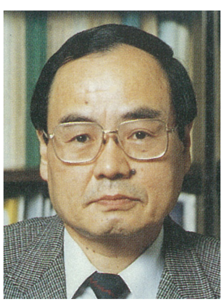

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