

Design of Broadband Planar Array Composed of 2x2 Slotted Cavities Fed by E-plane Waveguide Parallel-Feeding Circuit in Millimeter-wave Band

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Abstract – An 8x8 element array antenna is composed of the E-plane waveguide parallel-feeding circuit in the lower layer and the 2x2 slotted cavities in the upper layer. The E-plane waveguide parallel-feeding circuit consists of two plates and assembled at the center of the broad wall of the waveguide to achieve low-loss property and wide bandwidth simultaneously. The 2x2 slotted cavities are designed to obtain lower Q factor and an ideal radiation pattern in combination with the array factor of the cavity arrangement. The simulated bandwidth with reflection lower than -15 dB were wider than 5 GHz. The sidelobe level was lower than -12 dB and the gain was 26.0 dBi at 73.5 GHz.

Index Terms — Millimeter-wave, Waveguide, Wideband, Array Antenna, Parallel Feeding

1. Introduction

Millimeter-wave technologies have been expected for applications to wireless entrance systems, communication systems between base stations and 5G mobile communication systems [1], [2]. Wide bandwidth is necessary for communication systems which require a large transmission capacity. Parallel-feeding waveguide slot array antenna is attractive for low-loss property and wide bandwidth simultaneously. A double-layer waveguide array antenna which has the H-plane parallel-feeding circuit in the lower layer and the 2x2 slotted cavity in the upper layer has been developed [3]. However, the accurate electrical contact in fabrication is necessary for the antennas used in the millimeter-wave band. Therefore, an E-plane waveguide parallel-feeding circuit is proposed for the antenna fabricated by plastic molding with metal plating. The planar array antenna composed of an E-plane waveguide parallel-feeding circuit and 2x2 slotted cavities was designed at 73.5 GHz.

2. Double-layer Planar Array Antenna

Fig. 1 shows an 8x8 element planar waveguide slot array antenna composed of an E-plane waveguide parallel-feeding circuit and 2x2 slotted cavities. The parallel-feeding circuit in the lower layer is fed from the H-plane waveguide bend at the center. The 2x2 slotted cavities in the upper layer is excited in phase from the parallel-feeding circuit through the coupling slots. The antenna has double layer structure and each layers are designed individually at the design frequency and

combined to form the array antenna. The array antenna consists of three parts and has two assembled planes.

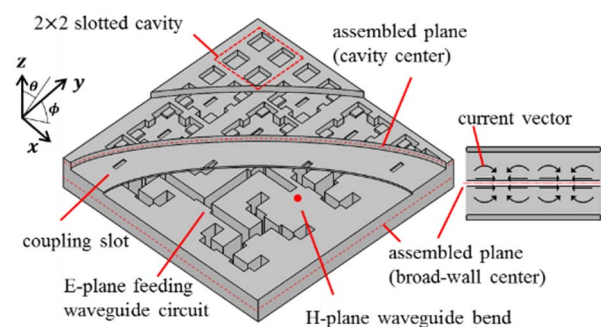


Fig. 1. 8x8 element planar array antenna

A) E-plane Waveguide Parallel-feeding Circuit

The E-plane waveguide parallel-feeding circuit is composed of E-plane T-junctions and E-plane bends. The feeding circuit is fed from the H-plane waveguide bend at the center on the back. The distance from H-plane waveguide bend to all the coupling slots is the same, therefore no frequency dependent. Fabricating the feeding circuit, two metal plates are assembled at the center of the broad wall of the waveguide, where the high-frequency current is not cut. Therefore, the lower layer has low-loss property and wide bandwidth simultaneously. The parallel-feeding circuit has a symmetrical structure and can be realized some kinds of element number, 4x4, 8x8 and 16x16 by increasing of the number of T-junctions according to the required aperture size and gain. All 2x2 slotted cavities in the upper layer are the same and independent of the number of the elements.

B) 2x2 Slotted Cavity

The 2x2 slotted cavity in the upper layer is shown in Fig. 2. This subarray is composed of four radiation slots backed on the cavity. The cavity is excited by the coupling slot. All radiation slots have the same size and wide slot width. The steps are designed under the radiation slots to adjust the coupling power. The radiation slots have common slot spacing 3.51 mm ($0.86\lambda_0$) in both x , y -directions. Subarrays are arranged in 7.02 mm spacing in both x , y -directions. In terms of radiation pattern, lower sidelobe level can be obtained by adjusting the null direction of the 2x2 slotted cavity. The wall

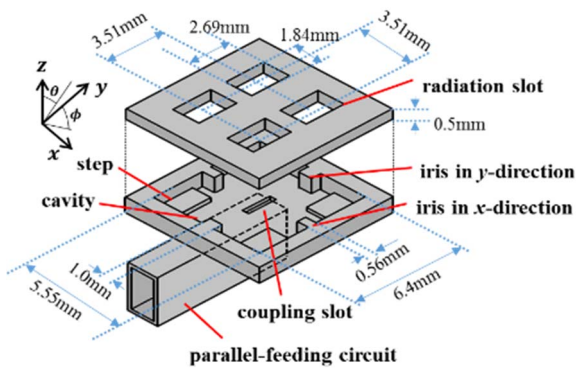


Fig. 2. 2x2 slotted cavity in the upper layer

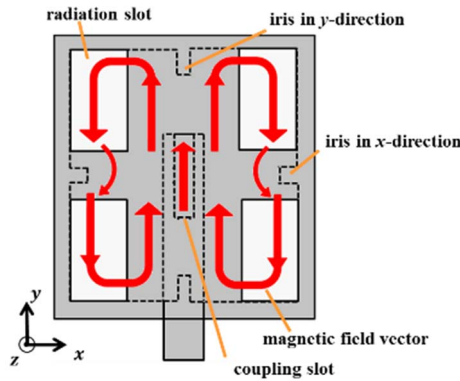


Fig. 3. Magnetic field vectors in cavity

thickness of the radiation slot is designed as 0.5 mm to control the exciting phase and the null direction. The coupling mechanism of the slot radiation of the 2x2 slotted cavity is shown in Fig. 3. The symmetrical magnetic field distributions with respect to the x -direction are excited in the cavity due to four iris. The four radiation slots are excited almost in phase.

3. Simulated Performance

The characteristics of the antenna are evaluated by simulation based on the finite element method. Fig. 4 shows the reflection characteristics of the 2x2 slotted cavity fed from the waveguide as shown in Fig. 2, the whole feeding circuit and the 8x8 element array antenna. The 2x2 slotted cavity and the feeding circuit were designed individually to obtain broadband reflection characteristics and combined to form the array antenna. The bandwidth for reflection lower than -15 dB was wider than 5 GHz centered at 73.5 GHz. Fig. 5 shows the radiation patterns of the 2x2 slotted cavity, the 8x8 element array and the array factor of the cavity arrangement for comparisons. The array factor is obtained by arranging the four elements in the 7.02 mm spacing. The radiation slots were excited almost in phase and the sidelobe levels were lower than -12 dB due to the null of the subarray. Fig. 6 shows the gain of the 8x8 element array and the antenna efficiency for comparisons. The gain in the design frequency was 26.0 dBi and the antenna efficiency higher than 60 % was wider than 10 GHz.

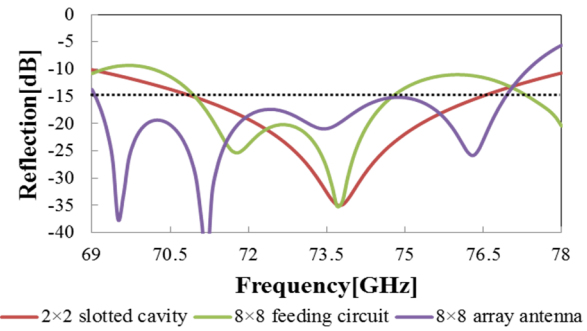


Fig. 4. Reflection characteristics of array antenna

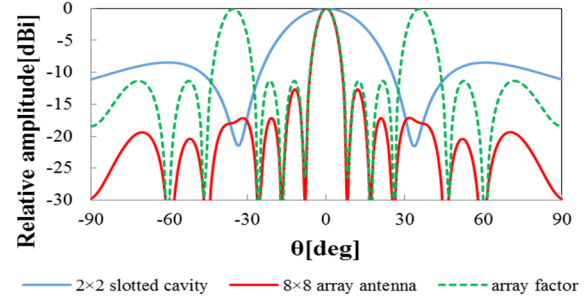


Fig. 5. Radiation patterns of array antenna

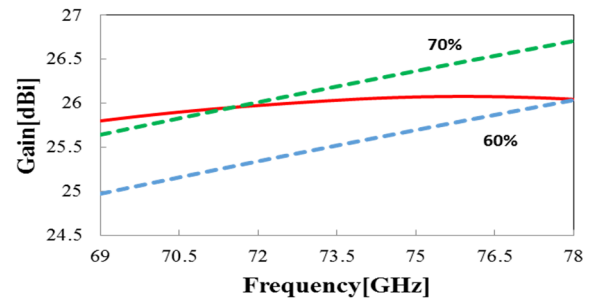


Fig. 6. Antenna gain of array antenna

4. Conclusion

The planar waveguide slot array antenna composed of the double-layer structure with 2x2 slotted cavities and an E-plane waveguide parallel-feeding circuit was proposed to obtain wide bandwidth of the reflection characteristics and high gain. The wide bandwidth of the characteristics, low sidelobe level, and high gain was confirmed by simulation.

References

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