Reflection Bandwidth Enhancement of a 2×2-element Wide Slot Sub-array on a Wall-inserted Cavity

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***Abstract*—In order to improve the gain bandwidth of a 16×16-element plate-laminated-waveguide slot array, the reflection bandwidth of the 2×2-element sub-array is designed. The reflection bandwidth of VSWR < 1.5 is enhanced from 9.2% to 20.4%. The bandwidth of the gain above 32.0 dBi is successfully expanded from 12.8% to 20.8% by simulation.**

I. Introduction

The 60-GHz band is one of the most promising candidates for multi-gigabit wireless communication because of the unlicensed broad bandwidth, 57 - 66 GHz. For point-to-point fixed wireless communications, high gain antennas with broadband characteristic are required. The antennas are preferable to be planar considering a compact package integrating wireless circuits. A microstrip array is planar and light but cannot realize high gain with high antenna efficiency because the dielectric loss becomes large in the millimeter wave band. A planar hollow-waveguide slot array has low transmission loss and can only realize high gain with high antenna efficiency in the millimeter wave band.

A 16×16-element plate-laminated waveguide slot array has been fabricated and realized 33.0-dBi peak gain, 83.6% peak antenna efficiency and 11.2% bandwidth of gain above 32.0 dBi in the 60-GHz band [1]. In order to improve the gain bandwidth, only the reflection bandwidth of the sub-array is required to be improved since the feeding part has already realized a sufficiently wide bandwidth. In this paper, we present the reflection bandwidth enhancement of the sub-array.

II. Antenna Structure

The 16×16-element plate-laminated-waveguide slot array is shown in Fig. 1. The array is composed of two parts: the feeding part in the lower layer and the radiating part in the upper layer. It is fed through the feeding aperture from its backside. The feeding circuit is a corporate feed and a combination of H-plane T-junctions. The coupling aperture is located at each end of the feeding circuit in order to feed the radiating part. The radiating part is composed of the 2×2-element sub-arrays as shown in Fig. 2. Four radiating slots are placed on the cavity with a constant spacing in the *x* and *y* directions and are excited in phase with equal amplitude.

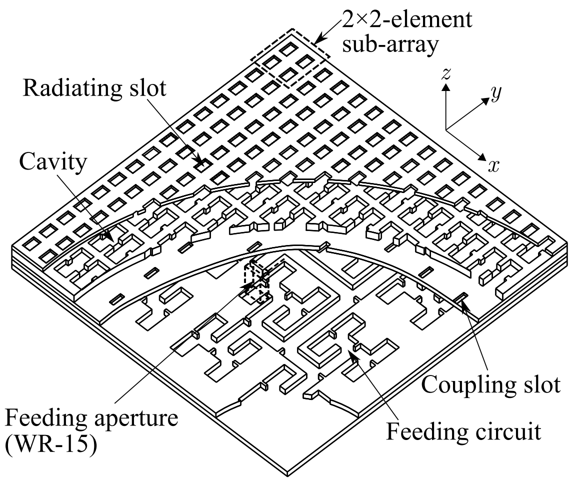

Fig. 1. 16×16-element plate-laminated-waveguide slot array

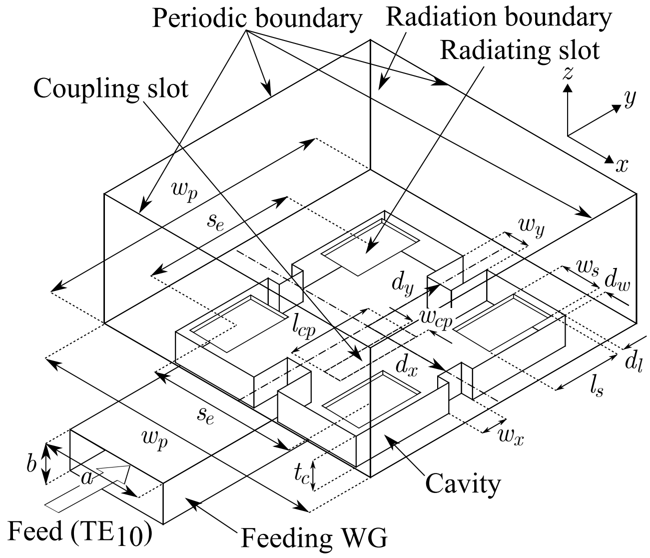

Fig. 2. 2×2-element wide slot sub-array

III. Wideband Design

In this section, we present a reflection bandwidth enhancement of the 2×2-element wide slot sub-array depicted in Fig. 2. The sub-array is analysed by the method of moments with numerical eigenmodes [2]. Design frequency is 61.5 GHz. The reflection bandwidth of VSWR below 1.5 is improved from 9.2% up to 20.4% through 5-step design as shown in Fig. 3.

At first, the designs 1 and 2 are presented. In the designs, wider radiating slots are adopted for lower Q. At the first step of design, the radiating slot width is increased by 0.05 mm. The impedance is matched so that VSWR at the design frequency is less than 1.2. The reflection bandwidth is improved from 9.2% to 12.0% as shown in Fig. 3, when the radiating slots become from 1.75 mm to 2.30 mm.

Next, the designs 3 and 4 are presented. In the designs, the narrower coupling slot is adopted for realization of triple resonance. As the coupling slot becomes narrower, the outer loop of the reflection locus in a smith chart becomes small. This means that another resonance frequency becomes lower. If the resonance frequency shifts to the operating band (57 - 66 GHz), further bandwidth enhancement is expected. When the coupling slot width gets narrower with matched impedance, the change of the bandwidth is shown in Fig. 3. The bandwidth is enhanced from 12.0% to 18.0% by decreasing the coupling slot width up to 0.25 mm.

Next, the design 5 is presented. The thickness of the cavity is adjusted and the thinner cavity realizes a wider bandwidth. The reduction of the height leads to lower Q of the radiation slots indirectly. The bandwidth is enhanced from 18.0% to 20.4% reducing the cavity height from 1.20 mm to 1.00 mm as shown in Fig. 3. 0.80 mm cavity height shows the widest bandwidth. However, the bandwidth of directivity is less than that for 1.00 mm height due to grating lobes. Therefore, we adopt the 1.00-mm cavity height model as the best designed model. The frequency characteristic (solid line) of the reflection coefficient is shown in Fig. 4 with the conventional one (dashed line). The reflection bandwidth of VSWR < 1.5 is enhanced from 9.2% up to 20.4%. Double resonance characteristic changes into triple resonance characteristic. All the parameters of the design model are listed in the Table 1.

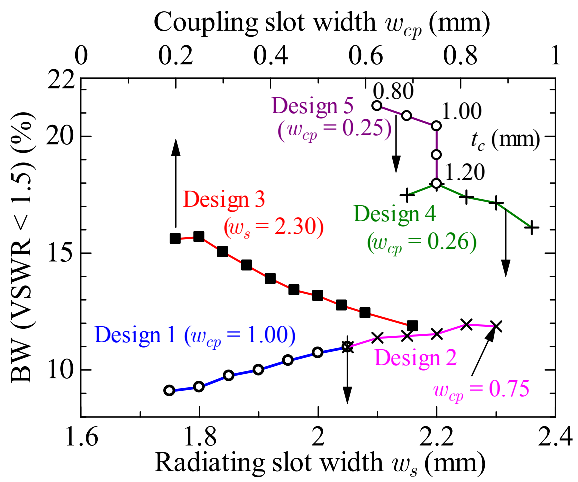

Fig. 3. Reflection bandwidth enhancement through 5 designs

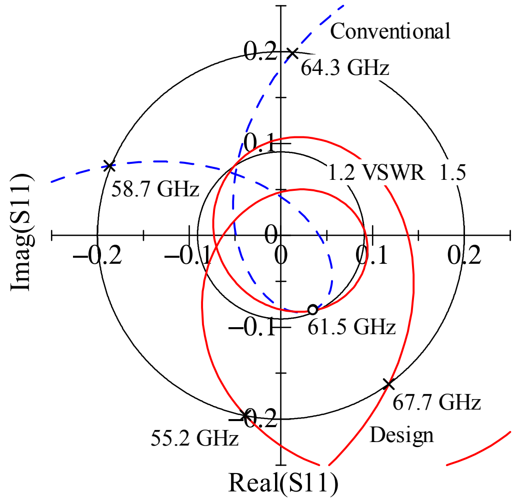

Fig. 4. Frequency characteristic of reflection

Finally, the 16×16-element array including the feeding circuit with the designed sub-arrays is analysed by HFSS in order to validate the wideband design. The conductivity of copper is assumed to be 5.8 × 10^7 S/m. The frequency characteristic of gain is shown in Fig. 5. At the design frequency, 32.9-dBi gain and corresponding 82.3% antenna efficiency are realized. The bandwidth of gain above 32.0 dBi is enhanced from 12.8% to 20.8%, 12.9 GHz from 55.8 GHz to 68.8 GHz.

TABLE I
DIMENSIONS OF THE DESIGNED SUB-ARRAY

Component	**Parameter**	**Dimension (Unit: mm)**
Feeding waveguide	$a \times b$	2.88 × 1.20
Coupling slot	$l_{cp} \times w_{cp} \times t_{cp}$	2.48 × 0.25 × 0.20
Cavity	d_l, d_w, t_c	0.17, 0.00, 1.00
Walls	w_x , d_x , w_y , d_y	0.86, 2.22, -, -
Radiating slot	$l_s \times w_s \times t_s$	3.21 × 2.20 × 0.20
Element spacing	s_e	4.20
Periodic boundary wall	w_p	8.40

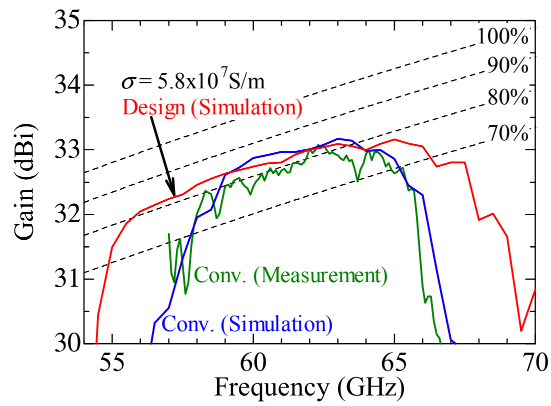

Fig. 5. Frequency characteristic of gain of 16×16-element array

IV. Conclusion

We have presented the reflection bandwidth enhancement of the sub-array in order to improve the gain bandwidth. The reflection bandwidth of VSWR < 1.5 is enhanced from 9.2% to 20.4%. The bandwidth of gain above 32.0 dBi is expanded from 12.8% to 20.8% by simulation.

Acknowledgment

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