

Post-wall waveguide slot arrays with water repellent coating and estimation of effective dielectric constant of wall-thickness region

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Abstract

We evaluate the coating of water repellent over a post-wall waveguide-fed parallel plate slot antenna. The slot array is originally designed for uniform field distribution for the dielectric constant to be 1.0 in the wall thickness region. After the coating, water repellent is filled in the wall thickness region in part, so that the dielectric constant in the wall thickness region is equivalently changed and the field distribution of the slot array should be tapered. The equivalent dielectric constant is evaluated by measuring the tapered field distribution. Then we redesign the slot array for uniform excitation by including the equivalent dielectric constant.

1. INTRODUCTION

The post-wall waveguide-fed parallel plate slot array antenna [1][2] is a candidate of high-gain and high-efficiency millimeter-wave planar antennas [3]. It is formed in a metal-clad dielectric substrate as shown in Fig.1. The post-wall waveguides can be fabricated by making via-poles densely and metal-plating their walls to act as solid metal wall equivalently. They can be made at low cost by conventional techniques for print circuit boards. The radiating part has a simple structure that consists of slots etched on the upper plate. The slots are designed for a desired aperture field illumination. However if rain or snow falls on the slot aperture directly, the operation of the slot array is changed drastically. Conventionally, a radome is installed in front of the antenna to prevent from it.

In this paper we propose coating of water-repellent over the slot aperture instead of using a radome. The slot array is originally designed for uniform field distribution for the dielectric constant to be 1.0 in the wall thickness region. After the coating, the water repellent is filled in the wall thickness region in part, so that the dielectric constant in the wall thickness region is equivalently changed and the field distribution of the slot array should be tapered. The equivalent dielectric constant is evaluated by measuring the tapered field distribution because the dielectric constant of the water repellent itself has not been measured yet and we do not know how the water repellent is filled in the wall thickness region.

Then, we redesign the slot array by including the evaluated dielectric constant in the wall thickness region.

2. STRUCTURE

A. Post-wall waveguide antenna

Fig.1 shows the post-wall waveguide-fed parallel plate slot array antenna. A feed waveguide is placed in the end of a parallel plate waveguide in a metal-clad dielectric substrate. The feed waveguide is a cascade of coupling windows spaced by one guided wavelength to be excited in phase. Additional window posts are placed in front of the coupling windows to avoid unwanted oblique propagation in the parallel plate waveguide. The coupling of each window is controlled by its width. Slots on the parallel plate waveguide are paired as the unit model shown in Fig.6 (a). In each slot pair, the length l_2 of one slot is for controlling radiation and the length l_1 of the other slot and the spacing d between the two slots are for suppressing reflection.

We design a slot array for uniform field distribution for the dielectric constant to be 1.0 in the wall thickness region. The design frequency is 61.25 GHz. The dielectric constant of the substrate is 2.17. The height of the substrate is 1.2 mm. The aperture size is 80 mm \times 80 mm ($16.3\lambda \times 16.3\lambda$). [1]. The post diameter is 0.5mm and the post spacing is 1.2mm. The wall thickness region has 40 μ m in height.

B. Water repellent

The water repellent used in measurements is named as HIREC, which mainly consists of fluorocarbon polymer and fluorinated varnish. It is uniformly coated on the slot aperture. Its thickness is about 15 μ m.

3. MEASUREMENTS OF WATER-REPELLENT-COATED ANTENNA

A. Aperture field distribution

Fig.2. shows the aperture field distributions of two types of the antennas. One is the no-coated antenna as reference and the other is the coated antenna. In each figure, the feed waveguide is placed on the left side and an incident TEM wave propagates from the left to the right. The field has a taper of 8 dB in amplitude 120 degrees in phase in the coated antenna, while it is almost uniform in amplitude and 30-degree taper in phase in the no coated antenna.

B. Radiation pattern

Fig.3 shows the radiation patterns in the E-plane. The main-beam direction is shifted by 1.0deg due to the 120-degree phase taper in the aperture field distribution. The measured 3dB beamwidth is 3.6 deg in the coated antenna and 3.5deg in the non-coated antenna. As for the H-plane pattern, there is not a significant difference between the two antennas.

C. Reflection and radiation pattern

Fig.4. shows the reflections. The coated antenna has -11.7dB and while the no coated one has -11.3dB at 61.25GHz. The frequency characteristic is almost similar to each other. The reflection is suppressed below -10dB over a wide bandwidth in the two antennas.

D. Gain and directivity

The measured peak gain is 31.9dBi in the coated antenna at 61.2GHz and 32.6dBi in the non-coated antenna at 61.4GHz as shown in Fig.5. The difference in gain includes the loss of the water repellent itself and the degradation by the change of aperture field. We also estimate the directivity depending on only the aperture field. The directivity is 34.3dBi in the coated antenna and 34.5dBi in the no coated antenna at 61.25GHz. This difference in directivity comes from the degradation by the change of aperture field. The peak gain and the directivity are summarized in Table 1. We extract the loss of the water repellent of 0.5dB, by subtracting the difference in the directivity from that in the gain (0.7dB-0.2dB=0.5dB).

4. ESTIMATION OF EQUIVALENT DIELECTRIC CONSTANT

Fig.6 shows the simulated excitation coefficients of the slot array together with the one-dimensional measured aperture field distribution. We analyze a one-dimensional array of slot pairs as shown in Fig.6(c). We assume uniform excitation of slot pairs in the transverse direction in the two-dimensional array. In the internal region, the parallel plate waveguide is replaced with a rectangular waveguide with periodic walls in the narrow walls. In the external region, the mutual couplings in the two-dimensional array are included discretely into the

center row of the slot pairs. The wall thickness is considered in the analysis. When the dielectric constant is set to 1 in the wall thickness region, we get uniform excitation both in amplitude and phase. We find the dielectric constant to be 1.8 by the analysis in order to give the measured taper of 5dB in amplitude and 120 degrees in phase, which is the difference between the measurements of the coated and no-coated antennas. Then we redesign the slot array by using the model for the slot pair as shown in Fig.6 (a) and assuming the dielectric constant equal to 1.8 in the wall thickness region. In the model, another rectangular waveguide with two sets of periodic walls is introduced in the external region to simulate mutual couplings in uniformly-excited two-dimensional array. Fig.8 shows the variation of the length of one slot l_2 in a pair to get uniform excitation in the one-dimensional array. The slot length in the coated antenna is shorter than that in the no coated antenna for equal coupling.

5. CONCLUSION

We have estimated the dielectric constant to be 1.8 in the wall thickness region by the analysis to give the measured taper in the coating of water repellent. Then we redesign the slot array by using the model for the slot pair and including the estimated dielectric constant in wall thickness region for get uniform excitation. We will make measurements for the redesigned antenna.

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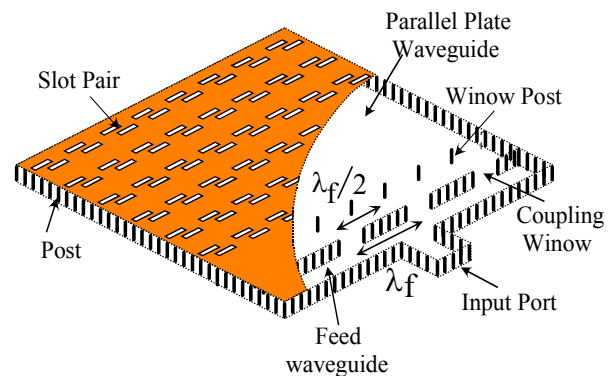


Fig. 1: Post-wall waveguide antenna

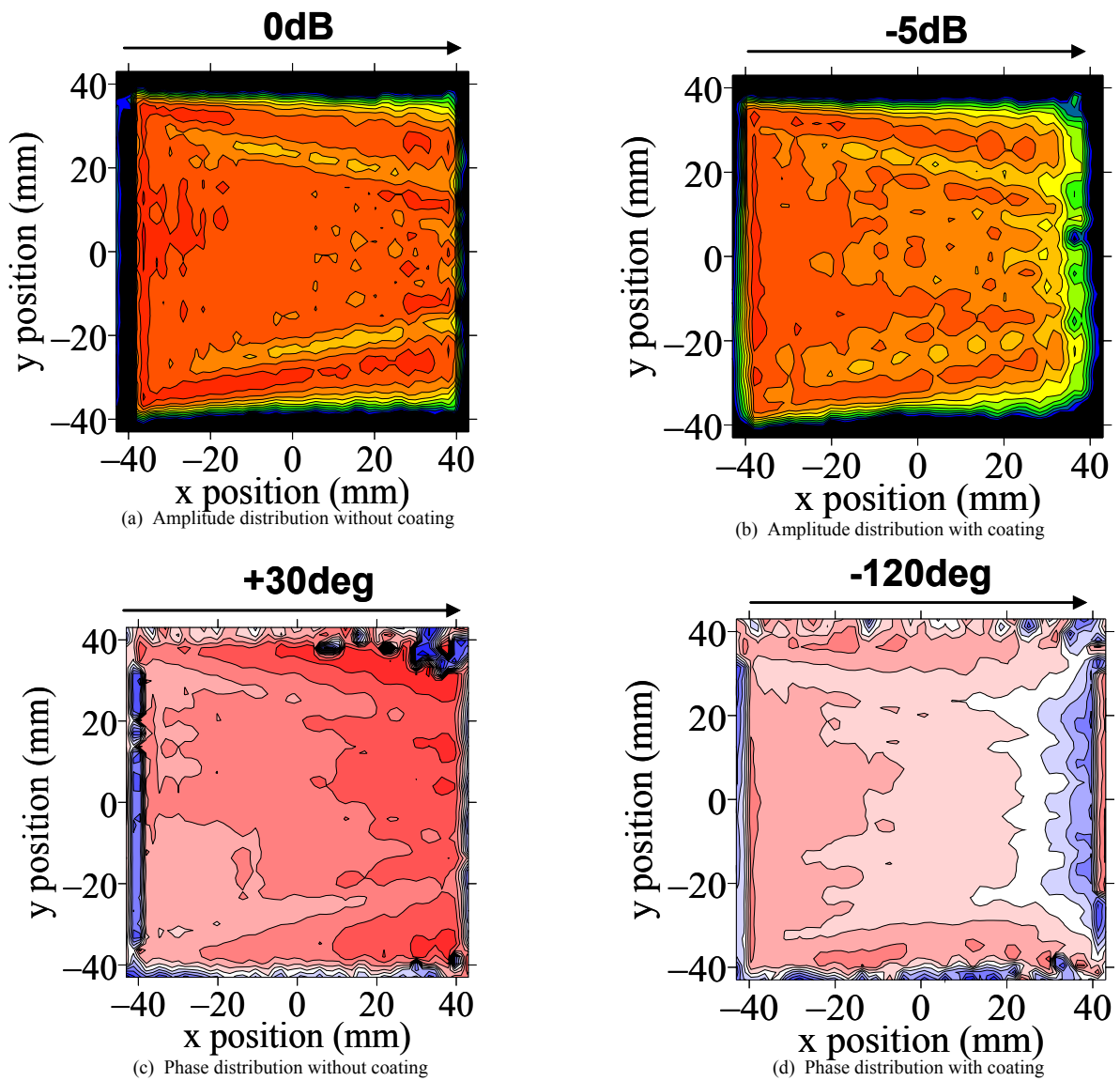


Fig. 2: Aperture distribution

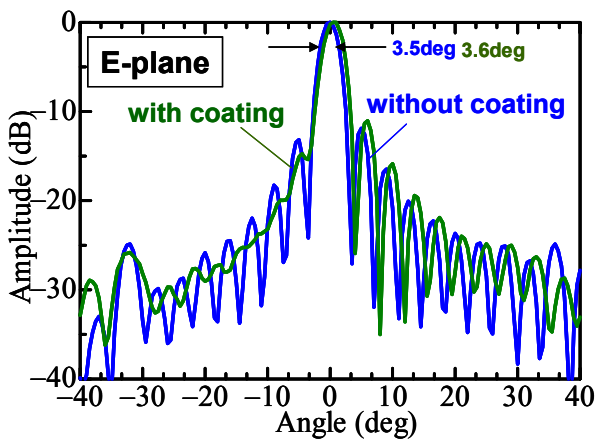


Fig. 3: Radiation pattern in the E-plane

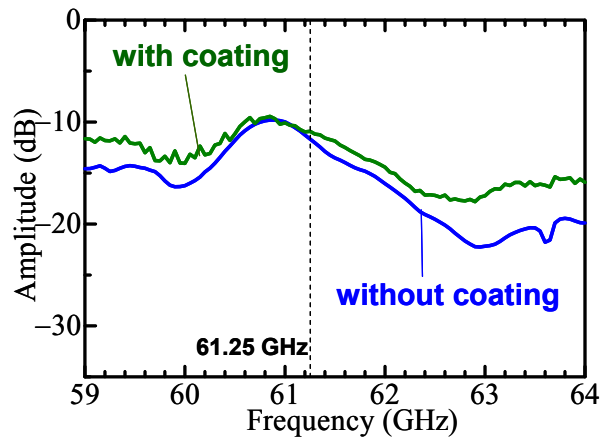


Fig. 4: Frequency characteristics of reflection

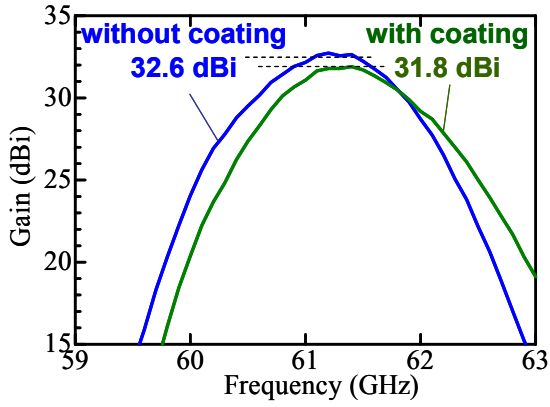
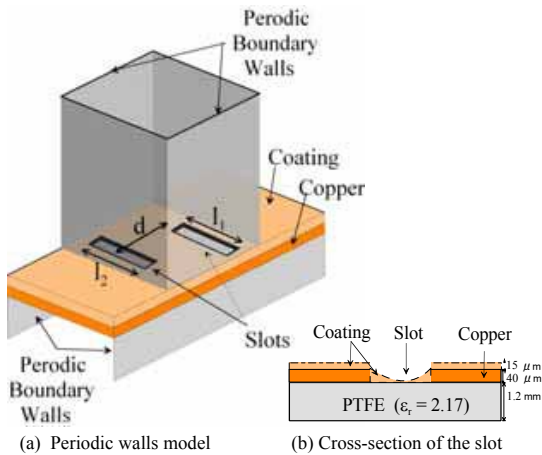


Fig. 5: Frequency characteristics of gain

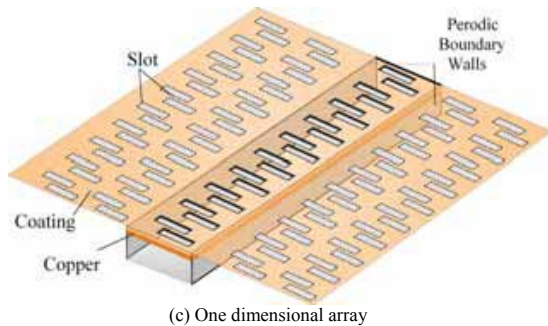
TABLE I. Gain and Directivity

	without coating	with coating	Difference
Gain	32.6dBi (at 61.2GHz)	31.9dBi (at 61.4GHz)	0.7dB
Directivity	34.5dBi (at 61.25GHz)	34.3dBi (at 61.25 GHz)	0.2dB
Coating Loss			0.5dB



(a) Periodic walls model

(b) Cross-section of the slot



(c) One dimensional array

Fig. 6: Design of radiation part

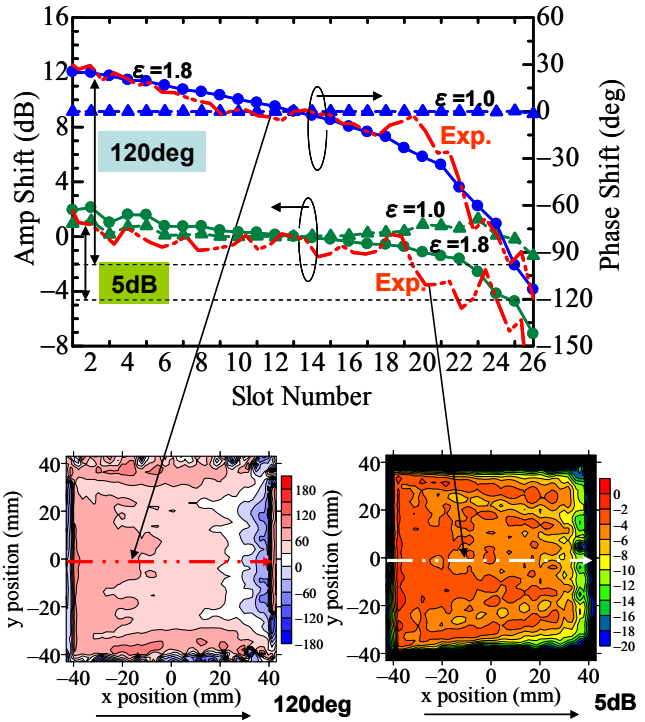


Fig. 7: Estimation of the dielectric constant

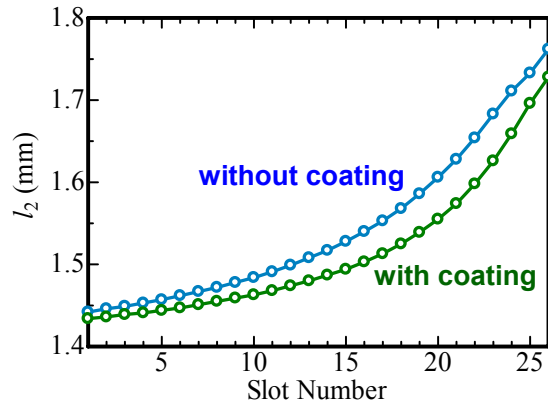


Fig. 8: Slot length