Sidelobe Suppression in a Corporate-feed Double-layer Waveguide Slot Array Antenna

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Abstract

The authors design the sidelode suppression in the 60GHz corporate-feed double-layer waveguide slot array antenna. The first sidelobes can be suppressed to -24dB, however -22.6dB sidelobes are observed in 30-40-deg. direction because the coupling slot in the bottom layer excites 2x2 radiating slots in the top layer with equal amplitude.

Keywords : waveguide slot array antenna, corporate-feed, Taylor distribution, waveguide T-junction

1. Introduction

A low-loss transmission line for the feed network is needed to realize high antenna efficiency in a high-gain planar array antenna with a large number of elements. A hollow waveguide slot array antenna has no dielectric and radiation loss compared with a microstrip line fed array antenna [1], so it achieves high antenna efficiency even in the millimeter waveband. In addition, it should have simple and low-profile structure. The feeding circuits in the waveguide slot array antenna are roughly classified into the series-feed type and the parallel-feed type. A waveguide slot array antenna with parallel-feed has broadband characteristic, but it usually is bulky and has been unsuited for mass production because of its complicated three-dimensional feeding structure [2],[3]. Using a multiple layer structure, the design restriction of the feed waveguide in parallel feed is improved for a wider bandwidth. The diffusion bonding antenna of laminated thin metal plates as shown in Fig.1 would realize multiple layer structures as a potentially cost effective method and the high precision needed to be suitable for the millimeter wave band [4]. The interelement spacing could be kept within the free-space wavelength by exciting 2x2 elements in phase through one slot at each end of the corporate-feed waveguide in the lower layer.

In this paper, a double-layer waveguide slot array antenna with a corporate-feed circuit is designed for sidelobe suppression. The aperture distribution based on Taylor Distribution is synthesized as an example, and only a quarter of the feed circuit due to the symmetry is designed by assembling H-plane T-junctions with asymmetric power division to realize the desirable aperture distribution.

2. Aperture Distribution

Figs. 1 and 2 show the structure of the double-layer waveguide slot array antenna, which can be fabricated by diffusion bounding of laminated thin plates. Its aperture consists of 16x16 elements. The corporate-feed circuit is placed in the bottom layer. Each waveguide vent feeds 2x2 elements and this 4-element radiating unit is excited in the same amplitude and phase. Therefore, in one dimension, these 2 elements in the primary direction have same amplitude and phase. In this paper, we denote this excitation method as “Pair Excitation”.

As an example, the one-dimensional aperture distribution is synthesized based on Taylor Distribution (sidelobe=-25dB, $\bar{n}$ =5, 16 elements). Fig. 3 shows one-dimensional aperture distribution with continuous, discrete and Pair Excitation of Taylor. Here, the Pair Excitation coefficients are calculated by averaging the discrete Taylor coefficients of every two adjacent elements. The inter-element spacing (d) is 4.20mm ($0.86\lambda_0$) and the design frequency is 61.5GHz.

In an array antenna, the array factor is controllable between 0 and 35.5 degree due to the $d=0.86\lambda_0$ value.

3. Design of a Feed Circuit

The feed-circuit consists of the H-plane T-junctions in corporate. The desired aperture distribution is realized by dividing power with a required ratio in each T-junction. The overall feed-circuit has biaxial symmetry, so it is necessary to only design the quarter of the circuit. Fig. 5 shows T-junction circuit model. This T-junction model is designed by using the method of moments (MoM) [5]. The distribution ratio is controlled by adjusting q, and the reflection is controlled by adjusting p and w. Furthermore, d is used to adjust phase difference. Fig. 6 shows change of distribution ratio and phase difference in output with respect to q. The power ratio between the two outputs is about 12dB at a maximum. However the phase difference is unable to be removed for the power ratio of more than 2dB. Using only three types of T-junctions α, β and γ, the quarter-circuit will realize the desirable Taylor Pair Distribution on the antenna aperture. Each T-junction has a different ratio of output distribution and each value is given in Fig. 7. Fig. 8 shows the frequency characteristics of power division ratios and phase differences for all the three types of T-junctions. As the power ratio of T-junction increases, its phase differences associated with the unbalance increases too. For instance, phase differences of T-junction α, β and γ are 21.1, 0.11 and 5.65 degree, so T-junction α and γ are required to be redesigned for compensating phase difference. Therefore, the input-waveguide of T-junction α and γ have to be displaced to compensate the phase difference as shown in Fig. 7.

One-dimensional array factors considering the effects of the feed-circuit are shown in Figs. 9 and 10. Fig. 9 shows the array factor without input-waveguide displacement and some shoulders are observed due to the phase degradation. On the other hand, Fig. 10 shows the array factor with input-waveguide displacement and those shoulders disappeared because the phase differences between elements are compensated almost perfectly. The first sidelobe level is fully suppressed at about -24dB. Meanwhile, high sidelobe levels at -22.6dB are observed in 30-40-deg. direction, due to the array construction as Pair Excitation. The two-dimensional directivity is 32.85dBi and 32.52dBi at 61.5GHz and 59.5GHz respectively.

4. Conclusion

In the corporate feed double layer waveguide aperture array antenna, its aperture distribution and corresponding feed-circuit for sidelobe suppression have been investigated in this paper. Taylor Pair Excitation, which is synthesized based on the Taylor distribution (sidelobe=-25dB, $\bar{n}=5$, 16 elements) has been applied to the aperture distribution. As one-dimensional array factor of Taylor Pair Distribution, first sidelobe level was suppressed at -24dB. However, large sidelobes (-22.6dB) rise in 30-40-deg. direction. A feed circuit for Taylor Pair Excitation has been realized by assembling T-junctions, which have been analyzed and designed by MoM. By assembling only three types of T-junctions and displacing their input waveguide to compensate the output phase differences, the array factor has been realized nearly identical to that of the ideal Taylor Pair Excitation.

References

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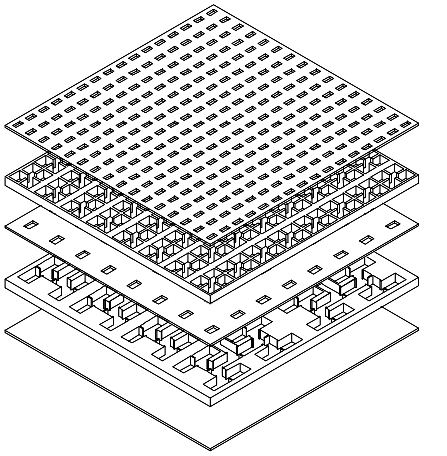

Fig. 1 A corporate feed double-layer waveguide aperture array antenna

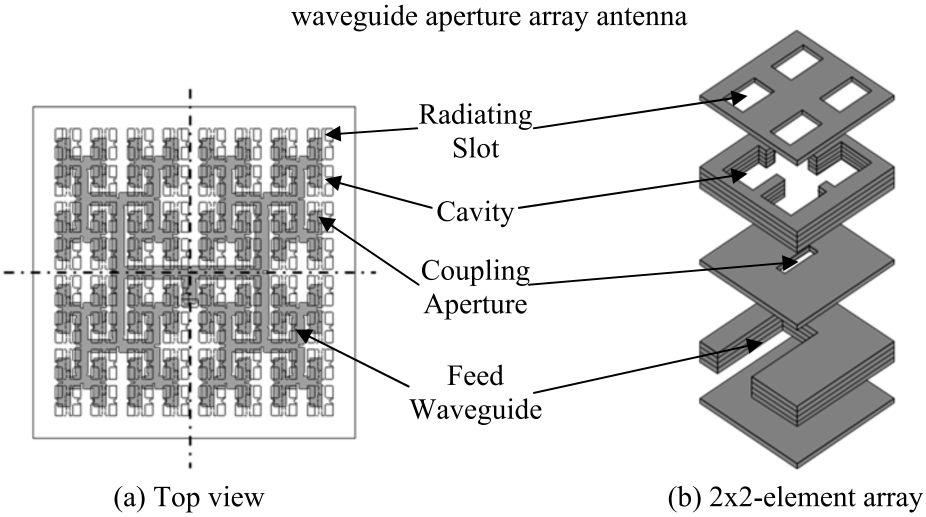

Fig. 2 Top view of the antenna and exploded perspective view of the 2x2-element array

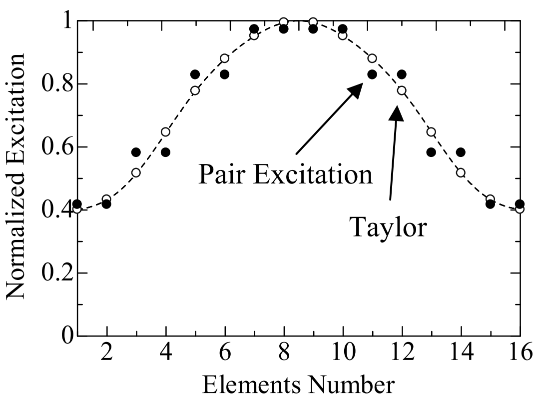

Fig. 3 One-dimensional aperture distribution

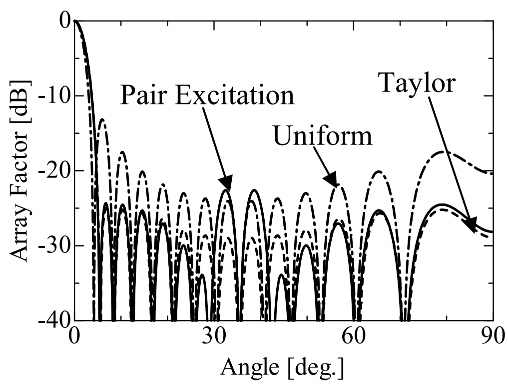

Fig. 4 One-dimensional array factor

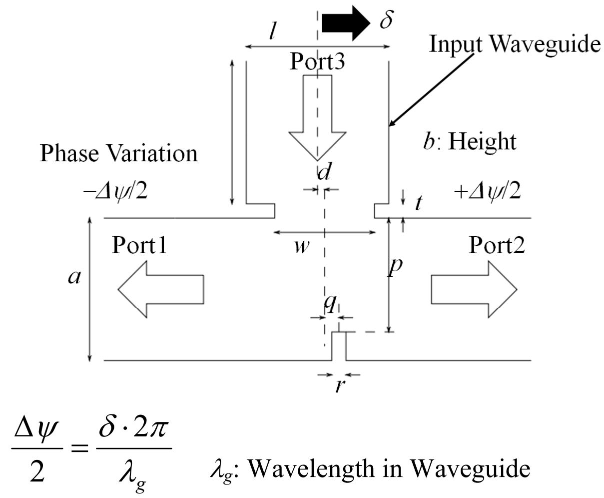

Fig. 5 H-plane T-junction circuit analysis model

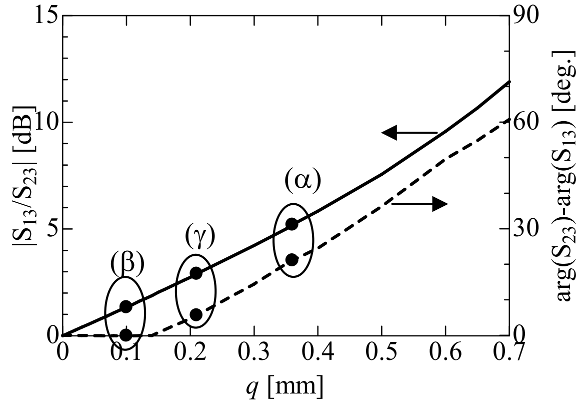

Fig.6 Distribution ratio and phase difference in T-junction

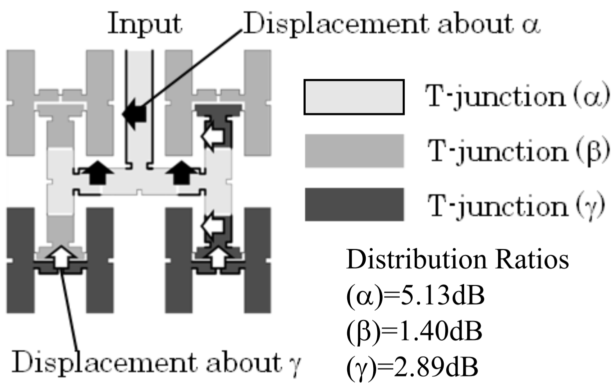

Fig. 7 1/4 feed circuit assembling 3 types of T-junction

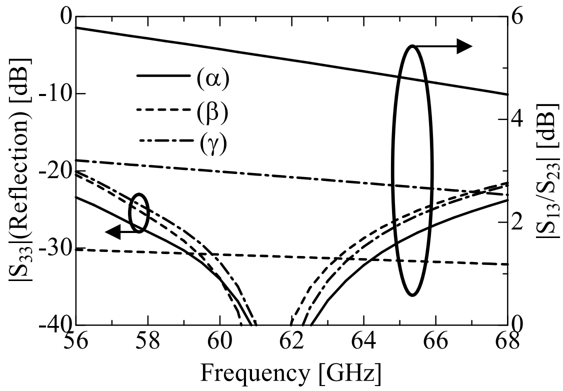

Fig. 8 Frequency characteristics of distribution ratios and phase differences

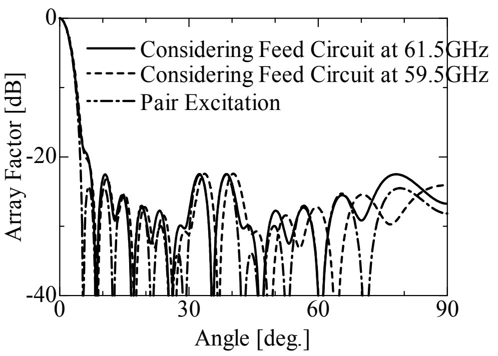

Fig. 9 One-dimensional array factor considering feed-circuit without displacement

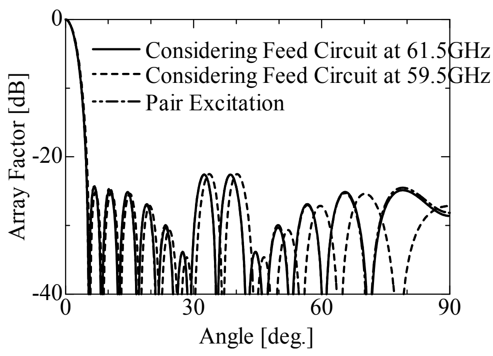

Fig. 10 One-dimensional array factor considering feed-circuit with displacement