

# A 40 GHz-Band Double-Layer Waveguide Slot Array fed from Four Corners to Suppress Sidelobes

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**Abstract** – A 22×20-element double-layer waveguide slot array antenna is designed for a fixed wireless access system in the 40 GHz band. To minimize the interference from surrounding buildings, the Taylor distributions are adopted in both longitudinal and transverse directions of antenna aperture to suppress the sidelobe levels below -30 dB. A four-corner feed structure instead of the typical center feed one is introduced for wideband operation. The perfect magnetic conductor terminations are also adopted at the center of feeding waveguides due to the symmetric feed from right-and-left ends. As the predicted antenna performance by using HFSS, the antenna gain of more than 31.8 dBi and the reflection of less than -12 dB are estimated over the operating frequency range of 39.0 ~ 41.5 GHz.

**Index Terms** — Waveguide slot array, Taylor distribution, four-corner-feed, double-layer structure, perfect magnetic conductor (PMC) termination.

## I. INTRODUCTION

A middle-range Fixed Wireless Access (FWA) system in the millimeter-wave band is under development in Japan to realize a maximum throughput of 2 Gbps. To utilize the frequency resources more efficiently, a Directional Division Duplex (DDD) is adopted to double the transmission capacity compared to the conventional Time Division Duplex (TDD) or Frequency Division Duplex (FDD). That is, a wireless terminal in DDD will use two independent antennas operated in same frequency and with same polarization to realize simultaneous bidirectional communication. In addition, the system interference due to the obstacles existing in the directions of sidelobes should also be taken into account. In this study, a double-layer waveguide slot array is to be designed in the 40 GHz band where the transmission loss is much lower than it in the 60 GHz band. An antenna gain higher than 31 dBi and a sidelobe level lower than -30 dB are to be realized. Meanwhile, the isolation of more than 80 dB between the adjacent transmitting and receiving antennas arranged in an  $H$ -plane is also required over the operating frequency range of 39.5 ~ 41 GHz.

## II. ANTENNA STRUCTURE AND DESIGN

A 20×22-element waveguide slot array as illustrated in Fig. 1 is designed at the center frequency of 39.75 GHz. To

suppress the reflections from the surrounding buildings, a low sidelobe level (SLL) below -30 dB is to be realized by introducing the Taylor distribution in both longitudinal and transverse directions [1-3] of antenna aperture. The desired aperture distributions with amplitude taper and uniform phase are calculated first. Before the design of feeding circuit, the relative merits between a center feed and a two-end feed is investigated in a linear array. The coupling factors according to each type of feeding circuits are calculated and summarized in Fig. 2 for comparison. Generally, the element with a small coupling factor exhibits wideband operation. In addition, the element with a coupling factor larger than 0.5 is difficult to be realized. It is observed from Fig. 2 that, the two-end feed array has the advantages over the center feed one in terms of large bandwidth and high feasibility. Hence, we are going to adopt this two-end feed in both longitudinal and transverse directions of a two-dimensional (2-D) array. That is, a four-corner feed array will be realized as illustrated in Fig. 1. By the way, this new feeding structure will result in an additional feeding distance as well as a little higher transmission loss compared to the conventional center feed array.

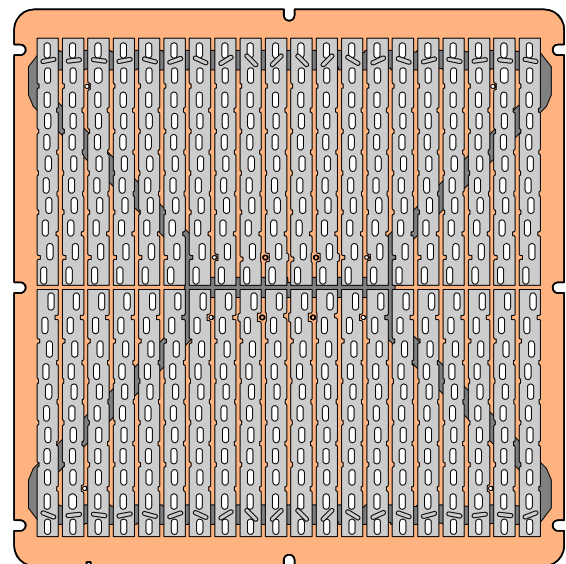


Fig. 1. Perspective view of a 22×20-element double-layer four-corner-feed waveguide slot array designed at 39.75 GHz.

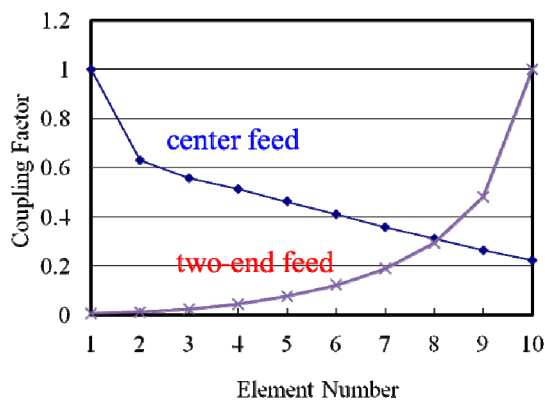


Fig. 2. Coupling factors of a center feed or a two-end feed 20-element array with a Taylor distribution (SLL = -35 dB and  $n = 5$ ).

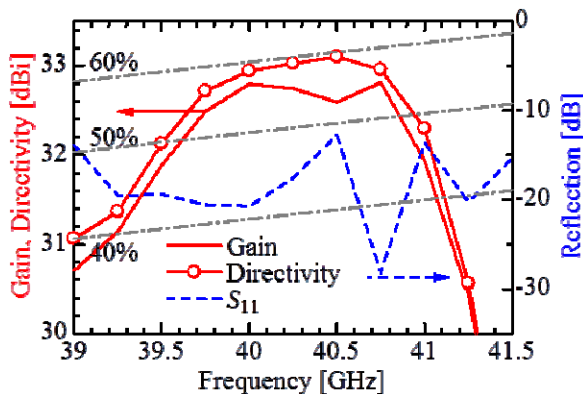


Fig. 3. Predicted antenna gain, directivity and overall reflection as a function of frequency.

The perspective view of a double layer waveguide slot array fed from four corners is shown in Fig. 1. The outer antenna size is limited within 136.4 mm by 134.4 mm. The whole antenna is fed by a Q-band standard waveguide from the backside. The feeding circuit with four arms stretches from the center to the four antenna corners. Then, the radiation waveguides in the upper layer are fed in co-phase through slot couplers which are cut in the upper broad-walls of feeding waveguides located in the bottom layer.

As the design of radiation slot and slot coupler, an inductive wall [4-5] is introduced to each element for local reflection suppression as well as travelling-wave excitation. A partially-corporate feed double-layer waveguide slot array with uniform distribution had been realized in the 38 GHz band as a similar work [5]. In addition, a Perfect Magnetic Conductor (PMC) termination [6] is also introduced at the center of feeding waveguides due to the symmetric feed from both ends.

The Finite Element Method (FEM) based electromagnetic field simulator, ANSYS's HFSS is used in this work for antenna design. The full-structure analysis by HFSS is also conducted. The frequency characteristics of antenna gain and overall reflection are summarized in Fig. 3. The antenna gain of more than 31.8 dBi and the reflection of less than -12 dB are estimated over the desired frequency range of 39.0 ~ 41.5 GHz. The predicted radiation patterns in the principal  $E$ - and  $H$ -planes are shown in Fig. 4. The sidelobes are suppressed below -30 dB at 40.0 GHz.

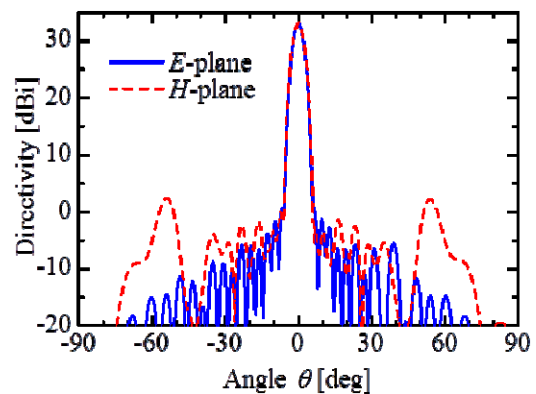


Fig. 4. Predicted antenna radiation patterns in the principle  $E$ - and  $H$ -planes at 40.0 GHz.

### III. CONCLUSION

A 22×20-element double-layer waveguide slot array with a sidelobe level less than -30 dB is designed for a DDD fixed wireless access system. A four-corner feed structure is newly introduced for wideband operation compared with a center feed structure. As the predicted antenna performance by HFSS, the antenna gain of more than 31.8 dBi and the reflection of less than -12 dB are estimated over the desired frequency range of 39.5 ~ 41.0 GHz. The designed antenna has been fabricated by a process call diffusion bonding of thin copper plates. The measured antenna performance including the isolation between transmitting and receiving antennas will be reported in the conference.

### ACKNOWLEDGMENT

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