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A High Gain Ridge Gap Waveguide Fed Slot Antenna Array for 60 GHz Applications

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***Abstract*— In this paper, a high gain high efficiency 16×16-element slot antenna array is presented for 60 GHz applications. The antenna is designed based on gap waveguide technology. A corporate feed network is realized by a texture of pins and a guiding ridge in a bottom plate. The simulated results show about 16% of reflection coefficient bandwidth ($|S_{11}| < -10$ dB) covering 57-67 GHz frequency range. Also, the gain of the antenna is more than 32.5 dBi with an efficiency higher than 85% over the desired frequency band.**

***Index Terms*—slot antenna array, gap waveguide technology.**

I. INTRODUCTION

Waveguide slot antenna arrays are attractive candidates for high-gain wideband planar antennas for many applications. They suffer neither from dielectric nor radiation loss and are suitable for applications requiring high gain and high efficiency. However, wideband waveguide slot arrays require corporate feed networks that become very complex and bulky. In addition, at high frequencies, such feed networks require accurate, high precision expensive manufacturing. The proposed waveguide slot antenna array in [1-3] has good performance, but their fabrication process is based on the diffusion bonding of laminated thin copper plates, which is relatively complex and uncommon. Briefly, the manifest challenges with such multilayer structures are high fabrication cost to achieve good electric contacts between different layers.

The aim of the present work is to design a planar slot antenna array with high-gain and high radiation efficiency based on gap waveguide technology. The gap waveguide technology introduced in [4-5] can be used to overcome the problem of good electrical contact associated with mechanical assembly. There are also many modern manufacturing technologies that will suit such planar surfaces with texture, such as die sink Electrical Discharge Manufacturing (EDM), Electron Beam Melting (EBM), multilayer die pressing, and 3D screen printing. Therefore, the gap waveguide technology has a large potential for millimeter wave applications. To date, some array antennas have been realized based on gap waveguide distribution networks: a 4×4 horn array at 15 GHz fed by inverted microstrip gap waveguide in [6], a 4×4 slot array at 60 GHz fed by microstrip-ridge gap waveguide, a 4×1 slot array fed by ridge gap waveguide [8]. In addition, recently, the use of gap waveguide distribution networks for design of W-band 8×8 slot arrays has been reported in [9, 10].

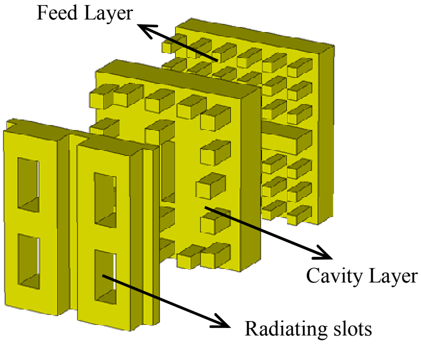

Fig. 1. Exploded perspective view of 2×2-element sub-array.

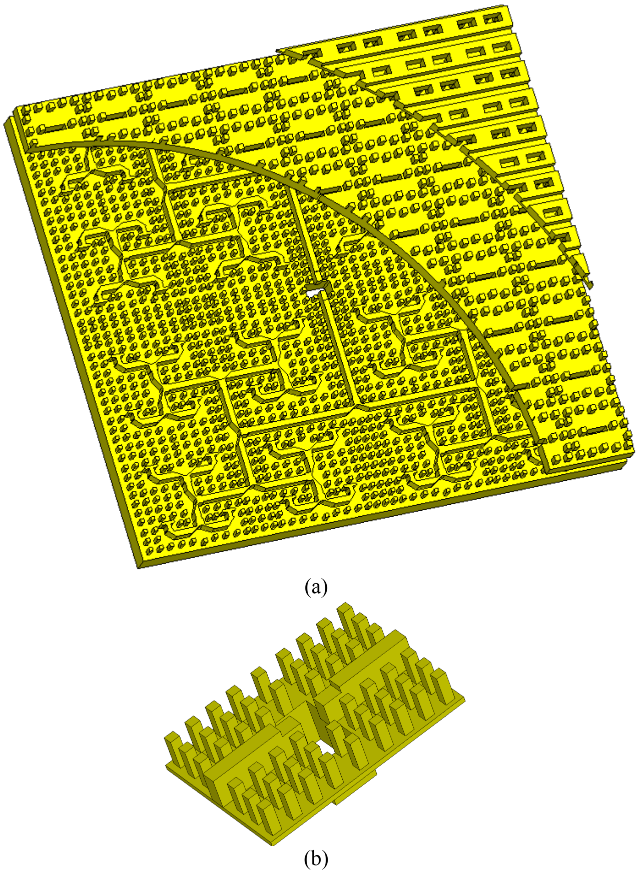

Fig. 2. (a) Configuration of 16×16-element array antenna (b) transition from ridge gap waveguide to WR15.

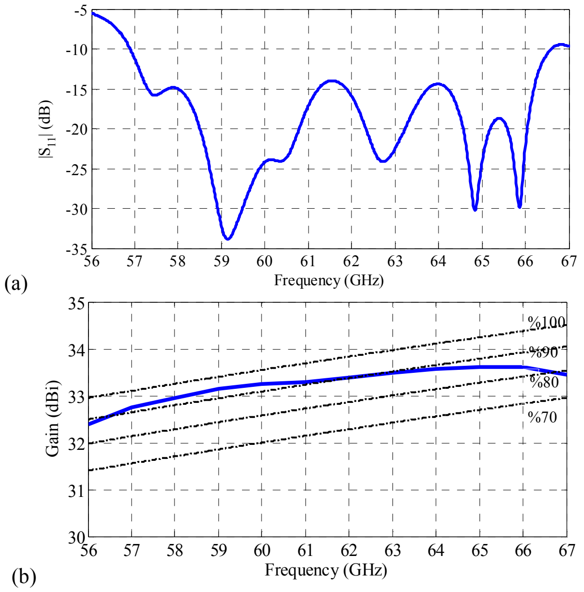

Fig. 3. (a) Simulated $|S_{11}|$ and (b) simulated gain of 16×16-element array.

Here, we present a 16×16-element slot antenna array with a distribution network based on ridge gap waveguide (RGW) technology. The antenna is designed numerically using CST Microwave Studio, by full wave simulations of the complete antenna.

II. ANTENNA STRUCTURE

A. 2×2-Element Sub-array

The 2×2-element sub-array consists of three layers as shown in Figure 1. The feeding part based on ridge gap waveguide in the lower layer, the coupling slot and cavity in the middle layer, and the radiating slots in the upper layer. By proper design of cavity, these four slots are excited equally in amplitude and phase to give a broadside beam.

Notice that from the practical point of view, using a thin metal plate in radiating layer led to some problems in fabrication and assembling process which may affect on the antenna performance. In the other hand, a thick one deteriorates reflection coefficient of the antenna. To overcome this problem and also decreasing grating lobes, some corrugations are created in the radiating layer. The width and depth of these corrugations are optimized to improve S_{11} and radiation pattern of the antenna.

The pin dimensions in the feed and cavity layers are chosen to be 0.5×0.5×1.5 mm^3 and 0.75×0.75×1.5 mm^3, respectively. The period of the pins and the air gap between the pins and the upper metal plate are chosen to be 1 and 0.25 mm, respectively, to achieve a parallel-plate stop-band approximately from 40 to 80 GHz.

B. 16×16-Element Slot antenna array

Fig. 2(a) shows the geometric configuration of the proposed 16×16-element slot array antenna. A 64-way RGW power divider is deployed to feed 64 cavities, each of which excites four radiating slots. Also, in order to excite a standard V-band rectangular waveguide (e.g. WR-15) from the bottom plane, a transition between WR-15 and ridge gap waveguide is designed. As shown in Fig. 2(b), we make a matching step at the end of each ridge to achieve a good matching from WR-15 to the ridge gap waveguide.

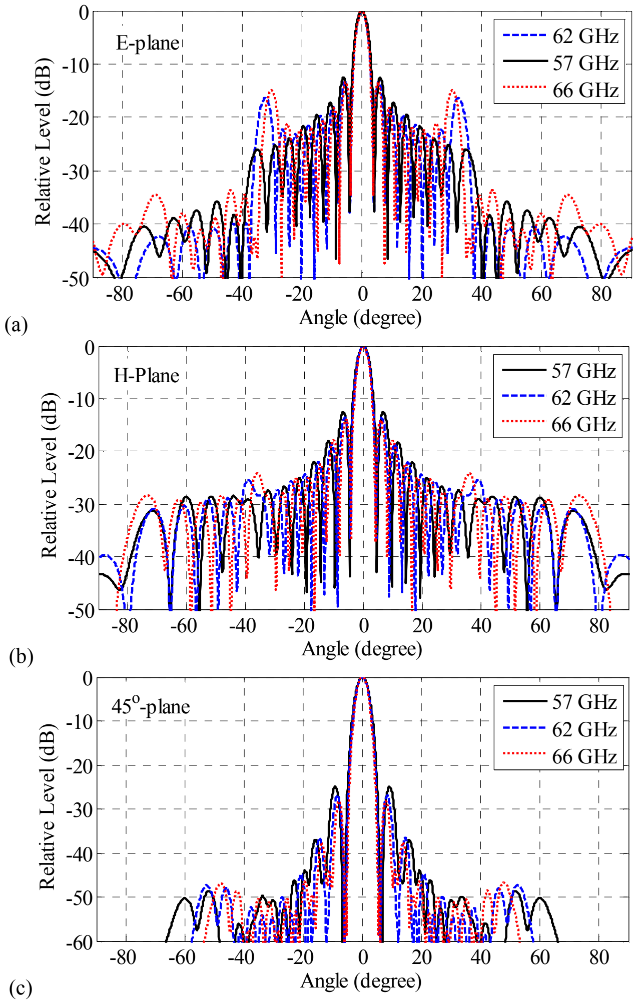

Fig. 4. Simulated radiation patterns of the fabricated 16×16-element array. (a) E-plane. (b) H-plane. (c) 45°-plane.

III. SIMULATION RESULTS

Fig. 3(a) depicts the simulated reflection coefficient of the complete antenna with the designed transition. Observe that the fabricated antenna exhibits an impedance bandwidth (SWR ≤ 2) of 16% from 57 to 67 GHz Also, the simulated frequency characteristics of the directivity and realized gain of the antenna is shown in Fig. 3(b). Observe that the obtained gain is more than 32.5 dBi with a simulated efficiency higher than 85%, i.e. -0.7 dB including conductive losses.

The simulated radiation patterns of the antenna at 57, 62 and 66 GHz in both E- and H-planes and 45°-plane are depicted in Fig. 4. Observe that the first sidelobe level in 45°-plane is around -25 dB.

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