# Ridge gap waveguide slot antenna array with 30% bandwidth for 60-GHz applications



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# Ridge Gap Waveguide Slot Antenna Array with 30% Bandwidth for 60-GHz Applications

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*Abstract*— **This paper presents a wideband high efficiency slot antenna array based on ridge gap waveguide technology at 60 GHz for millimeter-wave applications. The antenna sub-array consists of four radiating slots that are excited by a cavity. Some tuning pins are placed inside the cavity to achieve wideband performance. A 4×4 slots array antenna is designed using 4-ways power divider. The proposed structure exhibits 30% impedance bandwidth ($|S_{11}| \leq$ -10 dB) covering form 50 GHz to 67.8 GHz. The gain up to 21.5 dBi is obtained with total efficiency more than 90%.**

***Index Terms*—wideband slot antenna array, gap waveguide technology, 60 GHz applications.**

## I. INTRODUCTION

Investigation of the high-gain and wide-band planar antenna arrays in millimeter-wave has attracted increasing attention in recent years. Wave-guide slot antenna arrays are a common candidate in this frequency band but they require accurate, high precision and expensive manufacturing [1]. To overcome the manufacturing limitations, the gap wave technology is presented which uses the cut-off frequency band of a PEC-PMC parallel plate waveguide configuration to control desired electromagnetic propagation between the two parallel plates without the requirement of electrical contact [2-4]. This is done by using a bed of nails that act as PMC and introducing a conducting ridge between them to allow the propagating waves to exist.

The waveguide slot antenna arrays have narrow bandwidth and the manifest challenge with such antennas is the bandwidth improvement. A survey of literature on the 60 GHz antenna arrays indicates that different kinds of wideband antenna arrays have been designed [5-8]. A high gain slot antenna array based on the ridge gap waveguide technology is designed with 16% bandwidth [7]. A 17% bandwidth is achieved using groove gap waveguide technology to feed cavity backed slot antennas array [8]. A plate-laminated-waveguide slot array antenna is presented that achieved 19.2% bandwidth [6].

In this paper, a 4×4 slots antenna array with a distribution network based on ridge gap waveguide technology is presented. The design goal is to cover as much as of the V-band frequency range.

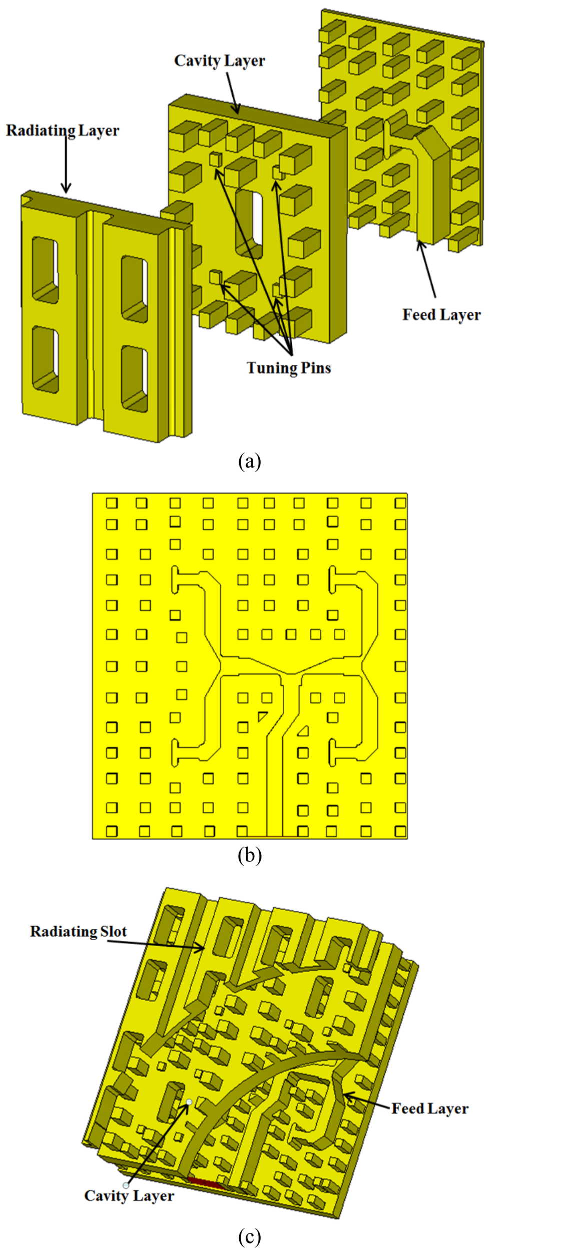


Fig. 1. Perspective view of the geometry of (a) 2×2-element sub-array, (b) 4-ways ridge gap waveguide power divider and (c) 4×4 slots array antenna.

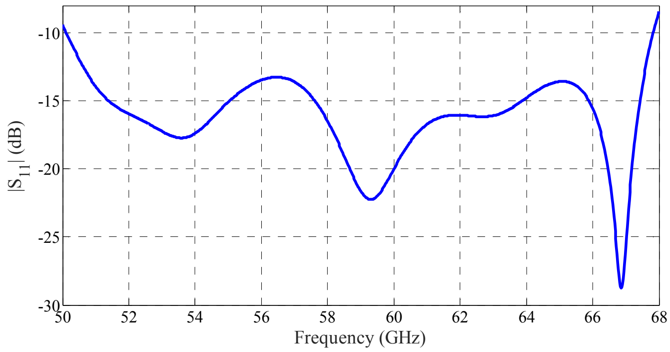


Fig. 2. Simulated reflection coefficient of the 4×4 slot antenna array.

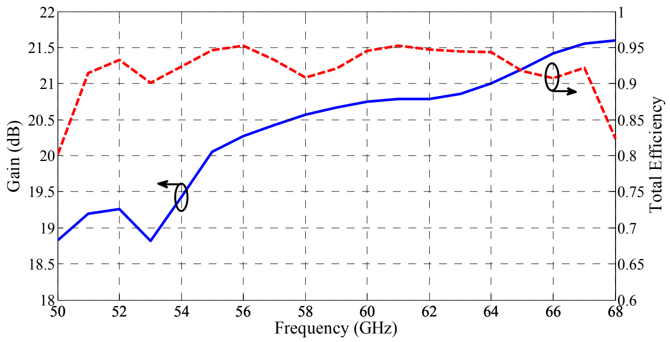


Fig. 3. Simulated gain and total efficiency of the 4×4 slot antenna array.

## II. Antenna Configuration

### *A. 2×2-Element Sub-array*

The 2×2-element sub-array structure is illustrated in Fig. 1(a). As can be seen, the sub-array consists of three layers. The lower layer is the feed layer which is based on ridge gap waveguide. The middle layer is a cavity which is fed by the feed layer via a coupling slot. The radiating slots are located in the top layer. To have mechanical stability, a thick metal plate is used in the radiating layer that deteriorates the antenna reflection coefficient. To overcome this problem, some corrugations are created in the radiating layer. By optimizing the corrugation dimensions, the sub-array reflection coefficient can be improved.

The cavity should excite four radiating slots equally in amplitude and phase in the whole bandwidth. To do this, four short pins are placed inside the cavity and by changing their height and position the cavity resonance mode can be controlled.

The sub-array has the transverse dimensions of 8 mm × 8.8 mm and the distance between radiating slots in the $x$ and $y$ directions are 4.4 mm and 3.8 mm, respectively. The pin dimensions in the feed layer are 0.5×0.5×1.5 $mm^3$ and in the cavity layer are 0.75×0.75×1.5 $mm^3$.

### *B. 4×4-Element antenna array*

A 4-ways power divider based on ridge gap waveguide is designed which is shown in Fig. 1(b).

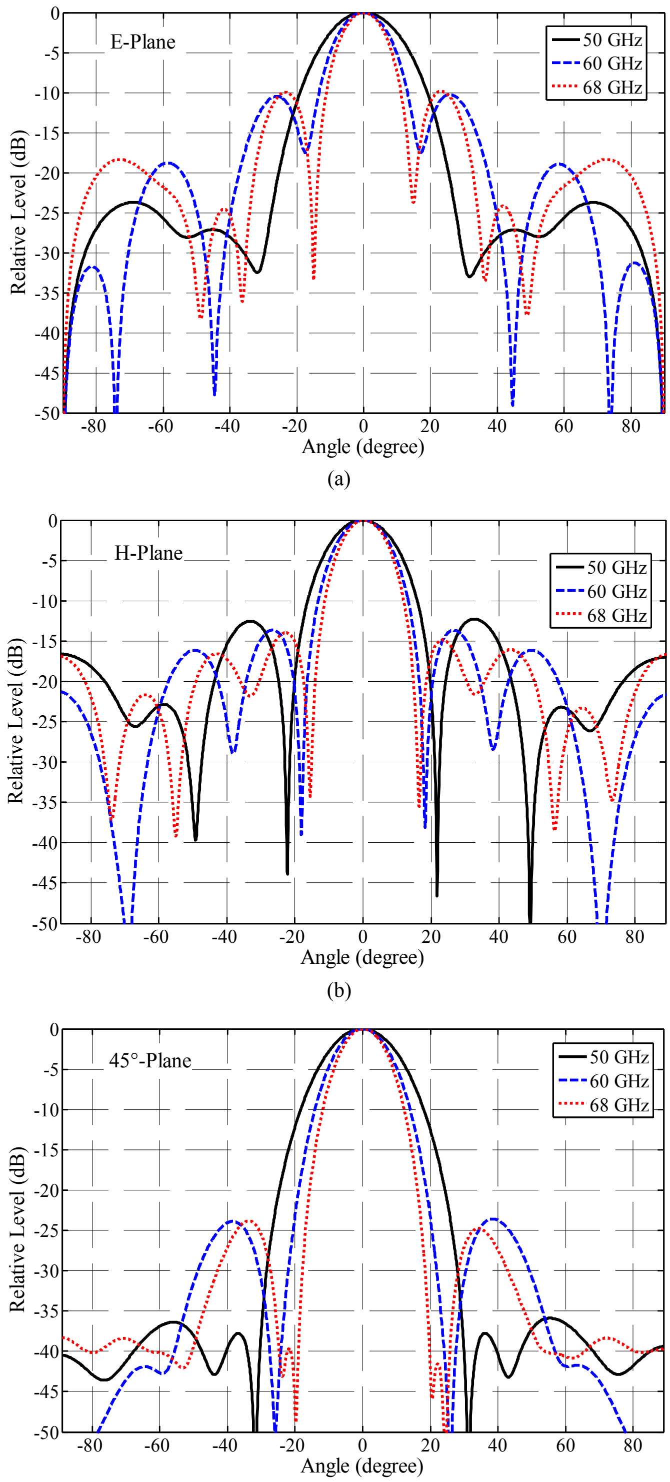


Fig. 5. Simulated radiation patterns of the 4×4 slot antenna array in (a) E-plane, (b) H-plane and (c) 45°-plane.

The power divider consists of 3 T-junctions which are optimized to cover the desired frequency bandwidth. The power divider is used to feed 4 sub-array elements and construct a 4×4 slots antenna array. The geometry configuration of the 4×4 slot antenna array is depicted in Fig. 1(c).

## III. Simulation Results

The CST Microwave Studio is used to perform the simulations. Fig. 2 shows the simulated reflection coefficient of the complete slot array antenna. As can be seen, the antenna exhibits an excellent impedance bandwidth ($|S_{11}| \leq -10$ dB) of 30% covering 50-67.8 GHz. The simulated gain of the array antenna is plotted in Fig. 3. The obtained gain is more than 19 dBi with efficiency higher than 90%.

The antenna far-field radiation patterns in E-plane, H-plane and 45°-plane at the frequencies 50, 60 and 67 GHz are depicted in Fig. 4. The radiation patterns are symmetrical in all planes and frequencies that show the radiating slots are excited equally in amplitude and phase in the whole bandwidth. The first sidelobe levels in E and H-planes are about -10dB and -13 dB respectively, but radiation pattern in the 45° -plane is clear and the sidelobe levels are less than -24 dB.

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