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# Design of A Wideband Array Antenna Prototype with Gap Waveguide for W-Band Wireless Links

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***Abstract*—This paper presents a wideband $45^o$ slot array antenna for W-Band wireless links. The proposed antenna prototype consists of 4×4 slot array, a wideband T-junction based on a groove gap waveguide and a vertical transition from WR-10 to groove gap waveguide. The simulated results show that the proposed prototype has an impedance bandwidth of 26.5% with input reflection coefficient better than -10 dB.**

***Index Terms*—groove gap waveguide, wideband power divider, wideband transition, 4×4 slot array.**

## I. INTRODUCTION

The frequency spectrum from 75 to 110 GHz (W-band) has been paid a lot of attention for high data rate wireless communication system because it has relatively small atmospheric path loss [1], as illustrated in Fig. 1. In a point-to-point wireless links system, a high-gain antenna is one of the key components for transmitting. Several antennas in the W-Band by substrate integrated waveguide (SIW) [2] and low-temperature co-fired ceramic (LTCC) [3] have been reported over the last few years. However, the SIW technology is unable to avoid the high dielectric loss in such a frequency band. On the other hand, it is also high cost to fabricate SIW and LTCC in the W-band. Thereby, low cost and easy fabricated technology is still needed in such a high frequency band. Recently introduced gap waveguide technology [3] is a good candidate for millimeter waves. The gap waveguide technology utilizes the basic cutoff of a perfect electrical conductor, perfect magnetic conductor (PEC-PMC) parallel-plate waveguide configuration to control desired electromagnetic propagation between the two parallel plates. In the realized gap waveguide, the PEC-PMC cutoff becomes a stopband, and this stopband can be achieved by a periodic structure, such as metallic pins or mushrooms surfaces. However, the textured surface must also incorporate guiding structures in the form of ridges, grooves or strips. As a result of the stopband, the electromagnetic waves can propagate along these ridges, grooves or strips without leaking away in other directions. A typical groove gap waveguide is illustrated in Fig. 2. Compared with inverted microstrip gap waveguide and microstrip-ridge gap waveguide, the groove gap waveguide is able to avoid the dielectric loss. Therefore, it is a good candidate to design a high efficiency antenna. Furthermore, the gap waveguide technology is also suitable for passive and active components integrated designs, since the is no need for electrical contact between metal blocks. Until now there have already been lots of applications of gap waveguide technology for MMIC packaging [5]-[6], antennas [7]-[12] and filters [13]-[15]. In this paper, we present a 4×4 W-band cavity-backed slot array fed by a groove gap waveguide. The slots on the top layer have been $45^o$ rotated in order to achieve good radiation patterns in both horizontal and vertical planes. The proposed antenna has a multilayer structure and suitable for manufacturing by computerized numerical control (CNC) techniques.

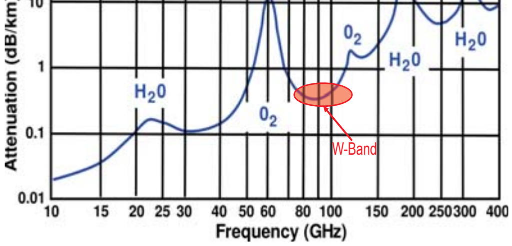

Fig. 1. Atmospheric attenuation at millimeter-wave frequencies in dB/km.

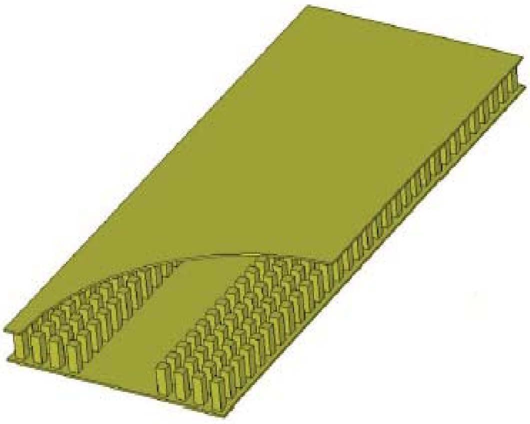

Fig. 2. Geometrical configuration for the groove gap waveguide.

## II. DESIGN OF TRANSITION FROM WR-10 AND POWER DIVIDER ON GROOVE GAP WAVEGUIDE

The pin dimensions of bed of nails should be chosen correctly to achieve a parallel plate stopband which covers as much as W-band. The way to obtain the geometrical dimension of metallic pins by given frequency stopband study in this work is very similar to those published works mentioned in [16]. The basic idea is numerical parametric analysis of the groove gap waveguide which is illustrated in Fig. 3. The PEC, periodic and PEC boundary conditions are added for the structure in $x$-, $y$- and $z$-axis, respectively. Correspondingly, the dispersion diagram of the structure is shown in Fig. 4, which is obtained by utilizing the eigenmode solver in CST Microwave Studio software. The obtained stopband is from 65 to 115 GHz, which covers the whole W-band (75—110 GHz). The required parameter values of the structure shown in Fig. 3 are presented in Table I.

In practice, in order to excite the antennas and measure them there should have a interface from a standard rectangular waveguide. In [17] a vertical transition from standard WR-15 to inverted microstrip gap waveguide is successfully designed. In this work, a similar transition from standard WR-10 to a groove gap waveguide is presented. As is depicted in Fig. 5, a metallic brick is placed under the top wall of the groove gap waveguide and above the waveguide keeps opening. In order to spread the bandwidth of the whole transition structure, the metallic brick is designed as a second order tapered transformer. The simulated reflection coefficient is lower than -20 dB from 70 to 100 GHz, as shown in Fig. 6.

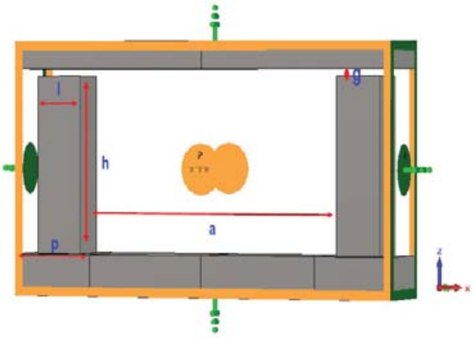

Fig. 3. A groove gap waveguide unit cell for determination of dispersion diagram.

TABLE I
DESIGN PARAMETERS OF THE STRUCTURE IN FIG. 3

| | |
|---|---|
| Width of the Groove [$l$] | 2.4 mm |
| Height of Air Gap [$g$] | 0.05 mm |
| Height of Pin [$h$] | 1.2 mm |
| Width of Pin [$l$] | 0.35 mm |
| Period of Pin [$p$] | 0.7 mm |

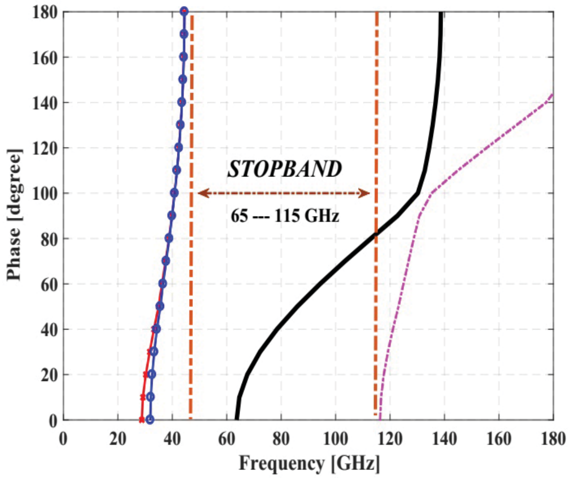

Fig. 4. Dispersion diagram for the infinite periodic groove gap waveguide unit cell.

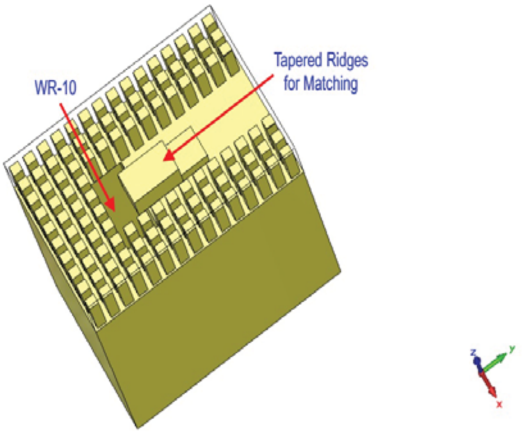

Fig. 5. Geometrical configuration for the vertical transition from WR-10 to the groove gap waveguide transmission line. The top PEC plate is hidden.

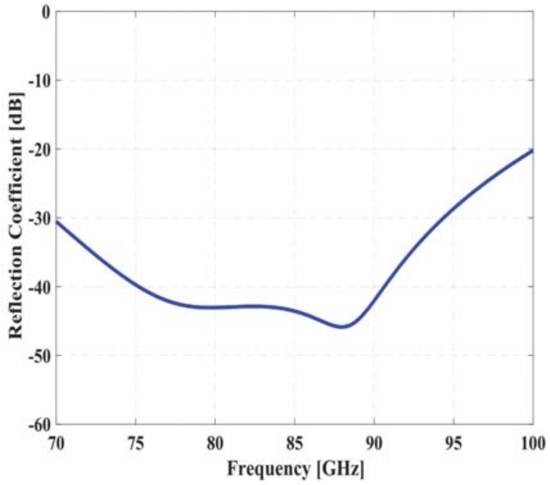

Fig. 6. Reflection coefficient of the vertical transition from WR-10 to groove gap waveguide illustrated in Fig. 5.

Essentially a T-junction power divider is a simple three-port network that can be utilized for power division or combining. Thereby, the T-junction power divider is a central component in distribution networks for feeding antenna array. In [7]-[12] the T-junction power dividers based on the ridge gap waveguide and the inverted microstrip gap waveguide have been already achieved. In this work a T-junction power divider on groove gap waveguide is presented, as depicted in Fig. 7. Two iris parts have been applied in the output ports so that the amplitude of the reflection coefficient and the input bandwidth are very well improved. As a result, the reflection coefficient of the T-junction with the irises as shown in Fig. 7 is below -25 dB over the 30% input impedance bandwidth.

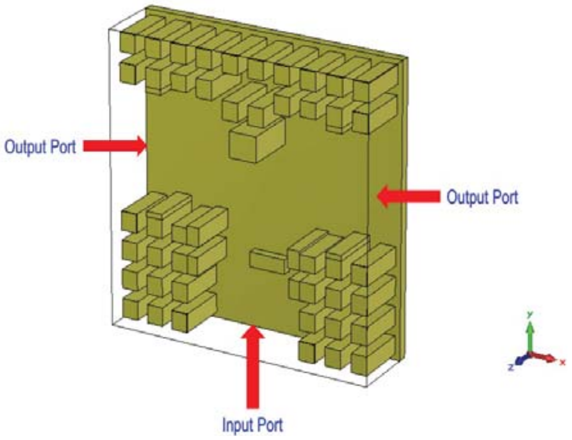

Fig. 7. T-shaped power divider on groove gap waveguide.

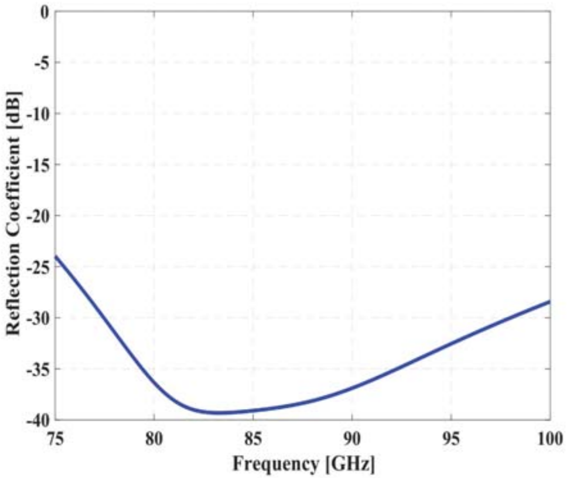

Fig. 8. Simulated reflection coefficient of the power divider on groove gap waveguide.

## III. 4×4 SLOT ARRAY ANTENNA SIMULATION RESULTS

In this section a 4×4 slot array antenna is presented based on the proposed transition structure and the T-junction power divider. Fig. 9 shows the configuration of the designed antenna. The antenna consists of three unconnected layers, — radiating layer, cavity layer and distribution layer. A corporate feed-network in form of groove gap waveguide is designed to feed the 4×4 array with the same phase and amplitude. For a compacted design, the feeding network is placed on the back side of the same plate of the cavity layer. The designed antenna is suitable for manufacturing by micromachining technology. The $45^o$ linear polarization enables low sidelobe characteristic because the principal polarization plane is along the diagonal of the square antenna. The slots on the top layer have been splitted in the middle in order to suppress the cross polarization [18]. The simulated input reflection coefficient of the designed array is shown in Fig. 10. The proposed antenna has broad impedance bandwidth (26.5%) with $S_{11}$ below -10 dB over the 75-98 GHz frequency band. Fig. 11 shows the simulated horizontal and vertical planes radiation patterns of the array antenna at 85 GHz. The array antenna has good radiation pattern. The first sidelobe is 13.4 dB below the main beam. The simulated radiation pattern of an array antenna with 16 × 16 slot aperture size in infinite array environment is also presented in Fig. 12. The E- and H-planes radiation pattern satisfy with ETSI class 3.

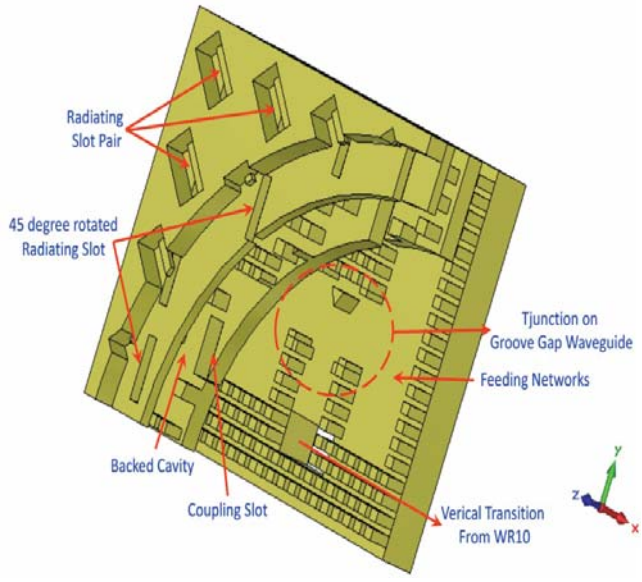

Fig. 9. Geometrical configuration for proposed 4 × 4 slot array antenna in this work.

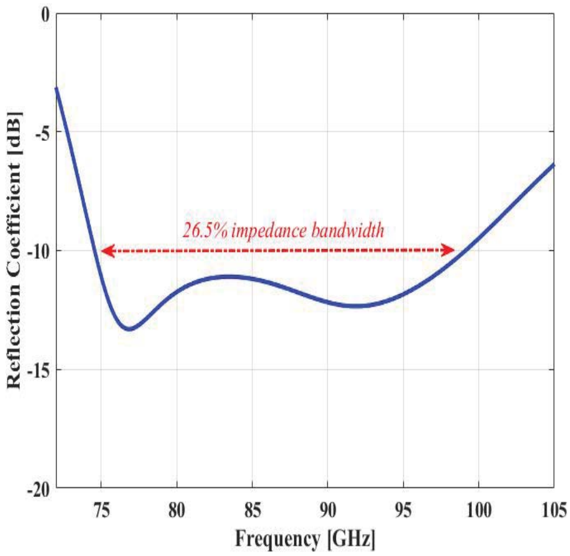

Fig. 10. Simulated reflection coefficient of proposed 4 × 4 slot array antenna.

## IV. CONCLUSION

A wideband slot array antenna on groove gap waveguide technology in W-band is presented in this work. The proposed array antenna consists of three uncontact layers. It makes the fabrication easier and cheaper. The designed antenna shows a good radiation pattern with a relative impedance bandwidth of 26.5% over the 75-98 GHz frequency band. The radiation patterns of 16 × 16 array

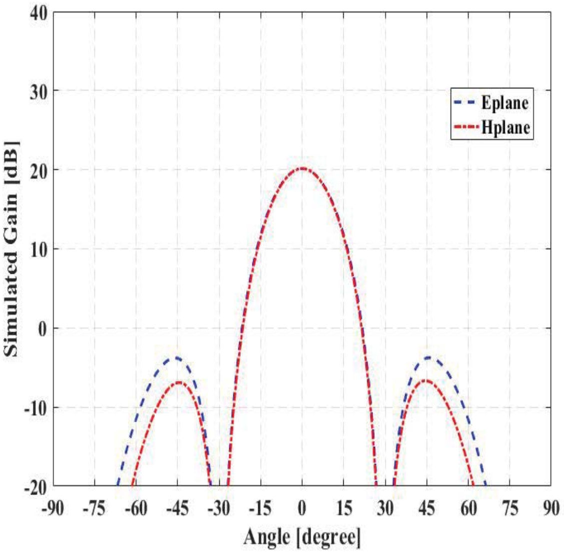

Fig. 11. Simulated radiation pattern of proposed 4 × 4 slot array antenna.

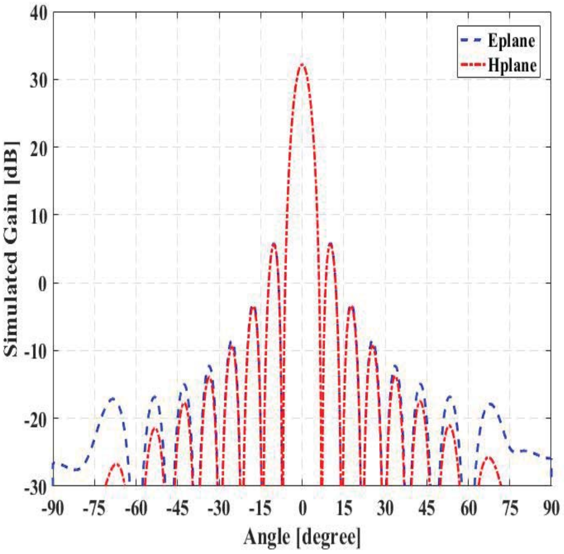

Fig. 12. Simulated radiation pattern of 16 × 16 slot array antenna in infinite array environment.

antenna is realized through infinite array environment and satisfy the ETSI class 3.

## ACKNOWLEDGMENT

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