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Design of a 38 dBi Slot Array on Gap Waveguide at 140 GHz

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***Abstract*—In this paper, a cavity-backed full-corporate feed slot array antenna based on ridge gap waveguide at 140 GHz is presented. In order to fabricate the proposed slot array by computerized numerical control (CNC) milling technology, the length of metallic pins is selected as large as possible. Since the full-corporate feed networks are very dense, and only one row of metallic pins is required to isolate the coupling effect between any two neighbored distribution networks. In the work, height value of the bed nails are well selected so that the mutual coupling are below -20 dB. The simulated results show that the proposed array antenna has an input impedance bandwidth of 11% better than -10 dB. The bandwidth covers 135-150 GHz frequency band. The simulated gain is higher than 38 dBi over 135-150 GHz.**

***Index Terms*—140 GHz, Slot Array Antenna, full-corporate Feed, Ridge Gap Waveguide.**

I. INTRODUCTION

Recently, the attention towards the frequency spectrum has been moved to the millimeter waves (mmWs) because of out of utilization in microwave frequencies. The D-band (from 110 to 170 GHz) have paid a lot of attention for many applications such as high data rate wireless systems, imaging and radar sensors. High-gain antenna in such a frequency band is one of the critical components in millimeter wave frequencies, due to the limited output power of RF electronics, especially for point-to-point wireless links. Traditional wave guiding structures, such as stripline, co-planar waveguide, microstrip and hollow rectangular waveguide, show some disadvantages in mmWs. In reality, hollow rectangular waveguide is fabricated in two symmetric parts and then assembled together. Thus, it always faces poor electrical contacts. On the other hand, microstrip lines usually suffer from unintentional couplings and high dielectric loss. A covered microstrip structure can somehow overcome these disadvantages. Nevertheless, it still faces losses in the dielectric as frequency increases.

One popular solution method to mmWs is the substrate integrated waveguide (SIW) [1]. Up to now, several different types of antennas based on SIW technology have been explored and developed [2]-[4]. Nevertheless, SIW has unavoidable dielectric losses in the substrate as the frequency increases. Therefore, it is necessary to find new technological solutions for waveguides above 50 GHz. Recently, the effectiveness of the newly introduced gap waveguide technology for mmWs has been demonstrated [5]. This novel structure has advantages of low loss properties compared to traditional wave guiding structures [6]. Secondly, the gap waveguide is able to maintain low loss property since the waves propagate in the air gap. Thirdly, this geometry is able to avoid the requirement of good electrical contacts. Lastly, the gap waveguide can have easy fabrication process by computerized numerical controlled (CNC) machine, molding or electrical discharge machining (EDM) technique.

In [7]-[9] several different slot array antennas in mmWs based on gap waveguide technology have been reported. A novel W-band low-profile monopulse slot array antenna on ridge gap waveguide has been reported in [10]. A novel leaky-wave antenna on groove gap waveguide has been recently presented in [11]. Some passive filters and novel transition structures based on gap waveguide technology have been reported in [12]-[15]. In this paper, we present a 32 $\times$ 32 slot array fed by the ridge gap waveguide distribution networks at 140 GHz. The proposed antenna has double-layer corporate feed structure and is suitable for manufacturing by computerized numerical controlled (CNC).

II. ANTENNA SUB-ARRAY

The pins in distribution networks layer present a stopband and prevent any unwanted modes and leakage in the designed frequency band. The dispersion diagram of a guiding ridge and pins unit cell in this work is depicted in Fig. 1. As is shown in

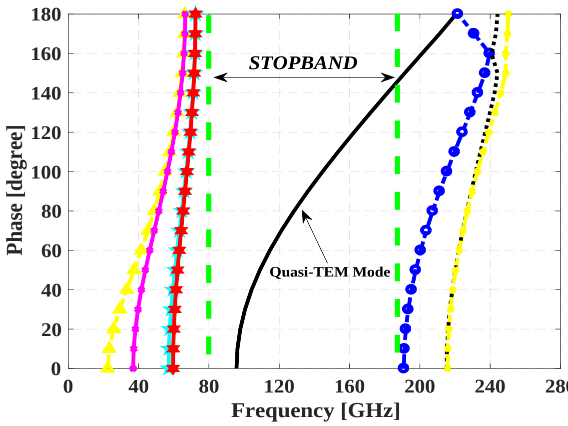

Fig. 1. The ridge gap waveguide in this work and the corresponding dispersion diagram.

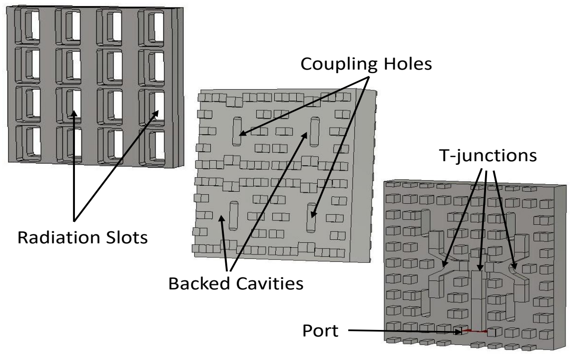

Fig. 2. 3-D view for the antenna unit cell in this work.

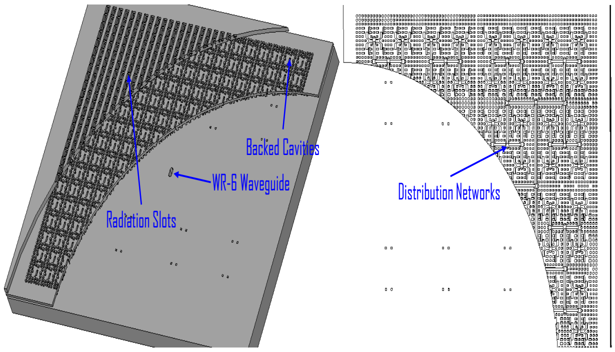

Fig. 4. Numerical model of the proposed 32 × 32 array antenna in CST Microwave Studio.

the figure, a quasi-TEM mode propagates within the air gap between the ridge and the lower lid. Fig. 1 illustrates a single mode propagation over the 75-188.94 GHz frequency band. The antenna unit cell is optimized with periodic boundary condition, where the mutual coupling between elements is considered by using CST Microwave Studio.

Fig. 2 illustrates the proposed cavity-backed geometry of the antenna unit cell. The antenna unit cell consists of three unconnected metallic layers as same as those introduced in [12]-[18]. Four slots feeds by an air-filled cavity on the top layer. The element spacing between slots is smaller than, but close to one wavelength to achieved high gain and avoid high grating lobes. The electromagnetic wave couples to the cavity through a coupling aperture, which is excited via a ridge gap waveguide feeding line. The distribution feed networks are placed on the back side of the cavity layer for more compact design. The lower layer is a smooth metallic plate. Every layer is separated with a small gap and no electrical contact between the different layers is required. Fig. 3 demonstrates the simulated reflection coefficient of the antenna sub-array with periodic boundary condition. The proposed antenna sub-array has input impedance bandwidth of 10.5% than -15 dB over the frequency band 138-150 GHz.

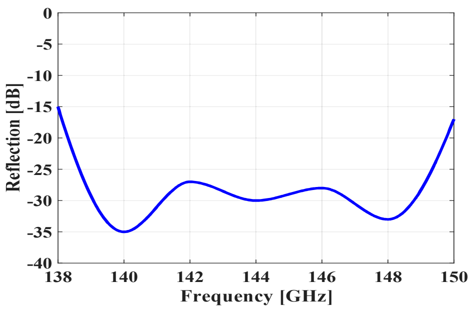

Fig. 3. Simulated reflection coefficient of the proposed antenna unit cell in periodic boundary condition.

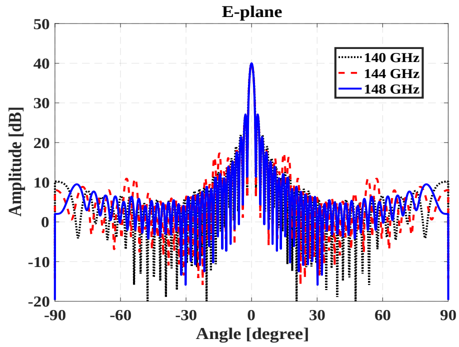

Fig. 5. Simulated E-plane radiation patterns at 140, 144 and 148 GHz.

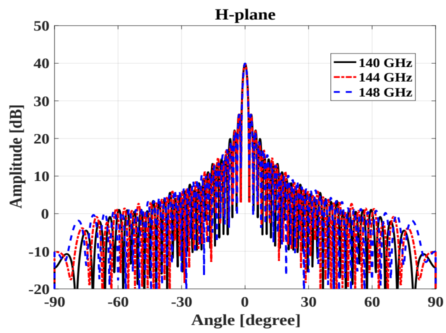

Fig. 6. Simulated H-plane radiation patterns at 140, 144 and 148 GHz.

III. SIMULATION RESULTS OF 32 × 32 SLOT ARRAY ANTENNA

A 32 × 32 slot array antenna is designed based on the proposed antenna unit cell. Fig. 4 depicts the configuration of designed antenna, which consists of three unconnected layers. The whole antenna is excited by a WR-6 waveguide in the phase center of the whole array antenna.

The simulated input reflection coefficient of the designed array antenna is shown in Fig. 7. The proposed antenna has a promising reflection coefficient which is below -18 dB from 140 to 148 GHz. Fig. 5 and 6 show the simulated E- and H-

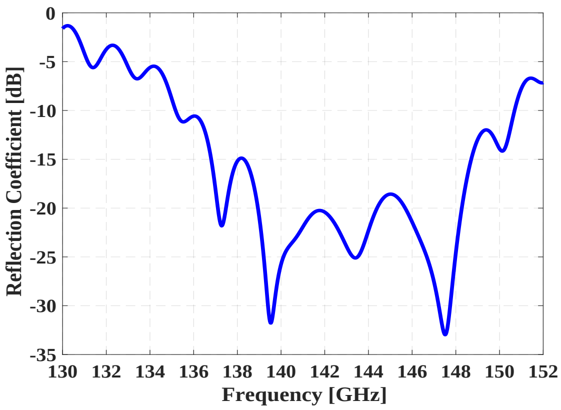

Fig. 7. Simulated reflection coefficient of the proposed 32 $\times$ 32 slot array antenna.

planes radiation patterns of the array antenna at 140, 144 and 148 GHz. The array antenna has good radiation pattern. The first sidelobe is 13.4 dB below the main beam.

IV. Conclusion

A low-profile wideband air-filled cavity-backed 32 $\times$ 32 slot array antenna is presented based on gap waveguide technology at 140 GHz. The designed antenna shows a good radiation pattern with a relative impedance bandwidth of 10.5% over the 136-150 GHz frequency band.

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