Wideband cavity-backed slot subarray with gap waveguide feed-network for D-band applications

Wideband Cavity-Backed Slot Subarray with Gap Waveguide Feed-network for D-band Applications

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***Abstract*—A simple and wideband subarray for D-band applications is presented in this paper. The proposed multilayer subarray consists of 2×2 cavity-backed slot subarray fed by a ridge gap waveguide transmission line. The simulated results show that the proposed subarray has a relative impedance bandwidth of 22.5% with input reflection coefficient better than -10 dB over the 126-158 GHz frequency band. An array antenna consisting of 8×8 slots is designed with the proposed subarray. The simulation results of the proposed subarray and antenna are presented.**

***Index Terms*—D-band, gap waveguide, slot array antenna.**

I. INTRODUCTION

The frequency spectrum from 110 to 170 GHz (D-band) have got a lot of attention for many applications such as high data rate wireless communication systems [1], imaging [2] and radar sensors [3]. High-gain and high-efficiency antenna is one of the key components in millimeter wave frequencies, due to the limited output power of RF electronics, especially for point-to-point wireless links. Several antennas including horn [4], micromachined dipole antenna [5], on-chip slot antenna [6], and microstrip patch antenna [7] have been reported at D-band over the last few years. However, low profile, hig gain, high efficiency and low cost planar antennas are more attractive for many applications.

Due to the losses in distribution network, fabrication complexity and cost, the design of high gain array antennas present a challenging task in millimeter waves frequencies. Planar array antennas with different technology, such as substrate integrated waveguide (SIW) slot array antenna manufactured by multi-layered low-temperature co-fired ceramic (LTCC) and corporate-fed waveguide slot array antenna manufactured by diffusion bonding of many thin plates are reported in [8], [9].

Several slot array antennas with high gain and high efficiency based on gap waveguide technology as a new guiding structures are presented recently [10]–[13]. This new transmission line shows low loss and flexible fabrication, especially for high gain array antennas with large number of elements which need low loss corporate feed-network. In gap waveguide technology, there is no need for electrical contact between the building blocks, which reduces cost and increases the assembly reliability. Therefore, gap waveguide could be a good solution for the problems in fabricating and mechanical assembly of millimeter wave components. The main principle of gap waveguide technology is the parallel PEC/PMC waveguide configuration cutoff and using of periodic band gap structures to control the wave propagation in the desired direction [14]. The gap waveguide technology is suitable for passive and active components integrated designs, since the is no need for electrical contact between metal blocks.

In this paper, we present a D-band broadband cavity-backed slot subarray fed by a ridge gap waveguide transition line with high efficiency and wide impedance bandwidth. An array antenna consisting of 8×8 slots is designed based on the proposed subarray. The proposed antenna has multilayer structure and suitable for manufacturing by micromachining techniques.

II. SUBARRAY DESIGN

Fig. 1 illustrates the proposed 2×2 cavity-backed subarray geometry. The subarray consists of three unconnected metal layers. 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 feeding network is placed on the back side

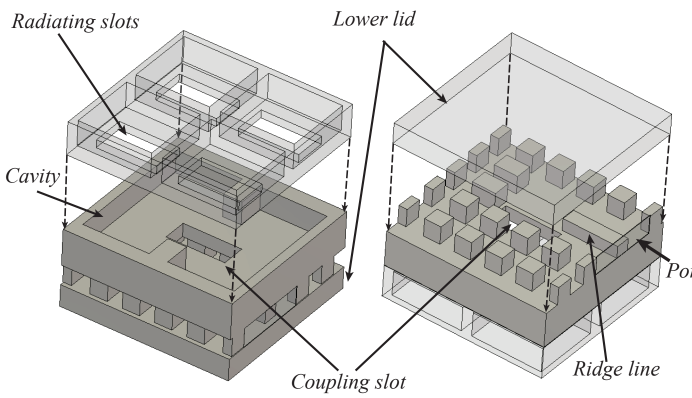

Fig. 1. Distributed view of the proposed 2×2 cavity-backed slot subarray.

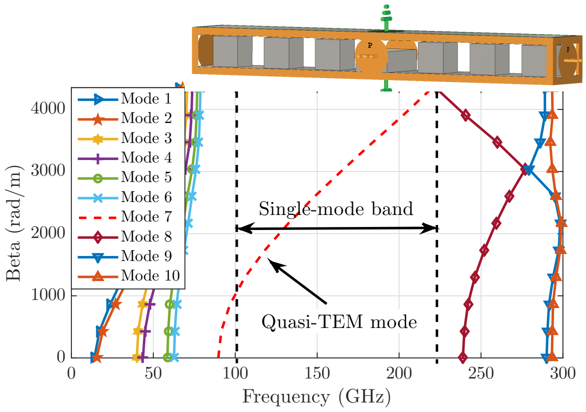

Fig. 2. Dispersion diagram for the infinite periodic a guiding ridge in pins texture

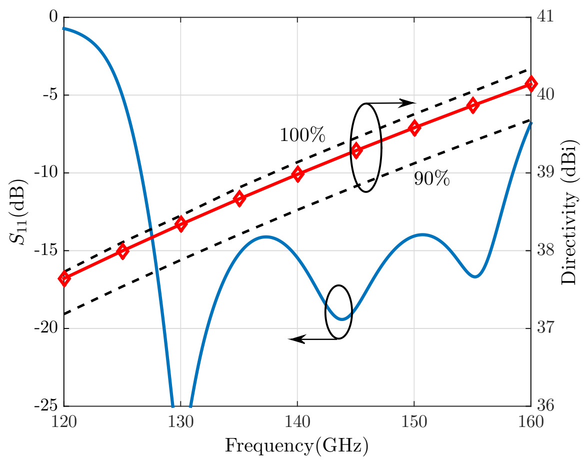

Fig. 3. Simulated results of reflection coefficient of the proposed subarray and directivity of an array with 32×32 slot aperture dimension in infinite array environment.

of the cavity layer for more compact design. The lower layer is a smooth metal plate. All three layers are separated with a small gap and no electrical contact between the different layers is needed.

The pins in the feeding layer presents 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 is shown in Fig. 2. A quasi-TEM mode propagates within the air gap between the ridge and the lower lid. Fig. 2 shows a single mode propagation over the 100-200 GHz frequency band. The subarray is optimized with periodic boundary condition, where the mutual coupling between elements is considered by using CST Microwave Studio.

Fig. 3 demonstrates the simulated reflection coefficient of the subarray in the infinite array environment. The proposed subarray has a relative bandwidth of 22.5% with $|S_{11}|$ better than -10 dB over the frequency band 126-158 GHz. The simulated directivity of an array with 32×32 slot aperture size

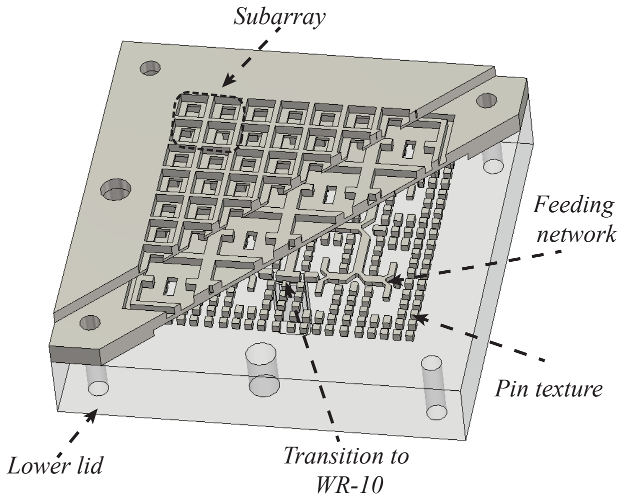

Fig. 4. Configuration of the corporate-fed 8×8 slot array antenna based on the proposed subarray.

in infinite array environment is also presented in Fig. 3. The maximum available directivities with 100% and 90% aperture efficiencies with the same aperture size (32×32 slot) is also presented, which shows high aperture efficiency of the proposed subarray.

III. 8×8 Slot Array Antenna Simulation Results

A 8×8 slot array antenna is designed based on the proposed subarray. Fig. 4 shows the configuration of the designed antenna. The antenna consists of three unconnected layers, i.e. radiating layer, cavity layer and flange layer. A corporate feed-network in form of ridge gap waveguide is designed to feed the subarrays 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. Different micromachining techniques have been already applied to fabricate millimeter wave gap waveguide structures [15].

The simulated input reflection coefficient of the designed array is shown in Fig. 5. The proposed antenna has broad impedance bandwidth (22.5%) with $|S_{11}|$ below -10 dB over the 126-158 GHz frequency band. Fig. 6 shows the simulated E- and H-planes radiation patterns of the array antenna at 145 GHz. The array antenna has good radiation pattern. The first sidelobe is 13.4 dB below the main beam. The designed antenna has wider bandwidth than the 8×8 slot array antenna presented in [12].

IV. Conclusion

A low-profile wideband air-filled cavity-backed slot subarray is presented based on gap waveguide technology for D-band. The proposed subarray consists of three layers without need of electrical contact between them. The subarray shows

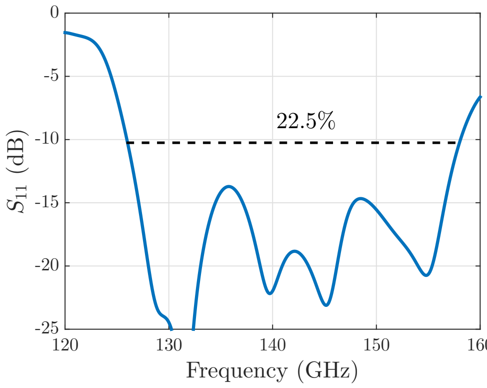

Fig. 5. Simulated reflection coefficient of the designed 8×8 slot array antenna.

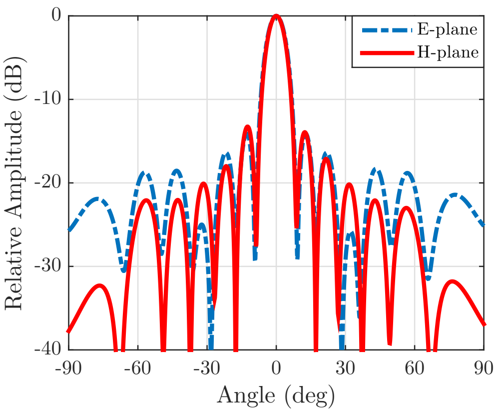

Fig. 6. Simulated E- and H-planes radiation patterns of the designed 8×8 slot array antenna at 145 GHz.

wider bandwidth than presented subarrays in [10], [13]. The proposed subarray is used to design an 8×8 slot array antenna. The designed antenna shows a good radiation pattern with a relative impedance bandwidth of 22.5% over the 126-158 GHz frequency band.

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