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E-band 3-D Metal Printed Wideband Planar Horn Array Antenna

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***Abstract*—This paper presents a wideband and high efficiency corporate-fed horn array antenna in the E-band. A horn antenna is used as the unit cell of the array. The radiation pattern and grating lobe levels of the unit cell are improved by splitting the horn's aperture with a septum in the E-plane. A ridge gap waveguide corporate distribution network feeds the horns with the same amplitude and phase via coupling apertures. A prototype consisting of 4×4-element horn array antenna is manufactured by Direct Metal Laser Sintering (DMLS) 3-D printing technique. The proposed antenna has a relative bandwidth of 24% with input reflection coefficient better than -10 dB and simulated total antenna efficiency better than 85% over the 69-88 GHz frequency band.**

***Index Terms*—gap waveguide, horn array antenna, 3-D metal printing, high efficiency, millimeter-wave.**

I. Introduction

Planar antenna with high aperture efficiency has received a lot of attention over the last few years and became very popular for the emerging wireless millimeter-wave systems. Horn and slot array antennas are the most common type of antennas used as high-directive planar antennas in the millimeter-wave frequencies [1], [2].

An array antenna with high gain and large number of elements requires a low loss distribution network. The gap waveguide technology as a new guiding structures shows low loss and flexible manufacturing characteristics, especially at millimeter-wave frequencies. This new guiding structure is based on soft/hard boundary conditions and the cutoff of a parallel PEC/PMC waveguide configuration [3]. The gap waveguide technology presents a solution to the existing problem of good electrical contact among the different antenna parts . Thus the gap waveguide based antennas have much simpler mechanical assembly at high frequency.

In this paper, we present the ridge gap waveguide based planar horn array with wide impedance bandwidth and high efficiency. The radiating performance of the antenna is improved by introducing a septum in the E-plane of a similar horn unit cell presented in [4]. A prototype consisting of 4×4-element horn array is fabricated by Direct Metal Laser Sintering (DMLS) 3-D printing technique.

II. Array Element Design

Fig. 1 shows the geometry of the proposed horn unit cell. The unit cell dimensions in the E- and H-plane is larger than one wavelength, which causes grating lobes. The grating lobes and sidelobes in the H-plane have been suppressed by inserting a septum in the middle of the horn's aperture in the E-plane. The horn unit cell is excited by a coupling aperture from a ridge gap waveguide distribution network on the back side of the same plate.

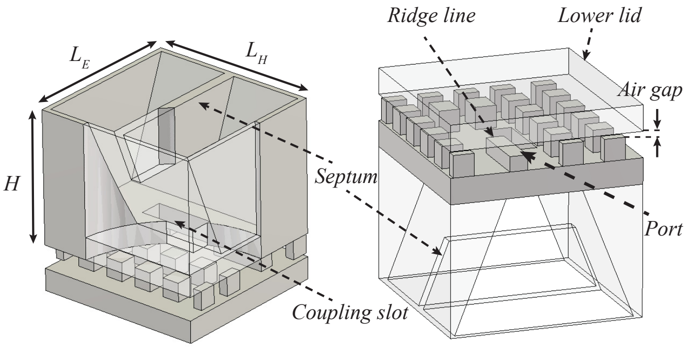

Fig. 1. The proposed horn unit cell ($L_E = 6\ mm$, $L_H = 6.1\ mm$, and $H = 5\ mm$)

A qusi-TEM mode propagates between the feed ridge and the lower lid within the air gap. The horn and its feeding network is separated from the lower lid with a small gap and no electrical contact between layers is needed. The pin surface

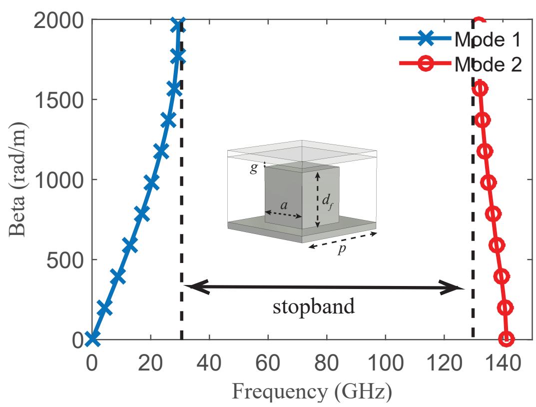

Fig. 2. Dispersion diagram of the infinite periodic pin unit cell (d_f = 0.68 mm, a = 0.64 mm, g = 0.04 mm, and p = 1.28 mm).

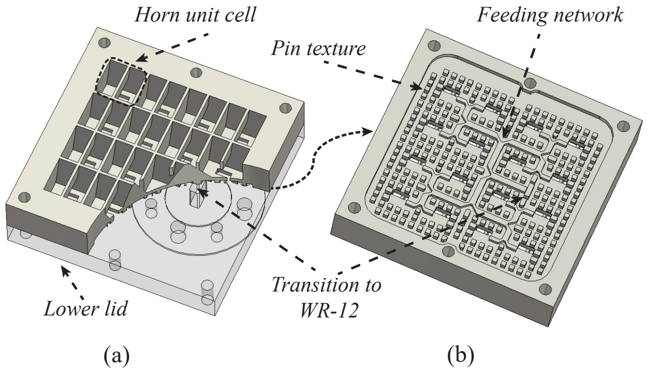

Fig. 3. Configuration of the corporate-fed horn array antenna. (a) Radiating layer. (b) Distribution feed network on the back side of the radiating layer.

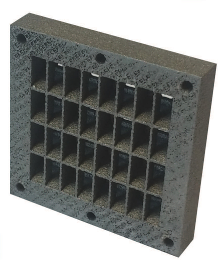

Fig. 4. Photograph of the proposed horn array antenna fabricated by 3-D metal printing.

together with the lower lid present a PEC/PMC stopband for the parallel-plate modes and prevent any possible unwanted modes and leakage. The dispersion diagram of the pin unit cell used to create the stopband is shown in Fig. 2. The unit cell parameters are optimized in the infinite array environment by using CST Microwave Studio.

III. Antenna Structure and Results

The configuration of the proposed antenna is shown in Fig. 3. The antenna consists of a double side metal layer. A 4×4-element horn array antenna is fed by a corporate feed network formed by ridge gap waveguide on the back side of the same plate. A prototype fabricated by DMLS 3-D printing technique is illustrated in Fig. 4. The total size of the antenna is $32 \times 32\ mm^2$ however, the effective array aperture is $24 \times 24.4\ mm^2$.

The measured and simulated input reflection coefficient of the prototype are shown in Fig. 5. The proposed antenna shows a very wide impedance bandwidth with reflection coefficient below -10 dB over the 69-88 GHz frequency band. The simulated boresight gain are also presented in Fig. 5. The dashed lines show the maximum available directivities with 100% and 80% aperture efficiency. The simulated total antenna efficiency is better than 80% over the same frequency band.

The simulated and measured normalized radiation farfield patterns of the antenna in E- and H-planes at 81 GHz are shown in Fig. 6. The computed radiation patterns of the an-

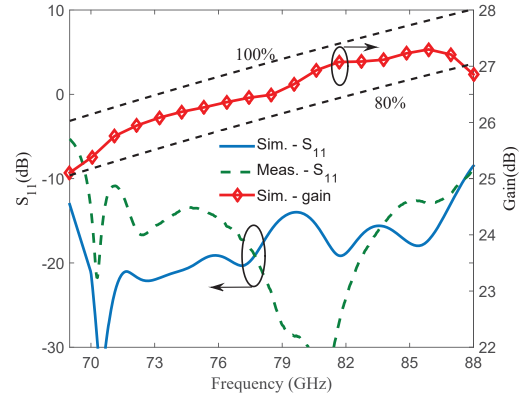

Fig. 5. Comparison of simulated and measured input reflection coefficient and simulated gain of the proposed antenna.

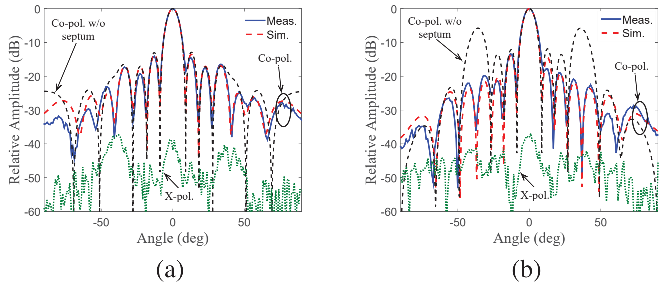

Fig. 6. Simulated and measured radiation patterns of the proposed array antenna at 81 GHz. (a) E-plane, (b) H-plane.

tenna with out the inserted septum are also presented in Fig. 6. We see that inserted septum improves the radiation pattern and suppress grating lobes in the H-plane. The measured cross-polar level of the proposed antenna is below -40 dB in the operating band. There is good agreement between simulated and measured results.

IV. Conclusion

We have presented a low-profile wideband corporate-fed horn array antenna based on gap waveguide technology. A prototype consisting of 4×4-element horn array is manufactured by DMLS 3-D printing technique. The proposed antenna shows a good radiation patterns and low cross-polar level with a relative impedance bandwidth of 24% over the 69-88 GHz frequency band.

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