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Corporate Distribution Networks for Slot Array Antenna Based on Groove Gap Waveguide Technology

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Abstract— This paper deals with the design of low loss wideband power dividers based on groove gap waveguide (GGW) technology. The advantages of GGW power dividers are low insertion loss, high power handling capacities, ease of fabrication and compatibility with integrated microwave networks. A 64-way power divider is designed and used as the feeding network of a 16×16-element slot antenna array at 60-GHz band. The results show that the gain and total radiation efficiency of the antenna are more than 32.5 dBi and 90% over the desired frequency range from 56 to 66.4 GHz.

Index Terms—corporate feeding network, groove waveguide technology, slot antenna array.

I. INTRODUCTION

Power dividers are building blocks of many microwave and millimeter-wave components and networks. Especially in microwave and millimeter-wave integrated circuits, the feeding system of an array antenna needs a power divider with low loss, high Q-factor and broad bandwidth. The conventional rectangular waveguide power divider can meet these requirements. For instance, power dividers fabricated from traditional waveguides have the advantages of low insertion loss and high power handling capacities, but their large size and high cost is a limiting factor.

In this contribution, the aim of the present work is to utilize groove gap waveguide (GGW) technology to design of power dividers for use in feeding networks of large slot antenna arrays. The gap waveguide technology was introduced in [1-3]. The advantage compared to microstrip and Substrate Integrated Waveguide (SIW) technologies is that this gap waveguide technology can keep a planar profile as well as being low loss [4-6]. In addition, this technology can be realized without good metal contacts between the different layers of multilayer structures. There are also many modern manufacturing technologies that will suit such planar surfaces with texture, such as die sink Electrical Discharge Manufacturing (EDM), Electron Beam Melting (EBM), multilayer die pressing, and 3D screen printing. Therefore, the gap waveguide technology has a large potential for millimeter wave applications.

To date, some array antennas have been realized based on gap waveguide distribution networks: a 4x1 slot array fed by

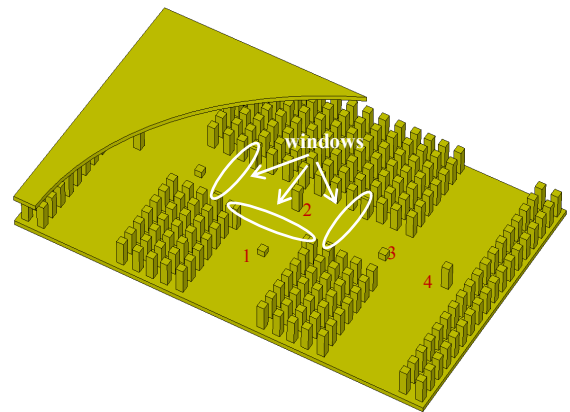


Fig. 1. The geometry of 4-way H-shaped GGW power divider.

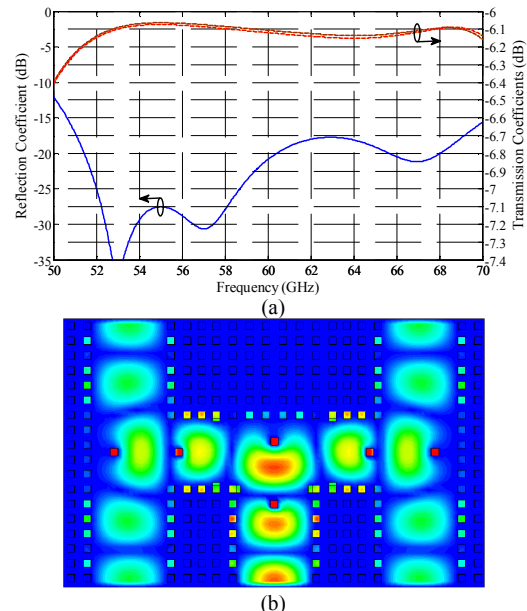
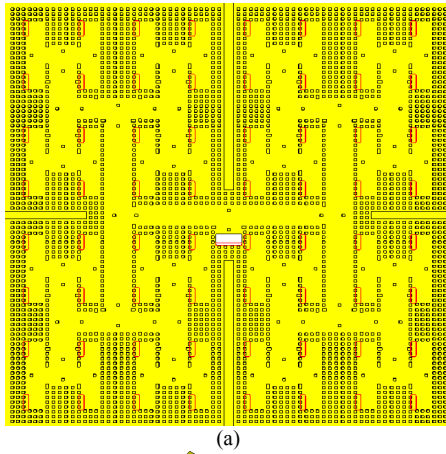


Fig. 2. (a) Simulation results for amplitudes of reflection and transmission coefficients. (b) Electric field distribution at frequency 60 GHz.

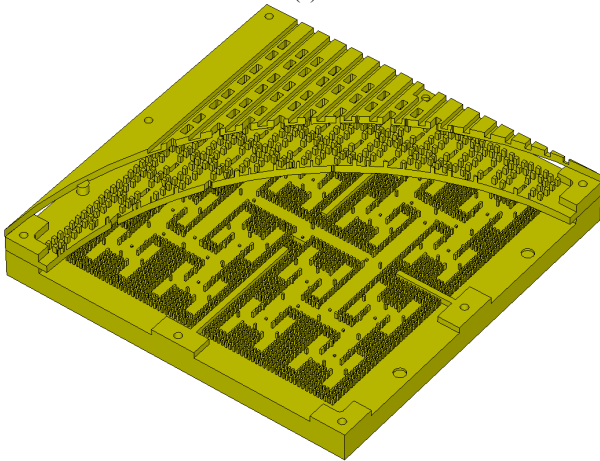
ridge gap waveguide [7], a 4×4 horn array at 15 GHz fed by inverted microstrip gap waveguide in [8], and a 4×4 slot array at 60 GHz fed by microstrip-ridge gap waveguide [9]. In

TABLE I. DESIGN PARAMETERS OF 4-WAY GGW POWER DIVIDER

| Component | Parameter | Value (mm) |
|--------------------|----------------------|------------|
| Vertical Grooves | width | 4.2 |
| | height | 1.35 |
| Horizontal Grooves | width | 3.6 |
| | height | 1.35 |
| Window 1 | width | 3.72 |
| | distance to junction | 0.0 |
| Windows 2 & 3 | width | 3.29 |
| | distance to junction | 2.5 |
| Pin 1 | height | 0.31 |
| | distance to junction | 0.81 |
| Pin 2 | height | 1.3 |
| | distance to wall | 1.42 |
| Pin 3 | height | 0.36 |
| | distance to junction | 0.43 |
| Pin 4 | height | 1.3 |
| | distance to wall | 1.47 |



(a)



(b)

Fig. 3. (a) Configuration of designed feeding network. (b) Configuration of complete 16x16-element slot antenna array.

addition, recently, the use of gap waveguide distribution networks for design of W-band 8x8 slot arrays has been reported in [10, 11].

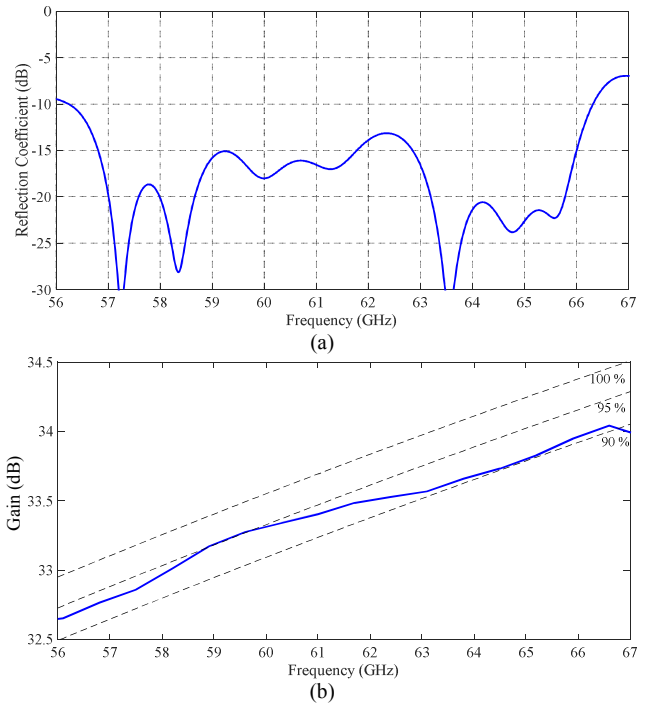


Fig. 4. (a) Simulated $|S_{11}|$ and (b) simulated gain of 16x16-element array.

The current paper presents a 16x16 slot array antenna fed by groove gap waveguide distribution network.

II. GGW POWER DIVIDER

A. 4-Way GGW Power Divider

A physically symmetric H-shaped 4-way power divider with equal-phase and amplitude based on GGW is shown in Fig. 1. The required power-split ratio and impedance matching are achieved by fine tuning the position and height of some matching pins and position and widths of windows. The optimized values of the dimensions of structure are given in Table I. Simulation results shown in Fig. 2 reveal that power divider can achieve stable power distribution in the bandwidth from 51 GHz to 70 GHz with a return loss better than 15 dB. This is a relative bandwidth of 1.37 which is larger than in any previous works on similar slot arrays with different waveguide technologies.

B. 64-way GGW Power Divider As Feeding Network of A Slot antenna Array

It is common practice to design multi-way power dividers by interconnecting small power dividers. Here, a 64-way GGW power divider is realized by interconnecting pre-designed 4-way power dividers, as shown in Fig. 3 (a). This power divider is deployed to feed a 16x16-element slot antenna array, as shown in Fig. 3(b). The input power equally divided into 64 portions and then has been coupled to the cavity layer with the assistance of the coupling slots. The distances between the coupling slots are chosen to be 8 and 8.8 mm along the x- and y-axis, respectively.

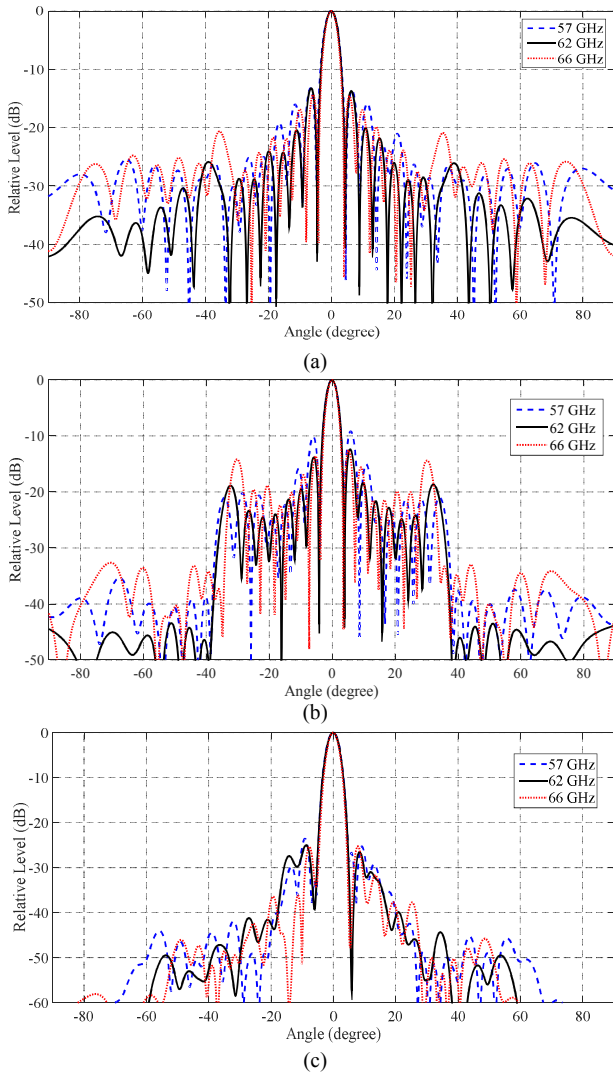


Fig. 5. Simulated radiation patterns of the designed 16×16 -element array. (a) $\varphi = 0^\circ$. (b) $\varphi = 90^\circ$. (c) $\varphi = 45^\circ$ -plane.

III. SIMULATION RESULTS

Fig. 4(a) depicts the simulated reflection coefficient of the complete antenna. Observe that the designed antenna exhibits an impedance bandwidth ($SWR \leq 2$) of 17% from 56 to 66.4 GHz. Also, the simulated frequency characteristics of the directivity and realized gain of the antenna is shown in Fig. 4(b). Observe that the obtained gain is more than 32.5 dBi with a simulated efficiency higher than 90%, i.e. -0.5 dB, including conductive losses.

The simulated radiation patterns of antenna at 57, 62 and 66 GHz in both the E- and H-planes and also 45° -plane are shown in Fig. 5. Observe that the first sidelobe levels in both E- and H-planes are around -13 dB. Also, the side lobe level of the designed array in the 45° -plane is below -25 dB over the desired frequency band.

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