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A Ridge Gap Waveguide Fed Aperture-Coupled Microstrip Antenna Array for 60 GHz Applications

D. Zarifi¹, A. Farahbakhsh² and A. U. Zaman³

¹ University of Kashan, Kashan, Iran, zarifi@kashanu.ac.ir

² Graduate University of Advanced Technology, Kerman, Iran, a_farahbakhsh@iust.ac.ir

³ Chalmers University of Technology, Göteborg, Sweden, zaman@chalmers.se

Abstract— This paper deals with the design of patch antenna arrays with Ridge Gap Waveguides (RGW) feed networks at 60-GHz band. An array of 64 radiating elements are designed and simulated to demonstrate the good performance of the proposed array. The proposed antenna shows the gain up to 22.6 dBi, efficiency higher than 80% and an impedance bandwidth of 13% covering 59-67 GHz. The results are valuable for the design and evaluation of wideband planar antenna arrays at millimeter-wave frequencies.

Index Terms—patch antenna array, gap waveguide technology, 60 GHz applications.

I. INTRODUCTION

In recent years, research on the planar antenna arrays working at millimeter-wave frequencies has attracted increasing attention. Different kinds of wideband antennas have been designed such as microstrip antennas, substrate-integrated waveguide (SIW)-based planar arrays, waveguide based slot array antennas. Realizing a high-gain array antenna in the millimeter-wave band requires a low-loss feeding network. As common candidates, corporate-feed waveguide slot arrays have been used to achieve high gain and efficiency. At high frequencies, these antennas require accurate, high precision and expensive manufacturing [1]. Recently, the gap waveguide technology introduced in [2-4] overcomes the problem of good electrical contact associated with mechanical assembly. To date, some wideband high gain and efficiency array antennas have been realized based on gap waveguide technology in different frequency range [5-11]. This gap waveguide technology uses the cut-off a PEC-PMC parallel plate waveguide configuration to control desired electromagnetic propagation between the two parallel plates without the requirement of electrical contact. This simplifies the mechanical assembly of the designed antennas and hence reduces the production cost for the antennas. Also, the gap technology can be used for RF packaging which makes it possible to integrate the RF electronics with the gap waveguide antennas [12-13].

In this paper, aperture-coupled microstrip antenna arrays fed by ridge gap waveguide (RGW) feed networks are investigated at 60 GHz band. An Array of 64 radiating elements is designed and simulated. The main advantage compared to planar slot arrays is that this structure can keep a two layer planar profile as well as being low loss and light. The performance of the RGW fed microstrip array antenna is

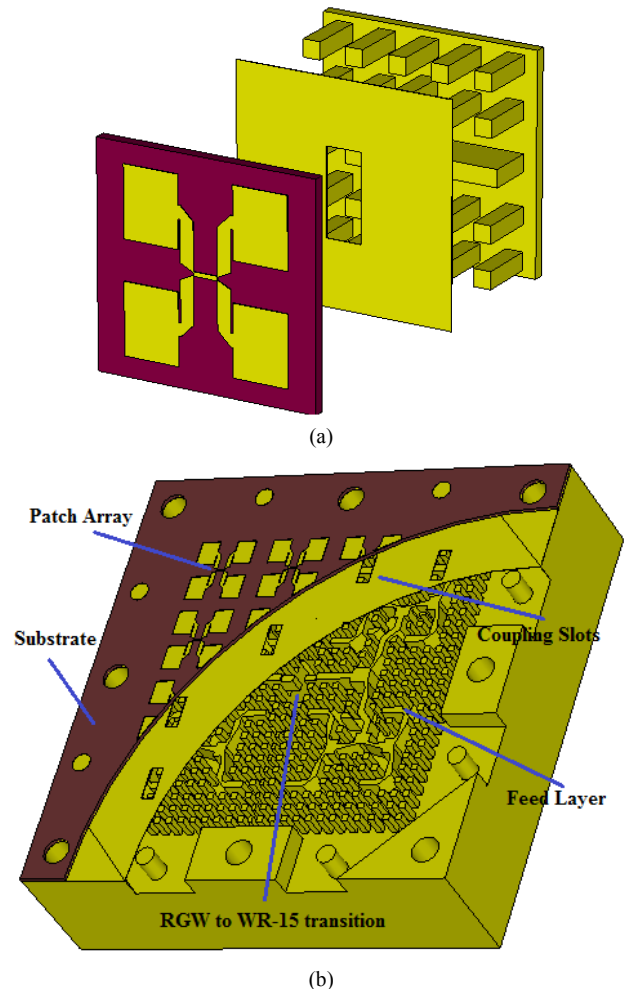


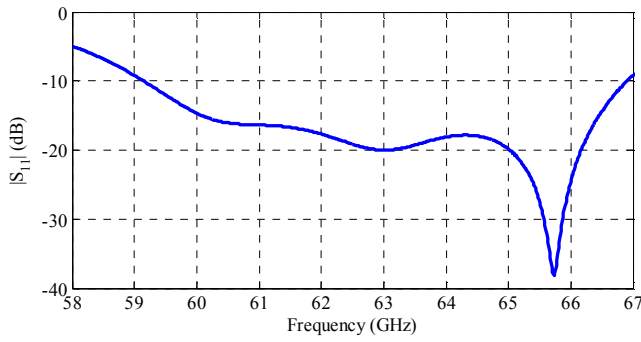
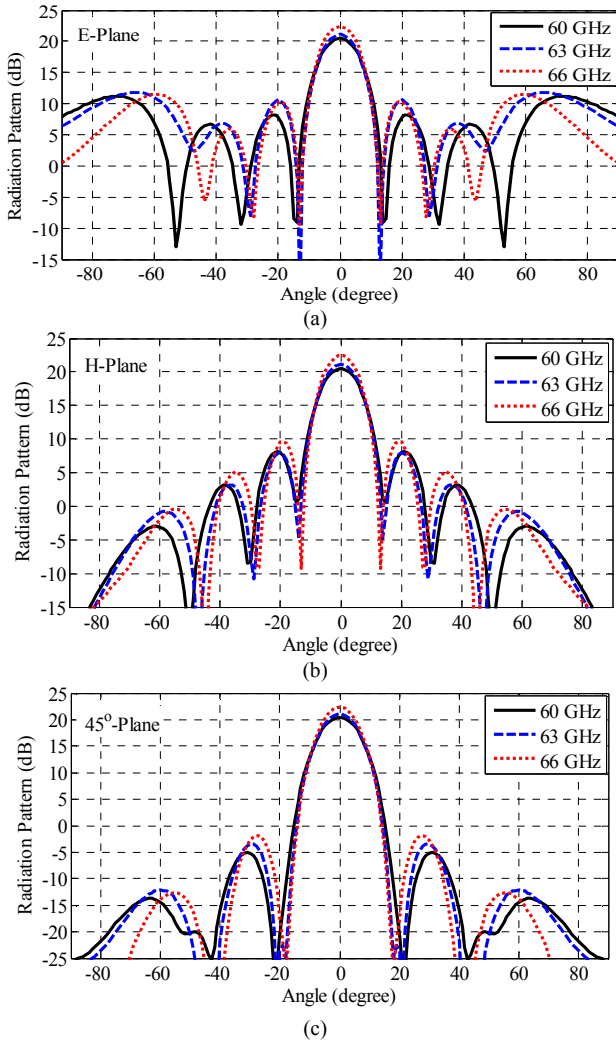
Fig. 1. (a) Exploded perspective view of 2×2-element sub-array. (b) Perspective view of 8×8-element sub-array.

also studied. The obtained results show that the proposed arrays have high gain and efficiency and good radiation pattern for 60 GHz applications. The metal feed network can be easily manufactured by CNC milling or by electric discharge machining.

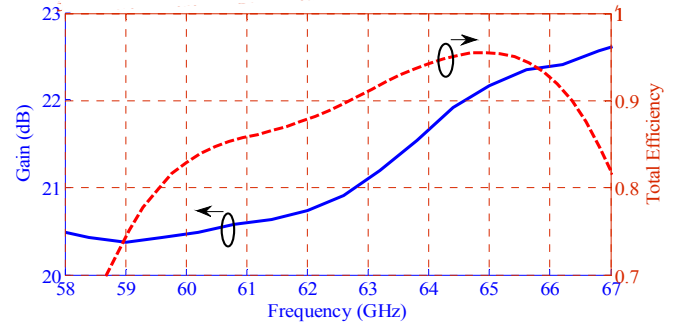
II. ANTENNA CONFIGURATION

A. 2×2-Element Sub-array

The detailed structure of 2×2-element sub-array is depicted in Fig. 1(a). The sub-array has the transverse dimensions of 5

Fig. 2. Simulated $|S_{11}|$ of 8×8 -element array.Fig. 3. Simulated radiation patterns of the 8×8 -element array. (a) E-plane. (b) H-plane. (c) 45° -plane.

$mm \times 5 mm$ and is composed of a RGW feed layer at the bottom, and a microstrip structure at the top layer. The RGW structure excites the coupling slot etched in the ground plane of the microstrip structure. By the proper design of the coupling slots and microstrip feed lines, four patches can be excited with same amplitude and phase. In our design, dielectric material of Rogers 6002 with permittivity 2.94,

Fig. 4. Simulated gain and total efficiency of 8×8 -element array.

thickness 0.254 mm and loss tangent 0.0012 is used as the substrate. The pins have the dimensions of $0.4 \times 0.4 \times 1.1 mm^3$ to achieve a stop-band from 40 to 80 GHz [6].

B. 8×8 -Element antenna array

The detailed topology of the 8×8 antenna array is illustrated in Fig. 1 (b). Observe that the input power to rectangular waveguide excites the antenna by a WR-15 to RGW transition and then flows through a RGW 16-way power divider. The design process of this type of transition has been discussed in [7]. The RGW feeding network is based on the basic 3-dB power divider or T-junction proposed in [8]. For achieving the desired matching, all the parameters of the power divider and microstrip structure are optimized.

III. SIMULATION RESULTS

The patch antenna array is optimized and simulated numerically using CST Microwave Studio, by full wave simulations. The simulated $|S_{11}|$ of the complete antenna is given in Fig. 2. The results show about 13% reflection coefficient bandwidth ($VSWR < 2$) covering 59-67 GHz.

The simulated far-field radiation patterns at the frequencies 60, 63 and 66 GHz in both E- and H-planes and also 45° -plane are presented in Fig. 3. Observe that the first sidelobe levels of the radiation patterns are around -13 dB, which are very close to the theoretical value of a uniform antenna array. The radiation patterns have -10dB sidelobes around 70° in the E-plane, but in the H- and 45° -plane the sidelobes are very low.

The simulated gain and total efficiency of the antenna are shown in Fig. 4. The gain at the design frequency band is up to 22.6 dBi and the corresponding aperture efficiency is more than 80%.

IV. CONCLUSIONS

We proposed a wideband patch antenna array based on a RGW feed network. The simulation results demonstrate about 13% of reflection coefficient bandwidth ($|S_{11}| < -10 dB$) with realized gain more than 22.6 dBi covering the 59-67 GHz frequency range. The proposed antenna has higher radiation efficiency compared with the similar 60-GHz microstrip antenna arrays [14-15] and can be used to design larger arrays.

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