60 GHz Substrate Integrated Waveguide Fed Dense Dielectric Patch Antenna Array

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***Abstract* - A wideband dense dielectric (DD) patch antenna array fed by a single-layered substrate integrated waveguide (SIW) feed network is demonstrated at 60-GHz band. A 4 × 4 prototype fabricated by employing standard printed circuit board (PCB) technology shows that an impedance bandwidth of 22% for SWR < 2, a gain up to 17.2 dBi, and symmetrical unidirectional radiation patterns with cross polarizations of less than -20 dB are achieved.**

***Index Terms* — Dense Dielectric (DD) Patch Antenna, Substrate integrated waveguide (SIW), antenna array, Millimeter-wave.**

I. INTRODUCTION

With the development of various millimeter-wave wireless communication applications, antenna arrays with high gain and wide bandwidth have attracted more attention in recent years. Different widely used patch antenna structures have been implemented at millimeter-wave frequencies to achieve wide impedance bandwidths [1], [2]. However, due to complex multilayered structures with buried vias or cavities, it is difficult to precisely fabricate these patch antenna arrays at millimeter-wave frequencies by applying conventional printed circuit board (PCB) technology. Therefore, most of these arrays were realized by using the low temperature co-fired ceramic (LTCC) technology with relatively high costs.

Recently, a new kind of antenna element designated as the dense dielectric (DD) patch antenna was introduced [3]. The results in [4] have demonstrated that the DD patch with a thin substrate of 0.03 λ_0 exhibits wide bandwidth and promising radiation performance. More importantly, because of the simple geometry without via or cavity, the DD patch antenna is much easy to implement at high frequencies.

In this paper, a DD patch antenna array fed by a single-layered corporate substrate integrated waveguide (SIW) feed network is proposed. The whole array can be easily realized by using standard PCB technology. With advantages of good performance, convenience of fabrication and integration, and low fabrication cost, the proposed antenna array is desirable for millimeter-wave applications.

II. ANTENNA GEOMETRY

The overall antenna array consists of three PCB substrates as shown in Fig. 1. With the assistance of two bonding films with a thickness of 0.1 mm, the antenna array can be

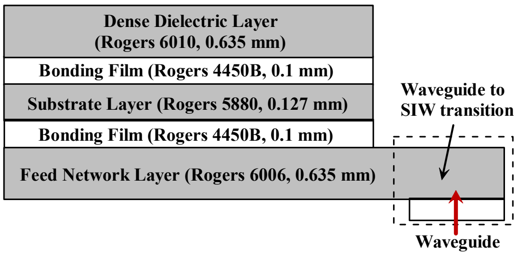


Fig. 1. Side view of the proposed antenna array.

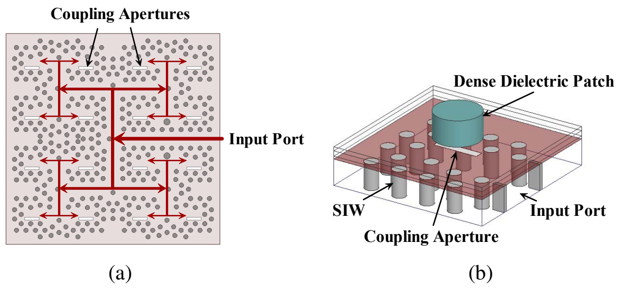
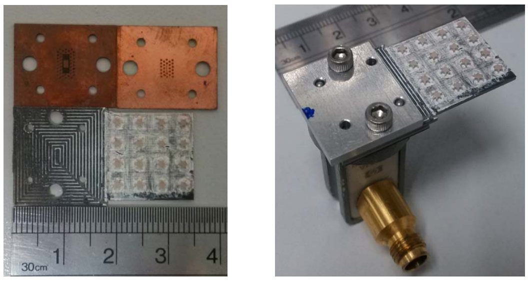


Fig. 2. Geometry of the proposed antenna array. (a) Top view of the SIW feed network, (b) Geometry of a single SIW fed DD patch antenna.

fabricated by applying the conventional multi-layered PCB facilities. Owing to the use of a Rogers 6006 PCB substrate with a relatively high dielectric constant of 6.15, the full corporate SIW feed network is successfully designed onto a single layer. A rectangular waveguide to SIW transition reported in [5] is also designed onto the right portion for antenna measurement. The detailed topology of the feed network is illustrated in Fig. 2(a). The input power flows through the feed network as indicated by the arrows. The structure of the aperture coupled DD patch antenna is shown in Fig. 2(b). The power is coupled through the offset longitude apertures located at the ends of the feed network. The DD patches are designed onto a Rogers 6010 PCB substrate with a high dielectric constant of 10.2. In fabrication, the DD patches are realized by milling the unnecessary portion of the substrate.

III. RESULTS

As exhibited in Fig. 3, a prototype was fabricated and measured to verify the proposed design. The aluminium plate shown in Fig. 3(b) is a fixture to compress the transition. The input impedance was measured by a millimeter-wave band Agilent Network Analyzer E8361A. The radiation



(a) (b)

Fig. 3. Photographs of the fabricated 4 × 4 SIW fed DD patch antenna array. (a) Top views of the substrates, (b) Whole antenna array with testing waveguide.

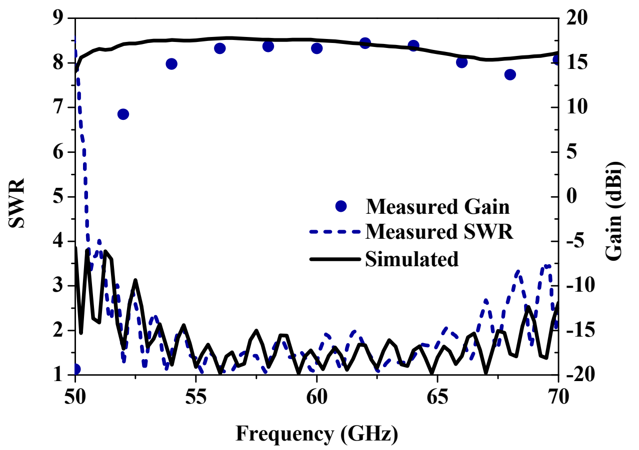


Fig. 4. Simulated and measured SWR and gain of the proposed SIW fed DD patch antenna array against frequency.

characteristics were measured by a far-field millimeter wave antenna measurement system as depicted in [6].

A. SWR and Gain

The simulated and measured SWRs of the fabricated antenna array are in good agreement as shown in Fig. 4. The simulated and measured bandwidths are 25.5% (53 to 68.5 GHz) and 22% (53.5 to 66.6 GHz) for SWR < 2, respectively. The measurement is slightly narrower than the simulation due to the fabrication tolerance.

Fig. 4 also exhibits the gains of the antenna array. The simulated and measured peak gains are 17.8 and 17.2 dBi respectively. Besides, the gain is stable over the whole operating band.

B. Radiation Pattern

Fig. 5 depicts the simulated and measured radiation patterns of the DD patch antenna array at 54, 60, and 66 GHz in both the E- and H- planes. The broadside radiation patterns are almost symmetric throughout the operating band. The measured first sidelobe level is around -11 dB, which is slightly greater than that of the measurement due to the fabrication and alignment tolerances. The sidelobe level in the E-plane increases with the frequency because of the effect of the surface wave. The measured cross-polarization level is less than -20 dB. The backward radiation patterns are not available due to the limitation of the measurement system in our laboratory.

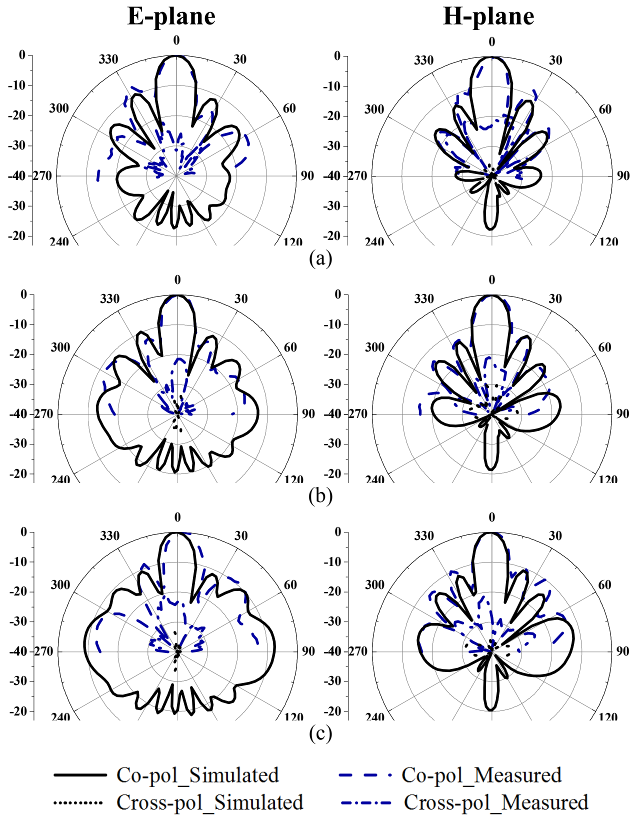


Fig. 5. Simulated and measured radiation patterns of the DD patch antenna array. *(a) f* = 54 GHz. *(b) f* = 60 GHz. *(c) f* = 66 GHz.

IV. Conclusion

A wideband substrate integrated waveguide fed dense dielectric patch antenna array has been presented at 60-GHz band. With merits of simple structure, convenience of fabrication, and good performance, the antenna array is attractive for millimeter-wave applications.

Acknowledgment

This work was supported by a grant from the Research Grants Council of the Hong Kong SAR, China. [Project No. CityU 118412]

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