Millimeter-Wave High-Gain Wideband Circularly Polarized Antenna Array by Employing Aperture-Coupled Magneto-Electric Dipoles

Yujian Li[1], Jingxue Wang[1], Junhong Wang[1], and Kwai-Man Luk[2]
1 Institute of Lightwave Technology, Beijing Jiaotong University, Beijing, China
2 State Key Laboratory of Millimeter Waves and Department of Electronic Engineering, City University of Hong, Kong, Hong Kong, China

Abstract **- High-gain wideband circularly polarized (CP) planar antenna array consisting of aperture-coupled magneto-electric (ME) dipole antennas is presented for millimeter-wave applications. Different from most reported CP antenna arrays, wide axial ratio (AR) bandwidth can be achieved by the proposed design without the use of sequential feed network. Furthermore, improved gain and antenna efficiency performance can also be obtained due to the advantage of low insertion loss of the full-corporate substrate integrated waveguide (SIW) feed network applied in the design.**

Index Terms **— Circular polarization (CP), 60-GHz, antenna array, millimeter-wave, magneto-electric (ME) dipole.**

1. Introduction

Millimeter-wave antenna arrays with circularly polarized (CP) radiation have been persistently investigated in recent years because of the increasing demand for high-gain planar antennas working at millimeter-wave frequencies and also the ability to suppress the possible multipath interference and polarization mismatch [1]-[2]. The microstrip patch antenna and the cavity antenna with CP properties are usually used as the radiating element to compose antenna arrays [3]-[5]. However, due to the narrow 3-dB axial ratio (AR) bandwidth of these antenna elements, the scheme of sequential feed has to be applied by array designs to achieve a wide AR bandwidth that is required by various wideband millimeter-wave wireless applications. The sequential feed is an effective mean to widen the AR bandwidth, but it also inevitably increases the complexity of the feed network of array designs. Therefore, most reported wideband millimeter-wave CP arrays usually employ feed networks consisting of strip lines or coplanar waveguides (CPWs) which are flexible enough to fulfill the required phase shifts in the sequential feed [3]-[4]. On the other hand, most millimeter-wave CP arrays fed by substrate integrated waveguide (SIW) and waveguide feed networks, which have advantage of lower insertion loss at millimeter-wave frequencies, still suffer from narrow AR bandwidths of around or less than 10% [5]-[6].

In this paper, by utilizing the CP aperture-coupled magneto-electric (ME) dipole antennas with a wide AR bandwidth proposed by us very recently as radiating elements [7], wideband CP antenna arrays fed by full-corporate SIW feed networks are realized at the 60-GHz band. Apart from wide bandwidth, high gain and good radiation efficiency are also achieved because of the low loss characteristics of the SIW feed network.

2. Design Configuration

Geometry of the proposed 16 × 16 CP aperture-coupled ME-dipole antenna array is presented in Fig. 1. Radiating elements are designed into Substrate 1, while apertures 1 used for exciting antenna elements are etched on the bottom metallic layer of Substrate 1 and the top metallic layer of Substrate 2, respectively. A full-corporate SIW feed network is divided into two parts which are arranged in substrates 2 and 3. Feed networks of 2 × 2 sub-arrays are located in Substrate 2. The rest portion of the SIW feed network is designed in Substrate 3 that is used for transmitting the input power to all 2 × 2 sub-arrays. Apertures 2 etched on the bottom metallic layer of Substrate 2 and also the top metallic layer of Substrate 3 are applied to couple power between the two layers. A wideband SIW to waveguide transition is arranged in Substrate 3 for the purpose of measurement.

A prototype of the 8 × 8 CP antenna array was fabricated by standard PCB facilities to demonstrate the correctness of the design as shown in Fig. 2. The S-parameter of the array was measured by an Agilent Network Analyzer E8361A. An *NSI* 2000 near-field measurement system was employed to test the radiation performance.

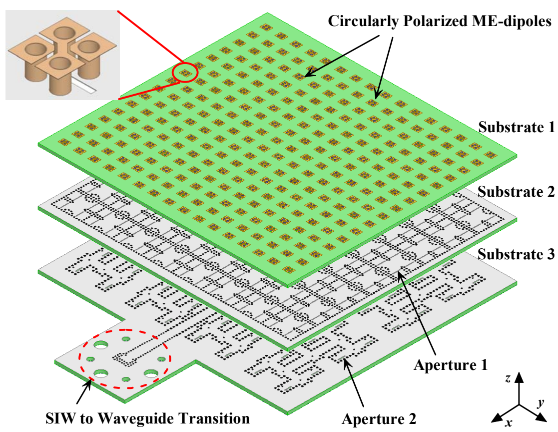

Fig. 1. Geometry of the 16 × 16 wideband high-gain CP aperture-coupled ME-dipole antenna array with the full-corporate SIW feed network.

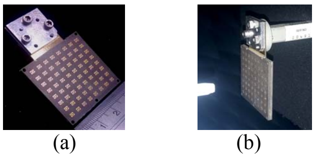

Fig. 2. Photographs of the fabricated 8 × 8 CP antenna array. (a) perspective view, (b) antenna under test.

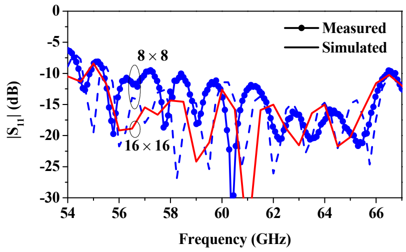

Fig. 3. $|S_{11}|$ of the proposed wideband high-gain CP antenna arrays.

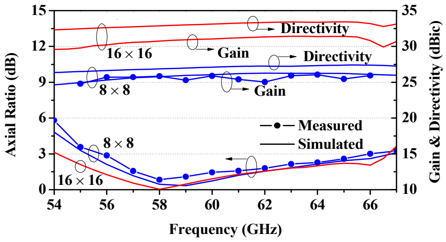

Fig. 4. Gain and directivity of the proposed wideband high-gain CP antenna arrays.

3. Performance and Discussion

Results of $|S_{11}|$ of the proposed CP ME-dipole antenna arrays are given in Fig. 3. The measured and simulated $|S_{11}|$ of the 8 × 8 array are less than -10 dB over the bandwidths of 18.2% (from 55.4 to 66.5 GHz) and 18.4% (from 55.7 to 67 GHz), respectively. The simulated impedacne bandwidth of the 16 × 16 array is 18.8% (from 55.1 to 66.5 GHz), which is similar to that of the 8 × 8 array.

Fig. 4 illustrates the measured and simulated AR of the antenna arrays. The measured and simulated 3-dB AR bandwidths of the 8 × 8 array are 16.5% (from 56 to 66 GHz) and 18.9% (from 55.4 to 67 GHz) respecively, which can cover the whole 60-GHz band from 57 to 66 GHz. The simulated 3-dB AR bandwidths of the 16 × 16 array is 21% (from 54 to 66.8 GHz). Moreover, the gain performance of the antenna arrays is also exhibited in Fig. 4. A measured gain up to 26.1 dBic is achieved by the 8 × 8 design, which is close to the simulated one. The variation of the measured gain is less than 1.3 dB throughout the operating band from 55 to 66 GHz. The simulated gain of the 16 × 16 array is up to 31.4 dBic with a 3-dB bandwidth of 28%. By comparing the gain with the directivity, the radiation efficiencies of the two arrays are 75% and 61% respectively at 60 GHz. As shown in Fig. 5 (a), the measured radiation pattern of the 8 × 8 array at 60 GHz agrees well with simulated one. Symettrically unidirectional radiation patterns are obtained by both array designs.

As shown in Table I, wide impedace bandwith can be achieved by the proposed arrays. More importantly, the AR bandwidth of the work is comparable to reported CP arrays with sequential feeds due to the use of ME-dipole elements with wide AR bandwidth. On the other hand, because of the low insertion loss of the SIW feed network, better antenna efficiency can also be achieved by the proposed designs.

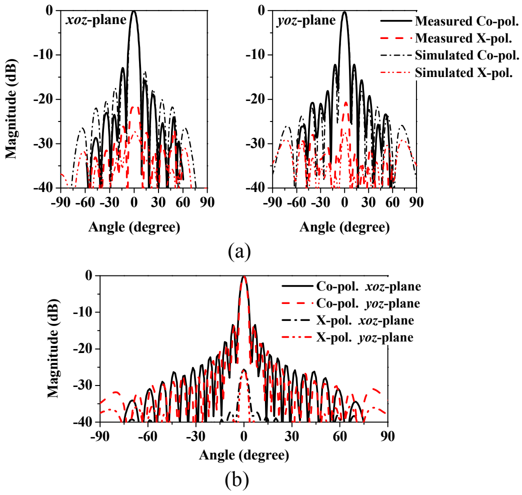

Fig. 5. Radiation patterns of the proposed wideband high-gain CP antenna arrays at 60 GHz. (a) 8 × 8 antenna array, (b) 16 × 16 antenna array.

TABLE I
Comparison between Proposed and Reported Millimeter-Wave CP Arrays

Ref.	Type	Feed	Imp. BW	AR BW	Efficiency
[3]	4 × 4 patch	Sequential (strip line)	28.1%	19.2%	52.5%
[4]	4 × 4 patch	Sequential (CPW)	17.8%	15.6%	34.1%
[5]	16 × 16 cavity	Corporate (waveguide)	5.7%	6.4%	89.6%
[6]	2 × 2 patch	Corporate (SIW)	6.7%	6.8%	70%
Our work	8 × 8 ME-dipole	Corporate (SIW)	18.2%	16.5%	75%.
Our work	16 × 16 ME-dipole	Corporate (SIW)	18.8%	21%	61%.

4. Conclusion

High-gain wideband circularly polarized planar antenna arrays fed by full-corporate SIW feed networks have been realized. With advantages of simple configuration and good performance, the proposed designs would be attractive to future wideband millimeter-wave wireless applications.

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