An E-band Circularly Polarized Antenna Array Fed by Substrate Integrated Coaxial Line (SICL)

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***Abstract*—A circularly polarized antenna array for E-band application has been designed, fabricated and measured. The antenna array is fed using substrate integrated coaxial line (SICL) technology, which can be realized by low-cost PCB process in millimeter frequencies. The simulated and measured S11 is below -10dB from 71GHz to 76 GHz. And the simulated and measured results show that both the gain of more than 11dBi and axial ratio of less than 2dB have been achieved over the interested frequency band.**

Keywords—Substrate integrated coaxial line (SICL), circularly polarized antenna array, sequential rotation technique.

I. Introduction

Millimeter-wave wireless communication has drawn an increasing attention these years due to many advantages like wide band potential and less crowd spectrum. As a key component in the wireless communication systems, antennas with high gain, broadband and high efficiency are required in applications of millimeter wave. Many approaches have been introduced to design millimeter wave antennas, like low temperature co-fired ceramic (LTCC) [1], silicon substrate [2], liquid crystal polymer (LCP) [3] and traditional printed circuit board (PCB) techniques[4-5]. In some papers like [4] and [5], substrate integrated waveguide (SIW) technology is used to feed the antennas. The feed network realized by SIW techniques features the advantages of low radiation, low insertion loss and easy to integration with other planar circuits. However, it is not easy to feed millimeter wave circularly polarized antenna using SIW structure because the lager area SIW required makes it hard to lay out. This paper introduces substrate integrated coaxial line (SICL) to feed a circularly polarized antenna array working at frequencies between 71 GHz to 76 GHz.

Substrate integrated coaxial line (SICL) can support TEM mode so it is a wideband and non-dispersive structure [6-7]. As a kind of planar coaxial line, SICL comprises a signal line between two metallic layers and two rows of metallic via holes working as shielding wall. In addition, the SICL structure can be achieved using cost-effective PCB technology which is suitable for large manufacture.

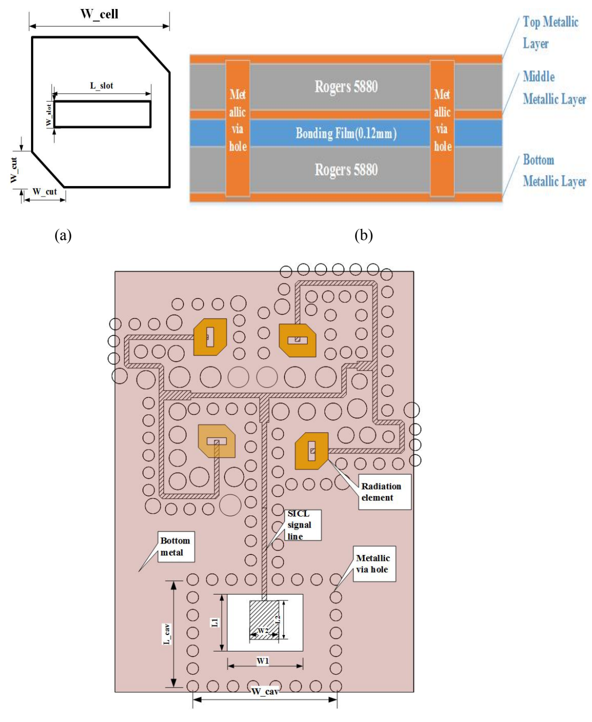


Figure 1. The geometry of proposed antenna array. (a) Radiation element. (b) Side view of the array. (c) Top view of the array.

In this paper, we present a circularly polarized antenna array composing four circularly polarized elements. Sequentially rotated technique has been employed to achieve wide band performance and all the feed network configurations have been designed using SICL technique. The antenna array is designed and fabricated using dual-layer PCB technology with a glue layer between two 0.254-mm Rogers 5880 substrates.

II. Design of Circularly Polarized Antenna Array

A. Antenna Element

There are two main kinds of approaches in designing circularly polarized patch antennas. While one is designing two

TABLE I
PARAMETERS OF THE PRESENTED ANTENNA ARRAY

Parameter	Value(mm)	Parameter	Value(mm)
W_cell	0.95	L_cav	2.76
W_cut	0.26	W_1	3.10
W_slot	0.18	L_1	1.55
L_slot	0.50	W_2	0.75
W_cav	3.70	L_2	1

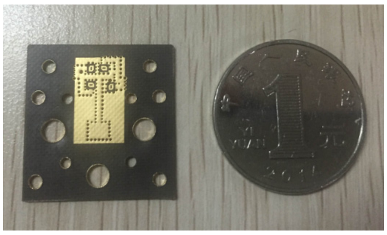


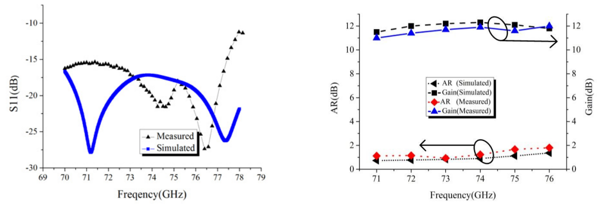
Fig. 2. Photograph of the antenna array

orthogonally located feeds to excite the patch antenna. The other is using perturbed patch to radiate circularly polarized electromagnetic wave. This paper choose the second approach, using a corner-truncated microstrip patch with a center slot as the element of the circularly polarized antenna array, shown in Fig.1 (a). The patch is surrounded by metallic via holes, which work together with the top and bottom metallic layers to form a cavity. The single-feed cavity-backed patch configuration can not only reduce the loss of feed line but also simplify the feeding network.

The element radiates between the frequencies from 71GHz to 76GHz. The antenna is implemented by a multi-layer PCB process with two 0.254-mm Rogers 5880 substrates (dielectric constant ε=2.2, and loss tangent tan δ=0.004) and three metallic layers, which can be seen in Fig.1 (b). The radiation patch is etched on the top metallic layer and fed by the signal line of the SICL, which is etched on the middle metallic layer. The configuration of the element is designed and optimized by the commercial software CST Microwave Studio.

B. Feed Network

The array is designed by applying the sequential rotation technique that connects four elements. It has been proved that the sequential rotation technique can help improve the performance of bandwidth and polarization purity of the antenna arrays [8-9]. In the array, the elements are spaced at about 2.7 mm (approximately 0.66 λ), where λ is the free space wavelength at the center frequency. 90 degree phase shift between the adjacent radiation elements can be achieved easily by different feeding length of SICL. The configuration of the antenna array is shown in Fig.1(c), the top metallic metal layer, the bonding layer and the two substrate layers are hidden in Fig.1(c) for clarity. It can be found from Fig.1(c) that the feeding structure can be lay between the elements while the



(a) (b)

Fig. 3. (a)Simulated and measured results of S11, (b) simulated and measured results of realized gain and AR.

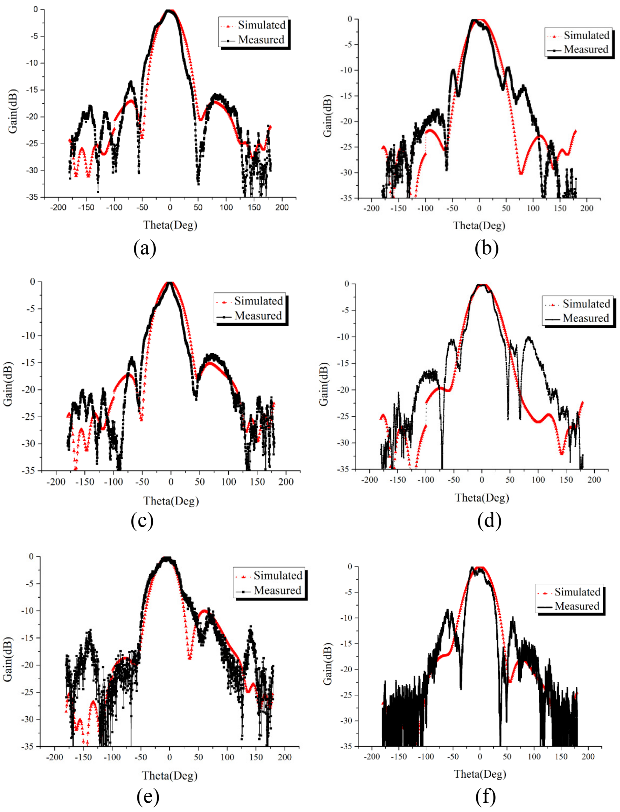


Fig. 4. Simulated and Measured patterns in xz-plane at (a) 71GHz (b)73GHz (c)76GHz and in yz-plane at (d) 71GHz (e)73GHz (f)76GHz

shielding metallic planes and metallic via holes can prevent radiation from feeding line.

This paper employs a waveguide-to-SICL transition to connect the antenna to measurement systems. The transition is based on an approach published last year [10]. One cavity and a stepped stripline are employed to guide the electromagnetic wave from waveguide to the SICL. The configuration of the transition is shown in Fig.1(c). The major dimensions of the antenna array are as in table Ⅰ.

C. Results and Discussions

The proposed antenna array is fabricated by PCB process. Fig.2 is the photograph of the four-element CP antenna array.

As can been seen from Fig.3 (a), the return loss exhibits a well matched behavior over the interested band. However, there is a sharp change at 75GHz can be observed from the measured results because the array are measured by the same vector network analyzer Agilent PNX 5245A (10MHz-50GHz) but different frequency extension modules, one is from 50GHz to 75GHz and the other is from 75GHz to110 GHz. So the dimensions of the waveguides for two bands are different as well.

The simulated and measured radiation patterns of the array at the planes φ=0° and φ=90° at 71, 73 and 76GHz are plotted in Fig.4. And the performance of axial ratios and peak gains over the bandwidth of 71-76GHz are also shown in Fig.3(b). The simulated peak gain is 12.3 dBi at 74 GHz while the measured peak gain is 12dBi, and the measured AR is below 2 dB from 71GHz to 76GHz. All these results are stable over the frequency band and meet the requirement of the E-band application well.

III. CONCLUSION

In this paper, an E-band circularly polarized antenna array is proposed. The antenna array is fed by the SICL technology, which proved to work well in millimeter frequency band and can be realized by low-cost PCB process. This work can also be used as planar feeder for transmit-array antennas and reflect-array antennas to achieve higher gain.

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