Compact 60 GHz Circularly Polarized Array Antenna with Enhanced Isolation in LTCC Technology

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***Abstract*— This paper describes the design, fabrication and measurement of an array of two circularly polarized antennas in Low Temperature Co-fired Ceramic (LTCC) technology used for 60 GHz and IEEE 802.11ad applications. Each antenna consists of four rotated patch elements with an approximate area of 25 mm^2. The antenna board consists of 7 metal layers. The measured antenna bandwidth is 8 GHz and the isolation between the two antennas is better than 21 dB over antenna bandwidth, while the board area is less than 100 mm^2. The isolation between antennas has been enhanced by a via fence connecting the top and bottom layers. The antenna left-hand peak gain is about 9 dBi and the right-hand peak gain is -5 dBi.**

I. INTRODUCTION

Circularly polarized (CP) antennas have superior performance in a multipath environment to reduce the delay spread by about half compared to linearly polarized antennas [1]. Besides, the performance of the CP antennas in a 60 GHz wireless link is less sensitive to the antenna rotation around its normal axis [2]. In this paper, we describe the design of a compact 60 GHz circularly polarized array antenna in Low Temperature Co-fired Ceramic (LTCC) technology. Reducing the antenna size is a critical issue for the Consumer Electronic (CE) applications. The main disadvantage of size/spacing reduction is the increase in coupling, thus we propose a method to reduce the antenna coupling.

One main application of 60 GHz devices is multi-gigabit per second indoor communication. Considering the propagation loss at this band (68 dB for 1 m range), and regulatory and technology limits on maximum output power [3], it can be shown that the antenna gain must be more than 5 dBi to establish a wireless link inside a regular room. Linearly polarized antennas such as patch, dipole, slot, horn, etc. can provide reasonable gain in one direction, but by rotating the antenna the gin significantly drops due to high cross polarization factor of such antennas.

On the other hand, the required precision in antenna fabrication at this band which is less than 50 µm necessitates the use of a precise fabrication technology such as LTCC, or High-Density Interconnect (HDI) PCB technology. In this work, we explore LTCC technology to design and fabricate very compact CP array antenna (area < 25 mm^2) at 60 GHz band with a reasonable gain (> 5 dBi).

II. CP ANTENNA DESIGN

A. CP Antenna Design

It is known that by sequentially rotating four patch antennas and designing proper feed network a circularly polarized antenna can be achieved [4]. In this design a truncated corner patch antennas is used as the building block of the CP array antenna [5]. The size of each patch is 1.35 mm x 1 mm. The peak gain of this patch element is around 6 dBi at 60 GHz. Since the four patch antennas are 90 degree rotated relative to each other, as shown in Fig. 1(a), the peak gain of the CP antenna is only 3dB higher than a single patch (not 6 dB as in a regular 4 element array). Considering the feed loss the peak CP antenna gain is expected to be less than this value. The size of array of 4 rotated patch is 4 mm x 4 mm (4.5 mm x 4.5 mm with lower ground plane). Fig. 1(c) shows a closer view of the CP antenna and feed. The feed sections have different lengths to accommodate the 90 degree relative phase shift. Fig. 1(d) shows the fabricated sample.

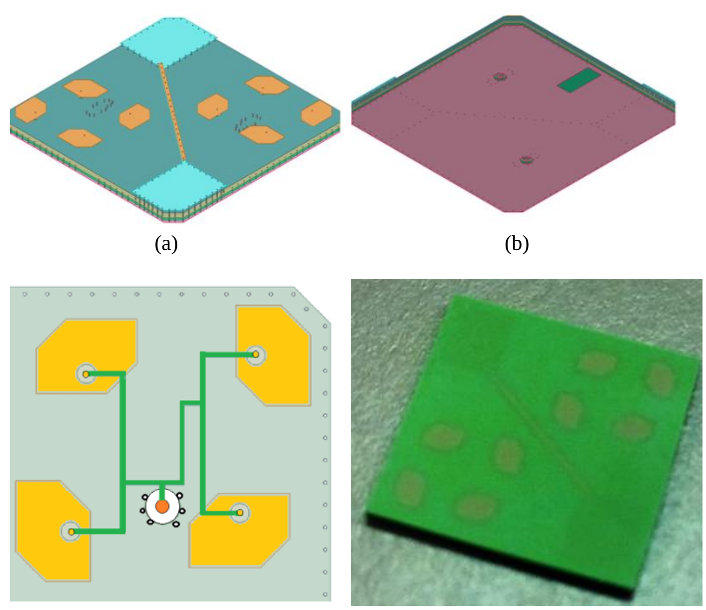

Fig. 1. Array of two CP antennas. (a) Top view, (b) bottom view, (c) antenna feed, and (d) fabricated sample in seven layer LTCC with a size of 10 mm x 10 mm.

B. Array of CP Antennas

In this design, the unit fabrication tile was a 10 mm x 10mm square where theoretically four CP antennas could be marginally placed in a unit cell. Nevertheless, we used only two CP antennas to be compatible with our single TX- Single RX 60 GHz die. The two CP antennas were place in the opposite corners of the tile as shown in Fig. 1(a) and (c). The excitation port of CP antennas is located on the bottom of the package, where the 60 GHz die will be flip-chipped. The spacing between two ports is 5.3 mm.

C. Increasing Antenna Isolation

To increase the isolation between the two CP antennas in package a dumbbell shaped ground region is formed on top layer of the package, consisting of two square patches with a size of 2mm x 2mm, and a narrow metal strip connecting the two squares with a width of 140 µm sufficient for placing one row of ground through hole vias (THV). Furthermore, one row of THV is placed close to the edge of each square.

D. Fabrication

The CP array antenna sample, shown in Fig. 1(d) was fabricated in a 7-layer LTCC package with 100 µm spacing between layers. The via diameter in this technology was 50 µm. Layer 1 was used for antenna patches and Layer 3 for antenna ground. The CP antenna feed was implemented in Layer 4, and the excitation ports were placed on bottom layer.

III. SIMULATION AND MEASURED RESULTS

A. Bandwidth and Isolation

Fig. 2 demonstrates the measured S-parameters of the CP array antennas (S_{11}, S_{12} and S_{22}). The package was flipped over, and both elements were excited by 175 µm GSG probes using a semi-automatic probe station and 67 GHz network analyzer (PNA-X). The package was placed on a 6 cm pile of paper to separate the antennas from metal chuck as much as possible. The permittivity of the paper is larger than air so the frequency response of the antenna shifts to the left.

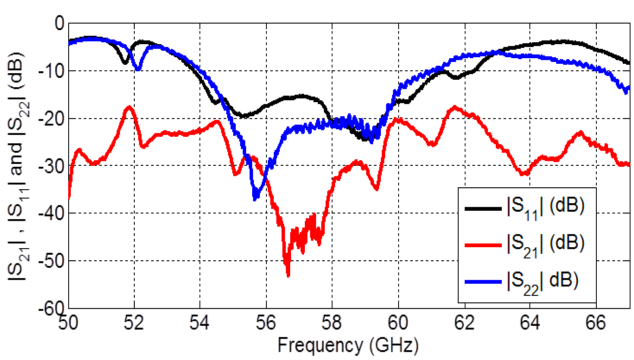

Fig. 2. Measured S-parameters of the CP array antennas.

The measured antenna bandwidth without de-embedding the paper holder effect ranges from 54 GHz to 62 GHz. The isolation between two antennas in this frequency range varies from -65 dB at 56.5 GHz to -20 dB at 62 GHz. At 59 GHz which is the resonance frequency of the CP antenna isolation is better than -31 dB. It shows that the technique applied ti increase antenna isolation has been successful in reducing the coupling between two CP antennas.

B. Radiatin Pattern and Peak Gain

Fig. 3 displays the Left-hand and Right-hand radiation patterns of the CP antenna in the two principal planes (φ=0 and φ= 90 degree). The half-power LH beamwidth is the same in two planes (approximately 80 degree) and the peak gain 9 dBi at 17°, but 8.5 dBi at 0°. The cross polarization pattern which is the right-hand CP pattern is almost 15 dB lower than LH pattern at 0 degree.

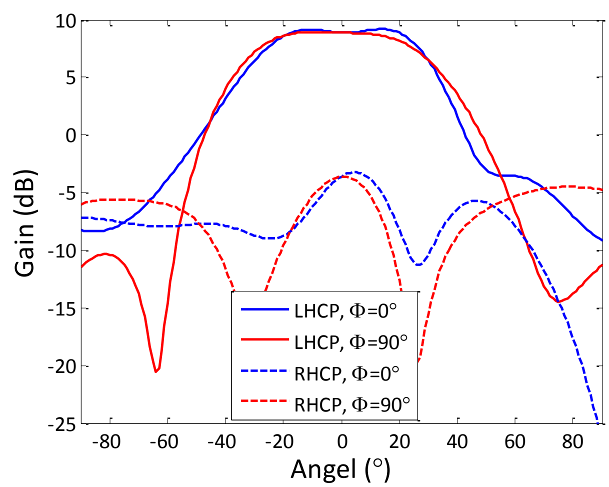

Fig. 3. Left-hand and Right-hand radiation patterns of the CP antenna in the two principal planes (φ=0 and φ= 90 degree).

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