Wideband Circularly Polarized LTCC Modular Phased Array Antenna at Ka-band

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***Abstract* — A wideband circularly polarized (CP) phased array antenna is proposed and demonstrated experimentally at Ka-band of 27.5 GHz – 30.5 GHz. The proposed phased array antenna system consists of 8×8 CP antenna elements with 16 Anokiwave ICs. For good CP performance, each 2 × 2 antenna subarray with one core chip is excited in a sequentially rotated manner. The beam can be steered electronically with a coverage of ±45° with gain of greater than 21 dBic across the frequency band of 27.5 -30.5 GHz.**

Keywords — Circularly polarized antenna, Phased array; Beam steering; Ka-band; Wideband.

I. INTRODUCTION

In recent years, the demands of large-capacity and high-speed wireless communication have increased drastically, so that the communication frequency expends to higher frequency range. Millimeter-wave (mmW) phased array antenna technology is playing a key role in next generation wireless communication, satellite systems, and connectivity systems specially at the Ka-band. A beam steering/beamforming antenna system is the key element for mmW 5G and satellite communications (SATCOM). To ensure highly reliable SATCOM at the mmW, the phased array antenna system must be circularly polarized (CP) and high gain with steerable narrow beam [1].

Different types of CP phased array antennas have been presented in the literature [1-4] for Ka-band applications. Low temperature co-fired ceramic (LTCC) technology is especially useful for mmW applications because the excellent physical and electrical properties of ceramic substrate and gold/silver conductive layers. LTCC based CP array/phased array antennas have been demonstrated at the Ka-band. In Ref. [5], a wideband LTCC based CP array antenna has been proposed by constructing a 1×2 sequentially rotated CP patch array with small inner element spacing in the antenna elements. The dual-feed based CP antenna element has been proposed in Ref. [6] for designing the CP phased array using LTCC technology.

In this paper, a single feed-based CP antenna element using LTCC technology at the Ka-band is proposed to demonstrate the phased array antenna. The antenna element consists of stacked configuration (radiating and parasitic patches) with square-ring and a grounded via in radiating patch radiator. An 8×8 CP phased array antenna system is demonstrated.

II. CP ANTENNA ELEMENT DESIGN

The cross-sectional view of the proposed wideband CP antenna element is shown in Fig. 1, wherein each LTCC layer thickness is 0.096 mm. The multilayered LTCC tape used is Ferro A6M with dielectric constant of ε_r = 5.9 and loss tangent of tanδ = 0.002. The CP antenna element is designed with 13 LTCC layers and an overall size of 6 mm × 6 mm × 1.55 mm, corresponding to $0.56\lambda_0 \times 0.56\lambda_0$ at 28 GHz. The antenna element consists of a parasitic slit-patch and a radiating ring-slotted patch with a grounded via. The parasitic square slit-patch (l_p = 1.48 mm) is placed over the square radiating patch (l_r = 1.46 mm) with 7 LTCC layers. A coaxial feed via is located at x_f = 1 mm from the center of the antenna element. A stripline feeding transition is needed to feed the antennas from the beamforming core chips mounted on the backside of the LTCC board, and 6-LTCC layers are used to design the transition for antenna element feed to IC chip's pin. To reduce mutual coupling between the antenna elements, metallic via wall is designed with via diameter = 1.0 mm and via pitch-to-pitch distance of 2 mm.

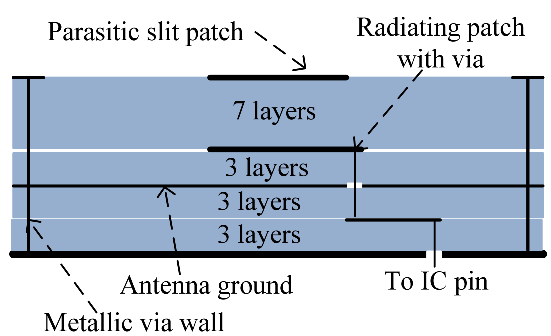

Fig. 1. Cross-sectional view of the wideband circularly polarized LTCC patch antenna.

Fig. 2 shows the simulated performance of the CP antenna element in terms of input reflection coefficient, realized gain, and axial ratio (AR) by using CST. The CP antenna element exhibits wideband impedance matching, gain and AR bandwidth with reflection coefficient below -15 dB from 25.7 to 30.5 GHz and below -10 dB from 25.03 to 31.6 GHz. The realized gain is 5.6 to 6.3 dBic over the frequency band of 25 to 32 GHz, with a 3dB AR bandwidth of 3.7 GHz from 26.6 to 30.3 GHz.

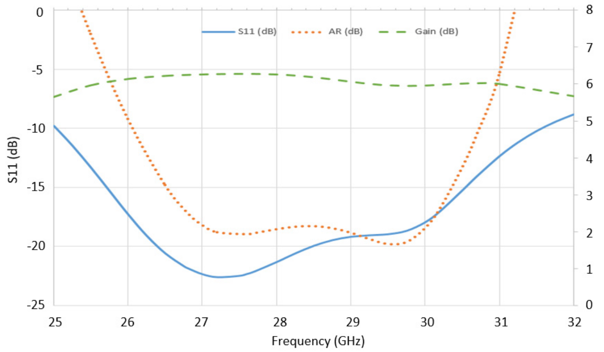

Fig. 2. Simulated performance of the LTCC CP antenna element in terms of realized boresight gain, reflection coefficient, and axial ratio.

III. Modular 8 x 8 CP Phased Array Antenna

The LTCC phased array antenna is built in modular architecture and one array module consists of 8 × 8 CP antenna elements fed by 16 beamforming core chips. It also integrates on-board RF signal distribution and calibration networks. Fig. 3 shows a photograph of a phased array antenna module prototype, where the top side is with antenna elements and the bottom side is with core chips.

The Ka-band RF signal is fed to the antenna module using a SMPM connector and distributed to the 16 core chips through coaxial transition and a three-stage stripline Wilkinson power divider that is embedded inside the LTCC board. A 40-pins edge type high-speed connector at the board center is used to route DC supply and SPI digital lines to the chips to control phase and gain setting for RF beam steering and tapering. The chip operates in half duplex fashion and supports four radiating elements in both Tx/Rx operation, but is limited to a single feed for each antenna. To increase AR bandwidth, the four radiating elements supported by one chip are arranged as a sequentially rotated 2×2 sub-array.

The 8×8 phased array antenna system has been measured in a full anechoic chamber. Fig. 4 plots the measured normalized far field radiation pattern at 28 GHz. The phased array antenna features sub-1 degree beam scanning resolution and wide scanning angle of ±45° with less than 2 dB scan loss, while keeping side lobe level of around -10 dB.

One advantage of the design is its built-in modularity. It gives the flexibility to scale up the antenna array size by simply adding more modules to increase EIRP and G/T based on the application specific link budget requirements. Fig. 5 shows the integration of a 16×16 array aperture using four 8×8 modules.

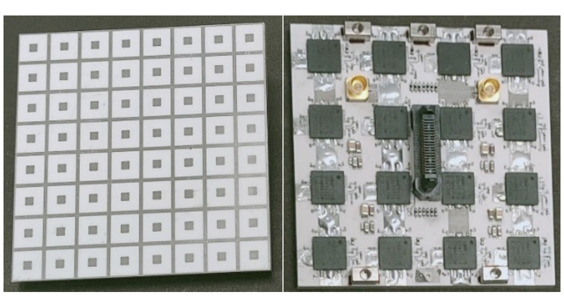

Fig. 3. Photograph of the phased array antenna module: top side with antenna elements and bottom side with beamforming core chips.

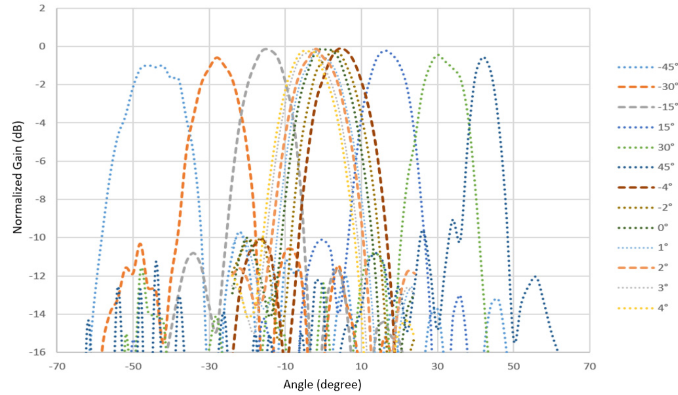

Fig. 4. Measured normalized radiation pattern of the 8×8 phased array antenna.

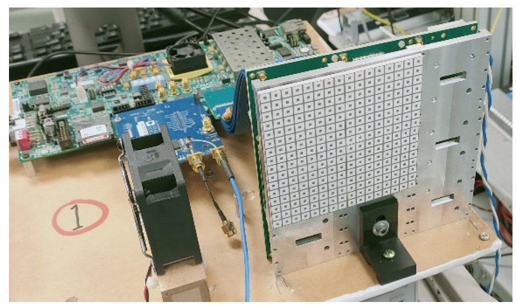

Fig. 5. Module integration in larger array aperture (4 modules).

IV. Conclusion

A highly integrated modular phased array antenna in LTCC technology, consisting of 8×8 circularly polarized antenna elements and 16 beamforming core chips, has been presented and demonstrated experimentally at Ka-band. The antenna array features ±45° scanning angle with boresight gain of greater than 21 dBic.

Acknowledgment

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