Dual Polarized FOWLP AiP for 5G Base Station Applications

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Abstract

This paper presents Fan-Out Wafer-Level-Packaging (FOWLP) based dual polarized Antenna-in-Package (AiP) array for 5G base station applications. The AiP features the double molding chip facing up configuration with the heat sink to cater for high power applications. The AiP 2×2 array design and its method of forming scalable array are illustrated. The AiP element features meta-surface radiator and two sets of orthogonally arranged power divider aperture feeds to achieve the wideband performance and pure dual polarizations. With a size of 6.75mm × 6.75mm × 0.742mm it shows a Return Loss > 15dB, an Isolation > 20 dB, a Gain of 5.68-6.6dBi over the 24.25-27.5 GHz as well as pure dual polarized patterns; when integrated with chip by bond wires the AiP element keeps Isolation and pattern performance and has a Return Loss > 11.5dB and Gain of 5.38-6.5dBi over the same bandwidth.

Introduction

The 5G base stations require large millimeter wave (mmWave) antenna array and power amplifier (PA) chips or millimeter wave monolithic IC (MMIC) to provide its high speed and large bandwidth communication with beam scanning function [1]. The AiP technology is one of the most favorable solution to realize such mmWave antenna array in a compact package with integrated MMIC and antenna, which helps to attain lower RF connection loss. For the current two leading plausible advanced technologies to implement 5G AiP phase array: Flip Chip BGA and Fan-Out Wafer-Level-Packaging (FOWLP), the FOWLP stands out in terms of performance, dimension and design flexibility as it avoids an additional substrate and solder bumps necessary to integrate the bare die into the package as in Flip chip BGA. This makes the RF-Antenna routing length shorter and the loss much smaller [2]. In this paper, we report the dual polarized AiP array for 5G base station applications based on Institute of Microelectronics (IME)'s Mold-on-Mold FOWLP technology [3,4,5].

FOWLP AiP cross section

Fig. 1 shows the FOWLP AiP cross section with thermal cooling solution for 5G base station applications. It features the double molding process with EMC1 and EMC2 used as well as the chip facing up configuration with the heat sink to cater for high power applications [6]; It also features the effective shielding of the chip from antenna radiation as helped by M1 ground plane while also making antenna not influenced by chip from electromagnetic aspects. In addition, it features smart routing as the PCB RF, DC and control signals are connected to the chip through solder balls, M2 and M3 RDL lines, and bond wires; while the chip RF signals are fed to the M0 antenna radiator through bond wires, M2 RDL lines and M1 ground aperture.

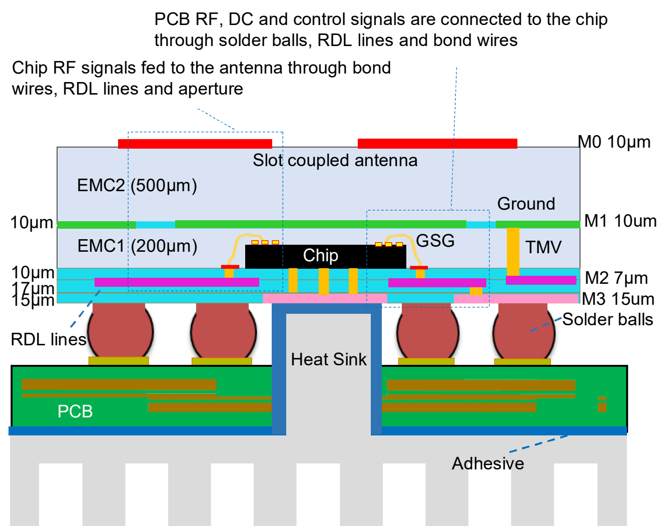


Fig. 1. FOWLP AiP cross section for 5G applications.

FOWLP AiP array for 5G applications

Fig. 2 shows our FOWLP AiP 2×2 array module and an illustration of its flexible forming the large scalable module array, using a 4×4 module array as an example. It is noted that the integrated 5G beam former chip is TX/RX mode switchable. In each TX or RX mode, there are 8 channels with amplitude and phase controlled separately to feed the 4 antennas thus to form phase arrays to produce separated Vertical (V) and Horizontal (H) polarizations.

The antenna element details are shown in Fig. 3. As shown in Fig. 3 (a) the AiP antenna element has RDL lines (M2) feeding to the meta-surface radiator (M0) through the symmetrical ground apertures (M1) in a power divider format thus producing linearly polarized radiations. With two orthogothal sets of such configurations the dual polarized (H and V) radiations are produced. The AiP element thus features meta-surface radiator and two sets of orthogonally arranged power divider aperture feedings that collectively help to achieve the wideband performance and pure dual polarizations. Fig. 3(b) also shows the details of antenna integration with the quarter chip by bond wire interconnections in G-S-G formats.

to the antennas to radiate out while with SPI for effective beam former control thus having beamforming functions. It should be noted that for the illustrated 2×2 subarray chip centered configuration and RDL feeding line routings some antenna elements will be in mirror status. For effective radiation the corresponding 180° phase compensation is necessary.

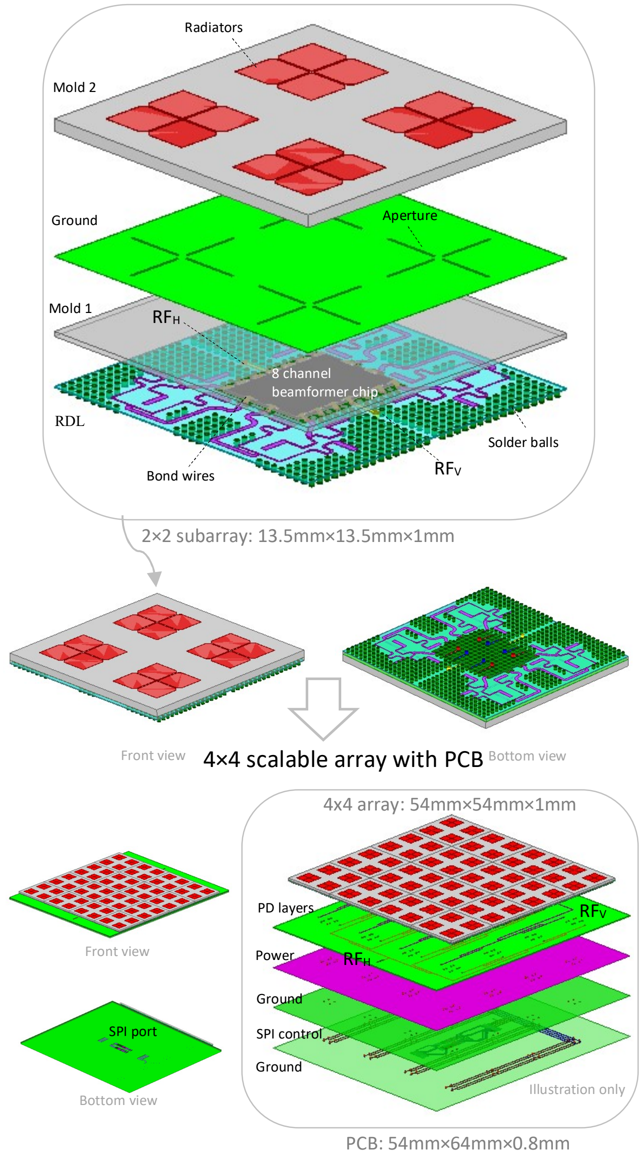


Fig. 2. FOWLP AiP array for 5G applications.

The compact phase array solution for 5G applications is demonstrated as shown in Fig.2. The size of the FOWLP 2×2 subarray is 13.5mm×13.5mm×1 mm. It further forms a 4x4 scalable array module with a size of 54mm×54mm×1mm. The whole array module is as compact as 54mm×64mm×1.8mm after landing on a 54mm×64mm×0.8mm PCB, which has the RF_V and RF_H power distribution network layer, DC power layer and SPI control layer separated by ground layers as well as a SPI, DC, ground signal interface at the bottom. The RF interface can be on the PCB top for less loss. It also can be routed to the PCB bottom if needed. As seen, RF_V and RF_H signals as well as SPI control and DC signals from PCB are first distributed to every subarray module and finally fed to the beam former chip with solder balls, RDL line routings, and bond wires in the package. The chip 8 channel RF signals are finally connected

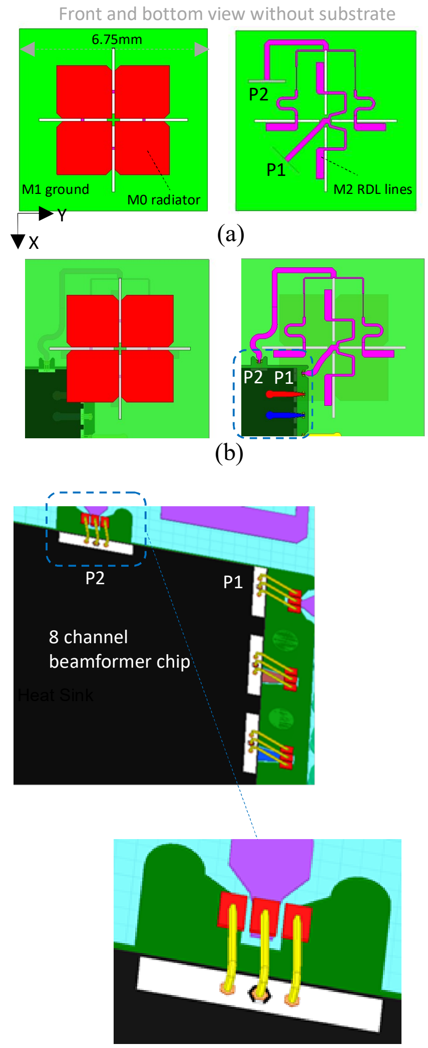
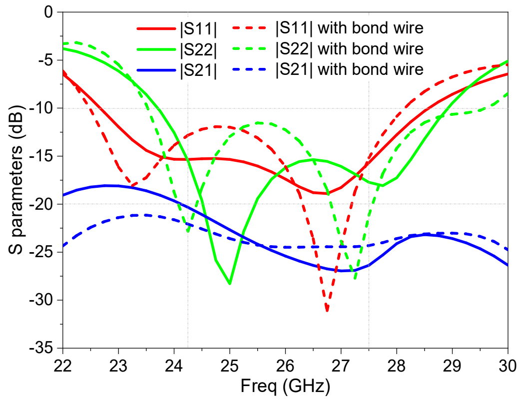


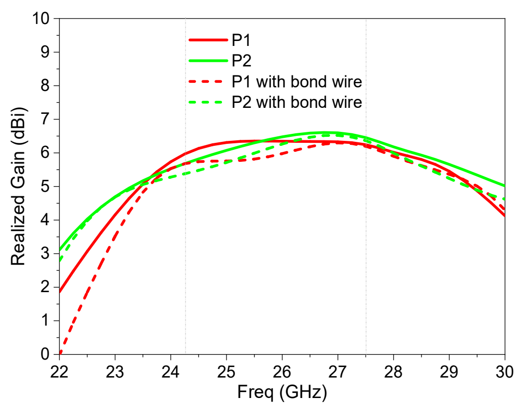
Fig. 3. The AiP element without (a) and with (b) integrated chip by bond wire interconnections.

FOWLP AiP element performance

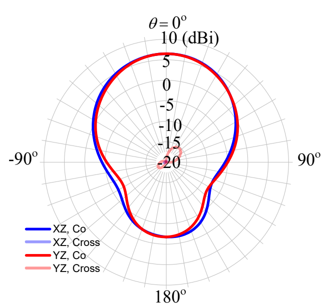
The simulated AiP element performance is shown in Fig. 4. Here, we use material with dielectric constant ε_r = 3.4 and loss tangent tanδ = 0.005 for EMC and ε_r = 2.7 and tanδ = 0.0075 for RDL polymer while the copper is used for all metal layers. with a size of 6.75mm × 6.75mm × 0.742mm the AiP element as in Fig 3 (a) achieves a Return Loss larger than 15dB, a two port Isolation larger than 20 dB, a realized Gain of 5.68-6.6dBi over the 24.25-27.5 GHz as well as pure dual polarized patterns with very small cross polarization components; while integrated with chip by bond wires the AiP element as in Fig. 3 (b) shows a Return Loss larger than 11.5dB, an Isolation larger than 20dB, a realized Gain of 5.38-6.5dBi over the same band as well as pure dual polarized patterns almost unchanged.



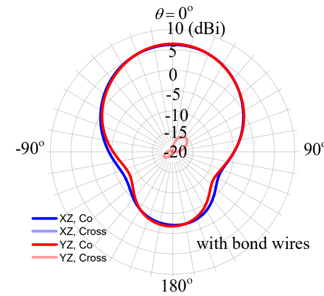
(a)



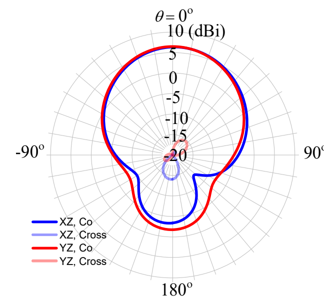
(b)



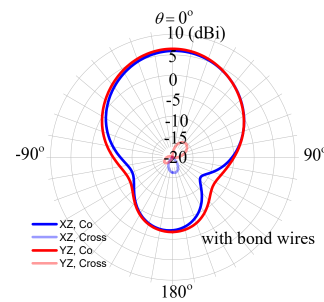
(c)



(d)



(e)



(f)

Fig.4. Performance of the AiP element: (a) Return loss and Isolation, (b) Realized Gain, (c) (d) P1 excited H polarized patterns at 26 GHz, and (e) (f) P2 excited V polarized patterns at 26 GHz.

Conclusions

This paper presents the concept illustration of double mold FOWLP to realize the dual polarized AiP array for 5G base station applications. The double mold chip facing up FOWLP AiP configuration with heat sink facilitates high power dissipation. The AiP element featuring meta-surface radiator and two sets of orthogonally arranged power divider aperture feedings demonstrates the wideband performance and pure dual polarizations as simulation validated. The AiP 2×2 array module and its flexibly forming scalable array has been illustrated. To facilitate easy customer integration by avoiding the complex antenna design and sensitive antenna-chip integration, as well as with great flexibility of forming different aperture size array, the scalable solution will have great advantage for mass production. As the major companies are developing 5G AiP phase array [1, 7], the presented concept illustration and designs based on advanced FOWLP AiP technology will be important for highly integrated 5G products development with beam scanning functions.

Acknowledgments

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