Monolithic Realization and Characterization of On-chip UWB Phased Arrays for mmW and THz Connectivity

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The short wavelengths in millimeter-wave (mmW) and terahertz (THz) bands enable antennas and arrays to be directly integrated with transceiver electronics, allowing for significant savings in radiator-to-front-end packaging and integration for 5G wireless networks operating in the 20-100GHz band. However on-chip antennas typically exhibit strong coupling to the transceiver substrates, resulting in extremely poor radiation efficiencies on the order of 10% or less. Alternatively, higher antenna efficiencies can be achieved using traditional packaging approaches such as wire- and flip-chip-bonding; however, these are typically narrow band and are not cost effective to facilitate large-scale adoption.

Here, we develop a novel on-chip ultra-wideband phased array topology that can continuously cover an unprecedented 2:1 bandwidth for mmW (e.g. 35-70GHz) and sub-mmW (e.g. 175-350GHz) operation and can be lithographically fabricated via wafer-scale processing, vertically integrated with transceiver electronics. The array design is based on the current sheet array concept and relies on capacitively-coupled dipole antenna elements isolated from the substrate using a ground plane. Isolation of radiating elements from transceiver substrate enables remarkable on-chip radiation efficiencies, typically over 60%. Above all, the proposed structure can be realized through a wafer-level lithographic fabrication process, allowing for large-scale cost-effective production. As the support substrate of the array, we use ultra-thick SU-8 dielectric film, which can be patterned by photolithography. Nevertheless, several key challenges in the SU-8 processing need to be addressed. In particular, the large residual mechanical stress in thick SU-8 films, poor adhesion of SU-8 to metals, and through SU-8 via formation must be tackled to realize array prototypes covering 35-70GHz band. Electrical connectivity among the array and feed layers, as well as the overall mechanical integrity of the multilayer SU-8 process have been optimized through the developed processing recipes. Moreover, key challenges for testing on-wafer antennas, such as impedance and pattern characterization of many-element phased arrays will be discussed at the conference.