Design and Empirical Investigation of Miniaturized mmWave Antenna Array Modules within Cellular Devices

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Millimeter-wave (mmWave) wireless technologies are projected to play an integral role in sustaining the ongoing explosive growth of worldwide data traffic in the next decade. Significant research and development efforts in silicon and compound silicon technology have enabled various forms of mmWave broadband wireless communication applications over the past decade. For example, fixed, point-to-point mmWave communications are increasingly being deployed for fronthaul and backhaul scenarios. For close-range communication applications, the 60 GHz-based IEEE 802.11ad/WiGig standard supports up to 6.75 Gbps. It is mainly targeted to be used in conjunction with legacy radios to support use cases such as extreme high resolution video streaming and high speed data transfers between user equipments (UE) or to a nearby base stations. Furthermore, mmWave mobile broadband (MBB) technology denoted as 5G is being conceived to enhance the capacity of 4G LTE.

Despite the extensive interest and research activities surrounding mmWave wireless communication technologies, the wide-spread adaption and market pull have been undeniably stagnant in recent years. One of the main factors is the fact that the vast majority of previously reported mmWave wireless modules are unrealistic in perspective of form factor, material composition and compatibility with existing components inside consumer electronics products. This becomes an extremely challenging issue particularly for compact mobile devices such as cellular phones as they are generally extremely stringent in terms of available space. Furthermore the unpredictable channel variation due to constant reorientation of cellular devices can potentially neutralize the benefits offered by mmWave radios. In that regards, the future mmWave antenna modules must simultaneously conform to practical limitations while operating under robust propagation conditions.

This paper presents one of the smallest, completely integrated 60 GHz radio ever reported in peer-reviewed literature. The devised antenna array module supports up to 16 separate RF paths and is capable of functioning as a scalable phased-array. The antenna elements are designed using substrate materials that are used in present day smartphones and feature profiles of less than $1.2 \times 0.3 \times 0.6$ mm^2 in profile. The proposed antenna modules are realized in different combinations of polarizations and its effects are extensively studied. Experiments are carried out while the modules are fully integrated within operating cellular devices and evaluated at the vantage point of the end user.