Doctoral Thesis

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Ultra-wideband Millimeter-wave Antenna Arrays and Front-end Systems

For high data rate 5G and high energy physics applications

Abstract:

The demand for wireless data communications is rapidly increasing due to factors including increased internet access, grown number of mobile users and services, realization of Internet of Things (IoT), high-definition (HD) video streaming and video calling. To meet the bandwidth requirement of new and emerging applications, it is necessary to move from the existing microwave bands towards millimeter-wave bands.

This thesis presents different antenna arrays at 60 GHz and 28 GHz that are integrated with the front-end RFIC to steer the beam in ≈ ±50° in the azimuth plane. The 5G antenna arrays at 28 GHz are designed to provide the broadband high data rate services to the end users. And to transport this high-volume data to the core network, a fixed wireless access (FWA) link requires the implementation of a broadband, high gain and steerable narrow-beam array. The 60 GHz antenna arrays, presented in this thesis, are good candidates for both FWA as well as backhaul communications. The two proposed arrays at 60 GHz (57-66 GHz) are: 1) stacked patch array and 2) connected slots array feeding the high gain lens antenna. The 2×16 stacked patch PCB antenna array is integrated with the front-end RFIC that can steer the beam in ±50°. This RF module provides > 40 dBm effective isotropic radiated power (EIRP). The other 60 GHz PCB antenna array is designed by feeding a linear connected slot at sixteen equidistant points, which is then used as a feed to a high gain dielectric lens. Peak measured gain of 25.4 dBi is achieved with this antenna. Moreover, instead of scan loss, the lens design provides higher gain when the beam is steered away from the broadside direction.

Furthermore, two compact antenna arrays are designed at 28 GHz (24.25 - 29.50 GHz). A linear polarized (LP) and a circular polarized (CP) array are realized in the fan-out embedded wafer level ball-grid-array (eWLB) package. In comparison with the PCB arrays, this antenna in package (AiP) solution is not only cost effective but it also reduces the integration losses because of shorter feed lines and no geometrical discontinuity. The LP array is realized as a dipole antenna array feeding a novel horn-shaped heatsink. The RF module gives 34 dBm peak EIRP with beam-steering in ±35°. Besides, the CP antenna array is realized with the help of crossed dipoles and the RF module provides 31 dBm peak EIRP with beam-steering in ±50°.

The wireless data demands are not limited to the telecom industry as the upgradation of accelerators and experiments at the large hadron collider (LHC) at CERN will result in increased event rates thus demanding higher data rate readout systems. This work also investigates the feasibility of 60 GHz wireless links for the data readout at CERN. The 60 GHz wireless chips are irradiated with 17 MeV protons [dose 7.4 Mrad (RX) & 4.2 Mrad (TX)] and 200 MeV electrons [dose270 Mrad (RX) & 314 Mrad (TX)] in different episodes. The chips have been found operational in the post-irradiation investigations with some performance degradation. The encouraging results motivate to move forward and investigate the realization of wireless links in such a complex environment.