60 GHz Antenna Module featuring Spherical Coverage for Nomadic and Mobile Gbps Applications

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Employing efficient, high directivity antennas is one of the most preferred techniques to alleviate the high material and atmospheric propagation loss which are commonly associated at millimeter-wave (mmWave) spectrum. Over the past decade, significant strides have been made in proliferating mmWave wireless technologies across a diverse range of user applications and markets. Consequently in addition to relatively well understood user scenarios such as mmWave backhaul and fixed point-to-point communication, the wireless industry has been actively investigating nomadic and mobile mmWave scenarios with focus on consumer electronics. For example, compact 60 GHz portable modules can be conceived in the form that resemble conventional USB dongles to support multi-Gbps wireless links for portable wireless devices. Mobile mmWave devises will most certainly be subject to frequent channel variations particularly due to constant orientation and position shifts. Extensive adaptive beamforming methodologies have been devised and researched by numerous research entities to ensure a secure wireless quality of service (QoS). However the effectiveness of mmWave adaptive beamforming algorithms are oftentimes diminished in non-line-of-sight (NLOS) propagation conditions which can eventually lead to wireless link failures. One of the primary factors that attribute to this practical but important technical challenge is the limited beam steering range associated with planar mmWave antennas such as broadside arrays. Ensuring high antenna gain across a wide range of atmosphere is subject to a series of technical tradeoffs and remains of the most elusive subjects in the mmWave wireless industry.

For the first time, to the author's best knowledge, this paper presents a 16-RF chain antenna array module exhibiting more than 10 dBi antenna gain over a spherical coverage at 60 GHz. A monolithic antenna element topology is conceived to function as a TE_{10} mode traveling waveguide and TM_{01} patch antenna for endfire and broadside radiation respectively. Furthermore the employment of substrate waveguides significantly reduces the insertion loss incurred due to extensive signal routings between the 60 GHz RFIC and the antenna elements, leading to enhanced antenna gain. In conjunction with a CMOS double-pole double throw (DPDT) switch and 2-bit phase shifters, portions of the 16-RF chain are selectively utilized in real-time to steer and switch the antenna main beam over a range of more than 240 degrees. Empirical investigations are extensively carried out in comparison to a conventional 16-RF chain planar patch array at the system level for full evaluation. Under identical NLOS conditions, the proposed antenna topology is found to reduce the probability of failed link connections by more than 60%.