A Model for Proximity Coupled Patch Antennas in mm-Wave Antenna-in-Package Design

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The W-band, defined to be 75 GHz to 110 GHz, is growing in importance for wireless communications, radar sensors, and imaging. Because of the small wavelength, these applications allow integration of integrated circuits (ICs) and antennas within a single package. Microstrip patch antennas using proximity coupling are compact with moderate gain, and do not require complex vertical transitions, making them suitable for mmWave AiP applications.

To understand the design space and produce rapid performance estimates of the proximity coupled patch, an intuitive model of the antenna and feed structure is desired. However, analysis of this antenna is challenging due to the complex interactions between the antenna and feed line. Several models have been proposed to explain the behavior of the proximity coupled patch, but to achieve sufficient accuracy, the complexity of these models makes them hardly more intuitive than optimization of the full-wave solution. Therefore, in this paper, we revisit the analysis of the proximity coupled patch antenna in order to generate an intuitive, yet accurate model for the structure. This new model estimates the dimensions required for certain operating frequency without resorting to time consuming numerical optimization.

For the targeted application, we consider the feed line as a fixed geometry and analyze the effects of the patch width, length, height, and substrate parameters on the design to develop the model. We predict the range of matched frequencies that can be achieved by coupling differing patch diemsnions to the fixed feed. Our baseline model is a rectangular patch antenna for W-band that is integrated on a thick quartz substrate (ϵ_r=3.8) and a feed line printed on a thin layer of SiO_2. Designs at several different operating frequencies are explored and validated with full-wave simulation.