RFIC Measurement and Off-Chip Antenna Excitation Through Proximity Coupling at 60GHz

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***Abstract*—Off-chip antenna excitation through magnetic inductive coupling at 60GHz has been proposed to facilitate the industrial RFIC measurement or the antenna connection to the RFIC chip. To verify the concept, a slot antenna at top layer of the PCB was excited through magnetic coupling from the RFIC chip set at the proximity of the antenna. Minimum return loss of -17dB, gain of 6dBi, and bandwidth of 7GHz at 60GHz achieved through simulation to serve all the applications at unsilenced 60GHz frequency. The case can be extended to multi-port or MIMO RFIC chips by using antennas with orthogonal polarization.**

I. INTRODUCTION

The increasing demand for RFIC CMOS chips with enhanced performance have caused further facilitation in the connection between the RFIC chip and off-chip antenna or probe station by replacing the wires with wireless link. Employing experts in the field carefully testing the mm-wave frequency RFIC chips using expensive probe stations imposes high cost to the companies. It causes measurement of RF CMOS chip to be a challenging issue in RF chip process. In addition to taking a lot of time, the probes may be damaged during measurement [1].

These issues are even more accentuated if the RF chip has more than one RF input/output ports which needs a multi-port probe-station such as phased array and MIMO systems. Even On-chip antenna can be integrated with RFIC transceivers, designing high performance antenna considering CMOS technology restriction is challenging. However, bonding off-chip antenna printed on high quality printed circuit board through via or wire is tricky and expensive especially at high frequencies [2].

Here, a proximity magnetic inductive coupling method is proposed to facilitate the measurement of multiport RF chips or eliminate the wired connection between a chip and an extra off-chip antenna at 60GHz. Instead of using multi-port probe station, an antenna can be fixed and calibrated in the small 60GHz chamber and the RFIC chips can be measure when they are the vicinity of the antenna. [3]. Alternatively, the proposed inductive coupling can be used to connect the excited antenna through wireless NFC link.

II. ANALYSIS AND DESIGN

The system consists of an off-chip antenna as well as its inductive link to the RFIC chip.

A. *Proximity Inductive Coupling at 60GHz*

A flipped feed stacked-transformer between 65nm CMOS chip and an external antenna on a Rogers standard PCB substrate designed and simulated. The primary loop of the transformer placed at M6 metal layer. This layer is not only the thickest metal layer in 65nm CMOS technology, but also it offers less loss and less capacitor with the substrate. The secondary loop placed at the bottom layer of the external Rogers RT/Duroid 6002 PCB with permittivity of 2.94. A 1.8um pass layer has been considered to model the distance between two boards. The whole configuration and related transformer are illustrated at Fig. 1 and Fig. 2, respectively.

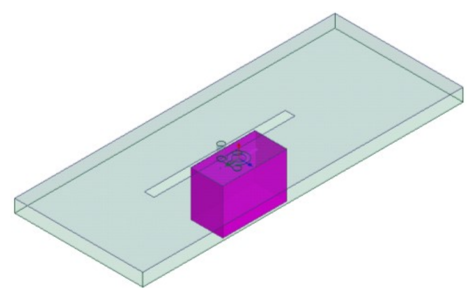

Fig. 1 RFIC chip in the vicinity of off-chip antenna

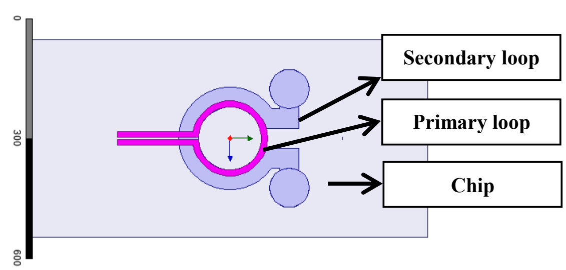

Fig. 2 Transformer consisting off-chip Secondary loop and on-chip primary loop

The primary loop of the transformer was designed by connecting an inductive loop to a capacitive differential line on M6 layer to adjust the ESR frequency of the transformer at the 60GHz when the secondary loop is in the vicinity.

The secondary loop of the transformer which is placed at the bottom layer of the PCB was designed considering the restriction in the PCB fabrication. As the fabrication devices of the PCB offer lower resolution compare to CMOS fabrication, widths of the line and the gaps is modified to meet the requirements and be feasible. The dimensions of primary and secondary loop of the transformer are shown in Table I.

TABLE I. DIMENSIONS

Parameters	Primary Inductor	Secondary Inductor
Width	15µm	50 µm
Radios	80 µm	80 µm
Capacitive Lenght	220 µm	120 µm
Gap in Capacitive length	5 µm	50 µm
Length of Slot Antenna	2200 µm	
Width of Slot Antenna	150 µm	

B. *Antenna design*

The external off-chip antenna can be placed at the bottom layer or top layer of the PCB, while its input impedance needs to be matched to the differential output of the secondary loop of transformer. Generally, one or two antennas with orthogonal polarization can be employed in the architecture to connect to one port or multiport RFIC chipsets.

Here a slot antenna on top layer of the PCB is designed and excited through two vertical vias connected to the differential output of the secondary loop. [4]. As the slot antenna is high impedance at center, the secondary loop and especially its connection to the antenna has been optimized to match the antenna. Additionally, the feeding port has an offset from center for proper impedance matching. Even the antenna can be meandered or miniaturized; we picked a half a wavelength slot antenna to verify the concept.

III. SMULATION AND RESULTS

As mentioned in the previous sections, an off-chip slot antenna fed through magnetic coupling from a CMOS RF chip designed and simulated by the aid of HFSS full-wave simulator. The simulation results of the antenna in the vicinity of the RF CMOS chip are illustrated in Fig. 3 and Fig. 4. A minimum input reflection loss of -19dB and maximum gain of 6.4dBi at 60GHz have been achieved.

IV. CONCLUSION

The wired connection between off-chip antenna and RFIC chip has been replaced by an inductive wireless link between two small loops placed in the chip and PCB. The coupling network feeding slot antenna has been analyzed, simulated and optimized and band width of 7GHz has been achieved to serve all applications at 60GHz unsilenced band. Proximity coupling to feed off-chip antennas can replace the traditional method of measurement to speed up the measurement process if the off-antenna is fixed and calibrated at mm-wave chamber with fixed probe and RFIC chips placed on the antenna for the measurement.

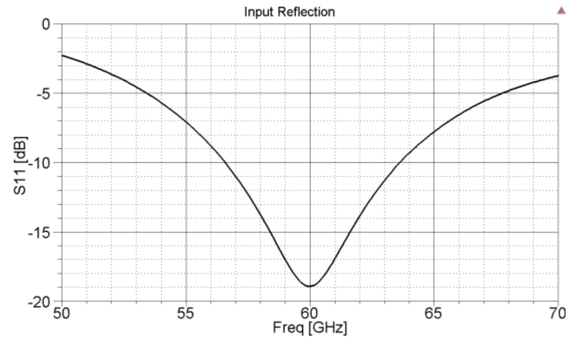

Fig. 3 Input reflection coefficient

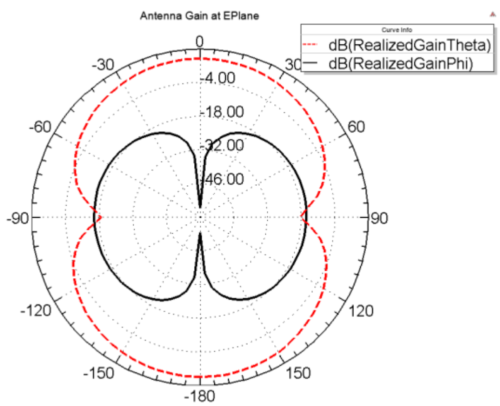

Fig. 4 Radiation Pattern at Electric field Plane

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