Studies on Designing On-chip Antennas with Improved Radiation Characteristics

DISSERTATION

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Abstract

With the advancement of VLSI technology, the continuous scaling of CMOS technology nodes puts forward to integrate different functional modules like voltage control oscillator, low noise amplifier, and digital baseband and signal processing unit of a complete RF system on a single board. However, the antenna; being the largest component; still remains outside of the chip. Integration of antenna along with other functional modules of a system on the same chip i.e., system-on-chip (SoC) leads to produce the truly compact and economical system. Though Silicon (Si) is preferable choice for the fabrication of integrated circuits (ICs), the major hindrance to integrate antenna on the IC chip is the incompatibility of the Si electrical properties for the efficient radiation characteristics. The high dielectric constant and low resistivity of Si make it unsuitable for lossless radiation. Further, at lower microwave frequencies (below 30 GHz), the antenna-size becomes much larger compared to the IC dice. Thus, a significant miniaturization is required to accommodate the antenna on chip. Hence, it's a challenging task to design an efficient antenna by simultaneously miniaturizing the antenna size as the antenna radiation performance is directly affected by the reduction of its aperture. In this thesis, some novel strategies have been investigated to improve the radiation characteristics of on-chip antenna (OCA). Various techniques such as fractal, slotting, and meandering are used to miniaturize the antenna sizes. By introducing some novel methods, the well-established gain enhancement techniques, such as dielectric resonator, micromachining, and defective ground structures have been embedded in the antenna structure so as to improve its overall performances. In order to reduce the substrate loss, the direct coupling of the antenna radiated electromagnetic (EM) waves with the substrate is restricted by introducing some propagation barriers in the intermediate layer of the CMOS layout. In this regard, a partially shield layer (PSL), a thin film of Oxide layer, namely, Hafnium Oxide (HfO_2), and a ferrite layer, namely, Cobalt Zirconium Oxide (CoZrO) are innovatively employed. The potentialities of the employed strategies are presented via representative simulation results, equivalent circuit model and analysis. Some of the simulation results are also validated through experimentally measured results. The study shows that the presented methods are useful in designing efficient OCAs for the compact wireless system devices.