Abstract

The size of radio frequency (RF) front-end circuits has reduced to a few square millimeters with the advent of sub-micron CMOS technologies. Keeping in pace with this chip size, the major advancement in the field of on-chip antennas (OCAs) has been for the millimeter-wave frequencies. As silicon die is costly, chip size must be kept small irrespective of the frequency band. Thus, the real challenge in designing OCAs is for the lower RF frequency bands, which require efficient antenna miniaturization techniques. The realized gain of standard CMOS OCAs is considerably low, primarily due to the lossy silicon substrate. Added to this, antenna miniaturization further reduces the gain for OCAs at RF frequencies. Nevertheless, such OCAs are worthy of high-speed Internet-of-Things enabled applications involving short-range wireless communication systems and implantable medical devices with the added advantage of smaller size yet comparable gain to that of off-chip antennas. In this thesis, the operating frequency for all circuits is chosen as 2.4 GHz. The reported works on OCAs are first reviewed. Then, conventional non-radiating on-chip passive components are discussed. Following this, two size-constrained high-performance RF passive structures are proposed. The first is a metal-oxide-metal capacitor and its co-design with an image reject filter with image frequency at 1.8 GHz. The image reject ratio is better than 35 dB. The second is a perfect-magnetically coupled 1:1 transformer for dc isolation applications. Next, a package-aware standalone OCA is described. The OCA in air when used for implantable purposes is shown to retain its impedance properties with tolerable gain degradation due to the package encapsulation. The philosophy of high-performance systems through antenna-circuit codesigns avoiding inter-stage matching circuits is subsequently introduced. A low noise amplifier is codesigned with an OCA for a noise figure of 1.7 dB. A design flow is proposed to find the optimum input impedance for achieving the maximum figure-of-merit for the receiver. Co-designs of energy harvesters including linear and circularly polarized

OCAs with single-ended and differential rectifiers are presented for high RF-dc power conversion efficiency over a wide dynamic input power range and −22-dBm sensitivity. Finally, conclusions are drawn with scope for future works.

Keywords: CMOS on-chip antenna, energy harvester, filter, implantable antenna, low noise amplifier, MOM capacitor, package, RF rectifier, transformer.