High-Performance RFID Systems

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Behnam Jamali

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Abstract

In this thesis, I present and analyze two of the most fundamental constraints of Radio Frequency Identification Systems (RFID), power rectification and signaling. These two issues play an important role in the continuing development of RFID systems.

A passive RFID tag draws power from the RF field created by an RFID reader and uses it to energize its circuitry. It does this by rectification of the reader's radiated RF field using rectifying circuitry. The power then available to the tag is dependent upon both the available field strength and the efficiency of the rectification process. One option for increasing the operating range of an RFID system without increasing the reader's field strength is to increase the efficiency of the tag's rectification structure. A major component of any rectification circuit is a diode type device and so, the first part of the thesis focuses on the design and implementation of a novel high efficiency Schottky Barrier Diode (SBD) on a standard CMOS process. The forward voltage drop of the SBD diode was investigated and analytic equations formulated considering the Schottky barrier drift region resistance and the contributions from the p^+ guard-grid. A design procedure to minimize the drift region resistance for any blocking voltage was derived. The fundamental trade-off between the forward voltage and leakage current in the novel SBD concept was determined.

Based on the critical review of the Schottky diodes fabricated in the first part, new structures of novel SBD were designed to address most of the open issues related to its reverse break-down voltage and series resistance. Detailed analysis of the important design parameters of the novel Schottky barrier diode were performed using HSPICE with the parameter set used in the calibration process. The novel structure was also compared to an alternative fabrication approach, specifically, a NMOS and PMOS gate-cross-connected bridge. The comparison shows that the novel structure provides a 10% higher

figure of merit for power rectification.

In the later part of the thesis, an analysis of circuit advantages enabled by the novel SBD is given. The circuit simulation showed that by utilizing the novel SBD the operating frequency of the circuit can be increased to the UHF region while maintaining approximately the same power efficiency as that achievable when using a discrete Schottky diode. This leads to the possibility of dramatic improvements in size, weight and cost of the RFID transponder circuits.

Signaling also plays an important role in the development of RFID systems. The choice of signaling methods and protocols determines not only the spectrum bandwidth usage, but also the data throughput. Also with constantly changing standards and regulations, it is important to be able to characterize and optimize these issues.

Therefore the second part of this dissertation presents the design, implementation and evaluation of a novel RFID data logging reader architecture based on software radio concepts. The system is designed to overcome the many challenges and exploit the advantages of performing real-time signal processing and data logging in an RFID environment. The proposed concept has a unique multi-band RFID tag reader platform and has been designed to read tags conforming to the Electronic Product Code (EPC) specifications in both the HF and UHF frequency bands. The hardware architecture consists of a general purpose analogue front end up/down-converter for each band, followed by a software radio based architecture allowing easy adaptation to new frequencies and protocols if required.

The last chapter presents the results of investigations conducted to determine the ability of the proposed reader architecture to communicate with tags in typical channel noise and environmental conditions present in an

RFID operational environment. Studies of the effects of reader interference in multi-reader environments and the development of an anti-collision protocol signaling to address and mitigate those effects are also presented.

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