論文の内容の要旨

All-Digital Fully-Integrated CMOS Wireless Transceiver for Chip-Chip Communication by Near-Field and Multi-Stage Resonance Coupling

（多段磁気共鳴結合と近接場によるチップ間通信に向けたデジタル CMOS 無線トランシーバに関する研究）

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This paper proposes an all-digital fully-integrated wireless transceiver to be used in short-range communication systems, like chip-chip.

Surveying recent transceiver systems research, most of the work is done either to accomplish very short-range communication, few μm, using inductive coupling, or long-range communication using RF. The first suffers from its limited range, whereas the second consumes higher amount of power while transferring data in less speed. This has shown a need to find a communication scheme in which higher data rates can be transferred for longer distances while consuming less amount of power. This research preserves power consumption using all-digital approach, and extends communication range by introducing the concept of multi-stage resonance data transfer.

Opposite to traditional approach, as will be discussed in chapter 3, the transceiver is designed using all-digital components on both its baseband and front-end. A novel modulation technique that allows employing only all-digital components in the transceiver is used, and the front-end uses all-digital sub-sampling for carrier demodulation, which does not need synchronization circuitry. Burst-errors generated by the front-end are corrected in baseband using hamming code and interleaving techniques. Experimentally, the all-digital transceiver was tested on FPGAs that performed successful wireless communication on distances up to 2 cm. Compared to recent researches, our transceiver has a higher data rate/MHz and smaller area.

To extend communication range, as detailed in chapter 4, an all-digital power amplifier architecture that is tunable and fully-integrated on chip using 0.18μm CMOS is used. The PA is designed using all- digital output-connected inverters controlled by a multi-phase clock generated using a multi-stage phase interpolator. Experimentally, in addition to the advantage of being all-digital and tunable, the PA consumed around 0.03 mW/MHz, which is less than power consumed in recently proposed designs.

Chapter 5 introduces multi-stage resonance, which is used to extend the communication range of the transceiver. This work experimentally evaluates the effectiveness of range extension by inserting 2 additional resonance coils in between the original transmitter and receiver coils to form a multi-stage resonance system. From measurement shown in chapter 6, total communication distance could be extended up to 100 mm, which is 42% increase compared to communication distance achieved when using single-resonance setup. Comparing with the state-of-the-art inductive coupling communication systems, this result shows 10 times higher (range/diameter) ratio.

In chapter 7, the system is implemented fully-integrated on-chip, and chip-chip communication is tested utilizing the analysis and measurement discussed in previous chapters. The efficiency of communication as a function of the quality factor of resonance and communication distance is analyzed, and the communication from a chip to chip is then tested experimentally, while recording the results.

The techniques and results presented in this thesis add a new perspective for the wireless transceiver system design. Instead of taking the typical approach and pursue the traditional path, by looking at the problem in a new perspective, and trying to solve it the unusual way, new solid results could be found, which can be used to introduce a new future for the wireless transceiver communication systems.