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Silicon prototype of an bandwidth reconfigurable UWB RFID tag with on-chip antenna.

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***Abstract*—Inexpensive and power efficient transmitters are essential in tiny RFID tags. Increasing the data rate while reducing the power consumption is possible by using UWB Impulse Radio as communication scheme. Moving the complexity to a reader station in a RFID scenario where computational power is available is an accepted compromise. In this paper we show simulations and measurements of our active bandwidth reconfigurable UWB RFID tag with on-chip antenna. The tiny grain with a size of 1x1.3 mm^2 is manufactured in a standard CMOS process and is suitable for very low power applications.**

***Index Terms*—UWB RFID tag, On Chip Antenna,UWB, OCA antenna design and characterisation**

I. Introduction

Using UWB Impulse Radio for RFID applications gained increased interest in research and development for tiny miniaturized tags. The power efficient communication scheme enables a multitude of new application scenarios, known as the buzz word smart dust. The manufacturing of silicon RFID chips with the antennas embedded directly on-chip, support this trend [1].
Consider multiple radiating tags which transmit a baseband pulse in the uplink [2], [3]. If the tiny tags are in close vicinity to each other, collisions at the reader side are likely to happen. A carrier based UWB Impulse Radio signal with an adjustable bandwidth is capable of avoiding this collisions. Multiple tags can communicate to the reader using a different center frequency.
The adjustable bandwidth of the transmitted signal can also be used to fine tune the matching of the on-chip antenna.
In this paper we show our simulated and measured results, performed with a small UWB RFID tag which features an on-chip antenna.

II. Silicon Prototype

The UWB transmitter (see Fig.1) consists of a voltage controlled oscillator which can be swept from the UHF to the X Band. The carrier signal is multiplied with a created glitch. The payload data can be selected via a multiplexer to be a continuous stream of pulses or a random pulse sequence. This random sequence is created by a linear feedback shift register. The bit rate of the data is set to 100 Mbit/s.
The glitch is created by a negated AND-gate with inverted and non inverted signals at its input. Digital coded voltage can be applied to this glitch generator, for a coarse adjustment of the glitch length with two bits and a fine adjustment with three bits.

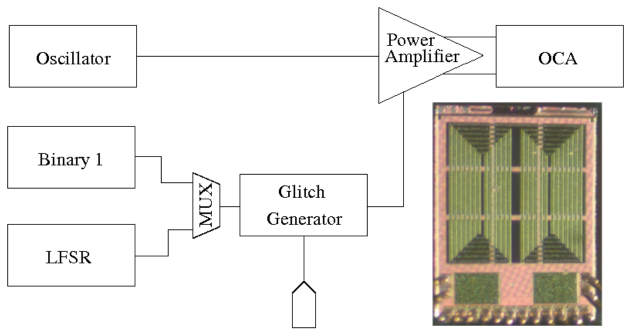

Fig. 1. Basic Diagram of the ultra wideband pulse amplitude transmitter, featuring a microscopic picture of the active UWB RFID tag manufactured in 130 nm CMOS.

The on-chip antenna itself is connected to the differential output of the power amplifier. The principle of the slotted coil antenna is mentioned in [4]. In this manufactured antenna the conducting line width and the spacing is 15 μm. The overall size of the slotted coil antenna is 1 mm^2 and placed on the last metal layer of

the 130 nm CMOS process.
The active grain with a size of 1x1.3 mm^2 is glued on a standard FR4 printed circuit board and connected with bond wires. These bond wires provide, amongst others, the positive supply voltage V_{DD}, the VCO voltage $\mathrm{V}_{\mathrm{DDRF}}$ and the binary settings for the selection of the pulse duration to the prototype.

III. Measurement

A. Conducted Measurements

The overall current consumption of the active driven grain is measured at the voltage pin V_{DD}. With increasing voltage of the VCO, the current consumption at V_{DD} increases with the carrier frequency (see Fig. 2). At a VCO voltage of $\mathrm{V}_{\mathrm{DDRF}} = 1$ V a continuous carrier of 5.3 GHz is available at the differential feed of the on-chip antenna. The current consumption is compared to the pulse mode of the grain. In the pulse mode we observe a drastic decrease of the current consumption, because the differential power amplifier is switched off between the pulses (idle mode).

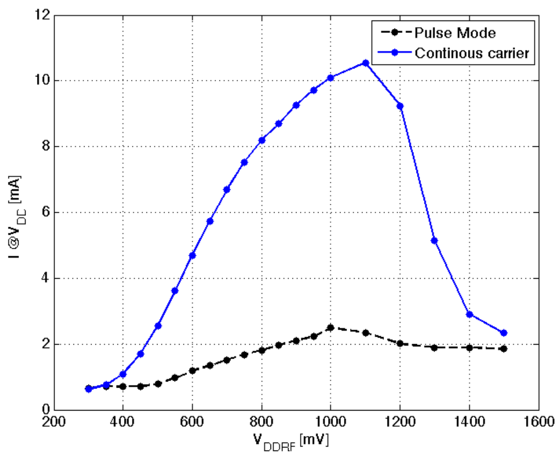

Fig. 2. Current consumption comparison for an unmodulated continuous carrier and pulse modulation.

The overall bandwidth tuning range created by the glitch length is shown in Fig.3. This measurement is carried out conducted at the differential output of the power amplifier and compared to simulation. The glitch duration is measured in the time domain with an oscilloscope and the bandwidth calculated as the inverse. The binary setting in the x-axes represents the fine adjustment and the color coded curves the coarse adjustment of the bandwidth. Simulation and measurement match well with a minimum frequency bandwidth of 100 MHz and a maximum of 1400 MHz.

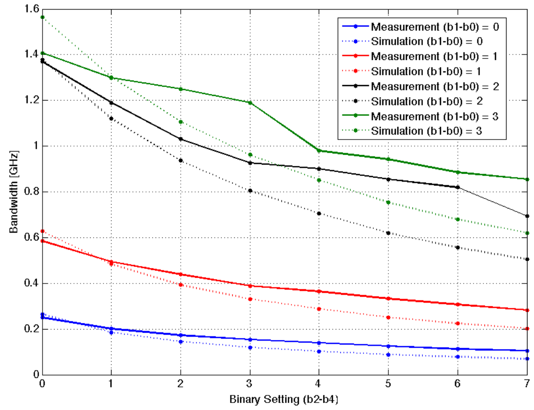

Fig. 3. Simulated and measured bandwidth created by the adjustable pulse width.

B. Radiation Measurements

For the radiation measurements a reference horn antenna is placed 60 mm above the grain. This horn antenna is connected to a wideband amplifier. A spectrum analyzer captures the received signal from the prototype. The specific measurement setting at the spectrum analyzer are a resolution bandwidth of 50 MHz, a video bandwidth of 3 kHz and a sweeptime of 50 ms. For the graphs in Fig. 4 the glitch generator is switched from continuous to random pulse stream and the data measured with the spectrum analyzer is captured. The pulses radiated at a center frequency of 7.4 GHz and 10.2 GHz. The pulse width and the pulse repetition frequency is constant for these measurements. For all frequencies, the continuous pulse mode shows strong peaks and higher amplitudes, compared to the random mode. The random signal as a packet of data, is with 15 dB above the noise floor for the lower and with 8 dB for the higher frequency. This behaviour can be explained that the measured radiation characteristic in this region shows a degradation to the noise floor at 8 GHz. Lower continuous and random stream is measured for the higher frequency area.

At these two frequencies the tuning range of the glitch duration from its minimum to its maximum is swept. The random pulse stream is set at the prototype and the 6 dB bandwidth is calculated from the radiated signal. In Fig. 5 the result of this post processing step is shown. The bandwidth of the pulsed signal radiated at 7.4 GHz can be selected between 240 MHz and 600 MHz and is compared to 10.2 GHz higher in amplitude. The 6 dB bandwidth tuning range of the 10.2 GHz signal is from 192 MHz to 2372 MHz higher, but the amplitude comes close to the noise floor with increasing bandwidth, which finally would lead to an increased bit error rate in the

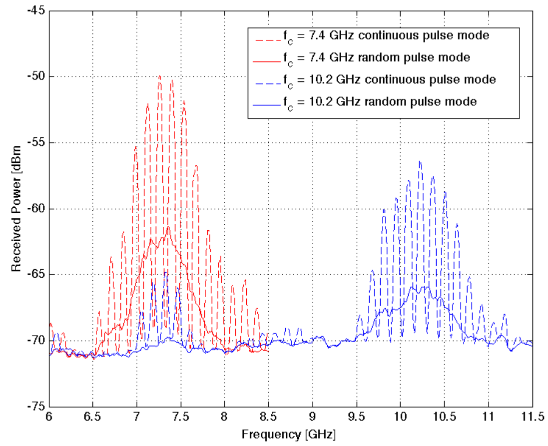

Fig. 4. Random and continuous pulse mode radiated by the coil on-chip antenna at 7.4 GHz and 10.2 GHz.

receiver.

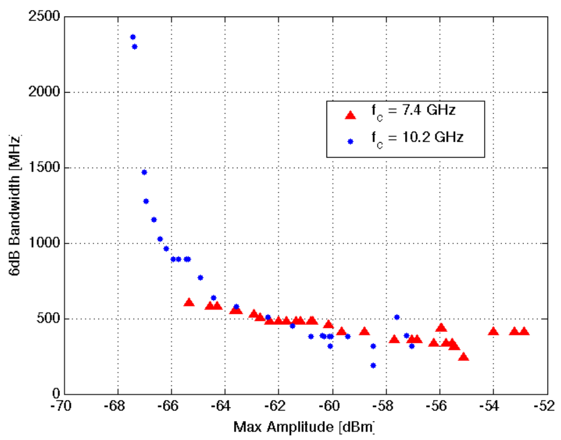

Fig. 5. The 6dB bandwidth of the random pulse stream versus received maximal amplitude.

IV. Conclusions

In this paper we have shown our prototype of a center frequency and bandwidth reconfigurable UWB Impulse Radio tag. This manufactured silicon tag with an on-chip antenna is driven actively and has been measured successfully. We observe a significant decrease in current consumption across the frequency by using impulse radio techniques, which shows the feasibility of UWB for power efficient wireless sensors or RFID tags. Depending on the on-chip antenna performance across frequency, we measured a bandwidth up to 1400 MHz.

Acknowledgements

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