Embedded indoor ranging system with decimeter accuracy in the 2.4GHz ISM band

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Abstract—**This paper presents a novel ranging system with decimeter accuracy. This indoor system combines the best of existing systems: a wideband ranging pulse to achieve a decimeter accurate delay measurement for ranging purposes and a narrowband communication system to achieve a high link budget. A proof-of-concept 2.4GHz ranging transceiver was developed to evaluate the system.**

Keywords— **ISM, WLAN, UWB, locaction awareness, ranging**

I. Introduction

WITH the rise of sensor networks, the demand for location aware sensors grows. Gathering information is one thing, knowing its location is equally important if not the most important part of the information. Different techniques for measuring distances and thus location awareness already exists. Well-known technologies for position awareness mostly address outdoor scenarios, e.g. the Global Positioning System (GPS); an adequate system for outdoor use in presence of a sufficiently strong line-of-sight signal. But GPS is no longer accurate when used indoor. This is mainly because of reflections and an obstructed line-of-sight, which complicates estimating the time-of-arrival of the broadcast signal.

To enable accurate indoor positioning various other techniques are used:

- Received-signal strength (RSS), based on sophisticated path loss models.
- Propagation delay of WLAN packets, difficult due to the narrowband signal suffering from typical multipath reflections in the indoor environment yielding only a $8m$ accuracy.
- Ultra WideBand (UWB) signals: these systems provided a superior delay measurement due there ability to distinguish line-of-sight signals from multipath reflections. The disadvantage is that the limited spectral power density reduces the communication link budget, and consequently, the range of the system.

Combining the advantages of broadband signaling and widespread WLAN technologies, a new system is proposed. Making use of a wideband signal for ranging and a narrowband signal for communication, requiring only a single radio transceiver. The idea is that a narrowband system can be stimulated to produce a wideband transient. By processing these wideband signals rather than just the narrowband communication signal the ranging accuracy can be greatly enhanced. To prove this, a prototype was developed.

II. Architecture

A standard WLAN transceiver is extended to transmit and receive wideband transient signals. A block diagram of this transceiver is shown in Figure 1 [1].

A standard transmitter consists of two separate modules: a dedicated WLAN transmitter with a typical bandwith of 20MHz and a separate power amplifier. Between those two stages a RF switch is placed to produce fast rise and fall times (2ns). The receiver consists of a standard I/Q zero-IF downconvertor with large

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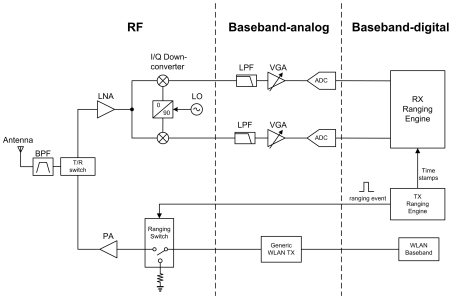

Figure 1. Ranging transceiver system

bandwith in both paths (>100MHz). Followed by a fast analog-digital conversion. This gives the ability to calculate an accurate receive time of the signal, due to the fast rising edge, which converts in an accurate distance measurement. Using digital signal processing to further down-sample the received signal and feeding it to a software radio makes lower bandwidth communication possible. The system is implemented with off-the-shelf componentens and shown in Figure 2 [3].

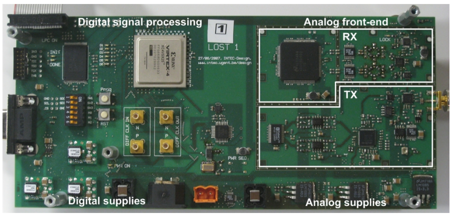

Figure 2. Ranging transceiver system

III. Measurements

The transmitted signal is fully compliant with the WLAN spectral mask (IEEE 802.11g) as long as ranging events occur at a reasonable rate, e.g. every 40μs. The system measures the round-trip-time (RTT) between two nodes to calculate the ranging distance. The results from a field trial [4] are shown in Figure 3. It can be seen that a submeter accuracy is obtained up to 500m with a single measurement. By averaging more than one measurement an even higher accuracy can be obtained, giving a true decimeter accuracy in most indoor environments.

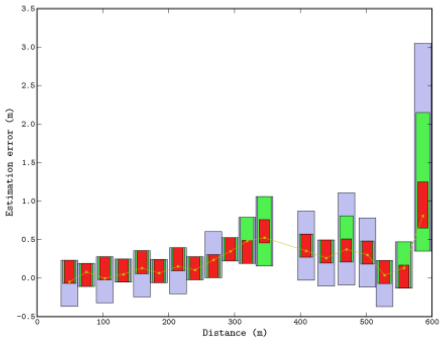

Figure 3. Percentile errors vs. distance for 67%-95%-99%

IV. Conclusions

A prototype of a WLAN transceiver with superior ranging capabilities is built. This prototype, proving the proposed techniques for accurate ranging, opens the way to full CMOS integration; to low power, low cost and small size integration. Yielding in a basic building block for future location aware sensor nodes.

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