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WIRELESS FIELD BUS COMMUNICATION WITH SOFTWARE DEFINED IR-UWB IN A MANUFACTURING ENVIRONMENT

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Abstract

This paper elaborates a concept for a wireless field bus communication with software defined ultra wide band with impulse radio modulation (IR-UWB) in manufacturing environments. A wireless field bus offers an important improvement to the smart factory due to increasing requirements for connectivity, adaptability and flexibility. Former analysis showed the benefit of using UWB technology for the wireless field bus transmission in manufacturing environment.

In order to determine the best type of IR-UWB modulation a software defined radio system with direct sequence synthesizers is convenient. For this purpose on the transmitter side a digital-analog-converter (DAC) with 25 GS/s controlled by FPGA feeds directly the UWB antenna. On the receiver side the received signal is amplified by a low noise amplifier (LNA) and converted to a digital signal by an analog-digital-converter with as well 25 GS/s. The digital signal is further processed with a FPGA. This enables the adaptation of transmission parameters during operation. Thereby the transmission parameter, channels, antennas and RF components can be investigated.

Keywords: UWB, software defined, modular testing platform, FPGA, DAC, ADC.

1. INTRODUCTION

1.1. SMART FACTORY

In the meantime many manufacturing companies achieve a high level of technology. In the business model "Stuttgarter Unternehmensmodell" [1] is shown that transformability in all layer of companies is a crucial factor to survive in a turbulent environment. In order to reach a high flexibility and transformability in the whole company the shop floor level has to be incremented in flexibility in the same way. For a smart factory it is also an important point to have a highly flexible information system. Therefore one of the central goals is to develop variable and reusable hardware modules. With a wireless field bus such modules can be realized very flexible, plug-and-play capable and easy to reconfigure.

1.2. APPROACH

In order to develop a wireless field bus at first the requirements have to be elicited and analyzed. These can be compared with the properties of the possible communication technologies so one can be chosen. For the selected wireless transmission standard, the architecture for the wireless field bus can now be designed. In order to evaluate the transmission a platform with replaceable modules has to be developed. However, this platform should be able to generate the IR-UWB signal in direct sequencing mode and digitize the received signal without down sampling of the signal. With this platform the wireless field bus can be evaluated and measured in the manufacturing environment.

1.3 RELATED WORK

Willig et al. [2] discuss the problem of meeting the requirements of industrial environments, the usage of existing wireless technologies for field applications and their combination with wired systems. Therefore, the authors compare Bluetooth, WPAN (IEEE 802.15.4) and WLAN (IEEE 802.11a/b/g). They additionally show that a wireless field bus is beneficial for industrial applications. They do not involve UWB in this comparison but see the UWB as a future opportunity.

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Furthermore Willig presents a wireless extension for PROFIBUS [3]. In this approach, he develop a device to couple the wired part of the field bus with a wireless virtual ring extension.

Körber presents a concept of a modular wireless real-time sensor and actuator network for factory automation applications [4], but he doesn't consider crucial requirements of robustness and security and hereby communication dependability in industrial environments. However, he doesn't include the UWB technology in the comparison.

Katja Schwieger [5] analyzes the energy efficiency of different wireless networks with low data rate. Different wireless technologies in the ISM-band are compared. She shows that UWB allows very energy efficient transceivers.

2. Requirements Engineering and Comparison of Possible Wireless Communication Technologies

In order to develop a wireless field bus communication the requirements have to be chosen very careful. In a earlier work the requirements have been elicited and analyzed [6]. The most important requirement detected is the dependability. Reliable data transmission for control and production data acquisition in a plant is a crucial issue. The main advantage of a field bus is the real time capability which relies on the dependability of the transmission. Therefore the wireless transmission has to be very robust against interference, strong attenuation and multipath propagation. Similar important is the requirement of energy efficiency. Consequently a very good energy efficiency can render possible completely autonomous sensor with small batteries or even an energy harvesting module [7].

Table 1. Decision Matrix.

Requirement	WLAN	ZigBee	Bluetooth	UWB	wired
Robustness	+	-	+	++	++
Energy Eff.	-	o	-	++	+
Real-Time	-	o	o	+	++
Flexibility	++	+	+	+	--
Total	o	o	o	++	

With the result of this decision matrix in Table 1 the wireless technologies WLAN, ZigBee, Bluetooth and UWB have been compared. UWB with impulse radio modulation has been selected for the implementation of the wireless field bus. UWB for low data rate transmission is defined in the IEEE 802.15.4a.

3. Concept

In order to develop the wireless field bus with UWB it is convenient to use an evaluation platform with different modules which can be replaced and reconfigured. So the optimum for modulation, coding and power efficiency can be elaborated. Furthermore the configuration of the evaluation platform is to be assigned with the field bus. Without loss of generality in this concept the field bus PROFIBUS (PROcess FIeld BUS) is used. PROFIBUS is a widely-used field bus in the automation technology.

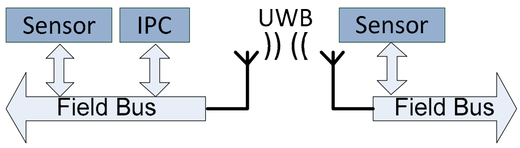

Fig. 1. An Example of a wireless field bus bridge with UWB

The intention of this wireless field bus realization is not the complete replacement of field bus wires, but the supplement of wireless field bus bridge (e.g. for a single movable sensor like it is shown in figure 1).

3.1. Architecture

The architecture of the testing platform provides a transparent wireless field bus bridge. The field bus interface receives the Profibus signal and passes the information with the shifted voltage levels to the FPGA. In the FPGA there are mainly two modules, first the modulator implemented with a DSP (Digital Signal Processor) and second the configuration module. The configuration module is connected to the Profibus as slave and can be addressed over the Profibus.

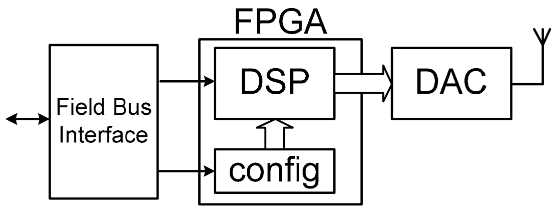

Fig. 2. Architecture of the Transmitter

This means a received bit of the field bus is coded into an impulse radio signal sequence by the DSP. The type of impulse can be selected by the configuration module as well as the destination address and the pre-distortion in order to equalize the distortions caused by the channel as well as the antennas. The DSP generates the digital stream for the DAC (Digital-to-Analog Converter) which converts it to the analog impulse for the UWB-antenna (Fig. 2).

On the receiver side, an LNA amplifies the received signal for the acquisition by the ADC (Analog-to-Digital Converter) avoiding analog components except the LNA and a band pass (BP) filter on the receiver side. The demodulation of the received signal can be conducted using a real-time implementation on an FPGA again (Fig. 3). Intending both the transmitter and the receiver as direct sequencing converter the

DAC and the ADC has to cope with the high UWB frequency up to 10 GHz. According to the Nyquist-Shannon sampling theorem the converters need at least a sampling rate of 20 GS/s.

3.3. DAC

The DAC of Alpert presented in [8] which is suitable for the proposed concept can achieve sampling rates up to 25 GSs^{-1}. With this DAC direct sampling in the first Nyquist band can be achieved for the whole UWB frequency range. In Fig. 4 the ENOB (Effective Number of Bits) are plotted from 0-12 GHz. The output of the DAC can directly feed the UWB antenna given the low power emission in the UWB.

3.4. ADC

The 6 bit ADC developed by Lang [9], with sampling rates of up to 25 GS/s and an ENOB of more than 3 bit for an analog input signal with 10 GHz (Fig. 5), can be used for direct sampling of the received and amplified signal.

4. Conclusion

The main benefit of the presented testing platform is the possibility to test in real time different implementation possibilities due to the fast DAC and ADC with a direct sequencing. The presented solution for the software defined IR-UWB transmission offers the possibility to detect the most efficient transmission. With the easy to use interface in the configurator connected with Profibus the modulation scheme can be adapted on the running system. Subsequently a energy efficient and easy to use single chip solution for the wireless field bus can be designed with the results of this testing platform.

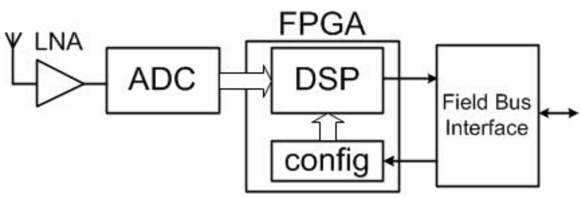

Fig. 3. Architecture of the Receiver.

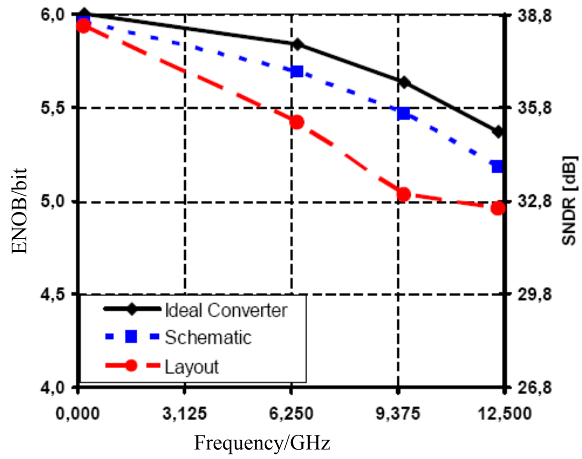

Fig. 4. ENOB of the DAC [9].

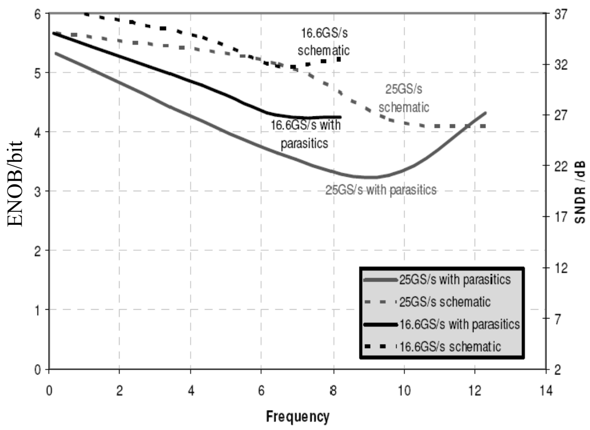

Fig. 5. ENOB of the ADC [10].

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