Study of Detection Capability of Novelda Impulse Transceiver with External RF Circuit

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Abstract—This paper reports a range of experience gained during application of Novelda impulse transceiver module in an ultra-wideband radar system. The paper describes the specific data acquisition procedure performed by the transceiver module. The external radio frequency (RF) circuit is proposed, which provides improved detection capability of the radar system. The antenna system is designed with respect to the application requirements. Some of the transceiver settings influencing the radar system performance are also discussed in details.

Keywords—impulse radar; clutter; antenna system; ultra-wideband system

I. INTRODUCTION

The number of applications of ultra-wideband (UWB) technique for detection and location of objects increases significantly. The first integrated transceivers are already commercially available on the market [1, 2]. This article deals with the attempt to use one of these transceivers to build the system for detection of falls and other dangerous incidents which elderly or disabled people may suffer from in indoor environment.

The NVA-R661 Radar Module evaluation board from Novelda/Xethru was used as a transceiver unit in the presented work. This board is equipped with NVA6201 chip – highly integrated impulse transceiver providing configurable high resolution sensing system with low power consumption and digital interface. The purpose of this work was to determine the optimal configuration of the chip and to develop an RF circuit allowing to obtain the best performance in the prescribed application for operation in 6-8.5 GHz band. The scope of the work includes the development of the antenna system and analog circuits, as well as studies of selected chip settings.

II. DATA ACQUISITION AND STRUCTURE OF THE SYSTEM

The data acquisition in the system is performed by the transceiver module. The principle of operation of the transceiver module involves sending a long series of UWB pulses and “strobed swept threshold” sampling [3] at the receiving end. This sampling method is based on digitization of the incoming waveform by comparing it with the threshold level using a comparator contained at the RF input of the Novelda NVA6201 transceiver chip. The threshold is successively changed with groups of pulses (one or more). By collecting the results the waveform can be reconstructed in the digital circuitry of the transceiver. The range and resolution of such analog to digital conversion is directly related to the range and step of threshold sweep and can be easily customized. The averaging may also be performed in order to enhance the quality of noisy signal.

The waveforms are available on the digital interface of the transceiver module in frames of 256 samples (the quantity specific for NVA6201 transceiver chip). The number of samples may be multiplied by use of frame stitching. The obtained data can be subjected to further processing [4, 5].

The transceiver has implemented special procedures for estimating effective sampling rate and other system parameters. Running the procedures enables obtaining accurate data. They should be repeated if operating conditions (e.g. chip temperature) are changed.

The block diagram of the investigated system comprising the impulse transceiver module is presented in Fig. 1. The transceiver module is connected to an antenna system through an RF circuit. Particular blocks and their impact on the system performance are described in the following sections.
III. THE ANTENNA SYSTEM

The antenna system before being covered with its casing is presented in Fig. 2. It is placed in front of a metal box enclosing the remaining part of the system. Consequently the box operates simultaneously as the system housing and as the antenna ground plane. Such an arrangement allows radiation pattern to be formed to maximize front radiation and minimize unwanted backward radiation. The radar system box is designed to be mounted on a wall.

The transmitting and receiving chains of the radar system are separated (Fig. 1). By this fact it is allowed to take advantage of different concepts of antenna sets for both of them, particularly to optimize antenna system design with regard to requirements of indoor ultra-wideband emission.

There are three bow-tie radiators constituting the antenna system (Fig. 1 and 2). One of them operates as transmitting antenna, and the remaining two as receiving antenna array.

The transmitting antenna gain should not be excessive due to the limitation of EIRP (Equivalent Isotropically Radiated Power) in an UWB system. Hence, the single radiator is used. The gain of the designed antenna does not exceed 7.5 dBi (Fig. 3).

The transmitting and receiving antenna arrangement is chosen so as to minimize mutual coupling between the antennas and simultaneously so as not to disturb the radiation patterns in the situation where the metal box provides limited space. The coupling between receiving and transmitting radiators is less than –23 dB.

IV. ANALOG RF CIRCUIT

The analog RF circuit is a part of the radar system (Fig. 1) and it consists of the receiving circuit and the transmitting circuit.

A. Receiving Circuit

The receiving circuit includes combiner, high pass filter and low noise amplifier (LNA). The combiner combines signal in phase from both radiators of the RX antenna array. Wilkinson power divider is used in this role, which has bandwidth wide enough for this purpose even in its one-section variant.

The high pass filter (6.01 GHz) is used in order to decrease susceptibility of the system to interference from other wireless systems operating in lower frequency bands. The NVA6201 chip occurred to be susceptible to such interference – Fig. 4 presents exemplary effect caused by external interfering signal at the frequency of 2.45 GHz and duration 2.5 ms. The disturbance of one frame is apparent, although the frequency of the interferer is outside the radar system frequency band. The disturbance is applied to a single frame only. This is caused by pauses between subsequent frame acquisition processes during which data are processed and transferred by the digital I/O interface. In this particular configuration the pauses last more than duration of the interfering signal, and thus the distortion affects single frame only. The filter effectively addresses the issue of out-of-band interferences.

The LNA is used to increase the signal amplitude. Without this the reflections from a person at a distance further than 2-3 meters might be lower than the receiver noise. Fig. 5 presents the measured transmission coefficients of the circuit comprising divider, filter and amplifier from both paths of the combiner.

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B. Transmitting Circuit

The transmitting circuit is much simpler as there is only one TX antenna to be connected to and the transmitted signal level is already adjusted to UWB requirements and does not need amplification. So the antenna could be directly connected to the transmitting port of the chip. However, there is a crucial aspect of this circuit. The miniaturized antenna for wideband application has moderate reflection loss (approx. 8 dB in the system frequency band) and at the same time the reflection loss of the transmitting output of the NVA6201 chip is very poor (approx. 5 dB). As a result, there is considerably high level of reflections reverberating in this circuit. Due to length of antenna connection and the principle of the system operation, these reflections result in echoes occurring in output sample stream in the time domain. Such echoes might significantly decrease the performance of detection algorithms. For this reason, the modification of this circuit is undertaken consisting in adding an attenuator to this circuit. Although such an attenuator (3 dB attenuator was used) decreases the signal amplitude and in consequence the signal to noise ratio, the unwanted reflections are reduced at least thrice by this attenuator (9 dB in case of 3 dB attenuator), which is preferred.

V. Configuration of the Chip

The NVA6201 chip from Novelda/Xethru has huge amount of configuration parameters. One of them called ‘PGSelect’ is a mode selector of the pulse generator. This parameter affects the pulse shape and in consequence the pulse spectrum too. Fig. 6 shows the set of spectra obtained with all twelve available PGSelect values (from 0 to 11). It can be observed that the center frequency increases with the parameter. Finally, PGSelect = 6 was chosen for the designed system, because this pulse spectrum is best suited to the 6-8.5 GHz frequency range.

Nevertheless, it should be noted that there is a non-negligible variation of the spectra obtained from different transceiver chips. Fig. 7 presents spectra obtained with six transceiver modules operating with the same configuration (particularly PGSelect was set to 6).

Another parameter called ‘MClkDiv’ determines the frequency division of the clock that triggers the pulse generator. Four settings are possible (0, 1, 2 and 3), which correspond to division by 1, 2, 4 and 8, respectively. In the default setting (division by 1) the pulse repetition is equal to approx. 100 MHz. This results in imposition of the previously generated pulses to the current record of data in the positions resulting from the pulse spacing. The NVA6201 chip has special algorithm implemented to remove such shifted pulses by randomization the time of pulse generation. Nevertheless, some uncancelled signal still remains, which is called clutter. Fig. 8 presents the clutter resulting from the crosstalk between antennas of the designed system measured in an anechoic chamber. In such a scenario, without external reflections, the clutter repeating every 1.5 m is clearly recognizable. This is undesirable phenomenon, because the clutter may mask a weak useful signal.
Participation of the clutter in the signal might be limited by speeding down the generator clock. Fig. 9 presents the measurement result taken in the same scenario with MClkDiv set to 2. Only every fourth clutter remained. The first one is visible at a distance of 6 meters now, which may ensure clear signal for many indoor scenarios. In case of higher distances setting the MClkDiv to 3 moves the clutter effect to be observable at a maximum available distance of approximately 12 meters.

This method of reducing the clutter comes at a price of slower data acquisition. However, the acquisition time has dominant contribution to system rate only when averaging over a large number of iterations is performed. For other cases the signal processing and transferring remain most time consuming process and slowing the system down is not noticeable.

There is another important effect related to the MClkDiv parameter. Reducing the pulse repetition frequency has impact on maximum mean EIRP density. The EIRP level is reduced by 3 dB per each next incrementation of MClkDiv setting (Fig. 10). This might facilitate satisfying the requirements of UWB standards.

VI. CONCLUSION

Modern integrated transceivers provide extensive set of features and advanced signal processing in a single miniature chip. However, the complexity of such systems increases with the degree of integration. Proper use of available features requires studies going far beyond the specification of data sheet. This paper deals with several aspects of application of Novelda impulse transceiver to an ultra-wideband radar system. The external RF circuit and antenna system designed to cooperate with the transceiver are presented and their properties influencing the system performance are discussed. Brief selection of the configuration options of the transceiver is presented and analyzed on the basis of a number of measurement experiments.

REFERENCES