M-SEQUENCE UWB RADAR ARCHITECTURE FOR THROUGHWALL DETECTION AND LOCALISATION

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ABSTRACT

This paper summarizes the advantages of using M-sequence as a stimulus for UWB radar and describes its architecture. In next the appropriate applications for this type of radar system are shown.

1 INTRODUCTION

Ultra WideBand (UWB) radar [1] is of great interest for a vast number of applications such as surface penetrating radar, surveillance and emergency radar, medical instrumentation, non-destructive testing in civil engineering and the food industry, industrial sensors and microwave imaging and many others. The fractional bandwidth of the sounding waves for such types of applications should be as close as possible to 200 % resulting in a high spatial resolution and good penetration in materials [2].

The extreme bandwidth is not only one requirement posed on the electronics of UWB system. The key to a powerful UWB radar is the use of an appropriate stimulation signal because the whole device hardware and signal processing depends upon it [3], [4].

In this paper an UWB radar, which uses as a stimulus a Maximum-Length-Binary-Sequence (in short M-sequence), is presented. The reasons for using such signal are summarized in Section 2. In Section 3 architecture of M-sequence UWB radar is described. Finally, general applications of this radar are mentioned in Section 4 and conclusions in Section 5.

2 BENEFITS OF USING M-SEQUENCE AS A STIMULATION SIGNAL

An M-sequence is a special kind of pseudo-random binary sequences. It is periodic and as such it is not really random, but it has properties which are very close to those of real random signals - for example a short pulse-like autocorrelation function [5], [6].

From Figure 1 the correlation function of two M-sequence can be seen. The ideal M-sequence with $2^N - 1 = 511$ chips is shown in upper side of figure, where N is number of shift register needed for generating M-sequence [5], [6]. In the middle part of figure the delayed and noised M-sequenced is depicted. Delay equals to 346 chips and Signal to Noise Ratio (SNR) is only 6dB. From correlation in the lower side of figure can be seen that the delay of so noisy signal can be easy find because of the high correlation gain of M-sequence that is equal to $2^N - 1$.

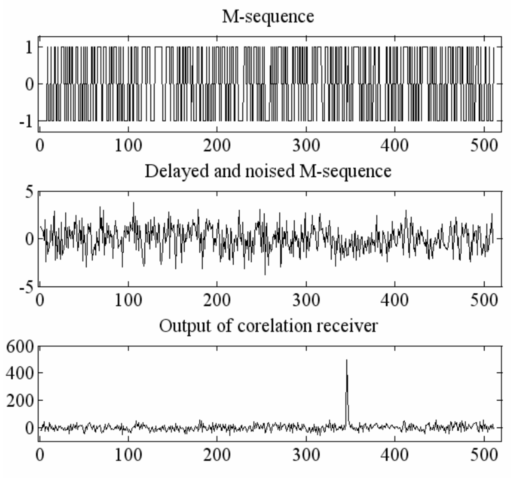

Figure 1: Illustration of correlation gain

Besides of the correlation gain, M-sequences have following advantages in UWB radar applications:

- They can be easily generated up to tenths of GHz of bandwidth by a digital shift register which is clocked by stable oscillator.
- The method permits monolithic integration of the RF-electronics in SiGe-technology.
- Since they are periodic it is possible to apply cost effective sub-sampling methods for signal recording and to avoid a spectral bias error.
- They have a low crest factor. Low crest factor signals distribute their energy uniformly over the time. This maximizes signal energy even at low peak voltages and also maximizes the SNR.
- They are characterized by small binary voltage amplitudes that allow extremely fast digital switching in integrated circuit technology. It allows to meet the demanding requirements on bandwidth and low jitter.
- They allow the real-time operations because of their high measurement speed.

This all supports effective application of M-sequence in practical UWB radar systems [4], [7].

3 ARCHITECTURE OF THE M-SEQUENCE UWB RADAR

One channel of the M-sequence UWB radar is presented in Figure 2. Controlled by a clock, a digital shift register generates the M-sequence. Since it is periodic and the measurement scenario can be assumed to be locally stationary, it is possible to acquire the M-sequence by the undersampling [2]. Here, the binary divider determines the undersampling factor and provides the receiver sampling clock. The measurement data are undersampled by a Track-and-Hold circuit (T&H), transformed into the digital domain (ADC), optionally synchronously averaged and finally stored for off-line processing or on-line processing. The impulse response results from an impulse compression which is typically performed by the Fast Hadamard-Transform (FHT). The FHT-algorithm is very close to the FFT-algorithm except that it is based on a pure summing of data samples which promises very fast operation for special hardware implementation.

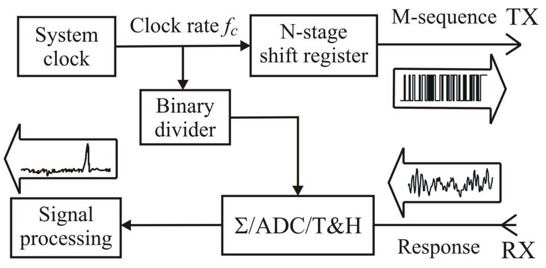

Figure 2: M-sequence UWB radar block diagram

As seen from Figure 2, the circuits for signal generation and signal capturing have a very simple structure. Since it is built from cost effective large-scale integrated components or customer integrated circuits as such the number of components is not an important cost factor for the overall system. This allows to build a true multi-channel system [4], [7].

4 APPLICATIONS OF M-SEQUENCE UWB RADAR

The general applications of M-sequence UWB radar systems are detection (object is or is not present), localization (determination of position) and tracking (determination trajectory of movement) object behind the obstacles like walls, avalanche, soil, waste etc. and imaging (display the shapes) the interior of rooms [1].

For detection and localization the triangulation and trilateration [8] techniques are used and for imaging the back-projection, back-propagation or full inverse problem methods are used [9].

5 CONCLUSIONS

Described M-sequence UWB radar is one of the basic hardware tools used within the scope of the project RADIOTECT - Ultra Wideband Radio application for localisation of hidden people and detection of unauthorised objects (project co-funded by the EU within the Sixth Framework Programme), which has been starting in January 2007. Our main tasks within this project are advanced signal processing algorithms development. These basic scenarios are considered: sensor network for the permanent monitoring of areas for people and their movement, detection and localisation of living people hidden from view during rescue or civil security operations, detection and localisation of unauthorised objects hidden under clothes and imaging of the interiors of a rooms or buildings from outside.

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