UWB Radar Signal Processing for Through Wall Tracking of Multiple Moving Targets

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***Abstract*— Through wall tracking can be very helpful in the situations where the entering of a room or a building is considered hazardous and it is desired to inspect its interior from outside through the walls. In majority of such cases, the tracking of multiple moving targets is needed. The radar signal processing for this application has to deal with several supplementary tasks in comparison with a single target tracking. Their solution is included in the complex signal processing procedure introduced in this paper. The experimental results obtained by the real radar signal processing confirm good performance properties of the proposed procedure.**

I. Introduction

It is well-known, that the bandwidth of ultrawideband (UWB) radars, e.g. up to several GHz, results in their high spatial resolution, typically a few cm. This unique feature together with facts that UWB radar devices may be built small and light weight whereby they employ low-power harmless electromagnetic waves which in the lower GHz range penetrate through most common building materials, is the reason, why UWB radars can be advantageously used for through wall tracking of moving targets [1]. Such tracking systems can be then applied in rescue, security or surveillance operations.

UWB radars for through wall detection and tracking can utilize various stimulus signals. In the literature, impulse [2], [3], [4], stepped frequency [5], or noise [6] waveforms have been reported. An alternate development represents a through wall radar employing a continuous-wave Doppler signals [7]. A common feature of the radars described in [2]-[7] is that they process raw radar data in such a way as to produce a radar image of the scanned area, where moving targets are seen as radar blobs (so-called radar imaging methods). There, the experimental results for multitarget tracking have been demonstrated in [3], [4] and [7]. From a signal processing view, the aproach of [3] is the most simple (subtracting of the received signals from the empty room response followed by a back projection algorithm). The others approaches employ more advanced signal processing methods, such as collecting of integrated samples over multiple segments for each antenna pair, assembling of waveform set as functions of time and time history, motion filtering, range filtering, image generation and image envelope detection in [4] or combining of Doppler processing and spatial beamforming with the CLEAN and RELAX algorithm implementation in [7].

The intention of this paper is to introduce a signal processing procedure for multiple moving targets tracked by UWB pseudo-noise radar [8]. As the result of this processing, the positions of tracked targets moving behind obstacle are not seen as radar blobs localized in the scanned area, but the target coordinates are analytically computed by the localization and tracking methods. For that purpose, the complex radar signal processing procedure for a single target scenario has been proposed in [9]. In this paper, the procedure will be extended for multiple target scenarios. Based on preliminary experimantal results achieved by processing of the real UWB signals, the practical analysis of the scenario with two moving targets will be performed.

II. Signal Processing Procedure

The radar signal processing described in this section was designed for signals provided by the UWB pseudo-noise radar system using maximum-length-binary-sequence (M-sequence) as the stimulus signal [10]. The experimental radar system of that kind equipped with one transmitting (Tx) and two receiving horn antennas (Rx_1, Rx_2) is shown later in Fig. 1(a). The system clock frequency of the radar device is about 4.5 GHz, which results in the operational bandwidth of about $DC - 2.25$ GHz. The M-sequence order emitted by radar is 9, i.e. the impulse response covers 511 samples regularly spread over 114 ns. This corresponds to an observation window of 114 ns leading to an unambiguous range of about 16 m.

The proposed signal processing procedure for through wall tracking of multiple moving targets consists of seven phases, namely background subtraction, weak signal enhancement, detection, time of arrival estimation, wall effect compensation, localization and target tracking. In the next paragraphs, a significance of the particular phases together with the specific methods providing stable, good and robust performance for the considered application are outlined.

A. Background Subtraction

Raw radar signals can be interpreted as a set of impulse responses of surrounding through which the signals emitted by the radar were propagated. The first task of radar signal processing is to improve a signal to noise ratio. It is done by the background subtraction which rejects especially the stationary and correlated clutter such as antenna coupling, impedance mismatch response and ambient static clutter, and allows the response of moving targets to be detected. The exponential averaging was chosen from variety of background