Detection of trapped people by UWB radar

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***Abstract*—In this paper M-sequence ultra-wideband radar as a tool for the detection of people buried beneath rubble is described. Any strong enough motion of the victims modulates the signals detected by the radar. However, breathing is considered as the most beneficent type of motion, since it is present even when person is unconscious. Besides, the periodical nature of breathing makes it possible to distinguish it from noise and clutter components. After the enhancement of a useful target signature, radar signals contain the information which could possibly be used to increase the efficiency of rescue operations.**

***Index Terms*—M-sequence, UWB radar, jitter, person detection, motion detection**

I. MOTIVATION

MOST state of the art techniques for the detection of living people buried beneath collapsed building debris make use of seismic/acoustic equipment, optical devices or search dogs. At the one hand, except for the dog, these methods fail to deliver reliable detection, especially when the trapped person fell unconscious and is unable to respond. At the other hand, the dog indicates also dead persons which occupy valuable time of the rescue team for the search of further victims. Besides, information about the location of buried person would be of great value for the rescue personnel, since it would help to reduce the time of operation and thus, help to save more lives.

Microwave techniques represent a promising technology for this application, since electromagnetic waves within the lower GHz-range can penetrate most of building materials [1]. Besides, UWB radar was shown to be capable of detecting breathing and even heartbeat signals [2], [3] through wall along with the larger motion.

Development of a radar device and software suited for the task is one of the goals of the EU-project RADIOTECT, along with through-wall and through-dress imaging systems for security and rescue applications.

II. M-SEQUENCE UWB RADAR

Due to the pulse-like form of the auto-correlation function of an M-sequence, it is possible to use it as a stimulus in the UWB radar [4]. The range profile is generated by calculating the cross-correlation function of the transmitted and received signals.

The basic diagram of the 2-channel M-sequence radar is shown in figure 1. The shift register is used to generate the stimulus waveform and the binary divider controls data acquisition. The system is pushed by a single-tone RF generator with good phase noise and drift characteristics.

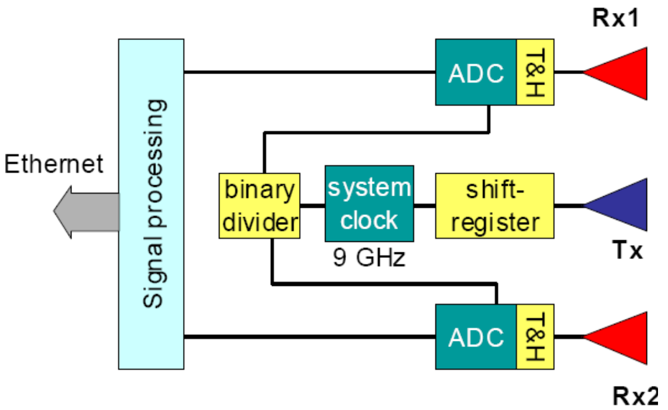

Fig. 1. Block-scheme of the 2-channel M-sequence radar.

The data capturing rate is about 20 Msps leading to more than 30.000 impulse responses per second. Since the maximum displacement speed of the targets of interest is relatively small, the data throughput should be drastically reduced in order to save processing power. Therefore, a basic signal processing is completed within FPGA. Typically, 256 hardware averages are always computed, which is sufficient to provide high data throughput and improve the SNR-value by 24 dB. Additional software averaging can be completed by DSP, if required.

The system guaranties excellent jitter performance, which is especially important for the detection of very slow and weak

Fig. 2. Person in the test position.

Fig. 3. Antennas in the test position.

movements (e.g. breathing) with an order of magnitude smaller then the range resolution of the radar system. In contrast to M-Sequence radar, conventional impulse radar systems suffer from stronger jitter since their timing control is less stable. Both the shift register generator and the binary divider shown in figure 1 deal with extremely sharp pulses (rise time about 30 ps) which finally leads to the low random jitter.

III. EXPERIMENTS AND DATA PROCESSING

A series of radar measurements on breathing detection in a test field for fire-fighters was carried out. The test field itself is a heap of heterogeneous rubble (mostly blocks of reinforced concrete and moist soil). There are tunnels beneath it, large enough to crawl in (see figure 2). For test purposes, the height from the antennas to the ceiling of the tunnel can be varied from 30 cm to about 120 cm depending on the position of the antennas. The tests were made after a long period of rain, which hinder a good wave penetration into the soil due to water absorption.

The measurement equipment included the M-sequence radar device with an internal clock-rate of approximately 9

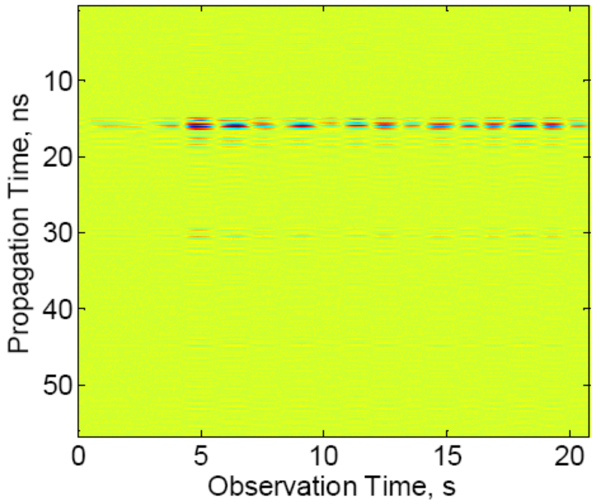

Fig. 4. Radargram after background removal of a sitting person behind a brick wall. Obviously, only the motion of the chest due to breathing remains in the data.

GHz (i.e. the upper limit of the operational frequency band is about 4.5 GHz) and an array of loaded bow-tie antennas covered with several pieces of absorbing materials (see figure 3) in order to prevent contamination of radar data with clutter signals coming from varying surrounding (e.g. fluttering trees). The system was operated by means of a laptop which was placed several meters away from the antennas to avoid interference of the operator's motion with radar data.

For initial system test and gathering of reference data of low perturbation, a simple laboratory test was made. In the

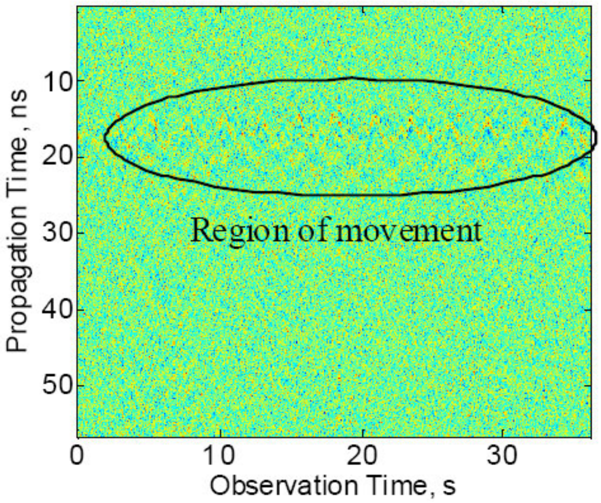

Fig. 5. Radargram (after removing the background) of a person beneath rubble moving strongly its chest and shoulders.

figure 4 a response from a person breathing behind an 18-cm thick brick wall is depicted.

After removing static scattering caused from rubble, tree trunks etc. by an appropriate method, it can be observed that a periodic cluster of pixels in the radargram appears. It is inherent to this type of motion and can be used to detect trapped breathing people. Under more harsh and realistic conditions for buried victims when the signature of breathing

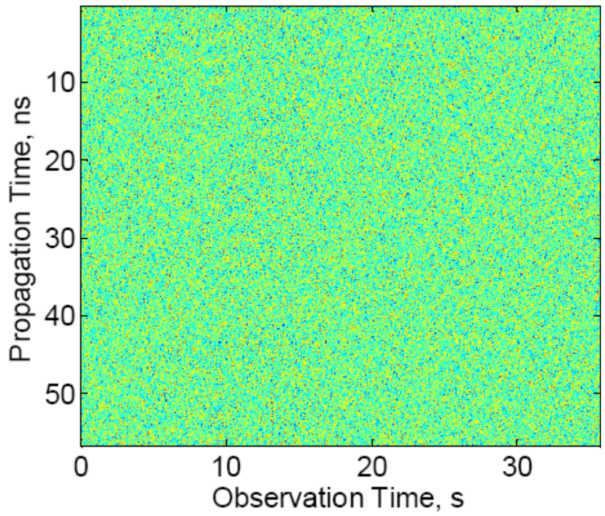

Fig. 6. Radargram of a breathing person beneath the rubble. Noise completely covers the breathing pattern as expected.

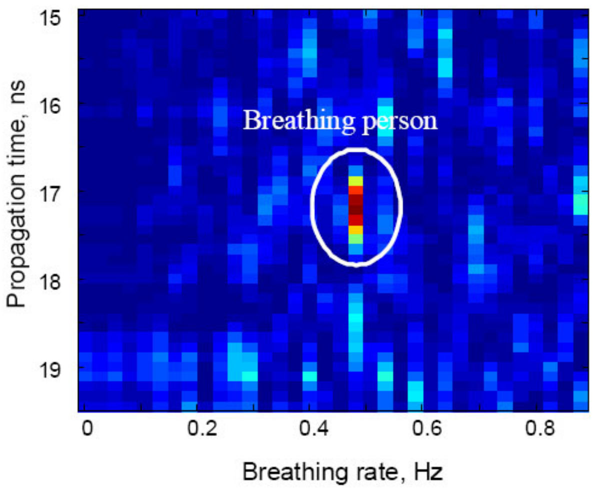

Fig. 7. Detection of a breathing person after enhancing the periodic structure of the clustered data within the radargram

is weak compared to noise this quality of the useful signal persists, and it can be used to enhance the detection as it will be demonstrated in what follows.

Under quite realistic conditions, two types of experiments were carried out for several positions of the person under test beneath the rubble. The first type refers to a strong periodical motion of the chest and shoulders of a person lying beneath the antennas. This data served as an indicator of how challenging the measurement position (i.e. depth of coverage) is for the detection of breathing, given the fact that the structure of the rubble at a certain position is unknown in most cases. Figure 5 shows the measurement signals after removing the static reflexions. Beside the noise, there is only a pale (due to high signal attenuation) pattern at about 10 … 20 ns propagation time visible. It is caused by the strongly moving person.

In the second type of experiments, the test person was breathing only. The body was not moved in order to simulate an unconscious victim.

Since the motion of the body is now quite low, the signal should be very weak. In figure 6, the response from the breathing person is shown. The same procedure as in figure 4 and 5 was applied to remove the background due to static scatterer. Obviously, nothing could be detected.

By respecting the periodicity of breathing and the fact that the back scattered signal of the breast extends over several time samples, an appropriate processing can reduce the noise influence leading to the detection of a buried people as depicted in figure 7. Since the waveform which produces breathing signature in propagation time is dependent on the position of body and on numerous additional factors, such as the material of rubble and its thickness, we cannot use the optimal correlation detector. Thus, to increase the target signature in propagation time we consider in pairs the cross-correlation functions of signals in several neighbouring propagation time instants. This approach takes into account that periodical breathing signals coming from neighbouring points are in phase and this leads to the additional increase of signal to noise ratio.

Since in observation time direction the breathing results in a periodic signal, FFT is applied to extract the breathing rate. The red spot in Figure 7 indicates a person breathing every 2 seconds laying at a depth of about 1m beneath rubble of wet concrete and soil..

The person can also be located via tri-lateration if both receive antennas are used. The method also allows distinguishing several persons or animals by their position and breathing rate.

IV. Summary

The detection of trapped persons below rubble by means of an M-sequence UWB-radar was demonstrated. In the case of wet rubble, the wave penetration is quite reduced thus the sensing signals are largely attenuated and covered by noise. Nevertheless, a detection of buried people is possible by enhancing specific signal features by an adequate filtering. Further points to reach a high detection sensibility is a wideband stimulus signal in which the spectral components below 1 GHz are of major interest and antennas which are largely shielded against mutual coupling and scattering from objects which are located outside the main beam of the antenna.

V. Acknowledgement

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