Detection of alive people with the Radiodozor-M device

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Abstract. The article discusses the approach to the restoration of radio images of objects behind dielectric barriers. The approach is based on the method of mathematical focusing of reflected ultra-wideband signals. The sounding system is a radar with a synthesized aperture. Here we present a method for improving the quality of radio images based on additional processing of received signals. The article also presents the results of numerical simulation and experiment.

1. Introduction
Dozens of catastrophes happen every year (traffic accidents, industrial disasters (accidents at nuclear power plants, oil pipelines)) and natural disasters (earthquakes, landslides, avalanches, fires, etc.). All had victims, the number of which is thousands and hundreds of thousands of people. In addition, mining mine collapses and avalanches happens almost every week, as well as more and more often happens terrorist attacks. Regardless of the scale of the incident, there is always the problem of saving lives. Searching and rescuing people in disasters, accidents, or emergencies is a very difficult task. Obviously, the task for creating locating devices for alive humans under collapse is relevant.

Most preferred are radio wave tomography techniques. The solution of object detection requires a development of special software and hardware with active location tomography. We believe that the use of clocked antenna arrays is promising, as was shown in the articles [1, 2, 4].

The developed device “Radiodozor-M” detects moving and motionless humans in real time behind reinforced concrete, brick walls, multi-layered structures and other building structures in smoke conditions, under the rubble. The device gives tactical advantages in rescue operations: accurate determination of location and distance, both to moving and stationary objects. The two-dimensional image shown on the screen allows you to quickly perceive in the situation and make decisions about further actions. Measuring the breathe rate of immobile people allow you to take emergency actions for saving people with low signs of life (weak breathing).

2. Signal processing
Algorithm for recovering a radio tomographic image based on focusing UWB signals reflected from objects. The main idea of data processing is the synthesis of aperture and focusing. We sums all received signals from different points of a scanning space for each given point of the image in phase.

This device implements the differential-difference method for detecting moving people, based on filtering signals from stationary objects. The essence of the method is calculating a difference of signal in the adjacent periods.

\[ dS(t, T_j) = S(t, T_j) - S(t, T_{j-1}) , \]

where \( dS(t, T_j) \) – filtered signal, \( S(t, T_j) \)-registered signal, \( S(t, T_{j-1}) \) - a signal, which one was received in the previous period of time. The signals, reflected from motionless, background objects of
the scene, will be the same for different periods and self-compensate after subtracting. The difference of signals $dS$ received from a moving object will non-zero. Next, the resulting set of perspectives will use for building a radio image of moving objects.

In cases where a person is stationary, you can determine his presence behind an obstacle by observing the movement of his chest and stomach. Look to Figure 1. The signal reflected from the chest in a breathe out position $S_2$, is different from the signal, which one reflected from a breathe in position $S_1$ by a time delay $T = 2\Delta{x}/c$, where $\Delta{x}$ - chest movement during change breathe in/out position.

![Figure 1. Registration of fluctuations, which are characteristic for human breathing.](image)

The device provides the transformation of data, which are obtained in UWB probing, to detect characteristic fluctuations for human breathing.

The complex amplitudes of the spectra of neighboring signals will differ from each other only by the multiplier $\exp\left(i\omega T\right)$:

$$SS_2(\omega) = SS_1(\omega) \exp\left(i\omega T\right)$$

The selected phase from the resulting expression will contain information about fluctuations of the chest.

3. Device description

Figure 2 shows developed the radio-tomograph UWB “RadioDozor-M”. The device includes an UWB clocked antenna array [3], a minicomputer-based hardware module for interfacing an antenna array with a RF emission module, and registration of signals. The RF module has a wide dynamic range and provides a range for detection of moving objects up to 20 meters. The developed software for the radiotomograph computes a radio image of moving and motionless people with a frequency about 5-10 frames per second. For motionless humans, in addition to their location, is possible to determine the frequency of their breathing. The device provides for the computing of the radio image of the scene with frequency 10 frames per second.
4. Results
Figure 3 shows results of sounding for two motionless humans. 30 seconds data collection is enough to accumulate an information for calculation locations and breathe rates of each person.

5. Summary
Developed methods of registration and tomographic processing of radio wave measurements of objects, which hidden behind dielectric barriers by using large-aperture synthesis focusing. The performance of the proposed approach verified by experimental data processing, that were obtained with using ultra-wideband radiation. The experiment involved two volunteers. In this article, we presented a developed method of filtering signals reflected from fixed objects to select moving objects behind dielectric barriers.
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