Detection of Human Breathing and Heartbeat by Remote Radar

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Abstract

The radar capable to detect and perform diagnostics of a state of the human being behind obstacles and in conditions of bad visibility could be used for the manifold applications. The potential consumers of the radar are: rescue services, antiterrorist detachments and law-enforcement bodies. It is possible also to use this device in medicine. In this paper, the experiments with using of continuous-wave subsurface radar are described. The recorded oscillograms and their frequency spectrums for heartbeat, respiration and articulation of a man, which is taking place behind an obstacle (wall), are presented.

Introduction

For long time, radars intended for sounding of opaque mediums were developed for detection of motionless objects, as a rule, in the ground. It is accepted in the scientific literature to name such radars by surface-penetrating radar [1]. The main fields of the surface-penetrating radars applications are much wider now:

- Ground sounding for inspection of subsurface communications (pipes, cables etc.) [1]
- Detection of mines and unexploded ordnances (UXO) [2, 3]
- Sounding of building designs for detection of built-in details, defects and latent objects (for example, overhearing devices) [4]
- Detection of the material evidence in criminalistics [5].

Traditional surface-penetrating radars are usual region of engineering, and the time-domain impulse subsurface radars are being produced in lots by many countries (the USA, Canada, Russia and so on).

There is now keen interest to use of methods and equipment of surface-penetrating radars for detection and diagnostics of the live persons, which are taking place under rubble or behind walls of buildings. This task could be solved by radars that operate in the wavelength range of 3 - 30 cm (frequencies correspond to 1 - 10 GHz). In this case, by subtraction of signals reflected from motionless objects it is possible to achieve high sensitivity at detection of objects, borders of which are subjected to mechanical fluctuations. According to estimation available in the literature, the sensitivity of the method could achieve 10^{-9} м [6]. Let's name the method as vibro-electromagnetic sounding. Though the objects subjected to mechanical fluctuations could have a various nature, in the present research we are limited only to detection and diagnostics of a live person.

Objects in man's body that are subjected more or less periodic fluctuations are cardiac muscle and lungs. Their reductions have frequencies in range of 0.8 – 2.5 Hz for heart and 0.2 – 0.5 Hz for lungs. Physical activity and medical state of the examinee determines the values of these frequencies. The remote or contactless measurement of breathing and pulse rates of the man behind an obstacle or in open space at some distance is the basic task of this experimental research.

The task may be solved under condition of creation of enough sensitive radar and development of selection algorithms of background reflections that can mask a valid signal. Last circumstance is a major factor constraining application of vibro-electromagnetic sounding for practical using. Background signals could be connected with reflections from the operator carrying out researches or other people, which are taking place in a zone of measurements. Besides that, working machines and mechanisms, vibrations of foliage and branches of trees, animal and other mobile objects can create interferences and noises also. This requires creation of the antenna with the minimal side and back lobe of the directional pattern or development of methods of their removal.

The main applications of vibro-electromagnetic sounding could be:

- Detection of live human persons under rubles of buildings that have been suffered from natural disasters, technical calamities or accidents. The urgency of task is defined by necessity for rescuers to begin dismantling of rubles and debris in the places, where is a hope to find out the alive people [11]
- Detection of the people and parameters of their moving inside of buildings during antiterrorist operations [8]
- Remote diagnostics of psychological condition of the persons during the latent or open checks, for example, at the airports (remote lie detector)
- Contactless measurement of parameters of heartbeat and breath for the patients, when the contact sensor for some reasons cannot be used [9, 10].

The further researches should show: could this method be also used for the recognition of speech and articulation behind obstacles without using of acoustics devices.

The Description of Experiments

During experiments, we applied the method of subsurface sounding by continuous-wave signals. This method was developed at creation RASCAN radar [4]. Accordingly, modified RASCAN radar with the following parameters was used:

Operating frequency	1.6 GHz (λ=19cm)
Gain factor	40 dB
Frequency range of recorded signals	0.03 – 3.0 Hz
Dynamic range	60 dB
Sampling frequency	20 Hz
Antenna's dimensions:	
diameter	120 mm
height	200 mm

The sketch of the experiment is shown below in Fig. 1. The thickness of a wall, behind which there was an examinee, equals 10 cm. The examinee was settled down at distance about 1 m from the wall. The radar's antenna was fastened directly on surface of wall. To decrease interference from a back hemisphere the radar's antenna and the part of the wall was veiled by antiradar covering with dimensions of 2×2 m. The radar's signals after amplitude detection through a interface block were recorded in computer memory.

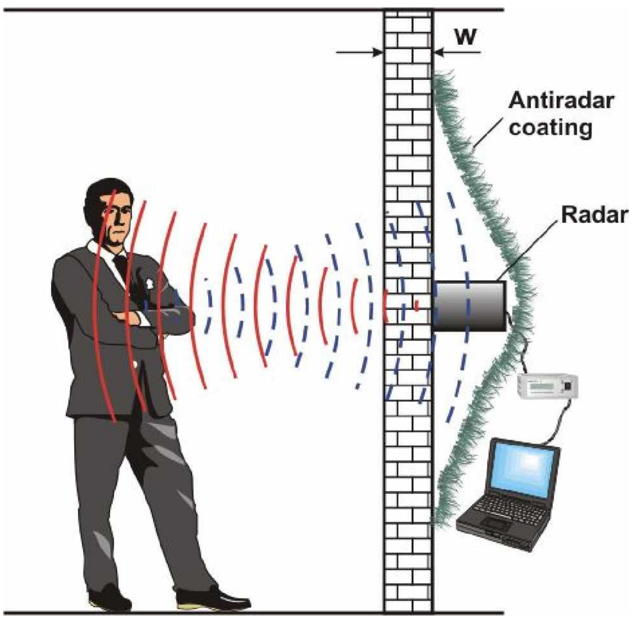

Figure 1. The sketch of the experiment

Experimental results

The work is at initial stage, and experimental results are presented below practically without processing and filtering.

In Fig. 2 and 4, pulse records of the examinee, which detained breathing, are presented. In Fig. 2, delay of breath is equal to approximately 30 s. And for signal in Fig. 4, the delay is about one minute. One can see that at increase of breath delay time the amplitude and rate of examinee pulse are also increased because of oxygen starvation. The frequency spectrums for signals in Fig. 2 and 4 are shown in Fig. 3 and 5 respectively.

The results of simultaneous recording of pulse and breath rate of the examinee are presented in Fig. 6. As amplitude of oscillations and volume of lungs considerably surpass similar parameters of heart, the reductions of cardiac muscle are observed as high-frequency modulation on the background of lungs oscillations.

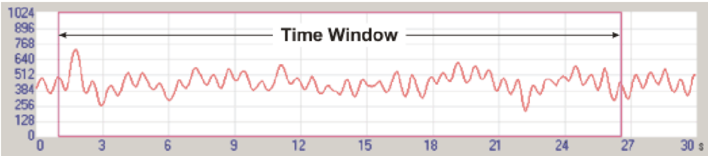

Figure 2. Pulse record of the examinee.
Breath delay is equal to approximately 30 s

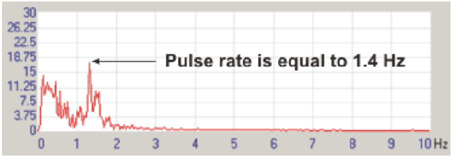

Figure 3. Frequency spectrum of
the signal presented in Fig. 2

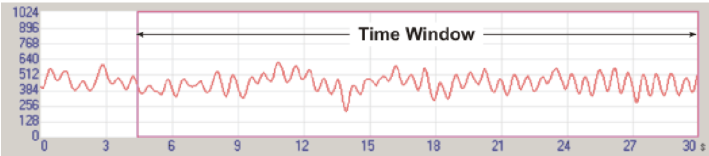

Figure 4. Pulse record of the examinee.
Breath delay is equal to about one minute

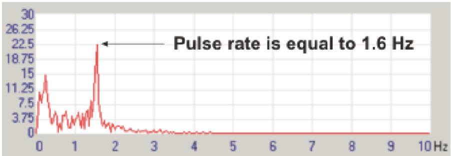

Figure 5. Frequency spectrum of
the signal presented in Fig. 4

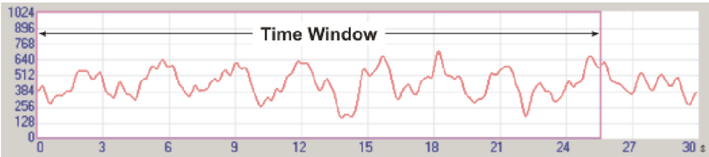

Figure 6. Breath and pulse record of
the examinee without breath delay

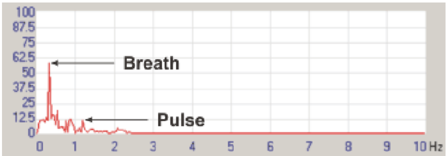

Figure 7. Frequency spectrum of
the signal presented in Fig. 6

Recording of speech of the examinee pronouncing consistently words: one, two, three... one, two, three...(in Russian) is presented in Fig. 8. In this experiment, three processes were combined: heartbeat, breathing and speech of the man. However taking into account that the transmission band of input filter is limited only 3 Hz, we have no ground for the time being to assert that the data of similar measurements could be used for recognition of man's speech yet.

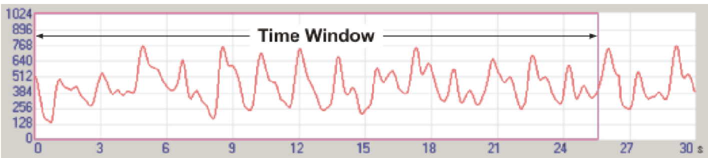

Figure 8. Breath and pulse record of the examinee pronouncing consistently words: one, two, three...(in Russian).

Figure 9. Frequency spectrum of
the signal presented in Fig. 8.

The results obtained in the experiments in many respects are similar to the signals registered by time-domain impulse radars in free space [9, 10]. However use of monochromatic wave radar simplifies the experimental installation and subsequent data processing.

Conclusion

The experiments on radar sounding of pulse beating and breathing of the man through a barrier (wall separating two adjacent rooms) allow to consider technically feasible the task of remote diagnostics of the man parameters with the help of the continuous-wave subsurface radar of RASCAN type. During the further works it is necessary to improve data processing and the equipment with the purpose of definition of distance up to object under investigation.

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