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BIORADIOLOCATION
AND
ITS APPLICATIONS

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1. Introduction

Method of bioradiolocation

Bioradiolocation is a method for detection and diagnostic monitoring of humans, even behind obstacles, by means of radar. It is based on the reflected signal modulation in time with move of the body surface and internals [1]. Objects in the human's body, subjected to more or less periodic fluctuations are cardiac muscle and lungs. Patient's physical activity and medical state determines values of these frequencies [2].

The modulation is caused by:

- cardiac beat (frequency band between 0.7 and 2.5 Hz, the chest movement amplitude is 2-3 mm);
- movements of the thorax during breathing (frequency band between 0.2 and 0.5 Hz, the chest movement amplitude, depending on the type of breathing, ranges between 0.5 and 1.5 cm);
- articulation or movement of the vocal apparatus (lips, tongue, larynx);
- movements of other parts of the body.

Possible applications of bioradiolocation

- Somnology – sleep disturbance diagnosis with the detection of apnea, motion and breathing activity;
- Contactless measurement of parameters of heartbeat and breath for patients, when the contact sensor for some reasons cannot be used (for burn centers, intensive care, incubators);
- Functional diagnostics – it can be used like biological feedback for estimation of therapeutic procedures effectiveness. It may be based on the simultaneous analysis of changes in the heart rate and respiration pattern;
- Space medicine -monitoring of astronauts movements inside and outside of spacecraft, and remote monitoring of their health;
- Remote estimation of small laboratory animals' health and behavior for medical and special purposes;
- Remote estimation of psycho-emotional state of the examinee (e.g. remote diagnostics of people in a waiting areas or security checkpoints of airports to identify possible subjects for closer examination);
- Disaster medicine - detection of live persons under debris of buildings that have been suffered from natural disasters, technical calamities or accidents. The urgency of the task is defined by

necessity for rescuers to begin dismantling of rubles and debris in the places, where is hope to find alive people.

- Detection of wounded people on the battlefield
- Antiterrorist operations - detection of people and details of their movements inside of buildings or under foliage
- Screening of shipping containers – detection of persons illegally crossing the border.

The main task of bioradiolocation is remote or contactless measurement of respiratory and pulse rates of human behind obstacles or in open space at some distance [3]. This problem was solved in 2003 by creation of enough sensitive monochromatic radar. Some experiments were carried out which showed that sensitivity of bioradar needs to be increased and also it was proposed to use not monochromatic but multi-frequency radar. Usage of such type of probing signal will allow also measure the distance to the object of the examination. That is why in 2006 multi-frequency bioradar which operates at frequency range from 3.6 to 4.0 GHz was created. This model of bioradar was used for almost all types of the experiments, which were carried out at BMSTU. The last radar photo of which is given in the low right corner was purpose-built in 2009 for monitoring of laboratory animals behavior.

2. Experiments

Bioradiolocation method at chest wall motion analysis during tidal breathing.

It was proved by the experimental data that bioradiolocation method can be used in monitoring of chest surface motion and breathing parameters. During this type of experiment quick-shot camera and radar were applied simultaneously as it shown in the figure 1. On the surface of the chest several markers for were fixed.

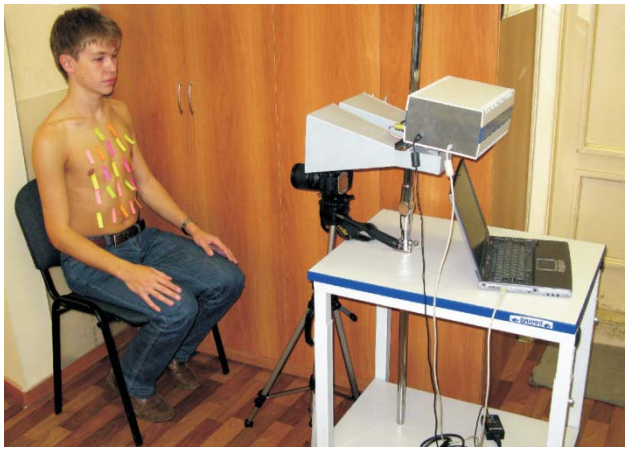

Figure 1. – Scheme of the experiment.

Kinematic model of markers placed on chest surface movements was taken as a basis [4]. The averaged horizontal plan projections of movement vectors of markers during quiet breathing are known from this model. Measuring the markers movement relative to the certain central axis in the frontal plane it is possible to determine the markers movements in the chest-back direction. Data obtained by both methods were compared. Comparison of the experimental results for two methods showed that the highest correlation can be seen for abdominal area movements [5] (Fig. 2).

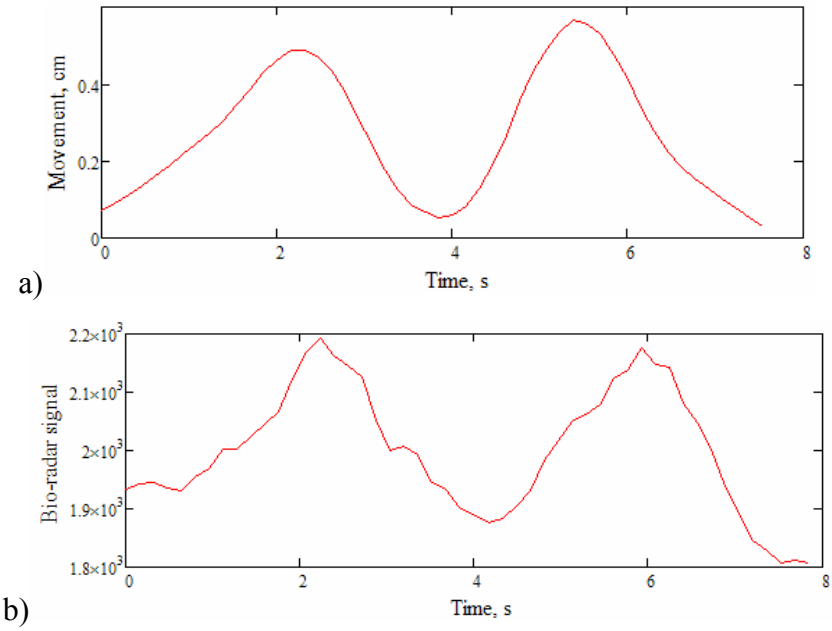

Figure 2. - The dependences with highest correlation:

a) *high-speed camera method; b) bio-radar.*

Comparative experiments for contact and non-contact methods.

Comparative experiments for contact and non-contact methods for heart rate parameter monitoring were carried out to confirm that bioradar can be used for heart rate monitoring. Sketch of the experiment is given in the figure 3.

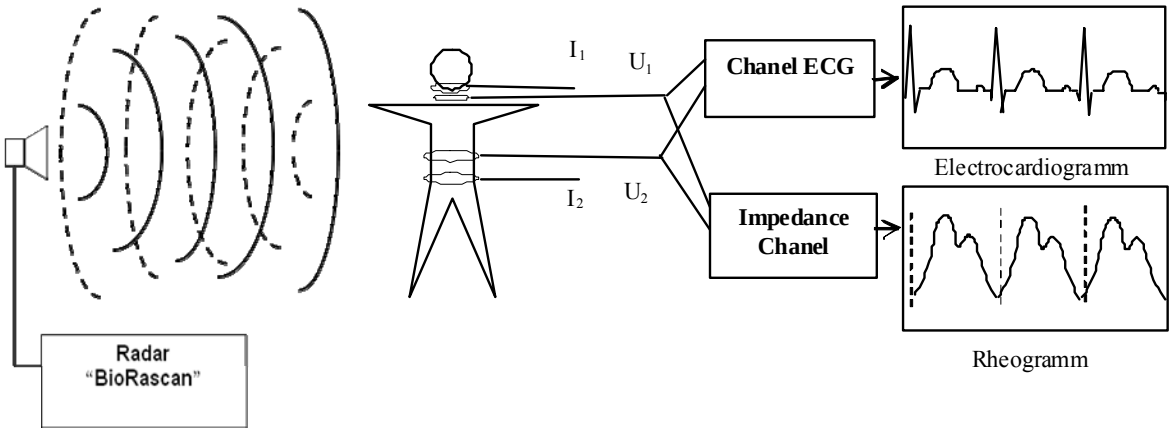

Figure 3. - Sketch of the Comparative experiments for contact and non-contact methods

Respiration and pulse parameters were simultaneously measured by contact method using Rheocardiomonitor and non-contact method of bioradiolocation. 52 adult examinees participated in the experiments, for each of whom radar and Rheocardiomonitor signals were recorded three times (duration of one record is 1 min).Values of breathing and pulse frequencies for contact and non-contact methods were compared, which is shown that they have agreement about 95 %.

Thus the feasibility of bioradiolocation for simultaneous measurements of breathing and heart rate parameters was proved.

Holding breath probe and influence of the external stress factor.

The method of bioradiolocation can be used for monitoring of small differences in respiration and heart beat patterns. For example, bioradar can be used during Shtange`s, Hench`s breath holding test which is widely known in medicine, and is used for estimating fitness of the human body. It is used at training of pilots, submariners and divers. After 1 min after holding breathing involuntary traction of breathing muscles takes place, examinee can hold his breathing even after they appears, but exact duration of this test for the examinee should be estimated without the period when such involuntary traction on breathing muscles take place.

Experiment with additional stress factor was carried out. Ringing mobile-phone was used as a stress factor. While phone was ringing amplitude of chest movements caused by breathing became two times lower then was before. As for BF its value slightly increased. This type of the experiment was carried out to prove high sensitivity of bioradiolocation method to the slightest changes in breathing pattern.

Human adaptive capabilities estimation for mental stress.

There are many methods for mental stress influence estimation. During this test examinee was proposed to sum 17+17+17+… Duration of experiment was 5 minutes. For more detailed studying changes in heart beating patterns histogram method was used. Histograms on heart beat intervals before and after test for one of the examinees are shown in the figure 4. During mental summing up HR increased (from 1.2 to 1.5 Hz) and heart pulse interval dispersion decreased (from 0.25 to 0.06 sec). In 90 % cases mental stress leaded to the raising in HR and narrowing of histogram width.

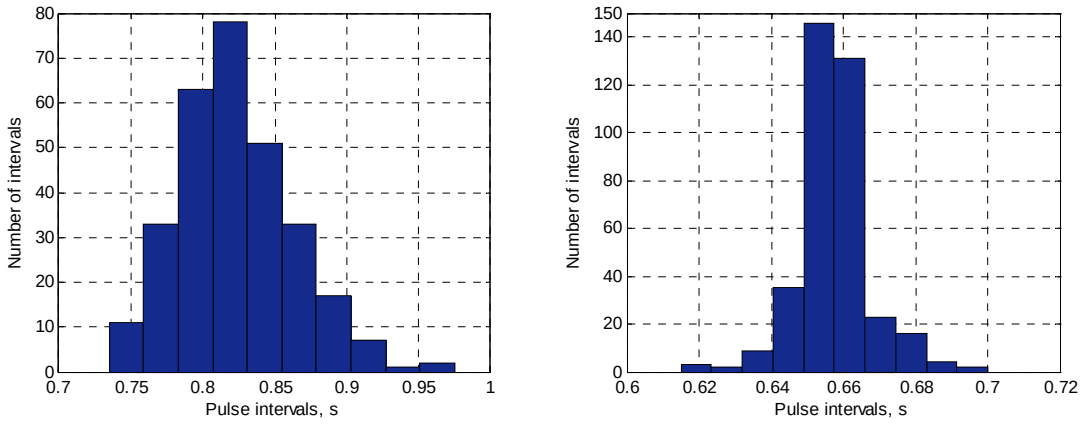

Figure 4. - Histograms on heart beat intervals before and after test for one of the examinees.

Estimation of changes in breathing pattern while using breathing training devices.

Some experiments were conducted to prove the possibility to use bioradar as a biological feedback while using breathing training devise. It is very important to diagnose respiratory tract diseases in time and take prophylaxis measures. It may sufficiently speed up heeling process and even prevent development of a disease. One of the way of training breathing muscles and prophylaxis of different illnesses of a respiratory system is based on usage of special breathing training devises, which helps to normalize breathing pattern. Special methods of training with using of these trainers are developed. But control of breathing pattern changes during trainings is still an actual task. It may help to obtain a reliable information about that changes, close biological feedback loop and thus to choose particular training methods not blindly but with a glance to individual response of the examinee to the trainings.

Automatic sleep disturbance diagnosis.

Sleep monitoring experiments are included into the program MARS-500, which began in March 2010 at Institute of Medical and Biological Problems, Russian Academy of Science, Moscow. It contains simulating different aspects of an interplanetary manned flight [6]. The main part is a series of experiments on long-term isolation of the crew in conditions of the specially built ground-based

experiment facility. Bioradar is used for remote measurements of movement activity, breathing and heart rate parameters of the crew while sleeping. It will detect any changes in these parameters, which may indicate sleep disorders (common problem for long-term isolation and space flights). All results of these experiments including preliminary can be publicized only after ending of MARS-500.

Estimation of animal's movement activity by means of the radar.

Bioradar was created for distant monitoring of movement activity, breathing and pulse of human. But it could be also used for tracking movement of small laboratory animals. The main problem is that the rat is just a little bit bigger than space resolution ability of the device. That is why for rats bioradar which operates at 15 GHz was created.

The photo of the experimental set up for estimation of animal's movement activity by means of radar is given in the figure 5. During experiment the animal was placed into a box with dielectric walls. Transmitting and receiving antennas of the radar were pointed to the box.

Figure 5. - The experimental set up for estimation of animal's movement activity.

The signal reflected from the animal was recorded for further processing. Distance between antennas' block and carton was approximately 1 m. Such short distance was caused by relatively small scattering cross section of an animal. Video signal was recorded also by means of a simple web-camera placed over the box. Information about behavior and movement activity of the animal during the experiment recorded by the camera was used for comparison with and identification of radar signals. This gives possibility to recognize different type of animals' movement and its behavior.

Several short term experiments were carried out, during which all types of animal's behavior were present.

It is known that power flux density near radar receiving antennas is inversely as a range to the object of location of degree four. That is why power of the signal, reflected from an animal and received by bioradar, depends greatly on distance between antennas block and animal. Because of this fact correct estimation of rat's movement activity becomes challenging task. To make power of signal indifferent to location of an animal inside the box we used corner reflector. It was formed by to walls and flour of the box. Metallized coat was put on these surfaces.

The results of the experiments are presented in the figure 6.

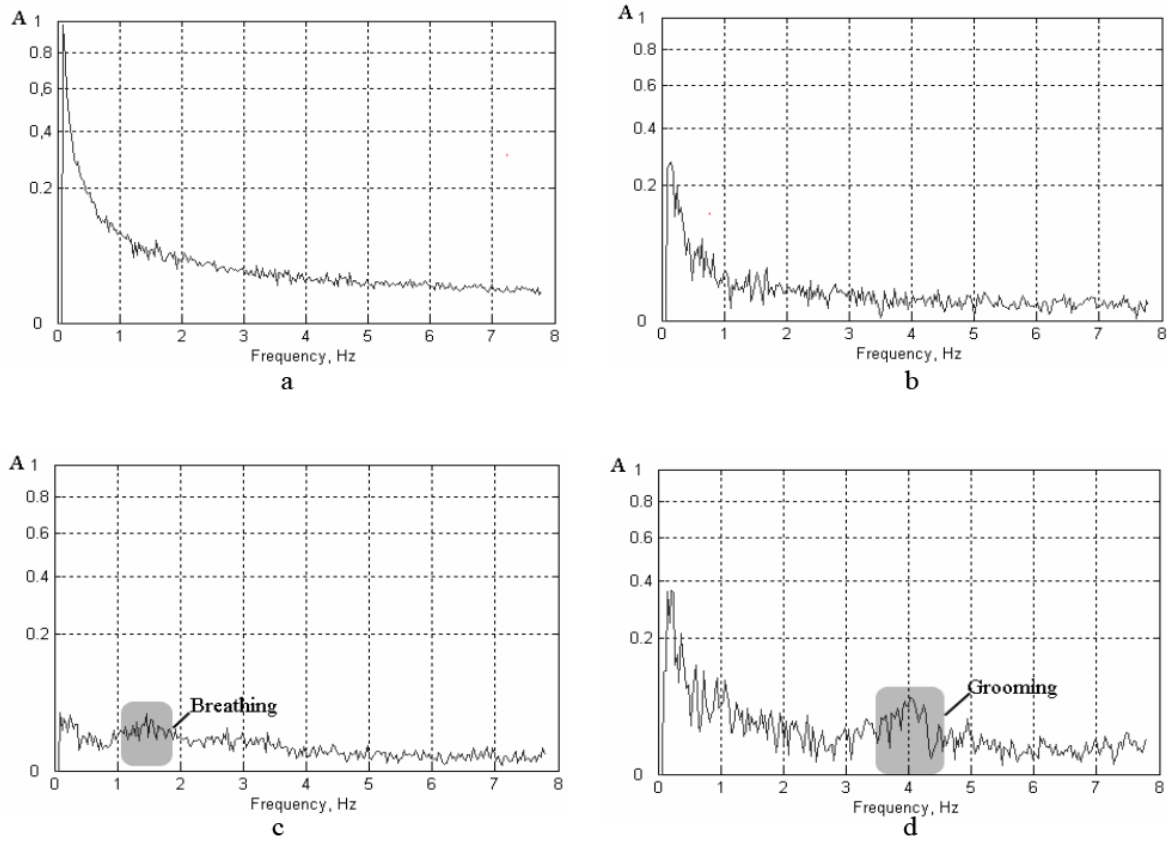

Figure 6. - The results of the experiments

(a – active movements, b – steady state, c – sleeping, d – grooming)

Periods of steady state and locomotion activity can be well recognized even without any additional processing. Specific frequency spectrums for different animal condition were obtained. They are given on slide. The spectrums differ one from another greatly by magnitude and form. That is why it is possible to distinguish grooming from steady state, sleeping or active movement of the animal. To make it easier to compare the frequency spectrums for different states of the animal, amplitude of the frequency spectrum is represented by using of nonlinear scale for vertical axis that is proportional to square root of amplitude.

3. Conclusions

This article gives an information about method of bioradiolocation, possible arias of its applications, the models of bioradars designed at BMSTU and experiments, which were carried out during last 4 years.

At present we are working on the new radar which will record signals within range from 300 Hz to 3 kHz. The radar is supposed to be able to record speech signals from behind an optically opaque obstacles. Also last year the first hand book devoted to the question of bioradiolocation was published at Bauman Moscow State Technical University.

4. Bibliography

1. A.S. Bugaev, V.V. Chapursky, S.I. Ivashov, V.V. Razevig, A.P. Sheyko, I.A. Vasilyev, Through Wall Sensing of Human Breathing and Heart Beating by Monochromatic Radar. Proceedings of the Tenth International Conference on Ground Penetrating Radar, GPR'2004, June 21-24, 2004, Delft, The Netherlands, Vol. 1, pp. 291-294.
2. S.I. Ivashov, V.V. Razevig, A.P. Sheyko, I.A. Vasilyev. Detection of Human Breathing and Heartbeat by Remote Radar. Progress in Electromagnetics Research Symposium (PIERS 2004), March 28-31, 2004, Pisa, Italy, pp. 663-666
3. A. S. Bugaev, I. A. Vasil'ev, S. I. Ivashov, and V. V. Chapurskii, Radar Methods of Detection of Human Breathing and Heartbeat, Journal of Communications Technology and Electronics, 2006, Vol. 51, No. 10, pp. 1154–1168.
4. A. De Groote, M. Wantier, G. Cheron, M. Estenne, M. Paiva. Chest wall motion during tidal breathing. – Journal of Applied Physiology, 1997, Vol. 83, Issue 5, pp. 1531-1537.
5. A.I. Dyachenko, V.I. Minyaev, A.V. Minyaeva. Methods of studying the role of the thoracic and abdominal respiration components in lung ventilation. Vestnik TvGU. Series: Biology and Ecology. - 2007. - № 6. - pp. 15-21.
6. http://mars500.imbp.ru/