Bioradar for Monitoring of Human Adaptive Capabilities

L.N. Anishchenko[1], A.S. Bugaev[2], S.I. Ivashov[1], A.V.Zhuravlev[1]

[1]Bauman Moscow State Technical University, 2nd Baumanskaya str. 5, 105005, Moscow, Russia,
anishchenko@rslab.ru, sivashov@rslab.ru, azhuravlev@rslab.ru

[2]Moscow Institute of Physics and Technology, Institutskii per., 9, 141700, Dolgoprudny, Moscow Region, Russia,
bugaev@cplire.ru

Abstract

This paper sums up the results of bioradiolocation experiments dedicated to the monitoring of human adaptive capabilities, which were conducted at Remote Sensing Laboratory (Bauman Moscow State Technical University) during last two years. The main task of bioradiolocation is remote or non-contact measurement of movement, breathing and pulse parameters of biological objects behind an obstruction or in open space at some distance. This method can be used in sleep medicine, functional diagnostics, pharmacology, zoo-psychology, restorative medicine and disaster medicine. Description of the bioradar experimental procedure is given.

1. Introduction

History of development and improvement of functional diagnostics methods has shown that methods with minimal influence on the object under investigation are preferable.

It is possible to reduce number of cables connected to the examinee by using bio-telemetric systems. These systems are usually equipped with contact sensors. If they are used prolonged time patient may have disagreeable feelings, which also may effect on measured parameters. For example it takes usually from 2 to 3 days (sometimes more) for patient to have a common sleep regiment while carrying out somnology testing with a full complex of contact sensors.

Creation of non-contact diagnostic sensors always seems to be an important scientific problem of biomedical engineering. At present specific radars are effectively used to get information about physiological processes.

Bioradiolocation is a method for detection and diagnostic monitoring of humans, even behind optically opaque obstacles, by means of radar. It is based on the reflected signal modulation caused by movements of the body surface and internal organs [1]. Objects in the human's body, subjected to more or less periodic fluctuations are cardiac muscle and lungs. There are many medical and engineering problems with could be solved with help of bioradars [2]. Among them are: sleep medicine (somnology), functional diagnostics, bedside monitoring, disaster medicine [3, 4], antiterrorist operations, space medicine, pharmacology and zoo-psychology [5].

2. Apparatuses and Methods

At Bauman Moscow State Technical University (BMSTU) method of bioradiolocation has been studied since 2002 [1]. At the beginning surface penetrating radar was used for bioradar. However, experiments showed that bioradiolocation requires specific apparatuses and algorithms to be designed [6]. That is why in 2005 a new bioradar was created at Remote Sensing Laboratory, BMSTU. As opposite to previous radar it uses step frequency modulated signal at frequency band from 3.6 to 4.0 GHz, which allows estimating the distance to the object of the exanimation.

It was proved by the experimental data that bioradiolocation method can be used in monitoring of chest surface motion and breathing parameters [7]. A quick-shot camera and radar were applied simultaneously. Data from quick-shot camera and bio-radar has the highest correlation for abdominal area movements.

Also 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. During this type of experiments breathing

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

and pulse parameters were simultaneously measured by contact method using Rheocardiomonitor and non-contact method of bioradiolocation. 27 male and 25 female 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.

During last two years the experiments dedicated to monitoring human adaptive capabilities to mental and physical stress, sleep monitoring, estimation of changes in breathing pattern while using breathing training devises and estimation of the laboratory animals' movement activity were carried out. In this paper only the results of the first type of the listed bioradiolocation experiments are given.

3. Estimation of human adaptive capabilities for physical stress

Examinees were divided into two groups. First group consists of 54 practically healthy examinees of both genders at 20-21 years of age. All of them are not taking up any kind of sport. Second group consists of 13 practically healthy examinees only male at 17-22 years of age. All of them were members of BMSTU ski select team. The examinees were taking up this sport for more then 3 years, 10 of them had first grade other 3 had second grade at skis.

The experiment was divided into three stages. During first stage monitoring of breathing and pulse parameters at steady state was carried out. It took from 3 to 5 minutes. During second stage breathing and pulse parameters after doing some physical activity were monitored. Examinees were proposed to do bob exercises for 1 minutes with frequency 60 bobs per min (or another adequate physical activity). After that monitoring of breathing and pulse signals were carried out repeatedly. Duration of radar signal registration depend on the level of endurance of the examinee. It was determined by period of time when breathing and pulse frequencies reached level that corresponds to steady state. During third stage monitoring of breathing and pulse parameters after doing physical activity of high intensity was carried out. Examinees were proposed to do bob exercises for 5 minutes with frequency 60 bobs per min (or another adequate physical activity). After that monitoring of breathing and pulse signals were carried out repeatedly. Duration of radar signal registration depended on the level of endurance of the examinee. It was determined by the period of time when breathing and pulse frequencies reached level that corresponds to steady state.

Hypothesis concerning statistical significance of changes in heart rate (HR) and breathing frequency (BF) while doing physical exercises was put to the test. Student t-test (for the first group) and Wilcoxon test (for the second group) were used for the checking of hypothesis. Second stage experimental data analyze revealed following facts. BF and HR suffer statistically dependent changes when doing physical work only for examinees from the first group. For members of the second group no statistically dependent changes were found. For both cases confidence probability was $p=0.80$. Third stage experimental data analyze showed that BF and HR had statistically dependent changes when doing physical work for both groups (confidence probability $p=0.80$).

Reproducibility of results was verified by retesting in one week time after initial experiment. For confidence probability $p=0.80$ there is no statistically dependent differences between initial experiment and retesting results.

While processing third stage experimental data not only BF and HR were estimated but also recovery time for both of them. These parameters showed how long it took BF or HR to return to the steady state level after doing physical work. For second group of examinees interesting fact was discovered. In Fig. 1, 2 examples of breathing and heart beating rhythmograms for one examinee are given.

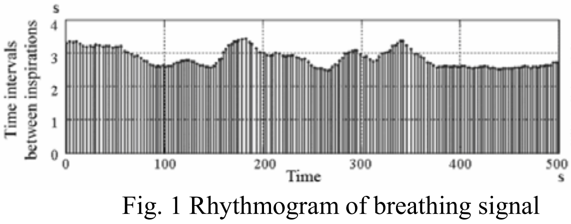


Fig. 1 Rhythmogram of breathing signal

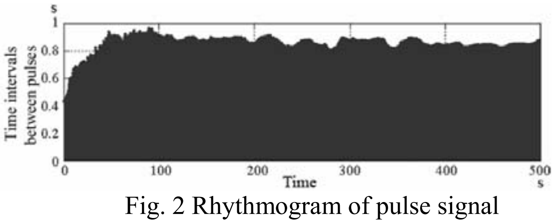


Fig. 2 Rhythmogram of pulse signal

The experimental analysis showed that it took different time for breathing and pulse frequencies to reach the level of steady state. Pulse rhythm stabilized in approximately 1 min after end of doing exercises. While BF early stabilized only after period of time from 100 to 150 sec, but then again went down to the level, which corresponds to doing physical work of high intensity. And finally it stabilized only in more than 6 minutes after beginning of bioradiolocation monitoring. Thereby stationary value of breathing frequency in this case was not equal to the steady state value of this parameter (breathing frequency became higher). It is possible that the specific reaction of breathing system in return on physical stress is caused by prolonged ski training history. This sport supposes not short-term but long-lasting physical stress. Hence it can be made out, that parameters of cardiorespiratory system under doing sport exercises change due to specificity for organism fitness.

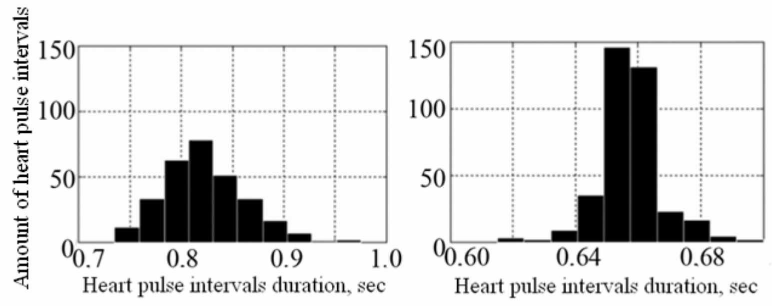
4. Estimation of human adaptive capabilities for mental stress

There are many methods for mental stress influence estimation [8]. However, because of the fact that during testing procedure examinee should be motionless the most simple mental stress test was used. Examinee was proposed to sum mentally 17+17+17+… Duration of experiment was 5 minutes. In this experiment the same groups of examinees as in experiments with physical stress participates.

Reproducibility of results was verified by retesting in one week time after initial experiment. For confidence probability p=0.80 there is no statistically dependent differences between initial experiment and retesting results.

Experimental data analyze showed that changes in BF were not statistically dependent but changes in HR were (confidence probability p=0.80).

For more detailed studying changes in breathing and heart beating patterns histogram method was used. In Fig. 3 a, b heart pulse intervals histogram for steady state and while suffering mental stress are given for one of the examinees. During mental summing up HR increased (from 1.2 to 1.5 Hz) and heart pulse interval dispersion decrease (from 0.25 to 0.06 sec). In 90 % cases mental stress leaded to the raising in HR and narrowing of histogram width.



a b

Fig. 3 Heart pulse interval histograms for steady state (a) and mental stress (b)

Experiment with additional stress factor was carried out. A ringing mobile-phone was used as a stress factor. During experimental procedure examinee was calmly sitting in front of the antennas block. Mobile-phone was located at the distance of 1.0 m from the examinee so that it could not be seen. During registration of bioradar signal without notification of the examinee on the phone was made a call. An example of the breathing signal extracted from the bioradar data is given on Fig. 4.

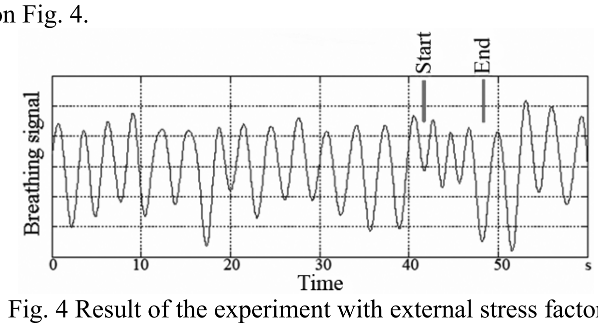


Fig. 4 Result of the experiment with external stress factor

It could be seen from Fig. 4 that while the phone was ringing amplitude of chest movements caused by breathing became two times lower than 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.

5. Conclusion

A new bioradar is created. It operates at higher frequency band of 7-8 GHz and 14-15 GHz. The radar has better resolution capabilities, which is highly important because it improves the quality of received information. With help of new bioradar it is supposed to continue bioradar experiments. The most promising areas for further investigations are different type sleep artifacts recognition in bioradar signal such as coughing, sneezing and overturning and creating fully automatic program for estimation of animals behavior which may operate with different types of animals. Also creation of subsurface electronic fence is under consideration. The fence will consist of radar and ultrasound sensors. It may be used for control state boarders and perimeters of the most important public and government objects (military bases, prisons, etc.).

6. Acknowledgments

This work was supported by grants of the RFBR # 09-07-00038-a, President of RF MK-118.2011.9, Russian Science and Education Ministry # 2.1.2/700, federal special-purpose program «Scientific, Research and Educational Personnel of Innovative Russia» 2009-2013.

7. References

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,” *International Conference on Ground Penetrating Radar Proceedings*, Delft, The Netherlands, 2004, Vol. 1, pp. 291-294.

2. E.M. Staderini “UWB Radars in Medicine,” *IEEE Aerospace and Electronic Systems Magazine*, January 2002. pp. 13-18.

3. B. David, “Non-Destructive Evaluation after Destruction,” Non-Destructive Testing in Civil Engineering, Nantes, France, 2009.

4. M. Bimpas, N. Paraskevopoulos, K. Nikellis, D. Economou and N. Uzunoglu “Development of a Three Band Radar System for Detecting Trapped Alive Humans under Building Ruins,” *Progress in Electromagnetic Research Symposium Proceedings*, Pisa, Italy, 2004, pp. 161-188.

5. L.N. Anishchenko, A.S. Bugaev, S.I. Ivashov, I.A. Vasiliev, “Application of Bioradiolocation for Estimation of the Laboratory Animals' Movement Activity,” *PIERS Online*, 2009, Vol. 5, No. 6, pp. 551 – 554.

6. S.I. Ivashov, V.V. Razevig, A.P. Sheyko, I.A. Vasilyev “Detection of Human Breathing and Heartbeat by Remote Radar,” *Progress in Electromagnetic Research Symposium*, Pisa, Italy, 2004, pp. 663-666.

7. D. Korchagina, M. Alekhin, L. Anishchenko “Bio-radiolocation Method at Chest Wall Motion Analysis during Tidal Breathing,” *European Radar Conference*, Paris, France, 2010, pp. 475-478.

8. L.N. Anishchenko, V.B. Parashin “Estimation of Adaptive Capabilities of a Human Organism by Means of Bioradiolocation,” *Russian-Bavarian Conference on Biomedical Engineering*. Munich, Germany, 2009, pp. 147-148.