Remote Monitoring of the Human Breathing and Movement Patterns during Sleep by Means of Bioradar

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***Abstract*- Possibility of non-contact method (bioradiolocation) for sleep disorders diagnostics is discussed. Technical characteristics of bioradar used for sleep pattern monitoring and the details of the experimental procedure are given. Designed algorithm extracts movement artifact episodes from received signal and allows to visualize respiration frequency and movement activity dynamics during sleep and thus to detect negative changes in sleep pattern caused by day stress or other factors.**

***Index Terms*- bioradiolocation, remote sensing, sleep disorders.**

I. INTRODUCTION

One of the most promising areas of biomedical engineering is the creation of non-contact or wireless devises for diagnostics which are much more preferable for patients than presently used contact methods.

One of such non-contact methods is bioradiolocation [1]. It is used for detection and diagnostic monitoring of humans, even behind optically opaque obstacles, by means of radar. The method is based on the reflected signal modulation caused by movements of the body surface and internal organs. Objects in the human's body, subjected to more or less periodic fluctuations are cardiac muscle and lungs. There are many areas in medicine where application of this method will improve quality of received data or even will help to get essential information about patient vital signs when traditional method cannot be used. Among them are:

- sleep medicine (somnology),
- functional diagnostics,
- bedside monitoring,
- disaster medicine [2, 3],
- antiterrorist operations,
- space medicine,
- pharmacology and zoo-psychology [4].

The most promising area of over listed applications is sleep medicine. In time of sleeping many life functions of an organism suffer considerable changes. It can be clearly seen in case of breathing pattern. Healthy people during slow or rapid sleep can suffer from reduction of breathing movement amplitude (hypopnea) or even complete stop of breathing (apnea). Chronic stress condition can be the origin of these or other negative changes in the breathing pattern of cosmonauts during sleep.

To provide an effective prophylaxis of sleeping disorders during the prospective flight to Mars it is necessarily to diagnose in time development of the examinees disorder and take measures. By means of bioradiolocation it is possible to control changes in movement activity and breathing parameters of cosmonauts during sleep without any physical contact with the examinee.

Experiments, which are described in this paper, are directed to the creation of such diagnostic methods. It is important to investigate the possibility of a remote respiration monitoring for cosmonauts during sleep, which is essential for both cosmic physiology and medicine and for terrestrial medicine. The results of such research may be the basis for creation of remote sleep disorders (apnea and hypopnea) diagnostics methods. In this paper results of the tentative experiments, which proved that bioradar can be used for respiration and movement pattern monitoring during sleep, are given.

II. APPARATUSES AND METHODS

At 2006 purpose oriented bioradar operating at 4 GHz was created at Remote Sensing Laboratory, Bauman Moscow State Technical University (BMSTU). Step frequency modulated signal is used as probing signal in this radar.

Other technical characteristics are given below:
number of frequencies: 16;
frequency range: 3.6..4.0 GHz;
maximum energy flux density: 1,36 mkW/sm^2;
recorded frequencies band: 0.01..5.00 Hz;
dynamic range of the recording signals: 60 dB.

The experiment for estimation of breathing frequency and movement activity during sleep is shown in Fig.1.

Fig.1. Sleep monitoring experiment

Bioradar was disposed near the bed. Antennas block was directed on the exact point of the bed were examinee's thorax supposed to be during sleep. Radar signal was recorder during whole period of time while examinee was sleeping. 24 overnight records were made. 6 adult male (from 25 to 40 years old) participated in the experiments. All of the examinees were practically healthy.

III. EXPERIMENTAL RESULTS

Processing of the recorded signals was organized on the base of MATLAB and included several stages. First of all bioradar signal was filtered by built-in MATLAB filter with cutoff frequency of 0.05 Hz (filter order was 8). The filter was used for baseline drift elimination. During the next stage of the algorithm intervals of movement activity were detected. It is obvious that level of the received signal which correspond to calm breathing and movement activity must differ greatly because of more than 10 times differences in amplitude of these movements. However, the main problem in movement artifacts detecting is the fact that during sleep patient may turn from one side to other. In this case the distance between antennas and examinee and scattering cross section of the object may change. As the result level of the received by bioradar signal may also vary significantly (Fig.2 a).

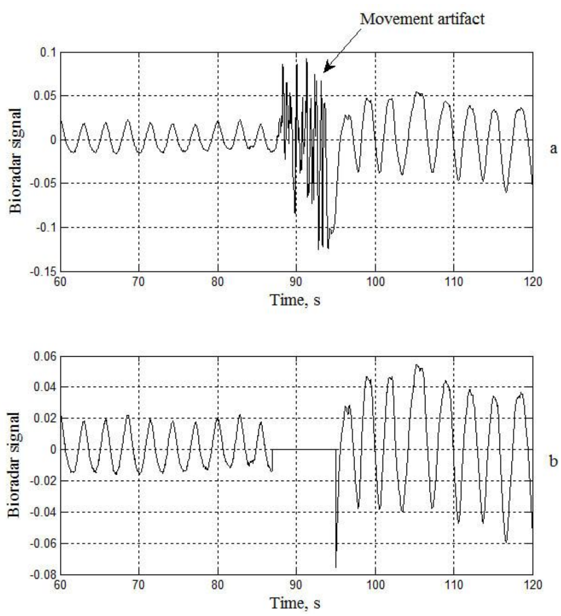

Fig.2. Bioradar signal before (a) and after (b) movement artifact extraction

That is why it is not enough to use only signal amplitude parameters for detecting of movement artifact episodes. However, episodes of signal, during which movement artifacts are present, contains frequency components higher than the same parameter for episodes of steady breathing. Frequency of normal steady breathing varies from 0.1 to 0.6 Hz, and the spectrum of bioradar signal intervals corresponded to movements may contain components higher than 1.0 Hz. These spectral distribution differences were used in the algorithm for movement artifact location. In Fig.2 radar signal before and after movement artifacts extraction is shown.

Respiration frequency may be estimated only for intervals free from movement artifacts. To do so bioradar signal after extraction of movement artifact was divided into intervals with 10 seconds duration. For each of these intervals the value of the respiration frequency was estimated. Any significant changes in this parameter may indicate sleep disorders such as apnea. However, to analyze dynamic of respiration frequency changes and movement activity during night sleep it is more convenient to use values of the parameters averaged for one hour. In Fig.3 and 4 the results of the experimental data processing are given.

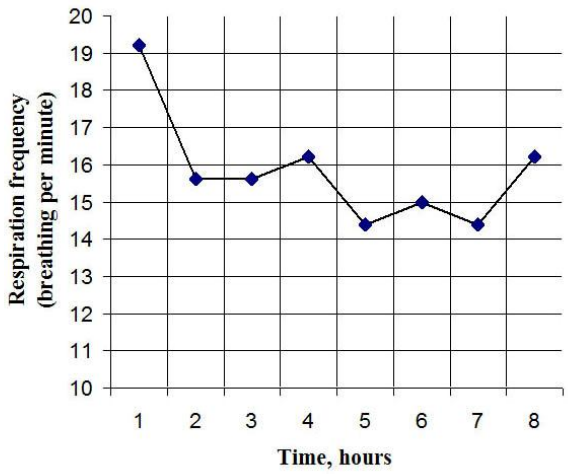

Fig.3. Respiration frequency dynamics during sleep

In Fig.3 it is clearly seen that after falling asleep value of the respiration frequency of the examinee decreased from 19 to 16 breathing acts per minute, and during last hour of sleep breathing frequency on the contrary became higher.

It is known that breathing pattern and movement activity dynamics do not change greatly from night to night usually and characterize individual sleep pattern [5]. If changes take place it may indicate that the examinee suffers from some kind of stress during day time. So, by using of proposed algorithm it is possible to monitor breathing and movement activity pattern and thus detect a sleep disturbance.

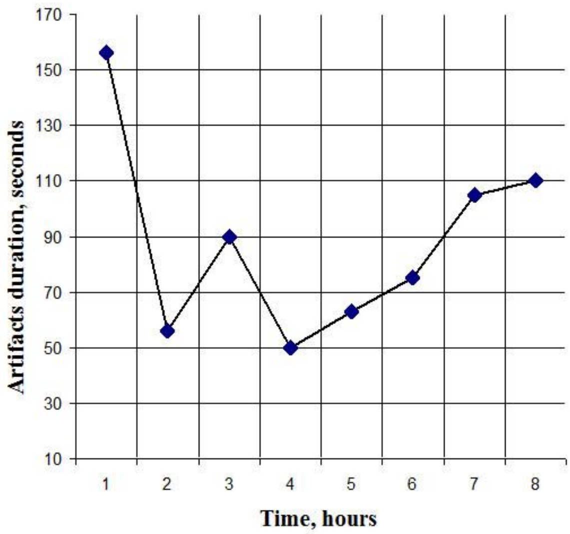

Fig.4. Movement activity dynamics during sleep

IV. CONCLUSION

At present bioradar experiments are included into the scientific program of international experiment MARS-500, which began in June 2010 at Institute of Medical and Biological Problems, Russian Academy of Science, Moscow. It contains simulating different aspects of an interplanetary manned flight. 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 and respiration frequency parameters of the crew while sleeping. It helps to detect any changes in these parameters, which may indicate sleep disorders (common problem for long-term isolation and space flights). After MARS-500 ending it would be possible to make a conclusion about prolonged isolation influence on respiration pattern and movement activity during sleep.

ACKNOWLEDGMENT

This work was supported by grants of National Association on Innovation and Development in Information Technologies.

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