A novel approach for non-contact screening of breath disorders during sleep based on bio-radiolocation

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***Abstract* — Application of bio-radiolocation technology in non-contact screening diagnostics of breath disorders during night sleep is substantiated. Influence of chest wall surface motion during tidal breathing on bio-radar signal forming is researched. Results of long night sleep monitoring are analyzed. A new method of bio-radiolocation signal patterns attribute space forming is given.**

Keywords: bio-radiolocation, breath disorders.

I. INTRODUCTION

One of the priority areas of sleep medicine nowadays is an examination of breathing malfunctions, which are character to many disorders of different types [1]. Universally recognized standard of diagnostics in this field is supposed to be polysomnography [2]. Results of such procedure give a very informative aspect of sleep dysfunctions but require a great amount of sensors and electrodes to be used. So application of new non-contact methods in somnology is an up-to-date scientific task.

Very often screening diagnostics of such breath disorder as sleep apnea syndrome can be carried out on the base of chest wall and abdominal breathing motions analysis and direct breath holding registration [2]. In this case one of the approaches providing the necessary information is bio-radiolocation technology [3]. It gives an opportunity to implement remote non-contact monitoring of patients during night sleep.

II. MATERIALS AND METHODS

Bio-radiolocation is a modern sensing technique giving the opportunity to detect persons remotely even behind opaque obstacles, not applying any contact sensors [4]. It is based on radar signal modulation by oscillatory movements of human limbs and organs. Electromagnetic wave reflected from human body obtains specific biometric modulation which is not present when interacting with motionless objects [4]. The main factors of such signal changes are: heartbeat; contractions of vessels; movements of limbs; oscillation processes of cutaneous integument of chest wall and abdomen areas.

In experiments a multifrequency continuous wave radar with signal step modulation was applied. The device was designed at Remote Sensing Laboratory of Bauman Moscow State Technical University [5]. It has 16 operating frequencies at the range from 3.6 to 4.0 GHz. The receiving signal is filtered using analog active filter with bandwidth from 0.03 to 5.00 Hz. The data is recorded at 62.5 Hz sampling frequency in two quadratures. The emitted power flux density is 1.6 uW/cm2 is safe for both patients and personnel.

III. EXPERIMENTATION

A. Bio-radar signal forming study

There is a great amount of techniques to measure lung volume and airflow at entrance into human respiratory tract [6]. They have acquired a good reputation and are widely adopted in medico-biological practice. However, no adequate mathematical model, describing with enough precision, chest wall surface movement patterns and their fluctuations during breathing process, has been created yet. To reveal the influence of breath motions on bio-radar signal forming series of experiments with synchronous parallel quick-shot camera application were carried out [7].

To form an experimental model the previous results [8] obtained with a large experimental group involved and applying image recognition system were used. The kinematic model for tidal breathing process represented a set of vectors of spatial displacements corresponding to movement in space of markers placed on a chest wall surface in five horizontal levels with equal distances between [8]. The same topology of markers was used. So with only one quick-shot camera involved it becomes possible, tracking changes of linear distances between markers and vertical central axis for every image, to describe transferences in other directions to be later compared with recorded bio-radiolocation data.

For image processing the values of markers displacements from the vertical central axis on the chest wall were used as source data for quick-shot camera method. Due to imperfection of markers detection technique an error occurred that led to appearance of sufficient distortions in graphical dependences. Therefore, before performing comparison with bio-radiolocation data smoothing stage was realized. In this case adaptive method of a symmetric nearest neighbor linear least-squares fitting was applied.

All in all, the fact was ascertained that chest wall surface motion has a great influence on bio-radar signal forming during breathing process. Strong pairwise correlation for bio-radiolocation and quick-shot camera techniques were occurred for markers situated at lower levels of abdominal area. The transference amplitude values for these markers turned out to be the most in comparison with the same magnitudes for markers at higher levels for both methods [7].

B. Long night sleep monitoring trials

To study bio-radiolocation method capability series of experiments on remote non-contact sleep monitoring in calm and stressful conditions were carried out [9]. The experiment was divided into two stages. Each one lasted for four days. During the first part on the base of BMSTU student dormitory the data was recorded corresponding to stressful sleep for the patient (during examination session and in unknown circumstances). The second time monitoring was held in calm home conditions.

Basing on experimental results [9] it can be noted that breathing pattern allows analyzing night sleep peculiarities and dysfunctions. Mostly bio-radiolocation method gives an opportunity to distinguish the states of sleep and awake. When falling asleep, receiving signal amplitude decreases. Speaking about troubled sleeping, vigil periods can be pointed out by movements registration in received signal. In this case character signal components can be revealed in low parts of spectrum.

C. Signal patterns attribute space forming

Multiresolution wavelet analysis is a modern mathematical apparatus which is very effective in non-stationery multicomponent signals processing [10]. For bio-radiolocation signal patterns classification a new approach of attribute space forming was given, based on setting a series of absolute values of high-level wavelet decomposition detail coefficients of signal quadratures components [11].

To estimate the approach efficiency three classes of patterns were analyzed, corresponding to different types of patient movements. The values of detail coefficients were calculated using discrete wavelet transform routine. Haar wavelet was taken as a base one. Each signal fragment length was chosen equal to 320 counts. It provided 20 components of the attribute representation vector on the fourth level of wavelet decomposition.

The patterns classification was performed by calculating the least Euclidian distance from the center of mass of each class set. Observed strong correlation between each attribute vector within the corresponding class and the vector of means for chosen types of bio-radiolocation movement patterns should be considered as significant with high level of reliability [11].

IV. CONCLUSION

Bio-radiolocation method turned out to be an effective instrument of non-contact sleep monitoring realization and its breath disorders and dysfunctions screening detection. Oscillating movements of abdominal area have a high influence on bio-radar signal forming during breathing process. An attribute space for bio-radiolocation signal patterns can be formed on the base of absolute values of wavelet decomposition detail coefficients of received signal quadratures.

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