Moscow-Bavarian Joint Advanced Student School

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Bioradiolocation and Its' Applications

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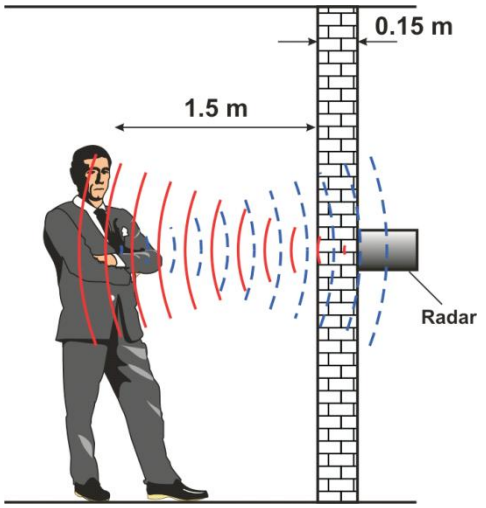
Bio-radiolocation

Bioradiolocation is the method for detection and diagnostic monitoring of humans, even behind opaque obstacles, by means of radar.



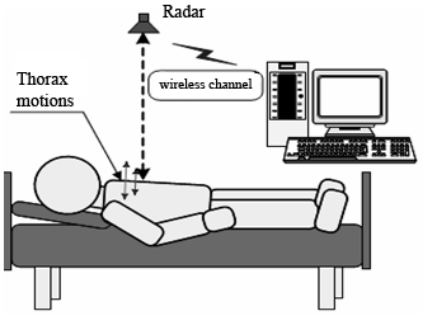
This technique is based on the reflected radar signal modulation caused by movements of the human skin and internal organs due to breathing and heartbeat, or speech, or movement of limbs.

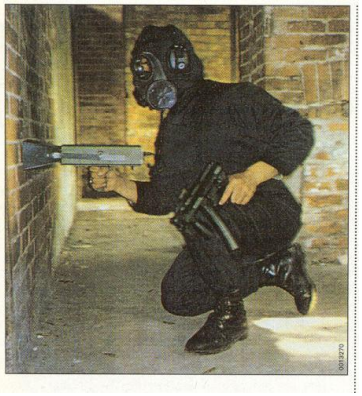
<u>The modulation is caused by:</u>

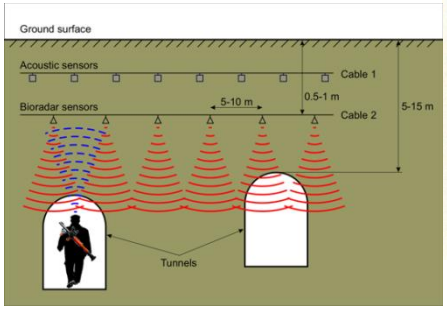
- cardiac beat (frequency band between 0.8 and 2.5 Hz, the chest movement amplitude is 2-3 mm);
- movements of the thorax during breathing (frequency band between 0.2 and 0.5 Hz, the chest movement amplitude, depending on the type of breathing, ranges between 0.5 and 1.5 cm);
- articulation or movement of the vocal apparatus (lips, tongue, larynx);
- movements of other parts of the body.

Possible applications for bio-radiolocation

- 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
- Detection of wounded people on the battlefield
- Antiterrorist operations - detection of people and details of their movements inside of buildings or under foliage
- Subsurface Electronic Fence (border guard, prison guard, protection of important military bases, protection of most important public and government objects)
- Screening of shipping containers – detection of persons illegally crossing the border.





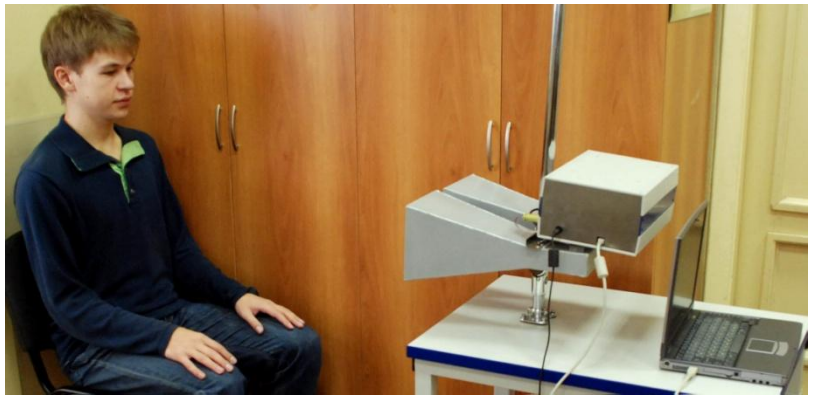


Models of Bio-Radars

Bioradar model	Monochromatic radar	BioRASCAN 4	BioRASCAN 15
Number of operating frequencies	1	16	16
Operating frequency, GHz (wavelength, cm)	1.6 (19)	3.6..4.0 (8)	13.8..14.2 (2)
Emitted power, mW	<10	<3	<3
Gain factor, dB	20	20	20
Frequency range of recorded signal, Hz	0.03..3	0.03..5	0.03..10
Dynamic range, dB	60		
Sampling frequency, Hz	20	62.5	62.5
Antenna dimensions, mm L / W / H	200/120/120	370/150/150	120/50/50

Monochromatic radar

BioRASCAN 4



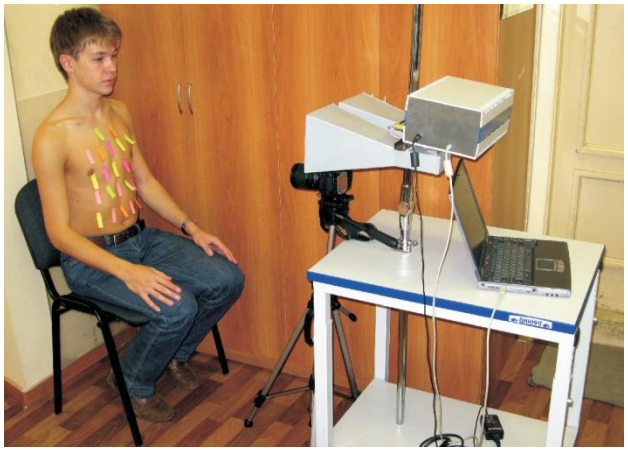
BioRASCAN 15

List of BioRadar Experiments (BMSTU, 2008-2011)

1. Comparative experiments for bioradiolocation and optical measurements of chest movements during breathing
2. Comparative experiments for contact and non-contact methods.
3. Human adaptive capabilities estimation for physical and mental stress.
4. Estimation of changes in breathing pattern while using breathing training devices.
5. Monitoring of movement, heart rate and respiration patterns during sleep.
6. Estimation of the laboratory animals movement activity.

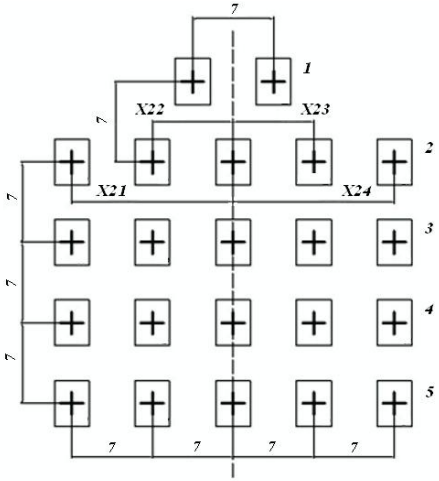
Bio-radiolocation Method at Chest Wall Motion Analysis during Tidal Breathing

Scheme of experiment

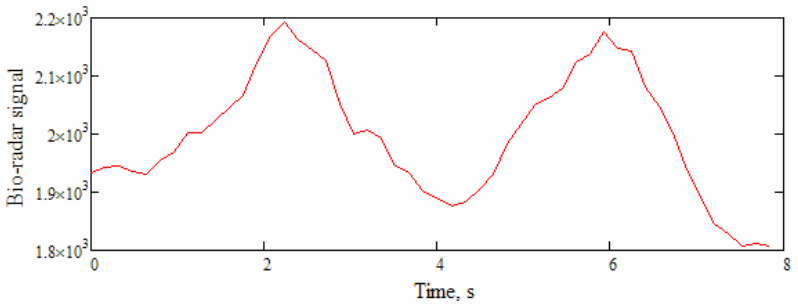


- Kinematic model of markers placed on chest surface movements was taken as basis.
- The averaged horizontal plan projections of movement vectors of markers during quiet breathing are known from this model.
- Measuring the markers movement relative to the certain central axis in the frontal plane it is possible to determine the markers movements in the chest-back direction.
- Data obtained by both methods were compared.

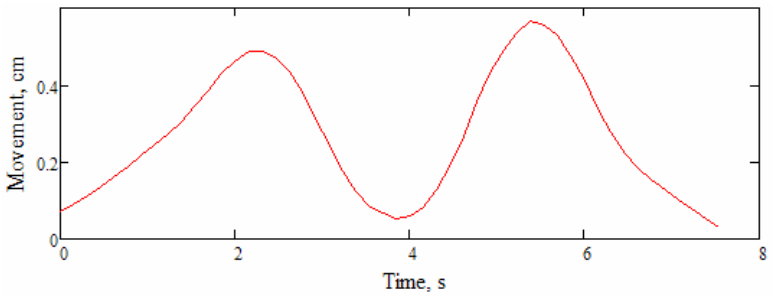
The location of markers on a chest surface



The dependences with highest correlation:



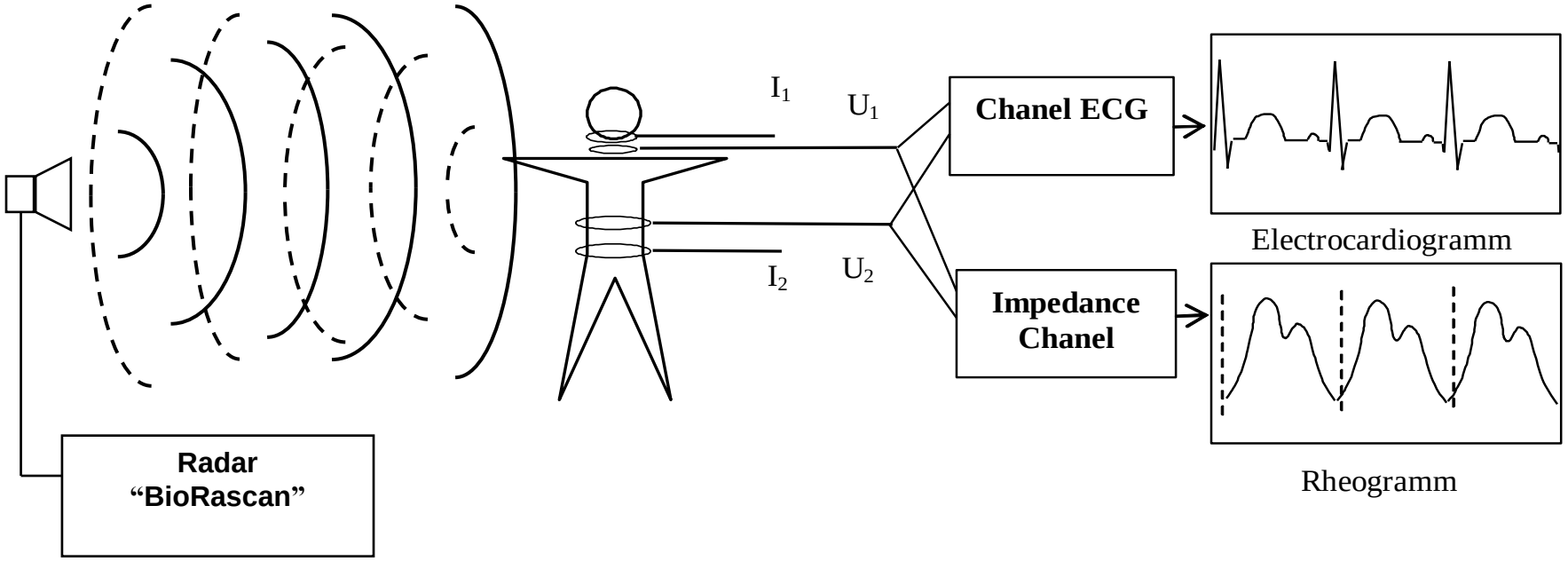
high-speed camera method



bio-radar

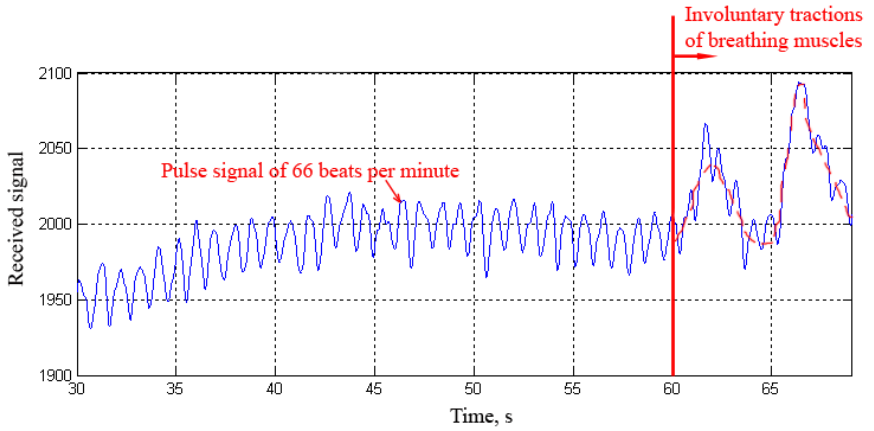
- The chest wall surface motion is reflected in bio-radar signal during tidal breathing.
- For the symmetric markers on the opposite halves the pairwise correlation is lower, than for markers, placed on the same half of the chest cage.
- The best correlation with the bio-radar signal is found for the markers on the lowest abdominal level.

Comparative experiments for contact and non-contact methods

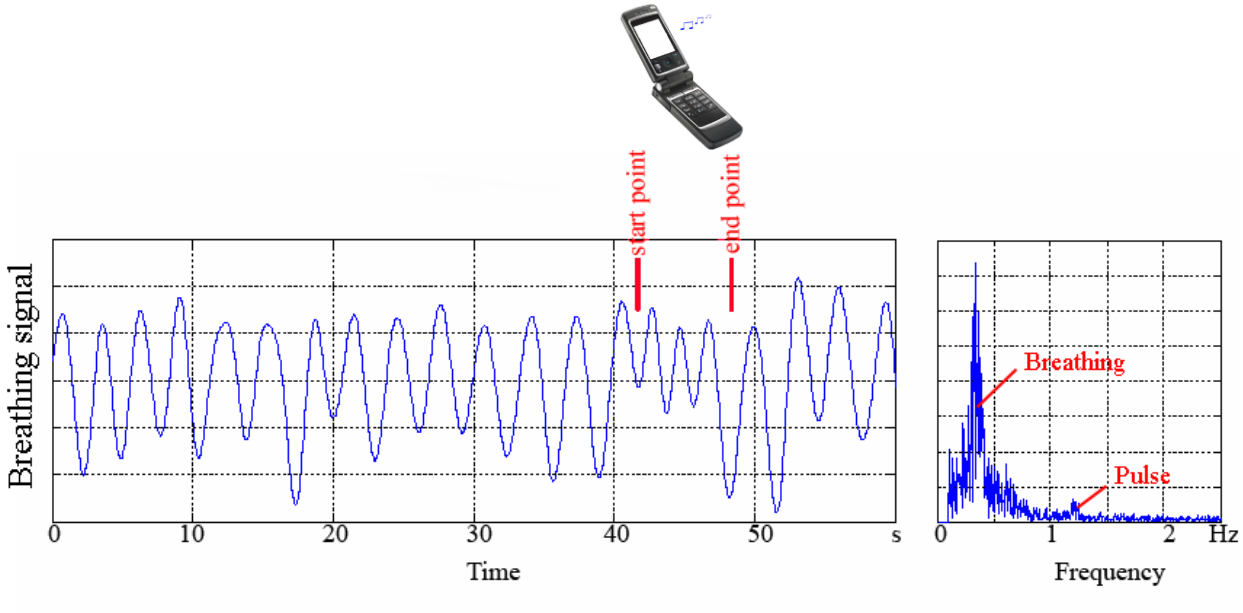


- 52 adult examinees participated in the experiments
- For each of them radar and rheocardiomonitor signals were recorded three times
- Agreement between values of the parameters recorded by contact and non-contact methods is about 95 %.

Holding breath probe and influence of the external stress factor



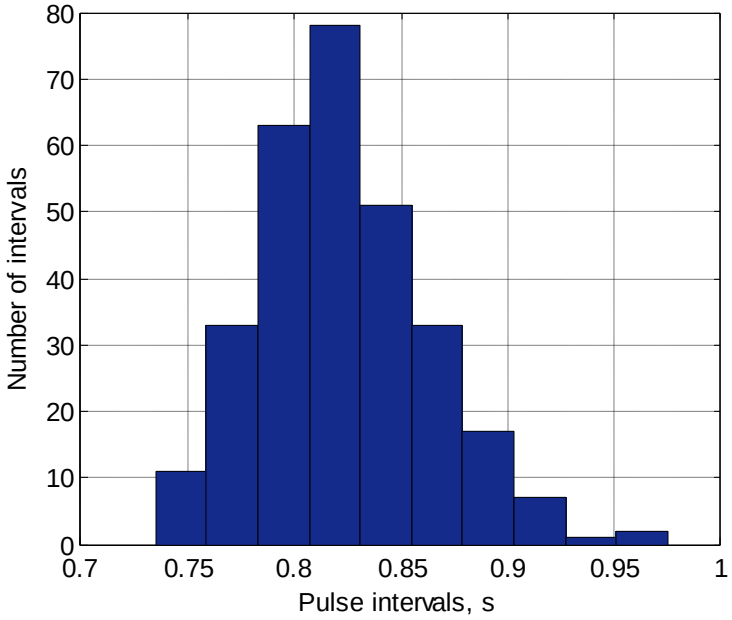
Involuntary tractions of breathing muscles with frequency of 0.2 Hz as a result of oxygen starvation
at breathing delay of 1 min



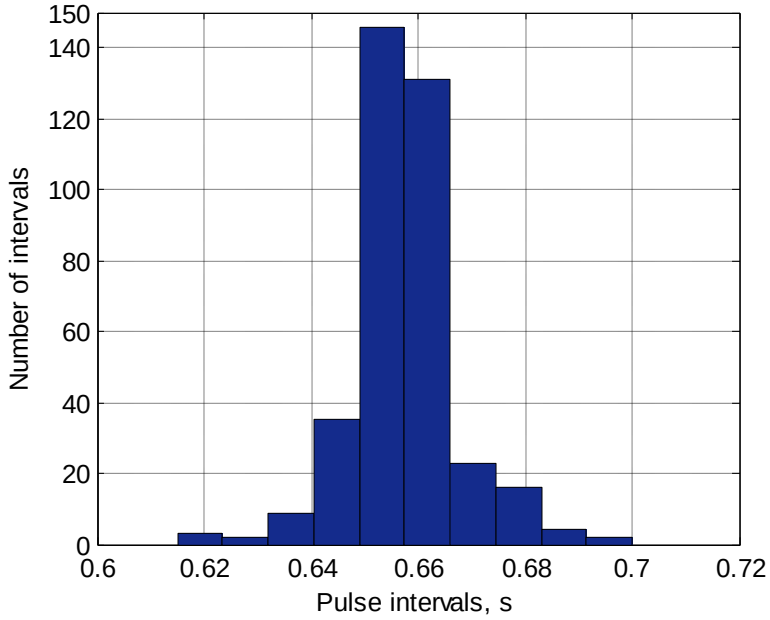
The experiment demonstrates influence of the external stress factor on a person.

Estimation of human adaptive capabilities for mental stress

Heart rate histogram for steady state

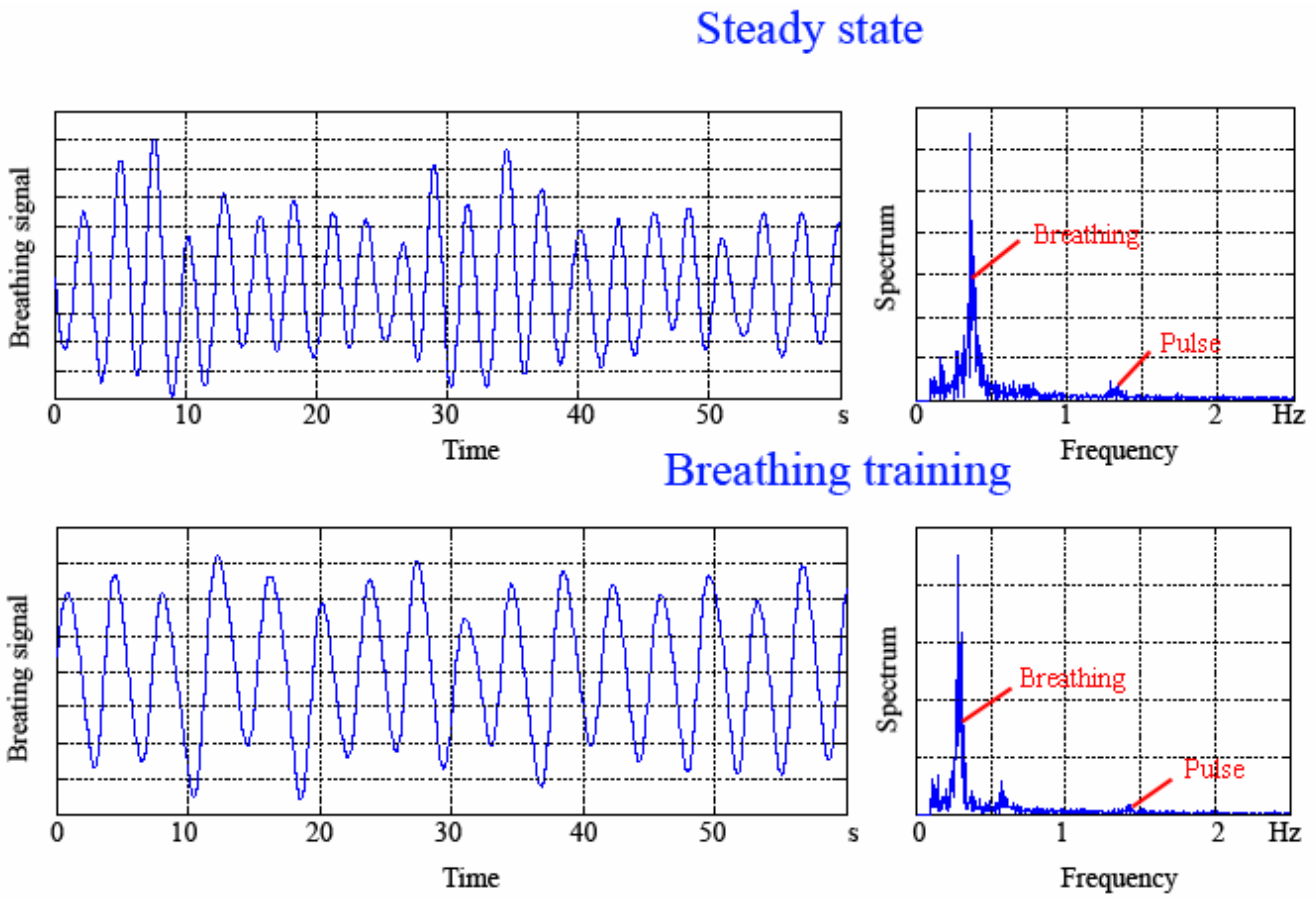


Heart rate histogram for mental stress state



Experimental data analysis showed that changes in HR were statistically significant (confidence probability p=0.80).

Estimation of changes in breathing pattern while using breathing training devices



Automatic sleep disturbance diagnosis

The development of methods of sleep analysis was based on the experimental data recorded in the course of the program “MARS 500”

Experiments are carrying out during the sleep of the crewman who is sleeping on the bed, antenna assembly is installed at the tripod near the bed.

Crew

Фото 1 из 7
Экипаж 520-суточной изоляции
фото: ИМБП/Олег Волошин

Wang Ye performs experiment “BIORASCAN”

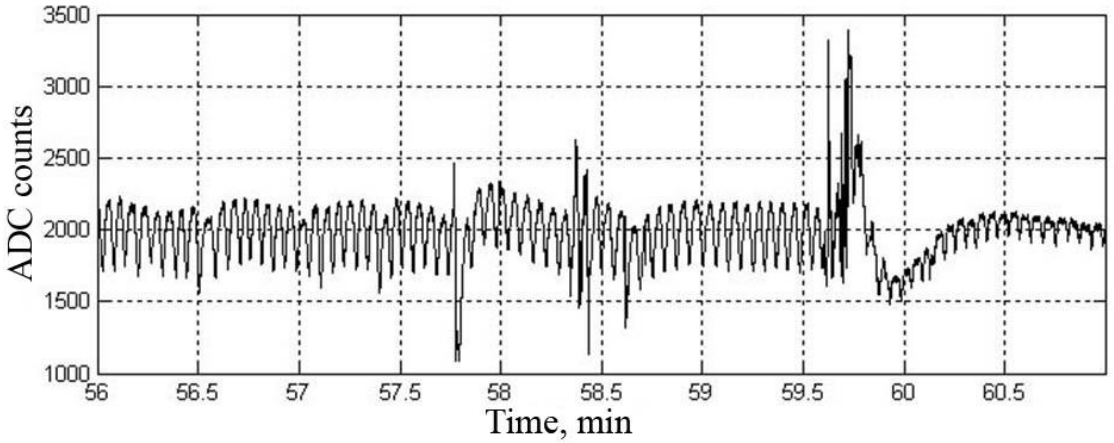
The external view of the facility

Фото 16 из 16
Внешний вид комплекса.
фото: ИМБП/Олег Волошин

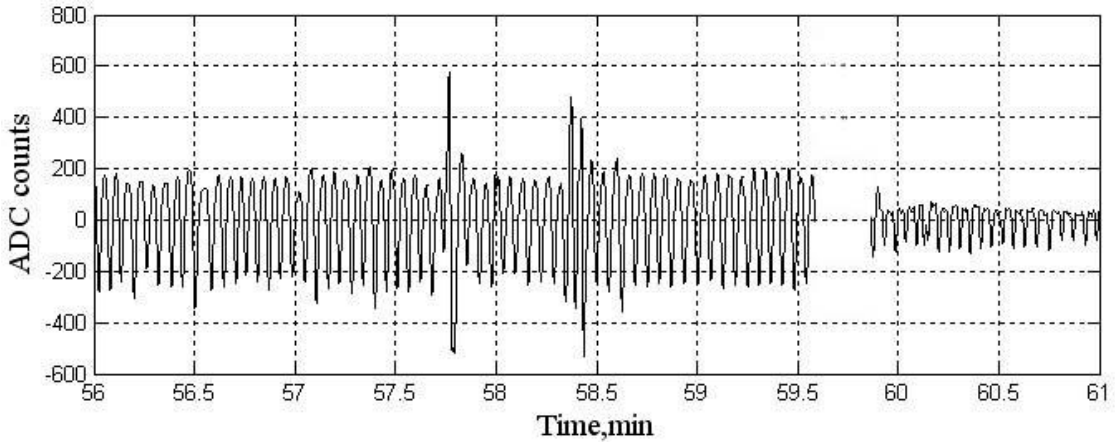
All photos are taken from MARS 500 official website/ Oleg Voloshin

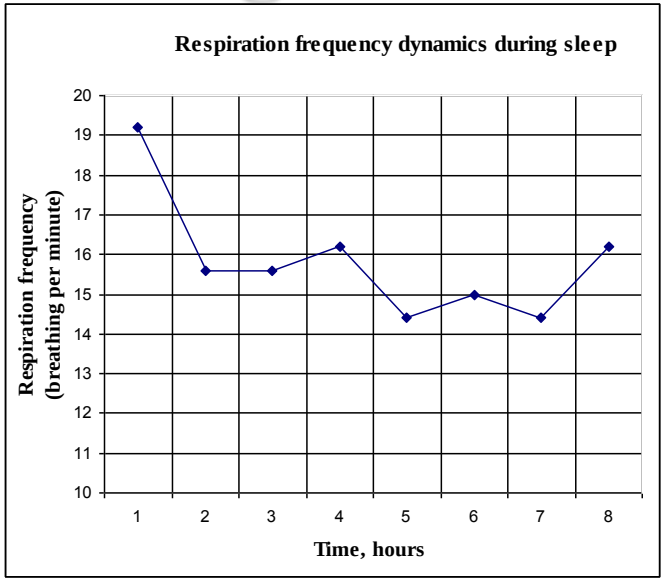
Automatic sleep disturbance diagnosis

Bioradar signal before processing



Bioradar signal after processing



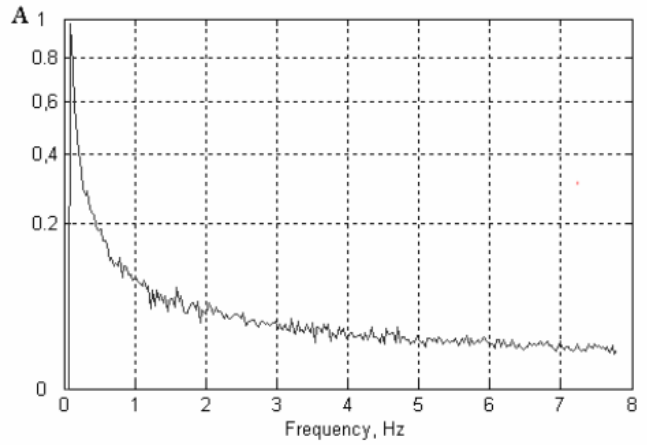


Time intervals, min	Movement artifacts duration, sec
0 ... 60 min	156
61 … 120 min	56
121 … 180 min	154
181 … 240 min	50
241 … 300 min	63
301 … 360 min	75
361 … 420 min	105
Total per night	16 min
Percentage % of the total sleep time	4 %

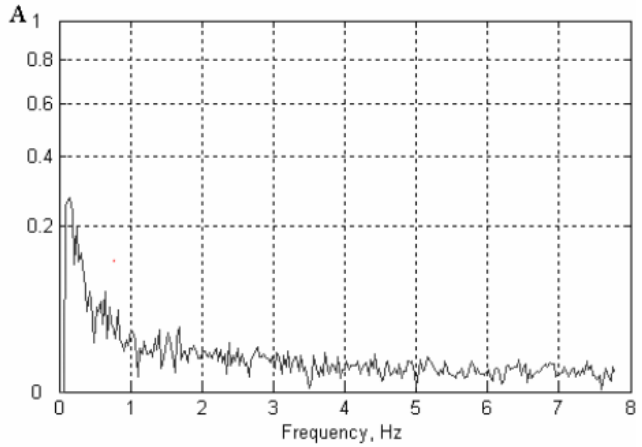
Usage of a Corner Reflector in Experiments

Power flux density for radiolocation $P \sim \frac{1}{d^4}$

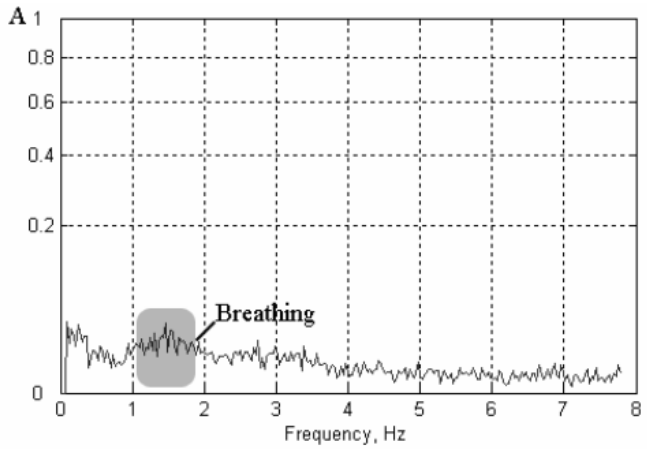
The frequency spectrums of the radar signals for animals' different conditions



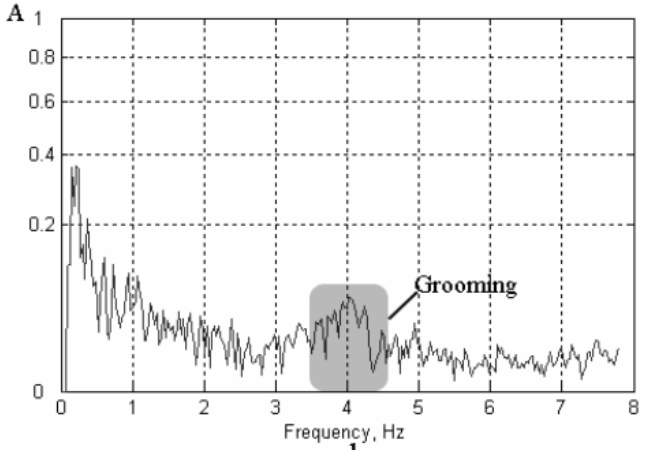
a



b



c



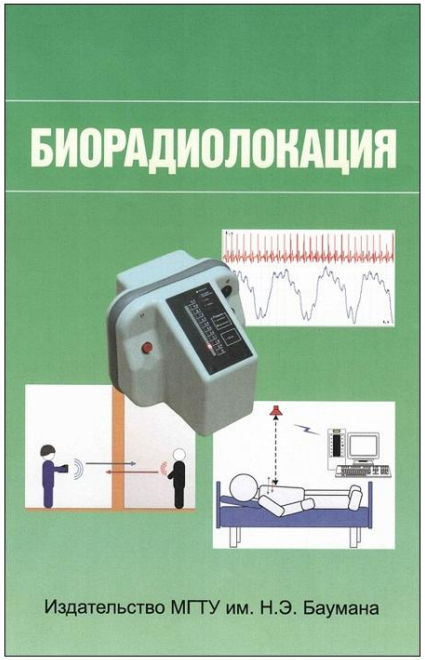
d

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

Conclusion

At present at BMSTU a new bioradar is under construction. It 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.

Book "Bioradiolocation" edited by Bugaev A.S., Ivashov S.I., Immoreev I.Y. was published in 2010 at BMSTU. It is the first handbook written for the field, containing comprehensive information on every aspect of bioradiolocation and its application for medical and special purposes.



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Освещены вопросы радиолокации биологических объектов (биорадиолокации) — метода, который может быть использован для обнаружения живых людей, находящихся за преградами, и дистанционного определения параметров их дыхания и сердцебиения. Биорадиолокация может найти применение в различных областях: спасательных операциях, антитеррористической борьбе, медицине и др. Описаны физические основы процесса биорадиолокации, особенности биорадиолокаторов с непрерывным и импульсным зондирующими сигналами, а также методы расчета и моделирования процессов в биорадиолокации.

Для научных работников, аспирантов и студентов старших курсов.

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Thanks for your attention!

Any Questions?