PAPER • OPEN ACCESS

Study of human skin radiation in the terahertz frequency range

To cite this article: K. Baksheeva *et al* 2019 *J. Phys.: Conf. Ser.* **1410** 012076

View the article online for updates and enhancements.

IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Study of human skin radiation in the terahertz frequency range

K. Baksheeva[1], A. Vdovydchenko[2], K. Gorshkov[1], R. Ozhegov[1,3], N. Kinev[4], V. Koshelets[4], G. Goltsman[1,3]

[1]Moscow State Pedagogical University, Moscow, 119992, Russia

[2]Moscow Institute of Physics and Technology, Dolgoprudny, 115184, Russia

[3]National Research University Higher School of Economics, Moscow, 101000 ,Russia

[4]Kotel'nikov Institute of Radio Engineering and Electronics, Moscow 125009, Russia

Abstract. The radiation of human skin in the terahertz frequency range under the influence of mental stresses has been studied in the current work. An experimental setup for observation of changes in human skin radiation, which occur under the influence of psychological stresses, by means of a superconducting integrated receiver has been developed. More than 30 volunteers participate in these studies, which allows us to verify presence of correlation between the signals from the superconducting integrated terahertz receiver and other sensors that monitor human mental stress.

1. Introduction

In 2007, the image of the sweat gland was obtained for the first time using optical coherence tomography [1]. In Figure 1 it can be seen that the upper part of the sweat duct has a spiral structure. Later, in 2008, based on the geometric dimensions and the fact that the ducts are filled with a conducting liquid, it was suggested that the sweat ducts can work as low-Q terahertz helical antennas [2].
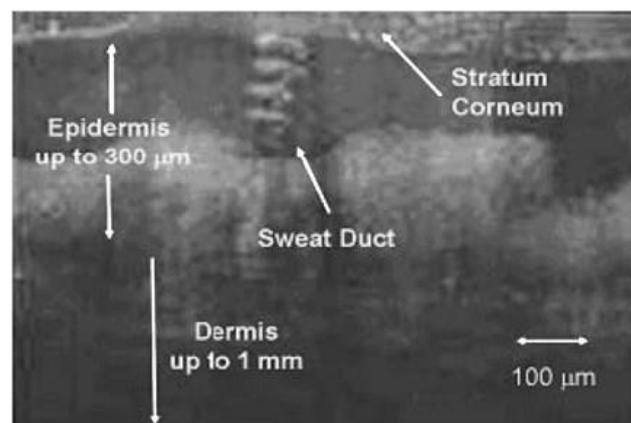

Figure 1. An image of the top layer of the skin obtained using optical coherence tomography.

This hypothesis is developed by a group of scientists led by J. Feldman, who works at the University of Jerusalem [3,4]. In their studies, they measure the characteristics of the duct antenna by removing

the terahertz signal reflected from the skin of the palm. However, if one assumes that the sweat duct acts like an antenna and the human skin is an absolutely black body, then such antennas can affect the power radiated from the skin as a function of wavelength. In this case, these antennas can be studied by measuring the self-radiation of human skin, which is the main goal of our work. The sweat glands are directly controlled by the sympathetic nervous system (SNS). The change in the work of the SNS occurs under the influence of both intense physical exertion, and under the influence of mental activity, as well as from stress and the emotional state of a person. In this case, stress and mental activity can serve as a modulating factor for the antenna, which is the sweat duct. We can change the level of human stress and study the radiation of such antenna.

2. Experiment

To solve this problem, our group has developed an experimental setup, which enables us to probe the radiation of human skin under the condition of mental stresses. A superconducting integrated receiver (SIR), which is under the development at IRE RAS [5, 6], has been chosen as the main receiver element of our setup. SIR is a unique receiver that combines a sensitive terahertz frequency mixer and a highly stable terahertz oscillator equipped with a phase-locked loop and allows recording brightness temperature changes of 10 mK. With the help of this receiver, the brightness temperature of human skin was recorded at a frequency of 550 GHz.

A galvanic skin response sensor (GSR - Galvanic Skin Response) was used to detect stress of human beings. This sensor records the conductivity of human skin. It allows us to track changes in the sympathetic nervous system of the person under stress. A thermometer and a photoplethysmograph were also used to monitor the pulse and the blood oxygen level. These sensors were attached to the person's arm, from which the radiation was detected. The hand itself during the experiment was fixed with the holder.

A test report was developed and prepared. This protocol can be divided into five parts. The first part - a period of relaxation, lasts for five minutes. At this time, views of nature are shown on the monitor in front of the subject, and relaxing melodies are fed into the headphones that are worn on him. The second part associates with to the period of mental stress at the subject. During this period, different types of mental stress alternate: the Stroop test and the figure test. In the Stroop test, a person is asked to correlate the color of a word, which means some other color, with one of the suggested options. So for example, if the word "red" is written in green, a person must find among the listed options "green" and select it. In the test with the figures, the subject is shown various shapes that follow each other, and the person must choose whether this image corresponds to what was previously. All this, as well as in the Stroop test, should be done in a limited time, accompanied by intense music. This stage also lasts for five minutes, one minute is allotted for each task. Then a five-minute period of relaxation takes place. The fourth stage is physical activity, during which the subject must compress the ball. This stage lasts for two minutes. And the test report also ends with a relaxation period that lasts for one minute. The entire protocol of measurements on one person takes eighteen minutes. Since the procedure was automated, the human factor during the tests was minimized.

3. Discussion

Currently, studies have been taken on 32 volunteers aged 18-35 years of both genders. According to the data obtained, correlations of the signals from the superconducting integrated receiver and the GSR sensor were calculated. Figure 2 (a, b) presents an example of the dependence of the normalized readings of the SIR and GSR signals on time and a graph of the obtained correlation of these signals. As can be seen from Figure 2 (a), the graph of GSR versus time (the blue line on the graph) decreases during the stages of relaxation, while under mental and physical loads, the graph increases dramatically, indicating a change in the state of the subject. Also, the graph of the dependence of SIR on time has its' peaks. These data differ from the readings taken with a thermometer, which indicates the presence of some additional signal component.

The primary results of the correlations were inconsistent. The results obtained during data processing showed that the correlation of signals is inhomogeneous both in time and from person to person. For

all subjects, the correlation of the signals had a different shape and meaning, for some people the correlation was positive, for the others it was negative, while for third group it was equal to zero.
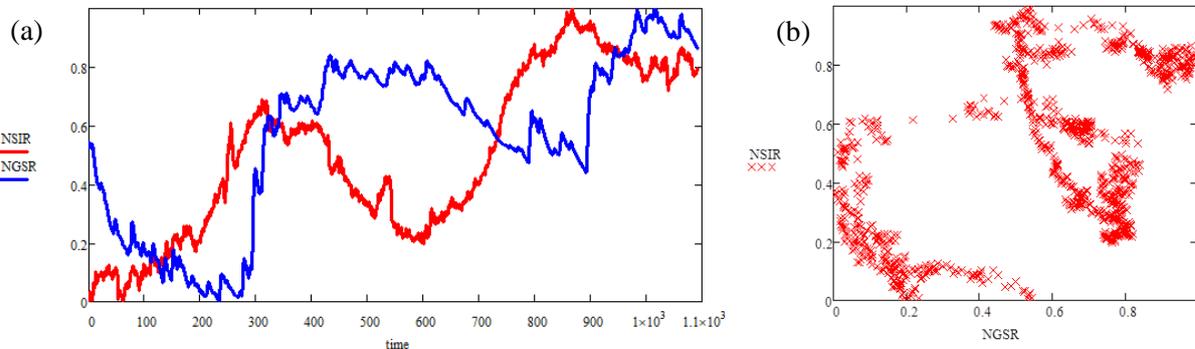

Figure 2(a, b). (a) Readings from the GSR and the integral receiver as the function of time; **(b)** Correlation between the readings from the integrated receiver and the GSR sensor.

From Figure 2 (a, b) it is clear that the correlation of signals is low and corresponds to 0.461. This may be caused by the difference in the relaxation processes of the galvanic response of the skin, which were described in [7], and its terahertz radiation. This fact leads to the necessity in further data processing. A matrix of correlations of signals GSR and SIR was constructed and considered, with additional processing of SIR data. Namely, it was considered how the correlation of the signals of these two receivers will change, after compression-defragmentation and a time shift analysis of the SIR data. The resulting correlation matrix is presented in Figure 3. The vertical axis represents the compression-tension of the raw SIR data over time. In this case, 0 corresponds to data stretching by approximately 30%, and 30 corresponds to data compression by approximately 30%. The horizontal axis represents the time delay of the received SIR data relative to the GSR data. In the resulting picture, the red areas correspond to the positive correlations, the blue ones to the negative, and the green ones to the absence of correlation.

The correlations obtained at very large time shifts were discarded from the consideration, since in such cases the data sets is too short for the correct correlation analysis. Thus, we considered the correlations of the signals which delay didn't exceed half of the total test time (400 seconds). In the figure 3, the region of maximum obtained correlation of signals with additional data processing is highlighted. When plotting the dependencies of the GSR and SIP data, taking into account the additional processing, which corresponds to the maximum correlation (Figure 4 (a)), we can see that the shapes of the data sets are very similar.
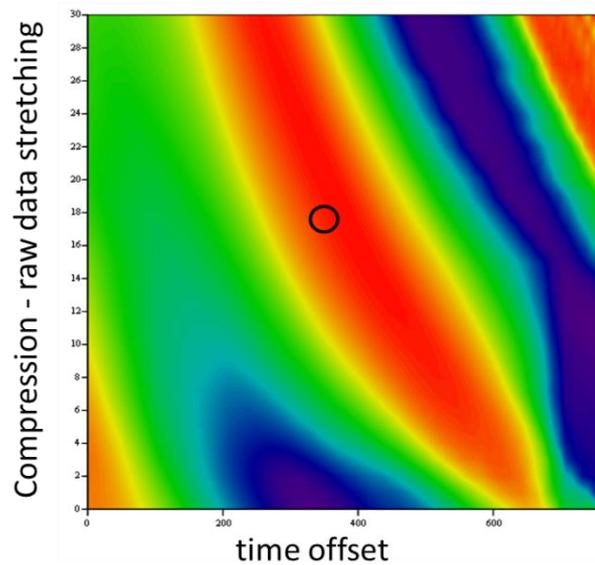
Figure 3. The correlation matrix of GSR and CIP signals, with the additional data processing

3. Results

The correlation achieved with additional data processing was 0.968. (Figure 4 (a, b)) Such correlation level was achieved when the CIP graph was shifted by 375 s. Such long signal delay may be caused by the difference in the mechanisms of the occurrence of signals recorded by the sensors. The difference in the response mechanisms leads to the difference in the response and relaxation time as the reaction to stress. These mechanisms are not well understood and require additional research.
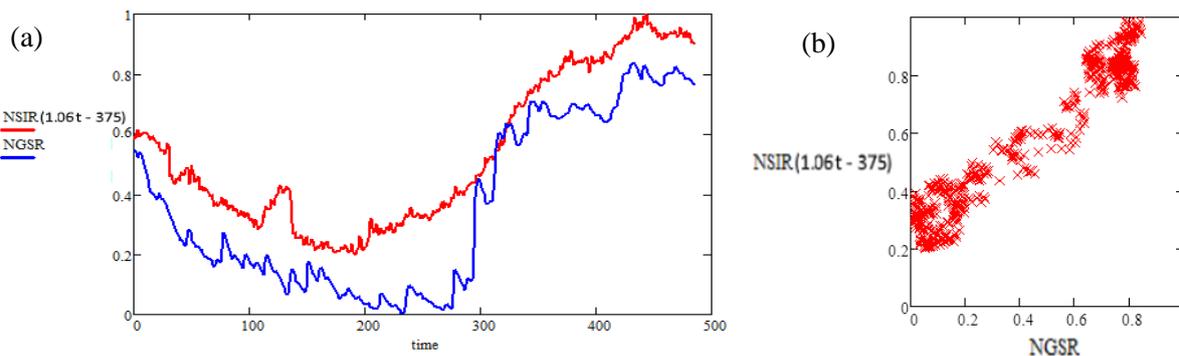

Figure 4(a, b). (a) Readings from the GSR and the integrated receiver as the function of time after additional data processing; **(b)** Correlation between the readings from the integrated receiver and the GSR after additional data processing.

Acknowledgments

References

[1] Lademann J., Otberg N., Richter H., Meyer L., Audring H., Teichmann A., Thomas S., Knüttel A., Sterry W. 2007 *Skin Res. And Tech.* **13**.

[2] Feldman Yu., Puzenko A., Ben Ishai P., Caduff A., A. J. Agranat A. J. 2008 *Phys. Rev. Lett.* **100**

[3] Safrai E., Ishai P.B., Caduff A., Puzenko A., Polsman A., Agranat A.J., Feldman Y. 2012 *Bioelectromagnetics* **33** 5

[4] Betzalel N., Feldman Y., Ishai P.B. 2017 *IEEE Transactions on Terahertz Sci. and Technol.* **7** 5

[5] Koshelets V.P., Shitov S.V., Filippenko L.V., Baryshev A.M., Golstein H., De Graauw T., Luinge W., Schaeffer H., Van De Stadt, H. 1996 *Applied Phys. Lett* **68**

[6] Koshelets V.P., Shitov S.V. 2000 *Superconductor Sci. and Technol* **13**.

[7].J. Bakker, M.Pechenizkiy, N. Sidorova 2011 *11th IEEE International Conference on Data Mining Workshops*