Do humans "shine" in the sub THz?

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***Abstract*— Radiometry experiments, performed on human subjects, show that in the vicinity of a central frequency of 507 GHz the emission of the human skin is substantially non-equilibrium in its nature. The intensity of the radiation registered using a superconducting integrated receiver (SIR) [1], was correlated with the level of the physical and mental stress of subject under examination. This result suggests that human skin may generate sub-THz waves.**

I. INTRODUCTION

Traditionally, the electromagnetic spectra of a human being has been considered only in terms of the Infrared. However, we present results that demonstrate that the traditional view is not complete. There is also a marked contribution in the sub-THz region, far in excess of the expected Blackbody contribution. This begs the question: Do humans produce radiation in the sub-THz frequency band? If yes, then one may ask where in the skin layer would it originate? In 2008, we demonstrated that the Human sweat gland ducts, coiled in the epidermis, could be regarded as electromagnetic entities [2] and in 2014 that they could behave as an array of helical antennas [3]. The results of our previous studies clearly indicate that the reflection coefficient of the human hand is correlated to universally accepted indicators of mental stress [4, 5]. One may speculate on these structures being at least involved with this new experimental observation.

II. METHODS

The radiometry measurements for 25 human subjects were provided with superconducting integrated receiver (SIR) at a frequency 507 GHz[1]. The block diagram of the experimental set-up is presented in Figure 1.

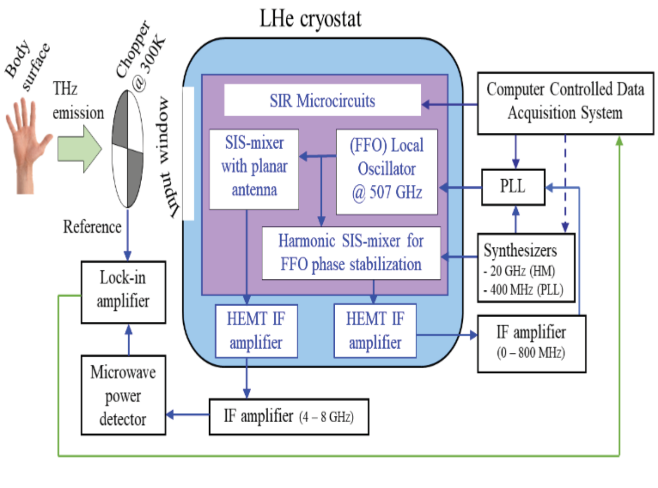

Figure 1 The block diagram of the experimental set up; the width of the heterodyne line in stabilized mode is ~ 0.1 MHz; the modulation frequency of the chopper ~ 15 Hz. The characteristic receiving signal on the synchronous amplifier is 0.7-1.5 mv [1].

During the radiometry measurements, the subject under examination was exposed to varying levels of physical and mental stress according to a well-defined protocol. In this setup, the hand was placed in front of a detector and the recorded signal was collected from the subject's hand in a double side band 499 - 503 and 511-515 GHz respectively [1]. The total distance between the measured palm and the lens plane is 295 mm and that corresponds to the far field zone, where the angular pattern size is proportional to the wavelength. The protocol lasted 18 minutes and consisted of consecutive rest and stress periods (Mental stress and Physiological) (See Figure 2).

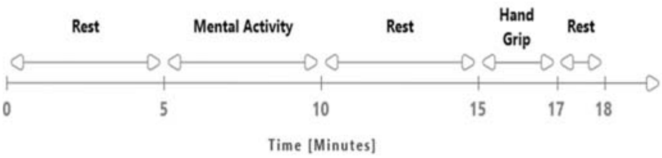

Figure 1 The timeline of experimental protocol

The SIR measurements were accompanied by several concurrent physiological measurements (Galvanic Skin Response (GSR), Pulse rate and Temperature).

III. RESULTS

An example of the de-trended and normalized SIR and GSR signals for one subject is presented in Figure 3.

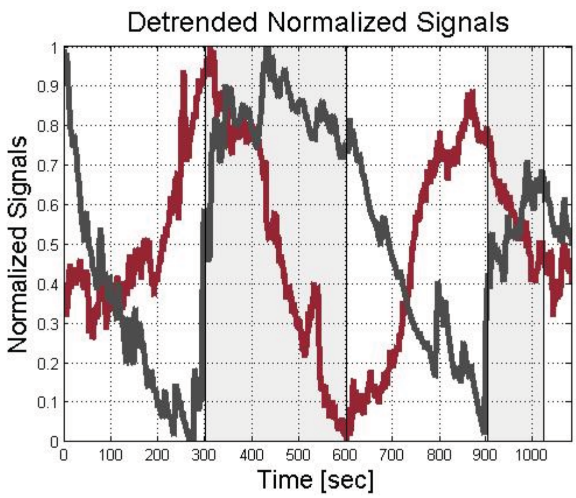

Figure 3 The de-trended and normalized SIR (Red) and GSR (Black) signals measured for one subject; The interval 300 -600 seconds corresponds to mental stress; the interval 900-1000 seconds corresponds to physical stress. Both stress intervals are marked by the shade boxes.

For this particular subject, the behavior of the GSR signal in both intervals of the protocol (mental and physical stress) is

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qualitatively the same and well known [6]. During the period of stress, the signal is increased dramatically, passed through the maximum and then subsided smoothly. While the SIR signal shows a negative correlation at all intervals, including rest intervals: the growth of the GSR signal is accompanied by a decrease in the SIR signature. Analytically, the dependence of the measured SIR signal from time is presented in the form of

$$SIR_{Raw}a(t) = K\left[\alpha_{eff}(t) \cdot T_h(t) - T_{ch}\right], \quad (1)$$

where K is a calibration factor, $\alpha_{eff}(t)$ is an effective grayness factor, $T_h(t)$ is a skin temperature, T_{ch} is the chopper temperature (equal to room temperature). Unlike the gray factor in the theory of equilibrium thermal radiation [7], the effective grayness factor can exceed 1, due to a non-equilibrium contribution of radiation from the human body. Putting in (1) $\alpha_{eff}(t) = 1 + \Delta\alpha(t)$, we will get

$$\Delta\alpha(t) = \frac{SIR_{raw}(t) - SIR_{BB}(t)}{KT_h(t)}, \quad (2)$$

where

$$SIR_{BB}(t) = K[T_h(t) - T_{ch}] \quad (3)$$

is an equilibrium skin radiation as an absolute black body. Figure 4 presents $SIR_{Raw}(t)$ and $SIR_{BB}(t)$.

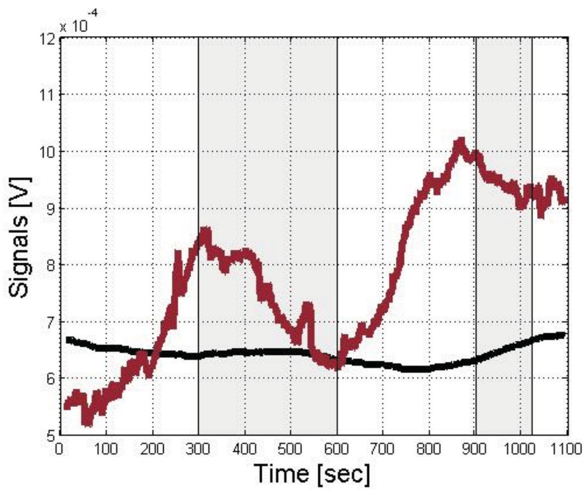

Figure 4 The comparison of SIR_{BB} (Black) and SIR_{Raw} (Red) during the time of protocol. Both stress intervals are marked by the shade boxes.

From Fig. 4 it is clear that there is an excess of the measured signal from the skin over a black body at the skin temperature. Because the black body radiation is an upper limit of equilibrium radiation, it can be argued that the observed excess indicates the presence of non-equilibrium contribution of human body emission. Furthermore, the variation of the raw signal amplitudes in Figure 3 significantly exceeds the amplitude of variations of skin radiation as a black body during the period of the stress/rest protocol.

Figure 5 presents the histogram of correlation coefficients (Spearman ranked correlation) between the GSR and the SIR signals for 25 subjects during the mental stress period of the protocol

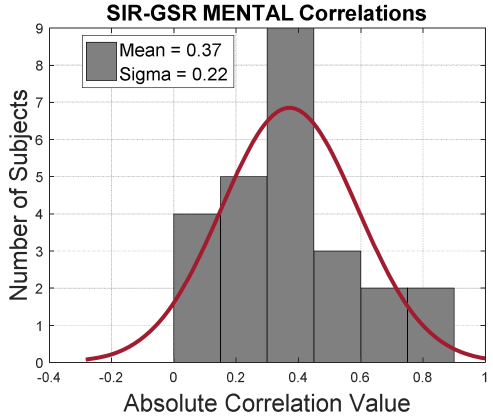

Figure 5. The histogram of modules of correlation coefficients (Spearman ranked correlation) between GSR and SIR for 25 subjects. The mean value of correlation is 0.4 with a standard deviation σ= 0.22

The results conclusively demonstrate that the human being is irradiating energy in the sub THz region and that the source of this energy cannot be assigned to a blackbody component. Furthermore, the intensity of this source can be influenced by the mental state of the individual. The inference is that the Sympathetic Nerve System [8] is engaged. Based on our previous work [2-5] on the reflection coefficient of human skin in the Sub-THz frequency range we suggest that the helical sweat ducts may play a significant role in this phenomenon.

AKNOWLEDGEMNTS

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