RF Sensing of Human Physical Condition in the mm-Wave / THz Frequency Range

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The objective of this study is to investigate the possibility of detecting mental and light physical stress via measurement of the reflectance of the skin in the mm-wave/sub-THz band. The combination of the spatial and temporal response of the reflectance offers the potential to enable a generic method for non-contact sensing of the physical and emotional state of human beings.

Various sources in literature have reported the possibility to detect stress based on changes in the galvanic skin response (GSR) [1]. It has also been shown that the GSR is correlated with the reflection coefficient of the skin and that it is possible to assess it via changes in the skin's reflectance at frequencies in the mm-wave / sub-THz band (e.g. 75-170 GHz).

Currently, these frequency bands can be reached with CMOS technology, which is capable of operation up to about 500 GHz. This, coupled with the fact that mm-wave / sub-THz radiation is non-ionizing, opens the door for realization of miniature, low-power, safe and low-cost solutions for potential applications in the domains of health (e.g. contactless scanner for stress sensing) and security (e.g. remote lie detector).

In the present study, the detection of physical and mental stress is investigated through measurements of the skin reflectance in two frequency bands: 75-110 GHz (Band-I) and 325-500 GHz (Band-II). The skin reflectance was measured during rest and after mental and physical stress. Physical stress was induced by grabbing a dynamometer with 15 N of force for 5 minutes. Mental stress was achieved with the use of the Stroop Test (online test(s) to test capacity to direct attention) for 15 minutes.

The measurement setup his shown in Figure 1 below.

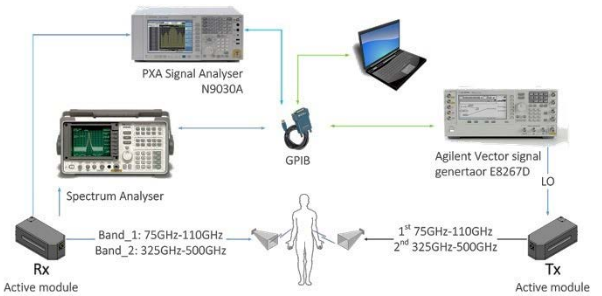

Figure 1: Measurement setup.

Three measurement conditions were considered: (1) Rest; (2) Mental stress: After stroop test for 15 minutes and (3) Physical stress: After dynamometer under 15 N of force for 5 minutes.

Stress measurements were always preceded by a rest period of at least 15 minutes. Three locations on the hand were considered for the purposes of the measurements (Figure 2): arm, hand and finger.

Figure 2: Measurement locations.

Figure 3 depicts the averaged results of measurements performed between 440 GHz and 480 GHz in frequency band II for at least five persons. It can be seen that the shape of the measured amplitude (i.e. the shape of the spectrum) over this frequency range is effectively the same in the case of stress as it is in the case of rest. However, there is a clear difference between the results at rest and under stress. The measured amplitude response is stronger in the case of stress than at rest (i.e. about 7 dB across the frequency range for measurements performed on a hand (top) and 3.5 dB in the case of measurements performed on a finger (bottom). Similar results were obtained in the case of frequency band 1, but the differential between case of stress and rest was found to be much smaller (i.e. 1 dB).

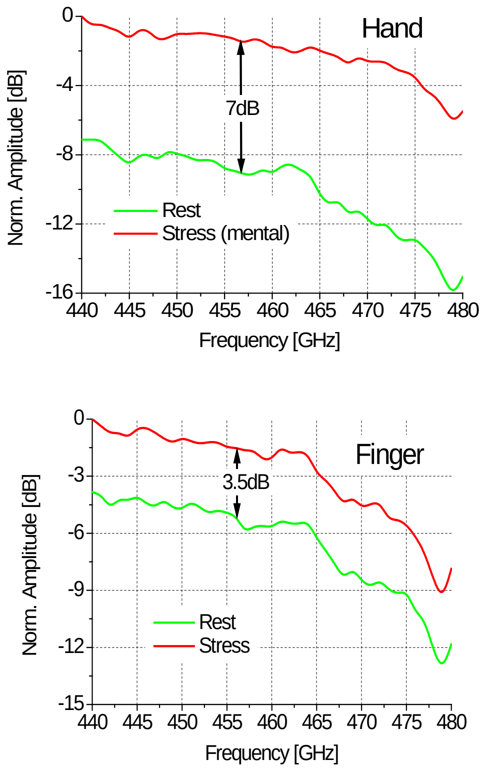

Figure 3: Mental stress based on measurement of the skin reflectance on a hand (top figure) and on a finger (bottom finger). The measurements were performed in frequency band II (440-480 GHz).

The results, in particular in frequency band II, demonstrate the potential for remote, non-contact sensing of stress [1]. This research has been supported by funding from an internal CSEM Grant and EU H2020 Framework program (M3TERA, grant no. 644039).

[1] M. V. Villarejo, *et al.*, "A stress sensor based on galvanic skin response (GSR) controlled by ZigBee", Sensors 5 (2012) 6075.