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Artificial Intelligence in Millimeter-Wave and THz Spectroscopy for Biomedical Applications

Tobias Liebchen[1,2], Adam Rämer[2], Torsten Djurhuss[1], Giacomo Ulisse[1], Viktor Krozer[1,2], Wolfgang Heinrich[2]
[1] Goethe Universität Frankfurt am Main, Frankfurt am Main, Germany, tobias.liebchen@fbh-berlin.de
[2] Ferdinand-Braun-Institut, Berlin, Germany, viktor.krozer@fbh-berlin.de

Abstract

Millimeter-wave and THz spectroscopy is an enabling technology for non-invasive biomedical applications, because the interaction of biological matter with signals in this frequency range reflect the metabolism and cell activity in human body. The complex signatures of spectroscopic responses require signal processing using advanced algorithms and artificial intelligence signal processing. This paper presents advances in THz technology and in AI based signal processing.

1 Introduction

Millimeter-wave and THz signals exhibit a strong interaction with biological matter, which can be efficiently employed in biomedical applications due to the non-ionization properties of electromagnetic waves (EM-waves) at these frequencies. Millimeter-waves penetrate deeply through the human skin and can therefore be utilized for metabolic studies of human health for invasive and non-invasive situations. THz signals do not penetrate through biological tissue due to high water content, but can be efficiently used for cell structure and activity studies.
We have developed components and systems in both frequency ranges and will present results on hyperglycaemia monitoring, non-invasive blood coagulation studies and THz camera devices for human skin monitoring.

2 Millimeter-Wave Systems

We have developed a W-band spectroscopy system for the studies of sustained hyperglycaemia and blood coagulations [1],[2]. In case of Diabetes monitoring we have performed initial clinical studies on 27 patients and processed the data of these using artificial intelligence and principal component analysis. The spectra are obtained by radiating the subject, through a skin fold, at 49 equidistant discrete frequencies in the range 75-110 GHz. The hyperglycemic state of the subjects leads to identifiable markers in the transmission spectrum, which allow a classification algorithm to flag a sample spectrum either healthy or diabetic.

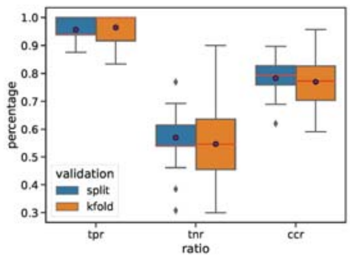

Figure 1: Boxplot describing the response statistics of the measured spectra and the DNN model discussed

The Figure 1 describes the statistics of the true positive (TP), true negative (TN) and correct classification (CC) ratios, obtained using two different validation methods. The boxes represent the quartiles of the dataset (i.e. 75%), while the bars extend to show the rest of the distribution, except for points that are determined to be outliers (diamonds). The mean of the distribution is represented by a dark dot whereas the median is shown as a red line. The DNN model is capable of predicting healthy subjects with accuracy, which can be substantially improved by increasing the number of the participants in the study.

3 THz Detector Arrays

THz spectroscopy is currently limited by the sensitivity of broadband detectors and by large area focal plane arrays. Both topics are being studied at FBH and we have developed a 144 element THz broadband THz detector array, as indicated in Figure 2 [3],[4]. This detector array can be assembled into a large pixel count THz camera for skin cancer studies and for industrial applications.

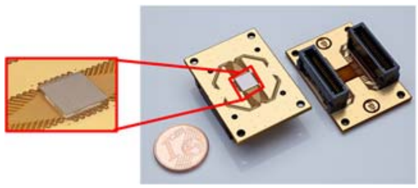

Figure 2: THz detector array based on GaN HEMT and broadband antenna structures.

4 References

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