ABSTRACT

In recent years, THz spectrometers and imaging systems have become part of standard laboratory tools thanks to the advancements in THz source and detector technology. Applications include explosive and concealed weapon detection, non-destructive testing, pharmaceutical quality control, and biomedical imaging. Sub-THz (0.1-0.3 THz) and THz (0.3-10 THz) radiation, which are non-ionizing and highly sensitive, have recently garnered great interest in tissue diagnostics and screening applications in vivo and ex vivo.

The use of electro-optical pulses into Time-domain Spectrometers (TDS) has become increasingly common for analyzing biological samples because they produce a broad spectrum of spectral responses. The electro-optic sampling-based TDS setups are cumbersome and expensive, so it is not practical to use this technology to develop portable and affordable imaging and sensing devices. Furthermore, the setup lacks accuracy in the sub-THz region due to the inefficiency of the laser source. Electronics based on sub-THz technology have eliminated this barrier, allowing the development of compact, robust, and easy-to-use devices for biological applications.

In addition, some biomedical applications of the electromagnetic spectrum require monitoring of real-time parameters associated with human physiological states. In these applications, signal processing of biomedical signals requires advanced computational methods that can be parallelized using high-performance platforms like GPUs and TPUs. The use of these computer technologies has enabled huge amounts of data to be modeled through machine learning. The aim of this thesis is to combine sub-THz technology with machine learning in order to develop an automated diagnostic strategy for obtaining and interpreting data from electronic sub-THz measuring equipment.

In this regard, the thesis discusses two important applications in which sub-THz electronics improve upon existing approaches for non-invasive blood glucose measurement and surgical tumor margin assessment. In the first application of non-invasive glucose measurement, S parameters' response from glucose samples of varying concentrations is measured using sub-THz waveguide probe sensors. The proposed sensor system has a sensitivity of 2 dB for a change in glucose concentration of 15 mg/dl, which is within the clinical range for non-invasive diabetes monitoring devices. As a result of including machine

learning in the system, the readability of the measuring system is improved because of the non-linear relationship established between S parameters and glucose concentration readings.

In the second application, a highly sensitive, highly efficient, and cost-effective sub-THz waveguide iris probe is designed for the detection of tumor margins during lumpectomies. This probe can detect both positive and negative margins over a frequency range of 110-170 GHz, suggesting its application in intraoperative tumor margin assessment. It is accomplished by placing the scanning probe in direct contact with the excised breast tissue. For both applications, numerical phantoms and physical phantoms are used to test the sensors' performance and accuracy at sub-THz frequencies. A demonstration of automation of imaging set up in a second application illustrates the importance of system automation for accelerating data acquisition and processing.