Characterizing and Mitigating Scattering Effects in Terahertz Time Domain Spectroscopy Measurements

by

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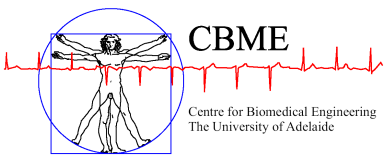

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Contents

Abstract

Terahertz research has came a long way since its inception in the mid 1980s when the first pulsed THz emission was reported using electro-optic sampling. With rapid advent in THz generation and detection techniques, research in terahertz time-domain spectroscopy (THz-TDS) has progressed to such a great extent that terahertz is finding potential use in real world applications such as biomedical sensing, security screening and defence related applications. While many researchers and commercial organizations have successfully demonstrated efficacy of terahertz, various challenges still exist before THz technology transitions from the realm of research into everyday life.

This thesis focuses on the topical area of characterization and mitigation of scattering in terahertz time-domain spectroscopy measurements. Motivated by the lack of theoretical models and signal processing techniques, this thesis, presents several pieces of novel work that include theoretical models, numerical methods, signal processing techniques and experimental procedures to estimate and mitigate the scattering contribution in THz-TDS measurements of dielectric materials. The thesis is divided in to three main sections:

Section I

Section I describes the various theoretical models developed for estimating and approximating the scattering cross-section, when an electromagnetic wave interacts with a random medium with characteristic particle dimensions comparable to the wavelength of the incident radiation. The section is divided in two main sub-sections, (i) scattering through a sparse distribution of particles, and (ii) scattering from dense media.

Section II

Section II presents several signal processing based approaches for estimating and mitigating scattering effects in THz-TDS measurements for samples that exhibit sharp and sparse absorption features, without requiring *a priori* information such as its granularity, refractive index, and density.

Section III

Section III discusses some common experimental techniques such as milling the material of interest into fine powder and time domain averaging spatially disjoint or multiple sample measurements, in order to reduce the presence of scattering features and effects in the THz-TDS measurements. Recognizing the invasive access and/or specialized measurement apparatus requirement for these techniques, we present our preliminary investigation in analysing multiple Fresnel echoes for estimating and mitigating scattering contribution in THz-TDS measurements.

In addition to this, the thesis offers an introductory background to THz-TDS, in areas of hardware, applications, signal processing, and terahertz interaction with matter.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Mayank Kaushik and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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25 January 2013

Signed

Date

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Conventions

Typesetting This thesis is type set using LaTeX2e software using the TeXnicCenter interface.

Referencing The Harvard style is used for referencing and citations in this thesis.

Spelling Australian English is adopted as spelling convention in this thesis.

System of units The units used in this thesis comply with the international system of units recommended in an Australian standard: AS ISO 1000-1998 (Standards Australia Committee ME/71, Quantities, Units and Conversations 1998).

Physical constants The physical constants comply with the recommendation by the Committee on Data of Science and Technology: CODATA (Mohr and Taylor 2005).

Definition In this Thesis, the terahertz band is defined as being from 0.1–10 THz (1 THz = 10^{12} Hz).

Publications

Journal Publications

Kaushik-M., Ng-B. W.-H., Fischer-B. M. & Abbott-D., (2012). Reduction of scattering effects in THz-TDS signals, *IEEE Photonics Technology Letters*, **24**(2), pp. 155−157.

Kaushik-M., Ng-B. W.-H., Fischer-B. M. & Abbott-D., (2012). Terahertz scattering by granular composite materials: An effective medium theory, *Applied Physics Letters*, **100**(1), art. no. 011107.

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Conference Publications

Kaushik-M., Ng-B. W.-H., Fischer-B. M. & Abbott-D., (2010). Mitigating scattering effects in THz-TDS measurements, *35th International Conference on Infrared Millimeter and Terahertz Waves (IRMMW-THz)*. DOI: 10.1109/ICIMW.2010.5612470.

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