# Engineering Aspects of Terahertz Time-Domain Spectroscopy

by

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# Abstract

Terahertz time-domain spectroscopy (THz-TDS) is a technique capable of measuring optical constants of materials with T-ray frequencies, bounded between 0.1 and 10 THz. Owing to the infancy of the technology, much work has to be carried out to improve its utility and reliability. Engineering aspects become vital to support its operation that relies on physical phenomena. This thesis, in the arena of engineering, encompasses a variety of original THz-TDS projects, which aim for (**Part I**) signal enhancement and classification, (**Part II**) system evaluation and optimisation, and (**Part III**) T-ray optics:

**Part I** is relevant to enhancement and classification of T-ray signals via digital signal processing. In one project, information underlying T-ray signals is enhanced through numerical removal of unwanted artefacts that are introduced by the response of water vapour during the measurement. In another project, machine learning is recruited in classification of visually indistinguishable T-ray signals probing materials of the same general class.

**Part II** focuses on THz-TDS systems with a particular interest in the measurement precision. An ISO standard for the evaluation of measurement uncertainty is adopted for assessing the uncertainty in THz-TDS measurements. The result is an analytical uncertainty model, which allows an improvement in the measurement precision through optimisation of a model parameter in the subsequent work.

**Part III** involves design, fabrication, and characterisation of THz-TDS hardware components, i.e., antireflection windows and multilayer interference filters. The designs are based upon conventional optical interference theory. Despite that, required materials and fabrication processes are completely different from those used in optics due to the distinctive operating wavelengths, which dictate material responses and structural dimensions.

In addition to these parts of the original contributions, the thesis offers an introductory background to THz-TDS, in the areas of hardware, applications, and data processing.

# 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 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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|---|---|
| | December 20, 2009 |
| Signed | Date |

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W. Withayachumnankul

# Conventions

**Typesetting** This thesis is typeset using the LaTeX2e software. TeXnicCenter is used as an effective interface to LaTeX.

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

**Spelling** Australian English spelling is adopted, as defined by the Macquarie English Dictionary (Delbridge 2001).

**System of units** The units comply with the international system of units recommended in an Australian Standard: AS ISO 1000—1998 (Standards Australia Committee ME/71, Quantities, Units and Conversions 1998).

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

**Frequency band definition** It is preferential to refer to the spectrum band from 0.1 to 10 THz as ’T-rays’, according to an argument by Abbott and Zhang (2007), rather than ’terahertz’. However, ’terahertz time-domain spectroscopy—THz-TDS’ and ’terahertz gap’ are acceptable owing to the general acceptance.

# Publications

## Journal publications

**WITHAYACHUMNANKUL-W.**, FISCHER-B. M., FERGUSON-B., DAVIS-B. R., AND ABBOTT-D. (2009). A systemized view of superluminal wave propagation, *Proceedings of the IEEE*, (Accepted, 23-09-2009).*

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**Note**: Articles with an asterisk are not directly relevant to this thesis.

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