Terahertz Reflectarrays

by

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Contents

Abstract

REFLECTARRAY, the concept combining the principles of phased arrays and geometrical optics, can produce predesigned radiation characteristics without requiring a complicated feeding network. A free-space excitation is used to illuminate reflectarrays with passive resonant elements made of metal and dielectric structures, whose individual reflection phase is dependent on the size and geometry of a radiating resonator. Reflectarrays offer the advantages of flat profile and high efficiency, and therefore various reflectarray structures have been intensively realised in the microwave region. With the development of integrated circuit lithography processes, the application of the reflectarrays has been extended to the infrared and even to the visible light regions. However, the realisation of the reflectarrays that can manipulate beams in the terahertz regime still remains largely under-explored, because of the high intrinsic material loss and due to the challenges associated with measurement technology in this frequency range. In recent years, owing to emerging solid-state sources and detectors in the terahertz spectrum, high-gain antennas have become intensively required for constructing terahertz wireless networking or imaging systems. Low-loss terahertz reflectarray antennas thus promise attractive potential for enabling the manipulation of terahertz radiation. This thesis will first introduce the background of terahertz technology, approaches for manipulating terahertz radiation, and fundamental theories for reflectarray design. Following the introductory chapters, the core of the thesis shows how several terahertz reflectarrays have been designed, fabricated, measured and analysed for the aim of (**Part I**) beam deflection with polarisation independence, (**Part II**) beam splitting with polarisation dependence, and (**Part III**) broadband operation:

Part I involves a terahertz reflectarray that is composed of resonant microstrip gold patches on a dielectric substrate. The relation between the patch size and the reflection phase is analysed for a realisation at 1 THz. A subarray is then configured based

on a progressive and cyclic phase distribution to deflect an incident beam into a predesigned angle off the specular direction. Both the numerical simulation and the experimental measurement verify that the proposed reflectarray can efficiently deflect the incident TM and TE polarised waves into the same desired direction at an operation frequency.

Part II focuses on reflectarray designs that can split an incident beam into two different directions with polarisation dependence. In the first realisation, two sets of orthogonal strip dipoles are arranged into interlaced triangular lattices, whereas the second realisation is based on metallic wire grids patterned into square layout with variable lengths backed with wire-grid ground layer. Both configurations of reflectarrays can separate the two polarisation components into different designed directions by deflection or transmission. The designs are realised for experimental validation, and the corresponding measurements are performed in a terahertz time-domain spectroscopy system. The measurement results verify the designs and show acceptable efficiency and high polarisation purity of these polarisation beam-splitters.

Part III concerns the design of novel radiating resonators for broadband reflectarrays. Three parallel elliptical dipoles with variable lengths are proposed to enable broadband operation. A reasonably linear phase response with a wide enough range is obtained by the proposed configuration while the phase curves for different frequencies are nearly parallel each other over a wide frequency range. The simulated field distributions and radiation patterns at different frequencies in the terahertz range demonstrate that the designed reflectarray can perform as expected in a wide frequency band.

These original designs along with corresponding experimental validations offer a first demonstration of reflectarray in the terahertz regime, with antennas composed of metal-dielectric resonators. This is an important progress in expanding approaches for terahertz wave manipulation. The designed reflectarrays with different structures can be utilised as high-efficiency components for advancing the technologies of high-speed communications and high-resolution imaging in the terahertz range.

Statement of Originality

I certify that this work contains no material that has been accepted for the award of any other degree or diploma in my name, 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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Signed

09/11/2015

Date

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Thesis Conventions

The following conventions have been adopted in this Thesis:

Typesetting

This document was compiled using LaTeX2e. TeXnicCenter was used as text editor interfaced to LaTeX2e. Adobe Illustrator CS2 was used to produce schematic diagrams and other drawings.

Spelling

Australian English spelling conventions have been used, as defined in the Macquarie English Dictionary (A. Delbridge (Ed.), Macquarie Library, North Ryde, NSW, Australia, 2001).

Referencing

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

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).

Publications

Journal Articles

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List of Figures

List of Tables