

Dielectric Resonator Antennas: From Multifunction Microwave Devices to Optical Nano-antennas

by

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Abstract

Since a cylindrical dielectric resonator antenna (DRA) was firstly proposed by Long et al. in the 1980s, extensive research has been carried out on analyzing DRA shapes, characterizing the resonant modes, improving their radiation characteristics with various excitation schemes. Compared with conventional conductor-based antennas, DRAs have attractive features such as small size, high radiation efficiency and versatility in their shape and feeding mechanism.

Importantly, various orthogonal modes with diverse radiation characteristics can be excited within a single DRA element. These modes can be utilized for various requirements, which makes the DRA a suitable potential candidate for multifunction applications. Based on this principle, this thesis presents different multifunction designs: Firstly a cross-shaped DRA with separately fed broadside circularly polarized (CP) and omnidirectional linearly polarized (LP) radiation patterns and, secondly, a multifunction annular cylindrical DRA realizing simultaneously omnidirectional horizontally and vertically polarized radiation patterns with low cross-coupling. The evolution, design process and experimental validation of these two antennas are described in details in the thesis.

The second part of the thesis dramatically scales down DRA to shorter wavelengths. Inspired by the fact that DRA still exhibits high radiation efficiency ($>90\%$) in the millimetre wave range, while the efficiency of conventional metallic antenna degrades rapidly with frequencies, this thesis proposes the concept of nanometer-scale DRA operated in their fundamental mode as optical antennas. To validate the concept, optical DRA reflectarrays have been designed and fabricated. Although the zeroth-order spatial harmonic reflection is observed in the measurement due to the imperfect nanofabrication, the power ratio of deflected beam to the specular component of reflection amounts to 4.42, demonstrating the expected operation of the reflectarray. The results strongly support the concept of optical DRA and proposes design methods and strategies for their realization. This proof of concept is an essential step for future research on nano-DRA as building block of emerging nano-structured optical components.

Statement of Originality

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Conventions

Typesetting

This thesis is typeset using the L^AT_EX2e software. WinEdt build 5.5 was used as an effective interface to L^AT_EX.

Referencing

Referencing and citation style in this thesis are based on the Institute of Electrical and Electronics Engineers (IEEE) Transaction style.

Units

The units used in this thesis are based on the International System of Units (SI units).

Prefixes

In this thesis, the commonly used numerical prefixes to the SI units are "p" (pico, 10^{-12}), "n" (nano, 10^{-9}), " μ " (micro, 10^{-6}), "m", (milli, 10^{-3}), "k" (kilo, 10^3), "M" (mega, 10^6), "G" (giga, 10^9), and "T" (tera, 10^{12}).

Spelling

The Australian English spelling is adopted in this thesis.

Abbreviations

AR	Axial Ratio
BAN	Body-Area Network
CP	Circularly Polarized
CPW	Coplanar Waveguide
DR	Dielectric Resonator
DRA	Dielectric Resonator Antenna
DWM	Dielectric Waveguide Model
EBG	Electromagnetic Band Gap
ECC	Envelope Correlation Coefficient
EM	Electromagnetic
FEM	Finite-Element Method
HD	High Definition
HEM	Hybrid Electric and Magnetic
HFSS	High Frequency Structural Simulator (a commercial simulation software)
HMSIW	Half-mode Substrate Integrated Waveguide
HP	Horizontally Polarized
LHCP	Left-Hand Circularly Polarized
LP	Linearly Polarized
MEG	Mean Effective Gain
MIMO	Multiple-Input Multiple-Output
MMW	Millimeter Wave

Abbreviations

MNG-TL	Mu-Negative Transmission Line
PCB	Printed Circuit Board
PEC	Perfect Electric Conductor
PIFA	Planar Inverted-F Antenna
RHCP	Right-Hand Circularly Polarized
SIW	Substrate Integrated Waveguide
SPP	Surface Plasmon Polariton
TE	Transverse Electric
TM	Transverse Magnetic
VP	Vertically Polarized
WPAN	Wireless Personal Area Network
XPR	Cross-polarization Power Ratio

Author Publications

Journal

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