

Advanced Transmitarrays and Their Beam Scanning For Future Wireless Communications

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CERTIFICATION OF ORIGINAL AUTHORSHIP

I, Xuan Wang declare that this thesis, is submitted in fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY, in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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ABSTRACT

In recent years, transmitarrays have attracted growing attention for many wireless communication systems. Transmitarrays combine both optical and antenna array theories, leading to high gain, high efficiency, low cost and flexible radiation performance. In this thesis, on the basis of the state-of-the-art of transmitarrays, three main contributions are made to meet the challenges that arise from future wireless communications.

The first contribution is the new approach to reduce radar cross section (RCS) of transmitarrays without sacrificing their radiation performance. Phase controllable absorptive frequency-selective transmission (AFST) elements are developed for low RCS transmitarrays, providing absorption-transmission-absorption responses. Moreover, the transmission phase within the transmission band can be controlled by rotating the AFST element. Based on these elements, a low RCS transmitarray has been designed. Compared with a reference transmitarray, the radiation performance of the low-RCS one is almost unchanged. Furthermore, significant RCS reductions have been realized in two absorption bands for wide-angle impinging electromagnetic (EM) waves.

The second contribution is the development of a dual-layer wideband conformal transmitarray at E-band. The dual-layer transmitarray element is designed based on multiple Huygens resonances at different frequencies to achieve both wideband and high efficiency properties. Continuous phase compensation of 360° is achieved, reducing phase errors of the array architecture. Employing the dual-layer Huygens elements, a cylindrically conformal transmitarray at 78 GHz has been designed. The measured results show a peak

realized gain of 26.6 dBi with an aperture efficiency of 35.9 % and 3-dB bandwidth of 20.4 % from 71 to 87 GHz, which can fully cover the E-band spectrum from 71 to 86 GHz.

The third contribution is the development of reconfigurable transmitarrays to achieve 2-dimensional (2-D) beam scanning. A new reconfigurable dual-layer Huygens element is developed. A 1-bit phase compensation with low transmission loss is achieved by controlling two PIN diodes integrated on the element. Compared with many other reconfigurable transmitarray elements using multi-layer structures with metallic vias, the developed reconfigurable Huygens element has a simpler configuration and a simpler biasing network, leading to a very robust design. This particularly facilitates large aperture array at higher frequencies. To validate the design concept, a transmitarray prototype at 13 GHz has been designed. 2-D scanning beams within $\pm 50^\circ$ in E-plane and $\pm 40^\circ$ in H-plane are achieved.

All in all, the developed advanced transmitarrays and their beam scanning represent significant knowledge advance on antenna technologies. They can find wide applications in current and future wireless communication systems.

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CONTENTS

1	Introduction	1
1.1	Background	1
1.1.1	Transmitarray Antenna Concept	1
1.1.2	Transmitarray Design Approaches	3
1.2	Motivation	8
1.3	Contributions	9
1.4	Thesis Organization	11
2	Literature Review	15
2.1	High-Gain Low-RCS Antennas	15
2.2	Wideband Conformal Transmitarrays	21
2.3	Reconfigurable Transmitarrays for Beam Scanning	28
3	Low RCS Transmitarray	35
3.1	Introduction	35
3.2	Phase Controllable AFST Element	37
3.2.1	AFST Element	37

3.2.2	Phase Controllable AFST Element Using Asymmetric Configuration	39
3.2.3	Equivalent Circuit Model of Phase Controllable AFST Element	40
3.2.4	Implementation of the Phase Controllable AFST Element	42
3.3	Low RCS Transmitarray Antenna	46
3.3.1	Low RCS Transmitarray Prototype Design and Implementation	46
3.3.2	Numerical and Experimental Results of the Low RCS Transmitarray Antenna	49
3.4	Summary	54
4	Wideband Conformal Transmitarray	55
4.1	Introduction	55
4.2	Wideband Dual-Layer Huygens Element	58
4.2.1	Dual-Layer Huygens Element	58
4.2.2	Dual-Layer Tightly Coupled Huygens Element	64
4.3	Wideband Conformal Transmitarray Antenna	73
4.3.1	Wideband Conformal Transmitarray Prototype Design and Implementation	73
4.3.2	Numerical and Experimental Results of the Wideband Conformal Transmitarray Antenna	77
4.4	Summary	78
5	Reconfigurable transmitarray	81
5.1	Introduction	81
5.2	1-Bit Reconfigurable Dual-Layer Huygens Element	83
5.2.1	Dual-Layer Huygens Element Design	83

5.2.2	Parametric Study	87
5.2.3	PIN Diodes: Experimental Characterization and Modeling	89
5.2.4	Reconfigurable Dual-Layer Huygens Element with PIN Diodes	92
5.3	Reconfigurable Transmitarray Antenna	95
5.3.1	Reconfigurable Transmitarray Prototype Design	95
5.3.2	Fabricated Prototype and Experimental Implementation	98
5.3.3	Numerical and Experimental Results of the Reconfigurable Transmitarray Antenna	100
5.4	Summary	105
6	Conclusions and Future Work	107
6.1	Conclusions	107
6.2	Future Work	109
	Bibliography	110

LIST OF FIGURES

1.1	Configuration of a transmitarray antenna.	2
1.2	Configuration of a M-FSS based transmitarray antenna.	3
1.3	Configuration of a receiver-transmitter based transmission element.	4
1.4	A dual-layer transmitarray element with periodic boundaries and Floquet ports in ANSYS Electromagnetics software.	5
1.5	Simulated transmission coefficients of a dual-layer element with different values of scale factor k at 78 GHz. (a) Transmission magnitudes. (b) Transmission phases.	6
1.6	Transmission phase distribution on the aperture of a transmitarray.	7
2.1	A low RCS and high-gain patch antenna based on a holographic metasurface [20]. (a) Element configuration of the holographic metasurface. (b) Configuration of the low RCS and high-gain patch antenna.	16
2.2	A slot antenna arrays with wideband RCS reduction [22]. (a) Frequency responses of the element. (b) Exploded view of 4×4 microstrip slot antenna array.	17
2.3	(a) Geometry of periodic AMC structure patterns [25]. (b) One period of the square checkerboard surface.	18
2.4	Periodic element of reflectarray element [27].	18

2.5	(a) Configuration of absorptive frequency-selective reflection structure element. (b) The prototype of the low-RCS reflectarray [29].	19
2.6	(a) Configuration of the band-notched absorber element. (b) Configuration of the low-RCS transmitarray unit cell. (c) Photograph of the low-RCS reflectarray antenna [30].	20
2.7	(a) Top view and (b) side view of the square perforated element. (c) The geometry of cylindrical perforated concave transmitarray. (d) The geometry of cylindrical perforated convex transmitarray [35].	22
2.8	(a) OFF state, (b) ON state, (c) layer stackup of the unit cell. (d) Transmitarray structure [36].	22
2.9	(a) Curved 4-layer transmission element and its transmission phases. (b) Cylindrically conformal transmitarray with a feed horn antenna [40].	23
2.10	(a) Top view and (b) side view of the ultra-thin triple-layer slot element. (c) 3-D view of the cylindrically conformal transmitarray antenna [37].	24
2.11	(a) Top and bottom layers; (b) 3-D structure of the dual-layer Huygens element. (c) High-efficiency dual-layer conformal transmitarray structure [39].	25
2.12	(a) Curve wideband element. (b) Cylindrically conformal transmitarray with a log-periodic dipole feed antenna [38].	26
2.13	The configurations of (a) the dual-layer malta-cross element with metallic vias [41] and (b) the dual-layer CP element without metallic vias [43].	26
2.14	The configuration of a dual-layer Huygens element [44].	27
2.15	The configurations of (a) a triple-layer transmitarray element [48] and (b) a six-layer transmitarray element [49].	28
2.16	1-bit electronically reconfigurable element [14]. (a) Side view. Top view of an element with (b) 1 biasing line, or (c) 10 biasing lines.	29

2.17	(a) CP transmitarray element architecture [57]. (b) Receiver unit. (c) Transmitter unit.	30
2.18	Reconfigurable element design [13].	31
2.19	(a) A 4-layer reconfigurable element integrated with two PIN diodes [60]. (b) A 5-layer FSS element integrated with 3 varactor diodes on each layer [61]. (c) A five stacked layers of square-slot FSS element integrated with 2 varactor diodes on each layer [62].	32
3.1	Conceptual depiction of a low RCS transmitarray.	36
3.2	Configuration of the AFST element. Top view of (a) top layer and (b) bottom layer. (c) 3D view and (d) side view of the AFST element.	38
3.3	Transmission and reflection magnitudes of the AFST unit cell.	38
3.4	Configuration of the phase controllable AFST element. (a) Top side of the first substrate. (b) Top or bottom side of the second substrate. (c) HFSS model of the phase controllable AFST element.	39
3.5	Equivalent circuit of the phase controllable AFST element.	41
3.6	Simulated results of the phase controllable AFST element. (a) Simulated transmission magnitudes. (b) Simulated transmission phases. (c) Simulated reflection magnitudes.	43
3.7	Simulated transmission coefficients of the phase controllable AFST element with Layer 3 removed. (a) Magnitudes. (b) Phases.	44
3.8	The schematic of the Low RCS transmitarray antenna.	45
3.9	Simulated reflection magnitudes of the phase controllable AFST element without resistors.	45
3.10	The prototype of the proposed low-RCS transmitarray. (a) Schematic of low-RCS transmitarray with a feed horn antenna. (b) Exploded view of the proposed low-RCS transmitarray.	47

3.11	Calculated transmission phase distribution of low-RCS transmitarray and reference transmitarray.	48
3.12	Photographs of the fabricated low-RCS transmitarray. (a) Front side. (b) Back side.	48
3.13	Simulated and measured reflection coefficients of low-RCS transmitarray and reference transmitarray.	49
3.14	Radiation patterns and realized gains versus frequency of low-RCS transmitarray and reference transmitarray. (a) E-plane radiation patterns at 12.5 GHz. (b) H-plane radiation patterns at 12.5 GHz. (c) Realized gains versus frequency. (d) Aperture efficiencies versus frequency.	50
3.14	Radiation patterns and realized gains versus frequency of low-RCS transmitarray and reference transmitarray. (a) E-plane radiation patterns at 12.5 GHz. (b) H-plane radiation patterns at 12.5 GHz. (c) Realized gains versus frequency. (d) Aperture efficiencies versus frequency.	51
3.15	Monostatic RCS of low-RCS transmitarray and reference transmitarray under normal impinging wave. (a) Vertical polarization. (b) Horizontal polarization.	52
3.16	Measured monostatic RCS of two transmitarrays under wide-angle oblique impinging waves. (a) Reference transmitarray. (b) Low-RCS transmitarray.	53
4.1	Configuration of the simple dual-layer Huygens element. (a) Top view. (b) Bottom view. (c) 3D view.	56
4.2	Transmission coefficients of the simple dual-layer Huygens element. . . .	57
4.3	(a) Equivalent circuit model of the simple dual-layer Huygens element. (b) Even mode decomposed circuit. (c) Odd mode decomposed circuit. The values of the parameters are as follows: $L_e = 3.26$ nH, $L_o = 2.73$ nH, $C_1 = 1.89$ fF, $C_2 = 0.55$ fF, $Z_0 = 377$, $Z = 254$, $\theta = 60.58^\circ$ and $R = 1.77 \Omega$	59

4.4	Induced surface currents on top and bottom layers of the simple dual-layer Huygens element in a time period T	60
4.5	(a) Electric field of the simple dual-layer Huygens element on xoz plane at $t = 0$ and $t = T/2$. (b) Surface and displacement currents of the simple dual-layer Huygens element on xoz -plane at $t = -T/4(3T/4)$ and $t = T/4$	61
4.6	Transmission coefficients of the simple dual-layer Huygens element with different values of scale factor k . (a) Magnitudes. (b) Phases.	62
4.7	Configuration of the dual-layer tightly coupled Huygens element. (a) Top view. (b) Bottom view. (c) 3D view.	63
4.8	Transmission coefficients of the dual-layer tightly coupled Huygens element.	64
4.9	Induced surface current distributions on top and bottom layers of the dual-layer tightly coupled Huygens element at 71 GHz.	65
4.10	Induced surface current distributions on top and bottom layers of the dual-layer tightly coupled Huygens element at 78.5 GHz.	66
4.11	Induced surface current distributions on top and bottom layers of the dual-layer tightly coupled Huygens element at 86 GHz.	67
4.12	Transmission coefficients of the dual-layer tightly coupled Huygens element with different values of scale factor k . (a) Magnitudes. (b) Phases.	68
4.13	Cylindrically conformal transmitarray antenna: (a) 3D view; (b) schematic of front view. (c) The No. of the scale factor k distributions on a quarter of the transmitarray.	70
4.14	Photographs of the fabricated wideband conformal transmitarray antenna.	71
4.15	Measured and simulated reflection magnitudes of the wideband conformal transmitarray antenna.	73

4.16	Measured and simulated realized gain patterns of the wideband conformal transmitarray antenna in E and H planes at different frequencies. (a) 72 GHz. (b) 74 GHz. (c) 76 GHz. (d) 78 GHz. (e) 80 GHz. (f) 82 GHz. (g) 84 GHz. (h) 86 GHz.	74
4.16	Measured and simulated realized gain patterns of the wideband conformal transmitarray antenna in E and H planes at different frequencies. (a) 72 GHz. (b) 74 GHz. (c) 76 GHz. (d) 78 GHz. (e) 80 GHz. (f) 82 GHz. (g) 84 GHz. (h) 86 GHz.	75
4.16	Measured and simulated realized gain patterns of the wideband conformal transmitarray antenna in E and H planes at different frequencies. (a) 72 GHz. (b) 74 GHz. (c) 76 GHz. (d) 78 GHz. (e) 80 GHz. (f) 82 GHz. (g) 84 GHz. (h) 86 GHz.	76
4.17	Measured and simulated realized gains and aperture efficiencies of the wideband conformal transmitarray antenna versus frequencies.	78
5.1	Configuration of the dual-layer Huygens element. (a) Top view. (b) Bottom view. (c) 3D view.	83
5.2	Transmission coefficients of the dual-layer Huygens element under the incidence waves with different angles.	84
5.3	Simulated current distributions on top and bottom layers of the dual-layer Huygens element.	86
5.4	Transmission coefficients of the dual-layer Huygens element with different values of parameter a . (a) Magnitudes. (b) Phases.	87
5.5	Transmission coefficients of the dual-layer Huygens element with different values of parameter l . (a) Magnitudes. (b) Phases.	88
5.6	Transmission magnitudes of the dual-layer Huygens element with different thickness h of the dielectric substrate.	89

5.7	(a) Fabricated fixture for the experimental characterization of the PIN diode. Equivalent models of the PIN diode under (b) forward bias; (c) reverse bias.	90
5.8	De-embedded and fitted results of the PIN diode under (a) forward bias; (b) reverse bias.	91
5.9	<i>S</i> -parameters of the equivalent circuits of the PIN diode.	91
5.10	Configurations of the 1-bit reconfigurable dual-layer Huygens element. (a) Top view; (b) bottom view; (c) 3D view of the element with 4 biasing lines. (d) Top view; (e) bottom view of the element with 20 biasing lines. (f) Top view of a part of the whole transmitarray.	93
5.11	Transmission coefficients of the reconfigurable dual-layer Huygens element with 4 or 20 biasing lines under ON and OFF states. (a) Magnitudes. (b) Phases.	94
5.12	(a) Schematic diagram of the phase compensation for a radiated beam in a desired direction. (b) The 10×10 reconfigurable transmitarray with its scanning-control board.	96
5.13	Simulated radiation patterns for different scan angles at 13 GHz in (a) E-plane and in (b) H-plane.	98
5.14	Photographs of (a) the fabricated reconfigurable transmitarray antenna (RTA) prototype and (b) the experimental setup of the RTA mounted in the anechoic chamber.	99
5.15	Measured and simulated input reflection magnitudes of the transmitarray radiating towards boresight.	100
5.16	(a) Measured and simulated boresight radiation patterns in E and H planes at 12.8 GHz. (b) Measured and simulated realized gains in boresight direction versus frequencies.	101

5.17 Measured radiation patterns for different scanning angles at 12.8 GHz in (a) E plane and (b) H plane.	102
5.18 Measured cross-polarization radiation patterns for different scanning an- gles at 12.8 GHz in E and H planes.	104

LIST OF TABLES

3.1	Comparison of Relevant Transmitarray (TA), Reflectarrays (RAs) or Patch Antenna	53
4.1	Transmission Losses and Phase Coverages of the Dual-Layer Tightly Coupled Huygens Element at Different Frequencies	69
4.2	Transmission Losses and Phases of the Dual-Layer Tightly Coupled Huygens Element with Different Values of Scale Factor K at 78 GHz	72
4.3	Comparison Between Reported Transmitarray Antennas	77
5.1	Transmission Magnitudes and Phases of the 1-Bit Dual-Layer Huygens Element with Four Biasing Lines at 13 GHz	95
5.2	Beam Scanning Performance of the Reconfigurable Transmitarray in E Plane	103
5.3	Beam Scanning Performance of the Reconfigurable Transmitarray in H Plane	103
5.4	Comparison Between the Reconfigurable Transmitarray Antennas	104

LIST OF ACRONYMS

2-D	2-Dimensional
3-D	3-Dimensional
5G	Fifth Generation
6G	Sixth Generation
AFST	Absorptive Frequency-Selective Transmission
AMC	Artificial Magnetic Conductor
BW	Bandwidth
CP	Circular-Polarization
DC	Direct Current
EM	Electromagnetic
FPGA	Field-Programmable Gate Array
FSR	Frequency-Selective Resorber
FSS	Frequency-Selective Surface
Gbps	Gigabits-Per-Second
IDC	Insulation-Displacement Contact
LED	Light-Emitting Diode
LP	Linear-Polarization
MEMS	Micro-Electro-Mechanical System
M-FSS	Multilayer-Frequency-Selective Surface
mm-wave	Millimeter Wave
MVG	Microwave Vision Group

PCB	Printed Circuit Board
PEC	Perfect Electric Conductor
RCS	Radar Cross Section
RF	Radio Frequency
RTA	Reconfigurable Transmitarray
RTE	TE ^y Plane Wave
RTM	TM ^y Plane Wave
SLL	Side Lobe Level
Tbps	Terabits-Per-Second
THz	Terahertz
UAV	Unmanned Aerial Vehicles
USB	Universal Serial Bus
VNA	Vector Network Analyzer