UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Advanced Conformal Transmitarrays for 5G and Beyond Wireless Communications

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under the supervision of Dr Peiyuan Qin
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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Lizhao Song declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in School of Electrical and Data Engineering/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

Transmitarray antennas (TAs) have received considerable attention as they can serve long-distance communications for space and terrestrial wireless systems. For many wireless communication platforms, such as aircrafts and unmanned aerial vehicles (UAV), conformal TAs, which can be flush mounted onto the shaped platforms, are highly demanded in order to meet the aerodynamic requirements. In this dissertation, a few innovative techniques have been developed for conformal TAs.

Firstly, a thin frequency selective surfaces (FSS) element is developed with a thickness of 0.508 mm ($0.04\lambda_0$ at 25 GHz). It is then applied to a curved TA conformal to a cylindrical surface. The prototype radiates a fixed boresight beam with a peak measured gain of 19.6 dBi and an aperture efficiency of 25.1%. Secondly, a mechanical beam-scanning conformal TA is proposed. Its size is about 2.5 times of the fixed-beam one, steering its beam to seven different radiation angles, i.e., ±15°, ±10°, ±5°, and 0°. The measured prototype shows a stable gain of 18.7 dBi at all beam angles.

Thirdly, to improve the aperture efficiency of conformal TAs further, Huygens metasurface theory is employed to design a dual-layer TA element. The element is composed of two metal layers printed on a single substrate with a 0.5-mm thickness ($0.017\lambda_0$ at 10 GHz). The oblique incidence effects are also considered in the process of element synthesis. Finally, a cylindrically conformal TA is developed, which achieves a measured gain of 20.6 dBi with a 47% aperture efficiency.

Fourthly, by combining connected arrays and true-time-delay lines, a novel technique is introduced to obtain ultrawideband (UWB) TAs. The elements consist of a horizontally connected slot bowtie and vertical meander slot-lines. The TAs have been designed in

both planar and conformal configurations. Stable boresight radiation patterns from 6 GHz to 17 GHz are obtained for both antennas. Compared to conformal TAs using multi-layer FSS elements, the proposed one has an ultra-wide bandwidth of 96% in terms of stable radiation patterns.

Fifthly, a conformal TA, with an elliptical cylindrical contour at a millimetre-wave (mm-wave) band, is presented for wide-angle multibeam radiations. A systematic design procedure is developed. The prototype provides eleven beams with a beam coverage of ±43°. The measured peak boresight gain is 27 dBi at 70.5 GHz with a less than 2.7-dB scanning loss.

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LIST OF ABBREVIATIONS

TAs	Transmitarray antennas
RAs	Reflectarray antennas
FSS	Frequency Selective Surfaces
UAV	Unmanned Aerial Vehicles
UWB	Ultrawideband
5G	Fifth generation
Mm-wave	Millimetre-wave
CP	Circular-polarization
2-D	Two-dimensional
3-D	Three-dimensional
EM	Electromagnetic
LPDA	Log-periodic dipole antenna
SLL	Sidelobe level