

# **KEY TECHNOLOGIES FOR ADVANCED CELLULAR BASE STATION ANTENNAS**

Haihan Sun

Faculty of Engineering and Information Technology  
University of Technology Sydney

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# Certification of Original Authorship

I, Haihan Sun, declare that this thesis, is submitted in fulfilment of the requirements for the award 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.

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9. C. Ding, B. Jones, **H. Sun**, P. Y. Qin, Y. J. Guo, and L. Ji, "Wideband feeding method for full-wave dipole," *2017 IEEE International Symposium on Antennas and Propagation (APS)*, 2017.
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*To my parents*

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## List of Abbreviations

|           |   |
|-----------|---|
| AR        | Axial Ratio   |
| BSA       | Base Station Antenna                                |
| CP        | Circularly-Polarized                                |
| GLL       | Grating Lobe Level                                  |
| FBR       | Front-to-Back Ratio                                 |
| HB        | High Band   |
| HPBW      | Half-Power Beamwidth                                |
| ICD       | Isolated Cross-Dipole                               |
| LB        | Low Band  |
| LHCP      | Left-Handed Circular Polarization                   |
| LP        | Linearly-Polarized                                  |
| ME-dipole | Magneto-Electric Dipole                             |
| MIMO      | Multiple-Input Multiple-Output                      |
| PDR       | Power Division Ratio                                |
| RHCP      | Right-Handed Circular Polarization                  |
| SLL       | Side Lobe Level                                     |
| TCCD      | Tightly-Coupled Cross-Dipole                        |
| XPD       | Cross Polarization Discrimination                   |
| 3G        | Third Generation of Cellular Mobile Communications  |
| 4G        | Fourth Generation of Cellular Mobile Communications |
| 5G        | Fifth Generation of Cellular Mobile Communications  |

# Abstract

Cellular base station antennas (BSAs) are critical components in mobile communication systems. As the cellular mobile communication systems evolve rapidly to the fifth generation (5G), BSAs that can simultaneously support different standards and have high data capacity are in high demand. Multi-band arrays and multi-beam arrays are good solutions, but they place additional stringent requirements on the antennas. Firstly, high performance characteristics of antenna elements are required. Secondly, cross-band scattering, which is a long-existing issue in multi-band antenna arrays, needs to be suppressed to maintain the performance and stability of antenna systems. Thirdly, for multi-beam antenna arrays, they are desired to have wide operating bandwidth and consistent patterns with low side-lobe levels. All of these are difficult to achieve. This thesis addresses the challenges mentioned above by making three main contributions.

The first contribution is the improvement of the base station antenna elements. Three configurations have been thoroughly studied, including square-dipole-array, cross-dipole and dual-dipole configurations. Different methods are investigated to enhance bandwidth, stabilize radiation patterns, or minimize beam squint, and the outcomes of these are implemented in antenna designs. In addition, circuit models of feed networks are proposed to facilitate wideband impedance matching. Two antennas featuring planarized configurations are designed for the ease of system integration. In total, eight antenna elements have been designed, fabricated and tested to achieve the desired wideband radiation performances.

The second contribution is the development of new approaches to minimize cross-band interference in multi-band BSA arrays. Chokes that can minimize scattering currents are implemented in the antenna designs. The working principles and capabilities of suppressing scattering of three different types of chokes are analyzed. Based on these techniques, two dual-band antenna arrays have been designed. Experimental results verify that cross-band scattering is suppressed and both arrays have stable radiation patterns across wide operating bandwidths. The techniques presented for suppressing cross-band scattering guarantee the co-existence of antennas for different services, and facilitate the evolution of communication standards.

The third contribution is the development of multi-beam antenna arrays to increase system capacity with a wide coverage area. Cross-dipoles with a compact configuration



and stable radiation performances are chosen as array elements. Wideband beam-forming networks formed by Butler matrices and power dividers are used to provide correct phase increments and power levels for elements. Three-beam antenna arrays have been designed with required beamwidth and crossover level. The proposed designs can be used in a wide range of LTE base stations to increase system capacity.

