

## CONTENTS

*List of Figures* xiv - xxv

*List of Tables* xxvi - xxix

*List of Abbreviations* xxx

*Preface* xxxi - xxxiii

### **CHAPTER 1 INTRODUCTION AND LITERATURE REVIEW 1-25**

|       |                                             |    |
|-------|---------------------------------------------|----|
| 1.1.  | Context and Background                      | 1  |
| 1.1.1 | Thinned Antenna (TA) Arrays                 | 3  |
| 1.1.2 | Non-uniformly Spaced Antenna (NUSA) Arrays  | 4  |
| 1.1.3 | Multi-functional Antenna (MFA) Arrays       | 6  |
| 1.2.  | Literature Review on Sparse Antenna Arrays  | 8  |
| 1.3.  | Research Objectives                         | 17 |
| 1.4.  | Motivation and Problem Definition           | 18 |
| 1.5.  | Contribution and Scope of the Research Work | 19 |
| 1.6.  | Outline of the Thesis                       | 22 |

### **CHAPTER 2 SYNTHESIS AND DESIGN OF SPARSE LINEAR ANTENNA ARRAYS 26-93**

|       |                                                                     |    |
|-------|---------------------------------------------------------------------|----|
| 2.1   | Context and Background                                              | 26 |
| 2.2   | Thinned Linear Antenna (TLA) Arrays                                 | 26 |
| 2.2.1 | Introduction                                                        | 26 |
| 2.2.2 | Geometrical Configuration and Problem Formulation for<br>TLA Arrays | 35 |
| 2.2.3 | Optimization Techniques for the Synthesis of TLA Arrays             | 38 |

|                                                                                                                          |    |
|--------------------------------------------------------------------------------------------------------------------------|----|
| 2.2.4 Numerical Analysis, Results and Discussion                                                                         | 39 |
| 2.2.4.1 PSLL Optimization in 100-element TLA Array at Boresight Using GA                                                 | 39 |
| 2.2.4.2 Optimization of PSLL and Maximization of Number of ‘OFF’ Element in 100- and 200-element TLA arrays Using MBC-GA | 41 |
| 2.2.4.3 PSLL Optimization in 100-element TLA Array at Boresight as well as upto $\pm 60^0$ Scan Angles Using PSO         | 48 |
| 2.2.4.4 Optimization of PSLL, HPBW, and Gain in 100-element TLA Array Using MBC-GA                                       | 55 |
| 2.3 Non-uniformly Spaced Linear Antenna (NUSLA) Arrays                                                                   | 58 |
| 2.3.1 Introduction                                                                                                       | 58 |
| 2.3.2 Geometrical Configuration and Problem Formulation for NUSLA Arrays                                                 | 66 |
| 2.3.3 Optimization Techniques for the Synthesis of NUSLA Arrays                                                          | 70 |
| 2.3.4 Numerical Analysis, Results and Discussion                                                                         | 71 |
| 2.3.4.1 PSLL Optimization in 24-element NUSLA Array at Boresight Using GA                                                | 71 |
| 2.3.4.2 PSLL Optimization in 16-and 32-element NUSLA Arrays by Devising Optimum Elements’ Density Using IW-PSO           | 74 |
| 2.3.4.3 PSLL Optimization at Boresight as well as at $\pm 30^0$ Scan Angles in 16-element NUSLA Array Using PSO          | 81 |

|                                                                                                                                                                         |               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 2.3.4.4 Optimization of PSLL in Uniformly Excited and Amplitude Weighted 36-element NUSLA array Using PSO                                                               | 84            |
| 2.3.5 EM Simulation and Experimental Validation of 24-element NUSLA Array                                                                                               | 86            |
| 2.4 Summary and Conclusion                                                                                                                                              | 93            |
| <b>CHAPTER 3 SYNTHESIS AND DESIGN OF SPARSE PLANAR ANTENNA ARRAYS</b>                                                                                                   | <b>94-180</b> |
| 3.1 Context and Background                                                                                                                                              | 94            |
| 3.2 Thinned Planar Antenna (TPA) Arrays                                                                                                                                 | 94            |
| 3.2.1 Introduction                                                                                                                                                      | 94            |
| 3.2.2 Geometrical Configuration and Problem Statement of TPA Arrays                                                                                                     | 107           |
| 3.2.3 Optimization Techniques for the Synthesis of TPA Arrays                                                                                                           | 111           |
| 3.2.4 Numerical Analysis, Results and Discussion                                                                                                                        | 112           |
| 3.2.4.1 Reduction of PSLL and Maximization of Number of ‘OFF’ Elements in $10 \times 20$ -Element TPA Array Using MBC-GA                                                | 113           |
| 3.2.4.2 PSLL Optimization with Minimum Number of Turn ‘ON’ Elements in $10 \times 10$ -and $14 \times 14$ -elements TPA Arrays over $\pm 40^0$ Scan Volume Using IBc-GA | 120           |
| 3.2.4.3 Optimization of Peak, Average and RMS SLL in $10 \times 20$ -element TPA Array Using PSO                                                                        | 136           |

|                                                                                                                                                                                |                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| 3.2.4.4 Optimization of PSLL by Jointly Determining<br>Thinned Configuration and Amplitude Weights<br>in $10 \times 20$ - and $8 \times 8$ -elements TPA Array Using<br>MBC-GA | 143            |
| 3.2.5 EM Simulation and Experimental Validation of $8 \times 8$ -<br>element AW-TPA Array                                                                                      | 156            |
| 3.3 Non-uniformly Spaced Planar Antenna (NUSPA) Arrays                                                                                                                         | 167            |
| 3.3.1 Introduction                                                                                                                                                             | 167            |
| 3.3.2 Geometrical Configuration and Problem Formulation<br>for NUSPA Arrays                                                                                                    | 170            |
| 3.3.3 Optimization Techniques for the Synthesis of NUSPA<br>Arrays                                                                                                             | 172            |
| 3.3.4 Numerical Analysis, Results and Discussion                                                                                                                               | 172            |
| 3.3.4.1 Peak SLL Optimization in $8 \times 16$ -element<br>UE-NUSPA Array Using PSO                                                                                            | 172            |
| 3.3.4.2 Peak SLL Optimization in $8 \times 16$ -element<br>AW-NUSPA Array Using PSO                                                                                            | 176            |
| 3.4 Summary and Conclusion                                                                                                                                                     | 179            |
| <b>CHAPTER 4 MULTI-FUNCTIONAL ANTENNA ARRAYS USING<br/>SPARSE CONCEPT</b>                                                                                                      | <b>181-201</b> |
| 4.1 Context and Background                                                                                                                                                     | 181            |
| 4.2 Randomly Spaced Planar Antenna (RSPA) Arrays                                                                                                                               | 182            |
| 4.2.1 Introduction                                                                                                                                                             | 182            |
| 4.2.2 Mathematical Formulation for $8 \times 16$ -element RSPA<br>Arrays                                                                                                       | 183            |

|                                                                                                                                                  |                |
|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| 4.2.3 Optimization Technique for the Synthesis of 8×16-element RSPA Arrays                                                                       | 185            |
| 4.2.4 Numerical Analysis, Results and Discussion of PSLL Optimization in 8×16-element RSPA Array Using MBC-GA                                    | 186            |
| 4.3 Multi-functional Antenna (MFA) Arrays                                                                                                        | 190            |
| 4.3.1 Introduction                                                                                                                               | 190            |
| 4.3.2 Mathematical Formulation for MFA Arrays                                                                                                    | 191            |
| 4.3.3 Optimization Technique for the Synthesis of MFA Arrays                                                                                     | 192            |
| 4.3.4 Numerical Analysis, Results and Discussion of 4×4- and 8×8-elements Multi-functional Array Sharing the Same Physical Aperture Using MBC-GA | 192            |
| 4.4 Summary and Conclusion                                                                                                                       | 201            |
| <b>CHAPTER 5 SUMMARY, CONCLUSION AND FUTURE SCOPE</b>                                                                                            | <b>202-214</b> |
| 5.1. Summary and Conclusion                                                                                                                      | 202            |
| 5.2. Future Scope                                                                                                                                | 213            |
| <i>References</i>                                                                                                                                | 215-224        |
| <i>Author's Relevant Publications</i>                                                                                                            | 225-227        |
| <i>Appendix- 'A'</i>                                                                                                                             | 228-244        |
| <i>Appendix- 'B'</i>                                                                                                                             | 245-248        |