

# Contents

<i>List of Figures</i> .....	<i>xvii</i>
<i>List of Tables</i> .....	<i>xxi</i>
<i>List of Abbreviations</i> .....	<i>xxiii</i>
<i>List of Symbols</i> .....	<i>xxv</i>
<i>Preface</i> .....	<i>xxvii</i>
<b>Chapter 1: Introduction</b> .....	<b>1</b>
1.1 Wireless Capsule Endoscopy .....	2
1.1.1 Background and Evolution of Capsule Endoscopy .....	2
1.1.2 Significance in Medical Practice .....	4
1.2 Implantable and Ingestible Antenna Design: Requirements and Challenges .....	5
1.2.1 Requirements for Implantable Antenna Design .....	6
1.2.2 Challenges in Implantable Antenna Design .....	9
1.3 RF Rectifier Design: Requirements and Challenges.....	12
1.3.1 Requirements for RF Rectifier Design .....	12
1.3.2 Challenges in RF Rectifier Design .....	13
1.4 Characteristic Modal Analysis (CMA) in Antenna Design .....	14
1.4.1 Introduction to Characteristic Modal Analysis (CMA).....	14
1.4.2 Principles of Characteristic Modal Analysis (CMA) .....	15
1.5 Motivation and Research Objectives .....	18
1.5.1 Motivation .....	18
1.5.2 Research Objectives .....	21
1.6 Thesis Roadmap .....	23
<b>Chapter 2: Literature Review</b> .....	<b>29</b>
2.1 Review of Implantable antenna design for wireless capsule endoscopy .....	30
2.2 Review of RF energy harvesting.....	37
2.3 Review of dual-band dual-sense circularly polarized (CP) antenna .....	43
2.4 Research Gap and Research objective .....	47
2.4.1 Research Gap.....	47
2.4.2 Research objective.....	48
2.5 Summary .....	48

<b>Chapter 3: Design of a Wide-Bandwidth Dual-Band Ingestible Antenna for Wireless Capsule Endoscopy .....</b>	<b>51</b>
3.1 Introduction .....	52
3.2 Antenna Design and Performance.....	53
3.2.1 Modal Analysis of the Antenna .....	54
3.2.2 S-parameter in Different Phantom.....	58
3.2.3 Effect of $H_1$ .....	61
3.2.4 Effect of Antenna Implantation Depth .....	61
3.2.5 Effect of Capsule shell thickness.....	63
3.2.6 Equivalent Circuit Analysis.....	64
3.2.7 Effect of Electronic Components .....	66
3.2.8 Specific Absorption Rate Evaluation .....	67
3.2.9 Link Budget Analysis .....	69
3.3 Measurement and Discussion.....	72
3.4 Summary .....	76
<b>Chapter 4: RF Energy Harvesting for Implantable Devices .....</b>	<b>79</b>
4.1 Introduction .....	80
4.2 Design and Analysis of the Dual-Band Rectifier Circuit.....	81
4.2.1 Design and analysis of the dual-band matching network .....	82
4.2.2 Final design of rectifier.....	84
4.3 Results and Discussion.....	86
4.4 Summary .....	90
<b>Chapter 5: Dual-Band Dual-Sense Circularly Polarized High Gain Suspended Plate Antenna for Bio-Telemetry Applications.....</b>	<b>91</b>
5.1 Introduction .....	92
5.2 Antenna Configurations .....	95
5.2.1 Characteristic Mode Theory for DBDS CP Antenna .....	97
5.2.1.1 Stage 1: Suspended Circular Plate Antenna.....	98
5.2.1.2 Stage 2: Modified Suspended Circular Plate Antenna with Slot .....	99
5.2.1.3 Stage 3: Further Modified Suspended Circular Plate Antenna with Inserted Slits.....	100
5.2.1.4 Stage 4: Further Modified Suspended Circular Plate Antenna with Orthogonal Slot Loading.....	101
5.2.1.5 Stage5: Implementing DBDS CP performance .....	102

5.2.2 Parametric Analysis.....	103
5.2.2.1 The Effects of $L_1$ .....	104
5.2.2.2 The Effects of $L_2$ .....	105
5.2.2.3 The Effects of $L_a$ .....	106
5.2.2.4 The Effects of $L_b$ .....	107
5.2.3 Equivalent Circuit analysis.....	108
5.3 Measured Results and Discussion.....	110
5.4 Communication Link Setup and Measurement.....	114
5.5 Summary.....	116
<b>Chapter 6: Conclusion and Future Scope .....</b>	<b>119</b>
6.1 Summary.....	120
6.2 Key Contributions.....	122
6.3 Scope of Future Work.....	123
<b>References.....</b>	<b>125</b>
<i>List of Publications.....</i>	<i>139</i>