Contents

List of Figures xv

List of Tables xix

Glossary xxi

1 Introduction 1

1.1 State of the art of reconfigurable antennas 1

1.2 Motivation 3

1.3 Objectives of the thesis 4

1.4 Structure of the thesis 5

2 Antennas from Characteristic Mode Theory perspective 9

2.1 Classical modal analysis in antenna design 9

2.1.1 Spherical Modes 10

2.1.2 Cavity Modes 10

2.1.3 Dielectric Waveguide Modes 11

2.2 Theory of characteristic modes: Definition and mathematical review of the modal attributes 13

2.2.1 Surface integral equation 14

a) Maxwell's equations 14

b) Electromagnetic Boundary Condition 15

c) Magnetic Vector Potential and Electric Scalar Potential 16

d) Diffraction problem analysis 17

e) Method of moments 19

f) Characteristic Modes formulation 21
g) Conventional Derivation 22
2.2.2 Physical interpretation of CM parameters 22
a) Physical interpretation of Eigenvalue 23
b) Physical interpretation of the Modal Significance . . 24
c) Physical interpretation of the Characteristic Angle . 25
d) Physical interpretation of the modal weighting coefficient 26
2.3 TCM applied to reconfigurable antennas 26
2.4 Characteristic mode analysis of some basic planar structures 28
2.4.1 Dipole structure 29
2.4.2 Rectangular structure 29

3 Modelling of switching electronic components employed in reconfigurable antennas 35
3.1 Introduction 35
3.2 PIN diode 36
3.3 Varactor diode 44
3.4 PIN diode and Varactor diode 51
3.5 Single-Pole Double-Throw (SPDT) switch 55
3.6 Conclusion 58

4 Design of frequency reconfigurable antennas using the TCM 61
4.1 Introduction 61
4.2 Characteristic Mode Analysis of a Patch Antenna over a Finite Ground Plane 62
4.3 Antenna Description and Simulations 66
4.3.1 Antenna Geometry 66
4.3.2 Simulation Results 68
a) Parametric Study of the Slot 68
b) Reconfigurable Antenna Simulation Methods 68
4.4 Prototype and Measurement Results 73
4.5 Conclusion 77

5 Design of radiation pattern reconfigurable antennas using the TCM **79**
5.1 Introduction 79
5.2 Design of a rectangular parallel plate antenna based on Characteristic Mode Analysis 80
5.3 Results and discussion 84
5.3.1 Reconfigurable antenna description 84
5.3.2 Bias circuit configuration 86
5.3.3 Prototype and measurement results 88
5.4 Conclusion 95

6 Conclusions **97**
6.1 Conclusions 97

References **100**

Appendices **111**
6.7 Related publications 111
6.7.1 JCR indexed journals 111
6.7.2 International conferences 111
6.8 Radiation Pattern Reconfigurable Antenna 3D video and Job Circuit 155