CONTENTS

LIST OF TABLES
LIST OF FIGURES
LIST OF SYMBOLS AND ABBREVIATIONS

CHAPTER I
INTRODUCTION TO THE RESEARCH PROBLEM
1.1 Introduction
1.2 The research direction
1.3 Thesis structure and outline
References

CHAPTER II
COMPOSITE PREPARATION AND MICROSTRUCTURAL STUDIES
2.1 Introduction
2.2 Material selection and synthesis
  2.2.1 Material selection
    2.2.1.1 Selection of inclusions
    2.2.1.2 Selection of host matrix
  2.2.2 Synthesis of nickel substituted cobalt ferrite nanoparticles
  2.2.3 Fabrication of magneto-dielectric composite material
2.3 Microstructural studies
  2.3.1 X-ray diffraction
  2.3.2 TEM results
  2.3.3 SEM results
2.4 Discussion and conclusion
References

CHAPTER III
CHARACTERIZATION OF THE MAGNETO-DIELECTRIC COMPOSITE MATERIAL: PHYSICAL, THERMAL AND MAGNETIC
3.1 Introduction
3.2 Density and water absorbance
3.3 Thermal conductivity
  3.3.1 Set up fabrication and measurement
3.3.2 Design of modified Lee’s method 28
3.3.3 Transducer element 29
3.3.4 Working principle 30
3.3.5 Thermal conductivity measurement results 31

3.4 B-H Curve 32
3.4.1 Hysteresis loop tracer 33
3.4.2 Measurement and results of hysteresis loop 35

3.5 Saturation magnetization study of the composite material 37
3.5.1 Theory of operation of VSM for magnetization study 37
3.5.2 Measurement and results of Co_{1-x}Ni_xFe_2O_4 / LDPE composites 38

3.6 Conclusion 41
References 43

CHAPTER IV
COMPLEX PERMITTIVITY AND PERMEABILITY ESTIMATION OF Co_{1-x}Ni_xFe_2O_4/LDPE MAGNETO-DIELECTRIC COMPOSITE AT X-BAND 44 - 73

4.1 Introduction 44
4.2 Measurement set-up 45
4.3 Shielded conductor backed coplanar waveguide technique 46
4.3.1 Conductor-backed CPW design considerations 47
4.3.2 Modified formulation for complex permittivity and permeability determination using scalar S-parameters 49
4.3.3 Fabrication of the conductor-backed CPW configuration 53
4.3.4 Calibration of the conductor-backed CPW 53
4.3.5 Impedance mismatch analysis 55
4.4 Measurements and analysis of results obtained from the conductor-backed CPW Technique for Co_{1-x}Ni_xFe_2O_4 / LDPE Composite 57
4.4.1 Computation and analysis of complex permittivity over X-band 57
4.4.2 Computation and analysis of complex permeability over X-band 61
4.5 Substantiation of permittivity and permeability value by cavity perturbation technique 64
4.6 Conclusion 69
References 70

CHAPTER V
DEVELOPMENT OF MODIFIED 3D FDTD APPROACH FOR MAGNETIZED MAGNETO-DIELECTRIC SUBSTRATE 74 - 106

5.1 Introduction 74
5.2 Problem Formulation
5.2.1 Expression of E and H curl equations in partial differential form 78
5.2.2 Expression of E and H partial differential equations in finite
differential form in spatial and temporal coordinates 81

5.3 Computer Implementation of FDTD code
5.3.1 Stability criteria in FDTD 90
5.3.2 Absorbing boundary conditions 91
5.3.3 Source considerations 93
5.3.4 Implementation of FDTD code to increase memory efficiency 94
5.3.5 Frequency dependent parameters 96

5.4 Numerical results and discussion
5.4.1 Stability criteria 97
5.4.2 Source consideration 98
5.4.3 PML terminating condition 99
5.4.4 Modification in algorithm to include permeability tensor 100
5.4.5 Post processing of the results 101

5.5 Conclusion 102
References 103

CHAPTER VI
TRANSMISSION RESPONSE OF MICROSTRIP LINE ON
MAGNETO-DIELECTRIC SUBSTRATE 107 - 177

6.1 Introduction 107
6.2 Composite material for microwave integrated circuit 108
6.3 Design and fabrication of microstrip line
6.3.1 Design formulation 110
6.3.2 Fabrication of microstrip line 113
6.4 Microwave measurement
6.4.1 Insertion loss measurement 115
6.4.2 Determination of quality factor and attenuation constant 117
6.5 Insertion loss measurement outcome 118
6.5.1 Insertion loss measurement on Co$_{1-x}$Ni$_x$Fe$_2$O$_4$/LDPE substrate for x=0.0 118
6.5.2 Insertion loss measurement on Co$_{1-x}$Ni$_x$Fe$_2$O$_4$/LDPE substrate for x=0.2 119
6.5.3 Insertion loss measurement on Co$_{1-x}$Ni$_x$Fe$_2$O$_4$/LDPE substrate for x=0.4 123
6.5.4 Insertion loss measurement on Co$_{1-x}$Ni$_x$Fe$_2$O$_4$/LDPE substrate for x=0.6 127
6.5.5 Insertion loss measurement on Co$_{1-x}$Ni$_x$Fe$_2$O$_4$/LDPE substrate for x=0.8 131
6.5.6 Insertion loss measurement on Co$_{1-x}$Ni$_x$Fe$_2$O$_4$/LDPE substrate for x=1.0 133
6.6 Transmission response inference 137
6.7 Transmission response discussion 140
6.7.1 Transmission response with varying magnitude of dc magnetic field 140
6.7.2 Transmission response by altering angle of inclination using coupled mode theory 141
6.8 Full-wave FDTD analysis of transmission response of microstrip line under obliquely biased magnetic field 145
6.8.1 E and H field distribution in 3D space at 10 time step 147
6.8.2 Transmission response of the microstrip line 171
6.9 Conclusion 173
References 174

CHAPTER VII
MICROSTRIP REFLECTION TYPE RADIAL STUB RESONATOR ON MAGNETO-DIELECTRIC SUBSTRATE 178 - 195
7.1 Introduction 178
7.2 Design of a microstrip reflection-type radial stub resonator 179
7.2.1 Dimensions of the circular disc resonator 179
7.2.2 Microstrip radial stub design 180
7.3 Fabrication of microstrip radial stub resonator circuit with hot press lamination method 182
7.3.1 Metallization of copper on the substrate 183
7.3.2 Preparation of microwave artwork 183
7.3.3 Transferring artwork to the metal surface 184
7.3.4 Etching the artwork 184
7.3.5 Removal of mask 184
7.4 Return loss measurement results and discussion 185
7.4.1 Return loss response of RRSR-8/11 187
7.4.1.1 The 8 GHz stub horizontally along the X-axis and 11 GHz stub vertically along Y-axis 187
7.4.1.2 The 11 GHz stub horizontally along the X-axis and 8 GHz stub vertically along Y-axis 188
7.4.2 Return loss response of RRSR-9/12 191
7.4.2.1 The 9 GHz stub horizontally along the X-axis and 12 GHz stub vertically along Y-axis 191
7.4.2.2 The 12 GHz stub horizontally along the X-axis and 9 GHz stub vertically along Y-axis 191
7.5 Conclusion 194
References 195

CHAPTER VIII
ACHIEVEMENTS, LIMITATIONS AND FUTURE DIRECTIONS 196 - 198
APPENDIX - A
THREE DIMENSIONAL PML EQUATIONS 199 - 204

APPENDIX - B
3D FDTD CODE MODULES 205 - 208

PUBLICATIONS 209