

Contents

Preface IX

Color Plates XI

1	Introduction	1
1.1	Purpose of This Book	1
1.2	The Solar Wind	1
1.3	Fluctuations in the Solar Wind	5
1.4	Early Observations of Geomagnetic Variations	7
1.5	Properties of Geomagnetic Variations	8
2	The Magnetosphere and Ionosphere	13
2.1	The Geomagnetic Field	13
2.2	Structure of Earth's Magnetosphere	19
2.3	Magnetospheric Current Systems	24
2.3.1	Magnetopause Current	24
2.3.2	Tail Current and Reconnection	24
2.3.3	Ring Current	26
2.3.4	Field-Aligned Currents	26
2.3.5	Ionospheric Currents	27
2.4	The Radiation Belts	28
2.5	The Inner Magnetosphere	30
2.6	Formation and Properties of the Ionosphere	33
2.7	Geomagnetic Disturbances	38
2.8	Space Weather Effects	42
3	ULF Plasma Waves in the Magnetosphere	45
3.1	Basic Properties of a Plasma	45
3.2	Particle Motions	47
3.2.1	Motions of Isolated Charged Particles	47
3.2.2	First Adiabatic Invariant	49
3.2.3	Second Adiabatic Invariant	50
3.2.4	Third Adiabatic Invariant	51

3.3	Low-Frequency Magnetized Plasma Waves	52
3.3.1	Equations of Linear MHD	53
3.3.2	The Wave Equation	54
3.4	The Shear Alfvén Mode in a Dipole Magnetic Field	54
3.4.1	Toroidal Oscillation of Field Lines	54
3.5	MHD Wave Mode Coupling in One Dimension	56
3.6	An Alternative Derivation of the Plasma Wave Equation, from Electromagnetism	61
4	Sources of ULF Waves	63
4.1	Introduction	63
4.2	Exogenic Sources	65
4.3	Boundary Instabilities	71
4.4	Field Line Resonances	74
4.5	Cavity and Waveguide Modes	79
4.6	Spatially Localized Waves	81
4.7	Ion Cyclotron Waves	84
5	Techniques for Detecting Field Line Resonances	87
5.1	Introduction	87
5.2	Variation in Spectral Power with Latitude	90
5.3	Variation of Phase with Latitude	91
5.4	Wave Polarization Properties	92
5.5	Spectral Power Difference and Division	95
5.6	Single Station H/D	95
5.7	Cross-Phase from Latitudinally Separated Sensors	98
5.8	Using ULF Wave Polarization Properties	100
5.9	Automated Detection Algorithms	103
6	Ground-Based Remote Sensing of the Magnetosphere	107
6.1	Estimating Plasma Mass Density	107
6.2	Travel Time Method of Tamao	109
6.3	Determining Electron Density	113
6.4	Verification of Ground-Based Mass Density Measurements	116
6.5	Determining Ion Concentrations	121
6.6	Field-Aligned Plasma Density	122
6.7	Plasma Density at Low Latitudes	126
6.8	Plasma Density at High Latitudes	128
7	Space Weather Applications	133
7.1	Magnetospheric Structure and Density	133
7.2	Plasmapause Dynamics	134
7.3	Density Notches, Plumes, and Related Features	139
7.4	Refilling of the Plasmasphere	145
7.5	Longitudinal Variation in Density	148

7.6	Solar Cycle Variations in Density	150
7.7	Determining the Open/Closed Field Line Boundary	152
7.8	Determining the Magnetospheric Topology at High Latitudes	153
7.9	Wave-Particle Interactions	155
7.10	Radial Motions of Flux Tubes	160
8	ULF Waves in the Ionosphere	163
8.1	Introduction	163
8.2	Electrostatic and Inductive Ionospheres	164
8.3	ULF Wave Solution for a Thin Sheet Ionosphere	167
8.4	ULF Wave Solution for a Realistic Ionosphere	171
8.5	FLRs and the Ionosphere	177
8.6	Remote Sensing ULF Electric Fields in Space	181
8.7	Quarter-Wave Modes	183
8.8	Detection of ULF Waves in the Ionosphere	186
8.9	Consequences for Radio Astronomy	192
9	Magnetoseismology at Other Planets and Stars	195
9.1	Magnetoseismology at Other Planets	195
9.2	Magnetoseismology of the Solar Corona	198
9.3	Introduction to Helioseismology and Asteroseismology	200
9.4	Field Line Resonances at Other Stars	204
	Appendix A	207
	Appendix B	211
	References	215
	Index	243