

CONTENTS

Abstract	1
1. General Introduction	3
1.1. Introduction	3
1.2. ELF emissions at high (≥ 3000 km) altitudes	4
1.3. ELF emissions at low (300–3000 km) altitudes	5
1.4. Contribution of the present work	6
2. Nonducted Propagation of Whistler Mode ELF Waves in the Magnetosphere	8
2.1. Introduction	8
2.2. Magnetospheric model for ray path calculation	9
2.3. Nonducted ray paths in the magnetosphere	11
2.4. Characteristics of the “penetrating ray paths”	15
2.5. Discussion	20
2.6. Summary	22
3. Nonducted ELF Emissions Observed by ISIS Satellites and on the Ground	24
3.1. Introduction	24
3.2. Wave normal direction of ELF hiss deduced from the satellite spin modulation	25
3.2.1. Introduction	25
3.2.2. Theory of wave normal detection	25
3.2.3. ISIS-2 observation on October 31, 1976	29
3.2.4. ISIS-1 observation on August 29, 1977	32
3.2.5. Statistical analysis on the wave normal direction of ELF hiss	33
3.2.6. Discussion and summary	34
3.3. Multi-ion cutoff of ELF hiss observed by ISIS satellites	35
3.3.1. Introduction	35
3.3.2. Seasonal variation of the lower cutoff occurrences	37
3.3.3. Latitudinal dependence of the lower-cutoff frequencies	39
3.3.4. Latitudinal dependence of the attenuation at the cutoff	45
3.3.5. Altitude dependence of the cutoff observed by two satellites	47
3.3.6. Discussion	49
3.4. Seasonal variation of ELF/VLF emissions observed by ISIS satellites and on the ground	55
3.4.1. Introduction	55
3.4.2. ISIS VLF observation	56
3.4.3. Ground-based ELF/VLF observation at Syowa Station	60
3.4.4. Discussion	62

4. Ducted Propagation Outside the Plasmapause	65
4.1. Introduction	65
4.2. Occurrence characteristics of periodic emissions.....	66
4.3. Spatial extent of periodic emissions	71
4.4. Diverging of ray paths from ELF duct exit	75
4.5. Summary	84
5. Simultaneous Observations of ELF Emissions and Auroral X-ray	85
5.1. Introduction	85
5.2. Relationship between X-ray and ELF slow variations.....	86
5.2.1. B ₅ -28 experiment	86
5.2.2. AZCO EXW1 experiment	88
5.2.3. B ₁₅ -3N experiment	89
5.3. Relationship between QP emissions and X-ray pulsations	91
5.4. Relationship between chorus bursts and X-ray fast pulsations	97
5.4.1. B ₁₅ -3N experiment	98
5.4.2. AZCO EXW1 experiment	100
5.5. Summary	104
6. Concluding Remarks	106
Acknowledgments	108
References	110
Appendices	115