Preface

Super low frequency (SLF: 30–300 Hz) and extremely low frequency (ELF: below 30 Hz) are the lowest frequency ranges in the applied radio spectrum. In SLF/ELF ranges, the wavelength is over 1,000 km, and the wave propagation in the Earth's space will be effected inevitably by the ground and the ionosphere. It is known that the excitation and emission in the space between the ground and the lower boundary of the ionosphere are of extreme difficulty. Meanwhile, because of the properties of low carried frequency, narrow bandwidth, and low information capacity, the applications of SLF/ELF waves do not range widely. However, in the past century the subject *Propagation of SLF/ELF Electromagnetic Waves* has been intensively investigated because of its useful applications in communication with submarines, geophysical prospecting and diagnostics, and seismic electromagnetic precursors monitoring. In the pioneering works of Wait, Budden, and Galejs, analytical solutions on SLF/ELF wave propagation are carried out. The subject has been investigated widely and the findings have been summarized in the classic book *Terrestrial Propagation of Long Electromagnetic Waves* by Galejs (1972). And some important findings are included in the book *Electromagnetic Waves in Stratified Media* by Wait (1970). In the past decades, some important progress has also been made. In the book *Resonances in the Earth–Ionosphere Cavity* by Nickolaenko and Hayakawa (2002), the fundamentals of ULF/ELF wave propagation and lightning problems are well summarized.

In this book it is investigated with an emphasis placed on the solution for SLF/ELF wave propagating in different regions, especially including Earth–ionosphere cavity or waveguide, anisotropic ionosphere, sea water, and layered Earth or sea floor. It is concerned with the approximated analytical solutions of the electromagnetic field radiated by a vertical or horizontal dipole. Usually, a simplified or idealized physical model is meant for solving a practical problem. From Maxwell's equations, and subject to the boundary conditions, the formulas of the electromagnetic field are always represented in the exact form of general integrals or in terms of special functions. Obviously, it is necessary to treat these by using mathematical techniques. The corresponding computations are also carried out, and some new conclusions are obtained.

In Chap. 1, the historical and technical overview is addressed for SLF/ELF wave propagation in the past century. Chapter 2 presents the fundamental theory of SLF/ELF wave propagation in Earth–ionosphere waveguide or cavity. Especially, the new algorithm is addressed to ELF range and the lower end of SLF range specifically. In Chap. 3, we treat the spherical harmonic series solutions for SLF/ELF field in the non-ideal Earth–ionosphere cavity and the speed-up numerical convergence algorithm. In Chaps. 4 and 5, we are concerned with SLF/ELF wave propagation in the regions consisting of the Earth, air, and ionosphere. Chapter 6 deals with SLF/ELF wave propagation along the boundary between sea water and ocean floor and the marine controlled-source electromagnetics (mCSEM) method. Chapter 7 addresses SLF field on the sea surface generated by a space borne transmitter. In Chap. 8, the atmosphere's noise in SLF/ELF ranges is summarized.

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