Techniques and Applications of VLF Propagation Modeling

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The ionosphere plays a role in radio propagation that varies strongly with frequency. At extremely low frequency (ELF, 3–3000 Hz) and very low frequency (VLF, 3–30 kHz), both the ground and the low ionosphere are strong reflectors of electromagnetic waves and together they form a concentric spherical Earth-ionosphere waveguide. Several different propagation regimes exist in this waveguide, from the global Schumann resonances below approximately 50 Hz, to the single waveguide mode regime between approximately 100 Hz and 1.5 kHz, to the highly multi-mode VLF band above approximately 3 kHz. While the underlying theory of ELF and VLF propagation in the Earth-ionosphere waveguide is well-understood, the ionosphere is a strongly anisotropic and highly inhomogeneous medium in all of these regimes, and accurately and realistically simulating propagation in these low frequency bands requires numerical methods.

We describe here our efforts to accurately develop models of non-global ELF and VLF electromagnetic propagation using a range of different techniques. Our main We will provide an up-to-date comparison of results from these different numerical techniques, including commercially available electromagnetic simulation tools. We will also describe and demonstrate several scientific and practical applications that rely on accurate modeling of ELF and VLF propagation, including ionospheric remote sensing and lightning remote sensing. Two likely targets here will be efforts to model the diurnal and seasonal variations of the phase of VLF transmitter signals and thus determine what ionospheric parameters are best able to reproduce the observed signals, and to model the propagation of broadband VLF and LF signals from lightning in an effort to extract key parameters about the source current.