Improved Spectral Analysis of Hiss and Chorus Observation in Ground-Based Data

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The dynamic evolution of the radiation belts is believed to be controlled in large part by two separate but related classes of naturally occurring plasma waves: ELF/VLF chorus and hiss emissions. Although whistler mode chorus has been extensively studied since the first reports by Storey in 1953, the source mechanism and properties are still subjects of active research. Moreover, the origin of plasmaspheric hiss, the electromagnetic emission believed to be responsible for the gap between the inner and outer radiation belts, has been debated for over four decades.

Although these waves can be observed in situ on spacecraft, ground-based observing stations can provide orders of magnitude higher data volumes and decades long data coverage essential for certain long-term and statistical studies of wave properties. Recent observational and theoretical works suggest that high resolution analysis of the spectral features of both hiss and chorus emissions can provide insight into generation processes and be used to validate existing theories.

Ground stations are intrinsically limited to sampling the portion of magnetospheric waves that are able to propagate to low altitudes and penetrate through the ionosphere. These measurable waves include either waves that have propagated such that their wavenormals are within the transmission cone at the ionospheric boundary or waves that have scattered from low-altitude meter-scale density irregularities. The whistler mode wave is intrinsically right hand circularly polarized (RHCP). When whistler mode waves couple into the Earth-ionosphere waveguide from the magnetosphere, they gradually become linearly polarized in accordance with allowable propagating waveguide solutions. The degree of circular polarization is quantified by the eccentricity (value between 0 and 1). We use the eccentricity as a filter to differentiate between magnetospheric and ionospheric effects in ground based observations. Being able to uniquely identify magnetospheric effects improves the utility of ground based observations.

Application of the classic Short Transform Fast Fourier (STFT) technique unfortunately yields a tradeoff between time and frequency resolution. In additional to Fourier spectra, we employ novel methods to make spectrograms with high time and frequency resolutions, independently using minimum variance distortionless response (MVDR). Moreover, wavelet analysis is capable of revealing aspects of data that other signal analysis techniques miss, aspects like trends, breakdown points, discontinuities in higher derivatives, and self-similarity. The major advantage afforded by wavelets is the ability to perform local analysis which allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information.

These techniques are applied to ground based data observations of hiss and chorus made in Alaska. Plasmaspheric hiss has been widely regarded as a broadband, structure less, incoherent emission. We quantify the extent to which plasmaspheric hiss can be a coherent emission with complex fine structure. Likewise, to date, researchers have differentiated between hiss and chorus coherency primarilyusing qualitative “naked eye” approaches to amplitude spectra. Using a quantitative approach toobserved amplitude and we present more rigorous classification criteria for these emissions.