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Observations of 50/60 Hz Power Line Radiation in the Low Latitude Ionosphere Detected by the Electric Field Instrument on the C/NOFS Satellite

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One of the most ubiquitous forms of EM radiation emanating from the earth's surface is that of power line radiation. Associated with AC electric power generation, such emissions are typically launched along conducting power lines that may travel hundreds, or even thousands of km, from generating stations. The fundamental frequencies of such emissions are characteristically 50 Hz or 60 Hz, depending on the regional standards for power generation/consumption. The frequency of this radiation is well below that of the plasma frequency of the ionosphere (typically several MHz) and hence the majority of the power reflects back to the earth and propagates in the waveguide formed by the earth's surface and the bottom ledge of the ionosphere, typically near 100 km. Nevertheless, a small fraction of ELF emissions associated with power line generation is observed in the ionosphere, in the same manner in which a small fraction of the power associated with ELF Schumann resonances and lightning sferics have been shown to penetrate into the ionosphere.

We present direct measurements of 50/60 Hz power line radiation detected by *in situ* probes on an orbiting satellite in the earth's ionosphere. The data were gathered by the Vector Electric Field Investigation (VEFI) tri-axial double probe detector flown on the Communication/Navigation Outage Forecast System (C/NOFS) satellite. C/NOFS was launched in April, 2008 into a low latitude (13 deg inclination) orbit with perigee and apogee of 400 km and 850 km, respectively, and re-entered in November, 2015. The electric field wave data were gathered by ELF receivers comprised of two orthogonal broadband channels sampled at 512 s/sec each, and digitized with 16 bit A/D converters. The data show distinct 60 Hz emissions while the satellite sampled within the Brazilian sector whereas distinct 50 Hz emissions were detected over India. Other, less distinct, emissions were observed over Africa and southeast Asia.

We discuss the characteristics of the received emissions, including their amplitudes and spectral features (i.e., harmonics, electric field polarization). We discuss the relation of the observed wave amplitudes to the ambient plasma density. We compare the altitude dependence of the observed electric field with theoretical predictions. We use these observations to advance our understanding of how natural terrestrial ELF emissions, such as those associated with Schumann resonances and lightning, penetrate into the ionosphere.