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Polar Cap Patches and Polar Holes in the High-Latitude Ionosphere: The Presence and Absence of Scintillation

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The high-latitude ionosphere is a highly complex plasma containing electron density structures with a wide range of spatial scale sizes. Large-scale structures with horizontal extents of tens to hundreds of km exhibit variation with time of day, season, solar cycle, geomagnetic activity, solar wind conditions, and location. Large-scale structures include polar cap patches and polar holes. The steep plasma density gradients at the edge of these features, and smaller-scale structures within polar cap patches are commonly associated with scintillation of trans-ionospheric radio signals, including those used by Global Navigation Satellite Systems (GNSS).

A series of multi-instrument case studies have been conducted using the EISCAT (European Incoherent Scatter) radars, a GNSS scintillation receiver, the SuperDARN radars and optical instruments. A polar cap patch was observed on the evening of the 14th December 2015 under moderately disturbed conditions (Kp=5). This showed an absence of both phase and amplitude scintillation. This suggests that small-scale irregularities had not grown within this large-scale plasma structure as it was transported across the polar cap, possibly as a result of the gentle plasma density gradient at the edge.

Polar holes was observed on the 17th December 2014 and 10th December 2015 under quiet (Kp=1) and moderate (Kp=3) geomagnetic conditions, respectively. There was an absence of both phase and amplitude scintillation of GNSS signals at the steep plasma density gradients at the edge of these holes, possibly as a result of the low plasma density inside the holes.

A series of special program experiments were run on the EISCAT radars in December 2018 and January 2019. These experiments were designed to identify steep plasma density gradients and determine whether or not they were associated with scintillation. These results are discussed. Minimum values for both the value of the plasma density and the gradient in this density required for scintillation of GNSS signals is determined.