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Methods to increase the precision of the frequency of FLR in SuperDARN VLOS and the magnetospheric density

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Some of the fluctuations in the solar wind, including those causing sudden impulses (SI), propagate into the magnetosphere and excite eigen-oscillations of the magnetic field lines and the frozen-in plasma via the mechanism called field-line resonance (FLR). It is known that the gradient methods enable us to effectively extract FLR signals from observed data. From the identified FLR frequency, one can estimate the mass density of plasma along the magnetic field line because, in a simplified expression, 'heavier' field line oscillates more slowly.

We have been applying the gradient methods to the VLOS (Velocity along the Line of Sight) data of the SuperDARN radars. The radars emit azimuthally-collimated beams of radio waves in the HF range, and some of them are backscattered by the ionosphere, while some others are backscattered by the ground and sea surface. From the Doppler shift of backscattered signals, one can calculate VLOS. Ionosphere-backscattered signals yield VLOS of the horizontally-moving ionospheric plasma (at mid- to low latitudes, VLOS also has a vertical component because the ambient magnetic field is tilted), while ground/sea-backscattered signals yield VLOS corresponding to the vertical motion of the ionospheric plasma because the length of the ray path of a beam can only be changed by the vertical motion of the ionosphere.

For a 30-min-interval event after an SI, we applied the gradient methods to VLOS data obtained from different beams and range gates, and successfully identified the FLR in both the ionosphere-backscattered signals and sea surface-backscattered signals. The mass density was thereby estimated using both scatters. As a result, the latter was significantly smaller than the former. This significant difference could come from a fairly large frequency spacing of the FFT analysis due to the fairly small duration (30 min) of the event. Thus, we have been trying a few methods to increase the frequency resolution.

We have already started testing the zero-padding method, and successfully obtained higher frequency resolution. We estimated plasma densities from these higher-precision FLR frequencies and confirmed that the above-stated density difference between the ionosphere-backscattered signals and the sea-backscattered signals became smaller. We have also noticed that the Hanning data window deletes most of the first oscillation just after the SI, having the largest oscillation amplitude. We have been examining the effect of this deletion on the FLR frequency estimation, including trying another data window called the Placnk-taper window. We have also started trying the direct Fourier Transformation and the AR (AutoRegressive) method. In this presentation, we report the progress of these examinations and tests.