Automatic identification of FLR events in the SuperDARN VLOS data by using the Gradient methods

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The FLR (Field Line Resonance) excites the eigen-oscillation of a magnetospheric magnetic field line where the frequency of an incoming wave matches the eigen-frequency of the field line. The FLR-generated eigen-oscillation has the following unique manner of change in its amplitude and the phase: The amplitude is maximum, and the phase-change rate is maximum, at the resonance point. This feature enables the identification of FLR-driven events. They can be identified in the ground magnetic field data and the ionospheric plasma velocity data. From thus identified eigen-frequency ('FLR frequency' below) one can estimate the magnetospheric plasma density along the field line which passes through the ground/ionospheric observation point.

In this study we use the SuperDARN radar data to identify the FLR: For each radar beam, the ionospheric plasma Velocity along the Line of Sight (VLOS) of the beam is obtained. Unlike the ground magnetometer data, the SuperDARN data is two-dimensional, enabling two-dimensional estimates of the magnetospheric equatorial plasma density and magnetospheric region identification.

To achieve that, it is important to identify as many FLR events as possible. However, overlapping non-FLR perturbations often hide FLR events. As a countermeasure to this problem, the Gradient methods (general name referring to both the amplitude-ratio and the cross-phase methods) have been applied to the ground magnetometer data; this method cancels out the overlapping perturbations by dividing the data from a magnetometer by the data from another magnetometer having an adequate latitudinal distance from the other. The Gradient methods are effective since the FLR frequency tends to depend on the latitude more strongly than the overlapping perturbations.

The Gradient methods are also applicable to the SuperDARN VLOS data. The field of view of each beam is divided into Range Gates (RGs below) having the same length along the beam. VLOS is obtained for each RG. Thus, each RG can be regarded as a 'virtual observatory.'

A difficulty in identifying FLR events in the SuperDARN VLOS data is that there is very large amount of two-dimensional data, making it time-consuming to visually identify FLR events. The Gradient methods enable automatic identification more easily than analyses of VLOS itself, since the Gradient methods yield positive-then-negative two peaks in the amplitude ratio and a single negative peak in the phase difference, and the latter single peak is located between the former two peaks; this pattern is fairly easy to identify.

Another advantage of applying the Gradient methods to the SuperDARN VLOS data is that we can choose any distance between the two RGs to which the Gradient methods are applied, since, as stated above, RGs are evenly located along each beam. It is expected that there is the best distance between two RGs to identify the FLR; This distance reflects the resonance width, which is an important quantity reflecting the diffusion and dissipation of the FLR energy.

We have been developing a computer code to automatically identify FLR events, and checking its preciseness by comparing the identified FLR events with visually identified FLR events. So far, we have applied the code to an FLR event visually identified at a few locations (each location is specified by a set of a beam number and an RG number) of two radars (HAN and PYK). For the most of those locations, the current version of the code has identified the FLR. It has also identified locations missed by visual inspection. Furthermore, it has found a location where the FLR signal was possibly masked by overlapping perturbations. For HAN, the best distance between two RGs was two in the RG number, corresponding to the latitudinal distance of 80 km. We also plan to apply the code to other SuperDARN radars.