Differential vector velocity effects on HF radar soundings in the equatorial and in the polar ionosphere

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We present results of numerical simulation of Doppler measurements and vector-velocity determinations based on them, for the equatorial and polar ionospheric F region. Ionosondes and some backscatter radars define the experimental situation, where 'echoes of opportunity' are measured to obtain their apparent directions of arrival, Doppler and other properties.

For the equatorial ionosphere we model a typical situation where the E region is filled with small-scale irregularities caused by the equatorial electrojet, and is moving at a velocity not equal to the F region velocity. Irregularities in ionospheric layers are modeled by small-scale (~2 km) wave-like structures, and the movements of the layers are modeled by movements of these structures. Parameters of the sounding radio signals are determined by multiple numerical solutions of the set of extended ray tracing equations. We assume that the E-region is underdense for the radio frequencies used to obtain F-region echoes.

We show that when F region vector velocities are calculated from the apparent directions and Doppler values, and are attributed to the reflection level according to standard assumptions, they demonstrate a significant bias if a differently-moving E-region is present. An earlier unnoticed peculiarity of this effect is that its magnitude depends not only on the E-F vector velocity difference, but also on the amplitude of the E-region irregularities.

This result is in qualitative and quantitative agreement with recent experimental observations by Woodman, Chau and Ilma [Geophys. Res. Lett., 33, L01103, 2006]. For the technique of vertical ionospheric sounding this suggests the necessity of a special inversion procedure for obtaining vector velocities that treats properly the differential motion of ionospheric layers.

For the polar ionosphere the case of oblique long-range propagation of an HF signal has also been treated. Differential motions of the E and F regions traversed by the ray path may be due to their significant geographical separation. Consequences of this effect for SuperDARN data interpretation are considered.