# Triple splitting and z-rays in automatic scaling of polar ionograms

Carlo Scotto
Istututo Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Roma, Italy

Many polar ionograms show the spread-F, which is caused by scattering from irregularities in the ionosphere across the entire radiation angle of the antenna. Besides, at polar latitudes, it is sometimes observed that the trace of the F2 region, instead of being double as usual, is triple. The ray that produces the supplementary trace is called a z-ray.
In this work the theory of propagation in a direction almost parallel to the Earth's magnetic field is reviewed and is demonstrated that a value of collision frequency $\nu > 0$ ensures that the divergence of the group refraction index for the ordinary $\mu_{\text{g-ord}}$, which for $\theta = 0$ ($\theta$ is the angle between the wave vector **k** and **B**) occurs when $X = 1+Y$, also occurs until $\theta < \delta$, $\delta$ being a small angle. It is shown that in this way, a propagation "hole" is created in the ionosphere, as discovered by Ellis (1956).
However ionograms sometime feature a duplicate ordinary trace due to reflection from two different directions. A duplicate trace displaced from the critical frequency of the ordinary ray by $f_B/2$, as would be expected of a z-ray, can lead to an uncertain interpretation of the radio propagation conditions.
The Autoscala computer program has been successfully applied to polar ionograms, using two supplementary routines designed specifically. These routines have been designed to identify Spread-F, which is the signature of scattering from irregularities in the ionosphere and ionograms with three separate traces. The group refractive index of the ordinary ray in the presence of electron-neutral collisions has been calculated numerically. The electron density profile usually estimated by Autoscala from the ordinary trace is used to restore the z-ray trace. It is shown that this procedure can help to separate the rare cases of z-rays from among the numerous cases of duplicate ordinary traces, due to reflection from two different directions. This procedure can be applied to automatic scaling of polar ionograms.
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