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Interactive Comment

Interactive comment on "Aspect sensitivity of VHF echoes from field aligned irregularities in meteor trails and thin ionization layers" *by* Q. H. Zhou et al.

W. Elford

wgelford@aol.com

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In the third line of the Introduction there is a reference to "Jones, 1991". There is a more recent paper on diffusion of meteor trails in the presence of the Earth's magnetic field that should also be referenced. The article is by R. E. Robson and is entitled "Dispersion of meteor trails in the geomagnetic field." Physical Review E, volume 63, 026404, 2001.

Robson is a theoretical plasma physicist with a distinguished publication record, and his philosophy regarding this paper is summed up in the introduction, "*Little attempt has hitherto been made to place the meteor [diffusion] problem in the context of main-stream plasma physics. A comparison is long overdue and is the first and primary task*

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of the present paper". I should point out that Robson wrote his paper before the theoretical papers by Oppenheim, Dyrud and vom Endt had been published. Thus there is no reference in Robson's paper to their work on the effect of plasma instabilities in meteoric ionisation.

As is indicated in the papers by Oppenheim et al the plasma instabilities in meteor trails are restricted to a limited height range, typically 95-105 km. For meteoroids that enter the atmosphere with speeds at the upper end of the speed distribution, say 60-70 km/s there is a significant fraction of meteor trails that form above 105 km. It is the diffusion of these trails that is of interest here, and to which the theory discussed by Robson is applicable. In his paper Robson derived the following expression for the effective diffusion coefficient,

$$D_{eff} = D_{||} \sin^2 \mu \sin^2 \theta + D_{\perp}(1 - \sin^2 \mu \sin^2 \theta), \quad (1)$$

where $D_{||}$ and $D_{\perp}$ are the ambipolar diffusion coefficients parallel and perpendicular to the magnetic field, θ is the angle the field makes with the trail, and μ is the angle between the wave vector and the normal to the plane of the trail and the field. Values of D_{II} and $D_{\perp}$ are given in Elford and Elford (2001).

An alternative expression to equation (1) can be derived that depends only on the direction of the radar beam and the direction of the magnetic field. In Robson's paper, equation (9) shows that the angle ψ between the magnetic field and the radar beam is given by

$$\cos \psi = - \sin \mu \sin \theta.$$

We can now recast the expression (1) in terms of the angle y as follows,

$$D_{eff} = D_{||} \cos^2 \psi + D_{\perp} \sin^2 \psi. \quad (2)$$

This expression immediately shows that when the radar beam is orthogonal to the field, i.e. $\psi = 90°$, the value of $D_{eff} = D_{\perp}$, which is also the minimum value of D_{eff}.

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To apply expression (2) to any meteor radar site we need to express ψ in terms of the beam direction and the coordinates of the magnetic field. We choose a coordinate system where the North direction is along the OX axis, the East is along the OY axis and the OZ axis is directed downward.

Let the magnetic field ***B*** have a dip angle i and an azimuth θ East of North. Then the direction cosines of ***B*** are (cos i cos θ, cos i sin θ, sin i).

The radar beam is assumed to have an elevation angle α and directed at an azimuth Φ east of north. The direction cosines of the beam are (cos α cos Φ, cos α sin Φ, - sin α).

Whence the angle ψ between the magnetic field and the radar beam is given by

$$\cos\psi = \cos i \cos\theta \cos\alpha \cos\Phi + \cos i \sin\theta \cos\alpha \sin\Phi - \sin i \sin\alpha$$
$$= \cos i \cos\alpha \cos(\theta - \Phi) - \sin i \sin\alpha. \quad (3)$$

A meteor trail of sufficient electron line density will produce a “transverse" radar echo if it lies in the “echo plane" orthogonal to the radar beam. Expressions (2) and (3) show that the effective diffusion coefficient applicable to such a trail is independent of the azimuth of the trail within the echo plane.

A measure of the extreme effect of the geomagnetic field on radar meteor echoes is the comparison of the durations of echoes from underdense trails at a given height when the radar beam is directed orthogonal to the field and when it is directed parallel to the field. The ratio of these two durations is a measure of the maximum enhancement in the echo duration due to the magnetic field, and is given by $D_{||}/D_{\perp}$.

As an example consider the MU Radar that is situated at a magnetic latitude of +49°. If the radar beam is directed at the same azimuth as the magnetic field ($\sim$ - 7°) the maximum enhancement in the duration of an underdense meteor echo will occur when the beam is at an elevation of 41°. The predicted enhancement is about 100 times at 105 km and over 500 times at 110 km.

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Even for beam elevation angles 10° from the position of orthogonality to the field, the predicted enhancement in duration is about 25 times at 105 km and more than 30 times at 110 km.

At the present time evidence for these predicted duration enhancements is mainly anecdotal, as there seems to be a lack of experiments dedicated to studying the duration of radar meteor echoes under the conditions described above.

References:

Elford, W.G. and Elford, M.T., 2001. The effective diffusion coefficient of meteor trails above 100 km. European Space Agency, SP-495, Proceedings of the Meteoroids 2001 Conference, Kiruna, Sweden, August 2001, 357-359.

Robson, R.E., 2001. Dispersion of meteor trails in the geomagnetic field, Phys. Rev. E Vol 63, 026404.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 731, 2004.