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Estimation of Turbulent Energy Dissipation Rate from Sporadic-E Parameters

Yurij V. Kyzyurov
Main Astronomical Observatory NASU, Kiev, Ukraine (KYZYUROV@MAO.KIEV.UA / 38044 5262147)

Neutral air turbulence plays a very notable role in the dynamics of atmospheric layers below the ionosphere and is important for the ionospheric D and E regions too. Above an altitude of 80 km a source of the turbulence may be destruction of the atmospheric gravity waves and tides propagating from the lower atmospheric layers and also the nonlinear interaction of planetary waves and tides. These large-scale atmospheric motions are also responsible for a vertical shear of the neutral wind that is necessary for the production of mid-latitude-type sporadic-E. The sporadic-E may serve as an example of the ionosphere-atmosphere interaction. If a sporadic-E height is below the homopause level, the turbulence exerts an essential influence on sporadic-E parameters. Hence we can estimate parameters of the turbulence from parameters of the sporadic-E. A fundamental parameter of turbulence is the mean rate of turbulent energy dissipation, ε. Estimation of ε from sporadic-E parameters was the purpose of this report. Results of the windshear theory of sporadic-E formation and the Richardson–Obukhov law that describes the turbulent diffusion caused by eddies with length-scales smaller than l:

$$D_T(l) = C_T\varepsilon^{1/3}l^{4/3}, \tag{1}$$

($C_T \approx 1$ is a dimensionless constant) were used to obtain expression that connects ε with sporadic-E parameters. Under assumption of sporadic-E formation by a sinusoidal neutral wave with amplitude u_0 and wavelength L_0, the rate of turbulent energy dissipation can be expressed through the thickness of the layer L_s as (in (1) $l = L_s$):

$$\varepsilon = L_s^2(2\pi u_0\beta_i \cos I/L_0)^3, \tag{2}$$

where β_i is the ratio of the ion gyrofrequency Ω_i to the ion-neutral collision frequency ν_i, I is the magnetic dip angle. The expression (2) was used to estimate ε when the sporadic-E altitude was near 100 km ($\nu_i = 3\times10^3\,\mathrm{s}^{-1}$, $I = 45°$, $u_0 = 70\,\mathrm{m\,s}^{-1}$, L_0=10 km) for two variants of the sporadic-E ion composition (the mean ion mass took values 31 and 51 a.u.m. or $\beta_i \approx 0.05$ and 0.03, respectively), and the thickness L_s was changed form 1 to 3 km. It was shown that in the case of $\beta_i \approx 0.05$, the rate ε changed from 4.1×10^{-3} to $3.7\times10^{-2}\,\mathrm{m^2s^{-3}}$, and for $\beta_i \approx 0.03$ from 9.2×10^{-4} to $8.3\times10^{-3}\,\mathrm{m^2s^{-3}}$. The maximum electron density in the layer N_0 was estimated also. For the background electron density in the E region $N_E = 3.0\times10^9\,\mathrm{m}^{-3}$, N_0 decreased from 1.2×10^{10} to $4.0\times10^9\,\mathrm{m}^{-3}$ with increasing L_s form 1 to 3 km. If the sporadic-E is above the homopause level then the windshear theory under the chosen values of parameters predicts its thickness L_s of about 152.5 m and $N_0 = 7.9\times10^{10}\,\mathrm{m}^{-3}$. Thus, even the weak turbulence (small values of ε) is very important for the sporadic-E.