SPORADIC E-LAYERS AS CURRENT GENERATORS

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Quasi two- and three-dimensional models of dense night-time sporadic E-layers of the earth's ionosphere as current generators are developed. The layers are assumed to be situated in an ambient plasma of about fifty times lower density and their neutral particles possess a rather high bulk velocity relative to the ions. The quasi-two dimensionality of the first model results from the assumption that relative electron-ion drifts in the neutral wind direction are almost compensated. The ion current in the neutral wind direction is caused by collisions with neutrals, but the electron current is a result of the appearing electrical polarization field. Within the proposed model the electron current is closed by an external circuit, for which a rough description is developed. The electrical polarization field is considered and estimated taking into account the altitude profile of the electrical conductivity in the external circuit. Further, a quasi-three-dimensional model of local current generation caused by the action of short-duration intense neutral winds on sporadic E-layers of finite horizontal dimensions is presented. In the analysis, the Hall and Pedersen currents in the sporadic layer as well as in the less dense plasma above the sporadic layer are taken into account. Thus, the currents in two horizontal plasma layers of different density and the field-aligned currents connecting the borders of these two layers are considered. A two-fluid hydrodynamic analysis of the system shows that maximum Hall currents occur if the sporadic layer-generator is situated at altitudes of about 120 km. The bulk electron velocity in these currents can reach values of the order of the neutral wind velocity.

1. INTRODUCTION

The morphology and creation conditions of sporadic E-layers (E₄-layers) in the mid-latitude ionosphere at altitudes of 90 km to 130 km have been studied for some decades [1-4]. It has been found that night-time mid-latitude E₄-layers contain large concentrations of metallic ions (Fe⁺, Mg⁺, Al⁺, K⁺, Ca⁺) in addition to the usual O⁺ and NO⁺-ions. Other typical E₄ parameters are: charged particle density nₑ ≈ 10⁴ cm⁻³, a vertical width of 100-500 m, and a horizontal extent of about 50-100 km [1]. Thus, E₄-layers can be considered as plasma clouds, which are denser and heavier than their surroundings. Further, it seems clear that strong earthquakes as well as strong anthropogenic activity in the vicinity of large industrial centers can cause E₄-layer anomalies [1, 5-7].

In order to explain the also unusually high electron velocities perpendicular to the magnetic induction \( \vec{B₀} \), a model of an E₄-layer as a current generator is developed. It is assumed that the sporadic layer moves under the action of an intense wave, which may be an acoustic wave (Fig.1). Acoustic waves have indeed been observed in the ionosphere, e.g., during seismic and strong anthropogenic activity [2, 8]. Moreover, acoustic waves can be generated under special meteorological conditions such as severe weather. According to ionospheric filter effects, waves with frequencies of \( 5 \times 10^{-3} - 0.1 \) Hz should propagate up to E-layer altitudes of 90-140 km. Thus, it is assumed that an acoustic wave with a period larger than 10 sec but smaller than the Brunt-Väisälä period of 500 sec directly transfers its momentum to the neutral particles of a sporadic layer and only slightly influences the environment of the sporadic layer. That is, a situation is considered in which when the half-length of the wave is of the order of the dimension of the sporadic layer in the direction of wave propagation, and the layer interacts with the positive wave phase. Observed neutral wind velocities \( Vₙ \) in the lower thermosphere at mid-latitudes in summer are of the order of 20-40 m/sec [2],

but occasionally higher values of up to 80 m/sec and more seem to occur.

In order to understand the main features of the phenomena which take place when an acoustic wave propagates through a finite sporadic layer, two simplified models (quasi-two-dimensional and quasi-three-dimensional) will be considered.

2. QUASI-TWO-DIMENSIONAL CURRENT GENERATOR MODEL OF E$_o$-LAYER

For simplicity, first a quasi-two dimensional model of the E-layer is considered, assuming that electrical currents in the neutral wind direction are quickly compensated by strong electric currents above the sporadic layer.

The main feature of the phenomenon of current generation by sporadic E-layers can be studied with the help of the following easy model (Fig. 2). A homogeneous in density $n_0$ and temperature plasma cloud has the form of a parallelepiped, which is placed in a plasma of much lower density $n_0$ perpendicular to a homogeneous magnetic field $\vec{B}_0$ directed along the $z$-axis. Under the action of an acoustic wave, the neutral particles of the cloud move in the $z$-direction, $\vec{V}_n^0 \parallel \vec{n}_z$. As a result of the Lorentz force at the edges of the cloud charged layers form and a polarization field $E_y$ occurs, which decelerates the electron motion in the $y$-direction. The electron current in the cloud is closed by Pedersen and field-aligned currents in the plasma layers above the sporadic E-layer. Thus, in this model the effects of the external circuit must be taken into account. Studies of the influence of external circuits using models for the electrical conductivity have already been partially done by Völker and Haerendel [9] for ionospheric plasma clouds above the E-layer, and by Jacobson and Bernhardt [10], who also considered electrostatic effects during acoustic influences.