ELF WHISTLER TRANSMISSION WINDOW IN MARTIAN DAYTIME IONOSPHERE

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1. Introduction

The NOZOMI spacecraft will be inserted into the elliptic orbit around Mars in 2004 to observe the Martian ionosphere and magnetosphere (PLANET-B Prelaunch Report, ISAS, 1998). One of the onboard instruments is the Low Frequency plasma wave Analyzer (LFA) which observes the plasma waves in the low frequencies from 10Hz to 32 kHz. Using LFA, we are planning to detect the Martian atmospherics related with the discharges during dust storms. The electrostatic discharge process has been studied by Conti and Williams [1975], Eden [1977], Melnik and Parrot [1998], and recently by Farrell et al. [1999]. However, so far as we know, there has been no experimental proof of both radio emissions and sporadic optical emissions from electric discharges in the Martian atmosphere.

The wave intensity at NOZOMI orbit depends on the radiation power from discharges, transmission characteristics of electromagnetic waves through the Martian ionosphere, and the propagation characteristics in the ground-ionosphere waveguide. In order to assess the possibility of the Martian atmospheric detection, we study the propagation characteristics of electromagnetic waves through the ionosphere.

2. Ionospheric Model

The electron density of the Martian lower ionosphere for the daytime is based on measurements by the Viking I spacecraft (Johnson et al., 1991) and the Phobos II spacecraft (Pedersen et al., 1991). Figure 1 shows the profile of electron density in the altitude range from 50 km to 200 km. In the dayside of Mars, the ionosphere has a peak around at 130km with an electron number density about 10^5 cm^{-3}. The full thick-line above 100 km indicates the electron number density fitted with these data, while the thin-line indicates their simple extension down to altitude 50 km.

Recent observations by the Mars Global Surveyor (MGS) show that there is no significant planetary magnetic field of global scale originated by the dynamo mechanism but there are multiple magnetic anomalies in the crust of Mars (Acuna et al., 1998). This magnetic field extends into the lower ionosphere and the maximum magnitude is about 1000 nT, therefore the ionosphere should be treated as a magneto-ionic medium. The magnitude and direction of such a crustal magnetic field varies from place to place. However, we assume that the magnetic field is constant in the space of consideration, that is, the area with the horizontal length with a few of hundred kilometers and altitude up to 150 km from the ground.

The collision of electrons with neutral particle affects the damping of electromagnetic wave energy and contributes also to the mode conversion among the characteristic magneto-ionic mode waves. The collision frequency is thought to be linearly dependent on the atmospheric pressure *P*. On the basis of the observations on composition and the altitude profile of the Martian upper atmosphere by Viking 1 and Viking 2 (Nier and McElroy, 1977) and recent observations by Mars Pathfinder (Schofield et al, 1997), we use the effective collision frequency, profile of which in the ionosphere from 50 km to 200 km is shown by the dotted line in Figure 1 for dayside during low solar activity.

3. Calculations

The Spacecraft NOZOMI is planned to go on the elliptical orbit around Mars and the perigee altitude will be as low as 150 km from the ground. Therefore we calculate the wave intensity in the altitude range from the ground to 200 km including the electron density peak. The calculation method of the electromagnetic wave propagating through the ionosphere has been developed by Nagano et al. [1975], and we here follow their full-wave method. The wave incident into the ionosphere from below is linearly polarized and the electric field intensity is normalized as 1 V/m [0 dBV/m] in the calculation. We have carried out the calculations in the various conditions for the wave frequency *f*, incident angle θ_i to the ionosphere from below, the magnitude B_0 and the dip angle *Dip* of the Martian magnetic field. Figure 2 shows the altitude profile of the electric field intensity of the wave which is incident from below into the ionosphere with incident angle $\theta_i = 10^0$ (upward propagation). For this case the magnetic field intensity B_0 is 400 nT and the dip angle *Dip* is 90^0 (vertical). The wave frequency is chosen as a parameter to make clear the frequency-dependence of wave intensity in the ionosphere. It is seen from Figure 2 that the wave intensity decreases as the wave propagates upward. At altitude around 100 km, it decreases abruptly. At altitudes above around 150 km, the wave intensity is nearly constant, because the wave propagates in the whistler-mode. The attenuation increases with increasing frequencies: it is 70 dB at 10 Hz, 80 dB at 50 Hz, 90 dB at 100 Hz and 110 dB at 200 Hz. Calculation results for the case of magnetic field of 100 nT show that the attenuation is very large: it is 90 dB at 1 Hz, 120 dB at 10Hz and 200 dB at 50 Hz. It is clearly demonstrated when the magnetic filed intensity is 10 nT, the wave intensity decreases considerably even in the frequency range of 10 Hz, although the calculation results are not shown here.

4. Discussions

The wave entering into the ionosphere propagates with less attenuation only in the region where the Martian magnetic field is intense, i.e., in the region of magnetic anomaly. As the intensity of magnetic field found by Mars Global Surveyor is the order of several hundreds of nT, the wave frequency is in the ELF band, 10 Hz ～ 200 Hz in the LFA receiver band, in which the wave propagates with low propagation attenuation. This interpretation is quite different from the previous understanding that the waves emitted from the impulses in the atmosphere cannot be observed from spacecraft because of the ionospheric shielding effect or large attenuation during the propagation through the ionosphere. Thus, we may have a possibility to receive the atmospheric noises by the LFA onboard NOZOMI orbiter in the ionosphere above the magnetic anomalies. Recently, Melnik and Parrot [1999] have calculated the attenuation in the ionosphere and made a conclusion that the waves can propagate on the nightside at wider frequencies in ELF and VLF bands less than 4 kHz. Our calculation is concerned with propagation characteristics in the dayside ionosphere and we have shown that there is a frequency window in the ELF band. The NOZOMI observation of impulsive radio emissions from the Martian atmospherics is important for the study of planetary atmospherics as of Earth.

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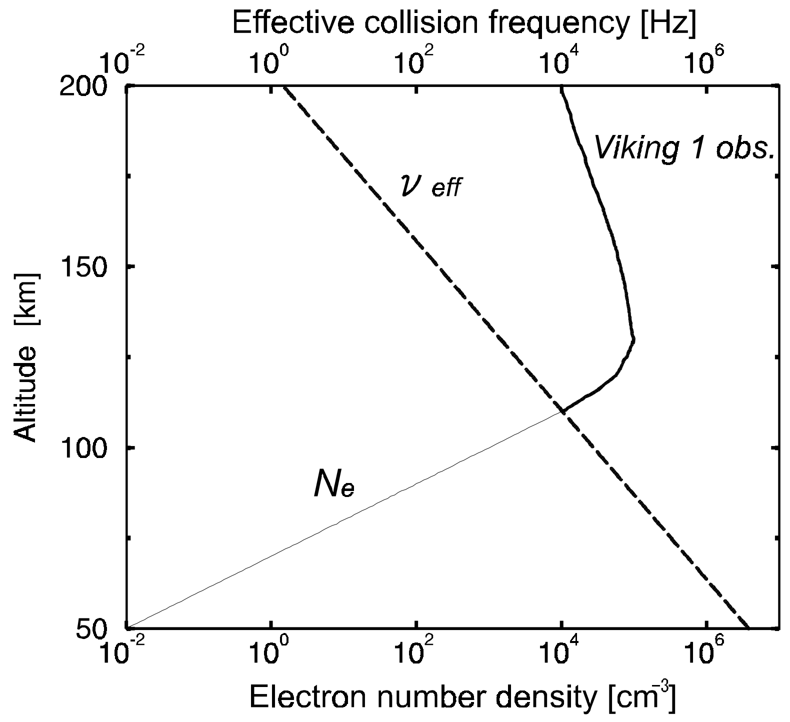

Figure 1. Ionospheric model with an electron density profile $N_e(z)$ and an effective collision frequency profile $\nu_{\mathrm{eff}}(z)$ of electrons with neutral particles

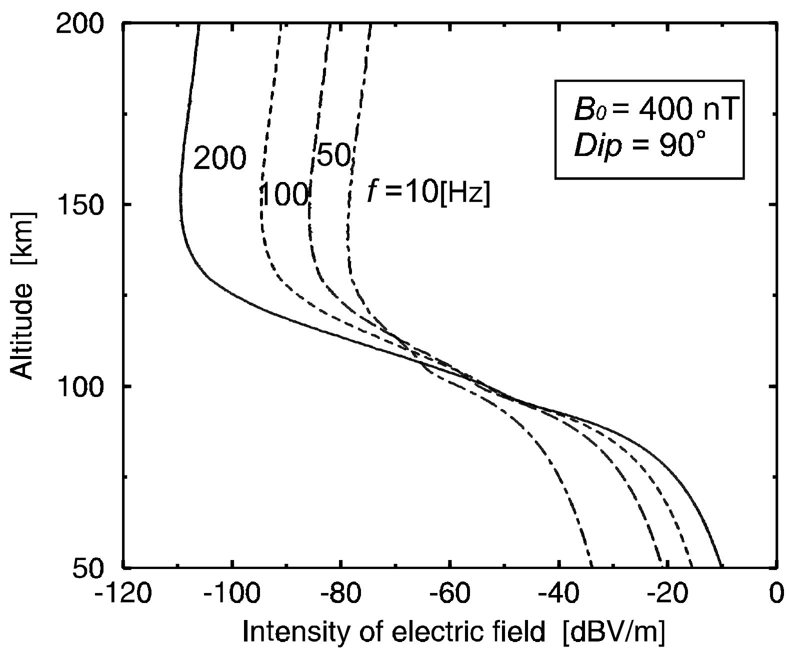

Figure 2. Calculation results of the frequency dependence of wave intensity in the ionosphere from 50 km to 200 km for the case of magnetic field of 400 nT