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Research Article

The Numerical Analysis of The Group and Phase Velocity of Waves in The Ionosphere is Thought to Be Collision-Free

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Abstract

The behavior of phase and group velocities of waves occurring in the ionosphere, which is considered collision-free, is the focus of this article. The phase velocities of the waves (ordinary, polarized waves) occurring in the ionosphere are larger than the speed of light, whereas the group velocities are less than the speed of light, according to the findings. The phase velocities are compatible with changes in electron density under acceptable conditions, however, the group velocities show an antisymmetric variation with the electron density. In the northern hemisphere, the extra-ordinary wave takes negative values, while in the southern hemisphere, it takes positive values.

Keywords: Waves in Ionosphere, Group-phase velocity

1. Introduction

The ionosphere layer surrounding the atmosphere is defined as a conductive and natural plasma that starts from 50 km from the ground and extends up to about 2000 km[1-3,11-23] The most basic parameter of the ionosphere is the electron density, which is formed depending on the wavelengths of different frequencies coming from the Sun.

Depending on the electron density, the ionosphere is divided into different plates. Two quantities affect electron density: physical and chemical processes[1-3]. Two quantities affect electron density: physical and chemical processes. However, the most effective reason for the change in electron density is solar radiation[8-10, 13-16]. Since the ionosphere contains free electron density, it can reflect, refract or transmit the wave (depending on the frequency of the wave) coming to the environment[4-7]. With the ionosphere remote sensing method, it is possible to have deep data and knowledge about the environment. While doing this, either from the ground to the ionosphere; or by sending mountains to the ionosphere from the satellite, the characteristics of the waves that pass through the ionosphere with a receiver or reach the receiver by passing through the ionosphere are examined, and information about the ionosphere is obtained[17-25]. There are serious studies on this subject both theoretically and experimentally in the literature. Since the electron structure of the ionosphere depends on many parameters, it can show instantaneous changes[11,13]. Therefore, it is not possible to fix studies on the ionosphere. When an electromagnetic wave with frequency enters the ionosphere, since the ionosphere is double refractive, it splits into two waves (right and left polarized wave) in the direction of the wave's travel, and two different waves, perpendicular to the direction of the wave's travel (ordinary and extra-ordinary waves)[4-8,10,12]. In this study, assuming that the ionosphere is collision-free, we studied the phase and group velocities of the waves mentioned above in the F- region of the ionosphere. Why phase and group velocity? Group velocity is often thought of as the rate at which energy or information is transported along with a wave. In most cases this is true and the group velocity can also qualify as a waveform signal. However, this information is not always correct if traveling in a wave-absorbing environment. Many studies and experiments since the 1980s have shown that the group velocity of laser light sent with specially prepared materials can exceed the speed of light in an air gap. However, in this case, faster-than-light communication is not possible because the signal speed is slower than the speed of light in all directions. It is also possible to reduce the group velocity to zero by stopping the current or creating a negative group velocity[4-8,10,12,18,25].

2. The Group and Phase Velocities of Waves Occurring without collision Ionosphere's F-Region

If the collisions are neglected, the wave propagation vector and the earth's magnetic field are taken as in figure 1, the waves occurring in the ionosphere, respectively: (ordinary, polarized, and extra-ordinary)

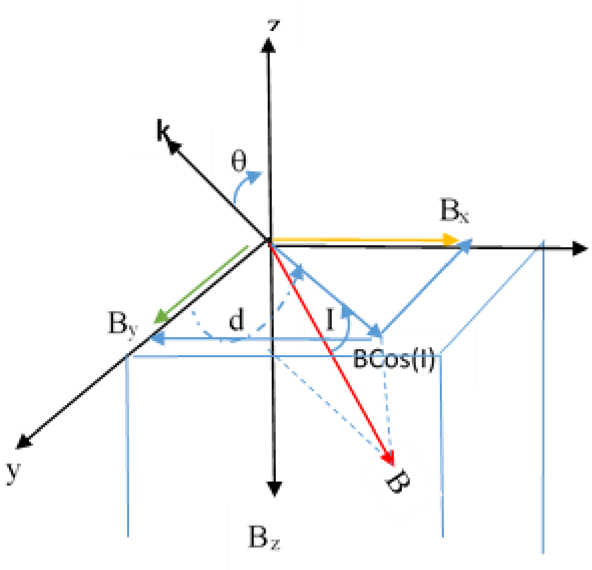

Fig.1. Earth's magnetic field geometry in the northern hemisphere[25]

$$n_o^2 = 1 - \frac{\omega_p^2}{\omega^2} \quad (1)$$

$$n_P^2 = 1 - \frac{X}{(1 \mp Y_z)} \quad (2)$$

$$n_x^2 = 1 - \frac{X(1-X)}{a} \quad (3)$$

The plasma parameters,

$$X = \frac{\omega_P^2}{\omega^2} \text{ and } Y_z = \frac{\omega_{cz}}{\omega}, \; a = 1 - X - Y_y^2 \quad (4)$$

ω_p : (electron plasma frequency), ω: wave frequency.

The group velocity of the wave depends on the refractive index of the medium

$$V_{g\delta} = \frac{c}{n_\delta + \omega \dfrac{\partial n_\delta}{\partial \omega}} \quad (5)$$

In which, δ is symbolized by O (ordinary wave), P;(the polarized wave) X; (extra-ordinary wave), respectively. The phase velocity of all of the waves is obtained by

$$V_{p\delta} = \frac{c}{n_{p\delta}}$$

(6)

3. Numerical analysis and Results

The magnitudes of the phase and group velocity of waves occurring in the ionosphere at low altitudes and maximum sunspots were investigated in this study utilizing IRI (International Reference Ionosphere) on equinox days. On equinox days, the sun's rays are perpendicular to the equator at midday, resulting in equal day and night. On June 21, the northern hemisphere experiences the longest day, and the days begin to shorten, while the southern hemisphere experiences the shortest day, and the days begin to lengthen. This day is regarded as the start of summer in the northern hemisphere and the start of winter in the southern hemisphere in some countries.. However, it is considered in other countries as the middle of summer or winter, and at 12.00 LT in the equatorial anomaly zone of the ionosphere (F-region 390 Km). The average of the phase and group velocities of each latitude and the related wave was used to calculate the heights. Our primary goal is to determine how the phase and group velocity of all waves in the ionosphere will behave at the same heights. To answer this topic, we first calculated the magnitudes of the phase and group velocities analytically. The fluctuation of phase and group velocities with latitude at low latitudes in collision-free ionosphere plasma is depicted in the diagram. As a result, in both seasons, phase and group velocities show symmetrical shifts. The phase velocity in the medium exceeds the speed of light, whereas the group velocity is less. The equator has the highest phase velocity and the lowest group velocity. The phase velocities are always greater than the group velocity and the speed of light when the figures are observed. Group velocities are symmetrical with regard to phase velocities, and phase velocities are compatible with changes in electron density.

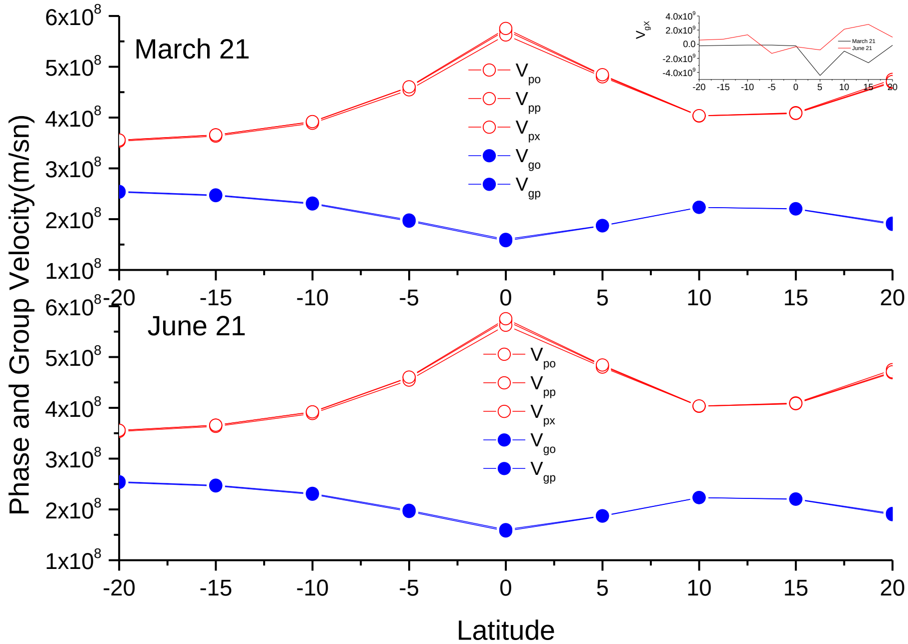

Fig.2 The change of phase and group velocity with latitude(21 March and June)

4. Conclusions

The magnitudes of phase and group velocities of waves occurring in the ionosphere are investigated in this work under collision-free ionosphere plasma circumstances. The phase velocities and group velocities, according to the data, are larger than the speed of light. The fluctuation in electron density is compatible with phase velocities, while group velocities are anti-symmetric with electron density. The extra-ordinary wave's magnitude of the group velocity behaves differently than the others. In the south and north latitudes, it resembles a vibrational movement. It necessitates values that exceed the speed of light. The magnetic field could be to respond.

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