PROPAGATION OF SHORT PULSES IN PLASMA
HALF-SPACE (IONOSPHERE)

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The exact solution of the problem in the half-space of non-homogeneous plasma is obtained, and an asymptotic method for the same task as well. The estimations of the non-linearity and the electron-atom collisions influence regarding the problem are carried out.

1. Introduction
This paper is the continuation of [1] where the rigorous solutions to the problem of short pulse propagation in plasma half-space for simplest models of the electrons density. Here, the asymptotic solution is presented enabling to approach the real distribution of electrons.

The 2-nd part of this work is on the peculiarities of taking into account the plasma electrons collisions with the atoms as short pulses are passing through.

2. The Asymptotic Solution
As a “large” parameter is proposed

\[ k = \frac{L}{t_0 c}, \]

where \( t_0 \) – the initial pulse duration at the medium boundary, \( L \) – the linear size of the pulse propagation region, \( c \) – the velocity of light.

In this case the field \( u(z,t) = Z(z)T(t) \) obeys the equation

\[ \frac{d^2 Z}{d\zeta^2} = k^2 p(\zeta) Z, \]

where \( \zeta = z/L \), \( p(\zeta) = t_0^2 \left[ \omega_p^2 (\zeta) - \omega^2 \right] \), \( \omega_p \) – the plasma frequency, and the ordinary equation for \( T(t) \).

If the field decreases as \( \zeta \) increases relatively arbitrary cross-section \( \zeta_0 \), we obtain [2]:

\[ dZ = \frac{B_d \omega}{\sqrt{k^2 - p(\zeta)}} \exp \left( -k \frac{\zeta}{\zeta_0} \sqrt{p(\zeta) d\zeta} \right), \]

\( \zeta > \zeta_0, \omega > \omega_p(\zeta), \)

If \( z = 0 \) at the plasma region boundary, then

\[ p(0) = -\omega^2 t_0^2, \]

\[ TdZ|_{z=0}^0 = \frac{B_d \omega}{\sqrt{k^2 - \omega^2 t_0^2}} \exp(-i\omega t). \]

The incident onto the plasma field at \( z = 0 \) [1] is as follows:

\[ (1 + R) \exp(-i\omega t) d\omega, \]

where \( R \) – reflection coefficient. As these fields are equal as well as their corresponding normal derivatives and in view of \( \frac{dZ}{dz} = \frac{1}{L} \frac{dZ}{d\zeta} \), one can obtain

\[ \frac{1 + R_\omega}{1 - R_\omega} = \frac{c t_0}{L} \sqrt{\omega_0 - \omega_0^2}, \]

\[ R_\omega = \frac{c t_0}{L} \sqrt{\omega_0^2 - \omega_0}. \]

Thence the frequency component of the Poynting vector of the reflected field is as

\[ d\Pi = \frac{E g H_{g \omega}}{64\pi^2} \left( \frac{1 - 5\omega^2 t_0^2}{(\omega_0^2 t_0^2 + 0.25)} \right)^2 \left( \frac{c t_0}{L} \sqrt{\omega_0^2 - \omega_0} \right)^2 d\omega. \]

Thence it is easy to obtain Poynting vectors of the reflected and transmitted fields. In particular, the latter is like...
The non-linearity of the electron-atom (ion) collisions in the plasma excludes any making use of the canonic results for monochrome fields and radio impulses when the short pulses are dealt with.

When the magnetic field influence is ignored, the system of equations for the directed movement of the plasma electrons under the electric field is as in [3]:

\[
\dot{y} = eE/m, \quad \dot{y}_0 = \frac{eE}{m} t + y_0,
\]

where \( y_0 \) – velocity of electron after the previous collision. The work by the field between the collisions is as

\[
\int_0^\infty \left[ 1 - \frac{5\omega^2 t_0^2}{(\omega^2 t_0^2 + 0.25)^2} \right]^2 \left[ 1 - \frac{c\omega_0 \sqrt{\omega_0^2 - L^2}}{c\omega_0 \sqrt{\omega_0^2 + L^2}} \right]^2 d\omega.
\]

3. The Peculiarities of the Collisions

The non-linearity of the electron-atom (ion) collisions in the plasma excludes any making use of the canonic results for monochrome fields and radio impulses when the short pulses are dealt with.

When the magnetic field influence is ignored, the system of equations for the directed movement of the plasma electrons under the electric field is as in [3]:

\[
m\ddot{y} = eE - mv\dot{y} \quad \text{for} \quad m = e - \text{electron's mass and charge}.
\]

After a short enough pulse has left, the equations determining the dynamics of leveling of the temperatures of the electrons and plasma are valid:

\[
\dot{y}_n = \frac{eE}{m} + \nu eE \sum_{i=1}^n (\sqrt{1 - 2m/M})^i.
\]

In the ionosphere, for layers “E” and “F” correspondingly

\[
\tau_E = 10^{-5} \text{ s}, \quad \tau_F = 10^{-2} \text{ s}.
\]

Consequently, the pulses with duration not greater than 10\(^{-6}\) s should have passed through without any collision effect at all.

References

Получены точное и асимптотическое решения задачи распространения коротких импульсов в полубесконечном пространстве с неоднородной плазмой. Дана оценка влияния в этой задаче нелинейности и столкновений электрон-атом.

Отмирован точный и асимптотический розв'язки задачи розповсюдження коротких імпульсів у півнескінченому просторі з неоднорідною плазмою. Дано оцінку впливу у цій задачі нелінійності та зіткнень електрон-атом.