REFLECTIONLESS PROPAGATION OF ELECTROMAGNETIC WAVES IN INHOMOGENEOUS MAGNETOACTIVE PLASMA WITH SMALL SCALE STRUCTURES

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It is considered the exactly solvable model of reflectionless electromagnetic wave propagation through the inhomogeneous magnetoactive plasma containing small scale structures. The spatial profiles of wave vector, wave field amplitude, plasma dielectric permittivity have a local relationship. It is investigated their dependence on problem incoming parameters. It has been shown that under some choice of these parameters the spatial profiles of wave vector, wave field amplitude, plasma dielectric permittivity correspond to the magnetoactive plasma case. It has been shown that the plasma inhomogeneity spatial profiles are sensitive enough to incoming parameters variations.

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INTRODUCTION

There are now actively developing studies of the electromagnetic waves interaction with inhomogeneous media, in particular, the analysis of the ability of reflectionless wave resonant tunneling through the barriers by usage of exactly solvable models. These models allow us to study the wave processes in an environment where approximate methods are unsuitable because there are the small scale inhomogeneities of large amplitude. In addition, these exactly solvable models predict new effects that are of great interest for many practical applications: 1) the large increasing of efficiency of powerful electromagnetic radiation absorption and 2) research on the effectiveness of anti-reflection coatings and absorption ones for the radio waves, the elaboration of radio-thin coatings for antennas, 3) it is of great interest to search for the optimal distribution of the dielectric constant on the antireflective layer thickness which will provide the minimum of reflectance or strong transmission of electromagnetic signals from the antennas covered with a layer of dense plasma. Moreover these investigations may provide the new methods for high density plasma heating by the electromagnetic waves.

BASIC EQUATIONS AND NUMERICAL CALCULATION RESULTS

Analysis of the interaction of electromagnetic waves with inhomogeneous media is based on the solutions of Helmholtz equation for the electromagnetic wave electric field $E(x,t) = F(x) \cdot \exp(i \omega t)$

$$d^2F/dx^2 + k_0^2 \cdot \varepsilon_{ef}(x) \cdot F = 0.$$  \hspace{1cm} (1)

Here $k_0 = \omega/c$ is the vacuum wave number, $\varepsilon_{ef}(x)$ is the effective dielectric permittivity of the inhomogeneous plasma. In the case of plasma without the external magnetic field $\varepsilon_{ef}(x)$ is determined by the spatial distribution of electron density. So we have $\varepsilon_{ef}(x) = 1 - (\omega_{pe}/\omega)^2 < 1$, where $\omega_{pe}$ is the Langmuir frequency of plasma electrons. For further calculations it is convenient to introduce the dimensionless spatial variable $\xi = k_0x$. In [2, 3], the exact solution of equation (1) is sought in the form of quasiclassical expression

$$F(x) = A \cdot \exp \left[ i \Psi(\xi) \right] \cdot \left[ 1/p(\xi) \right]^{1/2}, \frac{d\Psi}{d\xi} = p(\xi).$$

The first version of an exactly solvable model is

$$p(\xi) = \alpha / [A + B \sin(2 \beta \xi)], W(\xi) = 1/[p(\xi)]^{1/2},$$

$$\varepsilon_{ef}(\xi) = \beta^2 + (\alpha^2 - \beta^2)/(A + B \sin(2 \beta \xi))^2,$$

where $W$ is the normalized wave electric field amplitude.

For the case of parameters choice $\alpha > \beta, \beta^2 > 1$ we take $\alpha = 1.7, \beta = 1.68$ and the parameter $A$ is in the range $(1.02...6)$. For $A = 1.02$ the graphs of $p(\xi), W(\xi)$ are shown in Fig. 1,a and the graph of the effective dielectric permittivity $\varepsilon_{ef}(\xi)$ is given in Fig. 1,b.

![Fig. 1. Plots of $p(\xi)$ and $W(\xi)$ (a); Graph of $\varepsilon_{ef}(\xi)$ (b)](image-url)

In this case we have max $p = 2.076$, min $p = 1.392$, max $W = 0.847$, min $W = 0.694$, max $\varepsilon_{ef}(\xi) = 2.923$, min $\varepsilon_{ef}(\xi) = 2.868$.

Thus for values of parameter $A$ close to 1 the variations of effective dielectric permittivity $\varepsilon_{ef}(\xi)$ and the normalized amplitude of wave $W(\xi)$ are small but the variation of the dimensionless wave vector is close to 50%.

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In another case $A = 6$ with $\alpha = 1.7$, $\beta = 1.68$ graphs of $p(\xi)$, $W(\xi)$ are presented in Fig. 2,a and the graph of the effective dielectric permittivity $\varepsilon_f(\xi)$ is given by Fig. 2,b.

[Graphs of $p(\xi)$, $W(\xi)$, and $\varepsilon_f(\xi)$ are shown.]

In this version, we have:
- $\max p = 20.257$, $\min p = 0.143$,
- $\max W = 2.648$, $\min W = 0.222$,
- $\max \varepsilon_f(\xi) = 12.421$, $\min \varepsilon_f(\xi) = 2.823$.

Ratio $\frac{W_{\text{max}}(\xi)}{W_{\text{min}}(\xi)} = 11.96$, $\frac{p_{\text{max}}}{p_{\text{min}}} = 141.66$, $\max \varepsilon_f(\xi)/\min \varepsilon_f(\xi) = 4.4$. Thus in an inhomogeneous plasma the strong splashes are observed like soliton type of both wave vector and the effective dielectric constant in the layers where the plasma parameters are close to those for the upper hybrid resonance.

Note that in the plasma sheet the effective dielectric permittivity is positive. So the opaque (in the classic view) regions are absent. This opaque regions corresponds to the choice of the parameter $A$ corresponding to the case of strongly inhomogeneous magnetized plasma.

Consider the case $0 < \alpha < \beta$ for $\alpha = 1.7$, $\beta = 1.72$ with the values of parameter $A$ are in the following range (1.02...6). In this case we obtain $\max p = 2.076$, $\min p = 1.392$, $\max W = 0.847$, $\min W = 0.694$, $\max \varepsilon_f(\xi) = 2.913$, $\min \varepsilon_f(\xi) = 2.856$. Graphs of $p(\xi)$, $W(\xi)$ are shown in Fig. 3 and the graph of effective dielectric permittivity $\varepsilon_f(\xi)$ is given in Fig. 3,b. As we can see, for small differences in the parameters $\alpha$, $\beta$ and if $A$ is close to unity as in the previous case the variation of effective permittivity $\varepsilon_f(\xi)$, the normalized amplitude of wave $W(\xi)$ are small enough but the variation of dimensionless wave vector is close to 49%.

The increasing of parameter $A$ leads to an increase in wave amplitude and wave vector. If we take $A = 6$ we obtain $\max p = 20.257$, $\min p = 0.143$, $\max W = 2.648$, $\min W = 0.222$, $\max \varepsilon_f(\xi) = 2.958$, $\min \varepsilon_f(\xi) = -6.754$. Graphs of $p(\xi)$, $W(\xi)$ are shown in Fig. 4,a and the
The approach developed can be useful for a number of applications, in particular, for the plasma diagnostics and the dense plasma heating by powerful electromagnetic waves.

REFERENCES

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