RADIATION FROM A PULSE DIPOLE SOURCE IN A MOVING MAGNETOPLASMA

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ABSTRACT

The radiation from a pulse dipole source in a moving plasma described by a diagonal dielectric permittivity tensor is considered. A rigorous solution is obtained which determines the spatio-temporal behavior of the excited electromagnetic field. Based on this solution, the influence of the plasma parameters on the radiated field is analyzed.

ANALYSIS AND RESULTS

We consider a pulse dipole source on which the electric current can be written as

$$\vec{j} = \hat{z}_0\, I\, \delta(\vec{r})\, \delta'(t), \tag{1}$$

where δ and δ' stand for the Dirac delta function and its derivative with respect to an argument, and I is certain amplitude factor. The source is immersed in a cold collisionless magnetized plasma moving with a constant velocity $\vec{v} = \hat{z}_0 v$. An external magnetic field $\vec{B}_0$ is also applied in the z-direction ($\vec{B}_0 = \hat{z}_0 B_0$). The permittivity tensor $\hat{\epsilon}$ of the moving plasma in its rest frame is assumed to be diagonal with $\varepsilon_{ij} = 0$ if $i \neq j$ and

$$\varepsilon_{xx} = \varepsilon_{yy} = 1, \quad \varepsilon_{zz} = 1 - \omega_{\rm p}^2 \gamma^{-2} (\omega - \vec{k}\vec{v})^{-2}, \tag{2}$$

where $\gamma = (1 - v^2/c^2)^{-1/2}$ (c is the velocity of light), and $\omega_{\rm p}$ is the electron plasma frequency. It is known that the permittivity (2) can describe the plasma medium in a strong magnetic field.

We have obtained a rigorous closed-form solution for the electromagnetic field excited by the described source. It has been shown that the field components at a fixed point vanish with time. Therefore, the motion of the plasma medium eliminates the well-known divergence in the problem of radiation from point pulse sources, which is observed in a motionless loss-free magnetoplasma. The temporal behavior of the field depends significantly on the angle θ between the velocity of the plasma $\vec{v}$ and the direction from the source to the observation point. For acute angles ($\theta < \pi/2$), the temporal dependences of the field components represent "multi-humped" structures in which the envelope of the signal has several zeros (see Fig. 1 (a)). Upstream of the source ($\theta > \pi/2$), the signal envelope has one zero and behaves similarly to that observed in a motionless plasma with collisional losses (see Fig. 1 (b)). Our analysis shows that the signal duration decreases with increasing velocity of the medium. The presence of the collisional losses in the moving plasma also leads to a decrease in the signal duration without deformation of its shape.

The solution obtained represents the time-derivative of the spatio-temporal Green's function and may therefore be used for analysis of electromagnetic signals radiated from dipole sources having arbitrary temporal behavior.

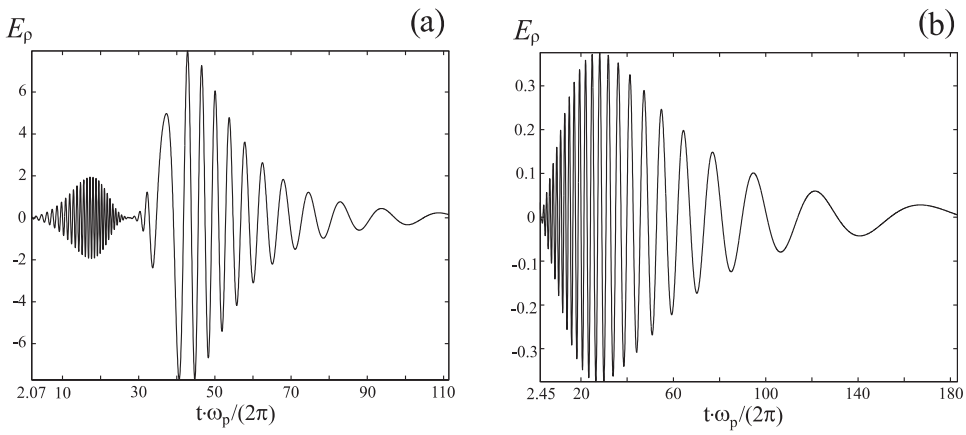

Fig. 1. Transverse component E_ρ of the electric field in the observation point as function of normalized time for (a) $\theta = \pi/6$ and (b) $\theta = 2\pi/3$; $r\omega_{\rm p}/c = 10$, $v/c = 0.05$.