Microwave Cherenkov Radiation from a Particle-in-flight to a Semi-infinite Layered Medium

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Abstract—Some part of the microwave Cherenkov radiation from a particle-in-flight from vacuum to semi-infinite layered medium is redirected by the periodical structure of medium in the backward direction. This part of radiation proves to be quasi-monochromatic.

I. INTRODUCTION AND BACKGROUND

The presence of matter may essentially influence the characteristics of high energy electromagnetic processes giving rise to the production of Cherenkov radiation, transition radiation etc. The effects of interest arise in periodical structures of different configurations (see, e.g., [1,2] and references therein).

II. RESULTS

The results of numerical calculations of \( I_{vz}(\omega, \theta) \) for \( 0 \leq \theta \leq 90^\circ \) are given in Figs. 2, 3. Fig. 2 corresponds to radiation in the forward hemisphere when the particle leaves the semi-infinite layered medium for vacuum (the case of \( v_z > 0 \) in Fig. 1), and Fig. 3 – to radiation in the backward hemisphere when the particle flies from vacuum to the semi-infinite layered medium (\( v_z < 0 \) in Fig. 1). The energy of particle (electron) is 30 MeV, the average permittivity of medium \( \varepsilon = 1.5 \), the variation profile of \( \varepsilon \) is the same as that in [3], \( \Delta \varepsilon = 0.5 \) (modulation depth of \( \varepsilon \), the loss-angle tangent \( \delta = 0.01 \), the permeability is 1. The light-colored areas in the figures correspond to larger values of \( I_{vz}(\omega, \theta) \) (the lighter the area, the larger is the value of \( I_{vz} \)). For radiation in the forward direction \( \max I_{vz}(\omega, \theta) = 3.48h \), and in the backward direction \( \max I_{vz}(\omega, \theta) = 0.45h \).
As a result of analyzing the data in Figs. 2, 3 the following conclusions have been made:

1. The forward radiation $I_{\nu,0}(\omega, \theta)$ (Fig.2) at the departure of relativistic particle from semi-infinite layered medium to vacuum is directional. Its direction ($\theta = 48.6^\circ$) is sufficiently well determined by the Cherenkov condition and by refraction law on the boundary of semi-infinite layered medium with vacuum if the average value of refractive index is used.

2. There is a downfall in radiation intensity in the range of $\omega = \pi v/l$ frequencies, since the electromagnetic waves with these values of $\omega$ fail to freely propagate in the layered medium. The width of this forbidden band decreases when $\Delta \varepsilon' \to 0$ (and is zero in the limit of semi-infinite uniform medium).

As TR formed at the departure of particle from the semi-infinite medium [4,5] is weak, it is not noticed in Fig.2, whereas the resonance radiation from particle induced by the periodical structure of layered medium [5,6] is emitted beyond the bounds of frequency range shown in Fig.2.

3. The backward radiation, $I_{\nu,0}(\omega, \theta)$ (Fig.3), in vacuum at the flight of particle into the semi-infinite medium is directional and quasi-monochromatic. The typical direction of radiation is the same as that in Fig.2.

(4) The range of emitted frequencies is adjacent to the forbidden band of the layered medium and is determined by the Bragg diffraction of CR on the periodical structure of this medium. The degree of radiation monochromaticity increases as the modulation depth $\Delta \varepsilon'$ decreases.

The contribution of resonance radiation is traced in Fig.3 as thin offshoots branching from the central peak. As is seen in Fig.3, $I_{\nu,0}(\theta)$ reaches the local maximum $= 0.07h$ for $\theta = 1.8^\circ$. The latter corresponds to TR from the relativistic particle diffracted backwards by the periodical structure of the layered medium [3]. Unlike TR, the value of $I_{\nu,0}(\omega, \theta)$ in the area of central peak is unlimitedly increasing when $\delta \to 0$ (increase in the transparency of the material of semi-infinite layered medium).

So, the periodicity of medium has the following effects on the radiation of charged particle:

- In the range of wavelengths of the order of period $l$ of the layered medium the relativistic particle does not generate CR in the forward direction.
- The part of CR spectrum adjacent to this forbidden band is redirected by the periodical structure of medium in the backward direction relative to the sense of particle motion.

Here:

- (Owing to the influence of particle) the layered medium generates CR and simultaneously redirects it back.
- The detection of this radiation permits to determine the period of layered medium by the radiation wavelength.

The periodical structure with tuned $l$ and $\Delta \varepsilon$ may be induced in the medium by using, e.g., ultrasonic vibrations. If that occurs one may control the radiation wavelength in the millimeter and sub-millimeter ranges by attuning ultrasonic vibrations in the range of frequencies in excess of $10 MHz$.

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