Weak Lacunae of Electromagnetic Waves in Dilute Plasma with Anisotropy

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As has been shown in our previous work, the Maxwell equations of electromagnetic field do not, generally speaking, satisfy the Huygens' principle, unless the electromagnetic waves propagate through a very simple medium, such as the vacuum or a dielectric with static response. Accordingly, lacunae and the sharp aft fronts of the waves will not, generally speaking, exist in the corresponding solutions because of the propagation after-effects. However, for an important case of the high-frequency transverse electromagnetic waves in dilute plasma, the governing equations reduce to the Klein-Gordon equation. The latter is not Huygens' per se, but it turns out that lacunae can still be identified in its solutions, although in an approximate sense. The aft fronts for these "weak lacunae" can be clearly observed, but they may not be as sharp as in the pure Huygens' case. Moreover, it can be shown that the "depth" of a weak lacuna, i.e., the magnitude of its residual field relative to the magnitude of the field inside the primary wave packet, is controlled by the dimensionless ratio ω_{pe}/ω, where ω_{pe} is the Langmuir frequency and ω is the dominant carrying frequency of the waves, $\omega_{pe} \ll \omega$.

The aforementioned study has been carried out for the isotropic dilute plasma with the parameters close to those of the Earth's ionosphere. It is known, however, that the actual ionospheric propagation may be noticeably affected by the magnetic field of the Earth. This field makes the plasma anisotropic and also introduces an additional temporal scale into the model given by the electron cyclotron frequency Ω_{ee}. The cyclotron frequency is typically about an order of magnitude lower than the Langmuir frequency. In the current work we show that the additional effect of the Earth's magnetic field on lacunae for the case of high-frequency transverse propagation is small. Quantitatively, it is about Ω_{ee}/ω times smaller than the previously studied effect of the primary wave dispersion in plasma, where $\Omega_{ee} < \omega_{pe} \ll \omega$.