Effects of Radiative and Collisional Energy Loss on the Scattering Properties of a Magnetized Plasma Cylinder at the Plasmon Resonances

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The features of electromagnetic wave scattering from cylindrical objects have received much careful study in view of their wide use in various electrodynamic systems. In the radio-frequency range, magnetized plasma scatterers of cylindrical shape have recently attracted enhanced attention as tunable resonant elements of antenna arrays with controllable properties [1]. Despite significant progress in the theory of resonance scattering of electromagnetic waves from plasma objects, some important effects occurring due to competition of radiative and dissipative energy loss in such scattereres are yet to be analyzed in greater detail. Recall that energy dissipation in a cold plasma is related to collisions of charged particles in it. It is the purpose of this work to discuss some unexpected features of scattering of electromagnetic waves by a magnetized plasma cylinder at the frequencies of plasmon resonances with allowance for collisions of charged particles in the plasma.

We consider a cylinder filled with a cold electron plasma and located in free space parallel to an external static magnetic field. The cylinder is irradiated by an H-polarized plane electromagnetic wave. The medium inside the cylinder is described by the general dielectric tensor with allowance for collisions of the plasma electrons. The emphasis is placed on the case where the angular frequency of the incident wave coincides with one of the surface- or volume-plasmon resonance frequencies of the cylinder [2]. The resonant frequencies of localized surface and volume plasmons are found and the Q factors and amplitude coefficients of the electromagnetic field at these resonances are determined. It is shown that competition of radiative and collisional energy loss can significantly influence the characteristics of plasmon resonances. Conditions have been established under which a given resonance is completely suppressed due to the effect of collisional loss. In particular, the volume plasmon resonances are found to be much more sensitive to even a small collisional energy loss than the surface plasmon resonances, and can be suppressed at very low electron collision rates. For the surface plasmon resonances, an interesting phenomenon of their inverse hierarchy has been revealed. It consists in that under certain conditions, the field magnitude in proximity to and at the surface of the collisional plasma scatterer can be notably greater at the quadrupole resonance than that at the fundamental dipole resonance.

In addition, we have determined the spatial structures of the field and energy-flow patterns, including regions with greatly enhanced magnitudes of the field and the time-averaged Poynting vector near the scatterer, at various plasmon resonances. It is demonstrated that allowance for collisional effects in the plasma cylinder can qualitatively change the topology of lines of the Poynting-vector field. For example, such singular points of the Poynting-vector field inside the scatterer as centers, around which the energy circulates along the closed trajectories in the case of normal incidence of a plane wave on the cylinder filled with a collisionless plasma, transform to spiral points in the presence of collisions. The field and energy-flow patterns in the case of an obliquely incident wave have also been analyzed in the resonance scattering regimes. The results obtained are shown to be useful in developing antennas and diffraction systems based on magnetized plasma scatterers.

This work was supported by the Ministry of Education and Science of the Russian Federation (project No. 3.1358.2017/4.6).

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