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Progress In Electromagnetics Research Symposium

Abstracts

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Spectral Problem in a Generalized Theory of Electromagnetic Waves

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Abstract— We consider the wave equations for the four-vector potential $(\mathbf{A}, \phi/c)$:

$$\Delta\mathbf{A} - \varepsilon'\varepsilon_0\mu'\mu_0\frac{\partial^2\mathbf{A}}{\partial t^2} = -\mu'\mu_0\mathbf{j}, \quad \Delta\phi - \varepsilon'\varepsilon_0\mu'\mu_0\frac{\partial^2\phi}{\partial t^2} = -\frac{\rho}{\varepsilon'\varepsilon_0}, \tag{1}$$

wherein $\varepsilon'\varepsilon_0$ and $\mu'\mu_0$ are respectively permittivity and permeability, $\mathbf{j}$ and ρ-charge density and current density. Instead Lorentz calibration we adopted a more general relationship:

$$B^*(x, y, z, t) = -\nabla\cdot\mathbf{A} - \varepsilon'\varepsilon_0\mu'\mu_0\frac{\partial\phi}{\partial t}, \tag{2}$$

where $B^*(x, y, z, t)$ is a scalar function, which has the magnetic induction dimension. This allows take into account the actual existing potential component of the magnetic field [1].

Solutions of the system (1) sought in the form of:

$$\begin{aligned}\mathbf{A} &= \mathbf{P}(x, y, z)\cdot\cos(\omega t) + \mathbf{Q}(x, y, z)\cdot\sin(\omega t),\\ \phi &= p(x, y, z)\cdot\cos(\omega t) + q(x, y, z)\cdot\sin(\omega t),\end{aligned} \tag{3}$$

where $\mathbf{P}(x, y, z)$, $\mathbf{Q}(x, y, z)$ — vector and, $p(x, y, z)$, $q(x, y, z)$ — scalar fields to be defined, ω — the oscillation frequency which should not be in a forbidden zone of frequencies [2].

For a bounded domain Ω of three-dimensional space the feedback for spectrum control of vibrational systems is effectively constructed in the form of minimum rank finite-dimensional operators on the space of square-integrable in Ω respectively vector and scalar fields, which form the current density $\mathbf{j}$ and charge density ρ.

The problem is reduced to the spectrum control for vector and scalar Laplace operator in the Hilbert space of square-integrable in Ω vector and scalar fields. It is known that for a bounded domain with smooth boundary for typical boundary conditions unperturbed Laplace operator has a real discrete spectrum.

We use the theorem on minimum rank perturbation. It shows that the minimum number of terms in optimal perturbation in each of these tasks is equal to the maximum of multiplicity of eigenvalues lying in the forbidden band (ω_0, ω_1) in the unperturbed spectral problem for Laplace operator. This allows us to build explicitly and approximately the optimal finite-dimensional perturbations for which solutions (3) are oscillated with a frequencies from the permitted range.

This approach leads to the construction of a generalized theory of electromagnetic waves, which takes into account, as the vortex and potential electromagnetic processes.

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