A. Straub · R. Unbehauen

Conservation of quasi-energy in electrodynamics

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The purpose of this comment is to correct some possible confusion, that has occurred in [1]. Our paper introduces the concept of quasi-power for two distinct radiation or scattering problems, the so-called electromagnetic states 1 and 2. The concept of quasi-power is unambiguously defined for time-dependent fields by equations (3) and (4), and for time-harmonic fields by equations (22) to (25). Each of these equations relates in a relatively simple manner various forms of quasi-power, i.e. quasi-power supplied to the sources of fields, quasi-power received by a volume and the flow of quasi-power through the boundary of the volume. For this reason, the mentioned equations should be interpreted as balance equations of quasi-power associated with two distinct and arbitrary states. It is important to recognize that a definition of stored quasi-energy density, similar to the formulation in Poynting's theorem, is impossible in the general case of two states characterized by two distinct media. The quasi-power terms

$$\sigma_2 E_1 \cdot E_2 + \varepsilon_2 E_1 \cdot \frac{\partial E_2}{\partial t} + \mu_1 H_2 \cdot \frac{\partial H_1}{\partial t}$$

and

$$\sigma_1 E_1 \cdot E_2 + \varepsilon_1 E_2 \cdot \frac{\partial E_1}{\partial t} + \mu_2 H_1 \cdot \frac{\partial H_2}{\partial t},$$

respectively, in equations (3) and (4) represent dimensionally the time rate of increase of quasi-energy densities. However, these terms do not allow an identification of quasi-energy densities as local functions of the states 1 and 2, i.e. as local functions of the state variables ($\mathbf{E}_1$, $\mathbf{H}_1$) of state 1 and the state variables ($\mathbf{E}_2$, $\mathbf{H}_2$) of state 2. This consideration made for time-dependent fields is confirmed by the expressions of the time average of quasi-power density for time-harmonic fields

$$\frac{1}{2} \operatorname{Re}(\bar{y}_2 E_1 \cdot \bar{E}_2 + z_1 H_1 \cdot \bar{H}_2)$$

and

$$\frac{1}{2} \operatorname{Re}(\bar{y}_1 \bar{E}_1 \cdot E_2 + z_2 \bar{H}_1 \cdot H_2),$$

respectively, in equations (26) and (27). In the particular case of dielectric homogeneous media, it can be easily seen that the time averages of quasi-power densities are not equal to zero. This fact can be understood by the occurrence of quasi-power dissipation, even in dielectric media.

On account of these considerations, it can be concluded that the existence of stored quasi-energy density as a local function of the states 1 and 2 is generally not verified. Nevertheless, the main results of our paper, i.e. the definition and properties of quasi-power for two arbitrary electromagnetic states are judiciously reported and analyzed. Within the restrictions set by the above discussion, it seems justified to assimilate the balance equations of quasi-power to a property of conservation of quasi-energy. The authors apologize for any misunderstanding.

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A. Straub
3 rue Dominique Ingres, 45100 Orléans, France

R. Unbehauen (✉)
Lehrstuhl für Allgemeine und Theoretische Elektrotechnik,
Universität Erlangen-Nürnberg, Cauerstrasse 7,
91058 Erlangen, Germany
E-mail: unbehauen@late.e-technik.uni-erlangen.de

Reference

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