The ECE Electromagnetic Equations Considering the Vacuum State

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Abstract

It is shown that the description of a circuit by electromagnetic ECE theory in one polarization state can be decoupled from the states of the electromagnetic vacuum. The circuit description is unaffected by the vacuum states. Only the geometry of the circuit arrangement impacts the vacuum states. Boundary conditions are discussed.

Keywords: ECE theory, Maxwell-Heaviside equations, electromagnetism, electromagnetic vacuum, boundary conditions

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1 Introduction

From experiment it is well known that there is a background or vacuum potential which interacts in certain cases with matter (for example Lamb shift in atomic and molecular spectra). In macroscopic electromagnetic devices such an effect is not observed, and is not predicted by conventional Maxwell-Heaviside theory. Exceptions will arise when the potential is multi-valued or non-separable [1-3]. In this cases energy can be transferred from the vacuum to the circuit without violating energy conservation [4], preferably by resonance effects.

In this paper we consider regular solutions of the ECE Maxwell-like field equations. In section 2 we will show that the field equations with inclusion of antisymmetry conditions allow for a complete decoupling of circuit solutions from the vacuum state. In section 3 we discuss boundary conditions of the vacuum state for a given geometry. This may be a prerequisite to find situations where energy transfer (or information transfer) from the vacuum is possible.

2 Relating the Vacuum State to the ECE Equations of Electromagnetism

The potential version of the ECE equations of electromagnetism have been written in terms of an electric scalar, a magnetic vector, and two spin connected potentials for a single polarization [1-4]. Since that formulation contains non-derivative values in the potentials, this requires that the potentials be referenced to a "zero" state. In an earlier publication [1] it was shown that the vacuum exists as a source-free field of non-zero oscillations in vacuum potentials, possibly stochastic, where both the electric intensity and the magnetic induction are identically zero and satisfy the equations of antisymmetry. This means that the total potentials are the sum of the potentials as defined by the application of circuits, geometries, etc. and the vacuum or background field as defined by that same situation[a], i.e.

$$\mathbf{A} = \mathbf{A}_f + \mathbf{A}_b \quad (2\text{-}1)$$

$$\phi = \phi_f + \phi_b \quad (2\text{-}2)$$

$$\boldsymbol{\omega} \times \mathbf{A} = \boldsymbol{\omega}_f \times \mathbf{A}_f + \boldsymbol{\omega}_b \times \mathbf{A}_b \quad (2\text{-}3)$$

$$\omega_0 \mathbf{A} = \omega_{0f} \mathbf{A}_f + \omega_{0b} \mathbf{A}_b \quad (2\text{-}4)$$

$$\boldsymbol{\omega} \phi = \boldsymbol{\omega}_f \phi_f + \boldsymbol{\omega}_b \phi_b \quad (2\text{-}5)$$

[a] The subscript "f" in the equations will refer to an applied field or "circuit" whereas the subscript "b" will refer to the vacuum or background field.

These give rise to electric intensity and magnetic induction given by

$$\mathbf{E} = -\nabla(\phi_f + \phi_b) - \frac{\partial}{\partial t}(\mathbf{A}_f + \mathbf{A}_b) - \omega_{0f}\mathbf{A}_f - \omega_{0b}\mathbf{A}_b + \boldsymbol{\omega}_f\phi_f + \boldsymbol{\omega}_b\phi_b \quad (2\text{-}6)$$

$$\mathbf{B} = \underline{\nabla} \times (\mathbf{A}_f + \mathbf{A}_b) - \boldsymbol{\omega}_f \times \mathbf{A}_f - \boldsymbol{\omega}_b \times \mathbf{A}_b \quad (2\text{-}7)$$

If these are substituted into the ECE-EM field equations for a single polarization,

$$\underline{\nabla} \cdot \mathbf{B} = 0 \quad (2\text{-}8)$$

$$\underline{\nabla} \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0 \quad (2\text{-}9)$$

$$\underline{\nabla} \cdot \mathbf{E} = \frac{\rho}{\varepsilon} \quad (2\text{-}10)$$

$$\underline{\nabla} \times \mathbf{B} - \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} = \mu_o \mathbf{J} \quad (2\text{-}11)$$

one gets

$$\underline{\nabla} \cdot (\boldsymbol{\omega}_f \times \mathbf{A}_f + \boldsymbol{\omega}_b \times \mathbf{A}_b) = 0 \quad (2\text{-}12)$$

$$\underline{\nabla} \times (-\omega_{0f}\mathbf{A}_f - \omega_{0b}\mathbf{A}_b + \boldsymbol{\omega}_f\phi_f + \boldsymbol{\omega}_b\phi_b) - \frac{\partial}{\partial t}(\boldsymbol{\omega}_f \times \mathbf{A}_f + \boldsymbol{\omega}_b \times \mathbf{A}_b) = 0 \quad (2\text{-}13)$$

$$\underline{\nabla} \cdot \left(-\frac{\partial(\mathbf{A}_f + \mathbf{A}_b)}{\partial t} - \underline{\nabla}(\phi_f + \phi_b) - (\omega_{0f}\mathbf{A}_f + \omega_{0b}\mathbf{A}_b) + (\boldsymbol{\omega}_f\phi_f + \boldsymbol{\omega}_b\phi_b) \right) = \frac{\rho}{\varepsilon_0} \quad (2\text{-}14)$$

$$\underline{\nabla} \times \left(\underline{\nabla} \times (\mathbf{A}_f + \mathbf{A}_b) - (\boldsymbol{\omega}_f \times \mathbf{A}_f + \boldsymbol{\omega}_b \times \mathbf{A}_b)\right)$$
$$- \frac{1}{c^2}\frac{\partial}{\partial t}\left(-\frac{\partial(\mathbf{A}_f + \mathbf{A}_b)}{\partial t} - \underline{\nabla}(\phi_f + \phi_b) - (\omega_{0f}\mathbf{A}_f + \omega_{0b}\mathbf{A}_b) + (\boldsymbol{\omega}_f\phi_f + \boldsymbol{\omega}_b\phi_b) \right) = \mu_0 \mathbf{J} \quad (2\text{-}15)$$

In addition, the antisymmetry equations for the total field are

$$\frac{\partial(\mathbf{A}_f + \mathbf{A}_b)}{\partial t} - \underline{\nabla}(\phi_f + \phi_b) + (\omega_{0f}\mathbf{A}_f + \omega_{0b}\mathbf{A}_b) + (\boldsymbol{\omega}_f\phi_f + \boldsymbol{\omega}_b\phi_b) = 0 \quad (2\text{-}16)$$

$$\frac{\partial(A_{fk} + A_{bk})}{\partial x_j} + \frac{\partial(A_{fj} + A_{bj})}{\partial x_k} + (\omega_{fj}A_{fk} + \omega_{bj}A_{bk}) + (\omega_{fk}A_{fj} + \omega_{bk}A_{bj}) = 0 \quad (2\text{-}17)$$

where cyclic permutation through non-repeating indices *i*, *j*, *k* is assumed.

The vacuum state was defined [1] by

$$-\nabla\phi_b - \frac{\partial \mathbf{A}_b}{\partial t} - \omega_{0b}\mathbf{A}_b + \boldsymbol{\omega}_b\phi_b = 0, \tag{2-18}$$

$$\underline{\nabla}\times\mathbf{A}_b - \boldsymbol{\omega}_b\times\mathbf{A}_b = 0 \tag{2-19}$$

plus the vacuum versions of the antisymmetry equations, namely

$$\frac{\partial \mathbf{A}_b}{\partial t} - \underline{\nabla}\phi_b + \omega_{0b}\mathbf{A}_b + \boldsymbol{\omega}_b\phi_b = 0, \tag{2-20}$$

$$\frac{\partial A_{bk}}{\partial x_j} + \frac{\partial A_{bj}}{\partial x_k} + \omega_{bj}A_{bk} + \omega_{bk}A_{bj} = 0. \tag{2-21}$$

Subtracting the divergence of equation (2-19) from equation (2-12) gives

$$\underline{\nabla}\cdot\left(\boldsymbol{\omega}_f\times\mathbf{A}_f\right) = 0. \tag{2-22}$$

Subtracting the curl of equation (2-18) and the time derivative of equation (2-19) from equation (2-13) gives

$$\underline{\nabla}\times\left(-\omega_{0f}\mathbf{A}_f + \boldsymbol{\omega}_f\phi_f\right) - \frac{\partial}{\partial t}\left(\boldsymbol{\omega}_f\times\mathbf{A}_f\right) = 0. \tag{2-23}$$

Subtracting the divergence of equation (2-18) from equation (2-14) gives

$$\underline{\nabla}\cdot\left(-\frac{\partial \mathbf{A}_f}{\partial t} - \underline{\nabla}\phi_f - \omega_{0f}\mathbf{A}_f + \boldsymbol{\omega}_f\phi_f\right) = \frac{\rho_f}{\varepsilon_0}. \tag{2-24}$$

And finally, subtracting the curl of equation (2-19) and the time derivative of equation (2-18) from equation (2-15) results in

$$\underline{\nabla}\times\left(\underline{\nabla}\times\mathbf{A}_f - \boldsymbol{\omega}_f\times\mathbf{A}_f\right) - \frac{1}{c^2}\frac{\partial}{\partial t}\left(-\frac{\partial \mathbf{A}_f}{\partial t} - \underline{\nabla}\phi_f - \omega_{0f}\mathbf{A}_f + \boldsymbol{\omega}_f\phi_f\right) = \mu_0\mathbf{J}_f. \tag{2-25}$$

Equations (2-22) through (2-25) are the ECE electromagnetic field equations for a given circuit ignoring the effects of the vacuum, as reported in similar form elsewhere (Eckardt eng model).

Subtracting (2-22) through (2-25) from (2-12) through (2-15) leaves

$$\underline{\nabla}\cdot\left(\boldsymbol{\omega}_b\times\mathbf{A}_b\right) = 0 \tag{2-26}$$

$$\underline{\nabla}\times\left(-\omega_{0b}\mathbf{A}_b + \boldsymbol{\omega}_b\phi_b\right) - \frac{\partial}{\partial t}\left(\boldsymbol{\omega}_b\times\mathbf{A}_b\right) = 0 \tag{2-27}$$

$$\underline{\nabla} \cdot \left(-\frac{\partial \mathbf{A}_b}{\partial t} - \underline{\nabla}\phi_b - \omega_{0b}\mathbf{A}_b + \boldsymbol{\omega}_b\phi_b \right) = 0 \tag{2-28}$$

$$\underline{\nabla} \times \left(\underline{\nabla} \times \mathbf{A}_b - \boldsymbol{\omega}_b \times \mathbf{A}_b \right) - \frac{1}{c^2}\frac{\partial}{\partial t}\left(-\frac{\partial \mathbf{A}_b}{\partial t} - \underline{\nabla}\phi_b - \omega_{0b}\mathbf{A}_b + \boldsymbol{\omega}_b\phi_b \right) = 0 \tag{2-29}$$

This shows that the vacuum satisfies the ECE engineering equations.

A similar analysis can be preformed on the equations of anti-symmetry. If we subtract equation (2-18) from equation (2-16), we are left with

$$\frac{\partial \mathbf{A}_f}{\partial t} - \underline{\nabla}\phi_f + \omega_{0f}\mathbf{A}_f + \boldsymbol{\omega}_f\phi_f = 0 \tag{2-30}$$

This is the electric antisymmetry equation for the applied field indicating that the vacuum state is independent of the applied field for this relationship.

Further, the vacuum terms in equation (2-17) are identically zero by virtue of the vacuum solution is defined to satisfy the magnetic antisymmetry relation (2-21), leaving

$$\frac{\partial A_{fk}}{\partial x_j} + \frac{\partial A_{fj}}{\partial x_k} + \omega_{fj}A_{fk} + \omega_{fk}A_{fj} = 0 \tag{2-31}$$

which is the magnetic antisymmetry equation for the applied field. This means that the vacuum field has no influence on the applied field in the magnetic anti-symmetry equation.

In this discussion it was shown that the solution to the vacuum equations could be added without consequence to the solution for a specific ECE-EM application as long as the boundary geometries are the same. The vacuum state obeys all of the ECE field equations when written in terms of vacuum potentials in a non-trivial manner, even though these same equations when written in terms of electric intensity and magnetic induction are trivial. We infer from this that disturbance in the vacuum propagates at the speed of light. It also means that the field set up by a circuit does not in any way depend upon, under normal circumstances, the vacuum state. The potential field generated by a given set of boundary conditions (the circuit) and the loading conditions (applied potentials) floats on top of the vacuum solution. We do not see the effects of the vacuum potential, if there are any, because current instrumentation measures from a state of zero electric intensity or magnetic induction which we recognize as the definition of the vacuum state.

3 Boundary effects of the Vacuum Conditions

Since the applied field floats upon the vacuum field normally without interaction, it would seem reasonable that the only possible place of interaction, should one exist, would be where the equations break down, i.e. near a singularity or discontinuity.

To consider the interactions between the circuit field and the vacuum field near such an occurrence, the equations of ECE-EM theory can be put into a simpler format more conducive to solution using the vacuum conditions first defined in [1]. In particular, it was found that

$$\underline{\nabla} \times \mathbf{A} = \boldsymbol{\omega} \times \mathbf{A} \qquad (3\text{-}1)$$

and **A** and **ω** are parallel. Therefore

$$\boldsymbol{\omega} = k\mathbf{A} \qquad (3\text{-}2)$$

with a scalar function k, and both terms of (3-1) vanish. In particular, **A** is a curl-free potential and represents a non-turbulent vacuum flow of energy. In total the potentials must satisfy the equations [1]

$$\underline{\nabla} \times \mathbf{A} = 0 \qquad (3\text{-}3)$$

$$\boldsymbol{\omega} \times \mathbf{A} = 0 \qquad (3\text{-}4)$$

$$\underline{\nabla}\phi - \boldsymbol{\omega}\phi = 0 \qquad (3\text{-}5)$$

$$\frac{\partial \mathbf{A}}{\partial t} + \omega_0 \mathbf{A} = 0 \qquad (3\text{-}6)$$

Equations (3-3) and (3-4) state that the magnetic induction is zero, and (3-5) and (3-6) state that the electric intensity is zero in the vacuum state. Let us assume that the variables have values indexed by "1" at a boundary. Then we have from (3-2)

$$\boldsymbol{\omega}_1 = k\mathbf{A}_1 \qquad (3\text{-}7)$$

and from (3-5)

$$\underline{\nabla}\phi_1 - k\mathbf{A}_1\phi_1 = 0 \qquad (3\text{-}8)$$

The function k is in principle known from the vacuum solution of $\boldsymbol{\omega}$. When there is a metallic boundary with ϕ_1=const, it follows

$$\mathbf{A}_1 = 0, \tag{3-9}$$

i.e. there is no flow of potential through this boundary. In the well known Casimir effect [5], the force between two planar metallic plates is reduced due to missing electromagnetic wave modes between the plates. The missing modes cannot be counteracted by an inflow of vacuum energy as we have shown, in accordance with experiment.

The boundary conditions of Equation (3-6) read

$$\frac{\partial \mathbf{A}_1}{\partial t} + \omega_{01}\mathbf{A}_1 = 0 \tag{3-10}$$

which in case of harmonic time behaviour of the form *exp(iβt)* with frequency *β* leads to

$$(i\beta + \omega_{01})\mathbf{A}_1 = 0 \tag{3-11}$$

This can either be fulfilled by no input flow ($\mathbf{A}_1 = 0$) or by identifying the imaginary part of ω_{01} with an oscillatory frequency, modulated by space-like functions as described in [1] in detail.

The example of the Casimir effect shows that transfer of energy from vacuum to a circuit probably requires an "open" geometry. For example in a closed metallic box, energy cannot flow from the environment into the box, thus impeding transfer of larger amounts of energy. A detailed analysis would require solving the ECE wave equation

$$(\square - R)\mathbf{A} = 0 \tag{3-12}$$

where *R* is the scalar curvature. In case *R* is constant, this is an eigenvalue equation for **A** which can be solved numerically. The solutions describe the allowed modes of **A** for given boundary conditions.

In full analogy to Eq. (2-1), the potential can be split into the circuit and background part,

$$\mathbf{A} = \mathbf{A}_f + \mathbf{A}_b \ , \tag{3-13}$$

and Eq. (3-13) is fulfilled if the wave equation is valid for both potentials independently:

$$\left(\Box - R_f\right)\mathbf{A}_f = 0, \tag{3-14}$$

$$\left(\Box - R_b\right)\mathbf{A}_b = 0, \tag{3-15}$$

where R_f and R_b are the eigenvalues for the circuit and background potentials respectively with

$$R = R_f + R_b. \tag{3-16}$$

4 Conclusions

In summary, we have that

1. The vacuum field acts independently from an electrical standpoint from the circuit field, but depends on the geometric arrangement of the circuit.

2. We can add the vacuum field to the circuit field without consequence as long as it is done appropriately.

3. The vacuum field satisfies the field equations of ECE-EM theory, thus verifying that a disturbance in the vacuum propagates at the speed of light.

4. Energy transfer from the vacuum probably requires an electrically open environment.

If one is to observe resonances and singularities in the solutions to the equations, it may be that the circuit field and the vacuum field have to be zero simultaneously at the same spatial location, which may be why it is not observed readily. This may hold the key to finding these events analytically.

Once a circuit has been built and set up and temporal disturbances have dissipated, the vacuum field is defined and unalterable unless something changes geometrically. This is the case for example in the Bedini machine [6] where the circuit continually changes so that changes in the vacuum field may get in phase with the circuit field. In the case of the Mexican device [7], the circuit appears to be geometrically fixed, but of course due to electrical-mechanical interaction, etc. it will move or change shape. The Mark Steven's toroidal coil [8] for example was said to vibrate. This then may allow the circuit and vacuum fields to be put in phase hence allowing unusual ECE effects.

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