Comments on “Displacement Current Does Not Exist”
by Michele D’Amico

Dear AntenneX,

I come across an article published on November 2002 Issue entitled “Displacement Current Does Not Exist”, authored by W. Miller.

Please let me comment that I disagree with what is stated in the article; in particular, I find the “problems” that the author identified as sufficient to negate the existence of the displacement current simply wrongly posed; they arise only from the lack of knowledge of what Maxwell equations really state.

Before going into details, let me make a general comment: IF the displacement current does not exists, than the curl of the magnetic field in vacuum (better, where generators are not present) must be zero; this has a dramatic impact on Maxwell equations, as we will soon show; let’s assume that the displacement current does not exists, and that:

$$\nabla \times \mathbf{H} = 0 \qquad (1)$$

remembering that in sinusoidal regime (i.e. AC)

$$\nabla \times \mathbf{E} = -j\omega\mu\mathbf{H} \qquad (2)$$

by applying the curl operator to both sides of (2) we get:

$$\nabla \times \nabla \times \mathbf{E} = -j\omega\mu\nabla \times \mathbf{H} \qquad (3)$$

by replacing (1) in (3) we will get

$$\nabla \times \nabla \times \mathbf{E} = 0 \qquad (3)$$

remembering that

$$\nabla \times \nabla \times \mathbf{E} = -\nabla(\nabla \bullet \mathbf{E}) - \nabla^2\mathbf{E} \qquad (4)$$

and being in vacuum

$$\nabla \bullet \mathbf{E} = 0 \qquad (5)$$

we will end up with the equation

$$\nabla^2\mathbf{E} = 0 \qquad (6)$$

Would the author please explain how can we obtain the wave equation from equation (6) ? In other words, how can a propagating wave exist, if eq. (6) is valid ? Unless we question the existence itself of propagating waves... but this is a philosophical matter.

My Comments to the three “problems” envisaged by the author:

Problem 1. The author seems not to be aware of the definition of “relaxation time”, i.e. the time it takes for the free charge density placed inside a conductor to decay to 1/e, or 36.8% of its initial value. For copper this time is $1.54*10^{-19}$ seconds [Bal]; the frequency related to this time constant is of the order of 10^{18} Hz, well above the frequencies that we are using so far.
Moreover, the author confuses the drift velocity of the electrons, defined as the product of the applied electric field times the electron mobility (drift velocity IS very low), with the velocity of the propagation of the electromagnetic perturbation on the conductor, that can as fast as the speed of light. Please note that when we talk on the phone with somebody on the other side of the town, we don’t have to wait for the electrons to “drift” till the other location... it would take ages !!

Problem 2. Sorry, this effect, IF exists, will be absolutely negligible.

Problem 3. I don’t understand what the author is stating here. Please note that the left side of author’s equation 5 has to be integrated along a closed path, so starting and ending points have to be the same. The right side of equation 5 is a surface integral, so starting and ending points make no sense.

My Comments to “Any Other Problems”

The author’s sentence “*is much easier to imagine a resistor that is “almost” zero that it is to imagine a current that is “almost” infinite*” shows that his knowledge of real-world voltage generators is far from accurate. Actually, it is the *internal* resistance of generators that usually limits the instantaneous current that they are able to provide; and this resistance is always *significantly* larger than zero, even in high current power supplies.

Conclusions

We can discuss for ages of what the “displacement current” actually is; but we could discuss for ages also on what an electromagnetic wave actually is, and if it “exists”; I would keep the discussions on the “existence” of things in the realm of philosophy. What we can state – being just engineers – is IF a theory works for us or not. On this respect displacement current works well, and will “exist” till the contrary is proven; I find the proves brought by the author flawed by a general mis-

References

[Bal] C.A. Balanis, “Advanced Engineering Electromagnetics”, Wiley, New York, 1989.

About the author

Michele D’Amico is Associate Professor in Electromagnetic Fields at University Politecnico di Milano, where is teaches Electromagnetic Fields, and “Antennas and Propagation”. He holds a Ph.D. in Mathematics from the University of Essex (UK). He has authored 2 books and more than 60 technical and scientific publications.
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