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The Telegrapher's Equations

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Abstract. Wireless EM radiation relates to magnetization while the waves that travel alongside the conducting wires in transmission lines relate to linear polarization. This article will examine how these two phenomena may or may not be treated using the same basic electromagnetic wave equations.

The Electromagnetic Wave Equations

I. The original electromagnetic wave equation,

$$\nabla^2\mathbf{H} = \mu\varepsilon\partial^2\mathbf{H}/\partial t^2 \qquad \textbf{(1)}$$

was derived for the magnetic intensity vector **H** by Scottish physicist James Clerk Maxwell in his 1865 paper ***"A Dynamical Theory of the Electromagnetic Field"***, and it was derived in connection with the electromagnetic momentum vector **A**, where curl **A** = μ**H**, [1]. Since **H** is a vorticity in the momentum field, equation **(1)** must be describing the propagation of angular acceleration through a sea of tiny aethereal vortices, [2].

This is further confirmed by the fact that another EM wave equation can be derived for the electric field vector **E**, where $\mathbf{E} = -\partial\mathbf{A}/\partial t$, providing that $\nabla.\mathbf{E} = 0$. This could be the case for a radial **E** providing that it obeys an inverse square law in distance, but then this would mean that $\nabla\times\mathbf{E} = 0$, whereas the derivation requires that $\nabla\times\mathbf{E} = -\mu\partial\mathbf{H}/\partial t$ (Faraday's Law). The only alternative is that **E** represents a force that accelerates **A** transversely to the polar origin, as would be the case when the aether flow is occurring between two neighbouring vortices. In a steady state magnetic field, **A** will represent the aether circulation within the individual vortices and no transfer will be taking place between neighbouring vortices, but in the dynamic state where angular acceleration takes place, there will be an overflow of aether from vortices to their immediate neighbours. This is known as time varying electromagnetic induction, and it is the basis of electromagnetic waves.

The speed of these waves will be c, where $c^2 = 1/\mu\varepsilon$, with μ representing magnetic permeability and ε representing electric permittivity, and where c is the speed of light. The magnetic permeability is related to the magnetic flux density while the electric permittivity is inversely related to the dielectric constant. The equation is then essentially Newton's equation for the speed of a wave in an elastic solid, equivalent to $E = mc^2$ in the context, **[3]**.

The Telegrapher's Equations

II. The electromagnetic wave equations apply to wireless EM radiation in space and the derivation involves both Faraday's law for time varying EM induction and Ampère's Circuital Law. In a similar manner we can derive a variant of equation **(1)** using either voltage, V, or current, I, in connection with self-inductance within a laboratory electric circuit involving conducting wires. These latter two equations are known as the *"Telegrapher's Equations"*, first derived in the 1880s by English electrical engineer Oliver Heaviside, **[4]**.

Around the same period, in 1883, English physicist John Henry Poynting made a proposal regarding the transfer of energy in electric circuits. He proposed that the energy is actually transferred through the space outside the conducting wires rather than inside the wires themselves, **[5]**. This idea was also taken up by Heaviside, **[6]**. While this is certainly so with respect to EM induction between two circuits, it's doubtful that the conducting wires wouldn't be the main source of energy transfer within a single circuit. What would the wires be doing otherwise? Who would ever observe a complex maze of electric wires and not think that they are the conducting channels for the flow of electrical energy?

Conclusion

III. The Heaviside signal that propagates alongside a conducting wire in a transmission line is a capacitive effect involving linear polarization in the surrounding dielectric. Faraday's law is not involved in a DC transmission line in the steady state, and so this wave phenomenon is clearly not being described by the electromagnetic wave equation at equation **(1)**.

The telegrapher's equations are in all essential details the same as the electromagnetic wave equations only they derive from the capacitance and the self-inductance within a laboratory electric circuit, with Q = CV

replacing $\mathbf{D} = \varepsilon\mathbf{E}$ in the wireless equivalent. Because electric permittivity, implicit and explicit in these two equations, can be linked to the speed of light through the 1855 Weber-Kohlrausch experiment, [7], it is believed that the telegrapher's equations relate to the speed of an electric signal in a conducting wire. But since capacitance acts perpendicularly to the conducting surfaces and since the current is not being powered by the self-induced back EMF, it's hard to see how these equations can relate to the signal speed in the wire. On the other hand, since experiments tend to confirm that the speed of an electric signal along a wire is indeed in the order of the speed of light, it would seem like a coincidence if the telegrapher's equations weren't in fact applicable in the context.

The problem might be resolved to some degree by returning to the older idea that electric current in a conducting wire primarily constitutes the flow of an aethereal fluid. It is proposed that this *electric fluid* emerges from positive particle sources and disappears into negative particle sinks, and at an average speed in the order of the speed of light. Between the terminals of a battery, positive particles in the conducting wire would be accelerated with the flow, while negative particles would eat their way in the opposite direction, but these particles would never reach the speed of the aether flow itself due to the circuit resistance R. We know that drift velocities are nowhere near the speed of light and so we should not consider the motion of charged particles to be the primary essence of electric current. However, if we consider electric current to be primarily an aethereal fluid, then changes in pressure (voltage) in an electric current would be propagated with the current flow at speeds in the order of the speed of light.

Wireless and cable telegraphy could then be reconciled on the basis that EM radiation in space is simply electric current passing at the speed of light between tiny neighbouring aethereal vortices that are acting as miniature electric circuits and filling all of space while aligned along their mutual rotation axes as per the prevailing magnetic field. The vector **A**, nowadays known as the magnetic vector potential, and where $\text{curl}\ \mathbf{A} = \mu\mathbf{H}$, would then become Maxwell's displacement current, [8].

When the power is first connected to a conducting circuit, the aethereal current leaks out into the surrounding dielectric in order to make the shortest return. In the case of a parallel wire transmission line, this means that the current crosses the gap between the two wires, causing dielectric polarization in the process. This effect propagates outwards from the power source. If the power is disconnected before the effect reaches the far end of the circuit, we will observe a discrete rectangular polarized region between the two wires with a circulating aethereal current surrounding its perimeter. This polarized region will be moving in

a wave-like manner towards the far end of the line like a caterpillar track and moving at a speed in the order of the speed of light.

In the case of an AC circuit, when the current reaches an antenna, the conduction current **J** disperses as wireless radiation **A** into the wider sea of tiny eddy currents that fill all of space, **[9], [10].**

References

[1] Clerk-Maxwell, J., ***"A Dynamical Theory of the Electromagnetic Field"***, Philos. Trans. Roy. Soc. London 155, pp. 459-512 (1865). Abstract: Proceedings of the Royal Society of London 13, pp. 531--536 (1864). Maxwell's derivation of the electromagnetic wave equation is found in the link below in Part VI entitled 'Electromagnetic Theory of Light' which begins on page 497, http://www.zpenergy.com/downloads/Maxwell_1864_4.pdf

[2] Lodge, Sir Oliver, ***"Ether (in physics)"***, Encyclopaedia Britannica, Fourteenth Edition, vol. 8, pp. 751-755, (1937) http://gsjournal.net/Science-Journals/Historical%20PapersMechanics%20/%20Electrodynamics/Download/4105 See pp. 6-7 in the pdf file in the link above, beginning at the paragraph that starts with, ***Possible Structure. −***, and note that while the quote suggests that the ether is incompressible, this is almost certainly not the case. The quote in question, in relation to the speed of light, reads,
"The most probable surmise or guess at present is that the ether is a perfectly incompressible continuous fluid, in a state of fine-grained vortex motion, circulating with that same enormous speed. For it has been partly, though as yet incompletely, shown that such a vortex fluid would transmit waves of the same general nature as light waves— i.e., periodic disturbances across the line of propagation—and would transmit them at a rate of the same order of magnitude as the vortex or circulation speed"

[3] Clerk-Maxwell, J., ***"On Physical Lines of Force"***, Part III, equation (132), Philosophical Magazine, Volume XXI, Fourth Series, London, (1861) http://vacuum-physics.com/Maxwell/maxwell_oplf.pdf

[4] Heaviside O. ***"Electrical papers"***, Volume II, p. 82, (1892)

[5] Poynting, J.H., ***"On the Transfer of Energy in the Electromagnetic Field"***, Philos. Trans. Roy. Soc. London 175, pp. 343-36, (1884) https://en.wikisource.org/wiki/On_the_Transfer_of_Energy_in_the_Electromagnetic_Field

[6] Heaviside, O., ***"Electrical Papers"***, Volume 1, p. 438, (1892)

[7] Tombe, F.D., ***"The 1855 Weber-Kohlrausch Experiment"***, (2019) https://www.scribd.com/document/294114501/The-1855-Weber-Kohlrausch-Experiment-The-Speed-of-Light

[8] Tombe, F.D., ***"An Interpretation of Faraday's Lines of Force"***, (2019)
https://www.researchgate.net/publication/332249473_An_Interpretation_of_Faraday's_Lines_of_Force

[9] Whittaker, E.T., ***"A History of the Theories of Aether and Electricity"***, Chapter 4, pages 100-102, (1910)
"All space, according to the younger Bernoulli, is permeated by a fluid aether, containing an immense number of excessively small whirlpools. The elasticity which the aether appears to possess, and in virtue of which it is able to transmit vibrations, is really due to the presence of these whirlpools; for, owing to centrifugal force, each whirlpool is continually striving to dilate, and so presses against the neighbouring whirlpools."

[10] O'Neill, John J., ***"PRODIGAL GENIUS, Biography of Nikola Tesla"***, Long Island, New York, 15th July 1944, Fourth Part, paragraph 23, quoting Tesla from his 1907 paper ***"Man's Greatest Achievement"*** which was published in 1930 in the Milwaukee Sentinel,
"Long ago he (mankind) recognized that all perceptible matter comes from a primary substance, of a tenuity beyond conception and filling all space - the Akasha or luminiferous ether - which is acted upon by the life-giving Prana or creative force, calling into existence, in never ending cycles, all things and phenomena. The primary substance, thrown into infinitesimal whirls of prodigious velocity, becomes gross matter; the force subsiding, the motion ceases and matter disappears, reverting to the primary substance".
http://www.rastko.rs/istorija/tesla/oniell-tesla.html
http://www.ascension-research.org/tesla.html