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Wireless Radiation at the Antenna Boundary

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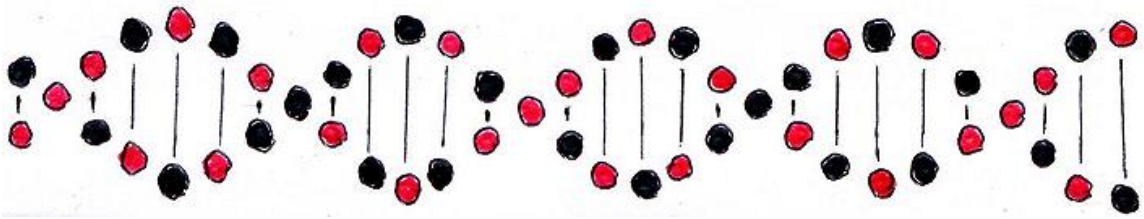
Abstract. **Wireless radiation emitted from an antenna is generated on the same principle as that of a magnetic field. One might therefore imagine that the power source would encounter a reactive impedance. The standard belief, however, is that *radiation resistance* is not in fact reactive, but rather that it is a resistive impedance. This matter will be investigated.**



Resistive Impedance

I. Ohm's Law in a DC circuit connects the applied voltage, *V*, to the induced electric current, *I*, in a similar manner to that in which the terminal velocity in a resisting medium such air, is related to the applied force. For example, as an object free-falls through the air under gravity, the air resistance increases as the speed increases, hence undermining gravity as the object tends towards a terminal speed, typically of around 120 mph. If we were to somehow increase the gravitational field strength, this terminal speed would increase proportionately. We could use the equation $V = IR$ to apply to a free-fall situation simply by treating *V* as if it were the force of gravity, and by treating *I* as if it were the terminal speed, and *R* as if it were the coefficient of air resistance. In both cases, energy input from the driving force is dissipated to the surroundings. In the case of electrical resistance, the input electrical energy is converted to other kinds of energy such as heat or light, and the terminal speed is reached so quickly that transient effects are generally ignored, even when we carry the principle through into AC theory.

It should be noted that when talking about the speed of electric current in relation to Ohm's Law, that we are talking about the drift velocity of the charged particles and not about the aethereal undercurrent which travels at close to the speed of light.

Inductive Impedance

II. Inductive impedance is of a different physical nature than resistive impedance. It is based on the back EMF that acts against the applied voltage during the creation of a magnetic field. It is the impedance that is the source of Lenz's Law, and it is associated with energy loss to the magnetic field. While inductive impedance is generally considered to be lossless because the magnetic energy can be returned to the electric circuit again, we also know that energy can be lost absolutely to EM radiation. It would seem therefore that there are two distinct physical aspects to inductive impedance. This matter will be investigated in more detail in sections **IV**, **V**, and **VI** below.

Phase Difference

III. As regards resistive impedance, Ohm's law tells us that *V* and *I* are in phase. As regards inductive impedance however, in the lossless case, *V* and *I* are out of phase. The applied voltage leads the induced current by 90 degrees. The question then arises as to whether, on the one hand, the in-phase relationship in the case of resistive impedance is ***because*** energy is being lost from the system, or on the other hand, if it is because the resistance, like air resistance, is velocity dependent.

If *V* and *I* are in phase ***because*** resistive impedance is velocity dependent, and not because energy is being lost from the system, then with respect to inductive impedance, we might wish to believe that *V* and *I* will be out of phase by 90 degrees whether energy is lost from the system or not, ***if we believe*** that the elastic interaction between the conduction current in the wire and the induced magnetic field is the same in the lossless case as it is in the case of radiation losses. In other words, if the physical interaction is the same, then when energy is being lost to wireless radiation, this should not affect the phase difference of 90 degrees between *V* and *I*. But this is not what is generally believed. It is generally believed that when energy is lost to wireless waves, that *V* and *I* will be in phase, and for the very reason that energy has been lost from the circuit. This is why it is important to examine whether or not the concept of *radiation resistance* is actually a different physical phenomenon than inductive impedance, and whether or not it behaves more like Ohmic resistance *R*.

The Antenna Impedance

IV. An antenna has a natural frequency which depends on its inductance, *L*, its capacitance, *C*, and its geometry. When it is tuned to this frequency, the overall

reactive impedance will be at a minimum, and a substantial amount of electromagnetic energy will be radiated into space in the form of wireless EM waves. The process is explained with reference to Maxwell's molecular vortices, **[1]**, **[2]**, **[3]**, **[4]**, **[5]**, in Section **II** of ***"Wireless Radiation Beyond the Near Magnetic Field"*** **[6]**. The principle is that electric current is primarily a fluid known as the *aether*, or *electric fluid*, and it is the same fluid that is involved in Maxwell's vortices. In the steady state, Maxwell explained Ampère's Circuital Law on the basis that these vortices would align such that their rotation axes trace out concentric solenoidal rings around their source electric current, and that these rings would constitute magnetic lines of force. It will now be assumed that at the point of contact in the steady state, the fluid flow in the conducting wire is in the opposite direction to that in the adjacent vortices, and so there can be no aether exchange. It is proposed that aether exchange between wire and field only occurs in the dynamic state when the vortices are precessing, and hence opening up an avenue for the aether to flow tangentially from the conducting wire into the vortices.

The main point here is that radiation resistance amounts to a leakage of energy in the form of pressurized aether. This occurs in the transient state in an electric circuit in the first moments after switching on the power, before the magnetic field has had time to properly align, or in the case of an AC circuit, it occurs twice in each cycle at the moment when the electric current reverses its direction. But once the magnetic alignment is complete, there can be no further loss of aether from the conduction wire, as it will be hemmed in by virtue of the fact that the adjacent vortices will be aligned edge-on to the wire and swirling in a direction such that the aether flow in the vortex is opposite to that of the current in the wire, at the point of contact. After that, any further increase in the electric current in the wire will increase the magnetic field strength by increasing the centrifugal pressure at the point of contact, and hence by conservation of angular momentum, this centrifugal pressure will cause the vortices to spin faster. But there will be no further loss of aether from the wire, and so when the power is switched off again, the magnetic field will simply unwind and induce a final forward surge of current in the wire.

A physical distinction does therefore exist as between inductive impedance and radiation resistance. The latter resembles Ohmic resistance, R, in the sense that it causes energy to be lost from the circuit. But as it occurs in an AC circuit at the moment when the current changes direction, it is not therefore velocity dependent. In fact, we might expect maximum radiation loss to occur when the voltage is maximum. In Section **VI**, we will take a closer look at the meaning of the power factor, VI.

The Impedance of Free Space

V. There is a concept known as the ***impedance of free space*** and it is defined as $Z_o = |\mathbf{E}|/|\mathbf{H}|$, where $|\mathbf{E}|/|\mathbf{H}|$ is the ratio of the magnitude of the electric field strength to the magnitude of the magnetic field intensity in a wireless EM wave in space. This ratio is believed to be 377 Ohms, based on plane wave solutions to Maxwell's equations. It is a fixed constant of space related to the electric permittivity, ε_o, and the magnetic permeability, μ_o, and hence to the speed of light, c. The definition, $Z_o = |\mathbf{E}|/|\mathbf{H}|$, is chosen for its semblance to Ohm's Law, which is interesting because Ohm's law is based on the principle of the terminal speed of charged particles that results when an applied EMF encounters a dissipating resistance. But in the case of EM radiation, we are dealing with a self-propagating wave that requires no on-going applied EMF. We are now in the realm of wave mechanics where the wave-speed is already fixed for other reasons. So, even though Z_o bears a set relationship to the speed of light, there is no need to take it into consideration when adjusting the resonant frequency, and hence the impedance, of an antenna. The concept of *impedance of free space* therefore serves no use in practice.

Power

VI. As regards the product, *VI*, as in voltage multiplied by electric current, which is usually introduced to younger students in connection with AC transformers, the meaning is ultimately *'rate of change of potential energy'*, as opposed to *'rate of flow of energy'*, although this subtle difference is not of very much significance in practice. The voltage, *V*, is defined as potential energy per unit charge. But, since ultimately on the deeper aethereal level, potential energy and charge mean the same thing, as in aether pressure or aether tension, the expression, *V*, really means potential energy per particle, or more simply, potential energy density. The electric current term, *I*, which is d*q*/dt, where *q* is electric charge, ideally means the rate of change of charge, as opposed to the rate of flow of charge, but it could be taken to mean either. Hence in circuit theory, the power product, *VI*, can be taken to mean the rate that electric energy flows into a circuit. †

In an AC transformer, the students are taught how, ignoring the inefficiency factor, the power V_pI_p at the primary coil will be equal to the power, V_sI_s, at the secondary. The idea of the step-up transformer is, that by stepping up the voltage, we step down the current, and hence from Ohm's law, $V = IR$, the power expression in the secondary becomes I_s^2R, and since I_s is small despite the squared factor, then energy loss to resistance is minimal.

What is missing from this argument, however, is that none of it actually tells us how much energy is lost to Ohmic resistance, *R*, and how much is lost to

EM radiation, and how much is not lost at all. It is true that in overhead power cables, the relatively low value of *I* and the relatively high value of *V*, means that most of the energy travels in the form of electrostatic energy by means of a capacitive effect transmission line effect, and that resistive losses are indeed comparatively low. But when it comes to an antenna that radiates wireless EM radiation into space, there is no theoretical way of determining how much of the *I* in *VI* goes to resistive losses due to R, and how much goes to EM radiation. All we know is that radiation losses are maximum when the circuit is tuned to the resonant frequency where the total reactive impedance is minimum.

Because the product *VI* is generally associated with energy lost from the system, this leads on to the unfounded assumption that energy losses must associated with *V* and *I* being in phase. They say that if *V* and *I* are out of phase, then there will be no energy losses. But while *V* and *I* are indeed in phase in the case of resistive losses, this does not mean that they must be in phase when it comes to energy lost to EM radiation. The physical reason why *V* and *I* are in phase in the case of resistive losses is to do with the fact that *I* is *speed-dependent*, but this factor does not apply in the case of radiation resistance. The phase difference between *V* and *I* is to do with the physical nature of the impedance rather than the issue of whether energy is lost or not.

† *See* ***Appendix I*** *for information on some vector quantities that are encountered in electromagnetism which also relate to energy flow.*

Conclusion

VII. In the case of a loop antenna, we can expect there to be significant Ohmic resistive losses in the conducting wire due to the flow of electric current. And because of these resistive losses, we can expect that *V* and *I* will largely be in phase with each other because of the speed-dependence of *I*. The current *I* is in effect a terminal velocity which is reached when the resistance force, *IR*, cancels the applied voltage, as per Ohm's Law, $V = IR$. But the in-phase relationship has got nothing to do with so-called ***radiation resistance***, which is not speed dependent. In a dipole antenna on the other hand, where the resistive losses are small, we should expect *V* and *I* to be much closer to the 90 degrees phase difference that comes with the elastic nature of Maxwell's sea of molecular vortices, and which is described by Ampère's Circuital law and Faraday's Law of Induction.

Appendix I

As well as the scalar power product *VI*, there are other quantities in electromagnetism with similar meanings. We need to compare and analyse these. We need to look at the current

density, **J**, the magnetic vector potential, **A**, the Poynting vector, $\mathbf{E}_K \times \mathbf{H}$, as applicable in wireless radiation, and the Poynting vector, $\mathbf{E}_S \times \mathbf{H}$, as applicable in a transmission line pulse. At the most fundamental level, electric charge is aether pressure or aether tension, while electric current is aether flow. It follows therefore that voltage, charge, and charge density, are ultimately the same thing. They all represent potential energy in the electric fluid. As regards the current density, **J**, this represents a flow of pressurized or tensile aether. It is a measure of the flow of energy per unit area through a surface. As regards the symbol **A**, known to Maxwell as the ***electromagnetic momentum***, this is the same thing as **J**, but its usage is restricted to the special case of the displacement currents in the luminiferous medium, as in Maxwell's sea of molecular vortices [7]. As regards $\mathbf{E}_K \times \mathbf{H}$, where $\mathbf{E}_K$ is the electric field that is induced by a changing magnetic field, this is the same thing as **A** in terms of its ultimate physical meaning, even if this cannot be demonstrated mathematically. Both **A** and $\mathbf{E}_K \times \mathbf{H}$ represent the rate of flow of pressurized aether through a surface. The same is so in transmission lines as regards, $\mathbf{E}_S \times \mathbf{H}$, where $\mathbf{E}_S$ is the electrostatic field [8], but to get the full rate of flow of energy in this case, we need to also consider **J** for that part of the electric energy that is flowing in the conducting wire.

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http://vacuum-physics.com/Maxwell/maxwell_oplf.pdf

[2] 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. It will be seen that Bernoulli is a thorough Cartesian in spirit; not only does he reject action at a distance, but he insists that even the elasticity of his aether shall be explicable in terms of matter and motion. This aggregate of small vortices, or " fine-grained turbulent motion," as it came to be called a century and a half later,* is interspersed with solid corpuscles, whose dimensions are small compared with their distances apart. These are pushed about by the whirlpools whenever the aether is disturbed, but never travel far from their original positions. A source of light communicates to its surroundings a disturbance which condenses the nearest whirlpools; these by their condensation displace the contiguous corpuscles from their equilibrium position; and these in turn produce condensations in the whirlpools next beyond them, so that vibrations are propagated in every direction from the luminous point. It is curious that Bernoulli speaks of these vibrations as longitudinal, and actually contrasts them with those of a stretched cord, which, "when it is slightly displaced from its rectilinear form, and then let go, performs transverse vibrations in a direction at right angles to the direction of the cord." When it is remembered that the objection to longitudinal vibrations, on the score of polarization, had already been clearly stated by Newton, and that Bernoulli's aether closely resembles that which Maxwell invented in 1861-2 for the express purpose of securing transversality of vibration, one feels that perhaps no man ever so narrowly missed a great discovery. Bernoulli explained refraction by combining these ideas with those of his father. Within the pores of ponderable bodies

the whirlpools are compressed, so the centrifugal force must vary in intensity from one medium to another. Thus a corpuscle situated in the interface between two media is acted on by a greater elastic force from one medium than from the other; and by applying the triangle of forces to find the- conditions of its equilibrium, the law of Snell and Descartes may be obtained. * Cf . Lord Kelvin's vortex-sponge aether, described later in this work."

[3] O'Neill, John J., ***"PRODIGAL GENIUS, Biography of Nikola Tesla"***, Long Island, New York, 15th July 1944, 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

[4] Lodge, Sir Oliver, ***"Ether (in physics)"***, Encyclopaedia Britannica, Fourteenth Edition, Volume 8, Pages 751-755, (1937)
This quote is in relation to the speed of light,
"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" (Sir Oliver Lodge, 1937)
The article then goes on to cite Lord Kelvin, **"The Vortex Theory of Ether,"** *Phil. Mag.* (1887) and *Math. and Phys. Papers*, vol. iv. and passim; also G. F. FitzGerald, *Proc. Roy. Dub. Soc.* (1899), or *Collected Papers*, pp. 154, 238, 472.
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