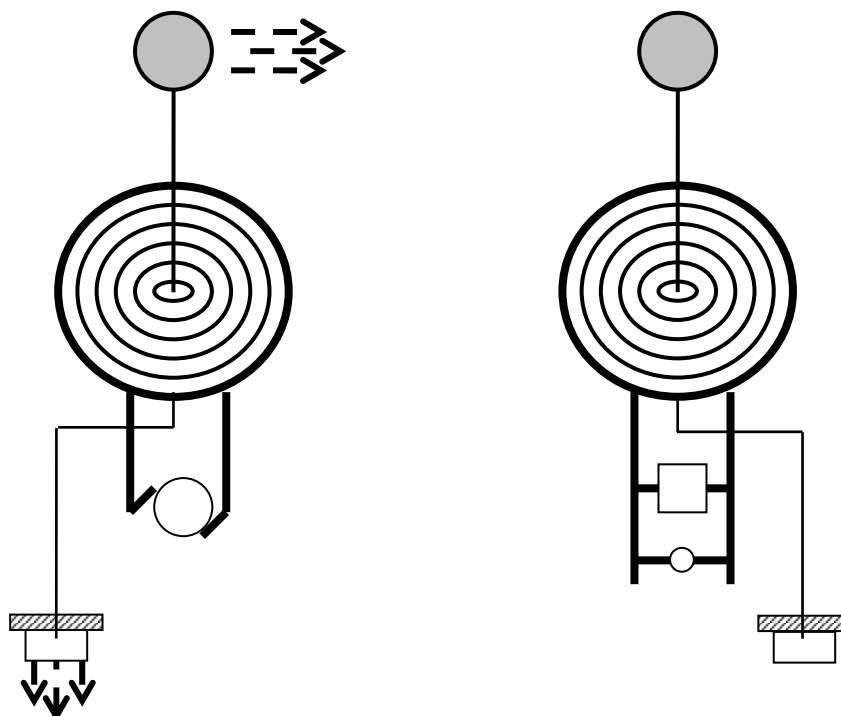# LONGITUDINAL DIELECTRIC WAVES IN A TESLA COIL AND QUATERNIONIC MAXWELL'S EQUATIONS.

Revised

Roberto Handwerker (Dr.Eng.)
2011 - DELTA Ingegneria® - Milan, Italy
deltaavalon.com

Longitudinal dielectric waves in a Tesla Coil and quaternionic Maxwell's equations.

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Abstract

   The Academic World has always officially considered the transformer known as the "Tesla Coil" with its peculiar characteristics only as an electrotechnics device, a pure and simple "transformer", and only as an apparatus for producing sparks, lightning-like discharges and high voltages impressive electric effects. By closer scientific investigation of the device it is however possible to throw new light on some aspects of the coil invented by Nikola Tesla more than a century ago, in particular regarding the emission of longitudinal dielectric waves. An analysis supported by a physics/mathematics approach which recalls the original quaternionic notation of Maxwell's equations, involving the prediction of the existence of dielectric scalar fields and longitudinal waves and also supported from empirical experimentation and research on the device itself is made. This new point of view discloses some new and striking facts regarding the coil and the related energy field, which leads to a completely new and surprising realm.
   However, it seems puzzling that the possibility of existence of scalar fields and of related longitudinal dielectric waves is still not accepted by the Academic World, which in turn gives neither sufficient justification nor proves to support its sceptical position which excludes the existence of said waves.

DISCLAIMER: **WARNING !** THE FOLLOWING EXPERIMENTS AND TESTS MAKE USE OF HIGH FREQUENCY RADIO WAVES AND HIGH VOLTAGE (POSSIBLE EMISSION OF X-RAYS, UV AND OTHER HARMFUL RAYS): PLEASE DON'T TRY TO REPLICATE THESE UNLESS YOU ARE WELL-EXPERIENCED AND SKILLED IN HIGH-TENSION ELECTROTECHNICS AND RADIO-TECHNOLOGY: DANGER OF SERIOUS AND EVEN FATAL INJURIES TO PERSONS, DAMAGE TO PROPERTY!

HIGH VOLTAGE HAZARD

RADIO WAVES HAZARD

1. Introduction

   It is well known that J.C. Maxwell issued in 1873 his *"A treatise on electricity & magnetism"*[1] where he presented in an elegant form the results of his studies, writing some 20 EM equations; in the beginning he thought to make use of quaternions[8], whose calculation was but not quite simple, later Heaviside and Gibbs introduced the vector notation, in order to "simplify" the equations. It will be useful to remember that quaternion numbers consist in four terms, whereas vectors consist only in three terms as in following example:

$$\mathbf{\tilde{A}} = a + b\mathbf{i} + c\mathbf{j} + d\mathbf{k}$$

$$\mathbf{V} = a\mathbf{x} + b\mathbf{y} + c\mathbf{z}$$

 The two systems follow different calculation rules, for instance the former has anticommutative property, the latter on the contrary has commutative property.

TESLA
COIL
XMTR

Ø 50
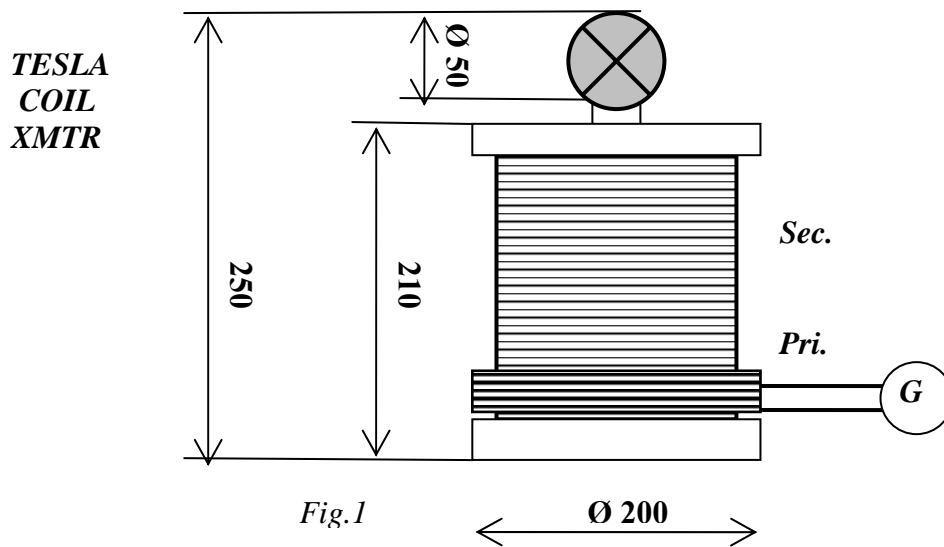
250

210

Sec.

Pri.

G

Fig.1

Ø 200

Fig.1: Tesla coil Transmitter (XMTR) used in laboratory during tests; the particular design utilized in the investigation is called "Extra Tesla Coil", having cylindrical form and being mainly constituted by a primary coil (Pri.), a secondary coil (Sec.), top capacitance (bulb) and a high frequency-high voltage generator (G). Measures are in [mm].

Regarding the existence of longitudinal dielectric waves, there are two possible explanations about why these do not appear in the well-known today's Maxwell's equations, which are the fundament of modern electromagnetism:

a) Today's vector notation was introduced, after the death of J.C. Maxwell, by Heaviside and Gibbs who "simplified" the original quaternionic[8] notation proposed by Maxwell; therefore the actual set of equations would be partially incomplete, excluding longitudinal waves.

b) J.C. Maxwell first issued his set of equations in 1865 including electromagnetism related phenomena which has been observed or at least which he reported, that he judged to be fundamental; but N. Tesla discovered new dielectric induction phenomena only later, in 1892. Anyway, the two above possibilities doesn't exclude each other.

2. Maxwell's equations

The (Heaviside's) commonly adopted vector notation of Maxwell's equation in differential form is following:

$$\nabla \cdot \mathbf{B} = 0 \qquad \text{(Magnetic flux theorem)}$$

$$\nabla \cdot \mathbf{E} = \rho/\varepsilon_\circ \qquad \text{(Gauss's Law-Dielectric flux)}$$

$$\nabla \times \mathbf{E} + \partial\mathbf{B}/\partial t = 0 \qquad \text{(Faraday's law)}$$

$$c^2 \nabla \times \mathbf{B} - \partial\mathbf{E}/\partial t = \mathbf{J}/\varepsilon_\circ \qquad \text{(Ampére's law)}$$

where: $\mathbf{E}$ = dielectric field; $\mathbf{B}$ = magnetic field;
ρ = charge density; ε_0 = dielectric constant in vacuum;
$\partial/\partial t$ = time partial derivative; $\mathbf{J}$ = current intensity.

Fig.2

Fig.2: Two flat spiral Tesla coils or "pancake" coils: a Transmitter (XMTR) and a Receiver (RCVR) both connected to the ground as described in Tesla's Patent n.649621 from May 1900.

 The employ of quaternions by informatics increases computer calculation speed and allows memory space spare up to 55%, which is a great advantage for instance in aerospace navigation (typically in inertial platforms)[5]; their application to Maxwell's equations reveals some unexpected elements.

 Starting from another point of view it would be possible to write the Maxwell set of equations by the quaternion notation, which even if it is more complicated on one hand, on the other hand it leads to some unexpected and striking results which in particular involve the prediction of the existence of longitudinal dielectric waves; this fact was already claimed by other Authors (for example Ignatiev G.F. & Leus V.A.)[10] and on the basis of some R.F. (= Radio Frequency) experiments by the employ of transmitting and receiving devices with ball-shaped "antennas" even from others. Besides this, if the claimed possibility by some physics (see appendix: Arbab A. & Satti Z.[6]) of deriving Maxwell's equations from only one *wave quaternion vector potential* or:

$$\tilde{\mathbf{A}} = (i\varphi/c \ , \ \mathbf{A})$$

where:

$$\tilde{\Box}^2 \tilde{\mathbf{A}} = \mu_o \mathbf{J} \quad , \quad \mathbf{J} = (ic\rho, \mathbf{J})$$

by respect of the Lorenz gauge will be considered as accepted, so it will be possible to take into account an extended result of today's Maxwell's vector form. This imply the existence, besides the well-known EM Transverse waves (T.E.M.= Transverse Electro-Magnetic), also of Longitudinal waves (L.M.D.= Longitudinal Magneto-Dielectric), whose scalar potential "φ" is related to its dielectric field "**E**" by following equation:

$$\mathbf{E} = \nabla \varphi$$

 This theoretical result was also supported from experimental laboratory investigation which made use of "Tesla Coils" which are, as it will be readily seen, not only "transformers" for high frequency
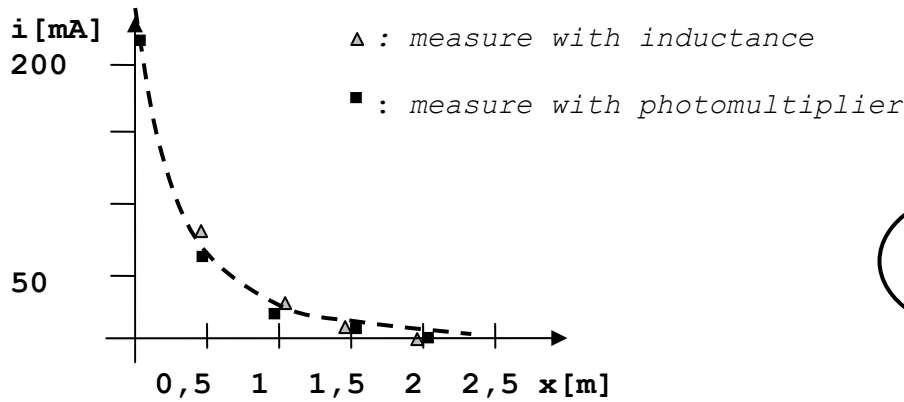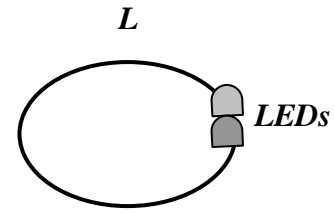
Fig.3

Fig.4

Fig.3: Diagram shows the relationship between energy field intensity and distance of the photomultiplier (type "931-A") from the XMTR Tesla coil as a function of current values read by quantitative measuring device (M); the dots shows normalised measured values whereas the dotted line shows the expected quadratic diminishing curve for waves by increasing distance (x) from the Transmitter.

Fig.4: Small wire loop (L) series connected with two LEDs of different colour and slightly different sensibility was used as a "detector" for resonance frequency and as an auxiliary qualitative measuring device of the Tesla coil field intensity for tuning purposes.

low voltage into high frequency (= HF) high voltage (= HV) or devices for creating spectacular lightning-like electric discharges, but are also a useful means to show the existence of the dielectric longitudinal field, which is generated by the peculiar design and construction of the coil itself. In fact, it will be shown the capability of this kind of field of transmitting electrical energy and not only weak signal in the surrounding medium, and to drive not only light bulbs and neon tubes as commonly thought, but even common DC electric motors under proper conditions. The investigation has been conducted by means of empirical observation, experiments and tests with the help of usual electrotechnics measuring devices as oscilloscope, analogic multimeter (having more "inertia" due to internal coil and indicator, so being less affected by fluctuations), small pocket AM radio receiver device, brass metal plates, copper wire loops with LEDs as detectors and other rather common devices to detect and analyse EM (= Electro-Magnetic) fields and waves: it was avoided the use of complicated systems according to the "keep it simple" philosophy also in order to make following experiments and tests fully replicable, which is of course the main requirement of scientific investigation and research. For the complete calculation reference is made to Arbab A. & Satti Z.[6], and it will be readily shown that according to their work, Maxwell's equations could be simply expressed in the quaternionic form by the following two equations:

$$1/c^2 \, \partial^2 \mathbf{E}/\partial t^2 - \nabla^2 \mathbf{E} = -1/\varepsilon_o \, (\nabla \rho + 1/c^2 \, \partial \mathbf{J}/\partial t) \qquad (1)$$

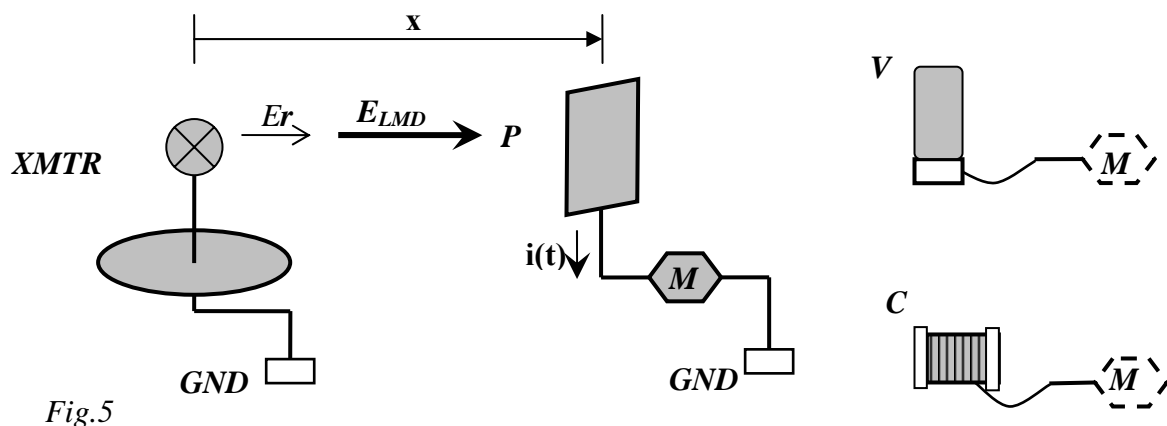$$1/c^2 \, \partial^2 \mathbf{B}/\partial t^2 - \nabla^2 \mathbf{B} = \mu_o \, (\nabla \times \mathbf{J}) \qquad (2)$$

Fig.5: Suspended insulated metal plate (P) (dimension: 120x130mm) series connected to a quantitative measuring device (M) and to ground; the plate acts as a receiver of energy, which gives rise in the plate to a comparatively strong current that flows through the device into the ground; a vacuum tube device (V) type "931-A" was then connected to the measuring device (M) instead of the metal plate (P) in order to further analyse the electric field.

The generic scalar field "Σ" was introduced and consequently also the current density can be written as $\mathbf{J} = \nabla \Sigma$, the following new gauge transformation can be considered:

$$\rho' = \rho + 1/c^2\, \partial\Sigma/\partial t \quad \text{and} \quad \mathbf{J'} = \mathbf{J} - \nabla \Sigma \qquad (3) \text{ and } (4)$$

it is then noted that the scalar Σ satisfies the wave equation:

$$1/c^2\, \partial^2\Sigma\, /\partial t^2 - \nabla^2 \Sigma = - (\nabla . \mathbf{J} + \partial\rho/\partial t) \qquad (5)$$

Further, from the above mentioned work it would descend that the charge density ρ and the current intensity $\mathbf{J}$ would travel at the speed of light; so Maxwell's equations could be seen as a special case of equations (1) and (2). Then, this implies that the scalar wave Σ distribution would therefore induce a

charge density:

$$\rho = -1/c^2\, \partial\Sigma/\partial t \qquad (6)$$

and a current intensity:

$$\mathbf{J} = \nabla \Sigma \qquad (7)$$

even if charge ρ and current $\mathbf{J}$ were not present in a particular zone. This aspect could help explain for example the working principle of an electric condenser (capacitor), otherwise stated why metal plates which are separated by a dielectric non-conductive material, therefore not in direct contact between them, do conduct an electrical current: it is
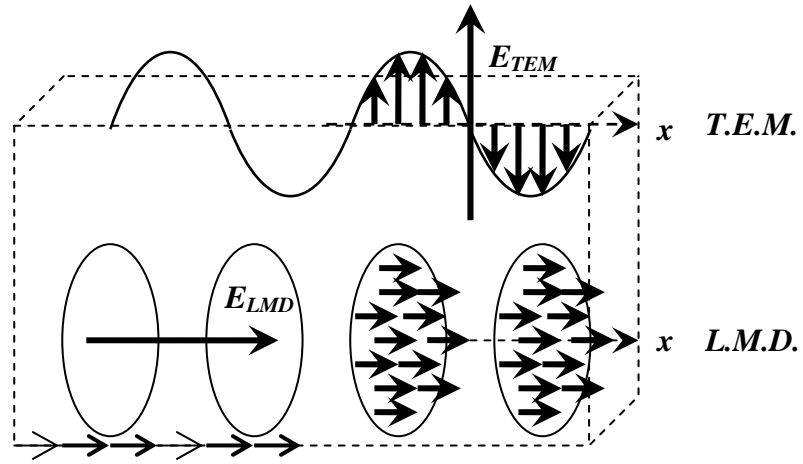
Fig.6: The two wave components present in the energy field are the T.E.M. (= Transverse Electro-Magnetic, E_{TEM}) and the L.M.D. (= Longitudinal Magneto-Dielectric, E_{LMD}) by the same propagation direction (x). Keeping in mind the "hydrodynamic analogy" between electrotechnics and fluidics, sea waves are ideally an example of both T.E.M. (surface waves) and of L.M.D. (deep "tsunami" pressure waves).

then noted that commonly alleged theories of "displacement currents" phenomena do not constitute a really convincing explanation, in particular it is not clear how an electron current could freely "pass" or "jump" through the dielectric according to common theories; an interesting hint to this is given by Steinmetz C.P.[7] if the possibility is considered, that by electrostatic (i.e. dielectric) fields charges are not only confined on the surface of the charged conductors, but are even present in the surrounding space, just in a similar way as it happens for magnetic fields.
This is a physical and mathematical approach and also a possible explanation to the question marked as "a)" in the introduction.

3. Dielectric induction phenomena and longitudinal dielectric waves

The second question set in the introduction and marked as "b)" departs from mere mathematical/physical calculation and is rather related to the researches and experiments of Dr. N. Tesla, which in 1892 observed what he often used to call "curious and striking phenomena" of electricity, which he described in his writings or during his academic lectures delivered before the Scientific Community[3],[4], and that made him practically abandon his studies on high frequency alternating currents and start exploring a new realm. The phenomena referred to have yet partially been observed for example in 1872 by Elihu Thomson[9] during a lesson at the Philadelphia High School, where he was a teacher. By doing a demonstration with a Ruhmkorff induction coil and willingly to better show the effects to the students sitting far from the device, he made some changes in the circuit obtaining, instead of the normally displayed purplish-blueish sparks, impressive big and white electric discharges, and metal objects in the room became strangely electrified and kept throwing sparks in the surrounding space as the device was turned on. This effect could have been due to a new and peculiar form of dielectric induction. Tesla realised a number of devices in order to better investigate the matter and at the end perfected his particular Coil, a seemingly simple device but hiding many peculiar characteristics as regards the transmission of energy and signal through the natural medium, which will not be discussed here, and last but not least, to
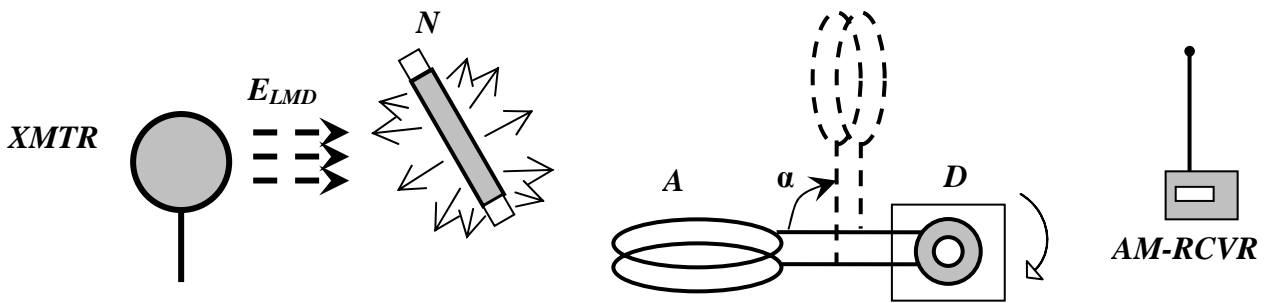
Fig.7

Fig.7: Neon tube (N) in the XMTR's energy field lit to its full brightness without any energizing wire connected to it nor other energy supply; a double copper wire loop (A) "antenna" series connected to a small DC electric motor (D) could be tilted up to an angle α= 90° with respect to a horizontal axis without affecting the energy transmission to the motor.

investigate the existence besides of a Transverse Electro-Magnetic, of a Longitudinal Magneto-Dielectric field in the medium around it. It is convenient at this point to shortly illustrate the construction of a typical "Tesla transformer" by its main components:

1-   The generator (HV & HF)
2-   The primary (coil) circuit
3-   The secondary (coil) circuit
4-   The top spherical inductance (lamp bulb / metal sphere)

 The generator is designed to provide currents of high frequency and high voltage to the primary circuit, which is basically constituted by a coil and a capacitor (which will be called here a "condenser" as used by Tesla time) and a spark-gap forming an oscillator; the primary is coupled to another coil without any iron core, on the top of which is another condenser, this time of spherical form, together forming the secondary of the transformer. The secondary coil can be connected or not to the ground. The above described coils with the related suitable generator constitute the XMTR (= Transmitter), whereas a similar device also comprising a primary and a secondary, but without the generator, constitutes the RCVR (= Receiver). The connection between the two devices can be made by a single wire, by the ground or by water, however here will be only discussed the XMTR with respect to the generation of longitudinal dielectric waves; of course the device emits also usual T.E.M. waves because of the solenoid form of its coils. It is to be noted that the capacitance on the top of the secondary coil has a spherical form; when the generator energizes the oscillator in the primary, energy transfer occurs to the secondary of the "transformer" by dielectric induction without the presence of any iron core in the coils. The energy of the primary is inducted to the secondary where the voltage is greatly increased to huge values depending from the construction parameters of the device as material, components, dimensions, proportions etc., even if it can be stated that already a few turns of wire in the secondary coil could give rise to hundreds and even to millions of Volts without any difficulty as it should be for well-tuned Tesla Coils. The HF-HV is maximum on the top of secondary corresponding to the sphere capacitance/condenser (in this case an argon lamp bulb because of the small dimension of the
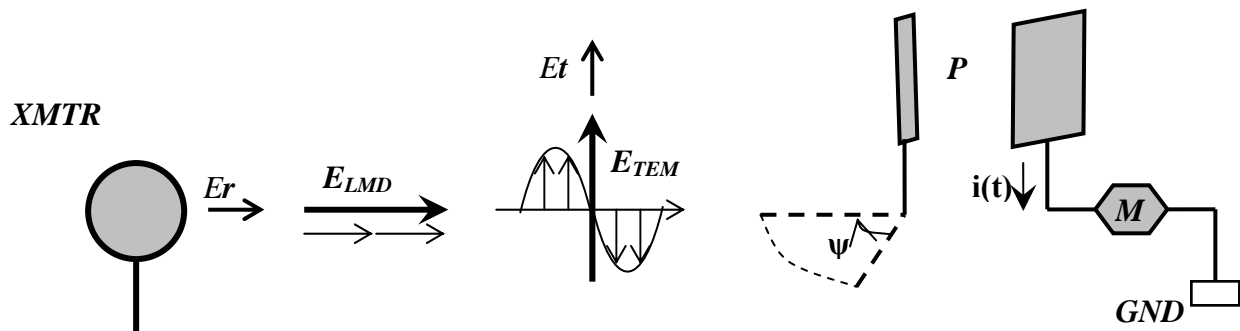
Fig.8

Fig.8: A brass metal plate (P) connected by only one wire to an analogic multimeter and then series to ground was used to analyse the field around the XMTR; by rotating the plate (P) around its vertical axis, the received energy varied as shown in diagram of Fig.9.

device) which together with the secondary acts as an "antenna"; it is useful to remember again that in Nature waves can exist in the transverse form, that is having direction perpendicular to the propagation direction, and in the longitudinal form, that is having direction parallel to the propagation direction. Transverse waves are, as is well known, typically generated by antennas such as conducting dipoles or even in general by AC electrified wires, but in the present case in addition to the cylindrical solenoid coils (the primary and the secondary) also a spherical "antenna" is present which cannot emit transverse waves because of its form which mathematically annuls the opposing components of the EM transverse waves, therefore only allowing the emission of longitudinal MD (Magneto-Dielectric) waves. As already stated, even if components of "usual" transverse EM waves are also present because of said cylindrical/solenoidal wire coils, however the latter are not the cause of the effects below described, which are not magnetic in their nature but dielectric. The term "electric field" comprises here both dielectric and magnetic fields, as referred to by Steinmetz[7]: so "dielectric" will not also encompass the magnetic part of the EM field. According to the "hydrodynamic analogy" between fluidics and electrotechnics, as in the sea both "surface waves" and "deep tsunami waves" (which are pressure or compression waves) do exist, for the analogy's completeness the same way should be for electric waves with transverse and longitudinal components, otherwise the "analogy" wouldn't valid because incomplete.

4. Transmission of energy through air and related measured values

Tests:

 in the laboratory several test were performed to investigate the emission of L.M.D. waves from the Tesla coil transmitter, even if it was quite not a simple thing to do.

- ### *Qualitative measurements:*

- First a simple and "crude" but clear test was readily made by keeping in the hand a common **neon** (fluorescence) tube without any
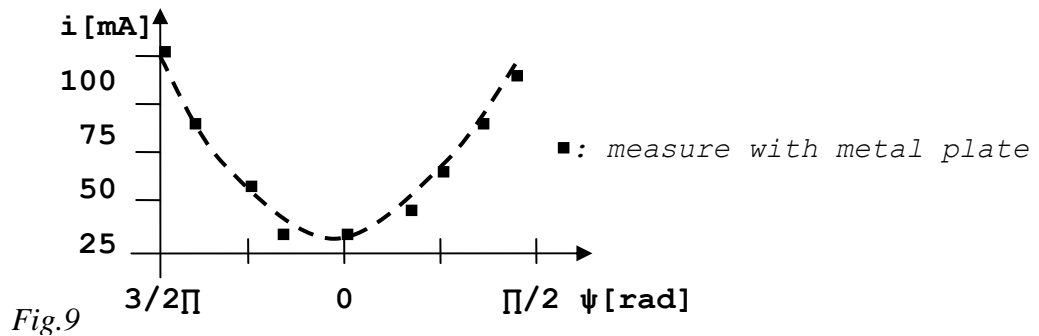
i[mA]

100
75
50
25

3/2∏   0   ∏/2 ψ[rad]

Fig.9

■: *measure with metal plate*

*Fig.9: Diagram shows the relationship between the ψ angle formed by the brass plate probe (P) and the propagation direction of the waves (versor **E**r): it is noted from the dotted line (a cosine function curve) that when ψ= 0 (0°) (or of course even when ψ= 2∏ (360°)) that is by versor **E**r parallel to plate, the measured value of current "i" or, in other words, the energy received from the brass plate (P) was at its minimum, while it was at its maximum by ψ= ∏/2 (90°) and ψ= 3/2∏ (180°)(by versor **E**r perpendicular to brass plate), showing that no transverse EM waves components play a relevant role but L.M.D. waves do. This shows that plate rotation around its axis in the vertical plane is indifferent to the vertical T.E.M. **E**t field, but not to L.M.D. **E**r field.*

connected energizing wires and by simply approaching it to the XMTR (see Fig.n.7): when the tube was moved to the Tesla coil i.e. it was set in its energy field, the neon tube amazingly lighted up, at first only faintly, until it came to its full brightness as it was moved closer to the coil (note that this result is very difficult if not impossible to achieve by magnetic fields, but not difficult at all by dielectric fields of well-tuned Tesla Coils).

- second, in order to exclude any relevant action due to the presence of magnetic fields, a normal **compass** has been moved in the energy field of the transmitter: the compass indicator stood still, never showing any kind of movement; on the contrary, when it was set on a normal small transformer its indicator immediately started to move (see Fig.n.10).

- and third, as a further qualitative **"detector"** of the field intensity of the XMTR was employed a common PVC insulated copper wire loop (square section: S=2,5mm^2, with wire loop diameter D= 100mm,inductance value L= 0,001mH) series connected with two oppositely paralleled LEDs, by different colours (yellow and blue), lighting up approximately at

$$U_{min}= 0,6 \div U_{max}= 2V$$

and having a slightly different sensibility; this detecting device was moved in the Tesla Coil field *in the horizontal plane* i.e. in an unfavourable position for T.E.M. waves so to detect mostly L.M.D. waves. It was also employed for tuning purposes as it readily and precisely detected the presence of resonance by voltage rise in the Tesla coil oscillator, therefore indicating when the intensity of the energy field was maximum as the LEDs were at maximum brightness.

Fig.10

Fig.10: A normal compass was set in the energy field of the Tesla Coil: its indicator (I) showed no movement, on the contrary when the compass was approached to a normal EM transformer the indicator immediately started to move, thus detecting a magnetic field.

 The energy field of the transmitter had not only the effect of lighting up neon tubes and LEDs but was used, always within the "near field", for energizing a small DC electric motor (D) to drive an electric vehicle (model) in the close range of the XMTR, which was of small power. The receiving antenna was constituted by a double turn of two coarse copper wire loops, series connected with a small electronic rectifying circuit and with the DC electric motor in order to transform the HV and HF received power into DC (rectified) low voltage; to prove that in the energy transmission no T.E.M. waves were involved, the double loop antenna was tilted from the vertical plane to the horizontal: the result was the same, i.e. energy transmission within said range from XMTR occurred by L.M.D. induction, By T.E.M. waves as a matter of fact, a receiving antenna must, in order to achieve maximum efficiency, always stand with its axis perfectly vertical to the ground just like the direction of (T.E.M.) vector **E**t. In the present case however, the antenna loop could without any problem be tilted to the ground that is to the horizontal plane and still continued to receive energy from the XMTR, proving that T.E.M. waves were here not mainly involved in driving the DC motor, which requires of course "power" and not only weak "signal" to run.

- A common small pocket **AM/FM radio receiver** was used to detect R.F. emitted from the Tesla Coil by moving the device away from the coil axis to a distance, to investigate the field of the XMTR itself, which generated an audible signal to about the range reported in Fig.n.3., so not very far from the AM-RCVR itself.

  - *Quantitative measurements:*

- An iron cored **inductance** (C) (a cylindrical copper wire coil with a ferrite core and with its coil terminals connected by two wires to the multimeter instrument), was employed to detect the magnetic field: the measurements were taken by moving the inductance away from the Tesla coil, at first with the iron core inserted in the same coil (having thereby an inductance of L= 10mH), then without the iron core (thus having an inductance reduced to L= 6mH): the normalised results of the test are illustrated in diagram of Fig.3, thus showing that there was no difference between values measured with or without the iron core because relevant magnetic induction on the coil was absent, but evident dielectric induction was present and preponderant.

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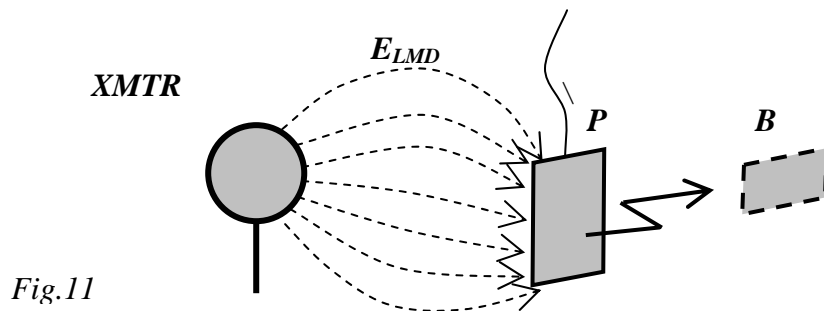
Fig.11: A suspended insulated brass metal plate (P) set in the energy field of the Tesla Coil became dielectrically charged and threw off sparks to approached objects, for instance to a small metal plate (B).

- Another test with related measurements was made by connecting by a single wire the analogic multimeter (used as a milliamperometer) to a **photomultiplier** vacuum tube (V) type "931-A" from "R.C.A.-U.S.A" (to its pin n.11 - cathode); then by moving the phototube away from the XMTR axis, the energy field was again measured giving similar results (normalised values) as regards to inverse square decrease with distance from the coil axis, once more showing that a dielectric field was involved (see Fig.n.3). In addition, the phototube device was rotated around its three axis in different positions but this didn't affect the results in a relevant way.

- Moreover, a further investigation of the energy field around the XMTR was made also by use of a suspended insulated **metal plate** made of brass, as well-known a non-magnetic material, which was connected in series by a single wire to a measuring device, in this case an analogic milliamperometer with a scale range of current i(t) = 0 ÷ 100 mA, which in turn was connected to ground. The comparison of this feature with the one described in Tesla's patent n.685957 of 1901, which illustrates an (apparent) puzzling use of a similar "insulated metal plate" for "utilizing radiant energy" also in association with other auxiliary devices, is remarkable. A measure of the (infinitesimal) absorbed power by the plate, i.e. received from the XMTR, could be made as follows with a plate dimension S = B x H (surface=width x height) and "ψ" the angle between plate and versor **E**r

$$dP = dV^2/dR$$

being R: ohmic resistance in a conductor, so

$$dR = dx/dS$$

where S= surface of brass plate conductor) and being:

$$dV = E_o \cos(\Psi) dx$$

the voltage in the infinitesimal part "dx" (being "dx" an infinitesimal "depht" element) of the receiving brass plate, so its infinitesimal absorbed dielectric power is then a function of cosine:
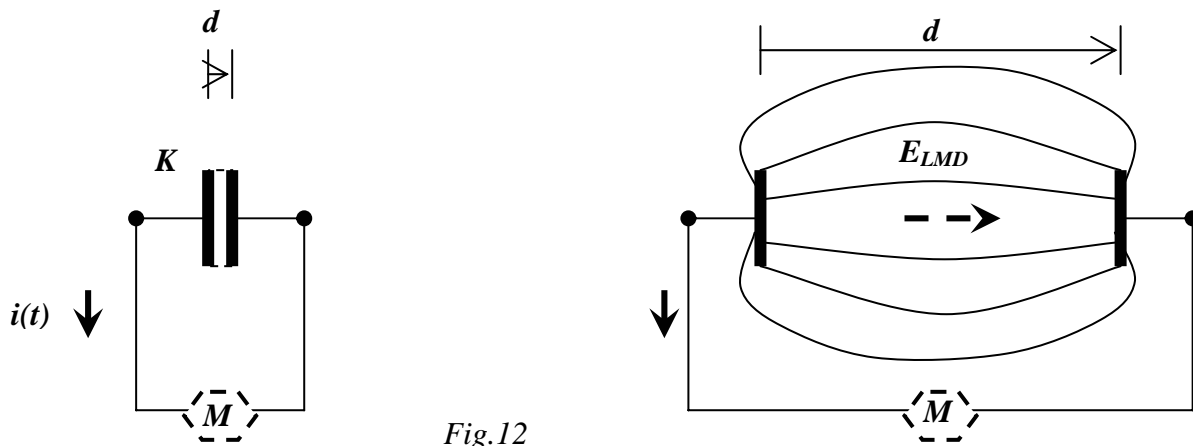
Fig.12: A common condenser (capacitor) (K): an electric current flows through opposite conducting plates even when separated from a dielectric; the plates could be separated and moved to a comparatively considerable distance, however a connected impedance-meter instrument (M) kept reading an impedance value: the plates "felt" one another.

and by mathematical integration it comes to the absorbed energy "A" from the plate itself:

$$dP= f((\cos^2(\Psi))\,dx$$

so it becomes:

$$A = f(\cos(\Psi))$$

- At the end of the investigation a last, but not least, test was performed: a suspended (by a non-conducting wire) insulated small (about 120x130mm as before) thin brass metal plate (P) which was set in the energy field of the Tesla Coil became strongly charged by dielectric induction from the coil: as a smaller (about 50x50mm) metal plate (B) was approached to the first plate (P), the (big) brass plate threw off sparks to the small one and even to an approached hand (see Fig.n.11).

 These experiments and tests could be useful to better understand the working principle of a common condenser: how an electrical current can "pass" or "jump" through the dielectric non-conducting material between the opposite metal plates ? According to the accepted theory, this would be caused by "displacement currents" on the surfaces of the plates. Therefore, a simple tests would made by positioning two parallel opposite condenser plates (square dimension: 40x40mm of very thin brass) with air as dielectric, each connected to one terminal of an impedance-meter (type *"MK5540"* from *"Mitek"*). At first the plates were set at a distance of 1mm from one another, then these were moved apart to more than d= 1m but kept always connected to the impedance-meter: the instrument read a capacitance value of C=0,040mH for near plates and of C=0,012mH for far plates. Even if the distance between opposite condenser plates was increased up to >1000 times, or equal to >25 times the plate dimension, the instrument did anyway read a value, so despite of distance the plates "felt" one another; according to
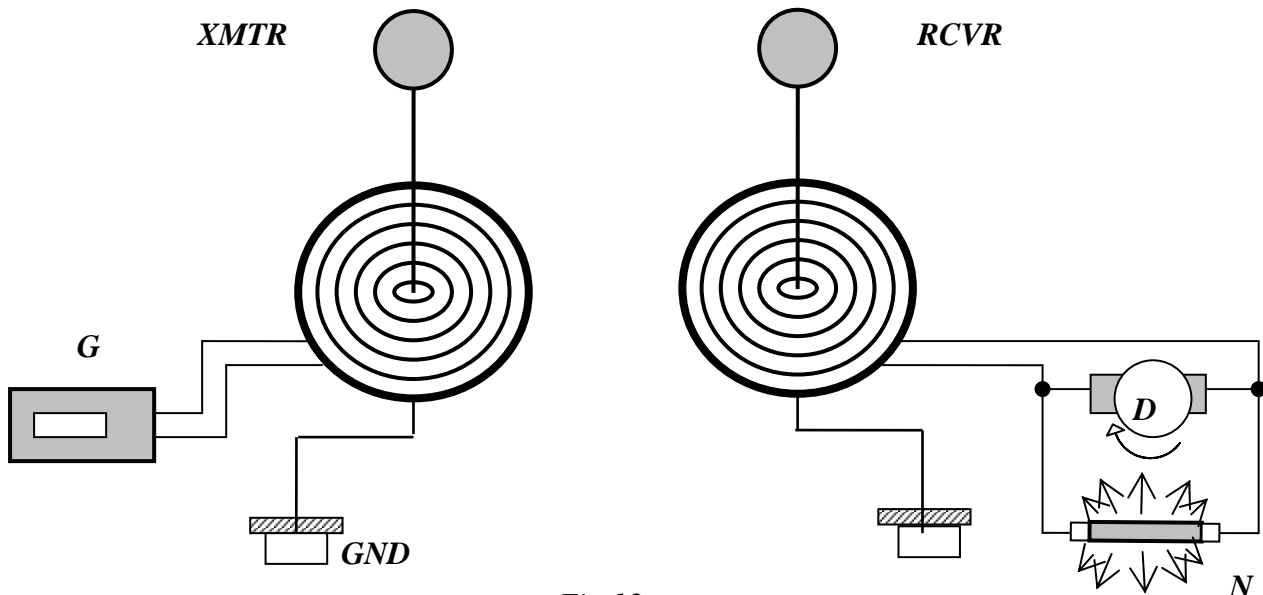
Fig.13

Fig.13: Two flat spiral "Tesla coils" or "pancake" coils connected through the ground; the XMTR with its (HV, HF) generator and the RCVR with its electric utilities: a neon tube and a DC motor.

Steinmetz[7] this phenomenon could be better explained as follows: the dielectric field is not only confined on the surfaces of the conductors but is also present in the surrounding space in a similar way as for the magnetic field. The dielectric field issues from the conductors and the related lines of force pass from one conductor to the other (see Fig.n.12). The commonly accepted theory of the "charge displacement" seems here to be a rather weak explanation with respect to the dielectric field and related lines of force.

5. Notes on Tesla Coil tuning

All these test were performed in order to investigate nature and intensity of the energy field around the Tesla coil, which was stronger when resonance in the device was present or, in other words, when the coil was "well-tuned".

To precisely detect the main frequency "f_o" of the Tesla coil XMTR, a digital oscilloscope "*GDS-820-S*" series from "*GW-Instek*" was used and the related wired "probe" was placed about d= 2m from the XMTR: the main resonance frequency was confirmed to be f_o= 2,755 MHz with another main frequency at f= 1,810 MHz; it is noted that the relationship between said main frequencies is: f_o / f= 1,527 MHz ≈ (∏/2)f. As it is:

$$\lambda_o= c \ / \ f_o \quad \text{(where c: speed of light in vacuum)}$$

said frequency corresponds to a wave length of λ_o= 113,64m or to λ_o/4= 28,41m (or "quarter wave-length"), this means that the tests were performed in the so-called "near field"; regarding this aspect it could be objected that it would invalidate the experiment but, on the contrary, just by keeping the distance "d" from the XMTR much smaller than a quarter wave-length "λ/4", the T.E.M. components of the wave had less possibility of influencing the test, thus allowing the L.M.D. components to mainly play.
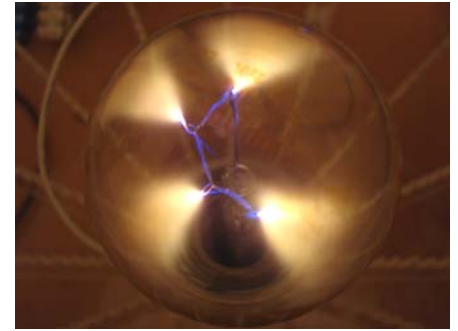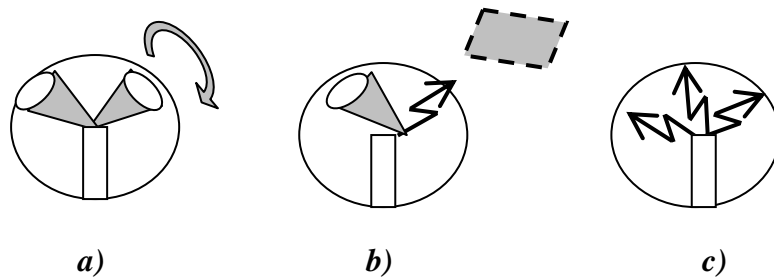
Fig.14

Fig.14: Light streams, brushes and discharge effects in Tesla coil's lamp bulbs (secondary top capacitance); picture shows streams as a).

6. Streams, brushes, discharges and effects in Tesla Coil's lamp bulbs

Beyond scientific investigation, well-tuned Tesla Coils shows curious effects: beautiful light "streams" or "brushes" are emitted when the secondary coil top capacitance is a lamp bulb instead of a metal sphere, for example an argon gas bulb[11]; when the coil is running, depending of the driving generator employed, strange light streams fill the bulb itself varying very much in the form with the coil design and also with voltage, frequency and a number of other parameters. For instance, the streams filling the bulb of the Extra Tesla Coils used by the present investigation looks more like "plasma" effects and have different colours among which mainly yellow, orange pink and violet. When the two Tesla Coils (XMTR and RCVR) are connected through only one wire or through the earth conductor (or even water) and they are well-tuned, they both show streams in their own bulbs. These coils really "communicate" with one another as it is fairly clear by just approaching a hand to the XMTR bulb: if its streams become weaker, on the contrary the streams in the RCVR bulb become stronger and vice-versa. It is not here a mere question of wave "transmission" from the XMTR to the RCVR as it happens for usual T.E.M. radio broadcasting, whereby the transmitter cannot be influenced in any way from the receiver, but a peculiar energy interaction between the two Tesla coils occurs, as true "conduction" phenomena were involved. Moreover, the movement of the streams is peculiar, as these sometimes even show at first a rotation around their axis, then they stop rotating and tend to establish a rather stable "flux" pattern issuing from the lamp filament to the glass bulb, depending of the adjusting of several parameters, and is also due to electrostatic or dielectric action according to the definition given by C.P.Steinmetz[7]; as before stated, the brushes or streams may change very much even in their "nature", from smooth and widening "plasma" flux spreading to the bulb (see Fig.n.14.a) to soon become a violent electric discharge (see Fig.n.14.b) when an object is moved close to the bulb. By higher pressures in the Tesla coil, the streams can turn into brushes of even strong discharge of blue, purple or of other colours (see Fig.n.14.c). These remarkable features should be closer investigated, as the sphere capacitance also emits L.M.D. waves, which as already stated are dielectric. Fig.n.15 shows two energized flat spiral "pancake" Tesla coils with streams in their top capacitance lamp bulbs; on left is the RCVR drives a small DC motor with a green LED connected to show it works by energy transmission[12].

Fig.15: Two energized flat spiral or "pancake" Tesla coil showing streams in the top spherical capacitance lamp bulbs.

By adjusting some parameters in the Tesla coil, curious effect of repulsion and attraction were then observed[11]: if a hand was approached to the lamp bulb, under certain conditions, a kind of "pressure" was felt by the hand; on the contrary, if a small suspended metal strip was approached to the same bulb, the conducting material was attracted to it. This effects are probably due to dielectric (electrostatic) action.

7. Conclusion

As expected, because of the comparatively moderated main resonance frequency of the Tesla coil (XMTR) itself, a limited aerial wave irradiation was obtained; the coil was in fact originally mainly designed for other purposes and not specifically to "transmit" energy through the air irradiating the surrounding medium with waves. Of course, a different design and construction with an eventual increase to higher levels of the main resonator's frequency would cause even a bigger amount of radiated energy in the air and a stronger energy field which however was not, as said, the aim of Nikola Tesla's project, whose ultimate target seemed rather to be the wireless transmission of energy through the earth/ground (see also his article[2]). In any case it is useful to remember that any scientific theory is valid as long as it will not be contradicted by empirical observation, experiment or research, and this must be true even for Tesla's "Wireless System".

The above experiments, tests and measurements performed with the "Extra Tesla Coil" XMTR together with other devices clearly showed that a number of "anomalous" EM phenomena did occur, indicating that a strong dielectric energy field was present around the coil itself, which could be ascribed to the action of L.M.D. waves rather than to T.E.M. waves. Not surprisingly these empirical results could, according to other Authors, be supported from a physics and mathematical point of view by the introduction, instead of today's (Heaviside) vector form, of the (original) quaternionic form of Maxwell's EM equations which, as could be clearly seen, do predict the possibility of the existence of scalar dielectric fields and of longitudinal dielectric waves besides the well-known transverse EM waves.

From the illustrated theory it descends that the scalar field "Σ" has the form of an electroscalar wave, which does no work to move free charges, and which has energy flow in the propagation direction, however without converting EM energy into neither mechanic nor heat, and having no magnetic component. A curious aspect is that said "Σ" wave has the dimension unit of a magnetic field intensity, or otherwise stated is a kind of "magnetic scalar".

Further scientific investigation and research is required and welcome, and the position of the Academic World who still excludes the existence of L.M.D. waves has to be supported by proves as it has, at the moment, neither theoretical nor experimental fundament.

*   *   *   *   *

Legenda:

U or V : tension [Volt]

I : current [A]

P : power [W]

F : force [N]

α : angle [rad]

ω : $2 \prod f$ [rad/s]

λ : wave length [m]

x : distance [m]

c : $1/ \sqrt{(\mu_o \varepsilon_o)}$ speed of light in vacuum [m/s]

v : speed [m/s]

φ : scalar potential [V/m^2]

A : vector potential [A/m^2]

Σ : scalar wave [H]

E : dielectric field [V/m]

B : magnetic field [A/m]

ρ : charge density [As/m^3]

J : current intensity [A/m^2]

ε_0 : dielectric constant in vacuum [As/Vm]

μ_o : magnetic permeability constant [Vs/Am]

ε : dielectric constant [As/Vm]

μ : magnetic permeability constant [Vs/Am]

$\partial/\partial t$: time partial derivative

d/dt : time derivative

d/dx : space derivative

∇ : Nabla operator

Ã : quaternionic vector potential

$\widetilde{\Box}$: quaternionic D'Alembertian operator

*(The **bold** notation represents a vector).*

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Dr. Eng. Roberto Handwerker

Milan, Italy

e-mail: info@deltaavalon.com
web: www.deltaavalon.com