Theory of Wireless Power

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1986

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1986

What About Today's Scientists?

"The scientists from Franklin to Morse were clear thinkers and did not produce erroneous theories. The scientists of today think deeply instead of clearly. One must be sane to think clearly, but one can think deeply and be quite insane."

"Today's scientists have substituted mathematics for experiments and they wander off through equation after equation and eventually build a structure which has no relation to reality."

— Nikola Tesla

1. The Principles of Wireless Power

a) Nikola Tesla and the True Wireless

In the period from 1890 to 1900 Dr. Nikola Tesla was engaged in the systematic research of high-frequency electric waves with the specific aim of developing a method for the transmission and reception of electric energy without the use of connecting wires.

Inspired by Dr. Heinrich Hertz's experimental researches into Maxwell's theory of electromagnetic waves, Dr. Tesla developed various apparatus for the purpose of exploring Hertzian phenomena. Progress was slow until Tesla developed his oscillating current transformer, later known as the Tesla Transformer.

Tesla discovered that the emanations from his oscillating current transformer were not transverse electromagnetic waves, but rather longitudinal dielectric waves, which he termed *electric rays of induction.*

Tesla stated:

> "For more than 18 years I have been reading treatises, reports of scientific transactions, and articles on Hertz-wave theory, but they have always impressed me like works of fiction."

b) The Failure of Hertzian Waves

Tesla found that Hertzian waves were unsuitable for the transmission of power due to their dispersive nature. Energy radiated in this form spreads spherically and obeys an inverse-square law.

Marconi, unconcerned with power transmission, adopted Tesla's patents and established commercial wireless communication using Hertzian waves.

By 1919, multiple high-power radio stations had been constructed, but none were capable of transmitting usable power.

Tesla criticized this approach as fundamentally flawed.

2. The Tesla System

a) Fundamental Principles

The Tesla system of wireless power transmission is *not* based upon electromagnetic wave propagation, nor upon earth-ionosphere waveguides.

Instead, it employs resonant longitudinal electric induction along standing lines of force connecting transmitter and receiver.

These lines are established by the Tesla Magnifying Transmitter (T.M.T.), which is harmonically tuned to the electrical condition of the Earth.

b) Earth Coupling

The lines of induction established by the T.M.T. are drawn into the Earth's interior, bypassing the screening effect of surface conductivity which blocks electromagnetic waves.

Tesla demonstrated this using metal-coated evacuated tubes which illuminated despite electrostatic shielding.

c) Energy Reciprocity

Energy not absorbed by the receiver is reflected back to the transmitter, establishing a standing wave of electric induction.

This standing wave exists at one of the Earth's natural resonant frequencies, greatly reducing energy loss with distance.

3. Operating Principles of the Tesla Magnifying Transmitter

Because energy is propagated through the Earth, the concept of "ground" as an electrical reference becomes invalid.

In the Tesla system, the Earth terminal is active, and grounding must be understood in terms of distributed inductance rather than absolute potential reference.

a) Five Elements of the T.M.T.

The Tesla Magnifying Transmitter consists of five fundamental elements:

1. Earth

2. Reflecting capacitance

3. Energy transformer

4. Coupling transformer

5. Resonant coil

Energy oscillates between Earth and reflecting capacitance at a natural terrestrial frequency.

4. Standing Waves and Virtual Ground

The resonant coil establishes a *virtual ground*, allowing energy exchange without mechanical reaction force.

This violates Newtonian action–reaction symmetry by separating cause and effect in space and time.

5. The Dimension of Time

a) Historical Background

Michael Faraday discovered that variations in magnetic induction produce electromotive force.

This law is expressed as:

$$E = \frac{d\Phi}{dt} \tag{1}$$

This discovery formed the basis of transformer theory.

Faraday also discovered dielectric induction, which produces current according to:

$$I = \frac{d\Psi}{dt} \tag{2}$$

b) Displacement Current

The complementary nature of magnetic and dielectric induction led Maxwell to formulate electromagnetic theory.

Tesla, however, rejected the assumption that magnetic and dielectric effects must propagate together.

6. Induction in the Dimension of Time

The interaction of magnetic and dielectric induction results in electric power:

$$P = EI \tag{3}$$

This relation represents the law of electric induction in the time dimension.

7. Rotating Magnetic Field

Tesla's discovery of the rotating magnetic field allowed the conversion between electrical and mechanical energy without commutators.

By applying polyphase currents separated in phase, a rotating magnetic vector is produced.

8. Oscillating Current Transformer

The oscillating current transformer differs fundamentally from conventional transformers.

It employs both magnetic and dielectric induction, producing longitudinal magneto-dielectric waves.

These waves propagate along the coil axis rather than radiating outward.

9. Fundamentals of Coil Induction

Two distinct forms of energy propagation exist in coils:

1. Transverse electromagnetic waves

2. Longitudinal magneto-dielectric waves

10. Coil Parameters

The inductance of a single-layer solenoid is:

$$L = \frac{r^2 N^2}{9r + 10l} \times 10^{-9} \tag{4}$$

The capacitance is:

$$C = pr \times 2.54 \times 10^{-12} \tag{5}$$

11. Resonant Frequency

The velocity of propagation along the coil is:

$$V = \frac{1}{\sqrt{LC}} \tag{6}$$

The resonant frequency is:

$$f = \frac{V}{4l} \tag{7}$$

12. Impedance and Energy Relations

The characteristic impedance is:

$$Z = \sqrt{\frac{L}{C}} \tag{8}$$

Energy conservation requires:

$$E_1 I_1 = EI \tag{9}$$

13. Summary of Early Principles

The Tesla system unifies:

- Longitudinal induction

- Earth resonance

- Energy recoverability

These principles are absent from modern electromagnetic theory.

(III) Induction in the Dimension of Space

a) Product of Conjugate Pair of Inductions

The wave theories in present usage for the study of electric propagation along coils and kindred apparatus all suffer from the fundamental drawback that they are representations of energy propagation along a single line or axis. The equivalent circuit of coil propagation is, however, best represented as in Figure 1, that is, two perpendicular paths for induction. Thus the propagation can occur in any direction on the surface of the mesh given by Figure 1. The nature of electric energy varies with the direction of propagation and departs significantly from the common electromagnetic form when the path is no longer along the usual axis. This departure in form is of singular importance in the study of Tesla's discoveries.

Figure 1: Equivalent circuit showing perpendicular paths of induction in coil propagation.

Since electric energy is the product in space of the flux of magnetic induction and the flux of dielectric induction, the nature of these fluxes, and the nature of their products, determines the characteristics of electric energy that appear in the Tesla Oscillating Current Transformer. It is thus important to investigate the nature of these components of electric energy.

When electric energy exists in any system of electric conductors, certain phenomena appear in the space surrounding the conductors, that is, magnetic and dielectric actions manifest themselves in the surrounding aether. Surrounding the conductors is what is called the magnetic field of induction. The intensity of this magnetic field is given by the total number of magnetic lines, Φ, filling the surrounding space. The portion of the total magnetic induction which is parallel to the surface of the conductor is called the transverse magnetic induction, Φ_T, and that portion of the total magnetic induction which is perpendicular to the surface of the conductors is called the longitudinal magnetic induction, Φ_L. In general, the transverse magnetic induction exists at right angles to the flow of energy and the longitudinal magnetic induction exists in line with the flow of energy.

Issuing from the surface of the conductors is what is called the dielectric field. The intensity of the dielectric field is given by the total number of dielectric lines of induction, Ψ. The portion of the total dielectric induction that terminates upon surfaces in the direction of the flow of energy is called the longitudinal dielectric induction, Ψ_L, and the portion that terminates upon surfaces perpendicular to the flow of energy is called the transverse dielectric induction, Ψ_T.

The total magnetic field of induction, Φ, and the total dielectric field of induction, Ψ, together constitute the total electric field of induction, Q, that is, units of electric induction.

b) Transverse and Longitudinal Components

Transverse electromagnetic waves, sometimes called Hertzian waves, are the result of the perpendicular crossing in space of lines of dielectric induction, Ψ, and lines of magnetic induction, Φ (see Figure 4).

The symbolic expression of this geometric relation is:

$$\mathbf{Q} = \Psi \times \Phi \tag{10}$$

This relation is called the cross product of the magnetic and dielectric inductions that constitute the electric induction. This relation is the basis for what is known as the Poynting vector, first discovered by Oliver Heaviside.

The trigonometric expression of this relation is:

$$Q = \Psi\Phi \sin\theta \tag{11}$$

where θ is the angle of crossing between the lines of Ψ and the lines of Φ.

It was shown by Prof. Alexander Macfarlane in the "Imaginary of Algebra" presented before the American Association for the Advancement of Science (Vol. XLI), 1891–1894, that it is a general principle of spherical trigonometry that the complete versor expression of Q is:

$$Q = \Psi \cos\theta + k\Psi \sin\theta \tag{12}$$

where the symbol k is no more than a distinguishing index indicating that the sine term is perpendicular to the plane in which the crossings of Ψ and Φ occur.

By substituting the relations

$$\Psi = \Psi_0 \cos\theta \tag{13}$$

$$\Phi = \Phi_0 \sin\theta \tag{14}$$

the symbolic expression of the complex induction is given by

$$Q = \Psi_0 + k\Phi_0 \tag{15}$$

Hence, the flux of electromagnetic induction is directed perpendicular to the inductions which give rise to it, propagating in the direction k.

The dimensions of electromagnetic energy are given by

$$W = mc^2 \quad \text{(watt-seconds)} \tag{16}$$

where m is the mass equivalent of energy and c is the speed of light.

The dimension of magnetic flux is

$$\Phi = \frac{W}{c^2} \tag{17}$$

Substituting equation (7) into (6) and substituting the law of dielectric induction

$$\Psi = \frac{Q}{t} \tag{18}$$

where t is time, gives the dimensions of the transverse electromagnetic induction as

$$Q = \frac{mc^2 t}{2m} \tag{19}$$

where t is the time interval during which energy is exchanged between magnetic and dielectric forms of energy storage. The dimensions of equation (9) are usually given as the numerical quantity

$$h = 6.6234 \times 10^{-34} \, \text{watt} \cdot \text{sec}^2 \tag{20}$$

or integer multiples thereof. This is usually portrayed as a flux of these units of energy-time flowing along direction k, called a flux of photons.

The fundamental relation given by equation (3) indicates that the electromagnetic induction Q is only a partial component of the complete electric induction Q, due to the existence of the complementary component

$$Q_L = \Psi \cos \theta \tag{21}$$

The geometric relation of Q_L is shown in Figure 6. The lines of induction, Ψ and Φ, in this case are in space conjunction and thus lay upon the same axis as the flux of electric induction to which they give rise.

Hence, a distinct form of electric induction exists when the lines of magnetic and dielectric induction are parallel rather than perpendicular. This longitudinal form of induction is not a wave in the conventional sense, but more of a ray or direct line of induction. This is the principle utilized in Tesla's system of wireless energy transmission.

c) Total Electric Induction

The total magnetic field of induction, Φ, and the total dielectric field of induction, Ψ, together constitute the total electric field of induction, Q. That is,

$$Q = \Psi + \Phi \tag{22}$$

The units of Q are units of electric induction. Electric energy exists only as the interaction product of magnetic and dielectric induction. When these two components are separated, electric energy ceases to exist in the usual sense.

d) Transverse Electro-Magnetic Induction

Transverse electro-magnetic waves, sometimes called Hertzian waves, are the result of the perpendicular crossing in space of lines of dielectric induction, Ψ, and lines of magnetic induction, Φ.

The symbolic expression of this geometric relation is

$$\mathbf{Q}_T = \Psi \times \Phi \tag{23}$$

This relation is called the cross-product of the magnetic and dielectric inductions. It is the basis of the Poynting vector.

The trigonometric form of this relation is

$$Q_T = \Psi \Phi \sin \theta \tag{24}$$

where θ is the angle of crossing between the magnetic and dielectric inductions.

e) Complex Induction and Versor Representation

Alexander Macfarlane showed that the complete versor expression for electric induction is

$$Q = \Psi \cos\theta + k\Psi \sin\theta \tag{25}$$

where k is a unit vector perpendicular to the plane of interaction.

The complex form of electric induction is therefore

$$\mathbf{Q} = Q_L + kQ_T \tag{26}$$

The transverse electromagnetic induction propagates perpendicular to the inducing fields.

f) Dimensional Analysis of Electro-Magnetic Energy

The dimensions of electro-magnetic energy are

$$W = mc^2 \tag{27}$$

The dimensions of magnetic flux are

$$\Phi = \frac{W}{c^2} \tag{28}$$

Using the law of dielectric induction,

$$\Psi = \frac{Q}{t} \tag{29}$$

the transverse electro-magnetic induction has the dimensional form

$$Q_T = mc^2 t \tag{30}$$

This quantity is usually expressed as the fundamental quantum

$$h = 6.6234 \times 10^{-34} \ \text{watt} \cdot \text{sec}^2 \tag{31}$$

or integer multiples thereof.

g) Longitudinal Electric Induction

The electromagnetic induction described above represents only a partial component of the total electric induction. The complementary component exists when magnetic and dielectric inductions are in space conjunction.

This longitudinal electric induction is given by

$$Q_L = \Psi\Phi \cos\theta \tag{32}$$

In this case the magnetic and dielectric lines lie along the same axis as the flow of energy. No transverse wave is produced.

This form of induction does not radiate. It propagates as a ray or line of force.

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h) Tesla Induction Versus Hertzian Radiation

Hertzian radiation is characterized by:

- Transverse field structure

- Energy loss by spatial dispersion

- Irretrievable energy

Tesla induction is characterized by:

- Longitudinal field structure

- Direct coupling between terminals

- Energy recoverability

The Tesla system operates exclusively upon longitudinal electric induction.

i) Energy Flow Without Radiation

In longitudinal induction the Poynting vector vanishes:

$$\mathbf{S} = \mathbf{E} \times \mathbf{H} = 0 \tag{33}$$

Yet energy flow exists. This demonstrates conclusively that the Poynting vector does not represent the totality of electric power flow.

j) Implications for Wireless Power

Since longitudinal induction does not diverge as $1/r^2$, energy transmission is not limited by distance in the conventional sense.

This principle underlies Tesla's claim that wireless power transmission could be achieved with negligible loss.

k) Failure of Modern Theory

Modern electromagnetic theory excludes longitudinal solutions by assumption. This exclusion renders it incapable of describing Tesla's apparatus.

Maxwell's equations permit longitudinal solutions, but these were later eliminated by boundary conditions imposed for mathematical convenience.

l) Summary of Dimensional Inductions

Electric induction exists in three distinct dimensional forms:

1. Transverse induction — space-dispersive

2. Longitudinal induction — space-conjunctive

3. Time induction — oscillatory exchange

Tesla's work unified all three.

Conclusion

Tesla's system of wireless power transmission is not based upon radiation, resonance of antennas, or propagation of Hertzian waves.

It is based upon:

- Longitudinal dielectric induction

- Earth-coupled resonance

- Non-radiative energy exchange

The failure to recognize these principles has resulted in the misinterpretation of Tesla's work for over a century.

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