

# Representations of Electric Induction

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## **The Principles Of Wireless Power: 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 of transmission and reception of electric energy without the use of connecting wires. Inspired by Dr. Heinrich Hertz's experimental researches into the Maxwell theory of electromagnetic waves, Dr. Tesla developed various apparatus with the object of exploring the developments of Dr. Hertz. Tesla found his progress slow until he developed his oscillating current (OC) transformer, known as the Tesla Transformer, which allowed for his progress beyond the original experiments of Dr. Hertz and thus beyond the original theory of electromagnetism.

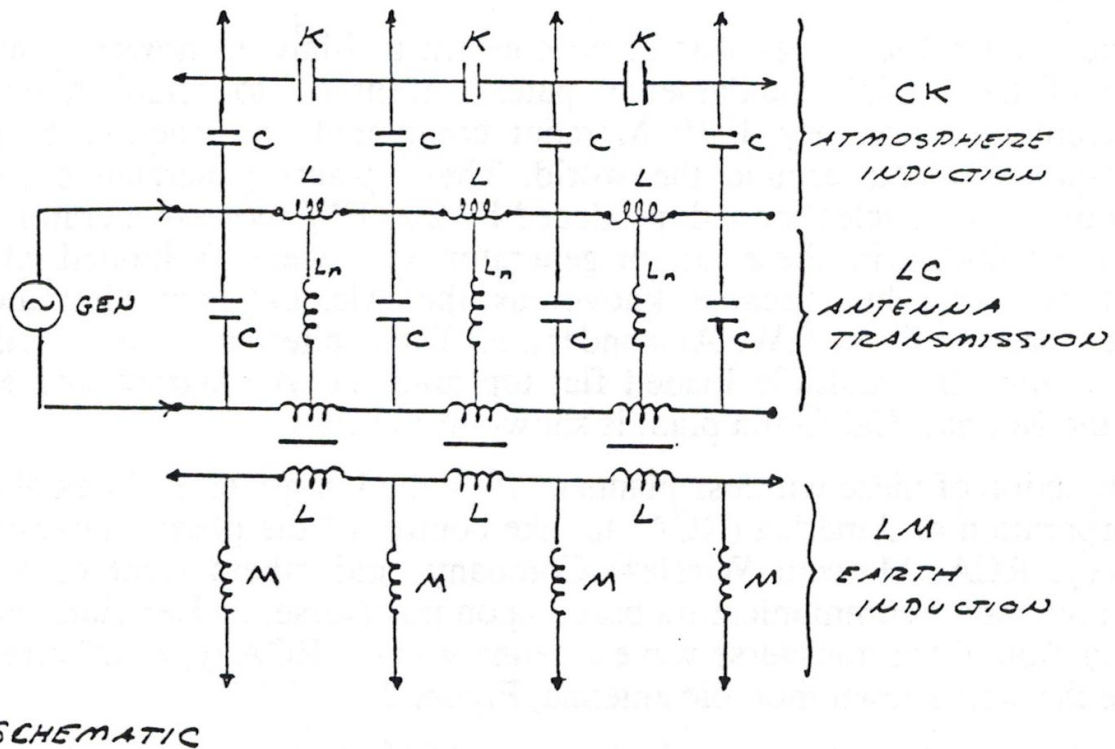
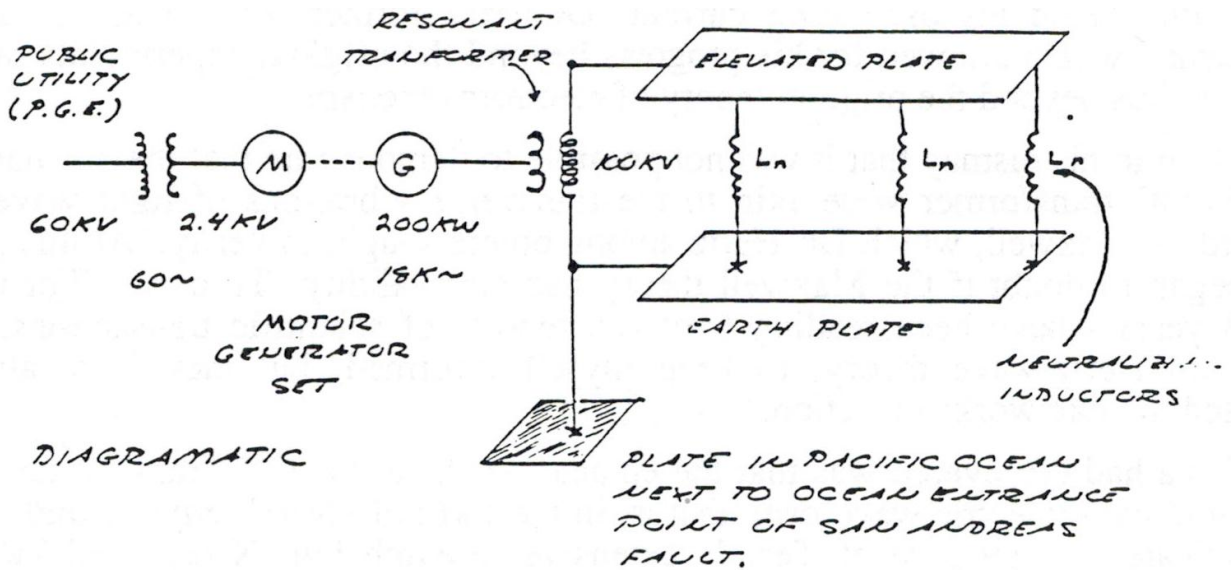
Tesla found to his dismay that it was not possible to demonstrate that the emanations from his OC transformer were akin to the transverse vibrations of light waves as theorized by Maxwell, which Dr. Hertz among others sought to verify. At this point Tesla began to doubt if the Maxwell theory had any validity. To quote "For more than 18 years I have been reading treatises, reports of scientific transactions, and articles on Hertz-wave theory, to keep myself informed, but they have always impressed me like works of fiction.

What Tesla had discovered was that the emanations from his OC Transformer were of longitudinal-dielectric waveform, that is, in the form of electric rays of induction. This indicates the purpose of Tesla's extensive research into X-rays and kindred forms of radiation, which were considered longitudinal waves in the luminiferous aether by Tesla and his contemporaries.

The theories of electric waves was of no concern to Marconi however, and by his adaptation of Dr. Tesla's fundamental patents went on to establish commercial wireless communication. By 1919 Marconi completed construction of five high-frequency power plants around the world. These plants generated currents at a frequency of 18,000 cycles/second – produced by 200 KW motor-generator sets. The alternators employed in these motor-generator sets were fashioned after those developed by Tesla but became known as the Alexanderson alternators, after Steinmetz's protege Ernst F.W. Alexanderson. These alternators delivered currents to what is called the multiple loaded flat top antenna. A diagram and equivalent circuit of the Bolinas, California plant is shown in Figure 1.

Upon completion of these wireless plants in 1919 the US government established the Radio Corporation of America (RCA) to take control of the plants constructed upon US territory. RCA, Marconi Wireless Company, and others went on to develop wireless (now radio) communication based upon transverse, or Hertzian, waveforms. The culmination of the transverse wave antenna was the RCA type "D' director, later to become the well known rhombic antenna, Figure 2.

These developments firmly entrenched the use of Hertzian waves in the practice of wireless communication, thereby diverting interest from the waveforms discovered by Dr. Nikola Tesla. Tesla's progress in commercial development was further delayed by his absolute insistence upon establishing a perfect system, the "World System", of wireless power and communication. The World System was much more costly and complex than the simple installations of Marconi. To quote Dr. Tesla's thoughts about the development of wireless at this point in history:



SCHEMATIC

Figure 1. A diagram and equivalent circuit of the Bolinas, CA wireless plant.

The commercial application of the art has led to the construction of larger transmitters and multiplication of their number, greater distances had to be covered and it became imperative to employ receiving devices of ever greater sensitiveness. All these changes have cooperated in emphasizing the trouble and seriously impairing the reliability and value of the plants. To such a degree has this been the case that conservative business men and financiers have come to look upon this method of conveying intelligence as one offering but very limited possibilities, and the Government has deemed it advisable to assume control. This unfortunate state of affairs, fatal to the enlistment of capital and healthful competitive development, could have been avoided had electricians not remained to this day under a delusive theory and had the practical exploiters of this advance not permitted enterprise to outrun technical competence.

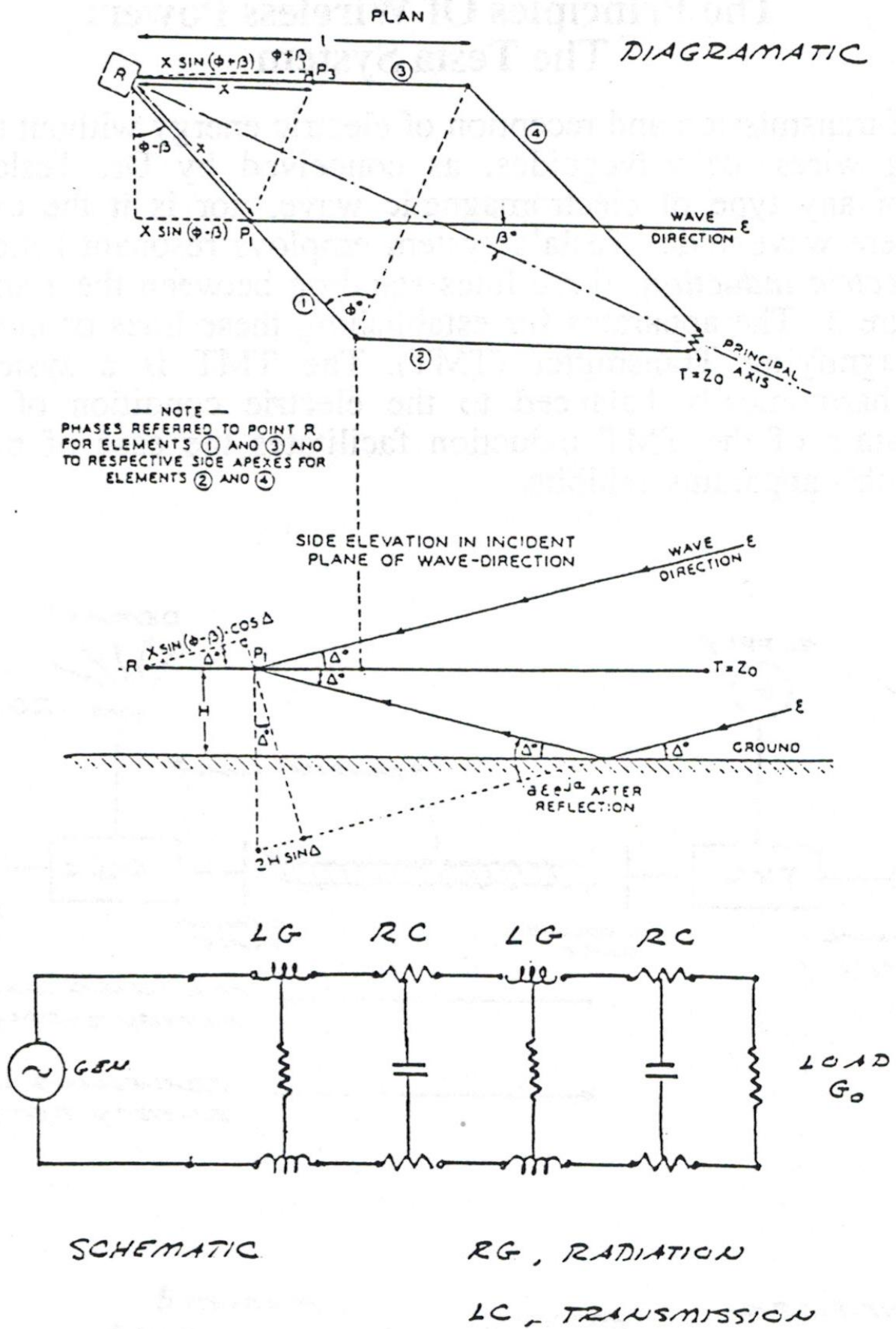


Figure 2. A diagram and schematic of an RCA type "D" director.

Dr. Tesla remained unswayed by these commercial developments and their impact upon scientific thought. Tesla understood that the transverse, or Hertzian, waveform was useless for the transmission of electric energy on an industrial scale. The scattering nature of these waves represents the primary limitation to efficient energy transfer, to quote:

Nothing illustrates this better than the recent demonstrations of a number of experts with very short waves, which have created the impression that power will be eventually transmitted by such means. In reality, experiments of this kind are the very denial of the possibility of economic transmission of electric energy.

This of course brings to mind the recent proposal to transmit from a satellite in outer space megawatts of photovoltaic energy via a microwave beam down to the earth's surface.

### The Principles Of Wireless Power: The Tesla System

The system of transmission and reception of electric energy without the employment of connecting wires, or waveguides, as conceived by Dr. Tesla IS NOT the propagation of any type of electromagnetic wave, nor is it the excitation of the earth-ionosphere waveguide. Tesla's system employs resonant actions along lines, or rays, of electric induction; these lines standing between the transmitter and the receiver, Figure 3. The apparatus for establishing these lines of induction is called the Tesla Magnifying Transmitter (TMT). The TMT is a system of resonant transformers harmonically balanced to the electric condition of the earth. The monopolar nature of the TMT induction facilitates the ease of transmission and reception that this apparatus exhibits.

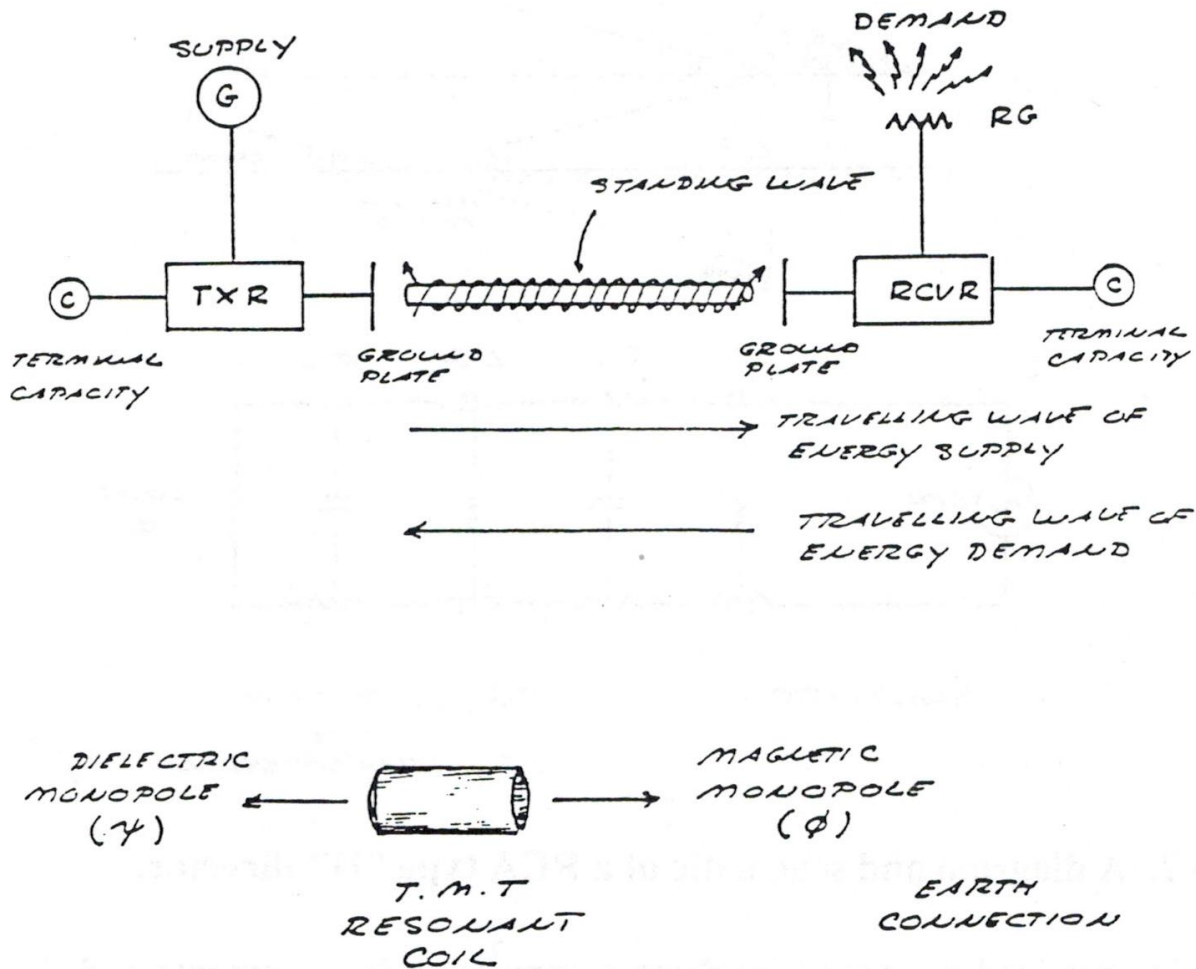


Figure 3. The Tesla System.

These lines of induction established by the TMT are drawn into the high inductivity of the earth's interior, despite the conductivity of the surface, which would screen electromagnetic waves. To illustrate this point consider Tesla's description of an experiment:

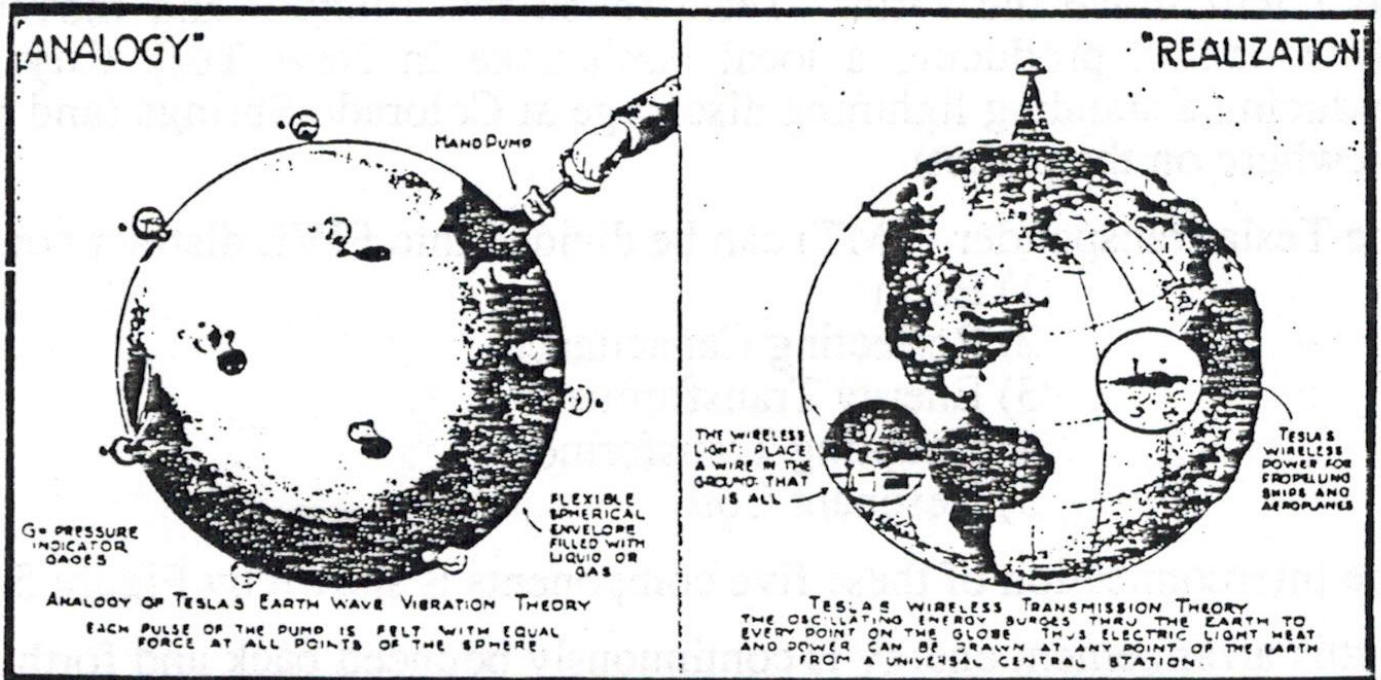
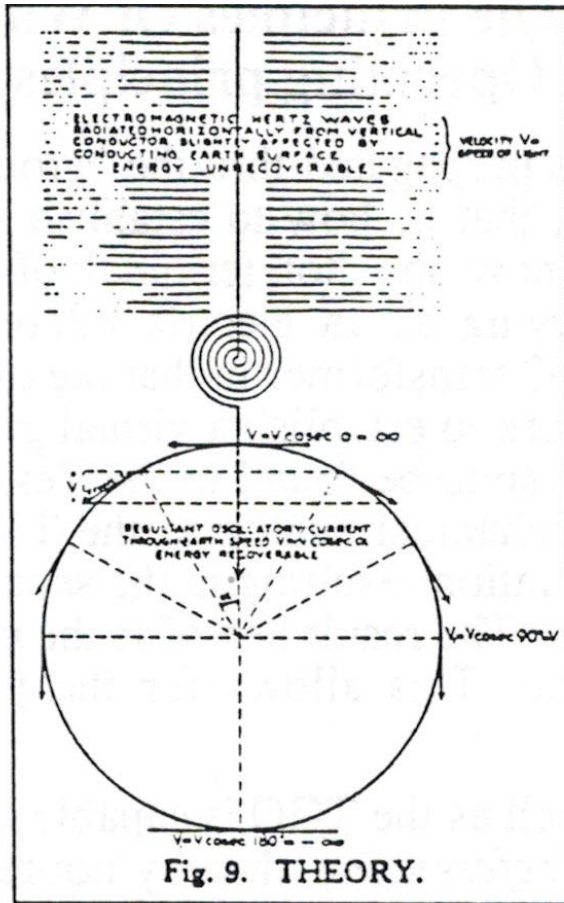
I have here a short and wide tube which is exhausted to a high degree and covered with a substantial coating of bronze, the coating allowing barely the light to shine through. A metallic clasp, with a hook for suspending the tube, is fastened around the middle portion of the latter, the clasp being in contact with the bronze coating. I now want to light the gas inside by suspending the tube on a wire connected to a coil. Any one who would try the experiment for the first time, not having any previous experience, would probably take care to be quite alone when making the trial, for fear that he might become the joke of his assistants. Still, the bulb lights in spite of the metal coating, and the light can be distinctly perceived through the latter. A long tube covered with aluminum bronze lights when held in one hand – the other touching the terminal of the coil – quite powerfully. It might be objected that the coatings are not sufficiently conducting; still, even if they were highly resistant, they ought to screen the gas. They certainly screen it perfectly in a condition of rest, but not by far perfectly when the charge is surging in the coating. But the loss of energy which occurs within the tube, notwithstanding the screen, is occasioned principally by the presence of the gas. Were we to take a large hollow metallic sphere and fill it with a perfect incompressible fluid dielectric, there would be no loss inside the sphere, and consequently the inside might be considered as perfectly screened, though the potential be very rapidly alternating. Even were the sphere filled with oil, the loss would be incomparably smaller than when the fluid is replaced by a gas, for in the latter case the force produces displacements; that means impact and collisions on the inside.

The dielectric induction thru the interior of the earth communicates the energy from the transmitter to the receiver as shown by Figure 4. The unused portion of energy is reflected back to the transmitter more or less completely. Operating this energy reciprocation between transmitter and receiver at the natural period and waveshape of the earth's own energy pulsation rate greatly overcomes the effect of distance; hence no significant loss of energy is apparent. Thus a standing wave of induction energy exists between the transmitter and receiver, or what can be called transponders, pulsating at one of the earth's natural harmonics. If the phase angle of the earth pulsation frequency lags the phase angle of the pulsating frequency energy is abstracted from the earth's supply of energy and delivered as “free energy” to the transponders.

It can therefore be seen that while the transmission of transverse waves involves the spraying of energy, with its consequent square law diminishment of energy density, and no hope of retrieving the unused energy, the Tesla system involves the direct connection of transmitter and receiver, via the pulsating lines of electric induction. Therefore, the transmitter and receiver are rendered as one apparatus.

### **The Principles of Wireless Power: Operating principles of the TMT**

Because the energy is propagated through the “ground” the question exists as to how to ground the apparatus. That is, how to establish an electric reference point, since the so-called ground is now the hot terminal of the transponders, and therefore is incapable of also serving as an electric reference point. Here exists the singular feature of the Tesla OC transformer in that the distributed mutual inductance and odd function resonance work to establish a virtual ground. This fundamental principle of virtual grounding is also to be found in the Tesla Telegeodynamic Oscillator (TGO) which serves as a mechanical analog to the TMT. The principle behind this is the geometrical reconfiguration resulting in the separation of cause and effect in not only time but also in space. The result hereof is the circumvention of the Newtonian laws of action and reaction. This allows for the production of heretofore unexplored phenomena.



Tesla's World-Wide Wireless Transmission of Electrical Signals, As Well As Light and Power, Is Here Illustrated in Theory, Analogy and Realization. Tesla's Experiments With 100 Foot Discharges At Potentials of Millions of Volts Have Demonstrated That the Hertz Waves Are Infinitesimal in Effect and Unrecoverable; the Recoverable Ground Waves of Tesla Fly "Thru the Earth". Radio Engineers Are Gradually Beginning to See the Light and That the Laws of Propagation Laid Down by Tesla Over a Quarter of a Century Ago Form the Real and True Basis of All Wireless Transmission To-Day.

Figure 4. Tesla Wireless System – Theory, Analogy and Realization.

Hence, the TMT as well as the TGO is capable of transmitting vibrations by virtue of the fact that it is self referencing, thereby not requiring any ground, that is, no solid backing from which to push against. This relates to the saying "Give me a fulcrum and I will move the earth." Tesla found this fulcrum and moved the earth; both mechanically, producing a local earthquake in New York City; and electrically, producing a standing lightning discharge at Colorado Springs (and possibly lightning elsewhere on the planet).

The Tesla transponder (TMT) can be divided into FIVE distinct components:

- 1) Earth
- 2) Reflecting Capacitance
- 3) Energy Transformer
- 4) Coupling Transformer
- 5) Resonant Coil

The interconnection of these five components is shown by Figure 5.

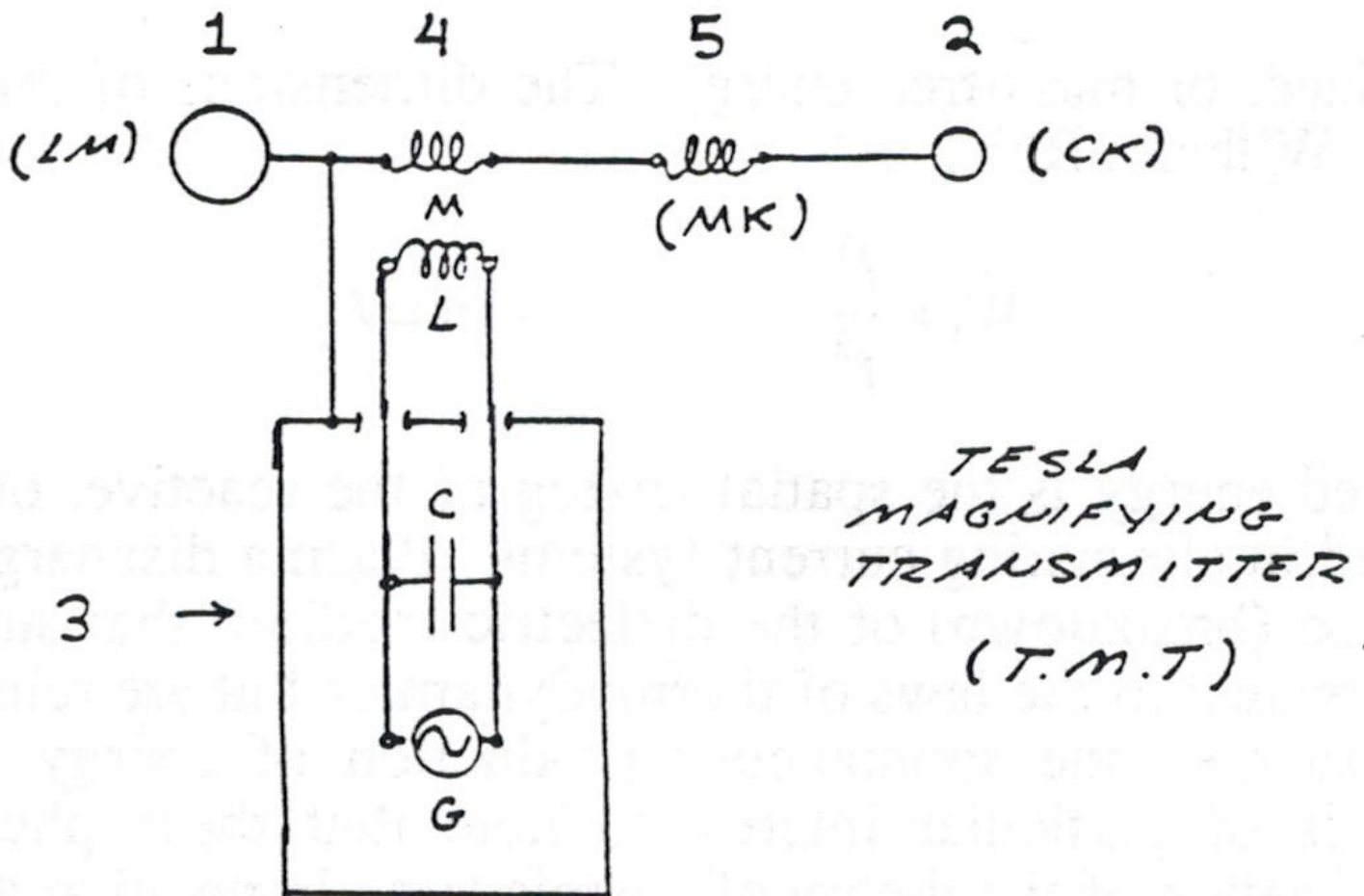


Figure 5. The Tesla Magnifying Transmitter (TMT) in its basic form.

In this arrangement energy is continuously bounced back and forth between the earth and the reflecting capacitance at a rate tuned to a natural rate of the earth. This standing wave of energy pulsation is maintained by the energy transformer which delivers electric energy to this standing wave via the coupling transformer. A certain percentage of this energy in the standing wave is refracted thru the earth-transformer reflection point and into the earth. This refracted energy establishes another standing wave in the earth. Hence, a pair of standing waves are produced which communicate energy thru the refraction.

The oscillating resonant coil, tuned to an earth harmonic, establishes a virtual ground at one terminal of the coupling transformer thus rendering the earth terminal active from the standpoint relative to the electric conditions surrounding the apparatus. The coil terminal designated as the reflecting capacitance appears active, and the earth terminal appears to be neutral – whereas from the earth's standpoint the earth terminal is active. Thus, the reason for the popular notion that the reflecting capacitance is the output of the apparatus. In light of the virtual ground theory this is obviously not correct. See Figure 6.

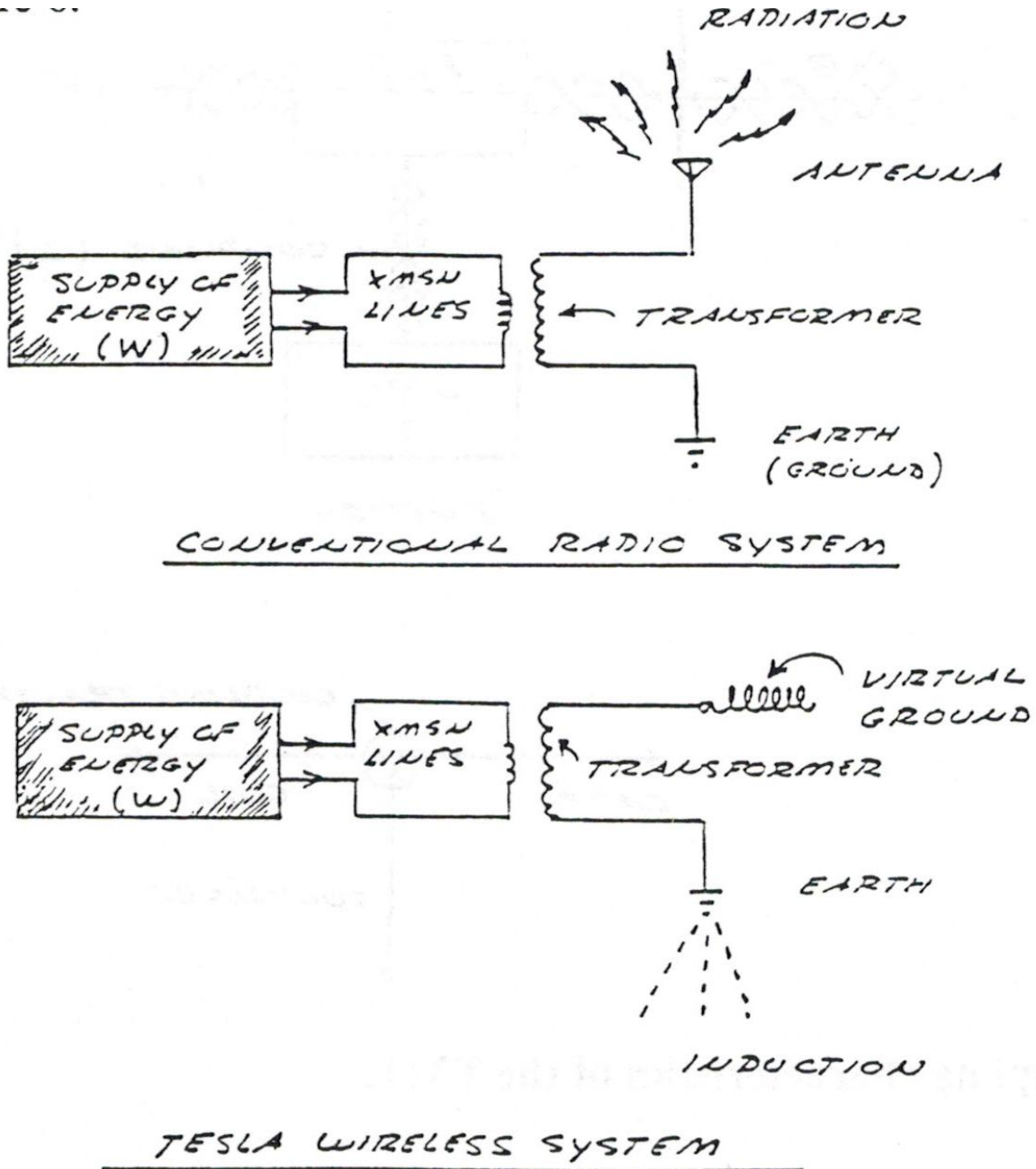


Figure 6. Conventional radio system as compared to the Tesla wireless system.

The electric conditions surrounding the TMT no longer can be represented by conventional, or electromagnetic, concepts because the system has converted the electromagnetic energy of the dimensions

$$W_{11} = mc^2 = m \frac{l^2}{t^2} \quad (1)$$



into a dematerialized, or mass-free energy. The dimensions of this form of energy were given by Dr. Wilhelm Reich as

$$W_1 = \frac{l^3}{t^2} \quad m = l \quad (2)$$

This dematerialized energy is the spatial analog of the reactive, or wattless, energy that is encountered in alternating current systems. Plasma discharges resulting from dielectric saturation (breakdown) of the dielectric medium that surrounds the TMT no longer can be related to the laws of thermodynamics but are related to the laws of organic growth, such as the spontaneous production of energy and Golden ratio proportioning. It is of particular interest to note that these phenomena serve as experimental verification of the theory of cosmic superimposition as put forth by Dr. Wilhelm Reich.

The pulsation of energy between the energy transformer, which is dielectric in nature, and the coupling transformer, which is magnetic in nature represents an additional standing wave independent of that of the resonant coil and independent of that of the earth. This new standing wave is called an electric oscillation and represents a standing wave in the dimension of time. The energy of this standing wave is refracted through the coupling transformer thereby exchanging energy with the other standing wave as shown schematically in Figure 7.

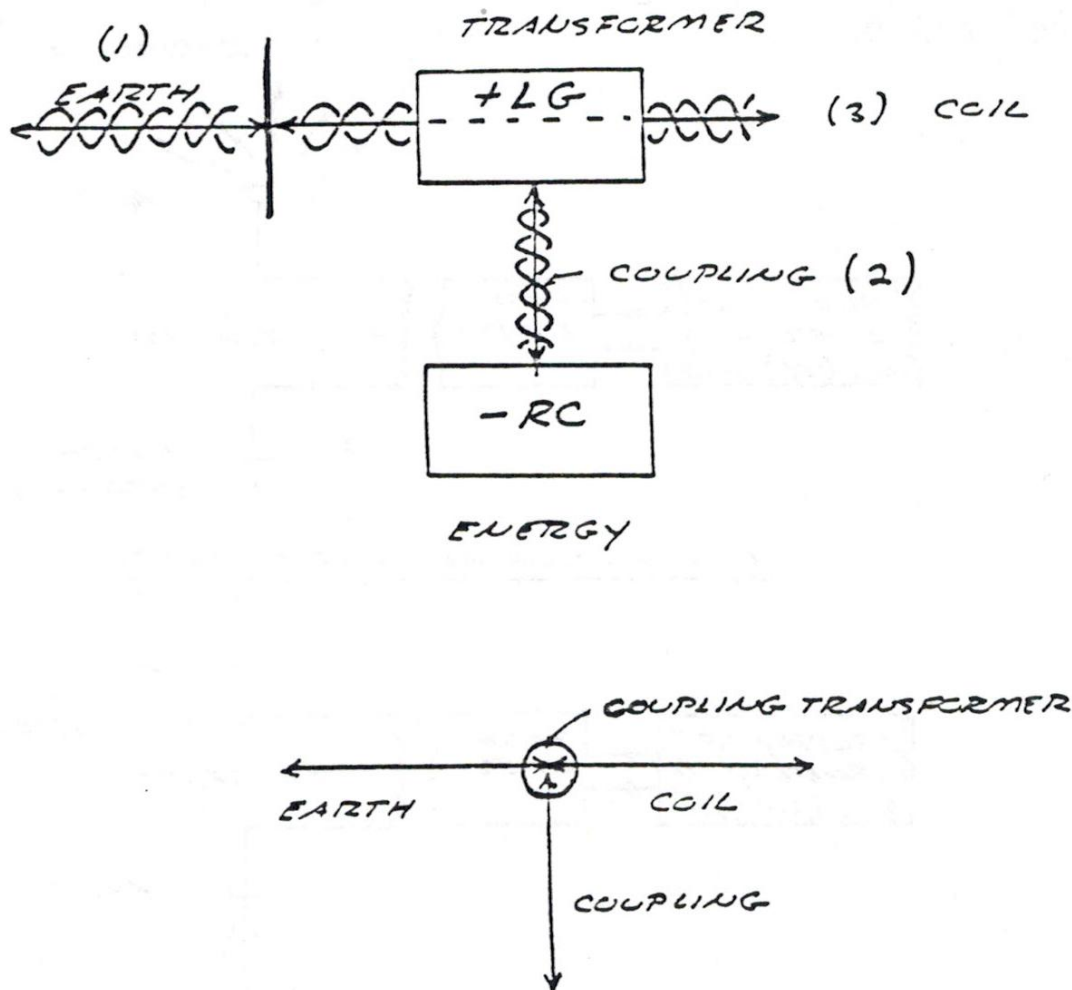


Figure 7. Coupling characteristics of the TMT.

It can be seen that the TMT involves three distinct standing waves in its operation, each coupled to the other through two points of refraction. Each of these standing waves represents a distinct dimensional aspect:

- 1) Earth Wave – Space Dimensional
- 2) Inter Transformer – Time Dimensional
- 3) Resonant Coil – Extra Dimensional

The analogous relations in musical representation are:

- 1) Harmony – Space Dimensional
- 2) Rhythm – Time Dimensional
- 3) Melody – Extra Dimensional

In order for this triple resonant, or sextic (6) energy transient to operate in consonant resonance, conjugate relation must be made to exist between all six energies. Unfortunately, very little theoretical knowledge exists for transients of more than double energy. This is primarily due to the limited understanding of the science of algebra with regard to the solutions of equations higher than second degree.

### **Induction In The Dimension Of Time: History of Discoveries**

The elemental principles of electric induction were first discovered by Michael Faraday in the early part of the 19<sup>th</sup> century. Faraday considered action at a distance through empty space as an improbable explanation of magnetic attraction and repulsion. By intuitive and experimental method he determined that space is pervaded with lines of induction. These lines of induction were considered by Faraday to be the polarization of the contiguous particles of the aether. The lines, or polarizations, displayed the curious property of not taking the shortest path between the poles of an inductor, but followed curved paths through space. This curvature of induction was unacceptable to Faraday's contemporaries, and he was sharply criticized for this discovery.

In the course of his experimental researches Faraday found that when a magnetic field surrounding an electric conductor is altered so as to change the amount of induction surrounding this conductor, an electromotive force (EMF) is produced along the conductor length in proportion to the quickness of the alteration. Algebraically it is

$$E = \frac{\Phi}{t} \quad \text{Lines per second (volts)} \quad (3)$$

That is, the EMF of magnitude E is directly proportional to the total number of lines of induction  $\Phi$  enclosing the conductor, and is inversely proportional to the length of time t required to produce or consume these lines of induction. In practical work the EMF is known as voltage. This discovery marks the beginning of our knowledge of transformer theory, and is called the *Law of Electromagnetic Induction*. Faraday also discovered the existence of another form of lines of induction distinct from the magnetic form. These lines appear around what are called “electrostatic charges”, and were given the name dielectric lines of induction. This field of induction is complimentary to the magnetic field of induction.

The experimental researches of Michael Faraday greatly impressed two of perhaps the most influential electrical scientists of the 19<sup>th</sup> century – J.C. Maxwell and J.J. Thompson. Maxwell sought to translate the experimental researches of Faraday into mathematical form in order to provide a more quantitative understanding of electric induction. Maxwell discovered a fundamental law complimentary to the law of electromagnetic induction, this being the *Law of Dielectric Induction*, or what is often called displacement current. Algebraically it is,

$$I = \frac{\Psi}{t} \quad \text{Lines per second (amperes)} \quad (4)$$

That is, the current of magnitude I is directly proportional to the number of lines of dielectric induction  $\Psi$  terminating on the conductor surface, and inversely proportional to the length of time t required to produce or consume these lines of induction. In practical work this is known as the amperes.

The complimentary nature of magnetic and dielectric inductions led Maxwell to discover the existence of a constant numerical proportion between the units of measure in magnetism and the units of measure in dielectrics, this constant being numerically equal to the velocity of light squared. This famous discovery led Maxwell to the *Theory of Electromagnetism* – this theory stating that electric waves are identical to waves of light, and thereby gave the notion that magnetism and electricity are inseparable.

The Maxwell theory of electromagnetism dominated research into electric waves, particularly after the experiments of H. Hertz. Nikola Tesla commented on this matter: “I do not hesitate to say that in a short time it will be recognized as one of the most remarkable and inexplicable aberrations of the scientific mind which has ever been recorded in history.” Unfortunately this time has not yet arrived.

Professor J.J. Thompson took a much less mathematical approach and more physical approach to Faraday's discoveries. Thompson considered Faraday's contiguous aether particles and lines of induction as *concrete physical realities*, despite the shift in contemporary thought (circa 1900) back to what resembles action-at-a-distance through an aetherless, and now a spiritless, dead, space.

Thompson considered the propagation of the two electric inductions as distinctly independent of each other, rather than these two inductions propagating conjointly as given by the theory of electromagnetism. He conceived the propagation of magnetic induction, because of the lines being transverse to the direction of propagation, as being retarded by the broadside drag they encounter in their motion through the aether; whereas the propagation of dielectric induction, because of these lines being directed along the path of propagation, are not retarded, but glide smoothly through the aether with little or no opposition to motion.

Analogously, the propagation of a parachute through the atmosphere is akin to magnetic propagation and hence the effect of drag, whereas the propagation of a missile thru the atmosphere is akin to dielectric propagation. Hence, dielectric induction propagates faster and thus arrives sooner than the magnetic induction, and thus sooner than the electromagnetic energy. This concept is of prime importance for the understanding of the works of Dr. Nikola Tesla.

In his search for the contiguous particles of the aether Professor Thompson discovered what is known as the electron. Much misunderstanding has developed with regard to the relation between this particle and dielectric induction. This has worked much harm into the proper understanding of Tesla's discoveries, and the understanding of electricity in general. To quote Charles P. Steinmetz on this matter:

Unfortunately, to a large extent in dealing with the dielectric fields the prehistoric conception for the electrostatic charge on the conductor still exists, and by its use destroys the analogy between the two components of the electric field, the magnetic and the dielectric, and makes the consideration of dielectric fields unnecessarily complicated.

There obviously is no more sense in thinking of the displacement current as current which charges the conductor with a quantity of electricity, than there is of speaking of the EMF of magnetic induction as charging the conductor with a quantity of magnetism. But while the latter conception, together with the notion of a quantity of magnetism, etc., has vanished since Faraday's representation of the magnetic field by the lines of magnetic force, the terminology of electrostatics of many textbooks still speaks of electric charges on the conductor, and the energy stored by them, without considering that the dielectric energy is not on the surface of the conductor, but in the space outside of the conductor, just as the magnetic energy.

In 1854 Sir William Thompson, known also as Lord Kelvin, published the theory of electric oscillations. This theory demonstrated the interaction of the law of electric induction with the law of dielectric induction, forming the law of electric induction in the dimension of time. Algebraically it is,

$$P = \frac{\phi}{t^2} = EI \quad \text{units per second squared (watts)} \quad (5)$$

Where

$$\phi = \Phi \psi \quad (5a)$$

In practical work this is called the electric power, or wattage. This theory, and its further development by Helmholtz, Heaviside, and Steinmetz, represents a fundamental principle behind nearly all of Tesla's apparatus. Lord Kelvin felt that it was possible to establish compressional waves, such as sound waves, thru the luminiferous aether, these waves being a version of Maxwell's displacement current. This current, often called capacitor current, flows through electric insulators, and even through so-called empty space. No conductors or electron flux is involved with this current. Kelvin indicated his feelings that these waves must propagate faster than the velocity of light. To quote Kelvin's description of the actions of the induction in the space between the plates of a capacitor fed by an alternator:

Now does anyone believe that, if the revolution were made fast enough, the electrostatic law of force, pure and simple, would apply to the air at different distances from each plate? Everyone believes that if the process can be conducted fast enough, several million times per second, we should have large deviations from the electrostatic law in the distribution of electric force through the air in the neighborhood. It seems absolutely certain that such an action as that going on would give rise to electrical waves. Now, it does seem to me probable that these electrical waves are condensational waves in the luminiferous aether; and probably it would be that the propagation of these waves would be enormously faster than the propagation of ordinary light waves.

The velocity of dielectric propagation was experimentally verified by Professor Wheatstone to be  $\pi/2$  times faster than the velocity of light. Tesla also states this velocity in his writings on wave propagation.

In view of these scientific discoveries, and the fact that Oliver Heaviside developed a theory of faster than light electrons which was confirmed by Dr. Tesla, it is a wonder how the present notions of electromagnetism and its limiting velocity as purported by Einstein and his followers have dominated electric theory. It is of particular interest to note that Steinmetz did not consider Hertzian waves as transmission of energy but as energy loss by the hysteresis of the aether.

### **Theoretical Concepts Of Tesla's Discoveries: Tesla, Physics And Electricity**

Research into the works of Nikola Tesla reveals electric phenomena that behave contrary to the theory of electricity in present use. Explanation of Tesla's inventions has been given from the standpoint of physics, yielding many misconceptions. The science of physics is based on the phenomena surrounding particles and mass, which finds little application in the study of electric phenomena.

The explanation of Tesla's discoveries are to be found in the science of electricity rather than the science of physics. The science of electricity has been dormant since the days (1900) of Steinmetz, Tesla and Heaviside. This is primarily due to vested interests which we may call the "Edison Effect".

This material serves as a preface to a theoretical investigation of Nikola Tesla's discoveries by the examination of the rotating magnetic field and high frequency transformer. It is assumed that the reader is acquainted with the commonly available material on Tesla, and possesses a basic knowledge of mechanics and electricity.

## The Rotating Magnetic Field

In the general electromechanical transformer energy is exchanged between mechanical and electric form. Such an apparatus typically employs a system of moving inductance coils and field magnets. It is desirable that the mechanical energy produced or consumed be of rotational form in order to operate with pumps, engines, turbines, etc. The method of producing rotary force, without the use of mechanical rectifiers known as commutators, was discovered by Nikola Tesla in the late 1800s and is known as the rotating magnetic field.

### The Rotating Magnetic Field: Elemental Principles

An examination of the rudimentary interaction between inductance coils and field magnets will provide some insight into the principles behind the rotary magnetic field.

Consider a simple electromechanical device consisting of a piece of iron with a copper loop winding around it along with a small bar magnet (Figure 8). Any variation in the distance ( $l$ ) between the pole faces of the inductance coil and magnet produces an electromotive force (voltage) at the terminals of the copper loop resulting from the field magnet's lines of force passing through the iron core of the inductance coil. The magnitude of this EMF is directly proportional to the speed at which the distance ( $l$ ) is varied and the quantity of magnetism issuing from the field magnet pole face.

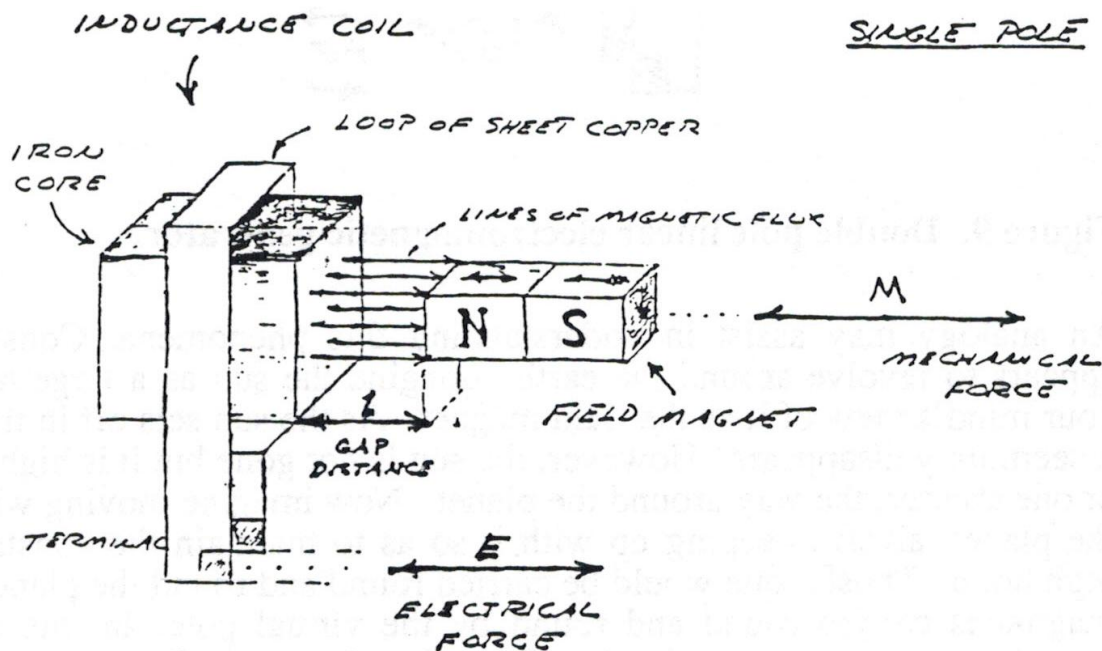


Figure 8. Single pole linear electromagnetic generator.

Conversely, if an electromotive force is applied to the inductance coil terminals, the distance ( $l$ ) varies at a speed directly proportional to the strength of the EMF and the quantity of magnetism issuing from the field magnet pole face. Thus electrical force and mechanical are combined in this device.

If a flow of electrical energy (watts) is taken from the coil terminals and delivered to a load mechanical resistance (friction) appears at the field magnet as a result of magnetic attraction and repulsion between the magnet and iron core. Mechanical force applied to the field magnet in order to move it results in power flow out of the coil. This flow of power generates an oppositional or counter electromotive force which repels the field magnet against the mechanical force. This results in work having to be expended in order to move the magnet. However this work is not lost but is delivered to the electric load.

Conversely, if the field magnet is to deliver mechanical energy to a load, with an EMF externally applied to the coil terminals, the field magnet tends to be held stationary by the resistance of the connected mechanical load. Since the field magnet is not in motion it cannot develop a counter EMF in the coil to meet the externally applied EMF. Thus electrical energy flows into the coil and is delivered to the field magnet as work via magnetic actions, causing it to move and perform work on the load.

Hence, mechanical energy and electrical energy are rendered on and the same by this electromechanical apparatus. Connecting this apparatus to a source of reciprocating mechanical energy produces an alternating electromotive force at the coil terminals, thus a linear alternating electromotive force at the coil terminals, thus a linear or longitudinal AC generator. Connecting this apparatus to a source of alternating electric energy produces a reciprocating mechanical force at the field magnet, thus a linear AC motor. In either mode of operation the field magnet reciprocates in a manner not unlike the piston of the internal combustion engine. Rotary motion is not possible without the use of a crankshaft and flywheel.

Arranging two inductance coils in a line as shown in Figure 9 and connecting these coils to a pair of alternating EMFs that are out of step by 1/2 of an alternating cycle with respect to each other results in the mechanical force being directed inwardly into the molecular spaces (inner space) within the field magnet. The field magnet is alternately stretched and compressed by magnetic action, and no external force is evident except as vibration and heat. However, arranging two of the pairs shown in Figure 9 at right angles to each other, connecting each to a pair of alternating EMFs that are out-of-phase or step by one-quarter-cycle (quadrature) with respect to each other produces a rotating travelling wave of magnetism, that is, a whirling virtual magnetic pole. This virtual pole travels from one pole face to the next during the time interval of one quarter cycle, thus making one complete revolution around all the pole faces for each cycle of alternation of the EMFs. The field magnet aligns with the virtual pole, locking in with the rotary magnetic wave, thereby producing rotational force.

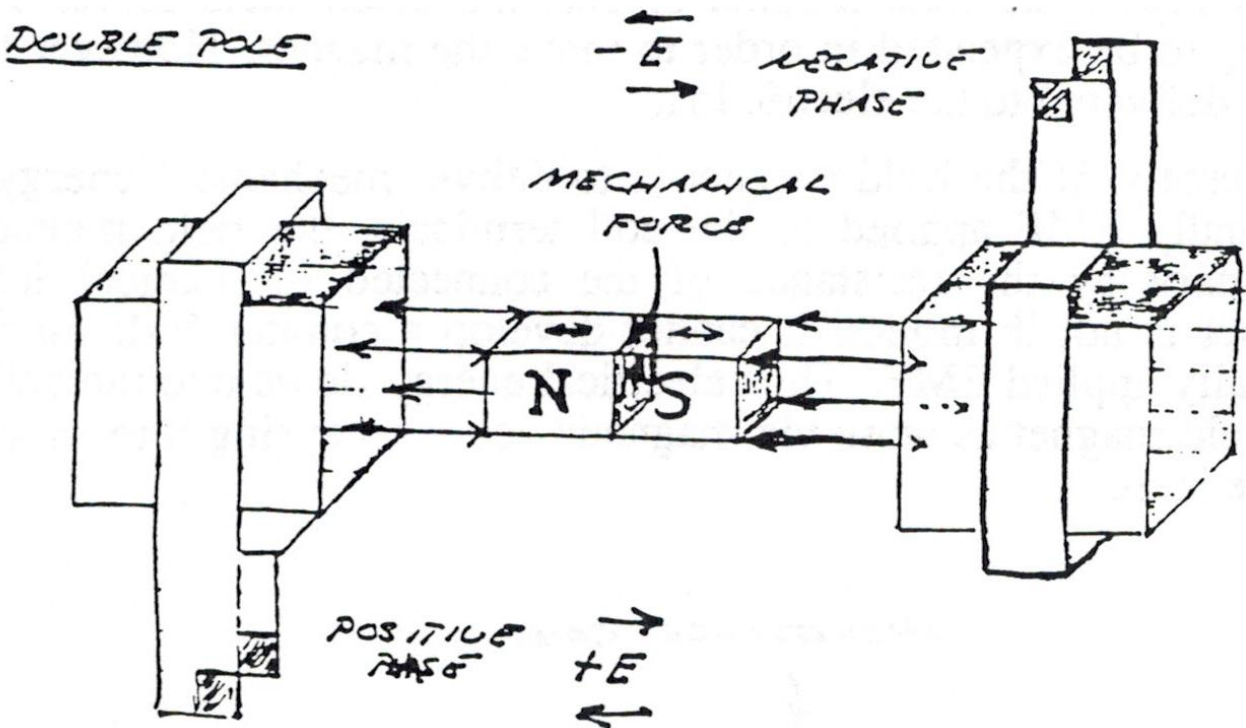


Figure 9. Double pole linear electromagnetic generator.

An analogy may assist in understanding this phenomena. Consider that the sun appears to revolve around the earth. Imagine the sun as a large magnetic pole and your mind's view of it as the field magnet. As the sun sets off in the distant horizon, it seemingly disappears. However, the sun is not gone but it is high noon 90 degrees, or one quarter, the way around the planet. Now imagine moving with the sun around the planet, always keeping

up with it so as to maintain the constant appearance of high noon. Thusly, one would be carried round and round the planet, just as the field magnet is carried round and round by the virtual pole. In this condition the sun would appear stationary in the sky, with the earth flying backwards underfoot. Inspired to thinking of this relation by the poet Goethe, Tesla perceived the entire theory and application of alternating electric energy, principally the rotating magnetic wave.

The glow retreats, done is the day of toil;  
it yonder hastes, new fields of life exploring;  
ah, that no wing can lift me from the soil,  
upon its track to follow, follow soaring ...

### **The Rotating Magnetic Field: Rotational Waves**

The fundamental principle behind the production of the rotary magnetic field serves as the principle behind all periodic electric waves. It is therefore of interest to investigate the discovery a little further.

The apparatus shown in Figure 8 develops mechanical force along the axis of the field magnet as shown in Figure 11. Likewise, mechanical counterforce is applied along the axis of the field magnet. Hence, if work is to be drawn or supplied respectively to the field magnet from an external apparatus, a connecting rod is required between the two machines. The flow of energy is along the axis of the rod and thus is in line (space conjunction) with the forces involved. A simple analogy is a hammer and nail: The hammer supplies mechanical force to the nail – the nail transmitting the force into the wood. The counterforce tends to make the hammer bounce off the nail. However, the wood is soft and cannot reflect a strong counterforce back up the nail and into the hammer. Thus the nail slides into the wood absorbing mechanical energy from the hammer which is dissipated into the wood.

The apparatus of Figure 9 develops mechanical force axially also, but it is entirely concentrated within the molecular space. Any counterforce must push back along the same axis. Thus the work is also along axis like Figure 11 and is delivered to the molecular structure. The analogy is two hammers striking a steel block from opposite sides, pounding the block and producing heat and vibration within it.

The apparatus of Figure 10 produces a quite different wave form (Figure 12). The mechanical force delivered to the shaft is applied at a right angle to the axis in clockwise direction. The counterforce is applied in the opposite rotational sense or counter-clockwise direction at a right angle to the axis. The flow of mechanical energy is still along the shaft as in Figure 11; however, it no longer pulsates in magnitude with the cycle but it continues – quite like the flow of electric energy in a direct current circuit.

An analogy is a screw and screwdriver. The screwdriver is forced rotationally clockwise by the hand or other motive force. The counterforce appears in opposition, that is counterclockwise, thereby arresting the rotation of the screwdriver. However, the wood is soft and cannot reflect the counterforce back into the screwdriver. Thus the screw travels longitudinally into the wood, perpendicular to the rotation of the screwdriver.

The form of this wave has been of great interest to a wide variety of fields of endeavor. It has been called the Caduceus coil, spinning wave, double helix, solar cross, and of course the rotating magnetic field. Applications are wide ranging, from sewage treatment plants and guided missiles all the way to the Van Tassel Integration and astrology.

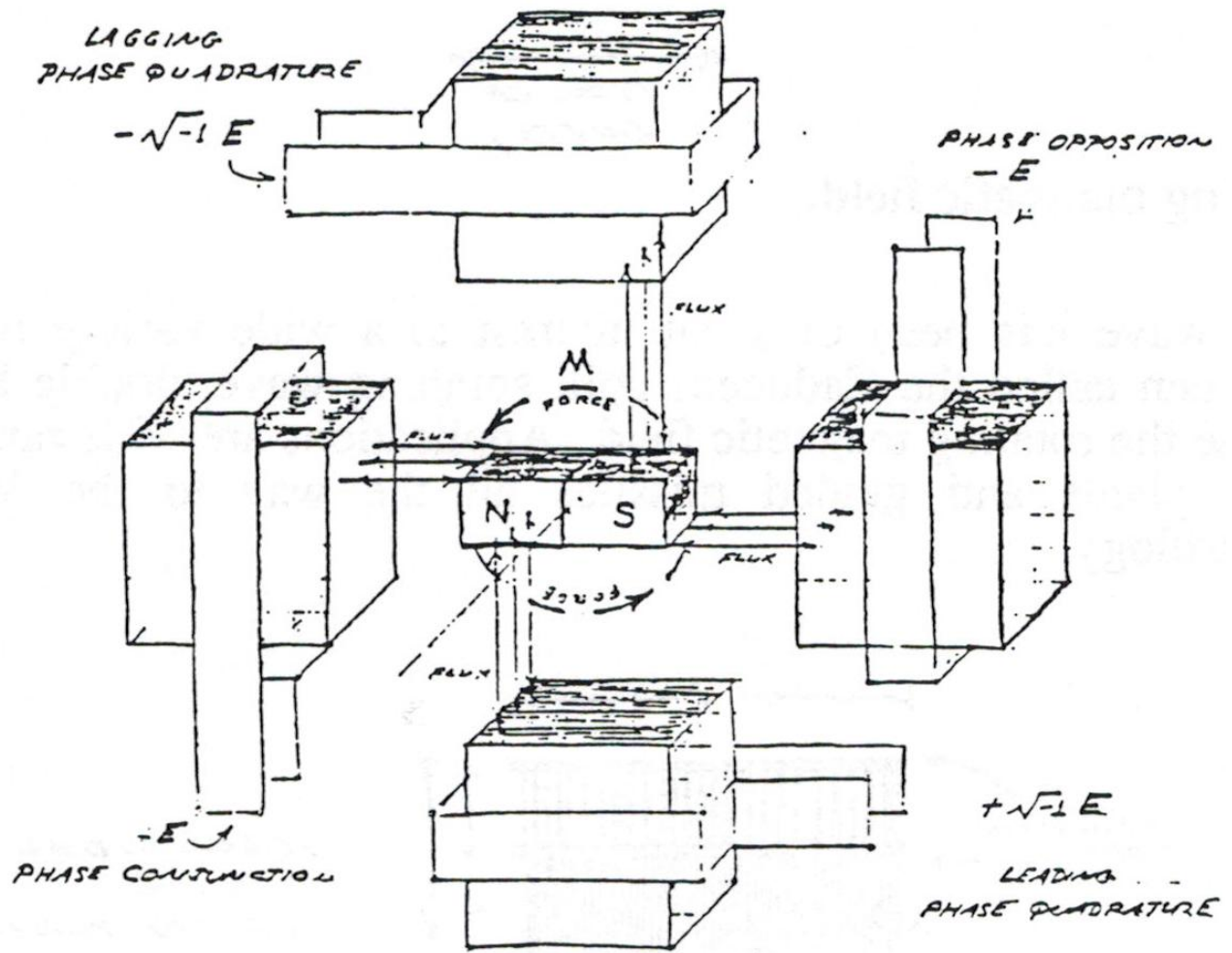


Figure 10. Basic quadrature electromagnetic generator.

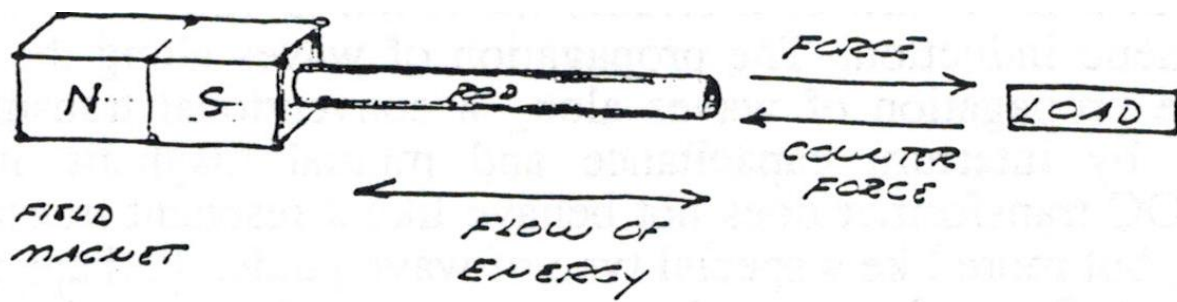


Figure 11. Force/load relationships.



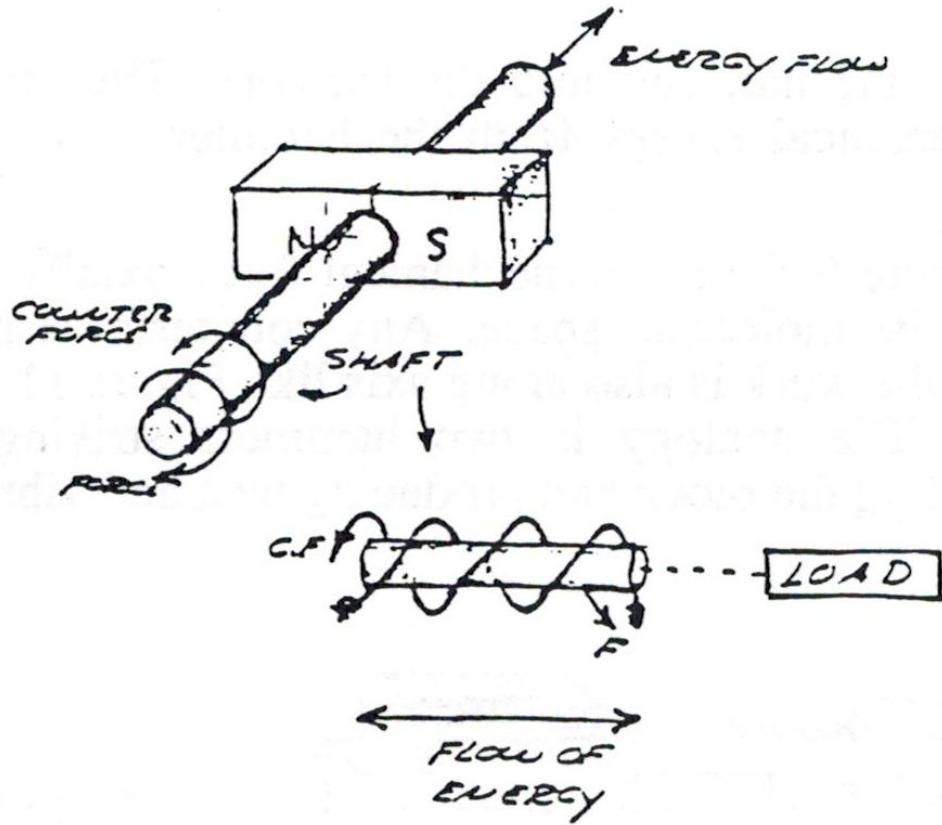


Figure 12. Rotating magnetic held.

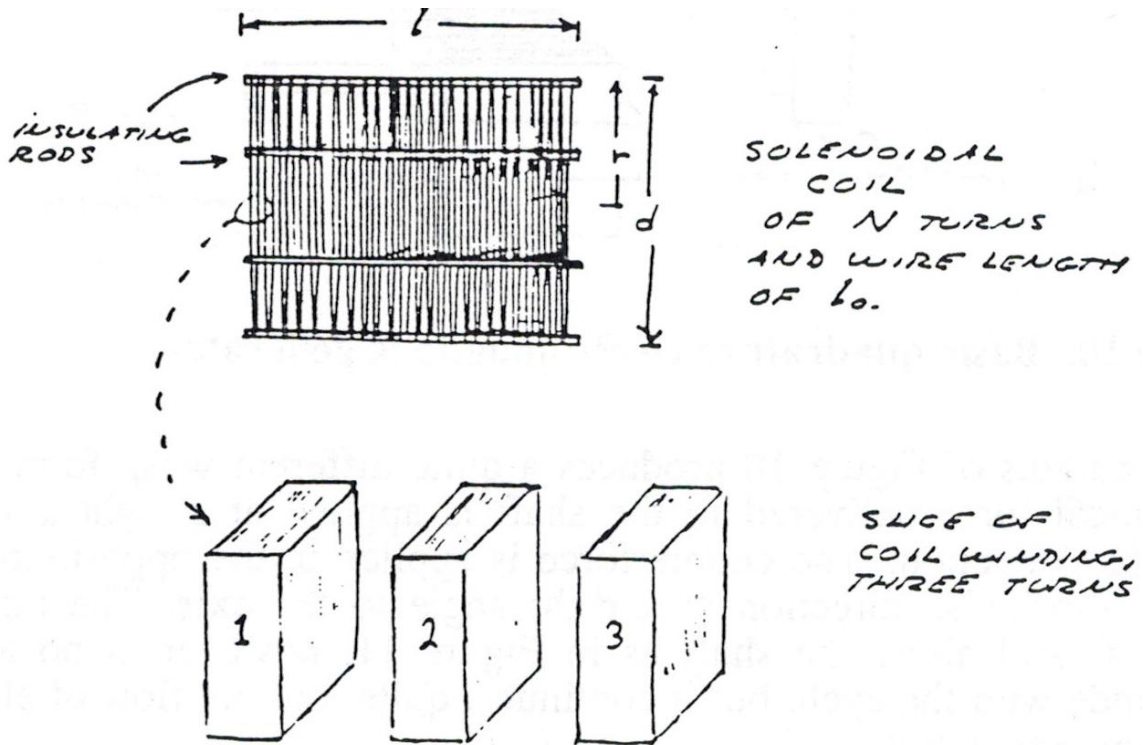


Figure 13. Solenoidal coil and representative slices of coil.

## The Oscillating Current Transformer

The oscillating current (OC) transformer functions quite differently than a conventional transformer in that the law of dielectric induction is utilized as well as the familiar law of magnetic induction. The propagation of waves along the coil axis does not resemble the propagation of waves along a conventional transmission line, but is complicated by interturn capacitance and mutual magnetic inductance. In this respect the OC transformer does not behave like a resonant transmission line, nor an RCL circuit, but more like a special type of wave guide. Perhaps the most important feature of the OC transformer is that in the course of propagation along the coil axis the electric energy is dematerialized, that is, rendered mass free energy resembling Dr. Wilhelm Reich's Orgone Energy in its behavior. It is this feature that renders the OC transformer useful for wireless power transmission and reception, and gives the OC transformer singular importance in the study of Dr. Tesla's research.

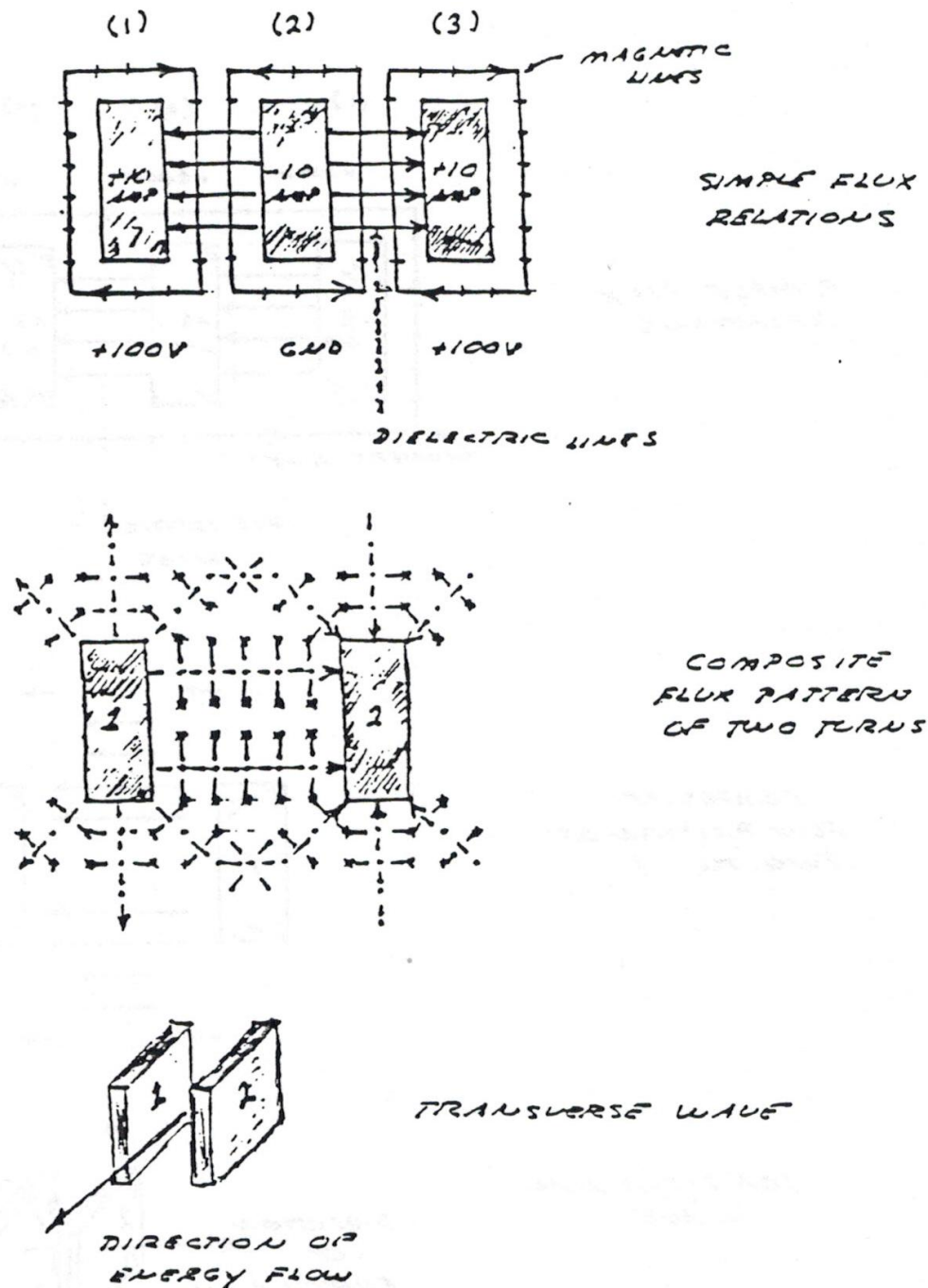


Figure 14. Flux relationships of the coil slice created by passage of *transverse electromagnetic wave*.

## The Oscillating Current Transformer: Fundamentals of Coil Induction

Consider the elemental slice of a coil shown in Figure 13. Between the turns 1, 2 and 3 of the coiled conductor exists a complex electric wave consisting of two basic components. In one component (Figure 14), the lines of magnetic and dielectric flux cross at right angles, producing a photon flux perpendicular to these crossings, hereby propagating energy along the gap, parallel to the conductors and around the coil. This is the transverse electromagnetic wave. In the other component, shown in Figure 15, the lines of magnetic flux do not cross but unite along the same axis, perpendicular to the coil conductors, hereby energy is conveyed along the coil axis. This is the longitudinal magneto-dielectric wave.

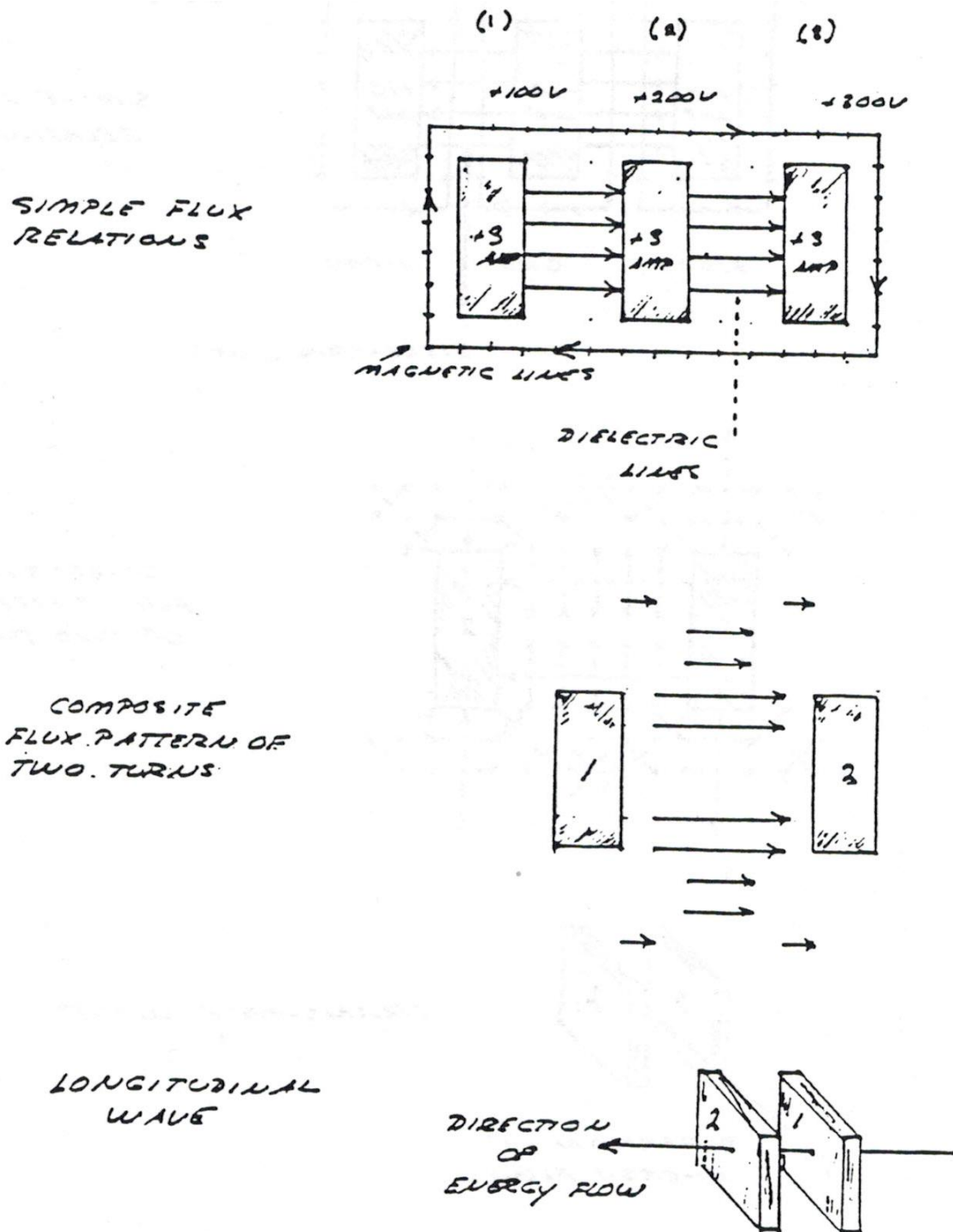


Figure 15. Flux relationships of the coil slice created by passage of longitudinal magneto-dielectric wave.

Hence, two distinct forms of energy flow are present in the coiled conductor, propagating at right angles with respect to each other, as shown in Figure 16. Hereby a resultant wave is produced which propagates around the coil in helical fashion, leading the transverse wave between the conductors. Thus the oscillating coil possesses a complex wavelength which is shorter than the wavelength of the coiled conductor.

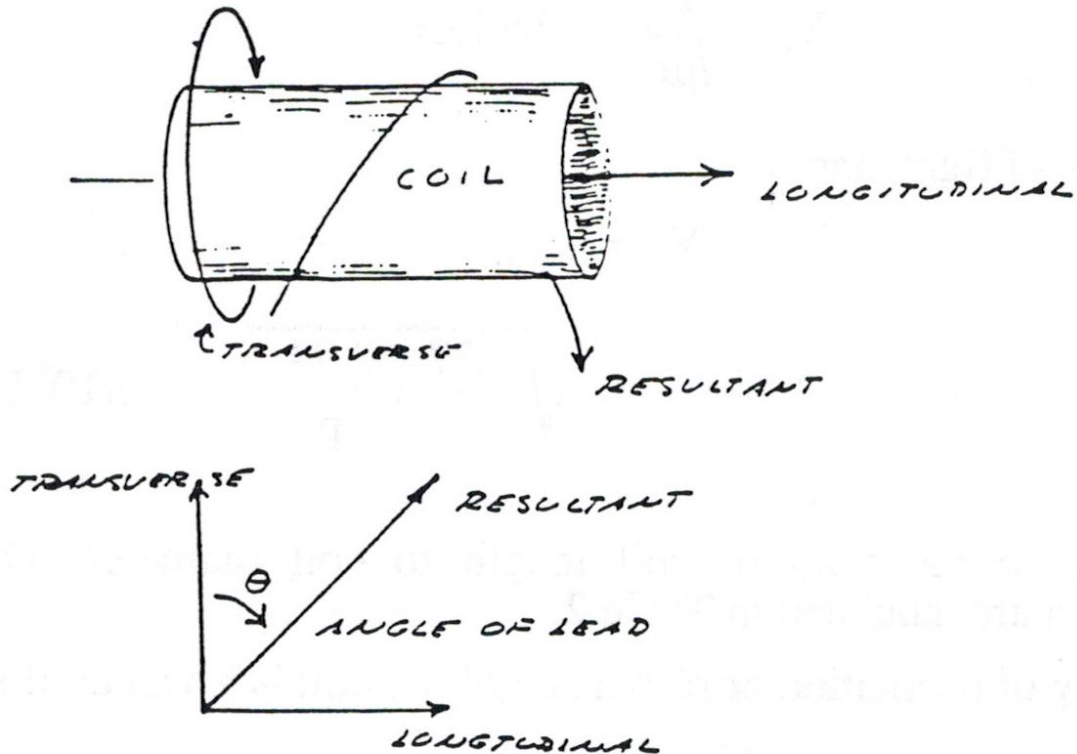


Figure 16. The longitudinal and transverse components passing through a coil creating a resultant wave.

### The Oscillating Current Transformer: Coil Calculation

If the assumptions are made that an alternating current is applied to one end of the coil, the other end of the coil is open circuited. Additionally external inductance and capacitance must be taken into account, then simple formulae may be derived for a single layer solenoid.

The well known formula for the total inductance of a single layer solenoid is

$$L = \frac{r^2 N^2}{(9r + 10l)} \times 10^{-6} \text{ Henry} \quad (\text{inches}) \quad (6)$$

Where

- r is coil radius
- l is coil length
- N is number of turns.

The capacitance of a single layer solenoid is given by the formula

$$C = p\pi \quad 2.54 \times 10^{-12} \text{ Farads} \quad (\text{inches}) \quad (7)$$

where the factor p is a function of the length to diameter ratio, tabulated in Table 1. The dimensions of the coil are shown in Figure 13. The capacitance is minimum when length to diameter ratio is equal to one.

**Table 1**  
**Coil Capacitance Factor**

Length/Width n	Factor P	Length/Width n	Factor P
0.10	0.96	0.80	0.46
0.15	0.79	0.90	0.46
0.20	0.70	1.00	0.46
0.25	0.64	1.50	0.47
0.30	0.60	2.00	0.50
0.35	0.57	2.50	0.56
0.40	0.54	3.00	0.61
0.45	0.52	3.50	0.67
0.50	0.50	4.00	0.72
0.60	0.48	4.50	0.77
0.70	0.47	5.00	0.81

Because the coil is assumed to be in oscillation with a standing wave, the current distribution along the coil is not uniform, but varies sinusoidally with respect to distance along the coil. This alters the results obtained by equation (6), thus for resonance

$$L_0 = L/2 \quad \text{Henry's} \quad (8)$$

likewise, for capacitance

$$C_0 = 8 C/\pi^2 \quad \text{Farads} \quad (9)$$

Hereby the velocity of propagation is given by

$$V_o = \frac{1}{\sqrt{L_o C_o}}$$

$$= \eta V_c \quad \text{Units/sec} \quad (10)$$

Where

$$V_c = \frac{1}{\sqrt{\mu\epsilon}} \quad \text{Inch/sec} \quad (11)$$

That is, the velocity of light, and

$$V_o = V_c \eta$$

$$= \sqrt{\frac{1.77}{p} + \frac{3.94}{p} n} \quad 2\pi 10^9 \text{ Inch/sec} \quad (12)$$

Where n is equal to the ratio of coil length to coil diameter. The values of propagation factor  $\eta$  are tabulated in Table 2.

<b>Table 2</b>					
Length/Widt h n	$V_o$ In/Sec x $10^9$	Percent Luminal Velocity $\eta$	Length/Widt h n	$V_o$ In/Sec x $10^9$	Percent Luminal Ve- locity $\eta$
0.10	9.4	79.8	0.90	21.4	181.0
0.15	10.9	92.2	1.00	22.1	187.0
0.20	12.0	102.0	1.50	25.4	215.0
0.25	13.0	110.0	2.00	27.6	234.0
0.30	13.9	118.0	2.50	28.7	243.0
0.35	14.8	125.0	3.00	29.7	251.0
0.40	15.6	132.0	3.50	30.3	257.0
0.45	16.4	139.0	4.00	30.9	262.0
0.50	17.2	146.0	4.50	31.6	268.0
0.60	18.4	156.0	5.00	32.4	274.0
0.70	19.5	165.0	6.00	33.0	279.0
0.80	20.5	176.0	7.00	33.9	287.0

Thus, the frequency of oscillation or resonance of the coil is given by the relation

$$F_o = \frac{V_o}{(l_o \cdot 4)} \quad \text{Cycles/sec} \quad (13)$$

Where  $l_o$  = total length of the coiled conductor in inches.

The characteristic impedance of the resonant coil is given by

$$Z_c = \sqrt{\frac{L_o}{C_o}} \quad \text{Ohms.} \quad (14)$$

Hence,

$$Z_c = NZ_s \quad \text{Ohms} \quad (15)$$

Where

$$Z_s = \sqrt{(182.9 + 406.4 n) p} \cdot 10^3 \pi / 2 \text{ Ohms-inches} \quad (16)$$

and N = number of turns. The values of sheet impedance,  $Z_s$  are tabulated in Table 3.

The time constant of the coil, that is, the rate of energy dissipation due to coil resistance is given by the approximate formula

**Table 3**

Length/Width n	Z <sub>s</sub> x 10 <sup>3</sup>	Length/Width n	Z <sub>s</sub> x 10 <sup>3</sup>
0.10	0.017	0.90	0.099
0.15	0.070	1.00	0.095
0.20	0.116	1.50	0.081
0.25	0.116	2.00	0.070
0.30	0.116	2.50	0.061
0.35	0.115	3.00	0.054
0.40	0.115	3.50	0.048
0.45	0.114	4.00	0.044
0.50	0.113	4.50	0.040
0.60	0.110	5.00	0.037
0.70	0.106	6.00	0.032
0.80	0.103	7.00	0.028

$$u = \frac{R_o}{2L_o} = \left( \frac{2.72}{r} + \frac{2.13}{l} \right) \pi \sqrt{F_o} \quad \text{Nepers-inches/sec} \quad (17)$$

Where

- r = coil radius
- l = coil length.

In general, the dissipation of the coil's oscillating energy by conductor resistance:

- 1) Decreases with increase of coil diameter, d;
- 2) Decreases with increase of coil length, l, rapidly when the ratio, n, of length to diameter is small with little decrease beyond n equal to unity;
- 3) Is minimum when the ratio of wire diameter to coil pitch is 60%.

By examination of Tables 1, 2, and 3, it is seen that the long coils of popular designs do not result in optimum performance. In general, coils should be short and wide, and not longer than n=1. The frequency is usually given as  $F_0 = V_c/\lambda_0$  which by equation (12) is incorrect. Winding on solid or continuous formers rather than spaced slender rods, as shown in Figure 13, greatly retards wave propagation as indicated in equation (6), thereby seriously distorting the wave. The dielectric constant of the coil, epsilon, should be as close to unity as is physically possible to ensure high efficiency of transduction.

The equations for the volt-ampere relations of the oscillating coil are

$$\dot{E}_1 = j(Z_c Y_o + \delta) \dot{E}_o \quad \text{Complex Input Voltage} \quad (18)$$

$$\dot{I}_1 = j(Y_c Z_o + \delta) \dot{I}_o \quad \text{Complex Input Current} \quad (19)$$

$$Z_1 = \frac{Z_c Y_o + \delta}{Y_c Z_o + \delta} Z_o \quad \text{Input Impedance, Ohms} \quad (20)$$

Where

$\dot{E}_o$  = Voltage on elevated terminal

$\dot{I}_o$  = Current into elevated terminal

$Y_c = Z_c^{-1}$

$Z_o$  = Terminal impedance

$Y_o$  = Terminal admittance

$\delta = u/2F_o = \text{Decrement}$

$j$  = root of  $\sqrt{-1}$

For negligible losses and absolute values

$$E_1 = (Z_c 2\pi F_o C_o) E_o \quad \text{Volts} \quad (21)$$

$$I_1 = (Y_c / 2\pi F_o C_o) I_o \quad \text{Amperes} \quad (22)$$

Where  $C_o$  = Terminal capacitance.

By the law of conservation of energy

$$E_1 I_1 = E_o I_o \quad \text{Volt-Amperes} \quad (23)$$

If the terminal capacitance is small then the approximate input/output relations of the Tesla coil are given by

$$E_o = Z_c I_1 \quad \text{Output Volts} \quad (24)$$

$$I_1 = E_o Y_c \quad \text{Input Amperes} \quad (25)$$

$$I_o = Y_c E_1 \quad \text{Output Amperes} \quad (26)$$

$$E_1 = I_o Z_c \quad \text{Input Volts} \quad (27)$$



## Induction in the Dimension of Space: 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 17, that is, two perpendicular paths for induction. Thus the propagation can occur in any direction on the surface of the mesh given by Figure 17.

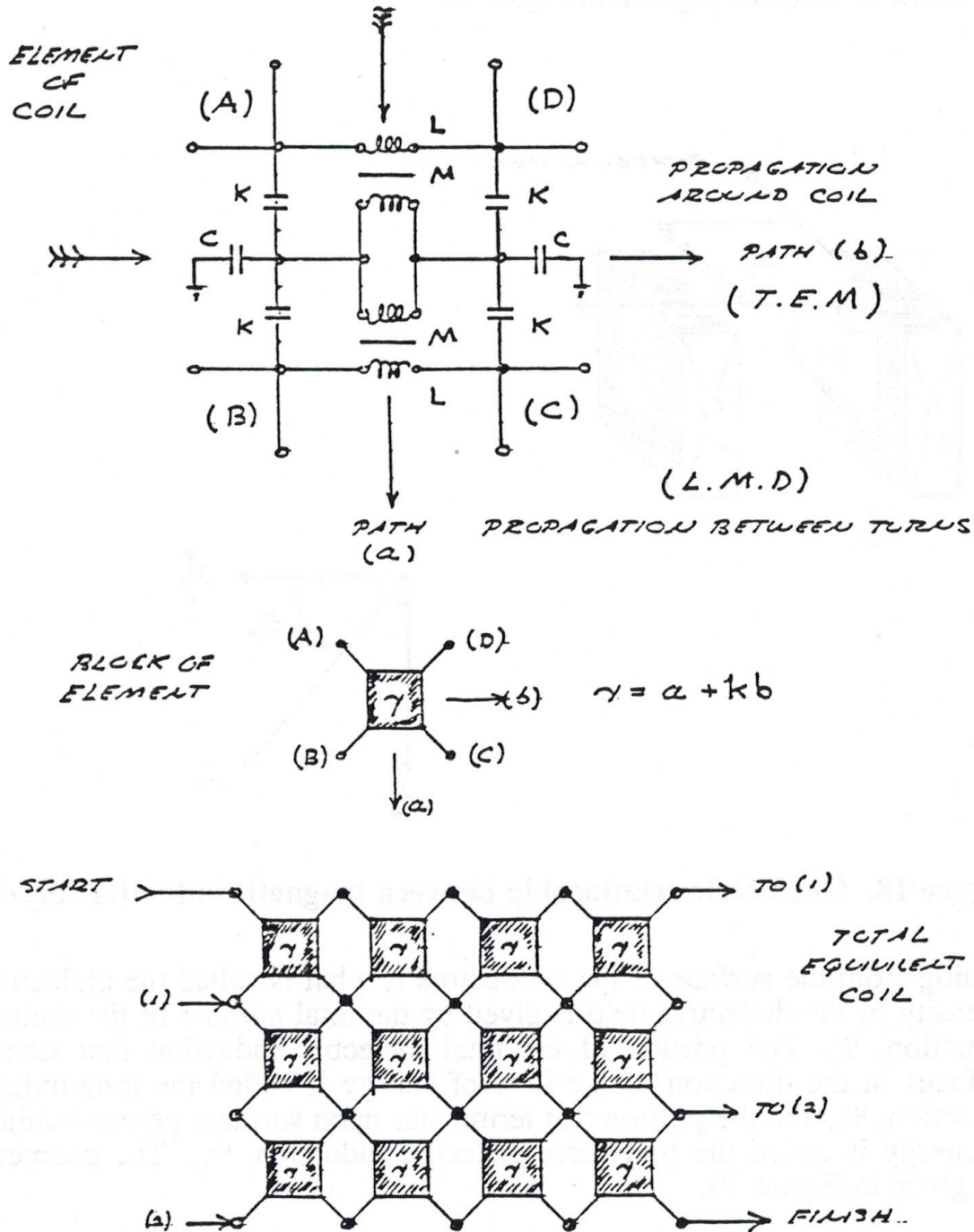


Figure 17. Coil represented as two perpendicular paths.

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.

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,  $\Phi_0$ , 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,  $\Phi_{11}$ , and that portion of the total magnetic induction which is perpendicular to the surface of the conductors is called the longitudinal magnetic induction,  $\Phi_1$ . 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. The geometric relations are given in Figure 18.

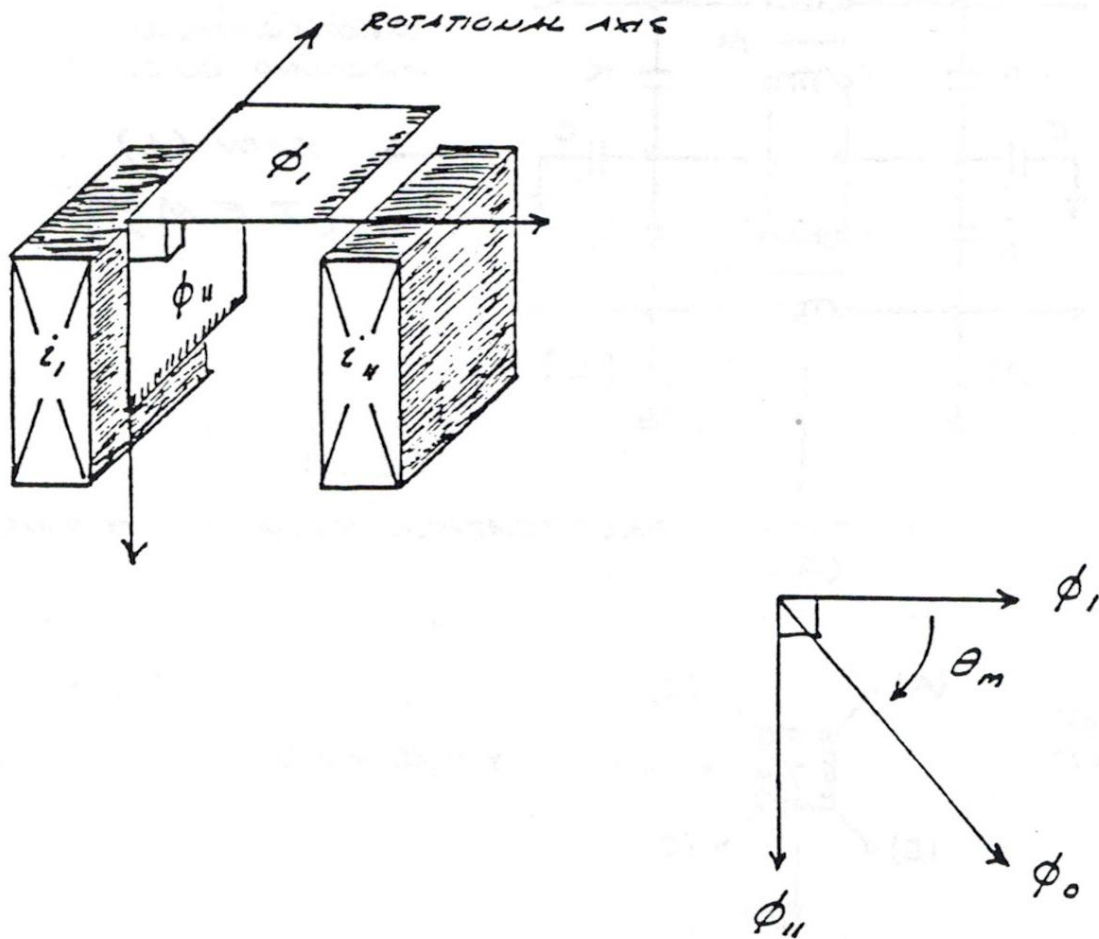


Figure 18. Geometric relationship between magnetic inductive forces.

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 the dielectric lines of induction,  $\Psi_0$ . 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,  $\Psi_1$ , and the portion that terminates upon surfaces perpendicular to the flow of energy is called the transverse dielectric induction,  $\Psi_{11}$ . The geometric relations are given in Figure 19.

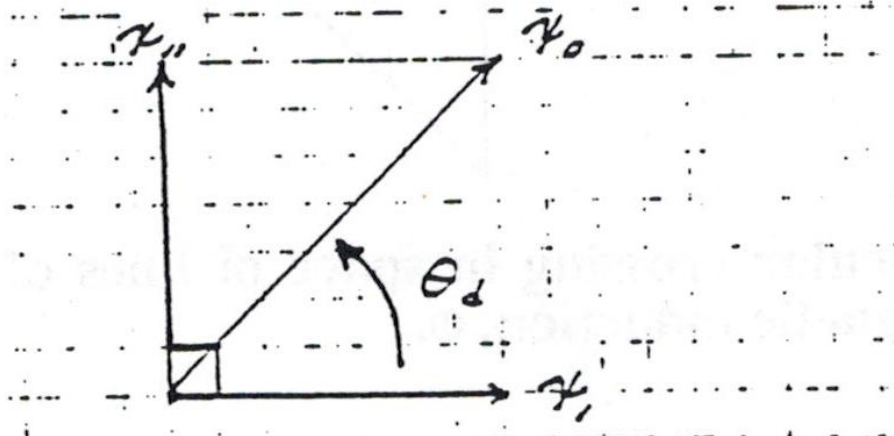
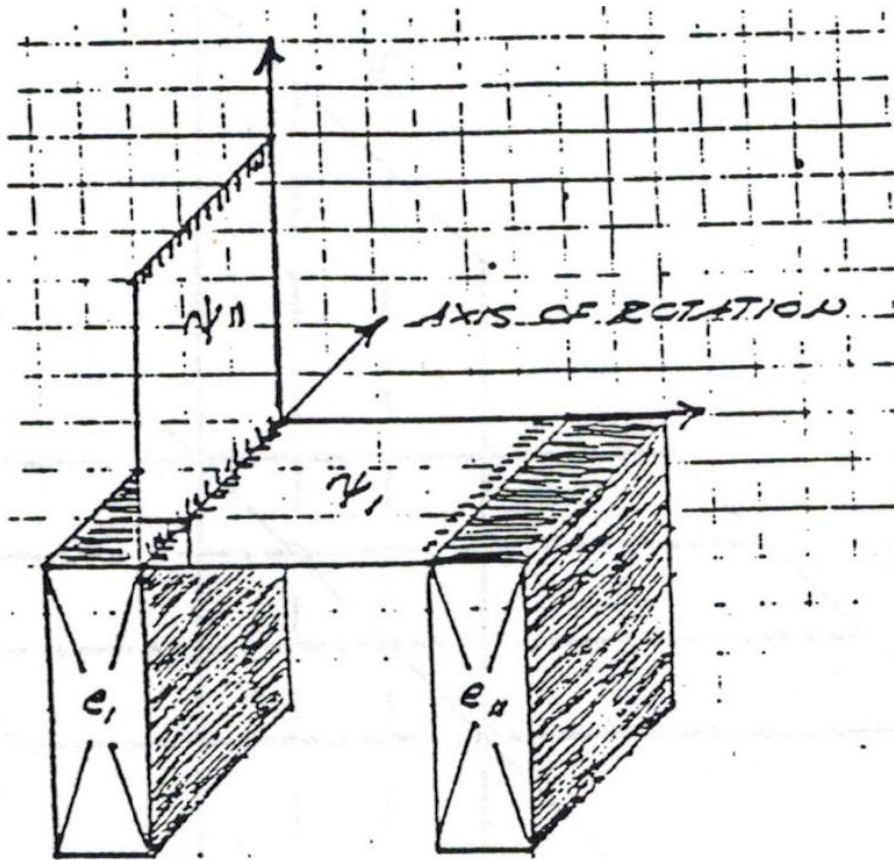


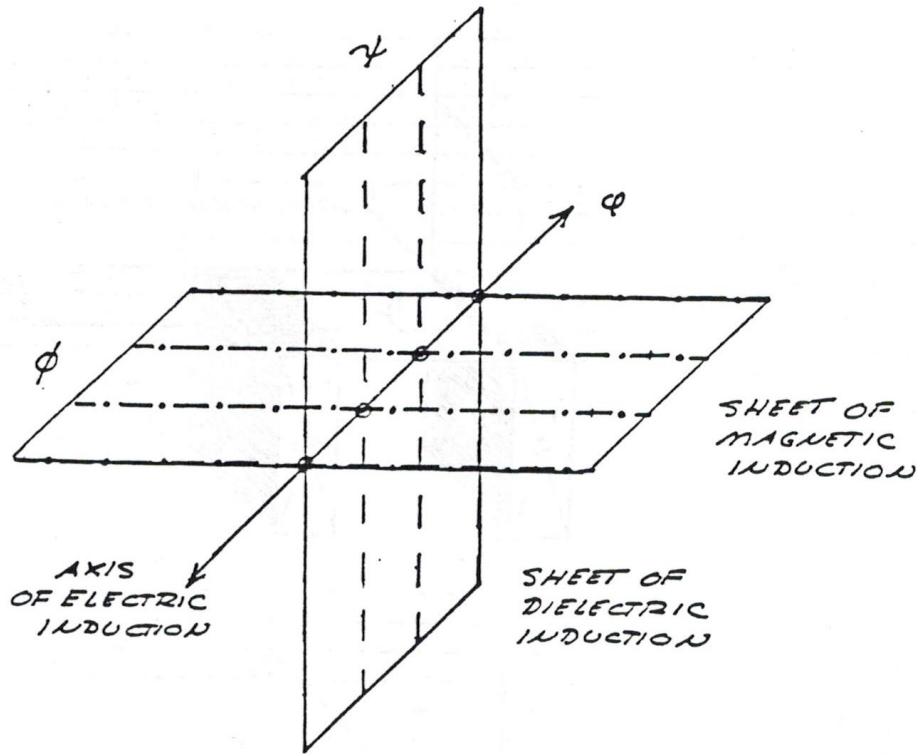
Figure 19. Geometric relationship between dielectric inductive forces.

The total magnetic field of induction,  $\Phi_0$ , and the total dielectric field of induction,  $\Psi_0$ , together constitute the total electric field of induction,  $\phi_0$ . That is

$$\phi_0 = \Phi_0 \Psi_0 \quad \text{units of electric induction} \quad (28).$$

## Induction in the Dimension of Space: 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,  $\Psi$ , and lines of magnetic induction,  $\Phi$ , as shown in Figure 20.



**Figure 20. Perpendicular crossing in space of lines of dielectric induction,  $\Psi$ , and lines of magnetic induction,  $\Phi$**

The symbolic expression of this geometric relation is

$$\phi = \Psi \times \Phi \quad (29).$$

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

$$\phi = \phi_0 \sin \theta \quad (30)$$

Where  $\theta$  is the angle of crossing between the lines of  $\Psi$  and the lines of  $\Phi$ .

It was shown by Professor 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  $\phi$  is

$$\phi = \phi_0(\cos \theta + \kappa \sin \theta) \quad (31)$$

Where the symbol  $\kappa$  is no more than a distinguishing index indicating that the sine term is perpendicular to the plane in which the crossings of  $\Psi$  and  $\Phi$  occur, Figure 21.

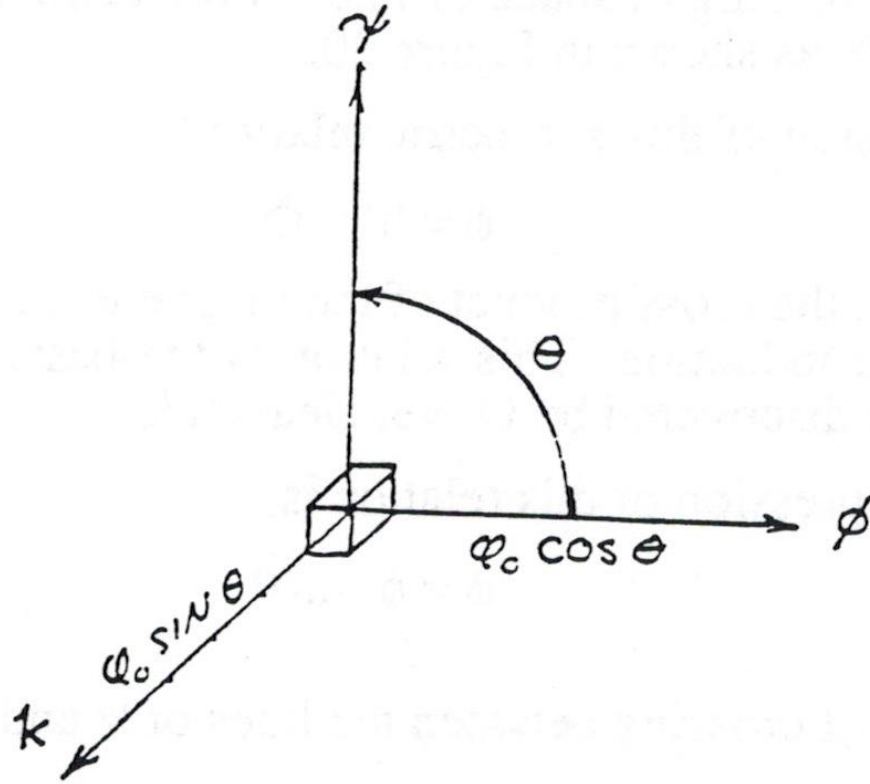


Figure 21. Geometric representation complete versor expression of  $\phi$ .

By substituting the relations

$$\phi_1 = \phi_0 \cos \theta \quad (32a)$$

$$\phi_{11} = \phi_0 \sin \theta \quad (32b)$$

The symbolic expression of the complex induction is given by

$$\bar{\phi} = \phi_1 + \kappa \phi_{11} \quad (33).$$

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

The dimensions of electromagnetic energy are given by

$$\begin{aligned} W &= mc^2 \\ &= m \frac{l^2}{t^2} \quad \text{watt-sec} \end{aligned} \quad (34)$$

and the dimensions of magnetic flux are

$$\begin{aligned}\Phi &= \frac{i}{W} \\ &= \frac{l^2 m}{t \Psi} \quad \text{Lines}\end{aligned}\tag{35}$$

Substituting equation (35) into (34) and substituting the law of dielectric induction

$$i = \frac{\Psi}{t} \quad \text{Lines/sec}\tag{36}$$

gives the dimensions of the transverse electromagnetic induction as

$$\begin{aligned}\phi_{11} &= mc^2 T \\ &= m \frac{l^2}{t} \quad \text{watt-sec}^2\end{aligned}\tag{37}$$

Where T is the time interval during which energy is exchanged between magnetic and dielectric forms of energy storage. The dimensions of equation (37) usually are given as the numerical quantity  $\phi_{11} = 6.6234 \times 10^{-34}$  watt-sec<sup>2</sup> or integer multiples thereof. This is usually portrayed as a flux of these units of energy-time flowing along direction  $\kappa$ , called a flux of photons.

The fundamental relation given by the equation (33) indicates that the electromagnetic induction  $\phi_{11}$ , is only a partial component of the complete electric induction,  $\bar{\phi}$ , due to the existence of the complimentary component  $\phi_{11} = \cos \theta$ . The geometric relation of  $\theta_1$  is shown in Figure 22. The lines of induction,  $\Psi$  and  $\Phi$  in this case are in space conjunction and thus lay upon the same axis as the flux of electric induction  $\phi_1$  to which they give rise. Hence, a distinct form of electric induction totally unlike the electromagnetic component  $\phi_{11}$ . The symbolic expression of this relation is

$$\phi_1 = \Psi \cdot \Phi\tag{38}.$$

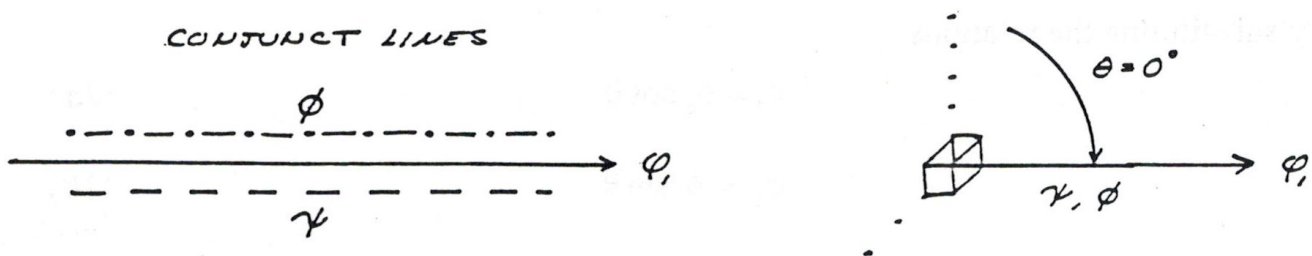


Figure 22. The geometric relation of  $\phi_1$ , is shown.

This relation is called the axial product, often wrongly called the scalar product (the term dot product is often used). This form of electric induction is the longitudinal magneto-dielectric induction (LMD) in contradistinction to the transverse electromagnetic induction of equation (29).

The dimensions of energy in this component of the electric induction are no longer represented by the relations in equation (34) and (37) but must be represented as a mass free energy. An example of this fact is that the LMD energy propagates at right angles, or perpendicular, to the electronic flux, such as the mutual inductance of a transformer, being longitudinal in form, conveys energy from the primary coil to the secondary coil perpendicular to the flux of electrons in the coil conductors. (Figure 23)

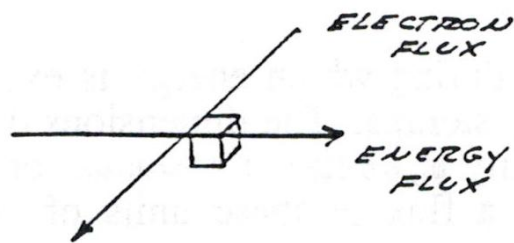
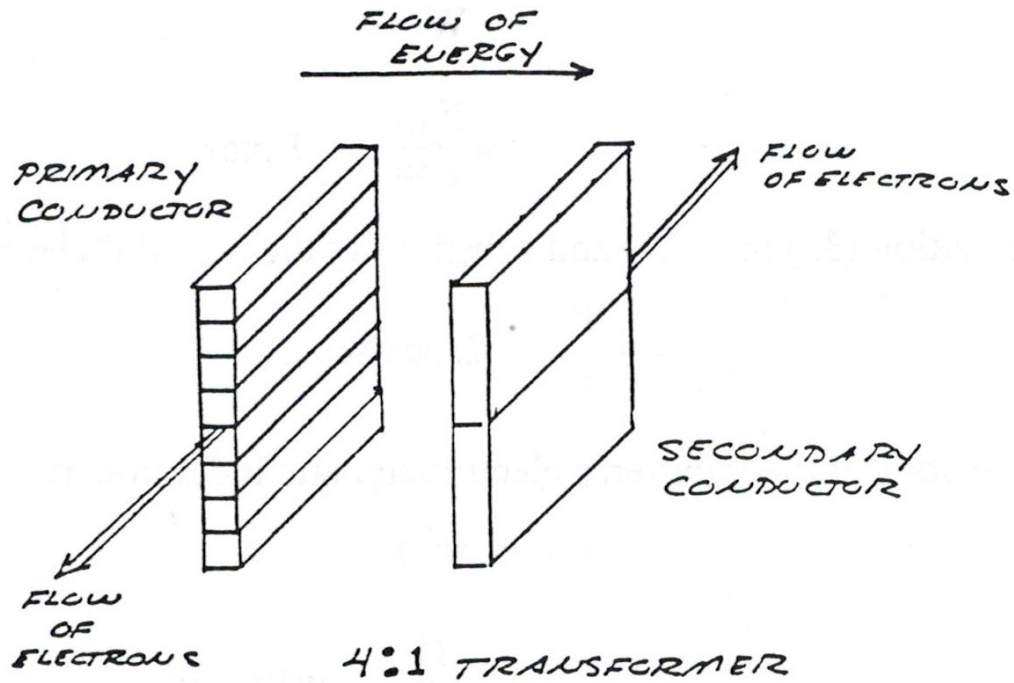


Figure 23. LMD energy propagating perpendicular to electronic flux.

The symbolic expression of the total electric induction of a system of conductors is the complex sum of that percentage of induction contained in the transverse component

$$a = \sin \theta \quad \text{Percent} \quad (39)$$

and that percentage of induction contained by the longitudinal component

$$b = \cos \theta \quad \text{Percent} \quad (40)$$

Hence, the complex quantity

$$\gamma = a + kb \quad \text{Units} \quad (41).$$

The versor equation of electric induction is hereby given as

$$\bar{\phi} = \gamma \phi_0 \quad (42).$$

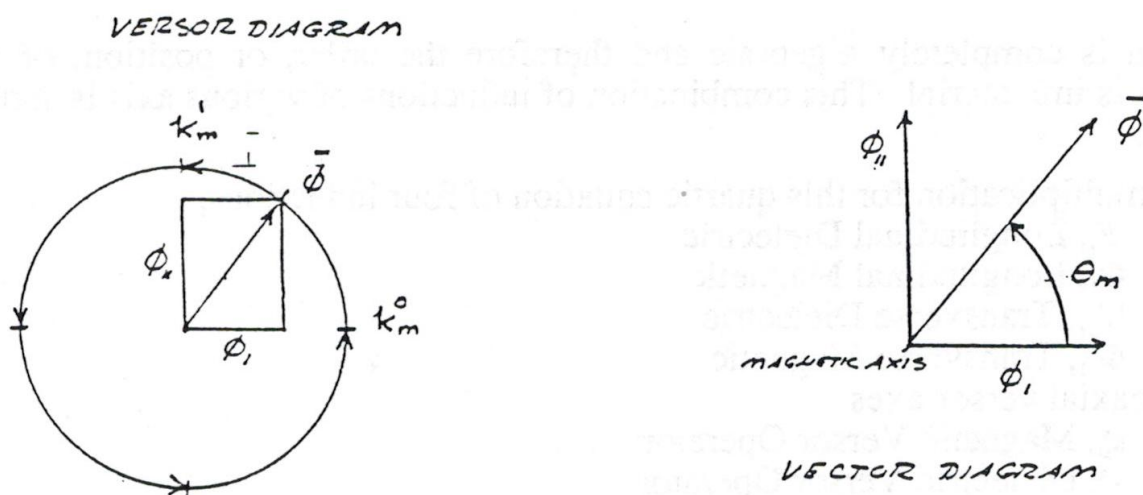
## Induction in the Dimension of Space: Product of Quadrature Conjugate Inductions

The previous equations dealt with the combination of a single magnetic induction and a single dielectric induction. However, in the windings of transformers and coils, the magnetic and dielectric inductions consist each of two parts as described at beginning the section, Product of Conjugate Pair of Inductions.

The versor relation of the complex combination of longitudinal (mutual) magnetic induction, and of transverse (leakage) magnetic induction is given by

$$\bar{\Phi} = \kappa_m^0 \Phi_1 + \kappa_m^1 \Phi_{11} \quad (43)$$

The geometric relations are given by Figure 24. The exponents 0 and 1 of index  $\kappa_m$ , represent the amount of rotation around the magnetic reference axis  $\kappa_m$ .



**Figure 24. Versor relation of the complex combination of longitudinal (mutual) magnetic induction, and of transverse (leakage) magnetic induction.**

The versor relation of the complex combination of longitudinal (mutual) dielectric induction,  $\Psi_1$ , and of transverse (leakage) dielectric induction,  $\Psi_{11}$ , is given by

$$\bar{\Psi} = \kappa_d^0 \Psi_1 - \kappa_d^1 \Psi_{11} \quad (44).$$

This geometric relation is shown by Figure 25. The exponents 0 and 1 of index  $\kappa_d$  has analogous relation to  $\kappa_m$ , that is, the amount of rotation. The minus sign indicate this rotation is backwards with respect to the magnetic rotation.

The total versor of electric induction is the algebraic product of the versor of magnetic induction,  $\bar{\Phi}$ , and the versor of dielectric induction,  $\bar{\Psi}$ . Hence,

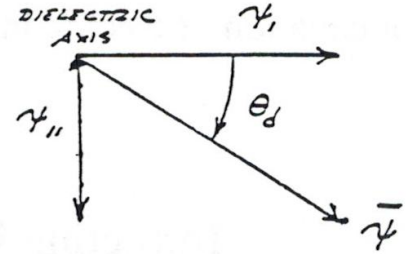
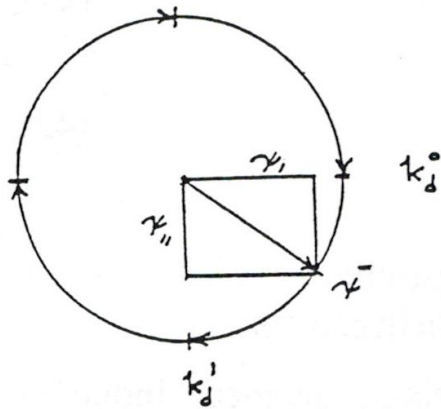
$$\bar{\Phi} = \bar{\Phi} \bar{\Psi} \quad (45)$$

and substituting (43) and (44) into (45) gives

$$\bar{\Phi} = (\kappa_m^0 \kappa_d^0 \Psi_1 \Phi_1 + \kappa_m^1 \kappa_d^1 \Psi_{11} \Phi_{11}) + (\kappa_m^0 \kappa_d^1 \Psi_{11} \Phi_1 - \kappa_m^1 \kappa_d^0 \Psi_1 \Phi_{11}) \quad (46).$$



## VERSOR DIAGRAM



VECTOR DIAGRAM

**Figure 25. Versor relation of the complex combination of longitudinal (mutual) dielectric induction, and of transverse (leakage) dielectric induction.**

This equation is completely algebraic and therefore the order, or position, of the various terms is immaterial. This combination of inductions of various axis is shown by Figure 26.

The rules of multiplication for this quartic equation of four inductions,

- 1)  $\Psi_1$ , Longitudinal Dielectric
- 2)  $\Phi_1$ , Longitudinal Magnetic
- 3)  $\Psi_{11}$ , Transverse Dielectric
- 4)  $\Phi_{11}$ , Transverse Magnetic

and for the coaxial versor axes

- a)  $\kappa_m^n$ , Magnetic Versor Operator
- b)  $\kappa_d^n$ , Dielectric Versor Operator

is given as

$$\kappa_m^0 \kappa_d^0 = 1_s^1, \text{ Longitudinal Product}$$

$$\kappa_m^1 \kappa_d^1 = 1_s^0, \text{ Scalar Product}$$

and

$$\kappa_m^0 \kappa_d^1 = +\kappa_s^1, \text{ Counter Clockwise Cross Product}$$

$$\kappa_m^1 \kappa_d^0 = -\kappa_s^1, \text{ Clockwise Cross Product.}$$

The symbols

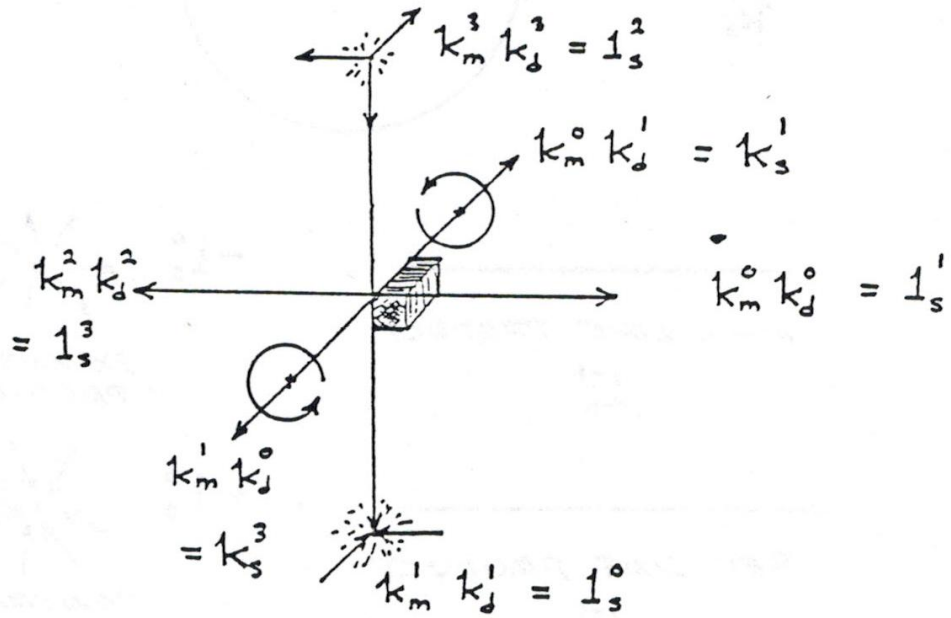
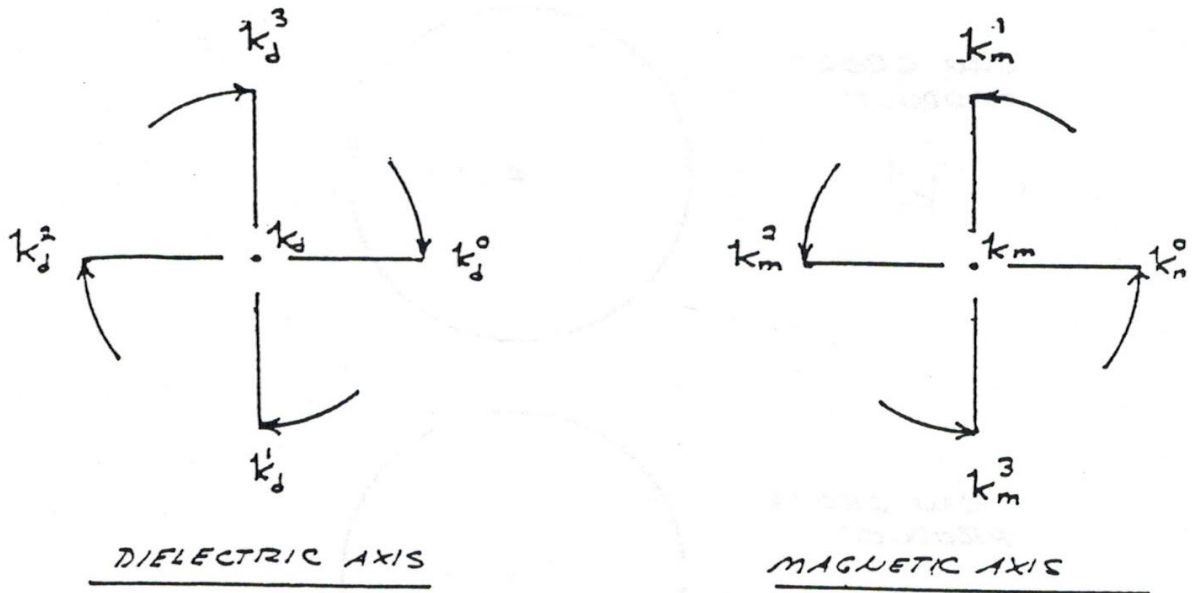
$1_s^0 = 1$ , represents a dimensionless unit

$-\kappa_s^1 = \kappa_s^3$ , represents two quadrants of rotation ( $180^\circ$ )

The symbol  $1_s^n$  is the space operator for the non-Hertzian component of the versor of electric induction and possesses the unique property of behaving like the versor, or time operator, described in Symbolic Representation of the Generalized Electric Wave, published by Borderland Sciences Research Foundation.

The symbol  $\kappa_s^n$  is the space operator for the Hertzian component, or circularly polarized TEM component, of the versor of electric induction.

Substituting the values of the multiplication rules into equation (47) gives the symbolic expression



**QUADRUPLE VECTORS PRODUCT**

**Figure 26. Combination of the various induction axis.**

$$\bar{\Phi} = (\Phi_{11} \Psi_{11} + 1_s^1 \Phi_1 \Psi_1) + \kappa_s^1 (\Phi_1 \Psi_{11} - \Phi_{11} \Psi_1) \quad (47)$$

Substituting

$$\bar{\Phi}_1 = (\Phi_{11} \Psi_{11} + 1_s^1 \Phi_1 \Psi_1) \quad (48a)$$

and

$$\bar{\Phi}_{11} = (\Phi_1 \Psi_{11} - \Phi_{11} \Psi_1) \quad (48b)$$

gives the general expression of the versor of complex induction in a form similar to equation (33),

$$\bar{\Phi} = \bar{\Phi}_1 + \kappa_s^1 \bar{\Phi}_{11} \quad (49).$$

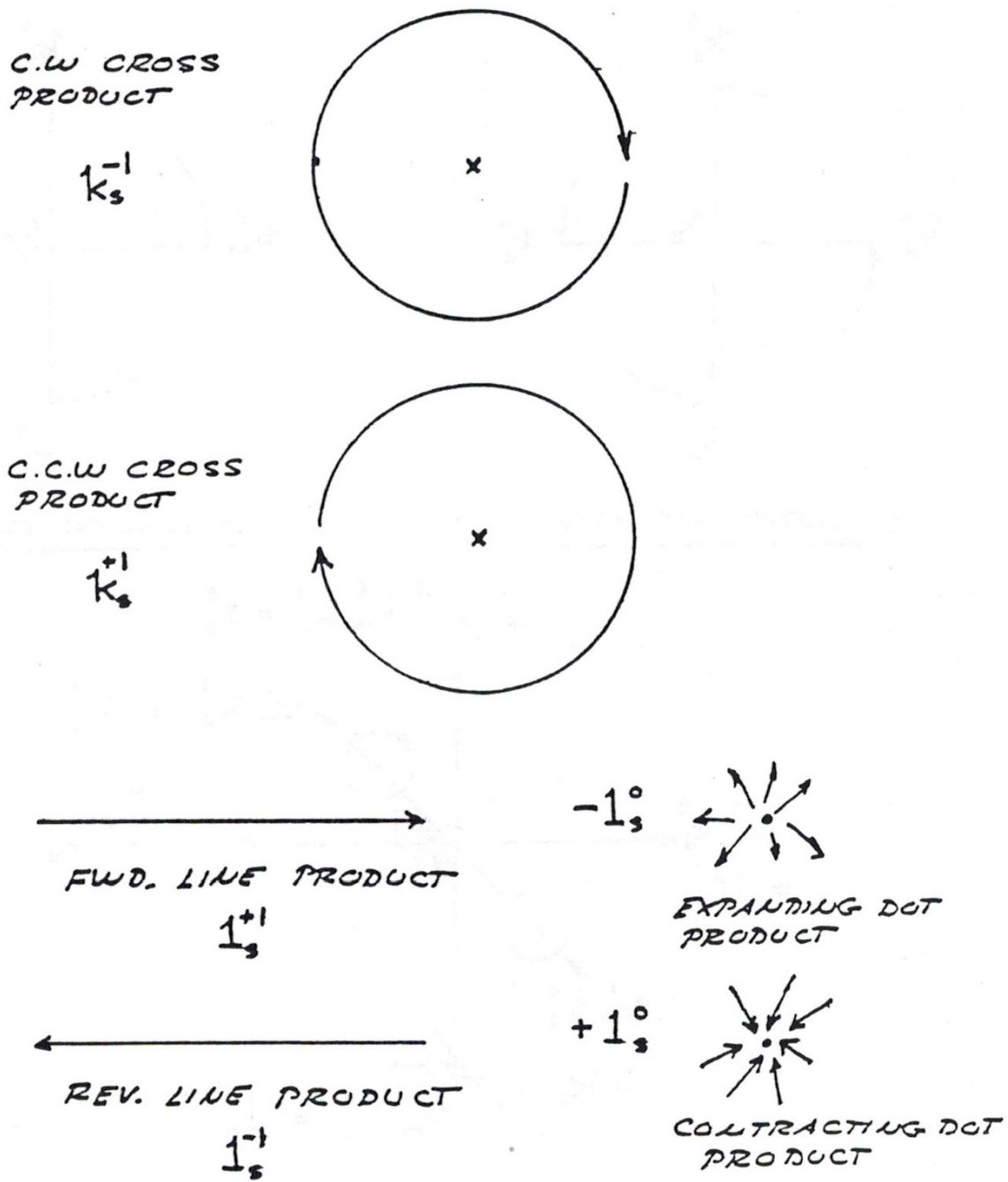


Figure 27. Geometrical representations of the products.

The multiplication of the four distinct inductions encountered thus gives rise to four distinct spatial distributions of electric induction:

- $\Phi_{11}\Psi_{11}$ ; represents that component of the electric induction that is scalar in form; that is, it exhibits no variation with respect to length or distance but is everywhere the same.
- $\Phi_1\Psi_1$ ; represents that component of the electric induction that is longitudinal magneto-dielectric in form; that is, it exhibits variation axially but not transverse to the direction of propagation along the transformer winding's axis.
- $\Phi_1\Psi_{11}$ ; represents that component of the electric induction that is transverse electromagnetic in form and is vertically polarized. This induction exhibits variation transverse, or perpendicular, to the

transformer winding's axis, and passes through the space between the conductor turns in a counter clockwise direction.

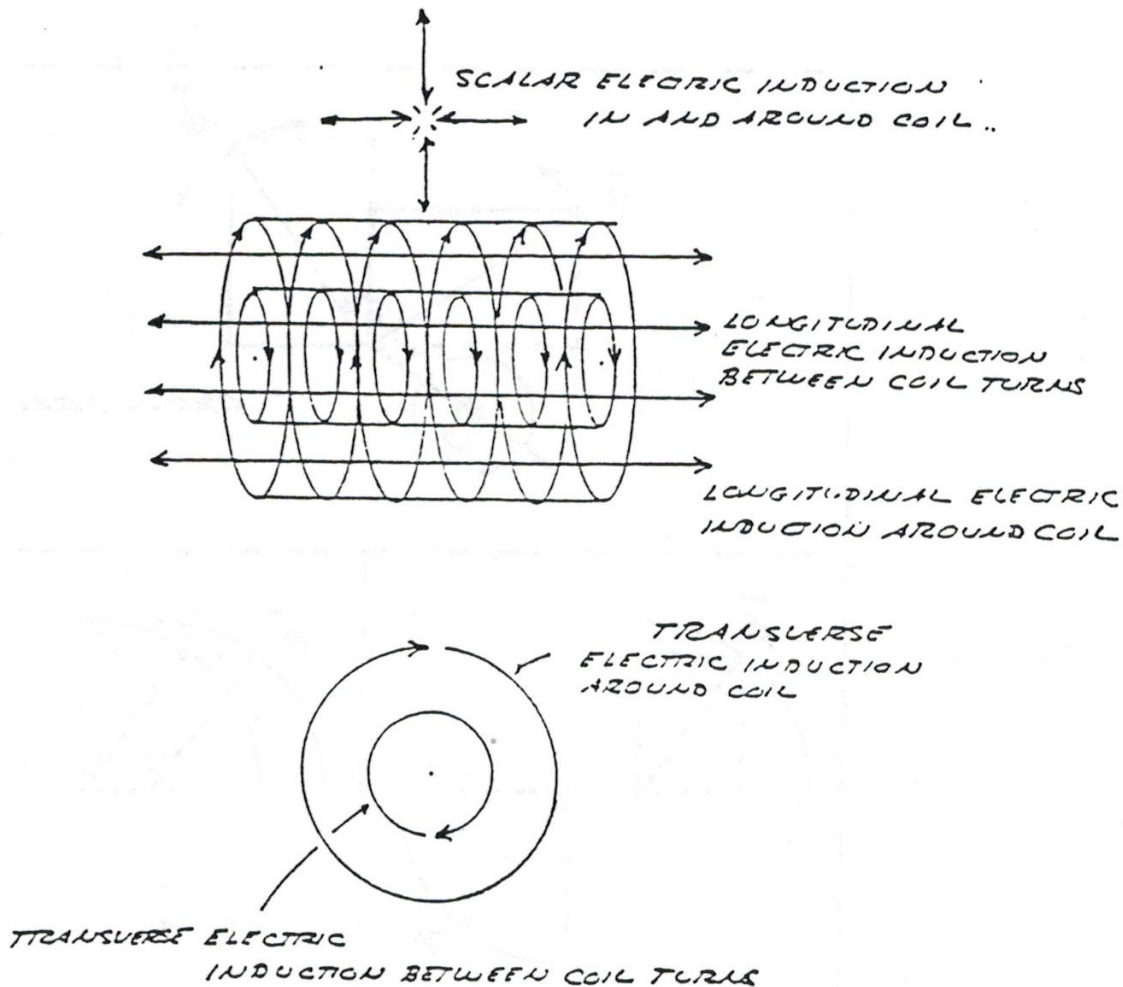
$\Phi_{11}\Psi_1$ ; represents that component of the electric induction that is transverse electromagnetic in form and is horizontally polarized. This induction exhibits variation transverse, or perpendicular, to the transformer winding's axis, and passes thru the space around the outside of the winding in a clockwise direction.

It can be seen that the two transverse inductions represent a pair of travelling waves moving in opposite directions around the winding.

While the scalar induction fills all space surrounding the transformer and does not propagate, it does pulsate in time, and therefore is not scalar in the dimension of time, but represents the true LC oscillation of the transformer as a lumped circuit ( $LC = T^2$ ). Hence, the complete transformer oscillation with spatial variation is given by

$$(LC - u_s^2) = T_0^2 \quad (50)$$

where  $u_s$ , is called the space constant.



**Figure 28. The various inductions and their relation to the transformer winding.**

The transverse component of the electric induction is neutralized if the condition exists that

$$\bar{\Phi}_{11} = (\Phi_1\Psi_1 - \Phi_{11}\Psi_{11}) = zero \quad (51)$$

and therefore

$$\frac{\Psi_{11}}{\Psi_1} = \frac{\Phi_{11}}{\Phi_1} \quad (52)$$

Hence

$$\tan \theta_d = \tan \theta_m \quad (53)$$

This is shown by Figure 29. Alternately, equation (51) becomes

$$\frac{\Phi_1}{\Psi_1} = \frac{\Phi_{11}}{\Psi_{11}} \quad (54)$$

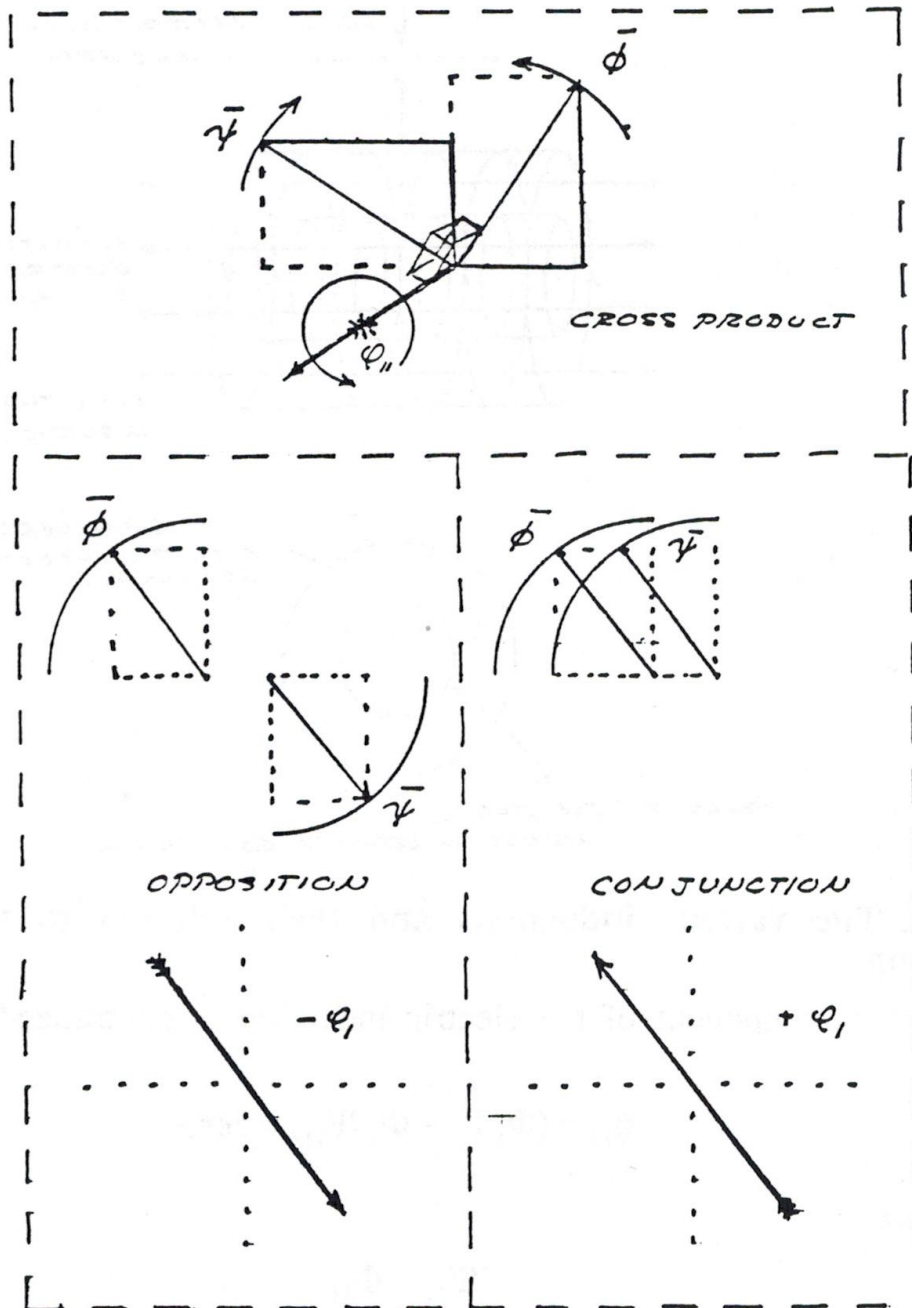


Figure 29. Neutralization of the transverse component of the electric induction.

that is

$$Z_1 = Z_{11} \quad (55)$$

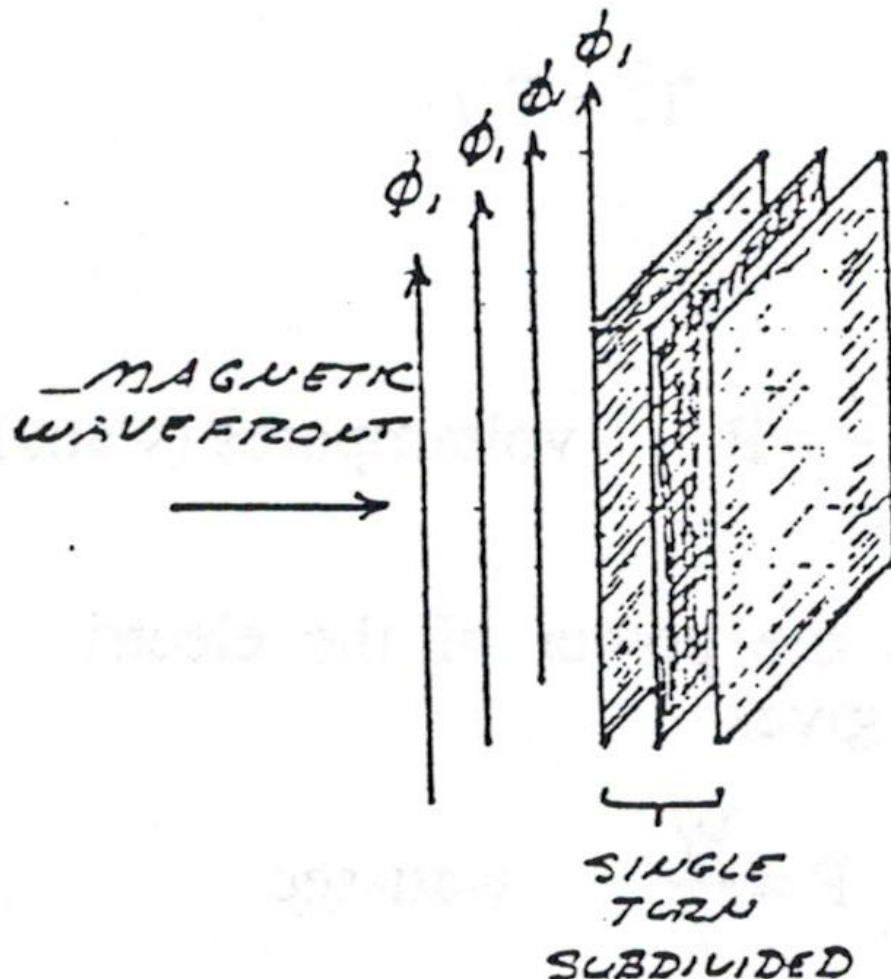
The characteristic impedance of the longitudinal electric induction is equal to the characteristic impedance of the scalar induction. In this case of neutralized TEM the winding may be said to be distortionless, thereby producing an undistorted harmonic waveform in oscillation.

The non-Hertzian component of the electric induction is neutralized if the condition exists that

$$\bar{\Phi}_1 = (\Phi_1 \Psi_1 + 1_s^1 \Phi_{11} \Psi_{11}) = \text{zero} \quad (56)$$

which does not seem possible since the two terms must be complex qualities.

It should be noted that the presence of the conductor material serves to distort the distribution of induction because it excludes the magnetic induction by the production of eddy currents. For this reason the conductor material must be laminated in a fashion similar to that found in transformer cores, Figure 30. Litz wire will serve as lamination in the winding of OC transformers.



**Figure 30. Conductor material laminated in a fashion similar to that found in transformer cores.**

Thickness of conductor sheets must be less than 10% of the skin depth of electronic conduction at operating frequency, or maximum harmonic there of ( $\approx 15F_0$ ). For 1000 K-cycles this is less than 0.001 inch.

## Introduction to Waves in Time

A fundamental quantity of electrical engineering is the energy, often known as the work, of the electric system. This quantity is commonly known as the kilowatt-hour in practical applications, and as the watt-second in theoretical applications. The dimensions of electric energy are given by:

$$W = \Psi\Phi F_0$$

$$= \frac{\Psi\Phi}{T_0} \quad \text{watt-sec} \quad (57)$$

where

W, work or energy in watt-sec

$\Psi$ , total dielectric flux, in lines, contained in the electric system.

$\Phi$ , total magnetic flux, in lines, contained in the electric system.

$F_0$ , frequency of energy pulsation, CPS

$T_0$ , period of energy pulsation, in seconds (often a complex quantity).

The quantities,  $\Psi$  and  $\Phi$ , represent the basic components of electric energy. The time rate of the production or consumption of these fluxes are represented by the relations:

$$E = \frac{\Phi}{t_1} \quad \text{lines per second (volts)} \quad (58)$$

$$I = \frac{\Psi}{t_{11}} \quad \text{lines per second (amperes)} \quad (59)$$

Equation (58) is the law of electromagnetic induction. The complimentary equation (59) is the law of dielectric induction.<sup>12</sup> Combining equation (58) with equation (59) and substituting the time relation

$$2t_1 t_2 = T_1^2 \quad (60a)$$

and

$$T_1^2 = T_0 t \quad (60b)$$

gives

$$E \cdot I = \frac{\Psi\Phi}{T_1^2} = P \quad \text{voltamperes (watts)} \quad (61)$$

This quantity, P, is known as the power of the electric system. Substitution of equation (57) into this equation gives

$$P = \frac{W}{t} \quad \text{watt-sec} \quad (62)$$

Hence, the power of an electric system is the time rate of energy production or consumption. Taking the ratio of equation (58) and equation (59), and substituting

$$\frac{t_1}{t_{11}} = 1, \text{ a dimensionless unit} \quad (63)$$

<sup>1</sup> Introduction to Dielectric and Magnetic Discharges in Electrical Windings, B.S.R.A. No. TE-2, 1982.

<sup>2</sup> Electric Discharges, Waves, and Impulses, Chapter. II, C.P. Steinmetz, McGraw Hill, N.Y., 1914, 2N.D. Ed.

gives

$$\frac{E}{I} = \frac{\Phi}{\Psi} = Z \quad \text{Volts per Ampere (Ohms)} \quad (64)$$

This quantity, Z, is known as the characteristic impedance of the electric system, and expresses the ratio of magnetic flux to dielectric flux within the system.

Since the dimension of time is a fundamental dimension in the important electric quantities – volts, amperes, watts – it is of interest to investigate its properties in relation to electric phenomena, and its representation in electric engineering calculations.

The variations of an electric quantity, U, with respect to time is usually expressed as

$$\frac{d^n U}{dt^n} = \gamma_t^n \quad \text{units/sec}^n \quad (65)$$

This is known as a differential operation. Since the properties of this type of representation are quite abstract and possesses a generality beyond that required for engineering calculations, it is desirable to develop a form of symbolic representation more suited for engineering calculations. One such symbolic expression that has found extensive application in alternating current calculations is:<sup>34</sup>

$$\gamma_t = j\omega \quad \text{radians/sec} \quad (66)$$

where  $j = \sqrt{-1}$  and  $\omega = 2\pi F$ .

The factor j is known as the imaginary unit. The exact nature and origin of this symbol is a mystery to most engineers and explanation as to how an imaginary number represents real phenomenon is seldom given.<sup>5</sup> The demystification of this symbol and the extension of such symbolisms to electric phenomena in general is the object of this portion of the paper.

In the study of electric phenomena, attention is usually focused on only two forms of electric waves. Those of alternating current (AC) and continuous, or direct current (DC). While these forms are representative of the commercial application of electric energy, they only represent special steady state cases. It is known that during switching operations, and in the process of modulation, other forms of electric waves appear due to energy readjustment within the electric system. These waves are known as electric transients. Theoretical understanding of these phenomenon is usually quite vague. These transients give rise to a new pair of waveforms, the oscillating currents (OC) and impulse currents. Thus, in general, the variation of electric quantities with respect to time may be divided into four distinct categories.

- 1) Continuous currents (DC); time function = zero.
- 2) Alternating currents (AC); time function = radians/second.
- 3) Impulse currents (IC); time function = Nepers/second.
- 4) Oscillating currents (OC); time function = Neper-radians/sec.

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<sup>3</sup> Symbolic Representation of Alternating Electric Waves, Eric Dollard, B.S.R.A. No. TE-3, 1985

<sup>4</sup> Theory and Calculation of Alternating Current Phenomena, Chapter. V, C.P. Steinmetz, McGraw Hill, N.Y., 1900 Third Ed.

<sup>5</sup> The Imagery of Algebra, Page 38-35, Alex McFarlane, American Association for the Advancement of Science, Vol. XLI (1891-1894)



The continuous currents represent the continuous time invariant, or scalar, component of the generalized electric wave. The alternating currents represent the continuous cyclic variation component of the wave. The impulse currents represent the discontinuous or acyclic component of the wave. The oscillating currents represent alternating currents that grow or decay with respect to time, thus being a combination of cyclic and acyclic variation.

The continuous current can be resolved into a pair of superimposed impulse currents: One impulse growing in amplitude with respect to time – representing the production of electric energy; the other impulse decaying in amplitude with respect to time – representing the consumption of electric energy. If the two rates are equal and opposite, and the two amplitudes are unequal, the resultant wave is a direct or continuous current. Likewise, an alternating current can be resolved into a pair of superimposed oscillating currents: One oscillation growing in amplitude with respect to time – representing the production of electric energy; the other oscillation decaying in amplitude with respect to time – representing the consumption of electric energy. If the two rates are equal and opposite, and the two amplitudes are unequal, the resulting wave is an alternating current.

### **Representation of Alternating Electric Waves**

The method most commonly employed for the representation of alternating electric waves is known as the graphical method of representation. Other names for this method are the phasor diagram and vector diagram. Despite the apparent simplicity of this form of representation it often becomes too complicated for application to practical situations involving many quantities.

Another common method is the trigonometric form of representation. This method, while being more suited for calculating purposes, is also complex. Additionally, the trigonometric functions possess a somewhat mystical character in the minds of most engineers<sup>6</sup> and require the use of tables or computing apparatus for their solutions.

The trigonometric functions do not completely represent the alternating electric wave since the functions sine and cosine represent horizontal and vertical projections, respectively, of the wave. The sine projection is known as the alternating current; however both the sine and cosine functions combined together represent the alternating power. Since the alternating electric wave is a quantity of constant amplitude rotating at a constant rate, the alternating electric wave may be called a rotating direct current. The trigonometric functions thus only represent shadows of the complete wave of electric energy,<sup>7</sup> that is, the current or voltage.

The primary drawback of both the graphical and trigonometric methods is that they serve as misrepresentations of the electric waves under investigation. These representations are actually representations of two-dimensional space, that is, a plane surface. The concept of a 'surface of time' is of little value for the theoretical investigation of electric waves since time is an axial dimension, typically given as points on a line.

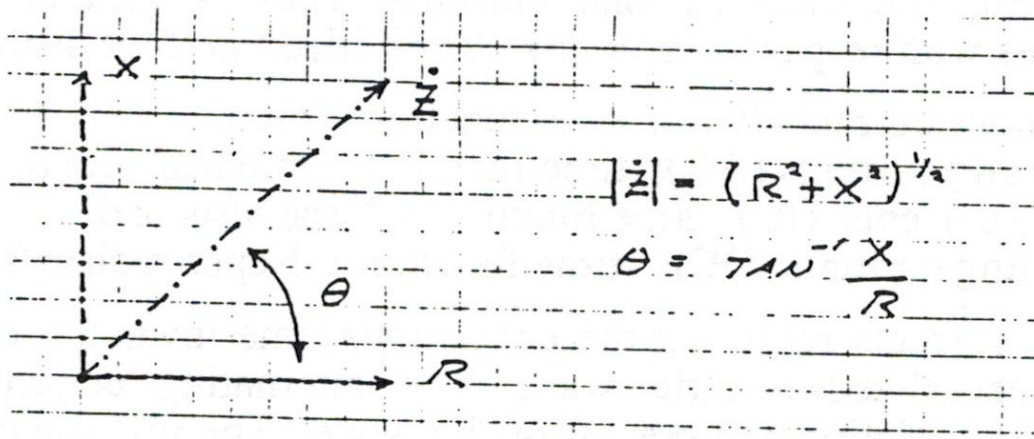
Consider the addition of electric resistance,  $R$  in ohms, and magnetic inductive reactance,  $X$ , in Henrys per second,  $(\gamma_t) L$ . The usual representation is shown in Figure 31.

The resistance of an electric system is, however a property of the system that is frequency, or time, invariant. Thus resistance is a scalar quantity independent of the time rate of variation of the applied electric wave. Resistance then is not a vector quantity as portrayed in Figure 31.

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<sup>6</sup> The Imagery of Algebra, Page 38-35, Alex McFarlane, American Association for the Advancement of Science, Vol. XLI (1891-1894)

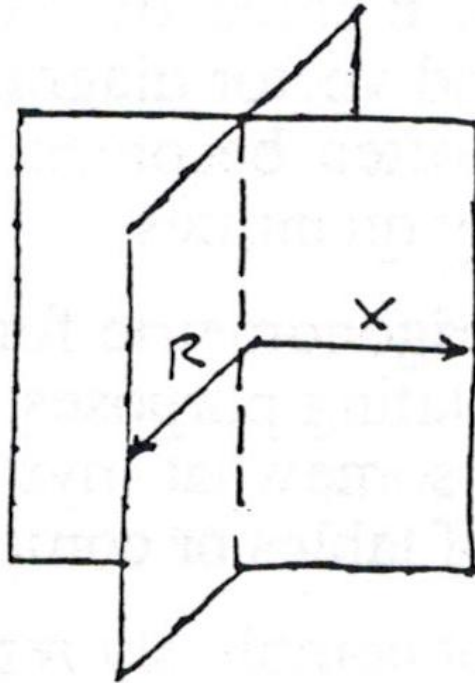
<sup>7</sup> Principles of the Algebra of Physics, A. McFarlane, American Association for the Advancement of Science, Vol. XL (1891-1894), Page 77



**Figure 31. The addition R and X.**

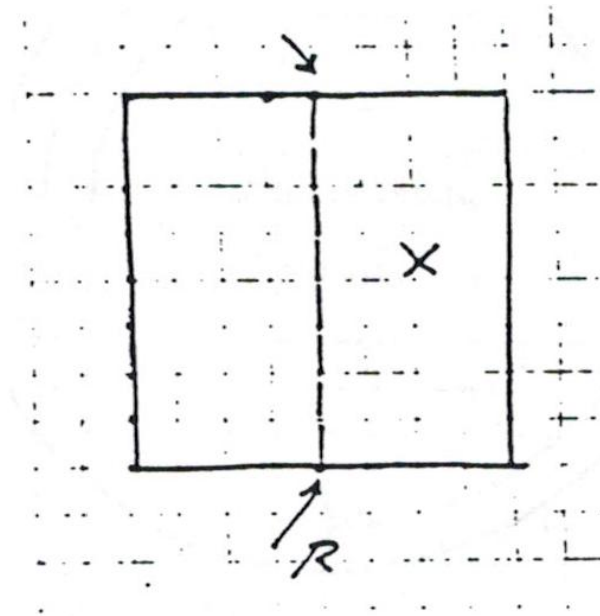
The reactance of an electric system is its magnetic inductance,  $L$ , multiplied by the time rate of variation of the applied electric wave,  $(\gamma_t)$ , and by equation (66) it is a time dependent quantity associated with a quadrature versor. Thus reactance is also not a vector quantity, hence the addition of resistance and reactance is not properly represented by a vector diagram such as Figure 31. The graphical method then really serves as a form of computing apparatus for calculating purposes and is incapable of providing the proper representation of the electric wave required for theoretical investigation.

An analogous representation is two perpendicular planes in space, Figure 32, containing the vectors of Figure 31.



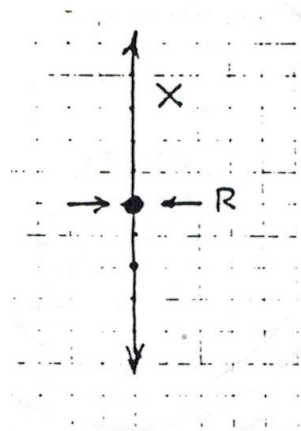
**Figure 32. Resistance and reactance vectors on intersecting planes.**

If the viewer faces one of the two planes straight on, plane X for example, then the quadrature plane, R, having no thickness by definition of a plane surface, disappears from view.



**Figure 33. View of plane X – straight on (Plane R is viewed edgewise).**

Going one step further, let the line, R, be reduced to a single point, the point being the thickness of a plane of infinitesimal area, and let the plane, X, be viewed edgewise reducing it to a single line, as shown in figure (34).



**Figure 34. Plane X viewed edgewise with R reduced to a point.**

The result is a single point, R, in the center of a line, X. Hence, the point, R, represents the resistance of the electric system, and the amount of resistance is given by the 'weight' of the point. The line, X, represents the reactance of the electric system, and the amount of reactance is given by the length of this line.

Despite its somewhat contrived nature of the representation of Figure 34, it is more representative of the electric phenomenon than is Figure 31.

### **Symbolic Representation of Alternating Electric Waves**

Since the aforementioned methods are only usable for situations involving few quantities and are misrepresentative of the electric relations to which they are applied, a method is therefore desirable that is capable of extensive calculation while retaining a basic simple form representative of the wave.

It is well known that the quadrature angle,  $90^0$  or  $\pi/2$  radians, represents a fundamental relation in AC theory. Since  $90^0$  is one fourth of a complete cycle, the complete alternating electric wave is represented in its entirety by four quadrants of rotation. These rotations are represented by Figures 35 thru 37.<sup>8</sup>

### List of Symbols

- A, Component of complex quantity, in percent
- B, Component of complex quantity, in percent
- B, Electric susceptance in MHOs or farads per second
- C, Component of complex quantity, in percent
- C, Dielectric inductance, in farads
- E, EMF of magnetic induction, lines per second , EMF complex versor quantity, in volts
- $\dot{E}$ , Frequency, in cycles per second
- G, Electric conductance in MHOs
- H, Electric receptance in negative OHMs
- I, MMF of dielectric induction, lines per second
- $\dot{I}$ , MMF complex versor quantity, in amperes
- L, Magnetic inductance, in Henrys
- N, Number of divisions of a complete cycle
- P, Electric power, in voltamperes or watts
- R, Electric resistance, in OHMs
- S, Electric acceptance, in negative MHOs
- T, Period, in seconds per cycle
- U, General electric quantity
- W, Electric energy
- X, Electric reactance, in OHMs or Henrys per second
- $\dot{Y}$ , Electric admittance, complex versor quantity in MHOs
- Z Electric impedance, complex versor quantity in OHMs
  
- a, Power factor in percent total wave
- b, Induction factor in percent total wave
- d, Magnification factor in percent total wave
- e, Basis of natural logarithms
- f, Function of ( )
- h, Negative versor Operator
- i, Arbitrary imaginary number
- j, Scalar or imaginary number
- l, Scalar or imaginary number
- k, Positive versor operator
- l, length, in centimeters
- m, Mass, in grams
- n, Angle of cyclic divisions traversed
- t, time variable, in seconds
- u, Imaginary frequency in nepers per second
- $\alpha$ , component of complex quantity
- $\beta$ , component of complex quantity
- $\gamma$ , Function of time, wave factor
- $\pi$ , 3.14159265, ratio of circumference to diameter
- $\theta$ , Time angle variable, in radians

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<sup>8</sup> Symbolic Representation of Alternating Electric Waves, Eric Dollard, B.S.R.A. No. TE-3, 1985

$\Phi$ , Magnetic flux, in total lines  
 $\psi$ , Dielectric flux, in total lines

## References

- [1] Introduction to Dielectric and Magnetic Discharges in Electrical Windings, B.S.R.A. No. TE-2, 1982.
- [2] Electric Discharges, Waves, and Impulses, Chpt. II, C.P. Steinmetz, McGraw Hill, N.Y., 1914, 2N.D. Ed.
- [3] Symbolic Representation of Alternating Electric Waves, Eric Dollard, B.S.R.A. No. TE-3, 1985
- [4] Theory and Calculation of Alternating Current Phenomena, Chapter. V, C.P. Steinmetz, McGraw Hill, N.Y., 1900 Third Ed.
- [5] & [6] The Imagery of Algebra, Page 38-35, Alex McFarlane, American Association for the Advancement of Science, Vol. XLI (1891-1894)
- [7] Principles of the Algebra of Physics, A. McFarlane, American Association for the Advancement of Science, Vol. XL (1891-1894), Page 77
- [8] Same as Reference [3]
- [9] Reference [4] Page 36, Paragraph 26
- [10] Reference [3]
- [11] Reference [5] Page 41
- [12] Reference [4] Page 478
- [13] Reference [5] Page 43-45
- [14] Reference [4] Page 395
- [15] Reference [4] Chpt. XXI & XXII
- [16] Reference (2) Chpt. 1
- [17] Electromagnetic Theory, Oliver Heaviside, Chelsea Press.  
Theory and Calculation of Transient Waves and Electric Oscillations,  
“Transients in Time and Space,” C.P. Steinmetz, McGraw Hill, 1910, Third Ed.
- [18] “Special Cases” in Steinmetz [17]
- [19] Reference [5] Page 40, 47
- [20] Impedance. Angular Velocities and Frequencies of Oscillating Current Circuits, A.E. Kennelly, Institute of Radio Engineers, Nov. 3, 1913
- [21] Vector Power in AC Circuits, A.E. Kennelly, Proc. AIEE, June 29, 1910

The source of this paper by Eric Dollard was the Proceedings of the 1986 International Tesla Society Symposium, pp 2-25 → 2-82. This copy was truncated on page 2-63 to reduce its size to a manageable level and because the remainder of the article is so mathematical its missing contents may be of interest to a limited readership.