ANALYSIS OF WIRELESS POWER TRANSMISSION

BY

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ATTESTATION

I, ABOYI PETER (99/9304EE) hereby declare that this project titled, "Analysis of Wireless Power Transmission" was carried out by me in the Department of Electrical/Computer Engineering under the supervision of Dr. E.N. Onwuka. All information utilized and their sources have been duly acknowledged.

Aboyi Peter	7/12/05 Date

CERTIFICATION

I hereby certify that this work has been supervised and meets part of the requirement for the Award of a Bachelors of Engineering (B.Eng) Degree in the Department of Electrical/Computer Engineering, Federal University of Technology, Minna, Niger State.

.... 07/12/05

Dr. E.N. Onwuka — Date

Project Supervisor

....

Engr. M.D. Abdullahi — Date

Head of Department

....

External Examiner — Date

DEDICATION

This work is dedicated first and foremost to God Almighty, to my parents, Mr. and Mrs. Clement E. Aboyi and to my brothers and sisters.

ACKNOWLEDGEMENT

My foremost gratitude goes to God Almighty for His guidance and protection through all these years, especially during the course of my studies.

My special thanks goes to my parents, Mr. and Mrs. Clement E. Aboyi for their love and support. Also to my brothers and sisters I say a big "thank you".

Many thanks to my project supervisor, Dr. E.N. Onwuka for her guidance and insightful contributions during the course of my project work.

I also want to use this opportunity to appreciate my friends and colleagues who have all contributed through sharing of their ideas with me to make this project work a success.

ABSTRACT

Transmission of power over long distances, across difficult terrain, and under environmentally unfavourable conditions had been capital intensive, dangerous and a source of power loss to energy generation and transmission through the use of cables.

Ways of checkmating or reducing the above have been of major interest in the last century. Several researches have been carried out to curb this trend and Wireless Power Transmission presents a viable solution to these problems.

Wireless Power Transmission involves the transmission of electrical energy from generation point to the consumer end without any physical connection between them.

This project takes a look at the existing electromagnetic laws, analyses them and supplies equations that prove that WPT is realized due to the presence of longitudinal electromagnetic scalar waves.

TABLE OF CONTENTS

CHAPTER FIVE - CONCLUSIONS AND RECOMMENDATIONS

CHAPTER ONE

1.0 INTRODUCTION

1.1 PREAMBLE

Technological development has unfolded new faces in many facets of engineering and sciences. Man has broken the barrier of distance communication with the invention of the telephone. Added to this, technology has opened a space to enable data, video and sound transmission without physical cabling.

Wireless data, video and sound transmission has sown a seed of possibility for transmission of power without cables. And to this end, researchers has plunged into the quest of making transmission of power without cables a reality.

Wireless power transmission is the transmission of electricity without physical cables. The quest has brought big organizations such as the American Space Agency to invest both financial and mental resources towards remote powering of heavy space machinery. The Siemen Engineering and other independent agencies are also undertaking research

The year 1888 was marked by the demonstration of Wireless Power Transmission (WPT) pulsed powered generated at 500MHz. Since then, only a few demonstrations and feasibility studies have been published at discrete time intervals. Among these, the most important is a feasibility study reported by a French research group in 1977, a Terrestrial Wireless Power Transmission Project. The aim of this project was to deliver a 10kW load from a grid system through AC – DC – microwave – DC – AC conversion to a 0.7km distance, a small tourist spot across a mountain in La re Union Island, an over sea territory of France. The project was termed as Grand Bassin Wireless Power Transmission Model after the name of the tourist village

A large part of the project is anchored on the physics and engineering of electromagnetism.

The project will enable us to review some of the classical electromagnetic equations.

Wireless power transmission can be implemented and realized by two basic methods:

1. Microwave power transmission
2. Transmission through the ionosphere

The post-war history of research on free-space power transmission is well documented by William C. Brown, who was a pioneer of practical microwave power transmission. It was he who first succeeded in demonstrating a microwave powered helicopter in 1964 using 2.45GHz in the frequency range of (2.4-2.5GHz) reserved for the ISM (Industrial Scientific and Medical) application of radio waves. A power conversion device from microwave to DC, called a rectenna, was invented and used for the microwave-powered helicopter [1].

The idea behind microwave power transmission is that Solar Power Satellite (SPS) consisting of panels of solar cells stretching many square kilometers in space converts the electricity penetrated from light into radio waves and beam them wirelessly to the earth. If the largest conceivable space power station was built and operated 24 hours a day all year round, it could produce the equivalent output of ten million kilowatt-class nuclear power stations; which is rather impressive and in 1983, a Japanese team succeeded in a first-ever experiment to transmit microwave energy through the Ionosphere using two rockets. In 1995, a team led by Prof. Nobuyuki Kaya of Kobe University managed to transmit electricity from the ground to an airship in the sky. Japanese scientists say that if microwaves carrying electric power can be beamed uniformly over the earth, they could be used as a power supply for mobile devices such as cell phones. The power of microwaves would have to be weaker than the regulatory standard to prevent any physical harm to people from the e3lectromagnetic rays. The mobile phones now in use require up to approximately 800mW of power. To receive microwave energy, they would need an antenna about 25-30cm square. As it would not be feasible for a mobile handset to itself serve as the antenna, the options would be to reduce the power consumption or devise a large antenna [1].

The fundamentals are already in place, but the Japanese say that the problem with microwave power transmission is the exorbitant cost of constructing an SPS around 2.4 trillion yen in total as a rough estimate.

The reported works does not reveal any design method or complete information about terrestrial Wireless Power Transmission and this has restricted further advancement in the research on WPT.

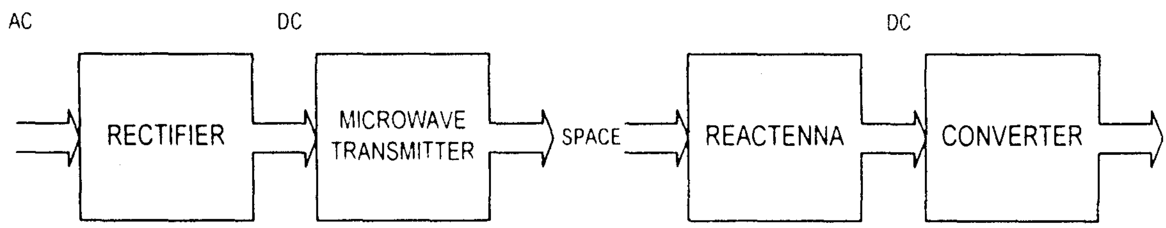

Fig. 1.0: Block Diagram of Microwave Wireless Power Transmission

The second method of transmitting power through space is the Tesla System of Wireless Power Transmission, in which a resonating cavity is activated with a high pulse wave which radiates EM wave from the cavity , there by causing the ionized gas transfer EM wave.

1.2 ADVANTAGES OF WPT

1. For Third World countries, where terrain and topology are barriers impeding against installation of Heavy sub-station and pylons to run high tension cables, this gap is bridged.
2. An implementation of wireless system for power transmission will involve rural areas in active production
3. It will bring the reality of unmanned aircraft to its full capability
4. Small electronic devices with small voltage requirements can be remotely powered
5. In a special case, it can be fashioned to serve as air defense munitions.

1.3 PROJECT OBJECTIVES

1. To review the classical electromagnetic laws
2. To show that there exists a longitudinal electromagnetic scalar wave
3. To also show that the consequence of longitudinal electromagnetic wave supports transmission of current in wave-like form

1.4 SCOPE

The scope of this work is limited to the electromagnetics as it applies to Wireless Power Transmission and the laws that justify its feasibility.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ENERGY NEED AND TRANSMISSION

One of the world's most important needs is energy and man has scrapped energy from wood, built machines capable of exploring fossil fuels and the best of engineering minds stream energy from the electron which is the bedrock of electrical engineering.

The world not only awaits an alternative energy source to fossil fuel but the ease of energy distribution to end users.

The field of electrical power has seen various changes starting from hydroelectric power (HEP) generation to nuclear power generation and all this has relied on cables for transmission of power to the final users. As man expands in mental coast, new engineering capabilities are given birth to and the reality of wireless power transmission is a consequence of man's mental coast, quest and need for a wireless grid systems.

Before major breakthroughs in engineering are made, they are ushered in by thesis and anti-thesis. The Bulk of these papers are centralized on electromagnetism and the argument on longitudinal electromagnetic scalar (LES) wave, Herztian wave and how this principle supports feasibility of wireless power transmission [12].

2.2 BRIEF RESEARCH HISTORY IN RELATION TO WIRELESS POWER TRANSMISSION.

The major events that were registered in wireless power transmission occurred in the era of electromagnetism and the time when Maxwell's equation was yet to be accepted. The research originated with its basics,lying in the fundamentals of electricity and magnetism or more preferably in the connection between the two as established by Hans Christian Orsted (1777-1851). Following this André-Marie Ampère (1775-1836) formulated the law of electromagnetism (Ampère's law) that describes mathematically the magnetic force between two circuits.

In 1804 Jean-Baptiste Biot (1774-1862) showed that the terrestrial magnetic field does not vary appreciably with altitude. In 1815 Augustin-Jean Fresnel (1788-1827) became involved in optics and pioneered in establishing the wave theory of light. Beginning in 1830, Karl Friedrich Gauss (1777-1855) worked closely with Weber (1804-1891). They organized a worldwide system of stations for systematic observations of terrestrial magnetism. The most important result of their work in electromagnetism was the development, by others, of telegraphy. Michael Faraday (1791-1867), Joseph Henry (1799-1878) Heinrich F.E. Lenz (1804-1865) were three scientists who studied and put forward the concepts of Magnetic induction.

Then came in the field the legendary figure, James Clerk Maxwell with the seminal mathematical synthesis of all the previous experimental work on electricity and magnetism. His main predictions were:

- ✓ That waves of electromagnetism should exist and be able to travel in any medium, the hypothetical ether included.
- ✓ That their speed could be deduced form purely electrical measurements.
- ✓ That given the close agreement between the speed of light determined in Kohlsrauch and Weber's experiment, and the speed predicted for Electromagnetic (EM) waves, light itself was an EM wave [5].

Maxwell's equations predicting the existence of electromagnetic radiation propagating at the speed of light were made public in 1865; in 1888 Hertz had demonstrated generation of electromagnetic waves, and that their properties were similar to those of light. Before the start of the twentieth century, many of the concepts now familiar in microwaves had been developed [6]: the list includes the cylindrical parabolic reflector, dielectric lens, microwave absorbers, the cavity radiator, the radiating iris and the pyramidal electromagnetic horn. Round, square and rectangular waveguides were used, with experimental development anticipating for several years Rayleigh's 1896 theoretical solution for waveguide modes.

Many microwave components in use were quasi-optical - a term first introduced by Oliver Lodge [4] He showed that EM waves could be transmitted along wires, but failed to show that they propagate in free space. Righi in 1897 published a treatise on microwave optics. Heinrich Rudolf Hertz (1847-1894) was successful and generated decimeter waves (wavelength of 66 cm); other Copost-Hertzian pre-1900 experimenters used wavelengths well into the short cm-wave region, with Bose in Calcutta [7] and Lebedew in Moscow independently performing experiments at wavelengths as short as 5 and 6 mm. Clearly Lodge's great reputation inspired those who either had his lecture or read his book. These include not only J.C. Bose and Guglielmo Marconi (1874-1937) but also Branly, Zehnder, Popov and even Rutherford. Marconi experimented with 25 cm-waves. In 1897 using a pair of parabolic cylinder reflectors separated by four miles he succeeded in convincing the British Post Office that "wireless" telegraphy was possible.

2.3 HISTORIC MODIFICATION OF MAXWELL'S LAWS

In the 1860s James Clerk Maxwell combined electrical fields and magnetic fields into a common model, and launched the present system of classical electrodynamics still being taught today, though in a more limited form. In his 1865 paper, Maxwell specifically lists his 20 equations and his 20 unknowns. His work was strongly contested, because few of the three dozen electrical scientists on earth at the time were capable in quaternion mathematics. Before he died in 1879, Maxwell himself had started rewriting his 1873 book for a second edition, with simpler equations.

In the 1880s Oliver Heaviside — a brilliant but self-taught scientist who never attended university — played a major role in converting (reducing) Maxwell's equations to what today is vector algebra, after Maxwell was deceased. Heaviside detested potentials, and stated that they should be "removed from the theory." The reduction work by Heaviside, Gibbs, and Hertz resulted in the modern four vector equations in some four unknowns. These are taught — along with a further truncation by Lorentz — in every university as "Maxwell's equations" [8].

They are in fact Heaviside's equations, further truncated by Lorentz symmetrical re-gauging. Before Lorentz regauging, the Maxwell-Heaviside equations are still difficult to solve analytically. Numerical methods are often required. This posed a calculation nightmare back in the mid 1800s, before the advent of modern computers and automated calculations. Today, numerical methods can be accommodated much more easily, using computers

To reduce the difficulty in solving the Maxwell-Heaviside equations and largely eliminate the need for laborious numerical methods, simpler "Maxwellian" equations were sought.

Lorentz further reduced the Maxwell-Heaviside equations by "symmetrically regauging" them [2]. This symmetry constrains the modern gauge freedom principle, whereby the potential field and the potential energy of an EM system can be freely changed at will. In those systems covered by the reduced theory, the potential energy can still be changed. But it can only be changed in such a manner that the two new free fields produced are equal and opposite. Hence the new fields "fight each other to a draw", changing the internal stress of the system but doing no external work (which requires a net nonzero force field). This has the effect of bottling up any excess EM field energy that might be received by the system from its environment, into a force-free stress potential inside the system the system can be freely energized by the environment to stress the system, but it cannot use the free stress potential energy to perform any external work. To perform work, such a system has to have an additional input of energy where a net force field also emerges.

In short, the system has to additionally be asymmetrically regauged so as to result in a net force — which means the extra asymmetrical regauging energy has to be input by the system operator or experimenter, since the Lorentz-regauged system itself prohibits the environment from furnishing such "energy with a net field".

2.4 THE ENGINEERING AND EXPERIMENT IN WPT.

The pre-world war physics of electromagnetism was much of the etheric principles and the fundamental science behind Wireless power transmission was built on three basic principles.

- Transmission along the earth

- Propagation through terrestrial resonant
- Conduction through the ionosphere.

Dr Tesla approach was to build a cavity resonator which will be place high above earth surface and the base of the pole will be earthed .As the cavity resonator is excited the charge activation in the atmosphere relative to the earth terminal will result in charge imbalance there by acting like a spherical resonator as a result the space will be able transmits current in wave like form.

Today it has been proven that electrical energy can be propagated around the world between the surface of the Earth and the ionosphere at extreme low frequencies in what is known as the Schumann Cavity. The Schumann cavity surrounds the Earth between ground level and extends upward to a maximum 80 kilometers.

Experiments to date have shown that electromagnetic waves of extreme low frequencies in the range of 8 Hz, the fundamental Schumann Resonance frequency, propagate with little attenuation around the planet within the Schumann Cavity.

Knowing that a resonant cavity can be excited and that power can be delivered to that cavity similar to the methods used in microwave ovens for home use, it should be possible to resonate and deliver power via the Schumann Cavity to any point on Earth. This will result in practical wireless transmission of electrical power.

2.5 WIRELESS POWER TRANSFER MILESTONE

Despite the fact that almost every book mentions Marconi (1874-1937) as the inventor of radio, the only thing Marconi did seems to be nothing more than reproducing apparition Tesla (1856-1943) had registered years ago.

1893: Tesla carries his first experiments with high frequency electric currents – the first demonstration of wireless communication. In his articles and lectures Tesla describes his first radio apparatus in detail.

1895: Marconi presents a radio device in London, claiming it as his invention. However, the device is the same as what Tesla had already described in his articles. Later on, Marconi will claim that he had not read Tesla's articles, despite that they were translated in many languages very quickly.

1897: First patent registered by Nikola Tesla on radio communication, Patent No. 645576.

1898: Tesla constructs the first remotely controlled boat and demonstrates it in New York. He registers this invention under Patent No. 613809.

1899: Tesla builds a large radio station in Colorado Springs, USA and starts his experiments.

1901: Tesla begins the construction of a huge radio station in Wanderclyffe, near New York. This station, Tesla's biggest dream, would transmit electric signals and energy to the whole planet. It was never completed, due to lack of financial means. The same year, Marconi's great triumph was in succeeding to receive signals transmitted across the Atlantic Ocean despite the general opinion that the curvature of the Earth would limit the range of communication by electromagnetic waves. This sensational achievement was the start of the vast development of radio communication and broadcasting. The world was impressed, but did not learn that Marconi was only using Tesla's Patent No. 645576 (1897).

1917: In an article in "Electrical Experimenter" Tesla announces a system to locate metallic Objects through radio signal reflection. This is the beginning of the radar.

2.6 MODERN DAY RESEARCHERS IN WPT

2.6.1 NON HERTZIAN WAVE

The term non-hertzian wave was used in relation to the Colorado spring experiment in which Tesla experimented on his systems for wireless power transmission. Amongst present day researcher Col. Tom Bearden has pioneer allot of researcher to unveil what Dr Tesla meant by the term non-hertzian wave. in the course of his research give birth to what is refer to as motionless electromagnetic generator (MEG) which he claims uses energy from the vacuum .The fundamental principle upon which the MEG and wireless power transmission works is on the controversial longitudinal electromagnetic scalar wave.

March 26 2002 recorded a silent history, a day which the motionless electromagnetic generator was patent with US patent agency. As we speak there is subscription for the product online at www.chenerie.org .The MEG was a proof to other researchers that what Tesla meant by non-hertzian was actually longitudinal electromagnetic scalar wave [13].

Another researcher justifying the existence of longitudinal electromagnetic scalar wave is Prof C. Meyl who complain on the application in relation to warhead and the likely the disasters when fashion into warhead. The analysis on longitudinal electromagnetic wave will be discussed in detail in the next chapter.

CHAPTER THREE

3.0 MATHEMATICAL ANALYSIS OF THE WIRELESS POWER TRANSMISSION PHENOMENON

3.1 ELECTROMAGNETIC EQUATIONS

The present day classical electrodynamic equations are consequence of Heaviside modifications on the original Maxwell equation. Heaviside also thought that scalar fields present in the original Maxwell equations were too complex and had less practical significance in relation to explaining material phenomenon which were based on electromagnetic principles, and therefore deemed it wise to eliminate the scalar field from the original equation.

One major limitation Maxwell encountered was the representation of the electromagnetic equation in Biquaternion form and calculus, and this was because at that time, large number of scientists and engineers were not familiar with the Biquaternion Calculus. So Maxwell had to revisit twenty published electromagnetic equations and after his death, Heaviside helped in modifying the equations to what we now have as the classical electrodynamic equations [8].

The argument as to what Tesla meant by non-Hertzian wave is built on what is known as Longitudinal Electromagnetic Scalar Wave (Leswave).

The reality of a wireless power transmission lies on the reality of longitudinal electromagnetic scalar wave. What seems missing is a consistent mathematical theory that offers a rational explanation for this important technology.

3.2 REVIEW OF ELECTRODYNAMIC EQUATIONS

Consider a homogenous medium of constant dielectricity ε and constant permeability μ, which is free of electric sources of current. Then all electromagnetic processes are governed by homogenous Maxwell equation [2].

(abbreviation $\delta t = \delta / \delta t$)

$$\nabla \times E = -\mu \partial_t H \quad (1)$$

$$\nabla . E = 0 \quad (2)$$

$$\nabla \times H = \varepsilon_0 \partial_t E \quad (3)$$

$$\nabla . H = 0 \quad (4)$$

From these equations, it can be derived by standard processes that both electric and magnetic vector E and H fulfills the wave equation.

$$\sigma \partial_t E + \mu_0 \varepsilon_0 \partial_t^2 E = \nabla^2 E \quad (5)$$

$$\sigma \partial_t H + \mu_0 \varepsilon_0 \partial_t^2 E = \nabla^2 H \quad (6)$$

(5)–(6): Helmholtz Equation

3.2 SEVENTH FIELD COMPONENT

From the standard Maxwell equations (Heaviside modified version), if the scalar potential that was eliminated is added, the seventh field component materializes [13]

Recall Electric Field Equation . $-\nabla \varphi - \partial A / \partial t = E$ (7)

$\nabla \times A = B$ Magnetic field (8)

Such that

$$-\lambda\varepsilon_0\mu\partial\varphi - \nabla.A = S \qquad (9)$$

for S = 0, λ = 0, the above equation transforms to

$$\nabla.A = 0$$

Recall that the transformation that results to the above equation is derived from the grad or Div of the magnetic potential A by Biquarternion Calculus.

From normal wave equation

$$\left.\begin{aligned} &\nabla^2 = \nabla.\nabla \\ &\nabla = \partial/\partial_x \text{ for x - dimension} \\ &\nabla = \partial/\partial_t.\partial/\partial_x \\ &\nabla = 1/c.\partial/\partial_t \end{aligned}\right\}$$

$$\nabla.\nabla = 1/c^2.\partial^2/\partial_t^2$$

$$\nabla^2 = 1/c^2.\partial_t^2 \qquad \text{From classical dimensional analysis}$$

For Biquarternion Calculus, the transformations are:

$A(a_0, a_1, a_2, a_3) \rightarrow a_0$ is the time component and a_1, a_2, a_3 are the spatial vectors.

$$\therefore A + B = (a_0 + b_0 + i[A \cdot B])$$

$$AB = a_0b_0 - A.B + 1[b_0A + a_0B + A \times B]$$

$$A^* = -a_0 + i.A$$

The biquarternion gradients are given as

$$\nabla = i/c.\partial_t + i.A \qquad (I)$$

$$A = i/c.\varphi + i.A \qquad (II)$$

$j = ic\rho + i.A$ (III)

$F = \nabla A = S + i.[E/(ic) + B]$ (IV)

Maxwell/Heaviside . $\nabla^* F = \nabla^* \nabla A$

$= \mu_0 J$

Field wave equation. $\mu \nabla J = \nabla \nabla^* F$

Power/ Force Theorem. $\mu_0 F = \mu_0 JF$

$= (\nabla^* F).F$

$= \nabla^* \nabla A(\nabla A)$

The wave function operator in Biquarternion form

$$\left.\begin{aligned} \nabla\nabla &= 1/c^2\partial_t^2 + \nabla^2 \\ \nabla\nabla^* &= 1/c^2\partial_t^2 - \nabla^2 \end{aligned}\right\} \quad 10$$

Note that the scalar constant, $\lambda_0 = 1$ in the Biquarternion but is inserted in the full equation.

The official theory of electrodynamics presumes that $S = 0$ always and this is called the guage condition. When $\lambda_0 = 0$ and $S = 0$, this is known as the Coulomb gauge condition and when $\lambda_0 = 1$ and $S = 0$. This is known as the Lorentzo gauge condition. Gauge conditions however are based on the the arbitualness of electromagnetic potential.

In order to predict possible electro scalar field effect, the scalar field potential is included to obtain a generalized form of electromagnetic equation.

The following decoupled non-homogenous wave equations (ρ is charge density, I is current density) [7].

$$\mu h_0 \varepsilon_0 \partial^2\varphi/\partial t^2 + \nabla^2\varphi = \rho/\varepsilon_0 \quad (11)$$

$$\varepsilon_0\mu.\partial^2 A/\partial t^2 + \nabla + \nabla x A - 1/\lambda.\ \nabla\nabla.A = \mu_0 J \qquad (12)$$

Together with two extra vector identities ($\nabla.\nabla x A = 0$) and ($\nabla x \nabla\varphi=0$) can be written into the Maxwell/Heaviside field equations with extra scalar field terms.

$\nabla.E - \partial_S/\partial_t = \rho/\varepsilon$ Generalized Gauss Law (13)

$\nabla x E = -\partial B/\partial_t$ Faraday's Law (14)

$\nabla x B + 1/\lambda.\ \nabla_S - \varepsilon_0\mu.\partial E/\partial_t = \mu_0 J$ Generalized Ampere's Law (15)

The generalized field equations are gauge invariant, since it is assumed the field S is not zero in general and related physical effect. The classical electrodynamic equation is considered a special case when S = 0.

Note that, the longitudinal wave solution of the decoupled potential wave equation also depends on λ_{rl} The speed of the phase velocity of electric potential waves and longitudinal magnetic potential wave is

$$V = \frac{1}{\sqrt{\lambda_{rl}\varepsilon_0\mu_0}} \qquad \text{For Lim } \lambda_{rl}$$

have infinite speed (immediate action at a distance) and for $\lambda_{rl} = 1$, the wave speed = C, which is also known as retard potential.

In reality, λ_{rl} can have values between $0<\lambda_{rl}<1$ for a vacuum, which means that these waves have superluminal finite speed.

The addition of the factor $\partial_t S$ and $1/\lambda_{rl}\ \nabla_S$ to the field equation is not unlike the additions of the displacement current $\varepsilon_0\mu_0\partial_t\mu$ by Maxwell, which leads to prediction of the transverse electromagnetic wave.

3.3 INDUCTION OF SCALAR FIELD

The addition of scalar field in Maxwell equation shows that the equations are not naturally homogenous as given in the case of transverse wave. This implies that it is a special case of the generalized Maxwell's equation. The big question is, how is the scalar field induced?

a. Electron Tunneling
b. Charge Density Wave (CDW)
c. Longitudinal current density wave (LCDW)

The above consequence is due to the following equations

$$\varepsilon_0\mu_0.\partial^2E/\partial t^2 + \nabla x\nabla xE - 1/\lambda.\ \nabla\nabla.E = -\ \mu\partial J/\partial t - \nabla\varphi/\lambda\varepsilon_0 \qquad (16)$$

$$\varepsilon_0\mu_0.\partial^2B/\partial t^2 + \nabla x\nabla xB = -\ \mu\nabla xJ \qquad (17)$$

$$\varepsilon_0\mu_0.\partial^2S/\partial t^2 - 1/\lambda\ \nabla.\nabla S = -\ \mu_0(\nabla.J + \partial\varphi/\partial t) \qquad (18)$$

If E = 0 and B = 0 in the Maxwell equation, the equation is reduced to

$$\left.\begin{aligned} &\nabla\rho + \lambda_0\varepsilon_0\mu_0.\partial J/\partial t = 0 \\ &\nabla xJ = 0 \end{aligned}\right\} (19)$$

There are two possibilities for electron transport in a conductor: Longitudinal current density, or thermal effect.

The theory of electrodynamics with the extra scalar fields actually predicts the longitudinal current density scalar wave. In most situations, the scalar field component

$\lambda_0\varepsilon_0\mu\partial_t\varphi$ is not strong to overcome the small factor $\varepsilon_0\mu_0 = 1.11 \times 10^{-17} S^2 m^{-2}$. Only a rapidly fluctuating source of high voltage, such as pulsed power system, can induce scalar field effect that are noticeable, also the other scalar field component, $\nabla.A$ is not very common since this scalar field is induced by diverging or converging currents [8].

3.4 CONDUCTION FROM CIRCULAR SURFACE TO SPACE

If we intend to conduct electricity through space, we need a cavity resonator placed at a high altitude for reduced a pressure and good contact with the ionospheric layer. We know that at high voltage and frequency, conduction through ionized gas is possible. When we use the term non-hertzian wave, it refers to purely electric field intensity or magnetic field intensity radiation. If the cavity resonator is activated by high pulse, scalar field is induced, thereby producing divergence of current through space. This current density wave can be sucked by $\lambda/2$ antenna and distributed within a defined wired grid [6].

From Helmoltz equation,

$$\nabla^2 = \sigma\partial E/\partial t + \mu_0\varepsilon_0\lambda_0\partial^2 E/\partial t^2,\ \lambda_0 = \text{Scalar constant}$$

$$E = E\varphi e^{jwt}$$

$$\therefore\ E_p'' + i/r.\ E_p = [\sigma\omega j - \omega^2\mu_0\varepsilon_0\lambda_0].E_p$$

$$-P^2 = \sigma\omega j - \omega^2\mu_0\varepsilon_0\lambda_0$$

$$E_p'' + 1/r.E_p' = -P^2E_p$$

$$E_p'' + 1/r.E_p' + P^2E_p = 0$$

$$r^2E_p'' + E_p' + r^2P^2E_p = 0$$

$$Z = rP$$

$$Z^2E_p'' + E_p' + Z^2P^2E_p = 0$$

For the ionosphere, the following parameters are not equal to zero ($\varepsilon_0, \mu_0, \sigma$).

Equation * is a Bessel equation of the second kind.

$$Ep = 2/\pi[J_0(z) \ln [rp/2 + r] + \Sigma [1 \frac{(-1)^m (rp)^{2m} H_m}{2^{2m} (m!)^2}]]$$

3.5 RECEIVING ANTENNA

Induction of scalar field will result to divergence of J (current density) which results in transmission of current in space. If the space signal is not properly matched (impedance matching), half of the wave will be reflected to it source point. To take care of this, we need an antenna for receiving the transmitted wave [6].

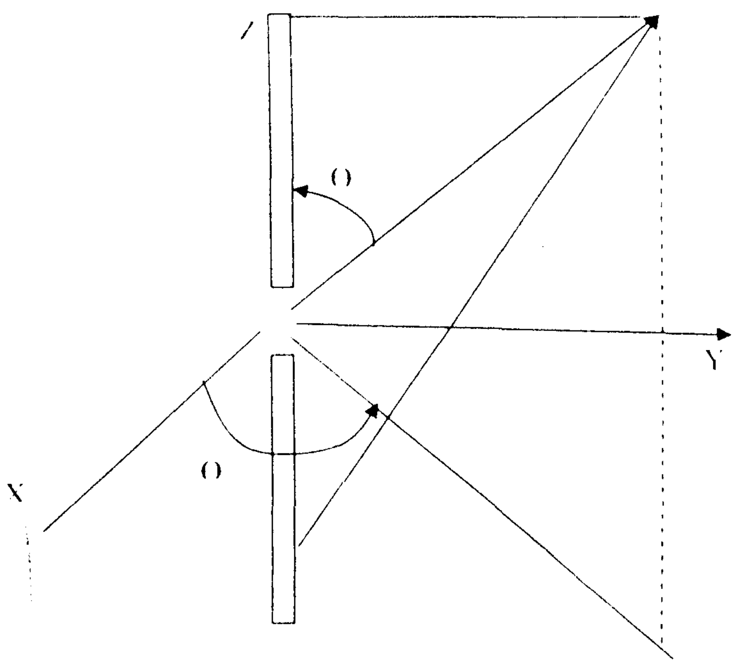

Fig. 3.1: Dipole for near field

The only way to receive energy is to transmit at a frequency of the energy transmitting system. So if an antenna is incorporated with an oscillator operating at similar frequency of the wireless power transmission system. The antenna will receive energy of resonance principle.

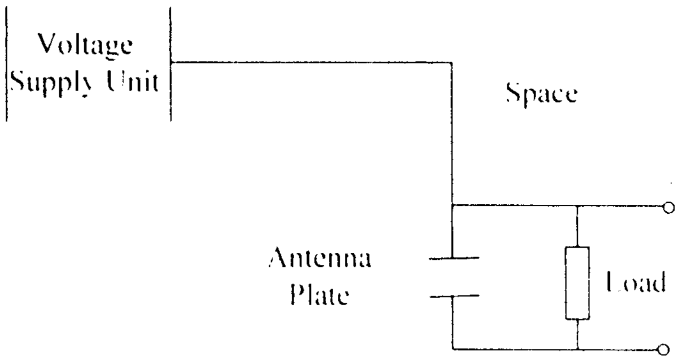

Fig. 3.2: Schematic of a receiving antenna

The fundamental problem with the above system is that the empty space around our metal plate acts like a voltage divider. If the sky has 10mV compared and if the metal plate above, the surface to the ground, then the plate only has a relatively tiny voltage and current, also tiny.

3.6 RESONANT ANTENNA

If a tuned circuit is added to the schematic, then at resonance, the 10pF capacitance of our metal plate effectively vanishes. A resonance circuit at resonance behaves like an infinite resistor. If the LC circuit is exactly at resonance, with the resistance of the wire take into consideration.

The voltage will increase rapidly to megavolt, the resonance circuit will continuously accumulate E.M energy until the voltage across the plate rise to the same value as the transmitter [6].

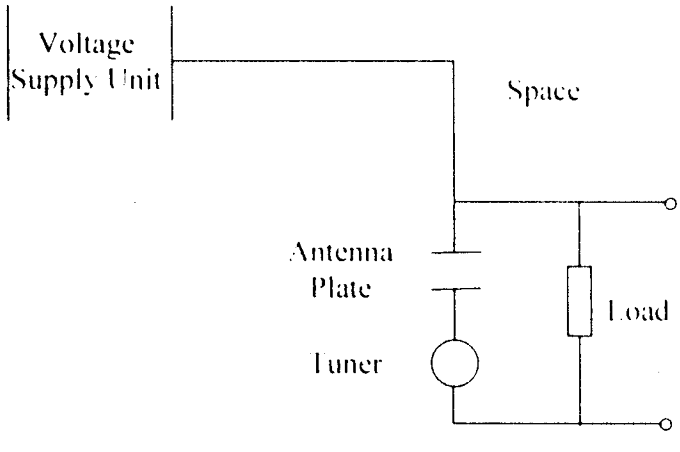

Fig. 3.3: schematic of a receiving antenna with a tuning circuit

CHAPTER FOUR

4.0 IMPLEMENTATION OF AN EXPERIMENTAL MODEL

The analysis from Chapter Three shows that the natural form of Maxwell's wave equation is non-homogenous. As a consequence of this non-homogenous nature, it was also established that we have a longitudinal electromagnetic scalar wave which also suggests that the scalar potential field can only be induced if we have high voltage pulse wave to suppress the effect of

$$\varepsilon_0\mu_0 = 1/c^2 \qquad (1.1 \times 10^{-17} s^2/m^2)$$

Since the scalar potential results in current divergence, this implies that current can flow through space if a high pulse wave is used to drive a Schumann resonator.

To implement an experimental model, we require the following:

1. Schumann Resonating Cavity
2. Receiver antenna with a resonator
3. High voltage pulse wave generator

4.1 STEP-TO-STEP DETAILS

Line voltage is stepped-up by the high-voltage transformer to a magnitude sufficient to charge the capacitor and force the spark gap to breakdown. This action is repeated at the 60Hz line frequency. Efficient energy transfer is enhanced by choosing a capacitor whose impedance is equal to that of a secondary winding [3].

Essentially, the capacitor and Tesla coil primary form one pair of a tank circuit. When the spark gap arcs, the momentary short circuit created dumps the capacitor's charge into the coil's primary. The resulting L-C circuit rings as the charge oscillates back and forth between the capacitor and the coil. The oscillations decrease in amplitude as the charge is dissipated by resistance.

The ringing generates what is referred to as a "Damped wave". The next half-cycle of 60Hz recharges the capacitor, starting the process anew. A train of high frequency waves, spaced at 60Hz intervals is generated. Resonance must be achieved to effect ringing. This demands that the capacitor and primary have the same reactance $X_L = X_C$. The circuit resistance (capacitor, coil and intermediate wiring) limits the overall efficiency of the tank circuit. The effect is minimized by winding primary with a few turns of heavy conductors, well spaced; over a large radius form.

The physical size and area should be minimized. This, however, works against large capacitance values and dictates the coil be wound with more turns.

The goal, then, is to achieve a workable range of component specification rather than to strive for overly close tolerances. Coils often are wound with tapped primaries to facilitate fine tuning.

The secondary coil is situated both electrically and physically within the primary coil. The secondary and its discharge electrode, generally a sphere or toroid, make up the second tuned circuit.

The winding supplies inductance, the capacitor is created by the electrode and the (Earth) wound-plane. Air is the dielectric.

Most Tesla coils employ secondaries of ¼ - wavelength at their operating frequencies. This establishes a configuration with maximum current at zero voltage with minimum current at the electrode.

This situation proves to be beneficial in that it enhances existing coupling with the high current primary, avoids arching between the primary and secondary and generates the desired high voltage at the top end.

The "Oudin" coil is a ½ - wave variation of the Tesla coil. It possesses the essential Tesla coil operational characteristics, but employs a horizontally placed secondary with discharge electrodes at both ends and a primary at the centre.

The "Oudin" primary sometimes is merely a pair of taps on the secondary (an autotransformer) [3].

The ½ - wave arrangement affords a coil with maximum discharge at each end and a virtual ground at the midpoint on the windings.

The above experimental model should be implemented with caution due to health problems associated with electromagnetic radiations.

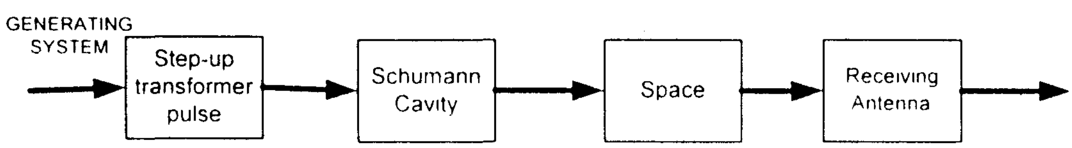

Fig 4 1 BLOCK DIAGRAM OF WPT

Table 4.1: Dipole field table

			1 metre	10 metres	100 metres	1 km
	Ev	Near	540kV/m	548V/m	0.62V/m	1.4mV/m
	Eh	Far	1.33V/m	0.13V/m	0.013V/m	1.3mV/m
	Eh	Near	0	0	0	0
Electric dipole	Hv	Far	0	0	0	0
	Ev	Near	0	0	0	0
		Far	0	0	0	0
	Ev	Near	2.25A/m	0.023A/m	230μA/m	2.3μA/m
		Far	0.0035A/m	350μA/m	35μA/m	3.5μA/m
	Eh	Near	0	0	0	0
		Far	0	0	0	0
	Hv	Near	0.59V/m	0.0059V/m	59μV/m	0.59μV/m
Magnetic dipole		Far	925μA/m	92.5μV/m	9.3μV/m	0.93μV/m
	Hh	Near	0.99A/m	0.001A/m	1.2μA/m	3nA/m2.5nA/m
		Fr	2.5μA/m	0.2μA/m	25nA/m	0
		Near	0	0	0	0
		Far	0	0	0	

Clearly, the electric dipole due to the voltage on the top of the electrode is the dominant source of radiation, and the magnetic dipole due to the coil current is relatively small [3].

4.2 SCALAR CONSTANTS BASED ON TESLA EXPERIMENT

From the experiment performed by Nikola Tesla, the time taken for the scalar wave potential to travel round the opposite side of the planet (circumference of the earth) is 0.0826 seconds [3]. This implies that the speed of potential

$V = D/T$ where $D = 2\pi R$ (Circumference of the Earth)

$D = 40,000$km

$V = (40,000/0.0826)$km/s

$= 4.8 \times 10^8$m/s which is greater than the speed of light

But, $V = 1/(\sqrt{\lambda_0 \varepsilon_0 \mu_0})$

$V = KC$

$K = V/C$

$1/\sqrt{\lambda_0} = 4.8/3$

$= 1.6$

$1/\lambda_0 = 2.56$

$\lambda_0 = 0.39$ which confirms the range for the scalar potential constant $0 < \lambda < 1$

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

From the foregoing, it is seen that Wireless Power Transmission is feasible because of the presence of longitudinal electromagnetic scalar waves. Scalar potential wave exhibits superluminal finite speed which is a factor that depends on the scalar constant (Z_0). It has also been seen that Wireless Power Transmission has tremendous application in the remote transfer of electrical power in the sense that the cost of power transmission is greatly reduced, power loss is minimal and the danger of transmitting electrical power over rough terrains is eliminated.

5.2 RECOMMENDATIONS

Given the benefits of Wireless Power Transmission network, the following recommendations are made:

- More research into totally harnessing this mode of power transmission should be undertaken
- Wireless power transmission standards should be set for proper component designs and specifications
- Incorporation of the concept of Biquartenion calculus into the themes of electrodynamics