Wireless transmission of electricity from a power source to an electrical load

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Introdution

Wireless energy transfer or wireless power is the transmission of electrical energy from a power source to an electrical load without artificial interconnecting conductors. Wireless power transmission is the future of electronic devices. Wireless transmission is useful in cases where interconnecting wires are inconvenient, hazardous or impossible. The problem of wireless power transmission differs from that of wireless telecommunications, such as radio. In the latter, the proportion of energy received becomes critical only if it is too low for the signal to be distinguished from the background noise. With wireless power, efficiency is the more significant parameter. A large part of the energy sent out by the generating plant must arrive at the receiver or receivers to make the system economical. The most common form of wireless power transmission is carried out using direct induction followed by resonant magnetic induction. Other methods under consideration include electromagnetic radiation in the form of microwaves or lasers.

Key Words : *Wireless Power, Wireless Energy, Wireless transmission*

1 Overview of Wireless Electricity Transfer

An electric current flowing through a conductor carries electrical energy. When an electric current passes through a circuit there is an electric field in the dielectric surrounding the conductor; magnetic field lines around the conductor and lines of electric force radially about the conductor. In a direct current circuit, if the current is continuous, the fields are constant; there is a condition of stress in the space surrounding the conductor, which represents stored electric and magnetic energy, just as a compressed spring or a moving mass represents stored energy. In an alternating current circuit, the fields also alternate; that is, with every half wave of current and of voltage, the magnetic and the electric field start at the conductor and run outwards into space with the speed of light. Where these alternating fields impinge on another conductor a voltage and a current are induced. Any change in the electrical conditions of the circuit, whether internal or external involves a readjustment of the stored magnetic and electric field energy of the circuit, that is, a so-called transient. A transient is of the general character of a condenser discharge through an inductive circuit. The phenomenon of the condenser discharge through an inductive circuit therefore is of the greatest importance to the engineer, as the foremost cause of high-voltage and high-frequency troubles in electric circuits.

Electromagnetic induction is proportional to the intensity of the current and voltage in the conductor which produces the fields and to the frequency. The higher the frequency the more intense the induction effect. Energy is transferred from a conductor that produces the fields (the primary) to any conductor on which the fields impinge (the secondary). Part of the energy of the primary conductor passes inductively across space into secondary conductor and the energy decreases rapidly along the primary conductor. A high frequency current does not pass for long distances along a conductor but rapidly transfers its energy by induction to adjacent conductors. Higher induction resulting from the higher frequency is the explanation of the apparent difference in the propagation of high frequency disturbances from the propagation of the low frequency power of alternating current systems. The higher the frequency the more preponderant becomes the inductive effects that transfer energy from circuit to circuit across space. The more rapidly the energy decreases and the current dies out along the circuit, the more local is the phenomenon.

The flow of electric energy thus comprises phenomena inside of the conductor and phenomena in the space outside of the conductor—the electric field—which, in a continuous current circuit, is a condition of steady magnetic and dielectric stress, and in an alternating current circuit is alternating, that is, an electric wave launched by the conductor to become far-field electromagnetic radiation traveling through space with the speed of light. In electric power transmission and distribution, the phenomena inside of the conductor are of main importance, and the electric field of the conductor is usually observed only incidentally. Inversely, in the use of electric power for *radio* telecommunications it is only the electric and magnetic fields outside of the conductor that is electromagnetic radiation, which is of importance in transmitting the message. The phenomenon in the conductor, the current in the launching structure, is not used.

The electric charge displacement in the conductor produces a magnetic field and resultant lines of electric force. The magnetic field is a maximum in the direction concentric, or approximately so, to the conductor. That is, a ferromagnetic body tends to set itself in a direction at right angles to the conductor. The electric field has a maximum in a direction radial, or approximately so, to the conductor. The electric field component tends in a direction radial to the conductor and dielectric bodies may be attracted or repelled radially to the conductor.

The electric field of a circuit over which energy flows has three main axes at right angles with each other:

1. The *magnetic field*, concentric with the conductor.
2. The *lines of electric force*, radial to the conductor.
3. The *power gradient*, parallel to the conductor.

Where the electric circuit consists of several conductors, the electric fields of the conductors superimpose upon each other, and the resultant magnetic field lines and lines of electric force are not concentric and radial respectively, except *approximately in the immediate neighborhood* of the conductor. Between parallel conductors they are conjugate of circles. Neither the power consumption in the conductor, nor the magnetic field, nor the electric field, are proportional to the flow of energy through the circuit. However, the product of the intensity of the magnetic field and the intensity of the electric field is proportional to the flow of energy or the power, and the power is therefore resolved into a product of the two components **i** and **e**, which are chosen proportional respectively to the intensity of the magnetic field and of the electric field. The component called the current is defined as that factor of the electric power which is proportional to the magnetic field, and the other component, called the voltage, is defined as that factor of the electric power which is proportional to the electric field.

In *radio* telecommunications the electric field of the transmit antenna propagates through space as a radio wave and impinges upon the receive antenna where it is observed by its magnetic and electric effect. Radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X rays and gamma rays are shown to be the same electromagnetic radiation phenomenon, differing one from the other only in frequency of vibration.

METHODS OF WIRELESS POWER TRANSMISSION

The electrodynamic induction wireless transmission technique is near field over distances up to about one-sixth of the wavelength used. Near field energy itself is non-radiative but some radiative losses do occur. In addition there are usually resistive losses. With electrodynamic induction, electric current flowing through a primary coil creates a magnetic field that acts on a secondary coil producing a current within it. Coupling must be tight in order to achieve high efficiency. As the distance from the primary is increased, more and more of the magnetic field misses the secondary. Even over a relatively short range the inductive coupling is grossly inefficient, wasting much of the transmitted energy.

This action of an electrical transformer is the simplest form of wireless power transmission. The primary and secondary circuits of a transformer are not directly connected. Energy transfer takes place through a process known as mutual induction. Principal functions are stepping the primary voltage either up or down and electrical isolation. Mobile phone and electric toothbrush battery chargers, and electrical power distribution transformers are examples of how this principle is used. Induction cookers use this method. The main drawback to this basic form of wireless transmission is short range. The receiver must be directly adjacent to the transmitter or induction unit in order to efficiently couple with it.

The application of resonance increases the transmission range somewhat. When resonant coupling is used, the transmitter and receiver inductors are tuned to the same natural frequency. Performance can be further improved by modifying the drive current from a sinusoidal to a nonsinusoidal transient waveform. Pulse power transfer occurs over multiple cycles. In this way significant power may be transmitted between two mutually-attuned LC circuits having a relatively low coefficient of coupling. Transmitting and receiving coils are usually single layer solenoids or flat spirals with series capacitors, which, in combination, allow the receiving element to be tuned to the transmitter frequency.

Common uses of resonance-enhanced electrodynamic induction are charging the batteries of portable devices such as laptop computers and cell phones, medical implants and electric vehicles. A localized charging technique selects the appropriate transmitting coil in a multilayer winding array structure. Resonance is used in both the wireless charging pad (the transmitter circuit) and the receiver module (embedded in the load) to maximize energy transfer efficiency. This approach is suitable for universal wireless charging pads for portable electronics such as mobile phones. It has been adopted as part of the Qi wireless charging standard. It is also used for powering devices having no batteries, such as RFID patches and contactless smartcards, and to couple electrical energy from the primary inductor to the helical resonator of Tesla coil wireless power transmitters.

4.3 Electrostatic induction method

The Tesla effect is shown with the illumination of two exhausted tubes by means of a powerful, rapidly alternating electrostatic field created between two vertical metal sheets suspended from the ceiling on insulating cords. It exploits the physics of electrostatic induction.

Electrostatic or capacitive coupling is the passage of electrical energy through a dielectric. In practice it is an electric field gradient ordifferential capacitance between two or more insulated terminals, plates, electrodes, or nodes that are elevated over a conducting ground plane. The electric field is created by charging the plates with a high potential, high frequency alternating current power supply. The capacitance between two elevated terminals and a powered device form a voltage divider.

The electric energy transmitted by means of electrostatic induction can be utilized by a receiving device, such as a wireless lamp. Tesla demonstrated the illumination of wireless lamps by energy that was coupled to them through an alternating electric field.

"Instead of depending on electrodynamic induction at a distance to light the tube . . . the ideal way of lighting a hall or room would . . . be to produce such a condition in it that an illuminating device could be moved and put anywhere, and that it is lighted, no matter where it is put and without being electrically connected to anything. I have been able to produce such a condition by creating in the room a powerful, rapidly alternating electrostatic field. For this purpose I suspend a sheet of metal a distance from the ceiling on insulating cords and connect it to one terminal of the induction coil, the other terminal being preferably connected to the ground. Or else I suspend two sheets . . . each sheet being connected with one of the terminals of the coil, and their size being carefully determined. An exhausted tube may then be carried in the hand anywhere between the sheets or placed anywhere, even a certain distance beyond them; it remains always luminous."

The principle of electrostatic induction is applicable to the electrical conduction wireless transmission method.

“In some cases when small amounts of energy are required the high elevation of the terminals, and more particularly of the receiving-terminal D', may not be necessary, since, especially when the frequency of the currents is very high, a sufficient amount of energy may be collected at that terminal by **electrostatic induction** from the upper air strata, which are rendered conducting by the active terminal of the transmitter or through which the currents from the same are conveyed."

Electromagnetic radiation

Far field methods achieve longer ranges, often multiple kilometer ranges, where the distance is much greater than the diameter of the device(s). The main reason for longer ranges with radio wave and optical devices is the fact that electromagnetic radiation in the far-field can be made to match the shape of the receiving area (using high directivity antennas or well-collimated Laser Beam) thereby delivering almost all emitted power at long ranges. The maximum directivity for antennas is physically limited by diffraction.

Beamed power, size, distance, and efficiency

The size of the components may be dictated by the distance from transmitter to receiver, the wavelength and the Rayleigh criterion or diffraction limit, used in standard radio frequencyantenna design, which also applies to lasers. In addition to the Rayleigh criterion Airy's diffraction limit is also frequently used to determine an approximate spot size at an arbitrary distance from the aperture.

The Rayleigh criterion dictates that any radio wave, microwave or laser beam will spread and become weaker and diffuse over distance; the larger the transmitter antenna or laser aperture compared to the wavelength of radiation, the tighter the beam and the less it will spread as a function of distance (and vice versa). Smaller antennae also suffer from excessive losses due to side lobes. However, the concept of laser aperture considerably differs from an antenna. Typically, a laser aperture much larger than the wavelength induces multi-moded radiation and mostly collimators are used before emitted radiation couples into a fiber or into space.

Ultimately, beamwidth is physically determined by diffraction due to the dish size in relation to the wavelength of the electromagnetic radiation used to make the beam. Microwave power beaming can be more efficient than lasers, and is less prone to atmospheric attenuation caused by dust or water vapor losing atmosphere to vaporize the water in contact.

Then the power levels are calculated by combining the above parameters together, and adding in the gains and losses due to the antenna characteristics and the transparency and dispersion of the medium through which the radiation passes. That process is known as calculating a link budget.

Microwave method

An artist's depiction of a solar satellite that could send electric energy by microwaves to a space vessel or planetary surface.

Power transmission via radio waves can be made more directional, allowing longer distance power beaming, with shorter wavelengths of electromagnetic radiation, typically in the microwave range. A rectenna may be used to convert the microwave energy back into electricity. Rectenna conversion efficiencies exceeding 95% have been realized. Power beaming using microwaves has been proposed for the transmission of energy from orbiting solar power satellites to Earth and the beaming of power to spacecraft leaving orbit has been considered.

Power beaming by microwaves has the difficulty that for most space applications the required aperture sizes are very large due to diffraction limiting antenna directionality. For example, the 1978 NASA Study of solar power satellites required a 1-km diameter transmitting antenna, and a 10 km diameter receiving rectenna, for a microwave beam at 2.45 GHz. These sizes can be somewhat decreased by using shorter wavelengths, although short wavelengths may have difficulties with atmospheric absorption and beam blockage by rain or water droplets. Because of the "thinned array curse," it is not possible to make a narrower beam by combining the beams of several smaller satellites.

For earthbound applications a large area 10 km diameter receiving array allows large total power levels to be used while operating at the low power density suggested for human electromagnetic exposure safety. A human safe power density of 1 mW/cm^2 distributed across a 10 km diameter area corresponds to 750 megawatts total power level. This is the power level found in many modern electric power plants.

Following World War II, which saw the development of high-power microwave emitters known as cavity magnetrons, the idea of using microwaves to transmit power was researched. By 1964 a miniature helicopter propelled by microwave power had been demonstrated.

Japanese researcher Hidetsugu Yagi also investigated wireless energy transmission using a directional array antenna that he designed. In February 1926, Yagi and Uda published their first paper on the tuned high-gain directional array now known as the Yagi antenna. While it did not prove to be particularly useful for power transmission, this beam antenna has been widely adopted throughout the broadcasting and wireless telecommunications industries due to its excellent performance characteristics.

Wireless high power transmission using microwaves is well proven. Experiments in the tens of kilowatts have been performed at Goldstone in California in 1975 and more recently (1997) at Grand Bassin on Reunion Island. These methods achieve distances on the order of a kilometer.

Laser method

With a laser beam centered on its panel of photovoltaic cells, a lightweight model plane makes the first flight of an aircraft powered by a laser beam inside a building at NASA Marshall Space Flight Center.

In the case of electromagnetic radiation closer to visible region of spectrum (10s of microns (um) to 10s of nm), power can be transmitted by converting electricity into a laser beam that is then pointed at a solar cell receiver. This mechanism is generally known as "power beaming" because the power is beamed at a receiver that can convert it to usable electrical energy.

Advantages of laser based energy transfer compared with other wireless methods are:

1. collimated monochromatic wavefront propagation allows narrow beam cross-section area for energy transmission over large ranges.
2. compact size of solid state lasers-photovoltaics semiconductor diodes fit into small products.
3. no radio-frequency interference to existing radio communication such as Wi-fi and cell phones.
4. control of access; only receivers illuminated by the laser receive power.

Its drawbacks are:

1. Conversion to light, such as with a laser, is inefficient
2. Conversion back into electricity is inefficient, with photovoltaic cells achieving 40%-50% efficiency.
3. Atmospheric absorption causes losses.
4. As with microwave beaming, this method requires a direct line of sight with the target.

The laser "powerbeaming" technology has been mostly explored in military weapons and aerospace applications and is now being developed for commercial and consumer electronics Low-Power applications. Wireless energy transfer system using laser for consumer space has to satisfy Laser safetyrequirements standardized under IEC 60825.

To develop an understanding of the trade-offs of Laser ("a special type of light wave"-based system):

1. Propagation of a laser beam (on how Laser beam propagation is much less affected by diffraction limits)
2. Coherence and the range limitation problem (on how spatial and spectral coherence characteristics of Lasers allows better distance-to-power capabilities)
3. Airy disk (on how wavelength fundamentally dictates the size of a disk with distance)
4. Applications of laser diodes (on how the laser sources are utilized in various industries and their sizes are reducing for better integration)

Geoffrey Landis is one of the pioneers of solar power satellite and laser-based transfer of energy especially for space and lunar missions. The continuously increasing demand for safe and frequent space missions has resulted in serious thoughts on a futuristic space elevator that would be powered by lasers. NASA's space elevator would need wireless power to be beamed to it for it to climb a tether.

NASA's Dryden Flight Research Center has demonstrated flight of a lightweight unmanned model plane powered by a laser beam. This proof-of-concept demonstrates the feasibility of periodic recharging using the laser beam system and the lack of need to return to ground.

"Lasermotive" demonstrated laser powerbeaming at one kilometer during NASA's 2009 powerbeaming contest. Also "Lighthouse DEV" (a spin off of NASA Power Beaming Team) along with "University of Maryland" is developing an eye safe laser system to power a small UAV. Since 2006, "PowerBeam" which originally invented the eye-safe technology and holds all crucial patents in this technology space, is developing commercially ready units for various consumer and industrial electronic products.

Electrical conduction

Means for long conductors of electricity forming part of an electric circuit and electrically connecting said ionized beam to an electric circuit. Hettinger 1917 -(U.S. Patent 1,309,031)

Disturbed charge of ground and air method

Single wire with Earth return electrical power transmission systems rely on current flowing through the earth plus a single wire insulated from the earth to complete the circuit. In emergencies high-voltage direct current power transmission systems can also operate in the 'single wire with earth return' mode. Elimination of the raised insulated wire, and transmission of high-potential, high-frequency alternating current through the earth with an atmospheric return circuit has been investigated as a method of wireless electrical power transmission. Transmission of electrical energy through the earth alone, eliminating the second conductor is also being investigated.

Low frequency alternating current can be transmitted through the inhomogeneous earth with low loss because the net resistance between earth antipodes is considerably less than 1 ohm. The electrical displacement takes place predominantly by electrical conduction through the oceans, and metallic ore bodies and similar subsurface structures. The electrical displacement is also by means of electrostatic induction through the more dielectric regions such as quartz deposits and other non-conducting minerals.

Alternating current can be transmitted through atmospheric strata having a barometric pressure of less than 135 millimeters of mercury. Current flows by means of electrostatic induction through the lower atmosphere up to about two or three miles above the plants (this is the middle part in a three-space model) and the flow of ions, that is to say, electrical conduction through the ionized region above three miles. Intense vertical beams of ultraviolet light may be used to ionize the atmospheric gasses directly above the two elevated terminals resulting in the formation of plasma high-voltage electrical transmission lines leading up to the conducting atmospheric strata. The end result is a flow electrical current between the two elevated terminals by a path up to and through the troposphere and back down to the other facility. Electrical conduction through atmospheric strata is made possible by the creation of capacitively coupled discharge plasma through the process of atmospheric ionization.

Terrestrial transmission line with atmospheric return

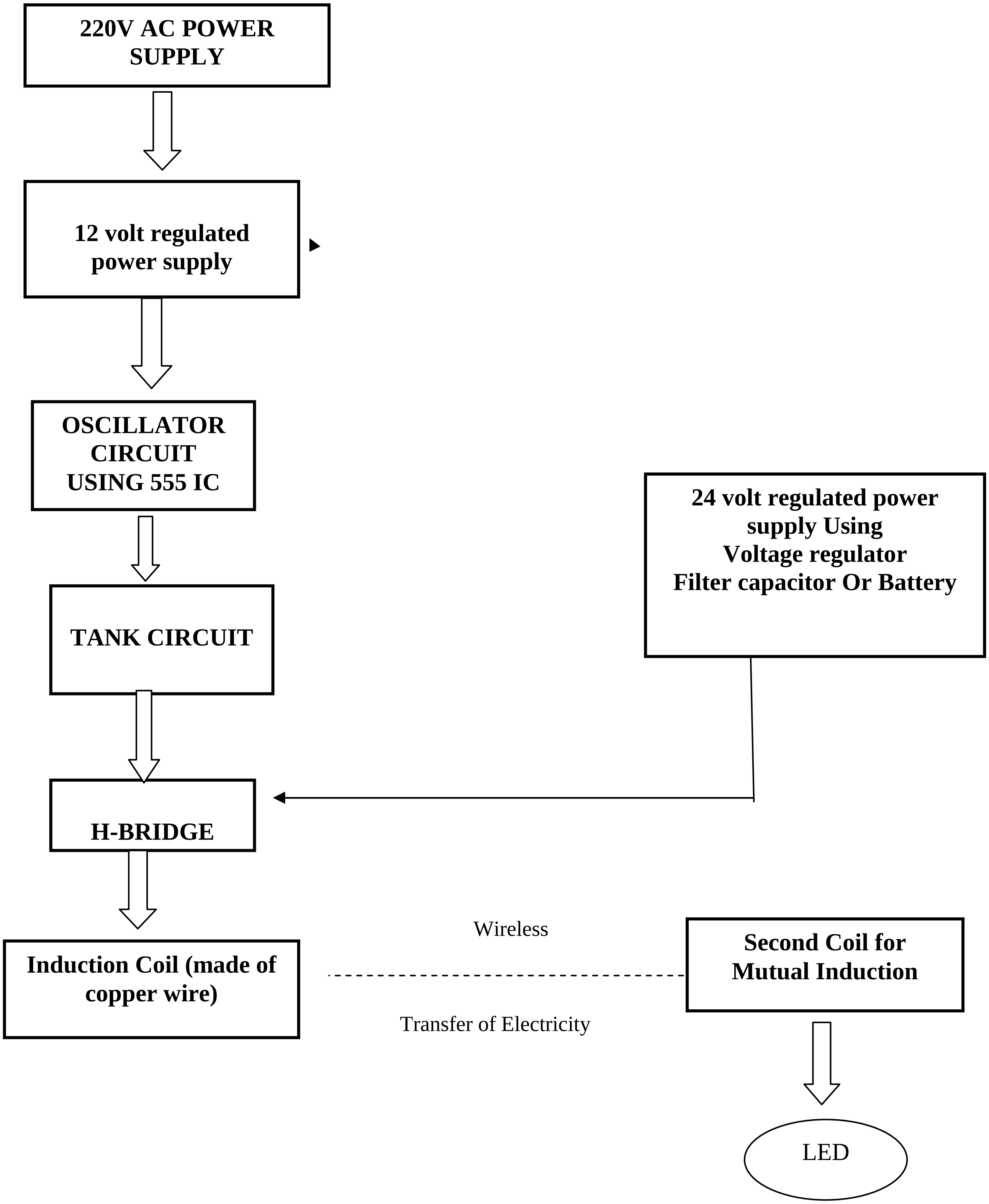
Tesla discovered that electrical energy can be transmitted through the earth and the atmosphere. In the course of his research he successfully lit lamps at moderate distances and was able to detect the transmitted energy at much greater distances. The Wardenclyffe Tower project was a commercial venture for trans-Atlantic wireless telephony and proof-of-concept demonstrations of global wireless power transmission. The facility was not completed because of insufficient funding. Earth is a naturally conducting body and forms one conductor of the system. A second path is established through the upper troposphere and lower stratosphere starting at an elevation of approximately 4.5 miles (7.2 km). A global system for "the transmission of electrical energy without wires" called the World Wireless System, dependent upon the high electrical conductivity of plasma and the high electrical conductivity of the earth, was proposed as early as 1904.

Terrestrial single-conductor surface wave transmission line

The same transmitter used for the atmospheric conduction method is used for the terrestrial single-conductor earth resonance method. The fundamental earth resonance frequency is claimed to be approximately 11.78 Hz. With the earth resonance method some harmonic of this fundamental frequency is used. "I would say that the frequency should be smaller than twenty thousand per second, through shorter waves might be practicable"and on the low end, "a frequency of nine hundred and twenty-five per second" is used, "when it is indispensable to operate motors of the ordinary kind."

Observations have been made that may be inconsistent with a basic tenet of physics related to the scalar derivatives of the electromagnetic potentials that are presently considered to be nonphysical.

Wireless Electricity Transfer Section



In a wireless power transmission circuit, the input voltage of 220v is given to a center tapped transformer, which gives the output of 24 volts. As the transformer is center tapped the output voltage can be used in the form of two separate voltage connections with each having voltage of 12volts.

These two voltage source connections are given to two separate circuits which comprises of an oscillator circuit with 555 timer IC and a tank circuit having associated with an variable resistance for the proper frequency generation due to resonance

The oscillator circuits generates the ac pulse waves with the help of 555 timer IC for the transmission,555 timer IC is used to provide time delay for the oscillator to generate the pulse waves. While as the tank circuit is used to provide resonance. As the resonance occurs at a particular frequency when the inductive reactance and the capacitive reactance are of equal magnitude, causing electrical energy to oscillate between the magnetic field of the inductor and the electric field of the capacitor.

Resonance occurs because the collapsing magnetic field of the inductor generates an electric current in its windings that charges the capacitor and the discharging capacitor provides an electric current that builds the magnetic field in the inductor, and the process is repeated. An analogy is a mechanical pendulum. At resonance, the series impedance of the two elements is at a minimum and the parallel impedance is a maximum. Resonance is used for tuning and filtering, because resonance occurs at a particular frequency for given values of inductance and capacitance. Resonance can be detrimental to the operation of communications circuits by causing unwanted sustained and transient oscillations that may cause noise, signal distortion, and damage to circuit elements.

Due to some distortions the theoretical value of the resonating frequency is different from that of practical one,so a variable resistance is used to determine it properly. After the generation of particular resonating frequency the combined output from the oscillator with 55 timer IC and tank circuit is given to the H bridge circuit. H Bridge is used to apply the voltage across the load in either directions, in other words its used to change the polarity of the current, the load in this circuit is the inductance coil.

When this copper coil is brought near another copper coil mutual inductance is generated from which the current is transferred to another coil, this transfer is confirmed by the glowing of led connected to other coil.

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