

Wireless energy transmission using a tesla coil engineering essay



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In this project the group aims to replicate Nikola Tesla's experiment the "Tesla Coil" to wirelessly transmit power from a primary or transmitter antenna to a secondary or receiver, to therefore be able to power devices at long distances and without the use of any wires. With the completion of this project we would be able to prove Tesla's technology and promote further investigation and possible implementation of his technology, which could possible solve many world energy problems of today.

Background

Wireless energy transmission

Wireless energy transmission is a process in which electrical energy is transmitted from a power source such as a Tesla coil to an electrical load without the use of physical connection. It can be achieved using various types of waves, and following similar principles (but yet distinct) as the ones used in the transmission of information (electromagnetic transmission). This kind of energy transmission was used in mid-19th century with the development of the tesla coil and the Wardenclyffe -or Tesla- Tower, or as some historians would say, since the construction of the pyramids in the ancient Egypt 3150 BC.[1]

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Figure1: Wardenclyffe Tower

There are different electrical energy transfer methods. The electromagnetic induction works with an electrical transformer that consist of circuits that transfer the energy by electromagnetic coupling to other circuits, these

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methods of energy transmission require a close range between transmitter and emitter in order to couple [2]. There is also electromagnetic radiation that uses radio waves which is also used to transfer information. Today's applications of these methods of energy and information transmissions are AM, FM and TV broadcasting, wireless internet and the Global Positioning System.

Nikola Tesla and the Tesla Coil

Inventor, mechanical and electrical engineer Nikola Tesla worked with this kind of energy transmission throughout his life. Considered the father of the modern age, he invented the radio, remote controlled devices, induction motors, among many others. One of his most important (and with most tremendous potential) invention is the Tesla coil. This system, apart from being a resonant transformer circuit, that produces high voltage and low current as well as high frequency AC electricity, can produce "longitudinal" or "scalar" impulses that transmit power or even information faster than the speed of light for very long distances and through almost any material (including Faraday cages), without any decrease on their intensity. Therefore this system is capable of transmitting electrical energy without the use of wires. The coil in this system transfers energy through loose coupling, from an oscillating resonant primary circuit to a secondary circuit over a number of RF cycles [3]. As the energy is transmitted from the primary to the secondary the output voltage increases until all the available primary energy has been completely transferred from one circuit to the other.

In the process of wireless energy transmission the tesla coil continuously oscillates scalar waves, using a helical resonator with elevated terminal; a <https://assignbuster.com/wireless-energy-transmission-using-a-tesla-coil-engineering-essay/>

similar antenna to this one is used for the energy reception. These impulses transmitted in the tesla coil, according to Tesla where a type of voltage decoupled from electron flow. He believed this voltage was a form of compressed aether, which is considered to be an atmosphere of very tiny, even smaller than electrons and very energetic, capable of penetrating any matter, particles that fill the vacuum that also conform the elementary particles in the atom. Tesla was able to channel this particles or aether and produce a ray that would be able to hit electrical conductors and produce current that can be used to power lights, motors, etc. [5]

In essence the most significant part of this system was the coil itself that consists of a flat spiral coil of wire between two bars of copper which conformed the primary coil, and an additional coil was considered the secondary of the circuit; similar to a today's transformer.

Overall, the common Tesla coil setup requires a power source of very high voltage; today's transformers are mostly used to achieve this. These transformers convert low voltage of main power into high voltages and are connected to several capacitors. Capacitors in a simple form are two plates of conductive material with a plate of insulating material in between. Once a difference in voltage is created across the conductive plates, a charge is built up and then released to power a load. A spark gap needs to be designed to work as an insulative barrier for the high voltage. The length of this gap would determine the amount of voltage needed to be applied to match the input voltage coming from the capacitors.

The primary coil or transmitter is connected to the circuit powered by the spark gap, or it can be even connected to the capacitors of the circuit. The primary coil will guide the voltage along its surface and then resonate with the secondary coil or antenna. Resonance is the phenomenon in which energy is transferred and maximized; it depends on the length of the primary and secondary windings and the frequency in which the waves are pulsed from the primary. The secondary coil or receiver will collect the power as long as is in resonance with the emitter. [6]

D: DownloadsJackson_wireless_power_transmitter_300. jpg
Figure 2: Tesla Coil or antenna

Therefore power can be successfully transmitted wirelessly through large distances and through any material and be sufficient enough to power motors, light bulbs and any other device just like Tesla did when he powered a light bulb in his hand absolutely wirelessly in 1901 in a demonstration of his experiments. All this can be possible due to the existence of the mentioned aether.

Scalar or Longitudinal Waves

The particles in the aether as mentioned previously fill the vacuum and make up the atom, these particles travel extremely fast, even faster than light, and they are able to penetrate even the Faraday Cages. These particles are the responsible of the wireless energy transmission due to the behaviour in which they travel. Scalar waves have amplitude that does not fluctuate up and down, their behaviour is more similar to that of a vibration of electric potential expanding and contracting in the direction of the propagation.

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These waves are composed of pure potential energy therefore they are capable of moving faster than the speed of light. They, as mentioned are capable of transmitting power and even magnifying it. This phenomenon is poorly known in science today; however, they have been proved and tested by Nikolas Tesla in many of his inventions and experiments. [7]

An Ancient Technology

In ancient Egypt, it is believed that similar technology was being used. The pyramids are believed to work as energy transmitters that would send energy to other receptors across Egypt, such as the Lighthouse of Alexandria and several other receiver devices similar to the antennas developed by Nikola tesla thousands of years after. The pyramids were constructed with insulating properties that would allow energy taken from underground aquifers to be conducted towards the tip of the pyramid (in which there was located a gold capstone, that would efficiently conduct electricity) and from there emitted trough large distances all across the country. This system of current generation from aquifers used by this ancient civilization follows the exact same principles of the Wardenclyffe Tower Tesla built and successfully operated as a wireless power transmitter. [8]

Proposed Solution

Humanity today seeks to find a new way to supply energy that could sustain the exceeded energy consumption of society. Due to the amount of energy required to power the entire world, humans have been forced to rely on non-renewable sources of energy, such as oil, which is getting closer every year to its depletion, another fact that enhances this situation is the way in which

oil-derived energy is being supplied, that contributes to the damage of the <https://assignbuster.com/wireless-energy-transmission-using-a-tesla-coil-engineering-essay/>

environment, and that has increased costs and affected the countries' economies. A new and more efficient way to supply energy has to be developed.

Tesla had imagined a new solution to the world's energy problems. He believed that with this new technology he could power the entire world, but in order to do so he would have to improve his technology further. His experiment was potentially able to supply the entire world with free of cost electrical energy, unfortunately for him that never became possible due to lack of financial support by the banks of his time and a fire in his laboratory located in New York in 1895. In order to honour Nikola Tesla's hard work and discoveries, to prove that his experiments were real (contrary to popular belief), and to promote further investigation and development of this technology, the purpose of our experiment is to replicate in a simpler scale the Tesla Coil, and to wirelessly, and therefore in a more convenient way, transmit electrical energy from a Tesla transmitter to a receiver and to power devices located at long distances.

Solution Objective and Targets

To achieve the purpose of our project of transmitting power without the use of any wires and following Nikola Tesla's experiment the "Tesla Coil" we researched deeply his technology and we concluded that the required targets to accomplish it were the following.

First, the power must be obtained from a wall outlet which is the most accessible voltage source available.

Following Tesla's theory of a needed resonance between the primary and secondary coils, we needed to change the frequency from the power outlet to a lower frequency that would be resonant with the one for the antenna.

To do so, we would need to convert that power to DC current using a rectifier circuit. Then, using an inverter circuit we would convert it back to AC, but now at the resonant frequency of the antenna.

For demonstration purposes we would use a 555 timer circuit to achieve the necessary frequency and to produce a pulsed DC wave that would be transmitted from an antenna to another one (the receiver).

Systems of Energy Transfer and Its Comparison to Tesla's Coil:

Induction

When magnetic flux flowing through a circuit changes, an electromotive force (emf) along with current is induced in the circuit. This effect is for example used in dynamos, electric motors and transformers. The central principle behind electromagnetic induction is Faraday's law, which relates to the induced electromotive force (emf) in any closed loop including a closed circuit. Induction can be used as a means of wireless power transfer. A changing current in one coil creates an emf, which in turn induces a current in another coil. The coils are not in contact and in this way energy can very simply be transported over short distances. This is used in for example an electric toothbrush charger. The short distance that is required for induction is the largest drawback of this way of wireless energy transfer, because it limits the applicability to very close-range situations. [8]

Comparison: It uses wave's impulses which are produced by coils, the difference lies in the spark gap that this coils have and their ability to produce transmit the aether which is what allows the power to be transmitted over long distances without decrease in its magnitude.

Radio Waves

The key component for wireless power transfer by radio waves is the rectenna. A rectenna is a combination of a rectifying circuit and an antenna. The antenna receives the electromagnetic power and the rectifying circuit converts it to DC electric power. A simple rectenna can be constructed from a Schottky diode placed between the antenna dipoles. The diode rectifies the current induced in the antenna by the microwaves. Schottky diodes are used because they have the lowest voltage drop and highest speed and therefore waste the least amount of power due to conduction and switching.[9]

Comparison: This system transmits only information such as sound, wireless internet, GPS, etc. different from the scalar waves or aether that can transmit voltage that can power devices. Also, they are transmitted using the rectenna, and not the tesla coil, that Tesla's experiment has.

Evanescent Wave Coupling

Evanescent wave coupling is a technique that has recently been investigated by researchers at MIT.

The physics behind this technique is rather complicated. At a glance, it basically extends the principle of magnetic induction to mid-range applications up to a few meters. The main difference is the use of resonance;

if sender and receiver have the same magnetic resonance frequency, energy can efficiently be transported, while losses to the non-resonant environment are small. Using resonance, for the same geometry, power can be transported approximately 10^6 times more efficiently than without resonance. [10]

Comparison: Uses receiver and emitter similar to the antennas (tesla coils). Both require resonance of both antennas to transmit the power. Unlike Tesla's this system works with magnetic induction but extended as the tesla coil transmits longitudinal waves that achieve similar purposes.

Laser

Power delivery that starts with sunlight has many advantages such as sustainability and the fact that the sun is present every day. However solar cells have limited efficiency and sunlight is not available at night. An alternative is to generate artificial light, from a laser, transmit it through air, and then convert it into electricity. New refinements are making this alternative more attractive. NASA has demonstrated flight of a lightweight model plane powered by laser beam, directed at a panel of infrared-sensitive photovoltaic cells mounted on the bottom of the aircraft. A theoretical setup consists of a laser (Light Amplification by Stimulated Emission of Radiation) and a photovoltaic, or solar cell.

First electricity is converted by the laser into a laser beam, which consists of coherent radiation. Next this beam is pointed towards a photovoltaic cell receiver, which in turn converts the received light energy back into electricity. This is generally called "power beaming".

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Both steps are not highly efficient and also a direct line of sight between laser and the photovoltaic cells is required. [11]

Comparison: This system obtains the power from light and this light is obtained from the sun, this implies that indirectly the power is being taken from a natural source, unlike our replica of Tesla's experiment which obtains the power from a wall outlet. Both systems allow us to power devices across long distances but they use different methods of energy transmission, one is the laser and the other is longitudinal waves.

Performance Measures:

The prototype was build using the concepts of tesla coils. It is assumed that the energy loss during this transfer will be almost zero but although we know that there is no device on this earth with 100% efficiency but it is still more efficient than the wired transfer of energy. The reason that it is more efficient than the wired transmission because wire has more energy loses depending upon what type material is used to make wires. In the process of wireless energy transmission the specific frequency is used to transfer the energy. This makes the process most efficient. The prototype uses the antenna which transmits the frequency in the form of energy and the receiver from the other end tuned to the same frequency as the transmitter receives energy. But for the purpose of showing the virtual process of transmission of energy, we used MULTISIM software and the way energy is transferred is as follows:

The input energy from the 12 volt battery is given to 555-timer which converts the voltage into DC pulse. When that voltage is transferred to the

receiver then BJT's used to make AC voltage and that can be used to power the load.

Theoretical background

“ A Tesla coil is an electrical transformer circuit invented by Nikola Tesla around 1891. It is used to produce high voltage, low current, high frequency and AC electricity. Tesla coils produce higher current than the other source of high voltage discharges, electrostatic machines. Tesla experimented with a number of different configurations and they consist of two, or sometimes three, coupled resonant electric circuits. Tesla used these coils to conduct innovative experiments in electrical lighting, phosphorescence, x-ray generation, high frequency alternating current phenomena, electrotherapy, and the transmission of electrical energy without wires. Tesla coil circuits were used commercially in spark gap radio transmitters for wireless telegraphy until the 1920s, and in pseudo medical equipment such as electrotherapy and violet ray devices. Today their main use is for entertainment and educational displays. But in this part of our report we are discussing the use of tesla coil in wireless electricity transmission.” [12]

“ A Tesla coil transformer operates in a significantly different fashion from a conventional (i. e., iron core) transformer. With Tesla coils, unlike a conventional Tesla coil's windings are “ loosely” coupled, with a large air gap, and thus the primary and secondary typically share only 10-20% of their respective magnetic fields. Instead of a tight coupling, the coil transfers energy from one oscillating resonant circuit (the primary) to the other (the secondary) over a number of RF cycles.” [13]

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“ As the primary energy transfers to the secondary, the secondary’s output voltage increases until all of the available primary energy has been transferred to the secondary (less losses). Even with significant spark gap losses, a well-designed Tesla coil can transfer over 85% of the energy initially stored in the primary capacitor to the secondary circuit. The voltage achievable from a Tesla coil can be significantly greater than a conventional transformer, because the secondary winding is a long single layer solenoid widely separated from the surroundings and therefore well insulated. Also, the voltage per turn in any coil is higher because the rate of change of magnetic flux is high at high frequencies

The optimized Tesla coil transmitter is a continuous wave oscillator with a break rate equalling the operating frequency. The combination of a helical resonator with an elevated terminal is also used for wireless reception. The Tesla coil receiver is intended for receiving the non-radiating electromagnetic field energy produced by the Tesla coil transmitter. The Tesla coil receiver is also adaptable for exploiting the ubiquitous vertical voltage gradient in the Earth’s atmosphere. Tesla built and used various devices for detecting electromagnetic field energy. His early wireless apparatus operated on the basis of Hertzian waves or ordinary radio waves, electromagnetic waves that propagate in space without involvement of a conducting guiding surface . A Tesla coil used as a receiver is referred to as a Tesla receiving transformer. The Tesla coil receiver acts as a step-down transformer with high current output.” [14]

A Tesla coil can receive electromagnetic impulses from atmospheric electricity and radiant energy, besides normal wireless transmissions.
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Radiant energy throws off with great velocity minute particles which are strongly electrified and other rays falling on the insulated-conductor connected to a condenser (i. e., a capacitor) can cause the condenser to indefinitely charge electrically.

D: DesktopCapture. PNG Figure 3: schematics of primary and secondary tesla coil

Wireless Power Transfer Sample Calculations

Details:

Diameter of the coil (D) = 16cm

Radius of the coil (r) = 8cm

Radius of the cross-section (a) = 0.4cm

Number of Turns (N) = 9 turns

Theoretical Calculation:

1. Inductance of the Winding:

Inductance of a circular coil = $N^2 \mu_0 r (\ln(8r/a) - 1.75)$

= $92 \times 4\pi \times 10^{-7} \times 8 \times (\ln((8 \times 8)/0.4) - 1.75)$

= 2.707mH

2. Resistance of the Winding:

Resistance of the Winding (R) = $\rho l/A$

Length of the coil (l) = Circumference of coil x N

$$= 2\pi r \times D \times N$$

$$= 904.8 \text{ cm}$$

$A = 2\pi r(r+h)$, where, h = width of the winding

$$= 442.34 \text{ cm}$$

ρ_i = Resistivity of Copper

$$= 1.796 \times 10^{-8}$$

$$R = 3.67 \times 10^{-8} \Omega$$

3. Resistance of Leakage path:

$$R = \rho_i l / A$$

ρ_i = Resistivity of Air = 106 (assumed)

l = length of air gap = 6.5 cm (Distance to be transmitted)

A = Area of air gap (Rectangular Area between two coils)

$$R = 1.54 \text{ M}\Omega$$

4. Resonant Frequency :

$$f = 1/2\pi \sqrt{LC}$$

$$L = 2.707 \text{ mH}$$

$C = 0.0047 \text{ nF}$ (Capacitor Used)

$f = 1.4 \text{ MHz}$

5. Resonance Condition:

For Resonance to occur, $X_L = X_C$

$X_L = \text{Inductive reactance (Reactance of Coil)}$

$X_C = \text{Capacitive Reactance}$

$X_L = 2\pi f \times L$

$= 23812 \text{ } \Omega$

$= 23.8 \text{ K}\Omega$

$X_C = 1/2\pi f \times C$

$= 24188 \text{ } \Omega$

$= 24.188 \text{ K}\Omega$

System Design

Prototype System Description

The main purpose of the project is to have wireless power transmission. It is made mainly of 2 antennas which act as transmitter and receiver. The transmitter is connected to the power source and the receiver is connected to the load (for us it's just a small LED).

At first we decided to use wall socket as the power source which would be AC and then convert it to DC using AC to DC converter. But then to simplify the circuit and pay more attention to the wireless transmission we started off with a DC power source. [15]

DC Power Source

It can be a simple battery or a Power supply unit. A power supply is a device that supplies electrical energy to one or more electric loads. The term is most commonly applied to devices that convert one form of electrical energy to another, though it may also refer to devices that convert another form of energy (e. g., mechanical, chemical, solar) to electrical energy. A regulated power supply is one that controls the output voltage or current to a specific value; the controlled value is held nearly constant despite variations in either load current or the voltage supplied by the power supply's energy source.

D: DesktopDC power supply unit. jpgD: DesktopBattery. jpg

Figure 4: types of power source

Now the DC current needed to be filtered and made into a DC pulse. So we connected it to a 555 Timer.

555 Timer Astable

The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation and oscillator applications. The 555 can be used to provide time delays, as an oscillator, and as a flip-flop element.

D: Desktop555 Timer. jpgFigure 5: the 555-timer.

The output from the 555 timer astable circuit gave us a DC pulse that looked like the positive sine curve. [16]

D: Desktopsin wave. gifFigure 6: Full wave Rectified Sine wave

Once this was achieved it was connect to the primary loop at the base of the antenna (transmitter). The other end would be connected to the antenna.

Now we needed to increase the voltage and reduce the current as much as possible so we looped another wire around the primary and connected the primary to the ground instead of the antenna. Now we made the ratio of primary to the secondary to be 14: 1 which acted as a step up transformer. Now the other end of the secondary could be connected to the antenna.

Step up Transformer:

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors-the transformer's coils. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF), or " voltage", in the secondary winding. This effect is called inductive coupling.

$$\frac{V_{\text{s}}}{V_{\text{p}}} = \frac{N_{\text{s}}}{N_{\text{p}}}$$

D: Desktop350px-Transformer3d_col3. svg. pngFigure 7: Schematic of transformer

The two antennas act like a two plates of a capacitor. When we adjust the frequency for the receiver and the transmitter to the same resonant frequency, the waves transmitted by the antenna is received by the receiver antenna. [17]

Capacitor:

A capacitor (originally known as condenser) is a passive two-terminal electrical component used to store energy in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors separated by a dielectric (insulator); for example, one common construction consists of metal foils separated by a thin layer of insulating film. Capacitors are widely used as parts of electrical circuits in many common electrical devices.

Now the receiver is connected to the primary winding which is then grounded. This surrounds the secondary winding whose one end is grounded and the other end has load (like a bulb or LED). [18]

Load:

If an electric circuit has a well-defined output terminal, the circuit connected to this terminal (or its input impedance) is the load.

The primary and the secondary winding act as a step down transformer and hence bulb gets light up with a low voltage. The voltage can be adjusted by changing the ratio of primary to secondary.

Case Studies:

We can easily transmit energy of very low and high voltage using various methods. But for some places it will be very useful if the energy transfer occur without wires. There are many different concepts used in the field of wireless energy transfer. The main concern is to transfer energy without any loss of energy during transmission. The methods which can be used to transfer energy wirelessly are as follows:

Transformer couple:

Energy transfer between two coils through magnetic fields. This method requires that distance between two coils should not be far apart. Otherwise there will be a loss in energy transfer.

Resonant induction couple:

Electromagnetic wave in a high angular waveguide is called as evanescent waves which carry no energy. A proper resonant waveguide is brought near the transmitter and then a tunnel is used to form the power drawing waveguide which can be converted in DC using rectifier circuits.

Radio and microwave energy transfer:

This method uses microwave which is sent to the long distances and can be received through antenna which changes microwave energy back to electrical energy. The problem is that the diameter of antenna should be at least a km length in order for it to work.

Laser beam transfer:

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Laser is beamed to the photo voltaic cells which then extracts the electrical energy.

Electrical conduction method:

The energy is supplied through the air medium. When the voltage in the conductor reaches the breakdown voltage then the energy starts transferring to the air medium and hence energy gets received by other end.

From all of these methods mentioned above we chose to use tesla coil approach in energy transmission. The approach is good to transmit energy efficiently at a medium level of transmission. If we want to transfer high amount of energy as 1200 V then we need to investigate before using this approach because transferring large amount of energy can make system less efficient or it may have some health concerns. But our wireless approach is good for transferring energy up to V. [19]

Analysis/ Results

Advantages

Disadvantages

- No need for transmission lines.
- Tesla Coil has absolute energy transmission with no loss.
- Uses resonant induction which have same principles as magnetic induction (magnetic fields to transfer current), but resonance used to increase the range yet maintain the efficiency in transfer.
- Energy transfers easily between resonating objects.

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- Wireless energy transmission can be conducted at mid-to-high range in distance
- Unaffected by weather, seasons or the day time cycle.
- System is highly eco-friendly system.
- Advantage for devices with use of midrange power.
- Uses scalar waves instead of transverse wave(common radio wave)
- Use of scalar waves makes It capable of penetrating any solid object. This includes Faraday Cages. Theoretically, the transmission can be done directly through earth.
- Use of scalar waves makes it transmit power faster than the speed of light depending on frequency.
- Use of scalar waves can magnify power during the process of transmission and reception.
- A conventional transverse wave transmitter cannot sense if a receiver has “ tuned in.” However, in a scalar system the transmitter and receiver interact because they are in a state of resonance.
- Very simple design in theory as well as physical model. Circuits are not as complex.
- Low cost of the entire system building.
- Power loss is less compared to wired electricity transmission.

- For powered transmission about 80% of the energy extracted is lost when using electronic products

-The resonance condition has to be satisfied. Any chance of error prevents from the possibility of power transfer.

- Low power transfer due to radiation for cases when a very strong ferromagnetic material is present

We successfully developed a prototype of functioning tesla coil, wireless power transmitting system that proves our topic of wireless power transfer.

Conclusion:

The prototype was made up on the concept experimented by Tesla. Using Tesla coil system, we successfully created functioning prototype of wireless power transfer. To make this happen, we had to use methods of tesla coil, connected to antennas that worked as a transmitter and receiver for the energy transfer. Wireless energy transfer holds a great potential for future, a dream of Tesla to provide energy to each and every one who needs it, and wherever they need it. The ability of transferring energy wirelessly has potential in all fields. Input had parallel leftover voltage amplitude 0. 328 Volts and output had parallel leftover voltage amplitude of 0. 325 Volts. The loss was negligible. Power is being transmitted by the aether, through longitudinal waves since we proved that: 1) the intensity of the light bulb did not vary with the change in distance from transmitter to receiver. 2) Power transmission was not interrupted by the metal plates positioned in between antennas. Wireless transmission could make all places in the world accessible to electricity.

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Appendix

MULTISIM of inverter

DC pulse square waves of 555-timer.

Output of the full circuit