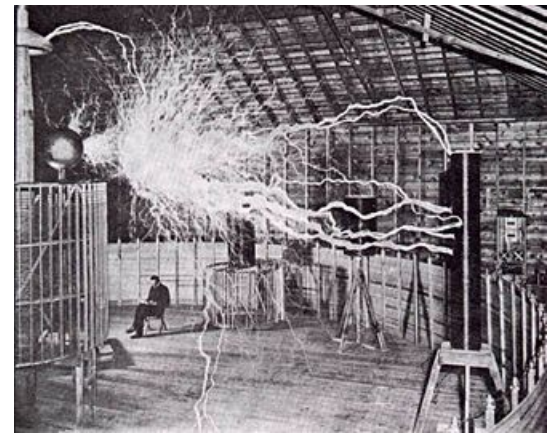


Nikola Tesla - Magnifying transmitter



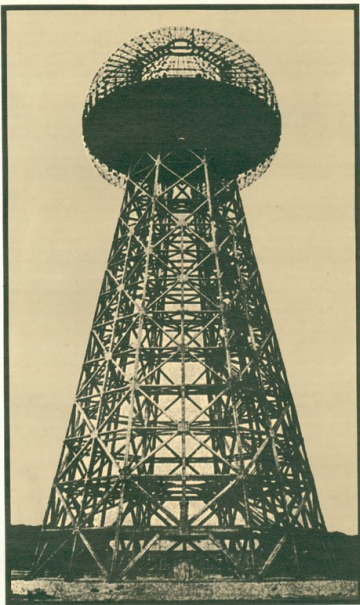
The **magnifying transmitter** is an alternate version of a Tesla coil. It is a high power harmonic oscillator that Nikola Tesla proposed for the wireless transmission of electrical energy.^[1] In his autobiography, Tesla stated that "...I feel certain that of all my inventions, the Magnifying Transmitter will prove most important and valuable to future generations."^[1] The magnifying transmitter is an air-core, multiple-resonant transformer that can generate high voltages. Tesla originally termed it self-regenerative resonant transformer, a term that is no longer in general use.

A publicity photo of Nikola Tesla sitting in the *Colorado Springs experimental station* with his "*Magnifying Transmitter*". The arcs are about 22 feet (7 m) long. (Tesla's notes identify this as a double exposure.)



History

The first 'Magnifier' was assembled in New York City between 1895 - 1898.^[1] In 1899 a larger magnifier was constructed in Colorado Springs, Colorado. This machine was used to conduct fundamental experiments in wireless telecommunications and electrical power transmission. Measuring fifty-one feet (15.5 m) in diameter, it developed a working potential estimated at 3.5 million to 4 million volts and was capable of producing electrical discharges exceeding one hundred feet (30 m) in length.^[2]



Colorado arrival

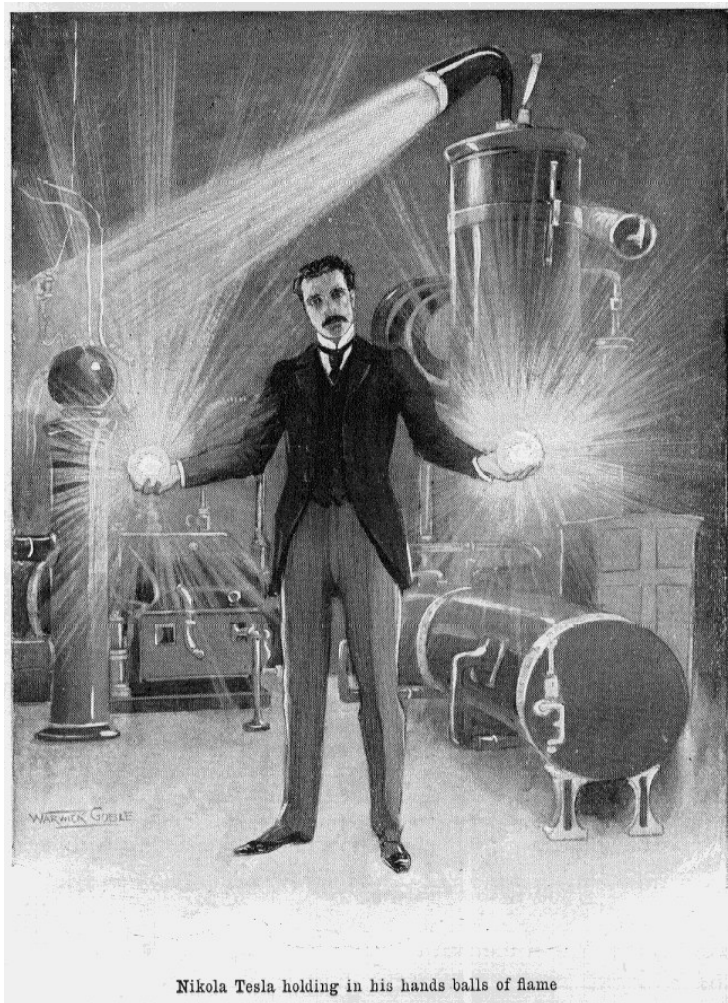
Tesla's Colorado lab was located in a highly geomagnetic location.

In 1899, Tesla decided to move and began research in Colorado Springs. He chose this location primarily because of the frequent thunderstorms, the high altitude (where the air, being at a lower pressure, had a lower dielectric breakdown strength, making it easier to ionize), and the dryness of the air (minimizing leakage of electric charge through insulators). Tesla kept a handwritten diary of his experiments in the Colorado Springs lab where he spent nearly nine months. It consists of 500 pages of notes and nearly 200 drawings, recorded chronologically between June 1, 1899 and January 7, 1900,

as the work occurred, containing explanations of his experiments.

See also: Colorado Springs Notes, 1899–1900

Tuned electrical circuits



Nikola Tesla holding in his hands balls of flame

While in Colorado, Tesla constructed many smaller resonance transformers and conducted further research on concatenated tuned electrical circuits. Tesla also designed various sensitive devices for detecting received electrical energy, including rotating coherers. These used a clockwork mechanism of gears driven by a coiled spring-drive which rotated a small glass cylinder containing metal filings. These experiments were the final stage after years of work on synchronized tuned electrical circuits. These instruments were constructed to demonstrate how a wireless receiver could be "tuned" to respond to a specific complex signal while rejecting others. Tesla logged in his diary on January 2, 1900 that a separate resonance transformer tuned to the same high frequency as a larger high-voltage resonance transformer (which acted as a transmitter) received energy from the larger coil, one of many demonstrations of the wireless *transmission* of electrical energy. These experiments helped to confirm Tesla's priority in the invention of radio during later disputes in the courts. These air core high-frequency resonant coils were the predecessors of systems ranging from radio to medical nuclear magnetic resonance

imaging.

Power transmission

On July 4, 1899, Tesla discovered terrestrial stationary waves within the earth. He demonstrated that the Earth behaves as a smooth polished conductor and possesses electrical vibrations. Tesla demonstrated that the Earth could respond at predescribed frequencies of electrical vibrations. Tesla conducted experiments contributing to the understanding of electromagnetic propagation and the Earth's resonance. He transmitted signals several kilometres and lit neon tubes conducting through the ground.

Tesla researched ways to transmit energy wirelessly over long distances (via transverse waves, to a lesser extent, and, more readily, longitudinal waves). He transmitted extremely low frequencies through the ground as well as between the earth's surface and the Kennelly-Heaviside layer. He received patents on wireless transceivers that developed standing waves by this method.

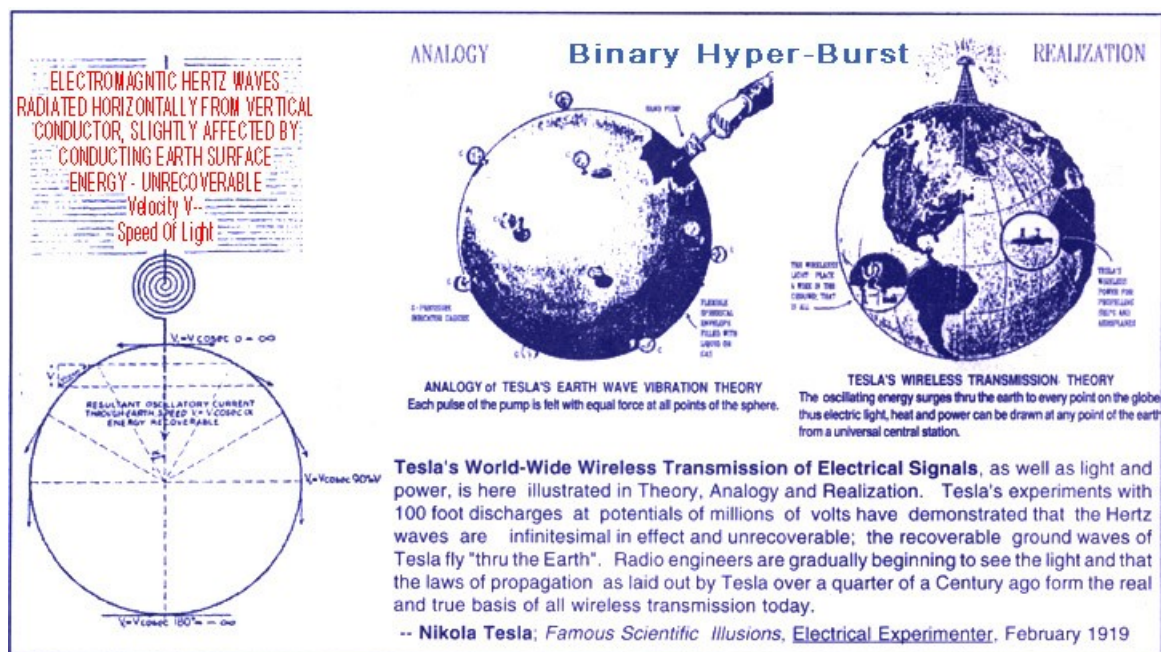
The magnifying transmitter was the basis for Tesla's Wardenclyffe Tower project. Although modern Tesla coils are designed to generate disruptive discharges, this system was designed for wireless communication and power transmission via longitudinal waves and telluric currents. In 1925, John B. Flowers advanced a proposal to test Tesla's system and to implement the system. H. L. Curtis, the chief of the Bureau of Standards Radio Laboratory in Washington D.C., and J. H. Dillinger, a physicist, reviewed the proposal but declined to implement the proposed plan. Flowers's mechanical analogy test was successful, though.^[3]

Electromechanical oscillator

Tesla developed a reciprocating electromechanical oscillator as a source of frequency stable or isochronous alternating electric current used in conjunction with both wireless transmitting and receiving apparatus. This circuit element was applied in much the same manner as quartz timer crystals are now. He also proposed the use of this device for geophysical exploration - seismology—a technique that he called telegeodynamics.

Magnifying transmitter and the Wardenclyffe Tower

The layout of the Wardenclyffe magnifying transmitter is well known, based upon Tesla's patents^{[4][5]} and various photographs^{[6][7]} in which the concept was implemented. The magnifying transmitter is not identical to the classic Tesla coil. It has the short thick primary and secondary inductor characteristic of the Tesla coil, although magnetic coupling between the two is tighter. Because of this, more aggressive measures have to be taken in terms of primary spark quenching and providing additional insulation between the primary and secondary. In addition to these two large-diameter coils that comprise the master oscillator, Tesla added a third inductor called the "extra coil."



Construction and theory of operation

In a classic Tesla coil the primary drives the ground end of the secondary coil to form the driver transformer, which resonates the entire secondary coil. In the magnifying transmitter the driving and resonating parts of the secondary are separate coils. From a circuit analysis standpoint, there is little difference between the classic coil and the magnifier.

The extra coil or helical resonator can be physically separated from the two close-coupled coils, which comprise the *master oscillator* or *driver* section. The power from the master oscillator is fed to the lower end of the extra coil resonator through a large diameter electrical conductor or pipe to minimize corona. The magnifying transmitter's base-driven extra coil behaves as a slow-wave helical resonator, the axial disturbance propagating at a velocity of less than 1% up to around 10%

the speed of light in free space. The Magnifying Transmitter's axial velocity electromagnetic field is established by the coil pitch and electrical charge propagation speed through the circuit.

Operation

Using low frequency harmonic Maxwellian oscillations, Tesla attempted to develop standing waves of extremely low frequency in the Earth's electro-magnetic circuit. Based upon observations made with the device, Tesla reported that a type of Earth resonance - involving the Earth's telluric energy - could be excited with the magnifying transmitter. He discovered that the resonance frequency of the Earth was approximately 8 hertz (Hz). In the 1950s, researchers confirmed that the resonance frequency of the Earth's ionospheric cavity was in this range. See Schumann resonance

In normal operation the device is relatively silent, generating a high power electric field, but if the output voltage exceeds the design voltage of the elevated terminal, high-voltage sparks will strike out from the electrode into the air.

Related Tesla patents

- *"System of Electric Lighting," U.S. Patent 454,622*, 23 June 1891
- *"Means for Generating Electric Currents," U.S. Patent 514,168*, 6 February 1894
- *"Electrical Transformer," U.S. Patent 593,138*, 2 November 1897
- *"Method of and Apparatus for Controlling Mechanism of Moving Vehicle or Vehicles ", U.S. Patent 613,809*, 8 November 1898
- *"System of Transmission of Electrical Energy," U.S. Patent 645,576*, Mar. 20, 1900
- *"Apparatus for Transmission of Electrical Energy," U.S. Patent 649,621*, 15 May 1900
- *"System of Transmission of Electrical Energy," U.S. Patent 645,576*, 20 March 1900
- *"Apparatus for Utilizing Effects Transmitted from a Distance to a Receiving Device through Natural Media," U.S. Patent 685,953*, Nov. 5, 1901
- *"Method of Utilizing Effects Transmitted through Natural Media," U.S. Patent 685,954*, Nov. 5, 1901
- *"Apparatus for Utilizing Effects Transmitted From A Distance To A Receiving Device Through Natural Media," U.S. Patent 685,955*, Nov. 5, 1901
- *"Apparatus for Utilizing Effects Transmitted through Natural Media," U.S. Patent 685,956*, Nov. 5, 1901
- *"Method Of Utilizing Radiant Energy," U.S. Patent 685,958*, 5 November 1901
- *"Method of Signaling," U.S. Patent 723,188*, Mar. 17, 1903
- *"System of Signaling," U.S. Patent 725,605*, Apr. 14, 1903
- *"Art of Transmitting Electrical Energy through the Natural Mediums," U.S. Patent 787,412*, Apr. 18, 1905
- *"Apparatus for Transmitting Electrical Energy," Jan. 18, 1902, U.S. Patent 1,119,732*, Dec. 1, 1914

Wardenclyffe Tower



Tesla's Wardenclyffe plant on Long Island in partial stage of completion. Work on the 55-foot diameter cupola had not yet begun. Note the coal car parked next to the building. From this facility, Tesla hoped to demonstrate wireless transmission of electrical energy across the Atlantic. Circa 1902.



Wardenclyffe Tower located in Shoreham, Long Island, New York. The 94 ft (29 m) by 94 ft (29 m) brick building was designed by architect Stanford White. The station, including the tower structure was not completed due to financial difficulties.



Wardenclyffe Tower (1901–1917) also known as the Tesla Tower, was an early wireless telecommunications tower designed by Nikola Tesla and intended for commercial trans-Atlantic wireless telephony, broadcasting, and to demonstrate the transmission of power without interconnecting wires.[1][2] The core facility was never fully operational and was not completed due to economic problems.[3]

The tower was named after James S. Warden, a western lawyer and banker who had purchased land in Shoreham, Long Island, about sixty miles from Manhattan. Here he built a resort community known as Wardenclyffe-On-Sound. Warden believed that with the implementation of Tesla's "world system", a "Radio City" would arise in the area, and he offered Tesla 200 acres (81 hectares) of land close to a railway line on which to build his wireless telecommunications tower and laboratory facility.



The Wardenclyffe World Wireless facility as envisioned by Tesla was to have been quite different from present day radio broadcasting stations. While there was to be a great similarity in the apparatus employed, the method in which it was to be utilized would have been radically different. Conventional transmitters are designed so as to maximize the amount of power radiated from the antenna structure. Such equipment must process tremendous amounts of power in order to counteract the loss in field strength encountered as the signal radiates out from its point of origin. The transmitter at Wardenclyffe was being configured so as to minimize the radiated

power.

The energy of Tesla's steam driven Westinghouse 200 kW alternator was to be channeled instead into an extensive underground radial structure of iron pipe installed 120 feet beneath the tower's base. This was to be accomplished by superposing a low frequency base-band signal on the higher frequency signal coursing through the transmitter's helical resonator. The low frequency current in the presence of an enveloping corona-induced plasma of free charge carriers would have pumped the earth's charge. It is believed the resulting ground current and its associated wave complex would have allowed the propagation of wireless transmissions to any distance on the earth's surface with as little as 5% loss due to radiation. The terrestrial transmission line modes so excited would have supported a system with the following technical capabilities:

Establishment of a multi-channel global broadcasting system with programming including news, music, etc;

Interconnection of the world's telephone and telegraph exchanges, and stock tickers;

Transmission of written and printed matter, and data;

World wide reproduction of photographic images;

Establishment of a universal marine navigation and location system, including a means for the synchronization of precision timepieces;

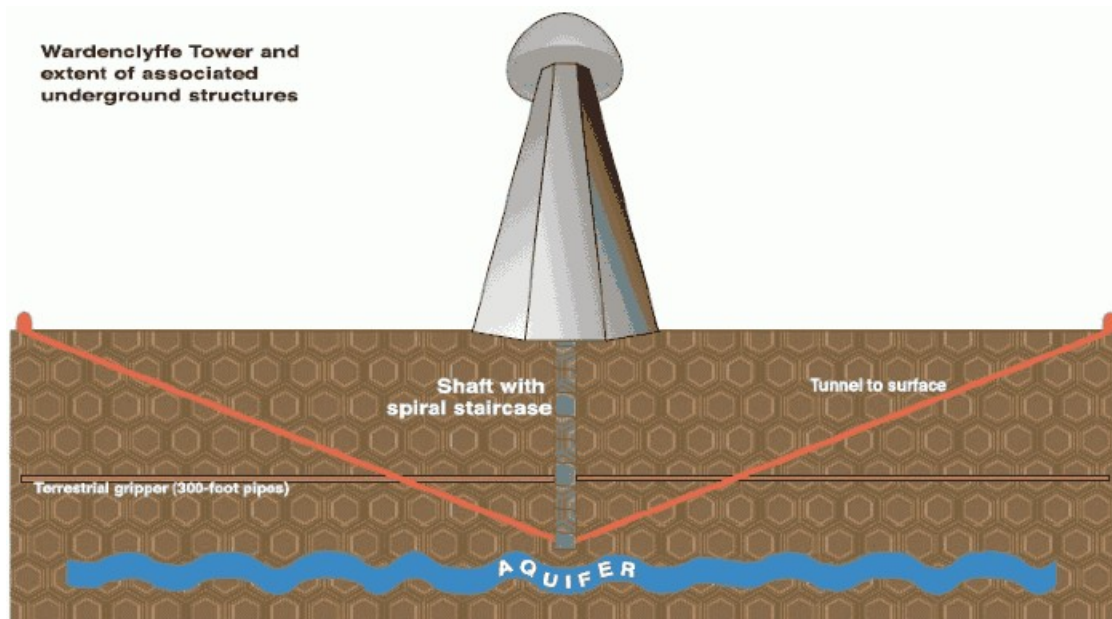
Establishment of secure wireless communications services.

The plan was to build the first of many installations to be located near major population centers around the world. If the program had moved forward without interruption, the Long Island prototype would have been followed by additional units the first of which being built somewhere along the coast of England. By the Summer of 1902 Tesla had shifted his laboratory operations from the Houston Street Laboratory to the rural Long Island setting and work began in earnest on

development of the station and furthering of the propagation research. Construction had been made possible largely through the backing of financier J. Pierpont Morgan who had offered Tesla \$150,000 towards the end of 1900.

By July 1904, however, this support had run out and with a subsequent major down turn in the financial markets Tesla was compelled to pursue alternative methods of financing. With funds raised through an unrecorded mortgage against the property, additional venture capital, and the sale of X-ray tube power supplies to the medical profession he was able to make ends meet for another couple of years. In spite of valiant efforts to maintain the operation, income dwindled and his employees were eventually dropped from the payroll. Still, Tesla was certain that his wireless system would yield handsome rewards if it could only be set into operation and so the work continued as he was able.

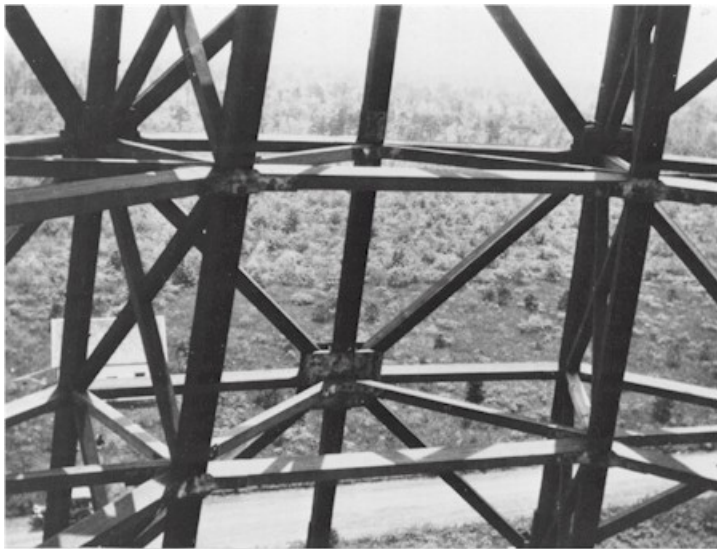
A second mortgage in 1908 acquired again from the Waldorf-Astoria proprietor George C. Boldt allowed some additional bills to be paid, but debt continued to mount and between 1912 and 1915 Tesla's financial condition disintegrated. The loss of ability to make additional payments was accompanied by the collapse of his plan for high capacity trans-Atlantic wireless communications. The property was foreclosed, Nikola Tesla honored the agreement with his debtor and title on the property was signed over to Mr. Boldt. The plant's abandonment sometime around 1911-1912 followed by demolition and salvaging of the tower in 1917 essentially brought an end to this era. Tesla's April 20, 1922 loss on appeal of the judgment completely closed the door to any further chance of his developing the site.



Nikola Tesla, as quoted from the New York Times, March 27th, 1904 -

"Much has already been done towards making my system commercially available, in the transmission of energy in small amounts for specific purposes, as well as on an industrial scale. The results attained by me have made my scheme of intelligence transmission, for which the name of "World Telegraphy" has been suggested, easily realizable. It constitutes, I believe, in its principle of operation, means employed and capacities of application, a radical and fruitful departure from what has been done heretofore. I have no doubt that it will prove very efficient in enlightening the masses, particularly in still uncivilized countries and less accessible regions, and that it will add materially to general safety, comfort and convenience, and maintenance of peaceful relations."

"It involves the employment of a number of plants, all of which are capable of transmitting individualized signals to the uttermost confines of the earth. Each of them will be preferably located near some important center of civilization and the news it receives through any channel will be flashed to all points of the globe. A cheap and simple device, which might be carried in one's pocket, may then be set up somewhere on sea or land, and it will record the world's news or such special messages as may be intended for it. Thus the entire earth will be converted into a huge brain, as it were, capable of response in every one of its parts. Since a single plant of but one hundred horsepower can operate hundreds of millions of instruments, the system will have a virtually infinite working capacity, and it must needs immensely facilitate and cheapen the transmission of intelligence."



"The first of these central plants would have been already completed had it not been for unforeseen delays which, fortunately, have nothing to do with its purely technical features. But this loss of time, while vexatious, may, after all, prove to be a blessing in disguise. The best design of which I know has been adopted, and the transmitter will emit a wave complex of a total maximum activity of 10,000,000 horsepower, one percent of which is amply sufficient to "girdle the globe." This enormous rate of energy delivery, approximately twice that of the combined falls of Niagara, is obtainable only by the use of certain artifices, which I shall make known in due course.

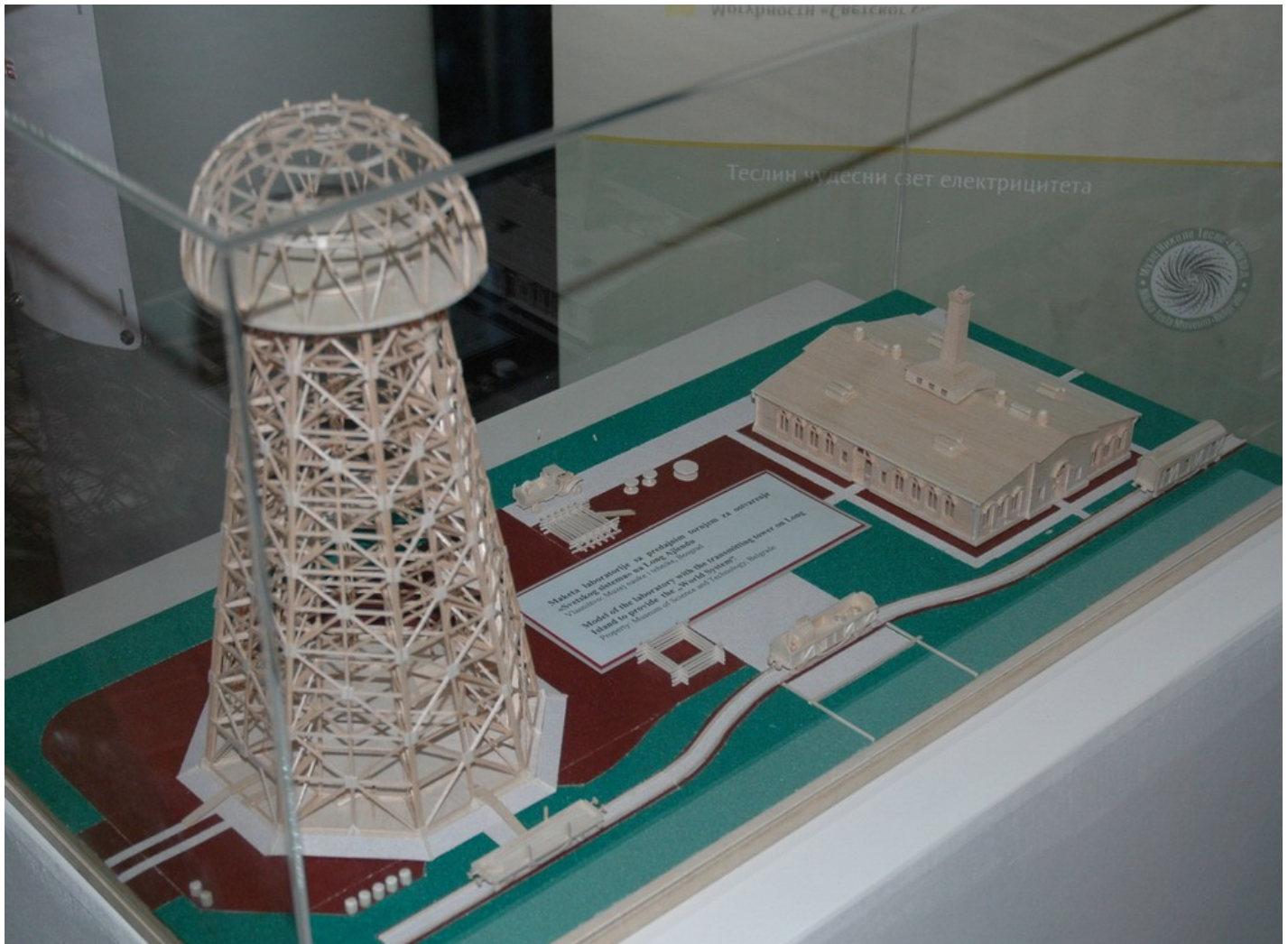
"For a large part of the work which I have done so far I am indebted to the noble generosity of Mr. J. Pierpont Morgan, which was all the more welcome and stimulating, as it was extended at a time when those, who have since promised most, were the greatest of doubters. I have also to thank my friend Stanford White, for much unselfish and valuable assistance. This work is now far advanced, and though the results may be tardy, they are sure to come. Meanwhile, the transmission of energy on an industrial scale is not being neglected. The Canadian Niagara Power Company have offered me a splendid inducement, and next to achieving success for the sake of the art, it will give me the greatest satisfaction to make their concession financially profitable to them. In this first power plant, which I have been designing for a long time, I propose to distribute 10,000 horsepower under a tension of 10,000,000 volts, which I am now able to produce and handle with safety."

"This energy will be collected all over the globe preferably in small amounts, ranging from a fraction of one to a few horsepower. One of the chief uses will be the illumination of isolated homes. It takes very little power to light a dwelling with vacuum tubes operated by high frequency currents and in each instance a terminal a little above the roof will be sufficient. Another valuable application will be the driving of clocks and other such apparatus. These clocks will be exceedingly simple, will require absolutely no attention and will indicate rigorously correct time. The idea of impressing upon the earth American time is fascinating and very likely to become popular."

"There are innumerable devices of all kinds which are either now employed or can be supplied and by operating them in this manner I may be able to offer a great convenience to the whole world with a plant of no more than 10,000 horsepower. The introduction of this system will give opportunities for invention and manufacture such as have never presented themselves before. Knowing the far reaching importance of this first attempt and its effect upon future development, I shall proceed

slowly and carefully. Experience has taught me not to assign a term to enterprises the consummation of which is not wholly dependent on my own abilities and exertions. But I am hopeful that these great realizations are not far off and I know that when this first work is completed they will follow with mathematical certitude."

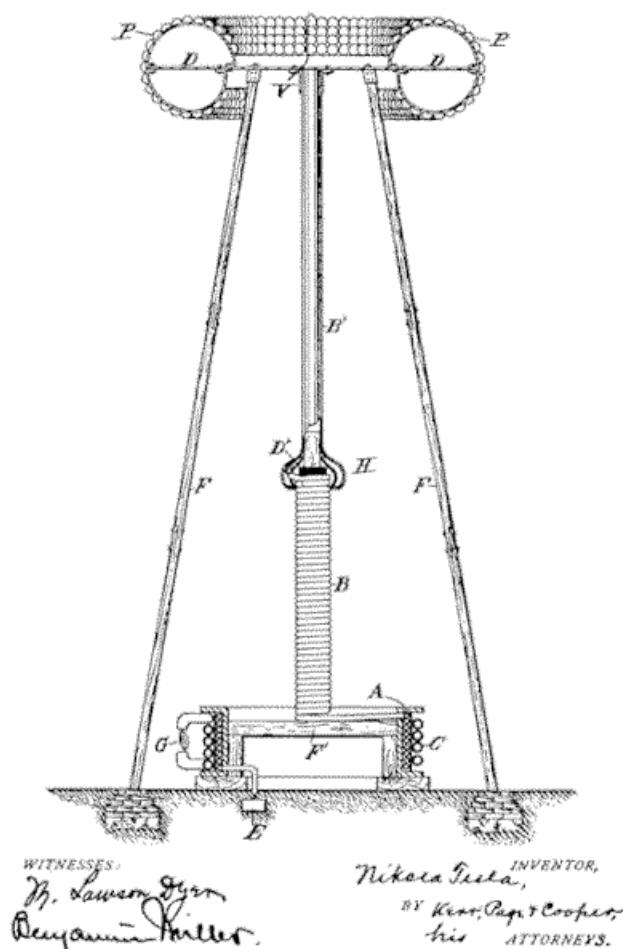
"When the great truth, accidentally revealed and experimentally confirmed, is fully recognized, that this planet, with all its appalling immensity, is to electric currents virtually no more than a small metal ball and that by virtue of this fact many possibilities, each baffling imagination and of incalculable consequence, are rendered absolutely sure of accomplishment; when the first plant is inaugurated and it is shown that a telegraphic message, almost as secret and non-interferable as a thought, can be transmitted to any terrestrial distance, the sound of the human voice, with all its intonations and inflections faithfully and instantly reproduced at any other point of the globe, the energy of a waterfall made available for supplying light, heat or motive power, anywhere...on sea, or land, or high in the air...humanity will be like an ant heap stirred up with a stick. See the excitement coming!" "Cloud born Electric Wavelets To Encircle the Globe: This Is Nikola Tesla's Latest Dream, and the Long Island Hamlet of Wardenclyffe Marvels Thereat," New York Times, 27 March 1904.



How it Works:

Rather than acting as a radiator, the large metallic spheroid, now known as an isotropic

N. TESLA.
APPARATUS FOR TRANSMITTING ELECTRICAL ENERGY.
1,119,732. Patented Dec. 1, 1914.
APPLICATION FILED JAN. 12, 1909. RENEWED MAY 4, 1907.



capacitance, which Tesla positioned above the extra coil was intended only as a reservoir for electrical charge. Another important component of Tesla's Long Island apparatus was an underground array of iron pipes which extended outward from the bottom of a deep shaft beneath the transmitter tower. When coupled with the transmitter these pipes provided a connection to the earth through which a powerful oscillating electrical current would flow. Unlike a conventional radio transmitter with an antenna that radiates dissipating electromagnetic waves out into space, the magnifying transmitter's extra coil excites a low-frequency ground wave called the Zenneck surface wave. In this case the propagating energy does not radiate into space but is concentrated near the earth's surface. Furthermore, Tesla asserted that it is possible to periodically disturb the equilibrium of the earth's electrical charge and cause it to oscillate with his apparatus. This would be accomplished by superposing an extra low frequency baseband signal on the somewhat higher frequency signal coursing through the resonator -- the low frequency current in the presence of an enveloping corona-induced plasma of free charge carriers produced by the oscillator in effect "pumping" the earth's charge.

In Tesla's own words:

"These and other inventions of mine, however, were nothing more than steps forward in a certain directions. In evolving them, I simply followed the inborn instinct to improve the present devices without any special thought of our far more imperative necessities. The "Magnifying Transmitter" was the product of labours extending through years, having for their chief object, the solution of problems which are infinitely more important to mankind than mere industrial development.

If my memory serves me right, it was in November, 1890, that I performed a laboratory experiment which was one of the most extraordinary and spectacular ever recorded in the annals of Science. In investigating the behavior of high frequency currents, I had satisfied myself that an electric field of sufficient intensity could be produced in a room to light up electrode less vacuum tubes. Accordingly, a transformer was built to test the theory and the first trial proved a marvelous success. It is difficult to appreciate what those strange phenomena meant at the time. We crave for new sensations, but soon become indifferent to them. The wonders of yesterday are today common

occurrences. When my tubes were first publicly exhibited, they were viewed with amazement impossible to describe. From all parts of the world, I received urgent invitations and numerous honors and other flattering inducements were offered to me, which I declined. But in 1892 the demand became irresistible and I went to London where I delivered a lecture before the institution of Electrical Engineers.

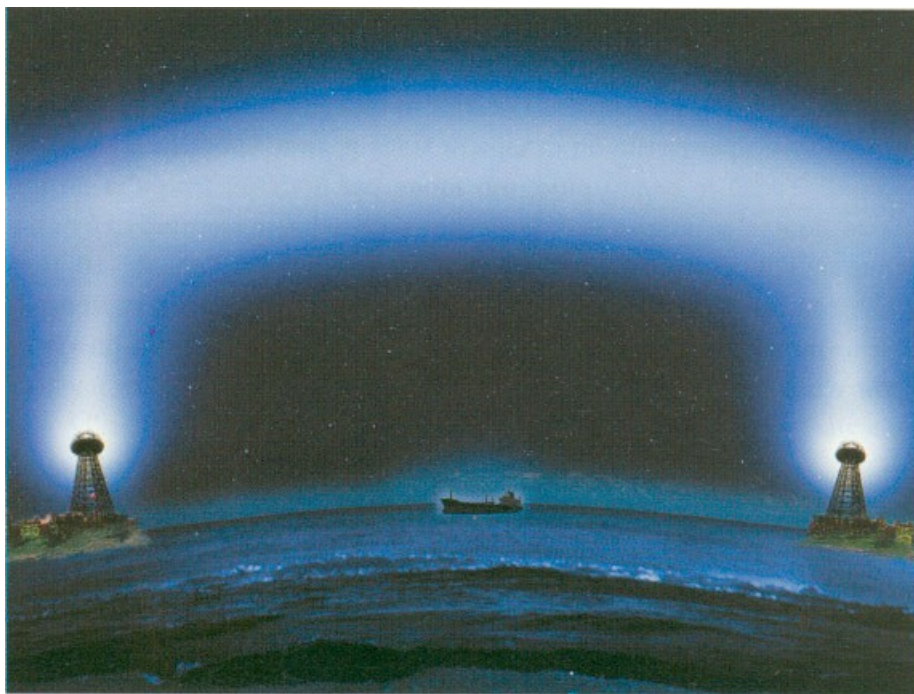
It has been my intention to leave immediately for Paris in compliance with a similar obligation, but Sir James Dewar insisted on my appearing before the Royal Institution. I was a man of firm resolve, but succumbed easily to the forceful arguments of the great Scotchman. He pushed me into a chair and poured out half a glass of a wonderful brown fluid which sparkled in all sorts of iridescent colors and tasted like nectar. "Now," said he, "you are sitting in Faraday's chair and you are enjoying whiskey he used to drink." (Which did not interest me very much, as I had altered my opinion concerning strong drink). The next evening I have a demonstration before the Royal Institution, at the termination of which, Lord Rayleigh addressed the audience and his generous words gave me the first start in these endeavors. I fled from London and later from Paris, to escape favors showered upon me, and journeyed to my home, where I passed through a most painful ordeal and illness. Upon regaining my health, I began to formulate plans for the resumption of work in America. Up to that time I never realized that I possessed any particular gift of discovery, but Lord Rayleigh, whom I always considered as an ideal man of science, had said so and if that was the case, I felt that I should concentrate on some big idea. At this time, as at many other times in the past, my thoughts turned towards my Mother's teaching. The gift of mental power comes from God, Divine Being, and if we concentrate our minds on that truth, we become in tune with this great power. My Mother had taught me to seek all truth in the Bible; therefore I devoted the next few months to the study of this work.



One day, as I was roaming the mountains, I sought shelter from an approaching storm. The sky became overhung with heavy clouds, but somehow the rain was delayed until, all of a sudden, there was a lightening flash and a few moments after, a deluge. This observation set me thinking. It was manifest that the two phenomena were closely related, as cause and effect, and a little reflection led me to the conclusion that the electrical energy involved in the precipitation of the water was inconsiderable, the function of the lightening being much like that of a sensitive trigger. Here was a stupendous possibility of achievement. If we could produce electric effects of the required quality, this whole planet and the conditions of existence on it could be transformed. The sun raises the water of the oceans and winds drive it to distant regions where it remains in a state of most delicate balance. If it were in our power to upset it when and wherever desired, this might life sustaining stream could be at will controlled. We could irrigate arid deserts, create lakes and rivers, and provide motive power in unlimited amounts. This would be the most efficient way of harnessing the sun to the uses of

man. The consummation depended on our ability to develop electric forces of the order of those in nature.

It seemed a hopeless undertaking, but I made up my mind to try it and immediately on my return to the United States in the summer of 1892, after a short visit to my friends in Watford, England; work was begun which was to me all the more attractive, because a means of the same kind was necessary for the successful transmission of energy without wires. At this time I made a further careful study of the Bible, and discovered the key in Revelation. The first gratifying result was obtained in the spring of the succeeding year, when I reaching a tension of about 100,000,000 volts -- one hundred million volts -- with my conical coil, which I figured was the voltage of a flash of lightening. Steady progress was made until the destruction of my laboratory by fire, in 1895, as may be judged from an article by T.C. Martin which appeared in the April number of the Century Magazine. This calamity set me back in many ways and most of that year had to be devoted to planning and reconstruction. However, as soon as circumstances permitted, I returned to the task.

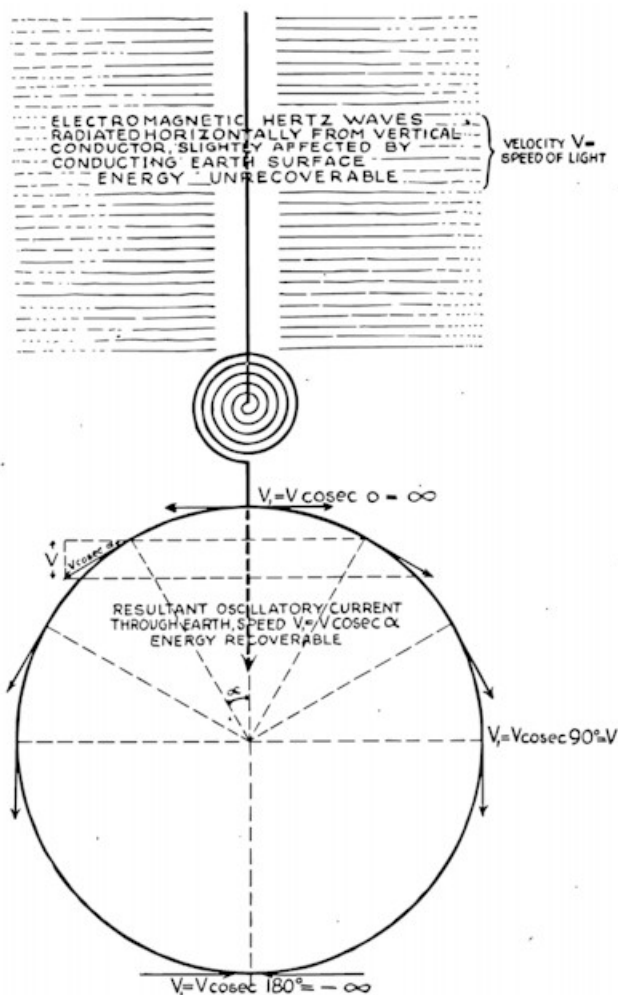


Although I knew that higher electric-motive forces were attainable with apparatus of larger dimensions, I had an instinctive perception that the object could be accomplished by the proper design of a comparatively small and compact transformer. In carrying on tests with a secondary in the form of flat spiral, as illustrated in my patents, the absence of streamers surprised me, and it was not long before I discovered that this was due to the position of the turns and their mutual action. Profiting from this observation, I resorted to the use of a high tension conductor with turns of considerable diameter, sufficiently separated to keep down the distributed capacity, while at the same time preventing undue accumulation of the charge at any point. The application of this principle enabled me to produce pressures of over 100,000,000 volts, which was about the limit obtainable without risk of accident. A photograph of my transmitter built in my laboratory at Houston Street, was published in the Electrical Review of November, 1898.

In order to advance further along this line, I had to go into the open, and in the spring of 1899, having completed preparations for the erection of a wireless plant, I went to Colorado where I remained for more than one year. Here I introduced other improvements and refinements which made it possible to generate currents of any tension that may be desired. Those who are interested

will find some information in regard to the experiments I conducted there in my article, "The Problem of Increasing Human Energy," in the Century Magazine of June 1900, to which I have referred on a previous occasion.

I will be quite explicit on the subject of my magnifying transformer so that it will be clearly understood. In the first place, it is a resonant transformer, with a secondary in which the parts, charged to a high potential, are of considerable area and arranged in space along ideal enveloping surfaces of very large radii of curvature, and at proper distances from one another, thereby insuring a small electric surface density everywhere, so that no leak can occur even if the conductor is bare. It is suitable for any frequency, from a few to many thousands of cycles per second, and can be used in the production of currents of tremendous volume and moderate pressure, or of smaller amperage and immense electromotive force. The maximum electric tension is merely dependent on the curvature of the surfaces on which the charged elements are situated and the area of the latter. Judging from my past experience there is no limit to the possible voltage developed; any amount is practicable.



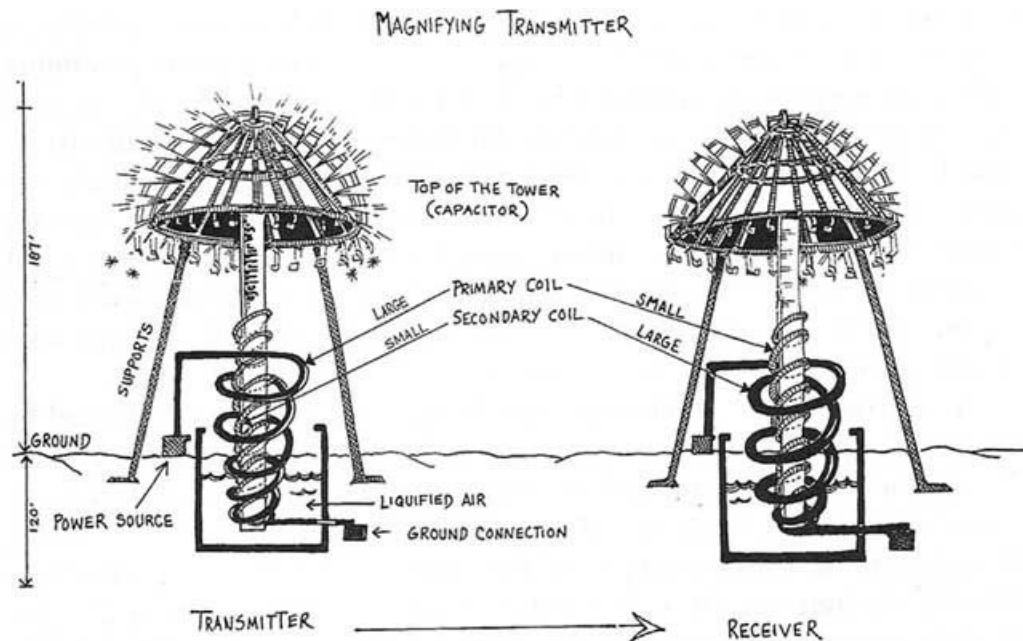
On the other hand, currents of many thousands of amperes may be obtained in the antenna. A plant of but very moderate dimensions is required for such performances. Theoretically, a terminal of less than 90 feet in diameter is sufficient to develop an electromotive force of that magnitude, while for antenna currents of from 2,000-4,000 amperes at the usual frequencies, it need not be larger than 30 feet in diameter. In a more restricted meaning, this wireless transmitter is one in which the Hertz wave radiation is an entirely negligible quantity as compared with the whole energy, under which condition the damping factor is extremely small and an enormous charge is stored in the elevated capacity. Such a circuit may then be excited with impulses of any kind, even of low frequency and it will yield sinusoidal and continuous oscillations like those of an alternator.

Taken in the narrowest significance of the term, however, it is a resonant transformer which, besides possessing these qualities, is accurately proportioned to fit the globe and its electrical constants and properties, by virtue of which design it becomes highly efficient and effective in the wireless transmission of energy. Distance is then **ABSOLUTELY ELIMINATED, THERE BEING NO DIMINUTIONS IN THE INTENSITY** of the

transmitted impulses. It is even possible to make the actions increase with the distance from the plane, according to an exact mathematical law. This invention was one of a number comprised in my "World System" of wireless transmission which I undertook to commercialize on my return to New York in 1900.

As to the immediate purposes of my enterprise, they were clearly outlined in a technical statement of that period from which, I quote, "The world system has resulted from a combination of several

original discoveries made by the inventor in the course of long continued research and experimentation. It makes possible not only the instantaneous and precise wireless transmission of any kind of signals, messages or characters, to all parts of the world, but also the inter-connection of the existing telegraph, telephone, and other signal stations without any change in their present equipment. By its means, for instance, a telephone subscriber here may call up and talk to any other subscriber on the Earth. An inexpensive receiver, not bigger than a watch, will enable him to listen anywhere, on land or sea, to a speech delivered or music played in some other place, however distant."



Engineering details:

Patents normally don't give many quantitative specifics, but Tesla's wireless power patent does give some about the big prototype power-transmission Tesla coil (which was, incidentally, used to conduct a demonstration before skeptical patent examiners). A 50,000-volt transformer charged a capacitor of .004 mfd., which discharged through a rotary gap that gave 5,000 breaks per second. The eight-foot diameter primary had just one turn of stout stranded cable. The secondary was 50 turns of heavily insulated No. 8 wire wound as a flat spiral. It vibrated at 230-250,000 cycles and produced 2 to 4 million volts. This coil evolved into the huge experimental magnifying transmitter

Tesla describes in his Colorado Springs notes. Housed in a specially built lab 110 feet square, the device used a 50,000 volt Westinghouse transformer to charge a capacitor that consisted of a galvanized tub full of salt water as an electrolyte, into which he placed large glass bottles, themselves containing salt water. The salt water in the tub was one plate of this capacitor, the salt water inside the bottles the other plate, and the bottle glass the dielectric. Various capacities were tried, incremental changes being made by connecting more or fewer bottles. A variable tuning coil of 20 turns was connected to the primary, which consisted of two turns of heavy insulated cable that ran around the base of the huge fence like wooden secondary framework. The secondary had 24 turns of No. 8 wire on a diameter of 51 feet. Various extra coils were tried, the final version being 12 feet high, 8 feet in diameter, and having 100 turns of No. 8 wire.

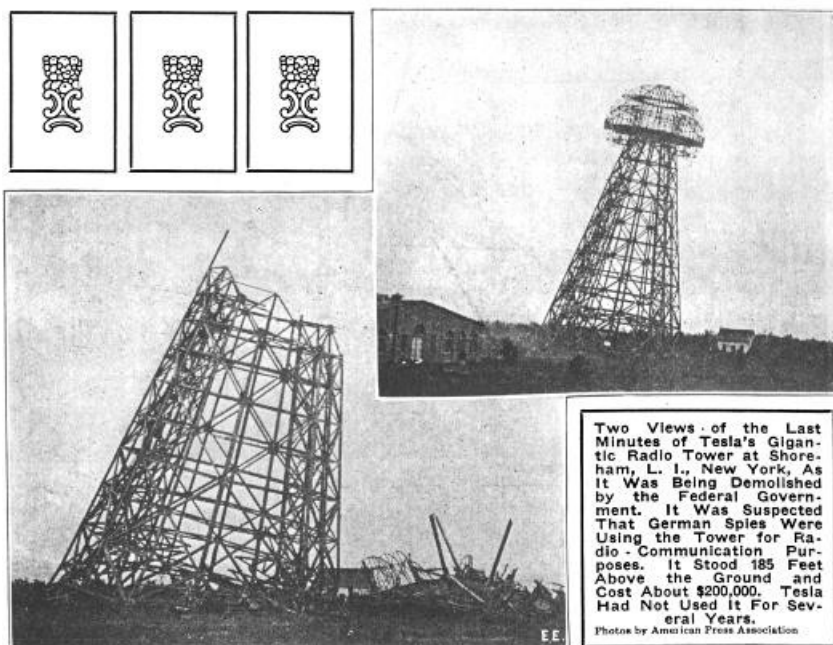
The antenna was a 30-inch conductive ball adjustable for height on a 142-foot mast. The huge transmitter could vibrate from 45 to 150 kilocycles. Even with the big transformer, this bill of

materials does not seem inaccessible to enterprising people, and the technology does not seem so abstruse, so it is no wonder that people have gotten together to build magnifying transmitters and experiment with wireless power without support from corporations or government.

One such group was the People's Power Project in central Minnesota in the late 70's. This group, largely farmers, objected to high voltage power lines trespassing on their land and set out to build an alternative. Limited by the sketchy information then available, the project was not successful. Another attempt, called Project Tesla, is being set up in Colorado. Endowed with more precise calculations and more experienced personnel, Project Tesla will try to repeat Tesla's wireless-power experiment and verify his theory by taking measurements at various remote locations.

Earth Resonance:

Among the appealing features of Colorado Springs for Tesla were the region's frequent and sensational electrical storms. For Tesla, lightning was a joyous phenomenon. Biographers report that, during storms back East, Tesla would throw open the windows of his New York lab and recline on a couch for the duration, muttering to himself ecstatically. In Colorado Springs he tuned in and tracked lightning storms using rudimentary radio receiving equipment. He thereby determined that lightning was a vibratory phenomenon, which set up standing waves bouncing within the earth at a frequency resonantly compatible with the earth's electrical capacity. This earth-resonant frequency, he reasoned, was the ideal frequency for wireless power transmission, and he tuned his ultimate magnifying transmitter accordingly.



The literature contains various reports on exactly what this frequency is. Some say 150 kilocycles, which would be at the upper range of the Colorado Springs transmitter. Others give frequencies considerably lower, 11.78 cycles, 6.8 cycles, frequencies Tesla's transmitter may have achieved harmonically. With reinforcement from the earth resonance, the power would actually increase in the process of transmission.

In one memorable experiment with the Colorado Springs transmitter, Tesla shot from the antenna ball veritable lightning bolts of 135 feet, producing thunder heard 15 miles distant, and, in the process, pulled so many amperes

that he burned out the municipal generator. In another experiment he lit up wirelessly, at a distance of 26 miles from the lab, a bank of 10,000 watts worth of incandescent bulbs. Two years after Colorado Springs, Tesla applied for patent for the far more refined magnifying transmitter shown at the opening of this chapter, a patent that was not granted until a dozen years later.

In this patent he no longer speaks of energy broadcast through the upper strata of the atmosphere but of a grounded resonant circuit. Tesla predicted that his magnifying transmitter would prove most important and valuable to future generations, that it would bring about an industrial revolution and

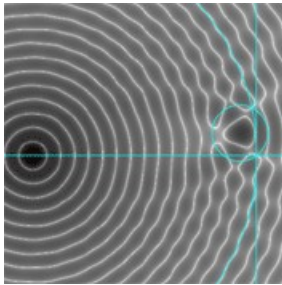
make possible great humanitarian achievements. Instead, as we shall see, the magnifying transmitter became Tesla's Waterloo.



Tesla's oscillator

Tesla's Oscillator is a mechanical oscillator conceived of and invented by [Nikola Tesla](#) in 1898. It is also referred to as the "Earthquake Machine." The machine which Tesla tested was small, around seven inches (178 mm) long, and weighing only one or two pounds; something "you could put in your overcoat pocket". In 1898, Tesla's New York lab was nearly shaken to pieces with this little device, operated by only five pounds of air pressure acting against a special pneumatic piston device. The whole assembly was designed to be powered by steam pressure.

Houston Street Lab



Tesla established a laboratory on Houston Street in New York at 46 E. There, at one point while experimenting with mechanical oscillators, he allegedly generated a resonance of several buildings causing complaints to the police. As the speed grew he hit the resonance frequency of his own building and belatedly realizing the danger he was forced to apply a sledge hammer to terminate the experiment, just as the astonished police arrived. (O'Neill, "Prodigal Genius" pp162-164)

The Discovery Channel's popular MythBusters show examined Tesla's claim that he had created an "Earthquake Machine" in their 60th episode. They tested the physical phenomenon known as mechanical resonance on a traffic bridge, which today are built to withstand such forces. While a single I-beam of steel was deflected several feet in each direction by their oscillator, and they reportedly felt the bridge shaking many yards away, there were no "earth shattering" effects. It is worth indicating that, in the time of the event undertaken by Tesla, buildings were not built to withstand such resonance.

How it Works

Tesla's oscillator is purely mechanical. Steam would be forced into the oscillator, and exit through a series of ports, the net effect of which was to cause the armature to vibrate at high speed, within its casing. The casing was by necessity very strong, as temperatures due to pressure heating in the upper chamber exceeded 200 degrees, and the pressure reached 400psi. Other versions of the machine were created, designed to produce electrical power, both alternating and direct, (without the need for rectifiers).

Sympathetic resonance

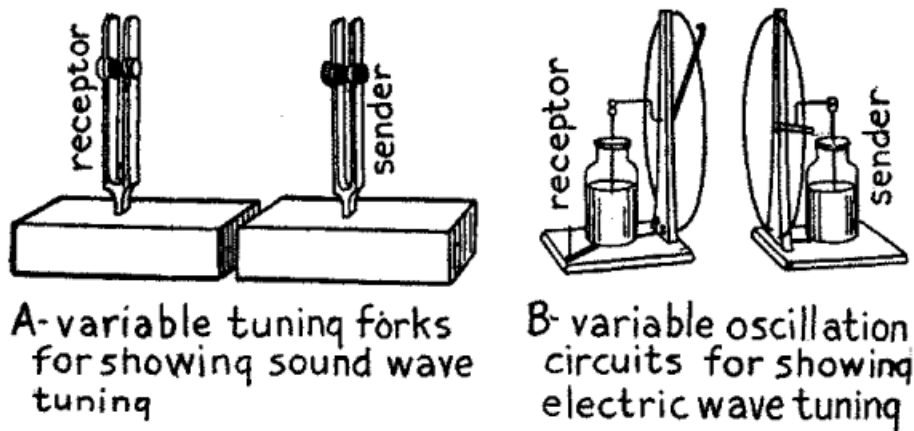


FIG. 36.—Sound Wave and Electric Wave Tuned Senders and Receptors.

Sympathetic resonance is a [harmonic](#) phenomenon wherein a formerly passive string or vibratory body responds to external vibrations to which it has a harmonic likeness. The classic example is demonstrated with two similar tuning-forks of which one is mounted on a wooden box. If the other one is struck and then placed on the box, then muted, the un-struck mounted fork will be heard. In similar fashion will strings respond to the external vibrations of a tuning-fork when sufficient harmonic relations exist between the respective vibratory modes. A unison or octave will provoke the largest response as there is maximum likeness in vibratory motion. Other links through shared resonances occur at the fifth and third though with less effect. The principle of sympathetic resonance has been applied in musical instruments from many cultures and times. Apart from the basic principle at work on instruments with many undamped strings, such as harps, lutes, guitars and pianos with the dampers raised, other instruments are fitted with extra choirs of [sympathetic strings](#), which respond with a silvery halo to the tones played on the main strings.

Lewcock *et al.* (2006) states that:

The property of sympathetic vibration is encountered in its direct form in room acoustics in the rattling of window panes, light shades and movable panels in the presence of very loud sounds, such as may occasionally be produced by a full organ. As these things rattle (or even if they do not audibly rattle) sound energy is being converted into mechanical energy, and so the sound is absorbed. Wood panelling and anything else that is lightweight and relatively unrestrained have the same effect. Absorptivity is at its highest at the resonance frequency, usually near or below 100 Hz.

Arden Wilken on his website provides a significant example of the power of resonance:

An example of proper sympathetic resonance is a windowpane rattling steadily at the very low powerful sound of a bus or truck engine going stationary. The rattling will usually occur at a higher harmonic of the sound made by the engine. As soon as the driver changes into gear the rattling will stop, often changing its rhythm before it stops altogether. Powerful sopranos bursting wineglasses fits in to the same category - sympathetic resonance at a distance.

Failure of the original Tacoma Narrows Bridge

Main article: [Tacoma Narrows Bridge \(1940\)](#)

The dramatically visible, rhythmic twisting that resulted in the 1940 collapse of the original [Tacoma Narrows Bridge](#), has sometimes been characterized in physics textbooks as a classical example of resonance; however, this description is misleading. The catastrophic vibrations that destroyed the bridge were not due to simple mechanical resonance, but to a more complicated oscillation between the bridge and the winds passing through it — a phenomenon known as [aeroelastic flutter](#). [Robert H. Scanlan](#), father of the field of bridge aerodynamics, wrote an article about this misunderstanding.^[1]

String resonance in music instruments

[String resonance](#) occurs on [string instruments](#). Strings or parts of strings may resonate at their [fundamental](#) or [overtone](#) frequencies when other strings are sounded. For example, an A string at 440 Hz will cause an E string at 330 Hz to resonate, because they share an overtone of 1320 Hz (3rd overtone of A and 4th overtone of E).

According to [Grove Music Online](#) (2007) article on *Duplex Scaling*, [Steinway](#) progressed a system of [aliquot scaling](#) to provide sympathetic resonance with the intention of enriching the [treble register](#) of the [pianoforte](#). In the 'octave duplex' piano by [Hoerr](#) of [Toronto](#), each note had four strings, of which two, three or four could potentially be struck by the hammer depending on the depression of one of four pedals. [Steinway's duplex scale](#) was precipitated a half century earlier by an experiment conducted by the German piano maker [Wilhelm Leberecht Petzoldt](#), in which a small bridge was placed behind the standard larger one with the intention of maximizing the potential additional [resonance](#) of a sympathetically vibrating additional length of string.

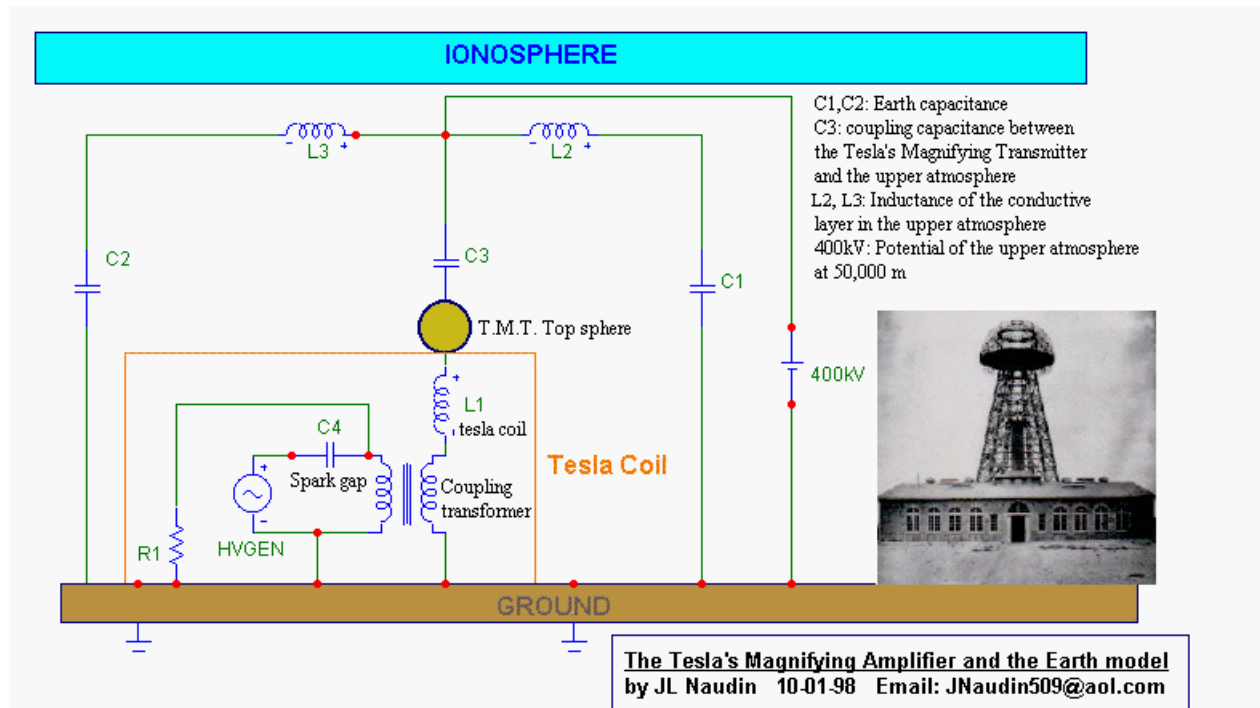
The Tesla Magnifying Transmitter

"...It is a **resonant transformer** with a secondary in which the parts charged to a high potential, are of considerable area and arranged in space along ideal enveloping surfaces of very large radii of curvature, and at proper distances from one another thereby insuring a small electrical surface density everywhere so that no leak can occur even if the conductor is bare. It is suitable for any frequency, from a few to many thousands of cycles per second, and **can be used in the production of currents of tremendous volume and moderate pressure, or of smaller amperage and immense electro-motive force**. The maximum electric tension is merely dependant on the curvature of the surfaces on which the charged elements are situated and the area of the latter." (1)

In the Tesla's Magnifying transmitter, the energy is continuously bounced back and forth between the earth and the reflecting capacitance at a rate timed to a natural rate of the earth.....(5)

Nikola Tesla has said in a patent about improvements relating to the Transmission of Electrical energy (4) : ".....Stated otherwise, the terrestrial conductor is thrown into resonance with the oscillations impressed upon it just like a wire. More than this, a number of facts ascertained by me clearly show, that the movement of electricity through it follows certain laws with nearly mathematical rigor. For the present it will be sufficient to state, that the earth behaves like a perfectly smooth or polished conductor of inappreciable resistance, with **capacity** and **self-induction** uniformly distributed along the axis of symmetry of waves propagation and transmitting slow electrical oscillations without sensible distortion and attenuation. Besides the above, three requirements seem to be essential to the establishment of the resonating condition.

1. **The earth's diameter passing through the pole should be an odd multiple of the quarter wave-length, that is, of the ratio between the velocity of light and four times the frequency of the currents.**
2. **It is necessary to employ oscillations, in which the rate of radiation of energy into space in the form of Hertzians or electromagnetic waves is very small. To give an idea I would say, that the frequency should be smaller than twenty thousand per second, through shorter waves might be practicable. The lowest frequency would appear to be six per second, in which case there will be but one node, at or near the ground plate, and, paradoxical as it may seem, the opposite the transmitter. With oscillations still slower the earth, strictly speaking, will not resonate, but simply act as capacity, and the variation of potential will be more or less uniform over its entire surface.**
3. **The most essential requirement is, however, that irrespective of frequency, the wave or wave train should continue for a certain interval of time, which I have estimated to be not less than one twelfth-or probably 0.08484-of a second, and which is taken in passing to, and returning from the region diametrically opposite the pole, over the earth's surface, with a mean velocity of about 471,240 kilometers per second....."**



" To produce an electrical movement of the required magnitude it is desirable to charge the terminal as highly as possible, for while a great quantity of electricity may also be displaced by a large capacity charged to low pressure, there are disadvantages met with in many cases when the former is made too large. The chief of theses are due to the fact that an increase of the capacity entails a lowering of the frequency impulses or discharges and diminution of energy of vibration....." (3)

"....If we could produce electric effects of the required quality, this whole planet and the conditions of existence on it could be transformed. The sun raises the water of the oceans and winds drive it to distant regions where it remains in state of most delicate balance. If it were in our power to upset it when and wherever desired, this mighty life-sustaining stream could be at will controlled. We could irrigate arid deserts, create lakes and rivers and provide motive power in unlimited amount. This would be the most efficient way of harnessing the sun to the uses of man....." (Nikola Tesla, June 1919) (1)

Reference documents :

- 1) "The Electrical Experimenter: My Invention by Nikola Tesla", June 1919
- 2) Tesla: Man Out of Time, by Margaret Cheney - Prentice-Hall, Inc
- 3) Tesla US Patent number 1,119,736 : "Apparatus for transmitting electrical energy" (issued Dec. 1, 1914)
- 4) Tesla US Patent number 8,200 : " Improvements relating to the transmission of Electrical Energy" (17th Apr., 1906)
- 5) Theory of Wireless Power, By Eric Dollard, B.S.R.A. 1986.