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WORLD SYSTEM OF WIRELESS TRANSMISSION OF ENERGY

by Nikola Tesla

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Telegraph and Telegraph Age, October 16, 1927

The transmission of power without wires is not a theory or a mere possibility, as it appears to most people, but a fact demonstrated by me in experiments which have extended for years. Nor did the idea present itself to me all of a sudden, but was the result of a very slow and gradual development and a logical consequence of my investigations which were earnestly undertaken in 1893 when I gave the world the first outline of my system of broadcasting wireless energy for all purposes. In several demonstrative lectures before scientific societies during the preceding three years, I showed that it was not necessary to use two wires in transmitting electrical energy, but that one only might be employed equally well. My experiments with currents of high frequencies were the first ever performed in public and elicited the keenest interest on account of the possibilities they opened up and striking character of the phenomena. Few of the experts familiar with the up-to-date appliances will appreciate the difficulty of my task with the elementary devices I had then at command, as accurate adjustments for resonance had to be made in every experiment.

The transmission of energy through a single conductor without return having been found practicable it occurred to me that possibly even that one wire might be dispensed with and the earth used to convey the energy from the transmitter to the receiver.

High Frequency Dynamo and Tesla Coil

Manifestly, currents such as were ordinarily employed in the arts and industries were unsuitable and I had to devise special generators and transformers for furnishing impulses of the requisite quality. First, I perfected high frequency dynamos which were of two types, one with a direct current field excitation and the other in which the magnet was energized by alternating currents of different phase, producing a rotating magnetic field. Both of these have found employment in connection with my broadcasting wireless system. In the first machine I exhibited an efficiency of ninety per cent. was attained, but it was necessary to run it in hydrogen or rarefied air to minimize the otherwise prohibitive windage loss and deafening noise.

In order to overcome the inherent limitations of such machines I next concentrated my efforts on the perfection of a peculiar transformer consisting of several tuned circuits in inductive relation which received the primary energy from oscillatory discharges of condensers. This apparatus, originally identified with my name and considered by the leading scientific men my best achievement, is now used in every wireless transmitter and receiver throughout the world. It has enabled me to obtain currents of any desired frequency, electromotive force and volume, and to produce a great variety of electrical, chemical, thermal, light and other effects, Roentgen, cathodic and other rays of transcending intensities. I have employed it in my investigations of the constitution of matter and radioactivity, published from 1896 to 1898 in the *Electrical Review* in which it was demonstrated, prior to the discovery of Radium by Mme. Sklodowska and Pierre Curie, that radio-activity is a common property of matter and that such bodies emit small particles of various sizes and great velocities, a view which was received with incredulity but finally recognized as true. It has been put to innumerable uses and proved in the hands of others a veritable lamp of Aladdin. As I think of my earliest coils, which were nothing more than scientific toys, the subsequent development appears to me like a dream.

The "Magnifying Transmitter" and Earth Resonance

While I was perfectly convinced, from the outset, that success would be ultimately achieved, it was not until by slow improvement I evolved the so-called "Magnifying Transmitter" that I obtained convincing evidence of the feasibility of wireless power transmission on a vast scale for all industrial purposes.

The chief discovery, which satisfied me thoroughly as to the practicability of my plan, was made in 1899 at Colorado Springs, where I carried on tests with a generator of fifteen hundred kilowatt capacity and ascertained that under certain conditions the current was capable of passing across the entire globe and returning from the antipodes to its origin with undiminished strength. It was a result so unbelievable that the revelation at first almost stunned me. I saw in a flash that by properly organized apparatus at sending and receiving stations, power virtually in unlimited amounts could be conveyed through the earth at any distance, limited only by the physical dimensions of the globe, with an efficiency as high as ninety-nine and one-half per cent.

The mode of propagation of the currents from my transmitter through the terrestrial globe is most extraordinary considering the spread of the electrification of the surface. The wave starts with a theoretically infinite speed, slowing down first very quickly and afterward at a lesser rate until the distance is about six thousand miles, when it proceeds with the speed of light. From there on it again increases in speed, slowly at first, and then more rapidly, reaching the

antipode with approximately infinite velocity. The law of motion can be expressed by stating that the waves on the terrestrial surface sweep in equal intervals of time over equal area, but it must be understood that the current penetrates deep into the earth and the effects produced on the receivers are the same as if the whole flow was confined to the earth's axis joining the transmitter with the antipode. The mean surface speed is thus about 471,200 kilometers per second--fifty-seven per cent. greater than that of the so-called Hertz waves--which should propagate with the velocity of light if they exist. The same constant was found by the noted American astronomer, Capt. J.T.T. See, in his mathematical investigations, for the smallest particles of the ether which he fittingly designates as "etherons." But while in the light of his theory this speed is a physical reality, the spread of the currents at the terrestrial surface is much like the passage of the moon's shadow over the globe.

It will be difficult for most people engaged in practical pursuits to measure or even to form an adequate conception of the intensity of inspiration and force I derive from that part of my work which has passed into history. I have every reason to consider myself one of the most fortunate men, for I experience incessantly a feeling of inexpressible satisfaction that my alternating system is universally employed in the transmission and distribution of heat, light and power and that also my wireless system, in all its essential features, is used throughout the world for conveying intelligence. But my pioneer efforts in this later field are still grossly misunderstood.

Short Wave Broadcasting and "Beam" Transmission

Nothing illustrates this better than the recent demonstrations of a number of experts with very short waves, which have created the impression that power will be eventually transmitted by such means. In reality, experiments of this kind are the very denial of the possibility of economic transmission of energy. I have investigated this special subject experimentally during a great number of years, using sometimes waves as short as one millimeter, and have found even these unsuitable for such a purpose, not to say that their production is inseparable from great waste.

In order to secure good results by this method it would be necessary to employ radiations of a wave length incomparably smaller than the dimensions of the reflector, as radiant heat, light, infra-red or ultra-violet rays. Notwithstanding my repeated explanations experts do not seem to realize that no concentration of energy such as I attain in my wireless power system can or will ever be achieved through the instrumentality of reflectors, for in transmitting energy in this manner the receiver can collect only an amount proportionate to the area exposed to the rays, while in my system it draws the energy from an immense reservoir in ever so much greater quantity. Similar considerations apply to directional transmission by short reflected waves or "beams." If we could produce economically electric vibrations of a frequency approximating that of radiant heat waves, efficient reflectors without appreciable dispersion, and prevent absorption--then such a mode of transmitting energy might become of great importance. But attempts to accomplish this purpose with relatively very low frequencies are sure to prove futile. More than twenty-five years ago my efforts to transmit large amounts of power through the atmosphere resulted in the development of an invention of great promise, which has since been called the "Death Ray," and attributed to Dr. Grindell Mathews, an ingenious and skillful English electrician. The underlying idea was to render the air conducting by suitable ionizing radiations and to convey high tension currents along the path of the rays. Experiments, conducted on a large scale, showed that with pressures of many millions of volts virtually unlimited quantities of energy can be projected to a small distance, as a few hundred feet, which might be satisfactory if the process were more economical and the apparatus less expensive. Since that time I have made important improvements and discovered a new principle which can be successfully applied without difficulty for various purposes in peace and war.

If I have understood the reports correctly, in the "beam transmission" with waves of a few meters length, an oscillating circuit, consisting of a straight vertical conductor, is placed in the focal line of a parabolic surface on which are placed many secondary straight wires parallel to the primary conductor. Now, this disposition is entirely faulty and to all evidence inefficient, as the secondary system does not operate in the manner of a parabolic reflector but merely produces a confused echo. The correct arrangement would require primary and secondary conductors situated in two vertical parallel planes separated by a distance equal to one quarter of the wave length. But even in this best form such a transmitter can only be of doubtful practical value. The two wave trains behind the reflecting, or rather echoing, system do not completely neutralize and there is considerable lateral dissipation. The energy of the primary system diminishes with the square of the distance, and this being also true of the secondary, the useful waves from the latter will suffer diminution of energy in proportion to the fourth power of their length. This means that only a very short wave can be used which, moreover, is unchangeable and difficult to regulate. One must be shortsighted not to perceive that better results will be obtained if the capital is all invested in a single directional system of proper design for the power available increases much more rapidly than the cost of the plant. Assuming even that the beam arrangement works with ideal perfection, it must still be inferior, since the requisite radiant energy is producible at smaller expense with the single system, which has the further advantages that it can be adapted to any wavelength, is equally effective in two directions and therefore of greater earning capacity. So palpably unsound is this scheme that I am at a loss to understand how it could pass the scrutiny of competent experts such as Dr. W. L. Austin and John Stone Stone.

The "World System"

Since I began the construction of the first power plant in 1899 I have expressed myself repeatedly in regard to it and the plans I had previously formed through the medium of the Electrical Review, Electrical World, Electrical Experimenter, Science and Invention and other periodicals, notably the Century Magazine of June, 1900, to which I contributed a lengthy article on the "Problem of Increasing Human Energy"; but certain facts must still be told. In the first place the fundamental difference between the broadcasting system a now practiced and the one I expect to

inaugurate is that at present the transmitter emits energy in all directions, while in the system I have devised only force is conveyed to all points of the earth, the energy itself traveling in definite paths determined beforehand. Perhaps the most wonderful feature is that the energy travels chiefly along an orthodromic line, that is, the shortest distance between two points at the surface of the globe, and reaches the receiver without the slightest dispersion, so that an incomparably greater amount is collected than is possible by radiations. I have thus provided a perfect means for transmitting power in any desired direction far more economically and without any such qualitative and quantitative limitations as the use of reflectors would necessarily involve.

Another distinction is that my system is based entirely on resonance, while in present practice reliance is placed chiefly on amplification by auxiliary devices generally consisting of various forms of vacuum tubes which have been brought to remarkable perfection. The foundation to their use was laid by Sir William Crookes, who discovered in 1876 that a highly heated conductor emits electrified particles. In 1882 a young French electrician, Vissiere by name, observed that a current issues from the filament of an incandescent lamp and made careful measurements with specially prepared bulbs, some of which I had opportunity to witness in Ivry-sur-Seine, a suburb of Paris, at that time. But these phenomena found no application in the art until in 1892 I produced a vacuum tube detector superior in sensitiveness to any other form of which I have knowledge. Amazing progress has been since then achieved, but the employment of the modern vacuum detectors and amplifiers is an impediment to advance in the right direction and most of the troubles experienced in broadcasting are due to this cause. Until quite recently the transmitted waves were lacking in uniformity of length, rendering accurate attunement impossible. This defect has been in a measure remedied by control through quartz crystals, and now, for the first time, it is practicable to carry out important refinements for bettering the service.

The electro-mechanical process of producing isochronous oscillations is one of my earliest inventions and I have applied it in many ways with great success. Its application to the operation of existing plants secures important advantages, but in spite of this and other improvements a change in the present apparatus and method of broadcasting is becoming daily more imperative and for this reason I am anxious to resume the introduction of my "World System" with novel transmitters of great effectiveness and receivers of elementary simplicity. In my apparatus the isochronism is so perfect and attunement sharp to such a degree that in the transmission of speech, pictures or similar operations, the frequency or wavelength is varied only through a minute range which need not be more than one hundredth of one per cent. if desired. Statics and all other interferences are completely eliminated and the service is unaffected by weather, seasonal or diurnal changes of any kind. The system lends itself particularly to World Wireless Telephony and Telegraphy as the current from the transmitter can be kept virtually constant and the control effected by a simple microphone without the elaborate means now employed. Any reasonable number of simultaneous and non-interfering messages is practicable and a speed of many thousands of words per minute can be attained in telegraphic transmission. The same principles are also applicable to operation through wires and cables. In 1903 I proposed to the Western Union and Postal Telegraph companies such multiplex transmission for their lines but received no encouragement mainly because the volume of business did not call for a great increase of working capacity. At a later date my improvements were introduced as "Wired Wireless." A quite inappropriate name inasmuch as the waves radiated from the wire are completely lost and of no effect on the receiver.

My plans for a power plant have been developed to the point of application, but I am still unable to say when I shall begin active work. There are no such difficulties in the way as confronted me from the outset, for at that time I was alone; now many are convinced that my undertaking is rational and practical. Needless to say that I am using every effort to give to the world my best and most important work as soon as possible and free of all blemish and flaw. I have in view a number of places which seem well suited for the purpose, but my warmest wish is to transmit power from Niagara Falls, where the first triumph with my alternating system was achieved.

One of the most important uses of wireless energy will be undoubtedly for the propulsion of flying machines to which power can be readily supplied without ground connection, for although the flow of the currents is confined to the earth an electro magnetic field is created in the atmosphere surrounding it. If conductors or circuits accurately attuned and properly positioned are carried by the plane, energy is drawn into these circuits much the same as a fluid will pass through a hole created in the container. With an industrial plant of great capacity sufficient power can be derived in this manner to propel any kind of aerial machine. This I have always considered as the best and permanent solution of the problems of flight. No fuel of any kind will be required as the propulsion will be accomplished by light electric motors operated at great speed. Nevertheless, anticipating slow progress, I am developing a novel type of flying machine which seems to be well suited for meeting the present necessity of a safe, small and compact "aerial fliver" capable of rising and descending vertically.

Television, as conceived by me in 1893, will be another valuable and timely application. At that time I advanced the idea that the formation of a clear mental image of external objects is accompanied by a reflex action on the retina, making it possible to read thoughts and even to project the images conceived on a screen and render them visible to an audience. This would be of inestimable consequence on all human relations but the idea can not be realized until some way is found to lay bare the retina. Continued reflections on this subject led me to evolve apparatus for transmitting instantaneously true vision without any moving devices, and in 1900 I had already solved three of the problems which confronted me, namely: to individualize and isolate a very great number of channels or "nerves"; to convey to the receiving apparatus energy in sufficient amount, and, to make the vision of the moving images independent of distance. Eventually also I hope to overcome the shortcomings of the selenium cell by a different device.

I am most interested, however, in the perfection of broadcasting which is now carried on with unfit apparatus and on a commercially defective plan. The transmitters have to be greatly improved and the receivers simplified and in the distribution of wireless energy for all purposes the precedent established by the telegraph, telephone and power companies must be followed, for while the means are different the service is of the same character. Technical invention is akin to architecture and the experts must in time come to the same conclusions I have reached long ago. Sooner or later my power system will have to be adopted in its entirety and so far as I am concerned it is as good as done. If I were ever assailed by doubt of ultimate success I would dismiss it by remembering the words of that great philosopher, Lord Kelvin, who after witnessing some of my experiments said to me with tears in his eyes: "I am sure you will do it."

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