Tesla's
WORLD SYSTEM

MUSEUM OF SCIENCE AND TECHNOLOGY
- BELGRADE

Tesla's
WORLD SYSTEM

Belgrade
august 2016

Tesla's
WORLD SYSTEM

Museum of Science and Technology – Belgrade
G a l l e r y A D | A u g u s t 2 0 1 6

Publication issued by
Museum of Science and Technology

For the Publisher
Sonja Zimonić, Director of the Museum

Author of Text
Zorica Civrić Flores

Graphic Design and Text Formatting
Matija Sadović

Reviewer
Jovan Cvetić

Proofreader
Jovanka Milošević

Translator
Katarina Spasić

Printing

Print run
300

CONTENTS

INTRODUCTION

"It was evident to me that wireless transmission of energy, if it could ever be accomplished, is not an invention; it is an art. Bell's telephone, Edison's phonograph, or my induc-tion motor were inventions, but the wireless transmission of energy is an art that requires a great many inventions in combination."

Nikola Tesla

Tesla's work in the field of wireless transmission of energy is the result his studies of high voltage and high frequency electrical phenomena and it began in 1888 with the first observations regarding the effect of the frequency on the work of alternating cur-rent motor. The same year Heinrich Hertz published an experimental proof of Maxwell's Electromagnetic Theory, which aroused interest and excitement in the scientific commu-nity, for which Tesla observed that "it had scarcely ever been experienced before"[1]. Besides that, in 1888 Oliver Lodge presented the results of his studies of propagation of waves along conducting wires and the effects of self-induction in an oscillation circuit.[2] Looking back at the beginning of his work in the field of high frequencies, Tesla emphasized that his early observations and theoretical possibilities in studies of high-frequency current, as well as the work of Hertz and Lodge, all had their influence on him to begin the system-atic research of high-frequency phenomena in 1889.[3] The work of Hertz and Lodge were an incentive not only for Tesla, but also for other scientists who studied electromagnetic phenomena, which was also confirmed by scientist Oliver Heaviside who stated that "the experimental work of Hertz and Lodge on the electrical vibrations and electromagnetic waves were the means of stirring up an amount of interest in [electromagnetic] theory that was quite wonderful to witness".[4]

Up until 1895 Tesla simultaneously worked on polyphase alternating current system for transmission of electric energy and a new system for wireless transmission of energy. Until 1891 he submitted 40 patents called Tesla polyphase system patents. In the period 1889–1890, after he signed a contract with George Westinghouse regarding the com-mercial use of 7 polyphase system patents[5], Tesla worked with engineering team from Westinghouse's company on resolving construction issues regarding alternating current motor. Until 1892 he was indirectly involved in the "war of currents" whose main protag-onists were George Westinghouse and Thomas Edison. At the same time certain event promoted the polyphase system – application of Tesla's system in transmission of electric energy in 1891 in Telluride, USA and in Germany, from Lauffen to Frankfurt, as well as the World Fair in Chicago in 1893.

1 Tesla, Nikola, "The True Wireless". *Electrical Experimenter* (New York: 1919): 28. Translations of Tesla articles in Serbian are cited under: Marinčić, Aleksandar, red. *Nikola Tesla – Članci.* Belgrade: Zavod za udžbenike i nastavna sredstva, 1995. Articles that are not tranlslated are cited separately in literature as *Članci Nikole Tesle*.

2 Lodge, Oliver J. "On the Measurement of the Length of Electro-magnetic Waves", "On the Impedance of Conductors to Leyden-jar Discharges". In *Report of the Fifty-Eighth Meeting of the British Association for the Advancement of Science held at Bath in September 1888*. London: John Murray, 1889.

3 Tesla, Nikola, „Visokofrekventni oscilatori za elektroterapeutske i druge svrhe." In *Niola Tesla – Predavanja.* Popović, Vojin, red. Belgrade: Zavod za udžbenike i nastavna sredstva, 1995, 235.

4 Heaviside, Oliver. *Electrical Papers Vol. 1*. London and New York: Macmillan and Co., 1892, preface. 5

Patents number. 381.968, 381.969, 381.970, 382.279, 382.280, 382.281, 382.282.

Early results in the application of high voltage and high frequency currents introduced Tesla to new fields such as lighting, wireless transmission of energy and medicine, as well as different industry branches such as materials technology, electrical insulation, genera-tion of ozone, etc. We encounter the announcement of possibility of wireless transmission of energy in a lecture he gave in 1891. As he later explained, the development of system of wireless transmission of energy didn't depend on whether it would be applied in wireless telephony or for any other purpose,[6] i.e. whether it will be used for wireless transmission of signal or power. The confirmation of this are the basic wireless transmission patents he submitted in 1897, which he intended for wireless transmission of energy as a whole, with the possibility to be used for wireless transmission of signal as well. In 1916 these patents became evidence in a suit by G. Marconi's company against the US Government for using his wireless telegraphy patents. The result of the suit and the significance of the scientific names linked to him brought a larger attention to Tesla's work in the field of wireless transmission of signal.

In order to achieve wireless transmission, he needed to:

1. develop a method and apparatus for generating electrical oscillations whose characteristics made transmission possible – high frequency and high voltage oscillations;
2. develop a method and a device for transforming the oscillations into a form of energy that can be transmitted over distances;
3. develop a method for isolating energy, i.e. prevent interference by which he would achieve selectivity of reception of only some oscillation compared to all the existing oscillations;
4. develop a method for reception and a device that will receive energy at a distant location;
5. determine the laws of propagation of waves through a natural medium – atmosphere and ground.

6 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 6, 52.

Tesla discovered new phenomena related to the nature of electromagnetic oscillations and electromagnetic properties of materials, as well as new phenomena related to the operation of electrical devices. This pointed him in the direction of not only defining new methods and techniques, but also the construction of entirely new devices, unknown in previous practice. He studied how waves travel though air, upper layers of atmosphere and ground, and all together he called this – transmission through the natural medium.

In order to perfect his method and devices for wireless transmission, he worked in the laboratory in Colorado Springs from 1899 to 1900. Encouraged by the results of his research, right after his return to New York in 1900, he made preparations to build a receiver on Long Island, near New York. In order to explain the goal of his work he published a bro-chure titled *World System,* in which he presented the possibilities of this system. He worked on Long Island from 1901 to 1907, when he stopped the works. At the start of the 20th century Tesla's *World System* was taken as his scientific vision, and at the end of the same century it was brought to life thanks to the development of modern telecommunications.

DEVELOPMENT OF DEVICES FOR THE GENERATION OF HIGH-FREQUENCY AND HIGH-VOLTAGE ELECTRICAL OSCILLATIONS

The same as the other scientists who were the pioneers of wireless telegraphy, Tesla conducted his first experi-ments with high-frequency currents by using an appara-tus used by Hertz, which was named Hertz oscillator or Hertz dipole after him. The first source (or generator) of high-frequency currents was an electric spark produced by using Hertz oscillator. Occurrence of spark on the transmitting end would induce a spark in the spark gap on the receiving end of the oscillator. The intensity of the spark was the measure of quality of the experiment.

Oscillator apparatus consisted of devices and means for generating and receiving oscillations, or waves.

The devices on the wave generating end:

- Ruhmkorff coil (induction coil, i.e. impulse transformer) for production of high volt-age, powered by source of direct current (battery), used for exciting spark gap;
- electro-mechanical switch located in the coil's primary circuit, whose number of interruptions could be adjusted;
- two metal sphere bodies or two metal panels that served as capacitors charged with impulse from the coil;
- two rigid conductors which both had the above-mentioned metal body or a panel on one end, while a metal ball was located on the other end;
- spark gap or a switch consisting of two metal balls between which, when the capacitor is charged up to breakdown voltage, a spark appears – the source of high-frequency currents; due to the two capacitors and this symmetrical position, the apparatus for generating oscillations was called Hertz symmetrical dipole.

Devices and means on the wave receiving end:

- conductor bended so that it forms a circular of rectangular contour with a gap be-tween the ends of the conductor;
- spark gap, consisting of a ball on each end of the bended conductor; the occurrence of spark between the balls makes the electromagnetic wave "visible";
- additional conductor, a wire, whose length is adjusted, which also adjusts the capacity of the loop.

In 1890 British scientist Oliver Lodge described a discovery he observed in an experiment with discharge of two layden jars, which was the key phenomenon in Hertz's experiment. He discovered that by equalizing "electrical dimensions" of two electric circuits it is possi-ble to get an electric effect that corresponds to the resonance of two mechanical vibrators of equal frequencies. The discovery of this phenomenon called syntonization was very im-portant for the development of wireless telegraphy, even though neither Lodge nor Hertz gave any indications that this apparatus might be used for communication.[7] Physicist Joseph John Thomson[8] mentions this discovery as the first and the most important in the chapter on resonance in his book from 1893 on resent researches of electricity and magnetism.[9] At the start of their work both Hertz and Lodge used a spark to determine the existence of electromagnetic waves, but they never got the idea to use the spark to produce currents.

Hertz's apparatus made it possible to achieve very high frequencies, up to 50 MHz By repeating Hertz's experiment, Tesla spotted the shortcomings of this apparatus. The greatest shortcoming what the fact that Hertz oscillator produced waves of very damped oscillations, small energy, insufficient for transmission outside the laboratory conditions, and there was no possibility for regulation of wave length – the range of transmission was up to 20 m.[10] In addition to this, significant losses of electrical energy of the spark were recorded, spent on thermal energy due to the large air resistance. These observations pointed Tesla towards the improvement of the method and the device for production of high frequency currents. The system of wireless transmission he developed was based on undamped oscillations, but also the frequencies lower than the frequencies of Hertzian waves. The method of transmission by conduction, instead of radiation method, present in working with Hertz oscillator, will result in lower frequencies in order to cut down the losses of energy due to dissipation.

7 Erskine-Murray, James. *A Handbook of Wireless Telegraphy: Its Theory and Practice*, 2nd. New York: D. Van Nostrand Company; London: Crosby Lockwood and Son, 1909, 8–9.

8 Sir Joseph John Thomson (1856-1940), professor of experimental physics in Cavendish laboratory at the University of Cambridge and the Nobel Prize winner in 1906 for his contribution to the theory of electrical discharge in gasses..

9 Thompson, Joseph J. *Notes on Recent Researches in Electricity and Magnetism Intended as a Sequel to Professor Clerk-Maxwell's Treatise on Electricity and Magnetism*. Oxford: The Clarendon Press, 1893, 395.

10 Different sources offer different information about the range, from 5 m to 20 m.

GENERATORS OF HIGH FREQUENCY CURRENTS

Tesla invented two types of devices for generation of high-frequency currents – multiple generator and oscillation transformer. At the very beginning of his research in 1888 he used machine generators as power source and he generated currents whose frequencies depended on the motor's number of revolutions. The purpose of these experiments was not only to study high-frequency currents, but also to improve the operation speed of the induction motor. After that Tesla began to use a generator in his experiments with trans-formers and capacitors as well, and by increasing the speed he began to achieve higher and higher frequencies. The upper threshold for the frequency of current produced by generator was defined by construction and the revolution rate of the generator's motor. In order to generate currents that had even higher frequencies, since 1889 Tesla began con-structing multipole alternating current generators or alternators, as these devices were also called. He considered these machines to be the first true high frequency machines ever.[11] They had a large number of poles on stators and they produced high-frequency currents thanks to the combination of construction and the highest possible rotation speed of the rotor. Out of the numerous alternators that Tesla constructed, two were the subject of patents he applied for in 1890. The first is related to their application in the improvement of arc lamps, and the second relates to their application in distribution of electrical energy.

With his patent *Method of Operating Arc-Lamps* he protected the method for reduction or suppression of noise produced by arc lamps by using alternator that produces at least 10.000 alternations of current per second.[12] The alternator had 384 poles on stator, ro-tational speed of 1.500 rpm, and in practice it could produce sinusoidal current with frequency range 10–20 kHz. In this way periodical heating and cooling of the electric arc in the lamp happens with such rapidity that it produces little or no perceptible effect upon the ear. According to Tesla, this alternator was the first step towards "evolution of a generator, of transmitter, which may be used to flash energy to distances, under practical and economic conditions"[13]. The patent contained no indications of using the alternator to transmit energy to distances.

11 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power*. Denver: Sun Publishing, 1992, 1.

12 Patent no. 447.920, for which he filed application on October 1, 1890, was aproved on March 10, 1891.

13 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power*. Denver: Sun Publishing, 1992, 3.

The patent *Method of Operating Arc-Lamps*, No. 447.920, in which Tesla protected multipole generator of high frequencies, the first of the Tesla's device in the evolution of generators or transmitters, which can be used to flash energy to distances, in his lecture held in 1891. Tesla used a generator constructed according to this patent.

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, CDXCI, 81 A.

With patent *Alternating Electric Current Generator* Tesla protected two types of alternators, both with toothed stator and a rotor in a shape of a flat plate.[14] The difference is that in case of the first altenator type the energizing core is rotating while the energizing coil is stationary, while in case of the second type it's the other way around. The first had 64 poles and developed speed of up to 12.000 rpm. Originally Tesla planned to use a turbine (which he will construct and patent some twenty years later) to run this type of alternator, so with the turbine as the driver he expected to achieve the speed of alternator of 20.000 rpm. He used this type of alternator until 1905/1906. At the beginning of his work in the Long Island laboratory in 1901 Tesla reduced the number of poles from 64 to 32, and then later to 16, by which he achieved frequency of the alternator of 3000–4000 Hz, which he further increased up to 100.000 Hz.[15] The other type of alternator had 480 poles, 25W of power and it could achieve frequency of up to 30.000 Hz.[16]

Patent *Alternating Electric Current Generator,* no. 447.921, which protected the type of alternator Tesla used until 1905/1906 – the only alternator that survived the fire in his laboratory in 1895.

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, CDXCI, 105 A.

14 Patent no. 447.921, for which he filed application on November 15, 1890, was approved on March 10, 1891.

15 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power*. Denver: Sun Publishing, 1992, 14–16.

16 Ibid.,17.

Tesla gave a detailed description of the alternator construction in February 1891 in an article titled *Phenomena of Alternating Currents of Very High Frequency*.[17] In it he presented the first results of his research conducted in a laboratory. He brought special attention to the role of discharge of capacitor charged by the source of high frequency current in transmission of energy: "With frequencies as high as the above mentioned, the condenser effects are of enormous importance. The condenser becomes a highly efficient apparatus capable of transferring considerable energy".[18] The same month, just before the publica-tion of the above-mentioned article, Tesla applied for patent *Method of and Apparatus for Electrical Conversion and Distribution*, by which he protected the method of conversion of electrical energy by using capacitor in an oscillation circuit.[19] Capacitor becomes not only a device for accumulation of energy, which was already known in science, but a transform-er of energy as well. It constantly receives new energy from generator, transforms it to oscillatory energy and provides rotor with high-frequency current.[20]

> *"This type of apparatus is identified with my name as certain as the law of gravitation is with that of Newton […] Moreover, it is important to realize that this principle is universally employed everywhere. The greatest men of science have told me that this was my best achievement and, in connection with this apparatus, I may say that a lot of liberties have been taken. For instance, a man fills this space [break D] with hydrogen; he employs all my instrumentalities, everything that is necessary, but calls it a new wireless system – the Poulsen arc. I cannot stop it. Another man puts in here [referring to space between self-inductive lines L L] a kind of gap – he gets a Nobel Prize for doing it. My name is not mentioned. Still another man inserts here [conductor B] a mercury [-arc] rectifier. That is my friend Cooper Hewitt. But, as a matter of fact, those devices have nothing to do with the performance. If these men knew what I do, they would not touch my arrangements; they would leave my apparatus as it is."*[21]

17 Tesla, Nikola, "Phenomena of Alternating Currents of Very High Frequency", *Electrical World* (New York: 1891): 296–300. 18 Tesla, Nikola. „Pojave kod električnih kola vrlo visoke frekvencije". In *Nikola Tesla – Članci.* Marinčić, Aleksandar, red., Belgrade: Zavod za udžbenike i nastavna sredstva, 1995, 168.

19 Patent no. 462.418, for which the application was filed on Febraury 4, 1891, was approved on November 3, 1891. 20 Bokšan, Slavko. *Nikola Tesla i njegovo delo.* Belgrade: Klub NT, 2006, 219.

21 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 48.

Patent *Method of and Apparatus for Electrical Conversion and Distribution*, no. 462.418.

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, CDXCII, 162 A.

TESLA'S OSCILLATION TRANSFORMER

Considering that the most efficient results in lighting are achieved by charging light bulbs with electrical current that has both high frequency and high voltage, Tesla began work-ing on improving the device that will produce not only high-frequency currents, which he already achieved with generators, but also high-voltage currents.

Soon after the publication of the above-mentioned article, in which he presented the first results of his research, in April 1891 he applied for a new patent - *System of Electric Lighting*[22], which protected the operating principle of a device reflecting the importance of the effect of the discharge of the capacitor. Instead of the phenomenon known at the time of oscillatory discharge of leyden jar (capacitor), through Ruhmkorff's coil, by using an electric spark, Tesla discharged capacitor through the primary of the transformer, which is loosely coupled with the secondary. This principle is the basis for the work of a device that became known as Tesla transformer and which is still largely used, even though the correct name of the device is Tesla oscillation transformer, which consists of:

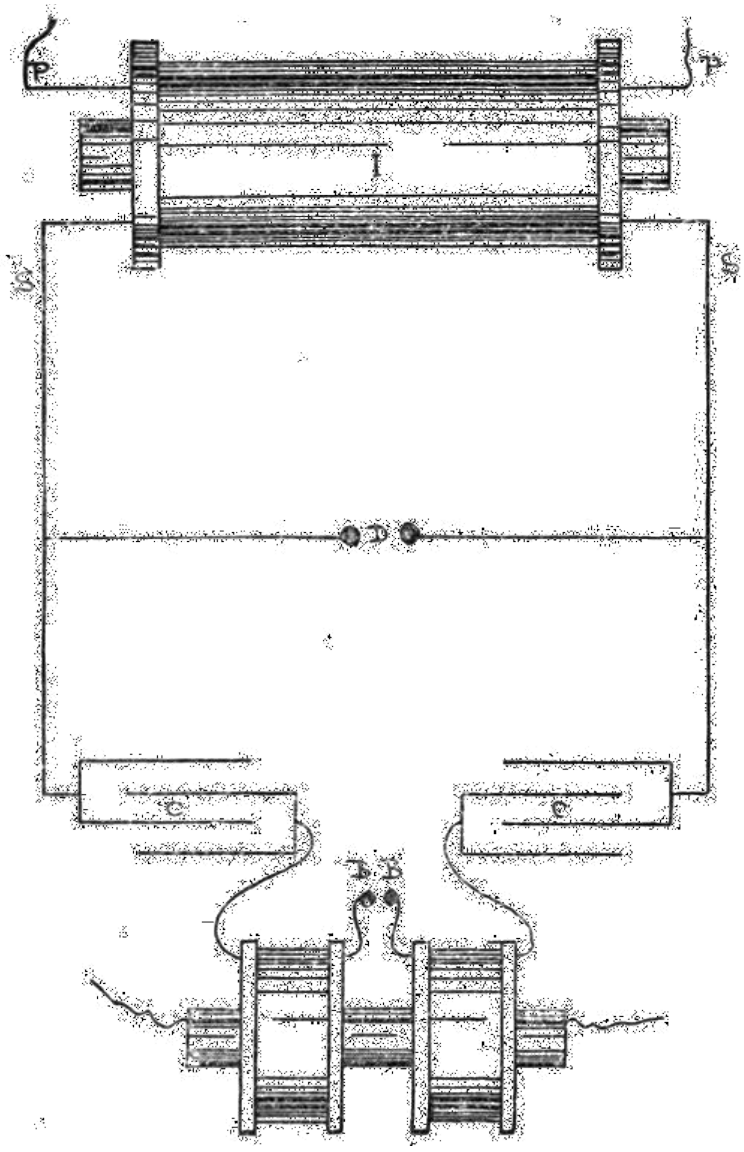
1. transformer without iron core, with two oscillation circuits (circuits of primary and secondary coil); The secondary of Tesla's transformer is a coil with open ends between which, as a result of resonance and the absence of iron core, occur voltage and electric oscillations with frequencies of several tens of thousands of Hertz;

2. capacitor in the primary circuit, discharged through primary circuit, charged with high voltage from direct or alternating current source; when capacitor is charged up to the breakdown voltage in the air spark gap, a sudden discharge of capacitor through primary occurs;

3. spark gap that regulates the number of sparks and their duration by switching them, and controls the charging and discharging of the capacitor; the sparks are the source of electric oscillations (long, undamped, or short, rapidly damped);

Revolutionary novelty in the construction of this device was omission of iron core, which is generally a part of the transformer, as well as the discharge of capacitor by using spark gap through coupled coils instead of just one coil. High-frequency oscillator achieves the best working effect when conditions for resonance are achieved in primary and second-ary of the transformer.

22 Patent no. 454.622, for which he filed application on April 25, 1891, and which was approved on June 23, 1891.



Early form of Tesla oscillator. In addition to his multipole generators, at the begging of his work Tesla used Ruhmkorff coil (I) for charging capacitor (C). In order to achieve "electrostatic" effects, as he called them, he added a new device into the circuit - transformer without iron core (B), so that the capacitor with the help of the spark gap (D) is discharged through primary circuit. Tesla presented the evolution of oscillator in a lecture in 1891.

Illustration source: Schneider, Norrie H. (Norman H. Schneider). *Induction Coils, How to Make, Use, and Repair Them*. New York: Spon & Chamberlain; London: E. & F. N. Spon, Ltd., 1901, 229.

The patent protected the method of producing high-frequency and high-voltage cur-rents by using oscillation transformer, as well as two completely new methods for elec-trical lighting. The first implies elimination of one of the conductors that connects light bulb with the power source, and the second implies elimination of both conductors. In this way, by improving the lighting methods, with the discovery that he can achieve transmission of energy by removing one or both conductors, Tesla stepped in the field of wireless transmission of energy. This will be confirmed in a series of lectures that he held from 1891 to 1893.

> *"Ever since the announcement of Maxwell's electro-magnetic theory scientific investigators all the world over had been bent on its experimental verifica-tion. They were convinced that it would be done and lived in an atmosphere of eager expectancy, unusually favorable to the reception of any evidence to this end. No wonder then that the publication of Dr. Heinrich Hertz's results caused a thrill as had scarcely ever been experienced before […] Recognizing the limitations of the devices he had employed, I concentrated my attention on the production of a powerful induction coil but made no notable progress until a happy inspiration led me to the invention of the oscillation transformer."*[23]

The first Tesla oscillators produced damped oscillations. By improving the spark gap he produced lightly damped oscillations. His observations regarding the properties of spark and the air gap in which the spark forms led him to new fields of research – studying the role of the environment in which discharge occurs in the oscillator (air, gas, insulation fluid), development of methods for quick extinction or interruption of spark in order to increase the number of interruptions, as well as improving the spark gap, the device that performs the interruption. During 1891 Tesla already developed several methods for in-terruption of spark – by using electromagnet's magnetic field, compressed air or other gases, as well as by applying the split or divided spark gap technique.[24] He protected dif-ferent types of rotary spark gap, with electrodes that move in proportion to one another, instead of previously immobile electrodes. Application for the first patent for this type or spark gap, *Means for Generating Electric Currents*, no. 514.168, was filed in August 1893.[25] The invention that is the subject of the patent is related to the improvements that can be applied to methods or systems for production or usage of electric energy, which he already presented in patent no. 454.622 – *System of Electric Lighting*.

---

23 Tesla, Nikola. "The True Wireless". *Electrical Experimenter* (New York: May 1, 1919): 28. 24
Bokšan, Slavko. *Nikola Tesla i njegovo delo.* Belgrade: Klub NT, 2006, 101–103.
25 Patent no. 514.168, for which the application was filed on August 2, 1893, was approved on February 6, 1894.

Patent *System of Electric Lighting*, no. 454.622, in which the work of oscillation transformer was described for the first time

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, CDXCII, 22 A.

He presented the device constructed according to patent no. 514.168 at the World Fair in Chicago in 1893. At that time he also demonstrated how the device works when he met prof. Dr. Hermann von Helmholtz[26], and he also introduced him to his plan for the wireless transmission. That was his first opportunity to present his great plan to someone outside his immediate surroundings. This encounter encouraged Tesla to continue with his work.[27]

Rotary spark gaps that later found their application in wireless telegraphy he protected in three more patents, no. 568.176, 568.178 и 568.180. During the period 1891-1898 he applied for 11 patents for high-frequency oscillator, among which are four patents for spark gap, one for a transformer and eight for various types of rotary spark gaps. He con-structed more than fifty types of oscillators for various purposes (wireless transmission, lighting, generation of ozone, electrotherapy, etc.) and various constructions. He gave a brief description of various types of oscillators in an article titled *Electric Oscillators* in 1919.[28]

Tesla's oscillation transformer has two oscillatory circuits, i.e. two electric circles. One oscillatory circuit is formed by inductivity of primary and capacitance of the capacitor that is connected in series with primary, and the other oscillatory circuit is formed by distributed inductivity of the secondary and the capacitance of objects connected to sec-ondary. By further improving the oscillation circuit, which will be explained later in the text, he produced undamped oscillations. Tesla's oscillation transformer thus became the most reliable source of high-frequency and high-voltage currents. As such it will become irreplaceable in experiments performed by many scientists who worked in the field of wireless telegraphy and radio technology. With the development of the technology the role of spark gap was taken over first by electronic tubes and then later transistors and thyristors.

In order to get as much voltage as possible, something he worked on in Colorado Springs, he added the third coil into the circuit and connected it in series with the free end of the secondary. In this manner Tesla's oscillator became a device with three oscillation circuits. Tesla oscillator is one the inventions that his *World System* of wireless transmission is based on and on which he worked on Long Island.

---

26 Hermann von Helmholtz (1821–1894), German physician and physicist. He is thought to be one of the scientists, together with Maxwell, had a crucial impact on the development of physics and philosophy in the 20th century. His greatest contributions to the science include: proof that Euclidian geometry doesn't describe the only possible visible and physical space, and theoretical step forward from physics based on the interaction of particles to the physics of theprz of electromagnetic fields. He achieved a great number of scientific results, which include formulation of the law on preservation of energy, eqations for thr flow of fluids, concept of free energy in thermodynamics and the invention of ophthalmoscope.

27 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 52; J. N. P. „Tesla Grips the World". *New York Sun* (New York: June 6, 1897).

28 Tesla, Nikola. "Electrical Oscillators". *Electrical Experimenter* (July,1919): 228–229, 259–260, 276.

Tesla's patents in which he protected high-frequency oscillator and rotary spark gap[29]

patent number	year of application	year of approval	oscillator	transformer	rotary spark gap
454.622	1891	1891	x		
462.418	1891	1891	x		
514.168	1893	1894	x		x
568.176	1896	1896	x		x
568.178	1896	1896	x		x
568.179	1896	1896	x		
568.180	1896	1896	x		x
577.670	1896	1897	x		
583.953	1896	1897	x		
593.138	1897	1897		x	
609.245	1897	1898			x
609.246	1898	1898			x
609.247	1898	1898			x
609.248	1898	1898			x
609.249	1898	1898			x
609.251	1897	1898			x
611.719	1897	1898			x
613.735	1898	1898			x
685.012	1900	1901	x		
723.188	1900	1903	x		

29 Stone Stone, John. "Signals through Space – From the Beginning". In Anderson, Leland ed. *John Stone Stone on Nikola Tesla's Priority in Radio and Continuous Wave Radiofrequency Apparatus*. New York: Antique Wireless Association, Inc., Holcomb, 1986, 30–31, 40; Marinčić, Aleksandar. Introduction in *Nikola Tesla – Od Kolorado Springsa do Long Ajlanda.* Belgrade: Nikola Tesla Museum, 2008, 23.

BASIC PLAN FOR WIRELESS TRANSMISSION OF ENERGY

In the period from 1891 to 1893 Tesla held a series of lectures on the phenomena of high-potential and high-frequency currents, both in USA and in Europe. In a lecture held in 1893, the same year it was announces that his sys-tem for production and transmission of electric energy by polyphone currents will be applied on Niagara, he presented the plan for a new system of energy transmission without using wires.

TRANSMISSION OF ELECTRICAL ENERGY THROUGH A SINGLE WIRE WITHOUT RETURN

Both methods of lighting are described in the above -mentioned patent no. 454.622, *System of Electric Lighting,* demonstrated during a lecture held in 1891 in front of the mem-bers of the American Institute of Electrical Engineers at Columbia University.[30] During a demonstration of lighting light bulbs connected to a power source with single conductor he explained that at the other end light bulb can be connected to "an insulated body of the required size", when "the insulated body serves to give off the energy into the surrounding space, and is equivalent to a return wire".[31] As an insulated body he used a metal plate hanging from the ceiling and he connected it to the secondary coil on one end, while the other was connected to the ground. As source of power for the electric circuit he used pre-viously mentioned and described first type of the alternator. This method of transmission of energy from the source to the consumer (light bulb) Tesla called this the transmission of electrical energy through wire without return (i.e. without return wire). This discovery pushed Tesla into thinking about using ground as a conductor, which was the introduction to studying wireless transmission of current at higher voltages.

As an ideal method for lighting rooms he suggested placing illuminating body anywhere in the space and leaving out both conductors that connect it with the rest of the circuit. In that case, two such bodies are placed in the room between two plates hanging from the ceiling. The same as in the case of energy transmission through single conductor, one end of the secondary is connected to the plate while the other is grounded. Tesla explained that in these conditions the body glows thanks to the existence of a powerful, rapidly al-ternating electrostatic field and he emphasized the advantages of electrostatic inductive effects over the effects of electromagnetic induction. He also observed other phenomena in the electrostatic field. This way, for example, when telephone receiver is connected by a wire with an insulated conductor located in an electrostatic field, a sound can be heard from the telephone receiver, and in case the field is particularly powerful, the sound may be perceived even without any wire. He also punctuated that the required electromotive force at a distance can be obtained with the help of resonance.[32]

30 Tesla, Nikola. "Experiments with Alternate Currents of Very High Frequency and Their Application to Methods of Artificial Illumination". *AIEE Transactions*, 5 (1888): 305–327. Tesla's lectures are translated and in the literature they are cited under: Popović, Vojin, red. *Nikola Tesla – Predavanja.*, Belgrade: Zavod za udžbenike i nastavna sredstva, 1995.

31 Tesla, Nikola. „Eksperimenti sa naizmeničnim strujama vrlo visokih frekvencija i njihova primena u veštačkom osvetljenju", in Popović, Vojin, red. *Nikola Tesla – Predavanja.*, Belgrade: Zavod za udžbenike i nastavna sredstva, 1995, 73.

32 Ibid., 77.

The apparatus he used at the lecture was created by improving a simple apparatus he already used at the laboratory to perform his first experiment with wireless transmission of energy, but he didn't speak about that at the lecture. He connected one end of the alternator located at the laboratory to a water supply pipe for grounding and the other end he ran out through the window of the lab to the roof of the laboratory building where he placed a group of devices that created capacitance and served as an antenna. His goal was to induce a disturbance in the Earth's electrical equilibrium near capacitance so that the disturbance would bring out the operation of anyone of those instruments. The begin-nings of improving this initial apparatus for wireless transmission were heading towards production of stronger currents that he would transfer through conductor from alterna-tor to antenna, which would cause a greater disturbance of the surroundings. In order to create high voltages and oscillations that can be regulated, he tested various layouts of inductance and capacitance in the circuit.

Apparatus that illustrates the transmission through single wire without return, from the lecture *Experiments with Alternate Currents of Very High Frequency and Their Application to Methods of Artificial Illumination* from 1891. Tesla discovered that by using the resonance principle it is possible to remove one out of the two conductors that connect the consumer with the energy source. He used an improved Crookes tube or a motor as a consumer. Instead of one conductor at the terminal of the power source he added a metal plate. Instead of a filament the tube has an electrode made of carbon or a special type of material whose capacitance, or the capacitance of the metal plate, in case of motor, serves to close the electric circuit by "electrostatic induction", as Tesla called this phenomenon, or capacitive coupling.

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, VI/C, 3.

He first added an induction coil in order to tune the system consisting of alternator, coil and antenna to the frequency of the alternator. Then he exchanged the coil for an adjust-able coil, and that he exchanged for a transformer without iron core. After that he added an adjustable capacitor connected in parallel in the circuit, in which way he achived the same way of connecting capacitor and transformer as in patent no. 454.622 – *System of Electric Lighting.* The next improvement was putting adjustable capacitor into the primary circuit, connected in series instead of in parallel with the rest of the circuit. This is the apparatus he used at the lecture in 1891, although he didn't speak of the idea that enticed him to create and develop the apparatus at the lecture.[33] This and other improvements were made with the purpose of obtaining undamped oscillations, as well as resonance conditions in electric, or oscillation circuits of the primary and secondary of the oscillator. The system described above that consists of capacitor connected in series with primary of resonant transformer and secondary connected on one end with ground and the other, open end, to the body of large capacity at a certain height represents the beginning of radio transmitter, while the elevated plate represents a rudimentary form of an antenna. This system was later called air-ground system.

The lecture was also published in British science journals *Electrical Engineer* and *Electrical Review*.[34] Due to the significance of the research results, after that Tesla received an in-vitation to hold a lecture at the Institution of Electrical Engineers of Great Britain in London. New lecture about the accomplishments with high-potential and high-frequency alternating currents he held for the members of the British, and then the French scientific societies as well, in February 1892.[35] The largest part of the lecture and the experiments he dedicated to the production of high-frequency currents for the purpose of wireless lighting and demonstration of the application of resonance in electrical circuit. He de-scribed methods he developed in order to improve the operation of oscillation transformer by switching, or stopping the spark in the spark gap. Besides that, he also demonstranted the work of numerous specially constructed vacuum tubes.

Tesla's confidence that signal can easily be flashed around the Earth was strengthened by the discovery of a phenomenon, which he demonstrated and described as a brush discharge, which appears at the outlet or close to the outlet of an excited vacuum light

33 Anderson, Leland, ed. *Nikola Tesla on His Work with Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 9–12.

34 Tesla, Nikola. "Experiments with Alternating Currents of High Frequency and Their Application to Methods of Artificial Illumination". *Electrical Engineer* (London: 1891): I June 17: 63–64; II July 24: 110–113; III July 31: 110 –113; IV August 7: 128–131; V August 21: 159–161, 177 – 179; Tesla, Nikola. "Experiments with Alternating Currents of High Frequency and Their Application to Methods of Artificial Illumination". *Electrical Review* (London: 1891): I July 24: 103–108; II July 31: 147–151; III August 7: 176–179.

35 Lecture *Experiments with Alternate Currents of High Potential and High Frequency* was held at the Institution of Electrical Engineers of Great Britain on February 3, 1892, then at the Royal Institution of Great Britain on February 4, 1892, at the Société Francaise de Physique and Société Internacionale Francaise des Électriciens on February 19, 1892. Tesla, Nikola. "Experiments with Alternate Currents of High Potential and High Frequency". *Journal of I. E. E*, 21, 97, (1892): 51–163.

bulb that contains conducting powder.He suggested that the brush, "the most delicate wireless detector known",[36] which can lead to the state of extreme sensitivity to the electrostatic and electromagnetic influence, can be used to detect small signals in teleg-raphy, but also for sending messages across the Atlantic.[37]

While demonstrating the work of high-frequency motor put into operation by transmis-sion of energy through a single conductor, he presented an idea for wireless motor that works on the principle of transmission through rarified air at significant distances. He described constructive solutions for spark gap on which he worked and the ways to ex-tinct sparks in the experiments he performed at the lecture. He also described the tuning of capacitance in the primary of transformer in order to achieve the maximum effect of primary's action. He expressed his views regarding the conductivity of ground, gas and air, as well as the Earth's behaviour as the capacitor. In the final part of the lecture Tesla spoke of a conductor that could be used for transmission of high-frequency currents at a distance. He describes it as a thin conductor with thick insulation sheathed with met-al screen and he states that it should be divided into isolated sections of significantly shorter wave length.[38] The more detailed description of this type of conductor that Tesla improved will only appear in 1894.[39] By concluding that this type of conductor will not be constructed because "soon intelligence – transmitted without wires – will throb through the earthlike a pulse through a living organism." In his lecture Tesla stated that "the won-der is that, with the present state of knowledge and the experience gained, no attempt is being made to disturb the electrostatic or magnetic condition of the earth, and transmit, if nothing else, intelligence."[40]

Looking back at this lecture scientist Reginald O. Kapp points out that a lot of the scientists who attended the lecture were for the first time introduced to the phenomenon of electromagnetic resonance at Tesla' lecture. The total novelty was the possibility that the spark as the source of high frequencies can be used for various purposes when it initiates oscillations in an adjusted circuit.[41] And while the meeting with British scientists in 1892, especially with Lord Rayleigh[42], encouraged Tesla to continue his research in the

36 Tesla, Nikola. "The True Wireless". *Electrical Experimenter* (New York: May 1, 1919): 30.

37 Tesla, Nikola. „Eksperimenti sa naizmeničnim strujama visokof napona i visoke frekvencije", in Popović, Vojin, red. *Nikola Tesla – Predavanja.*, Belgrade: Zavod za udžbenike i nastavna sredstva, 1995, 113.

38 This structure of waveguide without screen is now known as Goubau type. See: Marinčić, Aleksandar. „Nikola Tesla Contributions to the Development of Radio". *YUMTT Chapter Informer* (1994): 10.

39 "The Tesla High Potential Conductor". Electrical Engineer (New York: February 14, 1894): 133.

40 Tesla, Nikola. „Eksperimenti sa naizmeničnim strujama visokog napona i visoke frekvencije". In Popović, Vojin, red. *Nikola Tesla – Predavanja.* Belgrade: Zavod za udžbenike i nastavna sredstva, 1995, 164.

41 Kapp, Reginald O. "Tesla's Lecture at the Royal Institution of Great Britain in 1892". In *Centenary of the Birth of Nikola Tesla: 1856–1956*. Belgrade: Nikola Tesla Museum,1959, 190–196.

42 John William Strutt, Lord Rayleigh (1842–1919) was, at the time of Tesla's visit to London, a professor of natural philosophy at the Royal Institute (1887–1905). As the successor of James Clerk Maxwell (1831–1879) he previously worked as professor of experimental physicsat Cambridge. He researched the phenomena of sound and light. With Sir William Ramsay (1852–1916) he discovered inert gas argon. For this discovery he was rewarded with Nobel Prize for physics in 1904.

Development of transmitter for wireless transmission of signal in period 1891-1892. Tesla began his research by directly connecting multipole generator, or alternator (marked with circle) with an elevated body, i.e. antenna (diagram 1). After that he added transformer without iron core into the circuit and continued his research by adding adjustable capacitor and adjustable coil in order to obtain conditions of resonance. In his lecture held in 1891 he used diagram no. 7. Diagram no. 12 represents apparatus that will, in the following years, become common in Tesla's experiments with wireless transmission, which five years later resulted in patents for system and apparatus for wireless transmission.

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/C, 5.

direction he already started and to focus on some great idea[43], which will later become the system of wireless trasmission of energy, his meeting with Heinrich Hertz the same year in Bonn had a very different atmosphere. Bearing in mind that the discovery of res-onant oscillator was very important, together with his insights that led him to improve Hertz oscillator, Tesla decided to visit Hertz in Bonn. However, it appears that Hertz was so dissappointed with what Tesla conveyed to him, that Tesla even regreted this encoun-ter.[44]

> *"The announcement of Mr. Nikola Tesla's lecture to the Institution of Electrical Engineers excited widespread interest among all in the least degree interested in electrical science. The succession of almost marvellous experiments in which in great measure it consisted must have gone far beyond the anticipations of the most sanguine of those of the audience who had had no previous account of the nature and results of his work. lt is not too much to say that the Royal Institution lectures mark a distinct epoch in the progress of theoretical and applied electricity. While, on the one hand, the experiments which the lecturer showed seemed to point to a possible revolution of our methods of electric lighting, on the other hand they must have suggested, if not for the first time, in a new and forcible way, important questions of electrical theory, and the phys-iological effects of rapidly alternating currents […] To quote his own words: 'The field is wide and completely unexplored, and at every step anew truth is gleaned, a novel fact observed'."* [45]

After returning from Europe, Tesla perfected a transmitter whose rudimentary form he described in the lecture held in 1891. He finally got the apparatus for transmitters with two oscillation circuits consisting of resonant transformer whose secondary was con-nected on one end to an antenna (elevated body) and grounded on the other, adjustable coil in the antenna's circuit, adjustable capacitor and adjustable coil in the primary of transformer. This will, according to Tesla, become "one of the most common plans"[46] for transmitter apparatus for exciting the air-ground system that he will explain in his next lecture. He didn't protect neither this apparatus, nor the method for tunning the circuit, with a patent.

---

43 Tesla, Nikola. *Moji izumi*. Belgrade: Klub NT, Nikola Tesla Museum, 2003, 59.

44 Tesla, Nikola. "The True Wireless". *Electrical Experimenter* (New York: May 1, 1919), 28.

45 A. W. R. & G. "Mr. Tesla's Lectures on Alternate Currents of High Potential and Frequency". Nature (London: February 11, 1892): 346–347.

46 Detailed explanation of the development of the transmitter Tesla gave in 1916 as a witness in court proceedings "Marconi Wireless Telegraph Company of America v. Atlantic Communication Company, et. al.". See in: Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 9–12.

AIR-GROUND SYSTEM AND CONDITIONS OF RESONANCE IN OSCILLATION CIRCUIT

Finally, at the lecture held in 1893, Tesla will present his basic plan for wireless transmission of energy, by explaining not only the basic principles of the transmission itself, but also the reception of energy at a distant location, with the special emphasis on the role of resonance in the successful reception. As previously mentioned, Tesla developed his system of wireless transmission regardless whether it will be applied in wireless telegraphy or wireless telephony or used for any other purposes and in that manner he presented it at the lecture held in 1893. However, this lecture proved to be the key to recognition of Tesla's contribution to the development of technology for wireless transmission of signal, or radio technology.

In front of the scientific societies in USA in February and March 1893 Tesla gave the lecture whose title wasn't that different from the titles of his previous lectures.[47] In the chapter *On The Apparatus and Method of Conversion* he presented the methods for obtaining current, direct of alternating, of any required frequency and potential by regulating the ratio between the speed of charging and discharging of capacitor, as well as determining capacitance, inductance and resistance of the circuit. He presented the operating principle for the interrupter with electromagnet and air-blast and he considered the electric prop-erties of air and conditions of discharge in gas and air. In chapter *On Phenomena Produced by Electrostatic Force* he explained the phenomena that he observed in metal bodies, be-tween bodies and in light bulbs that were connected on one end to the secondary of coil. In chapter *On Current or Dynamic Electricity Phenomena* he again presented the method for transmission of energy through single wire without return to start an engine, analyzed diagrams of various layouts of inductive elements in the circuit and the effect of current in the circuit, the methods of conversion and distribution by applying capacitor, as well as the effects of electrostatic induction. In chapter *Impedance Phenomena* he described electrical phenomena in conductors with currents varying at rapid rate.

47 Lecture *On Light and Other High Frequency Phenomena,* held on February 24, 1893. at the Franklin Institute in Philadelphia and on March 1, 1893 at the National Electric Light Association in Saint Louis. Tesla, Nikola. "On Light and Other High Frequency Phenomena". *Journal of the Franklin Institute* (1893): July: 1–19; August: 81–98; September: 161–177; October: 259– 279; November: 351–360; December: 401–412; Tesla, Nikola. "On Light and Other High Frequency Phenomena". In *Proceedings of the National Electric Light Association*. St. Louis: National Electric Light Association, 1893,191–302.

Basic plan for radio technology that Tesla demonstrated at his lecture held in 1893.

Tesla foresees the air-ground system on both the side of the transmitter and the side of the receiver. By adjusting the capacitor of variable capacitance and coil of variable capacitance he achieves resonance between oscillation circuits of the transmitter and the receiver. Receiver's circuit also includes devices for detection of waves. Air-ground system and the principle of resonance are the key element of Tesla's radio technology plan.

> *"In connection with resonance effects and the problem of transmission of ener-gy over a single conductor, which was previously considered, I would say a few words on the subject which constantly fills my thoughts and which concerns the welfare of all. I mean the transmission of intelligible signals or perhaps even power to any distance without the use of wires."*[48]

In the most important chapter – *On Electrical Resonance* he gave more precise explanations for adjusting characteristics of the already described circuit with the alternator and ele-vated capacitance, in which he added capacitors and coils, and he considered conditions for achieving resonance. If it is required to obtain very high frequencies, Tesla suggests using oscillation transformer as the source of power and for lower frequencies he suggests alternating dynamo machine.[49] For the first time he also presented a transmitter whose primary coil of the oscillation transformer, the same as in the case of secondary of trans-mitter, needs to be connected to the ground on one end, while the other is connected to insulated capacitance. Sensitive detector shout be added to secondary coil. He also explains the importance of resonance for efficent and selective transmission of energy between synchronized transmitter and receiver.

48 Tesla, Nikola. In Popović, Vojin, red. *Nikola Tesla – Predavanja.* Belgrade: Zavod za udžbenike i nastavna sredstva, 210.

49 According to John Stones study the threshold value of frequency is 30.000 Hz. See: Stone Stone, John. "Signals through Space – From the Beginning". In *John Stone Stone on Nikola Tesla's Priority in Radio and Continuous Wave Radiofrequency Apparatus*, edited by Leland Anderson. New York: Antique Wireless Association, Inc., Holcomb, 1986, 27–40.

Tesla stated his opinion on the method for transmission of energy by induction or conduction: "Some enthusiasts have expressed their belief that telephony to any distance by induction through the air is possible. I cannot stretch my imagination so far, but I do firmly believe that it is practicable to disturb by means of powerful machines the electro-static condition of Earth and thus transmit intelligible signals and perhaps power".[50] He later asks why, if we know that electric vibration can be transmitted through single wire, we shouldn't try to use Earth for that purpose. After that he considers the conductivity of atmosphere and ground, as well. By assuming that the Earth is a conductor, Tesla stated the opinion that consumers, transformers and light bulbs, need to be grounded and that current should run to them through the ground. In relation to that he also raised the ques-tion of the frequency of Earth's oscillations: „If ever we can ascertain at what period the earth's charge, when disturbed, oscillates with respect to an oppositely electrified system or known circuit, we shall know a fact possibly of the greatest importance to the welfare of the human race. I propose to seek for the period by means of an electrical oscillator, or a source of alternating electric currents".[51]

Diagram of energy transmission over single conductor, from the experiment Tesla explained at the lecture held in 1893. He performed a similar experiment in his lectures from 1891 and 1892.

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/C, 85.

50 Tesla, Nikola. In Popović, Vojin, *Nikola Tesla – Predavanja.* Belgrade: Zavod za udžbenike i nastavna sredstva, 1995, 211. 51 Ibid.

In the last chapter – *On The Light Phenomena Produced By High-Frequency Currents* he described light effects obtained in gases and solid bodies – incandescence of solid bodies, phosphorescence, incandescence and phosphorescence of gases and luminosity produced in a gas.

Key results and observations that he presented in this lecture will influence the direction of his further research:

1. Environment where the end points of secondary of oscillation transformer in the air-ground system, which are air and ground, will become a special subject of Tesla's research in the following years. He will study the transmission of energy through air and upper parts of the atmosphere, as well as transmission through ground, or, as he called them together, transmission through natural medium;

2. The premise he presented regarding the oscillation of Earth led him to new studies of Earth as medium, and the final answer regarding the frequency of Earth he obtained thanks to his experiments in Colorado Springs from 1899 to 1900;

3. Because of his idea for transmission through ground he began studying transmission at lower frequencies in order to reduce the loss of energy due to radiation. Therefore, he developed antenna circuit with a great self-inductance and small capacitance, which contributed to the conditions of resonance in the circuit;

4. Study of conditions of resonance in oscillation circuits of transmitters and receivers will lead him to the discovery of the principle of "four circuits in resonance". This discovery will become the key to acknowledging his contribution to the wireless trans-mission of signal, or radio technology.

In working on wireless transmission Tesla deviated from his usual method of work, which he followed while he worked in the field of polyphase alternating currents, and which implied first obtaining a patent for an idea, method or apparatus and then publish it in an article. Not before, nor after the lecture in 1893, up until 1897, Tesla didn't apply for patent related to his key discoveries in this field.

Even though this one, compared to his previous lectures, contained a lot more explana-tions regarding the single-wire and wireless transmission, it still didn't include all of the theoretical and practical results Tesla achieved. The reasons why Tesla gave such limited announcements of things he already achieved can be found in an explanation he gave almost thirty years later. Looking back at this period, in 1919 he wrote that the experi-ments he performed at the lecture in 1891 were the first public experiments, not just with resonant circuits, but with high-frequency currents as well. And while the spontaneous success of his lecture, as Tesla himself saw it, came mostly from the spectacular effects

of the experiments, its key importance was the demonstration of transmission of energy through single wire without return. This was the initial step in the evolution of wireless system. After that he got the idea that it can be possible to wirelessly transmit energy through ground by respecting the conditions of resonance.

We should judge the way this idea might have been accepted in scientific and business circles of that time bearing in mind the existing knowledge regarding the nature of elec-trical phenomena at the time. When he was preparing the chapter on wireless transmission for a lecture in 1893, he accepted the advice of his friends who emphatically protested the publication of the chapter in the format that Tesla had planned.[52] They thought that presenting such far-fetched speculations would injure his reputation it the world of con-servative business men. Therefore, chapter *On Electrical Resonance* contained only a small portion of what he wanted to present.

52 Tesla specifically mentions Joseph Wetzler (1863–?) who was well acquainted with Tesla's work. See in: Tesla, Nikola. "The True Wireless". *Electrical Experimenter* (New York: May 1, 1919): 29. Wetzler cooperated Thomas Commerford Martin (1856–1924), who, among other things, is the author of the first book on Tesla's work, which was published in 1894. In 1891 Wetzler and Martin published a very important book on alternating current motor – *The Electric Motor and Its Applications*. New York: The W J. Johnston Company, Ltd., 1891.

FROM SAINT LOUIS TO COLORADO SPRINGS

Until 1897, when Tesla applied for key patents in the field of wireless transmis-sion, other scientists and engineers pub-lically presented their practical results in transmission of signal and acquired patents for them. Commercial applica-tion of patents also rapidly developed, the market for communication servic-es gradually developed and therefore, competition also appeared in construct-ing and exploiting the communication system. Other that Tesla's work in this field, here we will also present the work of Guglielmo Marconi, Oliver Lodge and John Stone, because the law suit that Marconi's company filed against the US Government put their contribution un-der the same magnifying glass and con-tributed to the valorization of Tesla's work.

FIRST PRACTICAL RESULTS OF WIRELESS TRANSMISSION OF SIGNAL – TESLA, MARCONI, LODGE

Many scientists in America and Europe worked on perfecting the apparatus for wire-less transmission of signal.[53] In the first days of the development of wireless technology apparatus for receiver was developing more slowly than the transmitter, for which there were several reasons – means for precise adjustments of the receiver were not developed, neither were the means for amplification of signal, and besides that, a wave detector that would be sensitive enough was not yet invented.

Simultaneously with perfecting the transmitter apparatus, starting from 1892 Tesla also perfected the receiver apparatus. The operating principle and technology of the receiver put this work in the field of wireless telephony. Following the observations regarding the reception of audible tone in the telephone receiver connected to a conductor or located near the conductor in an electrostatic field, which he presented at the lecture in 1891, until spring of 1895 he conducted experiments with the transmitter circuit located in the laboratory in South Fifth Avenue and the receiver circuit located at a distance of around 2,2 miles (3,2 km), in Hotel Gerlach, where he lived. He adjusted the features of the cir-cuit on the transmitting side and then, based on the characteristics and intensity of the registered tone in the telephone receiver on the receiving side he evaluated the quality of the receiver apparatus.[54] After that he constructed special receivers where, by using audio signal, he tested whether transmitter and receiver are in resonance. The receiver contained a spring wire and he adjusted induced current in the receiver's circuit by in-ducing mechanical oscillation of the wire with the help of magnetic field. In 1897 Tesla perfected the construction of the receiver that could receive tone transmitted from the maximal distance of around 30 miles (48 km).[55] Speaking about this result, Tesla stated that he "produced continuing trains of oscillations […] There were no signals actually giv-en. I simply got the tone but that was for me just the same."[56] The results of his work on wireless telephony Tesla didn't publish nor did he protect them with patents.

In June and August 1894, a year after the last of Tesla's lectures, Oliver Lodge performed three experiments with transmission of Hertz waves. As the source of electromagnetic waves he used Hertz oscillator, and as a detector of waves he used upgraded Branly co-

53 The following people worked on the development of radio technology: David Edward Hughes, Heinrich Hertz, Jagadish Chandra Bose, Édouard Branly, Nikola Tesla, Roberto Landell de Moura, Ferdinand Braun, Ernest Rutherford, Oliver Lodge, Adolph Slaby, Александр Степанович Попов, Julio Cervera Baviera, John Ambrose Fleming, Guglielmo Marconi, John Stone Stone, Reginald Fessenden, Lee De Forest.

54 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 23–26.

55 Ibid., 27.

56 Ibid.

herer.[57] In his memorial lecture on the occasion of Hertz's death in June 1894[58] Lodge performed an experiment in which he connected the mirror of a galvanometer to a coherer by which the received electromagnetic wave was visible to the spectators in the form of a movable ray of light. This lecture also signified the introduction of coherer in wireless telegraphy.[59] He repeated his experiments with certain variations during the annual meeting of the British Association for the Advancement of Science in Oxford on August 14, 1894. At that time he accomplished a reception of Morse code transmitted from the distance of 55 m. Because of this result a part of the British scientific community and historians of science consider him to be the first to demonstrate wireless telegraphy. However, similar to Hertz, at the beginning of his work, Lodge didn't see the application of electromagnetic waves in telegraphy as the final goal of his reception of Morse code, but the purpose of the experiment was to illustrate the theory of sight and the properties of electromagnetic waves.

During the fall and winter of 1894/1895 in his villa Griffone in Italy Marconi began experimenting with Hertz oscillator. Before the fall of 1895 he perfected the apparatus that he used, in front of over one hundred spectators, to register a signal sent from the distance of around 1,5 km. At the transmitting side one part of the Hertz oscillator was grounded, while the other end was connected to the elevated capacitance, or the antenna. At the receiving side he used a coherer as a detector, and it was grounded on one end and connected to the antenna on the other. It was the type of coherer that Marconi specially perfected.[60] Other than the specific coherer, the system used by Marconi corresponds to the system described by Tesla in 1893 because it is based on an antenna and the ground-ing of transmitter and receiver. Considering that the terrain where Marconi worked was hilly and that there were several obstacles between the position of the transmitter and the receiver, this result was considered to be important because it contributed to the understanding of the propagation of waves in real environment. That is why the scientific community and the historians of science consider 1895 to be the year of the discovery of radio and Marconi to be the man who discovered it.[61]The fact that he achieved the result, unlike Lodge, by consciously perfecting the apparatus for the purpose of communication, goes in Marconi's favour.

---

57 French physician Edouard Branly (1844–1940) developed a wave detector that consisted of a glass pipe filled with metal powder or metal filings, with electrodes on each end of the pipe. Under the influence of electromagnetic waves metal powder would vibrate.

58 Hertz died on January 1, 1894. Lodge held a lecture titled *The Work of Hertz* on June 1, 1894 at the Royal Institution of Great Britain in London. It was published in: Lodge, Oliver J. *The Work of Hertz and Some of His Successors*. New York: D. Van Nostrand Company; London: *The Electrician* Printing and Publishing Company, Ltd., 1894.

59 Lee, Thomas H. *Planar Microwave Engineering: A Practical Guide to Theory, Measurement, and Circuits, Volume 1*. Cambridge: Cambridge University Press, 2004, 32.

60 Marconi, Guglielmo. "Wireless telegraphic communication". *Nobel Lecture*. Nobelprize.org. Downloaded on 20. 12. 2015. http://www.nobelprize.org/nobel_prizes/physics/laureates/1909/marconi-lecture.pdf

61 In 1995 the world celebrated 100th anniversary of the discovery of radio. One of the more important events was the conference *International Conference on 100 Years of Radio* held in London from September, 5 to September, 7, organized by *Science, Education and Technology Division of the Institution of Electrical Engineers*, in cooperation with *British Vintage Wireless Society* and *International Union of Radio Science*. Some of the scientists and historians of science in England celebrated the anniversary in 1994, as the 100th anniversary of the Lodge's discovery of the radio.

Marconi attributed the success of the transmission of waves to the elevation of the el-evated capacitance, so initially he continued his experiments by increasing the height. In 1896 he continued his work in England, where in June of the same year he applied for patent no. 12.039 for modified Hertz oscillator.[62] By the end of the same year he applied for US patent, which was analogue to the British patent, and it was granted under no. 586.193.[63] Both patents, British and American, were approved in 1897. It protected the system with two oscillation circuits, one on the transmitting end and one on the receiv-ing end. Here Marconi used Tesla's system of grounded antenna (elevated plate). On the receiving side, antenna circuit contained coherer for detection of waves. Tuning of trans-mitter and receiver was achieved by carefully determining the size of the elevated anten-na plates, and not by adjusting resonance. However, patent by American physicist Amos Dolbear (1837–1910) *Mode of Electric Communication*, from 1886[64], was an obstacle for Marconi to protect and apply his system in the USA because system descried in Marconi's patent was similar to the system described in Dolbear's patent.[65] Dolbear's patent was approved even before Hertz published the proof for Maxwell's theory of electromagnetic radiation. Dolbear applied for patent in 1882, and the discovery was related to „the estab-lishing electric communications between two or more points without the use of wires or other like connections, and consists in establishing a potential at one point considerably above the normal and a potential at the other point considerably below the normal, and by varying the potential at the first point cause variations of the potential at the other point; the result is an impulse transmitted from the transmitter through ground without any conductor, sufficient enough to excite the receiver so that it gives an intelligible sig-nal". Dolbear waited four years for the approval because US Patent Office considered his invention to be impracticable. Only after Dolbear practically presented his apparatus, the patent was approved.[66] Original distance to which he transmitted the signal was around 18 m[67], and with the perfected apparatus from 800 m to 20 km[68]. On both transmitting and receiving side Dolbear used a primitive antenna and a grounded electrode. The fact that on both the transmitting and the receiving side one part of the apparatus is ground-ed and the other is free is what makes Tesla's system described in the lecture from 1893 resemble Dolbrear.

---

62 Patent *Improvements in Transmitting Electrical impulses and Signals, and in Apparatus therefor,* for which he applied on June 2, 1896, was approved on December 2, 1897.

63 Patent *Transmitting Electrical Signals*, for which he applied on December 7, 1896, was approved on July 13, 1897.

64 Patent *Mode of Electric Communication*, no. 350.299, for which he applied on March 24, 1882, was approved on October 5, 1886..

65 Fahie, John J. *A History of Wireless Telegraphy*, 2nd. Edinburgh and London: William Blackwood and Sons, 1901, 102; Sewall, Charles Henry. *Wireless telegraphy: its origins, development, inventions, and apparatus*, 2nd. New York: D. Van Nostrand Company, 1904, 103; Sarkar, Tapan K., Mailloux, Robert J., Oliner, Arthur A., Salazar-Palma, Magdalena and Sengupta, Dipak L. *History of Wireless*. Hoboken: Wiley-IEEE Press, 2006, 254.

66 Statement by Dolbear's son for *Electricity* journal, refered to in: "Who Invented Wireless Telegraphy". *The Literary Digest* (November 4, 1899): 556.

67 Erskine-Murray, James. *A Handbook of Wireless Telegraphy: Its Theory and Practice*, 2nd. New York: D. Van Nostrand Company; London: Crosby Lockwood and Son, 1909, 34.

68 Sewall, Charles Henry. *Wireless telegraphy: its origins, development, inventions, and apparatus*, 2nd. New York: D. Van Nostrand Company, 1904, 15.

In 1896 Marconi Company bought out Dolbear's patent and thus commercialized radio in the USA. However, not only that there was a similarity to Dolber's system, but Tesla, Alexander Popov and Oliver Lodge all rightly thought that Marconi's patent also contains their solutions presented at public lectures. This is the reason why in 1901 Marconi filed a new application for approval of patent in which he admitted that there is a similarity between his apparatus and Alexander Popov's apparatus, but not with Tesla's or Lodge's. In his new application he stated that the applicant for the patent believes that patent application no 586.193 from 1896 is invalid because the specification of the patent is not correct. The part that is invalid is the claim that he owns the right to the invention or the discovery described in the patent, which was more than what he had the right to do. This particularly regards the applications for patents related to his apparatus, but at the same time, they also relate to the apparatus that Popov publically presented on May 7, 1895 in his lecture[69] in front of the members to the Russian Physico-Chemical Society in Sankt Petersburg.[70] During his lecture Popov presented improved variant of Lodge's receiver. Instead of spark gap and symmetrical dipole antenna, used by Hertz and Lodge, the receiver contained a vertical antenna (the same as Tesla's system presented in 1893), whose circuit included coherer. In his lecture Popov stated that with this apparatus he transmitted and received a signal at the distance of 550 m. Marconi's repeated application was approved soon after it was filed and the issued patent was titled *Transmitting Electrical Impuls* and carried a number 11.913.[71]

Marconi again publically demonstrated wireless telegraphy in London in July 1895, when he achieved transmission of signal between two postal buildings separated by 300 m. In May 1897 he manages to transmit signal across the Bristol Channel to the distance of 6 km. Almost simultaneously with this success by Marconi, in May 1897 Lodge applied patent no. 11.575 in Great Britain, with which he protected apparatus with two electric circuits, transmitter that is a variation of Hertz oscillator and receiver with the same "elec-trical dimensions" as the transmitter.[72] Frequency was tuned by changing the capacitance of inductive coils on the receiving side. John Fleming[73] considered this Lodge's patent to be fundamental for solving the problem of selectivity, or the reception of waves of only specific frequency and protection from interference in sending and receiving the waves.[74]

---

69 Алекса́ндр Степа́нович Попо́в, „Об отношении металлических порошков к электрическим колебаниям",*Жу рнал Русского физико-химического общества. Часть физическая* (Санкт-Петербу́рг:Русское физико-химическое общество, 1895), 259-260.

70 „Wireless Telegraphy!". *Washington Globe* (November 10, 1901): 5, 8. Downloaded on February 14, 2016. http:// earlyradiohistory.us/1901awtt.htm

71 Patent *Transmitting Electrical Impuls*, for which the application was filed on April 1, 1901, and approved on June 4, 1901

72 Patent *Improvements in Syntonized Telegraphy without Line Wires,* for which the application was filed on May 10, 1897, and approved on August 10, 1898.

73 Sir John Ambrose Fleming (1849–1945) – professor of physics at the University College in London, member of the Royal Institution of Great Britain. Discovery of the electrode deemed him "the father of electronics". He tested Marconi's apparatus for wireless transmission in 1898 and in 1900 he became the adviser in Marconi Company for designing the transmitter which wil be used in 1901 to transmit the message across the Atlantic ocean.

74 Fleming, John A. *The Principles of Electric Wave Telegraphy and Telephony*. New York: Longmans, Green and Co., 1916, 593.

Theoretical and practical results and contributions that Tesla achieved until 1893 were seen from various perspectives by the historians of science, his contemporaries. The first historians of wireless telegraphy were the witnesses of the development of these fields in conditions when scientific theories, theory of propagation of radio waves and theory of antenna were at its very beginning. They mostly presented practical results, patents, experiments and apparatus used to publically achieve certain results in practice, and they dealt less with comparing and evaluating the issue of the priority of discovery. In the first edition of *History of Wireless* Telegraphy from 1899 John Joseph Fahie[75] only briefly men-tions Tesla's lecture from 1893: "Nikola Tesla, the lightning-juggler, proposed to transmit electrical oscillations to any distance through space, by erecting at each end a vertical conductor, connected at its lower end to Earth and at its upper end to a conducting body of large surface. Owing to press of other work, this experiment was never tried, so it re-mained a bare suggestion".[76] Fahie mentions Tesla only one other time in a footnote, in relation to his understanding of electricity and the theory of ether. In the second, revised edition of this book from 1901 in the footnotes the same author additionally indicates Tesla's "extraordinary research in 1892", the significance of Tesla oscillator as a source of high -frequency currents, as well as Tesla's announcement that wireless communication with any part of the world would soon be possible.[77] In the textbook for electric telegraphy and telephony from 1916 John Fleming recognizes the significance of Tesla's work in the field of producing electrical oscillations. Fleming gives explanations for Tesla's devices for production of high-frequency currents, and gives an especially detailed analysis of oscillation transformer and switches and gives a comparative analysis of high-frequency devices made by different inventors. However, for Fleming Tesla's work after 1892 doesn't exist because his name is completely omitted in chapters regarding radio technology.[78]

In his book *Wireless telegraphy: its origins, development, inventions, and apparatus* from 1904 Charles Sewall gives an overview of Tesla's discoveries and patents.[79]

In the first edition of the textbook for theory and practice of wireless telegraphy from 1907 James Erskine-Murray[80] gives an extensive overview of Tesla's work and spots Tesla's key contributions.[81] Ha emphasizes that, among numerous Tesla's inventions invented until 1893, probably the most important device for wireless telegraphers is

---

75 Member of the Institution of Electrical Engineers of Great Britain and Société Internacionale Francaise des Électriciens. 76 Fahie, John J. *A History of Wireless Telegraphy 1838-1899*, Edinburgh and London: William Blackwood and Sons, 1899, 199– 200.

77 Fahie, John J. *A History of Wireless Telegraphy*, 2nd. Edinburgh and London: William Blackwood and Sons, 1901, 140, 208, 228, 261.

78 Fleming, John A. *The Principles of Electric Wave Telegraphy and Telephony*. New York: Longmans, Green and Co., 1916.

79 Sewall, Charles Henry. *Wireless telegraphy: its origins, development, inventions, and apparatus*, 2nd. New York: D. Van Nostrand Company, 1904.

80 At the time when book was published, James Erskine-Murray was a lecturer of wireless telegraphy and telephony at the Institute Northampton in London, a lifelong member of the Royal Society of Edinburgh and the Physical Society of London, and a member of the Institute of Electrical Engineers of Great Britain.

81 Erskine-Murray, James. *A Handbook of Wireless Telegraphy: Its Theory and Practice*, 2nd. New York: D. Van Nostrand Company; London: Crosby Lockwood and Son, 1907.

Tesla transformer or Tesla coil, which he later describes in detail by using explanations from Tesla's lecture from 1892. He then points out that resonant transformer is used in almost all wireless telegraphy stations as the source of high -frequency and high- voltage currents, i.e. as a transmitter, or that telegraphy companies use the modification of that same device on the transmitting side. Erskine-Murray also describes the detector with brush discharge, which convinced Tesla in the possibility of wireless transmission.[82] He also concludes that in 1893 Tesla proposed a plan for wireless transmission of energy, which reminds of Dolbear's system in some aspects, but which also includes a fundamental im-provement. It relates to using elevated capacitance and grounding on both transmitting and the receiving side (air-ground system), as well as the proposal that self-inductance and capacitance of the receiver have to be tuned to the transmitter's frequency.[83] British patents, Marconi's patent no. 12.039, approved in 1897, and Lodge's patent no. 11.575, approved in 1898, Erskine-Murray considers to be the first patents related to resonant transmitter and receiver.[84] He states that Tesla's patent based on the principle of the resonance between electrical circuits of the transmitter and the receiver, which he sug-gested as early as 1893, will come after the patents by Lodge and Marconi. Besides that, Erskin-Murray also notices a significant difference between them – Tesla didn't propose free radiation as Lodge did, but rather conduction through ground.[85]

With Hertz oscillator as oscillation source, and even by using Tesla's idea of connecting the source to the ground and the antenna, the transmission to greater distances was not possible. It will turn out that the advancement in the development of wireless telegraphy and the foundation of modern radio technology will only become possible with Tesla's patents for wireless transmission of energy, which he filed for in 1897. However, the ab-sence of Tesla's patents in this early period of the development of wireless telegraphy, besides other reasons, had its effect on Tesla's contribution in this field to be neglected even among his contemporaries.

82 Erskine-Murray, James. *A Handbook of Wireless Telegraphy: Its Theory and Practice*, 2nd. New York: D. Van Nostrand Company; London: Crosby Lockwood and Son, 1909, 23–28, 231.
83 Ibid., 35, 51–52.
84 Ibid., 36.
85 Ibid.

PERIOD OF GLORY AND HIATUS IN TESLA'S WORK

1893 was the year of great success for Tesla. His lectures on high-frequency currents got a great attention from the public and an excellent opportunity presented itself for testing his polyphase system. Company *Westinghouse Electric and Manufacturing Co.* ob-tained the rights to distribute the electric energy, by applying Tesla's polyphase system, to machines and lighting at the World Fair in Chicago, which opened on May 1, 1893. At this Technology Fair Tesla had his own exhibition – he conducted experiments with high -frequency and high-voltage currents and demonstrated the application of multi-pole generators and high -frequency oscillators in wireless lighting. The same year the long-awaited decision on the method of using the hydro- potential of Niagara Falls was finally made. In October 1893 the International Committee for Niagara accepted the offer from companies which suggested application of Tesla's polyphase system. Tesla followed and participated in these events in an appropriate manner, but at the same time he was emerged in his experiments with wireless transmission of energy.

He made the key step in the development of an invention that he called "magnifying transmitter" in 1894 while discharging oscillator in order to excite earth in laboratory conditions. [86] The same year he stated that he absolutely trusts in the possibility to send messages through earth without using a conductor, but also that he had great hopes in the possibility to send large powers in the same manner without losing energy.[87] The new results of his work were published in Thomas Comerford Martin's article entitled *Tesla's Oscillator and Other Inventions* from 1895.[88]

In the year when the development of wireless telegraphy was rapidly advancing, Tesla suf-fered an irrecoverable loss. His laboratory on the South Fifth Avenue no. 35 burned in the fire on March 13, 1895, which caused Tesla to loose over 400 machines and instruments, most of which he himself designed or constructed. In the same year when his polyphase system achieved triumph with the Niagara Falls being put into operation, the development of his wireless system for transmission of energy got in danger.

86 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 72.
87 Brisbane, Arthur. "Our Foremost Electrician". *New York World* (July 22, 1894): 43.
88 Martin, Thomas C. "Tesla's Oscillator and Other Inventions". *Century Magazine* (April 1, 1895): 143–160.

By wirelessly lighting light bulbs Tesla contributed to the campaign for introduction of polyphase alternating currents into public use. By demonstrating the high-frequency currents going through his own body, he silenced all the inappropriate accusations that alternating currents are dangerous.

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/II, 184.

The photographs of Tesla's transmitter and receiver in his laboratory in the South Fifth Avenue no. 35 were published in the article *Tesla's Oscillator and Other Inventions* from 1895.

Left: Discharge of oscillator, which is connected to the ground on one end and excites Earth's electricity. In order to cut down the loses that happen due to radiation, Tesla lowered operating frequency.

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/C, 057.

Right: Receiver that Tesla puts into motion by using electromagnetic induction, joint action of two tuned circuits. This is the earliest trace on the road to Tesla's discovery of individualization method or "individualized control", which he perfected in Colorado Springs in 1899. In the article Tesla confirmed the importance of capacitance and inductance for achieving resonance between the transmitter and the receiver.

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/C, 056.

With the help of his friends and colleagues he continued his work in the laboratory in East Huston Street and rapidly constructed new devices in order to continue with his experi-ments. Thanks to the articles published up until this event, the appearance of machines that Tesla will never construct again was also preveserved for the benefit of the scientific community. This also relates to electromechanical oscillators, a type of oscillators that Tesla used to produce regular oscillations with constant period of oscillation – isochrone oscillations.[89] Besides working with lower frequencies in order to reduce radiation, he considered that departures from isochronism are reduced by reducing the frequency.[90]

> *"The destruction of Nikola Tesla`s workshop, with its wonderful contents, is something more than a private calamity. It is a misfortune to the whole world. It is not in any degree an exaggeration to say that the men living at this time who are more important to the human race than this young gentleman, can be counted on the fingers of one hand; perhaps on the thumb of one hand."*[91]

> *"I am in too much grief to talk. What can I say? The work of half my lifetime, very nearly; all my mechanical instruments and scientific apparatus, that it has taken years to perfect, swept away in a fire that lasted only an hour or two. How can I estimate the loss in mere dollars and cents? Everything is gone. I must begin over again."*[92]

> *"The dectruction of Mr. Tesla`s laboratory by a fire due to the carelessness of a lazy or stupid watchman is a very serious loss to the inventor and to the world; but it takes more than a fire to set back an inventor of such dauntless courage and such indefatigable originality."*[93]

89 "Tesla's Oscillator and Other Inventions". *Century Magazine* (April 1, 1895): 143–160; "Stages and Types of the Tesla Oscillator". *Electrical Engineer* (New York: April 3, 1895): 301–304 (Tesla's oscillators and electro-mechanical oscillators). „The Practical Tesla Oscillator". *Electrical Engineer* (April 3, 1895): 311; „Nikola Tesla's Lost Apparatus". *Electrical Review* (New York: April 3, 1895): 172–173 (electro-mechanical oscillators).

90 Anderson, Leland, ed. *Nikola Tesla on His Work with Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 171.

91 "Editorial: Destruction of Tesla's Workshop". *New York Sun* (March 14, 1895). 92

"Mr. Tesla's Great Loss". *New York Times* (March 14, 1895).

93 Stephenson, Walter T. "The Destruction of Mr. Tesla's Laboratory". *Electrical Engineer* (New York: March 20, 1895).

Hydropower plant at Niagara Falls was put into trial operation on August 26, 1895 and the official start of operation was on November 15/16, 1896. In an article titled *Electricity without Wires*, which was published on January 1896 in *New York Herald*, Tesla stated that his conviction that it is precisely the motive power transmitted wirelessly from a source such as Niagara Falls that would multiply the productive capacity of human kind.

Illustration source: Archive of Nikola Tesla Museum: sign. MNT, VI/I, 75.

On the firsr day of 1896 *New York Herald* published Tesla's statement which reflects the goal of his work on wireless transmission. In response to editor's question which dicovery would improve the living conditions of the human kind the most, Tesla said: "In my opin-ion, the demonstration that the earth's electrical charge can be disturbed, and thereby electrical waves efficiently transmitted to any distance without the use of cables or wires would be the most beneficial."[94] He later added that, in case we could wirelessly send messages to a distance, the first message to be sent should be: "Embrace each other now, you millions! The kiss is for the whole wide world!" („Seid umschlungen Millionen, diesen Kuss der ganzen Welt!"). This verse from Schiller's *Ode to Joy* reflects the purpose of Tesla's life and work.

> *"The conveying of motive power from sources such as Niagara in this man-ner to any place, however remote, would increase many times the productive capacity of mankind. It would bring millions of miserable creatures from the darkness of the coal pits to the light of day. It would cause a kinder feel-ing to spring up between the weak and the strong, which would lead to a generous adjustment of the evermore difficult questions of labor and capital.*
>
> *Even if power could not be distributed, the mere transmission of intelligible signals would be of incalculable benefit. Such a realization would do away with the instability of the financial markets, which is the cause of much suffering and misery. It would greatly facilitate the evolution of novel ideas, as well as the prevention of evils. It would increase the safety of travel and give a new impetus to the press and spread of knowledge."*
>
> Tesla, Nikola. "Letter: Electricity without Wires", *New York Herald,* New York, January 1, 1896

In the issue no. 8 from March 8, 1896 *The World's Magazine* published that the world is at the verge of an astonishing discovery.[95] Tesla's discovery that it is possible to use electrical charge of the Earth was seen in the context of abolishing the monopoly in the production of electrical energy. The magazine also wrote that Tesla successfully established wireless communication at the distance of 4 miles in an experiment he performed with a friend in the mountain district of Pike Pines in Colorado Springs. But the text says there are no detailed information about this achievement.

94 Tesla, Nikola. "Letter: Electricity without Wires", *New York Herald* (New York: January 1, 1896): 133. 95 Tesla, Nikola. "Earth Electricity to Kill Monopoly". *New York World* (New York: March 8, 1896): 147.

TESLA'S FIRST PATENT FOR WIRELESS TRANSMISSION OF ENERGY

In 1896, when Marconi's work already received a lot of attention, Tesla filed the first application for patent for wireless transmission of energy. In patent no. 568.178 – *Method of Regulating Apparatus for Producing Electric Currents of High Frequency*, which he applied for on June 20, 1896, he described a system of four circuits in resonance and he protected the methods for achieving resonance or, as Tesla called this phenomenon "electromagnetic synchronization" of circuits. The patent was approved on September 22, 1896. Tesla's methods made it possible to, by changing the number of impulses of current coming from the power source and by changing self-inductance of the charge circuit and the capaci-tance of the discharge circuit, create sensitive oscillation circuits, two on the transmit-ting side and two on the receiving side, which react only to waves that are in resonance. In order for the patent to be accepted, Tesla had to perform the experiment in front of the inspector from US Patent Office, which he did by simulating propagation of waves through earth anf rarified atmosphere.[96]

On June 6, 1897 magazine *New York Sun* published a long article with an overview of Tesla's work, which stated that Tesla wirelessly sent a signal to a distance of 20 miles, but that is not the only thing that the system he was developing can offer and that Tesla was hoping that he will succeed in wirelessly transmitting energy from one place to another.[97] Tesla didn't want to reveal the details of the apparatus he was developing, but he gave basic explanations regarding the electrical charge of the Earth. He confirmed that the final goal of his work is not commercial success, but he aims for the wireless system to become the means for bringing people closer together. He explained that transmission of signals is not the only result that his system can achieve, although when he started work-ing on it, he too thought that that will be its greatest achievement. Based on the results he already obtained, he expected that he will succeed in wirelessly transmitting power to great distances. During June and August of 1897, the same information also appeared in other magazines.[98]

Then, on September 2, 1897, Tesla filed application for a patent that will later be divided into two applications, so he would receive two patents, crucial for determining his place in the history of wireless telegraphy and radio technology. He waited three years for the patents to be approved. With patent no. 645.576, *System of Transmission of Electrical Energy,* approved on March 20, 1900, he protected the system of transmitting and receiving

96 Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 101, 105.

97 J. N. P. "Tesla Grips the World". *New York Sun* (New York: June 6, 1897): 75.

98 J. N. P. "Tesla's Latest Invention". *New York Herald* (June 7, 1897): 76; J. N. P. "Tesla Triumph". *The New York World* (June 7, 1897): 78; Serviss, Garrett P. "Tesla's Wireless Telegrams". *Electrical Review* (New York: 1897): 83; J. N. P. "Telegraphy without Wires". *Public Opinion* (June 17, 1897): 85; J. N. P. "Tesla's Transmission without Wires". *Electrical Review* (London: June 25, 1897): 88.

station for wireless transmission with four oscillation circuits. Here he explained that the given description of wireless transmission first of all deals with the method and system for transmission of energy to a distance via natural media for industrial purposes, but that the principles he introduced and the apparatus he demonstrated will have many other useful applications like, for example, when one wishes to transmit intelligible signals to great distances. Unlike Marconi's patent no. 12.039 and Lodge's patent no. 11.575 that were based on the method of radiation and two oscillation circuits, as well as Hertz oscillator (and because of that on production of short waves), Tesla's patent is based on a method of translation, four oscillation circuits (or electric circles) and high-frequency oscillator. Efficient transmission of signal is achieved when all four circuits are in resonance, or when they are all tuned to the same frequency, as he already stated in patent no. 568.178. In patent *Apparatus for Transmission of Electrical Energy*, no. 649.621, which was approved on February 19, 1900, Tesla defined elements and ways of connecting elements that consti-tute apparatus for transmitter and receiver. In these patents he emphasized that the total length of conductor, used to make the antenna and the coil for its attunement should be a quarter of the wave length used for radio transmission.

> *"Every wireless message that has ever been transmitted to any distance has*
>
> *been transmitted by this apparatus, there is no other way."*[99]

Drawing from patent no. 645.576 – *System of Transmission of Electrical Energy*

In patents no. 645.576 and 649.121 Tesla explains that transmission of energy involves the phenomenon of true conduction, which shouldn't be confused with the phenomenon of electrical radiation, which from the very nature and mode of propagation would render practically impossible the transmission of any larger amount of energy to such istances as are of practical importance. He also specifies that the conduction is done through upper layers of atmosphere, which are more suitable for conduction that the lower layers because they absorb lower frequencies. Speaking of the quantity of energy transmitted, these are not just small amounts necessary for operation of sensitive devices, or detectors, but also quantities suitable for industrial use.

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, CDXXXV, 2 A.

99 From Tesla's testimony, which he gave in 1916 in relation to the lawsuit that Marconi Company filed against the Government of USA. See: Anderson, Leland, ed. *Nikola Tesla on His Work with Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992, 105.

These two patents became the foundation for syntonized wireless telegraphy, or later modern long wave radio technology.[100]

Oliver Lodge filed application for patent *Electrical* Telegraphy no. 609.154 in February 1898 and it was approved the same year.[101] With this patent he protected apparatus with four electric circuits, as well as the method and means for tuning the circuit of transmit-ter and receiver antenna to resonance, which is done by placing adjustable inductance in the open circuit of the antenna of transmitter or receiver, or both. In Tesla's patent with "four circuits" this method of attunement is not included. Marconi Company became the owner of Lodge's patent in 1912, which shall be discussed in more detail later in the text.

In February 1900 American physicist and inventor John Stone[102] filed application for pat-ent no. 714.756 – *Method of Selective Electric Signaling.*[103] By mathematical analysis of syn-tonized or resonant circuits Stone came to the conclusion that selectivity of circuit can be achieved only when the signal emitted by the transmitter and received by the receiver is sinusoid function of constant period, which is apsolutely not the characteristic of a signal that can be produced on the emitting side by a spark gap. It is necessary to insert tuned resonant circuit on the emitting side between the spark gap and the antenna that will re-move parasite oscillations in the receiver. Similarly to this, on the emitting side resonant circuit has to be inserted between the transmitter and the detector that will only react to one frequency. In this way Stone uses resonant circuits as signal filters.

In April of 1900 Marconi filed application for patent in Great Britain, which was approved under no. 7777 in April 1901.[104] Here he protected the system that is improved compared to the one from previous patent no. 11.913 – now this was the system with four electric circuits, based on resonance and long waves, and the subject of protection is also the attunement of transmitter and receiver's circuit by adding adjustable conductivity in the open circuit of the antenna. This Marconi's patent is a combination of Tesla's and Lodge's patents. Only a month after he filed for patent for system with four circuits in the USA in 1897, Tesla filed application for an analogue patent in Great Britain, which was approved two years earlier that in the USA, in 1898.[105] Therefore, at the time when Marconi was applying for a system with four circuits in Great Britain, Tesla's British patent already ex-isted, but it was not an obstacle for issuing a patent to Marconi. However, the procedure for approving the analogue patent to Marconi in the USA will be more complex, as we shall see later, but the outcome will still be positive.

---

100 The term *syntonization* is used to describe technique by which two or more oscillation circuits are brought into resonance.

101 Patent *Electric Telegraphy*, for which the application was filed on February 1, 1898, was approved on August 16, 1898. 102 John Stone Stone (1869–1943) – American mathematician, physicist and inventor. One of the pioneers of radio technology. His greatest contribution was to the development of methods for attunement of circuits.

103 Patent *Method of Selective Electric Signaling*, for which the application was filed on Februar 8, 1900, was approved on December 2, 1902.

104 Patent *Improvements in Apparatus for Wireless Telegraphy*, for which the application was filed on April 26, 1900, was approved on April 13, 1901.

105 Patent no. 24.421 – *Improvements in Systems for the Transmission of Electrical Energy and Apparatus for use therein*, for which the application was filed on October 21, 1897,was approved on March 26, 1898.

EXPERIMENTS IN COLORADO SPRINGS AND LONG ISLAND

In order to perfect the method of transmission of elec-trical energy by conduction through natural medium (ground and layers of atmosphere), Tesla concluded that the following is necessary:

1. to develop a transmitter of great power;
2. to perfect means for individualizing and isolating the energy transmitted;
3. to ascertain the laws of propagation of currents through the earth and the atmosphere.

By developing high-frequency oscillator for the purpose of researching wireless transmission through Earth, in his laboratory in New York he produced voltages of ap-proximately four million volts and sparks approximately 5 m long. In order to continue his research he needed to produce high-frequency currents of even higher voltage, which required construction of an even larger oscillator.

TESLA'S WORK IN COLORADO SPRINGS

The largest high-frequency oscillator that Tesla used in New York had a secondary with a diameter of 2,44 m and an operating frequency of 240.000 Hz. Experiments in urban conditions became unsafe and impossible to perform with such high voltages and a secondary of that size so Tesla continued his work in a new laboratory. He chose a mountain-ous region, Pikes Peak plane, near the town of Colorado Springs. As newspapers wrote, here Tesla already achieved wireless transmission of signal, which he didn't confirm, and after coming to the laboratory he said that that was the first time he was in the Colorado State.[106] He expected that he will wirelessly transmit a message from New York,[107] or Pikes Peak[108] to Paris, where the World Fair for 1900 was being organized.

High voltages that he worked with also determined the large dimensions of transformer coils, which he achieved gradually. Initially high-voltage transformer was wound up aro-und a conus body with average diameter of over 12 m. Obtaining high voltages of up to 12.000.000 volts and frequency of over 100.000 Hz become possible in the next stage of his work, by connecting in a series a new element, additional coil, to the secondary. This layout of coils he already tested in his lab in New York. The next improvement was the change in the shape of the secondary and the application of cylindrical form with diameter of 15 m. In this way oscillation transformer became a system with three oscillation circuits and three resonant frequencies.

> *"Nikola Tesla, the famous electrician, is now in the city, and will remain for some time. His reputation is world-wide, and he has accomplished wonderful feats in his chosen field of electricity, one of the greatest being the harnessing of Niagara. For some time past his special field of work has been in wireless telegraphy, and his visit here is for the purpose of making experimentsin high altitudes. He is staying at the Alta Vista."*[109]

106 McGovern, Chauncy M. "Nikola Tesla on Top of Pike's Peak". *Denver Rocky Mountain News* (May 17, 1899): 122.
107 Solly, S. E., M. D. "Tesla Hopes to Telegraph From New York to Paris Without Wires", *New York Herald* (November 12, 1899): 168.
108 McGovern, Chauncy M. "Nikola Tesla Will 'Wire' To France". *Colorado Springs Evening Telegraph* (May 17, 1899): 121; Serviss, Garrett P. "Tesla's Colorado Experiments". *New York Tribune* (May 19, 1899): 130.
109 Serviss, Garrett P. "Town Topics". *Facts* (May 20, 1899).

In a period from June 1, 1899 to January 7, 1900 he kept a work journal with detailed notes on the results of his research. He used parts of the journal for preparing patent spe-cifications, which he later cited in his patent applications. The first analysis and explanati-ons of the course of Tesla's work, as well as the results he achieved was given by prof. dr. Aleksandar Marincic in 1976, in his commentary for *Colorado Springs Notes, 1899–1900*[110].

Overview of Tesla patents that came as the result of research conducted in Colorado Springs

patent number	name of the patent	date of application	date of approval
655.838	*Method of Insulating Electric Conductors*	June 15, 1900	August 14, 1900
685.012	*Means for Increasing the Intensity of Electrical Oscillations*	March 21, 1900	October 22, 1901
685.953	*Apparatus for Utilizing Effects Transmitted from a Distance to a Receiving Device through Natural Media*	June 24, 1899, (renewed May 29, 1901)	November 5, 1901
685.954	*Method of Utilizing Effects Transmitted through Natural Media*	August 1, 1899, (renewed May 29, 1901)	November 5, 1901
685.956	*Apparatus for Utilizing Effects Transmitted through Natural Media*	August 1, 1899, (divided in two on November 2, 1899, renewed on May 29, 1901)	November 5, 1901
725.605	*System of Signaling*	July 16, 1900	April 14, 1903
723.188	*Method of Signaling*	July 16, 1900	March 17, 1903
787.412	*Art of Transmitting Electrical Energy through the Natural Mediums*	May 16, 1900, (renewed on June 17, 1902)	April 18, 1905

110 *Дневник истраживања из Колорадо Спрингса 1899–1900.* Београд: Нолит, 1976.

Some of the most important discoveries Tesla made in Colorado, that are still current even today, include:[111]

- He laid out the variants of high-frequency oscillators that can be used for obtaining signals with modified amplitude. These diagrams can be considered as the diagrams of the first modulator of continual stream in radio technology;

- Even though he already observed the problems of selectivity and individualization of the transmitted compared to the received signal in his earlier experiments befo-re 1895, Tesla only solved these problems in Colorado. In his journal he described the transmitter and receiver circuits with multiple resonant circuits. The transmitter produces two or more signals of various freqencies and the receiver responds when these signals act simultaneously. This is the principle that is the basis for method of individualization or „individualized control", as it was called in Tesla's time. In modern radio technology, telecommunications and electronics this was the starting point for development of multifrequent carrier signals, theory of dispersed spectrum and logic „I" circuit. He protected this discovery with patents no. 723.188 – *Method of Signaling* and no. 725.605 – *System of Signaling*.[112] With these patents he improved the solutions from previous patent no. 613.809 – *Method of and Apparatus for Controlling Mechanism of Moving Vehicle or Vehicles*, by which he protected the working principle for remote control of boats by using radio waves.[113] The main shortcoming of this patent was the easy intereference of the signal sent to the receiver at the boat;

- In his journal he registered the discovery of standing waves, created by natural discharges by thunderstorms. Based on his research in Colorado he concluded that this type of waves can propagates on the surface of the Earth in all directions. He later protected this discovery with patent no. 787.412 – *Art of Transmitting Electrical Energy through the Natural Mediums*. He later described and commented on the discov-ery of standing waves in articles *Problem of Increasing Human Energy* from 1900, and *Transmission of Electrical Energy without Wires* from 1914.[114] The above-mentioned discovery of propagation of waves on the surface of the Earth influenced the direction of his further research and experiments on Long Island at the beginning of the 20th century;

111 Marinčić, Aleksandar. „Komentari i objašnjenja". In: *Dnevnik istraživanj aiz Kolorado Srpingsa 1899-1900.*, Belgrade: Zavod za udžbenike i nastavna sredstva, 1996, 460–554; Marinčić, Aleksandar. *Nikola Tesla – Stvaralaštvo genija.* Belgrade: Srspka Akademija nauka i umetnosti, 2006. 150; Marinčić, Aleksandar, Civrić, Zorica and Milovanović, Bratislav. "Nikola Tesla's Contributions to Radio Developments". *Serbian Journal of Electrical Engineering,* 2/3 (2006): 143.

112 After the application for patent a question has risen regarding the priority of discovery of individualization method. Tesla's patent was compared to the patent by Reginald Fessenden *Improvements in transmission and reception of signal,* which was approved on June 2, 1900. Court proceedings began in 1902. The verdict in Tesla's favour was helped by the testimony of his application of this method in 1899 in Colorado Springs.

113 Application for patent was filed on July 1, and it was approved on November 8, 1898. In Colorado he perfected the method of control protected in this patent and on July 16, 1900 he filed application for a new patent, which was divided into two applications in June 14, 1900, thus two patents were approved – *Method of Signaling and System of Signaling.*

114 Tesla, Nikola. "Problem of Increasing Human Energy". *Century Magazine* (1900): 19–55; Nikola Tesla, „Transmission of Electrical Energy without Wires". *Electrical World and Engineer* (1904): 166–168.

- He tested various types of receivers with coherers, as well as methods for connecting receivers, which was the continuation of his research in New York. During his stay in Colorado he applied for patents for receivers that use "accumulation method", which are discoveries made in New York laboratory, but which he perfected in Colorado Springs. Patent no. 685.953 - *Apparatus for Utilizing Effects Transmitted from a Distance to a Receiving Device through Natural Media* stands out among them and with this patent he protected a receiver which we now call an integrate and dump receiver.[115]

Laboratory in Colorado Springs. Tesla conducted experiments in secret and the laboratory was surrounded with a fence which had a warning sign – "Great Danger – Do not come near". Entrance was controlled. Above the entrance Tesla put on a sign with Dante's verse written on it: "Abandon hope all ye who enter here".

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/IV, 9.

115 Other patents are patent no. 685.954 – *Method of Utilizing Effects Transmitted through Natural Media* and patent no. 685.956 – *Apparatus for Utilizing Effects Transmitted through Natural Media* (these are the patents related to the modification of the receiver with sensitive devices and condensator method for magnifying effects, including self-excitement process).

TESLA'S WORK ON LONG ISLAND

Tesla returned from Colorado Springs to New York on January 11, 1900. Encouraged by the results of his work, he immediately starts the preparations for construction of strong transmitter in Wardenclyffe, on Long Island, near New York. He intended to apply the patents for wireless transmission of energy commercially and to achieve transmission of signal across the Atlantic.

Therefore, in 1900, according to the design by architect Stanford White, designs were prepared for a new laboratory with transmission tower. However, fire again threatened Tesla work. On March 8, 1900, five years after the fire that destroyed laboratory in South Fifth Avenue, there was a fire in the building in Houston Street. This time it was stopped in time, so there were no consequences for Tesla's laboratory.[116]

System of wireless transmission he was developing on Long Island Tesla called *World System of Wireless Transmission.* He explained that this system is based on his most important discoveries in the field of wireless transmission, which he illustrated in 1919, and they include:[117]

1. Tesla transformer for generating electrical oscillations – device which was as revolutionary as the discovery of gun powder was for warfare;

2. High-voltage transmitter – oscillator specifically tuned to excite the Earth and which holds the same importance for transmission of electric energy as the telescope has for astronomical observations;

3. Tesla's wireless system – it includes numerous improvements with the purpose of achieving transmission on any required amount of energy to the other end of the Earth, with the loss of energy of only several percent;

4. Individualization skill – compared to "primitive tuning" it is the same as perfect language compared to inarticulate expressions;

5. Standing waves on Earth – their existence means that the Earth reacts to electrical vibrations of certain frequency the same way the tuning fork reacts to certain audio waves.

116 Bottone, S. "Tesla Has Narrow Escape". *New York Herald* (March 9, 1900): 8.
117 Tesla, Nikola. „My Inventions Part Five – The Magnifying Transmitter". *Electrical Experimenter* (1919): 177.

The possibilities that Tesla announced with the system of wireless transmission, together with the already proven reliability and cost effectiveness of his polyphase system, were the reason why John Pierpont Morgan began financing the construction of the facility on Long Island. In the 1890s Morgan alredy held a position that will enable him to get the leading role in international economic business and become one of the key figures among those who influenced the USA to become the leading industrial force at the turn of the 20th century. One of the industrial branches that developed thanks to Morgan's capital was electrical industry.[118]

In February 1901, newspapers reported the news that Tesla's receiving station was established in Portugal, on the 40th parallel, for the reception of signal that Tesla would sent from the shores of New England in USA, from the location which is right across from the reception location.[119] There were also speculations that Tesla's collaborators are doing re-search at the shores on New England, near Boston.[120] In March 1901 he signed a contract with Westinghouse Company on the production of equipment that will be used on Long Island.

After 1901, Morgan stopped further funding of Tesla's work under the impression of the results in wireless transmission that Marconi achieved that year. In November 1900 Marconi filed an application for patent in USA that is equivalent to his British patent no. 7777. In January 1901 he transmitted a signal to a distance of around 315 km in England, between Isle of Wight and Cornwall. In December 1901 he sent a signal across the Atlantic by using the system described in the above-mentioned British patent, which was a combi-nation of Tesla's and Lodge's system. The impact that Marconi's practical results had was greater that the suspition regarding the originality of his system.

However, procedure for obtaining analogue patent in USA lasted until 1904. The appli-cation was rejected the first time by referring to work of Oliver Lodge and the previous Marconi's patent, the second time by referring to works of Tesla, Lodge and Brown and the third time by referring to Tesla's patents no. 645.576. and 649.621, which were ap-proved around the same time when Marconi filed application for patent in the USA. After Marconi's complaint, application was reconsidered and rejected by referring to Tesla's patents, results of Mihajlo Pupin and the Stone's patent no. 714.756. Marconi complained and after the patent examiner was changed, the application for patent was approved in 1904,[121] therefore, Marconi obtained patent in the USA no. 763.772 – *Apparatus for Wireless Telegraphy*.[122]

---

118 John P. Morgan was one of the shareholders of *Construction Company*, which owned the hydro power plant on Niagara. Other companies that he also helped establish include, e.g. *General Electric* and *U. S. Steel*.

119 "Tesla Ready to Try Transatlantic Talk". *New York Journal & Advertiser* (February 22, 1901): 171. 120
"Are They Tesla's Agents". *New York Sun* (February 17, 1901): 170.

121 Anderson, Leland. *Priority in the Invention of radio – Tesla vs. Marconi*. Bloomfield, NY: Antique Wireless Association Monograph, 1980, 1–9.

122 Patent no.. 763772 - *Apparatus for wireless telegraphy (Apparatus for Wireless Telegraphy)*, for which the application was filed on November 10, 1900, and was approved on June 28, 1904.

The construction of the tower began in 1901 and it was completed in 1902. Tower was 57 m high, with a dimmeter of the dome of 20,5 m, but it never received its originally designed look. Tesla worked in secrecy and released very few information to magazines and newspapers. Only when a light conture began appearing during the night experiments, which drew attention from many locals and journalists, he releases a short statement regarding his work. He explained that next to the high tower with the dome around which the light appears, there is also a part of the tower that is under ground, a hole which is around 45 m deep.

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/IV, 31.

For achieving resonance this patent uses Lodge's solution from patent no. 609.154 – adjustable inductance.[123] Practically speaking, when Marconi got the patent he was free to use Tesla's system of transmitters and receivers with four oscillation circuits under his name, but he couldn't apply his patent, without infringing Lodge's rights. That is why Marconi Company bought out Lodge's patent in 1912.[124] When Marconi Company filed its suit against the Government of the USA in 1916, whose main subject was the ques-tionable patent no. 763.772, the question of its originality was opened once again. Court proceeding lasted longer that the process for obtaining patent and the verdict reached in 1943 was also a late recognition to Tesla, as well as Lodge and Stone.

On June 29, 1916 Marconi Wireless Telegraph Company of America filed a claim against the Government of the USA in front of the Court of Claims. The subject of the claim was the infringement of rights to use the patents that were the property of Marconi Company. The patents in question were already mentioned patents no. 11.913, from 1901, and no. 763.722, from 1904, Lodge's patent no. 609.154, from 1898, and a patent by John Fleming from 1905.[125] The rationale of the claim stated that during the First World War the Government of the USA used, without the royalty payment for the use of pat-ent, technology based on the above- mentioned patents. In 1935 Federal Court reached a verdict in which it denied the claim by Marconi Company.[126] A new claim followed, this time to the Supreme Court of the USA, which reached the verdict on June 21, 1943.[127] The Supreme Court denied the claim, being of opinion that, when it comes to Marconi's patent no.763.722, „Marconi's patent doesn't contain any inventions that aren't already included in Tesla's, Lodge's or Stone's patents". In the rationale the Court referred to Tesla's patents no. 649.621 and no. 645.576, which defined the apparatus and the system of radio, and already considered patents of John Stone, no. 714.756, which involved a larger selectivity of circuit attunement, and Oliver Lodge, no. 609.154, which enabled the tuning of adjustable inductance.

However, Marconi's practical results from 1901 completely changed the destiny of Tesla's work on Long Island. From 1902 Tesla's laboratory and office were officially on Long Island.[128] The same year Tesla filed an application for patent for apparatus for transmis-sion of electrical energy, no. 1.119.732, which will only be approved in 1914. [129]

123 In this patent Lodge has not specifically specified the requirements for the resonance of the circuits of the transmitter and the receiver, because he considered that it is only the resonance of antenna what determines the frequency.

124 Aitken, Hugh G. J. *Syntony and Spark: The Origins of Radio*. Princeton University Press, 1985, 253.

125 Patent *Instrument for Converting Alternating Electric Currents Into Continuous Currents*, no. 803.684, for which the application was filed on April 19, 1900, was approved on November 7, 1905.

126 Only one claim for reimbursement was accepted, related to the use of Marconi's patent no. 763.722, and the recovery of damages was ordered.

127 Justia US Supreme Court. Marconi Wireless Tel. Co. v. United States, 320 U.S. 1 (1943). Preuzeto 14. 05. 2016. https://supreme.justia.com/cases/federal/us/320/1/case.html

128 In June 1902 Tesla asked the newspapers to report the news that he is moving to Long Island. See: "Tesla's Laboratory Removed to Wardenclyffe". *Electricity* (June 4, 1902): 93.

129 The application for patent was filed on January 18, 1902 and it was approved on December 1, 1914.

In patents no. 645.576 and 649.121 Tesla described apparatus of transmitter and receiver that became common in the radio technology, but which he didn't use in the way that is common in the radio technology. He used the transmitter so that it emits one part of the energy by antenna radiation, while the radiation of the antenna is minimal. He considers this energy to be lost because most of it dissipates in the surroundings, and only a small part can be used for operating a small instrument. The other, larger portion of the energy passes into the earth through grounding and only one percent of this energy is lost. In order to fulfill the condition for production of small radiation energy and a large quantity of energy that is transmitted to ground, it was necessary to lower the frequency and for the transmitter to have both great inductance and great capacitance. The technology of transmission based on this principle was protected by patent no. 787.412. The frequency shouldn't be greater that 30.000 to 35.000 Hz.

The electrical oscillations are impressed to the Earth through the grounded part and they produce standing or stationary waves. Tesla presumed that in electrical sense Earth behaves like a conductor of limited dimensions, so, the same as in conductor, standing or stationary waves are formed, which are created by the interference of impressed and reflected waves. The point in which the waves form is called the pole of wave, and at the opposite side of the Earth the antipode is formed. As you can see from the drawing, the waves propagate across the surface and across the center of the Earth, travelling at the speed that is proportionate to the product of the speed of light and consecant of the angle which the direction of speed makes with the axis of symmetry of Earth.[130]

Illustration source: Archive of Nikola Tesla Museum, sign. MNT, VI/C, 96.

1. Electromagnetic Hertzian waves radiate horizontally from vertical conductor, slightly affected by conducting Earth surface. The energy is unrecoverable. The speed of waves is equal to the speed of light.

2. Resultant oscillatory current through Earth. The energy is recoverable.

130 From Tesla's testimony regarding the law suit that Marconi Company filed against the Governemnt of the USA. See: Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power*. Denver: Sun Publishing, 1992, 139–143.

Drawing accompanying the patent no. 1.119.732 – *Apparatus for Transmitting Electrical Energy*

The patent, among others, protects the transmitter whose antenna is connected on one end to the grounded secondary. Conductive outer elements of the antenna are arranged in a way in which they create surfaces of large radius of curvature, which prevents the losses due to the occurance of corona. Tesla's intention on Long Island was also to confirm the idea regarding the resonance of Earth. He expected that these resonances will be 6,18 and 30 Hz. Experimental research from 1960s showed that the Earth resonates at around 8,14 and 20 Hz. These resonances are known as Schumann resonances.

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, CDXCVII, 59 A.

Drawing accompanying patent no. 787.412 – *Art of Transmitting Electrical Energy through the Natural Mediums*.

In this patent Tesla described the occurence of standing waves, for which he discovered that they vary in lenght from 25 to 70 km. He concluded that this type of waves can propagate across the Earth in all directions. The apparatus described in this patent included high-frequency oscillator, or generator of high frequencies, which he alredy described in patents no. 645.576 and 649.121. In order to cut the losses due to radiation, he recommended working on lower frequencies, with maximum working frequency being 20.000 Hz, and the minimum being 6 Hz.

Illustration source: Archive of the Museum of Nikola Tesla, sign. MNT, CDXCVI, 396 A.

In order to explain the possibilies of his *World system,* Tesla published a broshure, which appeared in the newspapers for the first time in 1904, and it was immediately called "A Striking Tesla Manifesto":[131]

1. The inter-connection of the existing telegraph exchanges or offices all over the world;
2. The establishment of a secret and non-interferable government telegraph service;
3. The inter-connection of all the present telephone exchanges or offices on the Globe;
4. The universal distribution of general news, by telegraph or telephone, in connection with the Press;
5. The establishment of such a 'World-System' of intelligence transmission for exclusive private use;
6. The inter-connection and operation of all stock tickers of the world;
7. The establishment of a 'World-System' of musical distribution, etc.;
8. The universal registration of time by cheap clocks indicating the hour with astronom-ical precision and requiring no attention whatever;
9. The world transmission of typed or handwritten characters, letters, checks, etc.;
10. The establishment of a universal marine service enabling the navigators of all ships to steer perfectly without compass, to determine the exact location, hour and speed, to prevent collisions and disasters, etc.;
11. The inauguration of a system of world-printing on land and sea;
12. The world reproduction of photographic pictures and all kinds of drawings or records.

More details regarding the principles of wireless transmission of great powers will become known in 1905, when Tesla's patent no. 787.412 was approved, for which he filed an application in 1900. According to Tesla's explanation patent is based on the results of experiments performed in Colorado Springs.[132] The apparatus for wireless transmission, already described in patents no. 645.576 and 649.121, are applied in this patent for production of standing waves and transmission of electrical energy by using the Earth's standing waves. With this patent Tesla protected the improved technology for transmission of electrical energy to distances, which is based on establishing standing waves in the ground and im-pressing upon the earth such oscillations that will produce standing waves.

131 Taylor, Frank H. "A Striking Tesla Manifesto". *Electrical World & Engineer* (New York: February 6, 1904): 159. 132 Stanley, William. "Notes: News of Tesla". *Electrical Review* (London: May 26, 1905): 110.

Besides that, he also protected technolo-gy for varying wave lengths and shifting nodal and ventral regions of the waves, as well as the technique for reception of waves. Even more detailed description of the technique for producing standing waves and the effects of transmission of energy by using standing waves we find in Tesla's patent no. 8.200, which he obtained in Great Britain and which is analogue to American patent no. 787.412.[133]

In 1907 Tesla worked on Long Island, but during the following years he occasionally conducted measurements and experiments there for his continued research in the field of wireless transmission of energy. The greatest frequencies he produced were up to 200.000 Hz, and the power of 200–300 kW. He didn't construct a special receiv-ing station but he used mobile instruments for the reception of waves. By using his high -voltage transmitter he managed to turn on 200 light bulbs wirelessly.[134]

THE ELECTRICAL EXPERIMENTER

H. GERNSBACK EDITOR
H. W. SECOR ASSOCIATE EDITOR

Vol. V. Whole No. 53 September, 1917 Number 5

U. S. Blows Up Tesla Radio Tower

SUSPECTING that German spies were using the big wireless tower erected at Shoreham, L. I., about twenty years ago by Nikola Tesla, the Federal Government ordered the tower destroyed and it was recently demolished with dynamite. During the past month several strangers had been seen lurking about the place.

Tesla erected the tower, which was about 185 feet high, with a well about 100 feet deep, for use in experimenting with the transmission of electrical energy for power and lighting purposes by wireless. The equipment cost nearly $200,000.

The late J. P. Morgan backed Nikola Tesla with the money to build this remarkable steel tower, that he might experiment in wireless even before people knew of Marconi. A complete description, revised by Dr. Tesla himself, of this unique and ultra-powerful radio plant was given in the March, 1916, issue of THE ELECTRICAL EXPERIMENTER. Everyone interested in the study of high frequency currents should not fail to study that discourse as it contains the theory of how this master electrician proposed to charge this lofty antenna with thousands of kilowatts of high frequency electrical energy, then to radiate it thru the earth and run ships, factories and street cars with "wireless power."

Most of our readers have, no doubt, read about the famous Tesla wireless tower, which structure involved the expenditure of a vast sum of money and engineering talent. From this lofty structure, which was designed some 20 years ago by Dr. Tesla and his associates, there was to be propagated an electric wave of such intensity that it could charge the earth to such a potential that the effect of the wave or charge could be felt in the utmost confines of the globe.

Further, it may be said that Tesla, all in all, does not believe in the modern Hertzian wave theory of wireless transmission at all. Several other engineers of note have also gone on record as stating their belief to be in accordance with Dr. Tesla's. More wonderful still is the fact that this scientist promulgated his basic theory of *earth current* transmission a great many years ago in some of his patents and other publications. Briefly explained, the Tesla theory is that a wireless tower, such as that here illustrated and specially constructed to have a high capacity, acts as a huge electric condenser. This is charged by a suitable high frequency, high voltage apparatus and a current is discharged into the earth periodically and in the form of a high frequency alternating wave. The electric wave is then supposed to travel thru the earth along its surface shell and in turn to manifest its presence at any point where there might be erected a similar high capacity tower to that above described.

A simple analogy to this action is the following: Take a hollow spherical chamber filled with a liquid, such as water; and then, at two diametrically opposite points, let us place, respectively, a small piston pump, such as a bicycle pump, and an indicator, such as a pressure gage. Now, if we suck some of the water into the pump and force it back into the ball by pushing on the piston handle, this change in pressure will be indicated on the gage secured to the opposite side of the sphere. In this way the Tesla earth currents are supposed to act.

The patents of Dr. Tesla are basically quite different from those of Marconi and others in the wireless telegraphic field. In the nature of things this would be expected to be the case, as Tesla believes and has designed apparatus intended for the *transmission of large amounts of electrical energy*, while the energy received in the transmission of intelligence wirelessly amounts to but a few millionths of an ampere in most cases by the time the current so transmitted has been picked up a thousand miles away. In the Hertzian wave system, as it has been explained and believed in, the energy is transmitted with a very large loss to the receptor by electro-magnetic waves which pass out laterally from the transmitting wire into space. In Tesla's system the energy radiated is not used, but the current is led to earth and to an elevated terminal, while the energy is transmitted by a process of *conduction*. That is, the earth receives a large number of powerful high frequency electric shocks every second, and these act the same as the pump piston in the analogy.

Quoting from one of Tesla's early patents on this point: "It is to be noted that the phenomenon here involved in the transmission of electrical energy is one of *true conduction* and is not to be confounded with the phenomena of *electrical radiation*, which have heretofore been observed, and which, from the very nature and mode of propagation, would render practically impossible the transmission of any appreciable amount of energy to such distances as are of practical importance."

Two Views of the Last Minutes of Tesla's Gigantic Radio Tower at Shoreham, L. I., New York, As It Was Being Demolished by the Federal Government. It Was Suspected That German Spies Were Using It for Radio Communication Purposes. It Stood 185 Feet Above the Ground and Cost About $200,000. Tesla Had Not Used It For Several Years.

Photos by American Press Association

The tower was demolished in 1917 by the order of the US Government based on the suspicion that it is being used by German spies.[135] In 1917 scientific journal *The Electrical Experimenter* reported the news that the tower in Wordencliff is being demolished. In 1919 Tesla explained: "My project was slowed by the laws of nature. The world was not ready for it. It was too far ahead of time. But the same laws will prevail in the end and make a triumphant".[136]

The ultimate goal of Tesla's *World System,* or the goal of Tesla's work on wireless transmission of energy is best seen in his article published in 1905:

133 Patent *Improvements relating to the Transmission of Electrical Energy*, for which he filed an application on April 17, 1905, was approved on April 17, 1906. See in: Erskine-Murray, James. *A Handbook of Wireless Telegraphy: Its Theory and Practice*, 2nd. New York: D. Van Nostrand Company; London: Crosby Lockwood and Son, 1909, 277–290.

134 Tesla, Nikola. „Moji izumi". In Marinčić, Aleksandar, ed. *Nikola Tesla – Članci.* Belgrade: Zavod za udžbenike i nastvana sredstva, 1995, 60.

135 "U. S. Blows Radio Tower". *Electrical Experimenter* (September 1, 1917): 125.

136 Tesla, Nikola. „Moji izumi". In Marinčić, Aleksandar, ed. *Nikola Tesla – Članci.* Belgrade: Zavod za udžbenike i nastavna sredstva, 1995, 62.

> *"To stop war by the perfection of engines of destruction alone, might con-sume centuries and centuries. Other means must be employed to hasten the end. What are these to be? Let us consider. Fights between individuals, as well as governments and nations, invariably result from misunderstand-ings in the broadest interpretation of this term. Misunderstandings are al-ways caused by the inability of appreciating one another's point of view. This again is due to the ignorance of those concerned, not so much in their own, as in their mutual fields. The peril of a clash is aggravated by a more or less predominant sense of combativeness, possessed by every human being. To resist this inherent fighting tendency the best way is to dispel ignorance of the doings of others by a systematic spread of general knowledge. […]*
>
> *To know each other we must reach beyond the sphere of our sense perceptions. We must transmit our intelligence, travel, transport the materials and trans-fer the energies necessary for our existence. Following this thought we now realize, forcibly enough to dispense with argument, that of all other conquests of man, without exception, that which is most desirable, which would be most helpful in the establishment of universal peaceful relations is – the complete Annihilation of Distance. To achieve this wonder, electricity is the one and only means. Inestimable good has already been done by the use of this all powerful agent, the nature of which is still a mystery."*
>
> Nikola Tesla, "The Transmission of Electrical Energy without Wires as a Means for Furthering Peace". *Electrical World and Engineer*, New York, January 7, 1905

At the start of the 20th century the possibilities of the *World System* were accepted only as a scientific vision for the rapidly developing world. Until the end of the 20th century with the development of science, technology and means of communication, this vision became a reality. Tesla's vision of the world communication did come to life, although the method of wireless transmission of energy is different from the one that Tesla discovered. Tesla's system of wireless transmission of energy is based on the use of surface waves of the Earth, while the modern system is based on the transmission of energy through conductive atmosphere.

However, the image of the world and the relationships between people and nations didn't improve in a way that is proportionate to the development of science.

LITERATURE

Aitken, Hugh G. J. *Syntonic and Spark: The Origins of Radio*. Princeton University Press, 1985.

Anderson, Leland. *Priority in the Invention of radio – Tesla vs. Marconi*. Bloomfield, NY: Antique Wireless Association Monograph, 1980.

Anderson, Leland, ed. *Nikola Tesla on His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power.* Denver: Sun Publishing, 1992.

Bokšan, Slavko. *Nikola Tesla i njegovo delo.* Belgrade: Klub NT, 2006.

Dnevnik istraživanja iz Kolorado Springsa 1899–1900. Belgrade: Nolit, 1976.

Erskine-Murray, James. *A Handbook of Wireless Telegraphy: Its Theory and Practice*, 2nd. New York: D. Van Nostrand Company; London: Crosby Lockwood and Son, 1907.

Erskine-Murray, James. *A Handbook of Wireless Telegraphy: Its Theory and Practice*, 2nd. New York: D. Van Nostrand Company; London: Crosby Lockwood and Son, 1909.

Fahie, John J. *A History of Wireless Telegraphy 1838-1899*, Edinburgh and London: William Blackwood and Sons, 1899.

Fahie, John J. *A History of Wireless Telegraphy*, 2nd. Edinburgh and London: William Blackwood and Sons, 1901.

Fleming, John A. *The Principles of Electric Wave Telegraphy and Telephony*. New York: Longmans, Green and Co., 1916.

Heaviside, Oliver. *Electrical Papers Vol. 1*. London and New York: Macmillan and Co., 1892.

Justia U. S. Supreme Court. *Marconi Wireless Tel. Co. v. United States*, 320 U. S. 1 (1943). Preuzeto 14. 05. 2016. https://supreme.justia.com/cases/federal/us/320/1/case.html

Kapp, Reginald O. "Tesla's Lecture at the Royal Institution of Great Britain in 1892". In *Centenary of the Birth of Nikola Tesla: 1856–1956*. Belgrade: Nikola Tesla Museum,1959.

Lee, Thomas H. *Planar Microwave Engineering: A Practical Guide to Theory, Measurement, and Circuits, Volume 1*. Cambridge: Cambridge University Press, 2004.

Lodge, Oliver J. "On the Measurement of the Length of Electro-magnetic Waves", „On the Impedance of Conductors to Leyden-jar Discharges". In *Report of the Fifty-Eighth Meeting of the British Association for the Advancement of Science held at Bath in September 1888*, 567. London: John Murray, 1889.

Lodge, Oliver J. *The Work of Hertz and Some of His Successors*. New York: D. Van Nostrand Company; London: *The Electrician* Printing and Publishing Company, Ltd., 1894.

Marconi, Guglielmo. "Wireless telegraphic communication". *Nobel Lecture*. Nobelprize. org. Preuzeto 20. 12. 2015.

http://www.nobelprize.org/nobel_prizes/physics/laureates/1909/marconi-lecture.pdf

Marinčić, Aleksandar. „Komentari i objašnjenja". In: *Dnevnik istraživanja iz Kolorado Springsa 1899–1900*. Belgrade: Zavod za udžbenike i nastavna sredstva, 1996, 460–554.

Marinčić, Aleksandar. *Nikola Tesla – Stvaralaštvo genija.* Belgrade: Srpska akademija nauka i umetnosti, 2006.

Marinčić, Aleksandar. "Nikola Tesla Contributions to the Development of Radio". *YUMTT Chapter Informer* (1994): 10–12.

Marinčić, Aleksandar, Civrić, Zorica and Milovanović, Bratislav. "Nikola Tesla's Contributions to Radio Developments". *Serbian Journal of Electrical Engineering,* 2/3 (2006): 131–148.

Marinčić, Aleksandar, red. *Nikola Tesla - Članci*. Belgrade: Zavod za udžbenike i nastavna sredstva, 1995.

Popović, Vojin, red. *Nikola Tesla - Članci*. Belgrade: Zavod za udžbenike i nastavna sredstva, 1995.

Попо́в, Алекса́ндр Степа́нович. „Об отношении металлических порошков к электрическим колебаниям". In *Журнал Русского физико-химического общества. Часть физическая*, 259–260. Санкт-Петербу́рг: Русское физико-химическое общество,1895.

Popović, Vojin, Serbian translation. *Nikola Tesla – From Colorado Springs to Long Island.* Belgrade: Nikola Tesla Museum, 2008.

Schneider, Norrie (Norman) H. *Induction Coils, How to Make, Use, and Repair Them*. New York: Spon & Chamberlain; London: E. & F. N. Spon, Ltd., 1901.

Sarkar, Tapan K., Mailloux, Robert J., Oliner, Arthur A., Salazar-Palma, Magdalena and Sengupta, Dipak L. *History of Wireless*. Hoboken: Wiley-IEEE Press, 2006.

Sewall, Charles Henry. *Wireless telegraphy: its origins, development, inventions, and apparatus*, 2nd. New York: D. Van Nostrand Company, 1904.

Stone Stone, John. "Signals through Space – From the Beginning". In *John Stone Stone on Nikola Tesla's Priority in Radio and Continuous Wave Radiofrequency Apparatus*, edited by Leland Anderson, 27–43. New York: Antique Wireless Association, Inc., Holcomb, 1986.

Tesla, Nikola. *Moji izumi*. Belgrade: Klub NT: Nikola Tesla Museum, 2003.

Tesla, Nikola. “Experiments with Alternating Currents of High Frequency and Their Application to Methods of Artificial Illumination”. *Electrical Engineer* (London: 1891): I June 17: 63–64; II July 24: 110–113; III July 31: 110 –113; IV August 7: 128–131; V August 21: 159–161, 177 – 179; Tesla, Nikola. “Experiments with Alternating Currents of High Frequency and Their Application to Methods of Artificial Illumination”. *Electrical Review* (London: 1891): I July 24: 103–108; II July 31: 147–151; III August 7: 176–179.

Tesla, Nikola. “On Light and Other High Frequency Phenomena”. *Journal of the Franklin Institute* (1893): July: 1–19; August: 81–98; September: 161–177; October: 259–279; November: 351–360; December: 401–412;

Tesla, Nikola. “On Light and Other High Frequency Phenomena”. In *Proceedings of the National Electric Light Association*. St. Louis: National Electric Light Association, 1893,191–302.

Thompson, Joseph J. *Notes on Recent Researches in Electricity and Magnetism Intended as a Sequel to Professor Clerk-Maxwell’s Treatise on Electricity and Magnetism*. Oxford: The Clarendon Press, 1893.

Articles by Nikola Tesla

Translated articles by Nikola Tesla are published in: Marinčić, Aleksandar, red. *Nikola Tesla - Članci*. Belgrade: Zavod za udžbenike i nastavna sredstva, 1995.

Articles that are not translated to Serbian:

“Earth Electricity to Kill Monopoly”. *New York World* (New York: March 8, 1896): 147.

“Electrical Oscillators”. *Electrical Experimenter* (July,1919): 228–229, 259–260, 276.

“Letter: Electricity without Wires”, *New York Herald* (New York: January 1, 1896): 133.

“The Transmission of Electrical Energy without Wires as a Means for Furthering Peace”. *Electrical World and Engineer* (New York: January 7, 1905): 21–24.

“The True Wireless”. *Electrical Experimenter* (New York: May 1, 1919): 28–30.

Articles about Nikola Tesla

A. W. R. & G. „Mr. Tesla’s Lectures on Alternate Currents of High Potential and Frequency”. *Nature* (London: February 11, 1892): 346–347.

Bottone, S. “Tesla Has Narrow Escape”. *New York Herald* (March 9, 1900): 8.

Brisbane, Arthur. “Our Foremost Electrician”. *New York World* (July 22, 1894): 43.

Guarini, E. “Tesla’s Flashes Startling”. *New York Sun* (July 17, 1903): 140. J.

N. P. “Telegraphy without Wires”. *Public Opinion* (June 17, 1897): 85.

J. N. P. “Tesla Grips the World”. *New York Sun* (New York: June 6, 1897): 75.

J. N. P. “Tesla’s Latest Invention”. *New York Herald* (June 7, 1897): 76.

J. N. P. “Tesla Triumph”. *The New York World* (June 7, 1897): 78.

J. N. P. “Tesla’s Transmission without Wires”. *Electrical Review* (London: June 25, 1897): 88.

Martin, Thomas C. “Tesla’s Oscillator and Other Inventions”. *Century Magazine* (April 1, 1895): 143–160.

McGovern, Chauncy M. “Nikola Tesla Will ’Wire’ to France”. *Colorado Springs Evening Telegraph* (May 17, 1899): 121.

McGovern, Chauncy M. “Nikola Tesla on Top of Pike’s Peak”. *Denver Rocky Mountain News* (May 17, 1899): 122.

Serviss, Garrett P. “Tesla’s Wireless Telegrams”. *Electrical Review* (New York: 1897): 83.

Serviss, Garrett P. “Tesla’s Colorado Experiments”. *New York Tribune* (May 19, 1899): 130.

Serviss, Garrett P. “Town Topics”. *Facts* (May 20, 1899).

Solly, S. E., M. D. “Tesla Hopes to Telegraph From New York to Paris without Wires”. *New York Herald* (November 12, 1899): 168.

Stanley, William. “Notes: News of Tesla”. *Electrical Review* (London: May 26, 1905): 110.

Stephenson, Walter T. “The Destruction of Mr. Tesla’s Laboratory”. *Electrical Engineer* (New York: March 20, 1895).

Taylor, Frank H. “A Striking Tesla Manifesto”. *Electrical World & Engineer* (New York: February 6, 1904): 159.

“Are They Tesla’s Agents”. *New York Sun* (February 17, 1901): 170.

“Editorial: Destruction of Tesla’s Workshop”. *New York Sun* (March 14, 1895).

“Mr. Tesla’s Great Loss”. *New York Times* (March 14, 1895).

“Nikola Tesla’s Lost Apparatus”. *Electrical Review* (New York: April 3, 1895): 172–173.

“Stages and Types of the Tesla Oscillator”. *Electrical Engineer* (New York: April 3, 1895): 301–304.

“Tesla Ready to Try Transatlantic Talk”. *New York Journal & Advertiser* (February 22, 1901): 171.

"Tesla Triumph". *The New York World* (June 7, 1897): 78.

"Tesla's Laboratory Removed To Wardenclyffe". *Electricity* (June 4, 1902): 93. "Tesla's Oscillator and Other Inventions". *Century Magazine* (April 1, 1895): 143–160. "The Practical Tesla Oscillator". *Electrical Engineer* (April 3, 1895): 311.

"The Tesla High Potential Conductor". *Electrical Engineer* (New York: February 14, 1894): 133.

"U. S. Blows Radio Tower". *Electrical Experimenter* (September 1, 1917): 125. "Who Invented Wireless Telegraphy". *The Literary Digest* (November 4, 1899): 556.

"Wireless Telegraphy!". *Washington Globe* (November 10, 1901): 5, 8. Dowloaded on February 14, 2016. http://earlyradiohistory.us/1901awtt.htm

Nikola Tesla's patents

US patents:

US patents by Nikola Tesla are published in: *Nikola Tesla – Patenti I-IV* Belgrade: Zavod za udžbenike i nastavna sredstva, 1996.

Other patents:

British patent no. 8.200, *Improvements relating to the Transmission of Electrical Energy*, for which the application was filed on April 17, 1905, was approved on April 17, 1906.

British patent no. 24.421, *Improvements in Systems for the Transmission of Electrical Energy and Apparatus for use therein,* for which the application was filed on October 21, 1897, was approved on March 26, 1898.

Amos Dolbear's patents

US patent no. 350.299, *Mode of Electric Communication*, for which the application was filed on March 24, 1882, was approved on October 5, 1886.

Reginald Fessenden's patents

US patent no. 727.325, *Improvement in the Transmission and Receipt of Signals*, for which the application was filed on June 2, 1900, was approved on May 5, 1903.

John Fleming's patents

US patent no. 803.684, *Instrument for Converting Alternating Electric Currents Into Continuous Currents*, for which the application was filed on April 19, 1900, was approved on November 7, 1905.

Oliver Lodge's patents

British patent no. 11.575, *Improvements in Syntonized Telegraphy without Line Wires*, for which the application was filed on May 10, 1897, was approved on August 10, 1898.

US Patent no. 609.154, *Electric Telegraphy*, for which the application was filed on February 1898, was approved on August 16, 1898.

Guglielmo Marconi's patents

British patent no. 12.039, *Improvements in Transmitting Electrical impulses and Signals, and in Apparatus therefor,* for which the application was filed on June 2, 1896, was approved on March 2, 1897.

British patent no. 7777, *Improvements in Apparatus for Wireless Telegraphy*, for which the application was filed on April 26, 1900, was approved on April 13, 1901.

US patent no. 586.193, *Transmitting Electrical Sugnals*, for which the application was filed on December 7, 1896, was approved on July 13, 1897.

US patent no. 11.913, *Transmitting Electrical Impuls,* for which the application was filed on April 1, 1901, was approved on June 4, 1901.

US patent no. 763.772, *Apparatus for Wireless Telegraphy,* for which the application was filed on November 10, 1900, was approved on June 28, 1904.

John Stone's patents

US patent no. 714.756, *Method of Selective Electric Signaling*, for which the application was filed on February 8, 1900, was approved on December 2, 1902.


(No Model.)
No. 447,
(No Model.)
1891.
No. 447,920.
No. 447,920
No Model.)
447,920.
447,920
Model.)
TESLA.
ARC LAMPS.
ited Mar. 10,
447,920
(No Model.)
1891.
No.
N. TESLA
OF