Celebration of the 150th anniversary of the birth of Nikola Tesla

Symposium "Tesla in Croatia"

PROCEEDINGS

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Welcome remarks

The Message about Nikola Tesla

Stjepan Mesić
President of the Republic of Croatia

The life and work of Nikola Tesla is in the focus of interest above all for his ingenuity and contribution to world science and engineering. Had the alternating electric current system been the only thing he ever invented, the name of Nikola Tesla will nevertheless remain permanently inscribed on the list of the most renowned people whose work has been of pivotal importance for the development of civilization. Moreover, knowing that Tesla invented or theoretically anticipated almost all technical devices people are using today, with which he helped usher in the Second Industrial Revolution, his role becomes immeasurable.

Tesla was not only a genius; he was a person of many virtues, which make him a great man. Above all, he was hard working, diligent, devoted, thorough, patient and determined to make his vision come true. Although he led a single life, quite lonesome, he nevertheless strongly believed that his work was for the sake and benefit of man and humankind.

More than that, Tesla was a highly moral person. Always willing to help others, but humble in character and far from trying to benefit from his position of a world-renowned scientist. Although he became famous and honored in his lifetime, he never boasted about his merits, nor did he show off, but he saved his pride not letting others to mock or criticize his ideas or even plagiarize them. "The present is theirs; the future, for which I really work, is mine", Tesla replied.

Nikola Tesla was a pacifist believing his inventions are his contribution to progress, peace and trans-national cooperation. In spite of his cosmopolitan broadness of spirit, he was proud of his Serbian descent and Croatian motherland, as is said in his letter to Vlatko Maček. His country, Zagreb and native Lika were always in his mind. Slowly but surely Croatia realized what a

precious son it has in the far away America insisting to give him finally the credit he deserves.

Tesla never showed any interest in politics. However, his humanism, positive patriotism and nationalism inspired people in Croatia and abroad who are still searching for patterns of coexistence, humanity and honesty – a model of serving a mother country even when living far away. The life and work of Nikola Tesla should be neither usurped nor divided. His name and work is the heritage of the world superseding its boundaries and differences. Croatia is more than happy to be the birth country of Nikola Tesla, a man born in Smiljan, a small village in the heart of Lika – a man whose whole work is entrusted to humanity and humankind.

Tesla Yesterday, Today, Tomorrow

Goran Granić, Ph.D.
Secretary General Croatian Academy of Engineering
Director of Energy Institute Hrvoje Pozar

To valorise the work in energy technology development is not an easy task nor can it be done to full extent, because Tesla's visions are not closed stories and they become more and more actual over time. It is not only about his technical inventions which enable execution of some functions in a better and more efficient way, but the whole dimension of his contribution to the technological progress and possible positive impetus to economic development, fairness in development opportunities for rich and for poor and social acceptability of costs of energy.

The crucial question about energy: *How to transform potential energy on earth or in atmosphere (space) in to a form needed for work and life and transport it to the place of consumption?* – does not change over time. These challenges were there at the time Tesla patented his inventions and they are present now, in our century. Only today needs for energy are even bigger, and the problems loom larger. Transport of energy has always represented a restrain, and so it is today. Additional limitations to the energy production which derive from environmental impact of energy installations are given more consideration than before.

Together with water, food and clean air, energy is a basic human need, and it is a measure of the quality of life. These needs are all interrelated, so the poor lack all of them, water and food and energy, while the rich enjoy high consumption of each one of them. The today's reality is that about two billion people do not have any facility to use modern forms of energy, and they make the most indigent population in the world.

Tesla was aware of the importance of energy and in his invention he gave the vision for solutions of how the needs for electric energy can be satisfied. He primarily saw electricity generation in the use of water power potential, as a renewable energy source. Although the technology of using renewable energy sources passed a long way from the times of Tesla, electricity generation from renewable energy sources, apart from hydropower plants and wind plants lately, has not seen much progress.

Tesla's inventions related to alternating current enabled generation and transmission of electric energy and development of devices that used motor as a key component in executing designed functions. Motors opened the way to the use of electric energy in all aspects of human needs, and as such they became the fundament of industrial strength of developed society.

Although Tesla's inventions enabled the transmission of electricity from a place of generation to a place of consumption, which presumes construction of transmission and distribution networks and related facilities, Tesla did not stop there because it represented a limitation in any aspect. His vision of wireless transport of electric energy is an unfulfilled dream of the today's generations as well and the challenge for the future.

In time when we expect energy crisis because of the growing needs for energy and limited quantities of fossil fuels and water power potential, some visions of energy future which result from Tesla's inventions seems to be in variance with the present, and in this moment out of reach. The present concept of energy development and energy technology development is based on the idea of open market, real economic prices and controlled technological development which does not undermine the established energy industry.

The actual question is whether it is in the interest of the energy industry to develop Tesla's wireless transmission of electric energy which would enable wireless transmission of energy to any place in the world and to any household. Equally, the question is whether the opportunity has been used to take from the atmosphere (space) as much energy as we need for life. Of course, these questions are a provocation to the dominant theories and opinions on energy development. If Tesla, in his time, had conformed to what his contemporaries thought about his visions and patents, he would have probably relinquished at the first step. But fortunately, Tesla believed that future belonged to him, as future belongs to all those who will developed Tesla's vision of wireless transmission of energy and use of renewable energy sources.

Why Tesla's vision of generation and transmission of energy is more important today than in his own time. Differences in economic and industrial strength and social status between developed (rich) and underdeveloped (poor) are greater than ever. Technological development and use of modern form of energy made developed countries increasingly rich and strong, thus widening the gap to the poor countries. The realisation of Tesla's visions of energy development may contribute to reducing poverty, increase opportunities for economic development and growth.

Do we need "new Tesla" today, who would bring a breakthrough in realising the visions of Nikola Tesla, or narrow interests of energy companies and developed countries shall prevail over a civilisation need to give equal chance to everybody through technological development. This question is crucial question of the today's civilisation, which by its concept of commercial globalisation reduces the universal responsible globalisation and does not assume co-responsibility for development of underdeveloped or less developed nations. This is maybe a basic obstacle to further work on application of Tesla's vision because in them there is much more than just commercial and profit-oriented view of energy development.

Croatia, as a small country and a developing country in transition, is equally interested to see Tesla's work evaluated in a proper way, and to see its full application, changing the world and development opportunities for all countries. If modern form of energy remain unavailable it would not be possible to fight famine and poverty and improve quality of life.

Even today, after 150 years Tesla was born, the paradigm of Tesla's life and research can be reiterated – ***Future belongs to Tesla.***

Zagreb, August 2006

Implications of Tesla's Inventions and His Moral Character on the Development of Contemporary Science and Technology

In Commemoration of the 150th Anniversary of the Birth of Nikola Tesla
(July 10, 1856, Smiljan, Croatia – January 7, 1943, New York City, USA)

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Abstract: Nikola Tesla's inventions, experiments, and intuition in the fields of electrical engineering and physics, together with his *ēthos*, are discussed in light of the philosophy of science. Several discoveries and basic experiments in the American phase of Tesla's life, after 1884, were decisive in the development of modern technologies. Tesla's famous lecture in 1891 at Columbia University, at which he demonstrated his transformer with revolutionary applications, is recalled. The technological progress resulting from Tesla's inventions is considered in light of the history of science, with reference to H. Hertz's discovery of electromagnetic waves, four years prior to Tesla's Columbia lecture, and O. J. Lodge's famous experiments on resonant electromagnetic oscillations. Another famous European who received a glorious welcome at Columbia University in early 1939 was Enrico Fermi. His arrival in America and subsequent scientific accomplishments in both theoretical and experimental physics are somewhat reminiscent of Tesla's case. However, unlike Fermi or Heisenberg, Tesla in no way violated the integrity of his moral character through his work in electrical engineering and physics, despite extensive coercion by scientists, industrialists and politicians to change his ethical orientation. There is also a discussion of superconducting radiofrequency science and technology (SRFS&T), where the main goal today is to achieve the highest possible cavity accelerating gradient for particles in linear superconducting colliders. The origins of this technology undoubtedly involve the use of Tesla's transformer as the source of the very high potential RF–field. Tesla's brilliant project involving a monopole antenna as the high power emitter, based on the principle of his transformer, is also discussed. Modern analysis and extensive analytical calculations within the framework of classical electromagnetic theory have been performed in order to justify the scientific foundations of Tesla's ideas on the long-distance wireless transmission of energy, information and electrical illumination. Tesla, owing to his fruitful and moral passion to help mankind through science and technology, remains an outstanding figure in the history of world science and culture.

Keywords: Tesla's inventions, Tesla's transformer, Tesla's monopole antenna, accelerator technology, Tesla's intuition, Tesla's *ēthos*, Tesla's ethical and bioethical model for the modern sciences

1. Tesla's Legacy in Modern Science and Unique Moral Character

Nikola Tesla Year 2006 has been proclaimed by the Republic of Croatia and also by UNESCO in commemoration of the 150th anniversary of the birth of this scientific genius in Smiljan, Croatia, on July 10, 1856, owing to his scientific contributions to mankind and outstanding moral character. Croatian science, art and culture, supported by Croatian state policy at the highest level, are intent upon correlating the facts and credible sources concerning the Croatian roots of Tesla's scientific work and complex personality. Moral support for the cultural and scientific orientation of the commemoration of Nikola Tesla Year in Croatia is provided by the small fact that although the first sentence of the entry **Tesla, Nikola** in the 2004 edition of the *Encylopaedia Britannica* states that Tesla is a "Serbian-American inventor and researcher," his place of birth is given as Smiljan, Croatia. Furthermore, in a table of the parameters of lunar craters on the NASA website, next to Tesla's Crater it is stated that Tesla was a "Croatian-American inventor."

In Croatia, scientific and cultural research on Tesla's life, work and the impact of his inventions has yielded some interesting symposia, books and articles, among a sea of commemorative and historical texts in the media and *ad hoc* symposia during Nikola Tesla Year 2006. We shall mention the most important. At the state level, there was an outstanding international scientific meeting held in Zagreb, The Life and Work of Nikola Tesla, June 28–29, 2006, under the patronage of the Croatian Parliament and co-organized by the Croatian Academy of Engineering and the Ministry of Science, Education and Sports of the Republic of Croatia. The proceedings of this meeting testify to the numerous valuable contributions penned by engineers, physicists, historians, lexicographers and economists [1], including an article I contributed. On the Croatian bestseller list during the late summer was an expertly edited and attractive monograph entitled *Nikola Tesla: istraživač, izumitelj, genij* [Nikola Tesla: Researcher, Inventor and Genius] (edited by J. Lončarić, Školska knjiga, d.d., Zagreb), the work of five authors: Tanja Rudež, Vladimir Muljević, Tomislav Petković, Vladimir Paar and Darko Androić. In this volume, scientists from the University of Zagreb describe the childhood, education, patents, inventions and highlights of Tesla's activities in the United States, his inventions in physics and his engineering intuition, vision, life, achievements and overall contribution to physics. One of the authors, Tanja Rudež, provided an interesting description of Tesla's life as a visionary, incorporating heretofore unknown photographs and objects from Tesla's extended family. The cover is adorned with an original pen and ink portrait of Nikola Tesla by the great Croatian artist Miljenko Stančić. As the middle section of my scientific trilogy on Tesla, I mention my contribution to this monograph, the chapter on Tesla's inventions in physics and his engineering intuition [2]. The interesting events in Croatia during Nikola Tesla Year 2006 also include the first original

Croatian scientific article, published in both Croatian and English, that deals with Tesla's long-distance electromagnetic transmission of energy and messages, published in the journal *Energija* (Hrvatska elektroprivreda, d.d., Zagreb), which by virtue of its interesting design and the quality of its articles, is the leading Croatian journal in the fields of the natural, social or related technical sciences. My article on Tesla's inventions in physics and his engineering spirit in the journal *Energija,* vol. **55** (2006), No. 3, provides a clear approach to Tesla's significant inventions, pioneering work in electromagnetic theory and their applications in modern accelerator technology [3]. In the section comparing Tesla with other great scientists who employed scientific methodology, the article, as the third part of my trilogy on Nikola Tesla, presents the "unknown" Tesla as a model for future scientists.

While working at world accelerator centers, the author of this article has had the occasion to witness the high esteem that contemporary physicists and engineers have for Tesla's research in the development of modern accelerator technology. This is one of the motives for the previously mentioned trilogy on Tesla's inventions and his engineering intuition. A second but no less important motive stems from my desire to continue a series I have written during the past decade on domestic and world scientists, philosophers and artists from the historical, scientific and philosophical points of view, including Albert Einstein, Enrico Fermi, Werner Heisenberg, Frane Petrić, Nikola Šop, Mirko Dražen Grmek and Hrvoje Požar [4] – [10], to which Nikola Tesla is a natural addition.

Nikola Tesla, owing to his inventions, broad spectrum of investigative interests and specific lifestyle, received many epithets during his lifetime, including dreamer, crazy scientist, scientific visionary, the initiator of the world wireless system and world communication, the researcher who received signals from extraterrestrial civilizations, a man who could split the earth in two like an apple, the creator of deadly penetrating long-distance rays etc. The author of this article recalls that during the 1980s, while he was performing experiments at the *SIN* Institute (later *PSI*) in Switzerland, he noticed an advertisement in the distinguished journal *Nature,* for a gathering of an international European association whose interests were exclusively oriented toward occult and parapsychological research. The association had named itself after Nikola Tesla, because that "solitary genius" best represented their aspirations and program. Although in this case Tesla's name was misappropriated, regarding the character and goals of this association, today the syntagma of Tesla as a "solitary genius" seems meaningful, not at all pejorative, as someone might think. Tesla was a loner, a brilliant inventor and a person of the highest ethical principles. Tesla was a loner, a brilliant inventor and a man of the highest ethical principles. He had the greatest respect and admiration for his parents. His father, Milutin, was the rector of a Serbian Orthodox parish. It was from his intelligent and unpretentious mother, Đuka née

Mandić, that he attributed his gift for invention. Tesla had a few close friends who were writers, including Mark Twain. However, it should be emphasized that Tesla, besides his brilliant inventive abilities, intuition and photographic memory, was a perfectionist in his work (preparing and conducting experiments) and highly disciplined in his daily life (physical activities and healthful diet).

In 1917, Tesla received the Edison Medal, the highest honor awarded by the American Institute of Electrical Engineers (AIEE). On the hundredth anniversary of Tesla's birth, the unit of magnetic flux density or magnetic induction, $\vec{B}$, was named **tesla** (abbreviated as "T") in his honor. In October 1960 in Paris, at the eleventh session of the General Conference on Weights and Measures (CGPM – *Conférence Générale des Poids et Mésures*), the unit *tesla* was officially accepted and included within the International System of Units (*SI – Sistème International D'Unités*) as the SI derived unit of magnetic flux density (or magnetic induction). Its definition is as follows: 1 T = Vs/m^2 = Wb/m^2 (one tesla equals the value of the magnetic flux of one volt-second per square meter; one tesla equals the value of the magnetic flux of one weber per square meter. One tesla also corresponds to 10^4 gauss (gauss is the old unit for magnetic induction).

One of the craters on the far side of the moon (latitude 38.5N, longitude 124.7E and 43 km in diameter) was named after Tesla, which is considered to be a high scientific and cultural honor.

Tesla's most important inventions in electrical engineering are polyphase alternating currents, especially three-phase. The three-phase system is the most common and most widespread manner of producing electrical energy. In May 1885, George Westinghouse, head of the company of the same name in Pittsburgh, purchased the patent rights to Tesla's polyphase system of alternating currents, including a polyphase voltage generator, transformer and Tesla's asynchronous electrical motor on the principle of the rotating magnetic field. That year, a tremendous battle was waged between Edison's system based on direct current and the Tesla-Westinghouse alternating system. Tesla's system won, bringing humankind into the modern era of electrical energy and industry. Tesla's discovery of polyphase alternating currents remains his lasting monument and contribution to the civilization of humankind. Using three-phase currents that are sent through coils appropriately positioned in space, it is possible to obtain a magnetic field in which the magnetic field strength $\vec{H}$ always has a constant value but is rotating in space. If the coils are spaced at 120° from one another, and three-phase AC voltage (*R*, *S*, *T*) is applied to the coils, the resulting magnetic field strength $\vec{H}$ at the intersection point of the coil axes does not change strength but rotates following the phase sequence at an angular velocity of w. However, the metal conductor at that position starts to follow the rotating mag-

netic field because of the currents induced in it that are affected by the forces of the coils' magnetic field. This corresponds to the phenomenon of so-called rotating magnetism in an experiment performed in 1825 by Dominique F. Arago (October 2, 1786 – February 26, 1853), only here it is the field that turns and there the conductor turned. A rotating magnetic field is the basis of the operation of Tesla's asynchronous electric motor. Tesla received American citizenship in 1891, a year that was otherwise particularly fruitful regarding his fundamental discoveries in the field of high frequency Tesla currents (the Tesla coil, and a lecture with a demonstration of a high frequency transformer at Columbia University, New York), which will be separately discussed in this article.

Following Nikola Tesla's death on January 7, 1943, a memorial service was held in his honor on January 10, 1943, during which the mayor of New York City, Fiorello Laguardia, delivered a eulogy, which was broadcast over New York Radio. The participants included the famous Croatian violinist Zlatko Baloković and the Slovenian choir Slovan. On January 12, approximately 2,000 persons, including Nobel prizes winners, high government officials and many other distinguished persons, paid tribute to Nikola Tesla at an impressive funeral service held the Cathedral of St. John the Divine, New York City. Among the numerous telegrams, we single out those from Mrs. Eleanor Roosevelt, on behalf of herself and President Franklin Delano Roosevelt, and three Nobel Prize winners: Robert A. Millikan, Arthur H. Compton and James Franck.[1] All three, as celebrated experimental physicists, described Tesla as one of the most distinguished minds of the world, who had outlined the paths for numerous technological developments of the modern age. Tesla's letters, articles, laboratory notes, diplomas and other honors were collected by his nephew, Sava Kosanović, and later turned over to the Nikola Tesla Museum in Belgrade, where they are still preserved. Tesla maintained ties with his ethnic roots and birthplace, saying: "*I am proud of my Serbian lineage and Croatian homeland.*"

On the occasion of the 150th anniversary of Tesla's birth, in addition to his contributions to the development of science and technology, we call attention to Tesla's ethical orientation as the foundation of his life and work. It seems to us that Tesla's ethics in modern science, technology and philosophy have not been sufficiently emphasized or considered within the philosophy of science, particularly modern bioethical currents. In this article, for the first time, we shall at-

[1] R.A. Millikan received the Nobel Prize in 1923 for the discovery of elementary charge of the electron and the photoelectric effect; J. Franck in 1925, together with Gustav Hertz, for research on the excitation and ionization of atoms by electron bombardment that verified the quantized nature of energy transfer; and A.H. Compton in 1927 for his explanation of the change in the wavelength of X–rays when they collide with electrons in metals, the so-called Compton effect caused by the transfer of energy from a photon to an electron.

tempt to consider Tesla's *ēthos* from a scientific and philosophical point of view in order to illuminate this dimension of his complex personality, which until now has only been mentioned incidentally. Unlike the great physicists Fermi and Heisenberg, the former involved in the Manhattan Project in the United States and the latter in the Uranium Project in Germany, it cannot be said of Tesla that his acts or insights in physics and electrical engineering violated his moral integrity, despite countless of attempts to sway his ethical orientation. In this article, it is demonstrated that Tesla's moral orientation in modern science and technology can serve as an ethical and bioethical model for the science of our time.

2. Tesla's Engineering Spirit and Intuition in Electrical Engineering and Physics

Nikola Tesla's engineering spirit, like that of Michael Faraday, manifested itself throughout his life as a passion for experimentation, predominantly oriented toward innovations in physics and electrical engineering that required theoretical analysis following their discovery. Faraday and Tesla had nearly identical philosophical attitudes regarding the role of experiments in science, i.e. experiments are crucial for the development of scientific theories and important sources of new knowledge, not merely tools for the confirmation or refutation of theoretical formulations.

Among the scientific community, particularly in the fields of experimental particle physics and accelerator technology, the two hundredth anniversary of the birth of Michael Faraday (September 22, 1791 – August 25, 1867) was celebrated magnificently during the year 1991. Scientific historians took the occasion to examine his scholarly, meticulous and systematic approach to research, the like of which has rarely been encountered throughout the entire history of the natural and technical sciences. During the period between 1831 and 1862, Faraday catalogued 16,041 scientific entries on his experiments in his laboratory log. The result of all these entries can be summarized in the fundamental discovery of electromagnetism, i.e. physics as a whole, that magnetic fields are characterized by lines of force. Through original engineering experiments, although lacking extensive knowledge of the mathematics and physics of his day, M. Faraday made the development of the physics of the electromagnetic field possible, this was brilliantly formulated by James Clark Maxwell in the year 1864. We speak of Faraday-Maxwell's laying the foundations of electromagnetic theory and classical electrodynamics that served as the model for Einstein's theory of relativity and modern field theories in particle physics. Faraday's celebrated diary, consisting of seven volumes, covers the period from 1820 to 1862. His correspondence, consisting of over 4,000 letters he either wrote or received, testifies not only to the

experimental style of research in the mid 19th century but also provides orientation for creative thinking in modern technologies. Tesla's notes in Colorado Springs (*Colorado Springs – Notes*) [11] and his description of his inventions (*My Inventions*) [12] are valuable sources and examples of creative thinking in modern technologies, particularly information and communication technology. Tesla's and Faraday's diaries are equally interesting from the viewpoint of the contemporary cognitive sciences.

Faraday believed that natural phenomena are linked and this was the main thread of his investigations. His work and contributions cover various areas, including chemistry and electrochemistry, electrostatics and electromagnetism (induced voltage, 1831), the experimental basis for the electromagnetic field theory and optics (the rotation of the plane of polarization of a polarized light beam by a strong magnetic field, 1845). The picture of Faraday as a scientist who worked with dedication in the basement laboratory of the Royal Institute is not a complete and accurate portrait. The experimenter Faraday was also Faraday the philosopher, an aspect of his personality that is unjustly neglected in the explanation of his life and work. In light of Faraday's original concept of the electromagnetic field, with closed lines of force in the electric and magnetic fields, he should also be remembered as the first physicist to begin the scientific dematerialization of matter. Similarly, many scholars of Faraday's life and work maintain that Faraday's Christian faith was important in his scientific endeavors. Faraday was a member of the Sandemanian sect,[2] whose beliefs are characterized by a literal understanding and interpretation of the Bible as the basis for moral values and behavior. Faraday's travels with Sir Humphrey Davy through European countries from November 1813 to April 1815 are considered to be an important element in the formation of his philosophy of research. Everything that we have said about Faraday and his philosophy of research is also more or less applicable to Nikola Tesla.

We can also justifiably compare Tesla to the German-born American physicist A. A. Michelson (Strelno, Prussia [now Strzelno, Poland], December 19, 1852 – Pasadena, California, USA, May 9, 1931), for whom the precise measurement of the speed of light through interferometric experiments were his scientific preoccupation, as the wireless transmission of energy and information (the Tesla World System) was for Nikola Tesla. In the year 1878, Michelson began work on the problem of the precise measurement of the speed of light, which was to be his scientific passion until the end of his life. In order to pursue advanced studies in optical methods, in 1880 Michelson traveled to Europe and spent two years at laboratories in Berlin, Heidelberg and Paris. In the year 1884, Tesla traveled in

[2] The sect was named after one of the founders: Robert Sandeman (1717–1773).

the opposite direction, i.e. from Europe to the United States, where he remained until the end of his life. In the year 1883, Michelson became a professor of physics at the Case Institute of Technology in Cleveland, Ohio, and completely devoted himself to the development of interferometry for the measurement of aether drift. Michelson's most significant scientific contributions were the measurement of aether drift with the null result (the Michelson-Morley experiment, first performed in Berlin, 1881, and later in Cleveland, 1887), the obtaining of the most precise data of his time on the speed of light by perfecting Jean-Bernard-Léon Foucault's method of the rotating mirror (1879), and the defining and measuring of the archive meter according to the number of wavelengths of red light emitted from excited cadmium atoms (1893). Michelson was the president of the U.S. National Academy of Sciences (1923–1927), and also received the gold medal of the Royal Astronomical Society in 1923. A crater on the moon bears Michelson's name, an honor also given to Tesla. However, for the construction of the interferometer that bears Michelson's name, and for a series of spectroscopic and metrological discoveries, he was awarded the Nobel Prize in Physics in 1907, the first American in history to receive this prize. Tesla did not live to see such an honor during his lifetime and there was no such honor after his death, although there were eulogies by Nobel Prize winners on the importance of Tesla's work at his funeral in New York.

On May 20, 1891, at a conference of the American Institute of Electrical Engineers (AIEE) held at Columbia University, Nikola Tesla presented a famous lecture, Experiments with Alternate Currents of Very High Frequency and Their Application to Methods of Artificial Illumination, accompanied by brilliant experiments. The history of physics and electrical engineering recognizes Tesla's pioneering role in discerning the importance of high frequencies in the investigation of electrical and magnetic phenomena (in the electromagnetic field theory), especially in the transmission of energy and information, and in methods of electrical illumination. In the lecture, Tesla prophetically placed emphasis upon new methods for obtaining and transmitting energy, especially in the production of light, because the old heavy machinery for this would not be necessary. In the lecture, a fundamental question is touched upon regarding the nature of electricity in the context of the Theory of Aether, fifteen years before Einstein's Theory of Relativity, but with a marked phenomenological approach. Tesla proposed the name "bound aether" for the electricity that occurs in molecules, and which is important for producing light. Sir J. J. Thomson considered such a view and name to be in error. However, it should be emphasized that in 1891 Tesla correctly noted that the occurrence of light is connected with disturbances in the electrostatic charge of molecules. Tesla should undoubtedly be entitled to historical recognition as the first to demonstrate experimentally, four years after Heinrich Hertz's discovery of electromagnetic waves in 1887 as anticipated by Maxwell's equations twenty-three years earlier, that high frequencies and

voltages are important for the occurrence of light and heat (electromagnetic waves) without additional chemical processes. Tesla's intuition regarding omnipresent energy and the need to harness it for the welfare of humankind is amazing.

At Columbia University, Tesla delivered another important lecture on May 16, 1888, on a new system for a motor and transformer using alternating currents. The importance of Tesla's lectures in the development of the physics and electrical engineering of the time is best confirmed by the fact that Columbia University awarded an honorary doctorate *(doctor in legibus)* to Nikola Tesla on June 13, 1894. This was the first honorary doctorate that Tesla received for his inventions, the highest recognition of the importance of his discoveries in electromagnetism. Subsequently, Tesla received more than ten honorary doctorates from universities in Europe and the United States.

In Tesla's engineering spirit, intuition was decisive. Leaving aside the scholastic tradition that distinguishes intuition from discursive cognition, considering Tesla's powerful visions and perceptions of his inventions (for example, the three-phase system and the rotating magnetic field), and their mathematical precision, we may say that Tesla had the gift of Cartesian intuitions. Tesla's intuitions of his inventions, according to the Latin *intueri,* were more than evident, and many have been very successfully applied in technology and industry. Tesla's opus includes approximately 700 patents, of which over 100 are in the area of electrical engineering and radio technology, constituting his greatest contribution, not only in these areas but in numerous contemporary technologies (high frequency illumination, television, the Internet and the cell phone). A digitally processed collection of Nikola Tesla's patents on CD-ROM was prepared by the State Intellectual Property Office of the Republic of Croatia (DZIV) on the occasion of Nikola Tesla Year 2006. There are 147 processed patents, according to the countries and phases of registration: 112 U.S. patents, 1885–1921, 29 British patents, 1886–1921, and 6 Canadian patents, 1886–1910.

Tesla discovered or obtained insight into his inventions in physics and electrical engineering with the same intuition that René Descartes commented upon in his first important philosophical work of a methodological nature, *Regulae ad directionem ingenii* [Rules for the Direction of our Native Intelligence]. Descartes probably wrote this brief work around the year 1628 or some years earlier. In the commentary on the third rule that speaks of intuition, Descartes created an interesting concept of the light of reason (Latin: *ratione luce*, in the French language: *lumière innée, lumière naturelle)*. Nikola Tesla approaches Descartes' ideal with his fundamental discoveries in electromagnetism and the corresponding technologies.

3. Applications of Tesla's Transformer in the Long-Distance Wireless Transmission of Energy and/or Messages and Modern Radio Frequency Technologies

Tesla's high frequency transformer (RF transformer) was truly a breakthrough in the development of modern radio frequency technology. We recall the experiments by Sir Oliver J. Lodge (June 12, 1851 – August 22, 1940) using electromagnetic oscillating circuits. Lodge was an English physicist, radio pioneer and the inventor of the coherer electromagnetic wave detector. Lodge's experiments are based upon two oscillating circuits that are spaced apart, consisting of capacitors (Leyden jars) and rectangular loops. A high-voltage DC generator charges up the capacitor in the first oscillating circuit. At some point, the capacitor discharges via a spark gap into the rectangular loop that has the role of an inductor. In Lodge's second oscillating circuit, separated by a space from the first one, the inside and the outside surfaces of the Leyden jar were connected to the rectangular loop and a movable loop that could slide across the rectangular loop. In this manner, the inductance changes and the frequency of the oscillating circuit are tuned. The second oscillating circuit has an auxiliary spark gap to detect oscillation in the second circuit. When the second oscillating circuit is close to the first one, and if the movable loop is in the resonance position, sparks in the auxiliary spark gap are generated, indicating that the charge in the second loop is oscillating at the same frequency as in the first loop. We can say that Lodge's oscillating circuits are in resonance because the electromagnetic lines of force in the first and second loop are coupled, which generates the oscillation of the charge in the second circuit. Within the context of Lodge's pioneering experiments, Tesla's achievements can be appreciated. He moved the second oscillating circuit into the center of the primary coil, thus inventing the Tesla transformer. This was Tesla's revolution in the field of high frequency technology.

3.1. Tesla's Transformer in the Development of Accelerator Technology

Tesla's high frequency transformer, without the characteristic iron core, is a resonant transformer with a high voltage secondary coil. A primary coil with several turns is part of the primary oscillating circuit together with the Tesla spark gap. The long secondary coil with many turns and stray capacitance between its turns is equivalent to a high frequency resonant circuit. The highest voltage and best tuning are achieved when the secondary coil is a part of the resonant circuit and when it is tuned to the resonant frequency of the secondary coil. This can be expressed as follows: $L_1C_1 = L_2C_2$, obtained by applying the Thomson equation for the resonant tuning (linkage) of the oscillating circuits. Tesla's transformer is a source of high-frequency high-power electromagnetic fields. An equivalent

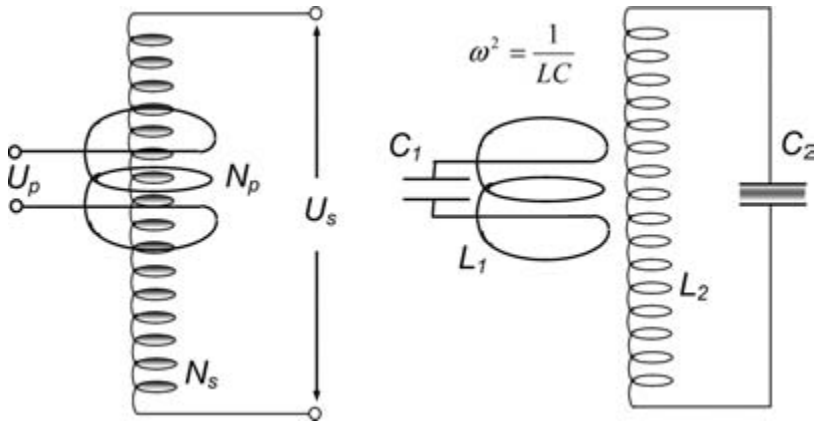

Fig. 1 – Equivalent scheme of Tesla's RF transformer. The voltage at the end of the long secondary coil is as follows: $U_s = U_P \cdot N_s / N_P$ under the following condition: $N_S >> N_P$ (the numbers of the turns of the secondary and primary coils).

scheme of the transformer, with the distributed stray capacitance of the secondary coil (C_2) indicated, is presented in Figure 1.

In Tesla's original calculations, according to his records in Colorado Springs [11], he determined the length of the wire of the secondary coil of the transformer so that it corresponded to a quarter of the wavelength of the electromagnetic waves in free space.

Tesla's fundamental invention for the investigation of electromagnetic phenomena was the Tesla coil. It is a cylindrical coil (one or several turns), made of copper or some other conductor. It is actually an oscillating transformer with primary and secondary condensers and a current switch (spark gap). When high frequency current passes through the coil, the magnetic field in the coil changes very rapidly. These changes in the magnetic flux are perpendicularly enclosed by the li l nes of force of the electrical field. If the coil is located in a rarified gas (for example, air) and if the intensity of the electrical field is sufficiently high, discharge into the gas occurs and a pink ring is seen around the Tesla coil that mimics the form of the coil or the closed electrical lines of force. Tesla discovered the coil in the year 1891 and it is used today in radio, television and many electronic devices.

In the presentation of the development of accelerator particle physics, especially the technology of linear particle accelerators, no one has so concisely and responsibly presented the role of Tesla's high frequency transformer as Prof. Helmut Wiedemann, Ph.D., from the Department of Applied Physics, Stanford

University, at the Stanford Synchrotron Radiation Laboratory [13]. In such development, sources of RF fields of suitable power also have an important role today. Tesla's RF transformer without an iron core was a breakthrough, especially due to the high voltages that can be obtained from the end of its secondary coil. During a half-period of voltage oscillation on the secondary coil, the voltage is used for accelerating the pulses of the particles (beam) in the accelerator channel. This method is particularly used in high technology today, especially in superconductor electron beam accelerators.

We shall describe it briefly, using the example of the Thomas Jefferson National Accelerator Facility (TJNAF, Newport News, Virginia, USA), one of the most famous superconductor electron accelerators in the world, where basic research in particle physics and nuclear physics is being conducted based upon quark models, superconductivity, the physics of materials and surfaces, the physics of lasers, applied research in medicine and biotechnologies, and various industrial applications. In the main channels in the form of an elongated ellipse, approximately 1 mile in length (roughly 1.6 km), there are two linear electron accelerators (so-called north and south *linac*) that together have 320 RF cavities in superconducting technology (material niobium *Nb*, critical or transition temperature to the superconducting state $T_k = 9.3$ K). In each accelerator, the energy of the electron beam is increased by 400 MeV. A billion (10^9) times per second, it focuses a million (10^6) electrons in order to obtain a continuous electron beam of the thickness of a human hair, with a diameter of approximately 200 μm (see the lower figure of Fig. 2). The acceleration of the electrons in the resonators is achieved using an RF field. The electron beam is accelerated linearly and synchronously arrives at the descending positive half-wave of the RF signal along the axial axis of the resonator each time. In branches of science and technology, very interesting technological developments and discoveries are occurring in our times involving the applications of radio frequencies in linear accelerators. There have been developments concerning the central problem, achieving the maximum possible gradient of particle acceleration in linear accelerators, expressed in units of MV/m (megavolts/meter). The goal is to deliver the maximum energy to a particle (beam) per unit length of the cavity in which the acceleration occurs. In the superconducting linear colliders operating today at −271° C (2.15 K), the accelerating gradient typically amounts to 28 MV/m. The most recent technological development at the Jefferson Laboratory in the year 2006 makes a gradient of 35 MV/m possible, while the world record known as the Cornell result of 46 MV/m was achieved in late 2004 (published in the year 2005). In the Cornell University Laboratory for Elementary-Particle Physics (LEPP, Ithaca, NY 14853, USA), the highest accelerating gradient of 46 MV/m in a superconducting niobium RF resonator at a temperature of 1.9 K has been achieved [14].

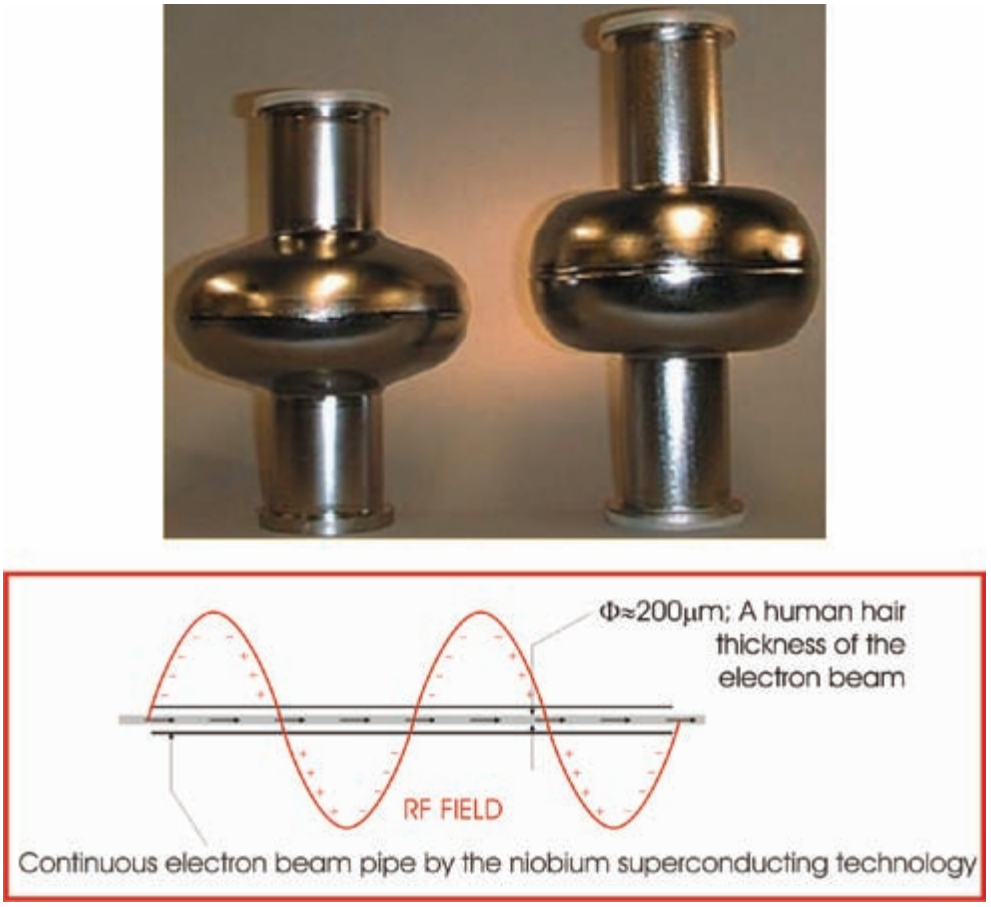

Fig. 2 – A photograph from Cornell and CERN in 2006 (above): a comparison of the standard Tesla resonator or cavity (left) and the new resonator (right) of a "re-entrant" cavity shape. The lower figure is a phenomenological representation of the acceleration of an electron beam in an accelerator pipe, and the electric voltage of acceleration obtained using the Tesla transformer method (author's concept). The physical picture is based on the situation that the force $\vec{F}$ acts on the continuous electron beam in the pipe as a negative accelerating gradient of voltage U ($\vec{F} = -\vec{\nabla}U$).

The roots of the cited achievements in the development of modern accelerator technology are in Tesla's transformer and the high frequency voltages obtained with it. The 1st TESLA Workshop, i.e. the first international workshop on radio frequency technology in superconducting linear accelerators, was held at Cornell University in the year 1990 [14].

At the Cornell University Laboratory for Elementary-Particle Physics (LEPP), there have been significant advances toward the fundamental goal of the maxi-

mum accelerating gradient in superconducting technology. The TESLA Technology Collaboration is located at Cornell. Its ambitious research and development programs are oriented toward three goals: (i) maximum accelerating gradient, (ii) simultaneous enhancement and preservation of the value of the Q-factor or the quality of the resonator and (iii) the geometric optimization of the shape and materials of the resonator or cavity. The achievement of these goals corresponds to the energy of the particle beam (typical electron beam) in the high terra-electron-volt region in superconducting linear accelerators. The previously mentioned peak maximum accelerating gradient of 40 MV/m stems from fundamental limitations due to the breakdown of superconductivity at the surface of the resonator. In this lies the greatest challenge: finding the shape for the beam aperture of the resonator and the entire ideal shape for the resonator in order to achieve the stated goals. The technological version of the resonator is called the Tesla resonator, after the project of the same name at Cornell. The most recent results refer to the technological improvement of the customary Tesla resonator as a more advanced resonator with a new "re-entrant" cavity shape. The two are compared in Fig. 2, according to photographs from Cornell and CERN dated 2006. The new resonator is characterized by a reduction in the ratio of the peak magnetic field value to that of the accelerating gradient (over 10% in comparison to the standard Tesla resonator). The downside of the new shape of the new resonator permits higher electric fields on its surface, which results in a higher electric field for the acceleration of the electron beam.

3.2. Analysis of Tesla's Monopole Antenna for Electromagnetic Waves of High Power and Range within the Framework of Classical Electromagnetic Theory

In our times, Tesla is one of the most frequently mentioned scientists on the Internet. Various websites describe and comment on his life and work, especially his patents and inventions. There are frequent web articles on Tesla's idea for the technical implementation of a world wireless system (the long-distance transmission of energy or messages). These scientific and frequently pseudoscientific articles contain analyses of actual Tesla towers with RF oscillators and transformers for the emission and wireless transmission of electromagnetic energy, based upon Tesla's research notes (*Colorado Springs – Notes*, June 1, 1899 to January 7, 1900, see [11]). One of Tesla's chief experimental discoveries from the measurements at Colorado Springs was that stationary waves are propagated through the earth. He continued this investigation with the construction of a massive tower for *world telegraphy* on Long Island in 1900–1902, which remained Tesla's unfinished project! Tesla's laboratory and tower on Long Island were devoted to fundamental experiments for the purpose of attempting to confirm his new model for the propagation of RF waves and the transmission of energy, unlike the stan-

dard Hertz model of directed radiation through free space. Tesla's scientific-technological areas of interest were fundamentally diverse: (i) authentic proofs of the earth's stationary waves (already noted in the research in Colorado Springs) that could serve for the economical transmission of energy on a large industrial scale and in the system of the earth-ionosphere for transcontinental (global) communication; (ii) the evidence of the model of the earth as a conductor and resonant system with low characteristic frequencies (6, 18, 30 Hz, Tesla's numbers); and (iii) the experimental search for the optimal transmitter ($\lambda/4$ monopole antenna) in the antenna-ground system, in view of the optimal technical ratio in electromagnetic transmission between the propagation of energy by EM waves and the energy current that travels the earth. The research and experiments on Long Island using the wireless transmission tower were supposed to be Tesla's crowning contributions to electromagnetic theory and technology, with revolutionary applications in wireless communication and energetics. This was the famous Tesla Wardenclyffe Project in the locality of Wardenclyffe, now Shoreham, Long Island, New York. The huge 187-foot (57-m) tower, designed according to Tesla's specifications by the famous American architect Stanford White, was erected in the year 1901. The project was terminated, however, in 1905 when its main backer, J. P. Morgan, refused to finance it further.[3]

Tesla's model of the long-distance wireless transmission of electromagnetic power or messages based on his fundamental intuition about the world wireless system is attracting renewed attention in 2006, on the occasion of the 150th anniversary of Tesla's birth and Nikola Tesla Year. Tesla believed that his transmission model using the antenna-ground system could transmit nearly 90% of the energy via the earth's surface and the remaining 10% via electromagnetic Hertz waves through the atmosphere. He attempted to construct a powerful transmitter for such transmission and determine wavelengths reliably through experiments, with the goal of defining the phenomenological laws of propagation through the earth and air. He attempted to construct a powerful transmitter for such transmission and determine wavelengths reliably through experiments, with the goal of defining the phenomenological laws of propagation through the earth and air. Tesla's antenna (transmitter, tower) was supposed to have weak impedance matching for the free space, in order to decrease wave energy propagation. In Hertz's transmission mode, the goal was the optimal matching of the antenna to the free space (377 Ω).

[3] It is interesting that the Tesla Wardenclyffe Project was revived as an aspect of Tesla's legacy in 2006 in Shoreham by the Tesla Science Center at Wardenclyffe. This center is also preparing an international conference in commemoration of the 150th anniversary of Tesla's birth, the First Tesla Museum and Science Center International Conference on Nikola Tesla, October 6–8, 2006, in Brookhaven, Farmingville, N. Y.

Arnold Sommerfeld, one of the most famous German physicists, was also engaged in the theoretical propagation of waves in wireless telegraphy during 1909 [15]. In addition to Sommerfeld, Jonathan Zenneck was also engaged in the wireless propagation of waves via air-ground, as two media. From the development of electromagnetic theory, it is known that wireless communication can be based upon the Zenneck-Sommerfeld solution to Maxwell's equations that particularly describe the propagation of waves by the earth's surface. In addition to Zenneck's and/or Sommerfeld's surface waves [15], there were many useful solutions later along this line of research. Tesla felt that such solutions provided great support for his model.

Electromagnetic calculations have once again been performed and revised for Tesla's approach, based on energy transmission by the earth and Hertz's approach using free space, and the results were published in the first original scientific article during Nikola Tesla Year 2006 in Croatia. This concerns the previously mentioned article in the journal *Energija* [3]. Tesla's device for the antenna-earth system is presented in Fig. 3. The oscillator operates at a frequency of 100 kHz. Tesla's transformer has a weak coupling and is used for adjusting the device. The monopole antenna has capacitive reactance that must be cancelled by inductive reactance, which is achieved via an additional serial coil (transformer), in which case there is maximum transmission of power to the antenna. The antenna is 60 m in length, rod-like and monopolar. The practical criteria of monopolarity according to the distribution of current on the antenna determine the length of a monopole antenna, which is less than of $\lambda/8$. In this case, the criteria are met: $L < \lambda/8$, (60 < 375). Since the device is authentically Tesla's, in this article we are presenting it with the corresponding physical parameters, descrip-

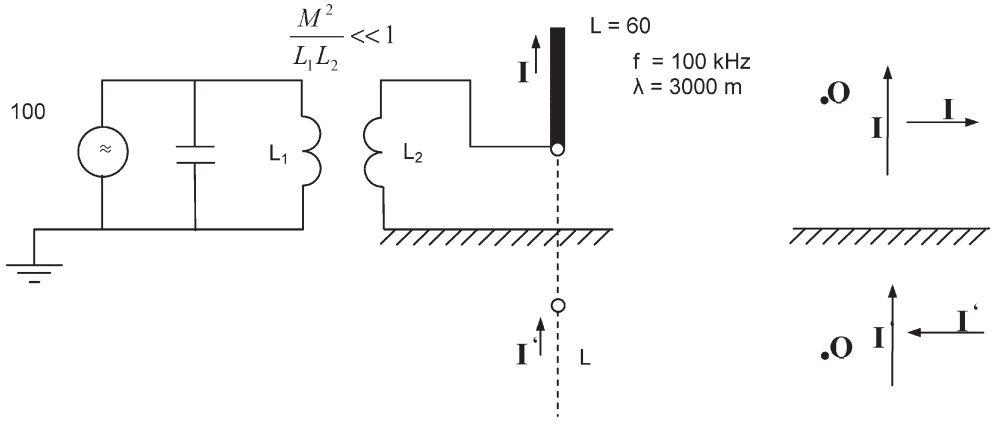

Fig. 3 – Tesla's device for the antenna-ground system. The modern scientific scheme of the equipment intended for the experimental investigation of Tesla's model of the wireless transmission of electromagnetic power or information based upon the fundamental concept of the wireless system.

tions and commentaries regarding our solutions. A monopole antenna is a single pole (half) half-wave antenna, the technical usefulness of which is based upon the phenomenon that the soil is a good conductor of low frequency currents of the two media (from 10 kHz to approximately 30 MHz). A monopole will be analyzed with a linear polarization (polarization of the electrical wave field radiated from the monopole), while the antenna is erected vertically to the ground. At vertical polarization, the imaged current has a value and direction that support the radiation emitted by the real monopole (Fig. 3). This is not the case for horizontal polarization: the current and its associated image are mutually compensatory. Therefore, vertical polarization is used because in the upper half of the space, the field of the monopole has the same intensity as in the case of a dipole. The purpose of such analysis is to provide detailed calculation and a mathematical demonstration, particularly at great distances from the radiating monopole (source). Such calculations assume that certain prerequisites have been met. The first is that the soil is ideally conductive or at least somewhat ideally conductive, so that the entire induced charge in the soil from the antenna charge appears as a surface charge at the phases between the soil and free space. It is assumed that such a charge is equal to that of the antenna (these conditions are met for ideal conductivity and for the dielectric constant of the soil that is far greater than that of the free space), and if it is known from the electrostatic image theory that the imaged charge does not depend on the coordinates, but rather upon the previously mentioned ratio of the dielectric constants, it is possible to present the distribution of the imaged charge using the same function as for the distribution of the current on the monopole.

The article concerns an analysis of Tesla's monopole antenna, based upon his fundamental research in Colorado Springs and Long Island in which such an antenna had a crucial role in the equipment for the long-distance transmission of electrical energy (Tesla's U.S. Patent No. 1 119 732 for an "Apparatus for Transmitting Electrical Energy," was filed on January 18, 1902 and registered on December 1, 1914). In this article, we performed original calculations of the wave intensity (RF field) and Poynting's power flow at significant distances from the antenna. The scientific motive is to confirm or refute Tesla's fundamental ideas in electromagnetic theory and applications at RF frequencies. The analytical calculations show that the electromagnetic field is small and the power is quite weak at great distances from the monopole. The entire calculation was performed for an ideal monopole: a monopole with a length far longer than that of the radius of the cross section, so that the influence of resistance loss is negligible in this case. Moreover, soil is never ideally conductive and, therefore, the consequent losses are very great. There are also great losses in the antenna coil. Some improvement is achieved by burying a metal strip in the soil under the monopole or by modifying the monopole itself. The monopole is bent at the tip in the form of the letter L or T, or has a sphere at the tip. The sphere receives a certain amount of

charge and thereby increases the current distribution surface. The L or T tip of the monopole performs the same role. Thereby, emission for such real modified monopoles is intensified. Transmission via the earth's surface (Tesla's mode) seems naturally and technically justified, as demonstrated by these calculations. Unfortunately, such transmission has remained a mere dream because Tesla did not complete his research or provide a technical solution, although his ideas were well founded scientifically.

4. Tesla's *Ēthos* (Moral Character) in Light of Contemporary Ethics and Bioethics

Tesla's moral character during both the European and American phases of his scientific research is perfectly congruent with Aristotle's concept of *ēthos* (Greek: ≈*θos*), which is customarily translated as *moral character* in Aristotle's ethics. According to the Aristotelian interpretation of moral philosophy, Tesla's rational decisions regarding his patents and inventions in physics and electrical engineering have devolved to serve the good of the person and humankind as a whole. None of Tesla's acts in science and technology violated the integrity of his moral character in any way, despite extensive coercion by scientists, industrialists and politicians to alter his fundamental ethical orientation. He is an exemplary figure in modern science, technology and philosophy. There have been no applications of Tesla's numerous industrial, scientific and technological patents for unethical or destructive ends. Tesla should be viewed as an ethical and bioethical model in modern science and technology by virtue of his unclouded life and work. The moral character of Tesla's work becomes particularly apparent when contrasted with that of scientists such as A. Einstein, E. Fermi and W. Heisenberg, whose discoveries either devolved to catastrophic applications, such as the atomic bomb, or who directly participated in the development of nuclear weaponry during the Second World War. These great physicists are universally venerated in popular as well as serious philosophical and scientific circles. Nonetheless, Nikola Tesla represents sharply contrasting values.

We shall briefly consider Fermi and Heisenberg, about whom the author of this article has recently published works. Fermi and Tesla have already been formally mentioned together in this article as Europeans whose American successes both began with their arrival at Columbia University in New York. I have written previously about Enrico Fermi regarding the question of the moral responsibility of scientists in terms of bioethics, as the last universal physicist of the 20th century [4]. Enrico Fermi, the celebrated Italian physicist who had discovered neutron-induced radioactivity, the recipient of the 1938 Nobel Prize in Physics, arrived in New York on January 2, 1939. Less than two weeks after his arrival, Niels

Bohr, the recipient of the 1922 Nobel Prize in Physics, arrived in New York and brought news of the discovery of the concept of nuclear fission by Otto Hahn, Fritz Strassmann and Lise Meitner. Fermi was welcomed in America as the ideal physicist who would continue his European research on nuclear reactions with neutrons. At Columbia University, he soon formed a group of physicists around himself (Herbert L. Anderson, Leo Szilard and Walter H. Zin), with the goal of investigating the fission of uranium nuclei. The group soon confirmed experimentally that ^{235}U is the fission isotope of uranium and that its fission is triggered by thermal neutrons. Thus, E. Fermi successfully began the American phase of his research at Columbia University in New York, as Nikola Tesla had done before him. Is Fermi's participation in the Manhattan Project for the development of the atomic bomb a stain upon his reputation as the last universal scientist? In my research into Fermi's life and work, I have concluded that Fermi's Italian phase up to the year 1938 was impeccable in the bioethical sense. In the American phase, the universality of Fermi's Italian phase was compromised by his role in the discovery, testing and use of atomic bombs in Japan during 1945. Fermi, like other great physicists confronting the moral dilemmas concerning the use of the atomic bomb, did not virtually calculate all the bioethical consequences and dangers to humankind. However, he was better acquainted with them than the others who participated in the project. Contemporary bioethical paradigms, unlike paradigms in physics, chemistry or even traditional ethics, do not provide stipulated postulates and laws in advance, i.e. final truths of a metaphysical or theological nature. Bioethics is more interdisciplinary, posing and preparing new universal paradigms rather than ultimately answering Pilate's famous question to Jesus: "What is truth?" (to which Jesus replies that everyone who belongs to the truth listens to his voice). Bioethics is primarily founded upon knowledge as such and the universal morality of the survival of life in the universe. Tesla's European and American phases were identical and unbroken in the ethical and bioethical senses, perfectly unclouded, in which it is not possible to discover any partial or general interest or intention except scientific and technological research for the good of humankind. This does not diminish Tesla's field of activity and research in electromagnetic theory and electrical engineering applications, as might be said of the great theory of nuclear physics of the 20th century and the applications of nuclear energy. It is generally acknowledged that Einstein's space-time relativity in physics with its new vision of the universe, quantum mechanics with its new vision of nature and natural phenomena, revolutionary philosophical ideas and man's role in the natural laws, together with the discoveries in nuclear physics of the 20th century, promised new meaning and function for theoretical and experimental research in the modern age. However, the brilliant electromagnetic theory that developed in the 19th century, culminating in Nikola Tesla's magnificent inventions, stands side by side with these other great theories. Its development in the physics of lasers, and information and communication in the foundation of the global electromagnetic culture of our

times, and Tesla's crucial contributions, without which such development would not have occurred, only confirm and justify our original notion of Tesla's *ēthos* in modern electrical engineering and physics.

When describing Tesla's scientific orientation, we recall the great physicist Heisenberg, his *ēthos* and scientific activity during the Nazi era in Germany, which continue to remain intriguing when considered within the legal and moral context of that time. Heisenberg, in response to the delicacy of his own situation as a leading physicist and philosopher, developed his principle of responsibility (*Verantwortung des Wissenschaftlers*) as a contribution to the ethical conflict between moral obligation and obedience to authority. I refer to my scientific and philosophical study of Heisenberg's case over the years, regarding contemporary moral dilemmas in science and technology in light of modern bioethical considerations. An article has recently been published on Heisenberg's life and works during the Nazi phase [6], and we particularly recall the moral model of Tesla's life and work. Although Tesla's trials are not comparable to those endured by Heisenberg under the conditions of the Third Reich, the obstacles Tesla encountered during his lifetime were not trivial.

Despite obstacles, disappointments and the failure to implement some of his great scientific intuitions during his life, there is a prevailing conviction that we still do not know Tesla, particularly in light of his famous statement: "The future belongs to me." Together with contemporary accelerator technology and all the inventions and intuitions we have described, exotic experiments in teleportation, Kirlian photography (invisible phenomena) and the missing objects and written notes which the secret services confiscated at the time of Tesla's death and burial are also aspects of Tesla's genius. In any case, Tesla's moral character remains resplendent.

5. Tesla's Inventions in the Foundations of Contemporary World Science and Electromagnetic Culture

It is known that Tesla studied the longest and best at the *Technische Hochschule* in Graz (1875–1878), and continued his education in Prague. He enrolled in the study of natural philosophy in 1880 at the University of Prague but already in 1881 went to Budapest, where he was employed at the Central Telegraphic Office. While in Budapest in February 1882, he experienced the most significant intuition of his life regarding the rotating magnetic field, which can practically be considered as the hallmark of electromagnetic technology. Walking in the city park with his friend Antal Szigety, reciting an excerpt from Goethe's *Faust,* "Before the City

Gates,"[4]. the idea of the rotating magnetic field struck Tesla like a bolt of lightning. He immediately drew a diagram of such a field in the sand with a stick, which Szigety understood at once. Thus, the ancient Greek Platonic situation was repeated when Socrates successfully explained the Pythagorean Theorem to a slave by making a drawing in the sand (*Meno,* dialogue from the transitional period of Plato's works). In *Faust,* Goethe tells of the struggle between good and evil, the spirit and body, life and nihilism, on the highest cosmic scale. The moving force and main protagonist in this struggle on the one side is the scientist Faust, disappointed and restless in his scientific aspirations, and on the other side is the satanic figure of Mephistopheles, a partner and opponent on Faust's investigative journey. Such a philosophical and poetic-mystical image made a profound impression on Tesla and greatly attracted him throughout his life. It was particularly Faust's philosophical choice, the rejection of the joys of this world as offered by Mephistopheles in favor of a fundamental commitment to human creativity, work and freedom, which signifies the historical and cosmic advancement of humankind.

There has been considerable recognition afforded to Tesla's inventions in physics and electrical engineering in Croatia. This is not merely due to an affinity toward a researcher from our homeland but the creative interest by Croatian university instructors of physics and electrical engineering in incorporating Tesla's ideas into the curricula. Such an attitude toward Tesla has also been expressed through the high honors that have been awarded by the Croatian scientific and cultural milieu. Nikola Tesla was chosen as an honorary member of the Yugoslav Academy of Arts and Sciences (today the Croatian Academy of Arts and Sciences) in 1896. On June 29, 1926, he received an honorary doctorate (*doctor honoris causa*) from the Department of Electrical Engineering, Faculty of Technology; University of the Kingdom of the Serbs, Croats and Slovenes, in Zagreb, which was presented to him in New York on the occasion of his 70th birthday, the first honorary doctorate of natural sciences awarded by the university. We present a translation of the listings of the original rulings and documents in the catalogue section of the archives of the University of Zagreb.

The rector's chain of office of the University of Zagreb dates from the year 1880 and is fashioned of a series of medallions with the likenesses of distinguished Croatian scientists and artists. On the occasion 300th anniversary of the University of Zagreb, 1969, a new rector's chain was fashioned with medallions of distinguished figures from the history of Croatian science, including one with the likeness of Nikola Tesla (the work of the academic sculptor K. Angeli Radovani). In the center of the city of Zagreb, a statute of Nikola Tesla (Fig. 4) has been

[4] Johann Wolfgang Goethe, Faust I und Faust II, Eine Tragödie, Werke Sechster Band, Insel Verlag, Frankfurt am Main, 1981, Faust I, Vor dem Tor, S. 45

DOCTOR HONORIS CAUSA, *NIKOLA TESLA*, Zagreb 1926

Nikola Tesla, scientist in the field of electrical engineering of worldwide reputation, received an honorary doctorate on June 26, 1926, in commemoration of the 70th anniversary of his birth. He is the first in the natural sciences to receive an honorary doctorate from the University of Zagreb

The text of the ruling of the Faculty of Technology, the University of the Serbs, Croats and Slovenes in Zagreb, dated May 28, 1926, on the awarding of an honorary doctorate of technical sciences to Nikola Tesla.

The text of a letter from the rector, Drago Perović, sent to the Office of the Dean of the Faculty of Technology on June 21, 1926, regarding the ruling of the University Council on the awarding of an honorary doctorate to Nikola Tesla.

Archives of the University of Zagreb, Rectorate, No. 2115/1926

Legend: Doctor honoris causa, spis, 1926, format A4, 2 pages, Nikola Tesla, the first honorary doctor of natural sciences awarded by the University of Zagreb

Figure 4 – The city of Zagreb erected a monument to Nikola Tesla near the entrance to Nikola Tesla Street. The inscription on the base reads as follows: "Nikola Tesla, 1856–1943, in commemoration of the 150th anniversary of his birth, the City of Zagreb, July 10, 2006."

erected, the work of the greatest Croatian sculptor, Ivan Meštrović. The statue was originally placed in the park of the Ruđer Bošković Institute in 1956 but during the series of events in commemoration of Nikola Tesla Year 2006 in Croatia, it was moved to the center of the city, at the intersection of Tesla Street, Preradović Street and Masaryk Street.

It should be noted that Tesla's experiments and attempts in physics and electrical engineering were not exclusively intended for patents. Nikola Tesla was a pioneer of public scientific experiments in electromagnetism, particularly during the American phase of his life and research. Tesla's experiments were magnificent. In addition to those concerning inventions, there were also those that were instructive, of the type known as the so-called *expĕrīmentum explānātum* – explanatory experiment, an experiment that *interprets* and *demonstrates,* but also *substantiates* a phenomenon. In the physics of the 21st century, great accelerator experiments in the world are being conducted, which include enormous accelerator facilities to be used for accelerating high energy beam particles, the colliding of which provide new scientific insights and data of significance to *particle physics* and *cosmology* (standard model), or as popularly expressed in contemporary physics, for *the theory of everything that exists.* At one time, great experiments were performed by one, two or three physicists. Contemporary great experiments are on a grandiose international scale in terms of the numbers of participants and countries that support them, but also because they unite the three most significant scientific approaches of our modern civilization: *theory*, *experiment* and *simulation*, as never before (see [17]). Moreover, with and for them, a *fourth* approach is being developed toward public opinion – the path of the popularization of new scientific knowledge, testimonies and information that such experiments yield, as well as the explanation of complex ideas regarding the conducting experiments. This is an essential characteristic of all accelerator experiments, from CERN, Fermilab (United States), DESY (Germany), to KEK (Japan). Every great experiment is necessarily accompanied by a popular scientific film, flyer or some other explanation to the various available mass media.

Heinrich Rudolf Hertz, Tesla's contemporary who discovered electromagnetic waves in 1887, announced on that occasion his inexhaustible belief in the power of the scientific experiment. Hertz's words still apply today: "What is due to experiment may always be rectified by experiment." Tesla's *credo* was similar: to demonstrate the power of electromagnetic theory with experiments, particularly in the long-distance wireless transmission of energy, messages and illumination.

Information and communication technology (in philosophical language the "electromagnetic culture") is in the background of the contemporary processes of globalization and global networking, e.g. the Internet. The high density, high volume flow of information at the greatest possible speeds corresponds to Descartes

metaphysical ideal concept of the *light of reason* [18]. Tesla's inventions, patents and experiments are incorporated in the foundations of contemporary culture. Tesla's name, work and his cosmopolitism, particularly his moral character and passion to help humankind through science, are paragons of human science and culture.

Acknowledgments

I acknowledge valuable discussions on the topics of technology, physics and philosophy in the paper with my sons T. Petković jr. and K. Petković, both scientific novices/assistants at the Faculty of Electrical Engineering and Computing and Faculty of Political Science of the University of Zagreb, respectively. I thank Professor Z. Kniewald, president of the Croatian Academy of Engineering, who included my paper in the prestigious symposium, "Tesla in Croatia," to be held in Paris on September 13, 2006. Ms. M. Casman-Vuko and Mr. M. Vuko translated the Croatian original of the paper into English with interest and great effort.

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Republic of Croatia
Ministry of Science, Education and Sports

Program for a Commemoration of the Year of Nikola Tesla in the Republic of Croatia

1. Introduction

The Republic of Croatia proclaimed 2006 the Year of Nikola Tesla, honoring a world known scientists and inventor who was born on July 10th 1856 in Smiljan, Croatia. The decision was brought by the Committee for Education, Science and Culture of the Croatian Parliament upon a proposal of the Croatian Government. On the basis of this decision the Croatian Parliament established an Implementation Committee. Also, the Operational Committee constituted of the representatives of the Croatian Parliament, Croatian Government, Croatian Academy of Science and Arts and representatives of distinguished scientific institutions was established. The same decision obliged the Ministry of Science, Education and Sports and the Ministry of Culture to operational implementation of the Program of the Nikola Tesla Year.

Tesla's words: "my project was slowed down by laws of the nature. It was ahead of the time" is still valid. Tesla preferred to describe himself rather as "discoverer" than "inventor", holding he shows the way to the others. Nowadays Tesla is comprehended as "a man who invented twentieth century", but the richness of his inventions indicates that he also invented 21st century as some of his inventions have only recently been discovered or explained.

Tesla's work encompasses around 700 patents, some of the most known are: electromagnetic coil, induction motor, alternating current electro magnetic motor, alternating electric energy, incandescent electric light, vacuum photograph tube, wireless transmission of electric energy, radio, remote control as a basis for contemporary robotics, cosmic radio waves and use of ionosphere.

He obtained his Honorary Ph.D. title at the University of Zagreb in 1926 with recommendation of the Faculty of Technology, University of Zagreb. From 1969 the image of Nikola Tesla is on the Rector's Chain of the University of Zagreb along with the images of other prominent scientists and researchers. Tesla's work has been honored by naming many important discoveries and institutions after

him; of instance, the unit for magnetic induction *tesla* (T) in 1960 and one of the craters on the Moon. World wide association of scientists – IEEE since 1976 every year grants an award "Nikola Tesla" to the most successful scientists.

The Year of Nikola Tesla is an opportunity for integral commemoration of Nikola Tesla's work and life, not only as extinguished scientist and inventor, but also as a devoted patriot who proudly accentuated his Serbian heritage and Croatian homeland.

2. Content and stakeholders of Program tasks

Commemoration of Nikola Tesla has to be joint project of different scientific, educational, cultural, religious, economic and other relevant Croatian institutions. In that respect, both Croatian and international public have from science, education and technical culture have to be included. The program of the Year commemoration encompasses following:

2a. In science

– Naming the yearly award in a field of technical sciences after Nikola Tesla

Stakeholder: Ministry of Science, Education and Sports, Croatia

– International scientific and professional meeting "The Life and Work of Nikola Tesla"

Stakeholder: Croatian Academy of Engineering

In cooperation with: Ministry of Science, Education and Sports, Croatia; Faculty of Electrical Engineering and Computing, University of Zagreb; Hrvatska elektroprivreda, Inc.; Ericsson Nikola Tesla, Inc.; Energy Institute Hrvoje Požar; Technical Museum, Zagreb; Croatian Association of Engineers; the American Embassy in the Republic of Croatia

– Publishing of the reprint of PhD thesis of Professor Vladimir Muljević

Stakeholder: Technical Museum, Zagreb

In cooperation with: Croatian Association of Technical Culture, Hrvatska elektroprivreda, Inc., Matica Hrvatska association, Ministry of Science, Education and Sports, Croatia

– N. Tesla exhibition in "Science Festival"

Stakeholder: Technical Museum, Zagreb

– Multimedia installation: Energetic-Information Grid

Stakeholder: "Ruđer Bošković" Institute

– International course and conference MIND AND BRAIN V: Physics and the Brain

Stakeholder: Faculty of Science, University of Zagreb

2b. In education

– Yearly stipend Ericsson Nikola Tesla, Inc.

Stakeholder: Ericsson Nikola Tesla, Inc.

In cooperation with: Ministry of Science, Education and Sports, Croatia; Croatian Academy of Engineering; Croatian Academy of Science and Arts; Faculty of Electrical Engineering and Computing, University of Zagreb; Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split

– Best pupils' award

Stakeholder: Hrvatska elektroprivreda, Inc.

In cooperation with: Institute for Education, Croatia; Ministry of Science, Education and Sports, Croatia

– Publishing of the leaflet and multimedia CD "Tesla's day"

Stakeholder: Institute for Education, Croatia

In cooperation with: Ministry of Science, Education and Sports, Croatia, Hrvatska elektroprivreda, Inc.

– "Physics express"

Stakeholder: Student Section of Croatian Physical Society

In cooperation with: MLAZ – Young Scientists Network

– Publishing of the leaflet for pupils

Stakeholder: Serbian National Council, Zagreb

In cooperation with: European Commission, Zagreb

2c. In culture

– Renovation of the permanent exhibition of Nikola Tesla's demonstrational cabinet in Technical Museum, Zagreb

Stakeholder: Technical Museum, Zagreb

In cooperation with: Ministry of Culture, Croatia; City Council for Education, Culture and Sport, Zagreb; Hrvatska elektroprivreda, Inc.; Ericsson Nikola Tesla, Inc.

– Bronze statue of Nikola Tesla by E. Bohutinski

Stakeholder: Technical Museum, Zagreb

In cooperation with: Hrvatska elektroprivreda, Inc.; City Council for Education, Culture and Sport, Zagreb

– Statue of Nikola Tesla by Fran Kršinić or Ivan Meštrović

Stakeholder: Ministry of Culture, Croatia

In cooperation with: Ministry of Culture, Serbia; Embassy of Republic Serbia in the Republic of Croatia; "Ruđer Bošković" Institute

– Promotion of "Nikola Tesla monograph" published by "Zavod za udžbenike", Republic of Serbia

Stakeholder: Serbian Educational Cultural Association "Prosvjeta", Zagreb

– Theater performance "Nikola Tesla" by National Theater from Belgrade in Osijek

Stakeholder: Serbian Educational Cultural Association "Prosvjeta", Zagreb

– Publishing of two books by Milovan Matić "Nikola Tesla bibliography" and "Milutin Tesla"

Stakeholder: Serbian Educational Cultural Association "Prosvjeta", Zagreb

– Calendar "Nikola Tesla" for 2006

Stakeholder: Serbian National Council, Zagreb

– Multimedia project "Tesla Broadcasting"

Stakeholder: Serbian Educational Cultural Association "Prosvjeta", Zagreb

In cooperation with: "WHW" Association; Ministry of Culture, Croatia

– Publishing of the special number of "Prosvjeta" review devoted to Tesla

Stakeholder: Serbian Educational Cultural Association "Prosvjeta", Zagreb

– Filming and promotion of a film "Nikola Tesla – the years of a genius"

Stakeholder: Serbian Educational Cultural Association "Prosvjeta", Zagreb

– Exhibition of Tesla's exponents from "Nikola Tesla" Museum from Belgrade

Stakeholder: Serbian Educational Cultural Association "Prosvjeta", Zagreb

– Filming of a documentary-animated story about Nikola Tesla

Stakeholder: Alt F4 Inc.; Bulaja publishing company, Zagreb

In cooperation with: Ministry of Culture, Croatia

– Conference DECro 03

Stakeholder: Alt F4 d.o.o. Bulaja publishing company, Zagreb

In cooperation with: Ministry of Culture, Croatia

– Establishing of a new extended museum exhibition of "Nikola Tesla" Museum in Smiljan

Stakeholder: Ministry of Culture, Croatia

In cooperation with: Technical Museum, Zagreb; Croatian Historical Museum; Lika Museum, Gospić

– Renovation of "Nikola Tesla" Museum and Ortodox Crurch in Smiljan

Stakeholder: Ministry of Culture, Croatia

In cooperation with: Hrvatska elektroprivreda, Inc.; Croatian Restaurateur Institute; KO Karlovac; Lika Museum, Gospić; Gospić Council

– Commemoration of the 150th anniversary of Nikola Tesla birth at UNESCO office in Paris

Stakeholder: Croatian mission of UNESCO at the Ministry of Culture, Croatia

In cooperation with: Croatian Academy of Engineering

– Restaurateur work on the furniture from Nikola Tesla's birth house in Smiljan

Stakeholder: Lika Museum, Gospić

– **Statue of Nikola Tesla in Zagreb**

Stakeholder: Zagreb City Council

– **Statue of Nikola Tesla in front of "Nikola Tesla" Elementary School in Zagreb**

Stakeholder: Elementary School "Nikola Tesla", RIZ

In cooperation with: Zagreb City Council

– **Exibition of sculptures by academic painter Pero Jelisić**

Stakeholder: Serbian National Council, Zagreb

– **Silver coin with image of Nikola Tesla by academic painter Pero Jelisić**

Stakeholder: Serbian National Council, Zagreb

– **Commemoration of Nikola Tesla in Vukovar**

Stakeholder: Vukovar Assembly

3. Promotion activities

– **Starting and updating of a bilingual web-site www.nikolatesla.hr**

Stakeholder: Ministry of Science, Education and Sports, Croatia

In cooperation with: Microsoft Croatia, Inc.; Croatian Academy of Engineering, Ericsson Nikola Tesla, Inc., Ministry of Culture, Croatia

– **Outdoor advertising – streetlight placards with Nikola Tesla motive in Zagreb**

Stakeholder: Hrvatska elektroprivreda, Inc.

– **In cooperation with:** HINA, HRT, publishers

Stakeholder: Operational Committee

Celebration of the 150th anniversary of the birth of Nikola Tesla

Symposium "Tesla in Croatia"

Under the patronage of Mr. Stjepan Mesić, President of the Republic of Croatia

Wednesday, September 13th 2006, at 9.30 a.m.
UNESCO house, Cinema Hall, 7 place de Fontenoy, Paris 7°

PROGRAM:

9:00 – 9:30	Registration of the participants
9:30 – 10:00	Welcome words and opening of the Symposium
10:00 – 10:15	Prof. Branka Zovko-Cihlar, Ph.D. (Croatia): From Tesla's Discoveries in the Fields of Radiocommunications to Digital Broadcasting for Multimedia Services
10:15 – 10:30	Prof. Kurt R. Richter, Ph.D. (Austria): Tesla's Time and Application of His Achievements in the Future
10:30 – 10:45	Gordana Kovačević, M.Sc. (Croatia): Ericsson Nikola Tesla: Following Tesla's Vision
10:45 – 11:00	Coffee break
11:00 – 11:15	Prof. Stjepan Car, Ph.D. (Croatia): Nikola Tesla and the Končar Group, Inc.
11:15 – 11:30	Ivica Toljan, M.Sc. (Croatia): Development and Connecting of Major Electrical Power Systems
11:30 – 11:45	Assist. Prof. Darko Huljenić, Ph.D. (Croatia): Tesla trough the Communication's Vision
11:45 – 12:00	Igor Mandić (Croatia): – Tesla's Galaxy
12:00 – 12:20	Movie about Nikola Tesla – Production by HEP
12:20 – 12:30	Closing remarks
12:30 – 13:00	Visit of the exhibition dedicated to Nikola Tesla.

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From Tesla's Inventions in the Field of Radiocommunications to Digital Broadcasting for Multimedia Services

Branka Zovko-Cihlar

Abstract – *In the early days of Tesla's research he explained the process of electromagnetic waves propagation. His experimentations with high frequencies, wireless communication systems, and high frequency oscillator are the base of transmission technology today. In this paper the influence of Tesla's inventions and results in the field of radiocommunications are described.*

Keywords – *Nikola Tesla, Inventions, Radiocommunications, Digital Video Broadcasting*

1. Introduction

Nikola Tesla was genius, whose discoveries in the field of alternating polyphase current electricity advanced whole world and explored and developed many of fundamental concept of modern technology. Tesla had imaginations and intuitive way of developing new ideas on scientific base.

Nikola Tesla was born on July 10, 1856 in the village Smiljan (near town Gospic, Lika), Republic of Croatia, in a Serbian family. Now we celebrate 150th anniversary of the birth of Nikola Tesla. Tesla finished his school in Karlovac and then studied electrical engineering at the Austria Polytechnic in Graz from 1875. In 1882 he moved to Budapest and worked for telegraph company (American Telephone Company). In 1882 he moved to Paris, France to work as an engineer for the Continental Edison Company. In 1884, Tesla arrived in United States of America and started to work in company Edison Machine Works, which produced direct current generators. His work in Edison Company resulted in differences in ideas between Edison and Tesla, because Edison did not want to accept Tesla's ideas that alternating current is better solution. 1885 George Westinghouse, founder of Westinghouse Electric Company in Pittsburg, bought patent rights for Tesla's alternating current systems.

In 1886, Tesla formed his own company: "Tesla Electronic Light & Manufacturing" with the plan for an alternating current motor. In 1887 he constructed the initial brushless alternate – current induction motor, and he demonstrated it in 1888 to the American Institute of Electrical Engineers (IEEE).

In 1888 Tesla started to work with George Westinghouse at Westinghouse Electric & Manufacturing Company in Pittsburg, USA, where he started with idea for polyphase systems which would allow transmission of alternating current electricity over the large distances. In 1888, in Westinghouse labs, Tesla had obtained patents on a whole polyphase system of a current dynamos, transformers and motors.

Tesla explained the principles of rotating magnetic field and induction motor by demonstrating how to make a cooper egg stand on end. This phenomenon, which he constructed, is known as the "Egg of Columbus".

In 1897 Tesla demonstrated a radio controlled boat to the US military, believing that the military would want use this invention for radio controlled torpedoes. In the filed of radiocommunications, 1898 radio controlled boat was demonstrated to the public during an electrical exhibition at Madison Square Garden and this radio remote control remained a novelty until 1960.

Between 1895-1899, Tesla designated the first hydro-electric power plant at Niagara Falls and this was the final victory of Tesla's alternating current over Edison's Direct Current, Fig. 1.

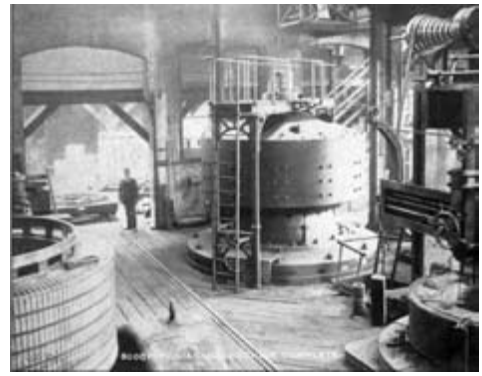


Fig. 1 – Nikola Tesla designed the first hydro--electric power plant at Niagara Falls (1895-1899)

During the next period of Tesla's work in his New York laboratories he made a research on wireless communications. The result of wireless transmission of electricity through ionosphere was Wardenclyffe Tower with electrical sparks for transfer electricity without wires. This was the first broadcasting system in the world, Fig. 2.

Fig. 2 – Tesla's Wardenclyffe Tower located in Shoreham, Long Island, New York, USA

Tesla wanted to transmit electricity from this tower to the whole globe. The source of the transmitted electricity was from the Niagara Falls power plant.

Tesla with his invention fundamentally changed the world. As Margaret Chaney said in Tesla's biography, he was "The Man out of Time".

2. Tesla's Inventions in the Field of Radiocommunications

Tesla's started with experiments to explore himself a phenomenon of high frequency electricity. In England in 1873 Maxwell theoretically predicted electromagnetic waves. Maxwell found mathematically that light could be electromagnetic wave which he defined with very well known "Maxwell equations". In 1888 Heinrich Hertz confirmed with experiments that an electric spark propagates electromagnetic waves into space. This result in a fact that electromagnetic waves could exist at all frequencies. Some years later Tesla presented wireless communication system at lower frequencies which made long distance communication possible. Today we know that electromagnetic waves penetrate deep into space and we can see television signal which was transmitted from the Moon to the Earth.

Fig. 3 – Illuminated gas – field phosphor coated light bulb

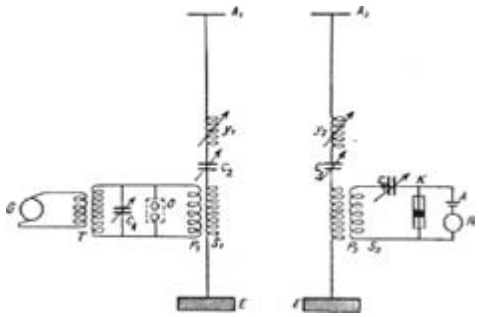
Tesla continued with experiments with high frequencies and in 1890 he illuminated vacuum tube by wireless transmission of energy through the air, Fig. 3. Tesla was holding

Fig. 4 – Experimental Station at Colorado Springs where the first wireless transmission experiments were preformed (1899-1900)

a gas field phosphor coated light bulb which was illuminated without wires by electromagnetic field from Tesla coil.

In 1891 Tesla patented Tesla coil with frequency sixty – cycle per second and stepped it up to extremely high frequency. Tesla coil could also generate extremely high voltages. In 1899 Experimental Station in Colorado Springs was design, where the wireless transmission experiments were performed, Fig. 4.

Nikola Tesla explained a wireless communication system – Tesla oscillator, Fig. 5. With Tesla coils he was able to transmit and receive powerful radio signals when the coils were tuned to the same frequency.



G – generator
T – transformer
C1, C2 – capacitors
P1 – primary coil
S1 – secondary coil
A1 – transmitter's antenna
O – spark oscillator
Y1 – inductance
A2 – receiver's antenna
K – dector (coherer)

Fig. 5 – Tesla oscillator

In Fig. 5, generator G and transformer T is power supply for transmitter. Resonant circuit C1 and P1 initiated by the spark oscillator to the resonant frequency of about 100 kHz. Antenna was vertical wire with the small capacity on the top. At 100 kHz antenna has high impedance. Oscillator is high frequency generator with small impedance. There exist mismatch between antenna impedance as a load and impedance of oscillator as a source. Because of this phenomena Tesla found the solution with his Tesla high frequency transformer which he connect between antenna and oscillator. Transformer's secondary coil with inductance Y1 and capacity C2 make the resonant circuit, which resulted in the impedance match between the load and source.

Tesla transformed the high current of the oscillator into a low current with high voltage in the transmitter's antenna and this solution is still in use and all broadcasting transmitters work on this principle. On the receiver side antenna has Tesla transformer to match the impedance of the antenna to the detector, which gives us the received signal.

In reality Tesla invented radio and not Marconi, and holds the original patent for his development.

In 1918 started electronic age and high frequency current could be generated by help of control – grid high – vacuum tubes, making higher frequencies possible. On this invention around 1924 the amplitude modulated radiocommunication signal with high frequency was possible which we still have today in the broadcasting transmission.

At the end of 20th century digital signal transmission started, and this new technology enabled development of mobile systems, computer technology, digital television broadcasting and multimedia services transmission.

3. Digital Video Broadcasting System

Standard for digital terrestrial broadcasting DVB-T started in 1990 in Europe. First important decision was selection of MPEG-2 for source coding of audio and video data at the input of digital video transmitter.

Multimedia services in future will require the transmission of very high data rates over broadband radio channels. The European terrestrial digital TV system continues its progression among the broadcaster community around the world. The interest for new services to sustain its successful technical and commercial deployment grows tremendously. The market introduction by the DVB-T forum of the Multimedia Home Platform (MHP) provides the broadcasters with terminal able to implement many categories of interactive new services. For multimedia data transmission is of great importance to distribute digital video signal with high quality of service – QoS, large amplifier efficiency and with nominal transmitter output power. With this requirement the main role is method of suppression non-linearity products in terrestrial digital video transmitter with apply of digital precorrection unit and output filter unit. Standard for digital terrestrial broadcasting DVB-T, established in 1997, opened a new era in digital TV technology for multimedia. Multicarrier techniques, COFDM modulation, digital precorrection GPS synchronization, are some of the features of a digital transmitter. COFDM modulation method is very resistant to different disturbances

(e.g. reflection and interference), and also spectrally economical, enabling the multimedia transmitter network to transmit the digital signal on only one channel.

Input signal to the transmitter is a MPEG-2 transport stream, with 5 Mbit/s to 34.3 Mbit/s data rate, depending on transmission mode and parameters chosen, Fig. 6.

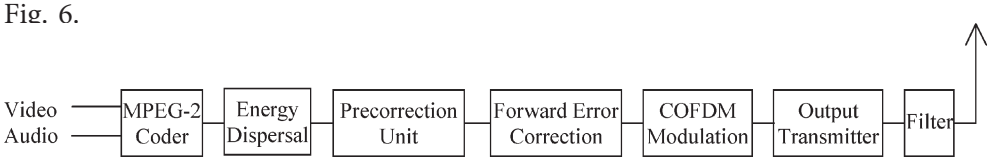


Fig. 6 – DVB-T transmission unit

To obtain OFDM signal, transport stream is divided into two (QPSK), four (16QAM) or six (64QAM) bit streams, forming a word of 2, 4 or 6 bits, defining the subcarrier vector. OFDM symbol is in 8K mode formed by 6817 subcarriers, and in 2K mode by 1705 subcarriers. Symbol duration is divided into two parts: useful and guard parts. Guard part can occupy 1/4, 1/8, 1/16 or 1/32 of the whole symbol duration.

In linear precorrection unit the input I/Q stream is treated in amplitude and phase to linearise the power-amplifier transfer characteristics.

Up-converter converts the IF signal to the desired UHF channel, which will be amplified for driving the output stage to the level needed.

Filter unit at the output of DVB-T transmitter is a two port network which allows power within defined frequency range to be transferred from the power amplifier to the antenna load, while in other frequency ranges it prevents almost all the power from passing to the load.

Filter Characteristic Specification

Standard EN 300 744 prescribes the spectral mask, which has to be filled by digital TV transmitter. Based on the prescribed mask and the frequency spectrum characteristics of the DVB-T signal at the amplifier output, selectivity needed of the filter unit together with other filter parameters is evaluated.

According to the filter specification as a frequency range, frequency bandwidth, insertion loss, output power, we can choose coaxial l/4 filters from 200 MHz up to 1 GHz.

Here is a short definition of filter parameters:

The **bandwidth** of band pass filter is defined as the frequency difference between the upper and lower -3 dB points (*cut-off frequencies*). However, if a pass band gain variation (i.e., 1 dB) is specified, the cut-off frequencies will be the frequencies at which the maximum gain variation specification is exceeded.

Insertion loss of filter is the ratio between the output power Pout and the input power Pin, defined as

$$\text{Insertion loss} = 10\log\left(\frac{P_{\text{out}}}{P_{\text{in}}}\right)\text{[dB]} \tag{3}$$

The output power of the filter is smaller than the input power, making the ratio in Eq. (4.1) less than one and the attenuation is a negative number.

Group Delay is defined as the derivative of a filter's phase with respect to frequency,. For an ideal filter, the phase will be linear and the group delay would be constant. Group delay, whose unit of measure is time in seconds, can also be thought of as the propagation time delay of the envelope of an amplitude modulated signal as it passes through a filter. Group delay distortion occurs when signals at different frequencies take different amounts of time to pass through a filter

$$\tau_{\text{g}} = -\frac{\text{d}\varphi}{\text{d}\omega} = -\frac{1}{2\pi}\frac{\text{d}\varphi}{\text{d}f} \tag{4}$$

Transfer Filter Characteristic

In circuit theory, a filter is an electrical network that alters the amplitude and phase characteristics of a signal with respect to frequency. Ideally, a filter will not add new frequencies to the input signal, nor will it change the component frequencies of that signal, but it will change the relative amplitudes of the various frequency components and their phase relationships. The frequency-domain behaviour of a filter is described mathematically in terms of its transfer function. This is the ratio of the Laplace transforms of its output and input signals. The voltage transfer function H(p) of a filter can be written as:

$$H(p) = \frac{L[Y(t)]}{L[X(t)]} = \frac{Y(p)}{X(p)} \tag{5}$$

where p is complex frequency variable.

Fig. 7 – Filter as two port network

The generalized transfer function is defined by:

$$H(p) = K\frac{a_0 + a_1 p + a_2 p^2 + \ldots + a_n p^n}{b_0 + b_1 p + b_2 p^2 + \ldots + b_n p^n} = K\frac{P(p)}{Q(p)}, \tag{6}$$

where a_n, b_n are polynomials coefficient, p = complex frequency, $P(p)$ and $Q(p)$ polynomials of n-th, and m-th order.

By factoring the numerator and denominator polynomials this may be written as:

$$H(p) = \frac{K(p - p_{01})(p - p_{02})\ldots(p - p_{0m})}{(p - p_{x1})(p - p_{x2})\ldots(p - p_{xn})}. \tag{7}$$

At the frequencies $p = p_{01}, p_{02}, \ldots p_{0m}$, where the numerator polynomial goes to zero the transfer function will be zero, and this frequencies are known as the zeros of the function. At the frequencies $p = p_{x1}, p_{x2}, \ldots p_{xm}$, where the denominator polynomial is zero the transfer function will have the maximum value; this frequencies are known as the poles of the function.

The concepts of complex frequency and poles and zeros are very helpful in network analysis and design.

Methods of Filter Design

According to the filter specification as a frequency range, frequency bandwidth, insertion loss, output power, we can choose one of three basic filter designs.

- helical filter
- coaxial l/4 filter
- waveguide filter

Each this filter structure is dominant in specific frequency range. Helical filters for high power will be used in the frequency range up to 300 MHz, coaxial l/4 filters from 200 MHz up to 1 GHz, and waveguide filter upper of 1 GHz.

Fig. 8 shows a form of coaxial resonator which operates in the transverse electromagnetic (TEM) mode and is a quarter-wavelength long at resonance. One end of resonator is open-circuited while the other is short-circuited, and tuning is accomplished by sliding the round centre conductor back and forth through the short-circuited region of resonator.

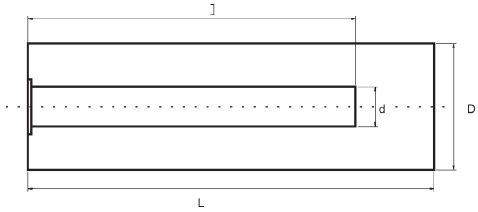


Fig. 8 – Coaxial l/4 resonator

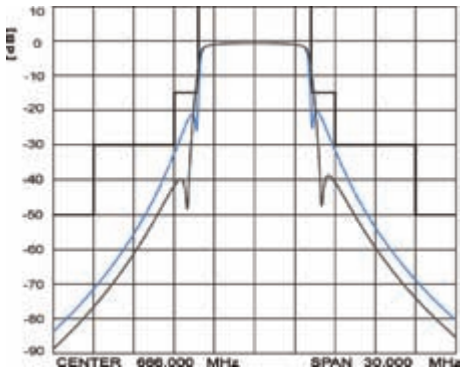


Fig. 9 – Simulation of filter characteristic with 6 cavities and a) two notch cavities, b) cross coupling

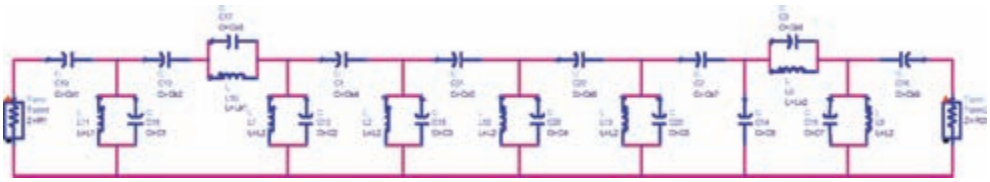


Fig. 10 – Filter circuit with six resonator cavities and two notch coupling

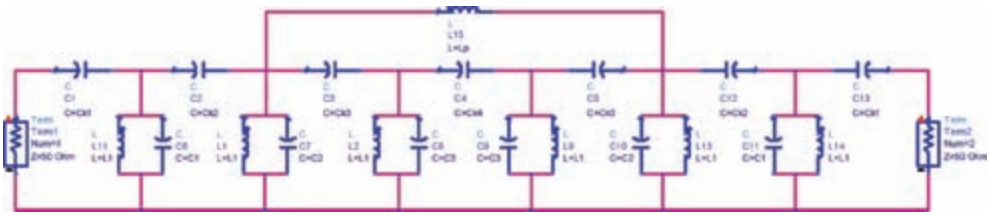


Fig. 11 – Filter circuit with six resonator cavities and cross coupling

4. Digital video broadcasting on handhelds (DVB-H)

Digital Video Broadcasting – Terrestrial (DVB-T), the current standard in digital video broadcasting, wasn't designed for mobile devices. However, as antenna technology improved, DVB-T mobile services became feasible, leading to extensive commercial trials. Digital TV reception on the move is an exciting advance in broadcasting.

However, handheld devices simply don't have the battery life to make DVB-T reception a viable option for consumers. A new solution was needed, DVB-H, or Digital Video Broadcast – Handheld, is that solution.

In addition to a great reduction of battery power consumption, DVB-H had other major requirements: maximum compatibility with DVB-T systems and networks, as well as the ability to receive 15 Mbit/s in an 8 MHz channel and in a wide area single frequency network at high speed.

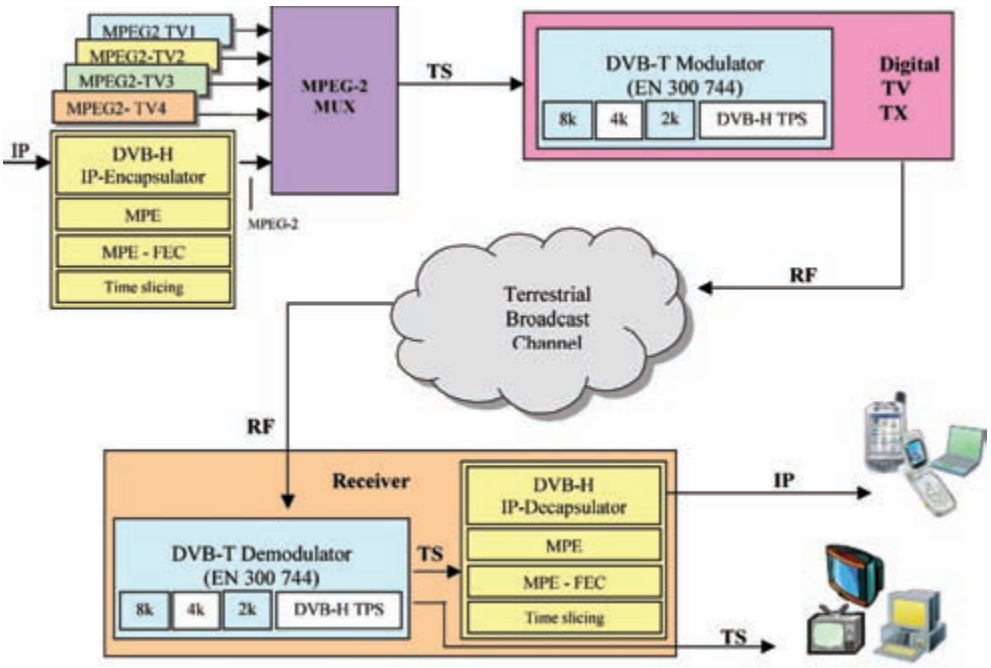


Fig. 12 – A conceptual description of using a DVB-H system

6. Conclusion

Today DVB-T is the most popular digital terrestrial television system in the world, adopted in more countries than any other. It has been successfully deployed in the UK, Germany, Sweden, Finland, Spain, Italy the Netherlands, Switzerland, Singapore and Australia. DVB-T trials are on-going in China, Malaysia, Thailand, Vietnam, Ukraine, Croatia, South Africa and others.

DVB-H is the latest development from the DVB Project targeting handheld, battery powered devices such as mobile telephones, PDAs, etc. Based on DVB-T excellent mobile performance, it answers need to ensure reliable, high speed, high data rate reception.

DVB-H combines broadcasting with a set of measures to ensure that the target receivers can operate from a battery and on the move, and is thus an ideal companion to 3G telecommunications, offering symmetrical and asymmetrical bi-directional multimedia services.

Intermodulation products caused by output power amplifier nonlinearities could be lowered to a great extent using a sufficiently large output backoff. That would mean a considerable amplifier efficiency factor drop, being uneconomical. As a compromise, the output backoff lowering is suggested to the extent, needed for the sum of IM products from output amplifier, of linear precorrection and of output filter unit to reach the value prescribed by EN 300744 standard for output spectral mask. For multimedia services is possible to distribute in frequency channel range (6, 7 or 8 MHz) four digital video signals with high quality or six digital video signals with lower quality.

Harris Broadcast Corporation Division attended award ceremony at the RAI Centre on IBC 2005 in Amsterdam with its new DVB-R Liquid Cooled Output Filter 5kW/UHF. Harris Broadcast Corporation received at IBC 2005 “Product of the Year” award by Cable and Satellite International. This filter was designed by Dr. Ivan Milak who received PhD degree with this work at the University of Zagreb, Faculty of Electrical Engineering and Computing, and his supervisor was Professor Branka Zovko-Cihlar, PhD.

All what Tesla foresee based on the development, experiments, patents from the field of high frequency we have today is result in his invention. All invention like alternating current, Tesla AC motors, Tesla coil, Tesla transformers, long distance current transportation, Tesla oscillator and many other innovation we used today.

All this new technology was Nikola Tesla's dream and this dream is now reality.

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[1] Tesla Memorial Society of New York, Available: http://www.teslasociety.com/

[2] Nikola Tesla, IEEE History Center – Legacies, Available: http://www.ieee.org/organizations/history_center/legacies/tesla.html

[3] B. Zovko-Cihlar, I. Milak, Intermodulation Products Suppression in Digital Video Transmitter for Multimedia Services, Proceedings of the 5th EURASIP Conference focused on Speech and Image Processing, Multimedia Communications and Services, EC-SIP-M 2005, Smolenice, Slovak Republic, 29 June – 02 July 2005, pp. I-1 – I-9

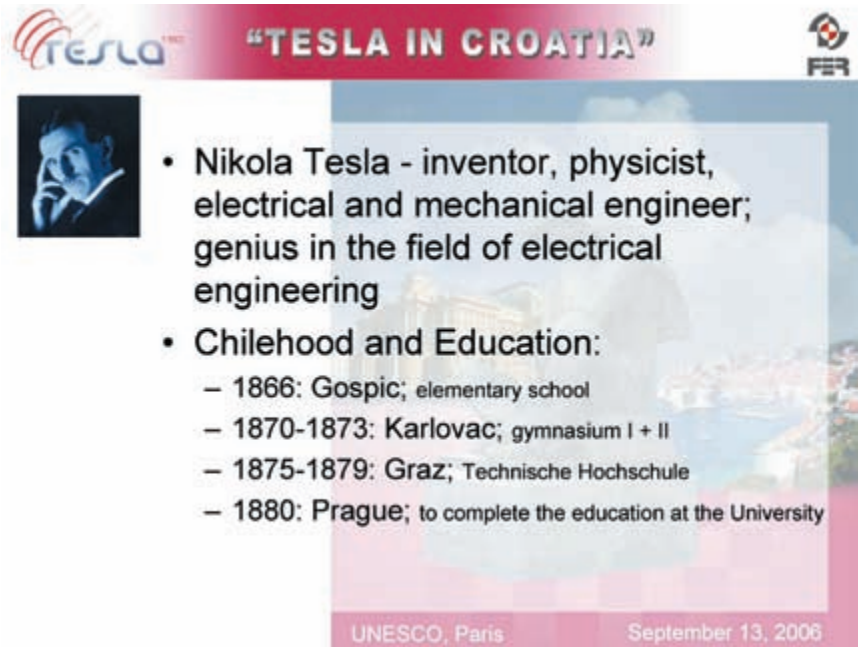
[4] H.H. Meinke, Electromagnetic Waves, "Nikola Tesla" Symposium, Zagreb, 07-10 July 1976, pp. 23-33

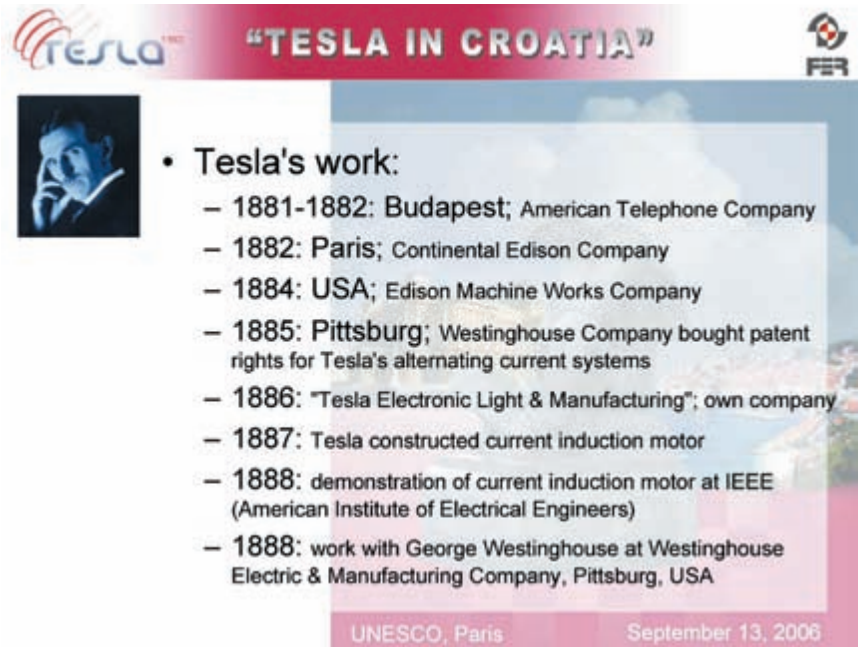
[5] A. Marincic, Nikola Tesla Research Notes from Colorado Springs, "Nikola Tesla" Symposium, Zagreb, 07-10 July 1976, pp. 47-60

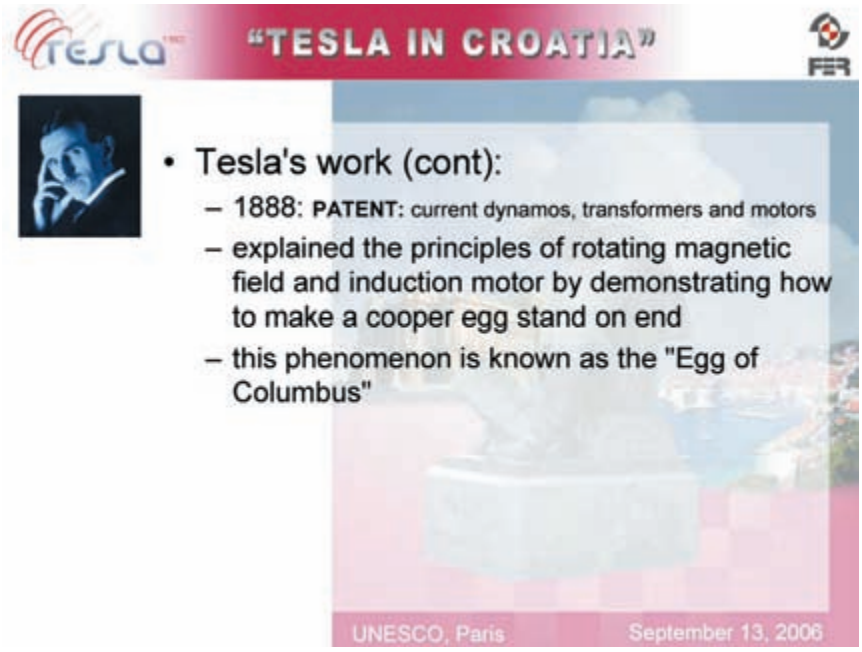
[6] Zovko-Cihlar, B., Tesla's Inventions in the Field of Radiocommunications, Proceedings of the 48th International Symposium ELMAR-2006 focused on Multimedia Signal Processing and Communications, Zadar, Croatia, 07-09 June 2006, pp. 1-4

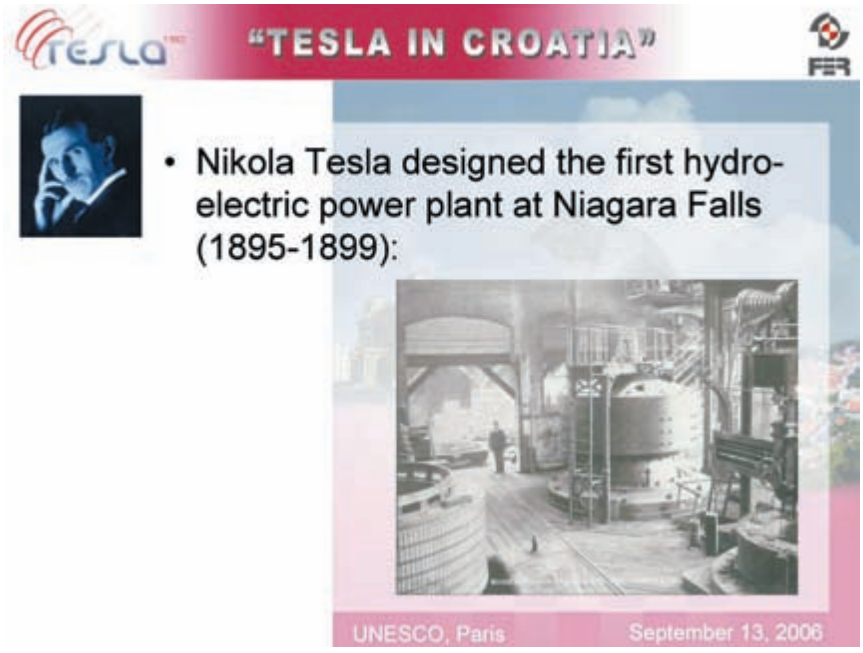
[7] Zovko-Cihlar, B., From Tesla's Inventions in the Field of Radiocommunications to Digital Broadcasting for Multimedia Services, Proceedings of the International Scientific and Professional Meeting "The Life and Work of Nikola Tesla", Zagreb, Croatia, 28-29 June 2006, pp. L14

Appendix


"TESLA IN CROATIA"
• Nikola Tesla - inventor, physicist, electrical and mechanical engineer; genius in the field of electrical engineering
• Chilehood and Education:
– 1866: Gospic; elementary school
– 1870-1873: Karlovac; gymnasium I + II
– 1875-1879: Graz; Technische Hochschule
– 1880: Prague; to complete the education at the University
UNESCO, Paris
September 13, 2006

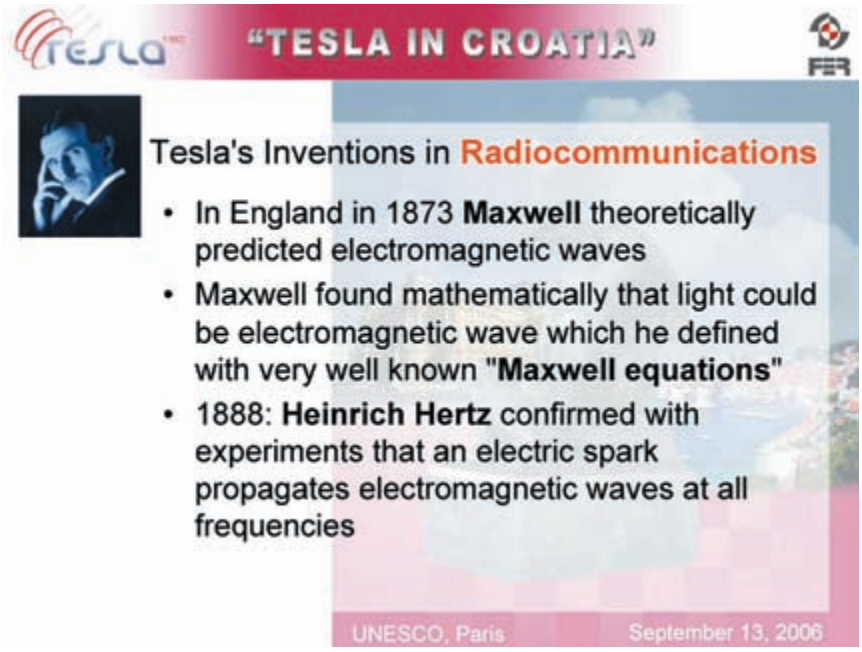

"TESLA IN CROATIA"
• Tesla's work:
– 1881-1882: Budapest; American Telephone Company
– 1882: Paris; Continental Edison Company
– 1884: USA; Edison Machine Works Company
– 1885: Pittsburg; Westinghouse Company bought patent rights for Tesla's alternating current systems
– 1886: "Tesla Electronic Light & Manufacturing"; own company
– 1887: Tesla constructed current induction motor
– 1888: demonstration of current induction motor at IEEE (American Institute of Electrical Engineers)
– 1888: work with George Westinghouse at Westinghouse Electric & Manufacturing Company, Pittsburg, USA
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
• Tesla's work (cont):
– 1888: PATENT: current dynamos, transformers and motors
– explained the principles of rotating magnetic field and induction motor by demonstrating how to make a cooper egg stand on end
– this phenomenon is known as the "Egg of Columbus"
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
• Nikola Tesla designed the first hydro-electric power plant at Niagara Falls (1895-1899):
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
• in the field of radiocommunications - 1898:
– radio controlled boat was demonstrated to the public during an electrical exhibition at Madison Square Garden
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
• Tesla - New York laboratories:
– research on wireless communications
– the result of wireless transmission of electricity through ionosphere was Wardenclyffe Tower with electrical sparks for transfer electricity without wires
– Tesla wanted to transmit electricity from this tower to the whole globe
"The Man out of Time"
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Tesla's Inventions in Radiocommunications
• In England in 1873 **Maxwell** theoretically predicted electromagnetic waves
• Maxwell found mathematically that light could be electromagnetic wave which he defined with very well known "**Maxwell equations**"
• 1888: **Heinrich Hertz** confirmed with experiments that an electric spark propagates electromagnetic waves at all frequencies
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Tesla's Inventions in Radiocommunications
• 1890 - illuminated vacuum tube by wireless transmission of energy through the air:
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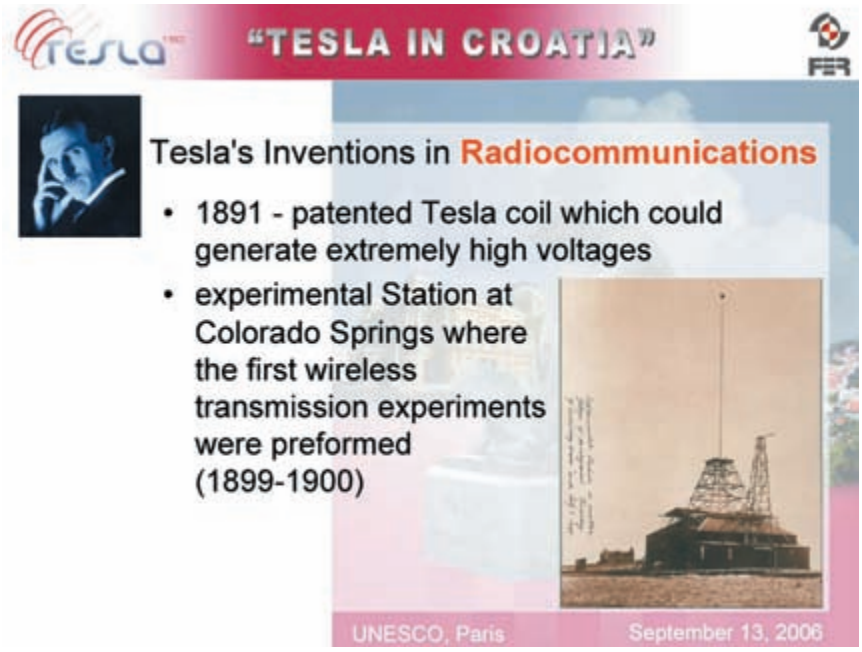
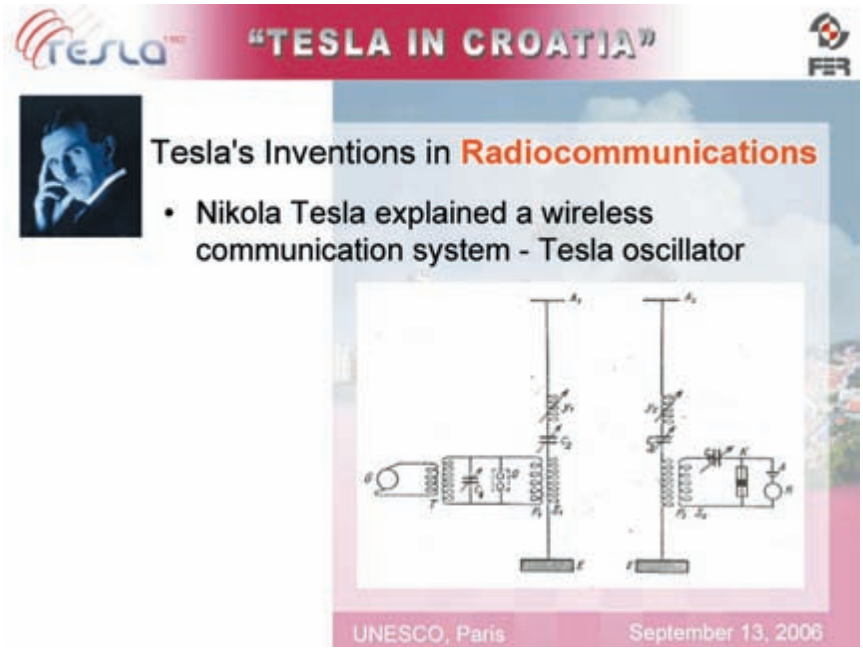
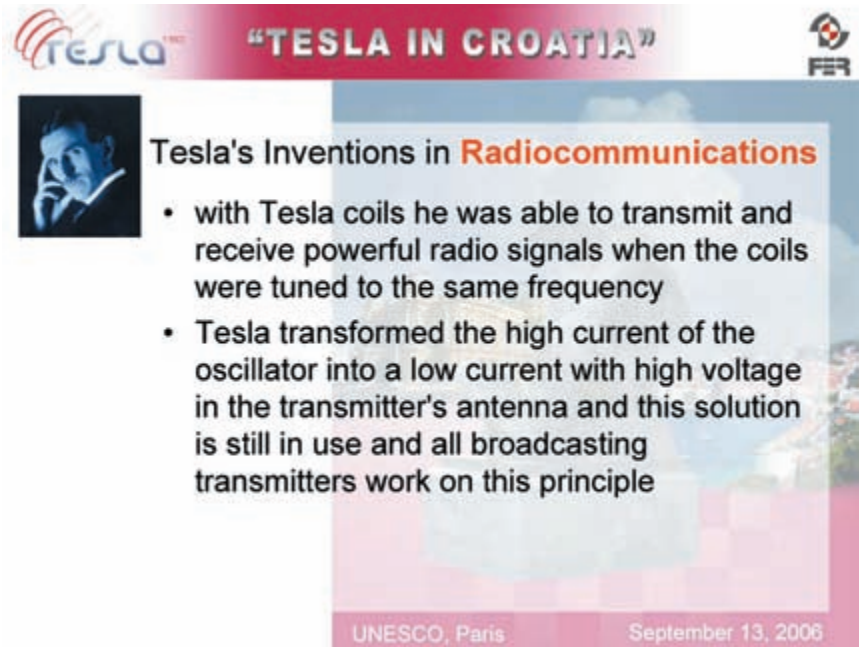
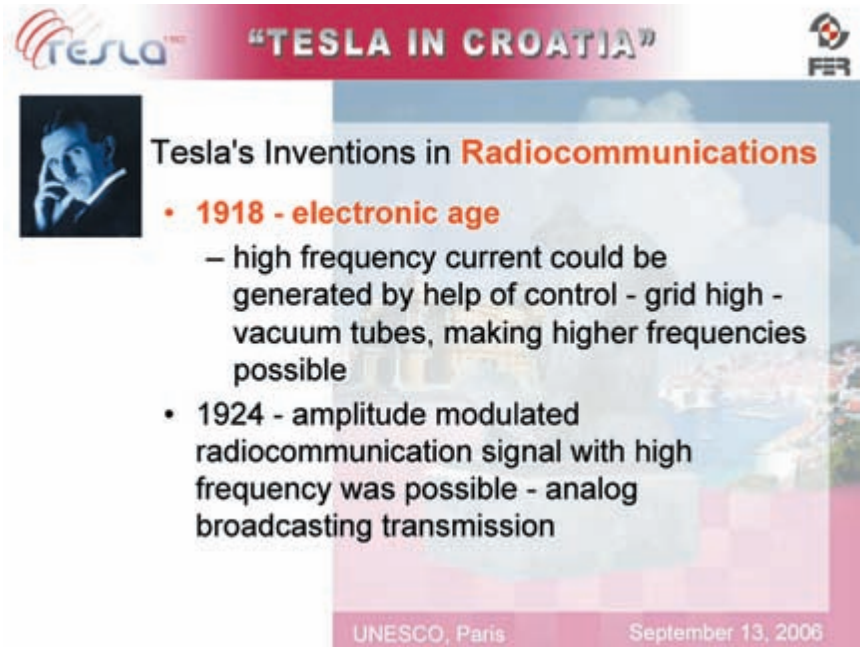

"TESLA IN CROATIA"
Tesla's Inventions in Radiocommunications
• 1891 - patented Tesla coil which could generate extremely high voltages
• experimental Station at Colorado Springs where the first wireless transmission experiments were preformed (1899-1900)
UNESCO, Paris
September 13, 2006

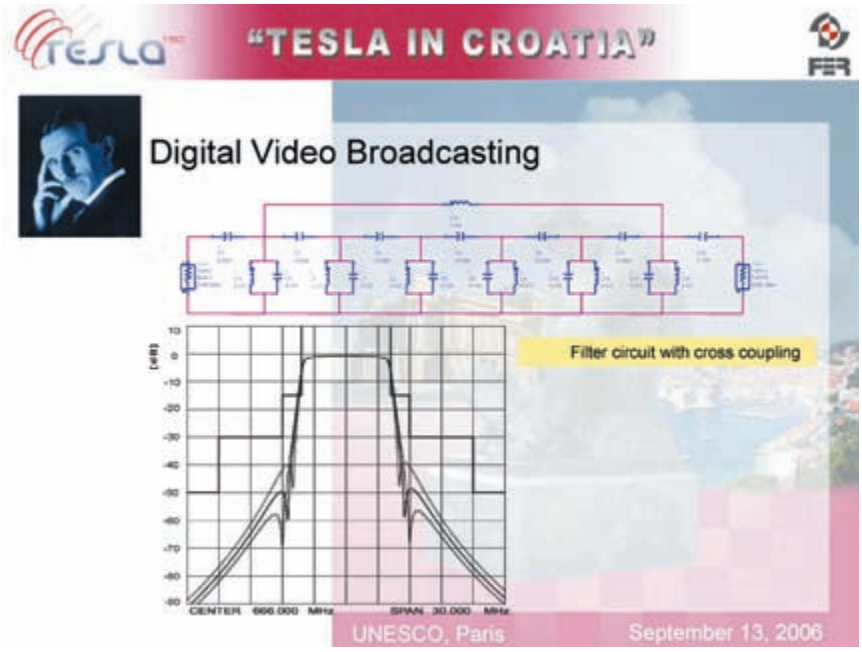

"TESLA IN CROATIA"
Tesla's Inventions in Radiocommunications
• Nikola Tesla explained a wireless communication system - Tesla oscillator
UNESCO, Paris
September 13, 2006

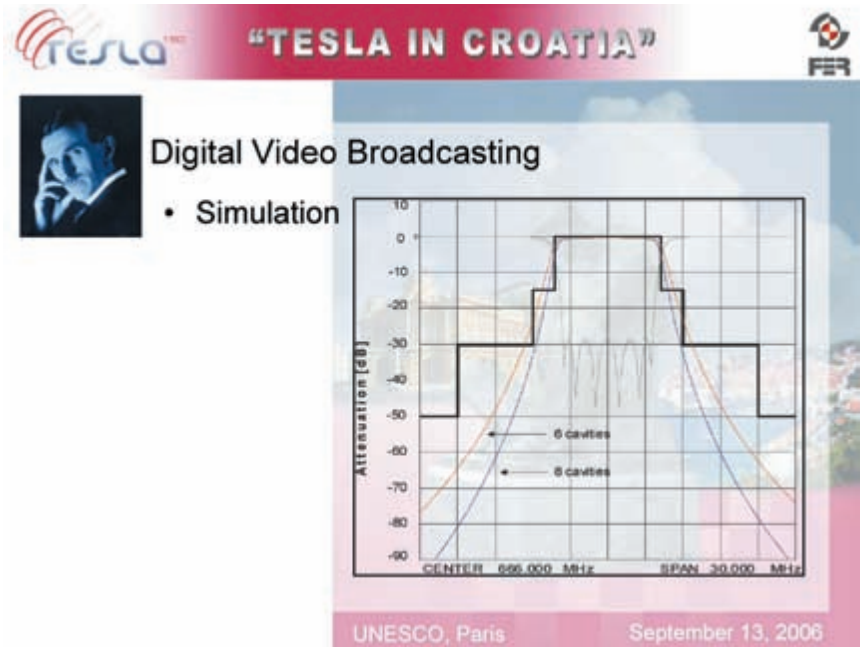

"TESLA IN CROATIA"
Tesla's Inventions in Radiocommunications
• with Tesla coils he was able to transmit and receive powerful radio signals when the coils were tuned to the same frequency
• Tesla transformed the high current of the oscillator into a low current with high voltage in the transmitter's antenna and this solution is still in use and all broadcasting transmitters work on this principle
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Tesla's Inventions in Radiocommunications
• 1918 - electronic age
– high frequency current could be generated by help of control - grid high - vacuum tubes, making higher frequencies possible
• 1924 - amplitude modulated radiocommunication signal with high frequency was possible - analog broadcasting transmission
UNESCO, Paris
September 13, 2006

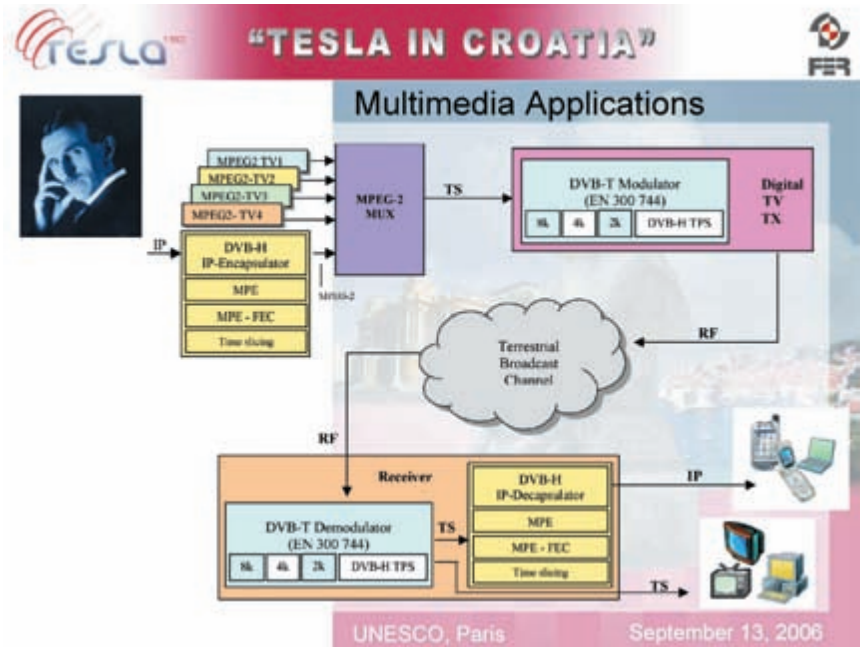

"TESLA IN CROATIA"
Digital Video Broadcasting
• at the end of 20th century digital signal transmission started, and this new technology enabled development of mobile systems, computer technology, digital television broadcasting and multimedia services transmission
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Digital Video Broadcasting
• RRC-0405 Regional Radiocommunication Conference
• Croatia is in revision of Stockholm planning in 1961
• the new digital Plan for Europe, Africa and part of Asia is in the frequency band of analog technology
• new is
– defining the conversion to "all digital future"
– defining out of work analog TV transmitters
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Digital Video Broadcasting
Filter circuit with cross coupling
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Digital Video Broadcasting
• Simulation
Attenuation [dB]
6 cavities
8 cavities
CENTER 666.000 MHz
SPAN 30.000 MHz
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Digital Video Broadcasting
• DVB-T Filter 5 kW
The Cable & Satellite International Product of the Year Awards 2005 were presented during IBC 2005 in Amsterdam
WINNER
Cable & Satellite International
2005
Product of the Year Awards
Best terrestrial wireless transmission solution
Harris Corporation
DVB-T Liquid Cooled Output Filter 5kW/UHF
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Multimedia Applications
MPEG2 TV1
MPEG2-TV2
MPEG2-TV3
MPEG2- TV4
MPEG-2 MUX
TS
DVB-T Modulator (EN 300 744)
8k
4k
2k
DVB-H TPS
Digital TV TX
IP
DVB-H IP-Encapsulator
MPE
MPE - FEC
Time slicing
RF
Terrestrial Broadcast Channel
Receiver
DVB-T Demodulator (EN 300 744)
DVB-H IP-Decapsulator
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
Conclusion
• today DVB-T is the most popular digital terrestrial television system in the world:
– UK, Germany, Sweden, Finland, Spain, Italy The Netherlands, Switzerland, Singapore, Australia, China, Malaysia, Thailand, Vietnam, Ukraine, Croatia, South Africa and others
• all this new technology was Nikola Tesla's dream and this dream is now reality
UNESCO, Paris
September 13, 2006

Kurt R. Richter, born in Vienna, Austria, in 1933, graduated in Communication Engineering in 1958 and received his PhD 1961 from the University of Technology in Vienna (TUW), Austria. He was Associate Professor at the TUW before he became Full Professor for Fundamentals of Electrical Engineering at the Technical University Graz (TUG), Austria, in 1975. Since 2000 he is Professor Emeritus at the TUG. From 1971 to 1973 he worked for 2 years as a scientist at the Advance Projects Directorate at the Goddard Space Flight Center of NASA in Greenbelt, MD, USA.

Since 1980 he is actively involved in IEEE in many positions (Founding chairman of the IEEE Austria Section, Director of IEEE Region 8 etc.). From 2001 – 2003 he was a member of the IEEE Educational Activities Board (EAB) and member of several EAB committees as the Committee for Global Accreditation Activities and others.

He is an IEEE Fellow, a corresponding member of the Austrian Academy of Sciences and honorary member of the Croatian Academy of Technical Sciences.

He is Senior Trainer in an IEEE Region 8 Workshop Program on "Development of Leadership Skills" and has conducted many workshops in Europe; Africa and the Middle East.

Nikola Tesla' European Time

Kurt R. Richter

In 2006 we celebrate the several outstanding personalities, like Wolfgang Amadeus Mozart, Sigmund Freud, Berthold Brecht, and, last not least Nikola Tesla. On the 10th July 1856 Nikola Tesla was born, the "Man who Invented the 20th Century" as the Austrian newspaper "Der Standard" entitled an article in 1992. On the 17th January 1756 Mozart was born and 100 years later, Tesla, two geniuses who were so different and yet very similar in their ingenuity. I even dare to compare Tesla and Mozart two outstanding personalities whose achievements, of course, were totally different. Mozart, for instance, wrote more than 600 compositions while Tesla's patented inventions count more than 200, some even count 700. Both had the ability to develop and design their ideas in their heads so completely that no corrections were necessary to be made at the later stage of realisation. Mozart's handwritten handwritten sheets of music of his compositions show almost no corrections. It was the same with Tesla who said about himself, that he had developed all his inventions and experiments in his head ready for realization. Tesla once wrote "The images I saw were to me perfectly real and tangible".

Tesla was a marvellous inventor, an "Ingenieur" in the very meaning of the word ingenious and not an engineer the roots of which are the engine. In my presentation I will try to cover the time Tesla lived, studied and worked in Europe before he left for the United States of America in 1884 to work as an employee of Thomas Alva Edison.

Fig. 1 – The k.k. Austro-Hungarian Monarchy (1914 and after World War I)

In my presentation I will try to cover the part of Tesla's time before he left Europe emigrating to the United States of America.

As one of 5 children Nikola Tesla was born in Smiljan in the province of Lika, which was in the frontier lands between the KK Austro-Hungarian Monarchy, one of the strong powers in Europe and the Osman Empire. Figure 1 shows the map Austria– Hungary before and after World War I, when it fell apart into several states of various nationalities.

Tesla was born after the Crimean War and died during the most disastrous World War II. No wonder he became a pacifist as so many others.

As a young boy he very soon became passionate about reading first in the library of his father who was a Serbian-Orthodox clergyman. However, after he had met Edison in USA Tesla believed he "… had studied a dozen languages, delved in lit-

erature and art, and had spent all my best years in libraries reading all sorts of stuff that fell in my hands". Later he became extremely self-disciplined and accurate. He learned to memorize whole books with poems which seems that he had trained his brain so much that he could imagine complicated structures and coherences.

Tesla's education started in primary schools of Smiljan and Gospic followed by 4 years at the middle school there. He finished middleschool in 1874 in Karlovac. Only after a critical Cholera disease his parents agreed that he might study physics, and so, in 1855, Tesla became a student at the "Kaiserlich-königliche Technische Hochschule in Graz" which is today the University of Technology in Graz. Only one year before Tesla registered the Polytechnic Institute, financed by the province of Styria, it was transferred to a Technical Hochschule which would be called nowadays a federal school. From 1878 on the "Kaiserlich-königliche Technische Hochschule in Graz" final examinations became "Staatprüfungen" (stately examinations). However, doctoral degrees could not be awarded before 1901.

But all this did not bother young Tesla. He left Graz without any degree after the Education Department of the "*K.K. Generalkommando in Agram* (Zagreb)", which administrated the Borderland, stopped the continuation of the stipend. The last recording in the registration reads: "*Wegen Nichtbezahlung der Unterrichtsgelder fuer das 1. Semester 1877/78 gestrichen*". Probably in order to avoid military service in the Austr-Hungarian monarchy he applied for financial support to the Serbian patriotic organization *Serbian Queen Bee* in Novi Sad on October 14, 1976. However, his request was rejected.

Tesla was an excellent student and in his annual report he had the best marks available even he had an interesting discussion with his professor in Experimental Physics. Prof. Poeschl was a well known professor of high reputation. In a lecture he demonstrated a Gramme machine which he had recently received when Tesla meant that a brushless motor would have much less spark generation and therefore less losses and noise. Poeschl answered that Tesla might be a very clever man, however, his ideas could never become reality because it would be equivalent to a *perpetuum mobile*.

Fig. 2 shows a photograph taken in those years either in Graz or Maribor.

Fig. 2 – Nikola Tesla

Much later, Tesla received the Honorary Doctorate from the *Technische und Montanistische Hochschule Graz* in 1937. That of the University in Vienna he had received already in 1908. Also in 1937 he was nominated for the Nobel Prize in Physics by the Viennese professor of Physics at the University of Vienna Felix Ehrenhaft (1879 – 1952).

Because of the lack of financial support Tesla left Graz without graduation and went for a short time to Maribor where he stayed from autumn of 1878 to March 1879. After almost one year in Gospic he went to Prague in 1880 following the request of his father to graduate from a university. He never graduated from the university there either and some biographers mention that he could not even register at the university because he did not speak Czech. However, the registry of the university in Prague show that Tesla was registered as an "external" studentattending lectures in analytical geometry and experimental physics.

When he felt that his parents had to make too great sacrifices for him he decided to be no longer a burden for them. He accepted a position at a Hungarian telephone company in Budapest. There, in February 1882, as a 25 years old man he had the innovative idea of the principles of rotating fields. 37 years later Tesla himself described it that the idea had enlightened him like a flash. It happened during a walk in the City Park of Budapest when the age of alternating current machines began. In this moment his further fate determined him to become an "engineer" and inventor whose genius even today seems to be an inexhaustible source for science and technology. Nevertheless, again and again his name became forgotten, however, popping up brilliantly periodically. This Symposium and all the events in connection with his 150th birthday are perfect opportunities to let Tesla's name shine as brilliant as it deserves.

In the same year of this important walk, in Budapest by recommendation of a friend he was offered a position at Continental Edison in Paris. There he experimented with rotary current field motors and built first models whenever he had the opportunity. In Summer of 1983, in Strasbourg he was successfully building the first operable motor without sliding contacts (brushes) and without commutator.

Encouraged by the director of Continental Edison and American friends in Paris he left Europe in June 1884 and joined Edison Machine Works in the United States. In 1891, when Tesla was 35 years old, he received the Citizenship of the United States of America. Until then all his inventions and all patents granted to him are achievements of a European living and working in the United States of America. At this time he was still a citizen of the Austro-Hungarian monarchy, and in particular a citizen of the Kingdom of Hungary.

His inventions and discoveries were pioneering in many areas. But already during his life time his personality was disputed and he was involved in many quarrels as far as his patents were concerned which all seemed to have been solved in his favour.

Already during the turn of the last century in many textbooks his name did not exist. Nowadays his name is remembered only by the Tesla transformer to generate high voltages at high frequency and by the measuring unit of the magnetic field. Also many of his patents are so much forgotten that today sometimes patents are issued which can be seen near those of Tesla's. Maybe Tesla himself contributed unconsciously to the loss of his high reputation by his patents applications and publications of his later years. Mostly the clarity of engineering thinking seems to be missing or are his ideas not understood yet? I do not dare to answer this question. Who knows what will be in the future and how many thoughts will be thought which Nikola Tesla had already thought.

What the application of his achievements in the future is concerned I would like to refer to what Niels Bohr once said: "*Predictions are very difficult to be made, in particular when they deal with the future*".

There are many open questions and open for speculations, like what Tesla meant by the *Death Rays*. Did he mean by it a corpuscular radiation? He was talking about these rays as a weapon, which will banish wars for ever? Unfortunately, however, in this case I believe he was absolutely wrong. Because with weapons wars are never avoided as soon as the other side possesses the same or equivalent weapons. I believe in Mahadma Ghandi's words: "*There is no way to peace, peace is the way*".

Another example is the *Free Energy* of Tesla which would help to solve the energy problem of the world. Is it just an illusion or had he already heard about the dark energy in space which plays an important role in cosmology nowadays?

After all the scientific community continues to be interested and mankind still benefits and even in the future will benefit from the numerous contributions to modern technology of this genius.

No doubt, his contributions changed the world and still are not out of date. They will help to keep on developing civilisation and the wellbeing of humanity.

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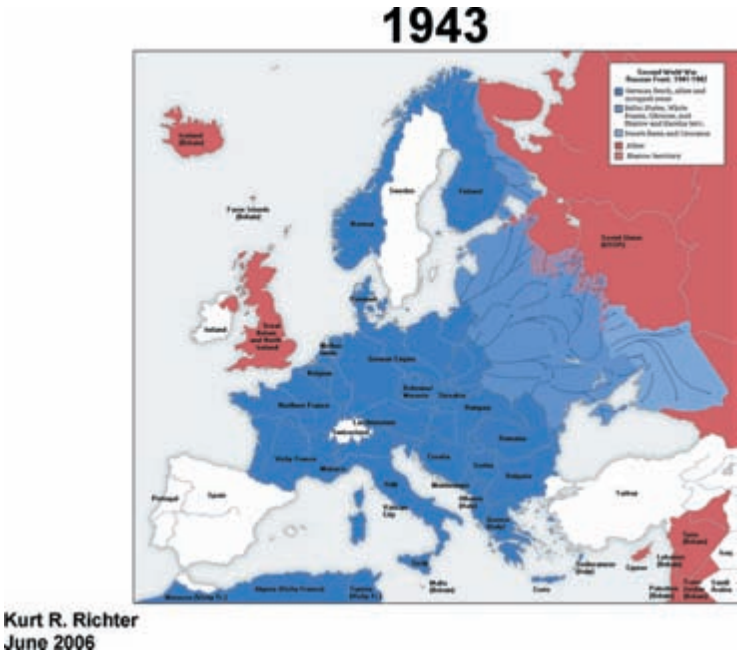
Appendix


Europe 1849
EUROPA
Kurt R. Richter
June 2006


Nationalities in k.k. Monarchy
Distribution of Races in Austria-Hungary.
Kurt R. Richter
June 2006


Nationalities
DEUTSCHES REICH
RUSSISCHES REICH
DEUTSCHLAND
SOWJETRUSSLAND
TSCHECHOSLOWAKEI
ÖSTERREICH
UNGARN
SCHWEIZ
ITALIEN
RUMÄNIEN
KÖNIGREICH DER SERBEN, KROATEN UND SLOWENEN
SERBIEN
BULGARIEN
ADRIA
Schwarzes Meer
Das Ende Österreich - Ungarns
Kurt R. Richter
June 2006


1943
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June 2006

Education

1862 – 1866	Gospic	Elementary School
1866 – 1870	Gospic	Real Gymnasium
1870 – 1873	Karlovac	Gymnazia Karlvac
1873	Karlovac	Graduation
1875 – 1878	Graz	Techn. Hochschule
1880	Prague	University ?

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Polytechnic Institute
Raubergasse

Built 1665 – 1674
Benedictine Monastery

1811 – 1874
Polytechnic Institute

1874 – 1888
k.k. TH Graz

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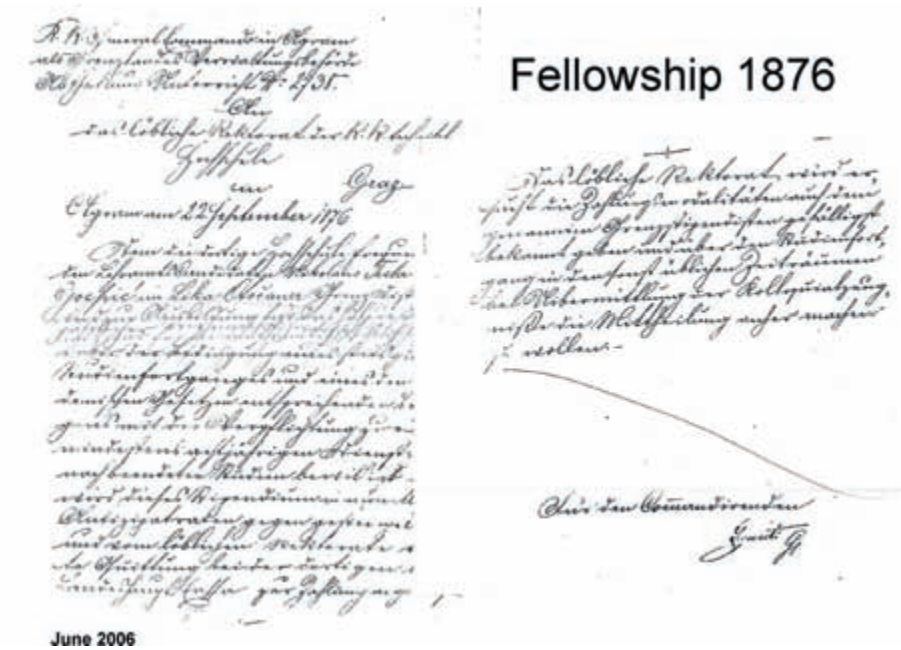
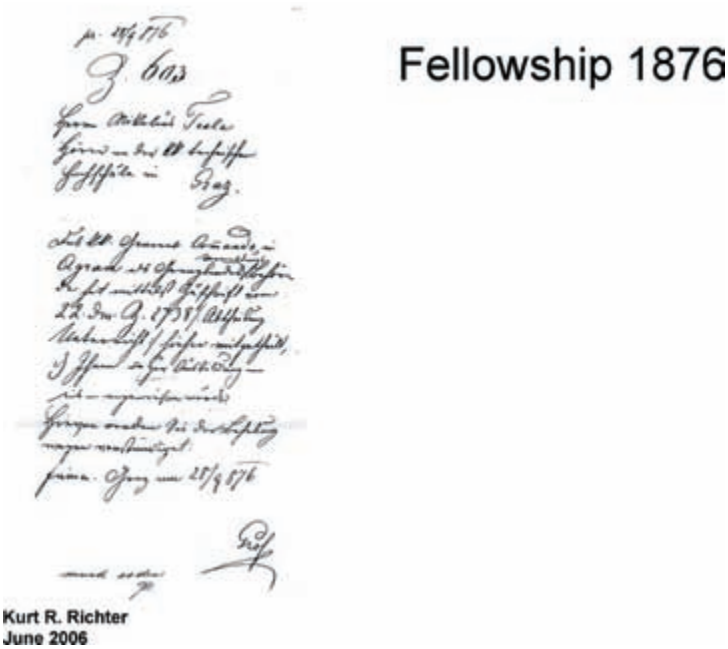
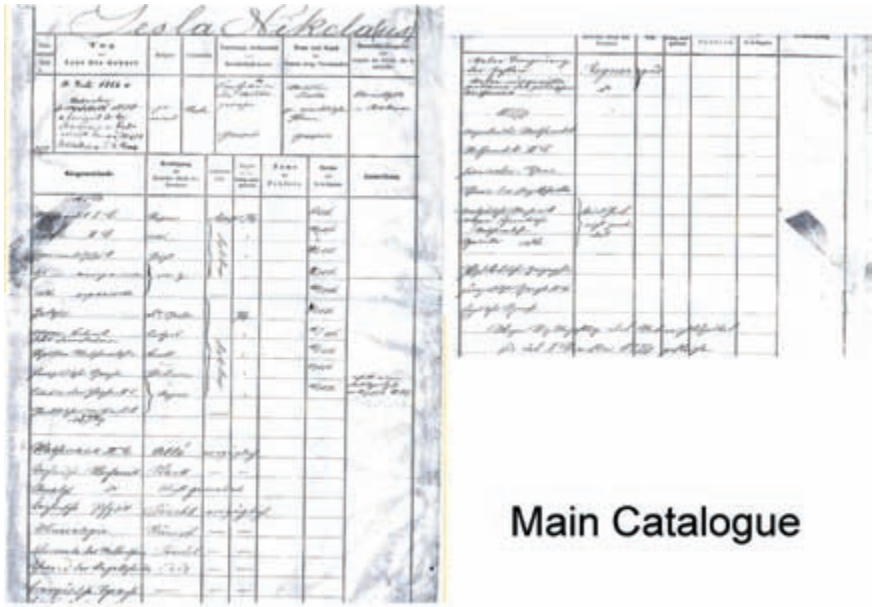

Fellowship 1876
June 2006


Fellowship 1876
Kurt R. Richter
June 2006



1875/76

Lecture		hours	Professor
Mathematics I	7	Rogner	excellent
Mathematics II	7	Allè	excellent
Experimental Physics	5	Pöschl	excellent
Organic Chemistry	5	Maly	excellent
Inorganic Chemistry	5	Maly	excellent
Zoology	5	Graber	excellent
General Botanic incl. Demonstrations	3	Leitgeb	excellent
Mechanical Eng.	2	Bartl	excellent
French Languish	3	Plisnier	excellent
Cubature of Planes 2	2	Rogner	excellent
Political Arithmetic	2	Rogner	excellent

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June 2006

1876/77

Lecture	hours	Professor	
Mathematics III	6	Allè	excellent
Technical Mech.	5	Stark	excellent
Analytical Mech.	2	Stark	No registration
Technical Physics	3	Pöschl	excellent
Mineralogy	3	Rumpf	–
Elements of Wave theory	2	Pöschl	–
Theory of Conic Sections	2	Pelz	–
French II	2	–	–
English	4	–	–
On Congruencies of Numbers	2	Rogner	o.k.
Problems in Political Arithmetic	2	Rogner	o.k.

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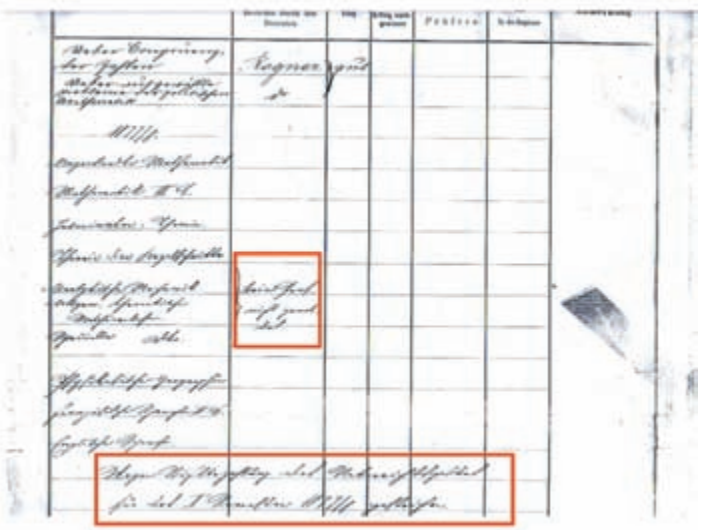
Last Year in Graz



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Request for Information

Tesla's Professional Activities

1879	Maribor, Technician
1881 – 1882	Budapest, Telephone Company
1882 – 1883	Paris, France, Continental Edison Company
1883 – 1884	Strasbourg, France
1884	Emigration to US
(1891)	(US Citizenship)

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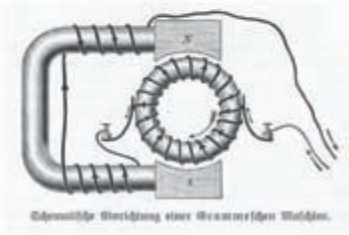
A Crucial Experience

Grammé Machine



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June 2006

Nikola Tesla and Jakob Pöschl

When in an experimental lecture in physics Tesla proposed an improvement of the Grammé machine demonstrated by Prof. Pöschl, the latter stated:

"Mr. Tesla may accomplish big things but in this he never will be successful. This would be similar to divert a continuous attraction like gravity into a rotating movement. It would be a Perpetuum Mobile. An impossible idea."

Kurt R. Richter
June 2006

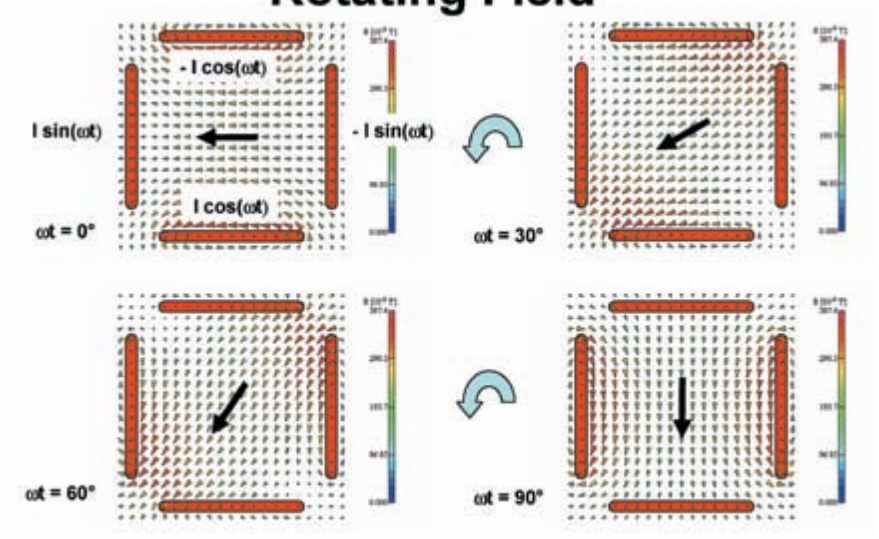
Budapest City Park Experience

..... the idea came like a flash of lightening and in an instant the truth was revealed. .....
.....The images I saw were wonderfully sharp and clear and had the solidity of metal and stone, ...
..... I cannot begin to describe my emotions. Pygmalion seeing his statue come to life could not have been more deeply moved. A thousand secrets of nature which I might have stumbled upon accidentally, I would have given for that one which I had wrested from her against all odds and at the peril of my existence.....

My Inventions: Autobiography of Nikola Tesla

Kurt R. Richter
June 2006

Rotating Field



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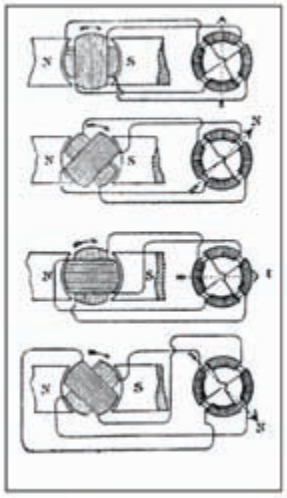
Tesla Motor



Reconstruction in Tesla Museum, Belgrade
and in Deutsches Museum, Munich

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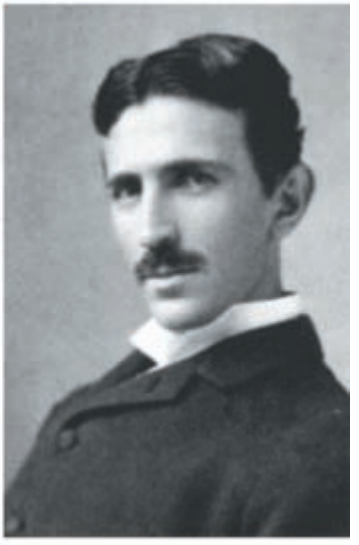
June 2006

Tesla (about 1884)

1884
The year of emigration
to the
United States of America



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Doctor honoris causa

University of Paris
Vienna Polytechnic Institute
University de Poitiers
University of Beograd
Techn. Hochschule Graz
University of Brno
University of Zagreb
Polytechnic Institute of Bucharest
University of Grenoble
University of Sophia
University of Prague

Columbia University
Yale University

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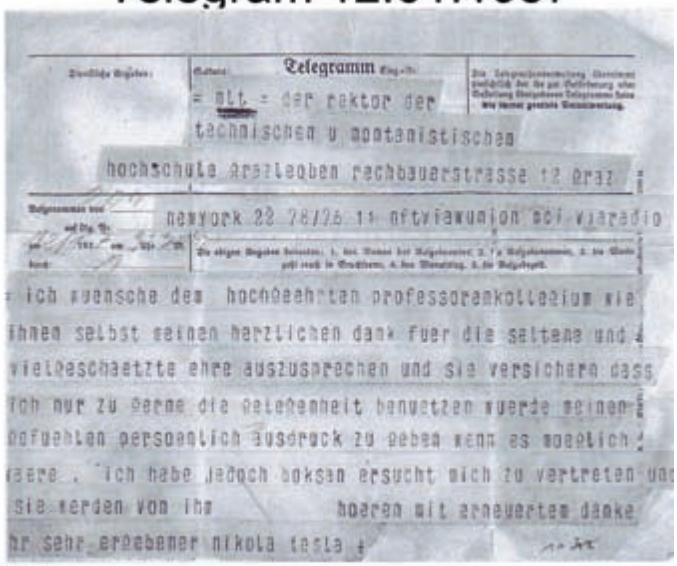
June 2006

Telegram 12.01.1937


Telegramm

= dlt = der rektor der
technischen u montanistischen
hochschule ersteleben rechbauerstrasse 12 graz
newyork 22 78/26 11 oftviewunion aci viaradio
ich wuensche dem hochgeehrten professorenkollegium wie
ihnen selbst seinen herzlichen dank fuer die seltene und
vielgeschaetzte ehre auszusprechen und sie versichere dass
ich nur zu gerne die gelegenheit benuetzen wuerde meinen
gefuehlen persoenlich ausdruck zu geben wenn es moeglich
waere . ich habe jedoch boksan ersucht mich zu vertreten
sie werden von ihm hoeren mit erneuertem danke
ihr sehr ergebener nikola tesla

Kurt R. Richter
June 2006

Kurt R. Richter
June 2006

Certificate

Kurt R. Richter
June 2006

Awards

- 1893 The Franklin Institute's **Elliott Cresson Gold Medal**
- 1916 AIEE (IEEE) **Edison Medal**
- 1934 **John Scott Medal**
- 1937 Nomination for an **undivided Nobel Prize**
  (by Prof. Felix Ehrenhaft, University of Vienna)

Kurt R. Richter
June 2006

Quotes

Niels Bohr (1885 – 1962), Danish Physisist

"Prediction is very difficult, especially about the future."

Nikola Tesla:

"Let the future tell the truth, and evaluate each one according to his work and accomplishments. The present is theirs; the future, for which I have really worked, is mine."

Kurt R. Richter
June 2006

Wardencliff Tower

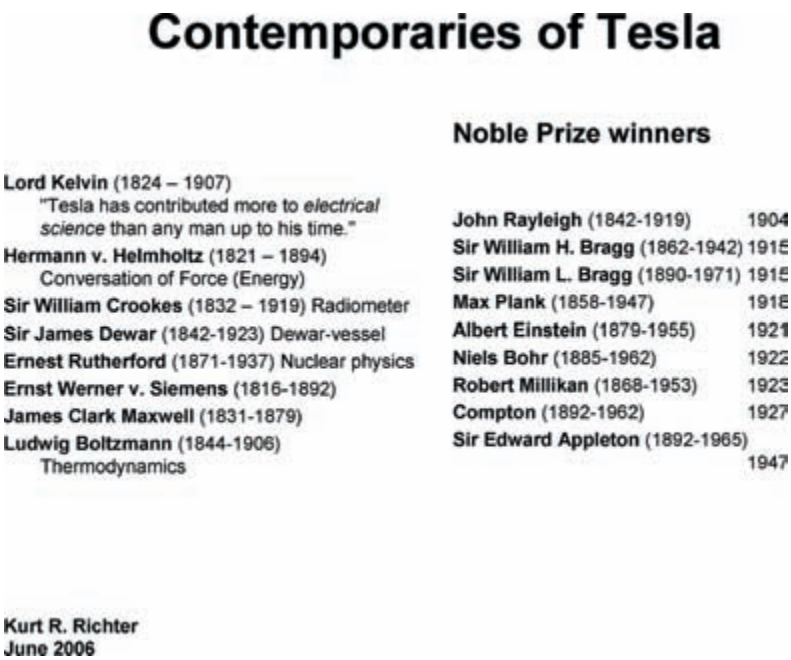
Kurt R. Richter
June 2006

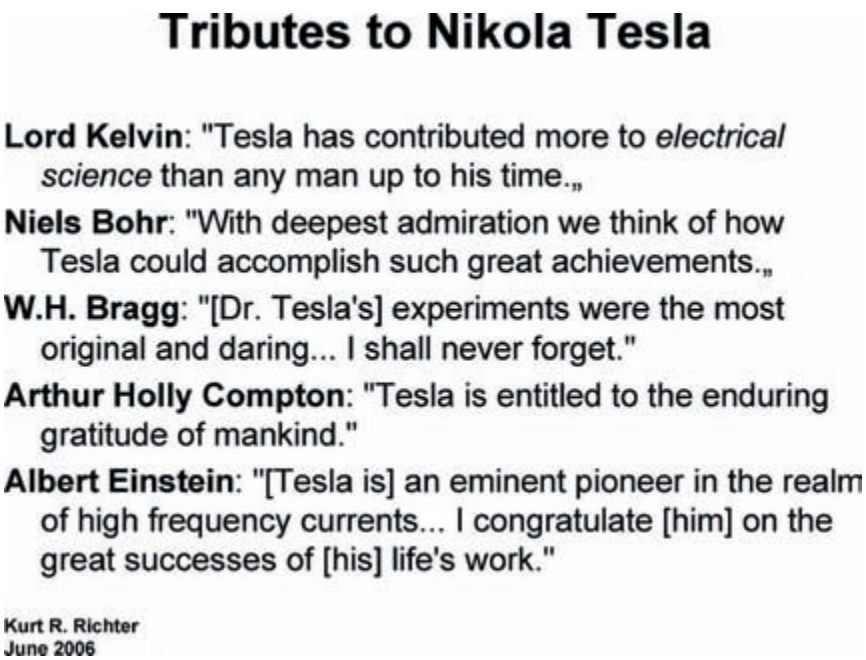
Societies of the Institute of Electrical and Electronic Eng. (IEEE)

Aerospace and Electronic Systems
Antennas and Propagation
Broadcast Technology
Circuits and Systems
Communications
Components, Packaging, and Manufacturing Technology
Computational Intelligence
Computer
Consumer Electronics
Control Systems
Dielectrics and Electrical Insulation
Education
Electromagnetic Compatibility
Electron Devices
Engineering Management
Engineering in Medicine and Biology
Geoscience and Remote Sensing
Industrial Electronics
Industry Applications
Information Theory
Instrumentation and Measurement
Intelligent Transportation Systems
Lasers and Electro-Optics
Magnetics
Microwave Theory and Techniques
Nuclear and Plasma Sciences
Oceanic Engineering Power Electronics
Power Engineering
Product Safety Engineering
Professional Communication
Reliability
Robotics and Automation
Signal Processing
Social Implications of Technology
Solid-State Circuits
Systems, Man, and Cybernetics
Ultrasonics, Ferroelectrics, and Frequency Control
Vehicular Technology

Kurt R. Richter
June 2006

Tesla's inventions contributed to 50% of the fields covered by the 38 IEEE Societies


Contemporaries of Tesla
Noble Prize winners
Lord Kelvin (1824 – 1907)
"Tesla has contributed more to electrical science than any man up to his time."
Hermann v. Helmholtz (1821 – 1894)
Conversation of Force (Energy)
Sir William Crookes (1832 – 1919) Radiometer
Sir James Dewar (1842-1923) Dewar-vessel
Ernest Rutherford (1871-1937) Nuclear physics
Ernst Werner v. Siemens (1816-1892)
James Clark Maxwell (1831-1879)
Ludwig Boltzmann (1844-1906)
Thermodynamics
John Rayleigh (1842-1919) 1904
Sir William H. Bragg (1862-1942) 1915
Sir William L. Bragg (1890-1971) 1915
Max Plank (1858-1947) 1918
Albert Einstein (1879-1955) 1921
Niels Bohr (1885-1962) 1922
Robert Millikan (1868-1953) 1923
Compton (1892-1962) 1927
Sir Edward Appleton (1892-1965) 1947
Kurt R. Richter
June 2006


Tributes to Nikola Tesla
Lord Kelvin: "Tesla has contributed more to electrical science than any man up to his time.„
Niels Bohr: "With deepest admiration we think of how Tesla could accomplish such great achievements.„
W.H. Bragg: "[Dr. Tesla's] experiments were the most original and daring... I shall never forget."
Arthur Holly Compton: "Tesla is entitled to the enduring gratitude of mankind."
Albert Einstein: "[Tesla is] an eminent pioneer in the realm of high frequency currents... I congratulate [him] on the great successes of [his] life's work."
Kurt R. Richter
June 2006

M. sc. **Gordana Kovačević**, President of Ericsson Nikola Tesla

Effective January 1, 2005 Gordana Kovačević has been appointed new President and CEO of the company Ericsson Nikola Tesla. Simultaneously, she is Vice President of the Market Unit Central Europe comprising seven European countries (Croatia, Slovenia, Bosnia and Herzegovina, Hungary, Poland, Czech Republic, Slovakia, Austria).

She received B.E. and M.E. in Telecommunications and Informatics from the University of Zagreb, Faculty of Electrical Engineering & Computing Science. In Nikola Tesla, where she started her professional career, Mrs. Kovačević as a respected professional was the head of the most complex Tesla's telecommunications projects on local and foreign markets. During her career in Nikola Tesla she was filling numerous managerial posts from department manager, director of project design office to technical director of marketing and sales.

In 1995, when Nikola Tesla became a part of the Ericsson corporation, Mrs. Kovačević was appointed Vice President of the company Ericsson Nikola Tesla and Vice President of the Ericsson Market Unit Central Europe. At the same time she was the Director of the Centre for Communications Solutions, Services, Logistics and e-systems in Ericsson Nikola Tesla.

In 2001 Gordana Kovačević was included in the program for training the highly-placed managers in the Ericsson corporation – "Executive Program" (Columbia University – Graduate School of Business). This program comprises carefully selected Ericsson leaders who have shown exceptional results in the most complex jobs and nonstandard tasks and have potentials to conduct business and organization successfully in the conditions difficult to predict.

Gordana Kovačević played a decisive role in the process of recognizing the company Ericsson Nikola Tesla at the corporate level. Namely, at all corporate levels, Mrs. Kovačević supported and managed to prove that the Croatian company, thanks to its competent specialists, obtained responsibilities to create complex projects for modern telecommunications solutions on numerous Ericsson markets. Successful realization of the projects fastened the position of Ericsson Nikola Tesla at the corporate level and also ensured the company to be a respectable regional and global centre of excellence and knowledge within Ericsson.

During her successful career Gordana Kovačević has received a lot of recognitions and awards:

In 2000 academician of the Russian International Telecommunication Academy;

The title of the Business Woman of the Year 2001 in Croatia.

In June 2004 the Manager of the Year within the ICT industry.

In November 2004 the best Croatian manager in 2004 in the category of big companies by the Croatian Association of Manager and Entrepreneurs – CROMA

In July 2006 The Order of Croatian Star with the Effigy of Nikola Tesla by President of the Republic of Croatia.

Ericsson Nikola Tesla: Following Tesla's Vision

Gordana Kovačević

It is not necessary to answer the question concerning to whom we owe today's way of living, but it is possible. Among the 19th century visionaries and scientists who set the foundations for the present – day standards of living there is a genius mind that stands out. The rich scientific heritage bestowed to humanity by Nikola Tesla (1856 – 1943) has been incorporated in our daily lives in so many ways that we use it hundreds of times a day without even being aware of it.

This year is the Year of Nikola Tesla, the year in which we remember and appreciate this great man, his discoveries and inventions.

He indebted the humanity by his inventions in the field of alternating current, the principle of rotating magnetic field and the improvements of induction motor and fluorescent lighting. By his series of about 700 of inventions he pointed way for the development of the modern civilization.

Tesla's dream comes true

Tesla was a visionary genius. There aren't many of them. And he was willing to give his life to his visions. And for that reason he probed deeply into the secrets of nature and gave us the contributions that he did.

In 1909, Guglielmo Marconi was awarded a Nobel Prize for his development of radio. The history books began to refer to him as "the father of radio."

Nikola Tesla is now credited with having invented modern radio; the Supreme Court overturned Marconi's patent in 1943 in favor of Tesla.

We still use radio in our everyday life, but the more important fact is that when we use the mobile phone…The mobile telephony made the dream about communication anytime, anywhere comes true. The basic modern human needs: mobility, availability and speed are satisfied.

It is impossible to find an answer to the question whether the progress of the mankind accelerated the development of communications, or whether the need for more effective ways to communicate set the path of human progress. The development of the human society and communications go hand in hand and it is neither necessary nor possible to separate them.

Today, Ericsson Nikola Tesla is a provider of total ICT solutions and member of the Ericsson group. The company's activities incorporate the entrepreneurship of Lars Magnus Ericsson and the visionary spirit of Nikola Tesla. Its name reminds the community of these two great men who contributed to the foundation of the new communications era. This described powerful combination has brought value to Croatia and to Ericsson as well as to our customers who will substantially benefit from that combination.

Our work approach has always been founded on innovativeness and flexibility and implied investigating the limits of current truths and trends. It seems to be quite natural for us to promote the greatness of Nikola Tesla and to provide opportunities for young specialists to participate in setting global technology trends. I sincerely believe that Nikola Tesla himself would be proud to know that in his old homeland there are research and development and also expert knowledge centers that successfully develop modern information and communication technologies. Ericsson Nikola Tesla endeavors to follow Tesla's lead on the way to prosperity. As a member of global Ericsson we participate in searching the possibilities to create better life for all people, an objective, I believe, worthy of Tesla and his legacy.

Inventions, Research and Development

The company has always tried to incorporate the fundamental features/qualities that Nikola Tesla cherished – knowledge, creativity, openness to new, different solutions, discipline, ambition and investigative approach to the world around us – in its everyday activities. Almost half of our employees work in research and development, we have growing responsibilities within the Ericsson Group, and several innovative solutions provided by our specialists resulted in /found their place in a widened corporate portfolio.

Based on outstanding results achieved in the preceding years the company has obtained higher responsibilities in the internal Ericsson market in the field of research and development and in the Global Service Delivery Center. For that reason the company employed 340 new associates in the last two years and this employment trend should be continued during 2006.

Ericsson Nikola Tesla now has some 1300 employees, 87% of them being college graduates, mostly electrical engineers. They are motivated, flexible and promising young professionals who have willingly adopted the philosophy of lifelong learning.

In view of current market competition the ability/capacity to produce innovative solutions has become a key distinctive feature between successful and less successful companies. Modern companies, among them the Ericsson corporation as well, have adopted the organizational culture that cherishes innovativeness as a strategic guideline so that research and development activities are fundamental to their market position.

However, modern innovators cannot successfully work independently like Nikola Tesla. Innovative development should be supported by organized activities, by a process with precisely defined and planned measures taken by teams built of experts and innovators. Such an Innovations Management System has been implemented in Ericsson Nikola Tesla.

The Research and Development Center of Ericsson Nikola Tesla enjoys a high reputation in the Ericsson Corporation, because of its expert resources and the complexity of projects and areas the Center deals with. The responsibilities assigned to the R&D Center range from the design of signaling solutions for fixed and mobile telephony based on AXE platform, to the design of new platforms, and to integration and verification services. The company has a modern laboratory for testing the 2G and 3G functionality, with installed mobile network switching nodes, with a comprehensive radio access network for GSM and WCDMA systems, with support nodes and testing tools.

When defining research and development objectives special attention is paid to current market trends so that all company projects are oriented to meeting the communication needs of end users and to improving the general standard of living. I wish to emphasize that the R&D Center is active/engaged in technologically and commercially highly promising areas and strategic projects relating to the company's core business. Accordingly, the main task of the research teams is to create new ideas, design the prototypes and let the development units further improve them, with the commercial phase to follow. Consequently, research activities of the R&D Center are the driving force for much of company business. Within the R&D Center the associates specialized in research and development of information and communication solutions and services deal with location-based services (LBS), networked virtual reality, agent and GRID technologies, remote software support maintenance and the implementation of the Bluetooth technologies in mobile access.

Ericsson Nikola Tesla today

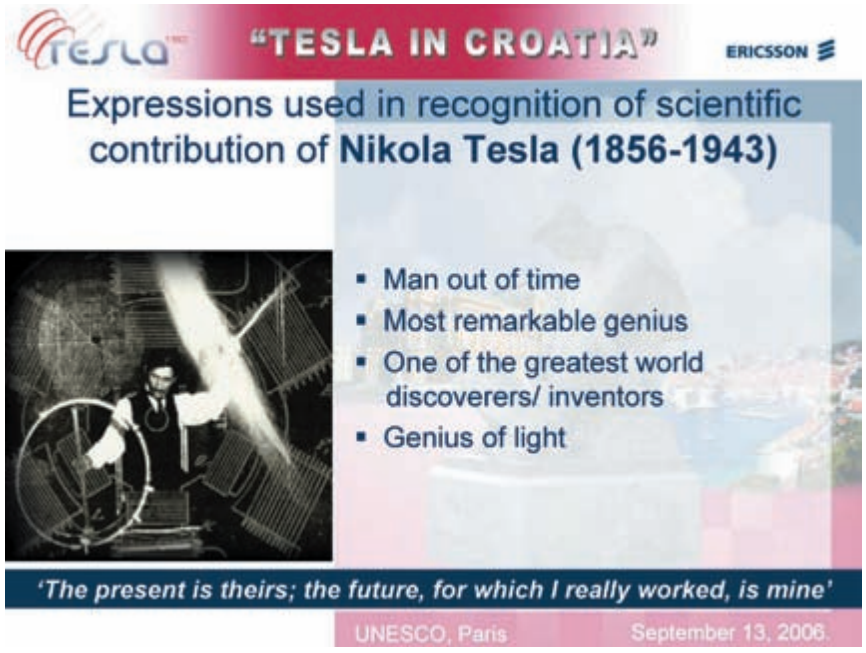
In 2006 when the 150th anniversary of the birth of Nikola Tesla is celebrated in Croatia and worldwide, the company has initiated several independent projects and established the Nikola Tesla Scholarship Funds for outstanding individuals to support their postgraduate studies in applied communication technologies or communication technologies development. With this scholarship, with research and development activities and expert centers, Ericsson Nikola Tesla endeavors to contribute additionally to making Croatia a knowledge society.

Professional expertise is indispensable in research and development. For that reason Ericsson Nikola Tesla permanently collaborates with academic and scientific institutions home and abroad. Company specialists take part in national and international conferences with reports and presentations and have articles published in professional journals, thus promoting the company both as the place producing new ideas in communication and information technologies and to participate and contribute in telecommunications development processes globally.

Erticsson Nikola Tesla as integral part of global Ericsson family, with global presence in more than 140 countries, is able to contribute to an all-communicating world and share the vision of the great thinkers, such as Nikola Tesla, to make people's life easier and richer, providing affordable communication to all. We believe that future belongs to Nikola Tesla and to us as well.

Appendix

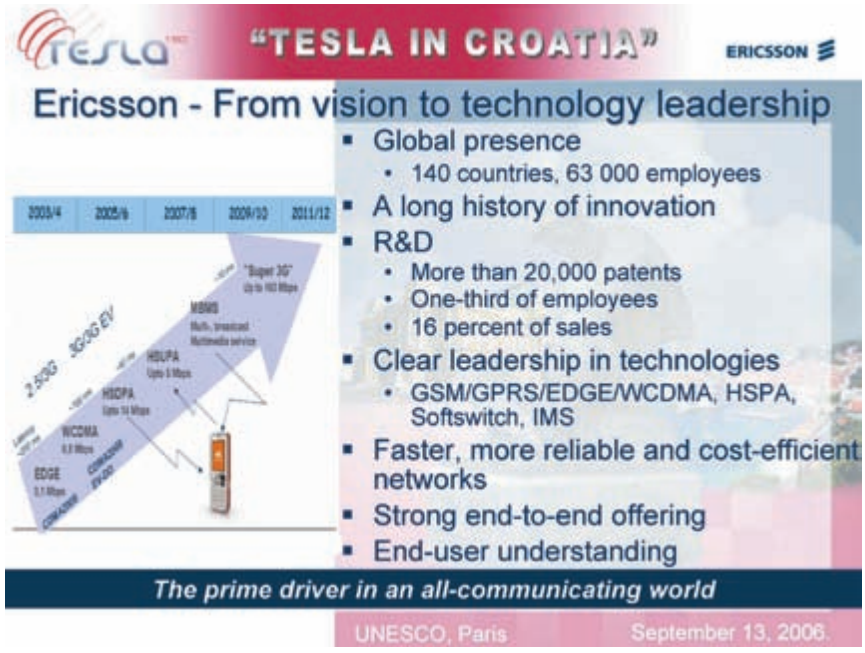

"TESLA IN CROATIA"
ERICSSON
Ten world geniuses* of the Second Millennium
1. Johann Gutenberg (round 1397-1468) printing press
2. Thomas Alva Edison (1847-1931) electrical energy utilization
3. Leonardo da Vinci (1452-1519) hydrodynamics, astronomy, flying machines, etc.
4. Nikola Tesla (1856-1943) electrical machines and devices
5. Michael Faraday (1791-1867) electric motor, generator and transformers
6. Charles Babbage (1791-1871) punched-card controlled calculator as a predecessor of modern computer
7. Alexander Graham Bell (1847-1922) – telephone
8. John Logie Baird (1888-1946) – television
9. Sir Frank Wittle (1907-1996) – jet engine
10. Sir Isaac Newton (1642-1727) – gravitation
*according to BBC
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Expressions used in recognition of scientific contribution of Nikola Tesla (1856-1943)
▪ Man out of time
▪ Most remarkable genius
▪ One of the greatest world discoverers/ inventors
▪ Genius of light
'The present is theirs; the future, for which I really worked, is mine'
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Tesla invented the new modern world
Visions and related research:
▪ wireless transmission of power
▪ electromagnetic radiation
▪ electrical conductors
▪ electrotherapeutics
▪ earthquake machines
Principles of:
▪ remote control
▪ radio communications
▪ robotics
▪ television
▪ cyclotron (atomic fission)
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Received honors
1896 Honorary member of the Academy of Arts and Sciences in Zagreb
1912 Nominated for the Nobel Prize in Physics (together with T. A. Edison)
1917 Received the Edison Medal
1926 Honorary Doctorate of the Zagreb University and of 14 most renowned universities in the world
1949 Telecom equipment factory "Nikola Tesla" founded in Zagreb
1956 Nikola Tesla Monument in front of the building of the International Union for Telecommunications (ITU) in Geneva. The Tesla (T), a SI unit of magnetic flux density named in his honor
1976 Statue of Nikola Tesla at the Niagara Falls
2006 The Nikola Tesla Year
UNESCO, Paris
September 13, 2006.

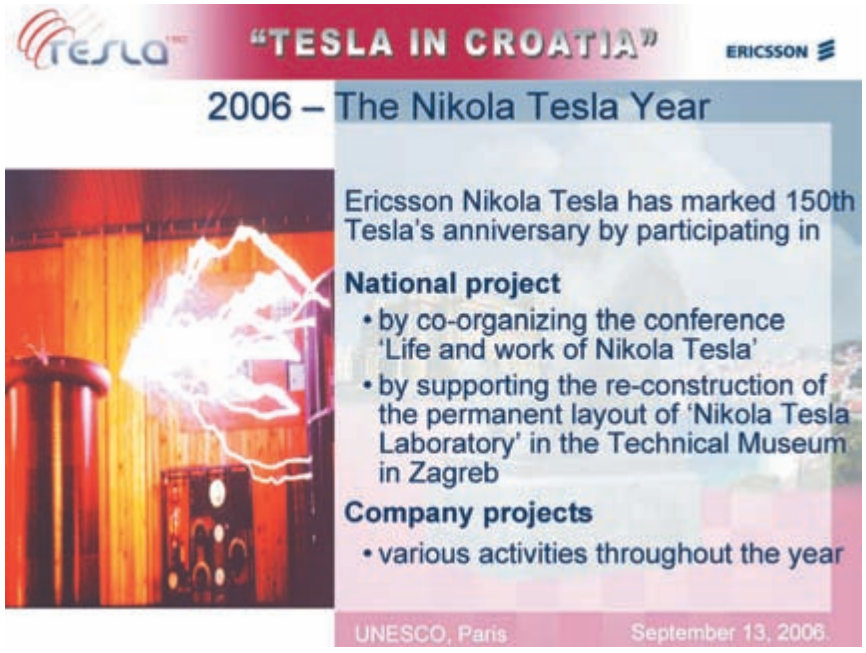

"TESLA IN CROATIA"
ERICSSON
Visionary prediction of the modern world
1925. Tesla: 'Newspapers will be printed by wireless in any home instead of being delivered, as for telecommunications, people will use devices that can be placed in a pocket and will be able to watch events such as world championships, natural disasters or wars as if they were physically present in those places'
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Ericsson - From vision to technology leadership
2003/4
2005/6
2007/8
2009/10
2011/12
2.5/3G
3G/3G EV
WCDMA
HSDPA
HSUPA
MBMS
EDGE
"Super 3G"
Global presence
140 countries, 63 000 employees
A long history of innovation
R&D
More than 20,000 patents
One-third of employees
16 percent of sales
Clear leadership in technologies
GSM/GPRS/EDGE/WCDMA, HSPA, Softswitch, IMS
Faster, more reliable and cost-efficient networks
Strong end-to-end offering
End-user understanding
The prime driver in an all-communicating world
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Ericsson Nikola Tesla- The company of knowledge
Company Nikola Tesla was founded in 1949
Ericsson's licensing partner since 1953
Integral part of Ericsson since 1995
Participation in global development projects
More than five decades on top of Croatian economy
Contributes to the development of Croatia and countries where it operates with state of the art technologies
Innovative spirit of Nikola Tesla
Entrepreneurship of Lars-Magnus Ericsson
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Ericsson Nikola Tesla today....
Strong R&D center
Global and regional Center of Excellence for total communication solutions
Global and regional Service Delivery Center
Regional System Integration Center
Leader in e-systems
Marketing and sales network
Comparing to others and learning from the best is a natural choice, but innovation and new ideas ensure our leading role
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Innovativeness
our way of working and our competitive advantage
I have a great idea please help!
Innovation is and should be integrated in everyday life
Innovation as a work method enabling everyone to express their ideas
Innovations at all levels and in all areas
Innovations are encouraged, supported and promoted
Tesla's legacy is included in the tradition and future of the company
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
2006 – The Nikola Tesla Year
Ericsson Nikola Tesla has marked 150th Tesla's anniversary by participating in
National project
• by co-organizing the conference 'Life and work of Nikola Tesla'
• by supporting the re-construction of the permanent layout of 'Nikola Tesla Laboratory' in the Technical Museum in Zagreb
Company projects
• various activities throughout the year
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Nikola Tesla Scholarship - for young scientists
ERICSSON
TAKING YOU FORWARD
The scholarship is founded and financed by Ericsson Nikola Tesla
The scholarship is granted to an outstanding individual for postgraduate studies in modern communication technologies including telecommunications, computing science and radio communications
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
The future is Tesla's and ours
'I have no regrets that they stole my ideas, but I do regret that they do not have their own'
'The present is theirs; the future, for which I really worked, is mine'
Nikola Tesla
'Good results cannot be achieved without innovation of any kind – it is an unwritten rule of company success today'
Program and process of "Innovations management" at Ericsson Nikola Tesla
UNESCO, Paris
September 13, 2006.

Stjepan Car, Ph.D. in engineering and lecturer at Zagreb and Rijeka Universities. He has been working in KONČAR without interruption since 1972 on research and development of rotating machines and drives, at the moment on renewable energy sources, and published more than 60 papers in scientific publications and proceedings. His entire work is oriented towards the application of scientific findings to the development of new and innovated products of electrical engineering.

For the last 7 years he is the president of the Managing Board of KONČAR – Electrical Engineering Institute, which operates very successfully due to applied research, diagnostics and development of electrical products and vehicles. Besides a number of professional and managerial duties, his function of a member of the international jury for evaluation of innovations in Geneve and the chairman of the jury of ARCA exposition of innovations are of special importance. Member of HATZ since 1995, where he is the president of the Committee for promotion and cooperation in the economy.

Nikola Tesla and Končar Group

Stjepan Car

Abstract – *It is almost impossible to imagine the world without polyphase alternating currents and rotating magnetic field discovered by the great visionary, scientist and engineer Nikola Tesla. Tesla's approach to making new discoveries was at the same time both scientific and economic: noticing a problem, birth of the idea and the solution, experimental verification, protection by a patent, presentation of the invention to the most competent, and the promotion of new possibilities to the benefit of all.*

Synchronous and induction machines in which electromechanical energy conversion is performed by rotating magnetic fields have today an enormous economic importance, and yet they are only a small part of his creative achievements. Application of new numerical methods, new materials with specific properties, high-temperature superconductivity and information and communication technologies are new challenges for the future development of rotating machines based on Tesla's inventions.

1. Introduction

Nikola Tesla (1856–1943) was one of those visionaries who pioneered electrical engineering at the end of the 19th and the beginning of 20th centuries. He was an inventor of genius whose creative mind was mostly on alternating currents and transmission of electricity, but who also gave a major contribution to the development of turbines, remote control, illumination, lasers, application of high-fre-

quency currents for therapeutic purposes, development of devices for X-rays, which are described in 113 U.S. patents, 17 patents in Great Britain, and 6 patents in Canada, as well as numerous confidential documents which the American Government took over after this death and classified.

On the 150th anniversary of Tesla's birth, it is enough to think back only to several of his inventions related to the rotating magnetic field and polyphase systems for electric power transmission to see the contribution of this great genius to the development of electrical engineering.

2. Tesla's rotating magnetic field

The story of epochal invention of the rotating magnetic field began in 1878, when **Nikola Tesla** studied electrical engineering at the Austria Polytechnic in Graz, and when Professor Jakov Poeschl, Tesla's teacher of theoretical and experimental physics, demonstrated the only just obtained sample of Gramme's direct current generator. When Tesla saw the sparking between the collector and the brushes, he made the bold remark that what should be invented next was a generator without brushes or sparking. The professor answered with a series of arguments and devoted his whole lecture to that problem, and finally concluded: "Mister Tesla will maybe make great things, but it is certain that he will not improve this one. "

Nevertheless, Tesla found the answer while walking with mechanical engineer and his friend Antal Szigety in the Budapest City Park one afternoon in February 1882. Reciting Göthe's Faust, which he knew by heart, he suddenly stopped, and started describing his friend in colourful terms, making drawings in sand, the generation of rotating magnetic field by two alternating currents that flow through two coils shifted in space and a rotating iron rotor. He, in fact, demonstrated the principle of operation of the induction motor, which he patented six years later. Tesla filed the patent application "Electro magnetic motor" on 12 October 1887, and on 1 May 1988 he was granted U.S. Patent 381968. A copy of the drawing from this history-making patent specification and the model of Tesla's two-phase induction motor from the Zagreb Museum of Engineering are shown in figure 1.

In the period from 1888 to 1891 Tesla was granted patents for 36 inventions related to alternating current motors and generators, and 9 related to the electric power transmission and distribution system. Tesla's inventions were very well received, so that he was invited to give a lecture at the American Institute of Electrical Engineering (AIEE) on 16 May 1888 as an AIEE fellow. The title of the lecture was "A New System of Alternate Current Motors and Transformers", and in it Tesla explained his major inventions and the theory of alternating currents. His public appearance was noticed in Europe as well. German journal

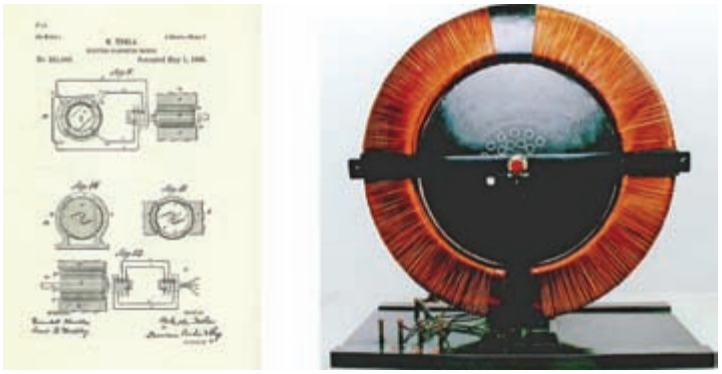


Fig. 1 – Copy of the printed patent specification for the induction motor of 1 May 1888, which Tesla applied for with the United States Patent Office on 12 October 1887, and the model of Tesla's two-phase induction motor from the Zagreb Museum of Engineering, which Tesla made and demonstrated in Strasbourg on 10 July 1883 – more than four years before the patent application.

Elektrotechnische Zeitschrift (ETZ) of July 1888 published on pages 343 and 344 the article by Du Bois-Reymond titled "Ein neues System von Wechselstrommotoren und Transformotoren von Nikola Tesla", in which he also informed that Tesla gave a lecture at AIEE, and reported in detail about Tesla's explanation and the drawing of the system for electromechanical conversion and transmission of electrical energy (figure 2).

Fig. 2 – Copy of a part of the article in ETZ, July 1888, pp. 343-344, on Nikola Tesla's new system of alternating motors and transformers presented at the American Institute of Electrical Engineers on 16 May 1888

Fig 3 – Demonstration of the effects of rotating magnetic field performed by Nikola Tesla for the first time at the World's Colombian Exhibition in Chicago in 1893

The big promotion of Tesla's polyphase system took place at the World's Colombian Exhibition in Chicago in 1893, where Tesla demonstrated the effects of the rotating magnetic field on a copper egg excited to rotation by the field, figure 4 – a demonstration which attracts the same attention of the public today as it attracted in 1893. On that occasion, 12 two-phase generators and 24 single-phase generators were made and connected by twos in a two-phase alternating system.

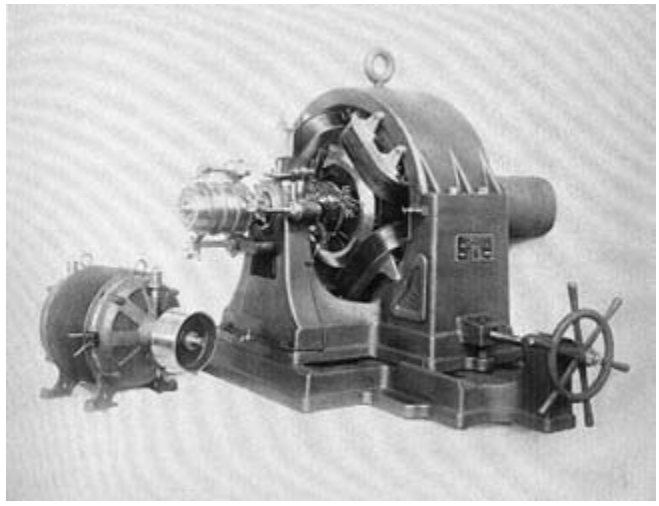


Fig. 4 – Synchronous generator and induction motor from the time of Nikola Tesla

Even before he was granted patents for polyphase systems, the American industrialist George Westinghouse (1846-1914), who was among the few who understood the importance of induction motors and polyphase systems, showed his interest. Since Tesla was not interested in his own industrial production, only in findings and inventions, in May 1888 Westinghouse Electric and Manufacturing Company bought off all of Tesla's patents in the polyphase current area for USD 1 mil. plus USD 1 for each horse power produced by the machines during the term of the patents (15 years). A photograph of synchronous generator and induction motor produced by Westinghouse under Tesla's patent is given in figure 4.

The greatest economic promotion of Tesla's polyphase systems was the construction of generators for Niagara Falls Hydro-electric Power Plant based on Tesla's patents, figure 5, which was completed in November 1896. At that time the first three-phase 35 kilometres long transmission line from the HPP to Buffalo was also put into service.

Fig. 5 – Interior of the turbine hall of Niagara Falls HPP and the name plate of Westinghouse Co. with the list of applied Tesla's patents

On that occasion professor of electrical engineering at the Yale University and former AIEEE chairman Dr. Charles F. Scott concluded his report with these words: "The evolution of electric power from the discovery of Faraday to the initial great installation of the Tesla polyphase system in 1896 is undoubtedly the most tremendous event in all engineering history."

Nikola Tesla had both adversaries and competitors. Tesla made his invention of the induction motor in Budapest in 1882, implemented it in Strasbourg in 1883, filed the patent application on 12 October 1887, and was granted patent on 1 May 1888. When Tesla made this public, two scientists disputed his claims on the invention: the Italian physicist Galileo Ferraris, who claimed the invention of

the rotating magnetic field, and in Germany the engineer Michael von Doliwo-Dobrowolski, who was granted German patent 51083 for the three-phase induction motor with short-circuited rotor in Berlin on 8 March 1889.

The patent litigation between Ferraris and Dobrowolski on the one hand and Nikola Tesla on the other hand continued until 1900, when the judge Towsend of the United States Supreme Court in Washington passed his judgement: "Before Tesla's inventions there were no alternating current motors in use … Tesla protected his inventions with patents, and thus developed methods and apparatuses what are nowadays widely known under the name of Tesla's polyphase system, and introduced in the engineering new methods, new means and new terminology …"

This was only a brief overview of Tesla's work related to the rotating magnetic field, electromechanical conversion of energy and polyphase systems, and it has presented only the beginning of Tesla's creative achievements in electrical engineering and energy which were of great importance for the development of electrical industry not only in the world but also in Croatia.

3. Manufacture and usage of alternating electrical machines in Croatia

The first thermal power plant with three steam-engine driven, single-phase 120 kVA, 2000 V alternating generators was constructed in Rijeka in 1892, while the first hydro-electric power plant on the Krka river was put into operation in Šibenik in 1895. Krka HPP had a two-phase 320 kVA, 3000 V, 42 Hz generator.

Although Dr. Milan Amruš, the mayor of Zagreb, invited Tesla as early as in 1892 to consultations about the introduction of electrical lighting and construction of a hydro or thermal power plant with the alternating system (that was on the occasion of Tesla's public appearance at the Old City Hall), the first thermal power plant (called "Munjara") with a Ganz 865 kVA, 5 kV, 50 Hz alternating generator was completed only in 1907.

On 24 January 1921, engineers Felix Rottenbücher, Josip Novaković and others founded in Zagreb a joint stock company **ELEKTRA** d.d. za elektrotehničku i strojarsku industriju (ELEKTRA Inc, electrical and mechanical engineering industries). Not long after its foundation ELEKTRA took over the representation of Siemens Schneckert Werke AG from Vienna. Several months later Siemens entered with their capital, and ELEKTRA was reorganised in Jugoslavensko SIEMENS d.d., with sections for low and high-power currents. That was the be-

ginning of servicing and maintenance of electrical motors in Zagreb – that was also the beginning of the company KONČAR.

Since in 1930 the law was passed in Yugoslavia that allowed domestic products to be 10–15% more expensive, SIEMENS organised in Zagreb the production of induction motors and various electromotor parts.

In 1927 Anton Dolenc became one of SIEMENS employees, and in 1932 he was appointed manager of the plant in Trešnjevka, Zagreb, where Siemens had bought land and built a workshop. He was the spiritus movens of the entire development of the company and inventor of many technical solutions. So, in 1930 the first induction motors with short-circuited rotor and stator winding with lacquered wire instead of cotton-insulated wire were put on the market, what was a novelty on a world scale.

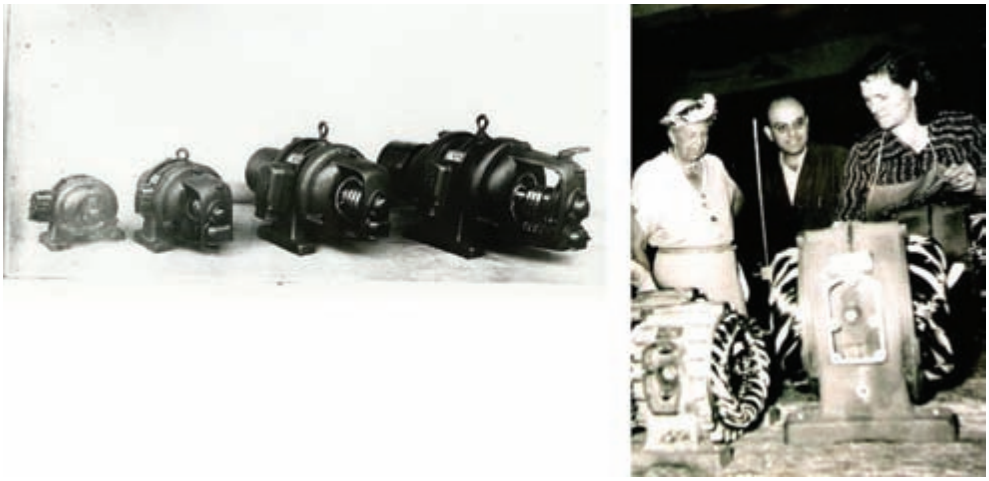


Fig. 6 – Series of induction motors produced by Jugoslavenski Siemens, and the tour of Eleanor Roosevelt of the production of induction motors in KONČAR in 1953

In 1941 the name of the company was changed in Hrvatsko Siemens d.d., and on 31 December 1946 the Government of FNRJ changed it in "RADE KONČAR". RADE KONČAR became a company of federal importance, whose production programme included the production of **electrical machines, transformers, switching devices and telephones, with 419 workers**, and from 1 January 1991 it operates as the joint stock company **KONČAR – Elektroindustrija d.d.** (KONČAR – Electrical Industry, Inc.) in mixed ownership, with a number of subsidiaries specialised in individual groups of products for the power sector, electric traction and household appliances.

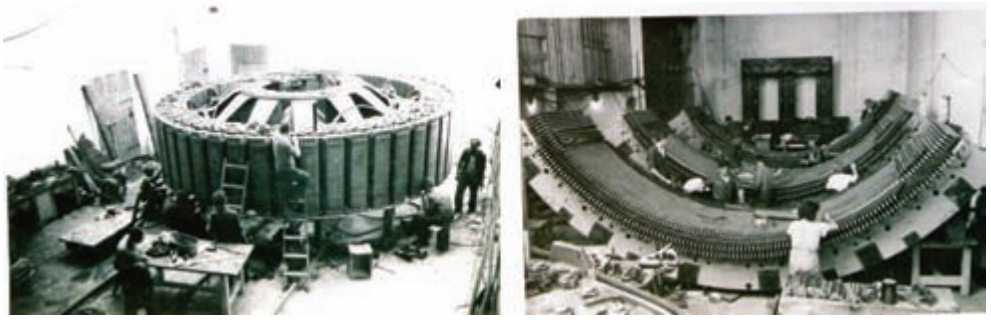


Fig. 7 – Manufacture of stator and rotor of 24 MVA, 10 kV, 125 r.p.m. synchronous generator for Mariborski otok HPP (1946)

The first induction motor whose diameter of the active part exceeded one meter was delivered in 1948, and in the same year the first Končar's 24 MVA synchronous generator was put into operation in the hydro-electric power plant HPP Mariborski otok (figure 7).

That traced the way for an independent development of alternating electrical machines in Croatia. The development could not be possible without qualified experts and engineers. In 1848 it was proposed to found the Zagreb Technical University, but it was done so. In 1926 the University became Faculty of Engineering. In 1956 the Faculty of Engineering became the Faculty of Electrical Engineering, and from 1995 it is called the Faculty of Electrical Engineering and Computing. The Faculty was the place where a number of engineers and eminent experts were trained, and many of them worked on the development, design and construction of electrical machines, and at the same time they were professors at the Faculty. Besides the legendary professor Anton Dolenc, a pioneer in the design and technical solutions of induction motors and synchronous generators, who was appointed part-time lecturer at the Zagreb Faculty of Engineering in 1930, there were also other engineers and university professors who made major contributions to the development of alternating machines, of which I shall mention only a few:

- Prof. Dr. Tomo Bosanac, who designed and managed the construction of 2x120 MVA hydrogenerators (the largest at the time) for Zakučac HPP, which was put into operation in 1962.
- Prof. Dr. Zijad Haznadar, world-renowned theoretician of electromagnetic fields, who was the first to introduce numerical methods for calculation of fields in machines, and studied the expansion and effects of electromagnetic waves
- Prof. Dr. Božidar Frančić, who patented the self-excited compound synchronous generator, and introduced the theory of dynamic states of alternating machines in the post-graduate studies

- Prof. Dr. Berislav Jurković, who set the methods for calculation of induction machines, and gave a number of new technical solutions for multi-speed motors for heavy duties
- Prof. Dr. Sc. Zvonko Sirotić, who designed the largest hydrogenerators for Đerdap HPP, and set the principles for building synchronous generators of limit powers
- Prof. Dr. Radenko Wolf, who set the method for calculation of small single-phase motors with an auxiliary phase, and gave an essential contribution to the physical image and theory of various kinds of electrical machines, in particular of small ones.

It is worth pointing out here to the name of Prof. Dr. Vladimir Muljević, who defended in 1942 the doctoral thesis "The emergence of higher harmonics in squirrel-cage rotors with numerous slots in Tesla motor" as the first doctoral thesis in Croatia dealing with alternating electrical machines.

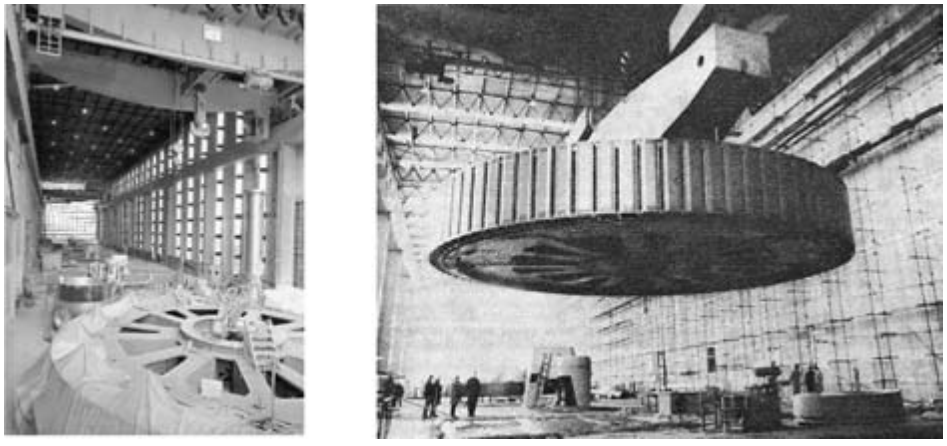


Fig. 8 – Interior of the turbine hall in Đerdap HPP under construction. KONČAR delivered three 190 MVA hydrogenerators, 1240 tons each, which were put into service in 1972.

In order to speed up the development and become competitive on the world market, KONČAR established within the Electrotechnical Institute, which was founded in 1961, the **Laboratory for Rotating Machines**, which was put into operation in 1971 with all the necessary facilities for research, testing and development of electrical machines and electromotor drives (the testing of electrical materials, electromechanical characteristics, noise and vibrations, temperature rises and cooling, climatic tests, tests of mechanical protection, tests with sinusoidal and non-sinusoidal voltages at various frequencies, and simulations of states in operation), figure 9.

Fig. 9 – Various testing points at the Laboratory for Rotating Machines in KONČAR – Electrical Engineering Institute, which has been put into operation in 1971.

For their scientific and research work and exceptional contribution to the development of KONČAR, as many as 14 engineers and scientists from the 33 winners of the Nikola Tesla Award so far have been working on rotating machines.

The greatest success of the domestic electrical industry today is our own development and production of the low-floor tramway for the City of Zagreb, with induction motors and frequency control of the speed of rotation of the rotating magnetic field, figure 10. The first tramway was delivered in autumn 2005, and today there are already 34 trams driving in streets of Zagreb (of total 70 tramways to be delivered under the first contract).

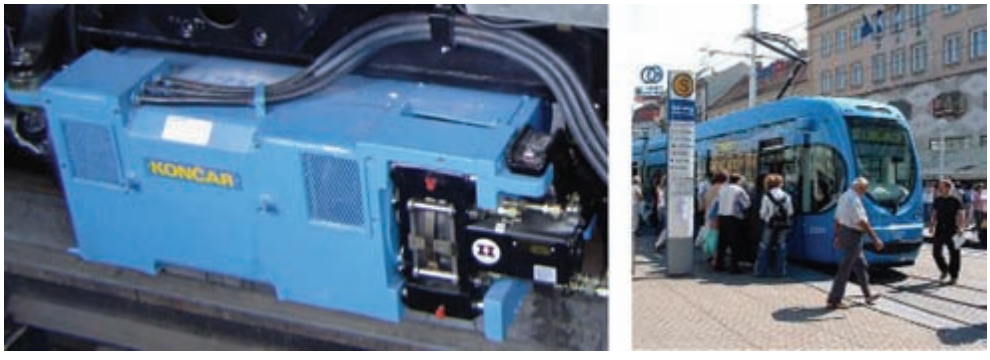


Fig. 10 – Induction motor for frequency-controlled electric motor drive of the low-floor tramway, and its first drive in Zagreb in 2005

4. Economic importance of the rotating magnetic field and rotating machines

The world market of electrical machines is worth today more than USD 4.7 b., and it is anticipated that its annual increase would be about 8%, in particular in the area of electrical propulsion for ships, figure 11. Končar alone produces rotating machines whose value exceeds € 35 mil. p.a. Almost 70% of them is exported.

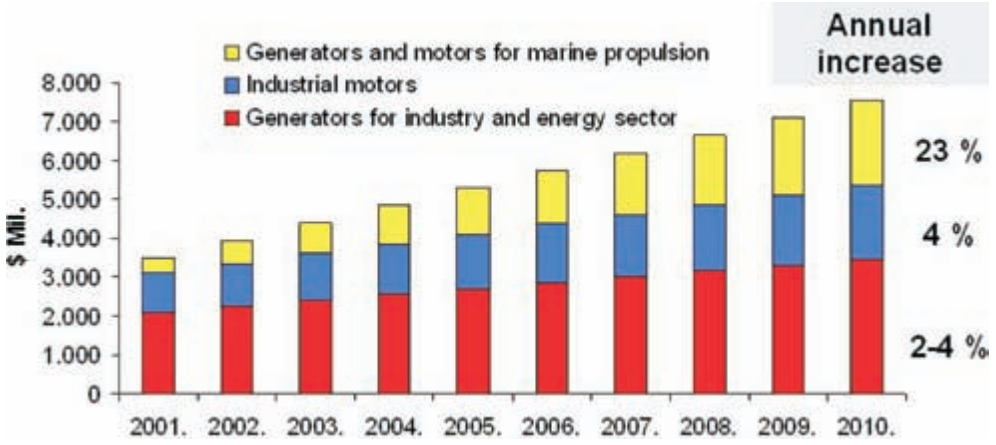


Fig. 11 – Estimation of the market of rotating machines (Source: AMSC, Arthur D. Little)

Electronic control by power converters and IT systems are more and more used in modern electric motor drives and plants with synchronous and induction machines, giving them quite new features.

Further development of alternating electrical machines, aided by new numerical methods for calculation and modelling and new materials with specific properties such as superconducting materials and rare-earth permanent magnets with new and improved features, goes in the direction of an increasing constructional and control integration of these machines in plants and processes, with the resulting permanent increase in the efficiency of electromechanical conversion of energy and reductions of machine size.

Ever since Nikola Tesla discovered the rotating magnetic field and electromechanical conversion of energy, alternating electrical machines have been not only of great technical and technological, but also of economical importance. Many jobs and the creation of added value are connected with them, and it is likely that that they will likely remain so for a long, long time.

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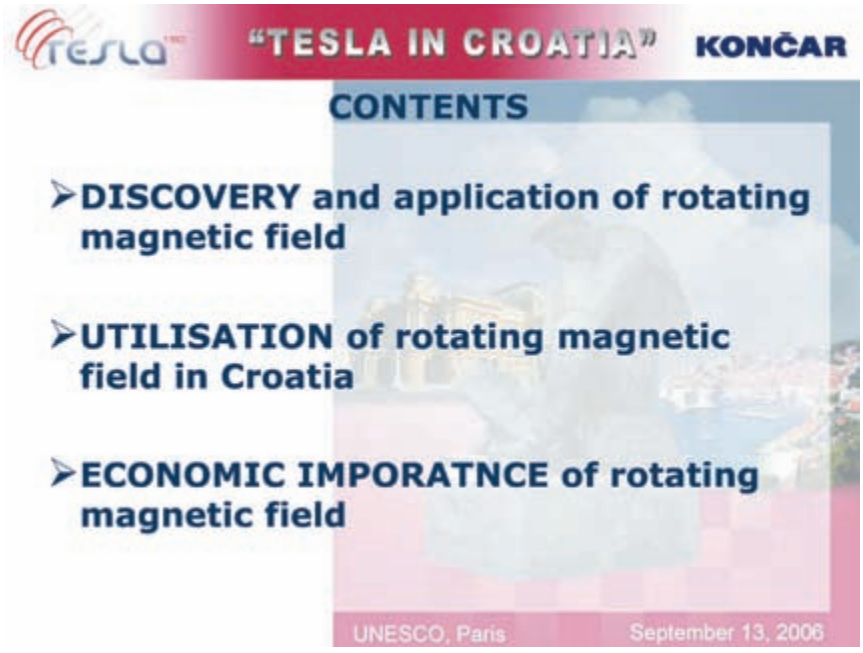
Appendix


"TESLA IN CROATIA"
KONČAR
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DISCOVERY and application of rotating magnetic field
UTILISATION of rotating magnetic field in Croatia
ECONOMIC IMPORATNCE of rotating magnetic field
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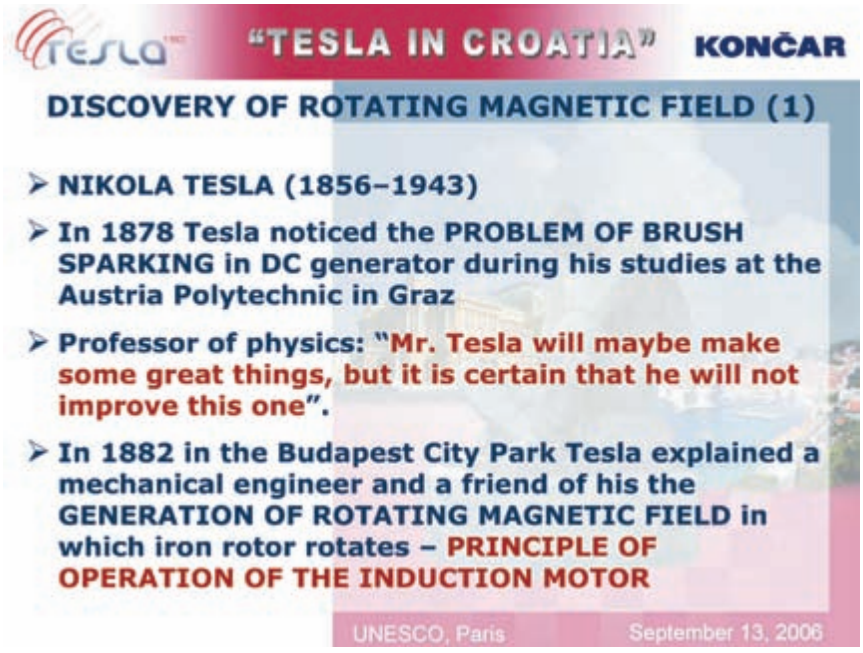
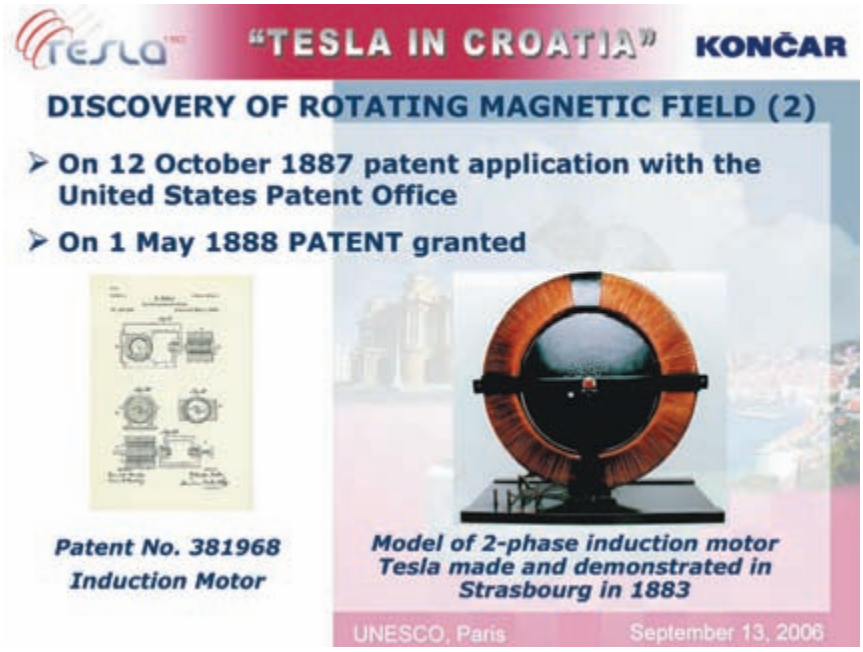
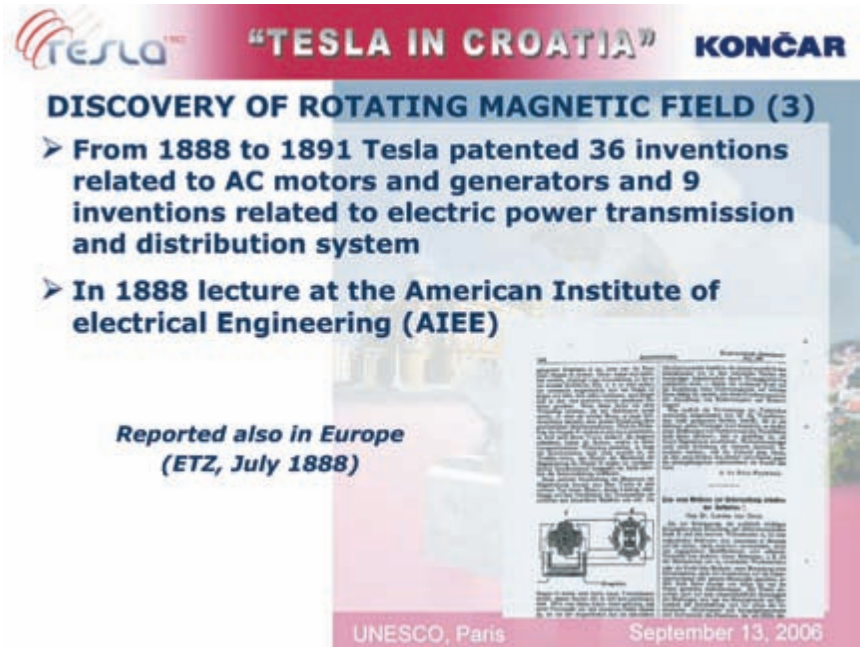
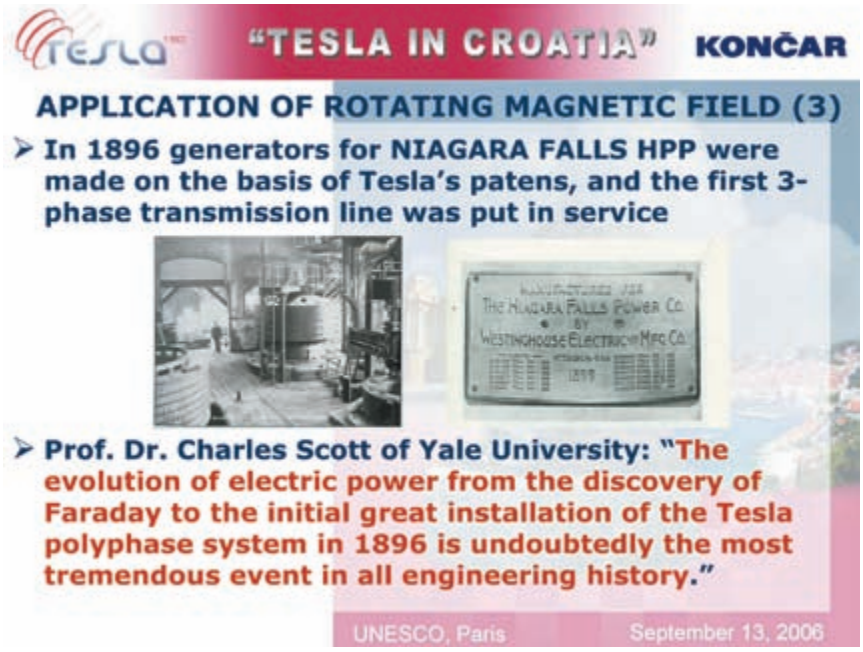

"TESLA IN CROATIA"
KONČAR
DISCOVERY OF ROTATING MAGNETIC FIELD (1)
NIKOLA TESLA (1856–1943)
In 1878 Tesla noticed the PROBLEM OF BRUSH SPARKING in DC generator during his studies at the Austria Polytechnic in Graz
Professor of physics: "Mr. Tesla will maybe make some great things, but it is certain that he will not improve this one".
In 1882 in the Budapest City Park Tesla explained a mechanical engineer and a friend of his the GENERATION OF ROTATING MAGNETIC FIELD in which iron rotor rotates – PRINCIPLE OF OPERATION OF THE INDUCTION MOTOR
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
DISCOVERY OF ROTATING MAGNETIC FIELD (2)
➢ On 12 October 1887 patent application with the United States Patent Office
➢ On 1 May 1888 PATENT granted
Patent No. 381968
Induction Motor
Model of 2-phase induction motor Tesla made and demonstrated in Strasbourg in 1883
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
DISCOVERY OF ROTATING MAGNETIC FIELD (3)
➢ From 1888 to 1891 Tesla patented 36 inventions related to AC motors and generators and 9 inventions related to electric power transmission and distribution system
➢ In 1888 lecture at the American Institute of electrical Engineering (AIEE)
Reported also in Europe
(ETZ, July 1888)
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
APPLICATION OF ROTATING MAGNETIC FIELD (1)
In 1893 PROMOTION of Tesla's polyphase system at the World's Colombian Exhibition in Chicago (12 pcs 2-phase 1000 HP generators and 24 pcs 1-phase 500 HP ones connected in a system)
Replica of a model for demonstration of effects of rotating magnetic field
KONČAR
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
APPLICATION OF ROTATING MAGNETIC FIELD (2)
In 1888 Westinghouse Electric and Manufacturing Company BOUGHT OFF for USD 1 mil. + USD 1 per HP all of Tesla's patents in the polyphase current area
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
APPLICATION OF ROTATING MAGNETIC FIELD (3)
In 1896 generators for NIAGARA FALLS HPP were made on the basis of Tesla's patens, and the first 3-phase transmission line was put in service
THE NIAGARA FALLS POWER CO.
BY
WESTINGHOUSE ELECTRIC & MFG. CO.
Prof. Dr. Charles Scott of Yale University: "The evolution of electric power from the discovery of Faraday to the initial great installation of the Tesla polyphase system in 1896 is undoubtedly the most tremendous event in all engineering history."
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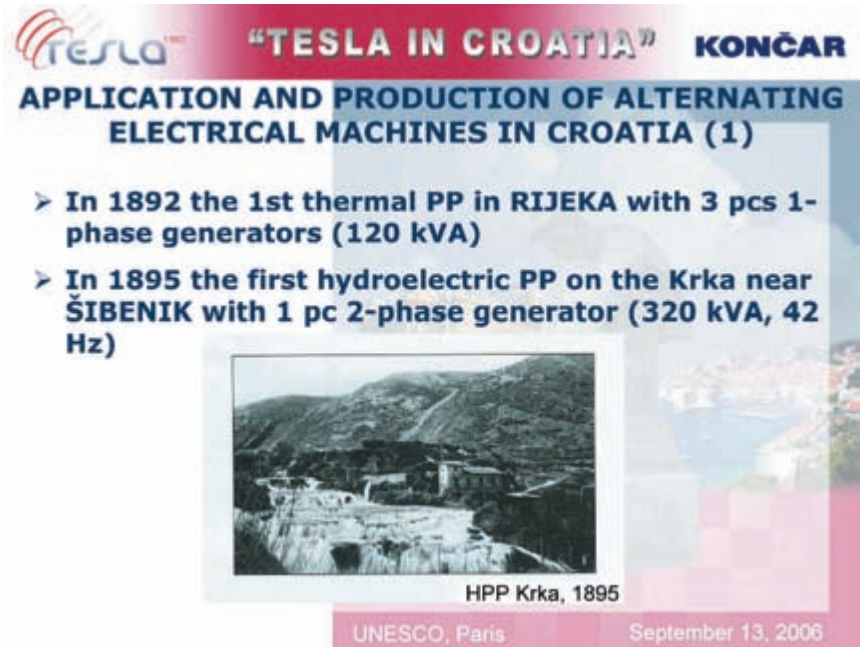
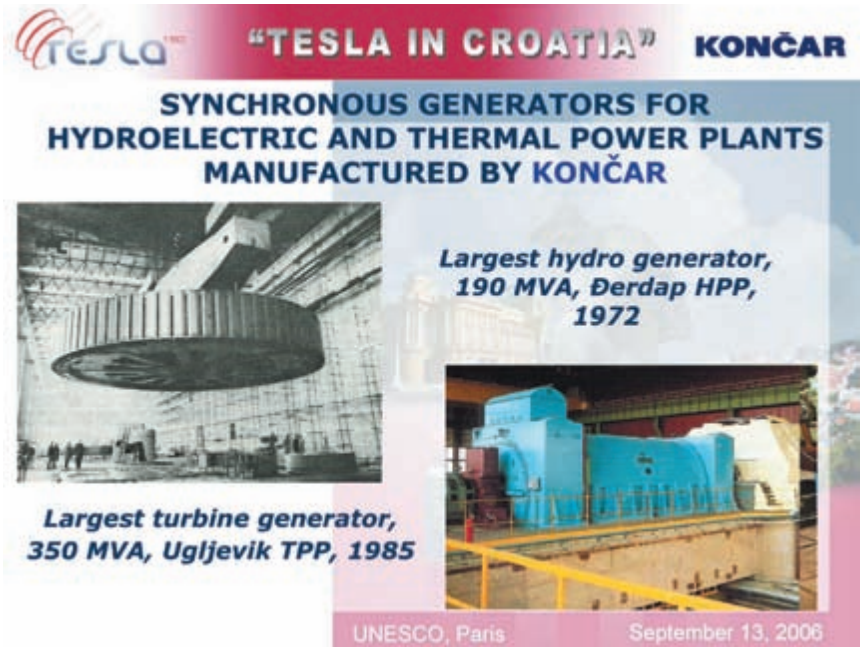

"TESLA IN CROATIA"
KONČAR
APPLICATION AND PRODUCTION OF ALTERNATING ELECTRICAL MACHINES IN CROATIA (1)
In 1892 the 1st thermal PP in RIJEKA with 3 pcs 1-phase generators (120 kVA)
In 1895 the first hydroelectric PP on the Krka near ŠIBENIK with 1 pc 2-phase generator (320 kVA, 42 Hz)
HPP Krka, 1895
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
APPLICATION AND PRODUCTION OF ALTERNATING ELECTRICAL MACHINES IN CROATIA (2)
In 1921 foundation of the company ELEKTRA, Inc. for electrical & mechanical engineering industries
Six months later: Jugoslavensko SIEMENS Inc., in 1941 Hrvatsko SIEMENS
In 1946 the company became social property and operated under the name RADE KONČAR
Since 1991 KONČAR - ELEKTROINDUSTRIJA d.d. with subsidiaries specialised in electrical power sector, electric traction and household appliances
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
APPLICATION AND PRODUCTION OF ALTERNATING ELECTRICAL MACHINES IN CROATIA (3)
Visit of ELEANOR ROOSEVELT to KONČAR's production of induction motors (1953)
Series of induction motors (1947)
UNESCO, Paris
September 13, 2006

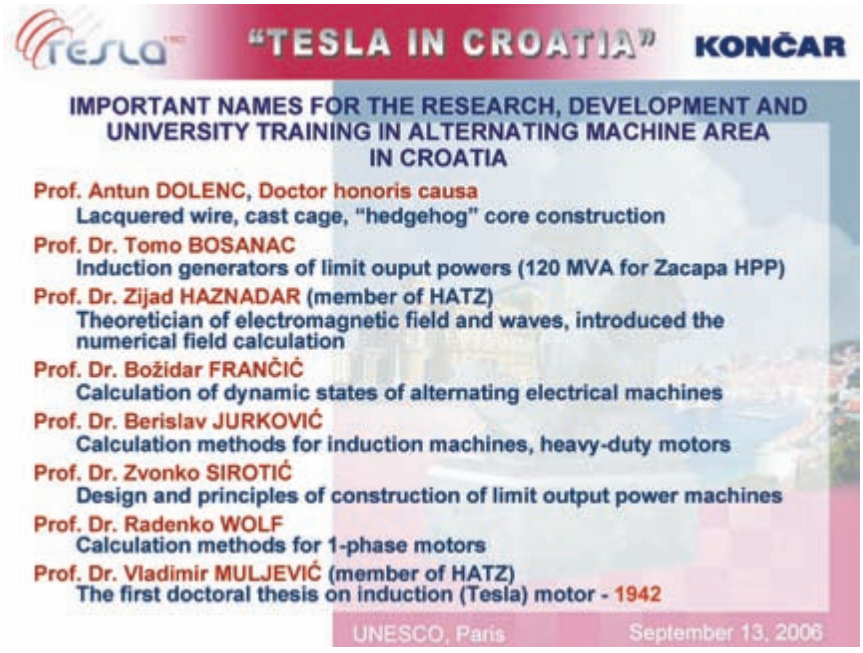

"TESLA IN CROATIA"
KONČAR
MANUFACTURE OF STATOR AND ROTOR OF 24 MVA SYNCHRONOUS GENERATOR FOR MARIBORSKI OTOK HPP IN KONČAR IN 1946
UNESCO, Paris
September 13, 2006

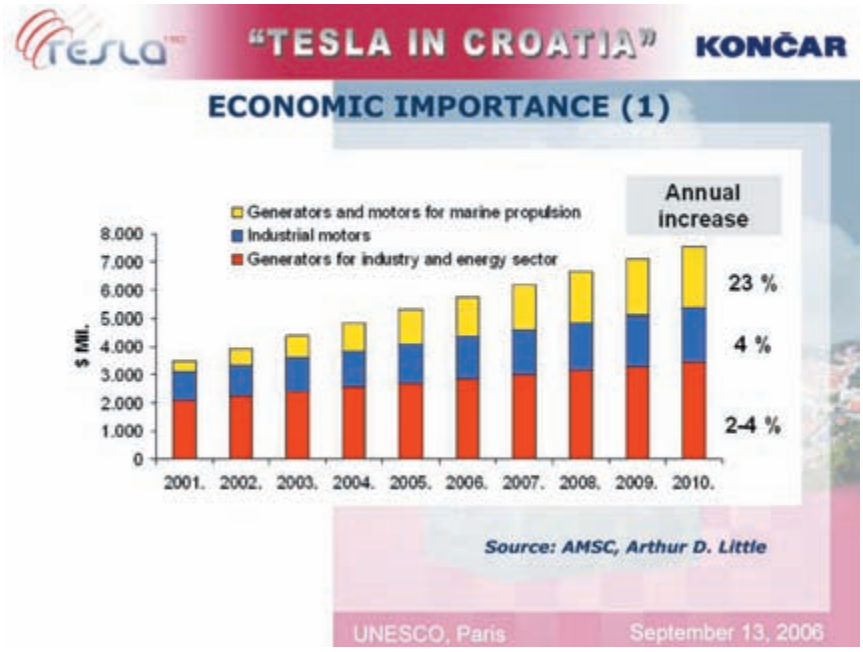

"TESLA IN CROATIA"
KONČAR
SYNCHRONOUS GENERATORS FOR HYDROELECTRIC AND THERMAL POWER PLANTS MANUFACTURED BY KONČAR
Largest hydro generator, 190 MVA, Đerdap HPP, 1972
Largest turbine generator, 350 MVA, Ugljevik TPP, 1985
UNESCO, Paris
September 13, 2006

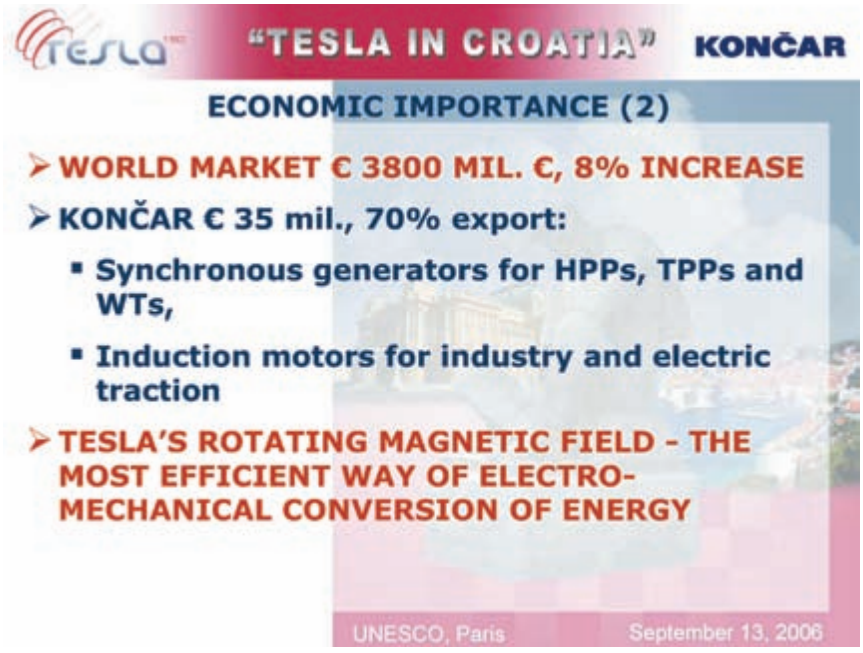

"TESLA IN CROATIA"
KONČAR
LABORATORY FOR ROTATING MACHINES
AT KONČAR INSTITUTE IN OPERATION SINCE 1971
As many as 14 engineers and scientists from the area of rotating machines have been awarded the NIKOLA TESLA STATE AWARD for their scientific and research work and exceptional contribution to the development of KONČAR
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
INDUCTION MOTOR FOR FREQUENCY-CONTROLLED
ELECTRIC MOTOR DRIVE OF LOW-FLOOR TRAMWAY
PRODUCED BY KONČAR
Commencement of production in 2005
Low-floor tramway for the city of ZAGREB (70 pcs)
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
COUNTRIES IN WHICH KONČAR'S ALTERNATING MACHINES ARE INSTALLED
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
IMPORTANT NAMES FOR THE RESEARCH, DEVELOPMENT AND UNIVERSITY TRAINING IN ALTERNATING MACHINE AREA IN CROATIA
Prof. Antun DOLENC, Doctor honoris causa
Lacquered wire, cast cage, "hedgehog" core construction
Prof. Dr. Tomo BOSANAC
Induction generators of limit ouput powers (120 MVA for Zacapa HPP)
Prof. Dr. Zijad HAZNADAR (member of HATZ)
Theoretician of electromagnetic field and waves, introduced the numerical field calculation
Prof. Dr. Božidar FRANČIĆ
Calculation of dynamic states of alternating electrical machines
Prof. Dr. Berislav JURKOVIĆ
Calculation methods for induction machines, heavy-duty motors
Prof. Dr. Zvonko SIROTIĆ
Design and principles of construction of limit output power machines
Prof. Dr. Radenko WOLF
Calculation methods for 1-phase motors
Prof. Dr. Vladimir MULJEVIĆ (member of HATZ)
The first doctoral thesis on induction (Tesla) motor - 1942
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
ECONOMIC IMPORTANCE (1)
Generators and motors for marine propulsion
Industrial motors
Generators for industry and energy sector
Annual increase
$ Mil.
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
2001. 2002. 2003. 2004. 2005. 2006. 2007. 2008. 2009. 2010.
23 %
4 %
2-4 %
Source: AMSC, Arthur D. Little
UNESCO, Paris
September 13, 2006


"TESLA IN CROATIA"
KONČAR
ECONOMIC IMPORTANCE (2)
➢ WORLD MARKET € 3800 MIL. €, 8% INCREASE
➢ KONČAR € 35 mil., 70% export:
▪ Synchronous generators for HPPs, TPPs and WTs,
▪ Induction motors for industry and electric traction
➢ TESLA'S ROTATING MAGNETIC FIELD - THE MOST EFFICIENT WAY OF ELECTRO-MECHANICAL CONVERSION OF ENERGY
UNESCO, Paris
September 13, 2006

Ivica Toljan, 47 was born in Brinje, Croatia. He graduated from the Faculty of Electrical Engineering and Computing in Zagreb, followed by the MBA in Zagreb and a post graduate Masters degree from the Faculty of Economics in Zagreb. He started his professional career in HEP more than 20 years ago first as a republic-level dispatcher, a Head for Energy Accounting, Managing Director for Transmission and finally a Member of the HEP Management Board in charge of transmission.

He is a member of the UCTE Steering Committee, president of the Croatian National Committee Cigre, one of the authors of the Croatian electric power system reform, a member of the Croatia-EU negotiation team for energy, author of numerous professional and scientific papers from the filed of electric power and a convener of the Executive Team for the I and II European electric power zone reconnection process.

European Electric Interconnection

Ivica Toljan

Tesla's inventions and works – science fiction? YES, because Tesla and his works were not understood by most of his contemporaries. Fortunately, there were some who trusted Tesla despite his at times difficult-to-understand experimentally illustrated ideas and inventions. Even with today's knowledge, it is difficult to escape the feeling that it is science fiction since up to the present day the human mind has not materialized some of Tesla's inventions. Science fiction, NO, because the future for which Tesla, as he would put it, worked, has irrefutably proved that his ideas and inventions were firmly grounded in the reality. Tesla was and has remained a mind outside his time and, by some of his ideas that have not been realized, outside today's space and time. Without Tesla, his ideas, inventions and works, there would not be many of the comforts of living on Earth, within and in the space surrounding it.

Thousands and thousands of electricity specialists all over the world are engaged in the electricity transmission. The fundamentals of the modern electricity transmission were established by Tesla toward the end of the nineteenth century by his inventions of polyphase alternating electric motor and electricity transmission. These inventions Tesla patented in 1888 when he was barely 32 years old. At that time it was difficult for Tesla to defend his ideas about polyphase alternating currents against the powerful Edison as the main proponent of the direct current. Tesla won, but Edison was the one who made use of his works and patents. A simple drawing from one of these of Tesla' patents (No. 390,721 dated October 9, 1888), depicts all the basic elements of the modern electricity system: generator, transformer, motor and end use.

It was from these ideas that the modern electric power system has been developed consisting of power plants, transmission lines, transmission substations and a whole spectrum of electricity users such as large industrial plants connected directly to the transmission network and distribution systems supplying electricity to end customers in public institutions, companies and homes. Tesla's ideas of making electricity and information available at any place on Earth, 150 years after his birth, are getting closer to being fully realized.

Can we today imagine living without electricity? Of course, it would be possible, but the world would be a very different place. We have come far from Tesla's childhood days when he in his hometown of Smiljan read and studied by a lamp and a candle. That life is unimaginable without electricity is reflected in the concrete data on electricity consumption. In 2004, consumption in North America was 4338 TWh, in Central and South America 734 TWh, Europe 3064 TWh, in the countries of the former Soviet Union 1148 TWh, in the Middle East 456 TWh, in Africa 422 TWh, Asia and Oceania 3921 TWh and Australia 196 TWh. The total world-wide consumption amounted to 14279 TWh. For comparison, the consumption in Croatia in 2004 was 16.5 TWh.

Such an impressive electricity consumption is made possible by modern electric power systems meshed in large and complex interconnected systems. The basic requirement for the functioning of an electricity system is to maintain balance at all times between production and consumption while ensuring quality of the two basic parameters of electricity, voltage and frequency. It has been proved that large interconnected power systems provide such benefits in terms of supply security and quality of electricity that their creation and expansion is unavoidable despite technical and organizational difficulties that must be overcome. Such a development can be illustrated by a historical review of the beginnings and development of European electric interconnected systems – UCTE, NORDEL, UKTSOA, ATSOI,…. The most significant among them is the UCTE (The Union for Coordination of Transmission of Electricity) established in 1999 by transforming UCPTE (Union pour la Coordination de la Production et du Transport de l'Electricite) on the basis of the well-known EU Directive 96/2. The UCTE encompasses transmission network in 23 countries and is one of the largest interconnected systems in synchronous operation in the world. With 600 GW of installed capacity in power plants and an annual production of 2500 TWh, the UCTE supplies electricity to 450 million people.

The war in the area of the former Yugoslavia split, in 1991, the then UCPTE interconnected system in two zones, each of which operated synchronously. The second synchronous zone comprised the electric power systems of South East Europe (eastern part of Bosnia and Herzegovina, Serbia and Montenegro, Macedonia, Greece, Albania, and later Romania and Bulgaria), and the first zone com-

prised all other countries, including Croatia and the remaining part of Bosnia and Herzegovina.

Following the reconstruction of the transmission network in Croatia and in Bosnia and Herzegovina and the construction of the strategically important 400 kV connection between Croatia and Hungary, the conditions were created for the reconnection of the two synchronous zones. An executive team was set up within the UCTE and careful preparations began for this complex task. As part of these preparations, on September 25, 2004, alignment of phase sequence was carried out on the interconnections between the Croatian system and neighboring countries of the first synchronous zone (Hungary and Slovenia).

The reconnection itself took place on October 10, 2004, beginning at 09:34 and unfolded as follows:

- switching on of the 400 kV line Sandorfalva (Hungary) – Arad (Romania), at the same time the synchronization of the two synchronous zones
- switching on of the 400 kV line Subotica (Serbia) – Sandorfalva (Hungary)
- switching on of the 400 kV line Trebinje (Bosnia and Herzegovina) – Podgorica (Montenegro)
- switching on of the 400 kV line Mukachevo (southwest Ukraine) – Rosiori (Romania)
- switching on of the 400 kV line Ernestinovo (Croatia) – Mladost (Serbia).

All the activities were coordinated from the National Dispatch Center in Zagreb. The dynamic behavior of the Croatian system was recorded and, using UCTE WAMS system, the frequency and differences in voltage angles in two characteristic nodes of the first and second synchronous zones were constantly monitored. Thanks to the good preparation and organization, the reconnection was successfully completed at 10:58, barely an hour and a half from the start of reconnection.

The dynamic behavior of the system during reconnection indicated a potential problem with inter-area oscillations, which was confirmed by later dynamics records. This problem should be approached with due care and is currently being addressed by a specialist working group of the UCTE.

In 2004, the UCTE interconnected system had the production of 2448 TWh, consumption of 2393 TWh, installed capacity of 595 GW and peak load of 370 GWh. It can be seen that the ratio of total installed generating capacity to peak load is 1.6, indicating a significant reserve of installed capacity and confirming the advantages of the interconnected system. The advantages of operating in the inter-

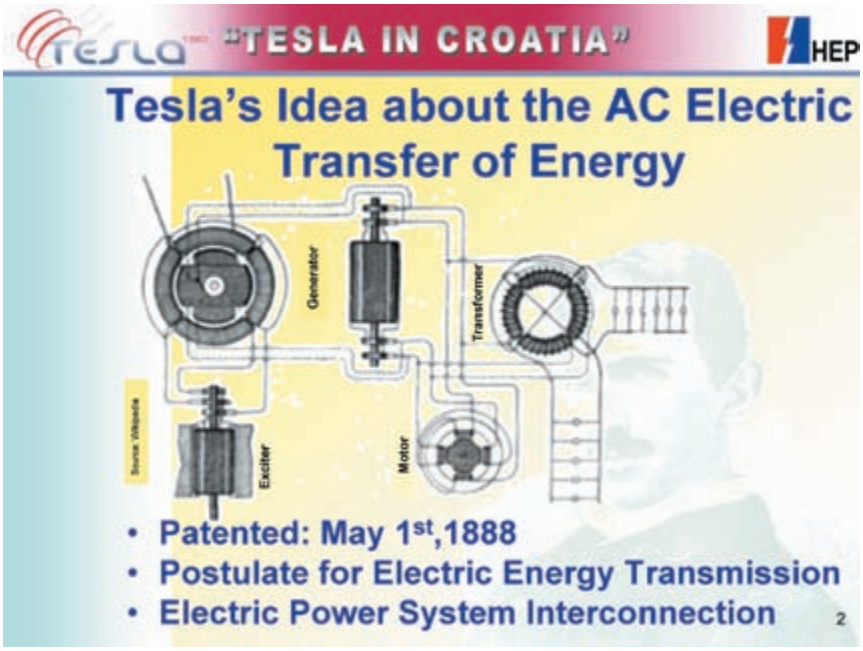
connected system are further underpinned by the data on the duration of peak load (total energy produced divided by the amount of peak load) which is 6464 hours. The main point worth stressing is that the peak load of the interconnected system is lower than the sum of peak loads of member countries by 6000 MW. This capacity would have to be built, distributed across all systems, if the interconnected system did not exist.

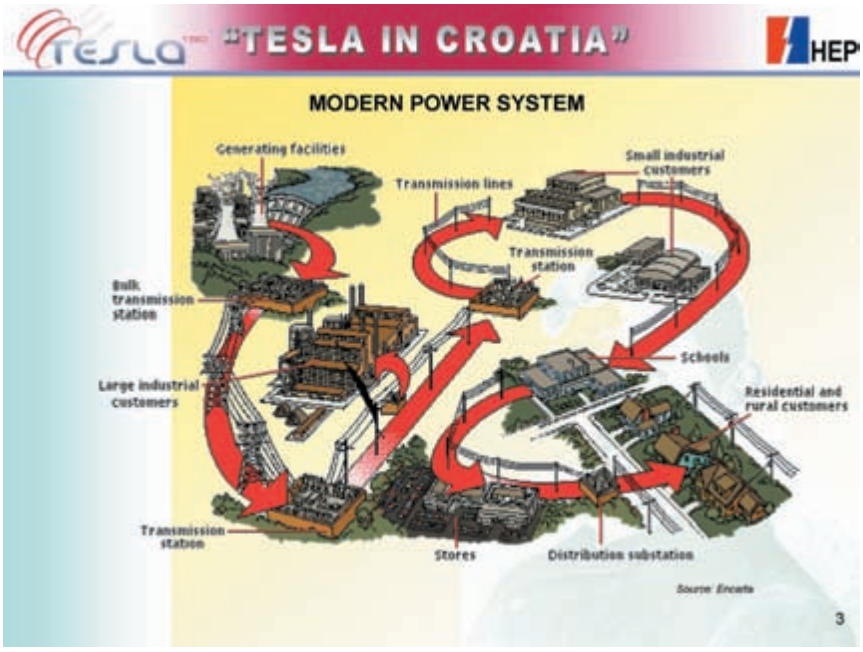
What does the future hold for us? Market opening encourages the growth in electricity trade, bringing along new requirements for transmission network operation and development. Currently underway are preparatory activities for further expansion of the UCTE system to include Turkey and the former Soviet Union (UPS/IPS) and under consideration is further expansion of the UCTE system in Africa.

A simple current circuit from the 1888 Tesla's invention of polyphase alternating currents has been constantly expanding over the past 118 years all over the globe, connecting countries and continents to bring people light and all the comforts of electricity, and the expansion of this ingenious invention is continuing into the future.

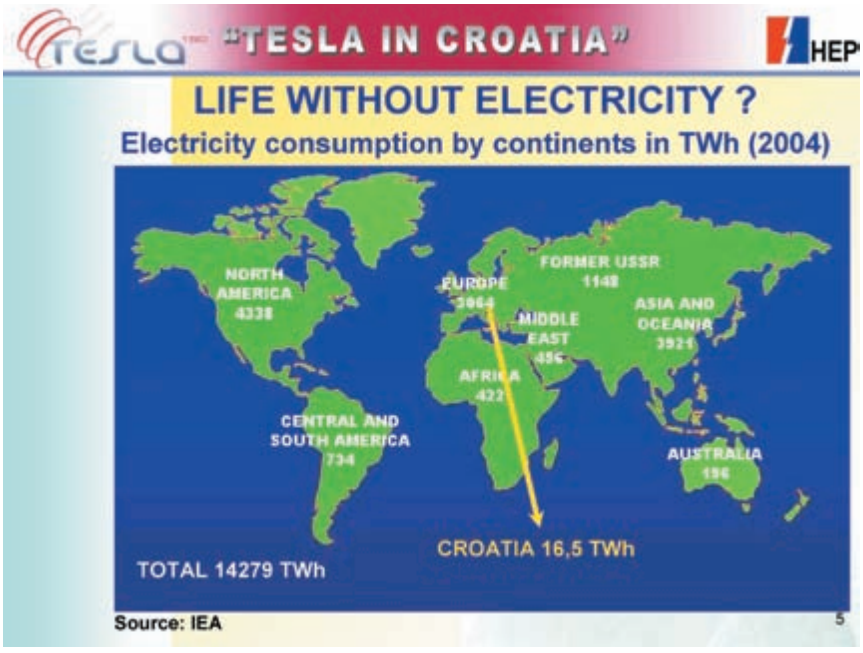
It may also happen that Tesla's idea of wireless transport of large quantities of energy over large distances using outer space becomes a reality.

Appendix


"TESLA IN CROATIA"
HEP
Tesla's Idea about the AC Electric Transfer of Energy
Generator
Transformer
Exciter
Motor
Source: Wikipedia
• Patented: May 1st,1888
• Postulate for Electric Energy Transmission
• Electric Power System Interconnection
2

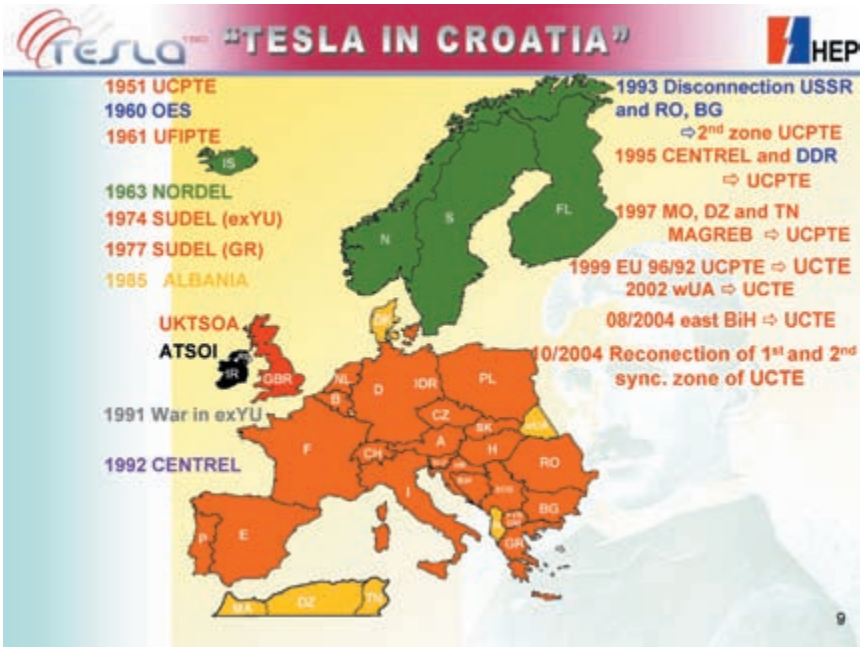

"TESLA IN CROATIA"
HEP
MODERN POWER SYSTEM
Generating facilities
Transmission lines
Small industrial customers
Transmission station
Bulk transmission station
Schools
Large industrial customers
Residential and rural customers
Transmission station
Stores
Distribution substation
Source: Encarta
3

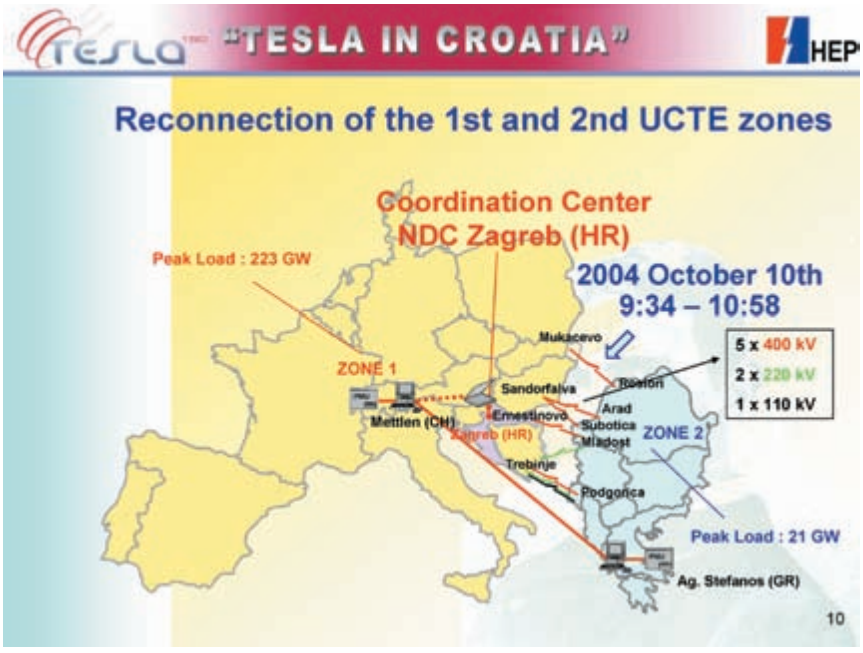

"TESLA IN CROATIA"
HEP
TESLA´s idea
to have electricity and information available at virtually any place on Earth...
...is now coming closer to reality.
4

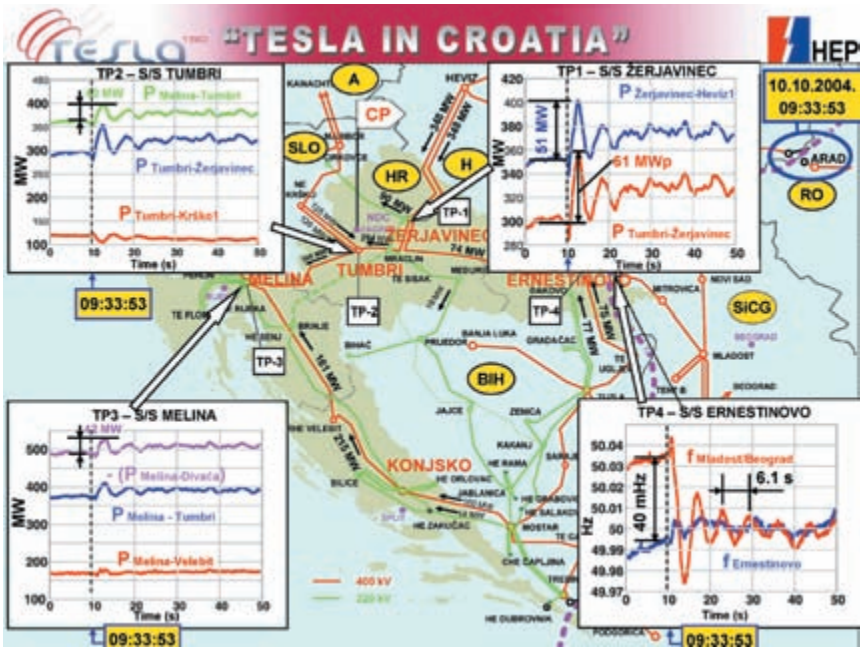

"TESLA IN CROATIA"
HEP
LIFE WITHOUT ELECTRICITY ?
Electricity consumption by continents in TWh (2004)
NORTH AMERICA 4338
EUROPE 3064
FORMER USSR 1148
MIDDLE EAST 485
ASIA AND OCEANIA 3921
AFRICA 422
CENTRAL AND SOUTH AMERICA 734
AUSTRALIA 196
CROATIA 16,5 TWh
TOTAL 14279 TWh
Source: IEA
5

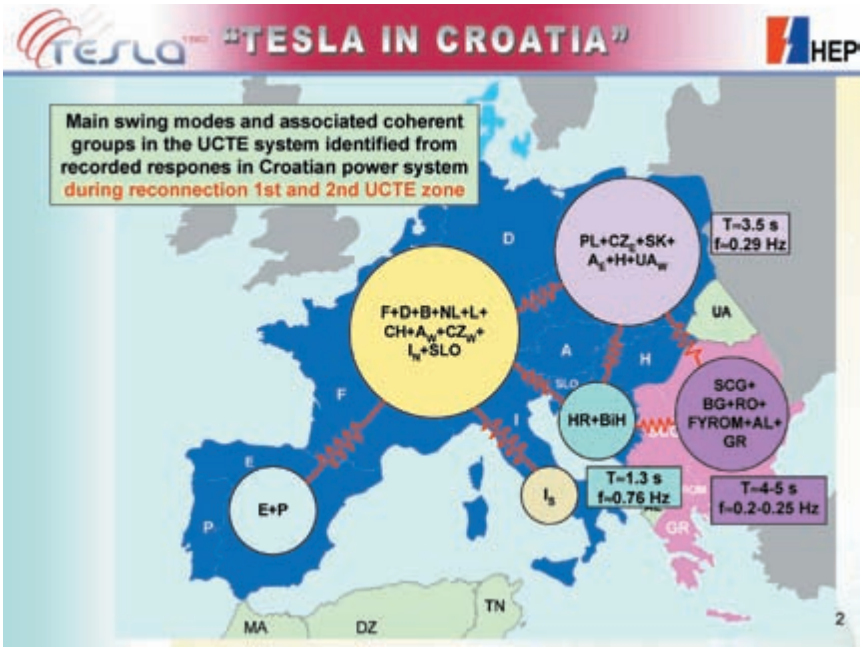

"TESLA IN CROATIA"
HEP
Electric Power System Interconnection
Advantages
• Higher reliability of supply
• High stability of frequency
• Decreased primary power reserve requirement for single power systems, especially smaller ones
• Large units can be installed in smaller power system
• Better utilization of the primary energy resources
• P daily peak_interconnection < ΣP daily eak_i =1...n: for spreading E ⇔ W
• Electric energy market
6

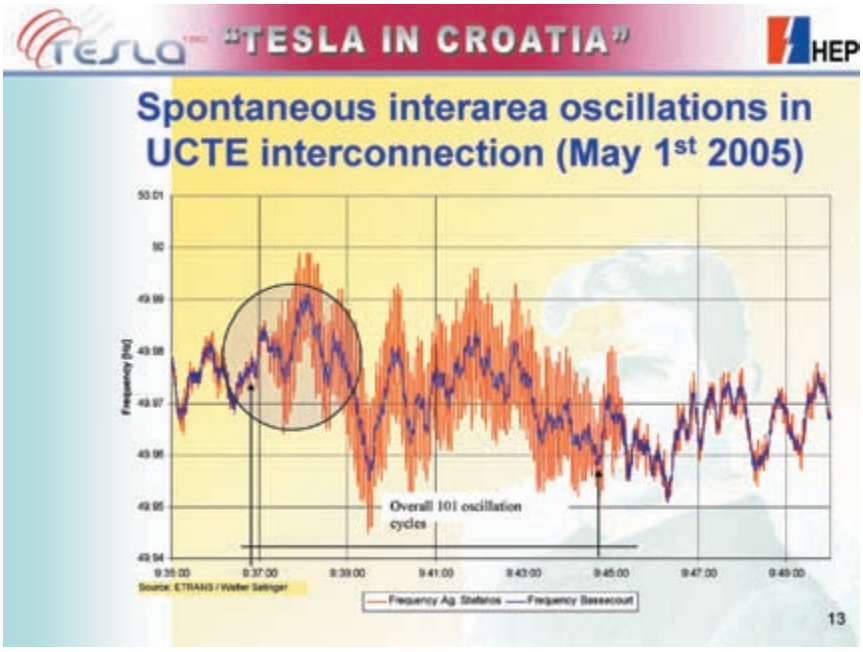

"TESLA IN CROATIA"
HEP
Electric Power System Interconnection
Disadvantages
• Compliance to Interconnection codes / rules
• Need for higher level of organisation and planning
• Risk of system-wide disturbance spreading
• Modern interconnected power systems: large and complex, geographic distribution, simultaneous generation and consumption
• Appearance of Interarea oscilation could be a problem ⇨ Problem of dynamic angle stabillity ⇨ Installation of PSS
7

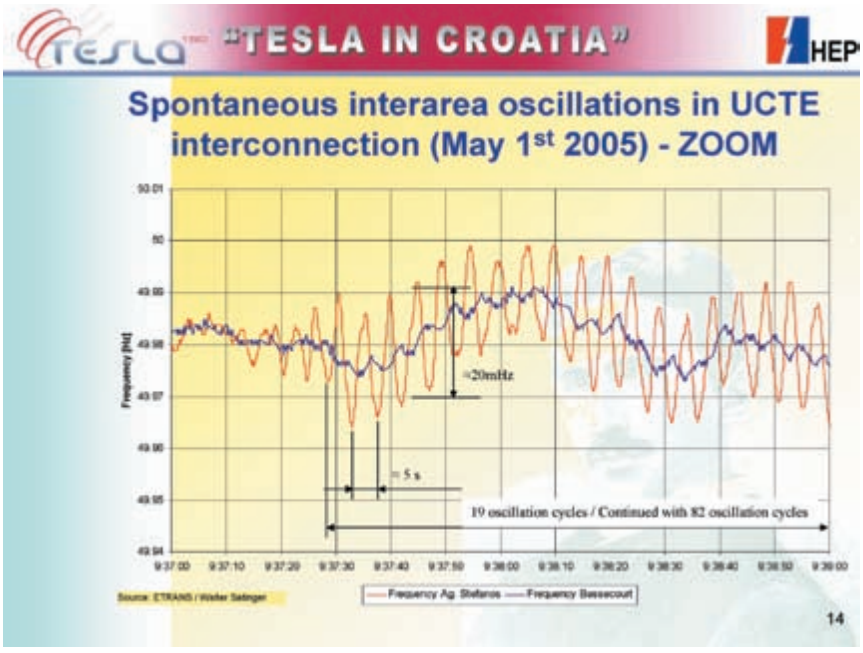

"TESLA IN CROATIA"
HEP
1951 UCPTE
1960 OES
1961 UFIPTE
1963 NORDEL
1974 SUDEL (exYU)
1977 SUDEL (GR)
1985 ALBANIA
1991 War in exYU
1992 CENTREL
1993 Disconnection USSR and RO, BG
⇨2nd zone UCPTE
1995 CENTREL and DDR
⇨ UCPTE
1997 MO, DZ and TN MAGREB ⇨ UCPTE
1999 EU 96/92 UCPTE ⇨ UCTE
2002 wUA ⇨ UCTE
08/2004 east BiH ⇨ UCTE
10/2004 Reconection of 1st and 2nd sync. zone of UCTE
UKTSOA
ATSOI
9


"TESLA IN CROATIA"
HEP
Reconnection of the 1st and 2nd UCTE zones
Coordination Center
NDC Zagreb (HR)
Peak Load : 223 GW
2004 October 10th
9:34 – 10:58
ZONE 1
ZONE 2
Mukacevo
Sandorfalva
Bekescaba
Arad
Subotica
Mladost
Ernestinovo
Zagreb (HR)
Mettlen (CH)
Trebinje
Podgorica
5 x 400 kV
2 x 220 kV
1 x 110 kV
Peak Load : 21 GW
Ag. Stefanos (GR)
10

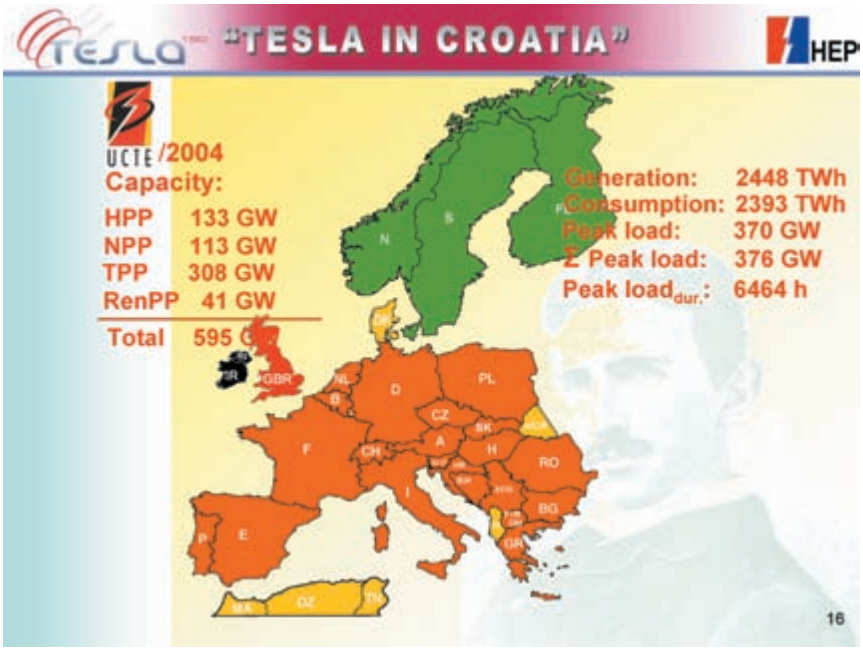

"TESLA IN CROATIA"
HEP
TP2 – S/S TUMBRI
TP1 – S/S ŽERJAVINEC
TP3 – S/S MELINA
TP4 – S/S ERNESTINOVO
10.10.2004.
09:33:53
MELINA
TUMBRI
ERNESTINOVO
ŽERJAVINEC
KONJSKO
SLO
HR
BiH
SiCG
RO
ARAD
61 MWp
40 mHz
6.1 s

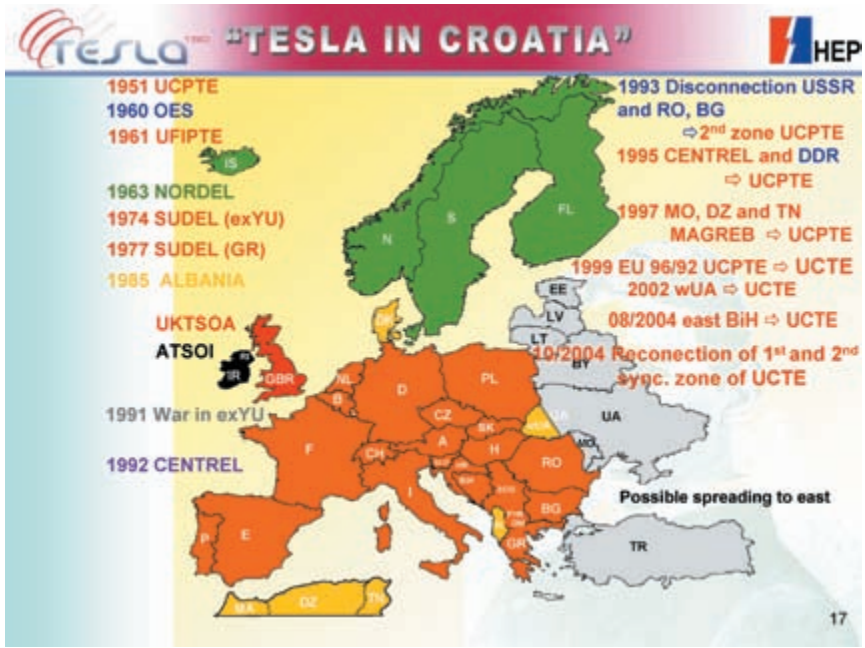

"TESLA IN CROATIA"
HEP
Main swing modes and associated coherent groups in the UCTE system identified from recorded respones in Croatian power system during reconnection 1st and 2nd UCTE zone
F+D+B+NL+L+ CH+A$_W$+CZ$_W$+ I$_N$+SLO
PL+CZ$_E$+SK+ A$_E$+H+UA$_W$
T=3.5 s f=0.29 Hz
UA
SCG+ BG+RO+ FYROM+AL+ GR
HR+BiH
E+P
I$_S$
T=1.3 s f=0.76 Hz
T=4-5 s f=0.2-0.25 Hz
TN
MA
DZ
2


"TESLA IN CROATIA"
HEP
Spontaneous interarea oscillations in UCTE interconnection (May 1st 2005)
Frequency [Hz]
Overall 101 oscillation cycles
Source: ETRANS / Walter Sattinger
Frequency Ag. Stefanos
Frequency Bassecourt
13


"TESLA IN CROATIA"
HEP
Spontaneous interarea oscillations in UCTE interconnection (May 1st 2005) - ZOOM
Frequency [Hz]
≈20mHz
≈ 5 s
19 oscillation cycles / Continued with 82 oscillation cycles
Source: ETRANS / Walter Sattinger
Frequency Ag. Stefanos
Frequency Bassecourt
14


"TESLA IN CROATIA"
HEP
Interconnected network of UCTE
UCTE
Two main UCTE control centers
Laufenburg (CH)
Brauweiler (D)


"TESLA IN CROATIA"
HEP
UCTE /2004
Capacity:
HPP 133 GW
NPP 113 GW
TPP 308 GW
RenPP 41 GW
Total 595 GW
Generation: 2448 TWh
Consumption: 2393 TWh
Peak load: 370 GW
Σ Peak load: 376 GW
Peak load dur.: 6464 h
16


"TESLA IN CROATIA"
HEP
1951 UCPTE
1960 OES
1961 UFIPTE
1963 NORDEL
1974 SUDEL (exYU)
1977 SUDEL (GR)
1985 ALBANIA
UKTSOA
ATSOI
1991 War in exYU
1992 CENTREL
1993 Disconnection USSR and RO, BG
⇨2nd zone UCPTE
1995 CENTREL and DDR
⇨ UCPTE
1997 MO, DZ and TN
MAGREB ⇨ UCPTE
1999 EU 96/92 UCPTE ⇨ UCTE
2002 wUA ⇨ UCTE
08/2004 east BiH ⇨ UCTE
10/2004 Reconection of 1st and 2nd sync. zone of UCTE
Possible spreading to east
IS
N
S
FL
EE
LV
LT
BY
UA
MO
RO
BG
TR
GR
IR
GBR
NL
D
PL
CZ
SK
A
H
CH
F
I
P
E
MA
DZ
TN
17

Darko Huljenić works in company Ericsson Nikola Tesla for more than 20 years. He goes through different positions in R&D community in the company and currently he is on position of technical adviser in R&D center in Zagreb, Croatia

He has more than 40 scientific and technical publications on international and national conferences and in magazines from the area of communications.

In parallel he is teaching at FER University of Zagreb, at postgraduate and undergraduate study.

His main scientific interests are: commincation protocols and open system architectures.

Tesla through the Communication's Vision

Darko Huljenić, Saša Dešić

1. Introduction

Nikola Tesla is perceived as a man of vision, especially when it comes to electrical power, because it is in that area that his patents found the fastest and most effective implementation. Furthermore, Nikola Tesla was a man out of time [1]. There are a lot of article and newspaper titles that enlighten the role and meaning of Nikola Tesla for modern society published around the world. Here are a couple of them that can express part of his importance: "*The man who invented twentieth century*" [2], "*An outstanding scientist, Nikola Tesla paved the way for modern technology*", "*Nikola Tesla – Man of three centuries*"[2].

To make only a short comment of these statements we can start to think about the industrial revolution and the main benefits derived from it in the twentieth century. We can ask ourselves if these things can be achievable without alternating current (AC) power, can the majority of equipment in our homes and at our work premises do anything without distributed AC power? Many other technological innovations that arose found their roots in Tesla's basic ideas and have started to be a commodity in our daily life. There are still some of Tesla's ideas from the nineteenth century unrealized or not fully understood in the twenty first century. To illustrate this we can take a decision from one United States of America forum regarding electrical energy distribution held in 2002, to have by 2020 a fully applicable system for wireless energy (electrical power) distribution [3], which was Tesla's experiment a century ago. It is amazing, but fully true,

those if we look around ourselves chances are that Tesla is somehow responsible for most of the things that make modern life so modern.

The idea of this article is to point out Nikola Tesla from his achievements and especially visions in the area of communication technology. We also know that his contribution in patents and ideas was significant in the field of communication procedures, especially in wireless transmission. Today most of us are fully aware of and involved in overall wireless communication and the use of wireless communication models and equipment. We are all aware of the fact that Tesla provides to us basic wireless communication principles based on ground technological inventions of H. Hertz and others.

As it stated in the first sentence of this article, Nikola Tesla was a great visionary and it is fascinating to read his statement about wireless systems that he wrote in 1904 [1]: "*I have no doubt that it will prove very efficient in enlightening the masses, particularly in still uncivilized countries and less accessible regions, and that it will add materially to general safety, comfort and convenience, and maintenance of peaceful relations*". This is only a small part but it shows the couple of things in connection with Tesla and his vision, and his relation between technology and the wellness of mankind. To analyze this statement we can ask the first question: is this true? With an entire century having passed and with experiences in the broad usage of wireless communication systems we can say this is TOTALLY true. Another question that can be asked is: is it still valid today? Once again the answer is "more than ever", and it can inspire all of us to enable full execution of this idea and make the world better, with this being the essence of many of Tesla's idea and his whole life's dedication.

The company Ericsson Nikola Tesla that carries his name acquired a global recognition as it incorporated in its activities the desire to permanently improve communication for the good of mankind. The joint names of Nikola Tesla and Lars Magnus Ericsson, the founder of the company Ericsson, represent an interesting synergy enabling us to show the present and perhaps the future of communications.

The paper provides a short history of mobile communication development and it analyzes the technological basis that enabled a widespread implementation of wireless transmission (*Global System for Mobile Communications* – GSM, *Universal Mobile Telecommunication System* – UMTS). The paper also analyzes the omnipresent and always available communication model realized through the use of various technologies, such as Bluetooth, *Wireless Local Area Network* – WLAN, *Radio Frequency Identification* – RFID and network backbone. For that combination of technologies we can use the term communication grid, similar to the vision Tesla had about electrical power grid. Additionally, some possible commu-

nication models are analyzed that could fulfill the concept of a communication grid and to prove the essence and validity of Tesla's statement from 1904.

2. Communication technology status today

In order to better understand Tesla's impact on our daily life it is good to make a short snapshot of where we are now in the area of communication technology. We have a very well established wireline network around the globe. We also have a well established wireless network infrastructure and constant growth of subscribers. Today there is wide deployment and use of the second and second and half generation of GSM (2G and 2.5G) networks and services within General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE). The main usage of current wireless network infrastructures is for voice communication, data services and Short Message Service (SMS). At this moment there is active deployment of the third generation of wireless systems (3G), called also Universal Mobile Telecommunication System (UMTS). Some basic infrastructure and terminals based on Wideband Code Division Multiple Access (WCDMA) coding technology are present. The main benefit of using this new generation of wireless network infrastructure is to provide users with rich services based on multimedia content. The real meaning of this will be better explained later through figures.

One additional technology under broader deployment is the IP Multimedia Subsystem (IMS) that will enable an infrastructure for a controlled service environment based on omnipresent IP technology. The idea is to make available/enable communication goods in a controlled environment to everyone. The main idea in IMS is managed and converged services to be enabled to every subscriber and with unified terminal capabilities. The main essence is to enable users to communicate in a preferable way, using voice or data or both at the same time. In the wireless communication first technology adoption and current research topics is now the fourth generation (4G) of mobile networks and service infrastructure. There are a couple of different standards that enable terminal and user mobility, with the main idea of 4G being to provide the synergy effect of different access technology in order to enable a user to be always connected. If we want to briefly describe the 4G wireless network we can based our description on the motto: "use of any possible access technology to be connected – use services wherever you are".

To illustrate what is going on and what is expected in the communication technology area, the best indication could be expected network traffic trends. Today's everyday life in business or a home environment totally depends

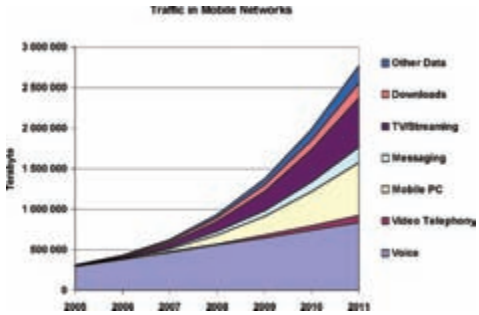


Fig. 1a – Mobile network traffic and service trends

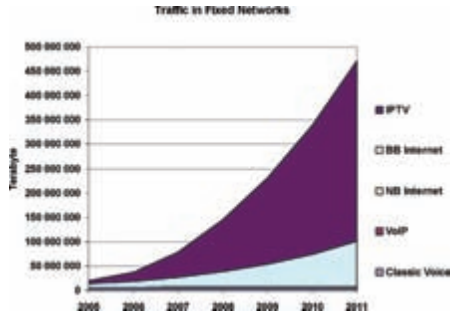


Fig. 1b – Fixed network traffic and service trends

on communication, and the main aim in developing a communication infrastructure is to have rich communication possibilities. The illustration of trends is presented in Figure 1a for mobile networks and in Figure 1b for fixed networks [4].

On both figures the x-axes shows the years of the analyzed period – starting from 2005 to 2011, while the y-axes shows Terabytes of expected traffic. Two things may be pointed out if we compare these two trends. The first is that in both situations there is a visible expectation of big traffic growth in coming years. Secondly, it is visible that there is a difference in expected service usage. In the fixed networks voice will stay in the same amount but with the expectation of big growth in services based on Internet Protocol (IP) technology, such as Voice over IP (VoIP) or IP based Television (IPTV). Furthermore, big growth is expected in Narrowband (NB) and Broadband (BB) Internet connections.

In the area of mobile networks there is space for more voice services growth, in addition to growth in many data services in connection with mobility (mobile PC, messaging, TV/Streaming and downloads). Both of these trends are in great correlation with Tesla's statement about his wireless system from 1900.

Activities and trends in wireless communications can be illustrated with the situation in year 2005 and with the achievement in June of year 2006 where the complete wireless community reached 2 billion users [5]. Figure 2 illustrates this situation.

As is visible on the first chart in Figure 2, for the year 2005 the dominant technology for wireless communication around the world was GSM. There were 1.4 billion GSM subscribers of the total world population of 6.4 billion. 2.6 billion of the population have the possibility to be subscribers because they have coverage with wireless signals but they are not subscribers yet. There is still 2.2 billion of

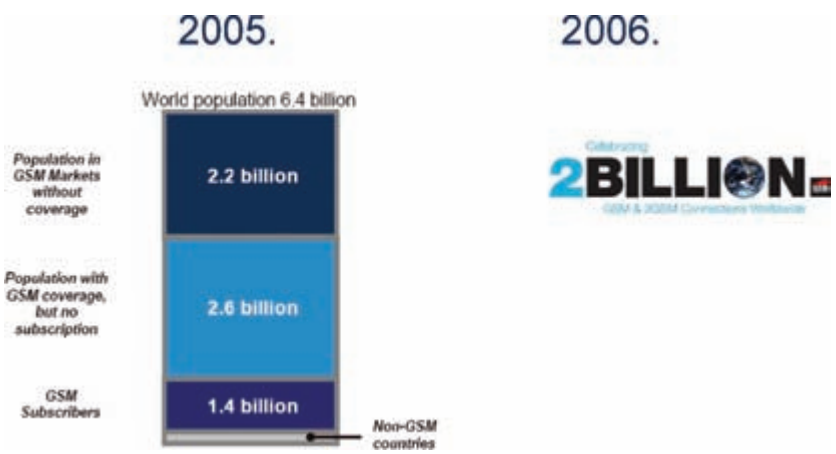


Fig. 2 – Users of GSM technology

the population without the possibility to be a subscriber because they do not have an infrastructure and access to a wireless network signal. Another visible thing on second part of Figure 2, year 2006, is that in less than one year there has been a growth in subscribers of approximately 43 percent, moving us closer to enabling as much of the population as possible to communicate. The main benefit of wireless systems is especially in poor countries to faster establishing communication infrastructure to have today civilization possibilities. It is visible that today GSM and 3G networks are gaining new subscribers at the rate of about 1000 per minute, with the total recently passing the 2 billion mark. Inline with the current population trend and acceptance of wireless communications, the expected amount of wireless subscribers is 4 billion.

Today's driver of mankind wellness is to have information at the right time or whenever you need it and wherever you are located. There are so many sources of information but in general we can divide them in correlation with our home or in correlation with our office or business environment. Life is today much connected with constant mobility and many of us are owners of mobile terminals that enable us to cover these two main daily requirements – possessing of information and mobility. The concept that best enable us to fulfill these two requests is called triple play communication environment as illustrated in Figure 3.

This concept of triple play forces the new convergence of different sources of information with all needed requests for office and for home. What we prefer the most at home regarding communication services are telephony, or voice communication, access to web sources of information and TV. At the office environment we prefer to use telephony and web-based services. All together we can converge on our mobile terminal device and we can be independent of our loca-

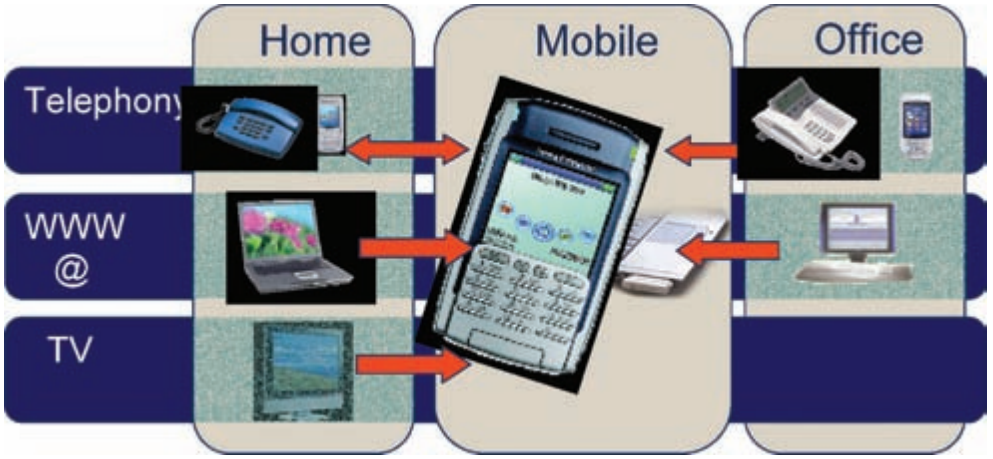


Fig. 3 – Triple play concepts

tion availability. Communication technology enables us to use different terminals but at the same time to have only one of them and to have full access to our preferable communication services. Thanks to Tesla and his great invention of the wireless communication principle.

3. Tesla's "World System"

The previous chapter enlightened only a part of Tesla's invention and vision regarding the area of communication. If we take 12 basic elements that Tesla wrote in articles, in the year 1902, 1915, and 1927, about his prediction about the "World System" we can see many visions of today technological elements and communication infrastructures trends. Tesla called these statements Action Plan.

Tesla's statements [6]:

1) Interconnection of the existing telegraph exchanges or offices all over the world;
2) Establishment of a secret and non-interferable government telegraph service;
3) Interconnection of all the present telephone exchanges or offices all over the globe;
4) Universal distribution of general news, by telegraph or telephone in connection with the Press;

5) Establishment of a World System of intelligence transmission for exclusive private use;
6) Interconnection and operation of all stock tickers of the world;
7) Establishment of a world system of musical distribution, etc.;
8) Universal registration of time by cheap clocks indicating the time with astronomical precision and requiring no attention whatever;
9) Facsimile transmission of typed or handwritten characters, letters, checks, etc.;
10) Establishment of a universal marine service enabling navigators of all ships to steer perfectly without compass, to determine the exact location, hour and speed, to prevent collisions and disasters, etc;
11) Inauguration of a system of world printing on land and sea;
12) Reproduction anywhere in the world of photographic pictures and all kinds of drawings or records.

Analysis of these statements can be done in many different directions, but in all of them there is a visible common denominator: the phrase world or around the globe, which can be interpreted as to all community. Another important visible fact is at the mentioning at that time of important communication principles such as telegraphy and telephony, with some important technology visions. Some of these technology visions were realized in the next couple of years but some of them in fifty years, for example statement five that predicts today's Internet and World Wide Web technology, or today very popular electronic music distribution. Looking from today's perspective we can say that all visions/statements are basically achieved in the context of technology but not all of them have reached global presence, especially in the context of being available to everyone as meant by Tesla with "World System".

Based on this last conclusion, with exclusion of some elements in connection with telegraphy that is in minor usage today, we can consider these statements as a communication manifest to enable global wellness to everyone. That was Tesla's background visions in his many technological inventions.

To discuss a little bit more the impact of ideas from Tesla's "World System", an important fact comes from his additional statement in the article [7]:

"*... the distribution of wireless energy for all purpose the precedent established by telegraph, telephone and power companies must be followed, for while the means are different the service is of the same character.*"

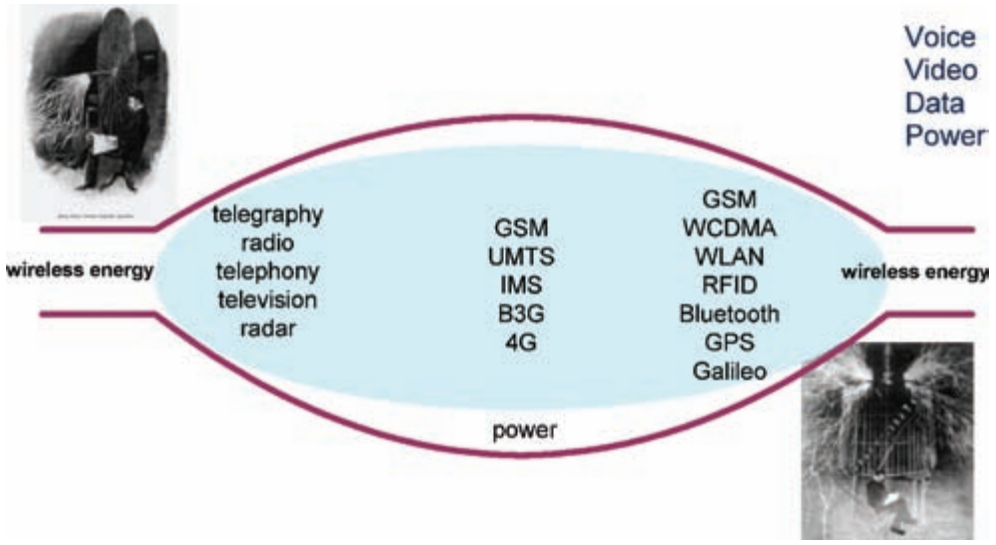


Fig. 4 – Wireless energy transmissions

Thinking about this statement and putting it in today's context, the idea was to make a graphical presentation as illustrated in Figure 4. Analyzing things in illustrated context it is visible that the starting point is with a couple of technological elements that was based on the concept of wireless energy transmission. After that come many development elements and trends that enable infrastructure to transmit and use this wireless energy. With all convergence trends, some of them are mentioned in the previous chapter, in the infrastructure and terminals the end point is very simple and once again in the concept of wireless energy transmission.

There are a lot of technological elements merged in the same context of wireless energy transmission, as Tesla wrote: "… service is of the same character". The basic start is in principles of telegraphy, telephony, radio, television and radar. In the middle are basic principles for infrastructure that enables building the broader, around the globe, transmission environment – network as from GSM to 4G. At the right side are some additional technological elements that enable basic wireless access or some additional data transmission such as positioning data. An additional element in the same context is electrical power. All of these elements and principles are used to transmit voice, video, data or power. All of these principle realizations will help in complete fulfillment of Tesla's statement about a World System and his visions about the role of communication for global wellness.

4. The communication grid

Analyzing Tesla's visions and invented principles in the aspect of communication and AC electrical power production and distribution it is important to think in a similar context. We have today an electrical power grid that provides to us pervasive access to power. This means that wherever we are in an urban area we can plug in our device and start to use AC electrical energy. The distribution systems for electrical energy are well connected around the globe and we do not ask where is this energy produced – we just use energy. The established system gives to us a lot of freedom.

Basic understandings of the electrical power grid and the needs for complex and demanding computing lead the science community to start to build a computing grid. The basic idea is to use computing power in the connected environment independent of the capabilities of our own computing device. Grid computing is an emerging computing model that provides the ability to perform higher throughput computing by taking advantage of many networked computers to model a virtual computer architecture that is able to distribute process execution across a parallel infrastructure. Grids use the resources of many separate computers connected by a network (usually the Internet) to solve large-scale computation problems. Grids provide the ability to perform computations on large data sets, by breaking them down into many smaller ones, or provide the ability to perform many more computations at once than would be possible on a single computer, by modeling a parallel division of labour between processes [8].

Based on our previous analysis about where we are now in communication technology development and what we tend to achieve in the research and development community, it is more than obvious that we want to have a communication grid. This means that we want to be reachable anywhere, anytime with our preferable services. The question can be how is this correlated with Tesla? The answer is that Tesla provided the deep roots with his basic invention of wireless communication and through his vision statements about communication aspects. It enables many other inventors and companies to produce technology that will enable us to have the full scope of a communication grid.

5. Conclusion

Analyzing Nikola Tesla from the aspect of communication he can be perceived as a man of visions, and the statement from the introduction of this article: "… Nikola Tesla paved the way for modern technology" can be fully proved. Taking

into account his great contribution to the AC electrical power systems it is visible that as AC electrical energy was important in enabling mankind wellness, or commodity, in the previous century, modern communication and especially wireless communications have become a commodity of 21st century. Full commodity of wireless communications will be achieved when it will be possible to have broad deployment of rich multimedia communications that will enable the communication grid concept. Tesla's visions in the area of communication inspire us a great deal, and we have a couple of things to make operable still. We will prove Tesla's statement by building the communication grid and enable the full scope of wireless energy transmission.

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[4] Ericsson internal material, 2006.

[5] http://www.gsmworld.com/news/press_2006/press06_29.shtml

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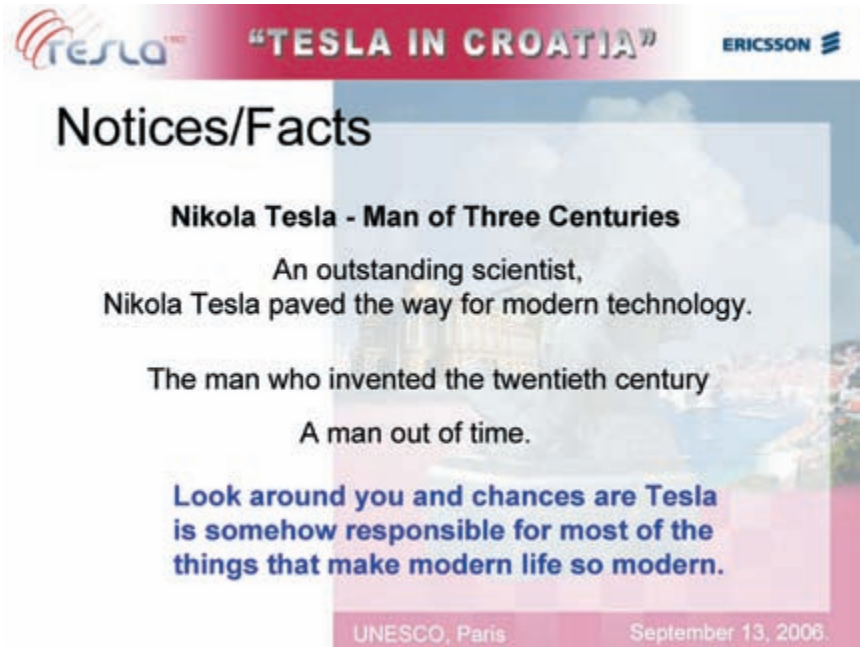
Appendix


"TESLA IN CROATIA"
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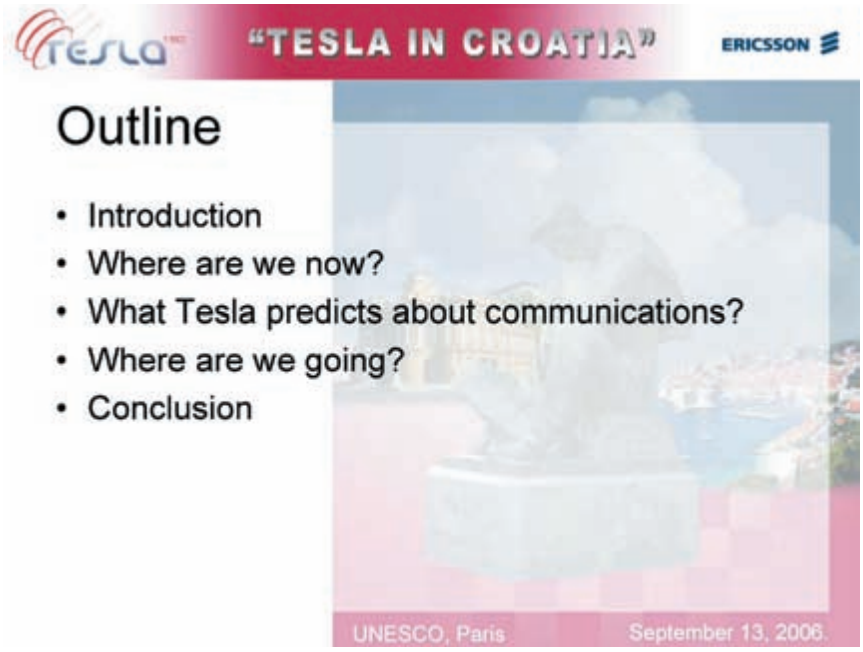
Notices/Facts
Nikola Tesla - Man of Three Centuries
An outstanding scientist,
Nikola Tesla paved the way for modern technology.
The man who invented the twentieth century
A man out of time.
Look around you and chances are Tesla is somehow responsible for most of the things that make modern life so modern.
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
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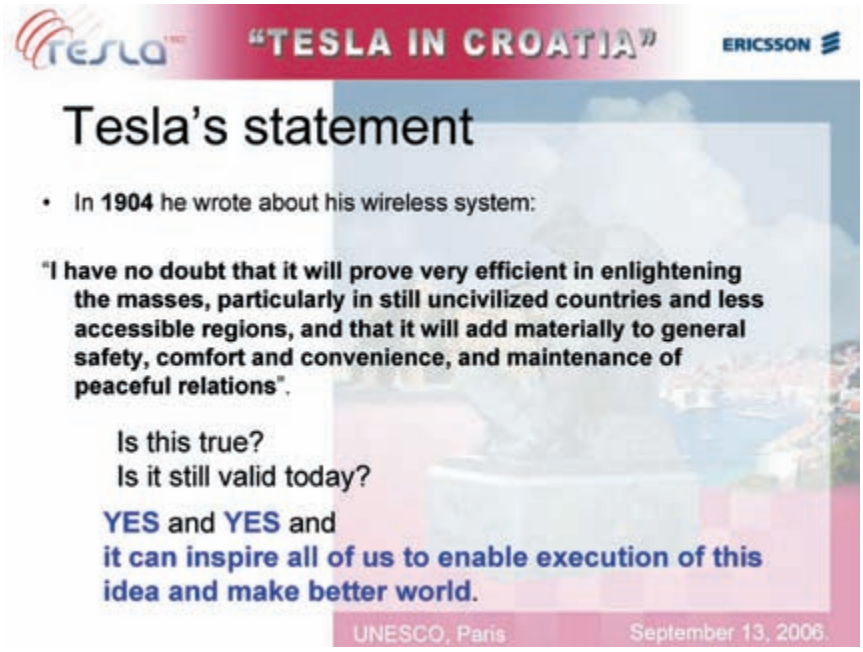
Outline
• Introduction
• Where are we now?
• What Tesla predicts about communications?
• Where are we going?
• Conclusion
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
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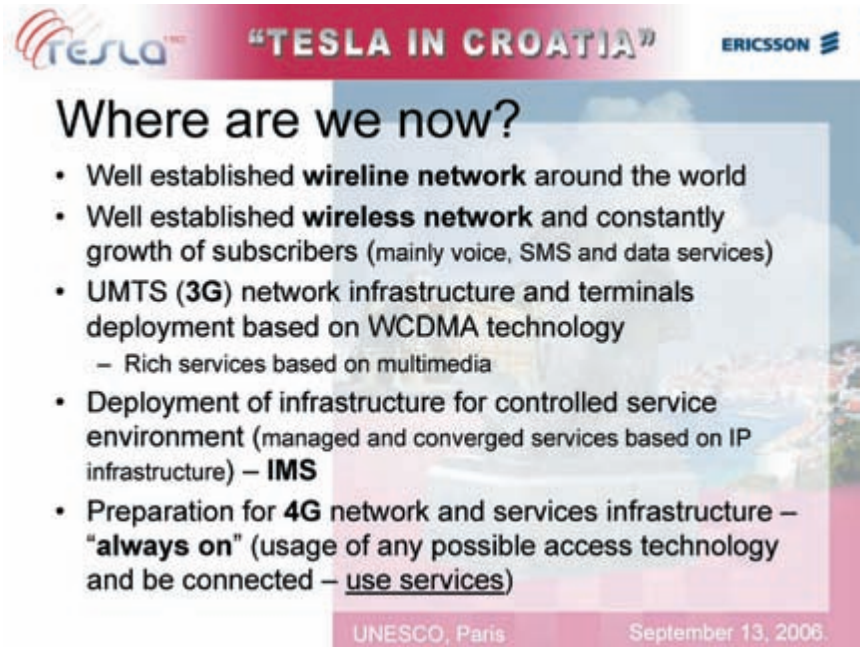
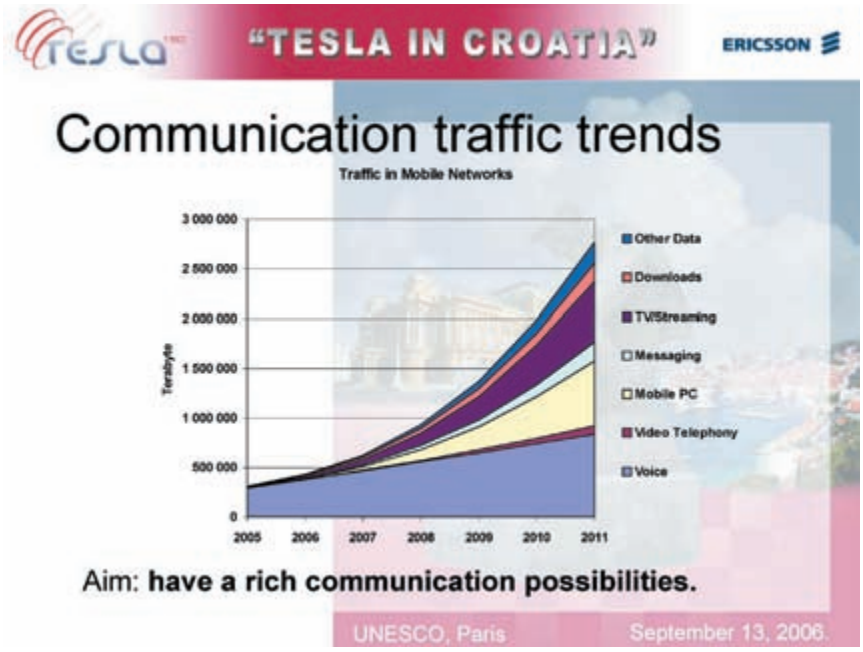
Tesla's statement
• In 1904 he wrote about his wireless system:
"I have no doubt that it will prove very efficient in enlightening the masses, particularly in still uncivilized countries and less accessible regions, and that it will add materially to general safety, comfort and convenience, and maintenance of peaceful relations".
Is this true?
Is it still valid today?
YES and YES and
it can inspire all of us to enable execution of this idea and make better world.
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Where are we now?
• Well established wireline network around the world
• Well established wireless network and constantly growth of subscribers (mainly voice, SMS and data services)
• UMTS (3G) network infrastructure and terminals deployment based on WCDMA technology
– Rich services based on multimedia
• Deployment of infrastructure for controlled service environment (managed and converged services based on IP infrastructure) – IMS
• Preparation for 4G network and services infrastructure – "always on" (usage of any possible access technology and be connected – use services)
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
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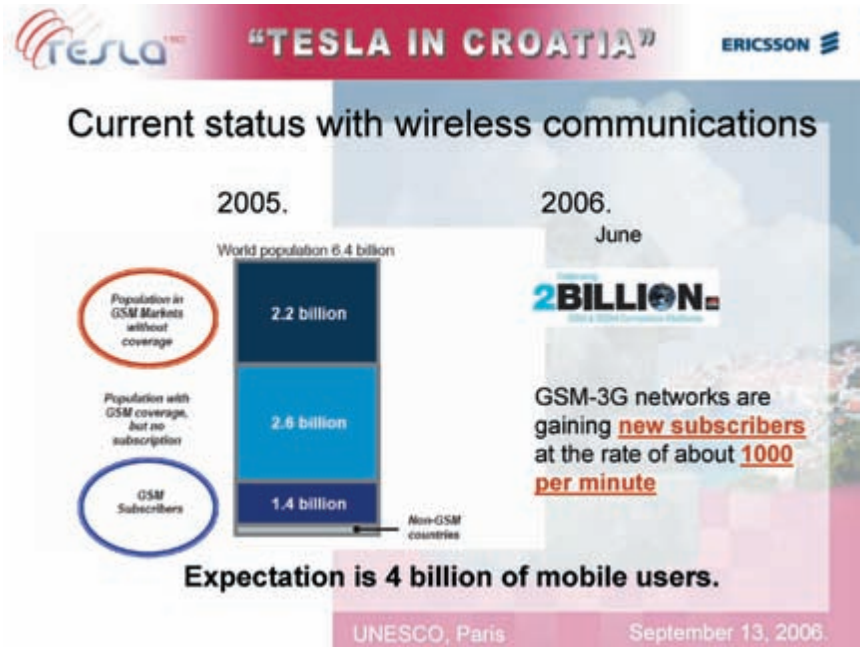
Communication traffic trends
Traffic in Mobile Networks
Terabyte
3 000 000
2 500 000
2 000 000
1 500 000
1 000 000
500 000
0
2005
2006
2007
2008
2009
2010
2011
Other Data
Downloads
TV/Streaming
Messaging
Mobile PC
Video Telephony
Voice
Aim: have a rich communication possibilities.
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
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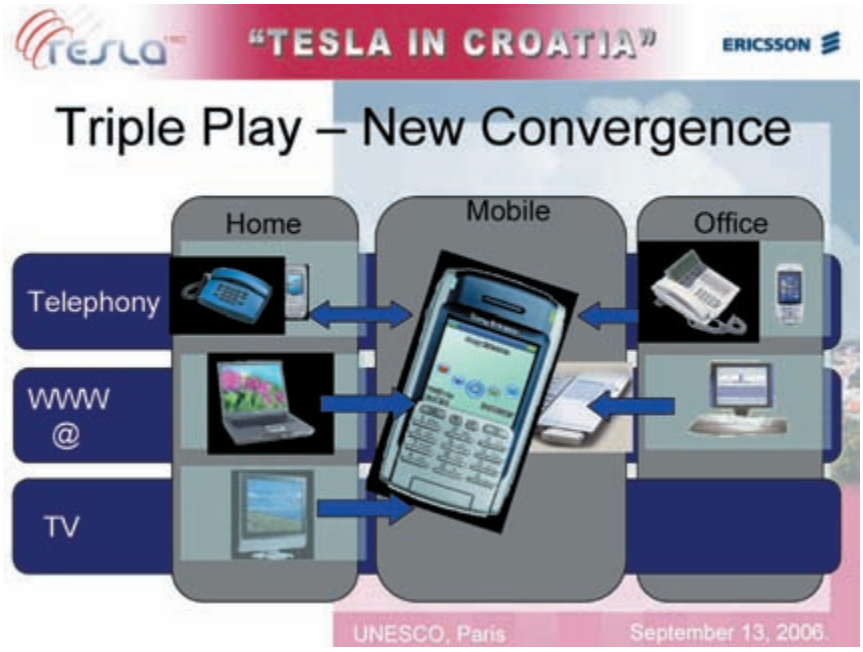
Current status with wireless communications
2005.
2006.
June
World population 6.4 billion
Population in GSM Markets without coverage
Population with GSM coverage, but no subscription
GSM Subscribers
2.2 billion
2.6 billion
1.4 billion
Non-GSM countries
2BILLION
GSM-3G networks are gaining new subscribers at the rate of about 1000 per minute
Expectation is 4 billion of mobile users.
UNESCO, Paris
September 13, 2006.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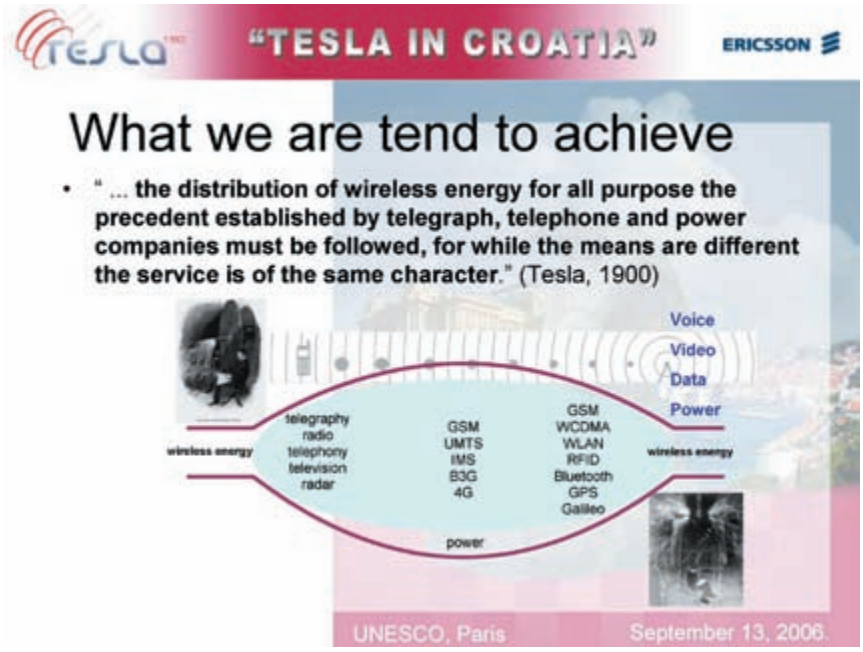
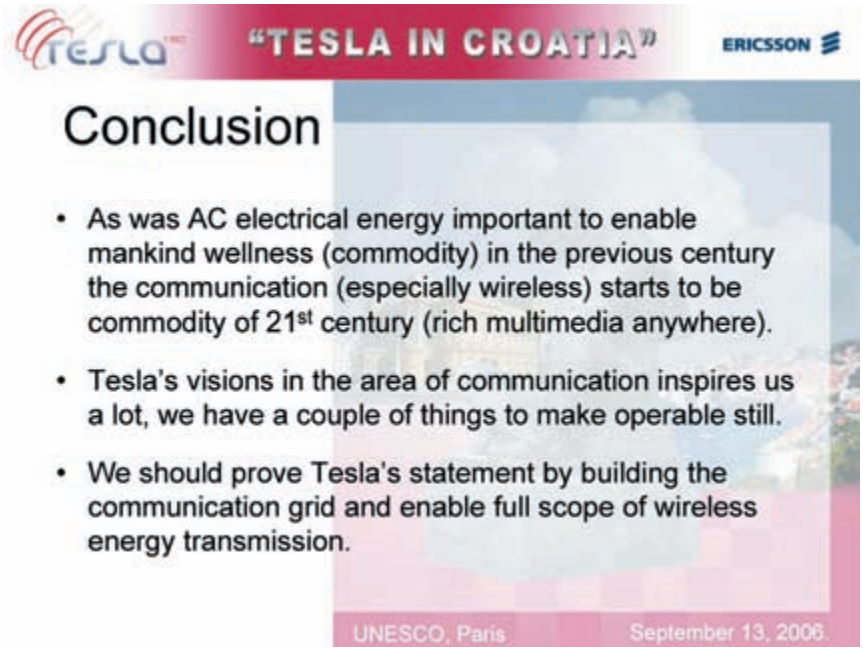
Triple Play – New Convergence
Home
Mobile
Office
Telephony
WWW
@
TV
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Tesla's "World System" (1902,1915, 1927)
ACTION PLAN
1) Interconnection of the existing telegraph exchanges or offices all over the world;
2) Establishment of a secret and non-interferable government telegraph service;
3) Interconnection of all the present telephone exchanges or offices all over the globe;
4) Universal distribution of general news, by telegraph or telephone in connection with the Press;
5) Establishment of a World System of intelligence transmission for exclusive private use;
6) Interconnection and operation of all stock tickers of the world;
7) Establishment of a world system of musical distribution, etc.;
8) Universal registration of time by cheap clocks indicating the time with astronomical precision and requiring no attention whatever;
9) Facsimile transmission of typed or handwritten characters, letters, checks, etc.;
10) Establishment of a universal marine service enabling navigators of all ships to steer perfectly without compass, to determine the exact location, hour and speed, to prevent collisions and disasters, etc;
11) Inauguration of a system of world printing on land and sea;
12) Reproduction anywhere in the world of photographic pictures and all kinds of drawings or records;
Is it fullfiled all or it can be used like communication MANIFEST?
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
What we are tend to achieve
• " ... the distribution of wireless energy for all purpose the precedent established by telegraph, telephone and power companies must be followed, for while the means are different the service is of the same character." (Tesla, 1900)
Voice
Video
Data
Power
wireless energy
telegraphy
radio
telephony
television
radar
GSM
UMTS
IMS
B3G
4G
GSM
WCDMA
WLAN
RFID
Bluetooth
GPS
Galileo
wireless energy
power
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
The power grid and communication grid
• We have a power grid
– Where ever you are in urban area you can plug in your device and start to use AC electrical energy
• We are building computer grid
– You can use computing power in the connected environment independent of your own computing device
• We want to have a communication grid
– Reachable anywhere anytime with our preferable service
UNESCO, Paris
September 13, 2006.


"TESLA IN CROATIA"
ERICSSON
Conclusion
• As was AC electrical energy important to enable mankind wellness (commodity) in the previous century the communication (especially wireless) starts to be commodity of 21st century (rich multimedia anywhere).
• Tesla's visions in the area of communication inspires us a lot, we have a couple of things to make operable still.
• We should prove Tesla's statement by building the communication grid and enable full scope of wireless energy transmission.
UNESCO, Paris
September 13, 2006.

Igor Mandić, literary critic, essayist and polemicist, was born in 1939 in Šibenik (a city on the Croatia's Adriatic coast). In 1963, he graduated from the Department of Comparative Literature, Faculty of Philosophy, University of Zagreb. As a student, he started publishing works of literary criticism. Since 1960s he has professionally bound his life and writings with the mass media. In such concubinage, Mandić has created an impressive body of work, publishing over 20 books, the nucleus of which are collections of literary critical texts ("Against the grain", 1970; "101 short critiques", 1977; "The literature and media culture", 1984; "Novels of crisis", 1996, etc.). To these, he has added books of genuine polemical charge ("Gentle heart", 1975; "Soul police", 1979; "Good-bye, dear Krleža", 1988.), as well as accessible analyses of modern times, mass culture and television ("Mysterium televisionis", 1972; "Naked mass", 1973; "Mythology of everyday life", 1976; "The shock of the time being", 1979; "What, really, do these women want? – the cataclysm of feminism", 1984; "The principles of crime stories", 1985; "Ecstasies and hangovers – an introduction to the poetics of thirst", 1989; "The problem of Priapus – vulgar essays", 1999). He has also published several books which are ideationally and polemically concerned with the destiny of survival in a post-communistic society ("For our cause", 1999; "Between two fires", 2000; "White crow", 2002; "Emergency room", 2005). His most recently published book, "Under one's own skin or an unintentional biography" ("Profil", Zagreb 2006.), has been at the top of Croatian bestseller lists for months.

Tesla's Galaxy

Igor Mandić

After the period of the culture of "typographic man" (15th-20th Century), which has been globally accepted under the syntagm "Gutenberg's Galaxy", it seems logical that the culture of "electrical man", pertaining to the electrical centuries (20th-21st Century), should be encompassed by the syntagm "Tesla's Galaxy".

Since the year 2006 has been most kindly pronounced by the UNESCO as "The Year of Nikola Tesla", and the Croatian Parliament has done the same, on many parts of this "electrified world" a lot of questions and remarks have been echoing: Is that really enough to sead once and for all the 150 years of the genius Nikola Tesla?

All around the world scientific meetings have been held, dedicated to revolutionary patents and discoveries of that modest man, in which their contribution have also the institutions in Croatia, whose mission is making efforts not to forget Tesla's achievements.

We also know that Nikola Tesla received many prizes during his lifetime, and even more after he deceased, and we can regret for the prizes that have not been presented to him or have been finally stolen from him, but also from time to time we could hear different commentaries that his name on the Moon is not enough for him to be worldly known.

In average global perception his name has been faded a little in front of the names of the other scientific stars, who were even some of his colleagues or concurrents. This is even more interesting if we can say that this electrified century was discovered by Nikola Tesla, because after his death in 1943 the whole civilized world has been definitely drowned into the electrical world.

So, trying to figure out some new metaphor, which could, as a simple syntagm encompass most of the consequences in which the mankind from the beginning of the 20th Century enjoys until today, and will enjoy even in distant future, a new term, "Tesla's Galaxy", has been invented, originally presented in 1979. Many people will, not only experts, react instinctively, feeling in this syntagm some contraposition, but also a continuation to the existing globally-famous syntagm "Guttenberg's Galaxy".

Since the early 60s of the past Century, McLuhan described the culture of typographic man defining it as a decade of the cultural history from the first half of the 15th Century until the beginning of the 20th Century, with syntagm "Gutenberg's Galaxy" being inseparatedly posted to it.

As everyone knows today, McLuhan in his books "The Gutenberg Galaxy" and "Understanding Media" presented in detail what has happened in global culture when the electricity endangered the ancient culture of literacy, but even he or his followers haven't deeply asked themselves was there a need or any sense, even metaphorically, in trying to visualize which galaxy would follow the Gutenberg's one.

For the great McLuhan that wasn't really necessary, so in few of his interviews he only referred to Edison or Marconi, but without a sufficient engagement. So for the empty space logical solution was the man who invented 20th and 21st electric century.

After the media culture had overflowed the mankind, it was overtaken with electrical light just as native man was with his first touch to the literacy.

So we found ourselves plunged into electrical light as in "pure information", and it took us so long to understand that it is our new nature. To McLuhan electricity is just an extension of our central nervous system. McLuhan speculating that on

the basis of technology which has been invented by Nikola Tesla. Nothing is more logical than that, after "typographic man", i. e. after the "Gutenberg's Galaxy", comes the "electrical man" under the mantling of "Tesla's Galaxy".

At the end, it seems that we could, by widely applying and even forcing this syntagm, demonstrate all our gratitude to the Tesla's greatness, generally putting his scientific achievements to the level of communicative and generally understandable vocabulary.

Croatia - Tesla - World

2006 - THE YEAR OF NIKOLA TESLA

HEP

2006 - The Year of Nikola Tesla

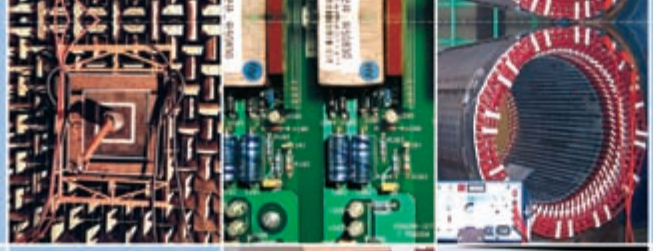
Tesla's inventions

www.ericsson.com/hr

Potential for the future

ERICSSON

Ericsson Nikola Tesla d.d.





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Non-profit, project oriented Institute

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CROATIAN ACADEMY OF ENGINEERING – HATZ

Founded in 1993
10000 Zagreb, 28 Kačić St., CROATIA, Europe
http:/www.hatz.hr – Tel.: +385 1 4922-559 – Fax: +385 1 4922-569

INTERNATIONAL COUNCIL OF ACADEMIES OF ENGINEERING AND TECHNOLOGICAL SCIENCES, INC. (CAETS)

CAETS

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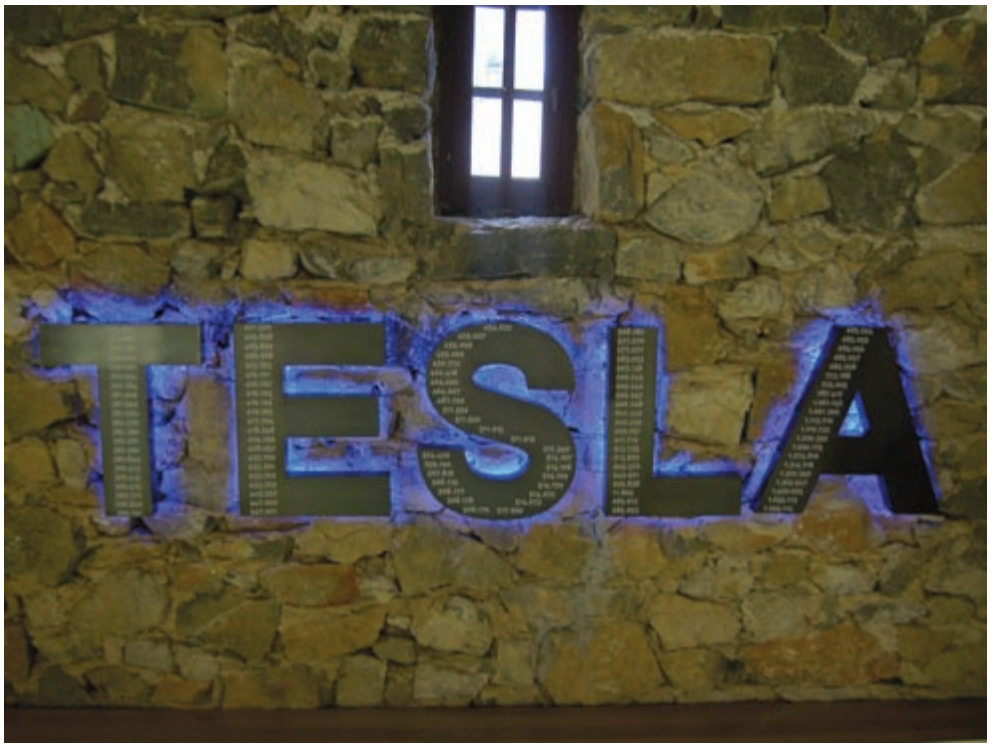
ACTIVITIES AND AIMS

HATZ is a non-profit association of selected prominent scientists in the fields of engineering and biotechnical sciences, which promotes engineering and biotechnical sciences, brings together and stimulates the co-operation of the scientists of various engineering, biotechnical and other professions in order to support the effective scientific and economic development of Croatia.

THE ACTIVITIES OF THE ACADEMY INCLUDE:

- fundamental, applied and experimental research,
- research and development in engineering and biotechnical sciences,
- technical testing and analyses,
- activities of professional organisations,
- simulation and organisation of scientific work,
- publishing results od scientific research,
- producing scientific studies, expertises, surveys and projects,
- discussing and putting forward statements on current scientific and economic issues,
- organising scientific and professional gatherings,
- issuing publications,
- co-operation with other academies, domestic and from abroad.



Detail from Tesla's house – foto by Z. Kniewald