

A Century of Remote Control

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Introduction

Nikola Tesla's invention of remote control by radio waves appeared in the early phase of radio development. It followed his work on *"Tesla coil and oscillation transformer (1889-1892), researches and experiments with currents of high frequency (1889-1898) and Tesla Wireless System (1891-1893)"*[1]. In this period also was the demonstration of wireless telegraphy made by Oliver Lodge in 1894, shown as a scientific curiosity at the Oxford meetings of the British Association for the Advancement of Science, using an induction coil and spark gap for a transmitter and a coherer and galvanometer for receiver. In the same year Guglielmo Marconi began his experiments in the attic of his father's villa in Bologna. By 1896 Marconi had a workable communication system to demonstrate to the British Post Office[2]. In his efforts to find practical solution for wireless energy transmission Nikola Tesla made several important steps to the radio development. Some time in 1890 he invented a new electrical oscillator with a spark gap and transformer without iron core, soon to become known as „Tesla coil“. In 1893 he described a system with a monopole antenna at the transmitting and receiving sides and suggested the use of continuous high-frequency currents and tuned receiver [3]. His system generated guided wave along the earth, and in contrast to Hertz's system it operated at long wavelength. Preoccupied with the idea to develop system that could transmit large amount of energy with negligible loss, Tesla fundamental radio patents, filed in 1897, on Apparatus for Transmission of Electrical Energy and System of Transmission of Electrical Energy [4,5], only mentioned possible use of Tesla's system and apparatus for message transmission.

In the early development of Radio one can distinguish two phases: one based on Hertz's apparatus disclosed in 1887 with a spark-gap generator producing pulses of highly damped, high frequency currents. The operating frequency of such system depended on the dipole antenna attached to the high voltage coil, it was unstable and its spectrum was wide. As a receiver Hertz used a wire loop with small balls separated at short distance. The received signal was detected by observing a tiny spark between the balls. Nikola Tesla began his radio research from the low frequency side of the spectrum. Hence, he worked with the continuous high frequency currents and that was the beginning of the second phase of radio development - so called „the continuous wave

radio"[2]. However, in spite of mentioning Tesla's contribution to the development of early phase of radio by some of his contemporaries[6], Tesla has not been recently mentioned between „Six great pioneers of wireless"[7].

Art of Teleautomaton

Many of Tesla's inventions were results of long thinking and careful observation of nature. Remote control of mechanisms is in no way an exception to this rule. In an article, written in 1900, Tesla wrote: *"It was not long before I was aware that also all my movements were prompted in the same way, and so, searching, observing, and verifying continuously, year after year, I have, by every thought and every act of mine, demonstrated, and do so daily, to my absolute satisfaction, that I am an automation endowed with power of movement, which merely responds to external stimuli beating upon my sense organs, and thinks and acts accordingly.."*[6].

Putting this reasoning in practice Tesla conceived the idea of constructing an "automation" which would mechanically represent him, but in a more primitive manner. Such an automation, in Tesla's words, *"had to have motive power, organs for locomotion, directive organs, and one or more sensitive organs as to be excited by external stimuli."* Tesla worked on the new "Art of Teleautomatics" in the period between 1879-1899. On July 1, 1898 he filed USA patent application and in just over four months the patent on "Method of and Apparatus for Controlling Mechanism of Moving Vessels" was granted to him [7]. In 1898 he was demonstrating wireless control of model ships in Madison Square Garden and predicting the imminent completion of a system that could transmit both power and intelligence over long distance without wires[2]. The principle he was developing was applicable to *"any kind of machine that moves on land or in the water or in the air"*, and to show this to an audience he constructed a boat shown in Fig.1. The motive power was furnished by a storage battery placed within, the speed and the direction of propeller revolution was controlled from a distance. The rudder was controlled by another motor taking place of the directive organs. As to the sensitive organ Tesla considered radio waves - not the light ray or Hertzian radiation, or any ray-like

No. 613,809.
Бр. 613,809.

Patented Nov. 8, 1898.
Патентирано

N. TESLA.

НАЧИН УПРАВЉАЊА И АПАРАТУРА МЕХАНИЗМА ЗА УПРАВЉАЊЕ
ПОКРЕТНИМ ПЛОВНИМ ОБЈЕКТИМА ИЛИ ВОЗИЛИМА
METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS
OR VEHICLES.

(No Model.)
(Без модела)

5 Sheets—Sheet 3.
5 ЛИСТОВА - ЛИСТ 3

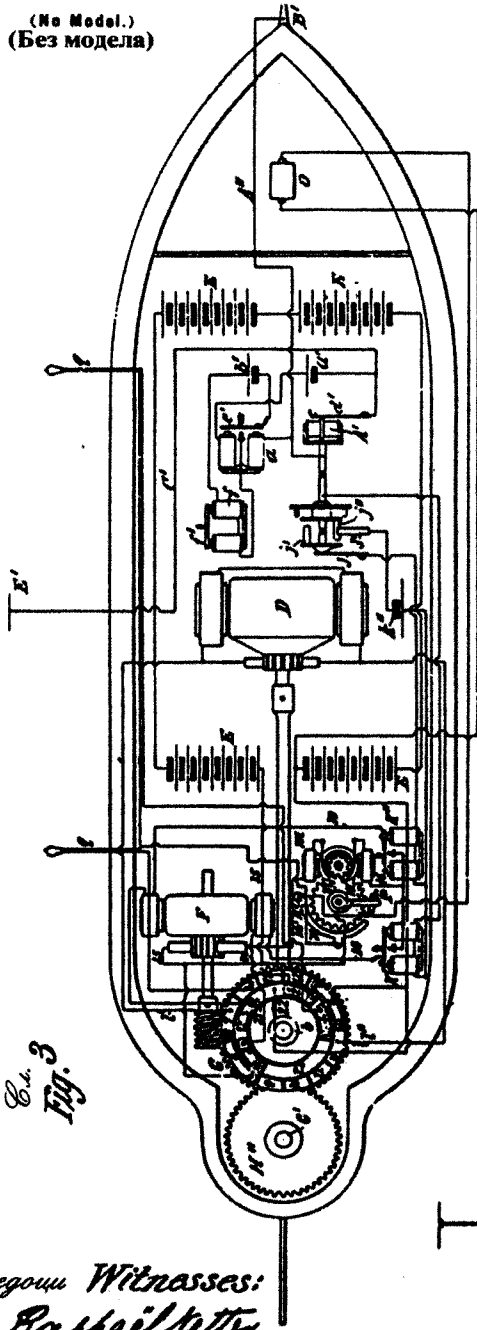


Fig. 3

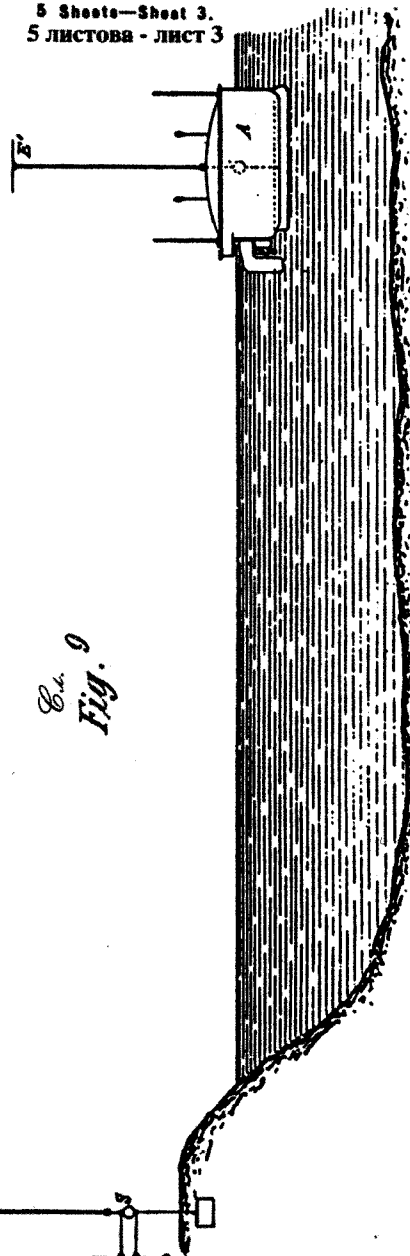


Fig. 9

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Fig. 1. Plan view of the vessel, apparatus and its circuit components.

propagating in straight lines, which would require that the operator continuously see the controlled vessel. In order to avoid "the line of sight" control he used waves that propagate in all directions through space, and used such circuits within the boat which were exactly tuned to electrical vibrations of the proper kind transmitted to it from the distant transmitter. The automation boat that Tesla constructed had "borrowed mind" and formed part of the distant operator who transmitted orders to it. But, to quote Tesla *"I purpose to show that, however impossible it may now seem, an automation may be contrived which will have its "own mind", and by this I mean that it will be able, independent of any operator, left entirely to itself, to perform, in response to external influences affecting its sensitive organs, a great variety of acts and operations as if it had intelligence. It will be able to follow a course laid out or to obey orders given far in advance; it will be capable of distinguishing between what it ought and what it ought not to do, and of making experiences or, otherwise stated, of recording impressions which will definitely affect its subsequent actions. In fact, I have already conceived such a plan "* [8].

Following his usual method of presenting new results, Tesla filed application for patent specification on the method and apparatus for controlling moving objects [9]. The patent is full of details about wireless means of transmitting command signals to the moving object. He prefers the use of high frequency currents which generate electromagnetic waves capable of reaching the moving object although it is not in the light of sight from the operator position. He also suggests the use of tuned circuit at the object to improve sensitivity and selectivity. His transmitting antenna can be an elevated conductor with another terminal of Tesla's coil connected to an earthed metal body, or the two terminals be connected to two remote points with grounded metal plates. The first is a monopole antenna and the second is the loop antenna formed by current spreading between the plates through the ground. He noticed that if the loop type of antenna is used one has to consider relative positions of the transmitting and receiving circuits which shows that he was aware of antenna radiation patterns. At that time Tesla had made many experiments with various antennas but never patented monopole or loop antenna as a separate device. The first appearance of the monopole antenna was in his lecture before Franklin Institute in 1893 [3], and the grounded loop is mentioned in patents applied in 1899 [8].

In the patent specification Tesla gave detailed description of all elements and circuit connections as shown in Fig.2. The pulsed signals from the transmitter are received by a monopole antenna in the middle of the boat and connected to a rotating

coherer attached to the clock mechanism. After each pulse, the coherer is shaken and ready to receive another pulse. The effect of received pulse is transmitted to one of the two relays that switch on rudder motor in one of the two possible direction of rotation. Depending on which of the relays is closed the rudder moves right or left. At the same time the main motor is put in operation. To stop the rudder it is necessary to send another pulse that stops the rudder. In case one need to change the course, another pulse activates the rudder to move in the opposite direction until the next pulse stops it at a new position. The system is such that one has to know position of the rudder and to be able to „see” its position, Tesla installed two incandescent lamps to indicate the rudder position. Any change of the course is relatively slow with this mechanism, but for a boat the speed is adequate. Tesla's method was classified as independent of time factor (today we would say „asynchronous”) and the one which uses one type of impulse to control a number of different mechanisms as opposed to Walter's method which depends on mechanical rotation [12]. Tesla's method was used later by other researchers.

Some work on remote control Tesla performed in his laboratory on 35th South Fifth Avenue. When this laboratory burned down in March 1895 it was a terrible blow to him and many experiments were stopped until the end of 1895 when he opened a new laboratory on 46th East Houston Street. In this laboratory he made, in his own words:

„striking demonstrations, in many instances actually transmitting the whole motive energy to the devices instead of simply controlling the same from distance. In '97 I began the construction of a complete Automaton in the form of a boat, which is described in my original specification #613,809... This application was written during that year but the filing was delayed until July of the following year, long before which date the machine had been often exhibited to visitors who never seized to wonder at the performances... In that year I also constructed a larger boat which I exhibited, among other things, in Chicago during a lecture before the Commercial Club. In this lecture I treated the whole field broadly, not limiting myself to mechanisms controlled from distance but to machine possessed of their own intelligence. Since that time I have advanced greatly in the evolution of the invention and think that the time is not distant when I shall show an automaton which, left to itself, will act as though possessed of reason and without any wilful control from the outside. Whatever be the practical possibilities of such an achievement, it will mark the beginning of a new epoch in mechanics.” [11].

After submitting USA patent on the apparatus and system for controlling moving objects, in the following 14 months Tesla submitted patents in 10

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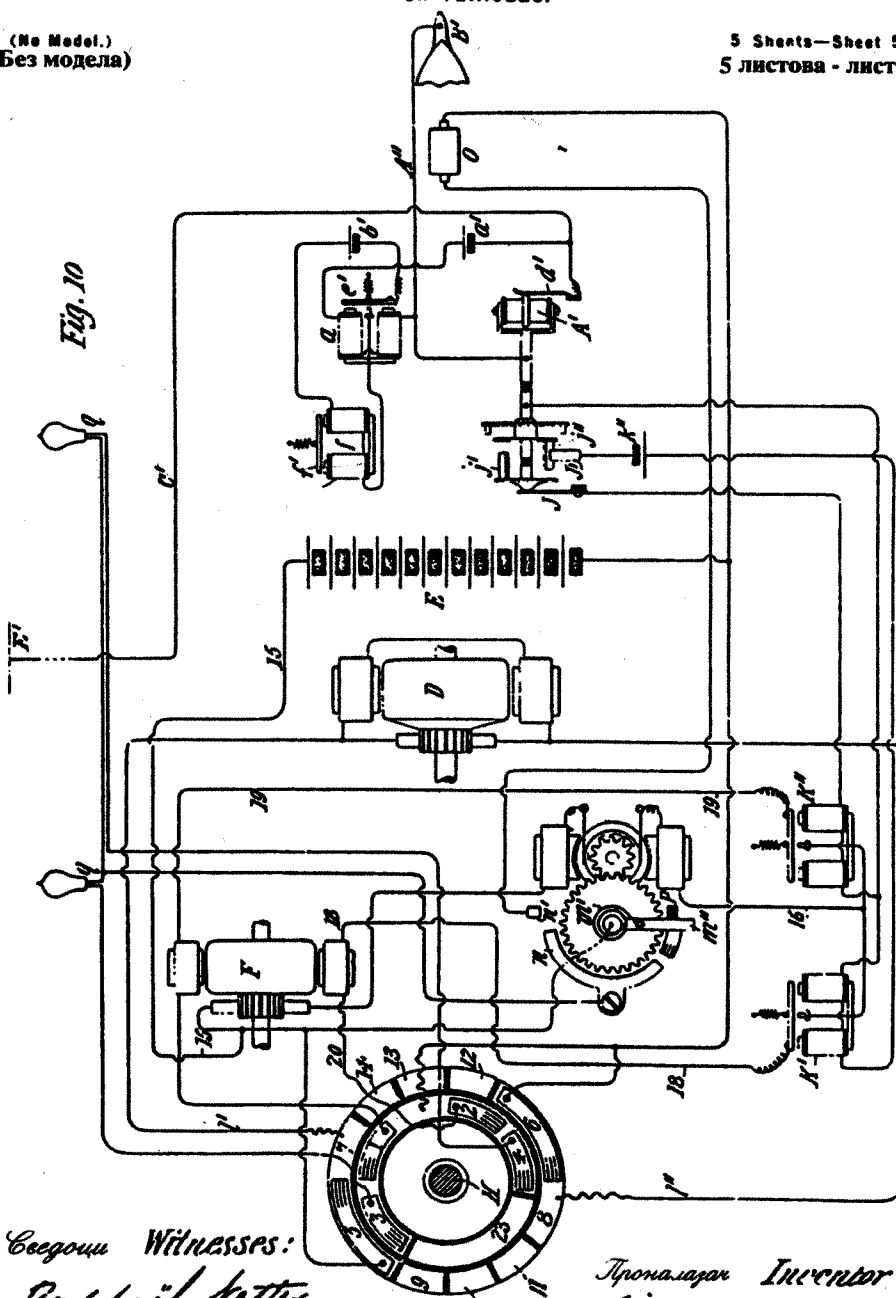
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Сведоци Witnesses:
Raphael Netter
Dr. Simon Dyer

Изобретатель Inventor
Nikola Tesla
By *Kerr, Curtis & Page*
attys.

Fig. 2. Detailed description of all elements and circuit connections.

other countries [13]. Some details about filing and issuing dates of these patents are given in Table 1.

Tesla's patent claims did not reflect all what he already knew at that time about new technique of remote control. His friends suggested him to omit

one of his greatest inventions in terms of shear ingenuity, originality and complexity of design. „*This device*”, Seifer writes, „*was unveiled at the Electrical Exposition held at Madison Square Garden during the height of the Spanish American War in May of*

TABLE 1

Patents issued to Nikola Tesla on Method of and Apparatus for Controlling Mechanisms at a Distance

STATE	DATE FILED	NO. OF PATENT	DATE OF ISSUE
SAD	01.06.1898	613,809	08.11.1898
Germany	08.09.1898	142,842	01.08.1903
Russia	26.10.1898	10,188	30.06.1905
Hungary	07.11.1898	24,842	01.06.1902
Great Britain	13.12.1898	26,371	09.12.1899
France	24.12.1898	284,352	30.03.1899
Italy	17.01.1899	50,371	13.04.1899
Switzerland	20.01.1899	18,652	19.12.1901
Belgium	30.01.1899	140,489	15.02.1899
Spain	31.01.1899	23,742	31.01.1899
Brazil	14.08.1899	2882	02.08.1901

quite a few things that he thought important in order not to overload the patent claims. In letter to Miessner Tesla wrote:

„I would call your attention to the fact that while my specification, above mentioned, shows the automatic mechanisms as controlled through a simple tuned circuit, I have used individualised control; that is one based on the co-operation of several circuits of different periods of vibration, a principle which I had already developed at that time and which was subsequently described in my patents #723,188 and 723,189 of March, 1903. The machine was in this form when I made demonstrations with it in 1898 before the Chief Examiner, Seeley, prior to grant of my basic patent on Method of and Apparatus for Controlling Mechanisms at a Distance”[11].

In original USA patent specification Tesla omitted to describe his „individualised control” which was a great step forward in providing safe and protected from disturbance control, as compared to simple mechanism control he described in his patent. When at a later date, on July 16, 1900, he submitted patents „Method of signalling”[14] and „System of Signalling” [15], to protect his method and system of „individualisation”, prior to obtaining patent he had to clear matter with Fessenden in a patent rights dispute [16]. This document included statements in favour of Tesla by his assistant Fritz Lowenstein and secretary George Scherff. Finally, in March 1903 Tesla obtained patent after more than five years from the moment he had developed and experimentally proved the invention of individualisation.

One of recent Tesla's biographer, Marc Seifer [17] writes that Tesla's remote control robotics boat is

1898, but earliest precursors could be traced to wireless motors which he displayed before the Institute of Electrical Engineers in 1892.... The electrical exhibition was organised by Garden manager Stanford White, who worked with Tesla to fashion a rainbow room of neon lights at the entrance, and it was presided over by Chauncey dePew, another Tesla friend, who was also one of the principals of the Penn Central Railroad and U.S. Senator from New York”.

In explaining possible use of his remote control, Tesla suggested that it could be applied to a submarine boat - torpedo boat without a crew [18]:

„My submarine boat, loaded with its torpedoes, can start out from a protected bay or be dropped over a ship side, make its devious way along the surface, through dangerous channels of mine beds,... discharge its deadly weapon and return to the hand that sent it... I am aware that this sounds almost incredible and I have refrained from making this invention public until I had worked out practically every detail”.

Description of Tesla teleautomaton appeared in a number of periodicals and newspapers. It was mentioned in Sewall's book (1903) under the title „Tesla's teleautomata” [19], in Italian book „L'Elettricità” (1909) where Nicola Tesla was presented as the originator of „raditelematics”, but was not mentioned in the chapter on alternating current and induction motor, or in connection with radio wave transmission [20]. In Miessner book „Radiodynamics - The Wireless Control of Torpedos and Other Mechanisms” (1916), part of chapter V was devoted to early work of Nikola Tesla, and in chapter XI on „The Advent of Wirelessly Controlled Torpedoes”, it is quoted

that „to Tesla, probably more than to any other investigator belongs the credit of first constructing a dirigible vessel which could be controlled from a distance without connecting wires. His experiments were begun in 1892 and from that time on he exhibited a number of wirelessly - directed contrivances in his Laboratory at 35 S.Fifth Avenue, New York city. In 1897 he constructed a complete boat (Figs.40,41 and 42), which would steer itself in obedience to guiding impulses of Hertzian waves sent out from a shore....”[12].

Ellison Hawks in his book on Pioneers of Wireless [21] gave Tesla's biography and mentions remote control. It is also interesting that Tesla's patent on remote control was listed in „Historical Perspectives of Microwave Technology” in Special Centennial Issue of the IEEE Microwave Theory and Techniques Society as the first among selected patent abstracts which date from 1898 to 1970 [22]. In the same Issue Tesla's contributions were mentioned in several articles dealing with the development of Microwave Communication, with the History of Biological Effects and Medical Application of Microwave Energy, and especially in connection with the History of Power Transmission by Radio Waves.

Conclusions

A century ago Nikola Tesla surprised his contemporaries with the invention of remote control applied to a boat exhibited at the Madison Square Gardens in New York. With this boat Tesla wanted to show another use of radio waves but by a number of others it was considered as pioneering invention in remote control and robotics (as we call it today). In Tesla's explanations, the boat was the first teleautomaton which is the predecessor of many similar devices in the future which will have significant role in the peace and war. He tried to apply this invention without success as it was far ahead of the technology of the time when appeared. Remote control, and even more than that, teleautomaton that can have a number of sensors and behave as an intelligent being, had to wait a long time before their introduction in the modern world began. Tesla predicted that a flying teleatomaton could be used as a very precisely guided weapon - not to destroy but more to defend and detract from the war. He had an idealistic view that some future war of teleatomatons will be a „game” without human losses. Tesla's invention is present today in remotely controlled missiles, aeroplanes, surface and underwater vehicles, satellites and guided exploring vehicles landed by rockets on the Moon and Planets.

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