Alexander Popov – a Great Contributor to the Development of Wireless Communication

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***Abstract* "This paper is devoted to the life and scientific activities of Alexander Popov who is regarded in Russia as the inventor of radio communication. It touches upon the most important contributions made by Popov to the development of electrical and radio engineering. In addition, it presents a brief review of the collection of the Memorial Museum of A.Popov in LETI (The St Petersburg State Electrotechnical University)."**

I. Introduction

Looking back at the most amazing discoveries and inventions of the 20th century we, the people of the 21st century, can't help feeling admiration of those of them, which had profound influence on the further development of mankind.

One of the most significant achievements of the very end of the 19th century and the beginning of the 20th century was the birth of wireless communication.

This important event is surely a milestone in the formation of the new information environment and consequently in the formation of modern lifestyles.

Nowadays it is impossible to imagine any successful cooperation, cultural or human contacts without such a considerable technological breakthrough as the transmission of electromagnetic signals, that is "inventing" wireless.

It is absolutely obvious that our ability to communicate with each other easily has made our life more enjoyable and has allowed us to exchange information including information on science and technology.

We have got this wonderful opportunity due to joint efforts of many prominent scientists. Among the great pioneers of wireless are such outstanding scientists as Mickle Faradey, James Maxwell, Henri Hertz, Edouard Branly, Nickolas Tesla, Oliver Lodge etc.

It is broadly agreed that the works of Mickle Faraday, Maxwell, Henry Hertz were vital in laying the foundation for practical application of electromagnetic waves.

Oliver Lodge provided independently a number of the essential elements that enabled to develop a system of wireless communication.

In most European countries Guglielmo Marconi is generally recognized as the first to exploit the practical application of electromagnetic waves. While in Russia Alexander Popov is regarded as the inventor of radio communication.

II. Popov's biography and scientific activities

Alexander S. Popov was born on the 16th of March in 1859 in Tourinskii Mining Village in the Urals where his father was a priest. He received a free seminary education to encourage him to follow his father's profession.

After graduating from the seminary in Perm he didn't continue his clerical education for he had become interested instead in physics, mathematics and engineering. He was admitted to the Faculty of Physics and Mathematics of St Petersburg University in 1877. While still a student Alexander Popov worked as a guide at the first Electrical Engineering exhibition in 1880 and an assistant to a professor of physics. In 1881 he began to work at the Electrotechnik workshop which ran the first electric power stations in Russia and the first electric lighting installations using arc lamps.

Thus Alexander Popov graduated from the University being not only an educated physicist, but also an experienced electrical engineer.

After graduating the St Petersburg University where he was awarded a higher degree upon completion of his dissertation, Alexander Popov was recommended by the Scientific Counsel to remain at the University in order to prepare for an academic career. However in summer of 1883 Popov was offered the post of a lecturer and the head of the physical laboratory in Kronstadt where he could do experimental research in electrical engineering.

In 1883 he started to teach at the Kronstadt Torpedo School, one of the most prestigious Higher Naval Engineering Schools in Russia at that time which trained naval specialists in all branches of electrical engineering.

In 1890 Alexander Popov began teaching in the Marine Engineering School which belonged to Naval Department. He was obliged to make a signed statement on non-divulgence of military secrets which later prevented him from getting a patent for his invention. He taught electrical engineering, mathematics and physics. Popov also conducted laboratory sessions in electricity and magnetism as well as on electrical machines and motors. It was in Kronstadt that he realized quite well the Russian navy's acute need for wireless communication.

The excellent equipment of the physics laboratory enabled Alexander Popov to run many physical experiments. He stayed at Kronstadt until 1901.

At the beginning of 1895, Popov re-ran the experiments of Henry Hertz and Oliver Lodge and refined the Branly-Lodge coherer. He ensured automatic sensitivity restoration of a coherer after receiving a signal by its shaking with a bell clapper. Besides, Popov added a receiving antenna and a relay to his scheme. As a result Popov designed the wireless telegraphy working receiver which was both reliable and stable. Using this apparatus A. Popov demonstrated that it was possible to transmit short, continuous signals (applying an improved Hertz oscillator as the transmitter) over a distance up to 64 meters.

In a public lecture "On the Relation of Metallic Powders to Electrical Oscillations" presented on the 7th of May 1895 to the Physical Section of the Russian Physical and Chemical Society in St Petersburg, Alexander Popov demonstrated the reception of electromagnetic signals for the first time. An account of this meeting was subsequently published in the August 1895 issue of the Russian Physical Chemical Society Journal which was widely known in the international scientific community.

The newspaper "Kronstadtskiy vestnik"

reported:

"Honorable Prof Popov… combined a special portable device responding to electric oscillation by a ringing bell, the device being sensitive to the Herz waves at a distance of up to 30 sazhens.

Last Tuesday Prof. Popov reported on his experiments to the Physical Department of the Russian Physical and Chemical Society and his report was met with a great interest and enthusiasm. These experiments were induced by a theoretical possibility of wireless signaling, like it is with optical telegraph but using the electric beams."

In January 1896 the same journal carried an article by A.Popov together with a detailed circuit diagram of the wireless apparatus which was called "an Apparatus for Detecting and Recording Electrical Oscillations". (See Popov's apparatus scheme in the reference №1 in the Appendix)

The article concluded with the following words: "… I hope that my apparatus, when perfected, may be used for the transmission of signals over a distance with the help of rapid electrical oscillations as soon as a source of such vibrations with sufficient energy is discovered".

In the summer of 1895 A. Popov had adapted his instrument for the automatic registration of atmospheric oscillatory discharges; it was later called a lightning recorder. Experiments with it led A. Popov to study the possible influence of atmospheric disturbances on the transmission of signals. Popov's lightning recorder was in wide use all over the world.

A. Popov went on to perfect his device for wireless communication enhancing the sensitivity of the apparatus and increasing the distance over which the signals could be carried. By the beginning of 1896 A. Popov had substantially improved his receiver and had obtained important results in transmitting and receiving signals. He demonstrated his apparatus at the meeting of the scientific society in March 1896. The distance between the transmitter and the receiver was 250 meters. Apparently A. Popov had signaled "Heinrich Hertz" in Morse using the telegraphy apparatus and the words had been written down on a blackboard by professor Petruchevsky – the president of the Russian Physical and Chemical Society. Before the summer of 1896 the improved apparatus was described in a total of 11 publications which made this invention accessible for a practical use.

In May 1897 the signaling system using electromagnetic waves was well tested at Navy in the Gulf of Finland at the distance over 600 meters.

III. Practical Application of Popov's Experimental Results

A. Popov took an active part in bringing wireless telegraphy apparatus into practical application. The first of them were manufactured according to his instructions by E. Diucretet, a French engineer and businessman in 1899 in France. Both Russian and French Navy were equipped with the wireless telegraphy apparatus. Its production in France started under the name Popov-Diucretet.

In 1899 A. Popov developed a wireless receiver based on the detector effect discovered by his assistants P. Ribkin and D. Troytskiy. This receiver was later patented in Russia, England and France.

On January 22, 1900 - this receiver was patented in France (№296354), on April 7, 1900 – it was patented in England (№2797), on November 30, 1901 - patented in Russia (№ 6066).

There exists the document which describes the A. Popov invention of the first practical semiconductor crystal diode. The copy of the patent which A. Popov accepted in

England on the 7th of April 1900 is enclosed. (See reference №2 in the Appendix)

In 1900 The Diucretet Firm in France started the industrial production of such diodes and A. Popov's detection radio receivers.

In 1875 Braun worked on the subject of semiconductors but his works were only theoretical. They showed one way conductivity of contacts between different objects (crystal and amorphous).

After the A. Popov's patents Braun has returned to the matter in question. The Germans refused a patent to Popov as Braun has already made a research on this subject but there was no practical application of his works.

As a result the German firm Siemens and Halske/Telefunken has signed a 3 sided agreement on the application of A. Popov's invention for the radio apparatus production.

In 1900 Popov's device was used when a 47 km kilometer long radio line, linking the island Kutsalo (town Kotka - Finland) and the island Gogland in the Finnish gulf was installed. The radio line was constructed to help a battleship "The General – Admiral Apraksin" which ran aground because of a navigation error. The first wireless message received by the radio line allowed saving the lives of 27 fishermen who had been carried away on a block of ice in the sea-way. That successful operation of the radio line resulted in taking a decision to use the radio at ships of the Russian Navy. This line was the first to use radio communication and it worked more than 3 months.

Continuously improving his radiotelegraph Popov succeeded in implementing radio communication in the army, navy and newly born aviation as well as civil branches. But the development of radio in the tsarist armed forces proceeded very slowly, compared with those of other European countries.

Popov was personally involved in launching the production of Popov system equipment not only at the E. Diucretet factory in Paris (1898), but also at the radio workshop in Kronstadt founded on his initiative in 1900 and at the Siemens and Halske factory in St Petersburg (1904).

In 1901 A. Popov was appointed Professor of Physics at the St Petersburg Electrotechnical Institute where he set up a wireless telegraphy research laboratory and gave a course on the subject.

Electrotechnical Institute founded in 1886 became the first to specialize in electrical communications. Together with his post-graduate assistant S. Y. Lifchits in 1904 A. Popov conducted experiments in transmitting the human voice via radio.

In 1905 he became the first elected director of this institute.

In December 1905 A. Popov was ordered by the Governor of St Petersburg to take repressive measures against student political disturbances (it was the time of the first Russian Revolution which was supported by many progressively – minded people including students and lectures). A. Popov refused to do it. He took these events too close to his heart which badly affected his health.

He died on the 13th of January 1906 at the relatively young age of 46.

IV. A. Popov's Heritage in St Petersburg

Historians of science in many countries of the world including Russia do full justice to numerous experiments and investigations sifting out from them those facts and interpretations that remain meaningful today. It should be mentioned that the most valuable arguments for the history of science are supposed to be those facts which are confirmed by archives documents.

There are 3 museums in St Petersburg that commemorate the prominent Russian scholar in the field of physics, electrical and radio engineering.

The first exposition of Popov's experimental devices was opened in Kronstadt in 1906.

The biggest collection is in The Central museum of communication named after A. S. Popov which keeps original devices designed by A. Popov himself such as his radio receiver, a lightning recorder, Hertz's vibrator (oscillator) used by A. Popov as a transmitting device in his radio signaling system.

The memorial museum of A. S. Popov in "LETI" (The St Petersburg State Electrotechnical University) is a scientific research and a scientific educational branch of St Petersburg State Electrotechical University which collects, keeps and studies apparatus, different publications, findings, historical facts, concerned with the life and activities of A. Popov – the inventor of radio and the founder of teaching programmes on wireless telegraphy for military and civil higher schools.

The Museum also takes great interest in the documentary material on the origin and development of electrical engineering and its main directions, the foundation of which was laid by A. Popov, his co-workers and followers. In collaboration with the Electrotechnical University the museum carries out scientific research on the history of the development of electrical engineering, radio engineering, electronics and communication.

On the basis of its scientific investigations the museum organizes different stationary and temporary exhibitions devoted to the history of science and engineering and to famous scientists and inventors.

The memorial museum of professor Popov was opened on the 25th of June in 1948 in his former laboratory in ETI where the scientist worked during the last period of his life from 1903 till 1906. A. Popov performed 42 laboratory experiments using his devices for the 1st and 2nd year students. A. Popov was an extremely gifted and many-sided scientist who carried on his own investigations in the field of electrical engineering, optics, radioactivity, wireless telegraphy. Physical devices and apparatus kept in the collection of the museum show Popov's professional activities and scientific interests. Numerous museum stands demonstrate the main periods of the scientist's life, his scientific and social activities. The museum collection started with over 80 devices which belonged to A. Popov and professors O. Hvolson and V. Skobeltzyn. The museum got these devices from the chair of physics of the Electrotechnical Institute.

Of special value in the museum collection is Popov's apparatus for transmitting and receiving signals made in 1896. A. Popov demonstrated this apparatus – the receiver and the vibrator with parabolic reflector at the section of the Russian Physical and Chemical Society at the St Petersburg University on the 24th of March in 1896. The apparatus transmitted and received signals at the distance of 250 meters between the buildings of St Petersburg University. At present the devices in the exposition of the museum – laboratory are arranged in such a way that it is possible to demonstrate the main phenomena of the electrical engineering just in the course of the excursion using the devices on display.

For example, electromagnetic induction phenomenon can be shown by the experiment performed with the help of M. Faraday's scheme. Riss's spirals made as far back as 1900 can also operate quite well even now enabling to reproduce some experiments on fundamental physical phenomena.

The museum collection consists of devices, instruments as well as scientific papers, letters and journals which are of

special interest to foreign scientists and historians in the field of science and engineering.

The museum keeps Popov's archives including the papers describing his first experiments in the field of wireless signalization as well as his own library and his correspondence with colleagues both in Russia and abroad.

The museum collection exceeds 15 000 items. Of special value are Popov's personal archives containing over 1000 papers, his own instruments and devices designed in the period from 1889 to 1906 and a wireless telegraphing system of commercial production.

As a matter of fact Popov's memorial museum is a unique scientific technical museum with wonderful opportunities for young specialists who take interest in the origin and history of electrical and radio engineering.

Speaking about the memorial museum one can't help mentioning Popov's younger daughter E.A. Popova-Kjandskaya (1899-1976) who was the first director and founder of the museum. She was an honorable person of the Russian Federation involved in the arts and an honorable member of the scientific and technical society NTORES named after A. Popov. For many years the museum was supervised by her daughter E.G. Kjandskaya (1934-1994) who contributed to the foundation and development of the museum. A. Popov's daughter published over 40 papers and presented about 50 reports. She took part in the work at 30 films devoted to Russian scientists and participated in the preparation of 46 museum expositions in Russia and abroad.

Due to their efforts the museum was included in the catalogues of the museum of the world. It is popular with tourists of St Petersburg. It is visited by tourists and delegations from USA, Germany, Great Britain, France, Poland, China and other countries.

In September 2003, the IEEE Russia North-West Section received High ranking Officers: IEEE President 2003 Michael Adler, his wife Virginia and 2001 IEEE President Joel Snyder in St. Petersburg. They visited the Alexander S. Popov museum.

V. Conclusion

Every country is proud of its great people: writers, poets, actors, composers, painters, scientists and inventors. Russia is not an exception. It is proud of prominent scientists and inventors who made great contribution to the development of different scientific fields and more rapid progress in science and engineering. One of such scientists and inventors was A. Popov.

To summarize Popov's achievements it is to be noted that A. Popov's scientific work can be treated as a balance between theoretical assumption and practical application of the latest findings. He succeeded in putting his own and other scholar's concepts into practice.

A. Popov often went abroad, he visited many European cities: Paris, Berlin, London, Zurich, made a trip to USA where he visited New York and Chicago. He met foreign scientists, exchanged scientific information and kept up working contacts with them. They discussed many scientific problems of common interest which turned out to be fruitful and efficient for scientific and engineering progress.

A. Popov wrote a letter to the editor of the Journal "The Electrician" on 26 November 1897 concerning the problem in question: "I constructed an apparatus very useful for the demonstration of the properties of the Hertzian electromagnetic waves and rays in a large lecture-room, also fit for registering

atmospheric electric disturbances... On using a sensitive relay in the circuit with the coherer tube, and an ordinary electric bell in a collateral line for sound signal and as an automatic tapper for the coherer, I received an apparatus which exactly answers every electric wave by a short ring and by rhythmical strokes, if electric vibrations be excited continuously..."

Opening the International Conference on wireless telegraphy in Berlin in 1903 the Minister of Posts and Telegraphy of Germany Kretke said: "… in 1895 A. Popov invented reception of telegraph signals by means of the Hertz waves. It is him that we should thank for the first radiographic set."

At the end of the 19th and at the beginning of the 20th century Popov had close contacts with prominent scholars of Russia – D. Mendeleev, S. Makarov, A. Krylov, A. Lodygin and others.

All these allied to his foresight and wide knowledge enabled him to get recognition in scientific community. A. Popov's contemporaries highly appreciated his achievements.

One should make reference to O. Lodge's letter dated September 1, 1908 "…I have always thought highly of Professor Popoffs work in connection with wireless telegraphy. It is true that I used an automatic hammer, or other vibrator driven by clockwork or other mechanism, to restore the coherer to sensitiveness; but Popoff was the first to make the signal itself actuate the tapper-back; and that I think is the novelty we owe to Popoff…"

"I conjecture that Popoff may have been one of the pioneers who applied the method to ship signaling of some rough kind at an early date."

"I shall be happy to answer any other questions, and am glad that professor Popoff should have his work recognized in his own country."

A. Popov was in the best and truest senses of the word both a remarkable personality and a genuine scientist: kindness, courtesy and consideration were part of his nature. These features of character enabled him to guide, assist and counsel on scientific, organizational and personal problems with a skill and tact which were highly effective.

A. Popov paid great attention to all new investigations not only in the field of physics, radio-activity and electrical engineering, but in making electrical machines and designing roentgen devices.

He designed and continually refined the apparatus used for radio communication, he organized the training of experts in this field and initiated the setting up of the first wireless telegraphy transmitters in Russia.

During his lifetime A. Popov was being held in high esteem in Russia and abroad. He was given many honorary titles and awards as a great inventor. A. Popov had an honorary title of an electrical engineer. A. Popov was awarded a gold medal and diploma at the World Exhibition in Paris in 1900 for developing wireless apparatus and a lightning recorder.

Monuments have been erected to him in several Russian towns. A gold medal and prize have been instituted in his honor and awarded by the Russian Academy of Science to Russians and foreigners for their outstanding work in the field of radio engineering. 20 Russian scientists were awarded this medal. One of them is J. Alferov, Nobel Prize Winner in the field of physics, a graduate of the Electrotechnical Institute who was awarded the gold medal named after A. Popov in 2000.

In 1945 on the 7th of May a state holiday, the Day of Radio was established. Every year on the 7th of May a tribute is paid to our great compatriot A. Popov – a great scientist and inventor.

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4. Popov A.S. The Apparatus for Detecting and Recording Electrical Oscillations.// Russian Physical Chemical Society, 1896, Vol. 28, №1, p.1-14
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10. Scobelzin V.V. A.Popov's apparatus for Detecting and Recording Electrical Oscillations.// Post – Telegraph Journal, 1896, April, Vol 46, p.546
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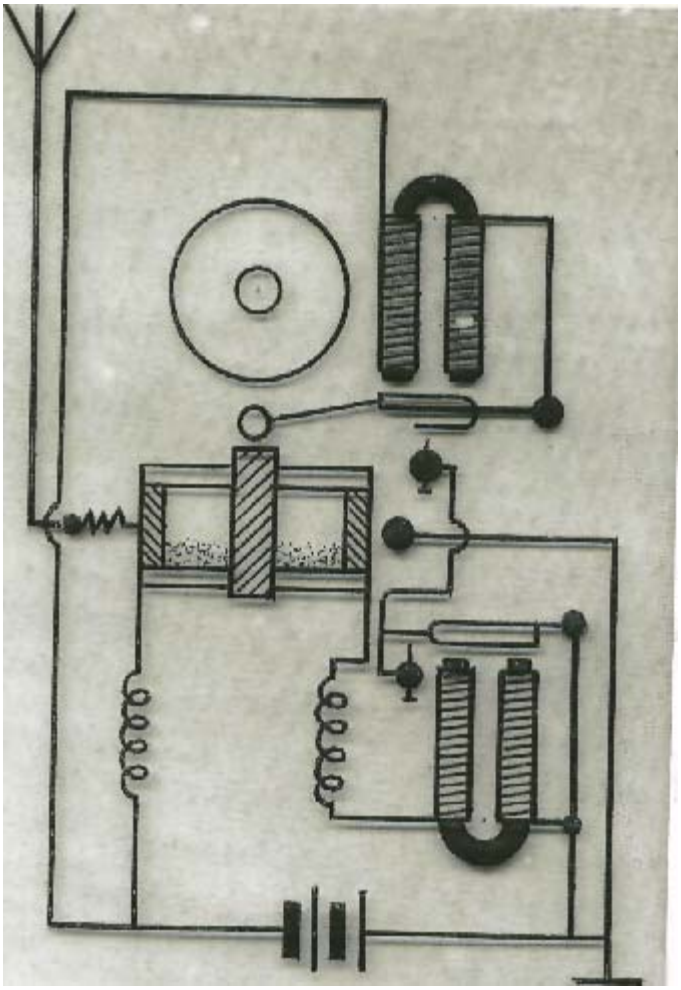
Appendix

Reference №1



Reference №2

A.D.1900 Feb 12 №2797
Popov's Complete Specification

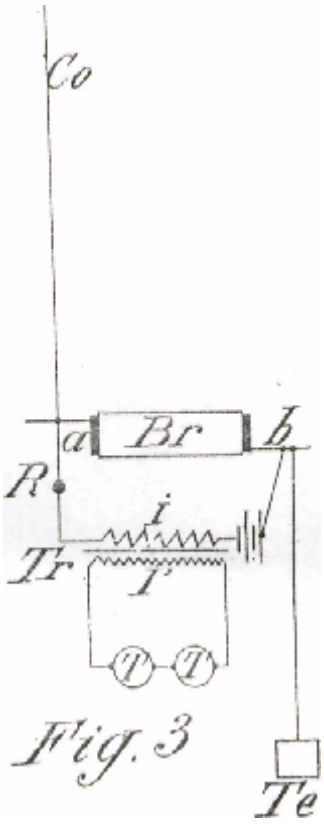


Fig. 3

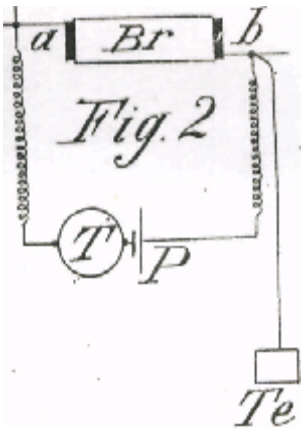


Fig. 2

Date of Application, 12th Feb., 1900-Accepted, 7th Apr., 1900

COMPLETE SPECIFICATION

Improvements in Coherers for Telephonic and Telegraphic Signalling.

I, ALEXANDER STEPHANOVICH POPOV, of Cronstadt, Russia, Professor, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement

The improved receiver of messages sent into space by means of electromagnetic oscillations, is based upon Branly's discovery of the tubes filled with filings, known as coherers or radioconductors and presenting a great resistance to the passage of electric currents and adapted to become suddenly conductors when influenced by electric oscillations, even when these oscillations have but little strength, which reach said tubes either directly or through conductors secured to the tubes, said conductors serving to collect the electric waves.

The change of resistance is ordinarily accomplished instantaneously and continued after the passage of the electric oscillation: in order to stop the conductibility of the metal filings, as quickly as is possible, the tube is ordinarily shaken or jogged, and to this end automatic devices have been invented.

My improved receiver comprises the omission of this means for restoring' the resistance of the filings, and it will be sufficient to compose my tube with the result to be obtained in view. The result has a real importance and is attained by composing the tube of a conducting chain formed of carbon and metal portions placed alternately and having what is known as "free micro-phonic contacts." Thus the changes or variations of the resistance are less considerable, and of shorter duration and constancy. At the first influence, the resistance of such radioconductors decreasing, it maintains still a certain value, and during all the time of the influence of electric oscillation, said resistance will be varying without it being- necessary to shake or jog the tube. These variations of the resistance are easily perceived in the telephone.

Under these conditions, the arrangement of the improved receiver, according to the accompanying drawings illustrating the invention by way of example, embodies in its main portion:—a circuit composing the tube filled with filings, one or more elements of a buttery, one or more telephonic apparatus in which the operator hears special sounds, which are dry, short or long and correspond to each discharge at the transmitting station; thus at the receiving station, I obtain a good reception of the signs of the Morse code. The character of the action of the switch for the induction coil is not at all affected and it is thus possible to distinguish from each other, cablegrams transmitted bv different stations and received at different moments.

The employment of the telephone in connection with Hertz's sounding board at micrometric intervals has been realized by Mr. Turpin, but this arrangement is convenient only for classic experiments at short distances, and cannot be combined with my system of tube (special radioconductor) filled with steel grains, having free contacts, and producing the shortest distances between them which cannot be obtained by any Hertzian sending board. My improved device enables me to transmit messages without conducting-wires to very great distances.

The radioconductors heretofore employed do not attain this result unless they

are arranged as above indicated. To this end, the most convenient metal is merchant steel in the form of polished pearls, which when crushed, produce grains, by means of which I obtain radioconductors of steady and perfect sensitiveness.

The support of such radioconductors must protect the latter from too sudden jerks during the reception of a message, which result in easily obtained by securing the support by means of soft india rubber or in any other suitable way.

The sound in the telephonic apparatus may be perceived at a certain distance from the ear. The employment of two telephonic apparatus enables the

10 operator to be insulated from the exterior sounds. The addition of a telephonic apparatus arranged in microtelephonic relays for the alarm and for recording messages, is well known.

The radioconductor (or coherer) I preferably employ, is arranged as follows: —

(see Fig. 1 of the drawings):—within a small tube of glues or other insulating 15 material arc secured two small blades of platina arranged in proximity to each other; said blades are secured to the mountings or pieces, and two outer conductors terminate these electrodes. The interior of the tube, receives hard steal grains produced by means of crushed pearls as already stated. However metals or hard carbon may be employed for the same purpose.

The size of the grains depends on the distance between the inner blades.

The groins produced by means of hard steel pearls have on their polished portions a thin layer of oxide, whilst the inner portions of the pearl have a thicker layer of oxide. Furthermore the parts which are broken away, present points or projections on which no oxide is formed. This variation of the state of oxidation on the surface of the metal grains, together-with the similarity of their form, ensures a perfect sensitiveness and steadiness, and the improved radioconductor is thus convenient for the telephonic reception of electromagnetic waves, produced at large distances.

In order to facilitate the uniform distribution of the grains, the tube may 30 be divided by means of partitions made of non-conducting material, into several sections or chambers.

Fig. 2 illustrates the most simple form of the device at the receiving station, but is possible to combine other devices intended to guard against the effect of atmospheric electricity and telluric currents; said devices are applied to 35 the wire or collector C *o* and to the ground wire and their circuits.

Fig. 3 shows a device having: a converter T r (I I' are the primary and secondary windings) as employed at microtelephonic stations; said device i n creases the intensity of telephonic sounds, but muy be omitted.

Having now particularly described and ascertained the nature of my said 40 invention, and in what manner the same in to be performed, I declare that what I claim is: —

1.—The combination of radioconductors with one or more telephonic apparatuses, for the purpose of dispensing with the usual means for shaking or jogging the radioconductor (or coherer), and with the relay usually inserted *45* into .the circuit of the radioconductor.

2.—The application of steel pearls crushed to grains of suitable size substantially as and for the purpose set forth.

Dated tins 12th day of February 1900.

ROBERT E. PHILLIPS, Assoc. M.Inst.C.E,,M.I. Mech. F.. 50
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