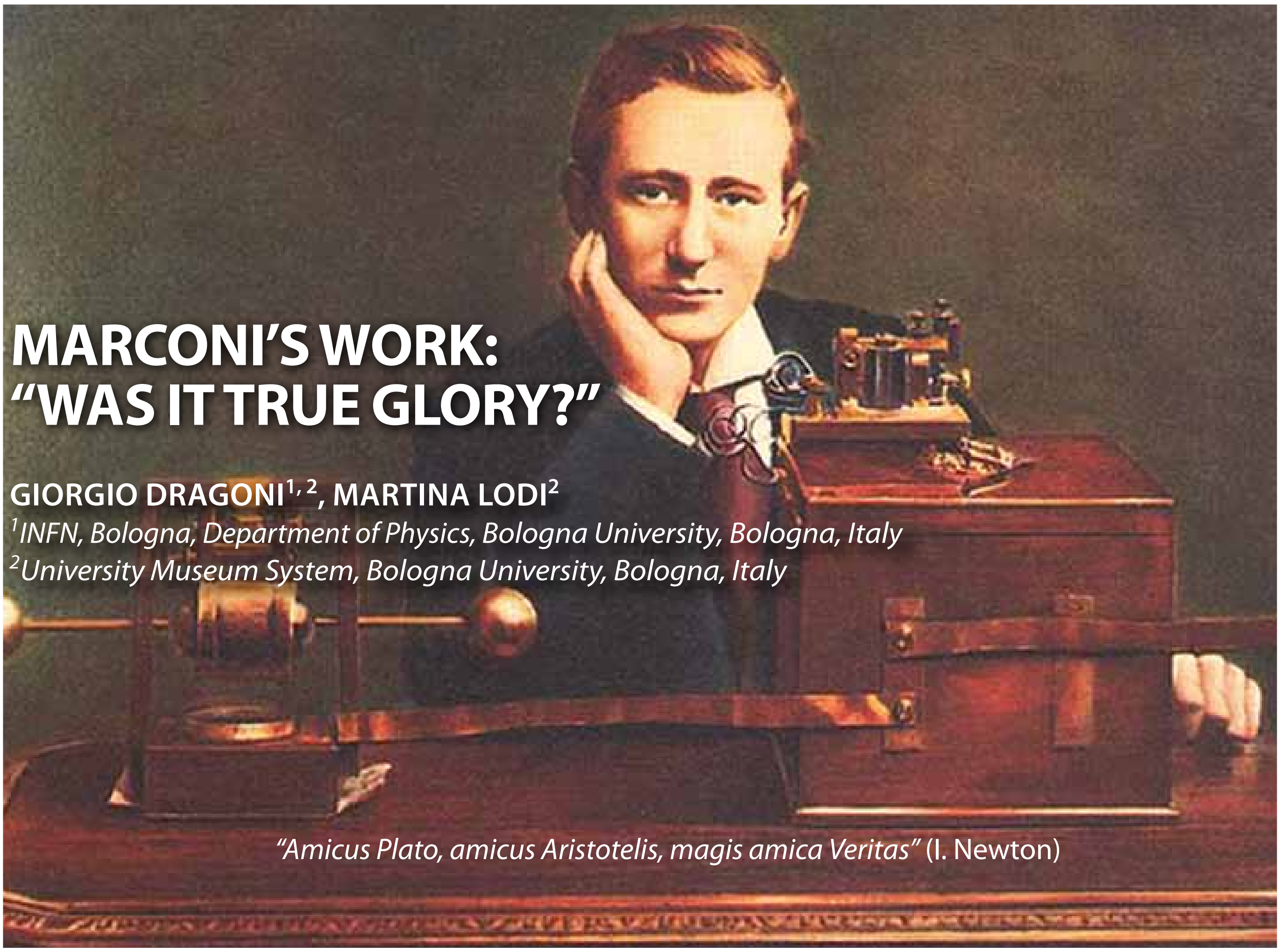

MARCONI'S WORK: "WAS IT TRUE GLORY?"

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"Amicus Plato, amicus Aristotelis, magis amica Veritas" (I. Newton)

Guglielmo Marconi at the time of his early experiments (Fondazione Marconi courtesy).

"Was it true glory? Posterity thine be the hard decision". (A. Manzoni)
The authors' answer is: Yes it was! To celebrate the centenary of the Nobel prize awarded to Marconi in 1909, the origin and the way in which wireless telegraphy was born and developed are reviewed

We shall describe in the following the very beginning of the young Marconi's cultural scientific education. The aim is to show how Marconi chose (perhaps unconsciously) a personal and very effective educational method to improve his practical experience and his conceptual knowledge of science, especially on electromagnetism. Thanks to his practical and scientific improvements on electromagnetism, Marconi was able to acquire important elements of innovation on a scientific background concerning oscillators and resonators employed by several scientists at that time, so as to achieve an effective and practical method of telegraphy without wires. A survey will be given of the personalities who contributed to develop the field of early electrical communication, preparing Marconi's work on which we intend to concentrate our attention. It is opinion of the authors that, in the context of his time, Marconi's role was, beyond any possible doubts, decisive for the invention and the development of wireless telegraphy, the radio.

1 Introduction

The history of wireless telegraphy is a very long and complex history to whose invention and development many technicians, scientists and inventors took part. It is our intention to offer our readers a reference historiographical frame to this history, so that it will be possible to get information about some of the people connected with the developing of wireless telegraphy since its very beginning.

For this purpose, we must quote at least six scientists who gave a contribution to this matter from 1830 to 1880. We mean P. S. Munck, S. A. Varley, J. Henry, M. Loomis, W. H. Ward, A. E. Dolbear.

- It was in 1835 that P. S. Munck af Rosenschöld (1804-1860) of Lund University published in the *Annalen der Physik und Chemie* an article in which he described the behaviour of metal filings and the variation in electrical resistance according to their physical dimensions and feature. Munck discovered a peculiar phenomenon, an electrical spark emitted from a Leyden jar changed immediately the electrical resistance of the filings preserved in a glass jar (from 1 MΩ to hundreds of Ω).
- Samuel Alfred Varley (1832-1921) in 1852 rediscovered the same effect of the falling down of the resistance of several winds of powders during the thunderstorms. These physical effects are at the basis of an important device of telegraphy without wires. We mean the receiver. In principle, in this effect we could recognize a sort of switch system to detect the electromagnetic waves arrival.
- More attention should be given to Joseph Henry (1797-1878), the first great American scientist after Benjamin Franklin. He discovered several important principles of electricity including self-induction and the laws upon which the transformer is based. According to wireless telegraphy, attention should be payed to the experiments performed and described in his article, published by the *Proceedings of the Smithsonian Institution* (Washington, D. C., USA, Vol. I, p. 203), in which Henry magnetised a needle in a coil at 30 feet distance, and magnetised a needle by a discharge of lightning at eight miles distance. He used an elevated antenna and sent signals between a tuned transmitter and receiver nearly fifty years before Lodge and Hertz.
- Another impressive case was that of Mahlon Loomis (1826-1886). In 1865 M. Loomis, an American dentist, transmitted wireless–telegraph messages between two Blue Ridge mountains tops in West Virginia (distance 22,5 km) using aerials held in the air by kites. Loomis obtained the U. S. patent (127.971) for a wireless telegraph in 1872. The patent was entitled *An Improvement in Telegraphing*, but he never obtained financial support to develop his system. In other words nobody believed him. Loomis last words as reported by his familiars are the following: "I know that I am by some, even many, regarded as a crank – by some perhaps a fool... But I know that I am right, and if the present generation lives long enough their opinions will be changed – and their wonder will be that they did not perceive it before. I shall never see it perfected – but it will be, and others will have the honour of the discovery".
- William Henry Ward (1843-1872) performed several experiments and on 30th April 1872 he was the first person to be granted a U. S. patent (126.356) relating to wireless telegraphy (*Improvement for Collecting Electricity for Telegraphing)*. His patent was received three months before Loomis' one, about which we have just given some information. Ward had invented an electrical tower for accumulating natural electricity for telegraphic purposes, including an aerial wireless telegraph system. We have, however, no evidence that this patented system could have actually worked.
- Amos Emerson Dolbear (1837-1910) was a professor at Tufts University in Medford (near Boston), Massachusetts, in the Department of Astronomy and Physics. In 1868 Dolbear invented the electrostatic telephone. He communicated over a distance of a quarter of a mile without wires and in 1886 he was issued a U.S. patent (350.299) for a wireless telegraph: *Mode of Electric Communication*.

2 The forerunners

Following the previous scientists, we must recall the singular and astonishing case of David Edward Hughes (1831-1900). Hughes was the co-inventor of the microphone and an accomplished Welsh musician and professor of music as well as chair of natural philosophy at a seminary for women in Bardstown (Kentucky). In December 1879 the Anglo-American inventor demonstrated the reception of electromagnetic signals from a spark transmitter located some hundreds of meters away. In these experiments he conducted a current from a voltaic cell through a glass tube loosely filled with zinc and silver filings, which "cohered" when electromagnetic waves impinged on it.

- David Edward Hughes (1831-1900) noticed electrical interference in an induction balance he was working with. The observed effect was due, according to Hughes' opinion, to electromagnetic waves. He improved the coherer (as later on called by Lodge) as a receiver (D. Hughes, *Proceedings of the Royal Society*, May 8 (1878)). In a letter (April 29, 1899) to J. J. Fahie, Hughes wrote: "…In December 1879 I invited several persons to see the results then obtained. Amongst others who called on me and saw my results were:
Dec. 1879. Mr. W. H. Preece, F. R. S.; Sir W. Crookes, F. R. S.; Sir W. Roberts-Austen, F. R. S.; Prof. W. Grylls Adams, F. R. S.; Mr. W. Grove.
Feb. 20, 1880. Mr. W. Spottiswoode, President of the Royal Society; Prof. T. H. Huxley, F. R. S.; Sir G. G. Stokes, F. R. S.
Nov. 7, 1888. Prof. J. Dewar, F.R.S.; Mr. R. N. Lennox, Royal Institution.
They all saw experiments upon aerial transmission, as already described, by means of the extra current produced from a small coil and received upon a semi-metallic microphone, the results being heard upon a telephone in connection with the receiving microphone. The transmitter and receiver were in different rooms, about 60 feet apart. After trying successfully all distances allowed in my residence in Portland Street, my usual method was to put the transmitter in operation and walk up and down Great Portland Street with the receiver in my hand, with the telephone to the ear. […] The President of the Royal Society, Mr. W. Spottiswoode, together with the two hon. secretaries, Prof. T. H. Huxley and Prof. G. G. Stokes, called upon me on February 20, 1880, to see my experiments upon aerial transmission of signals. The experiments shown were most successful, and at first they seemed astonished at the results; but towards the close of three hours' experiments Prof. Stokes said that all the results could be explained by known electromagnetic induction effects, and therefore he could not accept my view of actual aerial electric waves unknown up to that time, but thought I had quite enough original matter to form a paper on the subject to be read at the Royal Society. I was so discouraged at being unable to convince them of the truth of these aerial electric waves that I actually refused to write a paper on the subject until I was better prepared to demonstrate the existence of these waves". Our comment, in short, is the following: neither authoritative members of the Royal Society in London (1880), nor those of the Royal Institution (1888) understood the innovative technological importance of Hughes' experiments.
We must add to Hughes' case a singular appendix, thanks to the following episodes. Alan Archibald Campbell Swinton (1863-1930), the gentleman who helped the young Marconi (1896) when he had just arrived in London giving him a letter of introduction to

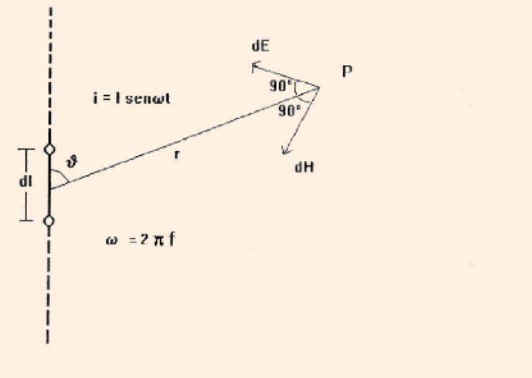
William Preece (1834-1913) – who was at the time Engineer-in-Chief of the British Post Office – was the person that in 1922, after Hughes' widow died, bequeathed some of Hughes' remaining notebooks preserved at the British Museum. Campbell Swinton examined these texts and he was able to find further notebooks and Hughes' original equipments. Following Campbell Swinton's analysis: "They prove that Hughes undoubtedly noted some of the effects now known to be due to high frequency waves. He used a small spark coil as a generator, and a Bell telephone and a battery generally connected in series with a microphone as a receiver. The microphone apparently acted sometimes as a coherer…He received signals up to distances of about a hundred yards…nine years before Hertz's memorable discoveries."

- Temistocle Calzecchi Onesti (1853-1922) wrote some articles about this issue: "*Sulla conduttività elettrica delle limature metalliche"* in *Il Nuovo Cimento*, 16 (1884) 58–64 and, with the same title *ibidem*, 17 (1885) 38-42; and "*Di una nuova forma che può darsi all'avvisatore microsismico*", *ibidem*, 19 (1886) 24-26. Through these studies he carefully investigated how the resistance of metal filings in an ebonite or glass tube is effected by electrical discharges. In 1884-85 Calzecchi Onesti found that copper filings heaped between two plates of brass were conductors or non-conductors according to the degree of heaping and pressure, and that in the latter case they could be made conductors under the influence of induction. In 1884 the Italian physicist observed that loosely packed metallic powders are bad electricity conductors until subjected to some external forces such as electric sparks generated by the opening and closing of an electrical circuit, or the presence of inductive fields, or by electrostatic induction. When the coherer is subject to the influence of radio waves (as is the electromagnetic field produced by a spark), probably because of microscopic electric arcs that weld together adjoining metal particles, an electric current can flow from one electrode to the other. In other words the coherer acts like a kind of semi-conductor device, something like a triode for alternating current, where the trigger is a radio wave instead of a current applied to the gate. In later times others went over his discovery and finally applied it to the detection of coded signals such as Morse coded radio broadcasts. For these experiments Calzecchi Onesti had actually constructed a glass tube (35 millimetres long and 10 millimetres internal diameter) (see fig. 1).

Fig.1 Coherer (*tubetto a limatura*) by T. Calzecchi Onesti (Calzecchi Onesti Family courtesy).

- Edouard Eugène Désiré Branly (1844-1940), physics professor at the Catholic University of Paris, began his work investigating the transmission of nerve impulses. His research over the next several years would result in what would later (Lodge) be called the "coherer", a device for detecting "Herzian waves". In 1890 Branly found that a nearby electromagnetic disturbance can lower the resistance of a thin layer of copper. It may be noted that the idea and use of "antenna" may be found in his paper published in 1891. However, the device which made Branly famous, the "filings tube", more generally known as a "coherer", is a very special sort of conductor. It consists in a glass tube filled with metal filings which acts as an insulator when placed in a circuit containing a battery and a galvanometer. However, if an electric spark is created some distance away, it becomes a conductor and lets the current pass into the circuit. When the tube is tapped lightly, it becomes an insulator again and interrupts the current. This phenomenon was described by Branly in 1890 in relation with researches carried out on the photoelectric effect. At that time, although the action of the spark on the tube could be observed across the walls of his laboratory and over a distance of up to twenty metres, Branly never dreamed of the possibility of transmitting signals by this means. He was mainly concerned with establishing a parallel between medicine and physics, and he was to offer the medical world an interpretation of nerve conductivity based on the model of the conductivity of filings tubes. It was the British physicist Oliver Lodge who was to publicly demonstrate the link between the filings tube and electromagnetic waves. He gave large resonance all over the world to Branly's experiments. In France Branly is considered the father of radio transmissions. As a matter of fact the results of Branly's investigations are clearly described in "*La lumière électrique*", in *Journal universel d'électricité* 13 (1886); "*Variations de conductibilité sous diverses influences électriques*", in *Comptes Rendus de l'Académie des Sciences* CXII (1890) 785-787; "*Variations de conductibilité sous diverses influences électriques*", *ibidem* 12 Jan. CXIII (1891) 90-93; "*Recherches sur les variations de conductibilité de certaines substances sous diverses influences électriques*", in *Société Française de Physique* (1891); "*Sur la conductibilité des substances conductrices discontinues*", in *Comptes Rendus de l'Académie des Sciences* CXIX (1895).
- Henrich Rudolf Hertz (1857-1894) was the famous German physicist who confirmed in laboratory Maxwell's work about the electromagnetic theory of light. Hertz used the damped oscillating currents in a dipole antenna, triggered by a high-voltage electrical capacitive spark discharge, as his source of electromagnetic waves. His detector in some experiments was another dipole antenna connected to a narrow spark gap. A small spark in this gap signified detection of the electromagnetic waves. In 1888 Hertz described, in an electrical journal, (H. Hertz, *Annalen der Physik*, 270, no. 5 (March, 1888) 155-170; no. 7 (May, 1888) 551-569) how he was able to trigger his electromagnetic waves with his oscillator. Hertz seemed uninterested in the practical importance of his experiments. In fact, when Hertz's students were impressed, and wondered what use might be made of this marvellous phenomenon, he denied this possibility. On 1st December 1889 a Munich electrician, Heinrich Huber, wrote to Hertz: "…I should be very interested to hear whether it would not be possible, according to your theory, to transmit the magnetic lines…over a distance. I am thinking in the first instance of transformers and telephone." (C. Susskind, "*Heinrich Hertz: a Short Life"* (San Francisco Press) 1995, p.161). In other words it means to use electromagnetic waves for wireless transmission. Hertz's reply came by return mail on 3rd December 1889: "…the oscillations of a transformer or a telephone are much too slow. Take a thousand oscillations per second, which is surely a high figure, yet the corresponding wavelength in the ether, would be 300 kilometres, and the focal lengths of the mirrors as large as a continent…" (H. Hertz, "*Electric Waves, being Researches on the Propagation of Electric Action with Finite Velocity Through Space"*, English translation by D. E. Jones (MacMillan, London, 1893)). Hertz's negative answer had a highly technical character, but it concerned

the transmission of voice, and not of signals.
The great American inventor Thomas Alva Edison (1874-1931) demonstrated by 1888 free-space system of telegraphy based on electric induction. In particular, during the Great Blizzard of 1888, Edison used his system to send and receive wireless messages from trains buried in snowdrifts. He received a patent for wireless telegraphy in 1891, as *Means for Transmitting Signals Electrically* (U.S. patent 465.971).
Anyway, the most successful inventor of an electromagnetic induction wireless system was William Preece (1834-1913), the Engineer-in-Chief of the British Post Office. Preece's tests were exploited across gaps of about 5 kilometres, *e.g.* the Bristol Channel (1892). However, his induction system required extensive and expensive length of wire, many kilometres long, at both the sending and receiving ends, which made it impractical for large use like on ships, islands, etc. In fact, within the electromagnetic field equations, which are at the basis of distance signals transmission, the inductive component quickly disappeared with the inverse of the square of the distance, while the other one, the radiative component, developed the phenomenon of electromagnetic radiation of signals (see fig. 2).



$$dH = -Idl\,\mathrm{sen}\,\vartheta \left[\frac{\mathrm{sen}\,\omega\left(t-\frac{r}{v}\right)}{r^2} + \frac{2\pi f \cos\omega\left(t-\frac{r}{v}\right)}{rv} \right]$$

Fig. 2 Inductive and radiative components of the electromagnetic field.

- Vincenzo Rosa (1848-1908) attended the university in Turin, where he was fellow-student and friend of Galileo Ferraris (1847-1897). He obtained a degree in mathematical physics in Turin in 1876. He was appointed as teacher in the school of Monteleone di Calabria. In 1879 he started teaching in Reggio Calabria, where he received the visit of the school inspector, the physicist Antonio Roiti (1843-1921) who was impressed by his background and he wanted him as his assistant in Florence in 1880. From 1887 he taught at the high school in Leghorn. He began to devise a system of synchronized clocks through an electromagnetic signal transmitted by a clock driver. Guglielmo Marconi's mother (Annie Jameson) had her son attended by Vincenzo Rosa in autumn of 1891 when the Marconi family stayed in Leghorn (Guglielmo Marconi was 17). Rosa had in his house a laboratory with several scientific models and instruments. Marconi learned to use them and to help Rosa preparing the lessons of the following days. Later Marconi began to follow the teacher in his school, and to act as his mechanic and helper during his lectures and his stay in school. Rosa gave to Marconi useful private lessons in physics, chemistry and electricity, from the autumn of 1891 to October 1892. It should be noted that in Rosa's laboratory, Marconi experimented for the first time the coherer as signaller of atmospheric discharges. Rosa was an industrious electrician and Guglielmo Marconi always considered him as his only true master.
- Sir William Crookes (1832-1919) discussed about wireless telegraphy in his paper *"On Some Possibility of Electricity"* (W. Crookes, *"On Some Possibility of Electricity"*, in *London Fortnightly Review*, February 1 (1892) 174-176): "Here is unfolded to us a new and astonishing world…Rays of light will not pierce through a wall, nor, as we know only too well, through a London fog. But the electrical vibrations of a yard or more in wavelength…will easily pierce such mediums, which to them will be transparent. Here, then, is revealed the bewildering possibility of telegraph without wires, posts, cables or any of our present costly appliances. Granted a few reasonable postulates, the whole thing comes well within the realms of possible fulfilment…". As J. J. Fahie commented on his book (J. J. Fahie, *"A History of Wireless Telegraphy", 2nd* ed., revised (1899) 289-316): "This is no mere dream of a visionary philosopher. All the requisites needed to bring it within the grasp of daily life are well within the possibilities of discovery, and are so reasonable and so clearly in the path of researches which are now being actively prosecuted in every capital of Europe, that we may any day expect to hear that they have emerged from the realms of speculation into those of sober fact. Even now, indeed, telegraphing without wires is possible within a restricted radius of a few hundred yards, and some years ago. I assisted at experiments where messages were transmitted from one part of a house to another without an intervening wire by almost the identical means here described." While Fahie was revising the last sheets of his work, it occurred to him to ask Sir William Crookes on some particulars of the experiments to which he alluded in his *Fortnightly* article. On April 22, 1899, Sir William Crookes replied as follows: "Dear Mr. Fahie, the experiments referred to at page 176 of my *Fortnightly* article as having taken place "some years ago" were tried by Hughes when experimenting with the microphone. I have not ceased since then urging on him to publish an account of his experiments."
- Oliver Joseph Lodge, professor of Experimental Physics at the University of Liverpool, delivered a series of seminal lectures entitled *"The Work of Hertz and Some of His Successors"* (1894). Following Hertz's death, on 1st January 1894, Lodge was invited to deliver these lectures at the Royal Society. Lodge's experiments stimulated a well known telegraph engineer, Alexander Murihead, to suggest that Hertzian waves might be used for communications purposes. A sensitive mirror galvanometer was connected to the coherer so that the detection of electromagnetic waves was visible to the audience in the form of a moving beam of light. Later that same month, Lodge used a small portable receiver based on similar equipment to demonstrate the detection of electromagnetic waves at the annual *"Ladies' Conversazione"* of the Royal Society in London. In particular, Lodge emphasized that Branly's powders were "the most astonishing sensitive detector of Hertz waves" and coined the term "coherer". Both at the Royal Institution, June 1, 1894, and later in the same year at the Oxford meeting of the British Association, Lodge showed how his form of Branly detector could be made to reveal signals at a distance of about 150 yards from the exciter. He wrote: "Signalling was easily carried on from a distance through walls and other obstacles, an emitter being outside on a galvanometer and detector inside the room." (*"The Work of Hertz and Some of His Successors"* (1897 ed.) p. 67). According to Sir Ambrose Fleming, Lodge was able to transmit a dot or a dash signal and by suitable combinations to send any letter of the alphabet in the Morse code and consequently intelligible messages. It is, therefore, unquestionable that on this occasion Lodge exhibited electric wave telegraphy over a short distance.

- In 1894 Jagadis Chandra Bose (1858-1937) was inspired to study the properties of electric waves after reading Oliver Lodge's "*The Work of Hertz and Some of His Successors*". Bose devised and fabricated a new type of radiator for generating radio waves. He also built a unique and highly sensitive "coherer" or radio receiver for receiving radio waves. Bose's coherer was far more compact, efficient and effective than the ones used in Europe by Branly and Lodge. In particular Bose replaced the irregular filings by fine wire spiral springs. In May 1895, he read his first research paper before the Asiatic Society of Bengal "*On the Polarisation of Electric Rays by Double Reflecting Crystals*". In the same years one of his papers titled "*On the Determination of the Indices of Refraction of Sulphur for the Electric Ray*" was communicated to the Royal Society of London by Lord Rayleigh. The paper was read before the Royal Society in December 1895 and was accepted for publication in the Society's proceedings in January 1896. Bose's articles were published in *The Electrician* of Friday 27 December. On April 27, 1899 J. C. Bose read his paper "*On a Self Recovering Coherer and Study of Cohering Action of Different Materials*", at the Royal Society in London. He clearly spoke about the invention of coherers using conductors separated by mercury. It must be noted that a drop of mercury decoherers automatically if it is compressed so as to just form a layer filling the space between the electrodes. He developed a complete system of generation, propagation and reception of wireless waves at a frequency as high as 60GHz. Although Bose filed for patent for one of his inventions due to peer pressure, his reluctance to any form of patenting was well known. Anyway Sara Chapman Bull succeeded in persuading him to file a patent application for *A Device for Detecting Electrical Disturbances*. The application form was filed on 30 September 1901 and it was granted on 29 March 1904 as U.S. patent No. 755.840.
- Alexander Stepanovitch Popov (1859-1906) is acclaimed in Russia as the inventor of wireless telegraphy. At the Meeting of the Russian Physical and Chemical Society on May 7, 1895, Popov demonstrated a system for detecting distant electromagnetic disturbances (lightning discharges in the atmosphere many miles away). Popov receiver consisted of a metal filings coherer he had developed as the detector element together with an antenna, a relay, and a bell. The relay was used to activate the bell which both announced the occurrence of a lightning discharge and served as a "decoherer" (tapper) to prepare the coherer to detect the next lightning discharge. In July 1895, Popov's apparatus was installed in the Observatory of the Forest Institute at St. Petersburg. In March 1896 Popov publicly obtained the transmission of a signal through a distance of 550 m between two campus buildings. Popov collaborated successfully with the French engineer-businessman Eugéne E. Ducretet (1844-1915), who began serial production of wireless telegraphy equipments in 1898. That apparatus was named "Popov-Ducretet system" and was used for the naval departments in Russia and France.
- Ernest Rutherford (1871-1937) is well known in the history of nuclear physics. Anyway, it must be underlined that at the very beginning of his research he devoted himself on the magnetic detection of electromagnetic waves. His thesis was entitled "*Magnetization of Iron by High-Frequency Discharges*" (1893). Rutherford's researches resulted in his first substantial scientific papers and won him a scholarship, which provided for further education in England. Rutherford employed a magnetic effect to detect Hertzian waves over a distance of two miles. He delivered an experimental lecture on his research before the Cambridge Physical Society. The lecture was published by the Royal Society of London (E. Rutherford, "*A Magnetic Detector of Electrical Waves and Some of its Applications*", *Proceedings of the Royal Society,* 60 (1896) 184). Marconi's magnetic detector follows Rutherford's magnetic principle.
- The physicist John Stone Stone (1896-1943) attended the Johns Hopkins University, where he graduated in 1890; he then began his career as a telephone engineer at the Research and Development Laboratory of the American Bell Telephone Company in Boston (Massachusetts). Stone's special ability in mathematical analysis led H.V. Hayes, chief engineer of the Telephone Company, to ask him to investigate the possibility of transmitting speech messages by telephone through Hertzian waves without the use of wire conductors. Stone made a masterly report of this work. He also filed patents covering his work on carrier current, or wired wireless, as it was termed later. Stone applied for a patent on tuning on February 8, 1900, and it was allowed February 2, 1902 (No. 714.756). This was a year and a half before the grant of Marconi's American patent No. 763.772 on tuning. Stone's arrangement featured a four–circuit wireless telegraph apparatus substantially like that later specified and patented in America by Marconi, who had previously been granted an equivalent British patent, the famous No. 7777 (1900).
- Adolph Slaby (1849-1913), who had studied with Heinrich Hertz, had actually witnessed some of Marconi's demonstrations in Britain. In the April 1898 issue of *Century*, he wrote: "…when the news of Marconi's first success ran through the newspapers, I myself was earnestly occupied with similar problems. …Quickly making up my mind, I travelled to England, where the Bureau of Telegraphs was undertaking experiments on a large scale. Mr. Preece, the celebrated Engineer-in-Chief of the General Post Office, in the most courteous and hospitable way, permitted me to take part in these; and in truth what I saw was something quite new". Slaby presently returned to Germany, continued his research and was soon awarded several patents. In collaboration with Georg Wilhelm Alexander Hans Graf (Count) von Arco (1869-1940) he developed the Slaby-Arco system, the foundation of Telefunken. Soon Slaby-Arco representatives would be submitting equipments and bids to the U.S. Navy Department, with considerable success.
- In 1893 the great inventor Nikola Tesla (1856-1943) proposed to transmit electrical oscillations to any distance through space, by erecting at each end a vertical conductor, connected at its lower end to earth and at its upper end to a conducting body of large surface (N. Tesla, "*Experiments with Alternating Currents of High Frequency*" in *Journal of the Institution of Electrical Engineers*, 97 (1892) 51). In particular, in Tesla's lecture "*On Light and other High Frequency Phenomena*" before the Franklin Institute in Philadelphia, Pennsylvania, February 1893, one finds disclosed the basis of modern radio transmission: "I mean the transmission of intelligible signals or perhaps even power to any distance without the use of wires…". Again, Tesla demonstrated the principles of wireless telegraphy – among other frames and outstanding physical effects like luminescent lamps, induction engine, … – in occasion of the World Columbian Exposition of the same year in Chicago. Unfortunately, the fire that destroyed Tesla's laboratory in New York on March 1895, postponed his further experiments not only on radio but also on electrical lighting and X-ray investigations. That is perhaps why he submitted two basic radio patents on 2nd September 1897 (No. 645.576; No. 649.621), a year after Marconi submitted his patent. A long legal dispute anyway started in comparison of Marconi's Company later on. In 1943, the U.S. Supreme Court gave to Tesla the priority for the invention of the radio thanks to some of his patents. The American sentence is based also on the validity of prior applications made by Tesla between 1891-1893. Anyway, since 1911 the British High Court gave the rights to Marconi's Company.

3 Young Marconi's scientific and practical education

In our opinion, for a better comprehension of Guglielmo Marconi's role in the birth of radio communications it is necessary to put under sharp examination his first scientific education. It is well known that Marconi was, to a very large extent, a self-taught man. In other words, he did not follow regular and public courses of study. He never got either a high school diploma or a university degree. He got only *honoris causa* degrees, later, when he had reached fame. On the contrary, it is not sufficiently understood that Marconi, consciously or unconsciously, made in his first scientific education specific choices of the arguments to be studied. These choices were in accordance with his interest in chemistry, physics and above all, since at least 1891, electromagnetic waves. Marconi's choices (and outstanding capabilities) were, of course, very personal and to a certain extent determined by his intellectual gifts, his health and family circumstances. It must be underlined, that the very efficient way chosen by Marconi for his education could be considered today almost as a model of scientific education. His choices were always selected according to his interests and ideas (good or not as they were). As a young inventor, he made a selection of the subjects to be studied according to his ideas: for instance he deepened, with every kind of reading, practical know-how, materials and instruments, his knowledge of a new type of battery or a traditional or new type of telegraphy. Another specific feature of his scientific method was to verify his experiments not just in a laboratory (as traditionally used by physicists of the time) but in the open air, in the wider space of the entire world. Another important feature of Marconi's approach to science and technique was to put forth for consideration his inventions and devices, thanks to his patents, at commercial and industrial levels. And this had inevitable risks.

Marconi was a scientist, radio inventor, but also a business man. He was the son of a wealthy Italian landowner, Giuseppe (1826-1904), by his second wife Annie Jameson (1843-1920), of a well known family of Irish whiskey distillers. Marconi was born in Bologna, Italy, on April 25, 1874. He was educated by private tutors because, due to his poor health, it was impossible for him to attend school regularly, even at the very beginning of his studies. For instance, he was enrolled at the private Istituto Cavallero at Via delle Terme near Piazza Santa Trinità in Florence (in which he developed a long life friendship with the young Marquis Luigi Solari, later on one of his most important collaborators) where he attended the first year of the junior secondary school; then he left school. In 1891 he was enrolled at the Technical Institute at Leghorn, in Via Cairoli, where he attended with enthusiasm professor Giotto Bizzarrini's lectures on physics. Moreover, to improve his knowledge in this field, Marconi, since the autumn of 1891, was privately educated not only by Bizzarrini but also, for more than a year, by professor Vincenzo Rosa, as we mentioned, of the Liceo Niccolini in Leghorn. According to Marconi's biographies, Guglielmo received lessons at the Liceo by Rosa and helped him as a technical assistant in his educational duties and research. Marconi asked for help to an old telegraphist, Nello Marchetti, who taught him Morse's alphabet and technique of classical (with wires) telegraph transmissions. In Leghorn Marconi, thanks to the sea air reinforced his health and also improved his culture. For a long while, thanks to his mother, he was much more fluent in English than in Italian. He improved his interests in physics, through free readings of technical articles about electricity, part of them delivered by his English relatives and thanks to fine books such as Benjamin Franklin's biography. Marconi was very interested in these subjects and he not only attended Rosa's lectures at his home, in which Rosa had a laboratory, but he accompanied him back and forth to his Liceo asking questions about technical and scientific arguments. The following year Rosa was moved to Alessandria in Piedmont, so it was impossible for Marconi to maintain direct links with him, but during the summer holidays of 1894, spent by Marconi's family in the Biellese mountains of Andorno, Guglielmo had the opportunity of meeting Rosa, who was spending his holidays not far from that place, at Candelo at about 10 km from Andorno. On this occasion Marconi had the possibility of discussing with Rosa Lodge's articles on Hertz's death (January, 1st 1894), above quoted, and his experiments about electrical waves. Once again, Marconi showed his determination in the research for scientific and technical information. Lodge's articles were published in *The Electrician* and in *Nature* of that year. Marconi's knowledge in that field was further improved thanks to his attendance at Righi's (a well known physicist professor at Bologna University) laboratory, library and lectures since 1892. During that period Righi was involved in his experiments – following those of Hertz (1887-8) published in the journal *Annalen der Physik und Chemie*, then in Hertz's first book, "*Untersuchungen Über die Ausbreitung der Elektrischen Kraft* (*"Investigations on the Propagation of Electrical Energy"*), Leipzig (1892). Hertz's book is considered to be one of the most important works of science: this is where he first describes his confirmation of the existence of electromagnetic waves – to confirm Maxwell's electromagnetic theory of light, published in several articles and in his *"Treatise on Electricity and Magnetism"* (1873). Righi confirmed and deepened Hertz's experiments and strengthened Maxwell's theory not yet accepted by the physicists of the time and hindered by Sir William Thomson, Lord Kelvin (1824-1907) (even in his "*Baltimore Lectures*" on modern theoretical physics delivered in 1884; revised and published in 1904), previously Maxwell's teacher and friend.

Fig. 3 Righi's Bench for electromagnetic waves, 1893 (Museum of Physics). An educational and experimental device shown by Righi to his university pupils; Marconi was among them.

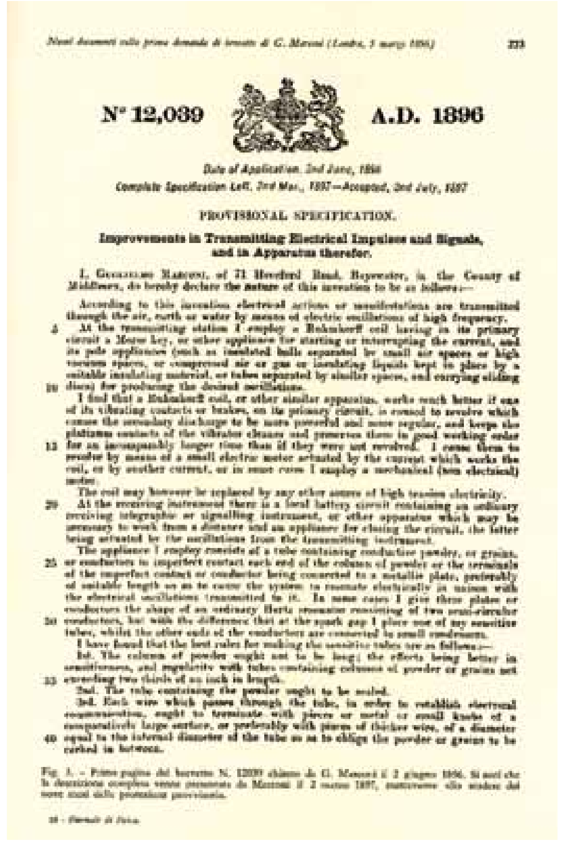
Attending Righi's laboratory, Marconi had the opportunity of acquainting himself with Hertz's oscillators and resonators, including those improved by Righi on short and micro-waves, and to read Righi's numerous articles on this subject (see fig. 3).
Hertz's and Righi's intentions were just to confirm Maxwell's theory. Decisive and definite proofs of Righi's interest concerning signal transmission through Hertzian waves are under research[1]. More information could come through the analysis of Righi's manuscripts preserved at the Museum of Physics (Department of Physics, University of Bologna), thanks to Righi's Family Endowment.
Marconi's original idea was, however, to use all this apparatus to develop a real practical and useful system of wireless telegraphy. It is the authors' opinion that Marconi, thanks to his personal, individual and peculiar style of education reached a knowledge level that no university degree could give him at that time.

4 From Marconi's first experiments on telegraphy without wires to the English and international experiments

As stated above, by the end of 1894 Marconi had a vast and profound physical knowledge of, and practical and conceptual experience, about electricity. He merely followed his interests, avoiding heavy literary and Latin studies (which would have been of no use to him). His education in this field was not simply that of a student but that of a real expert in physics, especially in the field of electricity. During the winter of 1894 Marconi devoted himself to the improvement of oscillators (as transmitters), resonators (as receivers) and every part of his system of telegraphy without wires. During the spring of 1895, following numerous experiments of smaller range, Marconi organized his demonstration to transmit signals from his scientific laboratory – the *stanza dei bachi* (silkworms' room) in the barn of Villa Griffone at Pontecchio, a few km from Bologna – to a distance of about 1.5 km beyond Celestini's hill at the back of the family estate. Then he tried to obtain the Italian Government's interest and help, only to be told that he should just ask for a patent. So thanks to his mother's relatives in England (particularly Henry Jameson Davies, his mother's cousin and engineer) Marconi left Italy for England, where he arrived on 2 February 1896 with his apparatus. Thanks to a letter of introduction by Alan Archibald Campbell Swinton, Marconi obtained the confidence of Sir William Henry Preece, the Chief Engineer of the English Post Office in London – who, as mentioned, had previously succeeded in transmitting electromagnetic signals, although only by an inductive method; Preece helped him directly and with some of his assistants (*e.g.* George S. Kemp). After several demonstrations – for instance on 27 July 1896 between the roof of the London General Post Office Building at St. Martin's–Le-Grand, and the roof of a Savings Bank Agency in Queen Victoria Street (300 m of distance) – Marconi organized, with the Post Office assistance, a more difficult experiment in September 1896 on Salisbury Plain, at Stonehenge, where he had success in transmitting signals in wireless telegraphy up to fourteen km. At these demonstrations, experts of the British Army and Navy took officially part as well as foreign experts kindly invited by the organizers. The newspapers gave great emphasis to these events. In the same period Marconi worked very hard to organize his patent. An application form had been submitted to the Patent Office in March 1896. The check of the existence of this request for patent was found on the review *The Electrical Engineer*, March, 13th 1896, page 308, on the schedule about "Provisional Patents, 1896" dated March, 5th with the following indication: *5028. Improvements in Telegraphy and in Apparatus Thereof. Guglielmo Marconi, 24, Southampton-buildings, Chancery-lane, London.* This provisional patent was then withdrawn and substituted on 2nd June 1896 by the first request for a patent for wireless telegraphy based on electromagnetism to be taken out in the United Kingdom, which was approved on 2nd July 1897 with No. 12039 (see fig. 4). Its title was: *Improvements in Transmitting Electrical Impulses and Signals and in Apparatus Thereof*. On 13 July Marconi obtained the same patent for the USA (No. 609.154). To be noted on his patent are the eleven drawings illustrating his apparatus with clear evidence of aerial-antenna and earth, and, particularly, detailed information about the features of his receiver (coherer). Marconi transformed the small Hertz's dipole in an enormous one. Thanks to these and other experiments, Marconi discovered his physical law in which the height of the antenna is proportional to the square root of the distance to be covered by long electromagnetic waves.

[1] The authors of the present article, with Giovanni Gottardi and Marina Manferrari, are going to publish a volume about Righi's scientific correspondence preserved at Accademia delle Scienze detta dei XL (Rome) under the auspices by CNR and SIF.

4


Nº 12,039 A.D. 1896

Date of Application, 2nd June, 1896

Complete Specification Left, 2nd Mar., 1897—Accepted, 2nd July, 1897

PROVISIONAL SPECIFICATION.

Improvements in Transmitting Electrical Impulses and Signals, and in Apparatus therefor.

5

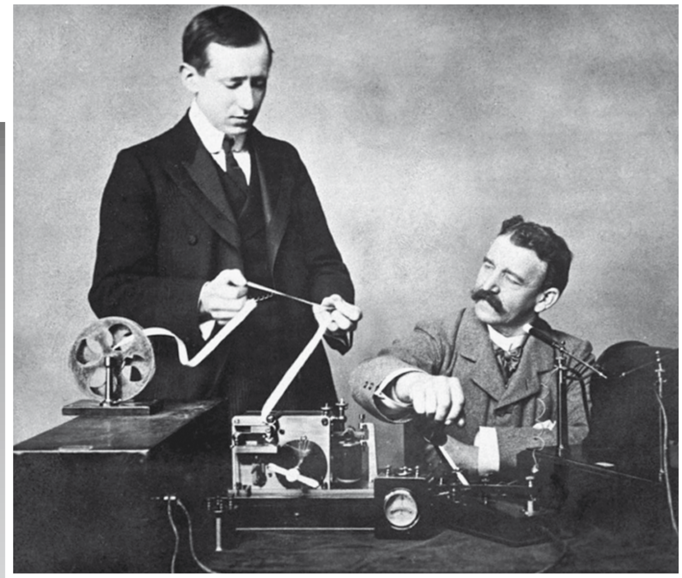


Fig. 4 Marconi's patent frontispiece (courtesy by `www.radiomarconi.com`).

Fig. 5 Marconi and his assistant Kemp working with a Morse's telegraph (courtesy by `www.scientific-web.com`).

It must be stressed that Marconi had heard about Galvani's detection of electric discharges, thanks to frogs, enhanced by the use of long metal wires as aerial and grounds, as well as of Franklin's experiments. Marconi's coherer was, in a certain way, like those above quoted of Calzecchi Onesti, Branly and of Lodge, but much more improved and reduced in scale. With his improvements Marconi's coherer became a very reliable receiver. In fact, every part of his telegraphy wireless system was improved and accurately verified in its functioning not just in the laboratory, but in the field of application, in the open air, through the sea, beyond and behind the mountains, on a larger and larger range. In May 1897 Marconi succeeded in transmitting Morse code signals across the Bristol Channel (about 15 km). In these experiments A. Slaby, a famous German scientist (who later on developed his own system of telegraphy without wires) took part as a guest. During the month of July 1897 Marconi, helped by the Italian Navy, organized several transmissions with his system between S. Bartolomeo's Arsenal at La Spezia to various places like Portovenere, Isle of Palmaria, Isle of Tino to a distance of between 5 and 7 km. Thanks to the use of the battleship *San Martino,* from the Gulf of La Spezia, it was then possible to transmit at a distance of 18 km. After his return to England, Marconi established the Wireless Signal and Telegraph Company (on 20 July 1897), then Marconi's Wireless Telegraph Ltd (in 1900). During the months of July and August 1898, Marconi transmitted several messages between the Royal Palace *(Osborne House)* on the Isle of Wight and the Royal Yacht *Osborne* to inform Queen Victoria about the health of her son, the Prince of Wales (later Edward VII). He was suffering from knee trouble following a fall. These messages were very much appreciated by the Queen (who was anxious about her son) and, of course, they were of great importance, in publicizing the new Company. Marconi's idea was to improve transmission distances, thanks to the use of long waves and very high antennas. He continued his experiments between the Needles rocks near the Isle of Wight, and a ship at a distance of 30 km and at Salisbury Plain between Salisbury and Bath (about 50 km). The importance of these experiments must be underlined; the transmissions were carried out under horizon line. Some experiments developed to syntonize the transmission were also carried out. It should be noted that in 1897 Lodge took out a patent (No. 11575) for the syntonic wireless telegraphy. In 1899 (27 March) Marconi succeeded in sending Morse code signals through the English Channel between South Foreland (near Dover) and Wimereux (about 5 km from Boulogne-sur-Mer). The international distance was about 50 km. The aerials used were about 54 m high. In the same year Marconi followed the America Cup's Regattas sending messages (about 1200) from the liner *Ponce* to inform the USA public of the challenges between the American *Columbia II* (the winner) and the English *Shamrock*. These episodes were a great commercial opportunity for a better general comprehension of the importance of wireless telegraphy for pacific uses (the military purposes were evident). The American Company for wireless telegraphy was established, according to the British Society, just at this time. There were, of course, several aspects of these early experiments to be improved. To avoid interference between several transmissions, and to obtain secret messages, Marconi developed a syntonic system (English patent of 26 April 1900, No. 7777; USA patent No. 763.772). Thanks to this patent it was possible to send signals from several stations at the same time without interference, with the use of different lengths and appropriate induction coils. The principle was that of having the same *LC* product (Induction $L \times$ Capacity C) both in the primary as in the secondary circuit. With this system it was possible to obtain a partial privacy and much larger distances of transmissions out to sea (about 300 km). These experiments were very important to achieve confidence in a transatlantic transmission that it was Marconi's intention to organize in a few months' time. This patent was the source of legal protests against Marconi's Company by Lodge and Braun. Later on their patents were acquired by Marconi's Company: Lodge sold his patent and agreed to be a consultant to the Company. In 1901 Marconi organized his transatlantic transmission. Several scientists had perplexities when they heard the news of this project. It seemed to them that the electromagnetic waves, like the optical ones, ought to propagate on straight lines, following the lines-of-sight, and that it would then be impossible to send messages beyond and behind large barriers like the enormous quantity of matter due to the earth curvature across the Atlantic Ocean. The curvature of the Earth – between Poldhu (Cornwall) and Signal Hill (Newfoundland) on a distance of about 3.400 km –corresponds to about 50 km. It was like an enormous mountain to be overcome by electromagnetic waves. It seemed at that time the dream of a visionary instead of a scientific and technological project. The scientists thought that Marconi did not understand physical and mathematical laws. For instance, the great mathematician Henri Poincaré (1854-1912) said that electromagnetic waves would be extinguished after a travel long no more than 300 km. Marconi had confidence in a lot of experiments he had carried out previously, even under horizon line, behind the Earth curvature. It was not of course a simple matter of intuition. Not at all. Be that as it may, Marconi organized the transmission from Poldhu in Cornwall to Signal Hill in Newfoundland. Notwithstanding a lot of difficulties – due to terrible thunderstorms, both in England and in USA and Canada at the sites of the stations, that destroyed the original very high antennas organized for transmission – he received with a kiteborne antenna (180 m wire long) the signals (three points, the letter *S* of Morse code) on 12 December 1901 (see fig. 5). Of course, Marconi ignored the existence of the *Kennelly-Heaviside layers* (discovered later on), but he had made several experiments of this type over longer and longer distances. In particular, for Marconi's transatlantic project were decisive the experiments between the Tyrrhenian coasts and Isle of Caprera (Maddalena archipelago). As a matter of fact the electromagnetic waves were reflected (really refracted several times) by the ionosphere. The transmission was a success: Marconi became a household name overnight. He was just 27 years old. In the following years, Marconi had to fight against a lot of enemies such as Cable Companies and to struggle against alleged inventors claiming for the priority of the discovery of wireless telegraphy. Among these we just mention: Lodge, Popov, Tesla. Notwithstanding this, he developed much of the technology necessary for its practical use and overcame a lot of initial deficiencies. Marconi was aware of the bad functioning of the coherer when a ship is in rolling motion due to trouble during navigation. So he introduced more reliable receivers: the magnetic detectors. The first was with rotating magnets, the second with fixed magnets. In 1902, Marconi patented his magnetic detector, perhaps inspired by E. Rutherford's articles (already quoted) on the same subject published in 1896. From the beginning of June 1902 Marconi (and his friend and collaborator Solari and their technicians) had at their disposal the Royal battle cruiser *Carlo Alberto* of the Italian Navy to carry on experiments during a journey from Naples (10 June) to Kronstadt (12 July) and back through Kiel, Portsmouth, Gibraltar, La Spezia (11 September). During these experiments it was possible to discover the negative effect of solar light on the transmission, and to have the certainty of the possibility of transmitting signals beyond high mountains of the European Continent, without negative effect on the reception of electromagnetic waves, and to make several experiments with his prototypes of magnetic detectors. Marconi was certainly helped by his skilful technicians, engineers and assistants, all of whom were electricity experts and enrolled in his Company. It was Marconi's great merit to organize a scientific *équipe* with among others: G. S. Kemp, P. W. Paget, R. N. Vyvyan, C. S. Franklin, H. J. Round and above all J. A. Fleming, Maxwell's pupil, Edison's consultant, Professor of Electrical Technology at the University College, London. Fleming was the inventor of the thermionic valve, the diode (1904) that in the following years (thanks to L. de Forest triode, 1907) became so important for radio-transmissions. Marconi organized his group well as a real research group, and largely appreciated the qualities of his collaborators, most of whom venerated him. In 1905 he developed his horizontal directional aerial to be used later especially with short waves. It must be remembered that the historical and sociological events of the period between the end of the XIX century and the beginning of the new century gave a large resonance to the political claim to transmit secret information with a total safety. The famous "Dreyfus case" (Alfred Dreyfus, 1859-1935) – celebrated by Émile Zola (1840-1902) in his *J'accuse* (1898) – in a certain way underlined the need to improve at a maximum level the most advanced equipment for transmitting electromagnetic signals. As well as the needs of the countries (in particular of the British Empire) to connect without wires several parts of their domain. Thanks to all of these facts Marconi's Company (and other companies at that time) obtained government benefits for their research and plants.

5 The years of Marconi's success

In 1905 Marconi married in London Beatrice O'Brien, daughter of Lord Inchiquin, descendant of the Kings of Ireland from the XVI century. In the same period, Marconi introduced his multiple-spark generator (1904) and his rotating disc discharger (1905) to avoid Rumkorff's induction coils and Hertz's and Righi's oscillators, which with their high resistances were the cause of waves attenuation. In 1909 Marconi was awarded the Nobel Prize for Physics. In that occasion he declared: "I did, however, attend one course of lectures on physics under the late Professor Rosa at Livorno, and I was, I think I might say, fairly well acquainted with the publications of that time dealing with scientific subjects including the works of Hertz, Branly, and Righi" (G. Marconi, "*Wireless Telegraphic Communication*", *Nobel Lecture*, December 11 (1909)). He shared the award with Karl Ferdinand Braun (1850-1918), who introduced his cathode-ray oscilloscope in physics and technology and who in the field of wireless telegraphy understood the limits in the wave transmissions of the use of Hertz's oscillator, due to the sparks. Braun proposed a transmitting system without sparks. In October 1911 the Italian war against the Turkish Empire began and Marconi, as civil consultant, helped the Italian Army and Navy, with his radio devices, to connect naval forces with land forces. He developed transportable radio sets, organizing trench stations, with aeroplanes transmitting systems. In November 1911, Marconi with Solari's help inaugurated a powerful Italian radiotelegraphic station at Coltano (near Pisa) on the Royal estate of San Rossore, to be connected for use in time of war with those in Tobruk and in Derna.
In 1912, Marconi developed his timed spark system to produce and generate continuous waves to be modulated for the transmission of signals. In this same year, Marconi was considered a benefactor to humanity thanks to the S.O.S. rescue of about 700 of the 2300 people in the Titanic shipwreck of 15 April 1912. Following this success, the Marconi scandal exploded. It began with some rumours about certain help obtained by Marconi's Company from ministers of the English Government, who were owners of shares in Marconi's Company. The newspapers suggested that in this way ministers could have an economic interest in helping the Company obtain the passing of the bill for the British Imperial Wireless Network. The government of Herbert Henry Asquith (1852-1928) almost toppled. Marconi had some trouble about it, but in the end he suffered no consequences and nothing came of it. As a recognition of his merits Marconi was knighted Sir by King George V. Between 1913 and 1914 Marconi studied the new thermionic valves as transmitters, with great appreciation for Meissner's patent. Along this path, with a modification of Meissner's device, Marconi developed the use of electronic tubes as transmitters. In particular, since 1913, Marconi's Company employed Marconi-Round electro-magnetic transmission system with the use of an electronic tube. At the beginning of the First World War Marconi joined the Italian Army, and then he was moved to the Italian Navy. During that period he introduced short-waves beam systems for war uses to obtain secret messages, thus saving energy for long–distance transmissions. He designed more advanced radio-range beacons, ground radio beacons and radiogoniometers. These researches continued in peacetime and produced results which helped to transform and enhance long-distance wireless communications. Marconi had the courage to turn upside down his own line of research and to develop short-waves (wavelength 100 m–1 m) technology to improve the reliability of communications, about 20 years later the experiments at that time developed with high antennas and very expensive and enormous radio-stations. In this case he was helped by his interest in information from *amateurs* about the discovery of short waves efficiency in transmitting signals. According to this, we have the pleasure to remember the original and innovative role about short waves played by Adriano Ducati (later Cavalieri Ducati). Some years later in 1928 Marconi admitted in Rome: "I made a mistake. I worked with long waves ..., but now we must work with short waves". As usual his Company and the other technicians followed him.
After the War he continued with his short wave experiments. He was helped by an outstanding new laboratory that he acquired in February 1919. Namely, the purchase of the steam-yacht *Rowenska* previously owned by the Archiduchess Maria Teresa of Austria. Marconi called it *Elettra* and it became his home, laboratory and mobile receiving station. A famous Italian poet, Gabriele D'Annunzio (1863-1938), called the yacht *"la candida nave che naviga nel miracolo e anima i silenzi aerei"* ("the snow-white ship sailing through miracles and giving life to aerial silences"). In April 1919 Marconi was appointed by the Italian Government plenipotentiary delegate to the Paris Conference, where the Treaty of Versailles was signed. From the beginning of 1920, after several experimental trials, he began broadcasting transmissions from *Elettra* in the Atlantic Ocean, about 30 miles from Lisboa to Monsanto (near Lisboa), where Solari was listening thanks to a loudspeaker connected with the receiver. In June 1922, in a speech given at the Institute of Radio Engineers in New York City, he talked about the capability of electromagnetic waves to be reflected by conductive bodies; in this way he predicted the possibility of having information about other ships or objects along the route even when the optical visibility was absent. It was the nucleus of radar detective system. In 1923 his wife asked for a divorce. A few years later, he was married again to Maria Cristina Bezzi Scali, a young Countess from a family of ancient nobility, related

to the famous Orsini and Barberini Italian families (1927). In the same year he established the worldwide radio-telegraph network on behalf of the British Government throughout the British Empire and he became President Founder of CNR (National Research Council) for Italy. He received many distinctions, recognitions and degrees *honoris causa* from all over the world. Among others, in 1914 he was appointed senator of the Kingdom of Italy and he obtained an Italian Marquisate in 1929. The year after he became President of the prestigious Scientific Academy of Italy. The political regime of that time used Marconi's well known fame all over the world as a symbol of fascist Italy. Marconi was the great propagandist of his discoveries thanks to his famous international experiments. In other words he had a great theatrical sense which he used on several occasions. It must not be forgotten that he loved music, and that his mother studied singing in Bologna. Great inventors and scientists of that time influenced without doubts Marconi's style of life. In particular, William Thomson (Lord Kelvin) used, since 1870, his *Lalla Rookh* yacht as a scientific laboratory rather than only for his spare time.

6 The last experiments open to the future

During the last few years of his life Marconi was involved in several important experiments concerning microwaves. We must remember the experiment officially demonstrated on 30 July 1934 between S. Margherita Ligure and Sestri Levante in which he developed the radio-beam microwaves (60 cm) technique to drive a ship blind: without a compass, without any visibility from outside, with just an instrument to detect the silence zone produced by microwaves interference.
Even more important for war consequences were his further experiments about object reflection (predicted since 1922). According to a technician of his, A. Landini, Marconi was carrying out experiments at Torre Chiaruccia near Civitavecchia trying to detect the movements of his car with 50 cm microwaves. It was the beginning of radar detection technology. We must agree with Edison's famous general quotation: "Genius: 1% inspiration, 99% transpiration", addressing to Marconi and his entire life devoted to research in this celebrated sentence. Many fantastic discoveries were attributed to Marconi. Some of them were, of course, just journalistic fantasy, like "death-rays" and others. It is true, anyway, that he had been working for years about the possibility of extracting gold from sea water, or transmitting electrical energy to a distance, or improving the growth of harvest and eliminating bacteria by means of electromagnetic waves. He also was interested in applying microwaves to TV transmissions. On 20 July 1937 following a series of heart attacks, due to a form of *angina pectoris,* that he had suffered for the last few years, Marconi died, aged 63, in Rome, Italy.

7 Some considerations as a conclusion

As a conclusive consideration, we would like to use two quotations. The first by Augusto Righi, the second one by Quirino Majorana. In 1903 Augusto Righi said:
"The indisputable merit [of Guglielmo Marconi is] to had taken a bold initiative, where others had made only timid proposals, and to have transported to the practice field what others had only looked through and realized in a smaller scale. But his ability and inventive faculties were fully proved later, through the capability with which he won numerous difficulties, and through many modifications and additions of detail, in large part essential for the practice success, which were joined by him in that ensemble that can rightly be called the Marconi System."
Q. Majorana was an experimental physicist, Professor of Physics at Bologna University, Righi's successor and one of the first scientists to transmit the voice in wireless telegraphy, without carrier wave and tubes (1903). His quotation of 1932 was the following: "Guglielmo Marconi was not satisfied with his first success, which would alone have been sufficient to assure him a lasting celebrity. He was always in the vanguard of the various improvements that in the meanwhile were introduced in the outstanding system carried out by him. This is true about syntonic problem, long-distance transmissions, directional transmissions, radiogoniometry, beam-system signalling and, more recently, about short waves and microwaves".
We think it is difficult to express more appropriate, clear and precise words than those above quoted. In our opinion Marconi was an authentic experimental scientist in the true sense of the word, meaning a man who was able really to improve science and technology; and, for all his life, he was able to make outstanding improvements in the field of electromagnetic waves. It was a life in which he had a complete confidence in the experimental method. He had as experimental laboratory the entire world, often struggling against official science opinions. In this continuous capability lies the great difference between him and the numerous other pretenders to the wireless telegraphy invention.

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