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About the beginnings of wireless

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Many scientists and engineers contributed – more or less successfully – to the development of radio and wireless. This historical survey describes briefly the projects realized more than a century ago by some of them, at the early beginnings of wireless. It is hoped, in this manner, to draw attention to the unknown or forgotten researchers who built up the considerable body of knowledge that led to Marconi's remarkable achievements.

Keywords: electromagnetism, wireless, radio, history of science, early developments

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I. INTRODUCTION

Who invented radio? This question is often asked, the kind of question that probably no one will ever be able to answer satisfactorily. As is generally the case with new discoveries, one particular individual has been singled out, and from then on this "privileged individual" gets all the credit (or the blame) – while we completely ignore that many other people also contributed significant advances, whose names remain unknown to all but a few specialists. In the case of wireless, the "privileged individual" is obviously Guglielmo Marconi, who started transmitting in 1894 or 1895, and whose "officially reported" transmissions covered increasingly significant distances from 1896 on.

A major effort to bring to light some of the less known people who also made invaluable contributions to the development of wireless was carried out by a team of specialists, who edited the "History of Wireless" [1]. Noting that Marconi's well-known contributions are widely covered in the technical literature, the authors decided that it was not necessary to include a chapter specifically devoted to him – but Marconi's name is cited in almost 100 places, all over the book!

The purpose of the present historical survey is to outline the preliminary stages in the development of wireless, showing how, after several years with small significant improvements, the range of transmissions suddenly increased by orders of magnitude, making it a useful way to communicate over long distances. In this way, one should get a comprehensive outlook about major events that took place over a century ago.

II. FROM ANTIQUITY TO MAXWELL

Electrical and magnetic effects were observed already very, very long ago, as the use of the compass by the Chinese was reported as early as 2637 BC [1]. Ancient Greeks provided the roots of the names currently used nowadays, based on the intriguing attraction properties exhibited by some materials, from "ελεκτρον," which means amber, and "Magnesia," a city in Asia Minor where the amazing properties of lodestone were discovered.

For many centuries, however, these two domains – electricity and magnetism – evolved independently. It is only in 1819 that Hans Christian Oersted, a Danish physicist adept of the "Philosophy of Nature," noticed that an electrical current could rotate the needle of a compass. From then on, Ampere, Gauss, Henry, and Faraday discovered and analyzed different interactions, for which James Clerk Maxwell provided a unified formulation in 1864 – postulating the existence of a displacement current. The set of Maxwell's equations forms the basis of electromagnetism. Oliver Heaviside simplified considerably their formalism in 1886 using vectors and differential operators. Maxwell's equations are still valid nowadays, they were not affected by the discovery of relativity and of quantum physics. Combining some of the equations yields so-called "wave equations," whose mathematical solutions are waves that would propagate at the velocity of light [2]. But at Maxwell's time this was merely theory, and for some time nobody managed to generate or to observe these electromagnetic waves.

III. SOME PRECURSORS

A number of researchers noticed effects more or less directly related to electromagnetic wave propagation, but for a variety of reasons their activities did not lead to further developments and to successful practical applications. Here are some of them:

In October 1866 an American dentist, Mahlon Loomis (1826–86) managed to transmit some bits of information over a distance of 29 km, between two metallic kites flying above the Blue Ridge Mountains in Virginia – from Cohocton Mountain to Bear's Den. Two hundred meter long wires were connected from the kites to the ground level. A switch alternately connected the first kite to ground, and then broke the connection, locally modifying the electric field in the clouds. A galvanometer detected minute voltage variations in the circuit of the second kite. Two operators

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had carefully synchronized their watches; the first one operated the switch of the first kite, whereas the second one watched the galvanometer and noted the exact times at which variations took place. These were found to coincide exactly with the switching sequence.

Loomis called this system "aerial telegraph" and dreamed of a multitude of fabulous applications. Three years later, in 1869, a group of Boston investors almost financed his project, but on September 24, "Black Friday," the potential investors were ruined at the time of the Fisk/Gould gold exchange scandal. Two years later, Chicago bankers planned to invest 20 000$ to develop the invention. Alas, on October 8 the Great Chicago Fire provided them with great possibilities in reconstruction, which would yield more lucrative investments than Loomis's experiments.

Loomis obtained patent No. 129971 in 1872, the first patent ever granted to a wireless transmission system. The House of Representatives even adopted a law, signed by President Ulysses Grant, instituting the "Loomis Aerial Wireless Telegraph Company." But this was not sufficient to generate adequate funds to pursue the experiments [3]. One still does not know how this approach would operate in the absence of clouds.

In 1875, the famous American inventor Thomas Alva Edison (1847–1931) noticed that an electric discharge in an inductive circuit produced sparks between distant metallic objects that were only connected through a common ground. He could thus send messages without wires. He was puzzled because a galvanometer did not detect the sparks received. He felt that this phenomenon was due to some radiant force, something that would be related on one side to light and heat, and on the other side to magnetism and electricity.

Edison named this effect "etheric force," and constructed a spark-gap detector that he called etheroscope. Unfortunately, he did not carry on further this research, favoring more profitable endeavors – otherwise, he might have invented a wireless telegraph some 20 years before Marconi [4].

In 1879, shortly after the death of Maxwell, David Edward Hughes (1831–1900) developed a sensitive microphone, and noticed that this instrument was affected by the noise produced by sparks in a faulty connection. He presented his experiment to Fellows of the "London Royal Society:" William Spottiswood (then President), Professor Huxley and Sir George Gabriel Stokes (1819–1903) – actually demonstrating transmission and reception at distances between 55 and 460 m! Hughes had thus observed electromagnetic radiation several years before Heinrich Hertz! But Professor Stokes declared that this was only an "effect of magnetic induction" and that, according to him, electric waves could not exist. Hughes was very discouraged by this unexpected rebuff, and he wanted to obtain a better proof before writing up his observations. But he did no further work on this topic, and mentioned his discouragement in a 1899 letter to J.J. Fahie. This put a final stop to a potentially promising approach: Hughes's microphone would have been more sensitive than coherers later introduced by Branly and Lodge [5].

The American physics professor Amos Emerson Dolbear (1837–1910), at Tufts College near Boston, patented in 1882 a "wireless telegraph." The transmitter used a transformer (coupled induction coils) with a microphone and a battery in the primary circuit, the secondary circuit being connected on one side to a capacitor, on the other to ground. The receiver, also connected to ground, contained a telephone receiver, capacitors and a battery. The setup presented some similarities to the ones used later on by Marconi, but with capacitors instead of antennas. An 1886 description mentions a range of 18 m, making use of very long wavelengths, which correspond to an audio signal [6].

On the same year 1882, Nathan Beverly Stubblefield, a melon grower of Murray, Kentucky, transmitted audio signals "without wires." A very secretive individual, he lived alone in a hut surrounded by alarm systems to prevent anyone from approaching. In 1892, he demonstrated the transmission of human voice over a distance of 800 m, using two "black boxes." He used an elaborate system of metallic rods and coils in the ground, forming a kind of battery, to power his transmissions – an experimental technique that is still not well understood today! Toward 1898 his system operated over about one and a half kilometer, and Stubblefield, holding a patent on his "wireless telephone" tried to commercialize it, but without success. In 1902 he achieved some recognition and made a number of demonstrations, obtaining even transmission rights. But a change of frequency allocations put a stop to Stubblefield's transmissions in 1916. He returned to his hut and died there in 1928 [7].

Another wireless approach considered the direct use of the magnetic field between two coils. The Welsh engineer and inventor William Henry Preece (1834–1913) experimented with such inductive systems, covering in 1892 a distance of 5 km between Penarth and Flatholm Island on the Bristol Canal. In 1894 Preece set up two rectangular induction coils facing each other across the 6.4 km wide Kilrannan Sound. The coils were made of two parallel lines 9.6 km long on each side, both 150 m above ground, with an ordinary land line at sea level (i.e., rectangular coils with dimensions 9.6 km × 150 m). The system operated well, but when removing the ground return lines and replacing them by earth plates at each end, the performance was significantly improved. However, the prohibitive size of the installations rendered this technique impractical [8]. Still, 5 km became a standard distance that wireless transmissions should cover to present a technical interest.

IV. RESEARCHERS IN ACADEMIA

The wave equations derived from Maxwell's equations, established in 1864, implied that some kind of electromagnetic waves could exist and propagate. But for more than 20 years, nobody managed to actually produce them or to measure them. Several researchers had observed some effects, but they either did not realize the significance of the observed phenomena, or tried to exploit them, but without success.

In Germany, on November 13, 1886, the physicist Heinrich Hertz, professor at Karlsruhe's Technical University, produced electromagnetic waves with a Ruhmkorff spark gap generator connected to a short dipole antenna. He detected them across the spark gap of a split coil, which resonated at the same frequency as the transmitting dipole. But this detector was quite insensitive, so that he observed the transmission over a few meters only. To produce standing waves, Hertz positioned the oscillator about 12 m away from a zinc reflecting plate. Using the ring detector, he recorded the magnitude and direction of the fields. He demonstrated that the wave velocity was equal to the velocity of light, just like Maxwell had predicted.

But Hertz did not realize the practical significance of his experiments. He stated that, "It's of no use whatsoever [...] this is just an experiment that proves Maestro Maxwell was right – we just have these mysterious electromagnetic waves that we cannot see with the naked eye. But they are there." In 1889, he even stated that these waves could not be used for telephony, because their (audio) wavelength would be 300 km long (modulation had not yet been invented) [9]. After several months of investigation, he reported his results, but he did not pursue further investigations, and he did not try to determine the origin of the phenomenon observed. From then on, he turned his attention to mechanics. On New Year's Day 1894 his untimely death put an end to his researches, just weeks before his 37th birthday [10].

Several physicists had noted that small particles tend to group themselves tightly, or "cohere," in the presence of an electric field. In France Pierre Guitard noticed this effect in 1850, then Samuel Alfred Varley studied it in Great Britain in 1866, and the Italian physicist Temistocle Calzecchi-Onesti observed the same effect with iron filings in 1884 – but these scientists did not make use of their discoveries [11]. While studying how nerves carry messages, the French scientist and physician Édouard Branly (1844–1940) also noticed that magnetized particles tend to cohere in the presence of fields. In 1891 he showed that the resistance of a glass tube filled with iron filings decreases in the vicinity of an electric spark, and that this effect could be used to detect electromagnetic waves. He developed in this way a detector more sensitive that the coil with spark gap originally used by Hertz [12].

Sir Oliver Joseph Lodge (1851–1940), professor of physics and mathematics at Liverpool University College in Great Britain, had thoroughly studied Maxwell's treatise on electricity and magnetism, and had tried to generate electromagnetic waves since 1879, without success. But Hertz had been the first to succeed. Lodge then carried on the research initiated by Hertz, and in particular perfected the study of resonant circuits. In 1893, he used in his receiver an iron filings "coherer" – improving upon the technique developed by Branly by adding a "trembler" to unclamp the iron filings after the reception of a signal. In this way he lengthened the distance covered, and carried on demonstrations to his students and to the "Royal Institution" in London.

But Lodge's interest was mostly scientific, and possible practical applications were not his first priority! Fortunately Alexander Muirhead, a telegraph engineer, suggested to use these waves to transmit messages. In August 1894, Lodge managed to transmit a Morse code message over a distance of about 60 m, crossing even several brick walls [13]. In 1898 Lodge and Muirhead were granted a patent for a wireless transmission system, which they sold later on to Marconi in 1912.

The British Chemist William Crookes (1832–1919) had heard of Lodge's researches, and in 1892 he published an article describing the amazing potentialities offered by wireless transmission [14]. He mentioned the "almost infinite" spans covered by these new waves, that scientists were studying in several European capitals. A new world was being born, and one could not doubt that it could carry intelligence. But this premonitory article did not attract a lot of attention when it was published – it was only "rediscovered" after Marconi's successes.

As far as history is concerned, the main contribution of Oliver Lodge was without doubt his Hertz memorial lecture to the "Royal Institution" in 1894, in which he described the German's research, completing it with some of his own results. This lecture and the articles that he published in several magazines met with a large impact [15, 16]. The whole world then heard of researches that had until then remained mostly confidential.

Another early follower of Hertz was Augusto Righi (1850–1920), professor at the University of Bologna in Italy. His early research covered a very wide range of experiments, involving capacitors, dielectric and ferromagnetic materials, electrical sparks, magneto-optical and photoelectric effects. Since 1893 he concentrated his studies on electromagnetism, on the basis of Hertz's experiments. He increased the violence of the spark by filling the space between the discharge knobs with petroleum jelly. In this way he increased the amplitude of the waves produced by the sparks. He also managed to obtain shorter wavelengths, around 10 cm or less (whereas Hertz did not obtain wavelengths shorter than 66 cm) [17].

In far away West Bengal, the great Indian scientist Sir Jagadish Chunder Bose (1858–1937) had also heard of Hertz's work. Born during the British Raj, Bose graduated from St. Xavier's College, Calcutta, and studied medicine at the University of London, in England but, due to poor health, he could not complete his studies. He returned to India as a Professor of Physics at the University of Calcutta. An outstanding experimenter, he had many interests: physicist, biologist, botanist, archaeologist, and the first science fiction writer in the Bengali language.

J.C. Bose actively pioneered the investigation of millimeter waves. In 1895 (or maybe already in 1894? there are some doubts about the year) in a public lecture in Calcutta, electromagnetic waves traveled from the lecture hall, through an intervening room, and into a third room 22 m away from the transmitter – crossing on the way two solid walls and the body of the chairman! The receiver activated a circuit that set a bell ringing, discharged a pistol and exploded a miniature mine. Bose had shown in this way that these waves could have several practical applications.

While improving upon the operation of his equipment, Bose introduced an impressive number of specialized devices for millimeter waves, such as waveguides, horn antennas, dielectric lenses, interferometers, couplers, absorbers, etc. – devices still in use nowadays. In 1899, he developed a sensitive "iron–mercury–iron" coherer. Later on, he used a galena detector in his receiver, making use of the rectification properties of contacts between a metal and sulfites – discovered in 1874 in Strasburg by professor Karl Ferdinand Braun (1850–1918) [18]. Bose's detector was the forerunner of semiconductor junctions – widely used later on in diodes and transistors – and Bose obtained a patent for it in 1904 [19, 20].

J.C. Bose subsequently got more interested in plant physiology, inventing a device, the crescograph, to measure plant response to various stimuli, and thereby scientifically proved parallelism between animal and plant tissues. J.C. Bose never tried to gain commercial benefits from his many inventions, because the very idea of commercialization of science was extremely repugnant to him [21]. Quite on the contrary, he distributed his inventions freely without charge, in order to stimulate others to further contribute to his research – a principle recently rediscovered with Linux and open source software.

The eminent professors listed in this section considered electromagnetic wave propagation as an interesting laboratory experiment, useful to demonstrate the validity of Maxwell's theory, and to present intriguing phenomena to their students. But they did not directly consider possible applications of these waves. Several of them also had other interests, and actually pursued their research in other fields.

At that time, it was generally felt that electromagnetic waves could only have a limited interest for transmissions. Since they are of the same nature as light, it was assumed that they would only propagate along the line of sight, so that only short spans could be covered, due to obstacles and the curvature of the earth.

In addition, during the years 1850–60, telegraphic cables had been installed across continents, and even on the bottoms of oceans: so why should one spend lots of effort and money to merely duplicate an existing service? Apparently, little thought had been given to maritime communications, and nobody had yet realized the enormous impact that wireless would soon encounter.

V. INVENTORS

There is a basic difference between science and technology. Pure scientists, generally attached to universities, try to uncover the secrets of the universe and to prove (or disprove) some theory. When they find something of interest, they quickly publish their results to gain priority. For some of them, research is an intellectual exercise, and they are generally not interested in applications outside of pure science.

On the other hand, in the fields of applied research and development (R&D), technicians and engineers try to solve specific problems. For this purpose, they use as much as possible existing knowledge but, if no adequate information is available for their purpose, they may also look for new principles. When they have solved their problem, and have therefore become inventors, they protect their inventions with patents. The researchers in the following sections were all actively looking for ways to transmit information in a wireless manner.

The prolific Serb inventor from Croatia Nikola Tesla (1856–1943, since 1884 in the US) had also noticed that electrical power could be transmitted between two circuits tuned to the same resonant frequency, but without connections between the two. In the Spring of 1893 he presented his ideas about wireless transmission of information in Franklin's Institute in Philadelphia, and to the National Electric Light association in St. Louis. In a number of lectures, he claimed that he was going to transmit signals without wires, and maybe even electrical power, across ground or any other medium. Between 1893 and 1896, he registered no less that 31 requests for patents, several of which involved high-frequency signal generation for wireless transmissions. He also published a dozen technical articles covering his research, stressing in particular the need for circuit synchronization, and for effective coupling between system components.

Tesla had designed electrical generators and used them to generate and transmit extra low frequency signals, with wavelengths in the kilometer range. In contrast, other researchers were using Ruhmkorff spark-gap generators, which yielded shorter wavelength signals. Tesla believed that the rarefied air of the higher atmosphere would conduct electrical currents. He also considered that the planet earth behaves like a spherical capacitor, so that one could charge it – disturbing the electrostatic or magnetic condition of the earth – in such a way that energy, and also signals, could then be picked up at any point on the globe [22]. Dealing with high powers and high voltages, surrounded by lightning bolts and noisy sparks, Tesla became the archetype of the "mad scientist."

Unfortunately, Tesla's research in wireless propagation was rather slow, because he carried on several other activities at the same time. In March 1985 his laboratory in South Fifth Avenue in New York burned down, stopping his research for most of the year. Tesla envisaged a worldwide wireless communication system using a huge spark transmitter, hoping to transmit signals from his Wardenclyffe wooden tower facility on Long Island to the Cornish coast of England. Unfortunately his sponsor, J. Pierpont Morgan, terminated his support, probably because in 1901 Marconi had demonstrated transatlantic wireless transmission using much simpler and less expensive equipment [23].

Tesla also experimented and obtained a patent for the remote control of vehicles. In a 1989 exhibition he demonstrated the control of a model boat through wireless transmission on a basin of Madison Square Garden.

The Russian physicist Aleksander Stepanovitch Popov (1859–1906) was since 1883 a professor at the highly renowned Russian Navy Torpedo School in Kronstadt, near Saint Petersburg. He knew therefore quite well that it is very difficult to communicate with ships at sea. With the excellent equipment available in the physics laboratory, he carried out many experiments, and reproduced at the beginning of 1895 the wireless transmission experiments of Hertz and Lodge. He brought several improvements to the design of the coherer, connected his receiver to a Morse code recorder, and improved its sensitivity by attaching it to a lightning rod detector. He could in this way detect storms, even at large distances, and also, using a Hertz generator, transmit signals over a distance of some 60 m.

Popov presented his experiments during the Spring of 1895 at a meeting of the Russian Society of Physics and Chemistry, and his presentation is reported in the Proceedings of the Society. In subsequent years, he transmitted signals over increasingly longer distances, developed broadcasting and published a number of technical papers. Russia considers that Popov is the inventor of radio, monuments were erected in his honor in several Russian cities, and a Popov gold medal is granted by the Russian Academy of Science to scientists who contributed in an exceptional manner to the development of radio and electronics. In May 2005 the Institute of Electrical and Electronics Engineers (IEEE) dedicated an Historical Milestone celebrating Popov's Contribution to the Development of Wireless Communication [13].

The Australian physicist Richard Threlfall (1861–1932) proposed to use electromagnetic waves for communications, and in 1891 the British Alexandre Pelham Trotter (1857–1947) pointed out that they would be particularly useful for ship-to-shore communications. The British Admiralty had recognized the significance of wireless telegraphy for war at sea, and since 1891 it pursued secret research, directed by Captain Henry Jackson, who was to become later on First Sea Lord of the Admiralty. The results of this research were never published, but it was reported that transmission between two ships over several hundred meters had been successfully achieved in 1895. Later on, Jackson had the opportunity to compare notes with Guglielmo Marconi [24].

Also during the year 1895 a young research student named Ernest Rutherford (1871–1937) came from New Zealand to Cambridge with a new detector developed the previous year, with which he managed to transmit over a distance of 18 m. He improved its performance, and reached about 800 m. Professor J.J. Thomson, Head of the Physics Laboratory, inquired at the City of London about the possibility to obtain some financial support, and was told that wireless communication was not likely to be of any practical use. Therefore Rutherford dropped the study of wireless, and assisted J.J. Thomson (1856–1940) in his research that discovered the electron, and followed the path that led him to discover the nucleus of the atom [17].

VI. AND THEN, MARCONI

On 27 July 1896, an unknown 22-year-old Italian youngster named Guglielmo Marconi (1874–1937) fascinated the directors and engineers of the British Post Office by realizing a wireless transmission over a distance of *more than 1 km* above the roofs of London. This was Marconi's first "officially" acknowledged wireless transmission, carried out under the auspices of the BPO. On the 2nd of September, a second transmission covered almost 3 km on Salisbury plain, and was widely reported in the press. William Preece, the Director of the BPO, became ecstatic about Marconi's achievements, as evidenced by a particularly enthusiastic lecture that he presented on the 12th of December. The local press called Marconi "Inventor of Wireless" – which infuriated Professor Lodge [6].

In March 1897, a duly recognized wireless transmission covered 14 km between Lavernock Point and Flat Holme Island in the Bristol Canal (where Preece had made some inductive coil transmissions in 1892) [25]. Among the participants at this event was the German scientist Adolf Slaby (1848–1913), Professor at the Technical University of Berlin-Charlottenburg, who later on contributed to the foundation of the firm Telefunken, which was to become the most active competitor of the Marconi Company.

What followed is well-known history: 50 km from Dover to Wimereux across the British Channel in 1899, 175 km from Antibes to Calvi, on the island of Corsica, in April 1901 and then, on December 12, 1901, 3500 km over the fabulous distance across the Atlantic Ocean! While the latter achievement has been the subject of some controversy, it is a fact that before very long, wireless messages of the Marconi Company were routinely crossing the Atlantic [26].

But who was this Marconi, who was suddenly becoming so famous? Where did he come from, and what had he done before these well-established achievements of 1896 and later years in Great Britain?

Guglielmo Marconi was the son of an Italian country squire and an Irish opera singer. He lived a quite venturesome youth, with his family moving between Great Britain, Bologna, Florence, and Leghorn (Livorno). As a boy, when conducting his sailboat in Leghorn, he realized that as soon as one got away from the coast, one could no longer communicate [27]. He picked up some physics and mathematics in Leghorn, under the supervision of Professor Vincenzo Rosa of the renowned Liceo Niccolini [28]. As a teenager, Marconi started experimenting with electricity and magnetism. However, there were many holes in his scientific background, so the Naval Academy in Leghorn and the University of Bologna both turned down his applications (contrary to common belief, Marconi never was a student of professor Righi, but he did attend some lectures). When he read technical articles at the time of Hertz's death in 1894, he saw right away the phenomenal possibilities that these new waves would provide for maritime communications.

Marconi used to keep detailed records of his experiments, and some notebooks were retrieved a century later in the Villa Griffone in Pontecchio – but they did not cover his experiments in wireless transmission [29]. Many years later, Marconi reported to his biographers that in September of 1895 he had transmitted over 2.5 km on the family grounds of the Villa Griffone. There are several versions of one particular experiment – in which the receiver was placed behind the Celestini Hill – but none of them is "official." [30] (see the Appendix). The most "popular" descriptions report that the event was announced by a gunshot – because the receiver was not on the line of sight of the transmitter. The exact date of this major achievement is apparently not known, and no journalist was around to hear the gunshot. The only major scientist in the area, professor Augusto Righi, had a rather dim opinion of Marconi's capabilities – therefore, Marconi would certainly not invite him to witness the experiment. The History Committee of IEEE recognized the sites of the Villa Griffone and of the Celestini Hill as milestones in electrical engineering and computing [31].

Many biographers do not mention the gunshot episode, and many technical articles – among them the ones claiming precedence for Bose, Tesla, or Popov – imply that Marconi only started wireless transmissions after his arrival in London in 1896; they refer to the Salisbury Plains event in 1896, or even to the Bristol Channel transmission in 1897 as being Marconi's first long-range transmissions.

Some basic questions may indeed be raised. Did Marconi actually realize long-distance transmissions before moving to Great Britain in 1896? Are the only testimonies that we have of the gunshot episode at Villa Griffone the ones given by Marconi himself? Is the testimony of a single person sufficient to certify an historical event? Marconi was an assiduous reader of the weekly magazine *L'Elettricità*, so why did he not report right away such a significant new achievement?

One might point out – as proof that he started experiments before coming to London – that he brought with him from Italy a complete transmission equipment. Unfortunately, overzealous customs inspectors, who feared a criminal attempt, had damaged beyond repair Marconi's transmitter, so we do not know what it looked like [32]. Marconi had to spend his first months in England finding or making replacement parts – and the equipment that he used on July 27, 1896 over the roofs of London was not entirely the one that he had brought from Italy.

But, fortunately, independent evidence does exist, indicating that during the summer of 1895 Marconi had sent wireless messages across more than 1 km. In the 1960s Maurice Gay-Balmaz, an elderly carpenter in the little town of Salvan, in Switzerland, recalled the old times when, as a boy, he had carried out Marconi's equipment over the hills and rocks surrounding the alpine resort, which was quite popular at the time. His testimony was recorded in 1965, 1968, and again in 1971 [33]. Independently, in 1975 an

Italian journalist interviewed several senior citizens of Salvan who also remembered Marconi [34–38]. And some people reported that Marconi had left behind copper wire in his room when leaving Salvan. The IEEE recognized the site of Salvan in 2003 by attributing an historical milestone in electrical engineering and computing [39], and the International Telecommunications Union (ITU) named the site Telecommunication's Heritage in 2008 [40].

VII. CONCLUSION

Evidently, Marconi was not the first person who transmitted signals using radio waves, because Hertz had already demonstrated this possibility many years before. When Marconi started his experiments, a number of other people had also been active, sending Morse code messages, inventing more sensitive detectors and improving their quality, making use of wire antennas, and even grounding their equipment. So, actually, what did Marconi discover?

Some people claim that Guglielmo Marconi did not deserve to become so famous, because he did not invent anything that was not already known, he only found by chance a path that other people had already laid out and was not the first one to follow it, and that he only took advantage of other people's ideas to start a commercial venture [41]. Marconi himself agreed that he had made use of known ideas (as everybody does every day), but that his instruments were improvements upon those of his predecessors, and also that he had introduced a few developments arising from his own observations. "It is only fair to say that the introduction of these new elements was the basis of my long distance success [17]."

The diagram of Fig. 1 shows that, for some 8 years after Hertz's first experiments, wireless transmissions only covered modest distances. One might feel that this was a rather long period for some preliminary tests. There was a lack of incentive, academic researchers were not looking for applications, while those who tried to increase the range did not possess the proper equipment, did not find the proper settings for their equipment, or did not obtain adequate funding. According to a specialist of the Italian radio RAI, who made many tests with ancient transmission material, none of the transmitters developed by others at Marconi's time would have been able to transmit messages much further than 100 m [42].

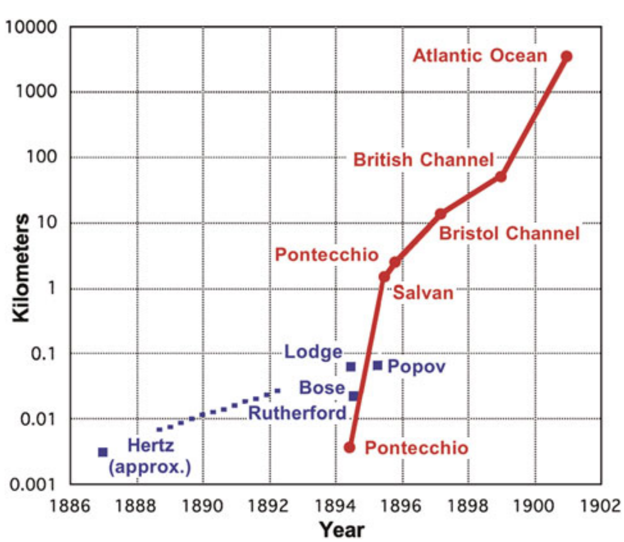

Fig. 1. Distances covered by Marconi (solid line) and by others (dotted line).

And then, as soon as Marconi appeared, the distances covered increased dramatically, by orders of magnitude over the next few years. Transmission ranges suddenly became quite significant, opening the way to long-distance communications. If Marconi became so famous, it is not because he was the first one to transmit a message or to obtain some patent, but because he took wireless out of the lab and into the wide world. Thanks to Marconi's genius, knack, single mindedness, and many years of obstinate work devoted to the improvement of wireless transmission capabilities, we now enjoy the use of radio, TV, radar, and portable phones. Wireless plays a fascinating role in today's world. By providing immediate communication to anyone, anywhere, at any time, it suppresses distances. We are often better informed about what happens at the other end of the world than of events taking place on our front door. While this situation presents incalculable advantages in many situations, it may also tend to create some psychological distortions.

But we must always remember that none of Marconi's achievements would have been possible without the research previously conducted by so many less known or anonymous researchers.

In July 1902, as Marconi was experimenting on board of the Italian Cruiser Carlo Alberto, at anchor in the Russian Imperial Navy base of Kronstadt, a Russian visitor came to visit him and said: "I am Alexander Popov, I want to pay my respects to the father of wireless [32]."

APPENDIX: ABOUT A GUNSHOT AT VILLA GRIFFONE

"Then arose the problem: Would the waves overcome obstacles such as hills? There was only one way to solve the problem, and that was by experiment.

I instructed my helper Mignani to take the receiver to the other side of the hill out of sight of the house and watch the signals. Take this gun, I told him. I'll tap three times. If there are three clicks on the receiver, fire the gun. Mignani went off with the gun, and I called my mother into the room to watch the momentous experiment. And here is what happened.

I waited to give Mignani time to get to his place. Then breathlessly I tapped the key three times. For what seemed an eternity I waited.

Then from the other side of the hill came the sound of a shot.

A few moments later Mignani came running excitedly down the hill to tell me that the experiment had succeeded. That was the moment when wireless was born [43]."

This unpublished narrative was kindly supplied by the Curator of the Marconi Museum in Pontecchio, near Bologna [44]. Noting that there was no date on the reference, a question to the curator prompted the following response: "The reason why there is no date is that the document is a draft prepared by Marconi for one of his biographers (Dunlap) but I can be pretty sure that it was written in the Thirties [45]."

Marconi's eldest daughter Degna gave a colorful description of the event: "It was the end of September now and the vines were heavy with purple grapes, the air golden. The walk over the rim of the hill took twenty minutes. Alfonso (Guglielmo's elder brother) led, followed by the farmer Mignani and the carpenter Vornelli, lugging the antenna. Finally Guglielmo, watching tensely from a window, lost sight of the small procession as it dropped over the horizon.

After some minutes I started to send, manipulating the Morse key connected to the Ruhmkorff bobbin.

In the distance a shot echoed down the valley [32]."

Other biographers also indicate that brother Alfonso carried out the experiment [46, 47] whereas Marconi's second wife Cristina credits for it the gardener Antonio Marchi [48].

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