AT THE DAWN OF THE WIRELESS ERA

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Abstract: *Many people contributed to the development of radio and wireless. The present historical survey hopes to provide a comprehensive outlook of the early beginnings of wireless, more than a century ago.*

Introduction: Who invented radio? The question is often raised, and will probably never elicit a satisfactory answer… As is often the case with new discoveries, one particular name has been singled out — the one of Guglielmo Marconi — while the names of many other people who contributed significant advances are completely forgotten. A team of researchers carried out a major effort to bring to light some of these other people, and to describe their contributions, in the book "History of Wireless." [1] But the authors did not specifically present Marconi's work, on the grounds that his contributions are already widely covered in the technical literature (but Marconi's name appears all over the book, in almost 100 places!) The purpose of the present (more modest) survey is to describe the preliminary stages in the developments of wireless, showing how the range of transmissions increased by orders of magnitude, making it a useful way to communicate over long distances.

1. From Antiquity to Maxwell

Electrical and magnetic effects were observed already very, very long ago, as the Chinese were already using compasses around 2637 B.C. [1] Ancient Greeks provided the names currently used nowadays, related to the surprising attraction properties exhibited by some materials, from "elektron," 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 deflect the needle of a compass. From then on, Ampere, Gauss, Henry and Faraday analyzed different interactions, for which **James Clerk Maxwell** provided a unified formulation in 1864. The set of Maxwell's equations — which was considerably simplified in 1886 by **Oliver Heaviside**, who used vectors and differential operators — forms the basis of electromagnetism (not affected by the introduction of relativity and quantum physics). Combinations of some equations yield "wave equations," whose mathematical solutions are electromagnetic waves that would propagate at the velocity of light. But at Maxwell's time this was merely a theory.

2. Some precursors

Several researchers noticed some effects, more or less related to electromagnetism, but for a variety of reasons their activities did not lead to successful practical applications.

In October 1866 an American dentist, **Mahlon Loomis** (1826-1886) transmitted minimal signals over 29 km., between two kites flying high above Cohocton Mountain and Bear's Den in Virginia. He called his system "aerial telegraph" and dreamed of fabulous applications. Some investors "almost" financed his project, he obtained a patent in 1872, (the first patent granted to a wireless transmission system) and founded the "Loomis Aerial Wireless Telegraph Company." But he did not obtain adequate funds to pursue the experiments. [2] One still doesn't know whether this approach would operate in the absence of clouds…

In 1875, the American inventor **Thomas Alva Edison** (1847-1931) noticed that a discharge in an inductive circuit produced sparks between unconnected conducting objects. He was puzzled because a galvanometer did not detect the sparks received. He named this effect "etheric force," and constructed a spark-gap detector, but he did not pursue this research, favoring more profitable applications — this was some twenty years before Marconi. [3]

In 1879, shortly after Maxwell's death, **David Edward Hughes** (1831-1900) developed a sensitive microphone, which detected noise produced by sparks in a faulty connection. He presented his experiment to Fellows of the "London Royal Society," demonstrating wireless transmission over distances between 55 meters and 460 meters! Professor Stokes declared that this was a simple "effect of magnetic induction," stating that electric waves could not exist. Hughes, very discouraged, did no further work on this topic. He had actually observed electromagnetic radiation several years before Hertz, and his microphone would have been more sensitive than coherers developed later by Branly and Lodge. [4]

American physics professor **Amos Emerson Dolbear**, of Tufts College near Boston (1837-1910) patented in 1882 a wireless telegraph resembling somewhat the ones used later on by Marconi, with capacitors instead of antennas. An 1886 description mentions a range of 18 meters, with very long wavelengths corresponding to an audio signal. [5]

On the year 1882, **Nathan Beverly Stubblefield**, a producer of melons of Murray, Kentucky, transmitted signals "without wires" and demonstrated in 1892 the transmission of human voice over a distance of 800 meters, between two "black boxes." (he was a very secretive individual, so nobody ever knew what was inside the boxes!). He obtained a patent on his "wireless telephone," and tried unsuccessfully to commercialize it. [6]

The Welsh engineer and inventor **William Henry Preece** (1834-1913) experimented with inductive systems, covering in 1892 a distance of 5 km on the Bristol Canal. In 1894 he set two induction coils facing each other across the 6.4 km wide Kilrannan Sound. The coils were rectangular, 9.6 kilometers long and 150 meters high. The system operated well, but its prohibitive size rendered this technique impractical. [5] Still, 5 km became a standard distance that wireless transmissions should cover to present a technical interest.

3. Scientific Researchers

For more than 20 years, nobody actually observed the electromagnetic waves predicted by Maxwell's equations of 1864. Several researchers had noticed related effects, but did not realize their significance, or did not manage to actually make use of them.

And then, on November 13, 1886, the German physicist **Heinrich Hertz** (1857 – 1894), professor at Karlsruhe's Technical University, produced electromagnetic waves with a Ruhmkorff spark gap generator connected to a dipole antenna, and detected them with a split coil. But this detector was quite insensitive, and transmission covered only a few meters. He demonstrated that the wave velocity was equal to the velocity of light, just like Maxwell had predicted. But Hertz did not realize that his experiments could present a practical interest: "*It's of no use whatsoever* [...] *this is just an experiment that proves Maestro Maxwell was right.*" In 1889, he even stated that these waves could not be used for telephony, because their (audio) wavelength would be much too long. [7] He did not pursue these investigations, but turned later on his attention to mechanics, and died on New Year's Day 1894.

Several physicists in France, Great Britain and Italy had noted that small particles group themselves, or "cohere," in the presence of an electric field. French scientist and physician **Édouard Branly** (1844-1940) noticed that magnetized particles also cohere in the presence of fields, so that the resistance of a tube filled with iron filings decreases, and that this effect could be used to detect electromagnetic waves. He developed in 1901 a detector much more sensitive that the coil with spark gap previously used by Hertz. [8]

Oliver Joseph Lodge (1851-1940), professor of physics and mathematics at Liverpool University College in Great Britain, carried on the research initiated by Hertz, perfecting the study of resonant circuits. In 1893, he used in his receiver a "coherer" based on Branly's discovery, adding a "trembler" to reset the instrument. He carried on demonstrations to his students and to the "Royal Institution" in London. Following the suggestion of Alexander Muirhead, a telegraph engineer, Lodge transmitted in August 1894 a wireless Morse code message over a distance of some 60 meters, across several brick walls. [9] But as far as History is concerned, the main contribution of Lodge was without doubt his Hertz memorial lecture to the "Royal Institution" in 1894, in which he described the German's research, adding some of his own results. This lecture and several articles met with a large impact. [10] The whole world heard of experiments that had remained until then mostly confidential.

Hearing of Lodge's research, the British Chemist **William Crookes** (1832-1919) published in 1892 an enthusiastic article describing the amazing potentialities of wireless transmission. He mentioned the "almost infinite" spans covered by these waves. [11] But this premonitory article did not attract much attention then — it was "rediscovered" after Marconi's successes.

Another early follower of Hertz was **Augusto Righi** (1850-1920), professor at the University of Bologna in Italy who, since 1893, concentrated his studies on electromagnetism. He filled the spark gaps with petroleum jelly, increasing in this way the amplitude of the waves produced. He obtained wavelengths in the 10 centimeters range. But, contrary to common belief, Marconi never was a student of professor Righi (he only attended some lectures). [12]

In West Bengal, the great Indian scientist **Jagadish Chunder Bose** (1858-1937) had also heard of Hertz's work. Professor of Physics at the University of Calcutta, he was an

outstanding experimenter: physicist, biologist, botanist, archaeologist, but also the first science fiction writer in the Bengali language. J.C. Bose actively pioneered the investigation of radio and millimeter waves, developing an impressive number of specialized devices, such as waveguides, horn antennas, dielectric lenses, interferometers, couplers, absorbers, etc. — devices still in use nowadays. In 1895, (or maybe in 1894 already?) in a public lecture in Calcutta, waves traveled from the lecture hall, through another room, and into a third room 22 meters 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. He developed in 1899 a sensitive "*iron-mercury-iron*" coherer and later on a galena detector, based on the rectification properties of semiconductors. This was the forerunner of solid-state devices like diodes and transistors. [13, 14]

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 financial benefits from his many inventions, because the very idea of commercially using science was extremely repugnant to him. [15] Quite on the contrary, he distributed his inventions freely without charge, in order to allow others to further develop his research — a principle recently rediscovered with Linux and open source software.

For the eminent professors listed so far, electromagnetic waves were an interesting laboratory experiment, useful to demonstrate Maxwell's theory and to present fascinating phenomena to their students, but they seldom considered potential applications. Since electromagnetic waves are of the same nature as light, it was assumed that they would propagate along the line of sight, only covering short spans limited by obstacles and by the curvature of the earth. In addition, during the years 1850-1860, telegraphic cables had been installed across continents and oceans: why should one spend lots of effort and money to 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.

4. Inventors

In applied research and development (R & D), on the other hand, technicians and engineers try to solve real problems. Whenever possible, they use existing information, but they may also develop new principles if necessary. When their problem has been solved, and they have thus become inventors, they protect their inventions with patents. The following researchers 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 U.S.) transmitted power between two unconnected circuits having the same resonant frequency. In 1893 he announced that he was going to transmit signals without wires, and maybe even electrical power. Between 1893 and 1896, he deposited 31 patent requests, several of them about high frequency for wireless. He published articles stressing in particular the need for circuit synchronization and coupling between components. Tesla believed that the rarefied air in the upper atmosphere would conduct electricity. He also considered that the Planet Earth behaves like a spherical capacitor, that one could charge — disturbing the electric field — so that energy, and also signals, could then be picked up at any point on the globe. Dealing with high powers and high voltages, surrounded by lightning and sparks, Tesla was the archetype of the "mad scientist." But his research on wireless was slow, because of other activities.

In March 1985 his laboratory in South Fifth Avenue burned down, stopping research for many months. Tesla proposed a worldwide wireless system, using a huge spark transmitter, to transmit signals from Long Island to England. But his sponsor, J. Pierpont Morgan, terminated his support when Marconi demonstrated transatlantic wireless transmission in 1901, using much simpler and less expensive equipment. [16] Tesla also demonstrated in a 1989 exhibition the remote control of a model boat on a basin of Madison Square Garden.

The Russian physicist **Aleksandr Stepanovitch Popov** (1859-1906), since 1883 a professor at the Russian Navy School in Kronstadt, near Saint Petersburg, was well aware that it is very difficult to communicate with ships at sea. With the equipment available in his laboratory, he reproduced the wireless transmission experiments of Hertz and Lodge, improved the design of the coherer, connected his receiver to a Morse code recorder, and attached it to a lightning detector. He could then detect distant storms, and also, using a Hertz transmitter, transmit signals over a distance of some 60 meters. He presented his experiments during the spring of 1895 at the Russian Society of Physics and Chemistry. In subsequent years, he transmitted signals over increasingly longer distances and developed broadcasting. [9] Russia considers that Popov is the inventor of radio, and Popov monuments were erected in many Russian cities. In May 2005, the Institute of Electrical and Electronics Engineers (IEEE) dedicated a Milestone celebrating Popov's Contribution to the Development of Wireless Communication.

Several scientists suggested the use of electromagnetic waves for communications, noting that they would be particularly useful for ship-to-shore transmissions. The **British Admiralty** recognized the significance of wireless telegraphy at sea, and since 1891 it started secret research, directed by Captain **Henry Jackson**, who was to become later First Sea Lord of the Admiralty. A successful wireless transmission over several hundred meters between two ships was reported in 1895, but the results of this research were not published. Later on, Jackson had the opportunity to compare notes with Guglielmo Marconi. [17]

Also in 1895 a student named **Ernest Rutherford** (1871-1937) brought from New Zealand to Cambridge a new detector, with which he received a message at 18 meters from the transmitter — and later on he reached about 800 meters. But, trying to obtain support from the City of London, he was told that wireless communication was not likely to be of any practical use. Rutherford then dropped the study of wireless, and started a research that led to the discovery of the nucleus of the atom. [12]

5. And then, Marconi

On 27 July 1896, an as yet unknown 22-year-old Italian named **Guglielmo Marconi** (1874-1937) surprised directors and engineers of the British Post Office by carrying out a wireless transmission over **more than one kilometer** above the roofs of London. This was Marconi's first "officially" confirmed transmission, carried out under the auspices of the BPO. On the 2nd of September, a second transmission covered almost three kilometers on Salisbury plain, and was widely reported. **William Preece**, Director of the BPO, became ecstatic about these achievements, as evidenced by an enthusiastic lecture on the 12th of December, and the local press called Marconi *inventor of wireless*. [18] In March 1897, another wireless transmission covered 14 kilometers from Lavernock Point to Flat Holme Island in the Bristol Channel. Among the participants at this event was the German Professor **Adolf Slaby** (1848-1913), of the University of Berlin-Charlottenburg, who later on took part in 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 kilometers across the British Channel from Dover to Wimereux in 1899, 175 kilometers from Antibes to Calvi, on the island of Corsica, in April 1901 and then, on 12th December 1901, 3500 kilometers across the Atlantic Ocean. While the latter achievement has been the subject of controversy, it is a fact that, before very long, wireless messages of the Marconi Company were routinely crossing the Atlantic. [19]

But who was this young Marconi, who had suddenly obtained such brilliant results?

Guglielmo Marconi, son of an Italian country squire and an Irish opera singer, lived a venturesome youth, with his family moving between Great Britain, Bologna, Florence and Leghorn (Livorno). He picked up some physics and mathematics in Leghorn, under the supervision of Professor Vincenzo Rosa of the Liceo Niccolini. [20] As a boy, when manning his sailboat in Leghorn, he realized that, when away from a coast, one could not communicate. [21] As a teenager, he experimented with electricity and magnetism. However, he was not accepted at the Naval Academy in Leghorn, nor at the University of Bologna. 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 offer for maritime communications.

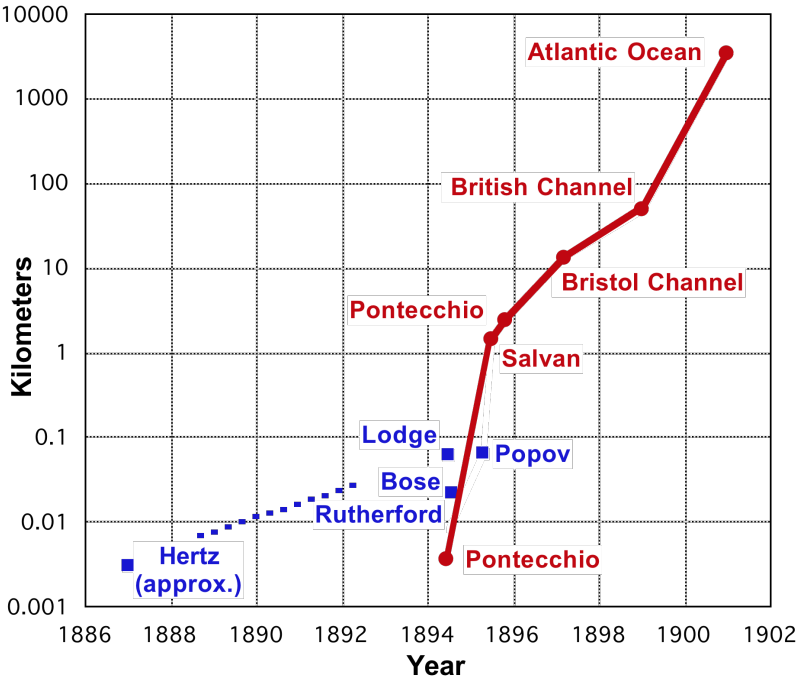
Marconi kept notes of his experiments, and some records were retrieved a century later in the Villa Griffone in Pontecchio — but these did not include wireless transmission. Many years later, Marconi reported that in September 1895 his transmission covered 2.5 kilometers on the family grounds of the Villa Griffone. In one experiment, the receiver was placed behind the Celestini Hill, and was therefore not visible from the transmitter. Several accounts of this event are reported in the literature, but none of the versions can be called "official." [22] The most "popular" ones tell that the success was announced by a gunshot, but they do not indicate the exact date, and no journalist was around to report it. Many biographers do not mention the gunshot, and some technical articles — among them those claiming precedence for other researchers — imply that Marconi only started long range 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.

One may indeed raise some basic questions. 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 didn't he report right away this outstanding achievement? Unfortunately, the transmission equipment that Marconi brought from Italy was badly damaged by British customs inspectors, so we don't know what it looked like. [23]

But, fortunately, independent evidence does exist, indicating that Marconi already transmitted a wireless message across more than one kilometer during the Summer of 1895. 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 Marconi's equipment over the hills and rocks surrounding the town. His testimony was recorded in 1965, 1968 and again in 1971. [24] Independently, in 1975 an Italian journalist interviewed several senior citizens of Salvan who still remembered Marconi. [25] And some villagers reported that Marconi had left some copper wire behind in his room when leaving Salvan. In 2003 the IEEE recognized the site of Salvan with an Historical Milestone, and in 2008 the International Telecommunications Union (ITU) named the site of Marconi's experiment Telecommunication's Heritage.

6. Concluding remarks

Some people claim that Guglielmo Marconi did not deserve to become so famous, because he did not invent anything that was not already known, and that he only took advantage of other people's ideas to start a commercial venture. [26] Marconi agreed that he had used 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. As he said: "*It is only fair to say that the introduction of these new elements was the basis of my long distance success.*" [12]



Looking at the diagram, we can easily remark that, for some eight years after Hertz's first experiments, wireless transmissions only covered modest distances. There was apparently a rather long period with preliminary tests. Academic researchers were not looking for applications, while those who tried to increase the range did not get the proper equipment. According to a radio specialist who tested ancient transmission material, none of the setups developed at Marconi's time would have been able to reach much more than 100 meters. [27]

And then, as soon as Marconi appeared, distances dramatically increased, by orders of magnitude over the next few years. They 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 laboratory and into the wide world. It is thanks to Marconi's genius — and many years of hard work and obstinate R & D efforts — that we now enjoy the use of radio, TV, radar and portable phones. But none of this would have been possible without the research previously conducted by many less known or anonymous researchers.

In July 1902, when 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 see him and said: "I am Alexander Popov, I want to pay my respects to the father of wireless." [23]

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