ON THE BIRTH OF WIRELESS TELEPHONY

John S. Belrose
Communications Research Centre Canada
Ottawa ON K2H 8S2
e-mail john.belrose@crc.ca

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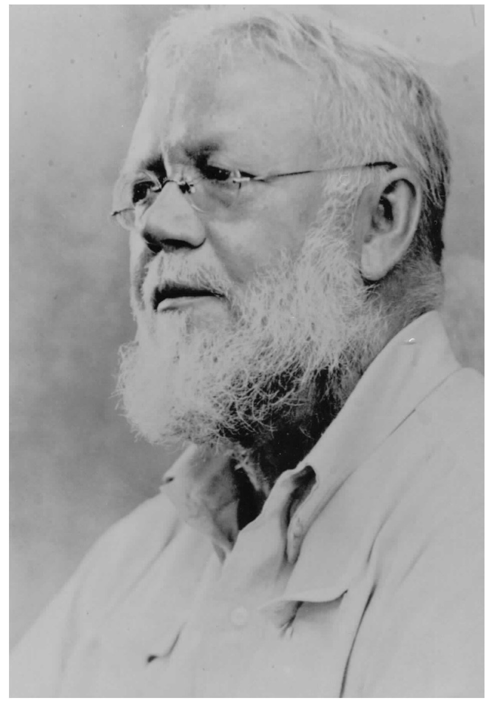
The year 2000 is the 100th anniversary of the transmission of the first voice over radio. On the 23rd of December 1900, Prof. Reginald Aubrey Fessenden, after many unsuccessful tries, transmitted speech over a distance of 1600 meters, between twin wireless aerial systems, employing 15 m masts, located on Cobb Island, MD. The quality of the received wireless telephony transmission was reported to be perfectly understandable, but the speech was accompanied by an extremely loud disagreeable noise, due to the irregularity of the spark. Spark? Yes. Fessenden had not yet developed his HF alternator. The sender was a spark transmitter, operating at 10,000 sparks/second with a carbon microphone inserted in the antenna lead. In spite of the primitive apparatus used, the poor quality of the transmission, and the short distance, intelligible speech by electromagnetic waves had been transmitted for the first time in the history of wireless.

A Brief History of the Birth of Radio

The very possibility of wireless communications is founded on the researches of James Clerk Maxwell, and his equations form the basis of computational electromagnetics. Their correctness was established by Heinrich Hertz, when in 1887 he discovered EM radiation at UHF frequencies as predicted by Maxwell. Since the pioneering work of Maxwell beginning in the middle 1850s, and of his followers, a small group that became known as Maxwellians, which included UK's Poynting and Heaviside, Maxwell's equations have been studied for over a century, and have proven to be one of the most successful theories in the history of radioscience. For example, when Einstein found that Newtonian dynamics had to be modified to be compatible with his special theory of relativity, he found that Maxwell's equations were already relativistically correct. EM field effects are produced by the acceleration of charges, and so Maxwell had automatically built relativity into his equations.

Hertz was not interested in the commercial exploitation of Maxwell's equations. Application of Hertz's work was left to Lodge, who also did little to exploit practical application, and to Fessenden, Marconi, and many others.

Nicola Tesla was the first pioneer to publically demonstrate wireless transmission. Remembering that Marconi made his first wireless transmission in Italy in 1895, and that he demonstrated his system in Britain in 1896, we see Tesla in 1893 describing his wireless system to the Franklin Institute, in Philadelphia, PA in March, and later in the same year in St Louis before the National Electric Light Association. The St. Louis, MO 1893 demonstration of sending radio waves through space was complete with a spark transmitter, grounded antenna, tuned circuits, a Morse key, and a receiver with a Geissler tube as an indicator [1,2]. The equipment that Marconi used to establish his radio fame was remarkably the same as shown in Tesla's widely published 1893 lectures



Prof. Reginald Aubrey Fessenden
(1866-1932)

Oliver Lodge is considered by some historians (Austin [3]) to be the first to transmit Morse code letters from his induction coil and a spark gap transmitter over a distance of some 60 m on 14 August 1894. The receiver consisted of a coherer, a Lodge invention, which was connected to either a Morse recorder which printed onto paper tape, or a Kelvin marine galvanometer, the deflected light spot made viewing by the audience easier. This demonstration, at a meeting of the British Association in Oxford, England was viewed by several notable scientists in their own right, including Sir J.A. Fleming. But Lodge made no attempt to protect the use by others of his apparatus, by a patent at that time, he did so three years later, in 1897; or to publicize and promote the idea of wireless telegraphy. Although (apparently) he described the experiment at the time as "a very infantile form of radio telegraphy", a statement reflecting his modesty but an undoubtedly significant one because it established what he had actually done when the induction coil was actuated by a Morse key by his assistant E.E. Robinson.

There is also on the basis of historical research, indirect evidence (however not disclosed until 30-years after the event) that Aleksandr Popov, a contemporary of Lodge and Marconi, gave a demonstration transmitting in the Morse alphabet the words Heinrich Hertz, before the Physico-Chemical Society on 12 March 1896. A description of the equipment used had been published prior to the demonstration, but no verbatim record of the demonstration survives (Süsskind [4] August 1969, p. 69). Certainly there is no record that he did transmit intelligence before Marconi's patent application of 2 June 1896. And, there is comparable evidence (e.g. letter to William Preece by A.A. Campbell dated 30 March 1896) that Marconi demonstrated the transmission of intelligence at an earlier date, although admittedly not to a scientific audience.

However what is clear is that Guglielmo Marconi was the first to describe (very primitive) apparatus suitable for wireless telegraphy in print (his British Patent No. 12039 granted on 2 June 1896), and he did achieve a demonstration of his apparatus to His Majesty's Royal Post Office later that same year, the transmission of intelligence by means of Hertzian waves over a distance of 100 meters. According to the generally accepted criterion, viz. public disclosure in print, Marconi is considered to be the inventor of an early form of radiotelegraphy, but others were before him.

Marconi's original patent filed in 1896, described a sending and receiving station with no tuning at all. Such a system would operate only over very short distances, since as soon as the spark gap which was across the antenna terminals opened, the damped oscillations would cease, c.f. Belrose [5]. Marconi's second patent, US re-issued patent 11,913 (original 586,193 granted on 4 June, 1901), was for a two circuit system, one circuit in the transmitter and one in the receiver. Again, a very inefficient system. This was in fact a Lodge circuit, claimed to be assigned to Marconi. Marconi's famous "4 sevens" so called **master tuning patent** of 1900, a four circuit system, was after more than three years rejected on 28 June 1904 for prior art, set forth in the Braun British patent, Lodge No. 609,154, Marconi No. 627,650 --- but principally the Tesla patent No. 645,576. Tesla and Marconi fought legal battles for over 30-years. Eventually the US Courts* in 1943 struck down the Marconi patent [6,7] ruling in Tesla's favor (US patent 645576 applied for on 2 September 1897). Tesla's stroke of genius was to use two tuned circuits in the transmitter (two in the receiver), inductively coupled, and so move the energy storage capacitance to the primary side, and add a ground connection. Tesla was the first to inductively couple the secondary side, the antenna side where the capacitances must be small, to a primary tuned circuit where the energy storage capacitance could be huge by comparison. This made possible the generation of RF signals immensely more powerful than the Hertz apparatus, which Marconi was initially using.

Marconi was also in trouble with respect to his Lodge patent, and in the same year 1943 -- of particular importance is the ruling of the US Supreme Court that the only valid patent of the three held by the Marconi company in the area of resonance or tuning was the one that the company had acquired from Lodge in 1911 [3].

Marconi, those working with him, and most experimenters in the new field of wireless communications at the turn of the century, were unanimous in their view that a spark was essential for wireless, and Marconi actively pursued this technology from the beginning in 1895 until about 1912. In fact he fought to quell any divergence from that mode --- because he wanted wireless communicators, particularly shore-to-ship and ship-to-shore operators to use Marconi apparatus, and to employ operators trained to use Marconi equipment.

To exemplify current thinking at that time, Fleming, in the first edition of his book on Electromagnetic Waves published in 1906, in reference to Fessenden's 1901 patent (No. 706737) describing the generation of CW wireless signals by use of a HF alternator, stated that an abrupt impulse was a necessary condition for wireless transmission, and that high frequency currents, even of sufficient frequency, could not produce radiation. This belief, and an earlier belief that the terminals of an antenna had to be bridged by a spark, show how wrong some of the early views were.

Marconi saw no need for voice transmission. He felt the Morse code adequate for communication between ships and across oceans. He was a pragmatist and uninterested in scientific inquiry in a field where commercial viability was unknown. He, among others, did not foresee the development of the radio and broadcasting industry. For these reasons Marconi left the early experiments with wireless telephony to others, Reginald Aubrey Fessenden and later Lee De Forest.

Fessenden, born in Canada, but working in the United States, recognized, early publications date to 1898 [8,9], that continuous wave transmission was required for speech, and he continued the work of Tesla, John Stone Stone, and Elihu Thompson on this subject. Fessenden also felt that he could transmit and receive Morse code better by the continuous wave method than with the spark-apparatus. Quite alone in this direction at the turn of the century, his CW patents had little impact on the users of wireless technology. CW transmission over a distance was not realized before the fall of 1906. However, reliable two way transatlantic telegraphy communications employing synchronous rotary spark transmitters (a Fessenden invention) at Brant Rock, MA, and Machrihanish, Scotland was achieved earlier, in January of that year. During January, February and on into March 1906, two-way telegraphy communications was established on a regular basis, exchanging messages about the working of machines, and each day improvements were made.

Fessenden's continuous waves, his invention of a new type of detector, and his invention of the method as well as the coining of the word heterodyne, did not by any means constitute a satisfactory wireless telegraphy or telephony system, judged by today's standards. They were, however, the first real departure from Marconi's damped-wave-coherer system for telegraphy, which other experimenters were merely imitating or modifying. They were the first pioneering steps toward modern radio communications and radio broadcasting.

Today, heterodyning is fundamental to the technology of radio communications. Some historians [10] consider that Fessenden's heterodyne principle to be his greatest contribution to radio. Edwin Howard Armstrong's super-heterodyne receiver is based on the heterodyne principle. Except for method improvement, Armstrong's superheterodyne receiver remains the standard radio receiving method today.

The First Voice over Radio

Fessenden realized from the very beginning of practical wireless communications [8] that to improve upon the Hertz-Henry damped wave spark generated transmission systems, with the Branley-Lodge-Edison bad contact (Fessenden's words) coherer

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* Although it took the courts several decades to figure this out, the facts were well understood by impartial technical men of the day that Tesla (not Marconi) was the inventor of "King Spark" (a term used by many as this form of signalling developed) or damped wave method of wireless transmission. Robert H. Marriott, the first president of the IRE, once said that Marconi had "…played the part of a demonstrator and sales engineer. A money getting company was formed, which in attempting to obtain a monopoly, set out to advertise to everyone that Marconi was the inventor and that they owned that patent on wireless which entitled them to a monopoly". [Radio Broadcast, December 1925 (Vol. 8, No. 2), pp. 159-162.]

detector system used by Marconi and others for the receiving wireless telegraphy signals, one needed a continuous wave signal. And, that for wireless telephony a CW signal was a necessity. Since there was no satisfactory means of generating a CW signal prior to c1903, his early work, which began in c1896, when was he was a professor at the University of Pittsburgh, PA, was to develop a more suitable receiver for Hertzian waves (CW or spark).

He knew that he needed a “continuously acting, proportional indicating receiver” (Fessenden’s words). He tried dozens of methods, in the period 1896-1902, methods proposed by others, as well as methods devised by himself. In 1900, and in earlier years, his liquid Barretter (US patent 727,331, dated 9 April 1903 for the basic detector; and 793,684 December 1904 for a sealed detector for shipboard use) had not yet been devised. Nowadays, and even then, this detector was called an electrolytic detector, but Fessenden did not like this name because, he believed at that time that its operation depended up a resistance change associated with heating at the point of contact with the sulfuric acid.

In c1898 he was using his modified version (US patent 706,736 and 706,737, dated 15 December 1899) of Elihu Thompson’s alternating current galvanometer (US patent 363,185, dated 20 January 1887). In the words of Fessenden, he describes how the ring of a short period Elihu Thompson oscillating current galvanometer rested on three supports, two pivots and a carbon block. A telephone receiver with a battery in series was used in the circuit with the carbon block. This primitive device must have produced resistance changes associated with amplitude changes of the received RF signal, which were detected by the telephone receiver.

In November, 1899, while experimenting with this receiver, listening to a spark generated telegraphy signal, produced by a transmitter with a Wehnelt interrupter for operating the induction coil used for sending, he noted that when the sending key was held down for a long dash, that he could distinctly hear the peculiar wailing sound of the Wehnelt interrupter. This immediately suggested to him that by using a spark rate above audibility, and with some means to modulate, change the amplitude of the transmitted signal by speech, that wireless telephony could be accomplished [11,12].

Recall that a method to generate CW was yet to be devised. So, proceeding along these lines of thought Fessenden decided to up the spark rate by a large factor, to better simulate a CW-like signal. Professor Kintner, who at that time was assisting Fessenden with his experiments, designed an interrupter to give 10,000 breaks/s. Mr. Brashear, a celebrated optician, constructed the apparatus, which was completed in January or February 1900.

But it was not before the fall of 1900 that this interrupter was used. The reason being that Fessenden was engaged in transferring his laboratory from Allegheny, PA to Rock Point, MA, and in setting up stations at Rock Point and on Cobb Island, MD.

It is clear that for his initial wireless telephony experiments in December 1900 that he was using a spark transmitter with the Kintner-Brashear interrupter, but author Belrose has found no mention of the type of receiver used. The detector was perhaps Fessenden’s version of the oscillating current galvanometer, because, as noted above, he probably had little time to devise a better detector. Nor was the frequency for this first experiment mentioned, but since the transmission took place between two twin tower antenna systems, on 15 m masts, 1600 m apart, the frequency could have been 5 MHz, probably much lower. The modulator for the spark transmitter was a carbon microphone inserted in the antenna lead, see Figure 1a; which also shows a later version of a Fessenden receiver (Fig. 1b), in use after 1902).

After many unsuccessful attempts, Fessenden was finally rewarded by success. Speaking very clearly and loudly into the microphone, he said: “Hello test, one two, three, four. Is it snowing where you are Mr. Thiessen? If it is telegraph back and let me know”.

Barely had he finished speaking and put on the headphones, when he heard the crackle of the return telegraphic message. It was indeed snowing since Mr. Thiessen and Prof. Fessenden were only 1600 m apart. But intelligible speech by EM waves had been transmitted for the first time in the history of radio. The received telephony transmission was described as words perfectly understandable, excepting the speech was accompanied by an extremely loud disagreeable noise due to the irregularity of the spark. The author using equipment similar to that used by Fessenden, excepting for the detector, has simulated the authenticity of that transmission (Belrose [13]).

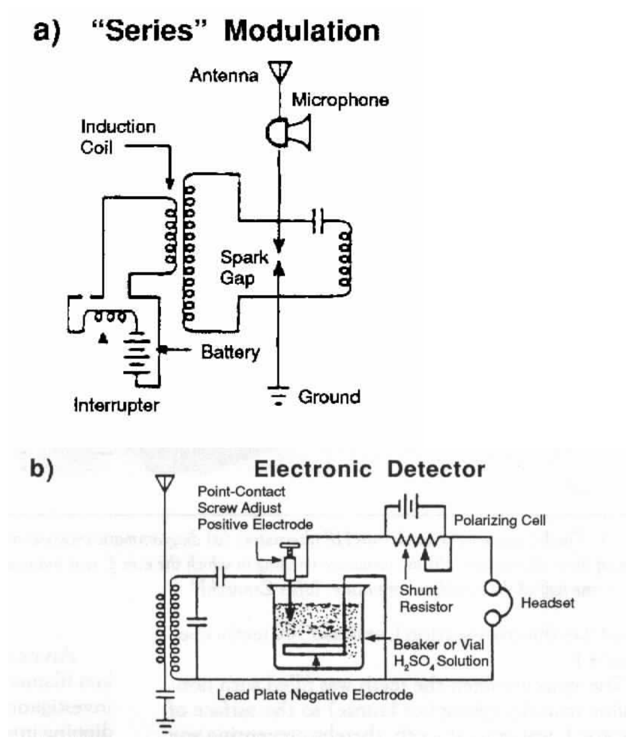


Figure 1 An early version of Fessenden’s spark gap telegraphy transmitter a); and b) Fessenden’s receiver employing an electrolytic detector.

Follow on Wireless Telephony Experiments

By the end of 1903, fairly satisfactory speech had been obtained by the more continuous arc method (more CW –like compared with spark). But reception was still plagued by a disagreeable noise. The receiver in use at this time was much improved, since it used Fessenden’s electrolytic detector, a method used until the much later development of the thermal electric diode c1912.

But Fessenden was still trying to develop an HF alternator giving an output frequency high enough to be useful with practical antenna systems used at that time. Work on the HF alternator (Fessenden called this device a dynamo) was begun in 1900, but his instructions (in Fessenden's words) were not followed by the manufacturer, and when delivered in 1903 its highest operating frequency was 10 kHz.

A second alternator was delivered in 1905. A letter from the GE Company that built the machine, stated that, in the opinion of the Company, it was not possible to operate it above 10 kHz. So Fessenden scrapped this alternator, excepting for the pole pieces, and rebuilt the armature in accord with his design, in his Washington, DC, shop. By the autumn of 1906 he had developed a machine that gave him 75 kHz and a power output of half a kilowatt. Later machines gave output frequencies as high as 200 kHz, and powers up to 250 kW. The problem had been solved. Fessenden could now transmit a pure CW wave.

His method of modulating his CW device, a HF alternator, was, as before, a carbon microphone inserted in the antenna lead. But with this apparatus he achieved important communication successes. In November 1906, on a night when transatlantic propagation was very good, Fessenden and his colleagues were conducting experimental wireless telephony transmissions between stations at Brant Rock and Plymouth, MA. Mr. Stein, the operator at Brant Rock, was telling the operator at Plymouth how to run the dynamo. His voice was heard by Mr. Armour at the Macrihanish, Scotland, station with such clarity that there was no doubt about the speaker, and the station log confirmed the report.

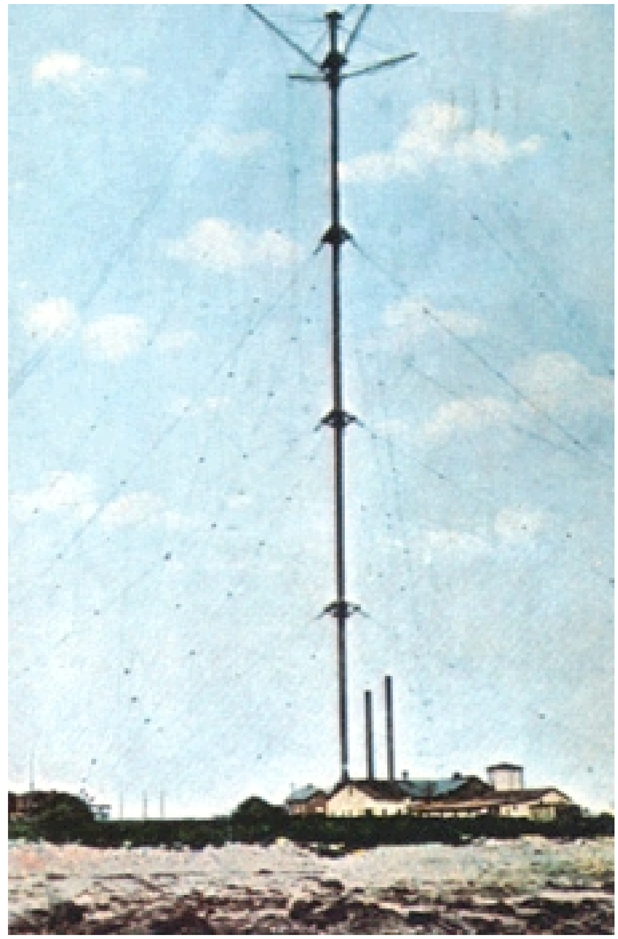
Fessenden's greatest triumph was soon to come. On the 24th December, 1906, Fessenden and his assistants presented the world's first radio broadcast.

The transmission included a speech by Fessenden and selected music for Christmas. Fessenden played Handel's Largo on the violin. That first broadcast, from his transmitter at Brant Rock, MA, was heard by radio operators on board U.S. Navy and United Fruit Company ships equipped with Fessenden wireless receivers at various distances over the south and North Atlantic, as far away as the West Indies. The wireless broadcast was repeated on New Year's Eve.

Closing Remarks

Historians (in the different nations) do not necessarily agree on who was the inventor of radio. Radio was not "invented" by a single individual. Its development into what we know as radio today was a result of many contributions over many years by a number of individuals, whose work was either theoretical or experimental. All one can do is to try and place the key contributions, which really are significant ones, into perspective and then give credit where credit is due.

Many scientists and engineers have contributed to the early development of electromagnetic theory, the invention of wireless signaling by radio, and the development of electromagnetic antennas needed to transmit and receive the signals. A few that we consider to be key pioneers have been mentioned above, but the list of contributors to the development of radio is long. Some of the early radio inventors were Loomis, Henry, Edison, Thompson, Tesla, Dolbear, Stone Stone, Fessenden, Alexanderson, de Forest and Armstrong in the United States; Hertz, Braun and Slaby in Germany; Faraday, Maxwell, Heaviside, Crooks, Fitzgerald, Lodge, Jackson, Marconi and Fleming in the UK; Branly in France; Popoff in the USSR; Lorenz and Poulsen in Denmark; Lorentz in Holland; and Righi in Italy.



Photograph of Fessenden's Brant Rock, MA, station.

The Marconi systems were based on spark technology. Marconi's perseverance with spark technology and the monopoly his company held and retained in the early part of the 20th century delayed the development of CW radio systems by a decade. Fessenden in his 1908 paper [8] posed the question as to whether the invention of the coherer-damped wave method was on the whole a misfortune, since it tended to lead the development of the art astray, into impossible and futile lines, thereby retarding the development of really practical systems. As CW systems were developed by Fessenden and later by others, Marconi continued to use his spark expertise to achieve a semi-continuous timed spark that approximated a continuous wave. His 1912 timed spark transmitter was in a sense the ultimate Marconi spark transmitter. Finally, in 1914 the Marconi Company purchased license to Fessenden's patents from the National Electric Signalling Company, which later became the Radio Company of America.

Fessenden was the first to use the words continuous wave (CW) and a method of generating CW; Fessenden was first to transmit voice over radio (in December 1900); Fessenden devised a detector for continuous waves (an electrolytic detector which was a standard for radio reception from about 1902 until it was replaced by the valve diode in c1913); Fessenden first devised the method, and he coined the word heterodyne. Today heterodyning is the very basis of radio, television and radar;

Fessenden was first to send and reliably receive **two-way** wireless telegraphy messages across the Atlantic ocean (in January 1906, between identical stations at Brant Rock, MA and Macrihanish, Scotland); Fessenden was first to send wireless telephony (voice) across the Atlantic ocean (in November 1906). The clarity was such that the speaker was recognized; and Fessenden made the world's first wireless broadcast (voice and music), from Brant Rock, MA, which was received by ships at sea in the South and North Atlantic, on 24 December 1906. This broadcast was repeated on New Year's eve, 1906.

In summary Fessenden is clearly the father of AM radio. As an inventor, he held some 230 patents. Fessenden did not confine his expertise to one discipline, but worked with equal facility in chemical, electrical, radio, metallurgical and mechanical fields. He was the inventor of sonic frequency echo sounding, a technology which later became known as SONAR (Sound Navigation and Ranging).

Fessenden, a genius, and a mathematician, was the primary pioneer of radio ***as we know it today.***

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