

ULTRA TCS – CANADIAN MARCONI HISTORY

Wireless Heroic Years [1901 – 1938]



TCS

INTRODUCTION

Ultra Electronics TCS is an expert in the field of tactical Software-Defined Radio (SDR) products with a long legacy of radio technology development and innovation. Its products are known for their superior RF and system performance and typically represent significant advances in technology (first cognitive radio in 1992, first military high capacity software modem in 1998, first dual Time Duplex/Frequency Duplex radio in 2010, first production MIMO, 1 Gbps military radio in 2013, etc.). This tradition for innovation and technology leadership traces its roots back to The Marconi Wireless Telegraph Communication Company of Canada, first established in 1903 in the City of Montreal. This document recounts the earlier years of this pioneering company, our company.



Recent mobility tests at High Capacity with the Royal Canadian Navy and the Canadian Armed Forces
Source: Ultra TCS

GUGLIELMO MARCONI, PIONEER AND ENTREPRENEUR

Guglielmo Marconi, 1st Marquis of Marconi, was an entrepreneur, businessman and founder of the UK based Wireless Telegraph & Signal Company (which later became the Marconi Company) in 1897. Marconi succeeded in making the radio a commercial success by innovating and building on the work of previous experimenters and physicists. Achieving his first experimentation success on his father's estate in Bologna, Italy in 1895, Marconi wrote to the Ministry of Post and Telegraphs, then under the direction of the honorable Pietro Lacava, explaining his wireless telegraph machine and asking for funding. He never received a response to his letter which was eventually dismissed by the Minister who wrote "to the Longara" on the document, referring to the insane asylum on Via della Lungara in Rome¹. Finding little interest or appreciation for his work in Italy, Marconi travelled to London in early 1896 at the age of 21, accompanied by his mother², to seek support for his work. A series of demonstrations for the British government followed, the English seeking better ways to remain in contact with their widely

¹ Solari, Luigi (1948), "Guglielmo Marconi e la Marina Militare Italiana, Rivista Marittima", febbraio, quoted in Wikipedia

² His mother was from the Jameson family, long established Ireland based whiskey producers which would have had some good contacts within the British government

dispersed fleet. By March 1897, Marconi had transmitted Morse code signals over a distance of about 6 km (3.7 mi) across the Salisbury Plain south of England. On May 13, 1897, Marconi sent the world's first ever wireless communication over open sea, achieving up to 16 km (9.9 mi) in range. The English Channel was crossed on March 27, 1899 and the first demonstrations in the United States took place in the autumn of 1899 with the reporting of the America's Cup international yacht races in New York³.



Guglielmo Marconi shortly after his arrival in England in 1896

Source: <http://sunnycv.com/steve/ww1/wireless.html>

At the turn of the 20th century, Marconi began investigating the means to signal across the Atlantic, in order to compete with the transatlantic telegraph cables. Marconi established a wireless transmitting station at Marconi House, Rosslare Strand, Co. Wexford in 1901 to act as a link between Poldhu in Cornwall, England and Clifden in Co. Galway, Ireland. Another station was built in Cape Cod, Massachusetts. When a storm damaged the Poldhu antenna, and it had to be replaced by a smaller one, Marconi decided to change the North American destination to St. John's, Newfoundland (now part of Canada). In any event, the Cape Cod station was itself destroyed in a storm⁴. Marconi soon made the announcement that on December 12, 1901, using a 500 feet (150 m) kite-supported antenna for reception, a message was received at Signal Hill in St John's which had been transmitted by the company's new high-power station at Poldhu, Cornwall⁵. The distance between the two points was about 3,500 km (2,200 miles).

³ Adapted from Wikipedia in May 2016 under the topic ``Guglielmo Marconi ``

⁴ www.heritage.nf.ca/articles/society/marconi-guglielmo.php

⁵ That first transatlantic wireless transmission (the letter ``S`` in Morse) was received by Guglielmo Marconi in an abandoned fever and diphtheria hospital (since destroyed by fire) that straddled the cliff facing Europe on the top of Signal Hill. After unsuccessful attempts to keep an antenna aloft with balloons and kites, because of the high winds, Marconi eventually managed to raise an antenna with a kite for a short period of time for each of a few days. Accounts vary, but Marconi's notes indicate that the transatlantic message was received via this antenna. The transmission, in Morse code, is generally believed to have been transmitted in the 350m band i.e. at 857 KHz



Left: Marconi (on the left) watching associates raising a kite used to lift the wire antenna at Signal Hill, Newfoundland, December 1901; Right: CMC Roger Hart and wireless heritage consultant Jim Kreuzer discover the original Marconi kites at CMC in 1991⁶

Source: Keith Farmer (Lachute, QC) and Jim Kreuzer (NY State)

Marconi had invented an entirely new science-based industry by integrating obscure and, to most people, unintelligible physics experiments from various people to design a functional transmitter-receiver system that enabled reliable wireless telegraphy⁷. Marconi had also seen the possibility of beyond-the-horizon communications. Years later in 1951, Edwin Howard Armstrong, one of the most celebrated radio engineers of the twentieth century summarized the breakthrough and key contribution made by Marconi:

"Had Marconi been more of a scientist and less of a discoverer, he might have concluded that his critics were right, and stopped where he was. But like all the discoverers who have pushed forward the frontiers of human knowledge, he refused to be bound by other men's reasoning. He went on with his experiments; and he discovered how, by attaching his transmitted waves to the surface of the earth, he could prevent them from traveling in straight lines, and make them slide over the horizon so effectively that in time they joined the continents of the world. Several years were to pass before agreement was reached on the nature of Marconi's great discovery, though Marconi himself understood very well how to apply it and to employ it usefully; and it proved to be the foundation upon which the practical art of wireless signaling was built."⁸

⁶ Marketing Manager Roger Hart had hired N.Y. based Jim Kreuzer to help appraise the company collection of historical apparatus which was found boxed up in the rafters of the boiler room of the Ville Mont-Royal building.

⁷ One of the major problems Marconi faced was interference between transmitting stations. The primary research undertaken at the time resulted in the creation of a transmitter and receiver system in which all four major components, the transmitter, the receiver, and the antenna circuits so constructed as to be resonant to the same frequencies as the closed circuits. This development was what gained Marconi a key Patent in 1901 "for improvements in apparatus for wireless telegraphy" for a structure and arrangement of four high-frequency circuits with means of independently adjusting each so that all four may be brought into electrical resonance with one another.

⁸ Armstrong, E.H. (1951), "Wrong Roads and Missed Chances", reprinted in "The Legacies of Edwin Howard Armstrong", p.289. Armstrong is best known for developing the superheterodyne receiver and the FM radio.

Following his successful transatlantic link at Signal Hill in 1901, an agreement was entered on March 17, 1902 between Marconi's Wireless Telegraph Company, the Marconi International Marine Communications Company and the King of England, represented by the Canadian Prime Minister, Sir Wilfred Laurier. \$80,000 CAN were offered to the two companies to erect two wireless stations, one in United Kingdom and the other in Nova-Scotia. The agreement resulted in the establishment of the Table Head station in Cape Breton which completed a successful transatlantic transmission test (Signal Hill had only been a receiver site) in December 1902⁹.



Left : the Table Head site (1902-1906); Right : same location in summer 2015¹⁰

Source: Canadian Marconi Company archives & Denis Couillard

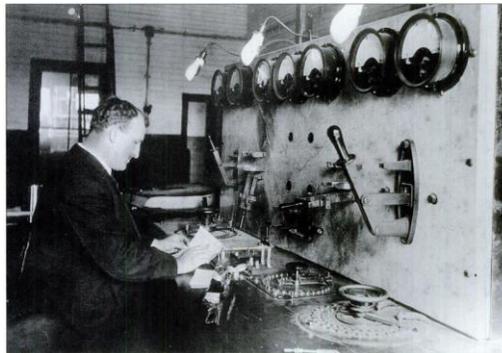


Table Head station at Glace Bay in 1907; L.R. Johnson is the operator

Source: Murray R.P. (2005) "The Early Development of Radio in Canada, 1901-1930"

The same agreement gave the Canadian Government the right to erect more stations as it saw fit for communications with its lighthouses, life-saving stations or any ships with an assurance that the

⁹ In December 1902 Marconi transmitted the first complete messages to Poldhu from the Table Head station at Glace Bay, Cape Breton, Nova Scotia. The frequency was 182 kHz.

¹⁰ In July 2015, Ultra TCS donated a complete Canadian Marconi AN/GRC-103 radio set (a 1965 design from the Cold War) to the 36 Signal Regiment, Detachment Glace Bay as part of the celebration organized for the renaming of their Glace Bay Armoury to "Dr. Guglielmo Marconi Armoury". The Armoury is located only a few hundred meters away from the historical Table Head site.

company will provide all necessary equipment at a fair and reasonable price. The first of these stations was built at Pointe-à-la-Renommée (Gaspé), in June 1904.



Left: Pointe-à-la-Renommée Marconi Wireless Telegraph Station, under construction in 1904;
Right: The site today

Source: Encyclopedia of French Cultural Heritage in North America, Gaspesian Heritage WebMagazine

This made possible the successful promotion of a new company in Canada, “The Marconi Wireless Telegraph Company of Canada” which was registered on November 1, 1902 with a right to use all of Marconi’s patents. The first directors’ meeting was held in January 1903 and by a special act of Parliament, “The Marconi Wireless Telegraph Company of Canada” was granted a Dominion (i.e. national) Charter on August 13, 1903¹¹. The new company’s first office was set up at “1724 Notre-Dame Street East” in January 1903 in the prestigious British Empire Building located between St. François Xavier and St. Jean in what is today Old Montreal. This was to be The Marconi Wireless Telegraph Company of Canada headquarters until 1913. This building still exists, its modern address being 200/210 Notre-Dame West.

¹¹ The company became profitable in 1912.



The new Marconi Company was first established in 1903 at the British Empire Building on Notre-Dame West (No 200-210 in modern numbering), Old Montreal on the corner of St. François Xavier
 Source: Annuaire Lovell 1903-1913, BANQ, Google Maps

A first factory was opened on De Lorimier Street (No 110) in 1909, between Ste. Catherine and Tansley Street. At the time, De Lorimer and St. Catherine was a busy intersection of the Montreal electric tramway system. The De Lorimier facility was used by the company until about 1916 when Marconi started to rent space in a building west of the city on William Street. There is nothing left of the De Lorimier building today. Located directly under the Jacques Cartier Bridge, it survived its 1925-1929 construction but did not make it to modern times.



The first factory on de Lorimier (used in 1909-1916); note the antennas on the roof
Source: Musée des Ondes Émile Berliner, Montréal

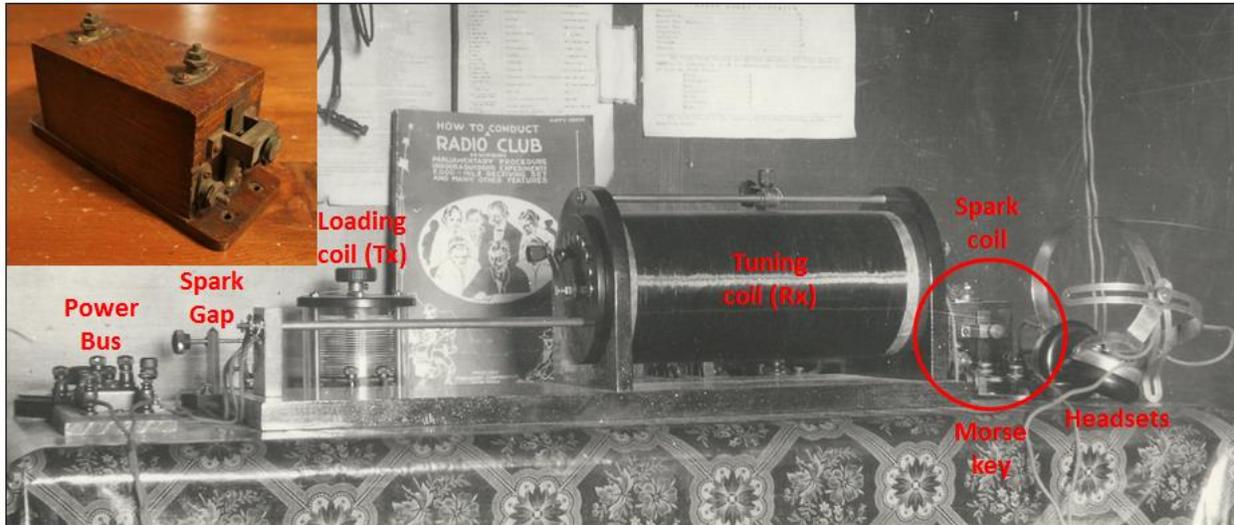
EARLY MARCONI RADIOS

The first wireless communications were all based on spark technology. If an electric spark is made to snap or crack between two metal points, its induced electro-magnetic wave can be sent at long distance from a wire elevated in the air at one end and connected to the ground at the other end. The signal is produced by means of a spark gap connected with an induction coil or "spark coil". The current is supplied by means of batteries, or in the case of high power long distance stations such as the ones used by Marconi, by dynamos¹². In a 1930 article, a Montreal journalist would recall these heroic years of Wireless Telegraphy noting that on-lookers walking by the De Lorimier Marconi plant (1909-1916) "saw the lightning-like blue flashes emitted by the heavy spark gaps, accompanied by the crashing sound of the high frequency currents."¹³

¹² During his early experiments at the Poldhu station, voltages of up to 150 kV were spoken about and may have been realized. See Belrose, J.S. (1995), "Fessenden and Marconi: Their Differing Technologies and Transatlantic Experiments During the First Decade of this Century"

¹³ The Montreal Daily Star newspaper, Friday September 5th, 1930, page 26

For amateurs of the 1910-1920 era, these coils were typically contained in a small box that could be easily connected to the circuit. Early radio amateurs would use automobile jump-start coils such as the ones used in the Ford-T which could be procured at a reasonable price from a garage¹⁴.



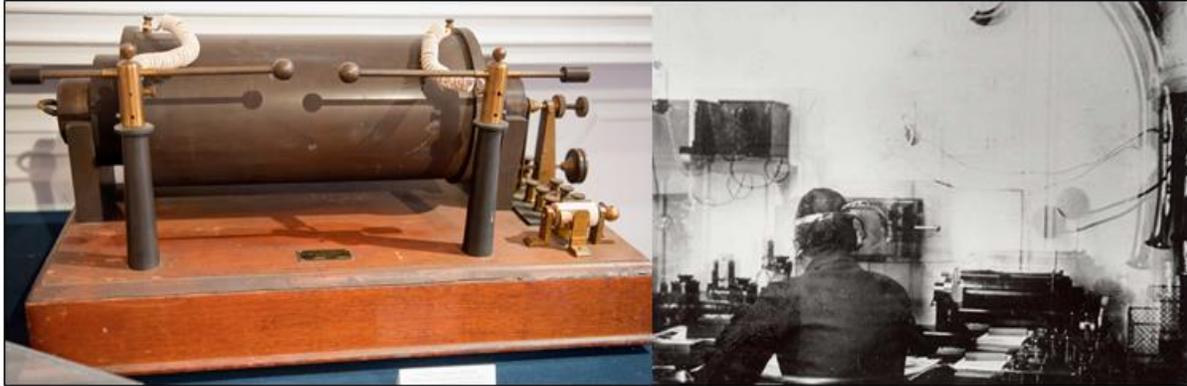
Left: Spark coil used by young Radio Amateur and future Canadian Marconi employee Eric Farmer¹⁵ in 1910-1920; Right: the same in a 1915 picture of Eric's radio installation in Farnham, QC

Source: Ultra TCS collection and Keith Farmer, Lachute

Marconi's longer range radios would use bigger inductor coils such as the one shown below built by the Montreal based Marconi Wireless Telegraph Company of Canada in 1907. Similar technology would be found on ships and wireless shore stations until the early 1920s.

¹⁴ Technical design information taken from BOY'S Life magazine, May 1920. A modern car uses the exact components found in a 1900 spark transmitter: a battery, an induction coil to step up to high voltage (ignition coil), a spark gap (spark plug) and an antenna (ignition wiring). All that's missing is a telegraph key. More on this in "How Spark Transmitters Work" by Hal Kennedy, N4GG in www.arrl.org

¹⁵ Eric Farmer (1897-1979) served at the Marconi Wireless and Telegraph Company of Canada between 1916 and 1966, starting as a Marconi Wireless Telegraphist (W/T) on board ships.



Left: Spark Transmitter Model 1216, S/N 007, Marconi Wireless Telegraph Company of Canada, 1907
 Right: The Titanic radio room on its last trip with a similar Marconi transmitter (April 1912)¹⁶

Source: Musée Québécois de la Radio, Sorel-Tracy¹⁷

The terminals of the spark gap are usually made of zinc and mounted so that they can slide back and forth to vary the length of the gap. An ordinary telegraph key is connected in circuit which makes it possible to turn the current off or on by the touch of a finger. This makes it possible to break the flashes into dots and dashes so that letters may be spelt out by the well-known Morse code. From one side of the spark gap, a wire runs to the ground while from the other, a wire runs to the antenna wires¹⁸.

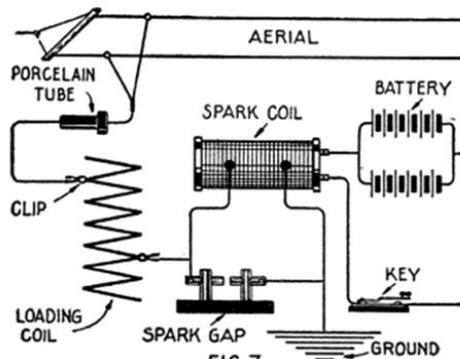


FIG.7
 Manner of connecting the several instruments making up the complete sending set

Schematic of an amateur spark transmitter using an automobile type inductance "spark coil"

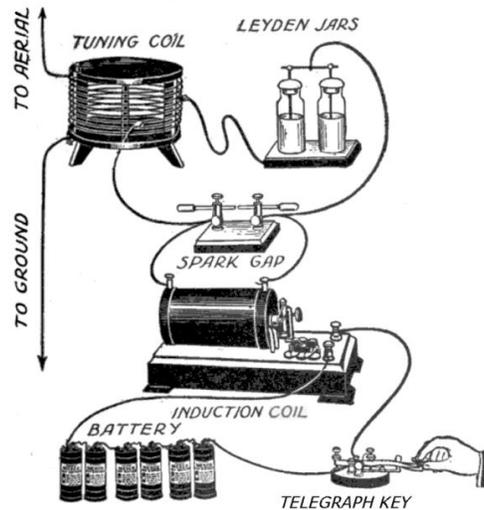
Source: Popular Science Magazine, October 1916

¹⁶ This exceptional picture was taken by Reverent Francis Browne who by chance was called back to Dublin by his superior when the ship docked in Queenstown, Ireland on its way to New-York City. He captured the last known images of the ship including many crew and passengers and, the Marconi Radio room. At per inter-company agreements, Canadian Ships would generally be fitted with Marconi Canada equipment and British made ships with Marconi UK equipment. Exceptions to that rule would cause profits generated from the sale to be split equally between the two companies.

¹⁷ This Marconi Canada artefact was donated in 2015 by the Musée québécois de la radio to the Phare-à-la-Renommée site

¹⁸ BOY's Life magazine, May 1920

Opening the spark gap too wide as well as other disturbances could cause misfiring, placing about 10,000 volts at the secondary of a typical induction coil directly on the antenna. This made for potentially lethal accidents. The solution was to add a capacitor across the induction coil secondary. The capacitor (Leyden jars in early systems) eliminated continuous arcing at the gap. Instead, the capacitor charged until sufficient voltage was achieved to fire the gap, at which point the gap fired, the capacitor was discharged and the spark extinguished. The introduction of the High Voltage (HV) capacitor across the gap greatly increased output power and narrowed radiated bandwidth. Both improved efficiency¹⁹.



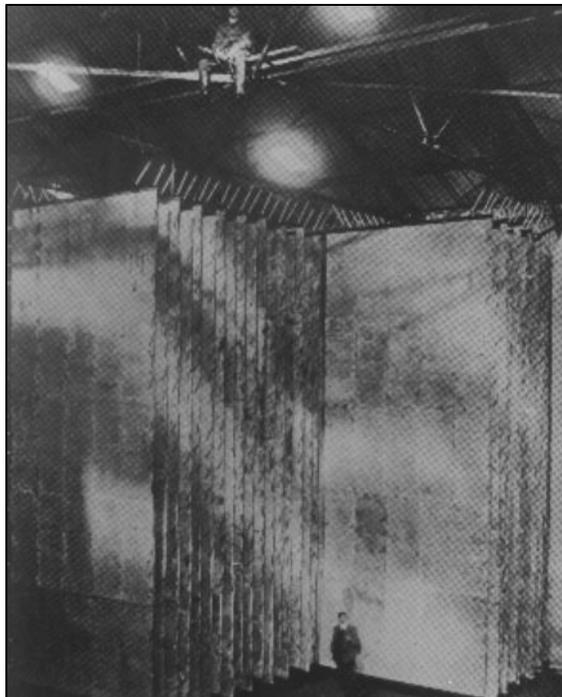
Simple spark-gap transmitter, typical of low power transmitters homebuilt by amateurs to explore the exciting new technology of radio

Source: Seton E.T. (1917) *The Woodcraft Manual for Boys*, Doubleday, Page & Co., New York

The discharge capacitor for the Marconi Clifden station in Ireland and the Marconi Towers station in Glace Bay consisted of thousands of steel plates hanging from floor to ceiling, which filled the wings of the building, and this room was subsequently called the "condenser building". The power supply was a 15 kV DC generator (three 5 kV generators in series) driven by a steam engine. The power source was DC and the standby batteries (6000, 2 volt, 30 AH batteries in series) at both stations may well have been the largest battery the world has ever seen. The heart of his Clifden/Marconi Towers stations was a whirling five foot spark discharge disk, with studs on its perimeter. Each time a stud passed between two electrodes, a 15 kV spark jumped the gaps. The regular spark rate was about 350 sparks/sec. The awesome size of the station and the din of the transmitter must have been something to behold. The power consumed by these stations was in the range of 100 to 300 kW, and the spark was a display of raw power. It is said that the awesome din of the transmitter could be heard several kilometers away.²⁰

¹⁹ See "How Spark Transmitters Work" by Hal Kennedy, N4GG in www.arrrl.org

²⁰ Belrose, J.S. (1995), "Fessenden and Marconi: Their Differing Technologies and Transatlantic Experiments During the First Decade of this Century"



Clifden, Ireland condenser under construction

Source: Belrose, J.S. (1995), "Fessenden and Marconi: Their Differing Technologies and Transatlantic Experiments During the First Decade of this Century"

With these primitive spark gap radio transmitters, the operator switched the transmitter on and off with a telegraph key, creating pulses of radio waves to spell out text messages in Morse code. So the radio receiving equipment of the time did not have to convert the radio waves into sound like modern receivers, but merely detect the presence or absence of the radio signal. The device that did this was called a detector. The magnetic detector or Marconi magnetic detector, sometimes called the "Maggie", was the radio wave detector used in Marconi wireless stations up to about 1912²¹.

The high power Marconi spark transmitters had to be operated by qualified Marconi Wireless Telegraphist (W/T) such as Eric Farmer who joined the company in 1916 for what was going to be a memorable mission to Russia, in the midst of the country's revolution²². Marconi operators would save

²¹ The Maggie was developed in 1902 by Marconi from a method invented in 1895 by New Zealand physicist Ernest Rutherford (Rutherford was Professor of Experimental Physics at McGill University between 1898 and 1907 and was awarded the Nobel Prize in Chemistry in 1908). Rutherford had first used the hysteresis of iron to detect Hertzian waves in 1896 by the demagnetization of an iron needle when a radio signal passed through a coil around the needle; however the needle had to be remagnetized so this was not suitable for a continuous detector. Marconi's Maggie was moving an iron band driven by a clockwork motor passing by stationary magnets and coils, resulting in a continuous supply of iron that was changing magnetization, and thus provided for continuous sensitivity (Wikipedia).

²² Eric Farmer's first Marconi assignment was to Russia, as Canadian Vickers in Montreal had built an icebreaker for the Russian Government (the Mikula Selianinovitch). In his memoirs he called this assignment his "great adventure", as the icebreaker was delivered to the Russians at Archangel in January 1917, with all of the ship's crew having to get back home via Siberia, Japan, and then steamer to Vancouver. When in Russia, the 1917

many lives on the Titanic in 1912 and again on the Empress of Ireland in 1914. The distress signal of the Titanic was heard by radio amateurs as far as Farnham near Montreal. The distress signal of the Empress of Ireland was heard and successfully rebroadcasted to other ships by the wireless station of the Pointe-aux-Pères lighthouse near Rimouski²³.

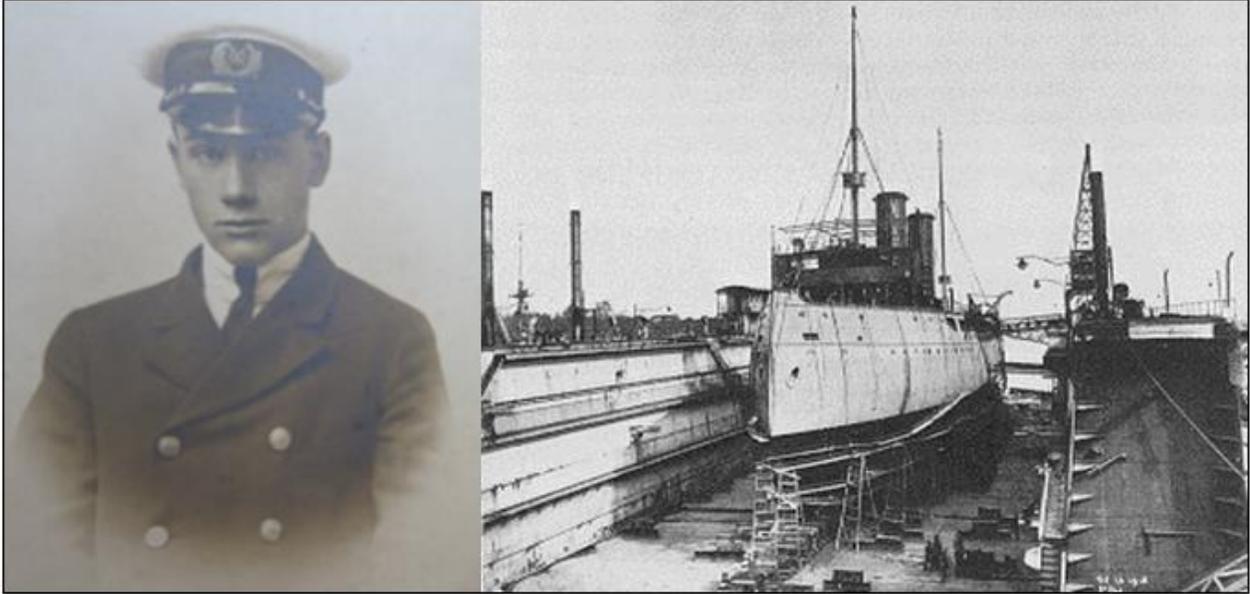


This is the actual Marconi Wireless Telegraph Company of Canada "Maggie" which received the Titanic distress call at the Cape Race wireless station on April 14, 1912

Source: Jim Kreuzer's collection, New York State

Revolution started. His observations on this assignment and trip are quite interesting. It took the crew about four months to get home.

²³ CQD, transmitted in Morse was the first distress signals adopted for radio use. It was announced on January 1904, by "Circular 57" of the Marconi International Marine Communication Company, and became effective, beginning 1 February 1904 for Marconi installations. The SOS was adopted at the second International Radiotelegraphic Convention held in Berlin in 1906 but the Marconi Company required all of its operators to use CQD for a ship in distress or for requiring URGENT assistance. In April 1912, RMS Titanic radio operator Jack Phillips initially sent "CQD", which was still commonly used by British ships. Harold Bride, the junior radio operator, jokingly suggested using the new code, "SOS". Thinking it might be the only time he would get to use it, Phillips began to alternate between the two (Information extracted from Wikipedia under "CQD").



Eric Westover Farmer in his Marconi Wireless Telegraph Company of Canada Wireless Telegraphist operator uniform and the Mikula Selianinovitch bound for Russia in its Montreal's Vickers dock (1916)

Source: Ultra TCS collection and Canadian Coast Guard



Bunnell type Morse key used by Canadian Marconi employee and Radio Amateur Eric Farmer around 1910-1930

Source: Ultra TCS collection

As a result of the aftermath of the Titanic disaster in 1912, the Maritime nations of the world passed regulations requiring all ships of certain classes to carry wireless equipment. This led to a period of expansion as the patents²⁴ held by Marconi and the early establishment of his Maritime business gave the Marconi companies a virtual monopoly on these Maritime communication systems.

²⁴ His most famous patent was the "four-seven's" (British 7777) issued to Marconi's Wireless Telegraph Company on April 13th, 1901. The Patent was granted "for improvements in apparatus for wireless telegraphy" for a structure and arrangement of four high-frequency circuits with means of independently adjusting each so that all four may be brought into electrical resonance with one another. The 1904 U.S. version of the 7777 patent, US patent No. 763,772, was found to be invalid in a celebrated 1943 Supreme Court decision. The Court based its decision largely on finding that John Stone Stone's patent, applied for February 8, 1900, was nine months prior to

All these early Marconi systems were based on spark technology. Québec born Reginald Fessenden (1866-1932) recognized that Continuous Wave (CW) transmission was required for speech, and he felt that he could transmit and receive Morse code better by the continuous wave method than with the spark apparatus that Marconi was using²⁵. With the help of General Electric, Fessenden developed a HF alternator²⁶ to accomplish the first transmission of human voice over wireless on December 24, 1906.

Fessenden ultimately developed the theory of AM radio and heterodyne receivers. In spite of these advances, "King Spark" was slow to die and would remain in service until about 1940 as a back-up emergency system on ships, its use being forbidden as early as 1924 in the new 80, 40, 20 and 5-meter amateur bands (spark transmissions were very noisy and inefficient in terms of spectrum use)²⁷.

To extract an audio signal (modulation) from a radio frequency carrier wave, receivers of the time were using crystal detectors to rectify and detect the low level radio signal. The most common way to build such a detector was to use a crystal mounted in a crystal holder. A thin copper wire known as a "cat's whisker" (hence the name given to these types of detectors) was then connected to a holder that could be moved to allow the wire to be placed on a suitable position on the crystal. At the point where the wire contacted the crystal, a point contact diode was formed which would then rectify the received signal. Although it would not conduct high currents, it was ideal for receiving radio signals²⁸. An alternative form of detector called a "Perikon" detector used two crystals in contact with each other.



Crystal based "cat's whisker" detector of WW2
Canadian Marconi MSL-5 Radio Receiver
Source: Denis Chouinard, Sorel-Tracy

Marconi's application for his American patent that covered tuning. The ruling did not dispute the fact that Marconi was the first to demonstrate workable wireless radio communication.

²⁵ This led to his development of the synchronous rotary spark-gap transmitter. An AC generator was used, which as well as providing the energy for the spark transmitter, was directly coupled to a rotary spark-gap so that sparks occurred at precise points on the input wave. The spark was between a fixed terminal on the stator and a terminal on the rotor, in effect the rotor was a spoked wheel, rotating in synchronism with the AC generator. See Belrose, J. S., (1994), "Fessenden and the Early History of Radio Science", The Radioscientist – vol. 5 No. 3 September

²⁶ In 1904, Reginald Fessenden contracted with General Electric for a High Frequency (HF) alternator that generated a frequency of 100,000 hertz for continuous wave radio. The alternator was designed by Ernst Alexanderson and was one of the first devices capable of generating the continuous radio waves needed for transmission of amplitude modulation (sound) by radio. HF generators would become obsolete by the early 1920s due to the development of vacuum-tube transmitters.

²⁷ Belrose, J.S. (1994), "The Sounds of a Spark Transmitter: Telegraphy and Telephony ", taken from www.hammondmuseumofradio.org/spark.html

²⁸ Crystal receivers also do not require a power source to operate, an interesting feature in emergency situations

The First Broadcast - Christmas Eve 1906

(<http://www.ohio.edu/people/postr/mrt/Cmas1906.htm>)

For their entire careers, the "Sparks", the ship wireless operators for the United Fruit Company, along with the US Navy, had only heard Morse code "dit - dahs" coming through their headphones. They had been alerted a few days earlier for a special message to come at 9 PM Eastern Time on Christmas Eve. Suddenly they heard something that made some think they were dreaming, a human voice coming from those headphones. Then they heard singing. There was a violin solo. Then a man made a speech. Some called their captain and ship's officers to come and listen.

The genius responsible was Reginald Fessenden. He had succeeded in transmitting voice and music over the air. Fessenden himself played a violin solo of "O Holy Night" accompanying himself as he sang the last verse. He also read the Biblical account of the birth of Christ from Luke chapter 2 over the air. The text of the angels' song "Glory to God in the Highest - and on Earth - Peace to Men of Goodwill " was heard as if by miracle.



Born in East-Bolton, Québec, Reginald Aubrey Fessenden (1866-1932) pioneered the use of continuous waves and radio-broadcasting, the first radio transmissions of voice and music
(photo from Wikipedia)

At the conclusion, Fessenden wished all a Merry Christmas and invited the Sparks to write him at Brant Rock, Massachusetts with reception reports. Reports were received from ships along the Atlantic northeast coast and from shore stations as far south as Norfolk, Virginia. A repeat broadcast on New Year's Eve was heard as far south as the West Indies.

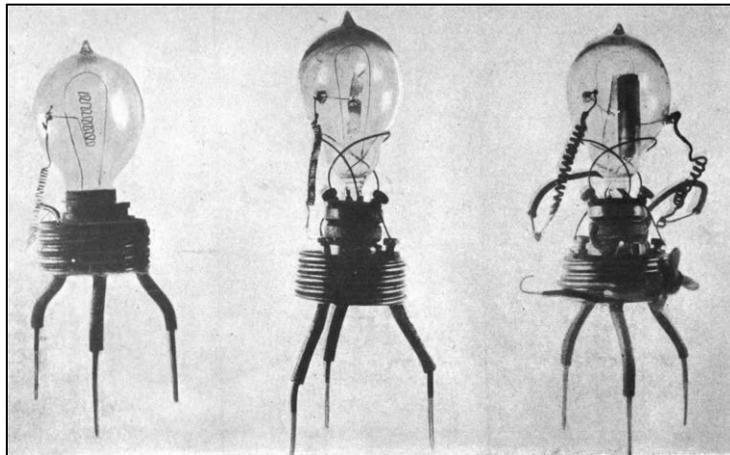
THE VALVE

While spark transmitters were being deployed on ships, coastal stations and long range wireless installations, revolutionary work was being done based on the incandescent light patented by Edison in 1881. The Fleming "valve" developed by British electrical engineer Sir John Ambrose Fleming (1849-1945) was the first practical application of thermionic emission, discovered in 1873 by Frederick Guthrie.

In 1899 Fleming became Scientific Advisor to the Marconi Company. He received a patent in 1904, on the two-electrode vacuum tube rectifier, which he called the oscillation valve.

The valve consisted of an evacuated glass bulb containing two electrodes: a cathode in the form of a "filament", a loop of carbon or fine tungsten wire, similar to that used in the light bulbs of the time, and an anode (plate) consisting of a sheet metal plate. Although in early versions the anode was a flat metal plate placed next to the cathode, in later versions it became a metal cylinder surrounding the cathode.

In operation, a separate current flows through the cathode "filament", heating it so that some of the electrons in the metal gain sufficient energy to escape their parent atoms into the vacuum of the tube, a process called thermionic emission. The AC current to be rectified is applied between the filament and the plate. When the plate has a positive voltage with respect to the filament, the electrons are attracted to it and an electric current flows from filament to plate. In contrast, when the plate has a negative voltage with respect to the filament, the electrons are not attracted to it and no current flows through the tube (unlike the filament, the plate does not emit electrons). As current can pass through the valve in one direction only, it therefore "rectifies" an AC current to a pulsing DC current²⁹ thus producing a continuous wave that can be radiated through an antenna (or in the case of a receiver and in these early years, sent directly to the operator's headphones).



The first prototype Fleming valves, built October 1904

Source: Fleming J.A. (1919), "The Thermionic Valve and Its Developments", Wireless Press

²⁹ Previous 2 paragraphs taken from Wikipedia under "Fleming valve".

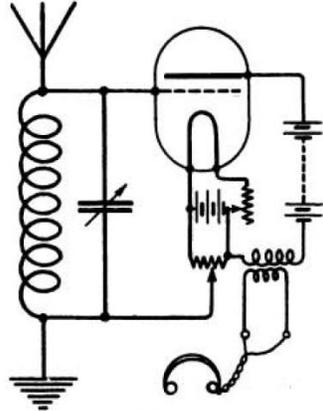


Marconi used Fleming Valve as detectors in the Glace Bay station as early as 1907; a row of 7 spare Fleming valves can be seen lined up to the left of the wireless operator. Marconi is seated on the left

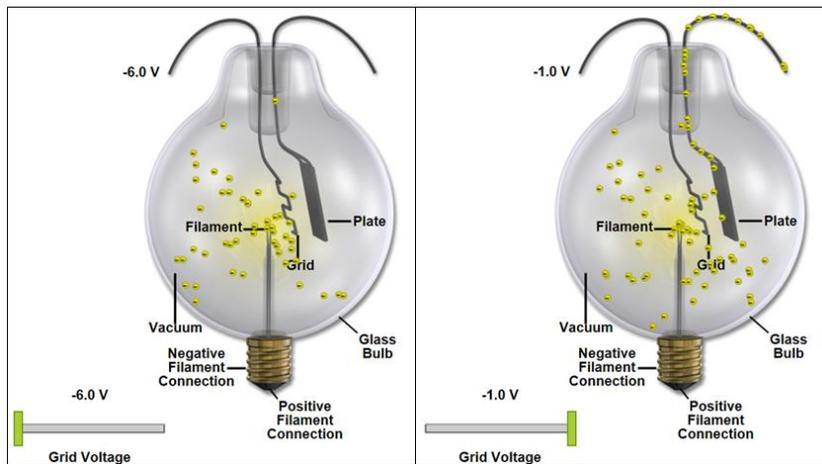
Source: Jim Kreuzer, New-York State

In 1906, Lee De Forest of the US added a control "grid" to the valve to create a vacuum tube RF detector called the Audion that could amplify, albeit only slightly, the strength of received radio signals. The sensitiveness of the two-electrode Fleming valve as a detector was greatly increased by placing between the filament and anode a third electrode which is known as the grid. The grid may be either a metallic plate with a number of holes punched in it, a spiral or a wire network. If the electrical potential of the grid is lower than that of the filament, it will, since the electrons are also minute negative charges, tend to repel them and consequently reduce the current between the anode and the filament (cathode). The current can be increased through the tube simply by reducing the negative charge of the grid.³⁰

³⁰ Barrel, W.S., "The theory of valve rectification", Wireless World magazine, August 1919

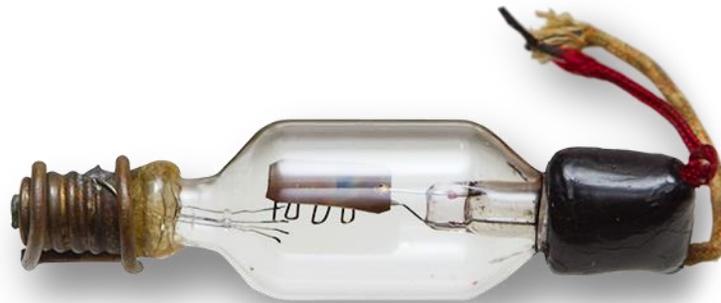


3-element (triode) vacuum tube receiver designed to receive and amplify a Spark transmission signal
 Source: Wireless World magazine, August 1919



Inner workings of the De Forest grid Audion (1906)

Source: <https://nationalmaglab.org/education/magnet-academy/watch-play/interactive/audion>



The Audion Vacuum Tube was the first electrical Amplifier device

Source: Photo taken by Maxwell, G.F. at "The History of Audio: The Engineering of Sound", an exhibition of the San Francisco Airport Museums, Terminal 3, 2006-2007.

The introduction of the valve was revolutionary as it provided an elegant solution for voice communications CW signal generation and significantly improved receiver range by providing power amplification of the weak received signals for the first time.

Several important circuits using valves had been produced by 1914. Valve amplifiers, detectors and oscillators were eventually universally adopted. American electrical engineer Edwin Armstrong patented the “regenerative receiver” in 1914, finding that the gain of a valve amplifier could be increased by feeding some of the energy from its output circuit back into its input with positive feedback (a process called regeneration). Because of the large amplification possible with regeneration, regenerative receivers could be used with a single vacuum tube. The valve oscillator, apart from its use as a continuous wave generator for radio transmitters, was also used in radio receivers in a heterodyne circuit and the resulting beat note produced an audible tone of the Morse signal in the headphones³¹.

Valves at this time were still at a primitive state of development. Those available were: the Fleming diode, the de Forest Audion triode and the C and T triodes designed by Marconi engineer Henry Round. All these triode valves were gas-filled to improve their sensitivity but had erratic performance.

WORLD WAR I

Both the C and T valves were used in the Marconi Short Distance Wireless Telephone Transmitter and Receiver. This radio, however, would not have been robust enough for use under battlefield conditions. The C valve, however, was used by the army in direction finding stations.

At the start of the war the only radios available in UK were a few Marconi 500-watt and 1500-watt spark transmitters and their crystal-detector receivers. The 500-watt pack sets were used with Cavalry Brigades and the 1500-watt wagon sets with Cavalry Divisional Headquarters and General Headquarters. The horse drawn wagon had two compartments, one for the Wireless equipment and one for the accumulators. These accumulators were either swapped out on location and taken away to be charged at a common central charging station or a mobile Charger came around once a day to each location³².

³¹ For the reception of CW radiotelegraphy (Morse code) signals, the feedback is increased to the level of oscillation (a loop gain of one), so that the amplifier functions as an oscillator (BFO or Beat Frequency Oscillator) as well as an amplifier, generating a steady sine wave signal at the resonant frequency, as well as amplifying the incoming signal. The tuned circuit is adjusted so the oscillator frequency is a little to one side of the signal frequency. The two frequencies mix in the nonlinear amplifier, generating a heterodyne (beat frequency) signal at the difference between the two frequencies. This frequency is in the audio range, so it is heard as a steady tone in the receiver's speaker whenever the station's carrier is present (Source: Wikipedia, under “Regenerative circuit”)

³² <http://marconiheritage.org/ww1-land.html>



One of the first tactical transmitter-receiver set made by Marconi UK, with its Royal Engineers Signal Service operator (1500W transmitter version)

Source: www.royal-signals.org.uk

The principal method of communication by the British army, up to late 1917, was by cable for speech and Morse transmission. Initially, a single cable was laid above ground and the earth used as the return. However, the cable was vulnerable to damage by enemy fire and by the passage of tanks across the battlefield, a problem not solved even when buried cable was used. Very often communication was not possible, particularly when troops were moving rapidly forward or in retreat. During the course of the war tens of thousands of miles of cable were laid and, at times, there was an acute shortage of replacement cable³³.

Shortly after the first gas attack in Ypres in April 1915 wireless was being used to facilitate communications between British observation balloons and the ground 1,400m below and to assure communications between headquarters and observation posts in the trenches³⁴. Transmitters were using spark as well as CW technology while the use of vacuum tubes would eventually allow wireless sets to be small enough for trench use. One of the earliest radios to be used in the trenches was the 50-watt Trench Set, also known as the BF Set which was used for communication from Brigade to Division. This went into action in the Battle of Loos in September 1915 and in the first Battle of the Somme on July 1st 1916. Its range was 3.7km with antennas mounted on masts but this was reduced to 1.1km when the antenna was run close to the ground.

³³ Material for the previous three paragraphs mostly gathered from Thrower, K., "Army radio communications in the Great War", <http://blogs.mhs.ox.ac.uk/innovatingincombat/category/military/>

³⁴ "With the Signal Corps Service at the Front", by a British Army Officer, *The Wireless Age*, April 1916



Wireless Telegraphy (W/T) Trench Set 50 Watt D.C. (also known as the BF set). The spark gap is clearly seen at the bottom

Source: Thrower, K., ``Army radio communication in the Great War``

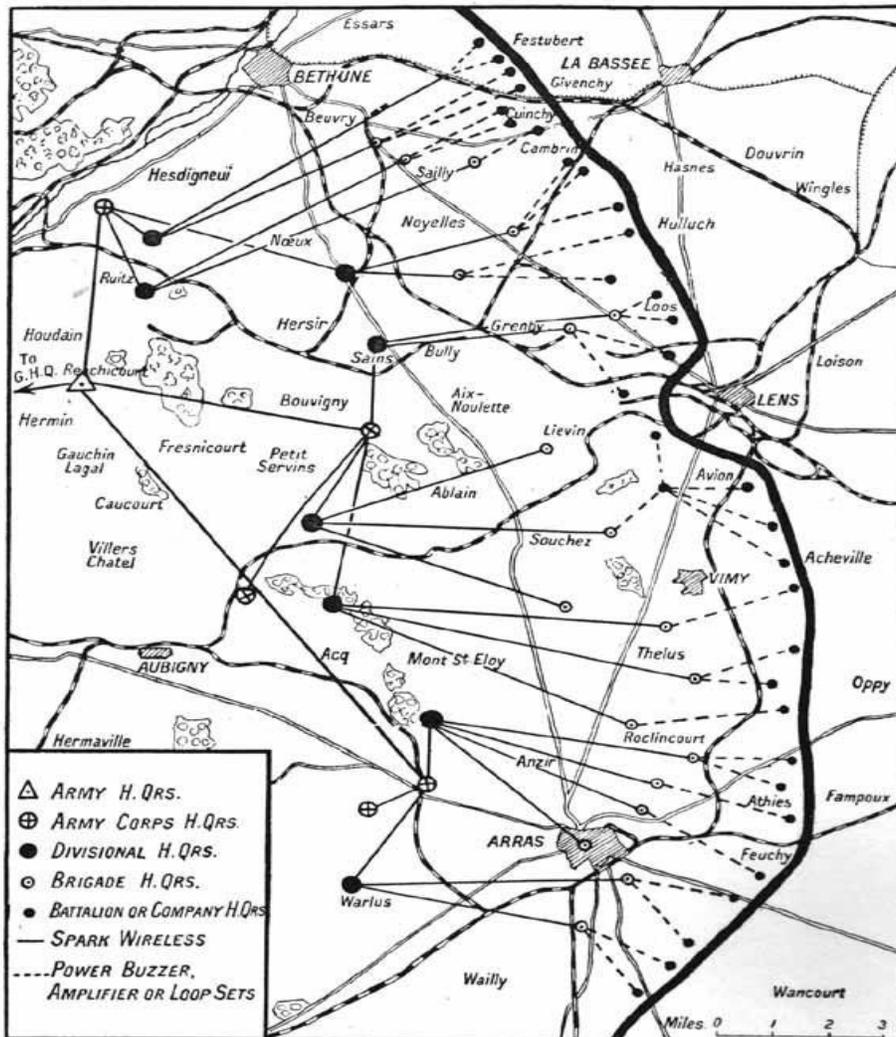


Tactical transmitter-receiver set made by Marconi for the British Army and trench warfare; Photo taken in 1917, at Moyenneville, Somme

Source: Imperial War Museum Q-27119

Careful planning of frequencies was required in order to minimize interference from neighboring spark transmitters, a problem much simplified when cleaner CW sets came into use. Towards the end of the Great War, radio had become more than just a back-up to wires, sometimes providing the principal means of tactical communications in the field. A striking example of wireless as sole means of communication was afforded by the "Canadian Independent Force", at the time a formidable collection of armoured cars, machine guns, and anti-aircraft autocannons mounted on cars and lorries. This force would ``sail into the blue`` once the fighting became open enough, engaging machine-gun nests and

anti-tank guns with great success. One car carried a CW radio set which kept the force in touch with a special set at a convenient head-quarter behind the lines³⁵.



The British First Army Front just prior to the Great Offensive in August 1918 showing
Wireless Telegraphy positions

Source: Wireless World magazine, August 1919

The war fueled rapid progress in radio design and established vacuum tubes as the corner stone of radio transmitter and receiver designs, putting a gradual stop to the use of spark transmitters after the war. In 1915, France produced the first hard vacuum triode called the Type TM. Over 100,000 of them were manufactured during the war. The Type TM was rapidly followed in 1916 by its British variant, the R-Type valve³⁶.

³⁵ Capt. Schonland, B.F.J., (1919) "W/T. R.E., An account of the work and development of field wireless sets with the armies in France", Wireless World magazine, August

³⁶ <http://www.electronics-radio.com/articles/history/vacuum-tube-thermionic-valve/history.php>

Increased activity during the war caused the Marconi Wireless Telegraph Company of Canada to leave its original Notre-Dame West location in 1914 and move to the fifth floor³⁷ of the nearby Shaughnessy Building on 137 McGill Street (now No 401/407). The de Lorimier factory activity was also transferred during the war to a new facility at 173 William Street (later renumbered No 1017) on the west side of the City, between today's Peel and du Shannon streets just behind Dow's Brewery.



For the duration of the war (1914-1918), the company office moves to the new Shaughnessy Building (built 1912) on McGill Street

Source: Annuaire Lovell 1913-1919, BANQ, Google Map

WIDE SPREAD USE AND MASS COMMERCIALISATION OF RADIO

In the period immediately following WWI, there was a marked increase in Maritime activities in Canada. Many new ships, in some cases whole new fleets, were built. The Canadian Government Merchant Fleet was established with approximately 70 vessels, all of which were fitted with wireless equipment supplied by the Marconi Wireless Telegraph Company of Canada³⁸. At that time, the company engineers were still focused on Maritime communications and probably had little idea that they were only months away from leaving the era of Wireless Telegraphy and stepping into the revolutionary age of "Radio".

³⁷ Office #507

³⁸ Murray R.P. (2005) "The Early Development of Radio in Canada, 1901-1930: An Illustrated History"



Type 2846B Maritime Receiver; originally designed as a crystal receiver in 1918 and 1920; later converted to vacuum tubes (ca.1925). It may have kept its crystal detector as a back-up mode

Source: Musée Québécois de la Radio, Sorel-Tracy

With business getting back to normal in 1919, the company moves out of its McGill street office and acquires the Merchants' Exchange building located at 11 St-Sacrement in Old Montreal (now No 211)³⁹. Marconi occupies office #5 while renting the remaining spaces to other companies.



The Merchants' Exchange building in Old Montreal (211 St. Sacrement) where the company will have an office from 1920 through 1949

Source: Annales Lovell 1919-1950, BANQ, Google Map

The large scale manufacture of wireless valves and the work done during the War had allowed the production of higher performance, more compact and lower cost radio sets. With peace came the

³⁹ Le Devoir newspaper owned and occupied this same building from 1972 to 1992.

explosion of commercial radio development and its rapid popularization⁴⁰. The first radio broadcast in Canada, and one of the first in the world, was accomplished by Marconi in Montreal on December 1, 1919 under the call sign XWA (for "Experimental Wireless Apparatus"). Rapidly, Marconi engineers added music to their programs, probably as much a convenient way to fill time in-between their tests as to interest the public to which they would now try selling receiver sets. Possibly to safeguard their limited R&D budget, the Marconi team refrained from buying a phonograph. Instead, they got one on loan from a music store on Ste. Catherine Street West in exchange for suitable acknowledgement of the store's product on the air. This may well have been the first advertisement ever broadcasted over the air⁴¹.



The Marconi Wireless Telegraph Company of Canada on William Street

Source: Musée des Ondes Émile Berliner, Montreal

The station call letters were changed to CFCF on November 4, 1920⁴². Experimental broadcasts continued from that date from the Marconi Wireless Company at 173 William Street (later renumbered as 1017) in Montreal⁴³. The station had begun regular programming on May 20, 1920 with a temporary

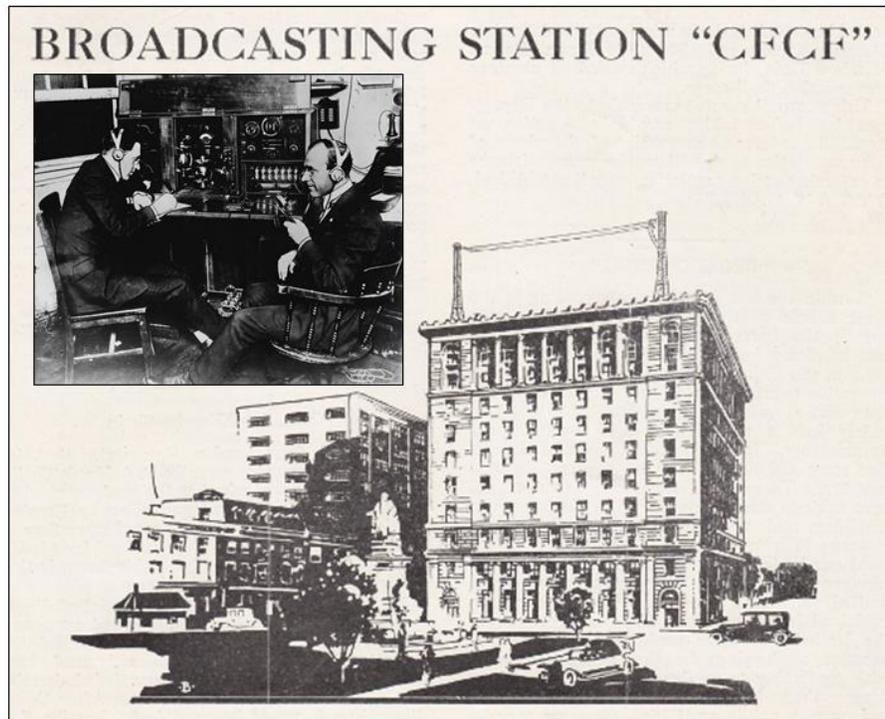
⁴⁰ Civilian use of Wireless Telegraphy was forbidden in Canada for the duration of the war. The Marconi Wireless Telegraph Company of Canada was the only one to retain the right to continue radio experiments for military use. This proved instrumental in giving Marconi Canada the lead in developing an experimental radio broadcasting station immediately after the war.

⁴¹ Adapted from Coates, D.R.P. (1940) "Adventures in Radio" in *Manitoba Calling*; quoted by Murray, R.P. in *Op. Cit.*

⁴² While the meaning of that call sign has never been officially confirmed, it is generally believed to be "Canada's First, Canada's Finest". There has been dispute as per which station between Montreal XWA and Pittsburg KDKA should be given credit for the first broadcast in North America if not in the world. While both stations were making test transmissions in 1919-1920, it appears that XWA was the first to broadcast regular, scheduled programs (see Murray, R.P. in *Op. Cit.*). Experimental broadcasts did not start in UK before 1920 and in France before 1921.

⁴³ This building which Marconi started using during WWI was located about 500 ft. away from the main entrance of École de technologie supérieure (ETS). In 2001, Ultra TCS established a NSERC Research Chair at ETS on Wireless Emergency and Tactical Communications, the only one of its kind in Canada. The building no longer exists but the original site remains vacant today.

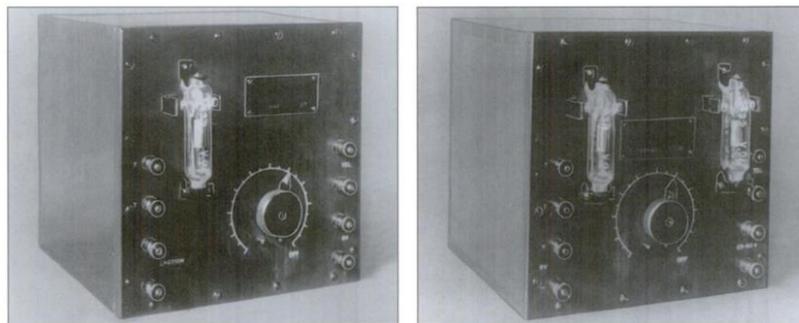
0.5 KW Marconi UK YC-3 portable set operating at 682 KHz. A more powerful 2 KW set followed in 1922. That same year, the first regular French language radio broadcast program started with the birth of CKAC, again with the support of the Marconi Wireless Company of Canada in Montreal.



In 1922, CFCF was located on the roof of the new Canada Cement building, located in Philip's Square
 Insert: Original XWA station on William St.; one of the men is Mr. Len Spencer of Ste. Rose, Laval, QC

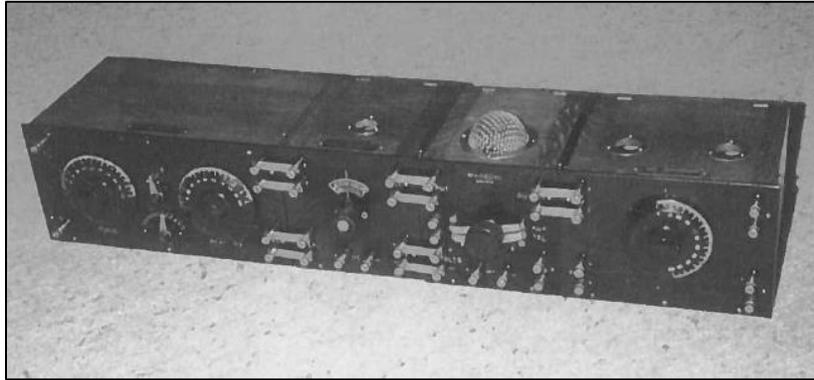
Source: Canadian Wireless Magazine, June 1922; Keith Farmer, Lachute

With the invention of broadcasting came the need to build a radio receiver that could be produced in quantity and sold at a reasonable price. This need translated into the rapid development of a prototype receiver using V24 valves made in England followed by the "Arcon Junior" type receiver (Arcon from the word Marconi without the letters M and I). The very first commercially produced receiver was Model "C" offered to amateurs in 1921.



Early prototype detector (left) and amplifier (right) using Marconi patented V24 valves

Source: Murray R.P. (2005) "The Early Development of Radio in Canada, 1901-1930"



Marconi "C" type receiver set

Source: Murray R.P. (2005) "The Early Development of Radio in Canada, 1901-1930"

The famous MARCONIPHONE family of products started in 1923 with Model 1. The MARCONIPHONE Model 1 was a regenerative receiver design using a single Radiotron UV-201-A valve for both detection and amplification. It was built into a mahogany cabinet and in the case of the one on display at Ultra TCS, apparently sold in music stores.



Marconiphone Model 1 (Mk I), Marconi Wireless Telegraph Company of Canada (1923) with a pair of Royalfone headset from Royal Electrical Laboratories, Newark, N.J., 1922

Source: Ultra TCS collection, on loan from École de technologie supérieure-ETS (Donation R. Mc Duff)

As an alternative to using a headset, customers had the option to buy a two valve audio-amplifier and to use a high speaker. The set could operate from 462 KHz (180m band) to 1,667 KHz (650m) with a range of up to about 1000 miles (1,600 km). A wire antenna of 60 or 120 feet long was recommended. The single set sold for 95\$CAN in 1924, a value of 1,321\$CAN in 2016 after taking inflation into account⁴⁴. In comparison, the Touring version of the Ford-T car was selling for 295\$CAN in 1924⁴⁵. Between 1921 and 1931, the company would develop 30 different types of domestic radio receivers.



Marconiphone Model 1 (Mk I) with its two-valve audio amplifier

Source: Murray R.P. (2005) "The Early Development of Radio in Canada, 1901-1930"

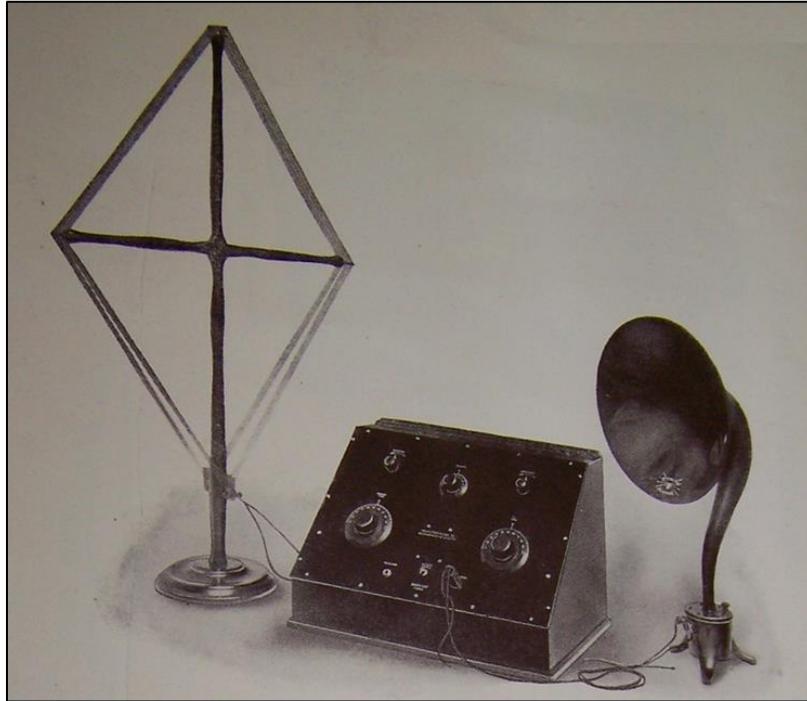


Marconiphone Model 1, inside view showing the single UV-201 valve

Source: Ultra TCS collection, on loan from École de technologie supérieure-ETS (Donation R. Mc Duff)

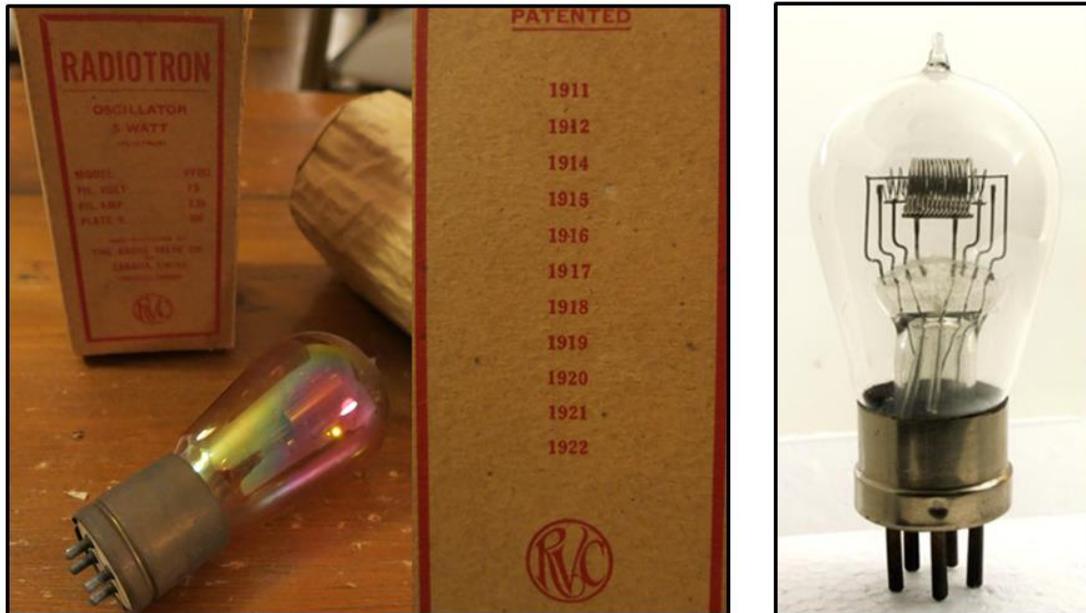
⁴⁴ The UV-201-A valve itself sold for 6.50\$CAN in 1924 i.e. about 90\$CAN in 2016

⁴⁵ http://modelt.org/index.php?option=com_content&view=article&id=11:original-model-t-ford-prices-by-model-and-year&catid=5:history-and-lore&Itemid=1. This Ford-T would sell for 295\$US in 1924, down from 393\$US in 1923. The US to Canadian dollar exchange rate being x1.0 in 1925 (<http://www.retailinvestor.org/hedge.html>), we estimate the 1924 Canadian dollar price to be 295\$.



Marconiphones (here a Model III) could be used with a 60 or 120 ft long external antenna or with a loop antenna for use inside buildings

Source: Company catalog, ca. 1925, Musée Québécois de la Radio, Sorel-Tracy



On the left, the UV-202 Radiotron 5 Watts Power output triode (1922); on the right, the Bower Electric K-4 four electrode valve with its 2 grids clearly visible (1924)

Source: Ultra TCS collection

With the wireless market booming, the Marconi Company of Canada also manufactured wireless system components in the 1920s, such as high quality distortionless audio transformers, inductances and condensers, including an innovative straight line frequency condenser patented in 1926. The new condenser allowed the rotating movement of the adjustment button to be directly proportional to the different signal frequencies the operator could select for reception, making the Marconi radios significantly easier to use than competing products. In 1925, the company changed its name to the Canadian Marconi Company (CMC).



**Distortionless Transformer and Straight Line Frequency Condenser,
Canadian Marconi Company (1925-1929)**

Source: Ultra TCS collection



**Galvanometer, Department of Marine and Fisheries, Canada; Based on the new
Canadian Marconi Straight Line Frequency Condenser (1926-1930)**

Source: Ultra TCS collection

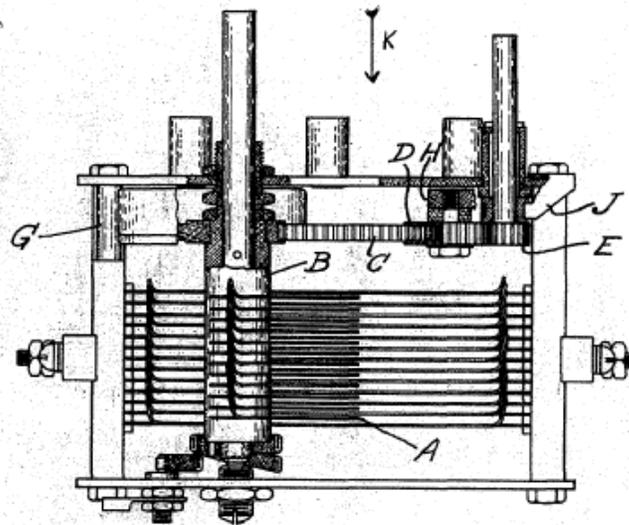
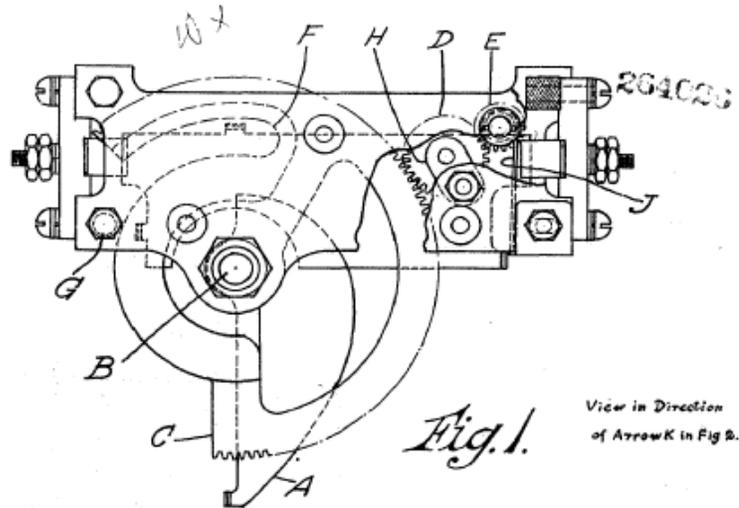


Fig. 2.

*Certified to be the Drawings referred to
in the Specification herewith annexed*

INVENTORS

Harold Edgar Mott
Jean. Pierre Maurer

BY *J. H. Houston & Co.*
ATTORNEYS

MONTREAL October 30th 1925

Straight Line Frequency Condenser Patent, Canadian Marconi Company;
this patent (CA-264026) was filed on October 1925 and granted on August 1926

Source: Canadian Intellectual Property Office

MODERNITY

In 1930, the company moved to a brand new consolidated facility in Ville-Mont-Royal (Town of Mount Royal) on Trenton Street which was to remain its headquarter for 64 year i.e. until 1994. Its inauguration in September 1930 was a significant event for Montreal.



A Company advertisement from 1931 presents ``the most modern radio plant in Canada``

Source: Montreal Industrial Commission, (1931) ``Montreal, the Metropolis of Canada: A Comprehensive Record of the Growth and Development of the Canadian Metropolis``

World War I had demonstrated that radios could be used in a wide range of operational environments including on both moving planes and vehicles. Vehicle mobility products were effectively launched in early 1930 when later that summer, a Canadian Marconi Company team lead by Eric Farmer⁴⁶ installed the first Police mobile radio system of the country in Winnipeg.

⁴⁶ Eric, the young Wireless Telegraphist hired in 1916 to work as a ship W/T, had obtained his Electrical Engineering degree in 1924 at McGill University and was Development Engineer at the Canadian Marconi since 1926



Canadian Marconi engineers demonstrate their new Police radio; Eric Framer is seating in the center of the car in front of the radio (ca. 1930)

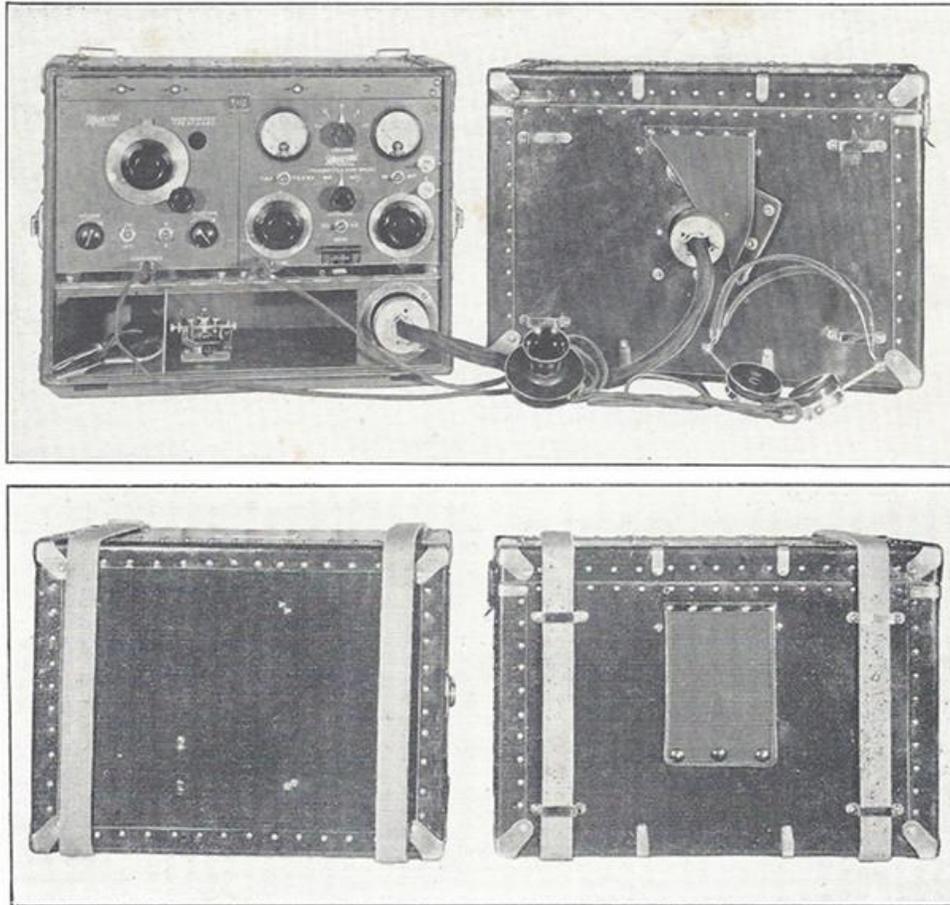
Source: Keith Farmer, Lachute

The transmission was one way and had a range of 50 to 60 miles (80 to 100 km) using a 600W transmitter in the 2.4MHz band. Officers could respond by using call boxes or chose to proceed directly to the emergency. The batteries allowed the Police car radio, installed in a shock-proof cradle to operate for 12 hours. The innovation proved an invaluable asset for the apprehension of criminals who by then were using cars to rapidly get away from crime scenes⁴⁷.

Sometimes around 1934, Canadian Marconi developed the Type PRS1, a 1.5-5.66 MHz portable radio telephone-telegraph Transmitter-Receiver set that likely had a significant influence on the design of the CD-12, a tactical radio the company would build at the start of World War 2. The entire Type PSR1 system was contained in two rugged weather-proof cases put together with plywood, fiber boards and a water proof rubber gasket. One of cases housed the transmitter, receiver and accessories (32 pounds –

⁴⁷ Manitoba Free Press, Winnipeg, Saturday, October 25, 1930 and Chu, J. (2001), ``Law Enforcement Information Technology``, CRC Press, 280 p.

14.5kg), the other the power supply (63 pounds – 28.5kg). The power supply included 6 V batteries and a dynamotor that provided a +300Vdc for the transmitter tubes. Power output was 2.5W for voice and 5W for CW telegraphy when the batteries were put in series. The batteries could be recharged with a gas engine generator or with an original windmill charger⁴⁸.

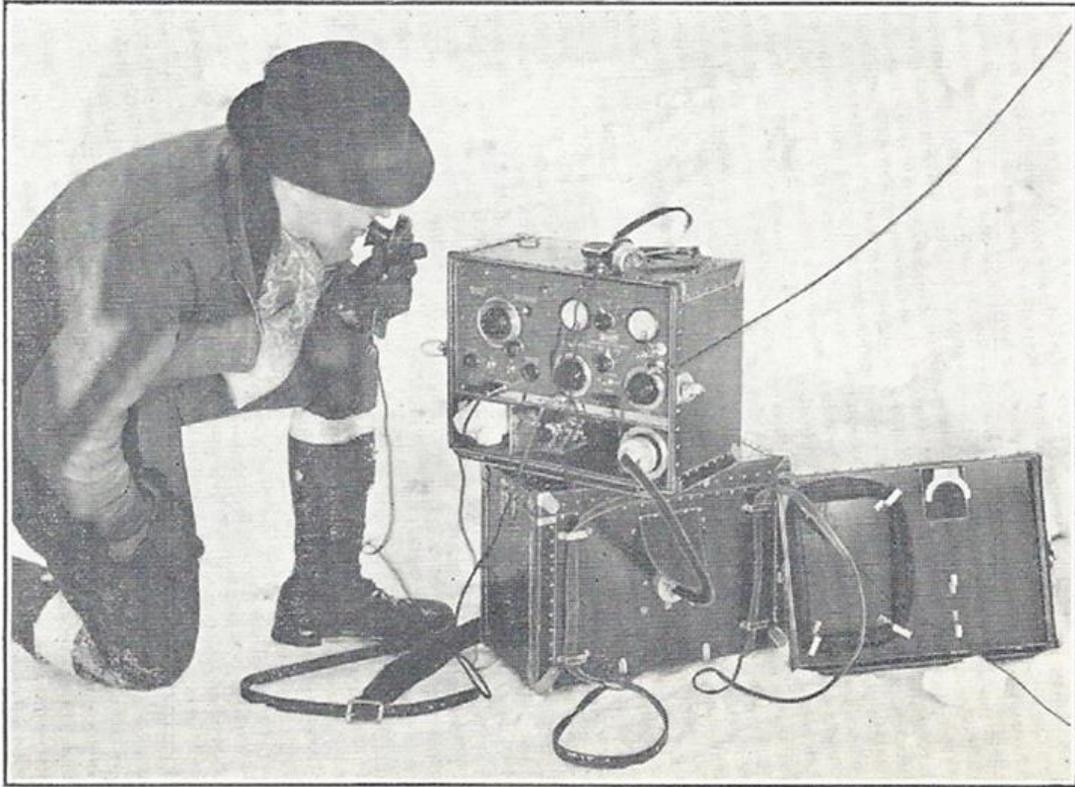


Above: Type PRS1 Transmitter-Receiver set coupled with Power Supply Unit

Below: Type PRS1 in closed carrying cases, ready for transportation

Source: Jacques Hamel, Contrecoeur

⁴⁸ The 1940 WW2 CD-12 Canadian Marconi radio could be powered by a human driven dynamo if the required +12Vdc battery was not available



Portable PRS1 in operation (1934)

Source: Jacques Hamel, Contrecoeur

In its product brochure, the company indicated that many of the radio features had been adopted “only after exhaustive field tests”. The Type PRS1 was proposed for service with fire rangers, explorers and surveyors, and could be conveniently transported by “canoe, motor-boat, pack-horse or dog-sled”.

The Canadian Marconi Company was also a part of Canadian television's prehistory. While John Logie Baird was experimenting with mechanical television in England and Philo T. Farnsworth and Vladimir K. Zworykin worked on it in the United States, the Marconi Company was active in Canada. Canadian Marconi experimented with television transmission briefly in 1923. Unfortunately, these operations were ordered closed by the Canadian government, since the government had no television policy. But the order did not deter the company's overall interest in television. Throughout the 1920s and the Depression years, CFCF-AM grew, providing the foundation and a platform for planning for television. Canadian radio historians have headlined CFCF-AM with the preeminence of KDKA in Pittsburg the first commercially licensed station in the US. By the 1930s, CMC was firmly established in three main areas: coast and beam stations, radio manufacturing and broadcasting.

Just prior to World War 2, the Canadian Marconi company was ready to put its plans for television into action. It approached the Canadian federal government asking for a license to begin an experimental television station. The company was the first to make such a request in Canada, but before a license could be approved by the government the war intervened. The advent of World War 2 changed CMC

direction as it geared to produce a number of tube based radios for the Land Forces, the Navy and the Air Force⁴⁹. It became Canada's first vertically integrated manufacturer - with a broadcasting and a production empire coming in the postwar era⁵⁰.



Canadian Marconi CSR-2 Receiver (1.5-22MHz), designed in 1937

Source: Keith Farmer`s collection, Lachute

⁴⁹ Including the Army CD-12 radio, Army Wireless Set No.9, No.11, No.19, and No.52, the Royal Canadian Navy FR-12 radio and its MSL-5 and CSR-5 Receivers. WW2 also marked a definitive transition from wood cabinets to all metal and/or Bakelite boxes for all commercial radios

⁵⁰ The information on Marconi Canada early television work is taken directly from Proc, J. "Brief history of Canadian Marconi" in <http://www.jproc.ca/marconi/history.html>