100 Years of radio: 1895–1995 – Some reflections

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Introduction

The world has witnessed many outstanding discoveries and inventions from time to time, which have greatly influenced mankind. The invention of 'Radio' in 1895 is one such and Guglielmo Marconi (1874–1937) is given credit to this. By his vision, ability and ceaseless efforts, he became one of the greatest inventors and created what was in his time a new and instantaneous means of electric wave communication. The world owes the immeasurable benefits of radio and all that has emerged from it to the farsighted genius and entrepreneurial skills of Marconi, who is rightly regarded as the 'Father of Radio'. Alexandre Stepanovich Popov (1859–1905) was another investigator who was also able to demonstrate wireless telegraphy at almost around this time. But Marconi is regarded as the inventor of radio because he developed the technique further, extended the range of coverage, made it practical and applied it with missionary zeal for the good of humanity. World-wide advances in long-distance communication by radio, radio broadcasting, television, various other applications of radio-like radar, radio aids to navigation, mobile communication, information highways and the tremendous progress in electronics that has made such systems possible, had their beginnings in Marconi's experiments on 'wireless' in the closing years of the 19th century. These experiments were based on the solid foundations of electromagnetics, telegraphy and telephony laid by several of his illustrious predecessors in the world of science and backed by his own intellect and skills. The impact of Marconi's contributions to radio on human society is so profound that the technological revolution of the 20th century would be unthinkable without radio.

The early years

In the physics of radio, three major discoveries of the 19th century stand out – a) Electromagnetic induction, by which relative motion between a magnet and a nearby conductor produces an electromotive force in the conductor and vice versa; i.e., magnetism producing electricity, just as electricity produces magnetism; discovered almost simultaneously in 1831 by Michael Faraday (1791–1867) in England and Joseph Henry (1797–1878) in USA; b) Electromagnetic theory of light and the famous field and wave equations of the electromagnetic field postulated and explained in 1873 by James Clark Maxwell (1831–1879) in England, based on Faraday's discoveries in electricity and his conception of electric and magnetic lines of force; c) Experimental researches verifying Maxwell's theory, 1887–1889, by Heinrich Rudolf Hertz (1857–1894) in Germany. Through these researches, Hertz was able to demonstrate the generation of electromagnetic waves and their transmission in free space (a few metres) in the laboratory. And soon, Hertzian doublet antenna and the radiation from it became the starting point for many studies/investigations including antennas and wave propagation in the following years.

Several leading scientists of the time pursued these investigations further. They included Oliver Lodge (1851–1940) in England, Augusto Righi (1850–1920) in Italy, Jagadish Chandra Bose (1858–1937) in India and Popov in Russia. While Bose conducted his work on quasi-optical researches with 'electric waves' at a wavelength of 5 mm and demonstrated in 1898 a microwave spectrometer containing transmitter, receiver, horn antenna and waveguides which many years later turned out to be essential parts of a microwave communication link, Lodge and Righi independently developed a 'coherer' in 1894, that could detect the presence of electromagnetic waves using iron filings in a glass bottle. At about the same time, Popov devised the first radio antenna in his attempts to detect electromagnetic radiation from lightning.

It was in this same period of radio science development that two major items of great interest in electrical communication were invented, viz. electric telegraph and telephone. Samuel J. B. Morse (1791–1872) gave a first public demonstration of the telegraph system (commonly known as the Morse system) in USA in 1838 over a 3 km line. This caught the imagination of the

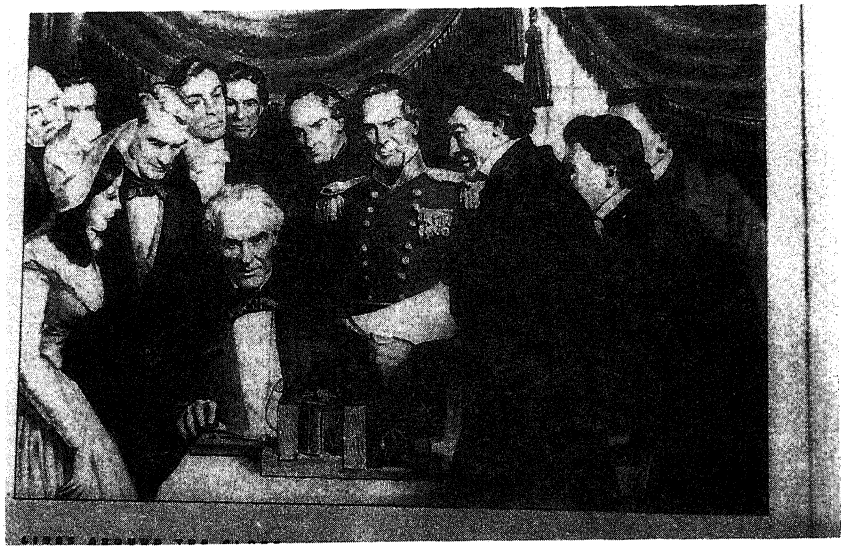

Figure 1. A reenactment of Samuel Morse sending the first telegraph message in 1844 (Reproduced from ref. 5).

public and Government alike and Morse was awarded the telegraph patent in 1840. He also got a contract to install the first public telecommunication link in the world, viz. Washington DC to Baltimore, a distance of 70 km. This was opened for public use by Morse himself in May 1844. The first message was prophetic: What hath God wrought? (Figure 1). Very soon the wireline telegraph network expanded and covered the whole of USA, Europe and many countries of Asia/Pacific as well. The control of rail road traffic, business and Government activities was largely conducted through this network. Besides, a transatlantic submarine cable was laid in about 1868 to connect Europe with USA.

At about this time, Alexander Graham Bell (1847–1922) was conducting his studies and experiments in USA to transmit human voice electrically. Bell succeeded in this in 1876 and was granted the US patent, when the first voice message was transmitted over a pair of wires just a few metres long. The message (calling his assistant) was 'Mr Watson, come here, I want you'. Since that first call, the impact of telephone on human communication has been quite profound. Easy to use and allowing direct real time contact between persons, telephony naturally overtook telegraphy as the communication's medium of choice (Figure 2). Developments in telephony – both transmission and switching – took place at a rapid pace in the following years and by 1895, the first automatic telephone switch became operational.

At this stage, the world was looking for a low cost transmission medium for long distance communication with high reliability. And, Marconi stepped in with his foresight, vision, courage and business acumen to engineer a practical radio communication system based on the excellent radio science that had developed by the 1880s, in association with the practical electrical communication technology that was rapidly expanding.

Marconi and his wireless

Marconi was born in 1874 in Bologna, Italy, the son of an Italian merchant and a Scottish-Irish mother. Due to family circumstances, he did not have the usual formal education in school/college; but, his early education was largely due to his mother and private tutors. However, even in his boyhood, Marconi showed keen interest in electrical science and mechanical systems. Hence, his imagination was quickly fired and he got excited by the following few events in his youth:

a) Chance reading (summer of 1894) of an obituary note on Hertz, who had passed away earlier that year, giving the details of his experiments for verifying Maxwell's electromagnetic theory;
b) Lecture-cum-demonstration on the transmission and reception of Hertzian waves by Lodge at the Royal Institution, London in June 1894;
c) Lectures on Hertzian waves by Righi at the University of Bologna in the autumn of 1894.

Marconi immediately took up the study of Hertz's work and the various further developments on it by other investigators in the field, in particular Lodge, Righi and Bose. While these scientists were interested in the fundamental scientific aspects of Hertzian waves, Marconi's main interest was in applying Hertzian waves for telegraph transmission through space. He conceived the idea of modulating the Hertzian waves to transmit intelligence through space and was convinced that such waves could be used for wireless transmission of telegraph signals. He conducted his preliminary experiments at his villa in Bologna using a spark-gap source, a Morse key and a coherer detector in 1895, and succeeded in transmitting telegraph signals across the room over a distance of 10 m. During these experiments, he found casually that the range increased markedly when one of the metal plates connected to the spark gap was held high and the other was kept on the earth. This was the origin of the aerial and the earth system.

Confident of what he had achieved, Marconi offered his new wireless telegraph system to the Italian Government in September 1895; but they did not show any interest. However, encouraged by his mother, Marconi moved to England early in 1896, where, after further experimentation and improvements, he demonstrated his system to the British Post Office in 1897 (Figure 3). This was well received and Marconi was awarded the wireless telegraph patent in 1897. With financial support from his mother's relatives, Marconi organized the Wireless Telegraph and Signal

Figure 2. Alexander Graham Bell inaugurating the New York–Chicago telephone service in 1892 (Reproduced from ref. 5).

Figure 3. Guglielmo Marconi with his wireless telegraph set in 1900 (Reproduced from ref. 5).

Company in England in 1897, to develop the wireless telegraph system commercially. Moving to longer wavelengths and higher power transmitters, he was able to communicate over a distance of 30 km by 1898. In April 1900, Marconi received his famous 'four sevens' patent (British Patent 7777) to cover resonance tuning of the transmitter and the receiver for enhancing selectivity of the wireless communication link. This encouraged Marconi to undertake further work, particularly to demonstrate transatlantic wireless communication. In December 1901, he was able to transmit signals from a high power Marconi transmitter located at Poldu in Cornwall, England to a receiving station near St. Johns in New Foundland, Canada, thereby making his goal a reality. The receiving antenna consisted of a 130 m long copper wire supported by a kite (Figure 4) and the detector was an Italian navy coherer consisting of a globule of mercury between iron terminals and connected to a telephone receiver. This was a great triumph which created sensation around the world and Marconi soon became a world renowned personality. His other technical developments included the magnetic detector – an improvement over the coherer – the rotary spark and the use of directional antennas. Honours came to him from far and near: Italian Knighthood (1897), Knight of the Russian Order (1902), Knight of the Civil Order of Savoy (1905) and the Nobel Prize (1909), to name a few. Later Marconi adopted many new technologies, including the diode valve, the crystal detector, CW transmission and the triode valve for providing more effective radio communication. As a result of these measures and the contributions of several other scientists/technologists of the period like Arthur Kennely, Oliver Heavyside, Edward Appleton, Arnold Sommerfeld and C. S. Franklin, radio communication developed rapidly in the early part of the 20th century. Of great significance in this period was the role of radio for many uses:

Ships at sea. British navy carried out the first radio communication tests in 1896. But the need of radio at sea was brought home in a striking manner, when the 46000 ton ocean liner 'Titanic' struck an iceberg and sank on the night of April 14–15, 1912. It was only through radio telegraphy that over 700 persons out of a total of 2200 in the ship could be saved. Ever since that time, ships at sea invariably use radio equipment. More recently, this has been extended to air and space travel also.

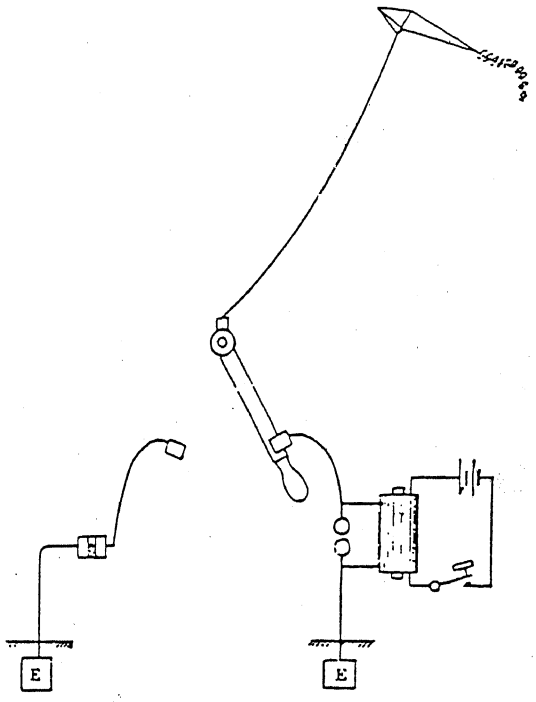

Figure 4. Marconi transmitting and receiving circuits with antennas sustained by a kite.

Intercontinental communication. In the early years, it was long-wave communication with limited utility. But Marconi commenced short-wave radio telegraph and telephone service between England and the British Commonwealth in the 1920s based on a better understanding of the ionosphere which had become possible by then and the use of directive antennas. This has greatly enabled global communication.

Radio broadcasting. Soon after the I World War, radio broadcasting at MW and SW bands became a reality. This was greatly assisted by the invention of regenerative amplifiers, superheterodyne principle and frequency modulation as an alternative to amplitude modulation during the period 1915–1935 by Edwin Howard Armstrong (1890–1954).

Microwave communication. Marconi continued to experiment at still shorter wavelengths including microwaves and set up a floating radio laboratory on board his yacht Elettra. In 1932, he demonstrated microwave communication at 50 cm successfully between Rome and Sardinia, a distance of 270 km. He also installed an operational microwave link between the Vatican and the summer home of Pope Pius XI, in 1933, a hop of 25 km. He also demonstrated the use of microwave radio beacons for blind navigation through narrow entrances.

Marconi founded many activities and programmes to support radio communication studies, and he spent many of his later years as an elder statesman and an inventor. He died of heart attack in 1937. In recognition of his great contributions to radio communication, Marconi was accorded a unique world-wide tribute of a two-minute silence by all radio stations across the world.

Growth of communications

World-wide communications have grown at an enormous pace since Marconi's times. While it was the extension of the radio frequency spectrum and regulating it for various communications services globally on one side, it was also the use of newer techniques and technologies for communications on the other side. The postulation of the Sampling Theorem (1923), Theory of Pulse Code Modulation (1937), devel-

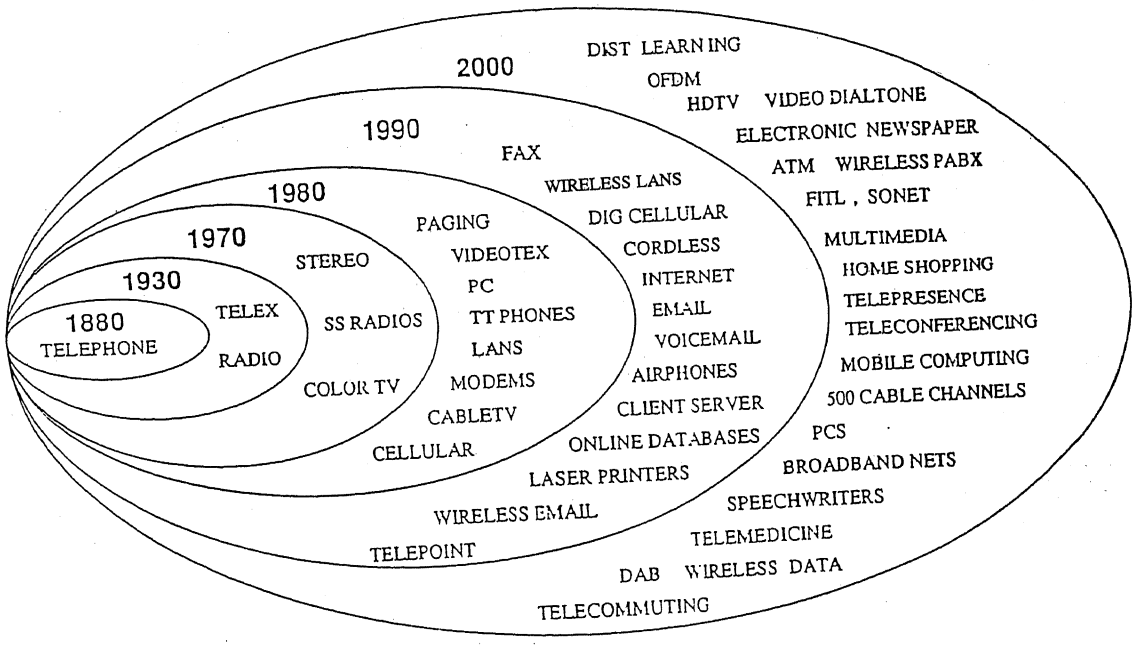

Figure 5. Growth of communication in the 20th century.

opment of digital computer (1945), invention of the transistor (1947) and the breathtaking advances in miniaturization in the post-II World War period have all contributed to these advances. In particular, progress in digital communication and microelectronics have heralded a new era in communications. The important developments and the recent trends are:

- Satellite communication, providing highly reliable global coverage using earth satellites in different orbits; GEOS, MEOS, LEOS;
- Digital transmission and switching in telecommunications, facilitating not only voice, but also many non-voice services like text, fax, data, graphics, image etc. on a world-wide basis; ISDN; Intelligent switches and networks;
- Broadband communication – both radio and fiberoptic, to provide information highways with high reliability; B-ISDN, ATM;
- Paging and cellular mobile communications facilitating mobility of individual users, eventually leading to personal communication system/ network on a global basis;
- Wireless local loops (WILL) to extend telecom services rapidly and at a low cost to rural homes in developing countries;
- Convergence of communications, computing and entertainment technologies, greatly facilitating many novel and innovative services; e.g., voice mail, telemedicine, multimedia, home shopping, distance learning, video on demand, etc.

Figure 5 gives a pictorial representation of the growth of communications through the 20th century, in particular since the 1970s, based on the strong foundations established by radio communication in the earlier period. Thus, while the world of communications continues to expand, the world we live in is shrinking in size, day by day, and is truly becoming a global village.

Conclusion

Marconi is truly one of the greatest benefactors of mankind in modern times. His work and achievements have not only brought into existence radio communication in the service of mankind, but also vast industries and utilities employing millions of persons around the world. The communications revolution triggered by Marconi nearly 100 years ago continues to grow even today and is poised for a big future in the coming century as well.

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