Jagadis Chandra Bose and His Pioneering Research on Microwaves

It is commonly believed that Guglielmo Marconi 'invented radio'; a more accurate statement might be that he invented long-distance wireless telegraphy. In the small town of Pontecchio outside Bologna in Italy, Marconi in 1895 succeeded in transmitting a wireless signal and detecting it with a receiver held over a mile away. Marconi's first public demonstration would, however, not come until two years later.

What is not so well known is that in Calcutta in 1895, the same year in which Marconi had his first success *but two years before* his first public demonstration, Jagadis Chandra Bose of Presidency College gave a public demonstration of wireless communication, using wireless waves to ring a bell a mile away. The Daily Chronicle in England reported in 1896 that "The inventor J C Bose has transmitted signals to a distance of nearly a mile and herein lies the first and obvious and exceedingly valuable application of this new theoretical marvel."

To understand some of the background for these events of 1895, it is helpful to step back some years. In 1865 James Clerk Maxwell published his equations unifying electromagnetic theory and predicting the existence of electromagnetic waves that travelled at the speed of light. Although this marks the beginning of a revolution in electrical science, it was over twenty years later that Heinrich Hertz, urged on by Helmholz, succeeded in the first experimental verification of Maxwell's predictions in his laboratory in Karlsruhe. The 1888 demonstration by Hertz used discharges across a spark gap to generate the waves, and a loop antenna with its own small spark gap to receive the waves. Hertz continued his research (discovering the photoelectric effect along the way), but died at the early age of 36. Nevertheless, his work quickly became well known, and by 1894 had prompted both Marconi and Bose to begin research on electromagnetic waves.

Marconi's early schooling had been with tutors at home. His Anglo-Irish mother taught him English, and she persuaded a physics professor at the University of Bologna to allow Marconi to attend his lectures. Marconi happened to read the obituary note on Hertz in 1894, and learned of his experiments verifying Maxwell's theory. In the same year, he also attended a memorial lecture on Hertz by the English physicist, Oliver Lodge. Listening to Lodge spurred Marconi, barely twenty years old at the time, to pursue Hertz's work.

Marconi's experiments on the grounds of his parents' estate were focused on extending the distance over which electromagnetic waves could be detected. He was specifically interested in their application to telegraphy. He adapted his physics professor's spark gap transmitter to produce waves of higher frequency and greater range than those used by Hertz, and also connected a telegraph key in the circuit to permit the dots and dashes of Morse code to be transmitted. For a detector, he replaced the spark gap that Hertz had used in his receiving antenna by a 'coherer' This was a device invented by Edouard Branly in France and improved on by Lodge. Finally, a major factor in Marconi's ability to transmit across significant distances, including over the hills beyond his home, was his accidental

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discovery of the improvement obtained by grounding the transmitter and the receiver.

After the first testing of wireless in his hometown, Marconi offered his invention to the Italian government. When they showed no interest, his mother took him and his two trunks of equipment to England. There he managed to interest the British Post Office in his ideas. In 1896 he obtained patents for wireless telegraphy, and set up the Marconi Wireless Telegraph Company. In 1897, Marconi held his first public demonstration of wireless transmission and detection on Salisbury Plain, some two years after Bose's public demonstration in Calcutta. In 1899, Marconi established wireless telegraphy between France and England, across the English Channel. In 1901, he transmitted the first wireless signal across the Atlantic Ocean, and this event made him a celebrity the world over.

Marconi went on to further develop wireless telegraphy and to establish the dominance of his company on both sides of the Atlantic. His success in this was partly a result of his tremendous flair for dramatic, headline-grabbing demonstrations, which kept his name and that of his technology and company constantly in the public eye. Fortune also favoured him when it frowned on others: in 1912 the distress call of the Titanic was picked up by the Marconi company operator on another ship, which directly led to the rescue of those who made it into the lifeboats, and then to widespread recognition of the practical importance of wireless. Marconi's success was also partly a consequence of the dedication with which he obtained patents on any device that he or his company had made any improvements on, whether or not they had invented the original version. (When he did this with a tuning circuit invented by Oliver Lodge, the latter was goaded into forming his own competing company.) Marconi received numerous international honours and awards, including the Nobel Prize for physics in 1909. He died in 1937 (coincidentally the year in which Bose died) at the age of 63.

The story of how wireless telegraphy evolved to wireless voice transmission and radio, and of how the American Marconi company correspondingly evolved to RCA, is very well told in Tom Lewis' 1991 book, *Empire Of The Air: The Men Who Made Radio.*

Jagadis Chandra Bose was born in India in 1858. He was educated in India and in England. He studied in London and Cambridge (1880 - 84) and in 1884 received a B A degree from Cambridge and a B Sc from London University. Bose returned to India upon graduation and joined Presidency College in Calcutta as a physics professor. He was an effective and popular teacher, with a reputation for extensive use of scientific demonstrations in lectures. Several of his students went on to distinguish themselves, including S N Bose, who became famous for his Bose-Einstein statistics.

J C Bose read Lodge's book on *Heinrich Hertz and His Successors* and was inspired, as Marconi was, to pursue Hertz's work vigorously. In 1894, he converted a small space in Presidency College into a laboratory, and set to work. He pursued fundamental experiments on the generation, transmission, refraction, diffraction, polarization and detection of electromagnetic waves, with wavelengths in the range of 0.5 to 2.5 cm. Several familiar microwave components of today – waveguides, waveguide lens antennas, horn antennas, polarizers, dielectric lenses and prisms, diffraction gratings – are found in his experiments, many invented by him (including such exotic objects as twisted-jute polarizers!). He also developed detectors using a variety of junctions; his receivers based on galena (lead ore) crystals were issued patents in 1904. W H Brattain, co-inventor of the transistor and Nobel Laureate, credits Bose with the first use of a semiconducting crystal to detect radio waves. Neville Mott, Nobel Laureate in 1977 for work in solid-state electronics, cites Bose as being "at least 60 years ahead of his time," saying that "in fact, he had anticipated the existence of p-type and n-type semiconductors."

In 1895, Bose gave the first public demonstration of wireless communication. At the subsequent invitation of his former professor, Rayleigh, Bose returned to England in 1897 to report on his microwave work, making presentations at meetings of the Royal Institution and other societies in England. Bose also made improvements in 1898 to the Branly-Lodge coherer that was used in Marconi's original experiments. Bose's invention of the 'iron-mercury-iron coherer with a telephone detector' was reported in the Proceedings of the Royal Society in April 1899. The relation of this coherer to those used subsequently by Marconi bears further investigation.

Around this time, Bose's interests began to shift fairly substantially. He turned to the study of plant response to, among other things, electromagnetic radiation. Following his pioneering work on microwaves, there was almost no further work in the area for nearly fifty years. After retiring from Presidency College in 1915, he continued his research as Director of the Bose Institute in Calcutta. In recognition of his distinguished research of a lifetime, he was elected a Fellow of the Royal Society in 1920, and was also knighted. He died in 1937, a week before his 80th birthday.

Much of Bose's original equipment is on display at the Bose Institute. A brief account of Bose's work (from which the present account is largely drawn) and a description – with photographs taken at the Bose Institute – of some of Bose's apparatus appear in a recent paper by Darrel T Emerson of the US National Radio Astronomy Observatory (NRAO) in Tucson, Arizona. The paper was presented in June 1997 at the International Microwave Symposium of the IEEE Microwave Theory and Techniques Society, and subsequently published in the December 1997 *IEEE Transactions on Microwave Theory and Techniques*. The paper may also be found on the Web, at http://www.tuc.nrao.edu/~demerson/bose/bose.htm.

Part of Emerson's interest in Bose is related to the fact that a new multiple-feed receiver operating at 1.3mm has recently been fabricated and placed on the 12m telescope at Kitt Peak, whose operation Emerson is responsible for. This receiver uses eight prism attenuators, a device that Bose investigated and reported on in the Proceedings of the Royal Society in 1897. Emerson notes that, outside of India, Bose is rarely given the deserved recognition. It is to be hoped that Emerson's paper, published in a widely read journal, will help to widen appreciation of Jagadis Chandra Bose's pioneering research on microwaves.

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