PIONEERS OF RADIO

Dr. Mahlon Loomis—first to demonstrate electrical communication through space.

by FRED SHUNAMAN

IN OCTOBER, 1866 A WASHINGTON dentist, Dr. Mahlon Loomis, flew two kites from Blue Ridge mountain peaks about 18 miles apart. Each had a 15-inch square of wire mesh on its underside and a 600-foot wire to ground "in a wet spot." Inserting a telegraph key in one wire and a galvanometer in the other, he was able to deflect the galvanometer in the circuit 18 miles away by keying his "aerial wire." Working back and forth with an assistant on a time schedule, "signalling continued for nearly three hours, when the circuit became inoperative as the upper electric body moved away," Loomis said.

For in Loomis's day, science had "proved" that there was a large ocean of positive electricity above the earth, (the earth was considered negative) separated from it by the insulating layer of air. Loomis expected, by suddenly connecting and disconnecting those two opposite charges, to set up "shocks and pulsations" in that sea—perturbations that would spread out like waves and affect the flow of electricity at any other aerial penetrating the "ocean." In modern terms, he envisioned an electric field in which waves could be set up that would affect other conductors in the field.

Loomis was able to interest financiers

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PIONEERS OF RADIO

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in his invention, but his first backers were wiped out in the "Black Friday" financial crash of 1869. A second supporter, Austin G. Day of New York, was forced to withdraw after the Great Panic of 1873. Meanwhile, on July 30, 1873, Loomis received the first patent ever granted (129,971) for wireless (radio) telegraphy.

After his two failures to get his invention off the ground, Loomis' image waned in the eyes of investors, and his further attempts to obtain capital failed. His pocketbook, his health, and finally his domestic relations suffered from his single-minded efforts to promote his invention. He left his family in Washington and retreated to his brother's home in West Virginia, where he died October 13, 1886.

Dr. Loomis has three claims to fame: He was the first person to conceive, propose and demonstrate electrical communication through space. He was the first to conceive an electrical field (he called it an ocean) that could be disturbed to produce intelligence-carrying waves. And he was the first to develop the antenna or aerial as a means of transmitting and receiving.

DID POPOV INVENT RADIO?

Aleksandr Popov (1859-1906)

By **THEODORE M. HANNAH**

We call Marconi "father of radio;" Russians give Popov credit. Who is correct and exactly what did Popov do?

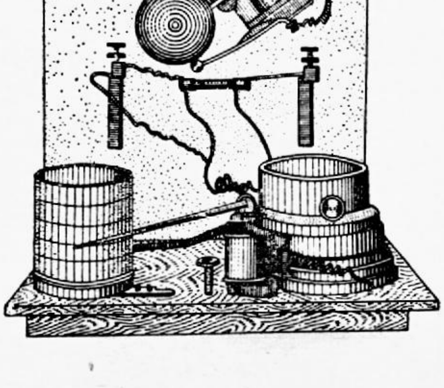
ASK an American who invented radio and he will probably say "Marconi;" ask a Russian and he will very likely say "Popov." Who is right? Can either Marconi or Popov be considered the inventor of radio? For that matter, who *is* Popov?

Throughout the communist world Aleksandr Stepanovich Popov is recognized as the sole inventor of radio. A cursory examination of any recent Russian electronics journal makes this abundantly clear, for 1959 was the centennial of Popov's birth (he was born March 16, 1859[1], in what is now the Sverdlovsk oblast). To commemorate the anniversary, a number of special events were held during 1959: scientific meetings in Moscow and elsewhere; dedication of a statue of Popov in Leningrad; the Russian amateur radio organization held an international radio contest on Popov's birthday and then offered a special award to any amateur who contacted 100 Russian amateur stations during 1959; special postage stamps have been issued, etc. Popov is memorialized in other ways too. The Russian equivalent of the IRE is known as the Popov Society; scientists —both Russian and foreign—who make outstanding contributions to the radio art receive Popov gold medals; the first page or so of every Soviet book on radio-electronics is ritualistically devoted to a tribute to A. S. Popov, "the inventor of radio."

The Russian claim of priority in the invention of radio is based on an event of May 7, 1895 (since 1945 this day has been celebrated as Radio Day in the Soviet Union). At a meeting of the Physics Branch of the Russian Physical-Chemical Society in Petersburg, Popov, then an instructor at the Kronstadt naval school, reported on and demonstrated his invention, a "radio receiver." The device was actually designed only to receive and record lightning discharges; the term "radio receiver" (usually prefaced with "the world's first") became commonly applied to Popov's device only after the advent to power of the Communists in Russia. This may be not so much willful distortion as it is a problem of definition. Popov's device *did* detect and record electromagnetic radiation (if only static crashes), and in that sense it *was* a radio receiver; yet, because there were no transmitting stations at that time, can his invention really be called a radio receiver?[2] In a way this is the reverse of the old question: "If a tree falls in the forest but there is no one there to hear it, is there any sound?" In 1895 there *was* someone to hear, but there was no *tree,* at least not near Petersburg.

While an instructor at Kronstadt, Popov had access to a well-equipped laboratory and a library well stocked with foreign periodicals and books. Popov was particularly interested in the work of Heinrich Hertz and he repeated many of the German's experiments in electromagnetic waves. The experiments and writings of Sir Oliver Lodge, Edouard Branly, Augusto Righi, and others also influenced his thinking. The detector which Popov demonstrated before the Physical-Chemical Society meeting was basically Branly's coherer (a metal-filing type) to which Popov added an arrangement for automatically tapping back the filings to a sensitive condition after they had cohered upon the reception of oscillations. Each static discharge caused a bell to ring or a mark to be made on a paper tape. The implication conveyed in some descriptions of Popov's receiver is that the tapping device was original with Popov.[3] Actually, an automatic tapper was a part of the receiver which Lodge demonstrated at a meeting of the British Association for the Advancement of Science in 1894.[4] What may have been original with Popov was the addition of choke coils to protect the coherer from the effects of local sparking at the relay contacts.[5]

Drawing illustrating Popov's first receiver (1895) which detected lightning discharges.



Contemporary Soviet accounts of Popov's invention attach considerable importance to the antenna which he used with his receiver. Described as a long vertical wire, insulated at the upper end and connected through the coherer to ground at the lower end, it is claimed to have been the final element needed for the reception of radio signals. The literature is not conclusive on this point; Hertz had been using a loop antenna for his experiments, but whether Popov was the first to employ an antenna and ground system remains an unanswered question. There is evidence that Marconi had been using such a system in his experiments conducted at or before this time.[6]

It should be pointed out that Popov foresaw that his invention might be used for purposes of communication. During his demonstration of May 7, 1895 he is reported to have said:

> "With further improvement, my device can be adapted to the distant reception of signals by means of rapid electric oscillations, as soon as a sufficiently powerful source of such oscillations is found."[7]

Perhaps unknown to Popov, a source of such oscillations had already been found. During the summer of 1894, at Pontecchio, near Bologna, Italy, a young man named Guglielmo Marconi succeeded in receiving *and* sending wireless signals over a distance of about three-quarters of a mile. Similar experiments had also been made by Lodge and Sir Henry Jackson. From then on, progress was swift. Marconi moved to England, and by the beginning of 1896 was receiving Morse code messages over a distance of nearly two miles. On June 2, 1896 Marconi applied for the first patent ever granted for a system of wireless telegraphy based on the use of electric waves.[8] During 1896-97, transmitting distance was increased to four miles over land, then nine miles across the Bristol Channel. In 1899 wireless signals spanned the English Channel, the first instance of international radio communication. In the same year British warships, using Marconi equipment, exchanged messages at distances of 75 miles. Only two years later, on December 12, 1901, with Marconi at the receiving station in Newfoundland, the letter "S" was transmitted across the Atlantic. World-wide radio communication was now within reach.

What was Popov doing during this time? In January, 1896 a report of his demonstration of the previous May was published in the *Journal* of the Russian Physical-Chemical Society under the title "A Device for Detecting and Recording Electric Oscillations." On March 24, 1896 Popov sent his first message by wireless. Transmitted over a distance of about 600 feet, the message consisted of two words: "Heinrich Hertz." Early the following year he was communicating with ships over short distances.[9] His equipment was employed in what was probably the first use of radio in the saving of human lives. In February, 1900 a message was flashed from Petersburg to the icebreaker "Ermak" instructing it to rescue some fishermen stranded on floating ice in the Gulf of Finland. In 1901, the year Marconi sent signals 2000 miles across the Atlantic, Popov established communication between ships on the Black Sea; the distance was 80 miles.

How then can the Russians claim that Popov invented radio? Two arguments are used: (1) that Popov's demonstration of 1895 predated Marconi's patent of 1896, and (2) that, in any case, Marconi's invention was a direct copy of Popov's.

Popov is said to have refused to take out a patent on his invention, contending that the discovery should benefit the scientific world at large.[10] This may be true (university professors are traditionally uninterested in patenting their discoveries), or it may be a convenient means of explaining how Marconi, rather than Popov, came to be almost universally recognized as the father of wireless communication.

With respect to the second argument, it is certainly true that no *one* inventor or invention was responsible for radio. And there *was* considerable similarity between the inventions of Marconi and Popov, just as Popov's was similar to and based upon Lodge's, Lodge's upon Hertz's, etc. But this is really not the point. The thing that the Russians seem to overlook is that neither Popov, nor Lodge, nor Branly, nor Hertz recognized the fact that radiation was the real key to wireless. And, as the courts later held, none of these scientists ever fully realized the practical possibilities of wireless as a means of communication. Marconi grasped both of these ideas. If not a creative inventor, Marconi was blessed with a genius for perfecting the crude laboratory-type apparatus of his predecessors and for promoting wireless telegraphy as a practical instrument of communication. He was, in short, the midwife of radio.

Without admitting that he was responsible for practical wireless telegraphy, Soviet sources, particularly the earlier ones, give at least some credit to Marconi for his contributions to the development of radio. A Soviet encyclopedia begins its article on Marconi by saying: "Marconi (1874-1937), Italian engineer and radio technician, the inventor, after Professor A. S. Popov, of the radiotelegraph."[11] This early source is kinder in its treatment of Marconi than one published in 1954. The latter dismisses Marconi as an opportunist who, taking advantage of the fact that Popov had not patented his invention, went ahead and obtained a patent on his device, which was, after all, only a copy of Popov's.[12]

The contributions of the men who pioneered in the study of electricity and electromagnetic waves—Galvani, Volta, Morse, Bell, Faraday, Henry, Thompson, Branly, and Lodge—are freely acknowledged in the Soviet literature, but in a condescending sort of way. The Russians take the attitude that what these men did was but prelude to Popov's "invention" of radio.

An interesting feature of Soviet accounts of Popov is that, of all the inventions claimed to have been made by Russians, radio seems to be the one first claimed. The argument that Popov was the real inventor of radio was put forth at least as early as 1925;[13] other Russian inventions (including baseball and the hula hoop) were announced considerably later.[14]

There is no denying the fact that Popov's considerable talents were little appreciated by the tsarist government. It must have been particularly galling to Popov to see, in 1902, his rival Marconi decorated by the Tsar with the Order of St. Anne. There is no record that Popov ever received similar recognition from his government.[15]

Popov's last few years were spent in Petersburg as a professor, then director, of the Electrotechnical Institute. He died on January 13, 1906 at the age of 47. The brain hemorrhage which caused his death was due, according to one recent Soviet source, to heated arguments between Popov and the tsarist minister to whom he was subordinate.[16]

Returning to our original question, did Aleksandr Popov invent radio? No, and neither did Marconi. The latter made wireless practical, but without the pioneering work of scientists like Popov, Marconi's achievements would have been impossible.[17]

An American scientist who recently visited the Soviet Union brings back an interesting anecdote. In a discussion of Russian claims that Popov invented radio, a Soviet electronics engineer is quoted as saying: "Well, Marconi did something too, and what difference does it make? We now have radio and that's good!" And it *is* too.

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[1] All dates are New Style.

[2] Dictionary definition of radio: "The transmission and reception of signals by means of electric waves without a connecting wire . . ."

[3] See, for example, *Bol'shaya Sovetskaya Entsiklopediya (Large Soviet Encyclopedia)*, First Edition, Vol. 46, columns 422-23, and *Encyclopaedia Britannica*, 1956, Vol. 18, pp. 230-31.

[4] W. H. Eccles, *Wireless*, London, Oxford University Press, 1933, pp. 53-54. Quoted in W. Rupert Maclaurin, *Invention and Innovation in the Radio Industry*, New York, Macmillan, 1949, p. 18.

[5] *Ibid.*, p. 20.

[6] Orrin E. Dunlap, Jr., *Radio's 100 Men of Science*, New York, Harper, 1944, p. 172, and *Encyclopaedia Britannica*, Vol. 14, p. 869.

[7] *Bol'shaya Sovetskaya Entsiklopediya*, *loc. cit.*

[8] This was British patent No. 12,039. The equivalent American patent, No. 586,193, was granted him on July 13, 1897.

[9] A description of Marconi's wireless system was not published until June, 1897.

[10] Dunlap, *op. cit.*, p. 127.

[11] *Bol'shaya Sovetskaya Entsiklopediya*, First Edition, Vol. 38, column 155.

[12] *Bol'shaya Sovetskaya Entsiklopediya*, Second Edition, Vol. 26, p. 299.

[13] Postage stamps honoring Popov as the inventor of radio were issued that year.

[14] Popov is also credited with discovering the principles of radar and radio direction finding.

[15] His contributions to the sciences were recognized by the Fourth International Electrotechnical Congress, held in Paris in 1900. There he received an honorary degree and a gold medal. *Bol'shaya Sovetskaya Entsiklopediya*, Second Edition, Vol. 34, p. 159.

[16] N. M. Izyumov, *Kurs Radiotekhniki (A Course in Radiotechnology)*, Moscow, 1958, p. 6.

[17] While acknowledging the contributions of some of his predecessors and contemporaries, Marconi appears never to have been aware of Popov's existence.

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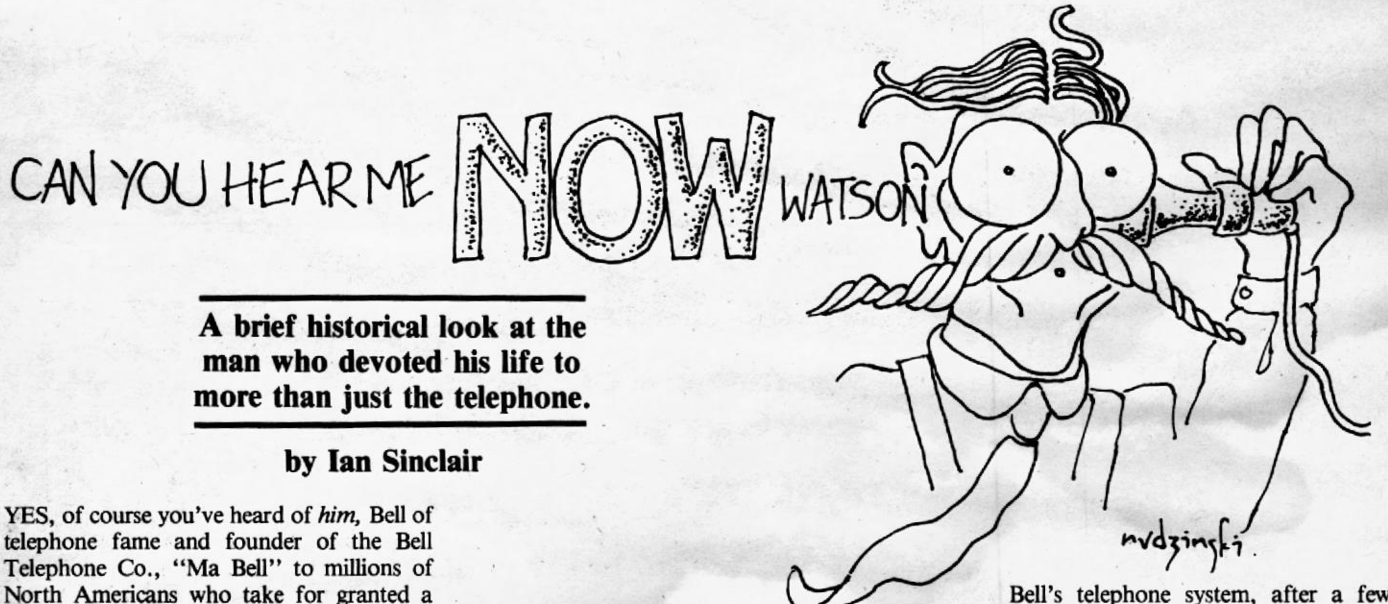
Alexander Graham Bell



A brief historical look at the man who devoted his life to more than just the telephone.

by Ian Sinclair

YES, of course you've heard of *him,* Bell of telephone fame and founder of the Bell Telephone Co., "Ma Bell" to millions of North Americans who take for granted a standard of first rate telephone service. But did you know that the decibel is named after him, or that he invented the telephone as a deaf aid? Read on, and discover more about the life of this remarkable pioneer.

Alexander Graham Bell was born in Edinburgh in 1847, to a family who had dedicated their lives to the service of the deaf and dumb — his father was the inventor of the hand signals which are still used to this day. His parents were established authorities in elocution and speech correction (what would they have made of CB?), and they did not send Alexander to school, preferring to draw on the considerable talents of the family for his education. The success of this education, unhindered by local authorities or social workers (not yet invented), gained Alexander his first job in 1864, as resident master at Weston House Academy, a small boarding school in Elgin, a cold grey town in the Highlands.

Devoted To The Deaf

In 1870, however, the whole Bell family decided to emigrate, like so many Scots before and since, in search of a better living in Canada, and they moved to Brantford, Ontario. Alexander found nothing to his liking there, and shifted again to Boston, Mass. in the USA, to open a small school, in 1872, for training teachers of the deaf, a topic in which he took a passionate interest.

He had very considerable success, and in a remarkably short time established a nationwide reputation for his methods of training teachers, particularly in the "hand alphabet" which his father had devised. This, incidentally, is a subject of controversy at the moment because it is no longer being so widely taught, and the change is bitterly resented by many deaf people who feel that a valuable method of communication may be lost to future generations.

As a result of Bell's success, he was asked to incorporate his school into Boston University, and he became Boston's first Professor of Vocal Physiology in 1873. It was as a result of this achievement that he was able to find time for research, with all the facilities of a University now available to him.

Telegraphy Progress

He was fascinated by the development of Telegraphy, because it was a method of communication which was open to people with severe hearing or speech defects — in fact many deaf people were trained as telegraph operators in those days, just as the tradition of training blind people as piano tuners grew up. Bell's interest in the electric telegraph led to the invention, along with his excellent but lesser known assistant Thomas Watson, of many improvements in telegraph design, and to Bell's increasing involvement in, and knowledge of, electrical circuits. Gradually he conceived a system which would convert the sound waves of speech into electrical signals, and back again, with the purpose of allowing the deaf to hear what was being said some distance away. Curiously enough, another emigre, David Hughes, was working in Virginia along similar lines.

Bell's telephone system, after a few false starts, took the simple form of a carbon microphone, a battery, and an earpiece. The carbon microphone was until very recently still being used in telephones, particularly in this country; it is now being replaced by the electret microphone, the only device sufficiently sensitive, and with a large enough signal output, to take its place.

The carbon microphone principle (which is attributed to Hughes) goes thus: a thin flexible membrane or diaphragm of metal is held in an insulating cylinder which has a metal backplate, and the space between the diaphragm and the backplate is packed with granules of carbon. Carbon is a resistive material, and the resistance depends very much on how tightly the carbon particles are packed together. With this arrangement, pressing the diaphragm inwards considerably, reduces the resistance between the diaphragm and the backplate; pulling the diaphragm outwards considerably increases the resistance. With a battery connected, the device becomes a variable current generator, with the amount of current depending on the movement of the diaphragm.

A Toast To Carbon

When a sound wave hits the diaphragm, it causes the diaphragm to vibrate at the same frequency as the sound wave, and with an amplitude (amount of movement) which depends on the loudness of the sound. In this way, sound waves hitting the diaphragm cause waves of electric current in the circuit connected to the carbon microphone. The useful and remarkable thing about the car-

continued on page 14.

bon microphone is the size of the electrical signal that it generates, putting several volts across a load with several milliamps flowing. Until the development of electrets there was nothing that came anywhere near such an output, and the defects of the carbon microphone, such as its narrow bandwidth and the resonances which it caused, were not of great significance in telephone use.

Bell's receiver was electromagnetic, using the arrangement which, once again, has survived more than a hundred years. This uses a magnetized metal diaphragm held close to an electromagnet, usually of horseshoe shape. The varying currents transmitted by the microphone are sent through the electromagnet of the earpiece, and they cause the diaphragm to be magnetically attracted to an extent that depends on the amount of current. In this way, the current waves that flow in the circuit when someone speaks into the microphone are converted back to a sound by the action of the earpiece.

According to the notes that Bell made at the time, the first words spoken over a telephone circuit were "Come here, Watson, I want you . . .". The fact that Watson heard them and rushed through to Bell's room was the start of something big. They took out a patent on their telephone system in 1876, and the invention was recognized by the confederation of the Volta Medal on Bell in 1880 by the French Government. By this time, the Bell Corporation was being set up to exploit the invention which in a few years was to change the habits of the whole world.

Enter The Decibel

Bell, at this stage, could have simply retired from active life, content to amass a fortune as President of one of the most important and rapidly-growing corporations in the U.S. It is typical of him that he did not, preferring to devote more time to research and to the twin ideals of developing his invention and of helping the deaf. His work on sound transmission soon highlighted a shortcoming of measurement, that there was no scale of comparative loudness of sound.

From a large number of careful measurements, Bell found that the apparent loudness of a fixed frequency from a telephone receiver was proportional not to the electrical power but to the *logarithm* of the power, and so he proposed a unit for comparative loudness, the logarithm of the power ratio of two signals. This was widely adopted, and named the Bel in his honour, dropping the final "l" to avoid any confusion between unit and name.

The Bel, however, is a larger unit, and just as we use microfarads instead of farads for measuring capacitance, it's more convenient to use tenths of a Bel, or "decibels", in place of Bels. Unfortunately the decibel is the most abused and least understood of all the units encountered in electronics.

Photos On The Phone . . .

Bell also worked on developments of the telephone system, as always, with a view to helping the deaf to communicate. One notable development, well ahead of its time, was the Photophone of 1880. This was a device to transmit photographic images over a telephone, a forerunner in many ways of the Photofax process and of slowscan TV.

The principle was simple and ingenious. A transparency is fastened to a glass cylinder so that a light can be shone through transparency and glass on to a photocell (using selenium), which is inside the hollow cylinder. The cylinder is spun around, and the photocell is slowly moved from one end to the other, so that varying currents are generated in a circuit connected to the cell as varying amounts of light reach it through the transparency.

These currents could be transmitted over telephone lines, and at the receiver a photographic method was used to recreate the image. A piece of moist sensitized paper (the original sensitizing chemical was potassium iodide) was then wrapped round a metal drum, which was the ground connection of the receiver. The signals from the transmitter were connected to a brush contact, which touched the moist paper as it revolved with the drum. The current flowing through the paper caused the chemical to decompose, leaving a stain (iodine, when potassium iodide is used), and the amount of staining depends on the amount of current. Provided that the receiver drum is synchronized with the transmitter drum, the received image is a reasonably good reproduction of the transmitted one. An incidental advantage is that the picture size can be scaled up or down by making the receiving drum a different size from the transmitting drum.

. . . Letters Down The Line

The Photophone principle was developed into Photofax, and its descendents are still used. Bell followed it up with the Graphophone of 1887, designed to allow writing to be transmitted along telephone lines — and a large part of his receiver principle for this device can now be seen in the form of XY plotters for computers.

Bell died in 1922, the Grand Old Man of the telephone, and to the end a benefactor of the deaf, to whom he left much of the vast fortune he had accummulated. His other monument was the founding of the American Association to Promote Teaching of Speech to the Deaf, now known as the Alexander Graham Bell Association for the Deaf. This institute sponsors a great deal of research, much of it nowadays into electronics, resulting in a constantly improving service to the deaf. In many ways, I think that Bell would be more interested in this than in the whole telephone service if he could return to see it all. **ETI**

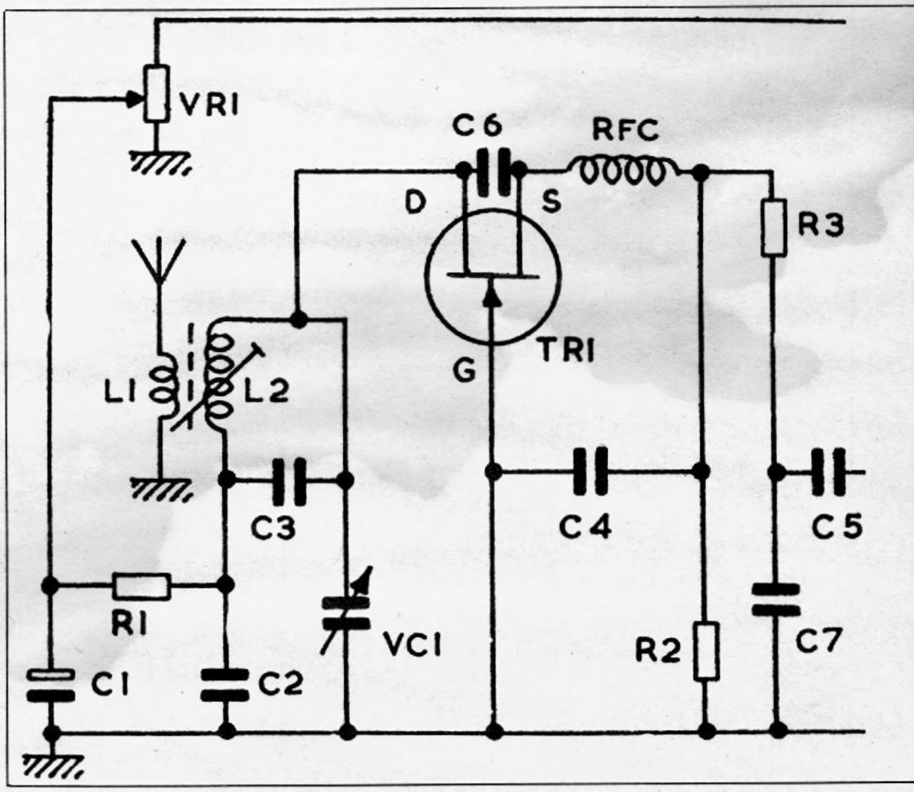
Armstrong

Few of us are aware of the enormous contribution Edwin Armstrong made to the development of radio. Sadly, like many famous inventors, he was bedevilled by legal wrangling over his patents.

THERE'S A VERY hallowed place in radio history not far outside New York City. After you escape from the confusion of Kennedy Airport, you cross the George Washington Bridge and take the green and pleasant Palisades Parkway, which points you towards upper NY State. Not far out, yet in wild, forested country, you'll see a transmitting aerial. Ask, and you'll be told that it is Edwin Armstrong's radio station.

Edwin Armstrong was born in Manhattan, New York, in 1890. His folks were well-to-do: his father a publisher, his mother a former schoolteacher, and between them they fostered in their son a fascination for the mechanical and electrical gadgets with which he was constantly surrounded. The turn of the century in New York was the age of the inventor. A steady stream of inventions were being registered at the US Patent Office, and each was eagerly seized on to be marketed and advertised. In many ways it was an inventor's paradise, but as many were to find out, the paradise had a few traps in it. Young Edwin caught the mood and at the age of 14, decided that he would be an inventor. The newest thing around was radio, and it was this field that Edwin chose, surrounding himself with coils and crystals, earphones and morse keys.

We know very little of what he did in those days, because like many inventors, he was shy and secretive. The next milestone in his career was his entry to Columbia University to study science and engineering — and to chalk his name on the list of radio pioneers long before his studies were complete. Radio at the time (about 1910) had very limited uses, mainly because of the very low sensitivity of receivers. Lee de Forest had just invented his Audion, a three electrode tube of the type we now call a triode, and this permitted some amplification of the feeble signals from a tuned circuit. At university, Armstrong, was able to lay his hands on one of the first of these tubes, and to start making use of it. Within a few months, he had made one of the major discoveries in radio, that of positive feed back.



A modern FET superregenerative receiver similar in operation to Armstrong's circuitry. VR1 controls the regenerative effect, increasing the gain by using positive feedback.

First Milestone — Regeneration

The idea was simple enough. The primitive tube had a very low gain at radio frequencies. Armstrong hit on the idea of feeding the signal back to be amplified again, and he called the idea regeneration. A regeneration receiver was hundreds of times more sensitive than the average receiver of the day, so that Armstrong's invention was undoubtedly one of the milestones in radio progress. It was immensely successful and every radio, from then on, with any pretensions to sensitivity, incorporated regeneration. Armstrong himself had already found out that excessive positive feedback could cause oscillation, and so paved the way for all electronic radio transmitters to replace the crude spark-coil or alternator types which were then used.

It could have, and should have, been the moment of his greatest triumph, but it was soured in a way that was to haunt him for the rest of his life. His patents were challenged by de Forest, and the judges and lawyers, ignorant of the principles involved, ruled that Armstrong's patents were invalid. To its great credit, the scientific community never accepted the legal judgement, and recognised Armstrong with every honour they could bestow. Many inventors from that day on, however, have regarded patent rights as a playground for lawyers and have preferred to get in first with the manufacturing of an invention rather than trust to their ability to profit from licensing agreements.

Second Milestone — The Superheterodyne

At the outbreak of war in 1914, Armstrong was appointed to the US Army Signal Corps to research into improved radio communications. Details of his work are not easy to obtain even now, because of the secrecy which surrounded the 'back-room boys', but one invention of this period is outstanding, and will probably remain so as long as radio is used. Until then, all radio receivers were either crystal sets, using no radio frequency amplification, or tuned radio frequency (TRF) receivers which used coils and capacitors to tune each amplifying stage to the frequency which was being received. TRF receivers are useful up to a point, but they have great disadvantages when large amounts of gain are needed. One disadvantage is that the tuning of each circuit has to be changed whenever a different frequency is wanted. Another is that even very small amounts of signal, if fed back from the output to the input, can make the receiver oscillate and so radiate interference. All this was solved by Armstrong's invention of the superheterodyne (superhet) receiver.

In a superhet receiver, each incoming frequency is tuned, amplified and then converted to an intermediate frequency (IF) by mixing it with a signal from an oscillator. The same IF is used no matter what the input frequency on that particular range happens to be. Tuning becomes easier because there are fewer variable tuned circuits, feedback is less of a menance because the signal which is most likely to feedback (the IF) is not at the same frequency as the input. It's difficult nowdays to imagine radio without superhet receivers: from the pocket transistor radio right through to the mighty radar receiver, all use Armstrong's superhet principle.

This work earned Armstrong more than fame. During the 1914-18 war, he had met David Sarnoff, founder of the Radio Corporation of America. (Armstrong had, in fact, married Sarnoff's secretary). Sarnoff was utterly convinced of the entertainment possibilities of radio, and he bought many of Armstrong's patent rights. In the early twenties, the sudden blossoming of radio as an entertainment medium meant a boom in radio manufacture, and made Armstrong a dollar millionaire because of the royalties which were paid by radio manufacturers.

Third Milestone — Frequency Modulation

Despite his new wealth Edwin Armstrong remained withdrawn, and continued to work at Columbia University. His theme now was the elimination of radio interference, a topic which was to occupy him to the day he died. His work was fruitful: in 1933 he took out patents on the frequency modulation system — FM. The idea of modulating the frequency rather than the amplitude of a radio wave makes it possible to design receivers which are completely insensitive to the amplitude modulation caused by interference. At the time, though, only the Army Signal Corps really saw the usefulness of FM. Armstrong found himself with an uphill struggle to convince even his friends that his new system was capable of providing broadcasting of a quality totally unknown at the time. He began the construction of an FM transmitting station, using his own personal wealth. It swallowed over $300,000 and was completed in 1939 — just in time for the wartime economy drive to make it out of the question to operate the station, or for manufacturers to switch to making FM receivers. Frequency modulation was to prove its value in World War II, however, and once again, Armstrong worked in military research projects.

After the war, FM started to be accepted slowly. The problem was mainly cost, and what boosted sales more than anything else was the new craze for hi-fi which suddenly brought in its wake an appreciation of better quality radio broadcasting. These could have been the days of triumph for Armstrong, but the nightmare which had haunted him from his early years was to recur. Once again, his patents were challenged in the courts, and he was put under the strain of trying to prove technical points to an audience of people who were technically ignorant and antipathetic to the quiet unassuming inventor. To add to his worries, his vast expenditure on FM was not yielding him any return, and in 1954, with his fortune spent and his brilliant invention being tossed about the courts by lawyers, Edwin Armstrong committed suicide.

He left behind him a monument as vast as any man can ever hope for. Every radio receiver and every FM transmitter in the world is the result of Edwin Armstrong's patient and little-publicised achievements. Only his name deserves to be better known. **ETI**

MARCONI-

We celebrate the 100th anniversary of the possible. Here is a brief

Guglielmo Marconi

On December 12, 1901, an event took place on a hill overlooking St. John's, Newfoundland, which was destined to have a profound effect on the social, cultural, political, and economic affairs of all people and nations on earth from that day onward. At 12:30 PM on that cold and blustery day, a handsome young man of 27 worked busily at a table on which an unusual collection of electrical equipment was assembled. The building in which the apparatus was housed barely sheltered him from the harsh winds that blew outside.

The young man held a telephone receiver tightly to his ear, listening intently, his features strained. Suddenly, his expression brightened. He beckoned to his assistant, who had been waiting nearby, and handed him the receiver. "Can you hear anything, Mr. Kemp?" he asked.

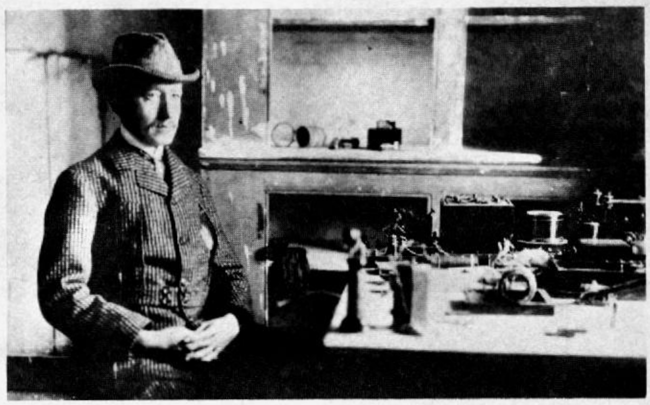
Kemp took the telephone and pressed it to his ear. He listened for several seconds, then he smiled and nodded affirmatively, handing the receiver back to the young man whose name was Guglielmo Marconi.

Both had heard the three faint clicks in the receiver, Morse Code for the letter "S." The signal which produced the clicks had traveled over 2000 miles without wires, having been sent toward its frigid St. John's, Newfoundland destination from Poldhu, near Land's End, in Cornwall, England. The two men, Marconi and Kemp, heard the signals again at 1:10 and 2:20 PM the same day, and at 1:28 PM the following day, Friday, December 13th.

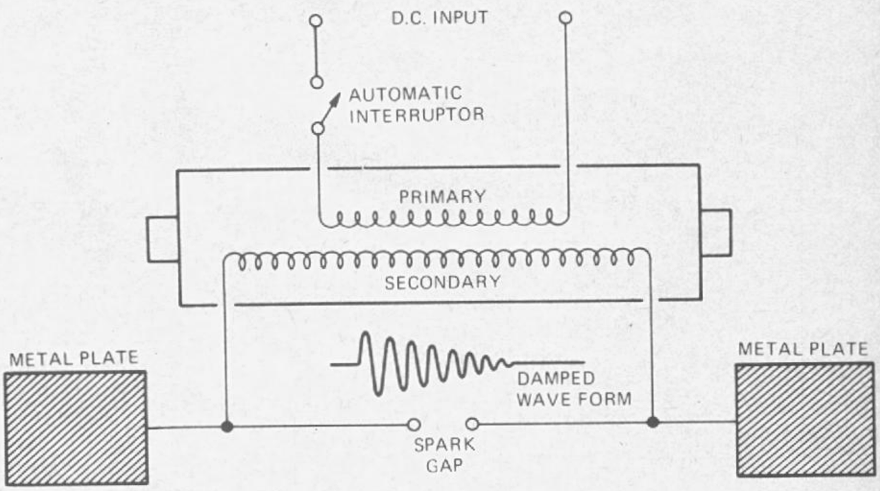
The announcement, given to the press on December 16, 1901, startled the world. Electrical signals had been sent across the Atlantic Ocean without the use of connecting wires!! The experiment, one of the more significant steps forward in the course of human history, climaxed seven years of work by the Italian scientist. The world would never be the same again.

GUGLIELMO MARCONI WAS BORN 100 years ago, on April 25, 1874, in Bologna, northern Italy. His father Giuseppe, was an able and well-to-do businessman. His mother, Annie Jameson, was Irish. She had been born in Dublin, the daughter of Andrew Jameson, who operated one of Ireland's largest whiskey distilleries. Annie had come to Italy to study bel canto. There she met, and later married, Giuseppe.

As a child, Guglielmo had few friends. At the age of five, he went to England with his mother for two years, and his first elementary school education was at a private school in Bedford. For several years thereafter, his education was provided primarily by tutors and by his mother, who taught him in English. He went to school in Florence at age 12, and at 13, attended the Leghorn Technical Institute. In his teens, Marconi attended some of Professor Righi's lectures. Augusto Righi was Italy's leading authority



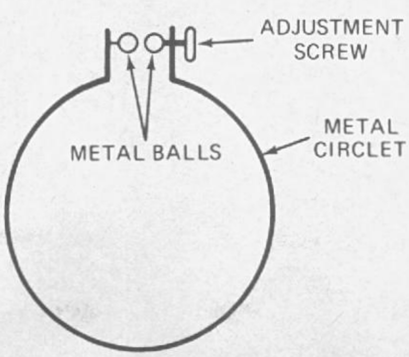
GUGLIELMO MARCONI in his room in the old Barracks Hospital on Signal Hill, St. Johns, Newfoundland. The receiving equipment he used to detect wireless telegraph signals from Cornwall, England—2200 miles away—is on the table.



HERTZ TRANSMITTER

HERTZ TRANSMITTER produced a damped spark chain at the gap as interruptor opened and closed. This induced similar spark chain in receiving loop.

HERTZ RESONATOR OR RECEIVER



on electromagnetic radiation. The lectures stimulated Marconi's interest in electrical phenomena, and by the time he was twenty he had read extensively on the subject.

The turning point in Marconi's life came when, at the age of 20 he read, while on vacation in the Italian Alps, a paper on the experiments of Heinrich Hertz. Using a battery, an induction coil, a switch, and a pair of metal plates with a spark gap between them, Hertz had produced an electrical dis-

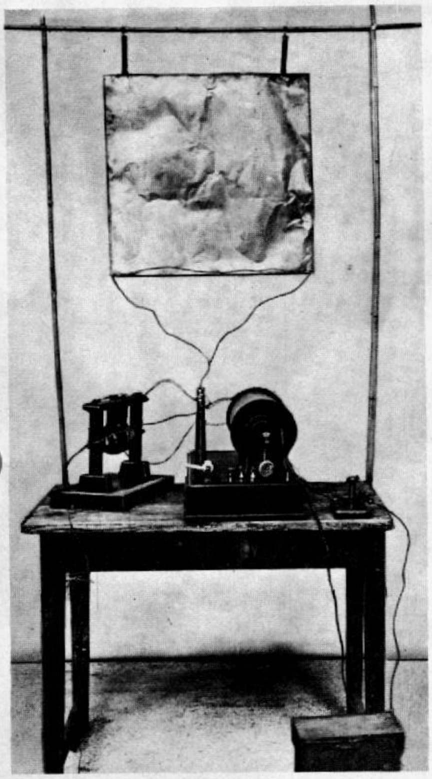
100th ANNIVERSARY

birth of the pioneer who made transatlantic radiotelegraphy
chronicle of events leading to the breakthrough

by STANLEY LEINWOLL

charge between the metal plates. The discharge was detected several feet away by a circlet of wire with a small gap in it. When the discharge between the plates occurred, tiny sparks could be observed across the gap in the circlet, indicating that energy had been transferred through space.

Although he knew that a theory had been proposed postulating such waves, Marconi



MARCONI'S FIRST TRANSMITTER in Italy in 1895 looked like this replica.

had not been aware that their existence had been proved experimentally. His imagination fired by the article, young Marconi curtailed his vacation and returned to the family's country estate, the Villa Griffone, outside Bologna. Signora Marconi had given her son a room on the third floor of the estate to use as a workshop and laboratory, and it was in this room that Guglielmo Marconi conducted his first experiments using electromagnetic waves as a means of communicating.

He started by duplicating the apparatus used by Hertz. After several failures, Marconi was successful. Guglielmo's early efforts consisted of modifying the Hertzian apparatus in an attempt to produce bigger sparks at greater distances. He had seen the possibilities immediately: Hertzian waves could potentially be used to transmit and receive messages over great distances without the use of wires!

It was not long before Marconi was able to produce a spark the full length of his room. This done, it became clear to Marconi that further development would have to lie in two directions: to increase the transmission distance of the sparks, and to make these sparks perform a function - to transmit intelligence in some manner. Young Marconi realized that development along these lines would take capital, and he went to his father for it. The elder Marconi was totally against his son's activities initially, but soon saw the commercial possibilities of his son's "wireless" experiments, and he gave the boy a substantial sum of money with which to continue his work.

He started with equipment being used by the others. This included the Hertzian transmitter in the sending circuit, and a receiver which substituted a coherer for Hertz's spark ring. The coherer had been developed by a French physicist, Edouard Branly, who found that if a small glass tube were filled with metal powder, then exposed to electromagnetic waves, the metal particles cohere — that is, their resistance dropped, and they were able to conduct electricity. Branly had used iron filings in his coherer. He used a galvanometer, an instrument designed to detect the flow of electric current, to show the coherer was working.

Although Marconi's new equipment worked, the ranges he obtained with it were comparable to those being achieved by other researchers in the field—a matter of yards at the most. Discouraged, Marconi turned to other electrical research —attempts to pick electricial discharges from thunderstorms using an elevated antenna. A sudden flash of insight inspired Marconi to combine the elevated antenna of the electrical storm experiments with his wireless equipment.

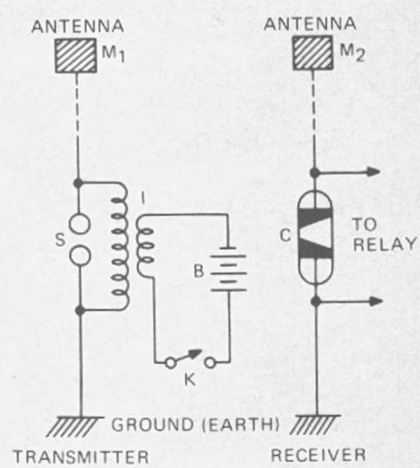
He mounted a copper plate atop a tall mast, and attached it to one end of his Hertzian transmitter. The other end was connected to a copper plate that was buried in the ground. At the receiver, Marconi erected a similar elevated antenna which was connected to one side of a coherer. The other side led to a metal plate in the ground. These modifications led to dramatic increases in the distance to which he could transmit his wireless signals. The grounded antenna, often referred to as a Marconi antenna, was the young inventor's first original contribution to radio, and for many years afterward, the symbol for wireless was an antenna with one end elevated and the other grounded.

The improvement in range was so marked that Marconi had to move his equipment out of doors to continue his experiments. There, he found that the distance he could transmit a signal varied approximately in proportion to the length of the vertical wires, as well as the height of the plates above ground. At this point, Marconi's equipment included a telegraph key and relay, which he had introduced in late 1894 and early 1895 experiments; this enabled him to produce long or short trains of sparks, depending on the length of time the key was depressed. In the receiving circuit, Marconi replaced the galvanometer used by Branly with a battery-operated relay and a Morse inker which recorded the signals being sent. He also introduced a tapper into the coherer circuit. The tapper worked like a hammer in an electric bell. When reception of Hertzian waves caused the coherer's electrical resistance to drop to a low value, an electrical circuit was established between a battery and the tapper. The hammer thereupon gave the coherer a light tap which decohered the metal particles, rendering them nonconducting until another train of waves arrived.

At the time the tapper was introduced, Marconi also introduced an improved coherer. He had found that the Branly tube was too erratic to provide reliable Morse signals, so he devoted considerable time to improving the device. He experimented with 300-400 different combinations of filings and metals before evolving a satisfactory coherer which contained nickel and silver. All of these modifications further improved Marconi's equipment as a communication device.

Each impulse reaching Marconi's receiv-

MARCONI TRANSMITTER AND RECEIVER



M_1, M_2 = Metal Plates
S = Spark Plug
I = Induction Coil
K = Morse Key
B = Battery
C = Coherer

GROUNDED TRANSMITTER AND RECEIVER with elevated antenna were the key to greater communications range.

ing equipment produced the same result: the particles cohered, current flowed, the tapper struck the tube containing the particles which decohered, and current stopped flowing. Using this device, Marconi was able to transmit dots and dashes on a continuing basis, over a distance of about one mile. He soon discovered that by placing the receiving equipment on the far side of a hill, signals could still be received, indicating that the radiation was either traveling through or over the hill.

In 1895, at the age of 21, the young Marconi offered his invention to the Italian Ministry of Posts and Telegraphs, which turned it down because it had no particular use for it. Marconi was told that his equipment would be more useful to a maritime nation because it seemed to lend itself more to communication between ships or between ship and shore. At that time, the world's most powerful maritime nation was England, and with his mother's friends and influential acquaintances in that country, it seemed a most logical place for him to take his wireless.

Marconi arrived in London in February of 1896 with two trunks containing his wireless equipment. Customs officials were suspicious of the young Italian immigrant, fearful that he was an anarchist and that his mysterious apparatus was a bomb, and they proceeded to dismantle his equipment completely. They were then unable to put it together again because some of it had been damaged in the process. Before he was able to proceed with demonstrations, therefore, Marconi had to make some hasty repairs and reassemble his equipment.

The first man to see the Marconi wireless operate in England was his cousin, Henry Jameson-Davis, an influential businessman in his own right; plans were immediately made to patent Marconi's invention. On June 2, 1896, Marconi applied for a patent—the first of its kind—for his wireless telegraph equipment. By this time, Marconi had already contacted several prominent engineers in Great Britain, among them William Henry Preece, chief engineer of the British Post Office. Preece had conducted his own research of telegraphy, and had tried to approach wireless by use of induction techniques which were not successful. He was amazed when he learned of Marconi's achievements. Preece, acting as a watchdog for the Post Office, keeping an eye on what might turn out to be a rival system to the existing line-conductor internal telegraph message carrying, offered to assist Marconi in any way he could. Marconi was interested in the Post Office because it was potentially a valuable customer. The two, therefore, formed an association of mutual convenience. Marconi demonstrated his equipment to officials of the Post Office and the War Office in July and August, 1896, transmitting signals to distances of several hundred yards. This brought a request for further demonstrations, and the equipment was moved to Salisbury Plain, where successful communication over a distance of one and three quarters miles was established. Subsequent tests extended the distance covered over Salisbury Plain to four miles, and a test across Bristol Channel extended the range of the equipment to eight miles.

Marconi used his wireless in 1898 to report the Kingstown Regatta yachting races for the Dublin Express. He followed the racing yachts in a tug which had been specially equipped with wireless equipment, sending back to shore a running commentary of race positions and developments in Morse code. This marked one of the first times wireless had been used for journalistic purposes.

Queen Victoria was so taken with the Kingstown Regatta reporting that she requested that wireless communication be established between her residence at Osborne House, on the Isle of Wight, and the Prince of Wales, who was recovering from an injury aboard the royal yacht Osborne, several miles away. Over 100 messages were exchanged between the queen and the prince, and wide newspaper coverage was given these exchanges.

In 1899, the French Government requested that Marconi conduct tests to determine whether communication between England and the European continent was feasible. The tests, carried out over a 30-mile distance, were a complete success, and were given wide publicity by the many reporters from both countries who witnessed them. At last, wireless was beginning to gain international attention.

In the same year, Marconi came to the United States to conduct a series of tests for the war and navy departments. The American military, satisfied that Marconi's system was the best available, adopted it for use by the army and navy. While in the United States, Marconi gained widespread publicity by reporting the results of the America's Cup yacht races off Sandy Hook.

Although press coverage during Marconi's stay in the United States was excellent, and purchases of Marconi's equipment were made by the U.S. Government, the most significant development of Marconi's visit was the formation, in November, 1899, of Marconi Wireless Telegraph Company of America, which, some two decades later, was to become the Radio Corporation of America.

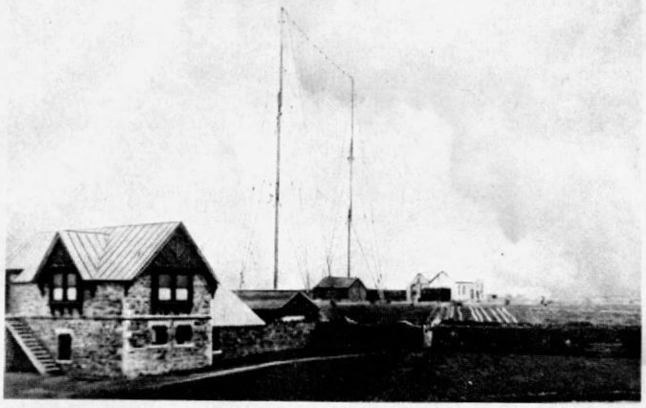
At 25, Guglielmo Marconi had gained what most men fail to achieve in a lifetime—international recognition and respect, wealth, a place in history. But the task was just beginning, and his greatest moments still lay ahead. By 1900, Marconi was experiencing serious competition from foreign sources, particularly from Germany, where Braun, Slaby, and Arco were notable workers. The head start Marconi had gained was being held, but others were close behind, and he needed some innovation that would give him a significant lead.

Frequency selection

One of the biggest problems at that time was co-station interference. Because control of the frequency at which the wireless equipment functioned was virtually nonexistent, it was a frequent occurrence to find that two stations operating in close geographical proximity drowned each other out. There was no way, in 1900, of separating a wanted from an unwanted signal, and since there was no regulation of usage, either geographically or in time, chaotic conditions often arose in which receiving stations could not work efficiently, receiving only a hodge-podge of incoming signals from two or more transmitting stations.

Marconi first addressed himself to the problem by improving his antenna systems, and experimenting with different types of coherers. Some improvement was noted, but it was not enough. It was evident to the young Italian genius that limiting the radiation by narrowing the band of frequencies transmitted was the answer.

The solution to the problem of interference was found by using tuned, or resonant, circuits. The principle of resonance, called "syntony" by Sir Oliver Lodge, who demonstrated it in 1897, made use of virtually identical antennas, inductances, and capacitances in both the transmitter and receiver. Braun had patented a similar device in 1899. But the systems that Lodge and Braun had patented had one serious drawback: very little energy was radiated into space. Two simple yet ingenious innovations by Marconi solved the problem. He coupled the an-



FAN-SHAPED TRANSMITTING ANTENNA used at Poldhu, Cornwall, England to send first transatlantic signals to Signal Hill at St. Johns, Newfoundland. The first—a circular array—came down in a seasonal gale.

MARCONI (extreme left) and assistants launch kite that raised antenna used at Signal Hill, Newfoundland to receive the first wireless signals from across the Atlantic Ocean. Storm made reception very difficult.

tenna inductively to the transmitter, and made both this inductance, as well as the capacitance in the transmitting circuit, variable. These changes enabled him to tune his transmitting circuit to resonance, and the resulting oscillations radiated considerable energy into space.

Marconi then matched his receiving circuits to those at the transmitter, tuning to the frequency being transmitted. No longer did his wireless equipment radiate a broad band of frequencies. By using syntonic circuits with variable inductances and capacitances, stations could operate in the same vicinity and, simply by varying the values of the circuit components, could transmit and receive with greatly reduced interference. As soon as he was certain that syntony was the answer, Marconi applied for an all inclusive patent on his system. On April 26, 1900, one of the most important patents ever granted, the famous No. 7777, was issued to Marconi by the United States. The stage for one of the great experiments of the age was rapidly being set.

Beyond the horizon

Coincident with the work on "syntonic" or tuned circuits, Marconi had become aware of an apparent paradox in connection with his wireless system. He knew that, according to the well-understood laws governing electromagnetic wave propagation, wireless telegraphy ranges should theoretically never greatly exceed optical distances. This is because radio waves, like light waves, travel virtually in straight lines. Therefore, because of the earth's curvature, they would be expected to leave the surface at a tangent to disappear out into space. While diffraction and refraction effects would increase the range to a little beyond the horizon, no significant extension could theoretically be expected.

Scientists of the day were therefore unanimous in declaring that wireless telegraphy communication would be limited to these just-beyond-the-horizon distances. Yet Marconi had found that in practice, he was obtaining ranges which were at least twice those that mathematical calculation indicated. He did not know why this should be so; he only knew that it was.

Encouraged by the 60- to 100-mile ranges he was already getting, Marconi decided to gamble by seeing whether the signals could bridge the Atlantic. The audacity of this scheme can be gathered by remembering that all wireless equipment at that time was small and battery-powered, whereas the transatlantic project would demand a huge power plant and antenna system of a kind of never before visualized. Marconi proposed to erect two such stations, one on each side of the Atlantic, with which he hoped to effect two-way communication,and thereby to deal a mortal blow to the cable companies.

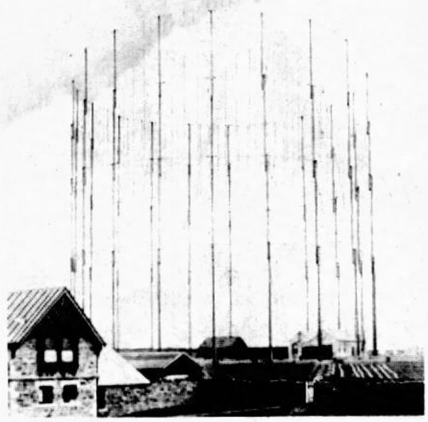
He put his proposal to his board of directors who were far from enthusiastic, for tremendous expenditures were involved and, according to the text books, the scheme could never succeed. At length, however, and with considerable misgivings, the board agreed.

When the news was released, many noted scientists scoffed. The earth was round, Hertzian waves traveled in straight lines, and the signals would be lost in outer space long before they reached their destination. There was no way, they said, that the experiment could succeed. Marconi was stubborn and would not be dissuaded.

To assist him, Marconi engaged the services of an eminent scientist and engineer, J.A. Fleming, who was Professor of Electrical Technology at London University. Fleming, who would later invent the diode dectector, was an expert in the operation of high-power alternating current generators, and was an authority on the work of Maxwell and Hertz, as well. He had duplicated Hertz's experiments, and followed closely the work of Marconi.

In mid-1900, a site at Poldhu, on a finger of land just east of Land's End, Cornwall, was chosen for the transmitter site, and construction was begun in October, 1900, the work being carried out secretly. The size of the Poldhu station was massive. In place of previously used battery power supplies, a 32-horsepower generator was installed to drive a 25-kilowatt alternator, whose output was 2000 volts. This voltage was stepped up to 20,000 volts by a transformer.

The antenna system at Poldhu consisted of 20 wooden masts, each 200 feet high, erected in a circle. Circumferential support was provided by horizontal triatics between each mast, and the guy wires anchoring the masts were broken up and held together with lanyards. From an engineering standpoint, the horizontal support arrangement left much to be desired, because it meant that if one mast were to fall, it would in all probability carry the others down with it. The designers were aware of this shortcoming, but decided the gamble was justified, in view of the relatively low losses the system would have from leakage current. They would need every bit of power possible.



FIRST TRANSMITTING ANTENNA at Poldhu — a circular array — was blown down in gale.

By March, 1901, the Poldhu station was nearly ready, and Marconi, satisfied that things were going well there, sailed with an assistant for the United States. An oceanfront site at South Welfleet, Cape Cod, Massachussetts was chosen, and Marconi left the construction of the receiving equipment and the receiving antenna system, which was identical to that at Poldhu, to an assistant, and he returned to England.

Preliminary tests conducted in the fall of 1901 from Poldhu to Crookhaven, on the west coast of Ireland, were successful. The distance between these points was 225 miles, well beyond the 186-mile record established from Poldhu several weeks before, and indicated once again that the Hertzian waves were not traveling tangent to the curvature of the earth. Since no other possibility was conceived of at the time, it was generally supposed by Marconi and his associates that the signals were traveling along the surface of the earth.

During the period of these preliminary tests, construction of the Cape Cod station continued while the finishing touches were being put to the Poldhu station. Then, in close succession, a double disaster struck. In September, the worst fears of the antenna designers were realized when a severe gale struck the west coast of England,and the antenna system at Poldhu was totally destroyed, with all 20 masts collapsing, leaving a mountain of twisted debris.

Marconi would not be deterred. He immediately ordered the wreckage to be cleared, and an alternate temporary antenna system erected. It consisted of 54 copper elements arranged in a fan shape, and mounted between two 150-foot wooden masts. Within the month, the site had been cleared, and the second array under test. While the tests on the temporary antenna were being conducted, plans were made to substitute a more powerful, permanent antenna. But the test with the temporary system was going so well that Marconi decided not to wait, but to use the alternative instead. Then, just as Marconi was ready to start his transatlantic tests, the second disaster, identical to the first, befell the Cape Cod antenna. In November, 1901, it collapsed in shambles during a northeastern storm. It seemed that fate was conspiring against the inventor.

Marconi decided that he could not wait for the reconstruction of the stateside system. Instead, he and two associates, George S. Kemp and P.W. Paget, set sail for the point of nearest landfall in the Americas—Newfoundland. They carried with them an assortment of wireless equipment, including different receivers and coherers, and antenna accessories, including large canvas kites, balloons, and varying lengths and thicknesses of wire.

Marconi and his associates landed at St. John's on December 6, 1901, and met with Sir Cavendish Boyle, the governor of Newfoundland, and Sir Robert Bond, the Prime Minister, both of whom promised Marconi all possible assistance. They made available to the party an abandoned barracks hospital which lay on a hill some 600 feet above St. John's harbor, facing Poldhu. The location, now called Signal Hill, was not far from where John Cabot, the discoverer of Newfoundland, first landed.

S . . . S . . . S . . . S . . .

By December 9th, Marconi and his assistants had assembled their equipment in a ground floor room of the hospital, and Marconi sent a cable to Poldhu instructing the technicians there to start transmission of test signals on December 11th. They were to send S's—three dots in the Morse code continuously between the hours of 11 AM and 3PM Newfoundland time. The choice of the letter S was made for several reasons. The switching arrangments at Poldhu were not constructed to withstand long periods of operation without considerable wear and tear on the equipment. This was especially so if dashes were to be sent. Furthermore, an automatic transmitting device could be employed if S's were sent. Finally, Marconi felt that three dots would probably be heard

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most easily in the presence of heavy atmospheric noise.

On December 10th, an antenna was sent up, carried by a large kite, in preparation for the tests which were to commence the following day. The operation went smoothly. On December 11th, the weather deteriorated. The wind increased steadily, and by mid-morning a full gale was blowing. Attempts to send an antenna aloft met with failure, and a kite and balloon were lost in the severe winds that lashed the hillside; no signals were heard that day.

The next day, December 12, 1901, the weather continued harsh, and a full gale continued to rage. In spite of the weather, an antenna carried by a kite was sent to an altitude of 400 feet, and Marconi began his listening vigil in the hospital room. But the howling winds made the motion of the kite highly erratic, dipping and soaring like a terrified bird. These sporadic movements altered the angle the antenna made with the earth, as a result of which the characteristics of the antenna were in a constant state of flux. Marconi heard nothing.

He had substituted a telephone receiver for the Morse inker which he had been using. The latter would have given Marconi a printed record of the experiment, but was not as sensitive to signals as the human ear. Marconi had also replaced his syntonic receiver with an older model. Different types of coherer were employed; one of these was to so-called Italian Navy coherer which had been developed by a lieutenant in the Italian Navy, Louigi Solari; it consisted of a glass tube with a plug of iron at one end and carbon at the other, with a globule of mercury between. The device is of particular historic interest because it appears to be a forerunner of the semiconductor rectifiers brought into use nearly half a century later. Semiconductors employ dissimilar materials to rectify current, and the mercury, coated by an oxide layer, constituted the elements of the rectifier.

Marconi listened intently, growing more discouraged by the moment. Suddenly, at 12:30 PM on December 12th, he heard the signals! Uncertain at first, he continued to listen. Soon, there was no doubt. The faint but unmistakable signals were there, and Kemp was shortly to confirm their presence. The series of dots could only be coming from Poldhu, some 2000 miles to the east. Marconi's second assistant, Paget, was ill on December 12th, and was not present; he would regret the illness the rest of his life.

On the following day, signals were heard again faintly for a brief period, in spite of a howling storm that raged. By December 14th, however, it had become apparent that obtaining evidence on the inker was not feasible with the equipment at hand, and that no better receiving apparatus could be erected because of the terrible weather conditions. Marconi then had to decide whether to announce the results to the world. There

:re, after all, no objective witnesses to the complishment. After cabling London with : results, Marconi advised the press on ecember 16th.

Marconi was immediately involved in veral stormy controversies. On December 16th, the Anglo-American Telegraph Company, which had a monopoly on es -carrying activities throughout e ndland, threatened legal action if e experiments were not terminated at nce. Marconi decided not to contest the ction, which could have been costly and meconsuming. The United States or Canada had no such monopolies in existence, and since no significant outlay for receiving equipment had been made in Newfoundland, there did not seem to be much purpose in fighting.

The second, and more far-reaching, controversy involved the accuracy of Marconi's report. In the absence of proof of his claim, many prominent scientists throughout the world expressed doubt about what he actually heard, believing that what he thought were signals could have been caused by heavy static.

It should be pointed out that to this day, a number of responsible and respected scientists believe that no signals were actually heard on December 12, 1901, and that the story was a "myth." Several reasons have been given to support the contention, the most important of which were the primitive nature of the receiving equipment and the wavelength of the signal. Although the exact wavelength was not measured at the time of the experiment, Marconi himself has stated it was about 366 meters (820 kHz).

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In light of our present knowledge of propagation phenomena, the tests took place at the worst possible time, because both the transmission site and the receiving site were in daylight. There is little possibility that the frequency of 820 kHz could propagate over 2000 miles during daylight because absorption by the ionosphere during those hours is at a maximum, and even powers of the order of thousands of kilowatts would not deliver a significant signal over the Atlantic in that frequency range.

G.R.M. Garratt has theorized that reception of the signals did not take place at the frequencies for which the equipment was designed, but at much higher frequencies: the Poldhu transmitter probably radiated considerable higher order harmonics which would be capable of being propagated over a daylight path, since absorption by the ionosphere decreases as the transmission frequency is increased. In view of the fact that radio amateurs of today are frequently capable of signalling across the Atlantic using powers of the order of watts, it is quite likely that Marconi actually heard the historic series of dots on that bleak and dreary day, but on a frequency in the 10,000 to 15,000-kHz range, in the short-wave portion of the electromagnetic spectrum.

Most of the doubts were dispelled less than three months later, when Marconi sailed across the Atlantic from Southampton to New York aboard the liner Philadelphia. The ship was equipped with Marconi's latest syntonic receiving equipment and an antenna lashed to a specially constructed 150-foot mast aboard the ship. A Morse inker recorded signals as they were received, and the captain of the ship verified all observations.

As the ship sailed on, signals continued loud and clear. At a distance of 700 miles, they were being recorded in broad daylight. Beyond that, the Poldhu transmitter could only be heard at night. This was the first observation of the curious nighttime effect which radio amateurs were to observe countless times—that signals traveled much greater distances at night than during the day.

During most of Marconi's historic voyage, signals were being received before witnesses. Poldhu's S's were recorded to a distance of 2099 miles, almost precisely the distance between Poldhu and St. John's. There could no longer be any doubt. The miracle of long distance communication without wires had come to pass. Much of the miracle lay in the fact that this was only the beginning! **R-E**