TELEPHONY

Prehistory of the Telephone

1667 Robert Hooke described the "string telephone", virtually two diaphragms connected by a taut string or wire. In its practical form the diaphragms are of thin wood, clamped at the edges and with an air chamber in front with either a mouthpiece for transmitting or a flexible tube and earpiece for receiving. The wire would be thin-stranded steel wire, taut and with a minimum of intermediate support. The Science Museum, London, has such an instrument supposed to have been used between signal boxes on the Great Eastern Railway.

Turn of 18th - 19th Century Speaking tubes and megaphones known and in use.

1823 Wheatstone proposed in a published paper, "Now Experiments in Sound", and in 1831 actually

1831 demonstrated, the acoustic transmission of musical sounds through solid rods of metal, and predicted optimistically that with homogeneous and non-dispersive materials, long-distance telephony could be accomplished by this means. The word "telephone" was certainly in use by 1841 for this sort of use, and therefore preceded the electrical telephone.

1837 Page (an American) noticed that an electromagnet mounted on a sounding board produced clicks when the current was made or broken.

1854 Bourseul (a Frenchman) published a paper on the transmission of speech, and proposed a flexible disc to make and break the current in a battery circuit when subjected to voice vibrations. At a distant point another disc could be vibrated by the current to reproduce the speech. He appears not to have pursued his experiments.

1860 Philipp Reis of Frankfurt made the musical telephone, using the Page effect by having a transmitter which made and broke current in the way proposed by Bourseul. But it is also claimed (by Denman, Science Museum, London, 1926) that Reis's transmitter was a "loose-contact" device rather than a make and break device, and if this is so, then it must have been the precursor of the carbon-granule microphone.

1865 Alexander Graham Bell (1847-1922) conceived the idea of using different tones to enable several Morse messages to be sent simultaneously on one wire - very like our more modern Voice-frequency Telegraphy. He wanted to use Hermann von Helmholtz's ideas of resonance by using a timing fork as the receiver of each channel.

1874 Bell conceived, but never made, the "electric harp", which had reeds which covered in their resonances the frequency range of the human voice. Speaking into the reeds would cause some of them to vibrate. At the receiving end, a similar system would give some sort of reproduction of the spoken sound.

The electric telephone proper

1875 Bell made his critical discovery that if the voice caused a diaphragm to vibrate an iron armature in the field of an electromagnet, current would be induced in the coil circuit without any battery being required, and that the inverse effect could be used to reproduce the speech. He had not realized that the effects could be so great, and it was a chance observation that brought the magnitude of the effect to his notice. He and his assistant, Thomas Watson, were working with vibrating reeds driven by electromagnets as part of Bell's work in developing multiplex telegraphy. Sometimes the reed would stick to the magnet and had to be freed by hand and set vibrating by plucking. When Watson so plucked a reed at the sending end, Bell noticed that the corresponding reed at the receiving end vibrated also. Thus a mechanically-induced vibration of one would produce vibration currents that were sufficient to drive another vibrator. The implications for telephony struck Bell at once. The way in which this discovery was made and the letters Bell wrote to his financial backer at the time were convincing evidence later when his patents were disputed. (Elisha Gray had also filed a patent for a telephone only a few hours after Bell.)

Initially Bell used electromagnets of rather crude design (see his drawing from his patent specification) and the quality of speech reproduction was very poor - more or less unintelligble.

By 1876 Bell had so improved his design that when shown and demonstrated at the Centennial Exhibition at Philadelphia it won high praise from the judges, Joseph Henry and Sir William Thomson. In 1877 he took a second patent for improvements, which included the use of permanent magnets, and an iron or steel plate in place of the membrane and armature.

It is worth noting in passing that the telephone receiver to this day is still essentially the Bell telephone - merely reduced in size and improved in performance.

The Bell Telephone Association was formed in 1877. It was an unincorporated company comprising Bell, his father-in-law G. G. Hubbard, and T. A. Saunders. Capital initially $300,000. The idea was to license agents throughout the country, who would lease telephones to customers, who would build their own lines, or pay the agents to do so.

The first telephone switchboard was put in service in New Haven, Connecticut, in 1878, connecting 21 telephones. This was a success, and the telephone system expanded rapidly - by 1881 there were 408 exchanges with 48,000 subscribers.

Bell Telephone changed its commercial form frequently, running through operating companies, licensing companies, etc., and turning into the National Bell Telephone Co. in 1879. Shares in the Co. increased in value rapidly. The value of telephony in business and social life was rapidly being realized.

Bell Telephone and Western Union.

The Western Union Telegraph Co. was a large company which Bell approached in 1876, offering his patents for £ 100,000. They declined the offer.

They soon regretted this and came to realize the potential of the telephone. They tried to establish their position in telephony by independent development. They acquired Elisha Gray's patent on the telephone, and they commissioned Thomas Edison to develop a telephone independent of Bell's patent. This he did, and they had the American patents, although Edison operated his system in England with his own company. Edison's transmitter used a carbon contact in which the contact resistance was varied by the voice pressure, which could in this way modulate a strong current and therefore be more powerful than Bell's electromagnetic transmitter. To avoid Bell's patent, Edison also developed a receiver of a quite different kind, using a rotating chalk cylinder, stylus and loudspeaking diaphragm (see biography of Edison) - but this was much less satisfactory than Bell's.

Because W.U.T.Co. had greater resources, they had by 1879 been able to install more telephones than Bell. So the Bell Co. in September 1878 started legal suit against the American Speaking Telephone Co. which was W.U.T.'s telephone subsidiary. W.U.T.'s Counsel advised them that Bell's patent would hold and so by November 1879 an agreement was reached in which W.U.T. agreed to retire from the telephone field and allow the Bell Co. to purchase their telephone interests; but Bell would pay W.U.T. 20% of all rentals and royalties for 17 years.

Later technical developments.

The microphone.

David Hughes (a Londoner who spent most of his life in America) was responsible for the step forward from Edison's transmitter which led directly to the type of microphone still our standard today. It was he who investigated the relation between contact pressure and current, and demonstrated in 1878 how the tramp of a fly could be heard as it walked about on the contacts, and it was he who gave the name "microphone" to the device. Hunnings and Blake in America and Deckert in Britain developed the granular carbon transmitter as such, and in 1892 White of the American Bell Telephone Co. developed the solid-back carbon transmitter, essentially the design still in use.

Telephone switchboards.

Edison's system of switching, developed as part of his English Co.'s enterprise and fitted in London soon after the Bell exchange in New Haven in 1878, comprised sets of vertical and horizontal strips of conductor with holes at the crossing points through which plugs could be passed to make any desired interconnection. Only 24 subscribers could be handled on one board, and so for larger exchanges several boards were needed, with calls handed on from one to another, i.e. two operators at least became involved in most calls.

Bell's switching system was by means of jacks for line terminations and cords with plugs at each end for interconnection. At first the same system of enlarging the exchange was used, involving two or more operators in most calls.

The big advance came with the invention of the subscriber's "multiple", by which, although only a small group of calling lines could be handled by any one operator, all subscriber's lines were available to every operator for connecting into. Evidently Edison's system was not capable of using this idea, but it suited the Bell system well. So from the invention of the multiple in 1883, the cord-type switchboard prevailed.

Of course there had to be much development of detail. E.g., "engaged" indications were necessary when a line was in use. The early clumsy systems of separate indicator boards were replaced about 1895 by lamp indications, and then later by the simple scheme of getting a click in the operator's earpiece when the tip of her calling plug was touched on the outer ring of the jack of an engaged line in the multiple.

A patent of 1892 covered the use of the central battery at the exchange for supplying all current to subscriber's microphones, and this system spread widely, being adopted for new exchanges in Britain from around 1900.

Automatic switching.

The system still effectively used in most automatic exchanges today (though not in new ones) is the Strowger system, patented by A. B. Strowger of Kansas City in 1892. He was an undertaker who got fed up with telephone operators and so worked out a system for doing away with them! It was an electromagnetic system and is generally well-known to everyone. The dial pulses cause switches to step round and/or to connect with the required lines on the switch multiples. It was first tried out at La Porte, Indiana, in 1892, and was working in a 10,000 line exchange in New Bedford, Mass., in 1900.

The economics of automatic exchanges were different then. The capital cost of an automatic exchange was high, and labour was cheap. But as in all industry, the trend is clear and the result inevitable - automation has to come as standards of living rise. Telephone switching will soon be entirely automatic. But then there was much less incentive to automate, and progress was slow.

The earliest exchanges used men and boys, but by 1881 women were replacing them. "With young ladies doing the work the service is very much superior to that of boys and men. They are steadier, do not drink beer, and are always on hand" - contemporary quote!

Telephone lines.

At first all lines were overhead, and towns rapidly became a nightmere of wires. Aerial cables were the first step forward. Later underground cables came into use. The first cables, in 1884, manufactured by Western Electric Co. of Philadelphia, had a dielectric of two wrappings of cotton and were lead covered. The need to reduce capacitance was quickly realized, and J.A.Barrett, of the American Telephone and Telegraph Co. announced in 1889 the invention and development of the use of manilla paper as the dielectric. The "dry-core" or paper cable has been standard ever since.

Long-distance lines and crosstalk.

Naturally telephone communication did not long remain confined to city boundaries, and inter-town links grew. To keep down losses of signal strength, very thick copper conductors on overhead lines had to be used, weighing several hundred pounds per mile, like stair rods. This was expensive - and unsightly.

For shorter distances, underground cables could be used, but not with any success until the principle of "loading" coils was discovered. It was fortunate, in overhead lines, that the condition which Oliver Heaviside worked out in 1887 for distortionless transmission:-

$$\frac{R}{L} = \frac{G}{C}$$

applied fairly closely. But cables necessarily had much higher capacitance and much lower inductance, and the condition could not be met, and consequently the attenuation increased rapidly with frequency.

M. Pupin, a theoretical physicist in the Electrical Engineering Dept. of Columbia University School of Mines, found the solution and announced it in 1889. It consisted in adding inductance coils at regular intervals along each pair in the cable. This made the circuit act like a low-pass filter, giving low attenuation of constant value over the required voice frequency range, with a sharp cut-off above it. This enabled cables to be used effectively over moderate distances. Later, when the thermionic valve permitted amplification at intervals in a cable, cables could be used over very long distances. It was 1915 that valves were first used for this purpose, and transcontinental telephony became possible.

Early telephone systems were single-wire with earth return, but this could not suffice with the growing system, as it introduced crosstalk. Then the crosstalk due to inductive coupling between circuits on the same-route had to be dealt with by introducing transpositions or twists in the system. This later process was invented by Hughes in 1895.

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