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A website of inquiry into the telephone system

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Telephone History Series

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Private Line's Telephone History Part 1 -- to 1830

"We picture inventors as heroes with the genius to recognize and solve a society's problems. In reality, the greatest inventors have been tinkerers who loved tinkering for its own sake and who then had to figure out what, if anything, their devices might be good for." Jared Diamond

I. Introduction

" . . . an inspired black-haired Scotsman of twenty eight, on the eve of marriage, vibrant and alive to new ideas." Alexander Graham Bell : The Life and Times of the Man Who Invented the Telephone

Alexander Graham Bell
1847 to 1922

On March 10, 1876, in Boston, Massachusetts, Alexander Graham Bell invented the telephone. Thomas Watson fashioned the device itself; a crude thing made of a wooden stand, a funnel, a cup of acid, and some copper wire. But these simple parts and the equally simple first telephone call -- "Mr. Watson, come here, I want you!" -- belie a complicated past. Bell filed his application just hours before his competitor, Elisha Gray, filed notice to soon patent a telephone himself. What's more, though neither man had actually built a working telephone, Bell made his telephone operate three weeks later using ideas outlined in Gray's Notice of Invention, methods Bell did not propose in his own patent.

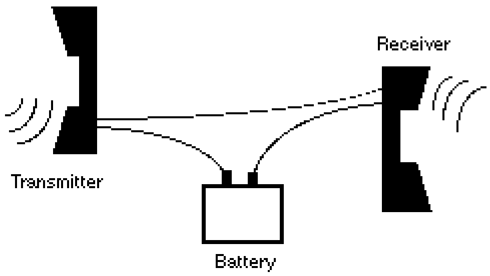
Intrigue aside for now, the story of the telephone is the story of invention itself. Bell developed new and original ideas but did so by building on older ideas and developments. Bell succeeded specifically because he understood acoustics, the study of sound, and something about electricity. Other inventors knew electricity well but little of acoustics. The telephone is a shared accomplishment among many pioneers, therefore, although the credit and rewards were not shared equally. That, too, is often the story of invention.

Telephone comes from the Greek word tele, meaning from afar, and phone, meaning voice or voiced sound. Generally, a telephone is any device which conveys sound over a distance. A string telephone, a megaphone, or a speaking tube might be considered telephonic instruments but for our purposes they are not telephones. These transmit sound mechanically and not electrically. How's that?

Speech is sound in motion. Talking produces acoustic pressure. Speaking into the can of a string telephone, for example, makes the line vibrate, causing sound waves to travel from one end of the stretched line to the other. A telephone by comparison, reproduces sound by electrical means. What the Victorians called "talking by lightning."

A standard dictionary defines the telephone as "an apparatus for reproducing sound, especially that of the voice, at a great distance, by means of electricity; consisting of transmitting and receiving instruments connected by a line or wire which conveys the electric current." Electricity operates the telephone *and* it carries your voice. With that important point established, let's look at telephone history.

Click here for a very large image demonstrating how a telephone works



The telephone is an electrical instrument

Speaking into the transmitter makes its diaphragm vibrate. This varies the electric current, causing the receiver's diaphragm to vibrate. This duplicates the original sound.

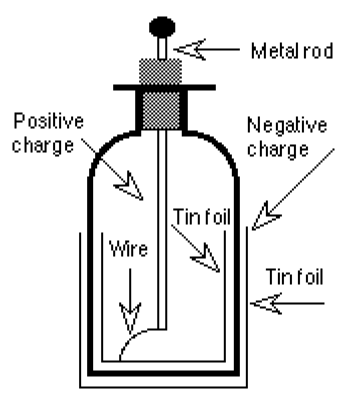
Modern telephones use electret microphones for transmitters and piezoelectric transducers for receivers but the principle described is the same. Sound waves picked up by an electret microphone causes "a thin, metal-coated plastic diaphragm to vibrate, producing variations in an electric field across a tiny air gap between the diaphragm and an electrode."[B] A piezoelectric transducer uses material which converts the mechanical stress of a sound wave upon it into a varying electrical signal.

Telephone history begins, perhaps, at the start of human history. Man has always wanted to communicate from afar. People have used smoke signals, mirrors, jungle drums, carrier pigeons and semaphores to get a message from one point to another. But a phone was something new. Some say Francis Bacon predicted the telephone in 1627, however, his book New Utopia only described a long speaking tube. A real telephone could not be invented until the electrical age began. And even then it didn't seem desirable. The electrical principles needed to build a telephone were known in 1831 but it wasn't until 1854 that Bourseul suggested transmitting speech electrically. And it wasn't until 22 years later in 1876 that the idea became a reality. But before then, a telephone might have been impossible to form in one's consciousness.

While Da Vinci predicted flight and Jules Verne envisioned space travel, people did not lie awake through the centuries dreaming of making a call. How could they? With little knowledge of electricity, let alone the idea that it could carry a conversation, how could people dream of a telephonic future? Who in the fifteenth century might have imagined a pay phone on the street corner or a fax machine on their desk? You didn't have then, an easily visualized goal among people like powered flight, resulting in one inventor after another working through the years to realize a common goal. Telephone development instead was a series of often-disconnected events, mostly electrical, some accidental, that made the telephone possible. I'll cover just a few.

There are many ways to communicate over long distances. I have reproduced a nice color diagram which shows the Roman alphabet, the international flag code, Morse Code, and semaphore signaling. Click here to view

II. Early Telephone Development



Leyden jar

For more information on Leyden jars, including photographs and instructions on how to build them, go this page at the Static Generator site:

http://www.alaska.net/~natnkell/leyden.htm

In 1729 English chemist Stephen Gray transmitted electricity over a wire. He sent charges nearly 300 feet over brass wire and moistened thread. An electrostatic generator powered his experiments, one charge at a time. A few years later, Dutchman Pieter van Musschenbroek and German Ewald Georg von Kleist in 1746 independently developed the Leyden jar, a sort of battery or condenser for storing static electricity. Named for its Holland city of invention, the jar was a glass bottle lined inside and out with tin or lead. The glass sandwiched between the metal sheets stored electricity; a strong charge could be kept for a few days and transported. Over the years these jars were used in countless experiments, lectures, and demonstrations.

In 1753 an anonymous writer, possibly physician Charles Morrison, suggested in The Scot's Magazine that electricity might transmit messages. He thought up a scheme using separate wires to represent each letter. An electrostatic generator, he posited, could electrify each line in turn, attracting a bit of paper by static charge on the other end. By noting which paper letters were attracted one might spell out a message. Needing wires by the dozen, signals got transmitted a mile or two. People labored with telegraphs like this for many decades. Experiments continued slowly until 1800. Many inventors worked alone, misunderstood earlier discoveries, or spent time producing results already achieved. Poor equipment didn't help either. Balky electrostatic generators produced static electricity by friction, often by spinning leather against glass. And while static electricity could make hair stand on end or throw sparks, it couldn't provide the energy to do truly useful things. Inventors and industry needed a reliable and continuous current. In 1800 Alessandro Volta produced the first battery. A major development, Volta's battery provided sustained low powered electric current at high cost. Chemically based, as all batteries are, the battery improved quickly and became the electrical source for further experimenting. But while batteries got more reliable, they still couldn't produce the power needed to work machinery, light cities, or provide heat. And although batteries would work telegraph and telephone systems, and still do, transmitting speech required understanding two related elements, namely, electricity and magnetism.

For an easy to read introduction and a link to a comprehensive article on Volta, visit RjC's site:

http://www.geocities.com/CollegePark/Classroom/8835/index.htm

In 1820 Danish physicist Christian Oersted demonstrated electromagnetism, the critical idea needed to develop electrical power and to communicate. In a famous experiment at his University of Copenhagen classroom, Oersted pushed a compass under a live electric wire. This caused its needle to turn from pointing north, as if acted on by a larger magnet. Oersted discovered that an electric current creates a magnetic field. But could a magnetic field create electricity? If so, a new source of power beckoned. And the principle of electromagnetism, if fully understood and applied, promised a new era of communication

For an excellent summary of Christian Oersted's life, visit:

http://www.mac-med.com/M%26C%20FILES/04maccs.html

In 1821 Michael Faraday reversed Oersted's experiment. He got a weak current to flow in a wire revolving around a permanent magnet. In other words, a magnetic field caused or induced an electric current to flow in a nearby wire. In so doing, Faraday had built the world's first electric generator. Mechanical energy could now be

Michael Faraday
1791 to 1867

converted to electrical energy. Is that clear? This is a very important point.

The simple act of moving ones' hand caused current to move. Mechanical energy into electrical energy. Although many years away, a dynamo powered turbine would let the power of flowing water or burning coal produce electricity. Got a river or a dam? The water spins the turbines which turns the generators which produce electricity. The more water you have the more generators you can add and the more electricity you can produce. Mechanical energy into electrical energy.

(By comparison, a motor turns electrical energy into mechanical energy. Thanks to A. Almoian for pointing out this key difference.)

Faraday worked through different electrical problems in the next ten years, eventually publishing his results on induction in 1831. By that year many people were producing electrical dynamos. But electromagnetism still needed understanding. Someone had to show how to use it for communicating.

For more information on Michael Faraday, visit the Institution of Electrical Engineers at:

http://www.iee.org.uk/publish/faraday/faraday1.html

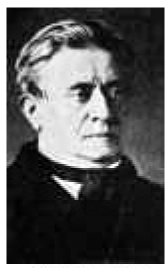
Resources

[B]"Telecommunications Systems: Telephone: THE TELEPHONE INSTRUMENT" Britannica Online. "In modern electret transmitters, developed in the 1970s, the carbon layer is replaced by a thin plastic sheet that has been given a conductive metallic coating on one side. The plastic separates that coating from another metal electrode and maintains an electric field between them. Vibrations caused by speech produce fluctuations in the electric field, which in turn produce small variations in voltage. The voltages are amplified for transmission over the telephone line."

<http://www.eb.com:180/cgi-bin/g?DocF=macro/5006/18/5.html> [Accessed 11 February 1999] 9
(*back to text*)

Private Line's Telephone History Part 2 - 1830 to 1870

In 1830 the great American scientist Professor Joseph Henry transmitted the first practical electrical signal. A short time before Henry had invented the first efficient electromagnet. He also concluded similar thoughts about induction before Faraday but he didn't publish them first. Henry's place in electrical history however, has always been secure, in particular for showing that electromagnetism could do more than create current or pick up heavy weights -- it could communicate.

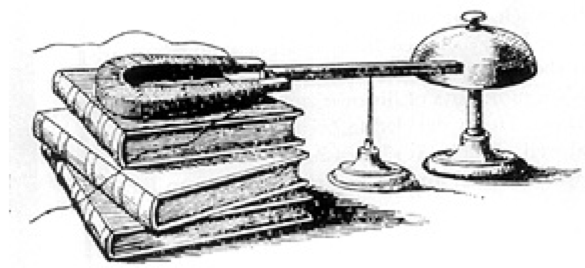


Joseph Henry
1797 to 1878

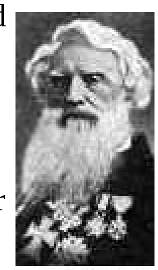
In a stunning demonstration in his Albany Academy classroom, Henry created the forerunner of the telegraph. In the demonstration, Henry first built an electromagnet by winding an iron bar with several feet of wire. A pivot mounted steel bar sat next to the magnet. A bell, in turn, stood next to the bar. From the electromagnet Henry strung a mile of wire around the inside of the classroom. He completed the circuit by connecting the ends of the wires at a battery. Guess what happened? The steel bar swung toward the magnet, of course, striking the bell at the same time. Breaking the connection released the bar and it was free to strike again. And while Henry did not pursue electrical signaling, he did help someone who did. And that man was Samuel Finley Breese Morse.

For more information on Joseph Henry, visit the Joseph Henry Papers Project at:

http://www.si.edu/organiza/offices/archive/ihd/jhp/index.htm



magazine, "a sketch of Henry's primitive telegraph, a dozen years before Morse, reveals the essential components: an electromagnet activated by a distant battery, and a pivoted iron bar that moves to ring a bell."



Samuel Morse
1791 to 1872

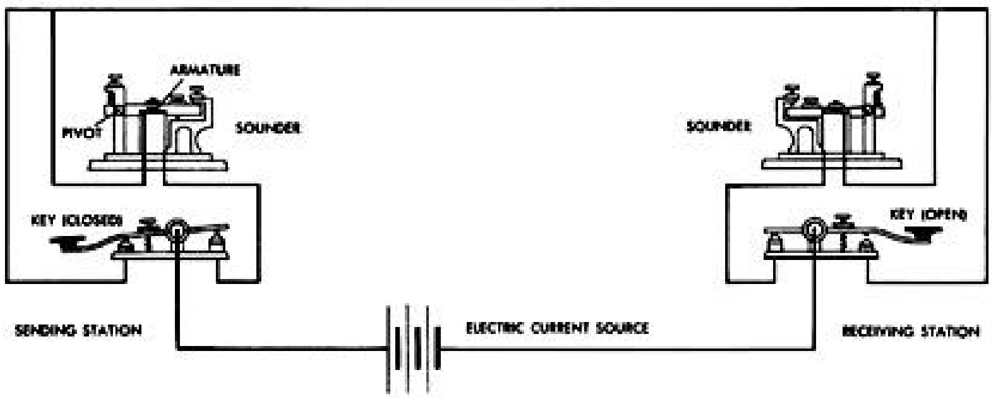
In 1837 Samuel Morse invented the first workable telegraph, applied for its patent in 1838, and was finally granted it in 1848. Joseph Henry helped Morse build a telegraph relay or rep eater that allowed long distance operation. The telegraph later helped unite the country and eventually the world. Not a professional inventor, Morse was nevertheless captivated by electrical experiments. In 1832 he heard of Faraday's recently published work on inductance, and was given an electromagnet at the same time to ponder over. An idea came to him and Morse quickly worked out details for his telegraph.

As depicted below, his system used a key (a switch) to make or break the electrical circuit, a battery to produce power, a single line joining one telegraph station to another and an electromagnetic receiver or sounder that upon being turned on and off, produced a clicking noise. He completed the package by devising the Morse code system of dots and dashes. A quick key tap broke the circuit momentarily, transmitting a short pulse to a distant sounder, interpreted by an operator as a dot. A more lengthy break produced a dash.

Telegraphy became big business as it replaced messengers, the Pony Express, clipper ships and every other slow paced means of communicating. The fact that service was limited to Western Union offices or large firms seemed hardly a problem. After all, communicating over long distances instantly was otherwise impossible. Yet as the telegraph was perfected, man's thoughts turned to speech over a wire.

This site has a small page on Samuel Morse:

http://web.mit.edu/invent/www/inventorsI-Q/morse.html

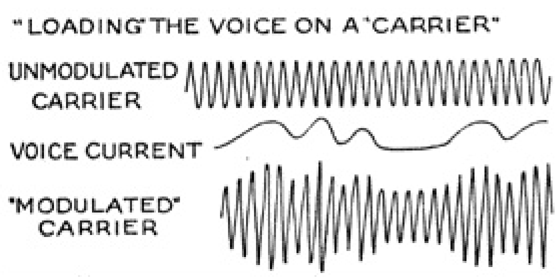


In 1854 Charles Bourseul wrote about transmitting speech electrically in a well-circulated article. In that important paper, the Belgian-born French inventor and engineer described a flexible disk that would make and break an electrical connection to reproduce sound. Bourseul never built an instrument or pursued his ideas further.

For more information on Bourseul and early communications in general, visit this German site:

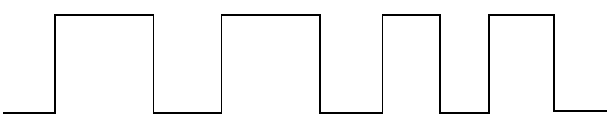
http://www.fht-esslingen.de/telehistory/1870-.html

In 1861 Johann Phillip Reis completed the first non-working telephone. Tantalizingly close to reproducing speech, Reis's instrument conveyed certain sounds, poorly, but no more than that. A German physicist and schoolteacher, Reis's ingenuity was unquestioned. His transmitter and receiver used a cork, a knitting needle, a sausage skin, and a piece of platinum to transmit bits of music and certain other sounds. But intelligible speech could not be reproduced. The problem was simple, minute, and at the same time monumental. His telephone relied on its transmitter's diaphragm making and breaking contact with the electrical circuit, just as Bourseul suggested, and just as the telegraph worked. This approach, however, was completely wrong.



Analog transmission. The unmodulated carrier is simply the electricity your phone operates on, the steady and continuous current your telephone company provides. It carries the conversation. Remember, the telephone is an electrical instrument; electricity works the phone and it carries your voice. When you talk the phone impresses your conversation on the current the telephone company supplies. Conversation causes the current's resistance to go up and down, that is, your voice varies or modulates the carrier, the electricity operating your phone.

Below is a simplified view of a digital signal. Current goes on and off. No wave thing. There was no chance the Reis telephone could transmit intelligible speech since it could not reproduce an analog wave, not by making and breaking a circuit. A pulse in this case is not a wave! It was not until the early 1960s that digital carrier techniques simulated an analog wave with digital pulses. Even then this simulation was only possible by sampling the wave 8,000 times a second. (Producing CD quality sound means sampling an analog signal 44,000 times a second.) In these days all traffic in America between telephone switches is digital, but the majority of local loops are analog, still carrying your voice to the central office on a modulated wave.



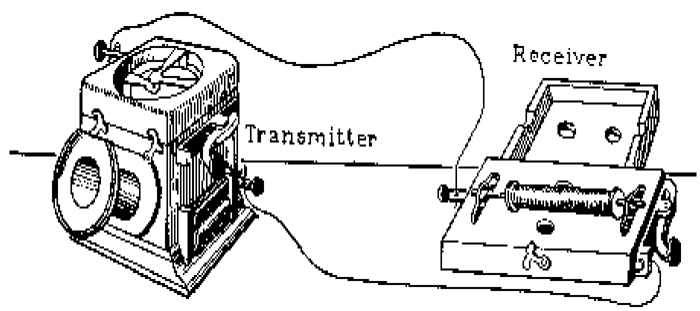
Reproducing speech practically relies on the transmitter making *continuous* contact with the electrical circuit. A transmitter varies the electrical current depending on how much acoustic pressure it gets. Turning the current off and on like a telegraph cannot begin to duplicate speech since speech, once flowing, is a fluctuating wave of continuous character; it is not a collection of off and on again pulses. The Reis instrument, in fact, worked only when sounds were so soft that the contact connecting the transmitter to the circuit remained unbroken. Speech may have traveled first over a Reis telephone however, it would have done so accidentally and against every principle he thought would make it work. And although accidental discovery is the stuff of invention, Reis did not realize his mistake, did not understand the principle behind voice transmission, did not develop his instrument further, nor did he ever claim to have invented the telephone.

The definitive book in English on Reis is:

Thompson, Silvanus P. Phillip Reis: Inventor of The Telephone. E.&F.N. Spon. London. 1883

For other views and explanations of the Reis instrument, visit Adventures in Cybersound:

http://www.cinemedia.net/SFCV-RMIT-Annex/rnaughton/REIS_BIO.html



The Reis telephone instrument

In the early 1870s the world still did not have a working telephone. Inventors focused on telegraph improvements since these had a waiting market. A good, patentable idea might make an inventor millions. Developing a telephone, on the other hand, had no immediate market, if one at all. Elisha Gray, Alexander Graham Bell, as well as many others, were instead trying to develop a multiplexing telegraph - a device to send several messages over one wire at once. Such an instrument would greatly increase traffic without the telegraph company having to build more lines. As it turned out, for both men, the desire to invent one thing turned into a race to invent something altogether different. And that is truly the story of invention.

Private Line's Telephone History Part 3 - 1870 to 1876

III. The Inventors: Gray and Bell

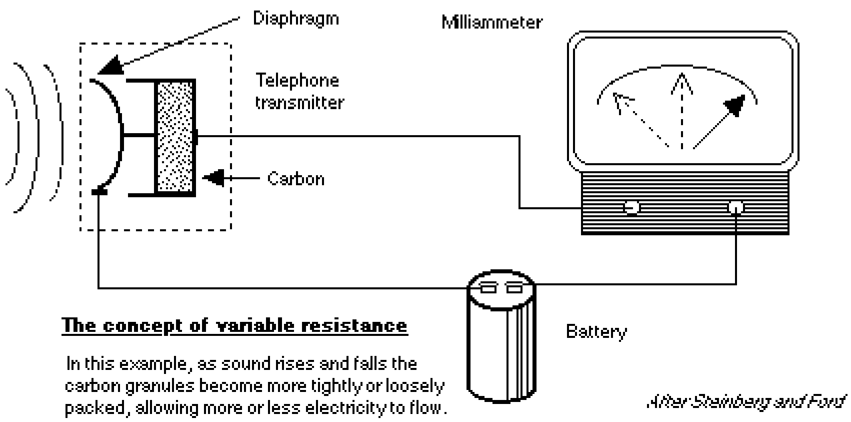
Elisha Gray was a hard working professional inventor with some success to his credit. Born in 1835 in Barnesville, Ohio, Gray was well educated for his time, having worked his way through three years at Oberlin College. His first telegraph related patent came in 1868. An expert electrician, he co-founded Gray and Barton, makers of telegraph equipment. The Western Union Telegraph Company, then funded by the Vanderbilts and J.P. Morgan, bought a one-third interest in Gray and Barton in 1872. They then changed its name to the Western Electric Manufacturing Company, with Gray remaining an important person in the company. To Gray, transmitting speech was an interesting goal but not one of a lifetime.

Alexander Graham Bell, on the other hand, saw telephony as the driving force in his early life. He became consumed with inventing the telephone. Born in 1847 in Edinburgh, Scotland, Graham was raised in a family involved with music and the spoken word. His mother painted and played music. His father originated a system called visible speech that helped the deaf to speak. His grandfather was a lecturer and speech teacher. Bell's college courses included lectures on anatomy and physiology. His entire education and upbringing revolved around the mechanics of speech and sound. Many years after inventing the telephone Bell remarked, "I now realize that I should never have invented the telephone if I had been an electrician. What electrician would have been so foolish as to try any such thing? The advantage I had was that sound had been the study of my life -- the study of vibrations."

In 1870 Bell's father moved his family to Canada after losing two sons to tuberculosis. He hoped the Canadian climate would be healthier. In 1873 Bell became a vocal physiology professor at Boston College. He taught the deaf the visual speech system during the day and at night he worked on what he called a harmonic or musical telegraph. Familiar with acoustics, Bell thought he could send several telegraph messages at once by varying their musical pitch. Sound odd? I'll give you a crude example, a piano analogy, since Watson said Bell played the piano well.

Imagine playing Morse code on the piano, striking dots and dashes in middle C. Then imagine the instrument wired to a distant piano. Striking middle C in one piano might cause middle C to sound in the other. Now, by playing Morse code on the A or C keys at the same time you might get the distant piano to duplicate your playing, sending two messages at once. Maybe. But probably not. Bell didn't experiment with pianos, of course, but with differently pitched magnetic springs. The harmonic telegraph proved simple to think about, yet maddeningly difficult to build. He labored over this device throughout the year and well into the spring of 1874.

Then, at a friend's suggestion, he worked that summer on a teaching aid for the deaf, a gruesome device called the phonoautograph, made out of a dead man's ear. Speaking into the device caused the ear's membrane to vibrate and in turn move a lever. The lever then wrote a wavelike pattern of the speech on smoked glass. Ugh. Many say Bell was fascinated by how the tiny membrane caused the much heavier lever to work. It might be possible, he speculated, to make a membrane work in telephony, by using it to vary an electric current in intensity with the spoken word. Such a current could then replicate speech with another membrane. Bell had discovered the principle of the telephone, the theory of variable resistance, as depicted below. [Brooks] But learning to apply that principle correctly would take him another two years.



For information on how closely Amplitude Modulation relates to the principle of variable resistance, click here

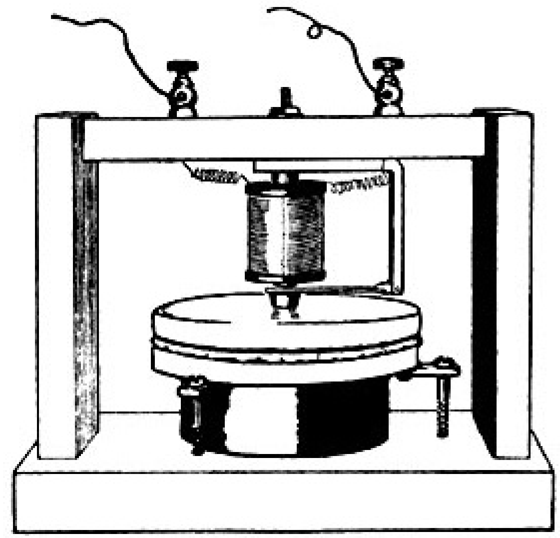
Bell continued harmonic telegraph work through the fall of 1874. He wasn't making much progress but his tinkering gathered attention. Gardiner Greene Hubbard, a prominent Boston lawyer and the president of the Clarke School for The Deaf, became interested in Bell's experiments. He and George Sanders, a prosperous Salem businessman, both sensed Bell might make the harmonic telegraph work. They also knew Bell the man, since Bell tutored Hubbard's daughter and he was helping Sander's deaf five year old son learn to speak.

In October, 1874, Green went to Washington D.C. to conduct a patent search. Finding no invention similar to Bell's proposed harmonic telegraph, Hubbard and Sanders began funding Bell. All three later signed a formal agreement in February, 1875, giving Bell financial backing in return for equal shares from any patents Bell developed. The trio got along but they would have their problems. Sanders would court bankruptcy by investing over $100,000 before any return came to him. Hubbard, on the other hand, discouraged Bell's romance with his daughter until the harmonic telegraph was invented. Bell, in turn, would risk his funding by working so hard on the telephone and by getting engaged to Mabel without Hubbard's permission.

In the spring of 1875, Bell's experimenting picked up quickly with the help of a talented young machinist named Thomas A. Watson. Bell feverishly pursued the harmonic telegraph his backers wanted and the telephone which was now his real interest. Seeking advice, Bell went to Washington D.C. On March 1, 1875, Bell met with Joseph Henry, the great scientist and inventor, then Secretary of the Smithsonian Institution. It was Henry, remember, who pioneered electromagnetism and helped Morse with the telegraph. Uninterested in Bell's telegraph work, Henry did say Bell's ideas on transmitting speech electrically represented "the germ of a great invention." He urged Bell to drop all other work and get on with developing the telephone. Bell said he feared he lacked the necessary electrical knowledge, to which the old man replied, "Get it!" [Grosvenor and Wesson] Bell quit pursuing the harmonic telegraph, at least in spirit, and began working full time on the telephone.

After lengthy experimenting in the spring of 1875, Bell told Watson "If I can get a mechanism which will make a current of electricity vary in its intensity as the air varies in density when a sound is passing through it, I can telegraph any sound, even the sound of speech." [Fagen] He communicated the same idea in a letter to Hubbard, who remained unimpressed and urged Bell to work harder on the telegraph. But having at last articulated the principle of variable resistance, Bell was getting much closer.

On June 2, 1875, Bell and Watson were testing the harmonic telegraph when Bell heard a sound come through the receiver. Instead of transmitting a pulse, which it had refused to do in any case, the telegraph passed on the sound of Watson plucking a tuned spring, one of many set at different pitches. How could that be? Their telegraph, like all others, turned current on and off. But in this instance, a contact screw was set too tightly, allowing current to run continuously, the essential element needed to transmit speech. Bell realized what happened and had Watson build a telephone the next day based on this discovery. The Gallows telephone, so called for its distinctive frame, substituted a diaphragm for the spring. Yet it didn't work. A few odd sounds were transmitted, yet nothing more. No speech. Disheartened, tired, and running out of funds, Bell's experimenting slowed through the remainder of 1875.



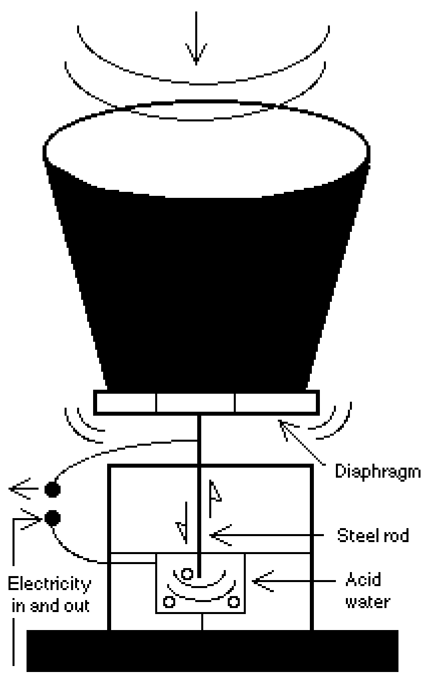
The gallows telephone

During the winter of 1875 and 1876 Bell continued experimenting while writing a telephone patent application. Although he hadn't developed a successful telephone, he felt he could describe how it could be done. With his ideas and methods protected he could then focus on making it work. Fortunately for Bell and many others, the Patent Office in 1870 dropped its requirement that a working model accompany a patent application. On February 14, 1876, Bell's patent application was filed by his attorney. It came only hours before Elisha Gray filed his Notice of Invention for a telephone.

Mystery still surrounds Bell's application and what happened that day. In particular, the key point to Bell's application, the principle of variable resistance, was scrawled in a margin, almost as an afterthought. Some think Bell was told of Gray's Notice then allowed to change his application. That was never proved, despite some 600 lawsuits that would eventually challenge the patent. Finally, on March 10, 1876, one week after his patent was allowed, Bell succeeded in transmitting speech. He was not yet 30. By coincidence or conspiracy, Bell used a liquid transmitter, something he hadn't outlined in his patent or even tried before, but something that was described in Gray's Notice.

The Watson-built telephone looked odd and acted strangely. Bellowing into the funnel caused a small disk or diaphragm at the bottom to move. This disk was, in turn, attached to a wire floating in an acid-filled metal cup. A wire attached to the cup in turn led to a distant receiver. As the wire moved up and down it changed the resistance within the liquid. This now varying current was then sent to the receiver, causing its membrane to vibrate and thereby produce sound. This telephone wasn't quite practical; it got speech across, but badly. Bell soon improved it by using an electromagnetic transmitter, a metal diaphragm and a permanent magnet. The telephone had been invented. Now it was time for it to evolve.

How the first telephone worked



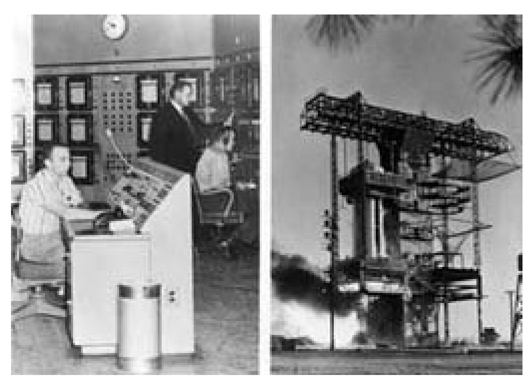
Simplified diagram of Bell's liquid transmitter. The diaphragm vibrated with sound waves, causing a conducting rod to move up and down in a cup of acid water. Battery supplied power electrified the cup of acid. As the rod rose and fell it changed the circuit's resistance. This caused the line current to the receiver (not shown) to fluctuate, which in turn caused the membrane of the receiver to vibrate, producing sound.

This transmitter was quickly dropped in favor of voice powered or induced models. These transmitted speech on the weak electro-magnetic force that the transmitter and receiver's permanent magnets produced.

It was not until 1882, with the introduction of the Blake transmitter, that Bell telephones once again used line power. The so called local battery circuit used a battery supplied at the phone to power the line and take speech to the local switch. Voice powered phones did not go away completely, as some systems continued to be used for critical applications, those which may have been threatened by spark. In 1964 NASA used a voice powered system described as follows:

"A network of 24 channels with a total of more than 450 sound powered telephones, which derive their power solely from the human voice, provide the communications between the East Area central blockhouse (left) and the various test stands at NASA's George C. Marshall Space Flight Center here. . ." The complete article is here:

http://americanhistory.si.edu/scienceservice/007016.htm



Resources

Brooks, John. Telephone: The First Hundred Years. New York: Harper and Row, 1975: 41(*back to text*)

Fagen, M.D., ed. A History of Engineering and Science in the Bell System. Volume 1 The Early Years, 1875 -1925. New York: Bell Telephone Laboratories, 1975, 6 (*back to text*)

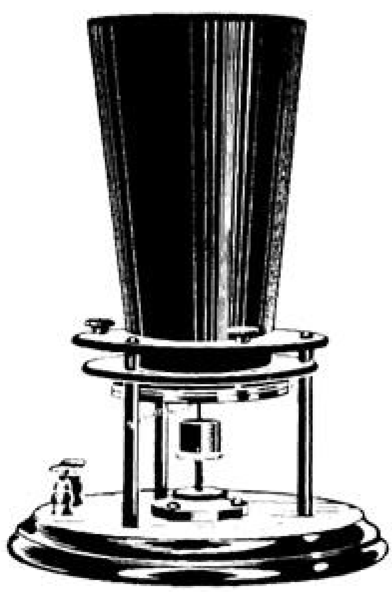
Grosvenor, Edwin S. and Morgan Wesson. Alexander Graham Bell :The Life and Times of the Man Who Invented the Telephone. New York: Abrams, 1997: 55 (*back to text*)

Rhodes, Beginning of Telephony 4-5, 13-14 Bell develops the idea for the telephone

Private Line's Telephone History Part 4 - 1876 to 1892

IV. The Telephone Evolves

At this point telephone history becomes fragmented and hard to follow. Four different but related stories begin: (1) the further history of the telephone instrument and all its parts, (2) the history of the telephone business, (3) the history of telephone related technology and (4) the history of the telephone system. Due to limited space I can cover only some major North American events. Of these, the two most important developments were the invention of the vacuum tube and the transistor; today's telephone system could not have been built without them.



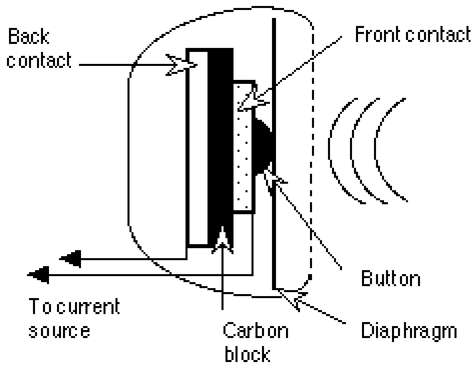
1876 - Bell's original telephone

Progress came slowly after the original invention. Bell and Watson worked constantly on improving the telephone's range. They made their longest call to date on October 9, 1876. It was a distance of only two miles, but they were so overjoyed that later that night they celebrated, doing so much began dancing that their landlady threatened to throw them out. Watson later recalled "Bell . . . had a habit of celebrating by what he called a war dance and I had got so exposed at it that I could do it quite as well as he could." [Watson] The rest of 1876, though, was difficult for Bell and his backers.

Bell and Watson improved the telephone and made better models of it, but these changes weren't enough to turn the telephone from a curiosity into a needed appliance. Promoting and developing the telephone proved far harder than Hubbard, Sanders, or Bell expected. No switchboards existed yet, the telephones were indeed crude and transmission quality was poor. Many questioned why anyone needed a telephone. And despite Bell's patent, broadly covering the entire subject of transmitting speech electrically, many companies sprang up to sell telephones and telephone service. In addition, other people filed applications for telephones and transmitters after Bell's patent was issued. Most claimed Bell's patent couldn't produce a working telephone or that they had a prior claim. Litigation loomed. Fearing financial collapse, Hubbard and Sanders offered in the fall of 1876 to sell their telephone patent rights to Western Union for $100,000. Western Union refused.

(Special thanks to William Farkas of Ontario, Canada for his remarks and corrections)

On April 27, 1877 Thomas Edison filed a patent application for an improved transmitter, a device that made the telephone practical. A major accomplishment, Edison's patent claim was declared in interference to a Notice of Invention for a transmitter filed just two weeks before by Emile Berliner. This conflict was not resolved until 1886 however, Edison decided to produce the transmitter while the matter was disputed. Production began toward the end of 1877. To compete, Bell soon incorporated in their phones an improved transmitter invented by Francis Blake.



Edison's telephone transmitter

This is Edison's carbon block transmitter. It made the telephone practical. It relies on an unusual property of carbon: its conductivity to electricity varies with pressure.

A soft carbon button behind the diaprhagm presses against the front contact. This contact is attached to a line wire. Next comes the carbon and then the back contact. Battery current or line voltage is passed from one contact to another. The diaphragm moves under acoustic pressure, impinging on the front contact. This causes the circuit's resistance to vary, thus converting sound into a varying electrical current.

Blake's transmitter relied on the diaphragm modifying an existing electrical current, an outside power source. This was quite different than the original invention and its improvements. Bell's first telephone transmitter used the human voice to generate a weak electro-magnetic field, which then went to a distant receiver. Bell later installed larger, better magnets into his telephones but there was a limit to what power the human voice could provide, Myer indicating about 10 microwatts. [COMING -- a more detailed explanation of how the earliest telephones worked]

On July 9, 1877 Sanders, Hubbard, and Bell formed the first Bell telephone company. Each assigned their rights under four basic patents to Hubbard's trusteeship. Against tough criticism, Hubbard decided to lease telephones and license franchises, instead of selling them. This had enormous consequences. Instead of making money quickly, dollars would flow in over months, years, and decades. Products were also affected, as a lease arrangement meant telephones needed to be of rental quality, with innovations introduced only when the equipment was virtually trouble free. It proved a wise enough decision to sustain the Bell System for over a hundred years.

In September, 1877 Western Union changed its mind about telephony. They saw it would work and they wanted in, especially after a subsidiary of theirs, the Gold and Stock Telegraphy Company, ripped out their telegraphs and started using Bell telephones. Rather than buying patent rights or licenses from the Bell, Western Union decided to buy patents from others and start their own telephone company. They were not alone. At least 1,730 telephone companies organized and operated in the 17 years Bell was supposed to have a monopoly.

Most competitors disappeared as soon as the Bell Company filed suit against them for patent infringement, but many remained. They either disagreed with Bell's right to the patent, ignored it altogether, or started a phone company because Bell's people would not provide service to their area. In any case, Western Union began entering agreements with Gray, Edison, and Amos E. Dolbear for their telephone inventions. In December, 1877 Western Union created the American Speaking Telephone Company. A tremendous selling point for their telephones was Edison's improved transmitter. Bell Telephone was deeply worried since they had installed only 3,000 phones by the end of 1877. Western Union, on the other hand, had 250,000 miles of telegraph wire strung over 100,000 miles of route. If not stopped, they would have an enormous head start on making telephone service available across the country. Though Western Union was then the world's largest telecom company, with an unchallenged monopoly on telegraph service, Bell's shrewd Boston lawyers filed suit against them the next year.

On January, 28 1878 , the first commercial switchboard began operating in New Haven, Connecticut. It served 21 telephones on 8 lines consequently, many people were on a party line. On February 17, Western Union opened the first large city exchange in San Francisco. No longer limited to people on the same wire, folks could now talk to many others on different lines. The public switched telephone network was born. Other innovations marked 1878.

For a detailed history of telephone exchanges, particularly dial, please see R.B. Hill's excellent history:

http://www.privateline.com/EarlyWork.html

On February 21, 1878, the world's first telephone directory came out, a single paper of only fifty names. George Williard Coy and a group of investors in the New Haven District Telephone Company at 219 Chapel Street produced it. It was followed quickly by a Boston Telephone Dispatch Company's listing. [First directory]

In 1878 President Rutheford B. Hayes administration installed the first telephone in the White House. [First tele] Mary Finch Hoyt reports that the first outgoing call went to Alexander Graham Bell himself, thirteen miles distant. Hayes first words instructed Bell to speak more slowly. [Hoyt]

In that year the Butterstamp telephone came into use. This telephone combined the receiver and transmitter into one handheld unit. You talked into one end, turned the instrument round and listened to the other end. People got confused with this clumsy arrangement, consequently, a telephone with a second transmitter and receiver unit was developed in the same year. You could use either one to talk or listen and you didn't have to turn them around. This wall set used a crank to signal the operator.

The Butterstamp telephone. Picture taken from a great page of telephone pictures. Please visit:

http://www.voicendata.com/aug98/snap.html

For another great page on the earliest commercial telephones go here:

http://www.cybercomm.net/~chuck/coffin.html

On August 1, 1878 Thomas Watson filed for a ringer patent. Similar to Henry's classroom doorbell, a hammer operated by an electromagnet struck two bells. Turning a crank on the calling telephone spun a magneto, producing an alternating or ringing current. Previously, people used a crude thumper to signal the called party, hoping someone would be around to hear it. The ringer was an immediate success. Bell himself became more optimistic about the telephone's future, prophetically writing in 1878 "I believe that in the future, wires will unite the head offices of the Telephone Company in different cities, and that a man in one part of the country may communicate by word of mouth with another in a distant place."

Subscribers, meanwhile, grew steadily but slowly. Sanders had invested $110,000 by early 1878 without any return. He located a group of New Englanders willing to invest but unwilling to do business outside their area. Needing the funding, the Bell Telephone Company reorganized in June, 1878, forming a new Bell Telephone Company as well as the New England Telephone Company, a forerunner of the strong regional Bell companies to come. 10,755 Bell phones were now in service. Reorganizing passed control to an executive committee, ending Hubbard's stewardship but not his overall vision. For Hubbard's last act was to hire a far seeing general manager named Theodore Vail. But the corporate shuffle wasn't over yet. In early 1879 the company reorganized once again, under pressure from patent suits and competition from other companies selling phones with Edison's superior transmitter. Capitalization was $850,000. William H. Forbes was elected to head the board of directors. He soon restructured it to embrace all Bell interests into a single company, the National Bell Company, incorporated on March 13, 1879. Growth was steady enough, however, that in late 1879 the first telephone numbers were used.

On November 10, 1879 Bell won its patent infringement suit against Western Union in the United States Supreme Court. In the resulting settlement, Western Union gave up its telephone patents and the 56,000 phones it managed, in return for 20% of Bell rentals for the 17 year life of Bell's patents. It also retained its telegraph business as before. This decision so enlarged National Bell that a new entity with a new name, American Bell Company, was created on February 20, 1880, capitalized with over seven million dollars. Bell now managed 133,000 telephones. As Chief Operating Officer, Theodore Vail began creating the Bell System, composed of regional companies offering local service, a long distance company providing toll service, and a manufacturing arm providing equipment. For the manufacturer he turned to a previous company rival. In 1880 Vail started buying Western Electric stock and took controlling interest on November, 1881. The takeover was consummated on February 26, 1882, with Western Electric giving up its remaining patent rights as well as agreeing to produce products exclusively for American Bell. It was not until 1885 that Vail would form his long distance telephone company. It was called AT&T.

Example of grounded circuit

On July 19, 1881 Bell was granted a patent for the metallic circuit, the concept of two wires connecting each telephone. Until that time a single iron wire connected telephone subscribers, just like a telegraph circuit. A conversation works over one wire since grounding each end provides a complete path for an electrical circuit. But houses, factories and the telegraph system were all grounding their electrical circuits using the same earth the telephone company employed. A huge amount of static and noise was consequently introduced by using a grounded circuit. A metallic circuit, on the other hand, used two wires to complete the electrical circuit, avoiding the ground altogether and thus providing a better sounding call.

The brilliant J.J. Carty introduced two wireservice commercially in October of that year on a circuit between Boston and Providence. It cut noise greatly over those forty five miles and heralded the beginning of long distance service. Still, it was not until 10 years later that Bell started converting grounded circuits to metallic ones. And ten years after that until completion.

Depending on local conditions and economies, some independent telephone companies did not introduce two wire for decades after. Consider this example from the Magazine Telephone Company of central Arkansas: "After the end of WW II, the R.E.A. System was introduced to the area. This electrification project induced noise into the one wire magneto system that was currently in use by the Telephone Company. Henry [Stone] converted the magneto system to a new system called common battery. Instead of just one wire, common battery required two metallic wires for each circuit."

For a short but well detailed history of an independent telco, visit the Magazine Telephone Company:

http://www.cei.net/~magtel/Magtel/heritage.htm

On February 28, 1885 AT&T was born. Capitalized on only $100,000, American Telephone and Telegraph provided long distance service for American Bell. Only local telephone companies operating under Bell granted licenses could connect to AT&T's long distance network. Vail thought this would continue the Bell System's virtual monopoly after its key patents expired in the 1890s. He reasoned the independents could not compete since they would be isolated and without long distance lines. With licensed companies providing local service, Western Electric manufacturing equipment and AT&T providing long distance, Vail's structuring of the Bell System was now complete.

In September 1887, Vail resigned from American Bell. They lost a great man. He was at odds with Bell's Boston bankers and financiers, people who often ignored an area if profits might be marginal. J. Edward Hyde explained the situation best:

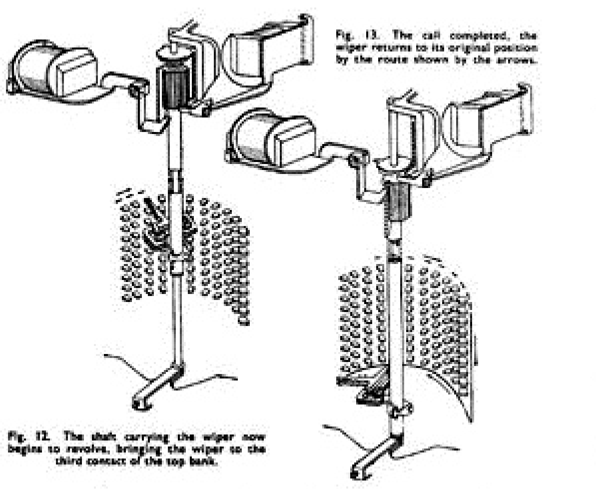
> "The singular worship of profits so disgusted Theodore Vail that he left the Bell Company in 1887. As a parting shot, he wrote: 'We have a duty to the public at large to make our service as good as possible and as universal as possible, and that earnings should be used not only to reward investors for their investment but also to accomplish these objectives.' Bell management thanked him for his comments and wished him a happy retirement. Those he left behind had neither his visionary business sense nor his sensible principles of customer service. Ignoring the protests of customers regarding exorbitant rates and the pleas of rural areas for service at any price, Bell's leadership plundered selected profitable areas during the remaining years of their exclusive ownership without realizing that they were pinning a target on their own chest in the neglected regions. Undoubtedly Bell's management suspected that bad times lay just on the other side of the initial patent expiration. Incredibly, they did nothing to prevent the deluge. In the cities where the Bell had its biggest stake, competitors appeared on nearly every corner."

In 1889 the first public coin telephone came into use in Hartford, Connecticut. The first payphones were attended, with payment going to someone standing nearby.

In 1892 Bell controlled 240,000 telephones. But the independents were coming on fast, especially by using better technology. The first automatic dial system began operating that year in La Porte, Indiana. The central office switch worked in concert with a similar switch at the subscriber's home, operated by push buttons. Patented in 1891 by Almon B. Strowger, this Step by Step or SXS system, replaced the switchboard operator for placing local calls. People could dial the number themselves. The first automatic commercial exchange began operating in La Porte, Indiana in 1892.

Strowger's switch required different kinds of telephones and eventually models with dials. A.E. Keith, J. Erickson and C.J. Erickson later invented the rotating finger-wheel needed for a dial. The first dial telephones began operating in Milwaukee's City Hall in 1896. Independents were quick to start using the new switch and phones.

The Bell System however, did not embrace this switch or automation in general, indeed, a Bell franchise commonly removed "Steppers" and dial telephones in territories it bought from independent telephone companies. Not until 1919 did the Bell System start using Strowgers durable and efficient switching system. This tardiness contributed to Bell's poor reputation around the turn of the century. Almon Strowger went on to help form Automatic Electric, the largest telephone equipment manufacturer for the independent telephone companies.



[First tele] From the official White House web site biography on President Hayes: http://www.whitehouse.gov/WH/glimpse/presidents/html/rh19.html (2000) (*back to text*)

[First directory] Stern and Gwathmey. Once Upon a Telephone: An Illustrated Social History. New York. Harcourt Brace and Company. 1994, 46 [back to text]

[Hoyt] Finch, Mary Hoyt "Hello, This is the White House." Good Housekeeping, June 1986 (back to text)

Watson, Thomas. Exploring Life: The Autobiography of Thomas Alva Watson. New York: D. Appleton and Company. 1926, 95 (*back to text*)

Private Line's Telephone History Part 5 - 1892 to 1921

At this time we should look at Strowger's achievement, before continuing our narrative. The automatic dial system, after all, changed telephony forever. Almon Brown Strowger (pronounced STRO-jer) was born in 1839 in Penfield, New York, a close suburb of Rochester. Like Bell, Strowger was not a professional inventor, but a man with a keen interest in things mechanical. Swihart says he went to an excellent New York State university, served in the Civil War from 1861 to 1865 (ending as a lieutenant), taught school in Kansas and Ohio afterwards, and wound up first in Topeka and then Kansas City as an undertaker in 1886. This unlikely profession of an inventor so inspired seems odd indeed, but the stories surrounding his motivation to invent the automatic switch are odder still.

Thanks to Joe Oster for supplying Strowger's birthplace

The many stories suggest, none of which I can confirm, that someone was stealing Almon Strowger's business. Telephone operators, perhaps in league with his competitors, were routing calls to other undertakers. These operators, supposedly, gave busy signals to customers calling Strowger or even disconnected their calls. Strowger thus invented a system to replace an operator from handling local calls. In the distillation of these many stories, Stephan Lesher relates a story from Almon's time in Topeka:

> "In his book, Good Connections, telephone historian Dave Park writes that Strowger grew darkly suspicious when a close friend in Topeka died and the man's family delivered the body to a rival mortician. Strowger contended that an operator at the new telephone exchange had intentionally directed the call to a competitor -- an allegation that gave rise to tales that the operator was either married to, or the daughter of, a competing undertaker."

Whatever the circumstances, we do know that anti-Bell System sentiment ran high at this time, that good telephone inventions commanded ready money, and that Strowger did have numerous problems with his local telephone company. Strowger was a regular complainer and one complaint stands out.

Swihart describes how Southwestern Bell personnel were called out to once again visit Strowger's business, to fix a dead line. The cause turned out to be a hanging sign which flapped in the breeze against exposed telephone contacts. This shorted the line. Once the sign was removed the line worked again. It may be supposed that this sort of problem was beyond a customer's ability to diagnose, that Strowger had a legitimate complaint. But on this occasion Southwestern Bell's assistant general manager, a one Herman Ritterhoff, was along with the repair crew. Strowger invited the man inside and showed him a model for an automatic switch. So Strowger was working on the problem for quite some time and was no novice to telephone theory.

Brooks says that, in fact, Strowger knew technology so well that he built his patent on Bell system inventions. It must be pointed out, however, that every inventor draws ideas and inspiration from previously done work. Brooks says specifically that the Connolly-McTighe patent (Patent number 222, 458, dated December 9, 1879) helped Strowger, a failed dial switchboard, as well as an early automatic switch developed by Erza Gilliland. But Strowger did not build the instrument since he did not have the mechanical skills. A rather clueless jeweler was employed instead to build the first model, and much time was wasted with this man, getting him to follow instructions.

As with Bell, Strowger filed his patent without having perfected a working invention. Yet he described the switch in sufficient detail and with enough novel points for it to be granted Patent number 447,918, on March 10, 1891. And in a further parallel with Bell, Almon Strowger lost interest in the device once he got it built. It fell upon his brother, Walter S. Strowger, to carry development and promotion further, along with a great man, Joseph Harris, who also helped with promotion and investment money. Without Harris, soon to be the organizer and guiding force behind Automatic Electric, dial service may have taken decades longer for the Bell System to recognize and develop. Competition by A.E. forced the Bell System to play switching catch-up, something they really only accomplished in the 1940s with the introduction of crossbar. And with only a few references to interrupt, let us return to the narrative.

For those interested in a fine one page summary of Almon Strowger, visit

http://www.siemenscom.com/customer/9801/11.html

Need something technical on Strowger's work? Try Hill's work which is in hardcopy. Click here.

I've put R.B. Hill's article on line:

http://www.privateline.com/Switching/EarlyYears.html

In 1893 the first central office exchange with a common battery for talking and signaling began operating in Lexington, Massachusetts. This common battery arrangement provided electricity to all telephones controlled by the central office. Each customer's telephone previously needed its own battery to provide power. Common battery had many consequences, including changing telephone design. The big and bulky wall sets with wet batteries providing power and cranks to signal the operator could be replaced with sleek desk sets. I'll cover telephone design in another chapter, but, briefly, there were four great overlapping eras in telephone development: Invention, Crank, Dial and Handset. They went from, respectively, 1876 to 1893, 1877 to 1943, 1919 to 1978 and 1924 to the present.

For more on common battery and the last manual switchboard to be retired in America, click here

In 1897 Milo Gifford Kellogg founded the Kellogg Switchboard and Supply Company near Chicago. Kellogg was a "graduate engineer and accomplished circuit designer"[Pleasance], who began his career in 1870 with Gray and Barton, equipment manufacturers for Western Electric. There he developed Western Electric's best telephone switchboards: a standard model and a multiple switchboard. Both were invented in 1879 and patented in 1881 and 1884, respectively. He retired from Western Electric in 1885, "and began making and patenting a series of telephone inventions of his own, which work extended over a period of 12 years and which culminated in the issue of 125 patents to him on October 17, 1897, besides which over 25 had previously been issued to him."[Telephony] He was also quite political, successfully winning suits against Bell and delaying other Bell actions to his benefit. Telecom History called him "probably the man in the American independent telephone business who first placed himself in opposition to the Bell Company."[Telephony]

His major accomplishment was the so called divided-multiple switchboard, of which two were built. One was sold to the Cuyahoga Telephone Company of Cleveland, Ohio and the other to the Kinloch Telephone company of Saint Louis. The Cleveland installation boasted 9,600 lines, with an ultimate capacity of 24,000! Such large switchboards were needed to handle increasing demand. The Kellog boards were much larger than Bell equipment, mostly designed by Charles Scribner. Saint Louis and Detroit independents started switching to Kellog boards, "threaten[ing] Bell's profitable urban markets."[Grosvenor] Under such pressure and once again running out of money, Bell regrouped.

In 1899 American Bell Telephone Company reorganized yet once again. In a major change, American Bell Telephone Company conveyed all assets, with the exception of AT&T stock, to the New York state charted American Telephone and Telegraph Company. It was figured that New York had less restrictive corporate laws than Massachusetts. The American Bell Telephone Company name passed into history.

In 1900 loading coils came into use. Patented by Professor Michael I. Pupin, loading coils helped improve long distance transmission. Spaced every three to six thousand feet, cable circuits were extended three to four times their previous length. Essentially a small electro-magnet, a loading coil or inductance coil strengthens the transmission line by decreasing attenuation, the normal loss of signal strength over distance. Wired into the transmission line, these electromagnetic loading coils keep signal strength up as easily as an electromagnet pulls a weight off the ground. But coils must be the right size and carefully spaced to avoid distortion and other transmission problems.

This is an excellent book on loading coils and early long distance working -- a great read:

Wasserman, Neil. From Invention to Innovation: Long Distance Telephone Transmission at The Turn of the Century. John Hopkins University Press. Baltimore: 1985

In 1901 the Automatic Electric Company was formed from Almon Strowger's original company. The only maker of dial telephone equipment at the time, Automatic Electric grew quickly. The Bell System's Western Electric would not sell equipment to the independents, consequently, A.E. and then makers like Kellog and Stromberg-Carlson found ready acceptance. Desperate to fight off the rising independent tide, the Bell System concocted a wild and devious plan. AT&T's president Fredrick Fish approved a secret plan to buy out the Kellog Switchboard and Supply Company and put it under Bell control. Kellog would continue selling their major switchboards to the independents for a year. At that time the Bell System would file a patent suit against Kellog, which they would intentionally loose. This would force the independents to rip out their newly installed switchboards, crushing the largest independents. The plan was discovered, aborted, and further scandalized AT&T.[Grosvenor2]

By 1903 independent telephones numbered 2,000,000 while Bell managed 1,278,000. Bell's reputation for high prices and poor service continued. As bankers got hold of the company, the Bell System faltered.

In 1907 Theodore Vail returned to the AT&T as president, pressured by none other than J.P. Morgan himself, who had gained financial control of the Bell System. A true robber baron, Morgan thought he could turn the Bell System into America's only telephone company. To that end he bought independents by the dozen, adding them to Bell's existing regional telephone companies. The chart shows how AT&T management finally organized the regional holding companies in 1911, a structure that held up over the next seventy years. But Morgan wasn't finished yet. He also worked on buying all of Western Union, acquiring 30% of its stock in 1909, culminating that action by installing Vail as its president. For his part, Vail thought telephone service was a natural monopoly, much as gas or electric service. But he also knew times were changing and that the present system couldn't continue.

In January 1913 the Justice Department informed the Bell System that the company was close to violating the Sherman Antitrust Act. Vail knew things were going badly with the government, especially since the Interstate Commerce Commission had been looking into AT&T acquisitions since 1910. J.P. Morgan died in March, 1913; Vail lost a good ally and the strongest Bell system monopoly advocate. In a radical but visionary move, Vail cut his losses with a bold plan. On December 19, 1913, AT&T agreed to rid itself of Western Union stock, buy no more independent telephone companies without government approval and to finally connect the independents with AT&T's long distance lines. Rather than let the government remake the Bell System, Vail did the job himself.

Known as the Kingsbury agreement for the AT&T vice president who wrote the historic letter of agreement to the Justice Department, Vail ended any plans for a complete telecommunications monopoly. But with the independents paying a fee for each long distance call placed on its network, and with the threat of governmental control eased, the Bell System grew to be a de facto monopoly within the areas it controlled, accomplishing by craft what force could not do. Interestingly, although the Bell System would service eighty three percent of American telephones, it never controlled more than thirty percent of the United States geographical area. To this day, 1,435 independent telephone companies still exist, often serving rural areas the Bell System ignored. Vail's restructuring was so successful it lasted until modern times. In 1976, on the hundredth anniversary of the Bell System, AT&T stood as the richest company on earth.

In 1906 Lee De Forest invented the electron tube. Its amplifying properties led the way to national phone service. Long distance service was still limited. Loading coils helped to a point but no further. Transcontinental phone traffic wasn't possible, consequently, a national network was beyond reach. Something else was needed. In 1907 Theodore Vail instructed AT&T's research staff to build an electronic amplifier based on their own findings and De Forest's pioneering work. They made some progress but not as much as De Forest did on his own.

A nice De Forest biography is at:

http://www.cinemedia.net/SFCV-RMIT-Annex/rnaughton/DE_FOREST_BIO.html

The site also includes the photograph below.

Lee De Forest
1873 to 1961

AT&T eventually bought his patent rights to use the tube as a telephone amplifier. Only after this and a year of inspecting De Forest's equipment did the Bell Telephone Laboratory make the triode, an amplifying electron tube, work for telephony. Those years of research were worth it. The triode in particular and vacuum tubes in general, would make possible radiotelephony, microwave transmission, radar, television, and hundreds of other technologies. Telephone repeaters could now span the country, enabling a nationwide telephone system, fulfilling Alexander Graham Bell's 1878 vision.

Recalling those years in an important interview with the IEEE, Lloyd Espenschied recounts "In May [1907], several of us had gone to a lecture that Lee De Forest had given on wireless at the Brooklyn Institute of Arts and Sciences. In this lecture, he passed around a queer little tube to all the audience. It was the first three-element tube to be shown in public, I found out afterwards. He passed this around and everybody looked at it and said, "So what!" Even De Forest said that he didn't know what it was all about. He looked on it as a detector. Actually it was an evolution of the Fleming valve, but he would never give credit to anyone." Later in the interview, Espenschied gives an opinion of De Forest shared by many at the time, "No, he was no engineer. He was just a playboy all his life. He's just plain lucky that he stumbled into the three-element device. Just plain lucky. But that was handed to him for persevering; he kept at it, grabbing and grabbing at all the patent applications without knowing what he was doing."

For more quotes like the above and a great oral history of early electronic and vacuum tube experimenting:

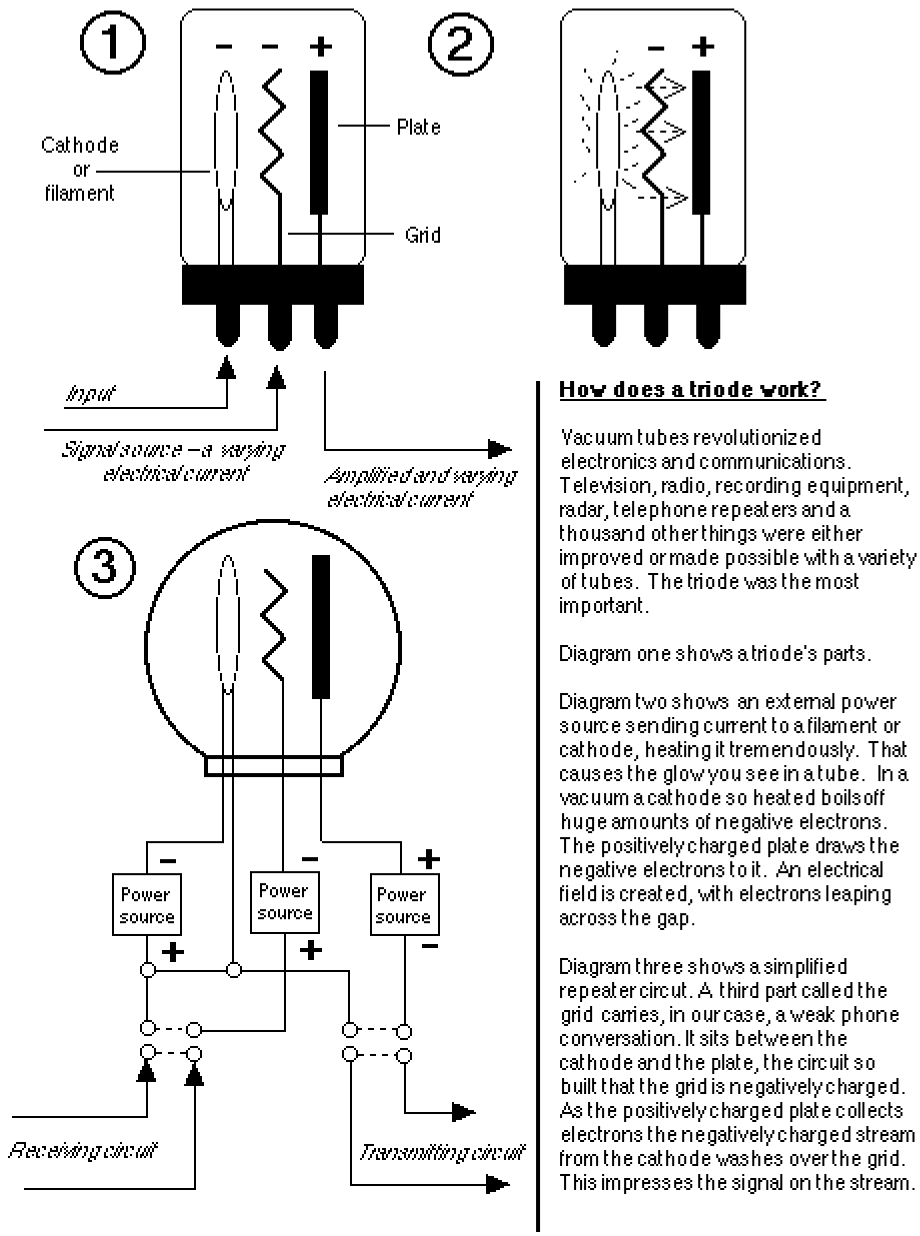
http://www.ieee.org/organizations/history_center/oral_histories/

transcripts/espenschied11.html

The vacuum tube repeater ushered in the electronics age. The device was a true amplifier, powered by an external source, capable of boosting strength as high as needed. A power source provides energy to a filament or cathode within a triode valve or vacuum tube. That's the glow you see in a tube. When heated the cathode gives off huge amounts of negative electrons. A positively charged plate a small distance away draws the negative electrons to it, much like a negative and positive magnet attract each other. An electrical field is formed, causing electrons to leap across the gap. The triode's third part is a grid or control grid, which carries in our case a weak phone conversation. It sits between the cathode and the plate, the circuit so built that the grid becomes negatively charged. As the positively charged plate collects electrons the negatively charged stream from the cathode washes over the grid. The electron stream thus gathers the signal, impressing it on the outgoing flow. While the original signal strength stays the same, it is effectively amplified by being on a higher voltage. Take a moment to ponder the diagram.

Did you know? A triode is sometimes called a thermionic valve. Thermions are electrons derived from a heated source. A valve describes the tube's properties: current flows in one direction but not the other. Think of a faucet, a type of control valve, letting water go in only one direction.

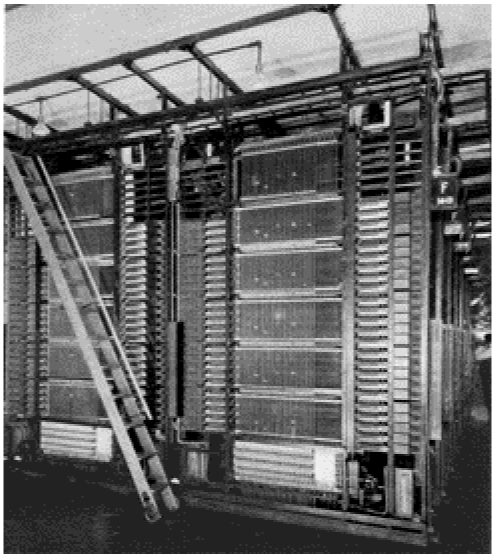
How does a triode work?



Special thanks to John Wong for his gracious help with this vacuum tube explanation

For more comments, read Ray Strackbein's comments below

As evidence of the triode's success, on January 25, 1915 the first transcontinental telephone line opened between New York City and San Francisco. The previous long distance limit was New York to Denver, and only then with some shouting. Two metallic circuits made up the line; it used 2,500 tons of hard-drawn copper wire, 130,000 poles and countless loading coils. Three vacuum tube repeaters along the way boosted the signal. It was the world's longest telephone line. In a grand ceremony, 68 year old Alexander Graham Bell in New York City made the ceremonial first call to his old friend Thomas Watson in San Francisco. In an insult to Lee de Forest, the great inventor was not invited to participate. This insult was carried over to the 1915 World's Fair in San Francisco, in which AT&T's theater exhibit heralded coast to coast telephone service without mentioning the man who made it possible. [Morgan]



In 1921 the Bell System introduced the first commercial panel switch, an odd beast if there ever was one. Developed over eight years, it was AT&T's response to the step by step switch so favored by the independents. It offered many innovations and many problems. Although customers could dial out themselves, the number of parts and its operating method made it noisy for callers. Ironically, some switchmen say it was a quiet machine inside the central office, emanating "a collection of simply delightful 'clinking,' 'whirring' and 'squeak, squeak, squeak' noises." Working like a game of Snakes and Ladders, the switch used selectors to connect calls, these mechanical arms moving up and down in large banks of contacts. When crossbar switching came on the scene in 1938, panel switches were removed where possible, although some remained working until the mid 1970s. Panel became the first defunct switch in the public switched telephone network.

For a wonderful history of early electronic pioneering, click here for a must read interview with Ray Sears:

http://www.ieee.org/organizations/history_center/oral_histories/transcripts/sears.html

Resources

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Grosvenor2. ibid, 167 (back to text)

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ibid 93 (back to text)

Ray Strackbein of http:///www.strackbein.com adds the following comments to the vacuum discussion:

> "On your diagram of the Vacuum Tube, remove the reference to "120 volts" on the filament. Some older tubes used common filaments and cathodes, but a long time ago

(certainly before 1950), someone discovered that since filament voltage was usually A.C., having a separate cathode would reduce the amount of 60-cycle hum being amplified by the tube (whether diode, triode, tetrode, or pentode). The filament voltage was usually 6.3 or 12.6 VAC that came off of the filament winding of the same power transformer that used a different winding to supply the system plate voltage to a rectifier (often a 5U4 vacuum tube) to be filtered with electrolytic capacitors to become reasonably pure DC of between about 200 to 500 VDC."

"The first numbered part of a vacuum tube part number told the voltage on the filament. For example, a 5U4 had a 5-volt filament, a 6SN7, 6AL5, and a 6U8 had 6.3 volt filaments, a 12SN7, 12AX7, and 12AT7 had 12.6 volt filaments. So simply remove that 120 volt filament reference and you will be fine."

Oh yes, I was once the Chief Engineer of a TV station that used 6 tubes in the final circuit that each took 120 Amps at 5 volts on their filaments. They ran rather warm." (back to text)

Private Line's Telephone History Part 6 - 1921 to 1948

In January, 1927, commercial long distance radio-telephone service was introduced between the United States and Great Britain. AT&T and the British Postal Office got it on the air after four years of experimenting. They expanded it later to communicate with Canada, Australia, South Africa, Egypt and Kenya as well as ships at sea. This service had fourteen dedicated channels or frequencies eventually assigned to it. The overseas transmitter was at Rugby, England, and the United States transmitter was at Deal, New Jersey. [BLR] Nearly fifty years would pass before the first telephone cable was laid under the Atlantic, greatly expanding calling capacity. In the next year The Great Depression began, hitting independent telephone companies hard, including the manufacturer Automatic Electric.

Although telephones had been used in the White House for many years, the instrument did not reach the president's desk until the Hoover administration at the start of the Great Depression. "In 1929, when the Executive Offices were remodeled the historic one-position switchboard which had served for so many years was retired from service and a new two-position switchboard, especially built to meet the President's needs, was installed. The number of stations was materially increased in addition to many special circuits for the use of the President. It was at this time a telephone was installed on the President's desk for the first time." [Hoover Library]

Thanks to L. Nickel for researching this point

In 1934 a New Deal measure enacted the Federal Communications Commission, an agency that dogged the Bell System's heels until its end. The FCC began investigating AT&T as well as every other telephone company. The FCC issued a 'Proposed Report' after four years, in which its commissioner excoriated AT&T for, among other things, unjustifiable prices on basic phone service. The commissioner also urged the government to regulate prices the Bell System paid Western Electric for equipment, indeed, even suggesting AT&T should let other companies bid on Western Electric work. The Bell System countered each point of the FCC's report in their 1938 Annual Report, however, it was clear the government was now closely looking at whether the Bell System's structure was good for America. At that time AT&T controlled 83 percent of United States telephones, 91 percent of telephone plant and 98 percent of long distance lines. Only the outbreak of World War II, two and a half months after the final report was issued in 1939, staved off close government scrutiny.

In 1937 coaxial cable was installed between Toledo, Ohio and South Bend, Indiana. Long distance lines began moving underground, a big change from overhead lines carried on poles. In that same year the first commercial messages using carrier techniques were sent through the coax, based on transmission techniques invented by Lloyd Espenschied and Herman A. Affel. Multiplexing let toll circuits carry several calls over one cable simultaneously. It was so successful that by the mid 1950s seventy nine percent of Bell's inter city trunks were multiplexed. The technology eventually moved into the local network, improving to the point where it could carry 13,000 channels at once.

Much telephone progress slowed as World War II began. But one major accomplishment was directly related to it. On May 1, 1943 the longest open wire communication line in the world began operating between Edmonton, Alberta and Fairbanks, Alaska. Built alongside the newly constructed Alaskan Highway, the line was 1500 miles long, used 95,000 poles and featured 23 manned repeater stations. Fearing its radio and submarine cable communications to Alaska might be intercepted by the Japanese, the United States built the line to provide a more secure communication link from Alaska to the United States.

For more information on Lloyd Espenchied's brilliant career, go here:

http://www.ieee.org/organizations/history_center/oral_histories/transcripts/espenschied11.html

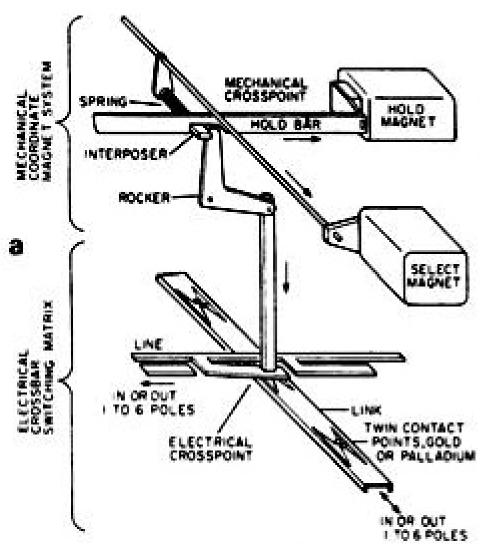
In 1938 retractile, spring, or spiral cords were introduced into the Bell System. A single cotton bundle containing the handset's four wires were fashioned into a spiral. This reduced the twisting and curling of conventional flat or braided cords. Spiral cords were popular immediately. AT&T's Events in Telecommunication History [ETH] reported that introduction began in April, with Western Electric providing 6,000 cords by November. Still, even with W.E. then producing 1,000 cords a week, the cords could not be kept in stock.

Thanks to Cliff Kennedy of Roseville Telephone Company for helping date the spiral cord's introduction

In 1938 the Bell System introduced crossbar switching to the central office, a system as excellent as the panel switch was miserable. The first No. 1 crossbar was cut into service at the Troy Avenue central office in Brooklyn, New York on February 13th.This culminated a trial begun in October 1937. [ETH]A detail of a crossbar switch is shown on the right.

Western Electric's models earned a worldwide reputation for ruggedness and flexibility. AT&T improved on work done by the brilliant Swedish engineer Gotthilf Ansgarius Betulander. They even sent a team to Sweden to look at his crossbar switch. Installed by the hundreds in medium to large cities, crossbar technology advanced in development and popularity until 1978, when over 28 million Bell system lines were connected to one. That compares to panel switching lines which peaked in 1958 at 3,838,000 and step by step lines peaking in 1973 at 24,440,000.

Note the crossbar's watch-like complexity in the diagram. Current moving through the switch moved these electro-mechanical relays back and forth, depending on the dial pulses received. Despite its beauty, these switches were bulky, complicated and costly. The next invention we look at would in time sweep all manual and electro-mechanical switching away.



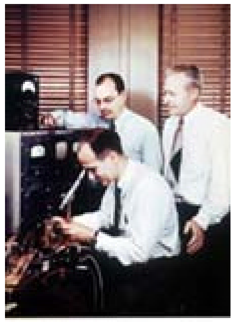
Resources

[BLR] "The Opening of Transatlantic Service on Shortwaves" 6 Bell Laboratories Record 1928: 405 (*back to text*)

[Hoover Library] Personal correspondence from the Hoover Library <library@hoover.nara.gov> to L. Nickel (10/19/2000)" (*back to text*)

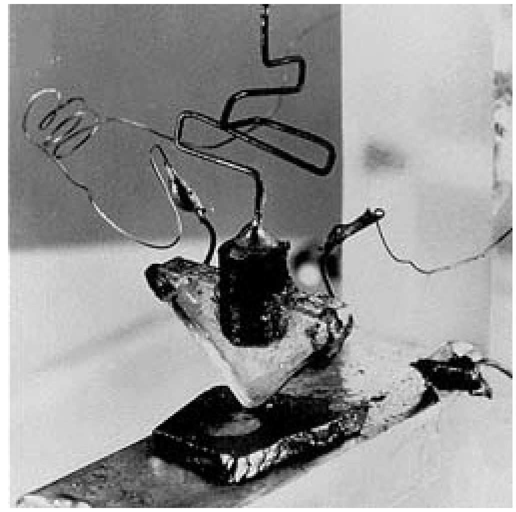
[ETH] Events in Telecommunication History, AT&T Archives Publication: Warren, New Jersey (8.92-2M), p53(*back to text*)

Private Line's Telephone History Part 7 - 1948 to 1951

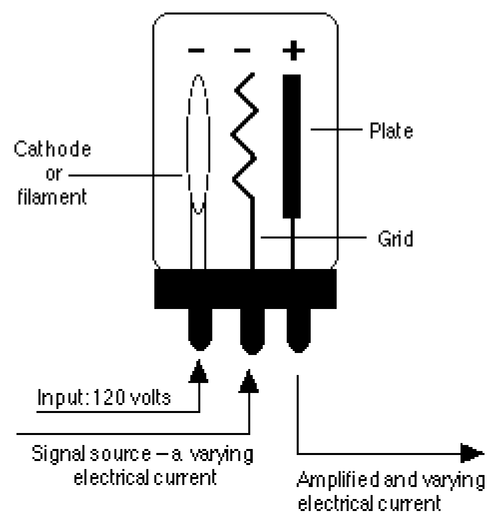


William Shockley 1910 to 1989
John Bardeen 1908 to 1991
Walter Brattain 1902 to 1987

On July 1, 1948 the Bell System unveiled the transistor, a joint invention of Bell Laboratories scientists William Shockley, John Bardeen, and Walter Brattain. It would revolutionize every aspect of the telephone industry and all of communications. One engineer remarked, "Asking us to predict what transistors will do is like asking the man who first put wheels on an ox cart to foresee the automobile, the wristwatch, or the high speed generator." Others were less restrained. In 1954, recently retired Chief of Engineering for AT&T, Dr. Harold Osborne, predicted, "Let us say that in the ultimate, whenever a baby is born anywhere in the world, he is given at birth a number which will be his telephone number for life. As soon as he can talk, he is given a watchlike device with 10 little buttons on one side and a screen on the other. Thus equipped, at any time when he wishes to talk with anyone in the world, he will pull out the device and punch on the keys the number of his friend. Then turning the device over, he will hear the voice of his friend and see his face on the screen, in color and in three dimensions. If he does not see and hear him he will know that the friend is dead." [Conly]Sheesh.



The first transistor looking as crude, perhaps, as the first telephone. Notice how similar the three leads or contacts appear compared to the triode below. The point contact transistor pictured here is now obsolete.



Capitalizing on a flowing stream of electrons, much like the vacuum tube, along with the special characteristics of silicon and germanium, the transistor dependably amplified and switched signals while producing little heat. Equipment size was reduced and reliability increased.

Hearing aids, radios, phonographs, computers, electronic telephone switching equipment, satellites and moon rockets would all be improved or made possible because of the transistor. Let's depart again from the narrative to see how a transistor works.

Transistor stands for transit resistor, the temporary name, now permanent, that the inventors gave it. These semiconductors, like the triode, control the electrical current flowing between two terminals by applying voltage to a third terminal. You now have a miniature switch, presenting either a freeway to electrons or a brick wall to them, depending on whether a signal voltage exists. Bulky mechanical relays that used to switch calls, like the crossbar shown above, could now be replaced with transistors. There's more.

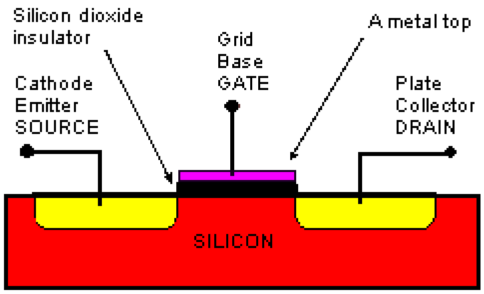
Transistors also amplify. Like the triode described before, a weak signal can be boosted tremendously. Let's say you have ten watts flowing into one side of the transistor. Your current stops because silicon normally isn't a good conductor. You now introduce a signal into the middle of the transistor, say, at one watt. That changes the transistor's internal crystalline structure, causing the silicon to go from an insulator to a conductor. It now allows the larger current to go through, picking up your weak signal along the way, impressing it on the larger voltage. Your one watt signal is now a ten watt signal.

Transistors use the same magnetic principles we've discussed before, "the attractive and repulsive forces between electrical charges." But they also use the properties of semi-conductors, seemingly innocuous materials like geranium and now mostly silicon. Materials like silver and copper conduct electricity well. Rubber and porcelain conduct electricity poorly. The difference between electrical conductors and insulators is their molecular structure, the stuff that makes them up. Weight, size, or shape doesn't matter, it's how tightly the material holds on to its electrons, preventing them from freely flowing through its atoms.

Silicon by itself is an ordinary element, a common part of sand. If you introduce impurities like arsenic or boron, though, you can turn it into a conductor with the right electrical charge. Selectively placing precise impurities into a silicon chip produces an electronic circuit. It's like making a magnetically polarized, multi-layered chemical cake. Vary the ingredients or elements and you can make up many kinds of cakes or transistors. And each will taste or operate a little differently.

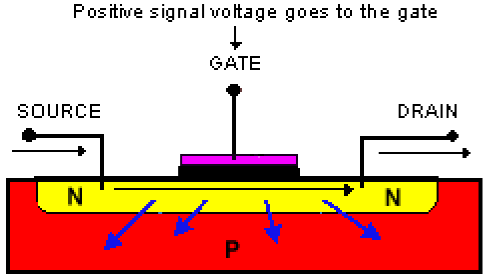
As I've just hinted, there are many kinds of transistors, just as there are many different kinds of tubes. I'll describe just one, a particular kind that amplifies, like the triode tube discussed before. It's the triode's solid state equivalent: the field effect transistor or FET. The FET we'll look at goes by an intimidating name, MOSFET for Metal Oxide Semiconductor Field Effect Transistor. Whew! That's a big name but it describes what it does: a metal topped device working by a phenomenon called a field effect.

A silicon chip makes up the FET. Three separate wires are welded into different parts. These electrode wires conduct electricity. The source wire takes current in and the drain wire takes current out. A third wire is wired into the top. In our example the silicon wafer is positively charged. Further, the manufacturer makes the areas holding the source and drain negative. These two negative areas are thus surrounded by a positive.



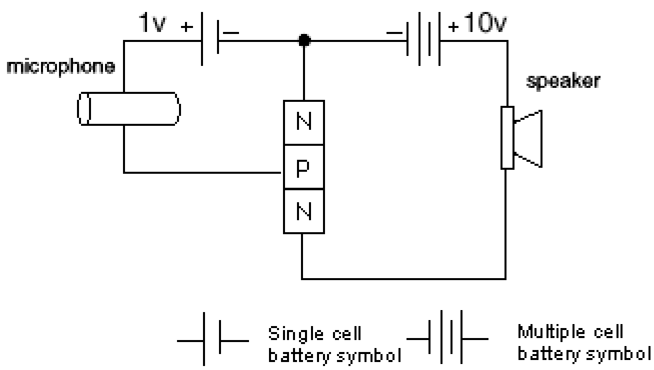
A MOSFET -- one kind of field effect transistor

Positive signal voltage goes to the gate



The two positive charges push each other aside temporarily, letting the current flow through.

Now we introduce our weak signal current, say a telephone call that needs amplifying. The circuit is so arranged that its current is positive. It goes into the gate where it pushes against the positive charge of the silicon chip. That's like two positive magnets pushing against each other. If you've ever tried to hold two like magnets together you know it's hard to do -- there's always a space between them. Similarly, a signal voltage pushing against the chip's positive charge gives space to let the current go from the source to the drain. It picks up the signal along the way. Check out this diagram, modified only slightly from Lucent's excellent site.



As Louis Bloomfield puts it:"The MOSFET goes from being an insulating device when there is no charge on the gate to a conductor when there is charge on the gate! This property allows MOSFETs to amplify signals and control the movements of electric charge, which is why MOSFETs are so useful in electronic devices such as stereos, televisions, and computers."

I know that this is a simple explanation to a forbiddingly difficult topic, but I think it's enough for a history article. Thanks to Australia's John Wong for help with his section. If you'd like to read further, check out Lucent's transistor page by going here:

http://www.lucent.com/ideas2/heritage/transistor/tech.html

Or for something more involved, go here:

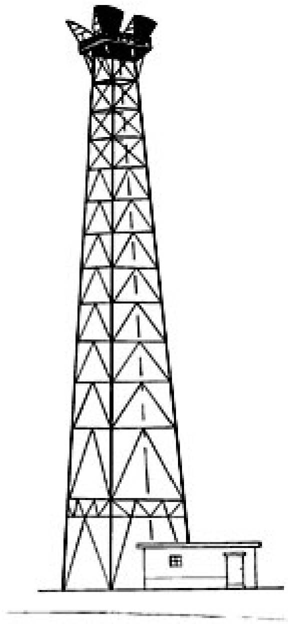
http://landau1.phys.virginia.edu/~lab3e/qsearch.cgi?searchs=transistor&sq=yes

If you have a better explanation or something to add, please e-mail me. And now back to the narrative.

Resources

Conly, Robert L. "New Miracles of the Telephone Age." The National Geographic Magazine. July, 1954. 87 (*back to text*)

Private Line's Telephone History
Part 8 - 1951 to 1974



We come to the 1950s. Dial tone was not universal until this decade in North America, not until direct dialing and automatic switching became common. While dial tone was first introduced into the public switched telephone network in a German city by the Siemens company in 1908, it took decades before being accepted, with the Bell System taking the lead. AT&T used it not only to indicate that a line was free, but also to make the dialing procedure between their automatic and manual exchanges more familiar to their customers. People in manual exchanges placed their calls first through an operator, who listened to the number the caller wanted and then connected the parties together. The Bell System thought dial tone a good substitute for an operator's "Number please" and required this service in all of their automatic exchanges. Before the 1950s most of the independent telephone companies, but not all, also provided dial tone. And, of course, dial tone was not possible on phones such as crank models, in which you signaled an operator who then later connected your call. [Swihart]

On August, 17, 1951 the first transcontinental microwave system began operating. [Bell Laboratories Record] One hundred and seven relay stations spaced about 30 miles apart formed a link from New York to San Francisco. It cost the Bell System $40,000,000; a milestone in their development of radio relay begun in 1947 between New York and Boston. In 1954 over 400 microwave stations were scattered across the country. A Bell System "Cornucopia" tower is shown at left. By 1958 microwave carrier made up 13,000,000 miles of telephone circuits or one quarter of the nations long distance lines. 600 conversations or two television programs could be sent at once over these radio routes.

But what about crossing the seas? Microwave wasn't possible over the ocean and radiotelephony was limited. Years of development lead up to 1956 when the first transatlantic telephone cable system started carrying calls. It cost 42 million dollars. Two coaxial cables about 20 miles apart carried 36 two way circuits. Nearly fifty sophisticated repeaters were spaced from ten to forty miles along the way. Each vacuum tube repeater contained 5,000 parts and cost almost $100,000. The first day this system took 588 calls, 75% more than the previous ten days average with AT&T's transatlantic radio-telephone service.

In the early 1950s The Bell System developed an improved neoprene jacketed telephone cord and shortly after that a PVC or plastic cord. [BLR.] These replaced the cotton covered cords used since telephony began. The wires inside laid parallel to each other instead of being twisted around. That reduced diameter and made them more flexible. Both, though, were flat and non-retractable, only being made into spring cords later. In the authoritative *Dates in American Telephone Technology*, C.D. Hanscom, then historian for Bell Laboratories, stated that the Bell System made the neoprene version available in 1954 and the plastic model available in 1956. These were, the book indicated, the most significant developments in cord technology since 1926, when solderless cord tips came into use.

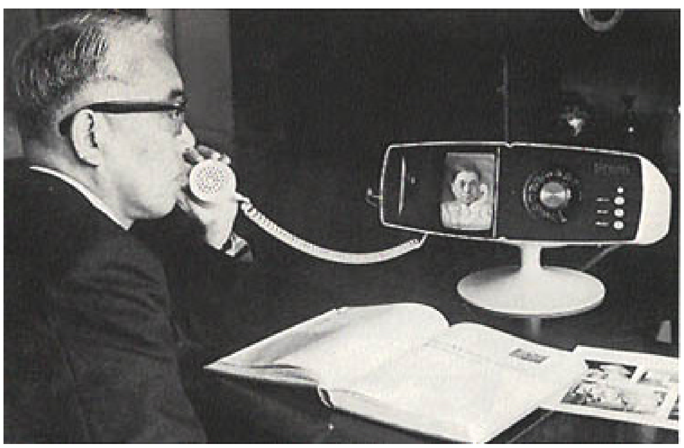
On June 7, 1951, AT&T and International Telephone and Telegraph signed a cross-licensing patent agreement. [Myer] This seemingly dry development marked what Myer says "led to complete standardization in the American telephone industry." Perhaps. I do know that ITT's K-500 phones are completely interchangeable with W.E. Model 500s, so much so that parts can be freely mixed and matched with each other. But whether Automatic Electric and other manufacturers produced interoperable equipment is something I am still researching. It is significant, though, that after seventy-five years of competition the Bell System decided to let other companies use its patents. Myer suggests a 1949 anti-trust suit against WECO and AT&T was responsible for their new attitude. On August 9, 1951 ITT began buying Kellogg stock, eventually acquiring the company. In 1952 the Kellogg Switchboard and Supply company passed into history, merging with ITT. Please click here for an excellent time line on the history of Kellogg.

Thanks to David Mikols for suggesting Kellog research and providing the ITT link

In the mid-50s Bell Labs launched the Essex research project. It concentrated on developing computer controlled switching, based upon using the transistor. It bore first fruit in November, 1963 with the 101 ESS, a PBX or office telephone switch that was partly digital. Despite their computer expertise, AT&T agreed in 1956 under government pressure not to expand their business beyond telephones and transmitting information. Bell Laboratories and Western Electric would not enter such fields as computers and business machines. In return, the Bell System was left intact with a reprieve from anti-monopoly scrutiny for a few years. It is interesting to speculate whether IBM would have dominated computing in the 1960s if AT&T had competed in that market.

In 1955 Automatic Electric merged into General Telephone, retaining its name but falling under a larger corporate umbrella. General was founded in 1926 as Associated Telephone Utilities by Sigurd Odegard. The company went bankrupt during the Great Depression and in 1934 reorganized itself as General Telephone. General had its own manufacturing company, Leich Electric, which began in 1907. Growth was unspectacular until Donald C. Power became president in 1950. He soon bought other companies, building General into a large telecommunications company. After the merger of Automatic Electric, General acquired answering machine producer Electric Secretary Industries in 1957, carrier equipment maker Lenkurt Electric in 1959, and Sylvania Electronics in that same year. In 1959 the newly renamed General Telephone and Electronics provided everything the independent telephone companies might want. Although they were not the exclusive manufacturer for the independents, Automatic Electric was certainly the largest. And where GTE aggressively went after military contracts, the Bell System did not. In the late 1950s, for example, Lenkurt Electric produced most of the armed forces' carrier equipment. GTE lasted until 1982.

The 1960s began a dizzying age of projects, improvements and introductions. In 1961 the Bell System started work on a classic cold war project, finally completed in 1965. It was the first coast to coast atomic bomb blast resistant cable. Intended to survive where the national microwave system might fail, the project buried 2500 reels of coaxial cable in a 4,000 mile long trench. 9300 circuits were helped along by 950 buried concrete repeater stations. Stretched along the 19 state route were 11 manned test centers, buried 50 feet below ground, complete with air filtration, living quarters and food and water. In the same era, the Bell System in 1964 put its star crossed videotelephone into limited commercial service between New York, Washington and Chicago. Despite decades of dreaming, development and desire by Bell scientists, technicians and marketing wonks, the videotelephone never found a market. But some long lived successes marked the age as well.



1968. Even the astute Japanese fell victim to developing picturephones, this model was probably developed by Nippon Telephone and Telegraph; the ultimate picturephone site is here: http://www.bellsystem.com/tribute/video_phone.htm

In 1963 digital carrier techniques were introduced. Previous multiplexing schemes used analog transmission, carrying different channels separated by frequency, much like those used by cable television. T1 or Transmission One, by comparison, reduced analog voice traffic to a series of electrical plots, binary coordinates to represent sound. T1 quickly became the backbone of long distance toll service and then the primary handler of local transmission between central offices. The T1 system handles calls throughout the telephone system to this day. In 1965 the first commercial communications satellite was launched, providing 240 two way telephone circuits. Also in 1965 the 1A1 payphone was introduced by Bell Labs and Western Electric after seven years of development. Replacing the standard three slot payphone design, the 1A1 single slot model was the first major change in coin phones since the 1920s.

In addition, 1965 marked the debut of the No. 1ESS, the Bell Systems first central office computerized switch. The product of at least 10 years of planning, 4,000 man years of research and development, as well as $500 million dollars in costs, the first Electronic Switching System was installed in Succasunna, N.J. Built by Western Electric the 1ESS used 160,000 diodes, 55,000 transistors and 226,000 resistors. These and other components were mounted on thousands of circuit boards. Not a true digital switch, the 1ESS did feature Stored Program Control, a fancy Bell System name for memory, enabling all sorts of new features like speed dialing and call forwarding. Without memory a switch could not perform these functions; previous switches such as crossbar and step by step worked in real time, with each step executed as it happened. The switch proved a success but there were some problems for Bell Labs engineers, particularly when a No.1ESS became overloaded. In those circumstances it tended to fail all at once, rather than breaking down bit by bit.

In June 1968 the FCC allowed non Bell equipment to be legally attached to Bell System lines. Despite restrictions the Bell System would impose on such equipment, many companies started producing products to compete with Western Electric. In 1969 Microwave Communications International began transmitting business calls over their own private network between Saint Louis and Chicago. Bypassing Bell System lines, MCI offered cheaper prices. AT&T bitterly opposed this specialized common carrier service, protesting that Bell System's long distance rates were higher since they subsidized local phone service around the country. Still, MCI was a minor threat, economically. The real problem started a few years later when MCI tried to connect to the Bell System network.

At the end of the 1960s AT&T began experiencing severe customer service problems, especially in New York City. The reasons were many but most had to do with unforeseen demand, coupled with reduced maintenance. The Bell System fixed the problems but not without an attitude that embittered people by the millions. In Boettinger's pro-Bell System history, he recounts the troubles this way: "In 1969, unprecedented jumps in usage and demand caused service deterioration in several large cities. Huge and rapid injections of equipment and personnel trained in accelerated programs were required before quality levels were restored. The experience showed how vital telephones had become to modern life (when even persons on welfare were felt to need a phone) and how frustrations with breakdown led to aggressive behavior." That the Bell System didn't understand how vital telephones were to modern life is beyond understanding; that welfare recipients weren't thought to deserve a phone is beyond acceptance, however, Ma Bell was not alone in dealing with dissatisfied customers. GTE also had problems.

GTE and Automatic Electric went through tremendous growth in the 1960s, with A.E. expanding to four different facilities. In 1969 their California facility in San Carlos made transmission equipment. Switchgear and related equipment came from Northlake and Genoa, Illinois, and telephones and other customer apparatus came from Huntsville, Alabama. Automatic Electric Limited in Canada also produced equipment. A.E.'s research in the 1960s resulted in their first computerized switch being cut into service into Saint Petersburg, Florida in September 1972. It was called the No. 1 EAX (Electronic Automatic Exchange). Growth wasn't handled well, though, by their parent company, General Telephone and Electronics.

GTE was then a poorly managed conglomerate of 23 regional phone companies and a maker of, among other things, televisions and light bulbs. They had their successes and failures. One notable achievement is below.

"Introducing a crimestopper so advanced Dick Tracy doesn't have it yet."

It should come as no news flash to you that there's no one easy way to stop crime.

But it may surprise you to know that a lot of the job is wrapped up in one man. The guy whose job it is to get the police to the scene fast. The police dispatcher.

As the calls come in, he has to track down the radio car closest to the scene.

And that's just for openers.

Because next he has to find out if it's available.

And then get in touch with it by radio.

Which is exactly where our new crimestopper comes in. The digicom system from GTE Sylvania.

Digicom records the availability of all radio cars on a TV screen down at headquarters.

It even records their exact location. (When the radio patrolman touches a spot on his digimap, the same spot lights up on the dispatcher's duplicate map.)

As for the cop on patrol, with digicom in his car, he can actually run five license plate checks a minute directly through the state computer file. And check up on suspicious characters.

Unlike conventional radio, nobody can listen in, and the channels are never congested. Because digicom doesn't transmit voices. It transmits data. Electronically.

Naturally, all of this means a lot to the police, who need all the help they can get nowadays.

The cop on the spot can make faster decisions, because he's better informed.

That goes for the dispatcher, too.

But it also means something to the average citizen.

Knowing which car to send where can not only save time, but lives. And at the very least, can just plain get help to a lot of people fast.

Of course, the police can't carry digicom around with them like Dick Tracy's wrist-radio.

Yet.

GTE
GENERAL TELEPHONE & ELECTRONICS

In1971 General Telephone and Electronics (GTE Sylvania) introduced a data system called Digicom. It let dispatchers identifying patrol car locations on a screen, and allowed officers to run license plate checks. When a patrolman touched a spot on the digicom screen it lit up the same spot on the dispatcher's map. Produced by their Sociosystems Products Organization, I do not know how many units were actually installed by GTE, but it certainly foreshadowed later developments. Today many police departments use cellular digital packet data (CDPD) to run plates and communicate in text with their dispatchers. CDPD runs on existing cellular networks, with data rates no more that 9.6 or 19.2 Kbs, adequate for most purposes but slow when you consider that in the year 2000, 29 years after this system was introduced, we are still laboring with creeping data rates. Click on the image above or here to get the full picture and story. (It's a huge graphic file so be careful: 364K)

GTE had their problems as well, especially with customer service, getting worse and worse through the late sixties, with the company admitting their problems by conducting a highly unusual national magazine ad campaign in November, 1971. The ad in the National Geographic read:

> "A lot of people have been shooting at the telephone companies these days. And, in truth, we've had our hands full keeping up with the zooming demand for increased phone service. But General Telephone and, in all fairness, the other phone companies haven't been sitting around counting dimes. For some time now, we've been paying a healthy 'phone bill' ourselves trying to make our service do everything you expect of it . . . During the next five years we'll be spending over $6 billion upgrading

and expanding every phase of our phone operation . . . Ladies and gentlemen, we're working as fast as brains, manpower and money can combine to make our service as efficient as possible."

And although GTE might not have "sat around counting dimes," GTE's poor service record continued, a reputation that haunts it to this day. Rightly or wrongly, the phone companies, particularly those in the Bell System, watched agog as customer relations got worse. Hacking and toll fraud increased dramatically, as the phone company became fair game, a soulless and uncaring monster to war against. Attacking Ma Bell became common and almost fashionable.

1972 Mad Magazine cartoon. The caption reads: "Stockholders Grow FAT As Telephone Users Go Mad As Rates Rise And Service Flops."

For a short discussion on wireless toll fraud go here

In 1974 the Justice Department began investigating AT&T again for violating antitrust laws. They recommended Western Electric and Long Lines be divested from AT&T. Many people in Justice as well as throughout the country were concerned with the size of AT&T and their monopoly status. Although everyone knew the Bell System provided the best telephone service in the world, it had done so with little or no competition. AT&T's assets stood at 75 billion dollars. Big was not good in the early 1970s, with anti-establishment feeling running high during the Vietnam and Watergate era. Contributing to the Bell System's woes, in July, 1977 the FCC instituted a certification program, whereby any telephone equipment meeting standards could be connected to Bell System's lines. Dozens and then hundreds of manufacturers started competing with Western Electric, making everything from answering machines, modems, fax machines, speakerphones, to differently styled telephones.

During the 1950s, 1960s, and 1970s, Stromberg-Carlson of Rochester, New York and then Lake Mary, Florida, produced a marvelously simple switch known as the X-Y. While an independent phone maker at the turn of the century, Stromberg-Carlson had by the early 70s been acquired by General Dynamics. They were later bought by Rolm and then by Siemens of Germany, who still owns it today. It's new name is Siemens-Stromberg. But back to their switch.

Little known outside the industry, the Stromberg-Carlson X-Y step by step switch solidly competed for business against Strowger technology (manufactured by Automatic Electric and others) in thousands of installations throughout rural America. Some may remain in Mexico and South America. Although the Bell System and many independents preferred the Strowger design for small communities, many telephone companies did not. Strowger equipment often worked reliably for decades but it was more complicated than X-Ys and it required a great deal of preventative maintenance performed by skilled craft workers. Ray Strackbein, who used to work for Stromberg-Carlson, says that X-Ys, by comparison, needed few repairs and fixes were simple. He writes, "I once met a husband-and-wife team that traveled throughout the Great Plains in their Winnebago motor home on a yearly cycle and routined hundreds of X-Y offices each year. They would work Arizona, New Mexico, and Texas in the winter, and Montana, Wyoming, and North Dakota in the summer. Even a Switchman who could not figure out how to wire a doorbell for a central office could maintain a C.O. full of X-Y switches."

Ray then goes on to describe the Stromberg-Carlson X-Y step by step switch, which could be configured or enlarged in blocks of 100 lines:

> "Describing it is rough, but it was a modular switch that was horizontally slid into a vertical bay of shelves. An array of 400 (10X10X4) bare copper wires ran vertically behind the switch for the whole length of the bay. Four circuits were needed to make a connection: Tip, Ring, Sleeve, and Helper Sleeve.
>
> Each switch sat on shelf about 12"X9"X2" (2" high). When someone dialed a number, the retracted switch moved horizontally -- the X direction -- (left-to-right as you faced it from the front), one step for each dial-pulse. Then when the dialed digit stopped pulsing, the switch rapidly extended horizontally away from you as you faced it, with four contacts, one for each circuit -- T, R, S, and HS -- sampling the 10 possible phone trunks for an idle trunk to the next selector.
>
> The design of the X-Y switch was brilliant. Unlike the Strowger that lifted the armature for each dial pulse then rotating through a half-circle to find an idle line, the X-Y switch lifted no weight. The moving switch rested on the plate and moved only horizontally. This made for a switch of a much more simple design than the Strowger." [Strackbein]

Crown Point Telephone Corporation central office with S.C. X-Y switch c. 1950s

Visit the well done, detailed Crown Point Telephone Corporation's company history page

AND

Please visit Ray Strackbien's site

Stromberg-Carlson introduced their first digital switch around 1978, the Stromberg Carlson System Century digital switch. As switches were going digital, so, too, were nearly all electronics in the telecommunication field. Still, a few technological holdouts remained, as the Bell System replaced their last cord switchboard in 1978, on Santa Catalina Island near the coast of Los Angeles, California. That's right, operators still placing calls by hand in the Age of Disco. "[T]he smallest version of Western's 160 toll switchboard" was replaced by a 3ESS, the first Bell switch, incidentally, to be shipped by barge. The city served would have been Avalon. This according to the June, 1978 Bell Laboratories Record and personal correspondence with P. Egly of Santa Rosa, California.

Egly relates the following about Avalon:

> "Tom, Avalon had its own inward operator and I even remember the route, 213 + 012 +... Calls off the island were handled by the same operator using She surely dialed all

> calls in the same way that any of the operators in the LA toll centers did. I am not sure if the trunks to the mainland were by microwave or by cable. "
> "[Since this was a manual exchange] There were no dial phones on Avalon, all were manual magneto service with even the payphones having cranks. Most of the private subscribers had 300 or 500 type sets with dial blanks connected to magneto boxes. The operator rang the subscriber from her board using her ring key to supply ringing current from a standard WECO ring generator."

He goes on to say that the Bell System had a like system in Nevada:

> "There was a similar situation in Virginia City, Nevada with the subscribers having the old walnut and oak magneto phones with local battery. In this case, most subscribers resisted the cutover to dial service, since the magneto phones were quite elegant. . . all polished wood and gleaming brass bells. They were part of the period atmosphere of the town."

This simple switching technology came within six years of outliving the most advanced telephone company on earth. But one manual toll board remained in the public switched telephone network even longer.

[Myers] Myer, Ralph O, 1995, *Old Time Telephones!: Technology, Restoration and Repair*, Tab Books, New York. 123 Excellent. (back to text)

[Swihart, Stanley] Telecom History: The Journal of the Telephone History Institute, Issue 2, Spring 1995 [back to text]

[Strackbein] Personal correspondence with Tom Farley, July 16, 2000. Another comment from Ray: "I didn't know that Strowger was from Penfield. That may partially explain why Stromberg-Carlson located in Rochester. As an aside, there is a building in Rochester called "Carlson Park" (as in industrial park). The parking lot looks just like it did in the mid '70's when I last saw it (I was teaching a class for Xerox in Webster last year and mentioned that I used to work for Stromberg and someone in the class said that the old plant was still there -- which it is -- so I drove over for a peek. The only difference is that they have sub-divided the administrative offices into private office suites and businesses.) Except for the new business signs, everything looks exactly as I remember it from 25 years ago."[back to text]

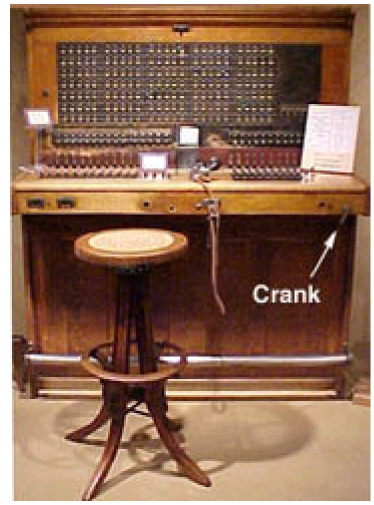
[ETH] Events in Telecommunication History, 1992 ,AT&T Archives Publication (8.92-2M), p53 (*back to text*)

[Bell Laboratories Record] "Coast to Coast Radio Relay System Opens." Bell Laboratories Record, May, 1951. 427 (back to text)

[Bell Laboratories Record] Weber, C.A., Jacketed Cords for Telephones, Bell Laboratories Record, May, 1959 187 (back to text)

Private Line's Telephone History Part 9 - 1983 to 1984

Michael Hathaway reports that "[My] parents owned the Bryant Pond Telephone Company in Bryant Pond, Maine, the last hand-crank magneto company to go dial. It was in our living room and the last call was made October 11, 1983." Hand crank magneto switchboards evolved around the turn of the century. Their arrangement was not common battery, where the exchange or central office powers their equipment and supplies electricity to customer's phones. Rather, as we saw earlier in this series, a crank at the switchboard operator's position was turned to signal a customer. Turn the crank and you caused a dial at a customer's telephone to ring, a magneto in the crank generating the power. To place a call a customer signaled the operator with a similar crank on their subscriber's. A big battery in the base of the customer's telephone supplied the talking power. Here's an example of a magneto switchboard below, a 1914 Western Electric Type 1200, known as a "Bull's Eye." This board is at the Roseville Telephone Company Museum and it still works for demonstrations. Click here or on the image below to see the large version.



So, you had many people on non-dial, candlestick or box telephones, as nearly a hundred years before. My father, incidentally, worked a magneto-powered switchboard in his youth, near Davidson, Michigan. Mike goes on to say that,

> "My father and mother Elden & Barbara Hathaway sold the Bryant Pond Telephone Company in 1981 but it took two years to convert. They did have about 400 customers (probably 200 lines - two switchboards full). When they bought the company there were only 100 customers. The Oxford County Telephone Company, which bought it, retained ownership of the last operating switchboards, and they are currently deciding what they would like to do with them. The options include giving them to the town of Bryant Pond, and I have heard there is interest from the Smithsonian. My mother, who is 83, thinks that's quite exciting.
>
> A lot of the family memorabilia has been donated to the Fryeburg Fair (Maine) Farm Museum, which although is only open during the 8 day

fair, is visited by many thousands each year. It is hoped to have within a year or so a working magneto switchboard there where someone can call from an old pay phone to anywhere. My mother has a lot of telephone parts left over which we are slowly marketing for her as memorabilia from the last old hand-crank magneto company. I've actually written a book about the Bryant Pond Telephone Company called 'Everything Happened Around The Switchboard.' It's (obviously) a story of family life around the switchboard and is light reading with hopefully humor and nostalgia. I have lots of copies left and sell it directly. The address is Mike Hathaway, PO Box 705, Conway, NH 03818. But it is also available from Phonecoinc.com, http://www.bibliofind.com, and several bookstores."

This site has a great list of ending dates in telephonic history: http://www.sigtel.com/tel_hist_lasts.html

To sum up, although some manual switchboards may have remained in the PSTN, those being small office switches, or PBXs, the Bryant Pond board remains the last central office manual exchange in America. On this happy and nostalgic note of technology passing away, so at the same time was the world's greatest telephone company coming to an end.

Although they had pioneered much of telecom, many people though the information age was growing faster than the Bell System could keep up. Many thought AT&T now stood in the way of development, rather than being the harbinger of it. And the thought of any large monopoly struck most as inherently wrong.

In 1982 the Bell System had grown to an unbelievable 155 billion dollars in assets, with over one million employees. By comparison, Microsoft in 1998 had assets of around 10 billion dollars. On August 24, 1982, after seven years of wrangling, the Bell System was split apart, succumbing to government pressure from without and a carefully thought up plan from within. Essentially, the Bell System divested itself.

Judge Harold Greene entered a decision called the Modified Final Judgment, since it impacted the 1956 decision limiting AT&T to the telephone business. In the MFJ as it is known, AT&T kept their long distance service, Western Electric, Bell Labs, the newly formed AT&T Technologies and AT&T Consumer Products. AT&T got their most profitable companies, in other words, and spun off the regional Bell Operating Companies or RBOCs. Complete divestiture took place on January 1, 1984. The operating Companies then consolidated into the seven large entities shown below.

New Regional Bell Operating Company	Old Bell Company
Ameritech	Illinois Bell Indiana Bell Michigan Bell Ohio Bell Wisconsin Bell
Bell Atlantic	Bell of Pennsylvania C&P Companies New Jersey Bell
Bell South	South Central Bell Southern Bell
NYNEX	New York Telephone New England Telephone
Pacific Telesis	Nevada Bell Pacific Telephone
Southwestern Bell	Southwestern Bell
US West	Mountain Bell Northwestern Bell Pacific Northwest Bell

In perhaps the most cumbersome part of the Modified Final Judgment, Judge Greene split the country into 160 local access and transport areas, loosely structured around area code boundaries. Essentially, local phone companies couldn't provide long distance service and long distance companies couldn't provide local service. Judge Greene thought the Baby Bells would dominate long distance service in their territories if allowed to provide it. He insisted that only a long distance company could pass LD traffic from one LATA to another. By now this prohibition has ceased on a federal level, however, many states have yet to allow complete local and long-distance competition. And although AT&T once again provides local service for a few select markets, local service remains a monopoly for most areas, just as Theodore Vail would have preferred.

Epilogue -- the death of Western Electric

> "On January 1, 1984, the Western Electric Company, then older than the telephone itself, ceased to exist (Hochheiser 1991, 143). On that day of court ordered divestiture, the Bell System was broken into seven regional operating companies (the Baby Bells) and a more compact AT&T. AT&T retained the long-distance part of the business, its venerable research organization (Bell Laboratories), and its manufacturing operations (which could no longer have exclusive supply arrangements with the operating companies). A newly created AT&T Technologies, Inc. assumed the corporate charter of Western Electric and continued making 500-type, 2500-type, and Trimline telephones under the AT&T Technologies label for several years at plants in Indianapolis and Shreveport. However, to become competitive in the market, AT&T shifted residential telephone manufacturing to the Far East, beginning in Hong Kong in late 1985, Singapore the following year, and later in Bangkok and elsewhere. Thus ended U.S. production of rugged electromechanical telephones, and though phones similar to the 500-type, the 2500-type, the Princess, and the Trimline are still made to-day, they are products of the modern electronics age, rather than a bygone culture."

From: Old Time Telephones:Technology, Restoration and Repair by Ralph O Myer, Published by TAB Books, a division of McGraw Hill, Inc., Blue Ridge Summit, PA 17294 1 -800-822-8158 (717)-794-2191 (717)-794-2103 FAX ISBN No. 0-07-041817-9 (Paperback) 1995 Recommend highly to anyone who repairs or wants to understand old telephones.

Miscellaneous History

Why is there no "Q" or "Z" on many telephones?

This fascinating story comes from http://www.LearningKingdom.com: Some voice mail systems don't take into account that not every phone has a Q or Z . . .

The telephone's pad of twelve buttons reflects its history. There are three letters on most buttons, except for zero, one, octothorp (#) and the star symbol (*), which have no letters. "Q" and "Z" are usually missing from the list. Why?

Instead of twelve buttons, telephones used to have circular plates with ten holes numbered from zero to nine. To make phone numbers easier to remember, the phone companies assigned letters to the numbers, so people could remember mnemonics like "Charleston" for C-H instead of the first two digits of a number. Of the ten digits, zero was already used to dial the operator and one was used for internal phone company signals. That left eight numbers to which letters could be assigned. Three letters per number took care of 24 of the alphabet's 26 letters, and the least common letters "Q" and "Z" were left out, but not forever. Many telephones now show "Q" on the seven button, and "Z" on the nine button.

Resources

The following lists many resources I consulted:

The Telecom Digest is an excellent place to start searching. A great archive and lots of good links:

http://massis.lcs.mit.edu/telecom-archives

Try also the Antique Telephone Collectors Association:

http://www.cybercomm.net/~chuck/atca.html

Also, search Yahoo by topic. Search for 'Telephone History' . Here you go:

http://search.yahoo.com/bin/search?p=telephone+history

If you get really stumped, go over to Dejanews.com to easily search the newsgroup or USENET postings. Someone will probably be able to help if you post your question:

http://search.dejanews.com/

Hardcopy or Print Bibliography:

Many of these books are out of print, however, several new resources are online to make finding old copies easier. My favorite, so far, is the Advanced Book Exchange at http://www.abebooks.com/

Boettinger, 1976, The Telephone Book, Riverwood Publishing, Croton on Hudson, New York

NB: This book was updated in 1983 by Stearn Publishers (formerly Riverwood) to include a chapter about divestiture. (Thanks to Dorothy Stearn of Stearn Publishers Ltd. for pointing this out.)

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Fagen, MD, ed., 1975, *A History of Engineering and Science in the Bell System. Volume 1 The Early Years*, 1875 - 1925. New York: Bell Telephone Laboratories

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Swihart, Stanley, Independents Show Bell The Way to Big-City Dial Service, *Telecom History* Issue 2 Spring 1995, p94

Thomas Watson, *Exploring Life*, 1926, New York

"GTE Corporation" Britannica Online. <http://www.eb.com:180/cgi-bin/g?DocF=micro/249/7.html> [Accessed 11 February 1999].