

EARLY RECEIVERS

by Bob Estreich

Part 1

The development of the telephone receiver followed a far simpler path than that of the transmitter. Bell and his company's engineers got it substantially right quite quickly, and most other early receivers consisted of developments to the basic design rather than attempts to beat Bell's patents.

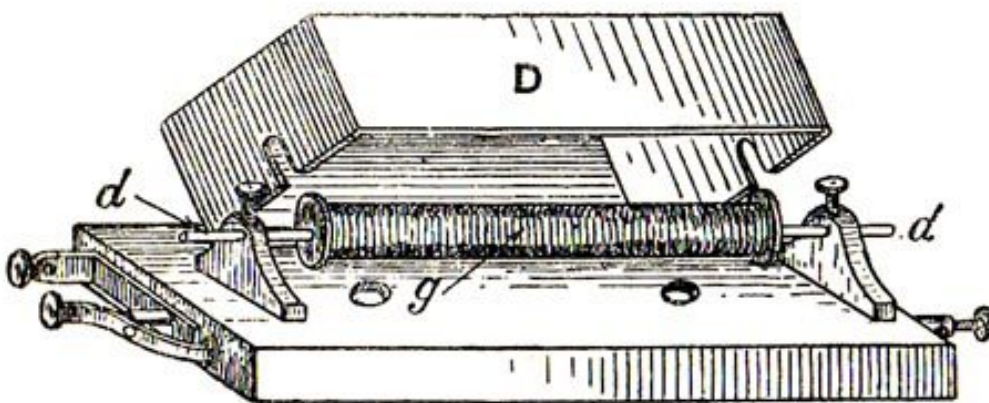
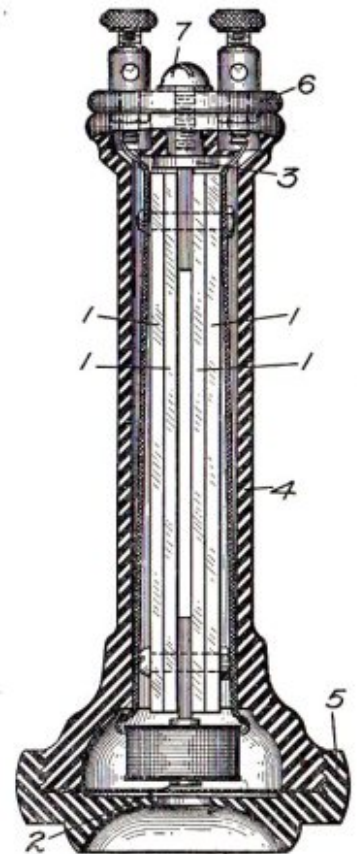
Reis

When you build a telephone receiver, you need to build a transmitter as well. There were many early experiments aimed at building a telephone, but that of Philipp Reis came closest to success. His transmitter was decidedly unreliable and only rarely carried speech, but the receiver he built to go with it was adequate. It was a unique design and used an obscure physical principle, so deserves a closer look. Early experiments in magnetism by C. G. Page and others demonstrated an effect called *magnetostriction*. If an iron rod was surrounded by a coil of wire, and an electrical signal was passed through the coil, a strong click would be emitted from the rod. This was caused by the rod actually changing its length slightly in the magnetic field generated in the coil. Under a rapidly varying current, the clicks would run into each other and produce tones.

Reis attached his iron rod (a *knitting needle*) to the sounding board of a violin to amplify the sound. It worked, although it was not very efficient. In his commercial *Telefon* he replaced the violin part with a cigar-box sized wooden case to act as a diaphragm. The success of the receiver depended on all parts being clamped tightly together, and a sufficiently strong signal being applied. Reis' transmitter was a poor design, and the *Telefon* faded away, but his work was well known to later inventors.



Bell
Butterstamp



Reis receiver

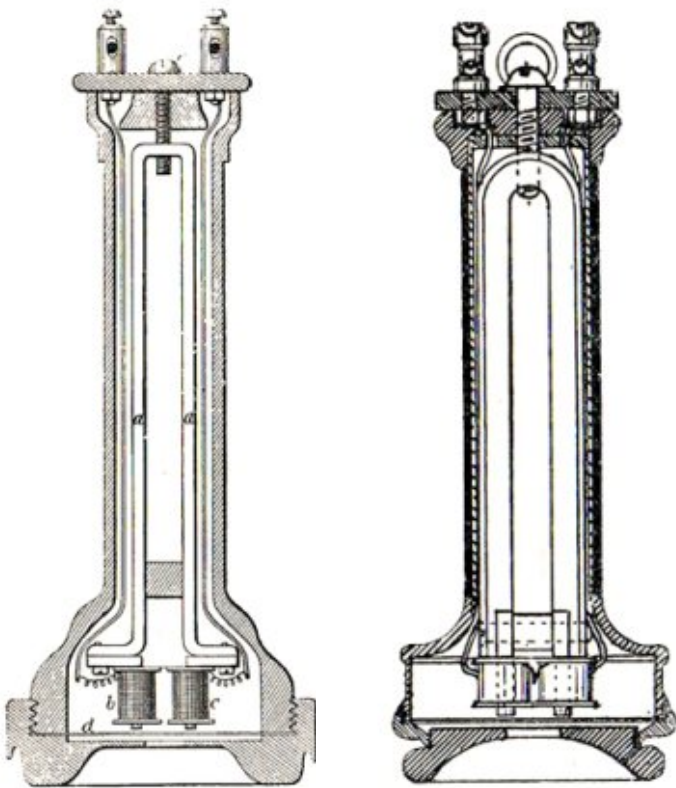
Bell

Alexander Graham Bell went along a different path for his receiver. He used a permanent magnet with a coil of wire wrapped around it, and an iron diaphragm just in front of but not directly connected to the coil. When the varying signal was passed through the magnet coil, the diaphragm vibrated in tune with the varying current. This was the basis of most telephone receivers ever since. Bell also used it as a transmitter, but although it worked, its low output limited the range severely. Transmitters developed along many alternate lines, but that's another story.

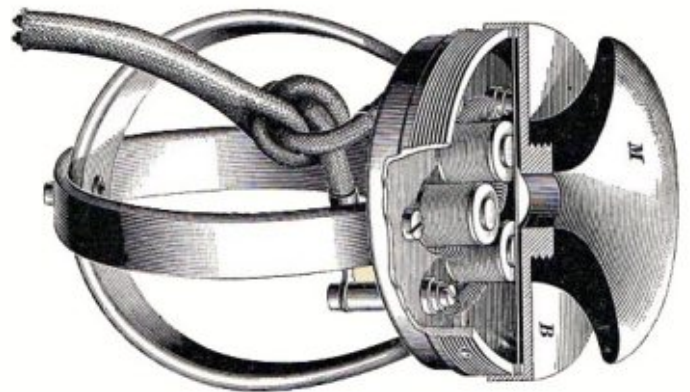
Siemens & Halske and others soon discovered that if a horseshoe magnet was used and a coil fitted to each pole of the magnet, the receiver's efficiency improved. The shorter magnet also allowed the receiver case to be made smaller. In spite of this, the binding-posts (*terminals*) were still mounted at the top of the receiver and protruded from the case. This style is called an "outside terminal receiver".

Multiple-Pole Receivers

If one magnet pole is good and two are better, it was inevitable that someone would add even more magnets to produce a multi-pole receiver. A Western Union engineer named Phelps developed such a receiver to go with Edison's transmitter to compete against the Bell company. Phelps used a number of magnets bent into near-circles, with the pole pieces all coming out inside the receiver.

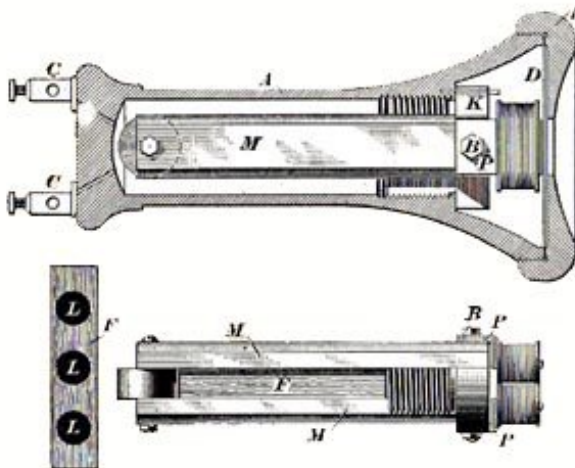


Bell Double Pole Receivers



Phelps Receiver

Each had its own coils and the resulting receivers were quite efficient. They were also clumsy and heavy. They were known as "crown" receivers. Western Union used them for some years with an Edison transmitter, before giving up the legal patent fight against Bell. At this point Bell adopted the Edison transmitter and teamed it with their own (*better*) receiver. The Phelps receiver disappeared into obscurity.



Bell Double Pole "Pony" compact receiver

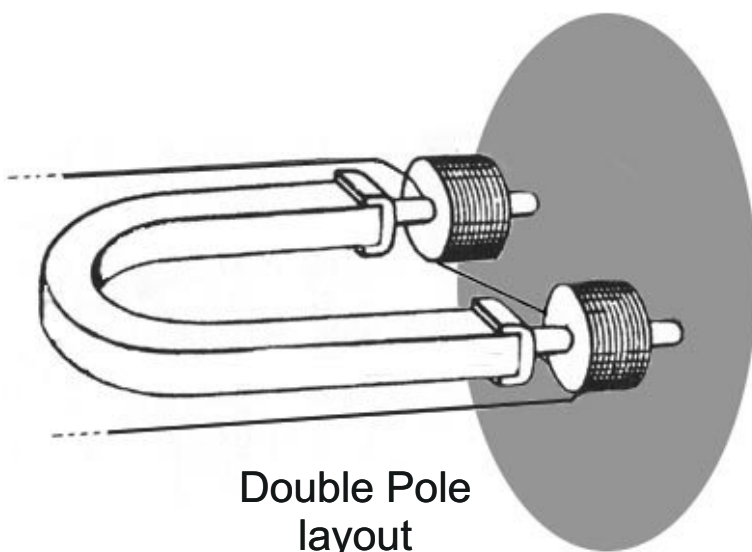
Construction of a Receiver

It is appropriate at this point to look at the construction of the typical single-pole and

double-pole receivers as they were now appearing in commercial production.

Magnets

These were the critical part of the receiver. A strong magnet could produce the magnetic field needed to make a sensitive receiver, and provide the weight needed to trip the switchhook. Such a magnet was rather large and clumsy, and the weight became considerable. European magnets were considered superior to American ones, although the reasons at the time were unclear. Advertising of the time refers to "*Best Swedish Magnet Steel*". Most European magnet steel came from iron ore deposits at Kiruna in Sweden, and from Germany. The ore from these mines is mostly a mineral called magnetite which contains a high amount of iron, and also contained small amounts of impurities like nickel and cobalt. We know now that the strength of a magnet can be increased by "doping" iron with these extra elements. American magnet steel came from iron ore deposits in Michigan and Minnesota. These were "*secondary*" ores, produced by erosion of the original deposits. They contained impurities like sulphur, phosphorus and silica, and less of the doping elements which had been leached out, but they were easier to smelt and work. Unfortunately the impurities weakened the magnet's strength, so American magnets in both generators and receivers tended to be bigger than their European equivalents.



To keep the size and cost of the horseshoe magnet down, makers evolved a technique of using two bar magnets joined at the top by a connecting piece of iron. This was just as effective as a horseshoe magnet but more compact and easier to assemble. Another advance was the discovery that a good bar magnet could be built up out of sheets of iron stamped out and laminated together.

Pole pieces and Spacers

The ends of the magnet near the diaphragm had to be held apart at a fixed distance by a spacer. This was often used to hold the coils in place. In many cases one was attached to each end of the magnet to hold the coils, and was called a "pole piece". Brass was used at first for the spacer and pole pieces as it was cheap and easy to work, but its expansion and contraction in different temperatures caused problems with accurate location of the coils relative to the diaphragm.

Wood was tried, and eventually a compressed fibre pole piece was developed. Ebonite or vulcanite (*hardened forms of rubber*) or Dr Traun's Material (*a high quality vulcanite*) were also used. These were better, but in the end the development of bakelite gave a dimensionally stable substance. These non-metallic substances gave a stronger magnetic field as well.

Diaphragm

Initially sheet iron diaphragms were used, but these were soon tinned, nicked or japanned (*japan is a form of baked-on black paint*). This fixed the changes in thickness caused by rust on the diaphragm. An improvement was achieved with the introduction of Stalloy, a doped soft iron that reduced eddy currents (*the back-current generated in the coil by the movement of the iron diaphragm in the magnet's field the same effect that was earlier used for a transmitter*). The optimum thickness was worked out by experiment to be about 9 to

12 thousandths of an inch, and the optimum diameter to be a little over two inches.

Receiver Cup

A constant source of problems was movement of parts within the receiver due to the different rates of expansion of the iron magnet and the other parts of the case. There was an optimum distance between the diaphragm and the coils, but in practice this distance varied with temperature, reducing the efficiency of the receiver. The magnets were generally not well supported within the receiver case and this caused further tolerance problems. The most common solution in use was to mount all the components in a brass cup at the base of the receiver. If accurately made, this kept all parts at the correct distance and supported the magnets as well.

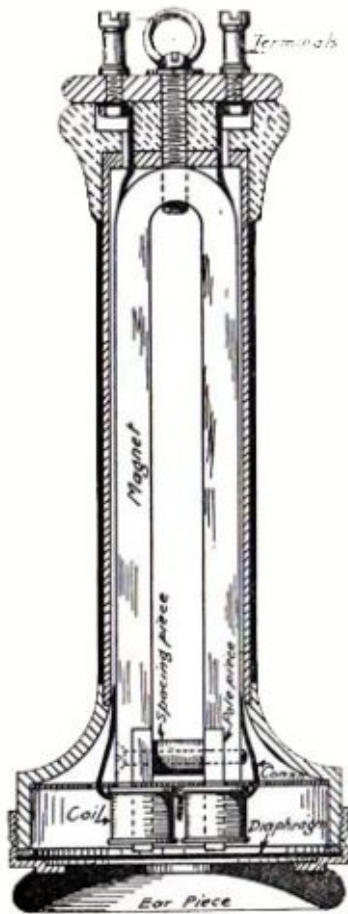
The movements here are in the order of some thousandths of an inch, so it can be seen that

precision and accurate construction were becoming essential in manufacturing. As well, inventors were refining the basic receiver in other ways.

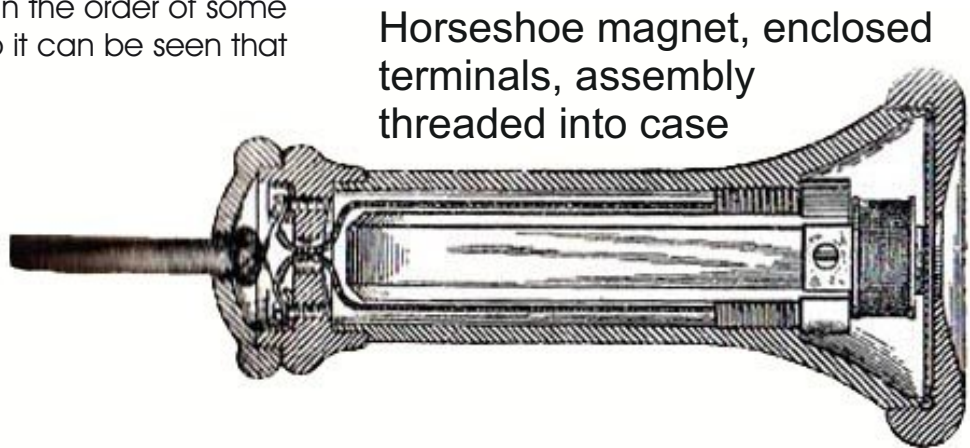
Kellogg

Milo Kellogg improved the rigidity of the parts in his later receivers by screwing the entire bipolar magnet, cup and coil assembly into a thread machined inside the bottom of the ebonite case.

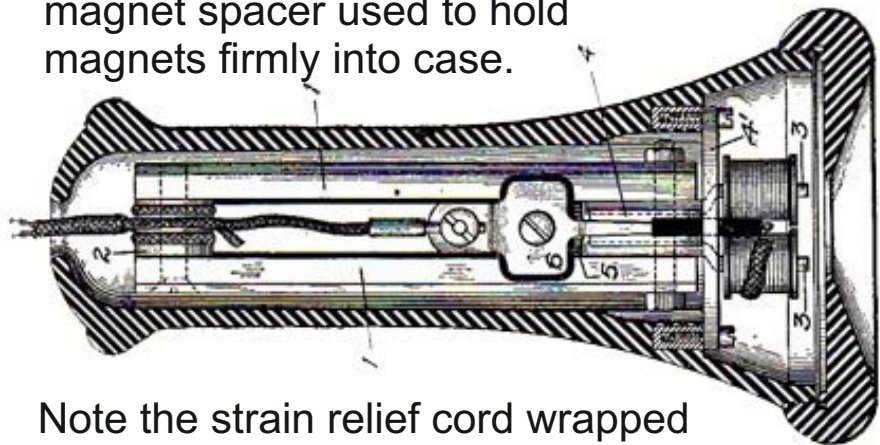
He also enclosed the terminals at the top with a screw-on cap. The cap soon became obsolete, and the wires were simply led deeper into the receiver case to a terminal strip located above the magnets.



Original Kellogg
OST Design



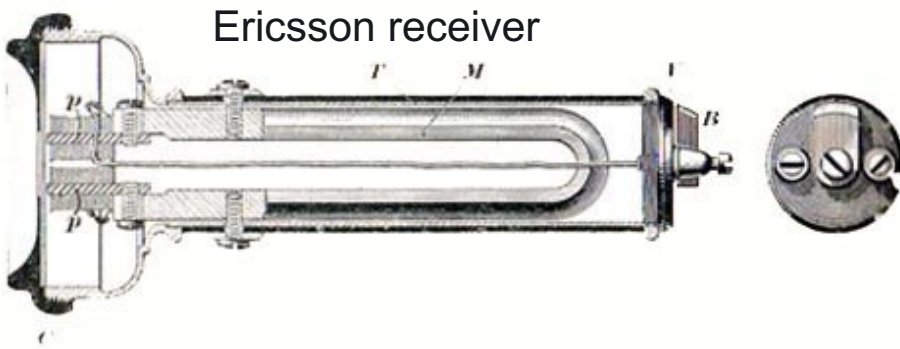
Joined bar magnets, no terminals at top, assembly held into case by screws, magnet spacer used to hold magnets firmly into case.



Note the strain relief cord wrapped around the top of the magnet assembly.

Ericsson

L M Ericsson tried to reduce the movement of the components by bolting the magnets to the brass case, through the sides. To improve the rigidity of the magnet they stayed with the horseshoe shape. All components were attached to the magnet poles so there would be little movement.



The top cap had a moulded ridge across the centre, through which the fixing screw fitted. It also served to stop frayed wires coming into contact across the outside terminals and shorting out the receiver.

Watchcase Receivers

In Europe the stronger magnets allowed the receiver to be built into a smaller case. It was about the size of a pocket watch and so was known as the Watchcase Receiver. Its exact origins are uncertain, but Ader and D'Arsonval in France seem to be strong claimants as its inventor. In any case, it was widely adopted and a number of variations came from it.

Ader Watchcase Receivers

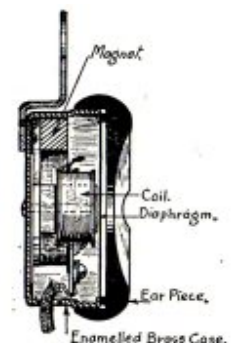
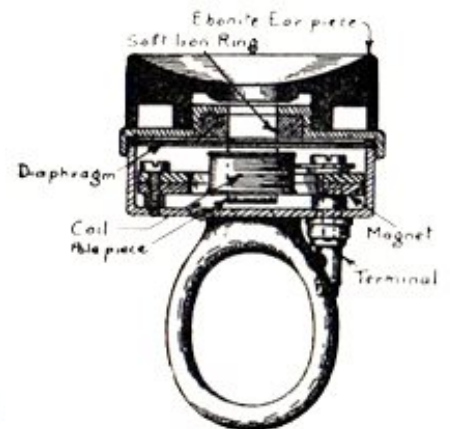
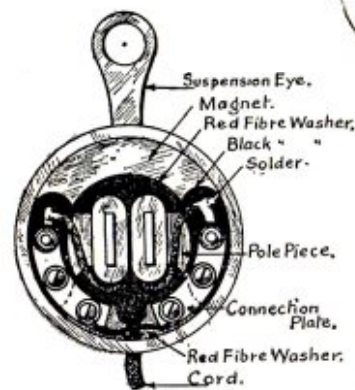
Construction was simple. A bar magnet was bent into a near-circle to fit inside the case, with its poles bent towards the

centre of the case. Two coils were mounted on these, a diaphragm was fitted to the circumference of the case, and an earpiece was screwed on to hold it all together. The receiver could be attached to a handle, giving a "spoon" or "wand" receiver.

These would have been easier to handle. It could also be fitted onto a headband for switchboard operators, leaving their hands free.

Ader's receiver is notable in that it had a soft iron ring mounted inside the diaphragm, around the rim. He called this a "sur-exciteur" ("over-exciter") and its effect was to concentrate the magnetic lines of force. Although it was regarded by telephone engineers such as Poole as a very efficient receiver, the simpler form of watchcase receiver soon replaced it, so the benefits of the over-exciter are doubtful.

Ader Watchcase Receivers



Early Receivers part 2
in the November Edition

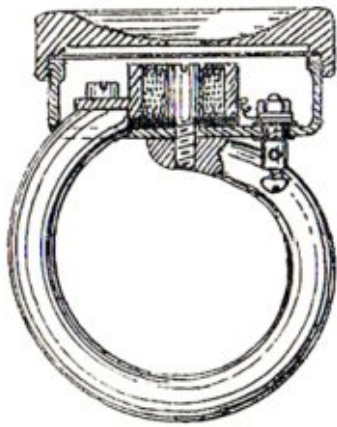
EARLY RECEIVERS

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Part 2

D'Arsonval Receiver

D'Arsonval fitted a coil to one pole only. To the other he mounted a soft iron cylinder which fitted over the coil, thus producing a sort of cylindrical electromagnet. This was also designed to theoretically concentrate the lines of magnetic force, and like the Ader it soon fell into disuse.



Theiler

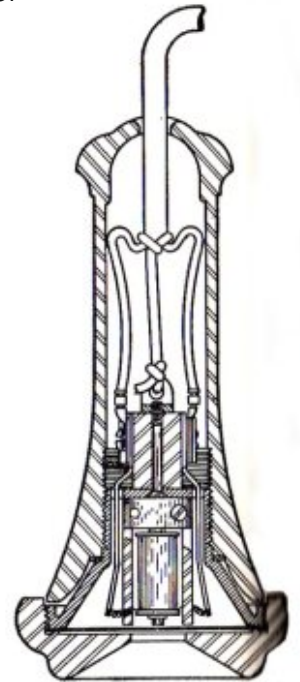
Theiler went a different way and mounted a larger ring magnet outside the case, with only the pole pieces inside. Mounted on a handle, this receiver would not have been as clumsy as it sounds, but details of its efficiency are unknown. It was used by a number of European manufacturers.



Electromagnetic CB receiver

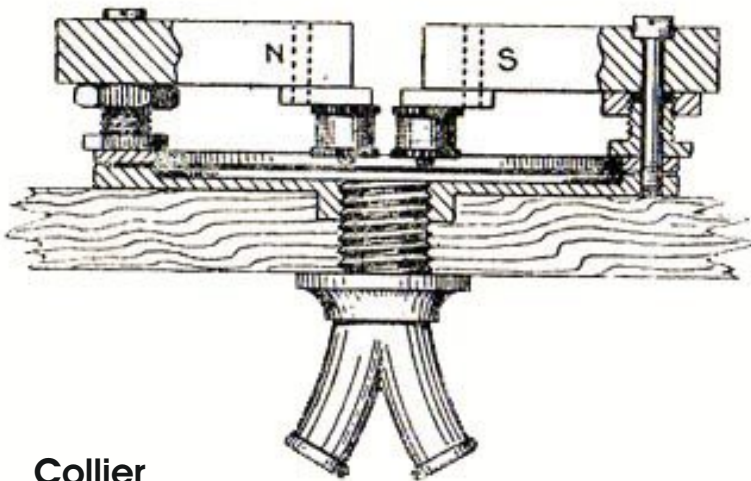
If a separate source of power was put through the coil to polarize the magnet, the resulting electromagnet would be smaller and more efficient. This was not practical with magneto phones powered by their own batteries, as the batteries would soon run flat. The opportunity presented itself with arrival of the Central Battery and automatic exchanges in the late 1890s. Power was fed down the line to the customers' phones from the exchange batteries, but only when the phone was "off-hook". The electromagnetic receiver was thus only energized when the phone was actually in use. Stromberg Carlson DC receiver

The Automatic Electric Company in the United States was probably the first to use this receiver, according to McMeen and Miller, but other companies soon followed. Another advantage was that the receiver was considerably lighter, and posed less risk of breaking the internal wires or the case if it was dropped.



Gower

Frederic Gower in Britain briefly produced a receiver that went into use with the British Post Office for some years as part of his Gower Bell phones. It used a large ring magnet to power a huge diaphragm over four inches across, thus making the most of low signal levels. The unit had to be mounted inside the telephone case and sound was fed to the ears by rubber tubes at the base. It worked, but the need to hold two tubes to the ears made it inconvenient. When Bell's receiver patents expired, the BPO sensibly updated their Gower Bells with conventional Bell-type receivers. Many other companies upgraded with Ader receivers.



Collier

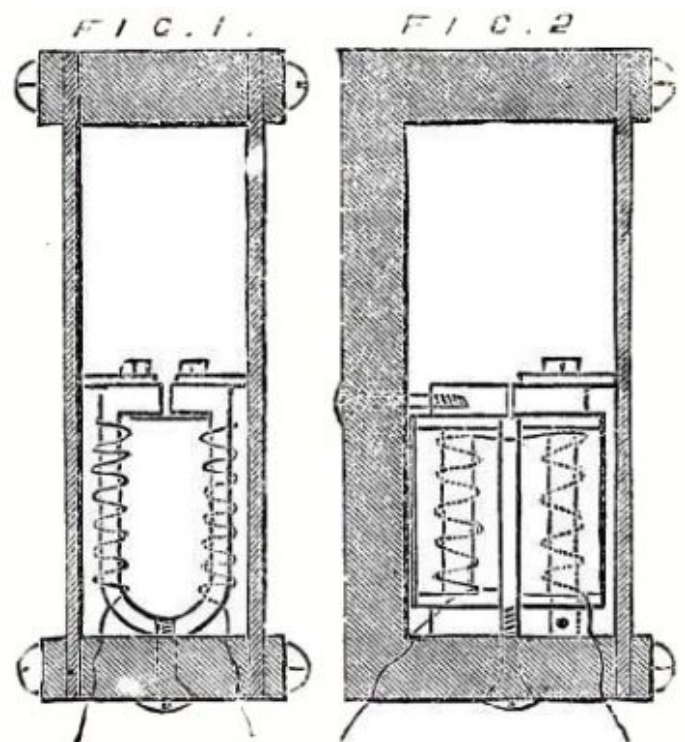
Collier attempted to improve the telephone's efficiency by making a better receiver. It used a large external horseshoe magnet with an iron core between the poles. Between each pole of the magnet and the corresponding end of the core a diaphragm was fitted. The coil, core and diaphragms were fitted into a brass drum case and sound was fed out into a single earpiece. It was ungainly and expensive, but it was undeniably efficient and was used in sending the first radio signals across the Atlantic.

Although it was never widely used on telephones it found a place as a signaling device on the Phonopore, a telephone designed to work over Morse telegraph lines. A vibrator was used to send a fluctuating current down the Morse line, and this generated a squawking noise in the Collier receiver. The vibrator and voice signals could be filtered out of the Morse signal. The

Collier receiver thus stayed in production as a loudspeaker for a long period (approximately 1885 to 1925) although the Collier telephone itself quickly vanished.

Theiler again

This Swiss engineer produced unusual single and double-diaphragm receivers of the electromagnetic variety. Instead of winding a coil onto the pole piece of each leg of the magnet, Theiler wound a coil directly around the magnet legs. The pole piece(s) were connected directly to the diaphragm(s). The receiver used the attraction and repulsion of the magnet legs themselves to move the diaphragms. It was not a successful design.

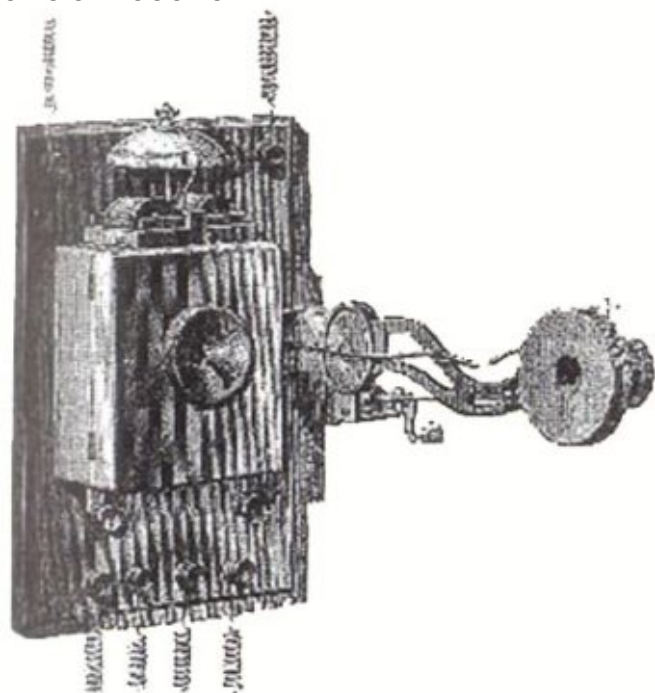


Edison

Thomas Edison returned to building telephones after some years. His transmitter patent had been passed to the Bell company, who also had the patent for the most practical receiver, so Edison needed to effectively reinvent the entire telephone.

In Britain he teamed up with Frederic Gower, who had a good carbon-pencil transmitter that, in Britain at least, did not conflict with Textbook Company, Scranton, 1899

the Bell patents. Using his earlier research Edison invented a receiver using a physical principle that had not so far been exploited in telephones. He called it the Motograph or Electromotograph. A stylus, held against a revolving cylinder soaked in a suitable electrolyte, could produce a sound in an attached diaphragm if a varying signal was fed into the circuit such as that from a telephone line. As the electrolyte decomposed from the electrical signal, the friction between the stylus and the cylinder was reduced and the stylus jumped slightly, moving the attached diaphragm. He designed this into a good, efficient receiver.

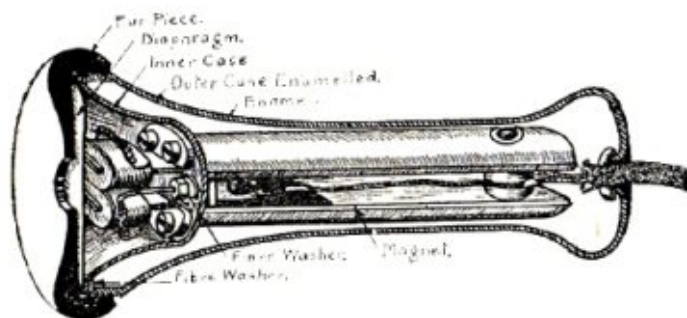


Edison Electromotograph

It was a bit too good the signal was loud, and it was eventually marketed as Edison's Loudspeaking Telephone (making a virtue out of a problem). The user turned a handle while using the phone, although clockwork versions were soon available. The telephone sold throughout Europe. It came to an end when the competing Bell and Edison companies amalgamated to avoid the legal problems over their patents. After the amalgamation, all the companies adopted the Bell receiver and Edison carbon transmitter combination.

That just about marked the end for receiver development. The final versions are probably

typified by the British Post Office's Standard Receiver, made by many companies. It used two half-round tungsten steel bars for the magnet, joined by a steel screw and spacer at the top. The bottom end of each magnet had an L-shaped pole piece fitted with a coil comprising 605 turns of fine wire. The last few turns were made of thicker wire for strength, and this was fed out of the brass cup to the internal terminals for the flexible cord. The cord itself included a strain relief core that was tied securely to the joining spacer at the top of the magnets. The entire assembly was a tight fit inside a japanned brass case. The diaphragm was mounted onto the flat machined rim of the case and secured by a bakelite end cap. The whole assembly was rugged and simple, but was the result of many years of experiment and development.



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