"Early Electromagnetic Telephone Receivers"

by Basilio Catania

Introduction

The birth of the telephone is often associated with the birth of the electromagnetic receiver, since the same instrument was used also as a transmitter in early telephone lines. Many inventors—in addition to Alexander Graham Bell—claimed to have invented this instrument, whose simplicity of construction is truly elegant, but whose proper functioning requires meeting a number of critical constraints. The following is a list of the most essential constraints:

1. the magnetic core's material, shape and size (height/diameter ratio);
2. the polarization (by either electric current or permanent magnetization) of the magnetic core in order to achieve the maximum amplification of the superimposed oscillatory component;
3. the coil's shape (height/diameter ratio), its position along the core and the (copper) wire's cross section and number of turns;
4. the diaphragm's material, shape (preferably circular), thickness and mode of clamping (preferably all along its circumference);
5. the air gap between diaphragm and the magnetic pole(s) and means of adjustments of the same for optimum performance;
6. the acoustic interface with the human ear (or mouth) both for maximizing the acoustic gain and minimizing any environmental noise capture.

In addition to the above, even if not strictly pertaining to the electromagnetic instrument proper, the call signaling as well as the anti-sidetone (AST)[1] layouts are important to achieve its best performance in actual operation.

Although much has been written on this subject, I have often found ambiguities, more or less of the same kind as those regarding the make-and-break transmitters as compared with the true variable resistance devices (e.g. carbon microphones), that I have pointed out earlier in *Antenna* [1]. More precisely, I will refer to some early telephone receivers that operated, fully or partly, by magnetostriction (see the article on magnetostriction on page 15), but claimed to be either pure electromagnetic receivers or improvements over the magnetostriction receiver, and also to some electromagnetic receivers that were used in conjunction to unsuitable transmitters and therefore could not exploit their potential nor enjoy subsequent improvements.

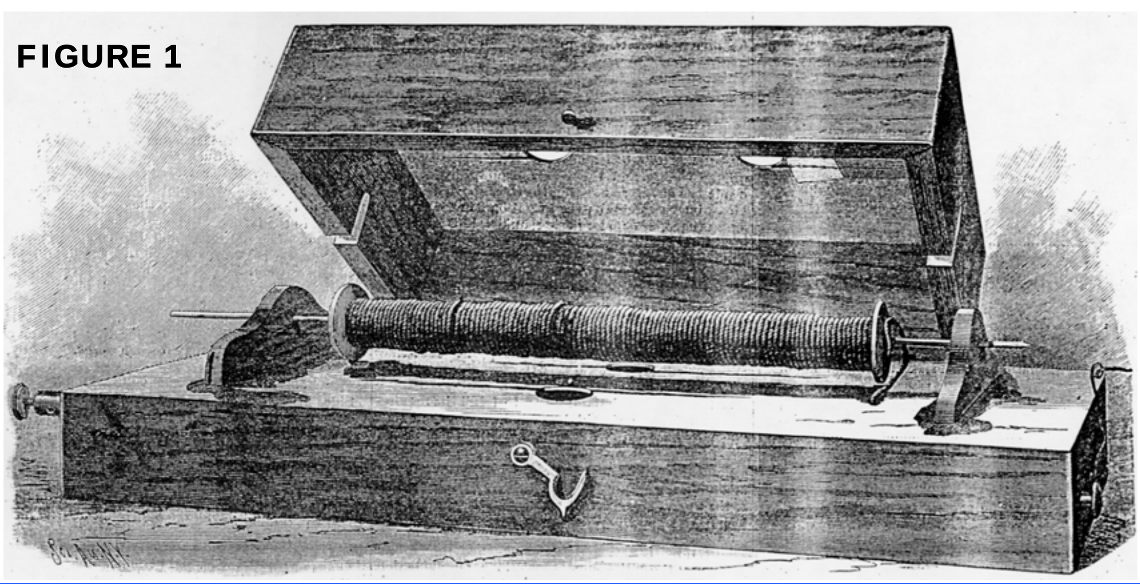
Let us review a few, among the most important ones, devised in the early times of telephony.

Van der Weyde's Reis Receivers

As already shown in [1], the magnetostriction receiver used by Philipp Reis (Figure 1, taken from [2]) exploited the elongation of the magnetic core of a solenoid each time the core was magnetized by an electric current. Reis used as the core of the solenoid a long =>

The Original Reis Receiver of 1861

FIGURE 1



1. An anti-sidetone (AST) layout is a circuit that prevents the speaker's telephone receiver from picking up the echo of the speaker's own voice as well as any background noise entering the speaker's telephone transmitter.

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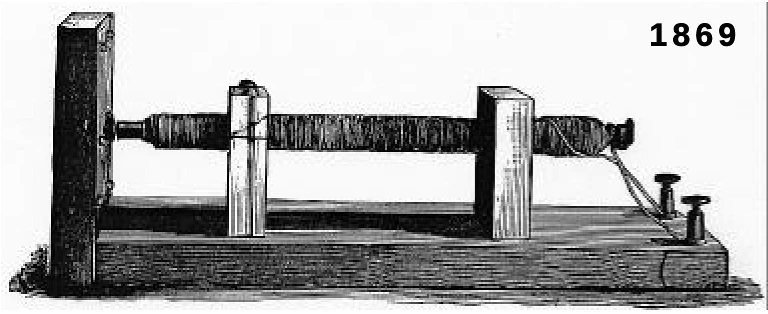

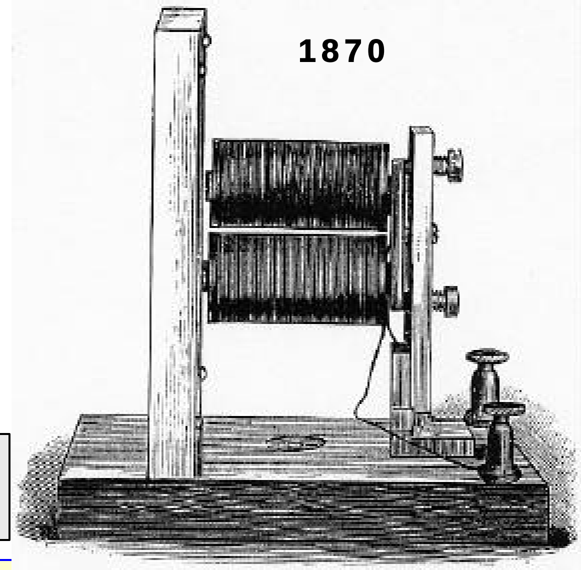

FIGURE 2

Van der Weyde's "Improved" Reis Receivers from 1869 and 1870

knitting needle clamped at both ends to two wooden bridges, and these in turn he glued to a wooden sounding box. This construction was necessary because of the feeble sound emitted by the needle alone.

Several inventors—among them Philip H. Van der Weyde—improved on the 1861 Reis receiver. In 1869 and 1870 Van der Weyde made a couple of interesting receivers (Figure 2) whose description appeared some years later in the *Telegraphic Journal and Electrical Review* [3] (and even later in *Scientific American* [4]). This is what the *Telegraphic Journal* columnist had to say (italics added):

". . . He [Van der Weyde] soldered an iron button to the centre of a brass plate (see fig. 11 [shown here in Figure 2]), placed *in front of* an iron bar, surrounded with a coil, and this was the instrument used as a receiver at the lecture of January 8th, 1869.[1] In August, 1870, he read a paper before the American Association for the Advancement of Science which that year assembled at Troy, N.Y., the paper being entitled "Further improvements in the method of transmitting musical melodies by telegraph wire." In the discussion which followed the reading of the paper, one or two of the members present stated that they had obtained good results by placing a tinned *iron plate in front of* the poles of a horse-shoe electro-magnet, and mentioned this as a well-known device; and on arriving at home in September, 1870, he constructed the apparatus shown in fig. 12 [Figure 2], in which a tinned iron plate was used."

Now, both receivers hardly resemble—not even in principle—the plain magnetostriction receiver made by Philipp Reis (Figure 1). It appears, in fact, from the two illustrations in Figure 2, that we now have an iron armature (either *an iron button* or *an iron plate*) and an air gap (however small) between the armature and the pole or poles of the electromagnet.[2] These are characteristics of an electromagnetic receiver. If, however, the air gap were very small, for instance with the armature *touching* the head of the magnetic core (which also could occur occasionally when the elongation of the core reaches its maximum value), then magnetostriction could have played a role—or the output sound could have been the result of the superposition of both the magnetostriction and the electromagnetic effects.

We must remark, however, that Van der Weyde's experiments were aimed at transmitting *musical melodies* [5, 6], and that he did not possess at the time a transmitter suitable for speech, excepting the Reis make-and-break transmitter (which was hardly suitable for that purpose). The word "telephone" found in Van der Weyde's articles [7, 8] referred to the Reis "telefon" with no allusion to the transmission of speech. Many years later, of course, he discovered that one could utilize it to transmit speech, but only in conjunction with a different telephone transmitter. =>

1. Van der Weyde gave similar lectures in the United States ([5] and [6]). These lectures are quoted in [7] and [8].
2. The account given in [4] is less accurate than that in [3], and the illustrations in the latter do not allow one to guess the size of the air gap—or whether there was one at all. However, the author states that the armature *faced* the poles of the electromagnet, implying that they were *not* in contact and therefore that actually *there was* an air gap.

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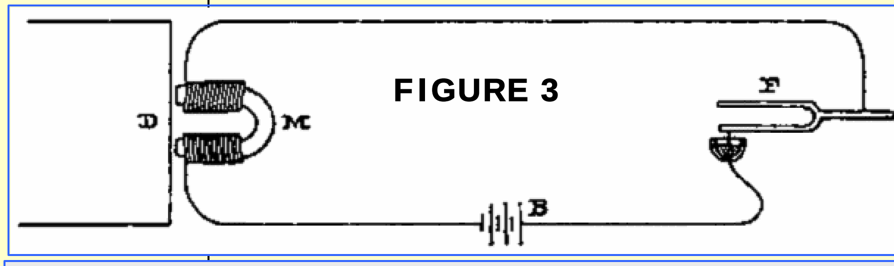
Pickering and Cross

During the aforesaid August 1970 lecture by Van der Weyde, Prof. Edward C. Pickering of the Massachusetts Institute of Technology (MIT) rose and "got up and described his tin-box receiver, which would make such transmissions even more audible" ([9], p. 117). We have an extended description of this receiver, made by Prof. Charles R. Cross, also associated with MIT, who had been using Pickering's tin-can receiver since 1869 ([10] p. 222). Prof. Cross testified as follows ([10], [11] p. 221-226) (italics added):

"Q. 17. When did you first take part in any experiments relating to the telephone? I use the word 'telephone' in its generic sense.

A. I do not remember exactly, but think that it must have been about 1869 or 1870, certainly not subsequent to the latter date. I connected a tuning-fork transmitter with a *receiver similar to that used by Reis*, with some slight modifications of my own, and produced thus, at the farther end of the line, a note having the same pitch as that of the tuning-fork transmitter [Figure 3]."



Cross's Electromagnetic Receiver (1872) Derived from Pickering's (1869) Tin-Box Receiver

"A. [22] . . . The new element in the apparatus was a receiver which was of a form that had been used in some experiments by Professor Pickering several years before in connection with an imperfect kind of circuit-breaking transmitter. The receiver exhibited at the date referred to consisted of a *large plate of tinned iron* which constituted the bottom or one side of a packing case in which some instruments had been imported. The case was rectangular in form, 38 inches long, 21 inches broad, and 19 inches deep. As shown in the lecture, the box was placed upon its side, so that the bottom of the box was in a vertical position. The box was secured to the table on which it rested so that it should be firm. Opposite the centre of the great diaphragm, formed by the bottom of this box, *was placed an electro-magnet*, whose legs were about six inches long, and whose cores were something over one inch in diameter. This magnet was fixed upon a support so that *its poles were quite close to the plate, but not in contact with it*, even when a current of electricity was caused to flow through the coils of the magnet. . . the particular tuning-fork used made 128 vibrations per second, so that when it was vibrating the circuit was broken 128 times in each second. . . . Whenever the circuit at the tuning-fork was closed, a current of electricity flowed through the circuit, including the coils of the electro-magnet, *and in consequence of the attraction of this electro-magnet*, the diaphragm was pulled towards the poles of the magnet. On the other hand, whenever, on account of the vibration of the fork, the stile attached to it was lifted out of contact with the mercury in the cup below it, the circuit was broken, the electro-magnet became demagnetized, and the pull on the diaphragm being released and thus under the influence of its own elasticity, the diaphragm moved away from the poles of the magnet. Since the tuning-fork *made and broke* the circuit 128 times per second the diaphragm was pulled and released the same number of times per second and hence executed 128 vibrations per second. Under these circumstances sound-waves corresponding to this frequency of vibration were produced in the air so that a note of a pitch corresponding to this rate of vibration was heard to issue from the receiver. . . ."

"Q. 23. Of what material was the diaphragm of the receiving apparatus described in your last answer composed?

A. It was the *ordinary tinned iron of commerce*."

"Q. 31. Will you please offer a diagram fully illustrating the construction of the apparatus which you used in your experiments of 1872?

A. I will, and hereby produce it.

[*Witness produces the diagram hereto annexed.*]

Q. 32. Please also indicate the parts of the apparatus by suitable letters.

A. In the diagram which I have produced, **F** is the tuning-fork transmitter, **B** is the battery, **M** is the electro-magnet, and **D** is the diaphragm formed by the bottom of the box which is represented in figure as resting upon its side."

There are several remarks I wish to make about

"Early Electromagnetic Telephone Receivers" by Basilio Catania (continued)

receiver is misleading, since it actually was a *tin-coated iron box*. Therefore, it acted as an armature (or diaphragm) respecting the electromagnet, whose poles were *quite close to the plate, but not in contact with it.* Once more, it had nothing to do with the Reis receiver—not even as a modification or as an improvement of the same—but was a plain electromagnetic receiver.

Once more, this receiver was used in connection with a make-and-break device (a tuning fork equipped with a stile dipping into a mercury cup acting as a breaker) and therefore the relevant experiments were all conducted with a *pulsating* current, instead of an *undulatory* current. This configuration prevented this receiver from being considered as a regular electromagnetic telephone receiver, although the difference was only in its use, not in its structure. This fact came out in 1879, when the American Bell Telephone Company asked Prof. Cross to demonstrate in court that his *tin-box* receiver anticipated Elisha Gray's *tin-can* receiver, specifically the claim that it was capable of reproducing speech. The following is what Prof. Cross declared before the Court ([10], [11] p. 233-234):

"My own apparatus was capable of doing everything which any apparatus described by Mr. Gray was capable of doing; and from this I have inferred that my experiments showed Mr. Gray's apparatus to have been anticipated, and hence of no particular importance in relation to speaking-telephone receivers, even admitting all claims put forward as to the date of its construction, and all arguments based on its mode of operation. . . . . my apparatus was earlier than Mr. Gray's . . ."

Elisha Gray[1] became interested in the transmission of musical tones in the Spring of 1874, soon after he resigned as superintendent of the Western Electric Manufacturing Company (of which he was the founder) and set out to become an independent inventor. He first developed an electric single-tone oscillator, which he called a *rheotome*, using a steel reed instead of a tuning fork as in Helmholtz's interrupter.[2] He then combined eight rheotomes into a "one-octave transmitter" in the hope of realizing an octoplex telegraph that would best the quadruplex telegraph patented by Thomas Edison and demonstrated at the New York Headquarters of the Western Union Telegraph Company on June 8, 1874 [17]. Gray's one-octave transmitter featured eight reed oscillators, each tuned to a note of the diatonic scale (the white keys of a piano), and made to vibrate by depressing a key on a piano-like keyboard. Figure 4 below shows his further improved instrument which covered two complete octaves (and so had 24 single-tone oscillators) and which he would use in his harmonic telegraph of 1876.

Gray demonstrated his "one-octave musical telegraph transmitter" on May 10, 1874, at the Western Union's headquarters in New York, on a 2,400-miles route without repeaters [17]. On June 13, 1874, he showed the same apparatus to a scientific audience at the Smithsonian Institution in Washington, DC, Joseph Henry presiding. He held other demonstrations in Boston and throughout Europe using various wideband receivers that merely acted as loudspeakers for the =>

Elisha Gray's Two-Octave Transmitter Used in his Harmonic Telegraph of 1876 (an improvement on his 1874 one-octave transmitter)

courtesy Oberlin College

FIGURE 4

1. Extensive information on Elisha Gray's life and work can be found in [13] and [14]. A remarkable archive on his work is kept at the Special Collections and Preservation Library, Oberlin College, Oberlin, Ohio.
2. Finding it necessary to maintain the vibrations of a tuning fork for a considerable time, Helmholtz constructed an electric single tone oscillator by placing an electromagnet between the prongs of the fork, using a circuit similar to that of the electric bell invented by the German physicist C. E. Neeff in 1831 [15]. The terms *interrupter*, *electrotome*, *rheotome*, and *trembler* [15, 16] indicated such single tone oscillators, including subsequent versions that replaced the tuning fork with a vibrating steel reed—such as those of Gray, Edison, and Bell.

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musical tones sent over the line. The *New York Times* [17] noted that, although Gray's demonstration consisted of playing and transmitting popular themes on his musical telegraph, "quite enough has been demonstrated to show that, from its basis, a new system of telegraphy, both for serial and sub-linking lines, of a simple, rapid and economical character can be introduced." In modern terms, Gray paved the way for the exploitation of a new principle in telegraph multiplexing, that of "frequency-division multiplexing" (FDM), and, in particular, of "harmonic telegraphy," the word "harmonic" being derived from the use of musical notes.[1]

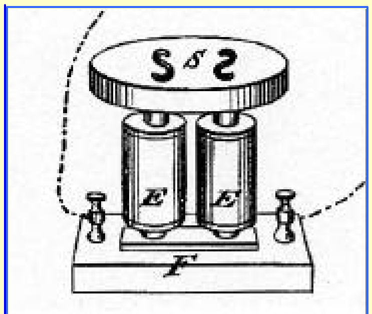
As we will see shortly, Gray finally would develop a selective receiver (which he called an "analyzing receiver") to separate (in modern terms, to demultiplex) the received tones and forward them individually to the corresponding Morse operators. However, we should first advance some considerations about his two wideband receivers—his "tin-can" and his "washbasin" receiver—employed in his aforesaid demonstrations.

Gray's tin-can receiver,[2] said to have been made in May of 1874, was described well in his two patents [18] and [19]. Both patented instruments are quite similar to each other, and both relate to his system for transmitting musical tones. The drawing shown at the top of Figure 5 is from Gray's U.S. patent #166,095 [19].

In the specification of this patent, Gray stated (italics added):

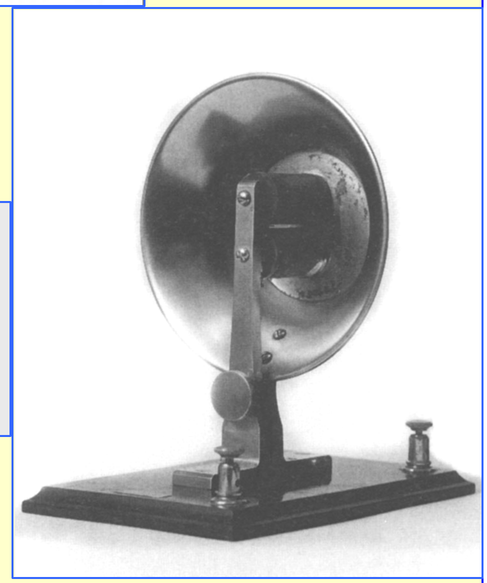
"My invention relates to what I term an 'electro-harmonic telegraph,' and is based upon the fact well known to electricians that *an electromagnet elongates* under the action of the electric current, and contracts again when the current ceases. Consequently a succession of impulses or interruptions will *cause the magnet to vibrate*, and if these vibrations be of sufficient frequency a musical tone will be produced, the pitch of which will depend upon the rapidity of the vibrations. . . . *As the receiving electro-magnet* is connected with this circuit it *will be caused to vibrate*, thus *producing a tone of corresponding pitch, the sound of which may be intensified by the use of a hollow cylinder, S, of metal, placed on*[3] *the poles of the magnet*."

Note that the same receiver is termed in the remainder of the patent specification an "electro-magnet



Gray's Tin-Can Receiver 1874

FIGURE 5



Gray's Washbasin Receiver 1874

receiver," although it clearly was conceived to operate by magnetostriction. This ambiguity is reflected in [14], in which the author, after noting that this instrument was equipped with a "*diaphragm*, originally an ordinary shoe-blacking box, supported near the poles of the electromagnet" (italics added), concludes that this receiver "anticipated the design of the modern telephone receiver." One finds similar statements in [13].

One must observe, however, that replacing the word "*on*" (i.e., *above and in contact*) with "*near*" and the phase "*hollow cylinder*" with "*diaphragm*" substantially alters the meaning of the description in Gray's U.S. patent. More precisely, as Gray's original receiver was intended to operate with zero air gap, the hollow cylinder **S** could not operate as a *diaphragm* in regular telephone receivers, but only as a more efficient acoustic radiator of the vibrations transmitted to it *mechanically* by the magnetic core of the electromagnet.

1. From these words, it appears that Robert Bruce's statement ([9] p. 118) that the New York Times "piece said nothing of multiple telegraphy" is incorrect.
2. As remarked in [13], Gray "happened to see two boys playing with a homemade toy known as a 'lovers' telegraph' . . . what would be known today as a tin-can telephone." Hence the name given to his receiver.
3. The preposition "on" describes something in a position above *and in contact* with the surface of something else.

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Gray developed his second receiver (bottom of Figure 5)[1] in July of 1874 and used it in his demonstrations in Europe in August and September of 1874. Among others, he showed the device to Prof. John Tyndall of the Royal Institution in London and to Latimer Clark, a prominent officer in the British telegraph administration [13, 14]. This receiver differed from the earlier tin-can receiver in that he substituted a washbasin in place of the shoe-polish can on top of the electromagnet, and he rotated the instrument so that it resembled parabolic acoustic radiator (in fact, it has been considered to be the forerunner of the modern loudspeaker). Of course, as a result he obtained a more powerful sound, because the surface of the air column set in movement by the elongation of the electromagnet was much wider than that of the shoe-polish can. Apart its efficiency, however, we do not see any novelty as far as its principle of operation is concerned.

In December 1874, Gray constructed his third receiver, which was a selective receiver. He called it an *analyzing receiver*, since its purpose was to discriminate among the eight tones sent over the line, so as to allow each Morse operator at the line's receiving end to receive the individual message carried by a particular "tone."[2] On March 17, 1875, he demonstrated his whole octoplex before the American Electrical Society [20], just after having filed a patent application on the same apparatus in England [21]. Gray later filed a patent application in the United States for the same apparatus on January 8, 1876 [22], from which comes Figure 6.

The following is the description of Gray's third receiver provided in his U.S. patent #175,971 [22]:

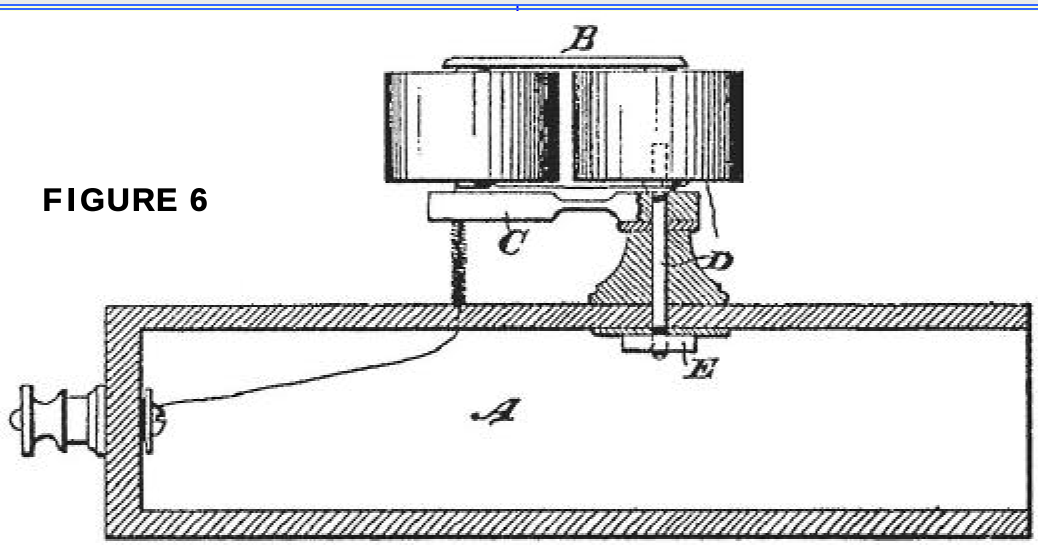
"A resonant-box, **A**, such as used for intensifying the sound of tuning-forks, is shown as closed at one end. A screw-bolt, **D**, or other suitable support secured upon this box, sustains an electro-magnet, **B**, of well-known construction. A vibrating tongue or reed, **C**, of steel, is also fastened upon the support **D**, and is united with one pole of the magnet **B**. The free end of the reed passes close to, but does not touch, the other pole of the magnet.

For convenience of removal or replacement, all the parts of the apparatus may be united by means of a common bolt and nut, **E**.

The box is tuned to produce a maximum resonance of the desired tone, and the reed is accurately tuned correspondingly. Consequently, as the reed vibrates, the sound of its fundamental tone is intensified by the resonance of the box in accordance with well-known laws of acoustics. =>

Gray's Harmonic Receiver (or Wooden Sounding Box Receiver) Used in his Octoplex Demonstrated at the Philadelphia Centennial Exposition on June 25, 1876

FIGURE 6



1. The original model is in the possession of the National Museum of History and Technology, Smithsonian Institution, Washington, DC [14].
2. Most Morse operators in the United States received by ear and wrote down the message directly in a telegram form. There were, however, a number of Morse machines that either wrote on a paper ribbon which later was glued in strips to the telegram form or were true typewriters that did the job without operators at all.

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If, now, the electro-magnet be connected in a telegraphic circuit in the same way as one of my analyzers described in the application aforesaid, and the note be transmitted by means of one of my transmitters described in said application for Letters Patent, the note will sound in the box, provided the tone transmitted corresponds with that of the box; otherwise the note will not be heard. Should a second analyzer be similarly placed in the circuit and tuned to a different pitch, and a second note of corresponding pitch be transmitted, it will sound in the box of corresponding pitch without affecting the other. The same rule holds with a larger number."

From the above, it appears that Gray's third (or *wooden sounding box*) receiver responded to only one tone determined by both the resonant frequency of the sounding box and the vibration frequency of the reed, which were made to match perfectly to each other as well as to the pitch of the corresponding transmitter.[1] On Sunday, June 25, 1876, Gray successfully demonstrated his octoplex on a telegraph line built between Philadelphia (starting from Western Union's stand at the Centennial Exposition) and New York along the poles of the Pennsylvania Railroads. On September 21, 1876, Gray demonstrated the same system at Western Union headquarters in New York City, which *Scientific American* reported on at length [23].[2]

His octoplex telegraph was a success. David Hounshell [13] noted that in the reports of the Centennial Exposition's awards committee [25] Gray's octoplex was cited as "promising important useful practical results," whereas Bell's electrical transmission of speech was characterized as a great "marvel," but without reference to "practical results."

As a matter of fact, Gray himself stated in a letter to his lawyer, Alex H. Hayes a few weeks later (October 29, 1875) [26]:

"Bell seems to be spending all his energies in the talking telegraph. While this is very interesting scientifically it has no commercial value at present, for they [Western Union] can do more business over a line by methods already in use than by that system. I don't want at present to spend my time and money for that which will bring no return."

Consequently, Gray was very busy until about the end of January 1876 in perfecting his octoplex and filing a number of improvement patents on the same [27, 28, 29, 30]. We, therefore, cannot find a satisfactory explanation of why and how Gray made up his mind and filed his well known caveat on the transmission of speech [31], only two weeks after having filed his four octoplex patents, without having done the least experiment on speech transmission—notwithstanding his aforementioned negative attitude towards the return of such an invention. As Hounshell [13] noted, the explanation that Gray had changed his mind after having seen two boys playing with the so-called lovers' telegraph is hardly credible.

At any rate, let us analyze the technical background of his caveat specification, in particular the receiver described there.[3] The caveat stated (italics added) [31]:

". . . my present invention is based upon a modification of the principle of said invention which is set forth and described in Letters Patent of the United States granted to me July 27, 1875, respectively numbered 166,095, and 166,096,[4] and also in an application for Letters Patent of the United States filed by me February 23, 1875."

". . . an electro-magnet of ordinary construction *acting upon a diaphragm to which is attached a piece of soft iron* and which diaphragm is stretched across a receiving vocalizing chamber **C** . . . . The diaphragm at the receiving end of the line *is thus thrown into vibration* corresponding with those at the transmitting end and audible sounds or words are produced."

It seems quite evident from the above description that it was jotted down, without clearly discriminating the principle of magnetostriction from that of =>

1. A sounder like Gray's receiver shown in Figure 6 often was called a "telephone," although intended for receiving not speech, but a single tone.
2. A full account of Gray's work in harmonic telegraphy carried out between 1867 to 1876 is provided in his 1878 book [24].
3. We have no remarks whatsoever regarding his liquid transmitter, it being derived from his earlier commercial water rheostats manufactured by the Western Electric Manufacturing Company 1872-1874, while Gray was superintendent at the company ([32], p. 153). Note that a similar device was utilized by Edison and others from 1873 [33].
4. Both patents were derivative of his English patent [18]. The latter was split into two parts that were filed and granted separately in the United States as patents #166,095 and #166,096.

"Early Electromagnetic Telephone Receivers"

by Basilio Catania (continued)

magnetodynamics, i.e. the attraction and repulsion of an armature or diaphragm under the action of an electromagnet. In fact, on one hand Gray refers to his "tin-can" or magnetostriction receiver discussed above, while on the other hand his electromagnet now faces a vocalizing chamber **C**, apparently with a non-zero air gap (Figure 7), instead of touching the shoe-polish can of his tin-can receiver (top of Figure 5) as describes in his U.S. patent #166,095 and quoted in his caveat.

Among the writers supporting the thesis that Gray's caveat implied the use of a true electromagnetic receiver is William Aitken, who wrote ([34] p. 63), referring to Gray's lecture of March 17, 1875,[1] before the American Electrical Society, that Gray's (wooden sounding box) receiver (italics added) "is a common electro-magnet having a bar of iron rigidly fixed at one pole, which extends across the other pole, *but does not touch it by about one sixty-fourth of an inch*." However, Gray's wooden sounding box receiver was a selective receiver intended to respond to one tone only and whose air gap (at the second pole of the electromagnet) allowed the tuned reed to vibrate at that same single tone.

In addition, Aitken neglected to report what Gray stated just two lines before the same quotation, namely (see [20], p. 9, italics added):

"It is a well known fact that *an iron rod elongates when magnetized, and contracts again when demagnetized*. The elongation and contraction are so sudden, that an audible sound is produced at each change. In order to convert this sound into a musical tone it is only necessary to repeat it uniformly and at a definite rate of speed, which shall not be less than sixteen nor more than four thousand per second."

These ambiguities in Gray's caveat—as far as its receiver is concerned—still remain and strengthen if we consider the events that followed Gray's octoplex demonstration at Philadelphia. Gray, in fact, on June 25, 1876—the same day of his octoplex demonstration—also watched Bell's demonstration of speech transmission, and he thought he had heard the words "Aye, there's the rub" ([9], p. 197). Soon after, he instructed his instrument maker, William Goodridge, to construct a liquid transmitter, as described in his caveat [31], and in July 1876, Gray tried it out using one of his octoplex "wooden sounding box" receivers. Obviously, the test failed and could not have done otherwise, since the receiver he utilized was absolutely unsuitable for receiving (wideband) vocal sounds, because it was tuned to a single tone.

Gray's "vocal sound receiver" as depicted in his caveat of 1876

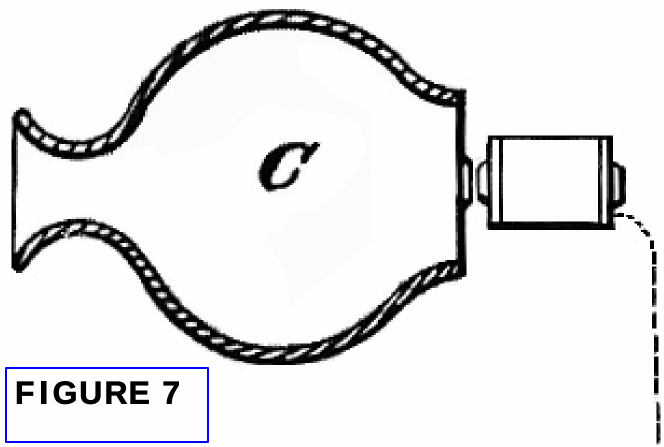

FIGURE 7

Gray himself later admitted that the failure was a result of using an inappropriate receiver type ([13] p. 155, [35] p. 457).[2] The fact, however, that he made this test with such a receiver and not with either his tin-can or washbasin receivers, does not rule in favor of his correct understanding of the basics of speech transmission.[3]

After said failure, moreover, Gray abandoned his telephone scheme. The following March 5, 1877, he wrote to Bell: "I do not, however, claim even the credit of inventing it, as I do not believe a mere description of an idea that has never been reduced to practice—in the strict sense of that phrase—should be dignified with the name invention." ([9] p. 269). In the end, after about

1. Aitken erroneously quotes this lecture as delivered on March 13, 1875.
2. Hounshell [13] quotes the "Deposition of William Goodridge," in *Elisha Gray's Case, Speaking Telephone Interferences*, p. 18. Prescott [35] quotes Gray's own statement (probably made in the same case).
3. Hounshell remarks ([13] p. 135) that Philadelphia was hit in those days by an unusual heat wave and that "he [Gray] passed out in the streets of Philadelphia either from heat prostration or a mild heart attack. He spent over a month in bed for recovering from this attack."

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five months from filing his caveat at the Patent Office, Gray could not get his invention to work satisfactorily or work at all.

Conclusions

I have attempted to reconstruct, from the original documents and statements of each inventor, the structure and principle of operation of some early electromagnetic receivers. I have shown that a few of them, which were represented as improvements of the Reis magnetostriction receiver, were actually true electromagnetic receivers, although their inventors may not have realized this difference. I have shown that other receivers actually embodied the principle of the electromagnetic receiver, but were used to reproduce single tones (not speech) or were conceived and described as being magnetostriction receivers and discovered only later that they could serve to reproduce speech.

I have done the same exercise for other inventors, including Alexander Graham Bell and Antonio Meucci, and I hope to report on their receivers in a forthcoming paper.

Acknowledgements

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Symposium on Postal History (Deadline July 1, 2006)

A call for papers went out for the Winton M. Blount Symposium on Postal History to be held at the National Postal Museum, Smithsonian Institution, in Washington, DC, on 3-4 November 2006. The sponsors are the National Postal Museum, Smithsonian Institution, and the American Philatelic Research Library of the American Philatelic Society (*www.stamps.org*).

Scholars of postal organizations and systems rarely meet and discuss their ideas and research with scholars of philately. This conference hopes to bridge that gap. In addition, the Blount Symposium aims to integrate philately and the history of postal operations within the broader context of U.S. history. The conference hopes to promote research, increase public awareness, and bring national visibility to resident scholars, libraries, and resources.

The symposium will begin with a plenary panel discussion on the topic "What is postal history?" Invited speakers include Michael Laurence, editor, *Classics Chronicle*; Richard R. John, professor, University of Illinois at Chicago (and a member of the **Mercurians**); John Willis, historian, Canadian Postal Museum; and Maynard H. Benjamin, president and CEO, Envelope Manufacturers Association.

Potential presentation themes include transportation and the mail, the technology of moving the mail, and the impact of the information age on communication.

Organizers of the Blount Symposium will post all papers on the website of the National Postal Museum, and publication of selected proceedings papers is under consideration.

Conference co-chairs are Cheryl R. Ganz, Allison Marsh, and David L. Straight.

"History of Wireless" by A. David Wunsch (continued)

recognized easily, such as the sinking of the Titanic in 1911 (page 406). Others are more insidious and are the cause of my caveat to students. For example, the Preface asserts that: "[with the start of broadcasting] around 1920 . . . the word 'radio' was introduced." Prior uses of "radio" abound. The U.S. Congress is not famous for being technically *au courant,* but it passed a famous Radio Act in 1912. The Institute of Radio Engineers (now the IEEE) was founded in 1912; the General Radio Company dates from 1915; and Lee de Forest had an earlier start with his Radio Telephone Company of 1909. I suggest that before the next printing, the contributors read the entire book and root out the mistakes of their coauthors.

Footnotes

1. Heaviside often is quoted as saying that "Maxwell was ½ a Maxwellian" because of his incomplete grasp of the implications of his own treatise. See [7], page 205.
2. Hunt[7], p.182, also asserts that after 5 years exposure to the Maxwellians, Hertz in 1893 "explicitly credited Heaviside with priority in having recast Maxwell's equations and explained [sic] their proper meaning and use."

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Magnetostriction by Basilio Catania

Magnetostriction is a property of magnetic materials—typically, ferromagnetic materials—in which the material changes its shape when influenced by a magnetic field. As the material is magnetized, it grows longer and inversely changes its thickness; when no longer magnetized, it quickly regains its original shape, typically in less than 1 microsecond.

J. Philipp Reis explained this mechanism in his October 26, 1861, lecture before the Physical Society in Frankfurt-am-Main [1]: "At each closing of the circuit, the atoms of the iron wire inside the distant spiral are moved away from each other . . . on breaking the circuit, these atoms seek to regain their position of equilibrium."

In the case of an electromagnet, magnetostriction occurs each time an electric current travels through the coil. As soon as the battery connection is broken, the magnet's length and thickness return to normal.

The magnetostrictive effect was first identified in 1842 by James Prescott Joule, who observed that a bar of nickel changed in length when he magnetized it [2]. Earlier, however, Charles Grafton Page of Salem, Massachusetts, discovered in 1837 that an electromagnet makes a sharp sound (often referred to as a "tick" or "click") when suddenly magnetized or demagnetized. Page also noted that "when the contact is made, the sound is very feeble; when broken it may be heard at two or three feet distance" [3].

Alexander Graham Bell also noted, "when the circuit upon which it [the electromagnet] is placed is rapidly made and broken, a succession of explosive noises [clicks] proceeds from the magnet" [4]. The ear perceives a continuous sound similar to a musical note whose pitch depends on the number of clicks per second. Hence the name "galvanic music" that Page attributed to this phenomenon. Page's public demonstrations of "galvanic music" were deemed by some as kicking off research on the speaking telephone.

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