

TECHNOLOGICAL ARCHAEOLOGY: TECHNICAL DESCRIPTION OF THE GAUSS-WEBER TELEGRAPH

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Abstract: This communication wants to describe the very beginning of electrical communications: the telegraph system implemented by two German scientists in 1832. These two scientists are Carl Friedrich Gauss and Wilhem Weber. We will describe the information we gathered about this system and how we managed to obtain a detailed electrical description.

I. INTRODUCTION

The initial situation was a bit hard: we wanted to analyze the Gauss-Weber system but we only had access to photographs and texts. The original material is exhibited in the "Niedersachsen und Göttingen Museum" (Museum of Göttingen and Lower Saxony).

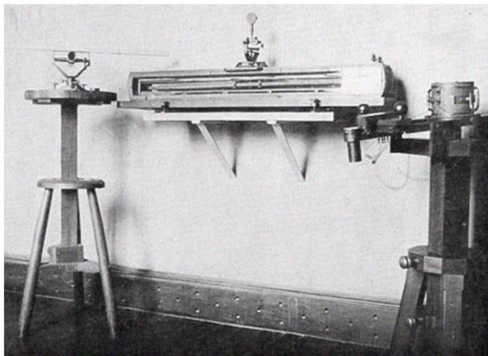


Figure 1.- Material from Gauss-Weber experiments.

II. THE MORSE TELEGRAPH

We started analyzing a more modern scheme. Gauss and Weber experience did not get the spreading that it deserved. Morse developed a new scheme in 1837 that gained general attention. A block diagram of the Morse telegraph would be like this:

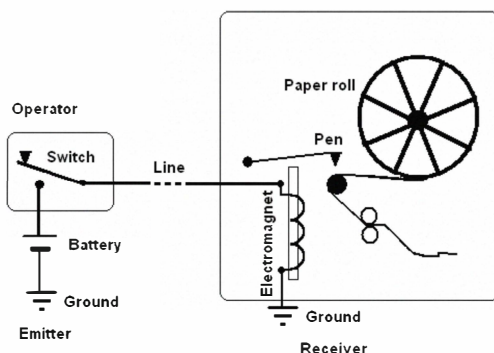


Figure 2.- Morse telegraph.

Emitter is based on a battery and a switch. As the negative terminal is connected to ground, if we act on the switch for one second the signal will be a voltage pulse:

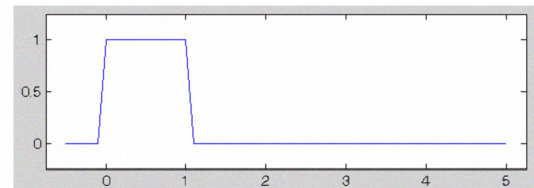


Figure 3.- Voltage pulse from a battery and a switch.

This pulse will travel to the other side through the transmission line made by the electric wire and earth.

When the pulse reaches the coil, the electromagnet will create some strength that will attract a metallic part linked to a pen. If the paper roll is continuously moving we will get the pen writing during the time we are acting on the switch. If we act for a very short time, we will get only an ink dot on the other side (pen is writing for a very short period). If we act more time on the switch, receiver will get a dash. With this we already have a communication, because we are able to send and receive two different symbols. Morse system uses a temporal modulation (based on pulse width).

III. THE GAUSS-WEBER TELEGRAPH

Starting from the insight of Morse system, we analyzed a letter in which Gauss describes the new device to the astronomer Heinrich Olbers [1]. From this information we could infer an equivalent circuit for Gauss-Weber emitter and receiver. We also found the waveform of the signals deducing that they used an amplitude modulation where the sign of the pulse carries the information. We checked that all our assumptions were consistent with the graphical information from the Göttingen museum: images of the original prototypes and a sheet describing a 5 bit code (fixed length) used by Gauss and Weber to code alphabetic messages [2].

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From all the above information, the electrical scheme of the Gauss-Weber telegraph was this one:

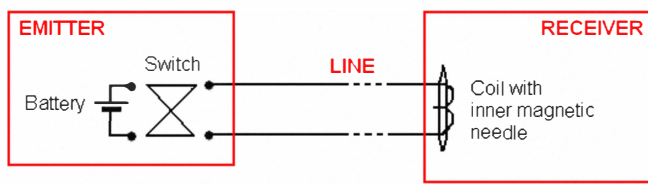


Figure 3.- Gauss-Weber scheme.

The emitter consists on some kind of power source or accumulator (Gauss in his letter to Olbers calls it a “Voltaic Pile”). In fact, in the photos we can see a cylindrical object that could be a kind of capacitor used to store the energy that will feed the signals (perhaps it could be something similar to a Leyden jar [3]).

After the first experiments (about 1835) Gauss decided to change the power source as the “Voltaic Piles” gave very unstable energy (reinforcing the idea that was some kind of capacitor). He designed an “inductor” that could be some primitive generator (a movable magnet inside a coil).



Figure 4.- Emitter.

Gauss and Weber Code was based on moving the receiving needle from the center to left or right position (coil is situated in a horizontal position, see figure 1). In this system, signal modulation will reside on voltage sign (we will have an amplitude modulation, not a temporal one like in Morse telegraph). Connection between the emitting battery and the line (a two wire line, not grounded) consisted of a three-state switch (Gauss speaks to Olbers about this switch):

- Neuter (idle): operator is idle → the battery two terminals are in open circuit.
- Sending a positive pulse: operator wants to move the needle to the right → positive terminal is linked to the upper wire and negative to the lower one. Signal on the line will be a positive pulse. Pulse duration is not very important (carries no information) but it will be the time that operator holds the switch position.

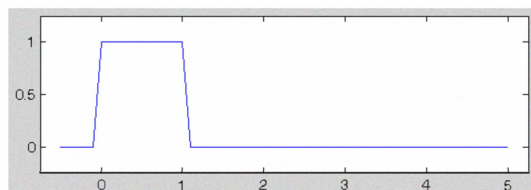


Figure 5.- Positive pulse.

- Sending a negative pulse: operator wants to move the needle to the left → positive terminal is linked to the lower wire and negative to the upper one. Signal on the line will be a negative pulse.

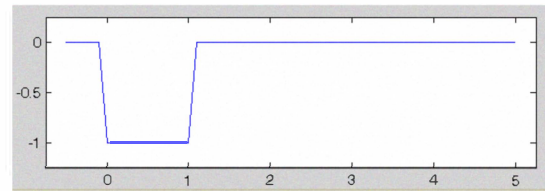


Figure 6.- Negative pulse.

Receiver consists of a coil and a magnetic needle. Gauss calls it “galvanometer” and, in fact, is a device similar to a D’Arsonval meter [4]. In a classical D’Arsonval meter, we would have a rotating coil inside a fixed permanent magnet. Here we have a magnetic needle inside a coil.



Figure 7.- Receiving coil (see the “communication two wire line” entering from above).

Note that pulses with opposite signs will generate opposite magnetic fields and opposite needle movements. In figure 8, we can see the original code that Gauss and Weber used. It was a fixed length code with 5 bits (32 symbols alphabet). We can see that instead “0” and “1” they used the mathematical symbols “+” and “-” which resemble the “sign based modulation” they were using.

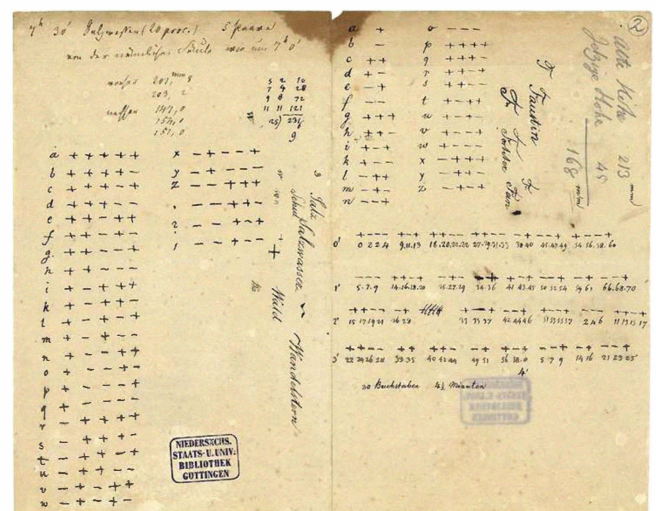


Figure 8.- Original code.

In this receiver they needed a small telescope to see the deflections in the needle as probably these movements were very weak. Probably the power source was not very strong and the losses in the line were important. Gauss speaks about a “pound” magnet and that suggests that the needle weight was also important. With the receiver design (needle “inside” the coil), probably they could not use an iron core to enforce magnetic field at the coil (Gauss letter says they use a 50 turns coil but says nothing about core).



Figure 9.- Telescope used to receive messages.

IV. THE FIRST TELEGRAPH LINE AND THE FIRST MESSAGE

The first telegraph line in history (and also the first electrical communications line) was setup in Göttingen (Germany) between the Astronomical Observatory (Gauss' workplace) and the Weber laboratory (in the Physics Department of local University). It consisted of more than two kilometers (eight thousand feet according to Gauss' words) of a two wire copper line (they started using copper and afterwards they used steel because of the bigger physical endurance).

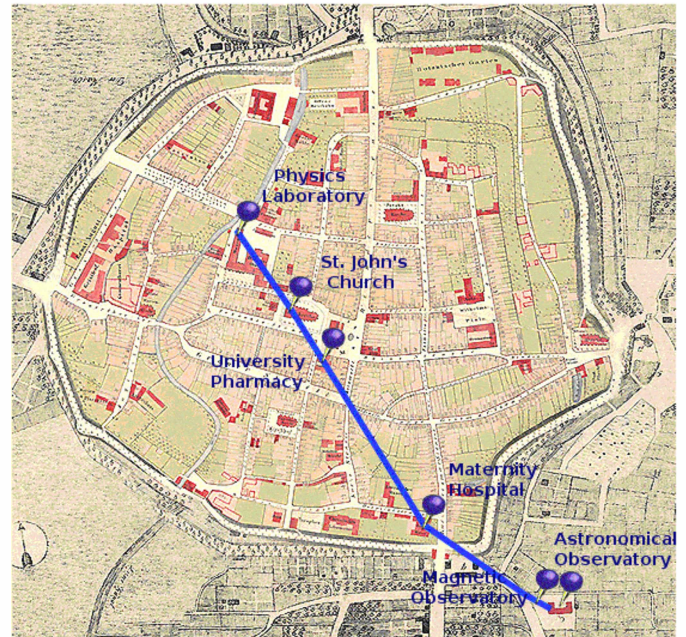


Figure 10.- Ancient map with the line path.

We found two versions about the first message sent. The more official one is based on a note in Gauss' own handwriting: “Wissen vor meinen, Sein vor scheinen“ (“knowing before opining, being before seeming”). Other version says that the first message was: “Michelmann kömmt” (“Michelmann is on his way”). According to this version Gauss was telling Weber that Michelmann (an assistant that worked with both researchers) was going from the observatory to Weber laboratory. Possibly both messages are true: the one about Michelmann would be the first test and the “more official” one was transmitted in a demonstration to local authorities.



Figure 11.- Endpoints of the first telegraph line (nowadays photo of Göttingen). Gauss observatory is on the right.

V. FINAL RESULT

Unfortunately the system developed by Gauss and Weber did not get much attention by local authorities. Although it was under consideration to be installed by the German railway company, project was dropped due to its high cost. Gauss-Weber telegraph was forgotten and became a historical curiosity. What's more, Wilhem Weber was expelled from Göttingen University in 1838 due to a political crisis (he did not accept the politics of new king Ernest August). After that, Gauss abandoned work in magnetism and electricity and he devoted himself to other math and physics disciplines.

VI. COMPARISON WITH MORSE SYSTEM

Comparing the two ancient telegraph systems: from Gauss-Weber and from Morse we draw the following conclusions:

- Main contribution from Gauss is the use of electrical pulses as means of transmission and its conversion to magnetic fields to be received. Nevertheless, it is not demonstrated that Morse had any knowledge of Gauss' experiments. Scientific diffusion in those years was very restricted. Gauss and Weber had only 181 subscriptions to their "journal on magnetism", all of them were sent to European countries.
- Main contribution from Morse is the first variable length code which is also a minimum mean length code (minimum entropy) [5].
- Gauss and Weber use two wire lines whilst Morse uses return by ground. So Morse lines are cheaper to install.
- Sign modulation (Gauss-Weber) is more robust than duration one. See that modulation and demodulation are performed by human beings. "Positive" and "negative" (or "left" and "right") are more objective than "long" and "short" writing.
- Morse receiver is clearly superior as it creates a printed copy of message and needs no strange elements like Gauss' telescope.

Recently we have known about the work of Carl August von Steinheil but we still have no reliable references. This man was a physics professor in Munich from 1832 to 1849 and he was a former student with Gauss and Weber. He is recognized as the discoverer of the ground return and it is said that he implemented an advanced version of Gauss-Weber telegraph in a railway line (using ground return and a printing receiver). It is also conjectured that Morse had some knowledge of Steinheil system and that this could be the link between Gauss-Weber and Morse telegraphs.

VII. CONCLUSIONS

We have gathered information about the first telegraph made by Carl F. Gauss and Wilhem E. Weber. From that information we have inferred the technical foundations of that ancient system. We have also compared the Gauss-Weber telegraph with the more well known of Samuel Morse.

VIII. REFERENCES

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