WIRELESS TELEGRAPHY.

Edwin Charles Cook.

Henry Theodore York.

WIRELESS TELEGRAPHY.

Edwin Charles Cook.
Henry Theodore York.

1. Wireless Telegraphy.
    1. Early Experiments.
        1. By J. B. Lindsay.
        2. By J. Trowbridge.
        3. By J. W. Preece.
    2. Signor Marconi's Method.
        1. Experiments and discoveries leading toward it.
            1. By Maxwell.
            2. By Lord Kelvin.
            3. By Von Helmholtz.
            4. By Hertz.
        2. Development of the coherer.
            1. Mechanical construction.
            2. Experiments by Varley on conducting dust.
            3. Marconi's Coherer.
                1. Construction.
                2. Adjustment.
        3. Description and operation of his system.
            1. Drawing of instruments and connections.
            2. Difficulties in practical operation.
                1. Sensitive coherer.
                2. Obstructions to radiations.
                3. Interception of messages. sion
                4. Expense of long distance transmis-
    3. Experiments by writers.
        1. Apparatus.
        2. Arrangement.
        3. Coherer.
        4. Distance transmission.

WIRELESS TELEGRAPHY.

The first experiments of note in wireless telegraphy were conducted by J. B. Lindsay in England about 1843. He sent messages across a river by placing two metal plates on each bank connecting the two on one side to the dispatching instrument and the two plates on the other side to the receiving instrument. He found by experiment that for the best results the distance between the plates should exceed somewhat the breadth of the river. Numerous experiments were made by others along this same line. This method never became of any practical use.

About 1880 Prof. John Trowbridge experimented along the line of induction but found that the size of coils necessary to telegraph any useful distance would be so great as to make the method impracticable.

The next experimenter we should notice, and the one to whom belongs the honor or developing the first practical system is W. H. Preece. In 1885 he conducted a series of experiments with remarkable results.

Insulated squares of wire each side 440 yards long were laid out horizontally on the ground one-fourth mile apart and distinct speech by telephone was carried on between them; while when removed 1000 yards apart inductive effects were still appreciable.

With parallel telegraph lines ten and a quarter miles apart, the ordinary working currents in the one were clearly perceptible in a telephone on the other.

In his system lines of heavy copper wire are laid parallel to each other and grounded. The sender consists of a make-and-break wheel to interrupt the current about 400 times per second, a small motor, 50 Leclanche cells to furnish the current, and a Morse key to break up the note given by the make-and-break wheel. The receiver consists of an ordinary telephone.

Besides the above mentioned systems, many other devices have been suggested. Many attempts toward carrying them out have been made but since none except that of Marconi's promises to become of commercial importance, they will not be here considered.

In order properly to lead up to the work of Signor Marconi we shall briefly mention a few of the theories and experiments of Maxwell, Lord Kelvin, Von Helmholtz and Hertz.

Maxwell was opposed to the theory of "action at a distance" and assumed the energy of an electric current to be conveyed by a stress in a medium. Acting on this theory, he deduced a set of equations identical in form with those for motion of an infinitely elastic solid. From these equations the theory was developed that light and electricity are carried in the same way. Or in other words, disturbances of electrical equilibrium at a place are produced by waves propated in ether in the same manner and with the same velocity as are those of light.

If this propagation was to be traced through the small space inside a laboratory, periodical disturbances of extreme rapidity must be set up so that the corresponding wave length may be not more than a few feet.

The oscillatory nature of a Leyden jar discharge was deduced by Von Helmholtz in 1849, and it was mathematically demonstrated by

Lord Kelvin in 1853. If a Leyden jar of an inductive capacity K and self induction L be discharged, and if the resistance of its circuit be less than $2\sqrt{L/K}$ a series of oscillations are produced and the period T of the oscillation is given by the equation $T = 2\pi\sqrt{KL}$.

A casual observation started Hertz on his series of marvellous investigations. While performing some experiments with a couple of Riess' spirals - short flat coils of insulated wire with the turns all in the same plane - he noticed that the discharge of a very small Leyden jar when passed through one, excited an induced current in the other which was detected by means of a small spark gap. Almost immediately he brought forth the following propositions:-

1. If we allow a condenser, such as a Leyden jar of small capacity to discharge through a short and simple circuit with a spark gap of suitable length, we obtain a sharply defined discharge of short duration which is the long sought for sudden disturbance of electrical equilibrium, the "exciter" of electrical vibrations.

2. Such vibrations are capable of exciting in another circuit of like form resonance effects of such intensity as to be evident even when the two circuits are separated by considerable distances. In this second circuit, Hertz discovered the "detector" of electric waves.

After this discovery, Hertz soon reproduced in corresponding electro-magnetic effects all the phenomena of light. Its identity with electricity was demonstrated.

The study of the propagation of electric radiations through space now for some time occupied Hertz's attention. The results of his researches were published in 1888. He brought out the fact that when sparks pass at the exciter rectilinear oscillations radiate out into space. He carefully studied this radiation and found it to obey the same law of radiation as does light. Proof was also given that the electric waves travelled with the same speed as light.

The detector used by Hertz was a metal wire bent into a circle and terminated by two small metal knobs between which the sparks passed. Many kinds of detectors have been used but none except those of the microphonic order enter into the Marconi system of telegraphy.

The world had now the "bricks" and "mortar" of the Marconi system. It did not take long to develop the exciter and the delicate detector or "coherer" now used, to produce a telegraphic system without the use of connecting wires. This had been the dream of Scientists as early as 1838.

The experiments that began the development of the modern coherer were conducted by S. A. Varley in 1866. He found that a loose mass of dust of conducting material opposed great resistance to a current of moderate tension, but if the tension were greatly increased, the particles arranged themselves under the influence of the electric waves and formed a good conductor. It was discovered later that after the particles had thus arranged themselves the resistance of the dust became very small, but on being disturbed the particles became disarranged and again offered a high resistance.

One of the first forms of the coherer and one based on the above principle, was that constructed by Prof. Lodge. It consists of an ebonite or glass tube about seven inches long, one half inch outer diameter, containing metal filings, and fitted at the ends with copper pistons which can be regulated to press upon the filings with any degree of pressure desirable. To bring back the filings to their normal non-conducting state, Lodge used a tapper worked either by clock work or by a trembling electrical machanism.

Mr. Popoff used a coherer very similiar to that constructed by Prof. Lodge. His apparatus for telegraphing was very much like Marconi's and he hoped to be able to telegraph long distances by the use of a more powerful transmitter. It is evident that he was looking in the wrong direction. It was not so much a more powerful transmitter that was needed as a more sensitive coherer. Mr. Marconi supplied this and in doing so, solved the most vital problem of wireless telegraphy. His coherer consists of glass tube four centimeters long and two and a half millimeters interior diameter, into which two silver pole pieces, one millimeter apart, are tightly fitted so as to prevent any scattering of the filings. The small intervening space is filled with a mixture of 96 parts mickel and 4 parts silver, not too finely powdered and worked up with a little mercury. By increasing the proportion of silver powder, the sensitiveness of the coherer is increased in proportion but it is better for ordinary work not to have too great sensitiveness, as the coherer then responds too readily to atmospheric electricity and other stray radiations. Similarly the smaller the powder space the more sensitive is the instrument but if too small the action is capricious. The quantity of powder required is of course very small but it must be treated with care; it must be

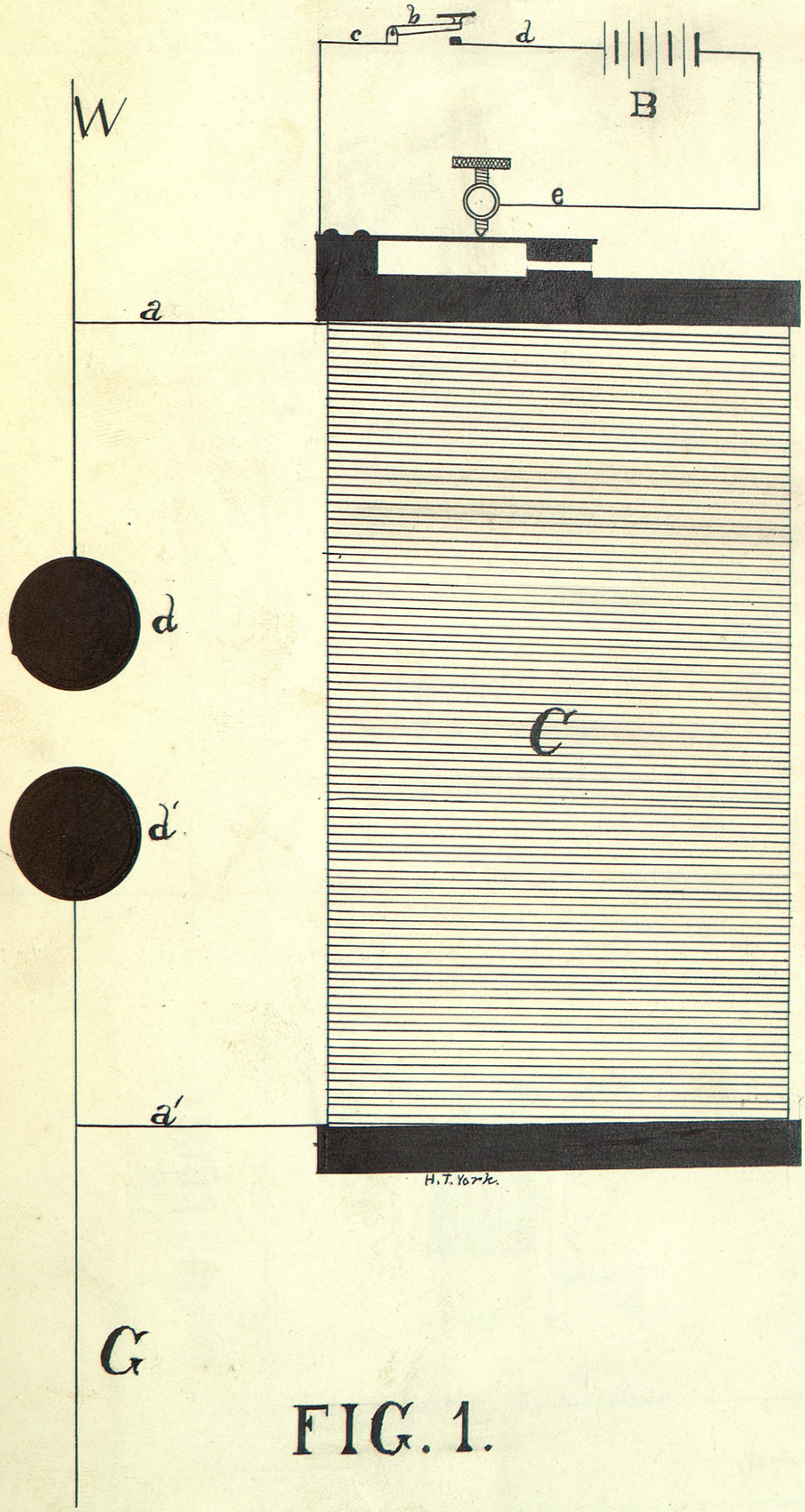

FIG. 1.

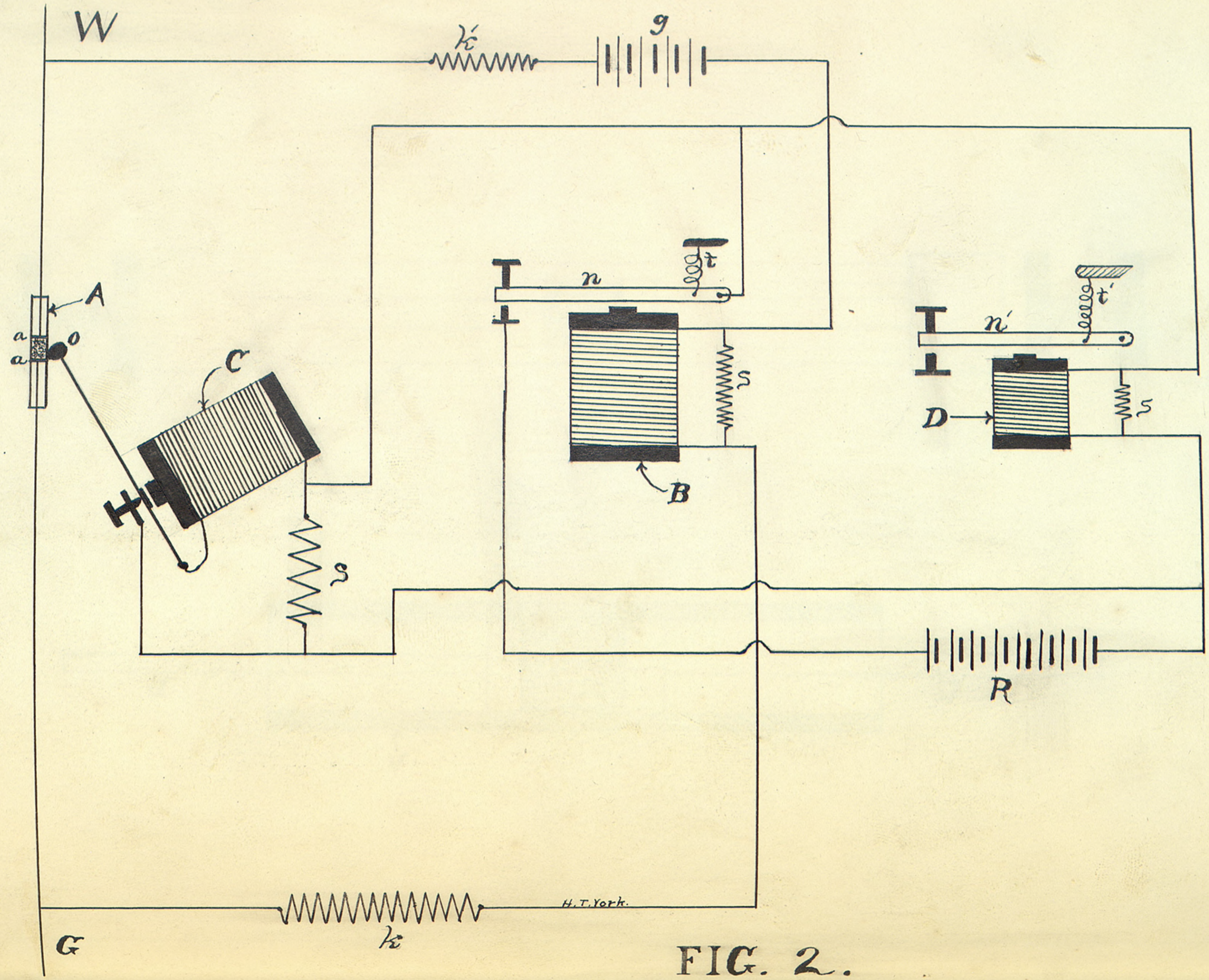

FIG. 2.

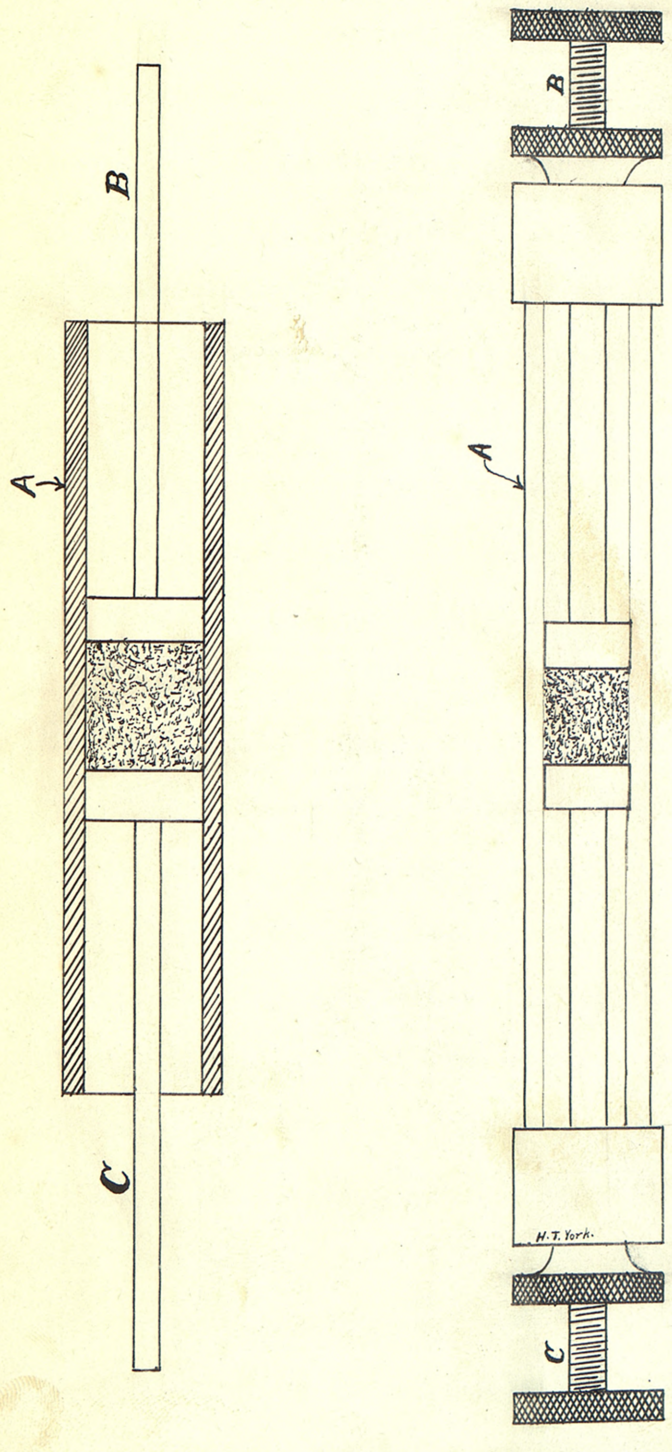

FIG. 3.

neither too compressed nor too loose; if too tight, the action is irregular and often the particles will not return to their normal condition or "decohere". If too loose, coherence is slight and the instrument is not sufficiently sensitive.

In its normal condition, as already stated, the powder is practically a non-conductor offering great resistance. The particles (to use Mr. Preece's expressive words) lie higgledy, piggledy, anyhow, in disorder. They lightly touch each other in a chaotic manner, but when electrical waves fall upon them, they are polarised cohere, electrical continuity is established and a current passes, the resistance falling from practical insulation down to a few ohms.

In the Marconi system, the dispatching instrument consists of an induction coil C, a battery B and a key b connected as shown in figure 1. The ends of the primary coil are connected to the wires c and e which form a part of the circuit in which are located the battery and key. When the key b is depressed, the circuit is closed and the current flows through the primary coil. This induces a secondary current in the secondary coil, the terminals of which are connected to the wires a a'. This current passes by wires a a' to wires W and G. G is connected with the earth and W with a wire that runs vertically up a supporting pole. The other ends of W and G terminate in two metal balls d d' which are placed a distance apart varying as the distance to be telegraphed over, a space of four inches being sufficient to telegraph from one to three miles. When the key b is depressed the secondary current induced in the coil passes to the wires G and W and not finding an outlet at the ends jumps across the space between the balls. In consequence of this sparking the wire W becomes a center from which electrical waves radiate and as the upper end is above surrounding objects, the waves can reach to a considerable distance. If at any point within range of the waves a receiving instrument is placed, it will detect this radiation. So long as the key is depressed the wire W will emit waves but these will disappear the instant the key is raised. From this it will be seen that by pressing b at proper intervals and for proper lengths of time, signals may be transmitted that can be easily read at the receiving station.

The receiving instrument is shown in Figure 2 and the important part the coherer is shown on an enlarged scale in Figure 3. The wires G and W are arranged in this instrument in the same way as in the transmitter, the wire G is grounded and W run up a high mast. The balls d d' of the transmitter are replaced by the coherer A. The wire from W leads to k' which is an inductive resistance then through a battery g a magnet B and another inductive resistance K and joins wire G. The coherer as shown in Figure 3 consists of a glass tube A fitted with two copper pistons C and B to which are attached the wires G and W of Figure 2. The pistons are a short distance apart and the space between them is filled with metal filings. The action of this coherer is identical with that of Marconi's described above.

The battery g cannot force a current through the coherer A in Fig. 2 as the pressure of the current it generates is not sufficient for the purpose, but when the electric waves from the sending station strike the wire W they induce in W a current of very high pressure that is capable of breaking through the resistance of the metal filings of the coherer. As soon as this high pressure current passes through, the resistance of the filings falls to practically nothing, and the current from the battery g follows up. This battery current passes through the battery b and causes the latter to attract the lever n and thus the circuit in which the battery R is located is closed. This circuit contains the magnets C and D; the first acts to vibrate the lever upon the end of which is knob o and the second one actuates the sounder key n'. The coherer A if not disturbed after it has been traversed by an electric current would remain of low resistance but it would not do to have it act in this way for then the current of the battery g would continue to flow and the sounder D would keep up a continuous rattle. If however the coherer is rapped gently after the current has passed through it, it returns to its high resistance state. For this purpose, the decoherer or striker o is provided. This is operated by the magnet C and is so adjusted that it strikes the tube every time the current passes through it. Therefore the battery g cannot send a current through this circuit except while the waves from the transmitter are passing.

The instrument described above contains all the important features found in those that have proven of commercial importance.

The first difficulty in practical wireless telegraphy was to produce a sensitive coherer. After many experiments, Marconi found that a mixture of coarse nickel and silver filings, in the proportion of nine-tenths nickel to one-tenth silver proved very successful. Other experimenters have been successful with pure nickel filings while others have used highly polished steel balls in place of filings. Another difficulty has been to secure an open space over which the waves may travel unimpeded. Trees, hills and other objects tend to absorb them and thus weaken the effect upon the receiving instrument. This has been obviated by the use of a vertical wire of length sufficient to give the waves a free path.

Many people think that wireless telegraphy would be unsuccessful in practical use because the message could be intercepted by an instrument for which the message was not intended; but as there are waves varying from a few feet in length to hundreds of miles, the instruments could be tuned to a definite wave length and it would take many settings before another instrument could find this particular wave. By the use of special codes such interception could be rendered useless.

The intensity of electrical radiation decreases as the square of the distance increases. For this reason a spark of great intensity is required to telegraph over 100 miles. To produce this spark necessitates the use of apparatus so costly as to make the system, in its present state of development, almost useless.

The writers of this paper in a short series of experiments at the Kansas State Agricultural College used an instrument similar to that shown in Figures 1, 2 and 3. We first experimented with mixtures of filings of different metals, in the coherer, to find the mixture that would make the coherer the most sensitive and still have its action regular. We found that the coherer would respond well with a mixture of three-fourths nickel and one-fourth silver. After many trials with mixtures of various metals, we finally used one of nine-tenths zinc to one-tenth copper. With this mixture the coherer was very sensitive and decohered almost perfectly.

During the first experiments the transmitter and receiver were in the same room. We then removed the transmitter to another room. In this way three stone walls were interposed between the transmitter and receiver. This however did not in the least hinder the action of the receiver and after a little careful tuning it answered perfectly to the signals given out by the transmitter.

Our final experiments were conducted with the instruments nearly one mile apart. In our first trial at this distance the receiving instrument did not respond to any signals of the transmitter most probably for the reason that the top of the vertical wire of the transmitter was below the lower end of the vertical wire of the receiver. The second attempt was more successful but only imperfect action of receiver was secured. In this case, the instruments were placed on the same level by aid of a surveyors transit. The vertical wire of the receiver was about twenty feet long but that at the transmitter only seven feet. The spark used was about three and a half inches long and passed between hollow brass spheres about two inches in diameter. The transmitter was grounded by inserting the end of the ground wire a few inches into moist earth; this made a very poor ground owing to the rocky formation where the transmitter was placed.

The current operating the transmitter was furnished by a chloride accumalator of three cells. For the relay we used a battery of five Leclanche cells and for the sounder, a battery of eight gravity cells. It is very probable that the messages in our last experiment would have been transmitted more perfectly if solid metal balls had been employed and a better ground connection secured.

The success that was ours in this short series of experiments has fully convinced us that the field is a rich and profitable one for all experimenters interested in electrical phenomena.

FINIS.