No. 726,735. PATENTED APR. 28, 1903.

E. F. NORTHRUP.

SYNCHRONOUS CODE TELEGRAPHY.

APPLICATION FILED OCT. 10, 1902.

NO MODEL. 2 SHEETS—SHEET 1.

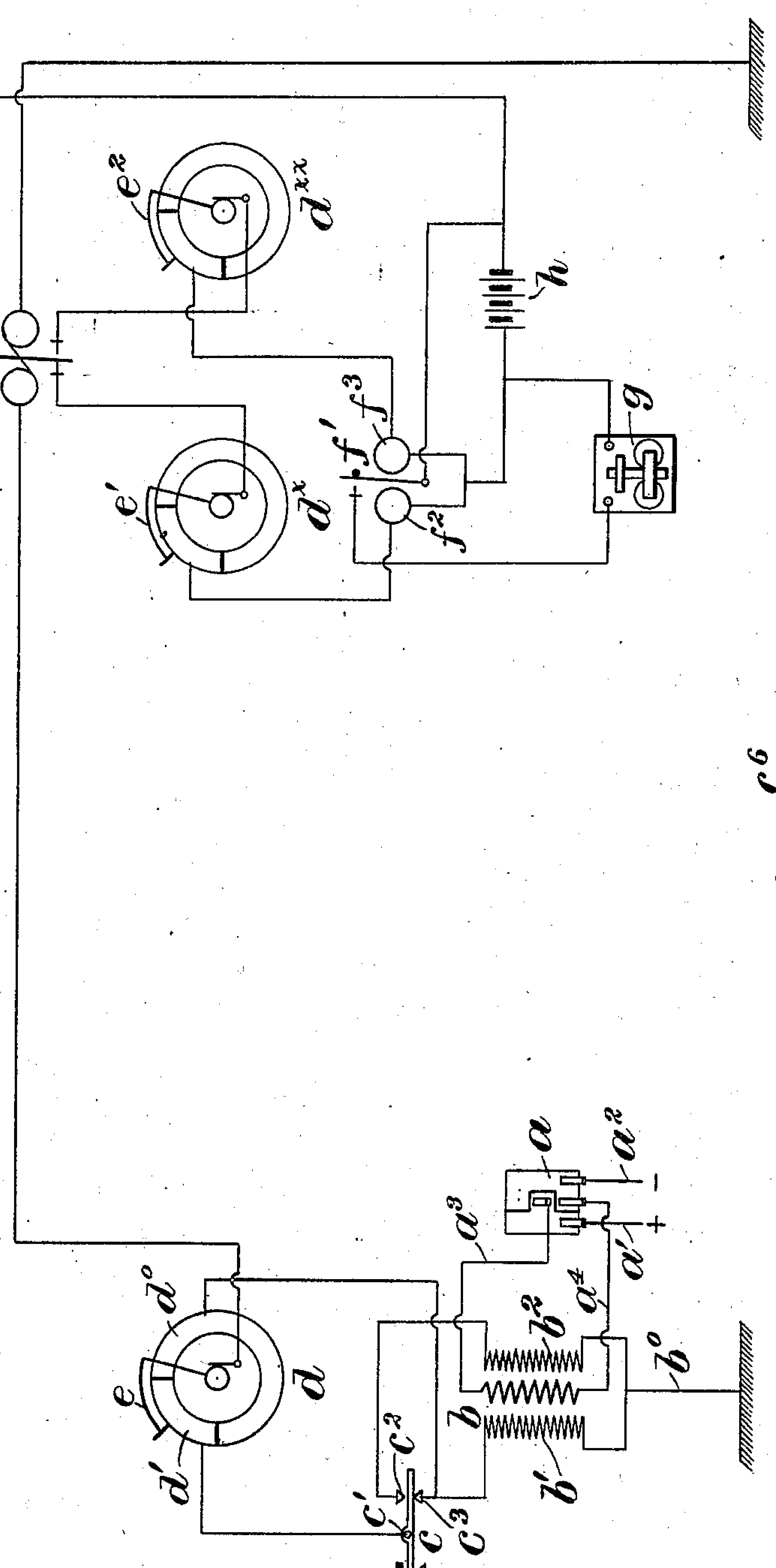

Fig. 1.

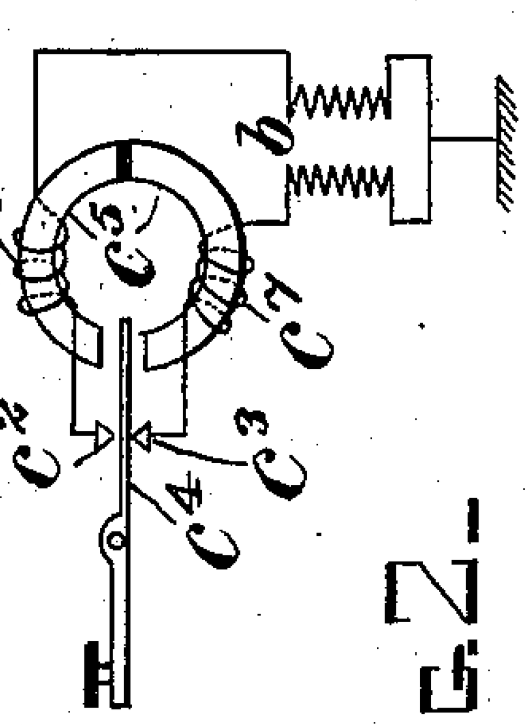

Fig. 2.

Witnesses

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NO MODEL. 2 SHEETS—SHEET 2.

FIG. 3.

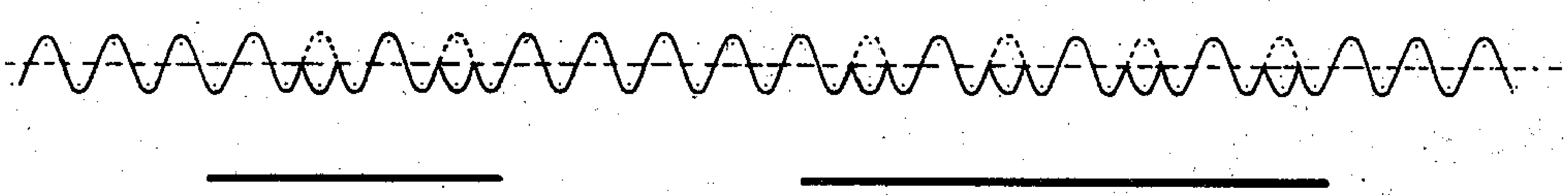


FIG. 4.

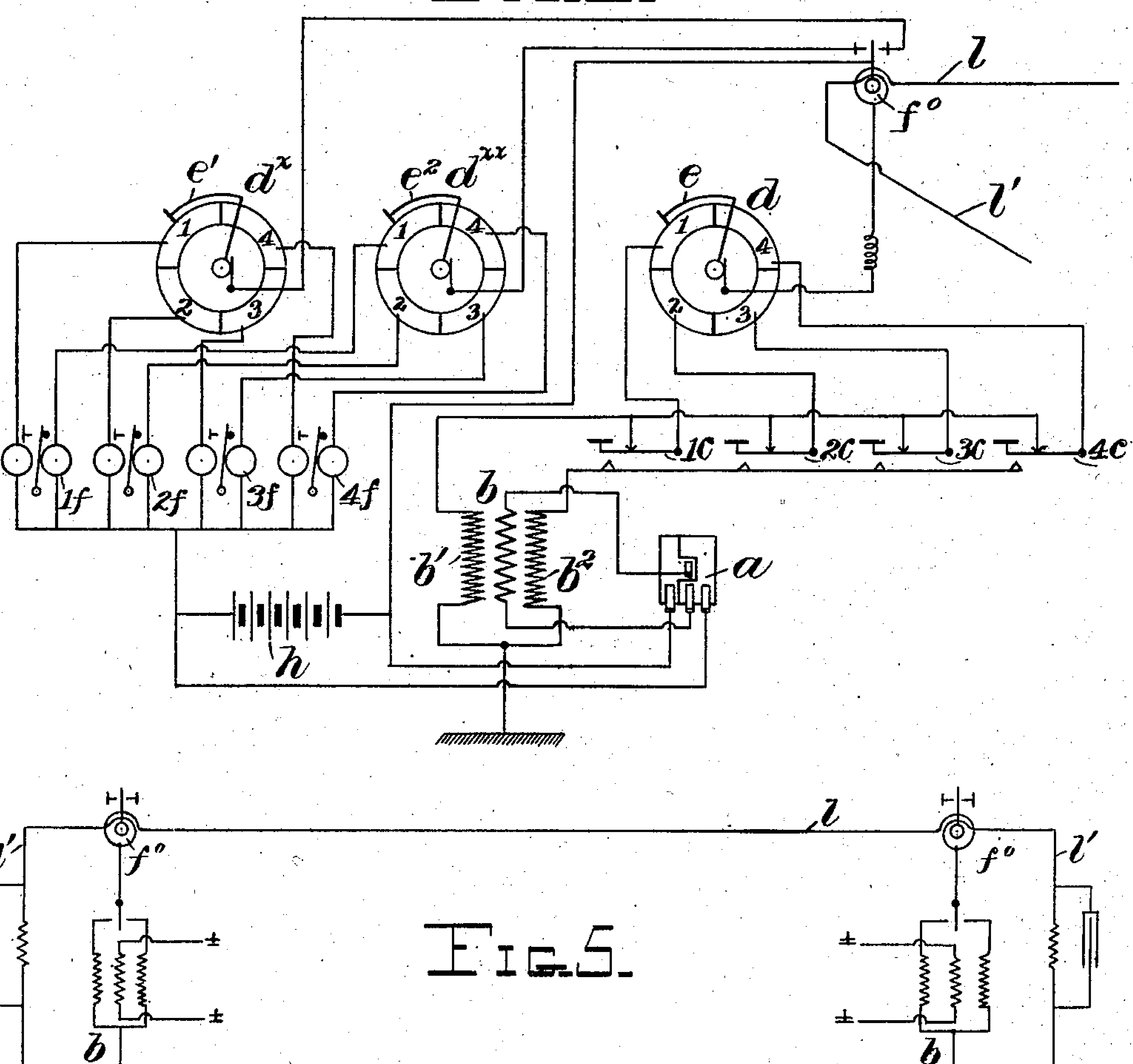
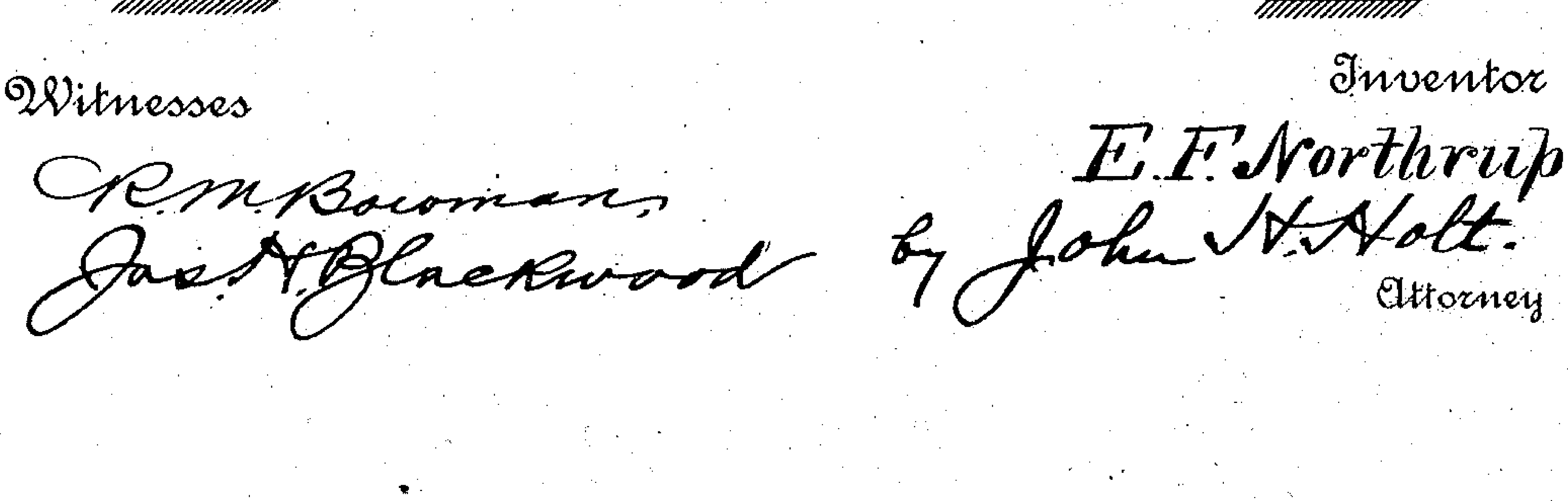


FIG. 5.



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EDWIN F. NORTHRUP, OF PHILADELPHIA, PENNSYLVANIA.

SYNCHRONOUS CODE TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 726,735, dated April 28, 1903.

Application filed October 10, 1902. Serial No. 126,744. (No model.)

To all whom it may concern:

Be it known that I, EDWIN F. NORTHRUP, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Synchronous Code Telegraphy, of which the following is a specification.

My invention relates to improvements in wire telegraphy, and more especially to a synchronous multiplex code telegraph system employing an alternating current for transmission.

The principal object of my invention is the adaptation of the alternating current for the transmission of Morse characters in the simplest possible manner and the providing of means whereby the very troublesome system of quadruplex Morse telegraphy now in general use may be supplanted by a system in which the line-relays when once balanced need no adjustment for weather and other changes, which so readily affect the Edison quadruplex.

According to my invention the line is multiplexed by the well-known method of employing synchronously-operated sunflowers, which allow the local operators the use of the line successively at rapidly-recurring intervals, and the line is also duplexed by balancing, so that at least four operators can be transmitting at each end of the line at the same time—that is to say, the capacity of the line is at least eight simultaneous messages.

My invention, moreover, makes it possible to employ the well-known Morse keys and sounders or registers or other well-known code-telegraph receivers without the necessity of devising special transmitters and receivers. The signals are impressed on the line by reversing impulses of the line-current—for example, by reversing one impulse for a dot and two for a long dash or any multiple of these numbers. In this manner I make up a complete Morse code which is readily receivable upon any of the well-known receiving instruments above referred to.

In order to more fully describe my invention, reference will be had to the accompanying drawings, in which—

Figure 1 is a diagram illustrating the principle of my invention and the simple case in which the line is used by a single operator transmitting messages to a single receiver. Fig. 2 represents a modified form of Morse key designed to reduce sparking. Fig. 3 is a diagram illustrating my method of forming a Morse code with alternating-current impulses. Fig. 4 is a diagram representing a transmitting receiving apparatus at one end of an octoplex line, and Fig. 5 is a diagram illustrating the principle of duplexing the system.

Similar characters refer to similar parts throughout the several views.

I will first describe the manner in which a single operator transmits signals, then how these are received, and finally how the line may be worked duplex or octoplex.

The transmitting of the dots and dashes of the Morse alphabet is accomplished by reversing one impulse or semicycle of the alternating current for a dot, two impulses for a short dash, and four impulses for a long dash, or preferably a multiple of these numbers. The apparatus herein shown, however, is so arranged that a single operator can reverse only every fourth impulse. Hence the time occupied in sending a long dash is equal to sixteen impulses of the line-current.

The term "impulses" is herein used as synonymous with "semicycle" and "half-period," being that portion of the current included between two successive zero-points.

Referring to Fig. 1, *a* represents a commutator used as a current-reverser and driven by any suitable motive power. The direct current enters this commutator by the leads a' a^2 and the alternating current leaves it by the leads a^3 a^4. The alternating current developed by this commutator completes its circuit through the primary of a small transformer *b*. This transformer has two secondary windings b' and b^2, with their turns wound in opposite directions. The secondary windings are connected to earth, as by conductor b^0, as shown. The commutator *a* simply represents a source of alternating current and may be an alternating-current dynamo or any device for producing an alternating electric current. Moreover, I do not confine my invention to any special form of current wave. A Morse key *c* is pivoted, as at c', and is provided with the contacts c^2 c^3. Operating in conjunction with this key is a sunflower d, provided with a long segment d^0, which extends around three-fourths of the circumference of the sunflower, and a short segment d', which extends over the remaining one-fourth of the circumference, the segment d' being connected to the point c' of the key, while the segment d^0 is connected to the lower key-contact c^3. This sunflower is provided with a trailer e, which revolves around the sunflower and over the segments at such a speed that the said trailer makes one complete revolution around the sunflower for each four complete impulses developed by the commutator a. This trailer is driven, preferably, at a constant speed and may be mechanically geared to the shaft which drives the commutator a or may be driven in any suitable manner. This sunflower may be provided with four segments of equal circumferential length and three connected to the wire which segment d^0 now connects to, while the fourth would be the segment d'. This, however, would be necessary only in case four operators wished to use the sunflower, which case will be hereinafter described. Since this trailer makes one complete revolution for each four impluses, it will therefore pass over the segment d' for each fourth impulse developed and over the long segment d^0 for the other three. When the key is not depressed, the alternating current induced in the winding b' of the transformer will flow down the main line, going only one-fourth the time by way of the key and into segment d' of the sunflower and for the rest of the time through the segment d^0. Every fourth impulse can therefore be controlled or modified by the key, and there will be a current on the line at all times. If the key is depressed when the trailer is on segment d^0, the secondary winding b^2 of the transformer is connected to the key through the contact c^2, and as soon as the trailer e reaches segment d' the line will receive current from this winding of the transformer. The current, however, from the winding b^2 is in opposite direction to the current which comes from the winding b', and hence depressing the key reverses every fourth impulse of the current. If the key is kept depressed only long enough to reverse one impulse, a dot will be transmitted, if long enough to reverse two impulses a short dash, and if long enough to reverse four impulses a long dash. This order of modifying the impulses will hold for any multiples of these numbers.

In Fig. 3 I have shown how the line-current is modified to send the letter "A," represented by a dot, space, and dash. In this case two impulses are reversed for a dot or a short dash, which is the same thing, and four for a long dash. The same rule may be applied to forming all the characters of the Morse code.

If by chance an operator should depress the key at the instant the trailer e is passing over the segment d', the reversal of the current would be attempted when the impulse was at a maximum, and this would probably cause a spark at contact c^3. I have, however, devised a modified Morse key (shown in Fig. 2) which will reduce this sparking to a minimum. In this case I provide the key with a thin steel spring extension c^4, which is adapted to move between the poles of an electromagnet c^5 when the key is depressed. This magnet has two windings c^6 and c^7, one connected in series with key-contact c^2 and transformer secondary b^2 and the other in series with the key-contact c^3 and transformer secondary b'. If the spring is against contact c^3 and current is flowing through coil c^7, then even if the key is depressed the contact will not be broken at c^3, since the spring will be attracted down by the magnet and will only bend; but if the key is kept depressed and the current through the coil c^7 ceases then the spring will move up and contact will be made at c^2. If current then flows through coil c^6, the contact at c^2 will remain closed even if the key is raised. Thus no sparking of any consequence can ever occur at contacts c^2 and c^3. In any case, however, the sparking will be small, and hence I do not consider this modified form of key essential for the successful operation of the system.

Referring now to the receiving end of the line, Fig. 1, the current transmitted over the line as above described maintains in vibration the tongue of a polarized relay f and then passes to earth, as shown. The local receiving apparatus consists of two sunflowers $d^\times$ and $d^{\times\times}$, similar to sunflower d, a local relay f', with two independent coils f^2 and f^3, a sounder g or Morse register, Bain chemical receiver or other well-known receiver of Morse or similar characters, and a source of local current h, all connected as shown. The trailers e' and e^2 rotate in synchronism with the transmitting-trailer e and, like trailer e, make one complete revolution for every four impulses of the line-current arriving. I do not herein claim any special method or means for maintaining synchronism between these trailers, as this may be done in a variety of ways. A method of maintaining synchronism well adapted to my system has been described in *Nature*, May 28, 1878, also in Lord Rayleigh's *Theory of Sound*, Vol. I, page 67. Other methods are described in the patents to Henry A. Rowland, Nos. 622,636, 689,753, 691,667, and others. The sunflowers $d^\times$ and $d^{\times\times}$ would in practice comprise two sections of one sunflower, but are represented separately in the diagram for the sake of clearness.

The operation of the receiving apparatus is as follows: Let it be assumed that as long as none of the impulses are reversed the tongue of the main-line relay f will always be against its right-hand contact when the trailers e' and e^2 are passing over the short segments. In this event whenever trailer e^2 arrives on the short segment of its sunflower the right-hand coil f^3 of the relay f' will receive current from the battery h and the tongue of this relay will be drawn against its back-stop. If, however, at the time the trailers arrive on the short segments an impulse is reversed, the tongue of relay f will be against its left-hand contact instead of its right—that is, against the contact to which it was drawn by the preceding impulse. The local circuit will then be completed through the left-hand coil f^2 of the relay f', which will draw the tongue of said relay against its forward contact, where it will remain until the trailers again return to the short segment, when the tongue will return to its back-stop unless another impulse has been reversed. If this be so, then the tongue will remain against its contact for another revolution of the trailers. As long as impulses continue to be reversed whenever the trailers arrive on the short segments just so long will the tongue of the relay f' remain against its forward contact. The shortest possible time of making a single dot of the Morse alphabet is therefore equal to the time of one revolution of the trailer. In general, however, a dot will correspond to two or more revolutions and the dash correspondingly increased. Obviously, then, the closing of this relay-contact for various lengths of time, determined by the number of impulses reversed, may be made to operate a Morse sounder g or register, chemical receiver, or any of the receivers of Morse or similar characters. I have shown a sounder g, connected in circuit with a battery h, and the tongue and forward contact of the relay f'; but obviously, if desired, I may use the relay f' alone as a sounder or as a visual receiver.

Since the operator transmitting may depress his key when his sunflower-trailer is at any part of its revolution, it would appear that if the key were to be depressed when the trailer was leaving the short segment d' and raised before the trailer returns again to this segment no impulse would be reversed. This, however, is not the case, since the trailer rotates at so great a speed that it will make more than one revolution before the hand, having depressed the key, can allow it to rise again. Moreover, there will be a difference in the duration of a dot or dash at the transmitting end of the line and a dot or dash at the receiving end—that is to say, a dash transmitted will not necessarily be of the same length or duration as a dash received; but this difference diminishes as the number of impulses that make up a dot or dash are increased. There will be greater uniformity when four impulses are reversed for a dot and eight for a dash than when two are reversed for a dot and four for a dash. The time representing a dot of four reversed impulses, or eight impulses in all, is, however, very brief, although the mark indicating the dot in Fig. 3 seems rather long. This will be more apparent when we consider that the characters may be sent with an alternating current having a frequency of one hundred and four periods or two hundred and eight alternations per second, or more.

The speed of the system depends upon the speed of the operators, as the line always has a greater speed capacity than an operator. If the alternating current has a frequency of one hundred and four periods per second, this corresponds to transmission of about forty words per minute per operator.

From the foregoing description it will be seen that it is not necessary for each operator to reverse or otherwise modify the same number of impulses always for a given element of the code, it being essential only that the number of impulses modified for one element shall bear a certain relation to those modified for the other element of a given character. For example, a certain operator may transmit by modifying two impulses for a dot and four for a dash, while the same or another operator with the same or similar apparatus may transmit by modifying four impulses for a dot and eight for a dash. In other words, the same limitations apply in this system as to the relation between the elements of the code as in the ordinary Morse system. Of course if a given operator commences to transmit a message and his speed of transmission is such that he holds down his key long enough to reverse two impulses for a dot and four for a dash he must preferably maintain the same rate during the transmission of the message.

The reversed impulses will of course not have the exact form at the receiving end of the line, as shown in the diagram Fig. 3, of the impulses as they pass from the transmitter, but they will be flattened somewhat, though there will be no harmful results at the receiving end of the line due to a tailing out or running together of the impulses.

The principles above explained whereby a single operator may transmit Morse signals in one direction may be readily extended to multiplex and duplex transmission.

The apparatus and one end of an octoplex-line connections are shown in Fig. 4. The apparatus at both ends of such a line are identical, with the exception that at one of the stations the commutator for producing the alternating current and the trailers are simply driven at a desired steady speed by any suitable motor, whereas the motor corresponding to this one at the other station has its speed regulated to synchronize with the first-mentioned motor. In other words, it is necessary to provide a synchronizing device at one of the stations to regulate the driving-motor, whereas at the other station this is not necessary.

The apparatus at the station shown in Fig. 4 consists, among other parts, of a differentially-wound main-line relay f^0, having one of its coils connected to the real line l and the other to the artificial line l'. In this way the line is duplexed. The transmitting and receiving sunflowers d and $d^{\times}$ $d^{\times\times}$ are in this case provided each with four segments corresponding to the short segment of the sunflowers shown in Fig. 1 and are indicated as segments 1, 2, 3, and 4, respectively. Correspondingly-numbered segments of the receiving-sunflower are connected to the right and left hand coils of the local relays 1^f, 2^f, 3^f, and 4^f, as shown, while the four keys 1^c, 2^c, 3^c, and 4^c are connected each to its respective segment of the transmitting-sunflower. The key-contacts are connected in multiple across the wires leading from the two secondaries of the transformer b. The commutator a and its connections are the same as shown in Fig. 1. The relays 1^f to 4^f may obviously be connected to any suitable receiving instrument, such as a sounder or others described with reference to Fig. 1, or may alone be utilized as receivers or sounders. Inasmuch as the main-line relay is balanced and responds only to impulses from the other end of the line, the operation of the keys does not affect the home relay, and hence the receiving apparatus may be in operation at the same time that the keys are being operated at the station. Moreover, the keys may be operated at will without in the least interfering with each other, as they can only affect the line-current when each is given the use of the line by its respective segment of the transmitting-sunflower. Taking each receiving-relay and key separately, its operation is exactly the same as described with reference to Fig. 1, each being independent of the other. By referring to Fig. 4 it will be seen that a person operating key 1^c can reverse only the impulses 1 5 9 13, &c., that a person operating key 2^c can reverse only impulses 2 6 10 14, &c., and so for key 3^c the impulses 3 7 11 15, &c. Hence each operator in transmitting is absolutely independent of the other. The receiving-relays 1^f to 4^f also operate independently of each other. Relay 1^f receives signals from its corresponding key 1^c at the other end of the line, and likewise with relays 2^f, 3^f, and 4^f. Thus it is seen how by means of the alternating current eight messages in the form of Morse signals can be sent over a long line at the same time. The number of the messages, however, is not at all limited to eight. For lines of moderate length the frequency of the line-current may be doubled, in which case sixteen messages could be simultaneously transmitted as easily as eight. In fact, the system is exceedingly flexible.

In practice any suitable means may be employed for "finding the operator"—that is, determining when a given receiver is adapted to receive messages from its corresponding transmitter and not from some of the other transmitters. This may be done by having a predetermined call and adjusting the receiving-sunflowers or their trailers or switches placed in the segment-circuits of the sunflowers until by trial the impulses sent by a given operator are received upon a corresponding relay. Obviously any of these receiving-relays may receive messages from any of the transmitting-keys, dependent upon the relative angular position of the transmitting and receiving sunflower segments or trailers or the order in which the relays are connected to the respective segments of the receiving-sunflowers.

In Fig. 5 I have shown how the line is duplexed, which consists merely in connecting one of the differential coils of each line-relay to an artificial line l' having capacity and self-induction equal to that of the real line and balancing the line-relay at one end of the line so that it is sensitive to current from the opposite end of the line only. A line thus balanced needs generally no further adjustment for weather and other changes, when duplexing becomes an easy matter. According to present telegraph practice when duplexing and quadruplexing are carried on by direct currents the lines are continually getting out of balance and the instruments necessitate constant adjustment to render them at all operative. With alternating currents this trouble may be greatly diminished.

Having thus fully described my invention and means for carrying out the same, what I claim, and desire to secure by Letters Patent of the United States, is—

1. The improvement in telegraphy, which consists in impressing upon a circuit a succession of periodic electrical impulses, and forming the elements of the characters of a code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

2. The improvement in telegraphy, which consists in impressing upon a circuit a succession of periodic electrical impulses, and forming the characters of a Morse code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

3. The improvement in telegraphy, which consists in impressing upon a circuit a succession of periodic electrical impulses, and forming the characters of a code by changing the phase of a number of impulses approximately one hundred and eighty degrees for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

4. The improvement in telegraphy, which

consists in impressing upon a circuit an alternating electromotive force, and forming the characters of a code by changing the phase of a number of impulses approximately one hundred and eighty degrees for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

5. The improvement in telegraphy, which consists in impressing upon a circuit a succession of periodic electrical impulses, and forming the characters of a Morse code by changing the phase of a number of impulses approximately one hundred and eighty degrees for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

6. The improvement in telegraphy, which consists in impressing upon a circuit an alternating electromotive force of sine-wave or approximately sine-wave form, and forming the characters of a code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

7. The improvement in telegraphy, which consists in impressing upon a circuit an alternating electromotive force of sine-wave or approximately sine-wave form, and forming the characters of a Morse code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

8. The improvement in telegraphy, which consists in impressing upon a circuit an alternating electromotive force of sine-wave or approximately sine-wave form, and forming the characters of a Morse code by changing the phase of a number of impulses one hundred and eighty degrees for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

9. The improvement in the art of telegraphy which consists in deriving electrical impulses from a source of sustained electromotive force, causing said impulses to act inductively to produce two simultaneous electromotive forces of different phase, normally impressing upon a telegraph-line the impulses of one of said induced electromotive forces, and forming the characters of a code by substituting on the line for said impulses, impulses derived from the second induced electromotive force.

10. The improvement in the art of telegraphy which consists in deriving from a source of sustained electromotive force, impulses of alternate polarity, causing said impulses to act inductively to produce two simultaneous electromotive forces of opposite polarity normally impressing upon a telegraph-line the impulses of one of said induced electromotive forces, and forming the characters of a code by substituting on the line for said impulses, impulses derived from the second induced electromotive force.

11. The improvement in the art of telegraphy which consists in deriving from a source of sustained electromotive force impulses of alternate polarity, causing said impulses to act inductively to produce two simultaneous electromotive forces of opposite polarity normally impressing upon a telegraph-line the impulses of one of said induced electromotive forces, and forming the characters of a Morse code by substituting on the line for said impulses, impulses derived from the second electromotive force.

12. The improvement in telegraphy, which consists in sustaining upon a circuit a succession of periodic electrical impulses, and forming the elements of the characters of a code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

13. The improvement in telegraphy, which consists in sustaining upon a circuit a succession of periodic electrical impulses, and forming the characters of a Morse code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

14. The improvement in telegraphy, which consists in sustaining upon a circuit a succession of periodic electrical impulses, and forming the characters of a code by changing the phase of a number of impulses approximately one hundred and eighty degrees for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

15. The improvement in telegraphy, which consists in sustaining upon a circuit an alternating electromotive force, and forming the characters of a code by changing the phase of a number of impulses approximately one hundred and eighty degrees for each element, the characters of said code being independ-

ent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

16. The improvement in telegraphy, which consists in sustaining upon a circuit a succession of periodic electrical impulses, and forming the characters of a Morse code by changing the phase of a number of impulses approximately one hundred and eighty degrees for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

17. The improvement in telegraphy, which consists in sustaining upon a circuit an alternating electromotive force of sine-wave or approximately sine-wave form, and forming the characters of a code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

18. The improvement in telegraphy, which consists in sustaining upon a circuit an alternating electromotive force of sine-wave or approximately sine-wave form, and forming the characters of a Morse code by changing the phase of a number of impulses for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

19. The improvement in telegraphy, which consists in sustaining upon a circuit an alternating electromotive force of sine-wave or approximately sine-wave form, and forming the characters of a Morse code by changing the phase of a number of impulses one hundred and eighty degrees for each element, the characters of said code being independent of a preselected number of impulses, but dependent upon the relation between the number of impulses modified to form one element and those modified to form another element.

In testimony whereof I affix my signature in presence of two witnesses.

EDWIN F. NORTHRUP.

Witnesses:
J. SNOWDON RHOADS,
C. MCELROY.