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COMPLETE SPECIFICATION.

Communicated from abroad by NIKOLA TESLA, of 46 East Houston Street, Borough of Manhattan, City, County and State of New York, United States of America, Electrician.

“Improvements in and relating to the Transmission of Electrical Energy”.

I, HENRY HARRIS LAKE, of the Firm of Haseltine, Lake & Co., Patent Agents, 45 Southampton Buildings, in the County of Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In certain systems for transmitting intelligible messages, or governing the movements and operations of distant automata, electrical impulses or disturbances, produced by suitable apparatus, are conveyed through the natural media to a receiving circuit, capable of responding to the impulses and thereby effecting the control of other appliances. Generally a special device, highly sensitive, is connected to the receiving circuit which, in order to render it still more susceptible and to reduce the liability of its being affected by extraneous disturbances, is carefully synchronized with the transmitter. By a scientific design of the sending and receiving circuits and other apparatus, and skillful adjustment of the same, these objects may be in a measure attained, but notwithstanding all constructive advantages and experimental resources, this method is in many cases inadequate. Thus, while it is practicable to operate, selectively, under certain favorable conditions, more than one hundred receivers, in most cases it is possible to work successfully but a few, the number rapidly diminishing as, either owing to great distance or other causes, the energy available in the synchronized circuits becomes smaller, and therefore the receivers necessarily more delicate. Evidently a circuit, however excellently constructed and adjusted to respond exclusively to vibrations of one period, is apt to be affected by higher harmonics, and still more so by fundamental tones. When the oscillations are of a very high frequency, the number of the effective harmonics may be large, and the receiver is consequently easily disturbed by extraneous influences, to such an extent that, when very short waves, as those produced by Hertzian spark apparatus, are employed, little benefit in this respect is derived from synchronizing the circuits. It being an imperative requirement in most practical applications of such systems of signalling or intelligence transmission, that the signals or messages should be exclusive or private, it is highly desirable to do away with the above limitations, all the more so, as it is a fact, that the influence of powerful electrical disturbances upon sensitive receivers extends, even on land, to distances of many hundreds of miles and consequently, in accordance with theory, still farther on sea.

To overcome these drawbacks and to enable a great number of transmitting and receiving stations to be operated, selectively and exclusively, and without any danger of the signals or messages being disturbed or intercepted, or interfered with in any way, is the object of my present improvement.

Broadly stated, my invention involves the employment of means for generating two or more kinds or classes of disturbances, waves or impulses of distinctive character, with respect to their effect upon a receiving apparatus, and a distant receiver, which comprises two or more elements, severally responsive to the

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different disturbances or impulses, and which is dependent for operation upon the conjoint or resultant action of two or more such elements.

By employing only two kinds of disturbances or impulses instead of one, as has heretofore been done, to operate a receiver, safety against the disturbing influences of other sources is increased to such an extent, that this number is probably amply sufficient in most cases for rendering the exchange of signals or messages reliable and exclusive, but in exceptional instances a greater number may be used, and a degree of safety against mutual and extraneous interference attained, such as is comparable to that afforded by a combination lock. The liability of a receiver being affected by disturbances emanating from other sources, as well as that of the signals or messages being received by instruments for which they are not intended may, however, be reduced not only by an increased number of the co-operative disturbances or series of impulses, but also by a judicious choice of the same, order and mode in which they are made to act upon the receiver.

Evidently there are a great many ways of generating impulses or disturbances of any wave-length, wave-form, number or order of succession, or of any desired special character, such as will be capable of fulfilling the requirements above stated, and there are also many ways in which such impulses or disturbances may be made to co-operate and to cause the receiver to be actuated and, inasmuch as the skill and practical knowledge in these novel fields can only be acquired by long experience, the degree of safety and perfection attained will necessarily depend on the ability and resource of the expert who applies my invention, but in order to enable the same to be successfully practised by any person possessed only of the more general knowledge and experience in these branches, I shall describe the simplest plan of carrying it out, which is at present known to me.

For a better understanding of the subject, reference is now made to the drawing, in which.

Fig. 1 and Fig. 2 represent diagrammatically the apparatus and circuit connections at the sending and receiving stations, respectively, and

Figs. 3, 4 and 5 modified means which may be employed in the practical application of my invention.

In Fig. 1 S^1 and S^2 are two spirally wound coils or conductors, connected with their inner ends to preferably elevated terminals D^1 and D^2 respectively, and with their outer ends to an earth plate E . These two coils, conductors or systems $D^1 S^1 E$ and $D^2 S^2 E$ have different and suitably chosen periods of vibration and their lengths should be such that the points of maximum pressure developed therein coincide with the elevated terminals $D^1 D^2$. By suitably chosen periods of vibration such periods are meant as will secure the greatest safety against interference, both mutual and extraneous. The most satisfactory results in this respect, are obtained when the different periods are related as the reciprocals of the smallest relative prime numbers, but whether this relation be observed or not, the vibrations should be so selected as to give, when passing through or acting upon a common path or circuit, the greatest practicable number of beats in the same. They should furthermore, as regards pitch, not approach too closely those of the order of the Hertzian, because with vibrations of such transcending rates, owing to the rapid radiation of energy into space, resonating systems, as $D^1 S^1 E$ and $D^2 S^2 E$ will not prove efficient intensifiers. The two systems may have electrical oscillations impressed upon them in any desired manner, conveniently by energizing them through primaries P^1 and P^2 , placed in proximity to them. Adjustable inductances L^1 and L^2 are preferably included in the primary circuits chiefly for the purpose of regulating the rate of the primary oscillations. In the drawing these primaries P^1 and P^2 surround the coils $S^1 S^2$, and are joined in series through inductances $L^1 L^2$, conductor F , condensers C^1 and C^2 , brush-holders B^1 and B^2 and a toothed disk D , which is connected to the conductor F and, if desired, also to the groundplate E , as shown, two independent primary circuits being thus formed. The condensers C^1 and C^2 are of such capacity and the inductances L^1 and L^2 are so adjusted that each primary is in close resonance with its secondary system. Care should be taken to obtain in each of the

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secondary systems $D^1 S^1 E$ and $D^2 S^2 E$ the true or fundamental note, as otherwise the apparatus may not perform satisfactorily. Assuming the capacities of the conductors S^1 and S^2 relatively small, the true notes will result when the product of capacity and inductance in each of the primaries is approximately equal to four times this product in each of the secondaries. The brush-holders B^1 and B^2 are capable, independently of angular and, if necessary, also of lateral adjustment, so that any desired order of succession or any difference of phase may be obtained between the discharges occurring in the two primary circuits. The condensers being energized from a suitable source S , preferably of high potential, and the disk D being rotated, its projections or teeth $p p$, coming at periodically recurring intervals in very close proximity to or, as the case may be, in contact with conducting rods or brushes $n n$, cause the condensers to be discharged in rapid succession through their respective circuits. In this manner the two secondary systems, $D^1 S^1 E$ and $D^2 S^2 E$, are set in vibration and oscillate freely, each at its proper rate for a certain interval of time at every discharge. The two vibrations are impressed upon the ground through the plate L , and spread to a distance, reaching the receiving station, which has two similar circuits or systems $e s^1 d^1$ and $e s^2 d^2$, arranged and connected in the same manner and synchronized with the systems at the sending station, so as to respond each exclusively to one of the two vibrations of one kind or class produced by the transmitting apparatus. The same rules of adjustment are observed in the receiving circuits, care being furthermore taken that the synchronizing be effected when all the apparatus is connected to the circuits and placed in position, as any change may more or less modify the vibration. Each of the receiving coils s^1 and s^2 is shunted by a local circuit containing, respectively, sensitive devices $a^1 a^2$, batteries $b^1 b^2$, adjustable resistances $r^1 r^2$, and sensitive relays $R^1 R^2$, all joined in series as shown. The precise connections and arrangements of the various instruments are largely immaterial, and may be varied in a great many ways. The sensitive devices a^1 and a^2 may be any of the well-known devices, as for example, two conducting terminals separated by a minute air-gap or thin film of dielectric, which is strained or weakened by a battery or other means to the point of breaking down, and gives way to the slightest disturbing influence. Its return to the normal sensitive state may be secured by momentarily interrupting the battery circuit after each operation, or otherwise. The relays $R^1 R^2$ have armatures $l^1 l^2$, which are connected by a wire w , and when attracted, establish electrical contacts at c^1 and c^2 , thus closing a circuit containing a battery b^3 , an adjustable resistance r^3 and a relay R^3 . From the above description it will be readily seen that the relay R^3 will be operated only when both contacts c^1 and c^2 are closed.

The apparatus at the sending station may be controlled in any suitable manner, as, for instance, by momentarily closing the circuit of the source S , two different electrical vibrations being emitted simultaneously or in rapid succession, as may be desired, at each closure of the circuit. The two receiving circuits at the distant station, each responding to the vibration produced by one of the elements of the transmitter, affect the sensitive devices a^1 and a^2 and cause the relays R^1 and R^2 to be operated and contacts c^1 and c^2 closed, thus actuating the receiver or relay R^3 , which in turn establishes a contact c^3 and brings into action a device a^3 by means of a battery b^4 included in a local circuit, as shown. But evidently, if through any extraneous disturbance only one of the circuits at the receiving station is affected, the relay R^3 will fail to respond. In this way communication may be carried on with much increased safety against interference, and privacy of messages may be secured. The receiving station shown in Fig. 2 is supposed to be one requiring no return message, but if the use of the system is such that this is necessary, then the two stations may be equipped similarly, and any well-known means, which it is not thought necessary to illustrate here, may be resorted to for enabling the apparatus at each station to be used in turn as transmitter and receiver.

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The terminals D^1 D^2 of the transmitting, and d^1 d^2 of the receiving apparatus are shown insulated from each other, but this, while advantageous, is not absolutely necessary, and each pair may be connected together, or else a single terminal, as D^1 or d^1 , may be used at either of the stations, instead of two, as illustrated.

In like manner the operation of a receiver, as R^3 , may be made dependent, instead of upon two, upon more than two such transmitting circuits or systems, and in this way any desired degree of exclusiveness or privacy and safety against extraneous disturbances may be attained. The apparatus, as illustrated in Fig. 1 and Fig. 2 permits, however, specific results to be secured by the adjustment of the order of succession or phase difference between the discharges of the primary circuits P^1 and P^2 . To illustrate, the action of the relays R^1 R^2 may be regulated either by adjusting the weights of the levers l^1 l^2 , or the strength of the batteries b^1 b^2 , or the resistances r^1 r^2 , or otherwise, so that, when a certain order of succession or difference of phase between the discharges of the primary circuits P^1 and P^2 exists at the sending station, the levers l^1 and l^2 will close the contacts c^1 c^2 at the same instant, and thus operate the relay R^3 , but will fail to produce this result when the order of succession or difference of phase is another one. By these or similar means additional safety against disturbances from other sources may be obtained and, on the other hand, the possibility afforded of effecting the operation of signalling by varying the order of succession of the discharges in the two circuits. Instead of closing and opening the circuit of the source S , as before indicated, for the purpose of sending distinct signals, it may be convenient to merely alter the period of either of the transmitting circuits arbitrarily in any of the well-known ways, as by varying the inductance of the primaries. It should be stated, furthermore, in regard to the apparatus illustrated in Fig. 2, that special and useful results are obtainable by connecting contacts c^1 and c^2 in multiple arc instead of in series, as shown, in which case the relay R^3 will be necessarily either provided with two windings each controlled by one of the contacts, or otherwise constructed or adjusted so that it will not operate unless both of the contacts are closed.

Obviously there is no necessity for using transmitters with two or more distinct elements or circuits, as S^1 and S^2 , since a succession of waves or impulses of different characteristics may be produced by an instrument having but one such circuit. A few of the many ways which will readily suggest themselves to the expert who applies my invention, are illustrated in Figs. 3, 4 and 5. In Fig. 3 a transmitting system e s^3 d^3 is partly shunted by a rotating wheel or disk D^3 , which may be similar to that illustrated in Fig. 1, and which cuts out periodically a portion of the coil or conductor s^3 , or, if desired, bridges it by an adjustable condenser C^3 , thus altering the vibration of the system e s^3 d^3 at suitable intervals and causing two distinct kinds or classes of impulses to be emitted in rapid succession by the sender. In Fig. 4 a similar result is produced in the system e s^4 d^4 by periodically short-circuiting a secondary p^4 , through an induction coil L^3 and a rotating disk D^4 with insulating and conducting segments, or otherwise. Again, in Fig. 5 three distinct vibrations are caused to be emitted by a system e s^5 d^5 , the result being produced by inserting periodically a suitable number of turns of an induction coil L^4 in series with the oscillating system by means of a rotating disk D^5 with two projections p^5 p^5 , and three rods or brushes n^5 , placed at an angle of one hundred and twenty degrees relative to each other. The three transmitting systems or circuits last described may be energized as those in Fig. 1 or in any other convenient way. Corresponding to each of these cases, the receiving station may be provided with two or three circuits, in an analogous manner to that illustrated in Fig. 2, it being understood, of course, that the different vibrations or disturbances emitted by the sender follow in such rapid succession upon each other that they are practically simultaneous, as far as the operation of the relays, such as R^1 and R^2 is concerned. Evidently, however, it is not necessary to employ two or more receiving circuits as s^1 and s^2 , but single

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circuits may be used also at the receiving stations, constructed and arranged like the transmitting circuits or systems illustrated in Figs. 3, 4 and 5, in which case the corresponding disks, as D³, D⁴, D⁵ at the sending will be driven in synchronism with those at the receiving stations, though this will not always be necessary.

The disks or other circuit controlling devices, operating synchronously at both the stations, may be constructed so as to enable the transmission of the impulses in any desired fixed or varying order of succession; and it is to be remarked that they will afford additional safety against interference in this instance, while they might prove ineffective in ordinary systems in which but one kind of disturbance is employed to operate a receiver.

To illustrate other useful features, reference may be again made to Figs. 1 and 2. I have found no difficulty in modifying the transmitting apparatus shown in Fig. 1 in such a way, that it will emit, instead of two, four vibrations of different periods. I accomplish this result by properly adjusting the inductances and capacities and the mutual induction co-efficients of the two primary and secondary systems. During the time interval when a primary circuit, as P¹, is closed by the make and break device B¹ D B², the secondary circuit S¹ in inductive relation to it may be made to vibrate at a different and considerably higher rate, owing to the diminution of its co-efficient of self-induction through the mutual induction of the circuits, and by proper adjustments of the quantities above named four oscillations of suitable frequency are generated by the transmitter. This being the case, the receiving station may be provided with two sets of apparatus, as illustrated in Fig. 2, and there will then be four relays or devices as R¹ R², which may be co-operatively connected or associated either in the manner shown in Fig. 2 or in any other convenient way, but so, that the desired effect upon a receiver will be produced only when all four receiving circuits are energized, and will not take place under any other circumstances.

When it is desired to modify the apparatus as and for the purpose above stated, the various quantities may be determined as follows: Designating, for the sake of convenience, by letters D¹ and S¹ respectively the terminal capacity and the inductance of the secondary system, its fundamental note, when the primary

is open, will be of a suitably selected period $T^1 = \frac{1}{n^1 k} = \frac{2\pi}{10^3} \sqrt{4 D^1 S^1 D^1}$

expressing the capacity of the elevated terminal in microfarads and S¹ the inductance of the secondary coil in Henrys. In conformity with the preceding the influence of the primary circuit should be so regulated that, when it is closed by the make and break device D the vibration in the secondary will be of a

smaller and arbitrarily chosen period $T^2 = \frac{1}{n^2 k}$ such that $\frac{T^1}{T^2} = \frac{\frac{1}{n^1 k}}{\frac{1}{n^2 k}} = \frac{n^2}{n^1}$, n^2

and n^1 being, preferably, small relative prime numbers and k a constant.

Designating further, conveniently, the inductance of the primary turn or turns in inductive relation to the secondary by the letter P¹, and the mutual induction co-efficient by M, the inductance of the secondary, when the primary circuit is closed, will be reduced to a value S¹ $(1 = \frac{M^2}{P^1 S^1})$ and the period will be approxi-

mately $T^2 = \frac{2\pi}{10^3} \sqrt{4 D^1 S^1 \left(\frac{1-M^2}{P^1 S^1} \right)}$ Similarly, if letters C¹ and L¹ denote respectively

the capacity in the primary circuit and inductance of the adjustable primary coil, the period of the primary circuit will likewise be $T^2 = \frac{2\pi}{10^3} \sqrt{C^1 \left[L^1 + P^1 \left(1 - \frac{M^2}{P^1 S^1} \right) \right]}$

Either of the two expressions found for T² may be used in the determinations of the quantities, but the latter is preferable, and it will be found most suitable in

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practice to ascertain the constants C^1 , P^1 , M and S^1 by measurement and calculate the approximate number of turns of coil L^1 , which permits of easy and precise adjustment by actual experiment.

The above given values for the two periods of the resonating grounded system as $D^1 S^1 E$ hold good only when the conductors, as S^1 , are directly connected to the ground. When, as the case may be, a condenser is interposed in the ground connection, the values will be modified in a way well known to experts.

A difficulty may be experienced in securing the proper attunement of a number of circuits of different periods when, as in the instance last described, they are excited through a common medium or channel. The task will be facilitated by graduating the effects in the circuits, which may be done by the adjustment of the ratio of the inductance to the resistance, or otherwise. As a rule it will be found desirable to equalize the actions of the several circuits as much as possible. In connection with the above it is useful to state, that an advantage may be secured by the employment of a circuit-making and breaking device, similar to that illustrated in Fig. 5, for the purpose of connecting the four receiving circuits intermittently to the ground, instead of permanently, it being understood, of course, that the effect of the various circuits upon the receiver is practically simultaneous. Such a device is valuable also in ordinary systems, as, for instance, when it is desired to receive signals from a number of stations at the same time.

By using a transmitter emitting four different vibrations or classes of impulses distinctive in their effect upon as many elements of a receiver, eleven receiving stations can be operated, that is, six by combining two of the vibrations, with great safety, four by combining three of the vibrations, with a safety enormously increased, and one by combining all the four vibrations with a safety which, for most practical purposes, may be considered absolute. The various receivers will obviously be distributed to suit the importance of the several stations. The degree of safety, as well as the number of stations which may be selectively operated, can be still further increased by producing the impulses at the transmitting stations in any arbitrary order of succession which, if desired, may be continuously varied, and using them, at the various receiving stations, to actuate the receivers, in accordance with a predetermined understanding, code, key or safety combination.

Obviously transmitters and receivers may be provided with a much greater number of distinctive elements which, combined and associated in every possible way, will permit the selective operation of a practically unlimited number of devices through a common natural or artificial channel, and such a degree of individualization of a receiver, that it will be absolutely secure against extraneous interference and may be safely called into action, whenever desired, from among innumerable devices of its kind.

It will be seen from a consideration of the nature and purposes of the invention, that it is applicable not only to the special system described, in which the transmission of the impulses is effected through the natural media, but to other systems for the transmission of telegraphic or telephonic signals or of energy for any purpose, and whatever be the medium through which the impulses are transmitted, that is to say, the broad principle of making the operation of a receiver dependent upon the conjoint or resultant action of two or more electrically different or tuned circuits is applicable not only to the special system of telegraphy described in which the electrical energy is transmitted through the natural media, but also to such systems as involve the use of a cable or wire as the conducting medium. Moreover, it is not necessary that the energy transmitted should be utilized to operate any special form of telegraphic instrument, or in fact any telegraphic instrument at all, as the receiver may be a relay or similar device which controls any other kind of device, such for example as the steering mechanism of a self propelled vessel. Therefore the invention is, broadly considered, one for the transmission and utilization in a special manner of electrical energy in general.

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Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, as communicated to me by my foreign correspondent, I declare that what I claim is:—

1. In a system for the transmission of energy, the combination with a receiver comprising a plurality of elements and dependent for operation upon their conjoint action, of a means for producing a plurality of distinctive kind of disturbances or impulses, severally adapted to actuate the elements of the receiver, as set forth.

2. In a system for the transmission of electrical energy, the combination with a receiver comprising a plurality of elements and dependent for operation upon their conjoint action, of a transmitter having a plurality of elements capable of severally producing distinctive kinds of disturbances or impulses, each kind being adapted to actuate one only of the elements of the receiver, as set forth.

3. In a system for the transmission of electrical energy, the combination with a receiver comprising a plurality of elements and dependent for operation upon the conjoint action of two or more of the same, of a transmitter adapted to produce a plurality of distinctive kinds of disturbances or impulses, each kind being adapted to actuate one only of the elements of the receiver, as set forth.

4. In a system for the transmission of electrical energy, the combination with means for producing two or more distinctive kinds of disturbances or impulses, of receiving circuits, each adapted to respond to the waves or impulses of one kind only, and a receiving device dependent for operation upon the conjoint action of the several receiving circuits, as set forth.

5. In a system for the transmission of electrical impulses and the operation or control of signalling or other apparatus thereby, the combination with a transmitter adapted to produce two or more distinctive kinds or classes of disturbances or impulses, of sensitive receiving circuits, each adapted to respond to the impulses or disturbances of one kind or class only, and a receiving device dependent for operation upon the conjoint action of the sensitive circuits, as set forth.

6. In a system for the transmission of electrical impulses, and the operation or control of signalling, or other apparatus thereby, the combination with a transmitter adapted to produce two or more distinctive kinds or classes of disturbances or impulses, of sensitive circuits at the receiving point or station, each adapted to respond to the impulses or disturbances of one kind or class only, a local circuit arranged to be completed by the conjoint action of the sensitive circuits and a receiving device connected therewith, as set forth.

7. In a system for the transmission of electrical impulses and the operation or control of signalling or other apparatus thereby, the combination with a transmitting apparatus adapted to produce two or more distinctive kinds of disturbances or impulses, of means for varying the relations of the impulses of the several kinds, sensitive circuits each adapted to respond to the impulses or disturbances of one kind only, and a receiving apparatus dependent for operation upon the conjoint action of the sensitive circuits, as set forth.

8. In a system, such as herein described, the combination with a transmitter adapted to produce a plurality of distinctive kinds of electrical disturbances or impulses, of a receiving apparatus comprising a plurality of circuits, a sensitive device and a relay included in each circuit, and adjusted to respond to the impulses or disturbances of one kind only, and a receiving apparatus in a local circuit controlled by the relays and adapted to be completed by the conjoint action of all of said relays, as set forth.

9. In a system of the kind described, the combination with a transmitter adapted to produce two or more series of electrical oscillations or impulses of different frequencies, of a receiving apparatus comprising a plurality of sensitive circuits each tuned to respond to the impulses of one of the series produced by the transmitter, and a signalling device dependent for its operation upon the conjoint action of said circuits, as set forth.

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10. The combination with a plurality of transmitter elements, each adapted to produce a series of impulses or disturbances of a distinctive character, and means for controlling and adjusting the same, of a receiver having a plurality of sensitive circuits each adapted to be affected by one of the series of impulses only, and dependent for operation upon the conjoint action of all of said circuits, as set forth.

11. The combination with a transmitter adapted to produce series of electrical impulses or disturbances of distinctive character and in a given order of succession, of a receiving apparatus comprising elements adapted to respond to such impulses in a corresponding order, and dependent for operation upon the conjoint action of said elements, as set forth.

12. In a receiving apparatus, the combination of a plurality of sensitive circuits, each tuned to respond to waves or impulses of a given kind or class, a receiving circuit controlled by the sensitive circuits and a device connected with the receiving circuit adapted to be operated when said circuit is completed by the conjoint action of two or more of the sensitive circuits, as set forth.

13. The method of operating distant receivers which consists in producing and transmitting a plurality of kinds or classes of electrical waves or impulses, actuating by the waves or impulses of each class one of the elements of a receiver, and controlling the operation of the receiver by the conjoint action of two or more of said elements, as set forth.

14. The method of signalling which consists in producing and transmitting a plurality of kinds or classes of electrical waves or impulses, developing by the waves or impulses of each class a current in one of a plurality of receiving circuits and controlling by means of such circuits a local circuit, as set forth.

15. The method of signalling which consists in producing a plurality or series of waves or impulses differing from each other in character or order of succession, exciting by the waves or impulses of each series one of a plurality of receiving circuits and controlling by such circuits a local circuit, as set forth.

16. The method of signalling which consists in producing a plurality or series of waves or impulses, varying the character or order of succession of the several series, exciting by the waves or impulses of each series one of a plurality of receiving circuits and controlling by such circuits a local circuit, as set forth.

Dated this 16th day of July 1901.

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Agents for the Applicant.

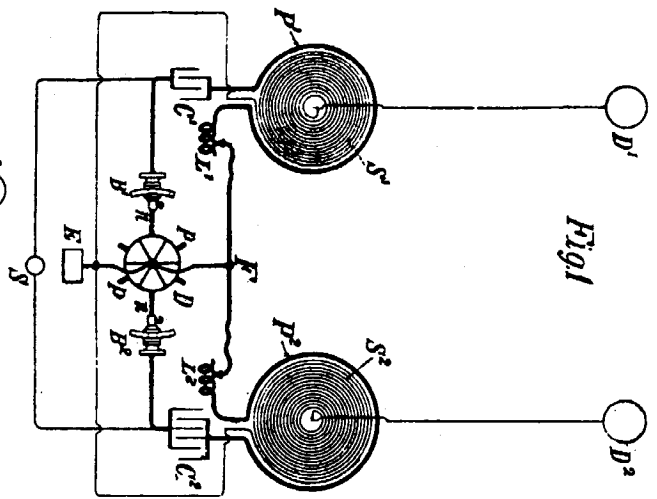


Fig 1

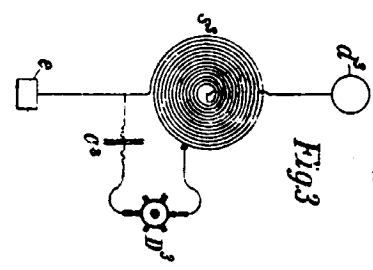


Fig 3

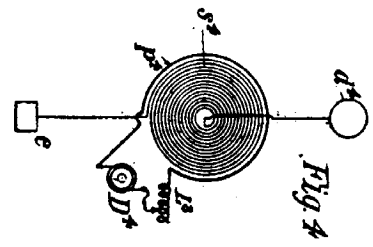


Fig 4

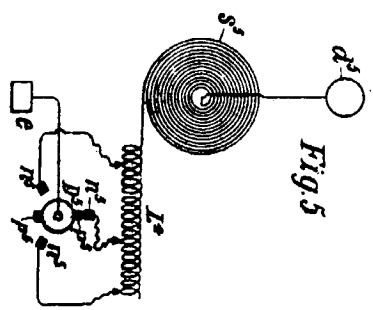


Fig 5

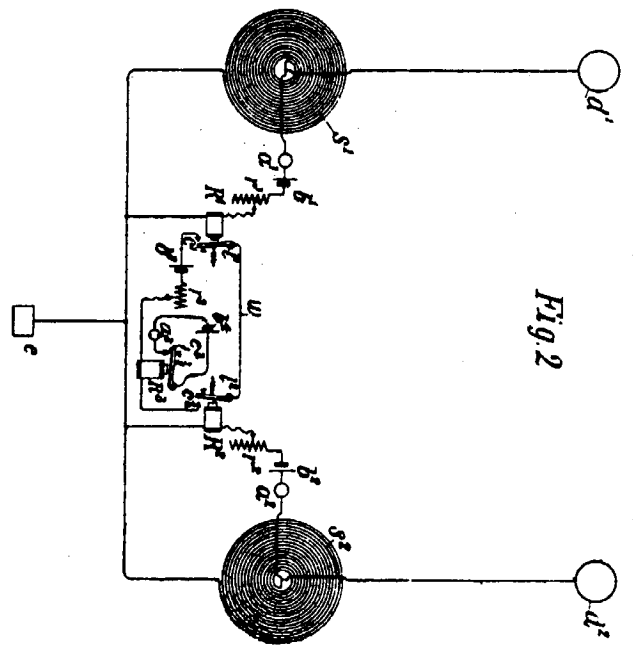


Fig 2