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PATENT SPECIFICATION

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COMPLETE SPECIFICATION.

Method and Apparatus for the Measurement of Distances by the use of Electromagnetic Waves.

We, ALEXANDRE KOULIKOFF, of 142, Boulevard de Grenelle, Paris, France, and CONSTANTIN CHILOWSKY, of 15, rue du Lunain, Paris, France, both Russian subjects, 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:—

Since the velocity of electromagnetic waves is known to be 300,000 kilometres per second at the surface of the earth, it is theoretically practicable to measure the distance between two stations by measuring the time elapsing between the transmission of waves from one station and their reception at the other station. However, such measurement requires the use of exactly synchronised clockwork in each of the stations, and in view of the great velocity of the electromagnetic waves, the required precision in the synchronising devices would prevent their practical use.

To obviate this objection, the present invention consists in a process which produces an automatic electromagnetic coupling or connection, either permanent or renewable, between the two stations, each of which is adapted to transmit and receive electromagnetic waves, and this coupling produces in the two stations beats or modulations, i.e. periodic variations in the intensity of the transmitted signals.

The frequency of these variations, which can be readily measured by the observers at the stations, depends upon the distance between the two stations. In practice, one of the stations sends out a signal which is received at the second station; the reception of this signal automatically causes the transmission of another signal of the same or different frequency, which is received by the first station and is automatically transmitted to the transmitting circuit of this station, and so on. The periodic modulation of the intensity of the sounds sent out by the stations is effected at frequencies which depend directly upon the distance between the two stations. At each arrival of the signal at one of the stations, a temporary increase in the intensity of the transmission is produced. The time required for a wave to travel from one station to another is equal to $\frac{d}{c}$, in which d is the distance between two stations and c the velocity of light, so that a wave sent out by a station will return to this same station after a time $T=\frac{2d}{c}$. If N_m is the frequency of the resulting modulation, this gives

$$N_m=\frac{1}{T}=\frac{c}{2d}, \text{ whence } d=\frac{c}{2N_m}$$

Under these conditions it is supposed that there is no appreciable time lost between the reception of a signal at and the sending of a new signal from a given station; if such a delay should take place, its constant value will be found and a correction will be made in the formula.

In order that this coupling between the two stations should take place and that a modulation should be produced, it is necessary in the case in which two different frequencies are used, that the receiving apparatus of one station should be sufficiently protected against the direct action of the transmitting apparatus at the same station. To obtain this result, each station may send signals at a different frequency, these frequencies not being in harmonic relation. On the other hand, each receiving circuit is in resonance with the transmitting circuit of the other station from which it is to receive signals.

Furthermore, all suitable means for protecting the receiving apparatus against the action of the transmitting apparatus may be used if necessary.

In addition to these means, we may also employ antennæ at the transmitting end and frame coils at the receiving end, the frame being oriented so that it will be protected against the field due to the antenna at this station. We may further employ such frames or coils both for sending and receiving, the frames being disposed in planes perpendicular to one another, and having a common horizontal axis, the axes of the frames of the two stations being parallel or in line with one another.

We measure the modulation in the circuits of each station by known methods, for instance by beats of the heterodynes, by wave-meters, or by like means.

The signals may be sent by means of sustained waves of a sufficiently high frequency relatively to that of the resulting modulations. The method is, however, applicable also to damped oscillations.

The waves from a station A, having a frequency of N_1, are received at B by a circuit which is in resonance with N_1; they are amplified and may be rectified. The rectified current acts upon the grid of the oscillating circuit of the sending station B at a frequency of N_2, for example, so as to effect the transmission. The waves of frequency N_2 are received by a receiving apparatus which is in resonance with N_2, disposed at the station A; which, after amplification and perhaps rectification of the waves, will act, for instance, upon the grid circuit of the sending station A, and so on.

In this manner, we obtain a succession of trains of waves whose period gives the distance A—B.

Our method may be employed to measure the distance fixed or variable between two or more radio stations, for instance the distance between vessels at sea in order to prevent collisions during fog, or the distance between short stations and vessels, the distance between aeroplanes or between land stations and aeroplanes, the distance between trains on railways, the situation of explorers in remote countries, or the like.

By coupling a movable station, such as one mounted on an aeroplane or a vessel, with two fixed stations situated at a certain distance, the coupling taking place simultaneously or successively, we can at once determine the exact position of an aeroplane, which is assumed to be situated at a known altitude.

To effect the coupling or connection between two or more stations, it is preferable that the sending antennæ should have a sufficient decrement of radiation. It is also preferable that the received and amplified current should—after perhaps rectification—be caused to act effectively upon the grids or other parts of the transmission circuit, thereby modifying considerably its condition and its efficiency as a high-frequency generator.

The receiving system may act upon the transmitting circuit of this station by electric means or by the use of suitable relays. As a general rule, it is preferable to separate the transmitting and the receiving apparatus of the same station by some distance.

The transmission and the reception in each station may be effected by the same antenna or coil frame. For this purpose we use electric filters to protect the oscillating circuit of the received waves against the effect of the sending circuit of different frequency of the same station. We may also use quartz stabilising apparatus. Also, we may utilise at the two stations the same frequency of transmission and reception by employing in each a single antenna and a single frame.

The following description, with reference to the accompanying drawings which are given by way of example, shows the manner in which the invention may be carried into effect.

Fig. 1 is a explanatory diagram.

Fig. 2 is a diagrammatic view showing two stations in which the same antenna is employed for sending and receiving.

Fig. 3 is a diagram illustrating the case in which at each station the transmission and reception are effected by means of two frames at right angles.

Fig. 3bis is a diagram illustrating the case in which at each station the transmission and reception are effected by means of two antennæ.

Fig. 4 shows the mounting of the antenna and frame at a station.

Fig. 5 shows a filter which may be used with a frame.

Fig. 6 is a diagram of the circuits in the case of a single antenna for sending and receiving.

Fig. 7 shows the use of a piezo-electric condenser as a filter.

Fig. 8 is a diagram of the circuits of a station sending out damped waves.

Fig. 9 shows a modification of these circuits with heterodyne excitation.

Fig. 10 shows a modified arrangement which may be used at a station employing a single wave length for sending and receiving with a single antenna.

In Fig. 1 the antenna 1 of the station A, shown in section, transmits waves of frequency N_1 which are received by the frame or coil 7 of station B. The circuit 8 which is tuned to the frequency N_1 transmits the waves, after they have been amplified at 9 and, if required, have been rectified, to the low-frequency amplifier 10 which in turn acts upon the transmitting circuit 11, thus affecting the antenna 12 which sends out waves of frequency N_2. These waves are received by the frame or coil 3 of station A. They are transmitted by the receiving circuit 4, tuned to the frequency N_2, to the amplifier 5 which transmits them, if required, after rectification, to the low-frequency amplifier 6 which in turn acts upon the circuit of the generator 2 whose frequency is N_1, thus modulating the intensity of the waves transmitted by the antenna 1. As previously explained, the period of this modulation depends upon the distance between the stations A and B. In like manner, the waves transmitted from the station B are modulated on an analogous principle.

The reference numerals 13 and 14 indicate filters which may be used to protect the receiving apparatus against the direct action of the transmitters.

Fig. 2 shows the same elements, which are indicated by like reference numerals, but instead of an antenna for transmission and a frame for reception, the plant comprises a single antenna for each station, the antenna serving both for transmission and reception. Obviously, two antennæ may be used at each station.

In the arrangement shown in Fig. 3, each station A and B uses for the reception and transmission a suitable frame, the frames 15 and 16 being employed for transmission and the frames 3 and 7 for reception. At each station, the frames are at right angles to one another, in order to eliminate mutual interference. As shown, the two frames of each station have a common axis, but they may be placed side by side. In all cases, each receiving frame should be disposed more or less in the same plane as the transmitting frame of the other station or in a parallel plane.

In Fig. 3^{bis}, each station utilises for transmission and reception two separate antennæ which are arranged so as to have no mutual interference, the transmitting antenna of each station being disposed and oriented so as to act upon the receiving antenna of the other station; for instance the transmission antennæ 130 and 131 shown in plan are vertical, and the reception antennæ 132 and 133 are horizontal, with wires descending to the station from their central points.

On transmission, the antenna 130 will, for instance, affect the two halves of the antenna 132 in opposite directions, and these two effects will mutually compensate, so that the antenna 132 may be assumed to be unaffected by the antenna 130.

Fig. 4 shows the details of the arrangements at a station.

The receiving frame 3 with the variable condenser 15 forms the receiving circuit, which is tuned to a wave having the frequency N_2 arriving from the sending station. In this circuit is mounted an induction coil 16. An induction coil 17 and a condenser 18 form a filter which will, if necessary, protect the receiver against the direct waves sent from the wave transmitter. It should be tuned to the wave length of the transmitted waves of the same station, whose frequency is N_1. As shown, the filter is inductively coupled, but any other coupling may be used. The valve 19 is a high frequency amplifier. A suitable number of such valves can be used. The valve 19 is coupled to the rectifying valve 22 by a capacity 20 shunted by a resistance 21. The rectified current is amplified by a low-frequency amplifier represented in the fig. by a single valve 23. The rectified and amplified current acts upon the grid circuit of the valve 62 of the transmitter. For this purpose, an induction coil 25 is coupled with an induction coil 24 of the wave transmitter circuit. The wave transmitter comprises the valve 62 provided with an oscillating circuit comprising an induction coil 63 and a variable capacity 64. The induction coil 63 is coupled with an induction coil 65 of the plate circuit connected to the antenna 1.

The wave transmitter is supplied at high tension from terminals 67 and 68. The continuous current circuit is protected against the oscillatory current by a choke coil 69. The continuous current is measured by the milliampere meter 70. The measurement of the antenna current is effected by the ammeter 71. The condensers 72 and 73 are stopping condensers. The induction coil 24, which is coupled with the induction coil 25 is connected to the terminals of the condenser 73. In addition to the coil 25 in the plate circuit of the last valve 23 of the amplifier, there is an induction coil 25^1 connected to a wave meter and an induction coil 26 which is connected through an intermediate circuit with a heterodyne. The wave meter comprises in addition to the coil 27 a variable condenser 28 and an electric measuring apparatus 29 of usual type. The wave meter should be adapted to be tuned to the frequencies of the trains of waves rectified by the amplifier. By tuning the wave meter, the modulation of the intensity of the waves is measured and the distance between the stations can be deduced. The measurement of the frequency of the trains of waves may also be effected by other means indicated in this fig.; 30 is a small generating valve which is mounted as a heterodyne. The plate induction coil 31 is coupled with the induction coil 32 of an intermediate circuit which through an induction coil 33 is coupled with the induction coil 26. When the heterodyne has a period near that of the modulation of the waves received in the amplifier, beats will be produced in the intermediate circuit. If the period of the heterodyne is known, we may measure the periodicity of the beats and may thus find the frequency of the modulation produced by coupling the

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two stations, and hence the distance between the stations A and B.

To measure the frequency of the beats, we may employ a telephone 34, or couple a known frequency meter with the coil 35. The variable condenser 36 serves to tune the intermediate circuit to the frequency of the beats.

Fig. 5 shows a filter device which is different from that shown in Fig. 4. The receiving frame 3 comprises a second frame 38 which is placed in the same or a parallel plane and is mounted in a closed circuit comprising an inductance 39 and a variable capacity 40. To protect the receiver 3 from the waves sent from the station, the circuit 38—40 is tuned to the wave length to be eliminated. To vary the coupling between the frames 3 and 38, the frame 38 may be placed at a greater or less distance or may be rotated on its axis.

Fig. 6 represents an arrangement in which a single antenna is used both for transmission and reception. The oscillations of the transmitter arrive at the terminals 42 and 43. A part of the energy is transmitted to the circuit comprising a variable condenser 44 and an induction coil 45. The currents, whose frequency is for instance N_2 and which are induced in the coils 46 and 47 by the antenna coil 48 and the coil 45, are in opposite directions, whilst the oscillations received from the other station by the antenna corresponding to the frequency N_1, are transmitted to the receiver by the coupled coils 48 and 46.

Fig. 7 shows a modified form of the filter, in which we utilise the property of quartz or other crystals to produce a very great difference in resistance according to the frequency of the oscillations to which they are subjected. They may thus be used as stabilisers for the oscillating circuits and the protection increased. 49 is a condenser of the piezo-electric type consisting of quartz or of a substance having like properties, which is connected in parallel with a variable condenser 18 and an induction coil 17 coupled with an induction coil 16 of the grid circuit of the amplifier. The circuit 17—18 is tuned to the wave length of the transmitter and acts like the filter shown in Fig. 4. We may also protect the receiving end against the direct action of the transmitted waves by connecting the quartz condenser in parallel with the variable condenser 15. In this case it should be selected so that it may be tuned to the received waves. Both of these methods of protection by piezo-electric condensers may be used at the same time.

Fig. 8 shows a transmission station employing damped oscillations. 54 is the secondary of a transformer which raises the voltage of an alternating or pulsatory current supplied to the primary 55. The transformer should be such that the potential difference is almost sufficient to produce the discharge in the spark gap 56. This spark gap is preferably chosen so that it has a great damping action, for instance as in the case of series or rotary spark gaps. The tension is raised to the sparking value by the E.M.F. produced in the inductance 57 by an oscillation or a train of waves set up in the coil 25 from the receiver of the station.

Fig. 9 shows a modified form of the transmitting and receiving installation; 3 is as before the receiving frame and is connected with the tuning condenser 15. The filter device 3—16—17—18 is the same as in Fig. 4. The valves 100 and 101 represent the high-frequency amplifying device. The number of these valves may be varied with the distance between the stations A and B. In this fig. they are connected by the resistances 102—103 and the capacity 104. In the plate circuit of the last valve 101 is mounted the coil 25 by which we modulate in the induction coil 24 of the transmission circuit the transmission of the antenna which is excited by the valve 62 used as a generator. The connections of the generator are similar to those shown in Fig. 4. The coil 105 of the transmission circuit is coupled with the exploring coil 106 of the heterodyne 30, comprising the valve 30, the oscillating circuit formed by the coil 107 and the variable condenser 109, the plate coil 107^1, and a galvanometer 108. When all the valves are energised the condenser 109 is adjusted. When the frequency of the heterodyne approximates to the frequency of the trains of waves in the circuit containing the coils 24 and 105, beats will be produced; these beats may be heard in the telephone 34 coupled by the coils 110—111 with the transmission circuit. The sound which has at first a high pitch will, when the condenser 109 is turned, diminish in pitch and will then disappear, then again appearing, and increasing in pitch and finally rising above the audible limit. It is then necessary to change the direction of rotation so as to find the proper middle point between the two low sounds. When the heterodyne has been regulated in this manner, the circuit 24, 111, 105 carries currents which will have the periodicity of the trains of waves common to the receiver and the generator; this periodicity can be read by the setting of the condenser 109 and serves to measure the distance between the two stations.

Fig. 10 shows a modification in which we use a single wave length for the transmission as well as for the reception, and a single antenna or a single frame. 112 is the antenna, 113 and 114 are respectively the inductance and the variable condenser forming the tuning device for the grid circuit of the valve 115, this circuit being tuned to the frequency N_1 common to the transmission and the reception. With the antenna is coupled another coil 116 in the plate circuit of the valve 115. The circuit of frequency N_1 contains the condenser 117, which is in parallel with the high tension supply. The circuit formed by the induction coil 118 and the variable condenser 119 is tuned to the frequency N_m of the modulation of the intensity of the waves of a frequency of N_1 due to the coupling. The induction coil 118 is coupled to the coil 120 of the grid circuit of the rectifying valve 121; in the plate circuit of the amplifying valve 122 is inserted an induction coil 123 which is coupled with an induction coil 124 connected to the terminals of the condenser 125. The plate circuit of the valve 115 is the seat of oscillations sent out by the antenna. Due to the mutual action of the two stations A and B, these oscillations are periodically modulated to a frequency of N_m. The current having the frequency of N_m, after modulation at the ends of the condenser 125, reinforces the transmission of the trains of waves by the antenna until it attains a condition of equilibrium. The variable condenser 119 is rotated and when the frequency of the circuit 118—119 coincides with the frequency of the modulations depending on the distance between the two stations, the amplitude of the oscillations in the circuit 118—119 will attain a maximum value. The distance between the two stations can be observed for instance by measuring the frequency of N_m by means of the condenser 119, or by measuring the beats produced by the coupling of a heterodyne by the use of the induction coils 123 or 124.

To set the apparatus in action, it may be advantageous to impart an initial shock, and this can be produced in a great variety of ways. It will suffice for instance to connect up the high tension of the amplifier when all the valves are already energised. We may also use a spark discharge to charge the condenser 73 of Fig. 4, or it may be periodically charged by a buzzer. This latter method has the advantage of assuring the operation of the apparatus even in the case in which, by reason of an imperfect adjustment, the modulations disappear after a certain time.

Obviously, the described arrangements are susceptible of various modifications in detail without departing from the principle of the invention.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is:—

1. Process for measuring distances between two stations by observing the time taken by electromagnetic waves in the forward and return passage between two stations of which the distance is to be measured, each station comprising a transmitting aerial, a receiving aerial and a source of electric energy, each transmitting aerial at one station sending electromagnetic waves to the receiving aerial of the other station, and each receiving station acting directly on its own transmitting aerial so as to affect or modulate the emission of this station, viz., to produce modulations in the intensity of the electromagnetic waves transmitted and received, the frequency of this modulation depending on the distance between the two stations and consequently enabling this distance to be determined.

2. Means for carrying out the process as claimed in Claim 1, in which each station sends out waves at a frequency which differs from the transmitting frequency of the other station, the receiving circuit of each station being tuned in resonance with the frequency of the waves transmitted from the other station and protected against the direct action of the transmitter of the same station, for instance by filters, or by using the stabilising properties of piezo-electric crystals.

3. Means for carrying out the process as claimed in Claim 1, in which the transmission and reception are effected by antennæ, by frames, or by a combination of both these means.

4. Means for carrying out the process as claimed in Claim 1, in which at each station the transmission and reception are effected by two distinct antennæ as and for the purpose described.

5. Means for carrying out the process as claimed in Claim 1, in which a receiver at one station is shielded from the effect of the transmitter at the same station by using at the same station a transmitting antenna and a receiving frame (or the converse arrangement), the frame and the antenna at the same station being disposed and oriented in space so as to be mutually unaffected but so that the antenna of one station will act on the frame of the other station.

6. Means for carrying out the process as claimed in Claim 1, applicable in the case

in which the transmission and reception are effected solely by frames and characterised by the disposition of the two frames at a station at right angles to one another, the transmitting frame of one station being parallel to the receiving frame of the other station.

7. Means for carrying out the process as claimed in Claim 1, in which the modulation in the circuit of each station is measured by wave meters, or by beats of a heterodyne.

8. Means for carrying out the process as claimed in Claim 1, in which the transmission is effected by continuous or damped waves of which the frequency is high relatively to that of the modulations.

9. Means for carrying out the process as claimed in Claim 1, in which the reception and transmission are effected by the same antenna or frame and, for this purpose, the windings which act on the antenna and the connections with the circuits of transmission and reception are disposed so that the receiving circuits are not directly affected by the transmitting circuits at the same station.

10. Means for carrying out the process as claimed in Claim 1, applicable in the case in which the transmission is effected by damped waves, and characterised by a transformer supplying the antenna at a tension not quite sufficient to produce discharge in the spark-producer, the rest of the required tension being furnished by the train of waves received in the receiving circuit of the station.

11. Means for carrying out the process as claimed in Claim 1, applicable to the case in which each station contains only a single antenna or a single frame, and the same wave length is used both for the transmission and reception.

12. Means for carrying out the process as claimed in Claim 11, in which a valve in the circuit coupled with the receiving antenna is arranged to act also as a generator of oscillations and to act on the receiving antenna which operates also as a transmitting antenna.

Dated this 3rd day of January, 1928.

ABEL & IMRAY,
30, Southampton Buildings, London, W.C. 2,
Agents for the Applicants.

[This Drawing is a reproduction of the Original on a reduced scale]

Fig: 1

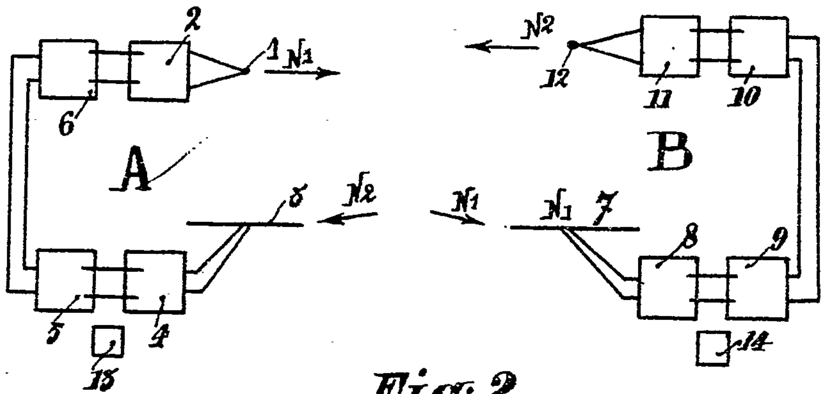


Fig: 2

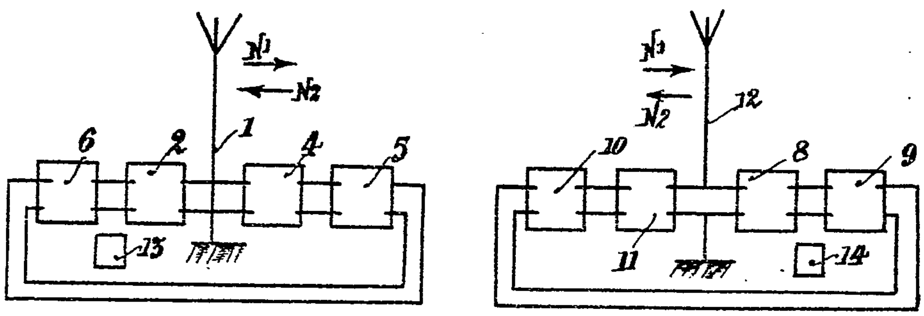


Fig: 3

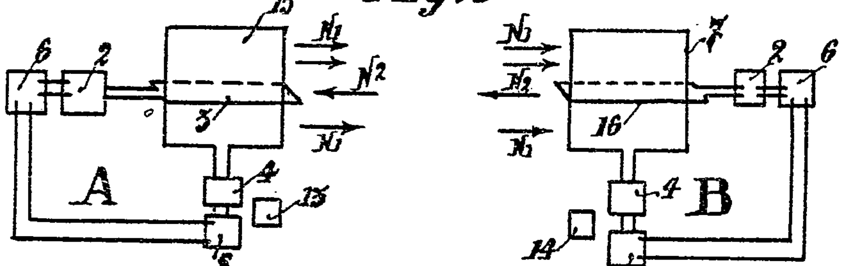
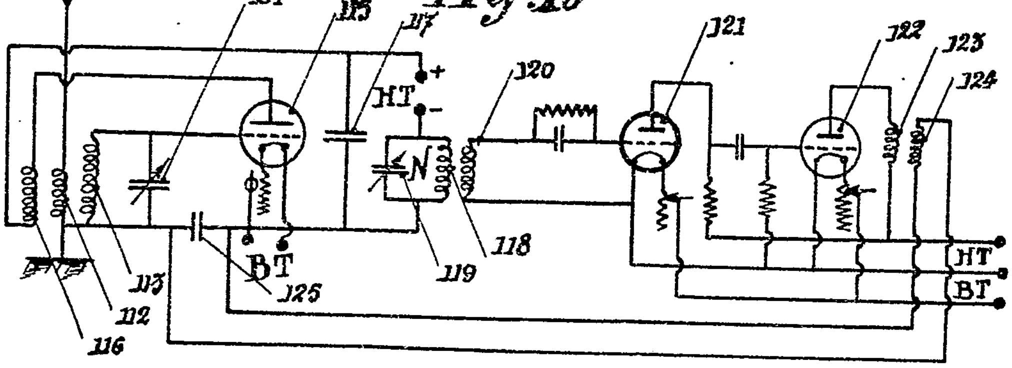


Fig: 10



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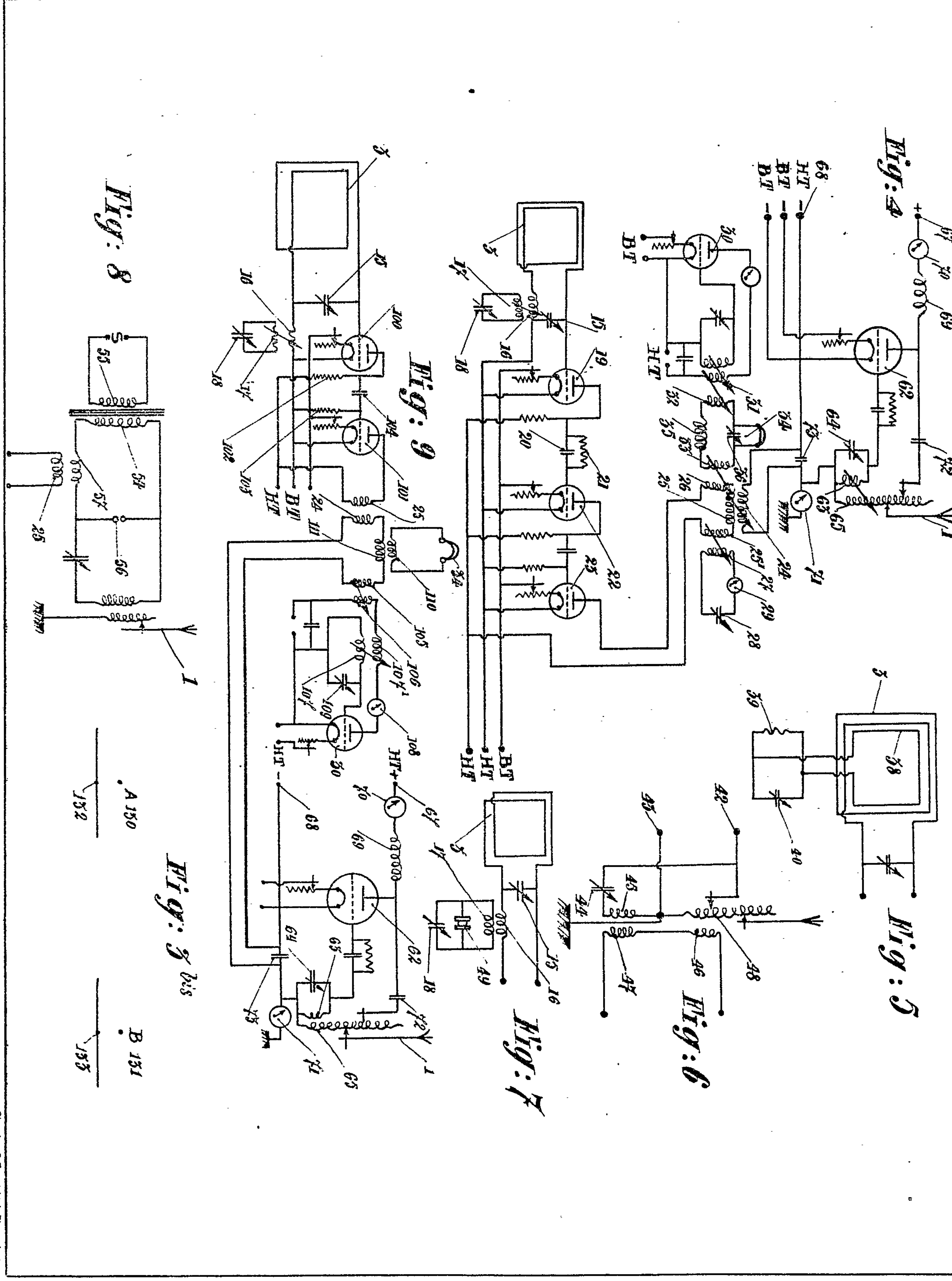

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Fig: 4

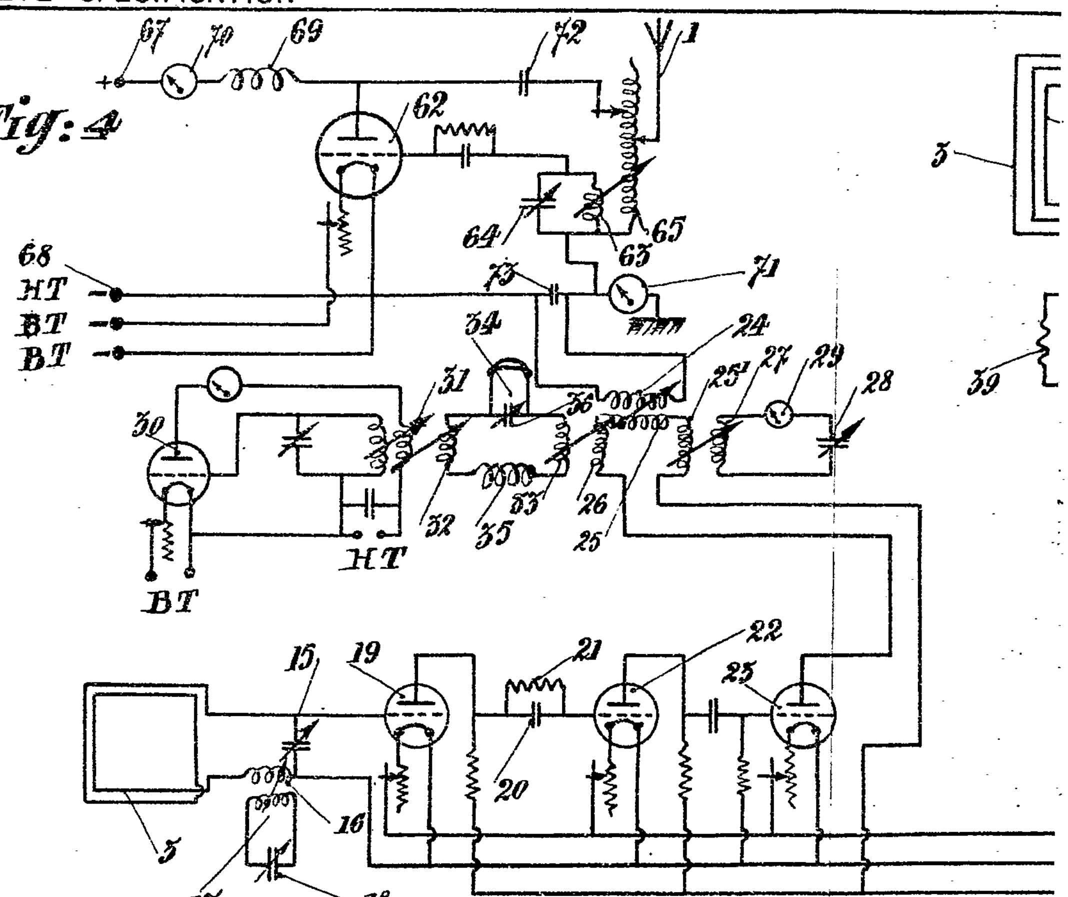


Fig: 9

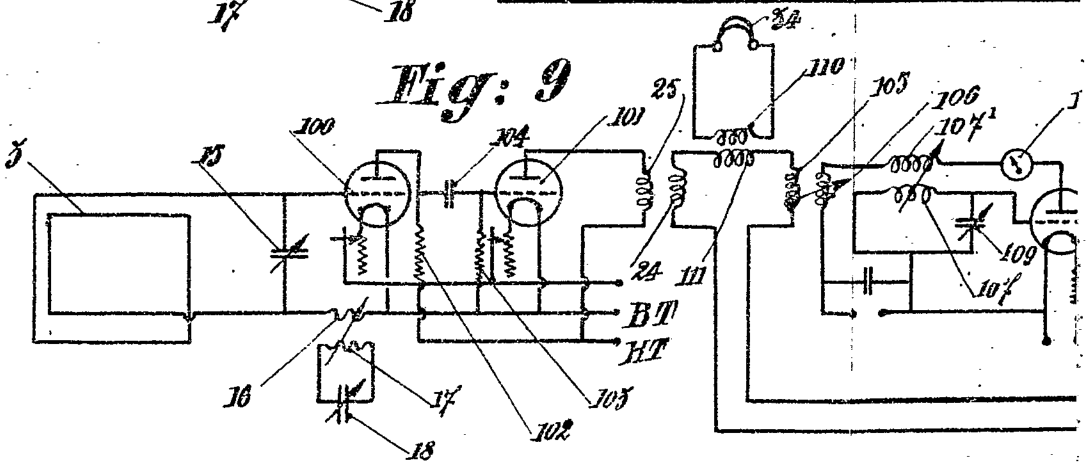
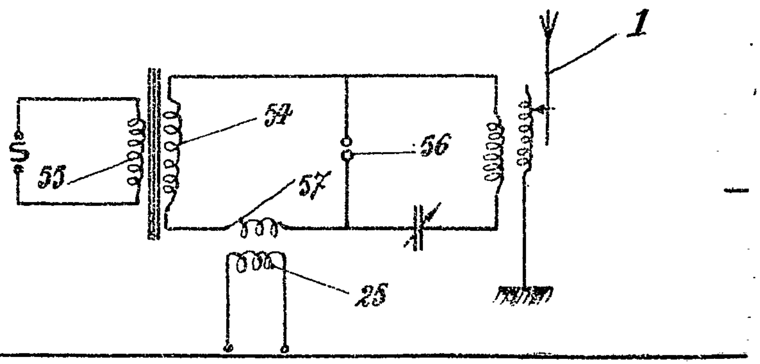
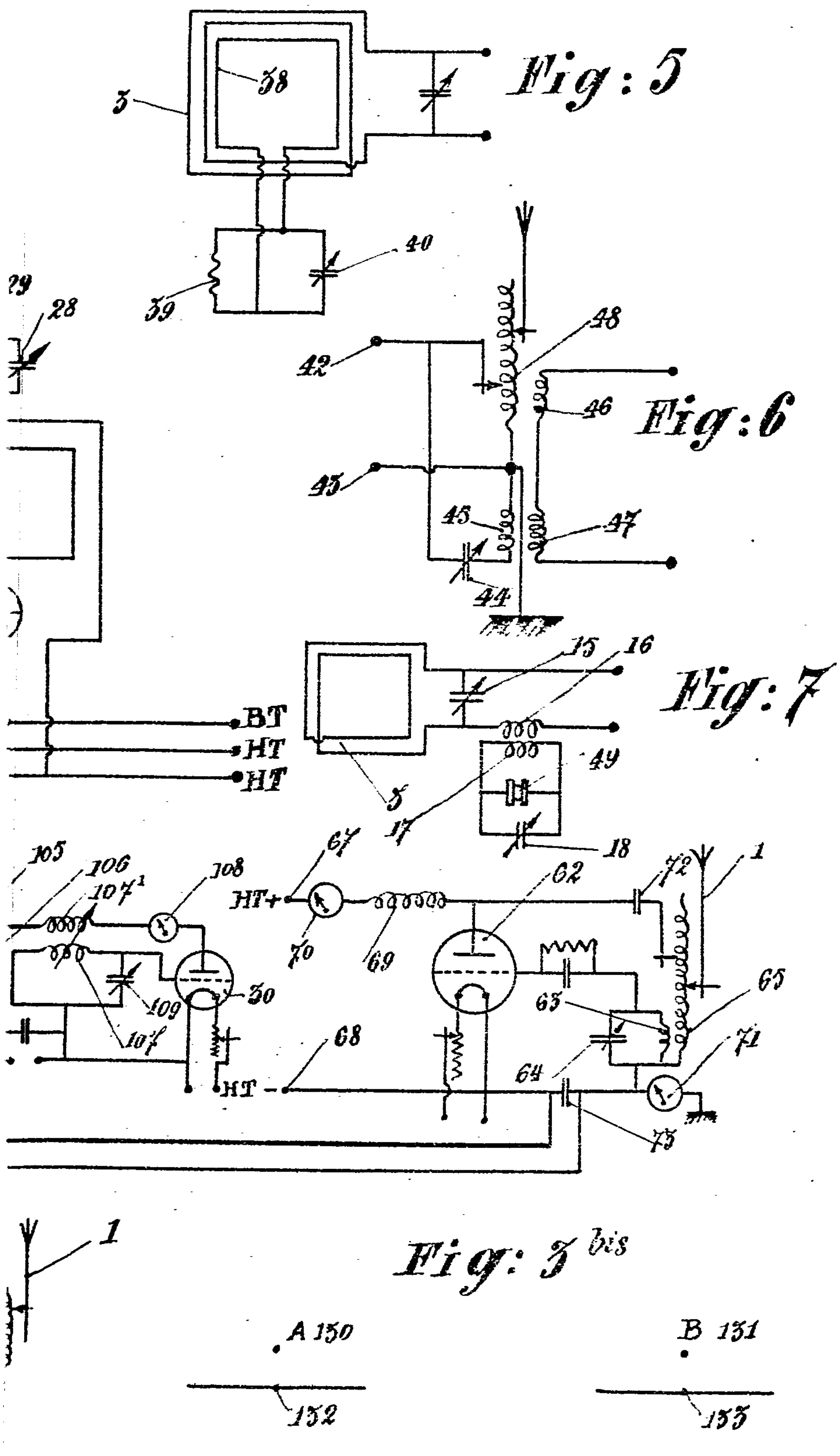


Fig: 8





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