PATENT SPECIFICATION

363,617

Application Date: June 21, 1930. No. 19,028/30.

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PROVISIONAL SPECIFICATION.

Improvements in and relating to Wireless Beacon Transmitters.

We, Reginald Leslie Smith-Rose and Horace Augustus Thomas, both British subjects, and both of The National Physical Laboratory, Teddington, Middlesex, do hereby declare the nature of this invention to be as follows:—

This invention relates to wireless beacon transmitters.

In a rotating beacon transmitter means is provided for emitting radiation, the intensity of which varies with time as the result of the rotation of some portion of the transmitter. This system employs a frame coil, from 6 to 10 feet square, rotating about a vertical axis at a uniform speed of one revolution per minute. The coil forms the inductance of the tuned circuit in which the oscillations are generated by the transmitting valve, and the intensity of the waves radiated varies with the cosine of the angle between the plane of the coil and the direction of transmission. As the coil rotates a characteristic signal is emitted to indicate when the plane of the coil is perpendicular to the geographical meridian. If an observer at a distant receiving station starts a watch or chronograph on hearing this signal and then observes the time interval which elapses before the signal passes through its minimum intensity, then the bearing of the receiver from the transmitter can be calculated from the known speed of rotation of the beacon (6° per second).

From practical experience under a variety of conditions this rotating loop type of beacon has been found to give reliable bearings at distances up to about 100 miles for transmission oversea. When the range is increased beyond this, however, the observed bearings are subject to errors due to the arrival at the receiver of waves which have travelled via the upper atmosphere.

The general theory of obtaining a minimum of signal intensity depends upon the assumption that there is no radiation from the loop in a direction perpendicular to its plane. The zero-radiation is, however, strictly confined to this linear direction, which for a vertical loop is horizontal. In directions inclined to the horizontal, however, there is considerable radiation from the loop, the intensity of the waves emitted increasing with the sine of the angle of elevation. It is the waves which are radiated in this manner into the upper atmosphere which are responsible for the night errors as mentioned above. A consideration of the mode of radiation of electromagnetic waves from a closed loop shows that this radiation towards the upper atmosphere is due to the action of the horizontal sides of the loop.

The present invention consists, broadly, in suppressing any effective radiation or minimising radiation in directions inclined to the horizontal.

Thus, where the aerial system comprises conductors arranged at an inclination with the vertical, which otherwise would be capable of radiating and emitting energy, means is provided for suppressing such radiation.

Thus according to the invention the aerial or aerials comprise a vertical component designed to emit energy in association with a pair of components arranged at an inclination with the vertical in such manner that the currents flowing in the two members of such pair are equal and opposite.

Where, for instance, the aerials comprise a vertical component connected with a coil coupled to the coil of a radio goniometer, the two ends of the coil are connected to the vertical elements of the aerial by feed conductors arranged horizontally or at an inclination with the vertical so that the currents flowing in the two feed conductors are equal and opposite.

For instance, the conductors may be arranged horizontally and parallel one with the other in a vertical plane or, preferably, in a horizontal plane in order further to reduce radiation or the feed conductors may be arranged so that they cross one another at intervals.

The invention also extends to a wireless beacon comprising an aerial system including four vertically arranged conductors coupled with a special goniometer.

[Price 1/-]

A further feature of the invention comprises the insertion of a tuning inductance in the aerial lead to balance up the current distribution in the horizontal leads, and normally central control of the inductance in question may be provided.

A further feature of the invention comprises the employment of a two-section goniometer, each with a fixed primary and a pair of similar rotating secondary coils.

A yet further feature of the invention comprises the use of a tuning fork controlled phonic motor to operate the beacon at a uniform speed.

Preferably, in accordance with the invention, an elevated aerial system is employed to secure symmetry of current distribution about the centre point and feed wires and the aerial system may comprise insulated masts as vertical components of the aerial system.

The invention will be described further in detail with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic view of one arrangement in accordance with the invention,

Figure 2 is an alternative arrangement, and

Figure 3 illustrates a means for securing a correct current distribution in the horizontal elevation;

Figure 4 illustrates an arrangement of the horizontal components of the aerial system in order further to minimise radiation therefrom; while

Figure 5 illustrates a means for supplying radiated frequency energy from a central transmitter to the aerial system by the employment of a special two-section type of goniometer.

For operation on short waves the dimensions of the aerial system can be kept reasonably small, and may therefore be rotatable about a central axis. In such a case the arrangement shown in Figure 1 would be suitable. Two vertical aerials AA^1, BB^1 are connected by horizontal leads CC^1, DD^1 taken from the midpoints of two coils L_1, L_2 which have equal mutual inductance with a third coil L_3 which is supplied with radio-frequency current from a generator, G. If the electrical constants of each of the aerial circuits $ACL_1C^1A^1$, $BDL_2D^1B^1$ are similar and such that they resonate as half-wave oscillators at the supply frequency, then the currents in the horizontal conductors C and C^1 are equal and opposite; and similarly with the conductors D and D^1. There will thus be no radiation from the horizontal members of the system. If further the coils L_1 L_2 L_3 and the radio-frequency generator be efficiently screened the effective radiation of the whole system will be confined to that due to the currents in the vertical aerials.

When the operating frequency is reduced to the value (287 Kilocycles per second) at present allocated to rotating beacons for marine navigation, it is necessary for efficient transmission to use a larger aerial system, the rotation of which introduces practical difficulties. It then becomes expedient to use a system of two pairs of aerials erected at right angles to each other, and supply these four aerials with currents of the correct phase and magnitude through a goniometer arrangement. Practical limitations of mast height preclude the use of a vertical aerial of more than one-tenth of the wave-length and also the location of the transmitting apparatus on the centre line of the aerial system as in Figure 1. It becomes necessary, therefore, to use an arrangement such as that shown in Figure 2, in which ABCD are the four vertical earthed aerials, with their horizontal feeder lines connected to them at a short distance above the ground.

Now in order to secure the desired result described above it is necessary that the constants of all four aerials shall be identical and also that the current distribution is such that the horizontal components are compensated. It is further necessary to supply each of these aerials with the necessary radio-frequency current at the correct phase and magnitude.

To secure identity of electrical constants of the aerials is largely a matter of careful design and construction, but it has been found useful to employ a counterpoise for each aerial in place of a direct earth connection. In order to secure the correct current distribution in the horizontal leads it is necessary to connect inductances at the bottom of each aerial as shown in L_A, L_B, L_C, L_D in Figure 2. By adjusting the values of these inductances the current distribution can be made as indicated in Figure 3. This is obtained when the portion of the aerial from the top to the centre point of the goniometer coil M_A is effectively tuned to a quarter wave-length, so that the current amplitude is a maximum at this point. On either side of this point, M_A, the current amplitude decreases symmetrically along the horizontal leads, and thus the currents in the feeder wires F and F^1 are equal in magnitude and opposite in direction. The radiation from this pair of conductors will thus be small. To decrease it to the absolute minimum these conductors may be transposed in the manner indicated in Figure 4. It may further be an advantage to keep both these feeders in a horizontal plane instead of a vertical plane as drawn in Figure 4.

In order to supply the radio-frequency energy from the central transmitted to the aerial system a special two-section type of goniometer has been devised (Figure 5). The aerials A, B of an opposite pair are connected by their horizontal leads to the coils L_{A1}, L_{B1}. These coils are wound in adjacent sections of the rotating former of the goniometer, and are small in dimensions compared with the stator coils L_{S1}, L_{S2}. These stator coils are the two halves of one primary coil which carries the main radio-frequency current supplied by the transmitter. The two coils L_{S1}, L_{S2} are arranged in spacing and dimensions according to Helmholtz' relationship for obtaining a uniform linear magnetic field at the centre over the small space occupied by the secondary or rotating coils L_{A1}, L_{B1}. The E.M.F. induced in these latter coils will thus bear a sinusoidal relationship with direction of the axis of the coil. A precisely similar arrangement is used to supply the current to the other two aerials. The two sets of primary coils are connected in series in the output circuit of the final power stage of the transmitter and the two sets of secondary rotating coils are geared off the same shaft. This shaft is driven by a phonic motor with tuning fork control so that it rotates uniformly at such a speed that the coils rotate at one revolution per minute. The coils connected to the second pair of aerials C and D, are arranged to be at right angles to L_{A1} and L_{B1} so that the currents in these aerials are in quadrature with those in the corresponding aerials A and B. L_{A1} and L_{B1} are so connected to aerials A and B that the currents in these aerials are in opposite phase.

In order to secure the correct current distribution in each aerial the values of the inductances L_A, L_B, etc. at the base of the aerials can be adjusted over a small range with the aid of insulated mechanical control rods.

The intensity of the waves radiated will vary as the system rotates and will be zero in the vertical plane at right angles to the plane containing the aerials. As described above this is the condition for absence of night errors in the observed bearings with such a rotating beacon transmitter.

The vertical aerials A and B may conveniently be formed by the metallic masts suitably insulated. This avoids distortion of the radiated field by the supporting masts if these are separate from the aerials.

Each section of the goniometer comprising the stator and rotor coils is enclosed in a separate screened box of sheet metal as indicated by the broken line in Figure 5. Each stage of the transmitter is also screened separately with sheet metal and finally the whole of the room containing the transmitter and its power supply is screened. These precautions are necessary in order to ensure that no portion of the installation other than the vertical aerial system gives rise to any effective radiation.

Dated this 21st day of June, 1930.

MARKS & CLERK.

COMPLETE SPECIFICATION.

Improvements in and relating to Wireless Beacon Transmitters.

We, Reginald Leslie Smith-Rose and Horace Augustus Thomas, both British subjects, and both of The National Physical Laboratory, Teddington, 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:—

This invention relates to wireless beacon transmitters.

In a rotating beacon transmitter means is provided for emitting radiation, the intensity of which varies with time as the result of the rotation of some portion of the transmitter. An existing system employs a frame coil, from 6 to 10 feet square, rotating about a vertical axis at a uniform speed of one revolution per minute. The coil forms the inductance of the tuned circuit in which the oscillations are generated by the transmitting valve, and the intensity of the waves radiated varies with the cosine of the angle between the plane of the coil and the direction of transmission. As the coil rotates a characteristic signal is emitted to indicate when the plane of the coil is perpendicular to the geographical meridian. If an observer at a distant receiving station starts a watch or chronograph on hearing this signal and then observes the time interval which elapses before the signal passes through its minimum intensity, then the bearing of the receiver from the transmitter can be calculated from the known speed of rotation of the beacon (6° per second).

From practical experience under a variety of conditions this rotating loop type of beacon has been found to give reliable bearings at distances up to about 100 miles for transmission oversea. When the range is increased beyond this, however, the observed bearings are subject to errors due to the arrival at the receiver of waves which have travelled via the upper atmosphere.

The general theory of obtaining a minimum of signal intensity depends upon the assumption that there is no radiation from the loop in a direction perpendicular to its plane. The zero-radiation is, however, strictly confined to this linear direction, which for a vertical loop is horizontal. In directions inclined to the horizontal, however, there is considerable radiation from the loop, the intensity of the waves emitted increasing with the sine of the angle of elevation. It is the waves which are radiated in this manner into the upper atmosphere which are responsible for the night errors as mentioned above. A consideration of the mode of radiation of electromagnetic waves from a closed loop shows that this radiation towards the upper atmosphere is due to the action of the horizontal sides of the loop.

In directional transmitters having a plurality of spaced vertical aerials each comprising vertical components it has been proposed to arrange conductors which connect the vertical portions together and to the transmitting apparatus and which are horizontal or have horizontal components so that the effective radiation is due only to those portions of the aerials which are vertical, the horizontal components being arranged, for instance, in close proximity one with the other and being crossed over.

The object of the present invention is to provide further improvements in directional transmitters comprising spaced vertical aerials.

A wireless beacon transmitter according to the invention comprises a plurality of spaced vertical aerials each having a vertical component designed to emit energy in association with a pair of components arranged horizontally or otherwise at an inclination with the vertical and an inductance in the aerial lead to balance up the current distribution in the horizontal or inclined pair of components.

A further feature of the invention comprises the employment of a two-section goniometer, each with a fixed primary and a pair of similar rotating secondary coils.

A yet further feature of the invention comprises the use of a tuning fork controlled phonic motor to ensure the operation of the beacon at a uniform speed.

Preferably, in accordance with the invention, an elevated aerial system is employed to secure symmetry of current distribution about the centre point and feed wires and the aerial system may comprise insulated masts as vertical components of the aerial system.

The invention will be described further in detail with reference to the drawings accompanying the Provisional Specification in which:—

Figure 1 is a diagrammatic view of a usual arrangement comprising two vertical spaced aerials each comprising vertical and horizontal components;

Figure 2 illustrates diagrammatically an arrangement in accordance with the invention comprising four aerials associated with a radio goniometer;

Figure 3 illustrates diagrammatically the current distribution in an aerial such as is comprised in the arrangement illustrated in Figure 2;

Figure 4 illustrates an aerial the horizontal components of which are arranged in known manner in order to minimise radiation and which, in accordance with the invention, comprises an inductance in the aerial lead to balance up the current distribution in the horizontal components;

Figure 5 illustrates a means for supplying radiated frequency energy from a central transmitter to an aerial system in accordance with the invention by the employment of a special two section type of goniometer, and

Figures 6 and 7 filed with the Complete Specification illustrate other arrangements of apparatus in accordance with the invention.

For operation on short waves the dimensions of the aerial system can be kept reasonably small, and may therefore be rotatable about a central axis. In such a case the arrangement shown in Figure 1 would be suitable. Two vertical aerials AA^1, BB^1, are connected by horizontal leads CC^1, DD^1 with two coils L_1, L_2 which have equal mutual inductance with a third coil L_3 which is supplied with radio-frequency current from a generator, G. If the electrical constants of each of the aerial circuits $ACL_1C^1A^1$, $BDL_2D^1B^1$ are similar and such that they resonate as half-wave oscillators at the supply frequency, then the currents in the horizontal conductors C and C^1 are equal and opposite; and similarly with the conductors D and D^1. There will thus be no radiation from the horizontal members of the system. If further the coils L_1 L_2 L_3

and the radio-frequency generator be efficiently screened the effective radiation of the whole system will be confined to that due to the currents in the vertical aerials.

When, however, the operating frequency is reduced to the value (287 Kilocycles per second) at present allocated to rotating beacons for marine navigation, it is necessary for efficient transmission to use a larger aerial system, the rotation of which introduces practical difficulties. It then becomes expedient to use a system of two pairs of aerials erected at right angles to each other, and supply these four aerials with currents of the correct phase and magnitude through a goniometer arrangement. Practical limitations of mast height preclude the use of a vertical aerial of more than one-tenth of the wave-length and also the location of the transmitting apparatus on the centre line of the aerial system as in Figure 1. It becomes necessary, therefore, to use, and such use is a feature of the invention, an arrangement such as that shown in Figure 2, in which ABCD are the four vertical earthed aerials, with their horizontal feeder lines connected to them at a short distance above the ground.

Now in order to secure the desired result described above it is necessary that the constants of all four aerials shall be identical and also that the current distribution is such that the horizontal components are compensated. It is further necessary to supply each of these aerials with the necessary radio-frequency current at the correct phase and magnitude.

To secure identity of electrical constants of the aerials is largely a matter of careful design and construction, but it has been found useful to employ a counterpoise for each aerial, in place of a direct earth connection.

In order to secure the correct current distribution in the horizontal leads it is necessary to connect inductances at the bottom of each aerial as shown in L_A, L_B, L_C, L_D in Figure 2. By adjusting the values of these inductances the current distribution can be made as indicated in Figure 3. This is obtained when the portion of the aerial from the top to the centre point of the goniometer coil M_A is effectively tuned to a quarter wavelength, so that the current amplitude is a maximum at this point. On either side of this point, M_A, the current amplitude decreases symmetrically along the horizontal leads and thus the currents in the feeder wires F and F^1 are equal in magnitude and opposite in direction. The radiation from this pair of conductors will thus be small. To decrease it to the absolute minimum these conductors may be transposed in the manner indicated in Figure 4. It may further be an advantage to keep both these feeders in a horizontal plane instead of a vertical plane as drawn in Figure 4.

In the arrangement illustrated in Figure 5, the radio-frequency energy from a central transmitter is supplied to the aerial system by a two-section type of goniometer. The aerials A, B of an opposite pair are connected by their horizontal leads to the coils L_{A1}, L_{B1}. These coils are wound in adjacent sections of the rotating former of the goniometer, and are small in dimensions compared with the stator coils L_{S1}, L_{S2}. These stator coils are the two halves of one primary coil which carries the main radio-frequency current supplied by the transmitter. The two coils L_{S1}, L_{S2} are arranged in spacing and dimensions according to Helmholtz' relationship ("Textbook of Practical Physics", Allen & Moore, London, 1920, pages 566 and 567) for obtaining a uniform linear magnetic field at the centre over the small space occupied by the secondary or rotating coils L_{A1}, L_{B1}. The E.M.F. induced in these latter coils will thus bear a sinusoidal relationship with the direction of the axis of the coil. A precisely similar arrangement is used to supply the current to the other two aerials. The two sets of primary coils are connected in series in the output circuit of the final power stage of the transmitter and the two sets of secondary rotating coils are geared off the same shaft. This shaft is driven by a phonic motor with tuning fork control so that it rotates uniformly at such a speed that the coils rotate at one revolution per minute. The coils connected to the second pair of aerials C and D, are arranged to be at right angles to L_{A1} and L_{B1} so that the currents in these aerials are in quadrature with those in the corresponding aerials A and B. L_{A1} and L_{B1} are so connected to aerials A and B that the currents in these aerials are in opposite phase.

In order to secure the correct current distribution in each of these aerials the values of the inductances L_A, L_B, etc. at the base of the aerials can be adjusted over a small range with the aid of insulated mechanical control rods.

The intensity of the waves radiated will vary as the system rotates and will be zero in the vertical plane at right angles to the plane containing the aerials.

As described above this is the condition for absence of night errors in the observed bearings with such a rotating beacon transmitter.

The vertical aerials A and B may conveniently be formed by the metallic masts suitably insulated. This avoids distortion of the radiated field by the supporting masts if these are separate from the aerials.

Each section of the goniometer comprising the stator and rotor coils is enclosed in a separate screened box of sheet metal as indicated by the broken line in Figure 5. Each stage of the transmitter is also screened separately with sheet metal and finally the whole of the room containing the transmitter and its power supply is screened. These precautions are necessary in order to ensure that no portion of the installation other than the vertical aerial system gives rise to any effective radiation.

Figure 6 illustrates an arrangement for feeding the aerial system with currents in the correct phase relationship by using a two-section goniometer on the low power side of the transmitter, and inserting two amplifiers, one in each of the supply leads to the two pairs of aerials.

In this figure the arrangement of the goniometer is similar to that previously described with reference to Figure 5, except that the coils C and D are fed directly from the master oscillator and the rotating coils A and B supply the input to the amplifiers 1 and 2. The outputs from these amplifiers supply each of the two pairs of aerials marked NS and EW in each of which is arranged an inductance to balance up the current distribution in the horizontal components thereof as in Figure 2, such inductances being indicated by the references L_A, L_B, L_C, L_D. These two amplifiers require to be accurately matched so that both the phase and magnitude of the currents supplied by them to the aerials are in the correct relationship to one another. The advantages of this arrangement are, first, that only comparatively feeble currents are flowing in the input coils of the goniometer so that any interfering radiation from these will be considerably reduced, and secondly, that practically no current flows in the output coils of the goniometer and consequently the sinusoidal relationship is more easily maintained and is unaffected by the magnitude of the aerial current The two rotating coils of the goniometer are entirely separate and adjustments to the aerial circuit do not affect the input system.

Figure 7 is a diagram showing an arrangement of aerials comprising inductances L_A, L_B, L_C, L_D adapted to balance up the current distribution in the horizontal components thereof, in which the goniometer is replaced by a suitable double potentiometer. The slide wire or row of contacts C has uniform resistance per unit length along the wire and it is supplied with radio-frequency current from the master oscillator. Two contacts A and B connected to the grids of amplifiers 1 and 2, respectively, are given a simple harmonic motion along the wire by means of any suitable mechanical device. These contacts are adjusted so that the potential differences applied to the two amplifiers differ in phase by 90° and the period of the simple harmonic motion is made equal to the time of rotation required for the beacon, i.e., the period will usually be 1 cycle per minute. By this means the sinusoidal variation of the current supplied to the aerial system is ensured free from any difficulties arising from the varying mutual inductances between the goniometer coils and also without incurring any troubles due to interfering radiation from the goniometer.

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. Wireless beacon transmitters comprising a plurality of spaced vertical aerials each having a vertical component designed to emit energy in association with a pair of components arranged horizontally or otherwise at an inclination with the vertical and in the aerial lead an inductance to balance up the current distribution in the horizontal or inclined pair of components.

2. A wireless beacon transmitter as claimed in Claim 1 in which the aerials comprise a vertical component connected with a coil coupled to the coil of a radio goniometer and the two ends of the coil are connected to the vertical elements of the aerial by feed conductors arranged horizontally or at an inclination with the vertical so that the currents flowing in the two feed conductors are equal and opposite.

3. A wireless beacon transmitter as claimed in Claim 2 in which the feed conductors are arranged horizontally and parallel one with the other in a vertical plane.

4. A wireless beacon transmitter as claimed in Claim 2 in which the horizontal components are arranged in the same horizontal plane in order further to reduce radiation.

5. A wireless beacon transmitter as claimed in Claim 4 in which the feed conductors for the aerials are arranged so that they cross one another at intervals.

6. A wireless beacon transmitter as claimed in any of the preceding claims

comprising an aerial system including four vertically arranged conductors coupled with a goniometer.

7. A wireless beacon transmitter as claimed in Claim 6 comprising a two-section goniometer, with fixed primary coils and a pair of similar rotating secondary coils.

8. A wireless beacon transmitter as claimed in any of the preceding claims comprising a tuning fork controlled phonic motor to operate the beacon at a uniform speed.

9. A wireless beacon transmitter as claimed in any of the preceding claims which the aerial system comprises insulated masts as vertical components of the aerial system.

10. A wireless beacon transmitter as as claimed in any of the preceding claims in which is employed a potentiometer giving the correct sinusoidal relationship to the aerial currents in the place of a goniometer for supplying energy to the aerials.

11. Improvements in wireless beacon transmitters substantially as hereinbefore described and as illustrated in and by the drawings filed with the Provisional specification and the accompanying drawings.

Dated this 23rd day of February, 1931.

MARKS & CLERK.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1932.

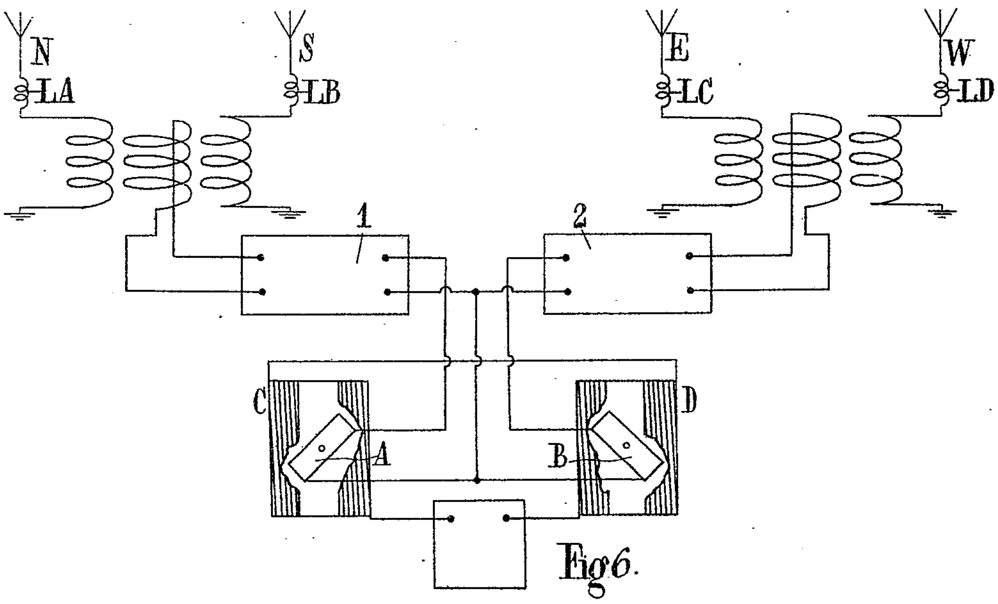

Fig 6.

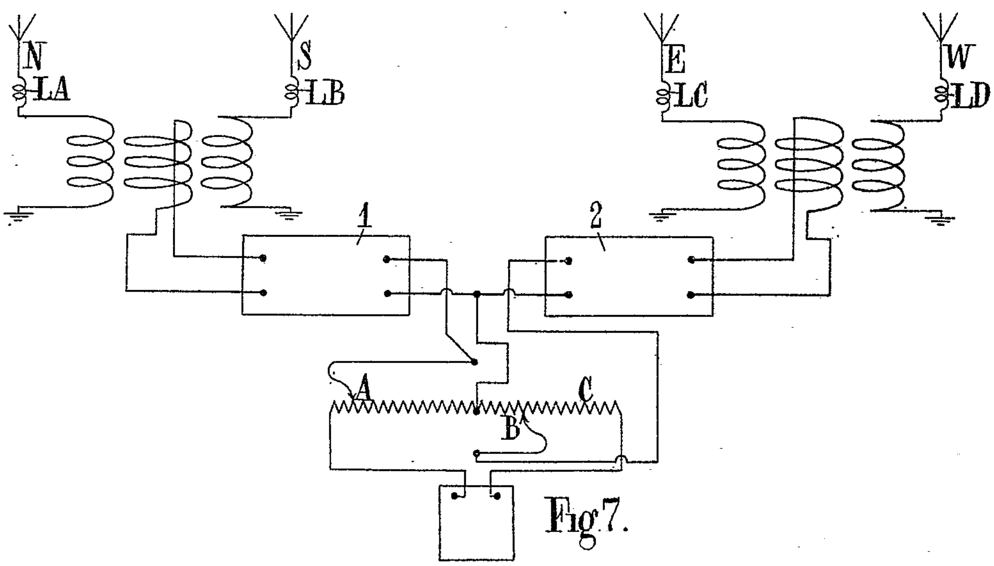

Fig 7.

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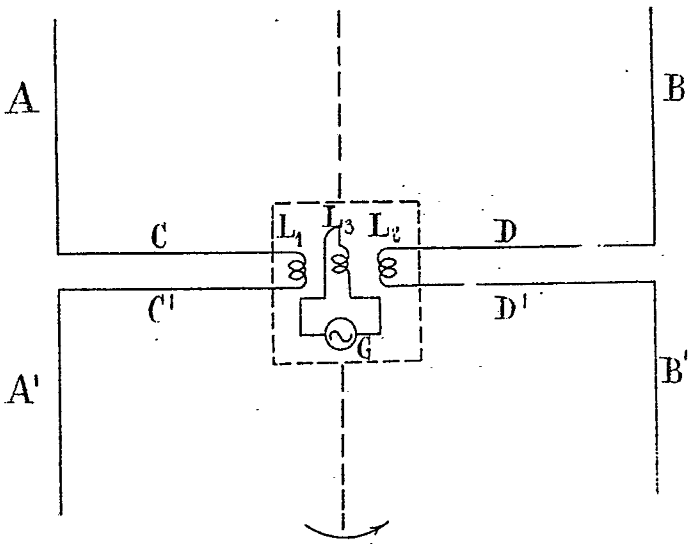

Fig. 1

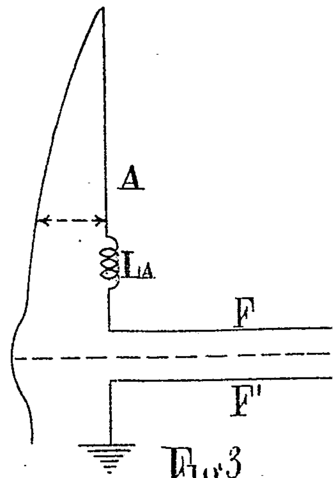

Fig. 3

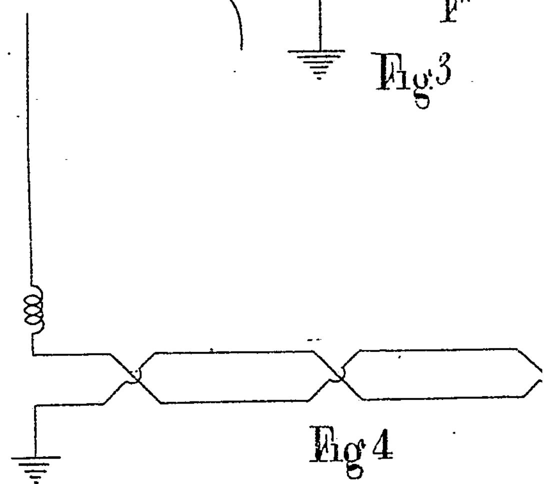

Fig. 4

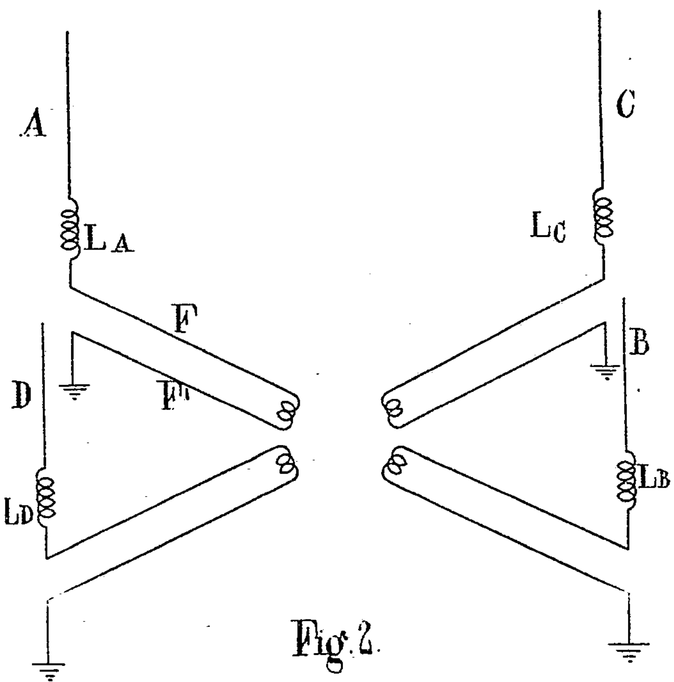

Fig. 2

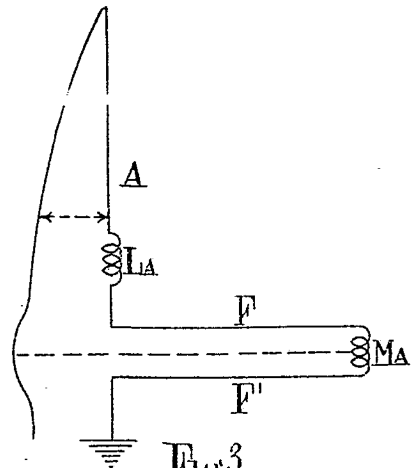

Fig 3

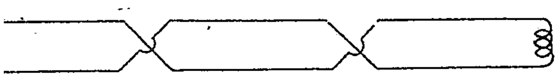

Fig 4

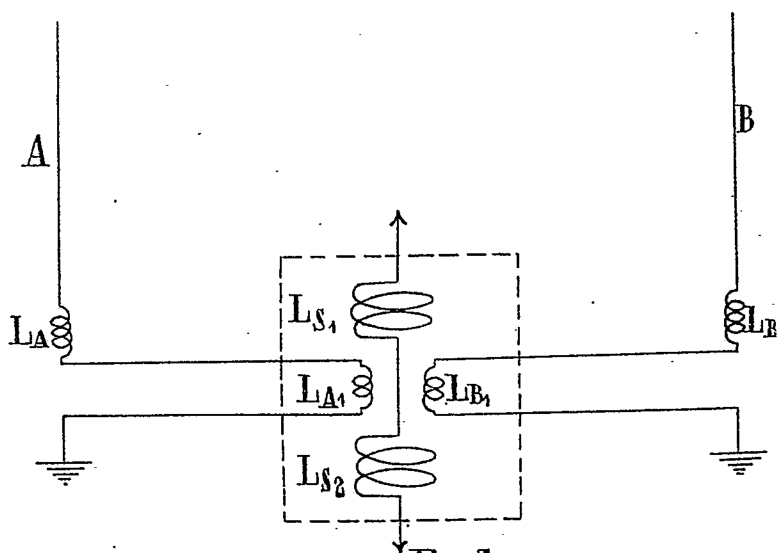

Fig. 5.

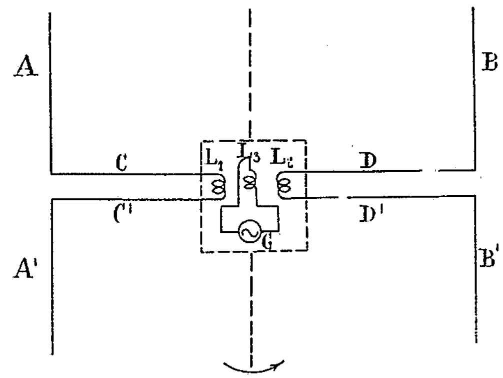

Fig. 1

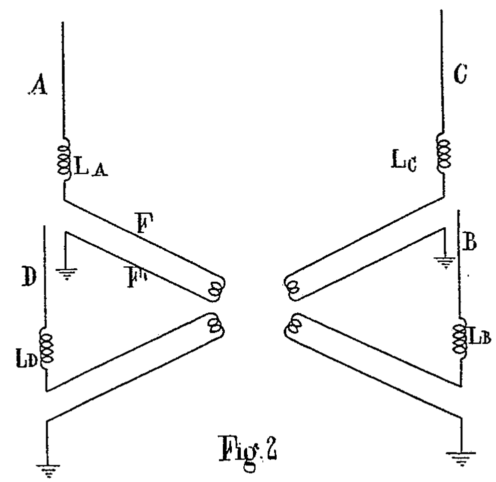

Fig. 2

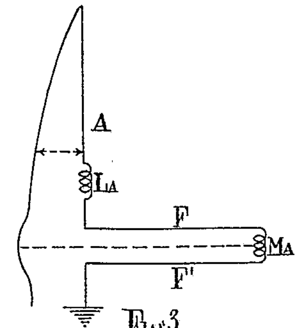

Fig. 3

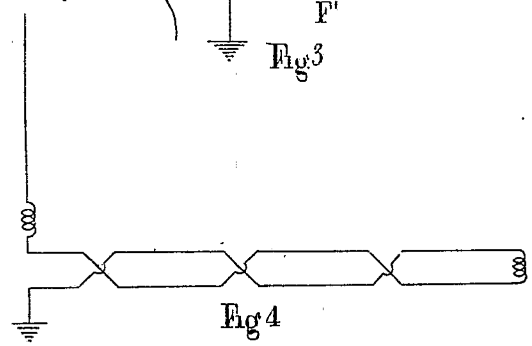

Fig. 4

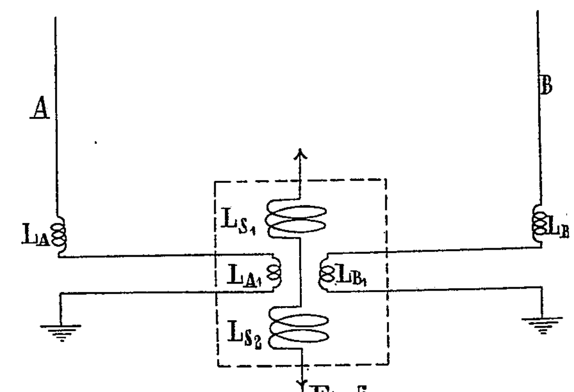

Fig. 5.

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