PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventor: BRIAN DOUGLAS WINTER WHITE

820,319

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Index at acceptance:—Classes 38(4), R(4: 31X); **40(5)**, 1L3A; **and 40(7)**, AE(4X: 6TX), DP1(D1: D2: G1: S2), DS5.

International Classification:—G05d. H04b, d, p.

COMPLETE SPECIFICATION

Improvements in or relating to Azimuth Guidance Systems

SPECIFICATION NO. 820,319

INVENTOR:- BRIAN DOUGLAS WINTER WHITE

By a direction given under Section 17 (1) of the Patents Act 1949 this application proceeded in the name of National Research Development Corporation, a British Corporation established by statute, of 1, Tilney Street, London, W. 1.

THE PATENT OFFICE,
19th November, 1959

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... a given line, most conveniently the centre line of a desired runway, for some distance (1 mile for example) prior to and after touchdown.

A known system of the kind referred to above makes use of a long wire or number of wires placed longitudinally on or near the desired runway. The wire or number of wires is fed with alternating current and an aircraft equipped with a pick-up loop or loops can detect the resulting electro-magnetic field and derive therefrom its position relative to the wire or number of wires and hence relative to the runway.

A typical application known as the single wire or switched loop system, uses a single wire, along the centre line of the runway, carrying a current of 2 amps at a periodicity of 1,800 c.p.s. An aircraft is equipped with two pick-up loops mounted in the aircraft nose at an angle of approximately 10° to the vertical, one inclined to port and the other to starboard. An alternating switch feeds each alternately and separately to an amplifier having automatic gain control. This alternating switching takes place about 20 times per second. The output from the amplifier is fed, by a second alternating switch synchronised with the first, alternately to each of two rectifiers one of which produces a positive

(a) Sensitivity is proportional to the height of the pick-up loops above the cable.

(b) When the aircraft banks (i.e. rotated about its angle of roll) an inaccuracy comes into existence due to the change of angle of the loops relative to the vertical.

(c) Due to "earth effect" the meter indication increases as the aircraft is moved laterally to a distance of about 40 feet from the centre line wire then decreases until at a distance of 70 feet the signal actually reverses. ("Earth effect" denotes the phenomenon of the lines of magnetic force, about a cable on the surface of the earth, being distorted towards the cable at the earth's surface. It is discussed *in extenso* by Bourgonnier in Bulletin de la Societe Francaise d'Electriciens, March 1934).

It is an object of the present invention to provide a system of the kind referred to in which

(1) the variation of sensitivity with height is reduced.

(2) The inaccuracy caused by aircraft bank angle is eliminated to a large extent.

(3) "Earth effects" are largely nullified.

According to the invention an azimuth guidance system of the kind referred to comprises field production means adapted to

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COMPLETE SPECIFICATION

Improvements in or relating to Azimuth Guidance Systems

I, THE MINISTER OF SUPPLY, Shell Mex House, Strand, London, W.C.2, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to azimuth guidance systems and has particular but not exclusive application to systems for providing accurate azimuth guidance for the final landing phase of an aircraft approaching and landing on to a runway.

Such systems usually provide information as to the azimuth position of an aircraft relative to a given line, most conveniently the centre line of a desired runway, for some distance (1 mile for example) prior to and after touchdown.

A known system of the kind referred to above makes use of a long wire or number of wires placed longitudinally on or near the desired runway. The wire or number of wires is fed with alternating current and an aircraft equipped with a pick-up loop or loops can detect the resulting electro-magnetic field and derive therefrom its position relative to the wire or number of wires and hence relative to the runway.

A typical application known as the single wire or switched loop system, uses a single wire, along the centre line of the runway, carrying a current of 2 amps at a periodicity of 1,800 c.p.s. An aircraft is equipped with two pick-up loops mounted in the aircraft nose at an angle of approximately 10° to the vertical, one inclined to port and the other to starboard. An alternating switch feeds each alternately and separately to an amplifier having automatic gain control. This alternating switching takes place about 20 times per second. The output from the amplifier is fed, by a second alternating switch synchronised with the first, alternately to each of two rectifiers one of which produces a positive signal the other producing a negative signal (relative to a convenient voltage level). Thus by connecting the two rectifier outputs in opposition in a left-right lateral displacement indicator circuit containing a centre-zero meter, for example, unbalance between the signals in the pick-up loops can be observed by a left-or-right movement, of the meter pointer. Since this unbalance is caused by the aircraft being to one side or the other of the runway centre line the meter will indicate simply that.

This system is, within certain limits, simple and accurate but suffers from three disadvantages:

(a) Sensitivity is proportional to the height of the pick-up loops above the cable.

(b) When the aircraft banks (i.e. rotated about its angle of roll) an inaccuracy comes into existence due to the change of angle of the loops relative to the vertical.

(c) Due to "earth effect" the meter indication increases as the aircraft is moved laterally to a distance of about 40 feet from the centre line wire then decreases until at a distance of 70 feet the signal actually reverses. ("Earth effect" denotes the phenomenon of the lines of magnetic force, about a cable on the surface of the earth, being distorted towards the cable at the earth's surface. It is discussed *in extenso* by Bourgonnier in Bulletin de la Societe Francaise d'Electriciens, March 1934).

It is an object of the present invention to provide a system of the kind referred to in which

(1) the variation of sensitivity with height is reduced.
(2) The inaccuracy caused by aircraft bank angle is eliminated to a large extent.
(3) "Earth effects" are largely nullified.

According to the invention an azimuth guidance system of the kind referred to comprises field production means adapted to produce a two-signal field in which each signal at any point of the field is characteristic of the lateral displacement of said point from a different one of two given lines spaced symmetrically each side of an azimuth line it is desired to use as a guide line, and an azimuth indicating equipment comprising a signal pickup loop device adapted to function as a single loop rotating about a mobile line it is desired to align in the same vertical plane as said azimuth line, filter receiving means adapted to derive from the output of said pickup loop device a pair of distinguishable signals each one corresponding to a different field signal, and indicating means, said pair of distinguishable signals being fed thereto and compared therein to show a left-right indication of the direction of movement necessary to align said mobile line with said azimuth line.

According to a feature of the invention said field production means comprises two wires spaced symmetrically each side of said azimuth line and each adapted to be connected to a different source of alternating current distinguishably characterised in the case of each wire but in a similar manner (e.g. by frequency or by modulation).

According to a further feature of the invention said two wires are spaced at constant distance from said azimuth line whereby said indicating means shows a left-hand indication of the lateral displacement of said mobile line from said azimuth line.

According to a still further feature of the invention said signal pickup loop device comprises a multiple loop system fixed relative to the mobile line but arranged by switching to function as a single loop rotating about said mobile line.

According to yet a further feature of the invention said alternating currents carried in each cable are distinguishably characterised by being each of different frequency.

According to yet a still further feature of the invention said alternating currents are of the same frequency and modulated each with a different distinguishing frequency.

According to a very interesting feature of the invention there is provided, said azimuth indicating equipment situated with its mobile line aligned with said azimuth line, field regulation means adapted to adjust said two-signal field, and servo means connected to the output of said filter receiving means and adapted in response to said pair of distinguishable signals to control said field regulation means.

In carrying the invention into effect the procedure is as follows and is described in a particular application to the final landing phase of approach, touchdown and taxiing of an aircraft on a runway.

Reference is made to the accompanying drawings which show schematically an arrangement by way of example of an azimuth guidance system according to the invention.

In the drawing two wires 1R and 1L are shown, equally spaced on either side of a desired azimuth line 2, (the centre-line of the runway (not shown) in this case). The wires 1L and 1R are fed with alternating currents of different frequencies LF and RF from sources 3L and 3R respectively. Thus an equisignal path is produced coincident with the desired azimuthal line 2 and a two-signal field exists overall.

In the aircraft (not shown) a pickup loop 4 is rotated by any suitable means about the axis of roll 5 of the aircraft, herein exemplifying the term mobile line, at about 10 revolutions per second. The output from the loop is taken off by slip-rings 6 and fed to an amplifier 7. The amplifier 7 which is automatically gain stabilised feeds into two filters 8L and 8R tuned respectively to frequencies LF and RF corresponding to those of the feed to runway wires 1L and 1R. The outputs of filters 8L and 8R are then fed to rectifier circuits 9L and 9R, rectifier circuit 9L thus dealing with left hand wire 1L signals, the other rectifier circuit 9R dealing with right hand wire 1R signals. The signals are fed to a left-right lateral displacement inidcator circuit 10 and polarised as described in the single wire case according to their left or right origin and then compared on a centre-zero meter indicated in the drawing on the circuit 10. This last stage is similar to that described above in connection with the final comparison of outputs in the single wire system, is therefore well known and will not be discussed further in this specification.

Since the pickup loop 4 is rotating continuously the direction of the field from each wire 1L or 1R is unimportant and hence rectified and polarised signals proportional to a first order to the distance of the loop 4 from each wire 1L and 1R are available for comparison to show a left or right lateral displacement on the indicator.

The use of the rotating loop 4 as well as nullifying the "earth effect ensures that any roll of the aircraft about its mobile line is of no practical consequence.

It should, of course, be understood that the use of a rotating loop 4 may be dispensed with by the use of a multiple loop system fixed relative to the aircraft but switched by any suitable means (e.g. electronically) to have the same properties as the pickup loop 4 rotating about and giving continuous uniform coverage about the mobile line 5.

In some situations variation of soil conductivity may upset the constancy of the two-signal field laid down by the two wires 1L and 1R. For instance, a shower of rain will cause the soil conductivity to change more for one frequency than another and the pattern will change so that the equisignal path will shift from the desired azimuth line 2 due to the difference in the changed field strengths thereon.

The solution to this problem is obtained by adjusting the alternating current flowing in one of the wires 1L or 1R until the equisignal path is realigned with the azimuth line 2. This is achieved automatically according to the invention by providing along the azimuth line 2 a complete rotating loop system 11 similar to that in the aircraft but feeding the two rectified and polarised signals to a servo unit 12 instead of a left-right displacement indicator. The servo unit 12 passes signals to the sources 3L and 3R to control the supply to each of the wires 1L and 1R respectively. By this simple means the equisignal line is maintained in coincidence with the required azimuth line 2.

Moreover since it is possible for standing waves of current to be set up in the wires 1L and 1R laid parallel to the axis of the runway 2 and their respective return paths (not shown), terminating resistances ZL and ZR each equal to the characteristic impedance of the particular circuit is placed in series with the wires 1L and 1R and their respective return paths (not shown) at the end of the approach path remote from the sources 3L and 3R of the field production means; this has the effect of reducing the standing waves to insignificant proportions.

Another arrangement according to the invention in which this difficulty is overcome is that of feeding each wire 1L and 1R with alternating current of the same frequency.

The field due to each wire 1L and 1R is then made distinguishable by using a modulation of different frequency in each wire. Any changes in soil conductivity will then effect the field of each wire similarly and prevent change of the field pattern. It is of course necessary in this case to make provision for demodulation of the signals from the rotating loop 4 in the aircraft. In this case the amplifier 7 would be tuned to the basic frequency of the wire currents and the stages indicated at 8L and 9L, 8R and 9R would comprise demodulating stages tuned to the respective modulating frequencies. The outputs from these stages 8L and 9L, 8R and 9R are then compared as before in the left-right lateral displacement indicator circuit 10. In this arrangement of course the rotating loop system 11 and the servo unit 12 are not required if changes of the two-signal pattern would be due only to changes of soil conductivity with frequency.

In the arrangements described the basic wire frequencies are preferably around 1000 c/s. To keep the impedance of the ground circuits low and to be able to obtain workable currents with reasonable safety an upper limit of about 2000 c/s is set, whereas to ensure that the aircraft loop is small a lower limit of about 500 c/s is desirable.

In consequence, it will be seen that around 1000 c/s represents a convenient value for practical work. When the modulation arrangement is adopted to distinguish the field of one wire from the other, suitable modulating frequencies are 90 c/s and 150 c/s to modulate a basic frequency in each wire of 1000 c/s.

WHAT I CLAIM IS:—

1. An azimuth guidance system of the kind referred to comprising field production means adapted to produce a two-signal field in which each signal at any point of the field is characteristic of the lateral displacement of said point from a different one of two given lines spaced symmetrically each side of an azimuth line it is desired to use as a guide line, and at least one azimuth indicating equipment comprising a signal pickup loop device adapted to function as a single loop rotating about a mobile line it is desired to align in the same vertical plane as said azimuth line, filter receiving means adapted to derive from the output of said pickup loop device a pair of distinguishable signals each one corresponding to a different field signal, and indicating means, said pair of distinguishable signals being fed thereto and compared therein to show a left-right indication of the direction of movement necessary to align said mobile line with said azimuth line.

2. An azimuth guidance system as claimed in claim 1, in which said field production means comprises two wires spaced symmetrically each side of said azimuth line and each adapted to be connected to a different source of alternating current distinguishably characterised in the case of each wire but in a similar manner, (e.g. by frequency, or by modulation).

3. An azimuth guidance system according to claim 2, in which said alternating current source feeds to the wire to which it is connected alternating current characterised by its frequency.

4. An azimuth guidance system according to claim 2, in which said alternating current source, in each case, feeds to its wire alternating current of one given frequency but characterised in each case by modulation with a different distinguishing frequency.

5. An azimuth guidance system according to claim 2, 3 or 4 in which said two wires are equally spaced at constant distance from said azimuth line.

6. An azimuth guidance system according to any one of the preceding claims, in which said signal pickup loop device comprises a multiple loop system fixed relative to the mobile line but arranged by switching to function as a single loop rotating about said mobile line.

7. In an azimuth guidance system accord-

ing to any one of the preceding claims, field regulation means adapted to adjust the two-signal field, one of said azimuth indicating equipments situated with its mobile line aligned in the same vertical plane as the azimuth line, and servo means connected to the output of the filter receiving means and adapted to control said field regulation means according to the output of said azimuth indicating equipment whereby said two-signal field is maintained constant.

8. An azimuth indicating means as used in an azimuth guidance system according to any one of the preceding claims.

9. An azimuth guidance system constructed and arranged substantially as described with reference to the accompanying drawings.

HERBERT W. GRACE,
Chartered Patent Agent,
Agent for the Applicant.

PROVISIONAL SPECIFICATION

Improvements in or relating to Azimuth Guidance Systems

I, THE MINISTER OF SUPPLY, of Shell Mex House, Strand, London, W.C.2, do hereby declare this invention to be described in the following statement:—

This invention relates to azimuth guidance systems and has particular but not exclusive application to systems for providing accurate azimuthal guidance for the final landing phase of an aircraft approaching and landing on to a runway.

Such systems usually provide information as to the azimuthal position of an aircraft relative to a given line, most conveniently the centre line of a desired runway, for some distance (1 mile for example) prior to and after touchdown.

A known system of the kind referred to above makes use of a long wire or number of wires placed longitudinally on or near the desired runway. The wire or number of wires is fed with alternating current and an aircraft equipped with a pick-up loop or loops can detect the resulting electromagnetic field and derive therefrom its position relative to the wire or number of wires and hence relative to the runway.

A typical application known as the single wire or switched loop system, uses a single wire, along the centre line of the runway, carrying a current of 2 amps at a periodicity of 1,800 c.p.s. An aircraft is equipped with two pick-up loops mounted in the aircraft nose at an angle of approximately 10° to the vertical, one inclined to port and the other to starboard. An alternating switch feeds each alternately and separately to an amplifier having automatic gain control. This alternating switching takes place about 20 times per second. The output from the amplifier is fed, by a second alternating switch synchronised with the first, alternately to each of two rectifiers one of which produces a positive signal the other producing a negative signal (relative to a convenient voltage level). Thus by connecting the two rectifier outputs in opposition in a circuit containing a centre-zero meter, for example, unbalance between the signals in the pick-up loops can be observed by a left-or-right movement of the meter pointer. Since this unbalance is caused by the aircraft being to one side or the other of the runway centre line and is proportional to the lateral distance from the centre line the meter will indicate simply that.

This system is, within certain limits, simple and accurate but suffers from three disadvantages:

(a) Sensitivity is proportional to the height of the pick-up loops above the cable.

(b) When the aircraft banks (i.e. rotated about its angle of roll) an inaccuracy comes into existence due to the change of angle of the loops relative to the vertical.

(c) Due to "earth effect" the meter indication increases as the aircraft is moved laterally to a distance of about 40 feet from the centre line wire then decreases until at a distance of 70 feet the signal actually reverses. ("Earth effect" denotes the phenomenon of the lines of magnetic force, about a cable on the surface of the earth, being distorted towards the cable at the earth's surface. It is discussed *in extenso* by Bourgonnier in Bulletin de la Société Française d'Électriciens, March 1934).

It is an object of the present invention to provide a system of the kind referred to in which

(1) the variation of sensitivity with height is reduced.

(2) the inaccuracy caused by aircraft bank angle is substantially eliminated.

(3) "Earth effects" are largely nullified.

According to the invention an azimuthal guidance system of the kind referred to comprises field production means adapted to produce a two-signal field in which each signal at any point of the field is characteristic of the lateral displacement of said point from a different one of two given lines each equally spaced on different sides of an azimuthal line it is desired to use a guide line, and an azimuthal indicating equipment comprising a signal pickup loop device adapted to function as a single loop rotating about a mobile line it is desired to align in the same plane as said azimuthal line, filter receiving means adapted to derive from the output of said pickup loop device a pair of distinguishable signals each one corresponding to a different field signal and indicating means, said pair of distinguishable signals being fed thereto and compared therein to show a left-right indication of the direction of movement necessary to align said mobile line with said azimuthal line.

According to a feature of the invention said field production means comprises two wires spaced symmetrically each side of said azimuthal line and each carrying an alternating current distinguishably characterised in the case of each wire but in the same manner (e.g. by frequency or by modulation).

According to a further feature of the invention said two wires are equally spaced at constant distance from said azimuthal line whereby said indicating means show a left-right indication of the lateral displacement of said mobile line from said azimuthal line.

According to a still further feature of the invention said signal pickup loop device comprises a multiple loop system fixed relative to the mobile line but arranged by switching to function as a single loop rotating about said mobile line.

According to yet a further feature of the invention said alternating currents carried in each cable are distinguishably characterised by being each of different frequency.

According to yet a still further feature of the invention said alternating currents are of the same frequency and modulated each with a different distinguishing frequency.

According to a very interesting feature of the invention there is provided, said azimuthal indicating equipment situated with its mobile line aligned with said azimuthal line, field regulation means adapted to maintain constant said two-signal field, and servo means connected to the output of said filter receiving means and adapted in response to said pair of distinguishable signals to control said field regulation means.

In carrying the invention into effect the procedure is as follows and is described in a particular application to the final landing phase of approach, touchdown and taxiing of an aircraft on a runway.

Two wires are equally spaced on either side of the desired azimuthal line, (the centre-line of the runway in this case) and are fed with alternating currents of different frequency. Thus an equisignal path is produced coincident with the desired azimuthal line and a two-signal field exists overall.

In the aircraft a pickup loop is rotated about the axis of roll of the aircraft, herein exemplifying the term mobile line, at about 10 revolutions per second. The output from the loop is taken off by slip-rings and fed to an amplifier. The amplifier which is automatically gain stabilised feeds into two filters each tuned to a frequency corresponding to that of the feed to different runway wires. The filter outputs are then fed to rectifier circuits, one rectifier circuit thus dealing with left hand wire signals, the other rectifier circuit dealing with right hand wire signals. The signals are polarised as described in the single wire case according to their left or right origin and then compared and fed to a left-right lateral displacement indicator. This last stage is similar to that described above in connection with the final comparison of outputs in the single wire system, is therefore well known and will not be discussed further in this specification.

Since the pickup is rotating continuously the direction of the field from each wire is unimportant and hence rectified and polarised signals proportional to a first order to the distance of the loop from each wire are available for comparison to show the left-right lateral displacement on the indicator.

The use of the rotating loop as well as nullifying the "earth effect" ensures that any roll of the aircraft about its mobile line is of no practical consequence.

It should, of course, be understood that the use of a rotating loop may be dispensed with by the use of a multiple loop system fixed relative to the aircraft but switched by any suitable means (e.g. electronically) to have the same properties as a pickup loop rotating about and giving continuous uniform coverage about the mobile line.

In some situations variation of soil conductivity may upset the two-signal field laid down by the two wires. For instance, a shower of rain will cause the soil conductivity to change more for one frequency than another and the pattern will change so that the equisignal path will shift from the desired azimuthal line due to the difference in the changed field strengths thereon.

The solution to this problem is obtained by adjusting the alternating current flowing in one of the wires until the equisignal path is realigned with the azimuthal line. This is achieved automatically according to the invention by providing along the azimuthal line a complete rotating loop system and feeding the two rectified and polarised signals to a servo system controlling a current regulator in the supply to each of the wires. By this simple means the equisignal line is maintained in coincidence with the required azimuthal line.

Moreover since it is possible for standing waves of current to be set up in the wires laid parallel to the axis of the runway and their respective return paths, a terminating resistance equal to the characteristic impedance of the circuit in question is placed in series with the wires at the end of the approach path remote from the field production means, this has the effect of reducing the standing waves to insignificant proportions.

Another arrangement according to the invention in which this difficulty is overcome is that of feeding each wire with alternating current of the same frequency.

The field due to each wire is then made distinguishable by using a modulation of different frequency in each wire. Any changes in soil conductivity will then effect the field of each wire similarly and prevent change of the field pattern. It is of course necessary in this case to make provision in the rotating loop system for demodulation of the signals. In this case the amplifier would be tuned to the basic frequency of the wire currents and followed by demodulating stages tuned to the modulating frequencies. The outputs from these stages are then compared as before.

In the arrangements described the basic wire frequencies are preferably around 1000 c/s. To keep the impedance of the ground circuits low and to be able to obtain workable currents with reasonable safety an upper limit of about 2000 c/s is set, whereas to ensure that the aircraft loop is small a lower limit of about 500 c/s is desirable.

In consequence it will be seen that around 1000 c/s represents a convenient value for practical work. When the modulation arrangement is adopted to distinguish the field of one wire from the other suitable modulating frequencies are 90 c/s and 150 c/s to modulate a basic frequency in each wire of 1000 c/s.

HERBERT W. GRACE,
Chartered Patent Agent,
Agent for the Applicant.

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