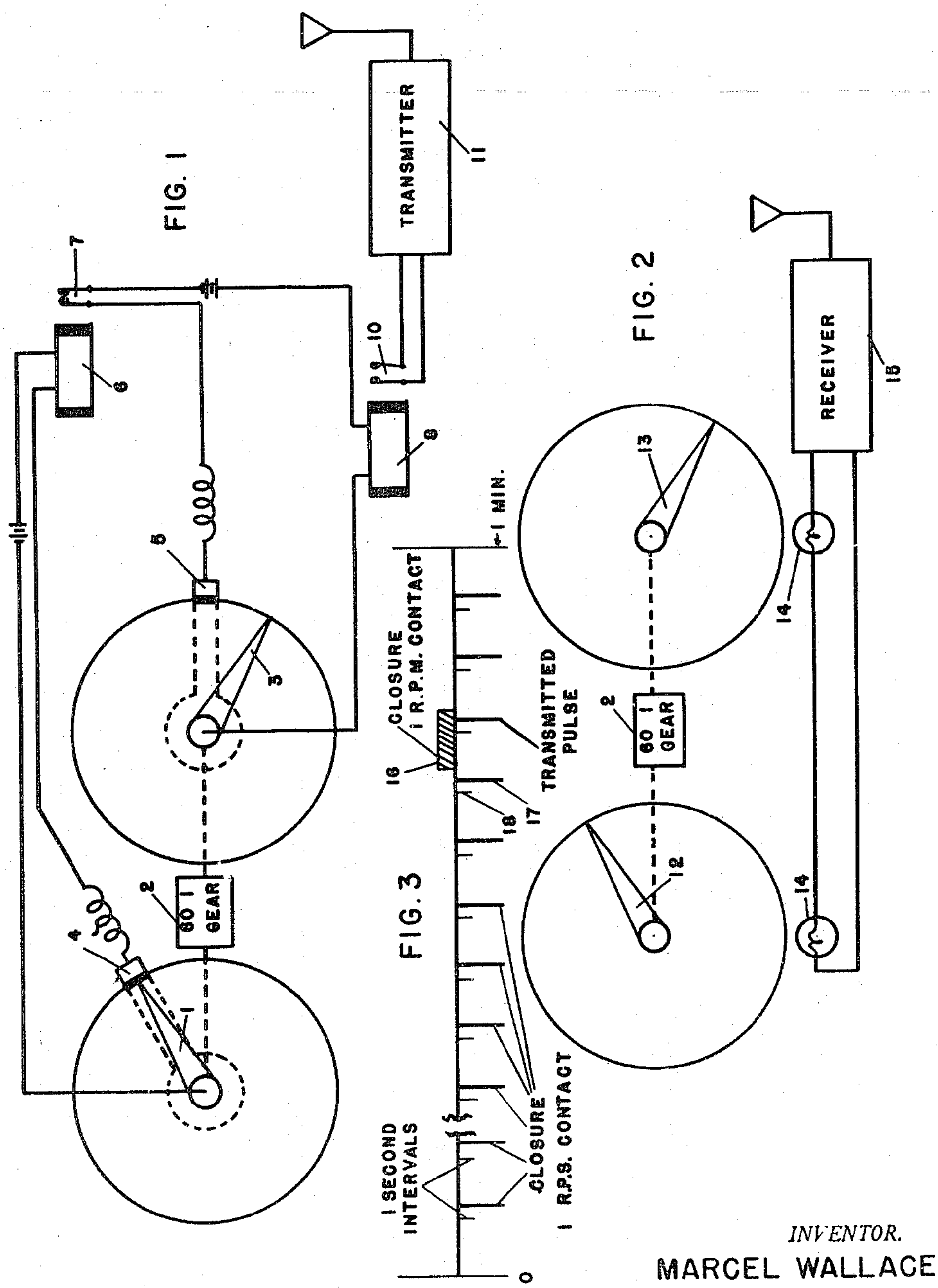
Dec. 19, 1950 M. WALLACE 2,534,842

DUAL SYNCHROMETRIC SYSTEM

Filed Oct. 10, 1947 4 Sheets-Sheet 1



INVENTOR.
MARCEL WALLACE

BY Hyman Hurwitz

ATTORNEY

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DUAL SYNCHROMETRIC SYSTEM

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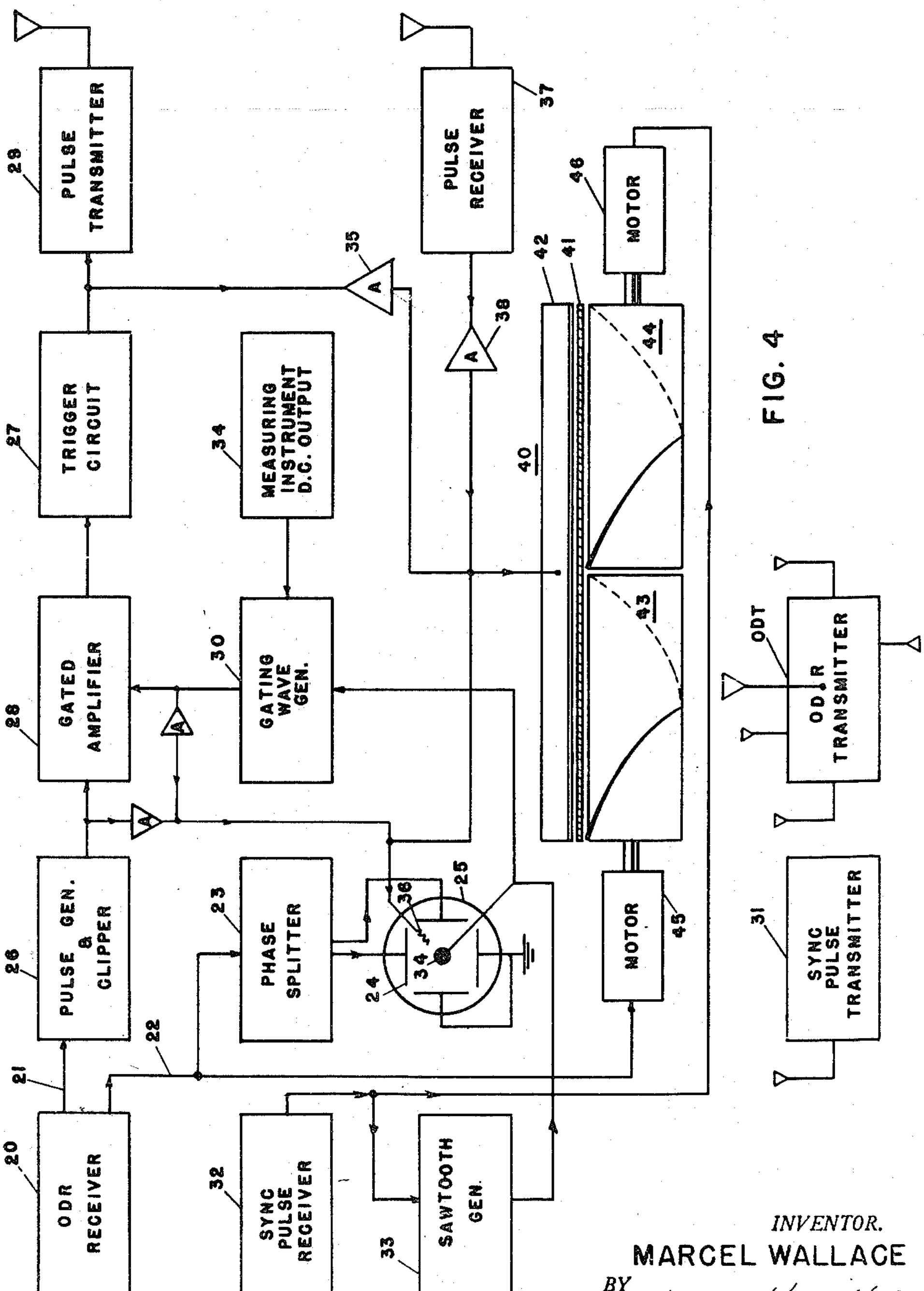

FIG. 4

INVENTOR.
MARCEL WALLACE
BY Hyman Hurvitz
ATTORNEY

Dec. 19, 1950 M. WALLACE 2,534,842

DUAL SYNCHROMETRIC SYSTEM

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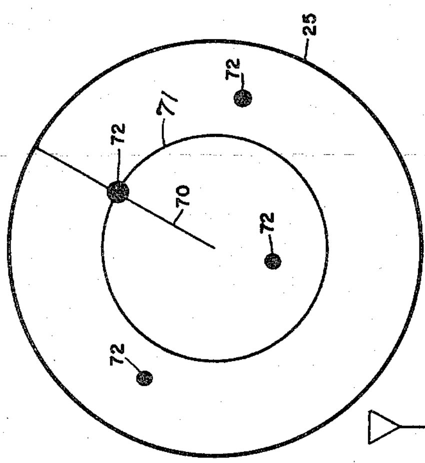

FIG. 8

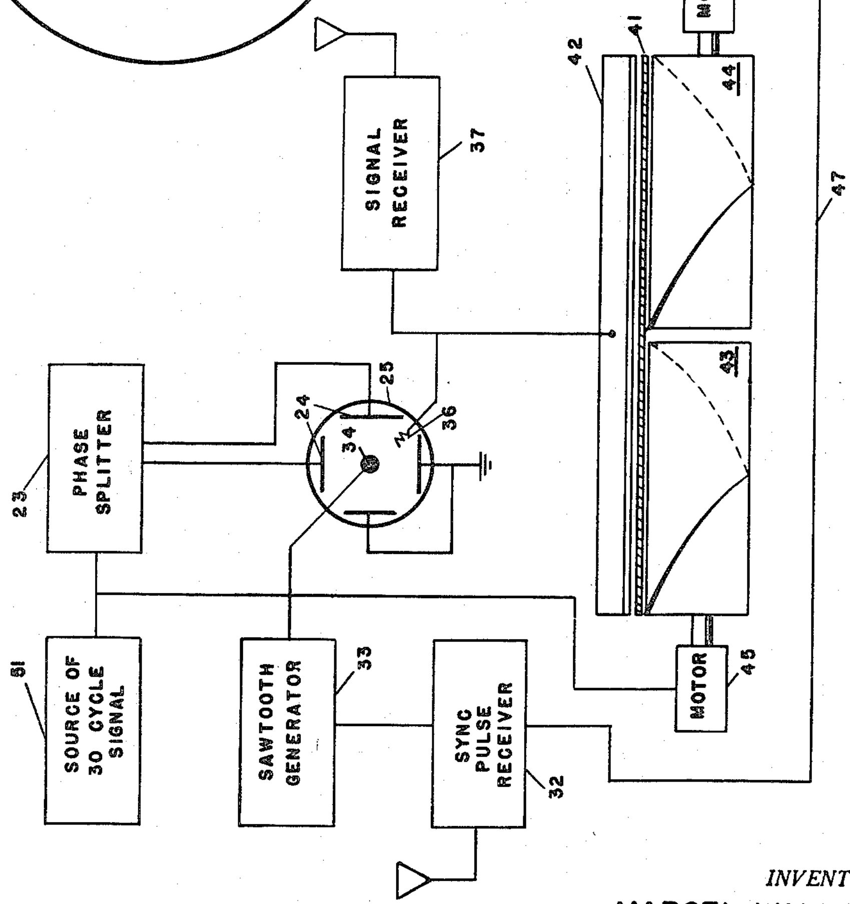

FIG. 5

INVENTOR.
MARCEL WALLACE
BY Hyman Hurvitz
ATTORNEY

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DUAL SYNCHROMETRIC SYSTEM

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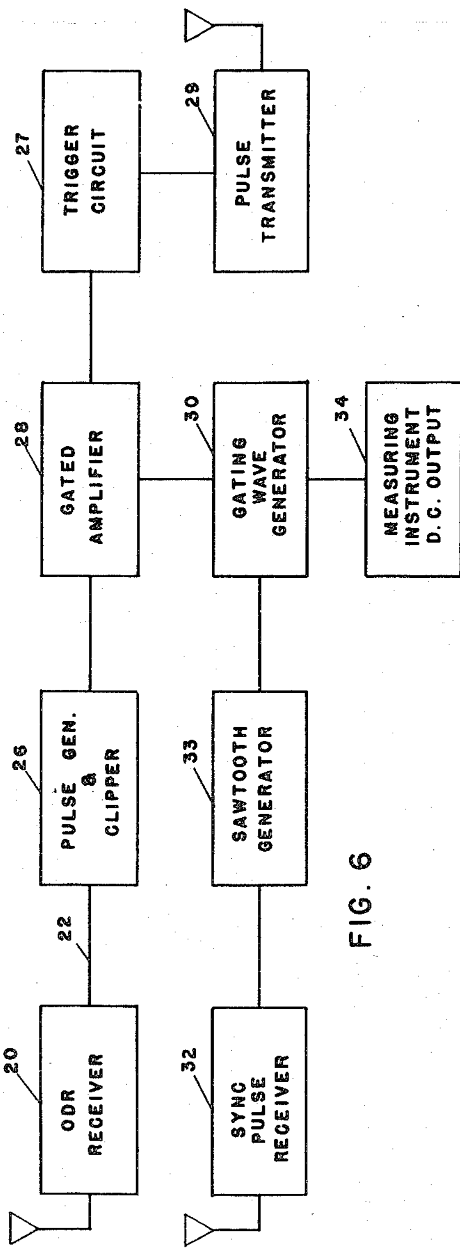

FIG. 6

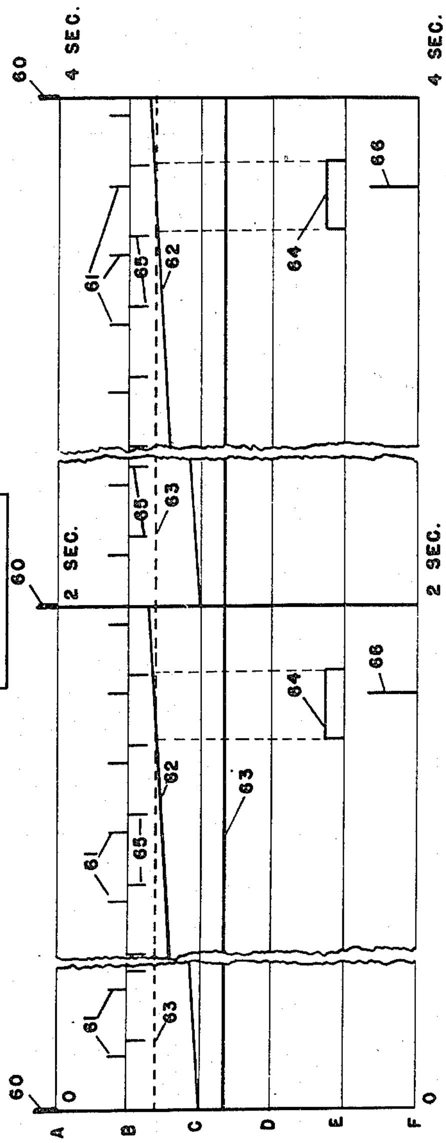

FIG. 7

INVENTOR.
MARCEL WALLACE
BY Hyman Hurvitz
ATTORNEY

Patented Dec. 19, 1950

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UNITED STATES PATENT OFFICE

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DUAL SYNCHROMETRIC SYSTEM

Marcel Wallace, East Port Chester, Conn., assignor of one-half to Panoramic Radio Corporation, Mount Vernon, N. Y., a corporation of New York

Application October 10, 1947, Serial No. 779,174

22 Claims. (Cl. 343—112)

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This invention relates generally to telemetric systems and more particularly to dual synchrometric telemetric systems, wherein values of two measurable quantities are transmitted in terms of the time position of a single transmitted pulse, which may be translated, at a remote point, into an indication or a record of the values of the quantities.

Broadly described, my invention involves the production of two sets of pulses, each set pertaining to one of the measured quantities, and the time positions of pulses within each set being determined in accordance with the value of one of the quantities. The time positions of pulses within the separate sets is determined, however, with respect to entirely different time bases, or basic time intervals, which may be, but need not be, of integral multiple length relation, the one of the other, and of locked relative phase. If we assume the time intervals of the different sets to have a ratio of durations of 60:1, for the sake of example only, and to commence from a common zero of time, every sixtieth short interval may be set to terminate at precisely the instant of commencement of a long interval. If now, periodic pulses are generated at time positions within the short intervals determined by the value of a measurable quantity; and if further periodic pulses are generated at time positions within the long time intervals determined by the value of a further measurable quantity, and if only that short interval pulse is transmitted which is generated in substantial coincidence with a pulse belonging to the long interval set, no pulses of the latter set being transmitted, the transmitted pulse will have a time position within one of the short time intervals which is precisely in accordance with the measured quantity pertaining to the short interval pulses, and will have a time position within the long interval at least substantially corresponding with the value of the measured quantity pertaining to the long interval pulses.

At the receiving station the time positions of received pulses may be measured, with respect to the short and the long intervals separately, to determine the values of the two measured quantities, the time position of a pulse with respect to a long interval representing the value of one of the quantities, and the time position of that same pulse with respect to the commencement of one of the short time intervals representing the other of the quantities.

It is, accordingly, a primary object of the invention to provide a telemetric system wherein

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the time positions of a single pulse with respect to two discrete time intervals represent the values of a pair of discrete quantities.

It is a further object of the invention to provide a synchrometric system of telemetering, utilizing a single recurring pulse time position as a measure of the values of a plurality of quantities.

It is still a further object of the invention to provide a time position modulating system wherein the time positions of pulses is determined simultaneously with respect to a plurality of discrete time intervals.

It is still another object of the invention to provide a synchrometric system of communication having a receiving and translating system for translating the time position of a single pulse into a plurality of values, by comparison of the time position of that pulse with respect to a plurality of different time intervals.

It is a more specific object of the invention to apply the principles and concepts above conveyed, to improved systems of radio aid to navigation, and particularly to such improved systems for transmitting from each of a plurality of aircraft telemetric signals representing navigational parameters of the craft, and for receiving and translating the telemetric signals aboard other craft and at ground stations in terms of visual indications of the values of the navigational parameters.

The term "synchrometric" as applied to telemetric systems and utilized herein is intended to refer to systems wherein a common, recurring, synchronous and identically framed time interval is established for a plurality of stations, measurements being accomplished by determining the time positions or phases of signals within those time intervals, and translations of time positions or phases being likewise accomplished by reference to the common time interval. Where two fundamental time intervals are utilized simultaneously, the system is described as "dual synchrometric."

Reference is now made to the accompanying drawings, wherein:

Figure 1 illustrates in schematic form a simplified embodiment of a transmitter in accordance with the present invention;

Figure 2 illustrates in schematic form an embodiment of a receiver and translator, in accordance with the invention, which is adapted for utilization with the transmitter of Figure 1;

Figure 3 is a timing diagram useful in explaining the system of Figures 1 and 2.

Figure 4 represents in schematic block diagram an airborne station comprised in a system of radio aids to air navigation, in accordance with the invention;

Figure 5 represents in schematic form and in functional block diagram a ground station, adapted to cooperate with the system of Figure 4;

Figure 6 represents in functional block diagram, an airborne station for reporting navigational parameters, and lacking facilities for receiving and translating transmissions from other aircraft;

Figure 7 represents a timing diagram useful in explaining the operation of the systems of Figures 4 to 6 inclusive, and

Figure 8 represents the appearance of the face of the cathode ray tube indicator, in the embodiment of the invention illustrated in Figure 4 of the drawings.

Referring now to Figure 1 of the drawings the element **1** represents a contact arm, which may be driven at a constant rate in any suitable manner, a rate of 1 R. P. M. being assumed for the sake of example. Thus the element **1** may represent the minute hand of a clock.

Driven from the hand **1**, as by means of a speed change gear **2**, is a further element **3**, which, for the sake of example, may represent the second hand of a clock, the speed change gear having a speed step up ratio of 60:1.

The specific ratio of 60:1 is understood to be for the sake of example only, and to carry out the description by analogy to a clock, but the invention may be practiced utilizing other speed ratios, as will be apparent as the description proceeds.

In the path of movement of the hands **1** is disposed a movable contact element **4**, and in the path of movement of the hand **3** a further movable contact element **5**. The elements **4** and **5** may be positionable, as by means of separate and completely independent motive devices, the positions assumed by the contacts **4** and **5** being representative of a positional parameter of the motive devices. So, if the motive devices be meter elements, the angular positions assumed by the contacts **4** and **5** represent the values of measurable quantities.

The angular width of the contact **4** is made equal to $1/60$ of the total circumference of the circle corresponding with the locus of possible positions of the hand **1** and of the contact **4**. Thus the hand **1**, once it has attained contact with contact element **4**, remains in contact for a length of time sufficient to enable one complete rotation of the hand **3**.

While the hand **1** contacts the contact element **4** an energizing circuit is completed for relay coil **6**, which when energized, closes contacts **7**, preparing an obvious circuit for relay coil **8**. When the hand **3** contacts the contact element **5** an energizing circuit is completed for the relay coil **8**, provided that contacts **7** are simultaneously closed. Energization of relay coil **8** effects closure of contacts **10**, which serves to energize radio transmitter **11** to transmit a short pulse of energy.

Referring to Figure 2 of the drawings, there is provided a receiving system having a clock system, similar to that of Figure 1, and comprising two hands **12** and **13**, which are synchronized with the hands **1** and **3**, in any convenient manner. The hands **12** and **13** may be assumed to be normally unilluminated, but to be subject to illumination by the lamps **14**. A radio receiver **15** is provided for receiving pulses transmitted by the transmitter, and for translating the pulses into energy suitable for energizing the lamps **14**.

If the positions of the hands **12** and **13** be noted at the instant of illumination thereof, the positions of contacts **4** and **5** will be discovered, since there is a complete correspondence between the positions of hands **1** and **12**, and between the hands **3** and **13** at all times. At the instant of generation of the transmitted pulse, the hands **1** and **3** represent the positions of contacts **4** and **5**, respectively, and hence the values of two independent measurable quantities.

It will be noted that the reading of the position of contact **4** may be in error by an amount equivalent to $\pm 1/120$ of the total range of positions of the contact **4**, by reason of the angular width assigned to the contact **4**. Such an error, of less than $\pm 1\%$, may be of no significance for many purposes, and the percentage error may be reduced, as desired, by driving the hand **3** at a greater speed relative to hand **1**, enabling a corresponding reduction in width of the contact **4**.

Referring now to Figure 3 of the drawings, I have illustrated one complete cycle of rotation of the hand **1** and 60 cycles of rotation of the hand **3**, occupying a total time of 1 minute, circuit closure effected by coincidence of hand **1** with contact **4** being represented by the long pulse **16**, extending for a total duration of $1/60$ second. Generation of pulses in response to coincidence of hand **3** and contact **5** are represented by recurrent lines **17**, occurring 60 times in each minute. The lines **18** represent equal time periods of 1 second, occurring within the time period of 1 minute.

The circuit of Figure 1 is so arranged that only upon coincidence of a pulse **16** with a pulse **17** will transmission take place from transmitter **11**, and the time of transmission is determined precisely by the time of occurrence of that pulse **17** which coincides with, or falls within, the time of occurrence of pulse **16**.

Hence, the time of occurrence of transmitted pulse **17** determines not only the time within the 1 second intervals, measured between any pair of succeeding lines **18**, corresponding with the position of contact **5**, but also identifies, subject to a small error, the position of the pulse **16** within the 1 minute time interval.

While I have disclosed the hands **1** and **3** as driven in locked phase, but slight consideration is required to discover that this is not essential, provided only that the motions of hands **1** and **12** be mutually locked or synchronized, and that the motions of hands **3** and **13** be mutually locked or synchronized.

The principles disclosed hereinbefore may be utilized in a system of radio aids to navigation, making use of that modulation of equal frequency and phase which is provided in all directions from an ODR or omni-directional range station. It is well known to those skilled in the pertinent art that modern omni-directional range beacons hereinafter denominated ODR beacon, and particularly that type of ODR system which has been approved by the Civil Aeronautics Authority for universal use in this country, provides a 30 cycle signal of equal phase omni-directionally and a further 30 cycle signal the phase of which at a receiver depends upon the bearing of that receiver from the ODR transmitter. By comparison of the phase of the 30 cycle signals as received, a determination of bearing is made available at the receiver.

The omni-directional 30 cycle signal may be utilized, in a dual synchrometric system, for providing one of the fundamental time intervals of the system, the remaining required interval being otherwise obtained. If, for example, I utilize a multiplicative factor of 60, with respect to the 30 cycle signal, I have two time intervals, one of 1/30 second, and one of 2 seconds, for use in the system.

The ODR system not only provides a time interval for use in the system of the invention, but also provides one of the measured quantities, directly in terms of a phase, and hence of a time position within a time interval, since the 30 cycle signal of phase variable in accordance with bearing from the ODR transmitter may readily be transformed into a series of 30 cycle pulses having time positions variable in accordance with bearing from the ODR transmitter. These thirty cycle pulses are not, however, all transmitted, but only that one pulse of each 60 pulses generated is transmitted, which corresponds in my example, with that pulse having a time position within the two second time interval above referred to, corresponding substantially with the value of a range from an ODR transmitter or of an altitude, or any other desired quantity of navigational significance.

The translation of the transmitted pulses may be accomplished in various manners. By utilizing a cathode ray tube indicator having a circular scan synchronized with the short time intervals, and a radial scan synchronized with the long time intervals, for example, a plan position type of display may be provided having visual indications at angular positions corresponding with bearings of dual synchrometric transmitters, and having simultaneous radial positions corresponding with range, or altitude, or the like. Simultaneous indication of plan positions of a large number of aircraft may be accomplished in this manner, either aboard each of the aircraft, or at a ground station.

Should it be desired to utilize recorders for translating the received pulses two line scanning recorders of the facsimile type may be utilized, one synchronized with the long time interval, and the other with the short time interval, and each providing a record, therefore, in response to received pulses, of the time positions of a single pulse within each of the time intervals utilized in the system.

Reference is now made particularly to Figure 4 of the drawings, wherein is illustrated a dual synchrometric transmitter and receiver-indicator in accordance with the invention, which may be assumed to be carried aboard an aircraft (not shown), and a plurality of such transmitters and aircraft operating adjacent to an ODR transmitter, ODT.

The reference numeral 20 denotes an ODR receiver, of conventional character, which provides two output signals on the leads 21 and 22 respectively, the lead 22 providing a 30 cycle signal of fixed phase omni-directionally and the lead 21 a thirty cycle signal of phase variable with azimuthal bearing of the ODR receiver 1 from the ODR transmitter, ODT.

The signal of equal phase omni-directionally is applied to a phase splitter 23, the output of which is applied to a pair of mutually perpendicular plates 24 of a cathode ray tube indicator 25, causing a circular trace of the beam of the tube at a 30 cycle rate, and which will be, moreover, of identical phase at all the stations of the system. The 30 cycle omni-directional signal, then, provides a reference synchrometic time interval of 1/30 second, for the system.

The signal of variable phase provided via lead 21 is applied to a pulse generator and clipper 26 which provides a sharp pulse, of but a few microseconds duration, or less, as the 30 cycle input signal passes through zero, alternate pulses being positive and negative, and a pair of pulses occurring for each cycle of input signal. The negative pulses are eliminated by clipping and the positive pulses transferred to a trigger circuit 27, via a gated amplifier 28, the output of the trigger circuit 27 firing a pulse radio transmitter 29.

The gating amplifier 28, as will be demonstrated, is controlled to pass, during each 2 second interval, one only of the 60 pulses applied thereto during the 2 second interval, by the pulse generator 26, that pulse being selected in accordance with a further measured quantity, such as range or altitude, by applying to the gated amplifier 28 a gating wave or pulse derived from a pulse time modulated gating wave generator 30, in a manner hereinafter described.

In order to provide identically framed and synchronous long time intervals at the various stations a ground transmitter 31 is provided, which transmits synchronizing and framing pulses, at two second intervals, in my specific example, and which may be received and detected by the receiver 32, the output of which may be applied to a sawtooth generator 33, for synchronizing and framing the sawtooth voltages generated thereby. The sawtooth generator 33 provides sawtooth deflection voltages of two second period, to the radial deflecting anode 34 of the cathode ray tube 25.

Since the sawtooth generators of all the stations of the system are synchronized ultimately from the same source, the sawtooth radial deflecting voltages at the various stations are of equal frequency and of identical phase or framing, to provide identical reference or synchrometric long time intervals at the various stations.

The output of the synchrometric sawtooth generator 33 may be further applied to the gating wave generator 30, for comparison with a voltage provided by a measuring equipment 34 which may be, for example only, a distance measuring equipment or radar, or a terrain clearance or altitude determining instrument. Upon substantial coincidence of values of the sawtooth voltage provided by generator 33, with the output voltage provided by the measuring equipment 34, an output pulse is generated, which is applied to the gated amplifier 28, as a gating wave. By proper design of the gating wave generator 30, the output pulse may be of proper duration, i. e. 1/30 second in our example, for performing properly its function in the present system.

The input of the pulse transmitter 29 may be applied, over an isolating or buffer amplifier 35, to a beam intensifying grid 36 of cathode ray tube 25. A pulse receiver 37 may be provided for receiving pulses transmitted from remote transmitters 29 (not shown) and for applying these pulses, via an isolating or buffer amplifier 38 to the intensifier grid 36 of the cathode ray tube 25.

There may be further provided a facsimile recorder 40, (or a pair of such recorders, if desired). The recorder 40 may have a time fed record receiving surface 41, a signal impressing platen 42 and a pair of independently driven, line scanning, helical markers 43 and 44. The signal impressing platen 42 may be supplied with pulse signals, in parallel with the grid 36 of tube 25. The helical line scanning markers 43 may be driven by a motor 45 which rotates in synchronism and frame with the 30 cycle signal provided by the lead 22, whereas the helical line scanning marker 44 is driven by a motor 46 which rotates in synchronism and frame with signals provided by the pulse receiver 32.

The line scanners 43 and 44 at all the stations operate at respectively identical speed, and in identical frame, at rates of 30 rotations per second, and at rates of one rotation in each two seconds, respectively, and provide therefore dual synchrometric time bases for recording of the simultaneous time values of a single pulse with respect to a pair of discrete but related time bases or intervals.

The ground station of the present system obviously may be simpler than the airborne stations since the ground stations are not required to report their positions, but in respect to synchronizing, indicating and recording may be identical with the airborne stations.

Reference is made to Figure 5 of the drawings wherein is illustrated in functional block diagram a ground station in accordance with the present invention, identical circuit elements in Figures 4 and 5 being identified by identical numerals of reference.

The ground station is synchronized from two sources of sync and frame signals, one a 30 cycle source 51, which may comprise the 30 cycle source of modulation applied to the transmitter ODT for omnidirectional transmission, or which may be derived from that source in any convenient manner, and the other a long time interval sync pulse receiver 32, identical with the receivers 32 of Figure 4. The system of Figure 5 otherwise comprises a phase splitter 23 which is driven from the 30 cycle source 51 and which serves to rotate the beam of the cathode ray tube indicator 25 in phase with the output of the source 51.

The output of the sync pulse receiver 32 may be applied to synchronize the output of sawtooth generator 33, the output of which may be applied to radial deflection electrode 34 of cathode ray tube 25, providing a long interval sweep. Dual synchrometric pulses from the airborne transmitters (Figures 4 and 6) are received by the pulse receiver 37 (Figure 5) and applied to intensifier grid 36 of cathode ray tube 25.

The output of sync pulse receiver 32 may be further applied to synchronize and frame the rotation of the helical line scanning marker 44, while the complementary line scanning marker 43 is synchronized and framed by the source 51. Signals deriving from the dual synchrometric pulse receiver 37 are applied to the recording electrode 42, the scanning markers 43 and 44 respectively analyzing the time position of any incoming pulse in respect to each of the basic time intervals of the system, and translating the time position into a pair of laterally positioned marks, the lateral positions being representative of two independent quantities.

Since in some applications, it is not necessary that navigational parameters be reported to aircraft but only from aircraft to ground, I have further illustrated in Figure 6 of the drawings, in functional block diagram, the dual synchrometric pulse generator and time position controlling equipment of Figure 4, omitting the indicating and recording equipment. Identical elements of Figures 4 and 6 are identified by the same reference numerals, and the operation and constitution of these elements being identical in Figures 4 and 6, no purpose will be served in providing a detailed description of Figure 6, which is, accordingly, dispensed with.

It will now be noted that in the system of Figures 1 to 3 inclusive, the long and short time intervals with respect to which synchrometric pulses are transmitted are locked to each other and that each short time interval commences at a definite time position within the long time interval. In the system of Figures 4 to 6 inclusive this is not true, at least as a matter of necessity. If desired, the long and short time intervals may be locked in respect to phase, but this is not essential to the system. Nor need there be a time ratio of fixed value between the time intervals, in the system of Figures 4 to 6 inclusive. So the sync pulse transmitter 31 may operate at only approximately one pulse per two seconds, without affecting the system.

Reviewing now the operation of the system of Figures 4 to 6 inclusive, by reference to the timing diagram of Figure 7, the line A of the latter figure indicates the long time intervals of two seconds, established by the pulses 60 transmitted by the sync pulse transmitter 31 and received at all the stations of the system by means of sync pulse receivers 32.

The line B of Figure 7 represents the commencement 61, of each short time interval established by the ODR transmitter ODT, in respect to its omni-directional transmission, and having, in our specific example, a fixed phase omnidirectionally and a period of $\frac{1}{30}$ second.

Line C of Figure 7 illustrates the character of the output of the sawtooth generator 33 at each information transmitting station of the system, the output waves 62 commencing at each of the long interval pulses 60, and terminating at a succeeding pulse 60, only to recommence immediately.

The line D of Figure 7 represents a steady D. C. value of voltage 63 established by a measuring equipment 34, at each reporting station, and which may have a magnitude at each station corresponding with the magnitude of the quantity measured.

The line E of Figure 7 represents the $\frac{1}{30}$ second pulses generated in the gating wave generator 30 upon substantial coincidence of magnitudes of the voltage 63 and of the sawtooth voltage 62.

The relatively long pulses 64 are applied from the gating wave generator 30 to the gate amplifier 28 antecedent to the telemetric pulse transmitter 29, and unblock that amplifier.

A second telemetric quantity, which is, in the present example, bearing from an ODR transmitter, is measured aboard each reporting station on the system, and is applied to determine the time positions of periodic pulses 65, within the short intervals established by the transmitter ODT, and existing between the time markers 61, at line B of Figure 7.

It will now be noted that one only of the periodic pulses 65, identified as 66, within each long interval between adjacent pulses 60, coincides with any portion of a long pulse 64, and that only that particular pulse 66 which does coincide with some portion of a pulse 64 can be transmitted by transmitter 29, since only while pulse 64 subsists is the transmitter 29 unblocked or gated open, with respect to transmission of pulses 65. The time positions of the transmitted pulses is illustrated at line F of Figure 7.

Consideration of the significance of the time position of the pulses 66, indicates that the pulses 66 have time positions with respect to the $\frac{1}{30}$ second time interval established for the system which is representative of bearing of a reporting aircraft, and has a time position within the 2 second time interval established for the system, which is representative to a close approximation of the time position of time gate 64, and hence of the value of the D. C. voltage 63, which as has been explained is representative of a measured quantity such as altitude, or range from a fixed geographic location, of a reporting aircraft.

In order to decode the dual telemetric significance of the transmitted pulses two time bases are established, repetitive scanning taking place with respect to these time bases, in synchronism and frame with the time intervals established respectively by the sync pulse transmitter 31, and the transmitter ODT. This may be accomplished in various ways, and with various instrumentalities, of which I have described and illustrated two, for the sake of example.

In the first of my examples, I utilize a cathode ray tube indicator, the beam of which is deflected radially in synchronism and frame with the long time intervals 60—60 (Figure 7, line A) by means of a sawtooth generator 33 synchronized from the sync pulse receiver 32, which is responsive to the sync pulse transmitter 31. The beam is simultaneously translated rotatively in synchronism with the time base 61—61 (Figure 7, line B), established by the transmitter ODT and detected by suitable means, as 20 or 51, at each indicating station.

Reception of a dual synchrometric pulse, 66, by a pulse receiver 37, is indicated by intensification of the beam of the cathode ray tube, in response to signal output from the receiver. The intensified beam provides a visual indication in the form of a dot on the face of the tube 25, having an angular position corresponding with the bearing of the transmitting craft, and a radial position corresponding with the value of the quantity measured by the instrument 34, on the transmitting craft. If the latter quantity is range a plan position indication is provided of the transmitting craft, with respect to the ODR transmitter. If the latter quantity is altitude, a modified type of plan position indication is provided, indicating altitude versus bearing in polar coordinates.

For recording purposes, two line scanning, facsimile type recorders may be utilized, or a single recorder having two line scanning elements. Each of the line scanning elements, 43, 44, are driven in synchronism with one of the fundamental time intervals of the system, and reception time of a dual synchrometric pulse is translated by comparing the time of reception of the pulse with the simultaneous positions of the line scanning elements, a pair of permanent marks being created on a record receiving surface 41 in response to each received pulse, in a manner well known per se.

Referring further to Figure 4 of the drawings, if desired the output of the gating wave generator 30 and the output of the pulse generator and clipper may be applied in parallel to the control or intensifier grid 36 of cathode ray tube indicator 25, over respectively associated isolating amplifiers A.

The output of generator 26 consists of spaces pulses, at the rate of 30 per second, which are phased to correspond with the bearing of the transmitting craft.

These pulses are in no way gated, and hence generate a series of dots radially on the face of cathode ray indicator 25 in a sense corresponding with the bearing of the transmitting craft, the bearing of other, or remote craft, being represented by a single spot. Since the CRT25 in the present system must have a long perisistence, of about 2 seconds, or longer, the series of dots above referred to may be visible substantially as a straight radial line.

The output of the gating wave generator 30 consists of a $\frac{1}{30}$ second pulse occurring at a time position with respect to the 2 seconds or long time interval of reference, corresponding with range, or altitude, as desired, and in accordance with the character of measuring instrument 34. This wave subsists, therefore, for the time of one complete revolution of the beam of cathode ray tube indicator 25, resulting in a substantially circular trace at a radial position corresponding with the range or altitude of the transmitting craft.

Reference is now made to Figure 8 of the drawings, wherein is provided an illustration of the appearance of the face of the CRT25, with radial line 70, at an angular position corresponding with the bearing of the transmitting craft, and with a circular line 71 at a radius corresponding with range or altitude of the transmitting craft. The ranges or altitudes, and the bearings, of remote craft, are indicated by dots 72.

While I have described and illustrated certain specific embodiments of my invention, it will be evident to those skilled in the pertinent arts, that various modifications and re-arrangements of the system as disclosed may be resorted to without departing from the true scope of the invention, as defined in the appended claims.

What I claim and desire to secure by Letters Patent of the United States is:

1. In combination, means for delimiting first periodic time intervals, means for delimiting a second time interval equal in duration to at least two of said first periodic time intervals, means for providing repetitive first periodic signals each at a time position within one of said first time intervals which correspond with the value of a first measurable quantity, means for providing a further signal at a time position within said second time interval which corresponds with the value of a second measurable quantity, means for selectively transmitting certain ones only of said first periodic signals selected in accordance with the time position of said further signal, and receiver-indicator means for receiving said signals transmitted by said means for selectively transmitting and for providing a composite single remote indication indicative of the values of both said first and said second measurable quantities in response to each of said certain ones only of said first periodic signals.

2. The combination in accordance with claim 1, wherein said receiver indicator means for receiving signals transmitted by said means for selectively transmitting comprises means for scanning a locus of points during said first time interval, means for scanning a different locus of points during said second time interval, and means for establishing an indicated common point in each of said loci corresponding with the

time position of said last mentioned signals with respect to said respective time intervals.

3. The combination in accordance with claim 1 wherein said receiver indicator means for receiving said signals transmitted by said means for selectively transmitting comprises a facsimile type recording means, said recording means comprising a first line scanning element, a second line scanning element, record receiving means, recording platen means, means for synchronizing scanning of said first line scanning element with said first time interval, means for synchronizing scanning of said second line scanning element with said second time interval, and means for applying said last mentioned signals to said recording platen means to impress marks on said record receiving means at positions corresponding with the instantaneous position of said line scanning elements at the time of reception of said last mentioned signals.

4. The combination in accordance with claim 1 wherein said receiver indicator means for said signals transmitted by said means for transmitting, comprises a cathode ray tube indicator having a face, means for establishing a pair of coordinates on said face, and means for providing indications of said face with respect to said pair of coordinates in accordance with the time positions of said last mentioned signals with respect to said time intervals.

5. The combination in accordance with claim 1 wherein said receiver-indicator means for said signals transmitted by said means for transmitting, comprises a cathode ray tube indicator having a scanning cathode ray beam, and a face scanned by said beam, means for scanning said beam in one coordinate of a coordinate system in synchronism with one of said time intervals, means for scanning said beam in another coordinate of said coordinate system in synchronism with the other of said time intervals, and means responsive to reception of said last mentioned signals for modifying said cathode ray beam.

6. In combination, means for transmitting in common to each of a pluralty of craft an alternating current signal having a phase aboard each of said craft which is determined by the bearing of said craft with respect to a predetermined geographic location, means aboard each of said plurality of craft for measuring a quantity having navigational significance, means aboard each of said plurality of craft responsive to said means for measuring for generating a signal having a time position with respect to a time interval common to said plurality of craft which is representative of said quantity, and means for transmitting from each of said craft a further signal having a composite time position determined by the time position of said a signal having a time position with respect to a time interval common to said plurality of craft which is representative of said quantity and the phase of said alternating current signal.

7. In combination, an omni-directional radio beacon transmitter for providing two periodic signals having measurable phases, one of said signals of equal phase omni-directionally and the other of said signals of phase dependent upon bearing from said transmitter, means aboard each of a plurality of aircraft for receiving said signals from said transmitter, means aboard each of said aircraft for generating periodic signals having each a time position dependent upon the phase of said signal dependent on bearing, means for establishing a further time interval common to said plurality of craft said further time interval enduring for at least a plurality of cycles of said signals provided by said beacon transmitter, and means for selecting and transmitting one only of said periodic signals from each of said craft in accordance with a time position established within said further time interval by the value of a quantity having navigational significance.

8. In combination, means for delimiting aboard each of a plurality of craft a first time interval and a second time interval, common to all said craft said time intervals having a ratio of relative duration of at least two to one, means for generating aboard each of said craft a signal having a time characteristic with respect to the longer of said time intervals corresponding with a value of a quantity having navigational significance associated therewith, means for modulating the time characteristic of signals generated aboard each of said craft in accordance with the value of a further quantity having navigational significance associated therewith, and means for transmitting said modulated signals from said craft, and means for receiving the transmitted signals from all said craft and for deriving therefrom the values of both said navigational parameters pertaining to each of said craft.

9. In a navigational system for aircraft, means for delimiting a first periodic time interval aboard an aircraft, means for delimiting a second time interval aboard said aircraft, means for providing repetitive periodic signals at time positions within said first intervals which correspond with bearing of said aircraft with respect to a predetermined geographic location, means for providing a signal at a time position within said second time interval which corresponds with the range of said aircraft with respect to said predetermined geographic position, means for transmitting at least one of said periodic signals selected in accordance with the time position of the other of said signals, a station having means for receiving said one of said periodic signals, means at said station for delimiting said first periodic time interval, means at said station for delimiting said second of said periodic time intervals, a cathode ray tube indicator at said station, said cathode ray tube indicator having an electronic beam, means for rotating said electronic beam in synchronism with said first periodic time interval, in a substantially circular path, means for deflecting said electronic beam radially of said circular path in synchronism with said second time intervals, and means responsive to one of said periodic signals, when received by said means for receiving, for modulating the intensity of said electronic beam to provide a visible indication on the face of said cathode ray tube indicator.

10. In combination, a first station having means for transmitting pulses having time positions simultaneously with respect to each of a pair of repetitive time intervals, the time positions of said pulses with respect to each said pair of intervals being representative of the value of a different quantity, a remote receiver for said pulses, a recorder responsive to pulses received by said remote receiver, said recorder comprising a record receiving surface, a first successive line scanning marker, a second successive line scanning marker, means for synchronizing scanning of said first successive line scanning marker with the first said repetitive time intervals, means

for synchronizing scanning of said second line scanning marker with the second of said pair of repetitive time intervals, and means responsive to the output of said pulses for actuating said markers simultaneously to generate marks on said record receiving surface in response to each of said pulses received by said remote receiver.

11. In a navigational system for aircraft, means aboard a plurality of relatively remote aircraft for generating and transmitting pulses, each pulse transmitted from each of said aircraft having a time position simultaneously with respect to each of a pair of repetitive time intervals which is determined with respect to each of said time intervals by the value of one of a pair of quantities having significance in relation to the geographic position of the transmitting aircraft, receiving means for said pulses, and means responsive to said receiving means for translating the time position of pulses received by said receiving means into visual indication of the values of said quantities pertaining to all of said aircraft.

12. In combination, means for establishing a pattern of radiant energy rotating at a fixed angular velocity with respect to a first geographic location, means for receiving radiant energy from said pattern at a further location and for translating said radiant energy into a periodic signal having a phase dependent upon the bearing of said further location with respect to said first location, a normally inoperative transmitter, means for applying said periodic signals to said transmitter for transmission thereby, and means for rendering said transmitter operative to transmit said periodic signals only at times determined in accordance with a value of a physical quantity.

13. In combination, a first station, a second station, means for supplying identical synchronizing signals to said first station and to said second station, first means at said first station for there measuring the value of a first quantity, first means at said second station for there measuring the value of a first quantity, second means at said first station for there measuring the value of a second quantity, second means at said second station for there measuring the value of a second quantity, third means of said first station for receiving said synchronizing signals, third means at said second station for receiving said synchronizing signals, fourth means at said first station for generating first periodic pulses having time positions determined by said synchronizing signals and by said value of a first quantity as measured at said first station, fourth means at said second station for generating first periodic pulses having time positions determined by said synchronizing signals and by said value of said second quantity as measured at said second station, separate means at said first and second stations for generating second periodic pulses having time positions determined by said synchronizing signals and by said values of said second quantity as measured at said first and second stations, respectively, the period of said second periodic pulses at both said stations including a predetermined number of periods of said first periodic pulses, and the duration of each of said second periodic pulses at each of said stations being equal to the period of said first periodic pulses, a pulse transmitter at each of said stations normally maintained inoperative to transmit, means at said first station for supplying said first periodic pulses generated at said first station to said transmitter at said first station for transmission thereby, means responsive only to said second periodic pulses generated at said first station for rendering said transmitter at said first station operative to transmit said first periodic pulses at said first station, means for applying said first periodic pulses generated at said second station to said transmitter at said second station for transmission thereby, means responsive only to said second periodic pulses generated at said second station for rendering said transmitter at said second station operative to transmit said first periodic pulses generated at said second station, means at each of said stations for receiving pulses transmitted by the other of said stations and for translating said pulses into visible indication of values of said quantities.

14. In a navigational system for aircraft, means for delimiting a first periodic time interval aboard an aircraft, means for delimiting a second time interval aboard said aircraft, means for providing repetitive periodic signals at time positions within said first time intervals which correspond with bearing of said aircraft with respect to a predetermined geographic location, means for providing a signal at a time position within said second time interval which corresponds with the range of said aircraft with respect to said predetermined geographic locations, means for selectively transmitting at least one of said periodic pulses selected in accordance with the time position of the other of said signals, and a remote station for receiving and translating said one of said periodic pulses to a visual indication of the range and bearing of said aircraft with respect to said predetermined geographic location.

15. In combination, in a navigational system for aircraft, means aboard an aircraft for transmitting pulses having time positions simultaneously with respect to each of a pair of repetitive time intervals, the time positions of said pulses with respect to each of said pair of intervals being representative of the value of a quantity having navigational significance, a remote receiver for said pulses, said receiver comprising means for translating the time positions of said pulses with respect to each of said pairs of intervals into a composite visual indication of the values of said navigational parameters of said aircraft.

16. In combination, in a navigational system for aircraft, means at each of a plurality of aircraft for generating and transmitting pulses, each pulse having time positions simultaneously with respect to each of a pair of repetitive time intervals, said repetitive time intervals having unequal duration, said time intervals being identical at all of said stations, and the time positions of said pulses generated and transmitted at each of said stations having time positions simultaneously with respect to both of said time intervals which are determined with respect to each of said time intervals by the range and bearing respectively of said transmitting aircraft, receiving means for said pulses, and means responsive to said receiving means for visually indicating the ranges and bearings of said transmitting aircraft.

17. In combination, means for delimiting first periodic time intervals, means for delimiting second periodic time intervals, means for providing groups of first repetitive periodic signals at time positions within said first periodic time intervals

which correspond with the value of the bearing of said aircraft, means for providing further signals at time positions within said second time intervals which correspond with the value of the range of said aircraft, means for selectively transmitting one only of each group of said first periodic signals selected in accordance with time positions of the other of said periodic signals.

18. In a navigational system for aircraft, an omni-directional radio range beacon transmitter for providing two cyclic signals, one of said cyclic signals having equal phase omni-directionally from said transmitter, and the other of said cyclic signals having a phase depending upon bearing of said transmitter, means aboard a remote aircraft for receiving said two cyclic signals from said omni-directional radio range beacon transmitter, means aboard said aircraft for generating periodic pulses having time positions with respect to the period of said first of said two cyclic signals which is determined by the bearing of said aircraft with respect to said transmitter as determined from the phase of the other of said two cyclic signals, means for establishing aboard said aircraft further periodic time intervals comprising each a plurality of periods of said cyclic signals, means for establishing a gating wave having a time position with respect to said further periodic time intervals which is determined in accordance with the range of said aircraft with respect to said transmitter, said gating wave having a time duration equal to the period of said cyclic signals, a normally inoperative transmitter aboard said aircraft, said transmitter having an input circuit and an output circuit, means for applying said periodic pulses to said input circuit, means for applying said gating wave to said transmitter to render said transmitter operative for the duration of said gating wave only, whereby only such of said pulses applied to the input circuit of said transmitter as overlap the time positions of said gating waves generate pulses at the output circuit of said transmitter.

19. In combination, means for transmitting pulses having time positions simultaneously with respect to each of a pair of repetitive time intervals, the time position of each pulse with respect to each of said pair of time intervals being representative of the value of a different measurable quantity, a recorder comprising a first successive line scanning marker and a second successive line scanning marker, means for synchronizing scanning of the first of said successive line scanning markers with the first of said repetitive time intervals, means for synchronizing scanning of said second line scanning marker with the second of said pair of repetitive time intervals, and means for actuating said line scanning markers to mark simultaneously in response to each of said pulses.

20. In a navigational system for aircraft, means for delimiting a first periodic time interval aboard an aircraft, means for delimiting a second time interval aboard said aircraft, means for providing repetitive periodic signals at time positions within said first time intervals which correspond with bearing of said aircraft with respect to a predetermined geographic location, means for providing a signal at a time position within said second time interval which corresponds with the altitude of said aircraft with respect to said predetermined geographic locations, means for selectively transmitting at least one of said periodic pulses selected in accordance with the time position of the other of said signals, and a remote station for receiving and translating said one of said periodic pulses to a visual indication of the altitude and bearing of said aircraft with respect to said predetermined geographic location.

21. In combination, in a navigational system for aircraft, means at each of a plurality of aircraft for generating and transmitting pulses, each pulse having time positions simultaneously with respect to each of a pair of repetitive time intervals, said repetitive time intervals having unequal duration, said time intervals being identical at all of said stations, and the time positions of said pulses generated and transmitted at each of said stations having time positions simultaneously with respect to both of said time intervals which are determined with respect to each of said time intervals by the altitude and bearing respectively of said transmitting aircraft, receiving means for said pulses, and means responsive to said receiving means for visually indicating the altitudes and bearings of said transmitting aircraft.

22. In combination, means for delimiting first periodic time intervals, means for delimiting second periodic time intervals, means for providing groups of first repetitive periodic signals at time positions within said first periodic time intervals which correspond with the value of the bearing of said aircraft, means for providing further signals at time positions within said second time intervals which correspond with the value of the altitude of said aircraft, and means for selectively transmitting one only of each group of said first periodic signals selected in accordance with time positions of the other of said periodic signals.

MARCEL WALLACE.

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