

July 9, 1946.

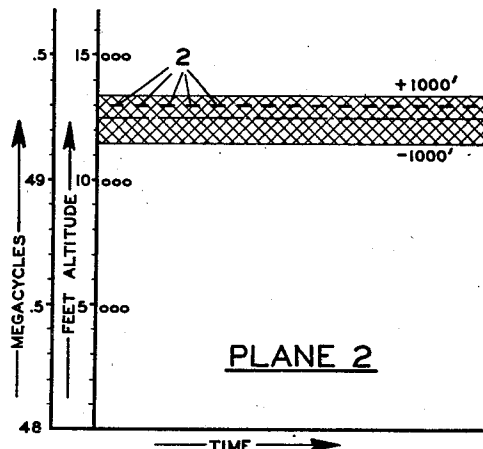
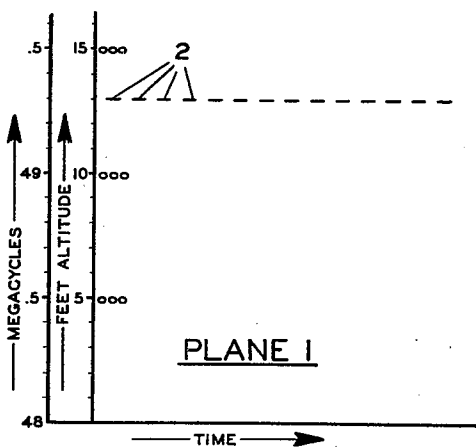
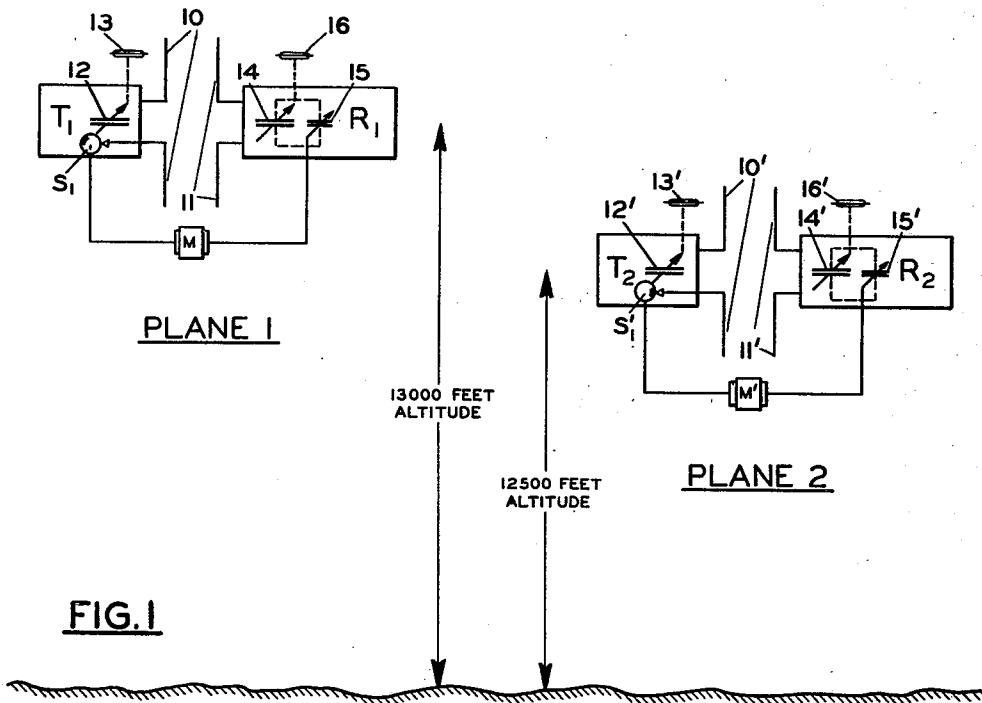
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2,403,603

WIRELESS COMMUNICATION

Filed Feb. 5, 1941

5 Sheets-Sheet 1



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5 Sheets-Sheet 2



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5 Sheets-Sheet 3

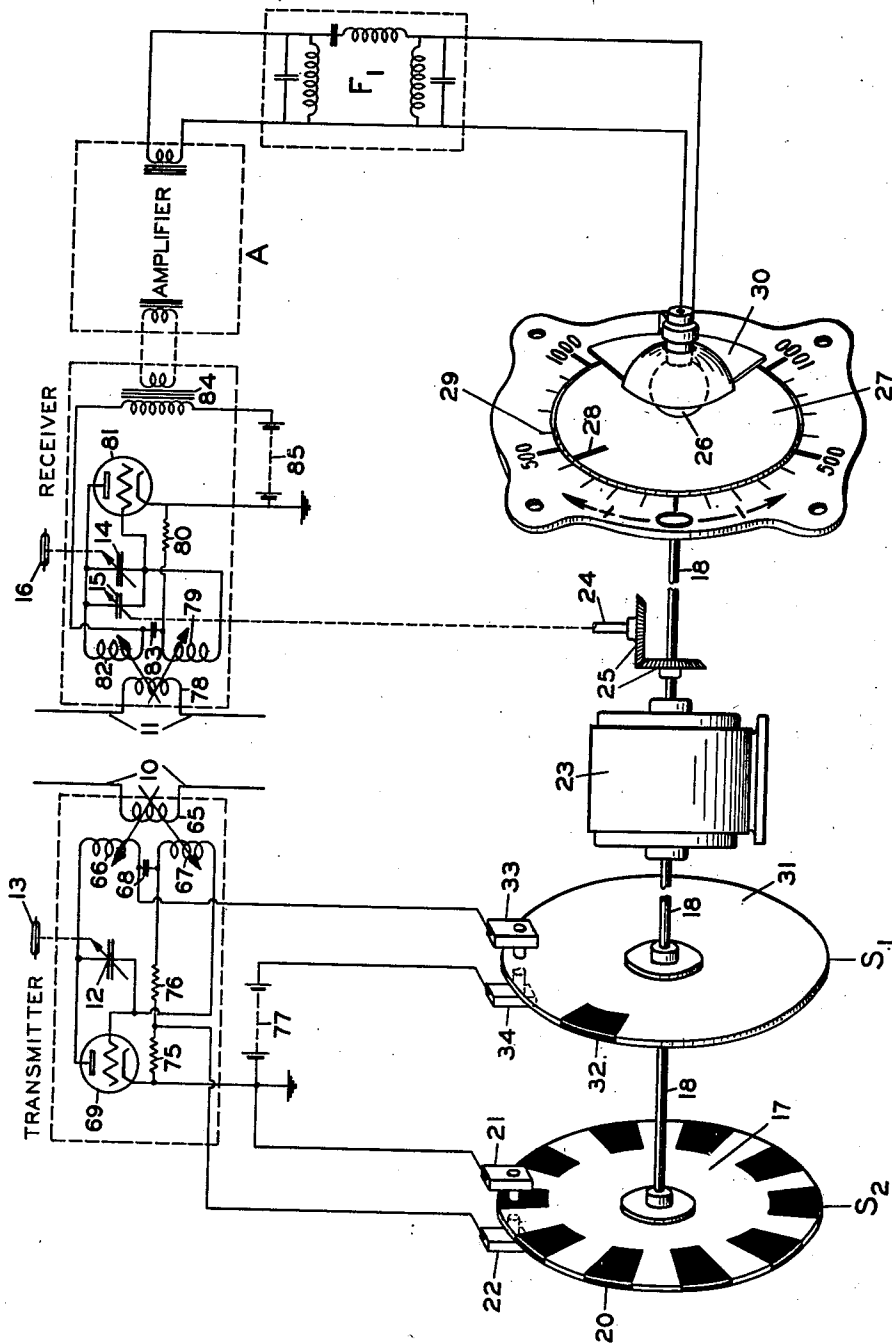


FIG. 4

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WIRELESS COMMUNICATION

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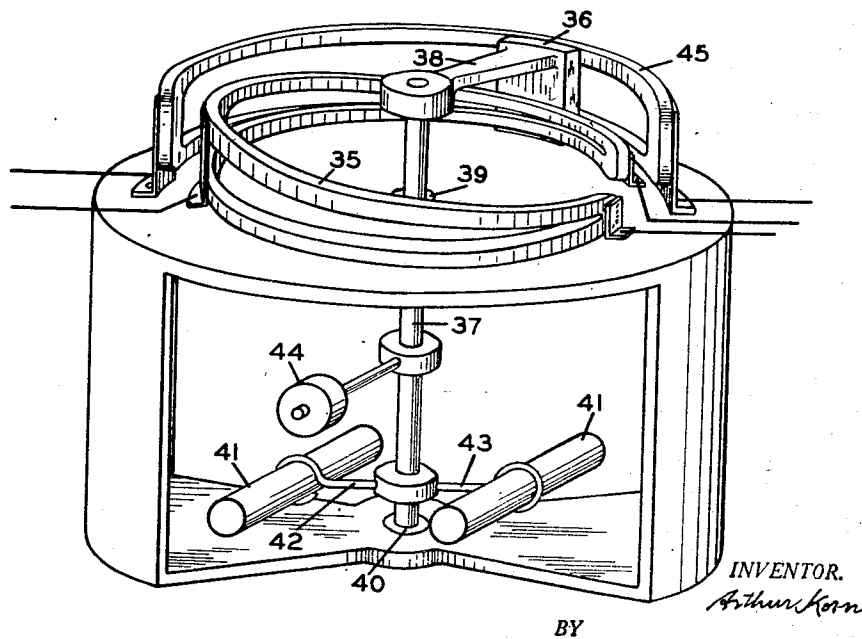
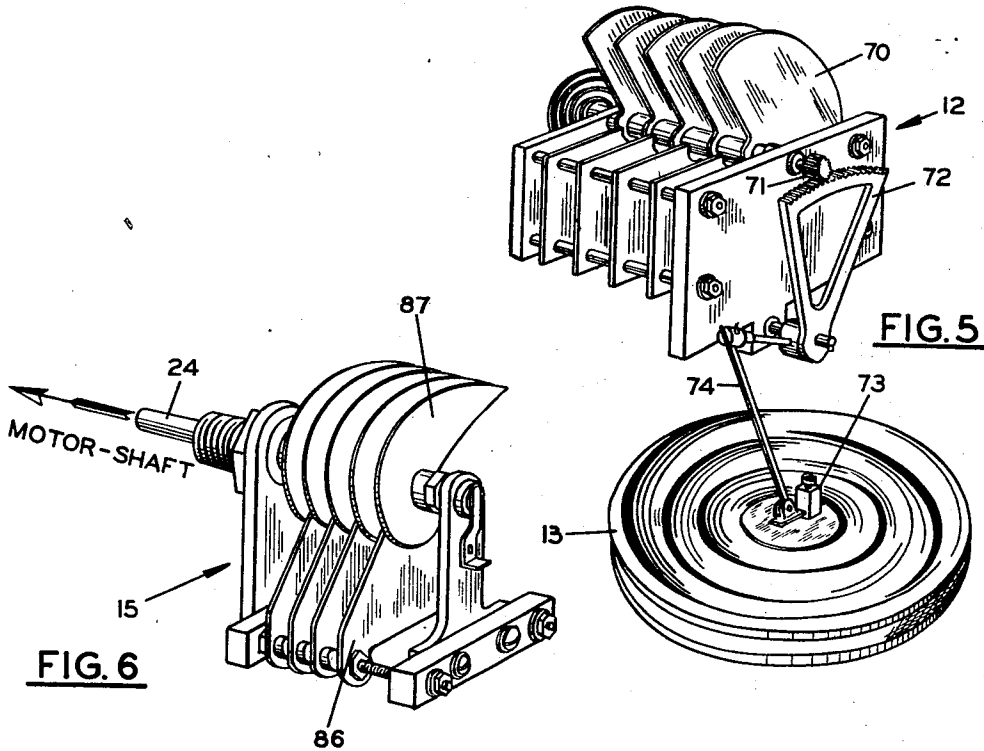


FIG. 8

July 9, 1946.

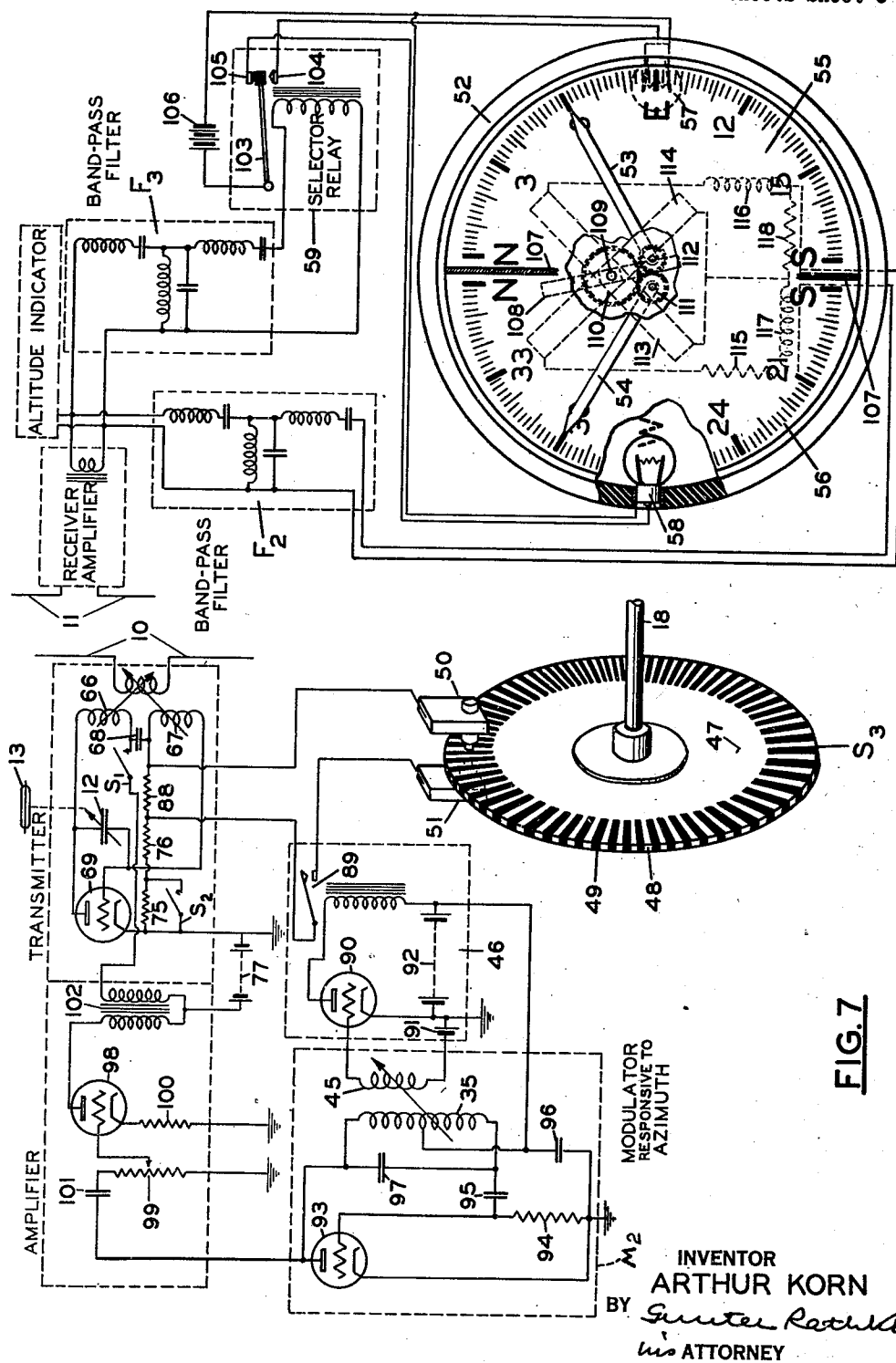
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WIRELESS COMMUNICATION

Filed Feb. 5, 1941

5 Sheets-Sheet 5



UNITED STATES PATENT OFFICE

2,403,603

WIRELESS COMMUNICATION

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Application February 5, 1941, Serial No. 377,516

21 Claims. (Cl. 250—11)

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This invention relates to a method of, and apparatus for, wireless communication, more particularly designed for communication with and between aircraft.

It is an object of this invention to provide a method of, and an apparatus for, wireless communication permitting an airplane in flight to communicate to other planes or a station on the ground within a predetermined range or distance certain flight data as, for example, its altitude and its direction of flight.

It is thus a purpose of the invention to communicate to the pilot of a plane in flight certain flight information such as altitude or direction of flight, or both, of other craft in the vicinity of the plane in order to eliminate the danger of collision in mid air especially during blind flying or poor visibility.

It is a further purpose of this invention to provide a method of, and means for, communication between an airport operator and planes in the vicinity of the airport giving the airport control officer visible indication of altitude and direction of all planes in the vicinity of the port.

For carrying out the above objects, the invention more broadly provides a method of communication for continuously informing a remote station of certain data of variable magnitude by causing the carrier frequency of a radio signal to be changed in response to one variable and, in case of transmission of several variables, to cause the carrier frequency to be modulated in addition by one or several modulation frequencies.

The invention further aims at providing suitable apparatus for practicing this method.

It is thus a further and more specific object of this invention to provide a transmitter for use on aircraft including means for changing its carrier frequency tuning in response to changes in altitude, for example by means of an altimeter, and including means for modulating the variable carrier frequency in response to azimuthal direction, for example by means of a compass or a directional gyroscope.

It is a further purpose of the invention to provide a receiving apparatus capable of interpreting such signals.

The invention thus aims at providing a receiving apparatus capable of scanning a certain band of carrier frequencies for signals and interpreting the carrier frequency of received signals in terms of the transmitted variable, such as altitude.

More particularly, the invention aims at providing a receiving apparatus capable of auto-

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matically scanning a band of carrier frequencies in dependence on the altitude of the receiving craft and indicating the presence of other craft in the proximity by indicating their relative altitude with respect to the receiving craft and, in further development of this invention, in addition, the direction of flight of such craft.

More specifically, the invention aims at providing a combined transmitter and receiver for the continuous transmission of signals representing altitude of a transmitting craft and simultaneously scanning a band of carrier frequencies in dependence on the altitude level of the transmitting craft including means for protecting the receiver from signals of the transmitter with which it is combined.

The invention further aims at improving the above method of, and apparatus for, communication by providing steps and means for eliminating interference by stray signals.

Further aims, objects and advantages of this invention will appear from a consideration of the description which follows with accompanying drawings showing for purely illustrative purposes embodiments of this invention. It is to be understood, however, that the description is not to be taken in a limiting sense, the scope of the invention being defined in the appended claims.

Referring to the drawings:

Fig. 1 is a diagrammatic illustration of the principle of this invention showing two airplanes each equipped with a transmitter and a receiver according to this invention;

Fig. 2a is a diagram illustrating the signals transmitted by plane 1 of Fig. 1;

Fig. 2b is a diagram illustrating the band of frequencies covered by the receiver of plane 2 of Fig. 1;

Fig. 3 is a block diagram illustrating the operation of a transmitting and receiving unit according to this invention;

Fig. 4 is a circuit diagram showing an illustrative form of circuit of a transmitter and receiver for altitude signals;

Fig. 5 is a perspective view of an altitude controlled tuning element of the transmitter and receiver of Fig. 4;

Fig. 6 is a perspective view of a motor controlled tuning element of the receiver of Fig. 4;

Fig. 7 is a circuit diagram showing a transmitter and receiver for the transmission and reception of directional signals; and

Fig. 8 is a perspective view of a tuning element of the transmitter shown in Fig. 6.

The principle of this invention will readily be

understood from the diagrammatic illustration of Fig. 1. It may be assumed that a first plane is at an altitude of 13,000 feet while a second plane is in its proximity at an altitude of 12,500 feet. In order to avoid collision between the two planes, the invention provides a method and means whereby the planes may exchange information as to particular flight data which will enable each pilot to steer his plane clear of the other plane.

Plane 1 is shown as equipped with a transmitter T₁ and a receiver R₁. The transmitter and receiver of the first plane are provided with antennas 10 and 11 respectively. A tuning element in the transmitter T₁ which may be a variable condenser 12 is controlled by an altitude responsive device diagrammatically illustrated as an evacuated aneroid capsule 13. The tuning element 12 changes the carrier frequency of the transmitter in dependence on the altitude at which the plane 1 flies.

In Fig. 2a there is shown how a band of frequencies may be co-ordinated with a range of altitudes. In the illustrated form of the invention a band of carrier frequencies extending from 48 to 51 megacycles is used to cover altitudes from zero to 30,000 feet.

The transmitter of the plane 1 flying at an altitude of 13,000 feet will, according to the chosen coordination of frequencies with altitude, transmit signals of a frequency of 49.3 megacycles. The signals may be transmitted periodically and are represented in Fig. 2a by dashes 2 parallel to the time axis.

These signals are picked up by the second plane which is equipped with means for interpreting the signals in terms of altitude. This is accomplished by automatically scanning a relatively narrow band of carrier frequencies coordinated to the altitude of the receiving plane. For this purpose a receiver is provided for picking up any signals transmitted by planes flying at approximately the same altitude as the receiving plane. As a practical example, the receiver may be so adjusted as to respond to all signals transmitted by planes flying within a predetermined distance of about five or ten miles and at an altitude differing from the altitude of the receiving plane by less than 1,000 feet altitude.

To this end, the receiver of each plane is equipped with a primary and a secondary tuning element. The purpose of the primary tuning element is to set the receiver for a carrier frequency in dependence on the altitude of the receiving plane.

The secondary tuning element permits periodic scanning of a relatively narrow frequency band corresponding to the altitude range in which the presence of other planes is to be ascertained. In the illustrated embodiment, the altitude range is chosen to extend from plus 1,000 feet to minus 1,000 feet with respect to the altitude of the receiving plane.

Referring now to Fig. 1 the transmitter and receiver of the second plane correspond in all particulars with the transmitter and receiver of the first plane. Primed reference numerals are accordingly used for denoting the elements of the second plane.

The transmitter T₂ is equipped with a transmitting antenna 10', the receiver R₂ includes an antenna 11'. A primary and a secondary tuning element is provided for tuning the receiver R₂ to the desired frequency.

In the illustration the primary tuning element 14' is automatically adjusted by an altitude responsive device represented by an evacuated aneroid capsule 16'.

Assuming that a band of frequencies corresponding to a range of altitudes of plus/minus 1,000 feet relative to the altitude of the receiving plane is to be scanned for signals, the altitude responsive device 16' will tune the receiver R₂ to the highest frequency of the band. In the illustrated example, the frequency of 49.35 megacycles corresponds to the altitude of 13,500 feet.

A secondary tuning element shown as a variable condenser 15' is mechanically operated by suitable means such as a motor M' for tuning the receiver R₂ successively to all frequencies from 49.35 to 49.15 megacycles thereby scanning the range of altitude from 13,500 to 11,500 feet.

The frequency band is indicated in Fig. 2b by shading. The dash-dot line in the center of the shaded band represents the altitude of the second plane which is 12,500 feet. The incoming signal of the first plane is represented as a series of dashes 2 and falls well within the band scanned by the receiver R₂.

As hereinbefore stated, the instantaneous tuning of the receiver is dependent upon the adjustment of the secondary tuning element, for example, the angular position of the rotor plates of the condenser 15'. Therefore, the adjustment of the secondary tuning element at the instant of reception of a signal is representative of the altitude of the plane from which the signal originates relative to the altitude of the receiving plane.

As will be outlined in greater detail below, an indicator may be associated with the movable member of the secondary tuning element, in the illustrated example the rotor plates of the condenser 15', to indicate the altitude of the transmitting plane relative to the receiving plane.

The scanning of the frequency band corresponding to the desired altitude range relative to the altitude of the receiving plane may be repeated at any desired number of cycles per unit of time.

I have found it convenient to traverse the tuning range approximately ten times per second which would correspond to a rate of rotation of the rotor shaft of the condenser 15' of ten revolutions per second, or 600 revolutions per minute.

An indicator such as a glow lamp operated by the receiver R₂ will, accordingly, be actuated ten times per second by a signal picked up by the receiver. This arrangement will be further illustrated in the succeeding detailed figures of the drawings.

From the foregoing it will appear that during each scanning cycle the receiver will also be tuned to the frequency of the transmitter with which it is associated in the same plane. Since it is undesirable to pick up a signal from the transmitter with which the receiver is associated, in other words, since it is undesirable to pick up the signal of the transmitter T₂ by the receiver R₂ during each tuning cycle, means are provided for protecting the receiver from signals of the associated transmitter.

Many forms of means and circuits are known in the art of electric communication which may be employed for this purpose.

In the embodiment of the invention described hereinafter in greater detail, I employ mechanically operated means for silencing the trans-

mitter for the period of time during which the receiver would respond to the signal of the associated transmitter.

This may conveniently be accomplished by means of blanking keys S_1 and S_1' operated by the motors M and M' , respectively, for interrupting the transmitter signals while the associated receiver is scanning the frequencies close to the transmitter frequency. This arrangement permits undisturbed reception of signals from other planes flying in the vicinity at the same altitude.

The communication method and system according to this invention permits simultaneous transmission of several variables to a receiving station.

Illustrating this feature by reference to a communication method and system for aircraft, it is possible to transmit, in addition to information regarding altitude, further data, such as direction of flight, or course of the transmitting plane.

Fig. 3 illustrates in the form of a block diagram the structure of a device for practicing the method for communicating a plurality of variable data.

Referring first to the method, a signal is transmitted and the carrier frequency of the signal varied within the limits of a predetermined band of carrier frequencies in dependence on a first variable, such as altitude in the present specific example.

The carrier may further be modulated by a predetermined fixed or variable modulating frequency. A variable modulation may be impressed on the carrier in response to the azimuthal direction of the plane transmitting the signals. This variation may be cyclic, that is to say, in traversing the entire azimuth circle from north via east, south and west to north, the modulating frequency may be caused to increase during one-half of the azimuthal circle and be caused to decrease again during the other half of the circle. For example, there may be caused an increase in frequency from a minimum to a maximum for directions between north and south through east. The modulation frequency may then be decreased again for directions within the second half of the azimuthal circle including west.

In order to eliminate ambiguity arising from the cyclic increase and decrease in the modulation frequency, a further and fixed modulation frequency may be impressed on the carrier for directions within one-half of the azimuthal circle. This modulation may be of a higher frequency. No such distinguishing modulation being provided for the other half, signals representing east and west-course become distinct although, according to the present example, the variable modulation frequency assigned to west is the same as the one assigned to east.

The modulated carrier frequency may further be modulated, preferably at a relatively low frequency, in order to give all transmitted signals a particular characteristic enabling filtering of the signal at a receiving station in order to eliminate stray signals or interferences.

A signal formed according to this method may be interpreted at the receiving station as to the various data transmitted by the signal. The carrier frequency represents one variable, such as altitude. In addition, the received signal may include further variables such as direction of flight represented by modulation frequencies.

Finally the received signal may be interpreted in terms of volume in order to determine change in distance from the transmitting station.

Referring now to Fig. 3, the transmitter T includes a tuning element shown as a variable condenser 12 for controlling the carrier frequency of a signal emitted by the antenna 10. The tuning element is controlled by an altitude responsive means shown as an evacuated diaphragm 13.

The carrier may be modulated to give the signal a distinct characteristic. A modulator S_2 for modulating the carrier frequency is shown in the form of a rotatable interrupter disk 17 mounted on a shaft 18 of a motor 23. The disk 17 includes insulating sectors 20 and rotates between brushes 21 and 22 periodically to interrupt the flow of current between the same.

Turning now to the receiver R , an incoming signal is picked up by the antenna 11. The receiver, as hereinbefore explained, includes a primary and a secondary tuning element shown as variable condensers 14 and 15. The condenser 14 is adjusted in response to altitude by an altitude responsive element illustrated as an evacuated diaphragm capsule 16.

A secondary tuning element shown as a variable condenser 15 is periodically operated by the motor 23, a shaft 24 being shown driven over a gear train 25 from the motor shaft 18. The condenser 15 is preferably of the type in which the capacity increases gradually during the greater part of one revolution and which after reaching a maximum capacity may be brought to its minimum capacity position by further rotation through a relatively small angle.

One form of condenser having this characteristic is known as a "270°-condenser" and is so constructed as to increase its capacity during 270° of rotation of its rotor from a minimum to a maximum. Further rotation of the rotor plates through an angle of 90° will restore the condenser to the position of minimum capacity.

The capacity of the condenser 15 is preferably added to that of the condenser 14, thereby changing the tuning of the receiver successively through a predetermined band of carrier frequencies. The upper limit of the band is fixed by the sum of the capacities of condensers 14 and 15 when condenser 15 has its minimum position, the lower limit by the sum when condenser 15 is at maximum capacity.

A signal of a frequency within the band scanned by the receiver R is amplified by an amplifier A and utilized for actuating an indicator. The altitude indicator is shown in the illustrated embodiment to include a glow lamp 26.

A band pass filter F_1 may be interposed between the amplifier and the indicator to eliminate interference by radio signals of other than a predetermined distinguishing frequency. The filter in the illustrated embodiment is tuned to the frequency of the modulator S_2 , the same distinguishing modulating frequency being used by all planes.

During each tuning cycle a received signal will cause the glow lamp 26 to light once. The glow lamp will respond at the exact moment at which the receiver is tuned to the carrier frequency of the particular signal. The angular position of the rotor of the tuning element 15 at the instant of reception of a signal thus becomes a measure of the carrier frequency of the signal. Indicating means are provided for indicating this position.

In the illustrated embodiment a rotatable disk

27 is mounted on the motor shaft 18. The rotatable disk carries a marker or pointer 28 which may be painted thereon to cooperate with the graduations of a fixed dial 29 preferably graduated in feet of relative altitude.

The glow lamp 26 preferably provides the sole illumination for the indicating means. At the instant of reception of a signal the glow lamp will light to render the momentary position of the pointer 28 visible relatively to the dial. Assuming the rate of rotation of the rotor shaft to be ten revolutions per second, the lamp 26 will light ten times during each second giving the appearance of the pointer 28 to be stationary due to the resulting stroboscopic effect.

The scanning cycle may be assumed to begin at the moment when the condenser 15 is in the position of greatest capacity. Since the motor 23 runs at a substantially constant speed, the scanning cycle is completed within a predetermined time, for example, one tenth of a second during which the pointer 28 makes a full revolution. The relationship in point of time of the periodic reception of a signal, also called time phase of the signal, with respect to a fixed zero point of the scanning cycle, for example the instant at which the condenser 15 assumes its greatest capacity, thus becomes a measure of the carrier frequency of the signal in the illustrated arrangement and, accordingly, of the altitude of the transmitting plane relatively to the receiving plane.

In the illustrated embodiment, the graduation of the indicator is spread over an arc of 270°, a 270° condenser 15 being used in the receiver R. The condenser will be described in greater detail below.

In the drawing the pointer is shown in a position of plus 400 feet altitude indicating that a signal is being received from a plane flying 400 feet higher than the receiving plane.

Since the condenser 15 after reaching its maximum capacity is rotated further into the position of minimum capacity, the lamp will light again during the remaining 90° of rotation of the condenser and the indicator. It is for this reason advantageous to provide a blanking sector 30 of 90° covering the marker or pointer 28 during the 90° movement from minimum to maximum capacity of the condenser. The glowing of the lamp 24 during the 90° movement of the condenser into its position of maximum capacity thus becomes unnoticeable.

It will be noticed that the mark in the center of the graduation represents a relative altitude difference of zero. A signal causing the lamp to light at this point will be a signal of the same carrier frequency as the one transmitted by the transmitter T associated with the receiver. Means are therefore provided for preventing the receiver from responding to the signals of the transmitter with which it is associated.

Such means may take the form of a switch or other device for rendering the transmitter inoperative during the period of time during which the receiver would respond to the signal of the associated transmitter.

In the illustrated embodiment this means is shown in the form of a blanking key S₁ comprising a disk of conducting material 31 including an insulating sector 32. The insulating sector is so arranged with respect to contact brushes 33 and 34 as to cut off the transmitter while the pointer 28 passes the zero mark on the graduation 29.

Further data may be transmitted by the same signal by additionally modulating the signal in dependence on such data. In the illustrated form of the invention, means are provided for transmitting information regarding the azimuthal direction of the transmitting plane by modulating the signal in response to azimuthal direction. A modulator M₂ is shown for this purpose controlled by a directional instrument, in the illustrated embodiment, a compass magnet.

Referring now also to Fig. 8, the modulator includes an inductance coil 35 wound substantially in the form of a triangle and curved so that its hypotenuse forms a circle normal to the curved area of the triangle. The coil 35 is acted upon by a movable mass 36, preferably of iron, adapted to modify the inductance of the coil. The mass 36 is mounted for rotation on the shaft 37 by means of an arm 38. The shaft 37 is rotatable in bearings 39 and 40. A direction responsive element shown as a pair of magnets 41 mounted on the shaft by means of arms 42 and 43 maintains the mass 36 fixed in azimuth. A mass 44 may be provided to counterbalance the mass 36.

As the craft turns in azimuth the inductance will be caused to rotate relatively to the mass 36 about the axis of the shaft 37 thus causing the mass to act on a wider or narrower area of the inductance 35. This movement causes the frequency of the modulator to increase and decrease depending on the direction of relative movement.

The device may be so adjusted that the mass 36 is opposite the narrowest part of the inductance while the craft is headed north. The mass will move into a position opposite the widest part of the inductance if the craft changes its course by 180°. This movement will cause the frequency of the modulator to decrease from a maximum to a minimum. If the craft continues to turn in the same direction the modulating frequency will again increase to assume a maximum after the turn of 360° has been completed.

The range of modulating frequencies is preferably so selected that it may be covered by one scale of a frequency meter. A suitable range would be 500 to 700 cycles.

The cyclic change in the modulating frequency entails an ambiguity since the same modulating frequencies are co-ordinated with either half of the azimuth circle. This ambiguity may be eliminated by impressing a further and distinguishing modulation on the signal during one-half of the azimuth circle.

In the illustrated embodiment there is shown a further inductance coil 45 curved as to form a half cylinder. The coil is coupled with inductance 35 so that when the iron mass 36 is opposite the coil 45 there is sufficient mutual induction to allow relay 46 to be energized. Relay 46 controls a further modulator S₂ shown in the illustrated embodiment as including a disk 47 mounted on the motor shaft 18 and having alternate conducting and insulating sectors 48 and 49 respectively. The disk is shown as moving between brushes 50 and 51.

This modulator will impress its characteristic frequency on the carrier when the azimuth lies in a chosen half of the azimuth circle herein chosen to be north to south through east. The frequency may be 3,000 cycles.

Referring now to the receiver, an indicator may be provided for indicating the data transmitted as variations in modulation frequency. In the illustrated embodiment there is shown an indi-

cator 52 having two pointers 53 and 54 movable over dials 55 and 56 respectively. The dials bear directional graduations, each dial covering one-half of the azimuth circle.

The pointers 53 and 54 are jointly actuated from the movable element of a frequency meter later to be described in greater detail. The frequency meter is connected to the amplifier A of the receiver R preferably through a band-pass filter F₂ permitting only frequencies of the modulator M₂ to pass through, in the illustrated form of the invention, frequencies between 500 and 700 cycles. The pointers 53 and 54 are connected to move in opposite directions.

Means are provided for distinguishing between the two halves of the azimuth circle to which equal bands of frequencies are co-ordinated. In the illustrated embodiment of the invention, transparent dials are employed lighted by one or the other of a pair of bulbs 57 and 58 selectively lighted through a selector relay 59. The selector relay may be combined with a band-pass filter F₃ permitting only frequencies of the distinguishing modulator 47 to pass through, in the illustrated form of the invention, 3,000 cycles.

Information regarding a change in distance of a transmitting plane from the receiving plane may be obtained by means of a distance indicator 60 which may be of the volume responsive type employed in radio receivers. The distance indicator is shown to be connected to the receiver and includes a pointer 61 movable over a dial 62 preferably graduated in units of distance. A setting marker 63 may be provided, adjustable by means of a setting knob 64, to permit an easy reading of a change in volume of an incoming signal. After setting into a position opposite of the pointer, the movement of the pointer relatively to the setting marker in response to changes in volume of the signal will be a measure of the change in distance from the transmitting plane. An increase in volume, causing the pointer to move to the right, therefore indicates a decrease in distance, while a movement in the opposite direction, towards the end of the dial, marked infinite, indicates that a transmitting plane moves away from the receiving plane.

The operation of the device illustrated in Fig. 3 is as follows:

The transmitter T transmits a signal, the carrier frequency of which is changed in dependence on changes in altitude of the transmitting plane as hereinbefore described.

A second plane or station equipped with the same communication device will pick up the signal with its antenna 11. The receiver R of the receiving station is tuned to a frequency co-ordinated to the altitude of the receiving plane and through its mechanically operated tuning element 15 scans a band of carrier frequencies corresponding to a predetermined altitude band above and below the altitude of the receiving plane.

The altitude indicator of the receiving plane is jointly actuated by the received signal and the mechanically operated tuning means to indicate the carrier frequency of a received signal in terms of altitude in a manner hereinbefore described. Upon reception of a signal the setting marker 63 of the distance indicator 60 may be set at a position opposite of the pointer 61 to determine changes in distance of the transmitting plane.

At the same time the azimuthal direction of motion of the transmitting craft may be read at the azimuth indicator indicating the modulating

frequency of the incoming signal in terms of azimuth direction co-ordinated to the modulating frequencies in a manner hereinbefore described. One-half of the indicator dial is rendered visible at a time, the distinguishing lamp 57 or 58 being lit through the selector relay 59.

At the same time the receiving plane transmits its own altitude by changing the carrier frequency of the outgoing signals in response to changes in altitude.

The receiver associated with the transmitter is protected from the outgoing signals through the blanking key S₁ interrupting the transmitter while the associated receiver is scanning the frequencies close to the transmitter frequency, thus permitting reception of incoming signals of the same frequency at which the transmitter operates.

Exact synchronism between communication sets of different planes is avoided by slight differences in the rate of the motor 23. In the absence of synchronizing means, the motors 23 of different planes will operate at slightly different speeds preventing a condition to exist for an appreciable length of time in which the transmitter of a second plane in the vicinity is silenced exactly during the period of scanning of the frequency band within which the frequency of the transmitter of the second plane lies. Temporary synchronism may thus exist during a few seconds only.

In Fig. 4 the wiring diagram of a communication device is shown for transmitting altitude signals. The device includes a transmitter and a receiver.

Referring first to the transmitter, the antenna circuit includes a doublet antenna 10 and an inductance 65. The antenna coil is coupled with the oscillator circuit in a suitable manner, in the illustrated embodiment there being shown a plate inductance 66 and a grid inductance 67 one or both of which are inductively coupled with the antenna inductance. The coils 66 and 67 are connected by blocking condenser 68. The oscillator is supplied with energy by a thermionic tube 69 and is controlled by a suitable tuning element, there being shown a variable condenser 12 mechanically connected to an altitude responsive diaphragm 13. The tuning element 12 changes the carrier frequency of the transmitter in dependence on the altitude to which the diaphragm 13 responds.

The altitude controlled condenser is shown in greater detail in Fig. 5. The diaphragm 13 actuates the rotor plates 70 of the condenser 12 by means of a pinion 71 and a toothed sector 72 to which the center piece 73 of the diaphragm is connected by means of a link 74.

In order to give a distinguishing characteristic to the altitude signals, the transmitter output may be modulated by a characteristic frequency. In the illustrated form of the transmitter there is shown a modulator S₂ including the motor driven disk 17 having insulating sectors 20 imbedded therein. The disk is driven by the motor 23 through the shaft 18 and moves between brushes 21 and 22 thereby changing the grid bias of the thermionic tube at a suitable frequency which may be of the order of about 100 cycles. The grid leak may consist of two resistances 75 and 76. The resistance 75 lies parallel to the brushes 21 and 22 of the disk and is short circuited periodically to reduce the grid leak to the value of the resistance 76 thereby modulating the carrier of the transmitter. Preferably resistance

75 is greater than 76 in order to secure deep modulation.

The transmission of signals is periodically interrupted while the associated receiver scans frequencies close to the carrier frequency at which the transmitter operates. For this purpose there is shown the blanking key S₁ including a disk 31 having an insulating sector 32 and moving between the brushes 33 and 34. The interrupter S₁ operates to interrupt the plate voltage supplied by the plate battery 77.

For reasons of simplicity, the heating devices for the cathode, such as for example the filament battery, are not shown in the wiring diagrams.

Referring now to the receiver, the antenna coil 73 of the doublet antenna 11 is coupled to the oscillator circuit of the receiver by means of a grid inductance 79 in the oscillator circuit. The constants of the detector circuit of the receiver, more particularly the magnitude of the grid leak 30, are so chosen that its self-oscillations are periodically interrupted in a manner causing super-regenerative action at a frequency above the range employed at the transmitter, this being, in the illustrated form, frequencies of more than 3,000 cycles. The detector circuit includes a thermionic tube 81 having a plate inductance 82 connected thereto, the other terminal of the plate inductance being connected to the plate inductance 79 through a blocking condenser 83. The plate circuit is completed through an amplifying transformer 84 and the plate battery 85.

The resonant frequency of the detector circuit is controlled by two tuning elements, the primary tuning being effected by a tuning element operated in response to altitude.

In the illustrated embodiment, there is shown a condenser 14 operatively connected to an evacuated diaphragm 16 in a manner illustrated in Fig. 5. A secondary tuning element shown as a condenser 15 is mechanically operated from a shaft 24 to permit periodic scanning of a band of carrier frequencies in the manner hereinbefore described.

The condenser 15 is preferably of the 270° type as shown in Fig. 6. The condenser has stator and rotor elements 36 and 37 so shaped that a rotation of the shaft 24 will cause a gradual increase or decrease in capacity during a rotary movement of 270°. After reaching the position of maximum or minimum capacity, the condenser is restored to its position of minimum or maximum capacity, respectively, by further rotation of 90° in the same direction.

The condenser 15 operates periodically to decrease the resonant frequency of the detector so as to effect scanning of a frequency band of predetermined width. A suitable band includes a frequency associated with plus/minus 1,000 feet of altitude difference with respect to the altitude of the airplane on which the receiver is used. Referring to the chart 2b, the width of the band is .2 megacycle.

The detector circuit operates through an amplifier A of conventional structure, an indicator of the form hereinbefore described. Preferably there is interposed between the receiver and the indicator a band-pass filter F₁ of conventional structure permitting only signals to pass through which have the characteristic modulation impressed by the transmitter, in the illustrated form of the invention this being a modulation frequency of 100 cycles. The elements of the band-pass filter are conventional and will, for this reason, not be further described.

In Fig. 7 a communication device is shown for transmitting in addition to information regarding altitude further information regarding the course of the airplane. The transmitter circuit is similar to the one described in Fig. 4 except for the provision of an additional grid leak 88 forming part of a modulator S₃ for impressing on the carrier an additional frequency for distinguishing between the two halves of the azimuth circle. The grid leak 88 is periodically short-circuited by the interrupted disk 47 having successive conducting and insulating laminations 48 and 49. The disk which is driven by the motor shaft 18 cooperates with brushes 50 and 51 connected to the grid leak 88 through a relay 46. The relay may be of conventional thermionic type and includes a make-contact 89 for rendering the modulator S₃ operative. The make-contact is operated through the output of a thermionic tube 90 controlled by the inductance 45 which forms part of the device shown in Fig. 8 for modulating the signals in response to azimuthal direction.

Preferably, the grid resistor 88 is made small as compared to resistors 75 and 76 in order to maintain the carrier output substantially constant regardless of whether the modulator S₃ is in operation or not. So proportioned, a distance indicator operating on the volume meter principle will remain practically unaffected by the modulator S₃.

The relay 46 further includes the usual grid bias battery 91 and plate battery 92. The relay is actuated in response to the movement of the mass 36 with respect to the inductance 45 for directions within one-half of the azimuth circle. For directions within one-half of the azimuth circle the make-contact 89 will be closed, thereby rendering the modulator S₃ operative. For directions within the other half of the azimuth circle, the make-contact 89 will be open and the outgoing signals will not be modulated by the modulator S₃.

A variable modulation frequency is impressed on the signal in response to azimuthal direction. The azimuth modulator M₂ operates preferably within the range of five to seven hundred cycles and includes the inductance 35 hereinbefore described in connection with Fig. 8 having a tap intermediate its terminals.

The azimuth-responsive modulator M constitutes an oscillator of the "Hartley" type, well known in the art, and includes a thermionic tube 93, a grid leak 94 and condensers 95, 96 and 97.

The output of the azimuth responsive modulator may be amplified by an amplifier including a thermionic tube 98. The amplifier is shown to be of conventional form and includes further a volume control 99, a bias resistance 100 and a coupling condenser 101. A coupling transformer 102 is provided to modulate the transmitter.

Referring now to the receiver, the detector and amplifier circuits as well as the altitude indicator are not shown in detail in this figure. The direction indicator 52 may be connected to the receiver through band-pass filters F₂ and F₃ which are of conventional construction and will, for this reason, not be further described.

The band-pass filter F₂ is tuned to permit only the frequencies to pass therethrough which are modulated in response to changes in azimuthal direction, in the illustrated embodiment frequencies between 500 and 700 cycles.

The filter F_3 is so tuned as to permit only distinguishing frequencies to pass through, in the illustrated form of the invention frequencies of about 3,000 cycles for actuating the selector relay 59.

The selector relay includes a movable armature 103 cooperating with a pair of contacts 104 and 105 for supplying current to lamps 57 and 58 respectively from a battery 106.

The lamps 57 and 58 illuminate opposite halves of the directional dial 55, a member 107 being provided to prevent light from one bulb from illuminating the other half of the dial.

Two pointers 53 and 54 are movable relatively to the dial to indicate direction. The pointers 53 and 54 are connected to an actuating member to move in opposite directions.

In the illustrated embodiment there is shown a movable element 108 having a shaft 109. A gear 110 on the shaft 109 meshes with the pinion 111 on the shaft of the pointer 54. A second pinion 112 on the shaft of the pointer 53 meshes with pinion 111 to move the pointer 53 in the opposite direction. The gear train 110, 111 is employed in order to amplify the limited movement of the element 108 to a movement of approximately 180° for actuating the pointers in order to obtain a dial similar to a compass dial. The movable element 108 moves relatively to two field coils 113 and 114 respectively.

One terminal of the field coil 114 is connected through a resistance 115 to one output terminal of the band-pass filter. The corresponding terminal of the other field coil 113 is connected to the other output terminal of the band-pass filter through an inductance 116.

The two remaining terminals of the field coils are connected to a point between an inductance 117 and a resistance 118 leading to terminals of the resistance 115 and the inductance 116, respectively.

An incoming signal, if modulated by a 3,000 cycle frequency, will cause one-half of the directional dial to be illuminated. If the signal is not so modulated, the other half of the dial will be illuminated. The movable element 108 will assume a position relatively to the field coils 113 and 114 in dependence on the variable modulating frequency representing azimuthal direction which is thus indicated to inform the pilot of the course of other craft in the vicinity.

In many applications of the present invention, it is advantageous to restrict the operating range of the transmitter and the receiver in order to limit the response of the receiver to transmitters within less than a predetermined distance. This may conveniently be done by limiting the output of the transmitter, or the sensitivity of the receiver, or both, to avoid a response to signals of transmitters beyond the predetermined range.

In aerial navigation, for example, it is essential only that a pilot be advised of flight data of other planes in his vicinity, while information about the altitude of remote planes is relatively unimportant since the danger of collision in mid-air does not exist in the latter case.

Obviously, the present invention is not restricted to the particular embodiments herein shown and described. Moreover, it is not indispensable that all the features of this invention be used conjointly as they may advantageously be employed in various combinations and sub-combinations.

What is claimed is:

1. The method of communication between air-

craft which includes transmitting wireless signals of a carrier frequency within the limits of a predetermined band; varying said frequency within said band in dependence on the altitude of the transmitting craft; modulating said carrier frequency by a modulating frequency; and varying said modulating frequency in dependence on the azimuthal direction of flight of said transmitting craft.

2. The method of communication between aircraft which includes transmitting wireless signals of a carrier frequency within the limits of a predetermined band; varying said frequency within said band in dependence on the altitude of the transmitting craft; modulating said carrier frequency by a first modulating frequency; varying said first modulating frequency in dependence on the azimuthal direction of flight of the transmitting craft over both halves of the azimuth circle; and modulating said carrier frequency by a second modulating frequency during one half of the azimuth circle.

3. In a communication system for aircraft; means responsive to the altitude of the craft; a radio transmitter controlled by said altitude responsive means for transmitting signals of a carrier frequency proportional to the altitude of the craft, said transmitter including means for modulating the transmitter output; and means responsive to the azimuthal direction of flight of the craft for adjusting said modulating means for varying modulating frequencies in dependence on the azimuthal direction.

4. In a communication system for aircraft; means responsive to the altitude of the craft; means responsive to the azimuthal direction of the craft; a radio transmitter controlled by said altitude responsive means for transmitting signals of a carrier frequency proportional to the altitude of the craft, said transmitter including first means controlled by said direction responsive means for modulating the transmitter signals by a modulating frequency increasing for one half of the azimuth circle and decreasing for the other half of the azimuth circle, and second means controlled by said direction responsive means for additionally modulating the transmitter signals during only one half of the azimuth circle, whereby altitude and direction of the craft are distinctly communicated.

5. In a communication system for aircraft the combination with a directionally and altitude controlled transmitter for transmitting signals of variable carrier frequency in dependence on altitude, and of variable modulation frequency in dependence on azimuthal direction of a craft; of signal receiving means comprising, in combination, periodically operated power means; a radio receiver including means operated by said power means for periodically tuning said receiver to successive frequencies, altitude indicating means jointly operated by said power means and the output of said receiver; a frequency responsive actuating element responsive to the modulation frequency of signals received by said receiver; and directional indicating means operable by said actuating element.

6. In a communication system for aircraft the combination with a directionally and altitude controlled transmitter for transmitting signals of variable carrier frequency in dependence on altitude, and of variable modulation frequency in dependence on azimuthal direction of a craft; of signal receiving means comprising, in combination, periodically operated power means; an al-

timer; a radio receiver including primary and secondary tuning means, said primary tuning means being connected to be operated by said altitude responsive means for tuning the receiver to a carrier frequency proportional to the altitude of the receiving craft, said secondary tuning means being connected to be operated by said power means for tuning said receiver during each cycle of operation to successive carrier frequencies within a frequency band of predetermined width the frequencies of the band depending on the primary tuning; altitude indicating means jointly operated by said power means and the output of said receiver; a frequency responsive actuating element responsive to the modulation frequency of signals received by said receiver; and directional indicating means operable by said actuating element.

7. In a communication system for aircraft the combination with a directionally and altitude controlled transmitter for transmitting signals of variable carrier frequency in dependence on altitude, and of multiple modulation including modulation by a variable frequency in dependence on an azimuthal direction of a craft and additional modulation by a fixed frequency for directions within one half of the azimuth circle; of signal receiving means comprising, in combination, periodically operated power means; an altimeter; a radio receiver including primary and secondary tuning means, said primary tuning means being connected to be operated by said altitude responsive means for tuning the receiver to a carrier frequency proportional to the altitude of the receiving craft, said secondary tuning means being connected to be operated by said power means for tuning said receiver during each cycle of operation to successive carrier frequencies within a frequency band of predetermined width the frequencies of the band depending on the primary tuning; altitude indicating means jointly operated by said power means and the output of said receiver; a frequency responsive actuating element responsive to the variable modulation frequency of signals received by said receiver; means responsive to said fixed frequency; and directional indicating means jointly operable by said actuating element and said fixed frequency responsive means.

8. A communication device for aircraft comprising, in combination, a motor adapted to run at substantially constant speed; a radio transmitter including a variable tuning device; means responsive to the altitude of the craft connected to said tuning device for tuning the transmitter to a carrier frequency in dependence on the altitude of the craft; a switch operated by said motor for periodically rendering said transmitter inoperative; a receiver including a first and a second tuning element; means responsive to the altitude of the craft for adjusting said first element to tune said receiver to a carrier frequency proportional to the altitude of the craft, said second element being driven by said motor for periodically tuning said receiver to successive carrier frequencies within a predetermined band, thereby scanning said band for signals, the location of the band being determined by said first tuning element controlled in response to altitude; an amplifier connected to said receiver for amplifying its output; and indicating means including a rotatable element driven by said motor, and a fixed element cooperating with said rotatable element, one of said elements being a glow lamp operated by said amplifier, whereby the instance of receipt

of a signal is indicated by the instantaneous rotary position of said rotatable element, the rotary position representing altitude difference of a transmitting craft with respect to the receiving craft.

9. A communication device for aircraft as set forth in claim 8 in which there is additionally provided a modulating device driven by said motor and controlling said transmitter for interrupting the transmitter output at a predetermined frequency; and a filter tuned to the frequency of said modulating device, said filter being interposed between said receiver and said indicating means for blocking from said indicating means signals of other than said predetermined frequency, thereby preventing erroneous actuation of said indicating means by stray signals.

10. A communication device for aircraft comprising, in combination, a first craft provided with an azimuth direction indicator; a first motor adapted to run at substantially constant speed; a radio transmitter including a variable tuning device; means responsive to the altitude of the craft for tuning the transmitter to a carrier frequency proportional to the altitude of the craft, a first modulator operable by said direction indicator for modulating the transmitter signals in dependence on the direction of the craft, and a second modulator operated by said direction indicator for additionally modulating said signals by a predetermined fixed frequency during flight directions within one half of the azimuth circle; a switch operated by said motor for periodically rendering said transmitter inoperative; a second craft provided with a receiver including a first and a second tuning element; means responsive to the altitude of the craft for adjusting said first element to tune said receiver to a carrier frequency proportional to the altitude of the craft, a second constant speed motor for periodically tuning said receiver to successive carrier frequencies within a predetermined band, thereby scanning said band for signals, the location of the band being determined by said first receiver tuning; an amplifier connected to said receiver for amplifying its output; altitude indicating means including a rotatable element driven by said second motor, and a fixed element cooperating with said rotatable element, one of said elements being a glow lamp operated by said amplifier whereby altitude of the second craft relatively to the first craft is indicated by the rotary position of said elements at the instant of lighting of said lamp; directional indicating means including a frequency responsive first actuating element connected to respond to the variable modulation frequency of incoming signals, a frequency responsive second actuating element connected only to respond to signals modulated by said first frequency, thereby distinguishing between directions within the two halves of the azimuth circle, and indicating means operated by said actuating elements.

11. A communication apparatus for aircraft comprising, in combination, a transmitter of wireless signals; a device responsive to the altitude of said apparatus for tuning said transmitter to a carrier frequency proportional to the altitude of said apparatus, and means for modulating said signals by a predetermined frequency to distinguish said signals over stray signals; a receiver of wireless signals including filter means for excluding signals of other than said predetermined modulation frequency, whereby interference by stray signals is prevented; a device

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responsive to the altitude of said apparatus for tuning said receiver to a carrier frequency proportional to the altitude of said apparatus; power operated means for varying the tuning of said receiver through a band of carrier frequencies bearing a predetermined relation with the tuning effected by said altitude responsive device; an altitude indicator jointly operated by said power operated means and by the output of said receiver; and means operated by said power operated means for rendering said transmitter inoperative during the period of tuning of said receiver to the transmitter frequency.

12. A communication apparatus for aircraft comprising, in combination, a transmitter of wireless signals, said transmitter comprising a first tuning element for varying the carrier frequency of said signals within a predetermined band of carrier frequencies, and a modulating oscillator including a second tuning element for varying the modulation frequency of said signals within a predetermined band of modulation frequencies; a device responsive to the altitude of the craft for operating one of said tuning elements in dependence on the altitude of the craft; a device responsive to the azimuthal direction of the craft for controlling the other of said tuning elements in dependence on the direction of the craft; a receiver of wireless signals including first power operated variable tuning means for tuning said receiver to incoming signals of carrier frequencies within said predetermined band, and second means for determining the modulation frequency of incoming signals; an altitude indicator; an indicator of azimuthal directions, one of said indicators being jointly operated by the output of said receiver and said first tuning means, the other indicator being operated by said second means; and means coupled with said first tuning means for rendering said transmitter inoperative during the period of tuning of said receiver to the transmitter frequency.

13. A communication apparatus for aircraft comprising, in combination, a transmitter of wireless signals, said transmitter comprising a first tuning element for varying the carrier frequency of said signals within a predetermined band of carrier frequencies, and a modulating oscillator including a second tuning element for varying the modulation frequency of said signals within a predetermined band of modulation frequencies; a device responsive to the altitude of the craft for operating said first tuning element; a device responsive to azimuthal direction of the craft for controlling said second tuning element; a receiver of wireless signals including tuning means for tuning said receiver to a frequency of incoming signals of carrier frequencies within said predetermined band; means responsive to the altitude of the craft for operating said tuning means to tune said receiver to a frequency proportional to the altitude of the craft; power operated means for varying the tuning of the receiver cyclically through a band of carrier frequencies bearing a predetermined relation to the tuning effected by said altitude responsive means; an altitude indicator jointly operated by the output of said receiver and said power operated means; means responsive to the modulation frequency of an incoming signal; a direction indicator operated by said modulation frequency responsive means; and means coupled with said power operated means for rendering said transmitter inoperative during the period

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of tuning of said receiver to the transmitter frequency.

14. A communication apparatus for aircraft comprising, in combination, a transmitter of wireless signals including a tuning element for tuning said transmitter to transmit signals within a predetermined band of carrier frequencies, and an oscillator for modulating said signals by a predetermined modulation frequency; an altitude responsive device for operating said tuning element to tune said transmitter to a carrier frequency proportional to the altitude of the craft; a receiver of wireless signals, said receiver including means for tuning said receiver to a carrier frequency of incoming signals; altitude responsive means for operating said tuning means to tune said receiver to a carrier frequency proportional to the altitude of the craft; power operated means for varying the tuning of the receiver cyclically through a band of carrier frequencies bearing a predetermined relation to the tuning effected by said altitude responsive means; indicating means jointly operated by said power operated means and by the output of said receiver; filter means for excluding from said indicating means signals of a modulation frequency other than that of said oscillator; and means operated by said power operated means for rendering said transmitter inoperative during the period of tuning of said receiver to the carrier frequency of the transmitter.

15. A communication apparatus for aircraft comprising, in combination, a transmitter of wireless signals, said transmitter including a tuning element for tuning said transmitter to transmit signals within a predetermined band of carrier frequencies, and an oscillator for modulating said signals, the oscillator including a variable tuning device; means responsive to the altitude of the craft for actuating said tuning element in dependence on the altitude of the craft, whereby the carrier frequency of the signals becomes a measure of the altitude of the craft; and means responsive to the azimuthal direction of the craft for actuating said tuning device in dependence on the direction of flight of the craft, whereby the modulation frequency becomes a measure of the azimuthal direction of the craft.

16. A communication apparatus for aircraft comprising, in combination, a transmitter of wireless signals, said transmitter including a tuning element controlling the carrier frequency of transmitted signals, a first oscillator for modulating said signals, said first oscillator including a variable tuning device, and a second oscillator tuned to a predetermined spot frequency; means responsive to the altitude of the craft for actuating said tuning element in dependence on the altitude of the craft, whereby the carrier frequency of the signals becomes a measure of the altitude of the craft; means responsive to the azimuthal direction of the craft for actuating said tuning device in dependence on the direction of flight of the craft, whereby the modulation frequency becomes a measure of the azimuthal direction of the craft; and means responsive to the azimuthal direction of the craft for rendering said second oscillator operative for directions within one half of the azimuth circle and inoperative during the other half.

17. The method of communication between aircraft which comprises transmitting from a first craft a carrier wave, varying the frequency of said carrier wave according to the altitude of said first craft, modulating said carrier wave by

a first modulating wave, varying the frequency of said first modulating wave according to the azimuthal direction of the first craft over both halves of the azimuth circle, modulating said carrier wave by a second modulating wave during only one-half of the azimuth circle, thereby communicating the altitude and direction of said first craft; receiving said communication on a second craft, said receiving comprising the steps of cyclically scanning said carrier wave through a band of predetermined width, varying the location of said scanned band according to the altitude of the second craft to derive an indication of altitude of said first craft, and deriving an additional signal from said first and second modulations to determine the direction of said first craft.

18. In a communication system of the character described including a transmitting craft having a transmitter sending a carrier wave whose frequency varies with the altitude of the transmitting craft, said carrier being modulated by a first modulating wave; a receiving craft comprising periodically operated power means including a rotatable member, a radio receiver including means operated by said power means for periodically tuning said receiver to successive frequencies on a band of carrier frequencies, altitude indicating means including a rotatable element coupled to said rotatable member and an element cooperating with said rotatable element to provide an indication, one of said elements being connected to be actuated in response to the receiver output whereby the altitude of said transmitting craft is determinable from the relative position of the two elements at the instant of reception, indicating means including modulation wave responsive means operated by the output of said receiver in dependence upon the transmitted modulated wave of the transmitting craft.

19. In a communication system of the character described including a transmitting craft having a transmitter sending a carrier wave whose frequency varies in proportion to the altitude of the transmitting craft, said carrier being modulated by a first modulating wave whose frequency varies with the direction of flight of the transmitting craft, said carrier wave being modulated by a second modulating wave for flight directions within one half of the azimuth circle; the combination with a receiving craft comprising periodically operated power means including a rotatable member, a radio receiver including means operated by said power means for periodically tuning said receiver to successive frequencies of a band of carrier fre-

quencies, altitude indicating means including a rotatable element coupled to said rotatable member and an element cooperating with said rotatable element to provide an indication, one of said elements being actuated in response to the receiver output whereby the altitude of said transmitting craft is determinable from the relative position of the two elements at the instant of reception, direction indicating means including a first modulation wave responsive means operated by the output of said receiver in dependence upon the first transmitted modulated wave to give over both halves of the azimuth circle an indication corresponding to the direction of flight of said transmitting craft, and second modulating wave responsive means responsive to said second transmitted modulating wave for visually distinguishing between the opposite halves of the azimuth circle.

20. In a communication system for aircraft, a first craft having a transmitter comprising means for transmitting a wave whose frequency has a value dependent upon the magnetic heading of the transmitting craft, the value of said frequency varying between maximum and minimum as the craft's heading changes from opposite points of the azimuth circle, said transmitter having means for transmitting a wave of a second and fixed frequency for headings corresponding to one-half of the azimuth circle between said opposite points; a second craft having a receiver comprising means for deriving said first wave for indicating headings between said opposite points, and means for deriving said second frequency for determining in which half of the azimuth circle said first means shall indicate.

21. In a communication system for aircraft, a first craft having a transmitter comprising means for transmitting a carrier wave, means for modulating said carrier wave with a modulating frequency having a value dependent upon the magnetic heading of the transmitting craft, the value of said modulating frequency varying between maximum and minimum as the craft's heading changes from true north to true south, said transmitter having means for modulating said carrier wave with a second and fixed modulation frequency for headings corresponding to one-half of the azimuth circle between north and south; a second craft having a receiver comprising means for deriving said first modulating wave for indicating headings between north and south, and means for deriving said second modulating wave for determining on which half of the azimuth circle said first means shall indicate.

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