My invention relates broadly to systems of radio navigation and more particularly to improved methods and circuit arrangements for radio beacons and panoramic reception systems for use in navigation of mobile bodies.

In U.S. Patent No. 2,279,151, for Panoramic Radio Receiving System, granted April 7, 1942, and U.S. Patent No. 2,273,914, for Radio Navigation System, granted February 24, 1942, I have shown that, by means of a panoramic receiver installed on board of a plane, it is possible to observe one or a plurality of signals which are radiated from transmitting stations located at danger points, such as mountain peaks, for warning the pilot of the approach of the plane to terrain which may be hazardous to aerial navigation.

One of the objects of the present invention is to provide a system for equipping a body, whether fixed or mobile, with a signal generator which emits a character-istic signal of a warning nature for indicating hazards to navigation.

Another object of my invention is to provide a system for emitting a signal of such a nature as to in-form those who receive it of the altitude of a fixed or mobile body equipped with the apparatus of my invention.

A further object of my invention is to provide an arrangement of a signal generator that can be synchronized with a receiver on board of a mobile body in such a manner that the signal supplied by the generator does not inter-fere with the reception of another signal on the same frequency originating from another mobile body.

Another object of my invention is to provide means for

creating a signal which gives directional information such as the direction of motion of a mobile body, or the direction of the wind at the location of a fixed body for navigational or landing purposes.

A further object of my invention is to provide a remote system for giving an additional set of information by means of transmitted signalling energy such as local pressure at a given location.

Still another object of my invention is to provide a system for imparting the knowledge of the wind velocity at a predetermined location by means of transmitted signalling energy.

Another object of my invention is to provide simple apparatus for the reception and convenient interpretation of signal indications, and information which can be received visually or both visually and aurally, so as to give a warning to the operator immediately upon receipt of any such signal.

A further object of my invention is to provide simple transmitting and receiving apparatus for providing navigational information without moving parts and with all the circuits electronically-controlled.

Still another object of my invention is to provide complementary receiving apparatus capable of giving navigational indiciations received from such transmitters, also fully electronically-controlled.

A further object of my invention is to provide an electronically-controlled transmitter capable of changing both its frequency and directivity at such a rate as to make the signals appear on a panoramic receiver as if

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simultaneously transmitted, thereby permitting the use of
one-half the effective power required by transmitters
operating continuously and reducing the problems due to
interference between two transmitters.

A still further object of my invention is to provide
special dual-frequency beacons which give a directly-
interpretable indication of direction of "on course", or
right, or left, by producing on the screen of a panoramic
receiver signals which are either symmetric or asymmetric,
higher to the right or left, and corresponding to the side
on which the observer is located with respect to the beacon.

Another object of my invention is to provide a system
for efficiently utilizing the available frequency spectrum
by distributing, along an airline, beacons the average
frequency of which varies proportionally to their distance
from a point of origin and enabling an observer to identify
their location from their average frequency and accordingly
to also watch the progress along a line of navigation. Such
a system is also very economical of the frequency spectrum
because it permits using it continuously without "gaps" due
to the necessity of separating fixed channels.

A still further object of my invention is to provide a
simple system for distinguishing between beacons of a given
system and others of another system, although such beacons
may use the same portion of the frequency spectrum, by
changing the rate of frequency change from one system to
the other. This is rendered possible by the use of
panoramic receivers having means for varying at will their
rate of frequency sweep so as to make it correspond to the
rate of frequency variation, or of a harmonic thereof, of

a dual-frequency beacon. This feature permits the elimination of sources of periodic noises such as those produced by vibrators, motors, etc.

Still another object of my invention is to provide a receiver which can simultaneously indicate the presence of any obstacles above or below the observer, and also how far above or below these obstacles the observer is situated, and to control a warning local transmitter and at the same time indicate a plurality of dual beacons. Such a receiver uses one common indicator which can give all these indications simultaneously.

Another object of my invention is to provide a dual-directional panoramic receiver which can instantaneously indicate the direction of each of a plurality of transmitting stations independently of their transmission pattern characteristics. I describe herein such receivers in which there are no moving parts, all functions being carried out electronically.

A still further object of my invention is to provide a simple transmitting apparatus which can automatically give an aircraft pilot all the indications required in case the pilot wishes to make a blind landing, such installations being practicable for installation and maintenance in emergency landing fields where no attendants are present.

Other and further objects of my invention will be apparent from the specification hereinafter followed by reference to the accompanying drawings, in which

Figure 1 is the diagram of an altimeter-controlled transmitter embodying my invention; Fig. 1A is a block

diagram showing the interconnections between an altimeter, a transmitter and a receiver according to my invention; Fig. 2 is another block diagram showing in a more detailed form the principal parts and their relationship in a fully electronically-controlled panoramic receiver, and of an altimeter-controlled transmitter, said receiver tuning off the transmitter automatically so as to prevent interference between the two; Fig. 3 represents a series of curves showing the action of various elements shown in Fig. 2; Fig. 4 is a detailed diagram of a receiver such as shown in Fig. 2; Fig. 5 is a block diagram of another electronically-controlled receiver and transmitter similar in function to those shown in Fig. 2, but covering two distinct portions of the frequency spectrum; Fig. 6 shows details of the special elements used in connection with the apparatus shown in Fig. 5; Fig. 7 shows a series of curves explaining the action of various elements of Fig. 5; Fig. 8 shows a special dynamically-balanced condenser combined with a synchronous commutator for obtaining mechanically whatever may be obtained electronically; Fig. 9 is a diagram of an apparatus in which the device of Fig. 8 is used; Fig. 10 shows a commutator and its connections for obtaining a square-wave current; Fig. 11 shows how the devices of Figs. 8 and 10 are used in a two-band mechanically-controlled panoramic receiver; Fig. 12 is a diagram explaining the action of the various parts of Fig. 11; Fig. 13 shows a combination between an electronic source of sweep voltage and a mechanical commutator and variable condenser and the method of synchronizing these elements; Fig. 14 shows in block form the principles used in a dual-

frequency beacon according to my invention; Fig. 15 shows

how a plurality of alternately-keyed dual-frequency beacon

signals appear on the screen of a panoramic receiver and

the type of calibration used on such receiver to determine

the ratio between two signals; Fig. 16 is a diagram of a

mechanically-controlled alternately-keyed dual-frequency

beacon; Fig. 17 is a block diagram of an electronically-

controlled dual-frequency beacon in which a master

oscillator gives alternately two different frequencies;

Fig. 18 is a diagram of the transmitter shown in Fig. 17;

Fig. 19 is a block diagram of a simplified transmitter in

which only two oscillator-transmitters are alternately

keyed; Fig. 20 is a sketch showing how remote points can

be found by the use of two dual-frequency radio range

beacons; Fig. 21 shows the appearance of the screen and

dial arrangement of a dual-band panoramic receiver showing,

simultaneously, a plurality of beacons, their geographic

position and also a plurality of obstacles and their

respective altitudes with respect to the observer; Fig. 22

is a reversible transmission pattern of a dual-frequency

beacon creating an equi-signal path; Figs. 22a and 22b

show how certain signals transmitted from a transmission

pattern such as shown in Fig. 22 appear on a panoramic

receiver; Fig. 23 is a diagram of a wind-controlled

directive beacon; Fig. 24 shows how a plurality of ships

having dual-frequency beacons can keep going in a definite

formation; Fig. 25 shows in block diagram form a dual-

directional panoramic receiver electronically-controlled;

Fig. 26 shows the indicating screen of such a receiver

and how various signals are visually reproduced; Fig. 27

is a diagram of a receiver represented in Fig. 25; Fig. 28
is a modified form of a part of a receiver of the type
represented in Fig. 25; Fig. 29 shows a further modified
and improved form of circuit embodying my invention and
Fig. 30 represents the transmission patterns of a dual-
frequency glide-path indicating beacon.

In the carrying out of my invention, advantage is
taken of the properties of a panoramic receiver, such as
described in my copending applications, supra.

In the system of my invention, I provide means
capable of:

1.   Continuously observing the variations of field
     strength of two or more signals.

2.   Observing the variations of frequency of two
     or more signals.

3.   Determining the frequency of modulation of any
     signal by synchronizing the receiver rate of
     frequency sweep with the modulation of the
     transmitter.

A signal is generated from the fixed or mobile body,
a signal whose frequency is characteristic of the altitude
or of the local pressure at the location of that body. A
portion of the frequency spectrum must be assigned for the
purpose of these indications and is subdivided according to
a predetermined manner so that a given frequency corresponds
to a given altitude. For example, if for altitude zero
(corresponding to seal level) the frequency $F_{min.}$ is assigned
and for an altitude of H feet a frequency $F_{max.}$ is allotted,
any intermediary altitude, for example $\underline{h}$, can conveniently
correspond to a frequency $F_h = F_{min.} + \dfrac{h(F_{max.} - F_{min.})}{H}$.

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Instead of this simple linear frequency versus altitude distribution other functions can be determined, which instead of being linear can be, for example, exponential, the frequency varying proportionally to the percentage of altitude variation, etc. An element such as an altitude or pressure-indicating instrument is employed for controlling the frequency-determining circuit of the signal generator.

For example, as shown in Fig. 1, an aneroid barometer 1 is made to vary the distance between plates 2 and 3 which are electrically insulated from each other by means of insulator 4. The capacity of the resulting condenser 2-3 varies according to the local pressure as impressed upon the barometer. This condenser operates to tune an inductance 5 and the whole tuned circuit determines the frequency of oscillation of a tube 6. This is a simple type of local pressure or altitude indicating oscillator and forms the basis of other arrangements of my invention described hereinafter.

Such oscillators can be mounted on the various landing fields in different geographical locations so as to inform the incoming pilots as to the actual local pressure and to permit the correction of their pressure-controlled altimeters. In order to effect this correction the pilot must know what the actual altitude of that field is, which information can be obtained from proper charts. The pilots can read in these charts what would be the normal pressure and, from the reading obtained from the frequency of the oscillator, the positive or negative correction of the altimeter is indicated.

The readings of the indications given by such oscilla-

tions are best made with a panoramic receiver such as des-
cribed in my copending applications, supra. The screen of
the cathode ray tube, which is the visual indicating means
used in such receivers, can be calibrated in frequency or,
preferably, in altitude, and, from the position where such
a signal appears on the screen, the altitude or local pres-
sure is indicated.

If the signal generator is mounted on board of an air-
plane also equipped with a panoramic receiver which tunes
in the "altitude band" of the frequency spectrum, the
locally generated signal covers that part of the screen
which corresponds to its own altitude. If another airplane
is in the proximity of the first, and at the same altitude,
the observer will not be able, therefore, to distinguish its
signal on account of said local signal.

In order to avoid this I provide a combination between
the local signal generator and the receiver in such a manner
that the latter controls the first. By means of a synchron-
ous switch, which can be either mechanical or electronic,
the transmitter is shut off entirely, or only reduced in
power, periodically, every time the receiver tunes through
or must indicate a frequency close to that of the local
transmitter.

An electronically-controlled combination of transmitter
and receiver is shown in Fig. 2 in the form of a block
diagram for explaining my invention. The panoramic receiver
illustrated consists of a signal input circuit A, an oscilla-
tor B, a mixer C and two channels of intermediate frequency
amplification D and E. The oscillator is periodically tuned
over a band of frequency by a frequency-modulating tube F

which, in turn, is controlled by a sweep voltage generator G. This generator produces the source of sweep voltage applied to one set of deflecting plates of the cathode ray tube H. The intermediate frequency channel D is sharply tuned and the signals passing through it are detected and applied to the other set of deflecting plates of the cathode ray tube.

The parallel channel E is broadly tuned or tuned slightly off the frequency of channel D and develops at its peak a much weaker signal than channel D. However, over certain portions of the frequency spectrum immediately adjacent the band pass characteristics of the channel D, it develops a stronger signal.

This is illustrated in Fig. 3 in which the abscissa represents the frequency variation (or time variation, the two being linked together) and the ordinate represents gain of channels D and E or power developed by oscillator transmitter J.

Supposing that the oscillator transmitter J emits a signal on frequency f_h, and the panoramic receiver starts tuning from a frequency F_{min}. towards a frequency F_{max}. As it approaches frequency f_h it passes through a region F_1-F_2 when the I.F. channel E develops an impulse which is applied at once to a keying tube which triggers off the transmitter J (see curve J on Fig. 3) before or almost at the time when the channel D could start building up a signal from the transmitter. The time constants of the trigger circuit are such as to maintain the transmitter turned off during a predetermined time interval equivalent to a variation of frequency of F_2-F_3, and when the oscillator starts again its frequency is out of the tuning range of the receiver, so that

the latter is unaffected by the presence of that local sig-
nal. The signals picked up by the channel D are detected,
amplified and applied to the other set of deflecting
plates of the cathode ray tube H. These signals will al-
ways be synchronized with the sweep applied to the first
set of deflecting plates, so that each deflection will
appear stationary in a position determined by the frequency
of the signal and of an amplitude determined by the signal
strength.

In parallel with the cathode ray tube it is possible
to feed an audible device such as a loud-speaker or head-
phones. This is important in case of collision warnings.
The speed of the planes being great, it is possible that
the pilot may not be aware of the appearance of a visual
danger signal on the screen, but his attention would be
drawn at once if this signal were to produce a distinct-
ive noise in the loud-speaker, which is exactly what
happens. This is a very important feature of my inven-
tion which adds to the safety of the flier.

Automatic volume control can be incorporated in the
panoramic receiver, as will be described hereinafter.
The effect of this control upon the signals is that it
will prevent a signal from building up in amplitude beyond
a given point and, instead, will compress the other signals
weaker than it, so as to maintain their amplitudes an in-
dication of their field strength.

In the circuit diagram of Fig. 4 the input circuit A
is constituted by a receiving antenna 8, an inductance
tuned by condenser 9 and an amplifier tube 12. The
frequency-modulated oscillator B is constituted by the tri-

ode 14 and a circuit tuned by condenser 11. Directly
connected to the tuned circuit of this oscillator, I show
the frequency modulating channel F constituted by a
thermionic tube 15 which acts as a reactance in parallel
with said tuned circuit. By properly adjusting the phase
relationship between the input and output circuits of
tube 15, as determined by capacities, resistors and choke
(40, 41, 42) the reactance of this tube will increase or
decrease the frequency of the oscillator 14 by an amount
depending on the voltage impressed on the grid 43 of the
tube 15 and in a direction depending on its polarity.

An alternating voltage, preferably produced by a saw-
tooth oscillator 16 and amplified by tube 17 (corresponding
to G in the block diagram), is fed to the variable react-
ance tube 15, through a potentiometer 26 and a voltage-
balancing potentiometer 70 which is shunted by a battery 71.
The adjustment of potentiometer 70 controls the biasing
voltage on the grid 43 and, consequently, the reactance
value of the tube 15 at the average saw-tooth voltage, and
determines, therefore, the average frequency at which the
receiver will operate, and potentiometer 26 controls the
amplitude of the voltage applied to grid 43 which in turn
controls the amount of frequency sweep of tube 15. The
frequency of the sweep voltage generator can be adjusted
by means of a multi-position selector switch 28 and the
plate voltage controlling rheostat 87.

The converter corresponding to C is tube 13 whose
grid 44 is coupled to the input amplifier tube 12 and
frequency-modulated oscillator 14. The converted signal
is developed in the I.F. transformer 45 having two second-

aries shown at 36 and 37. The secondary 36 is tuned to the same frequency as the primary of transformer 45 and feeds the high gain sharply tuned channel corresponding to D composed of two amplifying stages comprising the tubes 18 and 19 and transformers 46 and 47.

The signals are then detected and reamplified by means of a combined diode-triode thermionic tube 20. One diode plate 48 applies the rectified signal to a load 54 and the voltage drop through it is used to automatically control the gain of the amplifying tubes 18 and 19 by applying appropriate voltages at their grids through resistors 50 and 51 which are by-passed with condensers 53 and 52. The action of this automatic volume control is very important in the operation of the system of my invention.

The other diode 49 is connected to the diode 48 by means of a condenser 55 and develops a rectified pulsating current which is applied to an amplitude-controlling potentiometer 30 and from there through a condenser 56 to the grid of the triode section of the tube which acts as a low frequency amplifier of the pulsating current.

A potentiometer 31 is provided for the important function of "thresholding" the signals. This operates as follows: The anode 49 of the diode-triode tube 20 is returned to the power supply circuit by means of resistors 72 and 73 to this potentiometer 31 a leg of which is at ground potential. The anode potential is taken from the cathode ray elements power supply 74 which is dropped to ground potential through a series of resistors including 75, 76, 77 and 78, some of which act as "focus" and intensity controls for said cathode ray tube.

By being able to make the anode 49 of any potential
desired from zero up to a few hundred volts negative, it
is possible to cut out or prevent detection of any signal
which does not exceed a desired value. This control acts,
consequently, as an adjustable threshold device which is
useful for eliminating either noises (which are below the
signal levels) or weak signals which are not interesting
to the observer and which may confuse him. This threshold
potentiometer can be calibrated in field strength, whether
micro-volts or decibels, for measuring the field strength
of any signal. It is therefore useful also for measuring
the difference between the deflection amplitudes of two
signals.

The potentiometer 30, which controls the amplitude of
the signals applied to the output device, will cut all
signals in such a manner as to reduce them all in the same
proportion. Therefore, the signal ratios remain constant.
However, by using the threshold control we change the
ratio between the signal amplitudes and this becomes use-
ful when we want to exaggerate or emphasize the difference
of two signals nearly equal in amplitude as is necessary
in the dual-frequency beacons described hereinafter.

The pulses resulting from the reception of a series of
stations are of extremely short duration, this depending
upon the frequency of the sweep-voltage and the total
frequency band covered and the selectivity of the I.F.
stages. This means that the amplifier must have certain
frequency characteristics which permit the amplification of
sufficiently high frequencies of the order of a few
thousand cycles per second. These frequency characteristics

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are determined by the values of the grid, plate and cathode resistors 57, 58, 60. A resistor 59 connected to the high voltage source maintains the exact bias required under conditions of varying load. The amplified pulses are applied through a condenser 61 to one deflecting plate 62 of the cathode ray tube 23, but can also be connected by means of switch 35 to an auditive output device 34 for audible warning. The potentiometer deflecting plate 63 of the cathode ray tube is connected to the sweep voltage generator 16 after amplifying its output through tube 17. The frequency of this sweep is sufficiently high to produce a rapid sweep of the cathode ray beam which appears substantially flickerless on the fluorescent screen of the cathode ray tube.

The secondary 37 of I.F. transformer 45 feeds the transformer 64 which is connected to a diode detector and amplifier tube 21 which corresponds to the amplifying channel E of Fig. 2. A very strong signal produces across the condenser 65 and resistor 66 a substantial negative voltage which is applied to the grid of a keying or trigger tube 22, (corresponding to I). The plate of this tube is connected to the cathode of the transmitter oscillator tube 6 whose frequency is controlled, as explained hereinbefore, by the variations of pressure as impressed upon barometer 1.

The tube 22 offers the proper amount of resistance in the cathode of the oscillator 6 when no signal is applied to the grid 68, which is returned to ground by the grid resistor 67.

The signal however builds up on the condenser 69 and grid 68 a negative voltage which triggers off the plate

current of tube 6 which stays shut off until the charge of condenser 69 leaks out through resistors 66, 67.

The time constants of this circuit can be adjusted to keep the transmitter turned off just the length of time desired, as explained hereinafter.

The voltage developed by the tube 21 is very low even when signals of a few thousand micro-volts are present, as may be received from powerful nearby stations, but is great in the presence of the local signal which builds up to several hundred thousand micro-volts in that stage before the sharply tuned stages 18, 19 have time to build a sub-stantial signal. A variable coupling between the primary and secondary of transformer 64 permits the proper adjustment of the cut-off of the local transmitter. The tuning of this primary and secondary is such as to make it act as a filter of broad band pass characteristics.

All the potentials required for the panoramic receiver are produced by a common source of power supply and all can have a common ground return to the chassis.

The panoramic receiver described herein can be made to cover a rather substantial band by ganging the condensers 9, 10, 11. The electronic sweep will produce a panoramic reception effect on the screen of the oscillograph 23 of a band of frequencies whose width can be adjusted by the potentiometer 26. If the constants of the circuit of tube 15 are properly adjusted it is possible to make the frequency shift of the oscillator 14 equal both above and below its natural frequency, which permits a panoramic observation of the band immediately above or below a given "centre frequency". If the total band which must be covered is not

too great the input stages 12, 13 may be made of sufficient-
ly broad band pass characteristics to avoid the necessity
of tuning the condensers 9 and 10 and still obtain substan-
tial linearity of response over the desired band.

In this case we can vary the "centre frequency" of the
panoramic receiver either by adjusting the oscillator
condenser 11 or by adjusting the centre arm of biasing poten-
tiometer 70. This variation can take place either manually
or automatically and in the latter case it can be effected
by either the same barometer 1 which controls the transmitter
oscillator by mechanically linking it to condenser 11 (or
potentiometer 70), or by another similarly constructed
barometer (or altimeter). In Fig. 4 I have shown a dotted
line between 11 and 1 to show a mechanical link.

This control of the condenser 11 by an altimeter will
permit a constant returning of the "centre frequency" of
the panoramic receiver, this centre being at all times at
the frequency corresponding to its altitude, and the fre-
quency produced by the local oscillator-transmitter J. The
frequencies above and below it represent altitudes above
and below it and the band covered can be such as to cover
an altitude of, for example, 2500 feet above and 2500 below
the airplane. This is useful if the frequency assignment
covers a relatively wide band so as to take care of very
great altitudes. The ceiling of modern planes increases
continuously and if we would have to cover on a few inches
of an oscillograph screen all the band the readings may be
difficult to make or would not have sufficient accuracy.

With this method, however, of centering the observa-
tion and limiting it to a certain height above and below,

this objection is removed and, besides, the pilot has all the warning and information be wishes, as he is not interested in what happens too high above or too far below him.

This centering of the local altitude, corresponding to the frequency of the locally generated signal, greatly simplifies the design of the commutator controlling this signal. This commutator can be either mechanical or electronic, acting every time when the receiver tunes through the centre region of its band.

Such a continuous adjustment of condenser 11 would not be required for a receiver used on the control tower of an aerodrome which would wish to observe the whole altitude band at any time, but in these cases a very large diameter oscillograph may be used and a mechanically-controlled panoramic receiver provided which can be made to cover conveniently very wide frequency bands.

In my copending applications, supra, I have shown how I can simultaneously receive on a panoramic receiver two bands of frequency which can be observed on two different portions of the oscillograph tube. This is a very important requirement if the receiver is to be used for navigational purposes, avoiding as it does the carrying on board of several receivers. It may be assumed, for example, that the flier wishes to follow a string of radio range beacons of any dangerous obstacle, fixed or mobile. The beacons may operate on one band of frequencies and the collision signals on another band. An electronically-controlled receiver showing simultaneously two bands of frequencies can be used advantageously for the purpose.

The principle of its operation, as distinguished from the first, is the following: Synchronously with the saw-tooth generator I provide means for generating a "square-wave" alternating current. This is composed of a series of electrical impulses of a constant amplitude of half the frequency of the saw-tooth wave, each having a duration equal to the duration of each "saw-tooth" impulse. These impulses are intermittent, each being followed by an equal time period when no current is generated.

Fig. 7 shows on its lower part as M three cycles of such square-wave pulsating current impulses; N represents six cycles of the saw-tooth synchronous alternating current impulses and N+M represents an alternating current resulting from the combination or addition of these two types of impulses. The frequency controlling tube 15 (F in the block diagram, Fig. 5) in which I provide a circuit for feeding a current such as the one represented as N+M will alternately cover two bands of frequency whose separation from each other will be determined by the amplitude of the square-wave input.

On the right side of Fig. 7 I show an ordinate repre-senting frequency variation as produced by such a combination wave in the variable frequency oscillator. It alternately covers the frequencies F_1, F_2 and F_3, F_4. The frequency separation between F_2 and F_3 can be reduced to zero by reducing the amplitude of the square-wave voltage or be increased to a maximum by increasing that voltage. It can, therefore, be seen that variations of amplitude of M will shift only one band of frequencies (F_3 to F_4) and will not affect the other band. This shift can be obtained by apply-

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ing the-square wave to a biasing potentiometer such as 70
(Fig. 4).

Fig. 5 represents another block diagram showing how
this receiver operates. The same letters are used as in
Fig. 2 for the common elements of the two types of
receiver-transmitter combinations. In Fig. 5 in addition
S represents the square-wave generator and T the mixer of
the saw-tooth and square-wave currents. Previously to
being mixed the saw-tooth component is applied to one of
the deflecting plates 63 of the cathode ray tube and the
square-wave component to another deflecting plate 62,
normal to the first, where it is combined with the signal
from the channel D.

The effect of this application of the square-wave is
to recurrently, and at the end of each cycle of the saw-
tooth wave, shift the reference zero line of the cathode
ray tube so as to alternately obtain two parallel lines
on which the signals contained in the bands F_1 to F_2 and,
respectively, F_3 to F_4 are appearing.

The linear separation between these parallel lines
is a function of the amplitude of the square-wave voltage
applied to the deflecting plate, and this is controlled
through any appropriate means. The mixing can be obtained,
for example, directly in the frequency modulating element,
by applying the saw-tooth voltage as shown in Fig. 4 and
the square-wave voltage to biasing potentiometer 70.

Fig. 6 shows a detailed diagram of the elements G, S
and T of Fig. 5. Tube 80 is a double triode the grids of
which are cross-connected in such a way that each triode
section becomes alternately blocked. The frequency of this

blocking action is determined by the rate of charge and discharge of condenser pairs 84, 85, 86 (groups a and b) a pair of which are selected by switch arms 88a and 88b, and also by the value of the dual rheostats 87a and 87b.

Another tube 81 acts as a saw-tooth oscillator and the frequency-controlling elements, that is, condensers 84c, 85c, 86c and rheostat 87c, are so chosen that they produce a saw-tooth current of practically the same frequency as the square-wave current.

The synchronism is completed, however, by connecting the grid 89 of tube 81 to one of the plates of the tube 80. The frequency control of both tubes is therefore obtained by single controls 88a, 88b, 88c and 87a, 87b and 87c.

Tube 82 is another double triode which is used in the event that high signal voltages are required. Tube 82 acts as an amplifier in connection with the saw-tooth and square-wave oscillators.

The amplitude controls 92 and 93 are used to control the voltage of the deflecting currents put into the vertical and horizontal deflecting plates respectively, of the cathode ray tube and the amplitude controls 94 and 95 are used to control the voltages applied to the grids of the mixing tube 85 (T in Fig. 5). The mixed current obtained from the plates of this tube is applied to the frequency-controlling tube F.

The same results, as obtained by purely electronic means, can very well be obtained by either purely mechanical or combined electronic and mechanical means. The mechanically frequency-modulated oscillator is quite practical and readily made. A rapidly-rotating motor-driven condenser

produces the frequency shift required. One precaution,
however, must be taken. This is to avoid frictional
contacts in the tuned circuit, which are invariably noisy,
mostly on high frequencies. The best method to avoid this
is by using floating rotors which are not connected to the
circuit except through their varying capacity to two
opposite stators. Another precaution which must be taken
is to properly balance the rotors dynamically, so as to
avoid vibration. This can be obtained by using rotors
having several blades, two or three or more.

The effect of such multi-bladed rotors is to speed up
the number of images for a given motor speed. In ultra-high
frequency work, where the periodical variation of capacity
required is quite small and amounts only to a few micro-
microfarads, I prefer to obtain the capacity variations
necessary by simply rotating a dielectric of high constant
between two stator plates connected in the tuned circuit.
Several such dielectric rotors can be coupled on one shaft
to tune as many circuits as required. One of these rotors
can be used for mechanically producing a source of sweep
voltage by the periodical charge and discharge of a
condenser, as described in my U.S. Patent No. 2,279,151 and
my U.S. Patent No. 2,273,914. Fig. 8 is an example of such
a construction in which 96a, 96b represent the two blades
of a dielectric rotor having a 90° opening and rotating
between one or two pairs of stator blades 97a, 97b and 98a,
98b. We have in fact two distinct variable condensers which
can be used in two different circuits or can be connected
together for obtaining a larger variable capacitor.

The centre of this rotor has a metal bushing 99 which

is grounded through the shaft 105 of the motor 106 (Fig. 9)
rotating it, and also two small metal sectors 100a, 100b
connecting each of the blades 96a and 96b. A brush 101
rides alternately either over the dielectric or over the
grounded metal sectors in such a way as to pass from metal
to dielectric exactly at the moment of maximum or minimum
capacity of the condenser. This brush periodically dis-
charges condenser 102 to ground which condenser becomes
charged through a resistor 103 when the brush rides over
the dielectric.

The condenser 102 becomes a mechanical source of sweep
voltage which is noiseless because the only frictional
contact which takes place is to either the dielectric or to
a grounded part of the receiver which is not a part of the
tuned circuit.

The electrical connections of such a synchronized di-
electric condenser and sweep voltage generator are shown
in Fig. 9 in which, for the sake of simplicity, I show only
one periodically-tuned circuit, an oscillator which may be
the element B of the block diagrams. The synchronized
condenser and sweep generator replace the elements F and G
of those diagrams.

By a slight addition to this construction, I can ob-
tain an alternating coverage of two bands shown on two
different lines on the screen of the cathode ray tube, as
shown in block diagram Fig. 5.

On the same shaft 105 of this rotor, I mount a com-
mutator composed of two equal sectors 107 and 108, Fig. 10,
of double the opening of the blades 96a, 96b, that is 180°.
One of these sectors is of metal and grounded to the shaft,

and thence to the chassis; the other sector is of an insulating material. A brush 109 is connected to a high resistance potentiometer 110-111 connected on one side to a source of direct current (anode supply for example) and grounded on the other side. This brush will be alternately at a certain voltage or at ground potential as the commutator rotates; a square-wave is consequently created, mechanically, which can serve through condenser112 for shifting the image on the cathode ray tube as explained before. The same commutator can serve for alternately selecting one of two condensers which tune the oscillator circuit; it can also serve for mechanically shutting off or reducing the power of an altitude-indicating oscillator, as described above. Such a mechanical commutator can be made to open the cathode circuit of the oscillator for predetermined periods of time corresponding to the angle of the commutator sectors. The transmitter can be keyed off, for example, alternately during each part of that rotation cycle which produces images of signals on the screen of the receiver.

This can be better seen in Fig. 11 where, instead of having a condenser 11 permanently connected in the tuning circuit, I show two condensers 11 and 113, each being alternately connected through brushes, shown respectively at 114 and 109, to ground.

Two different frequency portions are then covered by the rotating condenser 96-97 previously described. By individually tuning the condensers 11 and 113, each band may be separately shifted. Condenser 11 can, as shown in Fig. 11, be controlled by a pressure-controlled device such

as an altimeter 1, and condenser 113 may be manually con-
trolled for special purposes, as shown hereinafter.

The block diagram of Fig. 5 can be fully adapted to
this arrangement.

The type of mechanically-produced sweep voltage just
described has one disadvantage: One-half of the images
are lost by grounding the condenser 102 half of the time.
This results in more tendency to flicker and less
brilliancy of the image, as evident from Fig. 12. I can,
however, advantageously combine electronic sweep and
mechanically-produced square-wave with elimination of this
disadvantage.

Figs. 13 and 29 show such arrangements. In Fig. 13
the condenser 102 has been replaced by a saw-tooth oscilla-
tor 16 whose grid 89 is synchronized with a mechanical
square-wave generator similar to the one heretofore
described, but using the 90° sectors 107a, 108a, 107b, 108b.

This form of sector alternately switches condensers 11
and 113 at double the rate obtained before. The number of
images obtained on the screen is double, because each
alternate saw-tooth cycle serves to put on the screen one
of the frequency bands covered.

In Fig. 29 I show a combination of electronic means
and mechanical means which permit the use of double the
number of images, with consequent double brightness of the
signals. Instead of using a motor which rotates a con-
denser I use, in this case, a loud-speaker unit 106A which
replaces the motor 106 and has a field coil 175 and a
moving coil 180 which bears a metal disc 97d whose distance
from a similar disc 97c can vary at a rate which is determined

by the vibration of said moving coil.

These discs are in fact the armatures of a periodically-variable condenser of a panoramic receiver, such as shown as 96-97 in Fig. 9. The rate of frequency variation of this condenser is determined by the rate of vibration of the moving coil 180 which rate is determined by an alternating current produced by the sweep voltage generator 16 and amplified by tube 177.

This frequency can be adjusted at will by variable adjustments 87 and 28. The extent of frequency variation is determined by the amplitude of vibration of said moving coil 180 and condenser plate 97d and this is adjusted by means of potentiometer 176. The same potentiometer controls also the extent of the movement of the cathode ray beam, so that by increasing or decreasing the frequency band the extent of the sweep may be automatically extended or decreased. A separate potentiometer 178 at the output of tube 177 permits adjustments of the sweep which are independent of the frequency adjustments. Naturally there is a perfect synchronism between such a frequency variation and the sweep, their source being pulsating current produced by the same tube 16. This arrangement has also the advantage of being able to follow much greater speeds than a double blade motor-driven condenser, and is free from frictional noises.

In Fig. 1 I have shown a simple transmitter-oscillator whose frequency is controlled by the local atmospheric pressure. I shall now show how I can supplement this information with that of a direction which may be readily interpreted to indicate a given course or to directly in-

dicate "right" and "left" with respect to said course. Two
transmitters have to be used instead of one, each operating
on a frequency slightly different from the other, and each
emitting a directional signal in such an angular relation
to the other as to create an equi-signal path along said
course.

Fig. 14 shows such an arrangement in which T_1 and T_2
are the transmitters feeding, respectively, into the
dipoles A_1 and A_2 at right angles, whereby the courses X_1, X_2
and Y_1, Y_2 are created. Supposing now that a panoramic
receiver is covering a frequency band of 2.5 mc., for ex-
ample, from 122.5 to 125 mc., spread over 2.5 inches of a
cathode ray tube screen. One-eighth inch separation between
two signals would mean 0.125 mc. If the two signals produced
by T_1 and T_2 are, in other words, 0.125 mc. apart from each
other, they will appear on the screen as two deflections at
1/8" separation. If the observer is on the equi-signal path
the peaks of the two signals will appear equally high. If
he is on one side or the other, one peak or the other will
predominate. The amplitude ratio of the two signals will
indicate the number of degrees off course.

This is very useful when the pilot wishes to keep with-
in a certain fixed angular direction with respect to such
a beacon. He adjusts the amplitude of one signal so as to
bring its peak at a given reference line and he can read
from the height of the other signal the angle "off course"
on a calibrated screen.

Fig. 15 shows such an arrangement of a screen. Natural-
ly, this presupposes the use of a series of such beacons,
each sending radiations having similar patterns; in other

words, the use of standardized and properly adjusted antenna structures.

I have found that it is essential to keep the difference of wave lengths between these signals as small as possible, so that the number of wave lengths travelled by each signal within 4-5 miles from the station - where the signals are generally more erratic and more subjected to the effects of reflection from obstacles - should be substantially equal, or differing only by one or two wave lengths. This practically reduces to zero the number of points where false indications would be obtained if this difference were greater. This is a fundamental part of my invention, distinguishing it from the usual type of dual-frequency radio ranges where no special precautions are taken to maintain this wave length separation within a minimum value. The panoramic receiver can be made of sufficient selectivity to distinguish between two carriers of any frequency separation, as there are no interfering side-bands such as would be produced by modulating such carriers.

Two signals of very close frequency with their antenna elements quite close to each other are difficult, however, to maintain properly tuned. There is a tendency for these two signals to "pull" each other in synchronism or to create side-bands by becoming intermodulated.

By proper shielding precautions it is possible to run the two transmitters together.

I can, however, completely avoid these difficulties by sending signals intermittently through each antenna in such a manner that when one is on the other is off. This switching of the antennas, each operating on a predetermined

different, and adjacent, frequency, can be obtained either mechanically or electronically. The first method has the advantage of great simplicity.

Fig. 16 shows such an arrangement in which a master oscillator 116 in the dotted rectangle has a frequency determined by inductance 117 tuned by either condenser 118 alone or by condensers 118 and 119 in parallel. Condenser 119 may be set either to a definite frequency or controlled by a device 1. These two condensers are periodically connected in parallel by a rotary commutator 120-121, turned by a motor 122. One half, 120, of this commutator is constructed of metal and is grounded. The other half, 121, of the commutator is insulated. Rapid commutation is obtained of the two frequencies F_1 and F_2 by the capacitance of condenser 119. Multiplying or buffer stages follow this master oscillator, and then a final amplifier 123 is provided. The output inductance 124 is connected to a commutator 125, 126 and 127 in such manner as to be alternately connected at each half rotation of this commutator with either antenna A_1 or A_2 (Fig. 14).

The position of all these commutator rings and segments is carefully arranged so as to obtain an absolute synchronism between the frequency switching and antenna switching. A common shaft 128 is used to rotate all these commutator rings. This mechanical system has the common disadvantage of requiring periodical maintenance. For this reason, as well as others described hereinafter, I prefer an electronically-controlled dual-frequency dual-directional system.

Fig. 17 shows in block diagram such a system. A master oscillator M periodically changes the frequency from F_1 to F_2,

as controlled by a frequency-determining circuit N which
in turn is controlled by a periodic current, preferably
from a square-wave generator O. The master oscillator may
be coupled to multiplying or buffer stages P, or be fed
directly into two final amplifiers T_1 and T_2. These
amplifiers are permanently connected to their respective
antennas A_1 and A_2, but only one operates at a time as the
keying tubes R_1 and R_2 alternately cut them off or block
their operation. These keying tubes are controlled by the
same square-wave generator O which controls the frequency
F_1 or F_2.

Fig. 18 shows the details of such a transmitter. The
parts corresponding to the block diagram Fig. 17 are
surrounded by dotted lines. Tube 129 is a square-wave
oscillator similar to tube 80 of Fig. 6. A push-pull ampli-
fier stage composed of tubes 130,131 follows it, the tube
131 acting as an amplifier phase-inverting tube. Part of
the square-wave voltage is applied through an amplitude-
controlling potentiometer 134 to the frequency-controlling
tube 132 which acts upon the oscillator tube 116 just like
the tube 15 acted upon the tube 14 in Fig. 4. The fre-
quency variation is determined by the adjustment of
potentiometer 134. The amplified push-pull square-wave
impulses are applied to the keying tubes 133A and 133B
which respectively bias or block the final amplifying tubes
123A and 123B.

These tubes receive their excitation from the master
oscillator 116, through the multiplying and buffer stages P,
and through a balance grid line 135. The two antennas A_1
and A_2 are permanently connected, but operate alternately and

only one-half of the total time.

As only one power amplifier draws plate and grid
current at any one time, the requirements of the power
supply are those of a single-ended transmitter. Further-
more, as each power amplifier has to dissipate current
only during one-half of the time, the tubes used can be
loaded up during the operation at much more than their
ordinary continuous ratings without harming them. The
plate and grid meters 136A, 136B and 137A, 137B, are used
for balancing the two amplifiers accurately.

Instead of using a master oscillator which is elec-
tronically-controlled, and followed by various stages
and power amplifiers, it is quite practical to use two
simple self-oscillating transmitters which work continu-
ously or are alternately keyed on and off like the final
amplifiers shown as 123A and 123B. This simplifies the
construction very much. Such a double oscillator is
represented in block diagram in Fig. 19 and can be
visualized in detail from Fig. 18 in which the stages M,
N and P, the grid line 135, and neutralizing condensers
138A and 138B are simply shunted. By using parallel line
plate and grid circuits of very high Q, and by not
heavily loading these oscillators, their frequency
stability is quite good and they make excellent simple
direct "right" and "left" indicating radio range beacons.
In the block diagram Fig. 19 I have also omitted the key-
ing tubes because the oscillator grids can easily be
controlled directly by the square-wave generator O which
applies sufficient voltage to entirely shut off each
oscillator alternately.

With reference to Fig. 18, this result would be obtained by connecting the two meters 137A and 137B, instead of to ground, to the cathode resistors 139 and 140 of the square-wave generator and replacing the tubes 133A and 133B by cathode biasing resistors.

In all these transmitter arrangements the frequency can be either preset or can vary within certain limits as controlled by a frequency-controlling element such as an aneroid barometer, as shown in Fig. 1. The two antennas, whose orientation determines certain courses, can either be fixed or of variable orientation and can be mounted either on a fixed body or on a mobile body. For example, such simple dual-transmitters of predetermined frequencies preset at a given small difference can be located at predetermined intervals along a navigational air line to determine a given line of flight. Such a line may extend in a curved course. By spacing such transmitters sufficiently near each other, and by properly setting each antenna, the flier can be guided along the given path. With a panoramic receiver aboard the pilot can see when the aircraft passes through the intersection of two such equi-signal courses.

Fig. 20 shows such a case where a series of such dual-frequency beacons S_1, S_2 and S_3 are so arranged as to lead a flier over a course S_1, P_{1-2}, S_2, P_{2-3}, S_3 in which P_{1-2} and P_{2-3} represent the surfaces determined by the intersections of the courses determined by S_1 and S_2, and S_2 and S_3, respectively. These intersections may be landing fields or other important points and it is important for some purposes to limit them to the smallest possible surface. It

can be shown that the area P of such a surface is a function of the two distances S_1 - P and S_2 - P of the angle ω between the two courses and the angular opening α of each course. That is to say, the angular opening within which a flier can determine that the aircraft is on the desired course is approximately determined by the following formula:

$$P = \frac{S_1 P \times S_2 P \times \sin^2\alpha}{\sin\omega}$$

It can be seen that this area varies proportionally to the square of the angle α and it is, therefore, important in such applications to use a very sensitive arrangement which shows at once when the aircraft is off course. The use of the threshold control on the panoramic receiver, as ex- plained hereinbefore, now becomes very important as it emphasizes small differences of amplitude between signals. Square-law detectors may also be used instead of linear- detectors for further emphasizing such differences.

Such an airline may use a series of such dual-frequency beacons whose average frequency (average between the two frequencies used) varies proportionally to the variation of distance of their location with respect to a fixed reference. This reference can be a line (a given meridian or parallel) or a point. In other words, let us say that the frequency band $F_{max.}$ to $F_{min.}$ is used to cover a distance of D miles extending between two such fixed references. Each dual transmitter uses two frequencies f_x and f'_x determined by a distance of x miles from one such reference. The average frequency

$$F_x = \frac{f_x + f'_x}{2} = \frac{x(F_{max.} - F_{min.})}{D} + F_{min.}$$

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A panoramic receiver on board of the plane covering such a route can be calibrated in miles and the flier can at all times see a plurality of such beacons along his course.

In order to extend the number of stations which can be used along the distance D, and not to crowd them too much on the screen of a cathode ray tube of relatively small diameter, I prefer to combine some manual tuning with panoramic tuning and, at the same time, use an indicator showing what part of the band is tuned in, this indicator being calibrated in units of distance.

Such an arrangement is shown in Fig. 21 in which 141 is the screen of a cathode ray tube and 142 is a slider which can move to right or left within certain limits by the action of idler pulleys 143, 144 and manually controlled pulley 145, over which a steel string 146 is wound. This string is connected to the two ends of the slider 142.

This slider can move so that either end of it can come in line with one extremity of the screen of the cathode ray tube. It is calibrated in miles, and their separation corresponds to the separation between signals appearing on the cathode ray tube screen; for example, as shown in Fig. 21, when all the way to the right it will show the stations from the reference point (zero miles) up to 200 miles and when all the way to the left it will show the stations from 200 miles up to 400 miles. This is obtained by connecting the pulley 145 with the shaft 147 of the rotor of a condenser 113 (see Figs. 11 and 13) or condenser 11 (Figs. 4 and 9). A frame in this

slider permits insertion of a card 148 showing in their
special relationship a series of beacon stations, for ex-
ample from Chicago to Erie. Each beacon station may
determine either a two-course or a four-course route
according to the type of aerials they use. A flier start-
ing from Chicago will set condenser 113 fully in, for
lowest frequency (F_{min}.) and the slider will, by this
motion, move to its extreme right position, and the be-
ginning of the dial on the left corresponding to distance
zero, indicating Chicago, will correspond to F_{min}. on the
screen. The dual-frequency beacons will appear one after
another, further to the right, as the flier progresses
along the course, several being seen according to the
height or distance of the flier. The observer can, if he
so wishes, gradually bring them to the centre and maintain
the true relationship between the readings on the card 148,
mileage indication on slider 142 and position of the signal
on screen 141. Such an arrangement as shown is the equiva-
lent of multiplying the diameter of the screen by two, and,
naturally, this can be multiplied still more if desired.
As the flier reaches the end of the course marked on the
card, he enters a new zone where the frequencies F_{min}.,
F_{max}. are repeated and he replaces the card 148 with a new
one, resetting his dial to zero miles. Such a receiver,
by reducing the sweep voltage applied through potentiometer
26 to the reactance tube, becomes an ordinary receiver
tuned at the "centre frequency" defined hereinabove. The
auditive device 34 will then reproduce the audible signals
of any station corresponding to that centre frequency and
which can be marked as a hairline on the centre of the

oscillograph screen (Fig. 21).

This dial arrangement can very well be used with a two-band panoramic receiver, such as shown in Figs. 5, 6, 7, 11, 13, in which one band is controlled by one manual setting such as just described (condenser 113), and the other band by an automatic setting (condenser 11) determined, for example, by an altimeter.

In Fig. 21 I show such a combination dial. Above the screen 141, a scale 148' of the diameter of the screen shows 0 in its centre and is calibrated in altitudes up to 2000 feet above to the right and 2000 feet below to the left of the centre line. An altimeter dial 149 gives the actual altitude which in Fig. 21 is 5200 feet.

A signal 150 appears on the screen, above the line of beacon signals, indicating the presence of a warning station about 1000 feet above the observer, in other words, at 6200 feet. This may be a mountain peak or another plane, and this matter is easily determined, as will be explained hereinafter, according to the rate of "blinking" or interruption of the signal.

In the first case the pilot knows that he must rise until the signal passes to the left of the centre line, that is, below him.

In the second case, certain traffic regulations are applied and, as each pilot either goes higher or lower, their respective change of position is seen by the two observers in their receivers.

The identification of stations can be obtained in various manners with a panoramic receiver and in ways impossible to be obtained with ordinary receivers.

One of the means which can be used is the rate of
interruption of a signal. From the foregoing explana-
tions, it results that either the dual-frequency beacons
or the collision warning signals sent by planes are
periodically interrupted signals. This rate of inter-
ruption corresponds to a modulation which can be
determined easily, provided that the frequency of the
sweep of the panoramic receiver is adjustable. This can
be obtained very readily with the electronically-
controlled sweeps shown and I have provided the necessary
controls for this purpose (see 84,87, Fig. 4). In a
mechanically-controlled receiver, continuously adjustable
speed devices must be used for this purpose, either by
varying the speed of the motor itself or of the devices
connecting the motor to the receiver.

By synchronizing the frequency of the sweep with the
frequency of modulation of a signal I can receive that
signal as if it were of unchanging nature because every
time the receiver sweeps through the frequency of the
signal, the signal is picked up at the same amplitude. If
such a signal is interrupted periodically a perfect syn-
chronism could cause it to be entirely absent in the
panoramic receiver. This can happen in case of the
collision signals sent by planes, which could be synchron-
ized by chance with a receiver, so that they would not be
received. This, however, would require a combination of
coincidental factors rarely met in practice, the two
receivers in two different planes would have to be swept
in absolute synchronism and be tuned to the same frequency
continuously. The chance of this condition occurring is

remote and is further reduced by reducing the total inter-
ruption time of the collision warning transmitter to the
shortest possible limit.

This synchronizing, however, can be made very useful,
for example for identifying a multiplicity of beacon
stations of different frequencies, but each along a given
air route, or for differentiating between beacons of
different zones or different routes, or for characterizing
certain fixed warning beacons.

All these dual-frequency beacons forming part of a
common system can be alternately keyed on and off at one
and the same frequency rate, determined by properly
adjusting the frequency of the square-wave keying current.
The observer can also adjust the sweep frequency of his
receiver so as to see, for example, a very slow change of
one frequency to another, or he may stop (momentarily and
during the identification test) the signal on one frequency
only.

By noting the position of the sweep frequency controls
at which this occurs the pilot can distinguish one set of
signals from another set. One set of beacons may have, for
example, an on-off rate of 27 cycles per second, another
of 32 cycles per second, and the different settings he
would require on his receiver to "freeze" one set of
motions will tell him which set he is considering. This
synchronizing is also useful for eliminating certain forms
of recurrent noises, such as from motors or vibrators. The
sweep frequency of the receiver can be adjusted in synchron-
ism with the source of noise, whereby such noise signals
become "frozen" in a fixed part of the screen.

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The dual beacons, therefore, give characteristic signals which generally appear as two V-like deflections, partly superimposed, if desired, these signals closing at the bottom. They cannot be mistaken for ordinary unmodulated signals which are open at the bottom.

The frequency difference of such dual beacons should be very small indeed in order to minimize to a negligible point the difference of propagation characteristics between the two frequencies. This difference can, also, either be fixed or variable so as to give another indication of value as will be shown hereinafter.

The two-course beacons are to be preferred to four-course beacons because they can be made to give a positive indication of "right" and "left".

In Fig. 22 I show a course X_1 - X_2 determined by such a dual-frequency beacon located at 0 and alternately emitting on each side of the course signals L and R on adjacent frequencies F_L and F_R. Suppose that frequency F_L is higher than that of F_R and a plane carrying a panoramic receiver flies in the direction of the arrow from X_1 to X_2. If the screen of this receiver is so disposed that higher frequencies are to the left, and if the plane happems to be on the left side of the line X_1 X_2, for example in points Y_1 or Y_2, the left hand signal becomes taller than the right hand signal (see Fig. 22a), and vice-versa if it happens to be on the right side Y_3 or Y_4, the right hand signal becoming taller than the left hand signal. (see Fig. 22b).

This is directly interpreted indication provided that the observer knows his direction with respect to the station.

In a multiplicity of stations which are near one another

this is relatively simple because the observer generally receives at least two adjacent stations simultaneously and from their variation of amplitude can tell, within a few minutes, which of the two he is approaching. It is possible to distinguish the two signals of each station independently of their respective frequency, in fact, even by making these signals of identical frequency, by keying the two transmitters L and R at two different rates. In other words, for example, I can make L operate for periods of time three to five times as long as R. In the panoramic receiver L will appear brighter and steadier than R. If, by convention, all stations transmitting a course in the general direction East-West key the signals directed North longer than the signals directed South, a flier situated on the northern side of the course $X_1 - X_2$ will see the brighter signal higher in amplitude than the dull one, and a flier situated on the southern side of that same course will see the brighter signal lower in amplitude than the dull one. These two conditions are represented in Figs. 22a and 22b in which the brighter signals are represented in heavy lines and the dull signals in dotted lines.

In these figures the signals are shown as of different frequencies, it being understood, however, that the same frequency can be used for each. The directional interpretations from a dual-frequency beacon are different for a flier going in one direction and for one going in a reverse direction. For the first flier a taller left hand signal is interpreted as indicating that the plane is bearing too much to the left and for the other flier a taller left hand

signal is interpreted as indicating that the plane is bear-
ing too much to the right. The flier can, however, easily
become accustomed to such indications which are natural as
one reverses his direction, but even this can be remedied
by either reversing the connections to one set of deflect-
ing plates so as to make the indications appear upside down
in one direction, or by rotating the tube 180° around its
axis.

The unequal keying time can be obtained electronically
by simply adjusting to one side the time-equalling poten-
tiometer 156 (Fig. 18) or mechanically by making unequal
the angular openings of the sectors of commutators 120-121,
126, 127 (Fig. 16).

Beacons giving, in combination, a number of simulta-
neous indications can thus be made. As an example I shall
describe one which simultaneously indicates altitude of a
point, barometric correction, and wind direction and
velocity. This is simply a combination of the principles
described above. The beacon is a dual-frequency two-course
radio range transmitter one frequency of which is fixed and
predetermined by its altitude, the other frequency swinging
above or below that frequency and being determined by a
barometer-controlled oscillator. The two are unequally
keyed in time, as explained above, the fixed frequency last-
ing about three times longer than the variable frequency.
These two frequencies permit the flier to make the necessary
correction on his altimeter in case he wishes to make a
landing there.

The antennas of these two transmitters are determining
a course similar to $X_1 - X_2$ of Fig. 22, but this course is

orientable according to the wind direction by pivoting the antenna array around a central point. Fig. 23 shows in simplified form an upper view of such an antenna array in which 151, 152 are the vertical antennas, each connected to one transmitter. Each antenna acts as a reflector for the other when one is directly energized, obtaining as a result two patterns opposed in phase and shown diagrammatically as 153 and 154. The array is rotated by a wind vane 155 in such a way that a given antenna is always on the same side with respect to the wind direction. For example, the brighter signal corresponding to the fixed altitude can be made to always be on the left side (151) of the wind whose direction is represented by an arrow in Fig. 23. A flier flies in the direction of the wind when approaching or receding from such a station if the brighter of the two signals (indicating constant altitude) becomes taller as he goes slightly off course to the left or flies into the wind for the reverse condition. The wind velocity can be indicated by the rate of switching of the dual-frequency beacon. Any velocity higher than a certain given velocity causes this keying speed to be changed. This can be done by using an anemometer which rotates a small direct current generator whose potential is used either for speeding up the motor 122 of Fig. 16 or for changing the electronic keying rate of the transmitter by applying its potential to the grid return of the square-wave tube 129 (Fig. 18) at point 127. This keying speed can be determined by the observed who can translate it directly into wind velocity.

A beacon such as just described may be used in an

emergency unattended landing field where a pilot can make a landing even if no personnel is there to assist him. His collision warning receiver will indicate if the field is clear and no other planes are in the vicinity, or, if there are, the receiver will indicate which plane is lower and which has the priority to make a landing. His altimeter can be corrected and he will know when he flies against the wind. It is possible to combine such a beacon with a complete instrument landing system by using the wind direction indicating beacon as a runway indicator, provided that this beacon is installed in the centre of the field and does not obstruct landings. A glide path indicating dual-frequency beacon can be established by emitting two signals according to transmission patterns which differ in the vertical projection. Fig. 30 shows such a dual-frequency glide path resulting from the combination of two vertical patterns, one emitted on frequency F and the other on an adjacent frequency F'. They are produced by two transmitters each radiating its power from an antenna of different height above the ground. The lower of the two will give the pattern shown as F, of very low angle, with a definite cone of silence above it. The other antenna, slightly higher, will give a pattern having main lobes of higher angle as well as some other lobes in the cone of silence of the first signal. An equi-potential surface having the shape of a cone is produced, its apex being in the point O where the antennas are situated. The lines OZ_1 and OZ_2 represent two possible glide paths resulting by the intersection of this cone with the vertical plane determined by the runway indicator.

The direction of the runway indicator is determined by
the wind direction, but a glide path is always indicated
for any wind direction. The centre lobes of the signal F'
serve for localizing the exact position of the landing
beacon, then further facilitating its location in conditions
of zero visibility. The flier will follow a substantially
straight glide path by maintaining the signals from F and F'
equal on the panoramic receiver. If the signal correspond-
ing to F is higher it means that he is too low and if F' is
higher he is too high.

A course determining a dual-frequency beacon can, as
mentioned above, be mounted on a mobile body such as a
ship, which may be an airplane carrier or the like, for
determining a given direction either for other ships or
planes. Several ships can keep up in formation by inter-
linking such courses, for example, as shown in Fig. 24,
where ships 158, 159, 160, and 161 are carrying four-course
dual-range beacons. Airships may keep in formation flight
by keeping at different altitudes as indicated by the
apparatus described. What can be accomplished with dual-
frequency beacons for indicating direction may also be
obtained very well with single frequency, non-directional
transmitters, but with dual-directional panoramic compasses.

In my U.S. Patent No. 2,279,151, April 7, 1942, such
compasses have been shown, but I shall show here a fully
electronically-controlled compass to clarify the application
of the various types of panoramic receivers which can be
made in accordance with the system of my invention.
Fig. 25 shows such a receiver in block diagram form.

Two radio frequency amplifying tubes are connected to

two directional antennas at right angles to each other; these are represented as input circuits A and A'. The grid returns of these tubes are alternately keyed off by a square-wave generator S. The two inputs are brought to mixer C together with a signal from oscillator B. The latter is frequency-modulated over a given frequency band by means of frequency-modulating element F which in turn is controlled by the saw-tooth oscillator G operating at exactly double the frequency of the square-wave as explained in connection with Fig. 7. This latter is synchronized in step with the square-wave oscillator S. The mixer alternately receives signals from input A or input A' and its output is amplified by the intermediate frequency stages following it and then detected at D. The properly amplified detected signals are fed into one deflecting plate of cathode ray tube H. The other deflecting plate at right angles, receives current from both the saw-tooth oscillator and the square-wave generator. The result is two series of images on one and the same axis of the cathode ray tube, but slightly displaced in relation to each other. This displacement is a function of the amplitude of the square-wave current which is fed to the deflecting plate. Each set of images corresponds to a separate input; for example, all the images at the left correspond to those received by one input, let us say A, and the other set, to the right, corresponds to the signals received by the other input A'. Fig. 26 shows a screen with three such images. Their amplitudes correspond to those fed by the two inputs A and A'. If their amplifying factors are properly balanced their amplitudes correspond

to the position of the station with respect to the ori-
entation of the two antennas. A signal received from the
plane bi-secting the plane of the two antennas will be
received equally well by the two channels A and A', con-
sequently they will appear of equal height 164. A signal
better received by one or the other channel will appear
with one peak predominating 162, 163. The ratio between
the two peaks indicates the angle of the station with
respect to the receiving antennas. Fig. 27 shows a
diagram of these elements. A number of the cathode ray
tube elements, stabilizing resistors and other elements
common to Fig. 4 have been omitted in Fig. 27. Some of
the numbers used are common to Figs. 4 and 6 and show
common elements. The tubes 12 and 12' are the two input
tubes A and A' with two directional antennas at right
angles. These tubes have a sharp cut-off and their
cathodes are using the common resistors 166 and 167 with
tube 165 which is a push-pull square-wave amplifier for
square-wave oscillator 80. The saw-tooth generator 16 is
synchronized to this square-wave generator through its
grid. It supplies adjustable sweep voltage to deflecting
plate 63 through potentiometer 169 or, if required,
through an amplifier. It also supplies frequency-modulat-
ing voltage to tube 15 through potentiometer 26. This
tube is coupled as shown before to an oscillator 14 which
is frequency-modulated in synchronism with the sweep. The
displacement of the two sets of images is obtained by
feeding a square-wave voltage also to deflecting plate 63,
which voltage is adjustable through potentiometer 168. In
lieu of electronic control I may employ mechanical control

by the use of rotary commutators as shown in Figs. 9, 11, 13 and 16.

There is also some advantage in unbalancing the time for operating each channel in the ratio of 2:1 or more. In this case one set of images will appear brighter than the other and will serve to eliminate the necessity of shifting the images along the axis, as explained in connection with dual-frequency beacons. Ultra-high frequency compasses, using the direct wave or the ground wave, are quite practicable and, as aerials, simple horizontal dipoles are very convenient. The transmitter can use an antenna array giving a non-directional signal and the receiver uses these two crossed dipoles.

Cardioid pattern reception diagrams, instead of figure-eight patterns, can be obtained by using the arrangement described in Fig. 28 in which 8N represents a non-directional antenna which may be, for example, on ultra-short waves, a tuned horizontal one turn loop if horizontally polarized waves are to be received; 8D represents in this case a horizontal dipole, having a figure-eight directivity pattern.

One of these antennas, in my example 8D, feeds into a push-pull circuit connecting the input tubes 12 and 12' which are alternately keyed off similarly to the operation in Fig. 27. The signals are, consequently, reversed in phase as they pass through either one or other of these tubes. The other antenna is fed to another radio frequency amplifying tube 12" which operates continuously. The signals from these two antennas are fed into tube 13 and the balance of the receiver is similar to the one shown in

Fig. 27. Signals from one antenna are alternately reversed
in phase while those from the other antenna are maintained
in the same phase. By proportioning or balancing the ampli-
fication obtained in the two channels 12-12' on one hand and
12" on the other, reversible cardioid pattern reception is
obtained. A flier can maintain a straight course between
two such non-directional beacons by maintaining equal the two
peaks of each double signal on the cathode ray tube screen.

Although I have mentioned an altimeter or an aneroid
barometer as the controlling device in the system of my in-
vention, I desire that it be understood that other instruments
may be used to serve similarly and to impart a certain know-
ledge; for example, a tachometer or speedometer may be
employed to indicate speed or velocity, a thermometer to
indicate temperature, etc. Therefore, in some of my claims
I have used the expression "an independent controlling device"
to signify any such device, which operates independently of
the radio receiving system, but which controls the operation
of the latter.

In the methods described I have shown only specific ex-
amples for obtaining certain results, but it will be understood
that I can obtain similar results by many other combinations
of the elements described for shifting frequencies, keying on
and off oscillators, periodically selecting one between a
plurality of circuits, etc.

While I have described my invention in certain preferred
embodiments, I desire that it be understood that modifications
may be made and that no limitations upon my invention are
intended other than may be imposed by the scope of the appended
claims.