RADIO REFLECTION DIRECTION AND DISTANCE DETERMINING SYSTEM

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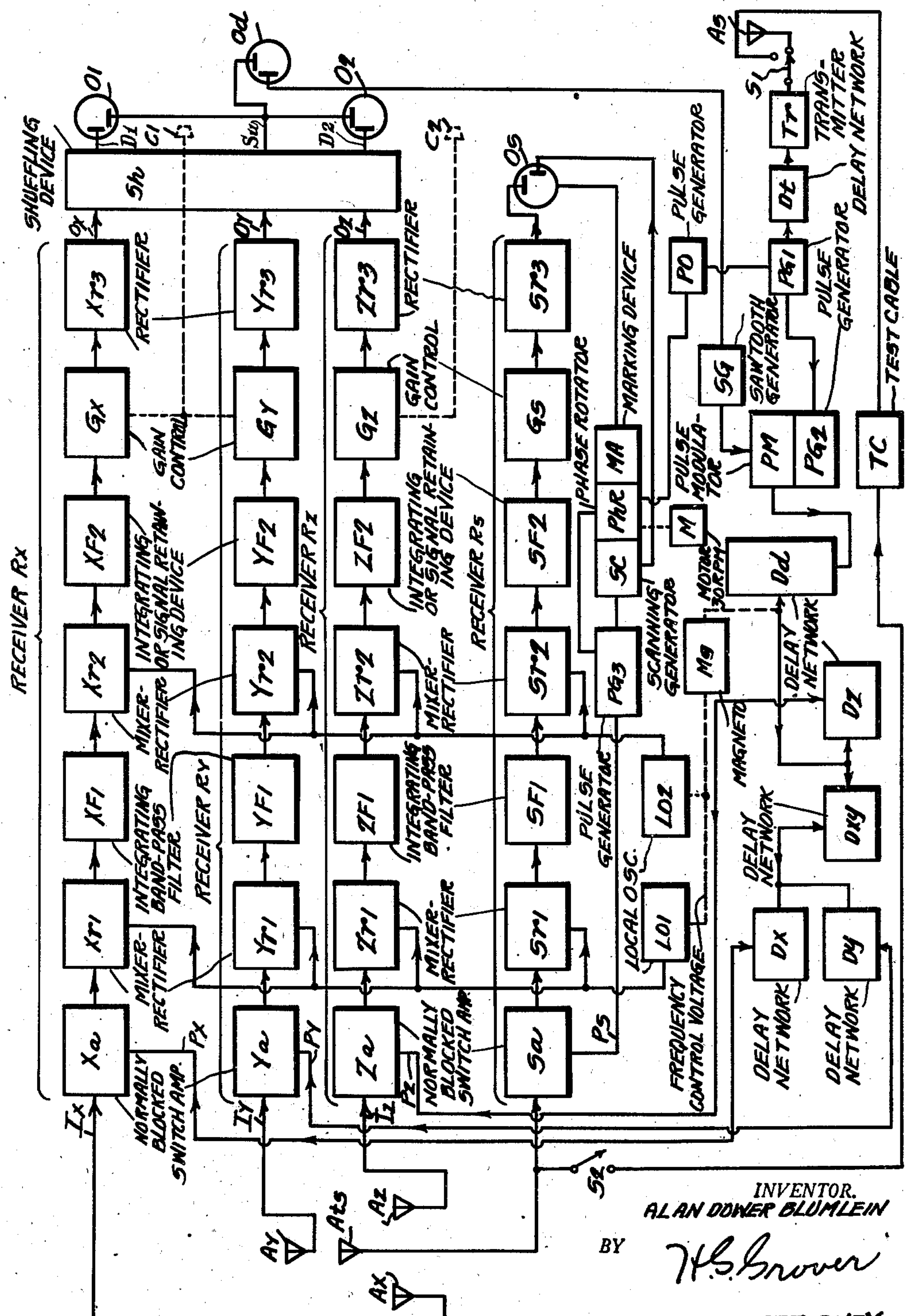

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RADIO REFLECTION DIRECTION AND DISTANCE DETERMINING SYSTEM

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This invention relates to apparatus for modifying recurrent signals having substantially the same waveform.

It is an object of the present invention to provide improved apparatus for deriving signals from a train of recurrent signals having substantially the same waveform or for measuring the difference of timing between two or more trains of such signals, and, if desired, for reducing the effect of random interference upon the observation or reception of such signals.

According to one feature of the invention there is provided apparatus for deriving a signal from a train of recurrent signals having substantially the same waveform which comprises a signal retaining device, switching means for selecting different portions of different recurrent signals, means for feeding said train of signals to said switching means and means for feeding said different portions from said switching means to said retaining device so as to develop therein a derived signal having substantially the same waveform as at least a part of the waveform of said recurrent signals.

Preferably, the timing of the time intervals during which said different portions are selected changes continuously in the same sense during a time period long compared with the time of recurrence of said recurrent signals. If random interference is superimposed on said train of signals, the same or a similar portion of said recurrent signals may be selected from a plurality of signals and said plurality of selected portions may be integrated so as to increase the minimum ratio of the amplitude of said recurrent signals and said random interference.

Said recurrent signals may be oscillatory signals having substantially the same envelope waveform and said selected portions may then be fed to a retaining device which is such that oscillations are set up therein by said portions in such manner that the oscillations set up in said device by said selected portions add substantially in phase. If desired, said oscillatory signals may be changed to a different frequency prior to said selection and integration, and said integrated signals may be rectified and further integrated after rectification.

According to another feature of the invention there is provided apparatus for measuring the difference of timing between two trains of recurrent signals, the signals of each train having substantially the same waveform, comprising a first signal retaining device, a first switching

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means for selecting at time intervals different portions of different recurrent signals, means for feeding the first of said trains of signals to said first switching means, means for feeding said different portions from said first switching means to said first retaining device so as to develop therein a derived signal having substantially the same waveform as at least a part of the waveform of said first recurrent signals, a second signal retaining device, a second switching means for selecting at time intervals different portions of different recurrent signals of the second train of signals, means for feeding the said different portions of said second train of signals to said second switching means, means for feeding signals from said second switching means to said second retaining device so as to develop therein a second derived signal having substantially the same waveform as at least a part of the waveform of said second train of recurrent signals, and means for adjusting and measuring the difference in timing between said time intervals during which said different portions of said first and second signals trains are fed to said first and second retaining device respectively, whereby when the timings of said time intervals are so adjusted that said first and second derived signals have substantially the same waveform, the difference in timing between said intervals in substantially equal to the difference in timing between said first and second train of signals.

The features of the invention above referred to many be used for detecting or for determining the position and/or distance of a source of recurrent signals having substantially the same waveform.

The application of the invention to the detection of, or the determination of the position or distance of a source or reflector of radiation will now be described by way of example with reference to the accompanying drawing, which shows a general schematic circuit arrangement of the transmitting and receiving apparatus.

The position and/or distance of sources of radiation may be determined by a method which comprises transmitting regularly recurrent "bursts" of radio frequency carrier waves, receiving the reflection of such waves due to reflecting objects such as an aircraft upon a number of spaced aerials, and determining the azimuth and elevation of such a reflecting object by measuring the difference in timing of the signals derived from said aerials. This difference in timing may either be measured directly or the signals derived from the aerials may be delayed by known amounts so as to equalise their timing. The present invention will now be described as applied to an apparatus of the latter type.

Referring to the drawing, Tr represents a radio frequency transmitter adapted to radiate "bursts" of carrier wave under the control of the master pulse generator PO. The carrier wave frequency may be 100 megacycles/sec. and the "bursts" may be 0.5 microsecond in duration and may recur every 200 microseconds, the master pulse generator PO then having a frequency of 5,000 cycles/sec. Preferably, the master pulse generator PO is arranged to drive a subsidiary pulse generator PG1, which has means for controlling the duration of the pulses, and the pulses are then fed to the transmitter Tr over a delay network Dt, which permits the adjustment of the timing of the pulses.

If the signal radiated by the transmitter in incident upon a reflecting object, such as a metal aircraft, it will be reflected. Such reflected signals may be received upon three aerials Ax, Ay, Az, situated in a horizontal plane at the apices of an equilateral triangle. The received signals are fed from these aerials to three receivers Rx, Ry and Rz respectively of a type which will hereinafter be described in which the timing of said signals may be modified and from the output of these receivers the signals are passed to a "shuffling" device Sh, hereinafter more fully referred to associated with cathode-ray oscillographs O1, O2 and Od, which indicate the relative timing of received signals.

The receivers Rx, Ry and Rz may comprise one more initial stages Xa, Ya, Za, respectively, having a relatively broad pass band of 100 megacycles$\pm$1.5 megacycles/sec. which are normally blocked so as not to transmit signals, but which are switched into an operative condition so as to transmit signals by a switching pulse 0.5 microsecond in duration and recurrent at 5,000 cycles/sec. derived from the pulse generator PG2, controlled by the master pulse generator PG1. Such stages may be of any suitable kind and may be supplied with anode voltages greatly in excess of the voltages normally used with the valves employed due to the fact that only intermittent operation is required. In this way the valves have an increased mutual conductance.

The signals passed by said switched stages are then successively heterodyned to lower frequencies and are finally reduced to a frequency which may be 20 kilocycles/sec. and fed to a circuit tuned to 20 kilocycles/sec. and having a pass band of $\pm$100 cycles/sec. in which the signals are effectively integrated over 25 successive cycles, whereby, as explained in the specification of copending application No. 446,970 filed June 13, 1942, Pat. No. 2,406,316, dated August 27, 1946, granted to A. D. Blumlein and E. L. C. White. The effect of random interference upon said signals is reduced.

Thus, the receiver Rx includes one or more initial switching amplifier stages Xa which selectively feed signals from the antenna Ax to a first mixer-rectifier Xr1 wherein the received signals are heterodyned by oscillations from a first local oscillator LO1. The heterodyned signals are fed through a first integrating or signal retaining band-pass filter XF1 to a second mixer-rectifier Xr2 wherein the signals again are heterodyned by oscillations from a second local oscillator LO2. Signals from the second mixer-rectifier Xr2 are applied to an integrating tuned oscillatory circuit or signal retaining device XF2. The finally integrated signals thence are applied through a gain control device Gx and a third rectifier Xr3 to the "shuffling" device Sh.

The receiver Ry includes similar initial switching amplifier stages Ya responsive to signals from the antenna Ay, a first mixer-rectifier Yr1 connected to the first local oscillator LO1, a first band-pass filter YF1, a second mixer-rectifier Yr2 connected to the second local oscillator LO2, a second integrating or signal retaining device YF2, a gain control Gy and a third rectifier Yr3 having its output connected to the "shuffling" device Sh.

The receiver Rz is similar to the receivers Rx and Ry and includes the elements Za, Zr1, ZF1, Zr2, ZF2, Gz, and Zr3. Signals applied to the mixer-rectifiers Zr1 and Zr2 are heterodyned respectively by oscillations from the local oscillators LO1 and LO2. The output of the third rectifier Zr3 is applied to the "shuffling" device Sh.

The timing of this switching pulse which renders the early stages of such receiver operative is varied in a cyclic manner by means of the pulse modulator PM which varies the timing of the pulses under the control of the saw-tooth waveform generator SG, which may conveniently have a frequency of 25 cycles/sec. The saw-tooth voltage provided by SG, is preferably added in the pulse modulator PM, to saw-tooth pulses derived from PG2. and a pulse is derived whenever the resultant voltage increases beyond a predetermined value. It may thus be arranged that the 5,000 cycles/sec. pulses occur successively later throughout successive periods of $^1/_{25}$ second, i. e., the timing of the pulses changes continuously in the same sense. The effect of this variation in the timing of the switching pulse is that different portions of successive recurrent signals are selected by the switched stages of the receiver and a signal having substantially the same waveform as the envelope waveform of the recurrent signal is thus reconstituted in the output of the receiver during the time period of the saw-tooth waveform which modifies the timing of the switching pulses, i. e., during a time period long compared with the time of recurrence of the recurrent signals.

It will be appreciated that although the successive selected portions of the signals are not strictly identical due to the continuous change in the timing of the switching pulse, provided that, as in the case in the present example, the change in the selected signal during the effective period of integration is small, the successively selected signal will be similar and will be integrated in the tuned circuit above referred to. The output signal, therefore, has substantially the same waveform as the envelope waveform of the incoming recurrent signal and may be observed on the screen of a cathode-ray oscillograph Od by applying the derived signal to one pair of deflecting plates and a saw-tooth waveform from the generator SG to the other pair of deflecting plates.

If only a limited portion of the waveform of the recurrent signals is of interest, the variation of the timing of the switching pulse may be localised to the neighbourhood of the timing of that portion of the waveform which it is desired to observe. In the present example, the variation of the timing of the switching pulse may be limited to a range of $\pm$.75 microsecond about the timing of the incoming reflected signal.

If the receivers Rx, Ry and Rz are simultaneously supplied with the same switching pulses in the manner referred to, derived signals having substantially the same waveform as the enveloped waveform of the incoming signals will appear in their output circuits, but these derived signals will have the same relative phase as the incoming signals. However, if a difference in timing be introduced into the switching pulses fed to the different receivers, the relative timing of the derived signals will be modified. If, for example, the timing of the signal received on aerial Ax is ahead of the timing of the signal received on aerial Ay, the derived signal appearing in the output of receivers Rx and Ry may be made to have the same timing by advancing the timing of the switching pulses for the receiver Rx, and this advance in timing will be a direct measure of the difference in timing between the signals incident upon aerials Ax and Ay.

The switching pulses from the pulse modulator PM are, therefore, fed to the receivers Rx, Ry and Rz over adjustable delay networks Dd, Dxy, Dx, Dy and Dz by means of which relative timing of the pulses fed to the three receivers may be changed by known amounts. The time delay netword Dd is provided to take up the time delay of the incoming signals due to their time of transit from the transmitter to the reflecting object and back to the receiver, and to provide for a range of 30 km., the delay available in Dd should be at least 200 microseconds. The delay provided by the time delay networks Dx, Dy, Dz and Dxy may, of course, be very much less than this, as these networks need only take up the small delays of a fraction of a microsecond due to the path difference from the reflecting object to the different aerials.

The difference in timing between the signals received on the aerials Ax, Ay, Az is thus determined by adjusting the delay network above referred to until the timings of the derived signals in the outputs of the receivers Rx, Ry and Rz are made equal. The relative timing of the derived signals is preferably indicated as follows:

The receiver outputs Ox, Oy and Oz are passed to the shuffling device Sh which produces outputs Su proportional to the sum

$$\frac{Ox+Oy+Oz}{3}$$

an integrated difference D1 proportional to $\int(Ox-Oy)\,dt$; and an integrated difference D2 proportion to

$$\frac{2}{\sqrt{3}}\int\left(Oz-\frac{Ox+Oy}{2}\right)dt$$

where t represents time. The aerials are preferably 50 metres apart, in which case there will be a maximum of 0.166 microsecond differenece in timing. The two difference waves D1 and D2 will be approximately similar in waveform and phase to the sum wave Su, but with magnitudes and senses relative to Su, depending on the relative timing of the signals from the receivers. The integrated differences D1 and D2 are applied to the horizontal deflecting plates of the bearing indicating oscillographs O1 and O2 and the sum Su is applied to the vertical deflecting plates of these oscillographs. If the timing of the receiver outputs is similar vertical lines will be traced. Any difference in timing will give inclined lines.

The pulses Px and Py are passed through delay networks Dx and Dy which are differentially controlled to alter the relative timing of Px and Py so as to make the outputs of receivers Rx and Ry similar so that the difference Ox—Oy is zero and a vertical line is therefore obtained on oscillograph O1. The setting of Dx and Dy now gives the relative timing of the received waves at the aerials Ax and Ay. Similarly, the relative timing of pulses Pz and the mean of Px and Py are adjusted by the differentially controlled delay networks Dxy and Dz so as to give no timing difference between Oz and Ox+Oy so that a vertical line is obtained at oscillograph O2. The settings of the delay controls now define the bearing of the pulse reflecting object. It is arranged that the differential control varies the delay in Dz twice as rapidly as in Dxy, thus always keeping the mean timing of Px, Py and Pz constant.

If Txy is the delay of Py relative to Px and if

$$\frac{\sqrt{3}}{2}Tz$$

is the delay of Pz relative to the mean of Px and Pxy when both oscillographs show vertical traces, then the azimuth angle of the reflecting object is

$$\tan^{-1}\frac{Txy}{Tz}$$

measured in sense xyz and the elevation angle is $\cos^{-1}\sqrt{Txy^2-Tz^2}$ when Txy and Tz are measured in units of 0.16 microsecond (that is, the aerial spacing of 50 metres divided by the velocity of light).

In the above no allowance has been made for the variation of delay between receiver and receiver, which may be allowed for by small preset delays inserted in the leads between Dx, Dy, Dz and the receivers. These may be adjusted by means of a test signal radiated from aerial Ats to be described later.

In order that a suitable reflection may be found and the delay Dd adjusted easily, a "Search aerial" Ats and a "Search receiver" Rs are provided. This is similar to the other receivers Rx, Ry, Rz, includes the circuit components Sa, Sr1, SF1, Sr2, SF2, Gs and Sr3, and shares the same heterodyning frequencies as the other receivers. The pulse Ps which periodically switches on this receiver is, however, derived separately from the pulsing oscillator PO. The 5,000 C. P. S. wave from PO is passed through a phase rotating device PhR, which may be similar to a goniometer with the two fixed coils fed in quadrature and an output obtained from the moving coil. The output of the moving coil is passed to a pulse generator PG3., similar to PG1., which generates the actuating pulses for the transmitter Tr. The phase of this pulse is determined by the phase of the output delivered by the phase rotator PhR. This latter unit is driven round slowly, as by a suitably geared motor, M, completing a revolution in, say, 2 seconds. Thus, every 2 seconds the pulse actuates the receiver Rs later and later during the 1/5000 sec. period so that the output of Rs traces out the envelope waveform of all the reflected waves received in the intervals between the transmitted pulses. This output is applied to the vertical deflection plates of a "Search oscillograph" Os, which is provided with a long lag fluorescent screen, having a fluorescent delay time of, say 5 seconds. The horizontal deflection plates are connected to a scanning generator Sc which scans the cathode ray across the screen once for every revolution of PhR. Thus, a picture of the envelope waveforms of all the received signals is obtained on the screen and movements of any particular reflecting object can be detected by the movement of the envelope waveform of the signals reflected therefrom on said screen.

In order that the approximate distance of any such reflecting object may be determined on the search oscillograph *Os*, for example, in order to facilitate setting the distance delay *Dd*, a marker device *Ma* is associated with the mechanical drive to phase rotator *PhR*. This marker is arranged by mechanical contacts to momentarily cut off the beam at, say, ten periods during the revolution, and further to reduce the beam brightness slightly at, say, nine points between each complete cut-off. Thus, the trace on the search oscillograph will be marked out into 100 divisions which for the case considered will each represent 300 metres distance from the transmitting and receiving apparatus.

The test and searching aerial *Ats* is preferably situated symmetrically between the other three receiving aerials. A test cable TC may be provided which may be of such a length as to provide, say, 4 microseconds delay for a 100 m. c. wave. Such a delay would correspond to a range of 600 metres. Switches S1, S2 are provided by means of which the transmitter output can be diverted from the transmitting aerial via the test cable to the test aerial. If the apparatus is correctly adjusted such a signal should give readings corresponding to an elevation of 90° and a distance of 600 metres plus the distance from the test aerial to the other receiving aerials less an allowance for the difference of length of feeders to the test aerial and the transmitting aerial. The controls to the distance delay *Dd* and the *x*, *y* and *z* delays are set to the correct values, and the adjustments made to give vertical lines on the bearing oscillographs and a central pulse on the distance oscillograph. The delays (not shown) in the leads *Px*, *Py*, *Pz* to the receivers *Rx*, *Ry*, *Rz* respectively are adjusted to give vertical bearing lines. The transmitter delay *Dd* is adjusted to give a centrally placed pulse on the distance oscillograph. The setting of the marking mechanism for the search oscillograph *Os* is similarly adjusted to bring the observed pulse to the 600 metre mark.

If the receiver gains are not equal, the lines on the bearing oscillograph will appear as ellipses. A control C1 may, therefore, be provided adjacent the oscillograph O1 to adjust the gain of *Rx* and *Ry* differentially. Similarly, a knob C2 adjacent O2 adjusts the gain of *Rz*. The knobs are adjusted to give straight line traces. Further gain adjustment of the receivers is preferably effected by means of variable attenuators included in the three receivers which are mechanically coupled to vary the gains of the three receivers equally and simultaneously. The search receiver *Rs* is preferably given a separate gain control and may if desired have an automatically variable control supplied from the scanning generator to make the receiver more sensitive for distant objects. The three bearing receivers may, if desired, have separate automatic volume control to maintain the received pulse amplitude constant.

It will be appreciated that it is desirable to limit the pass band of the receiving apparatus to a minimum in order to reduce the effect of interference. The pass band of the post detector stages may be limited to approximately twice the repetition frequency of the derived signal so as to pass the fundamental and first harmonic frequencies of this pulse. Thus, if the derived signal is reconstituted every 1/25 sec., the pass band of the post detector stages may be limited to 50 cycles/sec.

The pass band of the pre-detector stages is chiefly determined by consideration of the Doppler effect due to the motion of the reflecting object, and with the present speed of aeroplanes this pass band cannot safely be limited to less than, say, 100 cycles/sec. or 200 cycles/sec. to allow a tolerance for cumulative inaccuracies in timing frequency stability, etc. If, however, a correction be applied to reduce the frequency shift of the incoming signal due to the motion of the reflecting object, the pass band of the predetector stages may be reduced. Such correction may be applied by known automatic frequency control methods, but is conveniently applied automatically by the phase rotating device *PhR* associated with the search receiver *Rs* in the following manner.

As has been hereinbefore explained, the distance of the reflecting object is indicated on the distance delay network *Dd*, and as the object moves this network has to be continually readjusted. The rate of readjustment of this network will be proportional to the velocity of approach of said object and by coupling a device, such as a magneto *Mg*, with a rotating adjustment element of this network a voltage may be generated which is proportional to the rate of approach of the reflecting object and may be applied to adjust the frequencies of the heterodyning oscillations generated in the local oscillators LO1 and LO2 of the receivers so as to reduce the frequency shift in the final I. F. signal due to the motion of the reflecting object, for example, by changing the capacity or inductance in one of the frequency-determining circuits of said oscillator.

Reflected signals from other reflecting objects which are stationary, or which have a different component of velocity towards or away from the receiver 3, i. e., objects moving relative to the reflecting object which it is desired to observe, will have a different frequency from the signals reflected by said reflecting object and can be rejected by sufficiently reducing the passband of the I. F. circuits, or by tuning the I. F. circuits so as to be non-responsive to the intermediate frequency signal derived from the reflected signals received from such objects.

The system for the determination of the position and/or bearing of reflecting objects described above depends upon the measurement of the relative phase of the envelope waveform of the reflected signals, and as this phase measurement becomes ambiguous when the phase difference to be measured exceeds 180°, the separation of the aerials necessarily has to be less than that which would give rise to a phase difference approaching this value. With the present system, however, this limitation is removed, and difference in timing up to the time separation, in the present example 200 micro-seconds, if successive "bursts" of the high frequency carrier, may be measured. It is thus possible to provide more than one set of three aerials having different spacings so as to enable the aerials with the greater spacing to be switched into circuit to give more accurate bearings when required.

In order to reduce the effect of oscillator drift, the local oscillations may be derived in known manner by mixing an oscillation derived from the carrier frequency oscillator of the transmitter with an oscillation of the desired intermediate frequency derived from another oscillator, the frequency stability of which is good relative to the pass band required of the desired intermediate frequency. For example, the first heterodyning oscillation may be obtained by mixing the carrier frequency oscillations from the transmitter with a stable oscillation of 10 megacycles per second, the frequency drift of the latter oscillator being small with reference to 200 kilocycles per second. Alternatively, the carrier frequency of the transmitter may be synthesised from a number of lower frequency oscillations including those required for the heterodyning stages of the receiver. Thus, if the I. F. frequencies of the receiver are to be 10 megacycles/sec., 300 kilocycles/sec. and 20 kilocycles/sec. respectively, and the frequency of the transmitted carrier and the reflected signal to be received is 100 megacycles/sec. the local oscillator frequencies required will be 90 megacycles/sec., 9.7 megacycles/sec. and 280 kilocycles/sec. respectively. These frequencies may be generated by starting with oscillations operating at frequencies of 20 and 280 kilocycles/sec., mixing these oscillations to give the 300 kilocycles/sec. oscillation; mixing this 300 kilocycles/sec. oscillation with a 9.7 megacycles/sec. oscillation to give a 10 megacycle oscillation and finally mixing this 10 megacycles oscillation with a 90 megacycle oscillation to give the 100 megacycle oscillation required for the transmitter. Any variation of frequency of these oscillators, excepting the 20 kc. oscillations will then not change the frequency of the final 20 kilocycles/sec. I. F. signal. This arrangement has the further advantage that, since the heterodyning oscillation is not derived from a signal frequency oscillation, the risk of a slight admixture of the signal frequency in the heterodyning frequency is prevented and interference, which the presence of such a component would cause, is therefore avoided.

The interfering effect of a steady carrier frequency in the methods of reception which have been described above may be reduced by modulating the carrier frequency of the transmitter at a very low frequency. It will be seen that the frequency of the transmitter must not change by more than a small fraction of 200 cycles/sec. in $\frac{1}{5000}$ sec., as otherwise successive reflected signals will not add with a sufficient degree of accuracy because the received signal may be heterodyned by an oscillation derived from the transmitter $\frac{1}{5000}$ sec. after it has itself transmitted. A frequency variation of 10 cycles/sec. may, however, be permitted in $\frac{1}{5000}$ sec. and the frequency of the transmitter may be modulated over a range of ±2500 cycles/sec., in a period of $\frac{1}{5}$ sec. That is to say, the frequency of the transmitter may be increased steadily during $\frac{1}{10}$ sec. and then decreased steadily during the following $\frac{1}{10}$ sec. and so on. This may be done by means of a mechanically rotated condenser in one of the frequency-determining circuits of the transmitter. For a steady interfering signal, this frequency modulation of the transmitted carrier will give freedom from interference from such a signal for

$$\frac{5000-400}{5000}\times 100 \text{ per cent.}$$

i. e., 92 per cent of each $\frac{1}{10}$ sec. period. A slower variation of frequency than that suggested above may, of course, be used.

Although the timing of the switching pulses in the arrangement which has been described above changes continuously in the same sense during a time period long compared with the time of recurrence of said recurrent signals so that similar but not necessarily identical portions of successive recurrent signals are selected, it will be appreciated that the portions need not be selected from successive recurrent signals, since the switching may be arranged so that no portions are selected from some of the recurrent signals in the signal train. Further, the switching may also be arranged so that the same portion is first selected from a plurality of the recurrent signals and then another portion is selected from another plurality of the recurrent signals and so on, in which case the timing of the switching pulses will be arranged to change discontinuously. It will also be appreciated that it is not necessary to employ integration in carrying out the invention, as the derived signal may be developed by feeding the selected signal portions to a device which only retains a current or voltage representative of the amplitude of one selected portion until the next selected portion arrives, so that the current or voltage in the device is always directly related to the amplitude of the most recently received selected portion and is unaffected by previous signal portions. Such a device may comprise a condenser, or if the signal is oscillatory, an oscillating circuit tuned to the frequency of the signal oscillations, so arranged that the voltage or oscillatory current in said condenser and circuit respectively due to each selected portion disappears when the next selected portion is fed thereto. Such a device will be termed a retaining device and this term is to be construed so as also to include a device which retains its energy for a period longer than the interval between successively selected signal portions, so that integration takes place due to the addition of the energy due to each selected portion to the energy remaining from previously selected portions.

It will be understood that the arrangement described above may be modified to detect or determine the position of submarine sources or reflectors of supersonic vibrations in water. In this case short pulses of supersonic vibrations will naturally be used instead of short pulses of radio frequency radiation, but the system will be similar in principle.

Although the invention has been described above with reference to a system for the detection or location of reflecting objects, it will be appreciated that it is broadly applicable to the derivation of a signal from any train of recurrent signals having substantially the same waveform and preferably separated by equal time intervals. Said derived signals may have substantially the same waveform as the whole or selected part of the waveform of said recurrent signal and may have any desired timing. Further, if random interference be superimposed upon such a train of signals, the invention may also be applied to the reduction of such interfence in the reception or observation of such recurrent signals. Said recurrent signals may be oscillatory and have substantially the same envelope waveform and, in the case of such signals, the invention may be applied both before and after rectification.

What I claim is:

1. Apparatus for deriving a signal from a train of recurrent signals having substantially the same waveform which comprises a signal retaining de-

vice, switching means for selecting different portions of different recurrent signals, means for feeding said train of signals to said switching means and means for feeding said different portions from said switching means to said retaining device, and means for continuously changing the operational timing of said switching means feeding said retaining device for deriving a signal having substantially the same waveform as at least a part of the waveform of said recurrent signals.

2. Apparatus for deriving a signal from a train of recurrent signals having substantially the same waveform, which comprises a signal integrating device, switching means for selecting at time intervals different portions of different recurrent signals, means for feeding said train of signals to said switching means, means for feeding said different portions from said switching means to said integrating device, and means for continuously changing the timing of said intervals in the same sense during a time period long compared with the time of recurrence of said recurrent signals, whereby there is developed in said integrating device a desired signal having substantially the same waveform as at least a part of the waveform of said recurrent signals and whereby the minimum ratio of the amplitude of said recurrent signals to the amplitude of any random interference superimposed thereon is increased.

3. Apparatus for measuring the difference of timing between two trains of recurrent signals, the signals of each train having substantially the same waveform comprising a first signal retaining device, a first switching means for selecting at time intervals different portions of different recurrent signals, means for feeding the first of said trains of signals to said first switching means, means for feeding said different portions from said first switching means to said first retaining device so as to develop therein a derived signal having substantially the same waveform as at least a part of the waveform of said first recurrent signals, a second signal retaining device, a second switching means for selecting at time intervals different portions of different recurrent signals of the second train of signals, means for feeding the said different portions of said second train of signals to said second switching means, means for feeding signals from said second switching means to said second retaining device so as to develop therein a second derived signal having substantially the same waveform as at least a part of the waveform of said second train of recurrent signals, and means for adjusting and measuring the difference in timing between said time intervals during which said different portions of said first and second signal trains are fed to said first and second retaining device respectively, whereby when the timings of said time intervals are so adjusted that said first and second derived signals have substantially the same waveform, the difference in timing between said intervals is substantially equal to the difference in timing between said first and second train of signals.

4. Apparatus according to claim 3 in which each of said retaining devices comprises an integrating device and means are provided for continuously changing in the same sense said time intervals during a time period long compared with the time of recurrence of said recurrent signals, whereby the minimum ratio of the amplitude of said recurrent signals to the amplitude of any random interference superimposed thereon is increased in each integrating device.

5. Apparatus for deriving a signal from a train of recurrent oscillatory signals having substantially the same envelope waveform which comprises an integrating device adapted to have oscillations set up therein, switching means for selecting at time intervals different portions of different recurrent signals, means for feeding said train of signals to said switching means and means for feeding said different portions from said switching means to said integrating device, so as to set up oscillations therein, which oscillations are integrated to develop oscillations having substantially the same envelope waveform as at least a part of the envelope waveform of said recurrent oscillatory signals, and means for continuously changing in the same sense the timing of the intervals during which said portions of said signals are fed to said integrating device during a time period long compared with the time of recurrence of said recurrent signals, whereby the minimum ratio of the amplitude of said recurrent signals to the amplitude of any random interference superimposed thereon is increased in said integrating device.

6. Apparatus according to claim 5, comprising rectifying means, means for feeding said oscillations developed in said integrating device to said rectifying means, a further integrating device, and means for feeding the rectified signals in said rectifying means to said further integrating device whereby the minimum ratio of the amplitude of said rectified signals and any random interference is increased.

7. Apparatus for detecting a reflecting object comprising transmitting means for radiating short bursts of oscillatory signals having substantially the same envelope waveform, receiving means for receiving said signals after reflection by said object, frequency changing means for deriving oscillatory signals of lower frequency from said signals received by said receiving means, means for feeding said received signals to said frequency changing means, an oscillatory circuit of low decrement tuned to said lower frequency, means for feeding said signals of lower frequency to said oscillatory circuit so as to set up oscillations therein, switching means for selecting during time intervals different portions of different signals, said switching means being interposed between said receiving means and said oscillatory circuit, and means for continuously changing in the same sense the timing of the intervals during which said portions of said signals are fed to said oscillatory circuit during a time period long compared with the time of recurrence of said bursts of signals.

8. Apparatus according to claim 7, in which said frequency changing means comprises means for rendering said lower frequency substantially independent of changes in the frequency of said received signals due to motion of said reflecting object.

9. Apparatus for determining the position of a reflecting object, comprising transmitting means for radiating short bursts of oscillatory signals having substantially the same envelope waveform, receiving means for receiving said signals after reflection by said object, frequency changing means for deriving oscillatory signals of lower frequency from said signals received by said receiving means, means for feeding said received signals to said frequency changing means, an oscillatory circuit of low decrement

tuned to said lower frequency, means for feeding said signals of lower frequency to said oscillatory circuit so as to set up oscillations therein, switching means for selecting during time intervals different portions of different signals, said switching means being interposed between said receiving means and said oscillatory circuit, means for continuously changing in the same sense the timing of the intervals during which said portions of said signals are fed to said oscillatory circuit during a time period long compared with the time of recurrence of said bursts of signals so as to develop in said oscillatory circuit an oscillatory signal having substantially the envelope waveform as at least a part of the envelope waveform of said received signals, a further receiving means spaced from said first-mentioned receiving means for receiving said signals after reflection by said object, further frequency changing means for deriving oscillatory signals of lower frequency from said signals received by said further receiving means, means for feeding said received signals to said further frequency changing means, a further oscillatory circuit of low decrement tuned to said last-mentioned lower frequency, means for feeding said signals of said last mentioned lower frequency to said further oscillatory circuit so as to set up oscillations therein, further switching means for selecting during time intervals different portions of different signals, said further switching means being interposed between said further receiving means and said further oscillatory circuit, further means for continuously changing in the same sense the timing of the intervals during which said portions of said signals are fed to said further oscillatory circuit during a time period long compared with the time of recurrence of said bursts of signals so as to develop in said further oscillatory circuit an oscillatory signal having substantially the same envelope waveform as at least a part of the envelope waveform of said signals received by said further receiving means, means for adjusting and measuring the difference in timing between said time intervals during which said different portions of said signals received by said receiving means and said further receiving means are fed to said oscillatory circuit and said further oscillatory circuit respectively whereby when the timings of said intervals are so adjusted that the oscillations developed in said oscillatory circuit and said further oscillatory circuit have substantially the same envelope waveform, the difference in timing between said intervals is related to the bearing of said reflecting object from an imaginary line joining said receiving means and said further receiving means.

10. Apparatus for determining the distance of a reflecting object comprising pulse generating means for generating a train of recurrent pulses having substantially the same waveform, transmitting means for radiating oscillatory signals, means for feeding said pulses to said transmitting means so as to cause the radiation of said oscillatory signals only when said pulses are fed to said transmitting means, receiving means for receiving said signals after reflection by said object, frequency changing means for deriving oscillatory signals of lower frequency from said signals received by said receiving means, means for feeding said received signals to said frequency changing means, an oscillatory circuit of low decrement tuned to said lower frequency, means for feeding said signals of lower frequency to said oscillatory circuit so as to set up oscillations therein, switching means for selecting different portions of different signals, said switching means being interposed between said receiving means and said oscillatory circuit, an adjustable time delay circuit, means for feeding pulses from said pulse generating means to said time delay circuit, means for changing the timing of said pulses continuously in the same sense during a time period long compared with the time of recurrence of said recurrent pulses, means for feeding pulses from said delay circuit to said switching means so as to cause said switching means to select when said pulses are fed thereto, whereby when said time delay circuit is adjusted so that the envelope waveform of the oscillations set up in said oscillatory circuit is substantially the same as at least a part of the envelope waveform of said radiated signals, the distance of said object is related to the time delay introduced by said time delay circuit.

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