

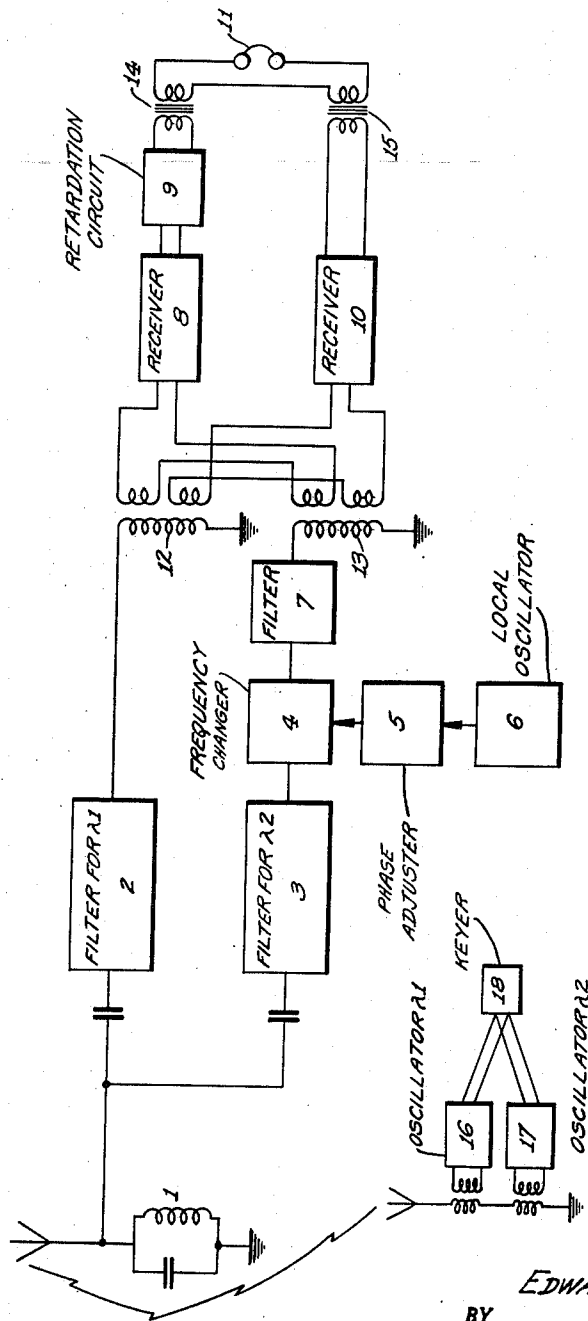
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SYSTEM OF RADIO COMMUNICATION

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SYSTEM OF RADIO COMMUNICATION

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This invention relates to a system of radio communication and more particularly to radio-telegraphic or radio-telephonic links or to sounding systems and detecting systems by means of electromagnetic waves.

The object of the invention is to provide radio link systems of this type which are not disturbed by echoes produced by reflections of the signals particularly from atmospheric layers (ionosphere).

With this object in view, according to the present invention means are provided for sending and receiving in such a manner that undesirable echoes are either not received or are automatically compensated at the reception.

A preferred embodiment of the invention which will now be explained with reference to the single figure of the attached drawing consists in the simultaneous transmission of two or more different wave lengths and in the adjustment of the receiver so as to receive waves and combine them in a manner to isolate the group of direct signals from the group of first echoes.

The apparent height of the ionosphere which reflects the electromagnetic waves depends on the wave length. Notwithstanding this, changes in this apparent height with changes in the wave length will be very slow except for the so-called "critical" frequencies. Within the scale of the short waves with which we are particularly concerned, the echoes of two waves, λ_1 and λ_2 , spaced in frequency by a few tens of kilocycles per second may be considered as coming from the same layer of the ionosphere. By simultaneously sending on the two wave lengths λ_1 and λ_2 , the direct wave λ_1 will follow the same path as λ_2 , and the first echo of wave length λ_1 will follow the same path as the first echo of wave length λ_2 , etc. The result of this is that the two direct waves as well as the pair of echoes will arrive together, but the echoes will lag behind more and more. At a given moment, there will be in a receiver tuned to receive at wave length λ_1 , a direct wave and a series of echoes. The same thing is true for a receiver tuned to receive the wave length λ_2 . In order to simplify the explanation, a single echo will be considered.

In the receiver, the direct waves will have the same relative phase as they had at the instant of emission in the transmitting antenna. By modifying the wave length and the phase of the wave λ_2 by a frequency changer (or a heterodyne circuit) in a manner to bring its frequency to the same frequency and to the same phase as wave λ_1 and by super-posing these two waves, the two will be added arithmetically.

Like the frequency of the wave and the speed of its phase variation, the heterodyne oscillator will change in phase during the time required for the waves to travel from the transmitter to the receiver. If the phase of this oscillator is so

arranged that the direct waves which are received will be aiding in phase, then the echoes which take longer to traverse this space will be added vectorially at an angle which depends on the difference of frequency corresponding to wave lengths λ_1 and λ_2 and the duration of the interval between the reception of the direct wave and the first echo. The frequencies of two waves are so selected that the two echoes will be substantially cancelling one another when the direct waves are added to one another. On the other hand, the system can be so arranged that the direct waves will be cancelling one another and the echoes will be added to one another. It is possible, therefore, to isolate the pair of direct waves and the pair of echoes and to utilise these two pairs, e. g. by combining them in such a manner as to increase as much as possible the relationship between the signal and the parasites.

Let

$\phi(t)$ be the low frequency wave to be transmitted
 $\sin \omega t$ the carrier wave corresponding to the wave length λ_1
 $\sin (\omega + \theta)t$ the carrier wave corresponding to the wave length λ_2 .

If at the receiver the direct wave λ_1 is

$$A\phi(t) \sin \omega t$$

where A is a constant, the echo will have the form

$$B\phi(t-T) \sin \omega(t-T)$$

where B is a constant and T the interval of time between the instants when the direct wave and the first echo are received.

The wave at the input of the receiver tuned to wave length λ_1 will have the form

$$R_1 = A\phi(t) \sin \omega t + B\phi(t-T) \sin \omega(t-T) \quad (1)$$

and the wave at the input of the receiver tuned to λ_2

$$R_2 = A\phi(t) \sin (\omega + \theta)t + B\phi(t-T) \sin (\omega + \theta)(t-T) \quad (2)$$

If the heterodyne is arranged to reduce all the frequencies of the wave form R_2 from $\theta/2\pi$, we will get

$$R_2' = A\phi(t) \sin \omega t + B\phi(t-T) \sin [\omega(t-T) - T\theta] \quad (3)$$

By making θ of a value so that

$$T\theta = (2n+1)\pi \quad (4)$$

one will obtain

$$R_2' = A\phi(t) \sin \omega t - B\phi(t-T) \sin \omega(t-T)$$

and therefore

$$R_1 + R_2' = 2A\phi(t) \sin \omega t \quad (5)$$

and

$$R_1 - R_2' = 2B\phi(t-T) \sin \omega(t-T) \quad (6)$$

To indicate the values, a lag T of 100 microseconds will not materially diminish the quality

of a commercial telephone conversation. On the other hand, a lag of 1 millisecond may be very damaging. In this case, since

$$\theta T = (2n+1)\pi$$

the difference in frequency between $\lambda 1$ and $\lambda 2$ is

$$\frac{\theta}{2\pi} = \frac{2n+1}{2T} = 500(2n+1) \text{ p. p. s.}$$

In order to avoid interference between waves $\lambda 1$ and $\lambda 2$ in the receiver, one may select n not less than 6 in the case of a passing band of ± 3000 p. p. s.

The relationship between the signal and the parasites in

$$R_1 \pm R_2^1$$

is 3 decibels higher than the ratio of the direct wave or the echo to the parasites in R_1 or R_2 , respectively. If all the power were concentrated in the channel of wave length $\lambda 1$, then the last-mentioned relationship would also be augmented by 3 decibels. Therefore, the use of two wave lengths will not cause any reduction in the ratio between the signal and the parasites in the direct wave or in the echo. Quite on the contrary, according to another feature of the present invention, this ratio can be increased by suitably mixing the signals $R_1 + R_2^1$ and $R_1 - R_2^1$ before or after detection, but after having retarded the first by T .

In practice, the mixing is accomplished after detection because the height of the reflecting layer is not rigorously constant and because the relative phase of the additive and subtractive signals varies. It is, however, possible automatically to control the phase of the heterodyne oscillator in any suitable or well-known manner so that the waves of the signals or Equations 5 and 6 remain in phase.

It should be noted that the condition expressed by the relationship 4 is not a necessary condition for isolating the pair of direct waves from the pair of echoes. As a matter of fact, in accordance with the relationships 1 and 3, one gets

$$R_1 = R_2^1 = B\phi(t-T)2\omega_s \left[\omega(t-T) - \frac{T\theta}{2} \right] \sin \frac{T\theta}{2}$$

that is to say, that the pair of echoes will be isolated. By suitably modifying the phase of the heterodyne, the pair of direct waves can be isolated in a similar manner. The condition 4 gives, therefore, only the optimum relationship between the signal and the parasites.

The only figure of the attached drawing schematically illustrates an embodiment of the invention.

In this figure a pair of transmitters 16 and 17 respectively tuned to the wave lengths $\lambda 1$ and $\lambda 2$ are coupled to an antenna and simultaneously keyed by a keying means 18. In the receiver, a tuned antenna circuit 1 is connected between the two filters 2 and 3 which are respectively tuned to the wave lengths $\lambda 1$ and $\lambda 2$. The output of the filter 2 is connected directly to the primary winding of a transformer 12 having two secondary windings, and the output of the filter 3 is connected to a frequency changer 4 which is connected to a heterodyne oscillator 6 through a phase adjuster 5. The output of the frequency changer is connected with a filter 7 tuned to the new wave length obtained after the change of frequency, in other words, to the wave length of the other channel. The output of the filter 7 is connected to the primary of a transformer 13 having two secondary windings. The windings of the secondaries are divided and con-

nected in pairs to two receivers 8 and 10 of any suitable well-known type. Their outputs are connected over individual transformers 14 and 15 in opposition to a telephone receiver or similar translating device. 9 is a retardation circuit for retarding the waves in one receiving branch by T as previously explained.

The operation of such circuit will be clear from the above, the transformers 12 and 13 permitting the application of the outputs of two channels in series in one and in opposition in the other. In order to reduce to a minimum the effect of the frequencies in a system embodying such receiver, the frequency of $\lambda 2$ may be obtained in the transmitter beginning with $\lambda 1$ and then adding or subtracting the difference between these two frequencies. In the same manner, the heterodyne oscillator in the receiver may have a theoretical frequency equal to the difference of frequencies corresponding to $\lambda 1$ and $\lambda 2$. In this manner, the frequency of the heterodyne will be low and it will be easy to obtain frequency stabilization which is of great importance to the proper functioning of the system.

In order to simplify the explanation of the operation, we have assumed in the above that only the frequency of one wave will be changed in order to convert it into the second frequency. In practice, the frequencies of two waves will be changed by reducing them to the same mean frequency. In this case, the frequency of a beat oscillator may be obtained from the frequency of the other beat oscillator by the addition or subtraction of the difference between the frequencies of the two transmitter waves.

A communication system embodying the features of the present invention is obviously not limited to the use of two simultaneously transmitted waves. If for example, three waves are transmitted, then by combining in a suitable manner the signals of the three receivers, two of the waves may be suppressed and only the desired wave preserved. We will have:

$$R_1 = A\phi(t) \sin \omega_1 t + B\phi(t-T_1) \sin \omega_1 (t-T_1) + C\phi(t-T_2) \sin \omega_1 (t-T_2)$$

$$R_2 = A\phi(t) \sin \omega_2 t + B\phi(t-T_1) \sin \omega_2 (t-T_1) + C\phi(t-T_2) \sin \omega_2 (t-T_2)$$

By heterodyning in order to obtain:

$$R_1^2 = A\phi(t) \sin [\omega_1 t + \epsilon_1] + B\phi(t-T_1) \sin [\omega_1 (t-T_1) + \epsilon_1 + T_1(\omega_1 - \omega_2)] + C\phi(t-T_2) \sin [\omega_1 (t-T_2) + \epsilon_1 + T_2(\omega_1 - \omega_2)]$$

$$R_2^2 = A\phi(t) \sin [\omega_2 t + \epsilon_2] + B\phi(t-T_1) \sin [\omega_2 (t-T_1) + \epsilon_2 + T_1(\omega_1 - \omega_2)] + C\phi(t-T_2) \sin [\omega_2 (t-T_2) + \epsilon_2 + T_2(\omega_1 - \omega_2)]$$

and by adding the three waves R_1 , R_2^1 , and R_3^1 , we will obtain three vectorial diagrams for the three direct waves and for each group of waves corresponding to the first or to the second echo.

In order to reduce the resultants of the echoes to zero, it is necessary that in each case the vectorial diagram be an equilateral triangle, that is to say

$$\epsilon_1 + T_1(\omega_1 - \omega_2) = \pm \frac{2\pi}{3} + 2N\pi \quad (7)$$

$$\epsilon_2 + T_1(\omega_1 - \omega_2) = \pm \frac{4\pi}{3} + 2n\pi \quad (8)$$

$$\epsilon_1 + T_2(\omega_1 - \omega_2) = \pm \frac{2\pi}{3} + 2M\pi \quad (9)$$

$$\epsilon_2 + T_2(\omega_1 - \omega_2) = \pm \frac{4\pi}{3} + 2m\pi \quad (10)$$

where the same sign will be obtained in Equations 7 and 8 and the same sign in Equations 9

and 10, but not necessarily the same sign in the two pairs of equations. By considering the case when all the signs are positive:

$$(T_2 - T_1) (\omega_1 - \omega_2) = 2(M - N)\pi \quad (11)$$

$$(T_2 - T_1) (\omega_1 - \omega_3) = 2(m - n)\pi \quad (12)$$

relationships where M, N, m, n are whole numbers. The conditions 11 and 12 determine ω_2 and ω_3 and the conditions 7 and 8 determine ϵ_1 and ϵ_2 for the given values of M, N, m, n . The sum of the waves R_1, R_2 and R_3 is therefore independent of the echoes and the direct wave will subsist therein at least unless ϵ_1 and ϵ_2 become equal to

$$\frac{2\pi}{3} + 2N'\pi \text{ and } \frac{4\pi}{3} + 2n'\pi$$

respectively, N' and n' being whole numbers. This last case can be easily avoided by choosing in a suitable manner the values of M, N, m, n , except in the case where $T_1 = 3p (T_2 - T_1)$, p being a whole number, having thus isolated the direct wave, it can be separated from R_1 and R_2 and thus re-establish the above case where we have only two waves.

Instead of dephasing R_2 and R_3 from ϵ_1 and ϵ_2 , respectively, the system may also be provided in such a manner that these dephasing angles be equal to zero and that R_1, R_2 , and R_3 be amplified to different degrees a, b, c before adding them. The following are the conditions for the closing of the vectorial diagram of the first echo:

$$a + b \cos T_1 (\omega_1 - \omega_2) + c \cos T_1 (\omega_1 - \omega_3) = 0$$

$$b \sin T_1 (\omega_1 - \omega_2) + c \sin T_1 (\omega_1 - \omega_3) = 0$$

and, for the second echo,

$$a + b \cos T_2 (\omega_1 - \omega_2) + c \cos T_2 (\omega_1 - \omega_3) = 0$$

$$b \sin T_2 (\omega_1 - \omega_2) + c \sin T_2 (\omega_1 - \omega_3) = 0$$

These four equations determine the four quantities $b/a, c/a, \omega_1 - \omega_2$, and $\omega_1 - \omega_3$ as a function of T_1 and T_2 .

Generally speaking, if the system utilises n waves, there will be $2(n-1)$ conditions which must be satisfied and $2(n-1)$ unknowns, although these conditions can always be satisfied.

It is to be noted that the wave lengths are so close to one another that if desired they can be transmitted by the same output stage of the transmitter. The installation cost of the transmitter is, therefore, very small.

The adjustment of the transmitter and the receiver may be effected in accordance with one of the features of the present invention by transmitting an impulse preferably at a predetermined frequency of repetition, e. g. 100 or 200 times per second. This impulse or series of impulses is received and detected at the receiver and then applied to an indicating apparatus, such as a cathode ray oscillator, the spot of which is subjected to a well-known sweep system, e. g. horizontally to sweep the frame of the oscillograph at a predetermined speed. In the case where a series of impulses is used, the sweeping in the receiver will be synchronised in a well-known manner. Thus the direct impulse and its echoes will appear on the oscillograph frame and the leg can be measured to determine the optimum frequency of the second wave with respect to the first wave in accordance with relationship 4 in the case of two waves, n being suitably chosen. In the case of a plurality of waves, it will usually be always possible to find frequencies which permit the addition of all di-

rect waves or all the echoes of the n th scale with a sufficiently small displacement.

The lag of the different waves will generally be constant during long intervals of time. It will, therefore, be sufficient for the practical application of the above described system if the regulation were effected at relatively widely spaced times, e. g. once every hour. The different waves are not subject to selective fading, but the weakening of an entire wave—carrier and side bands—is common enough. In practice, the use of more than one wave with suitable lag eliminates the effect of fading on the connection. The cost of the first installation may be reduced by giving up the simultaneous use of the different waves. In this case, in accordance with another feature of the invention, the fading will be reduced by selecting the strongest wave, e. g. by means of a mechanical or electrical relay.

A system embodying features of the present invention will, therefore, have two principal advantages: Improvement of the quality and suppression of fading. Although two or more wave lengths must be employed, those wave lengths can be employed which in practice would otherwise be useless on account of the phenomenon of echoes.

The invention is applicable to the elimination of echoes originating in atmospheric layers. However, the invention is applicable also to cases where the echoes are produced by the presence of obstacles in the path of the waves, e. g. mountains or even movable objects, provided that the lag of the echo does not vary too rapidly.

It will be obvious that the invention is not limited to the embodiments herein disclosed, but that it is capable of numerous modifications and adaptations without departing from the spirit thereof.

What is claimed is:

1. A radio signalling system comprising a transmitter having means for generating a plurality of carrier waves of different frequencies, means for modulating said carrier waves with the same signals, and means for radiating said modulated carrier waves, and a receiving arrangement comprising means for abstracting energy from said modulated carrier waves means for converting the received waves to the same frequency, a phase adjuster for converting the directly received waves at the different frequencies to the same phase, two receiving branches, means for isolating direct waves in one of said branches and echo waves produced by reflections in the other of said receiving branches, an output circuit for each of said branches coupled to a circuit including an indicating device and a retardation circuit in one of said output circuits whereby the direct signal waves and the echo signal waves are additive in the circuit of said indicating device.

2. A radio signalling system according to claim 1 wherein said retardation circuit retards the direct signal waves an interval equal to the interval between the arrival of the direct signal and the first echo.

3. In a radio signalling system a transmitter comprising means for generating a plurality of carrier waves of different frequencies, means for modulating said carrier waves with the same signals, and means for radiating said modulated carrier waves, and a receiving arrangement comprising means for abstracting energy from said radiated carrier waves, means for segregating said different frequency waves in separate cir-

cuits, means for converting the received waves of the different frequencies to the same frequency, means for modifying the relative phases of the received waves of different frequencies in such manner that the directly received waves are in the same phase, a circuit comprising two branches, and means for impressing said converted direct waves and echoes produced by reflections in such manner upon said last-mentioned circuit that in one branch said direct waves are additive in effect and said echoes substantially neutralize each other and in the other branch said direct waves substantially neutralize each other and said echoes are additive in effect and an output circuit including an indicating device coupled to the said two branches.

4. A radio receiver for simultaneously receiving a plurality of carrier waves of different frequencies modulated by the same signals, comprising means for abstracting energy from said radiated carrier waves, means for segregating said different frequency waves in separate circuits, means for converting the received waves of the different frequencies to the same frequency, means for modifying the relative phases of the received waves of different frequencies in such manner that the directly received waves are in the same phase, a circuit comprising two branches, means for impressing said converted direct waves and echoes produced by reflections in such manner upon said last-mentioned circuit that in one branch said direct waves are additive in effect and said echoes substantially neutralize each other and in the other branch said direct waves substantially neutralize each other and said echoes are additive in effect and an output circuit including an indicating device coupled to said two branches.

5. In a radio signalling system a transmitter comprising means for generating a plurality of carrier waves of different frequencies, means for modulating said carrier waves with the same signals and means for radiating said modulated carrier waves, and a receiving circuit comprising means for abstracting energy from said radiated carrier waves, means for segregating said different frequency waves in separate circuits, means for converting the received waves of different frequencies to the same frequency, means for modifying the relative phases of the received waves of different frequencies in such manner that the directly received waves are in the same phase, two receiving branches, transformers for coupling said separate circuits to said two receiving branches, the secondary windings of said transformers being divided into sections and a section of each secondary winding being connected in series aiding relation in the input circuit of one of said receiving branches and another section of each secondary winding being connected in series opposed relation in the other of said receiving branches and output circuits for said re-

ceiving branches and an output circuit including an indicating device coupled to said two branches.

6. In a radio signalling system a transmitter comprising means for generating two carrier waves of different frequencies, means for modulating said carrier waves with the same signals and means for radiating said modulated carrier waves, and a receiving arrangement comprising means for abstracting energy from said radiated carrier waves, filters for segregating said two different frequency waves in separate circuits, at least one heterodyne oscillator for converting the received waves of the two frequencies to the same frequency, a phase adjuster for modifying the relative phases of the received waves of the two frequencies in such manner that the directly received waves are in the same phase, two receiving branches, transformers for coupling said separate circuits to said two receiving branches, the secondary windings of said transformers being split into two halves, one half of each secondary winding being connected in series aiding relation in the input circuit of one of said receiving branches, and the other half of each secondary winding being connected in series opposed relation in the other of said receiving branches and an output circuit including an indicating device coupled to said receiving branches.

7. A radio receiver for simultaneously receiving two carrier waves of different frequency modulated by the same signals, comprising means for abstracting energy from said radiated carrier waves, filters for segregating said two different frequency waves in separate circuits, at least one heterodyne oscillator for converting the received waves of the two frequencies to the same frequency, a phase adjuster for modifying the relative phases of the received waves of the two frequencies in such manner that the directly received waves are in the same phase, two receiving branches, transformers for coupling said separate circuits to said two receiving branches, the secondary windings of said transformers being split into two halves, one half of each secondary winding being connected in series aiding relation in the input circuit of one of said receiving branches, and the other half of each secondary winding being connected in series opposed relation in the other of said receiving branches and an output circuit including an indicating device coupled to said receiving branches.

8. A radio signalling system according to claim 5 wherein the difference in frequency between the two carrier waves is equal to

$$\frac{2n+1}{2T}$$

n being a whole number and T being equal to the interval of time in seconds between the instants when the direct wave and the first echo wave are received.

EDWARD HILL ULLRICH

Certificate of Correction

Patent No. 2,350,702.

June 6, 1944.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 45, for " $\sin \varphi_1(t-T_2)$ " read $\sin \omega_1(t-T_2)$; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of August, A. D. 1944.

[SEAL]

LESLIE FRAZER,
Acting Commissioner of Patents.

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