March 3, 1931. R. A. WEAGANT 1,794,878

SIGNALING

Filed Aug. 30, 1928 2 Sheets-Sheet 1

Fig. 1

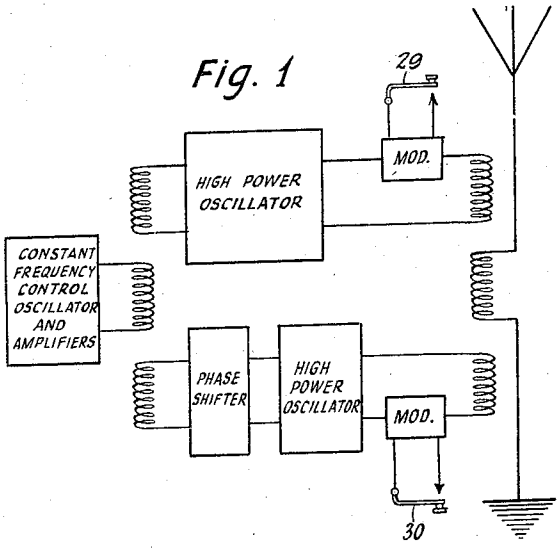


Fig. 6

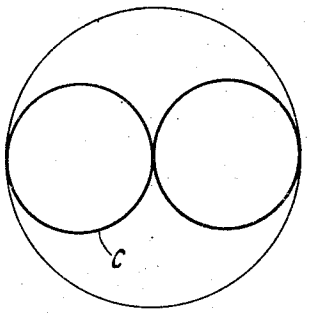


Fig. 3

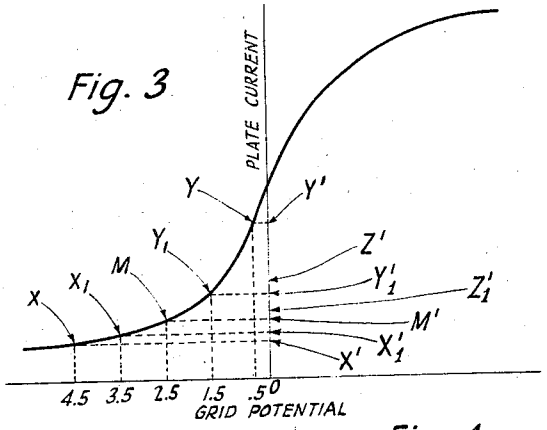


Fig. 5

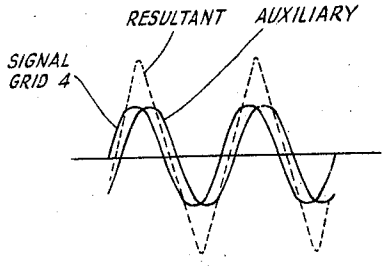
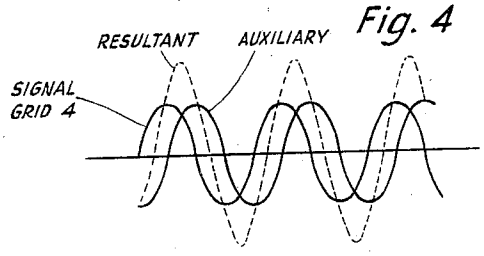
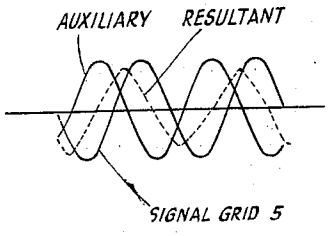
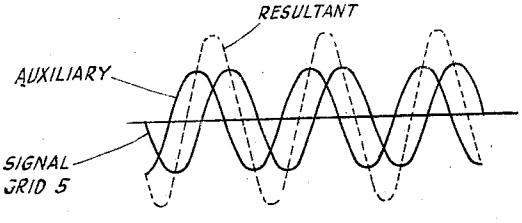


Fig. 4







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March 3, 1931. R. A. WEAGANT 1,794.878

SIGNALING

Filed Aug. 30, 1928 2 Sheets-Sheet 2

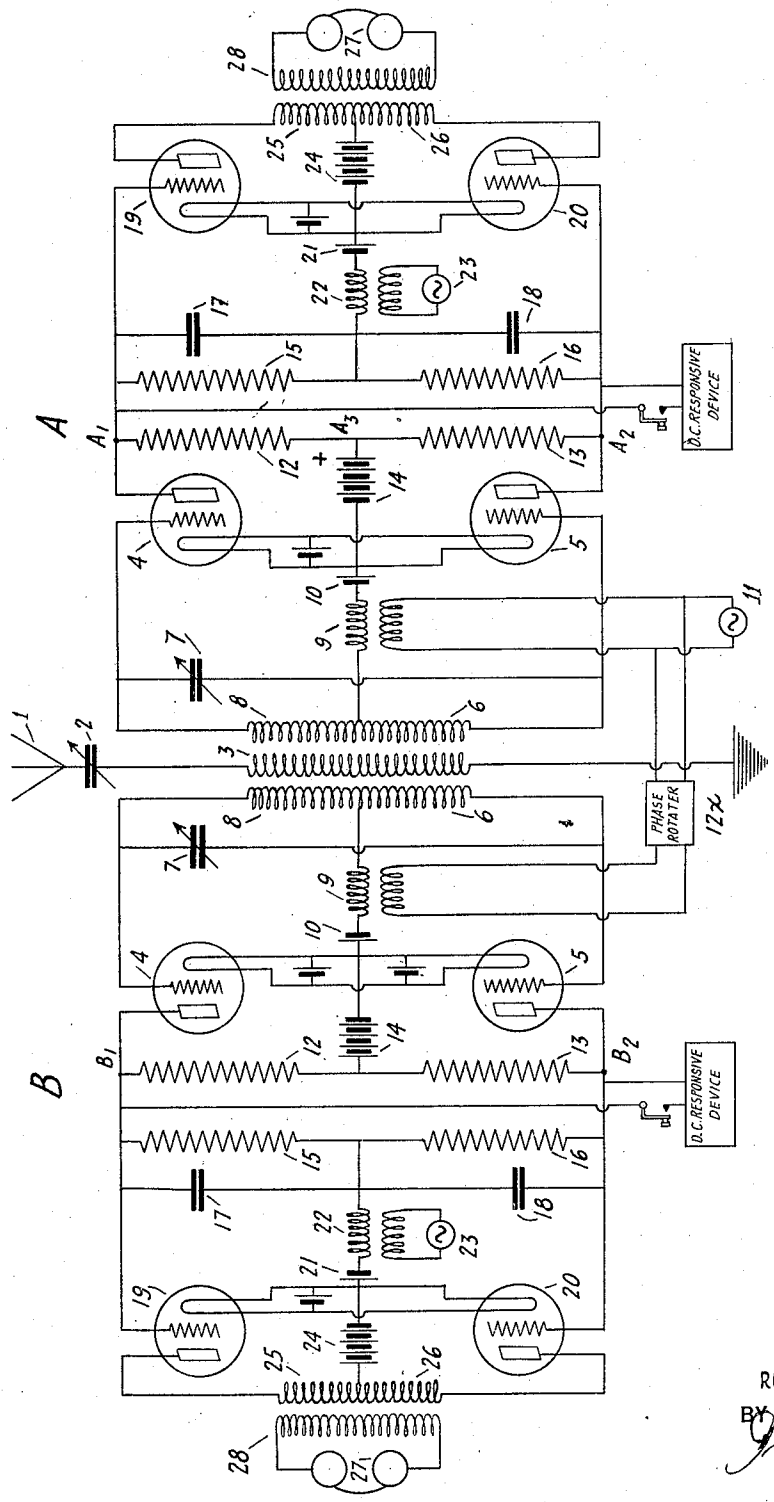


Fig. 2

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Patented Mar. 3, 1931 1,794,878

UNITED STATES PATENT OFFICE

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SIGNALING

Application filed August 30, 1928. Serial No. 303,095.

This invention relates to high frequency signaling and particularly to methods and arrangements for securing discrimination between desired signals and interference. Although the invention is applicable to signaling with high frequency currents over wires, it is particularly applicable to wireless signaling and will be herein described particularly in relation to the latter.

At present two fundamental methods of discrimination are known and widely used in radio signaling. The first depends on the utilization of receiving devices more sensitive to currents of the desired frequency than to currents of another frequency. By this means we eliminate signals from other stations of different frequency and that portion of the static or atmospheric interference which produces an effect or a frequency component different than the signal produces. This is commonly known as tuning and is always used; either alone or in connection with a second method of discrimination known as waves from a certain direction. This discrimination enables the elimination of interfering signals and static to the extent that the receiver is less sensitive to waves from directions different from the signal direction.

Although these fundamental methods of discrimination provide frequency and geographical selectivity, no method has heretofore been known, and as far as I am aware, has even been suggested for discriminating between oscillations of exactly the same frequency coming from the same direction.

The principal object of the invention is to provide a method and apparatus adapted to permit this distinction to be made.

In accordance with the invention this result is obtained by discriminating by means of differences existing between the phase of the oscillations. Phase discrimination is only possible between waves of identical frequency, and this excludes modulated waves, for the modulation results in side band frequencies which differ from the carrier, and which will therefore beat with a locally supplied carrier regardless of phase. My invention is more especially adapted to long wave work, and is limited to phase discrimination between code or other on and off signals transmitted on continuous waves or pure carriers of identical frequency. By this method of discrimination in conjunction with one or both of the usual methods of differentiation heretofore mentioned one or more benefits may be secured among which the following are mentioned by way of example.

(1) Currents due to atmospheric disturbance having the same frequency as the signal may be excluded, the extent of the exclusion being substantially similar to that effected by directional reception in respect to static coming from directions different than the signal direction.

(2) Two or more oscillations may be transmitted from the same place on the same wave length and received without interference, either on the same or different antennæ.

(3) The signaling, instead of being effected by detuning or changing the amplitude, may be accomplished by changing the phase without altering frequency or amplitude.

(4) The system is highly secretive as no ordinary tuned receiver can distinguish between the two signals.

Further objects, advantages and capabilities of the method and of structures employing the method will appear from the following description and drawings of several embodiments illustrating the invention.

The novel features which I believe to be characteristic of my invention are particularly set forth in the appended claims, the invention itself, however, both as to its construction and mode of operation, together with further objects and advantages thereof will best be understood by reference to the following description taken in connection with the accompanying drawings in which:

Figure 1 is a diagrammatic representation of a transmitting system adapted to be utilized in conjunction with the method and Figure 2 is a similar representation of a receiving station adapted to cooperate therewith.

Figure 3 is a curve showing the effect of

the certain electromagnetic forces on the receiving system.

Figures 4 and 5 illustrate the manner in which the signal and auxiliary electromotive forces are combined.

Figure 6 is a curve showing the characteristics of the system with respect to static elimination.

In securing discrimination between desired signals and other interfering signals or transient or atmospheric influences of the same frequency, in accordance with my invention, it is necessary to provide sources of oscillatory energy at the transmitter and receiver which are of very constant frequency. In general, the frequency of each of these controlling oscillators will be the radio frequency which is used for transmission. For satisfactory operation, the variations of frequency or the shifting of the phase relations between the controlling oscillators should only occur at such a slow rate that the variations can be conveniently taken care of by manual or automatic adjustment to maintain synchronism.

Whenever ordinary high frequency systems refer to the use at the transmitter and receiver of "circuits tuned to the same frequency" or "oscillators of the same frequency" it is always understood that a difference of ½% or even considerably more is accurate adjustment. As far as I am aware no high frequency signaling systems have even been suggested which require such constancy that the phase of the oscillations is material as a difference of ½ or even $\frac{1}{10}$ of 1% would be a large number of cycles. To distinguish from this ordinary usage, the constancy of the oscillators heretofore specified as necessary to the operation will be designated by the term "in substantially definite phase relations". This accuracy of frequency regulation may be reached with exceedingly carefully constructed vacuum tube oscillation generators employing crystal control with temperature regulated crystals and by utilizing such oscillation generators at both the sending and receiving stations the constancy necessary for the method may be maintained. In general, it will be advisable to use a constant oscillator at the transmitter merely as controlling means for the generators which supply the actual oscillating energy to the radiating system.

In Figure 1 a transmitting station is shown in which the output of a constant frequency separate control oscillator is amplified to produce two high power oscillations of constant and equal frequency. Each high power oscillation energizes the same antenna although obviously the oscillations if desired, may energize separate aerials. One set of oscillations is dephased relatively to those of the other by any appropriate well known means. In the drawing a phase shifter is shown for this purpose in the input or control of one of the high power amplifiers. The circuit arrangements of the control oscillator, amplifiers and the phase shifter are not shown in detail as my invention in this respect is not limited to any particular apparatus of circuit arrangement and for convenience legends have therefore been used. However, as the desired constancy at present is most easily obtained with vacuum tube amplifiers, in actual practice these will preferably be used.

If two transmitters, as shown, are operated without modulation on exactly the same wave length the phases may be adjusted so that the oscillations are 90° out of phase. A receiving arrangement which will now be described by way of example is adapted to selectively receive these oscillations despite the fact that they are or may be of the same frequency and direction.

Referring to Figure 2 a receiving antenna 1 is shown which may be tuned in the usual manner by means of condenser 2 and inductance 3. The antenna is coupled to two similar amplifying and detecting systems A and B the corresponding elements of which are designated by the same reference characters. A portion of each detecting system shown in the drawing is the well known Carson translator circuit. The translator circuits of receiver systems A and B each consist of two similar three element vacuum tubes, 4, 5, having their grids connected together by means of a coil 6 coupled to the aerial coil 3. A variable tuning condenser 7 is connected across the coil. The middle point of the coil is connected to the filaments of the tubes through a coil 9 and a biasing device such as a battery 10 for fixing the operating potential of the grids at a rectifying point of the characteristic curve, preferably at a negative potential. A local constant frequency oscillator 11 is coupled to the coil 9, the connection to coil 9 of system B including a phase rotator $12x$. The plates of the tubes are connected together by means of resistances 12 and 13 of equal value and preferably of substantially twice the order of magnitude of the impedance of the internal plate-filament circuits of the valves. Between the filaments and the junction point of these resistances is connected a plate battery 14 which supplies the plate filament circuits of the valves.

In order to utilize the Carson translator in my system I may employ to advantage a special type of detecting arrangement. This consists of a pair of equal resistances 15, 16 in parallel with the resistances 12, 13, the first mentioned resistances being shunted by condensers 17, 18. The condensers are of sufficiently large value to by-pass or in other words short circuit frequencies of the order of the radio frequency to be detected,

but not large enough to by-pass or short circuit the key or modulation frequency used in sending. Two tubes 19, 20 have their filaments connected to the junction point of the resistances 15, 16 and condensers 17, 18 through a biasing battery 21 and coupling coil 22 to which an audio frequency oscillator 23 is coupled. The grids of tubes 19, 20 which are connected to separated ends of the resistances, are adjusted to a rectifying point of the characteristic curve.

The plates of the tubes are connected to the positive terminal of a battery 24 through inductance coils 25, 26 of equal value wound in the same direction. A circuit containing a telephone 27 is coupled to inductances 25, 26 by means of a coil 28.

In the operation of the transmitting system two oscillations of the same frequency will be supplied to the radiating antenna each of these being interrupted for signaling in any appropriate manner, keys 29, 30 being shown in Figure 1 connected to a modulator or any suitable device for changing the antenna radiation. The oscillations will be maintained at a definite phase relative to each other for example, by coupling two amplifiers to the same master oscillator and dephasing the input of one of the amplifiers by means of the phase shifter.

In the particular system shown for the purpose of illustrating the method, the two transmitted waves are fixed to have a phase difference of 90°. The master receiving oscillator will be regulated to give substantially definite phase relation with the master transmitter oscillator and by means of the phase shifter the electromotive forces of the master receiving oscillator will be split to provide two electromotive forces at 90° phase. Obviously the single oscillator and the phase rotator at the receiver and transmitter is the equivalent of two separate sources in exact synchronism.

One of the auxiliary electromotive forces is adjusted to be in phase with one of the received oscillations with respect to the potential or the grid of one of the tubes of receiver A and it will then be 90° out of phase with the other received oscillation. The auxiliary electromotive force applied to receiver B will then be in phase with the received oscillation and 90° out of phase with the oscillation which is in phase with the auxiliary electromotive forces of receiver A. With this adjustment and method of operation it may be shown that each receiver is responsive to one of the oscillations and unresponsive to the other.

The operation of the system may best be shown by discussing some of its characteristics. It will be noted that when neither the transmitter nor the master receiving oscillator is working the potentials at A_1 and A_2 are the same because the resistances 12 and 13 are equal. No direct current potential is therefore applied to the tubes 19, 20 from the preceding portions of the receiver. The same is true of points B_1 and B_2 of system B and likewise no potential is applied to the corresponding tubes.

When the auxiliary oscillator 11 is working, but the transmitter is not, no effect is produced by the master receiving oscillator on the telephones of either system A or B as the fluctuations of the grid potentials of tubes 4 and 5 are the same and the corresponding fluctuations of the plate currents produce like changes in the potentials of points A_1 and A_2 of system A and points B_1 and B_2 of system B. It will then be evident that under these conditions no direct current potential is applied to either detector system. The high frequency fluctuations of potential of A_1, A_2 and B_1, B_2 also have no effect on the grids of tubes 19, 20 as they are short circuited by condensers 17, 18, and moreover, any effects on the grids of tubes 19, 20 is balanced in the plate circuits so that no effect is produced in the telephone circuit.

The effect on the receiver when the transmitter is sending two waves of the same frequency 90° out of phase, each of the received waves being substantially in phase with one of the component electromotive forces derived from the auxiliary receiver oscillator 11, is to produce a direct current potential across points A_1 A_2 of receiver A due to one of the waves and no direct current potential across these to points due to the other wave. Similarly in receiver B a direct current potential is produced across B_1 B_2 due to said other wave and no direct current potential across these points due to the wave which produces the direct current across A_1 A_2. It may also be shown that the signal frequency and the second harmonic also exist across the points A_1 A_2 but are not utilized in the detecting system.

It may be demonstrated mathematically that the direct current potential across A_1 A_2 or B_1 B_2 due to the signals and local source is equal to EF cos ϕ where E is the signal electromotive force, F the local electromotive force of the same frequency and ϕ the phase angle between the local electromotive force and the signal electromotive force. As the complete demonstration of this characteristic involves complex mathematics a simple specific illustration of the general proposition will be selected to show why direct current is produced across A_1 A_2 and B_1 B_2 as previously set forth.

Assume that the electromotive force of the received signal is the same as the electromotive force applied through the auxiliary source. When these electromotive forces are in such phase that they add in phase on the grid of tube 4 they will exactly oppose with respect to the grid of tube 5. The grid of tube 5 therefore will not vary in potential

and therefore, the plate current of tube 5 will not vary so that there is no variation whatever in the potential of point A_2. The grid of tube 4 however, will vary in potential with respect to point M from X to Y as shown in Figure 3. By operating at the point M of the characteristic curve the plate current of the tube will vary at a radio frequency from X′ to Y′, the average value of direct current being Z′, while as the plate current of tube 5 does not change its current corresponds to M′. As a result the direct current potential from A_3 to A_1 is greater than the direct current potential from A_3 to A_2 and between A_1 and A_2 there is a direct current potential proportional to Z′—M′. By similarly plotting grid potentials X_1 Y_1 corresponding to signal and auxiliary electromotive forces of half the first illustrated value it will be seen that the average of plate current Z_1', between X_1' Y_1' differs from M′ by an amount which is substantially one-fourth of Z′—M′. This shows graphically that the direct current potential across A_1 A_2 and B_1 B_2 varies as the product of the applied voltage, when the auxiliary electromotive force is in phase with the signal with respect to one of the grids. This can also be demonstrated mathematically as previously stated.

It will now be shown that there is no direct current across A_1 A_2 and B_1 B_2 due to the signal which is 90° out of phase with the auxiliary electromotive force applied to the grid of tube 4. Under these conditions the potentials applied to the grid 4 are shown in Figure 4. It will be noted that the resultant potential is a wave of the same frequency but greater amplitude than the components and the direct current in resistance 12 is correspondingly increased. For grid 5 the signal potential is opposite to that of grid 4 and when this is combined with the auxiliary potential the resultant is also a wave of the same frequency and greater amplitude than the components, but 90° behind the resultant on grid 4. The change of potential of the grid 5 however, is the same as that of grid 4 so that the direct current in resistance 13 is the same as that in resistance 12 and therefore, there is no direct current potential applied across points A_1 A_2 or B_1 B_2 for the signal which is 90° out of phase with the auxiliary potential. The combination of the effects of the two resultants gives an amplified signal frequency and a double frequency which are not effective in this arrangement, as the short circuiting condensers 17 and 18 are provided.

To show that there is some direct current between 0° and 90° phase relation of signal and auxiliary potentials the potentials are plotted for a 45° phase difference between the auxiliary and signal potential on grid 4 (Figure 5). It will be seen that these two potentials are sufficiently nearly in phase so that the resultant potential on grid 4 is considerably greater than either. As a result the direct current in resistance 12 is greatly increased, the explanation for this being similar to the previous explanation. However, in the case of the grid 5 the potentials are combined so nearly in opposite phase that the resultant is of less amplitude than either component. The direct current through resistance B will be somewhat increased, but the increase will be considerably less than the increase of direct current through resistance 12. As a result there is a direct current potential across A_1 A_2 and B_1 B_2 as well as the high frequency and second harmonic previously mentioned. This may be shown mathematically to depend on the cosine of the phase angle between the auxiliary and signal waves. In other words, considering the potential on grid 4 due to the signal and the potential on grid 4 due to the auxiliary source, direct current across A_1 A_2 and the phase between the potentials is as follows:

at	0°	*dc* potential	= + 1
	45°	*dc* potential	= +.7
	90°	*dc* potential	= .0
	135°	*dc* potential	= −.7
	180°	*dc* potential	= −.1
	225°	*dc* potential	= −.7
	270°	*dc* potential	= 0
	315°	*dc* potential	= +.7
	360°	*dc* potential	= + 1

It will therefore be evident that if two signals at 90° are sent and the adjustment of the phase of an auxiliary potential is made to give maximum direct current at A_1 A_2 for one of two signals, there will be no direct current effect at A_1 A_2 for the other signals. Even if the phase angle should be varied on either side by as much as 15° the direct current across A_1 A_2 due to the desired signal will only decrease from 1 to .98 and the direct current due to the undesired signal will increase from 0 to .26. The difference in the signal strength will, under these conditions, enable the selection to be made. The operation of system B in the reception of the other signal and the exclusion of the A signal will be the same as that already described.

The discrimination of the receiver as the phase relation is varied is illustrated in Figure 6 by the curve C which is the well known figure 8.

The curve C of Figure 6 shows that the selectivity characteristic with phase selectivity is similar to the directional selectivity of a loop antenna. That is, interference from signals or static of the same frequency which lead or lag behind the local oscillator by 90° is entirely eliminated and if in phase or in opposite phase they are received without diminution, but the direction of current flow is reversed if the phase is reversed. At intermediate phase angles interference is re-

duced depending upon the cosine of the phase angle of the local oscillator and the interference. An ordinary receiving system which is not selective in the manner described responds equally well to oscillations for which they are tuned regardless of their phase and the selectivity characteristic is represented by a circle, that is, the selectivity characteristic is analogous to that of a vertical antenna as shown in Figure 6. The area of the figure 8 may be shown to be equal to

$$\frac{2r^2}{4}$$

where r is the received effect when the local and received oscillations are in phase. As the area of the circle is r^2 phase selectively with the arrangement shown in Figure 2 eliminates 50% of the interference which is of the same wave length assuming the static to be uniformly distributed as to phase. This is analogous to the benefits of directional selectivity of a loop over a vertical antenna.

A shown diagrammatically in Figure 2 the signal may then be indicated by any form of direct current responsive devices such as a telegraph sounder. In actual operation, however, it will be preferable to utilize the direct current to control another frequency source which is adapted to actuate a telephone. The advantage of this is due to the superiority of the oral reception in distinguishing static noises from signals. To secure this result a second system may be used which is similar in some respects to the Carson translator. The direct current resulting from the desired signal is impressed across the equal resistances 15 and 16 the opposite ends of which are connected to the grids of tubes 19, 20, thereby causing the grids to be at different potentials while the signals are being received. This second pair of resistances 15, 16 are used to prevent a high positive potential from being applied to the grids of tubes 19, 20, from the battery 14. Direct current from the preceding portions of the circuit is impressed on the grids only when desired signals are being received. The condensers 17 and 18 are of such value that high frequency alternating current potentials are by-passed therethrough but the key frequency is not. To render the signals audible the local oscillator 23 of radio frequency is used. When no direct current is applied to the grids of tubes 19, 20, the local oscillator frequency is not heard in the telephone because the grid potentials are alike and the effects of the plate current variations on coil 28 are equal and opposite. When the grids of the tubes are biased to different potentials by the direct current resulting from the signal the variations in the plate currents in the valves are unequal and as a result the potentials impressed on the coil 28 by the coils 25 and 26 are unequal. The local oscillation frequency is therefore heard only when a desired signal is received. The operation of the two detectors of the direct current is identical except that each responds to only one of the two signals, and therefore, need not be further described.

From the foregoing it will be evident that certain important benefits are derived even when the method is used with only one transmitted wave. Where a single wave is transmitted it will also be advantageous to effect the signaling by shifting the phase of the transmitted oscillations 90° without altering the frequency or amplitude of the oscillations.

Furthermore, although I have illustrated and described a particular type of transmitting and receiving system operating with two waves 90° out of phase my invention is not limited to this number as the method may also be utilized with more than two waves and with different phase relations.

I claim:

1. A multiplex signaling system comprising a transmitter including a source of a plurality of carrier energy components of like constant frequency and different constant phase, and means for independently keying each of said carrier energy components in accordance with a different one of the signals to be transmitted, and a receiver including a source of portions of locally generated energy of like frequency and proper phase, relative to each of the received energy components, to discriminate therebetween, means to separately combine the received carrier energy with the different portions of the locally generated energy to separate the desired signals, pairs of pushpull connected tubes biased alike, relatively low frequency energy sources for applying to the input circuits of the tubes in parallel the relatively low frequency energy, and means for applying the separated signals to the tubes whereby relatively low frequency energy appears in the output circuits thereof and means for translating the energy so appearing.

2. A multiplex signaling system comprising a transmitter including a source of carrier energy of constant frequency and phase, means to key the carrier in accordance with a first signal, a source of carrier energy of like constant frequency and in constant phase quadrature, means to key this carrier in accordance with a second signal, means to transmit both of said carriers, and a receiver including a source of locally generated energy of like frequency and in proper phase to select the first signal, means for combining the received energy with the locally generated energy, means to translate the first signal, a source of locally generated energy of like frequency and in proper phase to select the second signal, means to combine the received en-

ergy with the locally generated energy, and translating means for the second signal, each of the translating means comprising pushpull connected tubes biased alike, a relatively low frequency energy source for applying in parallel to the input circuits thereof relatively low frequency energy, means for applying the selected signal to the tubes whereby relatively low frequency energy appears in the output circuits thereof, and a device for translating the low frequency energy so appearing.

3. A multiplex signaling system comprising a transmitter including a source of first carrier energy of constant frequency and phase, means to key the first carrier in accordance with a first signal, a source of second carrier energy of like constant frequency and in constant phase quadrature, means to key the second carrier in accordance with a second signal, and means to transmit the keyed carrier energy, and a receiver including a source of first energy of like frequency and like or opposite phase relative to the first received carrier, a first pair of electron emission tubes, means to apply one of said energies to the tubes in series, means to apply the other of said energies to the tubes in parallel, and a translating device responsive to the differential of the tube outputs for translating the first signal, a source of second energy of like frequency and like or opposite phase relative to the second received carrier, a second pair of electron emission tubes for combining the received energy and the second locally generated energy, means to apply one of said energies to the tubes in series, means to apply the other of said energies to the tubes in parallel, and a translating device responsive to the differential of the tube outputs for translating the second signal, each of said translating devices comprising a pair of pushpull connected tubes biased alike, a low frequency generator applying energy in parallel to the input circuits thereof and an electromechanical translating device coupled to the output circuit thereof responsive to the relatively low frequency energy appearing therein.

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