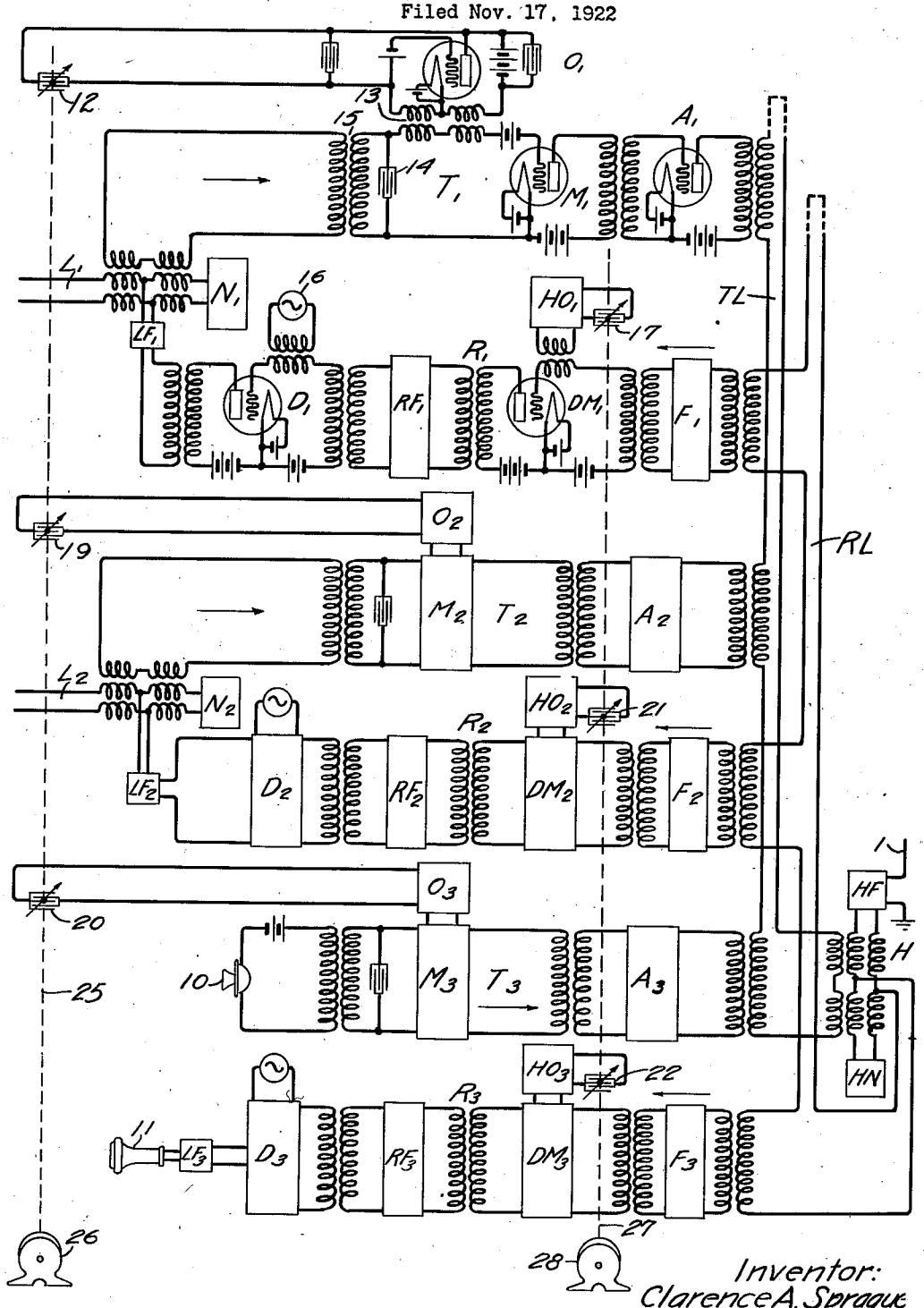
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C. A. SPRAGUE

ELECTRIC WAVE SECRECY TRANSMISSION

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by E. W. Griggs Atty

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UNITED STATES PATENT OFFICE.

CLARENCE A. SPRAGUE, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

ELECTRIC-WAVE SECRECY TRANSMISSION.

Application filed November 17, 1922. Serial No. 601,471.

To all whom it may concern:

Be it known that I, CLARENCE A. SPRAGUE, a citizen of the United States, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Electric-Wave Secrecy Transmission, of which the following is a full, clear, concise, and exact description.

The present invention relates to electric wave transmission for signaling or kindred purposes, and more particularly to secret transmission of signals and the like.

The invention is concerned with the type of signal transmission in which a sustained wave, hereinafter termed a carrier wave, is modified in some manner by the indications to be sent. It has been proposed to render a system of this general type secret by causing the carrier frequency to vary cyclically and in an erratic manner so that one not knowing the law of variation of the carrier frequency would have great difficulty in receiving the signal indications in an understandable form. Such a system is disclosed, for example, in Canadian Patent 197,181, issued February 10, 1920.

Varying the carrier frequency increases the frequency range employed in the transmission of the message over the range that would be required if the carrier frequency remained constant. This increased frequency range required for an individual message becomes of considerable importance particularly in the case of multiplex systems in which a different frequency range is set aside for use exclusively in transmitting each separate message.

It is an object of the present invention to provide multiplex secret transmission by carrier waves of varying frequency in which the range employed for one signal overlaps that employed for another so that the total range of frequencies used for three simultaneous messages, for example, is less than three times the range used for a single message.

A feature of the invention is the use of a plurality of carrier waves, the frequencies of which vary together preferably in a continually and definitely related manner.

A further feature of the invention is the use of a plurality of carrier waves, the frequencies of which vary within substantially the same extreme limits and in which the variations in frequency of the respective carrier waves go through the same or similar portions of the cycle of variation at different times so that the same portions of the frequency range are occupied successively by the different carrier waves.

Another feature of the invention relates to the derivation at a receiving point of a carrier wave of constant frequency from the transmitted wave of cyclically varying frequency.

Another feature of the invention relates to the derivation at a receiving point of a carrier wave of a different constant frequency from each of the transmitted carrier waves, the frequencies of which may vary over the same range.

Other objects and features will be apparent from the more detailed description to follow.

In accordance with the specific embodiment of the invention to be described, a number of carrier waves have their frequencies determined from a common control device in such a way that each wave follows through substantially the same course of variation, but the frequency limits between which any one wave varies overlap the limits between which another wave varies. In the extreme case to be specifically described, in which a plurality of carrier waves vary in frequency between the same limiting frequencies, the carrier wave frequencies execute different portions of their cycle of variations at any one time. That is, the cyclic variations of the respective carrier frequencies are displaced in phase. Each carrier wave is modified in accordance with a different signal, such as a different conversation, and the waves are simultaneously transmitted.

To receive the messages so transmitted, a plurality of locally controlled waves may be employed, the frequencies of which vary cyclically in the same manner as the frequencies of the carriers to be received. These locally generated waves may each vary about a different frequency so that at any instant the difference in frequency between one such locally produced wave and one of the received carriers has one constant value, while the difference in frequency between another locally produced wave and one of the received carriers has another constant value, and so on. However, if desired,

the locally produced waves may vary about the same frequency. In either case, the difference in frequency between one and only one of the locally controlled waves and a given carrier has a constant value since only in the case of this one of the locally produced waves does the frequency variation agree with the frequency variation of the particular received carrier in question. A different locally produced wave has a constant frequency difference from a different received carrier wave, and so on. This forms a basis of separation between the received waves. The received wave complex is combined in one circuit with a single one of the locally produced waves and a narrow band of frequencies including the constant difference frequency that results from interaction between this local wave and the particular received wave with which its frequency variations are in phase agreement is selected for separate detection. In another circuit the received wave complex is combined with another of the locally produced waves and the resulting constant difference-frequency wave with its modification, representing a different message, is selected into a different receiving circuit. By this process the individual messages are separately received.

Not only is the frequency range required for a given plurality of messages in this manner very materially reduced over that which would be required in systems heretofore suggested, but the degree of secrecy is increased due to the materially greater difficulty in receiving a message without a knowledge of the frequency relations employed.

In the drawing, a terminal of a two-way signaling system embodying the invention is diagrammatically illustrated.

In this drawing three two-way channels of communication are shown arranged for operating over the same high frequency carrier wave transmission path. This path is indicated as comprising in part a grounded conductor 1 which may be continued in the form of a transmission line to a distant station in case the carrier waves are to be guided to a definite point, or which may lead to an antenna in case the carrier waves are to be radiated to the distant point or points. This conductor serves in both transmitting and receiving carrier waves. The transmission circuit 1 is provided with a balancing network HN and a differential repeating coil or hybrid coil H in accordance with well-known repeater practice for enabling waves to be received from the circuit 1 and impressed on it without mutual interference. The network HN may contain a number and arrangement of electrical elements sufficient to simulate, as a whole, the circuit lying to the other side of the hybrid coil H, as will be apparent to those skilled in the art. Between the transmission circuit 1 and the hybrid coil is included a broad band filter HF for confining the frequencies transmitted between the conductor 1 and the terminal circuits to a definite range of frequencies. This filter, as well as the other filters to which reference will be made as the description proceeds, may be constructed in accordance with the disclosure of U. S. Patent 1,227,113 to Campbell, May 22, 1917. Associated with the hybrid coil H are a receiving loop RL and a transmitting loop TL related differentially with respect to said hybrid coil. Any number of receiving carrier wave channels may be connected to the receiving loop RL, and similarly any number of transmitting carrier channels may be connected to the loop TL.

Two of the channels comprising the respective transmitting sides T_1 and T_2 and the receiving side R_1 and R_2 are shown provided with low frequency terminations in the form of telephone lines L_1 and L_2, respectively. Each of these lines is provided with a balancing network N_1 or N_2 and a differential repeating coil to which the transmitting and receiving sides of the respective channel are differentially related. For the sake of illustration, the third channel is shown with a different low frequency termination, its transmitting side T_3 leading directly from the microphone 10 and its receiving side R_3 leading directly to the telephone receiver 11.

The circuit arrangement of each of the channels T_1, T_2 and T_3 may be the same, except for their frequency relations and likewise the circuit arrangement of the channels R_1, R_2 and R_3 may be the same, except as to frequency. Accordingly, only the two-way channel T_1, R_1 has been illustrated in detail. The transmitting side of this channel comprises the modulator M_1 having its input circuit associated both with the telephone line L_1 and the carrier oscillator O_1 and having its output circuit connected to the transmitting loop TL, preferably through an amplifier A_1. This modulator is shown as comprising a thermionic discharge tube of well-known type, although any suitable type of modulator or modulator circuit might be employed. The oscillator O_1 is of the general type disclosed in U. S. patent to Hartley 1,356,763, October 26, 1920, except that this oscillator is provided with a condenser 12 arranged to have its capacity continuously varied in a manner to be described later. The continual variation of capacity of condenser 12 causes the frequency of the wave generated by the source O_1 to be continuously varied. This varying frequency carrier wave is supplied through the coupling 13 to the grid circuit of the modulator M_1, the condenser 14 form-

ing a path of low impedance for the carrier frequency in shunt of the voice frequency input coil 15 connected to the line L_1. The receiving side R_1 of this channel comprises the filter F_1 associated with the receiving loop RL, the detector or demodulator DM_1, a second filter RF_1, a detector D_1, and low pass filter LF_1, the output side of which is connected to the line L_1. For a better understanding of the significance of "high pass filter" and "low pass filter" as these terms are employed in this description, reference is made to the April 1921 number of the Journal of the American Institute of Electrical Engineers, page 311, in the article entitled "Carrier current telephony and telegraphy," by Messrs. Colpitts and Blackwell. Also associated with the receiving circuit R_1 are the oscillators HO_1 and 16, the functions of which will be described later. The filter F_1 is designed to have a transmission frequency range broad enough to accommodate all of the frequencies comprised in the wave to be received by this channel and may be designed in accordance with the disclosure of the Campbell patent referred to. The demodulator DM_1 is shown as comprising an electron discharge device of the audion type. The heterodyne oscillator HO_1 may comprise a circuit identical with that of the oscillator O_1, except that its frequency adjustment may or may not be the same. It is provided with a condenser 17 adapted to have its capacity continuously varied so that the wave which is generated has a continuously varying frequency. The filter RF_1 is designed to selectively transmit to the detector D_1 the particular components of the wave in the output of the demodulator circuit which contain the signal indications to be detected. This filter would ordinarily be designed to have a relatively narrow transmission range. The detector D_1, into which the filter circuit RF_1 feeds, is shown as comprising an electron discharge device of the audion type. An oscillator 16 of constant frequency is preferably associated with this detector, although, in general, this oscillator is not necessary. This oscillator may be of the type disclosed in the Hartley patent referred to.

As stated, the circuit elements of the channels T_2 and T_3 may be duplicates of those shown and described in connection with the channel T_1. The carrier oscillator O_2 is provided with a condenser 19 and the carrier oscillator O_3 is provided with a condenser 20, each of which has its capacity continuously varied so that the carrier waves for these channels have continuously varying frequencies. Also the heterodyne oscillators HO_2 and HO_3 have the respective variable condensers 21 and 22 for causing the heterodyning frequency to vary continuously. The condensers 12, 19 and 20 for controlling the frequencies of the respective carrier waves are caused to vary in a definitely related manner, as, for example, by having their movable elements connected to the same shaft 25 driven from the motor 26. In a similar manner the condensers 17, 21 and 22 have their movable elements fixed to a common shaft 27 driven from motor 28. While separate motors for the two shafts have been shown, it would be obvious to drive both shafts from a single motor. Any suitable manner of varying the capacities of these condensers may be employed, as by simply rotating the movable element, as in an ordinary air condenser, or by rotating the movable element, and in addition making the movable plates with scallops or some kind of irregular configuration to give an irregular variation to the capacity.

As explained in connection with the filter F_1, the filters F_2 and F_3 are designed to have transmission ranges corresponding to the frequencies of the waves to be received by these channels. In the specific case in which all of the carriers used for transmitting in one direction vary within the same frequency limits, the filters F_1, F_2 and F_3 would have the same transmission range. In such a case the filters F_1, F_2, and F_3 could be omitted from the respective receiving channels, and if desired a single filter, the equivalent of one of them, could be included in the branch RW between the hybrid coil H and the receiving channels. And if the frequencies of the carriers used for transmitting in both directions vary within the same frequency limits, the filters F_1, F_2 and F_3 would each have the same transmission range as the filter HF, so that the one filter HF would suffice. However, the frequencies used for transmitting in one direction may comprise a different range from those used for transmitting in the opposite direction, and likewise the invention is not limited to the case in which the frequencies used for transmitting in the same direction vary within the same frequency limits.

The operation is as follows: The motor 26 drives the condensers 12, 19 and 20 to cause the frequencies of the carrier waves used by the three transmitting channels to vary in a definitely related manner so that the total range of frequencies used by the channel T_2, for example, overlaps the total range of the frequencies used by the channel T_1, and the total range used by the channel T_3 overlaps the total range used by the channel T_2. By definitely relating the frequency variations in the carrier wave of each channel to those of the adjacent channel, however, the messages of the several channels are transmitted without in-

terference. As stated above, in this description the extreme condition will be assumed to exist in which all three carrier waves used by the channels T_1, T_2 and T_3 vary throughout the same frequency range. In this case the magnitudes of the elements in the oscillators O_1, O_2 and O_3 may be identical, including the condensers 12, 19 and 20, but the rotating elements of these condensers are staggered on the shaft 25 so that the variations in the frequencies of the respective carrier waves are displaced in phase by a suitable amount.

Speech or other signals received over the line L_1 pass through the coil 15 to the modulator circuit M_1, which is also supplied with the carrier wave from the oscillator O_1. By the well-known action of the modulator circuit, the carrier wave is modulated in accordance with the signal wave and the resulting modulated wave is amplified at A_1 and impressed on circuit TL. In a similar manner, signals received from the line L_2 modulate at M_2, the carrier wave impressed from the oscillator O_2, and the wave so modulated is amplified at A_2 and impressed on the same circuit TL. This circuit TL also carries the wave received from the channel T_3 comprising a modulated wave produced at M_3 from interaction of the carrier wave from the source O_3 with speech waves spoken into the Microphone 10. This complex of waves in the loop TL is impressed on the hybrid coil H and is transmitted through the broad band filter HF to the transmission circuit 1.

The distant station to be communicated with may have an arrangement entirely similar to that shown in the drawing, and the manner in which the signals transmitted from the station shown are received at the distant station will be clear from considering the action of the circuit shown in the drawing in receiving signals.

The complex of waves incoming on the conductor 1, and similar to the complex of waves described above as being transmitted, pass through the filter HF, hybrid coil H and into the receiving loop RL. In the case assumed in which each of the received carriers varies over the same variation range, all three of the received carriers, together with their signal modulations, will pass through the filters F_1, F_2 and F_3. In fact in this case these filters are not essential but might be omitted. The local sources HO_1, HO_2 and HO_3 for producing the auxiliary waves used in receiving, have their frequencies varied according to the same law of variation as the received carrier waves. This may be done by constructing the condensers 17, 21 and 22 in a similar manner to the condensers used in the transmitting oscillators at the distant station and in driving the respective condensers at the two stations in synchronism with each other. For example, the motor at the distant station corresponding to the motor 26 in the station shown may be arranged in any suitable manner to run in synchronism with the motor 28. In the simpler case in which a single motor is used at each station in place of the two motors shown, any known system, of which there are several, for synchronizing these single motors at the several stations may be employed.

By causing the variations of the wave from the source HO_1, for example, to follow those of one of the received carrier waves and to be equal in amount to the variations in frequency of the received carrier wave, the beat or difference frequency wave obtained in the output of the demodulator DM_1 is of constant frequency, except, of course, for such effects on the frequency as are caused by the variations representing the signal. The actual frequency of this beat wave may be made any desired value depending on the frequency of the local source HO_1. The filter RE_1 is designed to select this beat frequency wave from the other output components of the demodulator and to supply it to the detector D_1. A simple detector might be employed at this point to yield the signal indications from the beat wave. However, a homodyne or zero-beat source 16 is shown, this source having the same frequency as the wave frequency of the beat wave, independent of the variations in this beat wave representing the signal itself. One advantage of employing such a zero beat source is that it aids materially in selecting the desired component from the undesired components since it has the effect of selectively amplifying the wave with which it agrees in frequency, that is, the wave carrying the signal indications to be received. After detection, the signal components, such as speech currents in the case of telephony, are selectively transmitted through the speech filter LF_1 to the line L_1.

It will be seen that only one of the received carrier waves will produce a beat wave of constant frequency by interaction with the source HO_1. At nearly all times the beat wave between either of the other received carrier waves and the auxiliary wave from HO_1 will have a different frequency from that of the constant heat wave which it is desired to receive in this channel, and hence the filter RF_1 will not select the other beat waves, which it will be noted, vary in a still more erratic manner than the received waves on account of the extra variation factor introduced by source HO_1. There will be instantaneous times in each cycle of variation when the wave to be received in this channel agrees in frequency with another one of the waves, but by ar-

ranging the frequency variations so that any two variation cycles cross each other at a point where the variation is rapid and in markedly different directions in the two waves, it may be made impossible for cross-talk between adjacent channels to take place, and any effacing of the signal to be received may be reduced to a negligible amount because of the extremely short interval during which a neighboring channel cuts in.

The generator HO_2 of the second channel is controlled as described so that its frequency variations follow those of a different one of the received carrier waves and the beat wave of constant frequency that is passed through the filter RF_2 therefor carries signal indications of a different message from those of the wave received in the channel R_1. Similarly HO_3 supplies a wave which when combined with the received waves produces a beat wave of constant frequency with a still different one of the received waves.

It is preferred that the frequencies about which the waves of the respective sources HO_1, HO_2 and HO_3 vary in frequency be different so that the beat wave in the first channel has one constant frequency while that in each of the others has a different constant frequency. This would be particularly advantageous for example, where the waves passed by the respective filters RF_1, RF_2 and RF_3, which in reality are simply speech-modulated carrier waves, are to be thrown on to the same line or circuit for transmission to a distant point.

The foregoing description sets forth the preferred arrangements for practicing the invention. The scope of the invention will now be defined in the appended claims.

What is claimed is:

1. In a carrier wave transmission system a common transmission path, means to generate and transmit over said common path a plurality of different carrier waves and commonly-controlled means for continuously varying the frequency of each of said waves by the same amount.

2. In a carrier wave transmission system, means for generating and transmitting a plurality of carrier waves of different frequencies and a common controlling means for causing the frequency of each of said waves to undergo periodic variations of the same magnitude.

3. In a carrier wave transmission system, means for generating and transmitting a plurality of different carrier waves and a common controlling means for causing the frequency of each of said waves to undergo characteristic periodic variations of the same magnitude.

4 In a multiplex carrier wave transmission system, a plurality of wave generators for producing each a different carrier wave, means associated with each of said generators for causing the frequency of each wave generated to be continuously varied by the same amount, and a common control means for all of said first mentioned means for controlling the variations in frequency of the respective carrier waves in definite relation to each other.

5. In a carrier wave transmission system, means for generating and transmitting a plurality of different carrier waves, means for causing the frequency of each of said waves to undergo similar periodic variations within a prescribed frequency range, and means for coordinating the variations of the respective carrier wave frequencies so that each of two carrier waves occupy at different instants a portion of the prescribed frequency range of the other.

6. In a carrier wave transmission system, means for transmitting a plurality of carrier waves, means for cyclically varying the frequency of each of said waves within definite extreme limits, the range throughout which each of said carrier waves varies in frequency over-lapping the range throughout which another of said carrier waves varies.

7. In a carrier wave transmission system, means for generating and transmitting a plurality of carrier waves and for causing each of said waves to undergo a periodic variation in frequency and means for coordinating the variations in frequency of the respective waves so that the frequencies of a plurality of said waves pass successively through a common range.

8. In a carrier wave transmission system, means for generating and transmitting a plurality of carrier waves and for causing each of said waves to vary in frequency periodically throughout the same range of frequencies, the frequency variations of the respective carrier waves being displaced in phase relative to one another.

9. In a carrier wave transmission system means for generating and transmitting a plurality of carrier waves and for causing each of said waves to vary in frequency periodically between the same frequency limits, and means for coordinating the variations in frequency of said waves whereby different ones of said waves occupy at different times the same portions of the frequency range comprised between said limits.

10. A system according to claim 1 and including means for impressing signal indications representing a different message on each of said carrier waves.

11. In a carrier wave signaling system, means to transmit a plurality of carrier waves and to impress a different signal on each of said waves, means to vary the frequency of each of said waves cyclically

throughout a definite frequency range, the range of variation of each of said carrier waves over-lapping the range of variation of another of said waves, a common receiving circuit for said waves, individual receivers for said different signals, and means for separating each of said different signals to a different receiver.

12. In a signaling system means to transmit a plurality of carrier waves and to vary the frequency of each of said waves by the same amount in a characteristic manner, means to receive said carrier waves, a plurality of sources of auxiliary waves, and means to vary the frequency of each of said auxiliary waves in the same characteristic manner as one of the transmitted waves.

13. In a signaling system employing a signal-controlled carrier wave of constantly varying carrier frequency, means to receive the signal, comprising a demodulator, a local source of sustained waves of constantly varying frequency, the frequency of the locally generated waves being from instant to instant different from the frequency of the carrier wave by substantially a constant and appreciable amount, connections for impressing both the received carrier wave and the locally produced wave upon said demodulator, and a signal receiver associated with the output of said demodulator.

14. In a signaling system, means to transmit a plurality of carrier waves and to impress a different signal on each of said waves, means to cause each of said waves to undergo characteristic periodic variations of the same magnitude in frequency, means to receive said waves, a plurality of sources of auxiliary waves, means to vary the frequency of each of said auxiliary waves in the same characteristic manner as one of said carrier waves, and means to cause interaction between each auxiliary wave and the carrier wave having the same characteristic frequency variation, to receive the respective signals impressed on said carrier waves.

15. In a signaling system, means to transmit a plurality of carrier waves and to impress a different signal on each of said waves, means to cause each of said carrier waves to undergo characteristic periodic variations in frequency in such manner that the respective frequency ranges throughout which said waves vary overlap each other, means to receive said carrier waves, means to step down the frequency of each of the received waves by a variable amount corresponding to the variable frequency of the respective wave to produce resultant waves of constant frequency each of which has impressed upon it one of said signals, and means to derive the signals from the respective waves of constant frequency.

16. In a signaling system, means to transmit carrier waves of constantly varying frequency, the frequency of each wave varying in a different characteristic manner, means to impress a different signal on each wave, a common receiving circuit for all of said waves, as many demodulators as there are carrier waves, a source of heterodyne waves of constantly varying frequency associated with each one of said demodulators, each of said sources having a different characteristic manner of frequency variation in accordance with the characteristic manner of variation of one of said received carrier waves, means to impress all of the received waves on each of said demodulators to cause interaction between all of said waves and each of said heterodyne sources separately, a circuit associated with the output of each demodulator for selecting out the constant difference frequency wave produced by the interaction of the associated source of heterodyne waves with the received wave having like frequency variations, and a signal receiver associated with each of said last mentioned circuits.

17. In a receiving system, means to receive a plurality of signal controlled carrier waves each of a constantly varying frequency, means to beat said waves separately with each of a plurality of waves having respectively similar frequency variations to produce difference frequency waves of constant frequency each controlled by a signal, and means to derive the signals from the respective waves of constant frequency.

18. In a signaling system employing variable frequency carrier waves, a common receiving circuit for said waves, as many branches to said circuit as there are waves to be received, means in each branch for differently changing the frequency of the received waves by a variable amount to produce from one of the received waves in each branch a resultant wave of constant frequency and from all the other received waves resultant waves of variable frequencies, a selective circuit connected to each frequency changing means for selecting the wave of constant frequency, and signal receivers connected to the respective selective circuits.

19. In a signaling system means to transmit a carrier wave of cyclically varying carrier frequency and to impress sound wave variations on said wave for transmission, means to receive said carrier wave of varying frequency with its sound wave variations and to produce therefrom a carrier wave of constant frequency with said sound wave variations impressed upon it.

20. In a signaling system means to transmit a plurality of carrier waves each of cyclically varying carrier frequency and to impress different signal indications on the respective waves, and means to receive said waves and to convert the received waves of

variable frequency into waves of constant and respectively different frequency each having impressed on it the same signal indications as the carrier wave from which it is converted.

21. In a signaling system means to transmit a plurality of carrier waves each of cyclically varying carrier frequency and to impress different signal indications on the respective waves for transmission, means to receive said waves and to produce from them respective waves of constant and respectively different frequency each having the same signal indications impressed on it as the corresponding received wave, means to select each of the waves of constant frequency and means to detect the signal indications of the selected waves.

22. In a signaling system means to receive a carrier wave of continuously varying carrier frequency, a local source of oscillations of frequency varying continuously in similar manner to the received waves, a modulating circuit, means to impress the received waves and locally generated oscillations on said circuit, a filter for selectively receiving from said circuit the wave component of frequency equal to the difference between the frequencies of the impressed waves, a detector, a circuit for impressing the selected wave component on said detector, and a signal receiver connected to said detector.

23. In carrier transmission, the method comprising transmitting a plurality of carrier waves over a common path and continuously varying the frequency of each of said waves by the same amount in definitely related manner to secure secrecy of transmission.

24. The method of secret signaling comprising modulating each of a plurality of carrier waves by a different signal, continuously varying the frequencies of each of said carrier waves by the same amount in related manner and simultaneously transmitting said waves.

25. The method of secret signaling comprising transmitting a plurality of carrier waves, varying the frequency of each of said waves cyclically by the same amount in definitely related manner, controlling each of the transmitted waves in accordance with a different signal, receiving said waves and separately detecting the signals transmitted by each wave.

26. The method of secret signaling comprising transmitting a plurality of carrier waves, varying the frequency of said waves cyclically, controlling each of the waves in accordance with a different signal to be transmitted, receiving said waves, producing at the receiving point local waves of cyclically varying frequency, combining each of said local waves with all of the received waves to produce difference-frequency waves, selecting the waves having a constant difference-frequency from said difference-frequency waves and detecting them to derive the signals.

27. The method of secret signaling comprising transmitting a plurality of carrier waves, varying the frequency of said waves cyclically, controlling each of the waves in accordance with a different signal to be transmitted, receiving the waves, producing at a receiving point local waves of cyclically varying frequency, the frequency of said local waves varying in unison each with the frequency of a different one of the received waves, combining each of said local waves with the received waves to produce as many difference-frequency waves of constant frequency as there are local waves, and selecting and detecting each of said difference-frequency waves to reproduce the signals.

28. A system according to claim 6 and including means for impressing signal indications representing a different message on each of said carrier waves.

In witness whereof, I hereunto subscribe my name this 11th day of November A. D., 1922.

CLARENCE A. SPRAGUE.