Dec. 25, 1928. 1,696,258

J. W. SCHMIED

CARRIER WAVE COMMUNICATION

Filed June 29, 1922

Fig. 1.

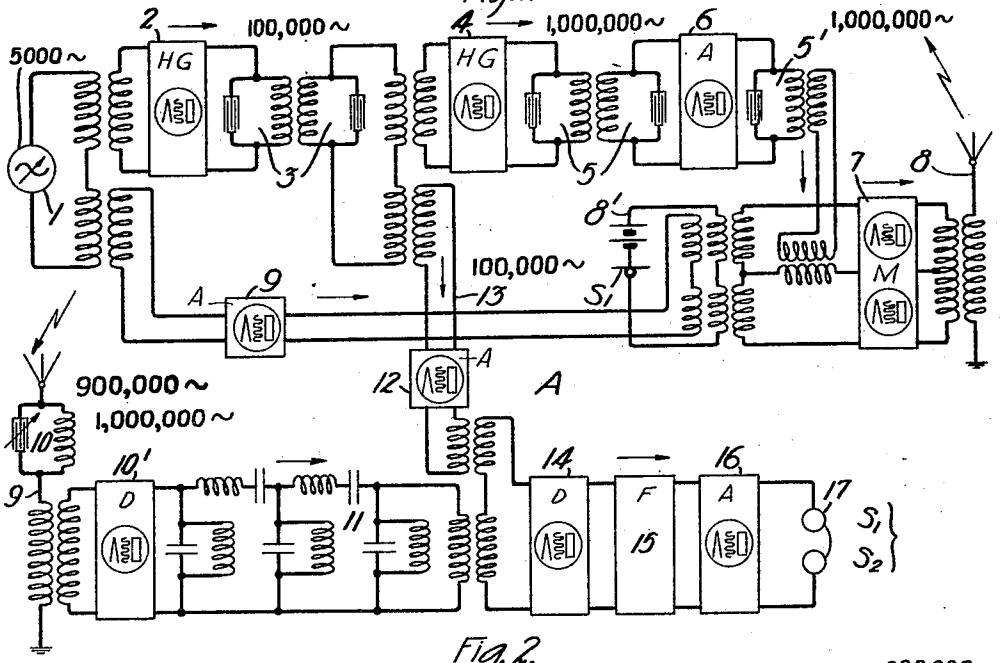


Fig. 2.

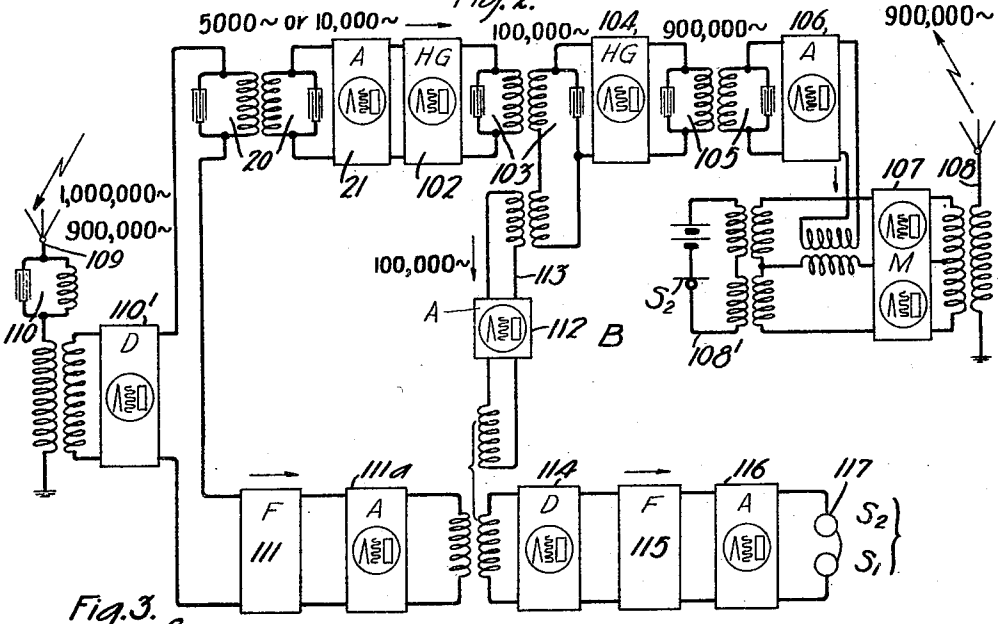
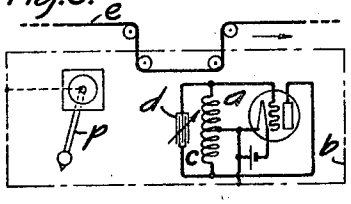


Fig. 3.



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UNITED STATES PATENT OFFICE.

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CARRIER-WAVE COMMUNICATION.

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This invention relates to methods of transmission and systems for carrying the methods into effect and is particularly exemplified in a radio system for two-way communication between two distant points.

In a prior system, incoming high-frequency carrier waves are combined with energy of the locally transmitted carrier wave frequency to produce an intermediate frequency wave which is detected or otherwise utilized to reproduce the signal. Such a system has numerous advantages among which are a high degree of selectivity, good amplification of received signals, and full opportunity to each of two persons communicating over the system to break in on each other at any time if they so desire.

Although all the features of the present invention are not limited in their application to systems of the kind just described, one object of the present invention is to adapt that type of system to operate in accordance with the principle of partial or complete suppression of the unmodulated carrier component. The method of unmodulated carrier component suppression is described in U. S. patent to Carson, Serial No. 1,343,306, granted June 15, 1920.

The present system utilizes suppression of the unmodulated carrier component, but it will be understood in connection with the following description that the unmodulated carrier component may be partly suppressed or may be as completely suppressed as possible. In this latter respect the system is an improvement upon those in which it is essential to the operation that a small portion of the energy of the unmodulated carrier frequency is transmitted.

A further object is to provide means for supplying an unmodulated component of the intermediate carrier frequency of large energy at each station and to maintain the frequency of the energy thus supplied at the correct value.

A feature of the present invention is that all the carrier frequency waves including the intermediate frequency carrier waves at each of two or more communicating stations are derived from a common control source. Any variation in frequency of one of these waves is therefore accompanied by a simultaneous variation of equal percentage in all the other waves owing to the fact that they are all multiples of the same control frequency.

A further object of the present invention is to provide means for introducing an element of secrecy into radio communication, as hereinafter described.

In radio telephone systems employing suppression of the unmodulated component of the modulated carrier wave it is essential that the unmodulated component should be reintroduced at the receiver.

Where successive detection at the receiver is employed the unmodulated carrier component may be introduced before the first stage of detection or at any time before the final stage of detection.

When two stages of detection are employed it is advantageously introduced as an intermediate frequency unmodulated carrier after the first and before the second stage of detection. An essential feature in any case is that the frequency of the unmodulated carrier component which is introduced be correct, i. e., it must coincide with the frequency of the unmodulated wave component which would be present at that point had the carrier not been suppressed at the transmitting station. Therefore a master radio station is provided with a source of frequency setting or base frequency oscillations, e. g., of 5,000 cycles frequency, to set all the carrier frequencies in the system. From these base frequency oscillations both intermediate frequency oscillations and principal carrier frequency oscillations are derived by harmonic generation. The principal carrier wave produced at this station is modulated in accordance with both base frequency oscillations and outgoing signals. Incoming carrier waves received at this station are combined with the outgoing carrier wave, from which they differ in frequency, to produce intermediate frequency waves which may be combined with the locally produced intermediate frequency waves to yield the incoming signal.

At each remote station the carrier wave from the master station is detected to produce base frequency oscillations and from these base frequency oscillations are derived intermediate frequency oscillations and principal carrier oscillations to be used respectively for reception and transmission

in the same manner as at the master station.

The invention will be described in detail in connection with the accompanying drawing wherein Fig. 1 is a circuit diagram of a master station A having associated therewith a frequency setting source or generator for the entire system; Fig. 2 is a circuit diagram of a typical form of station B which is adapted to communicate with a station such as the station A; and Fig. 3 is a diagrammatic illustration of an arrangement for varying the frequency of the frequency setting generator.

In the drawing, use is made of conventional indications of the well-known three electron discharge amplifier without, however, showing complete circuits associated with these devices. The manner of connecting up the complete circuits is well-known. This indicates that electron discharge devices of the type indicated are preferred forms of means for performing the functions described. However, any equivalent devices suitable for performing the same functions may be utilized.

At the station A (Fig. 1) is provided a master generator or frequency setter 1 which produces waves assumed in the present instance to have a frequency of 5,000 cycles per second. In this specification, the term "frequency" will be utilized to indicate "cycles per second."

The source 1 impresses waves having the frequency of 5000 cycles upon a harmonic producer 2 the function of which is to produce frequency components which are harmonics of 5000 cycles. Such harmonic producers are known in the prior art and in one form usually consist of one or more electron discharge tubes with suitable auxiliary elements. A suitable harmonic producer is shown in British Patent No. 131,426, granted November 13, 1919.

In the present instance, the harmonic producer is designed to produce in its output circuit a current component which is the 20th harmonic of 5000 cycles, viz, 100,000 cycles, which is selected from other accompanying components by a suitable system of selective circuits 3.

In the present specification, it is understood that the selective circuits 3 may be band filters or other circuits capable of performing the necessary selection.

A part of the current energy of the 100,000 cycle component, after selection by the circuits 3 is impressed upon another harmonic producer 4 to produce current of the tenth harmonic of 100,000 cycles, viz 1,000,000 cycles. The current of the last named frequency is selected by suitable selective circuits 5, amplified in a thermionic amplifier 6, and, after passing through a selective circuit 5', is impressed upon the input circuit of a modulating system 7 of the type described in U. S. patent to Carson, Serial No. 1,343,306, granted June 15, 1920. Also impressed upon this circuit are waves of speech frequency from a telephone circuit 8'.

The source 1 also supplies energy to the input of a thermionic unidirectionally conducting device 9 whose output circuit is also coupled to the input circuit of the modulating system 7. The modulating system is adjusted to suppress part or all of the unmodulated carrier component. Unbalance of the modulating system results in less complete suppression of the unmodulated component. Unbalance may be accomplished by applying a larger grid potential to one of the modulator tubes than the other. In practice absolute balance is difficult to attain.

The mode of operation with the unmodulated component only partly suppressed will first be described and thereafter will be described an optional method with the unmodulated component wholly suppressed. The output current from the modulator thus comprises a current modulated in accordance with speech and also modulated in accordance with current of 5000 cycles. The unmodulated component is largely suppressed from the output current. The radiating antenna 8 may be tuned to selectively radiate one side band of the modulated wave more efficiently than the other side band, or it may radiate both side bands equally well.

The receiving apparatus of the station A includes a receiving antenna 9, which receives carrier waves having a frequency of 1,000,000 cycles radiated from the antenna 8, and carrier waves having frequency of 900,000 cycles radiated from station B, hereinafter described, or from a station of similar nature.

The trap circuit 10 may be tuned to discriminate against the current of frequency of 1,000,000 cycles so that the energy of this frequency entering the receiving apparatus is reduced to an amount such that it bears a reasonable relation to that received from the station B. This is not to say, however, that the energy entering the receiving apparatus from the antenna 8 is to be reduced in amplitude to an amount equal to that received from the remote station B, since it may be desirable, under certain circumstances, to have as much as one hundred or more times as much energy enter the receiving system of the station A from its local transmitter as is received from station B.

The current energies of 900,000 cycles and 1,000,000 cycles frequency will be understood to consist of a relatively small or negligible unmodulated component together with one or two side bands resulting from modulation in accordance with speech and modulation in accordance with current of 5,000 cycles frequency. These currents in-

teract in the thermionic detector 10′ to produce a difference frequency current consisting of an intermediate carrier frequency current of 100,000 cycles frequency with accompanying speech side bands and side frequencies due to modulation with 5,000 cycles. Current of this frequency is selectively separated from other components of current by a band filter 11 or other equivalent selective means.

The band filter 11 may have a transmission band extending from 95,000 cycles to 105,000 cycles or it may exclude one side band in which case its transmission band will extend from and include 95,000 cycles to 99,800 or 100,000 cycles, or from 100,200 or 100,000 cycles to include 105,000 cycles.

The wave energy received from the distant and local stations will have but a small unmodulated component. For this reason the wave energy transmitted through the band filter 11 will have an unmodulated carrier component too small to permit good speech reproduction. There is, therefore, supplied from the output of the selective circuits 3 through the thermionic amplifier 12 in the channel 13 a relatively large unmodulated component of 100,000 cycles. This is impressed together with the energy from filter 11 upon a detector 14, from which the output current is supplied to a filter 15. The filter 15 is designed to pass speech frequencies and suppress other frequencies. It is particularly designed to suppress currents of the frequency of 5,000 cycles.

The output of the filter 15 is amplified by the amplifier 16 and impressed upon receiving telephones 17. An operator talking into the microphone of the circuit 8′ and simultaneously listening at the receiving telephone 17 will therefore hear his own conversation in the form of side tone. He will also hear the conversation of a person at the communicating station B.

At the station B, a receiving antenna 109 is tuned to receive waves from station A and also from the local transmitting antenna 108. At the station B, the trap circuit 110 in the antenna 109 is tuned to discriminate against waves of frequency of 900,000 cycles.

The received waves are impressed upon a thermionic detector 110′ in the output circuit of which will appear a small amplitude beat frequency component of 100,000 cycles together with accompanying side bands of large amplitude which result from modulation. This current is selected by a band filter 111 which may be a duplicate of the band filter 11. The current selected by the filter 111 is amplified by an amplifier 111ª. The amplified current thus produced is not suitable for signal reproduction on account of the small amplitude of the unmodulated component as compared with the accompanying side bands. Provision is therefore made to introduce a large unmodulated component. This is brought about in the following manner: In the output circuit of the detector 110′ will occur a small amplitude component having a frequency of 5,000 cycles. This current is selected by a system of circuits 20 to separate components of other frequencies therefrom. The selected current is amplified by an amplifier 21 and impressed upon a harmonic producer 102, in order to derive the 20th harmonic, viz, 100,000.

A portion of the current of 100,000 frequency, after selection by a suitable circuit 103, is transferred through a circuit 113 including a thermionic amplifier 112 and impressed on the input circuit of a detector 114 with the current transmitted through the filter 111 and the amplifier 111ª. The filter 115 and the amplifier 116 correspond to the filter 15 and the amplifier 16 of station A and function in a similar manner to select and apply the speech or other signal wave to the receivers 117.

If the suppression of the unmodulated component at both the transmitters of stations A and B is complete, or practically complete, there will be no component of 5,000 frequency in the output of detector 110′ of sufficient amplitude to be separated and amplified to a useful amplitude by the circuits 20 and amplifier 21. In this case the circuits 20 are tuned to select a component having a frequency of 10,000 cycles per second which will always be present when both side frequencies are radiated from the transmitter of the station A. No change in the system is necessary other than to tune the circuits 20 to select waves of 10,000 frequency rather than 5,000. The harmonic producer 102 will then function to produce the tenth harmonic of 10,000 rather than the twentieth harmonic of 5,000. The resultant will have a frequency of 100,000 cycles per second in either case.

The transmitting system of the station B will now be described.

A portion of the energy of 100,000 cycle frequency selected by the selective circuits 103 is impressed upon harmonic producer 104. The selective circuits 105 separate the 9th harmonic, viz. 900,000 cycles, from other components. The selected component is amplified in the amplifier 106 and impressed upon a modulator 107 which like modulator 7 is designed to prevent transmission of a large unmodulator carrier component.

The input circuit of the modulator 107 is connected to a telephone circuit 108′ in which is included a microphone into which the person at the station B speaks. If the person, speaking into the microphone in the circuit 108′, listens in the receiving telephones 117, he will hear his own conversa-

tion in the form of side tone together with the conversation of the person at the station A with whom he is communicating.

It will be noted that all carrier frequencies, both principal and intermediate, at each of the stations A and B are derived from source 1. This insures that any change occurring in any one of these carrier frequencies is accompanied by an equal percentage change in all of the others.

The mode of operation of this system will be readily understood from the preceding description.

A special mode of operation, however, lends itself to the introduction of an element of secrecy, whereby persons having ordinary receiving apparatus will not be able to intercept and receive messages readily. This special mode will now be described.

Let it be supposed that the generator 1 instead of generating a constant frequency of 5,000 cycles is caused by the use of any convenient means to undergo a slight variation in frequency. This variation in frequency may be cyclic or may occur at irregular intervals. Inasmuch as the frequency variation is a small one it may be brought about by means of a small conductive body moving in the neighborhood of the oscillator 1. See Fig. 3.

The 5,000 cycle source 1 consists, for example, of a thermionic generator *a* carefully shielded from magnetic, electrostatic, and other external disturbing influences by a shield *b* of conductive material. The frequency determining element is the usual tuned circuits. Mounted within the shield, adjustably adjacent the tuning condenser, is an electrically driven, self-winding clock. The pendulum *p* of this clock, as it swings to and fro adjacent the tuning condenser *d*, causes a small variation in effective capacity of the condenser. Other means for causing the small frequency variation may be employed.

For causing irregular small frequency variations a long thin magnetic wire *e*, such as a telegraphone wire, may be made of different permeability in various parts of its length and may be caused to pass slowly adjacent the tuning coil of the oscillator to vary the effective inductance of the coil by small amounts.

Suppose, by way of concrete example, that the current produced by the source 1 varies between 5,000 cycles and 5,001 cycles, that is, it undergoes a total variation of 1/50th of 1%, then all the other carrier frequencies in the system will undergo a similar variation of 1/50th of 1%. For example, the current of 1,000,000 cycles will vary between 1,000,000 and 1,000,200; current of 900,000 cycles will vary between 900,000 and 900,180; and the current of 100,000 cycles will vary between 100,000 and 100,020.

The signals in transit are therefore based upon a carrier wave from which the unmodulated component is largely suppressed, which carrier wave is varying over a total range of 200 cycles in the case of messages transmitted from station A, and over a range of 180 cycles in the case of messages transmitted from station B.

The difficulty of introducing an unmodulated component of the proper frequency will be considerable and persons having an ordinary receiving system including one or more local sources of high frequency current of constant frequency will be unable to intercept the messages. The difficulty of so doing is increased owing to the fact that the messages transmitted from the station A to the station B are transmitted on one carrier wave and those from station B to the station A are transmitted on another carrier wave. These waves undergo the same percentage variation but different absolute variations. The difficulties in the way of intercepting both the messages without the use of a receiving system involving practically all the essential elements of both stations A and B or their equivalents will therefore be considerable. However, the mode of operation in which the control frequency is varied will not prevent reception with the systems of stations A and B as described. The variation of all the frequencies will interfere very little with selection of the intermediate frequency component and its accompanying side bands.

In the case supposed, the total variation of intermediate frequency will be only 20 cycles and a relatively small increase in the width of the transmission band of the filters 11 and 111 and the selective circuits 3 and 103 will be sufficient to take care of this. It will be understood, of course, that the design of all the selective circuits of the system will be appropriately modified when the carriers are caused to undergo variations of frequency for secrecy or other purposes.

It will be obvious that source 1 can be utilized as a frequency setter for a plurality of stations B, each of which transmits and receives on a different set of carrier frequencies. Various harmonics of the source 1 may be used for signaling over different channels. At the station A, additional channels or duplicate sets of apparatus may be utilized to communicate with various remote stations such as the station B. The intermediate carrier frequencies of the various stations may be the same or different, but, of course, the principal carrier frequencies must differ if several messages are to be transmitted simultaneously.

A convenient manner of varying the source 1 is to cause it to generate at 5,000 cycles per second for about one half second and then change to 5,001 cycles per second

during alternate half seconds. In addition to producing desirable results by intentionally varying the frequency of the source 1 over a small range, the present system is admirably adapted to operate well if small changes in frequency of the source 1 occur at irregular intervals and from unpreventable causes.

Having described one form of the invention in detail, the various novel features inherent therein will be defined in the appended claims.

What is claimed is:

1. The method which consists in transmitting from each of two stations to the other on principal carrier waves, receiving said waves simultaneously at the receiver of each station and demodulating each with the other, selecting the demodulation products corresponding to the difference frequency of said carrier waves, demodulating said products with a reinforcing wave of frequency equal to the difference of said carrier frequencies, and deriving said carrier waves and said reinforcing wave from the same source.

2. In a two-way radio communication system having at each of two terminals a receiver adapted to receive and combine energy of an outgoing carrier wave with the energy of an incoming carrier wave to produce an auxiliary carrier wave, the method of controlling and maintaining fixed relationships amongst said waves which comprises deriving all of said waves from a master control wave.

3. In a two-way radio communication system having at each of two terminals a receiver adapted to receive and combine energy of an outgoing carrier wave with the energy of an incoming carrier wave to produce an auxiliary carrier wave modulated by the signal to be received, means for generating at one terminal a control frequency and deriving therefrom a carrier frequency, means for transmitting said control frequency on said carrier wave to the other terminal, means thereat for detecting said control frequency and for producing therefrom a second carrier frequency, means at both of said terminals for deriving from the control frequency auxiliary waves of frequency equal to the difference of the carrier frequencies, and means to combine said auxiliary waves with the aforementioned signal modulated auxiliary waves to yield the signal.

4. A carrier wave communication system comprising two stations having means for transmitting a modulated carrier wave and each having means for receiving and combining energy of its own outgoing carrier wave with the incoming carrier wave to produce an auxiliary carrier wave modulated by signals from each station and a single source of waves controlling the frequency of all of said carrier waves.

5. In a radio signaling system in which the carrier waves are derived from a master control frequency, the method of reception which comprises simultaneously receiving in a common path an incoming carrier wave and an outgoing carrier wave of different frequency, demodulating said received waves with each other, selecting the difference frequency demodulation products, subsequently demodulating said products with a reinforcing wave, and also deriving said reinforcing wave from said master frequency.

6. The method of radio communication between two stations which comprises deriving from a master control wave a carrier frequency wave and an intermediate frequency wave at each station, said carrier waves differing in frequency by an amount corresponding to a frequency above the range of audibility, modulating the carrier waves according to low frequency signals, simultaneously receiving in a common path an outgoing and an incoming carrier wave, demodulating said received waves with each other, selecting the difference frequency demodulation products, and subsequently demodulating said products with one of said intermediate frequencies.

7. The method of radio communication between two stations which comprises deriving from a master control frequency a carrier frequency wave and an intermediate frequency wave at each station, said carrier waves differing in frequency and said intermediate waves having a frequency equal to the difference of the carrier frequencies, modulating the carrier waves according to signals and transmitting the modulated waves, simultaneously receiving in a common path an outgoing and an incoming wave, demodulating and selecting the difference frequency products, and subsequently demodulating said products with said intermediate frequency waves.

8. The method of radio signaling between two interconnecting stations which comprises generating a control wave of frequency too low to radiate, deriving therefrom a carrier frequency wave and an intermediate frequency wave, modulating the carrier wave with the control wave, and radiating the modulated carrier wave, receiving the modulated carrier wave, detecting and selecting the control wave and deriving therefrom a second carrier wave and a second intermediate frequency wave, said intermediate frequencies being equal and said carrier waves differing in frequency by an amount equal to the intermediate frequency, modulating the carrier waves according to signals, simultaneously receiving an outgoing carrier wave and an incoming signal modulated

wave, demodulating and selecting the difference frequency products, and subsequently demodulating said products with one of said intermediate frequency waves.

9. A carrier wave transmission system for two-way communication employing at each station a carrier wave for transmission and reception and an auxiliary carrier wave for reception, comprising means whereby each station radiates a single modulated carrier wave with the unmodulated component largely suppressed, means at each station for combining said radiated waves, and means for supplying at each of said stations a large component wave of a frequency identical with the unmodulated component of the auxiliary carrier frequency which would result from the combination of the small remaining unmodulated carrier components of said radiated waves.

10. In a two-way radio communication system employing carrier waves of different frequencies varying in an arbitrary manner for transmitting in two directions, the method which comprises receiving at each station and combining an outgoing carrier wave with an incoming carrier wave to produce an auxiliary carrier wave modulated by signals, deriving said carrier waves from a master control wave, and varying in an arbitrary manner the frequency of said control wave.

11. In a two-way radio communication system having at each of two terminals a receiver adapted to receive and combine energy of an outgoing carrier wave with the energy of an incoming carrier wave to produce an auxiliary carrier wave, the method of securing secrecy which comprises deriving said carrier waves from a master control wave of low frequency, and varying the frequency of said control wave in accordance with an arbitrary law over a frequency range such that the resultant frequency variation of said carrier waves does not exceed the frequency range of audible speech.

12. In a two-way radio signaling system having at each terminal frequency selective transmitting and receiving apparatus and in which each receiver is adapted to receive and combine energy of an outgoing carrier wave with the energy of an incoming carrier wave to produce an auxiliary carrier wave, the method of producing secrecy which comprises deriving said carrier waves from a master control wave of low frequency and varying the frequency of said control wave in accordance with an arbitrary law over a frequency range such that the resultant frequency variation of said carrier waves does not exceed the limits of selective transmission and reception.

13. The method of wave transmission comprising transmitting messages as modulations of two carrier waves of different frequencies in the two opposite directions, combining at each of two stations the transmitted and received carrier waves to produce at each station an intermediate frequency wave modulated by the message being sent from each of the two stations, combining such intermediate frequency wave at each station with an unmodulated wave of the same frequency to reproduce the message, and deriving both the carrier waves and the unmodulated intermediate frequency wave at the several stations from the same source.

In witness whereof, I hereunto subscribe my name this 27th day of June A. D., 1922.

JAMES W. SCHMIED.