Mar. 27, 1923. 1,449,382.

J. R. CARSON.

METHOD AND MEANS FOR SIGNALING WITH HIGH FREQUENCY WAVES.

FILED DEC. 1, 1915. 3 SHEETS—SHEET 1.

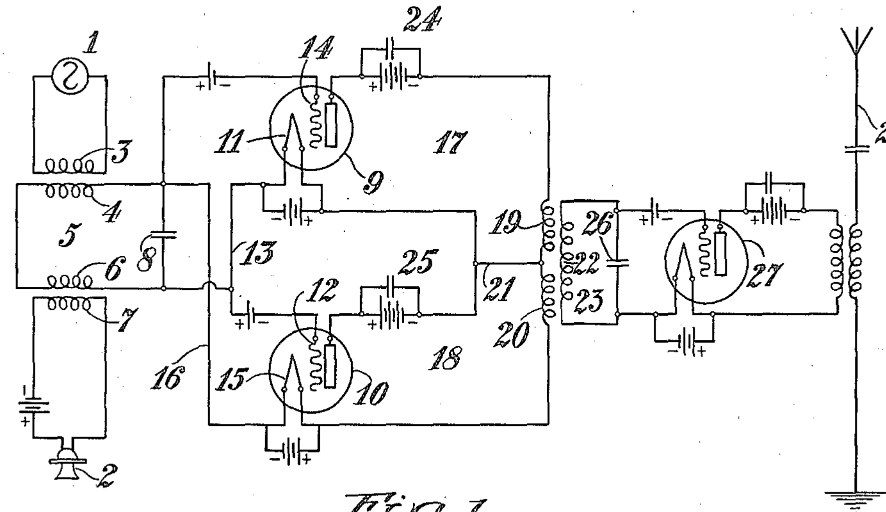

Fig. 1.

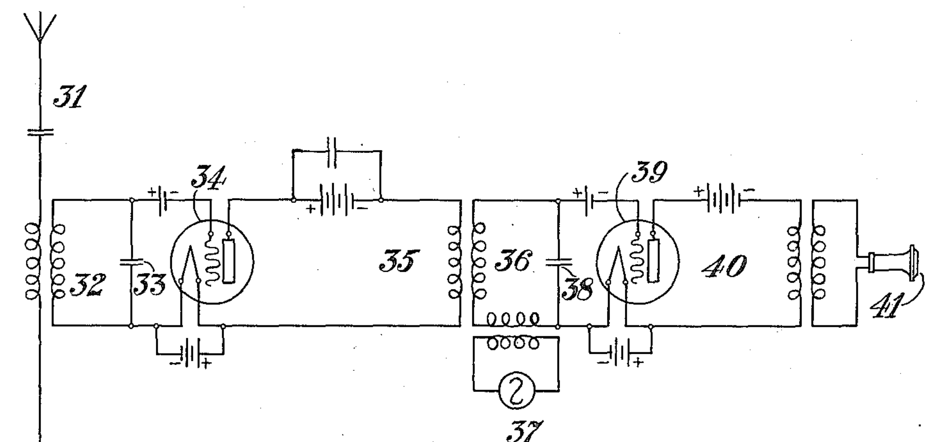

Fig. 2

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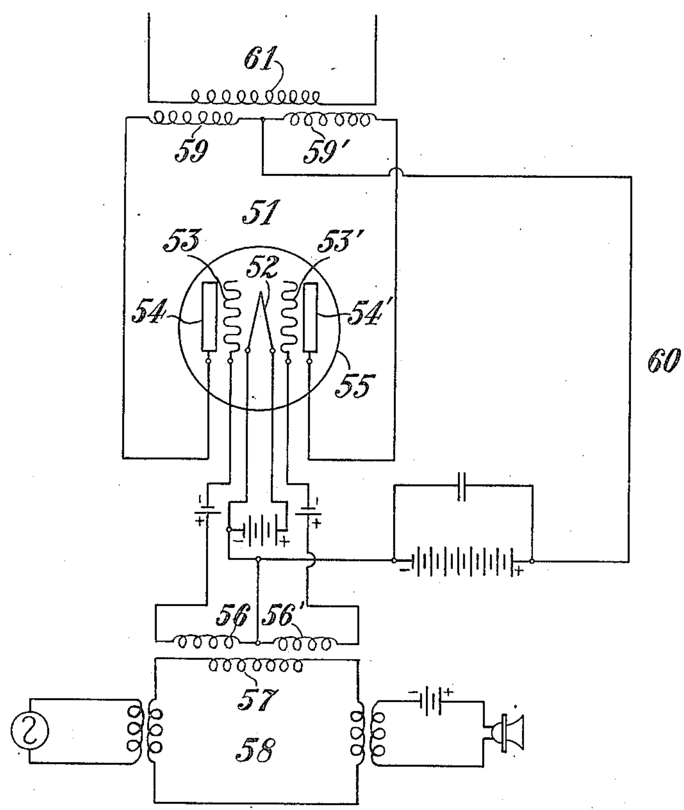

Fig. 3

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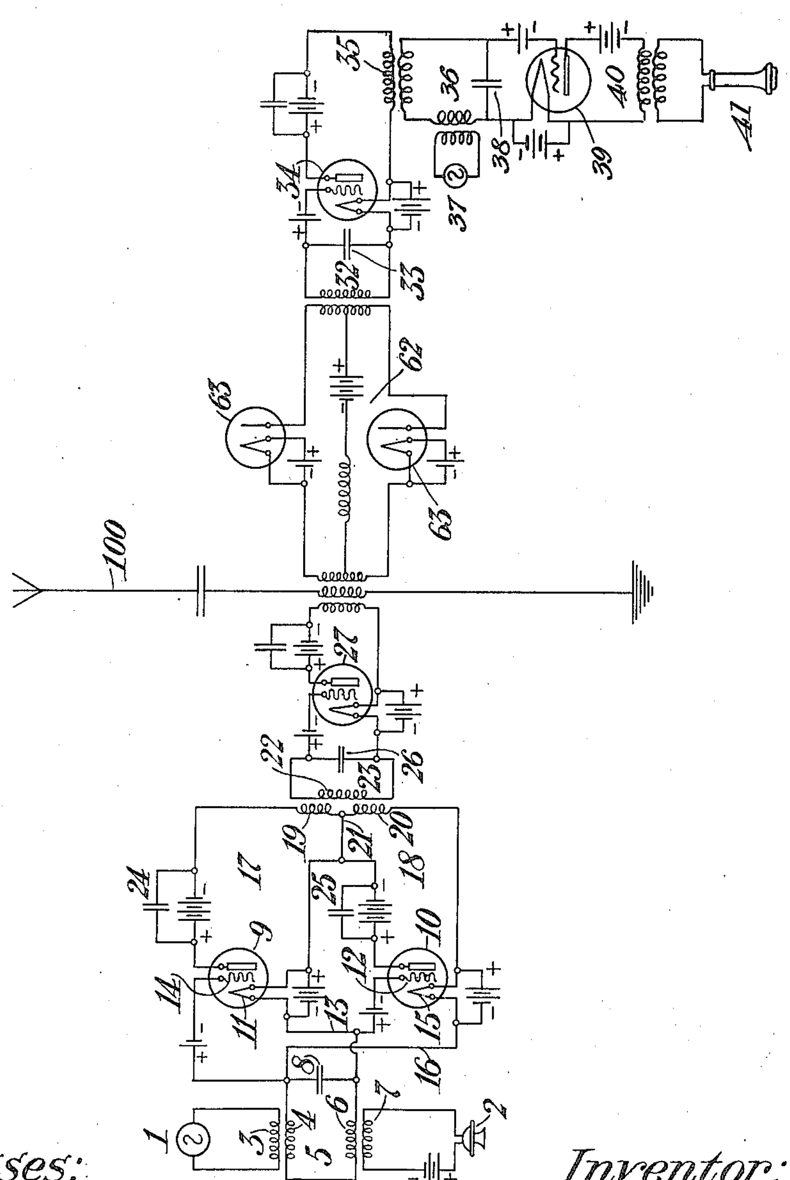
Fig. 4.



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Patented Mar. 27, 1923. **1,449,382**

UNITED STATES PATENT OFFICE.

JOHN R. CARSON, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

METHOD AND MEANS FOR SIGNALING WITH HIGH-FREQUENCY WAVES.

Application filed December 1, 1915. Serial No. 64,524.

To all whom it may concern:

Be it known that I, JOHN R. CARSON, residing at New York, in the county of New York, and State of New York, have invented certain Improvements in Methods and Means for Signaling with High-Frequency Waves, of which the following is a specification.

This invention relates to a signaling system wherein signals are transmitted by means of a modulated high frequency carrier wave, and more particularly it relates to a wireless telephone system. Its objects are: (1) to provide a transmitting system whose characteristic is such that the transmission or radiation of energy is automatically prevented except during the time when signals are actually being transmitted and the transmission or radiation of the unmodulated carrier wave is at all times prevented; (2) to provide novel tuning adjustments at both receiving and transmitting stations; (3) to provide means at the receiving station whereby both the quality and intensity of the received speech is improved as well as the selectivity of the receiving system; (4) to provide arrangements for the duplex transmission of signals; and (5) to provide a duplex translating arrangement comprising individual paths and a common path so associated with an outgoing circuit and two incoming circuits comprising sources of electrical variations, that said outgoing and incoming circuits will be independent of each other, and oscillations from one of said sources will only be transmitted through the translating arrangement to the outgoing circuit when the other source is active.

This invention, while hereinafter described in terms of a wireless telephone system, is not so limited in its scope but finds its application in any signaling system wherein signals are transmitted by means of a high frequency carrier wave, modulated in accordance with said signals. A further example of a signaling system in which my invention may be embodied is that commonly known as the Squier high frequency telephone system.

The arrangements characterizing a wireless telephone system may be briefly described as follows: At the transmitting station a source of high frequency energy, generating what may be termed the carrier wave, is operatively connected to the input side of a device known as a modulator. A circuit including a transmitting device, such as an ordinary telephone transmitter, is also operatively connected to the input side of said modulator so that when the transmitter is actuated by sound waves there are simultaneously impressed on the input circuit of said modulator the carrier wave and oscillations of audio-frequency, these latter corresponding to variations in the transmitter circuit. The function of the modulator, to be explained hereinafter in detail, is to combine said carrier wave and said signal wave oscillations into oscillations of carrier wave frequency, modulated in amplitude in accordance with said signal wave oscillations of audio-frequency. The modulator which is embodied in the arrangement of my invention may structurally be a repeating element though its operation as a modulator differs fundamentally from that of a repeater. The modulator commonly includes an input circuit and an output circuit including a source of direct current energy. The input and output circuits are unilaterally coupled in such a manner that oscillations in the input circuit set up variations of current in the output circuit. These latter variations are transmitted, preferably through tuned circuits and amplifiers, to the transmitting circuit proper such as the transmitting antenna in a wireless system or the transmission line in a wire system.

At the receiving station, the modulated carrier wave from the transmitting station sets up corresponding oscillations in the antenna or other receiving circuit. These oscillations are transferred, preferably through tuned circuits and amplifiers, to a detector, which may be structurally and functionally similar to a modulator, and thence to a receiving device such as a telephone receiver.

In such a system if the carrier wave frequency is $q/2\pi$ and the speech or other signal wave frequency is $p/2\pi$, the resultant wave after modulation can be resolved into three components of frequency

$$\frac{q-p}{2\pi}, \frac{q}{2\pi}, \frac{q+p}{2\pi}.$$

These three waves may be considered as separately transmitted and recombined at the receiving station.

When the carrier wave is not being modulated, that is, when the signals are not being transmitted, an unmodulated wave of frequency $q/2\pi$ is transmitted and the energy associated with said wave is wasted. Further, when signals are being transmitted, it is not necessary to transmit the unmodulated carrier wave. For, although this wave is desirable at the receiving station for the best quality of received signal, it may be generated at the receiving station and then combined with the received wave. A particular advantage of this method inheres in the fact that a relatively very feeble carrier wave generated at the receiving station, is equivalent to a very strong carrier wave generated at the transmitting station and transmitted therefrom to the receiving station.

Since this carrier wave of frequency $q/2\pi$ is required only at the receiving station my invention contemplates the suppression of the unmodulated carrier wave at the transmitting station and the generation at the receiving station of a continuous wave of the same frequency. As a further refinement the invention contemplates the transmission of one of the waves of frequency

$$\frac{q+p}{2\pi}$$

or

$$\frac{q-p}{2\pi}$$

respectively and the substantial reduction in magnitude of the other of said waves.

My invention is best understood by reference to the accompanying drawings in which Figure 1 is a diagram illustrating the embodiment of the arrangements of my invention in the transmitting part of a wireless telephone system; Figure 2 is a diagram illustrating the embodiment of the arrangements of my invention in the receiving part of a wireless telephone system; Figure 3 is a diagram illustrating a modulating device of the vacuum tube type which may be embodied in a transmitting system such as that illustrated in Figure 1, and Figure 4 is a diagram illustrating a wireless duplex telephone system.

The wireless transmission and reception of speech is characterized by such complex physical processes that an analysis of the phenomena involved seems best adapted to the elucidation of this invention. For the sake of simplicity this analysis will be limited to the case of the transmission of a musical note of frequency $p/2\pi$. The carrier wave will be taken as of frequency $q/2\pi$, q being large compared with p and in general of radio-frequency. The carrier wave may then be conveniently represented by the mathematical expression A sin qt while the signal wave of audio-frequency is represented by B sin $(pt-\varphi)$, A and B being the amplitudes of said waves, φ an arbitrary phase angle and t denoting time. The phase angle φ depends for its value on the phase relation obtaining between the low frequency wave and the high frequency carrier wave. This phase relation is uncontrollable and in particular with irregular speech tranmission it will be clear that φ may vary from 0° to 360°. The voltage v impressed on the input side of the modulating device is then proportional to

$$A \sin qt + B \sin (pt-\varphi) \quad (1)$$

In any voltage-operated type of repeater, detector or relay, it may be shown that the effect of impressing a voltage v on the input side of said device is to produce in the output circuit an effective voltage variation V, characterized by the equation:

$$V = av + bv^2 + cv^3 + dv^4 + \quad (2)$$

A current operated relay is characterized by an analogous equation

$$I = ai + bi^2 + ci^3 + di^4 + \quad (2')$$

obtained by substituting for v the input current, i, in the above equation. Since the type of relay illustrated in the accompanying drawings is voltage-operated the analysis will be confined to a device characterized by equation (2).

In equation (2), a, b, c, d, are constants of the repeating element, whose values depend on its physical structure and adjustment. Ordinarily the first term of equation (2) is very large compared with subsequent terms. This is the case in the ideal repeater or amplifier which is characterized by the equation

$$V = av \quad (3)$$

When it is desired to modulate a high frequency carrier wave in accordance with a signal wave by means of a modulating device which is characterized by equation (2), there is simultaneously impressed on the input circuit of said device the high frequency wave and said signal wave of audio-frequency. If we then substitute in equation (2) the value of v as given by equation (1), the value of V, ignoring the factor of proportionality, is given by

$$V = \begin{pmatrix} aA \sin qt + 2bAB \sin (pt-\pi) \sin qt + aB \sin (pt-\pi) \\ + bB^2 \sin^2 (pt-\pi) + bA^2 \sin^2 (qt) + cv^3 + dv^4 + \end{pmatrix} \quad (4)$$

Since all waves of frequency differing materially from the carrier wave frequency $q/2\varphi$ may be eliminated by tuning or filtering, only terms whose frequency lie in the neighborhood of $q/2\pi$ need be retained in equation (4). As shown hereinafter the expression $\sin^2 qt$ in reality represents a frequency not

$$\frac{q}{2\pi}$$

but

$$\frac{2q}{2\pi}$$

which is tuned out, and hence the term containing this expression disappears. Further by proper adjustment and design the term $d\ v^4$ and higher terms may be made negligibly small. Dropping negligible terms, equation (4) then becomes

$$V = aA \sin qt + 2bAB \sin (pt - \phi) \sin qt + cv^3 \quad (5)$$

Equation (5) shows that the wave V is composed of several terms or components. The first term, a A $\sin qt$, is a wave of carrier frequency $q/2\pi$ and constant amplitude, that is its amplitude is independent of the low frequency signal wave and it is present independently of the presence or absence of said signal wave. This wave or component wave will be referred to as the unmodulated wave or the unmodulated component. The second term, $[2b\ AB \sin (pt-\varphi)] \sin qt$, is a wave of carrier frequency $q/2\pi$ and of varying amplitude, the amplitude of said wave being proportional to B $\sin (pt-\varphi)$, that is to the signal wave. This wave is therefore a wave of carrier frequency $q/2\pi$ and of amplitude modulated in accordance with a low frequency signal wave; it will be termed a pure modulated wave. A wave as represented by the sum of the two said terms is a complex wave having an unmodulated and a modulated portion or component. The third term of equation (5) $c\ v^3$, represents oscillations which in general are quite small and which may, as hereinafter shown, be substantially eliminated from the transmitted wave.

By a well known trigonometric transformation, equation (5) may be written in the following form:—

$$V = aA \sin qt + bAB \cos ((q-p)t + \pi) - bAB \cos [(q+p)t - \pi] + cv^3 \quad (6)$$

Inspection of equation (6) shows that the pure modulated wave of frequency $q/2\pi$ whose amplitude in varying at audio-frequency is equivalent to the sum of two waves of constant equal amplitudes and of frequencies

$$\frac{q-p}{2\pi}$$

and

$$\frac{q+p}{2\pi}$$

respectively. These two waves will be referred to as the components of the pure modulated wave.

I have discovered, as hereinbefore stated, that it is not necessary to transmit the unmodulated wave as defined above. I have also stated the advantages consequent upon the elimination of this wave at the sending station. My invention in one of its aspects is therefore directed broadly to transmitting a substantially pure modulated wave to the exclusion of any unmodulated wave.

By a pure modulated wave is meant a modulated wave in which there is present no component having the wave form and frequency of the unmodulated high frequency oscillations, and in which the modulation is complete, in the sense that the modulation is effective throughout the entire cyclic period of the modulating wave. Where both modulated components are transmitted, the amplitude of such a wave may at all times be directly proportional to the instantaneous amplitude of the modulating signal wave. In a system in which this broad principle is embodied it is clear that not only is there no unnecessary transmission of energy during signal transmission but also transmission of energy occurs only when signals are actually being transmitted, and that energy transmission automatically ceases with the cessation of the low frequency signals.

It will be seen from equations (5) and (6) that in this particular system the unmodulated wave, as represented by the first term of said equations, is proportional to the constant a of the modulator and would evidently vanish if the constant a were zero. It may now be simply shown how a modulating device may be provided in which said constant a is substantially zero.

Assume that there is a modulating device characterized by equation (2) and a second similar and equal modulating device whose input circuit is so acted upon by the input voltage that voltages of equal amplitude and opposing phase are impressed on the input circuits of said modulators. Then if V′ denotes the effective voltage developed in the energy circuit of said second modulating device, evidently

$$\begin{aligned} V' &= a(-v) + b(-v)^2 + c(-v)^3 + d(-v)^4 + \\ &= -av + bv^2 - cv^3 + dv^4 - \end{aligned} \quad (7)$$

If now these two modulating devices are so related to a common transmitting circuit that their action thereon is additive, the combination is obviously equivalent to a single modulating device characterized by

$$V'' = (2\ b\ v^2 + 2\ d\ v^4 +) \quad (8)$$

This is a modulating device in which the constants a, c, are zero and the constants b, d, are doubled. From the analysis leading to equations (5) and (6) it follows that a modulator characterized by equation (8) has the ideal modulating characteristic in that the transmission of the unmodulated high frequency carrier wave is suppressed.

To elucidate the manner in which a modulator characterized by the equation $V''=2b\,v^2$ suppresses the unmodulated carrier wave, it is only necessary to substitute in the above equation the unmodulated carrier wave A sin qt for v. Then

$$\begin{aligned} V'' &= 2\,b\,(A \sin qt)^2 \\ &= 2\,b\,A(1/2-1/2 \cos 2\,qt) \\ &= b\,A(1-\cos 2\,qt). \end{aligned}$$

It will be seen that the unmodulated wave produces a wave of double carrier wave frequency. When the transmitting circuit arrangements are tuned to a frequency in the neighborhood of the carrier wave frequency, they present an enormous impedance to currents of double frequency so that the transmission of a wave of double frequency is effectually suppressed. It will be understood that, if the transmitting circuit arrangements were tuned to a frequency equal to twice that of the carrier wave, an unmodulated wave of double frequency would be transmitted. Tuned circuits, however, in cooperation with the modulator of my invention effectually suppress the unmodulated carrier wave and waves of double frequency.

It is to be understood that, while in the foregoing discussion similar and equal modulating devices are specified and that, while this is desirable, it is not essential to my invention that the two modulating devices be similar and equal. It is always possible to so relate anv two modulating devices to a common transmitting circuit that the transmission of the unmodulated carrier wave is prevented. It is to be further understood that for the successful attainment of my invention I contemplate the employment of tuned circuits which effectuall: prevent the transmission of waves whose frequencies differ materially from that of the carrier wave.

The importance of a modulator such as that described above will be readily appreciated. In ordinary systems there is, as shown above, continuous transmission or radiation of the unmodulated carrier wave even when no signals are being transmitted. This transmission of the unmodulated carriér wave, besides involving energy waste constitutes a serious bar against the operation of duplex systems. With the modulator of my invention, energy transmission or radiation automatically ceases when signal transmission is discontinued. A neighboring receiving system would therefore suffer interference from the transmitting system only during the time when signals are actually being transmitted, and the modulator of my invention, therefore, possesses ideal characteristics for embodiment in a duplex system. Further only energy modulated in accordance with the signals to be transmitted is at any time radiated.

Returning to equation (8), neglecting the v^4 term as small and substituting therein the value of v as given by equation (1) we get

$$V''=2\,b\,[A \sin qt+ B \sin (pt=\varphi)]^2$$

Expanding this expression and retaining only those terms representing oscillations of frequencies in the neighborhood of that of the carrier wave we get

$$V''=4bAB[\sin(pt-\varphi) \sin qt] \quad (9)$$

which may be also written

$$V''=2b\{A\,B \cos [(q-p)t+\phi]-A\,B \cos [(q+p)t-\phi]\} \quad (10)$$

It is thus seen that the modulated high frequency wave is analyzable into two waves of frequency

$$\frac{q-p}{2\pi}$$

and

$$\frac{q+p}{2\pi}$$

respectively, $q/2\pi$ being the frequency of the unmodulated high frequency wave. In the transmission of speech $p/2\pi$ varies over a range of about 2000 cycles per second, its mean value, denoted by

$$\frac{p_m}{2\pi},$$

being in the neighborhood of 1000 cycles.

If the transmitting and intermediate circuits as well as the antenna are sharply tuned, distortion of the transmitted wave as given by equation (10) occurs by reason of the variation of impedance over the range of frequencies having an upper limit $q/2\pi+2000$ and a lower limit

$$\frac{q}{2\pi}-2000.$$

If therefore it is desired to transmit a wave as represented by equation (10) it is necessary that the antenna be tuned to the frequency $q/2\pi$ and that the variation of impedance over a range of 2000 cycles per second on either side of $q/2\pi$ be as small as possible. This condition is difficult to satisfy, especially in weakly damped systems. If only one of the waves as given by equation (10) is to be transmitted the range of transmitted frequencies is halved and it is obviously desirable to tune the transmitting circuits and the antenna not to the frequency $q/2\pi$ but to either of the frequencies

$$\frac{q-p_m}{2\pi}$$

or

$$\frac{q+p_m}{2\pi}.$$

I have discovered that it not only is not necessary to transmit both waves as given by equation (10), but that it is undesirable to do so, and that better quality of received speech may be had when only one of said waves is received. I, therefore, contemplate, as a further refinement, tuning the antenna and intermediate circuits at the transmitting station to either the frequency

$$\frac{q-p_m}{2\pi}$$

or

$$\frac{q+p_m}{2\pi}.$$

I also contemplate tuning the receiving antenna and its associated circuits to the same frequency.

The modulated wave at the transmitting station is generated by V″, the effective voltage in the output circuit of the modulator, as given by (10), which as there-shown, consists of two components of equal magnitude $(2bA).B$, and of frequencies

$$\frac{q-p}{2\pi}$$

and

$$\frac{q+p}{2\pi}.$$

respectively, said components having a difference in phase angle of 2φ. Now the actual wave received from the transmitting station and finally presented to the input side of the receiving detector will have undergone phase changes in passing through the transmitting circuit, the ether, and the receiving circuits, and in particular if the circuits are tuned the two component waves will not have the same absolute values due to the discrimination of the circuits with respect to the two frequencies

$$\frac{q-p}{2\pi}$$

and

$$\frac{q+p}{2\pi}.$$

If we now assume that the final phase angle between the two received waves is θ, and for convenience choose a new time axis of reference it is clear that the received waves may be expressed in terms of the sine instead of the cosine and will be of the relative phases $\sin(q-p)t$ and $\sin[(q+p)t-\theta]$. Furthermore both waves will be proportional to the magnitude of V″, that is to $(2bA)B$. The factor $2bA$ is constant, while of course B is proportional to the amplitude of the low frequency wave. Also since the two waves are reduced in different ratios by the tuning adjustments we can say that one wave is proportional to B and other to K B where K represents the discrimination between the two waves. Finally therefore the waves are proportional respectively to

$$B\sin(q-p)t \text{ and } -KB\sin[(q+p)t-\theta]$$

By virtue of these tuning adjustments the wave presented to the input side of the receiving detector may be represented as proportional to

$$B\{\sin(q-p)t-K\sin[(q+p)t-\theta]\} \quad (11)$$

In this equation θ is an arbitrary phase angle depending upon the original phase angle φ and the phase changes due to transmission through tuned circuits and the ether between the modulator and receiving detector. It will vary if either the tuning or the low frequency

$$\frac{p}{2\pi}$$

is changed.

K is a correction constant which represents the discrimination between the two waves. If the antenna is tuned to

$$\frac{q-p}{2\pi},$$

K is less than unity, while if it is tuned to

$$\frac{q+p}{2\pi}$$

it is greater than unity. The departure of the value of K from unity is conditioned by and is proportional to the sharpness of tuning of both the transmitting and receiving systems. The wave which it is desired to discriminate against may be substantially eliminated by interposing between the receiving antenna and the detector a filter of a well known form which transmits freely all frequencies lying within the frequency range of one of said waves and substantially extinguishing the other of said waves or by interposing tuned oscillation circuits. The transmitted wave presented to the input side of the detector is then proportional to

$$B\sin(q-p)\,t \text{ or } B\sin(q+p)\,t \quad (12)$$

The wave as represented by equation (12) is not capable by the aid of a detector alone of producing an audio-frequency effect of frequency $p/2\pi$ in the receiving device. In my invention I contemplate providing a local source of energy at the receiving station, said source generating continuous waves of frequency $q/2\pi$, that of the carrier wave, and I contemplate operatively connecting said source of energy to the input side of the receiving detector. If this locally generated wave is represented by the expression

$$C \sin (qt-\chi)$$

the resultant wave impressed on the input side of the receiving detector is given by:

$$\begin{matrix} B \sin (q-p)t + C \sin (qt-\chi), \text{ or} \\ B \sin (q+p)t + C \sin (qt-\chi) \end{matrix} \quad (13)$$

Whether the first or second of the expressions given in formula (13) represents the resultant wave depends, of course, on which of the two expressions of formula (12) represents the transmitted wave.

It may be easily shown that the voltage or current of audio-frequency developed in the output side of a detector of the type which is hereinafter illustrated, is proportional to the square of the input voltage. This follows from the fact that the detector is of the same physical character and operates according to the same principle as the modulator; hence, equation 2 applies equally well to the detector and to the modulator. It will be noted that this equation contains a squared term, and as in the case of the modulator, the terms of the third and fourth power may be neglected for the detector as they are unimportant. If now the values given in equation 13 be substituted in the first two terms of the right hand side of equation 2, it will be seen that the first term may be neglected because it represents a frequency above the audible limit. So also certain of the expressions of the squared term may be neglected for the same reason. It is unnecessary to provide two tubes for the detector as the provision of a duplex tube arrangement in the case of the modulator is for the purpose of suppressing the unmodulated carrier frequency component as set forth by equations 7 and 8 and the equations immediately following. This portion of the mathematical reasoning does not apply to the detector, and as already stated, it is unnecessary to provide two tubes in the modulator, since the first term of the right-hand side of equation 2 is ineffective because of its high frequency. Squaring the input voltage as given by formula (13) and dropping radio-frequency terms, the received signal of audio-frequency is proportional to

$$C\,B \sin pt \quad (14)$$

It will be seen that this is directly proportional to the musical note impressed on the modulator of the transmitting station; it will be further seen that by making C large, the intensity of the received signal may be made large. This method of receiving by means of a locally generated high frequency wave bears a superficial resemblance to the heterodyne method; it is however radically different in principle and is distinguishable from the heterodyne method by reason of the fact that the frequency of the locally generated wave must be identically that of the carrier wave while in the heterodyne method said frequencies must differ by audio-frequency in order to produce beats. For this reason I have termed this method of receiving the homodyne method.

In order to show that the wireless system, as analyzed above, is superior to methods heretofore employed, the analysis need only be extended to the case when the homodyne generator is omitted, and ordinary methods are employed. In this case it may be readily shown that the received wave at the input side of the detector is proportional to

$$aA \sin (qt) + K_1 bAB \cos ((q-t)t-\theta_1) - K_2 bAB \cos ((q+p)t-\theta_2)$$

where θ_1 and θ_2 are arbitrary phase angles, and K_1 and K_2 are constants of the same order of magnitude and less than unity. Equation (15) follows from equation (6) by reasoning analogous to that employed in deriving equation (11) from equation (10). The arbitrary phase angles are of the same character as the phase angle θ in equation (11) and their values are determined by the same factors. The current of audio-frequency produced in the receiver is proportional to the square of the voltage as given by formula (15). Squaring formula (15) and retaining terms of audio-frequency only, it follows that the current in the receiver is proportional to

$$abA^2B\,(K_1 \cos (pt-\theta_1) + K_2 \cos (pt-\theta_2)) + K_1K_2b^2A^2B^2 \cos 2pt \quad (16)$$

It is at once seen that currents of two frequencies co-exist in the receiver of fundamental and double frequency respectively, and further that the fundamental term depends in value on uncontrollable arbitrary phase angles. Comparison of equation (14) with equation (16) shows at once the superiority of the system herein disclosed. It shows also the importance in the homodyne method of substantially reducing one of the waves of frequency

$$\frac{q+p}{2\pi}$$

or

$$\frac{q-p}{2\pi}$$

since their co-existence involves distortion of signal and the presence of a harmonic term.

It should be observed that the local generator is not alone effective in producing the best quality of received speech without the substantial elimination of one of the two waves which in combination are equivalent to the modulated carrier wave, and further that the elimination of one of said waves necessitates a local receiving generator in order to receive any audible signal. The combination however, of a locally generated wave of carrier wave frequency with one of said two waves theoretically provides ideal quality of received speech.

It should be observed that a further important advantage attending the suppression of the unmodulated carrier wave and the discrimination against one component of the modulated carrier wave lies in the fact that a receiving station which is not equipped with a local source of high frequency energy of carrier wave frequency receives signals of very poor and probably unintelligible quality. The system of my invention therefore attains a large measure of secrecy in that only those stations equipped with a local receiving generator can receive speech signals of good or intelligible quality.

While as shown above the suppression of the unmodulated carrier wave necessitates a locally generated wave at the receiving station for the best quality of received signal, said locally generated wave is essential to the reception of signals only when both the unmodulated carrier wave and one component of the modulated wave are suppressed. Suppose, however, that a simple detector circuit such as that shown in De Forest Patent No. 879,532 is used, the sending and receiving stations being both tuned to the carrier wave frequency; the two components of the modulated carrier wave will then be transmitted with equal amplitude and the wave presented to the input side of the receiving detector will be representable by

$$B\{\sin (q-p)t - \sin [(q+p)t - \alpha]\} \quad (17)$$

Equation (17) follows from equation (11) in the case where there is no discrimination between the two component waves, since in that case no factor K will occur. There will however, always be a relative phase angle which is designated as α.

The phase angle α is included for generality in order to represent the phase angle between the two components of the modulated carrier wave. Its value cannot in general be determined.

The audio-frequency oscillations in the receiver are then proportional to the terms of audio-frequency in the expression gotten by squaring formula (17), that is to

$$A^2B^2(\sin 2\ pt) \quad (18)$$

It will thus be seen that the received signal is then proportional in amplitude to the square of the amplitude of the audio-frequency oscillations in the transmitter at the transmitting station and of double frequency. The oscillations in the receiver in this special case are not therefore faithful copies of the oscillations in the transmitter but they serve for the reception of signals.

In the light of the foregoing discussion it will be seen that my invention, in its several aspects, is broadly directed: (1) to preventing the transmission of radiation of the unmodulated carrier wave, while providing for the efficient transmission or radiation of the carrier wave modulated in accordance with the signals it is desired to transmit; (2) to tuning the transmitting and receiving systems not to the carrier wave frequency, as has been customary, but to said carrier wave frequency plus or minus mean speech frequency, whereby one component of the modulated carrier wave is received more strongly than the other component; and (3) in combining with the foregoing a source of continuous undamped oscillations of carrier wave frequency at the receiving station, said oscillations being impressed on the input side of the receiving detector, whereby the intensity and quality of the received signal are improved. My invention contemplates also the embodiment, when desired, in the receiving system of an electric wave filter whereby one component of the modulated carrier wave is substantially eliminated to the considerable further improvement in the quality of the received speech signal.

Referring to Figure 1, which is a diagram of the transmitting part of a wireless telephone system embodying the arrangements of my invention relating to transmission, 1 conventionally represents a source of high frequency energy, said source generating the radio-frequency undamped wave referred to as the carrier wave. 2 is a transmitting device, preferably a telephone transmitter. By means of coupling coils 3 and 4 generator 1 is coupled to circuit 5; similarly by means of coils 6 and 7 transmitter 2 is coupled to circuit 5, which by means of condenser 8 may be tuned to the carrier wave frequency. 9 and 10 are three-element vacuum tube devices, preferably of the well known audion type and preferably similar and equal. It is well known that the three-element vacuum tube may be adjusted to function efficiently as a modulator, as hereinbefore defined, and in Figure 1, the modulators 9 and 10 act as cooperating modulators. Filament 11 of the tube 9 is connected to grid 12 of tube 10 by means of conductor 13; correspondingly grid 14 is connected to filament 15 by conductor 16. Conductors 13 and 16 are connected to opposite sides of condenser 8. The potential across condenser 8 is the sum of the low or audio-frequency wave, corresponding to variations of transmitter 2, and the carrier wave of radio-frequency, generated by 1. This potential difference is impressed between grid 14 and filament 11 of modulator 9 while an equal potential difference of exactly opposing phase is impressed between grid 12 and filament 15. As a consequence of the potential oscillations impressed between grid and filament of modulators 9 and 10, oscillations are developed in circuits 17 and 18, said circuits being the output circuits of modulators 9 and 10 respectively. Circuit 17 includes a coupling coil 19 while circuit 18 includes a coupling coil 20, preferably similar and equal to coil 19. Conductor 21 is common to both circuits 17 and 18. Coils 19 and 20 are so related to coil 22 of oscillation circuit 23 that inductive effects due to current oscillations of the same phase in circuits 17 and 18 are additive in their inductive action on coil 22 while current oscillations of opposing phase in circuits 17 and 18 oppose and substantially neutralize each other with respect to coil 22. Circuits 17 and 18 may contain condensers 24 and 25 whereby said circuits may be tuned to a frequency differing from that of the carrier wave by mean speech frequency. By means of condenser 26 circuit 23 is tuned to this same frequency. Bridged across condenser 26 is the input side of an amplifier 27 whose output side is operatively connected to a transmitting antenna 28, said antanna being preferably tuned to a frequency differing from that of the carrier wave by mean speech frequency, that is to the frequency to which circuit 23 is tuned.

It will be understood from the analysis appearing heretofore in this specification that, since voltage oscillations of opposing phase are developed in the input sides of modulators 9 and 10 and since output circuits 17 and 18, oscillation circuit 23 and the antenna are tuned to a frequency in the neighborhood of that of the carrier wave and offer a very great impedance to currents of double carrier wave frequency, the organization illustrated in Figure 1 effectually prevents the radiation of the unmodulated carrier wave; that is, substantially no energy is communicated to and radiated from the antenna 28 except when transmitter 2 is actuated by the voice and also only energy modulated in accordance with the transmitter oscillations is radiated. It will be further evident that since the component parts of the organization of Figure 1 are tuned not to the carrier wave frequency but to a frequency either greater or less than said carrier wave frequency by a frequency approximately equal to that known as mean speech frequency, one of the components of the modulated wave, into which said wave is analyzable, is transmitted at considerably reduced amplitude as compared with the other of said components. This discrimination between said components may be made as great as desired in a number of ways such as by increasing the number of oscillation circuits interposed between the modulators and the antenna.

In the organization illustrated in Figure 1 and described above, two separate modulators cooperate in their action on a common tranesmitting circuit arrangement to prevent the transmission or radiation of the unmodulated carrier wave. In Figure 3 is shown a modulating device of the vacuum tube type which in its operation is equivalent to the cooperative combination of modulators 9 and 10 of Figure 1. Referring to Figure 3, 51 is a vacuum tube device structurally similar to that disclosed in Patent #1,128,292 issued February 16, 1915, to Colpitts, said device comprising a heated filament 52, two similar and equal grids 53 and 53′ and two similar and equal plates 54 and 54′ enclosed in an evacuated vessel 55. Filament 52 is connected to the common point of two similar and equal coils 56 and 56′. Coils 56 and 56′ are inductively connected to coil 57 of circuit 58 on which the carrier wave and signal wave oscillations are to be impressed. Plates 54 and 54′ are connected to coils 59 and 59′, preferably similar and equal, and having a common terminal connected by conductor 60 with filament 52. Coils 56 and 56′ are so wound and so related to coil 57 that the inductive effect of coil 57 is such as to make the potential variation betwen grid 53 and filament 52 equal and opposite to the potential variations between grid 53′ and filament 52. Coils 59 and 59′ are so wound that the inductive action of current flowing from conductor 60 through coil 59 to plate 54 and of current flowing from conductor 60 through coil 59′ to plate 54′ is additive. A coil 61 of a transmitting circuit (not shown) is so related to coils 59 and 59′ that an increase of current in coil 59 balances and neutralizes with respect to coil 61 an equal decrease of current in coil 59′, so that for such a condition no voltage is induced in coil 61. It will be understood that with this arrangement the device does not function as an amplifier or repeater, but that it does function as a modulator in essentially the same manner as modulators 9 and 10 of Figure 1, in combination. It will be also appreciated that the arrangements for operation as a repeater and as a modulator are mutually exclusive.

Referring to Figure 2 which is a diagram of a wireless receiving system embodying the arrangements of my invention, 31 is the receiving antenna, tuned to the same frequency as the transmitting antenna of Figure 1. Loosely coupled to antenna 31 is an oscillation circuit 32 tuned to the same frequency as said antenna, that is a frequency differing from that of the carrier wave by mean speech frequency. Connected across condenser 33 of circuit 32 is the input side of an amplifier 34, preferably of the well known three-element vacuum tube type, whose output circuit 35 is loosely coupled to a second oscillation circuit 36, circuit 36 being tuned to the same frequency as circuit 32 and antenna 31. Loosely coupled to circuit 36 is a source of energy 37 generating continuous undamped waves of carrier wave frequency, said source of energy being conventionally represented. Across condenser 38 of circuit 36 is connected a detector 39, preferably of the three-element vacuum tube type, to whose output circuit 40 is connected a receiving device 41, preferably a telephone receiver.

The operation of the receiving system illustrated in Figure 2 will be readily understood in the light of the theory hereinbefore developed. Since the antenna and the oscillation circuits 32 and 36 are tuned to the same frequency as the transmitting antenna, the discrimination between the two components of the modulated carrier wave will be still further emphasized so that one of said components will be quite small compared with the other in oscillation circuit 36, the condition, as hereinbefore shown, for good quality of received speech. The cooperation of the wave of carrier frequency generated by 37 with the transmitted component of the modulated wave produces in the output circuit 40 and therefore in receiver 41 oscillations which faithfully reproduce the spoken signal actuating the transmitter at the transmitting station.

Referring to Figure 4 which is a diagram of one station of a duplex system embodying the arrangements of my invention, it will be seen that the organization is essentially a combination of the transmitting and receiving circuit arrangements of Figures 1 and 2 respectively associated with a single antenna 100. It should be understood that a second similar station is contemplated for duplex communication each station comprising sending and receiving arrangements. Coupled to antenna 100 is the transmitting system of Figure 1, the component parts of which are designated by the same characters in Figures 1 and 4. Coupled also to the antenna is a circuit 62, including two similar and equal thermionic devices 63, 63. Circuit 62 as a whole acts as a power limiting device, as fully described in Patent No. 1,168,270 of H. D. Arnold, and by virtue of the thermionic devices 63, 63 the current in said circuit cannot exceed a preassigned value depending on the adjustments of said thermionic devices. Coupled to circuit 62 is the receiving organization of Figure 2, like component parts of Figures 2 and 4 being designated by the same numerals.

The operation of the duplex organization will now be explained. In duplex communication it is understood that the communicating stations do not transmit simultaneously but that when one station is transmitting the other is receiving and vice versa. The interchange of the roles of transmission and reception in a wireless telephone system is of course very rapid just as in ordinary conversation.

Suppose, now, that the communicating station (not shown) is transmitting to the station of Figure 4. At this time transmitter 2 is not actuated and therefore, by virtue of the cooperation of modulators 9 and 10 no energy is communicated to antenna 100. The system is then in condition for the efficient reception of signals. When on the other hand, the station of Figure 4 is transmitting, energy is being communicated to and radiated from antenna 100. Without the power limiting circuit 62 destructive amounts of energy would then be absorbed by the receiving arrangements associating with antenna 100 since these arrangements are tuned to respond to the waves of the frequency radiated.

The current in circuit 62 cannot as heretofore stated, exceed a preassigned value, and therefore the energy transmitted to and absorbed by the receiving arrangements coupled to said circuit cannot exceed a preassigned value. This value is preferably adjusted to approximate equality with that of the signals received from the communicating station. The power limiting circuit 62, therefore, protects the receiving arrangements from excessive or destructive interference while permitting of the efficient reception of signals. It will be understood that the useful embodiment of the duplex arrangement is not limited to a wireless telephone system but embraces any signaling system wherein signals are transmitted by the agency of a modulated high frequency carrier wave. It will be understood further, that the principle of duplex operation is based broadly on the transmission of energy from one station only when signals are being transmitted from said station.

While I have shown and described my invention as a complete system embodying therein various features to make an efficient organization, it is to be understood that it is not necessary to have all of the novel features present or present in the specific form shown; for example it is not necessary to eliminate or suppress one of the components of the modulated wave but both components may be transmitted and received, either with or without a local generator and with results as pointed out previously. Nor is it necessary that the specific type of modulating device shown should be used, since the invention, as set forth in the claims, applies to any device which will suitably modulate the high frequency oscillations impressed thereon; that is in which the output has a term proportional to the square of the input voltage. Nor is it necessary that the transmitting and receiving systems be tuned to the carrier frequency plus or minus the mean speech frequency, for the antennae and associated resonant circuits may be tuned to the carrier frequency, and this is particularly desirable when both components of the pure modulated wave are transmitted.

It is further to be understood that any number of amplifying circuits and selective circuits may be introduced at the transmitting and receiving stations to amplify the oscillations to any desired extent or to render the system more highly selective for any given frequency.

What is claimed is:

1. In a signaling system wherein signals are transmitted by the agency of a high frequencry carrier wave modulated in accordance with a signal wave, the method of transmission which consists in transmitting approximately exclusively a pure modulated wave whose amplitude is directly proportional to the signal wave.

2. In a high frequency signaling system, the method of signal transmission which consists in generating a low frequency signal wave, generating a high frequency undamped carrier wave, modulating said wave in accordance with said low frequency wave to produce a modulated wave whose amplitude is directly proportional to the modulating wave, transmitting said modulated wave and automatically preventing the transmission of energy in the absence of said low frequency wave.

3. In a signaling system the method of transmitting signals which consists in generating a high frequency undamped continuous wave, modulating said wave in accordance with the signals to be transmitted to produce a modulated wave whose amplitude is directly proportional to the signal wave, preventing the transmission of the unmodulated high frequency wave, and transmitting the pure modulated high frequency wave.

4. The method of transmission of high frequency telephonic signals which consists in generating high frequency oscillations and signal oscillations, modulating said high frequency oscillations in acordance with said signal oscillations and simultaneously amplifying the modulated oscillations, suppressing the unmodulated portion of the high frequency output and transmitting the pure modulated portion of the high frequency output.

5. The method of high frequency telephonic signal transmission which consists in generating high frequency oscillations and oscillations in accordance with speech signals, modulating said high frequency oscillations in accordance with said signal oscillations and simultaneously amplifying the modulated oscillations, suppressing all but the pure modulated high frequency portion of the modulator output and transmitting this modulated portion.

6. The method of high frequency telephonic signaling which consists in generating high frequency oscillations and audio oscillations, impressing both of said oscillations upon a modulator, suppressing the unmodulated portion and one component of the modulated portion of the high frequency output, and transmitting the other component of said modulated portion.

7. The method of high frequency telephonic signaling which consists in generating high frequency oscillations and audio oscillations, impressing both of said oscillations upon a modulator, suppressing all of the output except one component of the pure modulated output, and transmitting this component of the modulated output.

8. In a signaling system, the method of signal transmission which consists in generating a high frequency undamped carrier wave, generating signal waves, modulating said carrier wave in accordance with said signal waves, to produce modulated waves whose amplitude is directly proportional to the signal waves, and in automatically preventing the transmission of energy in the absence of said signal waves.

9. In a wireless telephone system the method of transmission which consists in generating a high frequency continuous wave, impressing said wave upon a transmitting system resonant to a frequency differing from that of said high frequency wave by approximately mean speech frequency, modulating said high frequency wave in accordance with the speech signals

to be transmitted and preventing the transmission the unmodulated high frequency wave.

10. The method of receiving high frequency waves modulated in accordance with speech, which consists in impressing said waves upon a receiving system resonant to a frequency differing from the carrier frequency by the mean speech frequency, combining the received waves with locally generated oscillations of carrier frequency and translating the combination into audible signals.

11. The method of receiving high frequency waves modulated in accordance with speech, which consists in impressing said waves upon an antenna and associated circuits resonant to a frequency differing from the carrier frequency by the mean speech frequency, combining the received waves with locally generated oscillations of carrier frequency and translating the combination into audible signals.

12. In a signaling system wherein signals are transmitted by the agency of a modulated carrier wave the method of reception which consists in impressing said wave upon a receiving system resonant to a frequency differing from that of said carrier wave by approximately mean speech frequency and cooperatively combining the received wave with a locally generated wave of the frequency of said carrier wave.

13. The method of high frequency telephonic signaling which consists in generating high frequency oscillations and audio oscillations, modulating said high frequency oscillations in accordance with said audio oscillation and simultaneously amplifying the modulated oscillations suppressing the unmodulated portion of the high frequency output, transmitting the modulated portion of the high frequency output, receiving said transmitted portion and combining it with locally generated oscillation of the same frequency as the original unmodulated oscillations.

14. The method of high frequency telephonic signaling which consists in generating high frequency oscillations and audio oscillations, impressing both of said oscillations upon a modulator, suppressing the unmodulated component and one component of the modulated high frequency output, transmiting the other modulated component of the output, receiving said transmitted portion, and combining it with locally generated oscillations of the same frequency as the original unmodulated oscillation.

15. The method of high frequency telephonic signaling which consists in generating high frequency oscillations and audio oscillations, impressing both of said oscillations upon a modulator, suppressing the unmodulated component and one component of the modulated high frequency output, impressing the modulated component upon transmitting and receiving antennae and associated circuits resonant to a frequency differing from the carrier frequency by the mean speech frequency, receiving the said modulated waves, combining them with locally generated oscillations of the carrier frequency, and translating the combination into audible signals.

16. A method of transmitting high frequency telephonic signals which consists in generating high frequency undamped oscillations and telephonic oscillations; controlling and modulating the high frequency oscillations by means of the telephonic oscillations, whereby the amplitude of the resultant high frequency oscillations is directly proportionate to the amplitude of the telephonic oscillations; transmitting said modulated oscillations only; receiving said oscillations and combining them with locally generated oscillations of the carrier frequency; and translating the combination into audible signals.

17. In a high frequency signaling system, the combination of a source of energy generating a continuous high frequency undamped carrier wave, a transmitting device generating low frequency signal waves, means for modulating said carrier wave in accordance with said signal waves to produce a modulated wave whose amplitude is directly proportional to the signal wave, means for transmitting the modulated carrier wave, and means for preventing the transmission of the unmodulated carrier wave.

18. In a high frequency signaling system the combination of means for generating a high frequency undamped carrier wave, means for generating a low frequency signal wave and means for rendering the amplitude of said carrier wave directly proportional to the amplitude of said signal wave.

19. In a signaling system, the method of transmission which consists in generating a high frequency carrier wave, generating a low frequency signal wave, combining said waves into three waves of carrier wave frequency, carrier wave plus signal wave frequency and carrier wave minus signal wave frequency respectively, preventing the transmission of said first named of said three waves, impressing said waves upon transmitting and receiving systems resonant to a frequency differing from that of said carrier wave by approximately mean signal wave frequency, generating at the receiving station a wave of carrier wave frequency and combining it with the received wave.

20. In a system for the transmission of high frequency telephonic signals, a generator of high frequency undamped oscillations, a generator of audio oscillations, a modula-

tor, means for impressing the two oscillations on the said modulator to produce modulated waves whose amplitude is directly proportional to the audio waves, and means for suppressing the unmodulated portion of the high frequency output.

21. In a system for the transmission of high frequency telephonic signals, a generator of high frequency oscillations, a generator of audio oscillations, a modulator, means for impressing the two oscillations on the said modulator, means for suppressing the unmodulated portion of the high frequency output, and means for suppressing one component of the modulated portion.

22. In a system for the transmission of high frequency telephonic signals, a generator of high frequency oscillations, a generator of audio oscillations, a modulator, means for impressing the two oscillations on the said modulator, means for suppressing the unmodulated portion of the high frequency output, means for suppressing one component of the modulated portion, and an amplifier for amplifying the other component of the modulated portion.

23. In a system for the transmission of high frequency telephonic signals, a generator of high frequency oscillations, a generator of audio oscillations, a modulator, means for impressing the two oscillations on the said modulator, means for suppressing the unmodulated portion of the high frequency output, means for suppressing one component of the modulated portion, and a transmitting circuit tuned to a frequency differing from the frequency of the originally generated oscillations by the mean speech frequency.

24. In a system for receiving high frequency oscillations modulated in accordance with speech, comprising a circuit tuned to a frequency differing from a carrier frequency by the mean speech frequency, a local generator of oscillations of the carrier frequency, means for combining said received and said locally generated oscillations, and a translating device adapted to receive and translate the combination into audible signals.

25. In a system for receiving high frequency oscillations modulated in accordance with speech, comprising a circuit tuned to a frequency differing from the carrier frequency by the mean speech frequency and adapted to receive the modulated high frequency oscillations, a local generator of oscillations of the carrier frequency, means for impressing said received and said locally generated oscillations upon a detector, and a telephone receiver associated with said detector.

26. In a high frequency telephonic signaling system a generator of high frequency oscillations, a generator of telephonic oscillations, a modulator having an input and an output circuit, means for impressing the two oscillations on the input circuit of said modulator whereby modulated and unmodulated oscillations are set up in the output circuit, means for suppressing the unmodulated oscillations, a transmitting antenna tuned to a frequency differing from the carrier frequency by the mean telephonic frequency, a similarly tuned receiving antenna, a generator of oscillations of carrier frequency at the receiving station, a detector, means for impressing the received and the locally generated oscillations upon the detector, and a translating device associated with said detector.

27. In a high frequency telephonic signaling system, a generator of high frequency oscillations, a generator of telephonic oscillations, a modulator of the thermionic type having an input and an output circuit, means for impressing the two oscillations on the input circuit of said modulator whereby modulated and unmodulated oscillations are set up in the output circuit, means for suppressing the unmodulated oscillations, a transmitting antenna tuned to a frequency differing from the carrier frequency by the mean telephonic frequency, a similarly tuned receiving antenna, a generator of oscillations of carrier frequency at the receiving station, a detector of the thermionic type, means for impressing the received and the locally generated oscillations upon the detector, and a translating device associated with said detector.

28. In a high frequency telephonic signaling system, a generator of high frequency oscillations, a generator of telephonic oscillations, a modulator of the thermionic type having an input and an output circuit, means for impressing the two oscillations on the input circuit of said modulator whereby modulated and unmodulated oscillations are set up in the output circuit, means for suppressing the unmodulated oscillations, and amplifier of the thermionic type for amplifying the modulated oscillations, the transmitting antenna tuned to a frequency differing from the carrier frequency by the mean telephonic frequency, a similarly tuned receiving antenna, a generator of oscillations of carrier frequency at the receiving station, a detector of the thermionic type, means for impressing the received and the locally generated oscillations upon the detector, an amplifier of the therminoic type for amplifying the output of said detector and a translating device associated therewith.

29. A signaling system, wherein signals are transmitted by the agency of a modulated high frequency carrier wave, consisting of a transmitting station and a receiving station, said transmitting station comprising

a source of energy generating said carrier wave, a telephone transmitter, a modulating arrangement having a pair of input circuits and a pair of output circuits, said input circuits being connected with said generator and said transmitter in such a manner that oscillations of opposing phase are developed in said input circuits of said modulating arrangement, and a transmitting circuit to which the output circuits of said modulating arrangement are cumulatively connected; said receiving system comprising a receiving circuit, a source of energy generating undamped waves of the frequency of said carrier wave, and operatively connected to said receiving circuit, a detector whose input side is connected to said receiving circuit, and a receiving device connected to the output side of said detector.

30. In a wireless telephone system the combination of a transmitting station comprising a high frequency generator, a telephone transmitter, a modulator connected to both said generator and said transmitter, and an antenna connected to said modulator and tuned to a frequency differing from that of said generator by the mean speech frequency, with a receiving station comprising an antenna tuned to the same frequency as said first named antenna, a detector, a wave filter which substantially extinguishes currents of frequency differing by more than mean speech frequency from the frequency to which said antennæ are tuned, said wave filter connecting said detector with said receiving antenna, and a source of high frequency energy generating waves of the same frequency as said first named generator and impressing said waves on said detector.

31. In a wireless telephone system wherein signals are transmitted by the agency of a modulated high frequency carrier wave, the combination of a transmitting station comprising a source of high frequency energy generating said carrier wave, a telephone transmitter, a modulating arrangement comprising two symmetrical sections connected with said generator and said transmitter, said sections being so related to said generator and said transmitter that voltages of opposing phases are developed therein, an oscillation circuit similarly connected to both said sections, an antenna and an amplifier connecting said oscillation circuit with said antenna, said antenna and said oscillation circuit being tuned to a frequency differing from that of said carrier wave by approximately the mean speech frequency, with a receiving station comprising an antenna tuned to the same frequency as said first named antenna, an amplifier, an oscillation circuit tuned to the same frequency as said antennæ and connecting said second named antenna with said amplifier, a detector, an electric wave filter adapted to extinguish currents of frequencies differing by more than mean speech frequency from the frequency to which said antennæ are tuned, said filter connecting said detector with said amplifier, and a receiver connected with said detector.

32. In a system of telephony by means of a high frequency carrier wave, the combination of a transmitter, a source of high frequency energy, a modulating arrangement comprising a pair of input circuits and a pair of output circuits, said output circuits including a source of direct current energy, a transmitting circuit similarly connected to both said output circuits, one of said input circuits being connected to both said transmitter and said source of high frequency energy and the other input circuit being connected to said transmitter and said source of high frequency energy in such a manner that voltage variations of opposing phase are developed in said input circuits.

33. In a signaling system wherein signals are transmitted by the agency of a high frequency carrier wave, a modulating device comprising an input circuit and an output circuit including a source of direct current energy, and means whereby an oscillating voltage impressed on said input circuit produces substantially no voltage in said output circuit except a voltage proportional to the square of said oscillating voltage only.

34. In a signaling system wherein signals are transmitted by the agency of a modulated high frequency carrier wave a modulating device comprising an evacuated vessel containing a heated electron emitting cathode, two grids similarly related to said cathode and two plates similarly related to said cathode; a circuit for the thermionic current between said filament and one of said plates including a source of direct current energy and a coupling coil; a second circuit for the thermionic current between the filament and the other of said plates including said source of direct current energy and a coupling coil similar to said first named coupling coil, said two coupling coils being oppositely wound; a transmitting circuit inductively coupled to both of said coupling coils; and a coupling coil having one terminal connected to one of said grids and the other terminal connected to the other of said grids and having its mid-point connected to said filament.

35. In a high frequency duplex signaling system comprising a receiving arrangement and a transmitting arrangement associated with a common circuit, the method of duplex communication which consists in generating in said transmitting arrangement a pure modulated high frequency wave, impressing upon said common circuit said pure modulated high frequency wave, automati-

cally preventing the transmission of energy except when signals are being transmitted, receiving in said common circuit the waves from the communicating station, and preventing the energy absorbed by said receiving arrangement from exceeding a preassigned value.

36. A duplex high frequency signaling system consisting of two similar and equal communicating stations, each of said stations comprising a combined transmitting and receiving circuit, a source of high frequency energy, and a source of low frequency signal energy, connected with said combined transmitting and receiving circuit, means for modulating said high frequency energy in accordance with said low frequency signals, means for automatically preventing energy transmission except when signals are being transmitted; a receiving arrangement associated with said combined transmitting and receiving circuit, said receiving arrangement including a receiving device, a detecting device and means for preventing the energy absorbed by said receiving arrangement from exceeding a preassigned value.

37. In a signaling system, a source of high frequency carrier oscillations, a source of modulating signal oscillations, a modulating apparatus comprising two elements having opposite reactions with respect to energy applied thereto, and circuits therefor, said sources, modulating apparatus and circuits being so arranged and connected as to translate oscillations from said sources into oscillations of carrier frequency having an amplitude directly proportional to said signaling wave and into oscillations of double carrier frequency.

38. In a signaling system, a source of high frequency carrier oscillations, a source of modulating signal oscillations, a modulating apparatus comprising two elements having opposite reactions with respect to energy supplied thereto, and circuits therefor, said sources, modulating apparatus and circuits being so arranged and connected as to translate oscillations from said sources into oscillations of carrier frequency having an amplitude directly proportional to said signaling wave and into oscillations of double carrier frequency, and means to suppress said oscillations of double carrier frequency.

39. A translating apparatus comprising a pair of translator circuits, and two separate sources of current variations, one of said circuits constituting a source of signal variations, said translator circuits being symmetrically associated with one of said sources, the other source being so associated with said translator circuits as to be unaffected by currents transmitted through the translators from said first mentioned source, and means to so interconnect said sources and translator circuits that no effective energy due to one of said sources is supplied by said translator circuits when the other source is inactive.

40. A translating apparatus comprising a pair of translator circuits, two separate sources of current variations, one of said sources constituting a source of signal variations, said translator circuits being symmetrically associated with one of said sources, an outgoing circuit associated with said translator circuits, the other of said sources being so associated with said translator circuits as to be unaffected by currents transmitted from said translator circuits to said outgoing circuits, and means to so interconnect said sources and translator circuits that no effective energy due to one of said sources is supplied by said translator circuits to said outgoing circuits when the other source is inactive.

41. In a translating apparatus, a duplex translating arrangement comprising a pair of grids and a pair of plates, a pair of input circuits, one connected to each grid, a pair of output circuits one connected to each plate, two separate sources of current variations, said input circuits being in series with respect to one of said sources, the other source being so connected to said input circuits as to be independent of said output circuits and means to so interconnect said sources and translating arrangement that no effective energy due to one of said sources is supplied by said arrangement when the other source is inactive.

42. A translating apparatus comprising a duplex translating arrangement, a pair of input and a pair of output circuits for said translating arrangement, two separate sources of current variations, an outgoing circuit, said input circuits being symmetrically associated with one of said sources, and being also associated with the other source, said sources being unconnected with said output circuits, and said outgoing circuit being associated with both of said output circuits and means to so interconnect said sources and said translating arrangement that no effective energy due to one of said sources is supplied by said arrangement to the outgoing circuit when the other source is inactive.

43. A translating apparatus comprising a duplex translating arrangement; a pair of input and a pair of output circuits, a plurality of independent circuits, two of said independent circuits being associated with both input circuits, and unconnected with said output circuits, and another of said independent circuits being associated with each of said output circuits and means for so interconnecting said independent circuits and said translating arrangement that no effective energy is supplied from the

translating arrangement to said last mentioned independent circuit due to energy impressed upon the translating arrangement from one of said first mentioned independent circuits when no energy is being supplied to said translating arrangement from the other independent circuit.

44. A translating apparatus comprising a duplex translating arrangement, parallel circuits for said translating arrangement, including a common path and individual paths, a plurality of independent circuits including two incoming circuits and an outgoing circuit, one of said incoming circuits being associated with said individual paths, the other incoming circuit and the outgoing circuit being so associated with said parallel circuits that the incoming circuit will be unaffected by current transmitted from the translating arrangement to said outgoing circuit and means for so interconnecting said independent circuits and said translating arrangement that no effective energy is supplied from the translating arrangement to said outgoing circuit due to energy impressed upon the translating arrangement from one of said incoming circuits when no energy is being supplied to said translating arrangement from the other incoming circuit.

45. A translating apparatus comprising a duplex translating arrangement, including a common path and individual paths, a plurality of independent circuits, one of said independent circuits comprising a source of signaling current, another of said independent circuits comprising a source of locally supplied high frequency oscillations, another of said independent circuits comprising an outgoing circuit, one of said sources being associated with said individual paths and the other source and said outgoing circuit being so associated with said translating arrangement that said source will be unaffected by current transmitted from the translating arrangement to said outgoing circuit and means to so interconnect said sources and said translating arrangement that no effective energy due to one of said sources is supplied by said arrangement to said outgoing circuit when the other source is inactive.

46. In a signaling system, the method of transmitting signals which consists in generating a high frequency undamped continuous wave, modulating said wave in accordance with the signals to be transmitted, preventing the transmission of the unmodulated high frequency wave, and transmitting the pure modulated high frequency wave.

47. The method of transmission of high frequency telephonic signals which consists in generating undamped high frequency oscillations and signaling oscillations, impressing both of said oscillations upon a modulator, suppressing the unmodulated portion of the high frequency output, and transmitting the pure modulated portion of the high frequency output.

48. The method of signaling by means of modulated high frequency waves, which comprises suppressing the unmodulated carrier frequency wave at the transmitting station and restoring it at the receiving station.

49. The method of signaling which comprises modulating a carrier wave in accordance with a signal wave and suppressing two components of the modulated wave.

50. The combination of means at a transmitting station for generating a carrier wave and means for modulating the same in accordance with a signal, means for preventing transmission of unmodulated waves of carrier frequency, means for transmitting the modulated wave, means at a receiving station for generating a wave of the frequency of said carrier wave, means for combining said locally generated wave with said transmitted wave, and signal-receiving apparatus responsive to the resultant wave.

51. The method of signaling which consists in modulating a carrier wave in accordance with a signal wave, suppressing one of the resulting side frequency components of the modulated wave and in amplifying the unsuppressed portion of said wave.

52. A system for transmitting radio signals comprising a source of continuous radio-frequency current of a definite frequency, means for producing amplitude pulsations in the current derived from said source and a radiating antenna supplied with current from said source and tuned for resonance at a frequency equal to that of the source plus the most important frequency of the amplitude pulsations.

53. The method of transmitting radio signals which consists in producing amplitude pulsations corresponding to the signals to be transmitted in a continuous radio frequency current and supplying the current having amplitude pulsations therein to a radiating antenna system which is resonant to a frequency equal to the frequency of the source plus the frequency of the most important amplitude pulsations.

54. The method of high frequency carrier wave transmission which comprises producing and transmitting only waves from which the carrier frequency component is absent, receiving said transmitted waves and combining therewith a wave of the carrier frequency.

55. The method of telephony by means of modulated high frequency waves, which consists in rendering the transmitting circuit relatively unresponsive to unmodulated waves of the carrier frequency while highly responsive to waves of frequencies differing therefrom by frequencies occur-

ring in speech and in superposing upon the received signal waves a wave of carrier frequency.

56. The combination of a transmitting system for radio telephony including a source of high frequency waves, an antenna and means for suppressing unmodulated currents of said high frequency in the antenna, with a receiving system, including a generator of oscillations of the frequency of those suppressed.

57. In combination, means for generating a carrier wave, means for obtaining therefrom a pure modulated wave, and a receiving station comprising a detector, a local source of oscillations of carrier frequency, and means to impress said modulated wave and said locally produced oscillations upon said detector.

58. The method of carrier wave signaling which comprises producing a pure modulated wave modulated in accordance with a signal, transmitting one component only of said wave and combining therewith at a receiver a wave of carrier frequency.

59. In a signaling system, means for producing a pure modulated wave, means at the transmitting station for suppressing all but one of the components of said wave, and means for transmitting the unsuppressed component.

60. In a signaling system, means for producing a signaling wave, means for modulating said wave in accordance with a signal, means for suppressing the unmodulated component of said wave to produce a pure modulated wave, means for suppressing a component of said pure modulated wave, means for transmitting the unsuppressed component of said pure modulated wave, and means at a receiving station for combining with the received wave a wave of the frequency of said signaling wave.

61. In a signaling system, means for producing a high frequency wave, means for modulating said wave in accordance with a signal, said means comprising a space discharge modulator, and means for suppressing the unmodulated component of the modulated wave.

62. In a signaling system, the method of operation which comprises producing a high frequency alternating current, producing a space current and impressing variations upon said space current in accordance with said high frequency current and also in accordance with a signal, eliminating from the fluctuating current thus produced all unmodulated components, whereby a pure modulated wave is produced, amplifying said pure modulated wave and transmitting it to a receiving station and there modifying the received wave in such manner as to produce an indication corresponding to the original signal.

63. A modulating system comprising means for supplying a carrier wave modulated in accordance with signal impulses, amplifying means, and a filter between said supplying means and said amplifying means whereby only a portion of the modulated wave is transmitted from said supply means to said amplifying means.

64. A signaling system comprising means for supplying a carrier wave modulated in accordance with a telephonic signal, means for suppressing one of the resulting side frequency components of said wave, and means for amplifying the unsuppressed portion of said wave.

65. A sending station comprising means for supplying a carrier wave modulated in accordance with signal impulses, a high frequency transmission circuit, and means connecting said supplying means and said circuit for suppressing a component part of said wave.

66. The method which consists in generating high frequency oscillations modulated in accordance with a signal wave, attenuating the undesired components of the modulated oscillations and amplifying the resultant oscillations.

67. The combination in series energy relation of means for modulating high frequency oscillations in accordance with the signal, a filter for eliminating undesired components from the modulated oscillations and means for amplifying the resultant oscillations.

68. In a signaling system, a circuit over which modulated waves are received, a demodulator for translating the modulated waves into signals, means to supply to said demodulator unmodulated waves, and means to prevent the transmission of said unmodulated waves to said circuit.

69. In a signaling system, a source of carrier current, a source of signaling current, a modulator, means for impressing current from said sources upon said modulator to produce a current having an unmodulated component and two modulated components corresponding to the signal, said modulator comprising two elements balanced with respect to each other so as to balance out the unmodulated component, and selecting means for selecting one of the components corresponding to the signal to the exclusion of the other component corresponding to the signal.

70. In a signaling system, an alternating current source of constant frequency, a modulating current comprising a band of signaling frequencies, a modulator, means to impress said constant frequency current and said modulating current upon said modulater to produce a current having two side band components and an unmodulated component corresponding to said constant

frequency current, said modulator comprising two elements so balanced with respect to each other as to balance out said unmodulated component, and means for selecting one of said side band components to the exclusion of the other.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses, this twenty-sixth day of November 1915.

JOHN R. CARSON.

Witnesses:

GEORGE E. FOLK,

FRED'K S. ROBINSON.