May 19, 1931. R. K. POTTER 1,805,596

SIGNALING SYSTEM

Filed Sept. 24, 1926

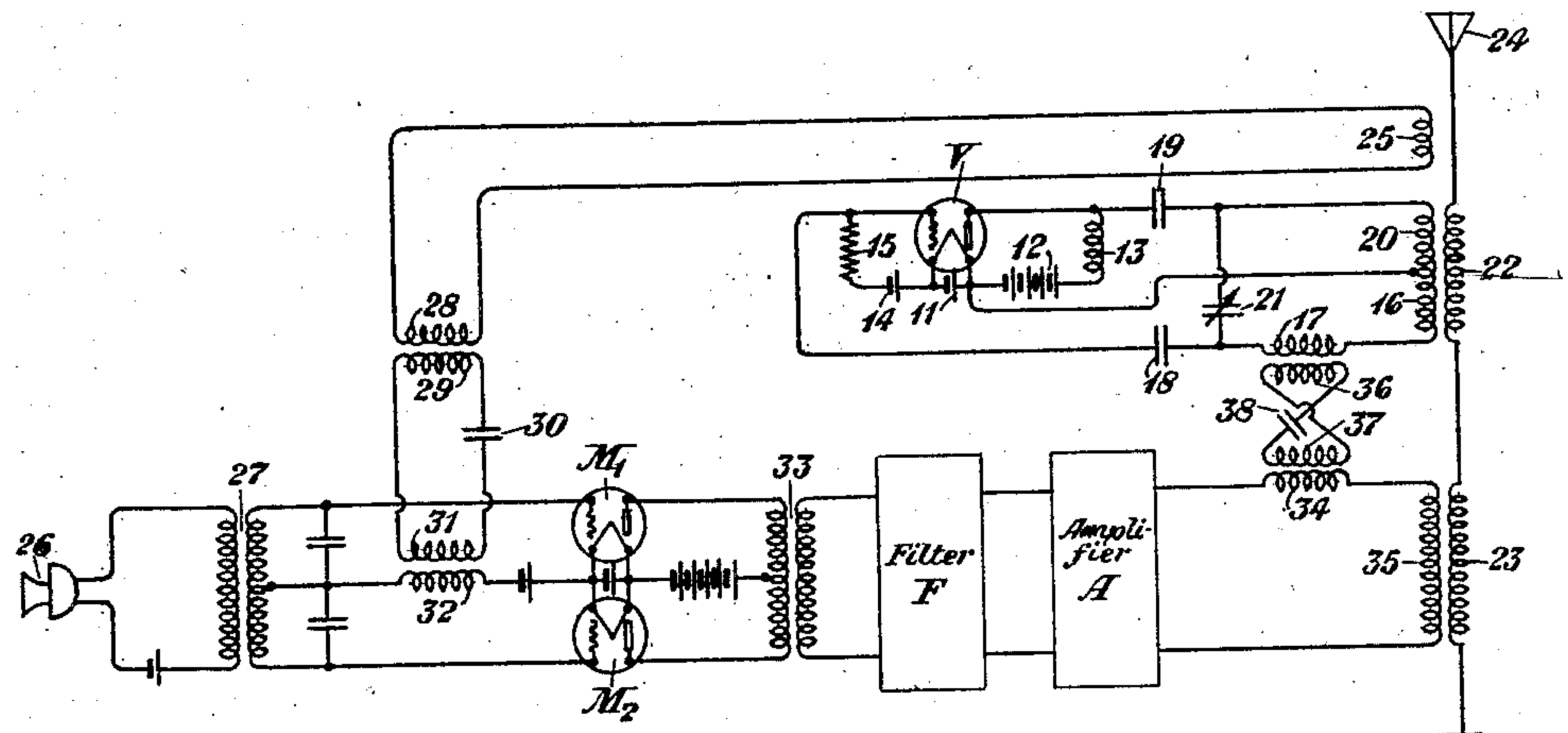

Fig. 1

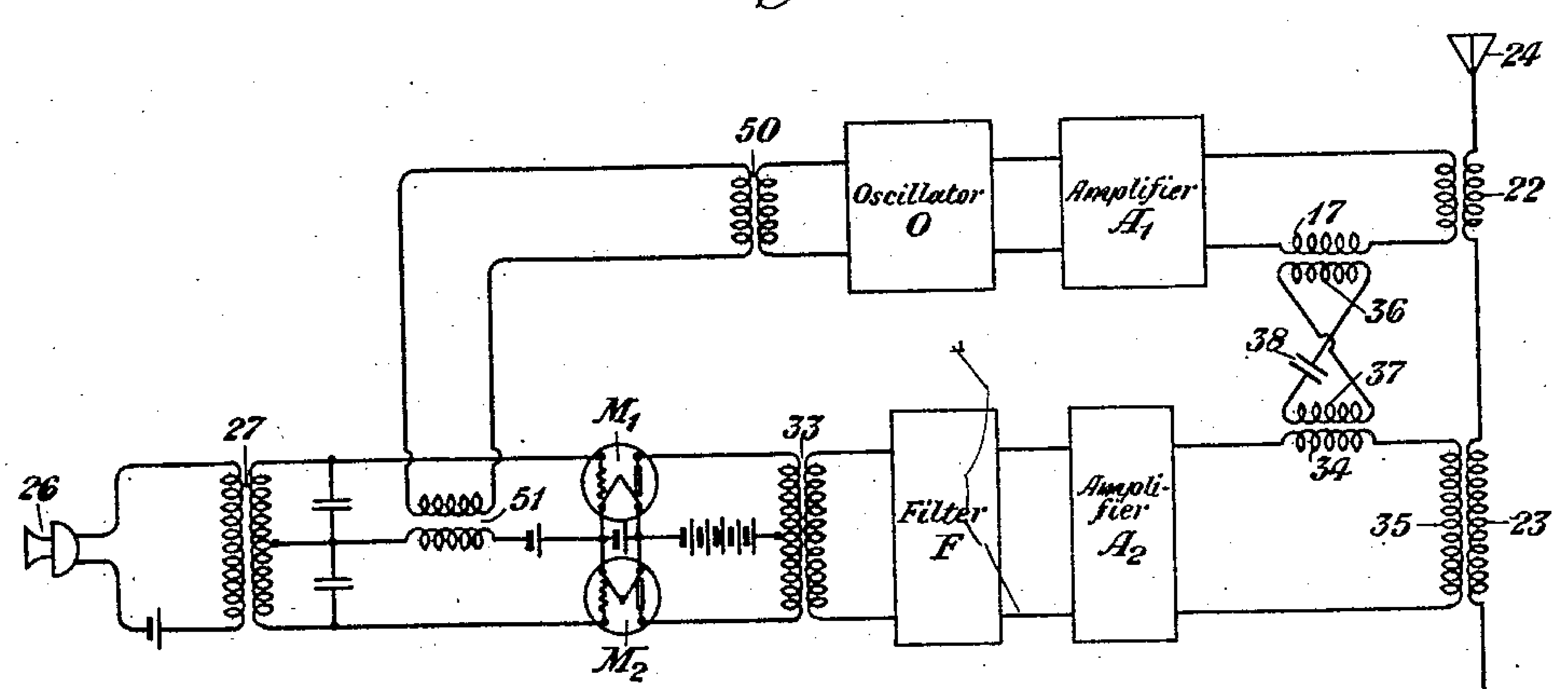

Fig. 2

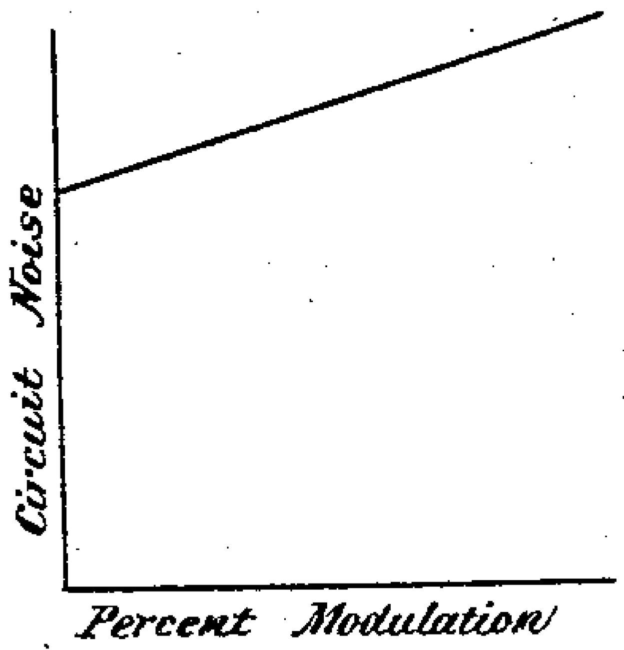

Fig. 4

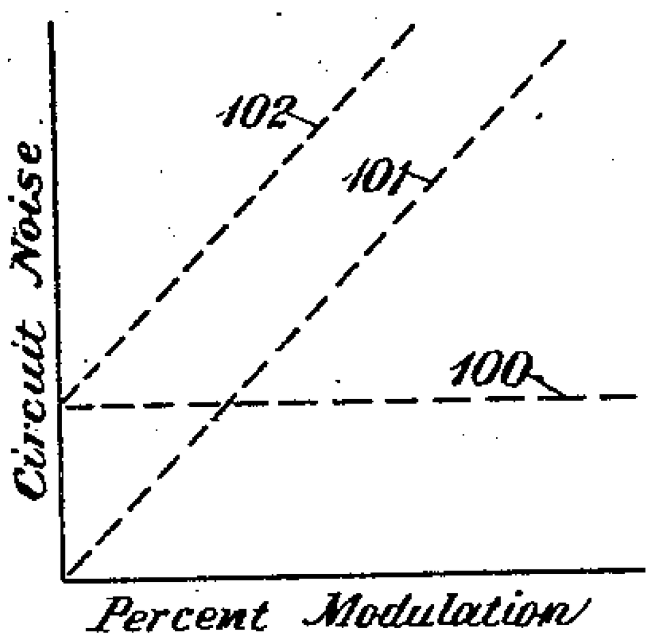

Fig. 5

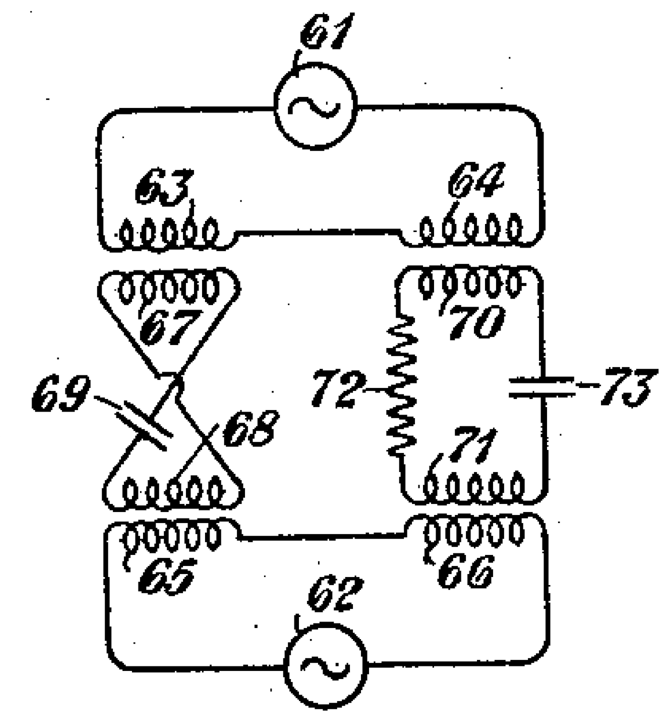

Fig. 3

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SIGNALING SYSTEM

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This invention relates to signaling systems, and particularly to such systems in which a carrier wave is generated at a high level and a band of signals is generated at a lower level and amplified to a level comparable to that of the carrier wave.

When a carrier wave is generated in one circuit and voice frequency, or, in general, low frequency signals are generated in another circuit, and when the circuits are combined in, for example, some suitable form of modulator in conjunction with some form of filter so that one or both side bands of the carrier wave are produced thereby as a result of modulating and filtering action, and, furthermore, when the carrier wave and the side bands are then both amplified by the same amplifier, the amplifier capacity must, in a high quality circuit, be several times that necessary to amplify the side bands alone. In addition, undesirable noise may be introduced into the amplified wave.

In this invention, a signaling system will be shown and described in which the overall efficiency is greater than has heretofore been possible of attainment and the effect of circuit noises is considerably reduced, particularly during the low modulation period, i. e., the period during which the level of low frequency signals is small as compared to the level of the carrier wave. The apparatus of this invention is so arranged that the carrier wave is generated and, if necessary, amplified in a circuit which is separate and distinct from the circuit generating and amplifying the side band signals. In such a system, the requirements of the vacuum tubes employed therein are less severe and the overall efficiency of the system greater than has heretofore been known, by virtue of the fact that the carrier wave is originally generated at a high level and does not pass through several stages of amplification as do the side bands. In addition the carrier frequency of this system may be much more easily stabilized than in a system in which both carrier and side band are generated at a high level.

While this invention will be pointed out with particularity in the appended claims, the invention, itself, both as to its further objects and features, will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawings in which Figures 1 and 2 represent signaling systems embodying the principles of this invention, in which Fig. 3 represents a neutralizing circuit showing how the mutual reaction of the carrier wave and band of signals is substantially neutralized, in which Fig. 4 represents a curve showing the noise characteristic of former similar signaling systems, and in which Fig. 5 represents the noise characteristic of the signaling system of this invention.

Referring to Fig. 1 of the drawings, there is shown an oscillator which generates oscillations of the carrier frequency at an energy level sufficient to be directly radiated through space. This oscillator comprises a three-element vacuum tube V, including a grid, an anode and cathode. The cathode is heated to an electron emitting temperature by a battery 11. A battery 12 supplies the space current for the vacuum tube V through a choke coil 13. A battery 14 is connected to the grid of the vacuum tube V through a resistance 15, this battery 14 rendering the grid suitably negative with respect to the cathode. The alternating current input circuit for the oscillator includes the grid and cathode of the vacuum tube V, an inductance 16, an inductance 17 and a condenser 18. The alternating current output circuit for the oscillator includes the cathode and anode of the vacuum tube V, the condenser 19 and an inductance 20. The oscillation circuit which controls the frequency of the oscillator includes the inductances 16, 17 and 20, and the condenser 21, all of which are designed to be sharply resonant at the carrier frequency. The inductances 16 and 20 are so coupled that some of the energy of the output circuit is fed back to the input circuit so that oscillations at the carrier frequency are most efficiently generated. A variable condenser 21 is used in tuning the oscillation circuit of the oscillator to the frequency of the carrier wave.

Inductances 20 and 16 are coupled to an

inductance 22, which inductance is in series with another inductance 23, an antenna 24 and ground. Another inductance 25 is coupled to inductances 16 and 20 so that part of the energy of the carrier frequency may be fed to, for example, a modulator, as will be described more fully hereinafter.

The voice frequency signals may be originated by a device such as a telephone transmitter designated herein by the reference character 26. Voice frequency signals generated by such a transmitter are impressed through a transformer 27 upon a modulator, which may, for example, be of any well known carrier suppression type, preferably of the balanced tube type as shown. The modulator comprises two three-element vacuum tubes M_1 and M_2. Energy of the carrier frequency is transmitted from the oscillator to the modulator through coupled inductances 28 and 29, condenser 30 and coupled inductances 31 and 32.

As is well known in the art, the carrier frequency transmitted to such a modulator is substantially suppressed, and side bands corresponding to the voice frequency signals raised in the frequency spectrum are transmitted thereby. A transformer 33 connects the output of the balanced modulator with a band filter F, which band filter transmits, for example, one side band of the carrier wave resulting from modulation, this side band corresponding to the voice frequency signals impressed by transmitter 26 upon the balanced modulator, band filter F substantially suppressing the other side band. The band filter F suppresses, moreover, all inter-modulation components which are above and below the limits of the band filter. The band of signals passed by filter F is then amplified by amplifier A, and is then transmitted through inductance 35 to the antenna circuit by virtue of the coupling existing between inductances 35 and 23. The circuit including the inductances 29 and 31 and the condenser 30 is a very sharply tuned circuit and serves as a means for properly adjusting the phase relations of the band of signals with respect to the carrier wave. The amplifier A raises the level of energy of the band of signals to a level approximating that of the carrier wave, or, in general, it may be said that the amplifier A raises the energy level of the band of signals to any predetermined magnitude to produce any suitable ratio of signal energy to carrier energy.

When feeding the tubes of two or more vacuum tube circuits into a common oscillating circuit, such, for example, as an antenna circuit by means of suitable coupling of the vacuum tube circuits to the antenna circuit, the coupling may cause considerable reaction of one vacuum tube circuit upon the other. In the arrangement of Fig. 1, the carrier output will be impressed upon the signal band output in the plate circuit of the signal band output amplifier, and will result in undesirable overloading and modulation, and similarly, the signal band output will be impressed upon the carrier output in the plate circuit of the vacuum tube supplying carrier (i. e., in, for example, the circuit of the oscillator), and will result in further undesirable overloading and modulation, unless suitable means are provided to prevent such interaction. To overcome such undesirable interaction and consequent intermodulation and overloading, a neutralizing circuit is provided. This neutralizing circuit consists of inductances 36 and 37 which are in series relationship with a condenser 38, inductance 36 being coupled to inductance 17 and inductance 37 being coupled to inductance 34. The object attained by providing this neutralizing arrangement is to induce voltages in the associated circuit equal and opposite to those induced by virtue of the coupling between the carrier output, signal band output and the antenna circuit. The manner in which this neutralizing arrangement effectively suppresses undesirable inter-modulating action will be described more particularly hereinafter in connection with Fig. 3.

In Fig. 2, a similar signaling system is shown in which the carrier wave is generated and then amplified before being impressed upon the antenna circuit. For the sake of convenience, similar reference characters will be employed in Fig. 2 to designate parts similar to those of Fig. 1. In this figure, the oscillator O generates the wave of the carrier frequency, which oscillator may be of any well-known type, preferably of the vacuum tube type, and may preferably be controlled as to frequency by, for example, a piezo-electric device, as is well-known in the art. This oscillator O is connected to the antenna circuit through an amplifier A_1 so that the level of the carrier wave may be raised to one suitable for proper radiation by the antenna circuit. Energy of the carrier wave is also transmitted to a balanced modulator to produce a band of signals corresponding to the voice frequency signals generated by the transmitter 26, this band of signals being also amplified by amplifier A_2, separately and distinctly from the carrier wave. Due to the fact that the amplifier A_1 amplifies the carrier wave alone, the level to which the carrier wave may be raised by the amplifier A_1 is much greater than the level to which the carrier wave might otherwise be raised, if one or both side bands of the carrier wave were present to be simultaneously amplified thereby. Amplifier A_1 may, as a matter of fact, be operated well beyond the limits of distortionless amplification and adjusted very nearly to, or even somewhat beyond, its point of oscillation so that oscillator O may act simply as a frequency regulator.

In Fig. 3, a simplified diagram of the neutralizing arrangement is shown. The carrier output is designated by the reference character 61 and the signal band output is designated by the reference character 62. Inductances 63 and 64 simulate inductance 17 and the combination of inductances 20 and 16 of Fig. 1, respectively. Inductances 65 and 66 simulate inductances 34 and 35, respectively. Inductances 67 and 68 are coupled to inductances 63 and 65, respectively, and these inductances 67 and 68 are in series relationship with a condenser 69. An adjustable resistance (not shown) may, if desired, be included in this series circuit. This series circuit is similar to the one shown in both Figs. 1 and 2 and referred to hereinabove as the neutralizing arrangement. Inductances 70 and 71 simulate inductances 22 and 23, respectively, of the antenna circuit, and resistance 72 simulates the radiation resistance of the antenna circuit. Inductances 70 and 71 and the resistance 72 are in series relationship with the capacity 73 which represents the capacity existing between the antenna 24 of Figs. 1 and 2 and ground. This latter series circuit simulates the antenna circuit of Figs 1 and 2.

When the inductance, capacity and resistance of the neutralizing circuit and the inductance, capacity and resistance of the antenna circuit are substantially equal, or, in general, when the coupling of the carrier to the signal band source through neutralizing circuit and through the antenna circuit are substantially equal and opposite, the effective coupling between the carrier output and the signal band output tending to produce mutual interaction will be substantially zero.

By the arrangement of this invention, the carrier wave and the band of signals corresponding to voice frequency signals may both therefore be impressed on a common circuit and then radiate through space substantially without interaction between the carrier wave and the band of signals. If the resistance included in the neutralizing arrangement (not shown) is made, for example, equal to the total radiation resistance of the antenna circuit, almost 50% of the carrier output and the signal band output, will be absorbed in the neutralizing process. When the resistance of the neutralizing arrangement is made very small as compared to the radiation resistance of the antenna circuit so that the loss therein is correspondingly small, the coupling between the carrier output and the signal band output may be adjusted to substantially neutralize mutual interaction due to the carrier wave; but for that condition only partial neutralization may be obtained for the signal band. However, by rendering the carrier output circuit extremely selective as is desirable in a highly efficient generator, the system need not necessarily be completely balanced to prevent interaction between the carrier output and the signal band output, because the high selectivity of the carrier circuit will operate effectively to obstruct the passage of signal band energy to the carrier output circuit. Moreover, the selective character of the carrier output circuit will at the same time minimize the transmission of any circuit disturbances such as are caused, for example, by what are known as ripples arising in the plate, filament or grid potential sources of supply for the carrier oscillator.

Fig. 4 shows the curve approximating the relation between the circuit noise, i. e., noise, for example, due to the disturbances in the power supply, and percentage of modulation when the carrier wave and the band of signals are both amplified according to present methods. In this circuit, when no low frequency signals are modulated on the carrier wave, the circuit noise will have a certain definite minimum value which is a large percentage of the maximum and which is dependent upon the magnitude of circuit disturbances and the magnitude of carrier present. When the level of the low frequency signals or modulating wave increases, assuming, of course, that these signals are amplified along with the carrier wave, the noise will increase almost uniformly, somewhat as is shown in this figure.

The relation between circuit noise and percentage of modulation in the arrangement described in connection with this invention, is shown in Fig. 5. When no low frequency signals are modulated on the carrier wave, the noise level is designated by the line 100. The noise in this case is determined entirely by what is present in the oscillator which may be of the type shown, for example, in Fig. 1. By the use of highly selective circuits, which are proper for use in an unmodulated oscillator, this noise may be made comparatively small. Line 101 represents the noise which is produced by the amplification of the band of signals. This noise increases as the level of the band of signals increases. The noise due to the band of signals is at a minimum when the level of the band is extremely small. Line 102 represents a line having ordinates substantially equal to the ordinates of both lines 100 and 101. Line 102 is, moreover, substantially parallel to line 101. From this figure it is seen that the noise due to the carrier wave will remain constant and will be of comparatively low value, while the noise due to the amplification of the band of signals will be in direct proportion to the percentage of modulation. Line 102 will obviously represent noise due to both the carrier wave and the band of signals.

The important difference between the line of Fig. 4 and line 102 of Fig. 5 is that in Fig.

4, the circuit noise level is comparatively high, even when no modulation is taking place, while in Fig. 5, the noise level is comparatively low when the percentage of modulation is low. With the arrangement of this invention, the circuit noise is approximately proportional to the percentage of modulation so that its interfering effect is much more nearly constant through the entire modulation range than will be ordinarily the case in systems in which the carrier and a band of signals are simultaneously amplified in common circuits.

A very important item of consideration in the case of higher power radio transmitter equipment is the saving of necessary tube capacity and power by the more efficient operation of tubes, as, for example, by operation in accordance with the principles of this invention, described hereinabove.

While the invention has been shown and described in certain particular embodiments merely for the purpose of illustration, it is to be understood that the general principles of this invention may be embodied in other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The method of signaling which consists in generating a wave of carrier frequency, transmitting the carrier frequency wave at a suitable energy level through space, generating voice frequency signals, producing a side band of the carrier frequency corresponding to said voice frequency signals, raising the energy level of the side-band to that of the carrier frequency, combining the side-band with the carrier frequency, and neutralizing the reaction of the energy of the carrier frequency upon that of the side-band.

2. The method of signaling which consists in generating a wave of carrier frequency, transmitting said carrier frequency wave at a suitable energy level through space, generating voice frequency signals, producing a side band of said carrier frequency corresponding to said voice frequency signals, separately amplifying said side band to an energy level substantially equal to that of the carrier frequency wave, transmitting said amplified side band through space, and neutralizing the reaction of the energy of the carrier frequency upon that of the side band before transmission.

3. The method of signaling which consists in generating a carrier wave of an energy level suitable for transmission, generating low frequency signals, producing a band of signals corresponding to said low frequency signals raised in the frequency spectrum, amplifying the said band of signals thus raised in the frequency spectrum to an energy level also suitable for transmission, neutralizing the reaction of the energy of the carrier wave upon that of the side-band, and transmitting through a spacial radiating medium both said carrier wave and said band of signals after neutralization.

4. The method of signaling which consists in producing a high frequency carrier wave of predetermined energy level, producing voice frequency signals at a low energy level, transforming said voice frequency signals into a band of signals raised in the frequency spectrum, amplifying said band of signals raised in the frequency spectrum to said predetermined energy level, substantially neutralizing the effect of the energy of the carrier wave upon the energy of the band of signals and transmitting over a spacial radiating medium, said amplified band of signals along with said carrier wave after neutralization, thereby increasing the overall efficiency of the system.

5. A signaling system comprising means for generating a wave of carrier frequency, means for transmitting said wave of carrier frequency through space at a suitable energy level, means for generating voice frequency signals, a modulator and filter for producing a side band of the carrier frequency wave corresponding to said voice frequency signals, and means for neutralizing the mutual reaction between said side-band and said carrier frequency wave at said transmitting means, said side band being combined with the energy of said wave of carrier frequency and being also transmitted through space by said transmitting means.

6. A signaling system comprising a generator of a carrier frequency wave, means for raising the energy level of the carrier frequency wave to a predetermined magnitude, means for generating voice frequency signals, a modulator and filter for producing a side band of signals corresponding to said voice frequency signals, means for amplifying said side band to an energy level substantially equal to that of the amplified carrier wave, means including elements of inductance and capacity for neutralizing the reaction between the energy of the amplified side band and that of the carrier wave, and means for transmitting through a common medium the said carrier wave and said side band after each has been amplified.

7. A signaling system comprising a generator of a carrier wave of an energy level suitable for transmission, a generator of low frequency signals, means for producing a band of signals corresponding to said low frequency signals raised in the frequency spectrum, means for amplifying said band of signals to an energy level substantially equal to that of the carrier wave, means for transmitting said carrier wave and said band of signals, and means including inductive and capacitative elements for neutralizing mutual interaction between the energy of the band of

signals and the energy of the carrier wave at said transmitting means.

8. The method of signaling which consists in generating a carrier wave at an energy level required for transmission, generating low frequency signals, producing a side band of the carrier wave corresponding to said low frequency signals, separately amplifying said side band to an energy level substantially equal to that of said carrier frequency, neutralizing the mutual reaction between the energy of the side band and that of the carrier frequency, and combining the said side band and said carrier frequency wave after amplification and neutralization for radiation mutually independently through a common spacial radiating medium.

9. The method of signaling which consists in generating a carrier frequency wave, generating low frequency signals, producing a side band of the carrier wave corresponding to said low frequency signals from part of the energy of the carrier wave and said low frequency signals, separately amplifying said side band and the remaining portion of said carrier wave, combining said side band and said carrier wave after amplification for transmission over a common spacial radiating medium, and substantially neutralizing the inductive and capacitive coupling between the side band and the carrier wave energies tending to produce mutual interaction at the point of combination.

10. The method of signaling which consists in generating a carrier wave at a predetermined energy level, generating low frequency signals, producing a band of signals corresponding to the low frequency signals displaced in the frequency spectrum, separately amplifying said band of signals and said carrier wave so that the energy level of said band of signals bears a definite relation to the energy level of the carrier wave, combining said band of signals and said carrier wave for transmission over a common medium, and substantially neutralizing the inductive and capacitive coupling between the energies of said band of signals and said carrier wave at the point of combination.

11. A signaling system comprising means for generating a carrier wave at an energy level required for radiation, means for generating low frequency signals, means for modulating a fraction of the carrier wave with the low frequency signals to produce a side band corresponding to low frequency signals, means for amplying said side band to a level desirable for radiation, a common radiator, means for preventing mutual interaction between the energy of said side-band and the energy of said carrier wave, and means for combining and transmitting said carrier wave and said side band over said common radiator.

12. In a signaling system, a generator of carrier frequency, means for amplifying a part of said carrier frequency, means for generating voice frequency signals, means for combining said voice frequency signals with another part of said carrier frequency in such a way as to produce a band of signals corresponding to said voice frequency signals but displaced in the frequency spectrum, means for separately amplifying said band of signals and said carrier frequency, means for preventing mutual interaction between the energy of said band of signals and the energy of said carrier frequency, a common radiator, and means for combining and transmitting the carrier frequency with the band of signals representing the voice frequency signals over said common radiator.

In testimony whereof, I have signed my name to this specification this 23rd day of September, 1926.

RALPH K. POTTER.