

Jan. 8, 1946.

DE WITT R. GODDARD  
RADIO COMMUNICATION SYSTEM

2,392,586

Filed Nov. 11, 1943

3 Sheets-Sheet 1

Fig. 1a

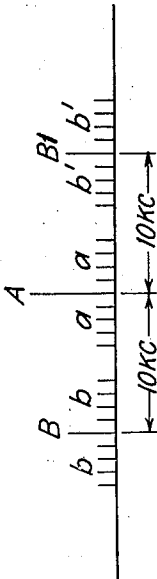


Fig. 1

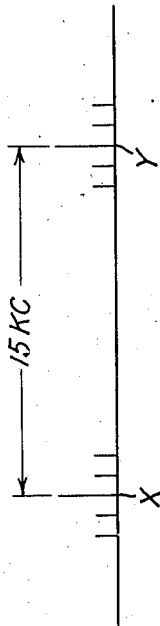
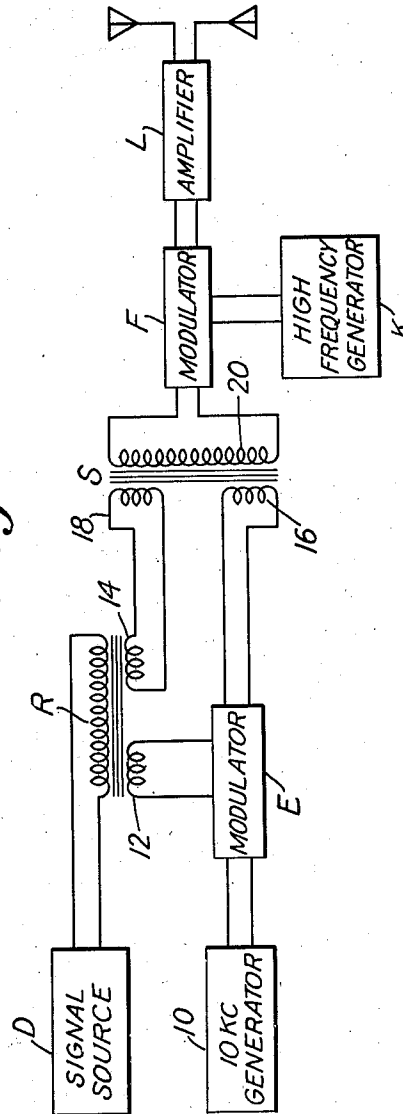


Fig. 2



INVENTOR.  
DE WITT R. GODDARD  
BY

H. S. Grover  
ATTORNEY

Jan. 8, 1946.

DE WITT R. GODDARD  
RADIO COMMUNICATION SYSTEM

2,392,586

Filed Nov. 11, 1943

3 Sheets-Sheet 2

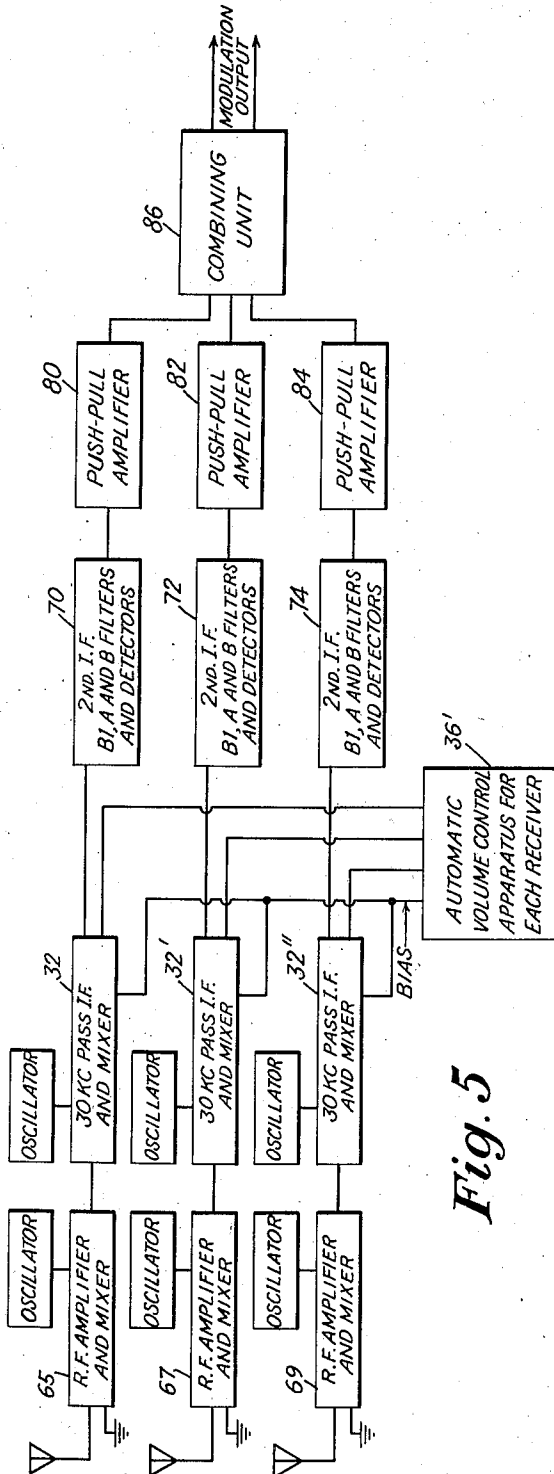


Fig. 5

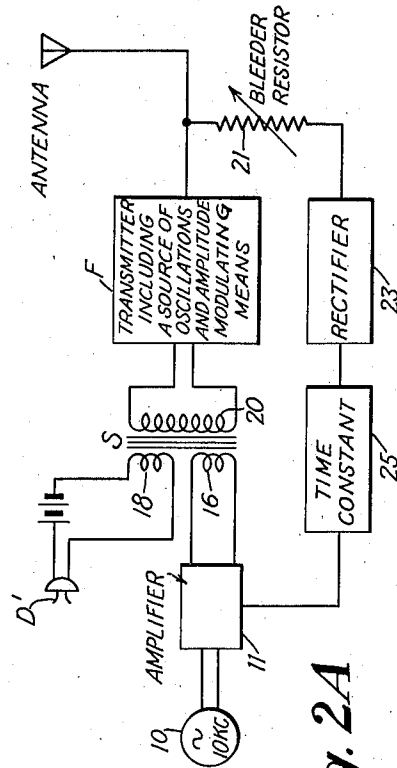


Fig. 2A

INVENTOR.  
DE WITT R. GODDARD  
BY *H. S. Brown*  
ATTORNEY

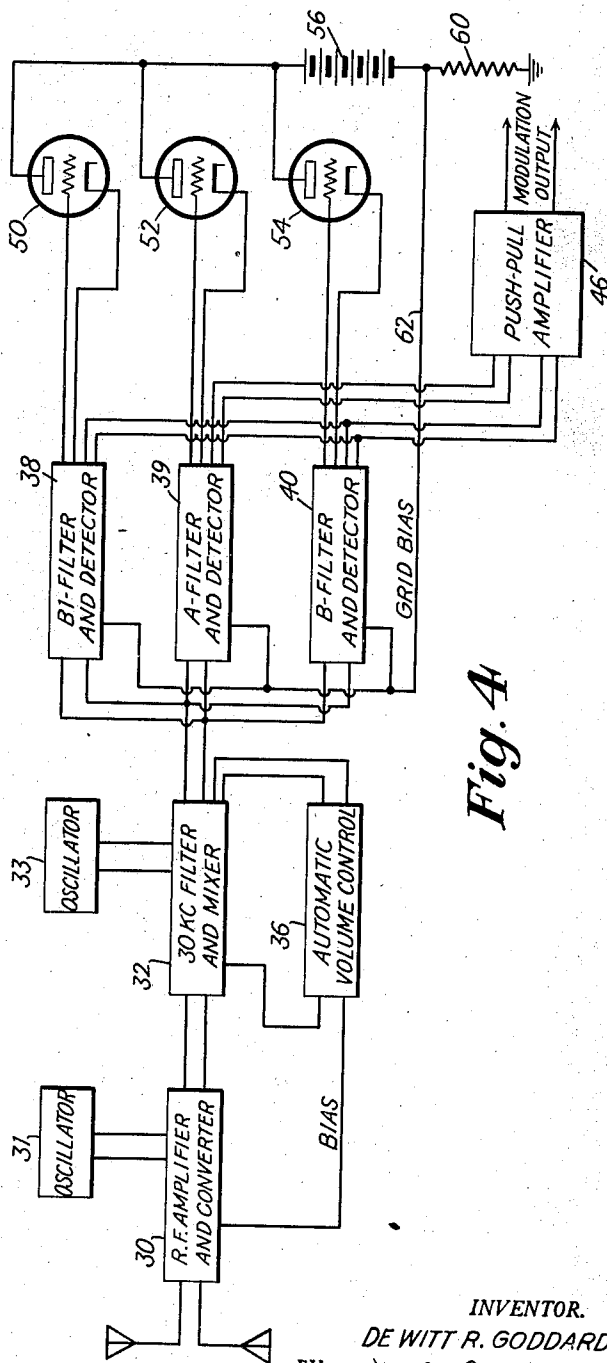
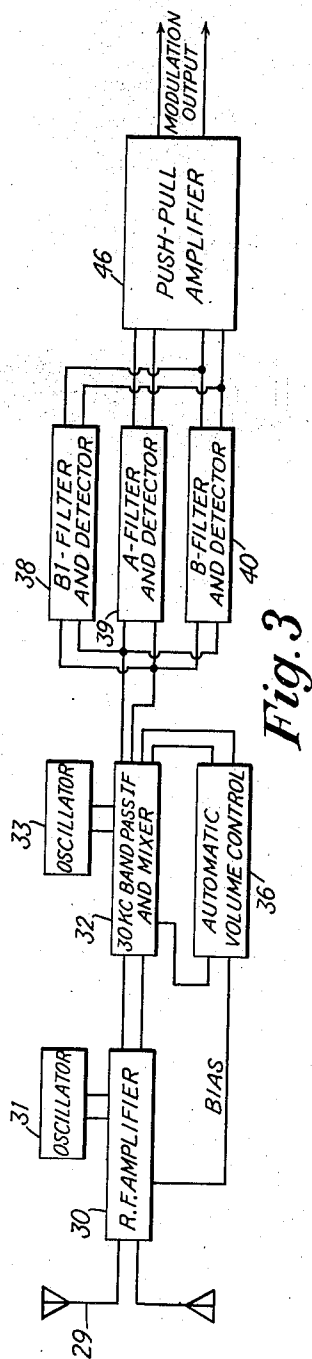
Jan. 8, 1946.

DE WITT R. GODDARD  
RADIO COMMUNICATION SYSTEM

2,392,586

Filed Nov. 11, 1943

3 Sheets-Sheet 3



INVENTOR.  
DE WITT R. GODDARD

BY

*H. S. Brover*  
ATTORNEY

## UNITED STATES PATENT OFFICE

2,392,586

## RADIO COMMUNICATION SYSTEM

De Witt R. Goddard, Riverhead, N. Y., assignor to  
Radio Corporation of America, a corporation of  
Delaware

Application November 11, 1943, Serial No. 509,872

17 Claims. (Cl. 250—6)

This invention pertains to signalling systems and particularly to improved short wave radio communication systems.

The signal emitted by an amplitude modulated transmitter varies in power from moment to moment depending upon the depth of modulation. Therefore, a receiving set using an automatic volume control must have its time constant adjusted to a value such that the automatic control will not respond to the lowest audio frequency that it is desired to receive or some of the modulation will be suppressed, giving rise to distortion. As a consequence, high intensity static crashes pass through the system and appear at the loud speaker thereby reducing the intelligibility of the incoming signal and causing great annoyance. These high intensity static crashes are frequently within the modulation range or above so that the slow automatic volume control systems known heretofore do not act quick enough to suppress the same.

In my new and improved system as described herein, it is made possible to use an extremely fast automatic volume control without affecting the modulation. In my system the time constant of the automatic volume control can be and is adjusted to a frequency higher than the highest modulation frequency to which the modulation amplifier system will respond.

With ordinary fading my automatic volume control will hold the signal steady in my improved system. Should static crashes, loud clicks etc., occurring in the house lighting supply etc., be picked up by the receiver, their intensity in the audio system can never rise above a fixed value determined by the setting of the volume control. This value is approximately equal to that of the incoming signal when modulated 100%. In my system, if a static crash of very high intensity occurs at a moment when the transmitter is being modulated 100% there will be practically no rise in speaker volume as the automatic volume control allows only a definite voltage to be detected, be it signal static or a combination of both. As a consequence, in my system all loud sharp crashes, that are so annoying, are suppressed in the loud speaker. Intelligibility is increased since it is well known that a sudden loud noise of short duration reduces the sensitivity of the ear for a comparatively long time.

In describing my invention in detail reference will be made to the attached drawings wherein Fig. 1 is used to illustrate the operation of my system.

Fig. 1a illustrates the relation of the carrier and its side bands radiated by a system modulated in accordance with my invention.

Fig. 2 illustrates mainly by block diagram and schematically a modulation system arrangement in accordance with my invention.

Fig. 2a illustrates a modification of the arrangement of Fig. 2.

Figs. 3, 4 and 5 illustrate by rectangles and schematically three forms of receiving systems adapted to the reception of energy transmitted by the system as illustrated in Fig. 2. The receivers have fast automatic volume controls which suppress static without affecting the modulation.

The desirable effects described above, and other valuable features to be described later are obtained in the following manner. In accordance with my invention a transmitter is modulated nearly 100% by a 10 kilocycle tone, which is in turn modulated nearly 100% by the signal. The transmitter is also modulated by the signal. In this modulation process the signal modulation of the transmitter carrier and the modulation envelope of the tone are caused to be 180° out of phase, that is, are opposed. This provides an output as illustrated graphically in Fig. 1a. The essential feature is that the modulation it is desired to transmit is impressed both on the 10 kilocycle tone and on the carrier but in such a way as to modulate the 10 kilocycle tone and the carrier in substantially exactly reverse phase relation. Therefore, in ordinary broadcast modulation frequencies the depth of modulation on the transmitter remains essentially constant, because when the power in B and B1 increases the power in A decreases and vice versa.

This will be clearer if one considers first two independent RF carriers separated say 15 kilocycles, and indicated in Fig. 1 by carriers X and Y. One of them, say X, is amplitude modulated in the conventional fashion, while Y is modulated the same amount with the modulation in opposed phase relation.

Now, it is evident that the power is constant in a receiver having a band width sufficient to include both carriers and their associated side bands. Therefore, an extremely rapid AGC (automatic gain control) system may be applied to this receiver without in any way affecting the modulation of either carrier. If, after the application of this automatic gain control, carrier X and its associated side bands be filtered off of the signal, it may be demodulated in the conventional manner yielding the original

modulation. The carrier Y will likewise yield the signal.

It is evident that by virtue of the rapid automatic gain control, rapid with respect to the modulation frequencies, static crashes will affect the gain of the receiver. The gain of the receiver will drop with sufficient rapidity to prevent powerful static crashes from appearing in the AF output with greater amplitude than the maximum modulation components.

Fig. 1a illustrates the relation of the side bands radiated by a transmitter modulated in accordance with my invention. In the illustration it is assumed that the modulated tone is of 10 kilocycles, but it will be understood that other tone frequencies may be used. In Fig. 1 A represents the carrier, while B and B1 represent the two side bands caused by modulation of the carrier by the signal modulated 10 kilocycle tone. *a, a* are the side bands of the carrier A and are caused by modulation of the carrier. *b, b* and *b', b'* are the side bands of B and B1 caused by modulation of the tone frequency.

Fig. 2 shows in a simplified manner a transmitter arrangement in accordance with my invention, and modulated as described above to fulfill the requirements of a system in accordance with my invention. In Fig. 2 the signal that it is desired to transmit originates at a studio or other source indicated at D. This audio signal passes into a transformer R which has two secondaries 12 and 14. The secondary 12 is coupled to an amplitude modulator E to feed thereto the signal for amplitude modulating therein the oscillations supplied by the source 10, which, as stated above, may have an output at 10 kilocycles. The output of the modulator E which is a modulated tone, is fed to the primary winding 16 of a transformer S having another primary winding 18 coupled by winding 14 of transformer R to the source D. The modulation envelope on the modulated tone supplied to 16 and the modulation itself supplied to 18 are 180° out of phase.

The secondary winding 20 of transformer S feeds a modulation system included in the rectangle F to modulate therein a high frequency carrier supplied from the high frequency generator K. The output of this modulator is fed through a high frequency power amplifier L to a utilization circuit such as an antenna. The apparatus in E, F, K and L is conventional and well known in the art and will not be described in detail herein.

Another arrangement for providing an output of the nature described above is illustrated in Fig. 2a. In this modification signals are supplied from a source D' to one winding 18 of transformer S and a superaudible tone is supplied through amplifier 11 to the other winding 16 of transformer S. In this modification note that the tone is not modulated directly by the signal but is modulated indirectly thereby in an inverse sense, as will appear hereinafter. The tone and the signal modulate the carrier in F, and after the desired amplification in amplifiers also in F the modulated carrier is transmitted. A small amount of the output is bled off by the lead including resistor 21 and rectified in 23.

The rectified current is fed from the rectifier in 23 through a time constant network 25 that operates rapidly with respect to the modulation frequencies but slowly with respect to the 10 kc. tone carrier. The output of the network in 25 controls the gain of the amplifier in 11 in a well known manner and the control is in accordance

with signals. This results in modulating the tone in the amplifier 11 in accordance with the signals and in such a sense as to keep the radio frequency power in the antenna substantially constant. That is, this power is constant as far as the modulation frequencies are concerned. Thus, we again have in the output of the transmitter at F currents which are represented graphically as in Fig. 1a. Here, as in Fig. 2, the source 10, amplifier 11, transmitter F, rectifier 23 and time constant network are so well known in the art that detailed disclosure is believed unnecessary.

It is obvious that a requirement of a receiver is that it selects all of the radiated energy and uses the same to control the quick automatic gain control action. Then one or more of the carriers are selected out and the signal derived.

Numerous receivers which take advantage of features of the transmission from my novel system, as described above, have been devised. Three preferred modifications will now be described.

In Fig. 3 the transmitted carrier is picked up on the aerial 29 and fed to a radio frequency amplifier 30, wherein it is amplified and fed to a mixer for heterodyning against oscillations from a source 31. The intermediate frequency is selected from 30 and fed to an intermediate frequency amplifier 32 which has a band pass sufficiently wide to pass the radiated carrier the side tone frequencies and the modulation side bands on the carrier and side tones. For example, 30 kilocycles are passed by the intermediate frequency amplifier in 32. 32 also includes a mixer tube wherein the intermediate frequency energy is heterodyned with oscillations from a source in 33 and the resultant energy is impressed on an automatic volume control system 36 and on three filters 38, 39 and 40 arranged to pass modulation corresponding to the side bands on the upper side tone B1, the side bands on the carrier A and the side bands on the lower tone B.

The intermediate frequency out of the 30 kilocycles IF amplifier and mixer in 32 is fed to the automatic volume control system in 36 wherein it is rectified and used to control the gain of the amplifiers or an amplifier in unit 30 and in unit 32. These amplifiers in 30 may be operating at intermediate frequency or at radio frequency. The time constant of this automatic control is equivalent to a frequency greater than 5000 cycles and less than 10,000 cycles. It is assumed here the modulation has an upper frequency of the order of 5000 cycles per second. These values as stated above are given by way of example and it will be understood that other values may be used depending upon characteristics of the signals.

The output of the amplifier in 32 is also fed to the three band pass amplifiers 38, 39 and 40. In the system illustrated the band pass width of the filters in 38, 39 and 40 is 10 kilocycles. Filter 38 passes say the 10 kilocycle side band B1 of Fig. 1a, with its modulation side bands. Filter 39 passes the main carrier A and its modulation side bands. Filter 40 passes the 10 kilocycle side band B and its modulation side bands. The three amplifiers 38, 39 and 40 include detectors. The output of the detectors in 38 and 40 are connected in parallel and pass to one grid and the cathodes of a pushpull amplifier in 46. The output of the detector in filter 39 passes to the other grid and the cathodes of the pushpull amplifier in 46. The output of this amplifier feeds the loudspeaker or other devices. The pushpull amplifier is used to combine the two modulations that are 180° out

of phase. Note as described above, side bands carriers B and B1 and their side bands are in phase with each other, but are opposed to main carrier A and its side bands.

Since, as stated above, the received modulated carrier peaks reach the same value irrespective of the extent of modulation (the modulation depth varies) the fast automatic volume control 36 etc., may be adjusted to prevent a rise in the output volume which exceeds that intensity which represents full modulation. Thus my means does not suppress the modulation but does suppress static and noise of a frequency higher than the highest modulation frequency. In other words, my control means presents to the detector in the receiver a definite adjustable voltage either signal or noise or static or a combination of the same. Of course the time constant of this automatic volume control should be such that it does not suppress potentials of the frequency of the modulated tone used at the transmitter being in the example given 10,000 cycles.

The arrangement of Fig. 4 makes use of frequency diversity. In this arrangement there are present at the output of the intermediate frequency amplifier 32 three frequencies 10 kilocycles apart as was seen in the description of Fig. 3. Each of these frequencies are modulated. In addition to the high speed automatic volume control 36 shown and described in Fig. 3, there is added in Fig. 4 additional detector tubes 50, 52 and 54 coupled to the outputs of the filters 38, 39 and 40. These additional detector tubes detect the outputs of the detectors and filters of 38, 39 and 40, and provide selective volume control potential in the resistor 60. That is, the plates of these tubes 50, 52 and 54 are all fed from a common source 56 through the resistor 60 and the voltage drop across the resistor 60 is used by way of lead 62 to supply bias to one or more tubes in the filters, amplifiers and detectors in units 38, 39 and 40. This bias varies the gain of the intermediate frequency amplifiers in these filters simultaneously. Therefore, if any one of the three signals is appreciably stronger than the other two signals, it will be used for control purposes, while the other two amplifiers will have their gain reduced to suppress the output thereof. This operation per se, it is believed, is well known, having been described and claimed in John B. Moore, U. S. Patent No. 1,849,632, dated March 15, 1932. This volume control arrangement including tubes 50, 52, 54, source 56 and resistance 60, necessarily has a sufficiently long time constant to prevent modulation frequency distortion.

In a modification illustrated in Fig. 5, a plurality of receivers 65, 67 and 69, similar to the one shown in Fig. 3 are used. By spacing the aerials of these receivers space diversity is obtained. Here each 30 kilocycle band pass amplifier 32, 32' and 32'' has part of its output passed through a separate automatic volume control detector tube in unit 36'. The plates of these detector volume control tubes are connected in a manner similar to the manner in which the plates of the detector tubes 50, 52 and 54 are connected in Fig. 4 to control the gain of the amplifiers in 32, 32' and 32''. The arrangement is such that the output of the amplifier wherein the strongest signal is received takes control primarily as described in the above identified patent. However, the time constant of the volume control in this system is made fast as in Fig. 3, to suppress static and other noises of the same character and frequency. The outputs of the 30 kilocycle band pass amplifiers and hetero-

dynes in 32, 32' and 32'' are fed to second intermediate amplifiers 70, 72 and 74, and thence to individual pushpull amplifiers 80, 82 and 84, and from the said amplifiers to a combining unit in 86 from which the combined and amplified modulation is derived. Each of the second intermediate frequency amplifiers 70, 72 and 74 include three band pass filters similar to filters 38, 39 and 40 of Figs. 3 and 4 which pass the bands B1, A and B. These filters and second intermediate frequency amplifiers also include detectors. Moreover, the outputs of the several band pass filters and detectors in each unit 70, 72 and 74 are combined in pushpull in amplifiers 80, 82 and 84 in the manner shown and described in connection with Fig. 1. That is, each unit 70 has a filter and detector for the side band carrier B and its side bands: the carrier A and its side bands, and the side band carrier B1 and its side bands. Moreover, the detected outputs of the detectors for B and B1 are combined in phase and the combined outputs combined with the detector for A in pushpull relation. The outputs of the pushpull amplifiers 80, 82 and 84 are combined.

In Fig. 4 the modulation output is derived in the same manner as in Fig. 3. That is, the outputs of the detectors in the filters passing current characteristic of B and B1 and their side bands are added in parallel and this energy and the output of the detector in the filter passing the current characteristic of the carrier A and its side frequencies are applied in pushpull to the pushpull amplifier in 46. In Fig. 4, the rectifiers 50 provide automatic gain control with diversity effect. In Fig. 5 the circuits in unit 70 and unit 80 include three filters and detectors such as 38, 39 and 40 of Fig. 3, and a pushpull amplifier as in 46 of Fig. 3. The same remarks apply to units 72 and 82, and units 74 and 84 of Fig. 3.

I claim:

1. The method of signalling with signal currents and carrier currents, and oscillations of superaudible frequency which includes these steps, modulating the oscillations in accordance with the signal currents, and modulating the carrier currents in accordance with the signal currents and signal modulated oscillations with the signal modulations and the modulations on the oscillations opposed to provide a modulated carrier the total power of which is substantially constant during operation.

2. The method of signalling which includes these steps, generating oscillations of carrier wave frequency, generating other oscillations of carrier wave frequency, deriving currents characteristic of signals, modulating said first oscillations in accordance with said currents, modulating said first oscillations in accordance with said other oscillations and modulating said other oscillations in accordance with said currents and in a sense such that the modulations on the other oscillations oppose the first mentioned modulations on said first oscillations.

3. The method of signalling with oscillations of carrier wave frequency and oscillations of superaudible frequency which includes these steps, modulating said oscillations of superaudible frequency in accordance with said signals, modulating said oscillations of carrier frequency by said signals and by said modulated oscillations of superaudible frequency while maintaining the modulation envelopes in opposed relation on said carrier.

4. The method of signalling which includes these steps, generating oscillations of carrier wave

frequency, generating oscillations of lower frequency, generating signal currents, modulating said oscillations of carrier wave frequency in accordance with said oscillations of lower frequency and in accordance with said signalling currents, and modulating said oscillations of lower frequency in accordance with said signalling currents and in a sense such that the signal modulations on the carrier wave are of opposed phase.

5. In a signalling system the method of signalling which includes these steps, generating oscillations, modulating said oscillations in accordance with signals, combining the modulated oscillations with the signals with the modulation envelope of the oscillations in opposed relation with respect to the signals during the combination and modulating carrier wave energy in accordance with the combined energy to derive modulation energy comprising the carrier and upper and lower side bands corresponding to the generated oscillations with the carrier and the side bands each having as side frequencies the signal frequencies.

6. The method of signalling which includes these steps, generating oscillations of carrier wave frequency, generating oscillations of lower frequency, generating signalling currents, modulating said oscillations of carrier wave frequency in accordance with said oscillations of lower frequency and in accordance with said signalling currents, rectifying the resulting modulated carrier, and controlling the amplitude of the oscillations of lower frequency used to modulate said oscillations of carrier wave frequency in accordance with rectified output components of a frequency below the highest signal current frequency.

7. The method of demodulating wave energy modulated as recited in claim 1 which includes these steps, amplifying wave energy characteristic of the said carrier and its two side frequencies with the signal modulations on each thereof, rectifying said energy, deriving from said rectified energy potentials of the frequency higher than the highest signal frequency, controlling the amplification of said modulated wave energy in accordance with said derived potentials, and demodulating said energy the amplification of which is controlled to derive therefrom the signal modulations.

8. The method of demodulating wave energy modulated as recited in claim 1 which includes these steps, amplifying wave energy characteristic of said carrier and its two side frequencies with the signal modulations on each thereof, rectifying said energy, deriving from the rectified energy potentials which recur at a rate above the highest signal current frequency and below the frequency of said other oscillations, controlling the amplification of said modulated wave energy in accordance with said derived potentials, and demodulating said modulated energy the amplification of which is controlled to derive therefrom the signal modulations.

9. The method of demodulating wave energy modulated as recited in claim 1 which includes these steps, amplifying wave energy characteristic of the said carrier and its two side frequencies with the signal modulations on each thereof, rectifying said energy to derive a potential to control at a rapid rate the amplification of said energy, demodulating said energy the amplification of which is controlled to derive therefrom the signal modulations on said carrier and its two side frequencies, combining the signal modula-

tions derived from the side frequencies and combining this resulting energy with the signal modulations derived from the said carrier differentially.

10. The signalling method including these steps, generating oscillations of carrier wave frequency, generating oscillations of sub-carrier frequency, modulating said first carrier in accordance with signals and in accordance with said sub-carrier oscillations, modulating said sub-carrier in accordance with signals, and in a sense such that the modulation envelope on the sub-carrier modulations on said first carrier oppose the modulation envelope of the signal on said first carrier, sending the modulation energy to a receiver, at the receiver, amplifying the received energy, deriving from the amplified energy potentials which depend upon the amplitude thereof, controlling the amplification of the modulation received energy in accordance with the derived potentials, and deriving from the received and amplified energy the modulations thereon.

11. The signalling method including these steps, generating oscillations of carrier wave frequency, generating oscillations of sub-carrier frequency, modulating said first carrier in accordance with signals and in accordance with said sub-carrier oscillations, modulating said sub-carrier oscillations in a sense such as to produce an output comprising as a main carrier said first carrier and as upper and lower side carriers the sum and difference of said first carrier and sub-carrier with modulation on each carrier, sending the modulation energy to a receiver, at the receiver amplifying the modulation energy, deriving from the amplified energy potentials which depend upon the amplitude thereof, controlling the amplification of the modulation energy in accordance with the derived potentials, and deriving from the amplified energy the signal modulations.

12. The signalling method including these steps, generating a sub-carrier, modulating said sub-carrier in accordance with signals, adding the modulated sub-carrier to the signals with the sub-carrier modulation envelope and the signal in opposed relation, modulating oscillations of carrier frequency with the resultant energy, sending the modulated energy to a receiver, at the receiver amplifying the modulated energy, heterodyning the amplified modulated energy to a lower frequency, deriving from the heterodyned energy potentials which depend upon the amplitude thereof, utilizing said potentials to control the amplification of the modulated energy, deriving from said heterodyning process modulation corresponding to that impressed on the carrier and on the sub-carrier considered as side bands of the said carrier, combining the modulation corresponding to the modulation on the said side bands and differentially combining the said combined energy with the modulation corresponding to the modulation on said carrier.

13. In a signalling system a source of oscillations of carrier wave frequency, a source of oscillations of lesser frequency, a source of signals, means for modulating oscillations from said source of oscillations of lesser frequency in accordance with signals from said source of signals, and means for modulating oscillations from said source of oscillations of carrier wave frequency in accordance with the signals and the modulated oscillations of lesser frequency and an output coupled to said last named means.

14. In a signalling system a source of oscilla-

tions of carrier wave frequency, a source of oscillations of lesser frequency, a source of signals, means for modulating oscillations from said source of oscillations of carrier wave frequency in accordance with signals and in accordance with oscillations from said source of lesser frequency, and means for controlling the amplitude of the oscillations of lesser frequency in accordance with the signal modulations on said oscillations of carrier frequency.

15. In a signalling system a wave energy pickup means, a radio frequency amplifier and a detector and a source of local oscillations coupled thereto, a band pass filter, a detector and a source of local oscillations coupled to said first named detector, an automatic gain control circuit having a small time constant and including a rectifier with its input coupled to said second mentioned detector and its output coupled to amplifiers in said first mentioned stages, three filters having their inputs coupled to said second detector, a detector for each filter, a pushpull amplifier and connections for impressing the output of two of said last mentioned detectors and the output of the remaining one of said last mentioned detectors in pushpull relation on said pushpull amplifier.

16. A system as recited in claim 15, including a rectifier coupled to each of said three detectors, an impedance in series with all of said rectifiers and connections from said impedance to stages in said filters to control the gain thereof.

17. In a signalling system a plurality of wave energy pickup means, a detector and a source of local oscillations coupled to each of said pickup means, a band pass filter, a separate wave amplifier, a second detector and a source of local oscillations coupled to each of said first named detectors, an automatic gain control circuit coupled to each of said second detectors, each of said gain control circuits having a small time constant and including a rectifier with its input coupled to a different one of said second mentioned detectors and its output coupled to said amplifiers, three filters coupled to each of said second detectors, a pushpull amplifier for each group of filters and connections for impressing the output of two of said filters of each group and the output of the remaining filter of each group in pushpull relation on a different one of said pushpull amplifiers.

DE WITT R. GODDARD.