

June 2, 1942.

R. M. MORRIS

2,285,044

WAVE LENGTH MODULATION SYSTEM.

Filed March 11, 1941

2 Sheets-Sheet 1

Fig. 1a

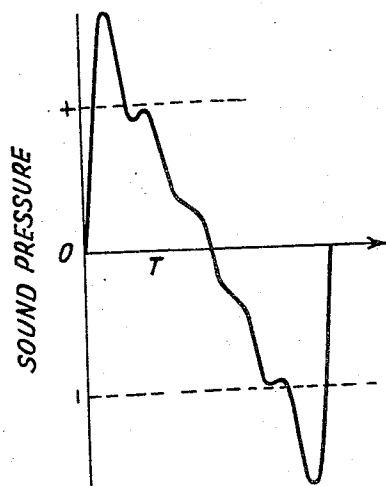


Fig. 1b

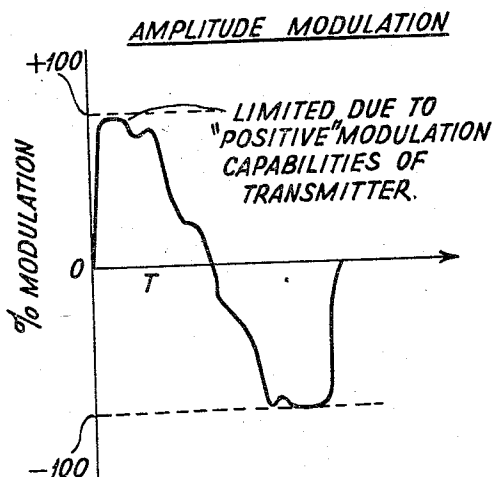


Fig. 1c

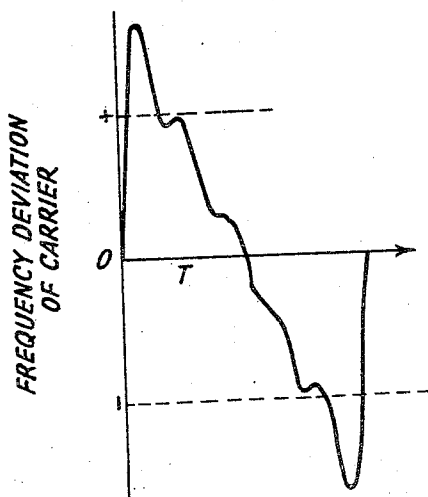
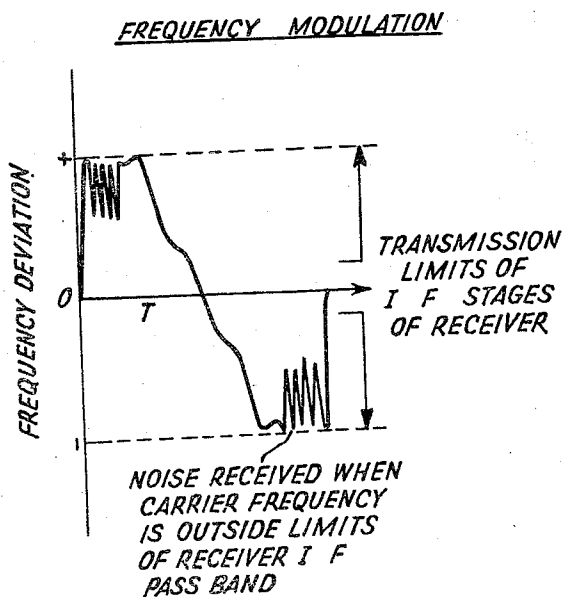


Fig. 1d



INVENTOR
ROBERT M. MORRIS
BY *H. H. Moore*
ATTORNEY

June 2, 1942.

R. M. MORRIS

2,285,044

WAVE LENGTH MODULATION SYSTEM

Filed March 11, 1941

2 Sheets-Sheet 2

Fig. 2

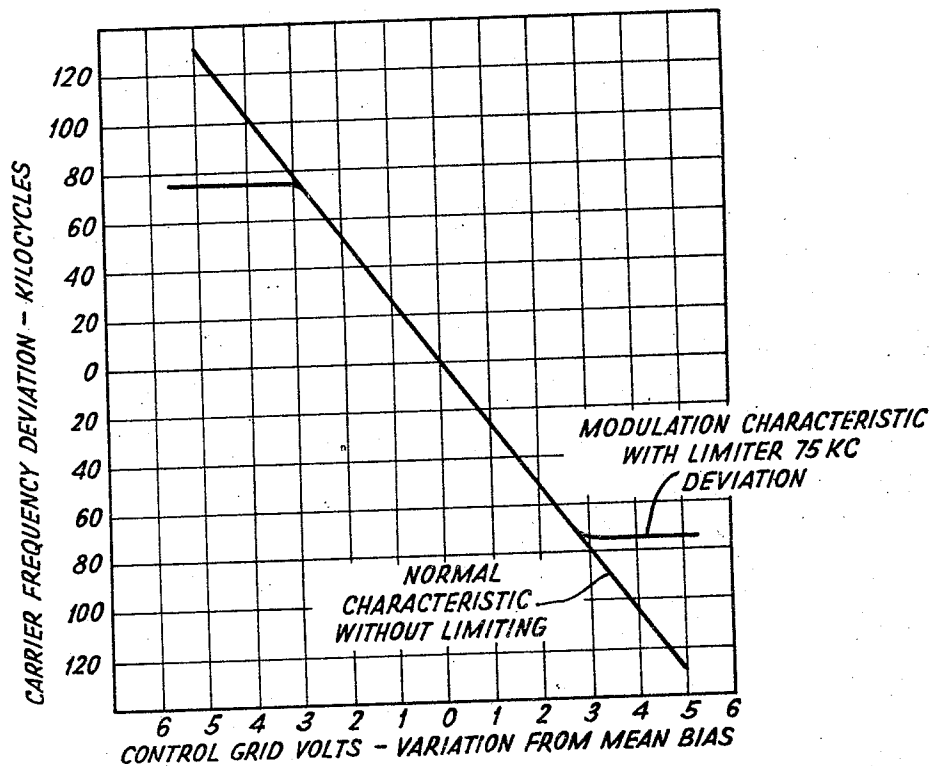
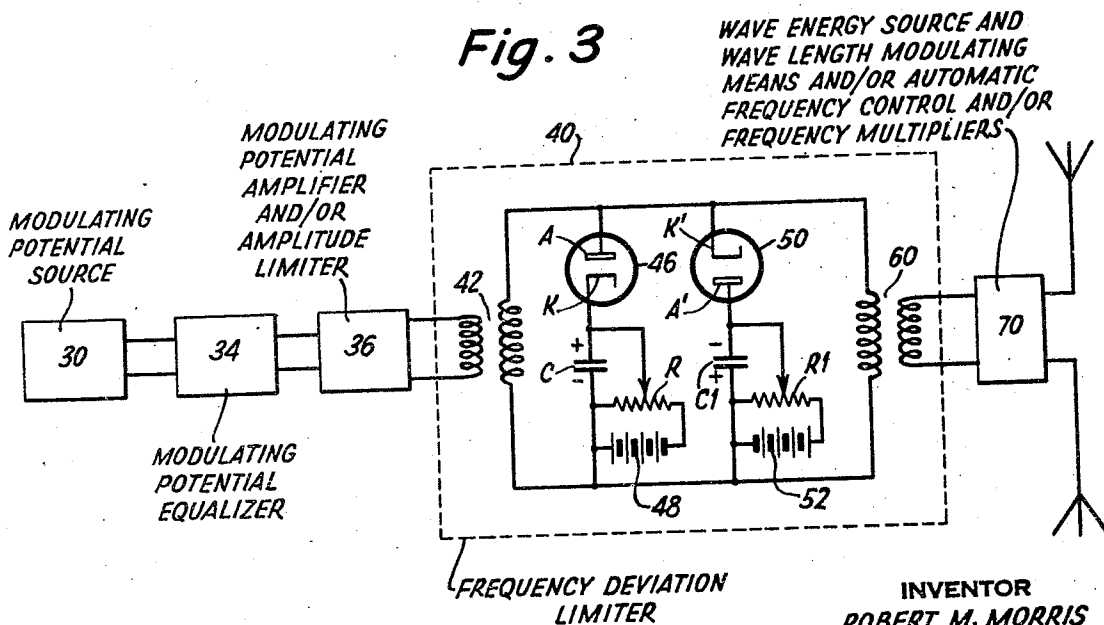


Fig. 3



INVENTOR
ROBERT M. MORRIS
BY *H. S. Brown*
ATTORNEY

UNITED STATES PATENT OFFICE

2,285,044

WAVE LENGTH MODULATION SYSTEM

Robert M. Morris, Millburn, N. J., assignor to
Radio Corporation of America, a corporation
of Delaware

Application March 11, 1941, Serial No. 382,716

19 Claims. (Cl. 179—171.5)

This application involves a new and improved method of and means for modulating the wave length of wave energy and has for an object an improved modulating means which provides increased efficiency at the transmitter without reduction of the quality of the signal at the receiver. In particular, my method and means involves the use of a novel instantaneous peak limiter in the modulator which operates on both halves of the modulation cycle to limit wave length deviations to an extent such that over-modulation which produces discernible distortion at the receiver is prevented. Over-modulation per se does not necessarily result in distortion at the receiver which is discernible to the listener, and I do not try to prevent such modulation. However, I do prevent carrier excursions which go outside the band of the receiver intermediate frequency amplifier and are then replaced by a rush of noise components which reach the listener.

In describing my invention reference will be made to the attached drawings wherein:

Figure 1a is a graph showing the form of a sound wave as it arrives at an amplitude modulation transmitter for modulation purposes from a microphone amplifier system output.

Figure 1b is a graph of the same wave form at a receiver after it has been transmitted through an amplitude modulated transmitter with the gain thereof raised to a point which, in the art, is considered normal. Note the maximum peaks are cut off by the limit of 100% modulation in the negative direction and by the modulation capabilities of the transmitter in the positive direction.

Figure 1c is a graph showing as an example the deviations or excursions of a carrier wave modulated through plus and minus 75 kc. with plus and minus 100% modulation or deviation marked on the graph. Note that the excursions extend beyond plus and minus 100% modulation.

Figure 1d shows graphically the resultant wave from the output of a frequency modulation receiver having an intermediate-frequency band-pass of 150 kc. Note that due to the excursions of the carrier outside the band, noise components appear at these points and these noise components appear in the output of the receiver.

Figure 2 is a graph illustrating by means of the straight line the characteristic of a frequency modulator used by me in the absence of the improved method and means of limiting of this application. The curved graph illustrates the

modulation characteristics, that is, the frequency deviations of the carrier in my system when the improved limiting means of this disclosure is incorporated therein.

Figure 3 illustrates a wave length modulation system incorporating my novel method and means for limiting the carrier deviations to the extent necessary to prevent distortion such as shown in Figure 1d of the drawings.

It has for some time been the practice in broadcast transmission to so adjust the modulation level that program peaks, as read on a volume indicator, reach a maximum value approximately 6-8 db. lower than the value of sine wave which produces 100% modulation. This has been found by experience to give the optimum compromise between signal to noise ratio and distortion. With this condition occasional peaks of modulation exceed 100% modulation or the linear portion of the modulation characteristic. In the case of amplitude modulation and reception this causes nothing more than wave form distortion of a nature which in general is not perceived by the ear. This form of distortion is illustrated in Figure 1b of the drawings.

With the advent of frequency modulated broadcast transmission the same practice has usually been followed at the broadcast station. However, in the case of frequency modulation reception when peaks exceed the portion of the modulation characteristic, for which the receiver is linear, a different effect than that in amplitude modulation takes place. Instead of the modulated wave merely being flattened off in the region where it exceeds the limit of linearity there is a high level of noise introduced during the period of time that the carrier has deviated beyond the band width of the intermediate frequency stages of the receiver. This noise effect creates to the ear the effect of distortion of a much higher magnitude, so that while the ear will not detect short periods of non-linear distortion it will respond to otherwise negligible periods of over-modulation which are filled with high amplitude noise. This effect is shown in Figure 1d.

In certain frequency modulation systems known today, the modulator per se provides but a small amount of carrier deviation and considerable frequency multiplication is resorted to to obtain the desired final deviation for transmission. In such systems where an effort is necessarily made to obtain sufficient carrier deviation the chance of carrier deviation beyond the assigned channel is not likely to be encountered in

general but often occurs because of the use of a large number of multipliers. Such systems, however, have disadvantages in that they are complicated, and require a large amount of additional apparatus in the form of frequency multipliers, etc.

Other frequency modulation systems such as, for example, systems of the nature of that disclosed by Crosby in his United States application Serial No. 136,578, filed April 13, 1937, now Patent No. 2,279,659, dated April 14, 1942, are true frequency modulations and readily provide more carrier deviation than can be used even in the wide channel (150 kc.) transmissions with which my invention is concerned.

In any case, however, when carrier deviations go beyond the channel assigned, they fall outside of the receiver intermediate frequency pass or transmission characteristic. Reception of these peaks which exceed the portion of the modulation characteristic, for which the receiver is linear, results in a different effect than that which takes place in the presence of over-modulation in amplitude modulation systems. Instead of the modulated wave being merely flattened out for the region where it exceeds the limit of linearity, there is a high level of noise introduced during the period of time that the carrier has deviated beyond the band width of the intermediate frequency stages or transmission characteristic of the receiver. When the carrier exceeds the permitted band, that is, swings out of the band-pass characteristics of the receiver, noise takes the place of the signal and there is a rush of noise at this instant, as indicated in Figure 1d of the drawings. This noise creates to the ear the effect of distortion of a much higher order of magnitude, so that while the ear will not detect short periods of non-linear distortion, it will respond to otherwise negligible periods of over-modulation which are filled with high amplitude noise.

I propose to prevent this discernible noise from reaching the listener, yet in doing so I do not propose to correct all distortion in the transmitted wave because certain kinds of distortion are not discernible to the listener and reduction thereof lowers the percentage modulation without providing noticeable improvement to the listener.

In the systems known heretofore, limiting has been used. However, such limiting as has been used in transmitters in the prior art is not instantaneous limiting. Although the limiting reduces peaks or short excursions of the carrier beyond the acceptance band of the receiver, this limiting does not take place instantaneously and considerable noise results during the time between the inception of the peak and the time at which the limiting takes effect.

In my system I use a wave length modulator of an improved type wherein a wide deviation of the carrier is easily obtained so that the desired deviation (no matter how great) is obtained readily. In my system I use a novel limiter in the modulation system of the wave length transmitter to effectively limit the deviation of the carrier to the value considered to be the standard maximum deviation for the receivers or for the system in use. For example, this deviation may be plus and minus 75 kc. or more or less. This limit must, of course, be for both positive and negative excursions or frequency deviation, and instantaneous in action to thereby prevent the occurrence of noise of the nature indicated in

Figure 1d and preferably a means is provided for separately adjusting the effect of the limiter at both ends of the carrier swing, that is for excursions of the carrier above and below the normal mean frequency thereof. My wave length modulator may have the characteristic indicated by the straight line 20 or graph in Figure 2 of the drawings. Note that the carrier may be swung in a linear manner plus and minus 120 kc. However, I have assumed that the receiver intermediate frequency band will accept only about plus and minus 75 kc. deviation and my improved limiter limits the carrier deviations of the wave length modulator as indicated by the curved line or graph in Figure 2 of the drawings.

In practice, the wave length modulator, the characteristic of which is indicated by the straight graph in Figure 2, may be of the type disclosed by Crosby in his United States application Serial No. 136,578, filed April 13, 1937. The curved line of Figure 2 of the drawings indicates the characteristic of the said Crosby transmitter when my method and means of limiting the carrier deviation is applied thereto.

Obviously many limiters may be devised for limiting the peaks of the modulation potentials on both halves of the swing. In Figure 3, I have shown a wave length modulated transmitter including the improvements of my invention. In Figure 3, signals from any source 30 such as, for example, a microphone and its amplifiers with an output as indicated in Figure 1a of the drawings supplies amplified modulating potentials to an equalizer 34, if desired, wherein the modulating potentials are modified as to relative amplitude to obtain the desired transmission characteristic. For example, this equalizer may have a rising characteristic; that is an output wherein the amplitude of the modulating potentials increases as the frequency thereof increases throughout the entire band or for a portion of the band. The output of the equalizer is supplied to an amplifier and/or amplitude limiter 36 of any approved known type such as, for example, an overloaded tube, or a tube subjected to gain control voltages, etc.

This amplifier 36 then supplies the equalized, amplified and/or limited modulating potentials to a unit 40 wherein both halves of the modulating wave are operated on. This limiter 40 comprises a reactor 42 on which the modulating potentials are impressed with a pair of tubes 46 and 50 in shunt thereto. The electron discharge tube 46 has its electrodes A and K in series with a condenser C across the alternating-current circuit, including impedance 42. The electron discharge tube cathode K is connected to a point on a resistance R in shunt to a source 48 so that the biasing potential thereof may be individually adjusted as desired. The electron discharge device 50 has its electrodes K', A' reversed with respect to those of electron discharge tube 46 and like tube 46 is connected with the condenser C so that the condenser and the impedance of tube 50 are in series across the alternating-current circuit including impedance 42. Electron discharge tube 50 also has an individual adjustable bias source comprising a resistance R1 and a source 52.

The output of this limiter is supplied by any means such as, for example, a transformer 60 to the wave length modulator 70 which, as stated above, may be of the Crosby type.

The unilateral device 46 does not pass current until the applied modulating potential voltage

exceeds the bias applied by source 48 and resistance R across condenser C. In a like manner, the unilateral device 50 does not pass current until the modulating potential voltage (say negative swings) exceeds the potential applied by resistance R2 and source 52 across condenser C1. However, when the positive swings exceed the charge across condenser C, the tube 46 passes current and reduces the peak swings. In a similar manner, when the negative modulation voltages exceed the potential across condenser C1, the tube 50 passes current to thereby reduce the negative peaks. These actions are instantaneous and this is an important feature of my invention.

In the limiters in use in the wave length modulation systems today, such as, for example, the limiter in 36, the limiting action is not instantaneous. For example, there may be a lag of .002 of a second between the inception of the peak and the time when the limiting action takes hold to lower the gain of the whole system. Conversely, the gain of the whole system remains lowered for some time after the peak has passed, that is, does not snap back instantaneously. Such limiters must be distinguished from my system wherein the action is instantaneous.

What I claim is:

1. The method of wave length modulation of carrier wave energy which includes the steps of, modulating the wave length of said carrier in accordance with modulating potentials and instantaneously limiting the peak values of said modulating potentials on at least one half cycle thereof to thereby limit the extent of said wave length modulation.

2. The method of wave length modulation of a carrier through a given frequency spectrum in accordance with modulation potentials which includes the steps of, modulating said carrier in accordance with said modulating potentials, and limiting the peak values of both halves of said modulating potentials to a value at which said carrier is not deviated beyond said given channel an amount sufficient to cause discernible distortion.

3. The method of wave length modulation of a carrier through a given frequency spectrum which includes the steps of, modulating said carrier in accordance with said modulating potentials, modifying the relative amplitudes of said modulating potentials to improve the signal to noise ratio of the transmitted energy and limiting the peak values of said modulating potentials on at least one half cycle thereof to a value at which said carrier is not deviated beyond said given channel at one side an amount sufficient to cause discernible distortion.

4. The method of wave length modulation of a carrier through a given frequency spectrum which includes the steps of, modulating said carrier in accordance with said modulating potentials and instantaneously limiting the peak values of both halves of said modulating potentials to a value at which said carrier is not deviated beyond said given channel an amount sufficient to cause discernible distortion.

5. The method of generating wave length modulated wave energy which includes the steps of, producing modulating potentials, producing carrier wave energy, limiting said modulating potentials on both halves of the cycle thereof, and modulating said carrier wave length in accordance with the resulting modulating potentials.

6. The method of generating wave length mod-

ulated wave energy which includes the steps of, producing modulating potentials, relatively modifying the amplitudes thereof to improve the signal to noise ratio of the received modulated wave, limiting said modulating potentials on both halves of the cycle thereof, producing carrier wave energy, and modulating the carrier wave length in accordance with the resulting modulating potentials.

7. The method of generating wave length modulated wave energy which includes the steps of, producing modulating potentials, the relative amplitudes of which are modified to improve the signal to noise ratio of the wave energy at the receiver, limiting said modulating potentials on both halves of the cycle thereof, producing carrier wave energy, and modulating said carrier wave length in accordance with the resulting modulating potentials.

8. In a wave length modulation system, a source of wave energy to be modulated, a source of modulating potentials, and an instantaneous limiter coupling said last named source to said first named source for modulating the wave length of the wave energy a limited amount in accordance with the modulating potentials.

9. In a wave length modulation system, a source of wave energy to be modulated, a source of modulating potentials, and an instantaneous full wave limiter coupling said last named source to said first named source for modulating the wave length of the wave energy a limited amount in accordance with the modulating potentials.

10. In a wave length modulation system, a source of wave energy the wave length of which is to be modulated, a source of modulating potentials, an amplitude limiter and an instantaneous full wave amplitude limiter in cascade coupling said last named source to said first named source for modulating the wave length of the wave energy a limited amount in accordance with the modulating potentials.

11. In a wave length modulation system, a source of wave energy to be modulated, a source of modulating potentials, and means coupling said source of modulating potentials to said source of wave energy to be modulated, said last named means comprising wave amplitude equalizing means, wave amplitude limiting means and instantaneous wave amplitude limiting means.

12. In a frequency modulation system, a source of wave energy to be modulated, a source of modulating potentials, a circuit coupling said source of modulating potentials to said source of carrier wave energy, and means in said circuit for limiting peak voltages of the modulating potentials on both halves of their cycle.

13. In a wave length modulation system, a source of wave energy to be modulated, a source of modulating potentials, a wave limiter coupled to said source of modulating potentials, a wave limiter comprising means for limiting negative and positive peaks of said modulating potentials coupled with said last named limiter, and means coupling said second named wave limiter to said source of carrier energy.

14. In a wave relaying system in combination, a wave amplitude limiter and an instantaneous full wave amplitude limiter in cascade, and means for impressing wave energy on said cascaded combination and deriving limited wave energy therefrom.

15. In a wave relaying system in combination, a wave energy wave forming means, a wave amplitude limiter, and an instantaneous full wave

amplitude limiter in cascade, and means for impressing wave energy on said cascaded combination and deriving wave energy therefrom.

16. In means for modifying the wave form of modulating potentials, an input impedance, an output impedance, a first unilateral device conductive in one direction and a condenser in series connected in shunt to said input impedance, a second unilateral device conductive in the opposite direction and a condenser in series connected in shunt to said input impedance, and means for impressing modulating potentials on said input impedance and from said input impedance to said output impedance.

17. In means for modifying the wave form of modulating potentials, an input impedance, an output impedance, an electron discharge tube impedance and a condenser in series in shunt to said input impedance, said tube impedance being conductive in one direction, a variable source of potential in shunt to said condenser, a second electron discharge tube impedance and a second condenser in series in shunt to said input impedance, said second discharge tube being conductive in the other direction, a variable source of potential connected in shunt to said second condenser, and means for impressing said modulating potentials on said first impedance and from said first impedance to said output impedance.

18. In a wave length modulation system, a source of wave energy to be modulated, a source

of modulating potentials coupled to said source of wave energy to modulate the wave length of the wave energy in accordance with the modulating potentials and means in said coupling for limiting the amount of said wave length modulation including a limiting amplifier having input electrodes coupled to said source of modulating potentials said limiting amplifier having output electrodes and an instantaneous full wave amplitude limiter including a circuit having an input coupled to the output electrodes of said amplifier and having an output coupled to said source of wave energy with two unilateral devices conductive in opposite directions connected across said circuit.

19. In a wave length modulation system, a source of wave energy to be modulated, a source of modulating potentials coupled to said source of wave energy to modulate the wave length of the wave energy in accordance with the modulating potentials, transmitting means coupled to said source of wave energy and means for improving the signal to noise ratio of the transmitted wave length modulated wave and limiting said modulation including a modulation potential equalizer wherein the modulating potential is caused to increase with increase of modulating potential frequency and a modulating potential amplitude limiter in the coupling between said source of modulating potentials and said source of wave energy.

ROBERT M. MORRIS.