

April 7, 1931.

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1,799,795

SOUND RECORDING AND REPRODUCING

Filed May 5, 1928

2 Sheets-Sheet 1

FIG. 1.

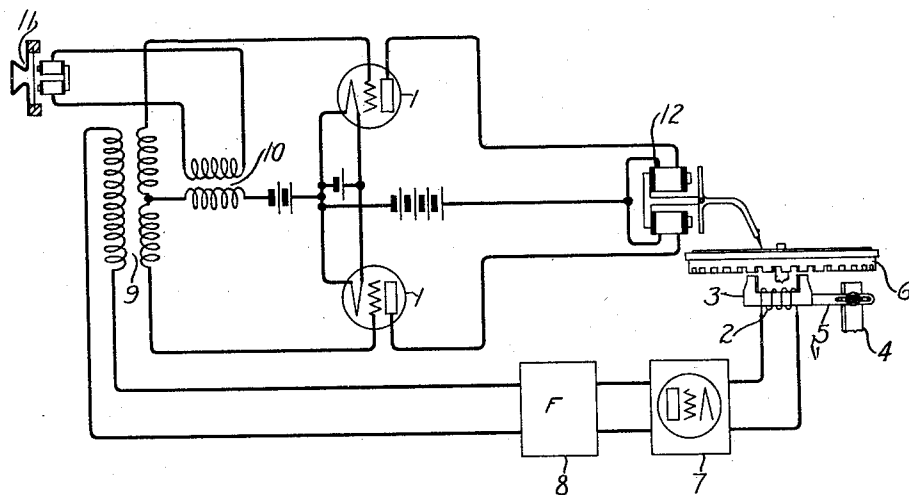
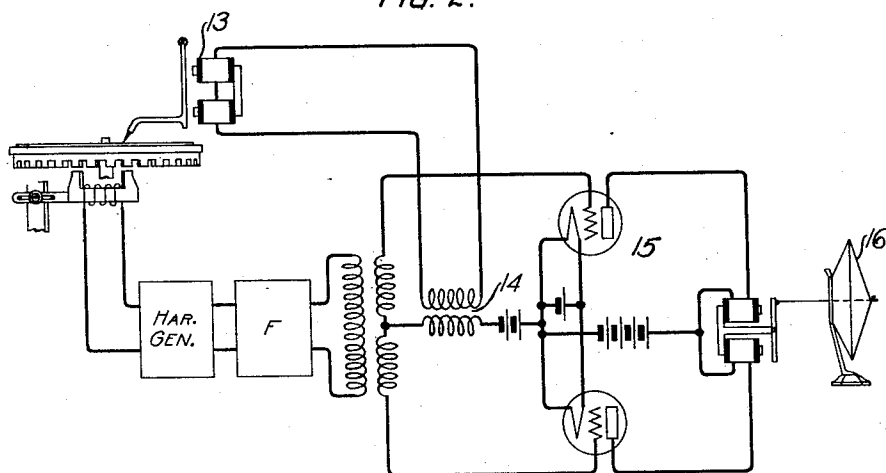


FIG. 2.



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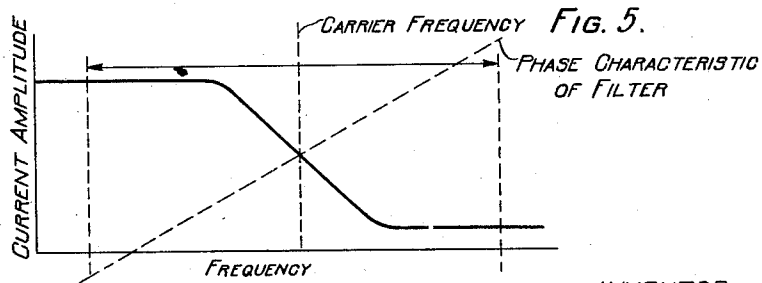
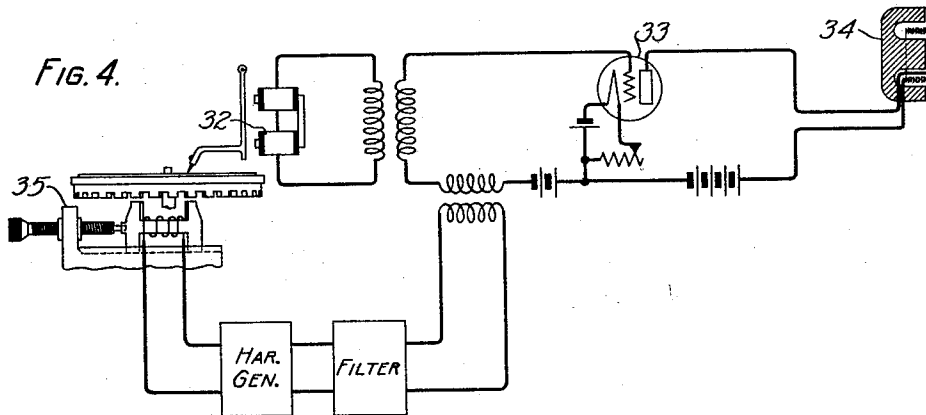
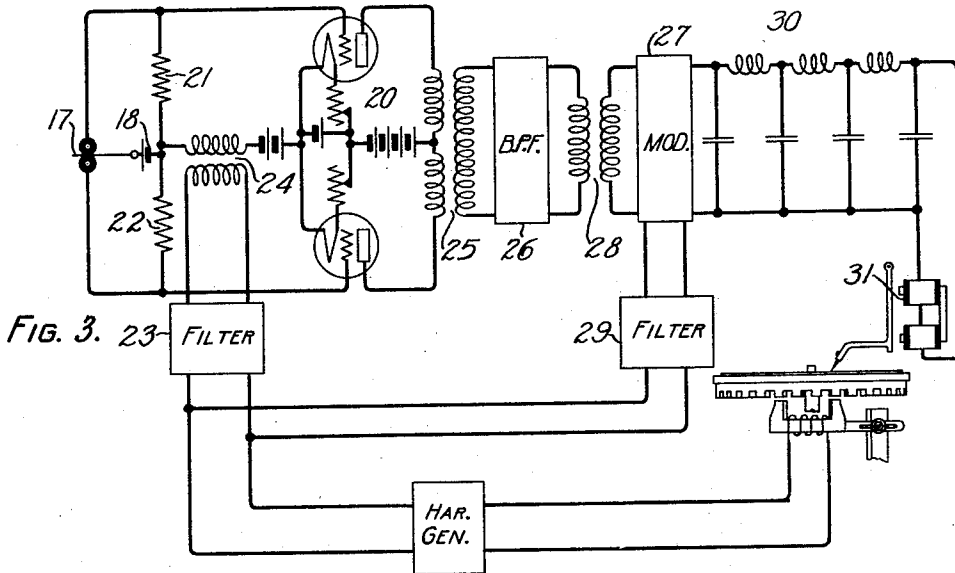
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2 Sheets-Sheet 2



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SOUND RECORDING AND REPRODUCING

Application filed May 5, 1928. Serial No. 275,409.

This invention relates to sound recording and reproducing systems and has particular reference to such systems wherein the sound waves are modulated before recording.

5 In U. S. Patent 1,603,287 to Mills, October 19, 1926, there is disclosed a recording and reproducing system wherein speech to be recorded is used to modulate a carrier. Only the lower side band is recorded so that in the
10 resulting record the frequency order is inverted and the whole frequency band may be displaced by an amount depending upon the frequency of the carrier employed. Such a record is of course unintelligible when re-
15 produced in the ordinary way but when the same carrier frequency is supplied in the reproducing circuit the original speech frequencies may be reproduced in proper order as described. The system proposed by Mills
20 is intended to be used as a method of making secret records.

The object of the present invention is to adapt such a system to the production of high quality records.

25 In accordance with the general features of the invention, the band of frequencies representing the sound to be recorded is displaced as well as inverted on the frequency scale in such a way that the percentage interval between the upper and lower limits is reduced so that the recording and reproducing mechanisms may be made more uniformly responsive to the frequencies involved. Elec-
30 tromagnetic means associated with the recording and reproducing turntables generate carriers which vary in frequency with the speed of the turntable so that any speed variation will shift the phase of the wave components in proportion to their frequency
40 as in the ordinary phonograph. For special purposes an alternative system employing a balanced pick-up device and double modulation permits the recording of all frequencies down to zero.

45 The invention may be more fully understood from the following detailed description when read in connection with the accompanying drawings. Figs. 1 and 2 of the drawings show recording and reproducing
50 systems suitable for making and reproduc-

ing high quality records of speech or music in accordance with one feature of this invention; Fig. 3 shows a special system which may be used for making records of sound frequencies extending down to zero; Fig. 4
55 shows a relatively simple reproducing system for such special records; and Fig. 5 illustrates the characteristics of the special filter required for the system shown in Fig. 3.

Referring now to Fig. 1, electron discharge
60 devices 1, 1 are arranged to act as a balanced modulator of a well known type, such as that disclosed in Fig. 8 of Patent 1,343,306 to J. R. Carson, granted June 15, 1920. A
65 coil 2 is wound on a U-shaped laminated core 3 which is adjustably attached to the frame 4 of the recording phonograph by a clamping device 5. The turntable 6 is composed of magnetic material slotted at its periphery to form alternate slots and pole pieces of
70 equal width, as indicated. The pole faces of the U-shaped core are preferably equal in width to those on the turntable and sufficiently separated from them to give the necessary
75 operating clearance. The harmonic generator 7 may be of the type disclosed in Patent 1,446,752, granted to Kendall, February 27, 1923, and the filter 8 may be merely a tuned
80 circuit arranged to pass to the input transformer 9 only a very narrow band including the harmonic frequency desired for the carrier in the recording system. The number of slots in the turntable may vary greatly but is
85 preferably as large as is consistent with good mechanical practice in order that the proper carrier frequency may be more easily obtained from the harmonic generator.

The necessary exciting current for the coil 2 may be supplied by a battery or other source associated with the harmonic generator 7, or as an alternate construction, the U-shaped core may be a permanent magnet and then no exciting current would be necessary. In either case the rotation of the turntable
90 will cause alternating currents to be generated in the coil. The frequency of these currents will depend upon the number of slots employed and will, of course, vary directly with changes in the speed of rotation. From this primary frequency the desired
95

carrier frequency is obtained by means of the harmonic generator and is passed to the modulating system by the filter circuit 8.

In the ordinary phonograph the frequency generated by any given component of the recorded wave is a function of the speed of rotation and any change in speed raises or lowers the frequency of each component by the same percentage of its original value so that their relative phase positions are not disturbed and the quality is not seriously impaired for small fluctuations. In the system of the present invention, however, the sound actually reproduced is of a pitch corresponding to the numerical difference between the carrier frequency and the component being reproduced at the time.

If the turntable speed varies somewhat from its proper speed, it will be evident that the carrier frequency must vary in the same manner or the change in pitch of the sound reproduced will be different for each component and the reproduction will be discordant.

The carrier generating device shown provides a simple method of obtaining a carrier of a frequency which is varied automatically to compensate for variations in turntable speed.

The function of the adjustable clamping device 5 may be briefly described as providing an easy means of bringing the carrier into phase with the components of carrier frequency in the inverted wave form. This adjustment becomes important when recording very low frequencies and will be further described in connection with Fig. 4. In other respects the systems of Figs. 1 and 2 are well known in the art so that no further description is required.

Heretofore it has been customary in systems for inverting speech frequencies to employ a carrier having a frequency of the order of the highest frequency to be inverted so that the lower side band occupied substantially the same position in the frequency scale as the uninverted frequencies. According to one feature of this invention the frequency ratio or percentage interval of the band to be recorded is reduced by employing a carrier of a frequency considerably higher than the upper limit of the band.

Assume for purposes of illustration that records are to be made of speech and music frequencies from 60 to 6000 cycles. With ordinary methods such records will have a frequency ratio of 100 to 1. It is very difficult to design recording and reproducing mechanisms which will operate with even an approximately linear characteristic over so wide a range. When the band is displaced, however, by employing a carrier of 7060 cycles for instance, the resulting lower side band will consist of frequencies between 1060 and 7000 cycles which reduces this ratio to

less than 7 and makes it possible to record and reproduce at practically constant efficiency.

With circuits arranged in the manner shown in Figs. 1 and 2, it is well known in the art that the currents of speech frequencies set up in transformer 10 by the action of sounds upon microphone 11 are balanced out in the plate circuit of the modulator and hence do not appear upon the record. Since the upper side band consists of frequencies between 7120 and 13060 cycles, it may be eliminated by designing the recorder 12 to be non-responsive to frequencies much in excess of 7000 cycles. In this way, the record made will include only the lower side band of frequencies between 1060 and 7000 and possibly a slight amount of the carrier which can be so nearly eliminated by the recorder as to be inaudible.

The reproducing system of Fig. 2 is practically identical with the recording system just described. The recorded inverted speech frequencies are picked up by reproducer 13 and translated into electric currents which traverse the primary of transformer 14. A 7060 cycle carrier obtained as in Fig. 1 is also supplied to the modulator 15 and causes a re-inversion of the frequency order to produce a lower side band of 60-6000 cycles in the output circuit. The windings of receiver 16 may be inserted directly in the output circuit as indicated to balance out in the magnetic structure of the receiver the magnetomotive forces due to space current. In this way the signal distortion is further reduced by the elimination of the usual output transformer.

The special system of Fig. 3 is similar in a general way to that of Fig. 1, but different in certain important respects on account of the special requirements of a system which is to be responsive to frequencies approaching zero. The double button pick-up device is energized by battery 18 and resistance coupled to the modulator 20 by resistances 21 and 22. With this construction all frequencies extending down to zero are effective to control the modulator.

This is readily seen from a consideration of the extreme case of zero frequency or a constant acoustic pressure in one direction. In such a case the transmitter is held continuously in one position so that a direct current traverses the closed loop circuit which includes one of the resistances 21 or 22 and one side of the transmitter. During this time the other loop circuit including the other of the resistances is carrying a greatly reduced current so that the grid potentials of the tubes comprising the modulator 20 are no longer equal. Under this condition the carrier frequency is not entirely balanced out in the plate circuit and is therefore transmitted as a representation of zero frequency.

The carrier frequencies used in this system

are generated in the manner previously described for the system of Figs. 1 and 2. In this case, however, the filter 23 is adapted to pass a higher frequency carrier such as 16000 cycles and this frequency is applied to the modulator through transformer 24. Since it is proposed in this case to record all frequencies between 0 and 6000 cycles, the lower side band will consist of frequencies between 10000 and 16000 cycles and the corresponding upper side band of frequencies between 16000 and 22000 cycles. In the secondary circuit of output transformer 25 a band pass filter 26 is adapted to cut off all frequencies below say 8000 cycles so as to eliminate the undesired products of modulation, such as the original sound frequencies.

Both side bands are therefore impressed upon the input circuit of a second modulator 27 which may be of any well known type, through transformer 28. The filter 29 is arranged to pass an 8000 cycle carrier to the modulator 27 so that the lower side band in the output circuit will consist of frequencies from 2000 to 14000. The upper side band will range from 18000 to 30000 which is of course beyond the limit of response of the system.

One further feature of this system should be particularly described. Since there is no separation between the upper and lower side bands in the output of modulator 27, it is physically impossible to record the desired frequencies delivered by modulator 27, namely 2000 to 8000, without also recording some part of the band from 8000 to 14000 which represent the upper side band of the first carrier. This condition is met according to this invention by inserting in the recorder circuit a special filter 30, which is designed to have a characteristic as represented by the diagram of Fig. 5. From the full line representing the amplitude of the currents of various frequencies passed by this filter, it is apparent that the major portion of the upper side band has been eliminated. In order to prevent the unsuppressed portion of the side band from passing to the recorder 31 and thereby introducing distortion into the record, the phase characteristic of the filter is a straight line through the intersection of the carrier frequency and the filter characteristic. With a filter of this type, the unsuppressed signal components above carrier frequency will be in phase with the corresponding components below that frequency, so that the resulting record will be substantially the same as if the upper side band had been entirely eliminated.

By way of a brief review of what has just been described, it is pointed out that the original band of sound frequencies extending from 6000 down to zero was first displaced upward in the frequency scale by the 16000 cycle carrier where it appeared as two

side bands ranging from 10000 to 22000 cycles. This displacement made it possible to effectively eliminate the original band by the filter 26. The next modulating process carried out in modulator 27 served to reconvert these side bands into frequencies that may be recorded. The carrier for modulator 27, however, is so chosen that the lowest frequency in the side bands, in this case 2000 cycles, is well removed from the lower range which is so difficult to record. The record made in accordance with this system will therefore be a representation of all frequencies between 0 and 6000 cycles, but will actually consist of a wave form of inverted frequencies ranging from 2000 to 8000 and upward.

A suitable system for reproducing these records is comparatively simple as shown by Fig. 4. An electromagnetic pick-up 32 may be employed to impress upon a simple modulating device 33 currents corresponding to the recorded sounds. The carrier frequency generating system is arranged to supply a carrier of a frequency equal to the difference between the carriers used in recording which in this case is 8000 cycles, so that the lower side band in the output circuit modulator 33 will comprise the same frequencies as were impressed upon the microphone of the recording system, namely 0 to 6000 cycles. The receiver 34 should be non-responsive to the 8000 cycle carrier or to its upper side band and of a type which satisfactorily reproduces the part of the range between 0 and 6000 cycles which is of particular interest. For instance, a moving coil type receiver would be preferable for low frequency sounds, but in cases where reproduction of frequencies below the range of audibility is desired, the receiver 34 might take the form of a visual indicating device responsive to these low frequency variations.

As previously pointed out, if a zero frequency variation could be produced to actuate the pick-up device 11 of Fig. 1 it would appear on the record as carrier frequency of 8000 cycles per second. Similarly in the system of Fig. 3 zero frequency is recorded as the difference between the frequencies of the carriers employed or 8000 cycles. A variation of one cycle per second would therefore appear as 7999 cycles in the record.

When a system, such as that shown in Fig. 4 is used to reproduce frequencies in the neighborhood of or below the limit of audibility, it is evident that any difference in phase between the carrier frequency components on the record and the carrier wave supplied locally will give rise to distortion. A micrometer screw adjustment 35 is therefore provided for the laminated core 3 to accurately adjust the phase of the local carrier.

What is claimed is:

1. A method of recording and reproducing

high quality sound records which consists in recording sound waves as a side band of a modulated carrier the frequency of said carrier being so chosen that the resulting side band is displaced on the frequency scale and occupies a range over which the response characteristic of the recording and reproducing mechanisms may be made substantially linear, reproducing and modulating said reproduced side band with a carrier wave of a frequency which varies in accordance with the speed of the reproducing turntable.

2. A method of recording and reproducing a band of frequencies extending down to zero frequency which consists in translating said band into other frequencies representative of said band, recording said other frequencies, reproducing said other frequencies and retranslating said other frequencies into said band.

3. A method of recording and reproducing a band of frequencies extending down to zero which consists of recording said band as an inverted displaced side band of a carrier wave reproducing said side band and inverting and replacing said side band within the range occupied by the original frequencies.

4. In a wax recording and reproducing system adapted to reproduce sound waves from a recorded side band of a modulated carrier, a method of maintaining the reproduced tones in their proper relative phase positions irrespective of changes in turntable speed which consists in demodulating said side band with a carrier wave generated by means associated with said turntable.

5. In a sound reproducing system a record of a sideband of a carrier modulated with sound frequencies, a turntable carrying the record, means associated with the turntable for generating a current of the frequency of the unmodulated carrier, means for reproducing the recorded frequencies, and means for combining said frequencies and the carrier frequency to reproduce the original sound frequencies.

6. In a sound reproducing system a record of a sideband of a carrier modulated with sound frequencies, a turntable carrying the record, electromagnetic means associated with the turntable for generating a demodulating carrier wave, means for varying the phase of the carrier wave with respect to the sideband, means for reproducing the record frequencies, and means for combining said frequencies and the carrier frequencies to reproduce the original sound frequencies.

7. In a sound recording system, a sound responsive device for translating sounds into electric currents, means for modulating said currents, a record blank, a turntable for revolving said record blank, recording means responsive to the output of said modulating

means, and means associated with said turntable for generating a carrier wave for said modulating means.

8. A method of recording a band of frequencies extending down to zero frequency which consists of modulating a carrier with frequencies to displace them in the frequency scale, zero frequency being represented by the unmodulated carrier, eliminating the undesired products of modulation, modulating a second carrier with the displaced frequencies to procure a lower sideband in the optimum recording range and recording said lower sideband.

9. In a sound recording system, a sound responsive device for translating sounds into electric currents, means for modulating the currents, a record blank, a magnetic turntable having a slotted periphery for revolving the record blank, recording means responsive to the output of the modulating means, and means for generating a carrier wave for the modulating means comprising a coil having a magnetic core in close spaced relation to the periphery of the turntable, a harmonic generator for multiplying the frequency generated in the coil, and means for selecting the desired multiple frequency.

10. In a recording system, a source of carrier frequency, a balanced modulator, means for recording a portion of the output of the modulator, and means responsive to a constant acoustic pressure in one direction for unbalancing the modulator and permitting the carrier frequency to actuate the recording means.

In witness whereof, I hereunto subscribe my name this 2 day of May, 1928.

JOSEPH W. HORTON.