

Nov. 8, 1932.

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1,886,616

MAGNETIC SOUND RECORDING SYSTEM

Filed March 30, 1931

3 Sheets-Sheet 1

Fig. 1.

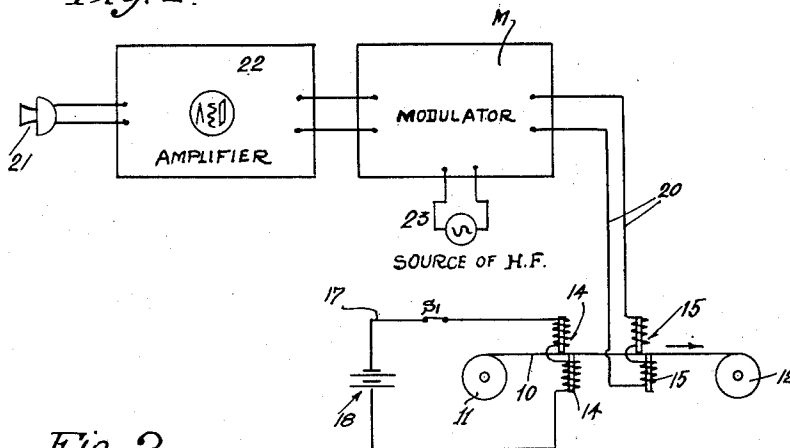


Fig. 2.

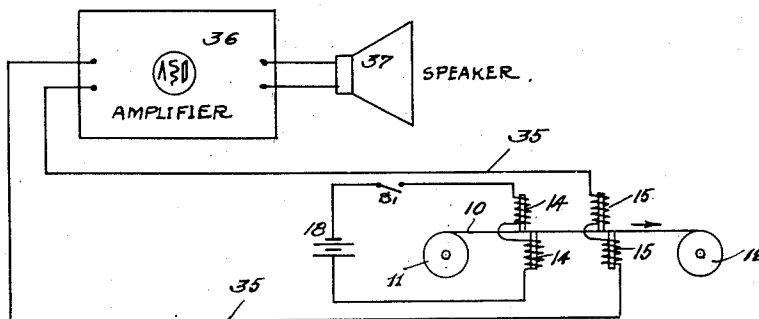
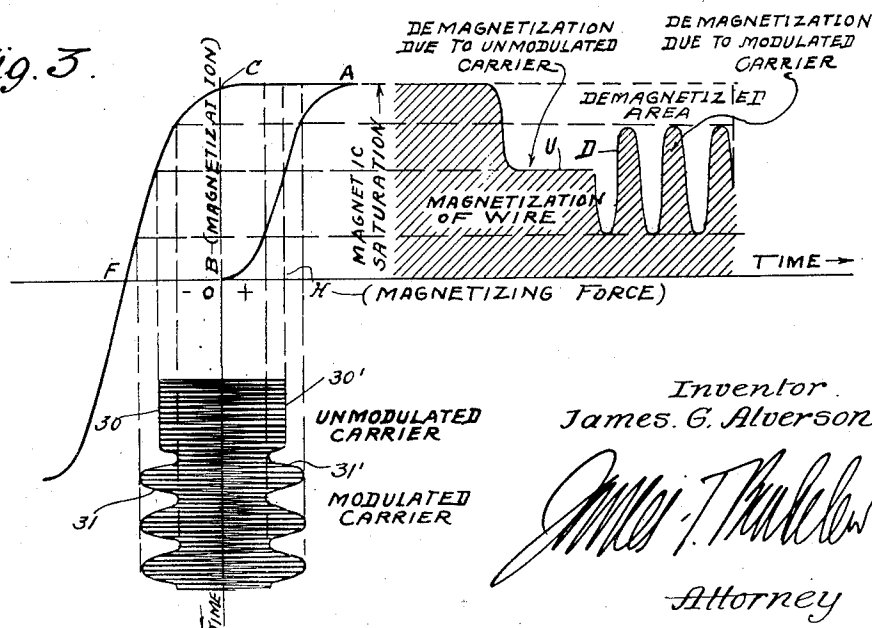


Fig. 3.



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Fig. 4.

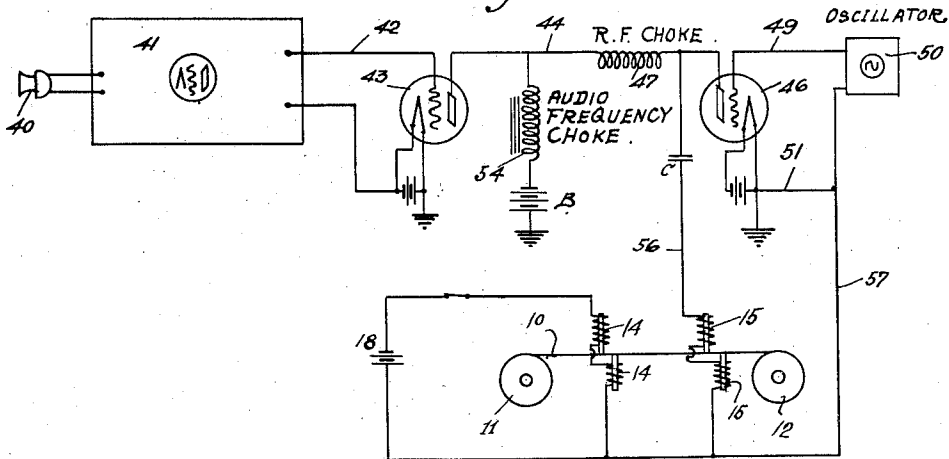
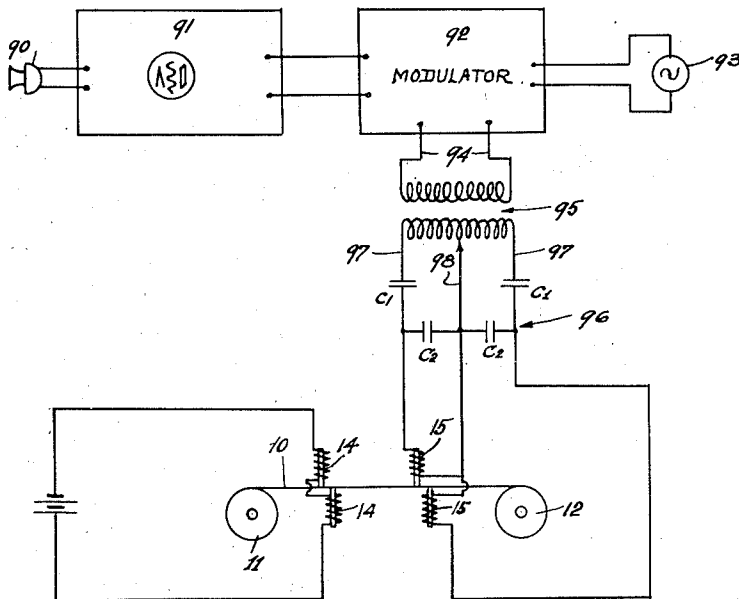


Fig. 7



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Fig. 5.

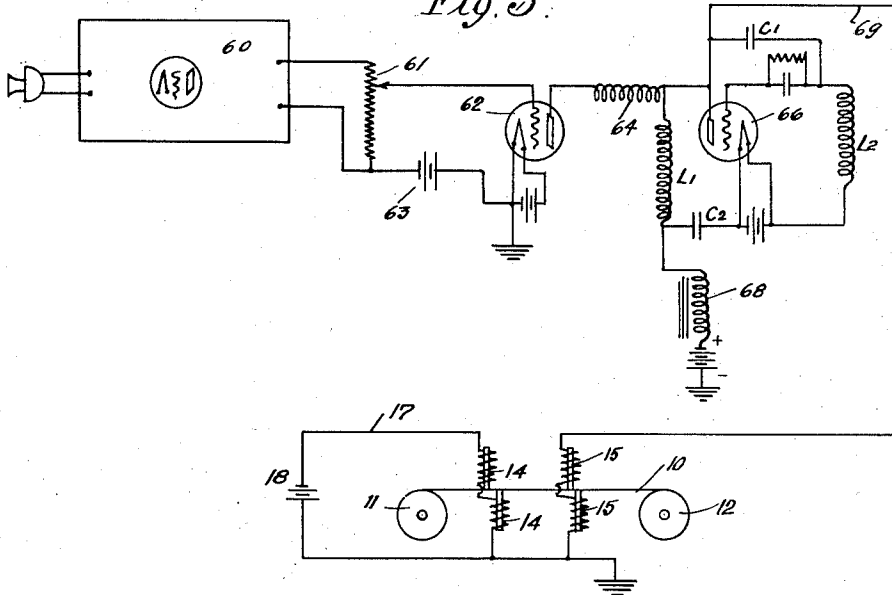
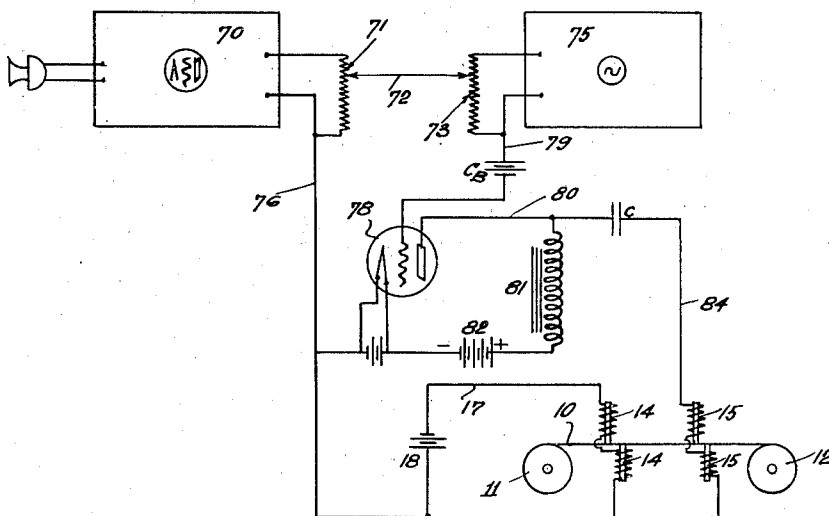


Fig. 6.



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UNITED STATES PATENT OFFICE

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MAGNETIC SOUND RECORDING SYSTEM

Application filed March 30, 1931. Serial No. 526,325.

This invention relates generally to the art of recording sound waves by local magnetization of a traveling paramagnetic recording element.

5 A magnetic sound recording system, commonly known as a telegraphone, comprises in its usual form a means for constantly moving the recording element, which element may advantageously be either a steel wire
10 or tape, and a pair of recording electromagnets between the poles of which the wire travels, so that the magnetic circuit at any instant includes the element of the moving wire between the poles at that instant. The
15 electromagnets are energized by a sound current, and the resulting varying magnetic field through the wire produces a corresponding permanent local magnetization therein. Upon subsequently running the wire
20 through the same or similar electromagnets, this time arranged in a receiving circuit, the varying magnetized wire produces E. M. F. variations in the windings of the electro-
25 magnet, which set up a corresponding current in the receiving circuit, and by means of a suitable electroacoustic converter the original sound waves may be reproduced.

The above gives a general outline of the fundamental principles underlying the mag-
30 netic method of recording sound. There are, however, many difficulties in the way of so magnetizing the wire that speech or music can be reproduced with desired fidelity. Among these difficulties may be mentioned
35 the normal non-linear characteristics of paramagnetic bodies as magnetizing flux is varied, distortion and phase shifts due to hysteresis effects, etc., and next, the variations of those effects with changing frequencies such as
40 are encountered in speech and music. Additional problems are encountered in effectively eliminating or erasing past history of the recording wire before taking a new record, and further, when recording, in subjecting
45 the recording wire to varying flux in such a manner that the feeblest as well as the strongest audio-frequency variations produce corresponding increments of magnetization in the wire, without distortion and
50 without loss or suppression of half-cycles.

Several methods of erasing past history on the recording wire have been proposed heretofore. The most usual method has been to saturate the wire with a strong direct
current magnetic field produced between a 55 pair of erasing poles, thereby obliterating all previous local magnetizations. When once saturated, however, the wire is in a condition which permits of no further magnetization in the direction in which the wire is mag-
60 netized, and an audio-frequency input under such circumstances will accordingly suffer loss of the half-cycles in that direction. Therefore, it has been common to return the magnetization of the wire either to a mid-
65 point on the B—H curve, or else to a neutral state, by the use of a D. C. polarizing current. Given an ideal paramagnetic recording medium, such a system would be ideal; but in
70 practice, using the most suitable recording medium available, the many difficulties referred to above enter to introduce a variety of serious distortions. For instance, the well
known hysteresis phenomena of paramag-
75 netic bodies (time lag of magnetization with respect to magnetizing current), which in itself would be of no consequence if it were constant for all frequencies, is found to vary with frequency and hence to cause a different
80 time lag for the high frequency harmonics than for the longer wave length fundamentals. The result is a phase shift between fundamentals and harmonics, which is responsible for a large part of the distortion
85 encountered in prior practice.

Another disturbing factor is the reduction in permeability with increase in frequency, which results in the higher frequency components being feebly recorded as compared with the lower frequency components. This
90 condition has necessitated the use of networks designed to suppress the lower frequencies for the purpose of obtaining a more nearly constant magnetic level for all frequencies.
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Another factor is the relatively large change in the inductance of the recording coils with frequency changes throughout the audio-range. This effect results in flux variations with variations in frequency, and
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hence leads to further permeability and hysteresis changes, with attendant disturbances.

As an alternative method of erasing, it has been proposed to subject the wire to the influence of a high or radio frequency flux, which has the property of returning the wire to zero magnetization on the B—H curve. A D. C. polarizing flux is then used to bring the condition of the wire back to a proper point on the B—H curve while recording. Such a system, however, is subject to all of the disabilities described above in connection with the first method.

It has also been proposed in the prior art to impose on the recording wire a high frequency flux simultaneously with but independent of the audio-frequency flux, so as to agitate the recording wire and thereby sensitize the wire to audio-frequency magnetization. Such a system per se, however, is also subject to a majority of the disadvantages referred to above.

It may now be stated as the general object of my invention to provide a system of magnetically recording sound which will avoid all of the difficulties herein described, and which will result in greatly improved fidelity of reproduction.

It is a general characteristic of my system that the recording electromagnets are energized by an audio-frequency modulated high-frequency carrier current. The exact manner in which the recording wire receives its magnetization according to my invention will not be exhaustively discussed until it can be taken up in connection with suitable diagrams, explained at a later point in the specification. However, it may here be stated that the wire is first saturated by a pair of erasing poles, and then subjected to the flux due to the modulated carrier waves. The wire then acts, in effect, to demodulate the carrier wave, being varyingly demagnetized in accordance with the audio frequency modulation characteristics.

Mathematical analysis of the simple case of a carrier wave of frequency f modulated by a sinusoidal audio wave of frequency f_1 shows that the modulated wave is made up of three components of frequencies f , $(f+f_1)$, and $(f-f_1)$. Thus assuming a carrier wave of a frequency of 50,000 cycles modulated by an audio wave of 5,000 cycles (which last is near the upper limit of the practical audio range), the three components of the modulated wave would be 50,000 cycles, 55,000 cycles and 45,000 cycles. Of course, a carrier wave of the same frequency modulated by a speech input involves a very great number of frequencies, as follows: f , $(f+f_1)$, $(f-f_1)$, $(f+f_2)$, $(f-f_2)$, ... $(f+f_n)$, $(f-f_n)$; but the entire frequency range would be substantially within the limits of 45,000 to 55,000 cycles given by the above

calculation for the high side of the audio range.

As is well known, the sound characteristics of a modulated carrier wave are carried by the side bands, i. e., $(f+f_1)$, $(f-f_1)$, etc., and it is to be noted that the audio frequency characteristics of the recording current are therefore carried by a high frequency wave made up exclusively of high frequency components. This fact is of great advantage from a number of standpoints. First, the permeability and hysteresis of the wire and the inductance of the recording coils are all very nearly constant for the limited high-frequency range includes in the two side bands of the modulated wave, as will readily be understood by those skilled in the art, and all of the various serious distortions due to the large variations of these factors with frequency variations throughout the audio range, are therefore practically eliminated in my system. Further, the high frequency wave has the property of demagnetizing the wire to an extent very closely proportional to its amplitude, its presence in the recording wave seemingly tending to lubricate the molecules of the wire, so to speak, and thereby causing the wire to be demagnetized in more perfect accordance with the audio frequency characteristics of the wave.

With this preliminary discussion in mind, the invention will be more fully understood from the following detailed description thereof, and of preferred circuits designed to carry the invention into practical effect, reference for this purpose being had to the accompanying drawings, in which:—

Fig. 1 is a diagram of the fundamental recording system;

Fig. 2 is a diagram of the fundamental reproducing system;

Fig. 3 is a diagram showing the manner in which the magnetization is put on the recording wire;

Fig. 4 shows a plate modulator recording circuit;

Fig. 5 shows a modulated oscillator recording circuit;

Fig. 6 shows a grid modulated recording circuit; and

Fig. 7 shows a balanced, resonant recording coil circuit.

Fig. 1 of the drawings shows the fundamental erasing and recording circuit. The recording element 10, here typified in the form of a steel wire, but without implied limitation thereto, is here shown as unwound from a supply reel 11, passing through the recording magnets, and then being reeled up on a reel 12. Suitable mechanical devices, not shown, are provided for driving the reels in either direction, and for insuring uniform reeling, such devices being well understood in the art. The wire in running from reel 11 to reel 12 passes first through the poles

of a pair of offset erasing electromagnets 14, and then through the poles of a pair of offset recording electromagnets 15. It may here be mentioned that the same electromagnets 15 used in recording may by suitable circuit switching be used as reproducing electromagnets in the reproducing system, illustrated in Fig. 2. The paramagnetic poles of each pair of electromagnets are arranged parallel to each other on opposite sides of the wire and at right angles thereto, but are slightly offset from each other to give a longer, angular path for the magnetic circuit through the wire. The erasing electromagnets 14, which are wound and connected so as to assist each other, are arranged in a circuit 17 including a battery 18 and a switch S_1 .

The recording electromagnets 15, which are also wound and connected to assist each other, are arranged in the output circuit 20 of modulator M. The microphone of the recording system is indicated at 21, its audio frequency output being connected to the input of amplifier 22, here indicated as of the vacuum tube type. The amplified audio frequency output of amplifier 22 is connected to the input of modulator M, which is supplied with a high frequency carrier current from a suitable source 23. Said source 23 is preferably, though not necessarily, a vacuum tube oscillation generator. The audio frequency input modulates the carrier wave, and the modulated carrier wave is transmitted by circuit 20 to the recording coils. The high frequency preferably should be at least twice the highest audio frequency note recordable so as to prevent the possibility of beats; and from standpoints of perfection of recording it may advantageously be considerably higher. Various schemes of carrier wave modulation are suitable, as will be described in more detail hereinafter.

In operation, the wire passes first between the erasing coils 14, which completely saturate it to prepare for the action of recording coils 15, and the wire then passes through the recording coils to be subjected to the flux produced by the modulated carrier current.

Reference is now directed to the diagram of Fig. 3, which shows a curve of the relation between the current in the recording coils or magnetizing force H , and the magnetization B produced in the wire. As shown by this curve, the erasing coils bring the condition of the wire up curve OA to saturation. After a given element of the wire thereafter leaves the erasing coils and the magnetizing force is therefore reduced to zero, the magnetization of the element remain about constant, bringing the condition of the element back on the return curve to point C.

The same diagram also shows on a vertical time axis through zero magnetizing current, the form of the carrier wave magnetizing current; and on a horizontal time axis

through zero magnetization of the wire, a curve D showing the amount of demagnetization of the previously saturated wire produced by the action of the carrier wave.

The carrier wave is conventionally shown in the diagram symmetrically disposed on opposite sides of its neutral axis, its unmodulated portion being bounded by straight lines 30 and 30', and its audio-frequency modulated portion being bounded by the symmetrical audio-frequency enveloping curves 31 and 31'. Sinusoidal audio waves are illustrated for simplicity, although the curves 31 and 31' will be highly complex when the carrier wave is speech modulated. Now it will be remembered that the modulated carrier wave is made up of high frequency components f , $(f+f_1)$, and $(f-f_1)$, where f is the carrier frequency and f_1 is the audio frequency, although the modulated wave is bounded by curves 31 and 31' of audio frequency f_1 (the negative half-cycles of the carrier wave being bounded by curve 31 and the positive half-cycles by curve 31'). The wire is therefore subjected to the influence of the positive and negative half-cycles of the modulated high frequency flux. Now the positive half-cycles of the carrier flux tend to magnetize the wire in the direction in which it is already saturated, as is clear from projecting curve 31' up to magnetization characteristic AC, and therefore produce no effect on the wire; but the negative half-cycles, on the other hand, reduce the magnetization of the wire along the curve CF, and by an amount at any point determined by the instantaneous amplitude of curve 31. Thus the amount of demagnetization of the wire can be found by projecting curve 31 up to characteristic CF, and then horizontally to produce curve D. The area above said curve D represents the amount the wire is demagnetized, and the shaded area below the curve represents the amount of magnetization remaining in the wire. It will be observed that the magnetization of the wire is at saturation before subjection to the unmodulated carrier (after erasing and before reaching the recording coils), is reduced to a constant intermediate neutral level U by the unmodulated carrier, and is varied as indicated by curve D by the modulated carrier. Curve D closely resembles curve 31 if adjustments are such that operation is on a linear section of curve CF, and since curve 31 has all of the characteristics, both positive and negative half-cycles, of the original audio wave, a complete audio record is therefore demagnetized into the saturated wire.

It will now be understood that the complete audio wave is recorded with the use of a modulated carrier wave which consists exclusively of high frequency components. There is thus avoided the many distortions which arise from the relatively rapid change

of hysteresis and permeability of the wire and inductance of the recording coils with variations of frequency over the audio spectrum, as compared with the changes in those factors throughout the high frequency band included in the components of the carrier wave. Thus, since the permeability is practically constant at the carrier frequency band, the higher frequency components are recorded without loss of amplitude relative to the lower frequency components; the improved stability of the hysteresis effect for all frequencies in the carrier wave results in avoiding the phase shift between harmonics and fundamentals noted in low frequency recording; and the more constant inductance of the recording coils at the higher frequencies avoids the flux amplitude distortions between varying frequencies of the audio range, as well as tending to stabilize permeability and hysteresis.

Further, the high frequency in the recording wave permits the wire to receive a more accurate magnetic impression, as well as permitting of the recording of feeble vibrations which would otherwise be lost.

Fig. 2 shows the fundamental reproducing circuit. The same reels 11 and 12 and electromagnets 14 and 15 used in the recording circuit are present in the reproducing system, and the record wire is driven in the same direction as before. When reproducing, however, switch S_1 in the erasing circuit is open, and the electromagnets 15, previously used for recording, are connected in a circuit 35 leading to the input of amplifier 36. The output of said amplifier may be connected, for instance, to a speaker 37. Upon running the magnetized wire through magnets 15, an E. M. F. corresponding to its magnetization is generated in the coils, thereby producing a current which is conducted to amplifier 36, and finally reproduced as sound by speaker 37.

I proceed now to a description of preferred circuiting arrangements for the recording system. Fig. 4 shows a circuit in which the plate modulation scheme (Heising Circuit) is utilized. Microphone 40 is connected to an amplifier 41, one output lead 42 of which is connected to the grid of modulator tube 43. The other output lead 44 of the amplifier is connected as usual to the filament circuit of tube 43. The plate of tube 43 is connected by wire 44 to the plate of the second tube 46, wire 44 including a radio frequency choke coil 47 for the purpose of isolating tube 43 from the high frequency current in the plate circuit of tube 46. The grid of tube 46 is connected by wire 49 with one terminal of a vacuum tube oscillator 50, or other source of constant high frequency current, the other terminal of oscillator 50 being connected by wire 51 to the filament circuit of tube 46, as shown. Connected to wire 44 is an audio frequency choke coil 54, the other side of

which is connected to the positive terminal of the plate battery B. The recording coils 15 are connected at one side to a wire 56 leading to the plate of tube 46, a blocking condenser C preferably being included in said wire for the purpose of keeping direct current out of the coils and preventing low frequency surges. The other side of the recording coils are connected by wire 57 to oscillator lead 51. The audio frequency variations in the plate current of tube 43 produce corresponding variations in the voltage drop across audio choke 54, and thereby, in effect, correspondingly vary the resistance of the plate circuit of tube 46, which circuit is furnished with high frequency oscillations by the oscillator 50 connected in the grid circuit of the tube. The varying resistance of the plate circuit of tube 46 then causes modulation of the high frequency oscillations therein in accordance with the audio frequency input, as is well understood in the art. This modulated high frequency carrier current passes through the recording coil circuit 56, 57 to magnetize the recording wire in accordance with the principles hereinabove set forth.

Fig. 5 shows another recording circuit, involving a modulated oscillator circuit. The audio frequency output of amplifier 60 is connected through a fader 61 across the grid and filament of a modulator tube 62, a C battery 63 being included in the grid circuit of the tube. The plate of tube 62 is connected through a radio frequency choke coil 64 to the plate of oscillator tube 66. Tube 66 is provided with an oscillator circuit L_1, L_2, C_1, C_2 , which is adjusted to cause the tube to oscillate in a steady state at high frequency. The plate circuit of the tube 66 is connected through an audio frequency choke coil 68 to the positive terminal of the B battery, the other terminal of which is grounded. The audio frequency variations in the plate circuit of modulator tube 62 cause a varying voltage drop across choke coil 68, and thereby modulate the high frequency oscillations in the plate circuit of oscillator tube 66. The plate of tube 66 is connected by means of circuit 69 through the recording coils 15 to ground, the recording coils being thereby energized by the modulated high frequency in the plate circuit of the tube.

Fig. 6 shows a recording circuit involving grid modulation. The audio frequency output of amplifier 70 is connected to a fader 71. From the adjustable arm of the fader a wire 72 leads to the adjustable arm of a second fader 73, which is connected across a high frequency vacuum tube oscillator 75. The second lead 76 from fader 71 is connected to the filament of vacuum tube 78, and the lead 79 from fader 73 is connected through a C battery C_b to the grid of tube 78. The plate circuit 80 of the tube includes an audio frequency choke coil 81 and B bat-

tery 82. The recording coils 15 are included in a lead 84 from the plate to the filament, in shunt with the B battery. A blocking condenser C is preferably included in lead 84. The battery C_b is adjusted to bias the grid so as to give operation on a knee of the grid potential—plate characteristic, under which conditions the plate circuit has an audio frequency modulated carrier current, as is well understood in the art. This modulated carrier is transferred through condenser C to the recording coils. The last described circuit has proved exceptionally advantageous in practice, and is at present the preferred system.

Fig. 7 shows a balanced, tuned circuit for the recording coil circuit. The microphone 90, amplifier 91, modulator 92, and oscillator 93 may be arranged in any suitable manner to produce the modulated carrier wave in circuit 94. Circuit 94 is coupled through transformer 95 to the recording coil circuit 96, which circuit is made up of outside leads 97 from the secondary winding of the transformer, said leads being connected together through coils 15, and a center lead 98 connected from a center tap on the transformer to a point between the recording coils, as shown. Leads 97 each contain a series condenser C_1 , while a condenser C_2 is connected between each lead 97 and the center lead 98. The several condensers are tuned with respect to the inductance of the transformer secondary and the recording coils so as to give a resonant condition conducive to high efficiency transmission.

It will be recognized that the illustrative system and circuits specifically described herein are capable of considerable modification and rearrangement without departing from the spirit and scope of my invention; and it is therefore to be understood that the following claims embrace all such modifications and equivalent arrangements as may fairly be construed to fall within the scope of my invention.

I claim:

1. The method of magnetically recording sound on a paramagnetic element, that comprises first magnetizing the element to a saturated state, and then passing the saturated element through a high frequency magnetic field produced by a sound modulated high frequency carrier wave.

2. The method of magnetically recording audio frequency waves on a paramagnetic element, that comprises first magnetizing the element to a saturated state, and then passing the saturated element through a high frequency magnetic field produced by an audio frequency modulated high frequency carrier current.

3. The method of magnetically recording audio frequency waves on a paramagnetic element, that includes moving the element

through a high frequency magnetic field produced by an audio frequency modulated high frequency carrier current.

4. The method of magnetically recording audio frequency waves on a paramagnetic element, that comprises first magnetizing the element to a saturated state, and then demagnetizing the saturated wire in a high frequency magnetic field produced by an audio frequency modulated high frequency carrier current.

5. The method of magnetically recording audio frequency waves on a paramagnetic element, that comprises first magnetizing the element to a saturated state, and then demagnetizing the saturated element in accordance with the audio frequency waves by subjecting the element to a high frequency magnetic field produced by an audio frequency modulated high frequency carrier current.

6. The method of magnetically recording audio frequency waves, that includes producing an audio frequency sound current, modulating a high frequency carrier current by said audio frequency current, so as to produce a modulated carrier current, producing a correspondingly modulated high frequency magnetic field from said carrier current, and demodulating the magnetic field in a paramagnetic recording element by passing the element through said field.

7. The method of magnetically recording audio frequency waves, that includes producing an audio frequency modulated high frequency carrier current, and demodulating said carrier current in a paramagnetic recording element by passing the element through a high frequency magnetic field produced by the carrier current.

8. The method of magnetically recording audio frequency waves, that includes producing an audio frequency sound current, modulating a high frequency carrier current by said audio frequency current, so as to produce a modulated carrier current, producing a correspondingly modulated high frequency magnetic field from said carrier current, and demodulating the magnetic field in a paramagnetic recording element by magnetizing the element to saturation and then passing said element through said field.

9. The method of magnetically recording audio frequency waves, that includes producing an audio frequency modulated high frequency carrier current, and demodulating said carrier current in a paramagnetic recording element by magnetizing the element to saturation and then passing said element through a high frequency magnetic field produced by the carrier current.

10. The method of magnetically recording audio frequency waves, that includes producing an audio frequency sound current, modulating a high frequency carrier current by said audio frequency current, so as to pro-

duce a modulated carrier current, producing a correspondingly modulated high frequency magnetic field from said carrier current, and passing a magnetically saturated paramagnetic recording element through said field.

11. The method of magnetically recording audio frequency waves, that includes producing an audio frequency modulated high frequency carrier current, and passing a magnetically saturated paramagnetic recording element through a high frequency magnetic field produced by the carrier current.

12. The method of magnetically recording audio frequency waves on a paramagnetic recording element, that comprises producing from the audio waves an audio frequency electric current, modulating thereby a high frequency carrier current, producing an alternating magnetic field by and corresponding to the audio frequency modulated carrier current, and magnetically saturating the recording element and then passing said element through the modulated high frequency alternating magnetic field, in such a manner that the half-cycles of said field in the direction in which the element was previously saturated are suppressed while the half-cycles of the field in the opposite direction produce a varying demagnetization along the element corresponding to the original audio waves.

13. In a magnetic sound recording system, the combination of a movable paramagnetic recording element, magnetic means for magnetically saturating said element, electro magnetic means for producing a magnetic field through which said recording element passes after being saturated, an energizing circuit for said electromagnetic means, and means for feeding to said circuit an audio frequency modulated high frequency carrier current.

14. In a system for magnetically recording audio frequency sound waves, the combination of a movable paramagnetic recording element, magnetic means for magnetically saturating said element, electromagnetic means for producing a magnetic field through which said recording element passes after being saturated, means for converting the sound waves into an audio frequency electrical current, means for producing a high frequency oscillating current, means for modulating said high frequency current by said audio frequency current, and an energizing circuit for the electromagnetic recording means fed by the modulated high frequency current output.

15. In a system for magnetically recording audio frequency sound waves, the combination of a movable paramagnetic recording element, magnetic means for magnetically saturating said element, electromagnetic means for producing a magnetic field through which said recording element passes after being saturated, means for converting the

sound waves into an audio frequency electrical current, a modulator-oscillator circuit fed by said audio frequency current, and an energizing circuit for the electro-magnetic recording means fed by the modulated high frequency current output of said modulator-oscillator circuit.

16. In a system for magnetically recording audio frequency sound waves, the combination of a movable paramagnetic recording element, magnetic means for magnetically saturating said element, electro-magnetic means for producing a magnetic field through which said recording element passes after being saturated, means for converting the sound waves into an audio frequency electrical current, a source of high frequency current, a modulator circuit fed by the audio and high frequency currents, and an energizing circuit for the electromagnetic recording means fed by the modulated high frequency current output of the modulator circuit.

17. In a magnetic sound recording system, the combination of a movable paramagnetic recording element, electro-magnetic means for producing a magnetic field through which said recording element passes, an energizing circuit for said electromagnetic means, and means for feeding to said circuit an audio frequency modulated high frequency carrier current.

18. In a system for magnetically recording audio frequency sound waves, the combination of a movable paramagnetic recording element, electromagnetic recording means for producing a magnetic field through which said recording element passes, means for converting the sound waves into an audio frequency electrical current, means for producing a high frequency oscillating current, means for modulating said high frequency current by said audio frequency current, and an energizing circuit for the electromagnetic recording means fed by the modulated high frequency current output.

19. In a system for magnetically recording audio frequency sound waves, the combination of a movable paramagnetic recording element, electromagnetic recording means for producing a magnetic field through which said recording element passes, means for converting the sound waves into an audio frequency electrical current, a modulator-oscillator circuit fed by said audio frequency current, and an energizing circuit for the electro-magnetic recording means fed by the modulated high frequency current output of said modulator-oscillator circuit.

20. In a system for magnetically recording audio frequency sound waves, the combination of a movable paramagnetic recording element, electromagnetic recording means for producing a magnetic field through which said recording element passes, means for converting the sound waves into an audio fre-

quency electrical current, a source of high frequency current, a modulator circuit fed by the audio and high frequency currents, and an energizing circuit for the electromagnetic recording means fed by the modulated high frequency current output of the modulator circuit.

21. In a system for magnetically recording audio frequency sound waves, the combination of a movable paramagnetic recording element, electromagnetic recording means for producing a magnetic field through which said recording element passes, means for converting the sound waves into an audio frequency electrical current, a source of high frequency current, means for modulating said high frequency current by said audio frequency current, and a tuned resonant circuit for conducting the modulated high frequency current to the electromagnetic recording means.

22. The method of magnetically recording audio frequency waves, that includes producing an audio frequency electrical current, modulating thereby a high frequency carrier current, producing a high frequency magnetic field from an electrical current that includes the half-cycles in one direction of the modulated carrier current, and passing a paramagnetic recording element through said field.

23. The method of magnetically recording audio frequency waves on a paramagnetic recording element, that includes producing an audio frequency electrical current, modulating thereby a high frequency carrier current, magnetically saturating a recording element, and passing said element through a magnetic field produced from an electric current including the half-cycles in one direction of the audio frequency modulated carrier current, the field resulting from such half-cycles being in a direction to demagnetize the recording element accordantly.

In witness that I claim the foregoing I have hereunto subscribed my name this 12 day of March 1931.

JAMES G. ALVERSON.