

July 22, 1952

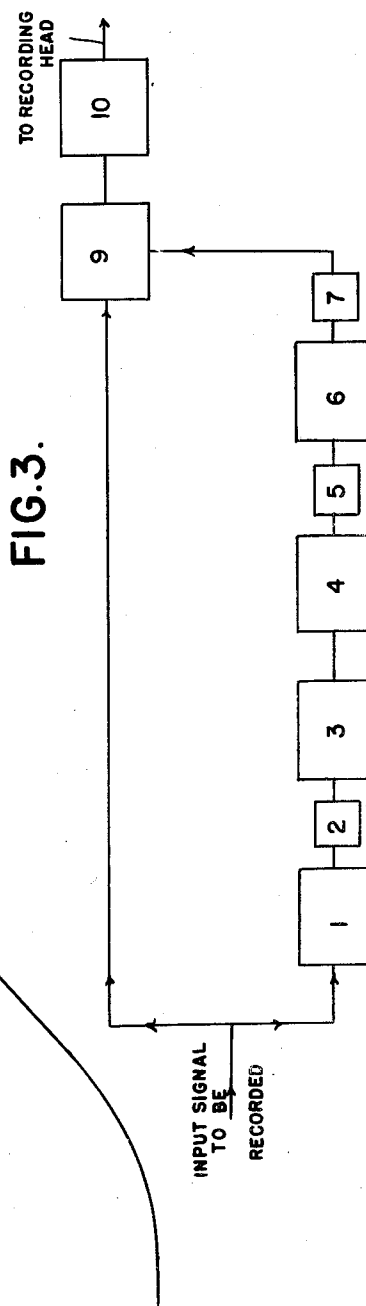
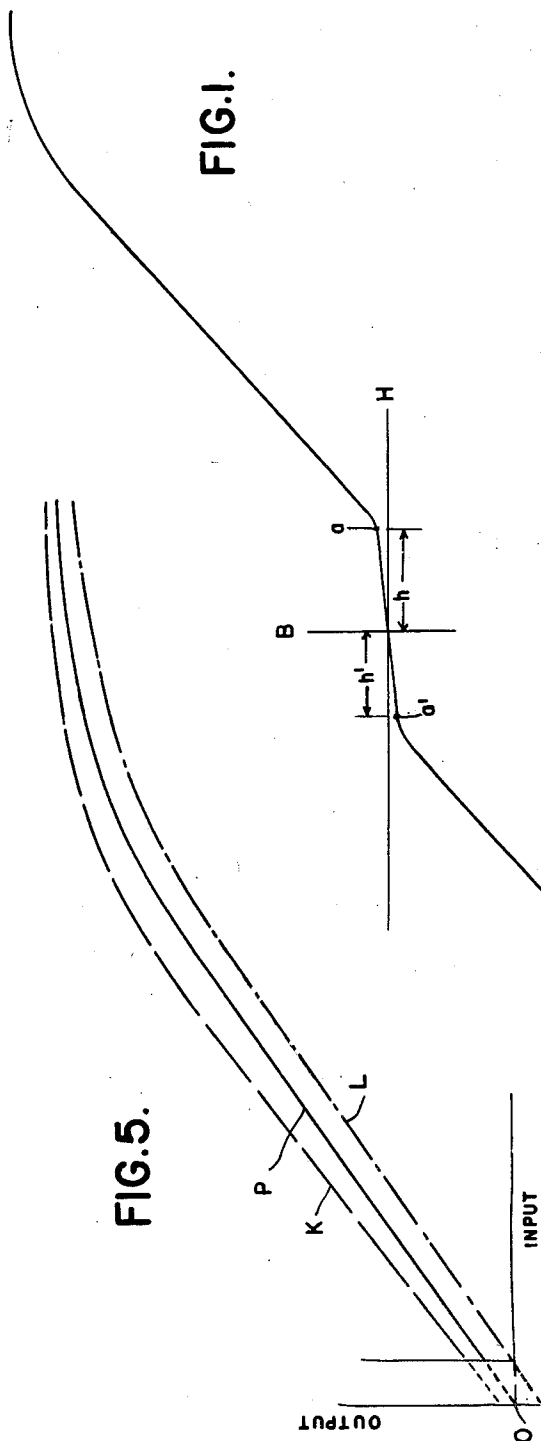
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2,604,546

BIASING SYSTEM FOR MAGNETIC RECORDERS

Filed Aug. 23, 1948

3 Sheets-Sheet 1



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FIG. 2.

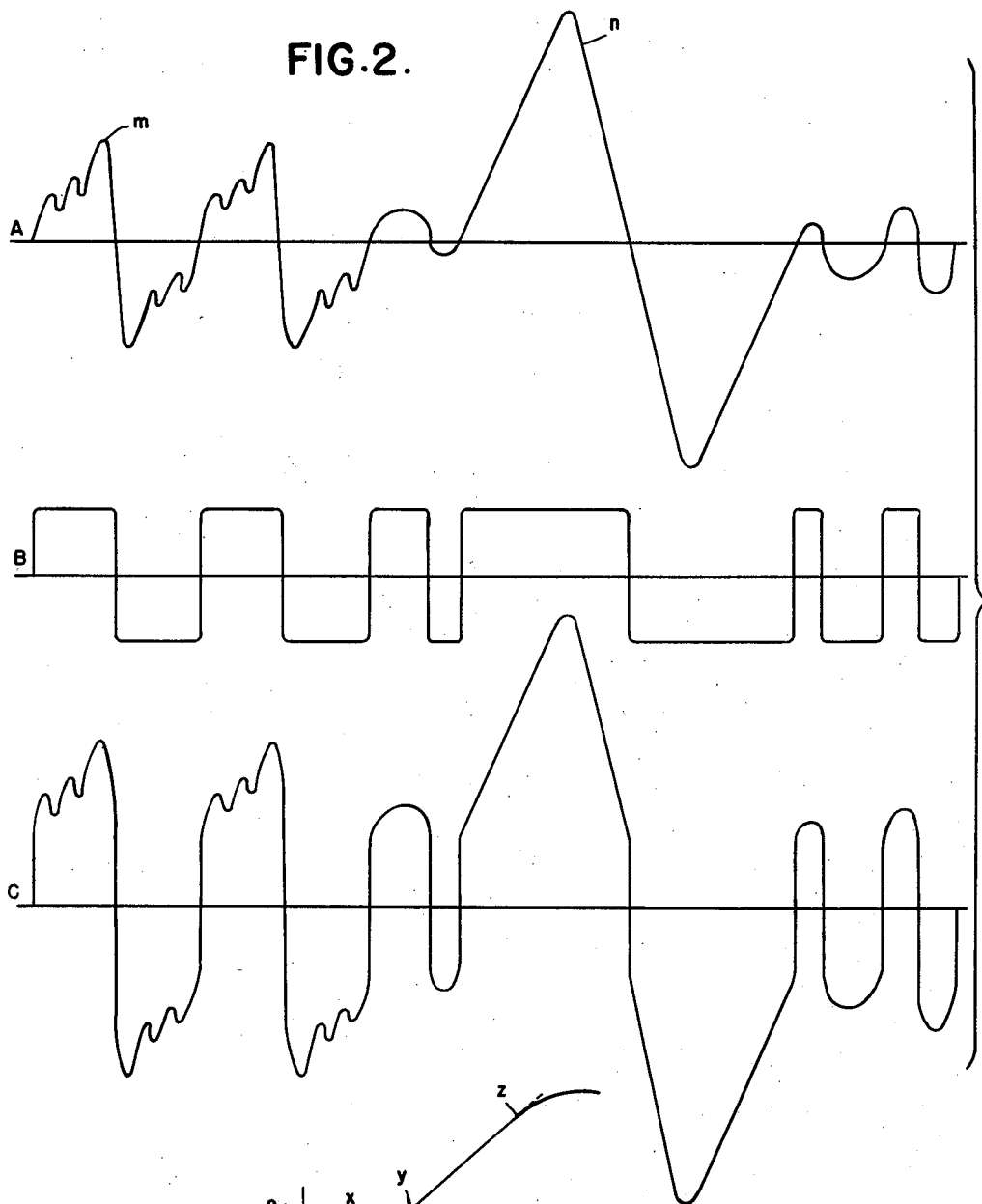
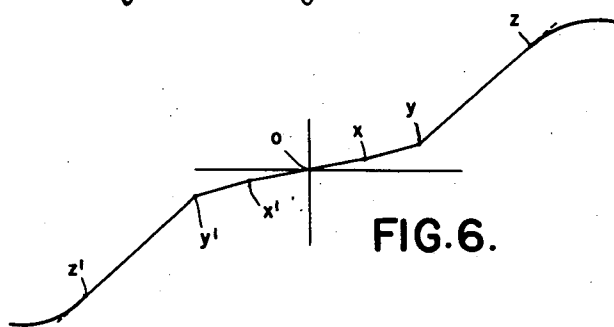


FIG. 6.



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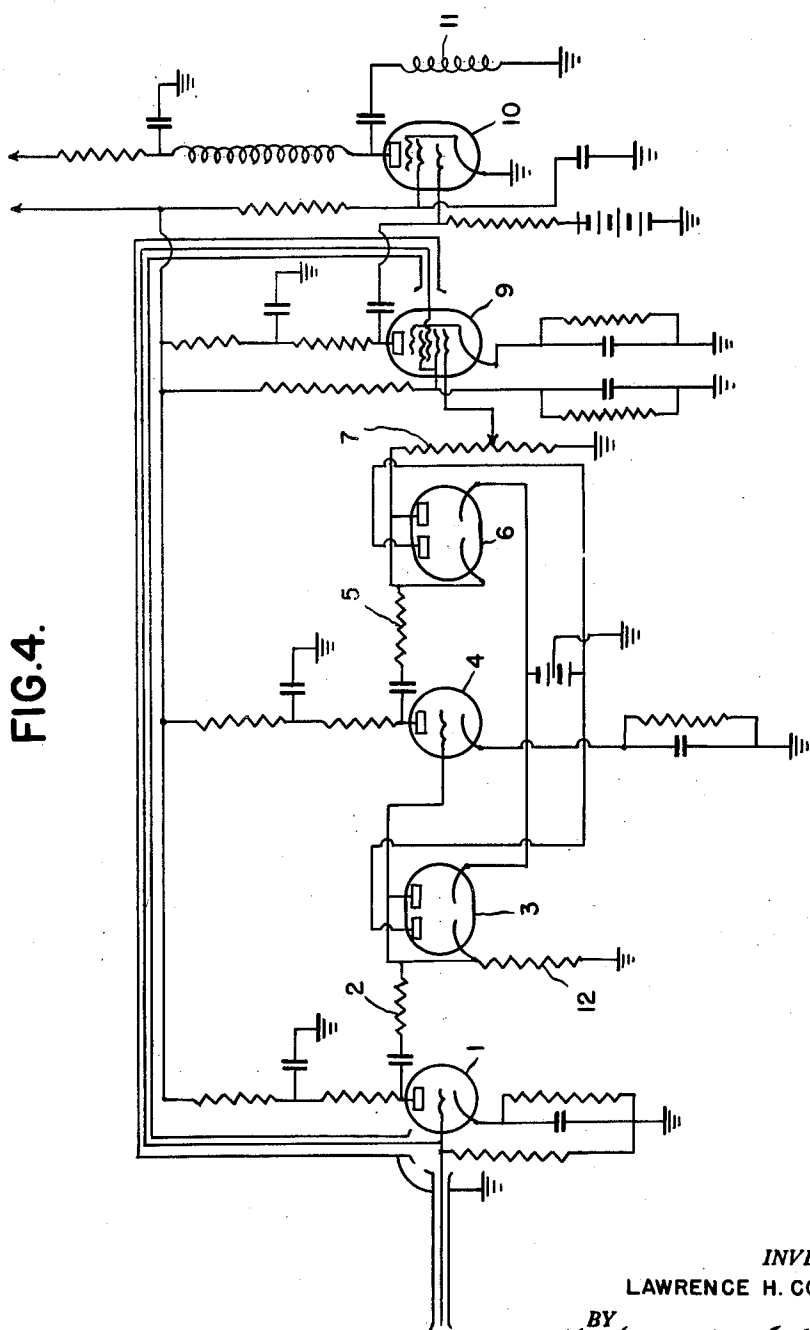
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BIASING SYSTEM FOR MAGNETIC RECORDERS

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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BIASING SYSTEM FOR MAGNETIC RECORDERS

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Application August 23, 1948, Serial No. 45,711

20 Claims. (Cl. 179-100.2)

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The present invention relates to method and apparatus for magnetic recording, and has for its primary object to so improve the quality of such recordings that they may be satisfactory in fields where fidelity is a requirement such as the recording and reproduction of music.

It is a further object of the present invention to so reinforce or augment the effect of a sound modulated controlling force that the strength of the magnetic field controlled thereby through which a record element is advanced is, while changing polarity in accordance with the sign or polarity of a sound pattern, at all times of a magnitude sufficient to efficiently impart a residual magnetization to the record element capable of reproduction.

More specifically it is an object of the present invention to provide apparatus and method for sound recording which operates from an audio pattern in which sound waves of reversing sign or polarity and of a magnitude which is variable from zero upwardly in both directions is used to control a magnetic field in such a way that the magnetic field reverses polarity substantially synchronously with reversals in sign or polarity of the audio pattern, and in which the magnetizing effect of the magnetic field varies directly with variations in the magnitude of the audio pattern.

It is a feature of the present invention to control a magnetizing current by two voltages, one of which is variable in magnitude and reverses sign or polarity in accordance with an audio pattern, the other of which reverses sign or polarity substantially simultaneously with the first, and which has the effect of insuring that the magnetizing current, except during the instant of reversal, is never below a magnitude sufficient to produce efficient recording.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a B-H diagram for the initial magnetization of a permanent magnet material suitable for use as a record element;

Figure 2 is a diagram illustrating the additive relationship of currents controlled by an audible sound pattern to be recorded and a reinforcing current of substantially uniform magnitude to the same instantaneous polarity as the sound modulated current;

Figure 3 is a block diagram disclosing a circuit for carrying out the present invention;

Figure 4 is a more detailed circuit diagram of the circuit employed;

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Figure 5 is a chart showing input during recording plotted against output during playback; and

Figure 6 is a B-H diagram for the initial magnetization of a different permanent magnet material.

Referring first to Figure 1, there is illustrated a B-H curve typical of permanent magnet materials suitable for record elements. This chart represents magnetization (B) for different values of magnetizing force (H), assuming the material to be unmagnetized prior to subjection to the magnetizing force, a condition which is substantially achieved in the present invention. It will be observed that from the origin to the symmetrically located points a, a' , the magnetizing effect is negligible for magnetizing forces represented by h, h' . Beyond the points a, a' , the curve is sensibly straight, and it will be noted that values h, h' are selected such that the prolongations of the straight intermediate portions of the curve intercept the H axis substantially at the selected values. For all values of magnetizing force above h, h' and to substantial saturation of the material, the response is linear, and magnetization of the record element is directly proportioned to the magnetizing force. This permits recording and reproduction of sounds of variable intensity at their low relative intensity or magnitude, so long as the magnetizing force attributable thereto exceeds the values h, h' . However, if the magnetizing force varies directly with the magnitude of the audio signal, low intensity sounds will produce magnetizing forces falling between the points a, a' on the curve, and these magnetizing forces are incapable of producing reproducible recordings.

This fundamental difficulty has been recognized in the past, and efforts made to overcome it. For example, it has previously been proposed to add a supersonic component to the magnetizing current supplied to the electromagnet used in recording. This has the effect of eliminating or reducing the hysteresis effect of the record element, and permits recording to include low intensity sounds as well as high intensity sounds. However, when employed with conventional recording heads, it either fails to record or acts to erase or partially erase very high audio frequencies, and further it results in amplitude and frequency modulation of medium high audio frequencies.

A second method intended to overcome the inherent difficulties in effecting recording of sound at true relative intensities involved the use of a direct current bias, or partial magnetization

of the record element prior to recording. This of course limits the portion of the B-H curve used and fails to take full advantage of the recording potentials of the record element.

According to the present invention, the audio signal is used to produce a first variable controlling force, such as a voltage, which reverses sign or polarity substantially simultaneously with reversals of the signal, and which varies in magnitude directly with the audio signal. The audio signal or the first variable controlling force is used to produce a second controlling force of like character (such as voltage) which however, while it changes sign or polarity substantially simultaneously with the first, is of a predetermined and preferably substantially constant magnitude. These two controlling forces are used to control a magnetizing force, as for example the current in the windings of an electromagnet, so that the current is proportional to the sum of the two controlling forces.

Therefore, if the magnetizing force attributable to the second of said controlling forces is equivalent to the magnetizing forces h , h' , very low intensity sounds will be recorded at their true relative intensity. The value of the forces h , h' , are selected such that any record attributable to these forces alone is below the noise level.

Referring now to Figure 2, there is shown a curve plotted along the axis A which the pattern of an audio modulated controlling force, such as current, voltage, light, or other force. It will be observed that this force varies considerably in intensity and also changes its sign or polarity. At the point of the curve designated m there is shown a force of moderate magnitude which includes minor peaks of relatively high frequency superimposed upon a peak of relatively low frequency. At n there is represented a relatively large peak of force. If the force represented in the foregoing is used to produce a corresponding current applied to the windings of an electromagnet, the magnetic field established by low values of this current will be insufficient to effect permanent magnetization of a record element.

According to the present invention the force illustrated at A is reinforced or augmented by the force represented at B. In this case it will be observed that the force B is of substantially uniform magnitude and is always of the same sign or polarity as the force plotted at A.

The invention contemplates the method of and means for producing a magnetizing current equivalent to the resultant force which would be obtained by adding the forces plotted at A and B, as shown at C. It will be observed that the curve at C results from the simple addition of values represented by the curves A and B. It will further be observed that all values of the audio modulated current are thus increased to a relatively high value sufficient to effect permanent recording without the introduction of any appreciable frequency or relative amplitude distortion.

In order to carry out the foregoing, the apparatus diagrammatically illustrated in Figure 3 is employed. In this figure an incoming signal of audible frequency is applied to the grid of an amplifier tube 1 which may be a high gain triode, such as a 6SF5. The same indicating signal is applied directly to a mixing circuit, such as to a grid of a mixing tube such as a 6L7. The signal will be of such magnitude that both tubes

operate as linear amplifiers. The output of the amplifier 1 is fed through a limiting resistor 2 to a biased dual diode 3, such as a 6H6 tube. The bias for the dual diode 3 may be furnished by constant voltage dry cells. The output of the tube 3 is therefore an amplified version of the original signal with its phase shifted 180 degrees and with its peak values limited to the voltage of the dry cell. This output is fed to another high gain amplifier 4, such as a 6SF5, so that it will handle the voltage of one dry cell applied to its grid without distortion. Again, the output of the amplifier 4 is limited and clipped by another dual diode 6 identical with the dual diode 3, a limiting resistor 4 being interposed. Bias for the dual diode 6 is furnished by the same dry cells which furnish the bias for the dual diode 3. The output is accordingly a substantially square wave and a second phase shift of 180 degrees has taken place so that the sign or polarity of the output is the same as that of the original signal. The desired portion of the resulting square wave is selected by a voltage divider 7 and is then fed into the other control grid of the mixing tube 9. Accordingly the two control grids of the mixing tube 9 are independently operated; one by a voltage of variable magnitude and reversing polarity corresponding to the audio pattern of the signal to be recorded; and the other by a voltage which is of substantially constant magnitude and which reverses its polarity substantially simultaneously with the first voltage so as to be at all times of the same polarity therewith. The output of the mixing tube 9 is fed to an amplifier such as a 6L6 diagrammatically represented at 10, the output of which is fed through a blocking condenser to the windings of the electromagnet of the recording head.

Satisfactory results are obtained if resistors 2 and 5 are .1 megohm and the grid leak 12 and voltage divider 7 are .5 megohm. Except for precautions noted hereafter, other electrical values in the system are conventional and will be readily apparent to those skilled in the art.

The amplifier 10 is preferably a pentode which is chosen as it has a very high plate resistance and in combination with the recording head it will produce a current sensibly proportional to the grid voltage applied thereto. It is desirable that the cathodes and screens have very low impedance, i. e. very large capacity to ground. Further the plate circuits should be thoroughly decoupled from each other. The recording head windings are highly inductive. At the time the polarity of the signal changes, the pentode generates a high voltage across their windings in an effort to make the current follow the voltage. There is thus a tendency to oscillate. This oscillation is between the inductance of the head and stray capacity to ground. Careful reduction of this stray capacity to ground eliminates the oscillation or makes it of such high frequency that it is undetectable on an oscilloscope.

While the foregoing is believed sufficient to constitute an adequate disclosure of the circuits employed, Figure 4 is presented to give a detailed disclosure of the various elements of the circuit, the diagram being self-explanatory in the light of the foregoing. It will be apparent to one skilled in the art that currents through suitable networks could be added to obtain the desired field, rather than controlling this field by impressing the voltages referred to above on the

grids of a mixing tube. It will still continue important to maintain phase relationship.

In setting up the system for optimum results, vacuum tube volt meters are connected to each grid of the mixing tube 9. A signal of fixed frequency from an audio oscillator is fed in. The volt meter indicating the output of the voltage divider 7 will stay almost constant for any given setting of the voltage divider even though the input may be varied over a wide range. A setting of the voltage divider 7 is chosen and a record is made with various input voltages. This record is played back and output voltages are measured. These values are plotted as indicated in Figure 5 in which are illustrated three curves representing output during playback against input during recording. It is desirable to obtain a curve such that its relatively straight intermediate portion if projected would pass through the zero-zero point of the chart. If the initial testing results in a curve such as shown at L, which represents a condition resulting from low amplification, the output of the voltage divider is increased. If the test develops a curve such as shown at K, which is the condition which would result from too high amplification, the output of the voltage divider is reduced. The optimum results are obtained when the test produces a curve indicated at P, which, it will be observed, includes a relatively straight intermediate portion whose projection passes substantially through the zero-zero point O of the chart.

Recordings made in accordance with the present invention will operate to record with surprisingly high fidelity to very high audible frequencies. The results obtained are in part dependent upon the use of a recording head characterized by a very small and effectively constant gap width. With proper selection of gap width and design of recording head in a manner set forth in considerable detail in my prior copending application Serial No. 43,288, filed August 9, 1948, it is possible to obtain high fidelity recording throughout the entire audible range.

The foregoing description applies to a relatively simple case in which a constant magnetizing force in effect breaks the B-H curve for the initial magnetization of permanent magnetic material into two linear parts. This has proved entirely satisfactory in practice but of course it depends upon the fact that the intermediate portions of the B-H curve intermediate saturation in opposite directions and the zero point are sensibly straight lines. If a magnetic material is employed in which these intermediate portions of the curve are not sensibly straight lines, a further correcting approximation may be made by dividing these curves into three parts as indicated in Figure 6, the parts being O-X, X-Y and Y-Z. The correction for the effect of the portion O-A would be accomplished as already described except that the constant magnetizing force, instead of going directly to the grid of the mixing tube, would go to a resistance network. A biased amplifier is provided which will begin amplification for a voltage corresponding to the point X and be limited at a voltage corresponding to the point Y. Precautions will of course be taken to keep the phase angle correct. The output would go to another arm of the resistance network which would combine the signals in the correct portions and apply them to the grid of the mixing tube.

Furthermore the same general theory may be employed to correct the portion of the curve

beyond the point Z and complete saturation. In order to obtain the effect of correct proportional recording, a low time constant biased expander would be installed in the incoming signal lead. The bias would be such that the expander would start operation at a point corresponding to the point Z and have such an expansion factor as to make the curve beyond Z as nearly as possible a continuation of the curve Y-Z. The extension of the curve is indicated by dotted lines in the figure.

Throughout the foregoing specification and in the claims, reference is made to the magnetic recording of "sound." It will be understood that the invention is applicable to the recording of other signals, information or data whose frequency is within the range of the equipment.

The drawings and the foregoing specification constitute a description of the improved method and apparatus for magnetic recording in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What I claim as my invention is:

1. In a recorder for magnetically recording sound which comprises a recording head provided with an electromagnet having spaced poles adapted to be engaged by a continuously advanced record element formed of permanent magnet material, and windings for said electromagnet; a circuit for connection to the windings comprising means for supplying a first voltage of variable magnitude and reversing polarity corresponding to a sound pattern to be recorded, other means for supplying a second voltage of reversing polarity substantially in phase with the first voltage, and means responsive to said voltages for establishing a current in the windings which varies in accordance with the additive values of said voltages.

2. In a recorder for magnetically recording sound which comprises a recording head provided with an electromagnet having spaced poles adapted to be engaged by a continuously advanced record element formed of permanent magnet material, and windings for said electromagnet; a circuit for connection to the windings comprising means for supplying a first voltage of variable magnitude and reversing polarity corresponding to a sound pattern to be recorded, other means for supplying a second voltage of substantially constant magnitude and reversing polarity substantially in phase with the first voltage, and means responsive to said voltages for establishing a current in the windings which varies in accordance with the additive values of said voltages.

3. A recorder for magnetically recording sound which comprises a recording head provided with an electromagnet having spaced poles adapted to be engaged by a continuously advanced record element formed of permanent magnet material, and windings for said electromagnet; a circuit for said windings comprising a mixing tube, an output circuit connecting said tube to said windings, said tube having a pair of grids, means for impressing on one of said grids a voltage which varies in magnitude and polarity in accordance with a sound pattern to be recorded, and means for impressing on the other of said grids a voltage which is of substantially constant magnitude and the same instantaneous polarity as the voltage impressed on the said one grid.

4. Apparatus for making magnetic sound recordings which comprises means for establishing a magnetic field, means for varying the magnitude and polarity of the field comprising first control means operable to effect variations in magnitude and polarity of the field in accordance with a sound pattern to be recorded, and second control means operable to effect variations in the field which are of the same instantaneous polarity as the variations effected by said first control means.

5. Apparatus as defined in claim 4 in which said second control means is operable to effect field variations of uniform magnitude.

6. Apparatus for making magnetic sound recordings which comprises first means for establishing a sound modulated magnetic field controlling force which varies in magnitude and polarity, and a second means for establishing a second magnetic field controlling force which is of the same instantaneous polarity as the force established by said first means.

7. Apparatus as defined in claim 6 in which said second means establishes a controlling force of substantially constant magnitude.

8. Apparatus for recording sound magnetically on a record element formed of permanent magnet material which comprises means for establishing a magnetic field, means for advancing said record element continuously through the field, and means for varying the magnetizing effect of the field comprising first control means operable to establish a sound modulated field controlling force, and second control means operable to establish a field controlling force which is of the same instantaneous polarity as the force established by said first means.

9. Apparatus as defined in claim 8 in which said second control means establishes a force of constant magnitude.

10. Apparatus as defined in claim 9 in which the magnitude of the force established by said second control means is sufficient to cause variations in the magnetic field substantially equal to the coercive force of a record element on which the record is to be made.

11. Apparatus for recording sound magnetically on a record element of permanent magnet material comprising an electro-magnet having spaced poles and energizing windings, means for advancing a record element continuously through the field adjacent said poles, and means for establishing a magnetizing current in said windings which is equivalent to the result of the addition of a sound modulated current varying in magnitude and polarity with an additive current of the same instantaneous polarity as the sound modulated current.

12. Apparatus for recording sound magnetically on a record element of permanent magnet material comprising an electro-magnet having spaced poles and energizing windings, means for advancing a record element continuously through the field adjacent said poles, and means for establishing a magnetizing current in said windings which is equivalent to the result of the addition of a sound modulated current varying in magnitude and polarity with an additive current of constant magnitude and the same instantaneous polarity as the sound modulated current.

13. Apparatus for recording sound magnetically on a record element of permanent magnet material comprising an electro-magnet having spaced poles and energizing windings, means for advancing a record element continuously through

the field adjacent said poles, and means for establishing a magnetizing current in said windings which is equivalent to the result of the addition of a symmetrically sound modulated current varying in magnitude and polarity with an additive current of constant magnitude and the same instantaneous polarity as the sound modulated current.

14. Apparatus for magnetic sound recording comprising a control circuit for a magnet including a mixing vacuum tube having two grids, means for applying a sound modulated voltage varying in magnitude and polarity to one of said grids, and means for applying to the other grid a separate constant voltage of the same instantaneous polarity as the voltage on the first grid.

15. Apparatus for magnetic sound recording comprising a control circuit for a magnet including a mixing circuit having a plurality of branches, means for applying to one branch of said mixing circuit a sound modulated voltage varying in magnitude and polarity, and means for applying to another branch of said mixing circuit a separate voltage of the same instantaneous polarity as the voltage applied to said first branch.

16. Apparatus for magnetic sound recording comprising a control circuit for a magnet including a mixing circuit having a plurality of branches, means for applying to one branch of said mixing circuit a sound modulated voltage varying in magnitude and polarity, and means for applying to another branch of said mixing circuit a separate constant voltage of the same instantaneous polarity as the voltage applied to said first branch.

17. Apparatus for magnetic sound recording comprising a control circuit for a magnet including a mixing circuit having a plurality of branches, means for applying to one branch of said mixing circuit a sound modulated voltage varying symmetrically in magnitude and polarity, and means for applying to another branch of said mixing circuit a separate constant voltage of the same instantaneous polarity as the voltage applied to said first branch.

18. Apparatus for magnetic sound recording comprising a control circuit for a magnet including a mixing circuit having a plurality of branches, means for applying to one branch of said mixing circuit a sound modulated current which varies in magnitude and direction, means for applying to another branch of said mixing circuit a separate current the direction of which is instantaneously arithmetically additive to the current in said first branch.

19. Apparatus for magnetic sound recording comprising a control circuit for a magnet including a mixing circuit having a plurality of branches, means for applying to one branch of said mixing circuit a sound modulated current which varies in magnitude and direction, means for applying to another branch of said mixing circuit a separate current of constant magnitude the direction of which is instantaneously arithmetically additive to the current in said first branch.

20. In a recorder for magnetically recording sound which comprises a recording head provided with an electro-magnet having spaced poles adapted to be engaged by a continuously advanced record element formed of permanent magnet material, and windings for said electro-magnet; a circuit for connection to the windings

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comprising means for supplying a first voltage of variable magnitude and reversing polarity corresponding to a sound pattern to be recorded, other means for supplying a second voltage of substantially constant magnitude and reversing polarity substantially in phase with the first voltage, and means responsive to said voltages for establishing a current in the windings which varies in accordance with the additive values of said voltages, the magnitude of the voltage supplied by said other means being sufficient to cause a current in the windings substantially equal in magnitude to the coercive force of a record element to be magnetized.

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