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D. E. WOOLDRIDGE

2,265,831

METHOD AND APPARATUS FOR MAGNETIC RECORDING

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FIG. 1

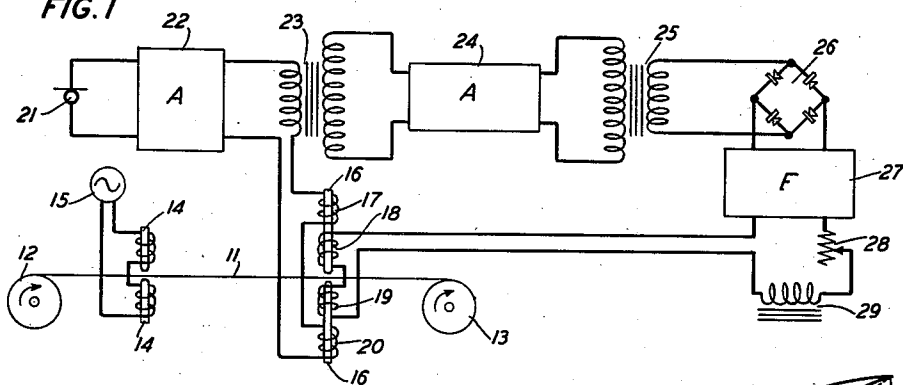


FIG. 2

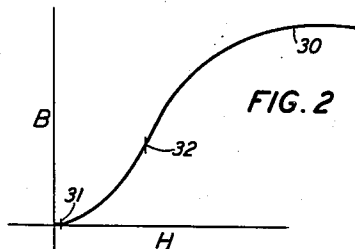


FIG. 4

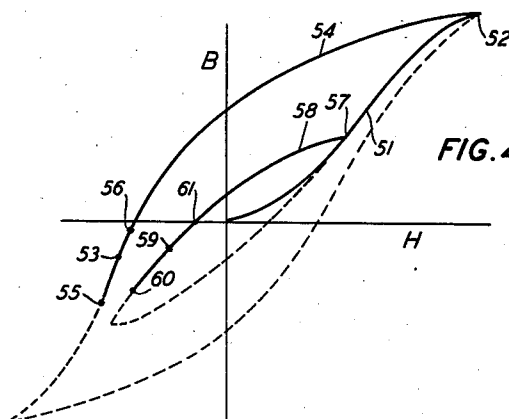
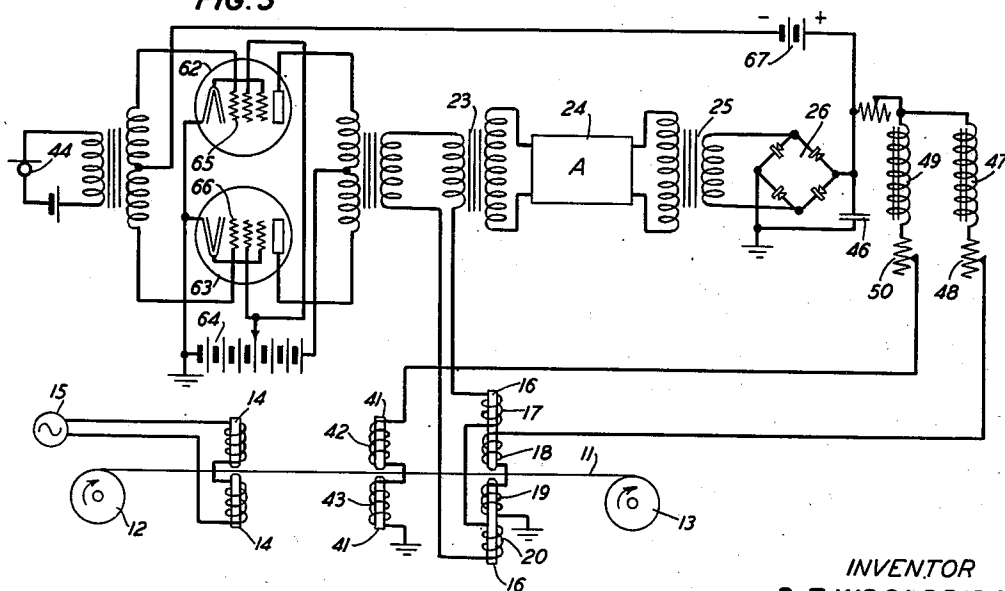


FIG. 3



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METHOD AND APPARATUS FOR MAGNETIC RECORDING

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14 Claims. (Cl. 179-100.2)

This invention relates to magnetic recording and the object of the invention is to increase the volume range of the record member of a magnetic recording system.

The lower limit of the useful volume range which can be recorded is largely determined by the inherent noise level of the tape or wire and the upper limit by the distortion produced when the tape is overloaded. Demagnetized tape has a lower inherent noise level than magnetized tape but undistorted signals of much higher level can be reproduced when the tape is properly biased during the recording operation.

In accordance with this invention, a wide useful volume range is obtained by recording low level signals on substantially demagnetized tape and providing the bias necessary for the high level signals to prevent them from being distorted. In one embodiment of the invention demagnetized tape is subjected simultaneously to the action of the signal flux and of a unidirectional flux which is automatically varied with the strength of the signal being recorded. In another embodiment of the invention the demagnetized tape is first passed through a unidirectional polarizing flux, then through a field composed of the signal flux and a depolarizing or biasing flux and both the polarizing and biasing fluxes are automatically varied in accordance with the strength of the signal.

These and other features of the invention will be more clearly understood from the following detailed description and the accompanying drawing in which:

Fig. 1 shows a system in which the demagnetized tape is variously biased in accordance with the signal;

Fig. 2 is a curve illustrating the operation of the system of Fig. 1;

Fig. 3 shows a system using polarizing and depolarizing fluxes both of which are varied according to the signal strength; and

Fig. 4 shows curves illustrating the operation of the system of Fig. 3.

In the system of Fig. 1, a magnetic tape or wire record member 11 is moved at a suitable recording speed by means of the usual reeling mechanism which is indicated by the reels 12 and 13. On leaving the reel 12, the tape member is first fully magnetized by the magnets 14, 14 which are energized by high frequency current from the source 15. This source may, for example, be a vacuum tube oscillating at a frequency, such as 20,000 cycles per second, which is well beyond the frequency range to be re-

corded to avoid the possibility of introducing noise.

The tape then approaches the recording pole-pieces 16, 16 in a completely demagnetized condition. These pole-pieces preferably each carry two coils 17, 18 and 19, 20, respectively, and may be of the type shown in Patent 1,944,238 to Hickman. The signals to be recorded are picked up by the microphone 21, amplified by the amplifier 22 and impressed on the recording coils 17 and 20 as shown. This recording current also flows in the primary of the step-up transformer 23 which impresses a relatively high voltage on the input of the power amplifier 24, the output of which passes through the output transformer 25 and is rectified by a suitable rectifier 26. The rectifier output passes through a low-pass filter 27 which must be effective to reduce the alternating components to a very low value. The filtered direct current is then supplied to the biasing coils 18 and 19 of the recording pole-pieces through a variable resistor 28 and a choke coil 29. The resistor permits the biasing current to be adjusted readily to the proper value and the high inductance of the coil prevents appreciable induction of voice currents in the biasing circuit from the recording coils.

With this system the rectified signal current carries the demagnetized tape approaching the recording magnets up the magnetization curve 30 of Fig. 2 a distance which varies continuously with the strength of the signals. The biasing circuit is so adjusted that for very low signal levels the bias current is sufficient to magnetize the tape only very slightly to the condition corresponding to a point such as 31 on the magnetization curve while for maximum signal levels the tape is brought to the condition represented by point 32 which may be about mid-way along the straight portion of the curve.

The alternating signal flux, which is superimposed on this unidirectional biasing flux then records by varying the condition of the tape up and down from the condition produced by the bias and the bias is automatically varied with the signal so that the record is always made with the minimum of biasing flux.

At very low signal levels the biasing current required is so small that the tape noise is not appreciably above the level of demagnetized tape and the high level signals are recorded with the same fidelity as can be obtained with a high constant bias. At the higher signal levels the inherent tape noise will, of course, be increased but due to the higher signal-to-noise ratio, this

increase in noise is much less objectionable and it does not limit the useful recording range.

With some record materials it is found that higher undistorted signal levels may be reproduced when the record is made on the hysteresis loop rather than on the magnetization curve. This involves first saturating the tape and then partially demagnetizing it and applying the signal to the tape in the partially demagnetized condition as explained in the Hickman patent referred to above.

The system of Fig. 3 combines this high signal level capacity with the low noise level feature of the system of Fig. 1. The telegraphone of Fig. 3 is similar to that of Fig. 1 in that the tape 11 is demagnetized by the magnets 14, 14 by high frequency current from the source 15, and the recording pole-pieces 16, 16 each have a signal winding and a biasing winding as in Fig. 1. There is, however, in addition, a third set of pole-pieces 41, 41 having windings 42 and 43 respectively, the purpose of which will be described below.

The sounds to be recorded are picked up by the microphone 44, amplified in the push-pull amplifiers 62 and 63, the output of which energizes the recording coils 17 and 20 and the transformer 23 which supplied signal energy to the rectifier 26 through the amplifier 24 and transformer 25 as in the system of Fig. 1.

The output of the rectifier is filtered to remove the voice frequency ripple by a suitable network or by a single condenser 46 of very large capacity. Direct current varying with the signal level in the coils 17 and 20 flows through the choke coil 47 and resistor 48 to the biasing coils 18 and 19 as before and a second current varying with the signal flows through choke coil 49 and resistor 50 to the coils 42 and 43 of the pole-pieces 41.

When the signal level is very high, the current in the coils 42 and 43 will be large and the demagnetized tape in passing the pole-pieces 41 will be carried up the magnetization curve 51 of Fig. 4 to some such point as 52. When an element of tape so magnetized reaches the pole-pieces 16, it is subjected to a flux produced by the combined action of the unidirectional current in the coils 18 and 19 and of the signal currents in the coils 17 and 20. The flux due to the current in coils 18 and 19 is in the direction to depolarize the tape and bring it to a condition which for the purposes of this explanation may be represented by some such point as 53 on the large hysteresis loop 54. This point is preferably determined empirically at the position which gives the maximum undistorted volume range. The action of the alternating signal flux in the coils 17 and 20, however, will cause the tape to be actually magnetized to the values indicated by points 55 and 56. It will be seen, therefore, that strong signals are recorded in the manner described in the Hickman patent with all the advantages inherent in that method of recording.

When the signal level decreases the polarizing current in the coils 42, 43 and the depolarizing or biasing current in the coils 18, 19 will both also be reduced. At some intermediate signal level, for example, the polarizing current will be sufficient to magnetize an element of tape passing the pole-pieces 41 only to the condition represented by point 57 on the curve 51. The flux due to the biasing current alone would bring the tape down along the curve 58 to some point 59 and the combined signal and biasing fluxes

demagnetize the tape to a condition between the limiting values of points 60 and 61 which are both within the relatively straight part of the curve. As the signal decreases still further in level, it is recorded without distortion on the straight parts of progressively smaller hysteresis loops. It will be observed that the progressively smaller signals are recorded with progressively less magnetization of the tape so that for very weak signals when tape noise is most objectionable, the tape is so slightly polarized as to produce but little, if any, increase in noise as compared with the noise level of demagnetized tape.

The values of polarizing and depolarizing current required will, of course, vary widely depending on such factors as the pole-piece design and the nature of the tape used. These values may be readily determined empirically for any given system, however, by varying the currents and observing the wave form reproduced with an oscilloscope in the manner well understood by those skilled in the art.

While changes in the polarizing and biasing currents do not affect a given element of tape at exactly the same time, the pole-pieces 41 and 16 may be spaced only one-half inch apart, or less, so that for a tape moving as little as 15 inches per second the delay in the changes in polarization is only one-thirtieth of a second and does not produce noticeable distortion or increased noise. It has been shown that by automatically varying both the polarizing and the biasing currents according to the signal strength, very strong signals are recorded without distortion and that the tape noise is reduced as the signal level falls so that even very weak signals will be well above the noise level.

With the system of Fig. 1, as already explained, very weak signals are recorded on the relatively straight portion below the toe of the curve 30 of Fig. 2 and very strong signals are recorded on the relatively straight portion above the toe. At some intermediate level the signals will, of course, be recorded on the toe portion and because of the appreciable curvature in this region some non-linear distortion will be introduced. This distortion is not nearly as great as might be expected, however, for the reason that the signals recorded on the toe are not of large amplitude and the deviation of the characteristic from linearity is not very great for the amplitudes involved.

An analogous situation may be presented in the system of Fig. 3 in cases where the curvature of the characteristic increases when the hysteresis loop becomes very small. Here again, however, the distortion introduced is less than might be expected because the characteristic is approximately straight for the small signal amplitudes which are recorded on such loops.

Any non-linear distortion is, of course, objectionable and it is, therefore, preferable to vary the polarizing current of the system of Fig. 1 and both the polarizing and depolarizing currents of the system of Fig. 2 with the signal level in such a manner that in Fig. 2, for example, the point at which the recording is made shifts very rapidly through the toe portion of the curve 30. In other words, the amplitude of the rectified signal current should vary with the signal strength in somewhat the same manner as the flux density B varies with the magnetizing force H in Fig. 2. Such a characteristic may be obtained in various ways, of which perhaps the most convenient is to bias one or more tubes

of the amplifier 24 nearly to cut-off to produce a plate current which first increases slowly and then more rapidly as the signal increases and to use a low plate voltage so that the tube overloads readily to limit the maximum amplitude of the plate current.

As already pointed out, the tape noise is most objectionable at low signal levels and in any case as the signal currents increase the tape noise increases to the value of magnetized tape so that the amplifier 24 or other current varying means may be adjusted to reach its maximum output at relatively low signal levels. When this is done the polarizing current may be made to increase rapidly with small increases in signal strength when the signals are recorded near the toe of the curve 30 so that the recording point moves through the curved toe to the straight portion of the curve with only a small change in signal level. In a similar manner any non-linear distortion in the system of Fig. 3 may be substantially reduced in cases where the hysteresis loops depart materially from straight lines over the portions used for recording purposes.

It will be noted that the slope of the curve 30 of Fig. 2 is much greater at the point 32 where high level signals are recorded than it is in the region near point 31 where the low level signals are recorded. Similarly when using the system of Fig. 3, slope of the loop 54 (Fig. 4) between the points 55 and 56 is considerably greater than the slope of the lower level signal loop 58 between the points 60 and 61. But a mere change in the slope of a straight characteristic does not produce non-linear distortion and for any given sound intensity the reproducing flux will at every instant be strictly proportional to the corresponding recording current.

An increase in the slope with increasing signal level will, however, produce a change in the ratio between the output flux and the recording current. As the tape passes away from the recording magnets and the magnetizing force H falls to zero, the residual induction left by a strong signal will be not only greater but also disproportionately greater than the induction produced by the weaker signal. In other words a given volume range of the signal currents is recorded in the tape as a wider range of magnetization. In one case a volume range of 35 decibels had a range of 50 decibels when reproduced. This expansion of the original signal may be advantageous in some cases but where, as in the usual case, the volume range of the recording medium is already a limitation of the system, this expansion is objectionable. When desired, it can be eliminated by varying the gain of the recording amplifier in such a manner as to compensate for the changing slope of the recording characteristic.

In Fig. 3 the amplifying tubes 62, 63 are preferably of a type in which the gain varies widely with the grid bias. They are connected in push-pull and supplied with power from a source 64 in the conventional manner except that the control grids 65, 66 are connected through the static biasing means 67 to the output of the rectifier 26 so that the negative bias on these grids increases with the signal level. The static and variable biases may be so chosen that as the signal level varies the variations in bias will so vary the gain of the tubes that the recorded volume range will correspond quite closely to the volume range of the original signals.

It will be understood that this variable negative biasing feature may also be used in connection with the system of Fig. 1 to compensate for the expansion introduced by the increasing slope of the characteristic 30 of Fig. 2. Any known type of filter suitable for the purpose may be used in the output of the rectifier of either system and the time constants of the filter circuit can be varied in accordance with known principles to suit the requirements of the particular case.

What is claimed is:

1. The method of magnetic recording which comprises subjecting the record member simultaneously to the action of an alternating flux representing signals to be recorded and to the action of unidirectional flux which varies with the strength of the signal from a small value which does not materially increase the noise level of the tape at low signal levels to a value which causes the stronger signals to be recorded without substantial distortion.
2. The method of recording, according to the preceding claim, in which the record member is first passed through a high frequency field.
3. The method of magnetic recording which comprises demagnetizing the recording member, moving it through a unidirectional polarizing flux, subjecting the polarized member simultaneously to the action of a depolarizing flux and an alternating flux representing the signals to be recorded and simultaneously varying the polarizing and depolarizing fluxes in accordance with the strength of the signal.
4. In a magnetic recording system, the combination with a moving record member, a source of high frequency current for demagnetizing the member, a recording pole-piece cooperating with the member and means for producing in the pole-piece an alternating flux representing signals to be recorded, of means for superimposing on the alternating flux a unidirectional flux varying with the strength of the signal.
5. In a magnetic recording system, the combination with a moving record member, a recording magnet cooperating with the member, and a source of currents representing signals to be recorded connected to the magnet, of a second connection between the source and the magnet including a rectifier.
6. In a magnetic recording system, a moving magnetic tape, means including a source of current of a frequency above the range to be recorded for demagnetizing the tape, a recording pole-piece having signal and biasing coils cooperating with the tape, a pick-up microphone, an amplifier having an input circuit connected to the microphone and an output circuit connected to the signal coil of the pole-piece, a rectifier having an input circuit connected to the output of the amplifier and an output circuit connected to the biasing coil, means for filtering out voice frequency components in the output of the rectifier and means for limiting currents induced in the biasing coil by currents in the signal coil.
7. In a magnetic recording system, the combination with a moving record member, polarizing and recording pole-pieces in closely spaced relation cooperating with the member and means for producing in the recording pole-piece an alternating flux corresponding to signals to be recorded, of means for demagnetizing the member before it reaches the pole-pieces and means for producing in the polarizing and recording pole-

pieces opposing unidirectional fluxes each varying with the level of the signals.

8. In a magnetic recording system, a moving magnetic tape, means including a source of current of a frequency above the range to be recorded for demagnetizing the tape, a recording pole-piece having signal and biasing coils cooperating with the tape, a pick-up microphone, an amplifier having an input circuit connected to the microphone and an output circuit connected to the signal coil of the pole-piece, a rectifier having an input circuit connected to the output of the amplifier and an output circuit connected to the biasing coil, a polarizing pole-piece cooperating with the tape between the demagnetizing means and the recording pole-piece, a polarizing coil on the polarizing pole-piece and a connection from the output of the rectifier to the polarizing coil.

9. In a magnetic recording system, the combination with a moving record member, polarizing and recording pole-pieces in closely spaced relation cooperating with the member and means including a pick-up microphone and an amplifier for producing in the recording pole-piece an alternating flux corresponding to signals to be recorded, of means for demagnetizing the member before it reaches the pole-pieces, means for producing in the polarizing and recording pole-pieces opposing unidirectional fluxes each varying with the level of the signals, and means for compressing the volume range of the output of the amplifier.

10. In a magnetic recording system, the combination with a source of current representing signals to be recorded, an amplifier for amplifying the current, a demagnetized record member, a recording magnet connected to the amplifier and cooperating with the member, means for variably polarizing and biasing the member in

accordance with the strength of the signals being recorded and means for varying the gain of the amplifier to compensate for the effect on the recorded volume range of the variations in polarization and bias of the member.

11. The method of claim 1 in which the rate of change of the unidirectional flux with changes in the strength of the signal is varied to minimize the distortion in the record member.

12. The method of claim 3 in which the rate of change of the polarizing and depolarizing fluxes with variations in signal strength is varied according to the characteristics of the material of the record member to minimize the distortion in the record member.

13. The method of magnetic recording which comprises subjecting a demagnetized record member simultaneously to the action of a unidirectional flux and an alternating flux representing signals to be recorded and varying the unidirectional flux with the signal strength from a value for weak signals which does not materially increase the noise of the record member to a value for strong signals which permits strong signals to be recorded without substantial distortion.

14. In a magnetic recording system the combination with a moving record member, a recording pole-piece cooperating with the member, a source of current representing signals to be recorded and means for producing in the pole-piece an alternating flux corresponding to the signal current, of means for superimposing on the alternating flux a unidirectional flux varying with the amplitude of said current, and means for varying the rate of change of the unidirectional flux with changes in said current and for limiting the maximum value of the unidirectional flux.

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