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(54) PRESSURE PICK-UP FOR THE PLAYBACK OF DEFORMATIONS OF A RECORD CARRIER MOVED IN RELATION TO IT

(71) We, TED BILDPLATTEN AKTIENGESELLSCHAFT AEG-TELEFUNKEN-TELDEC, A Swiss Body Corporate, of Postfach 126, Hanibuhl 8, Zug, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to a pressure pickup arrangement for the playback of deformations of a record carrier moved in relation to it.

A system has already been proposed for the reproduction of signals which have been recorded and stored on a record carrier, the surface of which possesses deformations corresponding to the recorded signal, a pickup being used which exerts, with its contact surface, a pressure force upon the record carrier surface moved past it. As pickup in this case a piezo-electric or magnetostrictive pressure pickup is used, excited by the variations of the pressure force which corresponds to the deformations of the record carrier surface. Thus, in this pickup, a transducer body is used which is compressed in the direction of the pressure force. The contact with the carrier surface takes place directly or through a coupling piece of substantially rigid form. In connection therewith, furthermore, the pickup device proposed enables even very high frequencies to be satisfactorily picked up, that is frequency ranges which differ greatly from those which come under consideration in the ordinary gramophone record. By way of example, such a pickup device should be able to serve for the reproduction of pictures which have been converted, according to the television standard, into signals and recorded on discs and duplicated in a similar way to that used in sound recording on discs. In this case the pickup must be capable of picking up frequencies of several megahertz from the disc.

For this purpose the piezo-electric or magnetostrictive pickup is formed as a small prismatic body in the form of a parallelepiped, for example a cube, which acts as an oscillator in the direction of its thickness. In this case, it has a length which is less than half of the wave length of a mechanical oscillation, in the transducer body, of the upper limit frequency of the pickup transmission range.

The known ceramic materials lead-zirconate-titanate or potassium-sodium-niobate are especially well adapted as material for the transducer oscillator, since their frequency constants render possible dimensions of the transducer which permit relatively simple production.

At first, it would appear that for satisfactory pick-up, as in the sound frequency record art, it would be necessary to make the tip of the pick-up so that it rests on the record carrier only over a fraction of one wave length. However, in the scanning of recorded television signals, in the case of a groove width of 10μ, wave lengths of about 3μ come into consideration, so that in practice it is hardly possible to work with a pick-up whose tip in the groove direction (as in the sound frequency record) has only an extent of less than one half wave length of the highest recorded frequency. With a still reliably realisable bearing force of 0.5 p. the strength limit of the record material would be far exceeded. Moreover such a pick-up would act like a plane and would shear off the raised parts of the groove modulation with its sharp point, such as would be necessary if the pick-up contact member rested on the record carrier only over the fraction of one wave length.

[*Price 25p*]

Price 75p

Moreover such a pick-up contact member would not be able to follow the deformation of the surface when scanning very high frequency recorded signals such as are present in a television recording, on account of the inertia of the mass of the contact member. The high points of the groove modulation must then yield elastically to the pickup contact member, which leads to distortion of the picked up signals.

Therefore, with the initially mentioned system, it has already been proposed to use a pickup contact member, the contact surface of which is so formed that, in the direction of the pickup path, it rests on a section which is greater than the largest recorded wavelength, and that in a plane section taken in the same direction and perpendicularly to the carrier surface it forms a defining curve which has different steepnesses at the leading and trailing sides. Wear of the contact surface of the pickup is reduced by its resting upon a plurality of peaks of the recording. The pressure force on the pickup surface is then proportional to the respective total value of the reaction forces applied by the individually deformed elements.

The resultant alternating force is the greater, the greater is the asymmetry of the pickup flanks. The resultant force reaches a maximum value when the flank steepness on the trailing side becomes infinity. Thus as far as possible this flank should stand perpendicularly to the support surface, that is the angle between the contact surface and the trailing edge of the pickup contact member is 90°. Smaller angles lead to the same result.

Under the influence of the bearing force, the surface of the record carrier, which is assumed to be elastic, will be deformed somewhat as represented in Figure 1, which shows a section through a pickup and a foil carrier in the longitudinal direction of a groove provided with a hill-and-dale recording.

The pickup comprises a piezo-electric ceramic body 1, to which a contact member in the form of a skid 3 of sapphire or diamond is secured by an adhesive or soldered joint 2. On a relative movement between the contact member and carrier 4, it registers the resultant force which is exerted by the foil carrier 4 upon the lower or contact surface of the pickup. This force changes according to the recorded wave length and is given by the average bearing force with respect to time. The direction of movement of the carrier 4 is indicated by an arrow in Figures 1 and 3.

For the following considerations it is assumed that the effective mass of the pick-up is so great that on the basis of the alternating force exerted upon it by the oscillation which corresponds to the wave length (for example several MHz in the case of video recording), it can carry out practically no movement perpendicularly to the carrier surface. With this assumption, an essential problem arising in the form of pressure play back as described consists in that for the production of the resultant force upon the pick-up, a three-dimentional relatively widely extending range of the groove modulation is necessary, the entire range containing playback information in chronological succession.

Due to different flank steepnesses of the pick-up skid on the leading and trailing sides, as well be explained further hereinafter, it is possible to achieve the object that the resultant force in first approximation corresponds to the effect of the information recorded on the record carrier which is situated in each case beneath a quite specific part of the pick-up skid. For reasons of carrier and pick-up wear, it is expedient to provide the pick-up skid on the leading side with a greater flank angle than on the trailing side.

In the play back of a foil carrier with a pick-up of the kind as described above, interference in the information picked-up can occur whereby the reproduction quality is impaired.

The invention seeks to reduce or eliminate the interference which makes itself especially noticeable in that, in the picked up signals, there are contained high-frequency signal proportions which are not present to the same extent in the recorded information.

According to the invention, there is provided a pressure pickup arrangement for the playback of deformations of a record carrier moved in relation to it said deformations being elastically compressible surface features formed in grooves and corresponding to the signal to be reproduced, comprising a mechanical-electrical transducer to which pressure variations are transmitted by a skid like portion separate from or integral with the mechanical-electrical transducer, said skid like portions engaging said deformations and having a length greater than the longest wavelengths intended to be reproduced and a low pass network, the limit frequency of which lies in the vicinity of or just below double the lowest instantaneous frequency of the signal to be reproduced, the signal being an angle-modulated signal.

Preferably, the angle-modulated signal is a frequency-modulated signal.

The invention will now be further described with reference to Figures 1 to 5 of the accompanying drawings.

Under ideal conditions, that is if the formation of the deformations of the record carrier surface is purely sinusoidal and these deformations are elastically entirely levelled under the influence of the bearing force of the pickup, in a pickup according to Figure 1 there occurs approximately the pressure distribution $p\ (x)$ represented in Figure 2 upon the contact member along its longitudinal extent x, measured from the edge situated on the left in Figure 1 and designated in Figures 2 and 4 with the co-ordinate value x_0.

As indicated in Figures 1 and 3, with the usual synthetic plastics materials as material for the record carrier, the situation in which the deformation of the support surface corresponding to the recorded signal is elastically entirely levelled under the influence of the bearing force of the pickup does not, however, occur. From this it results that the pressure distribution along the under side of the pick-up is not purely sinusoidal, but rich in harmonics, as shown by way of example by Figure 4.

Assuming the conditions according to Figures 1 and 4, the outcome is the resultant alternating force P (t) upon the pick-up as represented in Figure 5, which pick-up in the course of the time t — commencing with the moment to — moves over the deformations of the foil record carrier. When this resultant alternating force is converted by the mechanical-electrical transducer body of the pick-up proportionally into an electric voltage, the harmonics contained therein can make themselves interferingly noticeable in the reproduced signal.

For this reason the harmonics are suppressed by the filter formed in accordance with the invention. In order to suppress as little as possible the upper frequencies of the signal, one should place the limit frequency of the filter in the vicinity of or just below a frequency which is equal to twice the value of the lowest momentary frequency of the chronological course of the recorded signal amplitude. This presupposes that the lowest instantaneous frequency is at least half the highest instantaneous frequency.

The signal can be an angle-modulated, preferably a frequency-modulated signal. In this case the limit frequency of the low-pass filter network should lie in the vicinity of, or just below, double the lowest instantaneous frequency occurring in the modulated signal.

In order to be able to discuss further improvements of the pressure pick-up according to the invention, more detailed considerations of the processes occurring in pickup are necessary.

For this purpose a frequency-modulated recording with constant amplitude will be assumed.

The course of the alternating part of the deformation of the carrier surface corresponding to the signal is given by the function y.

Then: $y=\hat{y} \cdot \sin (k \cdot x)$ (Eq. 1)

where:

$\hat{y}$ is the amplitude of the alternating part of the surface deformation
x is the coordinate running in the groove direction
k is the number of waves of the recorded carrier wave at the contact point,
k is dependent upon location in the case of frequency modulation

Along the under side of the contact skid, under the conditions as selected in Figure 1, pressure occurs somewhat as illustrated in Figure 2. This pressure $p\ (x)$ can be approximated mathematically, in the range which is of interest, by the following function:

$$p\ (x)=\hat{p_o} \cdot e^{-a\ (x-x_0)}\ (1+\sin kx) \text{ for } x_0 \leqq x \leqq \infty \quad \text{(Eq. 2)}$$

In the equation:

x_0 is the location of the pickup contact edge (on account of the relative movement between scanner and support this location is variable, regarded from the support, in the case of constant scanning speed it is proportional to the time),
x is the coordinate running in the groove direction,
p_o is the amplitude of the alternating pressure in immediate vicinity of the scanner edge (lowest point of the scanner),
a is a measure for the steepness of the e-function,
k is again the number of waves of the recorded carrier wave.

Equation 2, or the equation 2a obtained by multiplying out: $p\ (x)=\hat{p_o}e^{-a\ (x-x_0)}+\hat{p_o}e^{-a\ (x-x_0)} \sin kx$ (Eq. 2a) illustrates the physical fact that the two sum terms (the mean pressure and the superimposed alternating pressure amplitude) are at a maximum

in the vicinity of the edge ($x=x_o$) and decrease gradually in the positive x-direction.

In the case of a modulation, assumed as sinusoidal, with the wave number: $k=k_o-k_1 \cdot \sin mx$ (Eq. 3) with the constants k_o, k_1 and m—m is a wave number which characterises a video signal of low frequency — the alternating component P~ of the resultant force on the scanner is ascertained by integration of the second term of Equation 2a over the bearing area as:

$$P\sim = p_o \cdot l \int_{x_0}^{L} e^{-a(x-x_0)} \sin (k_o + k_1 \sin mx) \times dx \qquad \text{(Eq. 4)}$$

l is the effective track width, $l \cdot dx$ accordingly an element of the bearing area.

P~ is a function of x_0 (the location of the pick-up edge) and of the effective pick-up length L. If the bearing length L is greater than one wave length, then the value of the integral will no longer be substantially changed if, to simplify the calculation, one assumes the upper limit of the integral as equal to ∞.

Although this resultant alternating force P~ does not correspond exactly to the signal recorded on the support $y=\hat{y} \cdot \sin (k_o + k_1 \sin mx)\, x$ (Eq. 1 and Eq. 3) by way of example a video signal recorded by frequency modulation can be scanned with adequate quality with a pressure pick-up, if this pressure pick-up effects a conversion of the alternating force acting upon it into an electric signal proportional thereto.

However the quality of the reproduction can be improved further if the pressure pick-up, together with networks connected after it, is suitable for the conversion of the resultant alternating force acting upon it into such a signal as its proportional, at least in the range of its low-frequency parts, approximately to the first derivation of the alternating force according to time.

The time differentiation of the voltage occurring on the output of the scanner due to the alternating force P~ contributes to restoring the original signal after the play back.

To this operation there corresponds mathematically a differentiation of Equation 4 towards the lower limit $x_o=v.t$, where v signifies the relative speed between pick-up and support and t the time. This differentiation is obtained according to Hütte I, 28th edn., p. 107, Para. 5

$$(5) \quad \frac{dP_\sim(x_0)}{dx_0} = -l\hat{p}_0\left[\sin(k_0+k_1 \sin mx_0)x_0 - \int_{x_0}^{\infty} ae^{-a(x-x_0)} \sin(k_0+k_1 \sin mx)\,x\,dx\right]$$

The integral still contained herein agrees, except for the constant factor, a, with the integral of Eq. 4, thus

$$\frac{d\,P\sim}{dx_o} = a\,P\sim - \hat{p}_o l \sin (k_o + k_1 \sin mx_o)\,x_o \qquad \text{(Eq. 6).}$$

The first part a P~ is negligible in comparison with the second part $p_o l \sin (k_o + k_1 \sin mx_o)\,x_o$, if $a \ll k$ or $a \ll k_o - k_1$. This can be seen especially from an example of low modulation, that is $(k_o + k_1 \sin mx_o) \approx k$:

For constant k there is valid:

$$P\sim = \hat{p}_o l \int_{x_0}^{L\to\infty} e^{-a(x-x_0)} \sin kx\,dx \qquad (7)$$

According to Hütte I, 28th edn. p. 96, No. 34 there follows:

$$(8) \quad P_\sim = \frac{-\hat{p}_0 . l . e^{-a(x-x_0)}}{a^2+k^2}\left[a \sin kx + k \cos kx\right]$$

$$(9) \quad P_\sim = \frac{+\hat{p}_0\, l\left[a \sin kx_0 + k \cos kx_0\right]}{a^2+k^2}$$

$$(10)\quad \frac{dP_\sim}{dx_0} = \frac{+\hat{p}_0 \ell}{a^2+k^2}\left[ak\cos kx_0 - k^2 \sin kx_0\right]$$

If $a \ll k$

$$(11)\quad \frac{dP_\sim}{dx_0} = -\hat{p}_0 \ell \sin kx_0$$

Thus

$$(12)\quad \frac{dP_\sim}{dx_0} = -\hat{p}_0 \ell \sin (k_0 + k_1 \sin mx_0)\, x_0$$

that is to say $\frac{dP_\sim}{dx_0}$ is proportional to the original signal (Eq. 1).

In the case of constant relative speed v between the pick-up and the record carrier, this signifies that the first time derivation must be formed from the alternating force $P_\sim$ in order to obtain the original signal, as true to life as possible.

If the mechanical-electrical transducer body of the pickup converts the resultant alternating force exterted by the record carrier upon the pickup into an approximately proportional electrical signal, the formation of the first derivation can be effected by a subsequently placed network which differentiates the electric signals generated during playback, before demodulation.

The circuit for differentiation of the output signals comprises either a differentiating element or a high pass filter which acts below its limit frequency as a differentiating element. The limit frequency is designed to lie below and in the vicinity in which the lowest frequency of the lower first side-band is located in the frequency spectrum of the frequency-modulated oscillation. Accordingly a high-pass filter connected in series after the transducer body can be provided for damping of the low frequency parts which are contained in the electric signals which are generated during playback.

The differentiation circuit of the high-pass filter can be produced with minimum expense in that the capacitance of the pickup is also used as part of the circuit, e.g. of the high-pass filter. In the electrical equivalent-circuit diagram of the transducer body of the pickup, this capacitance is connected, as internal impedance of the transducer body, in series with an equivalent voltage source. It is therefore sufficient to connect a resistance dimensioned in the correct ratio to the said capacitance to the electrodes of the transducer body. This resistance together with the capacitance can form the differentiation circuit arrangement of the high-pass filter.

If a high-pass filter with definite passband limit is connected in series after the pick-up for the scanning of an angle-modulated video signal, the limit frequency of this filter is to be placed above 50 kHz but below the lowest momentary frequency of the angle-modulated signal. On frequency modulation, the lowest momentary frequency corresponds to the lower limit of the range of the frequency-modulated oscillation within which the instantaneous values of the frequency of the modulated oscillation vary.

In general it can be shown that the pressure amplitudes do not have to die away according to an exponential function, as was assumed in Equation 2, but any gradual decrease can be permitted. This is given when the pick-up skid possesses only one "sharp" edge.

By "sharp" it is here to be understood that the edge is formed so that the record carrier, on the trailing edge, comes out of contact with the pick-up skid within a distance which is preferably less than one half wave length. The other side of the skid — the leading side in the example shown in Figure 1, must be so formed that a gentle constant rise of the alternating pressure is obtained to the rear "sharp" edge, which pressure then dies away there extraordinarily rapidly.

Such a course in practice can be achieved either by a shaping for the pick-up skid such as was assumed in Figure 1, or by a skid with a straight edge which is inclined slightly in relation to the upper surface of the record carrier, as shown in Figure 3. In this Figure again the piezo-electric ceramic body is designated by 1, the soldered joint by 2, the skid of sapphire or diamond by 3, the record carrier by 4, the leading straight edge of the skid 3 by 5 and the nearly perpendicular trailing edge by 6. The angle which the leading edge of the scanning skid forms with the upper surface of the carrier should lie between about 1° and 20°.

In the case of a pick-up skid with curved shaping according to Figure 1, good results have been achieved with a large radius of curvature on the leading edge in the groove direction, which is greater than about five times the maximum recorded wave length, and with a very small radius of rounding on the trailing edge which is less than half the smallest recorded wave length.

As already mentioned, the deformations of the support surface which correspond to the recorded signal do not need to be evened out elastically entirely under the influence of the bearing force of the pick-up. For $a \ll k$ in this case too the derivation of the resultant force upon the pick-up is proportional to the pressure course of the pick-up edge, in accordance with Equation 5:

$$\frac{d\ P\sim (x)_0}{dx_0}\sim - p(x_0)$$

Assuming the conditions according to Figure 1 and Figure 4, then a picked up voltage according to Figure 5 with high proportion of harmonics occurs.

In the examples described above the pressure pick-up is provided with a skid of wear-resistant material. The derived relationships are however also valid for the dimensioning of a pick-up without skid, that is where the ceramic piezo-electric or magnetostrictive body directly engages the surface of the record carrier.

For the conversion of the pressure fluctuations into electric voltages — as already mentioned at the outset — a piezo-electric ceramic body is expediently used. Likewise other transducers, for example piezo-magnetic or magnetostrictive transducers and also pressure-sensitive semi-conductors can also be used.

The skid 3 in Figure 3 — if it is to serve for the play back of frequency-modulated video signals — can have a length of about 0.2 mm. At the bottom it is made in wedge shape. The sharp edge of the wedge is however rounded off. This rounded edge forms the leading edge 5 of the skid 3, which is preferably inclined at about 10° in relation to the carrier surface. In the carrier surface there is a spiral groove. The groove flanks each have the elastically impressable, relief-type deformations as represented in Figure 3, the contour of which corresponds to a frequency-modulated oscillation. The rounded edge of the wedge-shaped skid slides on the deformations of both groove flanks and in doing so almost entirely levels out the deformations elastically. The ceramic body (transducer body) 1 effects a proportional conversion of the alternating force exerted upon it into an electric voltage. The limit frequency of the low-pass network 10 in Figures 1 and 3, that is the frequency at which the damping in relation to low frequencies has risen by 3 db, amounts to barely double the lowest momentary frequency of the picked up signal.

The high-pass filter 11 represented in Figure 3 possesses a limit frequency for example of 500 kHz, which lies above 50 kHz but below the lowest momentary frequency of the scanned signal.

The high-pass filter consists of the capacitance of the piezo-electric ceramic body (converter body) and a cross resistance. If a differentiating element is connected in series directly after the ceramic body, the capacitance of the ceramic body can likewise form a part of the differentiating element.

WHAT WE CLAIM IS:—

1. A pressure pickup arrangement for the playback of deformations of a record carrier moved in relation to it said deformations being elastically compressible surface features formed in grooves and corresponding to the signal to be reproduced, comprising a mechanical-electrical transducer to which pressure variations are transmitted by a skid like portion separate from or integral with the mechanical-electrical transducer, said skid like portion engaging said deformations and having a length greater than the longest wavelength intended to be reproduced and a low pass network, the limit frequency of which lies in the vicinity of or just below double the lowest instantaneous frequency of the signal to be reproduced, the signal being an angle-modulated signal.

2. An arrangement according to Claim 1, wherein the signal is a frequency modulated signal.

3. An arrangement according to Claim 1 or Claim 2, wherein said lowest instantaneous frequency is at least half the highest instantaneous frequency.

4. An arrangement according to any one of Claims 1 to 3, wherein the pressure pickup, together with networks connected in series with it, is adapted for the conversion of the resultant alternating force acting upon it into a signal such that, at

In the case of a pick-up skid with curved shaping according to Figure 1, good results have been achieved with a large radius of curvature on the leading edge in the groove direction, which is greater than about five times the maximum recorded wave length, and with a very small radius of rounding on the trailing edge which is less than half the smallest recorded wave length.

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For the conversion of the pressure fluctuations into electric voltages — as already mentioned at the outset — a piezo-electric ceramic body is expediently used. Likewise other transducers, for example piezo-magnetic or magnetostrictive transducers and also pressure-sensitive semi-conductors can also be used.

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The high-pass filter 11 represented in Figure 3 possesses a limit frequency for example of 500 kHz, which lies above 50 kHz but below the lowest momentary frequency of the scanned signal.

The high-pass filter consists of the capacitance of the piezo-electric ceramic body (converter body) and a cross resistance. If a differentiating element is connected in series directly after the ceramic body, the capacitance of the ceramic body can likewise form a part of the differentiating element.

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2. An arrangement according to Claim 1, wherein the signal is a frequency modulated signal.

3. An arrangement according to Claim 1 or Claim 2, wherein said lowest instantaneous frequency is at least half the highest instantaneous frequency.

4. An arrangement according to any one of Claims 1 to 3, wherein the pressure pickup, together with networks connected in series with it, is adapted for the conversion of the resultant alternating force acting upon it into a signal such that, at

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least the low-frequency portions are approximately proportional to the first time derivation of the alternating force.

5. An arrangement according to Claim 4, wherein the mechanical-electrical transducer body is adapted to convert the resultant alternating force exerted by the support upon the skid into an approximately proportional electric signal.

6. An arrangement according to Claim 5, wherein an electric network is connected in series with the transducer, which network differentiates the electric signals generated by the transducer, at least in the low-frequency range, before demodulation of the signal.

7. An arrangement according to Claim 1, wherein a high-pass filter is provided for damping of the low-frequency portions which are contained in the electric signals which are generated during play back.

8. An arrangement according to Claim 6 or 7, wherein the network or the high-pass filter incorporates the capacitance of the pressure pick-up.

9. An arrangement according to Claim 8, wherein for the play back of an angle-modulated video signal the high-pass filter possesses a limit frequency above 50 kHz but below the lowest instantaneous frequency of the angle-modulated signal.

10. An arrangement according to any one of Claims 1 to 9, wherein the skid has a leading edge so formed that the pressure increases over a distance of about one to a hundred wave lengths and a trailing edge so formed that the pressure drops off to zero over a distance which is equal, at maximum, to a half wave length.

11. An arrangement according to Claim 10, wherein the leading edge is curved and has a radius of curvature which is greater than about three times the maximum recorded wave length, and in that the trailing edge has a radius of rounding which is smaller than half of the smallest recorded wave length.

12. An arrangement according to Claim 10, wherein the leading edge is rectilinear and inclined at an acute angle to the carrier surface and the trailing edge is perpendicular or nearly perpendicular to the support surface.

13. An arrangement according to Claims 10 or 11, wherein the angle which the leading edge forms with the support surface is greater than 1° and less than 20°.

14. A pressure pickup substantially as described herein with reference to the drawings.

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