Noise Modulation in Recording

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Causes of noise modulation in disc recording and how they may be overcome

DUE PARTLY to the influence of the f-m program and partly to the competition of various new forms of sound recording, standards of performance in the disc recording field are improving rapidly. The newer British phonograph records, together with the advent of feedback recording heads, improved disc materials, shapes of styli, etc., have all served to make possible the use of wider range reproducing playback facilities.

However, widening of frequency response and improving of all forms of distortion uncover from time to time certain residual "inherent" defects of systems, recording or otherwise. For example, the appearance not long ago of higher quality loudspeakers met with harsh words at first in some quarters because when they were attached to existing systems already in operation by the customer they drew aside the curtain on all forms of high frequency trouble—c r o s s-modulation, non-linearity, and even parasitics. The speaker itself was blamed. These defects had theretofore been buried in the much greater shortcomings of the previous loudspeaker or concealed by its limited frequency response, or both. In the same way, shortcomings of the established disc recording methods are gradually being exposed. One of the most glaring deficiencies in disc recording (which incidentally has a certain parallel in magnetic wire or tape) is the matter of noise modulation.

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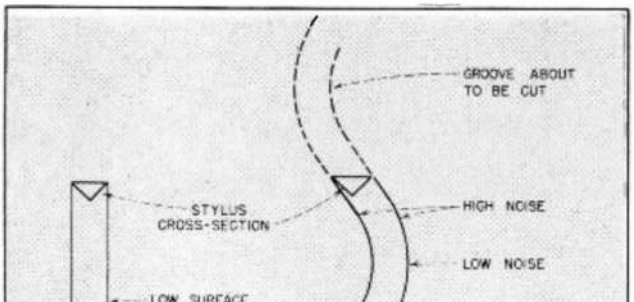
Introducing Noise Modulation

It is a matter of common knowledge with experienced disc recorders that one of the prime essentials to the obtaining of a quiet groove is the correct mounting in the cutter of the cutting stylus. The stylus set screw must of course come to rest directly upon the milled flat of the stylus shank in order that the stylus be pointing straight ahead. Otherwise, the stylus will be twisted in the mounting and a noisy cut will result. Yet a glance at *Fig. 2* will show that operation at an angle of twist is exactly what the stylus must do when engraving a signal in the groove. When the stylus is at the point in the sine wave shown at (*a*) it has no way of knowing—as far as noise is concerned—that it isn't being operated in a dead groove with twist (*b*).

The common method of measuring residual or surface noise in lacquer disc recording is to cut an unmodulated groove at the diameter and rpm indicated, insert in the playback circuit a high-pass filter to remove rumble and hum, and observe the resultant meter reading referred to "zero." As a practical matter the character of the sound thereby reproduced will be not unlike thermal agitation—random noise. But in this case the frequency spectrum of the noise is such that about 70% of the energy content lies between 3,000-10,000 cycles (if we were to double the speed to 150 rpm for instance, and use an appropriate reproducing head, the upper limit would naturally be extended). Unfortunately, this method of measurement is not necessarily a true index of performance of the stylus and lacquer, so far as surface noise is concerned, for in a way similar to that of intermodulation between two differing program frequencies, the actual reference noise level as measured by the dead groove method above, is modulating by the program itself. Unlike intermodulation, the noise modulation is *up*, i.e., when a cycle of program comes along, the noise in the sloping part of the groove is *higher* than it was in the unmodulated groove (see *Fig. 1*). The increase in noise may be in some way a function of the slope of the modulated groove (without regard for sign), but not necessarily so. It depends a lot on the stylus itself. The actual value of noise modulation is conveniently expressed in decibels, and is defined for the purpose of this discussion as being the number of decibels *increase* in noise obtained when a 35° slope occurs in the modulated track (see *Fig. 2*).

Listener Reaction

No mere butterfly chasing is being undertaken here in the matter of noise modulation. The writer is certainly *not* in the process of waving gleefully aloft a rare, microscopic, but otherwise utterly inconsequential specimen for examination by fellow entomologists. Any impulse on the part of the reader to suspect so must be reconciled with the fact that "before and after" listener tests made with regular styli and anti-noise modulation styli are hard to argue down. A "before and after" change so large in proportion that it is plainly distinguishable to the untrained ear stands out like a red nose in the measurements and instruments de-



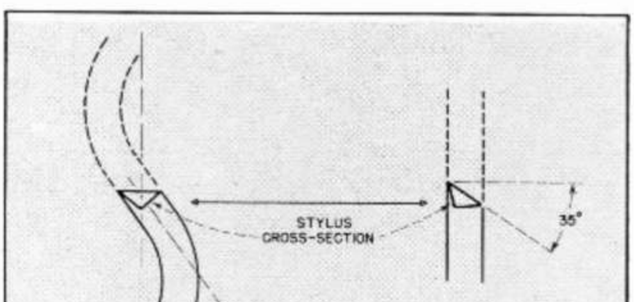


Fig. 1. The low noise-signal ratio measured in the dead groove (left) is only representative of what actually happens in one part of the a.c. alternation. Fig. 2 (right). The two methods of setting up to measure noise modulation—(a) dynamic, (b) static. At the instant shown, the stylus in (a) is just as embarrassed as the (b) stylus in its attempt to polish the sidewall to a noise-free surface.

partment, and can hardly be explained away any more easily.

It has already been well established in the art by numerous sources working in different ways, that cross or intermodulation is a more accurate index of listener reaction than amplitude or wave form distortion. It often does happen in reproducing sound systems that the phenomena which cause amplitude distortion also cause intermodulation at the same time; and since distortion content was at first easier to measure, this was used as a standard of performance.

Just as intermodulation between various program frequencies runs a close parallel to listener reaction in the overload level department, so noise modulation closely parallels reaction in the matter of *effective noise*. Although a conclusive probe into the matter of listener reaction has not been concluded, enough information is nevertheless at hand to warrant a few arbitrary statements concerned with the subject of the listening public vs. noise modulation.

1. When peak intermodulation is less than four per cent, frequency response reasonably flat to at least 8-10 kc and the whole playback channel including speaker is "clean," the effect of noise modulation is laid bare in its character as a residual trouble.
2. With any given set of circumstances (i.e., type of program, rpm, diameter, etc.) the use of high frequency pre-emphasis, since it produces sharper angles of groove excursion than a "flat" response, increases noise modulation, although it *decreases* the noise.
3. When shellac pressings originally recorded with no high frequency content over 5,000 cycles are played back into a channel flat to 15,000 cycles, the impression is given of distorted high frequencies. In listening tests it is easy to imagine that the recorded program contains components above 5,000 cycles even when such is known not to be the case. Modulation of the high shellac surface noise by the lower frequency signal produces this illusion. Indeed we do after a fashion have high frequency material present, in that the components of surface noise over 5,000 cycles heard in the wide-open playback system are being modulated or *cross-talked* at program frequencies.
4. The listener reaction ordinarily associated with plain *noise* is perhaps more correctly identified with *noise modulation*. There are some indications already that noise modulation, depending on a variety of circumstances, is the more important of the two factors.

For purposes of the present investigation an arbitrary stylus *Factor of Merit* has been devised which, although open for appropriate modification and change from time to time as the occasion demands, is nevertheless a signpost leading to an ultimate disposal of the problem.

$$\textit{Factor of Merit} = \frac{\left(\begin{array}{c}\text{Number of db be-}\\ \text{tween conventional}\\ \text{noise and 10 cm/sec}\end{array}\right) - 40}{\text{Noise modulation (db)}}$$

In order to give an idea of the range of *Factor of Merit* values, figures in the neighborhood of 1.0 are acceptable, 2.0 is excellent, and 0.5 is very poor. Obviously, the relation is shaky and starts to break down for values of unmodulated groove noise level noisier than −45 db. Fortunately, it appears that it is somewhat easier to manufacture a cutting stylus with a good noise modulation figure if the unmodulated groove value demanded in the application is not too severe. It is much easier, for instance, to make a stylus with only 6 db of noise modulation if it is a −50 db stylus than if it is a −60 db stylus.

Fig. 3. Half-cycle envelope of noise modulation obtained from playing back tone groove. This is an exaggerated case, however, and Fig. 6 shows a more typical stylus.

Measurement

The method of measurement used to establish the noise modulation figure for any given set of circumstances may be of two fundamental types, static and dynamic. The static measurement is easy to make, and as is so often the case with easy things, is not particularly reliable. It consists of turning the stylus 35° away on its own axis from the conventional position (*Fig. 2(b)*), cutting an unmodulated groove, and observing the increase in noise between this groove and an adjacent groove made with the same stylus without twist. The direction of twist must be tried both ways to correspond with the positive and negative velocities of the cycle in the groove. The unreliable feature of this measurement appears to be that since the stylus is operating under questionable conditions when twisted, the slightest imperfection in either it or the lacquer will hang up on the leading edge and stay there, causing a pessimistic reading, whereas in the dynamic method the stylus is continuously modulated or cycled as it would be with program, and particles which would be hung up under the static condition are thrown off. The dynamic method of measurement involves selecting a frequency which when operated to fill the groove to capacity will produce approximately 35° of slope as measured through the microscope. Naturally the frequency necessary to produce this slope will depend upon the diameter and the rpm, i.e., linear speed, of the groove. It is not surprising that the same stylus will show slightly different values of noise modulation at different linear speeds depending upon the dimensions of the various facets, etc.[1] The frequency necessary to produce the required angle will ordinarily be below 2,000 cycles so that in playing back the modulated (and noise modulated) groove

[1] Isabel L. Capps, "Recording Styli"—*Electronic Industries*, November 1946.

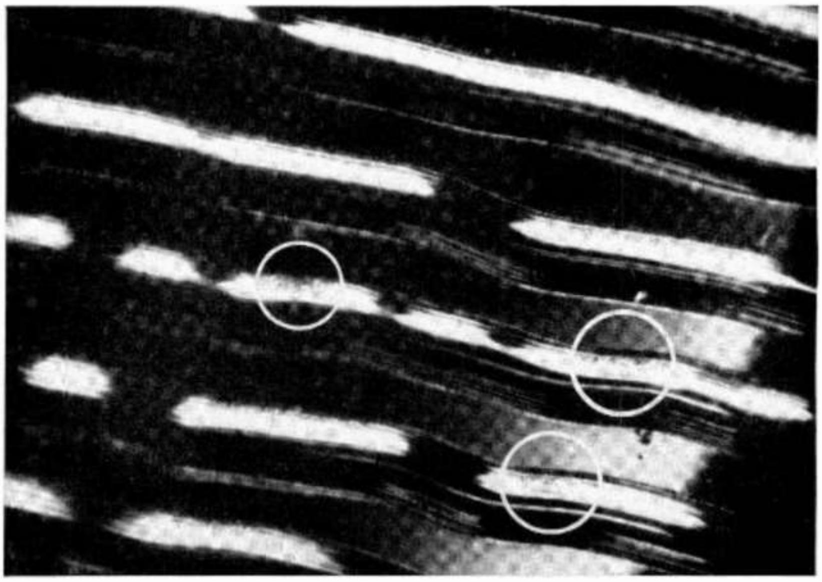


Fig. 4. Noise modulation in the sidewall is not hard to see with a low power microscope when the lighting is arranged properly.

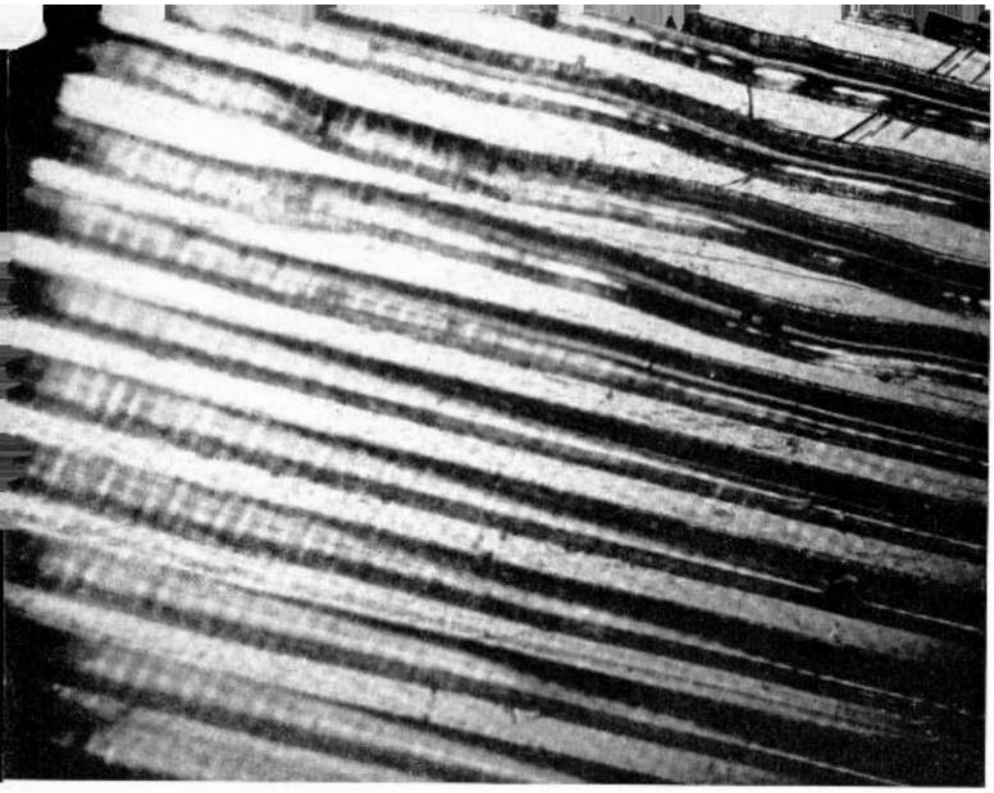


Fig. 5. Pressing from polished stamper. Note disappearance of 15-kc pilot signal on crests of modulation. Noise is also affected unevenly over the cycle by polishing.

a 2,500 cycle high-pass filter may be inserted in the circuit in a manner similar to that used for measuring intermodulation distortion.

Filtering out of the modulating tone, however, is a harder job than in the usual intermodulation measurement. Referring to the "dead" groove noise as a basis, there is normally at least 50-60 db between the modulating tone and the noise, whereas in intermodulation measurements the differential between the two signals is rarely over 10 db. This means that 100 db of high-pass filter discrimination must be achieved to assure a one per cent accuracy of final measurement. Half section must be piled on top of half section in profusion to obtain the required filtering. Although the final reading may be obtained from a meter as in the case of intermodulation measurements, it is much more informative to view the result on an oscilloscope screen where the sweep frequency will, of course, be adjusted to a sub-multiple of the original frequency cut on the record. An envelope modulation of grass or noise (*Fig. 3*) will then result and the difference between peak and trough in terms of db may be measured off.

There is still a third method of measurement of noise modulation, combining the advantages of both static and dynamic methods, which has not been fully probed but which may be reported in detail later. It involves the sinusoidal oscillation in rotation of the stylus about its own axis between clockwise and counterclockwise limits of 35° at an audio rate. The result is a groove containing nothing but modulated noise; even the audio rate at which the stylus is rotated does not appear as a lateral signal but only as a slight vertical tone in the groove which is discriminated against by a good lateral reproducer, providing the tracking error is small. Therefore no low-pass filter is required and the effect of any harmonic distortion of the original audio wave used in the dynamic method (*A, Fig. 2*) appearing in the high-passed playback signal is eliminated.

A typical "run-of-mill" stylus might be expected to show –55 db at zero angle or normal position, –25 db at + 35°, and perhaps –20 at –35°. This immediately dispels the line of thought which says, "Well, this whole business is all happening down 50-60 db below program level—so what's the difference?" –25 db under signal is a horrible noise level—even worse than some shellac. The fact that it comes and goes twice per cycle during loud signals merely serves to trick the ear into not recognizing it for what it is.

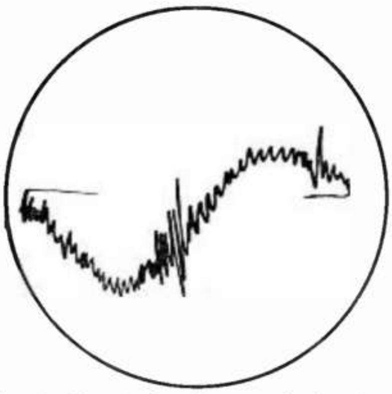


Fig. 6. Sketch of oscilloscope display showing noise modulation. Some of the fundamental tone is left in (dynamic method) to show relation in phase between noise and lateral velocity.

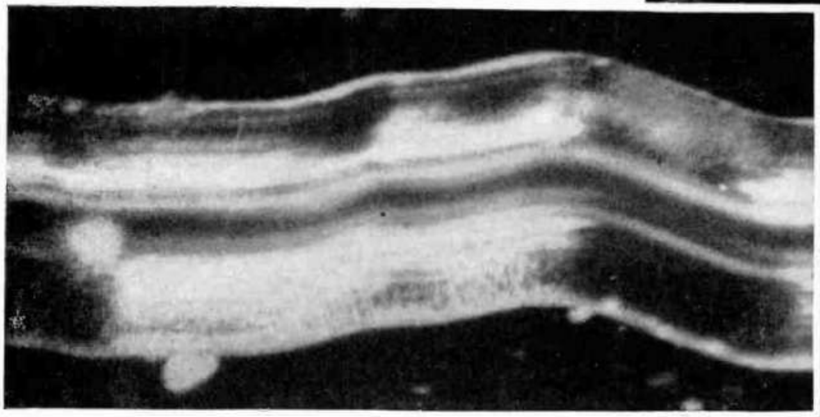
Polishing and Wiping of Masters and Matrices

As is common knowledge in the processing branch of the business where original lacquer recordings are sputtered (or silvered) and subsequently plated, the buffing, wiping or polishing of the metal surfaces of the discs in the various stages of processing is not at all uncommon. It is undoubtedly very difficult to resist putting a bright shine on the chrome of a stripped-master just for the psychological effect alone even if such is not shop policy, especially if all it takes is a surreptitious wipe while on the run from plating bath to lathe and press; but it is a deplorable business at best. True, not too much damage might be done by a polishing of the matrix (if the particular process involves a matrix), if the wipe could be made in such a way as to confine it to the "land" and not let it enter into the modulated groove. Indeed, such a wiping of the matrix should provide in most cases the desired result of maintaining the conditions required for producing a glossy, mirror-like pressing—saleable, with lots of eye appeal.

The ear appeal, however, is sadly sabotaged in the noise modulation department by the polishing operation, since, as will be immediately recognized upon reflection, the polishing cloth or other member will bring to bear with greatest force and polishing effect upon the crests or peaks of the modulation in the groove (and slopes leading to peaks in the direction of polish) and not on the far slopes and troughs (*Fig. 5*). Hence, we have a variation of polishing effect over the cycle, so to speak, and a corresponding variation of noise over the cycle. The effect is quite easily demonstrated by the simple experiment of recording a master with program music (and also tone if desired), all the while with a pilot signal of perhaps 20 kc in the super=audible range[2] on top of the normal modulation. The result of superimposing a high frequency on top of program material and sending it through a typical processing cycle in shown in *Fig. 6*. What happens to the pilot signal in the processing operation also happens to the surface noise; the pilot signal is somewhat easier to see with a microscope, though, and is therefore useful for demonstration.

At first thought one might jump to the conclusion that again we have encountered another of those imponderable freaks of nature, where the various good effects cancel each other out, and all the evil effects add up numerically instead of at random or in root-mean-square. Since with a normal stylus the noise is lowest at angle zero, this is also the point at which the greatest amount of polishing occurs and hence the noise on the metal master is still further reduced at the

[2] Generally thought of as super-audible, in disc recording at least.



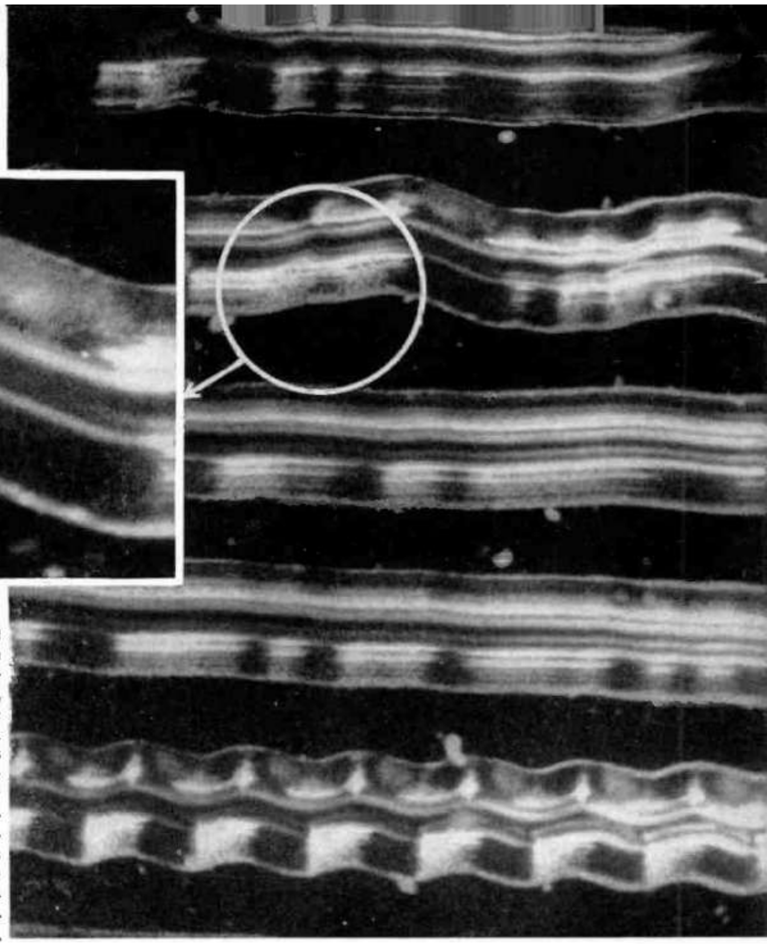


Fig. 7. Special lighting must be arranged when looking for noise modulation with a microscope, in order to illuminate evenly the sidewall. Here an ordinary stylus is roughing up one side of the groove at only 20°-25°. This is an unretouched photomicrograph of instantaneous lacquer. The pressing will be worse due to uneven sputtering and plating on the measled spots.

point in the groove where it is already lowest anyway. It would be discreet, however, to point out that not *all* polishing *reduces* surface noise, and shiny grooves are not always quiet grooves.[3]

In the case of shellac pressings, that school of thought which believes that processing raises the surface noise by N db over the original master surface noise as a reference cannot fail to take an active interest in the subject of noise modulation. There has been a widespread prejudice against the use of the higher audible frequencies, particularly in shellac pressings, quite likely engendered in part at least by the noise modulation factor. Simple listening tests will show that even in the case of shellac pressings, if a high quality original made with an Anti-Noise Modulation stylus is processed all the way to the final stamper with nothing more abrasive than an air blast allowed to come in contact with the sidewalls and bottoms of the grooves, listener reaction using a wide open playback system will be favorable. There will be no immediate impulse to jump up and "turn down the tone-control . . . ."

The effect of pronounced noise modulation in recordings where the *Factor of Merit* is 0.5 is that of producing rasping high frequencies—hoarseness as distinguished from amplitude distortion, an unnatural timber difficult to describe but immediately recognized as a familiar sound by the practiced listener. Noise modulation is probably largely responsible for effects which have been variously described in the literature as "a peculiar magnetic distortion," "pinch effect," "tracking trouble," etc. By all means this is not to deny these various other worthy factors their well deserved individual niches in the recording Hall of Fame, but rather to point out that noise modulation has always been present in lacquer recordings and in records pressed from lacquer originals to such a degree that in some cases it may have been a potent factor in listening tests where the crime was actually pinned, for instance, on an innocent bystanding B-H curve.

It might be guessed at this point that the whole matter of noise modulation is peculiarly tied in with the making of lacquer discs, and as such is associated with the polishing or burnishing surfaces of the cutting stylus used for lacquer recording.[1] It is true that the so-called feather edge type of stylus used in the making of wax masters probably did not produce much noise modulation and had a high *Factor of Merit*. It is equally true that in those days when wax masters were the rule rather than the exception, processors may have wiped with less abandon than they do today, or may have been more easily intimidated by the front office into a steady forbearance.

In any case, the solution to the noise modulation problem is certainly not a return to the use of "wax" for originals, with its inconvenience and increased cost of handling. Recent developments made in collaboration with Frank L. Capps & Co. have culminated in a positive solution to the problem, and a superior type of MRS with anti-noise modulation properties will be available for lacquer recording within a few weeks.

An article by Isabel M. Capps discussing the design and operation of the Anti-Noise Modulation stylus will appear in the next issue. Ed.

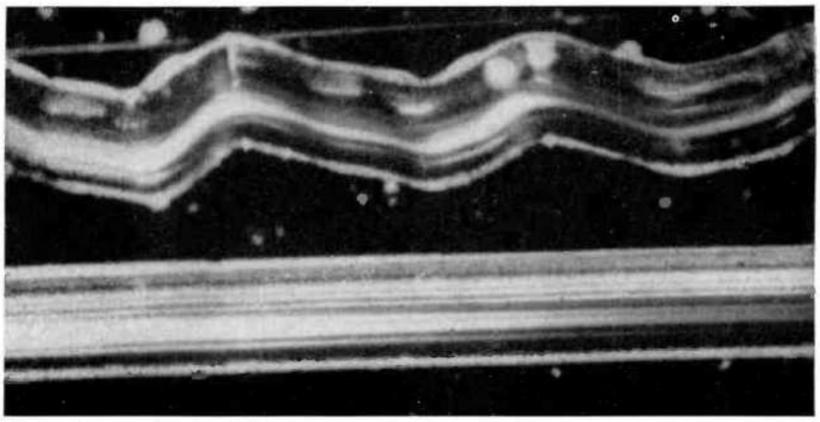


Fig. 8. A record made with an anti-noise-modulation stylus shows no egregious sidewall speckling even with 40° excursions. The same microscope lighting arrangement as that used for Fig. 7 had to be used at double brilliance to produce the same apparent sidewall illumination because the anti-noise-modulation stylus produces such a high polish. Although halation occurs in some spots, due to lack of retouching, direct viewing with the microscope eyepiece coupled with movement of the light sources discloses no unburnished sidewall areas.

[3] *Mathematical analysis of what happens to noise modulation in the groove as a result of polishing should be entered in the list of Approved Indoor Sports for Audio Engineers.*