LETTERS TO THE EDITOR

COMMENTS ON "BIRADIAL AND SPHERICAL STYLUS PERFORMANCE IN A BROADCAST DISC REPRODUCER"

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The above paper by Sank[1] calls for a number of comments. The peaks in the response observed on pickup X at 15 kHz and on the BDR-1 pickup at 20 kHz are almost certainly not the resonance of the mass at the stylus tip with the compliance of the record groove. Hunt [1] gives the equation for the stylus–groove resonance as

$$f_0 = 0.6382\, E_v^{1/3}\, r^{1/6}\, M_b^{1/6}\, M_s^{-1/2}$$

where

- E_v plane strain elastic modulus of record material, $= E/(1-\nu^2)$, where E is Young's modulus and ν is Poisson's ratio
- r stylus radius
- M_b playing weight
- M_s tip mass.

Hunt quotes the value of 3.76×10^{10} dyn/cm^2 for E_v, measured on a sample of record material. This agrees with measurements on record material by the writer, and with values quoted by the material manufacturers.

If the writer is correct in guessing the identity of pickup X, it has a tip mass of 1 mg. With a 0.0007-inch radius stylus and a playing weight of 2.5 g, the stylus–groove resonance is calculated as 29 kHz, agreeing with the upper peak at 30 kHz, shown in Sank's Fig. 7.

The accuracy of Hunt's formula is borne out by experience with a mono moving coil pickup. The armature was mounted in torsional rubber bearings, and was extremely stubby, so that there were no bending resonances. Over the years, many thousands of these pickups were made and the response of each one was measured. There was one top resonance only, averaging 19 kHz. The tip mass was 2.5 mg, the playing weight 3.5 g, and the stylus radius 0.001 inch, giving a calculated stylus–groove resonance of 19 kHz. This pickup was also supplied with a 0.0025-inch radius stylus for use on 78 r/min shellac records. On coarse-groove vinyl records, the resonance was about 22 kHz, again agreeing with Hunt's formula.

This formula is derived from the Hertz equation for the elastic range, whereas considerable plastic deformation takes place under any practical pickup. The groove deforms elastically and plastically until it is able to support the load without further plastic deformation; it then behaves elastically and the Hertz equations can then be applied (although not of course for predicting plastic deformation). Correction would need to be made for the lateral curvature of the permanent track made in the groove. The correction would be small, so that Hunt's formula is a close approximation. The value of modulus used is the static one; under dynamic conditions, the modulus will not be less than this, so that the formula will not overestimate the frequency of resonance.

The peak in response of pickup X at 15 kHz is probably due to a bending resonance of the rather slender cantilever. The peak at 20 kHz and subsequent fall in response of pickup BDR-1 are typical in shape of moving-magnet and induced-magnet designs. The peak appears to be the first overtone of the cantilever, simply supported at the stylus and being free or substantially so at the magnet end, as at these frequencies, the rubber mounting will appear very compliant. The fundamental resonant frequency of a simply supported free cantilever is zero. The first overtone would be supersonic in most commercial pickups if it were not for the mass of the magnetic material. The mass of the magnetic material is enough to bring the overtone down into the audio range. This is the chief limitation on the weight of magnetic material, rather than the effective mass of this material at the stylus tip; the effective mass of the magnet is usually much less than that of the cantilever and diamond.

Above this peak, the torsional resonance causes a dip in response, and this is sufficient to obscure the stylus–groove resonance and roll off the higher frequencies. Immediately before the torsional dip, in designs where there is little damping, there is a peak, quite different from the cantilever overtone. There is also the possibility of an electromechanical resonance of the electrical inductance of the coils with the mechanical mass in bending and torsion. To further complicate matters, many commercial pickups have sufficient shunt capacity in contacts and leads to resonate with the coil inductance in the audio range. This capacity prevents the develop-

[1] J. R. Sank, *J. Audio Eng. Soc.* **18**, 402 (Aug. 1970).

ment of heads with higher output voltage and/or lighter moving parts.

The sag in the response curve of the BDR-1 pickup above 1 kHz is typical of the majority of pickups. It may be offset by a lightly damped resonance higher up, or may be increased due to heavy damping. The sag is due to translation loss, not scanning loss. Translation loss, as defined by Hunt, might better be called differential curvature loss. On a convex surface, i.e., the crests of the recorded modulation, the stylus will penetrate more than on a flat surface for a given load. On a concave surface, i.e., the hollows of the waveform, the stylus will penetrate less. This gives a net loss of amplitude. The effect of the inertia forces due to the tip mass is to accentuate this. In practice, there is considerable plastic deformation and Hunt's formula for translation loss is not valid, although the general trend of results may be similar.

Scanning loss can only occur with curvature overload, i.e., when the radius of curvature of the modulation is less than that of the stylus. If there were no deformation, there would be no loss of peak–peak amplitude until curvature overload (although there would of course be considerable distortion of the waveform). Before this point is reached, the crests will have become of a similar order of size to the stylus, and considerable ploughing and loss of signal will result with any present-day pickup. Scanning loss is therefore of academic interest only at present. On the STR 120 record used by Sank, curvature overload only occurs at the highest frequencies on the inner bands.

The writer hopes to publish more detailed observations at a later date.

REFERENCES

1. F. V. Hunt, "The Rational Design of Phonograph Pickups," *J. Audio Eng. Soc.* **10**, 274 (Oct. 1962).

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I would like to thank Mr. Barlow for his contribution that appears for the most part to support the data and conclusions in my paper. His conclusions regarding stylus resonance seem to be in agreement with the paper. I hope to have the opportunity in the future to examine and positively identify the suspected stylus–groove resonance of the BDR-1 above the audio range.

Mr. Barlow's detailed explanation of the various types of stylus–groove loss appears to reveal the reasons for the observed responses. It is difficult to tell if he intends to disagree with my remarks in this regard. My remarks seem to be sufficiently general in nature so that there appears to be little room for controversy, save for minor points of interpretation, which is what he may be picking up.

CORRIGENDUM

J. G. McKnight, "Tape Flux Measurement Theory and Verification," *J. Audio Engineering Society* **18**, pp. 288-300 (June 1970).

The author is indebted to John C. Mallinson of the Ampex Research Department for pointing out the following error:

In Sec. 4.3, the thickness loss factor formula was incorrectly quoted: the formula should be $[1-\exp(-2\pi t/\lambda)]/(2\pi t/\lambda)$. For the values used, the loss factor is 0.94 (not 0.88 as given). Therefore, $\Phi/w = 195$ (not 183) nWb/m. Thus, in Sec. 4.4, the difference between the two measurements is actually 5% not 1%. Since this value is still within the estimated error of the measurements, the basic conclusions of this section and of the entire paper are unchanged.