Nakamichi Technical Bulletin 2

Playback Equalization

Amid rumors that Nakamichi employs non-standard playback equalization curves in their cassette recorders, this bulletin is being issued with hopes of demonstrating Nakamichi's strict adherence to Philips and IEC standards. Results of playback frequency response tests performed using commercial test tapes and Nakamichi cassette decks often point to a rising response above approximately 4,000 Hz with the 10 KHz reading being anywhere from 2 to 5 dB high. This publication intends to show that in such instances the test tape is in fact at fault.

Although the Philips standard (4th revision, October 1968) gives tape flux values from 31.5 Hz to 12,500 Hz, using the transfer function given in the same publication, it is possible to obtain theoretical values for a frequency range of 20 Hz to 20,000 Hz, the higher end of which is essential for any discussion of Nakamichi recorders. The transfer function is as follows:

$$\phi(\omega) = \frac{1}{\omega T_1} \sqrt{\frac{1 + \omega^2 T_1^2}{1 + \omega^2 T_2^2}} \qquad (1)$$

A plot of function (1) would show tape flux level as a function of frequency. To obtain the playback equalization curve one must take into account the "frequency response" of the playback head itself (the voltage at the head is basically a differential of the magnetic flux on the tape). The resulting transfer function is as follows:

$$G(\omega) = \sqrt{\frac{1 + \omega^2 T_2^2}{1 + \omega^2 T_1^2}} \qquad (2)$$

In the above functions ω is equal to 2π times the frequency in Hertz. T_1 and T_2 are time constants that determine the rollover points of the EQ curves. The time constants are established by Philips for standardization, and there are two sets of time constants, one each for standard ferric oxide and high resolution (high coercivity) tapes. For standard tape the previously mentioned Philips publication gives time constants of 1590 microseconds for T_1 and 120 microseconds for T_2. For high corecivity tapes, such as Nakamichi SX, TDK Super Avilyn and Chromium Dioxide, the Philips standard for High Resolution cassette tapes (published as an addition to IEC Publication 94A) of July 1972 gives time constants of 3180μs for T_1 and 70μs for T_2. The playback equalization curves in Figure 1 were drawn using the transfer function (2) above. These are the theoretical playback EQ curves as derived from Philips and IEC specifications. *

* Recent revisions by DIN have fixed the low frequency time constant T_1 at 3180μs for both types of tape.

Designing a correct playback equalization amplifier would seem, then, to be a simple matter of supplying an electrical network with the proper and accurate frequency response based on the theoretical curves. In reality, unfortunately, the problem is considerably more complex. There is, for example, the inductance of the head to be taken into account. Any measurement of the EQ amplifier's response would have to be made with the head "in circuit" to ensure that any anomalies caused by interaction are compensated. Figure 2 shows the circuit used by Nakamichi to measure EQ amp response.

Other considerations arise from the fact that no head is perfect, i.e. there are losses to be expected from a less than ideal magnetic device. Head gap loss and spacing loss are the two most frequently discussed factors that rob a tape playback system of high frequency response. Head gap loss can be minimized by proper design, but since the proper playback gap width is determined by a trade-off of design parameters, there is always a certain amount of loss to be expected. Figure 3 shows the efffect of head gap loss at various gap widths. The amount of loss can be calculated for any gap width, but it must be pointed out that such calculations assume an otherwise ideal head, something that does not exist in the real world. Spacing loss is caused by the microscopic space between the tape and the head at the point of contact. This, too, can be minimized by proper transport design and head lapping techniques. In fact, since spacing loss in the Nakamichi 1000 is less than 1 dB at

20 KHz, it can be ignored for the purposes of this discussion.

The tape deck designer, then, must take into account a multitude of factors before deciding on the final characteristics of his playback EQ amplifier. The job would be simplified if the designer could be sure that his standard playback frequency response test tape contained the proper flux levels as defined by the Philips standard at all frequencies. If this could be guaranteed, all that would be required is to play the test tape with the head to be used and design an EQ amp that would yield flat response. The problem, unfortunately, is that there is no totally accurate and reliable method for measuring the magnetic flux level on the tape, particularly at the shorter wavelengths (higher frequencies). The designer concerned with accuracy, therefore, is required to take a backward route to the solution. A careful calculation of all the losses involved backed up by exhaustive laboratory measurement to confirm theory is thus far the soundest approach to the design of an accurate cassette playback system.

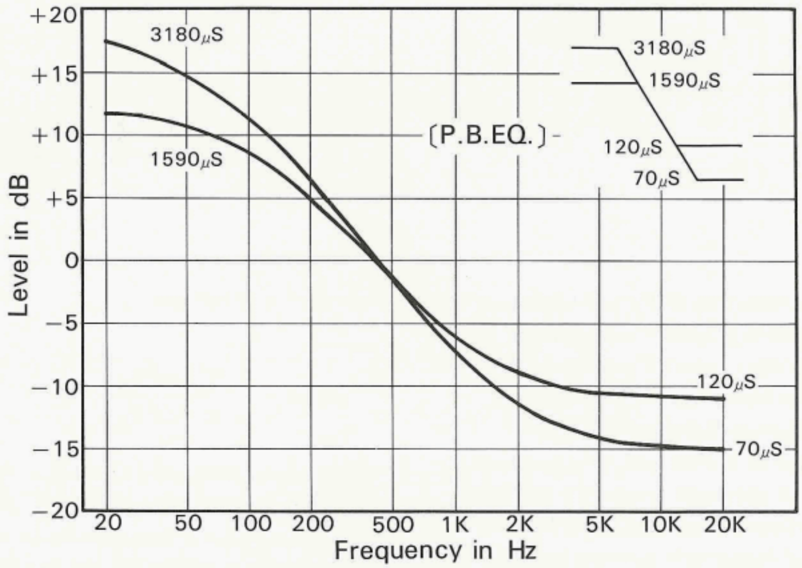

Figure 1 Theoretical Playback Equaligation Curves.

The success of this loss calculation approach largely depends on the ability to accurately measure the head gap width. Although an accurate physical measurement poses no great difficulty, magnetic extension caused by stresses imposed on the material during the manufacture of the head makes accurate calculation extremely difficult. A conventional head (mu-metal, permalloy or ferrite) with a physical gap of 1 micron may exhibit an "effective" gap of 2 microns. Head gap loss is correspondingly increased (see Figure 3), and the designer who does his calculation with the 1 micron figure would end up with a playback system lacking high frequency response. The Nakamichi Crystal Permalloy playback head in the Nakamichi 1000 and 700 cassette decks (a similar head with a slightly wider gap is used in Nakamichi 2-head machines) is manufactured using a highly proprietary low stress process. The discrepancy between physical and effective gap widths is virtually negligible. Figure 4 shows the playback equalization amplifier response for the Nakamichi 1000. Since the playback head has a physical and effective gap width of approximately 1.25 microns (0.9 micron gap spacer with 0.1 – 0.2 micron clearance on either side), the amount of correction required is determined almost solely by the head gap loss curve for 1.25 microns. Adding the 1.25 micron curve of Figure 3 to the response curves of Figure 4, in fact, yields almost exactly the theoretical curves of Figure 1.

Keeping this in mind, one proceeds to "measure" various commercially available test tapes using a Nakamichi 1000. Figure 5 is the result of such a

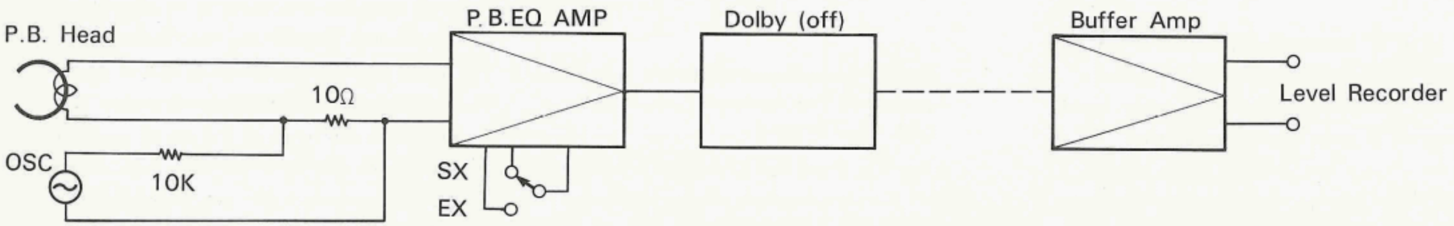

Figure 2 Method for Measuring EQ. Amp Response.

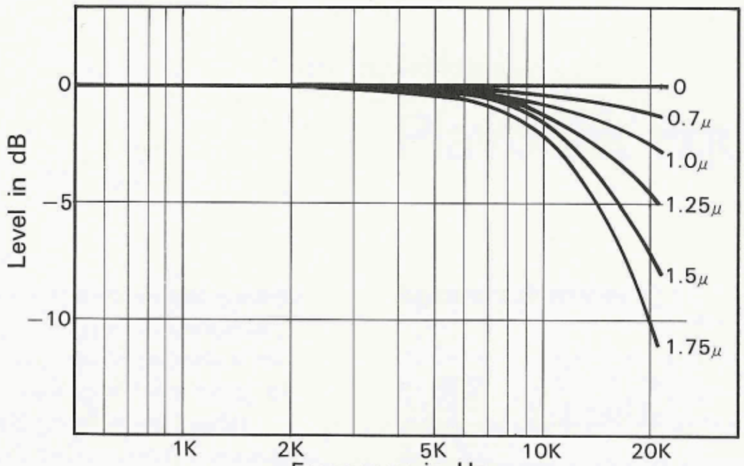

Figure 3 Head Gap Loss.

measurement. A popular test tape, claiming to represent Philips standard, was played on a Nakamichi 1000 known to have particularly close-to-theoretical playback characteristics. It can be readily observed that the response is 1 dB high at 4,000 Hz and 2 dB high at 10 KHz. A cassette recorder designed to this "standard" tape would yield dull sounding reproductions of tapes recorded to the correct Philips specifications. Conversely, a tape recorded on such a machine would sound bright when played on a correctly designed cassette deck.

Our further tests have shown that a large number of cassette decks on the market are adjusted to test tapes with rising responses. This is not difficult to understand. Test tapes exhibiting a rising high end with respect to the Philips standard work in favor of the cassette deck designer who is restricted to the use of inferior magnetic heads. For all intents and purposes, these test tape allow the designer to ignore the discrepancy between physical and effective gap widths because the characteristics of the test tape will cover up the lack of loss compensation in the playback EQ amplifier. This allows the designer to boost highs a bit more during record and thereby gain a few dB of signal-to-noise ratio, albeit at the expense of recording headroom.

To put the icing on the cake, another measurement was performed, this time with a Nakamichi 1000 whose playback EQ amp had been modified so that no loss compensation took place. The frequency response of this modified EQ amplifier is shown in Figure 6. As a comparison with Figure 1 will verify, the modified EQ amplifier's characteristics are an extremely close approximation of the theoretical playback EQ curves, which is as it should be since all loss compensation was removed. The measurement of the same test tape yielded results almost identical to those of Figure 5. Not only is this strong evidence that the test tape is incorrect; it points to the fact that at this writing the Nakamichi Crystal Permalloy head is virtually *ideal* (that is to say, loss-free) to 10 KHz, a rather remarkable achievement by any standard.

Although the playback equalization problem does not concern the cassette deck user who does all his recording and subsequent playing on a single machine, users with multiple decks or those who regularly exchange cassette recordings with others could conceivably run into serious compartibility problems. In worst cases, we have measured a playback EQ discrepancy of as much as 8 dB at 10 KHz between a Nakamichi deck and a cassette

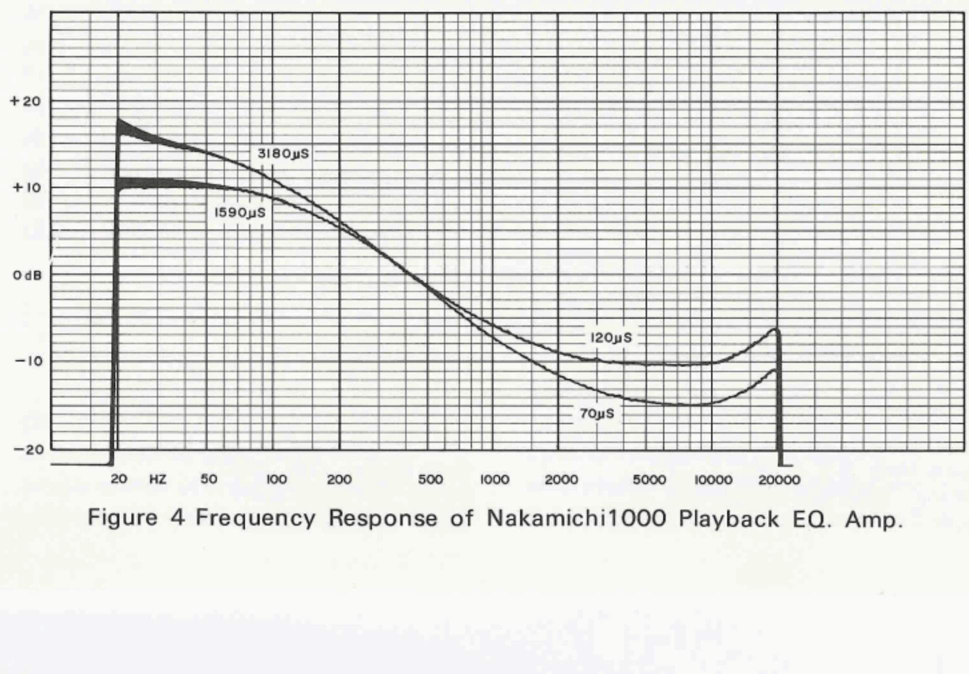

Figure 4 Frequency Response of Nakamichi1000 Playback EQ. Amp.

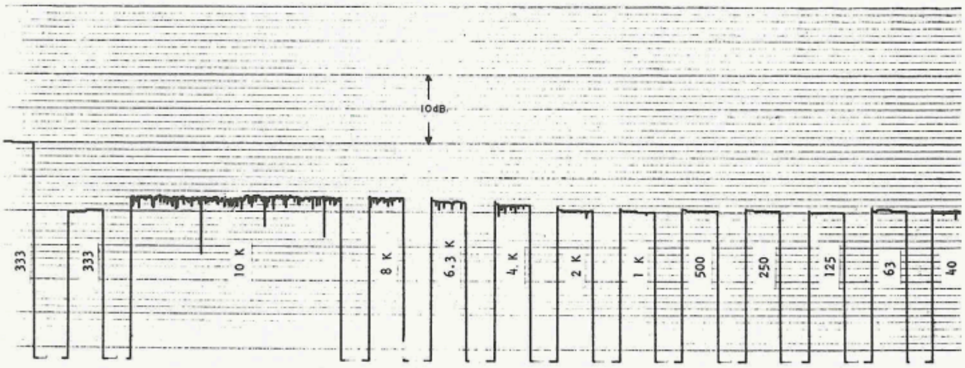

Figure 5 Output of a Popular Test Tape

deck of another well known brand. Improvements in magnetic heads will undoubtedly help reduce the number of non-standard test tapes and cassette decks, but it would seem that the industry is in need of stronger enforcement of standards.

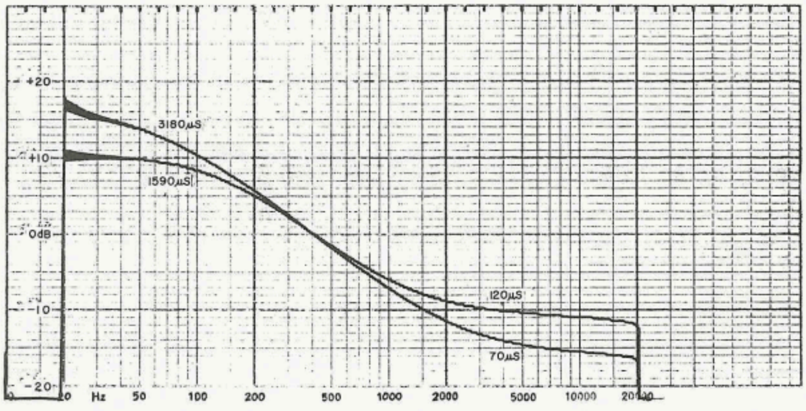

Figure 6 Frequency Response of Nakamichi1000 EQ. Amp Specially Modified for Test Purposes.

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