ON THE QUALITY OF SOME DIGITAL AUDIO EQUIPMENT MEASURED BY THE HIGH ACCURACY DYNAMIC DISTORTION MEASURING SYSTEM

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On the Quality of Some Digital Audio Equipment Measured by the High Accuracy Dynamic Distortion Measuring System

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Abstract

A useful method for measuring the signal quality of digital audio equipment under operating conditions is described.

An experimental system was made upon this method to measure 16-bit accuracy digital audio equipment, and the performance achieved is reported.

With this measuring system, several 16-bit analog to digital and digital to analog (A/D-D/A) conversion systems and an 8:7 digital sampling frequency converter are measured. Their accuracy proved to be 13 to 14.5-bits and about 15-bits, respectively, in terms of quantizing noise level.

0. INTRODUCTION

There have been great advances in the digital audio field since the first introduction of the digital tape recorder by NHK[1]. Today, many digital tape recorders and other digital studio equipment are in practical use. A great number of digitally mastered phonograph records can be found, and digital audio disks will be in use in the near future.

Yet there has been little effective measurement or evaluation of the quality of digital audio systems. This is because the distortion inherent in digital system varies depending on the input signals. Conventional methods such as total harmonic distortion measurement are thus unsuited to evaluate the behavior of digital systems. So, the dynamic distortion measurement method, which is suitable for monitoring the dynamic characteristics of digital audio systems, has been studied.

A new experimental equipment has now been developed by the authors. The equipment is capable of measuring distortion as low as 16-bit quantizing noise level.

In order to measure a digital system with this equipment, it is necessary to employ A/D-D/A conversion systems. So the A/D-D/A conversion systems were measured first. Then a digital sampling frequency converter was measured, for comparison with A/D-D/A conversion. In this way, we compared the quality degradation caused by analog and digital sampling frequency conversion systems.

1. MEASUREMENT METHOD

This system employs so-called dynamic distortion method[2]. It eliminates a certain frequency range from the test signal, and the rest of the signal is fed to the system under test. Therefore the signal appearing in this eliminated frequency range is considered to be distortion produced by object systems. This component is then measured and the amount of distortion is represented by the ratio of the measured level to the original signal level in that frequency range.

From the principle of measurement it is clear that no special test signal is needed. That is, ordinary programs such as those stored in conventional analog tape recorders can be used.

In this manner, the performance of audio equipment can be measured under operating conditions with real program signals.

2. STRUCTURE AND PERFORMANCE OF THE SYSTEM

Figure 1 shows the structure of the system. The system consists of (1) a set of band-elimination and band-pass filters for each frequency range, (2) a low distortion amplifier and (3) low noise amplifiers.

When measuring as low distortion as 16-bit quantizing noise level, the residual noise level should be kept negligible. The lower line in Figure 2 shows the calculated 16-bit quantizing noise level measured by this method, using USASI-weighted noise as a test signal. The residual distortion of the measuring system should be lower than these values.

USASI-weighted noise as shown by the upper line in Figure 2 was used throughout this experiment, and the signal level was 15 dB below maximum peak input level of the measured systems. (e.g. about +4 dBm for ±10 V p-p range A/D-D/A converters.)

Through experience with the previous trial systems[3], the performance shown by the bold line in Figure 3 was achieved for this system.

Some of the points in achieving this performance are described below.

(1) The system performance depends heavily on the attenuation characteristics of the filter combination. Therefore the slope characteristics of the band-elimination filters were designed to be 400 dB/oct., and the band-pass filters used in tandem to be 300 dB/oct. each.

The total feedthrough of the filter sets has become negligible (less than -110 dB). An example of the response of the filter sets is shown in Figure 4.

(2) Filters themselves produce considerable amounts of distortion when the input signal is high, as shown by the thin lines in Figure 4. In order to reduce this distortion, a low-noise, low-distortion amplifier was designed to feed +4 dBm level of test signal into the system under test, while keeping the input level to the band-elimination filter low enough to avoid harmful distortion.

(3) Amplifiers used were designed to meet the requirements of the system so that their noise was negligible compared to 600 ohm thermal noise.

The double band-pass filter design also helped reduce noise produced in the distortion detecting amplifier (A2 in Figure 1).

3. MEASUREMENT

3.1 DYNAMIC DISTORTION OF A/D-D/A CONVERSION SYSTEMS

Since it became clear that this measurement system was capable of measuring 16-bit quantizing noise level distortion, several nominally 16-bit A/D-D/A conversion systems were measured . The results are shown in Figure 5. Those conversion systems have 13 to 14.5-bit accuracy, expressed in terms of quantizing noise level.

Only an ideal A/D-D/A conversion system has no other distortion than quantizing noise. While the actual system shown in Figure 6 has anti-aliasing (low-pass) filters, a sample/hold amplifier and a deglitcher as analog section. They can cause other kinds of distortion. These A/D-D/A converters can also produce other distortion than quantizing noise. Here, Sample A is an expensive hybrid converter for industrial use, and others are for digital tape recorders. Sample B shows an effect of de-emphasis.

3.2 DYNAMIC DISTORTION OF ANALOG STAGE

In order to recognize which part of an A/D-D/A conversion system is the weakest link, each part of Sample A system is investigated except for the A/D and D/A converters.

Figure 7 and Figure 8 show the results. In Figure 7, a good quality low-pass filter has 16-bit accuracy and an average one has about 15.5-bits.

Figure 8 shows little difference among the conbinations of the sample/hold amplifier, the deglitcher and the filters.

It is seen from the results that at the analog stage, the quality of low-pass filters has primary importance and sample/hold amplifiers and deglitchers produce rather small amounts of distortion.

The amount of distortion caused by A/D and D/A converters is obtained by subtracting the results in Figure 8 from that of the total A/D-D/A conversion system, and is shown in Figure 9. The accuracy of the converters themselves is almost 15-bits.

3.3 SAMPLING FREQUENCY CONVERTER

Today several sampling frequencies are in use for sound recoding and transmission of sound programs. It is likely that some of them continue to co-exist, so it is necessary to have sampling frequency conversion to connect different systems.

Our method provides a convenient tool for measuring the quality of sampling frequency converters.

Here, an 8:7 sampling frequency converter is measured at the conversion from 50.4 kHz to 44.1 kHz. The result is shown in Figure 10.

As this measuring system uses an analog signal as the test signal, it is necessary to employ an A/D-D/A conversion system. Therefore the whole system including A/D-D/A converters is first measured. Then A/D-D/A converters are measured without sampling frequency converter, and this result is subtracted from the former to obtain the distortion of the sampling frequency converter. Figure 10 displays this finding.

The result shows that this 8:7 sampling frequency converter has almost 15-bit accuracy throughout the measured frequency ranges, except for the high end range where it has only 14-bit accuracy.

4. CONCLUSIONS

It is clear from our findings that this dynamic distortion measurement is useful for measuring analog-digital hybrid systems, such as A/D-D/A conversion systems.

The experimental system achieved enough accuracy to measure 16-bit digital systems. With this experimental system, nominally 16-bit A/D-D/A conversion systems were measured and their accuracy proved to be 13 to 14.5-bits.

Then each section of an A/D-D/A conversion system was checked for dynamic distortion, to find out which part is most liable to produce distortion.

It is obvious that among analog components, anti-aliasing filters are most critical and sample/hold or deglitching amplifiers have enough quality to meet 16-bit accuracy. When good quality filters are employed, the quality of analog sections meets 16-bit requirement. Therefore the accuracy of an A/D-D/A conversion system depends on the dynamic characteristics of A/D and D/A converters. These require more research and improvement.

As for the inter-connection between different sampling frequency systems, the digital sampling frequency converter operated better than A/D-D/A converters. However, their difference lies within one bit and it is safe to say that, with the improvement of IC technology, the sampling frequency conversion by D/A and A/D conversion is acceptable for cost sensitive applications.

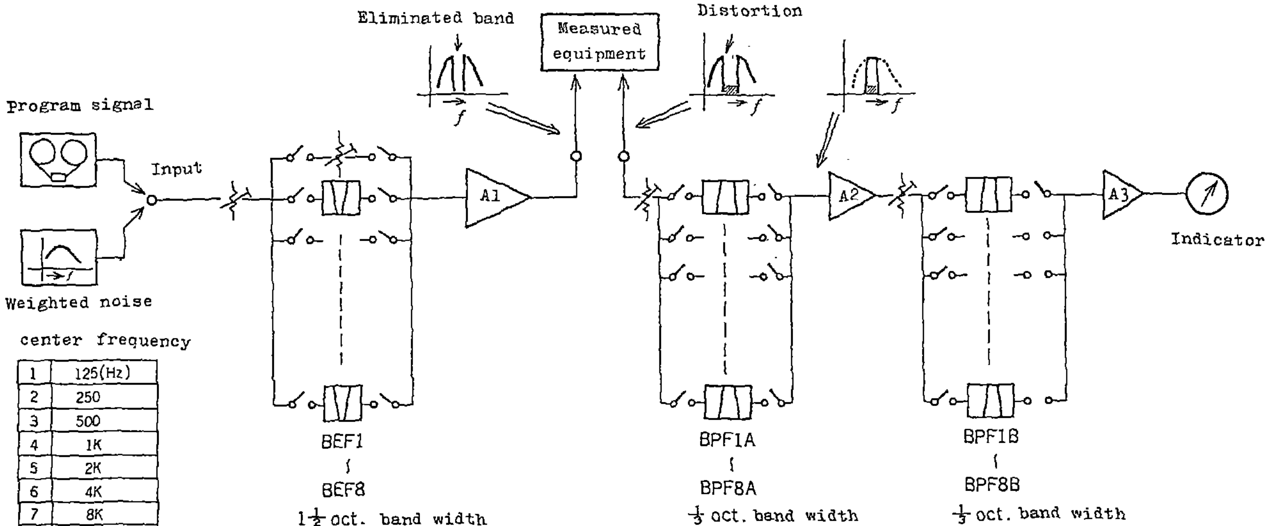
In the near future, we hope that the measurement and evaluation of complex ratio sampling frequency conversion (such as 48 kHz to 44.1 kHz) will also be attempted.

5. REFERENCES

(1) K. Hayashi, "PCM Stereo Recorder," NHK Laboratories Note, No.134 (March 1970).

(2) S. Nikaido, "Mesure dynamique de la distorsion non linéaire dans les dispositifs de transmission sonore," la Revue de l'U.E.R.-Technique, No.131 (février 1972)

(3) H. Tanabe and A. Mizoguchi, "Measuring Digital Audio Equipment with the Dynamic Distortion Method, "Acoust. Soc. Japan Spring Meeting Preprints, pp.73-74 (May 1980).



1	125(Hz)
2	250
3	500
4	1K
5	2K
6	4K
7	8K
8	16K

Figure 1. Structure of the measuring system.

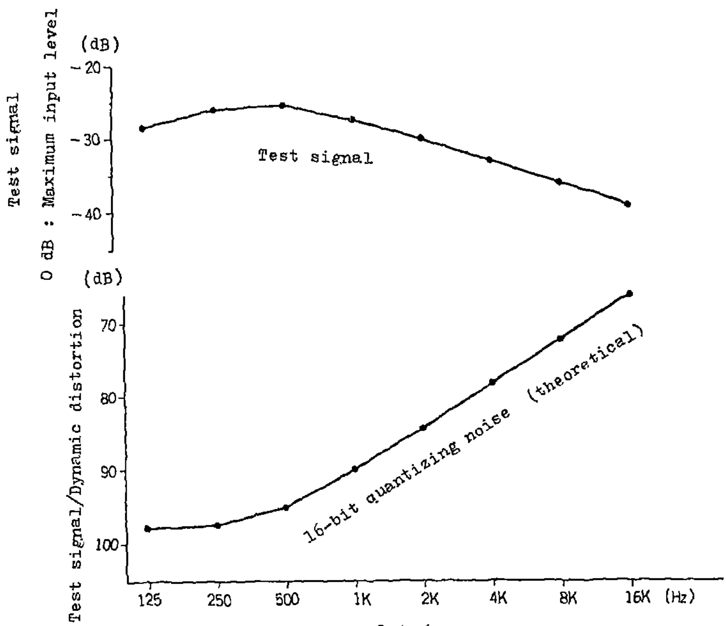


Figure 2. Test signal used and 16-bit quantizing noise.

(Measured with 1/3 oct. band width.)

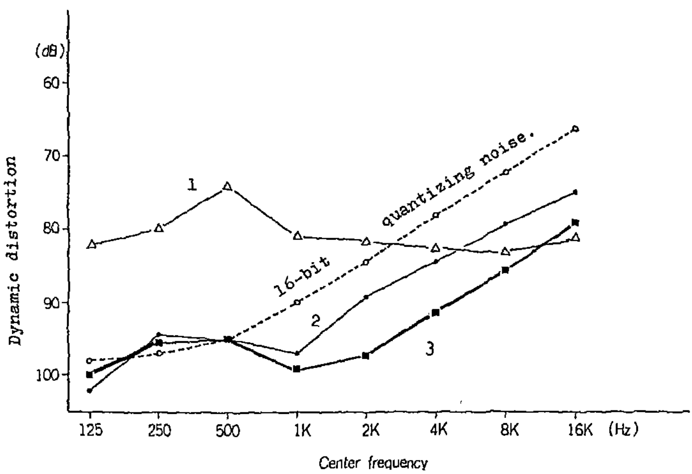


Figure 3. Residual distortion of the measurement system

1:Dynamic distortion of a filter set at +4dBm.

2;At -22 dBm. 3: Residual distortion achieved.

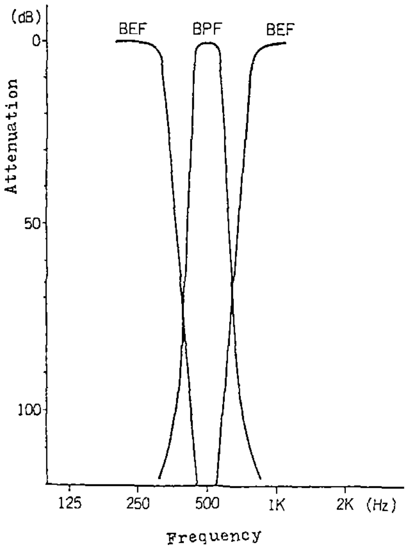


Figure 4. Example of filter responce.

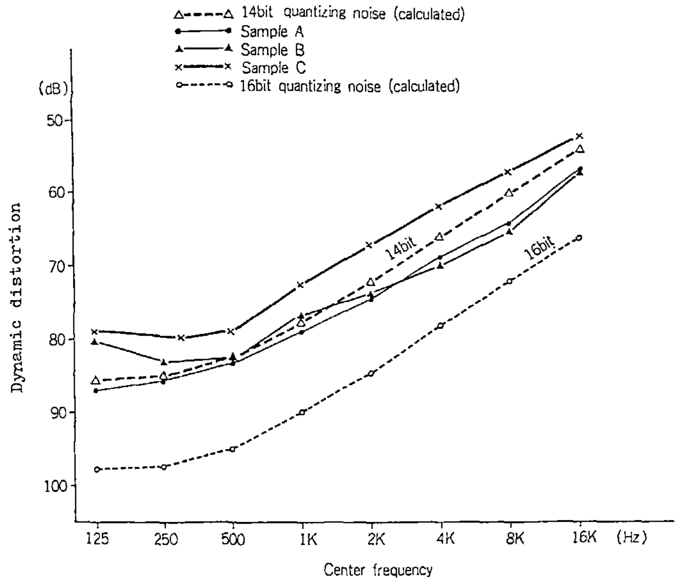


Figure 5. Dynamic distortion of A/D-D/A conversion systems.

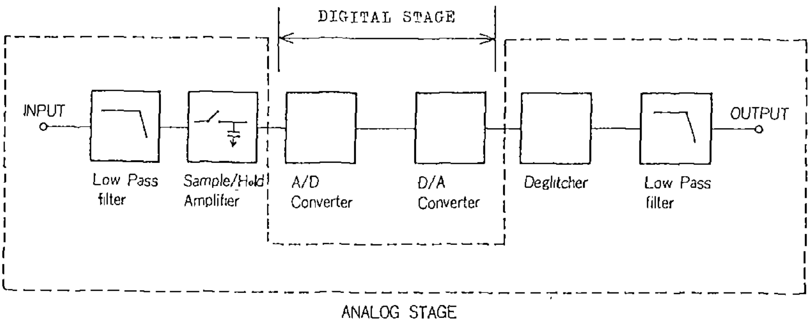


Figure 6. Block diagram of an A/D-D/A conversionsystem.

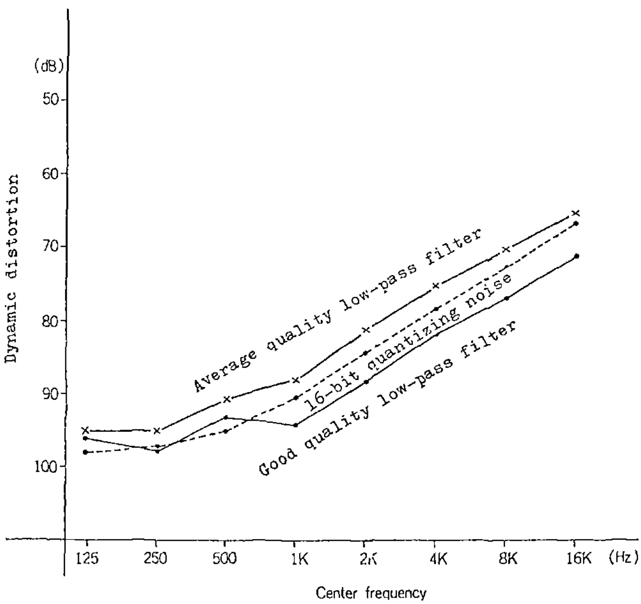


Figure 7. Dynamic distortion of low-pass filters.

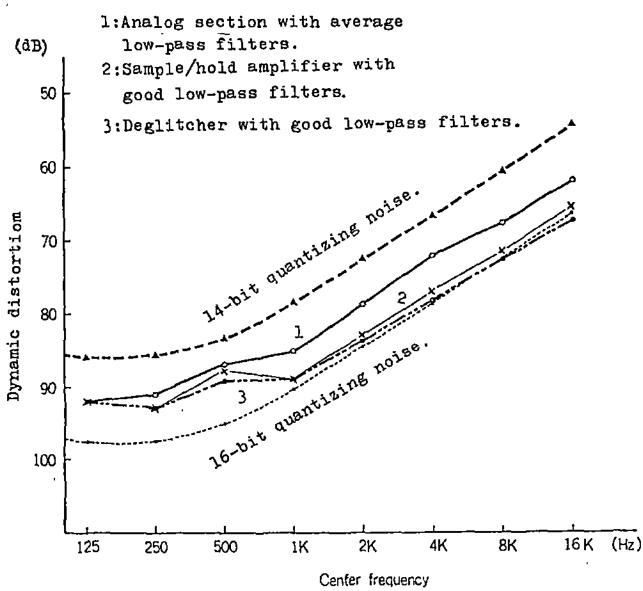


Figure 8. Dynamic distortion of an analog section.

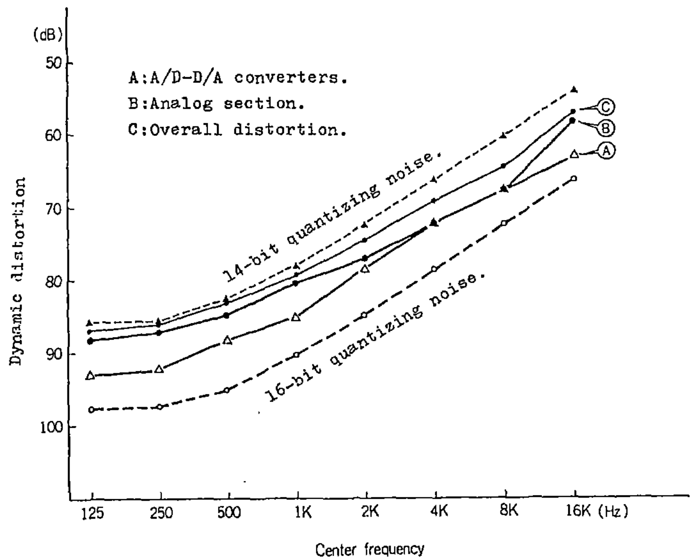


Figure 9. Dynamic distortion of an A/D-D/A converter combination.

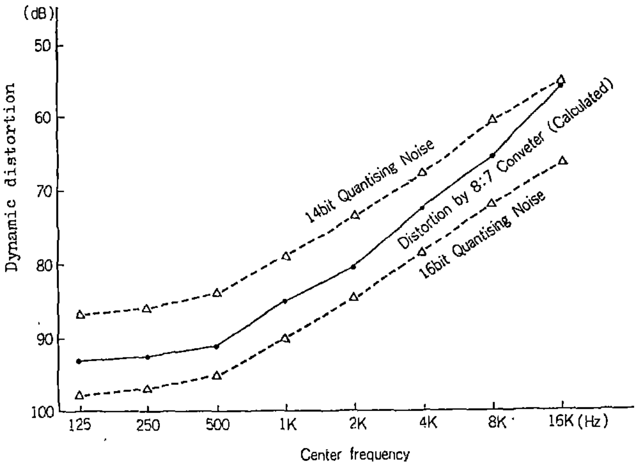


Figure 10. Dynamic distortion of a digital sampling frequency converter.