Sound quality degradation of audio equipment by hum noise induced by non-audible high frequency electrical noise

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Abstract. In recent audio equipment, induction and inflow of non-audible high frequency (HF) electrical noise to audio equipment is increasing more and more due to implementation of personal computer / network connectivity and high-resolution capability in digital audio equipment. In this study, in order to investigate another causes of influence of non-audible HF electric noise on playback sound, we measured a loudspeaker output of an audio amplifier by the audio analyser with inputting single HF sine wave from a function generator to analog input of the audio amplifier. From measured results, it was found that the power of harmonics of 60 Hz (hum noise) on the loudspeaker output of some audio amplifiers increased when single HF sine wave was inputted. Tendency of the increasing of the hum noise component depended on the frequency of the inputted sine wave and model of audio amplifier. These results show the importance of consideration of HF characteristic and countermeasure to the HF noise also in circuit design and tuning of audio equipment.

1. Introduction
In recent years, the progress of research and development on audio equipment leads to high-fidelity sound playback. However, equipment design and tuning are still done subjectively based on the knowledge and experience of the acoustic technicians even today. We think the one cause of this situation is that the playback-sound-quality-deterioration mechanism due to complex and interrelated additional factors, e.g. the operating state of the PC, the state and polarity of each AC power supply [1] in the equipment, cable materials, etc., has not been elucidated. To address this situation, we focused on non-audible high frequency (HF) electrical noise because the HF noise that audio equipment is concerned is increasing more and more due to implementation of personal computer / network connectivity and high resolution capability in recent digital audio equipment.

In our previous study, we confirmed that the HF electrical noise that had “plural” frequency components cause their intermodulation distortion (IMD) in audible frequency band [2]. However, the factors and modes of the sound quality degradation caused by non-audible HF noise were not considered. In this study, in order to investigate sound quality degradation caused by non-audible “single” HF electric noise on playback sound, we measured the loudspeaker output of 5 models of audio amplifier using the audio analyzer when inputting single HF sine wave to analog audio input of the audio amplifier in the frequency range from 1 MHz to 240 MHz.
2. Measurement method of sound quality degradation caused by non-audible single HF noise

2.1 Distortion characteristics of audio output signal caused by non-audible single HF noise

Figure 1 shows apparatus setup for measuring sound quality degradation in audible band of loudspeaker output signal of audio amplifier cause by single HF noise. We measure the frequency spectrum of the loudspeaker output of one model of the audio amplifier (Class A analog amplifier) with the audio analyzer (Audio Precision, APx525) when single non-audible HF sine wave is inputted from a function generator (Tektronix, AFG3252) to the right channel of an analog audio input (LINE IN) of the audio amplifier. The specifications of the FFT analysis is 48 kHz sampling frequency, 1 second measurement duration, and 3 measured spectrum averaging. The amplitude of the HF sine wave input to the audio amplifier is 1 Vrms and the frequency is 60 MHz. The gain of the audio amplifier is set to 0 dB at the 1 kHz sine wave. The power source of the function generator is a commercial AC power supply (100V, 50 Hz). The power source of the audio amplifier is a regulated AC power supply (NF EC1000S, 100 V, 50 Hz, or 60 Hz) connected with 3 poles cable, i.e. Line, Neutral, and Grounding. To prevent noise propagation to audio amplifier from measurement equipment, power source of the audio analyzer is DC / AC inverter (100 V, 50 Hz AC output) and battery (DC 48 V).

In order to confirm the increase of hum noise is caused not in measurement equipment, e.g. the function generator and the audio analyzer but in the audio amplifier under test, we measure the frequency spectrum of the function generator output. In addition, we also measure the noise floor of measuring system and the audio amplifier by outputting 0 V DC signal (equivalent for silent signal) from the function generator.

![Figure 1](image.png)

**Figure 1.** Apparatus set up for measuring sound quality degradation in audible band of loudspeaker output signal of audio amplifier caused by single HF noise.

2.2 Frequency and audio amplifier models dependency of the increase of hum noise

In order to research the frequency dependency and audio amplifier models dependency of the increase of hum noise in audible band caused by the non-audible single HF noise, we measure and compare the frequency spectrum of loudspeaker output of the 5 models of audio amplifiers when the frequency of the HF noise is changed 0.5 MHz each in the range from 1 MHz to 240 MHz. The 5 models of audio amplifiers consist of 3 models of analog amplifiers (model A, C, and D) and 2 models of digital amplifiers (model B and E). The amplifier models A and D has three poles, and the other amplifier, i.e. model B, C, and E, and has two poles. The audio amplifier with 3 poles inlet is connected to the regulated AC power supply with 3 poles power cable. Only the audio amplifier is driven by a regulated AC power supply at 60 Hz in order to distinguish the hum noise source. To evaluate the amount of increase hum noise quantitatively, calculate the sum of the harmonics of the hum noise up to the 5th order (300 Hz).
3. Measurement result of sound quality degradation caused by non-audible single HF noise

3.1 Distortion characteristics of audio output signal caused by non-audible single HF noise

Figure 2 shows the frequency spectrum in audible band of the loudspeaker output of the audio amplifier (model A) when the HF sine wave (1 Vrms, 60 MHz) is inputted to the analog audio input of the audio amplifier, and the noise floor of measured system and the audio amplifier.

From figure 2, it is confirmed that some frequency components such as harmonics of the 60 Hz hum noise increase remarkably in audible band, even though inputted noise is non-audible high frequency. The amplitude of the 60 Hz component increased 47 dBV and that of the 120 Hz increased 72 dBV.

Figure 3 shows the increase of the hum noise when the 60 MHz single HF noise was inputted. We measured and compared for the three cases that the audio amplifier was AC 100 V 50 Hz powered and AC 100 V 60 Hz powered, and the output of the function generator was directly measured with the audio analyzer not via the audio amplifier. The increase of the hum noise is difference between the sum of amplitude of the hum noise harmonics up to 5th order and the amplitude of the noise floor (without the HF noise inputted) at the frequency of the hum noise harmonics.

From figure 3, it is confirmed that the 50 Hz component and its harmonics are increased when the audio amplifier is AC 50 Hz powered, and the 60 Hz component and its harmonics are increased when the audio amplifier is AC 60 Hz powered. In the case that not via the audio amplifier, the hum noise was not increased even though the single HF noise was outputted from the function generator. It is found that these hum noise of the loudspeaker output caused by the single HF noise had relation with internal power supply of the audio amplifier.

From these results, it is found that the non-audible HF noise inputted to audio amplifier increases, hum noise, and degrades sound quality of audio equipment.

3.2 Frequency and audio amplifier models dependency of the increase of hum noise

Figure 4 shows the increase of the hum noise of the 5 models of the amplifiers, caused by the single HF noise in the range of 1 MHz to 240 MHz. The audio amplifier was AC 60Hz powered in this measurement.

From figure 4, it is found that the susceptibility to the single HF noise to the single HF noise
depends on the models of audio amplifier and the frequency of the HF noise. With the frequency range and audio amplifier models in this measurement, it is confirmed that the increase of the hum noise is caused in 2 models out of 5 models of the amplifier. The maximum increase of the harmonics of 60 Hz was 27.4 mV$_{\text{rms}}$ (-31.3 dBV) in the case that 64.0 MHz single HF noise was inputted to the model A audio amplifier. The harmonics of 60 Hz was also increased 7.89 mV$_{\text{rms}}$ (-42.1 dBV) in the case that 15.5 MHz single HF noise was inputted to the model B audio amplifier. However, the hum noise didn’t increase in the rest 3 models in these frequency range of the single HF noise. These susceptibility did not depend on the amplification circuit architecture, i.e. analog amplifier or digital amplifier.

![Graph showing the increase of the hum noise of the 5 models of the amplifier caused by the single HF.](image)

**Figure 4.** Increase of the hum noise of the 5 models of the amplifier caused by the single HF.

4. Conclusion
In this study, we investigated influence of non-audible “single” HF electric noise on playback sound of 5 models of audio amplifier in the frequency range from 1 MHz to 240 MHz. From measured results, we confirmed that non-audible single HF noise inputted to audio amplifier increased the hum noise related to the frequency of the AC power supply in the audio amplifier. It was also found that the susceptibility to the single HF noise depended on the models of audio amplifier and the frequency of the HF noise.

The results mean that circuit design and countermeasures with considering characteristics even in higher frequency over audible band is necessary to avoid the bad influence in audio equipment and connected audio equipment, particularly in modern electro-acoustic equipment with many HF noise source. Elucidation of the cause of the sound quality degradation mechanism which is found in this study is our future work.

References

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