

# NES Audio: Amplitude difference caused by triangle phase variation

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January 31, 2020

While working on the *NES* version of *MDFourier* we noticed that sometimes some of the channels being compared would change in amplitude between takes of the same console. The difference seems to be between  $-3dBFS$  and  $3dBFS$ , which is big enough to be considerable.

## 1 Understanding the plots, briefly

Many details will be overlooked, but for simplicity a good match between the compared files would imply all lines being flat following the  $0dBFS$  line. This is because the vertical axis represents the difference in amplitude between the files.

Here is a zoomed in example, presenting two recordings that match very closely:

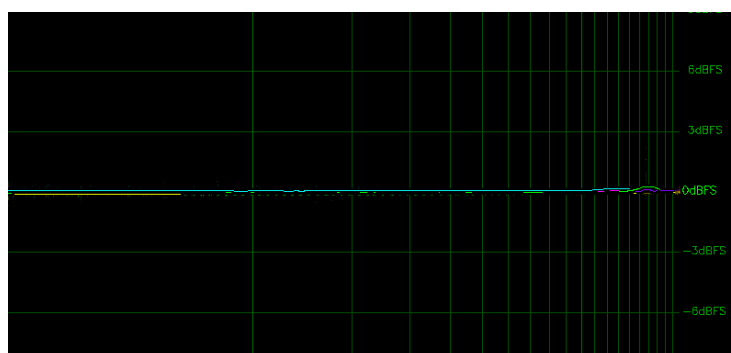


Figure 1 The same console compared against itself, matching all levels. (zoomed in)

The horizontal axis is the range of frequencies that is being compared, we typically go with  $20Hz-20kHz$  range, since this covers the human hearing spectrum.

All channels being compared have a specific color, as described in the following image:

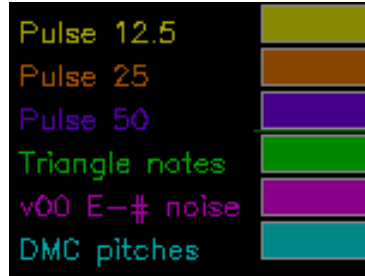


Figure 2 Colors used within the graphs in this document.

Here is an example of two recordings from the same console made consecutively, that show differences in amplitudes:

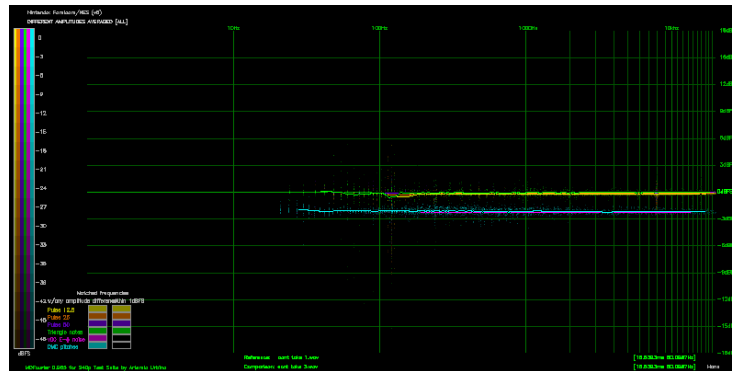


Figure 3 The same console compared against itself, presenting differences.

As you can see, there is a difference in the *DMC pitches* and *Noise* channels, which is flat through the whole frequency range at about  $-2dBFS$ .

## 2 The problem with triangle phase

These differences fluctuate between various values, while the other channels remain constant during consecutive recordings.

It was suggested that this could be caused by the triangle channel having slightly different phase each time the test tone was played. This correlation was confirmed by comparing the *Phase* and *Waveform* graphs from *MDFourier* as shown below.

Here are the wave forms of the first triangle pulses from matching recordings:

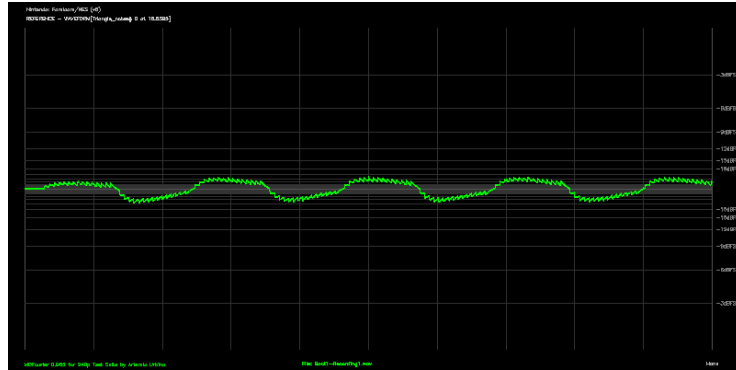


Figure 4 First Triangle wave form.

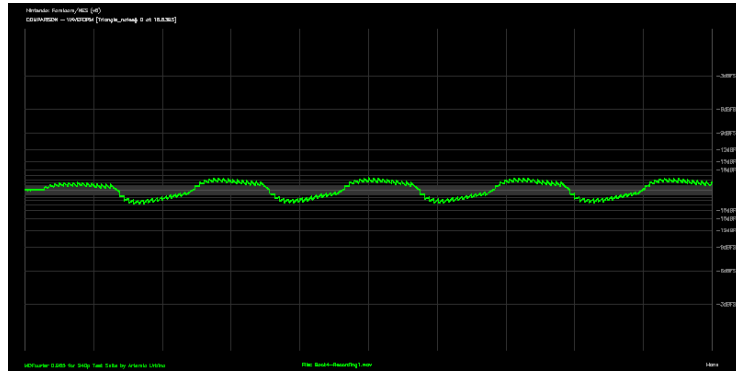


Figure 5 Second Triangle wave form.

In these graphs, the vertical axis is the amplitude and the horizontal axis is time, measured in frames indicated by vertical lines. As you can see, both signals start at the same point in time. This is what we call being in phase with each other. Deviations in position are measured in degrees, following what is used in trigonometric functions.

Here are the same segments taken from consecutive recordings, when the *DMC pitches* and *Noise* channels vary in amplitude.

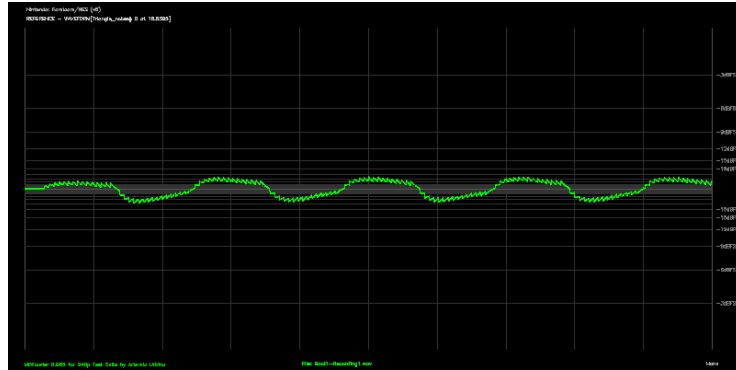


Figure 6 First Triangle wave form, out of phase.

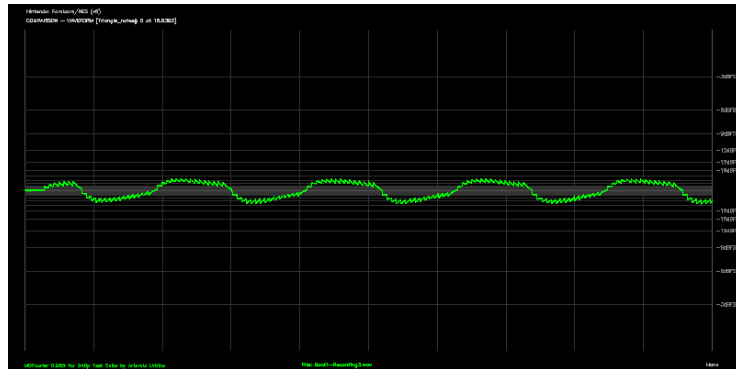


Figure 7 Second Triangle wave form, out of phase.

As you can see, the second triangle wave form is almost half a frame displaced horizontally to the left. This is an out of phase scenario, and causes the amplitude discrepancy in the two other channels.

Here is a *Phase Difference* plot from two matching recordings. The horizontal axis is frequency, and the vertical axis is the phase difference in degrees.

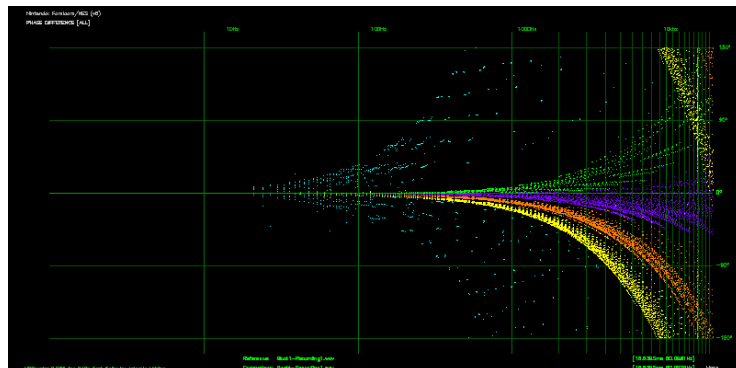


Figure 8 Phase difference graph between matching recordings.

These graphs have consistently shown that phases tend to diverge with frequency when compared this way<sup>1</sup>, but the part that has proven useful so far is the left part of the image. As you can see all signals start at 0 degree phase difference.

For contrast, here is the *Phase differences graph* of the same console against itself during consecutive recordings:

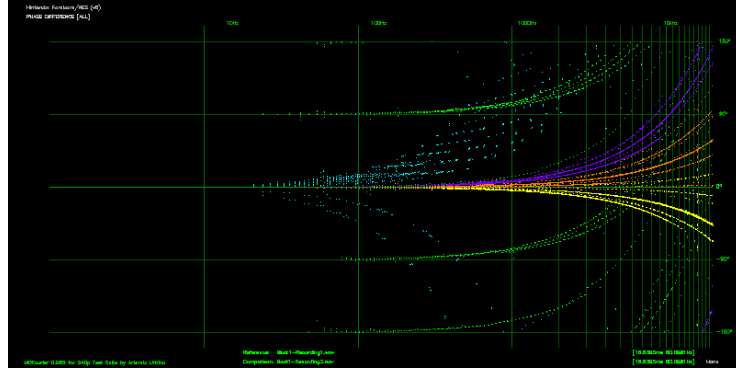


Figure 9 Phase difference graph between non-matching recordings.

You can see that although some triangle patterns start at 0 degrees, most of them are out of phase by 90 degree multiples. These are the results of comparing the phase from the waveforms in figures 6 and 7.

As to the amplitude effect over *DMC pitches* and *Noise* channels, the waveforms of each are presented for completeness.

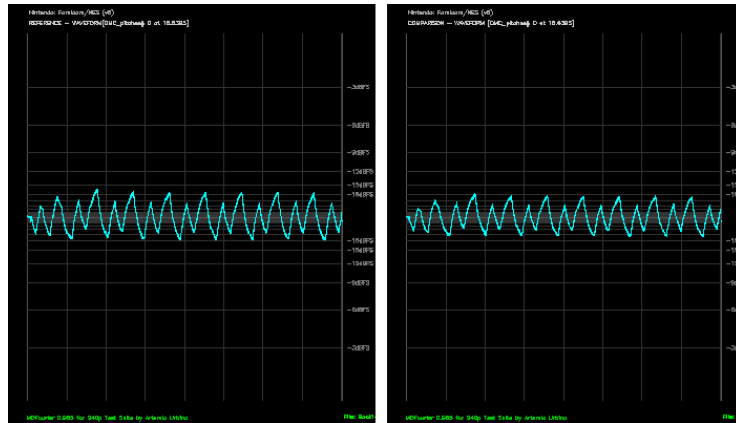
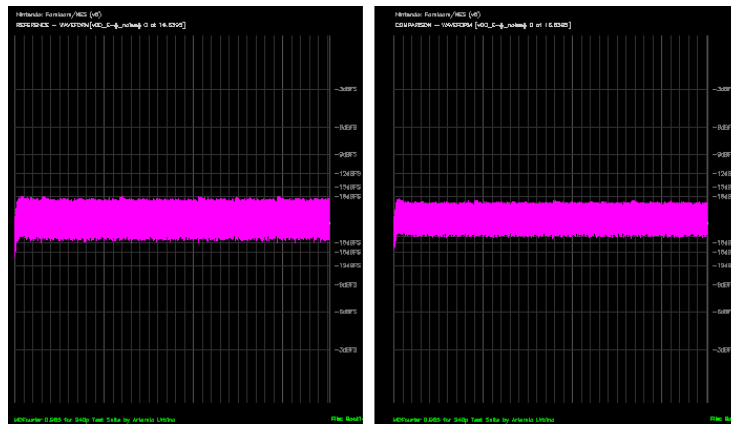


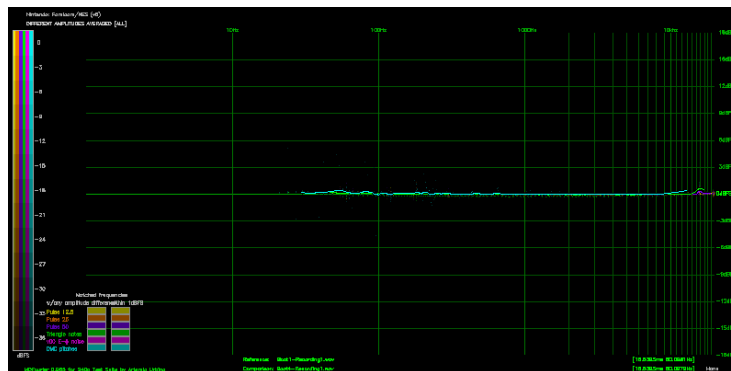
Figure 10 DMC amplitude difference

<sup>1</sup>I believe that this phase/frequency divergence is based on CPU cycles. I honestly need to understand this better yet



### 3 Solution

It was noted that recording after power cycling the *NES* console—*cold booting* it—would always produce the same phase, and thus create recordings without variation. This is a very important aspect of the project, since it gives repeatability and consistent results.



Due to the impact this issue presents, we are figuring out the measures to be taken. I personally believe that due to the severity of the differences we should enforce `mdfourier` to run only when cold boot is guaranteed.

## Glossary

**dBFS** decibels relative to full scale. 1

**Hz** Hertz. 1

**kHz** KiloHertz. 1