A Comparative Analysis Between Different Audio Cables.

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Abstract. This article aims to investigate the causes of the hearing difference between different interconnection cables between an analogue digital converter and a power amplifier. An audio system was set up to reproduce 41 sinusoidal signals with varying frequencies from 20 to 20 kHz, to investigate possible discrepancies between the cables. These signals were recorded on an audio interface with RCA input, with a sampling frequency of 192 kHz and 24 bits. Using the audio signals that were recorded, MATLAB was employed to determine the average of the peak values of each cable for each frequency. Subsequently, the values were compared with each other with the aim of determining which frequencies each cable exhibits greater intensity. As per our findings, the average discrepancy between frequencies ranging from 20 to 14100 Hz is 0.0238%, whereas the discrepancy between frequencies ranging from 16 to 20 kHz is significantly greater, ranging from 8.366% to -21.44%. Moreover, by analysing a 0.681 second piece of music, the RMS value of the signal was calculated, resulting in 0.04967 for the Lumix cable and 0.04961 for the Audio cable, with a percentage difference of 0.12% between the cables. Furthermore, a Fourier Transform was conducted to identify the frequencies possessing the highest energy. The analysis consisted of determining the cable with the highest energy for each frequency. For this, a weighted average was made between energy and frequency. For the Lumix cable, the weighted frequency of the signal was 510.86 Hz, and that of the Ataudio cable was 1097.34 Hz. In this manner, Lumix reproduces medium-frequency sounds with greater intensity, whereas Ataudio reproduces high frequencies with greater intensity. Moreover, it is noteworthy that a more accurate reproduction of high frequencies facilitates a better visualization of musical instruments in stereo listening, a feature coveted by high-end audio (HEA) systems.

Keywords. Cables, acoustic perception, measurements, high-fidelity, high-end.

1. Introduction

Music recording and reproduction serves a wide range of purposes, from simple amateur recordings to the recording and reproduction of professional music on high-fidelity devices, known as High Fidelity. The objective is to achieve the highest possible audio fidelity [1]. To achieve this, several specialized devices are needed, better designed, and built, such as a separate analog-to-digital converter, pre-amplifiers, audio interfaces and speakers, and interconnection cables are used to connect all this equipment.

In the audio community, particularly among enthusiasts of accurately reproduced music, there exists a significant debate regarding the impact of cables on the quality of music recording and reproduction. Various brands produce cables that are constructed with diverse materials and construction techniques and materials, including shielding from electromagnetic interference, gold, or silver coatings, and even cables that claim to be monocrystalline, claiming to enhance fidelity. Others argue that cables do not interfere and can be seen as a non-distorted, linear medium, which goes against the pre-established audio cable industry.

Furthermore, due to the lack of articles published on this topic, many myths arise within the audiophile community and, therefore, this article is necessary to investigate this discussion. After all, audiophiles hear differences between cables, and for this auditory difference, they pay hundreds of dollars, and this does not happen due to manufacturers' marketing.

The objective of this article is to investigate the causes of the hearing difference between different interconnection cables between an analogue digital converter and a power amplifier.

2. Methodology

2.1 Experiment Set Up

To investigate potential discrepancies, a setup was devised comprising a Blu-Ray Sony BDP — S480, which reproduces 41 sinusoidal signals at frequencies between 20 Hz and 20 kHz. It was connected to a DAC (Digital Analog Converter) Topping E30 via the RCA cable, which is intended for study, and to the Yamaha AG06 audio interface. Analog signals are recorded with a sampling rate of 192 kHz and with 24 quantization bits. The audio interface was connected to an Avell notebook via a USB A-B cable, and the 41 signals were recorded with Audacity software for the computer. A second recording was made from a YouTube video, with the notebook as the source and the audio signal decoded from digital to analog on the Topping E30. Figure 1 shows a schematic of the equipment connection.

One of the cables studied is an Ataudio digital cable (HIFI Red Spider Coaxial Cable) HIFI RCA Cable, an 8-wire cable, made up of 20 OCC (Ohno Continuous Casting) conductors and 8 wires made up of 20 Silver Plated conductors. The other cable, Lumix, was manufactured in a reputable audio equipment store located in Curitiba-PR, Brazil.

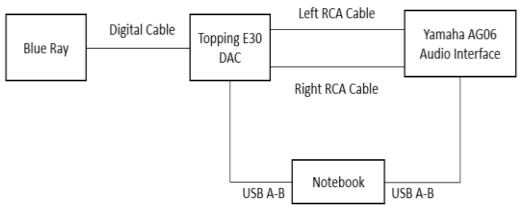


Fig.1 – Schematic of the connection between the audio components, with Blu-ray to reproduce the 41 sinusoidal signals.

2.2 Analysis

To conduct an analysis of the audio, we attempted to synchronize the recorded signals with Lumix and Ataudio cables by utilizing MATLAB software. However, a deviation in the signal sampling frequency was detected, rendering it unfeasible to synchronize the waveforms for the 20 kHz recording, despite its 192 kHz sampling rate.

To address this issue, an alternative approach was employed in the time domain. We sought the average value of the positive and negative peak values for each of the 41 frequencies by calculating the expression:

$$Vmpa = \frac{\sum_{i=1}^{N} Vpa}{N} \quad (1)$$

$$Vmna = \frac{\sum_{i=1}^{N} Vna}{N} \quad (2)$$

N being the number of maximum positive points, Vpa, or minimum negative points, Vna, found in the set of each of the 41 frequencies. The value of N varies depending on the signal frequency. For each frequency, the signal lasts 30 seconds. So, for example, for a frequency of 20 Hz. In terms of N= 30 × 20 = 600 points. For other frequencies, the number of peaks varies. With these maximum voltage peak values, it is expected to find a difference in average values for each cable, at each of the 41 frequencies.

3. Results

The CD-player/DAC set exhibits a variable output voltage response in accordance with the frequency, exhibiting a significant decrease from 14.1 kHz onwards. Figure 2 shows the two frequency responses for the average output voltage for the cables, Ataudio in red and Lumix in blue.

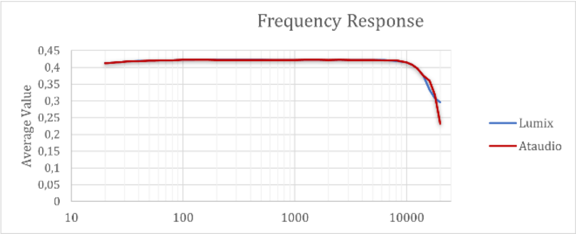


Fig.2 - Average positive voltage values as a function of frequency for Lumix and Ataudio cables.

To determine a more significant difference between the average values of the peaks between the two cables, see figure 3. The percentage difference between the maximum average values is shown with equation (3) as a function of the 41 frequencies:

$$difper(f) = \frac{(VmpaAtd(f) - VmpaLmx(f))}{VmpaLmx} * 100 \quad (3)$$

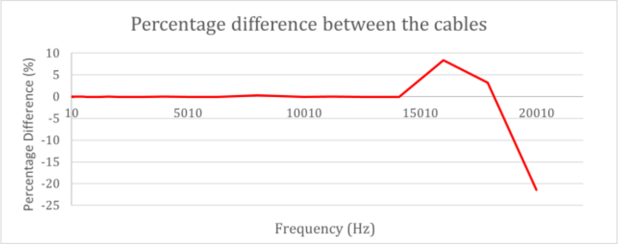


Fig.3- Shows the percentage difference as a function of frequency between the average peak values between Lumix and Ataudio cables.

According to equation (3), the average difference between frequencies of 20 and 14100 Hz is -0.0238%, while the difference between frequencies of 16, 17.9 and 20 kHz is significantly greater, ranging from 3.178% to a maximum of 8.366% and a minimum of -21.44%.

The time domain will be displayed for an audio signal extracted from a song found on YouTube — Raminchuvarevaru in Raaga Suposhini played by Mandolin U Rajesh [2]. The two waveforms that were recorded using the Lumix and Ataudio cables are closely aligned and visually overlapped, as depicted in figure 4. The audio duration was approximately 0.681 seconds, recorded at a sampling rate of 192 kHz and with a bit depth of 24 bits. The voltage difference between the two cables was calculated in this section, in the time domain. In Figure 5, there is a series of zooms to visualize the small difference in signal intensity.

To fully observe the voltage difference between the cables, the RMS value was obtained for the two recordings. For the portion depicted in Figure 4, a value of 0.04967 was determined for the Lumix cable, while a value of 0.04961 was determined for the Ataudio cable, utilizing the signal recorded with the Lumix cable as a reference. This means that the signal recorded with the Lumix cable is stronger than usual.

This can be explained by the behavior in the frequency domain, where the energy is greater at low and medium frequencies and lower at high frequencies. To gain a more comprehensive understanding, an analysis of the frequency spectrum was conducted using the Audacity program for a duration of 0.681 seconds, encompassing the audio recordings. Figure 6 shows the frequency spectrum analysis, which covers the range of 0 to 20 kHz.

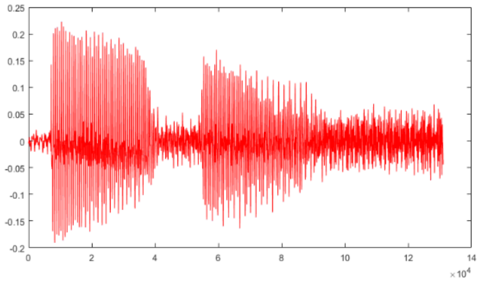
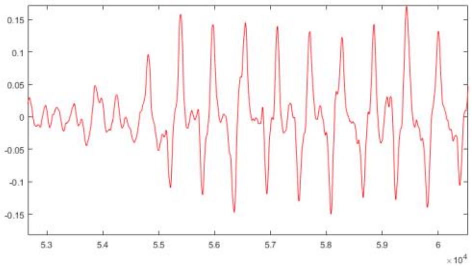
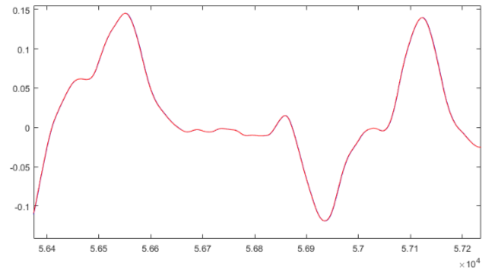


Fig.4 - Audio excerpt that will be analyzed in the time and frequency domain, with 131072 points and 680.83 ms.

A sequence of zooms is required to see the differences.





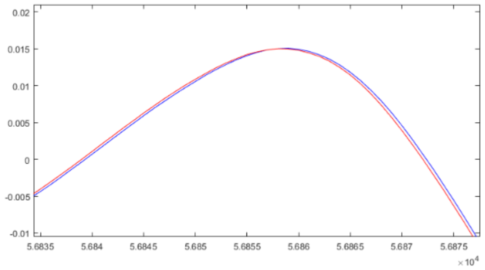


Fig.5 - Shows a sequence of zoomed in images to visually find the small difference in voltage between the cables (Red Ataudio, blue – Lumix).

For the high-energy signals, both cables have very similar waveforms. Audacity's frequency spectrum analysis generates a file in dB as a function of frequency. From the file, a graph was generated using the Fourier Transform of the section at the selected time, presenting the results in figure 6.

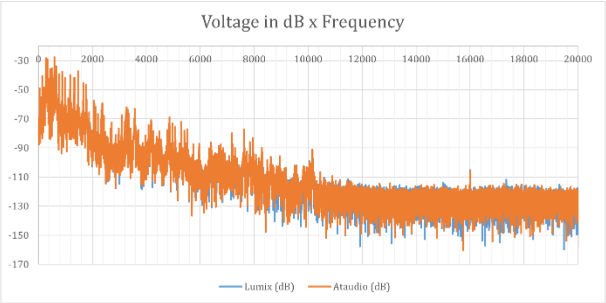


Fig.6 – Voltage levels of Lumix and Ataudio cables by signal frequency.

The signal is attenuated at different frequencies by different cables. As shown in Figure 2, the Lumix cable attenuates less at low, medium, and even high frequencies, around 14 kHz. To enhance the comprehension of the variances among cables in terms of frequency, it was discovered that in certain frequency bands, each cable exhibits a greater voltage intensity. The frequencies that have the highest voltage level are 296, 332 and 590 Hz, as shown in figure 7. The Lumix cable has the highest voltage level for these frequencies.

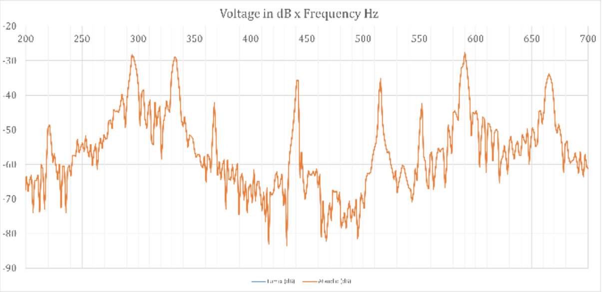


Fig. 7 – Maximum cable voltage levels between 200 and 700 Hz.

The absolute value, expressed in volts, of the signals was determined for the Lumix and Ataudio cables, respectively, as a function of frequency, utilizing the equation (4).

$$Val(Freq) = 1 * 10^{\left(\frac{ValdB}{20}\right)} \qquad (4)$$

The outcome is depicted in the fourth column of table 1 and the fourth column of table 2, with the decibel values for columns 2 and 3 of table 1.

The medium frequencies have greater intensity, as can be seen in the first 4 values in table 1. The Lumix cable exhibits a greater intensity at this band frequency, as illustrated in figure 7.

Tab. 1 – Frequency with maximum voltages, in dB, for each cable. For the Lumix cable, the voltage value.

Frequency (Hz)	Lumix (dB)	Ataudio (dB)	Lumix Value
590.332	-27.584	-27.594	0.0418
294.434	-28.275	-28.285	0.0386
332.520	-28.911	-28.921	0.0358
295.898	-28.956	-28.965	0.0357

In table 2, columns 2 and 3 show the energy of the signals from the Lumix and Ataudio cables, respectively.

The energy, for each frequency, is calculated for each cable with equation (5), and dt is the inverse of the sampling rate which is 52.08 micros seconds.

$$Energy(Freq) = Val(Freq)^2 * dt \qquad (5)$$

The energy of each cable, whether Lumix or Ataudio, was incorporated separately when it possessed a greater signal strength in comparison to the other cable. For instance, the Lumix cable exhibits a greater intensity at the first 20 frequencies of maximum value, and the energy of these 20 frequencies amounts to 57.43% of the total energy of the cable.

Tab. 2 – Frequencies with maximum energy and voltage value for the Ataudio cable.

Frequency (Hz)	Lumix Energy	Ataudio Energy	Ataudio Value
590.332	9,084E-9	9,064E-9	0,0417
294.434	7,748E-9	7,731E-9	0,0385
332.520	6,692E-9	6,678E-9	0,0358
295.898	6,624E-9	6,610E-9	0,0356

The Lumix cable has greater intensity at certain frequencies, while the Ataudio cable has greater intensity in different frequencies. To determine the location where each cable reaches its highest weighted intensity average, the signal energy was calculated using the equation (6).

$$MedSig_j = \frac{\sum_{i=1}^{N_j} Freq * Energy(Freq)j}{\sum_{i=1}^{N_j} Energy(Freq)j} \qquad (6)$$

Where j is the cable, 1 Lumix, 2 Ataudio, Freq is the frequency where each cable has a greater signal value, Energy (Freq) is the energy for each frequency, and Nj is the total number where each cable has a greater signal value.

The signal of Lumix is more prominent at low frequencies, whereas that of Ataudio is more prominent at higher frequencies. After some calculations, using the equation 6, it has been determined that the average weighted frequency for the Lumix cable is 510.86 Hz, whereas the average weighted frequency for the Ataudio cable is 1097.34 Hz.

To better understand auditory perception, how sounds transform into music, and how they generate an emotional connection with musicians, singers, bands, we present a methodology developed by Fernando Andrette [3] in the “Clube do Audio” magazine, where it reviews audio equipment, and even interconnection cables. From his methodology, it is possible to discern some audio signatures by listening to the recording made with the cables used in this study.

Starting with Tonal Balance, which consists of a balanced perception of bass, mid-range, and treble where metallic, aggressive trebles coming from digital sources must be avoided. In the Sound Stage item, it says that “high-pitched sounds contribute more to the location of the source”, confirming our results. High frequency also contributes to improving micro dynamics, which is the expression of the sound intensity within the instrumental plot. This allows the musical discourse of each instrument to be followed, in particular its dynamics. A further term is 'transients', which refers to the ability to respond quickly and in a controlled manner to sudden and non-periodic signals. The presentation of the methodology ends with the 'harmonic body,' which is the size with which the system presents its instrumental or vocal images.

The human hearing is very sensitive and has a high learning capacity [4]. The author learned to hear differences between one microphone and another and brands of magnetic recording tapes.

4. Conclusion

High frequency sounds provide a more spatial sound. The main question is not whether cables produce hearing differences, but rather, why do they? Auditory, it is clear that the better the reproduction at high frequencies, in stereo, the better the definition of the instruments and their spatial location between the speakers.

There are many elements of audio, such as those described by the methodology above, that need to be further studied. The present article deals only with the frequency response of standard sinusoidal signals and the analysis of just one musical excerpt with a predominance of medium-low frequencies (from 250 to 2000 Hz), where it is clear that a lower quality cable, Lumix, reproduces medium frequencies better and in better quality cable, Ataudio, reproduces high frequencies, above 6 kHz, better.

For a more detailed analysis, it would be necessary to work with musical excerpts from the most varied instruments, involving all audible frequencies from 20 Hz to 20 kHz, with dynamic variations, harmonic relationships, rhythm, between notes. Evidently, this would result in a more accurate analysis of how each cable reacts to music played by audio equipment reproducing musical signals.

It can be said that the most important point to be considered is how the auditory system behaves when faced with the sound heard from the music itself. The human ear is very sensitive [5] and capable of learning to perceive auditory differences produced when using different cables between audio equipment.

In this study, we sought to understand some reasons why people hear differences between interconnection cables manufactured with different materials. There is a small numerical variation between the two signals when measured with the two cables. Dividing sinusoidal frequencies from 20 Hz to 20 kHz into 41 times, for frequencies above 14 kHz the variation was up to 21%. For a musical segment of 0.681 seconds, with dominant frequencies in the medium frequencies, the variation was approximately 0.12%. Auditory, this excerpt exhibits minimal variation, but it is noteworthy that a more accurate reproduction of high frequencies facilitates a better visualization of musical instruments in stereo listening, a feature coveted by high-end audio (HEA) systems.

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