

Technical parameters vs. perception: Subjective and objective approaches to assessing the impact of speaker cables on sound

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Abstract—The speaker cable used to connect a power amplifier to a speaker is a topic of much debate between researchers and a group of music enthusiasts known as audiophiles. To analyse this issue, both objective and subjective measurements were conducted to study the impact of changing the type of speaker cable on the listener's auditory experience. The results of the objective research include the frequency characteristics of the tested cables, THD+N values, and measurements of the frequency response of the speaker system connected to the amplifier using different speaker cables. For the subjective tests, 15-second audio samples from three different music genres were used, along with a comparative evaluation method. The tested perceptual attributes were dynamics, clarity of sound, transparency, and overall rating. Gathered results made it possible to conclude that the influence of the loudspeaker cable in a music system is negligible. Subjective tests carried out on an expert group confirmed the theory that the loudspeaker cable used in a home music system has no effect on music reception in any of the genres tested.

Keywords—loudspeaker cables; Objective Measurements; figure

I. INTRODUCTION

Speaker cables with varying constructions and cross-sectional areas are used to connect speaker devices to power amplifiers. Due to the high currents flowing through such cables, especially when transmitting signals over long distances, a key parameter of the speaker cable is its resistance, which is inversely proportional to the cross-sectional area of the conductor. The resistance of the cable is also directly proportional to the type of conductor material used to make the cable.

The most common elements used in the production of cables are copper and aluminium, due to their electrical properties and cost. The resistivity of copper is $1.7 \times 10^{-8} \Omega \text{m}$, while that of aluminium is $2.8 \times 10^{-8} \Omega \text{m}$ [1]. Therefore, it can be concluded that aluminium is a less efficient, but cheaper, material for manufacturing cables. Two identical cables (with the same cross-sectional area and length), one made of aluminium and the other of copper, will have resistances that differ by a factor of two. This is due to the following formula (1)

$$R = \rho_0 \cdot \frac{l}{S} \quad (1)$$

Where:

R – resistance of the cable

ρ_0 – resistivity of the conductor

l – length of the cable

S – cross-sectional area of the cable's conductor

The effect of cable resistance on energy loss due to current flow becomes significant when transmitting signals over long distances.

In literature, the influence on sound perception when changing speaker cables is solely attributed to their electrical parameters, such as resistance, inductance, and parasitic capacitance. In the studies by Nicolas Bertini and France François Montignies [2], the electrical relationships of using different speaker cables in electroacoustic systems are discussed, along with practical guidelines for selecting cables for specific applications. These studies also confirm that the most important parameter of speaker cables is their resistance, which determines the power losses in the connection cables. This is particularly important in large professional speaker systems, where the distance between the speaker device and the amplifier can reach several kilometres.

In Malcolm Omar Hawksford's study titled "*Electrical Signal Propagation and Explores the Implications for Audio Cable Performance*" [3], the electrical relationships between signal propagation in the cable and the reception of the propagated signal are also presented. Once again, it was noted that electrical parameters such as resistance, inductance, and parasitic capacitance are the primary factors influencing cable quality. Therefore, the selection of a speaker cable should be based primarily on its electrical parameters, especially the resistance, which is determined by the cable's cross-section, length, and the conductor material.

In Fred E. Davis study entitled "*Effect of Cable, Loudspeaker and Amplifier Interactions*" [4] shows the electrical interaction between power amplifier, speaker cable and speaker system. In the given tests 12 different, not only amplifier – speaker system

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connections dedicated cables were measured. The study finds out that the inductance of the cable is the most significant factor, besides resistance, influencing speaker cable performance, especially at high frequencies. Moreover, a system consisted of speaker cable and speaker system may influence the delay characteristics of the amplifier. To reduce the cable inductance many independently insulated wire (Litz wire) cables should be used.

The main purpose of this article is to answer the question asked by those in the audiophile community ‘Do loudspeaker cables affect the sound of a music system’. To achieve that goal The objective and subjective measurement were conducted. The second paragraph of the article shows the results of the conducted measurements divided into two parts. First part presents the objective measurement data with measurements methodology and data analysis. Second part presents subjective test methodology, results and statistical analysis and interpretation of results. Third paragraph on basis of conducted tests give the answer to the given question.

II. RESEARCH METHODS

For research purposes, two types of measurements were conducted. First, detailed objective measurements were presented, followed by subjective tests.

A. Measurement Objects

- Vitalco LAUDIO – the cheapest measured speaker cable, 2 x 2,5 mm² OFC cable with Vitalco banana connectors,
- Frey NORDOST – silver plated OFC, 22 x 22 AWG litz wire, capacitance 10.3 pF/ft, inductance 0.135 μ H/ft
- Chord Signature XL - silver plated OFC, 2 x 10 AWG,
- Tellurium Q Black – no data provided by the manufacturer

B. Objective Measurements

Objective measurements were carried out using an AudioPrecision APx515B measurement device. A 0.5 m shielded BNC cable was used as the reference measurement. The measured cables were individually connected to the + terminals of channel 2 of the analyser and generator. The ground of output 2 and input 2 was connected using a 10 mm² cable, 15 cm in length. Measurements were conducted by applying a sweep signal at the output, covering a frequency range from 10 Hz to 45 kHz, with a voltage of 1 V RMS. The input impedance of the analyser was 100 k Ω . The measurements were performed using the Stepped Frequency Sweep module, employing a logarithmically tuned sine wave signal analysed at 300 points, without using filters.

1) Frequency Response

The frequency response was examined relative to the frequency response of the shielded BNC cable to eliminate measurement uncertainties resulting from the parameters of the measurement device used.

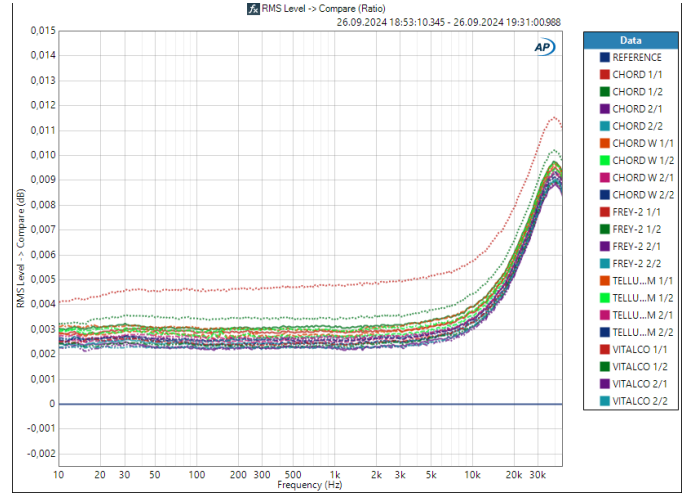


Figure 1 Frequency characteristics related to the characteristics of the BNC cable, of all tested cables

Analysing the results presented in Figure 1, it can be concluded that the transmission characteristics of all the tested cables are consistent within the range of +0.012/+0.002 dB. The average person can perceive a difference of 1 dB, which leads to the conclusion that the observed differences are imperceptible. The variations in levels result from differences in cable resistance. The deviations from the reference conductor at high frequencies may be due to the inductance of the cables under test, as assumed by Fred E. Davis [4].

2) THD+N

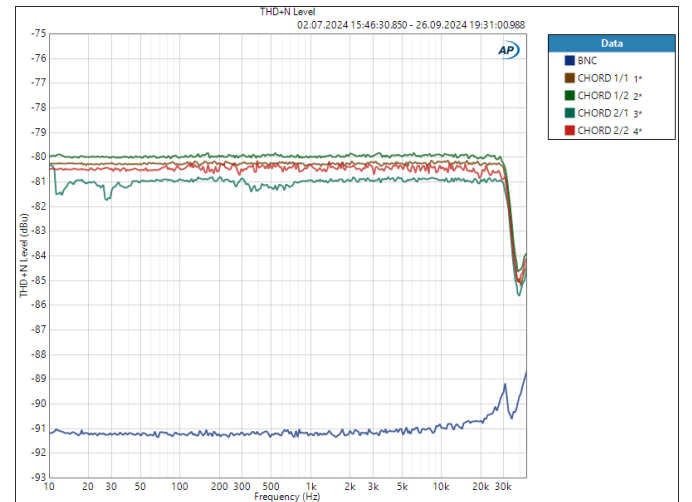


Figure 2 THD+N Values for Measurements of CHORD cable

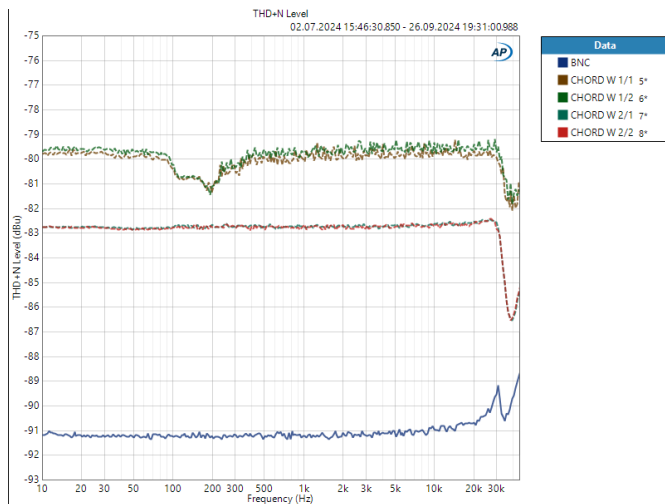


Figure 3 THD+N Values for Measurements of CHORD WHITE cable

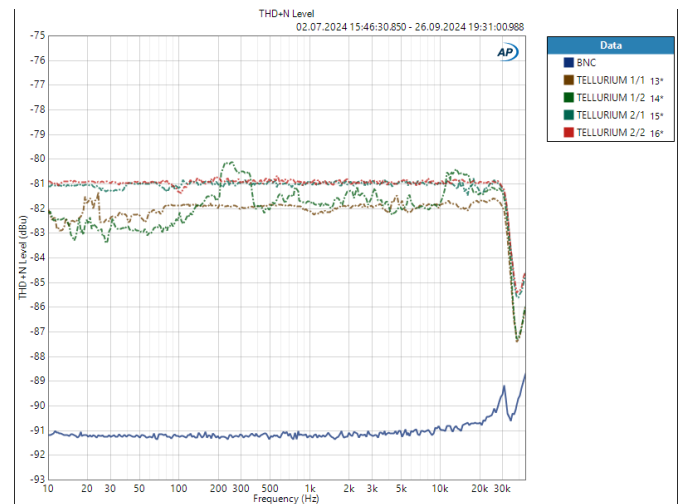


Figure 6 THD+N Values for Measurements of TELLURIUM cable

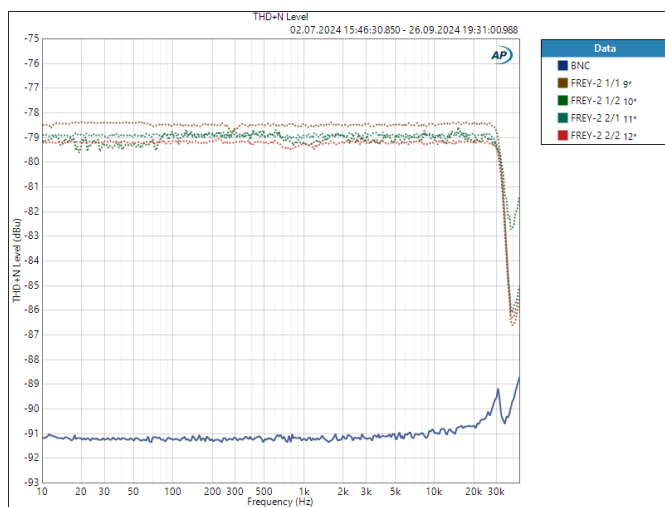


Figure 4 THD+N Values for Measurements of FREY 2 cable

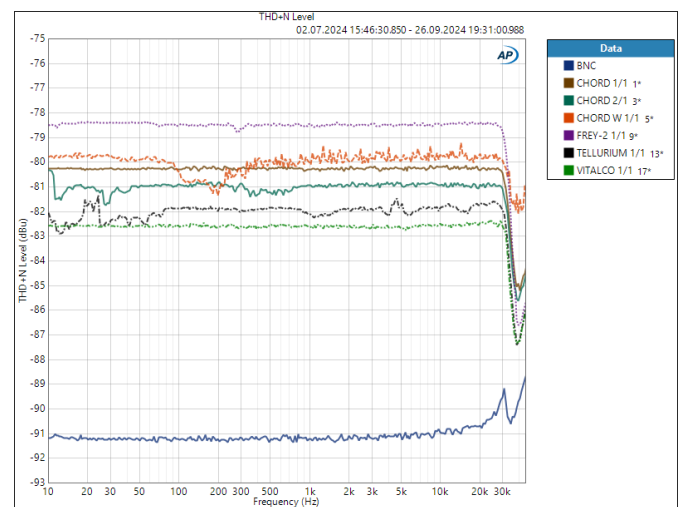


Figure 7 THD+N Values for Measurements of Different Speaker Cables

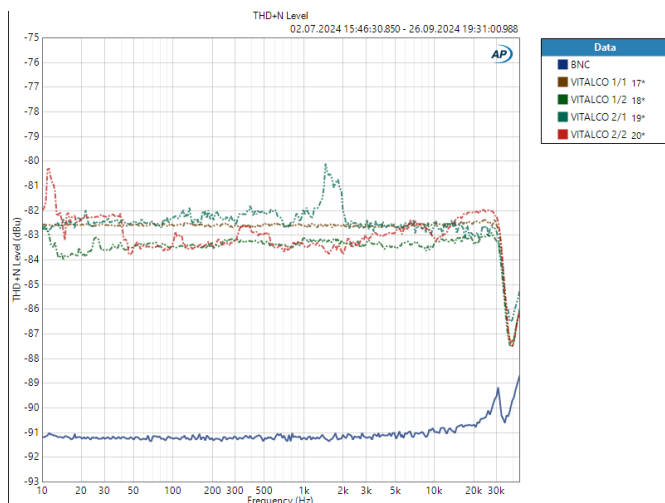


Figure 5 THD+N Values for Measurements of VITALCO cable

The THD+N (Total Harmonic Distortion plus Noise) of the tested cables, presented in Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7, is higher than that of the reference cable due to the lack of shielding, which isolates the cable from external interference. The differences in THD+N values are mainly due to the use of banana plugs, which do not provide a secure connection. The banana plugs used to connect Audio Precision analyser with the measured cable could not be changed. The given speaker cables and its banana plugs were treated as single object in the same way that they are sold and provided by manufacturers. THD+N levels of -80 dBu do not affect the cable's performance when used with speaker signals at average levels of +14.3 dBu, corresponding to an output power of 4 W with an amplifier load of 4 Ω speakers.

It is worth noting that differences in THD+N levels were also observed for the same type of cable, which was due to the use of banana plugs, where the quality of the connection to the measurement system was directly related to how the plug was seated in the socket.

3) Speaker System Frequency Response on Different Speaker Cables

Measurements were carried out by feeding a sweep signal with the same voltage to the amplifier and measuring the frequency response of the speaker system using a measurement microphone placed 1 meter away from the system, at a height of 1.2 meters, corresponding to the height of the tweeter in the tested speaker system.

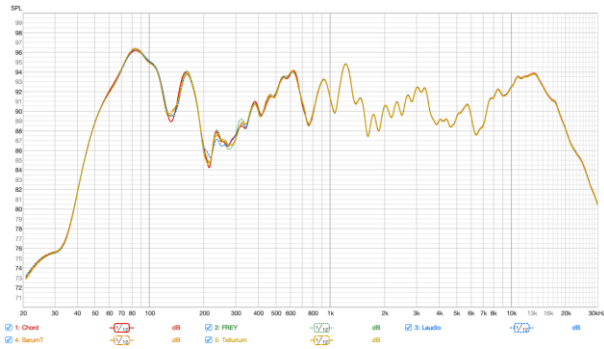


Figure 8 Loudspeaker response characteristics when measured using different loudspeaker cables

Figure 8 shows the frequency responses of a single speaker device measured with different speaker cables. A Hi-Fi class power amplifier was used (UNITRA WSH-805 working in AB class). As can be observed, the differences in frequency response across measurements are minimal and stem from the acoustic conditions in the room where the measurements were conducted. Using different cables with low resistance does not result in changes to the frequency response. For long cables with significant resistance, the frequency responses would be identical; however, at the same output voltage levels from the amplifier, differences in the measured sound pressure level would be observed.

C. Subjective measurements

1) Procedure

A group of 13 listeners participated in the study. Audiometric tests were conducted before beginning the experiments. All participants have a normal hearing curve with deviations not exceeding +10 dB, -0 dB.

For the listening material, three tracks from different music genres were used:

- **Pop:** "Alone" by Halsey (0:16-0:31),
- **Jazz:** "Tonight" by Oscar Peterson (0:32-0:47),
- **Rock:** "Teardrops" performed by Bring Me The Horizon (0:09-0:24).

Each audio sample was 15 seconds long [5] [6] [7].

The study was conducted in an acoustic chamber at Wrocław University of Science and Technology (the chamber is an anechoic chamber with sound reflecting floor), which meets the relevant standards [8] [9]. The speaker devices used for measurements were placed four meters apart. The listening point was determined based on the distance from the speaker setups in accordance with documents [10] [11]. The sound level at the reference point was $L_{Aeq} = 85$ dB. All samples were normalized to this level. The cables were not visible to the listening group during the test.

Two experiments were conducted to compare two types of cables. Initially, the Vitalco LAUDIO and FREY NORDOST cables were tested, followed by the Tellurium Q Black and CHORD SIGNATURE XL cables, shown in Figure 5. In both tests, the following perceptual characteristics were evaluated: clarity, dynamics, brightness of sound, and overall rating. A 3-point evaluation scale was used: better (+1), same (0), worse (-1).

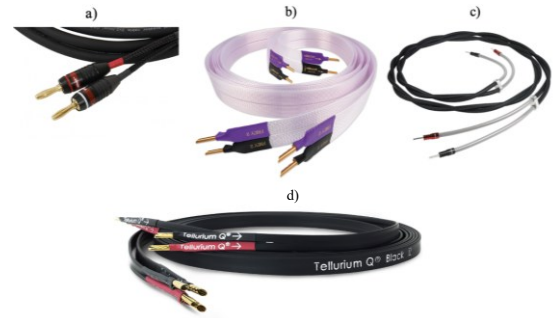


Figure 9 Appearance of tested speaker cables a) Vitalco LAUDIO, b) FREY NORDOST, c) CHORD SIGNATURE XL, d) Tellurium Q Black

The tests were based on comparative evaluations. Music samples were played in four sequences — two control sequences, in which the same cable was evaluated, and two test sequences. There was a 5-second break between samples and a 15-second break between sequences where listeners made their evaluations.

2) Results and Analysis

To analyse the obtained results, various measures and statistical tests were conducted, which are presented in the charts and tables. To illustrate the differences between sequences, the average scores for each perceptual characteristic and music genre were calculated (Figures 6 and 8). Histograms were also created to show the number of observations of each rating for the different sequences (Figures 7 and 9).

Two types of statistical tests were performed for detailed analysis: ANOVA (Table 2, Table 4) and Levene's test (Table 1, Table 3). The first test determines whether the mean values of each set are the same. Levene's test is used to assess the homogeneity of variances, with the null hypothesis assuming that these values are equal. The significance level, or statistical threshold, for both tests was set at $\alpha=0.05$.

All charts and statistical tests were conducted using STATISTICA 13.3 software [12] [13] [14] [15].

3) Analysis for the First Measurement

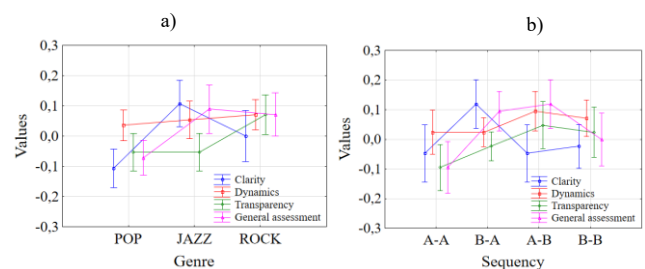


Figure 10 Graph of averages with marked 75% confidence interval (A- Vitalco LAUDIO, B - FREY NORDOST)

The calculated average values of answers given by listening critical group (Y axis in Figure 10 and Figure 12) are clustered around zero. Figure 10 shows slight deviations, but these do not exceed the value of 0.2.

Figure 10a presents the differences for each music genre. Listeners rated rock music samples similarly across all perceptual characteristics, with a mean of 0 for clarity. For pop music, ratings were slightly lower, though the average for dynamics was above 0. Jazz music showed greater variation in ratings across different perceptual characteristics. All differences were minor, with the confidence interval not exceeding 0.2.

Figure 10b displaying the differences in averages for the sequences shows some variation among the configurations; however, the control sequence B - B is centred around 0 for all assessed parameters. The observed differences are minor and may result from listeners' emotional states or unconscious expectations of differences.

TABLE I

LEVENE'S TEST OF HOMOGENEITY OF VARIANCE FOR VITALCO LAUDIO AND FREY NORDOST CABLES

Variable	SS Effect	df Effect	MS Effect	SS Err	df Err	MS Err	F	p
Transparency	0,114	2	0,057	24,804	165	0,15	0,379	0,685
Dynamics	0,119	2	0,06	15,576	165	0,094	0,631	0,533
Clarity of sound	0,032	2	0,016	19,768	165	0,12	0,134	0,875
General assessment	0,447	2	0,223	21,899	165	0,133	1,683	0,189

SS - error variance (within-group variance) or effect variance (between-group variance)

df - number of degrees of freedom

MS - mean squared effect (variance relating to between-group variability) or mean squared error (variance relating to within-group variability)

F - F-test

p - test probability

TABLE II

ANOVA ANALYSIS OF VARIANCE FOR VITALCO LAUDIO AND FREY NORDOST

Variable	SS Effect	df Effect	MS Effect	SS Err	df Err	MS Err	F	p
Transparency	1,286	2	0,643	38,714	165	0,235	2,74	0,068
Dynamics	0,036	2	0,018	20,482	165	0,124	0,144	0,866
Clarity of sound	0,583	2	0,292	27,393	165	0,166	1,757	0,176
General assessment	0,869	2	0,435	33,982	165	0,206	2,11	0,125

The result of Levene's test is statistically insignificant — the probability exceeds the significance level. This means that listeners rated the cables uniformly across all perceptual characteristics. This allowed for the use of a one-way ANOVA test, which also did not reveal statistically significant differences between the group means. This result indicates no differences between the means for the ratings of each sequence for the specified perceptual characteristics.

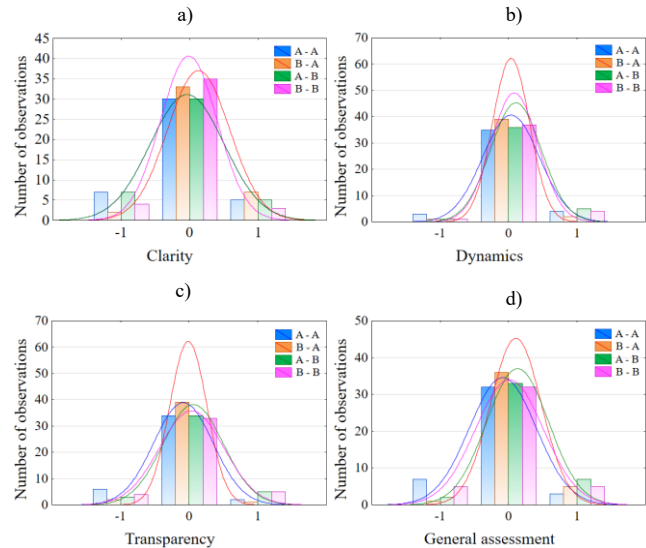


Figure 11 Number of grades selected depending on the sequence (A- Vitalco LAUDIO, B - FREY NORDOST).

Figure 11 shows the distribution of the number of each type of rating (-1, 0, +1). All diagrams, both for specific characteristics and sequences, display a normal distribution. Each chart is visibly centred around zero value. The number of observations for other rating values is minimal and does not exceed 20%.

The observed discrepancies stem from false detection of differences in the test sequences. This is especially evident in the overall assessment, where in sequence A – A, the second cable was rated as worse five times.

4) Analysis for the Second Measurement

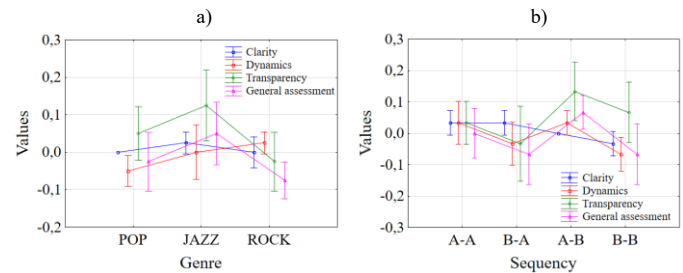


Figure 12 Graph of averages with marked 75% confidence interval (A- Tellurium Q black, B - CHORD SIGNATURE XL)

The calculated average values are clustered around zero. Figure 12 shows slight deviations, but these do not exceed 0.2.

The study results reveal minor differences between outcomes for specific music genres. For all perceptual characteristics, the results are similar — both pop and rock have averages close to zero. The average value for jazz music is centred below 0.2.

Figure 12b for sequence B – B is centred around zero. The remaining sequences are clustered around 0.1. Sequence A – B shows the greatest variation across the different perceptual characteristics. However, these differences are minor and may be influenced by various factors.

TABLE III
LEVENE'S TEST OF HOMOGENEITY OF VARIANCE FOR TELLURIUM Q BLACK
AND CHORD SIGNATURE XL CABLES

Variable	SS Effect	df Effect	MS Effect	SS Err	df Err	MS Err	F	p
Transparency	1,286	2	0,643	38,714	165	0,235	2,74	0,068
Dynamics	0,036	2	0,018	20,482	165	0,124	0,144	0,866
Clarity of sound	0,583	2	0,292	27,393	165	0,166	1,757	0,176
General assessment	0,869	2	0,435	33,982	165	0,206	2,11	0,125

TABLE IV
ANOVA ANALYSIS OF VARIANCE FOR TELLURIUM Q BLACK AND CHORD
SIGNATURE XL cables

Variable	SS Effect	df Effect	MS Effect	SS Err	df Err	MS Err	F	p
Transparency	0,017	2	0,008	2,975	117	0,025	0,328	0,721
Dynamics	0,117	2	0,058	8,875	117	0,076	0,769	0,466
Clarity of sound	0,45	2	0,225	23,25	117	0,199	1,132	0,326
General assessment	0,317	2	0,158	17,65	117	0,151	1,05	0,353

The result of Levene's test in the second measurement is also statistically insignificant. This indicates the homogeneity of listeners' ratings across all perceptual characteristics. Consequently, an ANOVA test was conducted, which also did not show statistically significant differences between the group means. This result indicates no differences in the means for the ratings of the individual sequences.

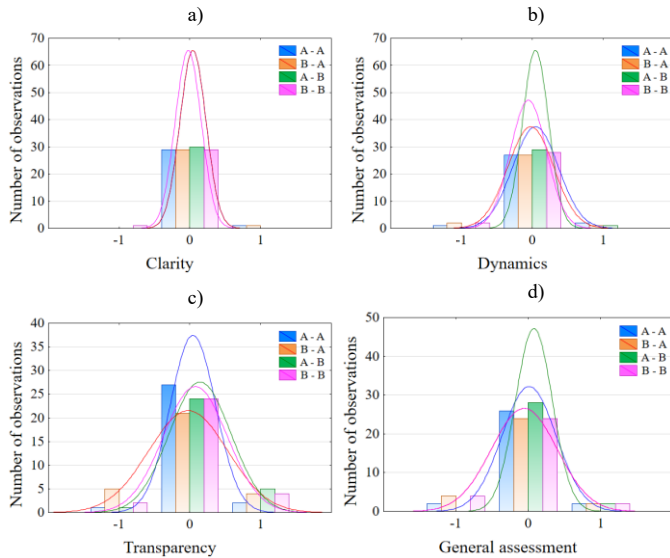


Figure 13 Number of grades selected depending on the sequence (A - Tellurium Q black, B - CHORD SIGNATURE XL).

Figure 13 shows histograms centred around zero value. This is particularly noticeable for the assessments of clarity and dynamics. Slight deviations are present for the remaining perceptual characteristics, though they are minimal and do not exceed 20% of all ratings.

The discrepancies in ratings may stem from expectations of differences between the cables, which could be very subtle. The

observed variations might also be due to an illusory perception of differences.

III. CONCLUSIONS

The most important parameter determining the quality of a speaker cable is its resistance, which dictates the power losses dissipated along the cable. This resistance is derived from the physicochemical properties of the conductor used in the cable (conductor material, cross-sectional area, and cable length). Cable resistance significantly impacts audio quality over long distances between the power amplifier and speaker devices.

Analysing the results shows that there are no noticeable differences between the tested speaker cables. Discrepancies in the THD+N graphs stem from the use of banana connectors, which do not ensure sufficient contact between the plug and socket, thereby increasing distortion in measurements. The use of SpeakON connectors would significantly improve the connection between speaker systems and the power amplifier, eliminating distortions and contact issues.

Subjective tests revealed no differences among the tested speaker cables, aligning with the findings of the objective tests. The expert group clearly indicated a lack of variation in clarity, dynamics, brightness, or overall assessment of the cables across both music genres and sequences.

The lack of subjective influence from the speaker cables is further supported by the indication of changes in sound for sequences A – A and B – B, while simultaneously noting no change for sequence B – A. These slight variations may be attributed to unconscious expectations of assessing different cables or potentially to the emotional states of the participants.

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