Emulating Commercial Headphones Through the Use of Frequency and Impulse Responses

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1 Abstract

This project investigated whether commercial headphones could be used to emulate other commercial headphones by measuring their frequency and impulse responses. Seven headphones were tested with one cheap and one expensive selected to emulate all the measured frequency responses. The equaliser (EQ) was implemented using the FreeDSP board and SigmaStudio. Limitations came from the restricted number of filters and filter summation. Non-flat inverse filters generated inaccuracies. Differences were found between accuracy and headphone cost in both objective and subjective testing. Subjective testing showed variations between the emulations and original headphones.

2 Background

The two key forms of headphone enclosure are circumaural, fully enclosing the pinna, and supra-aural, sitting atop the pinna (Borwick, 1994. P500).

The low frequency response is controlled heavily by the seal, with large variations between a strong or porous seal (Borwick, 1994. P501).

Large equalisations force loudspeakers to perform non-linearly, generating distortions (Gutierrez-Perera and Lopez, 2018. P2085).

Research into previous studies found it is conceivable to emulate many headphone transfer functions by superimposing another onto them, if it is a linear time invariant system (Voinier and Briolle, 1992. P249).

3 Aims and Objectives

Aims

To investigate whether commercially available headphones could emulate other headphones, through the use of frequency responses.

Objectives

- Create an EQ allowing the inversion and application of frequency responses
- Measurement and analysis of commercial headphone and emulation frequency and impulse responses
- Analyse whether cheaper headphones can emulate expensive headphones and vice versa.
- Use headphone acoustics and design to analyse emulation accuracy
- Complete subjective testing

4 Method

- Preliminary testing: Focusrite 2i2 frequency response measurement
  - Found to be flat between 20Hz-20kHz
  - Allows its use as the headphone amplifier
- Objective testing: Brüel and Kjaer HATS, NTi Flexus FX100, 5-second 20Hz-20kHz sine sweep, diffuse field
  - Following BS EN 60268-7:2011 (British Standards Institution, 2011. PP23-24)
- Headphones removed and replaced 5 times
  - Improves accuracy (Struck, 2016. P2) (Soeta and Ooi, 2018. P1)
- Subjective testing: the test song was David Bowie 'Rebel Rebel'; played through the emulations and originals for 30 seconds each
- Emulations graded from 3, 'exactly the same' to -3, 'completely different'

5 Results and Analysis

- Both the emulating headphones do not have a flat inverse filter
  - Clipping causes an 11dB peak at 15kHz for the DT770 Pros
- DT770 Pro inverse filter absolute mean difference = 0.49dB, T450 inverse filter absolute mean difference = -2.42dB
  - Due to the headphones working in its non-linear range and large equalisations (Gutierrez-Perera and Lopez, 2018. P2085).
- T450s performed worse than DT770 Pros
  - Average mean difference of -1.57dB compared to 0.911dB
  - Differences from seal variations
- Expensive headphones emulate cheap better than vice versa
  - Mean Pearson's Coefficient of 0.923 compared to 0.894.
- DT770 Pros showed greater correlation to originals compared to the T450s
  - Pearson's Coefficient of 0.945 compared to 0.927.
  - Circumaural DT770 Pros have a stronger seal than the supra-aural T450s (Toole, 1984. P4).
- Subjective testing: 80% of scores were negative
  - Suggesting subjective differences
  - More differences than objective testing
  - Needs testing with expert listeners
- Most accurate = T450s emulating Beats Solo3s, 'slightly similar'
- Least accurate = DT770 Pros emulating T450s, 'completely different'

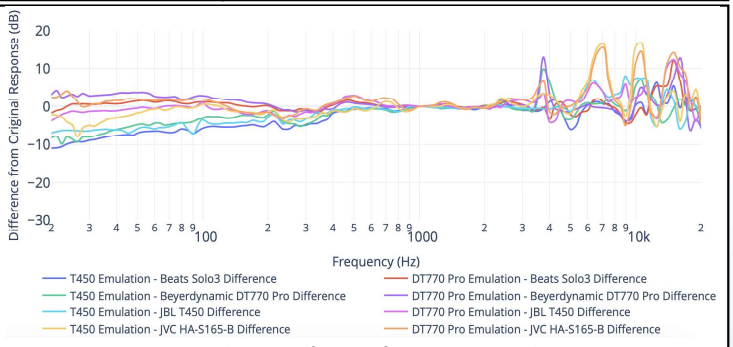

Figure 1: Emulation Difference from the Original Response

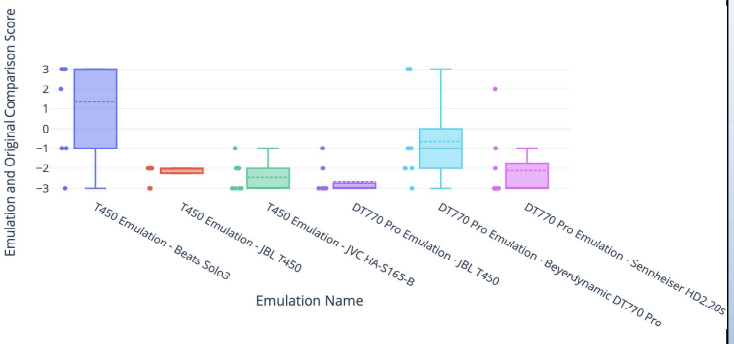

Figure 2: Subjective Testing Results

6 Conclusion

It is possible to emulate commercial headphones, but accuracy is limited by the filter precision. The EQs limited the emulations performance because it only permits a maximum of 15 filters. This led to filter summation, non-flat inverse filters, and smoothed responses. Cheaper emulations struggled to emulate expensive headphones due to leakage effects. Subjective testing yielded varying results and showed poor precision, further tests must be carried out on expert listeners.

References

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