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DRIVER POSITION FREQUENCY RESPONSE INFORMATION FOR A RANGE OF CAR AND AUDIO EQUIPMENT COMBINATIONS.

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1. SUMMARY

A linear averaging 1/12 octave Frequency Response Analyzer and a Head and Torso Simulator are used to measure the frequency response of a range of cars and audio equipment at the drivers head position. A single CD track is used as the stimulus. The CD is used directly where appropriate or via a CD to Cassette tape adapter when no CD player exists. Both detent and driver preferred responses are captured together with the Free Field response.

2. INTRODUCTION

Most people spend a considerable amount of time in their cars and a large proportion of that time listening to the Radio / Cassette Player / CD player fitted to that vehicle. In fact it is probably a greater length of time than that spent listening to their home system, which would be expected to be of superior sonic quality. Implicit in this statement is the expectation that the sonic quality and especially the intelligibility should be comparable with that of a fixed or home system, irrespective of the background noise due to engine, transmission, wind and tyre noise.

Vehicle manufacturers are known to spend a lot of time and money to improve the performance of their in-car systems. Indeed the Cassette Radio and loudspeakers fitted as standard nowadays will have a performance easily equal to the after-market units. This is seen by the manufacturers as a market differentiator. This was not the case a few years ago. One could argue that the Radio / Cassette Player / CD player after-market would be nothing like the size it is today if the performance of earlier factory fitted units had been adequate. After-market units were required for the few cars which were not fitted with radio's in the first place or for upgrades. Manufacturers are rather coy about publishing this sort of information, and so it was decided to perform this short investigation.

The author is professionally interested in audio quality and speech intelligibility wheresoever fitted and this work is a small step in quantifying audio performance in cars. The paper concentrates on the methodology employed rather than giving lists of results.

3. METHODOLOGY

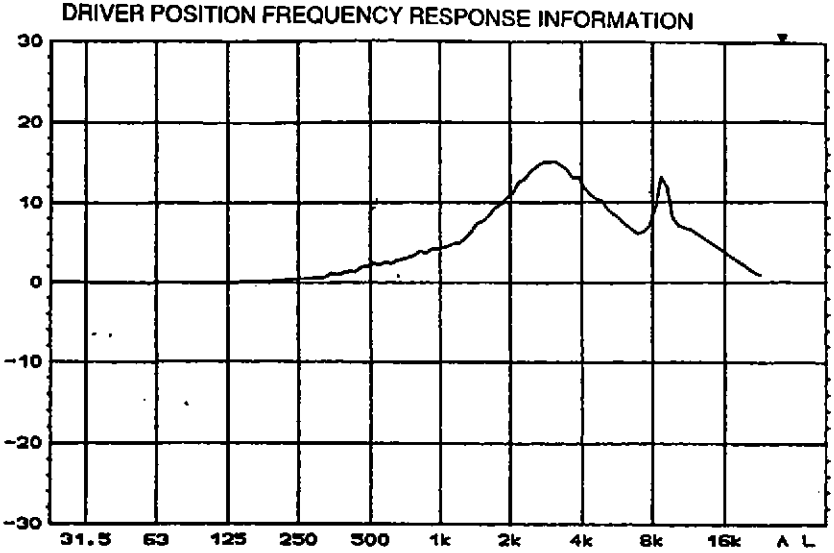
Fifteen different types of car were used in the experiment. The results for these five are reported here. The cars were: 1: Austin Maestro LX . 2: Vauxhall Astra Diesel Estate. 3: Citroen BX 19 Gti. 4: Vauxhall Cavalier 1. 8i. 5: Ford Cosworth Scorpio. A Head and Torso Simulator (HATS) was chosen as the preferred receptor in the car. Since the HATS is an

obstacle as well as a reflector in the relatively small space available, it will have a significant effect on the resulting response. The HATS was attached to a 1/12 octave Analyzer with a linear averaging function, set to measure over a 5 minute period from 23 Hz to 21.3 kHz. Rather than modify the cars' audio system to accept a pink noise, sine or MLSSA signal, it was realised that a quick measurement technique would enable a large range of cars to be measured, and thus gain a large corpora of data in a relatively short timescale. The source material in this experiment was a CD album track which met certain criteria, which are: 1: At least 5 minutes long. 2: An identifiable musical beginning (for cueing the Analyser manual trigger). 3: Little difference (over a 5 minute Leq) between Left and Right channels. 4: No periods of silence. 5: An extended frequency response. 6: Musically acceptable to the Author, as it was going to be heard up to four times per vehicle. Where a vehicle was fitted with a CD player the CD was used. Where the vehicle was fitted with a Cassette player a proprietary CD to Cassette adapter was used. One car was fitted with both, and so the opportunity was taken to investigate the difference in frequency response. It is recognised that this technique will give realistic in-car frequency responses at the expense of detailed distortion information. To overcome this, the audio gain was set individually to the maximum value which was subjectively undistorted. In order to reduce the data to be displayed, a single mono signal was created from the power sum of the stereo electrical input. Since the HATS is fitted with two ear simulators. A 1/12 octave 5 minute Leq measurement was performed for each ear and a power sum calculated from these two, on the assumption that degrees of left and right signal channels will be present at each ear.

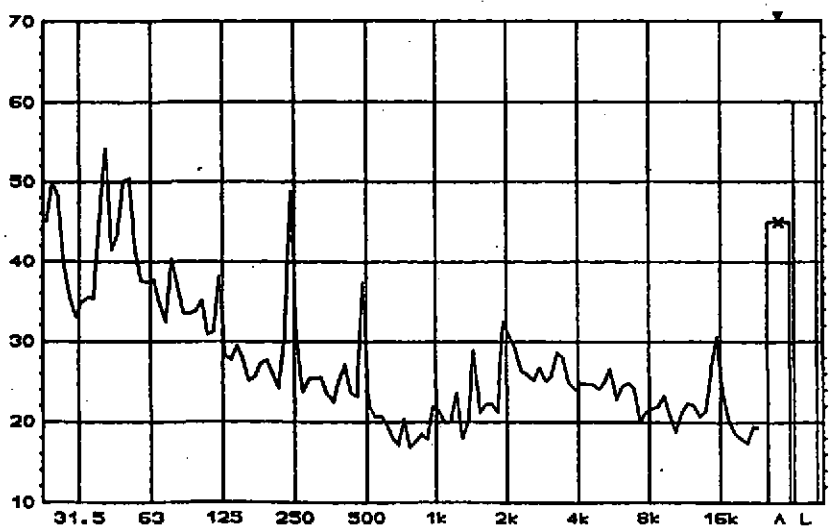
The opportunity has been taken in the Citroen vehicle to measure the difference between the Free Field response (i.e. the sound field at the centre of the HATS head - without the head in position) and the HATS output. This was done for both the left and right ear simulators. Additionally, the effect of the loudness and 'tone' controls could be observed with little difficulty. The difference between detent bass and treble control positions and those normally selected by the driver were not measured as was intended, mainly due to driver's using standard settings or, in the less expensive vehicles; no controls fitted.

4. RESULTS

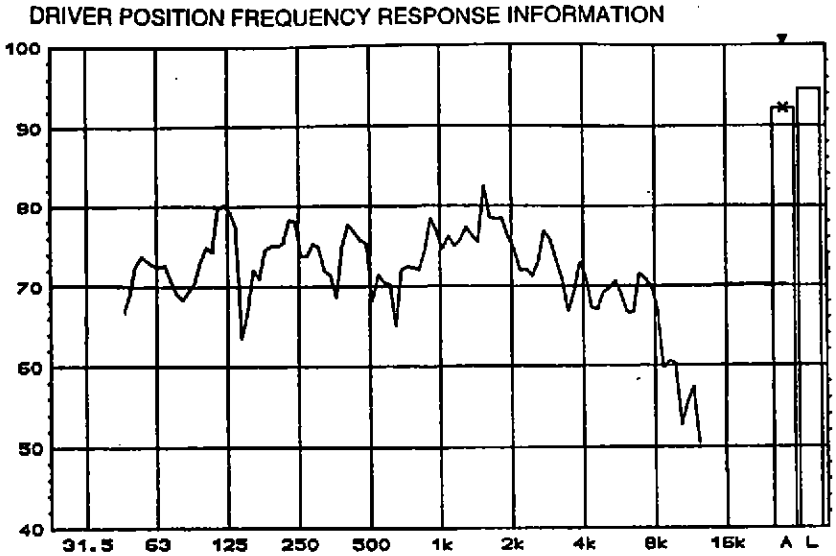
The frequency response curves for the six vehicle / source combinations at the drivers' position consist of the power sum of the outputs from the HATS ear simulators, corrected for the source frequency response (curve 13) and the HATS diffuse field response (curve 1). These responses can be found in curves 3 to 8. Curve 2 shows a typical background noise spectrum with the windows closed and the engine off. The cassette adaptor is fitted but the CD is not playing. This gives rise to some discrete tones transmitted via the loudspeakers. It is thought that these tones are induced into the replay head by the capstan motor and are usually masked by the source material. Curve 9 shows the difference between the CD player and the cassette response i.e. the CD player has a slight lift at high and low frequencies. However it should be noted that the coupling is entirely inductive and a cassette recording of the source CD would give a more accurate cassette response. Curve 10 shows the effect of the loudness control on the Citroen vehicle with a boost of 2 dB over the range and a gentle rise of 8 dB at low frequencies. Curve's 11 and 12 display the difference between the HATS' ear simulators and the Free Field response at the HATS head centre when removed.



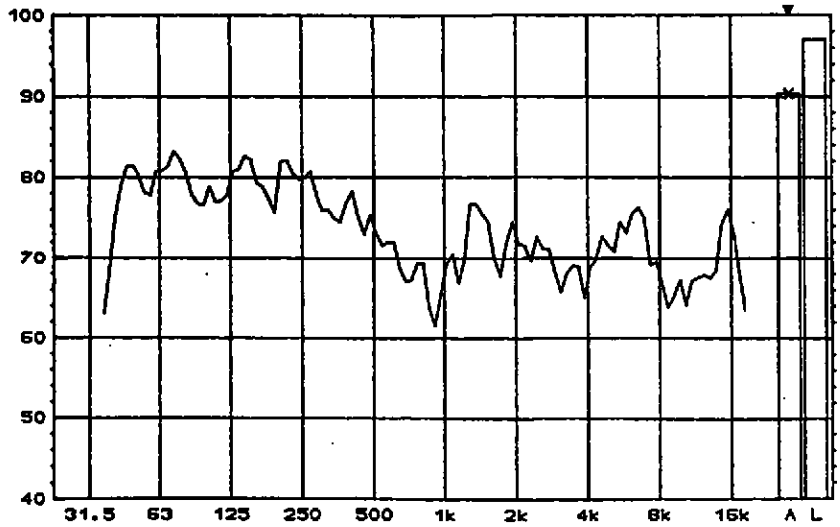
Curve 1: The diffuse field response of the HATS.



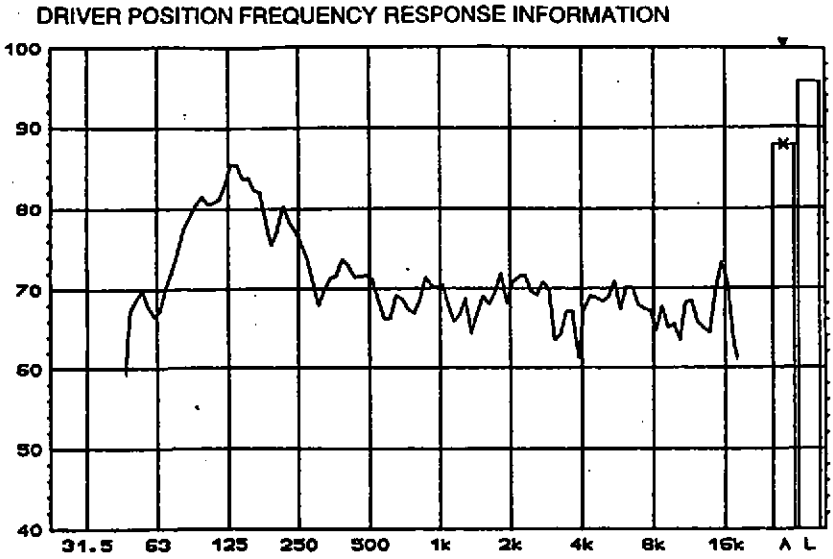
Curve 2: Typical background noise spectrum; engine off.



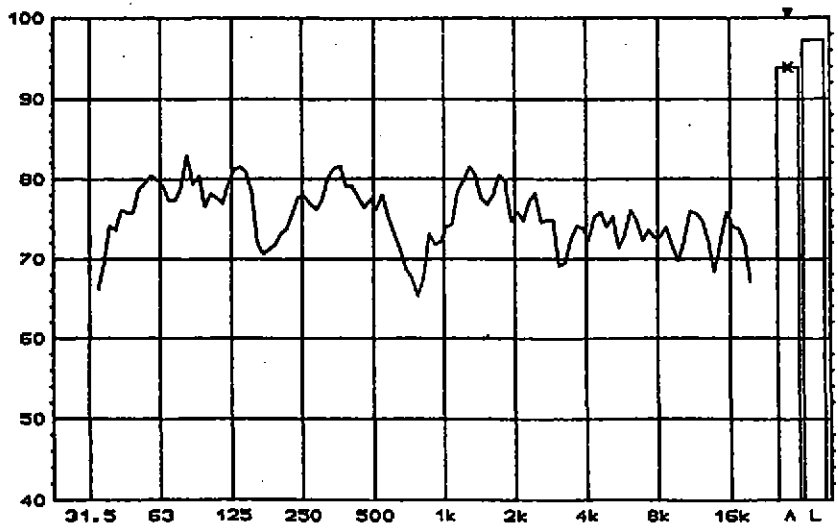
Curve 3: Cassette Response; Austin Maestro LX.



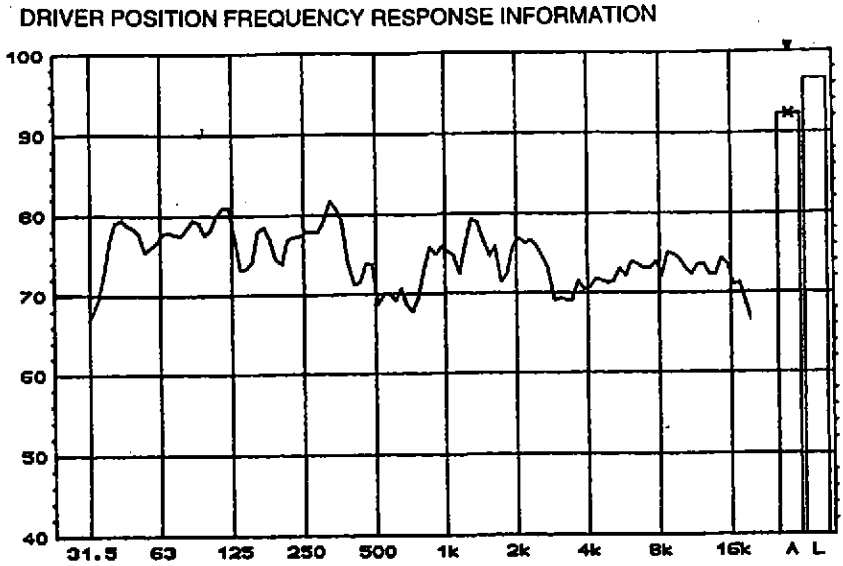
Curve 4: Cassette Response; Astra Diesel Estate.



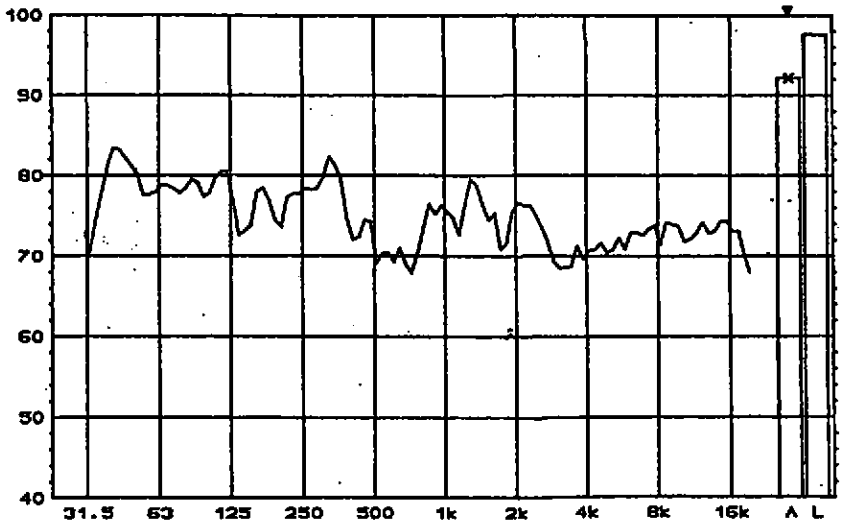
Curve 5: Cassette Response; Citroen BX19 GTi.



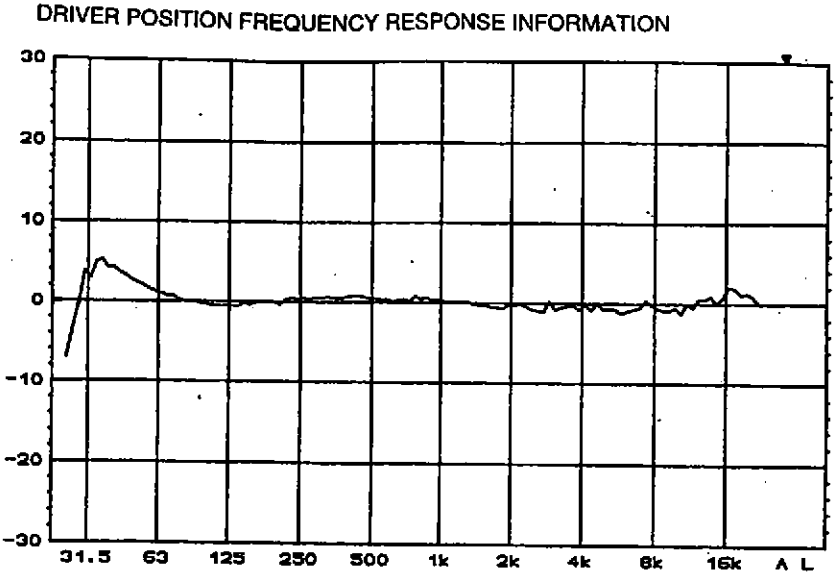
Curve 6: Cassette Response; Vauxhall Cavalier 1.8i.



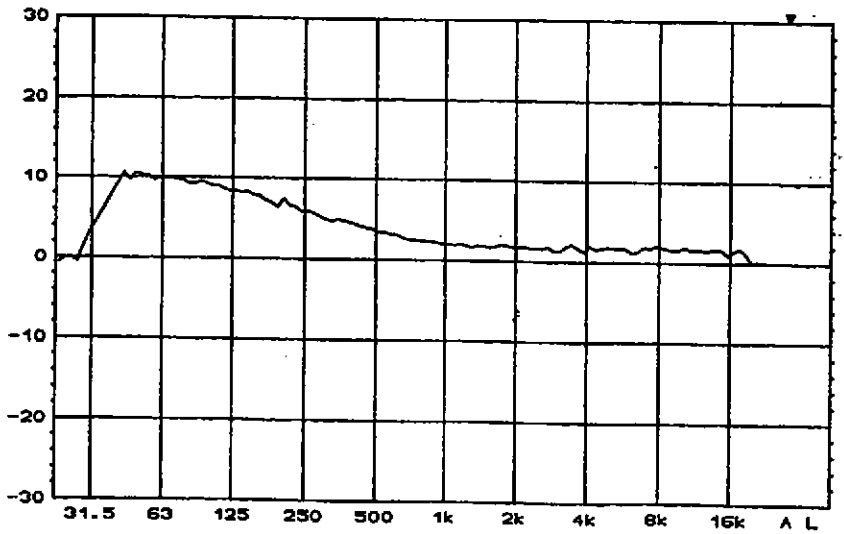
Curve 7: Cassette Response; Cosworth Scorpio.



Curve 8: CD player Response; Cosworth Scorpio.

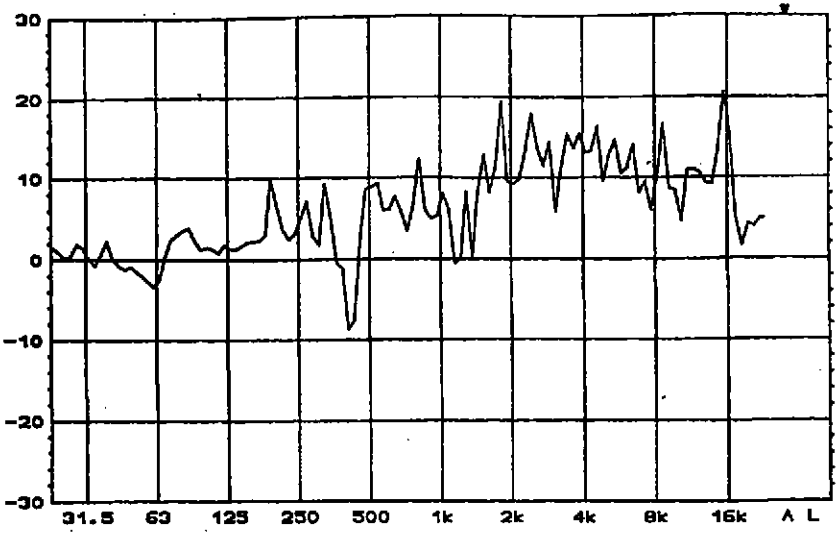


Curve 9: Difference between CD player and Cassette Response (Scorpio).

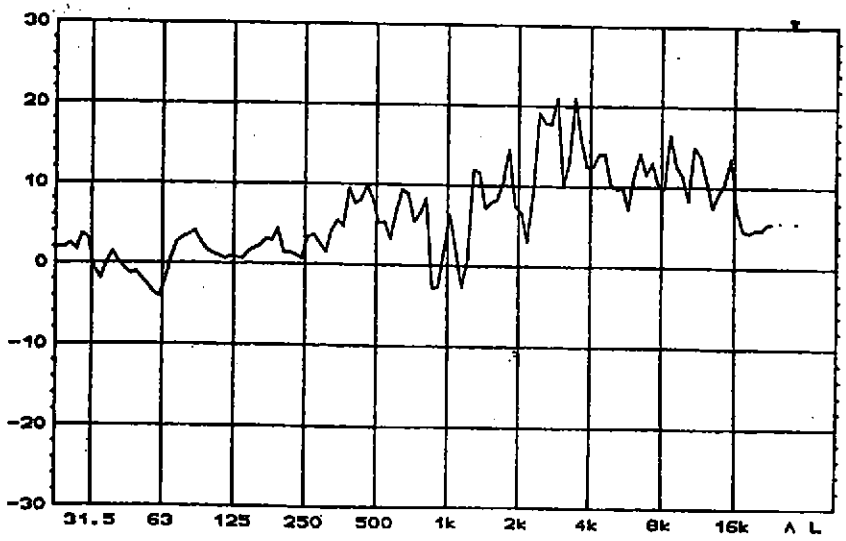


Curve 10: Citroen Cassette Player Loudness Control.

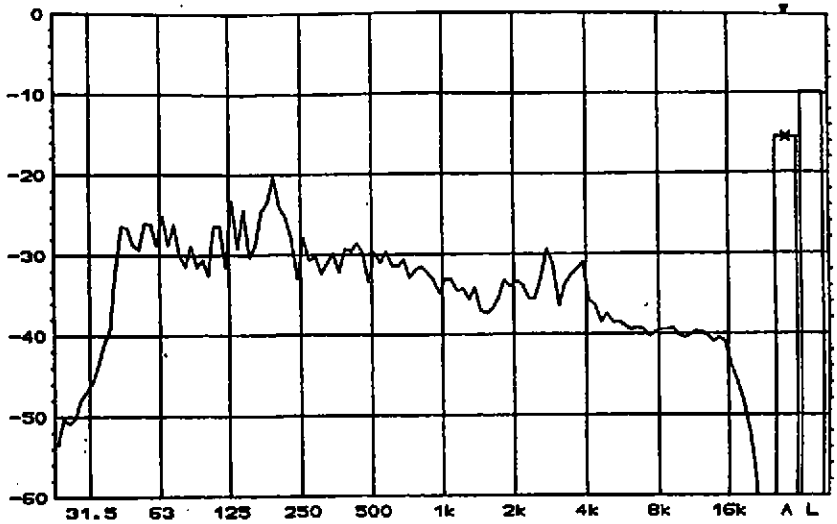
DRIVER POSITION FREQUENCY RESPONSE INFORMATION



Curve 11: Hats left ear referenced to the Free Field Response (Citroen).



Curve 12: Hats right ear referenced to the Free Field Response (Citroen).



Curve 13: Original 5 minute Leq music spectrum (dBV, L+R combined).

5. CONCLUSIONS.

1: The test method employed gives a relatively fast way of determining the modulus frequency response of a cars' stereo system. The use of a HATS is shown to be essential as the obstacle effect and reflective properties react with the car interior space in a first order manner. This can be seen by noting that the broad increase in sound pressure obtained by introducing the hats (curves 11 and 12) can be offset by the diffuse sound field correction of the HATS but that the remaining perturbations of +/- 5 dB are due to discrete reflections.

2: The CD to cassette adaptor performs better than expected and hardly modifies the basic response, although it does introduce some discrete tones at low level.

3: As expected, the larger cars with more panel damping and interior damping, including (presumably) higher quality loudspeakers perform the best of all, with a smooth response above 3 kHz and an overall deviation of +/- 6 dB from 40 Hz to 16 kHz.

4: The major feature of all of the car responses is the deviation from a flat response caused by reflections and panel resonance's, other than basic loudspeaker response. Put another way, the loudspeaker termination defined by the car interior represents an extremely reactive and resonant load. Keeping this under control by panel damping and speaker placement is the key to improvement.

5: Dire Straits' Sultans of Swing makes an ideal noise source for this sort of work.

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