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SOME EFFECTS OF EQUALISATION AND SPECTRAL DISTORTION ON SOUND SYSTEM INTELLIGIBILITY

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1. INTRODUCTION

Although there is considerable anecdotal evidence regarding the influence of equalisation on the perceived performance and intelligibility of sound systems, there is little or no quantitative analysis reported within the literature. Furthermore, the underlying acoustic and psycho-acoustic mechanisms are not well described. This paper reports the results of a series of pilot investigations concerning the relationships between intelligibility and sound system equalisation. The findings have a significant bearing on the currently accepted speech intelligibility measures such as Rastl, STI, %Alcons and C35 / C50 techniques. Errors of up to 20 % in these methods are reported if the spectral distortions are not taken into account.

2. SOUND SYSTEM EQUALISATION & SPECTRAL DISTORTION

Although equalisation is widely employed to smooth and tonally adjust the response of sound systems, a frequent additional effect is a reported improvement in apparent speech intelligibility and clarity. In the author's experience this would particularly appear to be the case in distributed loudspeaker systems operating in reverberant environments. There would appear to be virtually no quantitative information in the literature as to the potential improvements that can be obtained and the underlying mechanisms involved. A research project was therefore initiated to remedy this surprising finding.

Detailed response measurements were carried out on a number of sound system installations that either did not employ equalisation or that had their equalisation by-passed. When correctly equalised it was noted that the intelligibility and speech clarity could significantly improve, yet traditional measures such as STI and % Alcons did not show this effect. A series of word score tests were therefore performed in order to ascertain whether the improvements were real or imagined. The results showed that statistically significant improvements were obtainable.

The initial experiments were limited to distributed systems operating in reverberant but reasonably quiet environments (ie those exhibiting a good signal to noise ratio) such as Churches, Cathedrals, City Halls and Museums. This enabled the number of experimental variables to be controlled. A number of further experiments were then carried out in the laboratory using both a reverberant test room and electro-acoustic simulations in order to isolate particular variables and characteristics. A novel listening / assessment technique was adopted using binaural as well as monaural recordings. This enabled 'blind' listening tests to be carried out without the subject being influenced by the loudspeaker or environment. It also enabled tests to be carried out not only under controlled conditions but also on systems that otherwise would have been impractical. In each case detailed acoustic measurements were also carried out in order to characterise the environment. The results of the word tests showed that improvements of 15 to 20 % in intelligibility were found to occur when systems were appropriately equalised. Or to put that another way, not equalising (or incorrectly equalising) a sound system could lead to a 15 to 20 % potential loss of intelligibility or 15 to 20 % error by an indirect intelligibility system such as STI or %Alcons etc.

3. SOUND SYSTEM RESPONSE ERROR MECHANISMS

It was noted that the apparent power response of many of the loudspeakers employed in the systems tested was far from flat. Additional investigations were therefore carried out in order to identify the mechanisms at work and to characterise the loudspeakers themselves and their interactions with the room / acoustic environment. Other measurements such as distortion and coherence were also made in order to ensure the appropriate effect was being investigated. In the majority of the systems investigated, it appeared that system response anomalies in the bass / lower midband frequency range were the primary factors involved - particularly when associated with a curtailed high frequency response. From the investigations undertaken a number of primary mechanisms were identified. These included :-

Loudspeaker - Room Interactions

Loudspeaker - Loudspeaker Interactions

Incorrect Equalisation

Microphone Proximity Effects

Loudspeaker - Room Interactions include loudspeaker - boundary effects, frequency dependent room gain and the effects on the resultant response caused by containing or enclosing a sound source which inherently exhibits a far from constant acoustic power output characteristic. Figures 1 & 2 present typical PA system frequency responses exhibiting such behaviour.

Loudspeaker - Loudspeaker effects include the combining of devices to form 'clusters' or the frequency dependent coverage of overlapping of loudspeakers.

Incorrect or indiscriminate use of equalisation. (There is a prevalent view, particularly amongst 'DJs' and rock bands that excessive bass produces a better and 'more intelligible' sound).

Microphone Proximity effects are well known and well documented but still seem to catch the PA industry unawares. Figure 3 shows a family of typical microphone proximity curves.

4. SPECTRAL MASKING

In all the above cases and in the control experiments, the only variable is that of system frequency response. The conclusion is therefore drawn that the underlying mechanism is that of spectral masking. An preliminary analysis procedure has been investigated , the basis of which is shown in figure 4. The procedure requires the system response to be spectrally weighted and then split into ERB (equivalent rectangular band) components. These are then weighted and the potential speech masking evaluated. At present this procedure is at any early stage of development, however it would appear that a dynamic spectral analysis technique may required in order to fully assess such effects.

5. CONCLUSIONS

From the simulations and real environment testing, it is clear that significant improvements in intelligibility can be achieved by appropriately equalising a sound system. The effect was found to be most noticeable in systems with only 'fair' intelligibility although a slightly different effect was noted in better quality systems. The underlying psycho-acoustic effect is shown to be caused by spectral masking within the ear - brain hearing system, although an initial theoretical examination suggested that such mechanisms were likely to have limited effect. However, in the real world systems tested, surprisingly large frequency response variations were often found to occur.

It is hoped to be able to draw up a set of new optimum intelligibility guideline curves for systems operating in reverberant environments and then extend this to more favourable acoustic situations.

The work reported could have a major significance to our understanding of sound system performance and ways of setting up sound systems operating in reverberant conditions. Requirements for a new way of measuring and analysing such systems may be required as the results cast doubt on the reliability of current electro-acoustically based measures such as STI and % Alcons as these did not indicate the quantifiable improvements. A preliminary technique has been reported and will be further discussed in a future paper.

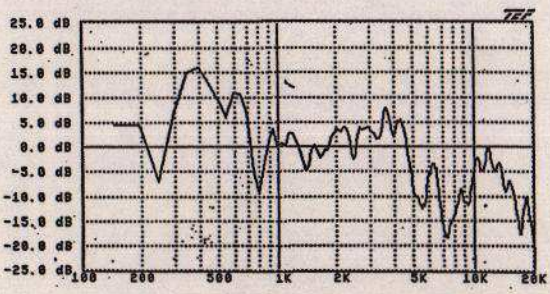


Figure 1 Sound System Frequency Response - with bass peak

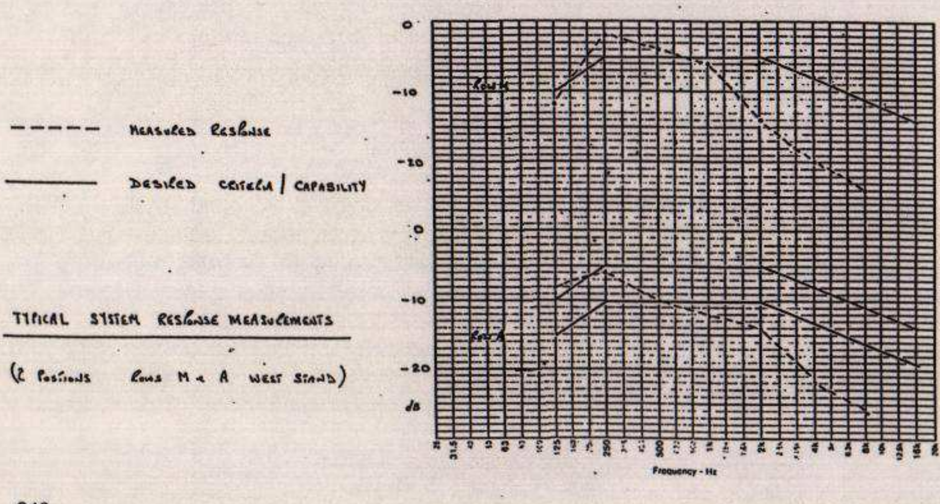
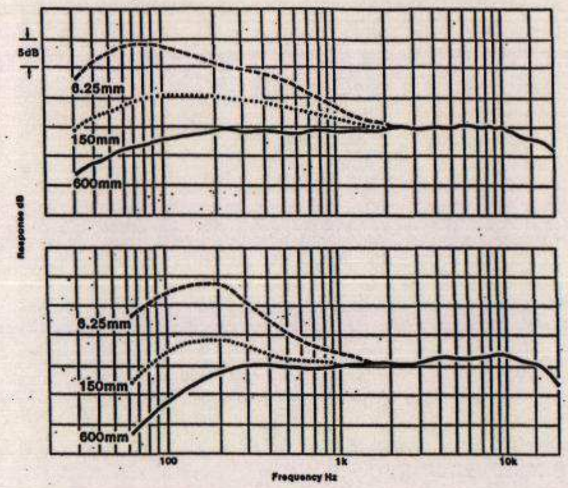


Figure 2



Typical microphone proximity effect response curves at various microphone - source distances.

Figure 3

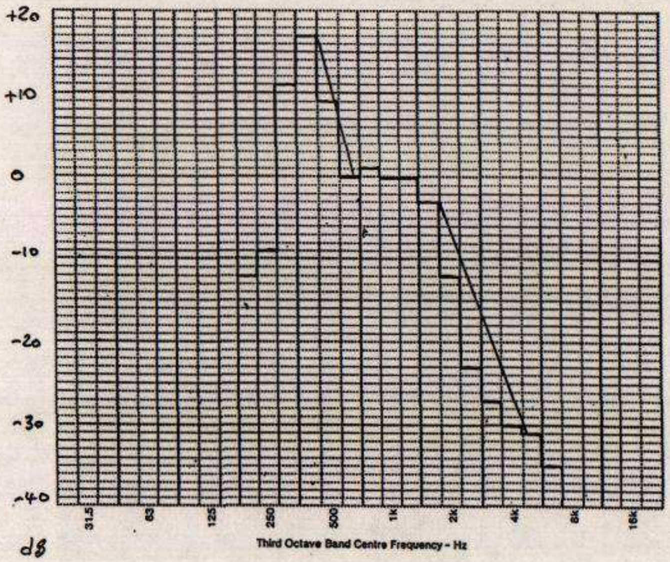


Figure 4 Preliminary Masking Evaluation

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