A Measurement of Colouration in Electroacoustic Enhancement Systems

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Abstract: The use of electroacoustic systems to enhance the acoustics of concert halls is becoming increasingly prevalent. Regenerative systems can produce unnatural acoustics due to the unequal enhancement of the response at different frequencies, leading to spectral colouration effects. In this paper, a method is developed for measuring spectral colouration by examining the statistics of transfer function magnitudes. Variance measures are derived, and a further measure is derived by modelling the underlying probability density function using the generalised gamma function. Results obtained from a simulator show that the measures increase with loop gain and are independent of other parameters in the system.

INTRODUCTION

Electroacoustics is being increasingly used to provide flexible control of concert hall acoustics (1). Non-in-line (regenerative) systems maintain the global property of reverberation, but can suffer from spectral colouration at high loop gains (2). The assessment of auditoria which employ electroacoustics should therefore include measures which correlate with the subjective effects due to colouration.

A method of measuring colouration from impulse responses is presented here which is based on the statistics of the transfer function magnitude. The measurements can thus be obtained in the same manner as other room acoustic parameters.

A STATISTICAL APPROACH TO COLOURATION

In any electroacoustically enhanced room, the statistics of the room transfer functions can be altered from those of the passive room transfer functions due to regeneration. It is well known that the magnitude of an ideal room transfer function has a Rayleigh density (3). In an enhanced room the probability density of the magnitude will differ from Rayleigh. This suggests that parameters that quantify the underlying probability density functions may provide a robust and accurate measure of system colouration.

The magnitude of the transfer function of a room transfer function has a variance of 0.2146 for a power gain of one. The variance of an assisted transfer function may therefore be normalised to one and compared with this value. Since the human hearing system tends to hear sound levels in a logarithmic fashion, it is also worthwhile comparing the variance of the enhanced magnitude in dB with the natural dB variance. It has been shown that the variance in dB of a transfer function with unit power gain is 31 dB (4).

An alternative approach is to model the measured histogram with a known probability density. The generalised gamma density has three parameters, and allows a wide variety of statistics to be modelled. The parameters may be determined from the cumulants of the log magnitude (5). A useful measure of the “distance” of the density from the Rayleigh density is the maximum deviation between their cumulative distributions.

RESULTS

In order to provide data for the assessment of colouration, an assisted reverberation system simulator was written in Matlab. The simulator uses a 24 channel reverberator to simulate a room, and a second 16 channel unitary reverberator (6) is placed in a feedback loop around the first to enhance the reverberation time.

In practice, it was found that the variance was more consistent than the dB variance and similar to the maximum deviation. Since the variance is easier to compute it is the preferred parameter for assessing colouration. However, the generalised gamma method also provides complete information about the underlying probability density and may be useful for more detailed analysis.

The statistics of the assisted transfer functions were found to be relatively insensitive to an increase in power gain. The sensitivity was improved by removing the early part of the impulse response to eliminate
the dominant direct sound and early reflections. This leaves the fine structure in the transfer function which is influenced by the regeneration in the system. The impulse response was renormalised to a power gain of one after truncation.

The variance is shown as a function of the truncation time $t_0$ for $G=1.0, 1.2, 1.4$ and 1.6 in figure 1. The enhanced responses show a diverging increase in variance with $t_0$, with no appreciable change for the passive response. The variance versus power gain, for $T_2 = 0.125, 0.25$ and 0.375s and $t_0 = 40\,\text{ms}$, is shown in figure 2. The variance increases with $G$, as expected. The $T_2 = 0.25\,\text{s}$ results are greater than those for $T_2 = 0.125\,\text{s}$, but are similar to the results for $T_2 = 0.375$.

The variance was found to be uncorrelated with the unitary reverberator reverberation time, showing variations smaller than those obtained from different input and output excitations (source and receive positions).

CONCLUSION

The variance of the transfer function magnitude derived from impulse response measurements provides a statistical measure of colouration that uses all information in the response. Improved sensitivity is obtained by truncating the early part of the impulse response. The parameters are not affected by variations in the reverberation time of a non-in-line system containing a unitary reverberator. The variance (and maximum deviation derived from the generalised gamma density) increase smoothly with power gain, and are possible candidates for the quantification of subjective assessments of colouration. However, subjective assessments are required to identify the degree of correlation, and any frequency dependence, before a final conclusion can be reached.

The technique presented must be applied above the Schroeder frequency, and over a frequency range where absorption is relatively constant. Furthermore, the transducer responses must be flat. It was found that relative measures of colouration were quickly dominated by large variations in the transducer transfer functions, obscuring the finer variations due to colouration.

REFERENCES