Variable acoustics using Multiple Channel amplification of Reverberation (MCR)

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The technique of MCR is based on the fact an amplification channel in a room increases the energy density causing the reverberation time to increase. For colorless amplification this increase is limited to two percent for one channel. When more amplification channels are used between which the correlation is minimized, the amplification of the individual channels can be added up. In this way a system can be build to adapt and/or correct acoustic parameters in a room. It works in a natural way because it acts like anti absorption and so it has higher sound quality then artificial reverberation systems. The limitation is that it has to be treated as natural variable acoustics and so in the design it has to be handled that way.

THE THEORY OF MULTIPLE CHANNEL AMPLIFICATION

When a sound generating source is installed in a room, the sound pressure produced by that source will decrease if the distance to the receiver will increase. The sound coming directly from this source is called the direct sound, decreasing 6dB by each doubling of distance.

$$p^2 = \frac{\rho c W Q}{4\pi r^2} \qquad (1)$$

At a certain distance the sound pressure will not decrease any further with increasing distance. This more or less homogeneous sound is called reverberant sound or diffuse sound and is formed by the reflections in the room. The point where the level of the direct sound and the reverberant sound are equal is called the critical distance (r_c) or Hall Radius (r_h) in German. The level of the reverberant sound is determined by the power radiated by the source and the acoustic absorption in the room. Mathematically it can be described in the following formula:

$$p^2 = 4\rho c W / A \qquad (2)$$

When a microphone is positioned in the reverberant sound field and a loudspeaker reproduces this reverberant sound, the sound pressure of the reverberant field sound will increase (distance source to microphone preferably > r_c to avoid amplification of the direct sound) as is shown in figure 1.

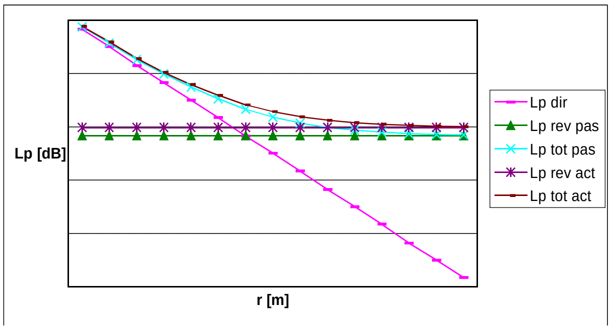

FIGURE 1. Decrease of sound pressure level with increasing distance without and with sound amplification.

If the level of the reverberant sound field increases and the power of the source remains constant, as in this case (the output of the sound source does not change), the absorption will decrease according to formula 2. If the absorption decreases, the reverberation time will increase according to the formula of Sabine:

$$T = 0.161x\frac{V}{A}[s] \qquad (3)$$

If formula 3 is substituted in formula 2, the following formula is obtained:

$$p^2 = 25\rho c W T / V \qquad (4)$$

Here is shown that the increase of the reverberation time is proportional to the increase of the squared sound pressure. So by varying the increase of sound pressure, the reverberation time can be varied. In this way the acoustics of a room can be made variable, because with the increase of the reverberation time also the clarity, strength etc. is varied.

If formula 4 is used to describe the situation with and without the microphone connected to the amplifier, there is a passive situation (amplification channel off) and an active situation (amplification channel on).
In the active and the passive situation there are different values for the sound pressure and the reverberation. All other quantities in the formula do not change. If the formulas for the passive and active situation are divided, the gain due to the addition of the amplification channel is obtained:

$$1+g^2 = \frac{p^2{}_{act}}{p^2{}_{pas}} = \frac{T_{act}}{T_{pas}} \qquad (5)$$

The amplification in an electro acoustic system with closed loops is limited. If one looks at the frequency characteristic of sound in a loop (see figure 2), one sees a very wild curve consisting of peaks and dips. The wide band average values in this curve determine the increase of the reverberant sound pressure level and thus of the reverberation time. The peaks determine the stability and thus the coloration.

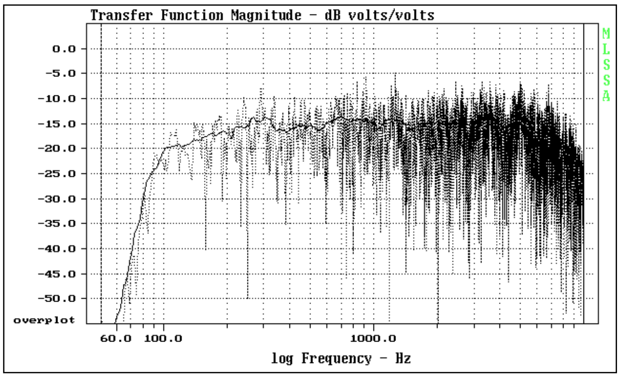

FIGURE 2. Transfer function of a close loop, averaged and non-averaged.

According to Schroeder the difference between the level at the highest peaks and the average level is app. 10dB [1] for an average concert hall. This means the average curve must be at least 10dB below unity gain to prevent oscillation. To prevent audible coloration the highest peak must be 7dB below unity gain. This means the average curve must be 17dB below unity gain to prevent oscillation and coloration. This requires careful equalisation of the frequency characteristics. A loop gain g^2=0.02 (-17dB) means an increase of reverberation time of 2%.
By connecting more loudspeakers and microphones to the same amplifier or mixing console the total amplification can not be increased. For more amplification, more microphone/loudspeaker combinations, each with its own amplifier and processing equipment, are required. There should be no audio electrical connection between these channels.
Furthermore, each microphone must be outside the critical distance of each loudspeaker, especially the one of the corresponding channel. In this way the correlation between the channels is minimised.
The total amplification, which can be obtained now, is the sum of the amplification of the N individual channels (energetic summation in stead of complex amplitude summation). In a multiple channel system each channel consists therefore out of its own microphone, equaliser, amplifier and loudspeaker. The increase in reverberation time can now be calculated as follows:

$$T_{act} = T_{pas}(1+Ng^2) \qquad (6)$$

To obtain the required increase in each frequency band, an equaliser is present in each channel. A typical channel is built up as shown in figure 3.

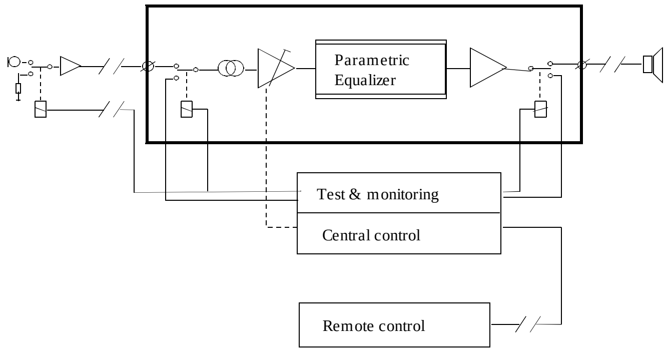

FIGURE 3. A typical amplification channel of a MCR system.

ACKNOWLEDGMENTS

The author wants to thank Stefan de Koning and Rob Dekkers for their assistance creating this paper.

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