THE "BACH" EXPERIENCE

BRING A CONCERT HOME

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GOALS

1. To develop a system that eliminates the effect of a room and impresses the sonic qualities of a different listening environment like a concert hall, a studio or a live music café.

2. To enable music lovers to have an authentic aural experience of those environments at the comfort of their homes.

OUTLINE OF THE METHOD

Impulse Response Measurement: The impulse response (IR) of a room tells us about the important attributes of its acoustical behavior. We have used IRs to characterize both, the room in which the audio will be played back and the desired listening environment.

Inverse Filters: A room is known to act like a LTI filter on acoustical signals. Hence, audio playback in a room is highly affected by its acoustical properties. Rooms being non-minimum phase systems make it challenging to find exact inverses that can help us reduce distortions and excessive reverberation.

However, the Multiple Input Inverse Theorem (MINT) allows us to find square invertible (IR) matrices and gives us exact inverses.

Acoustical Characterization of the room by Impulse Response measurement

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Modification of audio using the inverse room filter to simulate anechoic playback

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Convolution of the Impulse Response of the chosen listening environment with the modified audio file

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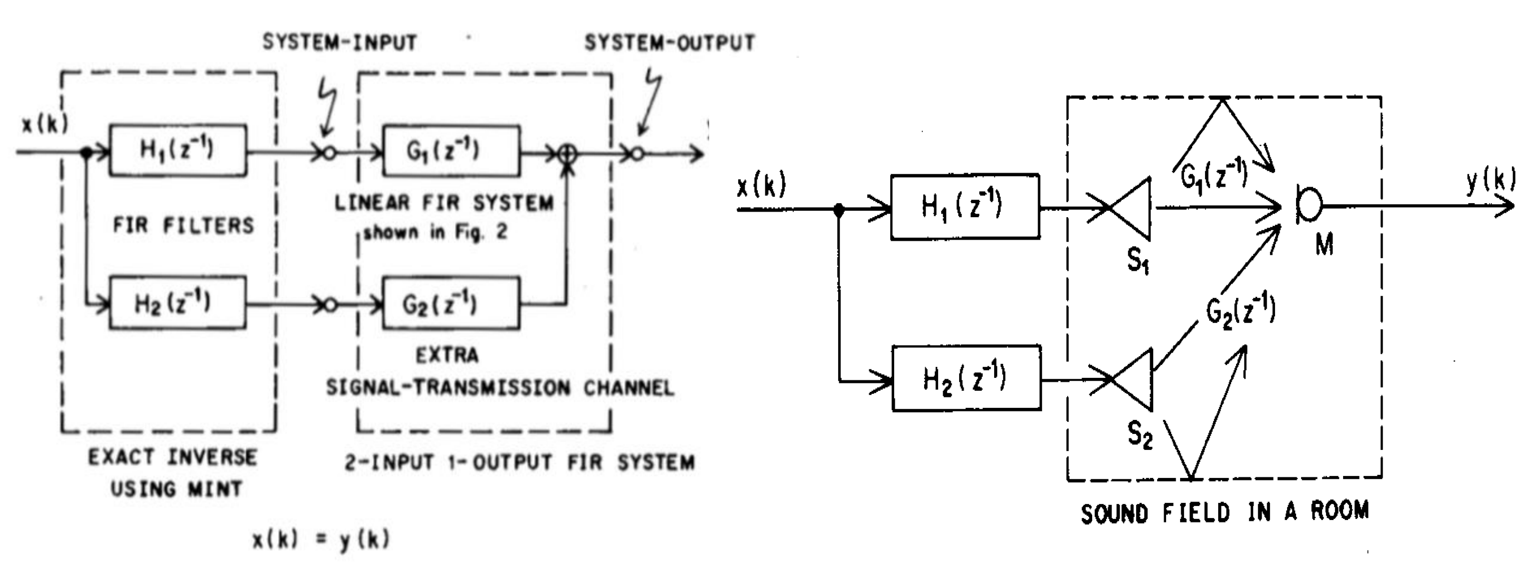
Authentic Listening Environment Reproduction

INVERSE ROOM FILTERING USING MINT

The setup to compute the room inverse filter requires two identical flat response loudspeakers and a measurement microphone. The microphone is positioned at a chosen location (M) in the room and the loudspeakers are carefully aligned to determine the signal-transmission channels G1 & G2.

To find G1 we turn on the first loudspeaker S1 while keeping S2 turned off and record the impulse response through the microphone at M. We then repeat the process to find G2.

The block diagram and the actual signal flow chain are shown in the figures below



We form the following Toeplitz matrix G containing the IRs G1 and G2. The exact inverses H1 and H2 can then be computed using inv(G) and the Delta Matrix D.

$$\underbrace{\begin{bmatrix}1\\0\\0\\\vdots\\0\end{bmatrix}}_{L+1} = \begin{bmatrix} g_1(0) & & & g_2(0) & & \\ g_1(1) & \ddots & 0 & g_2(1) & \ddots & 0 \\ \vdots & & g_1(0) & \vdots & & g_2(0) \\ g_1(m) & & g_1(1) & g_2(n) & & g_2(1) \\ & \ddots & \vdots & & \ddots & \vdots \\ 0 & & g_1(m) & 0 & & g_2(n) \end{bmatrix} \begin{bmatrix}h_1(0)\\h_1(1)\\\vdots\\h_1(i)\\h_2(0)\\h_2(1)\\\vdots\\h_2(j)\end{bmatrix}$$

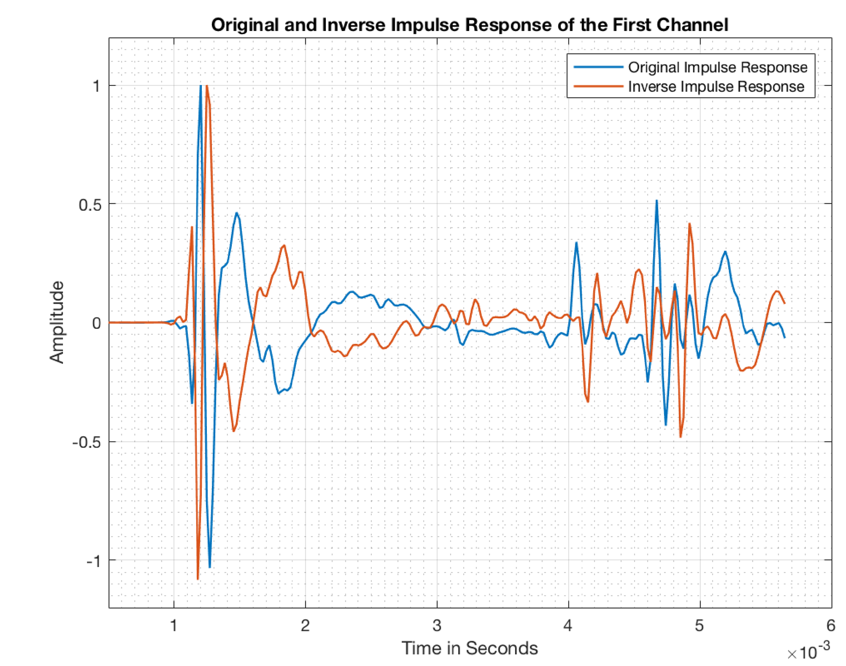
$$\begin{bmatrix}H_1\\H_2\end{bmatrix} = [G_1 \;\; G_2]^{-1} D.$$

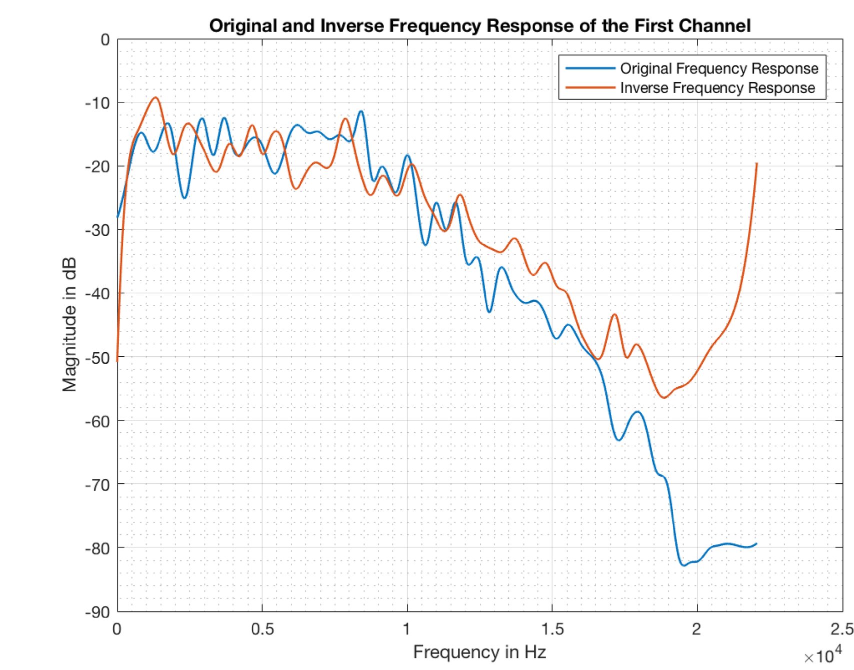
IR MEASUREMENT USING ROOM EQ WIZARD

We have used Room EQ Wizard to compute the IRs, frequency response and Energy Decay Curves of selected spaces. The specific signals and equipment used are:

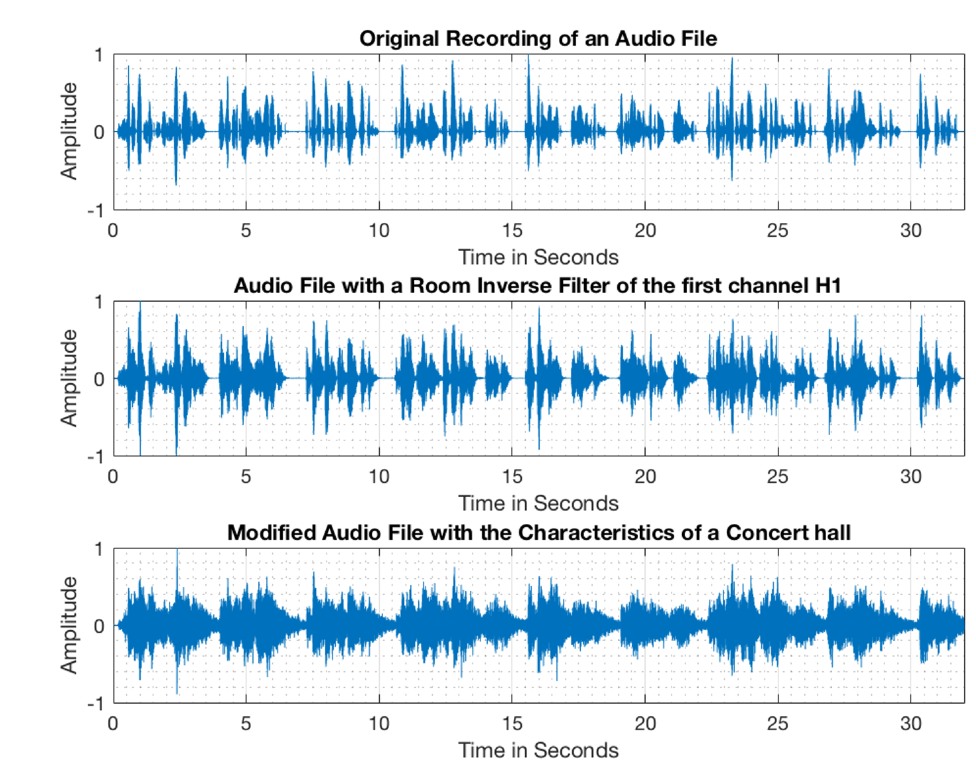
1. Logarithmic swept sines of 3-5 seconds duration between 20-20,000 Hz.
2. Behringer ECM 8000 and a Neumann KU 100 Binaural Dummy Head for capture at various locations in the desired listening environment.
3. A pair of 75-80 dBSPL calibrated Alesis M1 Active 520 Loudspeakers.

CONCLUSIONS AND FUTURE WORK





The frequency domain analysis for the two signal-transmission channels shows that H1(z) = 1/G1(z) and H2(z) = 1/G2(z)



1. The effect of the room was significantly reduced at a single listening position and the characteristics of the desired listening environment were reproduced.

2. The next step would be to characterize rooms at multiple locations and give the listener the freedom to choose from different seating positions in concert halls.

3. We would also like to research and apply more advanced room correction algorithms for better tuning of any speaker configuration and enhanced audio playback.

REFERENCES

[1] M. Miyoshi and Y. Kaneda, "Inverse Filtering of Room Acoustics" (1988), IEEE Transactions on Acoustics, Speech and Signal Processing

[2] A. Farina, "Simultaneous Measurement of Impulse Response and Distortion with a swept-sine technique", (2000), 108th AES Convention, Paris, France