Modeling of a Jecklin Disk for Stereophonic Recordings

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Abstract: The Jecklin Disk is a sound absorbing disk placed between two omnidirectional microphones. It is used to recreate some of the frequency-response, time and amplitude variations human listeners' experience, but in such a way that the recordings also produce a useable stereo image through loudspeakers. This paper presents a finite element model able to simulate the effects on sound propagation produced by a Jecklin disk. The simulated results matched experimental results giving the authors a strong standing for further work in this area.

Keywords: acoustics, sound propagation, Jecklin disk, stereophonics

1. Introduction

A Jecklin Disk[1] (figure 1) is a type of acoustic baffle used in stereo microphone recordings to improve the apparent width and clarity of the stereo soundstage by creating an acoustic 'shadow' between the microphones, the spacing of the microphones and the Jecklin disk simulates spacing between the ears and the effect of the human head. Jecklin disks are often used to record classical music (figure 2), and to record background noises in the film and television industries.

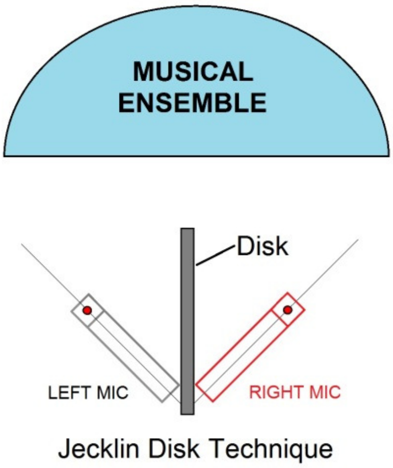

Figure 1. Schematic diagram of a Jecklin disk.

Figure 2. A Jecklin disk employed for a classical music recording.

The Jecklin Disk was designed by Swiss Radio engineer Jürg Jecklin based on the "Baffled Difference Technique"[2] proposed by Alan Blumlein in 1931. Jecklin affectionately termed the technique "Optimum Stereo Signal" (OSS). Although more complex methods to replicate the human head have been designed (such as the binaural microphone) this technique only works with headphone playback, whilst studies have shown both systems to show similar intelligibility results[3].

Of importance is minimizing any interference at the higher audible frequencies. This will greatly improve the reproduction of the stereo sound by reducing phase interference caused by crosstalk between the left and right stereo channels, as humans typically use the higher frequencies (between 1kHz and 8kHz) to determine the location of a sound source[4].

The original disk design had a solid metal core with thin absorptive sheets attached to each side. However this setup introduced reflective surfaces close to the microphones which in turn caused interference.

To minimize the effect of interference, this paper proposes a completely absorptive design using a Jecklin disk made entirely from Rockwool. Details are given on how such a disk was modeled and compares the simulated results to real-life experimental results.

2. Computation Methods

To simulate sound wave propagation about a Rockwool disk a two-dimensional model was constructed (figure 3). An omnidirectional sound source, 10cm in length was placed 3m from a Rockwool disk (22cm × 40cm). The pressure field up to 5m from the source was studied. An illustration of the model's geometry, not to scale, is depicted below:

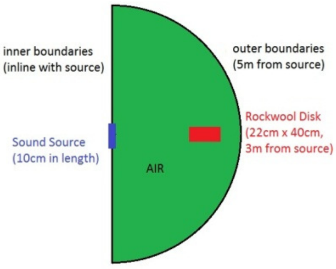

Figure 3. Illustration of the model's geometry.

For time-harmonic propagation, the subdomain was described with the Helmholtz equation:

$$\nabla.\left(\frac{1}{\rho}\nabla.\mathrm{p}\right)+\frac{\omega^2\mathrm{p}}{\rho c^2}=0 \quad (1)$$

where p is pressure, ρ is the density of air, ω = 2πf is the angular frequency, and c is speed of sound in air.

The boundary condition at the source was expressed as:

$$\mathbf{n}.\left(\frac{1}{\rho}\nabla.\mathrm{p}\right)+\mathrm{i}\frac{\omega}{\rho}\mathrm{p}=2i\frac{\omega}{\rho} \quad (2)$$

where **n** is the outward boundary normal vector.

The "outer" boundary conditions, 5m from the source, were expressed as:

$$\mathbf{n}.\left(\frac{1}{\rho}\nabla.\mathrm{p}\right)+\mathrm{i}\frac{\omega}{\rho}\mathrm{p}=0 \quad (3)$$

effectively making the outer boundaries perfect absorbers.

Making the assumption that the Rockwool disk is a perfect absorber, equation (3) was also used to describe the boundaries of the disk.

The "inner" boundaries, in-line with the source, assumed zero flux so that:

$$\mathbf{n}.\left(\frac{1}{\rho}\nabla.\mathrm{p}\right)=0 \quad (4)$$

Finally, the initial conditions in the subdomain assumed:

$$\mathrm{p}=0 \quad (5)$$

and

$$\frac{\partial \mathrm{p}}{\partial \mathrm{t}}=0 \quad (6)$$

The model was solved for a frequency of 3kHz, and to minimize numerical errors, the maximum mesh size was set to one-twelfth of a wavelength. A stationary solver was used, and a relative tolerance of 10^{-6} was specified.

Figure 4 shows the pressure field distribution obtained from a sound source operating at a frequency of 3kHz. The acoustic shadow cast by the disk is more apparent when plotting the absolute pressure (figure 5).

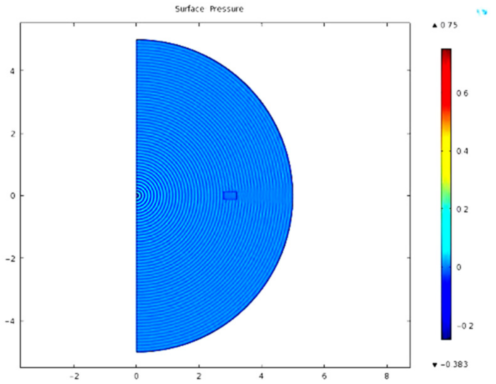

Figure 4. Sound wave propagation about a Rockwool disk.

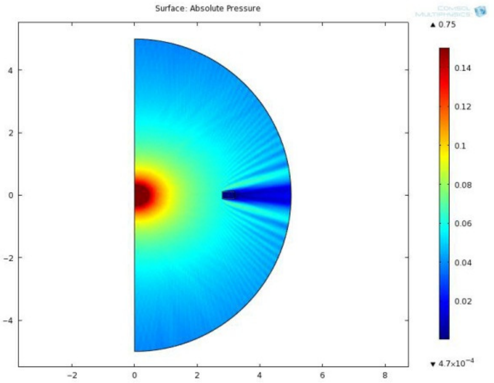

Figure 5. Absolute pressure about a Rockwool disk.

The acoustic shadow can clearly be seen when plotting the absolute pressure versus arc-length along the outer boundaries (figure 6). For comparison, the absolute pressure when no disk is present is also shown.

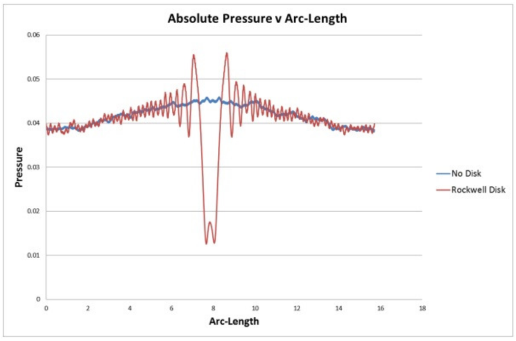

Figure 6. Absolute pressure versus arc-length.

As well as depicting the acoustic shadow, figure 6 also shows the fringes one would expect as sound waves diffract around the disk.

3. Results

To validate the finite element analysis, an experiment was set up in the University of the West of Scotland's Anechoic Chamber (figure 7). The Anechoic Chamber was used as it provides a neutral testing environment (i.e. – it provides no echo reflections) which might interfere with the results due to phase cancelation.

Figure 7. The Anechoic Chamber used to obtain experimental results.

A Genelec 8020B speaker was used as the acoustic source providing a 3kHz tone.

The 40cm x 22cm Rockwool disk was placed directly between the speaker and microphone, each subsequent tone burst was then measured using an Earthworks M30 reference microphone placed inline 3 meters away from the source. The microphone was then moved in 10cm increments perpendicular from the original position.

Each measurement was recorded into Logic Studio. The average volume levels (dB-FS RMS) were then determined with a Tischmeyer Technology Dynamic Range Meter plug-in then converted to absolute pressure levels.

Figure 8 shows a comparison between the experimental and finite element results.

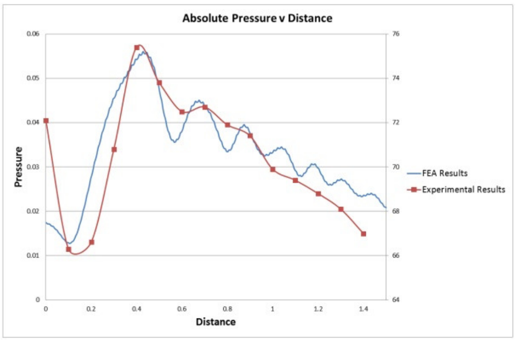

Figure 8. Finite element and experimental results showing absolute pressure versus distance.

It can be clearly seen the finite element and the experimental results follow the same trend. There is close match to the acoustic shadow directly behind the disk, and the first two maxima of the diffraction fringes match. The step size used between experimental measurements and the relatively small pressure level difference prevents the other fringes being resolved.

4. Conclusions

A brief review of the Jecklin disk and its applications was given. The problem formulation and COMSOL simulation details are provided. The finite element results matched those obtained experimentally within an anechoic chamber. The model may be used to optimize the size and construction of the Jecklin Disk, and the positions of the microphones. Further experiments are ongoing to refine the model.

5. Acknowledgements

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6. References

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