Introduction

Spatial Aliasing

Line Source Array Element

No Spatial Aliasing

Line Source Array Application

On Spatial-Aliasing-Free Sound Field Reproduction Using Infinite Line Source Arrays

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Wavefront Sculpture Technologies (WST)

[Fig 16. Border lines in the plane \( d'f' \)]

\[
\begin{align*}
\text{Individual Fringe} & : \varnothing/3 \\
\text{Individual Fringe} & : \text{Individual Fringe}
\end{align*}
\]

[Fig 9. 1992, 92nd AES Convy]

[Hill, 2001/2003, 11th AES Convy, JuES 51(10)]

T. Thompson, 2003, 11th AES Convy]

[Fiesel, 2009, 12th AES Convy]

\[
\text{Sound Pressure} = \sum_{N} \left( \frac{\nabla \cdot \mathbf{u} \cdot \mathbf{x}}{2} \right) \mathbf{x} \mathbf{u} \cdot \mathbf{x}
\]
\[ x \mathbf{p}_{x \gamma y} f + \Theta (\mathbf{m} \cdot \mathbf{z}, 0 \cdot \mathbf{x}) \mathbf{d} \int_{\infty}^{0} = (\mathbf{m} \cdot \mathbf{z}, 0 \cdot \mathbf{x}) \mathbf{d} \]

Using the one-dimensional spatial Fourier transform along \( \gamma x \):

\[ (\mathbf{m} \cdot \mathbf{z}, 0 \cdot \mathbf{x}) \mathbf{d} \int_{0}^{\infty} = (\mathbf{m} \cdot \mathbf{z}, 0 \cdot \mathbf{x}) \mathbf{d} \]

This corresponds to a multiplication in the \( \gamma x \)-domain:

\[ (\mathbf{m} \cdot 0 \cdot \mathbf{x}) \mathbf{d} \int_{0}^{\infty} = (\mathbf{m} \cdot \mathbf{x}) \mathbf{d} \]

Interpretation as a spatial convolution along \( \gamma x \):

\[ \mathbf{d} \int_{0}^{\infty} = (\mathbf{m} \cdot \mathbf{x}) \mathbf{d} \]

Continuous problem formulation with monopoles:

\[ (\mathbf{x}) \mathbf{d} \leftrightarrow (\mathbf{x}) \mathbf{d} \]

Signal Processing Model for Sound Field Synthesis

Problem Formulation

Cylindrical wavefront into \( z \)

Aim: Spatial aliasing free,

Loospeaker

Loudspeaker

Driving function

Sampled pressure

Sound pressure

\[ \mathbf{d} \int_{0}^{\infty} = (\mathbf{m} \cdot \mathbf{x}) \mathbf{d} \]

\[ \left\lfloor \mathbf{u} \cdot 0 \cdot \mathbf{x} \cdot \mathbf{x} \right\rfloor \mathbf{d} \int_{0}^{\infty} = (\mathbf{m} \cdot \mathbf{u} \cdot \mathbf{x}) \mathbf{d} \]

\[ \left\lfloor \mathbf{u} \cdot 0 \cdot \mathbf{x} \cdot \mathbf{x} \right\rfloor \mathbf{d} \int_{0}^{\infty} = (\mathbf{m} \cdot \mathbf{u} \cdot \mathbf{x}) \mathbf{d} \]
Ideal spectral sampling

Baseline Sampling for Spectral Signals

\[ x' = \frac{x}{2} \gamma \nabla \rightarrow (x)_D \]

\[ (0, 0, 0, 0) \quad (0, 0, 0, 0) \]

\[ \theta = \sin \left( \frac{\varphi}{2} \right) = x' \gamma \nabla \text{ for a 2D wave propagation problem} \]

\[ (\mathbf{m}, \mathbf{r}, 0, 0, 0, 0, 0, 0) \cdot (\mathbf{m}, \mathbf{r}, 0, 0, 0, 0, 0, 0) = (\mathbf{m}, \mathbf{r}, 0, 0, 0, 0, 0, 0) \]

Signal Processing Model for Sound Field Synthesis

\[ 0 = x' \gamma \nabla \text{ we want } \]

\[ \frac{x'}{2} \gamma \nabla + x' \gamma = \left( \frac{\varphi}{\varphi} \right) \]

\[ \begin{array}{c}
\text{Dispersion relation for a 2D wave propagation problem} \\
\end{array} \]

\[ (\mathbf{m}, \mathbf{r}, 0, 0, 0, 0, 0, 0) \cdot (\mathbf{m}, \mathbf{r}, 0, 0, 0, 0, 0, 0) = (\mathbf{m}, \mathbf{r}, 0, 0, 0, 0, 0, 0) \]
Spatial Aliasing due to Missing Spatial Pseudilloidal

Baseband Sampling for Spatial Signals

\[ \frac{x \nabla}{\pi} = x \gamma^2 \]
\[ (z', 0, x'y), D = (z, 0, x'y)D \]

Ideal sampling:

\[ \frac{\theta \sin \frac{\varphi}{3}}{\left( \frac{\theta \sin \frac{\varphi}{3}}{3} \right) \sin} = (x'y)^{\text{circ}}H \]

\[ \frac{\theta \sin \frac{\varphi}{3}}{\left( \frac{\theta \sin \frac{\varphi}{3}}{3} \right) \sin} = (x'y)^{\text{circ}}H \]

The position with length \( L \) is circular position with radius \( r \).

Faulty directivities have spectral lowpass characteristics.

Field model \( H(0, x') \) with the faulty directivities of a loudspeaker.

Use the loudspeaker as the spatial posittler.

Causal band sampling for spatial signals.
Line Array Prediction vs. Signal Model

Waveguide as a Spatial Lowpass Filter
\[
\frac{2^\frac{1}{3} \theta \sin \frac{2}{3} \theta}{(\frac{2}{3} \theta \sin \frac{2}{3} \theta)^\frac{1}{3}} = (x^\gamma)^{\text{re\_gen}}_H
\]

\[
\frac{2^\frac{1}{3} \theta \sin \frac{2}{3} \theta}{(\frac{2}{3} \theta \sin \frac{2}{3} \theta)^\frac{1}{3}}z_0 = (x^\gamma)^{\text{ch\_gen}}_H
\]

\[
\text{Line Pision (Waveguide): } \xi = x \nabla = I
\]

\[
\text{Circular Pision: } \xi = x \nabla = p
\]

Circular vs. Line Piston Model

Suitable for mid frequencies > 1.5 kHz

\[
\xi = x \nabla = p
\]

Suitable for lowest frequencies > 500 Hz

\[
\xi = x \nabla = p
\]
\[ \theta \sin \left( \frac{c}{f \mu} \right) = x \]

Waveguide Measurement: Isobars

\[ L = 36 \text{cm} \]

Waveguide measurement

Ideal waveguide model
Conclusion

 perfection of the talk available at http://spatialaudio.net/

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perfect spatial lowpass filter

waveguides should match ideal line position as best as possible

no gaps between waveguides

Spatial-aliasing-free sound field with a quasi-continuous line source array

Loudspeakers act as spatial lowpass filters

WST criteria 8: all preserved with sound field synthesis and spatial sampling theory