A Model for Rendering Stereo Signals in the ITD-Range of Hearing

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Directional Hearing

HRTF - Head Related Transfer Function
ITD - Inter-aural Time Difference below 800 Hz
ILD - Inter-aural Level Difference above 2 kHz

HRTF change with head movement
Horizontal plane for loudspeaker stereo
Phantom source placement by **Level** panning and/or **Time** panning

Left to right spatial rendering control

Fig. 1.4. Perceived directions with pink noise, constant loudness

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Model for Phantom Source Placement in the ITD-Range of Hearing

- Sphere model of head
- No head shading
- ITD = 263µs @ 30°
Level Panned Mono Source

a) SPL at each ear

SLD = 0 dB
SLD = 6 dB
SLD = 12 dB
ILD = 0 dB in all cases!

b) Group delay to each ear

Left ear
12 dB
6 dB
SLD = 0 dB

Right ear
6 dB
12 dB

17.5 cm sphere diameter
+/-30 degree sound incidence
Phantom Source Angle $\gamma$ as Function of Source Level Difference

Phantom Source ITD

17.5 cm dia. sphere

$\alpha$ - degree

$\gamma$ - degree

ITD - $\mu$s

SLD - dB

Rs/Ls - dB

R-ear at 500 Hz dB

Real Source ITD

Phantom Source ITD

263 $\mu$s
A *level panned* source signal produces *Time Differences* between the ears, but no level differences.

The time differences at the ears determine the phantom source angle $\gamma$. 

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Time panned mono source

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**Graphs showing the effect of time panning with mono source:**

- **a)** STD 250us on left
- **b)** STD 500us on left
- **c)** STD 1ms on left

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A time panned source signal produces Level Differences between the ears, but no time differences.

The level differences at the ears pull the phantom source towards the leading loudspeaker but depending upon frequency.
Automatic Level and Time Panning with Microphone Pairs

Spaced

Coincident
Coincident Microphone Pair

![Graph showing incidence angle vs. degree, gamma, ITD, and SLD dB values.]

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Coincident Microphone Pair

Spatially detailed rendering

Cardioid, 110 degree XY

+/-180°

+/-30°

LI+RI = Lr = Rr+Lr

L

R

Listener

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Spaced Microphone Pair

Spatially diffuse rendering

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Live Recording

Coincident microphone pair
Spaced microphone pairs
Individual microphones

Spatially creative Rendering
Optimum setup for rendering Stereo

- Constant directivity loudspeakers 20Hz to 20kHz, Dipole, Cardioid, Omni
- Loudspeakers >1 m from room boundaries
- Equilateral triangle
- Symmetrical relative to room boundaries
- Listening distance < 2x Reverberation distance
- RT60 around 450 ms above $F_{Schroeder}$
- Diffuse End - Dead End

Min. room size

Dead End

Diagram showing the setup with the following dimensions:
- Observer to left speaker: 1m
- Observer to right speaker: 1m
- 2.5m between the 2 speakers
- Ceiling height: 2.4m
- Room dimensions: 4.5m x 6m

Graph showing the relationship between Listening Distance/Reverberation Distance and Total SPL, Reverberant SPL, and Direct SPL.
Conclusions

Stereo recording and rendering must be considered as a unit, if communication of natural spatial relationships is important.

A sphere model of the human head can provide qualitative insight into the rendering of sound over two loudspeakers in the ITD frequency range of hearing.

Coincident microphone and level panned single microphone techniques yield spatially defined phantom sources.

Spaced microphones and time panned single microphone techniques yield spatially diffuse phantom sources.