

PERCEPTUAL ISSUES IN MULTI-CHANNEL ENVIRONMENTS

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The paper reviews the design of multichannel playback systems from the basic principles of psychoacoustics. Using auditory modelling as a guide, the author develops some examples on issues such as the audibility of errors which are potentially masked or unmasked in a 3-D presentation and the perceptual relationships between numbers of channels and frequency range –to clarify the subjective aspects of subwoofer splicing.

The paper opens the question of relating perceptual and cognitive responses to directional sound or to sound fields.

Introduction

This set of notes is not a paper in full Preprint format. It simply serves as a set of notes and references to accompany the lecture.

Perception

Peripheral auditory function

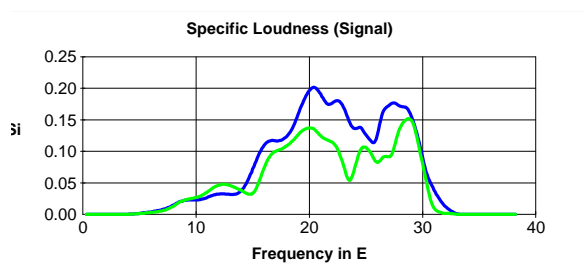
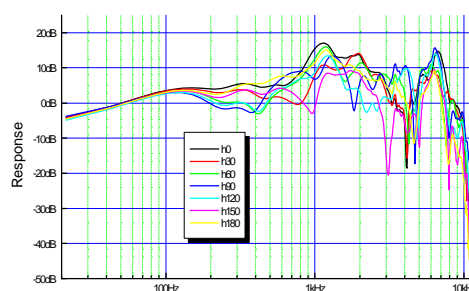
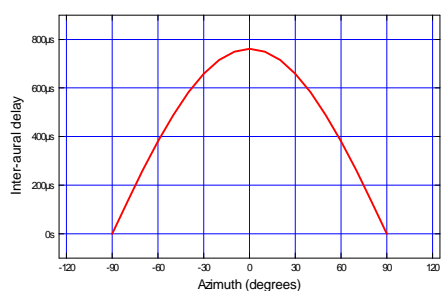
Sounds are encoded in the auditory periphery on a loudness-pitch basis. The neural code partially represents specific loudness and frequencies are dispersed in cochlea according to integral of auditory filtering function. Sounds have temporal encoding through

- onset and offset
- synchronously for waveforms or envelopes < 800Hz
- loudness dependency through threshold effects

Peripheral binaural auditory function

Two spaced ears mean time arrival difference for sounds in different locations - up to 0.7ms – and intensity difference due to head ‘shadow’.

Pinna effects make important spectral modification according to angle of incidence and this filtering action combined with head diffraction is used to encode direction.



Figs of inter-aural time delay and pinna effects with azimuth. Also internal representation of white noise from two incident angles (single near ear).

Localisation phenomena: Time-intensity trading

Cues in replay may be time, phase or intensity and may not relate ‘naturally’

Localisation phenomena: Sound-field

The sound-field method looks at the apparent direction of a source in the absence of a listener, or his binaural capability. Localisation can be confirmed by head-turning.

Localisation phenomena: Precedence

It is well known that sounds appear to come from the direction of first arrival, somewhat independently of amplitude – note the Haas and Franssen effects.

Localisation phenomena: Binaural cognition

Spatial perception can be modified by ‘inaudible’ components – underlining the sophistication of the ‘binaural processor’.

Central binaural processing

The central processor has substantially increased temporal acuity – we can perceive arrival-time differences of the order of 30 μ s at 50 phon.

In binaural listening there are significantly modified detectability thresholds, e.g.:

- binaural masking and release
- binaural masking-level differences (\cong 12dB)
- binaural beats
- subliminal perception: e.g. Groen

Binaural post-processing

The binaural process also significantly modifies the perceived sound. For example:

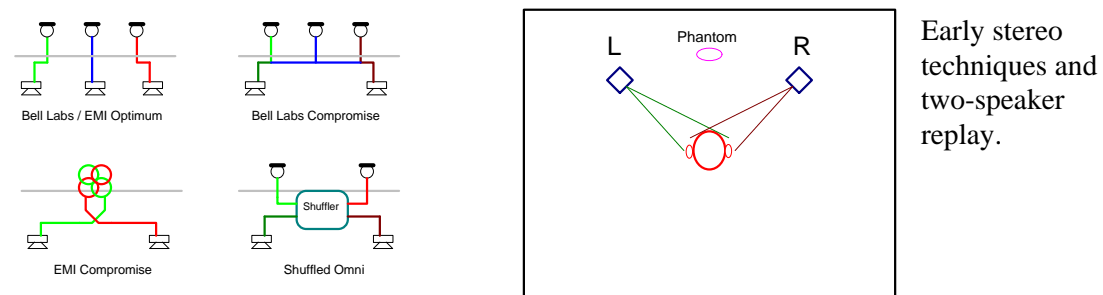
- removal of comb-filtering perceptions
- binaural pitch
- pitch - localisation
- Deutsch octave illusion

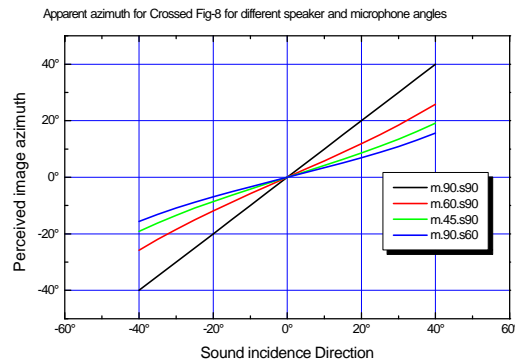
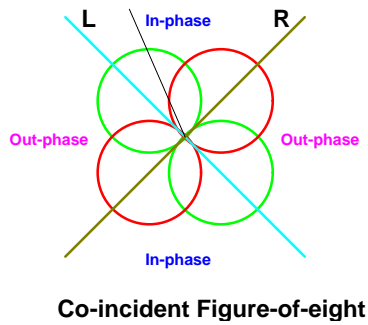
Binaural Loudness

Loudness for binaural presentation is not simply related to mono equivalent, lateral inhibition causes loudness in each ear to grow ‘as masked’.

Near threshold switching from mono to binaural gives approx. doubling in Sone i.e. 10 Phon; at mid-loudness (50 Phon) we see a 4 Phon increase; at high level (80 Phon) a 3 Phon increase. Therefore multichannel makes different loudness impression to mono or fewer presentations.

Stereo





Multichannel Perceptual Issues

Multichannel brings:

- Easier and more emphasised auditory object externalisation
- Simpler instrument streaming
- Changed loudness balance through the binaural process
- Changed timbre perception through location-correction
- Markedly different ambient perception
- Speaker directivity increased by $10 \log n$
- Direct to reverberant ratio change demotes listening-room acoustics
- Increased acuity for channel or processing errors

Cognition

Perception of objects

The perception of music in surround depends on our ability to ‘externalise’ perceptions into ‘acoustic objects’. Some factors that effect this ‘cognitive’ process are: amplitude, fundamental frequency, timbre, envelope patterns, onset disparities, correlated changes, contrast with earlier and later sounds and spatial location. Other models used to aggregate the perceptual attributes of acoustic object formation are: constancy, similarity, auditory streaming, continuation, common fate, language, rhythm, closure – replacement of missing sounds and attention.

Cognitive elements in sound

Regarding cognition, there are the following elements of the perceived soundfield:

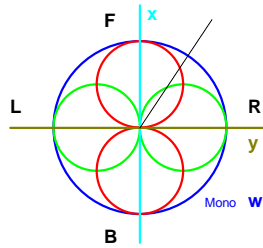
- Mono elements of sound; pitch, loudness, timbre; auditory object formation; ‘object’ grouping
- Binaural additions: auditory object location and separation, ‘object’ externalisation
- spaciousness, ambience recognition, distance perception

Cognitive elements of Music

Cognition of music can be viewed at several levels.

- Cognition of the Sound Object
- Cognition of the Music
- Cognition of the music’s Structure
- Cognition of Content

Encoding surround



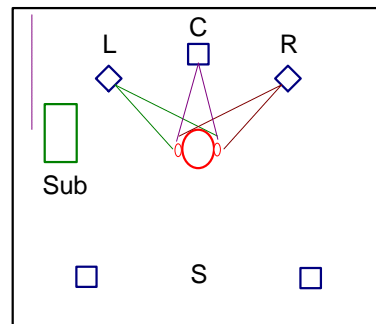
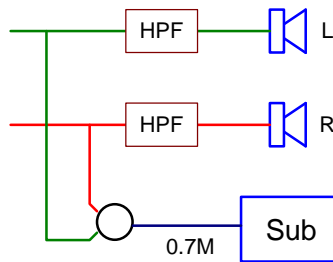
Horizontal Ambisonic

Multichannel azimuthal sampling is the general principle of sound-field encoding. Using azimuthal harmonic synthesis we can create an hierarchical structure of transmission channels for increasing accuracy of surround encoding. The transmission channels will be:

- Sum or omnidirectional channel
- Difference channel = Sum with phase shift: stereo is a special subcase with phase = 180°
- Tertiary channel = conjugate-phase version of Difference
- Quaternary channel using second harmonic

Tertiary and higher can be band-limited.

Low-frequency factors



Bass is directional

There is no evidence of lack of direction at LF and LF carries important ambient clues. Bass directionality can be confused in rooms because of standing-wave patterns and R_r build-up.

Bass-sharing strategies on record or decode

The bass power output is incorrect if the number of woofers is different from channels conveyed or encoded. LF loudness is foundation for 'continuity' in music

The table below illustrates that a mono subwoofer (derived as the sum of Left and Right channels, does not produce the correct in-room power for signals from each of the four cardinal directions Lt, Rt, M, S.

	Inputs at 0dB to:			
	Lt	Rt	M	S
	dB	dB	dB	dB
Pro Logic Output				
Left Front	0.0	-30.0	-30.0	-30.0
Right Front	-30.0	0.0	-30.0	-30.0
Centre	-30.0	-30.0	0.0	-30.0
Mono Sub	0.0	0.0	0.0	n/a
Sub needed	0.0	0.0	0.0	n/a
Stereo Output				
Left Front	0.0	-999.0	-3.0	-3.0
Right Front	-999.0	0.0	-3.0	-3.0
Centre	-999.0	-999.0	-999.0	-999.0
Mono Sub	0.0	0.0	3.0	-999.0
Sub needed	0.0	0.0	0.0	?

Data - reduction and associated factors

Difficulties with Coders

Psychoacoustic data-reduction coders present an hierarchy of problems in multichannel encoding or presentation. The following few problems are listed:

- Intensity stereo coding does not necessarily preserve phase or waveform, there is damaged potential for Soundfield systems.
- Potential for directional unmasking (binaural)
- Risk of underestimating masking through Pinna effects (perceptual)
- Compression/distortion of the stereo image

Summary

1. Multichannel design requires good understanding of both perception and cognition.
2. Cinema methods equate to multiple-mono using logic-assisted matrix decoders or 5 discrete channels.
3. 'Music' systems need to encode the whole soundfield by representing and producing the wavefronts in the absence of a listener (i.e. not binaural methods). Head and body movement are essential for multi-listener environments.
4. Soundfield transmission does not require 5 full-bandwidth channels so better use of any data rate is possible.
5. This is an urgent problem NOW for setting standards: cinema must not drive recording or channel design!

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