21M.380 · Music and Technology
Recording Techniques & Audio Production

Workshop: 5.1 surround sound

Session 28 · Wednesday, December 14, 2016

1 Review WR2

- A scene from *Wall-e* (Pixar, 2008): https://youtu.be/h1BQPV-iCkU
- Music recommendation software:
  How will I discover music I yet have to *learn* to like?

Table 1. 5.1 surround channels

L	Left
C	Center
R	Right
LS	Left surround
RS	Right surround
LFE	Low-frequency effects

2 How to set up a 5.1 surround system

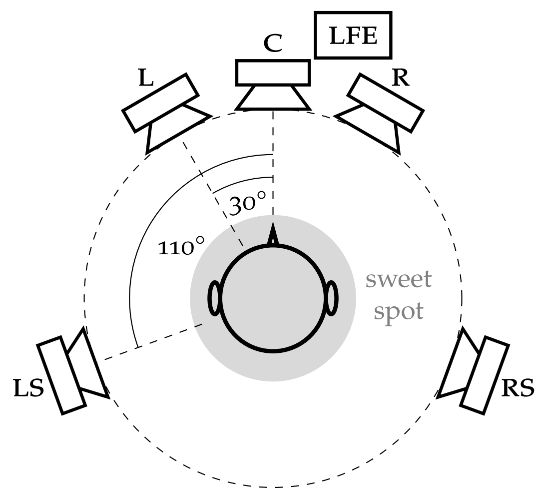

Figure 1. Standard 5.1 loudspeaker setup

- Let's set up a 5.1 system to listen to some surround demos:
  - Full-range speakers (5) arranged on a circle around listener
  - Subwoofer (.1) with no exact position specified[1]
- L & R positions as in standard stereo setup (±30°)
- C & LFE:: Historic heritage from movie theaters (dialog; LF effects)
- Surround channels (LS & RS)
  - Angled at ±110°
  - Remember: Bad localization on sides, rear worse (Blauert 1996, p. 41)

[1] A rationale for the unspecified subwoofer location could be that the human ear is not great at localizing very low frequencies. Do not confuse this property of auditory perception with the fact that low-frequency sound sources tend to emit sounds less directionally than higher-frequency sources (which is a physical rather than perceptual phenomenon).

3 Mixing in 5.1

Standard	1	2	3	4	5	6	7	8
C | 24, Film	L	C	R	LS	RS	LFE	—	—
SMPTE, ITU	L	R	C	LFE	LS	RS	—	—
DTS, ProControl Monitoring	L	R	LS	RS	C	LFE	—	—
D-Command, D-Control	L	—	C	—	R	LS	RS	LFE

Table 2. 5.1 channel order standards

- Yey, plenty of incompatible standards for channel order (cf., table 2)!
- Coming from stereo, 3 questions present themselves:

3.1 What to put on the center channel?

- Sometimes those instruments that you would center-pan in stereo
  - E.g., kick drum, bass, lead vocals
  - Common strategy for primarily close-miked music (pop, jazz)
- Sometimes nothing at all!
  - Idea: Don't jeopardize imagery of a main stereo mic
  - Probably more common in classical music recording

3.2 What to put on the LFE?

- Depends on mixing strategy
- Low-pass-filtered mono mix of all recorded channels
- Sometimes LFE channel is not used at all (e.g., string quartet)
- Sometimes it's used in the original sense: for low-frequency *effects*

3.3 What to put on the surround channels?

- Where should ambience appear from?
- Separating direct sound pickup from ambience by panning the former only to the front and the latter only to the rear channels can result in an incoherent acoustic imagery
- Can be avoided by routing ambience mics midway between rear and front stereo pair (rather than just to surround signals)

4 Surround recording techniques

	Coincident arrays	Spaced arrays
Envelopment	☹	☺
Sweet spot size	☹	☺
Size & portability	☺	☹
Localization accuracy	☺	☹

TABLE 3. Coincident vs. spaced surround recording techniques (DPA 2016)

- Coincident vs. spaced arrays
- Various surround extensions of M/S principle
- Some techniques limited to front or rear channels (mix & match)
- Freely available demos of different surround recording techniques:
  - Schoeps:[2] `http://www.schoeps.de/en/downloads/sound_samples`
  - DVD image with recordings from blind comparative test by ORF: `http://www.hauptmikrofon.de/stereo-3d/orf-surround-techniques`

[2] Some images from the environments in which these recordings have been conducted can be seen in a presentation by Wittek (2013).

4.1 Optimized cardioid triangle (OCT) family

- 3 related techniques by Günther Theile (cf., DPA 2015c; Schoeps 2004)
  - OCT: Capture front channels (L, C, R) of 5.1 setup
  - OCT 2: Same as OCT, but C mic shifted forward by 40 cm, not 8 cm
  - OCT surround: OCT with 2 extra mics to capture rear channels (LS, RS)
- All 3 techniques use cardioids and supercardioids

4.1.1 Demo: J. S. Bach – *Singet dem Herrn*

- `http://schoeps.de/documents/OCT-Demo16.zip`
- Final fugue of J. S. Bach's motet *Singet dem Herrn*
- Christuskirche Karlsruhe, Germany (June 18, 2010)
- Vocalensemble Rastatt, conducted by Holger Speck
- Recorded in OCT surround
- Microphones discretely routed to speakers & unprocessed

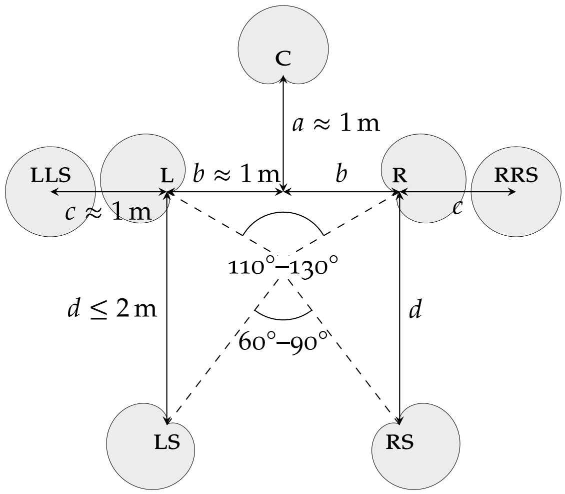

FIGURE 2. Fukada tree

4.2 Fukada tree

- Originally suggested by Akira Fukada at NHK (Radio Japan)
- 5 cardioids & 2 outrigger omnis (cf., figure 2)
- Geometry flexible (no psychoacoustic basis on recording angles etc.)
- Surround mics often located at hall's critical distance d_c from source (Rumsey and McCormick 2009b, p. 551)
- Cardioids discretely panned to 5 speakers
- Omnis panned between L ↔ LS & R ↔ RS

4.3 INA-5

- INA … *ideale Nierenanordnung* ('ideal cardioid arrangement'; 5 cardioids)
- Invented by engineers Ulf Herrmann und Volker Henkels
- 3 front mics L, C, R sometimes referred to as INA-3:
  - Interpreted as 2 adjacent stereo pairs L/C and C/R
  - Review: Mic base angle β (visible) vs. *recording angle* α (invisible)
  - Design goal: α_{LC} and α_{CR} perfectly adjacent (no gap, no overlap)
  - Fulfilled if (and only if) $\alpha_{LC} = \alpha_{CR} = \beta$ (why?)
  - Use *Williams curves* to derive suitable a, b, c combinations (table 4)
  - Not all of these theoretically possible geometries used in practice
  - Popular configuration: $2 \cdot \beta = 180°$, $\frac{b}{2} = c = 17.5\,\text{cm}$ (figure 3)
  - Exercise: Confirm $a = 25\,\text{cm}$ for that case through Williams curves
- Rear mic geometry (LS, RS) seems to have less theoretical foundation

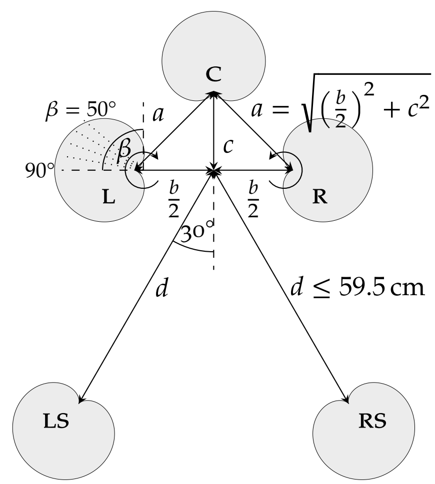

FIGURE 3. INA-5

TABLE 4. Different INA-5 geometries (Rumsey and McCormick 2009a, p. 550; Sengpiel 2005)

$2 \cdot \beta$	a/cm	b/cm	c/cm
100°	69	126	29
120°	53	92	27
140°	41	68	24
160°	32	49	21
180°	25	35	17.5

- Brauner ASM5 with SPL Atmos-5.1 processor (Owsinski 2005, p. 228)
  - Atmos-5.1: remote power, polar pattern control, stereo mixdown
  - $\frac{b}{2} = c = 17.5\,\text{cm}$ (but β and c apparently adjustable to some degree)
  - $d \leq 59.5\,\text{cm}$ (adjustable) at $\pm 30°$ (fixed)
- Ina-5 system by Microtech Gefell (Microtech Gefell 2017)
  - M930 (cardioid), M940 (supercardioid), or M950 (subcardioid) mics
  - $\beta = 90°$ (fixed)
  - $\frac{b}{2} \leq 17.5\,\text{cm}$ and $c \leq 17.5\,\text{cm}$ (adjustable separately)
  - $d \leq 59.5\,\text{cm}$ (adjustable) at $\pm 30°$ (fixed)
- All microphones routed discretly to corresponding speakers

4.4 Ortf surround

- Designed to capture all 5 channels, yet be extremely portable
- 4 supercardioids in double-ORTF arrangement
- But geometry differs slightly from original ORTF stereo technique
- Reason: Designed such that recording angle $\alpha = 90°$ for L/R and LS/RS
- Discrete routing of microphone signals to L, R, LS, RS
- C channel optional. How to derive?

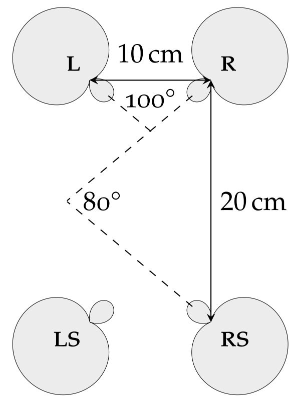

Figure 4. Ortf surround

4.4.1 Demo: Rainforest ambience

- http://schoeps.de/documents/BarbeauORTFSurround_1366290040.zip
- Recording by Philippe Barbeau
- Recorded in Gabon for Luc Jacquet's movie *It was a forest*

4.4.2 Demo: Soccer arena ambience

- http://schoeps.de/documents/ORTF_Surround_SoccerArena.zip
- Mic hanging from roof

4.5 Double M/S

- Surround extension of M/S with 2 M/S pairs (front & rear)
- But directional mics *must* be used for mid signals. Why?
  - Usually cardioids for both, front and rear mid signals
  - Schoeps Double M/S CMIT system uses shotgun mic for front mid
- Same figure-eight can be (but not always *is*) shared between M/S pairs

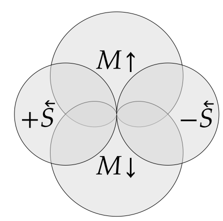

Figure 5. Double M/S principle

Equation 1. Double M/S to 5.1 decoder

$$
\begin{aligned}
C &= M\uparrow \\
L &= \frac{M\uparrow + \overleftarrow{S}}{2} \\
R &= \frac{M\uparrow - \overleftarrow{S}}{2} \\
LS &= \frac{M\downarrow + \overleftarrow{S}}{2} \\
RS &= \frac{M\downarrow - \overleftarrow{S}}{2}
\end{aligned}
$$

$M\uparrow$ front-facing cardioid
$M\downarrow$ rear-facing cardioid
$\overleftarrow{S}$ shared figure-eight (positive polarity left)

- Or deliberately space out separate M/S systems for signal decorrelation
  - Front pair within critical distance d_c from source
  - Rear pair beyond critical distance d_c
- Front M/S pair decoded to L/R; rear M/S pair to LS/RS
- More info by DPA (2015a) and Wittek, Haut, and Keinath (2010)

4.5.1 Demo: Shostakovich symphony №5, 4th movement (beginning)

- http://schoeps.de/documents/Schostakowitsch.zip
- Double M/S plus extra omni LP-filtered at 40 Hz for LFE
- Christophorus Symphonie Orchester Stuttgart (CSO)
- Recording by students at Hochschule der Medien, Stuttgart (Prof. Oliver Curdt), winter semester 2006–07

4.5.2 Demo: Market place ambience

- http://schoeps.de/documents/Marktplatz.zip
- Market place in Durlach, Germany
- Recording: Daniel Keinath

4.5.3 Demo: Piano concerto

- http://schoeps.de/documents/Klavierkonzert.zip

4.5.4 Demo: Castagnettes

- http://schoeps.de/documents/Kastagnetten.zip

4.5.5 Demo: Altstadtfest

- http://schoeps.de/documents/Altstadtfest.zip

4.5.6 Demo: DMS test

- http://schoeps.de/documents/DMS_Test.zip

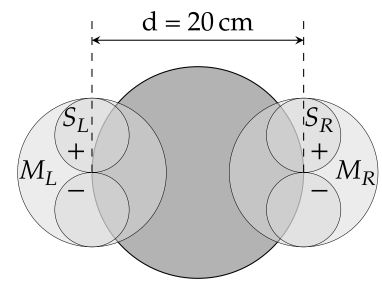

FIGURE 6. Schoeps KFM 360 principle

4.6 Schoeps KFM 360

- Based on Schoeps KFM 6 spherical surface microphone
- 2 front-facing figure-eights ($S_{L\uparrow}$, $S_{R\uparrow}$) added to 2 KFM 6 omnis (M_L, M_R)
- Another surround extension of the M/S principle
- But here M/S pairs are facing *sideways* & decoded to L/LS and R/RS!
- Control overall directivity pattern by adjusting omnis-to-fig-8 ratio
- Exercise: Derive 5.1 decoding equations for C, L, R, LS, RS

4.7 First-order ambisonic microphones

- Ambisonics: 3D extension of M/S
  - Stereo M/S: Fig-8 captures left-right differences
  - Ambisonics: 2 more fig-8s for front-rear & top-bottom differences
- First-order ambisonics (*B format*) requires 4 coincident microphones:
  - 1 omni (*W* channel)
  - 3 figure-eights (*X*, *Y*, *Z* channels)
- Problem: Impossible to put 4 mics into same physical location
- Compromise:
  - Arrange 4 cardioids in a tetrahedron instead
  - Convert output of cardioids (*A format*) to B format
  - How? Mixing; filtering to compensate for distance between mics
- But even B format cannot played back directly on loudspeakers!
  - Like M/S, B format needs to be *decoded* to actual loudspeaker signals
  - Nice: Can be decoded to *different* speaker configurations (e.g., 5.1) ☺
- Commercially available systems:
  - SoundField microphone (A-B: separate hardware processor)
  - CoreSound TetraMic (A-B: free *TetraProc* software, F. Adriaensen)

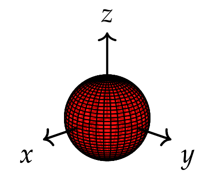

FIGURE 7. W channel

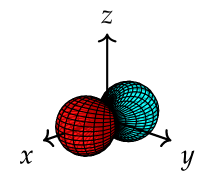

FIGURE 8. X channel

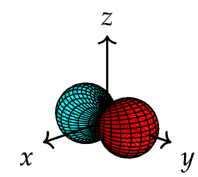

FIGURE 9. Y channel

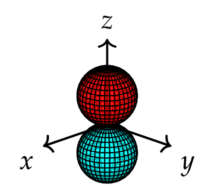

FIGURE 10. Z channel

4.8 Microphone arrays

- Example: em32 Eigenmike by mh acoustics
- Microphone array with 32 transducers on surface of sphere
- *Beamforming* (DSP technique) allows to 'aim' mic in any direction
- 3D surround recording beyond 5.1 (Ambisonics etc.)

4.9 IRT cross

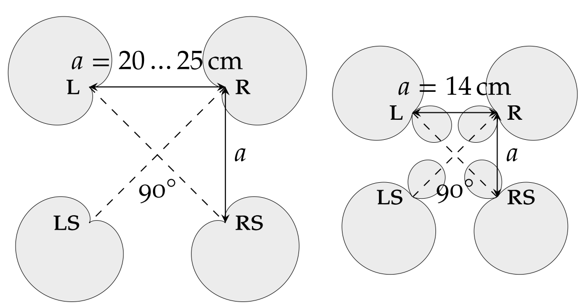

FIGURE 11. Two versions of the IRT cross

- Also known as *atmo cross*
- Designed to capture *ambience* rather than direct sound
- 4 cardioids in square of 20 cm to 25 cm side length (DPA 2015b)
- Or: 4 hypercardioids in square of 14 cm side length
- Mics face away from square's center
- Typically a few meters behind main L, C, R array (e.g., OCT)
- Discrete panning to L, R, LS, RS channels in 5.1

4.10 Hamasaki square

- Developed by Kimio Hamasaki at NHK Science & Research Laboratory
- Designed to capture *ambience* rather than direct sound (like IRT cross)
- 4 sideways-facing figure-eights in square of roughly ≈ 2 m side length
- Often mixed with Decca tree for front channels (Wittek 2012)
- 5.1 panning:
  - Rear mics discretely to LS & RS channels
  - Front mics discretely to L & R, or midway between L $\leftrightarrow$ LS & R $\leftrightarrow$ RS

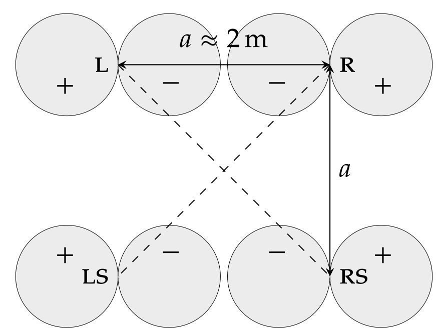

FIGURE 12. Hamasaki square

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