40th AES Conference
Tokyo, 8-10 October 2010

History and current state of the war between the two main approaches to surround sound: discrete speaker feeds versus hierarchical matrix

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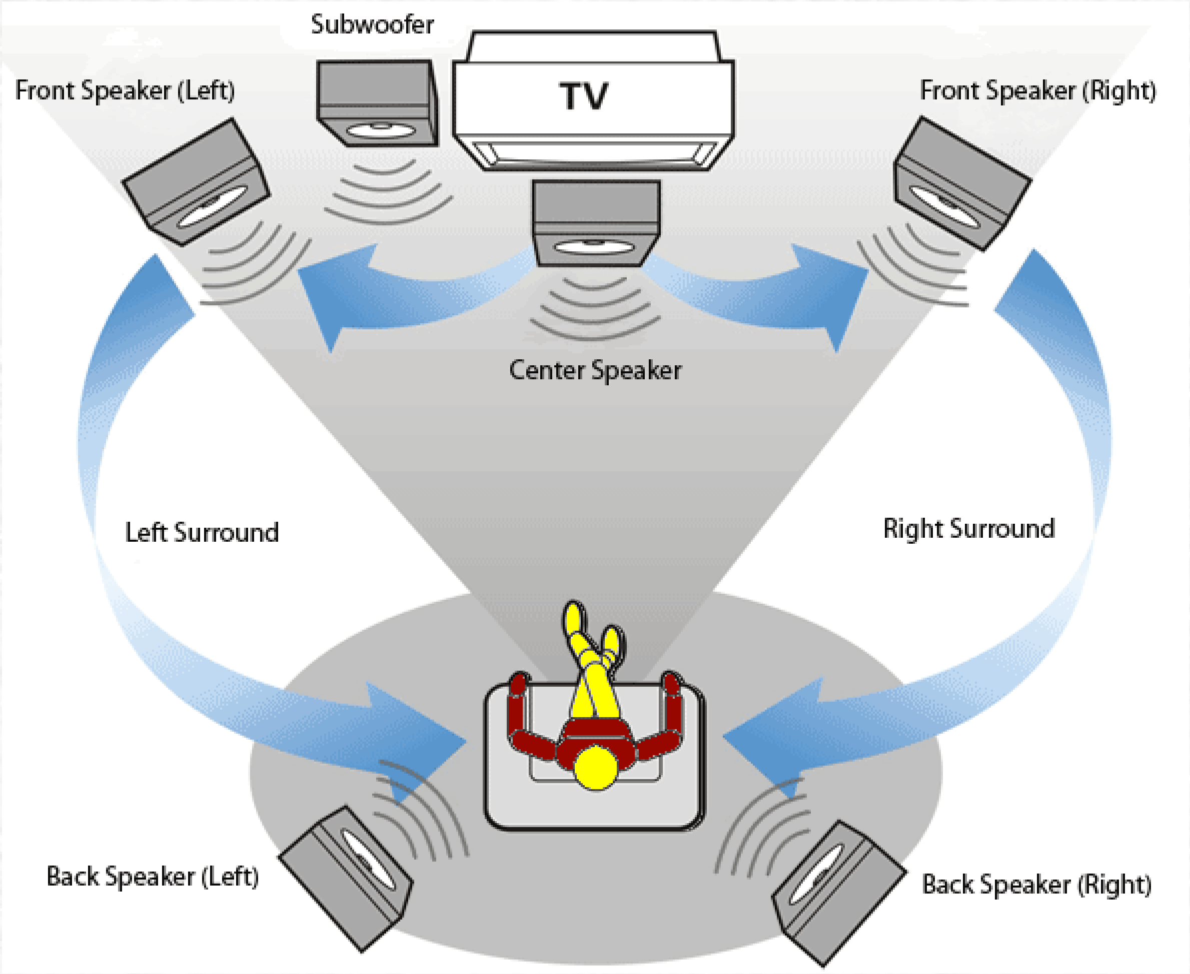
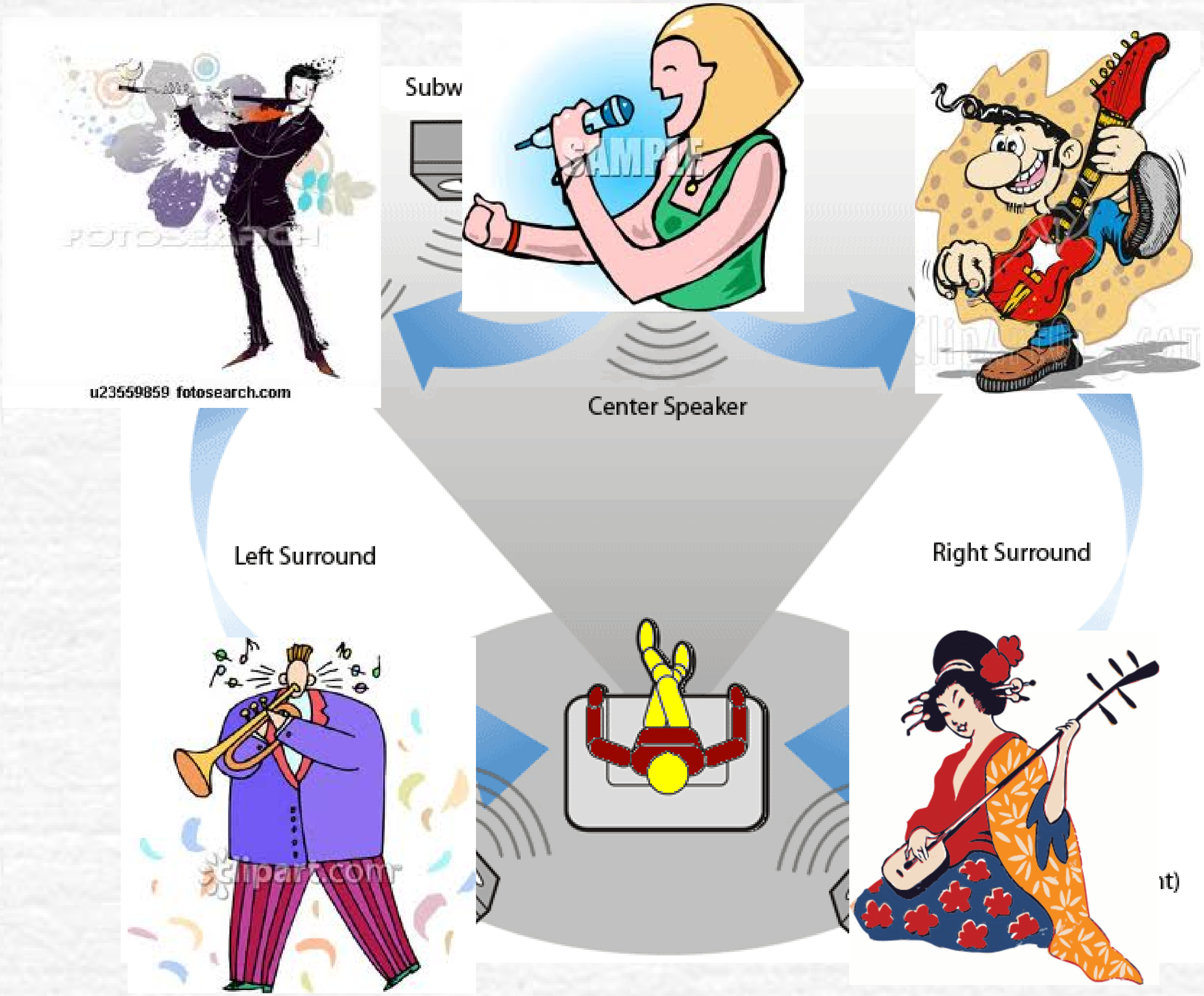
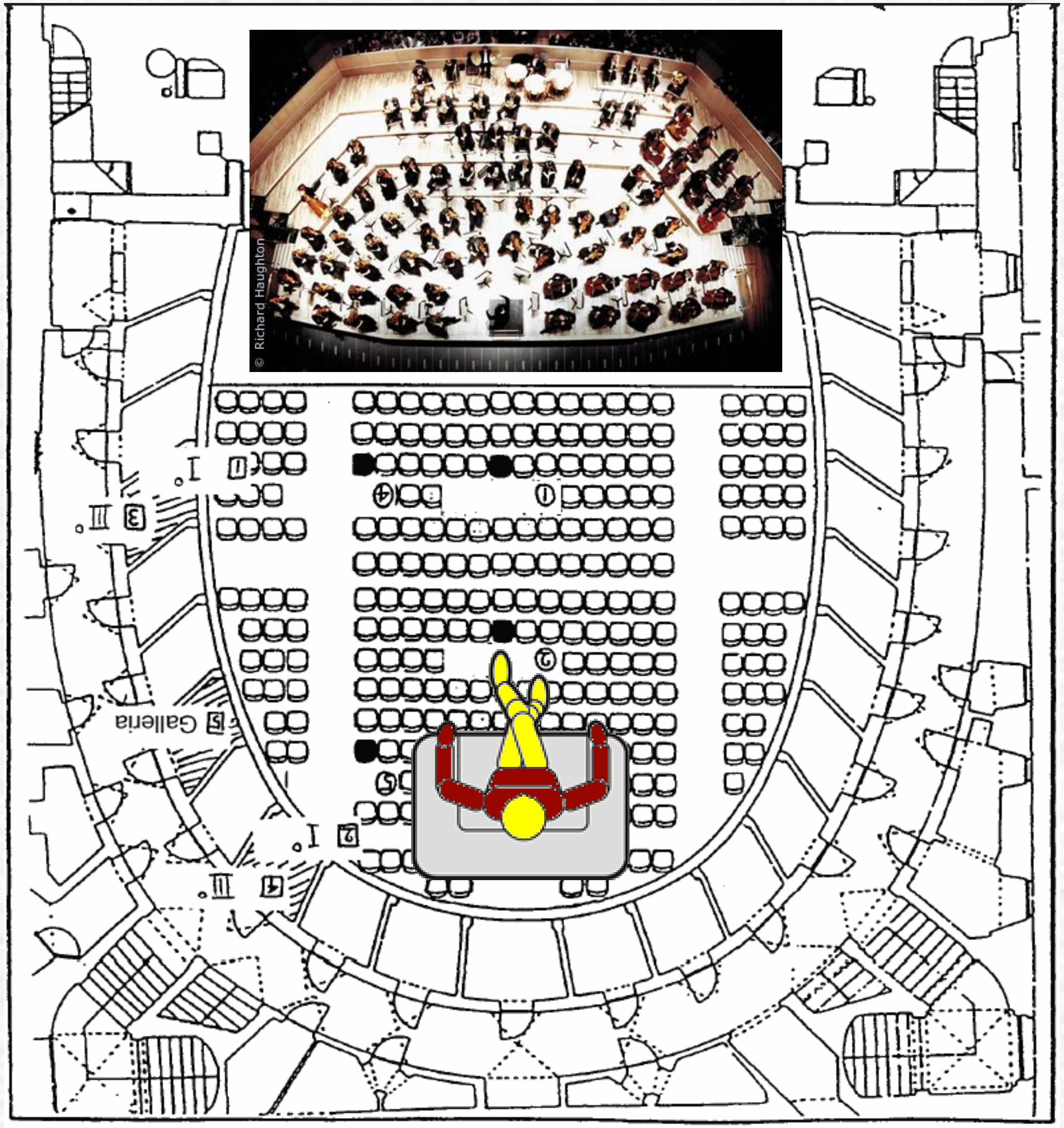
Who is where ?


Subwoofer
TV
Front Speaker (Left)
Front Speaker (Right)
Center Speaker
Left Surround
Right Surround
Back Speaker (Left)
Back Speaker (Right)

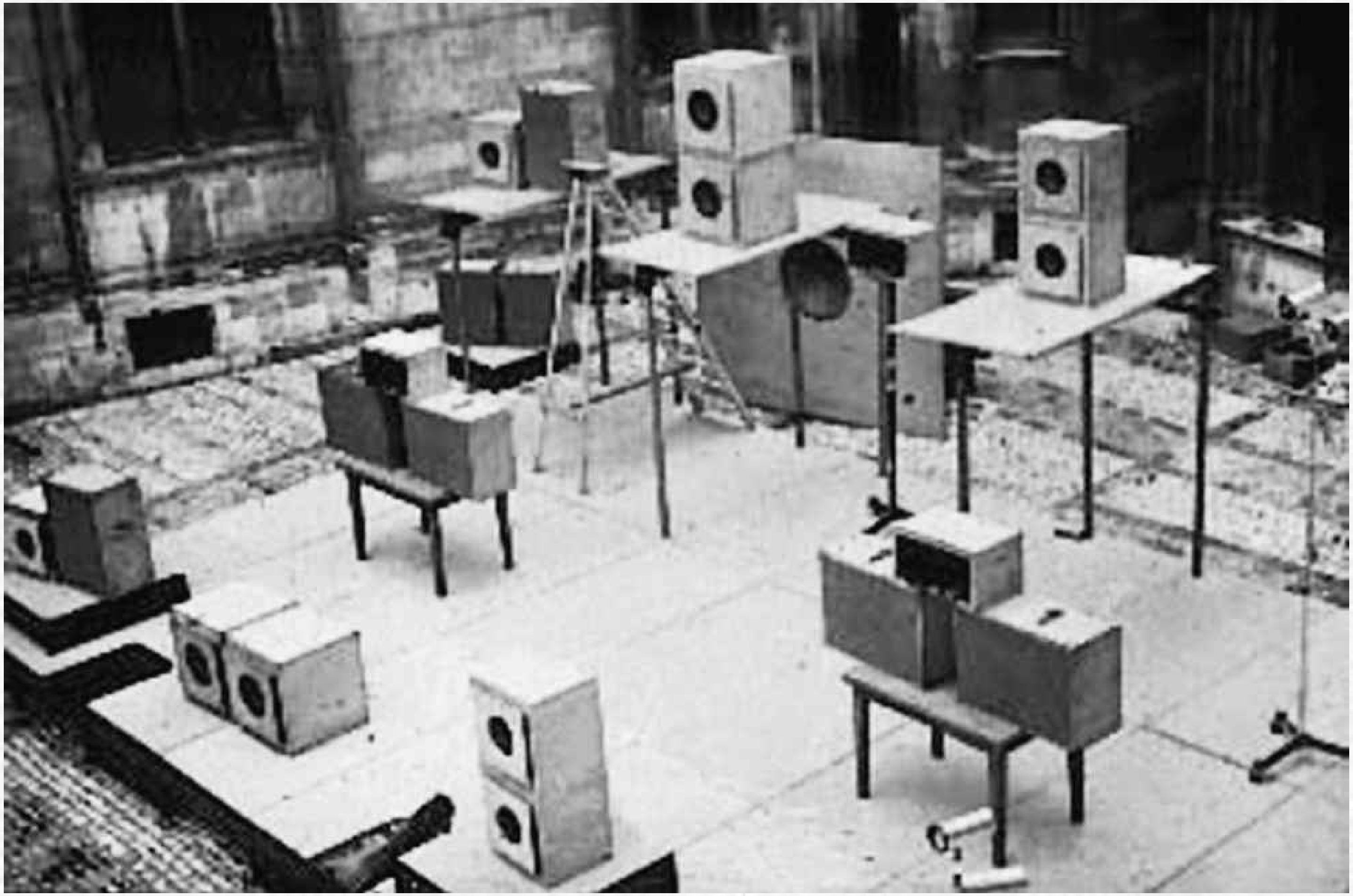
“They are here”



“You are there”



"They are here"



Gmebaphone (1973)

Discrete vs. Matrix

Discrete speaker feeds

- Quad-8

- OCT-Surround
- Williams MMA
- Fukada-Tree
- Hamasaki-Square
- INA-5
- Decca Tree

5 ch.

- **Spot mikes + panning**

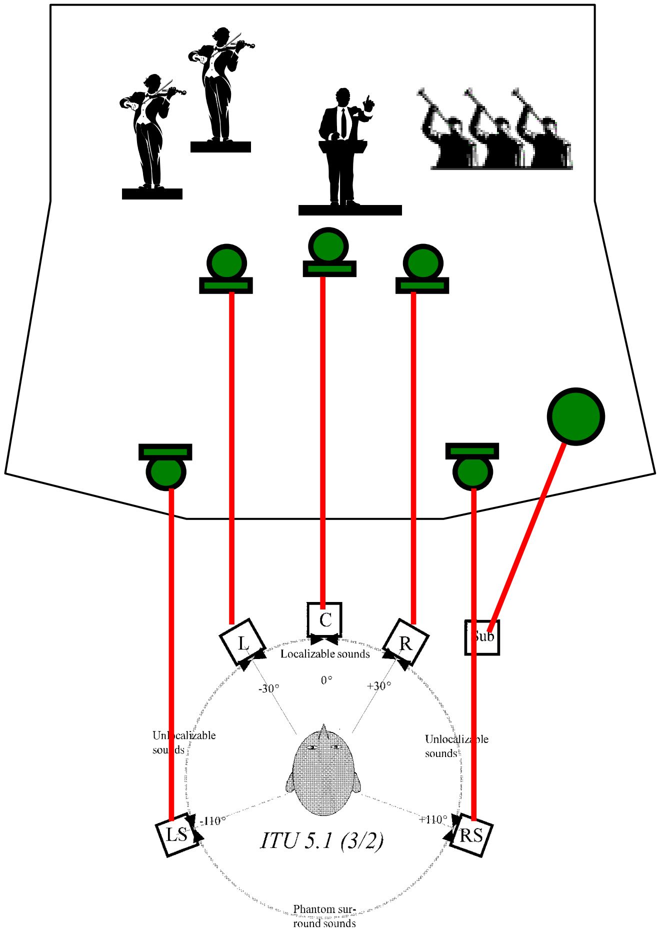
Hiearchical Matrix

- Quad SQ/QS/EV/DY
- Ambisonics UHJ
- Dolby Surround
- Dolby Pro Logic
- Logic 7
- SRS Circle Surround

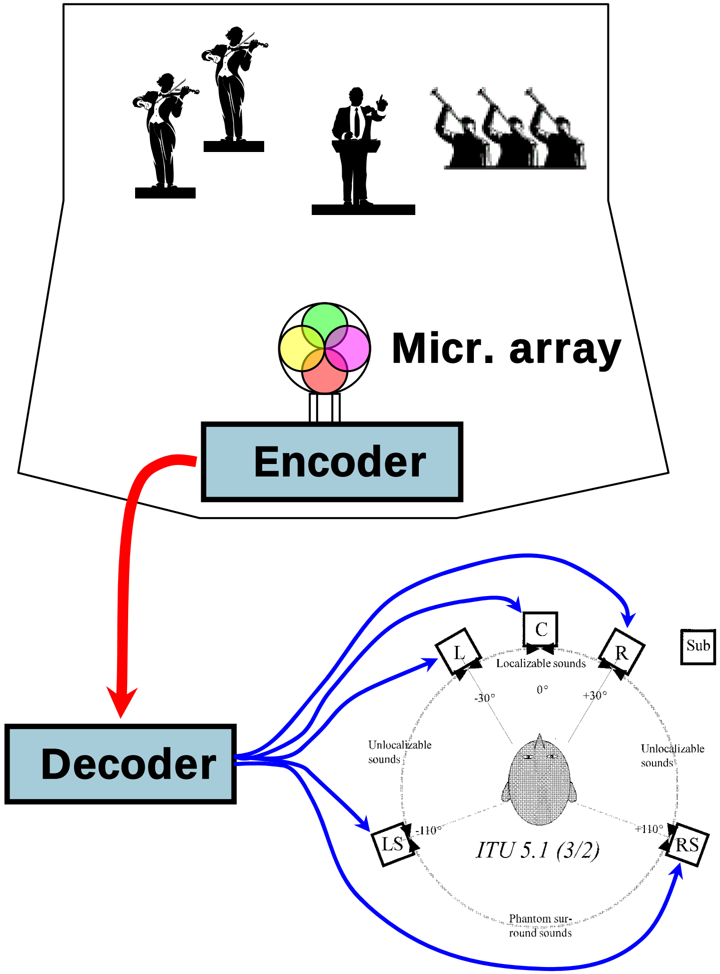
2 ch.

- 1st ord. Ambisonics
- SIRR / DirAC
- High Order Ambisonics

Discrete vs. Matrix

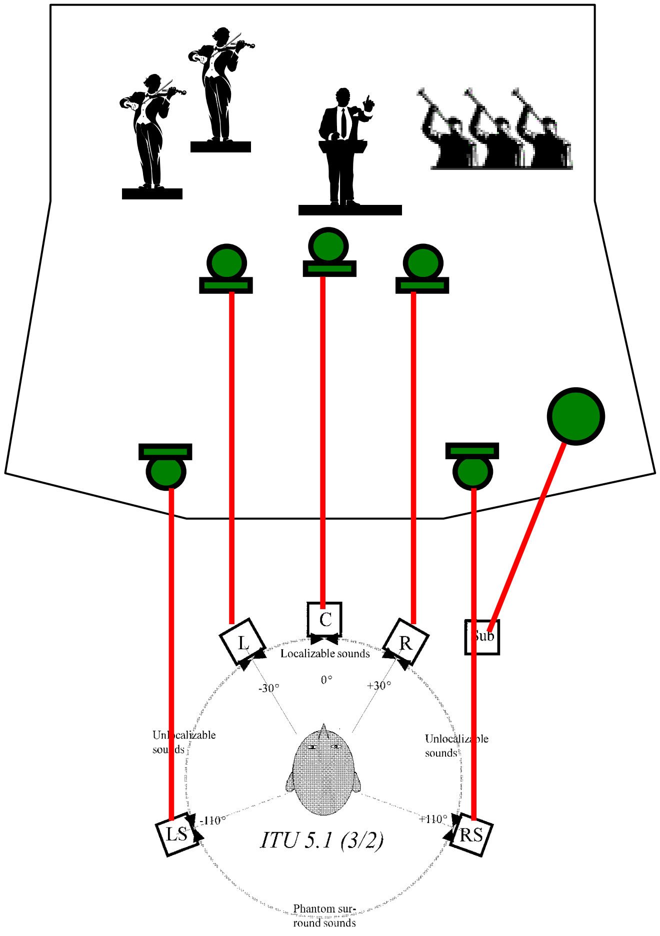


Discrete speaker feeds

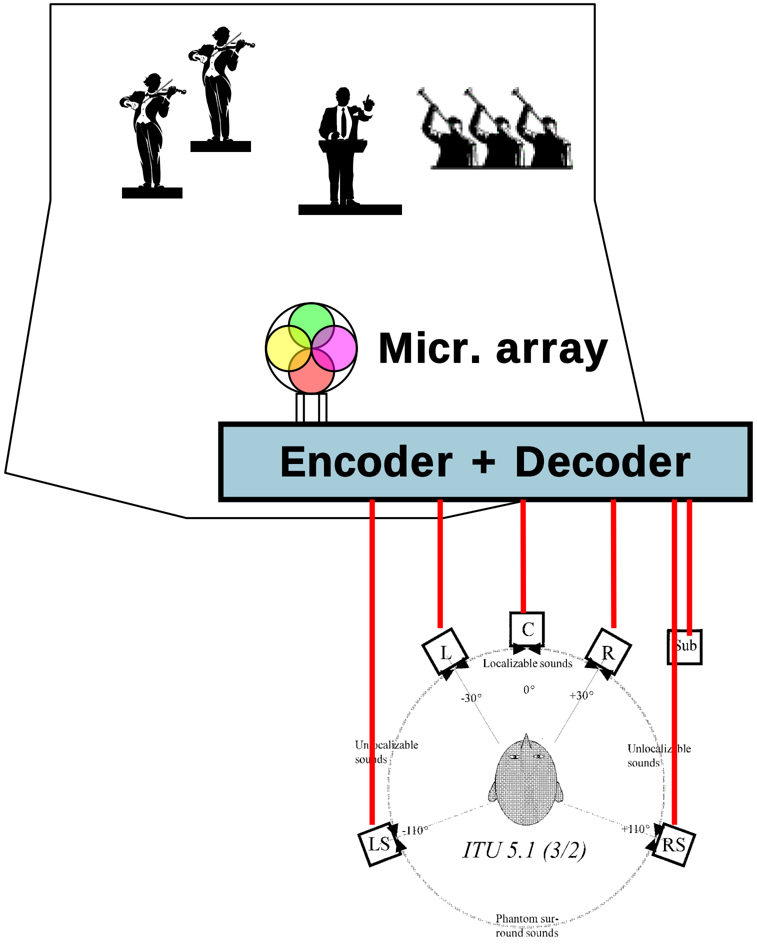


Hiearchical Matrix

Discrete vs. Matrix

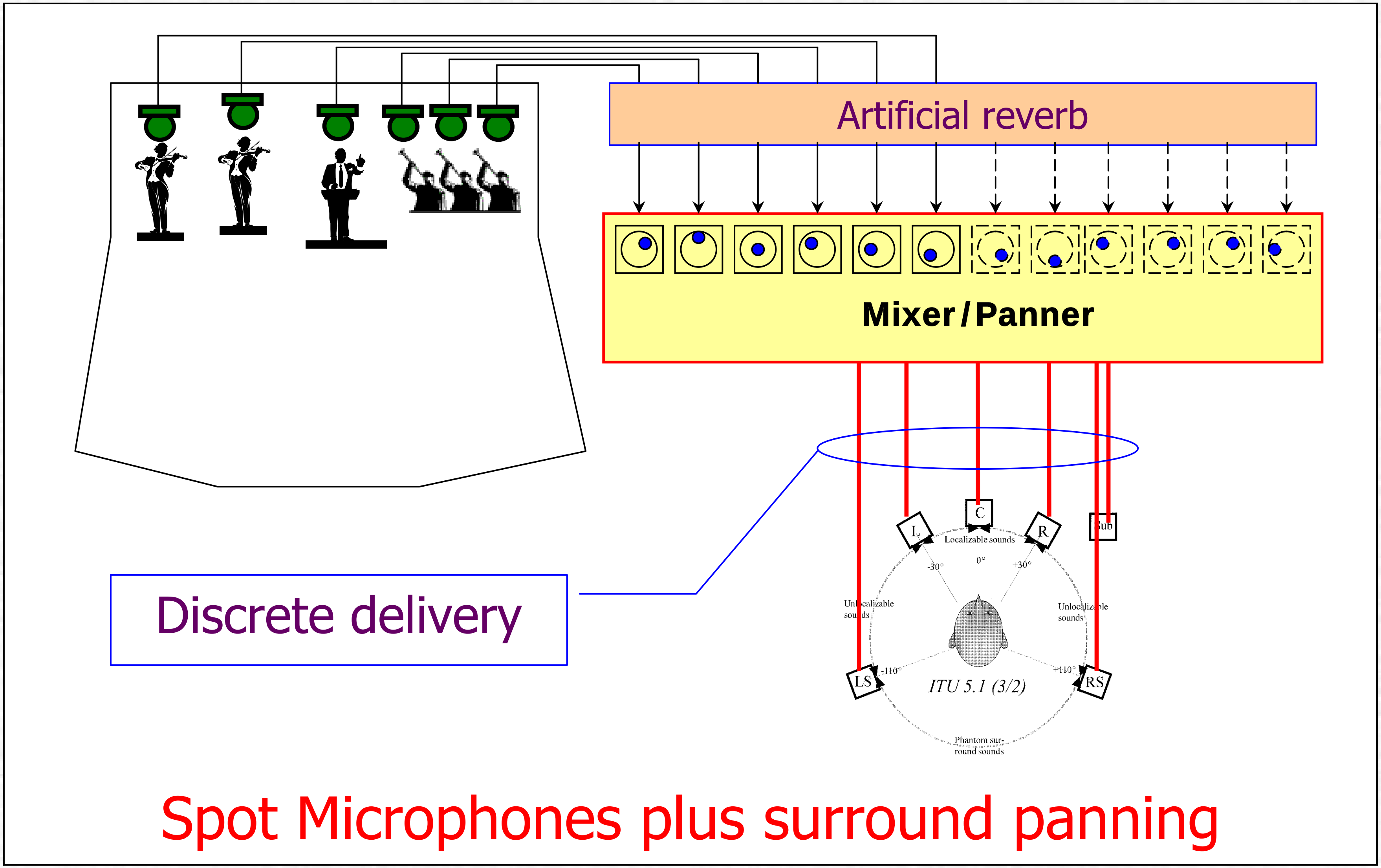


Discrete speaker feeds

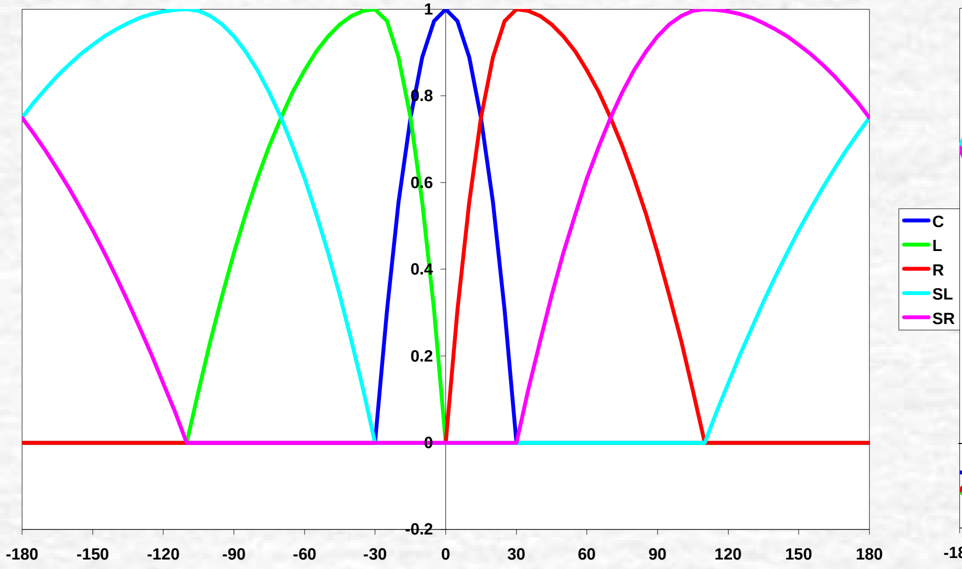


Hiearchical Matrix

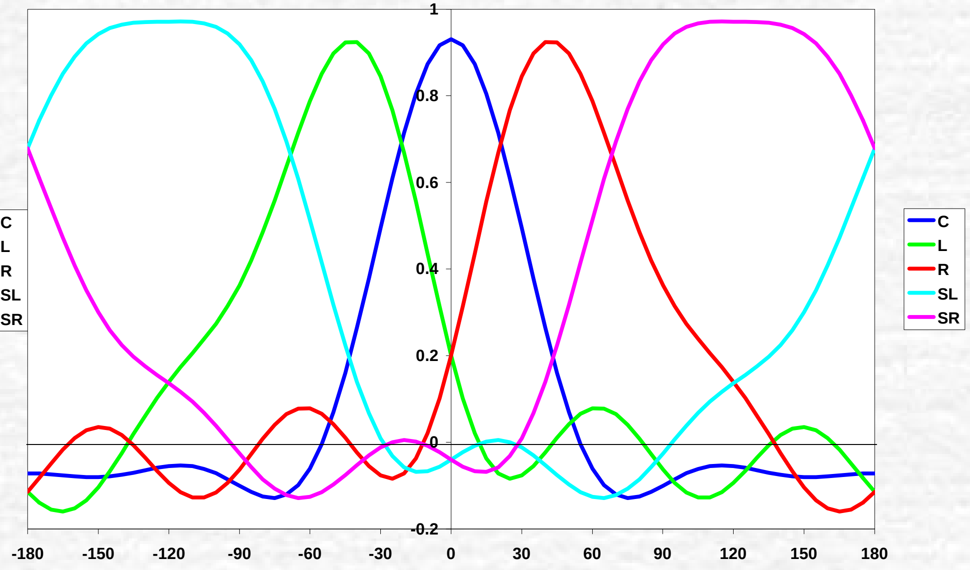
But more often the approach is this:



Surround Panning Laws



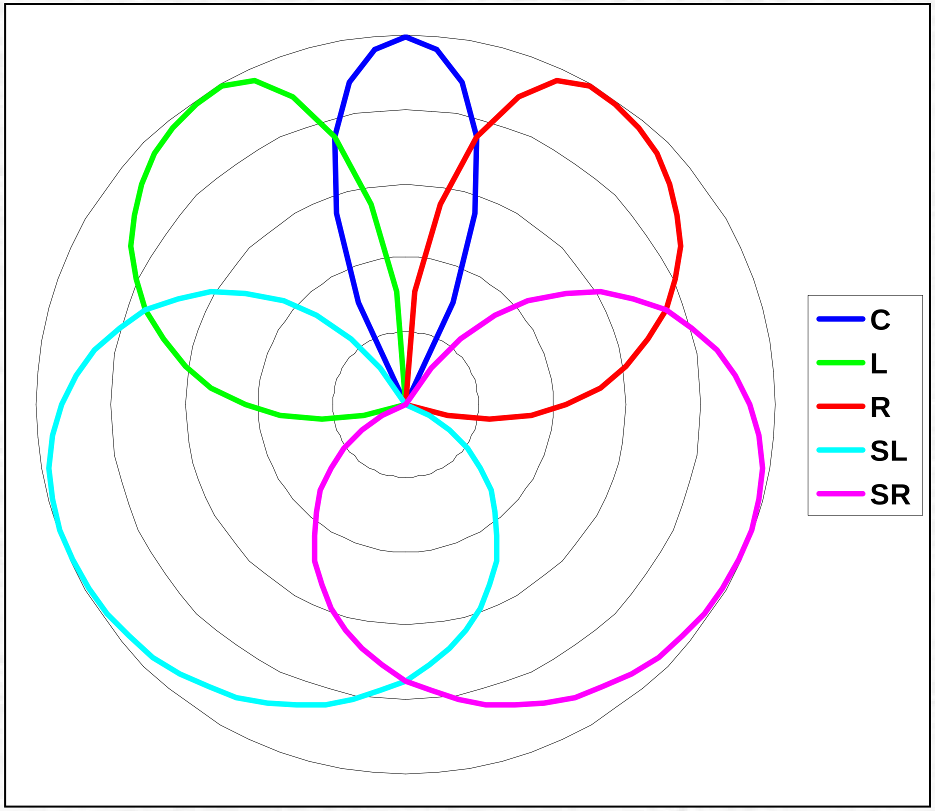
“Pairwise Panning” with constant power – signal is sent to just 2 loudspeakers simultaneusly



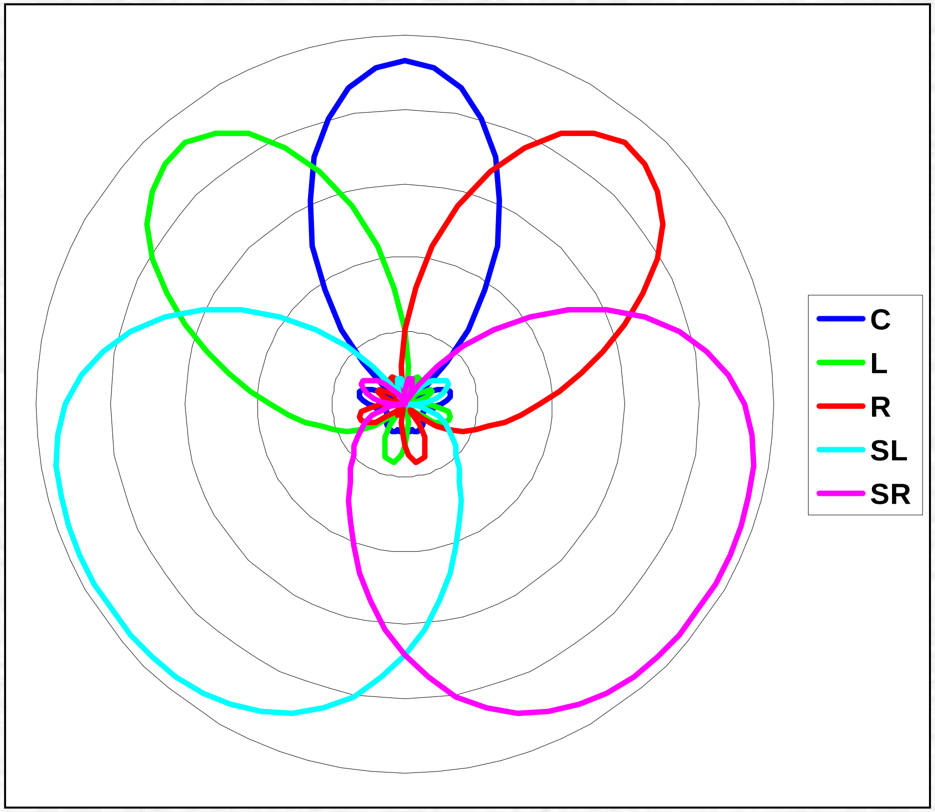
Peter Cravens’ panning laws based on high-order Ambisonics decoding; all 5 speakers are always fed

Many different amplitude-panning laws are available

Surround Panning Laws



"Pairwise Panning"



Peter Craven's panning

Polar patterns of the panning laws

Which type of surround is being emulated by the spot mikes + panning method?

- At a first glance, it is **discrete**, as the signals are usually delivered ready for the loudspeakers
- But, as the panner usually adjustes amplitude only, the signals are in reality much more similar to those created by a **hierarchical matrix**

So, what is the real difference between discrete and matrix?

- Whatever the method employed for recording or synthesizing the surround material, every loudspeaker can always be thought to be fed with a signal coming from one or more microphones (virtual or real)

So, what is the real difference between the two systems?

- In a Hierarchical Matrix system, the virtual microphones are always **COINCIDENT**, albeit some types of "Logic" decoders can add delays, which emulates virtual microphones more far from the source
- In a Discrete system, the microphones can be either real or virtual, and they **can** be **SPACED** providing some potential perceptual advantages (and consequent risks)

Historical review

- Here we show some milestones in the development of surround sound production
- Both **discrete** systems and **hierarchically matrixed** methods are described, as they interleaved during the years

Timeline

Discrete	Year	Matrix
Solid Music	1934	
Fantasia – Fantasound (4 ch.)	1940	
Cinerama (6 ch.)	1952	
Cinemascope (4 ch.)	1953	
Quadraphonic Q8 (4-4-4)	1970	
	1972	Quad over 2ch: SQ, QS (4-2-4)
	1973	Ambisonics

Timeline

Discrete		Matrix
	1975	Dolby Stereo (4-2-4, optical)
	1984	Dolby Surround (VHS tape)
	1987	Dolby Pro Logic (VHS tape)
Dolby Digital (lossy, 5.1)	1992	
DTS (5.1), SDDS (7.1), lossy	1993	
1998: The DVD !!!!		
	1999	Dolby Digital Ex, DTS Es (6.1)
	2000	Dolby Pro Logic II (5.1)

Timeline

Discrete	Year	Matrix
Lucas film THX 10.1	2001	Ambiophonics
	2002	Dolby Pro Logic II x (6.1)
	2003	Waves IR1, IR360
	2004	Dolby Digital Plus, Dolby TrueHD
NHK 22.2 surround	2005	
	2007	Schoeps Double MS
	2009	Dolby Pro Logic II z
	2010	High Order Ambisonics

2006: HD-DVD and Blue Ray Disc

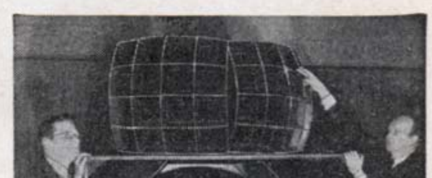
Solid Music (1934)

With discriminating projection of sounds from speakers properly spaced, the sources of sound seem to move invisibly about the auditorium.

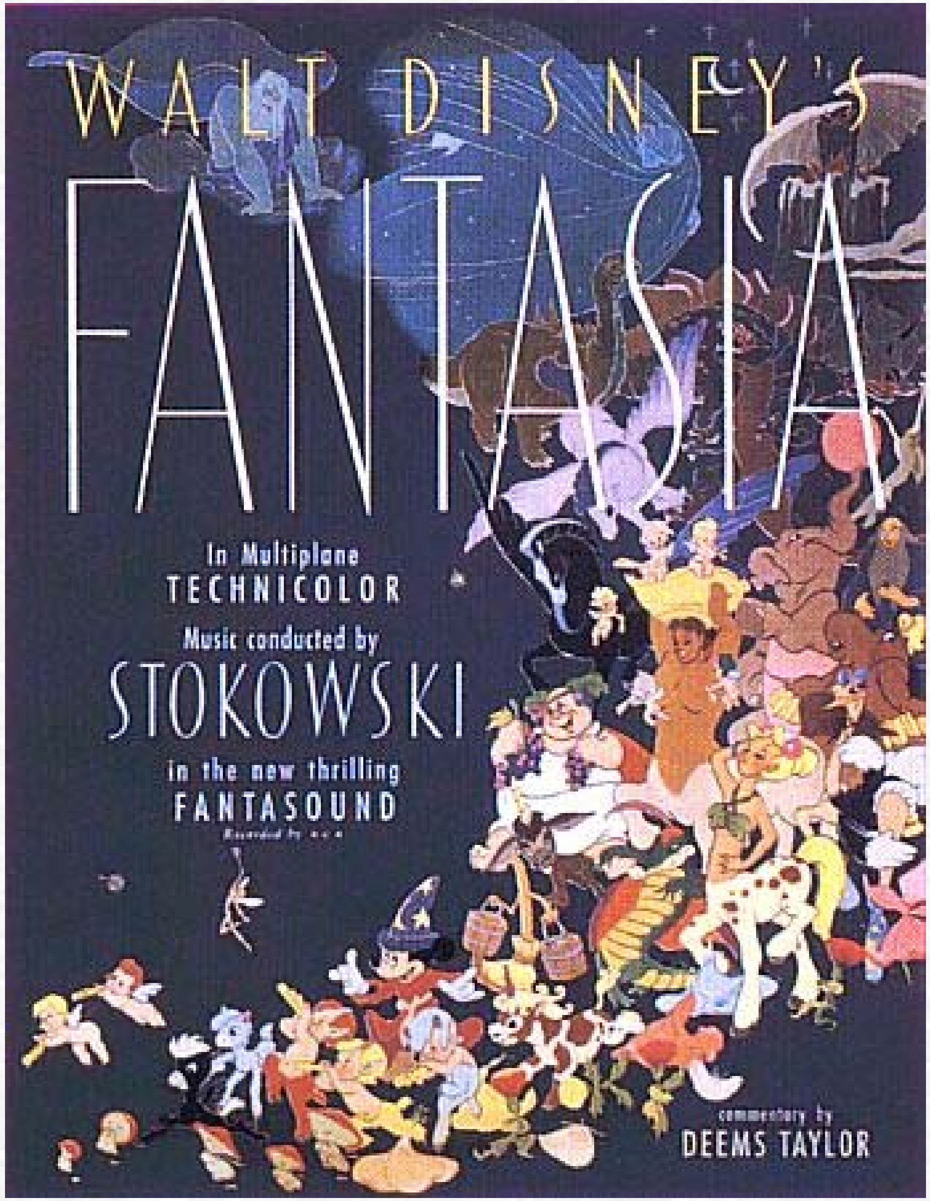
"Three-Dimensional" Sounds Created

● LIKE pictures on a screen, the best of public-address amplification and loud-speaker reproduction hitherto available has lacked reality. It is not that the in-

tion high, but each of the multiple speakers used is giving out a different interpretation of the sounds picked up. The result is that the ear, receiving varied



Fantasia - Fantasound (1940)



Fantasia - Fantasound (1940)

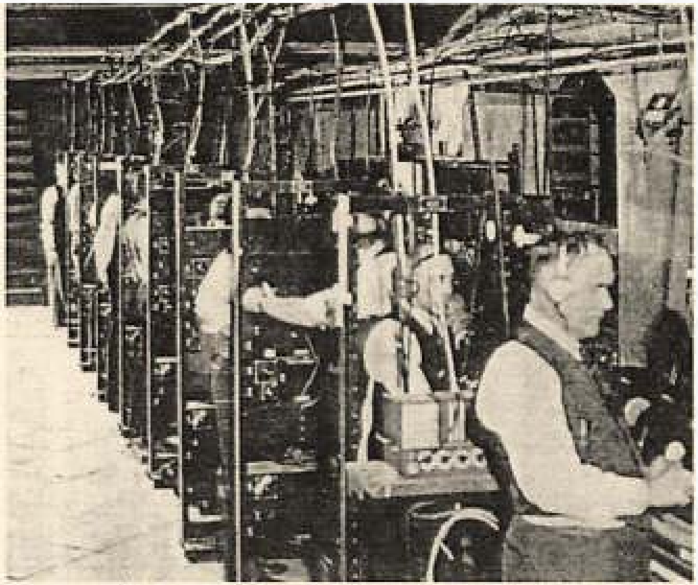


FIG. 11. View of eight recording channels at the Philadelphia Academy of Music.

FIG. 12. View of some of the mixer positions at the Philadelphia Academy of Music.

FIG. 13. View of the 3-channel mixing position used in scoring the *Fantasia* vocal numbers at Burbank. (Messrs. Hawkins, Hisserich, and Marr.)

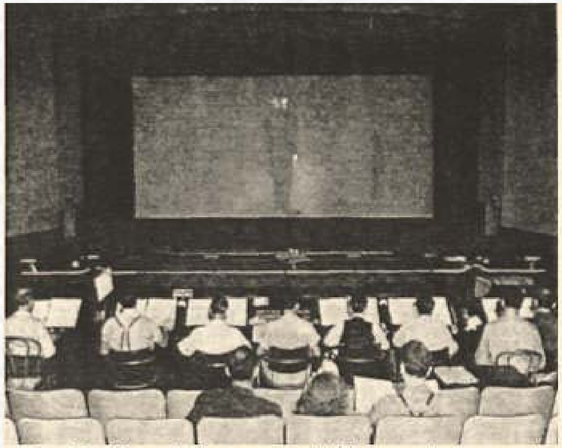
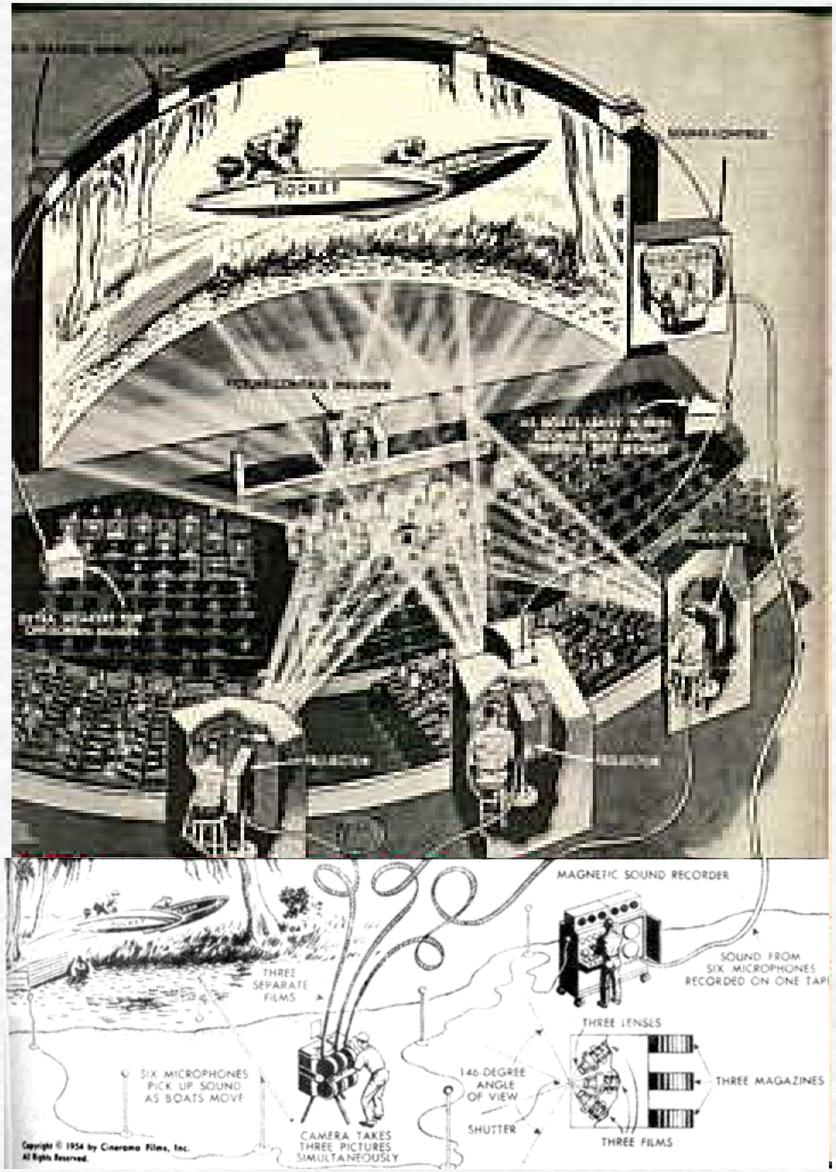


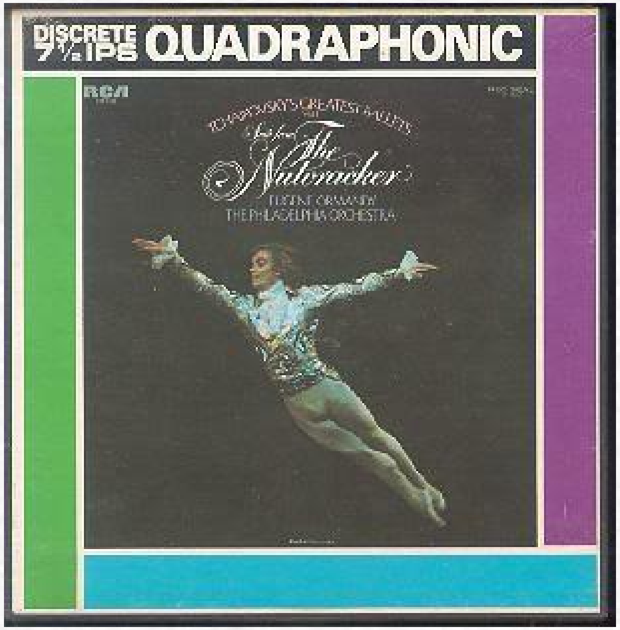
FIG. 14. View of the program dubbing console in operation. (Tone console not shown.) (Left to right, at console, Messrs. Blinn, Steck, Marr, Perry, Moss, Hawkins, Slyfield, and Hisserich. At rear, Ed Plumb, *Musical Director;* Luisa Fiels, *Asst. Music Cutter,* and Stephen Csillag, *Music Cutter.*)

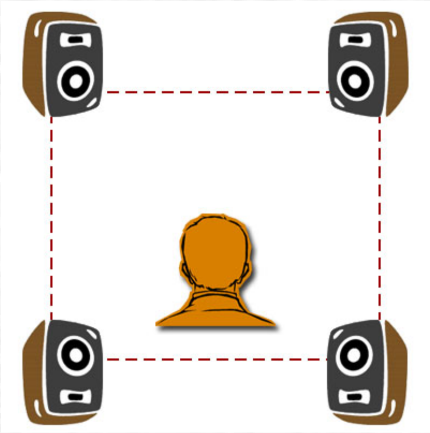
Cinerama (1953) – Cinemascope (1954)



Cinemascope was also a discrete magnetic 4-channels, but one of them was used for surround

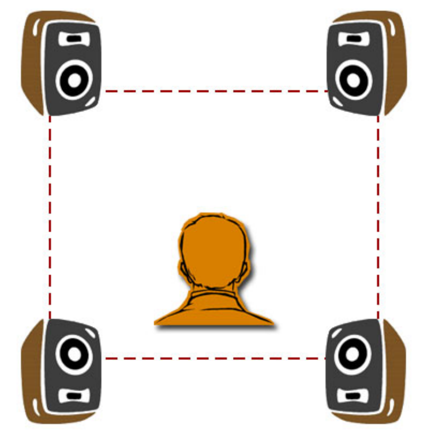
Quadraphony (1970)





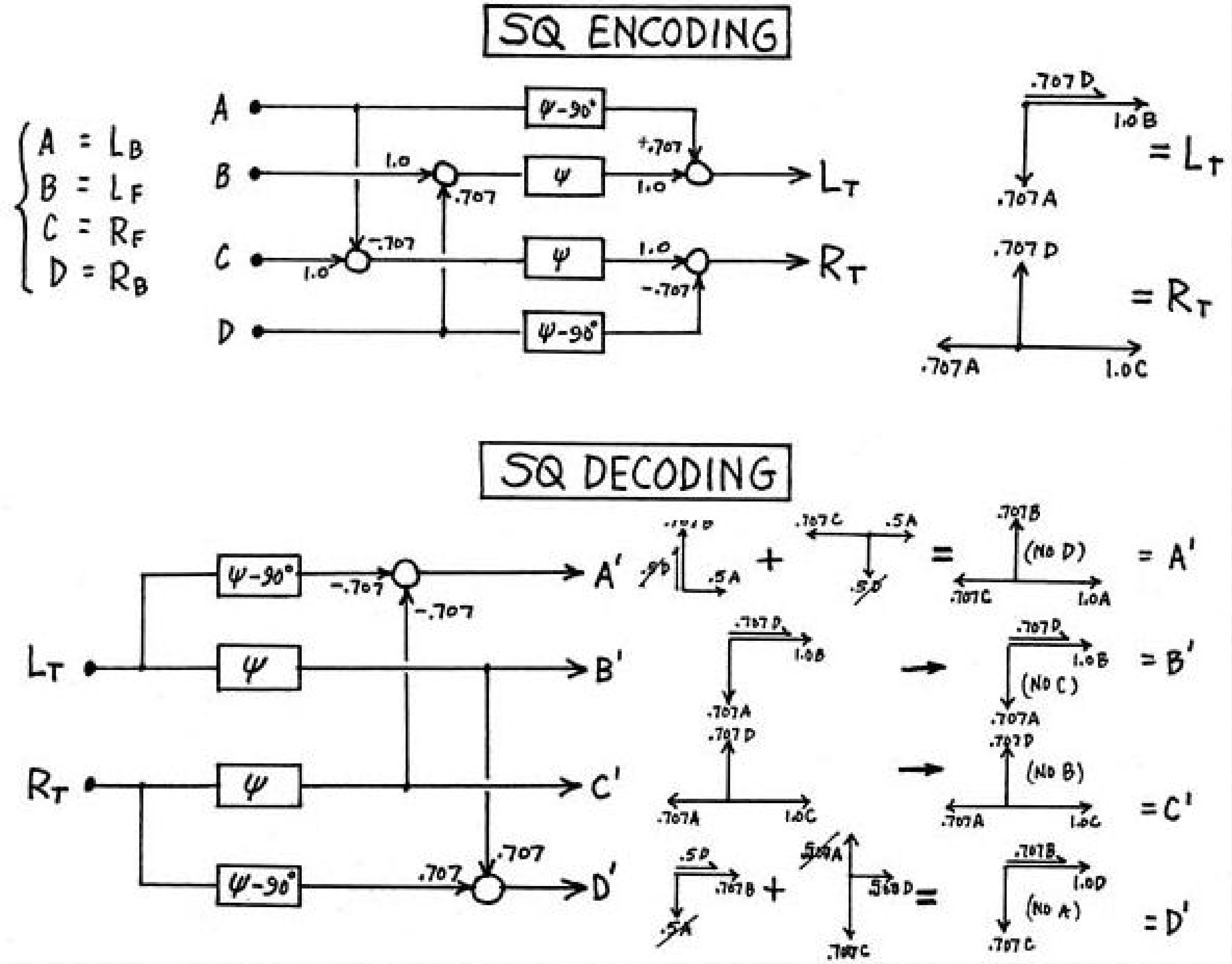
4-tracks tape, reel-to-reel deck, 4 loudspeakers

Quad matrixed QS, SQ etc. (1972)



Matrix-encoded vinyl,
analog decoder, 4 loudspeakers

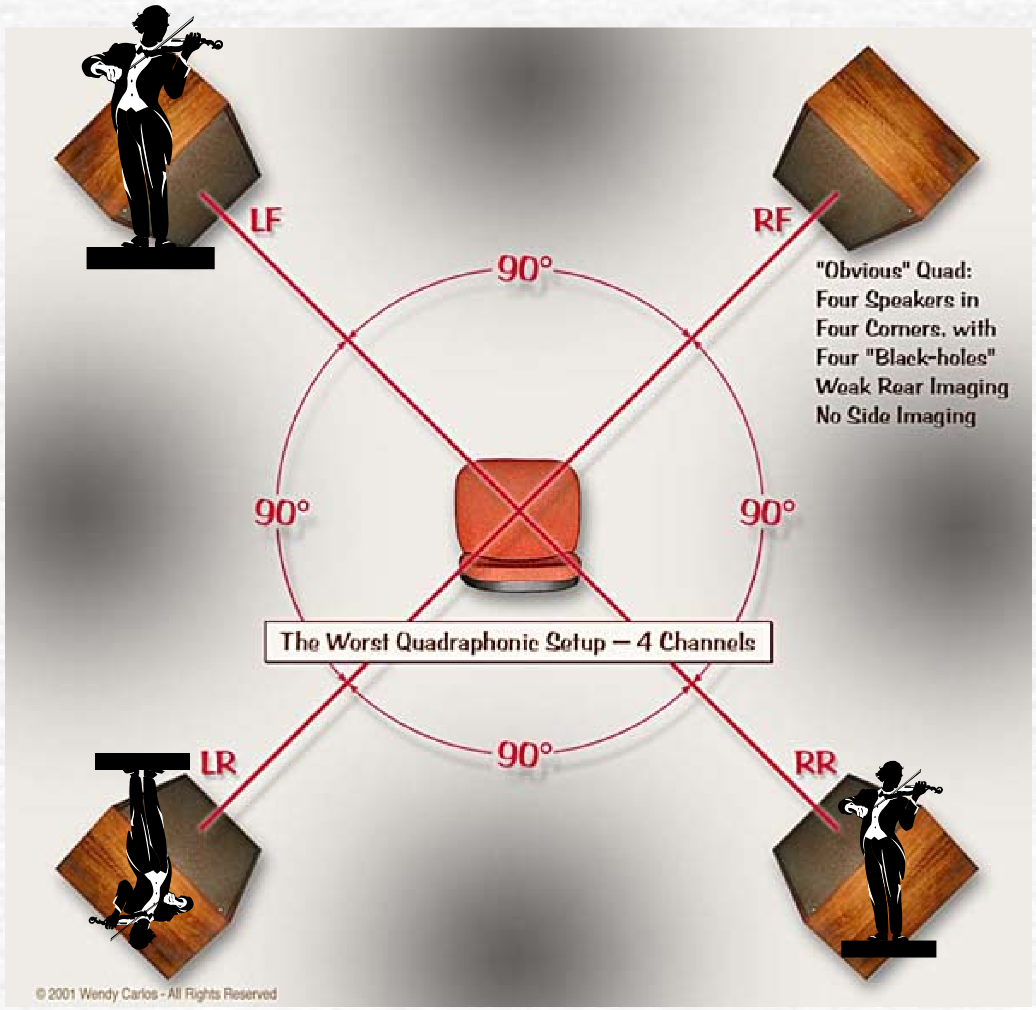
Quad matrixed SQ (1972)



Quad matrixed SQ (1972)

0 dB

-∞ dB



-3 dB

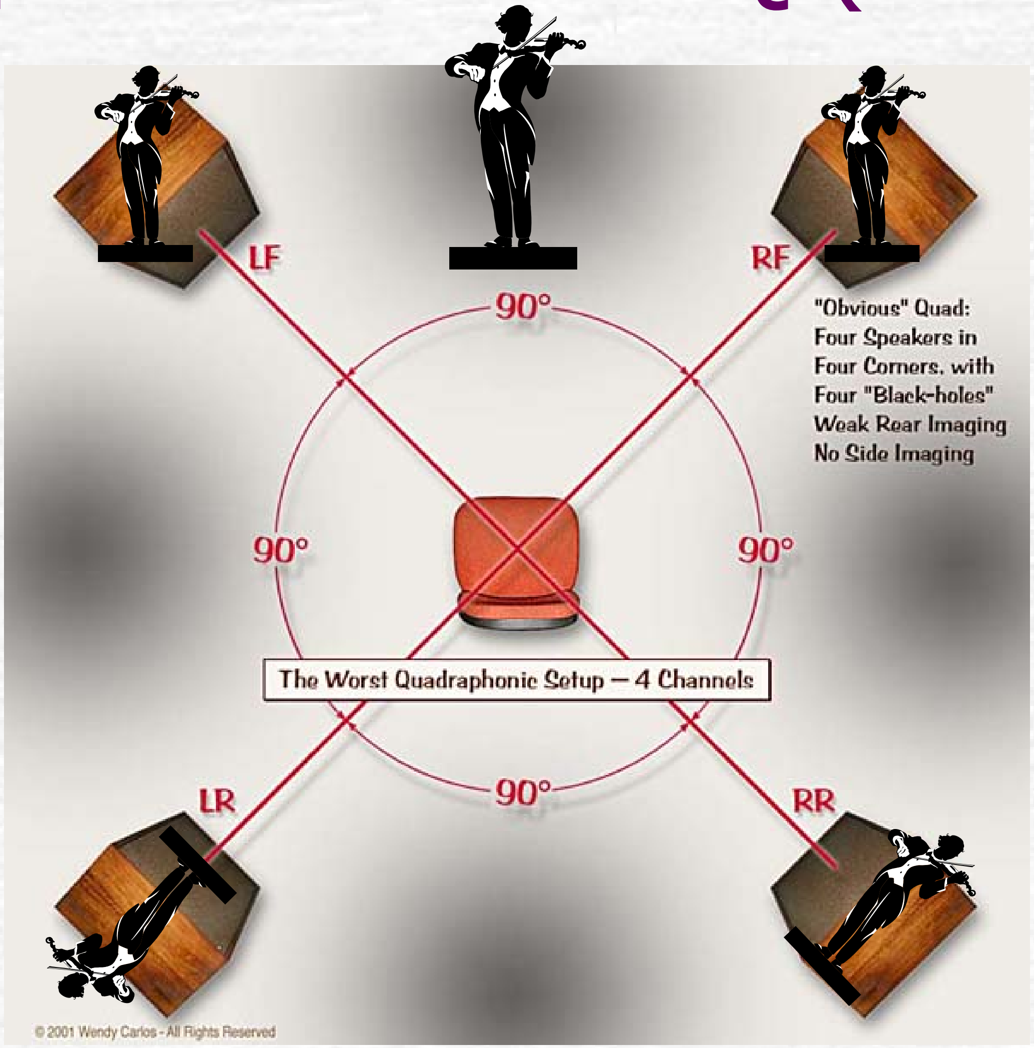
-3 dB

A signal Hard-panned Front Left

Quad matrixed SQ (1972)

-3 dB

-3 dB

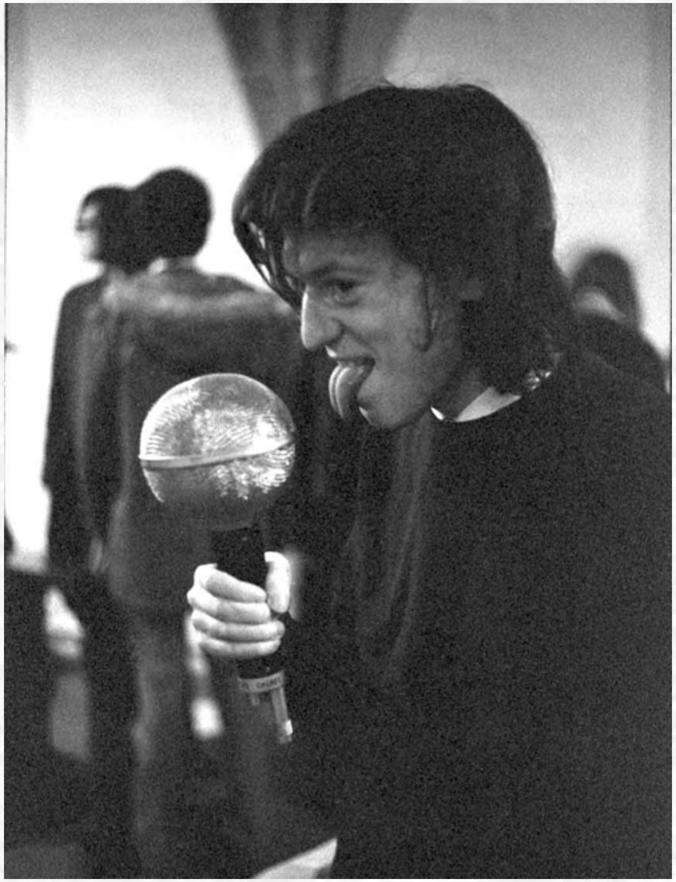


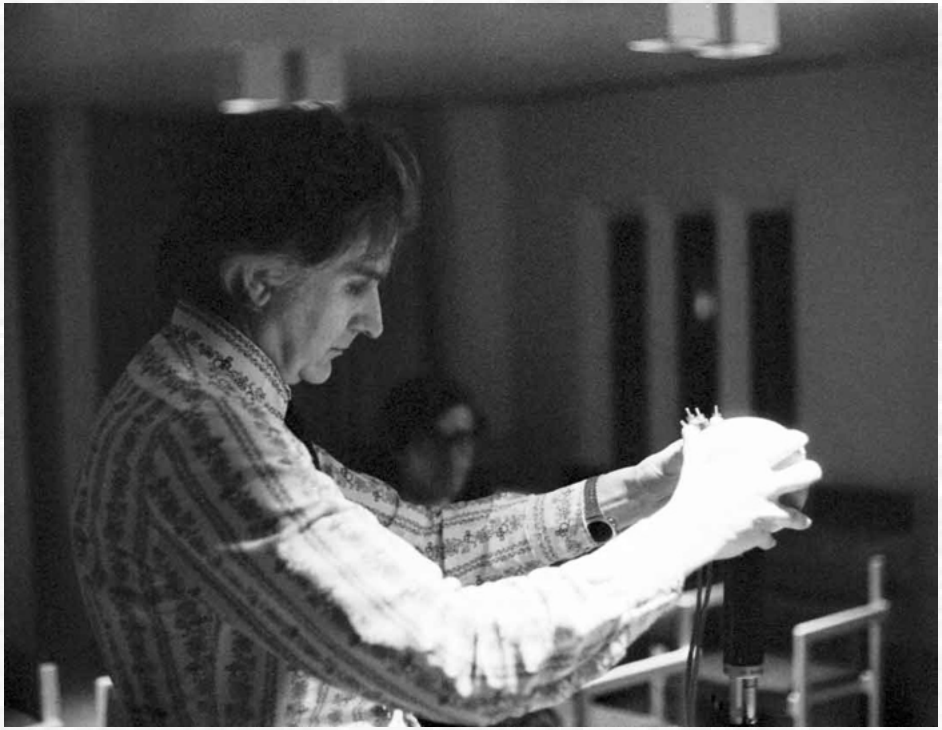
-3 dB

-3 dB

A signal Hard-panned Center

Ambisonics (1973)



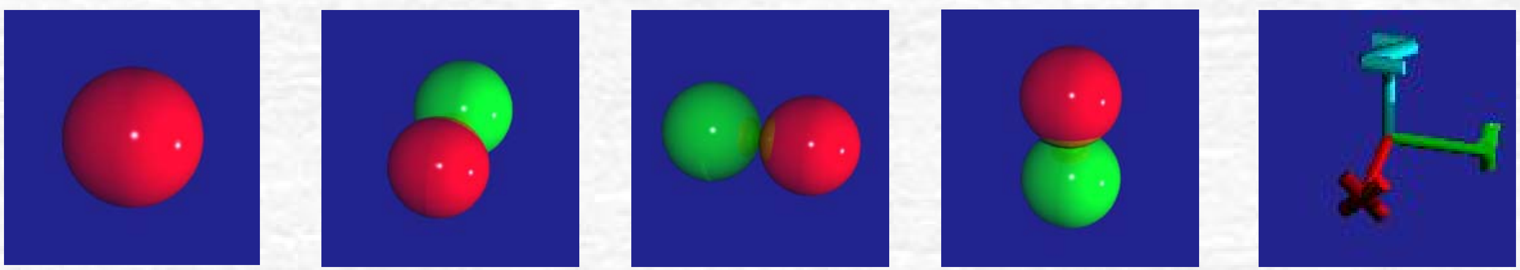


Michael Gerzon and Peter Fellgett

Ambisonics theory

It was the first method based on both mathematical/physical analysis and psychoacoustics

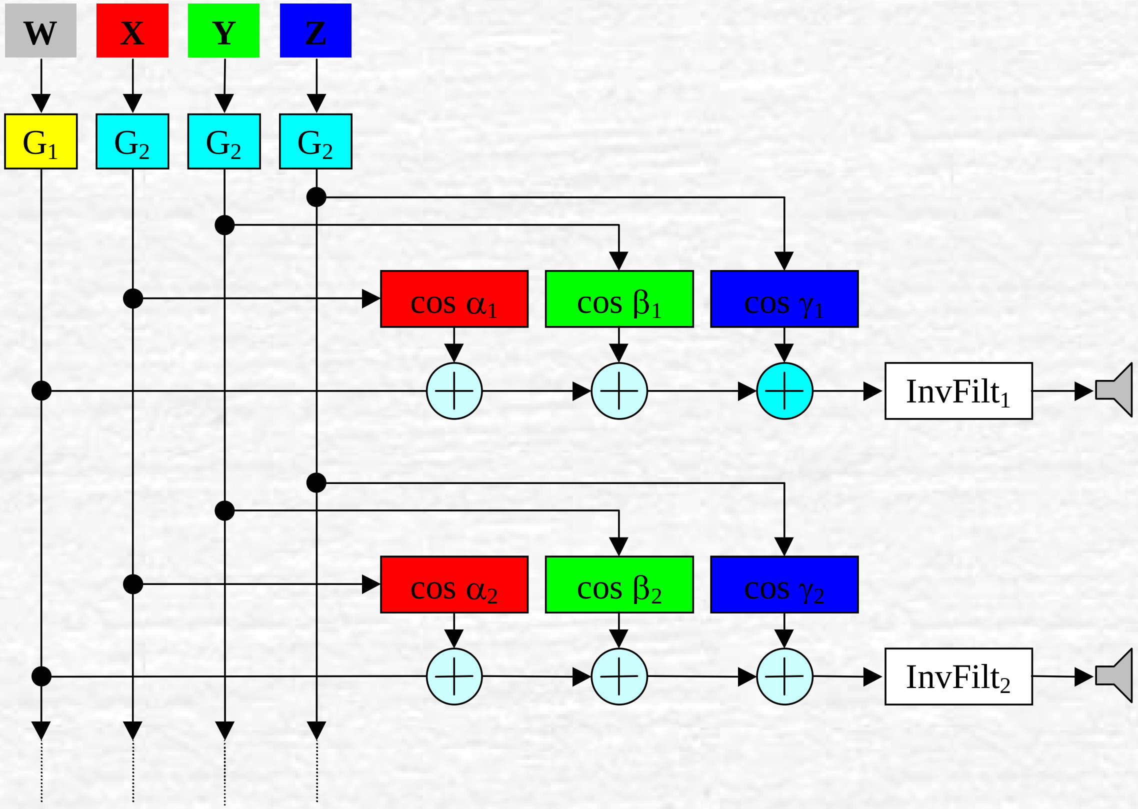
The spatial properties of the sound field in a point are described by 4 physical signals, the sound pressure and the three Cartesian components of particle velocity

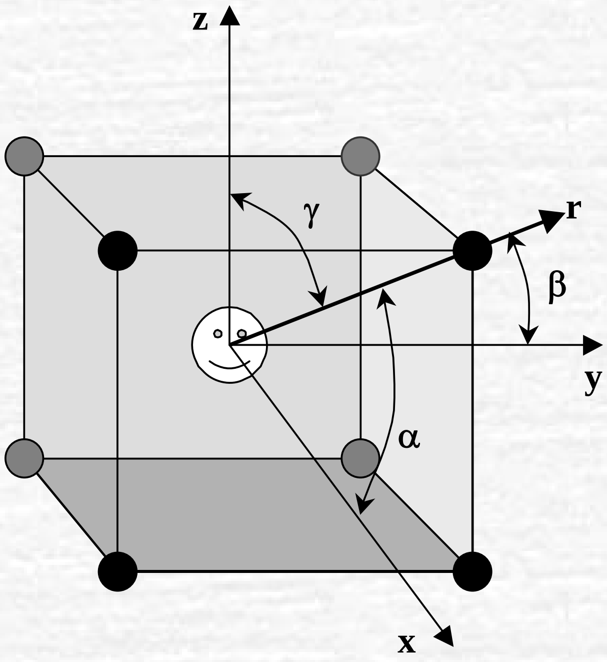


W X Y Z

Ambisonics theory

Each loudspeaker is fed with a proper mix of these 4 signals, with gains carefully computed for satisfying a psychoacoustic criterion





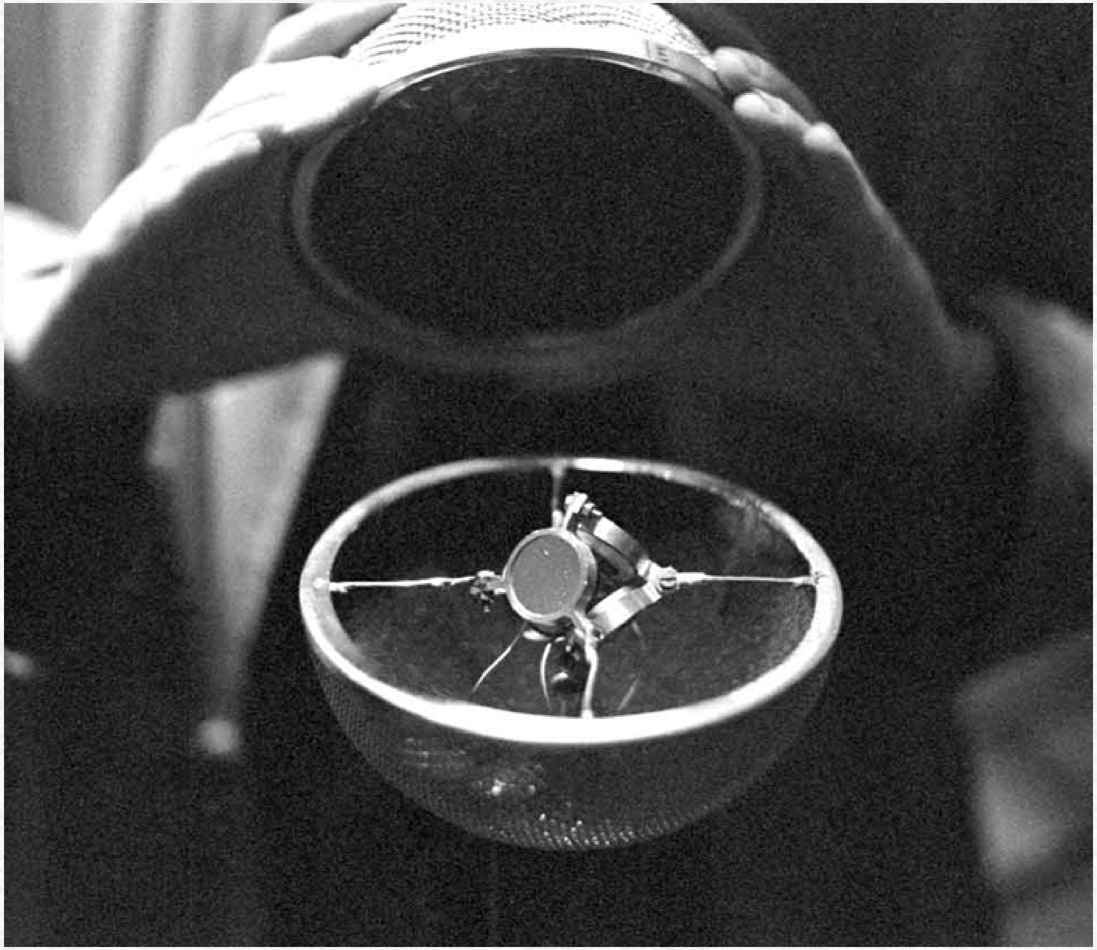
Psychoacoustic criterions

- At low frequency (<500 Hz), the gains are adjusted so that the pressure and particle velocity signals are carefully reconstructed at the center of the array, making use of "push-pull" effects obtained generating out-of-phase signals
- At higher frequencies, the gains are adjusted so that the Sound Intensity vector recreated at the center of the array is as close as possible to the original one
- Shelf filters are employed for making the gains frequency-dependent

Capturing the Ambisonics signals

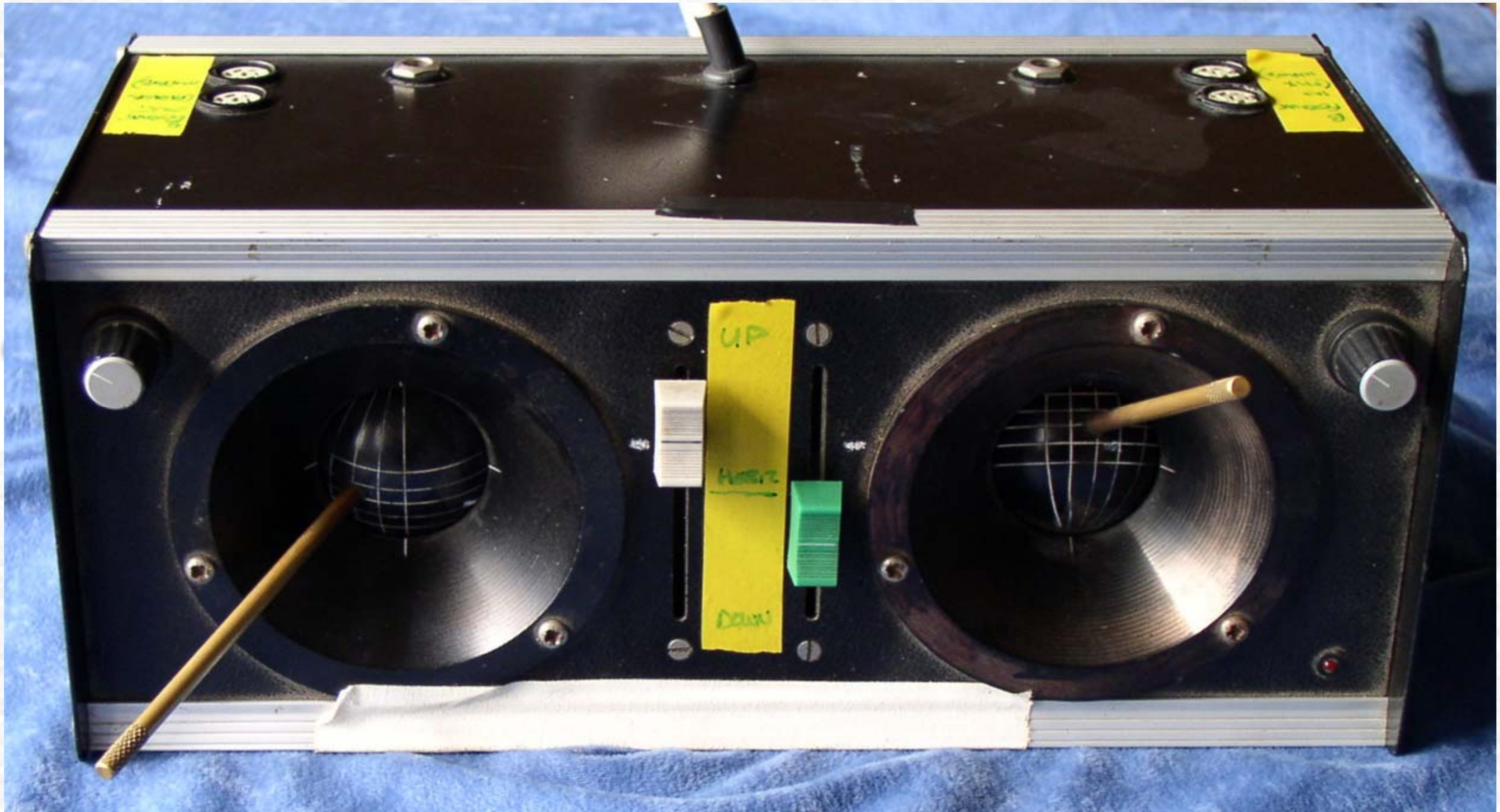
- A tetrahedrical microphone probe was developed by Gerzon and Craven, originating the Soundfield microphone

Soundfield microphones

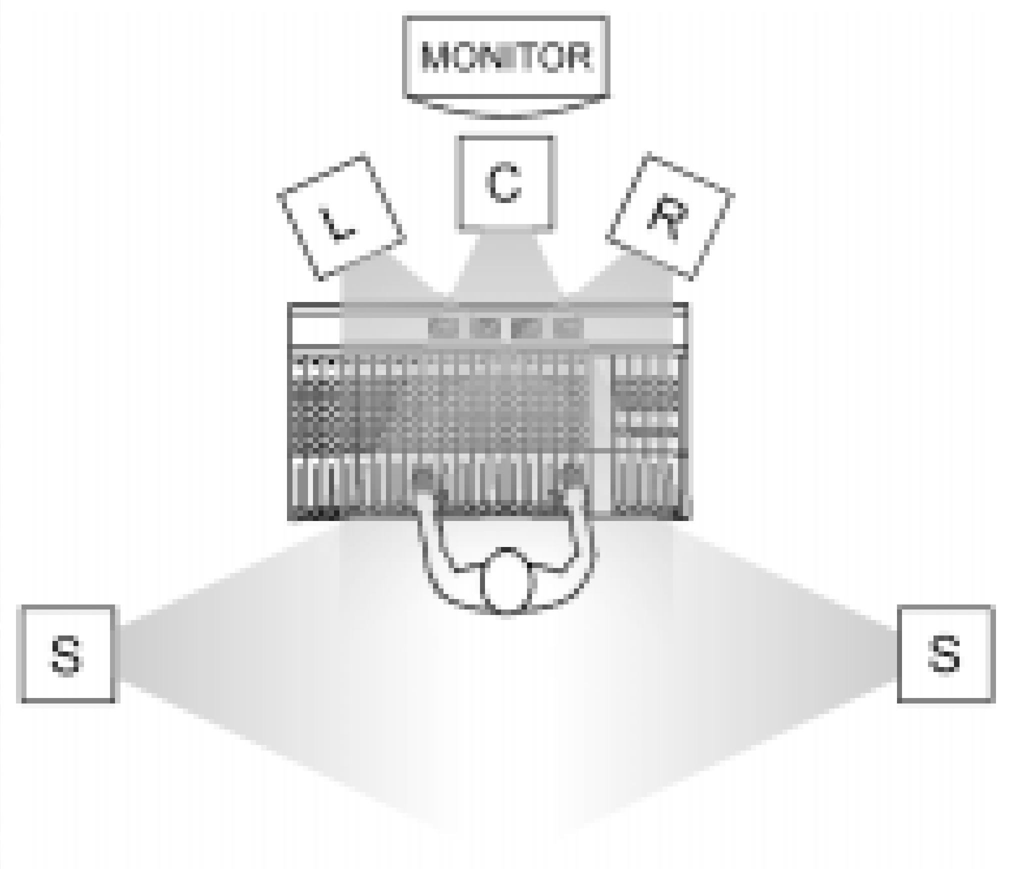


Synthetic Ambisonics signals

One of the most appealing advantages of Ambisonics is the capability of creating synthetic signals with simple encoding formulas, and to change dynamically the source position

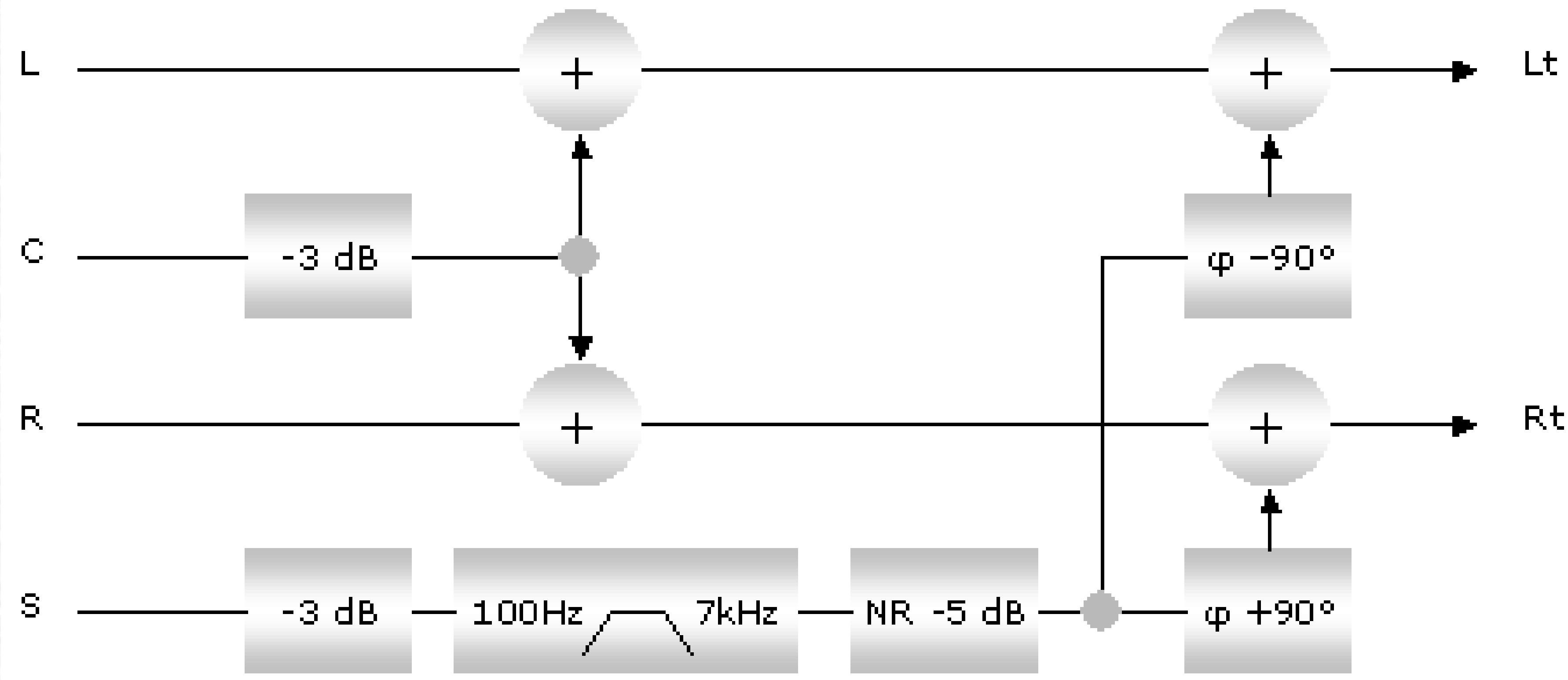


Dolby Stereo / Surround (1975)



Layout

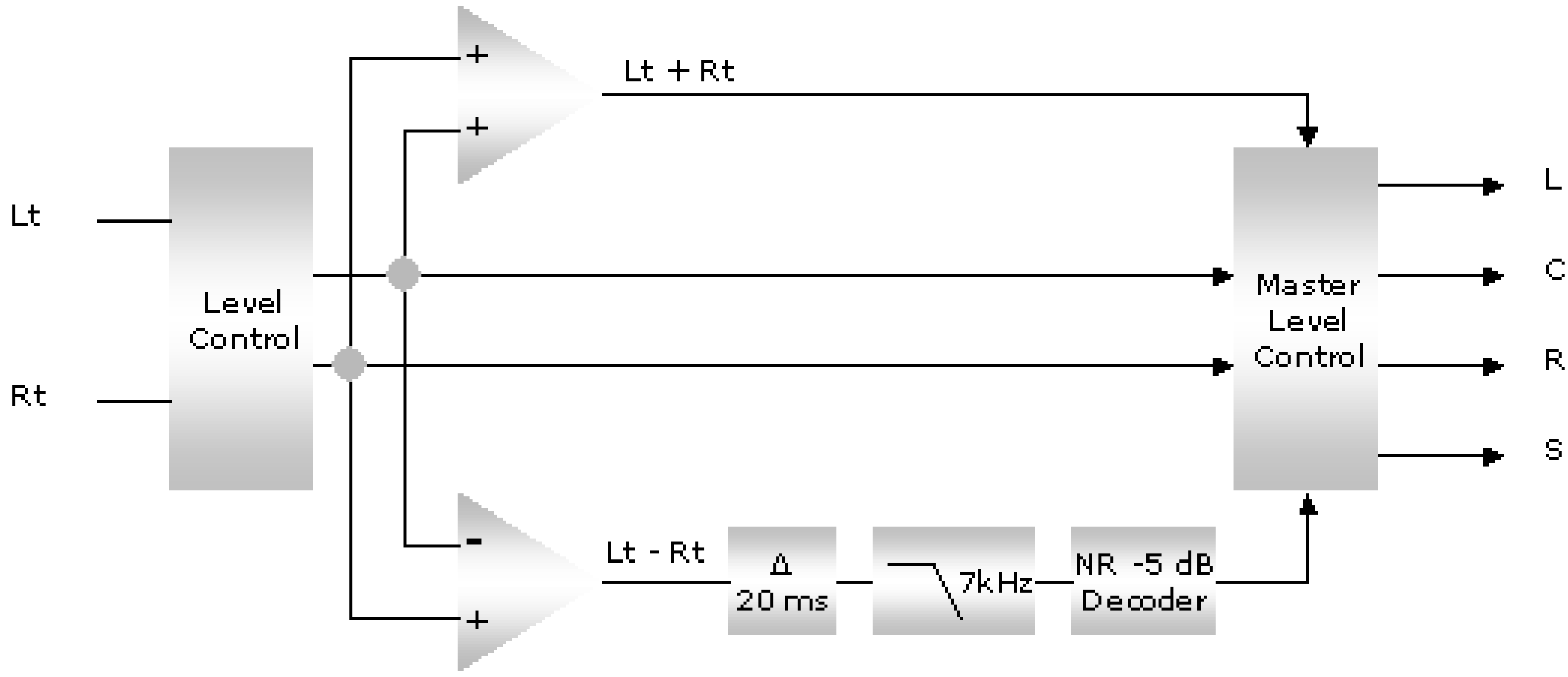
Dolby Surround



$Lt = L + 1/\sqrt{2}\, C + k\ 1/\sqrt{2}\, S$ and $Rt = R + 1/\sqrt{2}\, C + k'\ 1/\sqrt{2}\, S$

Encoder

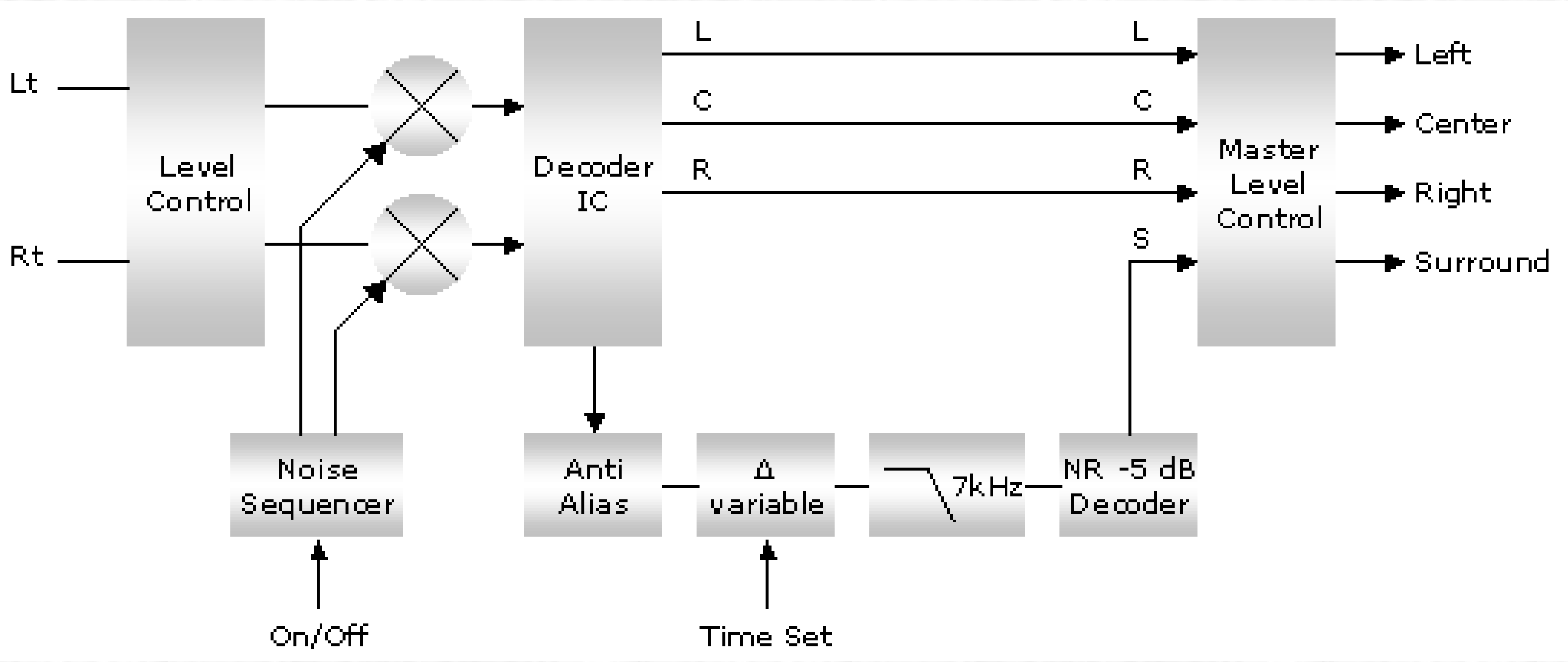
Dolby Surround



Lt + Rt = 2.4 C and Lt - Rt = L - R + 1.4 k S

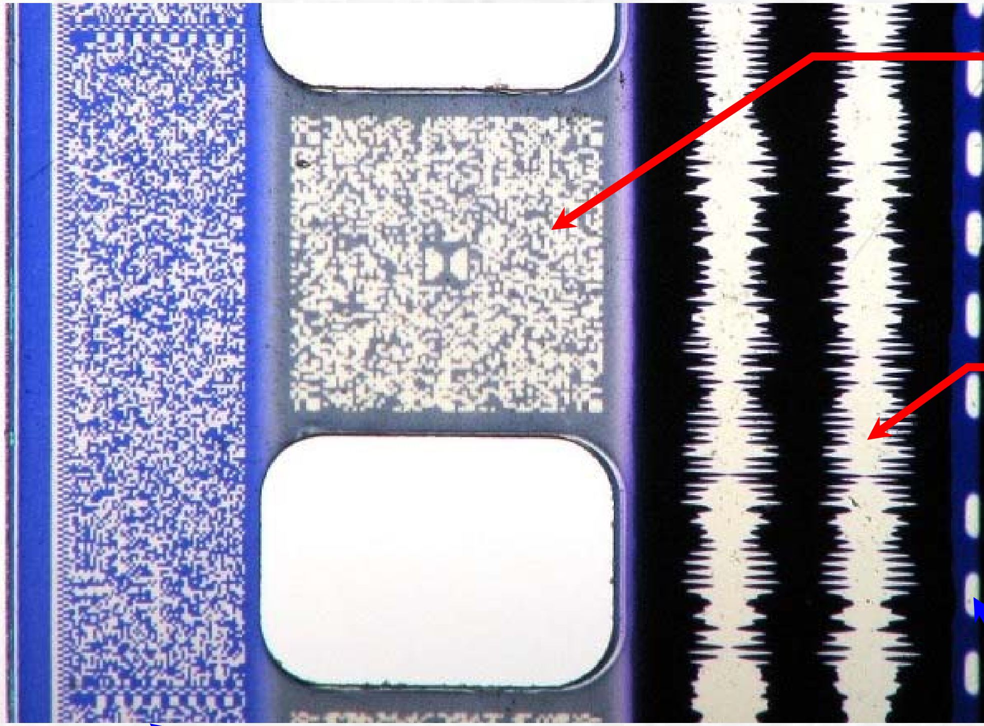
Decoder

Dolby Pro Logic (1987)



Decoder

Dolby Digital – AC3 (1992)



Dolby Digital pattern (5.1)

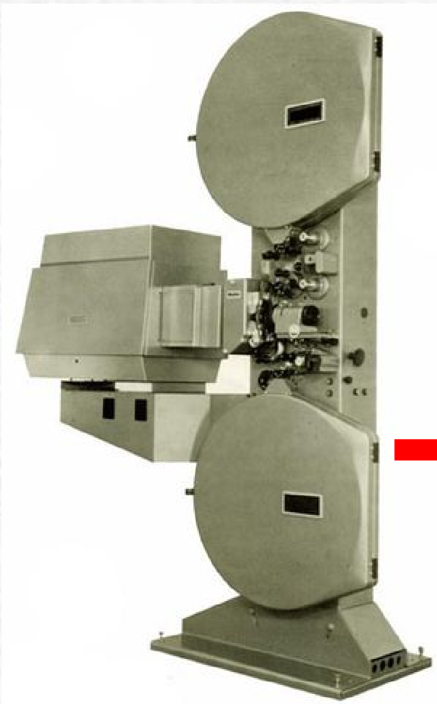
Dolby Stereo analog tracks

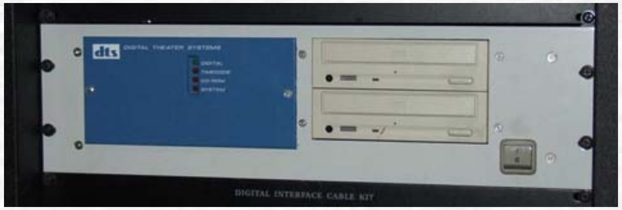
DTS timecode

Sony SDDS (7.1)

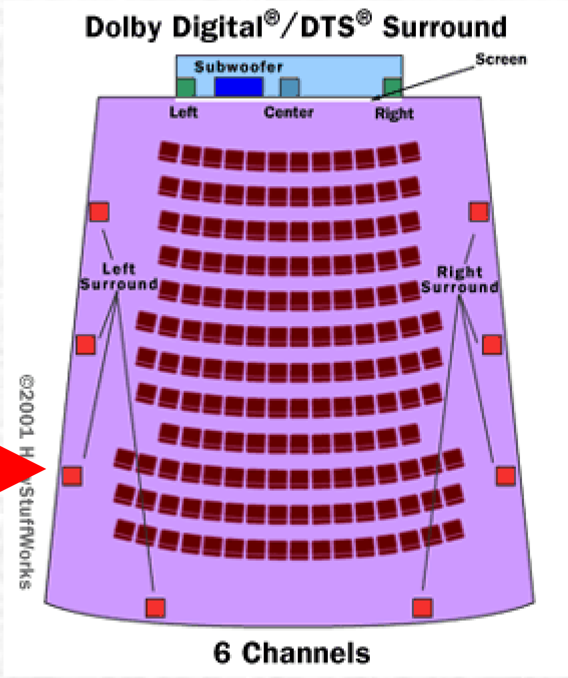
Optical digital patterns on the film

DTS (1993)





DTS-6



An optical timecode on the film synchronizes a CD player loaded with a DTS-encoded audio CD

Discrete microphone arrays

The new discrete digital formats allowed for true discrete microphone systems

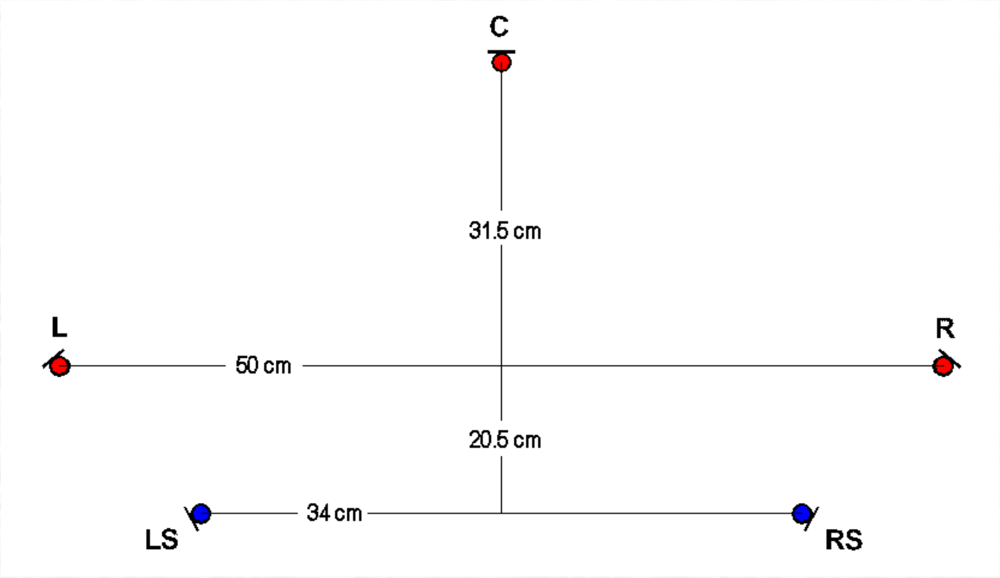
Discrete microphone arrays

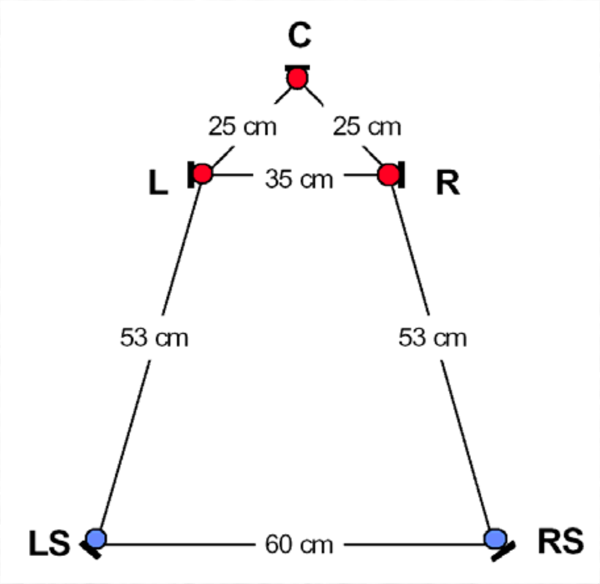
- Williams MMA

C : Cardioid, 0°
L, R : Cardioid, ± 40°
LS, RS : Cardioid, ± 120°

- INA-5

C : Cardioid, 0°
L, R : Cardioid, ± 90°
LS, RS : Cardioid, ± 150°



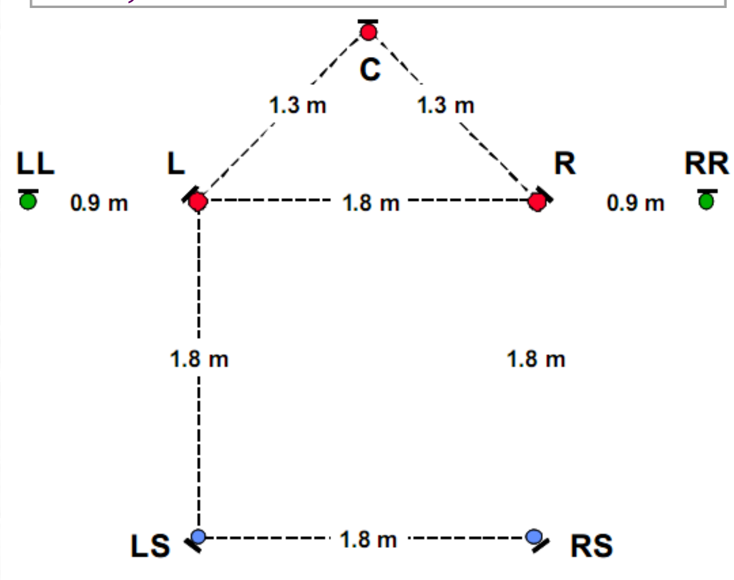


Several "standard" setups were developed

Discrete microphone arrays

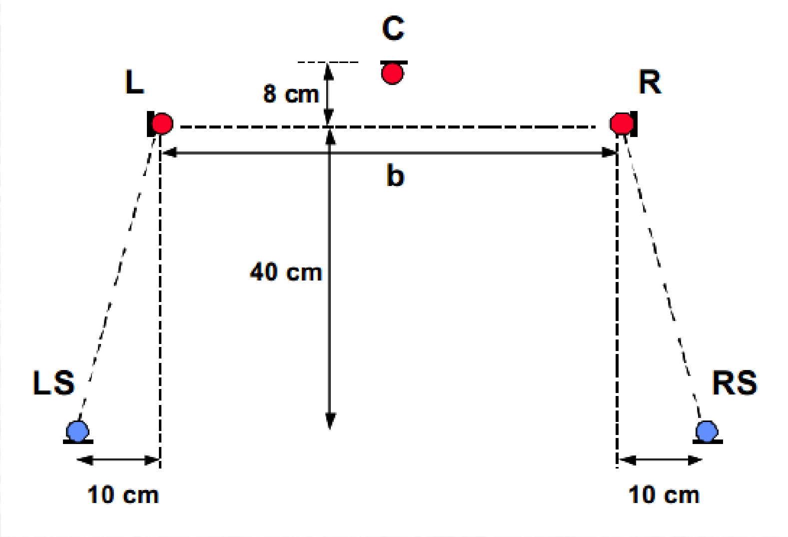
- Fukuda tree

C : Cardioid, 0°
L, R : Cardioid, ± 45°
LS, RS : Cardioid, ± 135°
LL, RR: Omni



- OCT-surround

C : Cardioid, 0°
L, R : Cardioid, ± 90°
LS, RS : Cardioid, ± 180°



Several "standard" setups were developed

Software for array design

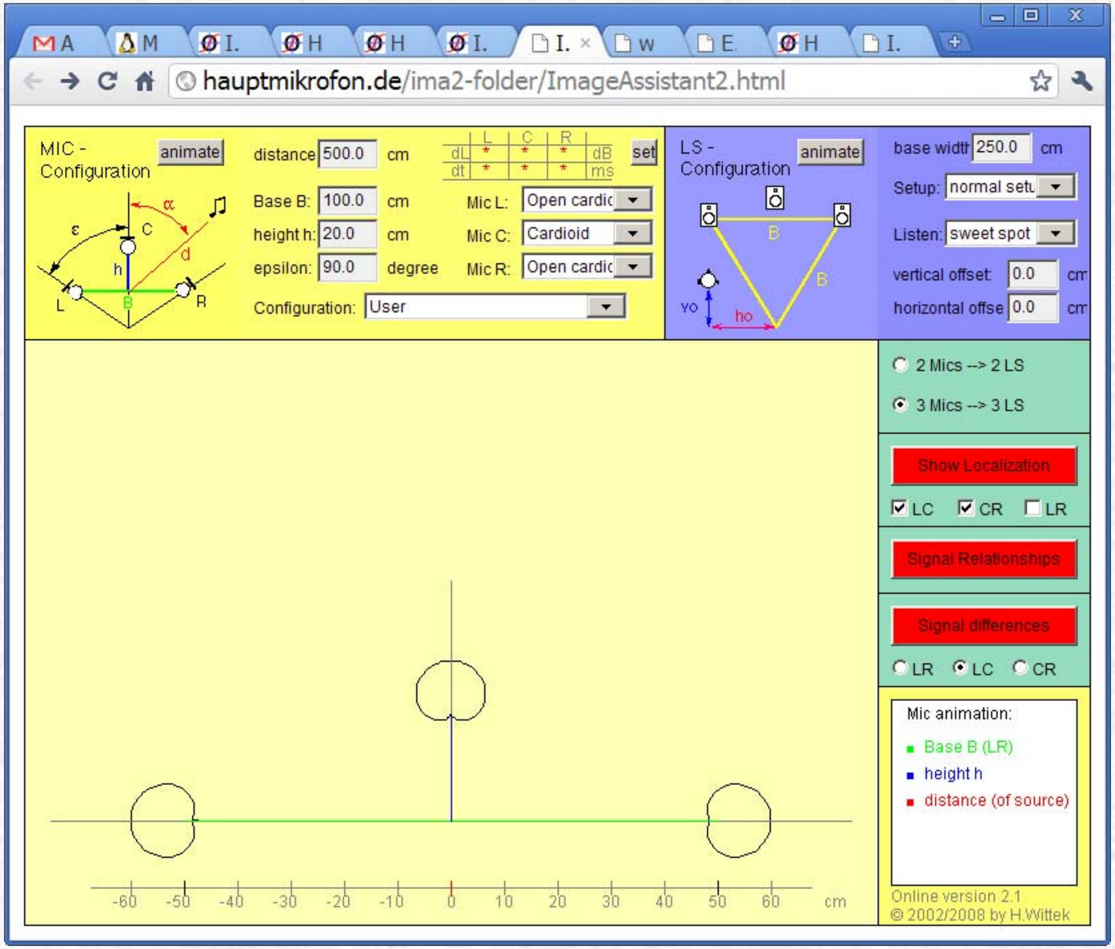


Image Assistant by H. Wittek

Software for array design

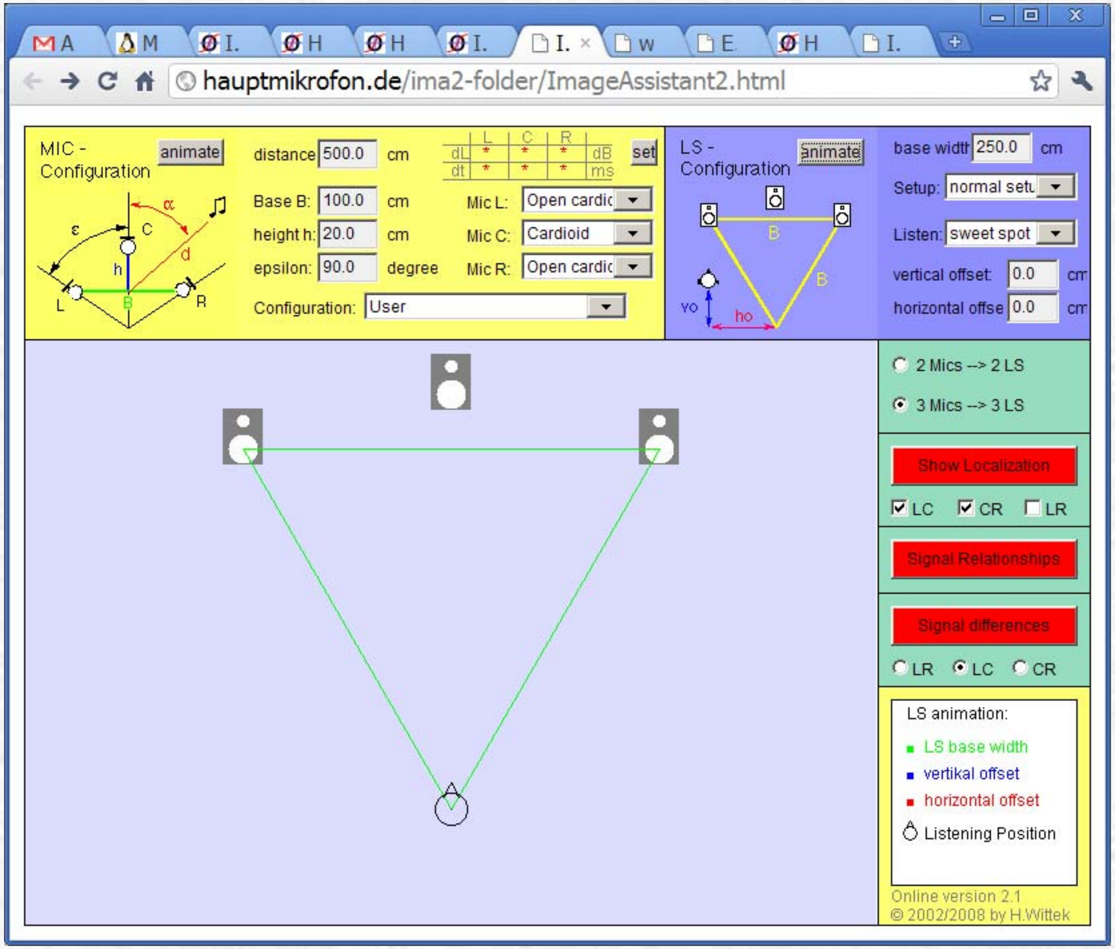


Image Assistant by H. Wittek

Software for array design

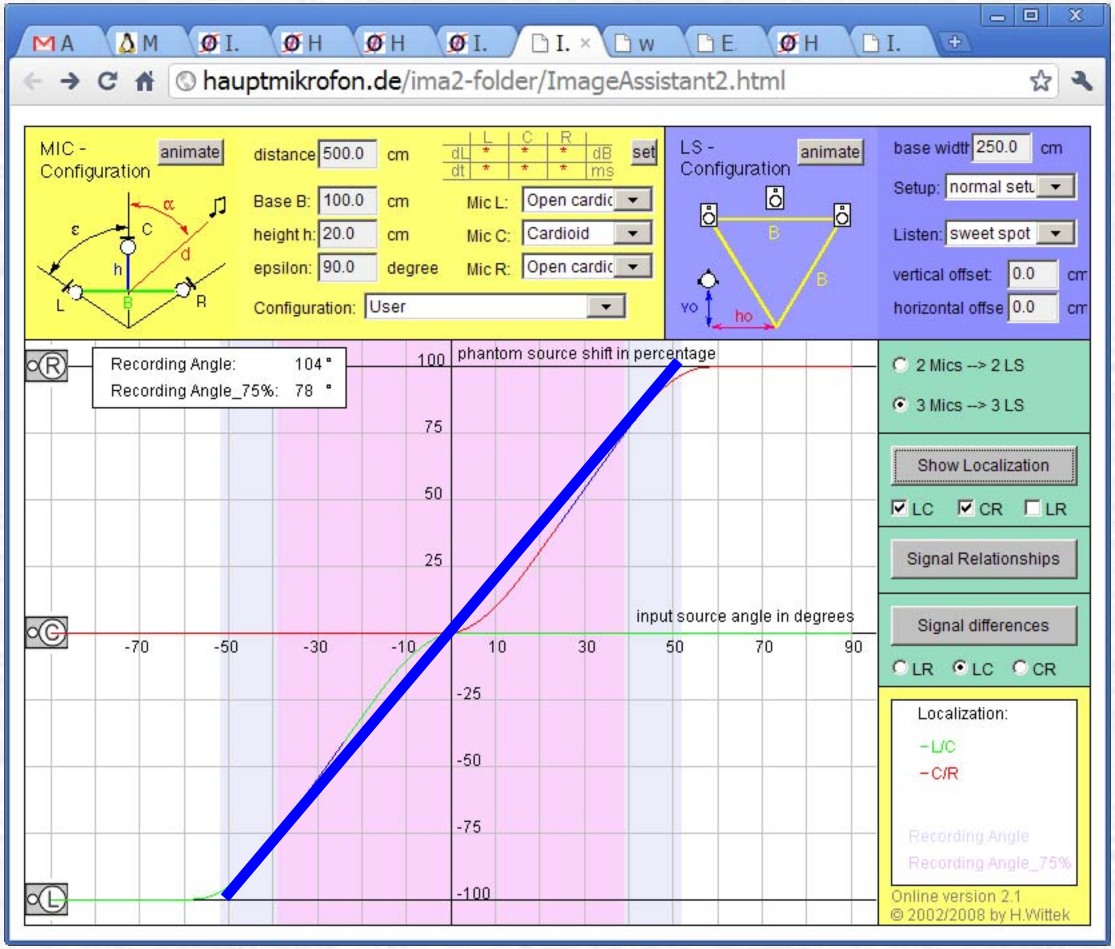
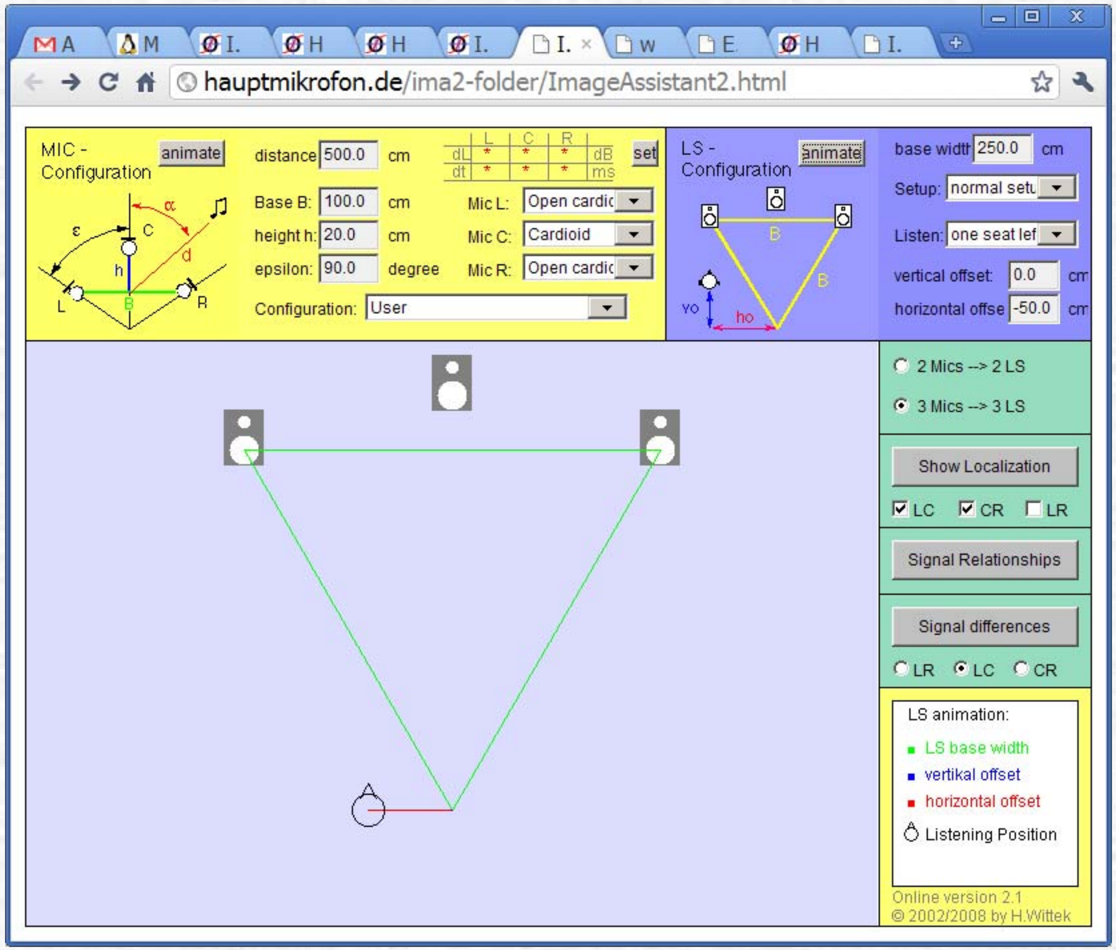


Image Assistant by H. Wittek

Software for array design



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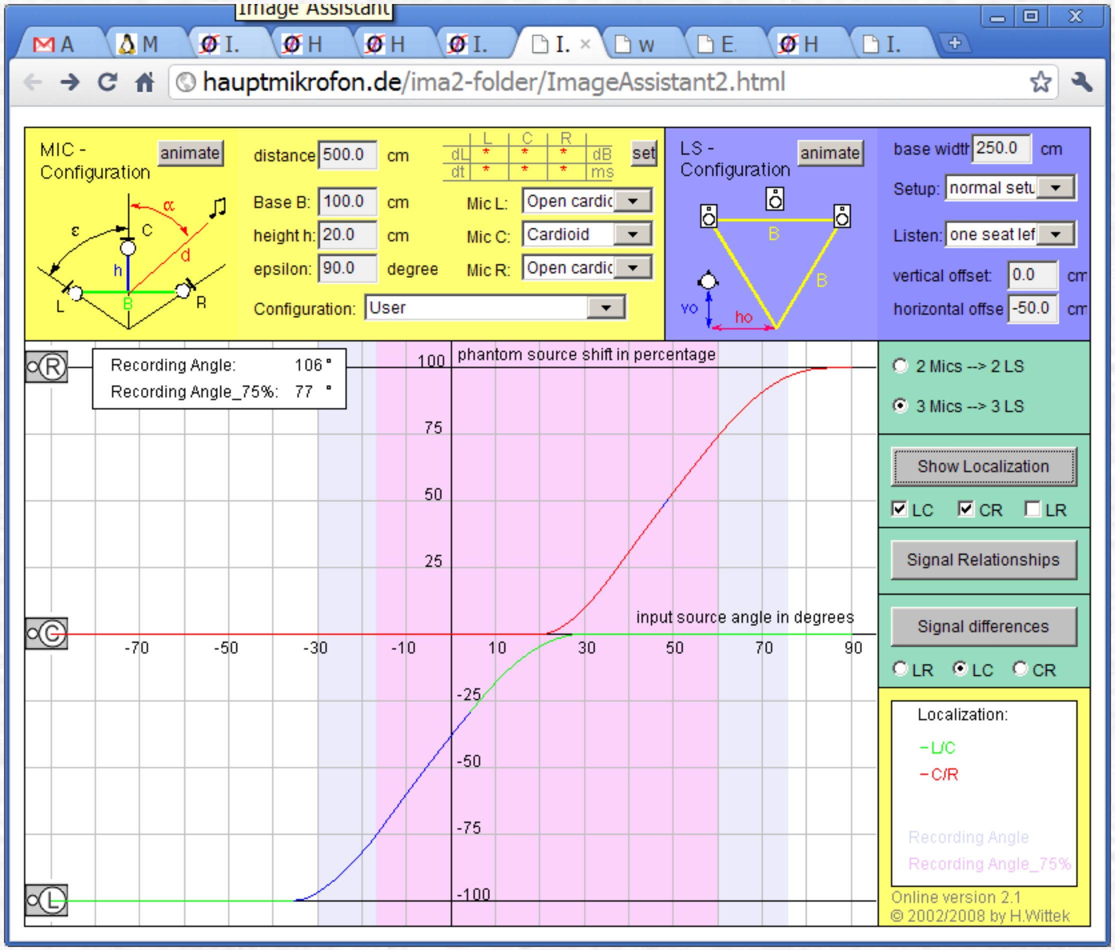
Software for array design



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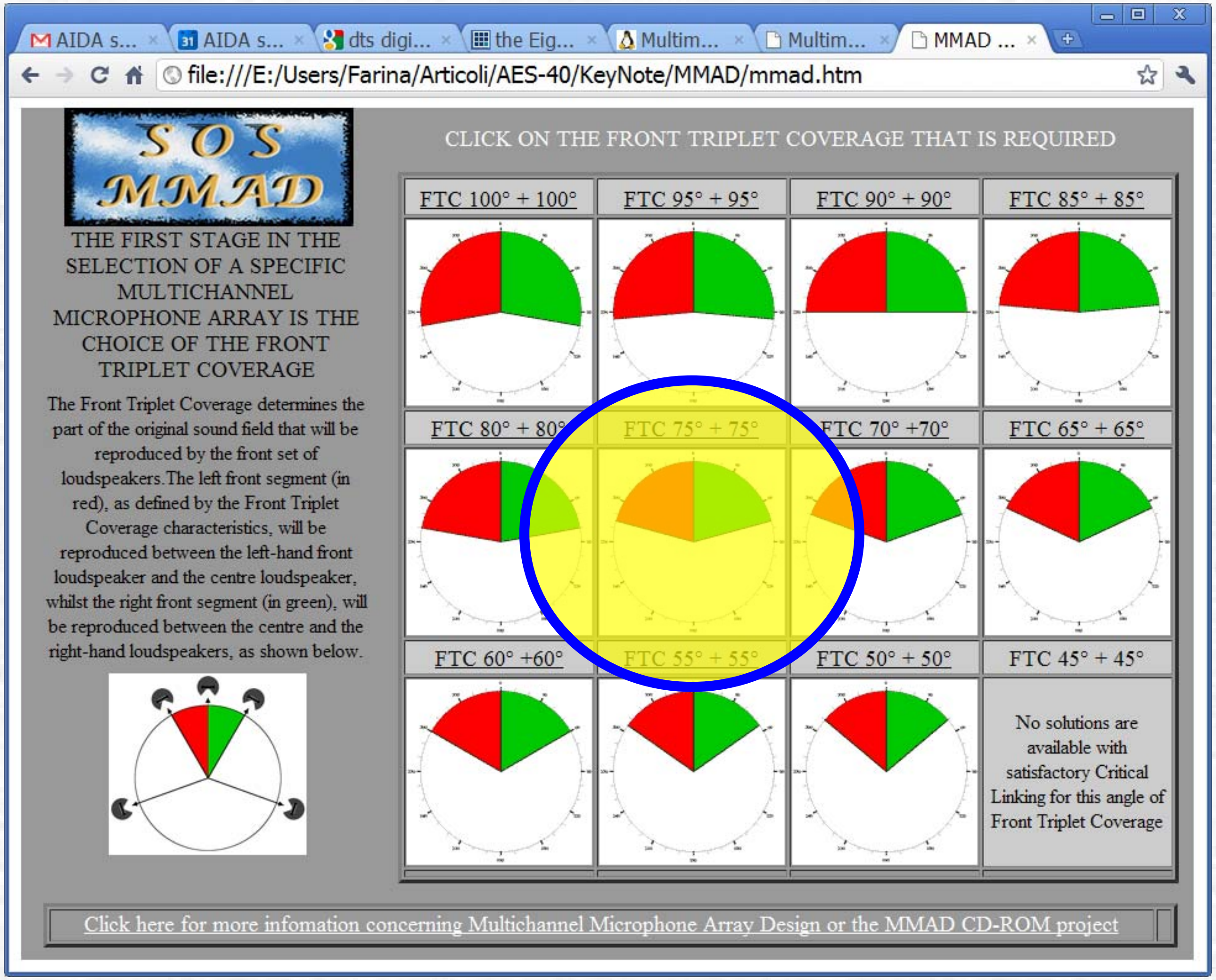
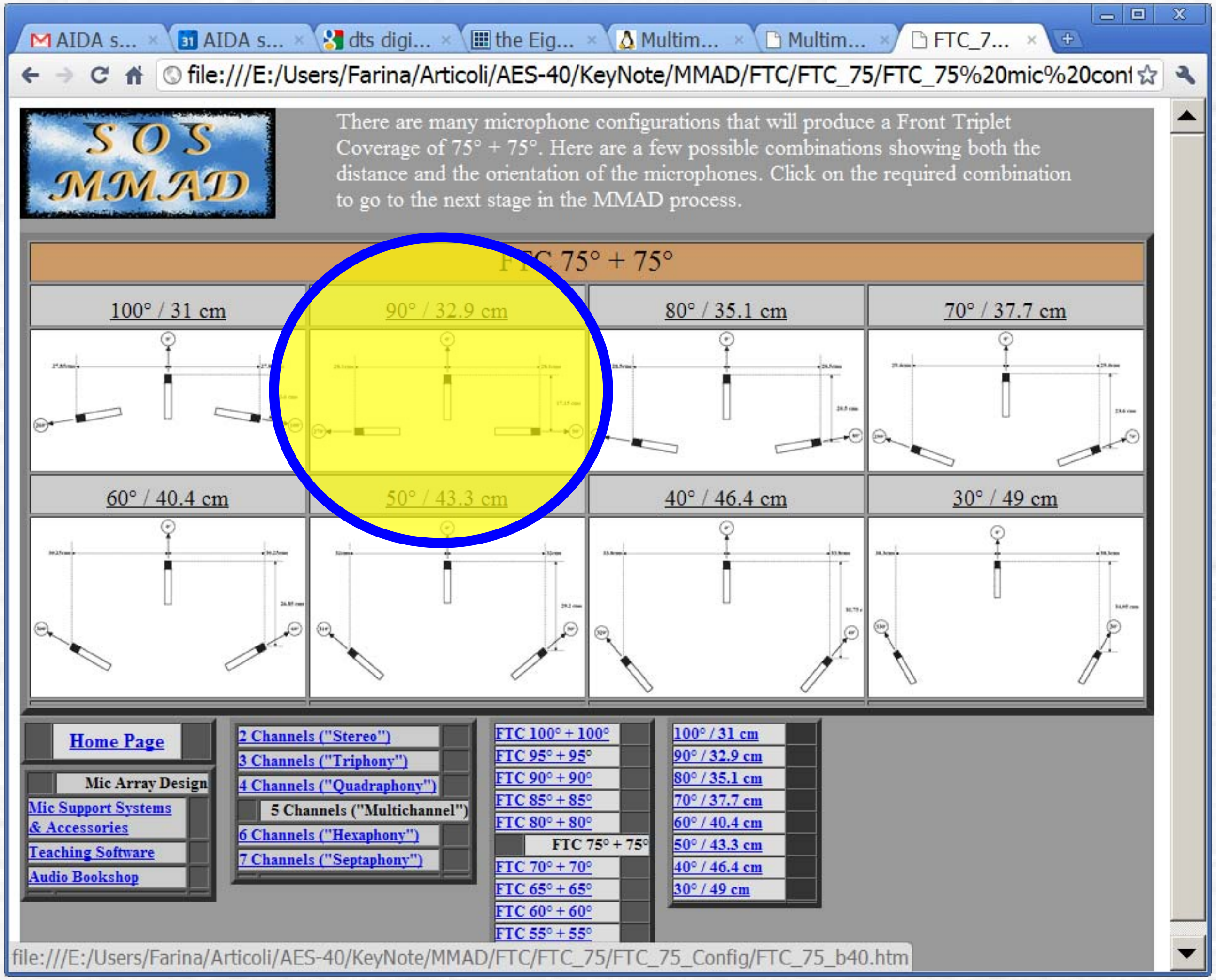
Software for array design



SOS MMAD by Mike Williams

Software for array design



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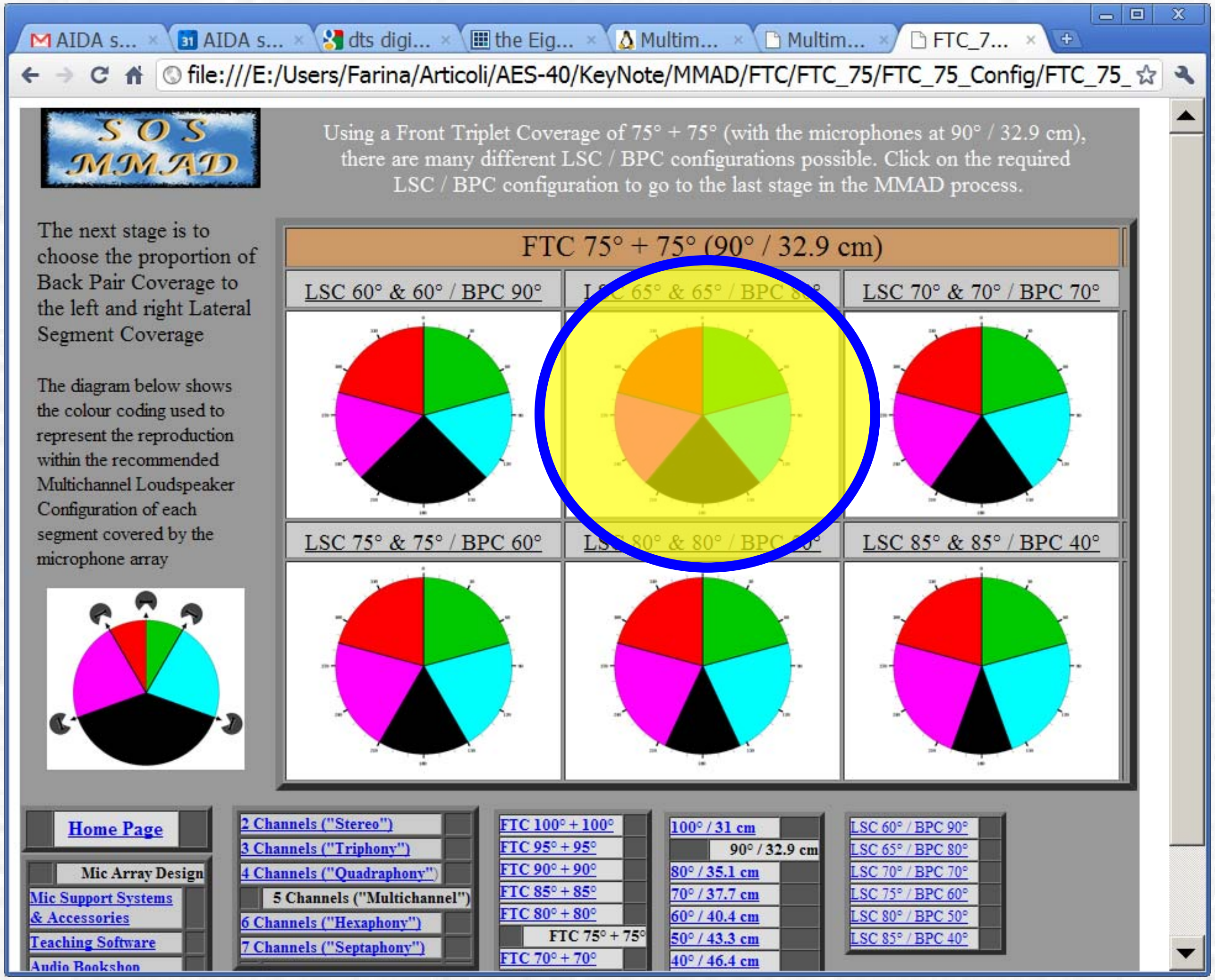
Software for array design



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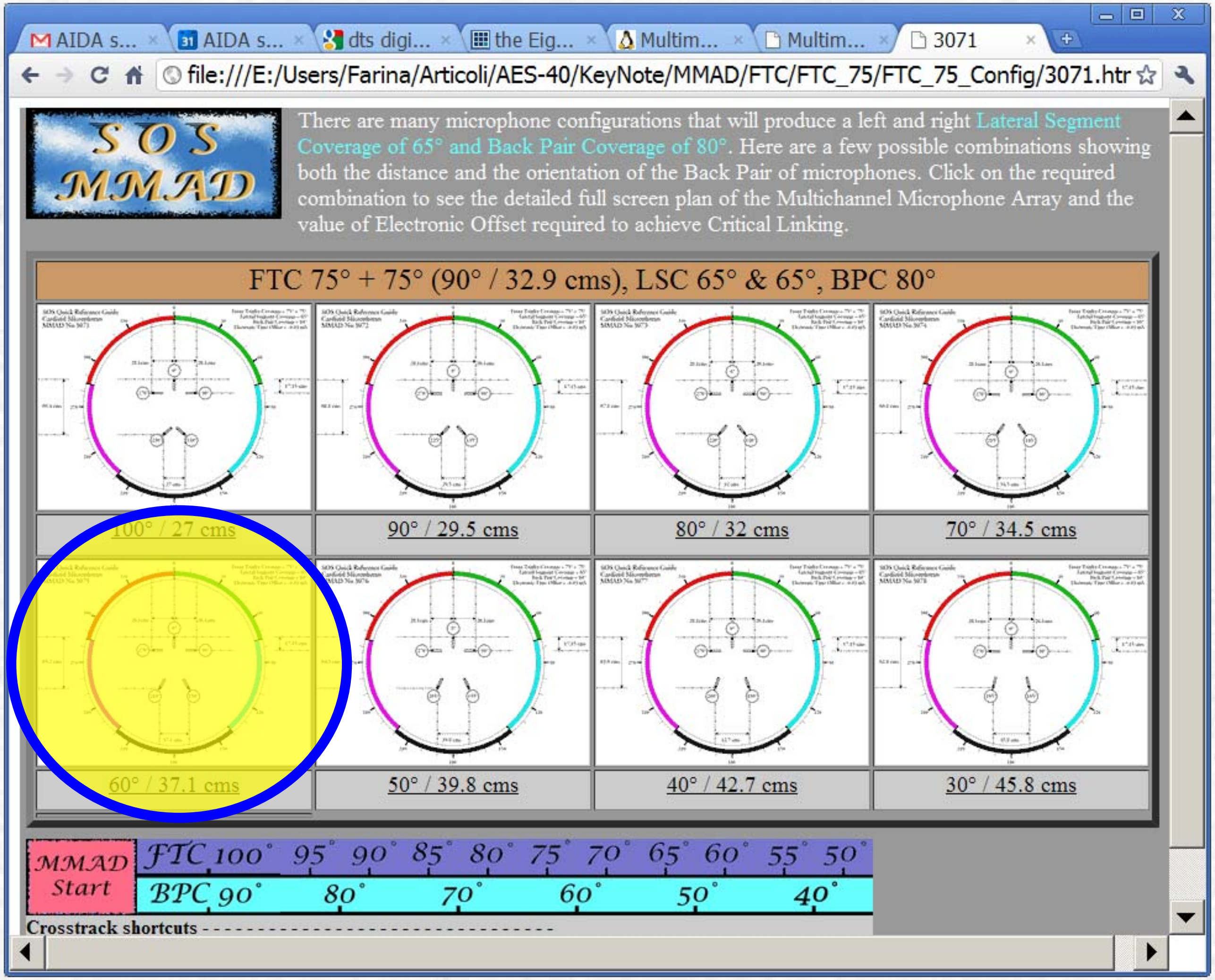

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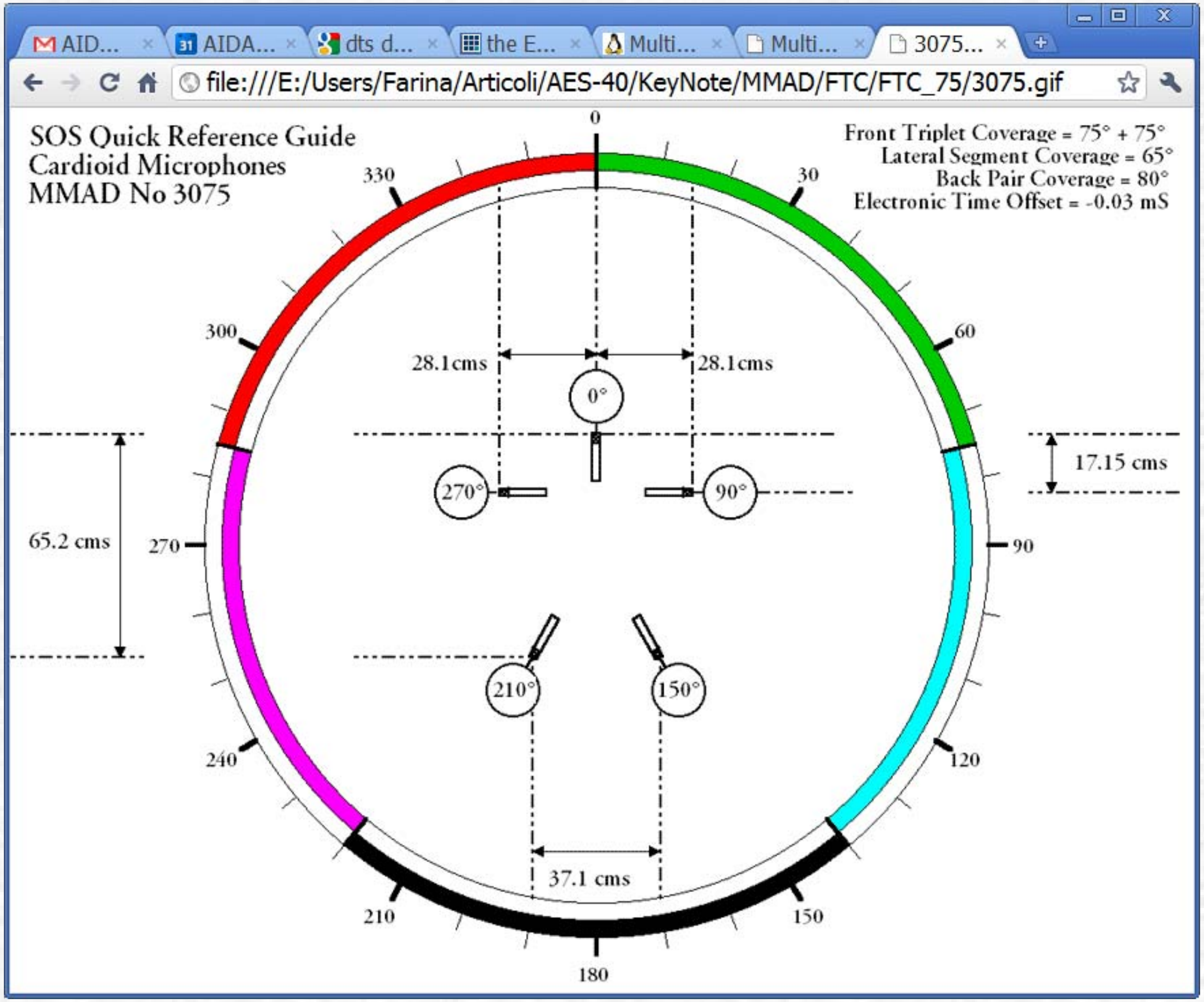
Software for array design



SOS MMAD by Mike Williams

A compact self-contained array

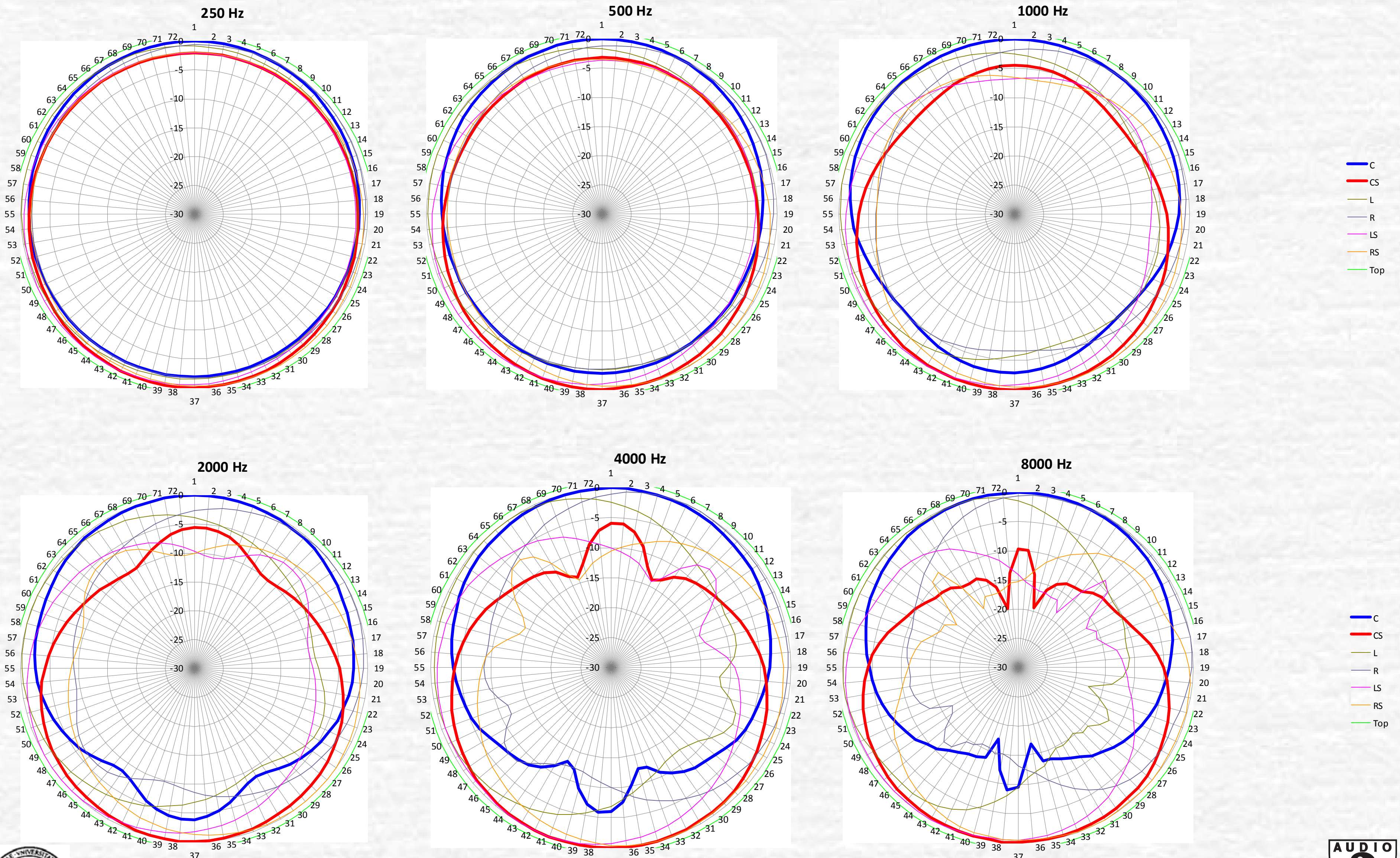
Holophone “pear-shaped” arrays

Characterization of the Holophone

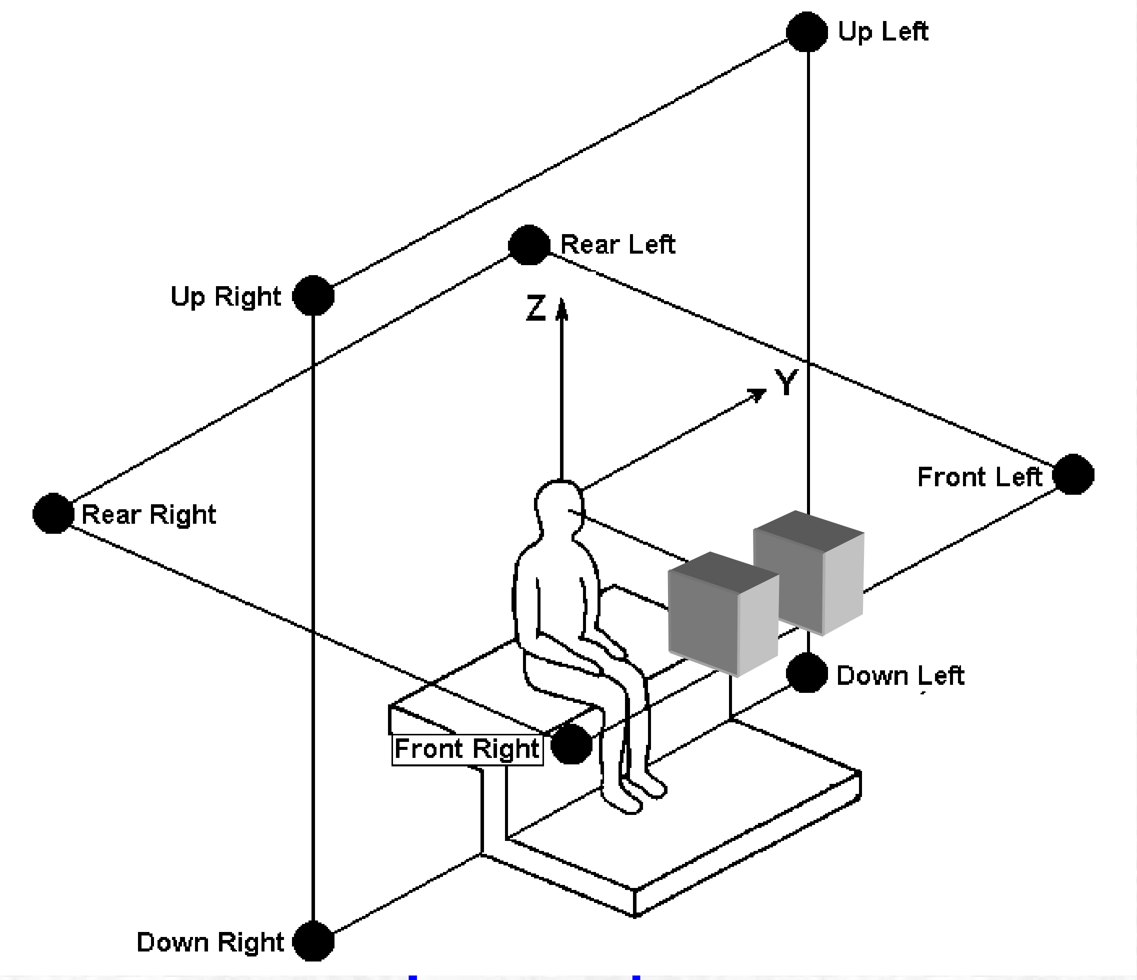
- The Holophone H2 Pro is a microphone system equipped with 8 capsules placed on a egg-shaped framework. The audio signals are delivered directly in G-format or using an audio mixer.

- The directivity of each Holophone capsule was measured in the Anechoic Room of "Università' di Ferrara" (Italy)

Holophone polar patterns

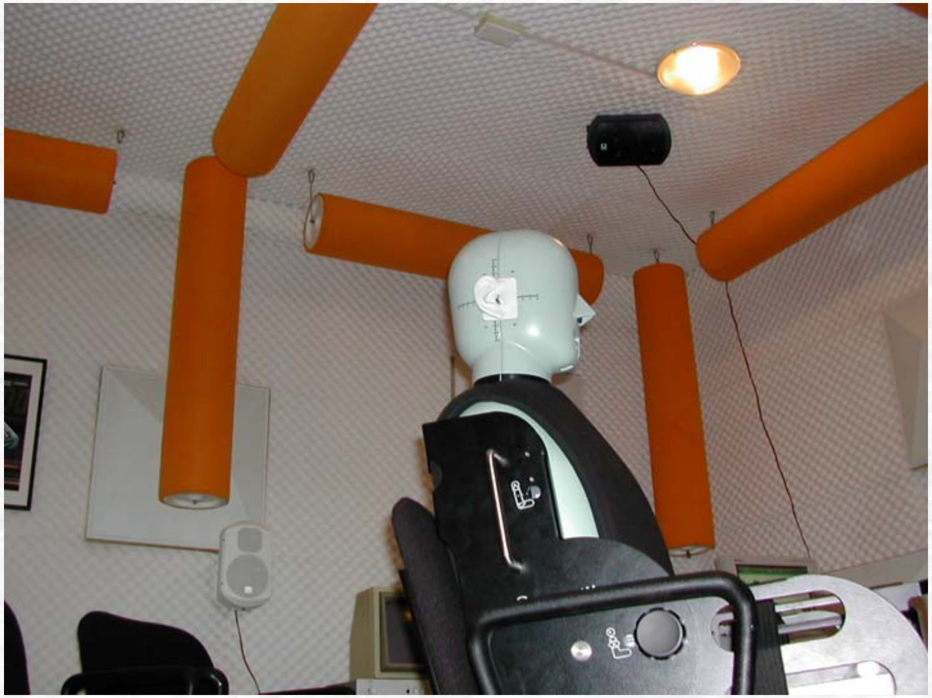


Ambiophonics 3D (2001)



Layout

Ambiophonics (2001)

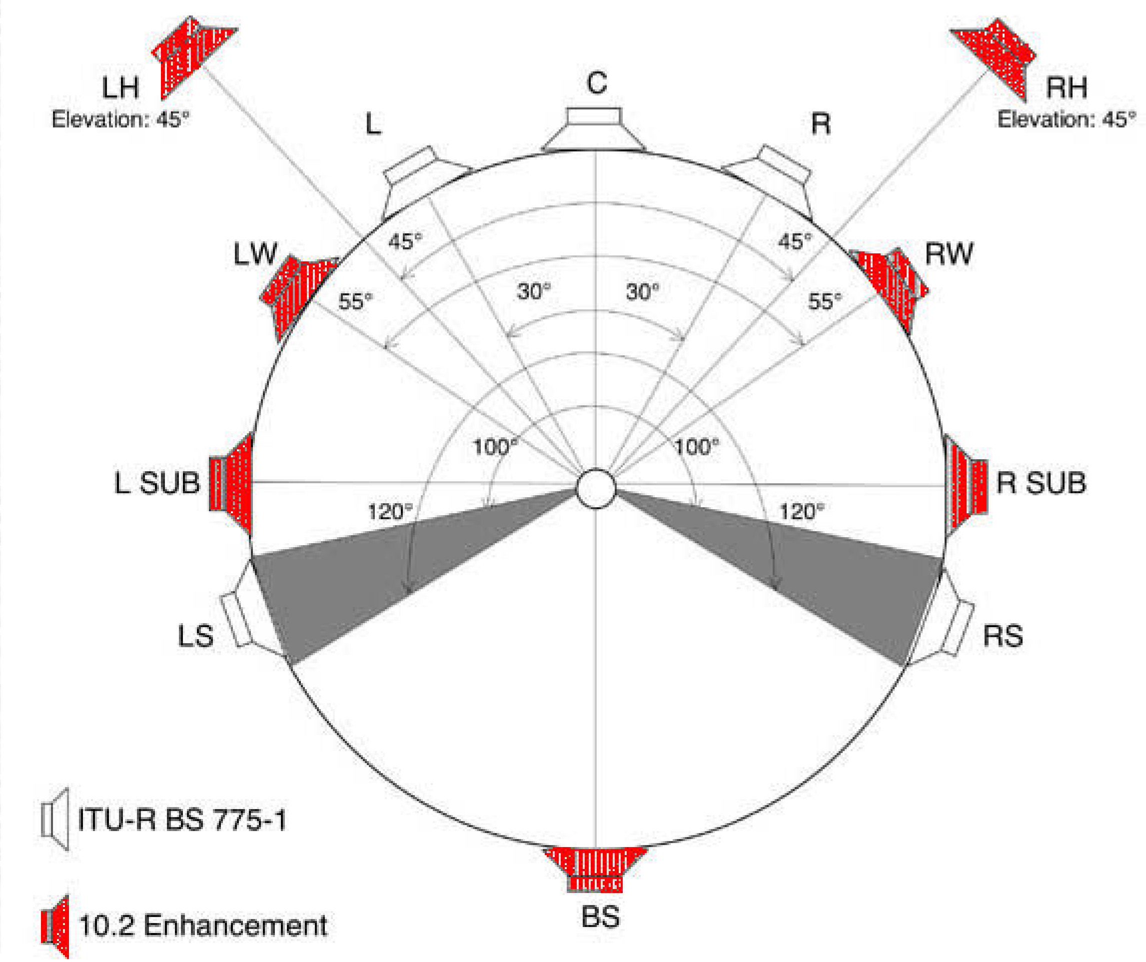


The Ambiophonics Institute

Photos taken on
16 december 2002

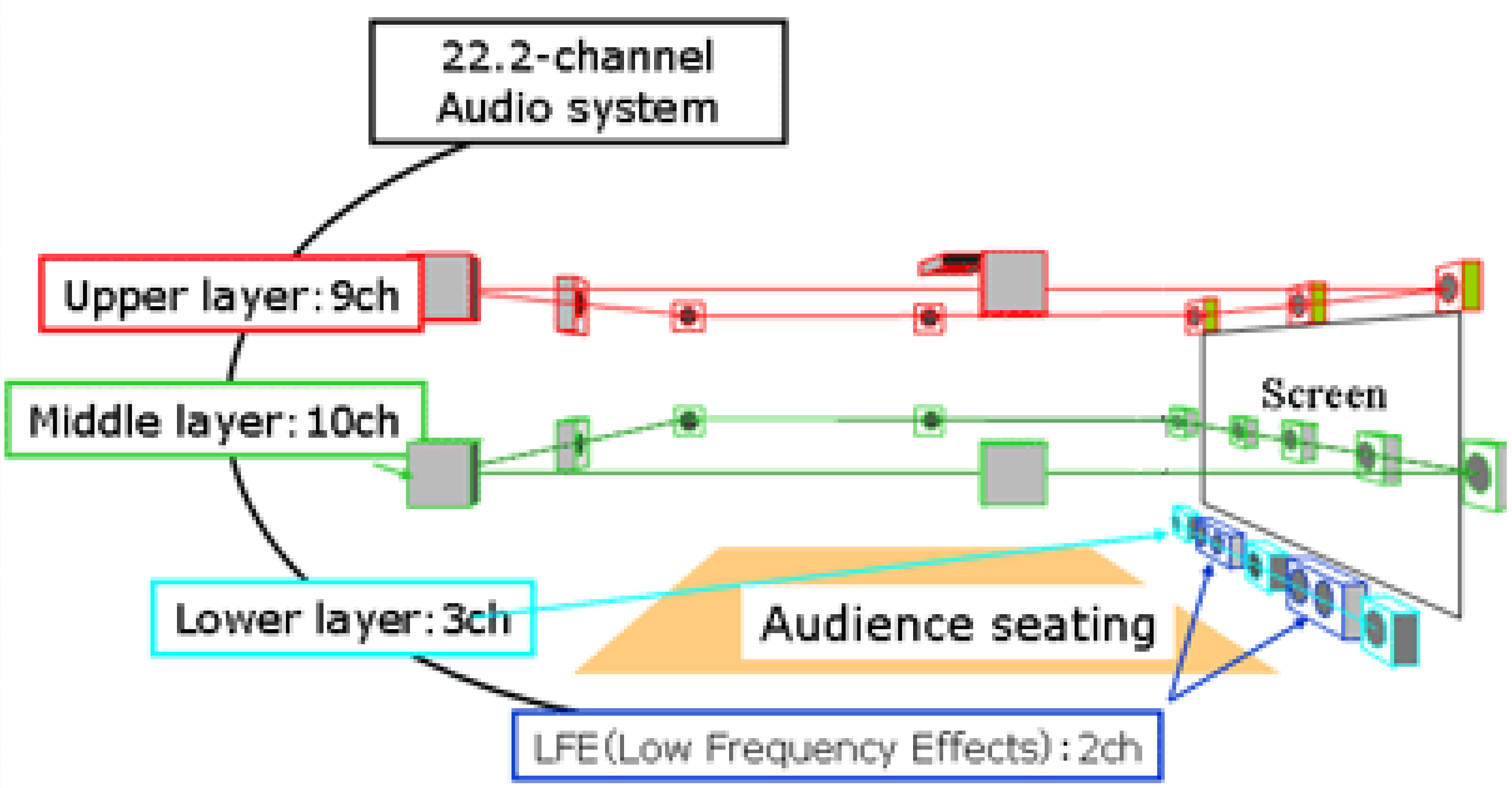
The Ambiophonic Institute

THX 10.2 Surround (2001)



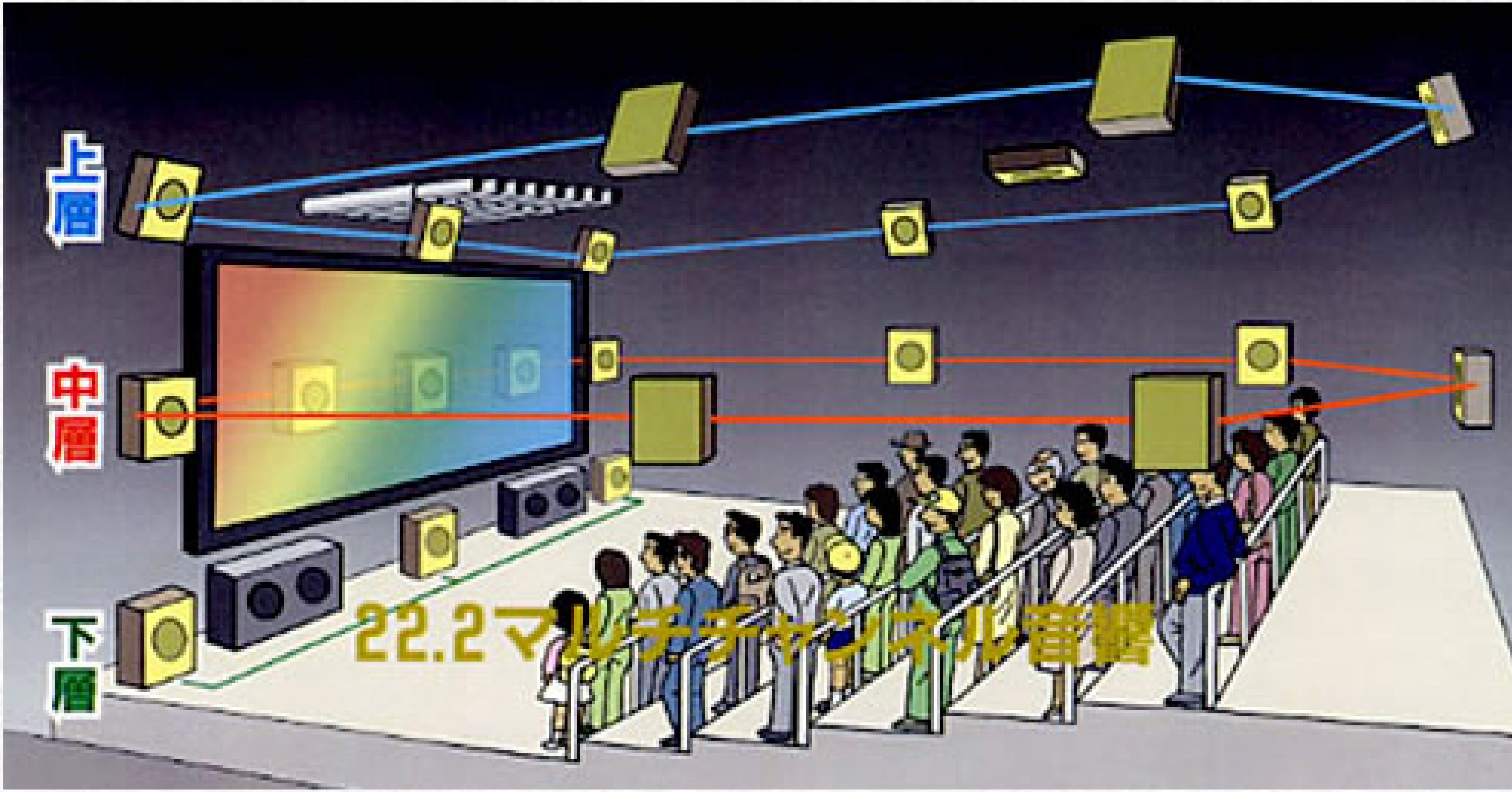
Layout

NHK 22.2 Surround (2005)



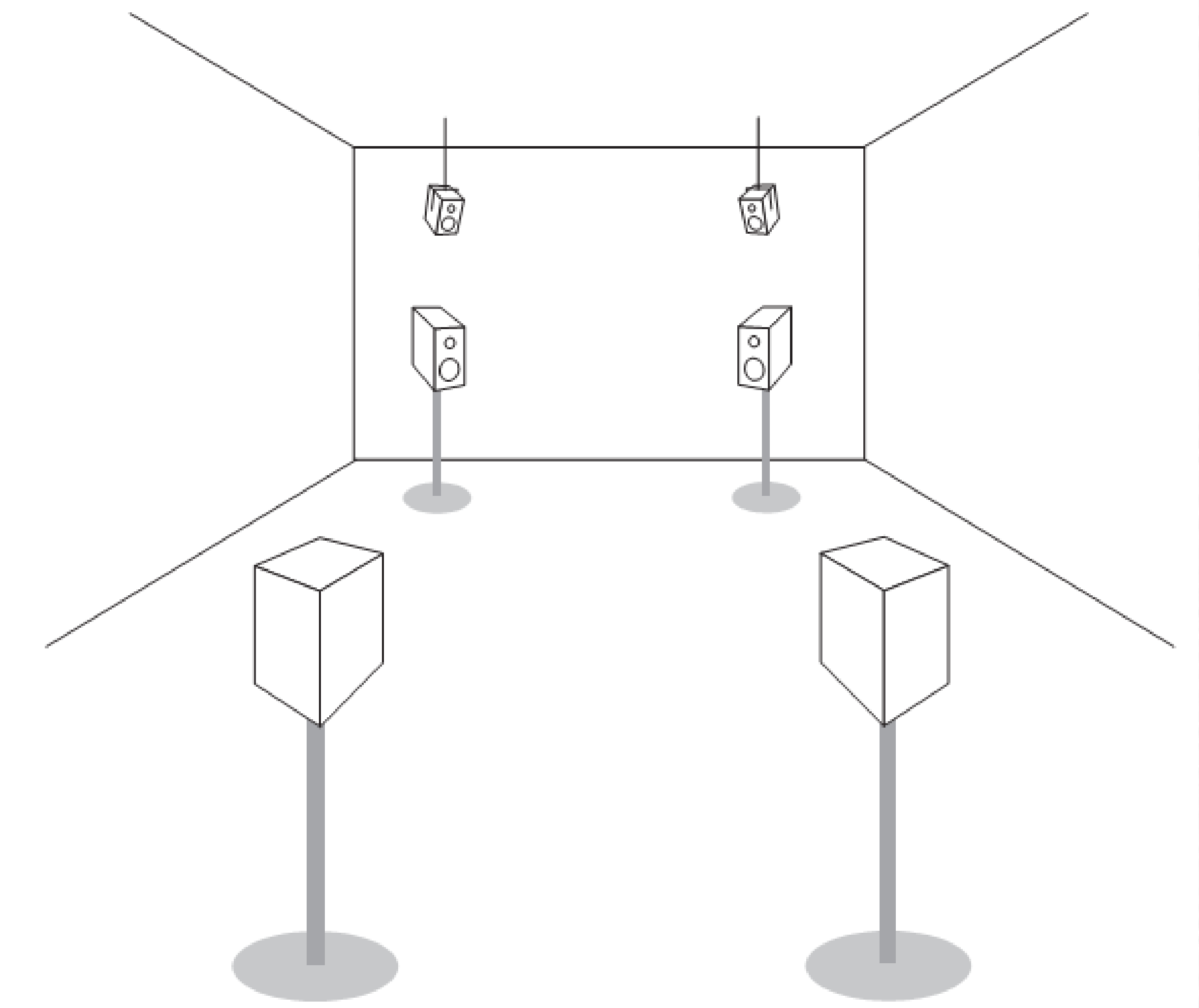
Layout

NHK 22.2 Surround (2005)



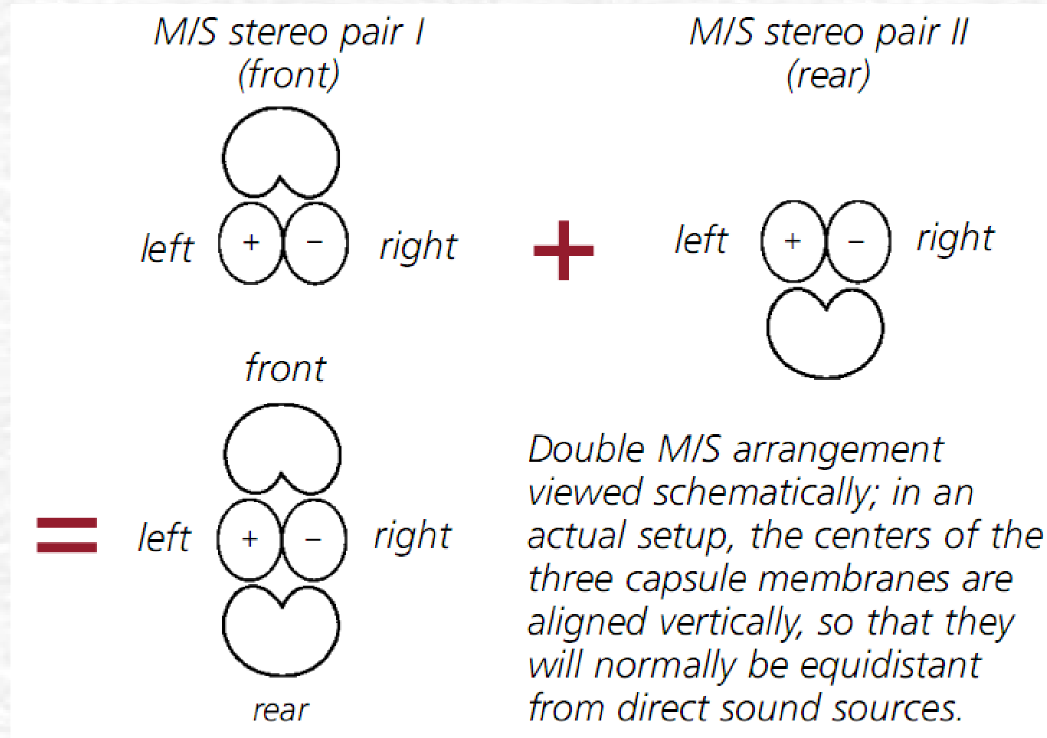
Layout

The 2+2+2 system (2007)



Layout

Schoeps Double MS (2007)



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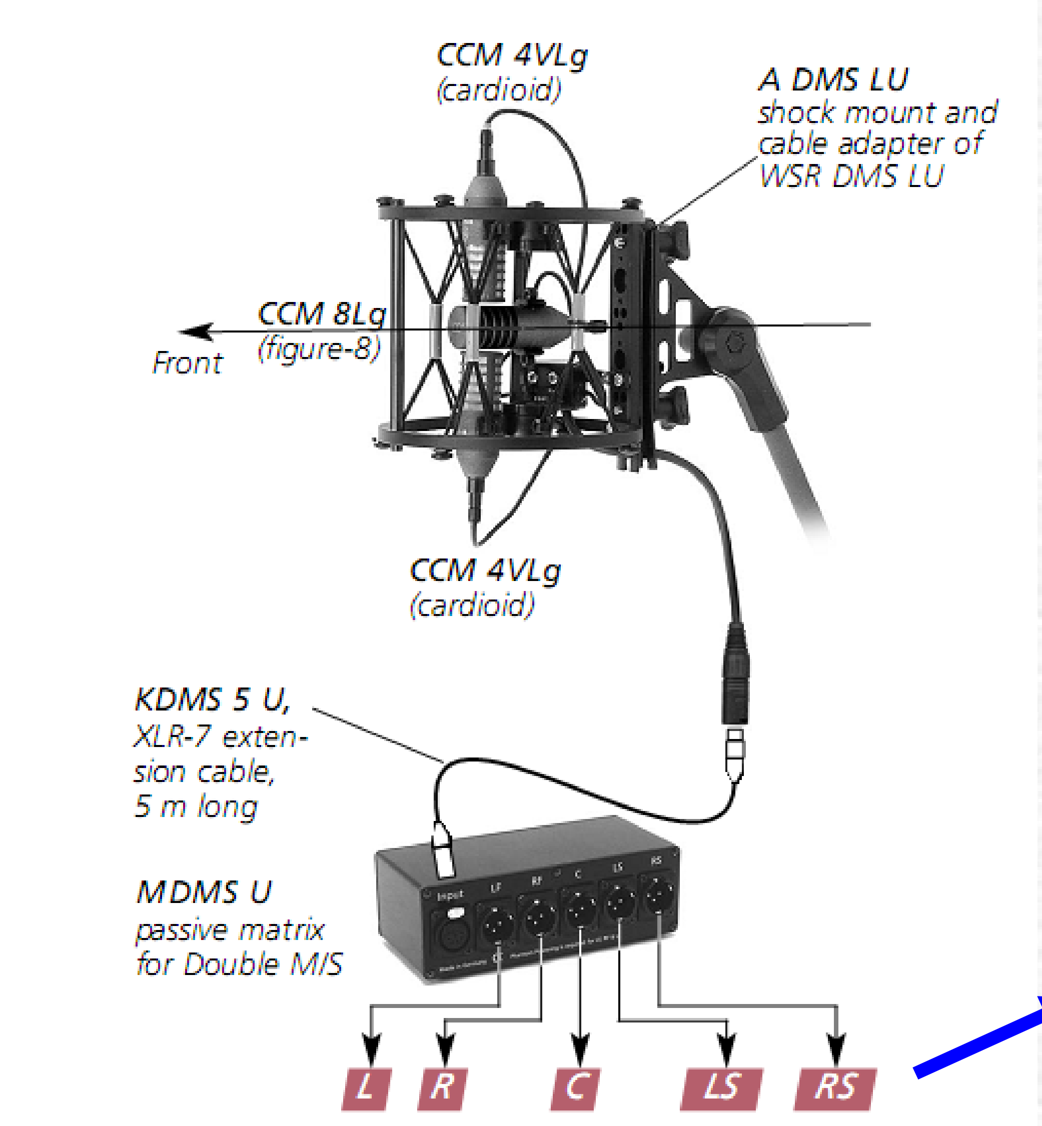
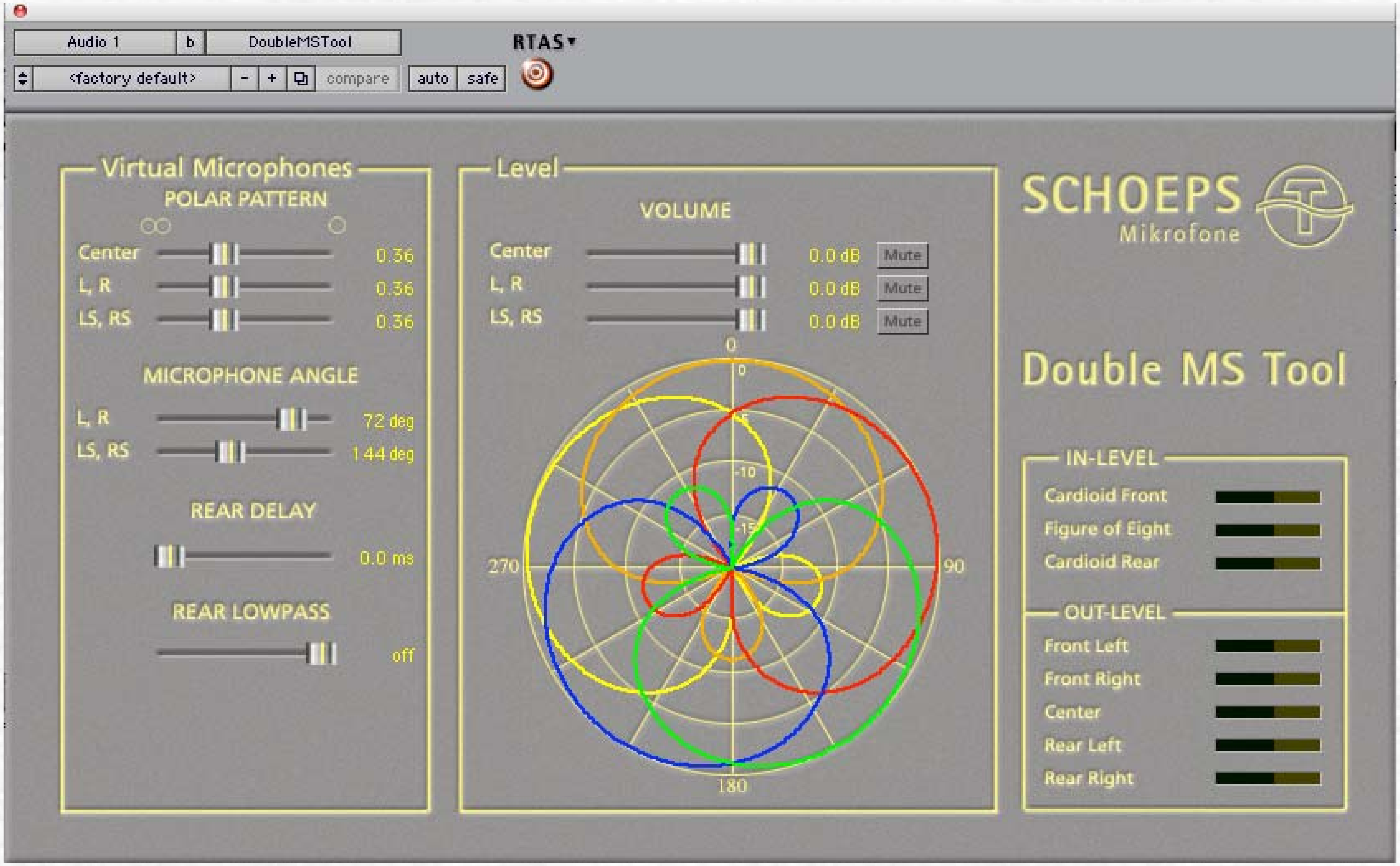
Schoeps Double MS (2007)



Standard 5.1 surround signals can be derived employing an hardware processor with pre-optimized decoding coefficients

Schoeps Double MS (2007)

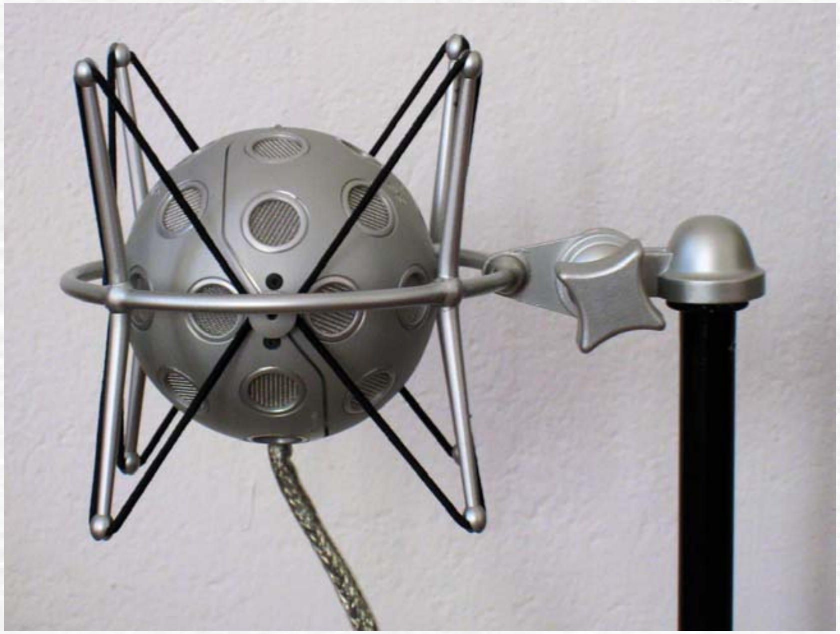


Greater control is obtained employing the free VST/RTAS plugin

Schoeps Double MS (2007)

- In practice, the double-MS system is another way of recording the horizontal components of the Ambisonics signals WXY (B-format), and decoding them with the "virtual microphone" approach
- Schoeps does not advertises this method as Ambisonics based, and relies on the superior quality of their capsules for beating the concurrent Soundfield microphone system

High Order Ambisonics (2010)



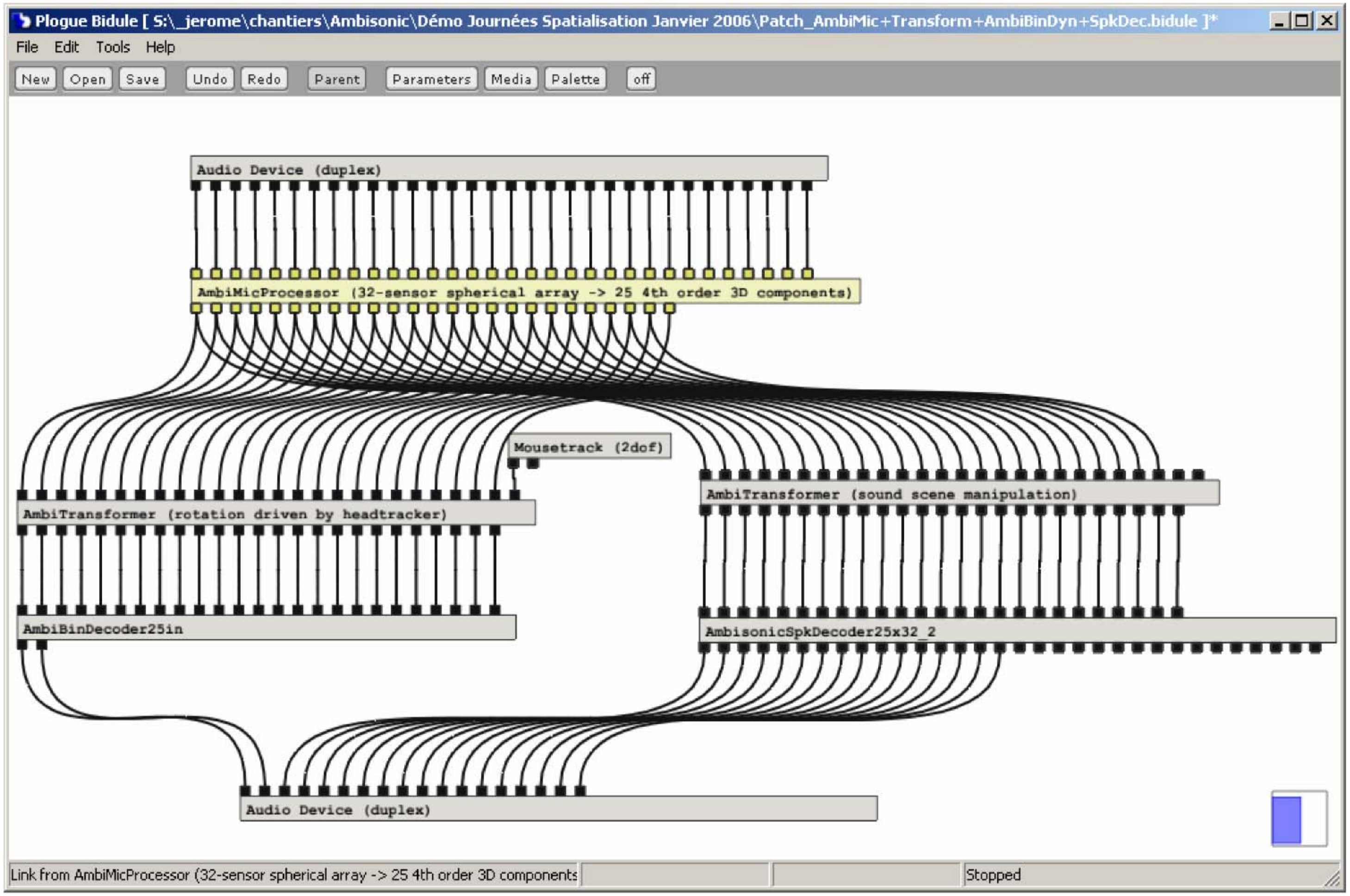
Eigenmike®

Rig at ISVR

4th order mike, 40 loudspeakers rig

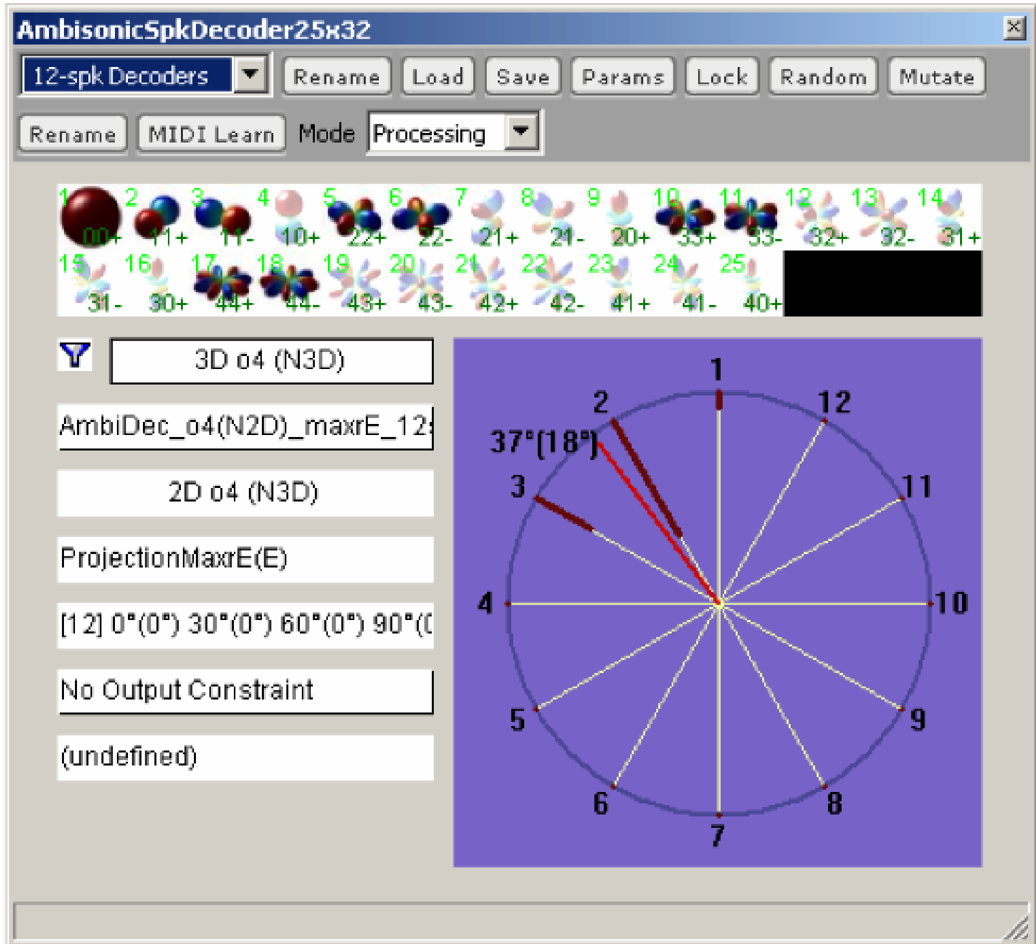
Software for 4th-order Ambisonics

- 32 ch. VST plugins developed by France Telecom

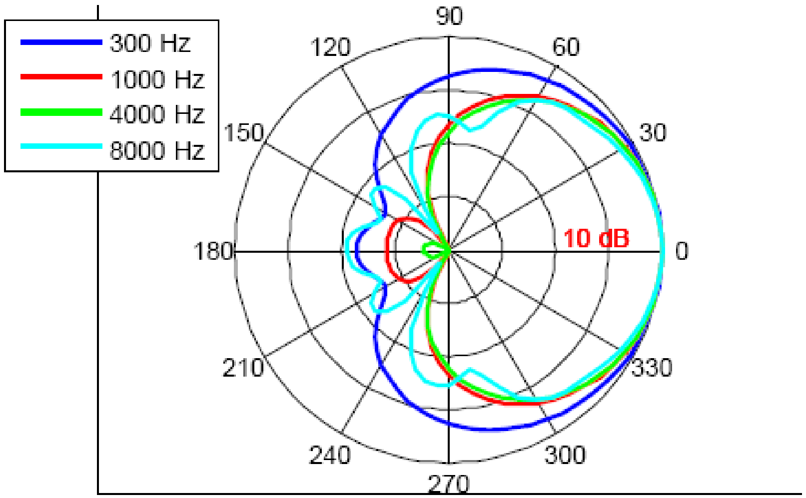


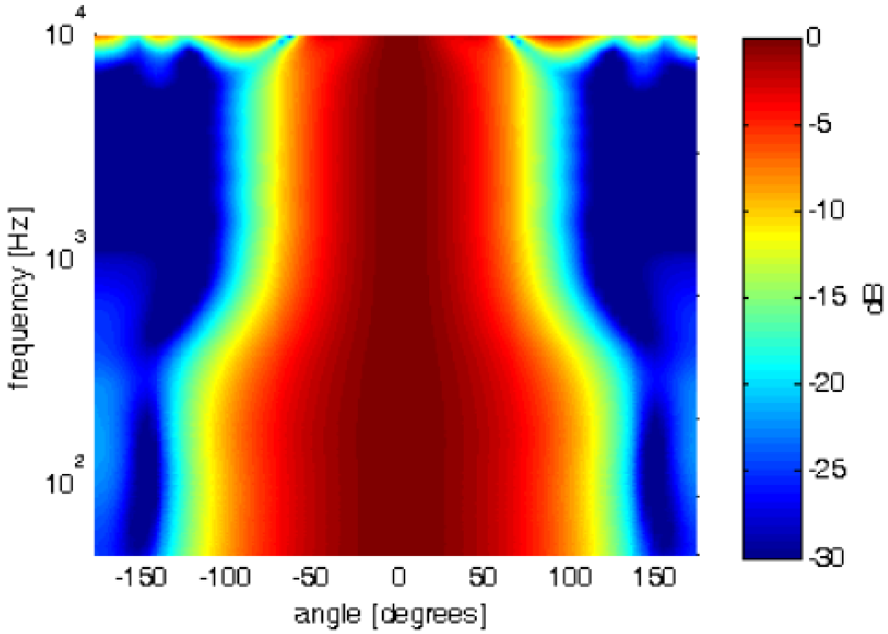
Software for 4th-order Ambisonics

- 32 ch. VST plugins developed by France Telecom



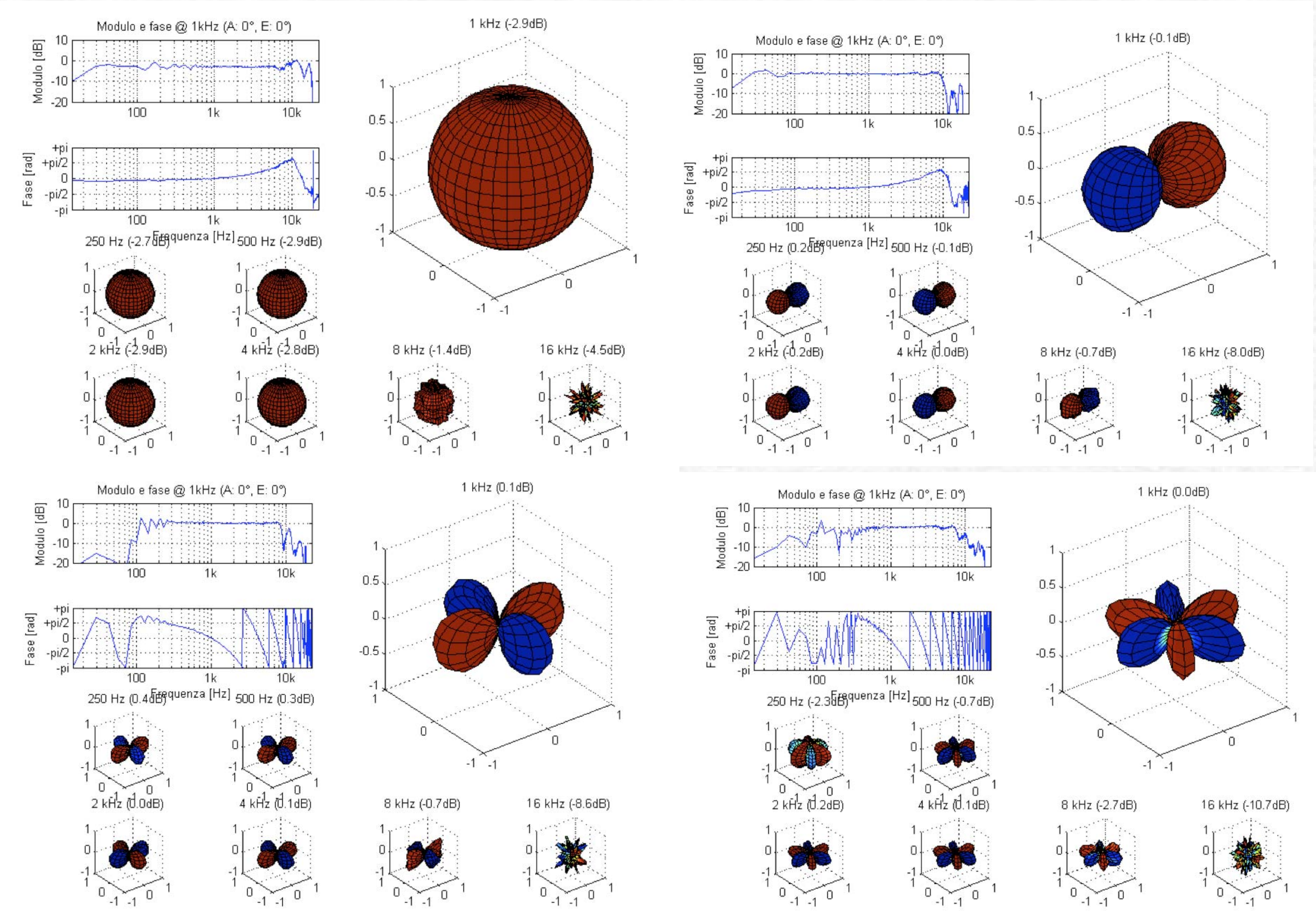
Eigenmike – virtual 3rd order cardioid





Directivity patterns

Spherical Harmonics



Comparative experiments

- We present here some sound samples coming from three experiments
- The first was the ORF Seminar, Wien 2001
- The 2nd was Verdi Projekt at TU Ilmenau in 2002
- The third is currently undergoing at RAI Research Center in Turin, Italy

The ORF seminar (Vienna)

www.hauptmikrofon.de/index.php?option=com_content&view=article&id=61&Itemid=58

hauptmikrofon.de

forum on sound engineering

AES42 White Paper

White Paper "Digital Microphones and AES42"/"Digitale Mikrofone und AES42"

- German version v2.1, 11.05.2010
- English version v2.1, 11.05.2010

The authors of the White Paper *"Digital microphones and*

Image Assistant

- Image Assistant 2.1

Main

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- about us

Topics

- AES-42 White Paper

Stereo

- ORF Surround techniques
  - Download DVD image
  - Listening test results

Ressources

- The Binaural Sky
- WFS (IRT literature)

ORF Surround techniques

Written by Administrator

Tuesday, 22 December 2009 11:48

The surround seminar at ORF (Vienna) performed a comparison of seven surround main microphones by a simultaneous recording with consecutive blindfolded listening test. *The recorded tracks are available for download now as a DVD image* in order to repeat the blindfolded listening test.

Introduction

The rehearsal of the Radio Symphony Orchestra Vienna was recorded using seven different 5.1 Surround main microphone setups (see below). They played two different music samples which were pieces from Mozart and Berio, representing contrasting dynamic characteristics.

The recorded samples can be compared in order to learn about the differences between the applied recording techniques. A DVD enables to compare intuitively by switching between the streams using the "audio"-button of the DVD player remote. This DVD can be produced using the DVD image available for download.

During the ORF Surround seminar and at an another later occasion the samples were compared in listening tests. The 18+14 participants had to assess different characteristics of these sound samples in a blind test. The results of these assessments are reproduced as mean values in 9 tables:

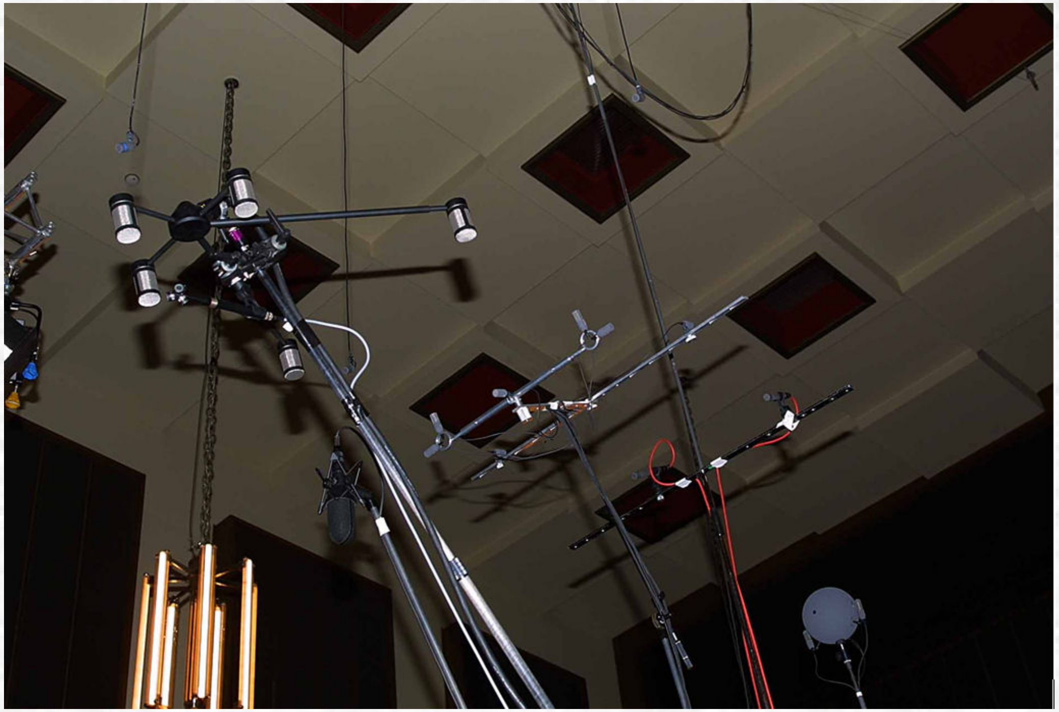
Results of the Vienna and Düsseldorf Listening Tests

The Vienna test was performed by Florian Camerer and Christian Sodl, ORF. The DVD was produced by John Oag, formerly IRT. The diagrams were made by Helmut Wittek.

Picture of the recording session - the simultaneous recording of all configurations

The ORF seminar

The ORF Seminar



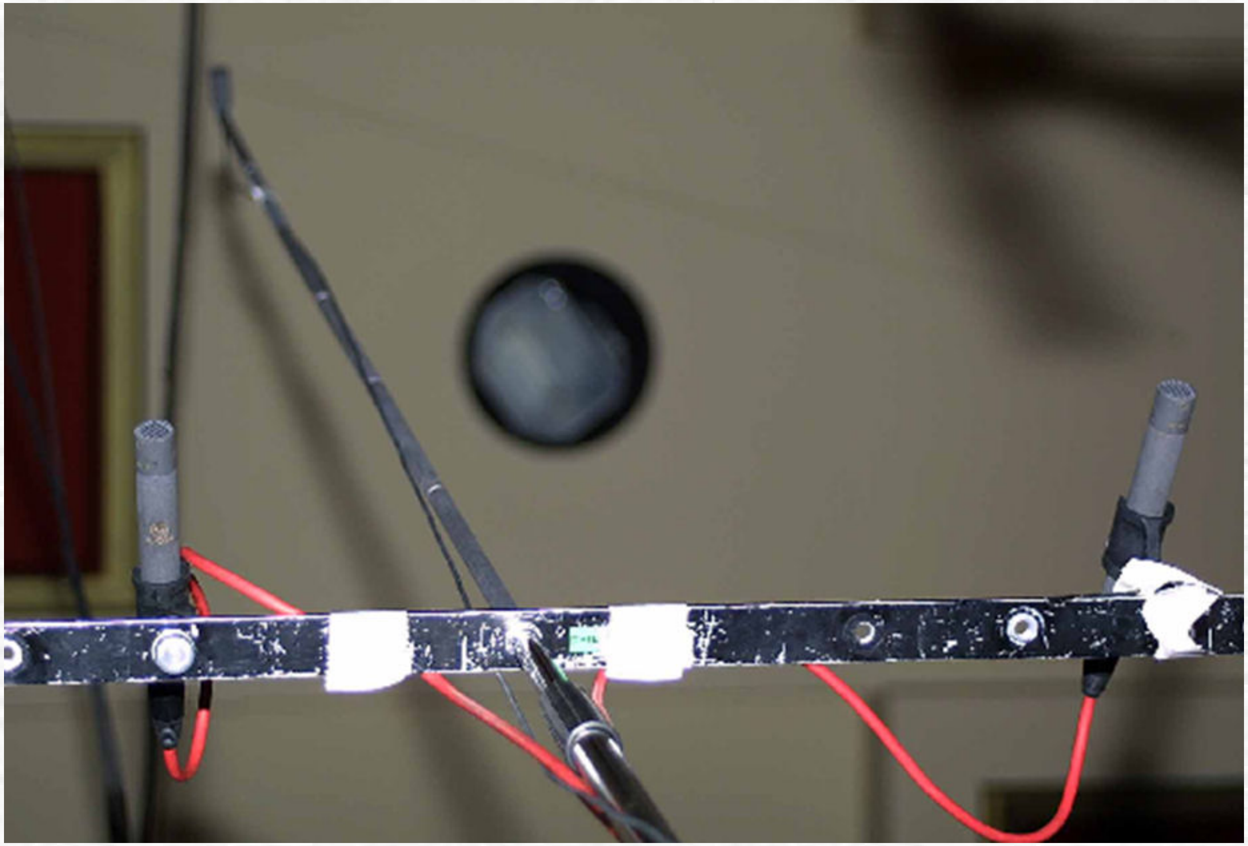
Recording hall: Grosser Sendesaal (big transmission hall) of the Austrian Radio;
Orchestra: Radio Symphony Orchestra of the ORF (RSO Vienna);
Musical program: 1. W.A.Mozart: „Maurerische Trauermusik" c-minor, KV 477
2. L.Berio: Concert for Trombone & Orchestra (the soloist was not present at the rehearsals);
Recording console AMS/Neve Capricorn;
Monitors: 2x Genelec 1034 for L + R; 3x Genelec 1037 for C, LS + RS;
No subwoofer (we did not record an LFE)
Recording machines 2x SONY PCM 3324 DASH Multitrack recorders;

The ORF seminar

8 Recording techniques:

- A: Stereo + C + Hamasaki square
- B: Decca-Tree + Hamasaki square
- C: OCT + Hamasaki-Square
- INA 5
- Schoeps KFM 360
- OCT Surround
- Soundfield MKV + Processor SP451

The ORF seminar

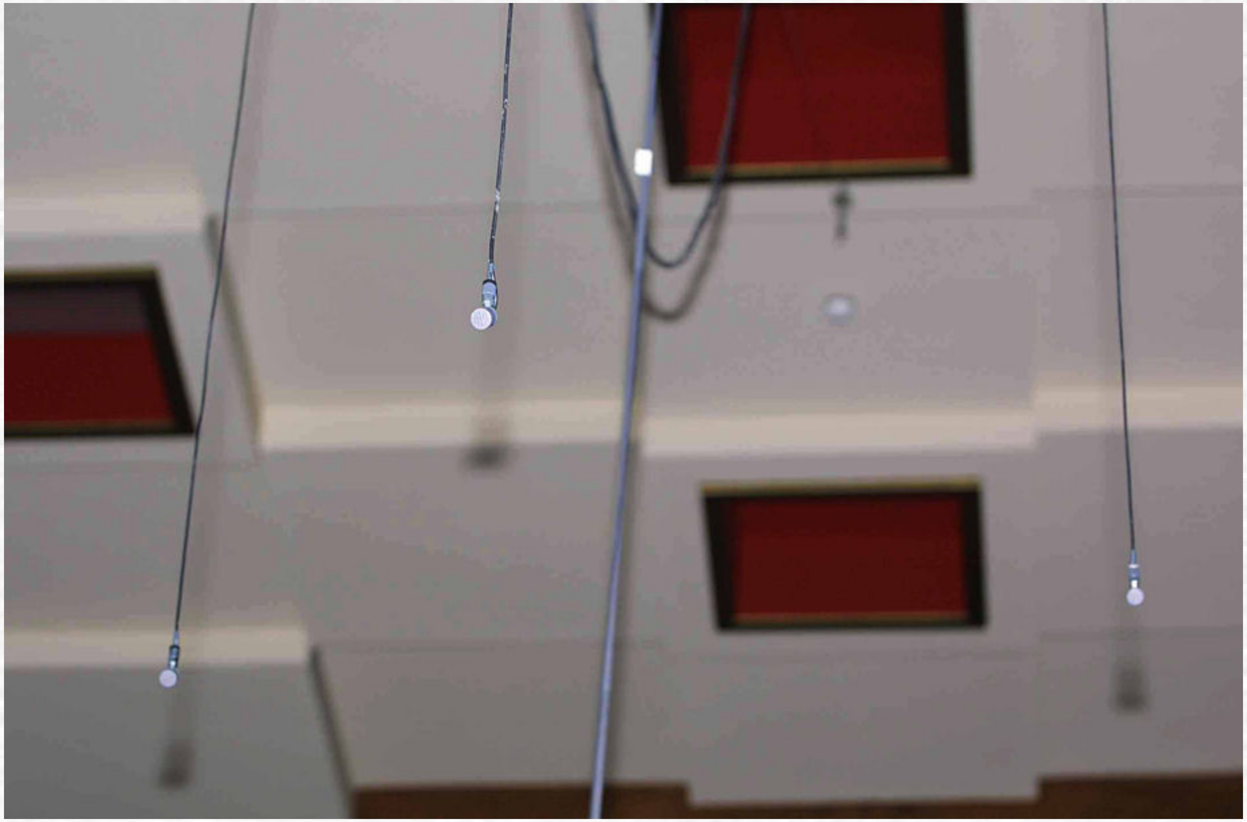


System A: Stereo + C + Hamasaki Square (after A.Gernemann);
This system is based on a „regular" main microphone for 2-channel stereophony like AB or MS with an additional omnidirectional microphone for the Center high above the main pair (>2m)

The ORF seminar

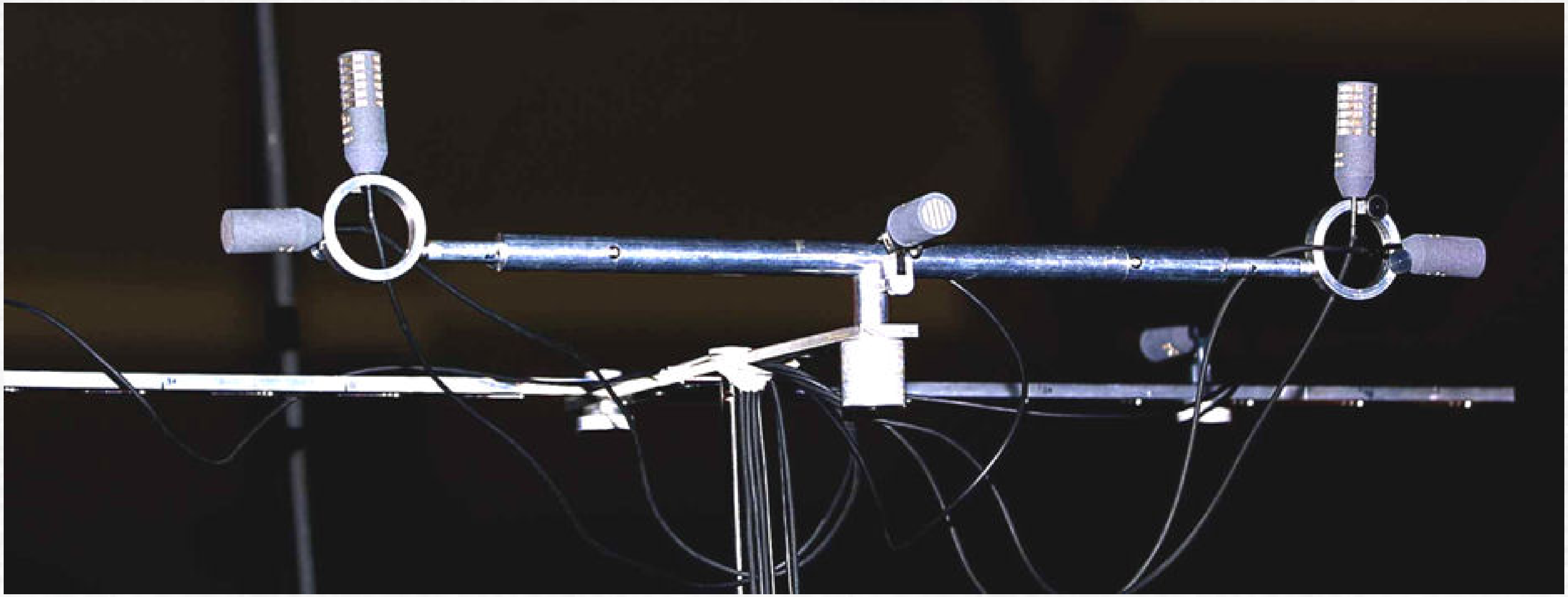
Hamasaki-Square: invented by Kimio Hamasaki of the NHK Science and Research Laboratory. This consists of 4 fig-of-eight microphones pointed to the sides (Schoeps CMC8) arranged in a square of about 2m sidelenght, placed not too far behind the main microphone (about 5m).

The ORF seminar



System B: **Decca-Tree + Hamasaki-Square;** This well-known setup with three omnis (here Schoeps CMC2S, see ***fig.3***) is used as the standard configuration for the numerous recording sessions taking place in the „Grosser Sendesaal" of the ORF (base-lenght: 1,5m). The system was reinforced with two additional Schoeps CMC2S omnis on the sides (3,5m), the so-called „out-riggers". The 4 fig-of-eight microphones of the Hamasaki-Square were panned as before for Stereo+C.

The ORF seminar

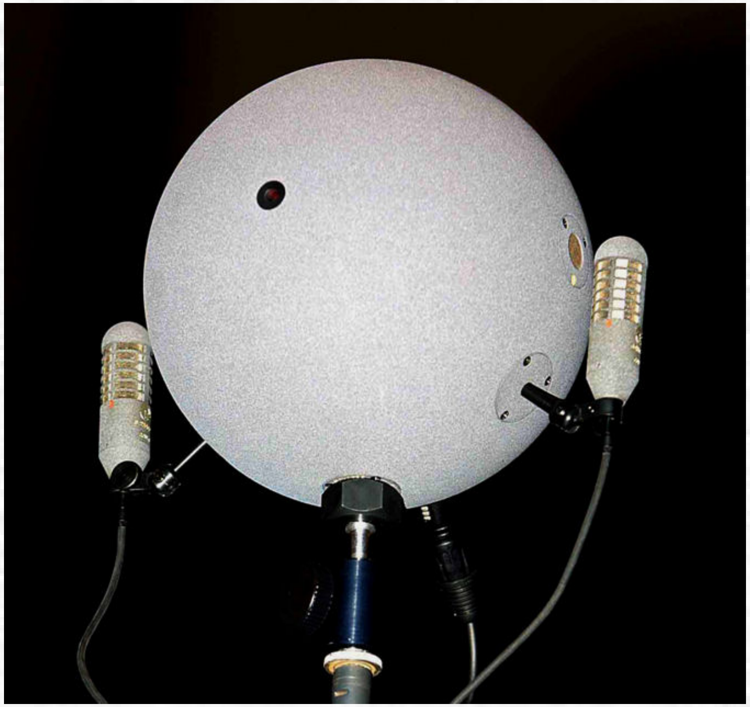


System C: **OCT (O**ptimised **C**ardioid **T**riangle**) + Hamasaki-Square;**
This system was devised by Guenther Theile. OCT chooses hypercardioids facing 90° away from the orchestra for L and R (base distance b=80cm) and a cardioid facing forward for C closer to the orchestra (h=8cm).
The somewhat poorer bass response due to construction principles is compensated with the addition of two omnis adjacent to the hypercardioids which are lowpass-filtered at 100Hz to provide low-end down to 20Hz (The hypercardioids and the cardioid are highpass-filtered at 100Hz accordingly.)

The ORF seminar

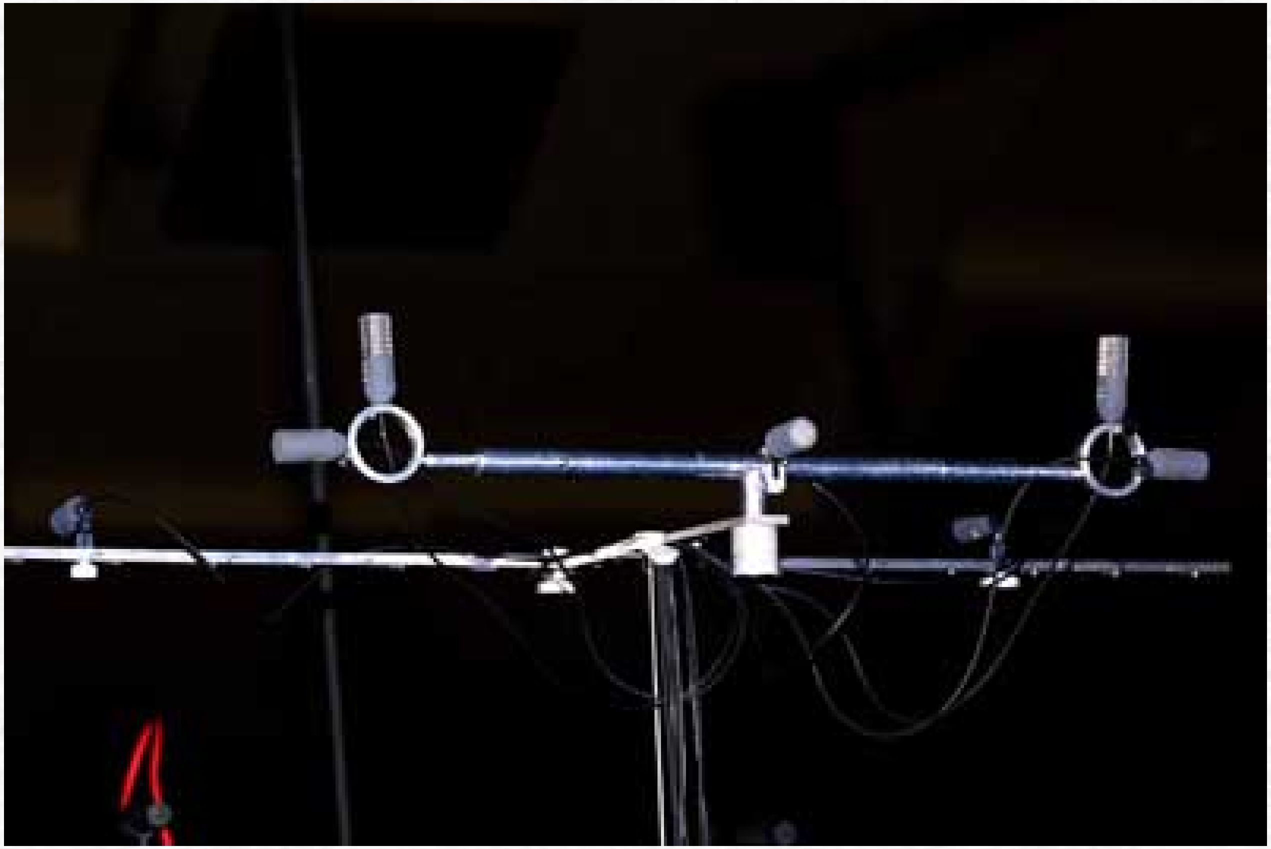
System D: **INA5 (I**deale **N**ieren**-A**nordnung (Ideal Cardioid Arrangement)**)** (after Herrmann/Henkels); This system is also based on the Williams localization curves, so that the recording angles of adjacent microphone pairs just touch each other (representing the „sweet-spot"-group)

The ORF seminar



System E: **Schoeps KFM 360** (after J.Bruck)**;**
A sphere microphone (after G.Theile) is accompanied by two fig-of-eight microphones on the sides adjacent to the pressure transducers. Each omni/fig-of-eight-combination forms an MS-stereo-pair that after decoding delivers one front- and one surround-signal respectively. An optional center-signal is derived through a special 2-3-matrix (after Gerzon).

The ORF seminar



System F: OCT Surround; Instead of the Hamasaki-Square for the surround signals two cardioids (Schoeps CCM4) are used right behind (50cm) the frontal OCT array and with a slightly extended base (100cm). The cardioids are oriented straight away from the orchestra (180°), so that their direct-signal-pickup is minimal.

The ORF seminar

System G: Soundfield MKV + Processor SP451; The Soundfield-microphone forms the practical basis of the **Ambisonics**-system (after M.A.Gerzon) that can provide complete periphonic sound-reproduction. For 5.1-loudspeaker-setups the special decoder (B-Format to 5.1) required is called „Vienna"-decoder.

The Soundfield-company produces their own B-Format-to-5.1-converter, the SP451 (not a Vienna-Decoder). It shall be noted that for horizontal reproduction the Z-channel is omitted.

The ORF seminar

Questionnaire

Spatial presentation of the orchestra:

Q 1	*wide – narrow*	*(1 – wide, 5 – narrow)*
Q 2	*close – distant*	*(1 – 5)*
Q 3	*deep – flat*	*(1 – 5)*
Q 4	*stable – unstable*	*(1 – 5)*
Q 5	*precise – blurred*	*(1 – 5)*

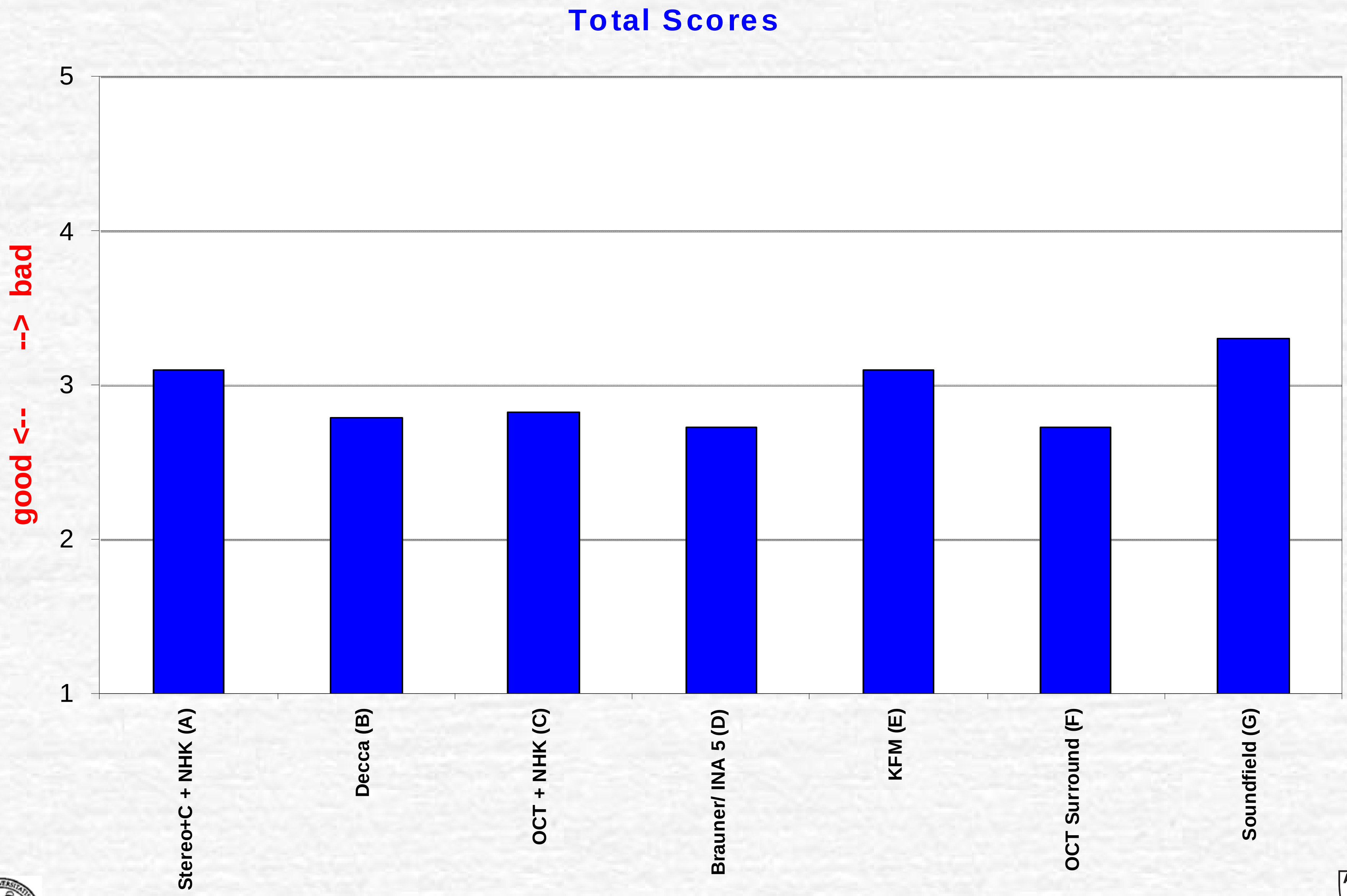
Timbre (sound-colour) of the orchestra:

Q 6	*satisfactory – unsatisfactory*	*(1 – 5)*

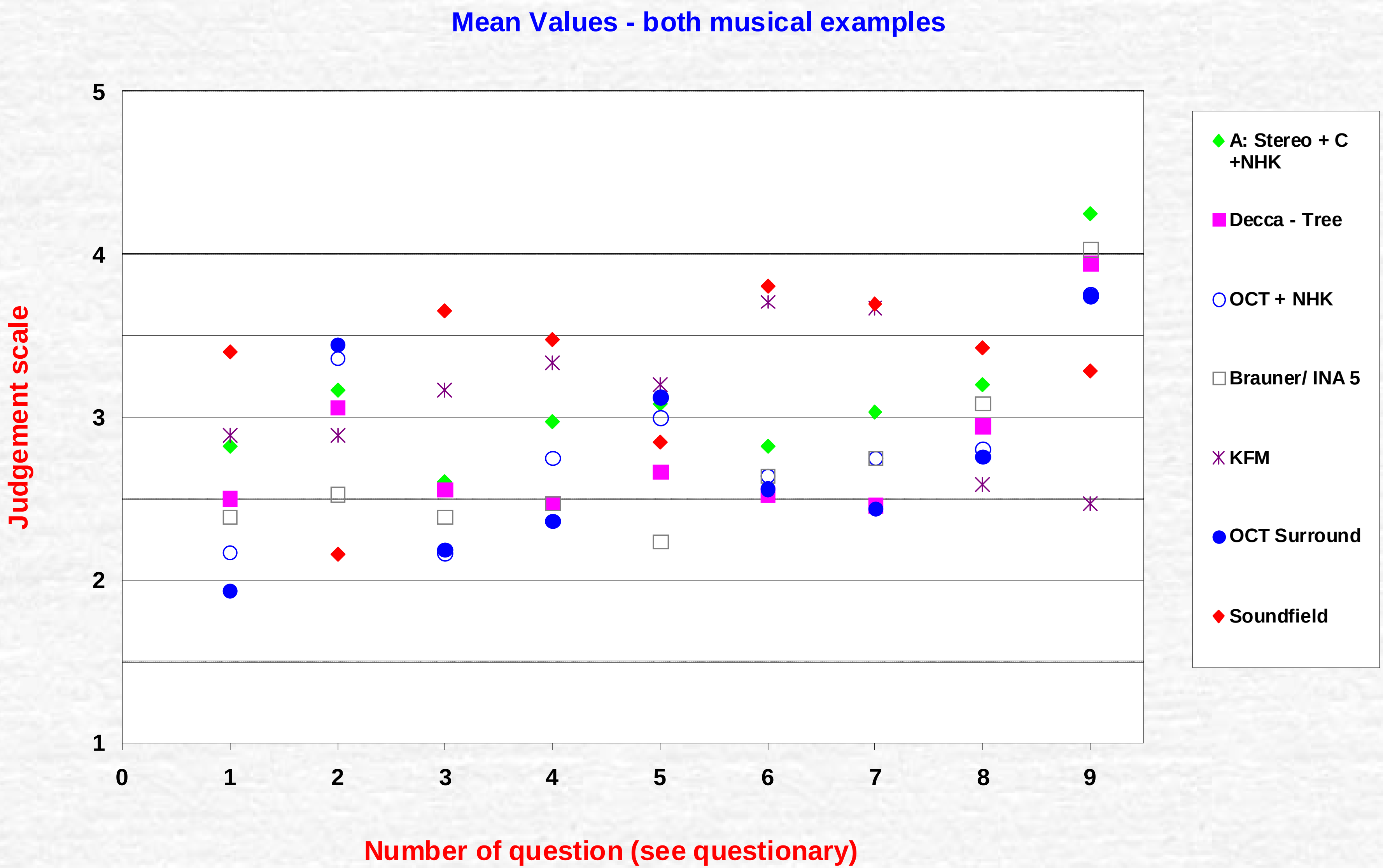
Spatial imaging:

Q 7	*perfect spatial impression – imperfect sp.imp.*	*(1 – 5)*
Q 8	*too much indirect sound – too little ind.sound*	*(1 – 5)*
Q 9	*surround channels identifiable – surr.ch. not id.*	*(1 – 5)*

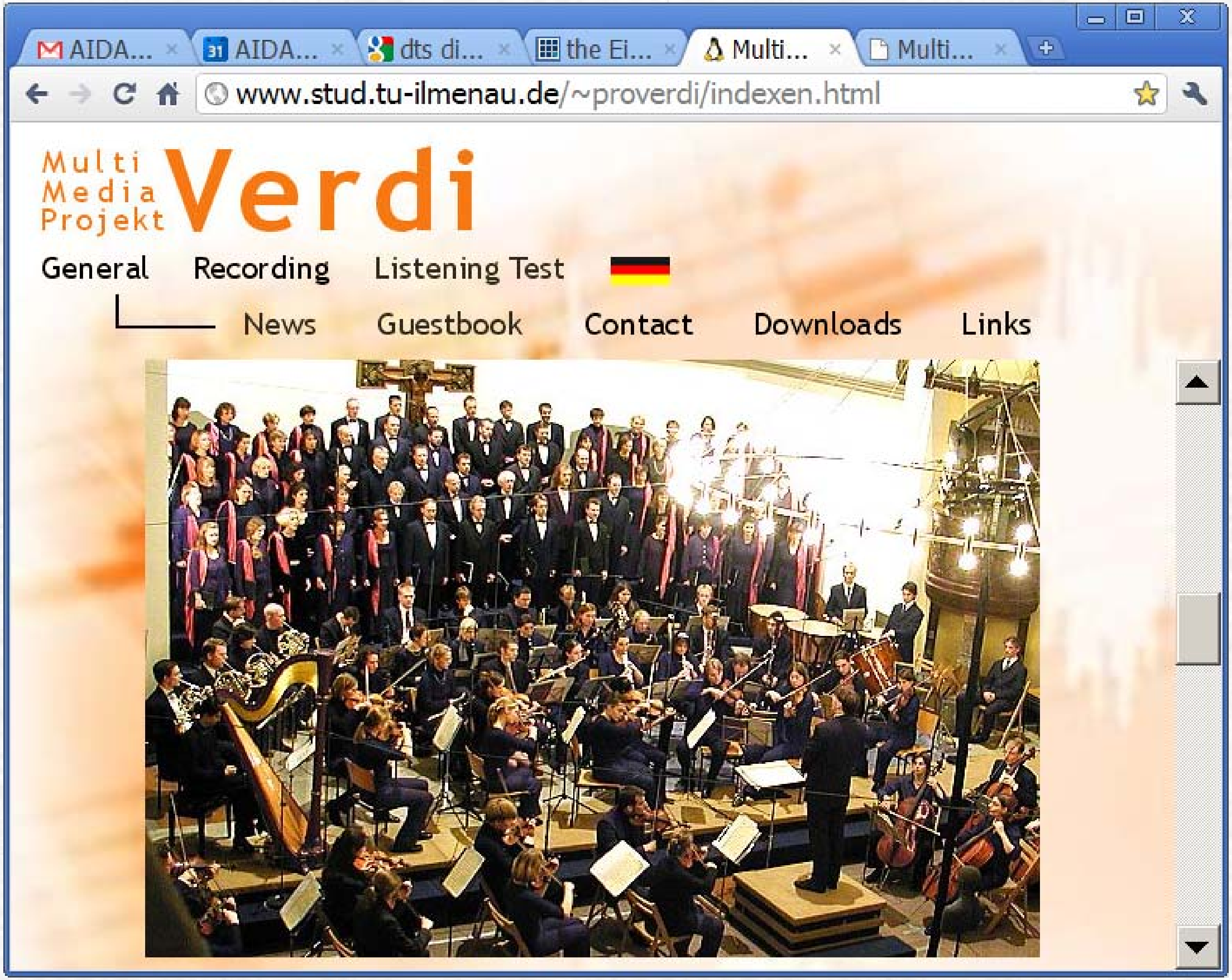
The ORF seminar



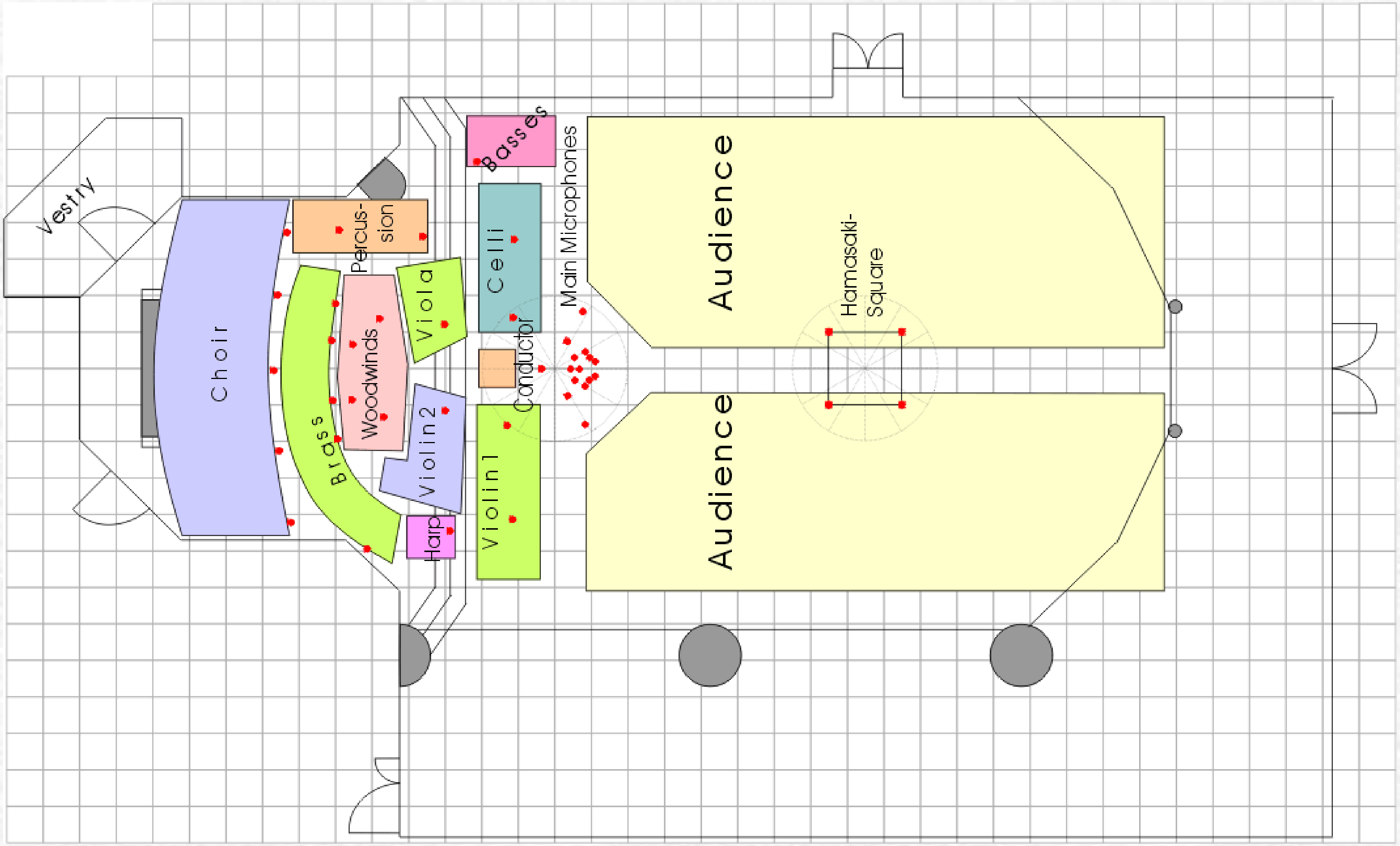
The ORF seminar



The Verdi Projekt



The Verdi Projekt



The Verdi Projekt

Some data:

- Recording made in a church in Hannover, on 25 November 2001
- 54-tracks simultaneous recording
- 18 technicians
- 9 microphone systems
- 6 resulting 5.1 productions
- 40 listeners for evaluating the 6 different mixes
- Additional test for 7 Soundfield-derived decodings (with few listeners and different rating scale)

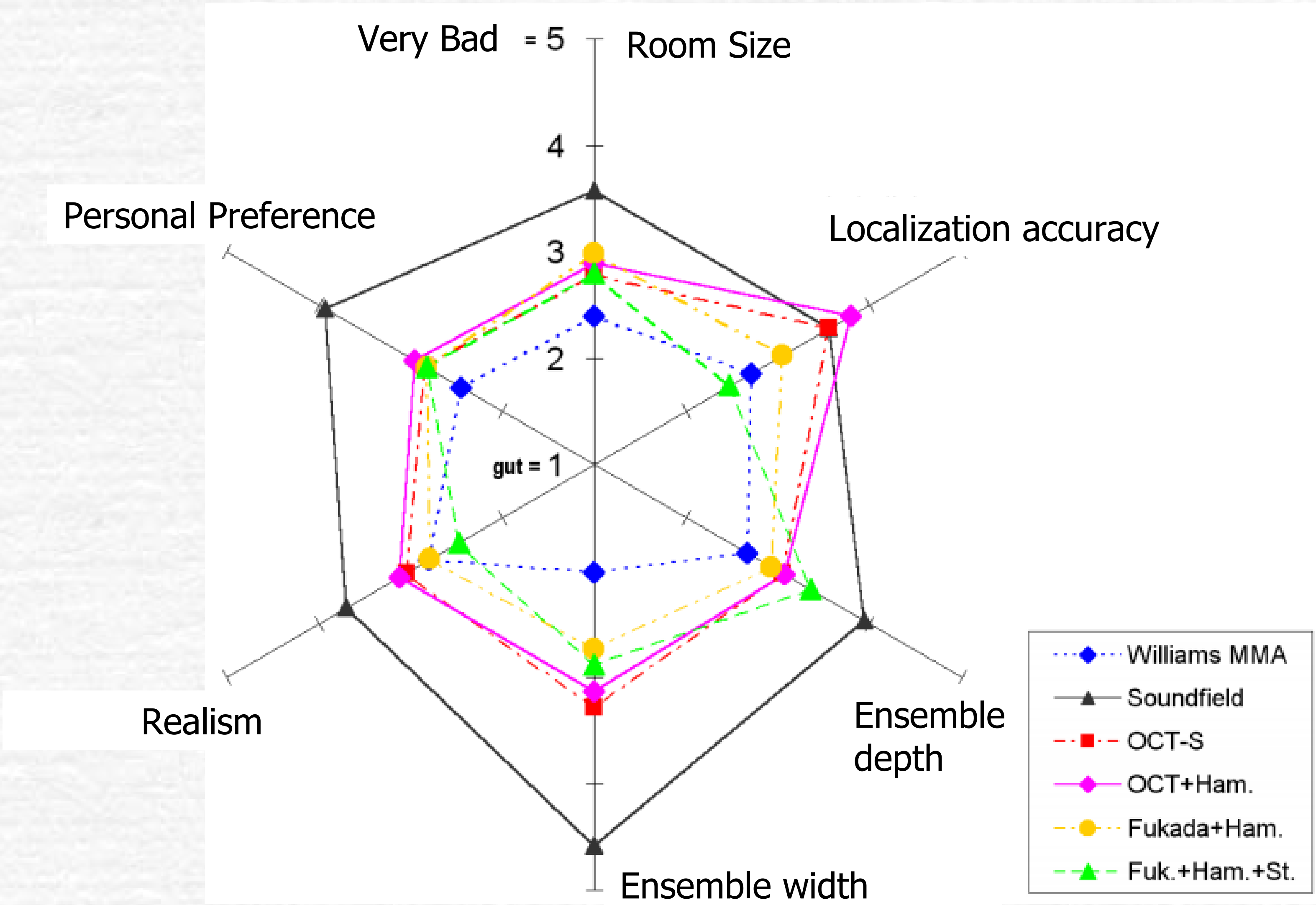
The Verdi Projekt

The 6 main mixes:	Overall SCORE	
• **Williams MMA**	**2.0**	**The best!**
• **Soundfield (NOT Ambi)**	**4.0**	
• **OCT Surround**	**3.2**	
• **OCT + Hamasaki Square**	**3.2**	
• **Fukada-Tree + Hamasaki Square**	**3.0**	
• **Mix with spot microphones & Hamasaki Square**	**2.8**	**The 2nd**

Note: 1 means optimum, 5 means very bad

The Verdi Projekt

Individual scores:



The Verdi Projekt: Soundfield

As the Soundfield decode did perform poorly, an additional session was organized, asking to skilled Ambisonics users to provide their decodes:

Decoding method	Score
A1 - Wiggins-HRTF	3 sufficient
A2 - Wiggins-VIEN	3 sufficient
A3 - Farina-Ambiophonics	3.5 poor
A4 - mac Caba	2.5 almost good
A6 – Dalenback	2.5 almost good
A7 - Rhonda Wilson	2.0 good
A8 - Williams MMA	1.0 very good

The RAI – CRIT project

Comparing the Holophone H2 Pro with the Eigenmike®

The RAI – CRIT project

Recording of “La Boheme” at Teatro Regio in Turin

Recording of Sostakovic symphony n. 10 at RAI Auditorium in Turin

The RAI – CRIT project

"La Boheme" was recorded with 1 Holophone and 2 Eigenmikes
Sostakovic was recorded with 1 Holophone and 1 Eigenmike

The RAI – CRIT project

Listening tests are being currently performed at Centro Ricerche Rai in Turin

A new method of processing the Eigenmike® signals is currently being developed at the University of Parma, and will be presented at AES 40 on Sunday, 10 October, at 13.30 in PAPER SESSION 8: MICROPHONE AND MIXING TECHNIQUES

And do not miss the demo, TOMORROW at lunchtime

DEMO sound samples

The presentation now includes some demos (if everything works….):

- Mozart sample from the ORF Seminar (there is also Berio, but I hate it….)
- Excerpt 2 from the main session of the Verdi Projekt
- Excerpt 2 from the Soundfield session
- La Boheme from the RAI-CRIT project
- Sostakovic Simphony 10 from the RAI-CRIT project