Surround recording using coincident and spaced microphones combined with 2-to-3 upmixing

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This presentation will...

1. ... present a general approach for achieving a few desirable goals in surround recording.
2. ... show how only 2 channels can be used to record the 3 front channels (L, C, R) at a small or nonexistent penalty.
3. ... present a slightly modified ambience recording method.
4. ... discuss how these methods can be combined in actual recording.
5. ... present a main microphone setup that fulfils some of these goals.

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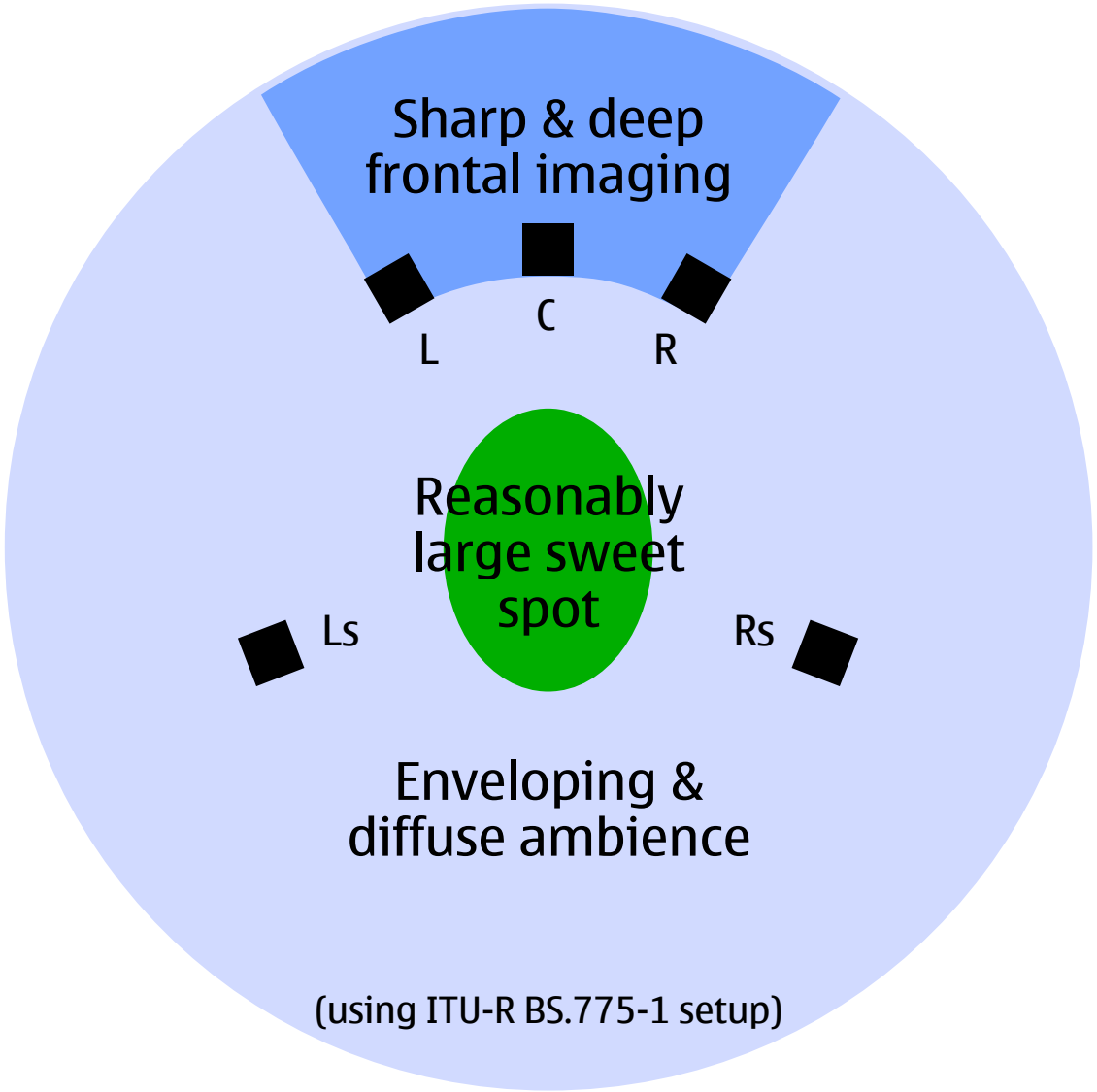
The intended goal in surround recording



Furthermore:

- 1st order microphone patterns (omni to figure-8),
- minimum number of channels.

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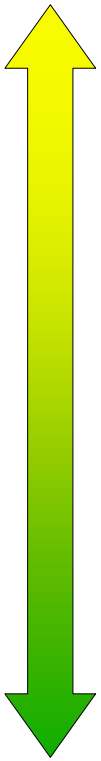
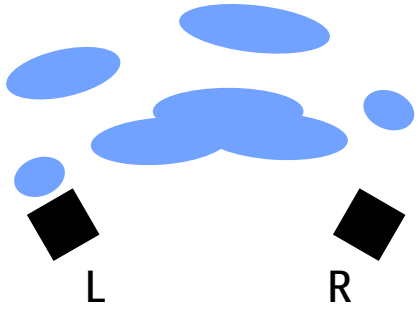
Stereo recording techniques & characteristics

Sharp & shallow imaging





Diffuse & deep imaging

XY (coincident)

MS & Blumlein (coincident)

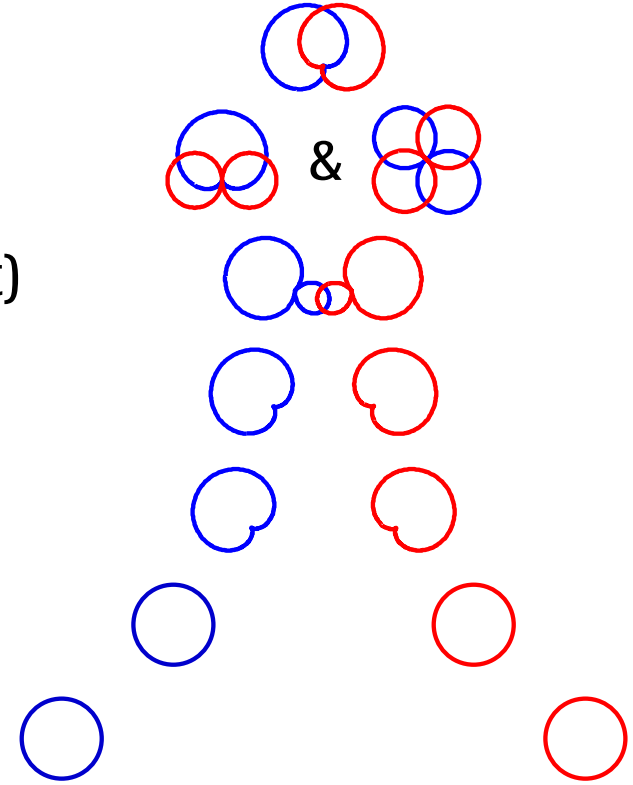
Stereo-180 (near-coincident)

ORTF (near-coincident)

NOS (near-coincident)

Small AB (spaced)

Large AB (spaced)



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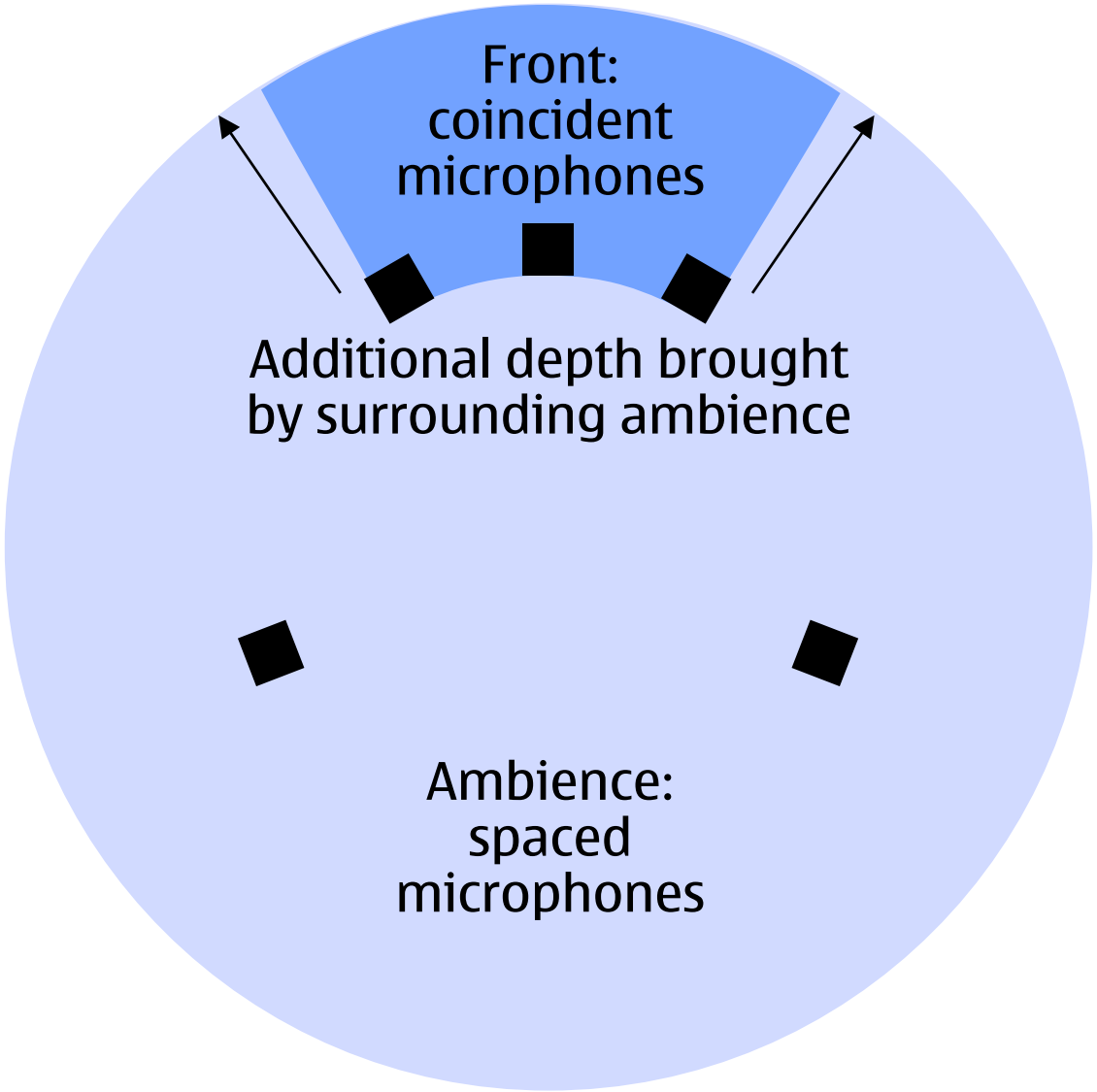
What it implies in surround recording



- For high imaging sharpness: front sector recorded using coincident techniques.
- For high envelopment and diffuseness: lateral and rear sectors recorded using spaced techniques.

Sharp L-C-R imaging + diffuse L-Ls-Rs-R imaging: why?

- Because the visual cues are lacking, the frontal image should be sharp to provide the directional resolution. (This is always a matter of subjective taste, of course...)
- Sharp imaging in the lateral and rear sectors is not even *possible* in 5.0/5.1 reproduction (except for sound panned to one of the loudspeakers), so it makes sense to provide it only where it can really be done: in the L-C-R sector.
- The lack of depth in the coincident recording is compensated for by the depth provided by the spaced ambience microphones *without sacrificing the imaging sharpness* (the *first* incident (direct) sound, not the reflections, provides the directional cue).

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The front channels

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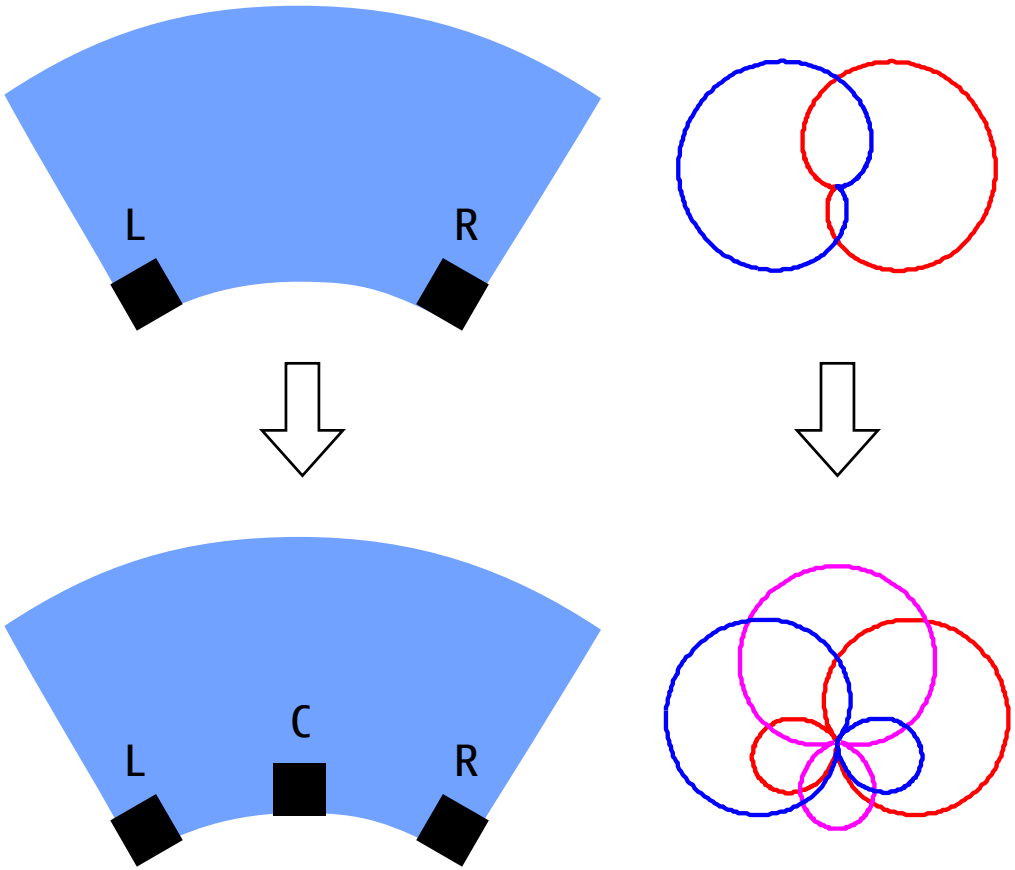
Coincident recording of the front channels (L, C, R)



(These 2 microphone setups have about the same recording angle.)

- Coincident recording is a valid method also in the 3-channel case.
- Since each channel generally corresponds to a narrower sector in the 3-channel case, the microphone patterns should generally also be narrower and/or the angle between microphones larger (for any given *recording angle*).
- The C channel microphone does not have to have the same polar pattern as the L and R channel microphones.

Coincident recording of the front channels (L, C, R)

Further advantages:

- Transient reproduction is as good as it can be (near-coincident and moderately spaced microphones smear transients).
- Mono compatibility is excellent.

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The virtual center channel microphone

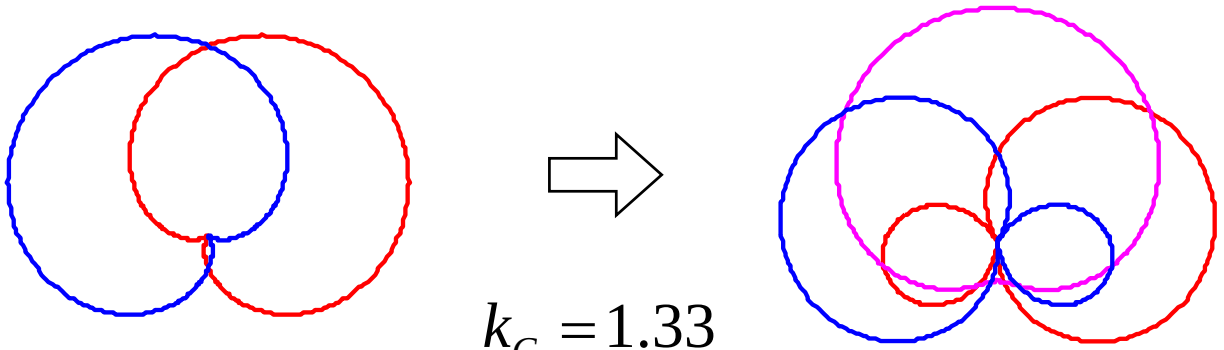
- The front channels L, C, R can also be recorded using 2-channel coincident stereo micing combined with 2-to-3-channel upmixing:

$$L_o = L_i + k_S\left(L_i - R_i\right)$$
$$C_o = k_C\left(L_i + R_i\right)$$
$$R_o = R_i + k_S\left(R_i - L_i\right)$$

- Adding a center channel (C) by summing L and R will make the stereo image too narrow, but this is counteracted when L and R are correspondingly widened – which is the very idea of the above equations. (The indices "i" mean "input", "o" means output.)

The virtual center channel microphone

- If the original recording is made using a *coincident* configuration (e.g. XY), the upmixing process will (a) change the apparent L and R channel microphone patterns, and (b) create a new “virtual” center channel microphone.

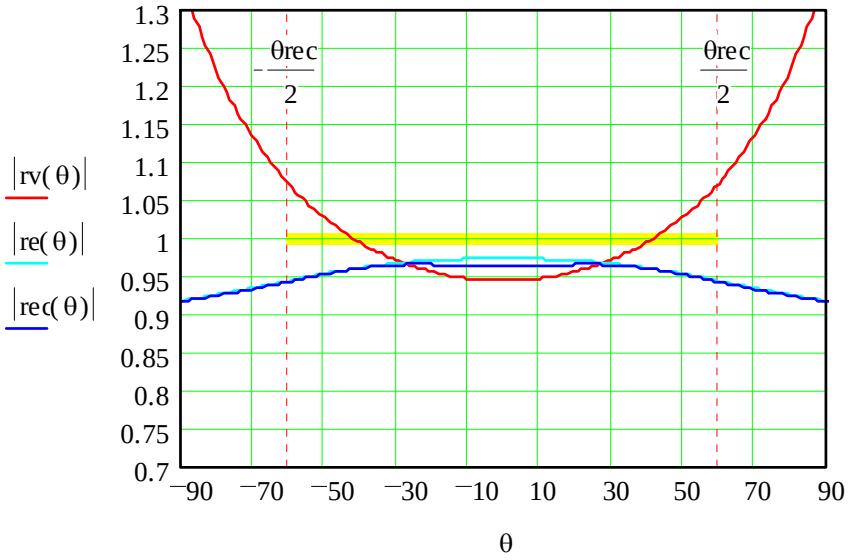


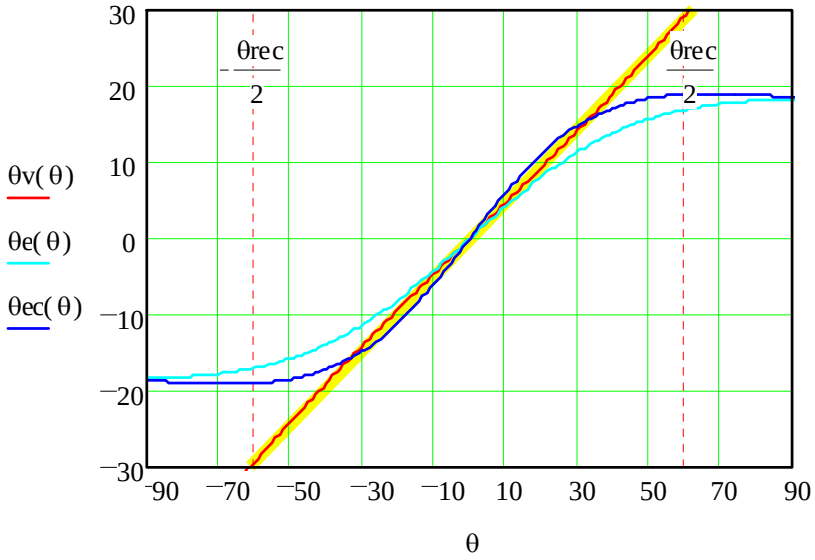
$$k_C = 1.33$$

$$k_S = 1.75$$

- Further image sharpening can be achieved by slightly amplifying the L and R channels, and attenuating the C channel, above about 4 kHz (0-2 dB is enough).
- Mono compatibility remains excellent.

The virtual center channel microphone





Velocity and energy vectors (magnitude and angle) for 3 coincident hypercardioids adjusted for about 100° recording angle (according to velocity vector). Red = velocity vector, cyan = energy vector, blue = energy vector with high-frequency correction, yellow = ideal value.

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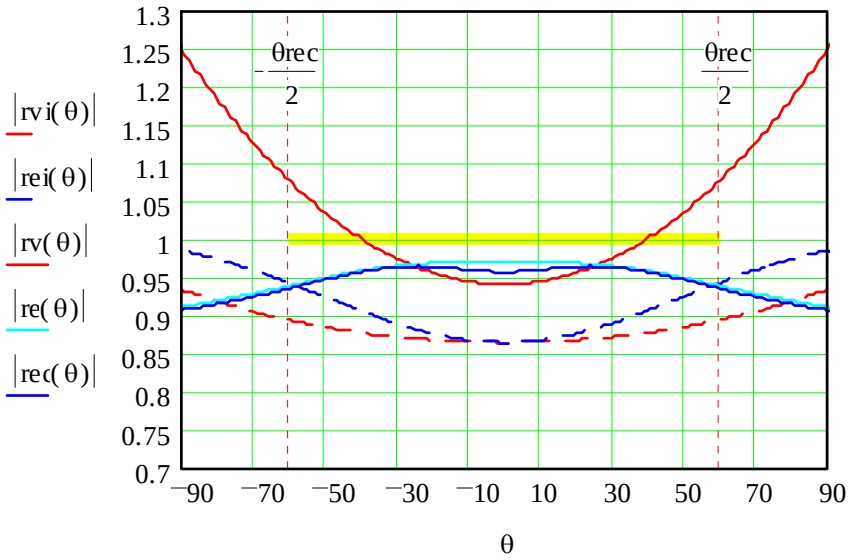
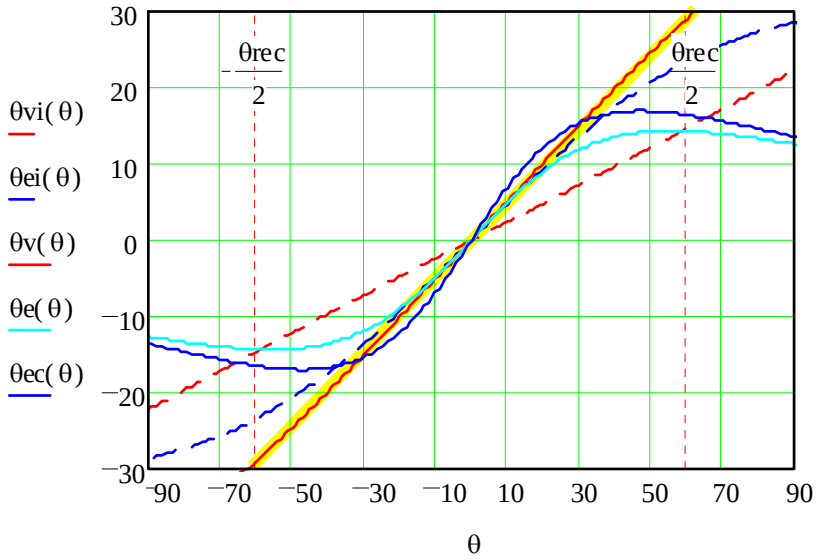
The virtual center channel microphone





Velocity and energy vectors (magnitude and angle) for 2 coincident cardioids + 2-to-3 channel upmixing adjusted for about 100° recording angle (according to velocity vector). Red = velocity vector, cyan = energy vector, blue = energy vector with high-frequency correction, dashed = cardioids without upmixing, yellow = ideal value.

- The similarity of these vectors to the previous case should be noted.
- The behaviour of the energy vector at the edges can be improved by further reducing the upmixing (above 4-5 kHz), but at the cost of comparably reduced center image stability for off-center listeners.

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The virtual center channel microphone

Does it make sense?

- The upmixing process frees one channel for other use (spot micro-phones etc.) – 3 channels are created from 2.
- The panning of spot microphones becomes particularly straightforward, as it is done as conventional amplitude panning in stereo (before the upmixing).
- Main microphone and amplitude-panned spot microphone images become perfectly consistent also for off-center listeners (which is not always wanted or needed, however).
- Other obvious advantages: size, cost, conventional coincident stereo microphones can still be used...

The virtual center channel microphone

General requirements:

- The polar patterns of the microphones must be very stable. This is usually fulfilled only by the small-diaphragm microphones in the highest quality category.
- The microphone capsules must really be as coincident as possible (if one capsule is even as little as 1.5 cm further away from the source than the other, it can be heard as a slight colouration and blurring of the stereo image).

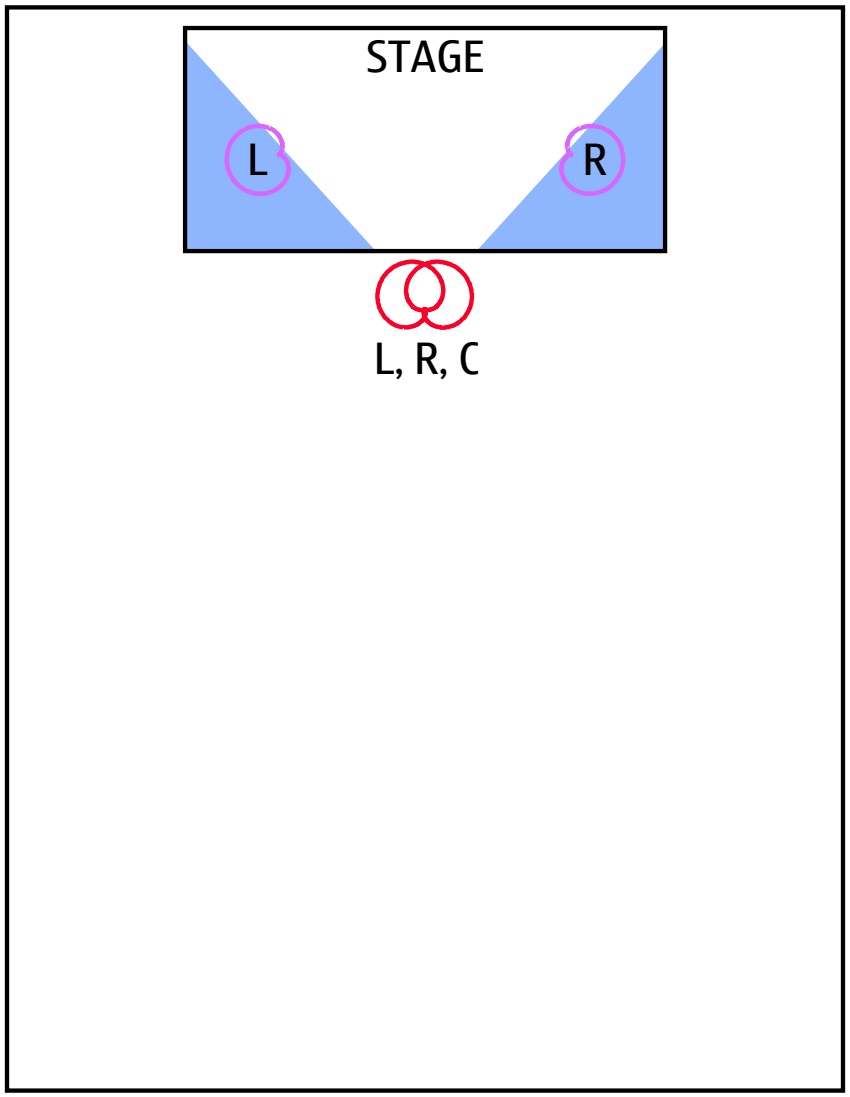
Two microphones (with lateral pickup) arranged for optimum coincidence in the horizontal plane.

The virtual center channel microphone

Any disadvantages?

- The stereo image may become a bit narrower.
- If the ensemble occupies a relatively small angle (and the stereo image has to be more widened in the upmixing), the edges of the soundstage might “fold over” for off-center listeners, and also some annoying out-of-phase effects may become audible.
- There are ways to reduce or eliminate both of these effects, however: good recording of ambience and early reflections, use of flanking cardioids at the left and right edges of the stage, or additional rear-facing cardioids (described below).

Use of flanking microphones



- To further solidify the extreme edges of the stage (and widen the stereo image somewhat), two additional flanking cardioids can be used as shown.
- To prevent blurring of the stereo image provided by the main pair, the flanking microphones should pick up as little from the more central parts of the stage as possible, and should be mixed in with utmost care.

The ambience

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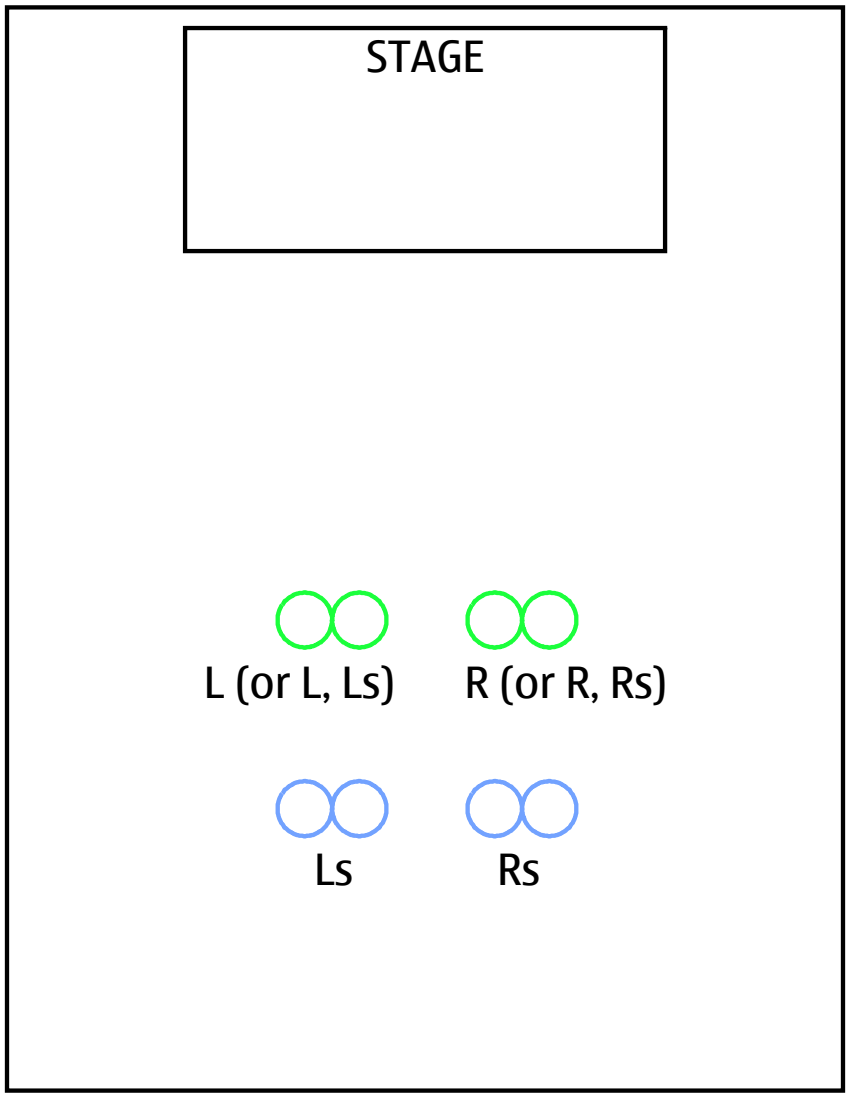
Spaced omnis & the Hamasaki square



- Ambience can be recorded using 2 spaced omnidirectional micro-phones (for the Ls and Rs channels) further back in the hall – however, this may occasionally cause too much leakage of direct sound into Ls and Rs.
- A more advanced ambience recording setup is the ”Hamasaki square” (pictured at left) typically consisting of 4 figure-8’s. However, even the figure 8’s have a couple of disadvantages in this application: (a) their ”rejection” sector is very narrow, (b) their pickup of low frequencies (essential for envelop-ment) is usually weaker.

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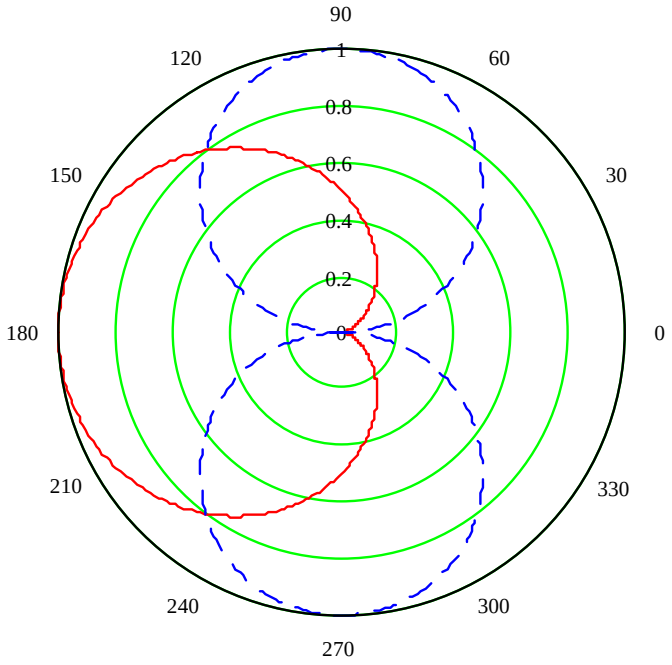
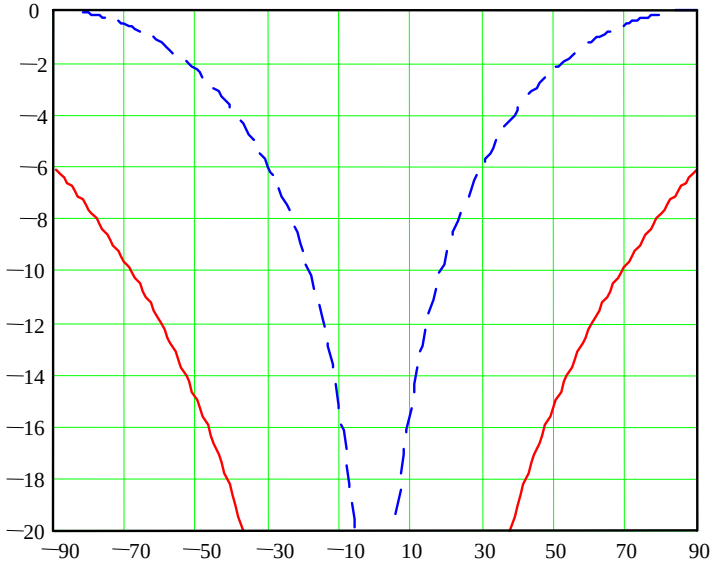
Cardioid vs figure-8: attenuating sector

- In a cardioid microphone (red, solid line) the attenuating sector is at least 3 times as wide as in a figure-8 (blue, dashed line).





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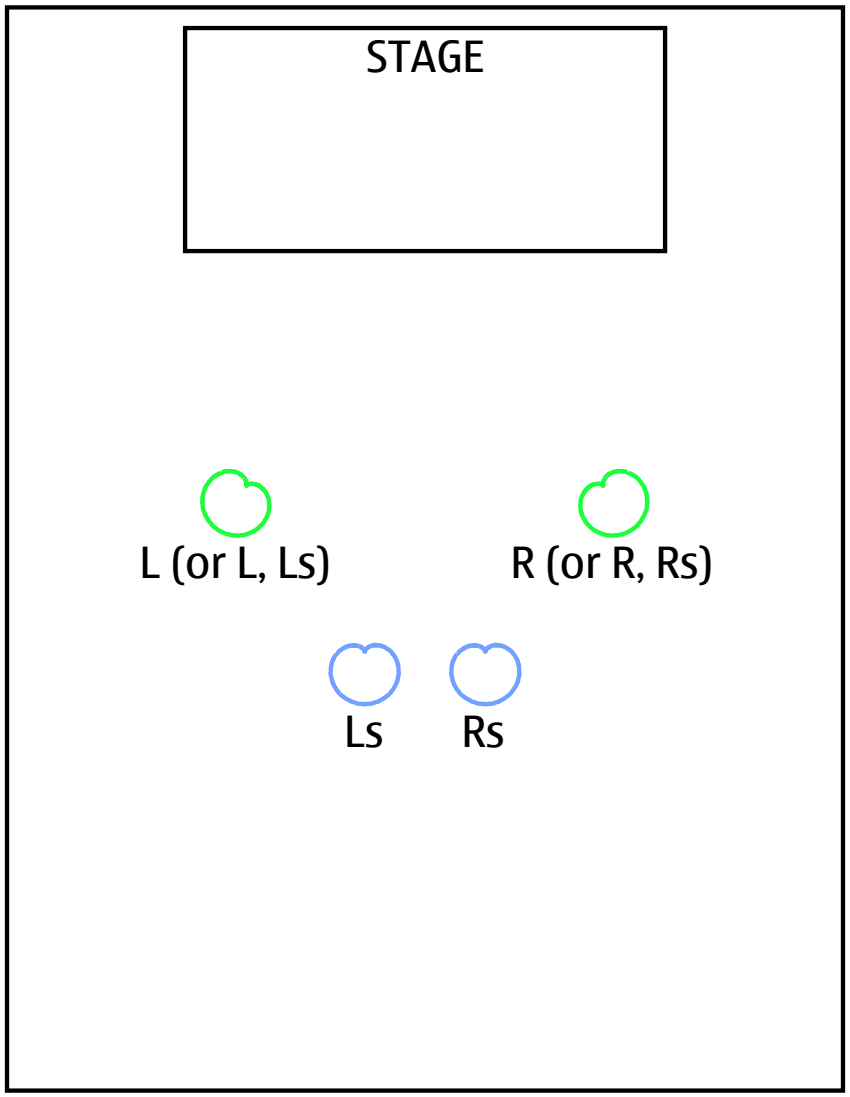
Modified ambience pickup array



- Cardioids arranged as shown on the left (facing away from the stage) to achieve a very smooth reproduction of hall ambience with minimum leakage of direct sound.
- The distance between the rear cardioids should not be too large in order to prevent possible ”hole in the middle” effects for higher-frequency hall sounds such as applause. About 0.2-0.5 m is a good starting point.
- The front cardioids may be mixed either to L and R, or ”in between” to both L and Ls, and R and Rs.

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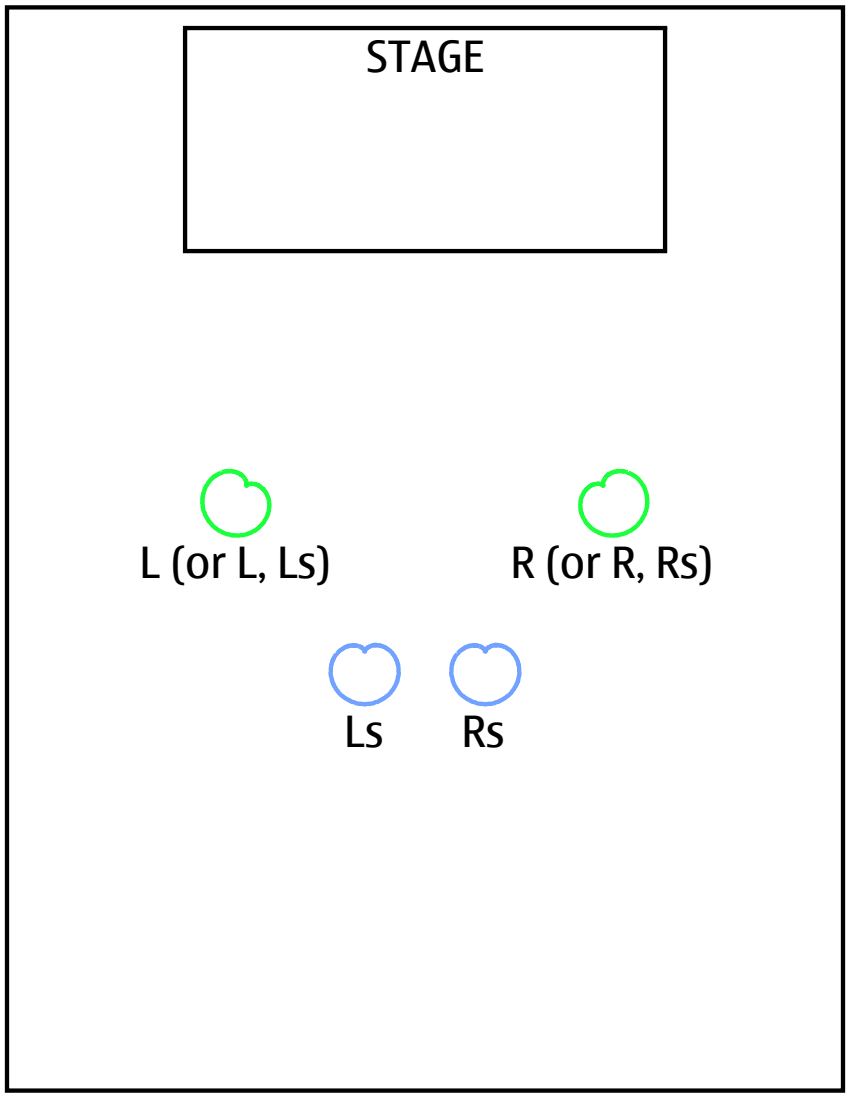
Modified ambience pickup array



- For the front cardioids a wider spacing (a few metres) is preferred since now a ”hole in the middle” is actually *desired* – this hole is to be filled in by the accurate stereo image provided by the coincident main microphone setup.
- If cohesive reproduction of sound sources (or early reflections) at the sides of the hall is particularly important, the front pair may have to be moved closer to the stage.

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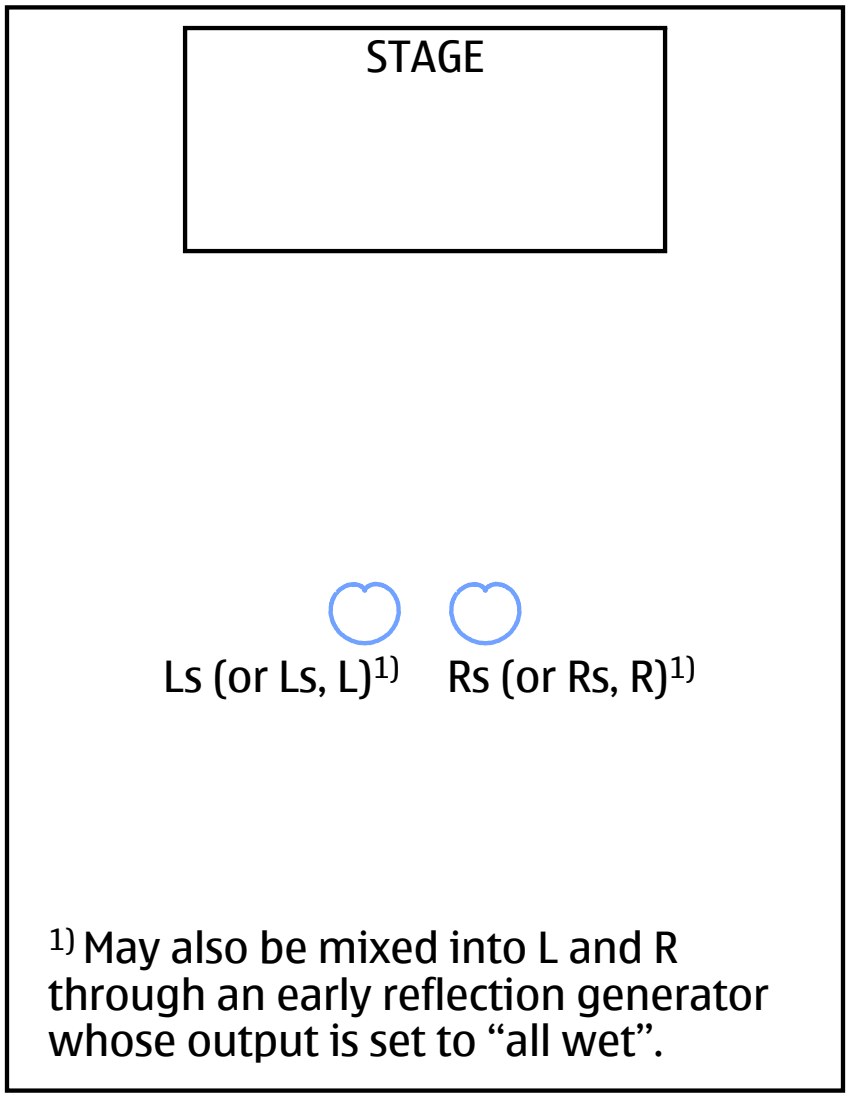
”Minimum” setup for ambience pickup



- 2 microphones is a minimum for acceptable ambience pickup, but for even better results the signals may be routed to both lateral loudspeaker pairs at once (using suitable weighting, i.e. mostly to Ls and Rs but also a little bit to L and R).
- A valid and working method is to generate early reflections from the recorded Ls and Rs signals and route these to L and R. This allows for some further tuning of the temporal envelope of the ambience. (As an example, it is usually desirable to suppress some of the ”muddying” ambience in the 50-100 ms range.)

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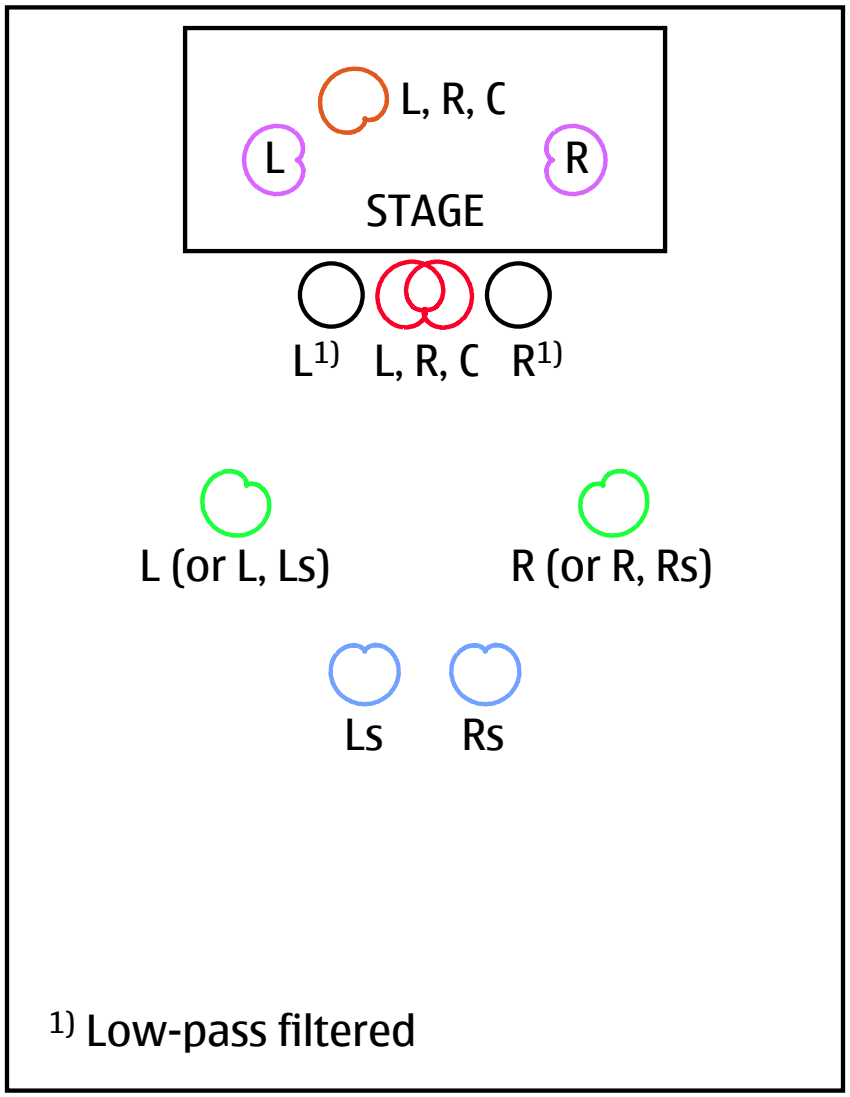
Putting it together &
an improved main microphone setup

Example of full surround recording array



- At the left is shown a setup to which has been added also (a) a spot microphone, (b) a secondary ”small AB” omnidirectional main pair for pickup of very low frequencies (black in the picture).
- The latter should be gently low-pass filtered to provide actual boost only to the frequency range in which the cardioids no longer provide full output. Otherwise e.g. the imaging accuracy will be destroyed.
- An additional advantage of picking up very low frequencies using a spaced pair is the improved sense of envelopment.

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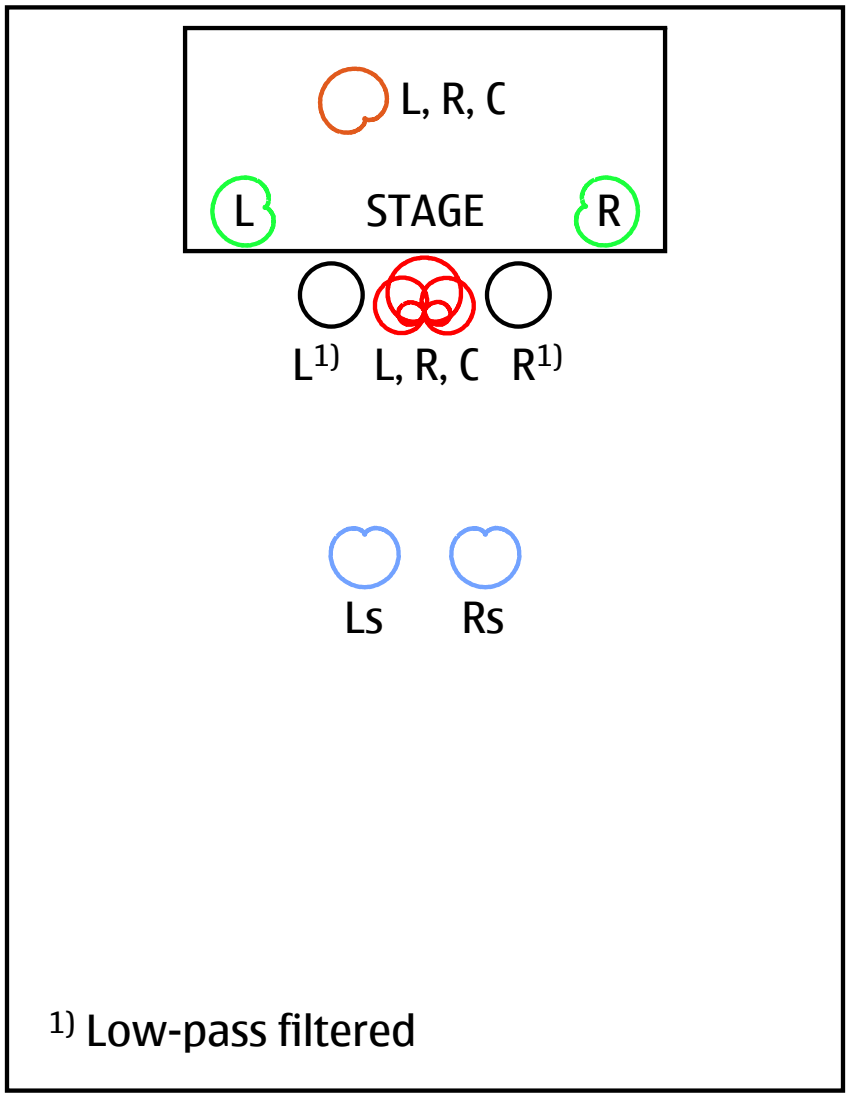
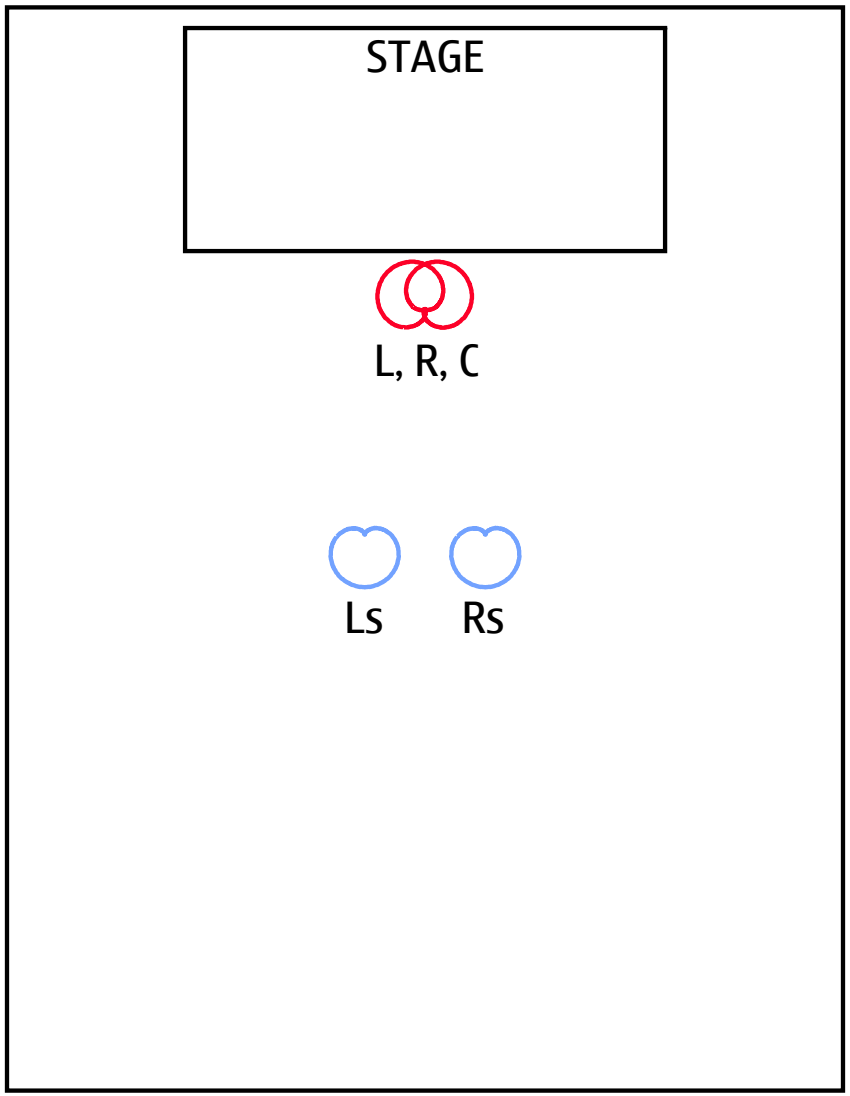
Example of full surround recording array



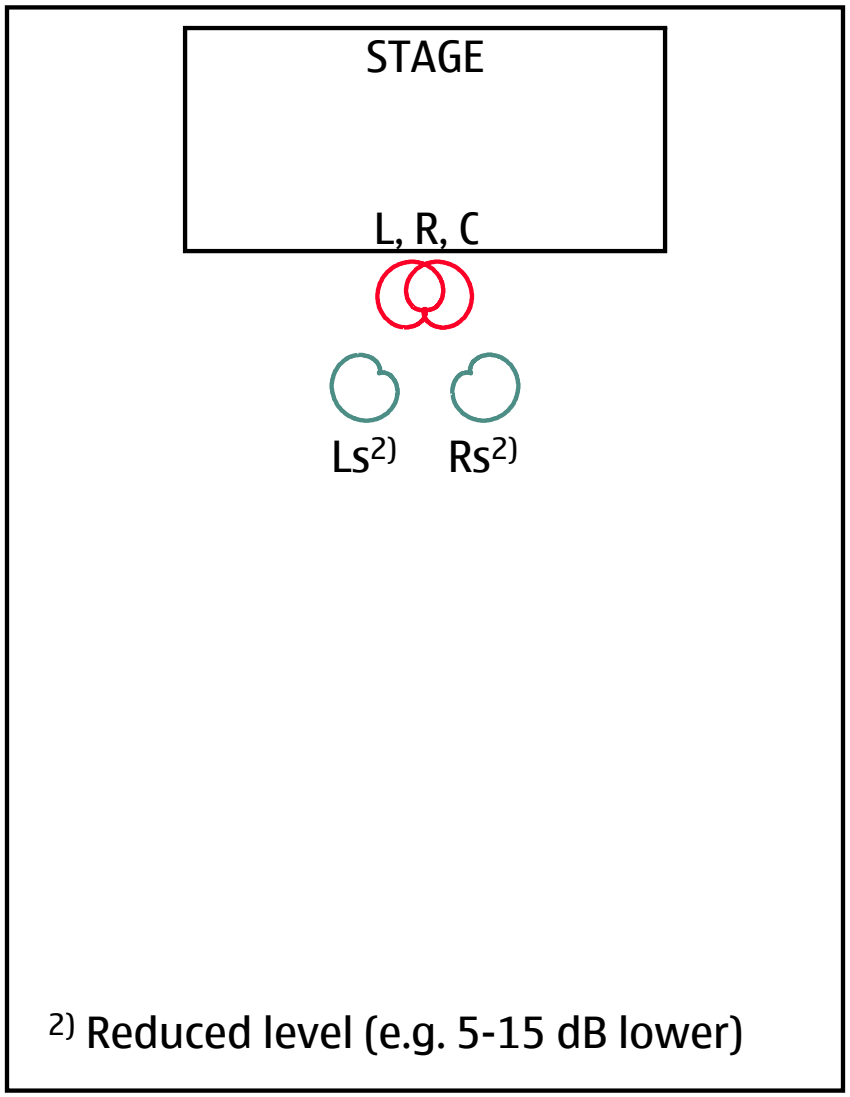
- The coincident main pair can of course also be implemented as 3 coincident super-/hypercardioids as shown here.
- Flanking and front ambience pairs may also be combined, but this requires even greater care when mixing.

Example of minimum surround recording array



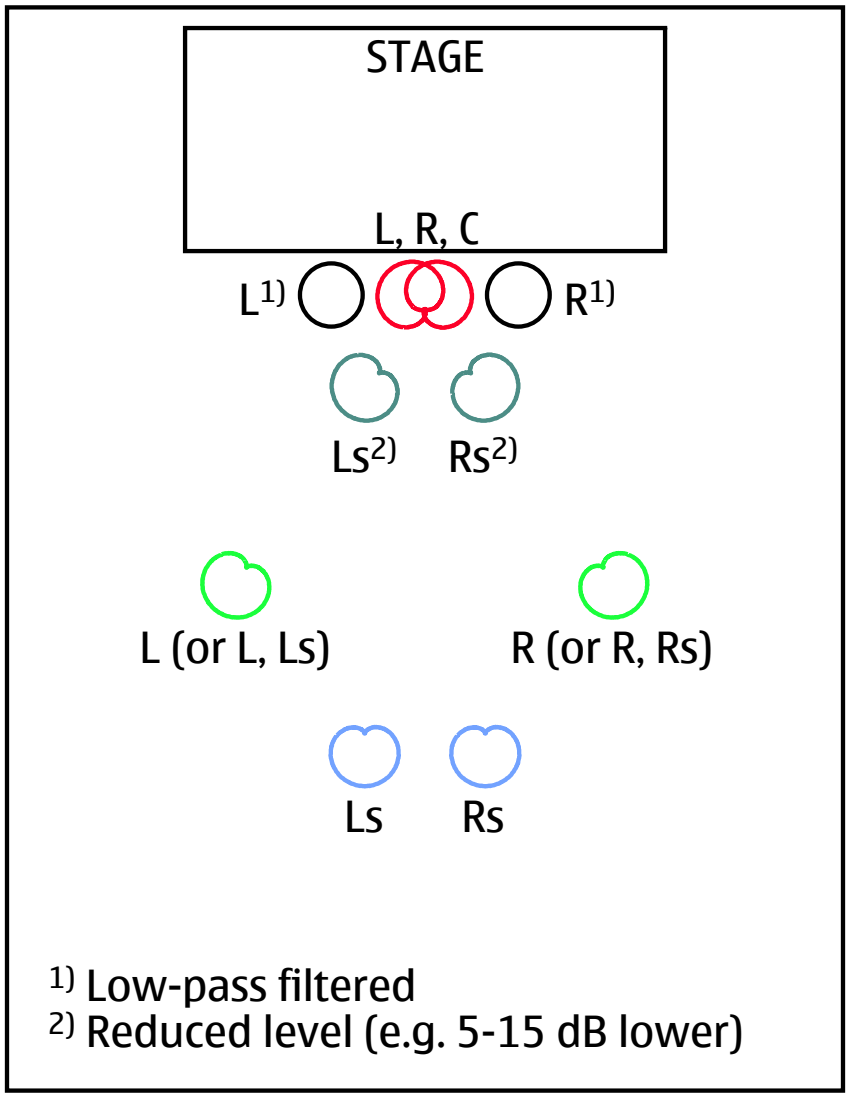
- This setup requires only 4 channels (the C channel may be derived as described earlier).
- Using a ”double MS” configuration (with a single ”M” microphone shared between front and rear channels, as shown by Schoeps in one of their application notes) would require only 3 channels, but at the expense of a reduced sense of depth and envelopment in the ambience.

An improved main microphone for surround



- This main microphone setup (where the distances between the coincident pair and the outer microphones can be some 20-30 cm) can be fitted on a single stand.
- The rear-facing near-coincident cardioid pair (which is mixed in at a lower level) serves 4 purposes: (a) it records some surround information, (b) it widens the frontal stereo image somewhat without degrading imaging sharpness in the L-C-R sector, (c) it makes the sweet area larger, (d) it generally makes the reproduction of ambience more cohesive.
- This setup is not treated in the actual paper.

An improved main microphone for surround



- In order not to degrade imaging sharpness, it is essential to attenuate the rear cardioid pair in the main microphone.
- As before, this main microphone can be complemented with an omni-directional pair for better low bass reproduction.
- As before, the upmixed pair may of course also be implemented as 3 separate coincident microphones.
- As before, the previously mentioned 4-microphone ambience array should be used for the main pickup of ambience.

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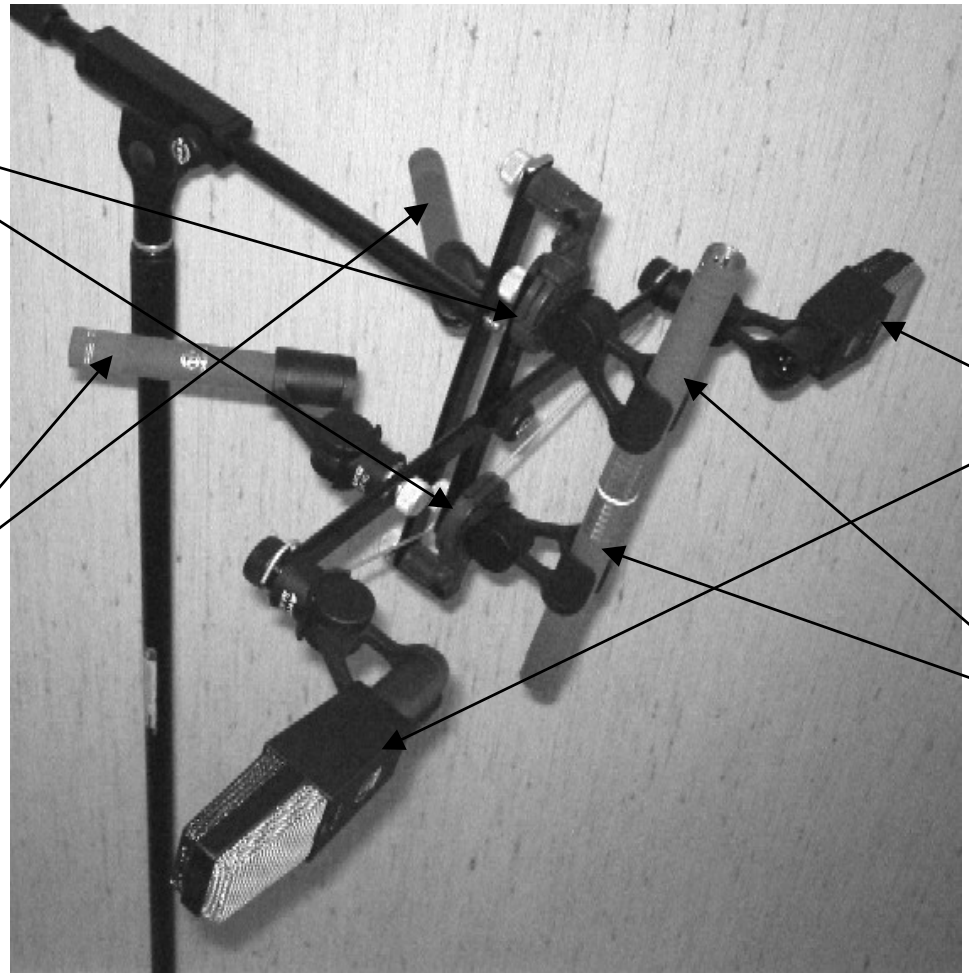
An improved main microphone for surround



Main microphone setup as used by the author (shown without cables for clarity).

Conclusions

- The balancing of optimized recording of (a) the central L-R-C image, (b) the L and R ”edge” image, and (c) the L-Ls-Rs-R ambience provides an effective way of combining imaging sharpness, stereo image stability, and depth.
- Using backward-oriented cardioids for all ambience pickup ensures minimum leakage of direct sound to the rear loudspeakers.
- The 2-to-3 upmixing method works well when the original recording is coincident. Synthesizing a ”virtual” center channel microphone from a coincident stereo pair (of suitably high quality) is a valid method. (Note: a special case of this upmixing method has been patented by M. Gerzon/ Trifield Productions.)
- A minimum setup for surround recording that can still provide acceptable performance (under terms defined in this presentation) is 4 microphones.
- A main microphone setup can be constructed that combines the sharp imaging with slight improvements in stereo image width and sweet area.

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Surround & mic technique DEMONSTRATION

- In lecture room next door
- Starts today at about 16.40
- Goes on tomorrow
- Computer-generated examples + real hall recording + concert recordings
- About 20-50 minutes depending on how much people want to hear

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