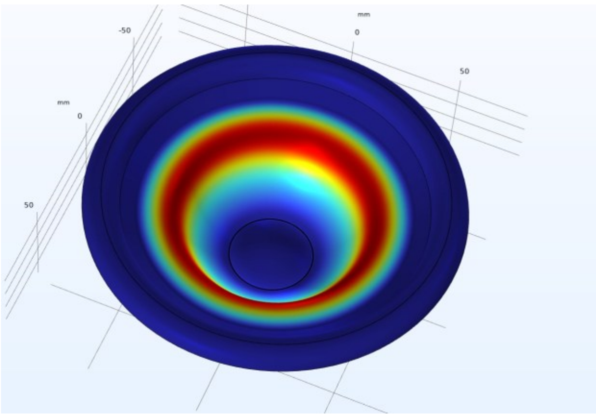
CURRENT RESEARCH WORKFLOW AND DEVELOPMENT PATH

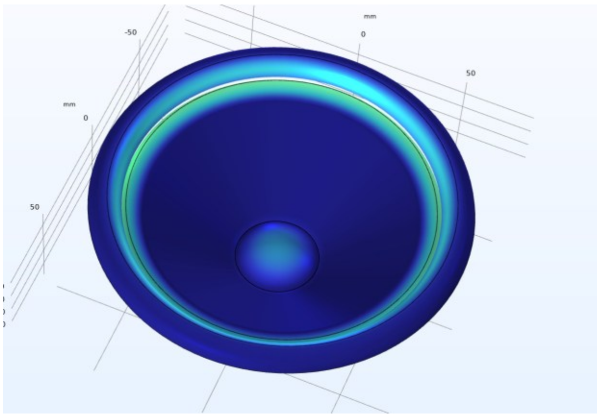
PHYSICAL LAB Rayleigh Add-in

See which regions of a vibrating surface support or oppose a selected receiver response

A surface can move strongly without every region acting in the same acoustic sense. The Rayleigh Add-in decomposes complex normal motion relative to a selected receiver reference, making constructive, destructive and quadrature behaviour visible within a reduced radiation model.



In-phase motion at 3 kHz — regions aligned with the selected common-reference phase in the reduced model



Anti-phase motion at 3 kHz — regions opposing that reference and associated with cancellation in the reduced model

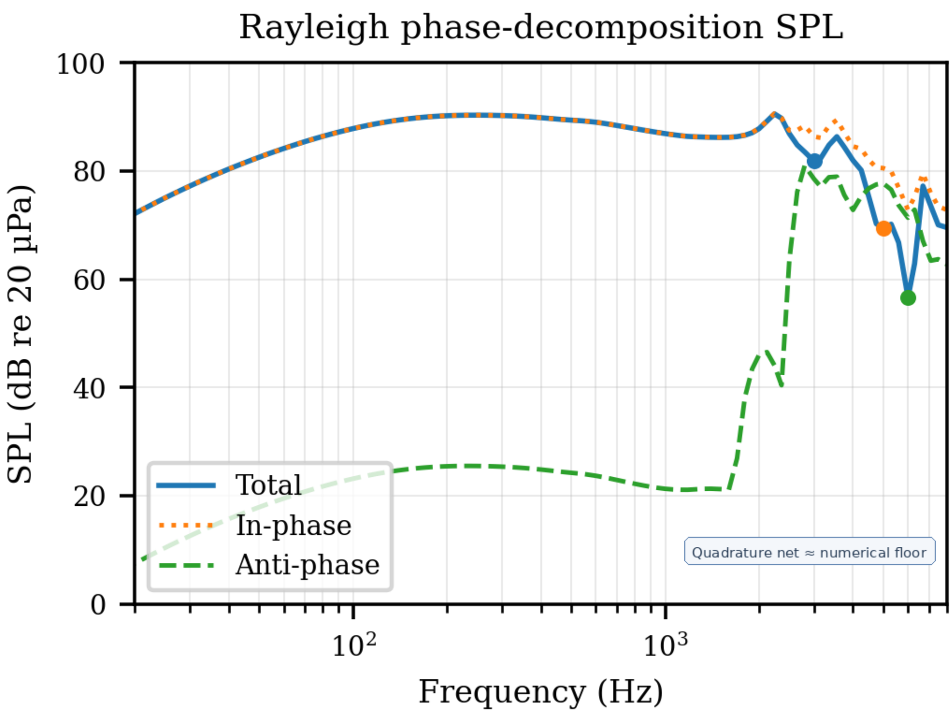
- Locate structural regions associated with constructive or destructive receiver-referenced behaviour.
- Interpret response dips, break-up and cancellation mechanisms instead of relying on displacement amplitude alone.
- Compare design variants and turn motion patterns into testable geometry, material or damping hypotheses.

AVAILABLE NOW	Receiver-referenced in-phase, anti-phase and quadrature decomposition, curved-surface normal-motion treatment and cross-method diagnostics in the validated 2D axisymmetric reference workflow.

How to read the current analysis

The Rayleigh pressure estimate integrates complex surface-normal velocity over the radiating surface. The receiver phase provides the common reference used to split each contribution.

$$p_R(\boldsymbol{r},\omega) = \frac{\mathrm{j}\rho_0\omega}{2\pi}\int_S v_n(\boldsymbol{s},\omega)\,\frac{\mathrm{e}^{-\mathrm{j}kR}}{R}\,\mathrm{d}S$$	Native, editable Word equation. Here v_n is complex surface-normal velocity, R is source-to-receiver distance, ρ_0 is density, ω is angular frequency and k is wavenumber.



Receiver-referenced Rayleigh decomposition across frequency. The total, in-phase, anti-phase and quadrature traces show how the reduced-model balance changes with frequency.

Result	Engineering interpretation
In-phase	Motion with the selected common-reference phase relationship associated with constructive behaviour in the reduced model
Anti-phase	Motion opposing the selected reference phase and therefore associated with cancellation in the reduced model
Quadrature	Motion near ±90° to the reference; useful for tracking transitions that are neither simply constructive nor destructive
Total	Complex sum of the reduced-model contributions at the selected receiver

These maps explain the receiver-referenced Rayleigh approximation. They do not by themselves establish complete full-wave attribution of the radiated sound field.

Practical engineering value today

The normal workflow is designed to be useful before a complete 3D full-wave attribution framework is available. It is strongest as an interpretable mechanism map that connects a solved vibration field to a chosen receiver question.

Application	What the current diagnostic can support	Boundary
Loudspeaker diaphragms and surrounds	Locate regions linked to break-up, cancellation and response dips; compare stiffness, mass, surround or damping changes	Quantitative conclusions remain tied to the reduced radiation assumptions
Panels and enclosures	Relate structural mode regions to constructive or opposing receiver-referenced behaviour	Radiation model must match baffle, geometry and receiver conditions
Machine housings and motors	Prioritize vibrating regions for structural changes or further acoustic investigation	General 3D/NVH cases require a suitable full-wave method
Vehicle and interior structures	Form receiver-specific hypotheses about panels and trim that reinforce or oppose a target response	Not presented as universal exact attribution for arbitrary 3D interiors

A disciplined decision loop

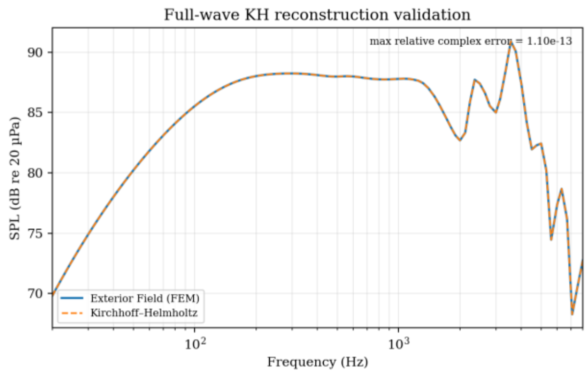
- Choose the receiver, reference and frequency range that define the engineering question.
- Inspect in-phase, anti-phase and quadrature patterns together with receiver SPL.
- Compare a geometry, stiffness, mass or damping variant using the same reference.
- Escalate critical decisions to full-wave FEM/KH or a suitable BEM/FEM-BEM formulation.

TRANSFERABILITY	The contribution-analysis concept can extend to many vibrating structures, but the radiation model and validity assumptions must match the geometry, surrounding acoustic field and receiver definition.

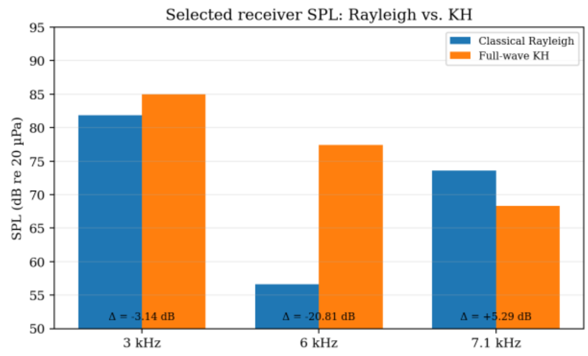
Typical design questions

- Which region is associated with a response dip at the selected receiver?
- Does a stiffness, mass or damping change reduce opposing motion without creating a new problem elsewhere?
- Does the reduced-model interpretation remain consistent with the full-wave receiver result?

Full-wave reference and the next fidelity layers



Symmetry-corrected Kirchhoff–Helmholtz reconstruction versus the COMSOL Exterior Field solution



Selected-receiver comparison: reduced Rayleigh estimate versus full-wave KH result

In the 2D axisymmetric moving-coil reference model, the implemented symmetry-corrected Kirchhoff–Helmholtz reconstruction matches the COMSOL Exterior Field solution at 126 stored frequencies from 1 Hz to 8 kHz. Maximum relative complex error is 1.10×10^{-13}; maximum SPL difference is approximately 4.3×10^{-14} dB. This is numerical cross-validation of the model, not experimental product validation.

The comparison also defines the limit of the reduced interpretation: at 3 kHz Rayleigh gives 81.85 dB and KH 84.99 dB; at 6 kHz the difference is −20.81 dB with a 177.74° phase offset. Strong structural anti-phase motion therefore need not imply equally strong full-wave cancellation at the receiver.

Status	Layer	Purpose
CURRENT	Reduced Rayleigh diagnostic	Receiver-referenced phase decomposition and curved-surface treatment in the validated axisymmetric workflow
CURRENT RESEARCH	KH full-wave reference	Control-surface reconstruction and comparison with Exterior Field in the validated axisymmetric model
NEXT DEVELOPMENT	Full-wave attribution transfer	Patch-transfer, acoustic-transfer-vector or reciprocal methods to relate receiver contributions back to structural regions
PLANNED	3D and imported geometry	Case-specific extension to broader geometry, receivers and directivity questions
LONGER-TERM	Exterior BEM / coupled FEM-BEM	Full-fidelity paths for structural-acoustic and NVH cases where the formulation is appropriate
LONGER-TERM	Reporting and comparison	Repeatable multi-design, multi-receiver visualization and engineering reports

Every higher-fidelity layer will require case-specific verification.

NEXT STEP

Discuss a Vibroacoustic Application

Request an assessment of your COMSOL model and receiver question | physical-lab.com/contact