COMSOL CONFERENCE
2016 MUNICH

DYNAUDIO ReSound
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Phase Decomposition for Loudspeaker Analysis

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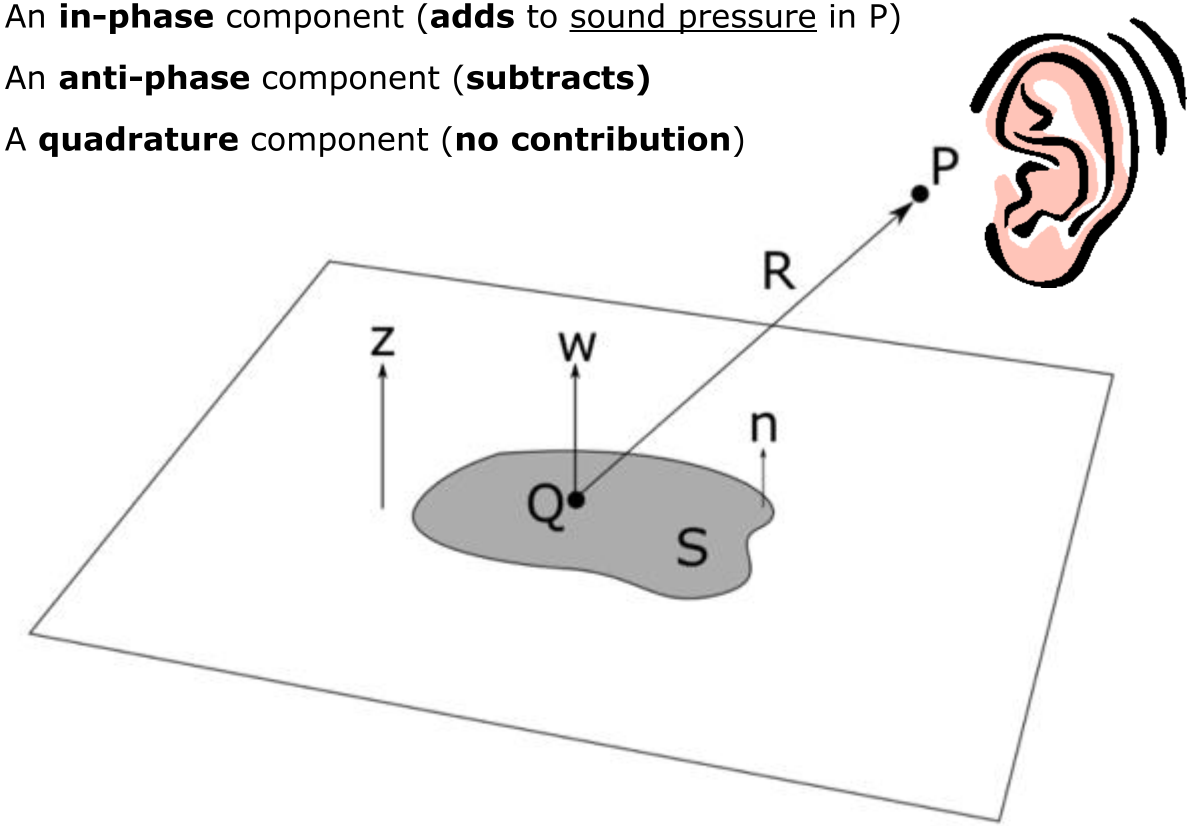
Introduction

- Task: Make phase decomposition functionality that, for a specific observation point P, splits a given total surface vibration into
  1. An **in-phase** component (**adds** to <u>sound pressure</u> in P)
  2. An **anti-phase** component (**subtracts)**
  3. A **quadrature** component (**no contribution**)



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Theory

- Assume
    - Flat vibrating surface…
    - …in flat infinite baffle
    - No obstructions in the acoustic path (no diffraction)

- Displacement components

$$\boldsymbol{w} = \boldsymbol{w}_{in} + \boldsymbol{w}_{anti} + \boldsymbol{w}_{quad}$$

- Total displacement $\boldsymbol{w}$ is known

Theory

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  - Flat vibrating surface…
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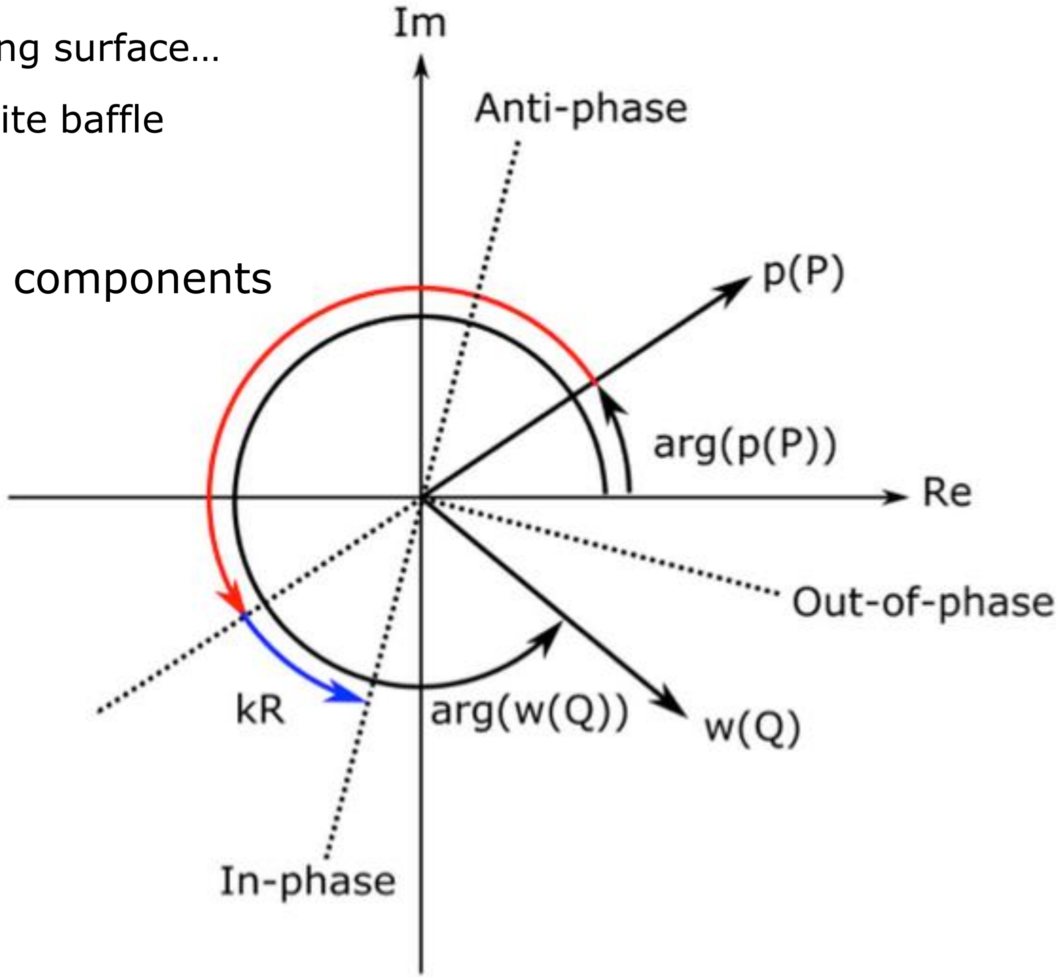

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Method

- Find the (phase of the) sound pressure level in point P using Rayleigh integral:

$$\boldsymbol{p}(P) = \frac{-\omega^2 \rho}{2\pi} \int_S \boldsymbol{w}(Q) \frac{e^{-ikR}}{R} dS$$

An acoustical domain is not necessary.

- Calculate displacement components

$$\boldsymbol{w}_{in}(Q, \boldsymbol{p}, R) = Re^{+}\left(\boldsymbol{w}(Q)\, e^{-i\varphi_{ref}}\right) e^{i\varphi_{ref}}$$

$$\boldsymbol{w}_{anti}(Q, \boldsymbol{p}, R) = Re^{-}\left(\boldsymbol{w}(Q)\, e^{-i\varphi_{ref}}\right) e^{i\varphi_{ref}}$$

$$\boldsymbol{w}_{quad}(Q, \boldsymbol{p}, R) = Im\left(\boldsymbol{w}(Q)\, e^{-i\varphi_{ref}}\right) e^{i\left(\varphi_{ref} + \frac{\pi}{2}\right)}$$

with $\varphi_{ref} = arg\left(\boldsymbol{p}(P)\right) + \pi + kR$

- Feed back displacement components to the Rayleigh integral to get sound pressure components

$$\boldsymbol{p} = \boldsymbol{p}_{in} + \boldsymbol{p}_{anti}$$

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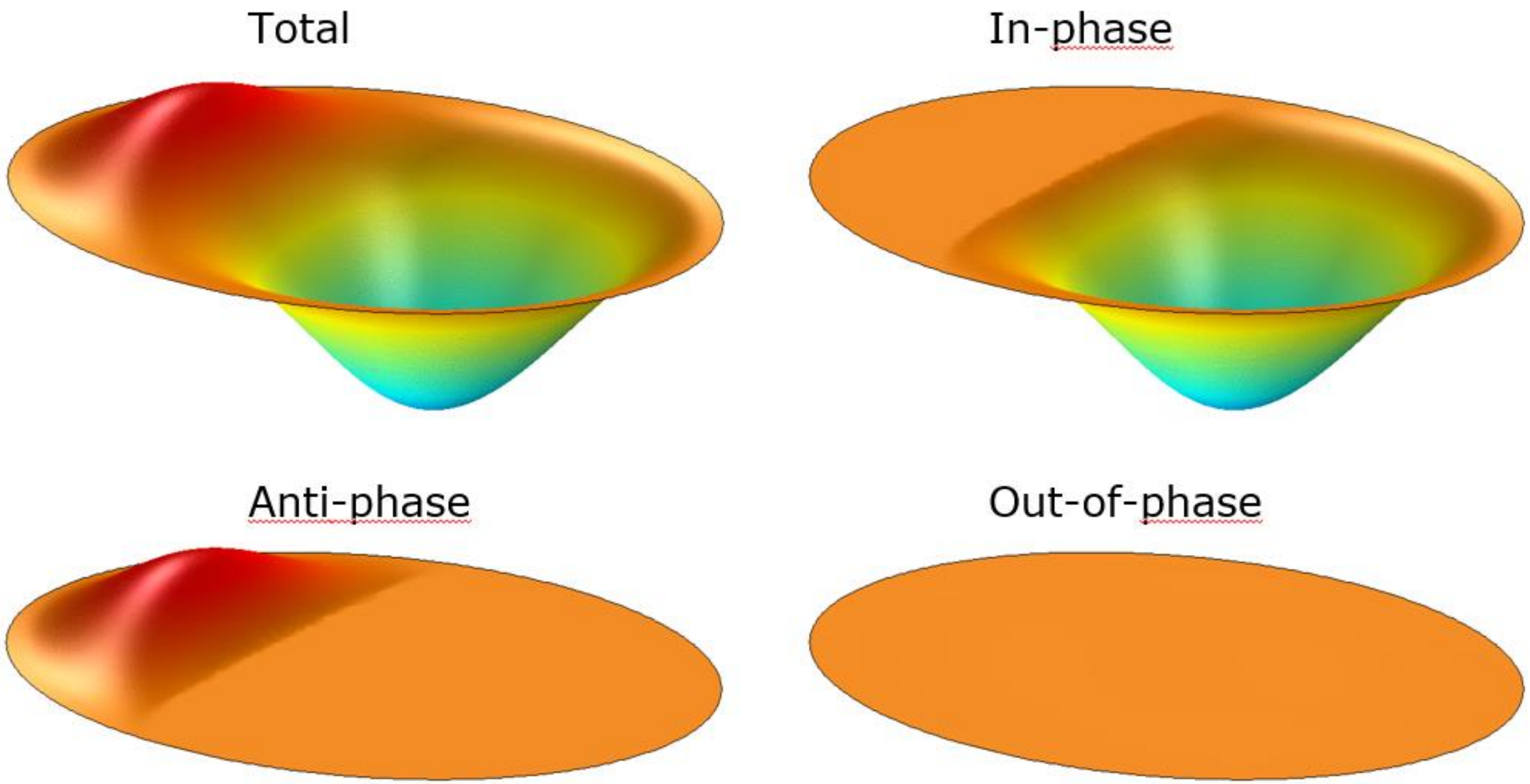
Validation case

- 1.6 kHz, far-field, on-axis



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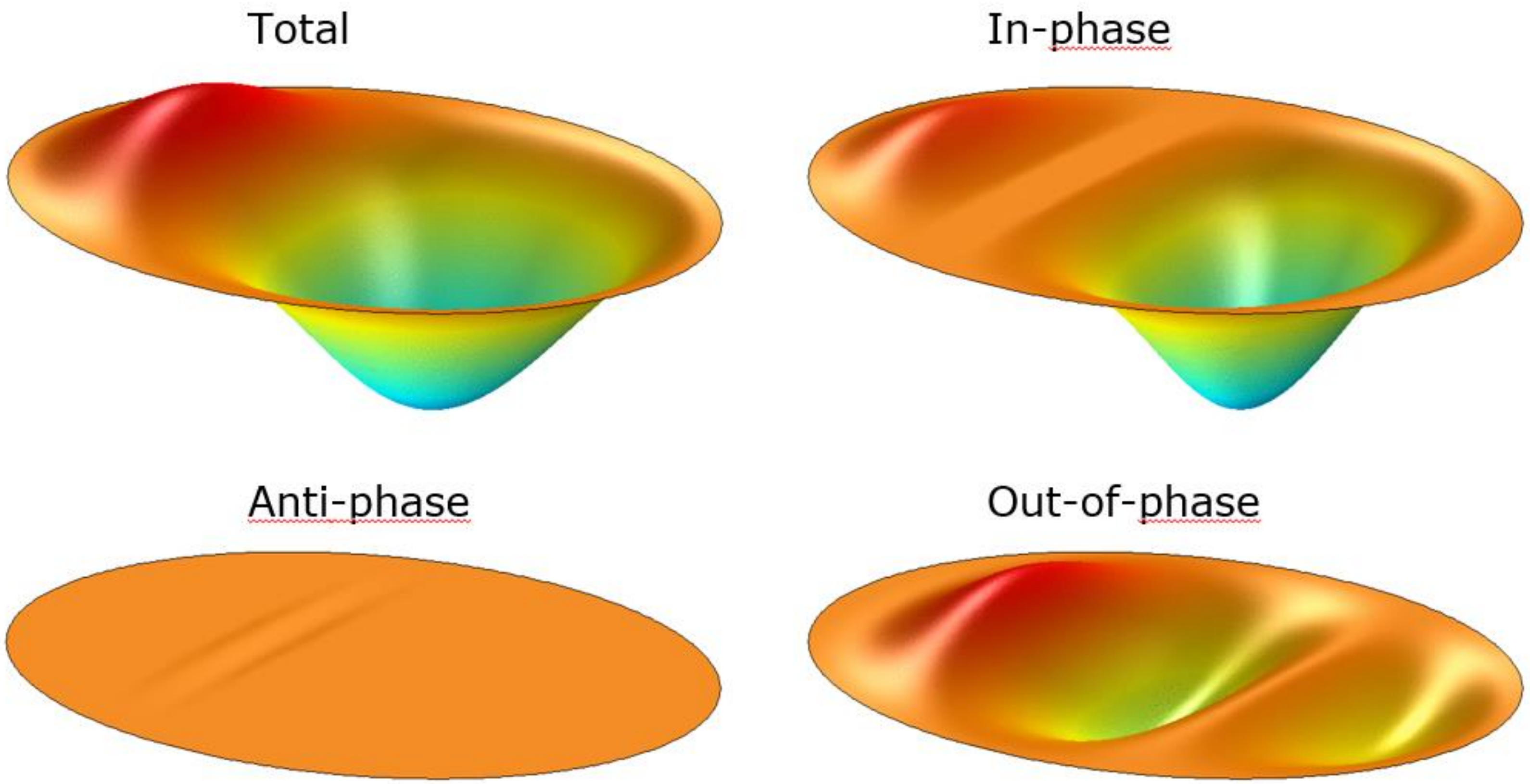

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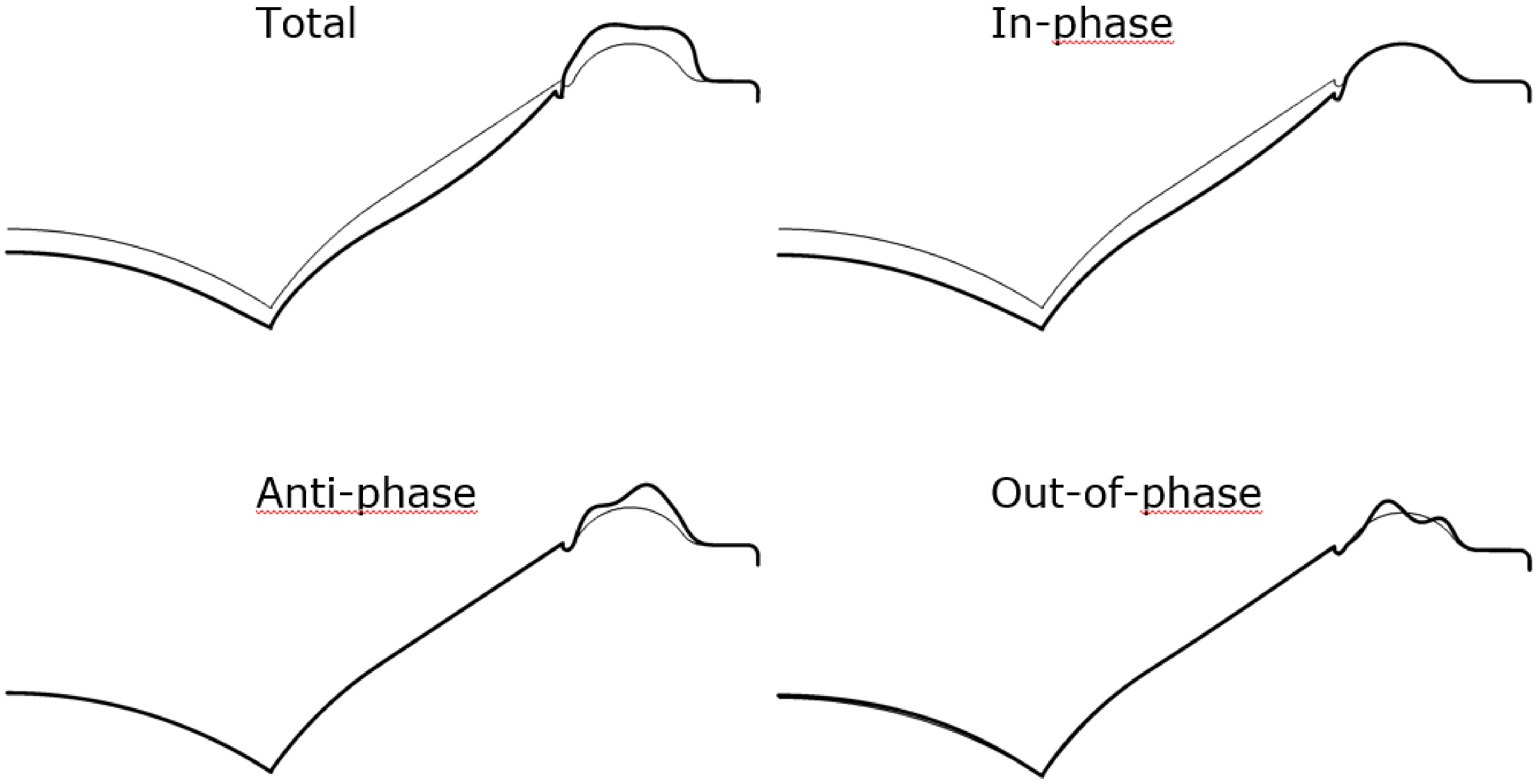
Application case

- Full-range loudspeaker driver, physical components

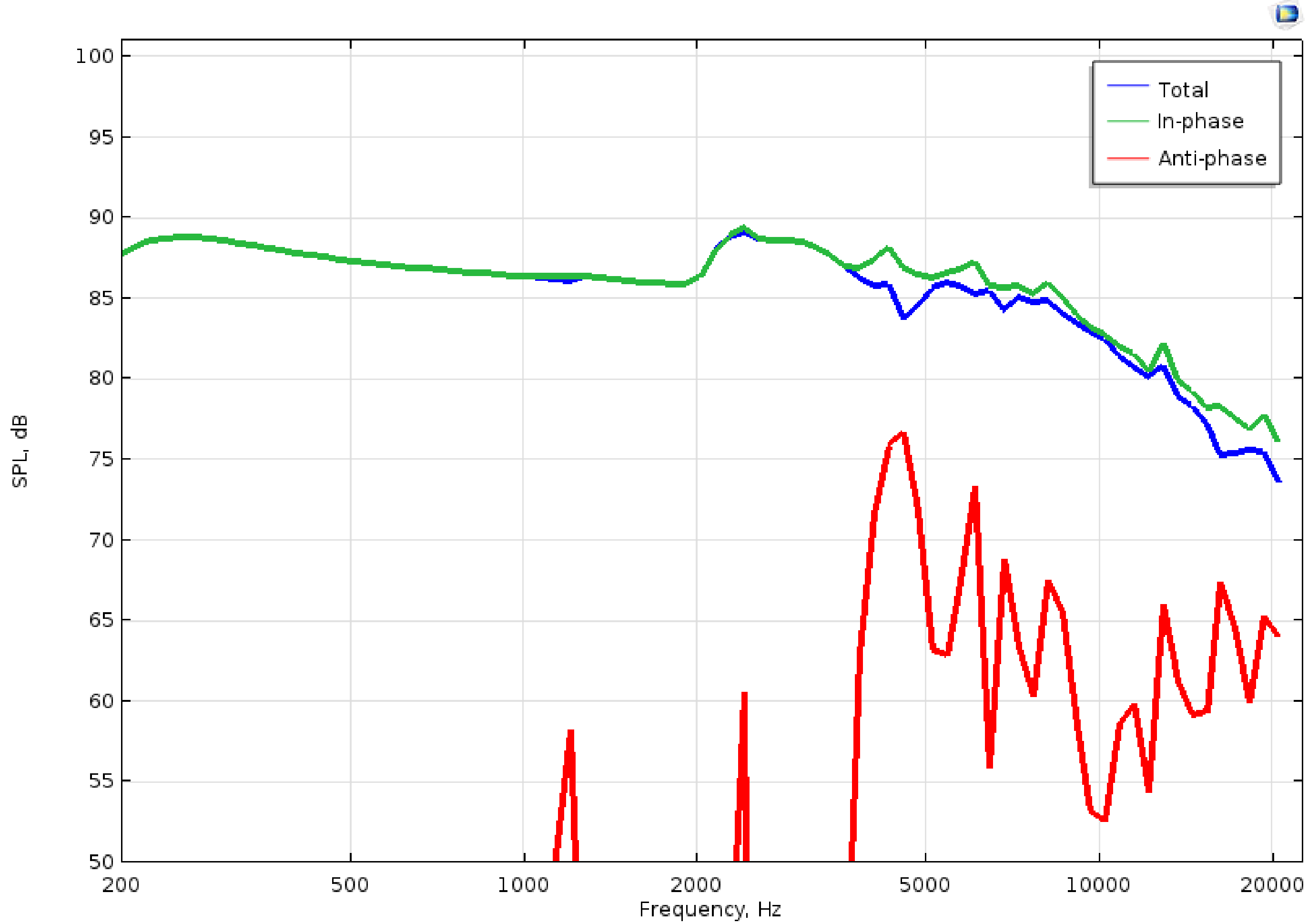
Application case

- Full-range loudspeaker driver, vibration components @ 4.5 kHz



Application case

- Full-range loudspeaker driver, frequency response



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Perspective

- Off-axis design and analysis

Conclusion

- A phase decomposition technique was successfully implemented in COMSOL Multiphysics
- The technique provides insight into the vibration of loudspeaker cones and their contribution to the sound pressure in an observation point

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