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Experimental Relationship Between Tire's Structural Wave Propagation and Sound Radiation

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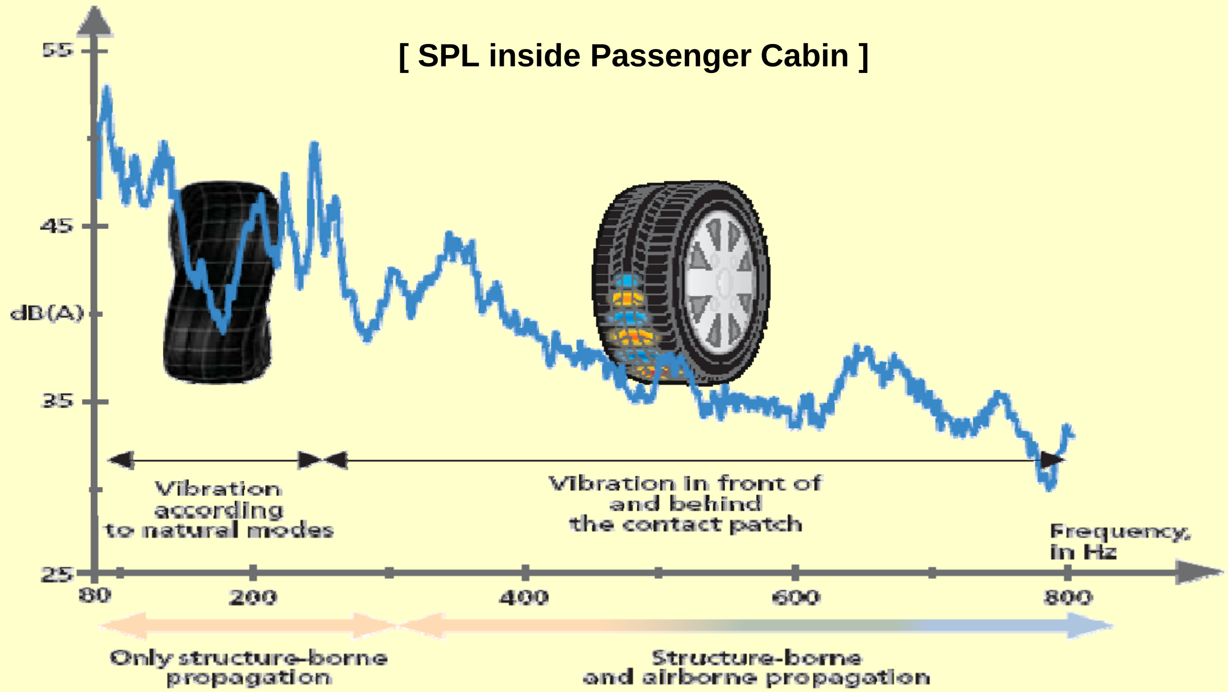
Tire Noise

■ **Significance of Tire Noise**



Vibration Mode (Structure-borne) Cavity Noise	Vibration ☞ Structure-borne ☞ Air-borne	Pattern (Whine) Air Pumping (Sizzle) Horn Effect

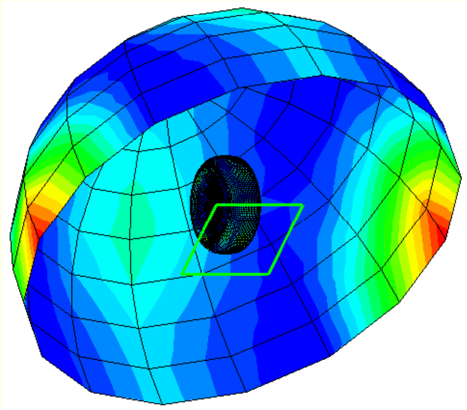
Objectives and Contents

■ **Objectives**

- To identify structural wave propagation on tire surface and its sound radiation experimentally

■ **Contents**

- Structural vibration on tire surface
  - Experimental structural mobility distribution on tire surface
  - Structural wave propagation characteristics on tire surface
- Sound radiation from a tire
  - Sound radiation measurement and calculation
  - Radiated sound power characteristics
- Relationship between structural wave propagation characteristics and its sound radiation



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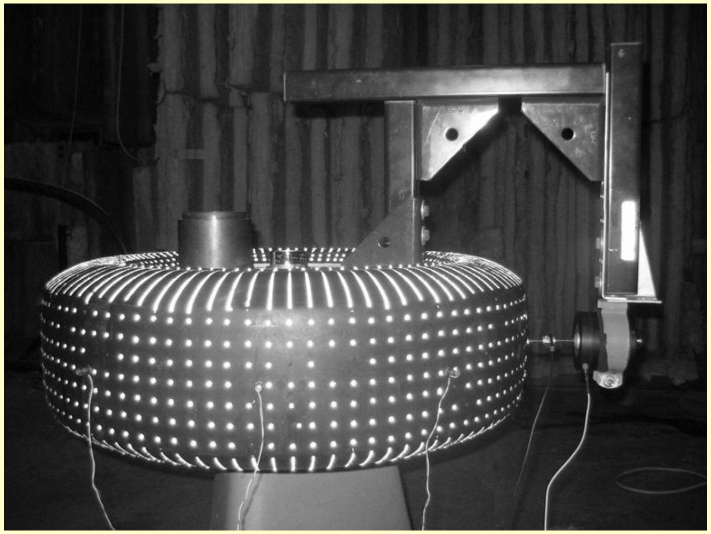
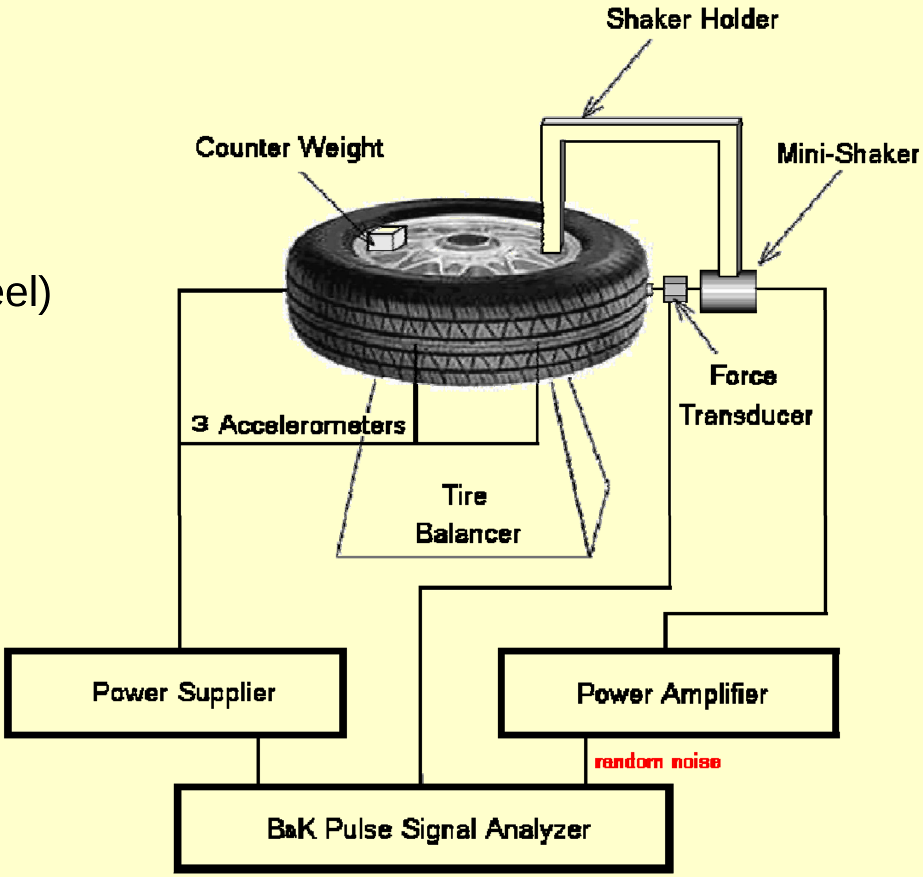
Structural Vibration Measurement

- **Structural vibration measurement on tire surface**
  - Normal harmonic force was applied on the treadband center point of the slick tire (205/70R14 Tire).
  - Structural mobility was measured on whole tire surface. (except on wheel)





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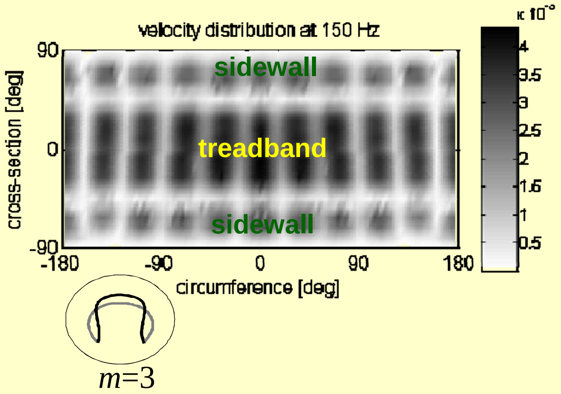
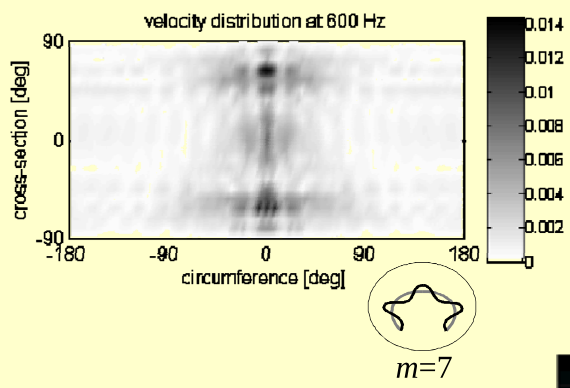
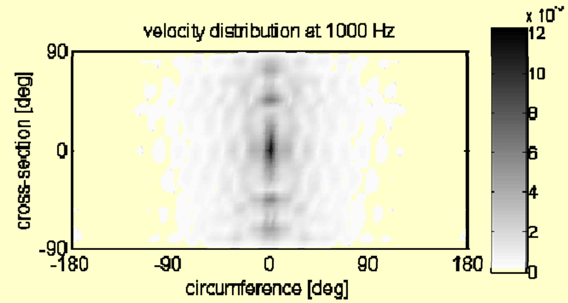
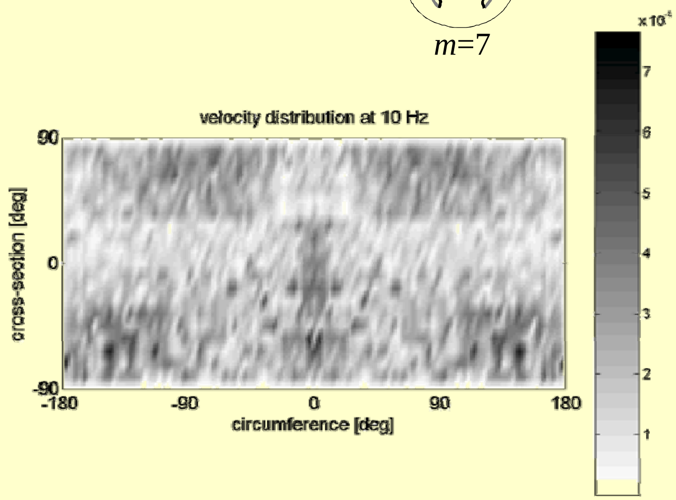
Structural Vibration Measurement

- **Structural velocity (mobility) distribution**









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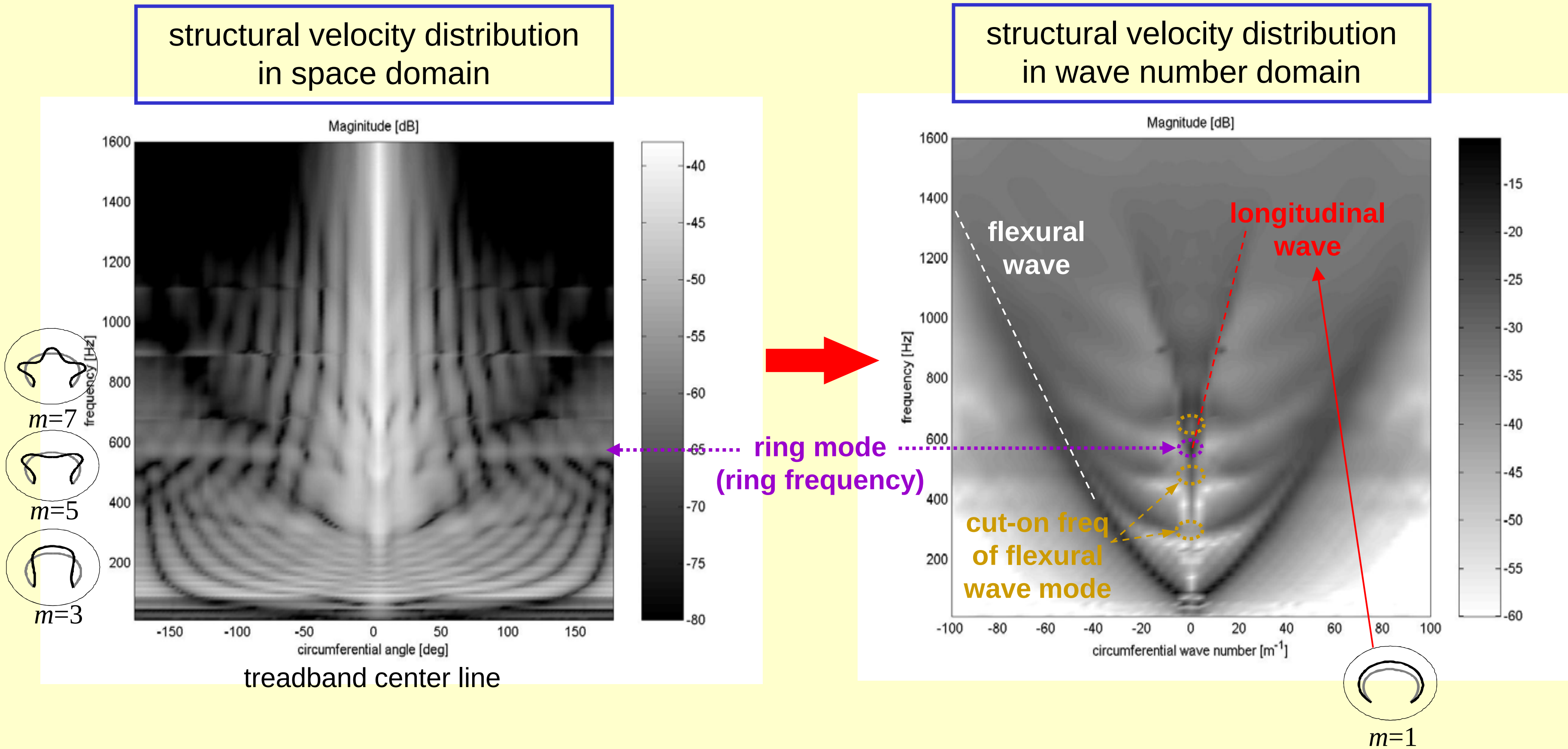
Structural Wave Propagation

■ **Circumferential Wave Number Decomposition**



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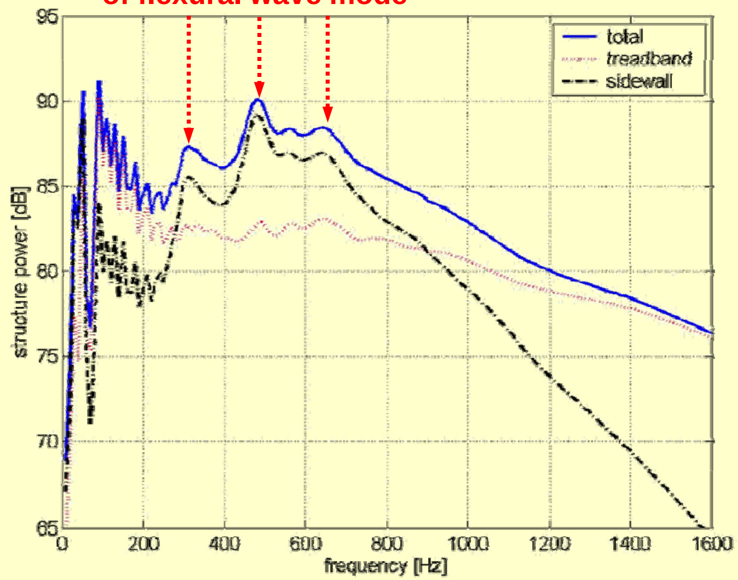
Structural Power Contribution

■ **Structural input power**

$$E = \rho_0 c S_b \left\langle \overline{v}_b^2 \right\rangle$$

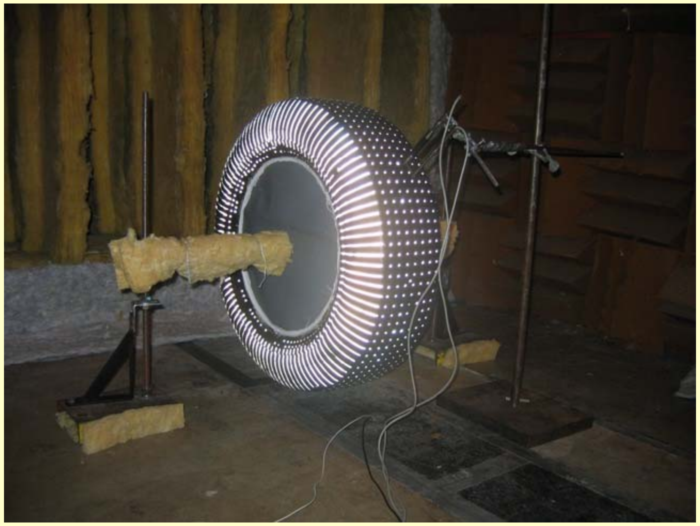


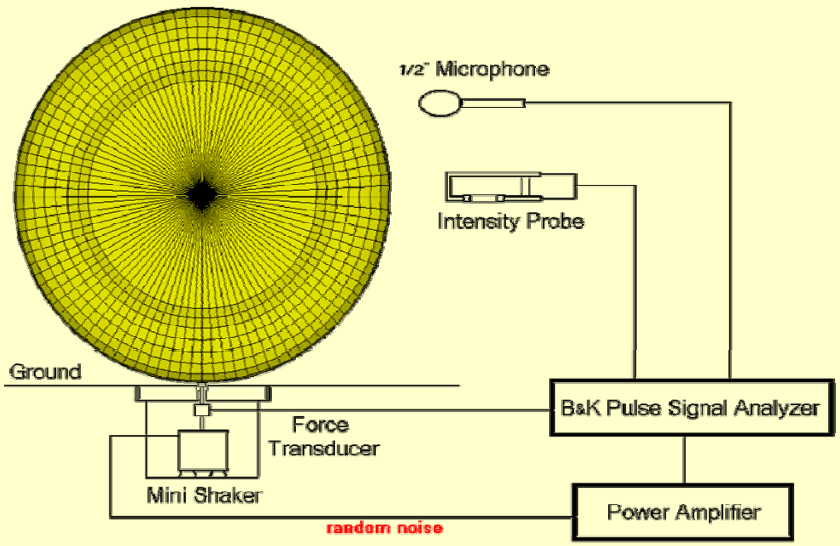
[experiment]

- Structural vibrations below 300 Hz, transferred to the interior cabin, appears mainly on treadband.
- Sidewall's contribution on structural power is higher in the mid-frequency region.

Sound Radiation Measurement

- **Nearfield SPL and intensity measurement and calculation**
  - Nearfield sound radiation resulting from a tire's structural vibration was measured and calculated.
  - Sound radiation was measured in the hemi-anechoic chamber.
  - Radiated sound calculation using D-BEM was based on the structural mobilities obtained in the structural vibration measurement.





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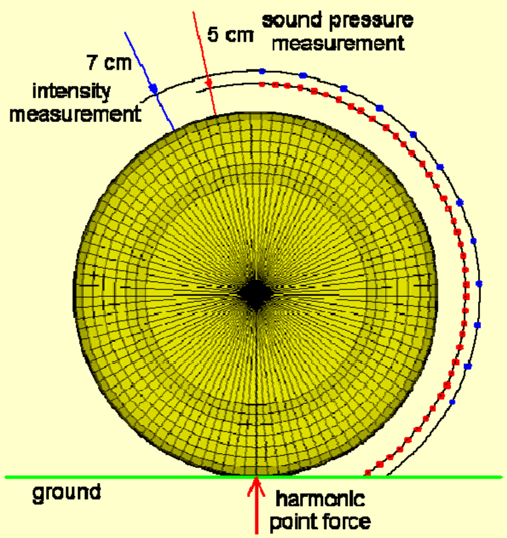
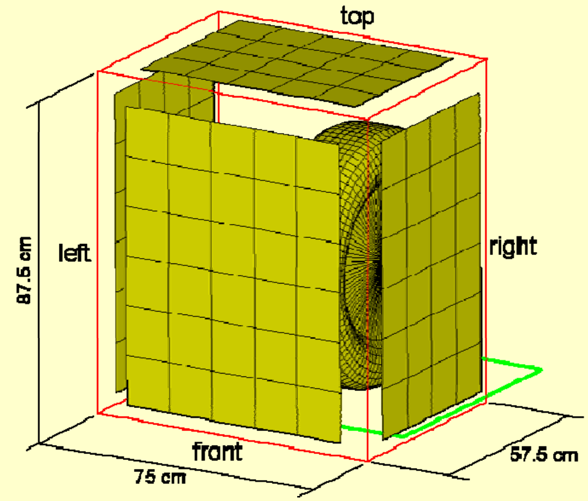
Nearfield Radiation Model

- **Nearfield Sound Radiation Model**
  - To validate BE calculation by comparing with measurement results
  - Nearfield SPL and intensity were measured and calculated in front of treadband centerline.
  - Nearfield radiated sound power was measured and calculated on half-box recovery surface.



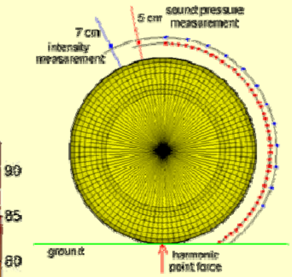
[nearfield SPL and intensity model]

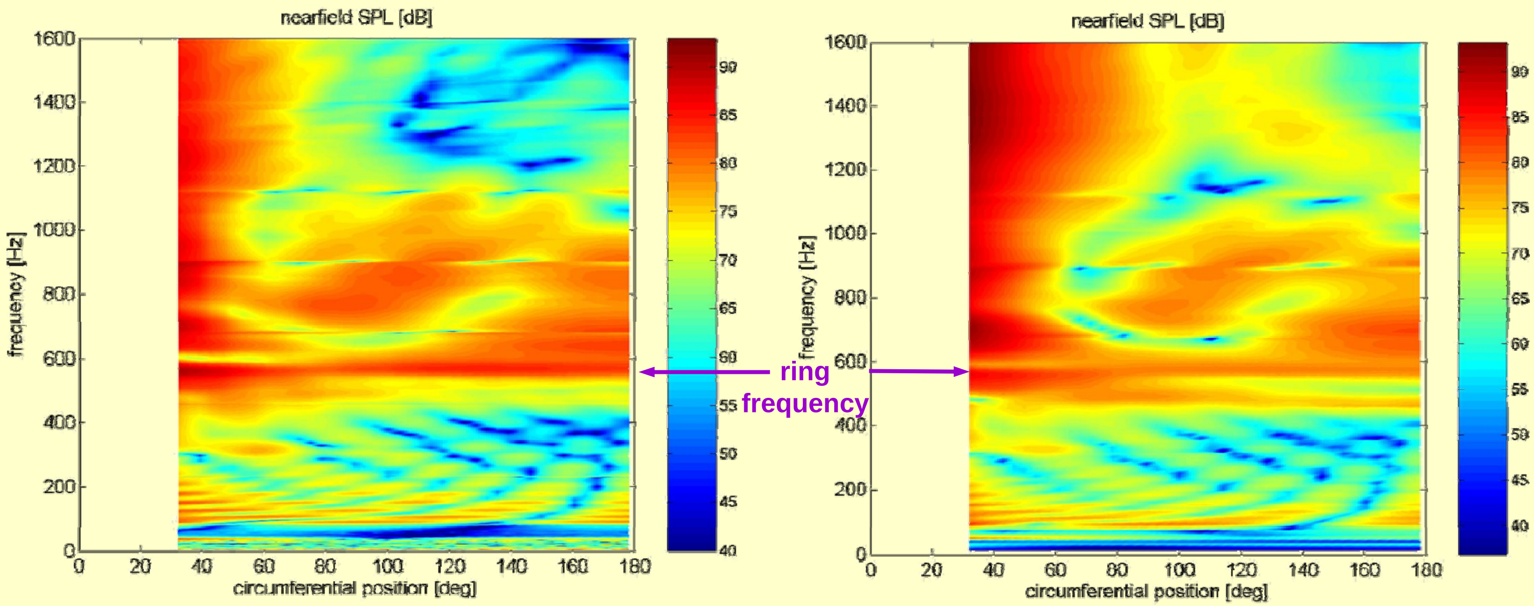


[nearfield sound power model]

Nearfield Sound Radiation

■ **Nearfield SPL distribution**





[measurement] [calculation]

- Generally calculation results are matching well with measurement results.
- SPL at the ring frequency, 570 Hz, is higher all over circumferential positions.
- Region close to contact patch area has high SPL level above 1000 Hz: **Horn effect characteristics.**

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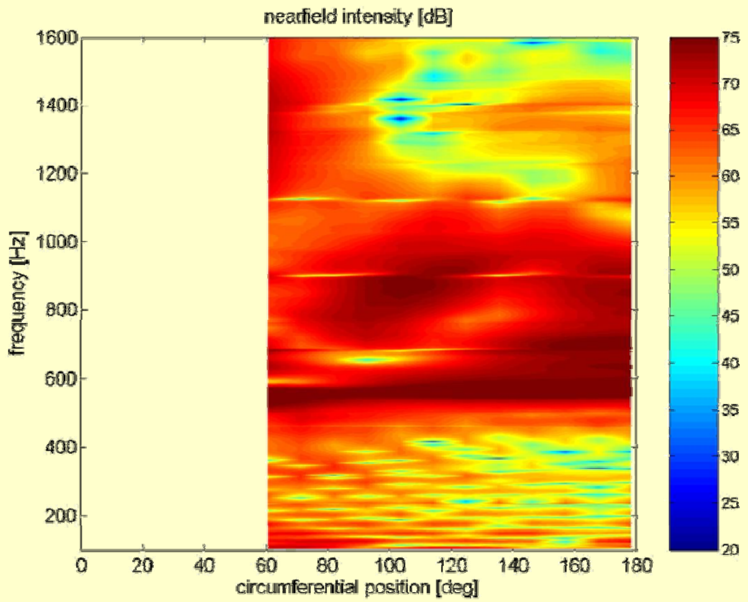
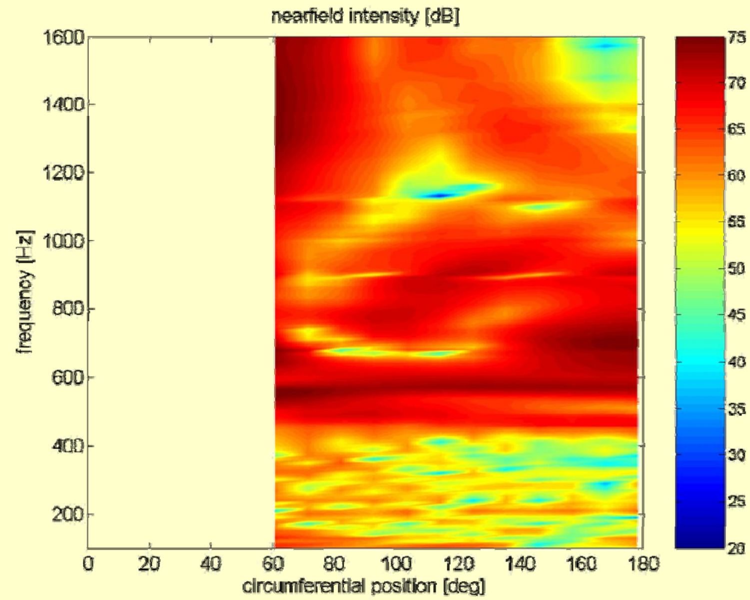
Nearfield Sound Radiation

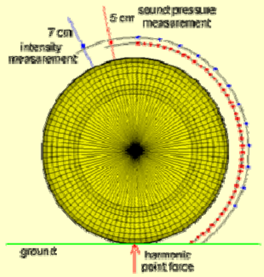
- **Nearfield intensity distribution**



[measurement]



[calculation]



- Generally calculation results are matching well with measurement results.
- Flexural motion on treadband contributes to nearfield sound radiation below 400 Hz.
- Intensity at the ring frequency, 570 Hz, is higher all over circumferential locations.

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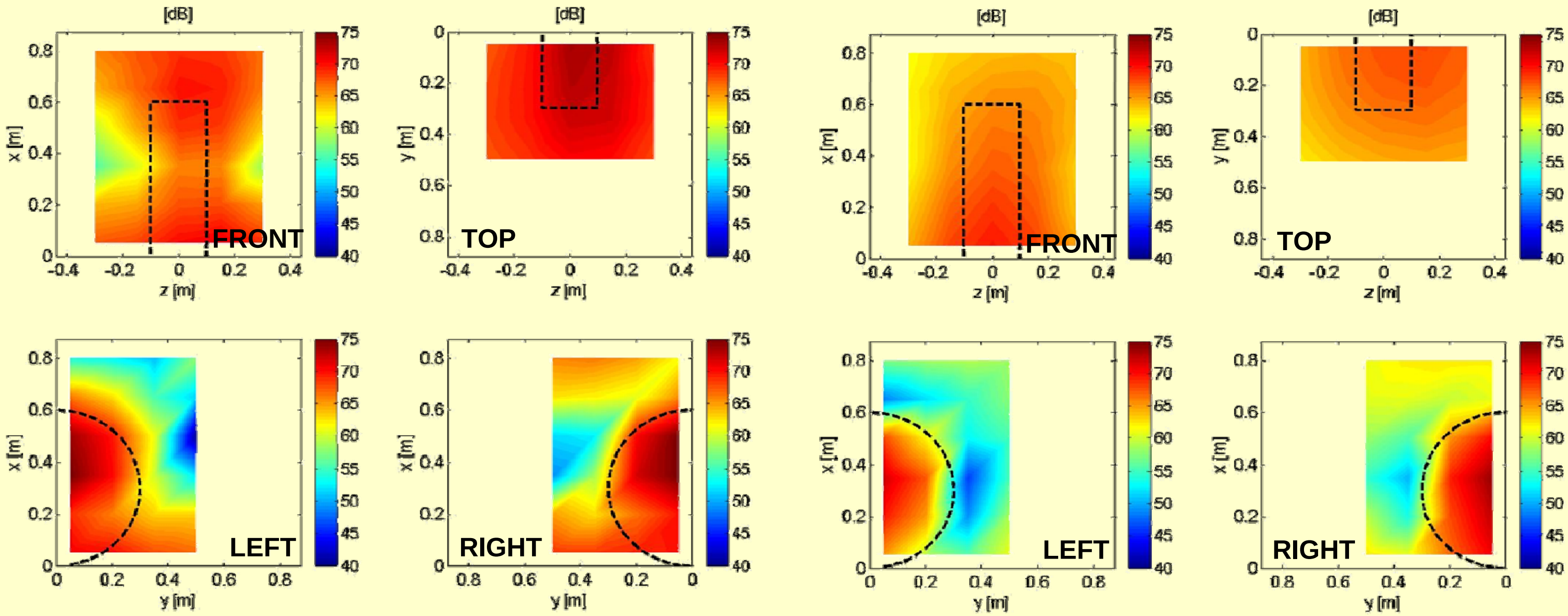
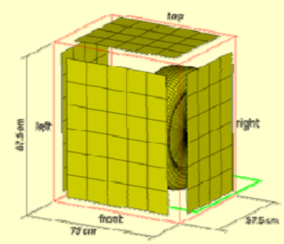
Sound Radiation from a Tire

- **Nearfield intensity distribution at 570 Hz**



[measurement]

[calculation]



- Generally calculation results are matching well with measurement results.
- Sound radiation from whole tire surface dominates at the ring frequency.

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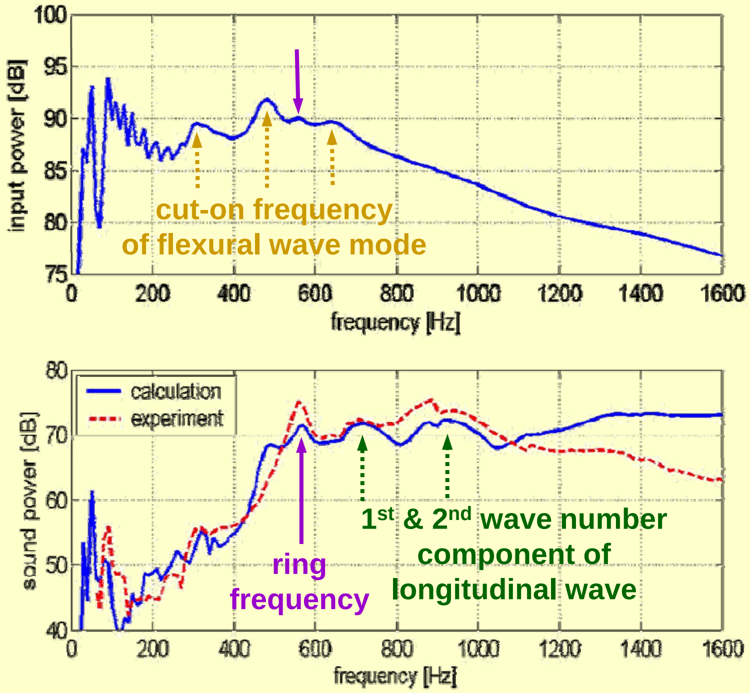
Structural Vibration/Radiation Relationship

- **Relationship between structural wave propagation and its radiation**
  - Radiated power peaks don't match with those of structural power.
  - Structural input power peaks appear at cut-on frequencies of flexural wave mode.
  - **Radiated power peaks appear when structural wave has low wave number.**
  - The peak at 570 Hz relates to '**ring frequency**'.
  - Structural vibration below the ring frequency does not contribute to sound radiation effectively.



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Summary and Conclusions

- The sound radiation resulting from the structural wave propagation was investigated.
- **The relationship between structural wave propagation on the tire surface and its radiation** was identified empirically.

- Most of a tire's structural vibration does not contribute to sound radiation.
- Effective radiation was found at the frequencies where low wave number components of the longitudinal wave appear
- The **fast longitudinal wave** propagating through the treadband contributes on sound radiation at the tire's ring frequency.

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Q & A

~ Thank you ~