Nearfield Acoustical Holography Applied to Sound Radiation From Tires

J. Stuart Bolton
Purdue University, bolton@purdue.edu

Huy-Sang Kwon

Darren L. Hallman

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NEARFIELD ACOUSTICAL HOLOGRAPHY APPLIED TO SOUND RADIATION FROM TIRES

Hyu-Sang Kwon and J. Stuart Bolton
(Herrick Labs., Purdue Univ.)
Darren L. Hallman
(GE Corporate R. and D.)
TIRE CARCASS DISPERSION CHARACTERISTICS - Static

- Tire carcass vibration is composed of superposition of “waveguide modes”
- Circumferential modes occur when $k_\theta \pi d = 2n\pi$

Diagram:
- Fast extensional mode (180 m/s)
- Slow flexural modes (60 m/s - 80 m/s)
- Circumferential modes
  - $m=1$
  - $m=3$
  - $m=5$
  - $m=7$
- Symmetrical modes only
- Frequency vs. circumferential wavenumber, $k_\theta$
TIRE NOISE SOURCE MECHANISMS

• Carcass vibration
  – induced by radial and tangential stress discontinuity at front and rear of contact patch
  – radiated from carcass, especially close to contact patch

• Tread impact
  – radiated from sidewall

• Tread cavity resonance
  – radiated from tire/road interface
  – broadly tuned owing to radiation damping
TIRE NOISE SOURCE MECHANISMS

- Tread impact
- Tread cavity resonances
- Fast carcass mode
- Slow carcass modes

Autopower for reference 1

LogMag (Pa**2)

Frequency (Hz)
MODAL SEPERATION ON ROLLING TIRE

- Waves travelling two ways around the tire

\[ c_p = c_{p/tire} - \Omega r \] shortened wave

\[ c_p = c_{p/tire} + \Omega r \] stretched wave

rolls
EXPERIMENTAL SETUP

- by using a rolling road
  - rolls were driven at 30 km/hr

32 x 16 measurement points
(using a vertical array of 16 mics.)

measurement aperture

rolls

tire

hologram is located 5 cm from tire face

reference position

plywood surface

3.8 cm

122 cm

80 cm

55 cm
SINGULAR VALUES

Number of incoherent source = Number of references

- 92, 104, 128, 208, and 1652 Hz: 3 references (refs. 1, 2, and 4)
- 640 and 1116 Hz: 1 reference (ref. 1)
COHERENCE AND PARTIAL FIELDS (92Hz)

Spatial coherence distribution on the hologram

1st partial field on the hologram

2nd partial field on the hologram

3rd partial field on the hologram

3 refs. (1, 2, and 4)
SLOW CARCASS MODE (92 Hz)

3 refs. (1, 2, and 4)
SLOW CARCASS MODE (104 Hz)

3 refs. (1,2, and 4)
SLOW CARCASS MODE (128 Hz)

Pressure (Pa) map reconstructed at the face of a rolling tire

Normal velocity (m/s) map reconstructed at the face of a rolling tire

Active intensity (W/m²) map reconstructed at the face of a rolling tire

Reactive intensity (W/m²) map reconstructed at the face of a rolling tire

3 refs. (1, 2, and 4)
SLOW CARCASS MODE (208 Hz)

Pressure (Pa) map reconstructed at the face of a rolling tire

Normal velocity (m/s) map reconstructed at the face of a rolling tire

Active intensity (W/m²) map reconstructed at the face of a rolling tire

Reactive intensity (W/m²) map reconstructed at the face of a rolling tire

3 refs. (1, 2, and 4)

n=6
m=3
TREAD UPPER SIDEBAND (640 Hz)

Pressure (Pa) map reconstructed at the face of a rolling tire

Normal velocity (m/s) map reconstructed at the face of a rolling tire

Active intensity (W/m²) map reconstructed at the face of a rolling tire

Reactive intensity (W/m²) map reconstructed at the face of a rolling tire

1 ref. (1)
TREAD CAVITY RESONANCE (1116 Hz)

Pressure (Pa) map reconstructed at the face of a rolling tire

Normal velocity (m/s) map reconstructed at the face of a rolling tire

Active intensity (W/m²) map reconstructed at the face of a rolling tire

Reactive intensity (W/m²) map reconstructed at the face of a rolling tire

1 ref. (1)
TREAD CAVITY RESONANCE (1652 Hz)

3 refs. (1, 2, and 4)
CONCLUSIONS

• Multi-reference NAH can be used to visualize vibration of tire and radiated sound fields
• Three incoherent sources at low frequencies, one at high frequencies except near 1652 Hz
• Below 500 Hz, clear evidence of circumferential tire modes, but they do not radiate sound effectively
• Active intensity originates near the contact patch, or sidewall (at tread passage frequency)
• Tread cavity resonance: sound radiation from pavement / tire interface
FAST CARCASS MODE (540 Hz)

Pressure (Pa) map reconstructed at the face of a rolling tire

Normal velocity (m/s) map reconstructed at the face of a rolling tire

Active intensity (W/m²) map reconstructed at the face of a rolling tire

Reactive intensity (W/m²) map reconstructed at the face of a rolling tire

3 refs. (1, 2, and 4)