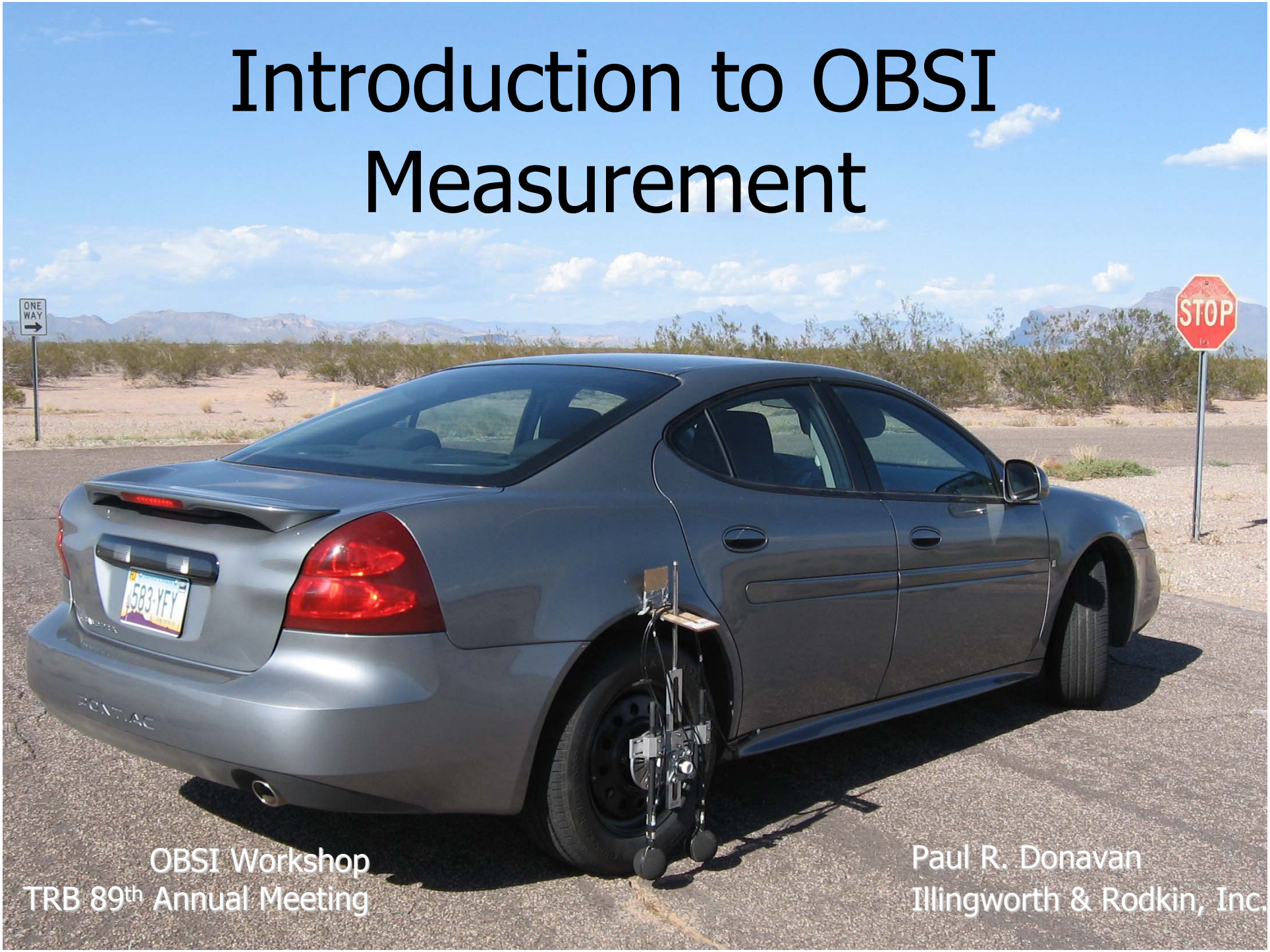
Introduction to OBSI Measurement



OBSI Workshop
TRB 89th Annual Meeting

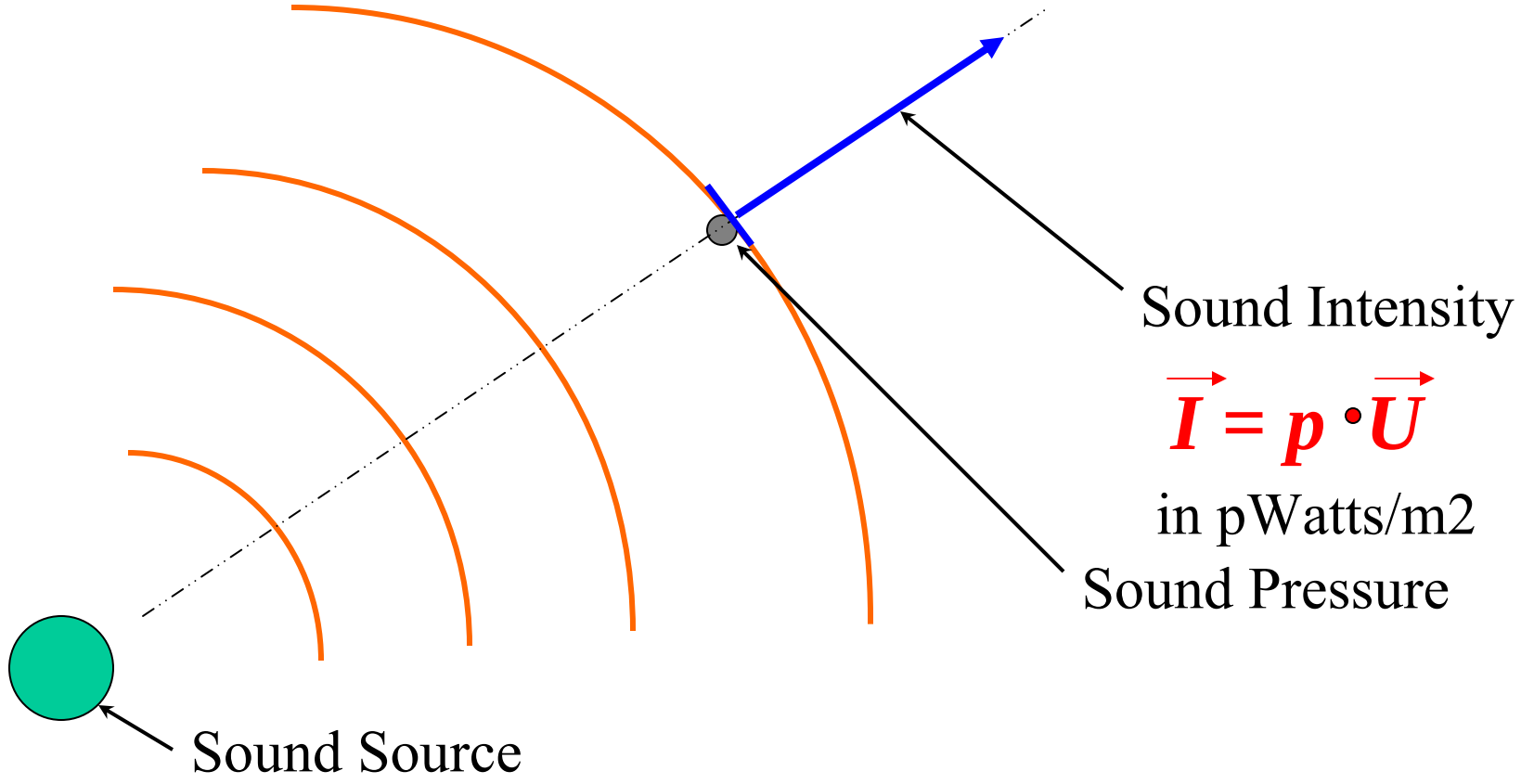
Paul R. Donavan
Illingworth & Rodkin, Inc.

Topics

- Introduction to sound intensity
- Application to tire-pavement noise
- Standard methods of measurement
  - Procedure
  - Data analysis/reduction
  - Reporting

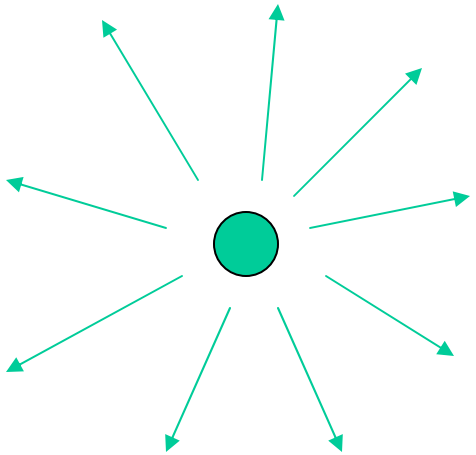
Definition of Sound Intensity

Acoustic or Sound Intensity is the average rate of flow of energy through a unit area in a given direction relative to wave propagation.



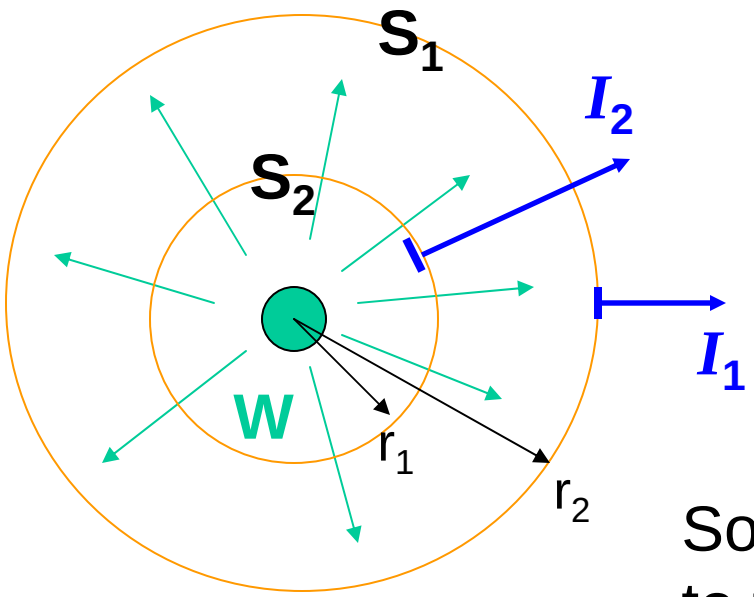
Sound Power of a Source

The total sound power, W, of a source is the rate at which it transfers energy to the surrounding media



Sound power does not depend on the distance away from the source, but is the characteristic output of the source

Relation of Sound Intensity to Sound Power



$$W = \int_s I_s \, dS$$

Sound intensity is inversely related to the size of the surface enclosing the source or from the distance away from the source ($1/r^2$)

Sound intensity can be used at any distance outside of the source to measure the propagating energy

Types of Sound Fields

Progressive (IL ~ SPL)

Sound propagating freely away from a sound source

Typically at larger distances from a source, r>>λ & r>>size of source

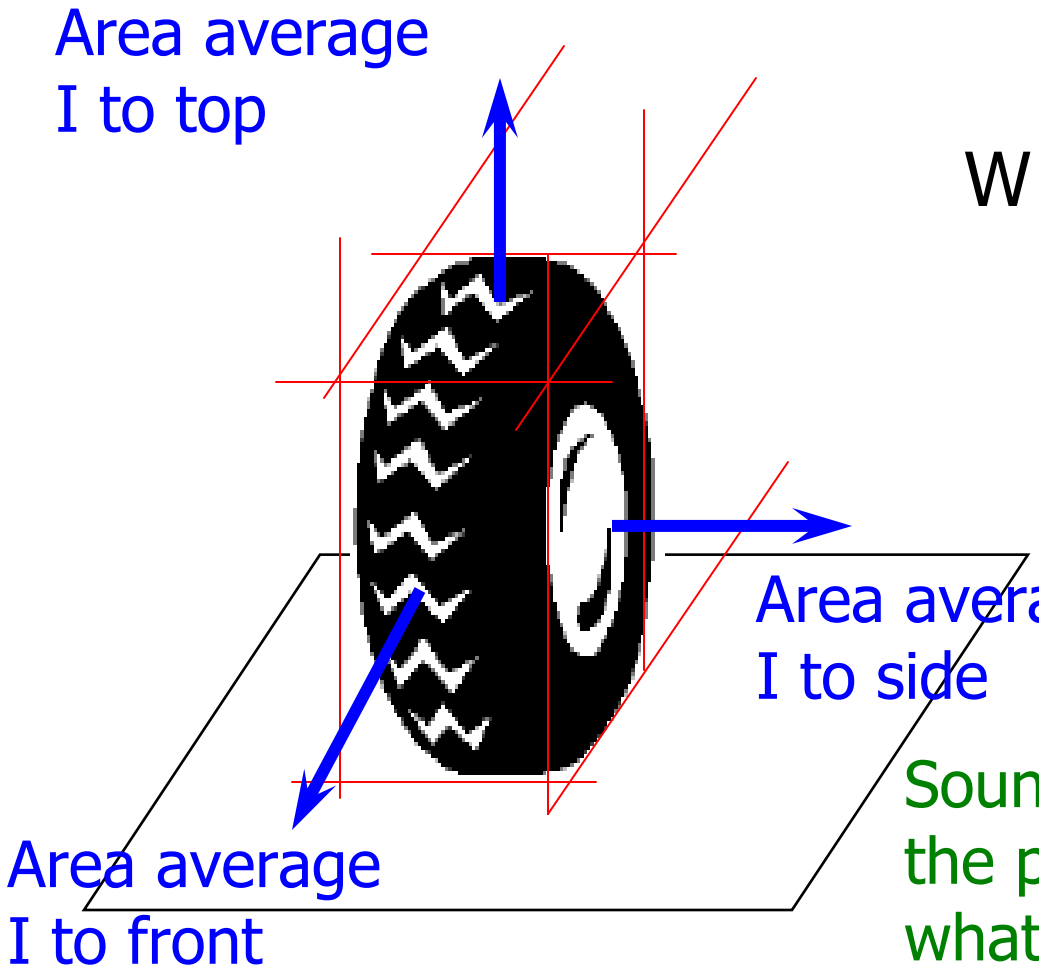
Reactive

Sound energy does not propagate away from the source

Common in the acoustic "near field" of a source

IL measures only the sound energy propagating away from the Tire!

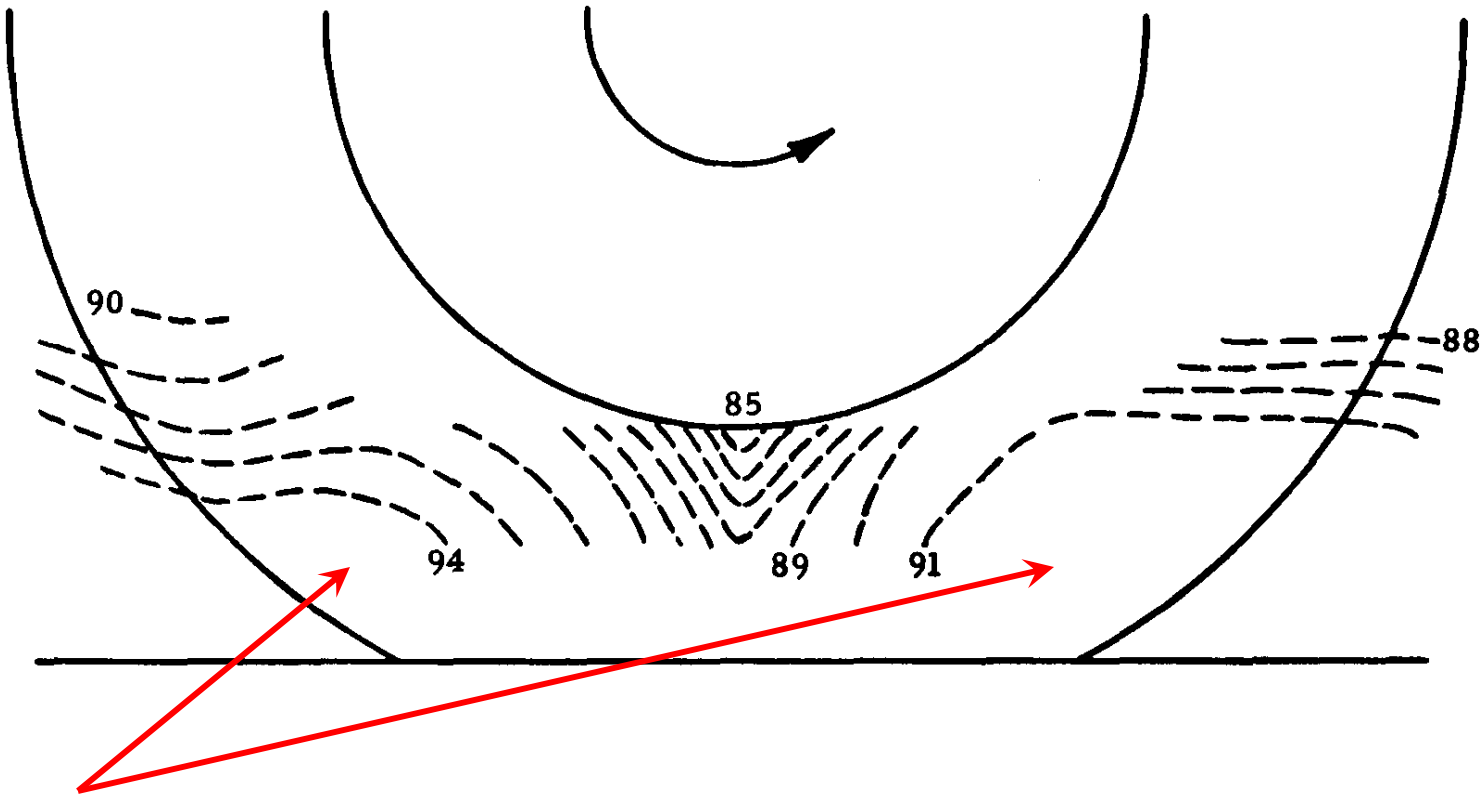
Sound Power of a Tire



$$W = \sum (I_{side} \times A_{side}), (I_{top} \times A_{top}), (I_{front} \times A_{front}), \ldots\ldots$$

Sound power through the plane to the side is what relates to far field SPL measured to the side of the vehicle

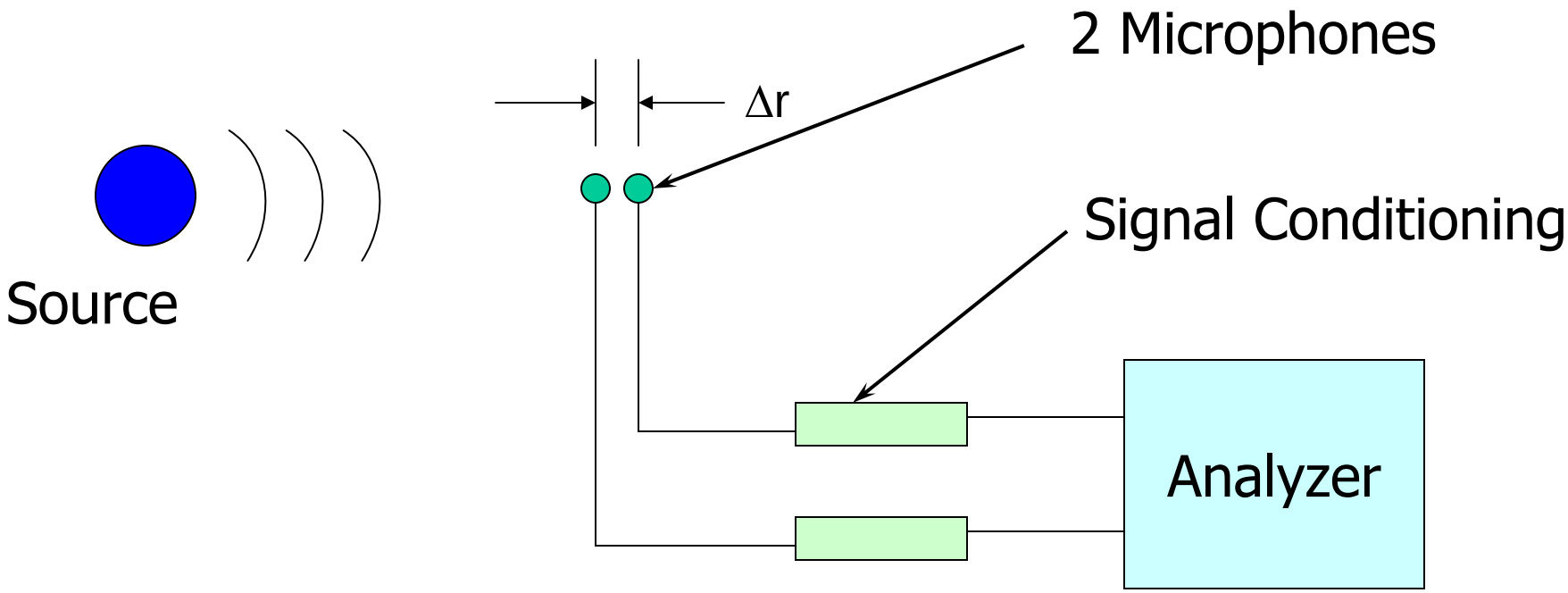
Sound Power / Intensity through Side Plane



Primary source regions above ~ 500 Hz & above -
defines average sound intensity through plane

Measurement of Sound Intensity

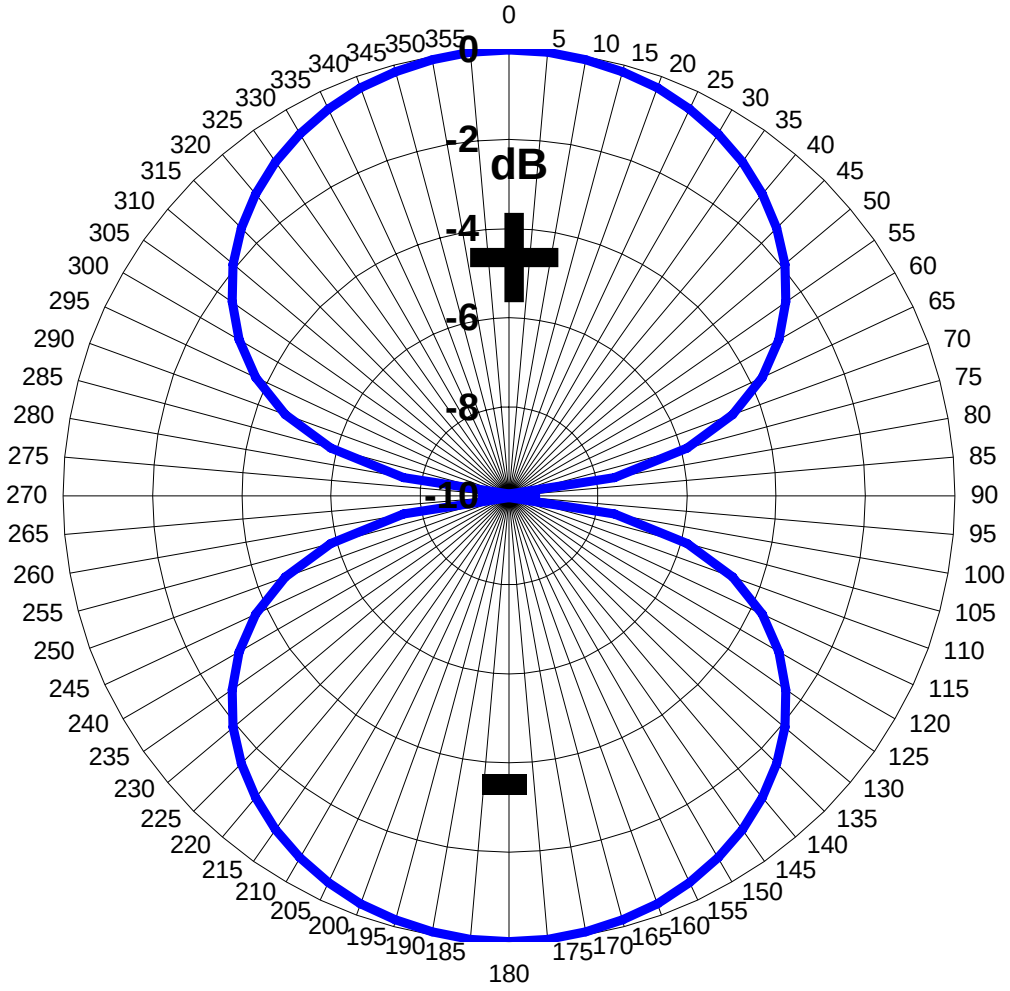
Basic measurement requirements:



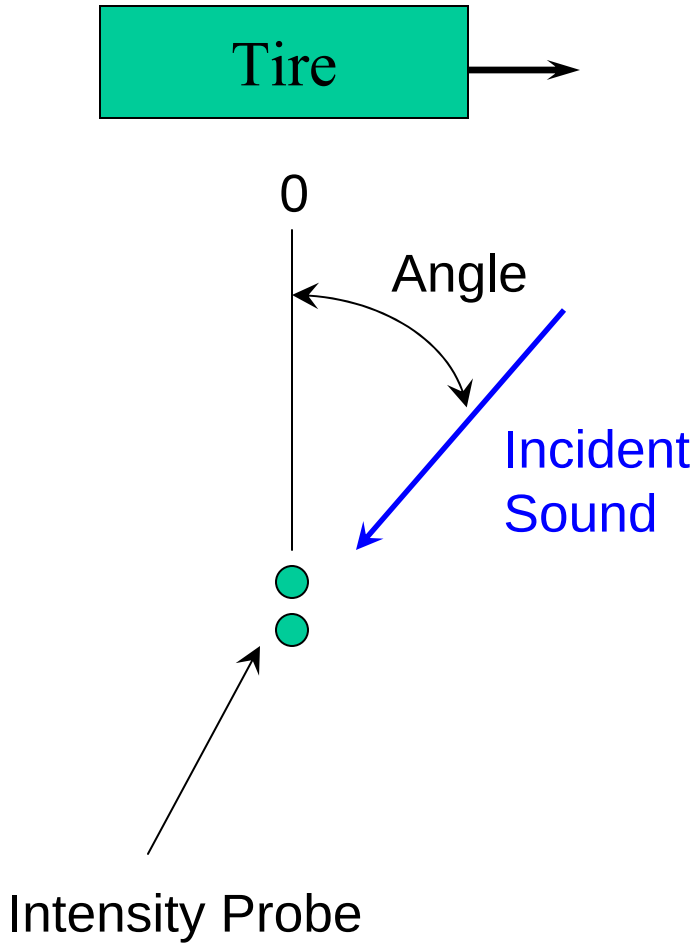
Finite Difference Calculation of Sound Intensity

$$I_r \approx < (p_1 + p_2)/2 \bullet -(1/\rho\Delta r)\int(p_2 - p_1)\, dt >$$

Directivity of a Sound Intensity Probe



Angle, degrees



Why Sound Intensity & Tire Noise?

- Measures sound energy propagating away from the tire regardless of proximity
- Can be measured very close to the tire to minimize effect of other vehicles in traffic
- Rejects wind induced noise (non-propagating energy)
- Directivity reduces influences of other vehicle noise sources: engine, exhaust, etc.
- Provides indicators of data quality

Data Quality Indicators for OBSI Measurements

Intensity Direction

- Direction must be positive
- Changing direction indicates wind noise contamination

Sound Pressure - Sound Intensity Level

- Sound intensity should be equal to & no less than 5 dB below the sound pressure
- Larger differences indicates noise contamination

Coherence

- Indicator of how related one pressure signal is to the other
- Should be close to 1 for accurate measurements

Standardization History

- General Motors test procedure documented in 1990's
- Caltrans standard practice in early 2000's
  - Applied to quantifying pavement noise performance in in-situ
  - Expanded user community outside California
- Later 2000's
  - OBSI ETG formed – initial AASHTO procedure
  - NCHRP 1-44 on-board measurement research
  - Other standards organizations – SAE & ASTM

AASHTO Procedure

- Need identified in Sept 2004 at TPN Workshop
- ETG formed & working draft in 2005
- 1st draft in 2006
- 2nd revision to be submitted in 2010

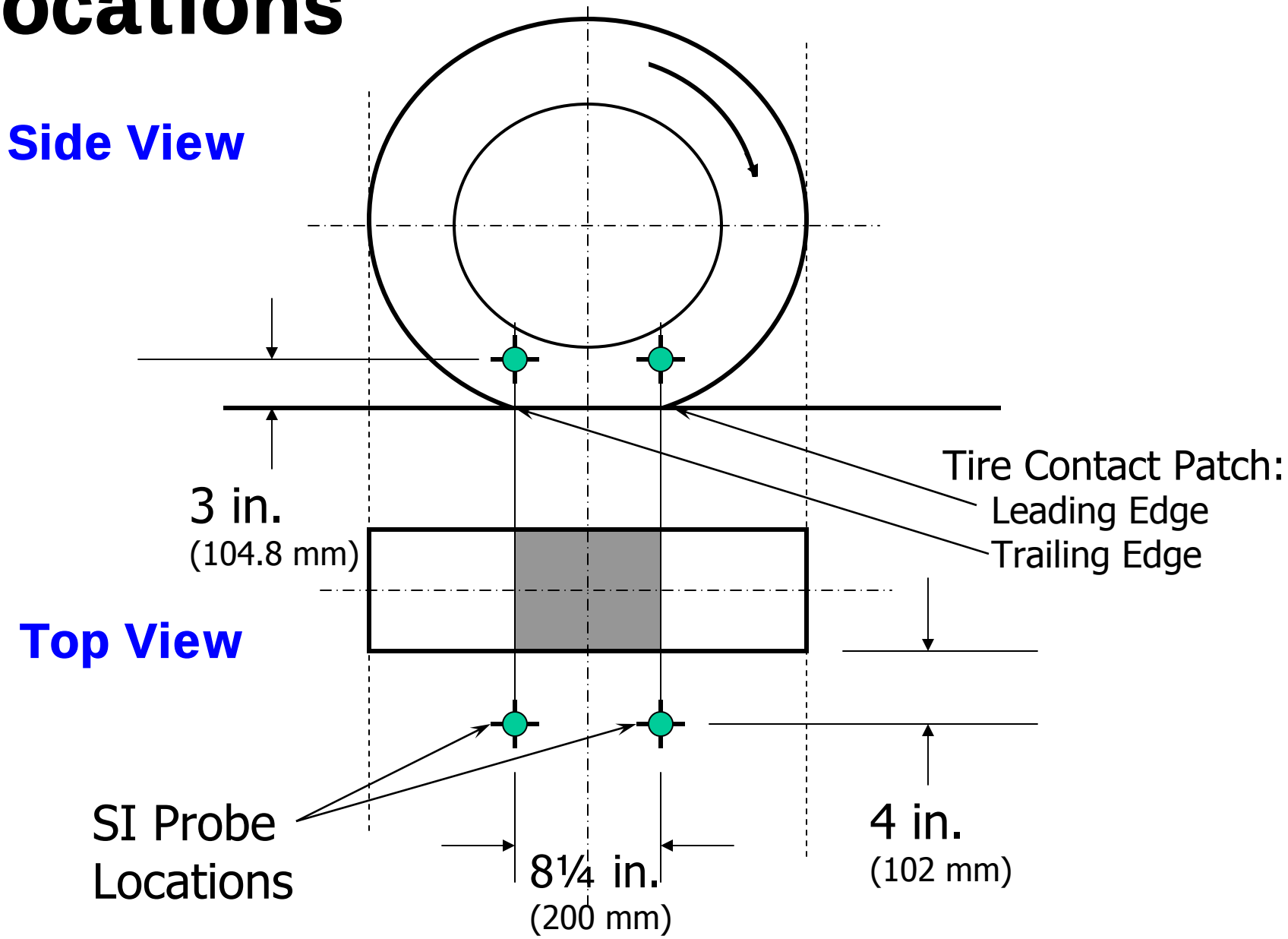
Standard Method of Test for

Measurement of Tire/Pavement Noise Using the On-Board Sour Intensity (OBSI) Method

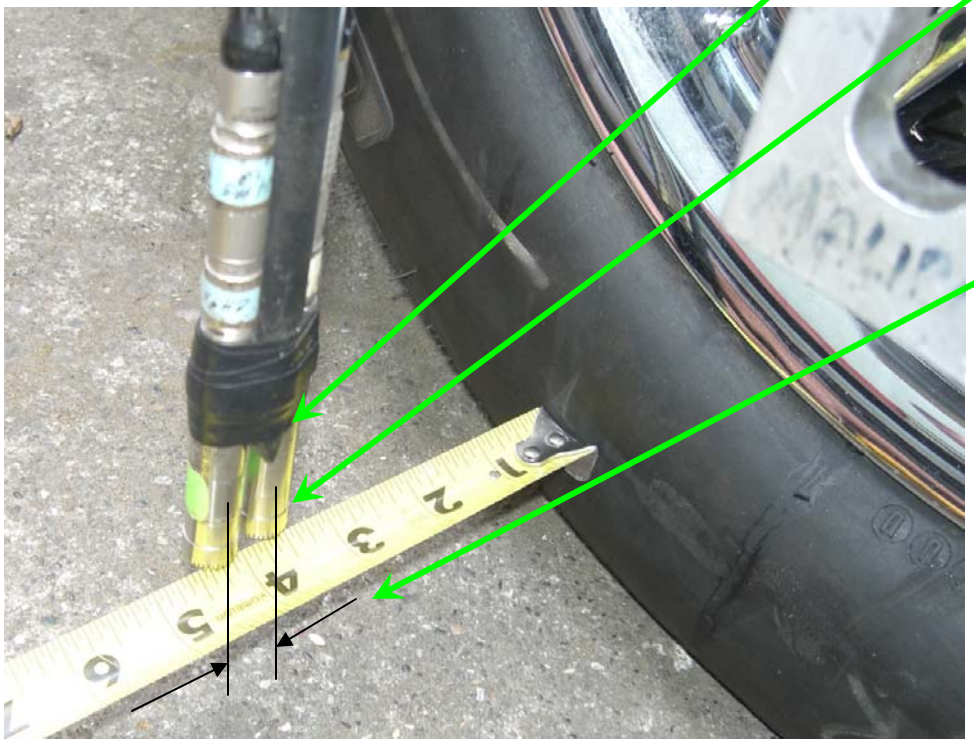
AASHTO Designation: TP 76-10 (proposed)

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standardized Measurement Locations



OBSI Probe Definition



- 2 microphone pre-amplifiers (½″)
- 2 Class 1 phase matched microphones (½″)
- Spaced 0.63″ (16mm) apart mic center-to-center
- 1 microphone windscreen, 3.3″ to 3.6″ diameter (not shown)

Probe Implementation

Dual Probe:

- 1 pass/run
- Energy average probes
- Numerical average of multiple runs

Single Probe:

- 2 passes/run LE & TE
- Numerical average of probes for multiple runs
- Energy average of probe averages

Instrumentation Implementation

- 2 or 4 channel RTA meeting Class 1 ANSI S1.9 SI measurement standard
- ⅓ OB's per S1.11
- Acoustic calibrator (or pistonphone) meeting ANSI S1.40
- A-weighting filters of input signals
- Verified end-to-end channel phase matching

Other Instrumentation / Measurement Requirements

- Independent vehicle speed measurement
- Tire inflation pressure
- Durometer hardness Type A
- Air & pavement temperature
- Determination of barometric pressure or air density

Effect of Environmental Conditions

Air Density effect on SI calculation

- $I_r \approx < (p_1 + p_2)/2 \times -(1/\rho\Delta r)\int(p_2 - p_1)\, dt >$
- Defined by temperature & barometric pressure
- Input per instrumentation supplier's instruction or manually apply correction

Vehicle Operation

- Use ASTM P225/60R16 SRTT test tire
- 60 mph standard speed; otherwise 45, 35, or 25 mph if 60 mph is unsafe or unreasonable
- Measurement length is 440 ft (5.0 sec. at 60 mph; 6.7, 8.6, & 12.0 at alt speeds)
- 2 runs minimum, 3 suggested

Other Data to Be Reported

- Time, date, & who performed the measurements
- Location of measurements & lanes tested
- Test speed(s)
- Instrumentation documentation: acoustic with cal date, speed, and meteorological
- Location of interferring objects
- Tire durometer hardness & date measured

Current Issues

- Precision & Bias statements
  - Initial evaluation in NCHRP 1-44
  - More rigorous research underway in 1-44-1
- SRTT Issues
  - Effective acoustic life cycle of SRTT
  - Combined tire/vehicle/load variation
- End-to-end sound intensity calibration
- Correlation between users