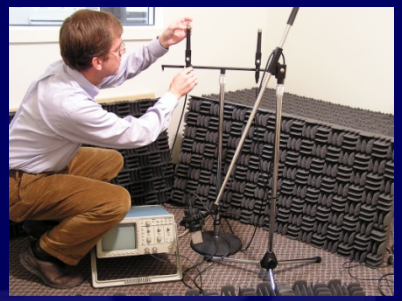


Acoustical Modeling of Gunshots Including Directional Information and Reflections

Robert C. Maher

Electrical and Computer Engineering

Montana State University - Bozeman

Outline

- Introduction
- Gunshot Acoustical Characteristics
- Recorded gunshots
  - Reverberation and reflections
  - Directional characteristics
- Directional modeling
- Conclusion

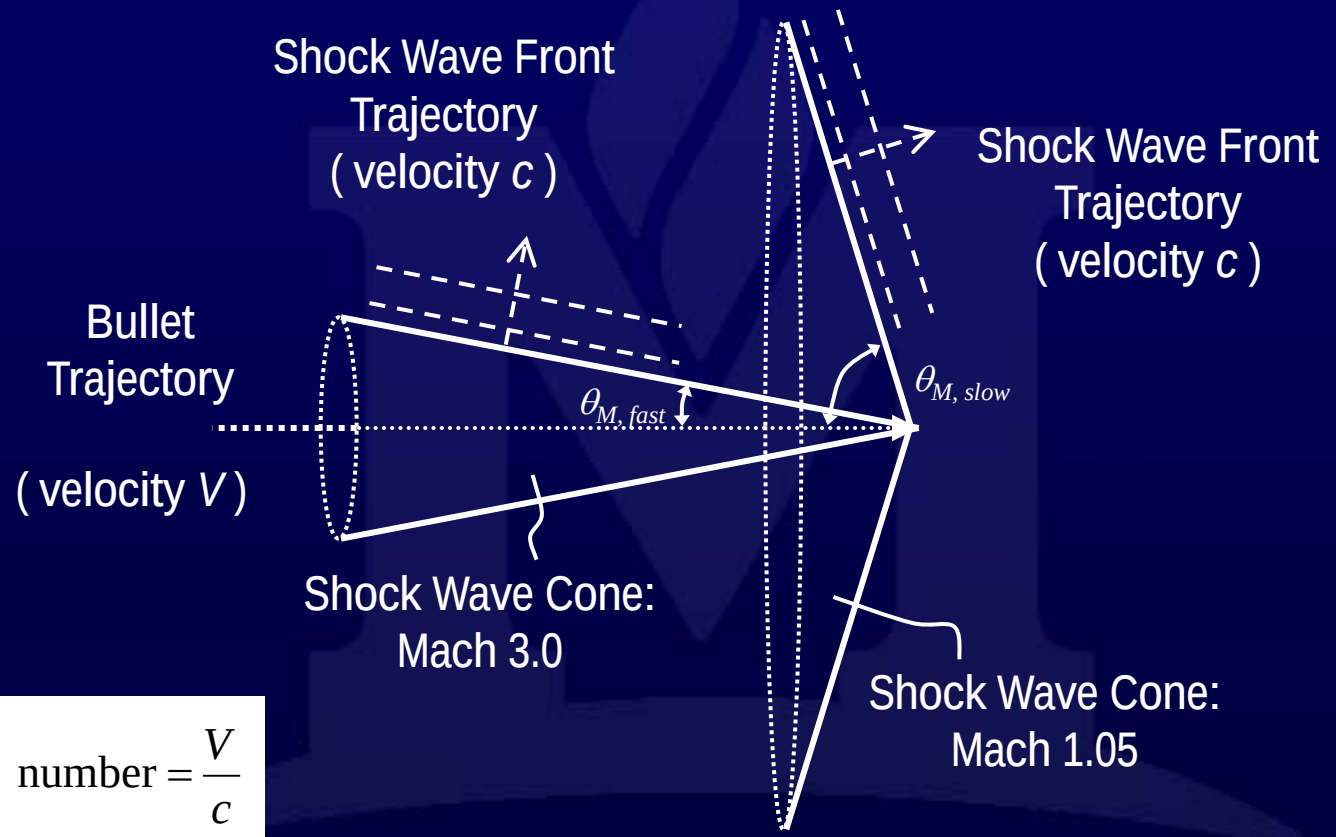
Gunshot Analysis Applications

- Real Time Tactical Information
  - Gunshot Detection
  - Sniper Localization
- Forensic Reconstruction
  - Timeline Assessment
  - Shooter Location and Orientation
  - Firearm Classification

Gunshot Evidence Issues Near the Shooter

- Mechanical Action
- Muzzle Blast
- Supersonic Projectile (shock wave)
- Surface Vibration
- Reflections
- Microphone Type and Location
- Audio Recording Issues (e.g., codecs)

Supersonic Projectile



$$M = \text{Mach number} = \frac{V}{c}$$

$$\theta_M = \arcsin\left(\frac{1}{M}\right)$$

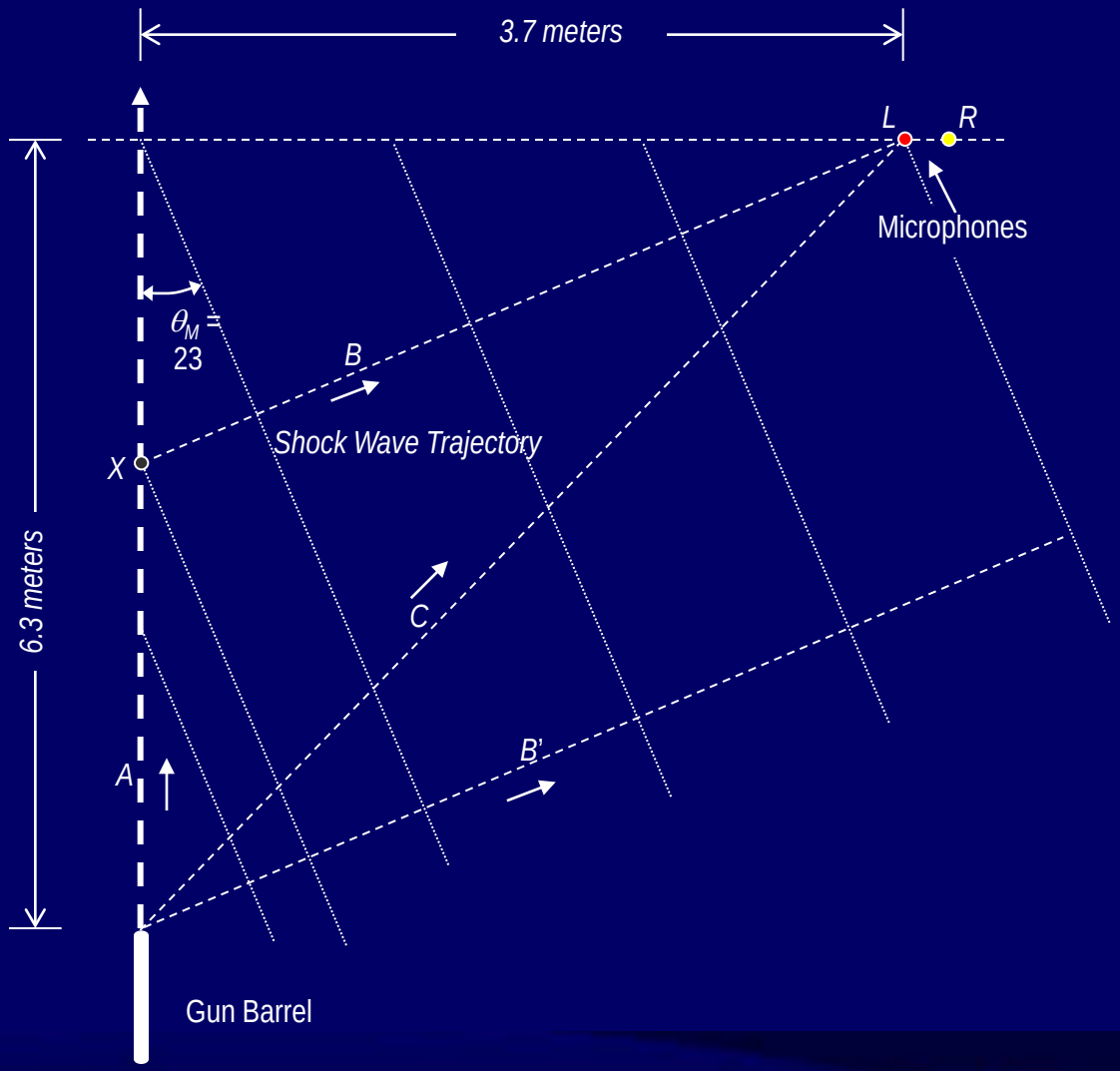
Example Recording

Bullet speed at muzzle:
2728 ft/sec (831.5 m/sec)

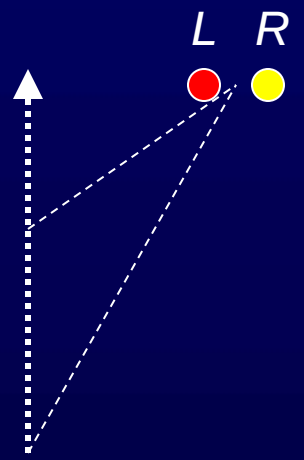
Speed of sound (*c*):
1075 ft/sec (328 m/sec)

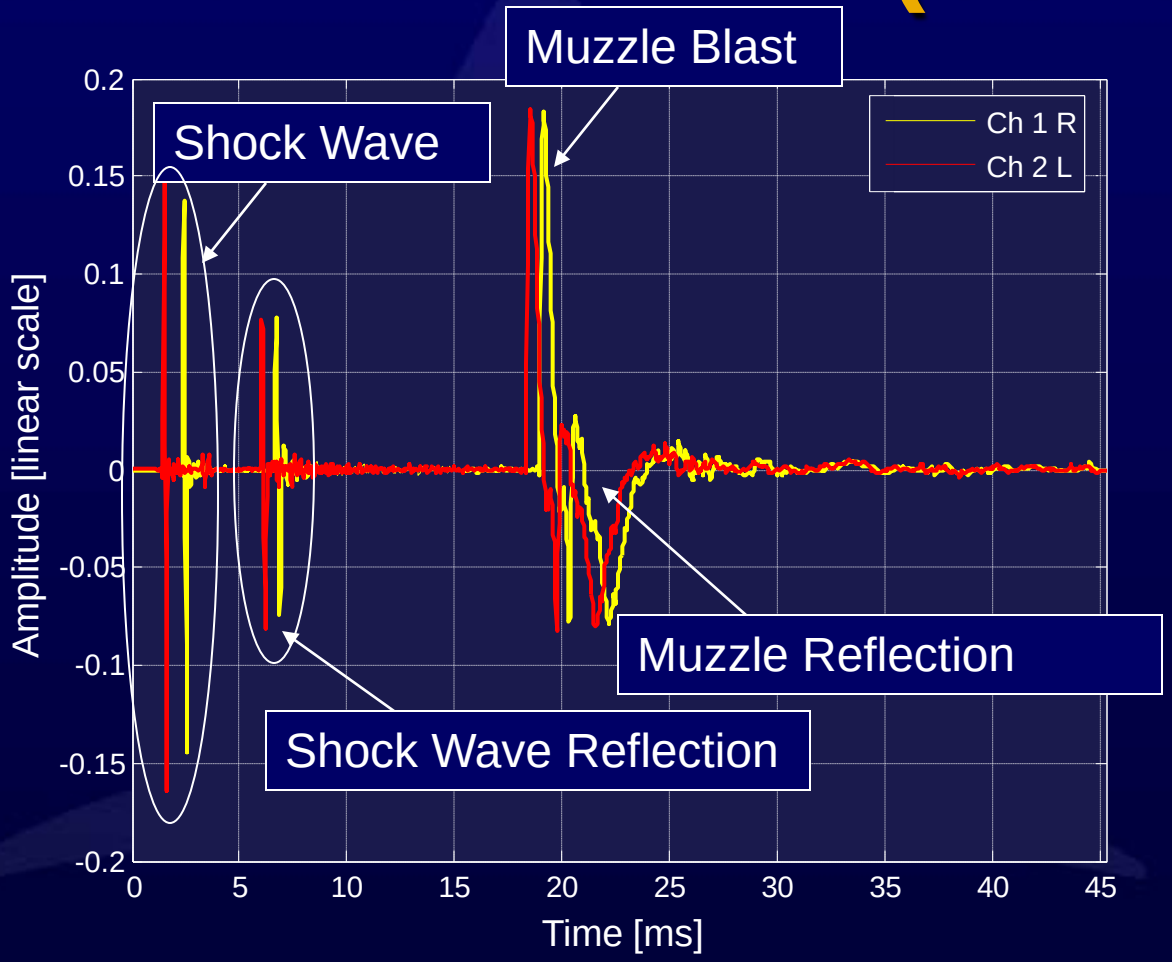
Mach Number (*V*/*c*):
2.54

Mach Angle (θ_M):
23.2°



Ground Reflection (cont.)

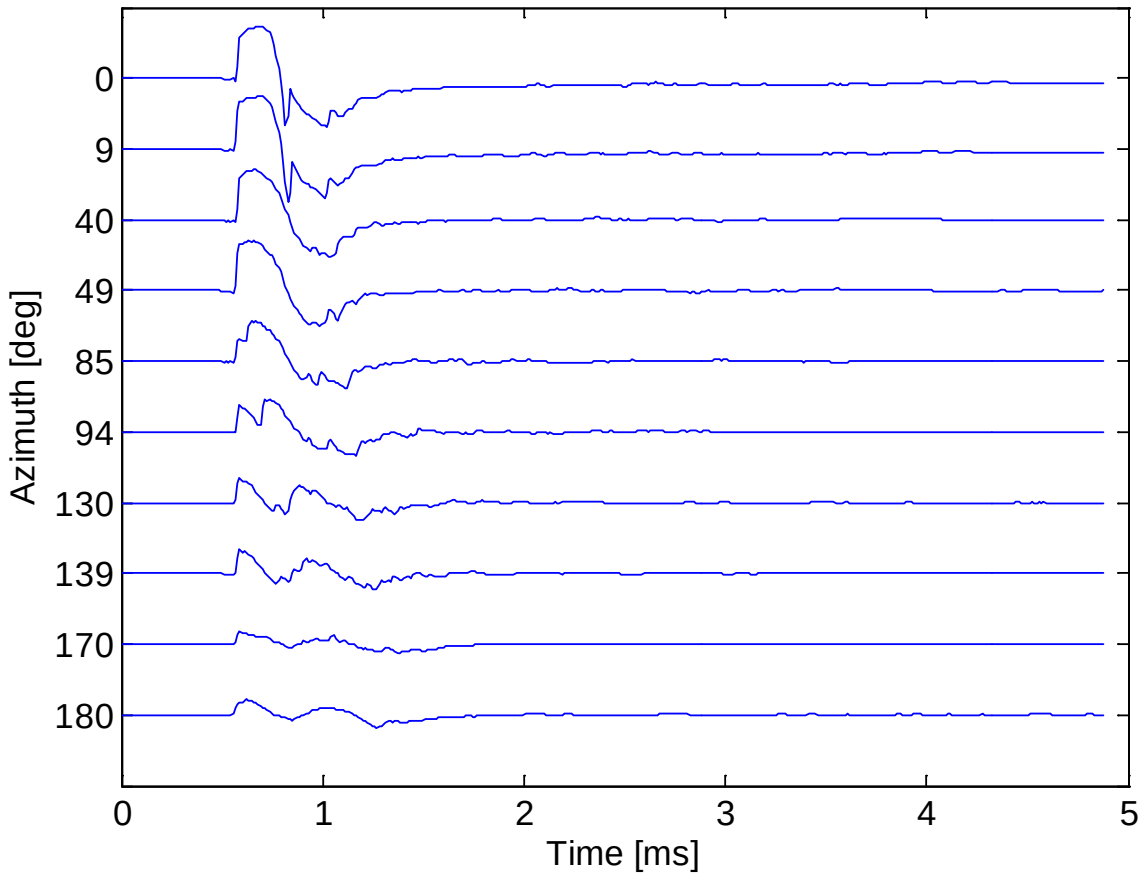




Directional Effects

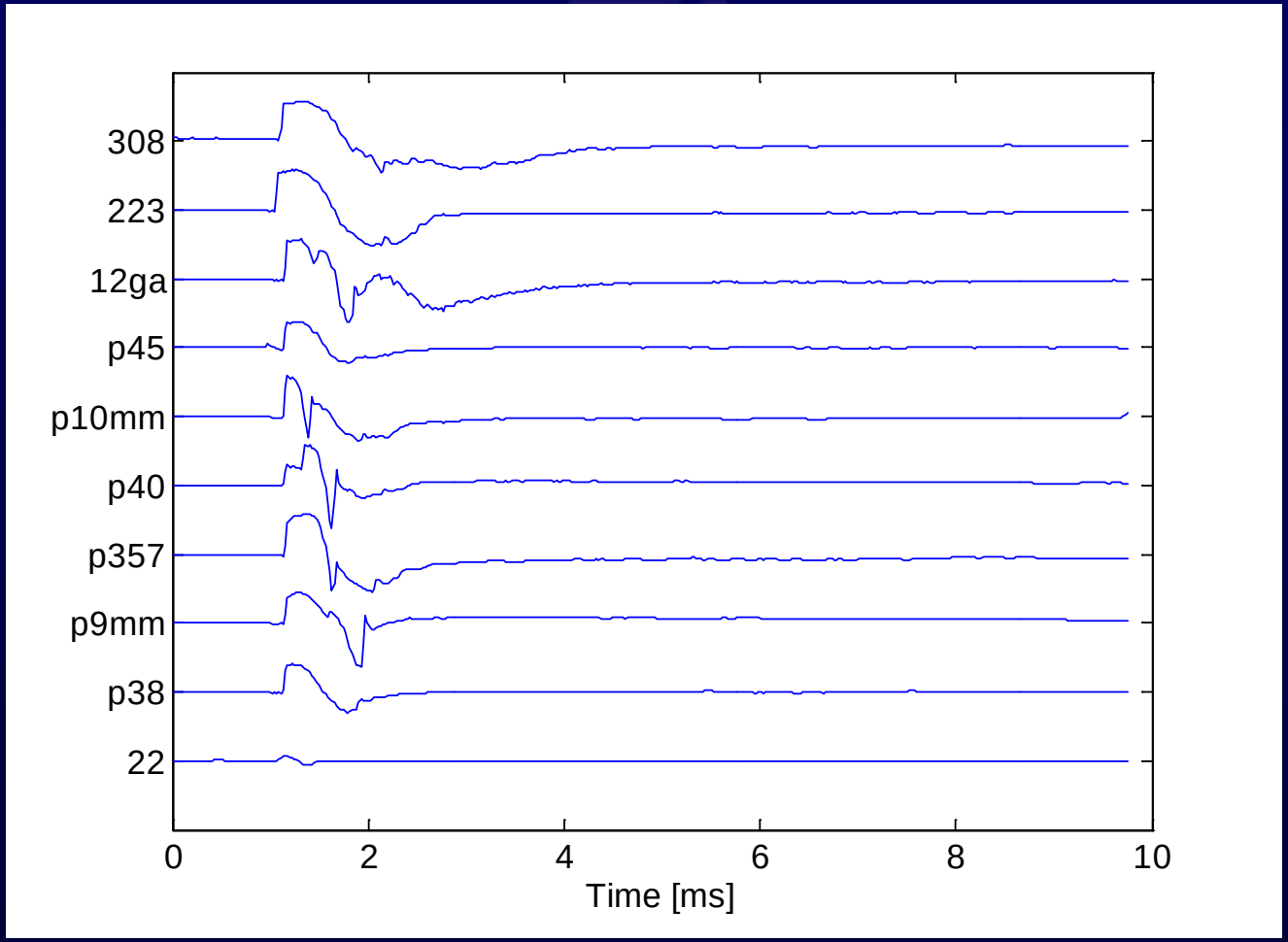
- Gunshot sound levels and waveform characteristics vary with firearm type and azimuth with respect to the barrel.
- Off-axis levels are typically 15-20 dB lower than on-axis levels.
- Waveforms from a particular firearm can vary substantially as a function of azimuth

Directional Effects (cont.)

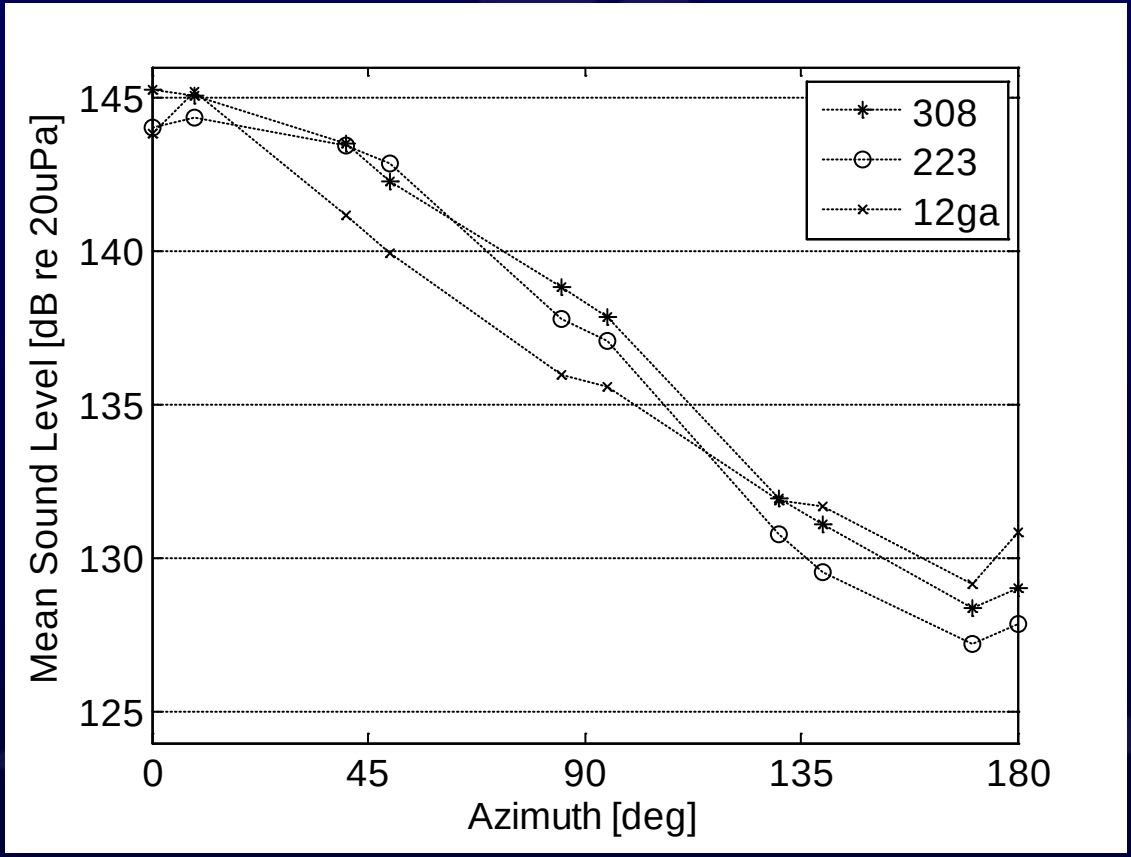


357 Handgun

Different Firearms On-Axis



Sound Level vs. Azimuth

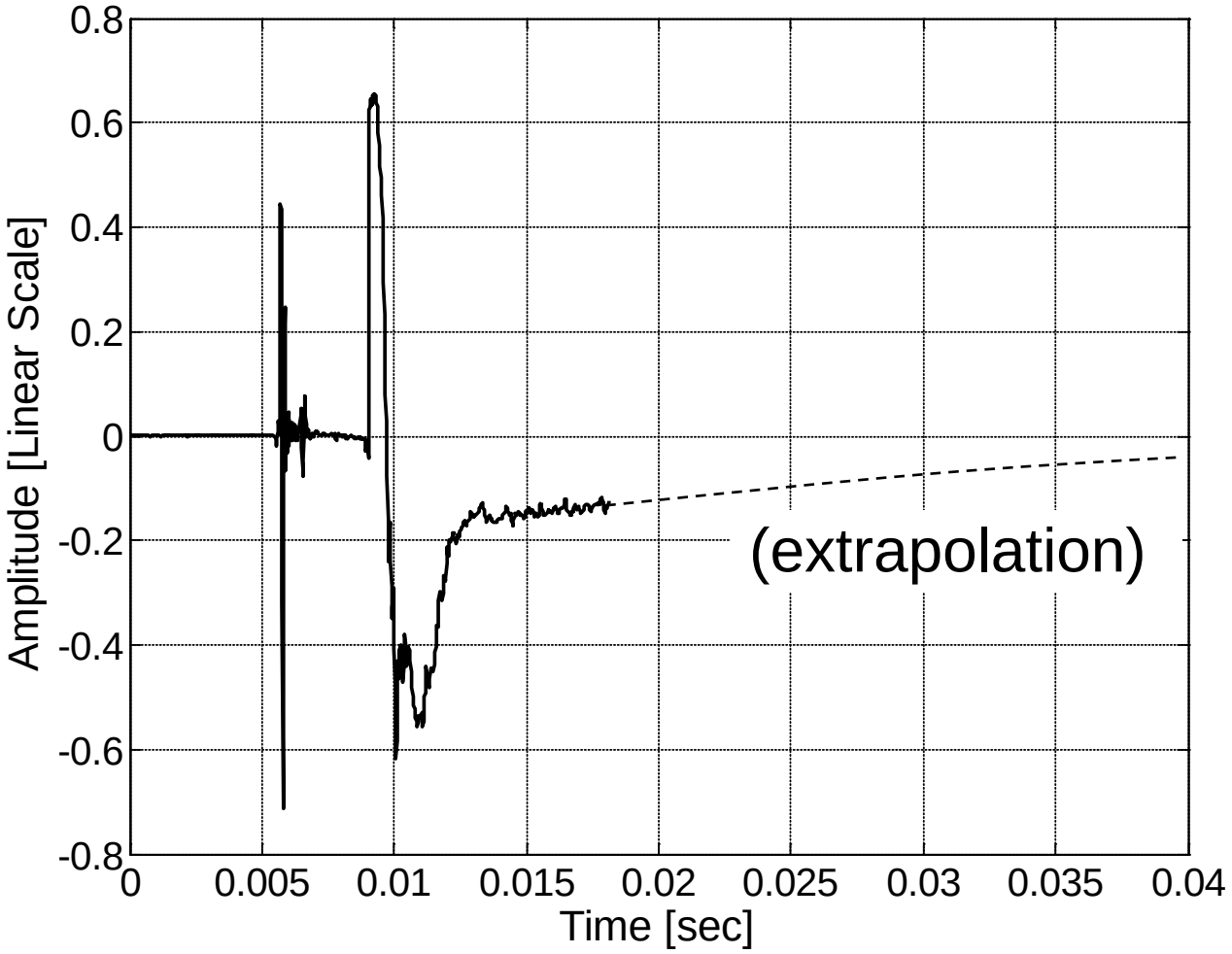


Effects Due to Surroundings

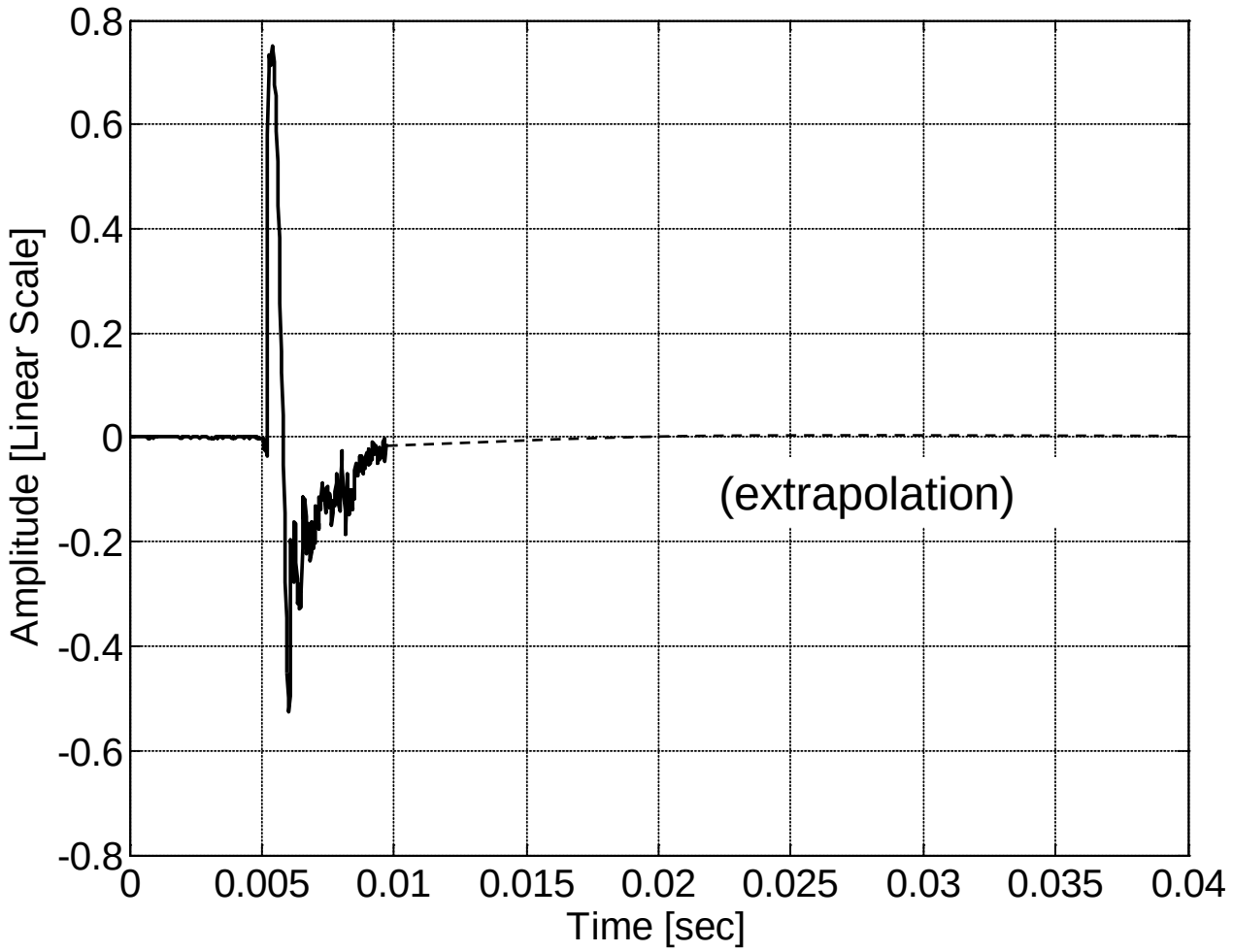
- A simple idea: "just convolve a gunshot recording with the 1-D acoustical impulse response between shooter and microphone"

- But this is the problem: the gunshot sound is highly directional, so a 3-D *spatial/directional* impulse response is required.

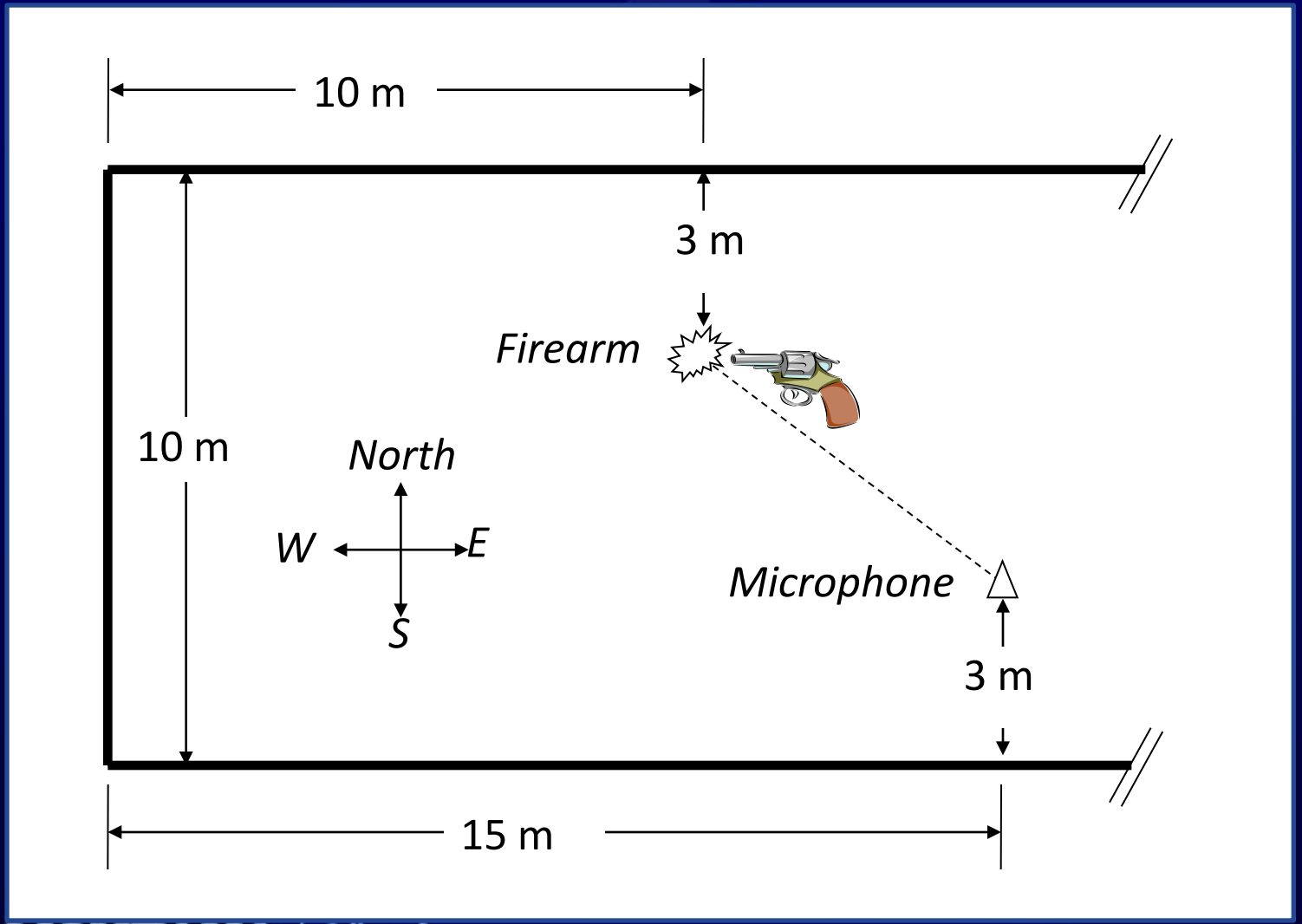
Anechoic Recording On-Axis



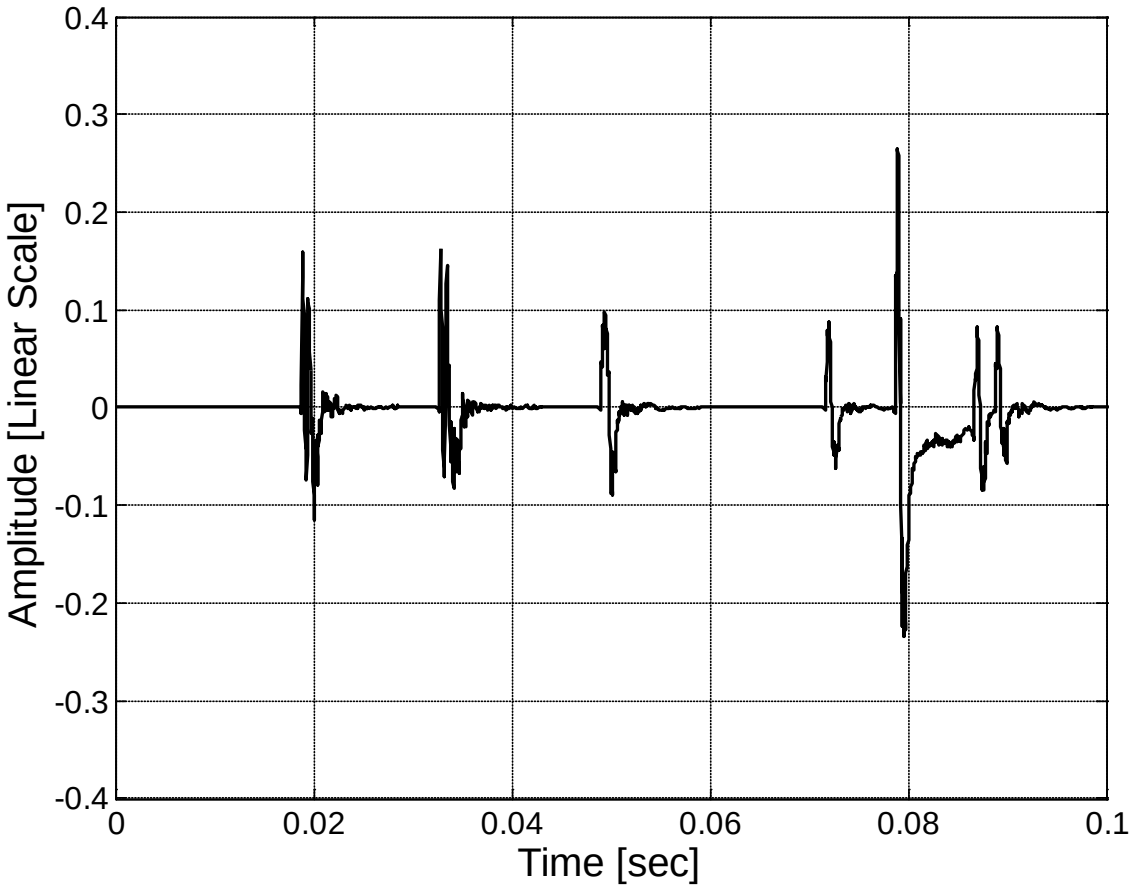
Anechoic Recording 20 deg



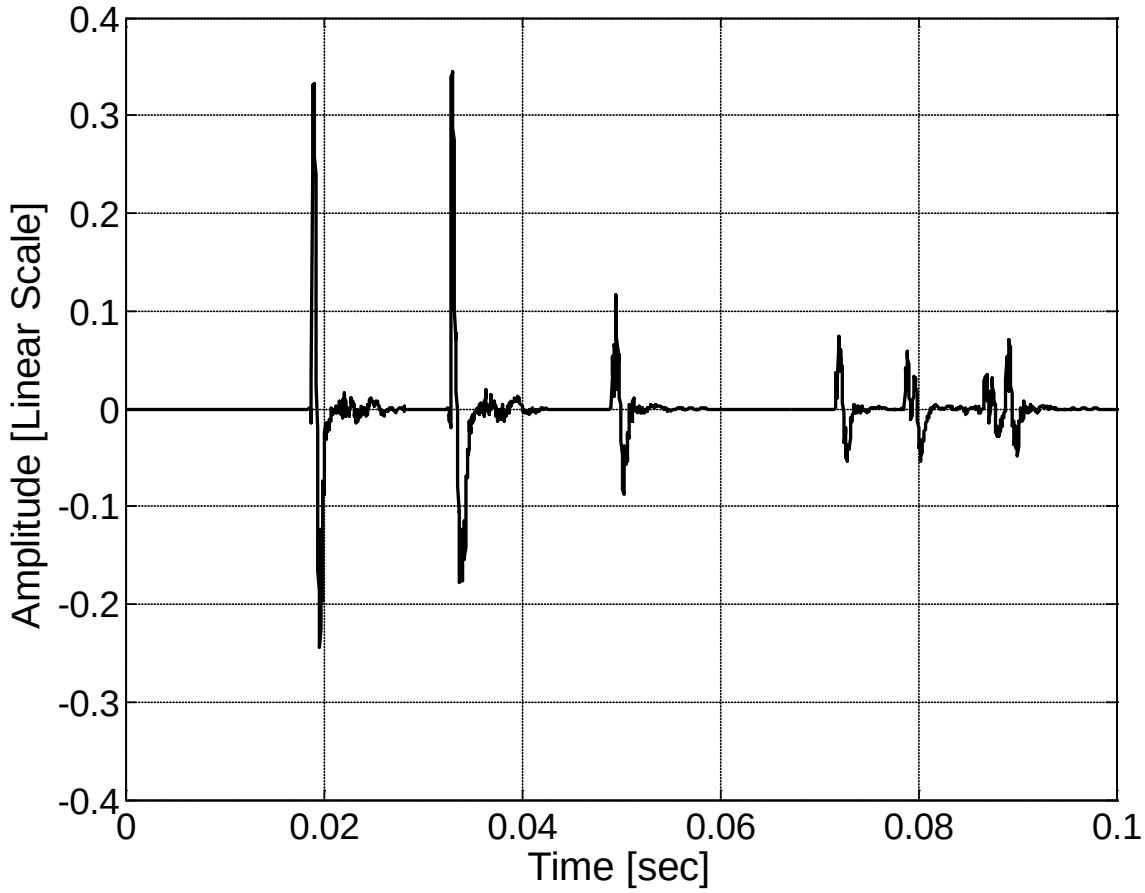
Example “alley” scenario



Model Result: Barrel to West



Model Result: Barrel to East



Recommendations

- Acoustical modeling and reconstruction of a shooting scenario inherently requires the directional characteristic of the firearm.

- Systems intended for gunshot classification also must consider the orientation of the firearm and the acoustical characteristics of the scene.

Conclusions

- Audio forensic examination must anticipate:
  - Acoustic variation among firearms
  - Acoustic variation of one firearm at differing azimuths
- Care is needed when applying convolution
  - A *spatial impulse response* is required.
- Pristine recordings are unlikely in most audio forensic scenarios.

Thank you for your attention.

http://ece.montana.edu/rmaher/