Radar Scanning for Development of Vehicle and Pedestrian Surrogate Targets for Vehicle Pre-Collision System (PCS) Testing

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PCS Test Procedure and Surrogate Target Development

**Project Overview**

- University of Michigan Transportation Research Institute (UMTRI)
  - Lead partner
  - Crash analysis
  - Active safety expertise
  - Test procedures & outcomes
  - Steerable target system
  - Vehicle testing

- Collaborative Safety Research Center (CSRC)
  - Radar signatures of vehicles and targets

- UMTRI
  - Vehicle testing

- Millimeter wave radar image

- Elapsed time
- Notification of danger by buzzer and alert on display
- Pre-crash brake assist on standby
- Pre-crash brake controlled
- Pre-crash seatbelt controlled
Vehicle types were chosen to reflect the General Estimate System (GES) crash database distribution of body style, with common make/models selected when feasible.
## Radar Signature - Vehicles Scanned

24 vehicles were chosen from GES Crash Data Analysis 2003-2008

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>Year</th>
<th>Rank for struck vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS Chevy pickup w/o cap</td>
<td>2005</td>
<td>2</td>
</tr>
<tr>
<td>Honda Accord</td>
<td>2007</td>
<td>3</td>
</tr>
<tr>
<td>Toyota Camry</td>
<td>2004</td>
<td>5</td>
</tr>
<tr>
<td>Ford Taurus (500)</td>
<td>2007</td>
<td>8</td>
</tr>
<tr>
<td>Toyota Corolla</td>
<td>2009</td>
<td>9</td>
</tr>
<tr>
<td>Honda Civic</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>FS GMC pickup w cap</td>
<td>2001</td>
<td>13</td>
</tr>
<tr>
<td>Nissan Altima</td>
<td>2003</td>
<td>15</td>
</tr>
<tr>
<td>Chevrolet Impala</td>
<td>2010</td>
<td>16</td>
</tr>
<tr>
<td>Toyota Tacoma 4WD</td>
<td>2002</td>
<td>18</td>
</tr>
<tr>
<td>Chevrolet Suburban</td>
<td>2009</td>
<td>21</td>
</tr>
<tr>
<td>RAV4</td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Jeep Patriot</td>
<td>2010</td>
<td>36</td>
</tr>
<tr>
<td>Toyota Sienna</td>
<td>2008</td>
<td>54</td>
</tr>
<tr>
<td>GMC Savanna</td>
<td>2010</td>
<td>63</td>
</tr>
<tr>
<td>Toyota Matrix</td>
<td>2009</td>
<td>196</td>
</tr>
<tr>
<td>Nissan 360Z</td>
<td>2005</td>
<td>197</td>
</tr>
<tr>
<td>Scion xB</td>
<td>2008</td>
<td>264</td>
</tr>
<tr>
<td>Subaru Outback w/ roof rack</td>
<td>2005</td>
<td>288</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>2010</td>
<td>&gt;300</td>
</tr>
<tr>
<td>NHTSA Target - version 2</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Toyota Yaris</td>
<td></td>
<td>not in dataset</td>
</tr>
<tr>
<td>Honda Fit</td>
<td>2009</td>
<td>not in dataset</td>
</tr>
<tr>
<td>Chrysler 200</td>
<td>2011</td>
<td>not in dataset</td>
</tr>
<tr>
<td>GMC Acadia</td>
<td>2007</td>
<td>not in dataset</td>
</tr>
<tr>
<td>Honda Nighthawk 750 w/ rider</td>
<td>1993</td>
<td>not in dataset</td>
</tr>
</tbody>
</table>
Radar Signature – Instrumentation

94GHz Instrumentation Radar

Radar on Pan Table

Measurement Radar

Radar Processing and Display

Translation Carriage

3.5 m
Radar Signature – Measurements

Total 30 measurements for each vehicle

1.5°

1m

40 m

180.0°
182.5° (1.75m)
185.0° (3.50m)

Azimuth
180.0
(+1.5°, +3.0°)

Elevation
1.5°
0.0°
Radar Signature – Results

Radar Cross Section (RCS) Distribution of Scanned Vehicle Types

Scale parameter

\[ \gamma_K \text{ (dBm}^2 \text{)} \]

\[ \gamma_K \text{ (unitless)} \]

Higher RCS

Lower RCS

More fluctuation

Less fluctuation

Shape parameter

- compact
- midsize
- truck
- motorcycle
- surrogate

SAE International™
• Consistently across the vehicle types, lower elevation scans produce greater signatures with greater range span of reflections
  – Returns collected with the radar aimed horizontally (0 degree elevation) show returns from
    • Rear bumper, License-plate shelter
    • Muffler
    • Rear-suspension, Differential and Chassis supports
  – Returns collected with the radar tipped up slightly (1.5 degree elevation) show returns from
    • Rear bumper, License-plate shelter
    • Interface of Rear-window and Roof, or back of cab on Pickup-Trucks
Radar Signature – Results

The Impact of Shape on Radar Signature is Much Greater than Size

- Radar return from the 2010 Yaris at left, are significantly stronger than the returns from the 2009 Chevrolet Suburban at right
  - Suburban’s largely rounded back-end and the bumper’s shape occludes much of the under carriage up to the forward suspension

Low clearance and relatively high bumper produces a very large return from the Yaris chassis
Radar Signature – Target Development

Major Radar Scatterer Locations for Test Target

<table>
<thead>
<tr>
<th>Scatter location</th>
<th>Target element</th>
<th>Size</th>
<th>Location</th>
</tr>
</thead>
</table>
| Bumper           | Curved rigid element (polyurethane sheet 2178T44) with conducting strip.       | Width of vehicle (~1.65m)                 | Height: 0.6 m  
|                  |                                                                              | Conductor 2cm wide                        | Fwd: 0.0 m  
|                  |                                                                              |                                          | Lateral: Centered         |
| License plate    | Conducting material                                                           | 30.5 x 15.2 cm                           | Height: 0.7 m  
|                  |                                                                              |                                          | Fwd: 0.1 m                
|                  |                                                                              |                                          | Lateral: Centered         |
| Tail lights (2)  | Actual tail lamps or conducting cylinder                                      | Actual lamps or Cylinder 6 cm tall x 2 cm| Height: 0.9 m  
|                  |                                                                              |                                          | Fwd: 0.1 m                
|                  |                                                                              |                                          | Lateral: Outboard 1m      |
| Muffler          | Flat plate reflector (e.g., metallic tape)                                    | 5 x 2 cm                                 | Height: 0.3 m  
|                  |                                                                              |                                          | Fwd: 0.45 m               
|                  |                                                                              |                                          | Lateral: 0.5m             |
| Rear suspension (2) | Reflective trihedrals                                                       | 3 cm on edge                             | Height: 0.3 m  
|                  |                                                                              |                                          | Fwd: 1.0 m                
|                  |                                                                              |                                          | Lateral: 0.75 offset      |
| Roof/rear window join | Conducting strip across width of window                                      | 1 cm wide                                | Height: 1.3 m  
|                  |                                                                              |                                          | Fwd: 0.95 m               
|                  |                                                                              |                                          | Lateral: Centered         |
Radar Signature – Results

Radar Cross Section (RCS) Distribution of Vehicles and Surrogate

Zoom-In Area on Next Page
Radar Signature – Results

Radar Cross Section (RCS) Distribution of Vehicles and Surrogate
Summary

- Radar scanning of 24 vehicles were done to develop radar reflection characteristics (RCS)
- The RCS was used to develop a surrogate test target
- The surrogate target was scanned to ensure accurate RCS and make any necessary changes
- Currently ongoing test track testing of the surrogate target with PCS equipped vehicles
Pedestrian PCS Test Procedure and Surrogate Target Development

Project Overview

Stereo Camera

Millimeter Wave Radar

CSRC

Indiana University
Purdue University
Indianapolis

TASI
Transportation Analysis & Safety Institute

SAE International

Ohio State University

Lead partner
Crash analysis
Naturalistic Driving Data Collection
Test procedures & outcomes
Surrogate target system
Vehicle testing

Radar signature of human subjects

Possible Collision Detected
High Collision Risk
Collision

Warning

A. Pre-Collision Brake Assist on Standby
B. Pre-Collision Brake Assist operated
C. Pre-Collision Seatbelt Operated

Pedestrian Cyclist

Warning
Human Radar Cross Section Measurement

Plane wave

\[ \hat{x} \]

\[ \phi \]

\[ y \]

Backscattering

RCS values
- Standing: 38.5 dBm^2
- Running: 40.1 dBm^2

RCS [dBm^2]

Standing human
Running human

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Radar Scanning Equipment

Vector Network Analyzer

Rx

10 MHz
0 dBm

13 GHz
-7 dBm

LO

67 GHz
77 GHz
+20 dBm

64 GHz

Transmitting Horn (23 dBic)

Receiving Horn (23 dBic)

front-end module

10 MHz
0 dBm

64 GHz

77 GHz
+20 dBm
Human Postures for RCS Data Collection

RCS: Radar Cross Section
Human RCS Measurement

**Measurements:**
- 0-360 degrees rotation with 0.2 degree increments
- At each angle increment, data recorded from 76.5-77.5 GHz in 20MHz increments
- Both stationary and walking postures

**Calculation:**
- Mean and standard deviation within a 5 degree running window

Measured RCS (dBsm) 
Mean (dBsm) (5° Running Window) 
Standard Deviation (dBsm) (5° Running Window)
Human RCS Simulation

Standing Adult (Male)  Running Adult (Male)  Standing Kid

RCS (dBsm)

$5^\circ$ moving window standard deviation

RCS Histogram

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Simulated vs. Measured RCS

Simulated

Measured

STD (5°)  

Mean (5°)

Simu. STD      
Mea. STD (summer cloth)

Simu. mean     
Mea. mean (summer cloth)
Standing vs. Walking

Standing Posture

Walking Posture
RCS Measurements - Effect of Clothing

Spring shirt: 100% cotton  Summer shirt: 100% polyester  Winter coat:
Coat shell: 100% Nylon
Insulation: 100% polyester

STD (dB)
(5° running window)

Mean (dBsm)
(5° running window)
Summary

▪ RCS characteristics of males in standing positions with various clothing and walking position are measured
▪ Radar scanning of females and children (5-6 years old) are in progress
▪ All RCS results will be used to design the surrogate pedestrian target
▪ The surrogate pedestrian target will be scanned and compared to the actual pedestrian RCS and will be modified if necessary
▪ Test track testing will be done with Pedestrian PCS equipped vehicles and the surrogate target.
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