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# The ARC Journal

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## New Projects

### . Vehicle In-Cabin Radar Test System (Proof of Concept)

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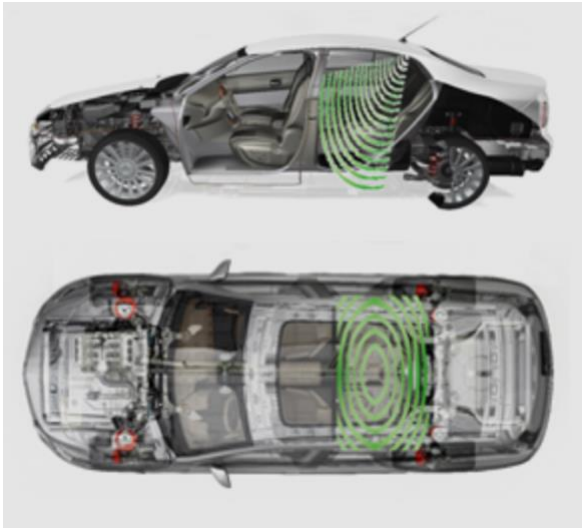
*Project Category: Automotive*

#### Purpose-Goals

The goal of this Proof of Concept (PoC) is to practically test whether we can mimic human physiological micro-movements-specifically breathing and heart rate-using a hardware-based simulation loop instead of real human subjects. Before manufacturing a full active reflector matrix array, we need to de-risk the core physics of the system on a smaller, faster scale.

The immediate technical objectives are:

- Establish a reliable baseline by collecting real, over-the-air (OTA) human vital signs using a TI AWRL6844EVM 60 GHz radar module.
- Verify if a corner reflector movement, can replicate sub-millimeter chest wall displacements within the necessary biological frequency bands.
- Build a single-axis motorized mechanical rig.
- Confirm that the radar module's out-of-the-box processing algorithms accept these mechanical signatures as a living subject, accurately reporting respiration rates and pulse metrics without software errors.



## Study Abstract

New automotive safety standards like Euro NCAP are pushing for mandatory inside-the-cabin monitoring, focusing heavily on Child Presence Detection (CPD) and wider Occupancy Monitoring Systems (OMS). Frequency-Modulated Continuous Wave (FMCW) radar operating at 60 GHz is the preferred hardware because it provides excellent spatial resolution and respects passenger privacy.

This study validates a method for simulating physical micro-movements by using automated retroreflectors driven by mechanical components.

## Project Abstract

This document outlines the execution of a Proof of Concept (PoC) engineering campaign focused on validating an alternative approach to vehicle cabin radar testing. Using a Texas Instruments AWRL6844EVM evaluation board, the engineering team will execute a tight schedule split into three distinct tasks: human baseline benchmark data collection, motor-driven mechanical tracking.

The development sequence begins with open-air human vital signs testing to capture clean benchmark datasets. The team will then design and build a single lightweight corner reflector. This setup will allow us to introduce highly controlled micro-oscillations into the radar's path using an integration lab setup.
Finally, the focus will shift to transitioning to a motorized slider mechanism, writing the microcontroller code to manage linear displacement profiles along the Z-axis. The project will conclude with a completed device datasheet and a final PoC report, validating the core mechanics before scaling up to a multi-channel array.

## Project Scope

The scope of this testing is strictly limited to ensuring rapid verification of the concept without getting bogged down in large-scale manufacturing.

- Initial configuration and firmware bring-up of the AWRL6844EVM radar module using standard Texas Instruments reference examples.
- Gathering Over-the-Air (OTA) baseline phase recordings from human subjects to map genuine heartbeat and respiration signatures.
- Development of a triangular corner target.
- Building a single-axis motorized translation track to control physical movement along the radar’s line of sight.

- Writing low-level firmware to control the actuator's displacement profile, cycle frequencies, and turnaround points.
- Drafting a preliminary technical specification sheet and a final PoC performance evaluation report.

## Challenges

Building an electromechanical simulator for millimeter-wave radars introduces several distinct physics-based bottlenecks:

- Electric motors generate subtle high-frequency jitter. At 60 GHz, a tiny mechanical vibration of just a few microns can completely distort the phase spectrum, flooding the radar's DSP with noise and masking the target's simulated heart rate.
- Any slight twisting, tilt, or mechanical play in the slider track shifts the reflector's phase center off-axis. This causes the target to lose signal stability or display false movement characteristics.

## Project Deliverables

The project will yield the following engineering deliverables:

- A structured collection of data captured from live human subjects during the initial OTA test.
- Physically machined, single triangular corner reflector optimized for 60 GHz return loss.
- A benchtop testing fixture consisting of the fabricated reflector driven by analog laboratory instruments.
- Software deployed on a microcontroller to manage single-axis motor translation, turnarounds, and acceleration curves.
- A technical specifications document outlining the mechanical limits, achievable displacement amplitudes, and frequency ranges of the single-axis setup.
- A comprehensive engineering document comparing the simulated motor signatures against the live human benchmarks to prove the concept's viability.

## Next Steps

Following the validation of this single-axis baseline proof of concept, the project will advance to full system scaling:

- Moving from a single active reflector to the matrix configuration featuring completely independent elements.
- Building a real-time embedded control board to handle synchronized channels.

## Commercial Potential

Validating this test methodology addresses immediate needs within the automotive manufacturing and safety ecosystem:

- Provides a repeatable, standardized Over-the-Air (OTA) verification tool for automotive Tier-1 suppliers to calibrate in-cabin radar modules without needing human operators in the test cells.
- Radar software developers can programmatically simulate specific, or rare biological events (such as sleep apnea, sudden infant distress, or extreme hyperventilation) instantly within a lab environment, shortening design cycles.

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