

FMCW Radar System for Object Detection, Mapping, and Tracking

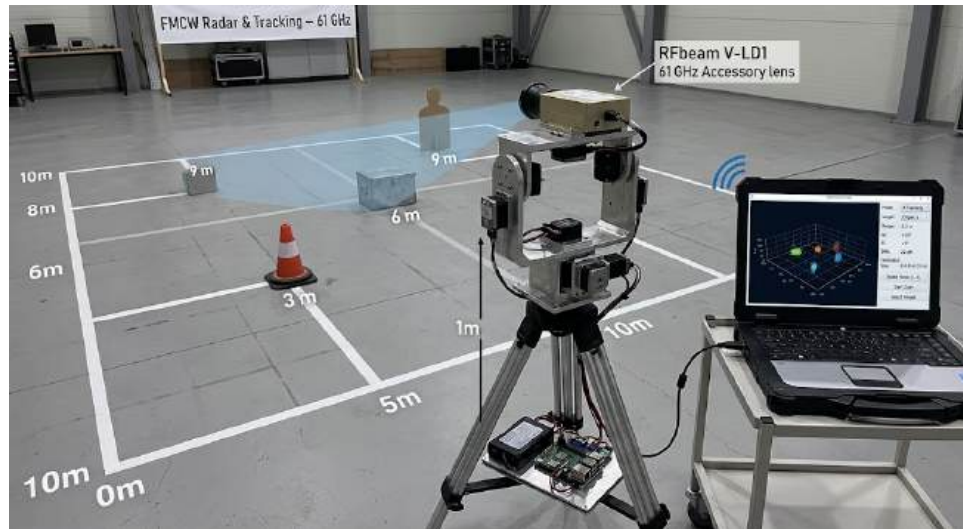


Image produced by Gemini

This project aims to develop a robust radar system capable of detecting, mapping, tracking of the objects placed in a 10 m × 10 m environment, using a single-channel Frequency Modulated Continuous Wave (FMCW) radar mounted on a gimbal. The radar system will have several modes, which are detailed in the system requirements section.

A two-axis (azimuth–elevation) gimbal to point the FMCW radar in desired directions will be developed. The gimbal shall move smoothly and repeatedly across its range in both axes and incorporate a position feedback mechanism, so that the pointing angle is known and can be logged alongside each radar measurement for mapping purposes. The radar will execute an automatic search over a defined region to detect all objects present in accordance with the selected mode. It will then display each detected object's position (angle and distance) relative to the radar via a GUI.

The system should use the RF beam V-LD1, a single-channel 61 GHz FMCW distance radar, to extract range and return-amplitude information from the target objects. When the accessory lens of V-LD1 is used, the expected antenna beam-width is $8^\circ \times 8^\circ$, which sets the fundamental angular resolution of the system.

System Requirements

Testing will take place in a flat 10 m × 10 m region. Objects will be placed at various positions inside this 10 m × 10 m region.

- The radar–gimbal assembly will be placed at the middle of one edge of the region at a height of 1 meter, facing into the field; hence, the required maximum measurement range is ≈ 11.2 m (within the V-LD1's 20 m range setting).

- The gimbal designed by the students must carry the radar sensor and move freely with a minimum range of $\pm 90^\circ$ in azimuth (180° total sweep) and -10° to $+40^\circ$ in elevation.
- The system must include an embedded processing unit that runs the algorithms in real-time, and interfaces with both the gimbal and the radar module.
- The gimbal shall reach any commanded angle within its azimuth/elevation range with a positioning error less than $2^\circ \times 2^\circ$ and shall report its current azimuth/elevation angle to the computing unit with at least the same resolution.
- The computing unit shall implement a search pattern that covers the full $10\text{ m} \times 10\text{ m}$ test area.
- The GUI shall display, at minimum: a 3D map of all detected objects, the current range measurement, current azimuth/elevation angles, the selected search pattern, and the status of the currently locked/tracked target.
- The radar system must include the following three modes:
 - **Mode 1:** The radar will search the whole area to create its map and continuously update and show changes on it.
 - **Mode 2:** After the search and detection, the radar will orient itself to the object that satisfies the selected rules including nearest object, furthest object, and object with the highest SNR.
 - **Mode 3:** After the search and detection, the radar will orient itself to the selected object from the GUI.
 - **Mode 4:** After the search and detection, the radar will orient itself to the selected object from the GUI and track it as it moves. For this, once a target is selected, the gimbal shall periodically re-scan at the last known target angle/range and re-center on it if the target has moved, keeping the boresight approximately on the target without requiring a full re-scan of the search area.

Extra Modes and Features

- **Mode 5:** The radar will continuously search the area to track moving targets only. For this, the radar dynamically collects reflections from the scene and compares subsequent scans/pulses bin-by-bin so stationary background is suppressed, and only moving objects are reported as detections.
- **Mode 6:** After the search and detection, the radar will orient itself to the selected object and estimate its size. For this, using the target's estimated range and the radar's angular resolution in both axes, the system shall produce an approximate estimate of target size. Students should design their own method for extracting the target size estimate from the available range and angle data.
- The communication between the radar system and GUI (on a tablet, laptop, etc.) shall be established using a wireless link.