Application Brief

Understanding Range and Angular Resolution in mmWave Radar Devices

Figure 1. Modern home utilizing Radar in various applications

In today's rapidly evolving world sensing technologies are being integrated into a variety of applications, from cars and robots to HVAC units and televisions in homes. These applications require precise detection for tracking people, vehicles, and objects in the surrounding environment. Making the accuracy of various sensing technologies such as mmWave Radar and LiDAR increasingly crucial for functional and safety purposes.

Radar localizes objects in space along a spherical coordinate system, meaning that it detects objects based off their range, azimuth angle and elevation angle. For radars, range resolution and angle resolution are two parameters that determine if the radar can distinguish between two objects that are nearby in range and in angle. However, other sensors, such as cameras and Lidar, define range resolution and angle resolution differently, which makes it critical for any engineer to understand how these terms are defined for each technology.

Range Resolution and Range Accuracy

Range Resolution refers to the sensor's ability to differentiate between objects that are positioned closely together along the range axis, which refers to their separation along the line of sight of the sensor. For radar, a smaller range resolution value signifies better performance, as it enables a more accurate range measurement of objects at a precise distance. This means that a radar sensor can distinguish between objects that are spaced closer together. It doesn't necessarily refer to the radar's ability to localize a single object's position in space more accurately. For example, consider two radar sensors: one with a range resolution of 10 cm and another with 5 cm. The first sensor can only separate two objects if they are more than 10 cm apart, whereas the second sensor can distinguish between objects as close as 5 cm apart.

It is important to note that range resolution is not the same thing as range accuracy. When there are multiple objects range resolution represents the minimum separation between the objects. Range accuracy is how precise the radar can measure the true distance of a target, so if an object is placed exactly at 1 m away and the radar reads the object at 0.95 m away then the Range Accuracy of the radar is within 0.05 m.

Terminology	Definition	Value
Range Resolution	Ability to distinguish two closely spaced objects	~ 3 cm
Range Accuracy	How precise radar can measure the true distance of a target	~ 1 mm

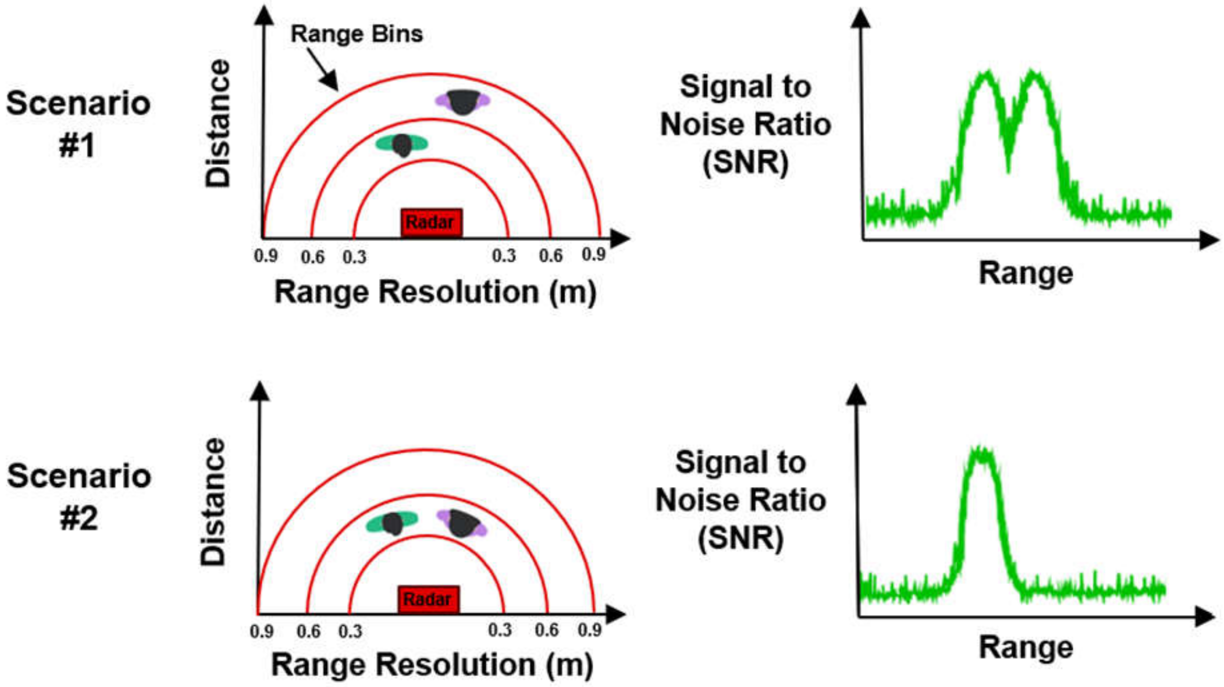

Figure 2. Top-down view of Radar differentiating between two objects using range resolution

Texas Instrument's mmWave radar sensors can achieve a range resolution as fine as 3 cm without requiring hardware or firmware modifications. In practice, given that a human body is significantly larger than 3 cm in both width and depth, a person will appear as a dense cluster of detection points separated based on the radar's range resolution and angular accuracy/resolution. This allows radar to easily detect objects and separate objects close together based on their differing ranges with range resolution.

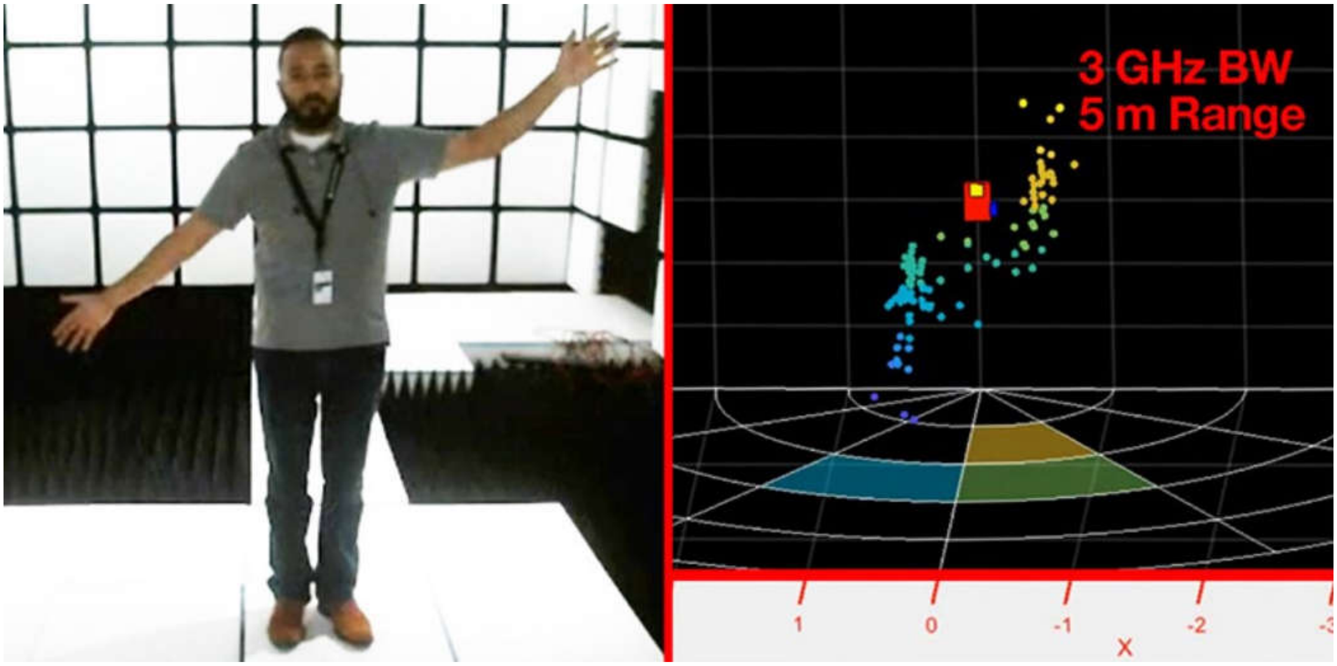

Figure 3. Radar demonstrates dense point cloud on human utilizing range resolution

Understanding Angular Resolution and Accuracy

Angular resolution in Radar sensors determines the ability to differentiate between two detections at the same range as each other. This means that angular resolution is only relevant when two objects are closer together in distance than the range resolution can differentiate. Classic angular resolution of a Radar system considers only these static objects at exactly the same range when quoting angular resolution. This is a straightforward calculation based purely on the number of antennas in each angle dimension.

$\Delta\theta = \lambda / (d * (N))$

Where:

- $\Delta\theta$ is the angular resolution (in radians)
- λ is the wavelength of the radar signal
- d is the spacing between the antennas (assuming a uniform linear array)
- N is the number of virtual antennas (in either azimuth or elevation directions)

Assuming a uniform linear array of antennas with spacing $d = \lambda/2$, we can see the angular resolution is inversely proportional to the number of antennas used in the system. For example, an antenna array with 4 antennas in the azimuth direction and 2 antennas in the elevation direction (like the IWRL6432AOP) would have an angular resolution of 28.6° in azimuth and 57.3° in elevation.

But keep in mind these numbers ONLY applies to static point targets at exactly the same range when processed with classic FFT beamforming. If the objects are at different ranges, or moving at different velocities, or processed with more sophisticated methods, these resolution limits no longer hold.

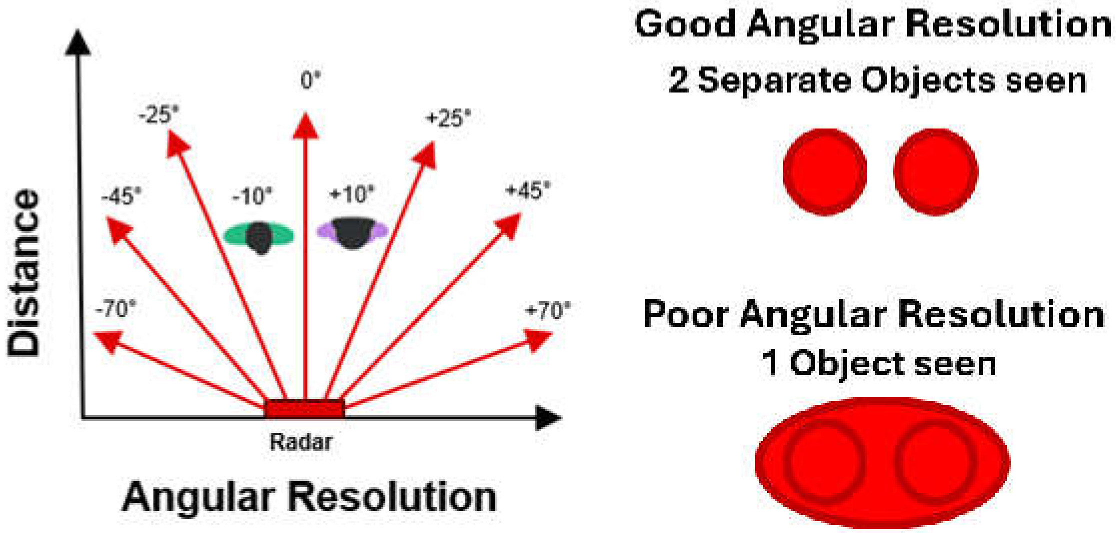

Figure 4. Top down view of Radar utilizing Angular Resolution to differentiate between two objects

Angular accuracy, is the definition for determining how precise a radar or sensor is able to determine the correct angle that an object is at. For example, an object is placed directly 45 degrees from the boresight of the sensor if the radar determines the angle to be 46 degrees then the angular accuracy is 1 degree.

Terminology	Definition	Value
Angular Resolution	Ability to distinguish two objects at the same range	25° in Azimuth 30° in Elevation
Angular Accuracy	How precise radar can measure the true angle of an object	+/- 1°

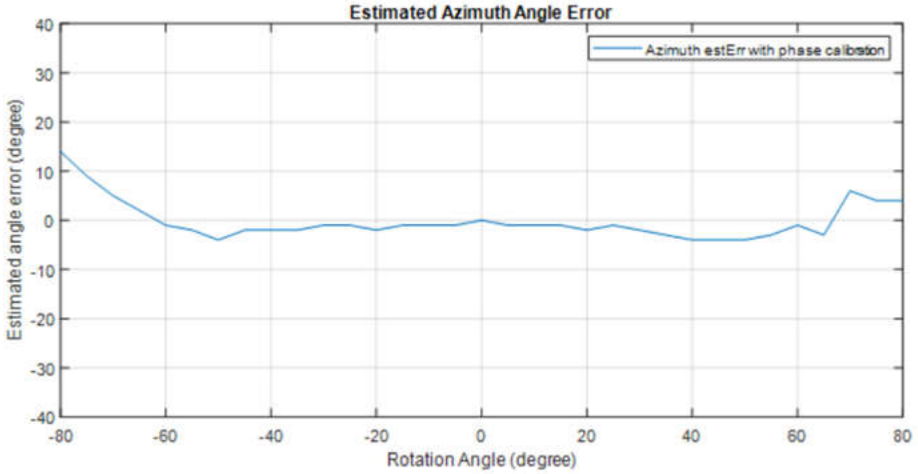

Figure 5. TI IWRL6844 Angular Accuracy margin of error relative to angle

On TI's mmWave Radar devices, angular accuracy is around 1 degree at boresight and up to 5 degrees at the maximum field of view (+/- 70 degrees). Angular accuracy is also dependent on many system parameters such as number of antennas, number of chirps per frame (or in general SNR), antenna pattern, which can all be configured and changed.

Comparing Radar, Camera, and LiDAR: Accuracy Matters More

Cameras and LiDAR are often compared to radar, but the definition of resolution and accuracy can differ across these technologies. Cameras operate on visual data, offering very high angular resolution but no direct velocity or range measurement. LiDAR offers fine angular resolution and high accuracy, but with higher cost, power consumption and sensitivity to weather and lighting.

With radar traditional angular resolution is defined by the ability to separate objects in the same range bin, modern radar processing can improve angular resolution through Doppler separation and advanced MIMO algorithms. Radar uniquely measures range, angle, and velocity, unlike cameras or LiDAR. This means even if two objects share the same range and angle, different Doppler signatures allow separation. TI's mmWave radar devices offer fine range accuracy (~1 mm) and angular accuracy (1–5°), which are ideal for people tracking, object detection, and automation tasks at a fraction of LiDAR's cost.

Additionally, while the traditional FFT-based angle estimation algorithm can distinguish between objects at a precision of X, more complex angle of arrival (AOA) estimation methods also exists with higher levels of resolution for the same number of antennas. For example, the MVDR, or Capon beamforming algorithm can typically halve the resolution of the FFT beamformer by running more complex analysis on the received signals. This algorithm can run efficiently on many of the TI radar devices, including IWRL6432 and IWRL6844, and provides denser point clouds and clearer object separation with fewer antennas.

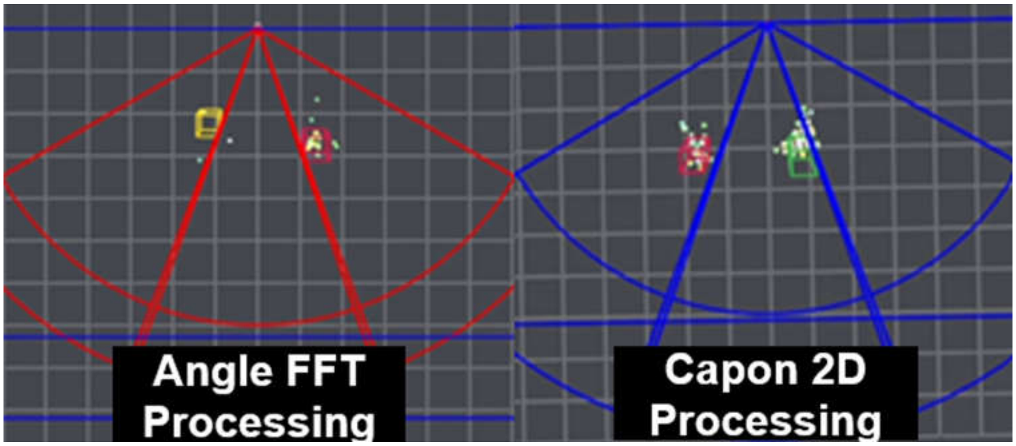

Figure 6. Two different ways of processing Radar data showing a much denser point cloud utilizing the Capon 2D FFT processing method

Conclusion

As various sensing needs continue to advance more reliable, cost-effective, and efficient sensing solutions are available than ever. Unlike LiDAR or cameras, radar simultaneously measures range, angle, and velocity, which provides a richer set of information for differentiating objects in real-world environments. Its fine range accuracy (on the order of millimeters), robust angular accuracy, and ability to utilize Doppler separation and advanced processing algorithms allow radar to achieve reliable performance that far exceeds what its "paper" parameters suggest.

TI's mmWave radar offers a compelling alternative, providing high accuracy, the ability to operate in diverse environments, and the flexibility to enhance angular resolution through advanced antenna configurations. By leveraging radar's strengths fine range resolution, Doppler-based separation, and scalability applications from people detection to object tracking can achieve robust sensing at a fraction of the cost .

Resources:

- Order an IWRL6432AOPEVM or IWR6843AOPEVM
- Learn more about Radar in the Radar Academy

- Explore more demos today on the Radar Toolbox

Trademarks

1 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from October 31, 2025 to January 31, 2026 (from Revision * (October 2025) to Revision A (January 2026))	**Page**
• Updated Top down view of Radar utilizing Angular Resolution to differentiate between two objects diagram...	1

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