Application Report

mmWave Radar Sensors: Object Versus Range

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ABSTRACT

This application note includes an object versus range table to list the detection range capabilities of TI's mmWave radar sensors. The method used for data collection is reported and the data for the maximum range recording for each objects is provided. Intuitions that can be gained from the table regarding radar cross section and maximum range detection are included.

Table of Contents

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1 Introduction

When developing end applications using mmWave radar sensors, determining the maximum detectable range for a target of interest can be challenging. Radar system parameters, detection algorithm settings, and physical characteristics of the environment and target all play a role in determining the maximum detectable range of a target. The focus of this application note is to provide examples of the range detection capabilities of TI's mmWave radar sensors and to briefly review the important factors when detection range is a primary concern.

2 Object Versus Range

Table 2-1 lists objects versus range in meters.

Table 2-1. Object Versus Range

Object	EVM Measured Range (m)												
	1	5	10	20	30	40	60	80	100	120	140	160	199
Truck(2)	●	●	●	●	●	●	●	●	●	●	●	●	
Car(2)	●	●	●	●	●	●	●	●	●	●	●(3)	●(3)	●(3)
Motorbike(2)	●	●	●	●	●	●	●	●					
Bicycle with human(2)	●	●	●	●	●	●	●						
Human(1)	●	●	●	●	●	●							
Metal chair(1)	●	●	●	●	●								
Soda can(1)	●	●	●	●	●								
Wooden chair(1)	●	●	●	●									
Plastic chair(1)	●	●	●										
Cup of coffee(1)	●	●	●										
Large dog(1)	●	●	●										
Small dog(1)	●	●											
Coins (US quarters)(4)	●												

(1) xWR1443 using low RCS chirp configuration from object versus range.
(2) xWR1443 using high RCS chirp configuration from object versus range.
(3) xWR1642 using long range chirp configuration from traffic monitoring.
(4) xWR1443 using best range resolution chirp configuration from the out-of-box (OOB) demo.

In Table 2-1, several commonly found objects are listed along with dots indicating the ranges at which the object was detected using a specific radar system configuration as well as measurement protocol. For more details on how the data was gathered please refer to the appropriate associated document.

Details for XWR1642 using Long Range chirp configuration from traffic monitoring can be found in *Traffic Monitoring Object Detection and Tracking Reference Design Using Single-Chip mmWave Radar Sensor*.

Details for XWR1443 using best range resolution chirp configuration from OOB demo can be found in the *Detecting Quarters Using mmWave Experiment*.

TBD cover usage of an IWR1443 with low RCS and high RCS chirp configurations to generate the remaining entries for the object versus range table.

2.1 Measurement Protocol

For data collection, an IWR1443 EVM running the mmWave SDK out-of-box demo was used with a Windows laptop running the *mmWave Demo Visualizer*. Further details related to using the mmWave Demo Visualizer can be found in the user's guide for *mmWave Demo Visualizer*.

Objects were considered to be detected at the specified distance if the visualizer returned a detected object marker at the range of interest.

Depending on the target object characteristics the EVM was either configured with the Low RCS chirp configuration or the High RCS chirp configuration. The chirp specifics can be accessed from the *mmWave Chirp Database*.

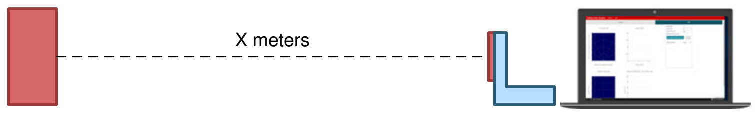

Figure 2-1. Measurement Setup

For each measurement, the object was resting on the ground while the EVM was at the specified distance from the object and mounted with the antenna boresight approximately in line with the center midline of the object. Target objects were static while measurements were collected. Figure 2-1 shows an example of the measurement setup.

Note

The measurements were taken in minimal clutter environments such as an empty parking lot.

Following setup for each object, the next measurement was taken by advancing the object to an increased distance and repeating the data collection. If the object was not detected, the target object was returned to the previous distance and the maximum range was noted. The object was then removed and a measurement was taken to capture the range profile produced from any clutter and the background environment.

2.2 Object Details and Results

Section 2.2.1 through Section 2.2.12 show the results of the maximum range measurement for each object.

Each plot includes three traces:

- Noise profile
- Range Profile: With Object
- Range Profile: No Object

The No Object range profile represents the clutter and background environment. For the With Object trace, the peak with the annotation denotes the maximum range at which the object was detected under these measurement conditions. Each accompanying photo depicts the object during measurement.

2.2.1 Truck

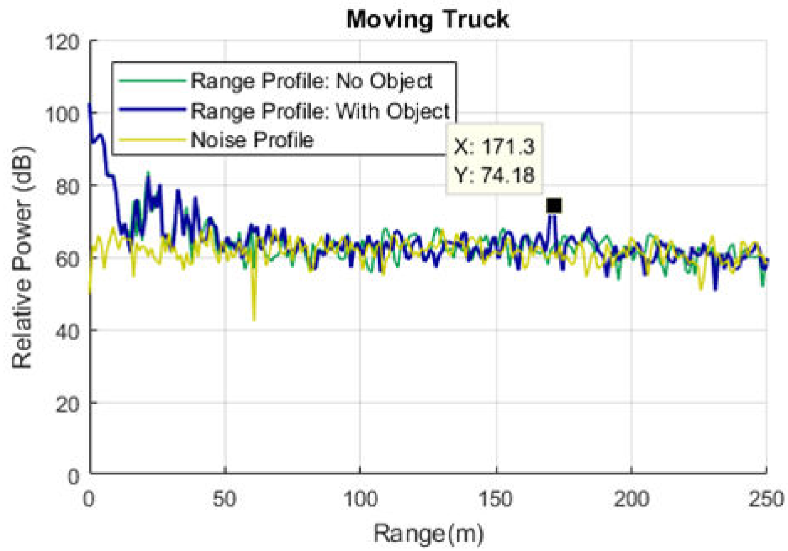

Figure 2-2. Moving Truck

Figure 2-3. Moving Truck Distance Test

2.2.2 Car

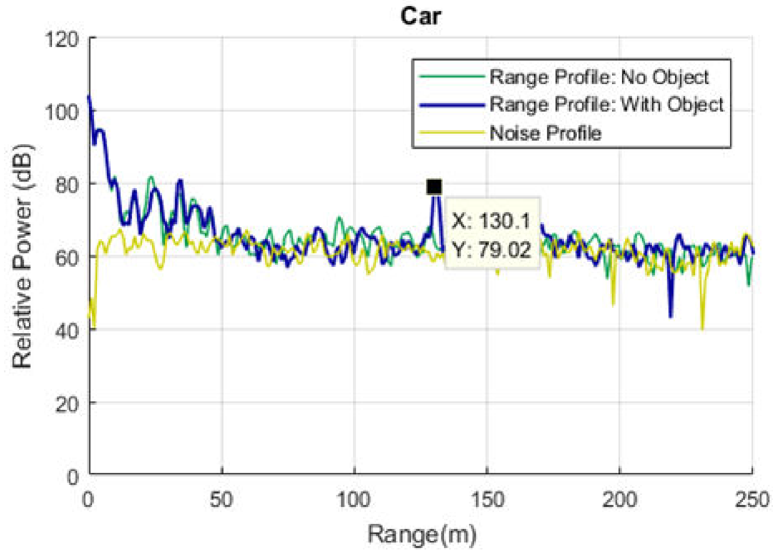

Figure 2-4. Car

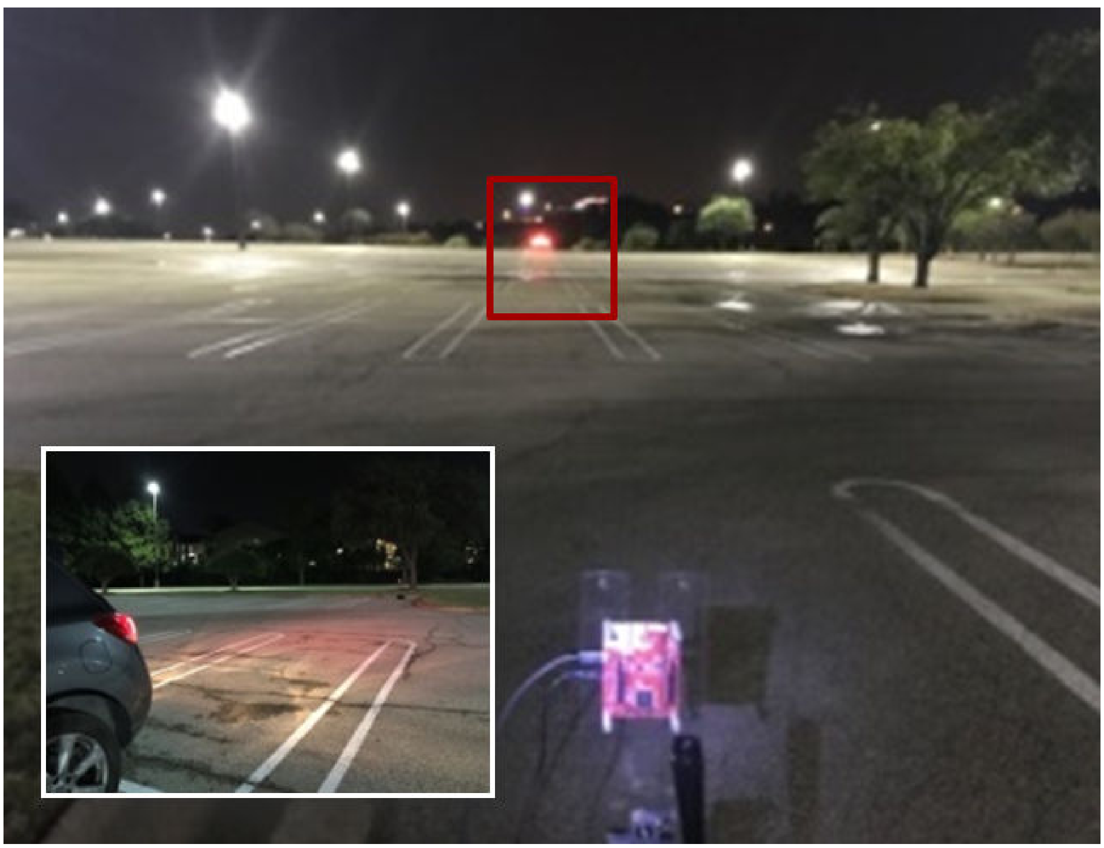

Figure 2-5. Car Distance Test

2.2.3 Motorbike

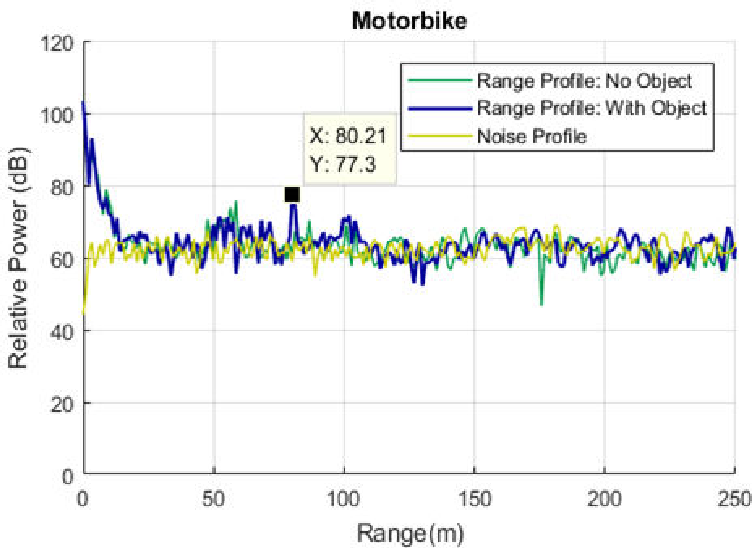

Figure 2-6. Motorbike

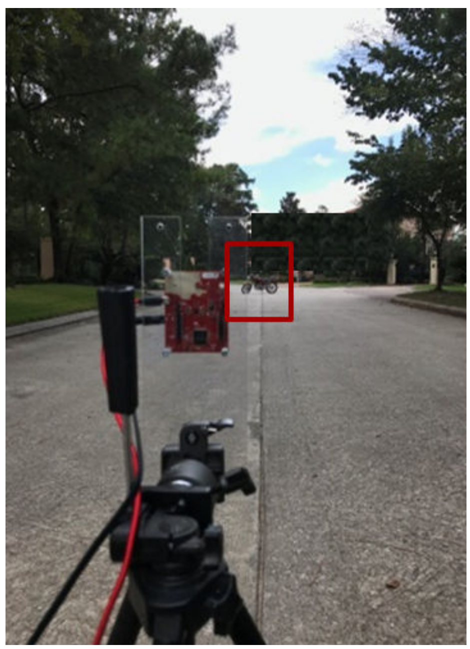

Figure 2-7. Motorbike Distance Test

2.2.4 Bicycle With Human

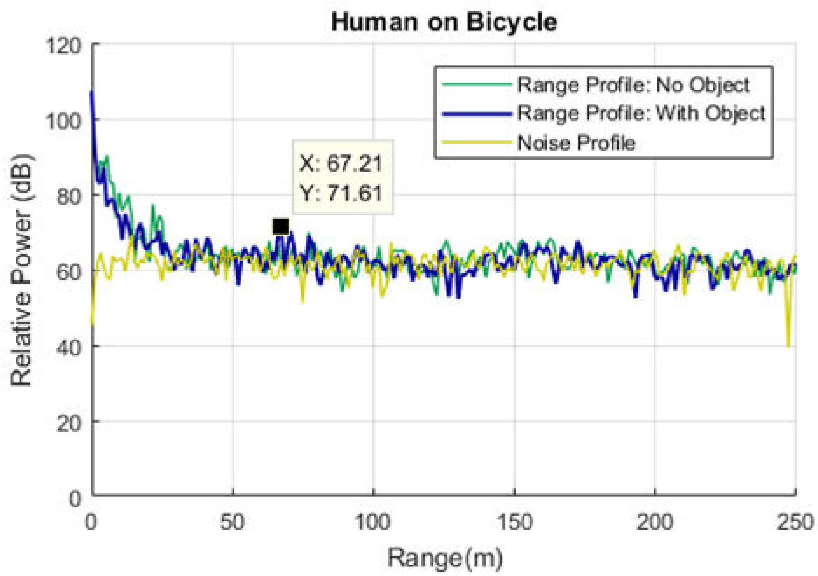

Figure 2-8. Bicycle With Human

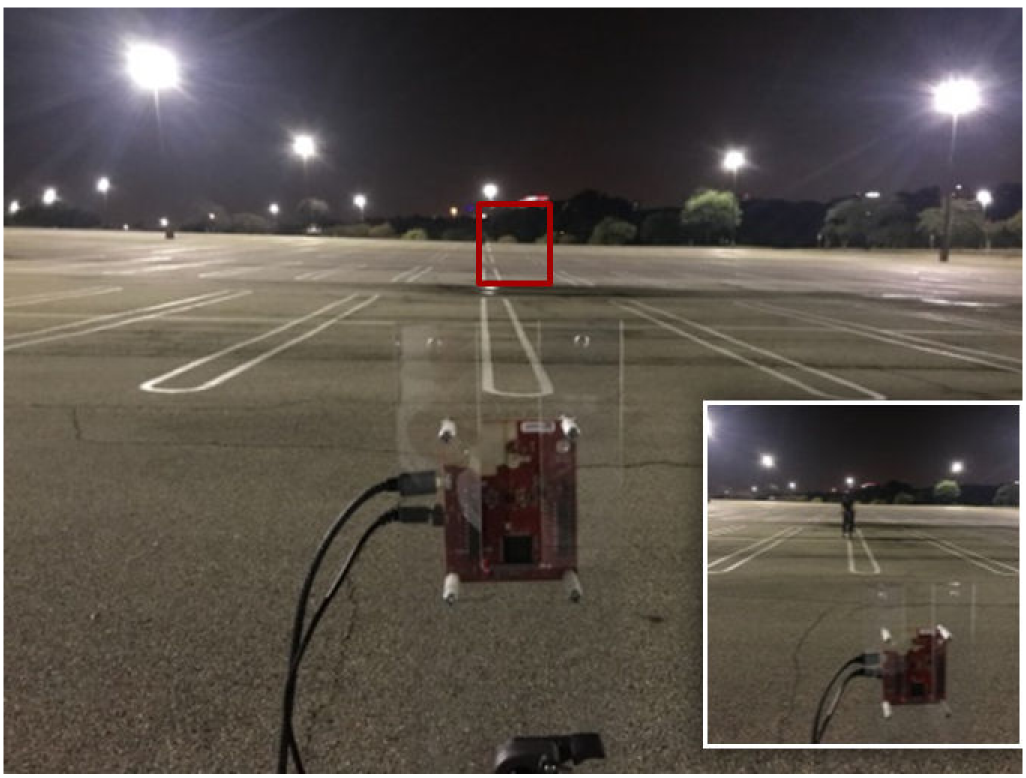

Figure 2-9. Bicycle With Human Distance Test

2.2.5 Human

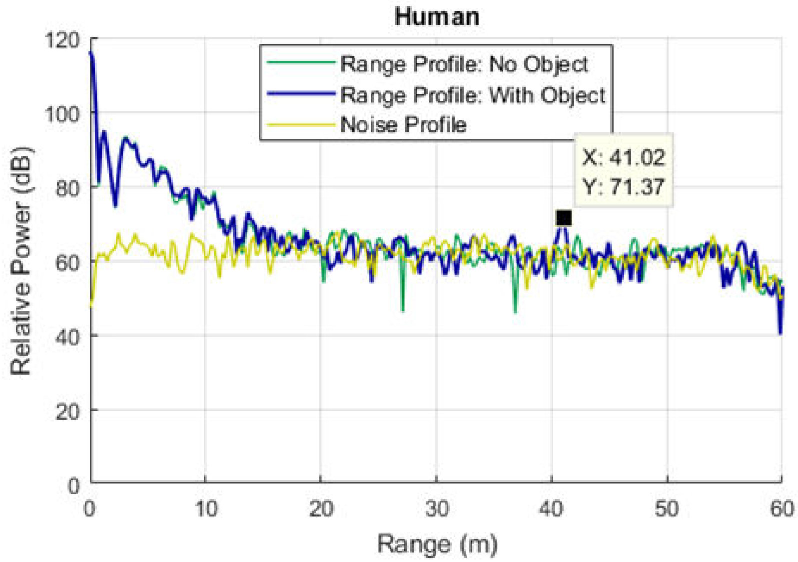

Figure 2-10. Human

Figure 2-11. Human Distance Test

2.2.6 Metal Chair

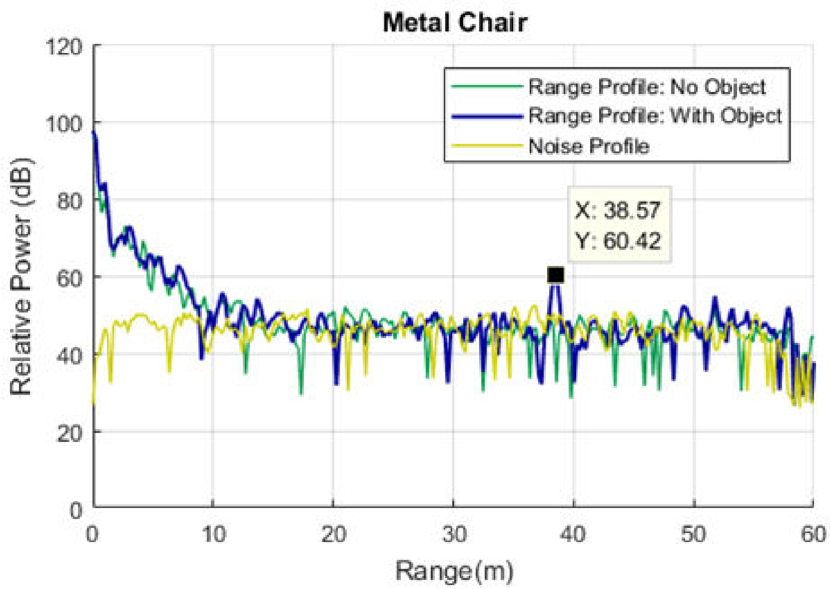

Figure 2-12. Metal Chair

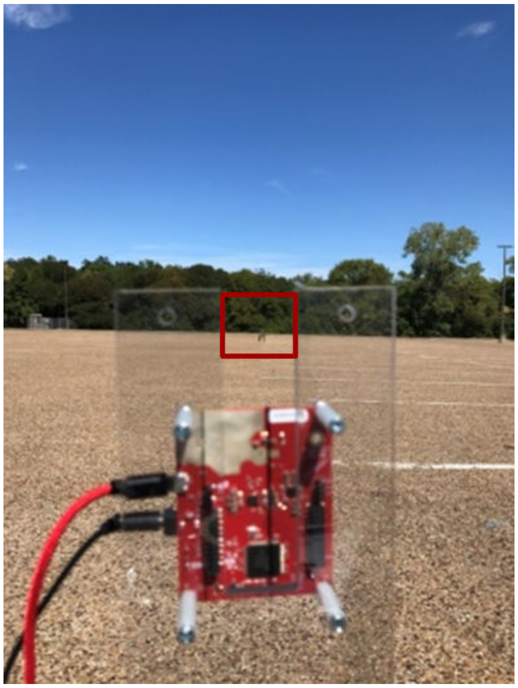

Figure 2-13. Metal Chair Distance Test

2.2.7 Soda Can

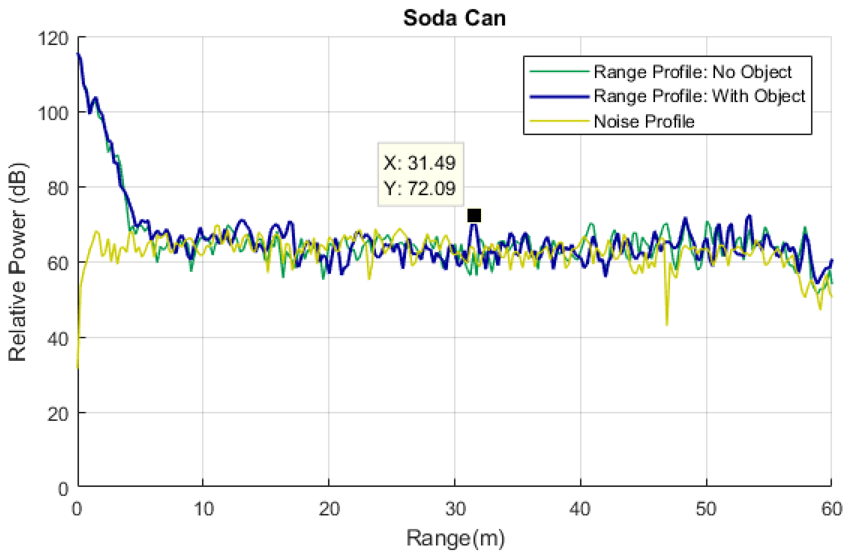

Figure 2-14. Soda Can

Figure 2-15. Soda Can Distance Test

2.2.8 Wooden Chair

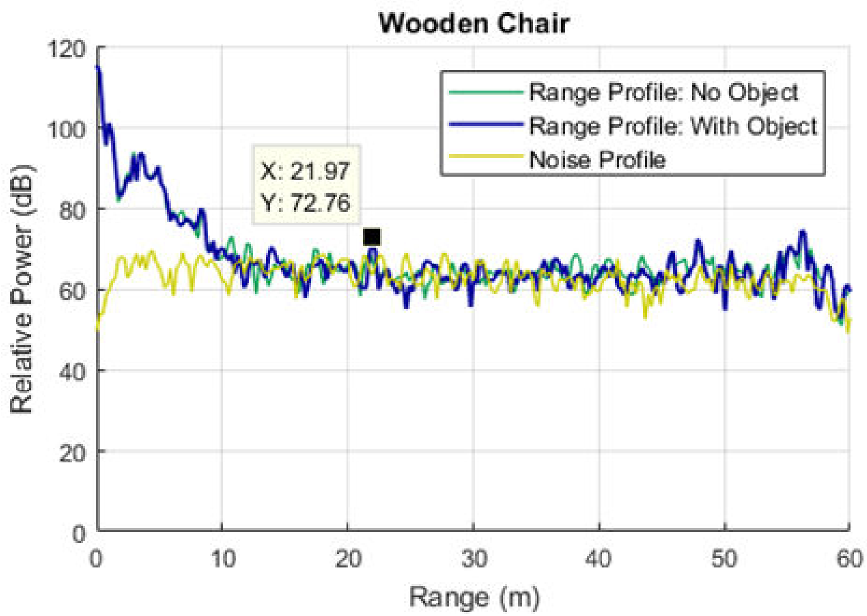

Figure 2-16. Wooden Chair

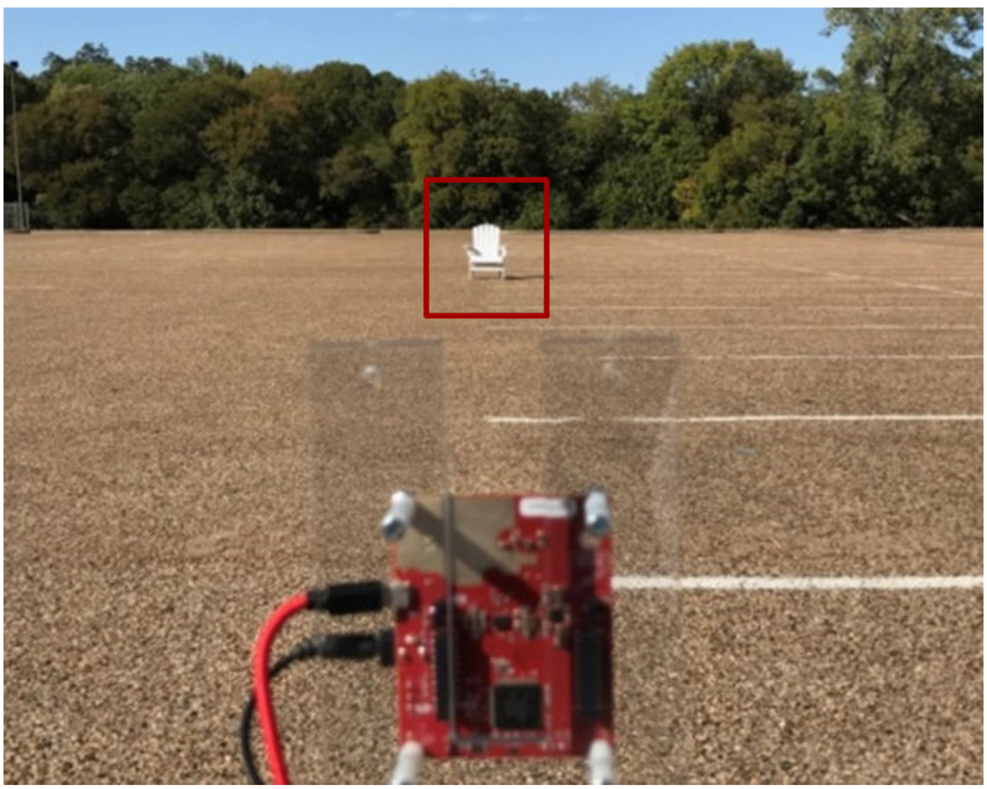

Figure 2-17. Wooden Chair Distance Test

2.2.9 Plastic Chair

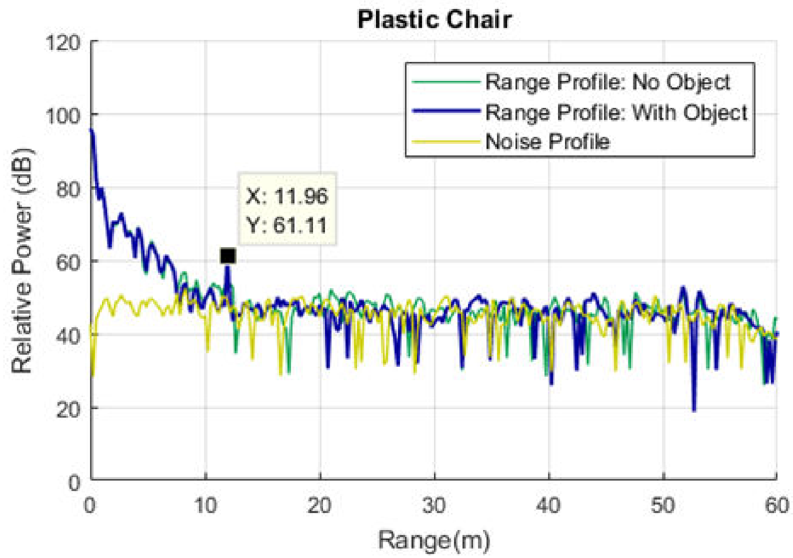

Figure 2-18. Plastic Chair

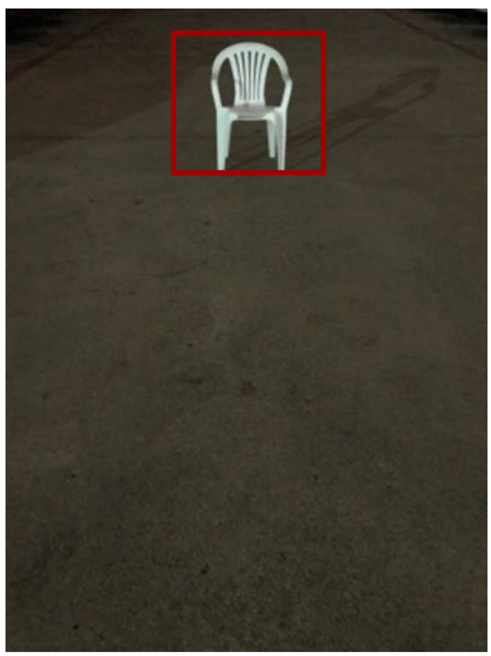

Figure 2-19. Plastic Chair Distance Test

2.2.10 Cup of Coffee

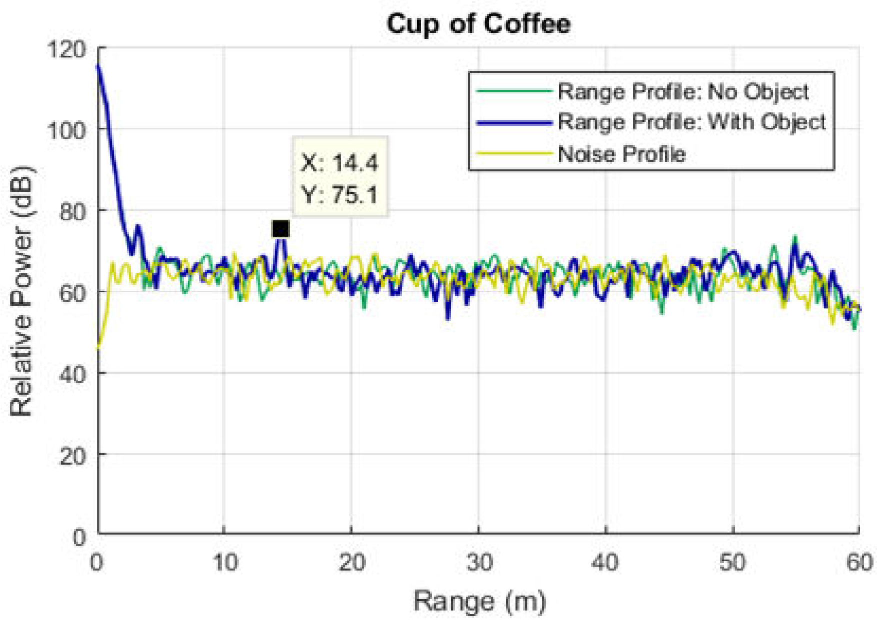

Figure 2-20. Cup of Coffee

Figure 2-21. Cup of Coffee Distance Test

2.2.11 Large Dog

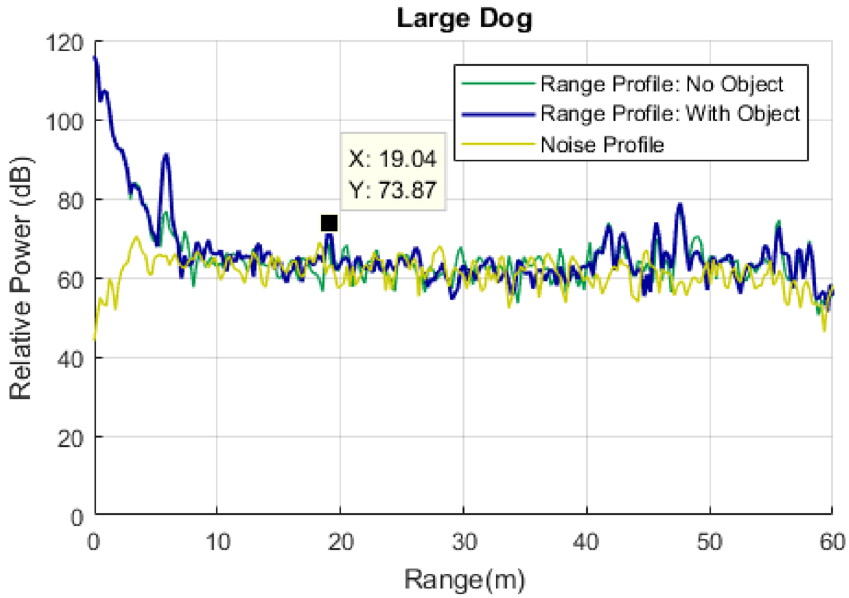

Figure 2-22. Large Dog

Figure 2-23. Large Dog Distance Test

2.2.12 Small Dog

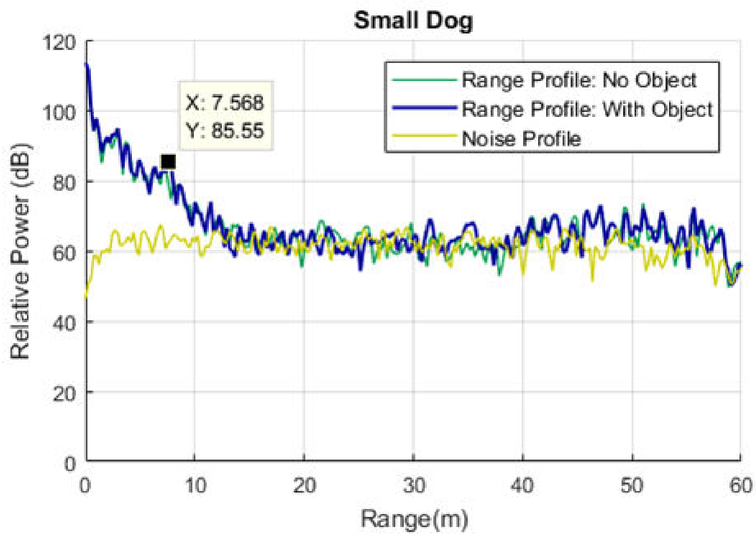

Figure 2-24. Small Dog

Figure 2-25. Small Dog Distance Test

3 Discussion and Object Considerations for Maximum Range

The object versus range data points listed in Table 2-1 list a qualitative gauge for the possibilities of range detection using TI mmWave sensors. However, for specific end applications, the exact maximum detectable range will differ and be influenced by radar system parameters, target characteristics, and background effects (clutter, noise, and more). The relationship between these parameters and maximum range are detailed in Section 3.1.

The radar range equation and the effects of radar system parameters are further detailed in *Programming Chirp Parameters in TI Radar Devices*.

Section 3.1 details how target characteristics relate to maximum range.

3.1 Radar Range Equation and Radar Cross Section

Each target object has a property referred to as radar cross section (RCS): a measure of the ability of the target to reflect radar signals in the direction of the radar receiver. A greater RCS indicates greater ability to be detected for a given radar sensor system.

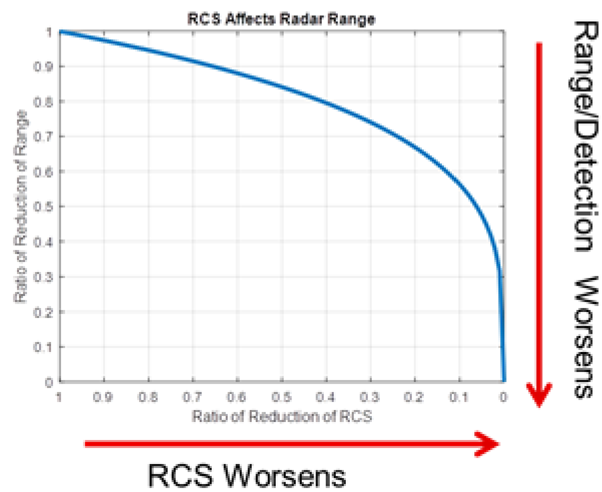

Figure 3-1. RCS and Detection Range Relationship

Figure 3-1 illustrates how relative changes in RCS affect maximum detection range (given that all other parameters are held constant and only the object of detection with its corresponding RCS changes). For example, if the RCS of the target is reduced to 10% then the maximum range the target can be detected reduces to approximately 55%.

3.2 Factors Affecting Radar Cross Section

For the same radar system and environmental settings, an object with a higher RCS can be detected at a further range than an object with a lower RCS.

The relationship between RCS and maximum detection range can guide understanding of the detection ranges achieved by the various objects in Table 2-1.

3.2.1 Material of Target Object

When comparing the soda can and the cup of coffee, which were measured under the same conditions, it is evident that the detection range of the soda can is greater. The material of the soda can is aluminum and the cup of coffee is paper. This exemplifies a primary factor affecting RCS: material of the object. In general, conductive materials have higher RCS values than non-conductive materials. For non-conducting materials, materials with higher dielectric constants have improved RCS values.

3.2.2 Size, Shape, and Orientation

For the truck and car, even though both are largely comprised of metal, the physically larger truck has a greater detection range.

Because RCS is a measure of reflectivity back to the radar, a larger object will generally give a stronger radar reflection. However, it is important to note that it is not just the increase in surface area that would improve RCS, but rather surface area normal to the radar. Therefore, the shape and orientation of the target object relative to the radar can affect the RCS.

In the case of the car and truck from Table 2-1, the measurements were intentionally taken with the radar oriented towards the short or backside of the vehicles as the more challenging case.

When developing applications using a radar system, considering the properties of the target object that affect RCS is necessary.

4 Conclusion

This document includes examples of the range detection capabilities of TI's mmWave radar sensors in an object versus range table (see Table 2-1). An intuitive understanding of how RCS can increase or decrease radar detection range can be developed from Table 2-1.

5 Revision History

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

Changes from Revision * (January 2018) to Revision A (May 2021) **Page**

- Updated the numbering format for tables, figures and cross-references throughout the document..................2

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