Technical White Paper

mmWave Radar Benefits in Thermostats

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ABSTRACT

This document introduces 60GHz millimeter wave (mmWave) radar as a transformative technology for smart thermostats. It overcomes the limitation of traditional PIR sensors, Combine AI-based algorithms, it can avoid false alarms triggered by pets, foliage, or even environmental disturbances. This capability verifies significant energy savings by preventing the conditioning of empty spaces while consistently maintaining occupant comfort. The ability of the sensor to operate through plastic enclosures also allows for an exquisite appearance. Overall, mmWave radar redefines the smart thermostat experience by merging technical superiority with user-centric innovation.

1 Introduction

In recent years, thermostats have undergone a significant transformation from simple temperature control devices to sophisticated smart hubs that integrate various features and technologies. As people seek to optimize the indoor climate and reduce energy consumption, the demand for advanced thermostat designs has grown. Modern smart thermostats are now equipped with an array of features, including geofencing, voice control, predictive maintenance, and personalized comfort settings.

One of the key technologies driving this evolution in smart thermostats is millimeter wave (mmWave) radar, a highly sensitive and accurate sensing technology that enables precise occupancy detection. mmWave radar systems use high-frequency electromagnetic waves to mmWave Radar systems use high-frequency electromagnetic waves to detect the velocity of an object, range and angle of arrival. By leveraging mmWave radar, smart thermostats can provide enhanced indoor climate control, energy efficiency, and occupant comfort. This also significantly reduces HVAC system usage, resulting in lower energy bills and a reduced carbon footprint.

2 Why Use TI 60GHz Radar

mmWave radar systems transmit electromagnetic wave signals by TX antennas. When the signals touch the objects in a path, the signal reflects. The mmWave Radar systems RX antennas capture the reflected signal, and calculate the range, velocity and angle of the objects.

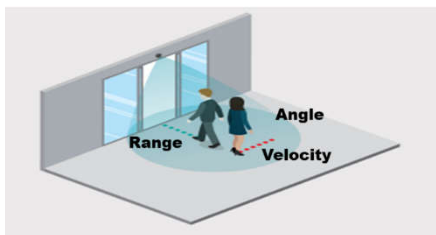

Figure 2-1. The Range, Velocity and Angle of The Objects

Compared to PIR (Passive Infrared Sensor), PIR sensor can only detect the motion of people in an area and are sensitive to the range of area. mmWave radar can not only detect people but also track precisely where objects are in a 3D environment and count the number of people in an area to improve space utilization for thermostats. Other features such as gesture recognition, fall detection and false detection mitigation help to improve the end users experience with *smart* thermostats.

Nowadays more RF sensors use 60- and 77GHz radio bands instead of 24GHz frequency bands. The main reason is that 60GHz has richer point-cloud data and better range and velocity resolution. For more information, see *Choosing 60-GHz mmWave sensors over 24-GHz to enable smarter industrial applications*.

Table 2-1. Comparison Table of Radar RX, TX Numbers and PIR

Feature	2TX, 3RX	1TX, 1RX	PIR	Remarks
Presence and Range Detection Major motion	✓	✓	✓	FOV and how far away the person is from the sensor. PIR cannot detect distance
Presence and Range Detection Minor motion	✓	✓	×	Can a person remain detected with little to no movement. PIR cannot detect minor motions
False Detection Mitigation	✓	×	×	More RX TX provides doppler, height, size, angle, and location better classification and filtering to mitigate false detection
Localization	✓	×	×	More RX TX provides zone occupancy detection – precise location of the person. 1*1 can only provide distance & presence in 1D
Tracking	✓	×	×	More RX TX provides predictive and historical direction.
Gesture Classification	✓	✓	×	Left to Right, Right to Left, Up to Down, Down to Up, Clockwise Twirl, Counterclockwise Twirl, Shine. Toward to sensor. Away from sensor
Vital Sign	✓	✓	×	More RX TX measures multi-person heart/breath rate from various locations. 1*1 limited to single person, no other movement and subject is at boresight of sensor

× = Not possible, ✓ = Limited usability

3 Radar Benefits for Thermostat

mmWave radar technology in thermostats has brought about numerous benefits, enhancing the overall user experience and energy efficiency.

3.1 Saving Energy

One of the most significant advantages of using mmWave radar in thermostats is energy saving. This can be achieved by continuously monitoring the space for presence or absence of people, adjusting for the temperature setting. This dynamic approach ensures that the thermostat is optimized for the actual number of occupants, eliminating unnecessary heating or cooling, and thus reducing power consumption. As a result, homeowners and businesses can enjoy substantial savings on their energy bills while contributing to a more sustainable environment.

In addition, incorporating a thermostat into a thermostat not only saves energy but also makes it easier for the thermostat to obtain Energy Star certification, making the product more competitive. For more information on Energy Star requirements and details, see *ENERGYSTAR® Program Requirements For Connected Thermostat Products* .

Table 3-1. Connected Thermostat Energy Saving Criteria

Metric	Statistical Measure	Performance Requirement
Annual % run time reduction, heating (HS)	Lower 95% confidence limit of weighted national average	≥8%
	Weighted national average of 20th percentiles	≥4%
Annual % run time reduction, cooling (CS)	Lower 95% confidence limit of weighted national average	≥10%
	Weighted national average of 20th percentiles	≥5%
Average resistant heat utilization for heat pump installations (RU)	National mean in 5°F outdoor temperature bins from 0 to 60°F	Reporting requirement

3.2 People Tracking and Screen Wake Up

The ability of the mmWave radar to track people within sensing range also enables another useful feature in smart thermostats – the screen wake-up on presence detection. This functionality makes sure that when someone enters or exits the room, the thermostat screen wakes up, providing users with real-time information about the indoor climate and any adjustments made. The integration of this dynamic feedback loop empowers homeowners to better understand energy usage patterns and makes it easier to optimize thermostat settings for improved comfort and efficiency.

Figure 3-1. Thermostat Screen Wakeup

3.3 Compact and Exquisite Appearance

Passive Infrared (PIR) sensors have been used in thermostats for years; often with bulkier designs compared to modern millimeter wave (mmWave) radars. PIR sensors typically require a wider field-of-view lens and detection unit, resulting in larger overall dimensions. This design can appear less streamlined or sleek compared to the compact mmWave radar. In contrast, mmWave radar technology is built around miniaturized components and advanced algorithms that enable precise temperature sensing without the need for bulky lenses or detectors. When considering installation, this slimmed-down profile of mmWave radar modules allows for greater design flexibility, enabling seamless integration with various home decor styles or architectural features.

To highlight the visual appeal difference between these technologies:

PIR sensor: Typical size range around 4-6 cm^3; distinct lens and detector components visible from an external perspective. mmWave radar: Approximately 1-2 cm^3 in volume; compact, inconspicuous design with negligible visual impact on surroundings.

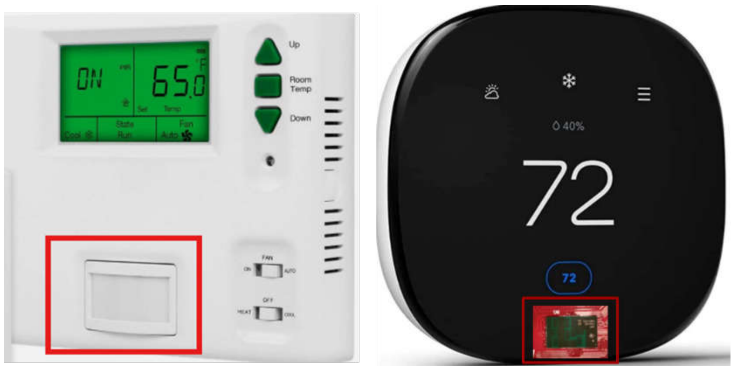

Figure 3-2. PIR size vs mmWave Radar Size in Thermostat

By embracing a more refined and compact user interface design combined with the tiny mmWave radar component, there is a complete makeover in both function and style of smart thermostats. This new approach to product development encourages thinking about how digital products interact, coexist, and become integral parts of lives of the users.

3.4 False Detection Filtering with AI

In motion detection systems leveraging mmWave radar, false alarms triggered by pets, foliage, or even environmental disturbances have long been a pain point, leading to inefficiencies in energy management (for example, thermostats activating unnecessarily) or security systems generating unwarranted alerts. By integrating AI into mmWave radar pipelines, these challenges are systematically addressed. Trained in vast datasets of human movement patterns and signal profiles from non-human objects, AI algorithms can dissect high-fidelity data of the mmWave in real time, distinguishing between meaningful human presence and irrelevant noise with remarkable precision. This not only elevates user experience by eliminating disruptive false triggers but also optimizes system reliability, making sure that applications such as smart home automation, commercial occupancy sensing, or security designs operate with unwavering accuracy, even in complex and dynamic environments.

4 TI Design and Resource Helps Quick Evaluation

4.1 TI Radar Device and Resource

TI provides a board portfolio of mmWave radar device for different use scenarios. The key parts for industrial applications are IWR6843/AOP and IWRL6432/AOP.

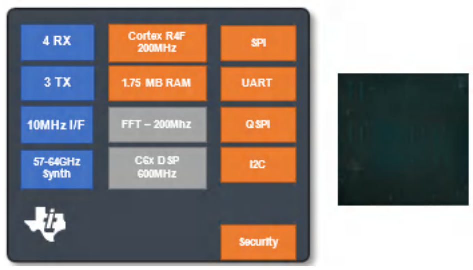

Figure 4-1. IWR6843/AOP

IWR6843/AOP focuses on high performance applications. IWR6843/AOP supports 3 transmitter and 4 receiver antennas. IWR6843AOP has 1-patch antennae on package (AOP). So, no external antennas are needed for layout simplification and cost saving. IWR6843/AOP can track up to 10 people with 85% accuracy and can detect range up to 100 meters. Fluent classification and application are fulfilled on IWR6843/AOP, like human fall down detection.

Compared to IWR6843/AOP, IWRL6432/AOP focuses on low power consumption and low-cost applications. supports two transmitters and 3 receiver antennas. IWRL6432AOP also has 1-patch antennae on package (AOP). IWRL6432/AOP can track up to 5 people with 85% accuracy and can detect range up to 20 meters. IWRL6432/AOP has a high-performance Cortex M4F 160MHz MCU and an FFT CFAR-CA detection 80MHz Radar hardware accelerator. Cortex M4F MCU supports AI algorithm designs, such as tree waves and pets in area filtering out.

Figure 4-2. IWRL6432/AOP

So, for most residential homes the low cost and power IWRL6432 is a preferred design to utilize the additional technology benefit. The small size and no external need of antenna makes IWRL6432AOP to be installed in compact mechanical housing and no open window is shown on the thermostat surface.

4.2 TI Reference Design about Radar

TIDA-010254 demonstrates the use of a battery powered IWRL6432 60GHz mmWave radar with a sub-1 GHz or Bluetooth® 5.2 wireless communication.

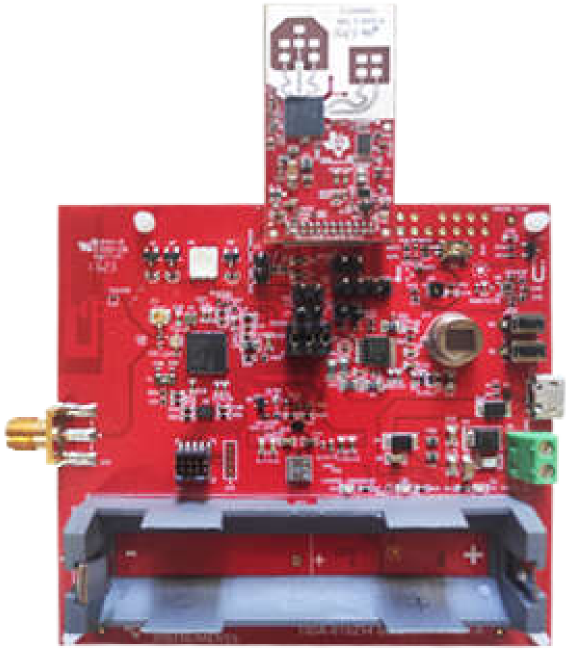

Figure 4-3. TIDA-010254 Demo Boards

Two boards are designed for communication between the IWRL6432 60GHz mmWave radar and the CC1352R1 wireless part, shown in Figure 4-4. The PCB board size of IWRL6432 module is 41mm × 21mm, which can be ordered on IWRL6432FSPEVM. For details of schematic and layout design, see the design files of IWRL6432FSPEVM and design guide of TIDA-010254.

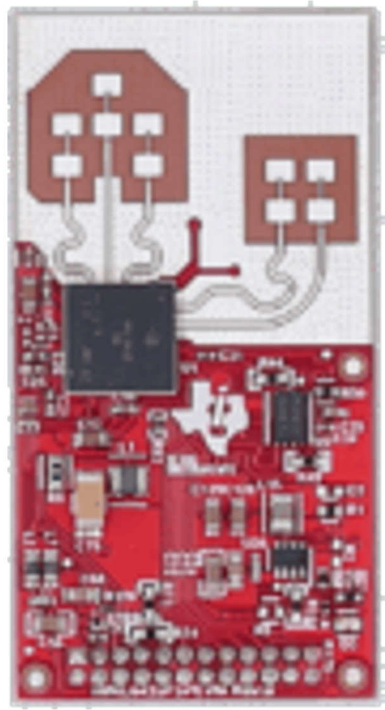

Figure 4-4. IWRL6432FSPEVM

TIDA-010967 demonstrates the low-cost and low-power capabilities of IWRL6432AOP mmWave sensor. The design supports interfaces with connectivity devices through the use of castellated pins or 1.27mm-pitch connectors. This design uses a UART-to-USB converter for flashing the firmware and running the demonstration. The reference design is developed with FR4 material using a two-layer PCB stackup.

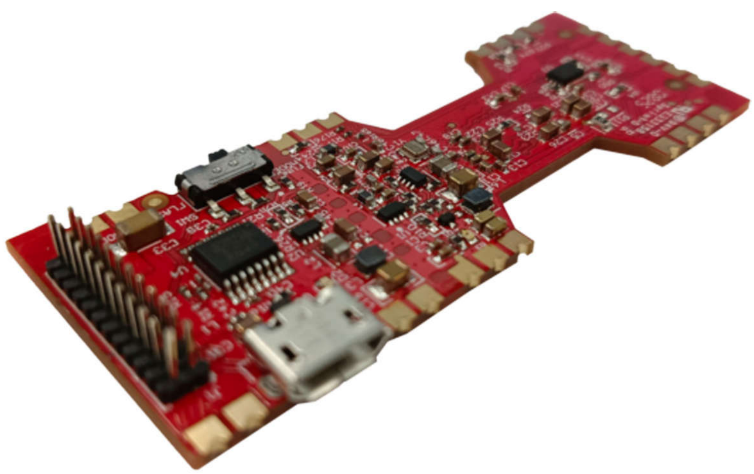

Figure 4-5. TIDA-010967 Demo Board

5 Summary

To sum up, 60 GHz mmWave radar empowers smart thermostats with accuracy, reliability, and innovation. By embracing this technology and available resources, developers can deliver smart thermostats that are more efficient, user-centric, and capable of redefining home climate control.

6 References

1. Texas Instruments, *IWRL6432AOP data sheet, product information and support | TI.com*, product page.
2. Texas Instruments, *Battery-powered mmWave radar sensor with sub-1-GHz and Bluetooth® 5.2 reference design*, reference design.
3. Texas Instruments, *Low-power two-layer mmWave radar reference design*, reference design.
4. Texas Instruments, *False Detection Mitigation with mmWave Radar*, video.

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