How Antenna-on-package Design Simplifies mmWave Sensing in Buildings and Factories

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Traditional sensing technologies have been used to tackle the challenging problems of people counting, motion detection, industrial area scanning, and robotics to detect objects and avoid collisions.

As more industrial applications move toward autonomous functioning, sensing becomes more important to generate and process a variety of data so that systems can become autonomous and make real-time decisions. With Texas Instruments' highly integrated millimeter-wave (mmWave) radar sensors, a larger amount of processing can occur within the sensor, thus enabling intelligence at the edge.

TI mmWave sensors perform in a variety of environmental and lighting conditions for indoor and outdoor applications. These extremely rugged sensors can be mounted directly behind enclosure plastics without external lenses, apertures or sensor surfaces, which makes this technology capable of accurate sensing in many building and factory applications. TI's 60-GHz frequency modulated continuous wave (FMCW) mmWave technology allows open-band mmWave sensing for most industrial applications worldwide. To make industrial sensing even more streamlined, small size antenna-on-package sensors enable designs in form factors that were never possible before.

Antenna-on-package Sensor Design

In radio-frequency (RF) sensor-based systems, antenna design is just as important as sensor selection. The antenna configuration determines the maximum object range, the maximum field of view (FoV) and the resolution, which is important for several applications. With a single sensor and the right antenna configuration, an industrial system can cover a wide area for simultaneous object detection. Traditionally, mmWave antennas have been designed on a printed circuit board (PCB) using Rogers material to deliver high-accuracy sensing. Although highly effective, this does require RF expertise to design and manufacture an antenna to work alongside the sensor.

A new antenna-on-package (AoP) design simplifies board manufacturing and system design vastly, so that engineers with minimal RF expertize can integrate TI mmWave sensors into their systems with great ease. AoP sensors result in a 40% board reduction compared to a standard TI 60- GHz sensor and a 75% board reduction compared with other radar technologies. **Figure 1** illustrates the size reduction possible when moving from a traditional 60-GHz mmWave sensor to a 60-GHz mmWave AoP sensor.

The key benefits of using TI mmWave AoP sensors include:

- Reduced system and manufacturing cost and complexity, for faster time to market.
  - Flexibility to manufacture anywhere in the world with a simpler, cheaper FR4 design.
  - Minimal RF expertise needed to design and develop a sensor solution in-house.
- Small form factor.
  - Viable for industrial market applications that need a smaller sensor footprint.
- Higher efficiency due to zero board routing loss.
  - Better range performance.

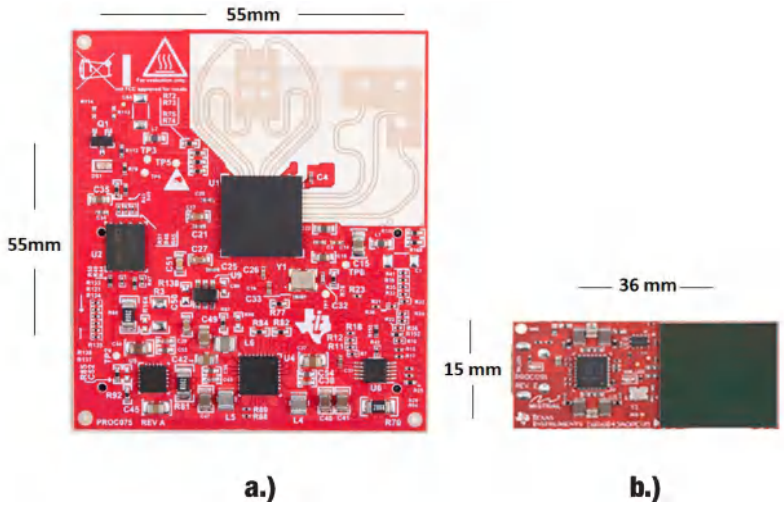

Figure 1. *Comparing a 60-GHz 55-Mm-by-55-Mm TI mmWave Evaluation Board with External Antenna; and the New 15-Mm-by-36-Mm Evaluation Board Design with TI's mmWave AoP Sensor.*

Using TI mmWave Sensors with an AoP Design for Industrial 3D Sensing

An mmWave sensor requires the capture of both location and accuracy data from its environment. Key data sets include the range of the object from the sensor and the speed of the object. To maximize useful data collection, a 3D sensing system should also be able to detect the height of an object and filter out ground clutter. This maximizes a sensor's accuracy and measurement performance.

An AoP antenna's wide FoV configuration provides a 130-degree view in the azimuth and elevation, which provides true 3D sensing whether the sensor is ceiling- or side-mounted. This antenna configuration, along with the small size of TI mmWave AoP sensors, makes radar sensing possible nearly everywhere in building automation, factory automation, smart homes, personal electronics and industrial systems.

Let's focus on three applications that AoP sensors enable: robotics, occupancy detection, and automated doors and gates.

Robotics: Collision Prevention over a Wide Area

Industrial robots are designed to move slowly when operating alongside humans. Robotic arm and autonomous robot makers must implement a high level of environmental sensing and redundancy into robot systems to quickly detect and prevent possible collisions, using 3D sensing capabilities to define safe and danger zones.

Figure 2. *TI mmWave AoP Sensors Enable Automation in a Variety of Robots in Factories and Homes.*

TI mmWave AoP sensors enable a wide variety of robotic applications, as shown in **Figure 2**. A wide FoV translates into more coverage around robots for collision avoidance on factory floors, and the small form factor makes it easy to fit into smaller robot designs like cleaning robots.

Along with 3D object detection for robotics applications, AoP sensor design addresses three main challenges for factory automation:

- Wide coverage with single sensor: An AoP design can detect objects across a 130-degree FoV, which enables wider area coverage from which to detect multiple moving objects or people for better incident management in robotics. This in turn reduces the number of sensors used for area scanning and reduces overall system cost.
- Small form factor: The smaller form factor of AoP sensors means that they can fit into smaller enclosures, which is important for sleek, small autonomous robot designs such as autonomous guided vehicles, delivery robots, and smaller robotic arms in factories for sense-and-avoid applications.
- Fast time to market: By eliminating expensive PCB substrates and RF expertise, AoP sensors simplify the design and manufacturing process, enabling in-house designs and reducing time to market.

Occupancy Detection: Simplified Sensing in Wall- and Ceiling-mounted Placements

Sensing solutions in building automation are generally concerned with detecting and understanding the occupancy of rooms or areas of interest in commercial or residential buildings. Besides the advantages that TI mmWave technology brings, such as motion sensitivity, location accuracy and privacy, an AoP design brings additional value to the building automation market.

TI mmWave AoP sensors have a wide FoV and small form factor to bring installation and design flexibility to unique building automation sensing applications such as elderly monitoring and air conditioners, as shown in **Figure 3**.

Solution complexity can be an incredible barrier to entry for a sensing technology in building automation. AoP sensors simplify and accelerate the design process so that engineers in building automation applications can focus their investment on differentiating software for people detection and identification.

The AoP sensor's antenna configuration makes it suitable for both wall- and ceiling-mounted orientations. In building automation, this wide FoV provides flexibility in mounting installations so that sensors can be placed closer to power and data routing in commercial buildings, or in conjunction with existing automation systems, to reduce the installation cost and number of installed systems.

Through its ability to fit in smaller enclosures, the smaller form factor enables cleaner industrial designs, which can help clear the visual ceiling clutter or "ceiling acne" common with sensing installations in commercial buildings today.

Automated Doors and Gates: Position- and Velocity-based Operation in Tight Spaces

Intelligent sensors play a key role in automated door and gate applications by allowing safe, cost-effective and energy-efficient solutions. Along with the benefits of TI mmWave sensors, AoP design brings further advantages in an application space where designers and manufacturers do not necessarily have RF expertise in antenna design. The ease of integration of AoP sensors enables them to focus on making doors and gates smarter, as opposed to spending resources on sensor development.

With a wide FoV, one sensor has the ability to cover the entire area of interest for a particular door or gate. An AoP design resolves the common issue of "dead zones" that a typical door sensor detection zone may not reach, eliminating the need for multiple sensors in a system.

Figure 3. *Building Automation Sensing Applications Using TI mmWave Sensors Include Elderly Monitoring and Air Conditioners.*

Counting the number of people in a revolving door to avoid overcrowding or determining the height of an obstacle blocking a garage door is simplified by using an AoP design, which seamlessly fits into tight spaces where bulkier sensor modules are not feasible. An AoP sensor's small form factor seamlessly integrates into entrance systems while still covering a wide FoV for convenient door operation, as shown in **Figure 4**.

Conclusion

Combined with the existing benefits of TI mmWave technology, building and factory designers can take automation and intelligence to the next level with an AoP sensor design. With a wide FoV, small form factor and simplified design, these sensors make it possible for industrial system designers to quickly and easily integrate mmWave technology into existing designs and new applications.

Additional Resources

- Learn about **industrial mmWave AoP sensors**.
- Read the white paper, **"Choosing 60- GHz mmWave sensors over 24 GHz to enable smarter industrial applications."**
- View the reference design, **"Autonomous robotics reference design with Sitara™ processors and mmWave sensors using ROS."**

Figure 4. *Examples of Automated Entrance Systems in Buildings and Warehouses Enabled by TI mmWave AoP Sensors.*

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