Choosing 60-GHz mmWave sensors over 24-GHz to enable smarter industrial applications

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Cities, buildings and factories have become more intelligent, driving the need for more robust sensing. In recent years, millimeter-wave (mmWave) sensors have gained a lot of traction due to their ability to sense the range, velocity and angle of objects in a scene.

mmWave sensors use radio frequency (RF) sensing rather than light or sound, which offers unique advantages because the sensors can detect people and objects through a variety of materials such as glass and drywall. These sensors can also operate even when environmental factors such as smoke, rain and low-light conditions are present. Such robustness enables strong performance in both indoor and outdoor applications, including displacement transmitters, safety guards, lighting control and intelligent transport systems.

Radar sensing uses multiple RF bands, and each band is governed by regulations that may vary across regions. Most RF sensors use the 24-, 60- and 77-GHz radio bands. The 77-GHz band is common in automotive applications but has restrictions in most global regions for industrial factory, building, and city infrastructure applications, including those that require human/machine interaction.

Spectrum regulations and standards developed by the European Telecommunications Standards Institute (ETSI) and Federal Communications Commission (FCC) prohibit new products from using the 24-GHz ultra-wide band, starting in September 2018. All existing products using 24-GHz ultra-wide band must be phased out by 2022. These regulatory changes directly reduce a sensor's range resolution and negatively impact its robustness and accuracy. Engineers relying on dense point-cloud data will need a new solution in order to reach top performance once the available bandwidth on the 24-GHz band is reduced.

RF usage on the 60-GHz band is not limited by current or future regulations, however. Sensors using this band are capable of gathering rich point-cloud data with high accuracy, making 60 GHz a good alternative for radar-sensing applications in worldwide industrial settings moving forward.

The 24- and 60-GHz frequency bands

The 24-GHz frequency band has two main components: an ultra-wide band (UWB) and a narrowband (NB), shown alongside the 60-GHz

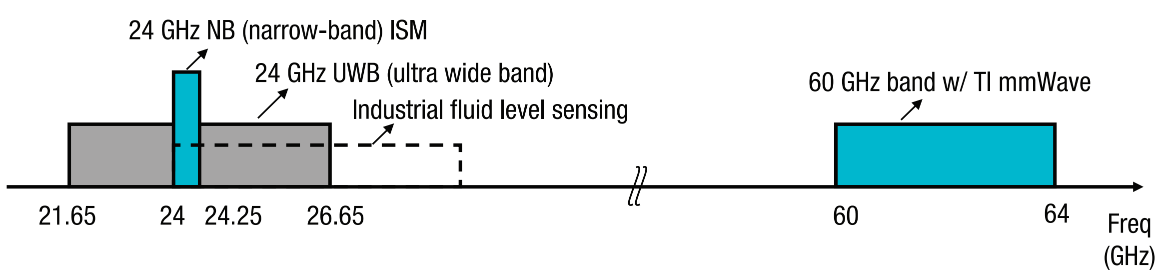

Figure 1. *The 24- and 60-GHz frequency bands.*

band in **Figure 1**. The UWB spans from 21.65 GHz to 26.65 GHz, offering a bandwidth of up to 5 GHz. The NB is an industrial, scientific and medical (ISM) band that ranges from 24.0 GHz to 24.25 GHz, offering only 250 MHz of bandwidth.

Due to spectrum regulations and standards developed by the European Telecommunications Standards Institute and U.S. Federal Communications Commission, the UWB for 24 GHz will be phased out. As of Jan. 1, 2022, the 24-GHz UWB will no longer be allowed for industrial use in both Europe and the United States. Other regions are expected to implement similar regulations.

Comparatively, TI 60-GHz mmWave sensors provide 4 GHz of UWB bandwidth, resulting in 16 times the available bandwidth once the regulations take effect. Because the range resolution is heavily dependent on available bandwidth, 60-GHz mmWave sensors will offer significantly better performance than 24-GHz sensors for high-accuracy radar applications.

Rich point-cloud data

Sensing objects is a key function for mmWave sensors, but many applications need more than just simple object detection. For example, motion detection is a standard use case that mmWave can address. While other technologies may sufficiently detect there are people in a room, people counting and tracking requires a large amount of point-cloud data to accurately identify people while avoiding false triggers.

Rich point-cloud data can identify the number of objects in an mmWave sensor's field of view (FoV), indicate their location and classify them. An example of classification would be detecting a human among indoor clutter such as ceiling fans, shutters or other objects. With mmWave, it could even be possible to identify what specific objects are, such as distinguishing between a dog and a human, such as in a perimeter security application.

Traffic and intersection monitoring is another application where the sensor needs to accurately distinguish between two cars driving at parallel speeds, count the number of cars in a parking lot or track pedestrian movements. In each of these scenarios, rich point-cloud data is critical to maintain high measurement accuracy. Point-cloud data comes from four parameters in mmWave sensors: data in the x, y and z-axes and radial velocity data. Gathering meaningful data requires fine range and velocity resolution from the sensor.

Range resolution

Fine range resolution enables industrial systems to reliably identify and separate closely spaced objects. Range resolution is a function of the available bandwidth from the radar signal. Although the 60- and 24-GHz bands currently offer comparable performance, when the regulation changes limit 24 GHz to 250 MHz of bandwidth, the massive drop in range resolution will impact all radar-sensing applications.

The Texas Instruments (TI) IWR6843 mmWave sensor offers up to 4 GHz of bandwidth, and the resulting range resolution is 3.75 cm. The best possible range resolution for a 24-GHz sensor using 250 MHz of bandwidth is 60 cm. For range resolution, lower numbers offer finer and denser point-cloud data results. **Table 1** compares the range resolution offered by various radar-sensing technologies in 2022.

Figure 2 compares the point-cloud data acquired by the IWR6843 sensor using both 4 GHz and

Technology	60-GHz ISM band (4-GHz bandwidth)	77-GHz band (4-GHz bandwidth)	24-GHz ISM band (250-MHz bandwidth)
Range resolution (cm)	3.75	3.75	60

***Table 1**. Range resolutions available in 2022 for common radar sensors.*

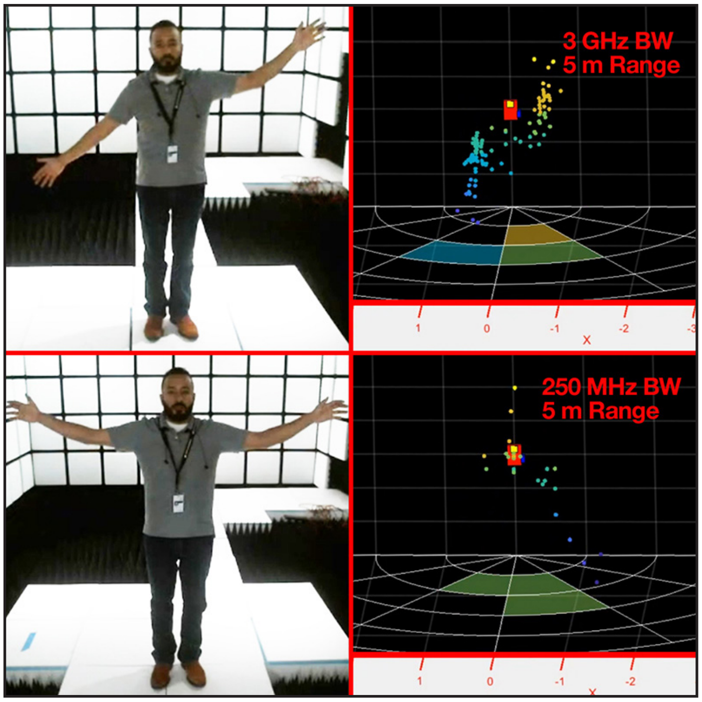

***Figure 2**. Point-cloud comparison image.*

250 MHz of bandwidth at a distance of 3 m. The result of the experiment illustrates the impact that range resolution has in gathering rich point-cloud data, and why the 24-GHz bandwidth reduction in 2022 is such a critical change.

Velocity resolution

Unlike range resolution, fine velocity resolution depends on a variety of parameters. At a fundamental level, velocity resolution scales proportionally with center frequency rather than bandwidth. Thus, 60-GHz radar can also offer as much as 2.5 times better velocity resolution performance than 24 GHz, due to the higher center frequency band.

The impact of weaker point-cloud data sets will often result in the need to revise algorithms. Even if algorithm optimization offered the same performance with less point-cloud data, it would require additional processing time and more resources, which could affect system-level performance or processing costs.

Fine velocity resolution enables better tracking of lateral movements to allow more stable detection of moving objects. In applications like people counting, object separation and lateral motion tracking are vital to accurately detect individuals walking closely together or across a sensor in order to minimize false or missed detections.

Intelligent processing

It's possible to avoid false detections by applying algorithms for environmental modeling and object classification to point-cloud data. These algorithms rely on robust data inputs in order to minimize errors and accurately detect and classify objects within the sensor's FoV.

Processing point-cloud data for object identification and classification requires processor-intensive algorithms. Many systems rely on a dedicated digital signal processor (DSP) to process the raw data acquired from mmWave sensors. TI's mmWave sensor has an integrated microcontroller (MCU), DSP and fast Fourier transform acceleration to handle not only data acquisition, but also advanced applications such as object classification on a single chip, providing intelligence at the edge.

TI mmWave sensors are capable of not just sensing and extracting the range, velocity and angle of objects, but also leveraging that information to count people, navigate rooms and classify objects. This processing capability enables the sensor to make decisions on the spot and reduce system complexity, while still communicating with the bigger network.

PCB space savings

Package size is a key concern for many sensor designers. Whether the available physical space is limited or the sensor needs a slim and small design to be able to better hide in a room, minimizing printed circuit board (PCB) size is a challenge. Smaller PCBs make it easier to design unobtrusive sensor casings, whether they need to be mounted on a wall or ceiling, placed alongside a camera, or installed in space-constrained locations such as inside machinery bumpers.

One of the largest portions of a PCB for radar-sensing designs is the antenna array. Antenna arrays are designed to meet specifications such as FoV and gain, and part of the design needs to account for the wavelength of the radar signal. Longer wavelengths will require larger antenna arrays. However, as the wavelength shortens, it is possible to minimize the size of the antenna array and achieve the same performance.

With just antenna scaling alone, the antenna portion of the PCB can be reduced by a factor of 6 compared with existing 24-GHz sensors, as shown in **Figure 3**. The ability to downscale will enable new sensors to include an antenna within the sensor, further minimizing sensor size and deployment costs.

TI mmWave sensors also integrate signal and data processing into a single chip, which results in fewer components to reduce both board space and bill-of-materials (BOM) costs.

As **Figure 4** shows, to achieve a two-transceiver (2TX) and four-receiver (4RX) system, 24-GHz sensors require multiple components compared to a single mmWave sensor. In addition, the analog front end and digital processing need careful routing and may even require separate PCBs, adding both system complexity and cost.

Between having a higher center frequency and offering an integrated single-chip solution, TI mmWave solutions can significantly reduce the footprint for sensor designs compared to current 24-GHz offerings. This leads to reduced system size and weight, lower installation and BOM costs, and easier integration into mechanical designs.

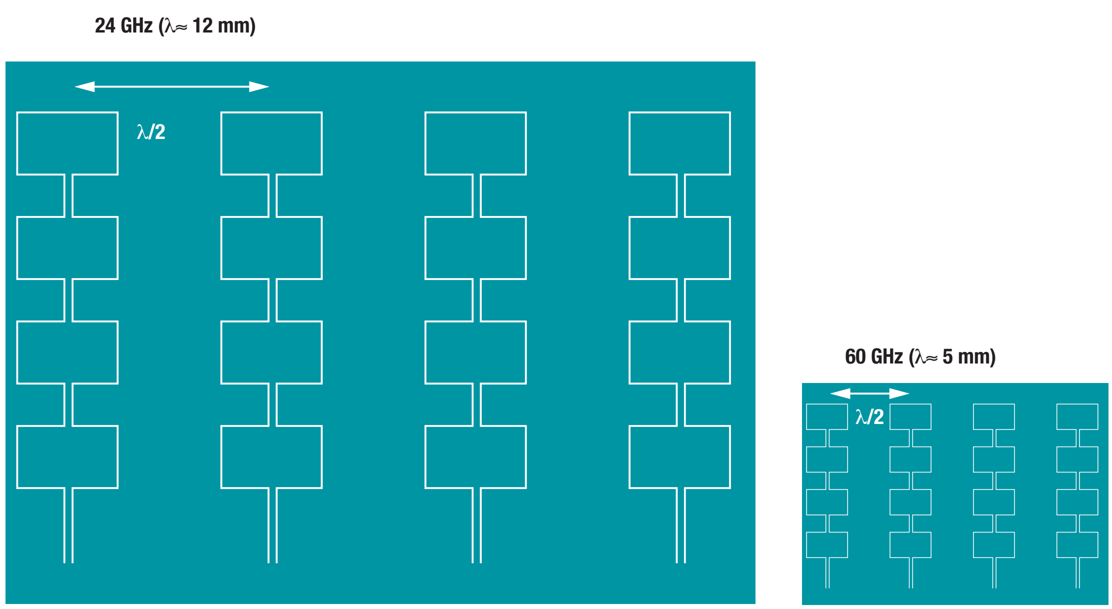

***Figure 3**. Impact of higher RF frequency on shrinking antenna sizes.*

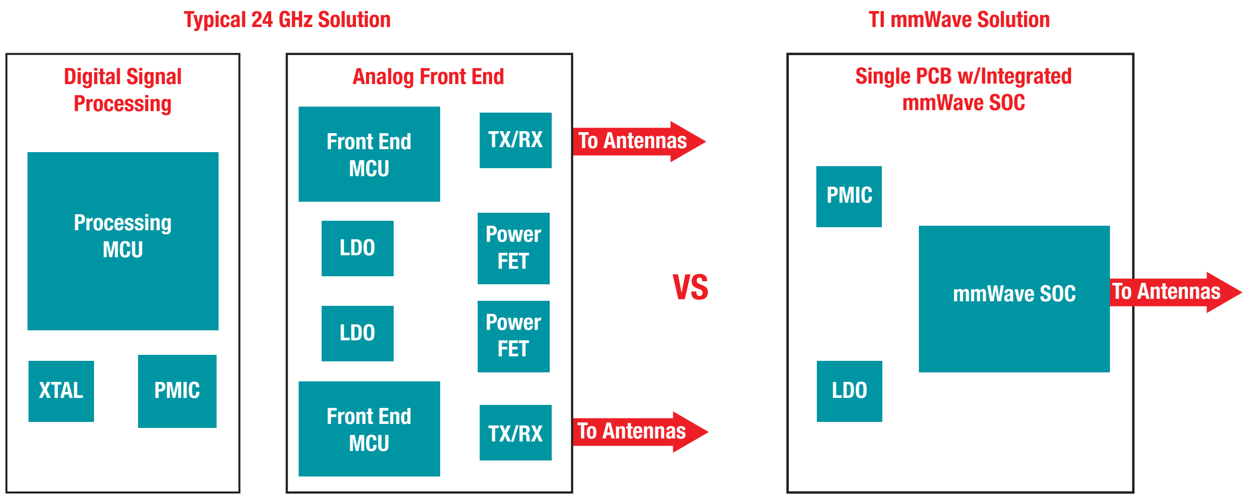

***Figure 4**. Comparison of a typical 2TX/4RX design for a 24-GHz system vs. a TI mmWave 60-GHz system.*

Conclusion

As the 2022 regulation changes begin affecting industrial designs, any systems leveraging the 24-GHz band need reassessing to determine their future viability. Range-resolution reductions will impact dozens of applications, and design changes need to begin now to be ready by 2022.

Any current evaluations for 24-GHz solutions should account for this upcoming change, and established users of the technology must take action immediately to determine whether the reduction in bandwidth will break applications or force redesigns.

Designers of industrial sensing solutions should consider the benefits of TI's 60-GHz integrated single-chip sensors, from their ability to acquire rich point-cloud data in a compact form factor to high range and velocity resolution and integrated processing.

References

- Get started with our modular development platform
- Download the People Counting and Tracking Reference Design Using mmWave Radar Sensor

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