Moving from legacy 24 GHz to state-of-the-art 77 GHz radar

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Radar technology has been in existence for nearly a century across a wide variety of applications, ranging from military to law enforcement to commercial. Interest in the use of radar has exploded in the last decade, especially in the automotive and industrial space.

In the automotive space, primary radar applications can be broadly grouped into corner radars and front radars. Corner radars (at both the rear and front corners of the car) are typically short-range radar (SRR) sensors that handle the requirements of blind-spot detection (BSD), lane-change assist (LCA) and front/rear cross-traffic alert (F/RCTA), while front radars are typically mid- and long-range radars responsible for autonomous emergency braking (AEB) and adaptive cruise control (ACC). In the industrial space, the applications for radar include fluid and solid level sensing, traffic monitoring, robotics and more.

In this article, two frequencies, 24 GHz and 77 GHz, commonly used in these applications will be discussed. We will discuss the shift in the industry toward 77 GHz radar and the various benefits you can achieve. Texas Instruments has a family of highly integrated radar sensors that enables customers to leverage the benefits of the 77 GHz frequency band for radar applications in both the automotive and industrial markets.

24 GHz and 77 GHz frequency bands

Let's start by reviewing the relevant frequency bands of interest (see **Figure 1**). The 24 GHz band includes an industrial, scientific and medical (ISM) band from 24.0 GHz to 24.25 GHz, which is often called the narrowband (NB), having a bandwidth of 250 MHz. This band is unlicensed and can be used as per provisions in [1, 2, 3]. The 24 GHz band also includes an ultrawide band (UWB), which is 5 GHz wide.

For short-range radar, the 24 GHz NB and UWB bands have been in use in legacy automotive sensors. For simple applications like basic BSD, you can use NB ISM, but in most cases, including ultra-short-range radar applications, the need for high-range resolution dictates the use of the UWB band.

Due to spectrum regulations and standards developed by the European Telecommunications Standards Institute (ETSI) and the Federal Communications Commission (FCC), the UWB band will be phased out soon [4, 5, 6, 7]. The 24 GHz UWB band will not be available after January 1, 2022,

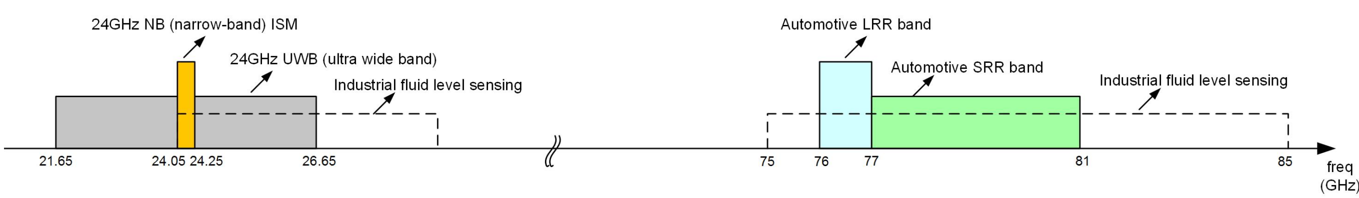

***Figure 1**. 24 GHz and 77 GHz frequency bands.*

known as the "sunset date," both in Europe and the U.S.; only the narrowband ISM band will be available long term. This lack of wide bandwidth in the 24 GHz band, coupled with the need for higher performance in emerging radar applications, makes 24 GHz unattractive for new radar implementations. This is especially true considering the significant interest in the automotive industry for advanced applications like automated parking and 360-degree view.

Looking at 77 GHz, there is a 76-77 GHz band available for vehicular long-range radar applications. This band has the benefit of high allowed equivalent isotropic radiated power (EIRP), which enables front long-range radar applications like adaptive cruise control. This band is also available in Japan [9], as well as in Europe[7] for fixed transport infrastructure radar systems to enable applications such as vehicle counting, traffic jam or accident detection, vehicle speed measurement and vehicle detection for traffic light activation. The 77-81 GHz short-range radar (SRR) band is a new entrant; this band has recently gained significant traction both from a worldwide regulation perspective, as well as industry adoption. The availability of wide sweep bandwidth up to 4 GHz in this band makes it attractive for applications requiring high range resolution. Moving forward, most 24 GHz automotive radar sensors will likely shift to the 77 GHz band.

The 75-85 GHz band is available for industrial fluid and solid level sensing applications [8], making 77 GHz radar sensors attractive for industrial applications. Let's discuss the various benefits of using the 77 GHz frequency band in both automotive and industrial applications.

High-range resolution and range accuracy

One of the key benefits of 77 GHz is the wide bandwidth available in that band. Compared to the 200 MHz ISM band, which is available at 24 GHz, there is significantly higher bandwidth available at 77 GHz. Specifically, the 77-81 GHz SRR band offers up to 4 GHz of sweep bandwidth.

The availability of wide bandwidth significantly improves range resolution and accuracy. The range resolution of a radar sensor signifies its ability to separate two closely spaced objects, whereas the range accuracy signifies the accuracy in measuring the distance of a single object. Since range resolution and accuracy are inversely proportional to the sweep bandwidth, a 77 GHz radar sensor can achieve 20x better performance in range resolution and accuracy compared to 24 GHz radar. The achievable range resolution is 4cm (versus 75cm for 24 GHz radar).

High-range resolution results in better separation of objects (such as a person standing near a car) and provides a dense point cloud of detected objects (see **Figure 2**), thus improving environmental modeling and object classification, important for

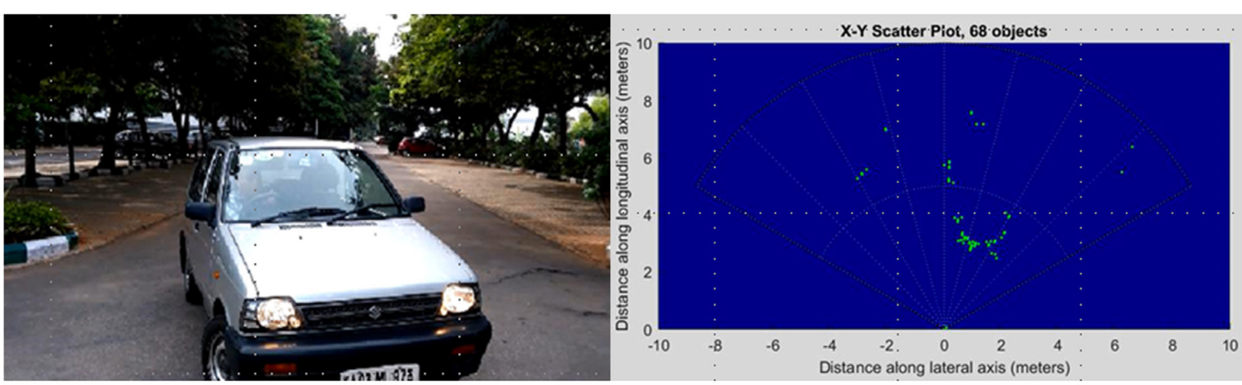

***Figure 2**. High-resolution 77 GHz radar results in a dense point cloud showing the silhouette of the car.*

[1]Regulations around the world are constantly evolving and information on allowed applications in specific bands may change over time.

developing advance driver assistance algorithms and enabling autonomous driving features. Also, higher-range resolution helps the sensor achieve better minimum distances. For automotive applications like parking assist, a minimum distance of detection is very important; the use of 77-81 GHz radar provides a significant advantage in this aspect in comparison to technologies like ultrasound sensors.

For applications like industrial level sensing, range accuracy (down to sub-millimeter) is a key priority. The wide bandwidth available in the 77 GHz band makes range measurements very accurate. Also, the high resolution helps separate the fluid level from any unwanted reflections at the bottom of the tank. This enables the sensor to measure the fluid level "down to the last drop" – minimizing the dead zone at the bottom of the tank, as shown in **Figure 3**. And since high resolution improves the minimum measurable distance, it helps measure the fluid level until the very top of the tank when the tank is full.

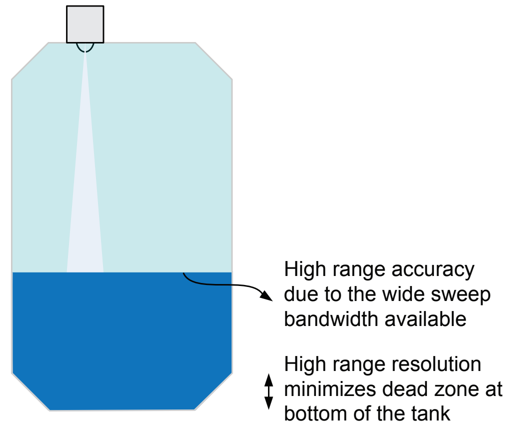

Figure 3. *High-resolution 77 GHz radar improves performance for industrial level sensing.*

For automotive park-assist applications, velocity resolution and accuracy are critical, due to the need to accurately maneuver the vehicle at the slow speeds during parking. **Figure 4** shows a representative 2-D fast Fourier transform (FFT) range-velocity image of a point object at 1m and depicts the improved resolution of the 2-D image obtained with 77 GHz.

Further, recent research has led to advancements in algorithms that use radar for pedestrian detection and advanced object classification, using the higher resolution and micro-Doppler signature available from the sensor. The increased precision of velocity measurements helps industrial applications as well, in the context of autonomous factory vehicles, improved traffic monitoring and more.

Improved velocity resolution and accuracy

The velocity resolution and accuracy are inversely proportional to the radio frequency (RF). Thus, a higher RF frequency leads to a better velocity resolution and accuracy. Compared to 24 GHz sensors, the 77 GHz sensor improves velocity resolution and accuracy by 3x.

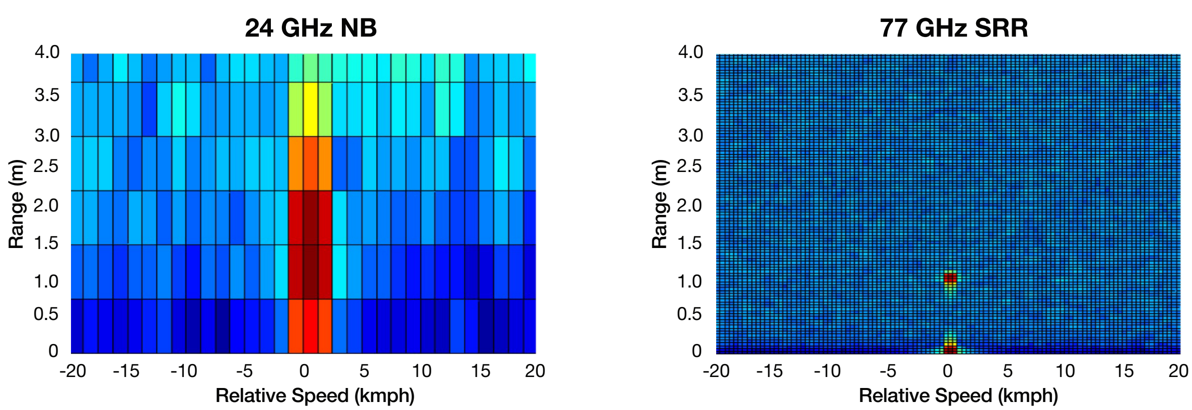

Figure 4. *Ultra short-range radar image illustration – 20x better range resolution, 3x better velocity resolution with 77 GHz.*

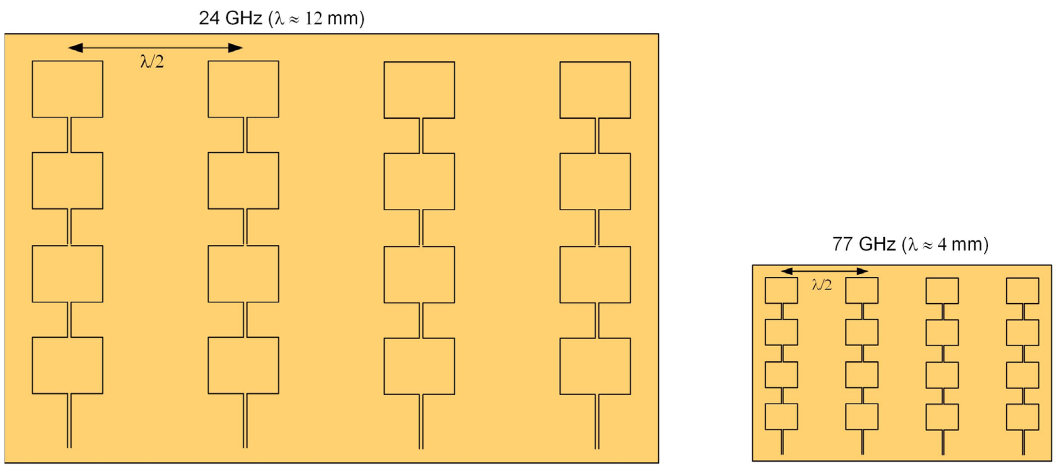

Figure 5. A higher RF frequency enables a smaller form factor for the sensor antenna array.

Smaller form factor

One of the key advantages of a higher RF frequency is that the sensor size can be smaller. For a desired antenna field of view and gain, the size of the antenna array can be ~3x smaller each in the X and Y dimensions when comparing 77 GHz to 24 GHz (see **Figure 5**). This size reduction is particularly useful in the context of automotive applications (where sensors need to be mounted in tight spots behind the bumper); in other spots around the car, including doors and trunks for some proximity applications; and inside the car for in-cabin applications.

Switching to an industrial fluid-level sensing application, the higher RF frequency provides a huge benefit by enabling a narrower beam for the same sensor and antenna size. As illustrated in **Figure 6**, the narrower beam mitigates unwanted reflections from the sides of the tanks and also other interfering obstructions within the tank. This results in better-quality measurements with reduced clutter. Alternately, for the same beam width, the higher RF frequency enables a smaller sensor and results in a compact, easy-to-mount form factor.

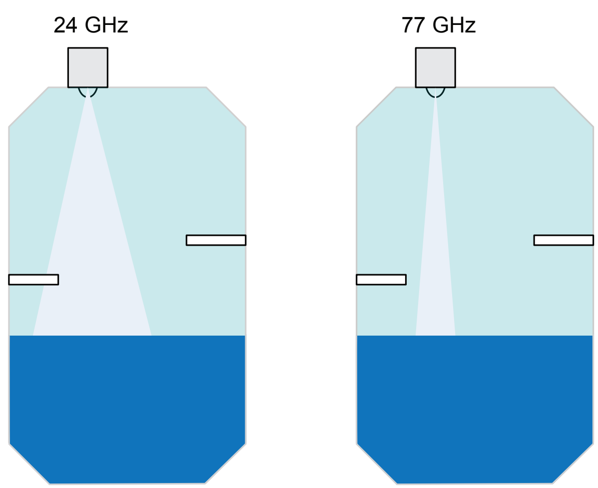

Figure 6. A higher RF frequency enables a more focused beam.

Summary

24 GHz has the advantage of being in the unlicensed ISM band and worldwide frequency regulation support, it is hampered by the availability of only 200 MHz of bandwidth, compared to 4 GHz of bandwidth available at 77 GHz. The time has come for 77 GHz radar sensors to become mainstream and leverage the benefits of a wider bandwidth and a higher RF frequency to achieve increasingly precise range and velocity measurements, as well as a significantly smaller form factor for the sensor. The Texas Instruments family of highly integrated, easy-to-use 77 GHz radar devices enable the development of compact and high-performance radar sensors for a variety of automotive and industrial applications.

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