Moving from 24 GHz to 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, the 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 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.

The two frequencies commonly used in these radar applications are 24GHz and 77GHz. The industry is shifting toward 77GHz radar, with a variety of benefits accompanying this shift in both the automotive and industrial markets.

24GHz and 77GHz frequency bands

The 24GHz 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 [1, 2, 3]. The 24GHz band also includes an ultrawide band (UWB), which is 5GHz wide.

Due to spectrum regulations and standards developed by the European Telecommunications Standards Institute (ETSI) and the Federal Communications Commission (FCC), UWB will be phased out soon [4, 5, 6, 7]. Future use of the 24GHz wideband and UWB band vehicular radars will not be available after 2021, 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 24GHz band, coupled with the need for higher performance in emerging radar applications, makes 24GHz 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. Moving forward, most 24GHz automotive and industrial radar sensors will likely shift to the 77GHz band (regulations around the world are constantly evolving and information on allowed applications in specific bands may change over time).
Figure 1 24 GHz and 77 GHz frequency bands

High-range resolution and range accuracy

One of the key benefits of 77GHz is the wide bandwidth available in that band, which significantly improves range resolution (which allows the sensors to separate two closely spaced objects) and accuracy. Since range resolution and accuracy are inversely proportional to the sweep bandwidth, a 77GHz radar sensor can achieve 20× better performance in range resolution and accuracy compared to 24GHz 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 developing advanced driver assistance algorithms and enabling autonomous driving features.

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

For applications like industrial level sensing, range accuracy (down to sub-millimeter) is a key priority. In addition, 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 tank is full.
Improved velocity resolution and accuracy

Velocity resolution and accuracy are inversely proportional to frequency. Compared to 24GHz sensors, 77GHz versions improve velocity resolution and accuracy by a factor of three.

For automotive park-assist applications, velocity resolution and accuracy are critical to accurately maneuver the vehicle at slow speeds during parking. 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.

Smaller form factor

Another benefit of the higher frequency is that sensor size can be smaller. For a desired antenna field of view and gain, the antenna array is linearly one third the size (see Figure 4). This reduction is particularly useful in automotive applications, where sensors need to be mounted in tight spots behind the bumper or in other locations around the car, including doors and trunks for proximity applications, and inside the car for in-cabin applications.
For fluid-level sensing, the higher radar frequency provides a huge benefit by enabling a narrower beam for the same sensor and antenna size. The narrower beam mitigates unwanted reflections from the sides of, and other obstructions within the tank.

Summary

While 24 GHz has the advantage of being in the unlicensed ISM band with worldwide regulatory support, it is hampered by the availability of only 200 MHz of bandwidth. The time has come for 77 GHz radar to become mainstream, leveraging the wider bandwidth and higher frequency to achieve more precise range and velocity measurements as well as a significantly smaller form factor.

References

1. ETSI EN 300 400 - Radio Equipment to be used in the 1 GHz to 40 GHz frequency range
2. FCC 47 CFR 15.245 - Operation within the bands 902-928 MHz, 2435-2465 MHz, 5785-5815 MHz, 10500-10550 MHz, and 24075-24175 MHz
3. FCC 47 CFR 15.249 - Operation within the bands 902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHZ, and 24.0-24.25 GHz
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