

Technical White Paper

Millimeter Wave Use Cases in Drone Applications



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1 Introduction

Unmanned aerial systems (UAS), more commonly called drones, are increasingly becoming part of the everyday lives of people. From consumer drones for taking pictures or videos, to commercial drones for near instant delivery of food or household items, drones are integrated and (mostly) accepted in society. Similarly in defense applications, drones have changed the landscape of modern warfare more than any other technology in the past few decades.

The growth of drones brings new challenges for safety, reliability, and detection that have been missing or limited in early models. Just as automobiles progressed in safety standards, drones are also following a similar path. Car manufacturers have increasingly adopted millimeter wave (mmWave) radar as a tool for blind spot awareness, adaptive cruise control, and collision avoidance because it allows for object detection and recognition in all weather environments while being small and cost effective. It is easy to see how this technology could also be applied to several use cases in drones.

2 Radar Overview

First, let's explore some radar characteristics. Traditional radar systems transmit pulses of electromagnetic waves and look for reflections of these pulses. The delay time between the transmit and receive of the pulse determines the distance to the target while the doppler shift is proportional to the velocity of the target (with respect to the transmitter). These traditional radar systems operate at frequencies between 30MHz (UHF) and 18GHz (Ku band). Lower frequencies can travel further due to lower atmospheric absorption while higher frequencies allow for smaller antennas and narrower beams for higher angular resolution and better target discrimination.

In contrast to traditional radar, mmWave devices use a system called frequency modulated continuous wave (FMCW), which uses continuously changing frequencies rather than short pulses. FMCW systems can often be smaller, lower power, and better adapted to short-to-medium range radars. Millimeter wave radars, as the name implies, operate with short wavelengths and therefore higher frequencies such as 60GHz or 77GHz. Since antennas are generally optimally placed at $\frac{1}{2}$ wavelength spacing, mmWave systems can be significantly smaller than their traditional counterparts. The higher frequencies also allow for smaller object detection, higher range and angular resolution, and better target discrimination.

3 Drone Use Cases

There are four primary use case where mmWave radar is being used for drones:

1. Collision avoidance (medium-to-long range, medium field of view (FOV): Just as in automotive applications, drones can move at relatively high speeds among obstacles like trees, powerlines, and buildings. Detecting and avoiding these obstacles is critical for not only the safety of the drone itself but also the people and property that may be around or under the drone.
2. Altimeter (short-to-medium range, narrow FOV): Situational awareness for safe operation requires that the drone not only see around its perimeter, but also below to determine its altitude above the ground or other obstacles. Equally important to landing as altitude is determining what type of surface is below the drone since landing in water would likely lead to the loss of the vehicle. Radar is very adept at determining distance and surface classification and this information can also be used for mapping and velocity estimation through a concept called optical flow when combined with camera information. These techniques can be used to navigate in electrically contested environments.
3. Proximity detection (short range, wide FOV): In defense applications, drones are increasingly being used to intercept other drones or munitions. Radar can be used to guide the drone to the target, but hitting a small

drone with another drone can be very difficult. To improve the chance of interception, radar can be used to determine when the target is close enough for the payload to be triggered.

4. Counter UAS (longest range): Since the number of drones are proliferating rapidly due to their low cost, detecting single drones or drone swarms is critical for protection of troops and bases. Traditional defense radars cost millions of dollars and are relatively large making them impractical for protecting small, distributed squads of troops. Millimeter wave radar can be utilized to create less expensive, vehicle-mounted or man-portable detection systems.

4 Antenna Types

Using modern semiconductor process technologies, mmWave radar systems including the low noise amplifier (LNA), power amplifier (PA), mixer, local oscillator (LO), data converters and microprocessor/digital signal processor can now be implemented in a single integrated circuit (IC) or chip. These devices can be paired with different types of antennas which each have different advantages:

1. Patch antenna that can be implemented on printed circuit board (PCB) for low cost and best performance/range.
2. Waveguide antenna where the IC transmits the electromagnetic waves through the bottom of the package into the waveguide which is called Launch-on-Package (LOP). This allows for smaller size and good performance/range. Different LOP antennas can be used with the same PCB to achieve different system level requirements.
3. Modern packaging technology also allows for the complete radar antenna to be integrated on the IC package called Antenna-on-Package (AOP). AOP provides the smallest size and lowest cost but is meant for shorter range operation.

5 Summary

Texas Instruments offers devices that are targeted to these different applications and antenna combinations. For example:

	Collision Avoidance	Altimeter	Proximity Detection	Counter UAS
Radar Chip	AWR2944P	AWR2944P	IWRL6432AOP	AWR2188
Antenna type	Patch or Waveguide	Patch or Waveguide	Antenna-on-Package	Waveguide
Processor/DSP	Integrated	Integrated	Integrated	TDA4VEN-Q1
Power Management	LP87745-Q1	LP87745-Q1	TPS650365-Q1	LP87725-Q1

Some examples of test run by TI using mmWave radar EVM modules can be found here:

- Collision avoidance: [Drone obstacle detection](#)
- Altimeter: [Drone Altimeter xWRL6432AOP User Guide](#)

Additional information about TI's full mmWave radar portfolio can be found here: [mmWave radar sensors | TI.com](#)

As the requirements and use cases for drones continue to evolve, the use of mmWave radar will grow due to its combination of small size, low weight and power, high performance and low cost.

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