2029 Becker Drive
Bioscience & Technology Business Center,
Lawrence, KS 66047 USA
p 785-727-9650 e info@aerotenna.com

AEROTENNA TECHNOLOGY WHITE PAPER

Currently the majority of consumer and business drones fly within line of sight, as they either lack the necessary sensors to aid in detecting their surroundings, or aren't equipped with the advanced on-vehicle processing that ensures the real-time sensor input required to determine and correct flight courses. These deficient capabilities have dramatically limited Unmanned Aerial Vehicle(UAV)s' potential in our lives. Aerotenna envisions broadly reaching opportunities to provide beneficial and meaningful changes for autonomous drones. Whether UAVs can be utilized to fill labor shortages in precision agriculture by spraying seed or feed at large farms, or offer emergency delivery of medical samples between hospitals in highly congested urban areas, trans-Atlantic cargo shipment or last mile e-commerce delivery, each of these progressive options requires UAVs to fly without human intervention, with the added ability to detect and avoid objects in their path in order to safely reach their destination. These opportunities present unique technical challenges for smart-sensing and high-capacity on-board flight controller for UAVs. In addition, consideration must be given to the regulatory mandate to fly UAVs safely by 2020.

While aviation, military, and other industries have long deployed radar sensing solutions for their needs, these solutions typically weigh 13 pounds or more, not lending themselves well to UAVs, which must be designed to be lightweight to allow for optimal flight time and payload. Price tags averaging thousands of dollars are often prohibitive for some applications. Additionally, the existing UAV flight controllers on the market either lack the process capabilities for large amounts of data and the flexibility for multiple sensor inputs, or the compute architecture is not optimized for real-time processing.

We at Aerotenna have set out to develop complete autonomous flying solutions for UAVs that are intelligent and affordable; our vision and design will unleash and maximize the full potential of UAVs, and do so for a wide range of markets. The Aerotenna team is comprised primarily of scientists with Ph.D. degrees and highly specialized engineers. We strive to draw on years of academic research and industry know-how to deliver leading and complete self-driving solutions for UAVs.

WHAT IS AEROTENNA TECHNOLOGY?

With patent-pending miniature designed electronics and advanced algorithms, Aerotenna develops an integrated autonomous flying solution in highly compact form with ultra-low power consumption. The pillar components of the solution are Aerotenna radar-based sensing technology, and FPGA enabled Aerotenna flight control intelligence; both are purposely developed and integrated for landing, collision sensing and avoidance, and self-flying scenarios commonly required in UAV applications.

WHAT DOES AEROTENNA RADAR BASED SENSING TECHNOLOGY DO?

Traditional approaches such as laser and infrared sensors require clear visibility in order to provide accurate measurements; Aerotenna radar-based sensing technology operates in K-band (24 GHz) frequency microwave radar signals. These signals propagate through a multitude of atmospheric conditions and are less affected by rain, dense fog, blizzards or clouds, allowing for accurate measurement in all weather conditions, as well as superior performance in low light, such as during the night.

	LiDAR	Passive Infrared	Aerotenna Radar
Sunny and well lighted	Yes	Yes	Yes
Night	Yes	Yes	Yes
Heavy rain, snow, or fog	Degraded in range and function	Degraded in range and function	Yes
Smooth solid surface	Yes	Yes	Yes
Water	No	No	Yes
Bushes	No	No	Yes
Power line detection	Yes	Not reliable	Yes

Using Frequency Modulation Continuous Wave (FMCW), Aerotenna radar sensing technology can detect both moving and stationary targets, and provide the range, velocity, and angle of the recognized targets. The distance between the radar and target is calculated from the frequency difference, or beat frequency, between the transmitted signal and received echo signal. The relative velocity of a target can be determined by measuring the Doppler frequency shift in the received echo. The phase differences between two or more receiving antennas can be used to measure the location of the target, or azimuth angle.

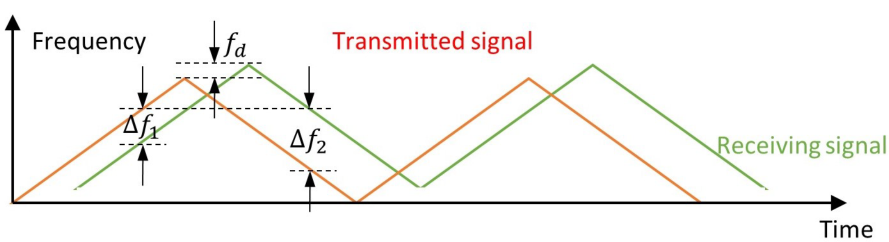

Figure 1: FMCW Waveform Pattern

Figure 1 shows the example of transmitting and receiving waveform, in which Δf_1 and Δf_2 are the frequency differences on the two edges between the transmitted signal and receiving signal and f_d is the Doppler frequency shift caused by the movement of the target. So, the beat frequency is calculated by: $f_d = (\Delta f_1 + \Delta f_2)/2$ and the Doppler frequency of a moving target is: $f_d = |\Delta f_1 + \Delta f_2|/2$. The distance between target and radar is proportional to the beat frequency, which can be derived as $r = f_b cT/(2B)$, where c is the speed of light, T is the period of the up-down chirp and B is the bandwidth of the transmitted signal.

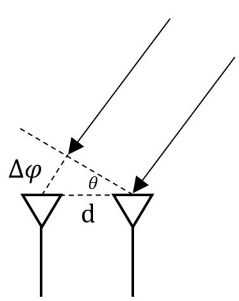

Figure 2: Illustration of Phase Differences of Receiving Signal Between Two Antennas

When the target is in the far-field region, the reflected signal can be seen as plane waveform, and when the target is not in the broadside of the array, will arrive at each receiving antenna at different times. This time differences will be shown as the phase offset among each antenna. Figure 2 shows the phase difference between two receiving antennas. The spacing, d, between two antennas and the phase difference between two antennas, $\Delta\lambda$, are known. The direction of arrival can thus be calculated as $\theta = arcsin\ \Delta\lambda/(2\pi d)$, in which λ is the wavelength.

With advanced algorithms, our solutions are able to provide smooth, above ground altimeter measurements for water surface and bushes; other sensors may be confused by jittering measurements in such environment. In addition, Aerotenna has developed the intelligence to accurately detect items that are commonly found while flying in urban environments, items such as cars, buildings, pedestrians, power lines, and tree branches. Our solutions can even reliably detect small items such as city power lines within 0-5 meters range. With Aerotenna sensing solutions, UAVs will have the ability to fly and land safely by detecting and avoiding these objects autonomously.

Aerotenna radar technology powered altimeter is ideal for UAV applications requiring a 0-150 meter range and 2 cm accuracy, including operations such as precision agriculture and last-mile e-commerce delivery. They are excellent solutions for autonomous takeoff, landing, and way-point navigation, and maintaining a target altitude during flight.

Aerotenna radar technology powered sense-and-avoid sensors scan 360 degrees without blind spots, detecting and locating obstacles on the horizon quickly and reliably, allowing for correction of flight course and collision prevention. The system incorporates adaptive sensing technology that adjusts the sensing range based on flying speed (up to 200m), and optimizes its response; it is ideal for applications that require high resolution, in-flight sensing and collision avoidance for walls, buildings, tree branches and other obstacles in outdoor environments.

Aerotenna altimeter and sense-and-avoid radars are the building blocks for autonomous UAVs. They provide peace of mind with UAVs that will fly safely regardless of weather conditions and types of surfaces encountered.

WHY IS AEROTENNA RADAR TECHNOLOGY BETTER?

Compact : Aerotenna radar scientists and engineers have taken a vastly innovative approach and departure from traditional radar systems. Our teams have redesigned the microwave sensing system in order to create compact sensors with miniaturized antennas and RF circuits and signal processors that meet the strict payload limitations of smaller UAVs. Aerotenna radar technology powered altimeter has the smallest form factor in the industry, measuring at 68x78x15mm, and weighing only 30g without the enclosure. Aerotenna sense-and-avoid radars are even more compact, measuring at 65x45x8mm, and weighing 18g without the enclosure. These patent-pending sensing solutions are suitable even for the smallest UAVs on the market.

Ultra-Low Power Consumption: We have given special considerations to reduce the power consumption of our radar products. Aerotenna radar technology empowered sensors consume merely 1.25W or less at 5V, 250mA; whereas traditional radar sensors typically consume 25W and above. This power consumption shift allows UAVs to fly longer without recharge.

Ultimate Ease of Integration: Aerotenna radar technology powered sensing solutions support multiple

I/O interfaces, including UART, I2C and CAN. Our solutions self-calibrate automatically based on collected geometrics information, so users don't need to—simply plug and play to integrate with UAV flight controller.

BENEFITS TO UAV DEVELOPERS AND INTEGRATORS

- Low cost
- Fit into small UAVs
- High accuracy in all weather conditions
- Detection for all-terrain
- Low power consumption for longer flight time
- Easy plug and play integration

WHAT DOES SYSTEM ON CHIP (SOC) BASED AEROTENNA FLIGHT CONTROLLER DO?

We at Aerotenna believe that safely flying UAVs out-of-sight requires the UAV to not only be cognitively aware of its surroundings but also intelligent and intuitive in choosing real-time flight course. Creating these autonomous UAVs requires redesign of the hardware. Essentially, rethought system design needs to replicate drone operator intelligence with the high-level thinking on the vehicle. Determining how to handle unexpected situations—such as navigating among dense buildings and other man-made structures—entails a great deal of processing. At present, various industry drones fly at 85 mph or more; for these drones, most processing is done on board and quickly, since there may be lack of time for the vehicle to generate messages and receive instructions about an unexpected situation. To make UAVs truly cognitive, it is necessary for an array of sensors to be embedded throughout the vehicle. These sensors will generate a high volume of data, which requires substantial computing capabilities and real-time processing ability. We believe that SoC are ideally suited to perform these tasks. FPGA is able to meet the strict timing requirement of real-time signal processing, while the dual-core ARM processor is able to handle the complicated algorithm designed for specific application.

Aerotenna is the first to introduce the SoC FPGA-based flight control solution to address autonomous UAV needs. The OcPoC flight controller, a system-on-chip processor composed of an FPGA and a dual-core ARM processor, conducts radar signal and autonomous flight control processing. This control solution functions as the brain of the smart drone, providing clear advantages over the micro-controller unit (MCU), in terms of processing power and I/O capability.

WHY IS AEROTENNA SYSTEM ON CHIP (SOC) BASED CONTROLLER BETTER ?

AI-Capable Processing Power: With the drone industry quickly reaching new commercial and consumer markets with creative and advanced applications, including 3D modeling and delivery services, drone applications are becoming increasingly more complex, and require more processing power. OcPoC flight controllers are designed to support complex applications with load-balancing, FPGA logic which enables sensor fusion, real-time data processing and deep learning; these functions free up the CPU in order to better perform high-level decision making and flight control.

Unmatched Flexibility: The OcPoC flight controllers offer the most flexible computing platforms, and are able to process radar, vision, and other sensing inputs; they are equipped with over 30 programmable I/Os which support most standard interfaces. Built on the configurable nature of FPGAs, Aerotenna OcPoC, flight controllers are able to be reprogrammed in order to support the latest algorithms, and are also able to be customized for various performance requirements without complete custom hardware. They have ASIC capabilities, but with convenient flexibility for changes.

Industrial Grade Redundancy: OcPoC flight controllers are designed to function in cases of unexpected system component failures during flight. To ensure continued flight for urgent missions, triple-redundancy for critical components—such as GPS, IMU, and more—are built into the system.

Developer Friendly: The OcPoC flight controllers are able to run a variety of embedded operating systems, such as Linux, making it easy to develop and modify. The controllers support popular open-source software suites, such as PX4 and ArduPilot, and come with Aerotenna collision-avoidance algorithms which offer added intelligence in idea and solutions development. Aerotenna simplifies the development process, putting every idea within reach.

BENEFITS TO UAV DEVELOPERS AND INTEGRATORS

- Load balancing high performance computing
- Compact, lightweight design with low power consumption
- More than 30 programmable I/Os and support most standard interfaces
- Re-programmable
- Industrial grade redundancy for mission critical flight summary

Aerotenna's all-in-one system provides state-of-the-art, miniaturized microwave sensors seamlessly integrated with SoC FPGA based flight controllers. Offering innovative and complete autonomous solutions for active sensing and obstacle collision avoidance, Aerotenna's system maximizes drone ability in order to achieve safe and reliable out of line of sight flying.

Key Contacts:
Zongbo Wang, Ph.D. - Founder & CEO - zongbo@aerotenna.com
Yan Li - Sensing Team Lead - yli@aerotenna.com
Dave Royer - Flight Controller Team Lead - dave@aerotenna.com