

Drone Detection for an Elevated Threat Environment

Identification, Classification, and Localization of FPV Drones and their Operators, based on Advanced R2-ODIN Passive RF Sensor Technology

Introduction

The war in Ukraine has developed from an artillery- and tank-centric conflict into a highly dynamic confrontation in deep and low airspace, as well as an **intense exchange of electronic and information-based battle**. To a large extent Electronic Warfare (EW) and the **rapid evolution of drone and counter-UAS (C-UAS) technologies** are at the centre of this development.

In consequence of this technological cat-and-mouse game **development and adaptation cycles have reduced to just a few weeks**. Thousands of First-Person View (FPV) drones now dominate the battlefield. These are often improvised, extremely low-cost systems built from commercial off-the-shelf (COTS) components. They transmit only analog video signals, without GPS or traditional digital telemetry, rendering traditional decryption-based detection technology ineffective.

In fact, it clearly exposes the **fundamental limitations of signal and protocol decryption** and makes the need for alternative, more robust detection methods quite evident.¹

One of the most technologically advanced responses to this challenge is the **R2-ODIN system**. The platform combines Time Difference of Arrival (TDoA), FDoA, and AoA for precise RF geolocation, and also RF fingerprinting for the analysis of characteristic hardware properties. Based on its capabilities, R2-ODIN is recognized as one of the most agile and scalable, protocol-independent RF detection solutions available, offered as **fixed sensor installations, tactical/mobile units**, and more recently as **airborne payloads** carried by drones, other aircraft or Robodogs.

The system is suitable for military environments (e.g., air defence systems (i.e. Patriot), air bases, radar positions, naval basis, medical facilities, mobile command posts) and for civilian critical infrastructure (refineries, transmission system operators, offshore platforms, airports, transport hubs, borders, event venues, and more).

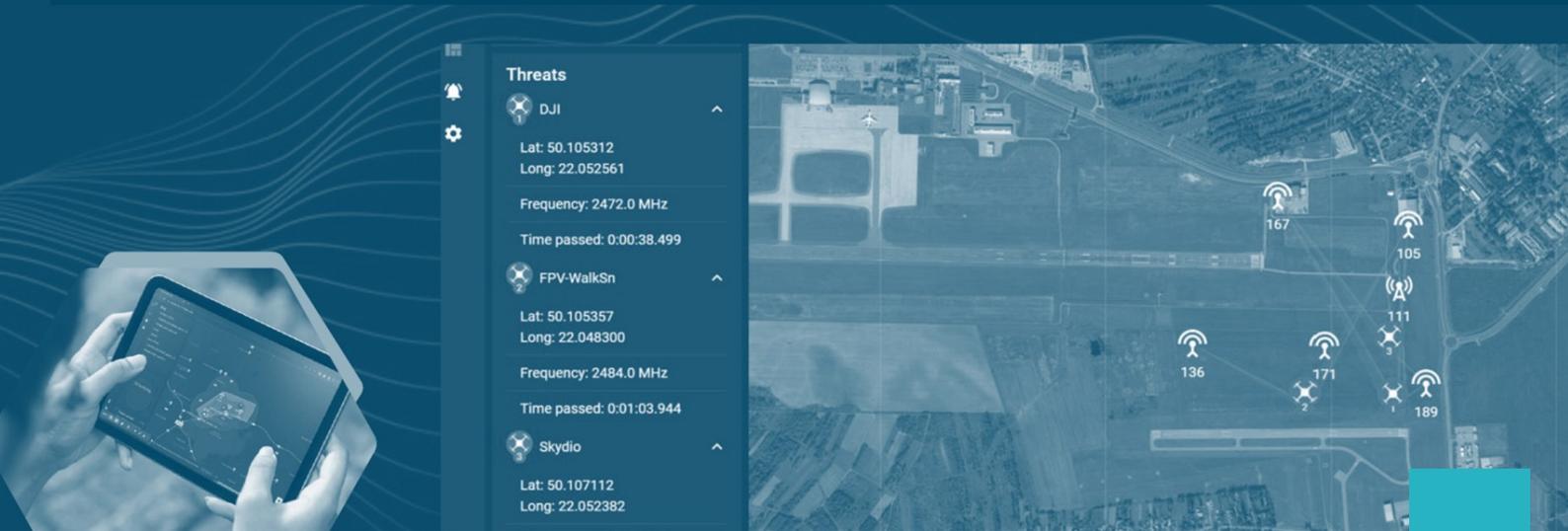
R2-ODIN can be seamlessly integrated with **complementary sensor systems** such as radar, optical systems, or acoustic sensors, as well as established command-and-control (C2) platforms and Physical Security Information Management (PSIM) architectures. This creates a **robust foundation for a multi-modal, resilient situational awareness in the electromagnetic spectrum**.

In contrast, **radar-based C-UAS systems** encounter **natural performance limits** when dealing with very small, lightweight FPV drones; minimal radar cross-sections (RCS), irregular flight profiles, and strong ground and bird reflections complicating clean signature analysis. This results in high false-alarm rates and limited classification capability, particularly when radar systems are lacking R2-ODIN's complementary RF sensor technology.



Intuitive User Interface of the R2-ODIN C2

Comprehensive consolidated operational picture with multi-domain support across operational fronts and interfaces. Open architecture (API) enabling seamless integration with C2 platforms, video and radar systems and effectors.



This is in fact where the strengths of the **R2-ODIN system** come into play. It uses proprietary Deep-Learning models to **detect, classify, and localize RF emitters independent of protocol, frequency, or modulation**. The technology is not limited to drones but also detects tactical radios, satellite phones, cellular and Wi-Fi signals, as well as any other emitter in the electromagnetic spectrum.

The scientific foundation of these capabilities are based on the work of Dr. Yiftach Richter, Rey Richter, and their research partners, the founders of R2 Wireless Ltd. Their approaches, some of which have been published in **patents** and **academic publications**, cover among other things TDoA-based geolocation, selective deep-learning methods, and sensor fusion for creating unified electromagnetic situational awareness.²

R2-ODIN is available as a standalone hardware platform but can also be operated on existing third-party hardware, provided the required raw RF data is made available. While radar, optical, and acoustic systems can contribute to a modern C-UAS architectures, the **technological focus** is clearly shifting toward **software-defined RF sensor technology, edge AI, and intelligent multi-sensor fusion**. ODIN embodies this transformation through passive, scalable, and adaptive RF capabilities that are suitable as a **primary detection system** for operators of critical infrastructure.

The system architecture and capabilities of R2-ODIN enable **area-wide configurations across entire regions** while allowing precise adaptation to **local conditions, infrastructure clusters**, or specific **terrain characteristics**. Depending on the environment, transmission scenario, and antennas used, the detection radius of an R2-ODIN sensor can reach up to 7 km and even 12 km in some environments.

In practice, installations can be implemented within a short time and easily integrated into existing security architectures.

¹ Rapid firmware adaptations, new encryption mechanisms, GPS spoofing, and the growing dominance of GPS-independent FPV drones are increasingly pushing the capabilities of traditional, protocol-based detection approaches to their operational limits

² Y. Richter, Y. Richter, Y. Saraf, and N. Noga, "Experimental results of UAS localization and tracking by passive TDoA," in Proc. IEEE Int. Conf. Microwaves, Communications, Antennas, Biomedical Engineering and Electronic Systems (COMCAS 2024), 2024, doi: 10.1109/COMCAS58210.2024.10666172.

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Technical Characteristics

- **Average detection range:** 3 km to 12 km (with fixed installed sensors, depending on antenna selection)
- **Frequency range:** 100 MHz – 6 GHz (on existing hardware)
- **Detection:** Any drone profile^{*1/2} with extension through “one-shot learning” across all protocols and frequencies
- **Geolocation:** Machine-learning-based TDoA method (Time Difference of Arrival)
- **Detectable drone types:** Commercial, anonymized, LTE, Wi-Fi, cellular, DIY, FPV, and fixed-wing drones
- **RF protocols:** Drones of any design, tactical radios, Wi-Fi, Bluetooth, LTE, and other cellular protocols^{*1/2}
- **Accuracy:** < 5° (depending on signal-to-noise ratio, SNR)
- **Power consumption:** < 20 W
- **Weight:**
Standard sensor < 4 kg
Payload sensor < 900 g
- **Dimensions:** Standard sensor 30 × 30 × 7 cm (fixed system on tripod)
- **Certifications / Standards**
MIL-STD-810, IP66, CE, RoHS, REACH
- **System architecture:** Cloud-based solution or on-premise installation
- **C2 compliance:**
FAAD-C2, ATAK, SAPEINT, SITAWARE
- **GDPR compliance:** Access to personal data related to drone IDs restricted to authorities (critical infrastructure application)

^{*1} Drone RF classification including LTE, Wi-Fi, digital and analog video links, as well as radio controllers (RC), e.g.: DJI, Parrot, Autel, Skydio, SwellPro, Ruko, Hubsan, Yuneec, ZeroZero

^{*2} FPV drones: including DIY, hacked, and anonymized drones; analog systems, O3, O4, Dragon, Vista, WalkSnail, as well as their RC systems (e.g. Futaba, ELRS, FrSky, Crossfire). No detection of fiber-optically controlled or autonomous drones without a video link.



Use Cases for the Protection of Critical Infrastructure

Transmission System Operators (TSO and DSO)

- **Protected assets:** High-voltage substations, switchyards, and control centres in power grids; transmission and distribution networks.
- **Threat:** Commercial quadcopters and fixed-wing drones for reconnaissance, disruption, or payload drops (short-circuit wire, incendiary loads, IEDs); internally placed RF devices, e.g., on solar installations.
- **R2-ODIN capabilities:** RF detection, classification, and geolocation within the perimeter and surrounding environment, including controller (pilot) detection. Possible sensor fusion with AI powers cameras and radar systems. Logging of criminal offenses. Enhanced controller localization and tracking via single or multiple payload sensors.
- **Tested/Deployed:** ODIN is actively used at electrical substations in Germany, water utilities in Israel and more. Further installations are in preparation, including focused and/or regional protection of industrial facilities, ports, and other civilian/government critical infrastructure sites.



Civil airports & medical facility protection

- **Protected assets:** Civilian airport runways and military field hospitals.
- **Threat:** Quad and FPV drones for ISR and MISO; dropping small but effective payloads near aircraft, fuel storage facilities, medical personnel, and civilians.
- **R2-ODIN capabilities:** Fixed or rapidly deployable RF sensors contributing to a fused air picture or use of individual sensors to protect entrances and exits; automatic alerts, drone and pilot geolocation, and evidence preservation for civilian legal proceedings.
- **Tested/Deployed:** R2-ODIN has been tested at Bundeswehr, IDF, NATO, U.S. Army, UK war games, Brazilian Facilities and Japanese Ministry of Defence exercises, and in critical infrastructure environments. In red-team evaluations, the R2-ODIN system regularly outperforms competing solutions.

Additional applications

Parliaments



Prisons



Border protection



Events



Pipelines



Off-Shore



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- Development and management of key accounts & value-added resellers (VARs)
- Public, Investor, and Stakeholder relations
- Technology import and contract manufacturing
- Requirements and site analyses
- Configuration planning
- Coordination of API-integration (C2 / PSIM)
- Support and supervisions of PoCs (Level 2 Support)