RACCOON radar system for detection and tracking of ground, surface and air targets

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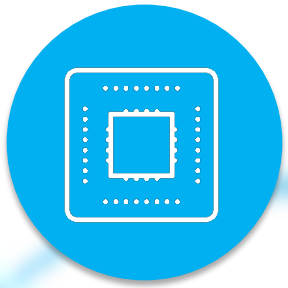
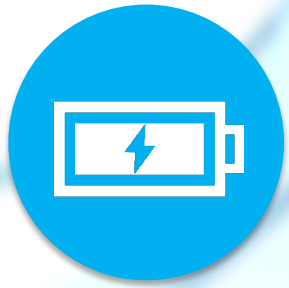
Emergence of light and durable composite materials



Rapid development of microelectronic component base



Emergence and development of effective renewable energy sources

Inventions in the field of highly resourceful electric motors, jet and reciprocating engines

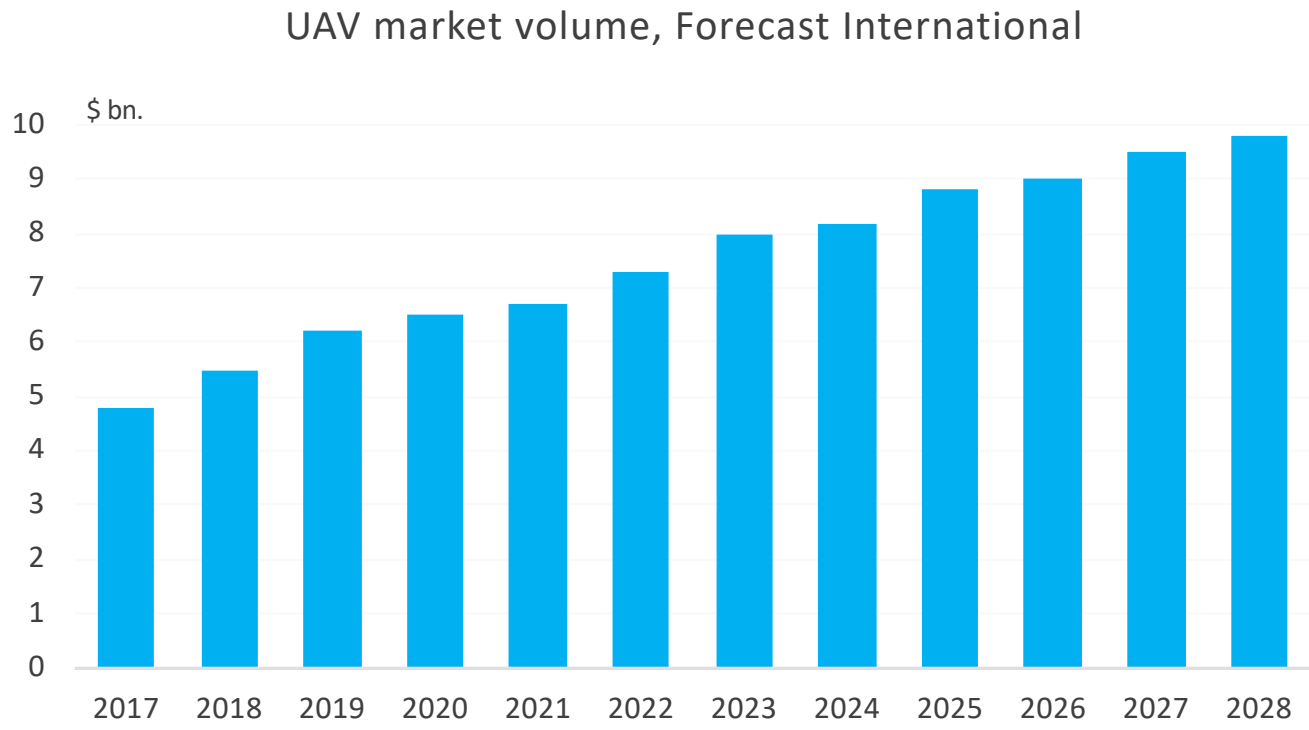
Development of the global navigation satellite system

Development of computing hardware, mathematical and algorithmic tools

UAVs have become widespread

UAV market volume

- According to Forecast International, the UAV market volume will account for **$10 000 000 000** by 2028
- According to Business Insider, the UAV market volume will amount to **$12 000 000 000** by 2024, with more than **$3 000 000 000** thereof being civil UAVs



UAVs have become widespread

UAV outspreading

- According to Forecast International, more than **105 mln.** UAVs will be produced between 2017 and 2031, worth a total of **$ 120 bn.**
- DJI, Parrot and 3DR will keep the leadership on this market
- The market share of DJI will account for 61% of the overall UAV production

DJI Spark

Beebop Parrot

3DR Iris Plus

UAVs have become widespread

Classification of UAVs by categories

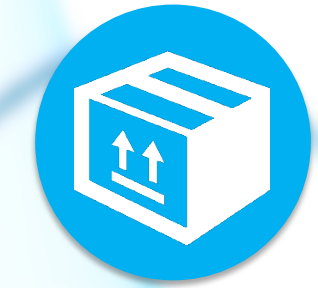
Class	Category	Name	Takeoff weight, kg	Operating range, km	Flight altitude, m	Flight duration, h
Small	I	Nano	<0,025	<1	100	<1 hour
		Micro	<5	<10	3000	1
		Mini	<25	10-40	3000	≤4
Light	II	Short-range class 1	25-50	25-70	3000	2-4
		Short range class 2	50-150	50-100	3000	≤6
Medium	III	Short-range	≤200	≤150	4000	6-8
		Medium-range	≤500	200	5000	10-12
	IV	Medium-range, long endurance	500	500	8000	10-18
		Low-altitude, long range	≤250	>250	≤4000	1,5-2
Heavy	V	Low-altitude, long endurance	≤250	>500	4000	18
	V-VI	Medium-altitude, long endurance	≤1000	>1000	8000	24
	VII	High-altitude, long endurance	≤2500	>4000	20000	>24
Combat	VIII	Unmanned combat	>1000	>500	12000	1,5-2
		Decoy target	150-500	0-500	50-5000	<4
		Air target	10-10000	5-200	50-10000	>0,5

The majority of widely used civil UAVs belong to the Small and Light classes

Useful applications of UAVs

Monitoring
Facilities guarding, monitoring of utility systems and navigation, mapping, mineral exploration, etc.

Entertainment
Event support, competitions, model aircraft flying, advertising



Delivery
Mail, construction materials, assembly and maintenance, medications, injury evacuation

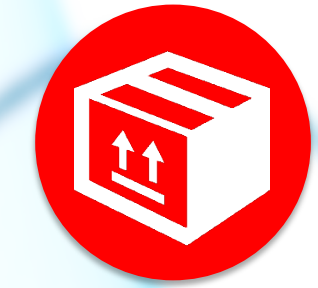
Broadcasting of audio and other signals
Extending the range of radio communication channels, mounting light equipment, loud speakers, and generating units, etc.

UAVs can be efficient in construction, farming, logistics, security, entertainment, and many other industries

Malicious applications of UAVs

Monitoring
Unauthorized surveillance of private and high-security facilities for reconnaissance and obtaining confidential information

Entertainment
A risk of collision with small aircrafts, damaging ground facilities and injuring people



Delivery
Transportation of prohibited substances or hazardous goods

Broadcasting audio and other signals
Jamming various devices

Organizational and legal regulation of UAV application is required

UAV detection

Aerial vehicles of the Small and Light classes are the most difficult to detect:

- small dimensions, low flight speeds and altitudes make detection, tracking , identification and counteraction of UAVs difficult against the background of the territory

- small dimensions, high flight speeds and high manoeuvrability reduce the data accumulation time sufficient for detection and the decision-making time

It is necessary to create effective means of UAV detection and counteraction

Summary

- UAVs have become widespread, their number is growing rapidly
- The majority of widely-used civil UAVs belong to the Small class
- UAVs are applicable in many areas
- UAVs of the Small class might be dangerous and are the most difficult to detect
- Organizational and legal regulation of UAV application is required
- **Organizational measures are ineffective when UAVs are intentionally applied illicitly**

It is necessary to create effective means of UAV detection and counteraction

UAV counteraction

UAV counteraction means

				
Radio fixing and jamming aids	Electro-optical reconnaissance aids	Acoustic intelligence aids	Radar aids	Passive (concealed) radar aids
Ineffective when the UAV is carrying out a flight assignment in the radio silence mode. Besides, the jamming system affects the operation of authorized radio-electronic equipment	Ineffective in bad weather conditions. Their range is also comparably low	Ineffective in natural acoustic noise environment. They are also not very effective for detecting vehicles with low internal acoustic noise	Do not address the task to the full extent, especially when the UAV speed is low against the terrain	Ineffective in urban environment, the increase in the number of targets results in a dramatic rise in coordinate measurement error

The effectiveness of each particular UAV detection method is limited

Advantages of using radar detection and ranging for UAV detection

Longer range

Lower dependence on weather conditions

Effective detection of UAVs carrying out a flight assignment in the radio silence mode

The effectiveness of the task completion improves when integrated solutions are applied, a radar system being an essential component

Disadvantages of the available solutions

- Extremely high price
- Too large dimensions
- Unavailability in the civil market
- Inability to detect small UAVs at short distances and low flying speeds

We need a solution which provides:

- Optimal value-for-money ratio
- Small dimensions and weight
- Effective detection of small and low-speed UAVs

The efficiency of the solution can be improved by complex application of various means and technologies

Summary

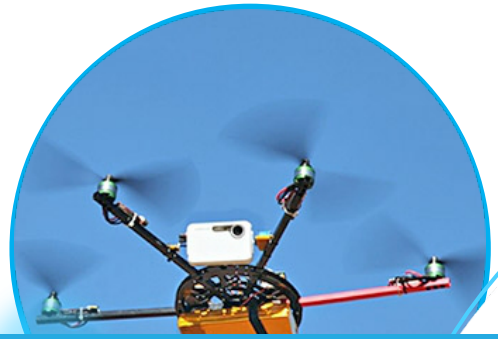
- The effectiveness of each particular detection method is **limited**
- The efficiency of a solution can be improved by **complex application** of various means and technologies
- **A radar system is a necessary means** of UAV detection
- **Even the most up-to-date military radar systems**, including the ones for detection of air threat and attacking elements of high-precision weapons, **do not address the challenge completely**
- The main problem of detecting small-class vehicles is **the necessity to separate the small low-speed UAVs from the background** and reflections of bright ground objects (including the moving ones) and hydrometeors

There is a need to create effective means for UAV detection and counteraction

The task

- **There is no point in imposing extreme requirements on such a system** in terms of the detection range and angle measurement accuracy
- The system should be **as efficient** in detection of small low-speed vehicles **in a relatively short range as possible**
- **The above points will allow significant reduction in the price, weight**, dimensions and power consumption

ELVEES R&D Center, JSC, offers a solution for UAV detection and counteraction



RACCOON radar station

Problem description

To detect UAVs of the Small class, a radar system should complete two contradictory tasks simultaneously:

- Providing sufficient time of observation (fractions of a second) of each element of the coverage area
- Fast (1-2 seconds) updating of the information about the coverage area

Solution– multiwave receiving systems

To detect UAVs of the Small class, a radar system should complete two contradictory tasks simultaneously

RACCOON radar system

- Task: to design and pre-test experimental prototypes of RACCOON radar subsystem for detection, tracking and jamming of small UAVs

- The product can additionally be used in ground-based security systems, and specifically as an alternative to commercially available Orwell-R radar system

Development project ‘Development of a radio-technical system for detection of ground, surface and air targets’, codename RACCOON

The purpose of RACCOON radar system

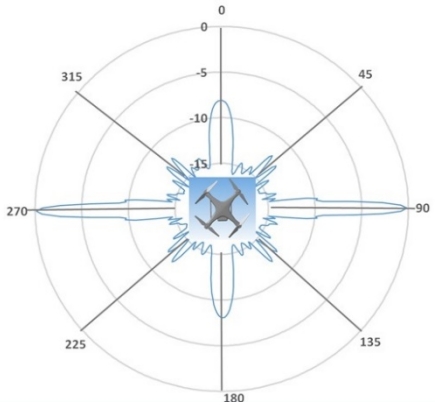
The product being designed within the scope of the development project is intended for:

- radar scanning of the above-ground (above-water) and air space
- automatic detection of small aerial vehicles (UAVs of the Small class)
- measuring the coordinates of the detected targets (range, azimuth, elevation, and speed)

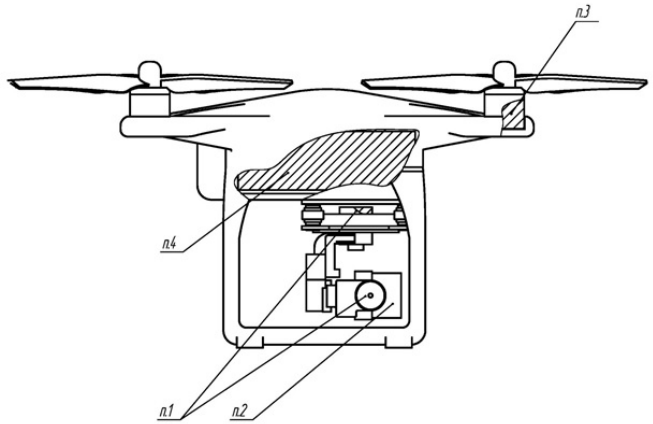
Detection and tracking of ground, surface and air targets

A typical radar target

An average radar cross-section of a typical target is 0.01 m^2 (approximately corresponds to DJI Phantom-3 unmanned aerial vehicle of the multi-rotor type in X-band)



The estimate of the radar cross-section in X-band



A simplified diagram of metallic element arrangement

DJI Phantom 3 – an example of an UAV of the Small class

RACCOON radar system: specification

0,01m²	1 800 m	4 000 m	360° x 60°	10 kg	-40 … +50
Radar cross-section of a typical target (DJI Phantom-3 drone)	Detection range of a typical target	Human detection range	Viewing angle sector	Weight	Operating temperature range

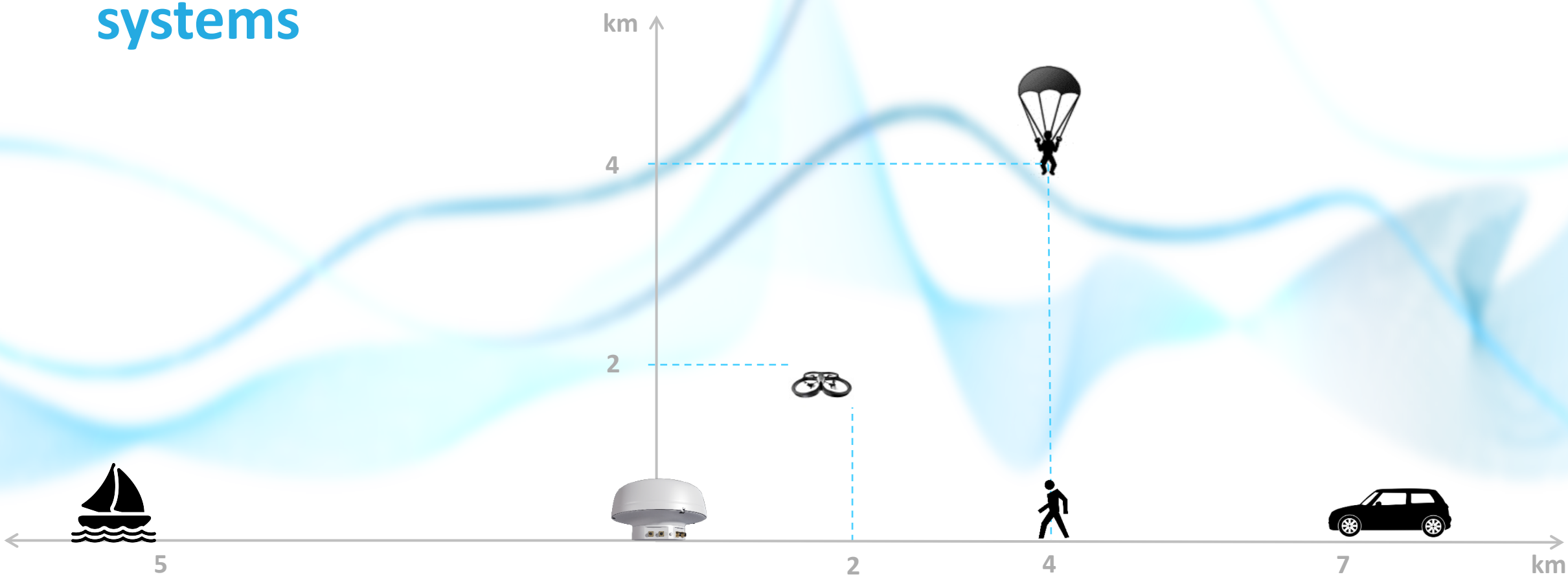
Detection of small UAVs at a distance of up to 2000 m

RACCOON radar system: design concepts

- X-band (9200 – 9500 MHz)
- Stacked beam in the elevation plane
- The system includes a LAN switch to which a PTZ dual spectrum video camera and other network devices are connected
- The hardware option of the embedded computer carries out data processing and automatic PTZ camera control
- The hardware option of the global navigation satellite system receiver and the inertial navigation system allows placing several devices in a single geo-referenced network environment and provide operation on a PTZ platform
- No external switch modules are required, all data streams of data transmission and control are switched inside

Detection of small UAVs at a distance of up to 2000 m

Application of RACCOON radar system in ground-based systems



RACCOON radar system – detection on the ground, on the water surface, and in the air

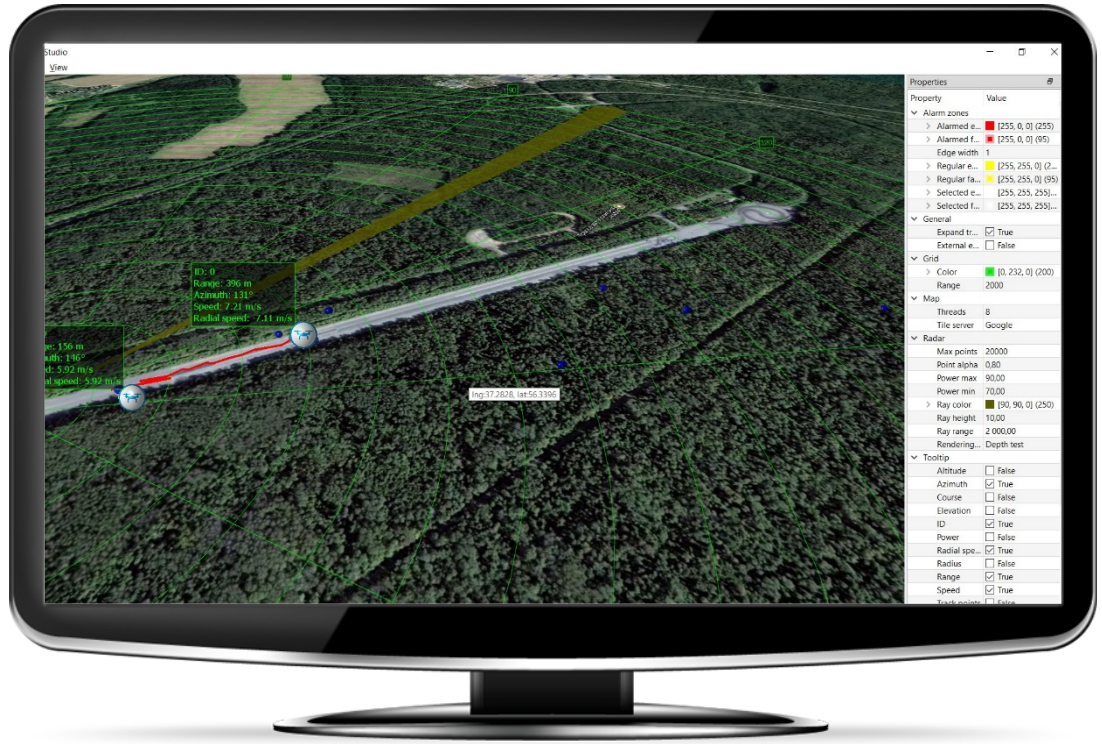
Experimental prototypes of RACCOON radar system

- Two experimental prototypes of RACCOON radar system have been developed
- The experimental prototypes of RACCOON radar system under went field tests from 2 to 6 July 2018 at a testing facility near Moscow
- The tests proved the capability of the system to detect small UAVs
- DJI Phantom 4 PRO and DJI Inspire were used as UAV targets

Experimental prototypes of RACCOON radar system have been developed

User interface of RACCOON radar system

- Icons of the targets detected by RACCOON radar system (drones, humans, vehicles) are displayed on the map of the guarded facilities
- Motion trajectories of the detected targets are displayed
- The distance to the detected targets, motion speed and altitude are indicated
- The movements of the beam of RACCOON radar system are indicated

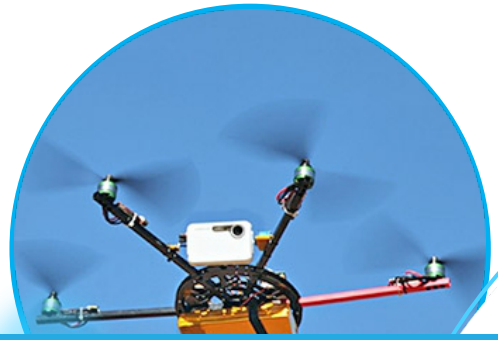


Displaying clear information sufficient for the security system operator

Summary

- RACCOON radar system does not support extreme detection range or elevation measurement error, which are required for detection of high-speed attacking elements of high-precision weapons, cruise missiles, and so on
- That said, the radar system is effective in terms of detecting UAVs of the Small class (small-size, low-speed) at distances sufficient for making a counteraction decision
- RACCOON radar system can be applied in the ground security systems
- Lower weight, power consumption and price compared to military solutions

RACCOON radar system is an effective system of UAV detection and tracking



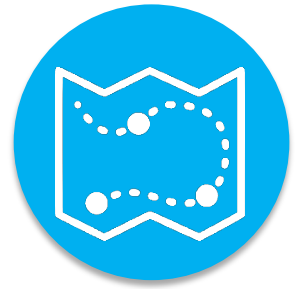
Designing a complex solution

A complex system for small UAV detection, tracking and counteraction

Components:

- RACCOON radar system
- video and thermal imaging camera on a PTZ platform
- directed jamming system
- mobile complex of electro-magnetic and electro-optical UAV jamming

Control blocking



Deception

Mission failure

Landing in a safe place

Counteractions against the detected UAVs

Functionality

Hypnotist PTZ platform consists of a visible range camera or a thermal imaging camera as well as a system for jamming of remotely controlled aerial vehicles.

The effect of this anti-drone is mission failure, control blocking and deception. As a result, the UAV advancement along the route is blocked (UAV goes out of control), the UAV returns to the starting point of the route or lands in a safe place near the interference place (the drone behavior depends on the model and the presence of a mission). The drone recovers when the jamming stops and/ or the drone restarts. No physical damage is inflicted on the drone owner.

Parameter	Value
Maximum effective distance	500 m (maximum distance of drone visibility for the security system operator)
Operating principle of the jamming complex	Based on the interruption of control, data transmission and navigation channels
Effects	• Mission failure • Control blocking • Deception

Counteractions against the detected UAVs

Functionality

- Automatic detection of ground, surface and air targets
- Measurement of coordinates and speed, class identification
- Real-time display of icons of the detected targets on the 3D map
- Alerting the operator about the presence of a potential intruder at the guarded facilities using a sound signal and a graphic display
- Full-function operation both as a separate air space security system and as a part of a security complex
- Solving the problem of UAV deactivation by means of control channel jamming (interception) and (or) UAV positioning and safe landing

Counteractions against the detected UAVs

Threat prevention

Transportation of prohibited substances and devices

Photo and video recording of high-security facilities and defence-industrial companies

Conducting intelligence along the state boundaries and illegal boundary crossing

Creating hazards to aircrafts in the sky (accident provocative acts)

Carrying out acts of terrorism and inciting technological disasters at the national and international levels

A new level of protection against UAVs

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