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# MULTI-FUNCTIONAL AERODROME CONTROL RADAR BY USPR TECHNOLOGY

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## Abstract

*Problems of multi-functional aerodrome control radar development by Ultra-Short Pulse Radar (USPR) Technology are investigated. Major drawbacks of the existing Radar Airfield Surveillance (RAS) systems are considered. RAS based on Ultra-Short Pulse Radar (USPR) Technology is proposed as alternative. Problems of radar information capacity expansion, improvement of images and ways of such problems solution are also under consideration. The major problems and advantages of such radars were illustrated by the results of USPR RAS pre-prototype field tests.*

## 1 Introduction

Air-traffic volume growth entails growth of accident incidence rate in the airport zone involving considerable economic losses. The most typical problem remains the problem of foreign objects and vehicles on the airfield and dangerous crossings of aircrafts. Besides, due to increased rate of terroristic threats, number of reports of terrorist penetration on the airfield reaching aircraft are growing.

Such circumstances stimulate researchers to consider the problem of developing new radar systems for airfield remote monitoring including adjacent territories. To simplify introduction procedure of such means, it is advisable to extend functionality of existing RAS systems basing on new the Ultra-Short Pulse Radar Technology.

At present, in Russia, airports safeguarding is assured by a complex of regulated administrative, programmatic, technical and radio-technical facilities [1-3]. Here are some drawbacks of the existing radio-technical systems:

- insufficient spatial resolving power, including inability to control object orientation at low travel speed, hindering prediction of an object motion pattern and collision-risk proximity.
- Low radiometric contrast ratio of radar images, does not allow to mark out birds and low-sized objects (including motionless) on an air-strip and taxiway
- Limited algorithms Selection of Moving-Target (SMT) capabilities does not allow to detect moving people on a background of low-reflection air-strip and taxiways, but even on a background of other surfaces (all over airfield area).
- Insufficient stability of images hinders introduction of up-to-day selection methods, without Doppler effect.
- Dramatic weather sensitivity of the equipment, making imposable full-scale use not only optical, but also radar systems (partially operating in Ku band) under heavy rain or sleet conditions.

Solution of such problems is mainly restricted to usage of higher frequency range [4], allowing to improve azimuthal resolution, but does not resolve weather sensitivity problems. But at present, Ultra-Short Pulls Radar USPR Technology was developed and fully tested, allowing to produce wide range of multi-functional radar systems, cured of such drawbacks [5-8].

USPR means technology of producing and application of radars working in X and Ku band, using as a probing high-frequency-filled single radio-impulse of approximately 10 ns duration. Choose of a probing single duration is dictated by a number of factors: on the one hand by minimal range of impulse volume, when compared with other broad band signal, which along with "absence" of side-lobes of ACF single impulse, improves contrast and allows to detect and identify target on a background of reflection from underlying surface. On the other hand, by ability of equipment-specific processing the required frequency range by every component of a radar system. That is why probing signal 10 ns duration to-day is effectiveness - cost compromise.

## 2 The main properties of USPR technology

Properties and features of this technology are as follows:

- Distance high resolving power and high precision of distance and speed measurements.
- Absence of side-loops of impulse signal autocorrelation functions, assuring high resolution of objects with considerable difference of Radar Cross-Section (RCS).
- High anti-interference from passive sources (underlying surfaces) property due to small impulse volume and implementation of Selection of Moving-Target (SMT) without blind speeds.
- Revealing object classification by its remote image.
- Improved stability of standard object tracking due to reduction of RCS interference.
- Ability to work at close distance from 7-10 m (practically no "blank zone")
- Obtaining non-flight path information concerning aircraft orientation on radar at low speed (in radio-vision mode).
- High detailization of radar map and good coincidence with digital map.
- High elctro-magnetic compatibility.

Up to the present day, development of USPR technology was restrained by problems of master, booster and receiver systems realization, as well digital computing technology with sufficiently high performance.

Recent years digital and computer technique advancement and achievements of solid-state microwave electronics provided background of the fully solid-state radar on USPR technology experimental model development. Such USPR experimental model was build-up in Moscow Aviation Institute (MAI) in cooperation with specialized industrial companies. Model general view is presented in Fig. 1.


Fig.1. Specifications and general view of EM (experimental model) USPR

Low EM pulse power (45 Watt) allows to work everywhere without restrictions and, at the same time to carry out a mission of a USP radar performance investigation. Radar with such output power is considered as "Ecologically clean". Solid-state transmitter was assembled from standard elements used in solid-state APAA (active phased array antenna).

Results of radar based on USPR technology field tests, conducted on various airfields, proved USP radar advantages.

Fig.2 presents photo and respective radar image of aircraft AN-24 maneuvering on taxiway. Dimensions and orientation of the aircraft on the taxiway is clearly visible on Radar image. Also it shows contrast boundary between airfield grass an taxiway concrete.

Fig. 2. Monitoring of aircraft AN-24 orientation on taxiway

Traditionally, radar designed to locate people in the background of reflections from surfaces, use Doppler selection and requires considerable time for analysis of each azimuthal element, which slows down area surveillance. Solution of a number of problems concerning practical realization of SMT by location, allowed to locate a man, preserving high surveillance rate, specific to RAS. Fig. 3 illustrates optical image of surveillance area fragment: flying machines, a man (waking to the left) different surfaces (grass, concrete).

Fig. 3. Photo of a man on the grass background, nearby airplane

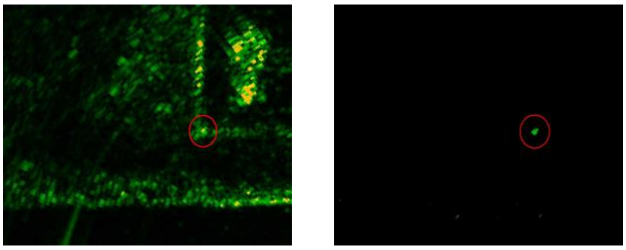

Fig. 4. Image of a man on the grass background before and after SMT algorithms application.

Fig-4. (left) - radar image fragment. A man on the boundary between grass and concrete nearby flying machines parking. In the right upper corner of Fig-4, reflection from a flying machine is clearly visible. At the bottom of the image, there is a clear view of the boundary between grass and concrete of a runway. Fig-4. (right) - the same radar image after Selection of Moving-Target (SMT) procedure.

Selection was performed by means of inter-surveillance processing (SMT by position) with sequent application of threshold (threshold was adjusted manually). Since object Radar Cross-Section (RCS) is small (about 1 sq m), selection by threshold processing on the background of reflection from flying machines inefficient. Low speed of an object (about 1 m/sec) does not allow to identify it with the help of Cross-Period Compensation. SMT by position procedure, used in USPR does not have "blind" speeds and allows to select extraneous non-moving objects (comparing with running image with recorded standard).

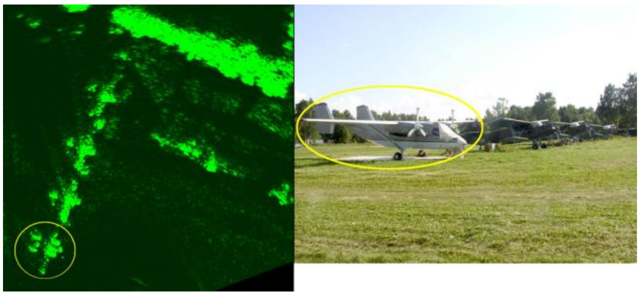

Fig. 5. Parking of light airplane

Fig.5 illustrates capabilities of general purpose aviation control on soft/unprepared airfield. Fig.5 illustrates that light flying machine type can be easily identified.

Fig.6 illustrates capabilities to register extraneous small RCS objects (vehicles) near a plain and on an airfield. Utilization of inter-surveillance processing allow to single them out automatically.

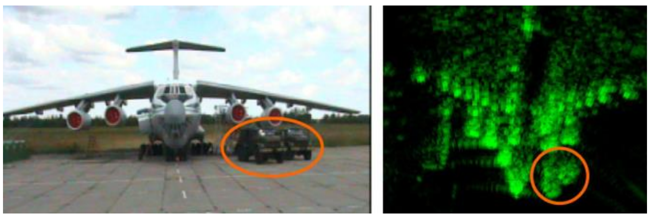

Fig. 6. Independent observation of aircrafts and vehicles

Tests prove, that EM USPR does not cause interference for aerodrome radio-network What is more, that the high impulse ratio limits the average transmitted power on the level of several watts, assuring its ecological safety.

Thus, unique multifunction detector was created. Its application is highly expedient in monitoring systems for airport safety assurance. The proposed system is not an universal panacea and shall be integrated in ACS together with means of communication, illuminating engineering, etc.

At the same time, introduction of a highly informative detector will allow to improve considerably traffic safety, reducing load of runway controllers and security service. To improve efficiency and extension of traditional optical detectors applicability in airport security service, it is proposed to integrated it with RAS.

Advantages of integrated television and radar systems:

1. automation of monitoring process (no need of Operator continuing supervision), including target acquisition and tracking in radar channel,
2. increase the rate of target acquisition in television channel (ten times), when working by a target designator of a radar channel,
3. reduction of false alarm rate in radar channel due to observability and target identification (alarm withdrawal) in television channel,
4. Assured observation of all control zone under any weather condition, including smoke, dust, snow and rain squalls (in a radar channel),
5. high precision of distance measurements (1.5m at least) without additional equipment (by means of radar channel).

Use of the proposed technology will provide for considerable improvement of automation of aerodrome control and security services with regard to all-weather, twenty-four-hour monitoring of illegal entry and traffic rerouting on an airfield.

Within the scope of USPR technology, together with known traditional solutions, inevitably spring up development of new devices of high complications (realization of which was impossible up to recent years) that is: modulation devices, generation and transmission of nanosecond and ultra-wide-band signals, switching arrangements and synchronization of nanosecond processes, data processing devices. Besides, practically all algorithms of detection, identification, orientation finding, etc., developed within the proposed technology are essential modernization of the existing ones.

Main competitive advantage of USPRT RAS:

- Distance high resolution: 1.5 meters,
- High rate of surveillance:1 sec,
- Detection of slow moving targets (men) on the background of surface reflections,
- Detection of small size objects (e.g. birds),
- Detection of unauthorized small size motionless object on an air-strip,
- Non-flight path assessment of aircraft orientation when maneuvering.

Essentially lower harmful effect of the new Radar generation based on USPR technology (considerably shorter probing signal allows to reduce average transmitted power 30-100 times, bringing it down to the level of mobile communications transmitting power. Under conditions of densely built-up area and now-day infrastructure, that allows to improve ecological conditions over an airfield, reducing microwave exposure dose for personnel and passengers.

The designed equipment and algorithms can also be widely used in allied spheres of radar applications. Here are some such examples.

## 3 Radar control of anchorage area

Such radar system operational objectives are similar to that of RAS, but with certain particularities: target lower speeds, wider range of RCS and dimensions, larger area under control, restricted visual field (from on-shore locations). Such specifics require decreased rate of observation, use of large aperture antenna system, etc. But the main functional modules of USP radar and specific equipment of USPR are the same. USPR technology is capable to provide the following functions: piloting ships along navigation pass using DCW with exact main ship channel mapping or ability (not available with traditional radars) to see buoy and beacon (without retroflectors) in close vicinity to a vassal; all-weather detection and tracking surface object of any type, even boats and swimmers; control of pollutants discharge of vassals (oil films on water surface);

estimation of vassals allowance for wind or current with forecasting of actual course; control of drifts in the course of docking; providing navigation and safety in the controlled zone.

## 4 Radar control of the air space over metropolis

Objective economical demand to open air space over major towns is restricted at present by necessity to provide objective control over air space situation, adhesion to prescribed air-corridor and flight level. Systems of such class have not been actualized, in spite of flagrant necessity There are several reasons for that, name a few: high level of reflective noise from urban development area disastrously degrades signal-to-background ratio (in that case noise of reliever is insignificant) of classical Radar; ecological requirements (low level of average power) also unattainable in traditional radar systems.

Solution of aforementioned problems can be found by USPR technology means. Let us consider it in more detail.

To reduce interfering noise, reflected from city buildings and structures USPR technology proposes several effective solutions:

- reduction of impulse volume and as the result intensity of reflection in a separate resolution cell,
- Absence of side-loops in selection function, consequently, good localization of reflecting areas,
- use of solid-state power amplifier, consequently, high stability of probing signal, allowing effective use of alternate-periodical and inter-surveillance algorithms of noise compensation,
- use of highly detailed local maps, allowing flexible control over signal amplification (using digital attenuators) and thresholds of secondary field forming.

Basic tasks of such Radar could be stated as following. Continuous monitoring of air space, detection, identification and tracking of all targets, control of adhesion to air-corridor and flight level, Takeoff and Landing control, recognition of potentially dangerous situations.

Naturally it is impossible to cover air space over, for example, Moscow with single Radar. On the one hand the required control over adjacent territory extends surveillance zone up to more than 50 km (exceeding radar horizon for low-flying target) On the other hand, shadows of high buildings cause considerable gaps in operating zone. The system should be initially designed as segmented and extensible. As minimum, 4 - 5 Radar systems required, located between MRHW (Moscow ring highway) and the Third Transport Ring on high-rise buildings (receiver). All Radar data shall be processed in one computer coordination center. Design shall provide possibility to integrate airway traffic information from the other Radar sources (such as Aircraft Defense and Antimissile Defense) into computer coordination center.

## 4 Conclusion

Presented USPR technology allows to develop new-generation of multi-function RAS, providing solution of such tasks as of airfield surveillance, detection of men and other foreign objects; assuring high ecological safety due to low level of microwave radiation.

Full scale of such radars with high spatial resolution is realizable only with development of specific algorithms of radar images processing. Development of specific algorithms, take into account statistical properties of bottoming surface scattering allowed to solve the problem of man detection at high rate of space surveillance, specific to RAS.

Presented USPR technology alternative applications are not a complete range its capabilities. At present, USPR technology applications cover all tasks pertaining to target tracing on a background of reflections from underlying surfaces at close range (up to radar horizon). Presented applications are the most theoretically and experimentally developed. Still waiting for consideration such practically important problems as, for example, shipboard radar, where USPR technology is defiantly promising.

Basing on range of developed modules of specific USPR technology devises and special computers, a new generation is radio-location means can be developed, providing solution of all traditional and a number new practically important tasks, specific for RAS and security systems.

Introduction of USPR technology in considered spheres will allow to improve and develop considerably end-user radar performance: improve radar image contrast and precision of target location, improve probability of a target detection, especially under complicated weather conditions, obtain additional information, such as aircraft orientation on a taxiway, target type by distant image, etc. In certain field (monitoring of air space over metropolis) introduction of USPR technology will allow to develop new class of Radar system with new end-user properties unparalleled at present.

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