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ULTRA-WIDEBAND SPACE RADAR – PROSPECTS FOR THE FUTURE

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Key words: *Space reconnaissance, Synthetic-aperture Radar (SAR), Ultra-wideband (UWB) radar;*

Abstract: *The incontestable advantages of space radar systems for remote monitoring of Earth are pointed out in the article. The condition of modern space radar in orbit is described. Projects and their realization for Ultra-wideband (UWB) Synthetic-aperture Space Radar (SASR) are emphasized. The projects „TerraSAR"and"Аркон-2" ("Arkon-2") are examined. Main missions resolved by Ultra-wideband space radars are defined.*

МНОГОДИАПАЗОННИ КОСМИЧЕСКИ РАДАРИ – ПЕРСПЕКТИВА ЗА БЪДЕЩЕТО

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Ключови думи: *космическо разузнаване, радиолокатори със синтезирана апертура, многодиапазонни радари;*

Резюме: *В статията са посочени неоспоримите предимства на космическите радиолокационни системи за дистанционно наблюдение на земята. Описано е състоянието на съвременните космически радиолокатори в орбита.. Основно внимание е отделено на проектите и реализацията на многодиапазонни космически радари.със синтезирана апертура. Разгледани са проектите „TerraSAR" и "Аркон-2". Дефинирани са основните задачи, решавани от многодиапазонните космически радари.*

I. Introduction

According to expert opinion about the twenty first century, a tendency exists for satellite radar monitoring systems and they are to be used not only for control over missions in emergency situations by modern military and civil agencies, but also as a powerful tool aiming to boost the economy and modern technology. With this in mind the volume of the gathered radiolocation images and their trading by the world market will increase rapidly compared to the rate of gathering and trading of optic images. Possible areas of practical application of the images gathered by space radar include areas of interest for power agencies, oil and gas companies and also organizations dealing with geological investigation, hydro-meteorological and ecological monitoring, cartography, evaluation for agricultural yields, etc.

Space radar monitoring systems have many indisputable advantages:
- independent of meteorological conditions or time of the day;
- combination of a wide lane of large distances and high resolution;
- multiple regimes and flexibility for control of the work of Synthetic-aperture Radars (SARs), allowing fast corrections of the location and size of the area monitored, resolution and forms for presenting of the information;
- high operation capabilities for receiving data from drilling, close to the actual time scale.

Radar data are invaluable in extreme situations, problem solving in polar regions, cartography, forestry, finding oil and others.

II. Current condition of radars in space

Development and exploitation of space radars is a complicated and expensive activity. Due to the fact at this stage only countries with highly developed economics and financial abilities own satellites with SAR with large resolution. Operators from twelve countries with active space activities (USA, European Space Agency, Japan, Germany, Canada, Italy, Israel, China and South Korea) have or plan to launch into orbit space apparatuses with SAR. Prospective satellites are with both civilian and military purposes and some of them are developed as projects with a double purpose.

Table 1. Main prospective systems with SAR

Country	Civil and Military SA with SAR /deployment year
USA	Radarsat 2/2005, FIA/2008, Lacrosse/2006, SBR/2012
Canada	Radarsat 2/2005, Radarsat 3/2009
Japan	ALOS/2005, IGS-R1/2006, IGS-R2/2008, ALOS-2/2013
Germany	Infotera-X/2006, Infotera-X2/2007, SARLupe 4,5/2008,TeraSAR/2012
United Kingdom	Infotera-L/2008, TerraSAR-L/2011
Italy	COSMO/2006, Skymed 3/2008
India	RISAD-1/2006, RISAD-2/2009
China	GSMS/2007, Tsyanbin-5/2008, Yaogan-6/2009
Israel	TesSAR/2008,Ofeq-8/2012, Ofeq-10/2014
Russia	Almaz-1/1991,Arkon-2/2010, Condor/2013
Ukraine	Sich-1M/2004
SouthKorea	KompSAT-5/2013
EuropeanSpaceAgensy	Envisat-1/2006, ERS-2/2097, CryoSAT-2/2010

In this report specific space programs of different countries are not examined in details, despite each of these programs being able to illustrate opportunities and intentions. We will only emphasize some incredible achievements, which are defining for the modern condition and patterns in purpose and development of space radars.

Historically it is necessary to mention the USA's reconnaissance system and it's three "Lacrosse" satellites. These satellites allow for radiolocation reconnaissance enabling monitoring of various objects during daytime, nighttime and cloudy weather. The radar images are transferred for development via Tracking and Data Relay Satellite (TDRS), flying in geostationary orbit, in a close to real timescale, with resolution of the image in the range of 0,6 - 3m and competing with that of optic apparatuses. In the operation "Union power" the two Artificial Satellites of

Earth (ASE) "Lacrosse" from an orbital formation have been flying over the territory of Yugoslavia for 4-7 times in a twenty four hour period, with at least two of them over Kosovo. The "Lacrosse" satellites supplied the necessary operational information to military command in the followed battle actions in Iraq and Afghanistan.

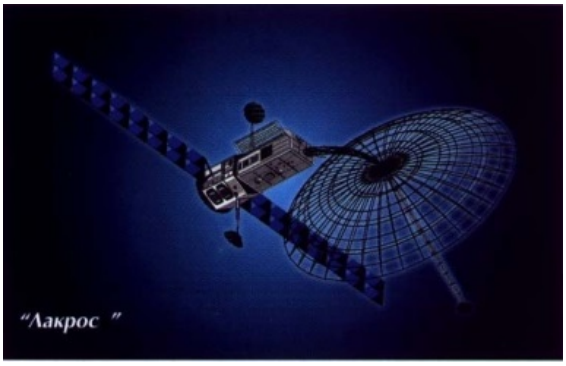

Fig. 1. General appearance of the “Lacrosse” satellite

The first radar fleet in space - 5 "SAR-Lupe" satellites simultaneously in orbit - is achieved by Germany. The creation of a radar fleet "SAR-Lupe" is argumented with the aim of the German government to find and monitor crisis situations in their beginning stages and also to avoid one sided dependency in reconnaissance areas. The five satellites that are simultaneously in orbit move in unison with one another in the shape of a large letter "X". Each satellite is a radar with synthesised wideband in the X - range. From a military and political perspective the system puts Germany on the same level with the leading space countries in the matter of satellite reconnaissance. The "SAR-Lupe" system is to be used not only by German military and civil departments. It is to become part of the European system for global monitoring of Earth.

Fig. 2. SAR-Lupe satellite on the launch-pad and on the Space

The space systems for radar reconnaissance are essential for Russia more than any other country. A large portion of its territory is in the northern longitude and covered by clouds in the larger time of the year (according to some up to 80%) or unlit by the Sun during the polar winter lasting for weeks. Due to this the development of space apparatuses for radiolocation monitoring begins as early as the year 1959, but truly important from a practical perspective is the development and exploitation of space apparatuses "Алмаз-1“ (Almaz-1). On 06.27.2013 Russian space departments launched in orbit another space radar – „Кондор“ (Kondor). It works in the S-frequency range and its unique advantage is that it combines a high resolution with better classification for vegetation and deeper subterranean radio wave reach. The "Kondor" radar allows for making of terrain maps of the areas and finding changes in the surroundings.

The most recently launched satellite in orbit is the Israelite radar named "Ofek-10" on 04.09.2014. Made for the "Etgar" project and aimed for radar images on the surface with a high resolution and identification of a wide range of objects including moving ones.

It is interesting to note that closely related from technical perspective radars execute different informative tasks. For Canada - it is monitoring of arctic glaciers, for China - monitoring of the sea aquatory, for Italy - cartography, for Israel - observing Iran's territory, etc. The European satellite "ERS" is with a relatively low resolution (20 - 30m), but the information received by it is actively used by NATO countries for finding ships and keeping track of events in the seas.

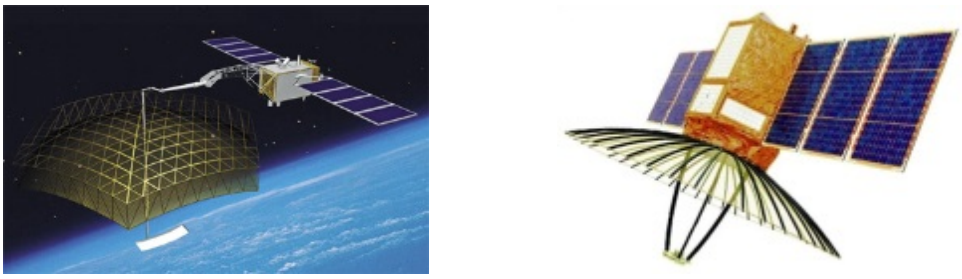

FIG. 3. „Kondor” and “Etgar” radars

Lastly - something curious - radars will save us from space garbage. From conservative estimates around half a million space debris from satellites, rockets and other scrap currently orbit Earth, gathering up ever since 1957. The speed they move around with is 27 000 kilometers per hour. By clashing with one on other they become smaller, thus they threaten both piloted and unpiloted flights. The company "Lockheed Martin" won an auction of the United States Air Force for the making

of an aerospace system for monitoring called "Space fence". The new system of radars on Earth, situated on the Marshal islands will track and catalogue space debris.

III. Current Ultra-wideband space radars - projects and realisation in space

It is well known that the quality and the information of the radar images strongly depend by the radar wavelength. Photographing in the centimeter "X"- range (wavelength - 3cm) allows for radar images with resolution close to that of images from fiber systems. Radars of "S"-range (wavelength - 9.5 cm) allow for the ability to make a terrain map of the area and to detect changes in the surrounding environment. Systems of the decimeter "L"-range (wavelength - 23cm) allows for seeing trough the leaves of trees. Lastly the R-range (wavelength - 70cm) SAR allows drilling under a layer of dry soil. Naturally the question arises - can we not receive a complex image that contains simultaneously the capabilities of radars with different wavelength ranges. Thus we get to the idea and later to the realization of Ultra-wideband space radars. The complex processing of radar data from different wideband channels of this type of space radars provides new informative qualities while increasing the efficiency of deciphering and analyzing the received images, widens the range of problems solved including finding objects in forests and buried objects.

The high information quality of the images of Ultra-wideband synthetic-aperture radars was demonstrated by the American complex "SIR-C". Despite the short duration of the three flights, carried out by the board complex of the space shuttle “Chattel” during the 90s, the received digital information was processed for many months afterwards. The “SIR-C” complex has formidable size – a total weight of 11-13 tons, with an antenna system that weighs 3.3 tons and 12 meters long.

Multiple leading space countriesintend to develop two or three wideband SARs. Such are the projects of the space reconnaissance “Lacrosse/Onyx” by the USA, “IGS-R” by Japan, “Jogan(Czian Bin-5)” of China, the German-British project “TerraSAR” and “Arkon-2” of Russia.

The German-British project “TerraSAR” is planned from the year 2000 as a two–wideband - in “X” and “L” range. The space apparatus is designed especially for trading and scientific purposes. Previous space radars for monitoring are not completely satisfying for the demands of the commercial users, which needed detailed and adaptive information. The data needs to be always available and independent of night and day or season conditions.

Most likely because of the high value and complexity of technical realization the project “TerraSAR” was divided into two separate satellites – “TerraSAR – X” and “TerraSAR – L” for a tandem flight and in latest years the two project are looked upon as separate.

The shape of the satellite will be a hexagonal parallelepiped with length 5.2m and diameter 2.2 m. The useful cargo of the satellite is radar in the “X”-range with phased wideband. The size of the antenna of the radar is length 4.8 m and width – 0.8 m. The space apparatus is about 1230 kg. The planned term of active existence of the satellite in orbit is at least 5 years. It is planned for it to be launched into space with the Russian carrier rocket “Днепър“(Dnepar).

”TerraSAR – X” will work in three modes:

- pictures with high resolution: the size of the shooting frame is 5-10 km for every 10 km, with the resolution of the are reaching 1 m;
- pictures of the lane: the space aperture takes lane photos with width 30km and length 1500kn with resolution area up to 3m;
- scanning: picture of a corridor with width 100 km and length 1500 km with resolution are – 16m.

The satellite will be launched in polar orbit with height 500 km which will allow receiving images of any area of Earth’s surface with a minimum of one every three days. The captured information will be stored on board the space apparatus and later transmitted to the ground complex in German Aerospace Center - DLR, situated in the city of Neustrelitz. In addition to all of this the apparatus will be able to transmit information immediately to user receiving stations.

Developers also plan a variant to use in a tandem simultaneously two space apparatuses TerraSAR-X (a project by TanDEM – X). According to their information the two satellites can form an interferometer capable of providing a stereoscopic image of Earth’s surface with a resolution less than two meters.

The project “Arkon-2” by the Non-government organization “S. A. Lavochkin” (Russia) claims that a large-size space apparatus with a three wideband radars made for highly-informative images of objects with high and middle resolution for a wide range of consumers can be created – Federal Space Agency, Ministry of Natural Resources and Environment, Federal Agency of Geodesy and Cartography, Ministry of Affairs for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters, Ministry of Internal Affairs, Hydro meteorological Centre, Federal Agency for Marine and River Transport and other government and trade organizations . Usage of the satellite for ensuring national safety for Russia is also assumed.

Fig. 4. “TanDEM – X” satellites on the Space

The choice of “X”- “L”- and “R”- ranged space apparatus “Arkon-2” allows solving of multi-planned tasks. The usage of R-range will be the first ever known case of montage of analogical aperture in a space platform.

The satellite “Arkon-2” will provide a detailed image of the region with sizes 10 x 10 km with a resolution up to 1m, astronomical images in lane with length 450 km with resolution up to 50m and route images with lane length 400 – 4000 km.

For transmission of large data volumes the satellite is planned to be supplied with highly informative lines for information transmission immediately to ground consumer stations of information and trough a satellite – repeater with speed of 15 up to 600 Mbit/sec. For an increase in the operation of processing and reduction of data volumes, transmitted to small-scale mobile receiving complexes, implemented perspective technologies for on board synthesis of images is being planned.

Fig. 5. Satellite “Arkon-2”

Main problems, solved by Multi-wideband space radars include:

- Operative control of crisis situations – dynamics of river spills and dam spills, floods, avalanches, forest fires, consequences from natural, technological disasters and so on.
- Planning of construction and situation of road and highways;
- Land division and control of construction of underground areas;
- Control of glacier movement and operative security of safety for sea navigation;
- Agriculture and Forestry;
- Geology and searching for minerals;
- Control over highway piping condition;
- Monitoring of coastal areas and finding oil spills;
- Hydrology and Oceanology;
- Cartography, topography and others.

IV. Conclusion

Analysis of modern conditions and prospective for development of space radars allows us to reach the following conclusions:

- Development and realisation of ultra-wideband space radars is a relatively new and promising field of Earth monitoring from space.

- Complex development of radiolocation information of this type of radars allows new information qualities and significantly increases the effectiveness of deciphering and analyzing the received images;

- Space radars of this sort will supply detailed panoramic and route highly informative pictures of objects, including masked in forests or buried under the surface, with wide and middle range for a wide customer usage;

- Realisation of projects for ultra-wideband space radars demands for experience, application of most modern technology and a huge amount of funds and because of this, only the most powerful space countries can afford it.

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