SPACE BASED RADIOLOCATION SYSTEMS - PRESENT STATE AND PERSPECTIVES FOR DEVELOPMENT

Petar Stoyanov, Venzislav Markov, Mihail Mihov, Georgi Kiprov

Space Research Institute - BAS6, Moskovska St. P.O.Box 799, 1000 Sofia, Bulgaria
E–mail: pstoyanov@abv.bg:

The article describes the condition of the contemporary space radars. The features of seven radio locating spacecrafts currently into orbit (3 civic and 4 military) are presented. Special attention is given to the perspectives for development of space systems with Synthetic Aperture Radars (SAR). The prospective satellites, developed by ten countries for civil and military purposes, such as United States, Japan, Germany, Canada, Italy, United Kingdom, India, Israel, China and Russia, are represented. As a conclusion, the common features of perspective satellites with space radars are defined.

Keywords: space, satellite systems, space radars

1. INTRODUCTION

The predominant majority of currently used systems for remote surveillance of Earth are the systems for optoelectronic observation. Yet the leading space countries are attempting to include in its national spacecrafts satellites supplied with synthetic aperture radars (SAR). It comes because of some indisputable advantages the radio locating systems for observation/control have in comparison to optical ones:

- ♦ independency from the weather conditions and the day time;
- ♦ combination of broad range of long distance observations with high resolution;
- ♦ multiple regime and flexibility of the control of SAR allowing fast alteration of location and size of the observed area, resolution and form for representation of information;
- ♦ high efficiency of received data from surveillance, with near real time capability.

The radio locative information is indispensable in extreme situations, solving problems in polar areas, in cartography, forestry, petroleum search, etc.

The choice of spacecraft bands solves many multiple tasks. Taking pictures in the centimeter X-band (wavelength – 3 cm) gives high resolution radio images with quality of extension, close to the images made by optical systems. The systems with decimeter L-band (wavelength – 23 cm) allow an observation between the tree leafs. And finally SAR operating in P-band acquires data over a layer of dry soil (wavelength – 70cm).

2. CONTEMPORARY SPACE RADARS

On the current stage only the countries with high developed economics possess satellites with high resolution SAR. In 2006 seven radio locating space ships has been put into operation (3 civic and 4 military). They are from the number of four space

systems – United States, Canada, Japan and the European countries (tab. 1). All the countries possessing spacecrafts with SARs are planning further development and elaboration of these systems. The only exclusion is the European Space Agency (ESA), which after putting in operation the most expensive in its history 8-tone satellite Envisat-1 operating in C-band abandoned the idea for future design of analogical spacecrafts. For that reason the satellites with SAR will be launched by European projects, and their exploitation in interest of Europe will be coordinated by different projects (for example via GMES program, European Center for Space Reconnaissance, etc.)

Table 1. Specifications of currently launched Spacecrafts with SAR

Name (Operator)	**Launch date**	**bearer/ mass of the spacecraft, t**	**Cost of the spacecraft /system**	**Spatial resolution ,m**	**Application**
Radarsat-1 (RS)	04.11.1995	Delta-2/2.7	642mill$/-	8-100	operational
ERS-2 (EKA)	21.04.1995	Ariane 4/2.5	650mill$/1.1bill$	25-30	Limited
Envisat-1 (EKA)	01.03.2002	Ariane 5/8.2	872mill$/2.5bill$	30-150	operational
Lacrosse (NRO) USA-69 USA-133 USA-152	 08.03.1991 24.10.1997 17.08.2000	Titan 4/16	>600 mill$/-	<1	operational and reserve (69)
IGS-R1(CSICE)	28.03.2003	H-2A1.2	416mill$/2.2bill$	1-3	operational

There are no Russian satellites with SAR with high resolution since 1991, after the spacecraft "Almaz-1" stopped operating in 1991. The satellites form the "Ocean" class series, launched under name "Sich", are equipped with side-view radar and have spatial resolution more than 1 km, and do not assign to this category. However, according to Russian specialists in next few years the situation in the world should be changed.

3. PERSPECTIVES FOR DEVELOPMENT OF SPACECRAFTS OPERATING WITH SYNTHTIC APERTURE RADARS

Eight countries, implementing space activity (Japan, Germany, Canada, Italy, the UK, India, Israel, and China) are planning to launch into orbit 10-14 space ships equipped with SAR for the period 2006-2007 (fig. 2). The prospective satellites are designed for civil and military purposes, and some of them are with double purpose.

The US work on design of two military projects. The National Reconnaissance Office (NRO) finances the development of spacecrafts for reconnaissance operating with SAR under FIA program. After 2008 they are supposed to replace now functioning satellites Lacrosse. From another side in 2004 the Ministry of the Air Forces started a competition for design of multi-satellite system for global reconnaissance of mobile targets SBR (Space Based Radar). According to the competition's regulations in 2007 will be appointed the winner company, which till 2012 will design and launch into orbit the first satellite of the SBR system. The approximate cost for elaboration of the system for the next 5 years is 4 billions USD.

Table 2. Main prospective systems with SAR

Country	Civil Spacecrafts equipped with SAR /year of launch	Military Spacecrafts equipped with SAR /year of launch
USA	Part of the resource of Radarsat 2/2005	FIA/2008, SBR/20012
Canada	Radarsat 2/2005, Radarsat 3	
Japan	ALOS/2005	IGS-R2/2006
Germany	Infoterra-X/2006, Infoterra-X2	SAR-Lupe/5 KA 2005-2007
United Kingdom	Infoterra-L/2008	
Italy	COSMO/4 KA after 2006	Double purpose
India	RISAT/2006	
China	GSMS/2007	
Israel	TecSAR/2006	Double purpose
Russia	Arkon-2, Kondor-E, Monitor-R, Стрелка	
Russia, Ukraine	Січ-1М/2004	

The United States have no civil satellites with SAR, because according to mutual / interdepartmental agreement they receive 15 % of the imageries of the spacecraft Radarsat 1 in return for the launch of the satellite into orbit with American carrier rocket. In fact, for the period 1996 – 2003, 43 % of the imageries made in American interest are taken with the sources of Radarsat 1.

While trying to keep its leadership on radar imageries market, Canada is planning to launch into orbit a new satellite Radarsat 2 with SAR with higher spatial resolution (3m instead of 8m) and polarization picture mode. For the first time on a civil satellite will be realized a selective mode for moving targets. In extreme situation an image of any object can be taken for 4-12 hours after client's request.

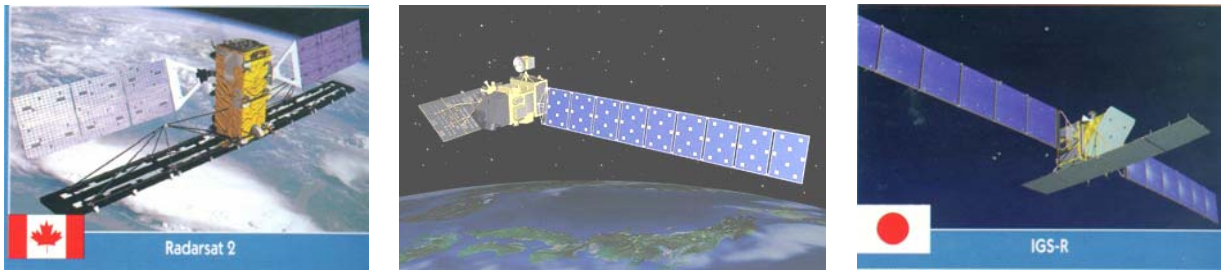

Fig.1 Satellites Radarsat 2, ALOS and IGS-R

Japan Space Agency JAXA is planning to launch into orbit a multifunctional civil spacecraft ALOS with SAR operating with L-band and providing 10-20 m spatial resolution. The satellite is intended to transmit the image information via channel for intersatellite connection and directly to the small reception stations. The government announced the plans for further development of national system for space investigation MIGS, which after the launching of new satellites in 2006 will includes two satellites IGS-R with SAR and two satellites ISG-O with optic-electronic apparatuses.

After 2005 Germany will launch into orbit five small satellites for space reconnaissance SAR-Lupe operating in X-Band. The new system is planned to implement day-and-night operative reconnaissance of any spot on the Earth with system response time of 36 hrs (from the moment of request to receiving of the

image) and 12 hrs for downlink with high spatial resolution 0.5 m. According to the intergovernmental agreement the data gained by SAR-Lupe satellites will be used by France, Italy and other European countries. German Space Agenncy DLR and EADS Astrium co-operatively finance a project for civil spacecraft TerraSAR-X with high-resolution X-band radar (up to 1 m), that is to be launched into orbit in the end of 2006. DLR agency is reviewing a proposal to launch second analogical spacecraft TanDEM-X for images in tandem flight mode of the two satellites.

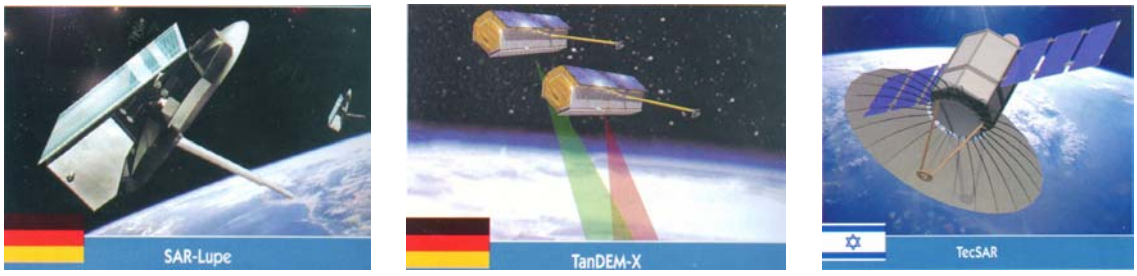

Fig 2. Satellites SAR-Lupe, TanDEM-X and TerraSAR-L

In Great Britain leading developer of space radars is the company Astrium Ltd which plans in 2008 to launch into orbit the satellite TerraSAR-L with SAR operating in L-band. Specific for this project is the big antenna with dimensions 11x2,5 m, which folded is placed under the stream-line of middle class rocket.

The Italian Space Agency develops a double purpose system, consisting of four spacecrafts COSMO with SARs operating in X-band with high spatial resolution (<1m). The satellites that are intended to be launched into orbit after 2007 will become part of French-Italian investigation system ORFEO. France will participate with two satellites for optical reconnaissance Pleiades. After their launch the period for secondary observation of the objects will be less than 12 hrs.

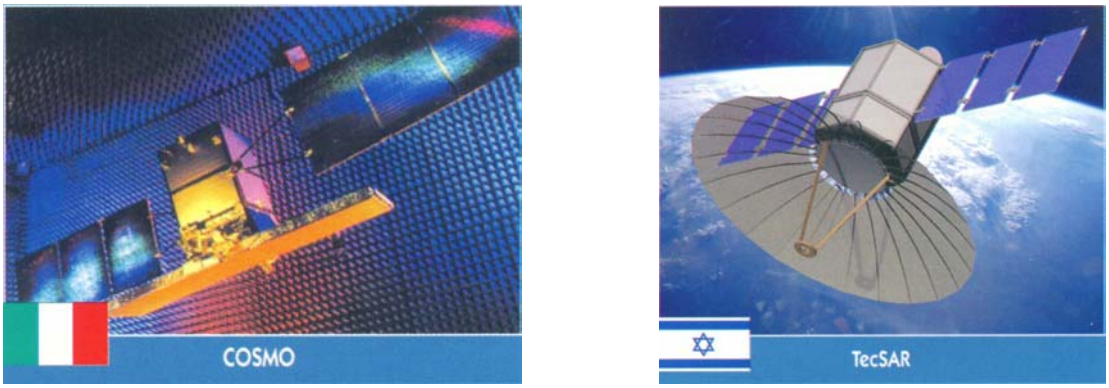

Fig. 3. The satellites COSMO and TecSAR.

The Indian Space Agency ISRO finances the development of satellite RISAT with SAR operating in C-band and plans to launch it into orbit in 2006. Yet this date is not realistic because India is not experienced in space based SAR design.

China simultaneously develops several projects for spacecrafts with SAR operating in high spatial resolution. In 2007 is possible the launch of satellites with optical and radar installations operating in L-band, designed by the Chinese National

Space Administration for Emergency control CNSA. Deadlines for development and detail description of the projects are not mentioned in the literature.

The Israeli corporation IAI develops a project for mini spy satellite TecSAR with total weight of 300 kg equipped with SAR with high resolution. Initially it was planned to be launched into orbit in 2006-7, yet the schedule may be reconsidered because of the failure launch of Ofeq-6 spacecraft in 2004.

During last years in Russia simultaneously are developed several projects for satellites with RSA capable of high resolution survey – the satellite "Kondor-E" equipped with SAR operating in S-band, satellites from the Monitor – R series, the long-term satellite project "Strelka" for monitoring of oil and gas facilities and finally the multi-role satellite "Arkon-2" which has a three-band SAR.

4. CONCLUSION

The analysis of all the programs represented above, allows formulating of the main characteristics of the advanced satellites with SAR, as follows:

- Replacement of the heavy space platforms with complex efficient loading in respect to the small or mini platforms; , taking measures for reducing the mass and cost of the systems;
- Design of SARs operating in one of the three most widespread frequency bands (L-, C-, or X-) with super broadband signal (spectral range up to 300 MHz) and high spatial resolution (up to 0.5 m);
- Increase of the frequency and efficiency of the images through development of multi satellites systems (from two to five spacecrafts);
- Provision of opportunity for receiving images from the both sides of the airways of the spacecraft through adjustment of the antenna or the whole satellite;
- Usage of active phased antenna lattices and new technologies for high qualitative images in poliametric (POLSAR) mode, selective mode of moving targets (MTI), interferometric (InSAR) and stereometric modes for design of digital models of relief of the area.

The new technologies for processing of radar images that appeared during the last few years (InSAR, MTI, stereo image), give impressive results in monitoring a centimeter upheaval of the strata – for example land sliding in the areas of underground engineering, consequences of earthquakes, landslips, etc. It also gives an opportunity for detecting moving targets and their imposition upon detail imagery of the area, automatic detection of alteration of the observed objects and design of 3D models of the relief of the area.

5. REFERENCES

[1] *Russian cosmonautic academy named Ziolkovski Collection research works* vol.4, p51 Moscow. 2002 (in Russian).

[2] Favorski, V., Mesheryakov, I. *Voenno-Kosmicheskie Sily*, (in Russian) Vol. 1. Nauka, Moscow, St. Petersburg 1997.

[3] Clark P., The *History and Projects of the Yuzhnoye Design Bureau*, Journal of the British Interplanetary Society, Vol. 49, July 1996, p. 267-276.