

# **HIGH RESOLUTION RADAR WITH ON-BOARD IMAGE SYNTHESIS SYSTEM FOR SMALL SATELLITE**

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The project of high-resolution synthetic aperture radar system designed for a small satellite is proposed. It is intended for expeditious producing of detailed radar images of natural and artificial origin objects. The offered radar system has space resolution of 3 meters and four non-coherent accumulations (looks). The system key feature is, that images synthesis and their normalization are carried out immediately on the satellite. The obtained radar image is exposed to compression. These operations reduce volume of data, transmitted on the ground by tens time. For a data acquisition the antenna of 1-m diameter could be used. The survey is realized in telescope mode, and the result is produced by square frames of  $10 \times 10$  kilometers. Weight of radar is about 100 kg, including radar antenna and radio link equipment.

The offered project of the radar system with on-board image synthesis, designed for a small satellite, which have mass no more than 250 kg, open qualitatively new possibilities for expeditious production of detailed radar images. The radar system is intended for observation and evaluation of consequences of ecological disasters, earthquakes, floods of the rivers. Its space resolution (3 m) is 5 – 10 times higher, than one of modern satellites for Earth radar observation (ERS, RADARSAT, SIR-C). Such space resolution allows, for example, to observe separate streets and buildings in inhabited localities.

The offered radar system is a new word in the area of space systems of radar observation (fig. 1). Its key features – synthesis and processing of high-resolution radar images immediately aboard the satellite. While the known radar systems of space observation and mapping «Venus-15 and 16», «Almaz-1», Magellan, SEASAT, SIR-C, ERS, RADARSAT, JRS only stored received reflected signal (radio hologram) or at once relayed it on the ground, the offered system synthesizes images (usual or complex) immediately aboard the satellite. The obtained radar image is exposed to compression. These operations reduce volume of data, transmitted on the ground by tens time, and it simplifies a radio link cardinal and increases efficiency of data acquisition.

The raw data radio link requires a large ground antenna. For example, the ground data acquisition terminal of the radar system ERS is equipped with an antenna of 7 m diameter. The absence of on-board storage device limits survey to direct visibility between a satellite and ground terminal (about 2000 km).

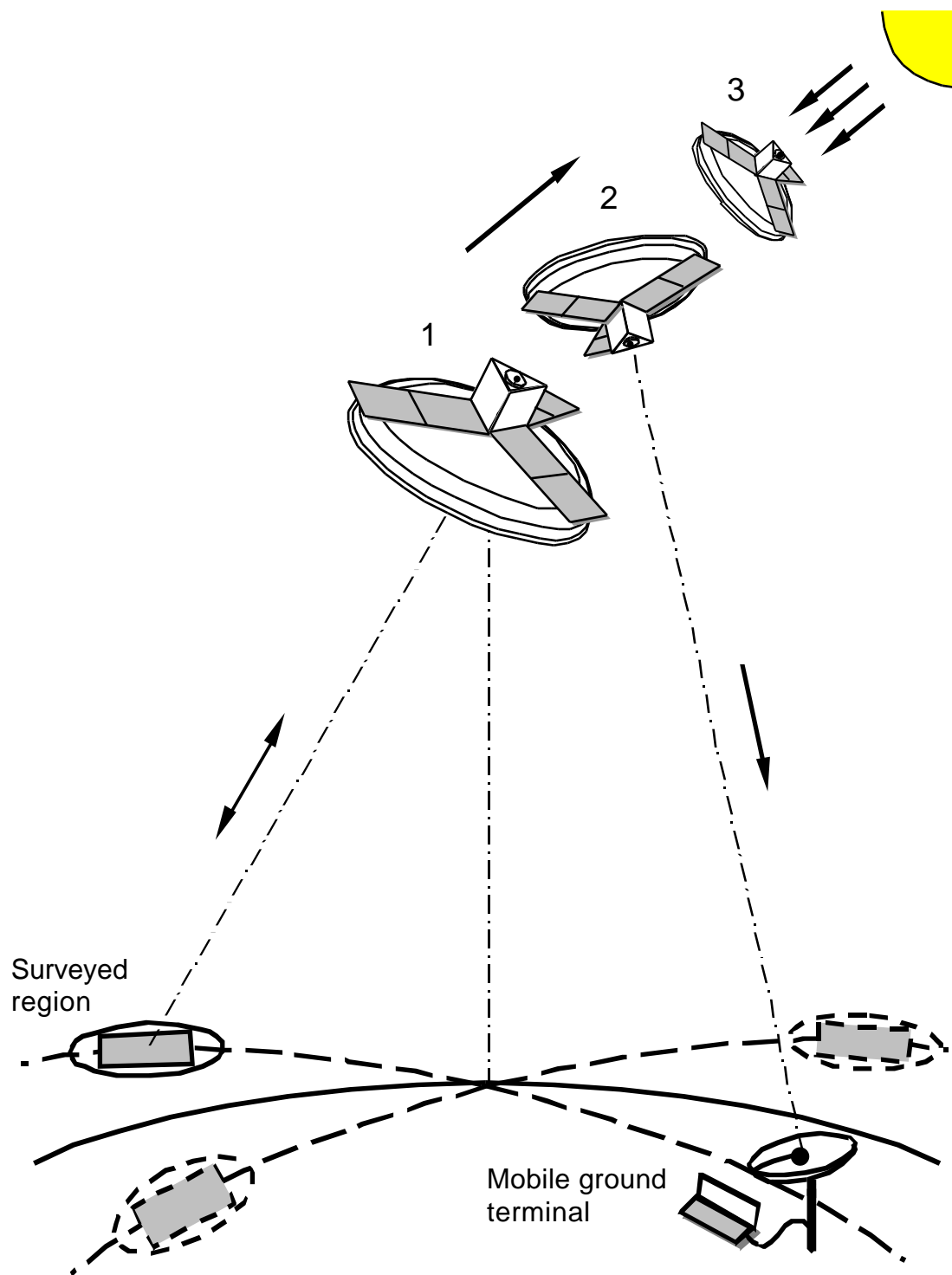


Fig.1. Operating the small satellite with on-board high resolution SAR.

1 – radar survey; 2 – data transmission to the ground terminal; 3 – battery re-charge.

The offered radar system has simple ground terminal equipment. For a data acquisition the antenna of 1-m diameter could be used. The necessary radio link throughput is provided at the expense of on-board directional antenna. In a data transmission session this antenna is directed on the ground terminal (see fig. 1). Besides, the high directional on-board antenna application increases confidentiality of data transfer.

Image normalization (looks accumulation, brightness equalization over the field, reduction to the selected map projection) is supposed to be conducted aboard also. In this case ground operations will be reduced to image reconstruction, thematic processing, visualization and filing in a database. For this purpose an available computer can be used.

Similarly to photographic shooting, the radar survey is conducted by frames, appropriate to square areas of a terrestrial surface with the size of  $10 \times 10$  kilometers (see fig. 1). For realization of 3 meters space resolution and four non-coherent accumulations to reduce a speckle-noise the «telescope» mode is used, when antenna traces the center of surveying area. The signal processing mode realized at on-board system, ensures surveying possibility not only on the traverse direction, but ahead or behind it also (see fig. 1).

The basic survey parameters (Table 1) are maintained in bands of a terrestrial surface located from the left and from the right sides of flight trace on a distance from 230 to 830 kilometers. Maneuvering possibility ensures group of frame acquisition.

Table 1

### **Radar system specification**

1. Carrier frequency 3200 MHz (S-band).
2. Surface resolution along ground trace and across it 3 m.
3. Size of area, mapped in one frame,  $10 \text{ km} \times 10 \text{ km}$ .
4. Satellite orbit height 650 - 622 km.
5. Surveyed areas are located on distance 230 - 830 km from the trace.
6. Range of azimuth angles  $\pm 30^\circ$  from traverse.
7. On-board antennas dish diameter 6.0 m.
8. Transmitter power:  
Pulse 150 W,  
Average 60 W.
9. The specific backscatter reflectivity, for which signal power, reflected by resolved element, is equal to receiver thermal noise power, 0.01.
10. Number of non-coherent accumulations (look) 4.
11. Two-dimensional autocorrelation function side lobes level, no more than -25 dB.
12. Output image coordinate system - orbital equiscaled.
13. Radar image volume compression coefficient 8: 1.
14. Overall one image surveying and processing time 25 s.
15. Radio link throughputs rate 32 Mbite/s.
16. Ground terminal antennas dish diameter 1.0 m.

17. Mass of the on-board equipment, including a radio link and SAR antenna 100 kg.
18. On-board primary network power consumption 850 W.

The on-board processing system ensures storage up to 10 image frames obtained during one period of revolution. A radio hologram or complex image can be transmitted to the ground terminal also.

Radar survey 1, data transfer to the ground terminal 2 and primary power supplies recharging 3 require different orientation of a satellite. The satellite rotation is executed by system of flywheels. Herewith the irreplaceable resource (fuel) is not spent.

The possible appearance of a small satellite with the on-board high- resolution radar system is shown on a fig. 2.

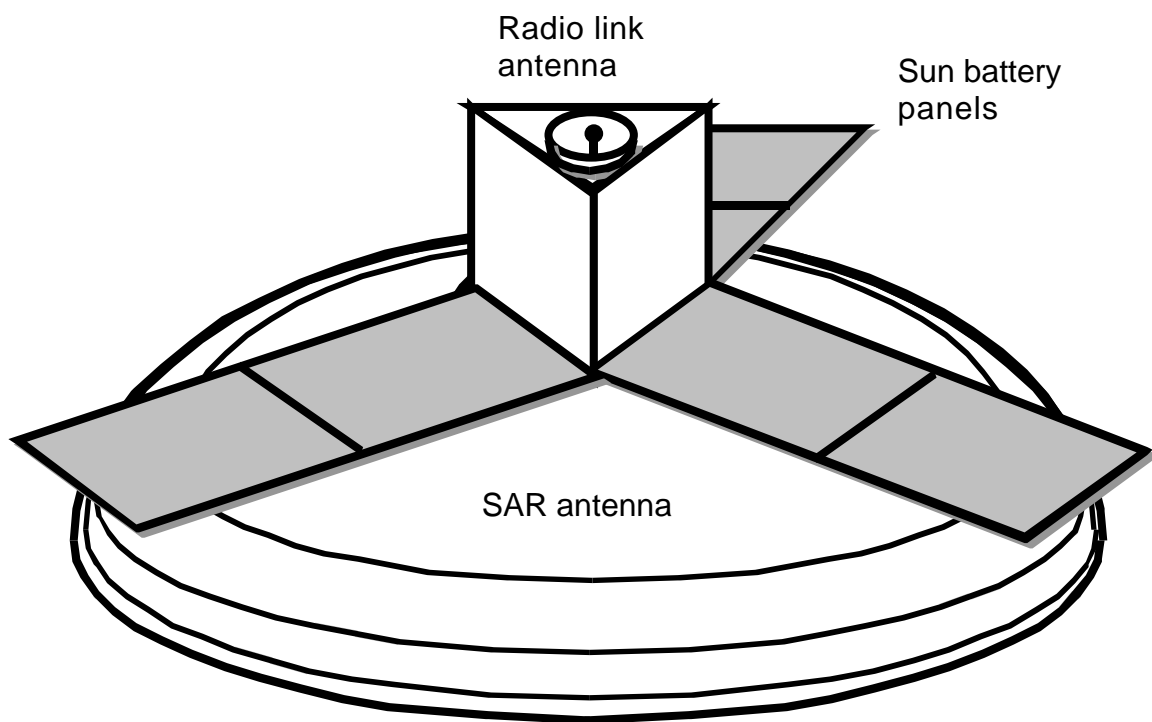


Fig.2. Overview of the small satellite with on-board high resolution SAR. Antennas dish diameter 6.0 meters.