IMAGE RECEIVERS DESIGNED FOR SMALL SATELLITES

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The paper presents the research results on possibility and efficiency of using the new types of image receivers. At present the Earth observation space systems are usually furnished with CCD (charge –coupled device) receivers of visible range with pixel 9 –12 _m and Cd-Hg-Te receivers in infrared range. The results of research show larger efficiency of CCD receivers with smaller pixel and infrared receivers on indium antimonide. The paper shows specific estimations of mass and informative benefits of small satellites, furnished with receivers, proposed by Russian companies.

1. THE ANALYSIS OF POSSIBILITY AND EFFICIENCY OF CCD RECEIVER PIXEL REDUCTION

At present the Earth observation space systems that are in service or under development usually use CCD receivers with comparatively large pixel size. Thus, the size of pixel for IKONOS satellite is 12 _m, for Russian satellites of RESURS series, which are under development now - 9 _m. Modern technology allows in principle the use of receivers with smaller pixel size. There is data on development of receivers with pixel ~ 3 _m. The receiver with the TDA (time delay and accumulation) mode and pixel 6 _m is at present under development in Russia. We shall analyze the efficiency of such receiver for a specific design of surveying camera with entrance pupil diameter 0,7 m and aperture ratio 1:10.

The most deep indicator of system informativeness is its ground resolution, estimated by mire under qualification conditions, similar to service ones. The following conditions may be taken as qualification ones for solar- synchronous orbit: solar angle 40˚, mire contrast 0,24, background albedo 0,08.

In this case, the calculation, using Lloyd method, gives the following values of resolution for different types of receivers for 900 km survey altitude.

Table 1.

Pixel, _m	6	9	12
Resolution, m	1,05	1,38	1,70

The estimations are given for receivers with TDA mode (128 accumulated lines), quantum efficiency 0,45 (max) and noise level in processing route 50 electrons. The estimations show that the receiver with 6 _m pixel provides 70% increase of resolution in comparison with 12 _m pixel receiver. It is impossible to compensate this loss in the system with increased pixel by enlargement of focal length in dimensional limits of a small satellite. That will result in reduction of field of vision or loss of image quality. The only way is to increase the entrance pupil diameter. The estimations of main parameters of surveying cameras with the same mass limitations are shown in Table 2.

Table 2.

Pixel size, _m	Resolution, m	The entrance pupil diameter, m	Surveying camera mass, kg
6	1,05	0,70	190
9	1,33	0,88	190
12	1,69	0,94	190

The estimations in Table 2 are given for the camera with coverage zone ~ 40 km. Camera consists of optical system, photo receiver, processing route with the unit of video signal compression. The given estimations show the advantages of receiver with small pixel. The increase of optical aperture does not lead to significant improving of image quality, being limited by pixel size.

Some designers of observation systems doubt that at reduction of pixel the dynamic range of registered image will be narrowed. Our estimations show that in case of one technology and receivers` scheme arrangement the pixel reduction doesn't result in narrowing of dynamic range and number of transmitted levels of brightness.

2. THE ANALYSIS OF IR- RECEIVERS USE

Systems of space observation usually use now Cd-Hg-Te receivers. We suppose this approach is not sufficiently valid (at least for the systems that do not demand spectral ranges and are used to obtain the thermal picture). Cd-Hg-Te receivers have two principal drawbacks:

- large dark currents at temperature ~ 80K, that do not allow to use the mode with limiting by background.;
- high price (~250-400 $/pixel).

The alternative option for development of thermal vision systems may be InSb receiver, operating under 80K in the range of 3-5 _m.

We shall analyze the efficiency of both types of receivers with account of Russian technological possibilities on example of thermal vision system, providing resolution (by test object) 5 m for coverage zone 10 km from 700 km altitude.

The circuit with two mirrors, aberration corrector and actual exit pupil near FPU for suppression of structural background will be taken as an optical system. The diameter of entrance pupil is at the level of 1m and aperture ratio – 1:12. The shooting is supposed for the image motion velocity 30mm/s (with pitch deceleration). The size of receiver's pixel is 35 _m, number of accumulated lines – 32 (number mode TDA). The detective possibility of Cd-Hg-Te receiver is D*=5 10^{10} W^{-1}sm Hz –(in a solid angle 30˚ at 300K background in the range of 8 -12,5 _m under operating temperature 80K). Threshold sensitivity of InSb receiver is characterized by multiplexer noises ~ 600 electrons and dark current 2 10^{-11}A. Quantum efficiency (at maximal sensitivity) for Cd-Hg-Te and InSb receivers is 0,8 and 0,6 correspondingly. The cryogenic cooling system is done at Steerling machine and provides cooling of receivers up to 80K.

The estimations show that for the same mass (~220 kg SC power supply system) the thermal vision system in the range of 3-5 _m. with InSb receivers has higher thermal sensitivity in comparison with the system on Cd-Hg-Te receivers (0,4 and 4,3K correspondingly).

The thermal sensitivity is given by mire with 5 m resolution .

The main reason of low sensitivity of Cd-Hg-Te receivers is large dark currents (~ 1,2 10^{-6}A). They can be suppressed by reduction of operation temperature up to 50-60K, however this method leads to significant increase of systems` mass. The estimations show that to achieve the same sensitivity (as InSb) it will be necessary to spend not less than 80 kg for power supply and cooling system of SC. That is hardly acceptable for small satellites.

3. CONCLUSIONS

The proposed image receivers allow reducing significantly the mass of and increasing of self-descriptiveness of small Earth observation satellites. Russian technologies are opened for designers of such systems and can provide the design of receivers or systems, based upon them, including development of survey cameras and small satellites.

The specifications of proposed receivers are given in Table 3.

Table 3.

Parameter	CLI receiver	IR receiver
Photosensitive material	Si	InSb
Spectral sensitivity, _m	0,4 – 1,1	3 – 5,5
Maximal sensitivity, _m	-	4,6
Receiver’s size	1536 _ 128	128 _ 32
Pixel size, _m	6	30 (50)
TDA mode	analog	digital
Number of accumulated lines	8 -128	1 - 32
Number of exit registers	2	2
Maximal clock frequency in the register, MHz	11	3
Maximal velocity if image motion, mm/s	86	45 (70)
Quantum efficiency (max)	0,45	0,6
Noise at readout	30	600
Operating temperature, K	293±5	80±2