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Energy resolution of dual-channel opto-electronic surveillance system

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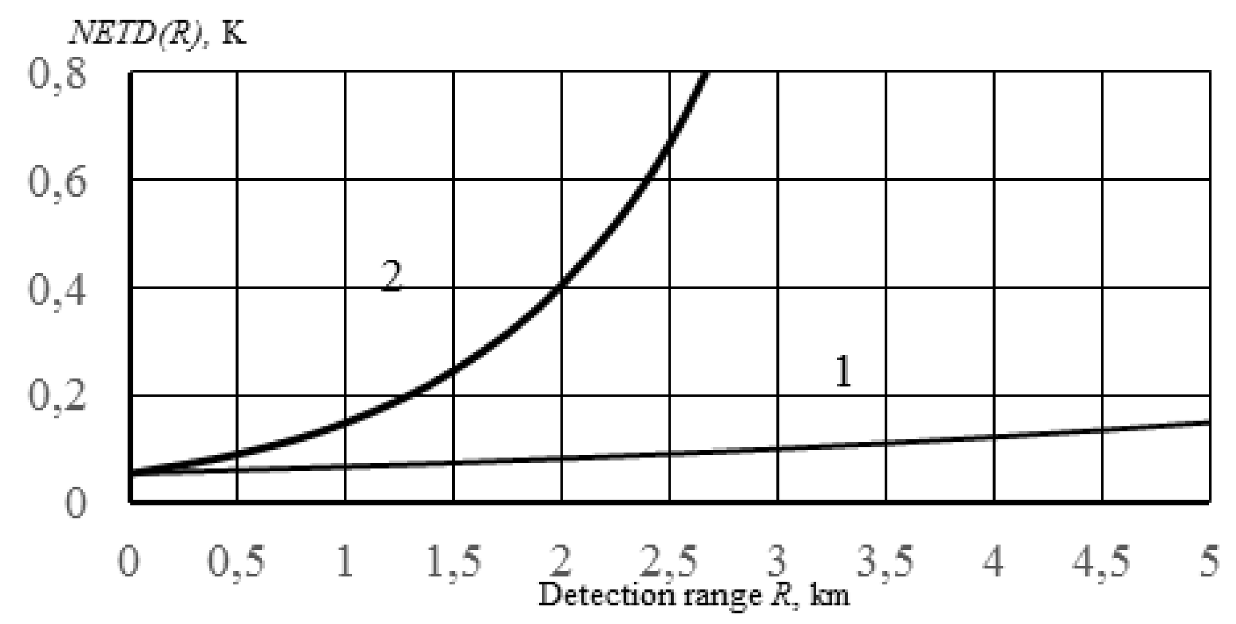
SUMMARY

Many areas of human activity need an interface between object and observer. Opto-electronic surveillance systems (OESS) are widely used as such interfaces in remote sensing of the Earth, security surveillance, medical thermodiagnosis, etc. 1-5. Depending on the image acquisition technique, OESS are divided into one-channel, dual-channel, multichannel and hyperspectral 6-8. Increase in spectral channels number leads to OESS informational capacity growth. On the other hand, it causes a deterioration of the energy resolution.

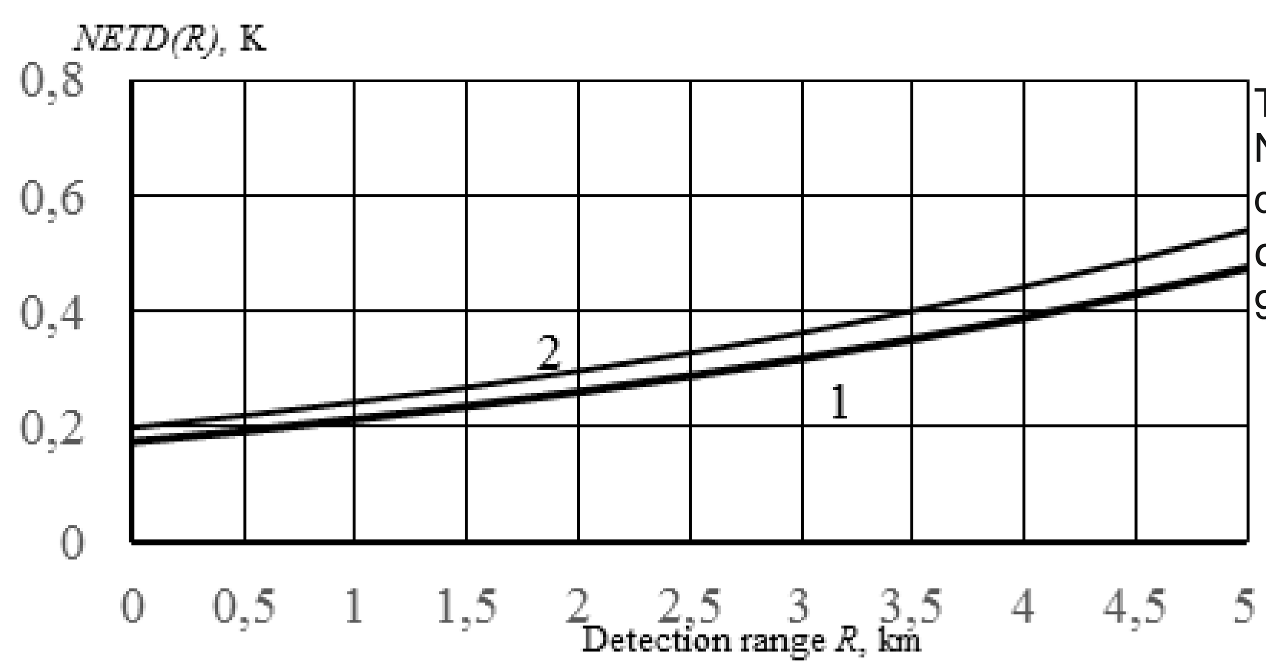
Dual-channel OESS that operate in visible and infrared (IR) ranges of optical spectrum became widespread in recent decade. Television systems (TVS) work in the visible range and thermal imaging systems (ThIS) work in the IR range. Simultaneous or separate use of channels depends on the time of day/night, weather conditions, as well as the tasks performed by the OESS. Energy resolution is one of the main characteristics of OESS. It is the ability of the system to detect objects with minimum energy contrast at certain distance with a given probability. Evaluation of imaging systems performance differs greatly depending on the field of usage. For instance, microscopes can be evaluated via the normalized least-square error, the correlation coefficient or the information rate of the output signals 9. OESS are commonly evaluated using spatial or energy features which oftenly mean resolution 10-12. Noise equivalent temperature difference (NETD), minimum detectable temperature difference and minimum resolvable temperature difference are commonly used to measure ThIS energy resolution 10,13. For TVS, it is proposed to use noise equivalent brightness difference (NEBD), which is analogous to NETD for ThIS. Large number of monographs and articles 1,2,14-18 are devoted to the development of TVS and ThIS energy resolution calculating methods. At the same time, there are obviously insufficient amount of simple evaluation methods for dual-band OESS energy resolution. Therefore, the development of such methods is an urgent task.

The purpose of this research is to develop methods for calculating the energy resolution of thermal imaging and television channels of OESS, which allows to determine preference of using one or another channel, depending on external conditions.

Noise equivalent temperature difference

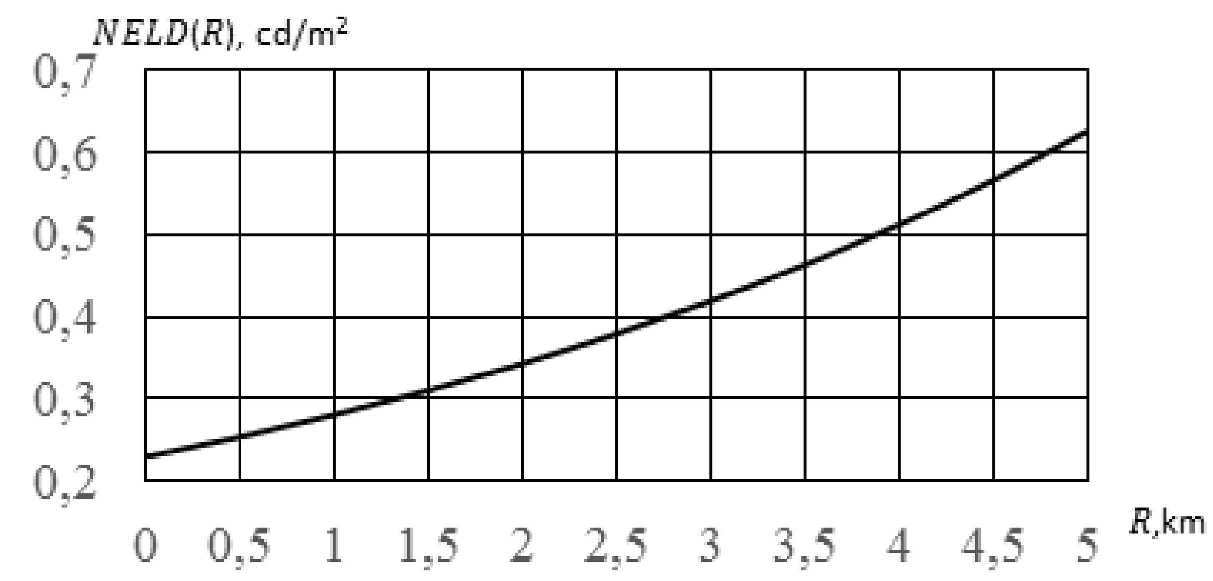


Thermal imaging system NETD dependence on the detection range for the atmospheric absorption rate: 0.2km^{-1} (1) and 1.0km^{-1} (2).

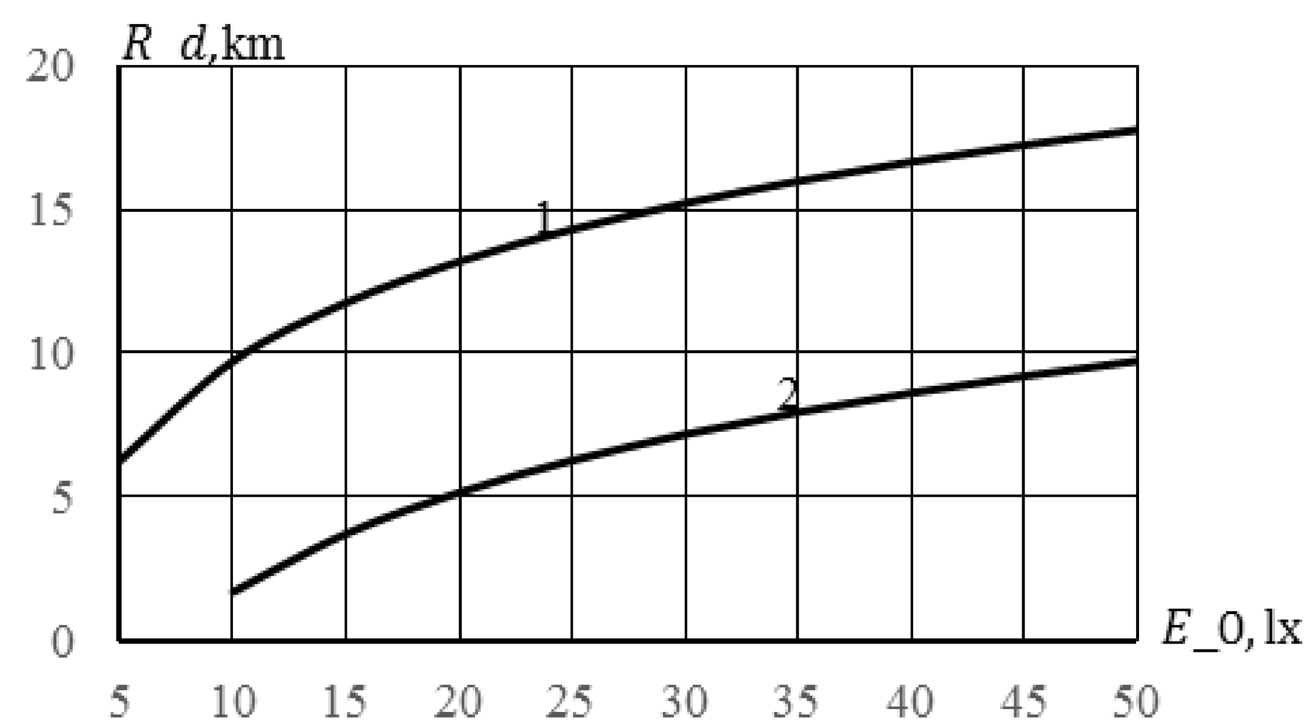


Thermal imaging system NETD dependence on the detection range for the detection probability 90% (1) and 80% (2).

Noise equivalent brightness difference



Maximum detection range



CONCLUSIONS

A physics-mathematical model of a dual-channel optoelectronic surveillance system was developed to determine energy resolution of the system. The model study showed that:

1. It is advisable to use noise equivalent temperature difference (NETD) as an energy resolution criterion for the thermal imaging channel and the noise equivalent brightness difference (NEBD) as an energy resolution criterion for the television channel. Both differences are determined in the plane of the test object.
2. Equations for calculation of NETD and NEBD were received. They take into account characteristics of a test object, atmosphere, lens and matrix detector. Analysis of these equations allowed to define dependencies of NETD and NEBD on the range to the object and the detection probability. Also, dependence of TV system (TVS) maximum detection distance on the test object illumination was determined.
3. An algorithm for selection of thermal imaging system or TV system as operating channel is developed. The choice depends on external illumination of the test object, its temperature contrast and contrast of the reflection coefficient, as well as on the distance to the object.
4. Further research should concider more design parameters of lens and detector. Also more attention should be directed to research of dual-channel non automatic opto-electronic surveillance system .