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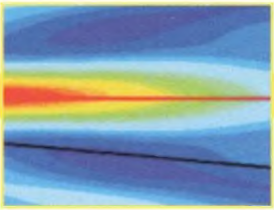
ACTUAL PROBLEMS OF RADIOPHYSICS

Proceedings of the VI International Conference "APR-2015"

October, 5–10, 2015, Tomsk, Russia



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CALCULATION OF PARAMETERS OF DETECTORS OF TERAHERTZ RANGE BASED ON THE SYSTEM IMMERSION LENS-PLANAR ANTENNA-SEMICONDUCTOR SENSING UNIT

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Barko, A. V., Voitsekhovskii, A. V., Levashkin, A. G., and Kokhanenko, A. P. (2016). Calculation of parameters of detectors of terahertz range based on the system immersion lens-planar antenna-semiconductor sensing unit. In. *Actual problems of radiophysics. Proceedings of the VI International Conference "APR-2015"*, (pp. 9-11). London: Red Square Scientific.

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Abstract. In this work results of calculation of parameters of detectors of terahertz range based on mercury-cadmium telluride (MCT) semiconductor material are given. For increasing the connection with emission of detector it is proposed to use the system immersion lens-planar antenna-semiconductor sensing unit. The dependence of sensitivity of detector on frequency for MCT samples with different types of conductivity is considered. Estimations of optimal parameters of system immersion lens-planar antenna-semiconductor sensing unit for detectors of 1 to 5 THz range are conducted.

Keywords: detectors of terahertz range, immersion lens, planar antenna, MCT.

Terahertz radiation is electromagnetic radiation in the frequency range from 0.3 to 10 THz, i.e. from $0.3 \cdot 10^{12}$ to $10 \cdot 10^{12}$ Hz (wavelengths from 1 mm to 30 mm). This frequency range covers a part of the electromagnetic spectrum between the infrared (IR) and microwave bands, so it is often also called the far infrared or the sub-millimeter range.

However, the terahertz range is still studied not enough and there are few solid-state devices that could emit and detect this radiation in a selective way. Such devices could have wide application, for example, for formation of THz images in medicine, as chemical and biological sensors, in broadband communications, radio astronomy, for diagnostics of atmosphere from satellites, etc. [1].

Photodetectors based on solid solutions of telluride-cadmium-mercury (MCT) is widely used to create infrared photodetecting systems. One of the main advantages of this material is the ability to change the band gap energy by changing the composition of MCT from HgTe toward CdTe. At the same time MCT is a perspective material for the manufacture of semiconductor hot electron bolometers (HEB) due to the narrow band gap, high electron mobility μ_n and relatively small electron relaxation time τ_{nE} and lifetime of free electrons τ.

For the characterization of direct detection receiver the noise equivalent power (NEP) is used. NEP is the radiation power, creating at the receiver input signal equal to the noise [2]:

$$NEP = \frac{U_N}{S_V (\Delta f)^{1/2}},$$

where U_N is the noise voltage, S_V is the volt-watt sensitivity of the detector, Δf is the bandwidth of measuring path near the central frequency.

The results of calculations, carried out on the basis of the model applicable to the consideration of HEB detectors based on semiconductors and shown in Figure 1, and comparison of the results with published data are given in table 1.

As shown in the table 1, the MCT detectors can compete with existing uncooled detectors due to the high frequency modulation and a wide range of operating frequencies.

In terahertz range as well as detecting element an important role plays the antenna-substrate-lens system [2, 3]. Figure 2 shows a schematic repre-

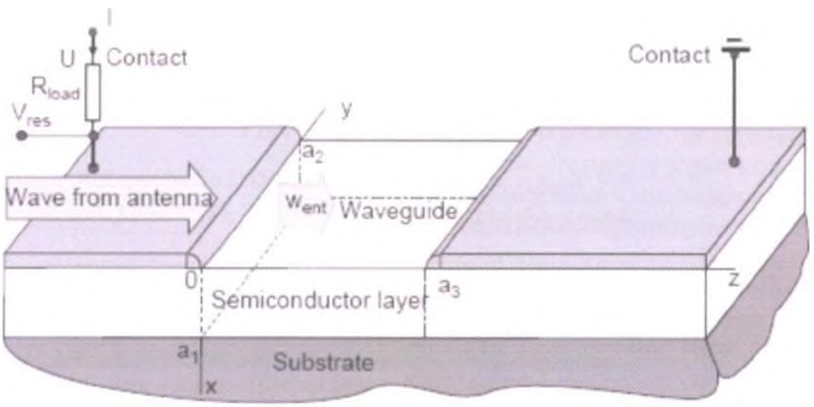

Fig. 1. – Configuration of MCT bolometer.

Table 1. Compare uncooled terahertz detectors.

Types of detectors	Characteristics		
	Modulation frequency (Hz)	Operating frequency (THz)	NEP (W/Hz$^{1/2}$)
Golay cell [3]	<20	<30	$10^{-9}-10^{-10}$
Schottky diodes [3]	$<10^{10}$	< 10	$>10^{-10}$
SIS detectors [3]	$3\cdot10^{4}$	0.645	$\approx3\cdot10^{-10}$
HgCdTe HEB	$<10^{8}$	≈0,5–5	$\approx5.58\cdot10^{-10}$

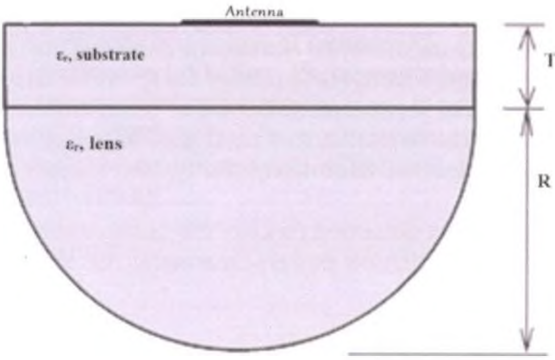

Fig. 2. The antenna-substrate-lens system.

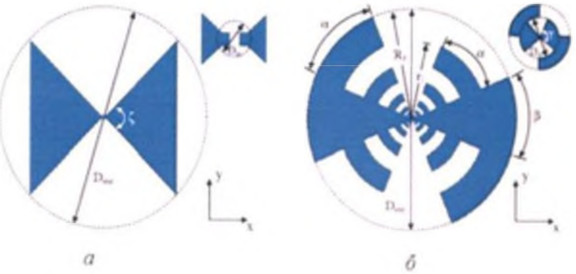

Fig. 3. – The self-complementary antennas:
a – butterfly-shaped; b – log-periodic.

sentation of the antenna on the basis of a hemispherical lens [4].

Lens geometry plays an important role in maximizing directivity, while antenna structure controls the transmission bandwidth. When modeling the projected antenna should not have excitation systems, as their main application is photoconductive antenna, which will be initiated by a terahertz source. In this work were carried out calculations of parameters of the butterfly-shaped and the log-periodic antennas with different parameters (Figure 3).

Calculations of the dependency of gain on the frequency for the different sizes of antennas were carried out (Figures 4, 5). Optimization of the geometry

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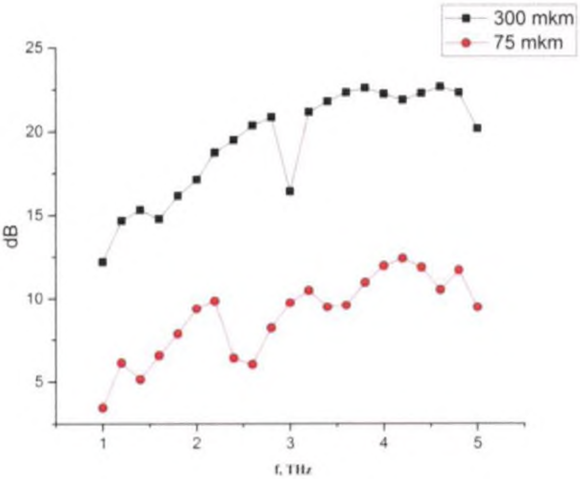

Fig. 5. – Dependence of the gain for log-periodic antenna with a radius of 300 μm and 75 μm.

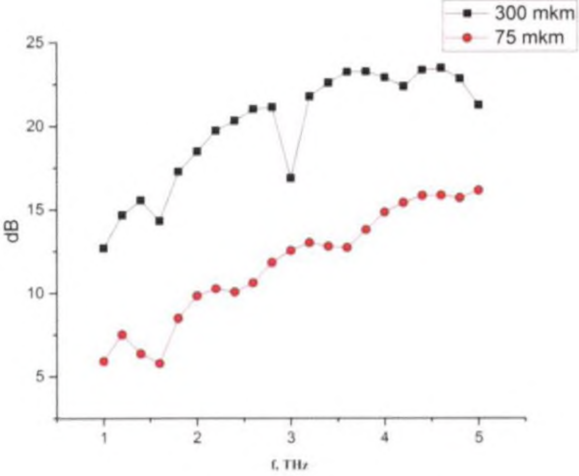

Fig. 6. – Dependence of the gain for butterfly-shaped antenna with a radius of 300 μm and 75 μm.

of a log-periodic antenna was also done. The variant of construction of teeth of log-periodic antenna was offered. Figures 4, 5 shows the results for the butterfly-shaped and log-periodic antennas with different radius ($r = 75$ μm corresponds to the upper boundary wavelength for $L = \lambda/4$, $r = 300$ μm corresponds to the upper boundary wavelength for $L = \lambda$). It is seen that the value of amplification depends on the sizes of the antenna and increases with increasing the frequency in the range from 1 THz to 5 THz. No significant differences in the results depending on the type of antenna were observed.

Thus, in this work the possibility of creation of a terahertz detectors based on MCT is considered. Calculations of sensitivity of HEB detectors based on MCT and analysis of immersion lens – planar antenna – semiconductor sensor system are carried out. The possibility and prospects of using such a system for creating sensitive terahertz HEB detectors based on narrow-gap MCT solid solutions is shown.

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