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Hybrid-integrated version of SBD amplitude detector intended for the 400–600 GHz frequency range

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Abstract. A finline version of detector with flat Schottky barrier diodes is developed. It is intended for operation in the 400−600 GHz frequency range. The detector electrical parameters are studied. The detector conversion ratio at a frequency of 420 GHz is 97 V/W.

Keywords: THz range, amplitude detector, Schottky barrier diode (SBD), microstrip line, hybrid integrated microcircuit.

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1. Introduction

In recent years, considerable number of engineer complexes and applied research works are dealing with THz radiation. It has great potential for applications in radar and ultra wide band communication systems, security arrangements (THz introscopy), medical diagnostics, earth remote sensing, spectroscopy of chemical and biological objects, plasma physics researches, etc [1, 2]. In the above cases, the most important problem is development and production of radiation receivers for the corresponding frequency ranges. Such receivers have to involve a demodulator – e.g., detector with Schottky barrier diode (SBD detector) capable of separating a desired modulating signal from the carrier component.

2. Choice of design and fabrication of SBD detector

The most widespread type of amplitude detector is that involving a nonlinear element and a load at which detected voltage is applied. Semiconductor diodes often serve as nonlinear elements [3, 4]. In the case of THz frequencies, it is reasonable to use beam-lead SBDs as nonlinear elements. They have uniform electrical parameters, square-law current-voltage characteristics, low loss resistance and heightened electrical overload tolerance [5]. Connection of beam-lead SBDs to a waveguide is made using finlines [6]. Such a finline presumes detector fabrication based on a hybrid-integrated version of microstrip transmission line mounted in the waveguide longitudinal section (E-plane). In this case, the microstrip line is matched to the waveguide with a taper [7, 8].

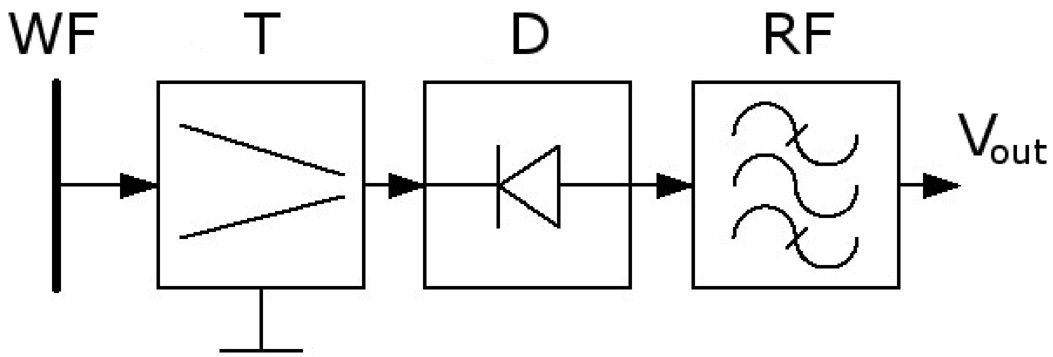

Fig. 1. SBD detector block diagram: WF – waveguide flange, T – waveguide-to-microstrip taper, D – diode, RF – rejection filter, V_{out} – output voltage.

A block diagram of the developed SBD detector intended for the 400–600 GHz frequency range is presented in Fig. 1. A microwave signal comes to the input waveguide flange WF of detector, and then it goes to the diode D through the waveguide-to-microstrip taper T. The signal envelope is taken aside with a rejection filter RF.

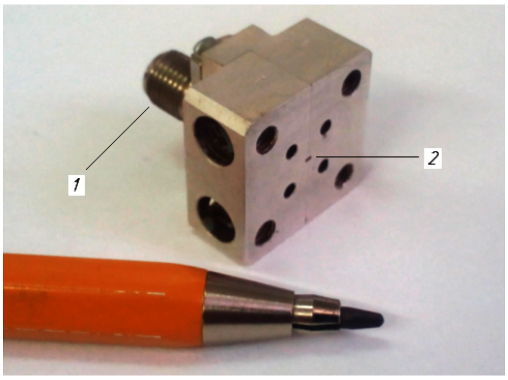

Fig. 2. Experimental model of SBD detector for 400–600 GHz frequency range: *1* – low-frequency coaxial output (SMA connector), *2* – detector waveguide input (waveguide WR-1.9, cross-section of 0.483×0.241 mm^2).

To develop a wide band detector, we performed simulation of impedance characteristics of active and passive elements, microwave integrated board and SBD by using the node voltage method. As a result, we obtained a model of taper (whose profile is described with exponential function) from a WR-1.9 waveguide (channel cross-section of 0.483×0.241 mm^2) to a microstrip line. The taper ensures wave impedance transformation over a wide frequency band and, consequently, supply of microwave signal power to SBD, with minimal losses and required field configuration. The taper is ground. Its losses in the 400–600 GHz frequency range do not exceed 0.5 dB. The microstrip line is on a silica substrate with metallization based on Ti-Au layers.

For microwave current flowing through SBD, it is necessary to ensure (using a rejection filter) a short-circuit mode in the plane of diode turn-on in the operating frequency band. The rejection filter also serves as a low pass filter for video signal and provides with bias supply to SBD. Such filter is made with quarter-wave resonators and has Chebyshev characteristic. A spacing between the diode and rejection filter was chosen from the resonance condition for a quarter-wave line segment loaded with the diode capacitance [9]. Such filters give damp over 40 dB at operating frequencies.

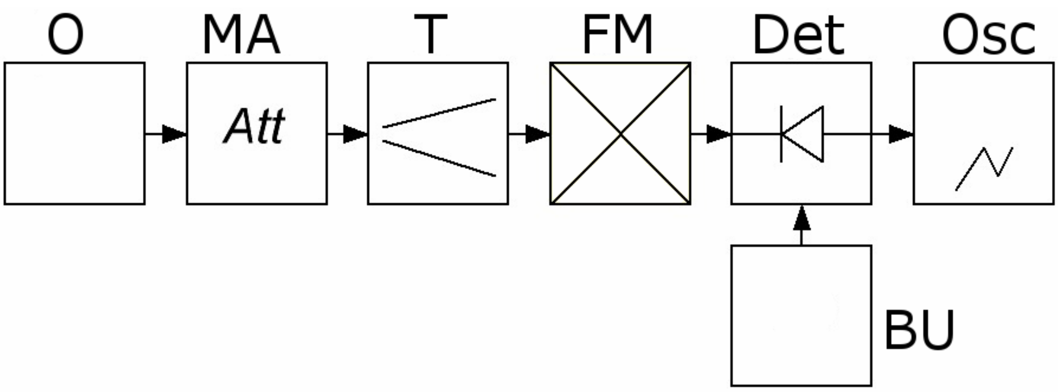

Fig. 3. Functional block diagram of SBD detector measuring section (at a frequency of 420 GHz): O - oscillator, MA - mechanical attenuator, T - taper, FM - times 3 frequency multiplier, Det - detector, Osc - oscillograph, BU - bias unit.

Based on the results of simulation, an SBD detector for the 400–600 GHz frequency range was developed, and its experimental model was fabricated (its photograph is presented in Fig. 2). The experimental model has a beam-lead SBD whose barrier capacitance $C_0 \leq 7$ fF.

3. Study of electrical parameters of SBD detector

The electrical parameters of the detector developed were measured at the frequency 420 GHz under normal climatic conditions. Fig. 3 presents the functional block diagram of detector measuring section: O is the pulse self-excited oscillator with IMPATT diode (frequency of 140 GHz), MA – mechanical attenuator, T – taper from a 1.6×0.8 mm^2 flange to WR-5.7 flange, FM – times 3 frequency multiplier (product of Virginia Diodes [10]), Det – detector with a WR-1.9 input flange, BU – bias unit of the SBD detector, Osc – oscillograph.

In the course of experiment, the 1-mW signal (whose power was set by the mechanical attenuator MA) went from the oscillator O through the taper T to the frequency multiplier FM which gave a 10 dB damping. Then the 100 μW signal went to the detector (a bias was supplied to the detector SBD from the bias unit BU), and the detected signal came to the oscillograph Osc. Thus, the SBD detector ensured the conversion ratio 97 V/W at the frequency 420 GHz.

4. Conclusions

We have developed and made an experimental model of SBD detector intended for the 400–600 GHz frequency range. Simulation of impedance characteristics of active and passive elements, microwave integrated board and SBD was performed using the node voltage method.

The electrical parameters of detector have been studied under normal climatic conditions. It has been found that the detector ensures the conversion ratio 97 V/W at the frequency 420 GHz.

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