Submillimeter-Wave Power Measurements with Commercial Infra-Red Detectors

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Abstract— **In this paper, we present studies of the capability of commercially available infra-red detectors at submillimeter-wavelengths. The detection is based on pyro- and thermoelectric effects. These technologies have been developed to a mature level for applications in infra-red regime. The detectors are low-cost, compact, and robust – qualities that a typical submm-wave power detector does not possess. The IR detectors are not confined to be operated only in infra-red regime. The principle of power detection remains the same also at submm-wavelengths. Results of measurements at 625-814 GHz with commercial IR detectors compared to dedicated submm-wave power detectors are presented. Sensitivity and noise-equivalent power of the pyroelectric detector is estimated to be 600 V/W and 0.6 μW/Hz^{½} at 784 GHz at 20-Hz chopper frequency.**

Index terms— **bolometers, power measurement, pyroelectric detectors, submillimeter wave measurements**

I. Introduction

Calibrated wide-band power detectors are needed in multitude of applications in submillimeter-wavelengths. Such a detector is needed in, e.g., system efficiency characterization, THz-spectroscopy, THz-imaging, and power monitoring of a THz-source.

Typical power detectors used at submm-wavelengths are based on photo-acoustic or calorimetric detectors. Photo-acoustic detectors, such as Golay cell, convert the incident radiation to pressure variation in a sealed container. The pressure variation is then detected in microphonic or optical fashion. Photo-acoustic detectors are suitable for measuring power in quasi-optic systems. Calorimetric detectors are based on absorbing of radiation in a waveguide termination equipped with a sensitive thermometer. The change in temperature due to radiation is compared to that of due to a heating element. The dissipated power in the heating element is accurately known, and is the same with the radiated power when the temperature changes are equal. Calorimetric power detection is mostly used to measure power propagating in a waveguide. While being very sensitive, as the Golay cell, and allowing absolute power measurement, as the calorimeter, they are relatively expensive, bulky, and fragile.

Both pyroelectric and thermoelectric effects are utilized in detectors measuring power at mid-infra-red (MIR) wavelengths. The technology has been developed to a quite mature level since first used in infra-red applications decades ago. Despite designed for detection at 5-15 μm, the detectors are also used at submm-wavelengths [1]-[3].

Reference [1] provides direct comparison of power measurement with Golay cell and Murata IRA-E700ST0 [4] pyroelectric detector. For frequencies above 730 GHz, the responses of the detectors are similar. This implies, that this pyroelectric detector can be readily used above 730 GHz as a calibrated power detector. Furthermore, results in [1] show considerable detected signal level from the pyroelectric detector at above 300 GHz.

In this paper, we present further studies of power detection at submm-wavelengths with pyroelectric detector Murata IRA-E700ST0 [5]. A thermopile detector Melexis MLX90614 was also studied for submm-wave detection. Inspite of earlier reports of successful submillimeter-wave detection with thermopile [3], the complications of the specific detector output rendered the measurement results unreliable and thus they are not presented here. The pyroelectric detector is characterized with response measurement at 638-814 GHz, with directional pattern measurements at 625, 784, and 814 GHz as well as with sensitivity and noise-equivalent-power (NEP) measurements. Response, sensitivity and NEP are calibrated against the Golay cell. The sensitivity of the Golay cell is known, thus making it possible to estimate that of the pyroelectric detector. While concentrating on the performance pyroelectric detector, the sensitivity and NEP as a function of modulation frequency is measured also for a Golay cell, for a photo-acoustic power meter, and for a microbolometer [6] operated in room temperature.

II. Detectors

Both pyroelectric detector IRA-E700ST0 and thermopile MLX90614 are widely used in consumer electronics. In the following, the operation principle and physical parameters are described. Also the microbolometer and the photo-acoustic power meters are described in brief.

A. Pyroelectric Detector IRA-E700ST0

Pyroelectricity is a property of certain material to induce an electrical potential when its temperature changes. Such material placed in between capacitor plates and with absorption to the incident radiation makes a detector, which has charge depending on the change of the absorbed power.