NEW STRUCTURE FOR DC-60 GHz THERMAL POWER SENSOR

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ABSTRACT

We have developed a new structure thermopile-type thermal power sensor for the millimeter wave range (dc to 60 GHz). It consists of a ceramic substrate, metal and microcrystalline-SiGe thin films. Both fast or high-sensitivity sensors can be manufactured.

INTRODUCTION

Use of microwaves, especially at frequencies greater than 30 GHz (millimeter wavelengths) is attracting interest. R&D in this frequency region is brisk, in anticipation of collision avoidance systems for vehicles, use in local area networks (LAN), etc. To use millimeter waves, a high-performance sensor that can measure power accurately, quickly and at high-sensitivity is needed. The thermal power sensor has the advantage of measuring power most accurately, independent of signal waveforms[1].

Conventional thermal power sensors use a waveguide-type sensor composed of a Bi-Sb thermopile[2]. Therefore, the power measurement system requires an inconvenience coaxial-waveguide transformer to detect millimeter wave power with coaxial cable. Moreover, the power sensor has some disadvantages: the response time is slow and the burnout power level is low, requiring an attenuator when detecting high power.

The object of this research was to design and develop a new thermopile- type thermal power sensor to overcome the above disadvantages. The main development targets were quick response, high-sensitivity, ultra-wide frequency range and high burnout level.

DESIGN CONSIDERATION AND DEVICE FABRICATION

Thermal principles have long proved suitable for precise measurement of the root-mean-square (rms) value of ac signals, based directly on the definition of the rms value. The power converted by a resistance heater is used as a measure of the rms value of the applied signal [1]. As seen in Fig. 1, in a thermal rms-dc-converter, this power (Q) flows as thermal energy via a path with a well-defined thermal resistance to a heat sink, causing a temperature gradient (ΔT) along the heat flow path. This gradient is converted by temperature sensor to an electrical output signal (Vout).

To design a thermal power sensor with a thermopile temperature sensor, a self-heating or

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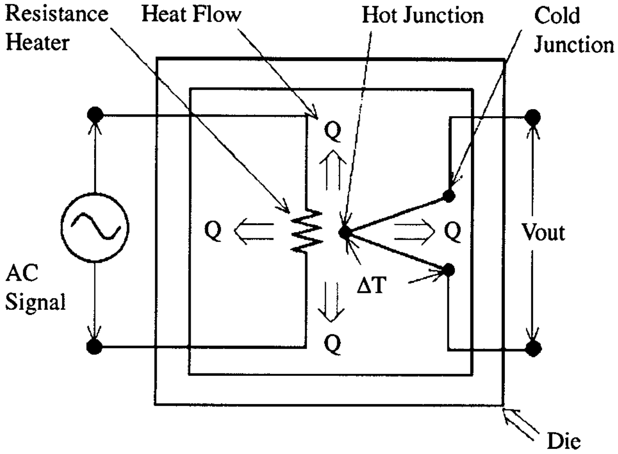


Fig. 1 Schematic diagram of thermal rms-dc-converter

indirectly-heated type can be used. The self-heating type consists of a thermocouple which is also composed of a resistance heater. Therefore, the conversion of electrical power to thermal energy is high and quick. However, the leg resistance of the thermocouple is restricted to 100 Ω. On the other hand, the indirectly-heated type consists of a separate thermocouple and resistance heater. Therefore, the conversion efficiency and response time are inferior to the self-heating type. However, only the heater resistance is restricted to 50 Ω. Therefore, the resistance heater figure pattern design can be flexible bringing well-matched impedance with wide frequency range. Because of this input/output resistance flexibility, the indirectly-heated type was chosen for the new thermopile power sensor.

Fast and high-sensitivity thermal power sensors were designed and developed. A sapphire substrate with a high thermal conductivity is used for the fast sensor. A glass substrate with low thermal conductivity is used for the high-sensitivity sensor. The thermopile of each sensor is made of platinum and microcrystalline-SiGe films with a large Seebeck coefficeint[3].The chip size is 1 x 1 mm^2.

RESULTS

The power sensor chip was mounted on a co-planar alumina substrate module and the electrical characteristics were measured. Figure 2 shows the input-output characteristics of the high-sensitivity thermal power sensor. The sensitivity is 2.1 mV/mW. This value is ten or more times better than conventional sensors[4]. This sensor permits measurement of -40 dBm power levels when used with a newly-developed power meter. The fast sensor has a sensitivity of 0.25 mv/mW. Figure 3 shows the response characteristics of the fast sensor. The rise (10%-90%) and fall (90%-10%) are both 3.06 ms. The values are 41 ms and 39 ms for the high-sensitivity sensor. Figure 4 shows the frequency dependence vs. output voltage of the fast sensor. It is flat from dc to 60 GHz. The burnout power level is 500 mW for the fast sensor and 120 mW for the high-sensitivity sensor. The main characteristics of the sensors are listed in Table 1.

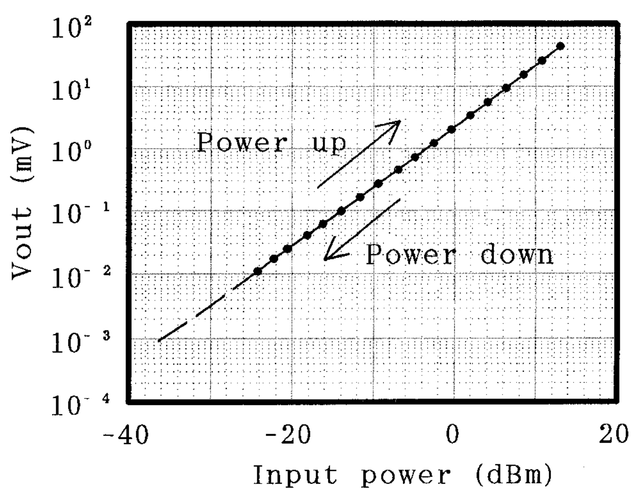
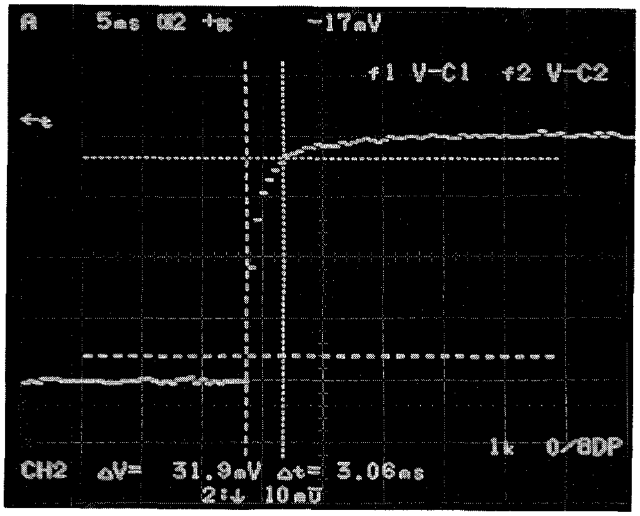
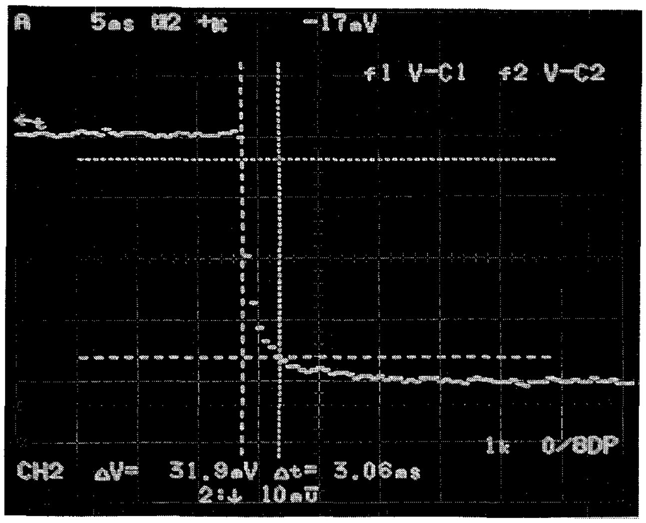


Fig. 2 Input power vs. output voltage



Input power=10 mW
Rise time (10% to 90%)=3.06 ms



Input power=10 mW
Fall time (90%to 10%)=3.06 ms

Fig. 3 Response characteristics of sensor

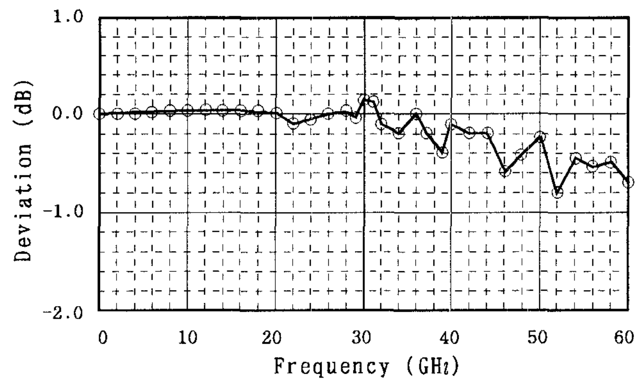


Fig. 4 Frequency characteristic of sensor

Table 1 Characteristic of sensor chip

Item	Type	
	FAST	HIGH-SENSITIVITY
Substrate	Sapphire	Glass
Input Resistance (Ω)	50±2	50±2
Output Resistance (Ω)	900	950
Sensitivity (mV/mW)	0.250	2.10
Burnout Power (mW)	500	120
Response Time (ms)		
t_r: 10% to 90%	3.06	41
t_f: 90% to 10%	3.06	39
Frequency Range (GHz)	dc-60	dc-40

SUMMARY

New thermopile-type thermal power sensors for the millimeter wave range (dc to 60 GHz) have been successfully developed to measure power quickly and accurately with high sensitivity.

REFERENCES

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