THERMOELECTRIC TRANSDUCERS
FOR SHORT MILLIMETER-WAVE POWER MEASUREMENT

Itsuo Sugiura and Hiromichi Toda

Anritsu Electric Co., Ltd., Tokyo, Japan

Abstract

Experimental results on the thermoelectric transducers for short millimeter-wave power measurements up to 260 GHz are described. The transducers showed low VSWR and flat sensitivity of more than 60μV/mW throughout their full waveguide frequency ranges.

Introduction

As a broad-band power sensor in the millimeter-wave region a Matched-Load-Type (MLT) thermoelectric transducer was proposed and its characteristics at frequencies under 110 GHz were reported before (1).

In this article, the results of an experiment to extend the usable frequency range of that kind of transducer up to the short millimeter-wave region are described.

Manuscripts

Design and Construction

According to the design criteria reported in the precede papar (1), transducers which had the same structures as the lower frequency ones shown in Figure 1 were made first for two different waveguides of IEC-R-1400 (equivalent to WR-7) and IEC-R-2200 (equivalent to WR-4). The measured performances of these transducers are shown in Figure 2.

These transducers showed expected good matching characteristics. However, the sensitivity and its deviation throughout the waveguide frequency band are remarkably degraded compared with ones for lower frequency bands especially in the higher band with R-2200 waveguide.

The reasons of degradation of the performances of the MLT transducer of the short millimeter-wave region were mentioned as follows;

1. the decrease of the sensitivity due to decrease of the thermal resistance between the hot junction of the element and waveguide (cold junction) because of the reduction of the waveguide height in relation with the use of the element's substrate of the same thickness.
2. the decrease of the sensitivity due to the increase of the waveguide loss.
3. the decrease of the sensitivity and the degraded sensitivity flatness due to the unsuitable dimensions of the thermoelectric element.

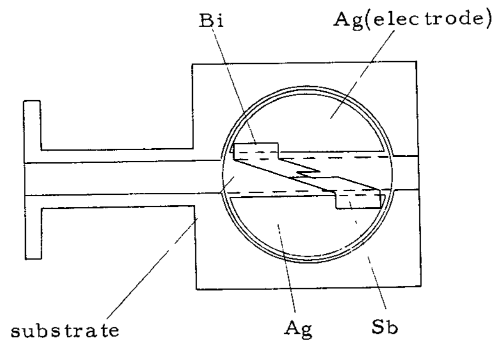

Fig. 1 Structure of the Prototype thermoelectric transducer

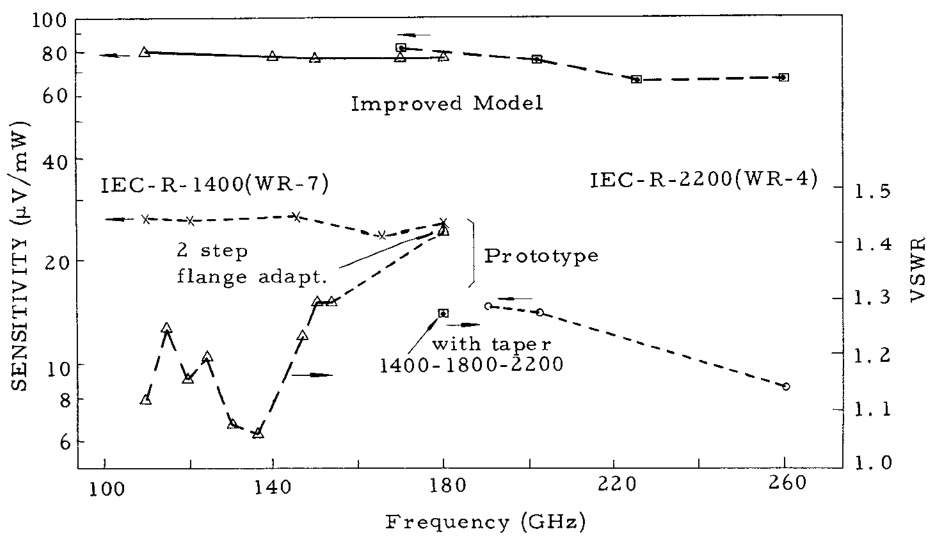

Fig. 2 Characteristics of the improved thermoelectric transducers

Regarding to the first item, due to the reduction of the waveguide height and the same thickness of the substrate, the thermal resistance between the hot and cold junction is decreased. The thickness of the substrate couldn't be reduced because of not only difficulty of obtaining thinner film but also difficulty of handling for practical use.

Concerning the second item, the loss of an IEC-R-2200 waveguide at 200 GHz were measured as high as 17 dB/m. It means, only one inch of waveguide length will cause the decrease of sensitivity by 10%.

The improved models were designed taking above items into consideration. For the item 1 and 2, the shape of the waveguide was changed to square from the standard rectangular as shown in Figure 3. The portion of the waveguide where the thermoelectric element is located is square and the height is reduced to the standard rectangular at the output flange. A circular waveguide operating in the TE11 mode is better for both increasing the waveguide height and decreasing the waveguide loss. However, machining a very small circular waveguide corresponding to the IEC-R-1400 or IEC-R-2200 waveguide is very difficult and it will cost very large. The ratios of the waveguide height and loss are shown in Table 1 for the different shape of waveguides with the same cutoff frequency.

For the item 3, the taper angle of the resistive film was increased relatively with that designed for the lower frequency. In addition, the slit on the resistive film was enlarged and the hot junction part was narrowed.

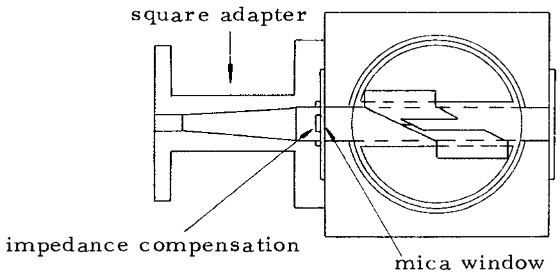

Fig. 3 Structure of the improved thermoelectric transducer

Table 1 Ratio of the waveguide height and transmission loss for different types of waveguide

	HEIGHT RATIO	LOSS RATIO *
RECTANGULAR	1.00	1.00
SQUARE	2.00	0.77
CIRCULAR	2.34	0.51

* Loss: calculated at midband

As a result of these change of dimensions, it is expected that the moving range of the maximum temperature point on the resistive film by the change if frequency is narrowed and heating is concentrated at the hot junction and so the part and so the sensitivity and its flatness would be improved.

Furthermore, for the practical use, the hermetic sealing of the transducer was essential to assure the performance for long duration. Concerning the hermetic sealing, the compensation of the reflection caused by the sealing window was important problem because of increased window thickness relative to the wavelength. The structure of the compensation must be very simple because of the difficulty of machining on a very small size waveguide. A simple round carving was applied for the improved models. The effects of compensation are remarkable as shown in Figure 4. A measured example at a little lower frequency range with IEC-R-1200 waveguide is shown in Figure 5.

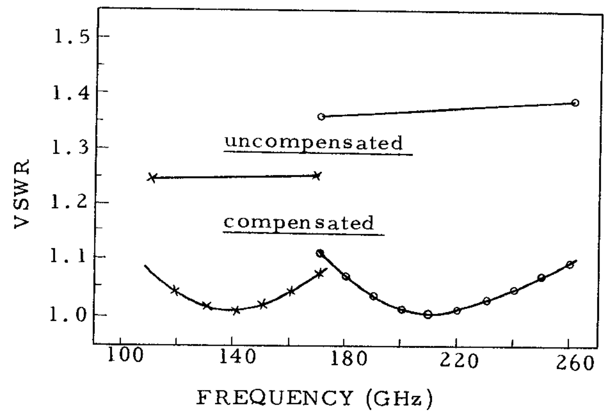

Fig. 4 Calculated VSWR of the sealing window for the square waveguide (thickness of the mica: 10μm)

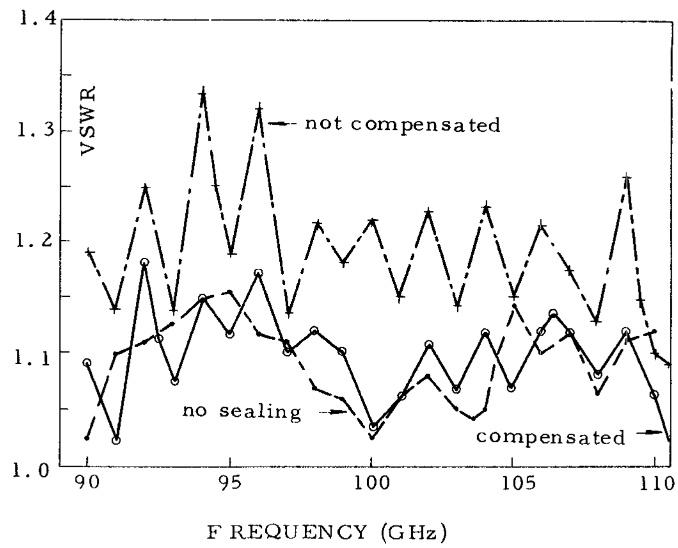

Fig. 5 An measured example of the effect of compensation (R-1200 waveguide)

Results and Conclusion

The observed performances of the improved models were almost satisfactory as shown in Figure 2 comparing with the performances of prototype transducers.

An improved transducer for IEC-R-1400 waveguide showed the average sensitivity of 77.4 μV/mW * and its deviation was evaluated less than ±5% throughout the full waveguide band (110 to 170 GHz). These figures are as good as those for lower frequency transducers reported before (1). A transducer for IEC-R-2200 waveguide showed a characteristics a little worse than the lower band but still usable figures like the average sensitivity of 71 μV/mW * and its evaluated deviation less than ±13% throughout the waveguide band (170 to 260 GHz).

* The sensitivity calibrations of these transducers were carried out with newly developed short millimeter-wave calorimeters which use auxiliary heaters and Peltier cooling elements (2).

Acknowledgement

The authers wish to thank Dr. M. Akaike and others of Wireless transmission Section, Yokosuka Electrical Communication Laboratory, NTT, and also Dr. M. Omori and others of Semiconductor Device Section, Musashino Electrical Communication Laboratory, NTT for giving facilities for measurements.

We also thank to Dr. T. Nemoto and T. Inoue of the Electrotechnical Laboratory for their valuable discussions.

References

1. I. Sugiura, H. Toda et al., "A Matched-Load-Type thermoelectric transducer for power measurements in the millimeter-wave region, "IEEE trans. Instrum. Meas., Vol. IM-23, No. 4, pp. 408-413, Dec. 1974.
2. Should be published at CPEM '78.