PROGRESSES IN THE DEVELOPMENT OF CENAM'S PRIMARY STANDARD FOR MICROWAVE AND MILLIMETER-WAVE POWER UP TO 50 GHZ

Mariano Botello-Pérez[1,3], Jae-Yong Kwon[2], Israel García-Ruiz[1], and Hildeberto Jardón-Aguilar[3]
[1]Radiofrequency Direction, National Center for Metrology (CENAM), Queretaro, Mexico
[2]Center for Electromagnetic Wave, Korea Research Institute of Standards and Science (KRISS), Daejeon, Korea
[3]Communications Section, Research and Advanced Studies Center (CINVESTAV), Mexico City, Mexico
mbotello@cenam.mx

Abstract: This paper presents the progresses achieved in the development of a 2.4-mm coaxial microcalorimeter and its associated thermoelectric transfer standards, which together will constitute the Mexican Primary Standard for Microwave and Millimeter-wave Power up to 50 GHz. Relevant design aspects of both the microcalorimeter and its transfer standards are shown; also measurement results of the adiabatic lines S-parameters and the transfer standards linearity are discussed.

1. INTRODUCTION

Over the last few years CENAM has seen an increase on calibration service requests for measurement and generation instruments of RF power up to 50 GHz, mainly used for conformity assessment of electrical, electronic, telecommunications and, automotive equipment. With the aim of providing support to these needs and assure the traceability for RF power measurements in Mexico; CENAM launched a program to develop power measurement capabilities for microwave and millimeter-wave frequencies.

The first steps of this program was the development of a reference system to calibrate RF power sensors up to 50 GHz. This system is of the direct comparison type, with 2.4 mm coaxial connectors and an ovenized thermistor mount, capable of working up to 50 GHz and currently traceable to the National Institute of Standards and Technology, as reference standard. Because the mexican law establishes that measurements for conformity assessments of products, with respect to official standards and regulations, need to be traceable to national domestic standards, a further step on the program was to develop a primary standard up to 50 GHz (PSMP). The PSMP is realized through a microcalorimeter and associated transfer standards.

The microcalorimeter is used to determine the effective efficiency of the transfer standards (TS) by calorimetric measurements [1]. The TS will then be used in our direct comparison system to calibrate any other reference standards with traceability to mexican domestic standards. In the following sections relevant aspects on design of the PSMP are discussed, along with measurement results on the performance of the adiabatic lines and transfer standards as well.

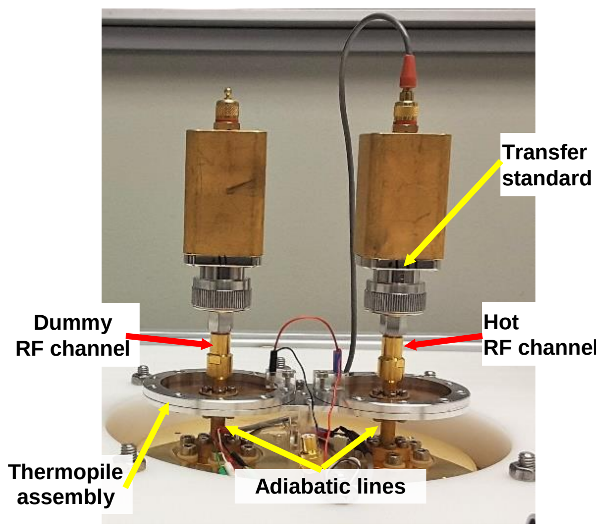

Fig. 1. *Twin-type microcalorimeter.*

2. DESIGN OF THE PRIMARY STANDARD

The components of CENAM´s primary standard for microwave and millimeter wave are shown in Fig. 1. It consists of a 2.4 mm coaxial microcalorimeter, a pair of thermoelectric TS, and a metal cover. The microcalorimeter is of the twin type with two adiabatic 2.4 mm coaxial lines [2] and a thermopile assembly.

Each adiabatic line (AL) has a customized 2.4 mm female connector on the top, a commercial female connector on the bottom, and a thermal isolation section. The top connector is made of gold-plated beryllium copper. To thermally isolate the heat in the transfer standard and top connector [3] from other heat sources in the AL, the thermal isolation section has an outer conductor made of gold-platted ABS (Acrylonitrile Butadiene Styrene) plastic. The inner conductor is a solid rod made of a gold-plated beryllium copper. The inner and outer conductors of the AL are designed according to the specifications given by IEEE Std 287-2007.

The thermopile assembly has a pair of thermopiles, an aluminum (Al) base plate, and a pair of Al holding rings to keep the thermopiles in place. The thermopile is a ring made of 97 Cu-Constantan junctions on a thin film, the ring of inner thermocouple junctions is in thermal contact with the outer conductor of the AL's top connector, and the circle of outer thermocouple junctions is in contact with the Al made base plate and holding rings. The TS consist of four parts: a sensor head, a custom-made printed circuit board, wiring, and a gold-plated plastic cover [4]. The head is a DC-coupled version of a N8487A thermoelectric power sensor, which is suitable for implementing DC or AC power substitution methods; therefore traceability to DC or AC voltage standards is guaranteed. The head output voltage is filtered and measured through the circuit board. The cover helps to prevent the coupling of external noise into the circuit board. The TS is about 75 mm in length and 74 g in weight.

The metal cover is part of a passive thermal shield that minimizes the effect of external temperature changes and also allows the microcalorimetric measurements to be performed in a temperature controlled water bath. The room temperature is controlled within ± 0.5 °C; however, the temperature changes of the transfer standards are expected to be very small. Therefore, the water bath will help to improve the microcalorimeter´s temperature stability.

3. ADIBATIC LINES' MEASUREMENTS

The performance of the ALs is evaluated through its power losses. Figure 2 shows that the measured power losses of both ALs are less than 0.9 dB with almost the same loss pattern up to 50 GHz, and differences less than 0.33 dB (worst case at around 32.35 GHz). This is a great result due to the difficulty of making 2.4 mm adiabatic coaxial lines.

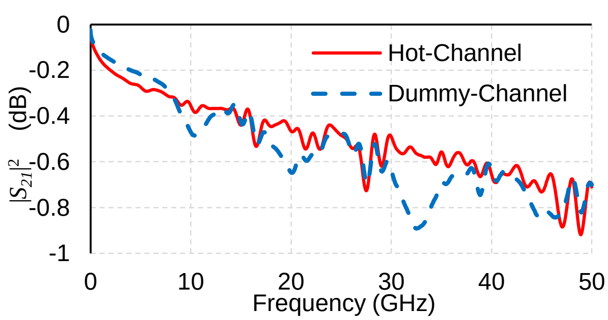

Fig. 2. *Measured power losses of the AL.*

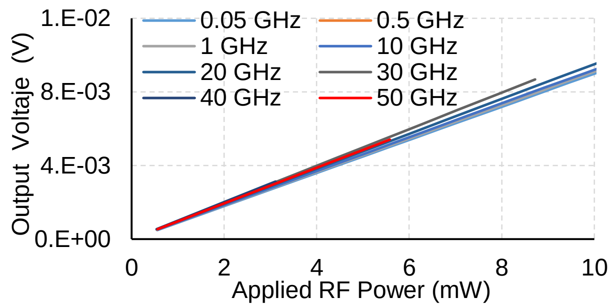

Fig. 3. *Measured sensitivity and linearity of a TS.*

4. TRANSFER STANDARDS´S MEASUREMENTS

The sensitivity of the TS was measured through the ratio of the voltage output to the RF input. Fig 3 shows that the TS has a sensitivity of about 1116 μV/mW within the power range of interest, as well as consistent linearity from 0.05 GHz to 50 GHz.

5. CONCLUSIONS

The design features that determine the performance of a 2.4-mm coaxial microcalorimeter of the twin type and associated thermoelectric transfer standards have been presented. In addition, the measured performance of the designed thermoelectric transfer standard and ALs shows they have the quality to be used as part of the Mexican Primary Standard for Microwave and Millimeter-wave Power up to 50 GHz.

ACKNOWLEDGEMENTS

The authors thank KRISS for its support in developing CENAM´s 2.4-mm microcalorimeter and Dr. Eric B. from Keysight Techs. for providing the sensor heads.

REFERENCES

[1] F. R. Clague, "Microcalorimeter for 7 mm Coaxial Transmission Line," NIST TechNote 1358, 1993.

[2] J.-Y. Kwon, T.-W. Kang, J.-H. Kim, and T. Crowley, "Development of a 2.4-mm coaxial microcalorimeter for RF and microwave power standards at KRISS," in Proc. CPEM, Jul. 2012, pp. 734–735.

[3] J.-Y. Kwon, T.-W. Kang, J.-H. Kim, and N.-W. Kang, "Development of a Type-N Coaxial Microcalorimeter for RF and Microwave Power Standards at KRISS," *IEEE Trans. Instrum. Meas.*, vol. 66, no. 6, pp. 1520–1526, Jun. 2015.

[4] J.-Y. Kwon, T.-W. Kang, D.-J. Lee, and N.-W. Kang, "Thermoelectric reference standards and a measurement system for microcalorimeters," in Proc. 81st ARFTG Microw. Meas. Conf., Jun. 2013, pp. 1–3.