A MILLIMETER WAVE HOT LOAD

A. Larsen, E. J. Wendt, J. deGruyl, and J. Whelehan
AIL, a division of CUTLER-HAMMER
Melville, New York 11746

Abstract

A new and simple millimeter wave hot load has been developed with an equivalent temperature of 888 ±10.7 Kelvins (K) (±1.3 percent) for the 50 to 75 GHz frequency band. The load is operated in an oven at a temperature of 1000 K.

In the determination of receiver sensitivity by the standard Y-factor method, the overall accuracy of the noise factor measurement is directly related to the determination of the equivalent noise power of the noise sources that are used for the measurements. A new and simple hot load with an equivalent temperature of 888 K with an error of less than ±1.3 percent has been developed for the 50 to 75 GHz frequency band. The simplicity of approach lends itself very favorably to the development of equivalent noise sources up to 200 GHz and beyond. With the use of this precision hot load, it is possible to obtain noise temperature measurement accuracies equivalent to those commonly made in the microwave region either by a direct noise temperature measurement or by calibrating the excess noise ratio (ENR) of commercially available gas noise sources. Figure 1 shows the millimeter wave hot load.

Previous approaches to the development of hot loads have employed a wedge of high-resistivity silicon (50 ohm-cm) inserted into a 5-inch section of waveguide (reference 1). The wedge itself was 1-inch long and it was necessary to maintain the temperature of the load uniform in the oven while the outside flange was maintained at 100°C by water cooling. A lossless length of waveguide was used between the flange and the wedge. The new approach was to take advantage of the inherent lossiness of a long section of stainless steel waveguide that is very simply machined into a circular rod. An efficient thermal isolator is used to connect the hot load with the mating interface flange which is approximately at room temperature without the requirement of water cooling. This approach resulted in an equivalent temperature at the interface of 888 ±10.7 K while the load proper is operated at an oven temperature of 1000 K.

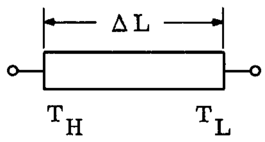
The hot load consists of a stainless steel rod that is 17 inches long and 1-7/8 inches in diameter. The rod was split in half parallel to the longest axis. A 47-inch run of WR-15 waveguide was machined into one of the pieces in a serpentine fashion. Output interface flanges were provided at both ends of the stainless steel cylinder which enables both VSWR and transmission measurements to be performed. The two split stainless steel sections were bolted and clamped to form the complete waveguide section. Two thin-walled stainless steel waveguide sections, each 2-1/2 inches long, were constructed and attached to the hot load on both extremities. These small sections were used as thermal isolators which enabled a physical connection to be made to the hot load for actual measurements without altering its thermal characteristics. Figure 2 shows a sketch of the internal section of the hot load.

Repeated temperature cycles of the load were made to ensure that temperature changes due to temperature cycling where held to an absolute minimum. The oven was set to 1000 K and the total attenuation through the hot load at the elevated temperature was measured to be 62 dB. The attenuation of the thermal isolators was measured by placing a physical short circuit at the abutment of the thermal isolator and the hot load and measuring the input VSWR from which the loss of the section could then be determined. At the elevated temperature, the insertion loss of the thermal isolator had to be known to a greater degree of accuracy than the hot load since its effect on the determination of the equivalent temperature is more critical. The insertion loss of the thermal isolator was measured to be 1.0 dB. The measurements were performed across a 10-percent band in the 50 to 75 GHz region with no measurable deviation. From these microwave measurements, the actual loss per unit length (both of which are different) for both the hot load and the thermal isolator were determined.

The temperature profile of the hot load was measured by inserting a chromel/alumel thermocouple into the waveguide and recording the absolute temperature. (The error of the thermocouple is 0.75 percent.) The thermocouple was moved in 1/2-inch increments and temperature measurements were performed with the thermocouple inserted into both ends of the waveguide. It was assumed that the temperature measured at a point in the waveguide was constant across the load perpendicular to the plane of the waveguide. The absolute temperature was measured with a Honeywell 2745 potentiometer and referenced to an ice water load. Figure 3 shows a temperature profile of the load. The measured attenuation of the hot load was considered to be linearly distributed as were the measured losses of the thermal isolators. With this measured data, sufficient information is available to calibrate the equivalent temperature of the hot load.

A room temperature load at 300 K was assumed as a termination for one end of the hot load. The noise equivalent temperature of the hot load was then calculated based on a cascade of 104 half-inch lossy sections. The temperature for each half-inch segment was taken from the temperature profile curve. The actual calculation was performed with a computer program with the aid of the following equation for each segment:

$$T_e = \frac{T_H}{\alpha} + \left(1 - \frac{1}{\alpha}\right) T_C$$



where

T_H = hot temperature

T_L = lower temperature

α = loss per unit length

Based on these calculations, which were used for each of the 104 individual segments that comprise the hot load, and on the actual attenuation measurements, the equivalent temperature at the flange was calculated to be 888 K.

The errors that were considered in determining the accuracy of the calibration were:

- Accuracy of thermocouple (0.75 percent)
- Accuracy of microwave measurements (0.1 dB)

Since the errors attributed to these sources were assumed to be uncorrelated, the total error was determined to be less than ±1.3 percent on an RMS basis.

In summary, a very simple hot load operating at a temperature of 1000 K with a calculated equivalent temperature of 888 K with an error of less than ±1.3 percent has been developed for use in the millimeter wave region. The simple approach used lends itself very favorably to utilization for both calibration and measurement of noise temperature in all waveguide bands where applicable.

Reference

1. W. Jasinski and G. Hiller, "Determination of Noise Temperature of a Gas Discharge Noise Source for Four-Millimeter Waves." Proceeding of the IRE, April 1961.

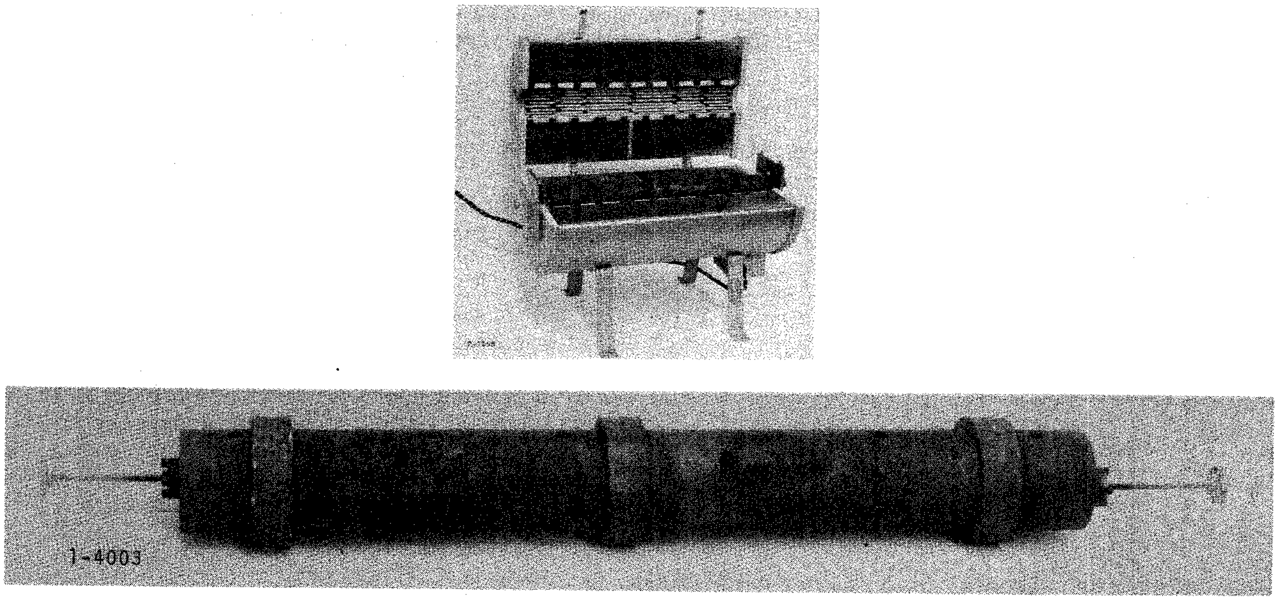


FIGURE 1. PHOTOGRAPH OF 1000K LOAD

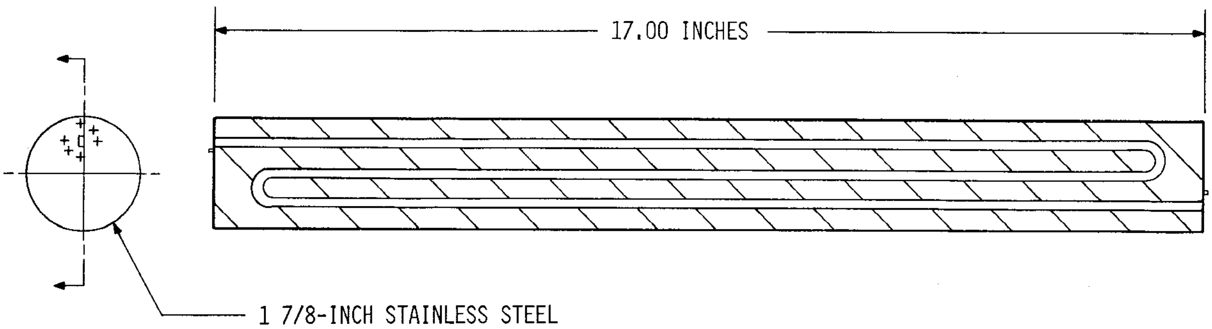


FIGURE 2. INTERNAL STRUCTURE OF HOT LOAD

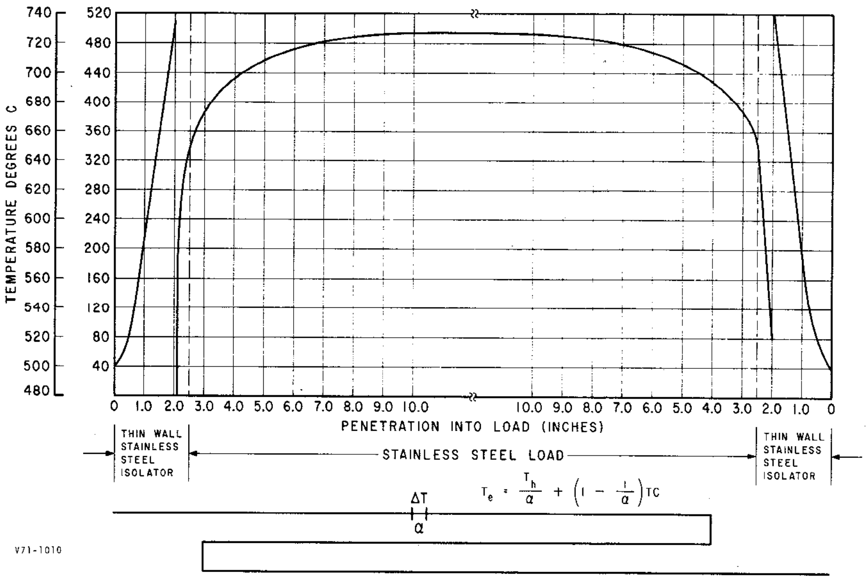


FIGURE 3. TEMPERATURE PROFILE OF HOT LOAD