A REFERENCE NOISE STANDARD FOR MILLIMETER WAVES

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Abstract

The WR15 Thermal Noise Source that is used as the National Reference Standard of noise power in the frequency range from 56 GHz to 64 GHz is described in the following summary. The source forms a basis for both the noise power comparison service and noise figure service offered by the National Bureau of Standards in this frequency range.

Summary

The Electromagnetics Division of the Institute for Basic Standards of the National Bureau of Standards offers calibration services of effective noise power emerging from a noise generator. These are in both coaxial and rectangular waveguide,in frequency bands and at spot frequencies ranging from 3 MHz to 18 GHz as detailed in NBS Special Publication 250[1]. Addition of the 56 GHz to 64 GHz frequency range (WR15) to these traditional services is now being completed[2]. Along with this extension a calibration service for the effective input noise temperature of amplifiers operating in this frequency range is also being initiated in WR15.[2] This new type of service is being prepared in recognition of the fact that a large proportion of the noise generators being calibrated are used in noise figure measurements, and in response to the expressed needs of "ultimate users." This service, like its more traditional counterpart, is solidly based on accurate primary reference noise standards like the one described in this summary.

The new noise standard discussed in this paper features a new-design and small size providing a rapid warm-up time which allows the standard to be used within two hours after being turned on. This obviates the time consuming practice of calibrating secondary gas discharge standards as is done in the other waveguide bands[3], and allows a customer's device to be compared directly against the national standard. The output noise temperature of the standard is variable, but is usually operated in the neighborhood of 1210 kelvins and is known to an accuracy of better than ± 2.4 kelvins.

The noise temperature, T, at the output flange of the standard is calculated from the following new and more exact formula[4] once the temperature distribution and electrical resistivity along the waveguide are known:

$$T = T_m + \Delta T,$$

where ΔT is the correction temperature added to the measured termination temperature T_m. The formula for the correction temperature is

$$\Delta T = (T_o - T_m)(1 - \alpha_o) + \int_o^{\ell} T'_x\,(1 - \alpha_x)dx$$

where T_o is the waveguide temperature at the position of the termination, T'_x is the temperature gradient at position x measured from the termination towards the flange at position ℓ. The quantity α_x is given by the following formula:

$$\alpha_x = \frac{(1 - |\Gamma_x|^2)e^{-2\int_x^{\ell} a_y dy}}{1 - |\Gamma_\ell|^2}$$

Γ_x is the reflection coefficient looking towards the termination from point x in the waveguide. Γ_ℓ is the reflection coefficient looking into the flange towards the termination. Both Γ_x and Γ_ℓ vanish if the load is matched to the characteristic impedance of the waveguide. The factor a_y is the propagation constant of the waveguide at position y along its length, and is a function of the electrical resistivity at that position. This formula does not suffer from the restriction that the termination must be matched to the waveguide as is the case in previous formula [5,6]. For the WR15 standard T_m and ΔT are approximately 1236 kelvins and -26 kelvins respectively.

A photograph of the standard with its auxiliary heating and cooling apparatus is shown in Figure 1. The cylindrical item in the center of the photograph is the oven that heats the termination and waveguide. The small output flange of the waveguide can be seen in the center of the face at the left end of the cylinder. Both the flange and the outer casing of the oven are cooled to room temperature by distilled water from the recirculating water bath shown at the right in the photograph. The flange temperature is maintained at 22°C ± 0.1°C. The insert shows a rear view of the oven with the control and temperature monitoring thermocouples protruding from the rear plate of the cylinder. The vacuum bottles in the insert are the thermocouple reference junction ice baths. The cylindrical oven and bottles sit in a carriage that allows them to be positioned anywhere along a rail like the one shown. The oven contains three servo-controlled heating coils that maintain an appropriate temperature distribution along the waveguide and maintain the waveguide termination at a uniform temperature. The rack on the left in the photograph contains four microvoltmeters, three of which control the heating coils in the oven, the upper one being used as a null detector for the temperature monitoring potentiometer at the top of the rack.

An assembly drawing of the oven and carriage is shown in Figure 2. The waveguide and termination are items 26 and 41 respectively. The waveguide is manufactured from a platinum-10% rhodium alloy to insure a high degree of reliability in predicting its loss characteristics. The termination is a wedge of 40% silicon carbide impregnating a beryllium oxide host.

The termination in the waveguide is centered longitudinally in a heat distributor (item 32) to insure a uniform temperature along the termination. The three heating coils (not shown in the drawing) that are wound onto the heat distributor are constructed from a resistive wire stock that is considerably more resistant to oxidation than the wire used in previous noise standards[6]. An insulating material (not shown in the drawing) is packed between the heating coils mounted on the heat distributor and the heat distributor sleeve (item 33). The insulating material used was a felt form of zirconium oxide that has an extremely low thermal conductivity. Cooling coils (item 30) are pressed against the inner circumference of the outer casing (item 31) of the oven. The waveguide flange is cooled by a water jacket (item 28). Items 1 through 22 describe the oven carriage assembly.

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References

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Fig. 1

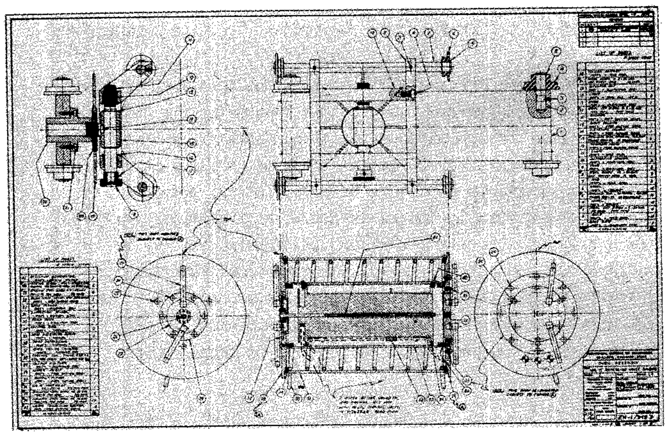

Fig. 2