# The Noise Temperature of an Arbitrarily Shaped Microwave Cavity with Application to a Set of Millimetre Wave Primary Standards

*W. C. Daywitt*

**Abstract.** An expression for the noise temperature of an arbitrarily shaped microwave cavity is derived and illustrated. The result is applied to a horn/cavity noise source and forms the basis for a set of primary reference noise standards that covers the millimetre wave frequency range in thirteen bands from WR-42 to WR-3. Power attenuation coefficients for sectoral horns are also presented.

## 1. Introduction

A microwave cavity is defined here as a cavity with one output line that supports a single propagating mode. The line can be a coaxial or a hollow waveguide transmission line or, as in the case of the millimetre wave noise standards to be discussed, a pyramidal horn. Thermal radiation from the cavity walls is conducted by the line to an output connector where it appears as an available, broadband (spectral) noise power.

The line itself emits and absorbs radiation due to its own dissipative losses, changing the magnitude of the noise available at the output connector. This change is called excess noise and is a positive or negative addition to the cavity wall noise depending upon whether the physical temperature of the line is greater or less, respectively, than the physical temperature of the cavity. An accurate estimation of this excess noise is central to the design of primary noise standards but, unfortunately, accurate estimates are increasingly difficult to achieve in the higher millimetre wave frequency bands as line losses increase with frequency.

It was the larger noise temperature errors caused by the higher line losses that led to the following horn/cavity design and the requisite theory. And, while the horn/cavity configuration is not new, the rigorous mathematical foundation required of a primary reference standard is. The most accurate description available to date [1] relies on the plane wave scattering matrix theory of antennas that is valid only in the far and radiative near fields, but excludes the reactive near field which is unavoidable in noise standard design. The present work corrects this shortcoming, adds a few new insights to the theory of thermal sources, and presents equations for the attenuation coefficients of sectoral horns that are unavailable in the open literature.

W. C. Daywitt: Reference Grade Standards, 140 Iroquois Dr., Boulder, CO 80303, USA.

## 2. Noise Temperature of an Arbitrarily Shaped Microwave Cavity

The spectral power of a noise source is the power per unit bandwidth available at the source's output port. This is true whatever the character of the source, whether solid state, gas discharge or thermal in nature. This power is conveniently described in terms of a noise temperature which is defined [2] as the spectral power divided by Boltzmann's constant, making the noise temperature of a thermal source of uniform physical or thermodynamic temperature equal to its thermodynamic temperature (quantum effects are discussed in Appendix A).

The purpose of this section is to derive a fundamental relationship for the noise temperature that is independent of the physical geometry of the cavity and the emissivity of the cavity walls. The result provides the foundation needed in Section 4 to describe the output of a horn/cavity type of source.

A cavity of arbitrary shape is shown in Figure 1 where $T_n$ is the output noise temperature and $T$ is the cavity wall temperature which varies with position. The wall temperature is constant ($T_m$) in the

Metrologia 1993/94, **30**, 471-478