RADIATION FROM THE CRYOGENIC CALIBRATION LOAD FOR MICROWAVE RADIOMETERS

Lu Ying  Guo Wei  Zhang Zuyin
(Huazhong University of Science and Technology, Wuhan 430074)

Abstract  A styrofoam layer is introduced to the cryogenic calibration load for microwave radiometers in order to keep the antenna at ambient temperature while calibrating. Obviously the insulation layer has nonuniform temperature profile. A novel approach based on the transmission-line theory is presented to calculate the emission from the load. According to the sample calculation through this new approach, the contribution of the insulation layer to the load radiation can not be neglected.

Key words  Cryogenic calibration load; Layered media; Brightness temperature

I. Introduction

Nowadays, the technique most commonly employed to calibrate microwave radiometers is that utilizing blackbodies at two temperatures filling the beam of the radiometer input feedhorn. By measuring the output when the feedhorn is viewing each of the loads, the radiometer noise figure and gain can be determined. Most calibration systems have employed microwave absorbers at ambient and at liquid-nitrogen temperatures placed in front of the feedhorn. For a cryogenic calibration load shown in Fig.1, a styrofoam insulation layer is adopted to prevent the leakage of the cryogen and keep the antenna at ambient temperature. In order to achieve accurate calibration, the radiation of the load should be determined precisely. In other words, the emission of layered media with nonuniform temperature profile should be accurately calculated.

Fig.1 Construction of the cryogenic calibration load for microwave radiometers

A new approach based on the transmission-line theory to solve the problem is described
in next section. First the general expression of the output noise power of a cascaded network with nonuniform physical temperature is derived. Then by replacing the insulation layer with an equivalent cascaded network, we obtain the radiation equation of the cryogenic calibration load. Unlike the incoherent method\cite{1}, this approach accounts for both the amplitudes and phases of the fields reflected within the media. Furthermore, it is rather simple compared with the analysis of electromagnetic field within each sub-layer\cite{2}. At the end of the paper, sample calculation results are given.

II. Theoretical Analysis

1. Radiation from layered media with nonuniform temperature profile

For a two-port network with uniform temperature $T_n$ shown in Fig.2(a), the internal noise power $\Delta P_{no}$ could be determined under the thermal equilibrium condition. At Port 2,

\[
kT_n B \alpha_1 \eta_{12} + \Delta P_{no} = kT_n B \alpha_2
\]

where $k$ is Boltzmann's constant and $B$ is the noise bandwidth; $\alpha_i$ and $\eta_{12}$ are the mismatch loss factor of interface $i$ and the transmission factor of the two-port network respectively, which are given by the expressions:

\[
\alpha_1 = \frac{(1 - |R_G|^2)(1 - |R_1|^2)}{|1 - R_GR_1|^2}
\]

\[
\alpha_2 = \frac{(1 - |R_R|^2)(1 - |R_2|^2)}{|1 - R_RR_2|^2}
\]

\[
\eta_{12} = \frac{|S_{21}|^2(1 - |R_G|^2)}{|1 - S_{22}R_R|^2(1 - |R_1|^2)}
\]

Fig.2 (a) Two-port noisy network with input and output both connected to fictitious resistors at $T_n$ temperature; (b) Cascaded system with different physical temperature within each subsystem