RF-DC DIFFERENCES OF THERMAL VOLTAGE CONVERTERS ARISING FROM INPUT CONNECTORS*+

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Abstract

The RF-dc differences of thermal voltage converters (TVC's) caused by skin effect and transmission line effects of different length input structures have been previously studied. Discrepancies do exist, however, between simple mathematical models and measured results for commonly used input connectors. This paper reports a study of these discrepancies.

Introduction

Measurement errors may occur when different input connections are used for high frequency voltage measurements. Sometimes it is necessary to account for variations in the input structure, for example, between the configuration at the time of calibration and at the time of use. It is, therefore, desirable to study the variations and estimate the magnitudes of the differences. Formulas do exist which can be used to calculate the skin effect and transmission line effect, but the practical situations are generally more complicated.

Skin Effect

The RF-dc difference of a TVC caused by the skin effect of the connector and associated input transmission line is positive and increasing with rising frequency. Sometimes the skin effect contribution is not easily observed, either because it is small in absolute value, due to the presence of a large input resistance, or because it is small in a relative sense due to the existence of large RF-dc differences caused by the transmission line effects. The skin effect can be directly observed in low voltage range TVC's around 1 MHz. The ac-dc difference (δ_s) caused by the skin effect can be calculated by the following formula:

$$\delta_s = (R_{rf} - R_d)/R_{in} \quad (1)$$

where R_{rf} and R_d are the RF and dc resistance of the connector and line, respectively, and R_{in} is the input resistance of the TVC. The rf resistance, R_{rf}, of a transmission line can be calculated using a formula from Stratton [1] as a function of the inner and outer diameters, frequency, the resistivities, and the permeabilities of the conductors. Using this formula from Stratton, the changes in

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RF-dc differences predicted from equation (1) were calculated for the insertions of 10 and 20 cm air lines between a TVC and the plane of reference. Significant differences between measured and calculated values were found and some results are given in table 1 taken with a 0.5 V TVC.

Table 1.
Measured-Calculated RF-dc Difference from Skin Effect

	1 MHz	3 MHz
10 cm	65 ppm	106 ppm
20 cm	96 ppm	142 ppm

TRANSMISSION LINE EFFECT

The RF-dc difference caused by a lossless transmission line at the TVC input can be expressed in terms of the characteristic impedance, inductance, and capacitance of the line and the input impedance of the TVC. The relation yields a first order approximation for RF-dc difference proportional to line length and frequency squared. For voltage ranges of several volts or more, measurements confirm square law dependence on frequency, but for many TVC's it is difficult to determine the correct electrical length.

These relationships have been studied, in part, by the fitting of data to equations containing square root of frequency and frequency squared[3]. Some results are given in fig. 1.

REFERENCES

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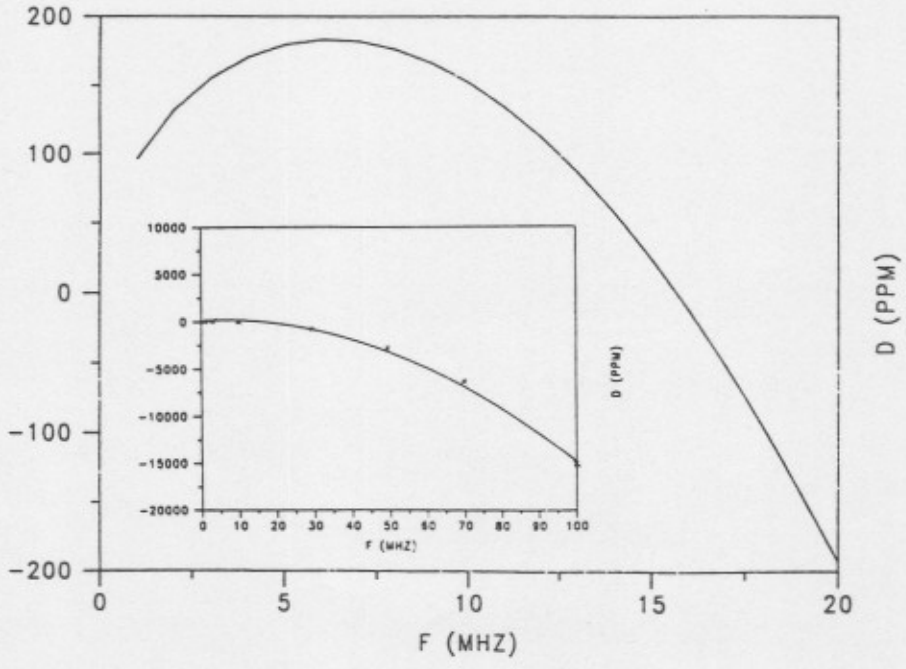

Fig.1 Change in RF-dc difference for a 0.5 V TVC resulting from the insertion of a 10 cm air line.