VIRGINIA Diodes Inc.

VDI APPLICATION NOTE
Power Measurement above 110 GHz
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Abstract

This document describes the method VDI uses to measure power in the frequency band above 110 GHz. The method involves the use of a commercial calorimeter with a WR-10 waveguide input and a calibration method to compensate for the measured loss of structures used to couple the power from VDI sources into the waveguide. The calibration factors currently used at VDI from 100 GHz to 2 THz are presented.

Introduction

For power measurements above 110 GHz VDI uses an Erickson calorimeter, described at www.ericksoninstruments.com. The Erickson meter is a waveguide based calorimeter which has a WR-10 waveguide input. There are two basic configurations for power measurements above the WR-10 band. The first is for components that have a waveguide output. The basic layout of this measurement is:

Power Measurements for DUT with Waveguide Output

{DUT} + {WR-## to WR-10 taper} + {WR-10 waveguide (1" length)} + {Power Meter}

At the highest frequencies (roughly 1 THz and higher) the waveguide interface becomes challenging, and so an integral feedhorn is used at the output of VDI's components. For these cases there is no taper used; rather the output of the horn is attached directly to the WR-10 waveguide. In this case the configuration is:

Power Measurements for DUT with Feedhorn Output

{DUT} + {WR-10 waveguide (1" length)} + {Power Meter}

The WR-10 1" section (an Aerowave 10-1201) is external to the Power Meter, and is used as a "connector saver" to reduce wear and damage to the Erickson Power Meter flange. Note that VDI makes no attempt to correct for losses in the WR-10 waveguide section internal to the Power Meter.

VDI has several versions of Erickson power meters in use, ranging from the PM1B to the PM4. All of the Erickson meters at VDI have been adjusted so that they read the same output power (to within about one percent). In addition, these power meters have been compared with an Agilent WR-10 sensor (with calibration traceable to NIST), and were found to have little difference in the WR-10 band.

Basic Calibration Methodology above WR-10

There are no standards against which to calibrate the power meter at frequencies above the WR-10 waveguide band. Thus, the calibration at higher frequency bands relies on the accuracy of the power meter as well as the assumption that whatever power reaches the termination in the meter is entirely absorbed, regardless of the frequency or spatial mode.

The issue then becomes the determination of the loss in waveguide components used to couple the energy from the DUT to the input flange of the Erickson meter; specifically the 1” section of WR-10 waveguide and waveguide taper (when used).

Loss of the WR-10 1” Section

The losses in a 1” section of the WR-10 guide can be measured by a simple substitution method, i.e. measuring power from a source both with and without the 1” section. Because of the small amount of loss, measurements were performed with two or more 1” sections, and then averaged to find the loss of a single section. A series of measurements were performed from 100 GHz to 1.9 THz, and are presented in Figure 1.

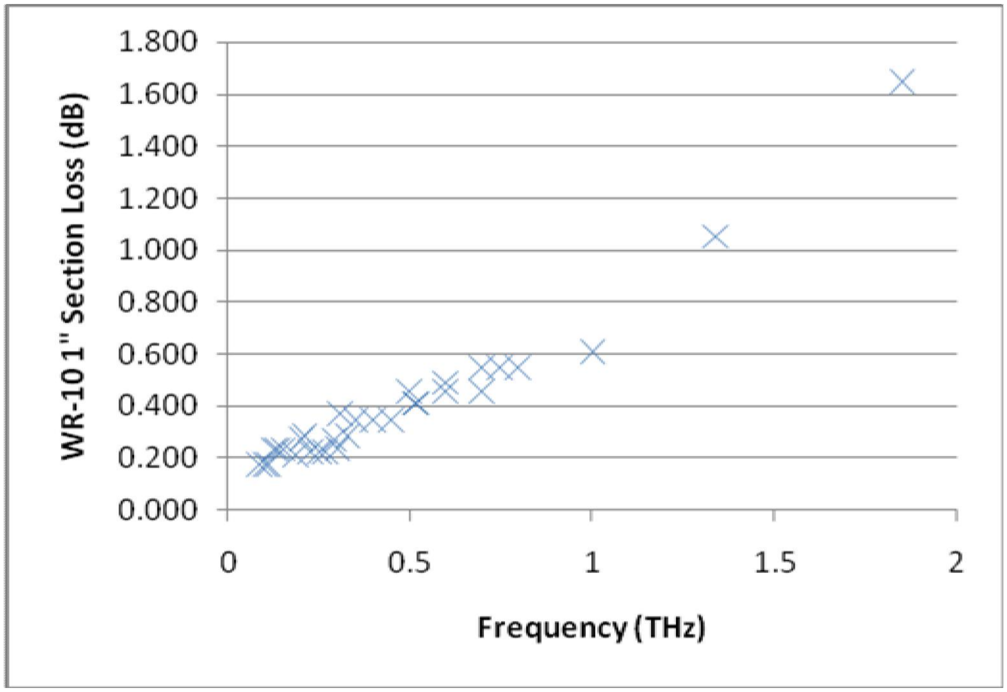

Figure 1. Measured loss of 1” WR-10 waveguide sections (Aerowave 10-1201).

Loss of the Waveguide Taper

The substitution technique used for the WR-10 waveguide sections doesn’t work for tapers since the DUT cannot be directly connected to the meter, which has a WR-10 input. Calibration for tapers is therefore done by gathering 3 or more similar tapers and using a swap-method to determine the individual taper loss.

There are a variety of ways to go about this. For example, if we have three tapers, A, B, and C, then we can make the following measurements:

{DUT} + {A} + {PM} à P_A
{DUT} + {A} + {B} + {C} + {PM} à P_{ABC}

We can then define the loss for tapers B and C as

$$L_{BC} = P_A / P_{ABC}$$

The average loss of tapers B and C is then

$$L_{taper} = \mathrm{sqrt}\,(L_{BC})$$

This measurement can be repeated for three different combinations (ABC, BAC and CAB) and then the loss of each individual taper can be determined. However, the loss from one taper to the next was found to be very similar, and so the average loss value for the tapers was used.

There are several sources of measurement error that affect this measurement, including source drift, sensor drift, and waveguide flange assembly repeatability. The dominant error for the high frequency measurements was found to be the flange repeatability, and so a series of measurements were made after connecting and re-connecting the waveguide flanges. The results were then averaged. The results of these measurements are shown in Figure 2.

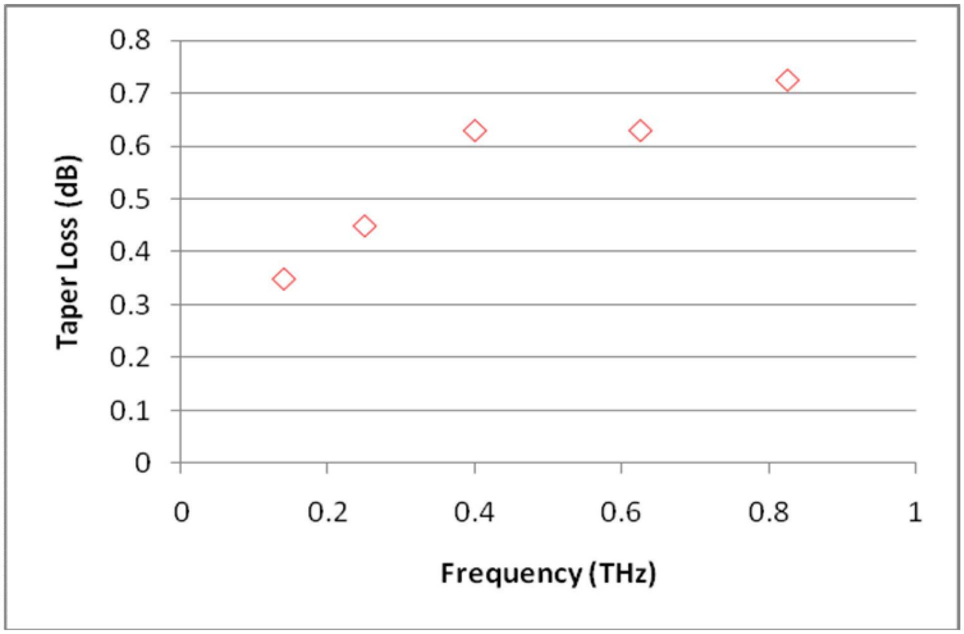

Figure 2. Measured loss of waveguide tapers.

Power Correction Factors Used At VDI

In order to determine a simple formula to correct for the loss of the WR-10 1" section and the taper, a linear equation is used to give an estimate of the loss as a function of frequency. The measured data and the linear curves used are shown in Figure 3. The two equations used are:

Loss (WR-10 1" Section) = 0.5 * Freq(THz) + 0.1 dB

Loss (Taper) = 0.5 * Freq(THz) + 0.25 dB

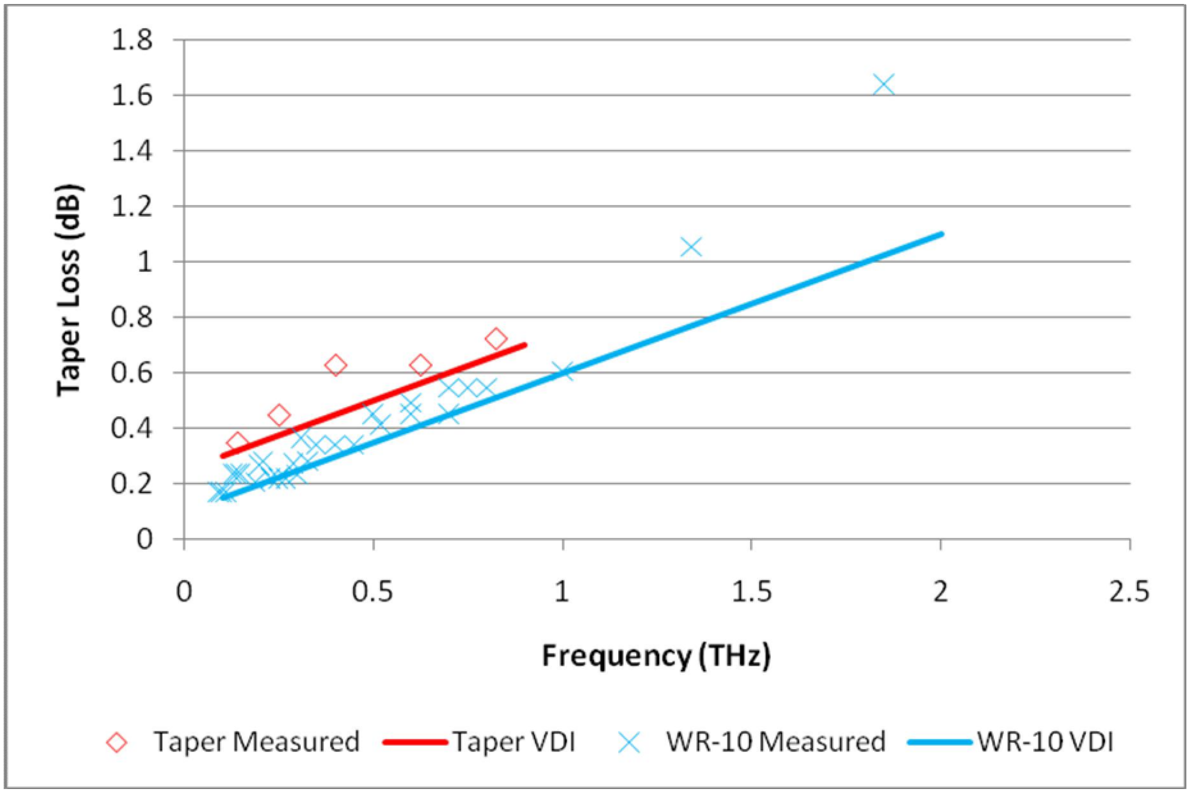

Figure 3: Summary of VDI Correction factors for taper and WR-10 1" section.

A table listing the VDI calibration factor as a function of frequency is given in Table 1.

Freq.	WR-10 1"		Taper	
(THz)	(dB)	(lin)	(dB)	(lin)
0.1	0.15	1.035	0.30	1.072
0.2	0.20	1.047	0.35	1.084
0.3	0.25	1.059	0.40	1.096
0.4	0.30	1.072	0.45	1.109
0.5	0.35	1.084	0.50	1.122
0.6	0.40	1.096	0.55	1.135
0.7	0.45	1.109	0.60	1.148
0.8	0.50	1.122	0.65	1.161
0.9	0.55	1.135	0.70	1.175
1	0.60	1.148		
1.1	0.65	1.161		
1.2	0.70	1.175		
1.3	0.75	1.189		
1.4	0.80	1.202		
1.5	0.85	1.216		
1.6	0.90	1.230		
1.7	0.95	1.245		
1.8	1.00	1.259		
1.9	1.05	1.274		

Conclusion

There are no generally accepted standards for power measurements above about 100 GHz. The purpose of this application note is to describe the methods that VDI uses to measure power levels from VDI sources. In this way VDI hopes to keep its customers fully informed of its measurement techniques and foster a greater discussion of the best methods to perform such measurements. Possible methods to compare power measurements made by different research laboratories is also an important topic, but has not been considered here.

VDI will update this document from time to time to reflect improved measurement techniques and equipment upgrades.