Calibration of the RF Power Monitors for the 3.9 GHz Vertical Coupler Test Stand

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Abstract: ***Calibration data for various RF power monitors used in the 3.9 GHz vertical coupler test stand are presented. This data can be used to calculate system power levels.***

Introduction

A 3.9 GHz vertical coupler test stand for ILC R&D has been set up at the A0 Photoinjector Lab. The couplers are tested for performance by driving them with an 80 kW peak, 3.9 GHz klystron. Forward and reflected power measurements of the klystron and coupler test stand are monitored using RF diode peak detectors. The forward power of the klystron preamplifier is also monitored in this manner.

Calibration Procedure

The RF diode peak detectors need to be calibrated. The calibration coefficients can be determined from the equation[1]

$$V_s = c_0 |V_o| + c_1 \ln(c_2 |V_o| + 1) \quad (1)$$

where V_s is the peak input voltage, V_o is the diode output voltage, and c_0, c_1, and c_2 are coefficients that can be determined using a generalized regression method. The absolute value is used to allow either negative or positive polarity diode detector outputs.

The diode detectors used are Narda model 503A, which are negative peak detectors. A IFR2042 10kHz-5.4GHz signal generator was used as a signal source at 3.9GHz to measure the peak input voltage as a function of the diode detected output voltage. The diode was connected directly to the signal generator, and the output of the diode detector was terminated in a 1kΩ load. This technique can be used since the return loss for the detectors was around -21dB with the 1kΩ load, so it presents a fairly good match to the signal generator. The diode detected output voltage was measured using a Tektronix TDS3014B oscilloscope. The experimental setup is shown in Fig. 1.

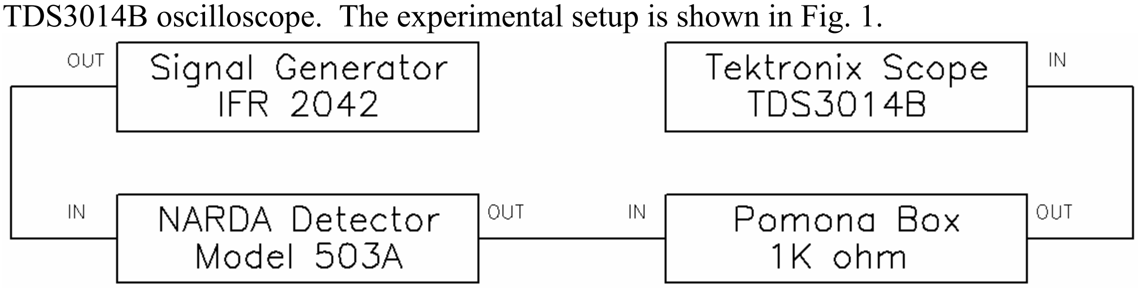

Figure 1. Detector output response calibration.

[1] See T. Berenc, "RF Diode Peak Detector Calibration for the CKM SCRF Q-Measurement System", Fermilab RF Note #034 18 July 2002 , <http://www-rfes.fnal.gov/global/technotes/TN/TN034.pdf>

Once the output response is measured, the signal generator was connected to an Agilent E4418B power meter to allow an accurate measurement of the source power. The signal generator levels are those that were measured for each detected output voltage.

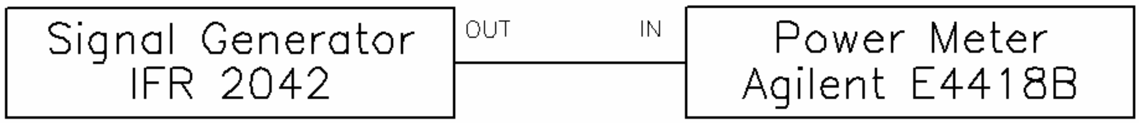

Figure 2. Source level measurement.

Since it is the power that is of interest, we must transform Eq. (1). Assuming a 50Ω system, the input power to the diode detector can be expressed as

$$P_{in} = \frac{V_s^2}{100} \quad (2)$$

Using Eq. (1) and Eq. (2) the input power for each monitor can be expressed as

$$P_{sys} = A \cdot [c_0 |V_o| + c_1 \ln(c_2 |V_o| + 1)]^2 \quad (3)$$

where c_0, c_1, and c_2 are the same coefficients as above and A is a term that incorporates all the constant multiplicative terms that result from coupling factors, cable attenuation, power splitters, and additional attenuators that are placed before the diode detectors. The A term also includes the 1/100 factor from Eq. (2). All attenuation measurements were made in-situ to account for interconnection losses and for ease of measurement. A HP8753E network analyzer set to CW at 3.9GHz was used as the RF source and an Agilent E4418B power meter was used to measure the attenuation of the ½" Heliax cable and Amaren 2 way 2-4GHz power splitter for each monitor signal, as can be seen in Fig. 3. The coupling factor for the directional couplers was not measured, since the system was set up before a measurement could be made. The company of origin placed the coupling factors on the directional couplers, which is assumed to be accurate.

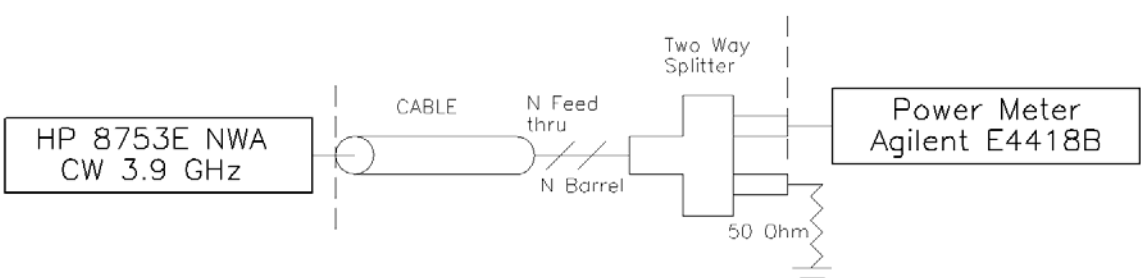

Figure 3. Measurement of cable attenuation and 2 way splitter.
Note: Dashed lines are measurement reference plane.

Measurement Data

The calibration procedure above was applied to 5 diode detectors that are used to monitor the forward and reflected power of the klystron and the coupler test stand, respectively, and the forward power of the pre-amplifier that drives the klystron. The attenuator and coupling values used in the forward and reflected power calculations are shown in table 1.

TABLE 1: Attenuation and coupling coefficients (dB)

Device	Forward Power	Forward Coupling	Reflected Power	Reflected Coupling
Klystron	16.179	49.22	20.397	29.47
Load	16.247	49.3	20.56	29.49
Pre-Amp	-	20.923	-	-

The cable loss and power splitter loss, along with the insertion loss between the pre-amplifier and directional coupler are shown in table 2. The insertion loss between the pre-amplifier and directional coupler include the circulator at the pre-amplifier output and several Type N interconnects.

TABLE 2: Insertion Loss (dB)

Device	Forward Power	Reflected Power
Klystron	3.84	3.91
Load	4.41	4.76
Pre-Amp	0.345	-

A generalized regression method using Mathcad was used to calculate the diode detector coefficients from Eq. (1). A typical response curve for the diode detectors is shown in Fig. 4. that represents the klystron forward power detector.

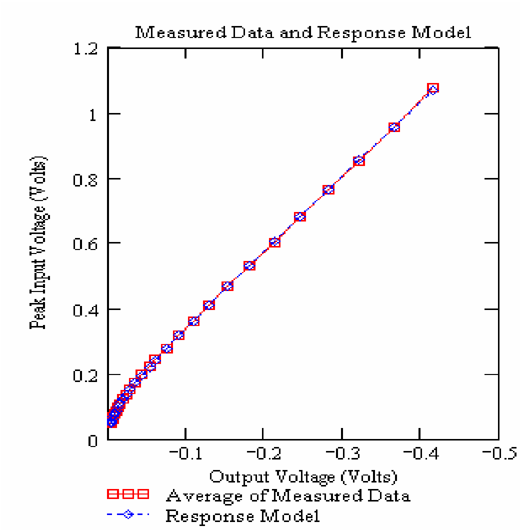

Figure 4. Response of klystron forward power detector.

The constant multiplicative term A is found by summing all of the forward and reflected power attenuation, coupling, and insertion loss coefficients, and converting the logarithmic attenuation to a linear attenuation factor. The results for each diode detector's calibration coefficients, along with its multiplication factor, are presented in table 3.

TABLE 3: System Power Level Calibration Coefficients

Diode Detector Monitor #	C_0	C_1	C_2	A
1. Klystron Forward Power	2.207	0.024	1673	83926.67
2. Klystron Reflected Power	2.183	0.024	1890	2386.162
3. Load Forward Power	2.167	0.024	1816	99014.77
4. Load Reflected Power	2.205	0.025	1910	2992.265
5. Pre-Amp Forward Power	2.196	0.025	1515	1.33906

The percent error of the response model relative to the experimental data can be found for each detector in figures 5 through 9. From the figures, the errors for accurately calculating power from the response model are ± 2% for detected output voltages of approximately 20 mV. The maximum power output of the klystron is 80 kW. Thus, the dynamic range for accurately calculating power using these detectors is around 26 dB, or down to 200 W of klystron output power. This is more than sufficient given normal operating conditions.

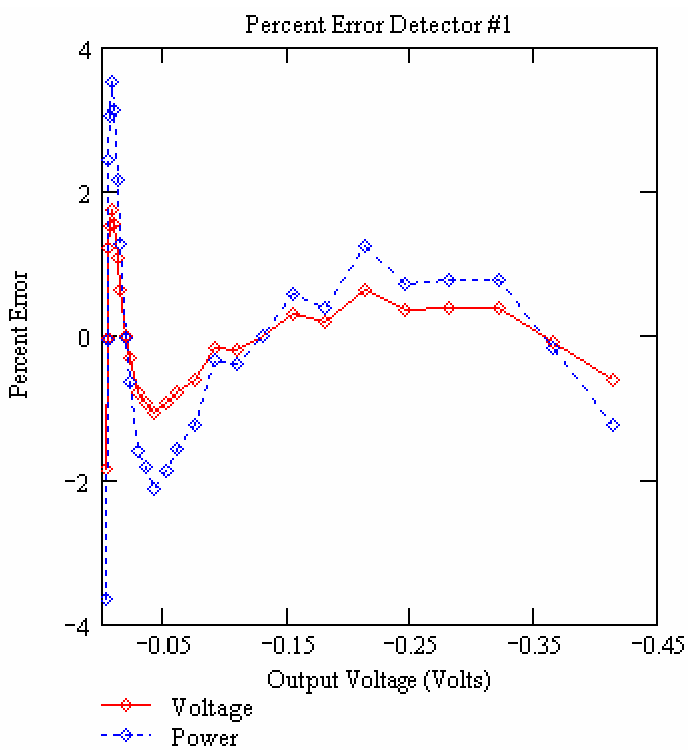

Figure 5. Klystron Forward Power Response Model Error

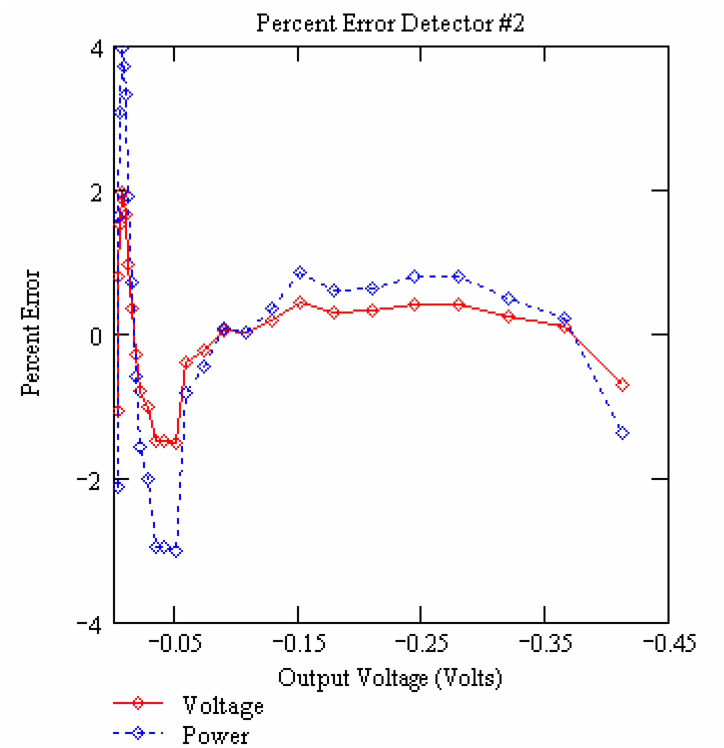

Figure 6. Klystron Reflected Power Response Model Error

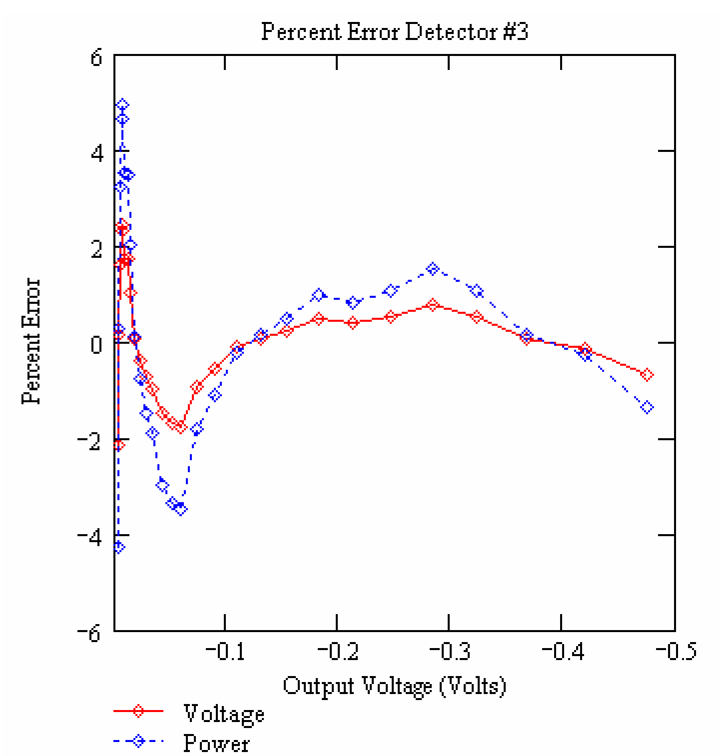

Figure 7. Load Forward Power Response Model Error

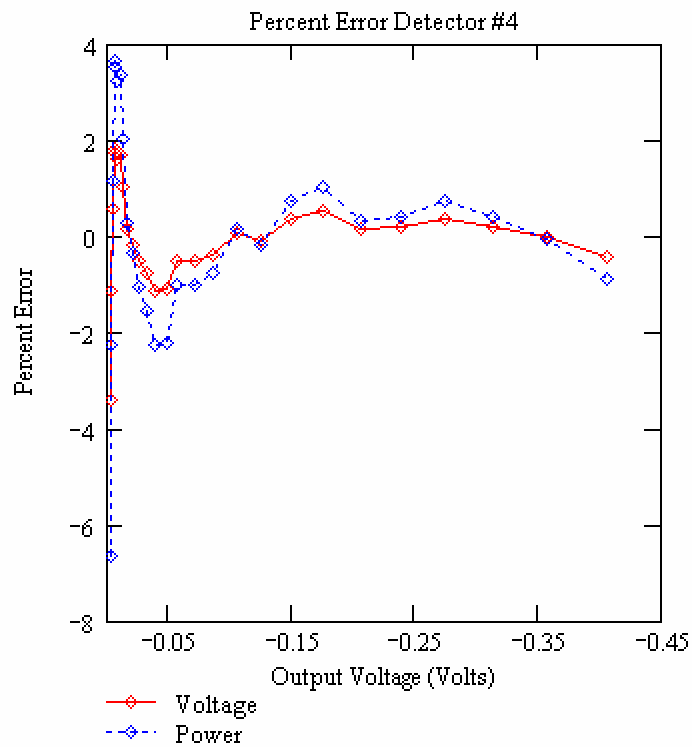

Figure 8. Load Reflected Power Response Model Error

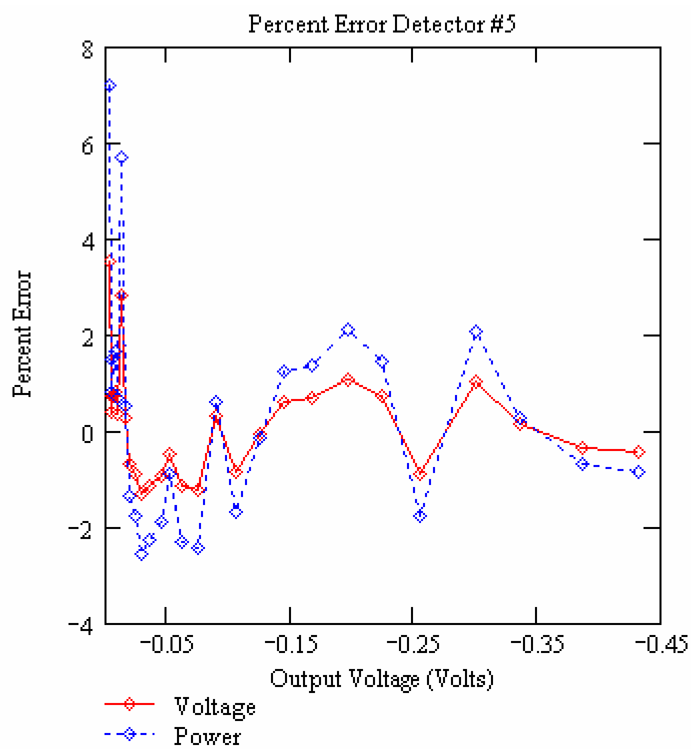

Figure 9. Pre-Amplifier Power Response Model Error