Calibration of the RF Power Monitors For the Photoinjector Laboratory RF System

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8/27/2002

Abstract: *Calibration measurements of the radio frequency diode peak detectors of the Photoinjector Laboratory located at A0 are presented. The calibration results are applied to the calculation of the system power levels.*

Introduction

There are two radio frequency (RF) systems installed at the Photoinjector (PI) Laboratory in the A0 area; the electron-gun (E-Gun) system and the 9-Cell superconducting RF (SCRF) cavity system. The power levels within each system are monitored using RF diode peak detectors. Calibration measurements of these peak detectors were made in-situ to include system cabling effects. The results of these measurements and their application to the calculation of system power levels are presented.

The Calibration Procedure

Each of the PI RF systems monitor the power delivered to the cavity through directional couplers on the cavity input transmission line. Additional probe monitors are provided for sampling the energy inside the cavity. A simplified block diagram representative of each system is shown in Fig. 1. The input directional coupler, with forward and reflected coupling ratios C_{FWD} and C_{REF}, is separated from the cavity through a length of transmission line with an insertion loss of T dB. The directional coupler signals are fed through an additional lossy path of attenuation A_{FWD} and A_{REF} respectively to the point at which calibration measurements are taken. Similarly, the probe monitor is fed to the calibration point through a lossy path of attenuation A_{MON}. Beyond the location of calibration, all of the signals are fed to their respective diode detectors through some lossy path. Finally, the output of each diode detector is transmitted into the control room to be monitored at the oscilloscope.

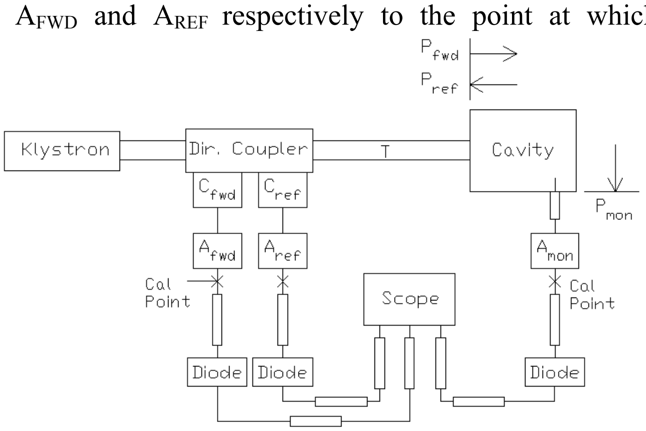

Figure 1: Block Diagram of System Monitors

The calibration of each monitor began by breaking the monitor path at the calibration point. A signal generator, HP E4422B, was then used to provide a RF signal to the diode detectors at the system operating frequency of 1.3GHz. At the control room oscilloscope, the detector output was measured as a function of the signal generator level. Furthermore, the signal generator level of each data point was separately calibrated with a HP E4419B power meter.

The peak input voltage to the detector, V_S, can be described in terms of the detector's output voltage, V_o, by the equation[1]

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

where c_0, c_1, and c_2 are coefficients which can be determined using a generalized regression method. The absolute value of V_o is used to allow for both positive and negative polarity diode detector outputs. The formulation of Eq. (1) is included in Appendix A.

The power, P_{IN}, associated with this peak input voltage, assuming a 50Ω system, is

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

$$P_{IN} = \frac{V_S^2}{100} \quad (2)$$

The power level of interest in the system, P_{SYS} , whether it is the forward or reflected power at the cavity plane or the power coupled to the monitor probe, can then be calculated from

$$P_{SYS} = P_{IN} \cdot 10^{\frac{\beta}{10}} \quad (3)$$

where β represents the ratio of P_{SYS} to P_{IN} in decibels and includes all attenuation in the path from the system level to the calibration point. Thus from Fig 1, $\beta = A_{FWD} + C_{FWD} - T$ for the forward power, $\beta = A_{REF} + C_{REF} + T$ for the reflected power, and $\beta = A_{MON}$ for the monitor probe. To allow for a general expression for all monitors, β is defined to be

$$\beta = A + C + T\,, \quad (4)$$

for which A, C, or T can be zero, positive, or negative in decibels. Furthermore, if the losses in the signal path are changed through the addition or extraction of any element at some point in the future, the change in attenuation can be accounted for by changing any one of A, C, or T in a manner that is appropriate.

Combining Eqs. (1) through (4), the overall calibration equation which calculates the system power level, P_{SYS} , in Watts in terms of the voltage, V_o, in Volts as measured at the control room oscilloscope is

$$P_{SYS} = \frac{\left[c_0\left|V_o\right| + c_1 \ln\left(c_2\left|V_o\right| + 1\right)\right]^2}{100} \cdot 10^{\left(\frac{A+C+T}{10}\right)}\,. \quad (5)$$

The Calibration Measurements

The system power level monitors which were calibrated included the E-Gun P_{FWD}, the E-Gun P_{REF}, the E-Gun ½ Cell P_{MON}, the 9-Cell P_{FWD}, the 9-Cell P_{REF}, and the 9-Cell P_{MON} . The measurement data can be found in Appendix B along with the Mathcad files used to process the data for each detector. The percent error of the power level, $P_{predicted}$, at the calibration point, as predicted using the square of equation (1), to the actual power, P_{actual}, supplied by the signal generator during calibration, as calibrated with the power meter, is defined as

$$\%Error = \frac{P_{predicted} - P_{actual}}{P_{actual}} \cdot 100\,. \quad (6)$$

Figure 2 shows this resulting error as a function of the voltage appearing at the control room oscilloscope for each monitor.

The signal path attenuation terms A, C, and T for each monitor were determined through a combination of measurements and records. Measurements were made on easily accessible components such as attenuators while records of past measurements were used for the directional couplers. In particular, the forward and reflected coupling ratios, represented by C in Eq. (4), for the directional couplers were taken from the handwritten data that is pasted on both the E-Gun and the 9-Cell input directional couplers. The attenuation, represented by A in Eq. (4) and existing in the form of cables and attenuators between the directional couplers and the calibration point, was measured using a calibrated network analyzer. The waveguide losses, T, were estimated from waveguide length measurements and manufacturer catalog attenuation data.

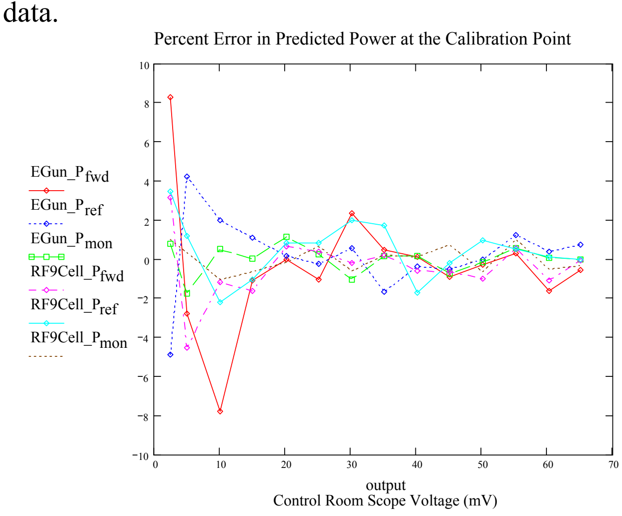

Figure 2: Percent Error in the Predicted Power at the Calibration Point

Table 1 lists all the coefficients of Eq. (5) resulting from the complete calibration process for each monitor with its associated diode detector. The calibration information for all the monitors is also conveniently summarized in Appendix C and D.

Table 1: System Power Level Monitor Calibration Coefficients

Monitor with (Diode Detector)	***c0***	***c1***	***c2***	***A***	***C***	***T***
E-Gun P_{FWD} (A0-PI-01)	19.60	0.0446	3642	47.42	35.6	-0.07
E-Gun P_{REF} (A0-PI-02)	4.50	0.0306	17870	19.66	60.6	0.07
E-Gun ½ Cell P_{MON} (A0-PI-03)	11.84	0.0510	14230	49.35	0	0
9-Cell P_{FWD} (A0-PI-04)	13.84	0.0560	21120	0	59.92	-0.02
9-Cell P_{REF} (A0-PI-05)	30.35	0.0790	3743	0	59.81	0.02
9-Cell P_{MON} (A0-PI-06)	36.30	0.0675	18032	19.56	0	0

Conclusion

A general calibration equation representing the Photoinjector Laboratory RF diode peak detector monitors was formulated. The coefficients of this equation were determined from experimental data for each monitor. The equation describing each monitor can be used for calculating the system power levels during operation of the Photoinjector RF systems.

Remarks

I would like to thank Rick Zifko for assisting in the measurement of the experimental data.

Appendix A
The Diode Detector Circuit Solution

Figure 1 shows a simplified diode peak-detector circuit model. Assuming that the diode responds only to the envelope of the source voltage and that the source envelope is constant, a simplified analysis of the circuit can be performed.

The voltage source, V_s, is assumed to be a DC source. The diode current-voltage relationship is approximated as[2]

$$i_D = I_s\left(e^{\frac{v_D}{c_1}} - 1\right) \qquad (1)$$

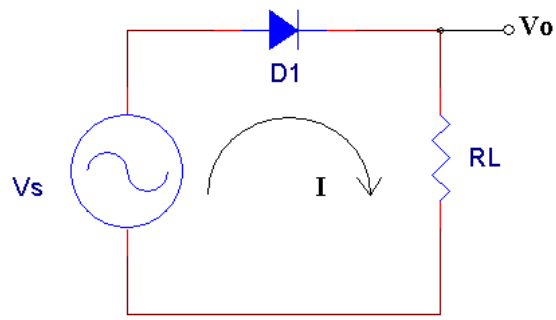

Figure 1: Simplified Diode Peak Detector Model

where v_D is the voltage across the diode, c_1 is a physical constant, and I_s is the saturation current of the diode. Solving Eq.1 for v_D results in

$$v_D = c_1 \ln\left(\frac{i_D}{I_s} + 1\right) . \qquad (2)$$

The current in the circuit, I, is expressed as,

$$I = \frac{V_o}{R_L} = i_D \quad . \qquad (3)$$

Using the above equations, the source voltage can be expressed as,

$$V_s = V_o + v_D \qquad (4)$$

$$V_s = V_o + c_1 \ln\left(\frac{V_o}{R_L I_s} + 1\right) \qquad (5)$$

Equation 5 suggests that the source voltage, V_s, can be calculated from the measured output voltage, V_o, using an equation of the form

$$V_s = c_0 V_o + c_1 \ln\left(c_2 V_o + 1\right) \qquad (6)$$

where c_0 , c_1, and c_2 are coefficients. Given a set of measurements of V_s versus V_o for an actual detector, the coefficients of Eq.6 can be determined using a generalized regression method.

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[2] See A.S.Sedra & K.C.Smith, *Microelectronic Circuits*, 3rd Edition, Saunders College Publishing, NY, 1991, Chapter 3.

Appendix B
Experimental Data & Mathcad Files

Electron Gun RF System Experimental Data

E-Gun
Forward Input Power Monitor
Detector Serial #A0-PI-01
(Narda 503A-03)

Signal Generator Level (dBm)	Power Meter Reading (dBm)	Control Room Scope (mV)
-6.66	-6.7	2.5
-2.64	-2.65	5.0
1.42	1.42	10.0
3.54	3.55	15.0
5.34	5.36	20.1
6.84	6.87	25.1
7.92	7.96	30.1
9.08	9.11	35.1
10.04	10.07	40.1
10.92	10.96	45.1
11.66	11.7	50.1
12.34	12.39	55.2
13.06	13.12	60.2
13.58	13.65	65.0

E-Gun
Reflected Input Power Monitor
Detector Serial #A0-PI-02
(Narda 503-01-0 3)

Signal Generator Level (dBm)	Power Meter Reading (dBm)	Control Room Scope (mV)
-7.38	-7.41	2.7
-6.06	-6.08	5.0
-3.9	-3.9	10.0
-2.46	-2.49	15.0
-1.34	-1.36	20.1
-0.44	-0.45	25.1
0.3	0.29	30.1
1.08	1.08	35.1
1.64	1.65	40.1
2.22	2.23	45.1
2.74	2.74	50.1
3.18	3.19	55.2
3.68	3.69	60.2
4.1	4.11	65.2

E-Gun
Probe Monitor Cabling+Detector
Detector Serial #A0-PI-03
(Narda 503)

Signal Generator Level (dBm)	Power Meter Reading (dBm)	Control Room Scope (mV)
-3.44	-3.46	2.5
-1.02	-1.06	5.0
1.4	1.38	10.0
3.1	3.09	15.0
4.38	4.38	20.1
5.5	5.51	25.1
6.5	6.51	30.1
7.28	7.29	35.1
8.02	8.04	40.1
8.76	8.76	45.1
9.36	9.36	50.1
9.92	9.92	55.2
10.48	10.48	60.2
10.96	10.97	65.0

Note: A total of 50dB inserted at the Det. was Removed for Measurements

9-Cell SCRF System Experimental Data

9-Cell
Forward Input Power Monitor
Detector Serial #A0-PI-04
(Narda 503-01-03)

Signal Generator Level (dBm)	Power Meter Reading (dBm)	Control Room Scope (mV)
-1.86	-1.91	2.5
0.62	0.59	5.0
2.9	2.89	10.0
4.56	4.56	15.0
5.78	5.78	20.1
6.86	6.87	25.1
7.82	7.83	30.1
8.64	8.64	35.1
9.42	9.42	40.1
10.1	10.1	45.1
10.74	10.74	50.1
11.26	11.26	55.2
11.86	11.87	60.2
12.3	12.31	65.0

9-Cell
Reflected Input Power Monitor
Detector Serial #A0-PI-05
(Narda 503A-03)

Signal Generator Level (dBm)	Power Meter Reading (dBm)	Control Room Scope (mV)
-1.78	-1.83	2.5
1.72	1.71	5.0
5.54	5.54	10.0
7.82	7.83	15.0
9.54	9.54	20.1
10.96	10.96	25.1
12.1	12.11	30.1
13.14	13.16	35.1
14.2	14.23	40.1
14.94	14.99	45.1
15.62	15.69	50.1
16.3	16.41	55.2
16.9	17.06	60.2
17.4	17.63	65.0

9-Cell
Probe Monitor Cabling+Detector
Detector Serial #A0-PI-06
(Narda 503A-03)

Signal Generator Level (dBm)	Power Meter Reading (dBm)	Control Room Scope (mV)
0.84	0.82	2.5
3.72	3.72	5.0
7.1	7.12	10.0
9.32	9.33	15.0
11.04	11.05	20.1
12.4	12.41	25.1
13.62	13.65	30.1
14.6	14.65	35.1
15.5	15.57	40.1
16.26	16.37	45.1
17	17.18	50.1
17.56	17.81	55.2
18.14	18.51	60.2
18.6	19.07	65.0

Note: A 20dB Pad inserted at the Det. was Removed for Measurements

A0 Photo-Injector E-Gun
Cave Roof *Forward Power Monitor* Calibration
with Detector #A0-PI-01

data := READPRN("y:\project\hlrf\Berenc_Zifko\A0_PhotoInjector\Pfwd_Roof_NardaDetector.txt")

$k := 0 .. \mathrm{rows}(data) - 1$

$freq := 1.3 \cdot GHz$

$input\_dBm_k := data_{k,1} \qquad input_k := \sqrt{0.001 \cdot 50 \cdot 2} \cdot 10^{\frac{input\_dBm_k}{20}}$

$output_k := \dfrac{data_{k,2}}{1000}$

Define Function and it's first partial derivatives wrt it's coefficients. Provide a guess for it's coefficients, and then find a fit to the data. Furthermore, truncate the resultant coefficient matrix to applicable significant digits

$$F(v_o, c) := \begin{pmatrix} c_0 \cdot v_o + c_1 \cdot \ln(c_2 \cdot v_o + 1) \\ v_o \\ \ln(c_2 \cdot v_o + 1) \\ \dfrac{c_1 \cdot v_o}{c_2 \cdot v_o + 1} \end{pmatrix} \qquad c\_guess := \begin{pmatrix} 4 \\ 1 \\ 100 \end{pmatrix} \qquad P := \mathrm{genfit}(output, input, c\_guess, F)$$

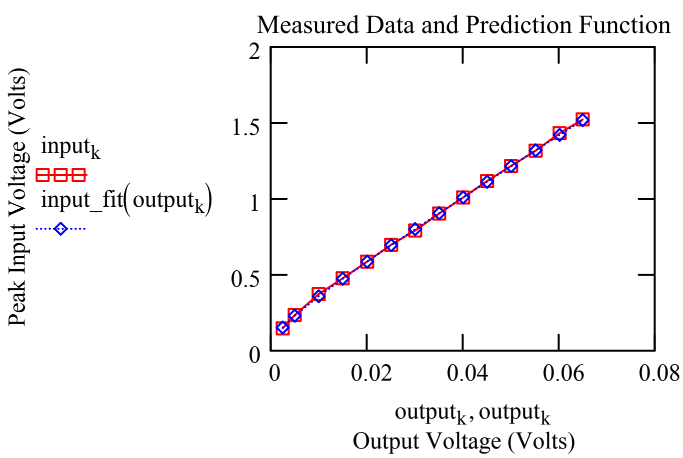
Solution *Truncated*

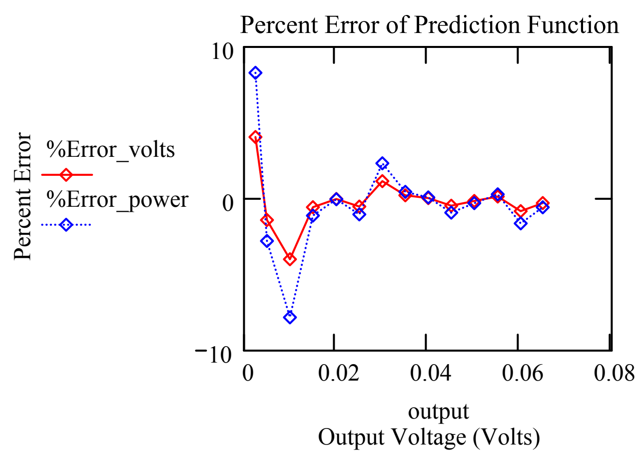
$$P = \begin{pmatrix} 19.6326 \\ 0.0446 \\ 3641.7407 \end{pmatrix} \qquad P := \begin{pmatrix} 19.6 \\ 0.0446 \\ 3642 \end{pmatrix}$$

$input\_fit(v_o) := F(v_o, P)_0$

Error between prediction function and actual data: $\%Error\_volts_k := \dfrac{input\_fit(output_k) - input_k}{input_k} \cdot 100$

$$\%Error\_power_k := \frac{(input\_fit(output_k))^2 - (input_k)^2}{(input_k)^2} \cdot 100$$





A0 Photo-Injector E-Gun
Cave Roof *Reflected Power Monitor* Calibration
with Detector #A0-PI-02

data := READPRN("y:\project\hlrf\Berenc_Zifko\A0_PhotoInjector\Pref_Roof_NardaDetector.txt")

$k := 0 .. \mathrm{rows}(data) - 1$

$freq := 1.3 \cdot GHz$

$input\_dBm_k := data_{k,1}$ $\qquad input_k := \sqrt{0.001 \cdot 50 \cdot 2} \cdot 10^{\frac{input\_dBm_k}{20}}$

$output_k := \frac{data_{k,2}}{1000}$

Define Function and it's first partial derivatives wrt it's coefficients. Provide a guess for it's coefficients, and then find a fit to the data. Furthermore, truncate the resultant coefficient matrix to applicable significant digits

$$F(v_o, c) := \begin{pmatrix} c_0 \cdot v_o + c_1 \cdot \ln(c_2 \cdot v_o + 1) \\ v_o \\ \ln(c_2 \cdot v_o + 1) \\ \frac{c_1 \cdot v_o}{c_2 \cdot v_o + 1} \end{pmatrix} \qquad c\_guess := \begin{pmatrix} 4 \\ 1 \\ 100 \end{pmatrix} \qquad P := \mathrm{genfit}(output, input, c\_guess, F)$$

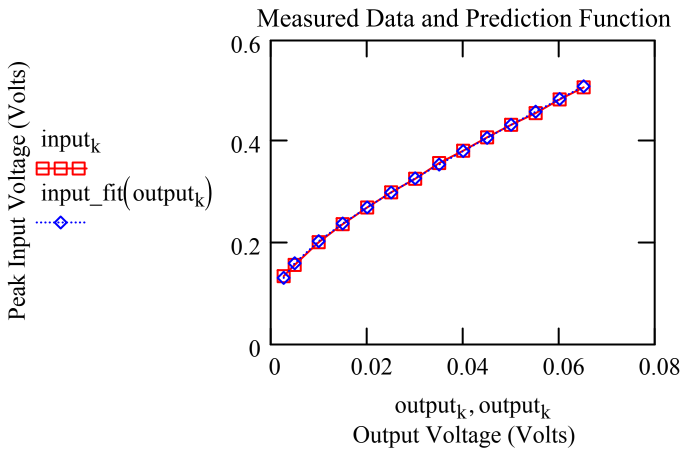
Solution $\qquad$ *Truncated*

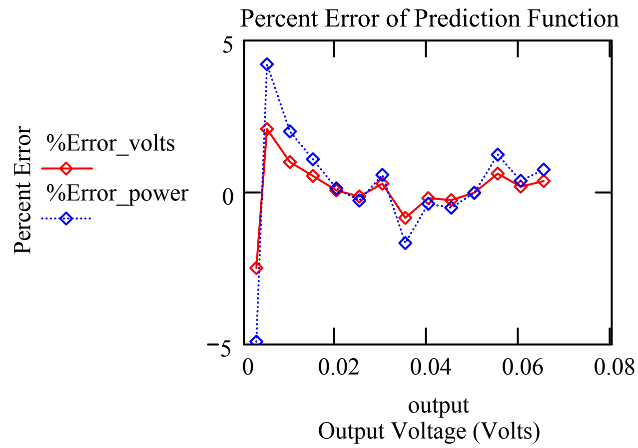
$$P = \begin{pmatrix} 4.4884 \\ 0.0306 \\ 1.7868 \times 10^4 \end{pmatrix} \qquad P := \begin{pmatrix} 4.5 \\ 0.0306 \\ 17870 \end{pmatrix}$$

$input\_fit(v_o) := F(v_o, P)_0$

Error between prediction function and actual data: $\%Error\_volts_k := \frac{input\_fit(output_k) - input_k}{input_k} \cdot 100$

$$\%Error\_power_k := \frac{(input\_fit(output_k))^2 - (input_k)^2}{(input_k)^2} \cdot 100$$





A0 Photo-Injector E-Gun
***Half-Cell Probe Monitor* Calibration**
with Detector #A0-PI-03

data := READPRN("y:\project\hlrf\Berenc_Zifko\A0_PhotoInjector\EGun_HalfCellPickup.txt")

$k := 0 .. \mathrm{rows}(data) - 1$

$freq := 1.3 \cdot GHz$

$input\_dBm_k := data_{k,1}$ $\qquad input_k := \sqrt{0.001 \cdot 50 \cdot 2} \cdot 10^{\frac{input\_dBm_k}{20}}$

$output_k := \frac{data_{k,2}}{1000}$

Define Function and it's first partial derivatives wrt it's coefficients. Provide a guess for it's coefficients, and then find a fit to the data. Furthermore, truncate the resultant coefficient matrix to applicable significant digits

$$F(v_o, c) := \begin{pmatrix} c_0 \cdot v_o + c_1 \cdot \ln(c_2 \cdot v_o + 1) \\ v_o \\ \ln(c_2 \cdot v_o + 1) \\ \frac{c_1 \cdot v_o}{c_2 \cdot v_o + 1} \end{pmatrix} \qquad c\_guess := \begin{pmatrix} 4 \\ 1 \\ 100 \end{pmatrix} \qquad P := \mathrm{genfit}(output, input, c\_guess, F)$$

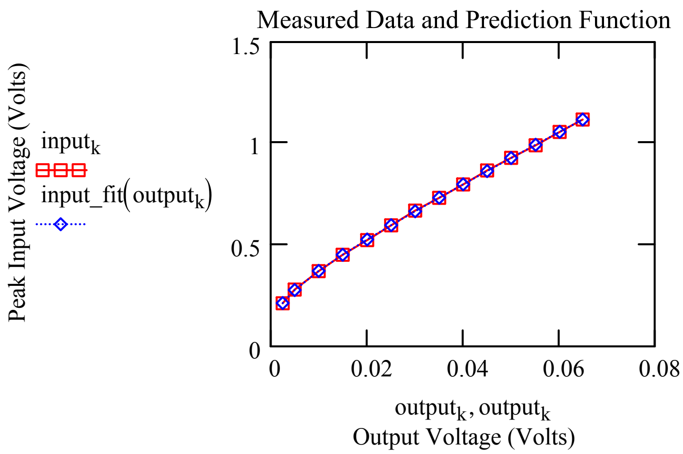
Solution $\qquad$ *Truncated*

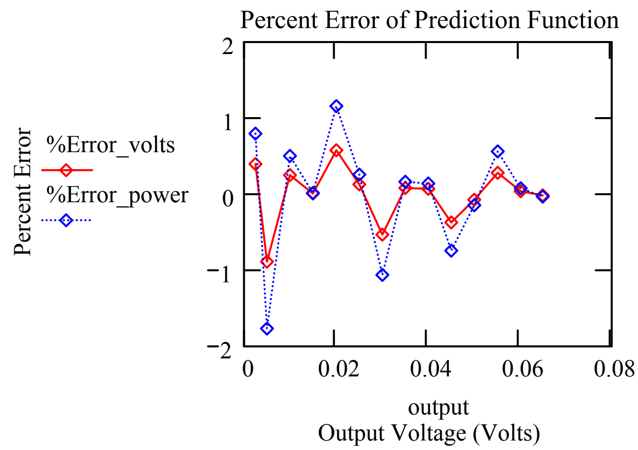
$$P = \begin{pmatrix} 11.8377 \\ 0.051 \\ 1.423 \times 10^4 \end{pmatrix} \qquad P := \begin{pmatrix} 11.84 \\ 0.051 \\ 14230 \end{pmatrix}$$

$input\_fit(v_o) := F(v_o, P)_0$

Error between prediction function and actual data: $\%Error\_volts_k := \frac{input\_fit(output_k) - input_k}{input_k} \cdot 100$

$$\%Error\_power_k := \frac{\left(input\_fit(output_k)\right)^2 - \left(input_k\right)^2}{\left(input_k\right)^2} \cdot 100$$





A0 Photo-Injector 9-Cell
***Forward Power Monitor* Calibration**
with Detector #A0-PI-04

data := READPRN("y:\project\hlrf\Berenc_Zifko\A0_PhotoInjector\9Cell_Pfwd.txt")

$k := 0 .. \text{rows}(\text{data}) - 1$

$\text{freq} := 1.3 \cdot \text{GHz}$

$\text{input\_dBm}_k := \text{data}_{k,1}$ $\qquad \text{input}_k := \sqrt{0.001 \cdot 50 \cdot 2} \cdot 10^{\frac{\text{input\_dBm}_k}{20}}$

$\text{output}_k := \dfrac{\text{data}_{k,2}}{1000}$

Define Function and it's first partial derivatives wrt it's coefficients. Provide a guess for it's coefficients, and then find a fit to the data. Furthermore, truncate the resultant coefficient matrix to applicable significant digits

$$F(v_o, c) := \begin{pmatrix} c_0 \cdot v_o + c_1 \cdot \ln(c_2 \cdot v_o + 1) \\ v_o \\ \ln(c_2 \cdot v_o + 1) \\ \dfrac{c_1 \cdot v_o}{c_2 \cdot v_o + 1} \end{pmatrix} \qquad \text{c\_guess} := \begin{pmatrix} 4 \\ 1 \\ 100 \end{pmatrix} \qquad P := \text{genfit}(\text{output}, \text{input}, \text{c\_guess}, F)$$

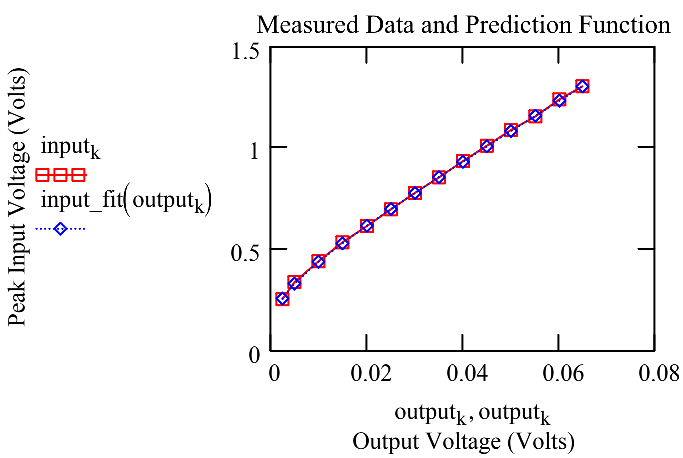
Solution $\qquad$ *Truncated*

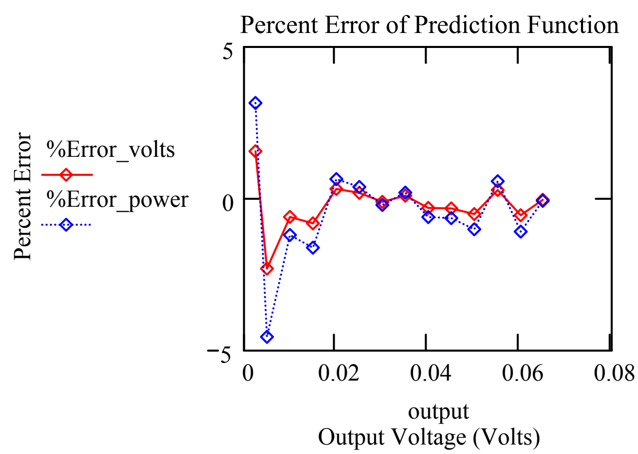
$$P = \begin{pmatrix} 13.8434 \\ 0.0562 \\ 2.112 \times 10^4 \end{pmatrix} \qquad P := \begin{pmatrix} 13.84 \\ 0.056 \\ 21120 \end{pmatrix}$$

$\text{input\_fit}(v_o) := F(v_o, P)_0$

Error between prediction function and actual data: $\%\text{Error\_volts}_k := \dfrac{\text{input\_fit}(\text{output}_k) - \text{input}_k}{\text{input}_k} \cdot 100$

$$\%\text{Error\_power}_k := \frac{\left(\text{input\_fit}(\text{output}_k)\right)^2 - \left(\text{input}_k\right)^2}{\left(\text{input}_k\right)^2} \cdot 100$$





A0 Photo-Injector 9-Cell
***Reflected Power Monitor* Calibration**
with Detector #A0-PI-05

data := READPRN("y:\project\hlrf\Berenc_Zifko\A0_PhotoInjector\9Cell_Pref.txt")

$k := 0 .. \mathrm{rows}(data) - 1$

$freq := 1.3 \cdot GHz$

$input\_dBm_k := data_{k,1}$ $\qquad$ $input_k := \sqrt{0.001 \cdot 50 \cdot 2} \cdot 10^{\frac{input\_dBm_k}{20}}$

$output_k := \frac{data_{k,2}}{1000}$

Define Function and it's first partial derivatives wrt it's coefficients. Provide a guess for it's coefficients, and then find a fit to the data. Furthermore, truncate the resultant coefficient matrix to applicable significant digits

$$F(v_o, c) := \begin{pmatrix} c_0 \cdot v_o + c_1 \cdot \ln(c_2 \cdot v_o + 1) \\ v_o \\ \ln(c_2 \cdot v_o + 1) \\ \frac{c_1 \cdot v_o}{c_2 \cdot v_o + 1} \end{pmatrix} \qquad c\_guess := \begin{pmatrix} 4 \\ 1 \\ 100 \end{pmatrix} \qquad P := \mathrm{genfit}(output, input, c\_guess, F)$$

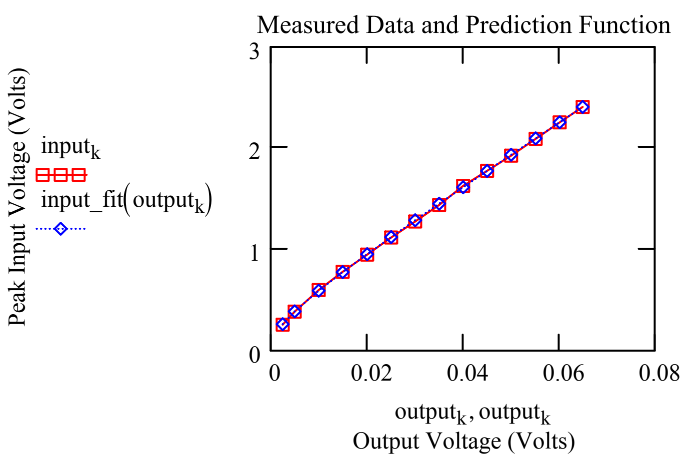
Solution $\qquad$ *Truncated*

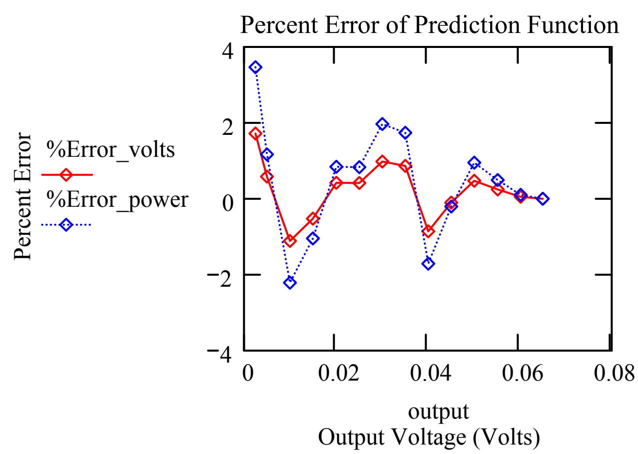
$$P = \begin{pmatrix} 30.3458 \\ 0.0786 \\ 3742.5077 \end{pmatrix} \qquad P := \begin{pmatrix} 30.35 \\ 0.079 \\ 3743 \end{pmatrix}$$

$input\_fit(v_o) := F(v_o, P)_0$

Error between prediction function and actual data: $\%Error\_volts_k := \frac{input\_fit(output_k) - input_k}{input_k} \cdot 100$

$$\%Error\_power_k := \frac{(input\_fit(output_k))^2 - (input_k)^2}{(input_k)^2} \cdot 100$$





A0 Photo-Injector 9-Cell
***Probe Monitor* Calibration**
with Detector #A0-PI-06

data := READPRN("y:\project\hlrf\Berenc_Zifko\A0_PhotoInjector\9Cell_Pickup.txt")

$k := 0 .. \text{rows}(data) - 1$

$freq := 1.3 \cdot GHz$

$input\_dBm_k := data_{k,1}$ $\qquad$ $input_k := \sqrt{0.001 \cdot 50 \cdot 2} \cdot 10^{\frac{input\_dBm_k}{20}}$

$output_k := \frac{data_{k,2}}{1000}$

Define Function and it's first partial derivatives wrt it's coefficients. Provide a guess for it's coefficients, and then find a fit to the data. Furthermore, truncate the resultant coefficient matrix to applicable significant digits

$$F(v_o, c) := \begin{pmatrix} c_0 \cdot v_o + c_1 \cdot \ln(c_2 \cdot v_o + 1) \\ v_o \\ \ln(c_2 \cdot v_o + 1) \\ \frac{c_1 \cdot v_o}{c_2 \cdot v_o + 1} \end{pmatrix} \qquad c\_guess := \begin{pmatrix} 4 \\ 1 \\ 100 \end{pmatrix} \qquad P := \text{genfit}(output, input, c\_guess, F)$$

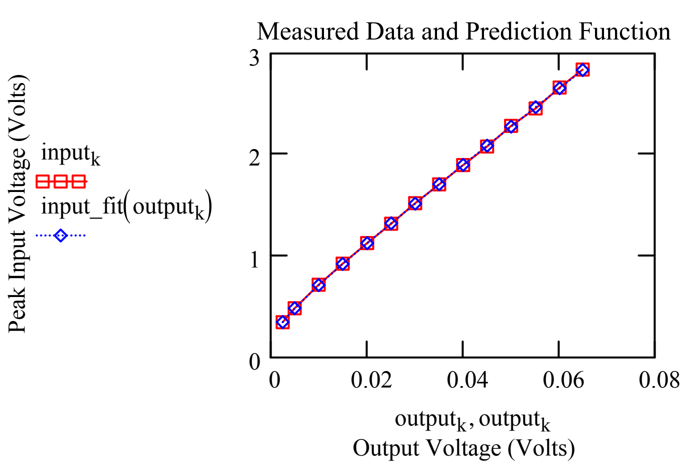
Solution $\qquad$ *Truncated*

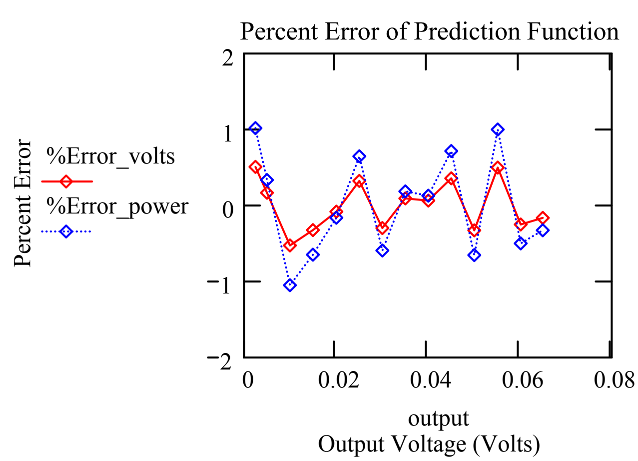
$$P = \begin{pmatrix} 36.3054 \\ 0.0675 \\ 1.8032 \times 10^4 \end{pmatrix} \qquad P := \begin{pmatrix} 36.30 \\ 0.0675 \\ 18032 \end{pmatrix}$$

$input\_fit(v_o) := F(v_o, P)_0$

Error between prediction function and actual data: $\%Error\_volts_k := \frac{input\_fit(output_k) - input_k}{input_k} \cdot 100$

$$\%Error\_power_k := \frac{(input\_fit(output_k))^2 - (input_k)^2}{(input_k)^2} \cdot 100$$





Appendix C

A0 Photoinjector Laboratory RF System
Power Level Monitor Calibration Summary

Calibration Equation

$$P_{SYS} = \frac{\left[c_0 \left|V_o\right| + c_1 \ln\left(c_2 \left|V_o\right| + 1\right)\right]^2}{100} \cdot 10^{\left(\frac{A+C+T}{10}\right)} \quad \text{Watts}$$

Calibration Equation Coefficients

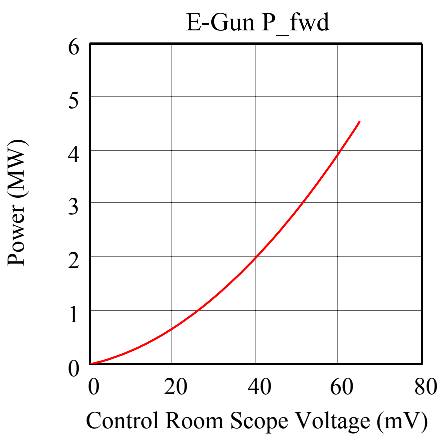
Monitor with (Diode Detector)	***c0***	***c1***	***c2***	***A***	***C***	***T***
E-Gun P_{FWD} (A0-PI-01)	19.60	0.0446	3642	47.42	35.6	-0.07
E-Gun P_{REF} (A0-PI-02)	4.50	0.0306	17870	19.66	60.6	0.07
E-Gun ½ Cell P_{MON} (A0-PI-03)	11.84	0.0510	14230	49.35	0	0
9-Cell P_{FWD} (A0-PI-04)	13.84	0.0560	21120	0	59.92	-0.02
9-Cell P_{REF} (A0-PI-05)	30.35	0.0790	3743	0	59.81	0.02
9-Cell P_{MON} (A0-PI-06)	36.30	0.0675	18032	19.56	0	0

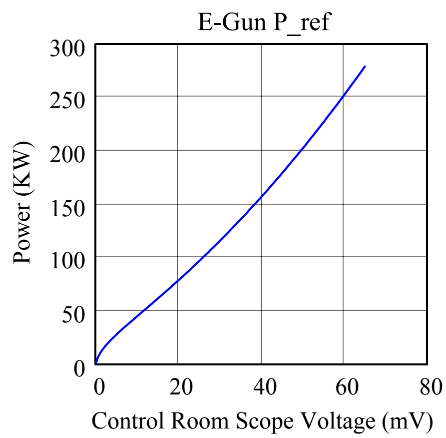
V_o : Control Room Oscilloscope readout in Volts
c_0, c_1, c_2 : Coefficients determined from experimental calibration data
A : Attenuation in dB between system coupler and calibration point
C : Attenuation in dB of system coupler
T : Attenuation in dB between coupler and system reference plane

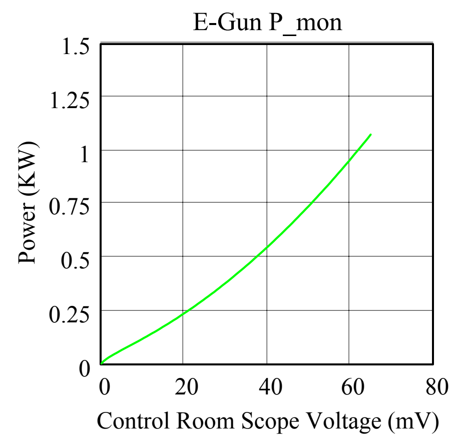
Appendix D

System Power Levels vs. Control Room Scope Voltage

E-Gun Power Monitors







9-Cell Power Monitors