# MASSACHUSETTS INSTITUTE OF TECHNOLOGY
## HAYSTACK OBSERVATORY

WESTFORD, MASSACHUSETTS 01886

April 25, 2008

*Telephone*: 781-981-5407
*Fax*: 781-981-0590

To: Broad Band Development Group

From: C.Beaudoin, A.E. Niell, M.Porier

Subject: **Results of Westford Dewar Y Factor Measurements**

## 1. Purpose

a. To document recent activity and results in obtaining system temperature estimates of the Dewar system to be installed on the Westford antenna.
b. Inform the bbdev group of activity not distributed in written form to the date of this memo.

## 2. Introduction

In the past weeks, efforts have been put into estimating the system temperature[1] of the VLBI2010 Dewar system to be installed at the Westford station. The experimental setup used for Y factor measurements is displayed in Figure 1(sorry my copy of Visio hasn't shown up yet). A 8564EC Agilent spectrum analyzer equipped with a GPIB interface was used to collect the spectra. The spectrum analyzer was operated with 2 MHz and 3 MHz resolution and video bandwidth, respectively, 1000x video averaging, and the input attenuation was set to 0 dB; the specific frequency parameters are provided in the results section. The spectra were downloaded from the analyzer over the GPIB connection by a laptop running a LabView program which handled communication with the analyzer.

Based on initial estimates of the Dewar's system temperature, the vertical polarization channel containing LNA serial #140D was consistently observed to have a significantly lower gain (~5dB) and higher noise temperature than the horizontal polarization channel containing LNA serial # 145D while operating at the bias voltages provided by Caltech which are specified in Table 1. Emphasis was put on the bias voltages in the previous sentence because the drain current drawn by LNA #140D and #145D at the specified voltages were only 15.4 and 16.9 mA, respectively. These drain current quantities are in conflict with those reported in Table 1.

## 3. Results

*4/7/2008*

Y-factor measurements were conducted and the spectra are displayed in Figure 2. Figures 2a,b display the 8-10 GHz spectral measurements taken for the experiment, and Figure 2c displays the system temperature estimates obtained from the Y-factor

[1] The system temperature estimates are obtained from Y-factor measurements as described in reference [1]

measurements[2]. Also shown in Figure 2c are cubic-order polynomials fit to each system temperature curve. To be sure that the lack of performance in the vertical channel was due to LNA performance, the Dewar was warmed-up, the LNA's were swapped from their respective H/V channel and the Dewar was cooled.

*4/9/2008*

Investigation into the gain imbalance resumed. Figures 3a and 3b display the measured spectra obtained from the hot load measurement over 8-10 GHz and 1-15 GHz[3], respectively. Unfortunately, on this day the sky was not clear enough to obtain the cold load measurement so an estimate of the system temperature was not available. However, comparing the hot load (absorber) measurements in Figure 2a with those of Figure 3a, we concluded that the lack of performance was due to LNA #140D.

*4/14/2008*

In an email conversation with Hamdi Mani on 4/10/2008, he suggested adjusting the drain voltage on the LNAs until their respective drain currents were as specified in Table 1. Figure 4 displays hot load spectra over the 1-15 GHz spectra for the given bias voltage/current settings. From these results we observed gain improvement in both channels in both channels and Figure 4c demonstrates approximate gain balance. Having been satisfied with the gain improvement in both channels, Y factor measurements were then conducted on the dock outside the Westford station. Figure 5 displays the Y-factor measurements (a),(b) and system temperature estimates (c) which also have been fit with a cubic polynomial. As seen in Figure 5, there is a significant difference in system temperature between the two polarization channels. Since the Y factor measurements were obtained on the Westford dock, in the immediate vicinity of the Westford radome, we anticipated a large source of error due to the fact that the radome is visible to the Dewar.

*4/16/2008*

In order to circumvent the error introduced by the radome's visibility to the Dewar, a 220VAC extension cord (for the liquid helium compressor) was obtained to relocate the Y factor experiment to the middle of the Westford parking. The area around the experiment was coned-off to isolate the Dewar from any nearby potential sources of radiation (unfortunately this does not include RFI). The first Y factor experiment was conducted using the same bias settings utilized in Figure 5, the only difference between the two experiments being the relocation of the Dewar. The results of this experiment are shown in Figure 6 and as can be observed by comparing Figure 5c and Figure 6c, the overall system temperature estimate improved by relocating the Dewar. The H polarization channel system temperature, however, still exceeded that of V polarization channel(in this case by 20K).

At this point it was worth while to investigate the dependence of the H channel's system temperature on the drain current drawn by LNA #140D. With the idea that too much current draw may increase the noise Figure of the LNA, the drain current was

---

[2] These data were distributed to the bbdev group in an email on 4/10/2008

[3] At this point, we realized we should really be observing over the full spectrum expected to be utilized for VLBI2010

decreased to 20 mA and the Y factor experiment was repeated for H polarization only. The results are shown in Figure 7[4] and comparing Figures 6c and 7c the H pol. system temperature increased by ~5K.

To assess the repeatability of the experiment, the H pol. LNA's drain current was restored to 24.8 mA, the Y factor experiment was repeated again only for H pol. and the results shown in Figure 8[4] indicate that the system temperature observed in Figure 6c is reproduced in Figure 8c. This being the case, the H pol. LNA's drain current was then increased to 26.8 mA and both H and V polarization channels were measured for the Y factor experiment; the results are shown in Figure 9. As observed in Figure 9, the V pol. system temperature did not vary significantly(we didn't expect it to) while that of the H pol. channel decreased by ~5K.

Becoming suspicious that polarized RFI was introducing errors into the system temperature estimate, the entire linear polarization feed was rotated 90° to observe whether or not the channel temperature imbalance flipped polarizations. The results of this Y factor experiment are shown in Figure 10 and by comparing these with those of Figure 9 and noting little change, we conclude that polarized RFI did not appear to be introducing error.

At this point, the H pol. LNA's drain current was increased once again to 28.8 mA and the Y factor experiment was repeated only for H pol. in this case. The results in Figure 11[5] show that this had the affect of further decreasing the H pol. system temperature. So once again, the H pol. LNA drain current was decreased, this time to 29.8 mA, and the Y factor experiment was repeated for H pol. alone and the results recorded in Figure 12[5]. Comparing the results in Figure 12c with those in Figure 11c indicates that this served to only slightly decrease the H pol. system temperature.

As the final experiment of the day, the dependence of the system temperature estimates on the orientation of the hot load absorber was investigated. The H pol. LNA drain current was decreased to 24.8 mA to introduce a channel temperature imbalance and the hot load absorber was rotated 90 degrees from the orientation at which it was placed during Y factor measurement conducted throughout the day. By comparing the results shown in Figure 13c with those of Figure 6c (the measurement at Id = 24.8 mA with the absorber in it's normal orientation), the orientation of the absorber does not appear to impact the system temperature estimates.

To avoid having to read the above text to decipher the differences between respective measurements taken on this day, a compilation of the relative changes between the experiments is displayed in Table 2.

*4/18/2008*

Dewar system temperature estimates conducted up to this point in time were made without having the Dewar in the same configuration as the Dewar currently installed on the MV-3 antenna at GGAO. The Dewar was allowed to warm-up at which point the

[4] Since it was the bias settings for the H pol. LNA alone that were changed in this experiment, V pol was not measured. As such the V pol. results in this figure are a reproduction of those in figure 6.

.

[5] Since it was the bias settings for the H pol. LNA alone that were changed in this experiment, V pol was not measured. As such the V pol. results in this figure are a reproduction of those in figure 10.

plastic backing on the Lindgren feed were replaced with Cuming Microwave FFS-125 microwave absorber. The thermocouple place on one of the antenna's fins to monitor it's temperature was removed for concerns that it may be disrupting currents traveling down the broadside of the fin. Once these modifications were performed the Dewar was reassemble and cooled to ~18K. A Y factor experiment was conducted with the Dewar in the new configuration with the bias settings and results shown in Figure 14. As is quite obvious, the system temperature in both channels increased significantly with respect to Figure 9c (results of the Dewar in the old configuration with the same bias settings). The experiment was conducted at ~5 pm and at that time it was believed that the setting of the sun may have made it visible to the Dewar.

*4/22/2008*

As the results taken on 4/16/2008 were considered to be good results and were taken late morning to early afternoon, the Y factor experiment conducted on 4/18/2008 was conducted once again but this time at approximately 8:20 am while the sun was still relatively low and considered to be out of the Dewar's range of visibility. The results of the experiment are shown in Figure 14 and as is plainly obvious they differ very little from the results obtained on 4/18/2008.

## 4. Conclusions/Future Endeavors

Currently, we are not positive about why the recent modifications to the Dewar appear to have had such a negative impact on the system temperature estimates obtained on 4/16/2008. Our best hypothesis is that by chance the collections made on 4/16 were taken during a period when the area surrounding the Westford station was a relatively low RFI environment while the collections made on 4/18 and 4/22 were done so during a period when RFI levels were high. The Haystack, fortunately, is equipped with a screen room that we are considering for use to conduct the Y factor measurements in a RFI-controlled environment. To conduct these measurements, however, requires substituting the sky measurement for one of cold load. The availability of such a cold load at the Haystack or possibly Lincoln is currently being investigated.

## References

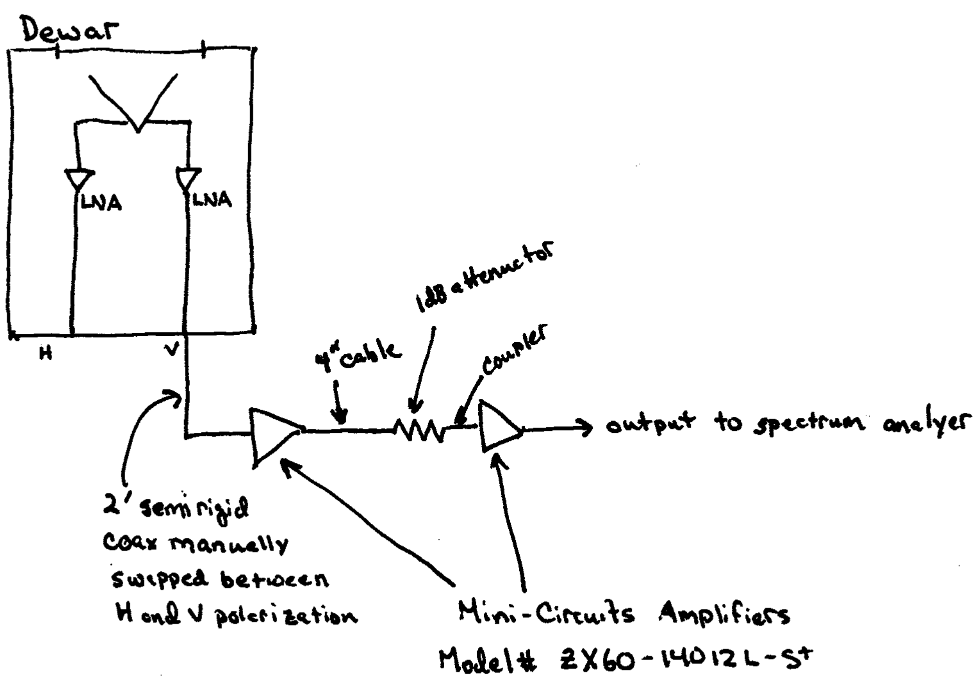
1. A. Niell, et al. "Results of first LNA test-1," 2007/10/03.

| LNA Serial # | Pol. Channel Pre 2008/04/08 | Pol. Channel Post 2008/04/08 | $V_d$ (V) | $V_{g1}$ (V) | $V_{g2}$ (V) | $I_d$ (mA) |
|---|---|---|---|---|---|---|
| 145D | Horizontal | Vertical | 1.2 | 0.7 | 0.7 | 20.6 |
| 140D | Vertical | Horizontal | 1.2 | 1.45 | 1.45 | 20.2 |

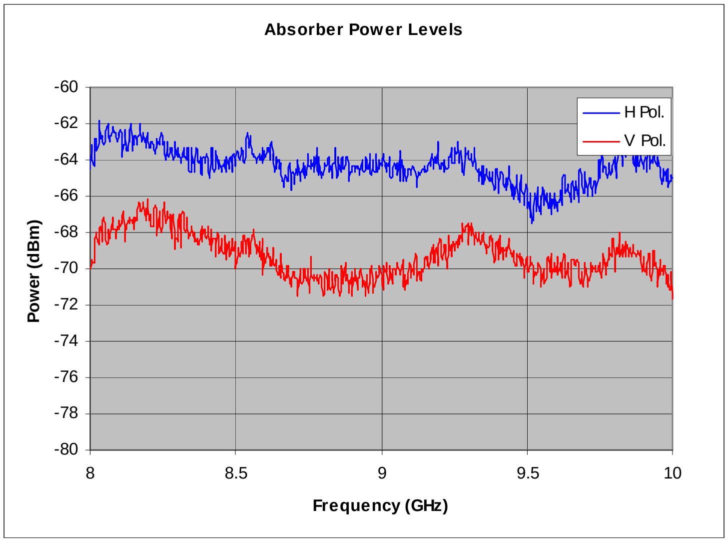
Table 1: 15 K Bias Settings and Polarizations associated with the Caltech LNAs used in the Dewar

| **Experiment Label** | **Variant** | **Measured Channels** |
|---|---|---|
| A | Experiment performed in Westford parking lot. Bias setting per Figure 6 ($I_d$ = 24.8 mA) | H,V |
| B | H Pol. $I_d$ decreased to 20.0 mA | H |
| C | H Pol. $I_d$ restored to 24.8 mA to assess measurement reproduction | H |
| F | H Pol. $I_d$ increased to 26.8 mA | H,V |
| G | Same bias as previous but rotated entire Dewar 90° to test for polarized RFI | H,V |
| H | H Pol. $I_d$ increased to 28.8 mA | H |
| I | H Pol. $I_d$ increased to 29.8 mA | H |
| K | H pol. LNA biased at $I_d$ = 24.8 mA; absorber rotated 90° for hot load measurement | H,V |

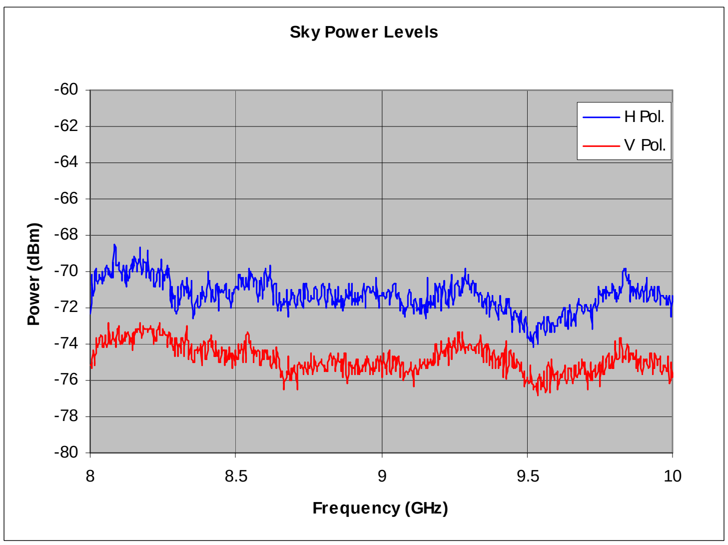
Table 2: Variation Among Experiments Taken on 4/16/2008 (figures 6-13)




Figures 1: Experimental Setup used for Dewar Y Factor Measurements



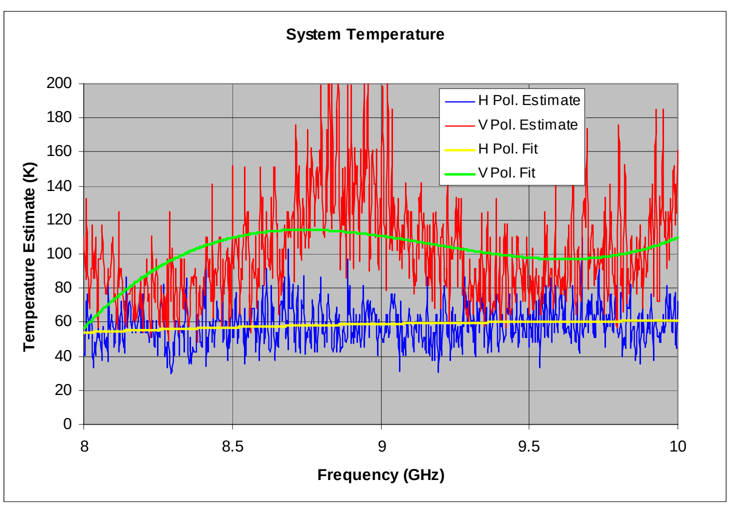

(a)




(b)

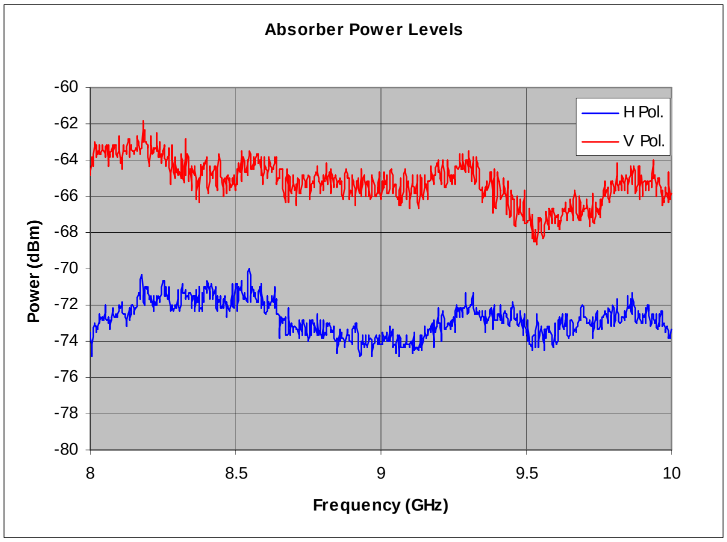
Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.2V | 1.2 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 15.4 mA | 16.9 mA |



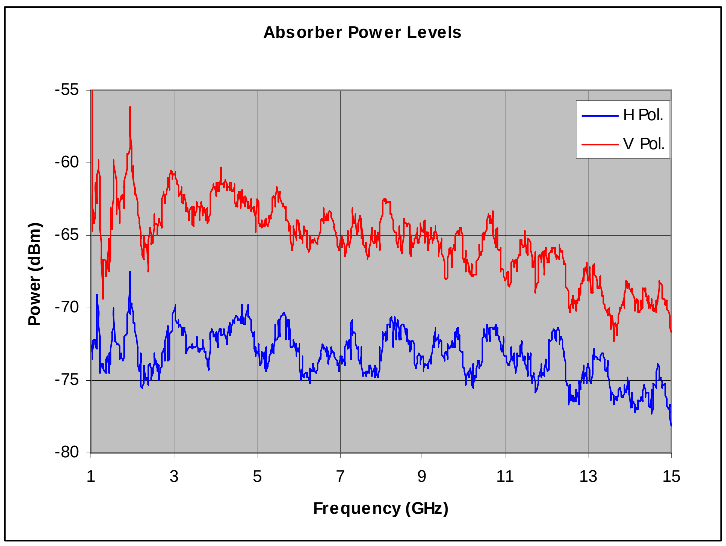

(c)

Figures 2: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/07/2008



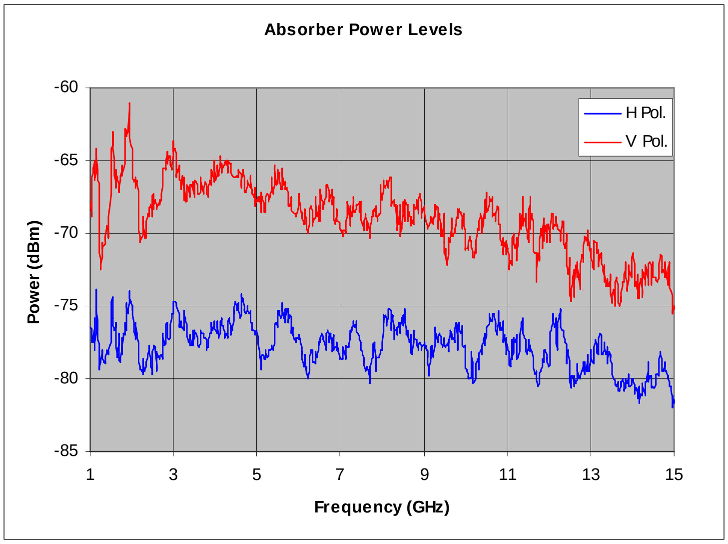

(a)

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.2V | 1.2 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 15.4 mA | 16.9 mA |




(b)

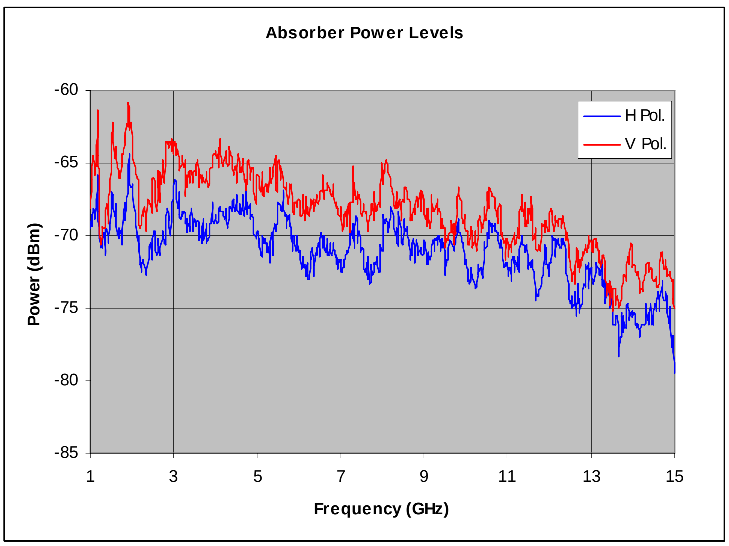
Figures 3: Hot Load Spectra Measured on 4/09/2008 over 8-10 GHz(a) and 1-15GHz(b)
Note: the H/V LNAs were swapped to the opposite channel prior to this collection.




Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.2 V | 1.2 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 15.4 mA | 16.9 mA |

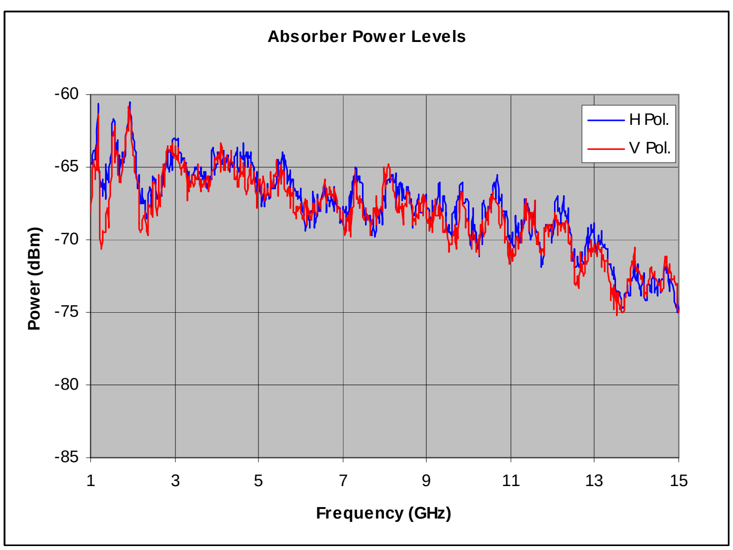
(a)




Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.45 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 20.0 mA | 20.0 mA |

(b)

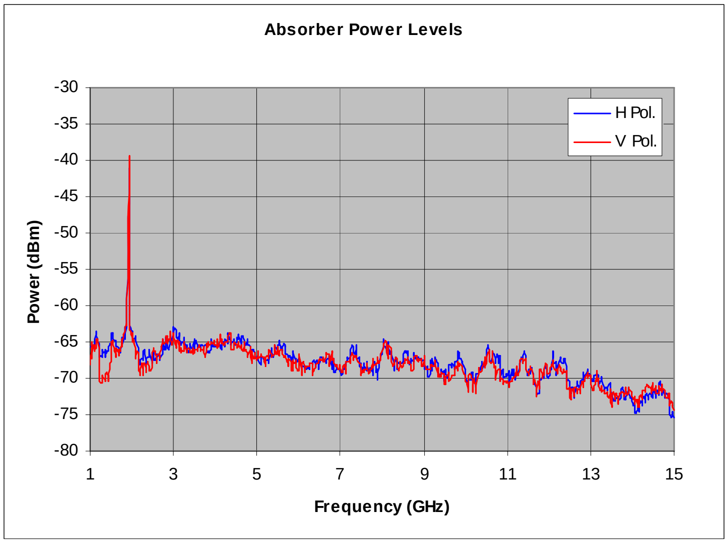



Bias Settings

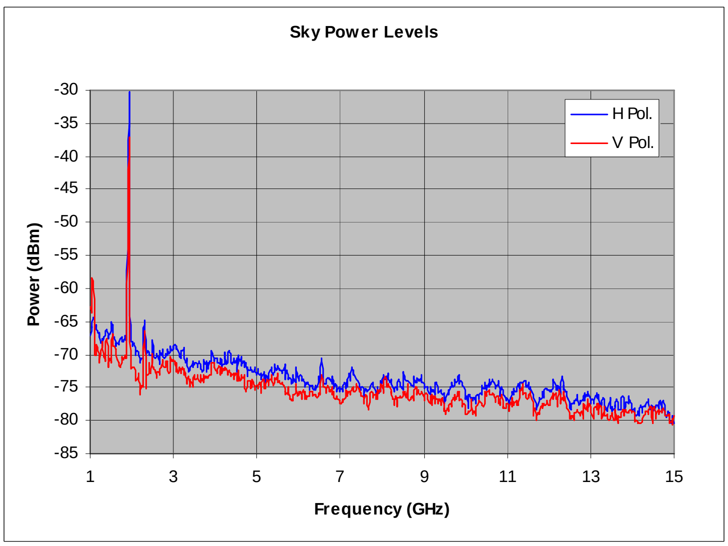
| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.66 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 24.3 mA | 20.0 mA |

(c)

Figures 4: Hot Load Spectra Collected 4/14/2008 at the Associated Bias Settings



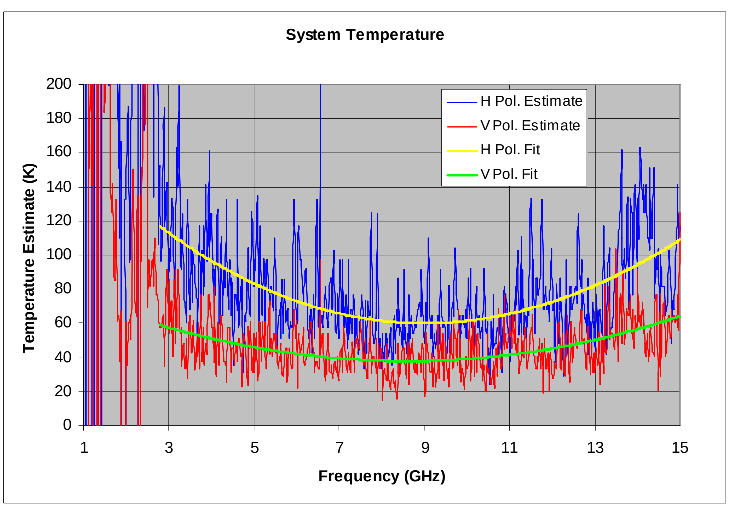

(a)




Bias Settings

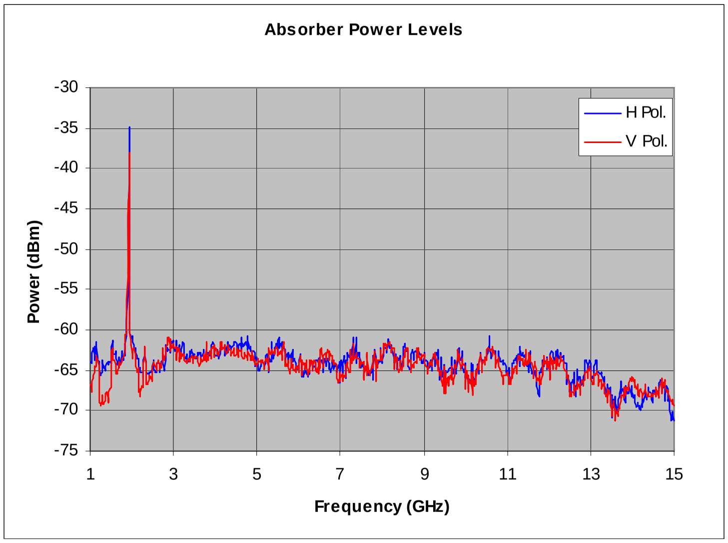
| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.66 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 24.8 mA | 20.0 mA |

(b)

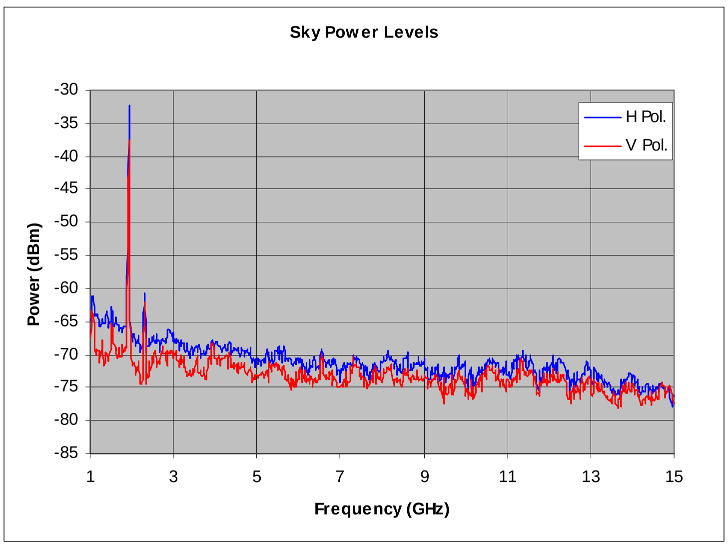



(c)

Figures 5: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/14/2008



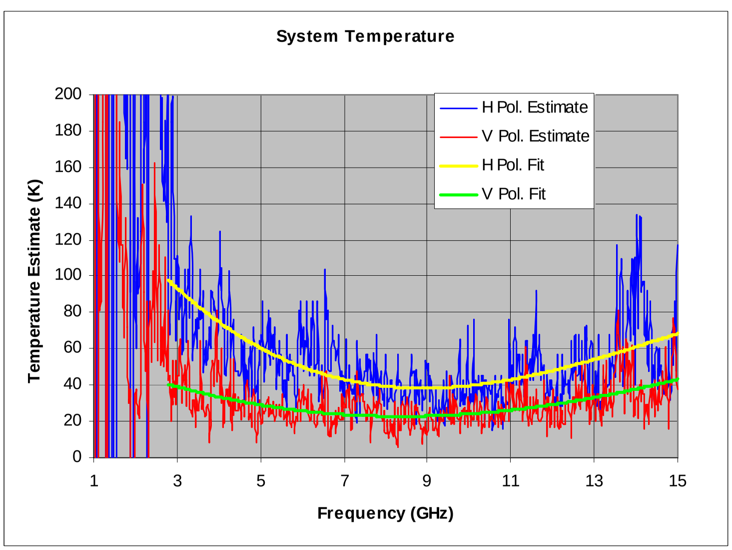

(a)




Bias Settings

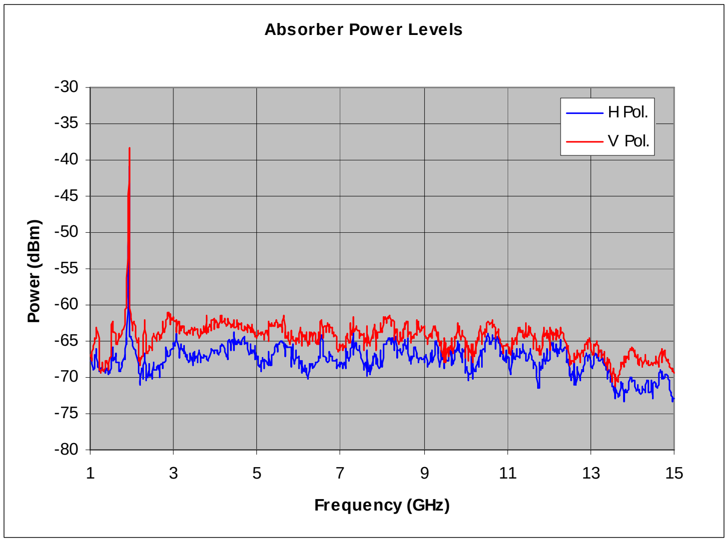
| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.66 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 24.8 mA | 20.0 mA |

(b)

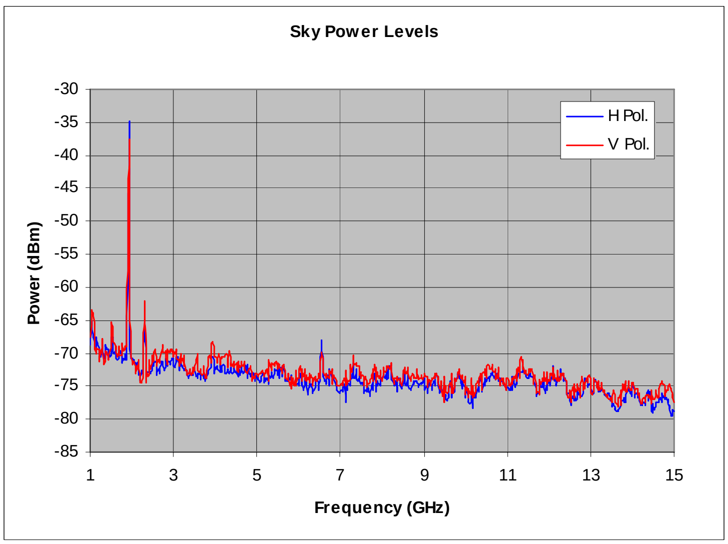



(c)

Figures 6: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp. A (see Table 2)



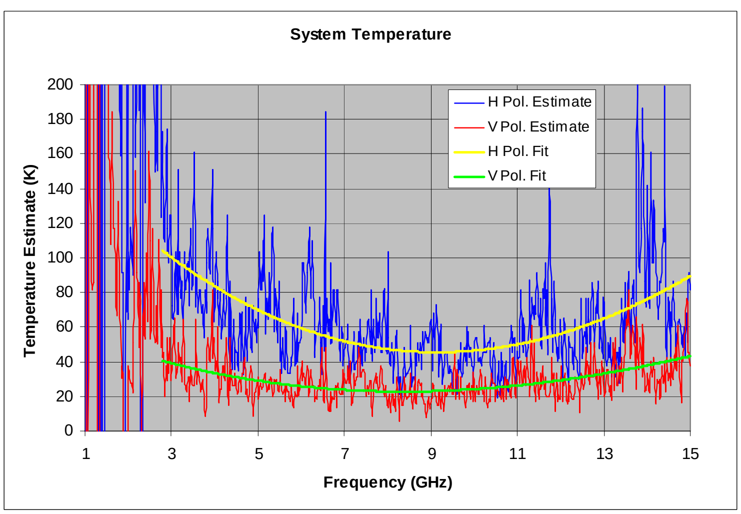

(a)




(b)

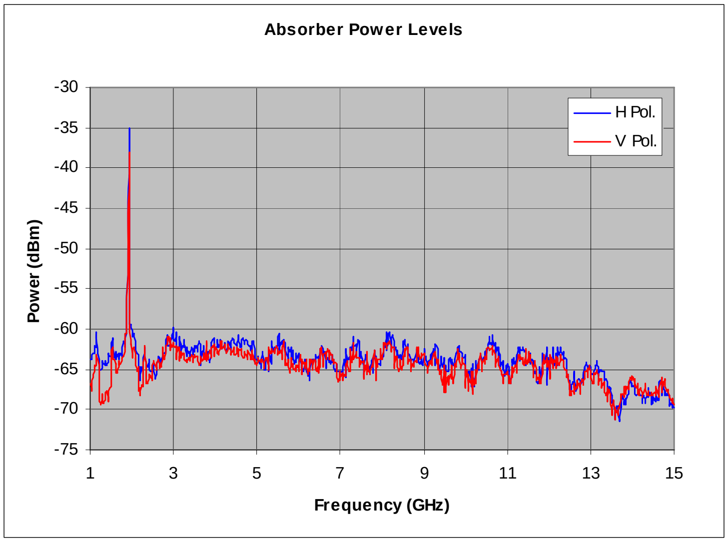
Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.43 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 20.0 mA | 20.0 mA |

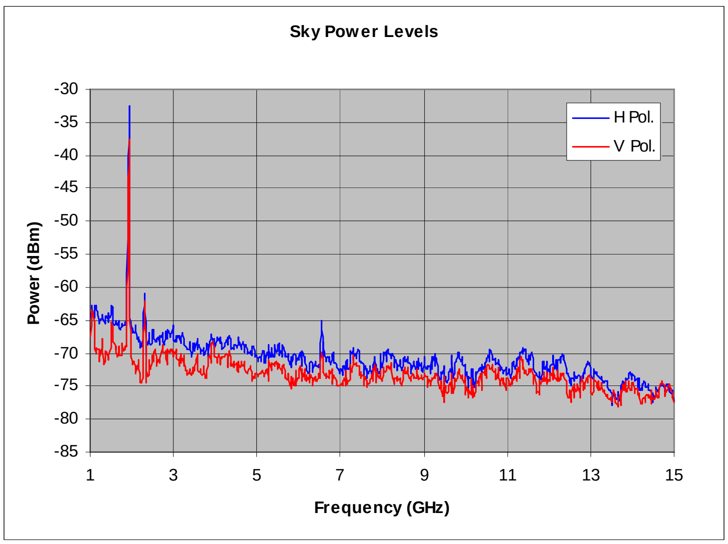



(c)

Figures 7: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp. B (see Table 2)



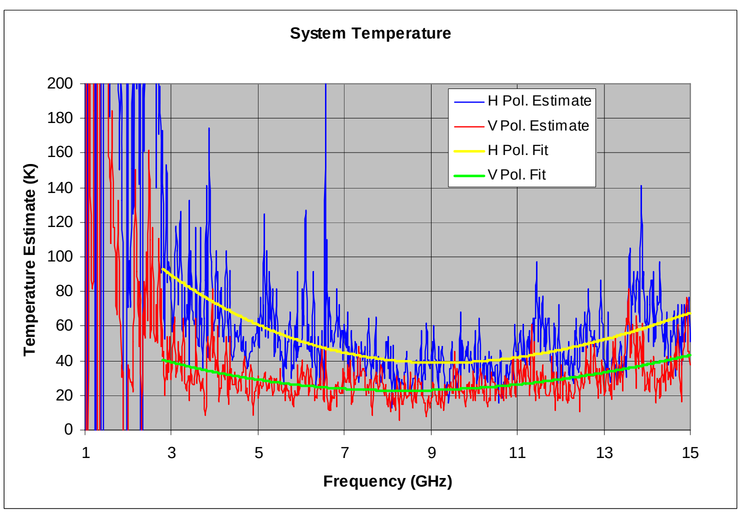

(a)




(b)

Bias Settings

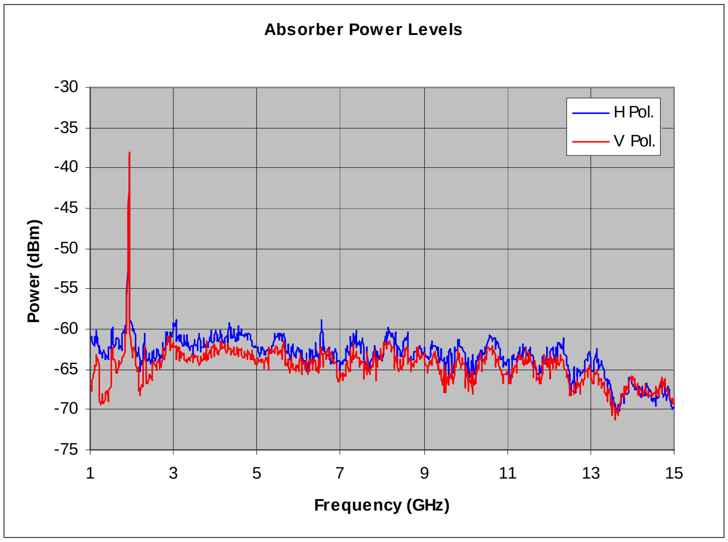
| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.66 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 24.8 mA | 20.0 mA |




(c)

Figures 8: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp C (see Table 2)

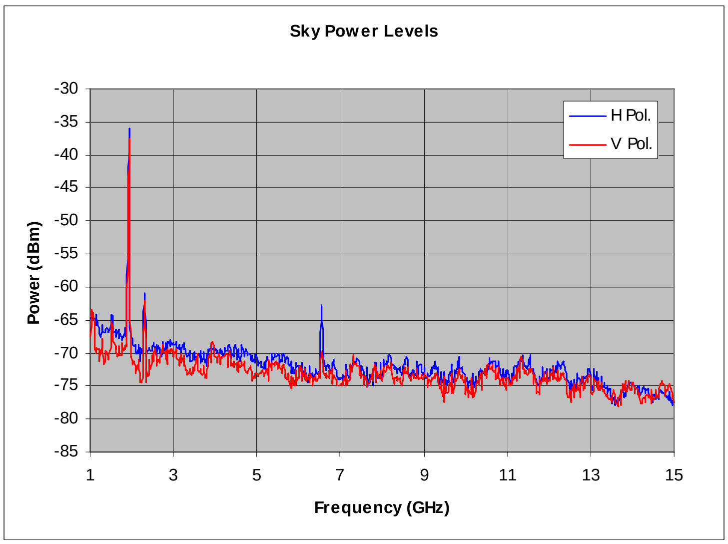
(a)



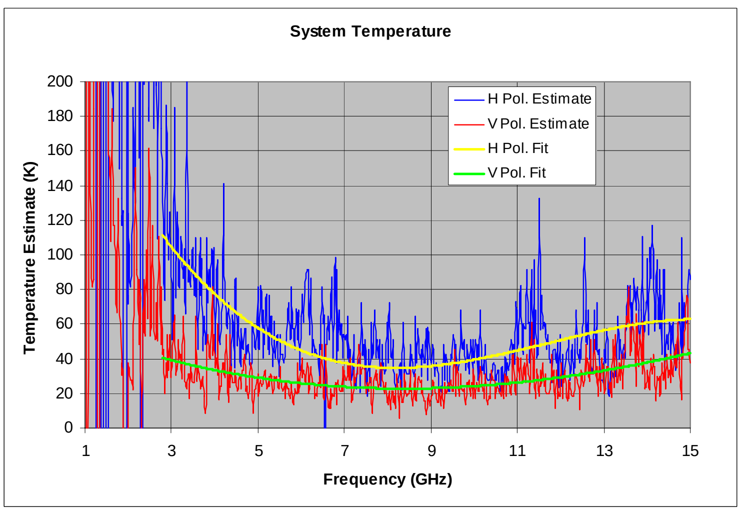

(a)

Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.70 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 26.8 mA | 20.0 mA |

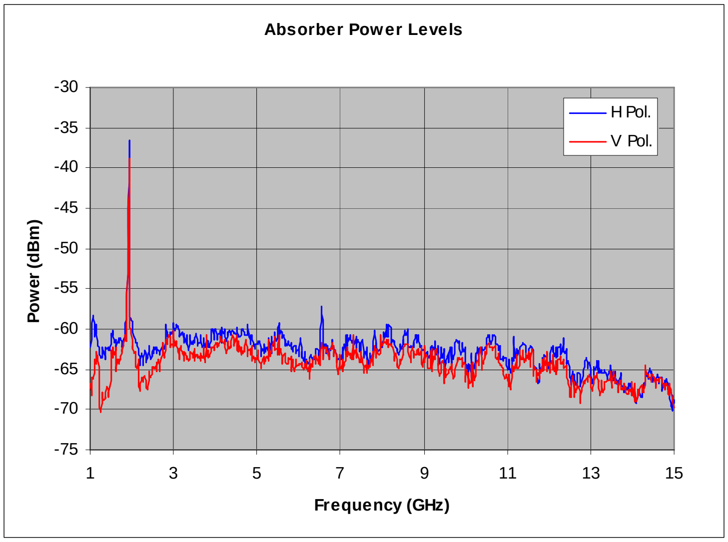



(b)

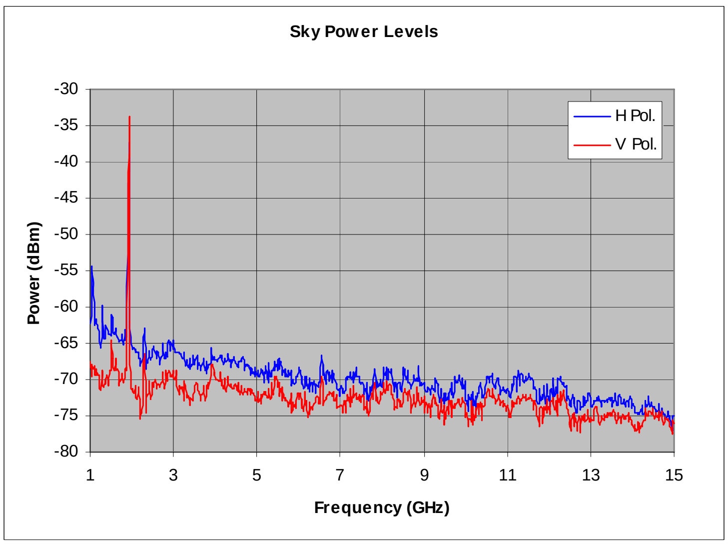



(c)

Figures 9: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp. D (see Table 2)



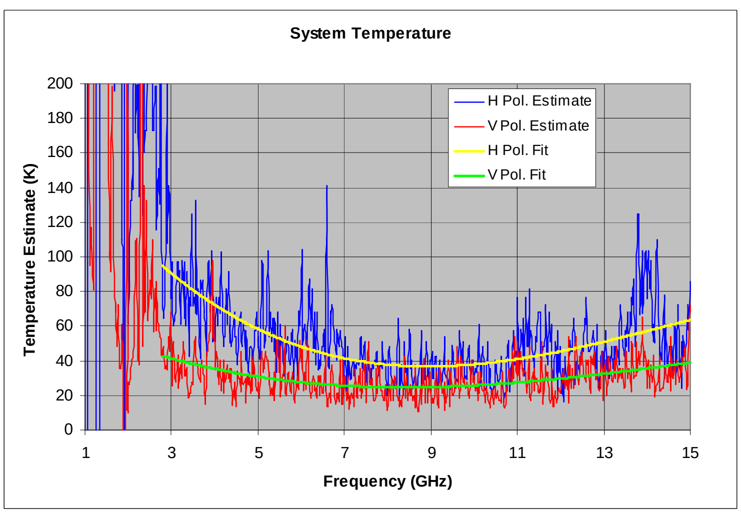

(a)




Bias Settings

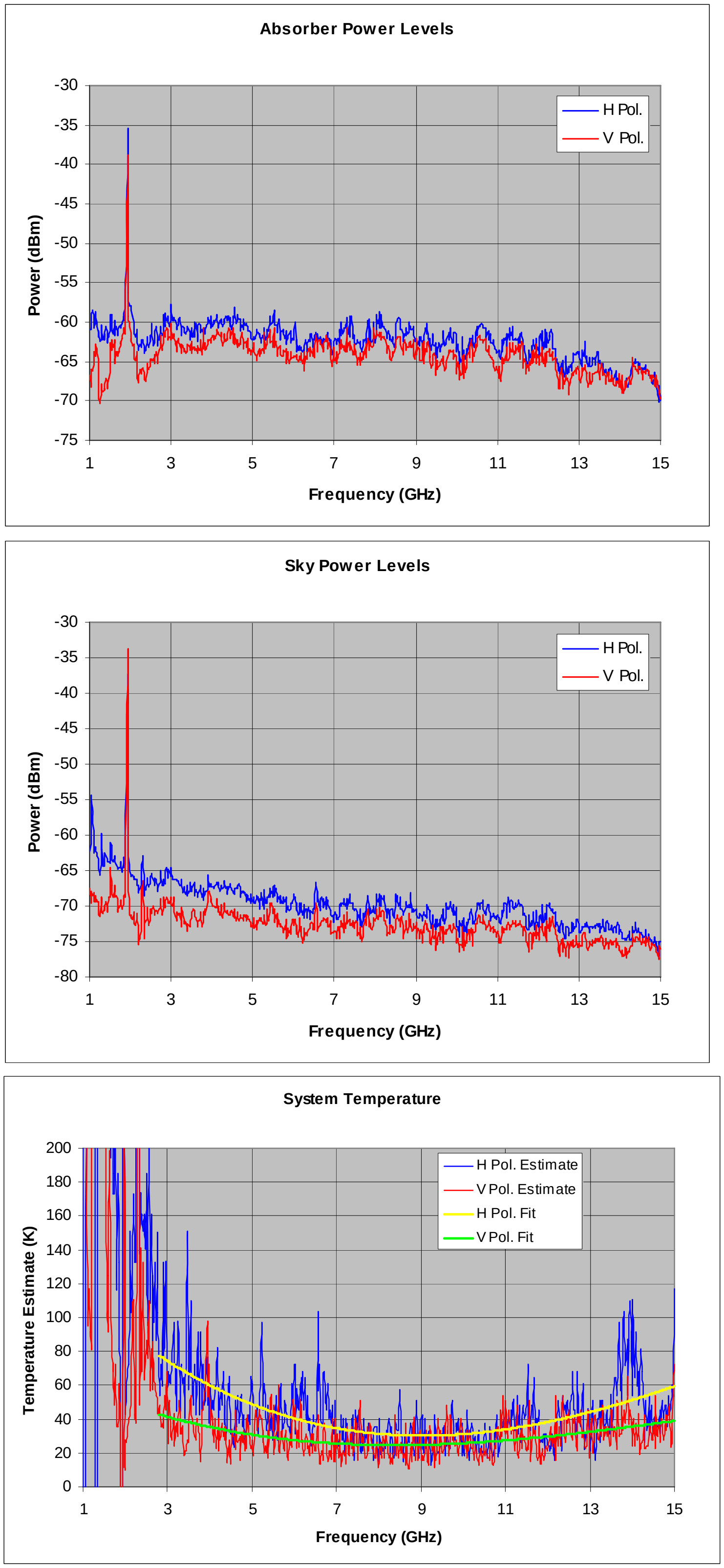
| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.70 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 26.8 mA | 20.0 mA |

(b)




(c)

Figures 10: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp. G (see Table 2)




(a)

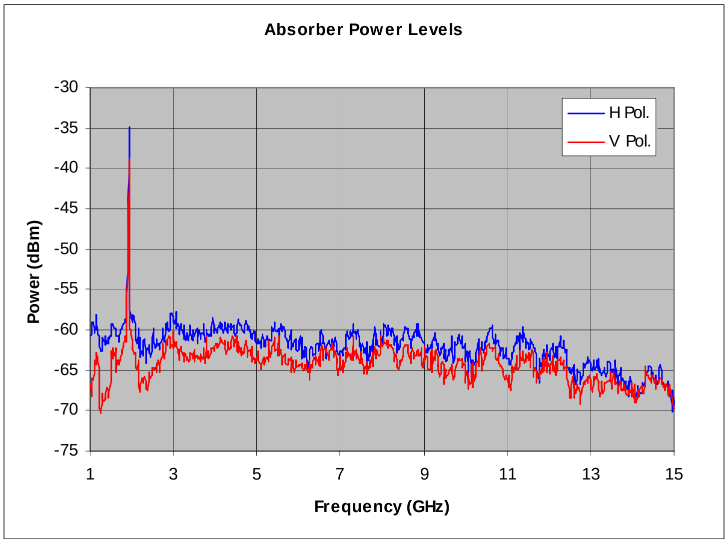
(b)

(c)

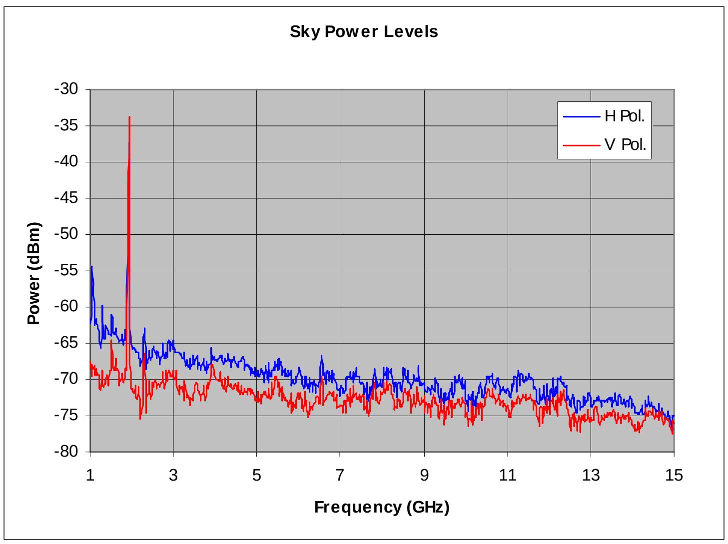
Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | ~ | 1.34V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 28.8 mA | 20.0 mA |

Figures 11: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp. H (see Table 2)



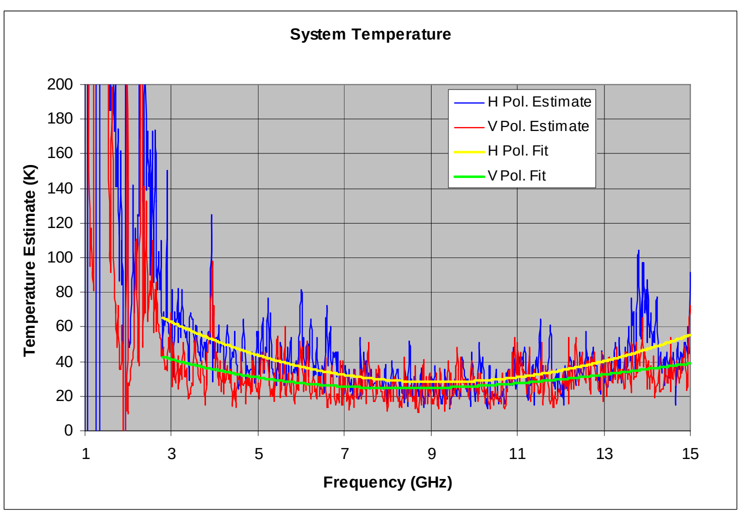

(a)




Bias Settings

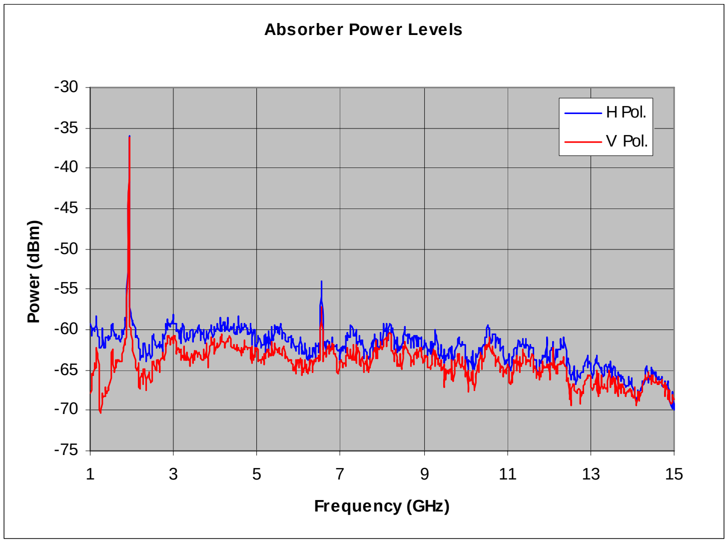
| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | ~ | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 29.8 mA | 20.0 mA |

(b)

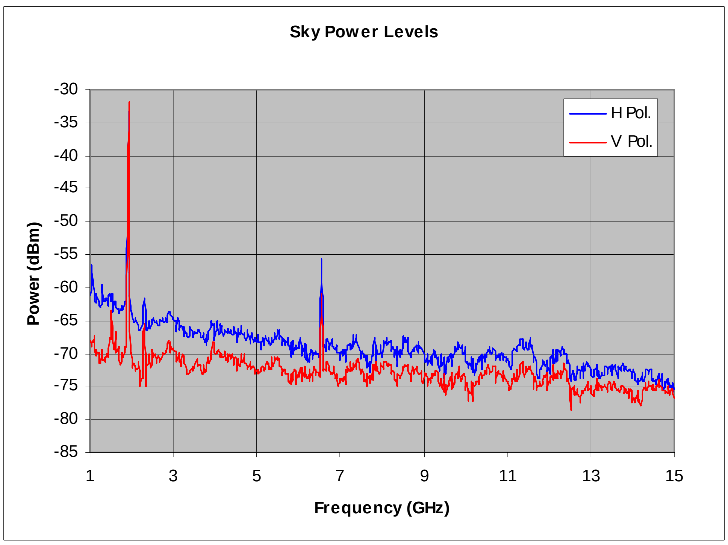



(c)

Figures 12: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp. I (see Table 2)



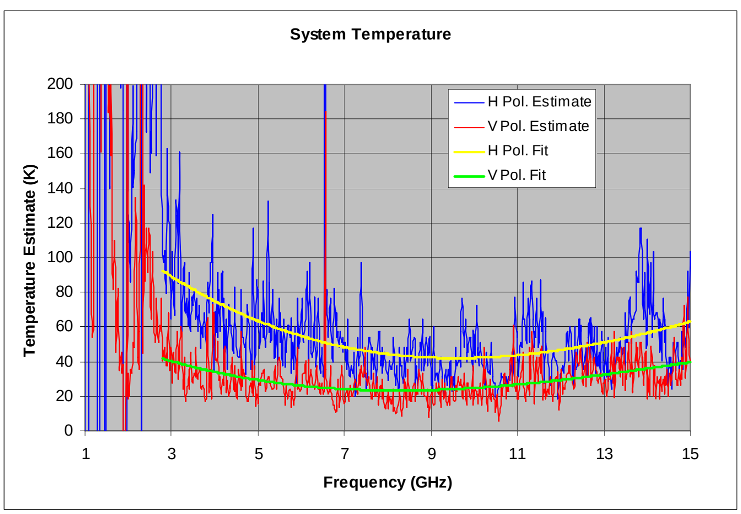

(a)




Bias Settings

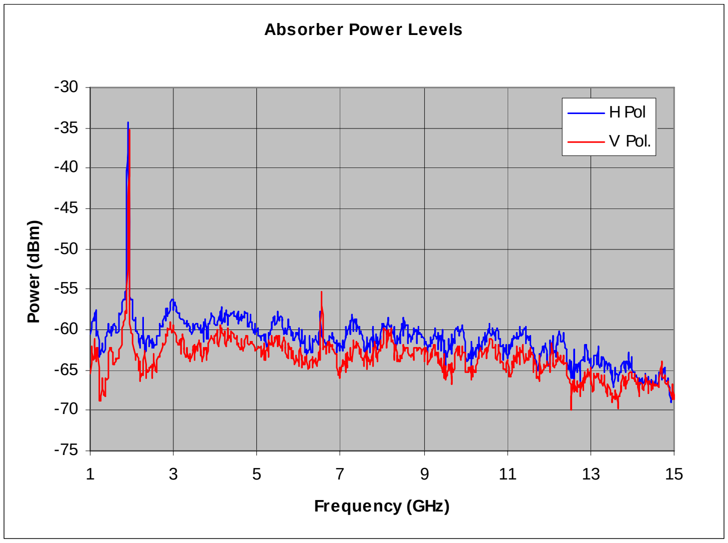
| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.66 | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 24.8 mA | 20.0 mA |

(b)




(c)

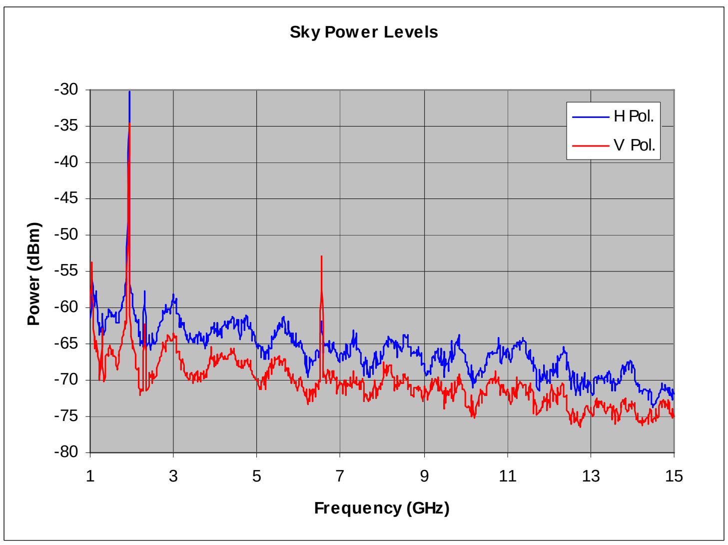
Figures 13: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/16/2008 Exp. K (see Table 2)



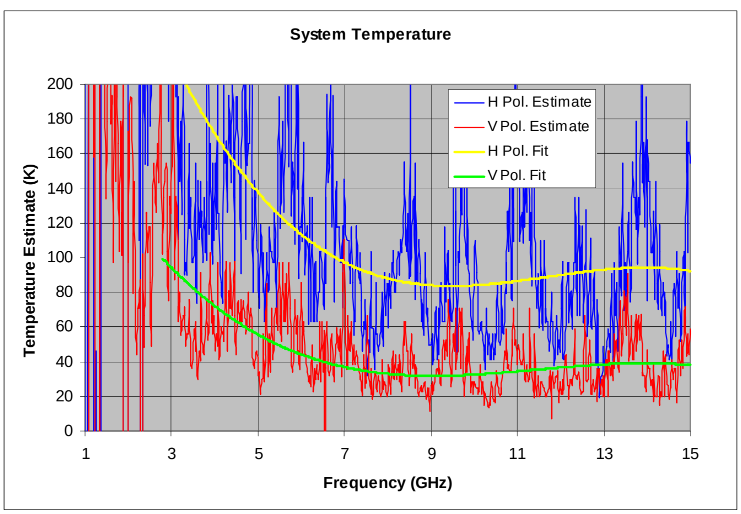

(a)

Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.70V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 26.8 mA | 20.0 mA |

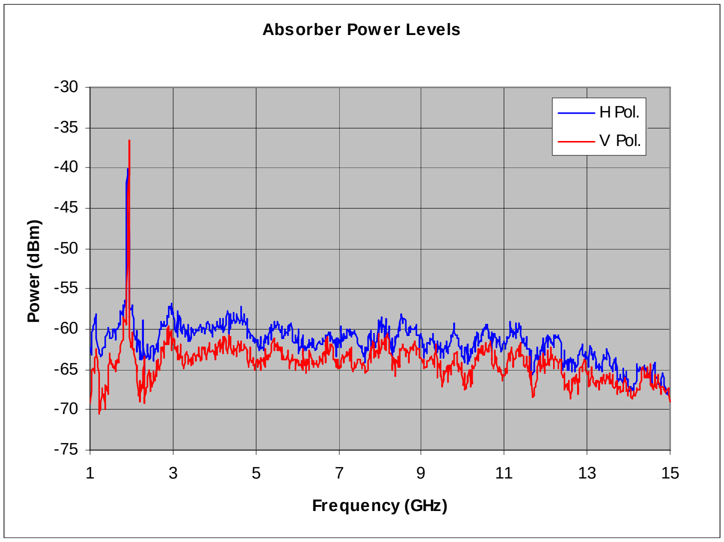



(b)

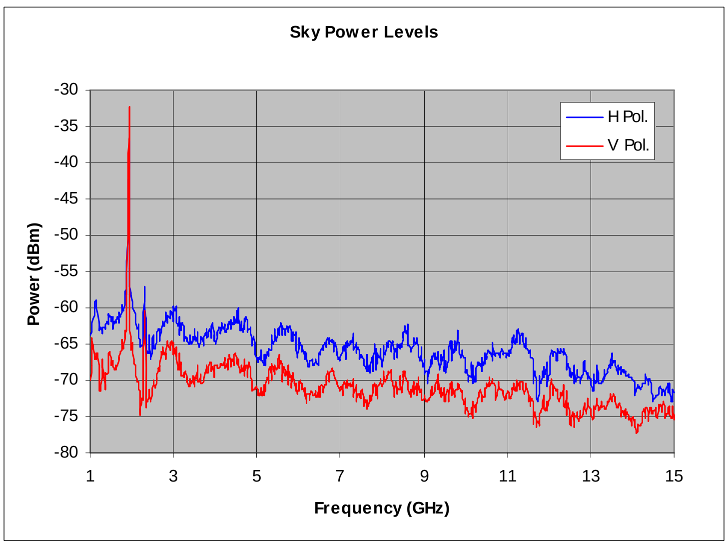



(c)

Figures 14: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/18/2008



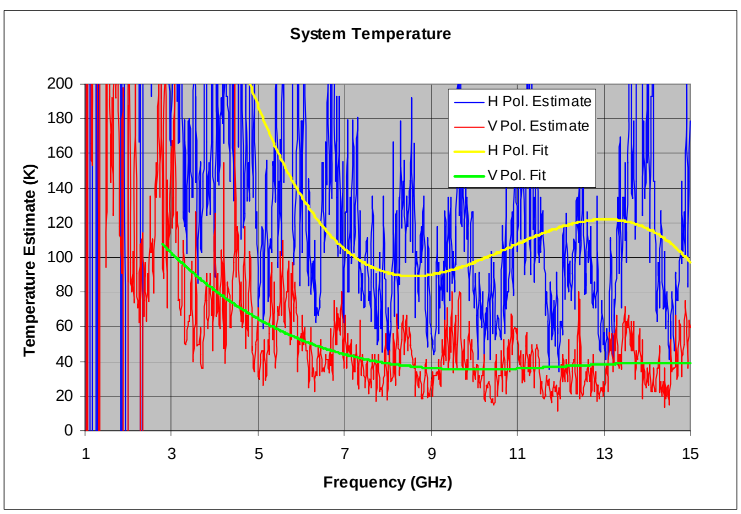

(a)




Bias Settings

| | LNA #140D | LNA #145D |
|---|---|---|
| Vd | 1.70 V | 1.34 V |
| Vg1 | 1.45 V | 0.7 V |
| Vg2 | 1.45 V | 0.7V |
| Id | 26.8 mA | 20.0 mA |

(b)




(c)

Figures 15: Y Factor Measurements(a),(b) and $T_{sys}$ Estimate (c) on 4/22/2008