August 2004 Lab Measurements of the Optical Drive Module Linearities

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1 Introduction

During the GBT Development Cycles 5 and 6 (June 16 – September 15, 2004) each Optical Drive Module (ODM) was removed from telescope operations one at a time. Each module was adjusted to minimize zero offsets and to reduce non-linearities in their gain. Each module's linearity was also measured in the lab. In this memo we report on the results of these measurements.

2 The Measurements

All the laboratory measurements used the spare noise source for the IF Rack as input. The errors effecting the measurements were: 1) deviations from linearity and the associated temperature effects of the power meter head; and 2) the bandwidth effects of the precision attenuator and associated changes in attenuation due to temperature effects. Two power meter heads were compared: 1) a diode detector type Agilent E4412A, which was used as the standard for all measurements; and 2) a thermocouple type HP 8485D, which is more linear but over a narrow range. Comparing the power heads, the E4412A was found to deviate less than 1% from linear over the range −35 dBm to −25 dBm. External pads were added to the ODM under test to ensure the output power was in the proper range.

Each ODM's linearity and square law response was measured with a bandwidth of 1280 MHz at frequency centers of 3.0 GHz and 6.0 GHz. For the 3 GHz measurement, the 500 MHz bandwidth mode of the noise source was selected. A 6/1280 MHz bandpass filter was inserted before the attenuator during the 6 GHz measurement to reduce the bandwidth effects of the attenuator outside of the measurement range.

Each ODM was adjusted for zero offset and a −1.0 V square law detected output for a −5.0 dBm power output. (This corresponds to ∼ 1 V for the IF Rack power level.) The attenuator reading of the ODM was recorded so that a measure of gain differences between units could be recorded. The power input to the E4412A was adjusted to −25 dBm with a 20 dB attenuator. The precision attenuator was changed in 1 dB steps. The power output reading and square law detected voltage output was recorded for each step. When the maximum range of 11 dB of the attenuator was reached, the ODM's attenuator was adjusted to return the output power to approximately −5 dBm. A 30 dB attenuator was then inserted giving a power reading of ∼ −35 dBm. The 11 dB of attenuation was removed 1 dB at a time with the power and voltage reading recorded for each step.

3 Optical Drive Modules

The results of the measurements for the linearity of the ODMs are presented in Tables 2–5. The first column is the amount by which the input power was changed during the measurements. The second column is the IF center frequency. The third through fifth columns in each table give the error in the output power as compared to the expected linear response (*i.e.* these columns are $\Delta P_{in} - \Delta P_{out}$) for the Optical Drive Modules. The attenuator levels were determined by inserting a known input power level into the attenuators and then using a power meter to determine the output power level. The results are also plotted in Figures 1–6.

IF Channel	serial number
1	1
2	5
3	4
4	6
5	
6	8
7	2
8	

Table 1: Relationship between IF Channel number and Optical Driver Serial Number on September 21, 2004. These pairing are subject to change without notice.

ΔP_{in} (dB)	ν_{IF} GHz	sn001 (dB)	sn002 (dB)	sn004 (dB)
11.004 ± 0.007	3	0.134	-0.078	0.002
10.010 ± 0.03	3	0.108	-0.084	-0.015
8.986 ± 0.006	3	0.108	-0.055	-0.001
7.993 ± 0.035	3	0.086	-0.061	-0.015
7.018 ± 0.035	3	0.109	-0.022	0.014
6.028 ± 0.013	3	0.082	-0.031	-0.002
5.006 ± 0.029	3	0.090	-0.007	0.014
4.014 ± 0.023	3	0.067	-0.017	-0.002
3.001 ± 0.054	3	0.090	0.015	0.028
2.010 ± 0.017	3	0.065	0.001	0.010
0.994 ± 0.046	3	0.068	0.013	0.017
-1.026 ± 0.009	3	0.015	0.018	-0.006
-2.047 ± 0.013	3	0.017	0.025	-0.004
-3.062 ± 0.015	3	0.016	0.031	-0.003
-4.051 ± 0.017	3	0.016	0.034	-0.003
-5.061 ± 0.018	3	0.012	0.036	-0.002
-6.068 ± 0.019	3	0.011	0.040	-0.001
-7.075 ± 0.019	3	0.010	0.041	-0.001
-8.020 ± 0.019	3	0.007	0.040	0.001
-9.028 ± 0.019	3	0.014	0.042	0.001
-10.034 ± 0.020	3	0.014	0.044	0.000
-11.042 ± 0.020	3	0.015	0.044	0.001

Table 2: Optical Driver Module linearity measurements. The first column is the amount by which the input power was changed. The second column is the IF center frequency (the bandwidth was 1280 MHz). The fourth through sixth columns give the error in the output power as compared to a linear response (*i.e.* $\Delta P_{in} - \Delta P_{out}$) for the Optical Drive Modules.

3.1 ODM sn001

The results for ODM sn001 are shown in Figure 1. ODM sn001 does not differ from linearity by more than 0.1 dB (2.3%) from -11 dB to 7 dB. This corresponds to a range from ~ 0.08 V to ~ 5 V for the IF Rack power level.

ODM sn001 does not differ from linearity by more than 0.043 dB (1%) from -11 dB to 0 dB. This corresponds to a range from ~ 0.08 V to 1 V for the IF Rack power level. Note that ODM sn001 does show a trend for gain compression above 0 dB. A linear fit to the ODM sn001 data with $\Delta P_{in} \geq 0$ dB results in

$$\Delta P_{out} \propto \Delta P_{in}^{0.992 \pm 0.002} \tag{1}$$

where ΔP_{in} is the change in the input power and ΔP_{out} is the change in the output power.

3.2 ODM sn002

The results for ODM sn002 are shown in Figure 2. ODM sn002 does not differ from linearity by more than 0.1 dB (2.3%) from -11 dB to 7 dB. This corresponds to a range from ~ 0.08 V to ~ 5 V for the IF Rack power level.

ODM sn002 does not differ from linearity by more than 0.043 dB (1%) from -11 dB to 5 dB. This corresponds to a range from ~ 0.08 V to ~ 3 V for the IF Rack power level. Note that ODM sn002 does show a trend for gain expansion above 3 dB. A linear fit to the ODM sn002 data with $\Delta P_{in} \geq 3$ dB results in

$$\Delta P_{out} \propto \Delta P_{in}^{1.015 \pm 0.002} \tag{2}$$

where ΔP_{in} is the change in the input power and

ΔP_{in} (dB)	$\nu_{\rm IF}$ GHz	sn001 (dB)	sn002 (dB)	sn004 (dB)
10.994 ± 0.030	6	0.077	-0.149	-0.042
10.084 ± 0.037	6	0.068	-0.139	-0.034
8.975 ± 0.030	6	0.110	-0.110	-0.023
8.060 ± 0.033	6	0.071	-0.094	-0.008
6.953 ± 0.009	6	0.055	-0.069	-0.001
6.048 ± 0.012	6	0.046	-0.055	0.002
4.957 ± 0.010	6	0.045	-0.036	0.008
4.050 ± 0.014	6	0.033	-0.026	0.008
2.904 ± 0.006	6	0.021	-0.012	0.009
2.000 ± 0.004	6	0.012	-0.008	0.005
0.904 ± 0.005	6	0.011	0.000	0.006
-0.915 ± 0.005	6	-0.001	-0.005	0.010
-2.013 ± 0.004	6	0.006	0.005	0.010
-2.932 ± 0.007	6	0.001	0.004	0.017
-4.068 ± 0.008	6	-0.002	0.013	0.023
-4.978 ± 0.010	6	-0.002	0.014	0.023
-6.077 ± 0.011	6	0.005	0.017	0.029
-6.982 ± 0.012	6	0.000	0.017	0.026
-8.089 ± 0.014	6	-0.008	0.018	0.030
-8.993 ± 0.014	6	-0.008	0.017	0.028
-10.084 ± 0.013	6	-0.005	0.018	0.026
-10.987 ± 0.012	6	-0.009	0.014	0.019

Table 3: Optical Driver Module linearity measurements. The first column is the amount by which the input power was changed. The second column is the IF center frequency (the bandwidth was 1280 MHz). The fourth through sixth columns give the error in the output power as compared to a linear response (*i.e.* $\Delta \mathrm{P_{in}} - \Delta \mathrm{P_{out}}$) for the Optical Drive Modules.

ΔP_{in} (dB)	$\nu_{\rm IF}$ GHz	sn005 (dB)	sn006 (dB)	sn008 (dB)
11.004 ± 0.007	3	-0.004	-0.014	-0.010
10.010 ± 0.03	3	-0.018	-0.033	0.070
8.986 ± 0.006	3	0.002	-0.011	-0.008
7.993 ± 0.035	3	-0.013	-0.033	0.070
7.018 ± 0.035	3	0.018	0.010	-0.070
6.028 ± 0.013	3	0.002	-0.015	0.017
5.006 ± 0.029	3	0.019	0.004	-0.054
4.014 ± 0.023	3	0.004	-0.008	0.034
3.001 ± 0.054	3	0.031	0.022	-0.103
2.010 ± 0.017	3	0.012	0.005	-0.014
0.994 ± 0.046	3	0.018	0.016	-0.094
-1.026 ± 0.009	3	0.016	-0.001	-0.010
-2.047 ± 0.013	3	0.018	-0.003	-0.019
-3.062 ± 0.015	3	0.020	-0.010	-0.024
-4.051 ± 0.017	3	0.021	-0.013	-0.028
-5.061 ± 0.018	3	0.021	-0.013	-0.031
-6.068 ± 0.019	3	0.023	-0.016	-0.032
-7.075 ± 0.019	3	0.022	-0.016	-0.033
-8.020 ± 0.019	3	0.022	-0.019	-0.034
-9.028 ± 0.019	3	0.022	-0.016	-0.035
-10.034 ± 0.020	3	0.021	-0.012	-0.036
-11.042 ± 0.020	3	0.019	0.013	-0.037

Table 4: Optical Driver Module linearity measurements. The first column is the amount by which the input power was changed. The second column is the IF center frequency (the bandwidth was 1280 MHz). The fourth through sixth columns give the error in the output power as compared to a linear response (*i.e.* $\Delta \mathrm{P_{in}} - \Delta \mathrm{P_{out}}$) for the Optical Drive Modules.

ΔP_{out} is the change in the output power.

3.3 ODM sn003

ODM sn003 is known to behave nonlinearly and has been taken out of service. It is awaiting the construction of better (and linear) amplifiers.

3.4 ODM sn004

The results for ODM sn004 are shown in Figure 3. ODM sn004 does not differ from linearity by more than 0.043 dB (1%) from -11 dB to $+11$ dB. This corresponds to a range from ~ 0.08 V to ~ 12.6 V for the IF Rack power level. ODM sn004 does show indications of gain expansion above ~ 5 dB.

3.5 ODM sn005

The results for ODM sn005 are shown in Figure 4. ODM sn005 does not differ from linearity by more than 0.1 dB (2.3%) from -11 dB to 9 dB. This corresponds to a range from ~ 0.08 V to ~ 7.9 V for the IF Rack power level. Note that ODM sn005 does

ΔP_{in} (dB)	ν_{IF} GHz	sn005 (dB)	sn006 (dB)	sn008 (dB)
10.994 ± 0.030	6	-0.082	-0.030	0.000
10.084 ± 0.037	6	-0.102	-0.035	0.000
8.975 ± 0.030	6	-0.080	-0.019	0.000
8.060 ± 0.033	6	-0.085	-0.008	0.000
6.953 ± 0.009	6	-0.023	0.000	0.000
6.048 ± 0.012	6	-0.030	0.001	0.000
4.957 ± 0.010	6	-0.020	0.003	0.000
4.050 ± 0.014	6	-0.029	0.007	0.000
2.904 ± 0.006	6	0.011	0.006	0.000
2.000 ± 0.004	6	0.005	0.005	0.000
0.904 ± 0.005	6	0.010	0.002	0.000
-0.915 ± 0.005	6	-0.005	0.001	0.000
-2.013 ± 0.004	6	0.000	0.000	0.000
-2.932 ± 0.007	6	-0.001	0.008	0.000
-4.068 ± 0.008	6	0.007	0.015	0.000
-4.978 ± 0.010	6	0.001	0.020	0.000
-6.077 ± 0.011	6	0.011	0.019	0.000
-6.982 ± 0.012	6	0.003	0.024	0.000
-8.089 ± 0.014	6	-0.002	0.021	0.000
-8.993 ± 0.014	6	-0.007	0.021	0.000
-10.084 ± 0.013	6	-0.003	0.016	0.000
-10.987 ± 0.012	6	-0.005	0.017	0.000

Table 5: Optical Driver Module linearity measurements. The first column is the amount by which the input power was changed. The second column is the IF center frequency (the bandwidth was 1280 MHz). The fourth through sixth columns give the error in the output power as compared to a linear response (*i.e.* $\Delta P_{in} - \Delta P_{out}$) for the Optical Drive Modules.

show a possible trend for gain expansion above 3 dB.

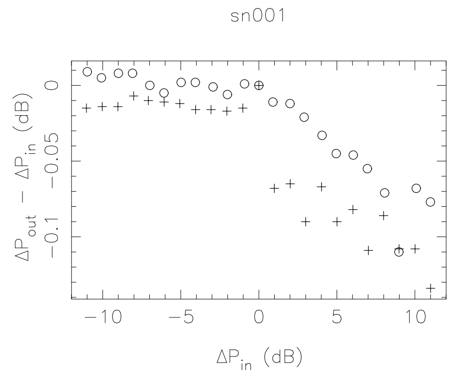

Figure 1: Difference in output power relative to the expected linear behavior as the input power is changed for ODM sn001. The data represented by the plus signs had an input signal with a center frequency of 3000 MHz while the data represented by the circles had an input signal with a center frequency of 6000 MHz. The bandwidth for both sets of data was 1280 MHz.

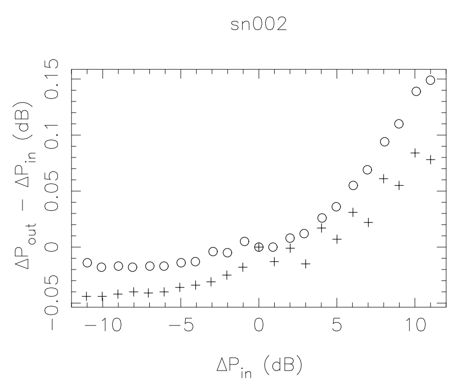

Figure 2: Same as Figure 1 but for ODM sn002.

3.6 ODM sn006

The results for ODM sn006 are shown in Figure 5. ODM sn006 does not differ from linearity by more than 0.04 dB (0.9%) from −11 dB to +11 dB. This corresponds to a range from ~ 0.08 V to ~ 12.6 V for the IF Rack power level.

3.7 ODM sn007

ODM sn007 is known to behave nonlinearly and has been taken out of service. It is awaiting the construction of better (and linear) amplifiers.

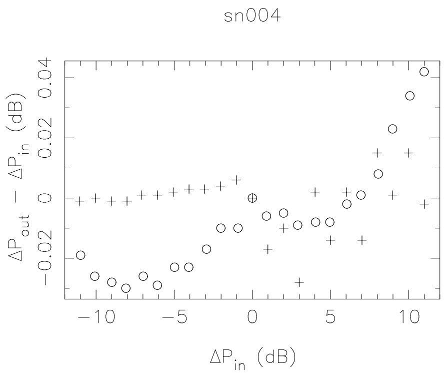

Figure 3: Same as Figure 1 but for ODM sn004.

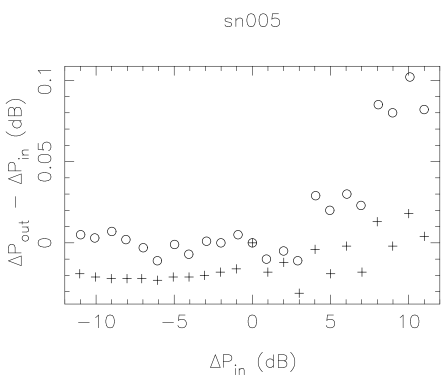

Figure 4: Same as Figure 1 but for ODM sn005.

3.8 ODM sn008

The results for ODM sn008 are shown in Figure 6. ODM sn008 does not differ from linearity by more than 0.04 dB (0.9%) from −11 dB to 0 dB. This corresponds to a range from ~ 0.08 V to ~ 1 V for the IF Rack power level. Above 0 dB ODM sn008 behaves a bit erratically but remains within ~ 0.1 dB (2.3%) from linear.

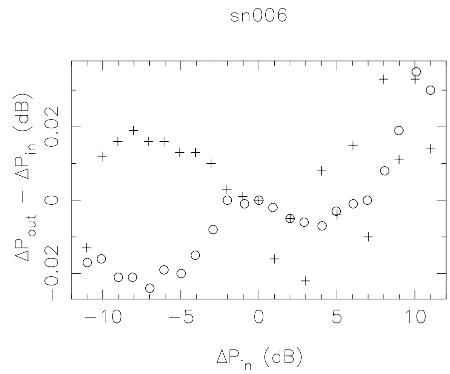

Figure 5: Same as Figure 1 but for ODM sn006.

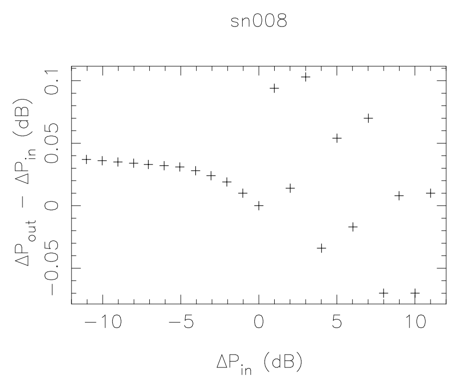

Figure 6: Same as Figure 1 but for ODM sn008.

4 Square-Law Detectors

The results of the linearity measurements for the Square-Law detectors for each ODM are presented in Tables 6–9. The errors are typically under 1% except for the largest changes in the input power levels (the highest IF Rack power levels). These results are also presented in Figures 7–12.

4.1 ODM sn001

The Square-Law detector linearity results for ODM sn001 are shown in Figure 7. The Square-Law detec-

ΔP_{in} (dB)	ν_{IF} GHz	sn001 (Pct.)	sn002 (Pct.)	sn004 (Pct.)
11	3	21.23	3.19	5.97
10	3	0.76	1.03	-0.14
9	3	-1.14	0.77	-0.23
8	3	-1.00	0.55	-0.22
7	3	-0.81	0.47	-0.20
6	3	-0.65	0.41	-0.12
5	3	-0.48	0.35	-0.04
4	3	-0.29	0.28	-0.01
3	3	-0.17	0.24	0.05
2	3	-0.02	0.15	0.06
1	3	0.01	0.10	-0.01
-1	3	0.00	0.00	0.00
-2	3	-0.17	0.00	-0.20
-3	3	-0.39	-0.11	-0.35
-4	3	-0.42	-0.38	-0.45
-5	3	-0.46	-0.48	-0.34
-6	3	-0.49	-0.57	-0.39
-7	3	-0.47	-0.69	-0.51
-8	3	-0.47	-0.77	-0.56
-9	3	-0.48	-0.82	-0.26
-10	3	-0.63	-0.92	-0.52
-11	3	-0.68	-1.14	-0.79

Table 6: Square-Law Detector linearity measurements.

ΔP_{in} (dB)	ν_{IF} GHz	sn001 (Pct.)	sn002 (Pct.)	sn004 (Pct.)
11	6	9.847	12.53	6.39
10	6	-1.110	-1.20	-0.78
9	6	-0.367	-1.24	-0.90
8	6	-0.982	-1.01	-0.60
7	6	-0.774	-0.85	-0.38
6	6	-0.591	-0.65	-0.27
5	6	-0.409	-0.48	-0.06
4	6	-0.290	-0.29	0.03
3	6	-0.170	-0.15	0.20
2	6	-0.115	-0.04	0.14
1	6	0.007	-0.06	0.25
-1	6	0.000	0.00	0.00
-2	6	-0.144	0.00	-0.07
-3	6	-0.193	-0.20	-0.18
-4	6	-0.389	-0.29	-0.21
-5	6	-0.465	-0.41	-0.14
-6	6	-0.481	-0.52	-0.25
-7	6	-0.549	-0.54	-0.14
-8	6	-0.568	-0.74	-0.29
-9	6	-0.603	-0.78	-0.07
-10	6	-0.574	-0.84	0.30
-11	6	-0.614	-0.86	0.53

Table 7: Square-Law Detector linearity measurements.

tor is linear to within 1% from -11 dB to 7 dB. This corresponds to an IF Rack power level range from 0.08 V to $\sim$ 5 V.

4.2 ODM sn002

The Square-Law detector linearity results for ODM sn002 are shown in Figure 8. The Square-Law detector is linear to within 1% from -10 dB to 7 dB. This corresponds to an IF Rack power level range from 0.1 V to $\sim$ 5 V.

4.3 ODM sn004

The Square-Law detector linearity results for ODM sn004 are shown in Figure 9. The Square-Law detector is linear to within 1% from -11 dB to 10 dB. This corresponds to an IF Rack power level range from 0.08 V to $\sim$ 10 V.

4.4 ODM sn005

The Square-Law detector linearity results for ODM sn005 are shown in Figure 10. The Square-Law detector is linear to within 1% from -11 dB to 6 dB. This corresponds to an IF Rack power level range from 0.08 V to $\sim$ 4 V.

4.5 ODM sn006

The Square-Law detector linearity results for ODM sn006 are shown in Figure 11. The Square-Law detector is linear to within 1% from -10 dB to 6 dB. This corresponds to an IF Rack power level range from 0.1 V to $\sim$ 4 V.

ΔP_{in} (dB)	$\nu_{\rm IF}$ GHz	sn005 (Pct.)	sn006 (Pct.)	sn008 (Pct.)
11	3	3.108	13.048	11.31
10	3	2.175	1.199	-0.09
9	3	1.765	1.550	-0.29
8	3	1.352	1.017	-0.27
7	3	1.150	1.091	-0.27
6	3	0.926	0.027	-0.20
5	3	0.776	-0.078	-0.12
4	3	0.592	-0.244	-0.06
3	3	0.442	-0.373	0.01
2	3	0.300	-0.470	-0.02
1	3	0.176	-0.639	0.03
-1	3	0.000	0.000	0.00
-2	3	-0.051	-0.182	-0.15
-3	3	-0.350	-0.245	-0.27
-4	3	-0.443	-0.577	-0.45
-5	3	-0.517	-0.625	-0.56
-6	3	-0.581	-0.596	-0.59
-7	3	-0.660	-0.787	-0.56
-8	3	-0.495	-0.744	-0.62
-9	3	-0.496	-0.859	-0.73
-10	3	-0.439	-0.936	-0.68
-11	3	-0.588	-1.065	-0.64

Table 8: Square-Law Detector linearity measurements.

ΔP_{in} (dB)	$\nu_{\rm IF}$ GHz	sn005 (Pct.)	sn006 (Pct.)	sn008 (Pct.)
11	6	8.648	18.892	11.26
10	6	-1.479	0.196	-0.13
9	6	-1.614	-0.328	-0.32
8	6	-1.812	-0.271	-0.32
7	6	-0.642	-0.256	-0.25
6	6	-0.636	-0.160	-0.22
5	6	-0.618	-0.091	-0.09
4	6	-0.663	-0.005	0.00
3	6	0.134	0.040	0.07
2	6	0.125	0.060	0.11
1	6	0.079	0.084	0.09
-1	6	0.000	0.096	0.00
-2	6	0.698	-0.157	-0.15
-3	6	0.466	-0.399	-0.22
-4	6	0.271	-0.565	-0.38
-5	6	0.116	-0.493	-0.51
-6	6	-0.005	-0.609	-0.55
-7	6	-0.011	-0.344	-0.62
-8	6	-0.123	-0.223	-0.57
-9	6	-0.030	-0.338	-0.64
-10	6	-0.168	-0.447	-0.58
-11	6	-0.162	-0.412	-0.55

Table 9: Square-Law Detector linearity measurements.

4.6 ODM sn008

The Square-Law detector linearity results for ODM sn008 are shown in Figure 12. The Square-Law detector is linear to within 1% from -11 dB to 10 dB. This corresponds to an IF Rack power level range from 0.08 V to $\sim$ 10 V.

5 Observational Consequences

ODM sn001 (current IF Channel 1) is OK to use below $\sim$ 5 V IF Rack power if no more than 2.3% gain errors are desired. The observer should not use ODM sn001 if they want to introduce no more than 1% gain error into their measurements.

ODM sn002 (current IF Channel 7) should be used below $\sim$ 3 V IF Rack power if the observer wishes to have no more than 1% gain errors. Below $\sim$ 5 V IF Rack power the observer can expect 2.3% gain errors or less.

ODM sn004 (current IF Channel 3) is OK to use below $\sim$ 10 V IF Rack power and will produce less than 1% error.

ODM sn005 (current IF Channel 2) will produce less than 1% gain errors below $\sim$ 4 V IF Rack power. It can be used below $\sim$ 7.9 V IF Rack power if $\leq$ 2.3% gain errors are acceptable.

ODM sn006 (current IF Channel 4) will produce less than 1% gain errors below $\sim$ 4 V IF Rack power. It can be used below $\sim$ 10 V IF Rack power if $\leq$ 2.3% gain errors are acceptable.

ODM sn008 (current IF Channel 6) is OK to use below $\sim$ 10 V IF Rack power if no more than 2.3% gain errors are desired. The observer should not use

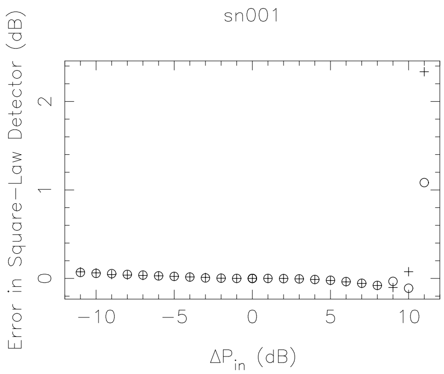

Figure 7: Error in the Square-Law detector output versus the expected linear behavior as the input power is changed for ODM sn001. The data represented by the plus signs had an input signal with a center frequency of 3000 MHz while the data represented by the circles had an input signal with a center frequency of 6000 MHz. The bandwidth for both sets of data was 1280 MHz.

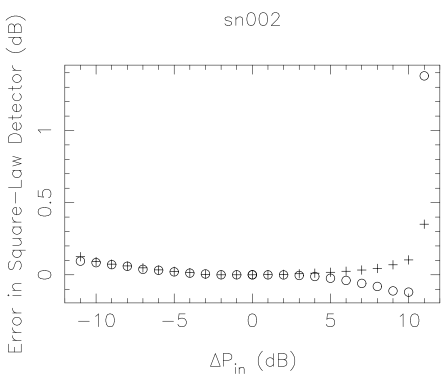

Figure 8: Same as Figure 7 but for ODM sn002.

ODM sn008 if they want to introduce no more than 1% gain error into their measurements.

At higher frequencies it has become customary to balance the IF Rack to a target level of ~ 3 V. The reasoning behind this was to get enough power to the backends, especially for widely separated frequencies,

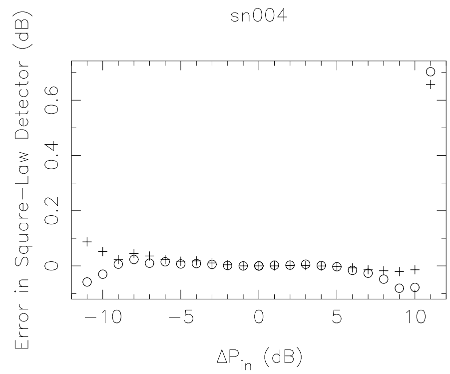

Figure 9: Same as Figure 7 but for ODM sn004.

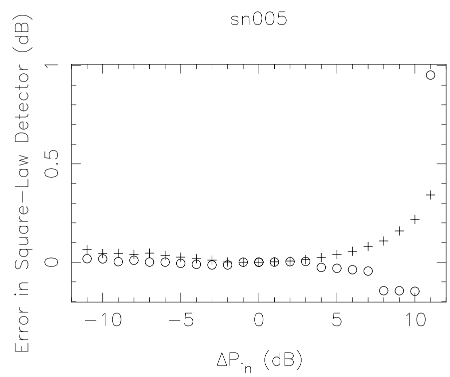

Figure 10: Same as Figure 7 but for ODM sn005.

in order that the backends could be balanced. We see that in many cases this could lead to significant gain errors in the data.

If gain errors up to 3.5% are acceptable to the observer then they can use the entire IF Rack voltage range with impunity. If the observers desire $\leq 2.3\%$ gain errors from the ODMs then they just need to make sure that no IF Rack power level exceeds ~ 4 V. In order for observers to achieve $\leq 1\%$ gain errors from the ODMs several changes need to take place. These are: 1) the observers need to set the IF Rack target levels lower – in the $1-2$ V range and they

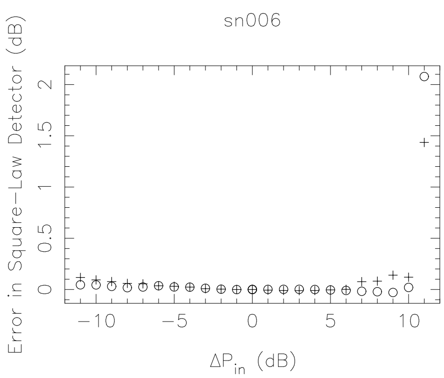

Figure 11: Same as Figure 7 but for ODM sn006.

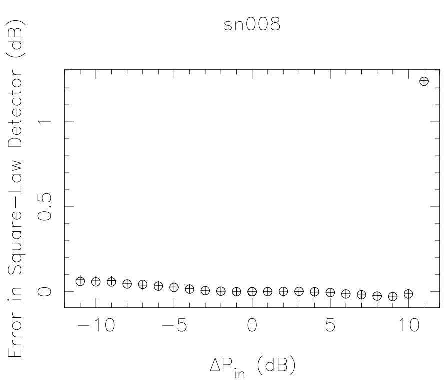

Figure 12: Same as Figure 7 but for ODM sn008.

need to keep this ≤ 3 V; and 2) ODM modules need to be moved around so that one module that is OK for $\leq 1\%$ errors is available for each polarization of two beams (*i.e.* four signals).

Re-arranging of the ODMs to maximize the ability to make observations with the lowest gain error would be accomplished by moving sn003 or sn004 into either IF channel 5 or 6. This would mean that each IF Channel pair ([1,2], [3,4], [5,6] and [7,8]) would have one ODM which was suitable for observations with $\leq 1\%$ gain errors.

Once new amplifiers can be made, we should be able to make all ODMs have $\leq 1\%$ gain errors over most of the measured voltage range.

ODM		Linearity Ranges		
sn	IF Channel	$\leq 1\%$	$\leq 2.3\%$	$\leq 3.5\%$
1	1		≤ 5 V	≤ 10 V
2	7	≤ 3 V	≤ 5 V	≤ 10 V
4	3	≤ 10 V	≤ 10 V	≤ 10 V
5	2	≤ 4 V	≤ 7.9 V	≤ 10 V
6	4	≤ 4 V	≤ 10 V	≤ 10 V
8	6		≤ 10 V	≤ 10 V

Table 10: Linearity regime limits for the ODMs. This includes both the linearity of the amplifiers in the ODMs and the Square-Law Detectors.

6 Conclusions

The linearity of the Optical Driver Modules has been greatly increased since May 2004. All of the operating ODMs are now linear to within 3.5% over the entire IF Rack voltage range. The ODMs are linear to within 2.3% or better in the range -10 dB to 6 dB which corresponds to an IF Rack power level range of 0.1 V to ~ 4 V. ODM sn002, sn004, sn005 and sn006 (current IF Channels 7, 3, 2, and 4) are linear to $\leq 1\%$ below 3 V IF Rack power.

If the observers wish to achieve $\leq 1\%$ gain errors from the ODMs then they will need to use lower IF Rack target levels. We will also have to re-arrange ODMs so that all observations can achieve $\leq 1\%$ gain errors from the ODMs.