Linearity of the GBT IF Rack to DCR Square Law Detectors, March 2006

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1 Introduction

The linearity of the square law detectors used by the DCR when receiving data from the IF Rack have been re-measured. Special attention was paid in reducing any DC offset that these devices may have had to improve their linearity at low input powers. Measurements of all the square law detectors in the IF Rack have also been made.

2 The Measurements

The measurements were done with the same equipment, setup and procedures as described in GBT Memo 235[1] and the reader is referred there for details on the measurements.

3 Square-Law Detectors

The results of the linearity measurements for the Square-Law detectors for each ODM are presented in Tables 1–9. The errors are typically under 1% (0.0432 dB) difference in output power versus input power except for the highest IF Rack power levels. These results are also presented in Figures 1–9.

3.1 ODM sn001

The Square-Law detector linearity results for ODM sn001 are shown in Figure 1. The Square-Law detector is linear to within 1% from −11 dB to 9 dB for

sn001			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
10.9840	9.4705	10.9280	9.8916
9.9720	9.4546	10.0180	9.8736
8.9680	8.9131	8.9400	8.9720
7.9590	7.9213	8.0270	8.0600
7.0140	6.9890	6.9390	6.9673
6.0070	5.9891	6.0290	6.0521
5.0050	4.9907	4.9510	4.9688
3.9980	3.9905	4.0410	4.0553
3.0170	3.0103	2.9080	2.9177
2.0090	2.0058	1.9970	1.9792
1.0060	1.0036	0.9110	0.9149
-1.0240	-1.0123	-0.9290	-0.9237
-2.0390	-2.0206	-2.0210	-2.0083
-3.0460	-3.0297	-2.9380	-2.9221
-4.0340	-4.0134	-4.0600	-4.0430
-5.0330	-5.0076	-4.9700	-4.9549
-6.0340	-6.0090	-6.0560	-6.0404
-7.0360	-7.0130	-6.9650	-6.9519
-7.9820	-7.9511	-8.0590	-8.0486
-8.9830	-8.9574	-8.9640	-8.9621
-9.9830	-9.9615	-10.0460	-10.0439
-10.9810	-10.9587	-10.9520	-10.9514

Table 1: Square-Law Detector linearity measurements for sn001. 0 dB input power corresponds to ~ 1 Volt.

[1] GBT Memo 235 is available at http://wiki.gb.nrao.edu/pub/Knowledge/GBTMemos/GBTmemo237.pdf

sn002			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
11.0130	10.5225	10.9750	11.0083
10.0010	9.9551	10.0570	10.0837
8.9870	8.9564	8.9740	8.9961
7.9790	7.9561	8.0580	8.0742
7.0270	7.0104	6.9620	6.9715
6.0210	6.0076	6.0490	6.0531
5.0140	5.0029	4.9700	4.9693
4.0080	4.0001	4.0570	4.0519
3.0210	3.0132	2.9190	2.9134
2.0160	2.0102	2.0060	1.9984
1.0060	1.0012	0.9150	0.9121
-1.0160	-1.0174	-0.9280	-0.9255
-2.0360	-2.0365	-2.0250	-2.0135
-3.0490	-3.0427	-2.9450	-2.9332
-4.0440	-4.0308	-4.0730	-4.0562
-5.0510	-5.0359	-4.9860	-4.9701
-6.0600	-6.0413	-6.0730	-6.0568
-7.0660	-7.0460	-6.9860	-6.9737
-8.0160	-7.9928	-8.0870	-8.0771
-9.0210	-8.9934	-8.9970	-8.9868
-10.0280	-9.9977	-10.0820	-10.0757
-11.0340	-10.9920	-10.9930	-10.9953

Table 2: Square-Law Detector linearity measurements for sn002. 0 dB input power corresponds to ~ 1 Volt.

sn003			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
10.9710	10.6820	10.9300	10.8102
9.9670	9.8912	10.0180	10.0132
8.9620	8.9065	8.9390	8.9423
7.9560	7.9182	8.0290	8.0372
7.0130	6.9856	6.9400	6.9542
6.0090	5.9869	6.0300	6.0463
5.0050	4.9923	4.9520	4.9659
4.0000	3.9913	4.0420	4.0563
3.0180	3.0129	2.9080	2.9186
2.0120	2.0105	1.9980	2.0073
1.0070	1.0065	0.9140	0.9184
-1.0190	-1.0090	-0.9160	-0.9122
-2.0300	-2.0154	-2.0050	-1.9940
-3.0410	-3.0223	-2.9200	-2.9055
-4.0270	-4.0083	-4.0430	-4.0284
-5.0340	-5.0159	-4.9540	-4.9390
-6.0340	-6.0243	-6.0410	-6.0308
-7.0440	-7.0337	-6.9500	-6.9433
-7.9860	-7.9805	-8.0470	-8.0455
-8.9920	-8.9960	-8.9540	-8.9636
-9.9950	-10.0092	-10.0370	-10.0469
-10.9970	-11.0223	-10.9450	-10.9633

Table 3: Square-Law Detector linearity measurements for sn003. 0 dB input power corresponds to ~ 1 Volt.

both $\nu_{IF} = 3$ and 6 GHz. This corresponds to an IF Rack power level range from 0.08 V to ~ 7.9 V.

3.2 ODM sn002

The Square-Law detector linearity results for ODM sn002 are shown in Figure 2. The Square-Law detector is linear to within 1% from -11 dB to 11 dB for $\nu_{IF} = 6$ GHz. This corresponds to an IF Rack power level range from 0.08 V to ~ 12.6 V. For $\nu_{IF} = 3$ GHz 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 ~ 10.0 V.

3.3 ODM sn003

The Square-Law detector linearity results for ODM sn003 are shown in Figure 3. The Square-Law detector is linear to within 1% from -11 dB to 10 dB for $\nu_{IF} = 6$ GHz. This corresponds to an IF Rack power level range from 0.08 V to ~ 10.0 V. For $\nu_{IF} = 3$ GHz the Square-Law detector is linear to within 1% from -11 dB to 9 dB. This corresponds to an IF Rack power level range from 0.08 V to ~ 7.9 V.

3.4 ODM sn004

The Square-Law detector linearity results for ODM sn004 are shown in Figure 4. The Square-Law detec-

sn004			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
10.956	10.9944	10.901	10.9713
9.952	9.9937	9.993	10.0627
8.950	8.9910	8.922	8.9826
7.948	7.9867	8.016	8.0692
7.001	7.0352	6.923	6.9677
6.000	6.0309	6.017	6.0525
4.999	5.0237	4.944	4.9694
3.998	4.0152	4.037	4.0561
3.012	3.0257	2.901	2.9135
2.009	2.0183	1.993	2.0018
1.002	1.0090	0.909	0.9128
-1.032	-1.0285	-0.947	-0.9327
-2.052	-2.0378	-2.045	-2.0321
-3.066	-3.0453	-2.971	-2.9554
-4.064	-4.0388	-4.102	-4.0853
-5.070	-5.0436	-5.015	-5.0024
-6.077	-6.0556	-6.100	-6.0936
-7.081	-7.0634	-7.010	-7.0063
-8.028	-8.0182	-8.112	-8.1169
-9.032	-9.0230	-9.020	-9.0346
-10.036	-10.0395	-10.100	-10.1201
-11.038	-11.0463	-11.009	-11.0406

Table 4: Square-Law Detector linearity measurements for sn004. 0 dB input power corresponds to ~ 1 Volt.

sn005			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
10.989	10.7218	10.974	10.0492
9.978	9.8959	10.048	10.0247
8.967	8.9086	8.955	8.9818
7.960	7.9171	8.039	8.0648
7.014	6.9813	6.946	6.9726
6.010	5.9856	6.034	6.0591
5.005	4.9872	4.954	4.9735
4.000	3.9882	4.044	4.0600
3.019	3.0093	2.908	2.9195
2.014	2.0065	1.998	2.0065
1.008	1.0025	0.910	0.9157
-1.017	-1.0071	-0.918	-0.9145
-2.031	-2.0167	-2.013	-2.0035
-3.042	-3.0262	-2.929	-2.9176
-4.033	-4.0146	-4.056	-4.0458
-5.039	-5.0244	-4.968	-4.9580
-6.046	-6.0344	-6.055	-6.0500
-7.053	-7.0503	-6.966	-6.9702
-8.001	-8.0057	-8.061	-8.0731
-9.004	-9.0183	-8.968	-8.9901
-10.008	-10.0338	-10.053	-10.0907
-11.012	-11.0521	-10.962	-11.0112

Table 5: Square-Law Detector linearity measurements for sn005. 0 dB input power corresponds to ~ 1 Volt.

tor is linear to within 1% from -11 dB to 6 dB for $\nu_{IF} = 6$ GHz. This corresponds to an IF Rack power level range from 0.08 V to ~ 4.0 V. The Square-Law detector is linear to within 2% over the entire measured range. For $\nu_{IF} = 3$ GHz the Square-Law detector is linear to within 1% from -11 dB to 11 dB. This corresponds to an IF Rack power level range from 0.08 V to ~ 12.6 V.

3.5 ODM sn005

The Square-Law detector linearity results for ODM sn005 are shown in Figure 5. The Square-Law detector is linear to within 1% from -11 dB to 10 dB for $\nu_{IF} = 6$ GHz. This corresponds to an IF Rack power level range from 0.08 V to $\sim$ 10.0 V. For $\nu_{IF} = 3$ GHz the Square-Law detector is linear to within 1% from -11 dB to 8 dB. This corresponds to an IF Rack power level range from 0.08 V to ~ 6.3 V. The Square-Law detector is linear to within 2% up to 10 dB ($\sim$ 10.0 V).

3.6 ODM sn006

The Square-Law detector linearity results for ODM sn006 are shown in Figure 6. The Square-Law detector is linear to within 1% from -11 dB to 9 dB for both $\nu_{IF} = 3$ and 6 GHz. This corresponds to an IF

sn006			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
10.971	9.6840	10.930	9.7481
9.960	9.6750	10.014	9.7395
8.955	8.9187	8.937	8.9827
7.949	7.9227	8.027	8.0686
6.999	6.9825	6.928	6.9643
5.996	5.9852	6.020	6.0507
4.994	4.9862	4.947	4.9707
3.991	3.9869	4.038	4.0569
3.007	3.0049	2.898	2.9110
2.005	2.0031	1.990	2.0002
1.002	1.0014	0.908	0.9131
-1.011	-1.0050	-0.920	-0.9139
-2.028	-2.0114	-2.008	-1.9915
-3.039	-3.0165	-2.917	-2.9096
-4.030	-4.0046	-4.049	-4.0353
-5.035	-5.0076	-4.955	-4.9469
-6.040	-6.0116	-6.038	-6.0269
-7.042	-7.0207	-6.946	-6.9368
-7.994	-7.9680	-8.045	-8.0489
-8.997	-8.9748	-8.947	-8.9491
-9.999	-9.9846	-10.024	-10.0307
-11.000	-10.9696	-10.930	-10.9368

Table 6: Square-Law Detector linearity measurements for sn006. 0 dB input power corresponds to ~ 1 Volt.

sn007			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
10.972	9.8367	10.958	9.8273
9.963	9.8367	10.040	9.8295
8.957	8.9258	8.957	8.9857
7.952	7.9283	8.044	8.0711
7.007	6.9905	6.942	6.9659
6.003	5.9917	6.034	6.0539
5.001	4.9902	4.955	4.9691
3.997	3.9884	4.047	4.0574
3.016	3.0082	2.906	2.9106
2.011	2.0046	1.998	1.9991
1.004	0.9994	0.909	0.9113
-1.016	-1.0144	-0.912	-0.9105
-2.028	-2.0192	-2.010	-1.9989
-3.039	-3.0316	-2.923	-2.9070
-4.028	-4.0105	-4.051	-4.0335
-5.035	-5.0157	-4.962	-4.9410
-6.041	-6.0228	-6.051	-6.0336
-7.044	-7.0262	-6.959	-6.9410
-7.990	-7.9714	-8.062	-8.0493
-8.994	-8.9745	-8.967	-8.9561
-9.998	-9.9737	-10.052	-10.0430
-11.000	-10.9708	-10.958	-10.9496

Table 7: Square-Law Detector linearity measurements for sn007. 0 dB input power corresponds to ~ 1 Volt.

Rack power level range from 0.08 V to ~ 7.9 V.

3.7 ODM sn007

The Square-Law detector linearity results for ODM sn007 are shown in Figure 7. The Square-Law detector is linear to within 1% from -11 dB to 9 dB for both $\nu_{IF} = 3$ and 6 GHz. This corresponds to an IF Rack power level range from 0.08 V to ~ 7.9 V.

3.8 ODM sn008

The Square-Law detector linearity results for ODM sn008 are shown in Figure 8. The Square-Law detector is linear to within 1% from -11 dB to 11 dB for $\nu_{IF} = 6$ GHz. This corresponds to an IF Rack power level range from 0.08 V to ~ 12.6 V. For $\nu_{IF} = 3$ GHz the Square-Law detector is linear to within 1% from -5 dB to 7 dB. This corresponds to an IF Rack power level range from 0.3 V to ~ 5.0 V. The Square-Law detector is linear to within 2% from -11 dB to 10 dB (0.08 V to ~ 10.0 V).

3.9 ODM sn009

The Square-Law detector linearity results for ODM sn009 are shown in Figure 9. The Square-Law detector is linear to within 1% from -11 dB to 10 dB for $\nu_{IF} = 6$ GHz. This corresponds to an IF Rack power

sn008			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
10.991	10.8691	10.956	10.9624
9.982	9.8883	10.041	10.0534
8.973	8.9004	8.961	8.9743
7.967	7.9119	8.048	8.0607
7.018	6.9750	6.954	6.9642
6.014	5.9799	6.045	6.0508
5.005	4.9837	4.966	4.9702
4.010	3.9888	4.054	4.0560
3.024	3.0051	2.917	2.9150
2.017	2.0097	2.005	2.0032
1.008	1.0035	0.914	0.9122
-1.020	-1.0089	-0.930	-0.9292
-2.037	-2.0184	-2.028	-2.0137
-3.054	-3.0214	-2.949	-2.9348
-4.047	-4.0092	-4.078	-4.0566
-5.054	-5.0111	-4.990	-4.9696
-6.063	-6.0158	-6.078	-6.0562
-7.068	-7.0195	-6.989	-6.9727
-8.015	-7.9652	-8.087	-8.0657
-9.017	-8.9723	-8.994	-8.9774
-10.023	-9.9794	-10.079	-10.0518
-11.026	-10.9755	-10.988	-10.9686

Table 8: Square-Law Detector linearity measurements for sn008. 0 dB input power corresponds to ~ 1 Volt.

sn009			
$\nu_{IF} = 3$ GHz		$\nu_{IF} = 6$ GHz	
ΔP_{in} (dB)	ΔP_{out} (dB)	ΔP_{in} (dB)	ΔP_{out} (dB)
11.003	10.9035	10.962	10.2458
9.992	9.9174	10.043	9.9996
8.983	8.9233	8.962	8.9311
7.976	7.9261	8.046	8.0164
7.030	6.9877	6.961	6.9399
6.024	5.9886	6.048	6.0321
5.018	4.9891	4.970	4.9544
4.013	3.9875	4.054	4.0419
3.028	3.0093	2.920	2.9069
2.021	2.0044	2.005	1.9953
1.011	1.0015	0.916	0.9097
-1.020	-1.0210	-0.933	-0.9315
-2.040	-2.0314	-2.031	-2.0211
-3.060	-3.0418	-2.958	-2.9410
-4.040	-4.0290	-4.085	-4.0639
-5.050	-5.0345	-5.003	-4.9758
-6.060	-6.0350	-6.091	-6.0634
-7.070	-7.0345	-7.005	-6.9763
-8.010	-7.9742	-8.097	-8.0688
-9.020	-8.9748	-9.010	-8.9783
-10.010	-9.9687	-10.093	-10.0599
-11.020	-10.9534	-11.006	-10.9720

Table 9: Square-Law Detector linearity measurements for sn009. 0 dB input power corresponds to ~ 1 Volt.

level range from 0.08 V to $\sim$ 10.0 V. For $\nu_{IF} = 3$ GHz the Square-Law detector is linear to within 1% from -8 dB to 7 dB. This corresponds to an IF Rack power level range from 0.16 V to $\sim$ 5.0 V. The Square-Law detector is linear to within 2% from -11 dB to 11 dB (0.08 V to $\sim$ 12.6 V).

4 Conclusions

All of the Square-law detectors in the IF Rack will be linear to within 2% for the DCR from -11 dB to 9 dB (0.08 V to $\sim$ 7.9 V). They are linear to within 1% from -5 dB to 7 dB (0.31 V to $\sim$ 5.0 V). Taking data with input powers outside of the 2% range will result in data that is quite non-linear.

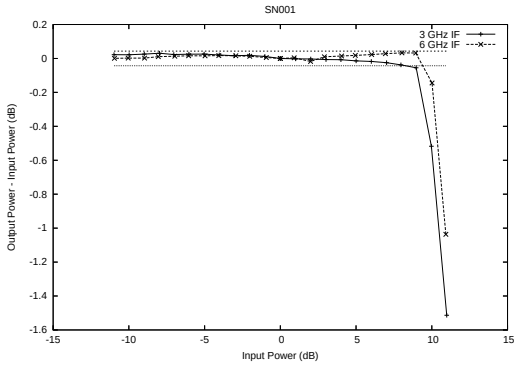

Figure 1: Error in the Square-Law detector output versus the expected linear behavior as the input power is changed for ODM sn001. The data represented by the plus signs had an input signal with a center frequency of 3000 MHz while the data represented by an x had an input signal with a center frequency of 6000 MHz. The bandwidth for both sets of data was 1280 MHz. The two horizontal lines show the 1% error deviation levels.

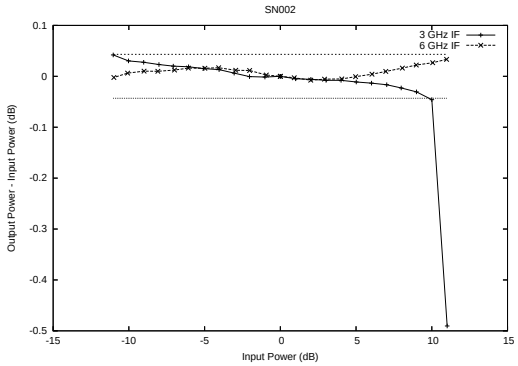

Figure 2: Same as Figure 1 but for ODM sn002.

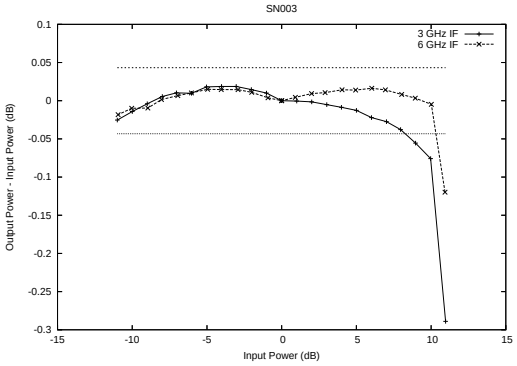

Figure 3: Same as Figure 1 but for ODM sn003.

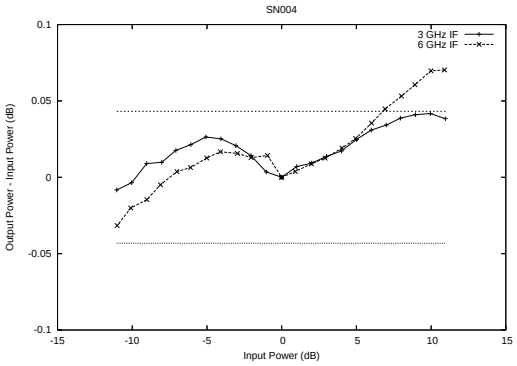

Figure 4: Same as Figure 1 but for ODM sn004.

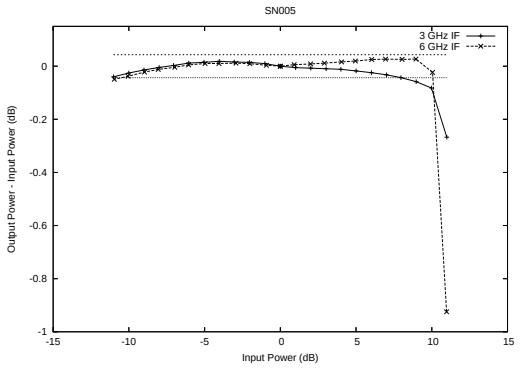

Figure 5: Same as Figure 1 but for ODM sn005.

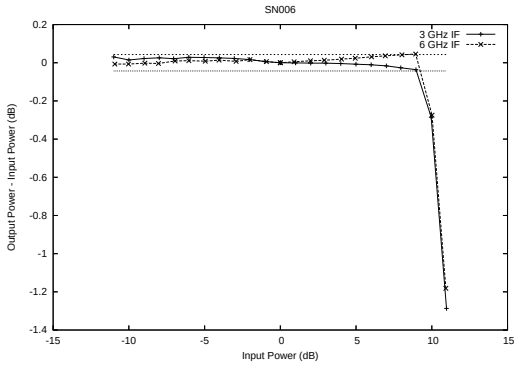

Figure 6: Same as Figure 1 but for ODM sn006.

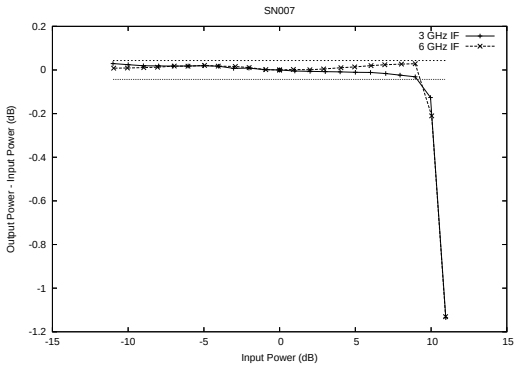

Figure 7: Same as Figure 1 but for ODM sn007.

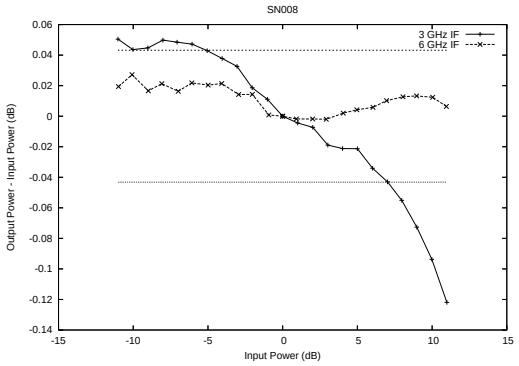

Figure 8: Same as Figure 1 but for ODM sn008.

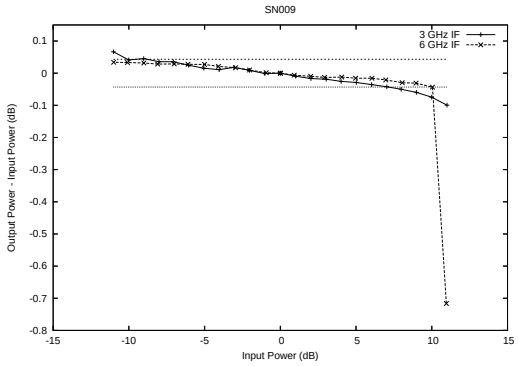

Figure 9: Same as Figure 1 but for ODM sn009.