MEMS-based CAOS Smart Camera 177 dB Linear Extreme Dynamic Range Imaging Tests with Calibrated and Controlled Incoherent White Light and Laser Light Targets

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Abstract. Highlighted are the linear extreme dynamic range calibrated target imaging tests of the CAOS smart camera showing a 177 dB linear dynamic range operation with an optical attenuation controlled bright laser target

1 Introduction

Linear Extreme Dynamic Range (XDR) imaging is required in applications where objects of interest occur in a scene with extreme brightness to weak light zones with low contrast targets of interest embedded within these extreme zones. Recently introduced and demonstrated is the Coded Access Optical Sensor (CAOS) smart camera that has the fundamentals to provide an linear XDR along with a wide spectral response, e.g., 350 nm to 2700 nm [1-2]. This smart XDR camera with a linear camera response function is designed on the principles of the XDR RF multi-access wireless mobile network and operates with a variety of image access modes to suit the pixel extraction environment [3]. This camera engages the classic operations CMOS/CCD/FPA sensor to provide a "DC" mode of operation initial image and CAOS time-frequency modulated imaging modes representing the "AC" modes of operations for XDR capture. The CAOS smart camera is an AC+DC camera optimized based on imaging conditions and the application. In fact, such optimizations can take place using a variety of computational processing methods, including machine learning. This paper highlights updated processed Dynamic Range (DR) data from the experimental set-up in ref.4 where the CAOS smart camera underwent linear XDR imaging tests with calibrated and controlled incoherent white light and laser light targets [4].

2 CAOS Smart Camera Linear Extreme Dynamic Range Imaging Tests

The details of the CAOS smart camera test conditions are described in ref.4. Highlighted here are the updated processed linear DR imaging results presented as tables and a plot. The LG3 Image Engineering (Germany) light-box is used as the white light illumination source. A custom 36 patches target with different designed patch DR values giving an overall 160 dB test scene XDR is used to check the designed (D) linear DR values in dB versus the measured (M) numbers in dB observed using the CAOS smart camera. Table 1 shows the DR for the CMOS-mode of the camera showing accurate recovery till a DR of 32 dB. Table 2 shows the improved linear imaging DR via the CDMA-mode of the camera showing accurate recovery till a DR of 45.8 dB.

Table 1. CMOS-Mode White Light Imaging DR Data.

Patch #	D (dB)	M (dB)	SNR	Patch #	D (dB)	M (dB)	SNR
1	0	-	545	11	45.8	42.28	4.2
2	4.6	4.69	317	12	50.2	45.27	3
3	9.2	9.19	189	13	54.8	48.26	2.1
4	13.8	12.99	122	14	59.4	50.35	1.7
5	18.2	17.41	73	15	64.0	51.72	1.4
6	22.8	21.94	43.5	16	68.6	52.87	1.24
7	27.4	26.32	26.33	17	73.2	54.05	1.08
8	32.0	30.41	16.4	18	77.8	54.63	1.012
9	36.6	33.72	11.2	19	82.2	54.64	1.009
10	41.2	37.70	7.1	20	86.8	54.72	1.0001

Table 2. CDMA-Mode White Light Imaging DR Data.

Patch #	D (dB)	M (dB)	SNR	Patch #	D (dB)	M (dB)	SNR
1	0	-	1802	8	32.0	32.78	41
2	4.6	4.21	1110	9	36.6	33.65	37
3	9.2	8.20	701	10	41.2	40.27	18
4	13.8	13.77	370	11	45.8	43.8	10.6
5	18.2	18.28	220	12	50.2	44.61	5.8
6	22.8	22.19	140	13	54.8	49.82	3.5
7	27.4	25.85	92				

Table 3 shows the additional improvement in linear DR via the FM-TDMA mode of the camera showing accurate recovery till a DR of 73.2 dB. Experiments indicate that

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inter-patch crosstalk at the image plane such as due to camera front lens optics is limiting the higher DR (weaker patch) recovery. Hence the CAOS FM-TDMA mode is re-engaged while blocking target plane light from all patches except the patch under measurement.

Table 3. FM-TDMA Mode White Light Imaging DR Data.

Patch #	D (dB)	M (dB)	SNR	Patch #	D (dB)	M (dB)	SNR
1	0	-	4620	10	41.2	41.10	41
2	4.6	4.07	2891	11	45.8	44.11	29
3	9.2	9.10	1621	12	50.2	49.35	16
4	13.8	13.83	940	13	54.8	53.02	10.3
5	18.2	18.09	576	14	59.4	59.78	4.7
6	22.8	22.25	357	15	64.0	61.05	4.1
7	27.4	25.23	253	16	68.6	67.46	2
8	32.0	32.71	107	17	73.2	70.02	1.5
9	36.6	34.51	87	18	77.8	72.15	1.1

Table 4. FM-TDMA Mode XDR Data with patch blocking.

Patch #	D (dB)	M (dB)	SNR	Patch #	D (dB)	M (dB)	SNR
1	0	-	100	15	64.0	62	97.8
2	4.6	4.8	98.3	16	68.6	66.4	97.5
3	9.2	9.3	98.9	17	73.2	71.6	96
4	13.8	13.9	97.6	18	77.8	71.1	93
5	18.2	14.8	95.6	19	82.2	80.9	88
6	22.8	19.2	98.3	20	86.8	85.7	71
7	27.4	23.6	98.2	21	91.4	91.1	50
8	32.0	28.6	98.2	22	96.0	95.9	34
9	36.6	32.3	98.1	23	100.6	101.3	20
10	41.2	39.2	98.2	24	105.2	106	8.2
11	45.8	42.1	97.9	25	109.8	111	13.3
12	50.2	47.2	97.7	26	114.2	115.2	8.4
13	54.8	51.4	97.8	27	118.8	124.4	7.4
14	59.4	57.2	98.4	28	123.4	125.3	9.4

Table 5. FM-mode XDR Data with a laser patch target.

Attenuation (OD)	D (dB)	M (dB)	SNR	Attenuation (OD)	D (dB)	M (dB)	SNR
0	0	-	269.3	6.5	130	128.1	8.4
1	20	19.9	268.7	7.4	148	147.3	5.4
2	40	39.3	268.7	7.7	154	152.5	6.8
3	60	57.9	268.3	7.8	156	154.7	5
4	80	80	161.3	8.4	168	163.9	17.3
5	100	97.4	36.06	8.8	176	173	6.3
5.5	110	107.6	10.74	9	180	177	4

Table 4 shows the further improvement in DR recovery to 123.4 dB. Table 5 shows DR data taken using a laser beam as an Optical Density (OD) controlled single patch up-to a 180 dB XDR value. These readings are taken using the FM-mode, showing a recovery up-to a 177 dB XDR. Fig.1 plot shows the linear 177 dB XDR response of the demonstrated CAOS smart camera.

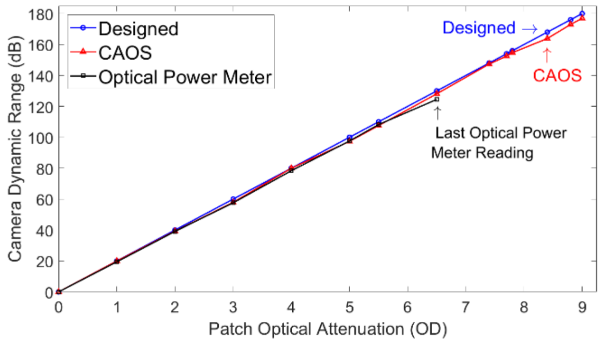

Fig. 1. Linear 177 dB XDR response using Table 5 Data.

3. Conclusion

Calibrated target image testing is a robust method to ascertain the linear DR imaging capability of a camera. Hence highlighted are such initial tests for the CAOS smart camera that both point to the limitations of the testing infrastructure and the deployed camera operations. For example, brightness limits on a pixel basis of the white light LG3 source-based XDR test allowed image recovery to 123.4 dB DR. The brighter visible laser single patch OD-controlled target allowed linear XDR recovery to 177 dB.

References

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