RER, FWHM, MTF
from Landsat-8 OLI Lunar data (Level 1R) (Draft)

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Purpose

- **Measuring the Spatial Characteristics from Landsat-8 OLI Lunar data (Level 1R)**
  - ✓ RER, FWHM, MTF

- **Major Initial Considerations**
  1. Not Geometric Corrected
     a. CCD Geometry
  2. Not Circle (Level 1R)
  3. Not Uniform Brightness
  4. Shadow area

LO800U0006422013175LGN00
Level 1R, Band_8, PAN

Assumption & Uncertainty

1. **Minor initial effects**
   a. Almost circle of Lunar data after Geometric corrected (Level 1R)
   b. Symmetric LSF each direction of Landsat-8 OLI
   c. Outer line of Lunar data is almost circle line at the Landsat 8 resolution (30m)
   d. Brightness variation in one Step angle (Pie)
   e. Inflection point on LSF may be the starting point of Bright & Dark area
   f. Top inflection point on LSF may be the center of RER by CSAPS

2. **Geometric Correction with CCD Geometry (Minor initial effect)**
   a. Scanning rate on Pitch for imaging the Moon may be Constant.

3. **Drop out the low reliable angle values**
   a. Big Brightness variation in one Step angle (StdDev_B_Y) (> 0.07)
   b. Angle: 0, 90, 180, 270deg
   c. etc.

Step to Calculate (1/6)

1. **Decide Initial value**
   a. Step angle (Pie): '5 deg'
   b. Fitting method: Fermi-Direct (Symmetric LSF)
   c. Width of Bright/Dark area from Starting point: '1 pixel'

2. **Read CPF & Get the CCD Geometric data**
   a. Get 'OLI_FOCAL_PLANE' & 'OLI_DETECTOR_OFFSETS' in CPF
   b. Band: 9, SCA: 14
   c. Save them into 'MAT' file for Matlab

3. **Read L8 Lunar data (Level 1R), HDF5 & temp Mapping XY**
   a. Search the Number of SCA that has Lunar data
   b. Read Legendre & Offset with Band & SCA from (2.c)
   c. temp Mapping XY(Along & Across) from Legendre & Offset

4. **Search, Subset & Display the only Lunar data**
   a. Search & subset the area of the Lunar data on the whole image
   b. Make temporarily circle(?) Lunar data by applying with nearly offset '2' & nearly '8' (2 x 8 = 16)
   c. Display it

4.c

LO800U0006422013175LGN00
Level 1R, Band_1

5.b

5. Find the Shadow angle range with the subset Lunar data (4.b)

a. 'imgradient(4.b)' in Matlab

b. Remain the only Edge area from (5.a)

c. Calculate the next value for every pixel in Edge area (5.b);
   1) Angle from temp center
   2) Distance from temp center
   3) DN
   4) Y, X (row, column)

d. Calculate the next value for Step angle (1.a);
   1) StdDev(Distance * DN)
   2) Mean(DN)
   3) Max(DN)

e. Calculate the next value for Step angle from (5.d)
   a. Ang = 0 : (Step angle, 5 deg) : 355
   b. Mean[(5.d)(Ang : Ang+180)]

f. Shadow angle range is
   1) (Start) Min(5.e) ~ (End) Max(5.e)

g. Edge angle range is
   1) (Start) Max(5.e) ~ (End) Min(5.e)

5.g: Start

5.e,f,g
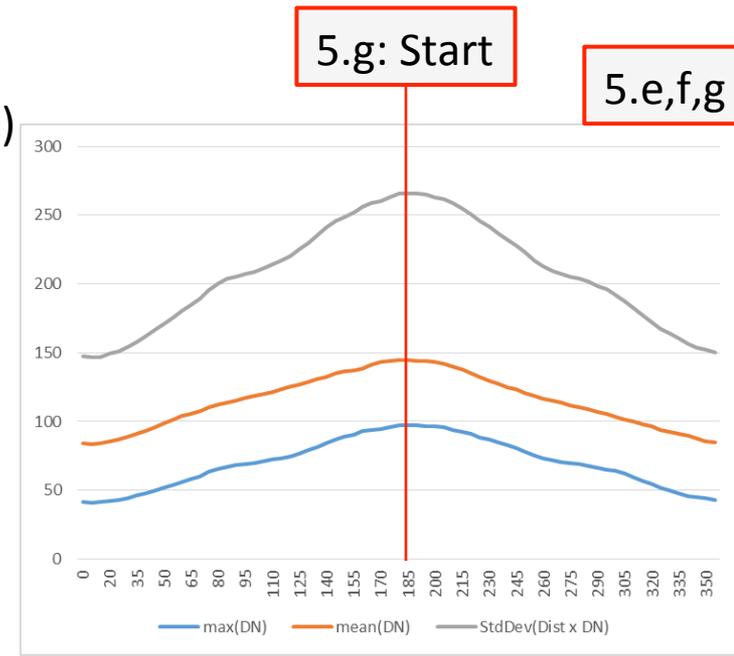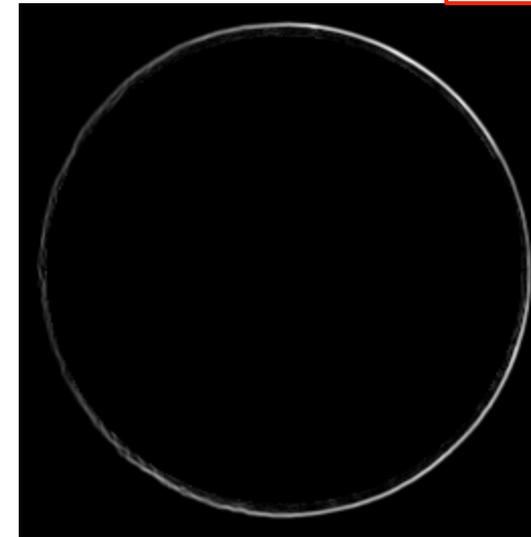
6. Get 'Alpha, deltaY(along) / deltaX(across)'
   a. Apply imgradient in Matlab to the Lunar data of only Odd or Even detector
   b. Remove the Shadow angle range by (5.f)
   c. Ellipse fitting
   d. Get the next;
      1) Center (x0, y0)
      2) a (deltaY, along), b (deltaX, across)
      3) Alpha = a / b

7. Get the Final Map XY
   a. Multiply 'Alpha' to MapXY with the number of Row(Y) & Column(X) (integer) by the size of the subset Lunar data (4.a)
   b. Apply temp Mapping XY (3.c) to MapXY (7.a)

Gradient and Ellipse fitted on Level 1R

- Gradient
- Fitted

6.a,b,c,d

8.a

Step angle of each Pie 5 deg

(x0,y0)= (143.33, 1132.03)

a= 988.72, b= 121.39, Alpha= 8.1451
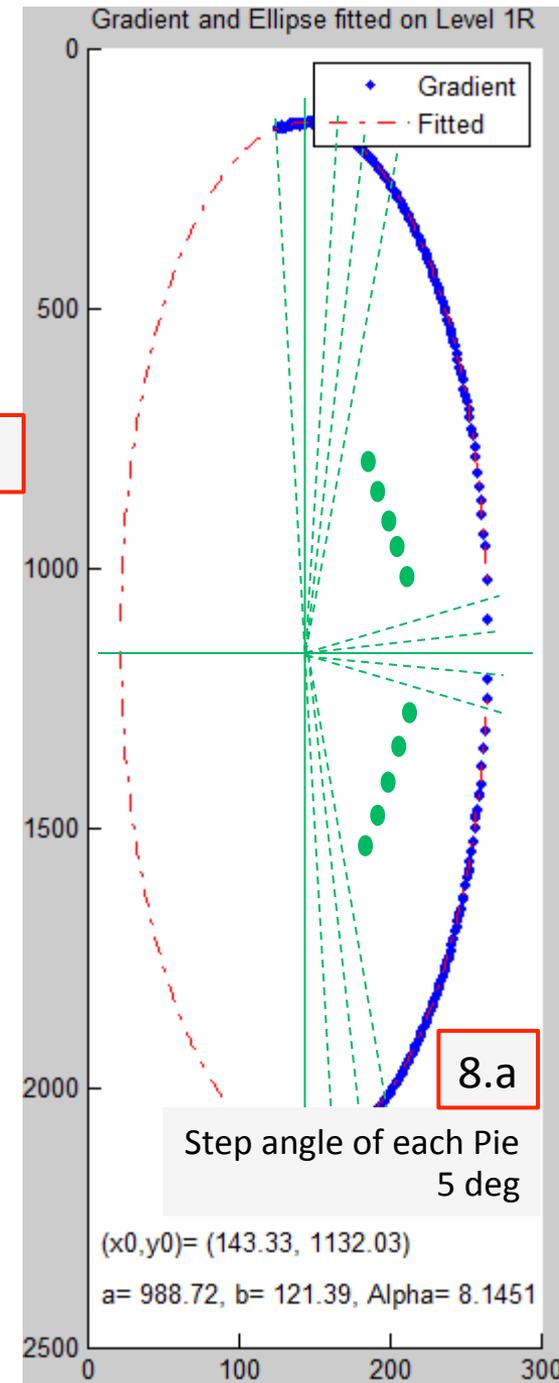
Step to Calculate (4/6)

8. **Get ESF (Edge Spread Function)**
   a. Divide Pies by Step angle (5 deg) on L1R Lunar data
   b. (X-axis) Every pixel's distance from the center (6.d.1) of the L1R Lunar data to MapXY (7.b)
   c. (Y-axis) Every pixel's DN
   d. Getting the Inflection points in LSF by CSAPS fitting (TBD)
   e. Trim the Bright & Dark area with 1 pixel (TBD) width from the inflection points
   f. Fitting ESF by Fermi-Dirac function (L8 OLI has a symmetric LSF)
   g. Calculating the Standard Deviation of X & Y at Bright & Dark area

Edge in each Angle (210 deg)

8.a

Edge Spread Function (Fermi)

8.e   8.g

$RER = 0.961$

$SD_B = 0.034$

8.f

8.d
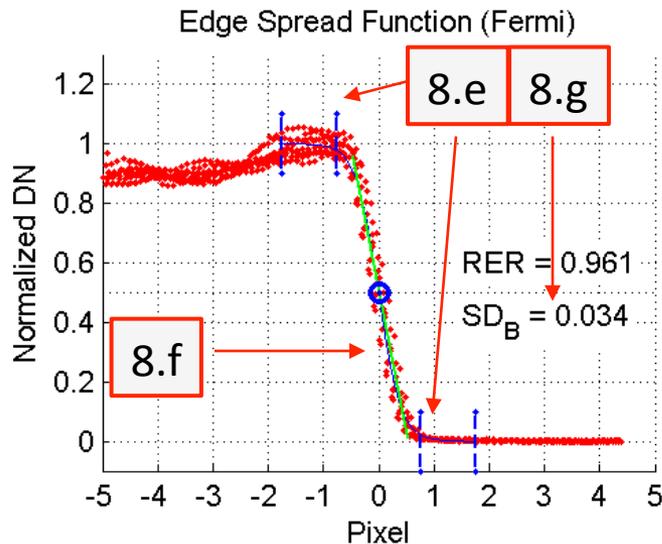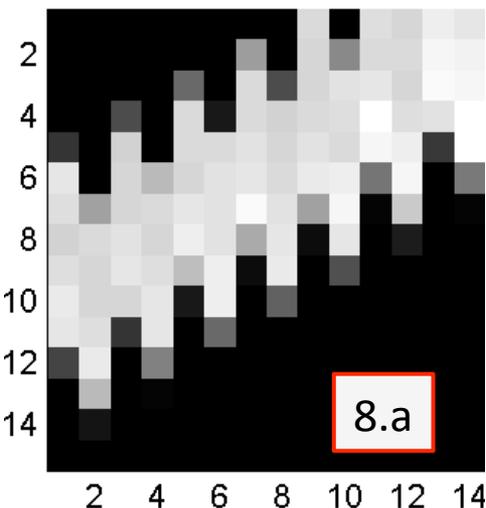
(8.b)
X-axis: Distance from Center to a Pixel
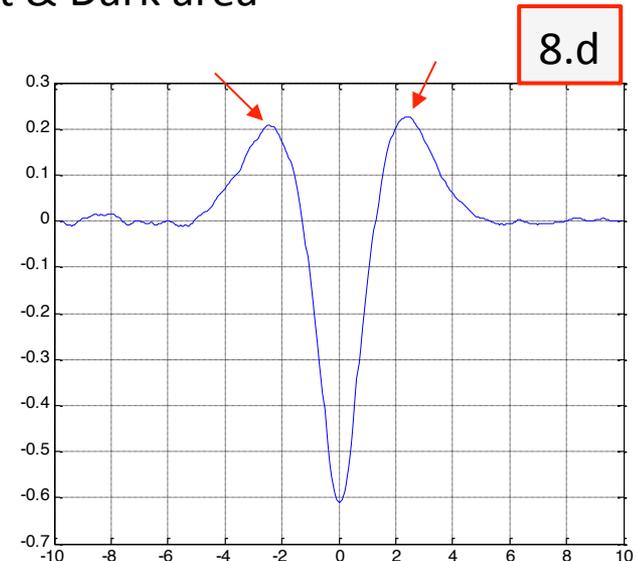
Step to Calculate (5/6)

9. Getting RER, FWHM, MTF at Nyquist fr.
   a. RER with the center of the LSF inflection point
   b. FWHM, FWHM80, FWHM25
   c. MTF value at Nyquist fr.

MTF

9.c

MTF at Ny. = 55.78%

Edge Spread Function (Fermi)

9.a

RER = 0.961

SD_B = 0.034

Line Spread Function (Resolution x 0.05)

9.b

80% = 0.388

FWHM = 0.712

25% = 1.061
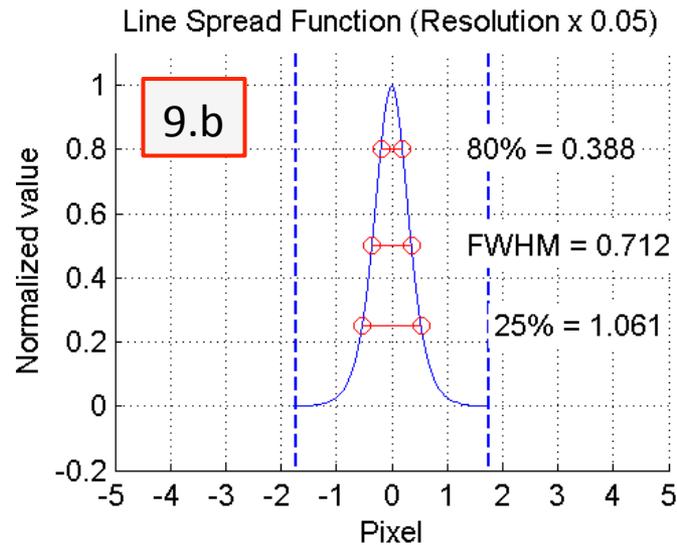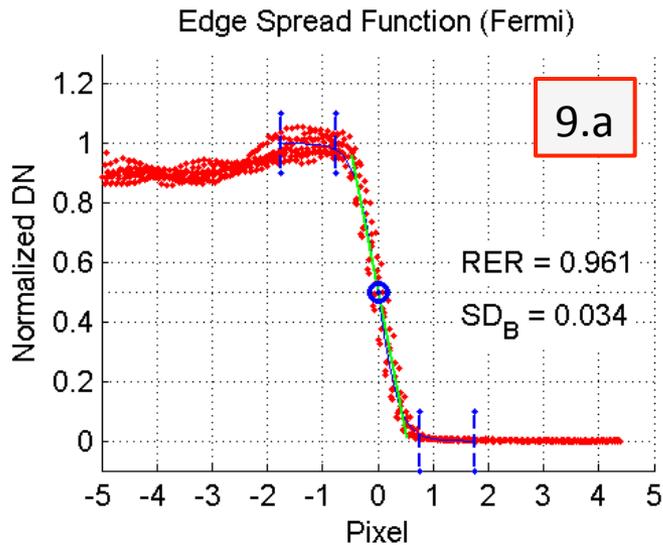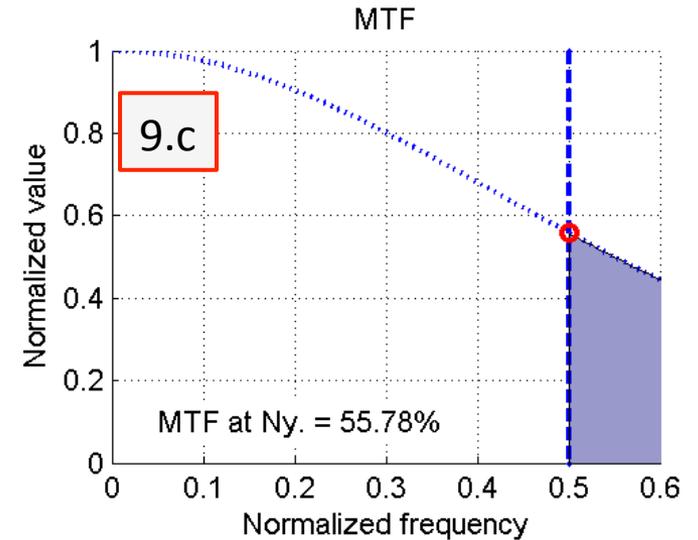
Step to Calculate (6/6)

10. Get the plot of RER, FWHM, MTF by each Step angle(pie)
   a. Plot by 0~360deg except the Shadow area by 5deg
   b. Drop out the low reliable results with the bad conditions

11. Get Mean, Along & Across
   a. (Mean) Average
   b. (Along) Value at angle 0, 180
   c. (Across) Value at angle 90, 270
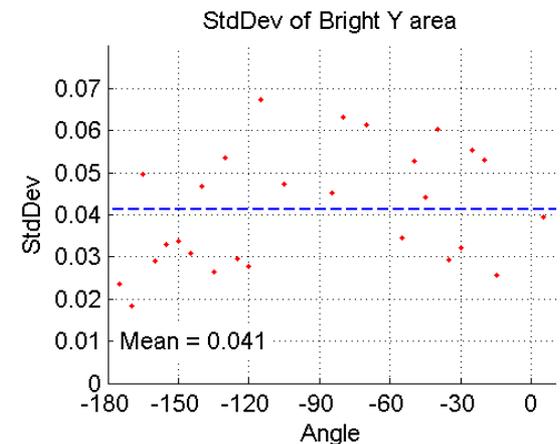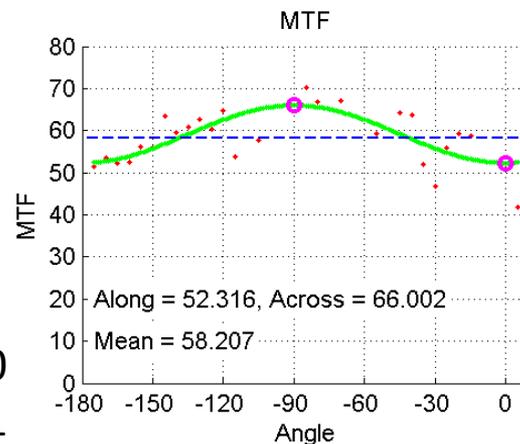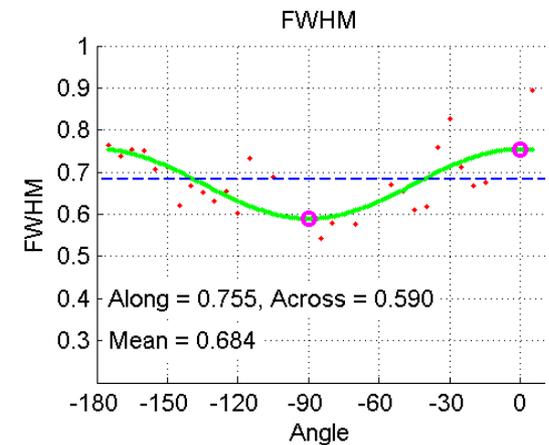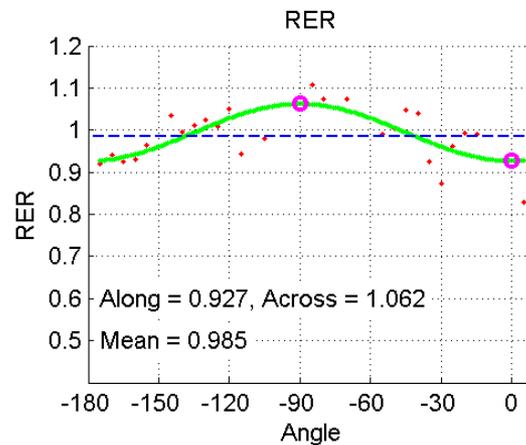
LO800U0006422013175LGN00
Level 1R, Band_1

Drop out the low reliable angle results (1/4)

1. **StdDev**
   a. StdDev_Y_min < 0.02
   b. StdDev_Y_max > 0.07 (Big Brightness variation in one Step angle)
   c. StdDev_X_min < 0.2
2. **Biggest RER & Lowest RER**
3. **Angle**
   a. 0, 90, 180, 270
4. **Peculiar angle**
   a. (Difference with adjacent angle > 0.15) & (StdDev_Bright_Y > 0.07)
   b. Difference with adjacent angle > 0.2

1.b

Edge Spread Function (Fermi)

RER = 0.700

SD_B = 0.102

Normalized DN

Pixel
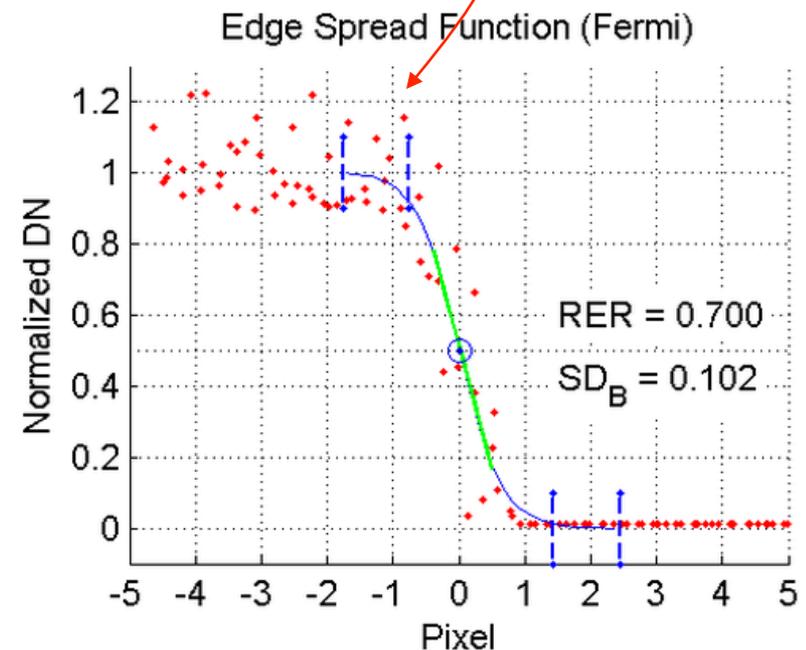
Drop out the low reliable angle results (2/4)

1. StdDev

   a. StdDev_Y_min < 0.02

   b. StdDev_Y_max > 0.07

   c. StdDev_X_min < 0.2

   d. StdDev_X_max < ?? (TBD)

Edge Spread Function (Fermi)

1.c

RER = 0.874
$SD_B = 0.095$

Edge Spread Function (Fermi)

RER = 1.013
$SD_B = 0.058$
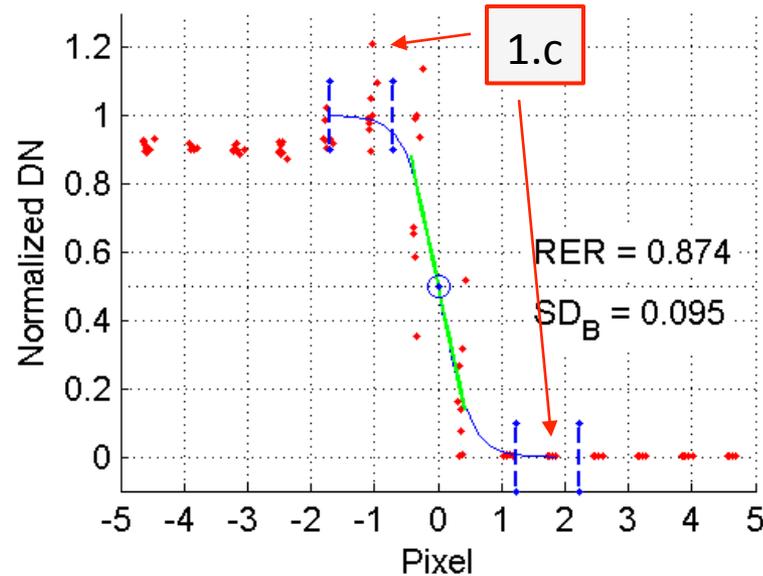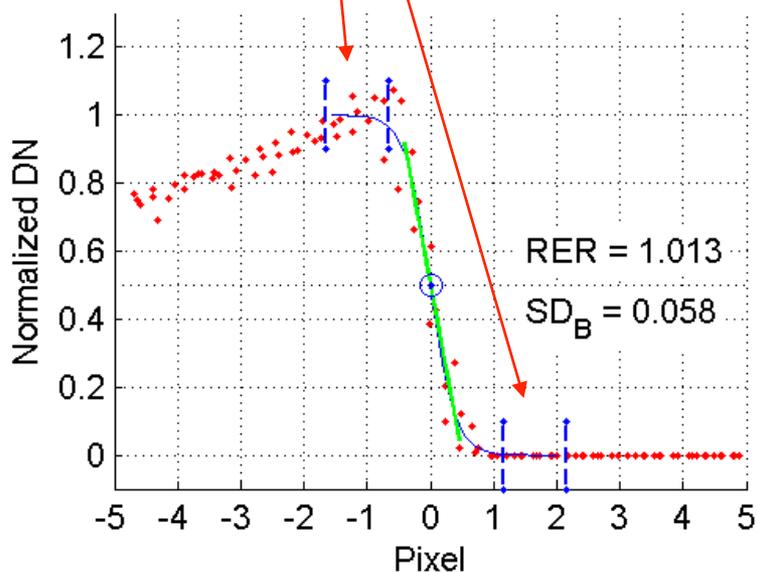
StdDev of Bright Y area

1.b

1.a

mean(StdDev) = 0.050
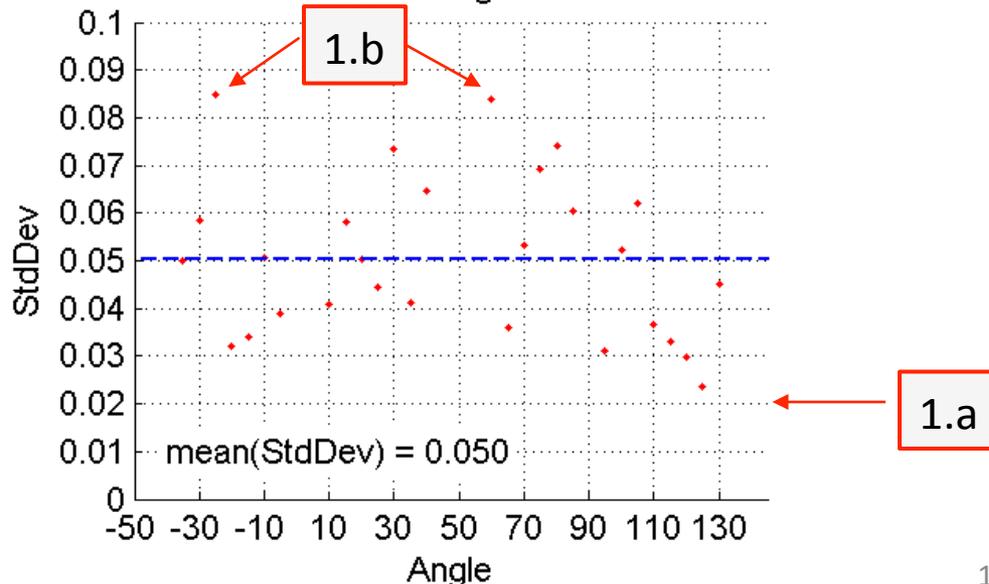
Drop out the low reliable angle results (3/4)

1. **StdDev**
2. **Biggest RER & Lowest RER**
3. **Angle**
   a. 0, 90, 180, 270

Edge in each Angle (0 deg)

Edge Spread Function (Fermi)

RER = 0.776

$SD_B = 0.013$
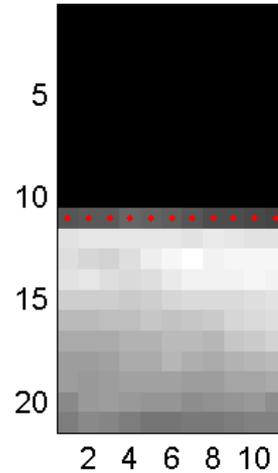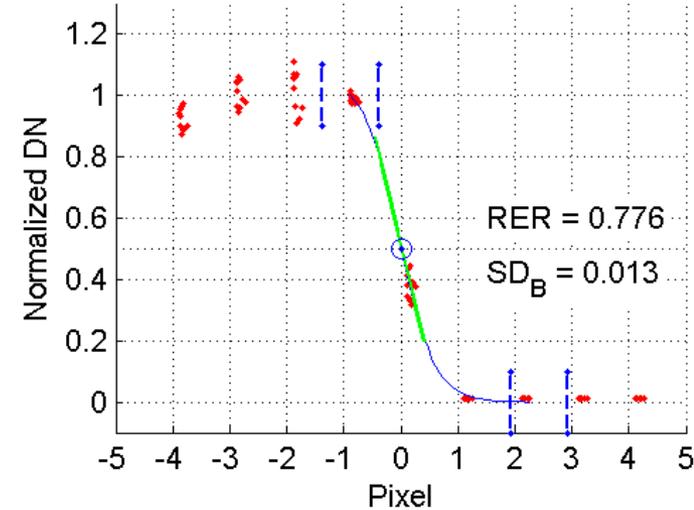
Edge in each Angle (90 deg)

Edge Spread Function (Fermi)

RER = 0.845

$SD_B = 0.044$
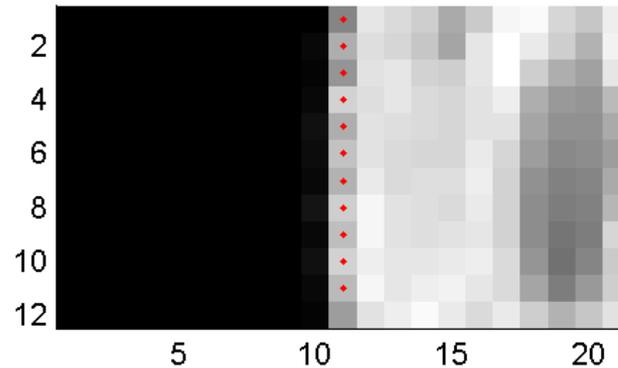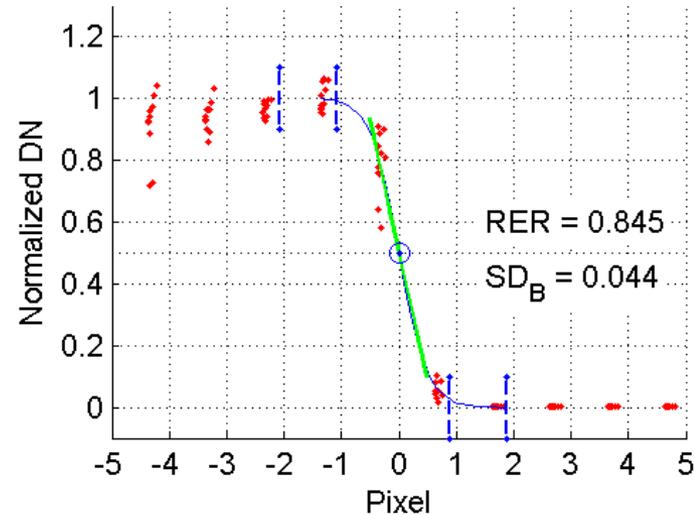
Drop out the low reliable angle results (4/4)

1. **StdDev**
2. **Biggest RER & Lowest RER**
3. **Angle**
4. **Peculiar angle**
   a. (Difference with adjacent angle > 0.15) & (StdDev_Bright_Y > 0.07)
   b. Difference with adjacent angle > 0.2
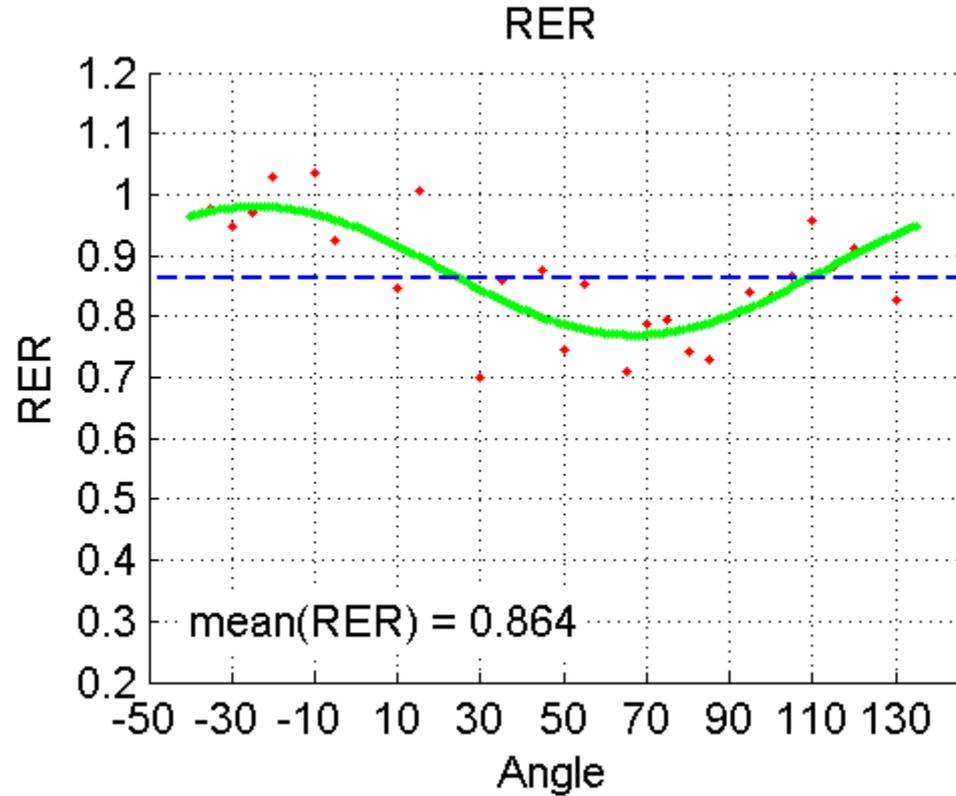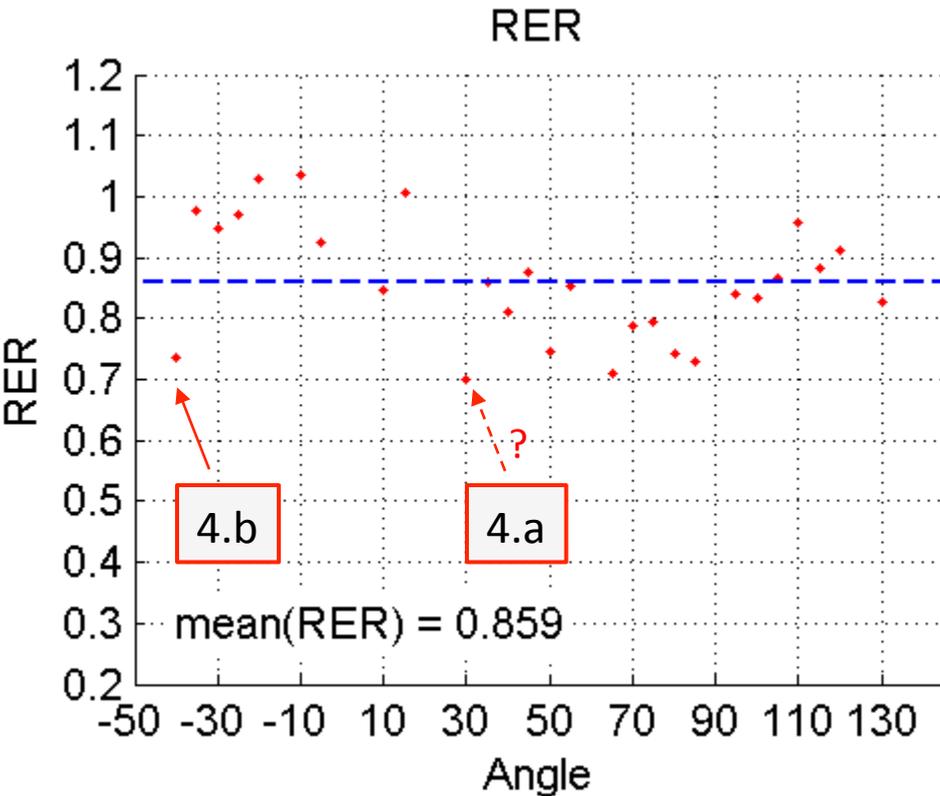
Results of L1R_LO800U0006422013175LGN00

ESF, LSF, MTF (Band_1, Angle: 210deg)

Edge in each Angle (210 deg)

Edge Spread Function (Fermi)

RER = 0.961

SD_B = 0.034

Line Spread Function (Resolution x 0.05)

80% = 0.388

FWHM = 0.712

25% = 1.061

MTF

MTF at Ny. = 55.78%
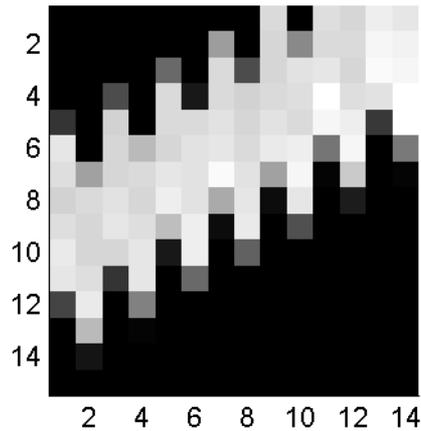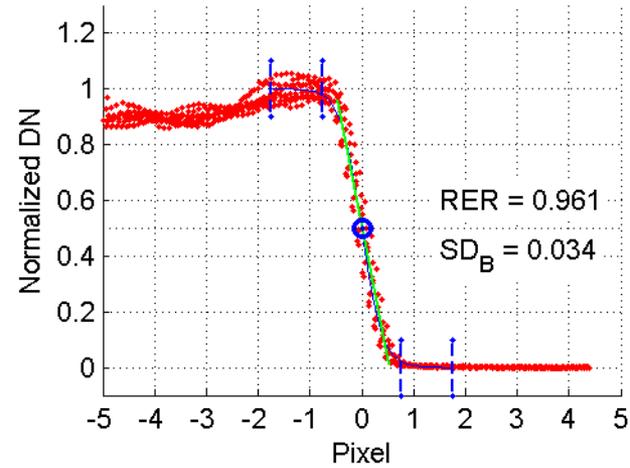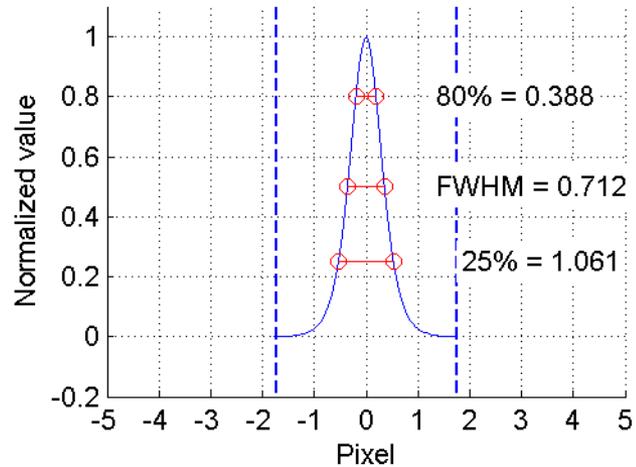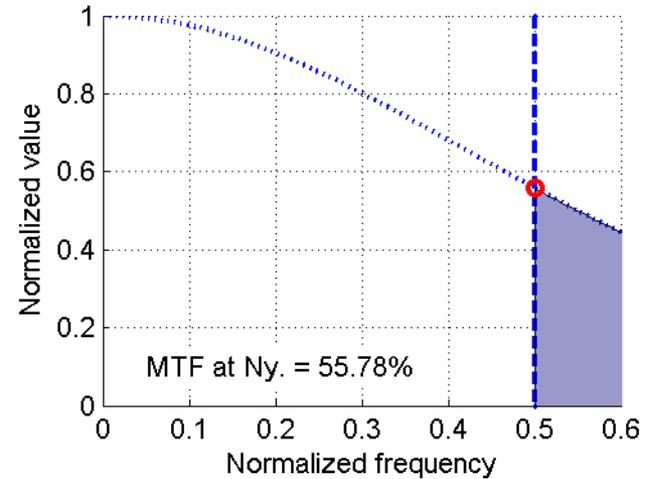
# ESF, LSF, MTF (Band_2, Angle: 210deg)

Edge in each Angle (210 deg)

Edge Spread Function (Fermi)

RER = 0.952

SD_B = 0.032

Line Spread Function (Resolution x 0.05)

80% = 0.392

FWHM = 0.719

25% = 1.073

MTF

MTF at Ny. = 55.14%
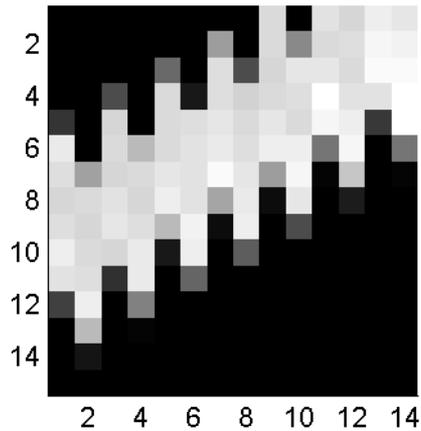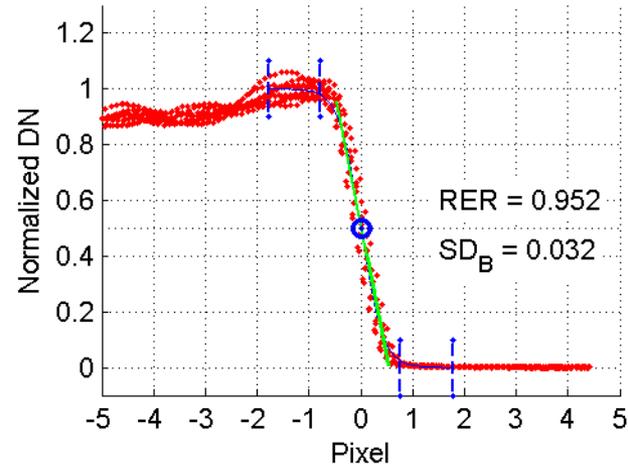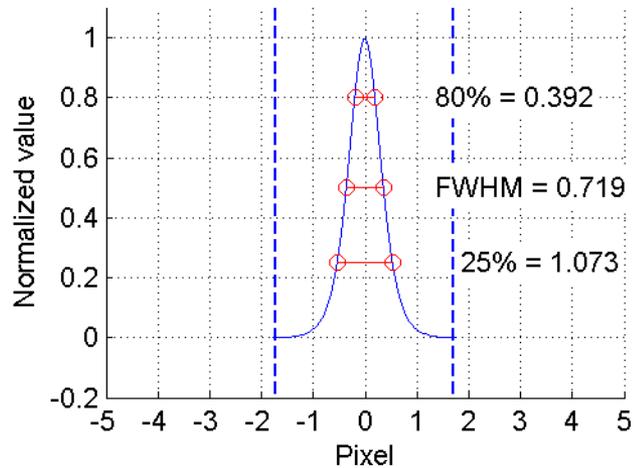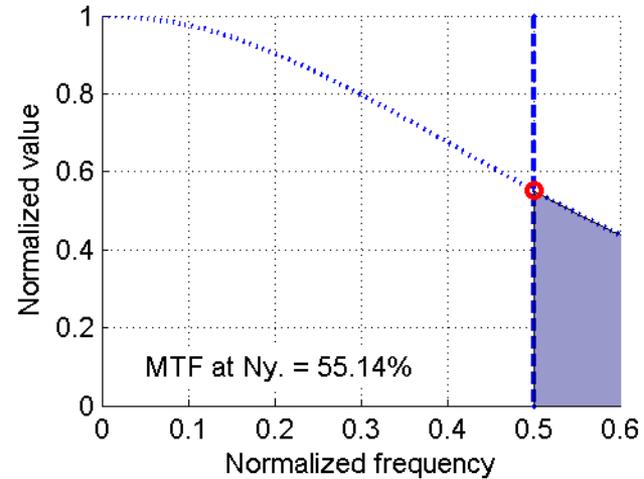
ESF, LSF, MTF (Band_3, Angle: 210deg)
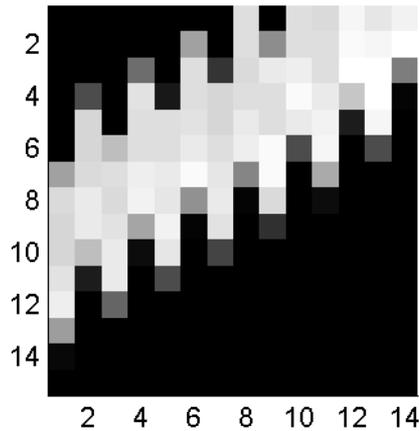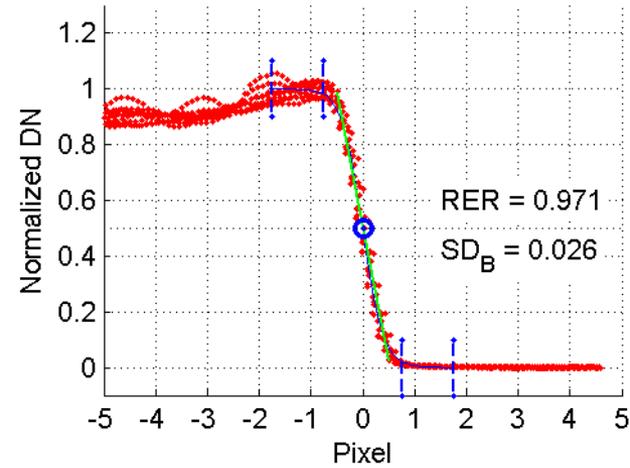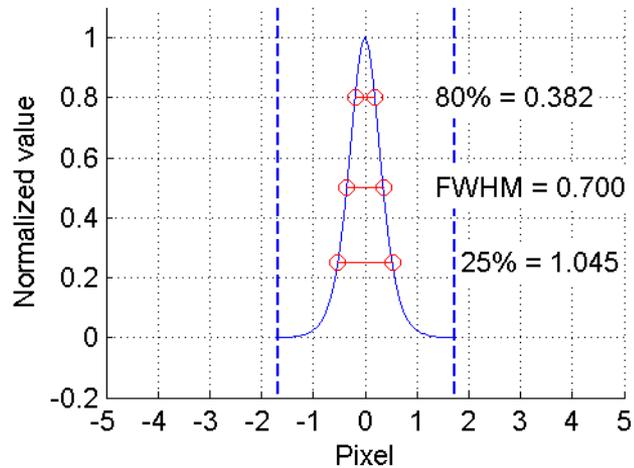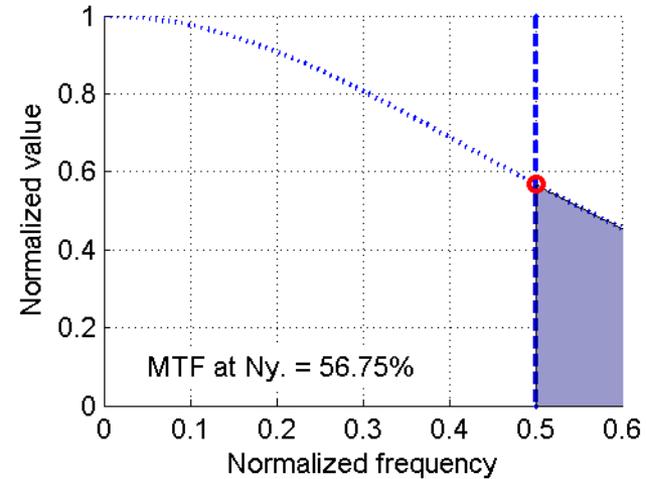
ESF, LSF, MTF (Band_4, Angle: 210deg)
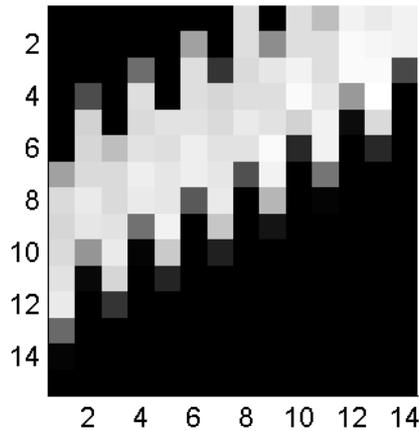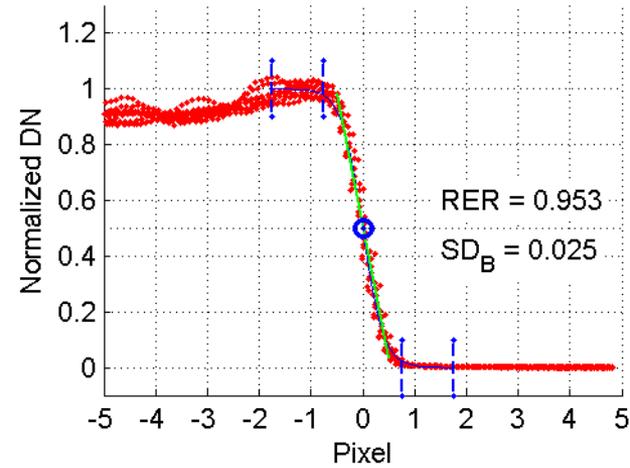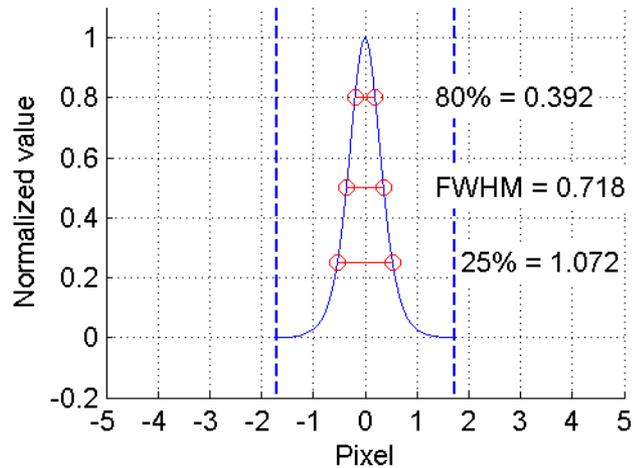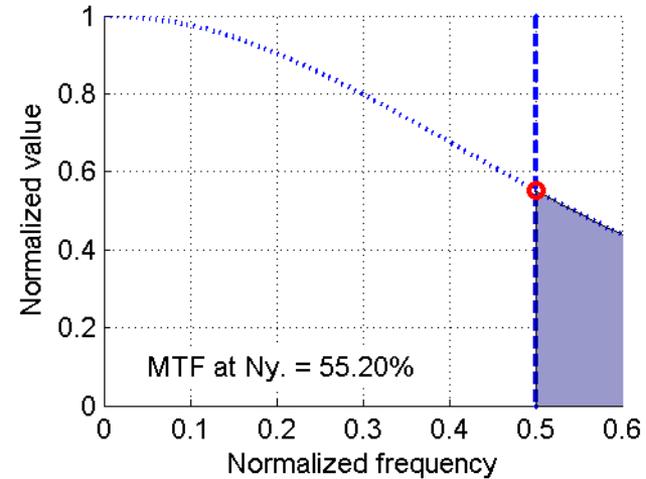
ESF, LSF, MTF (Band_5, Angle: 210deg)

Edge in each Angle (210 deg)



Edge Spread Function (Fermi)

RER = 0.947

$SD_B = 0.022$

Line Spread Function (Resolution x 0.05)

80% = 0.398

FWHM = 0.730

25% = 1.090

MTF

MTF at Ny. = 54.26%
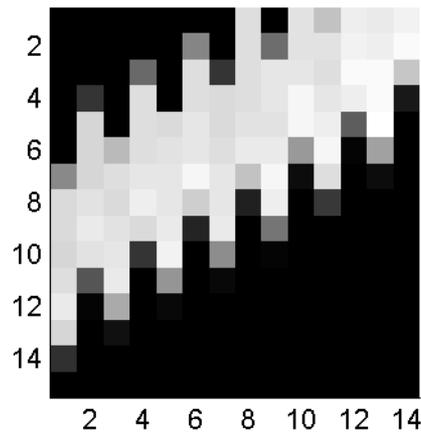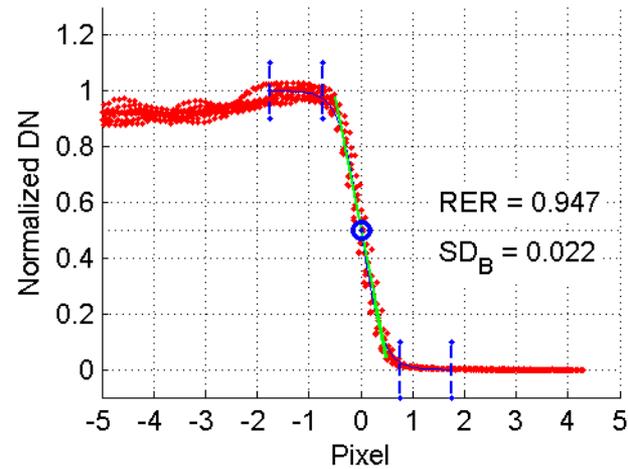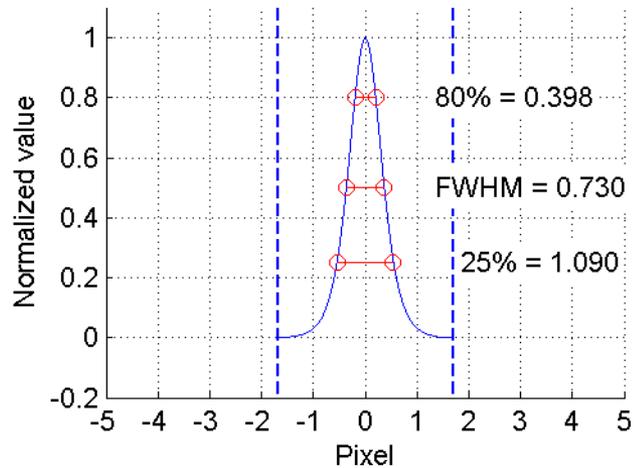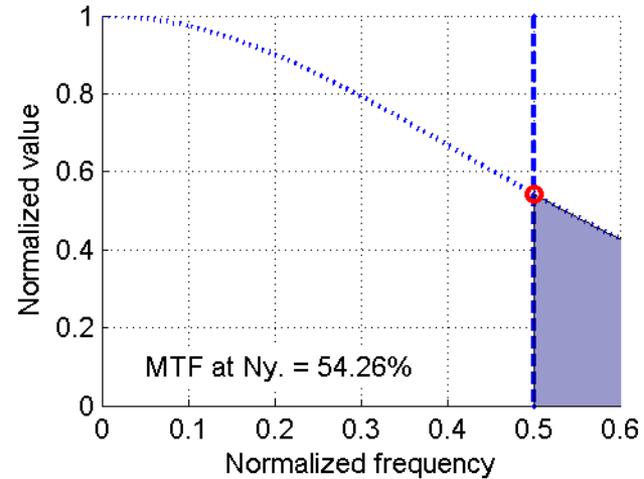
ESF, LSF, MTF (Band_6, Angle: 210deg)
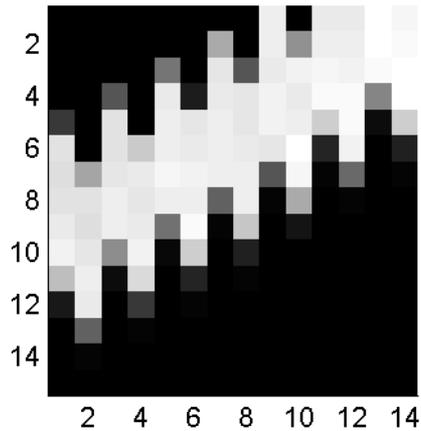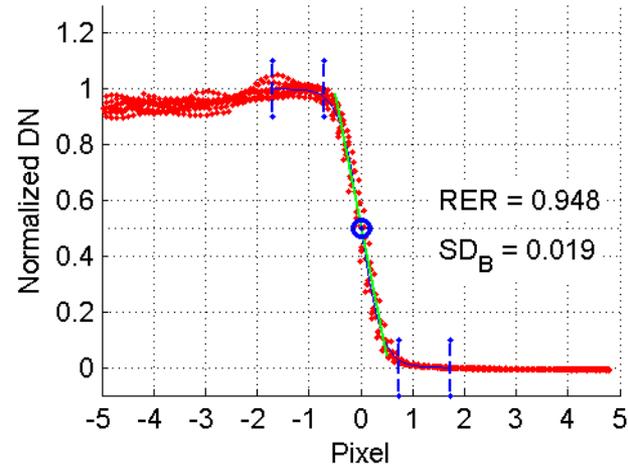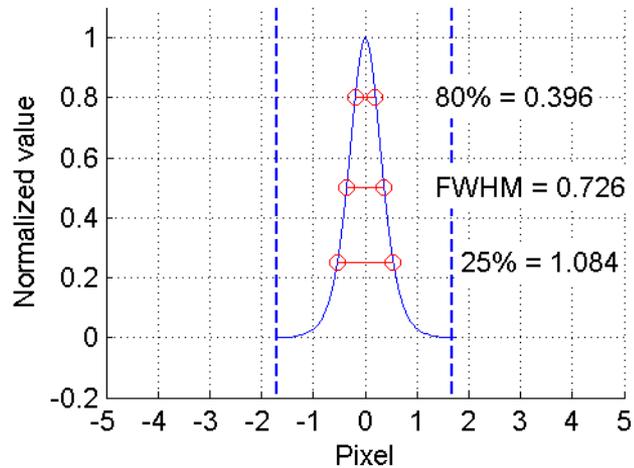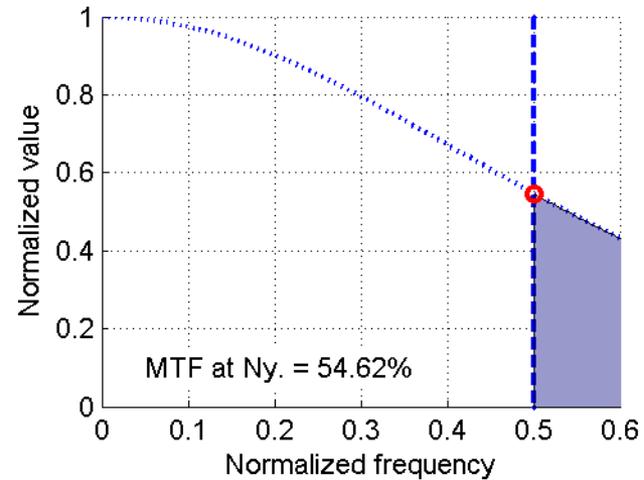
ESF, LSF, MTF (Band_7, Angle: 210deg)
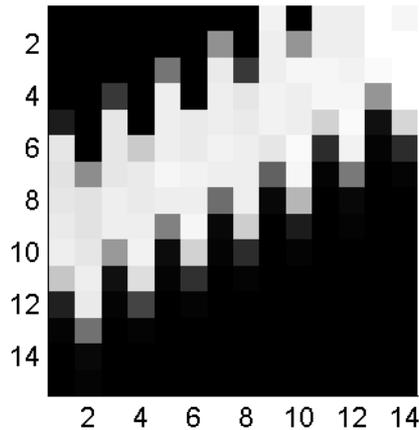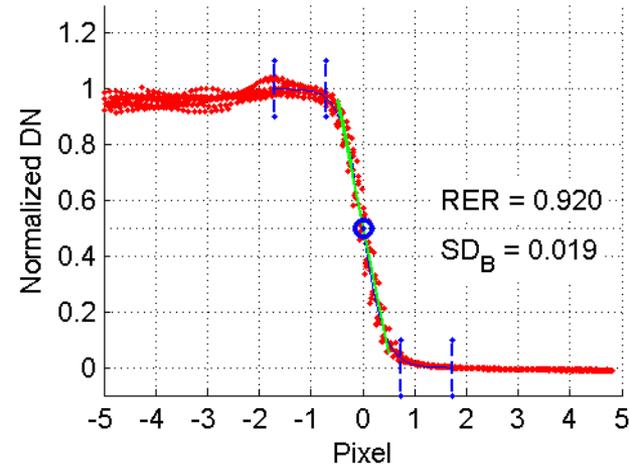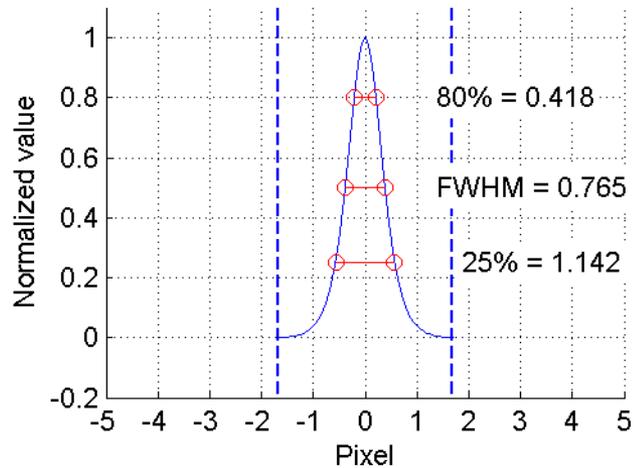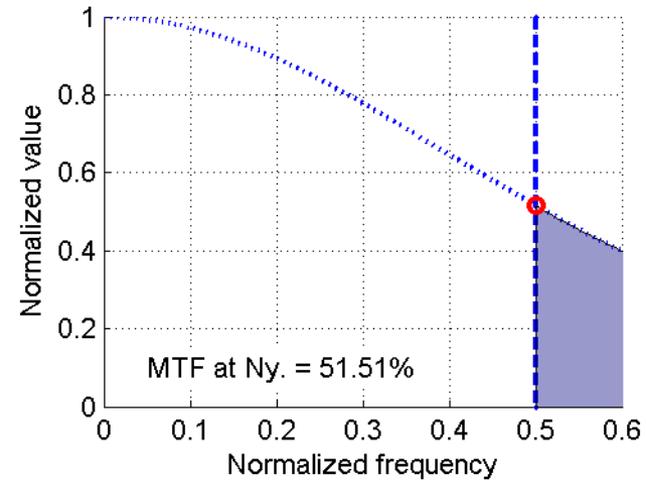
ESF, LSF, MTF (Band_8, PAN, Angle: 210deg)


Edge in each Angle (210 deg)

Edge Spread Function (Fermi)

RER = 0.820

SD_B = 0.028

Line Spread Function (Resolution x 0.05)

80% = 0.494

FWHM = 0.905

25% = 1.349

MTF

MTF at Ny. = 41.02%
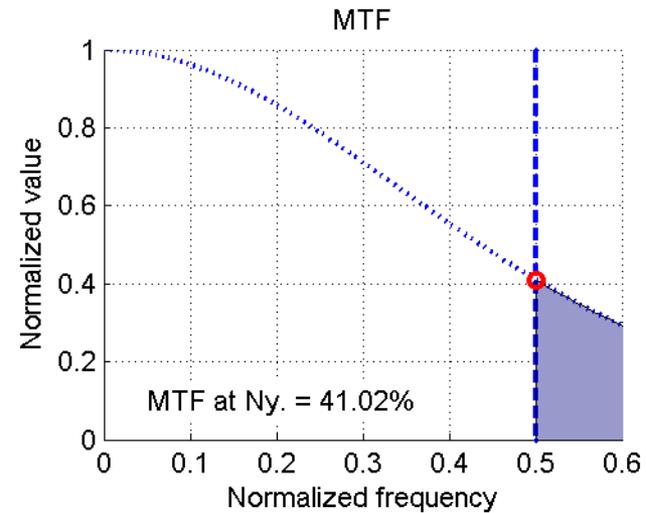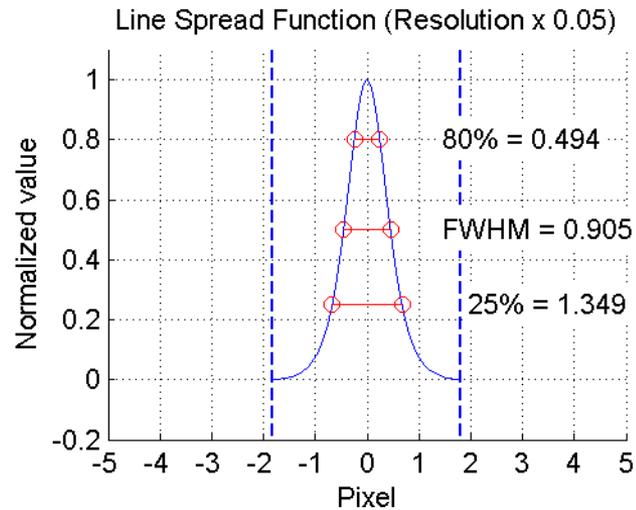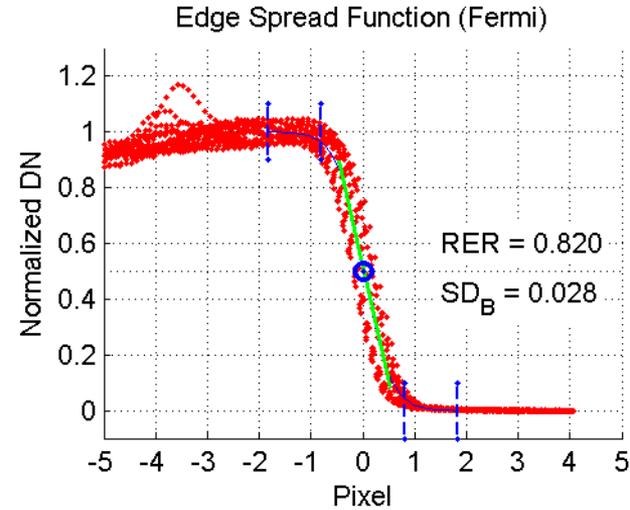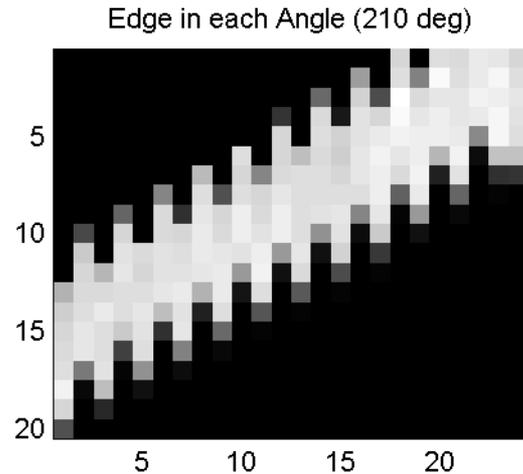
ESF, LSF, MTF (Band_9, Angle: 210deg)

Edge in each Angle (210 deg)

Edge Spread Function (Fermi)

RER = 0.954

$SD_B = 0.021$

Line Spread Function (Resolution x 0.05)

80% = 0.390

FWHM = 0.716

25% = 1.068

MTF

MTF at Ny. = 55.46%
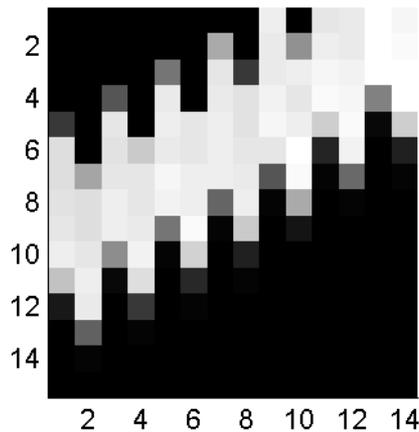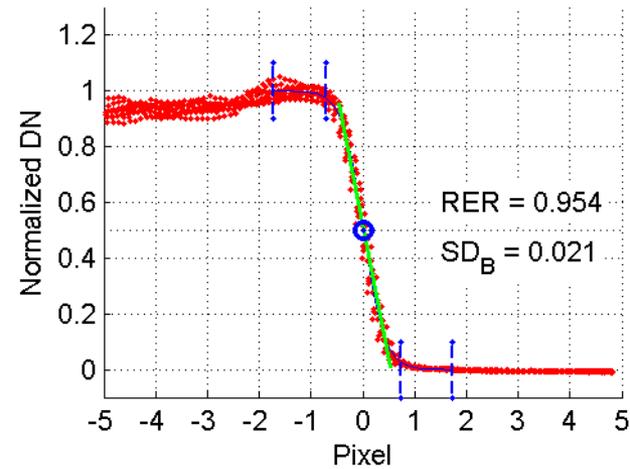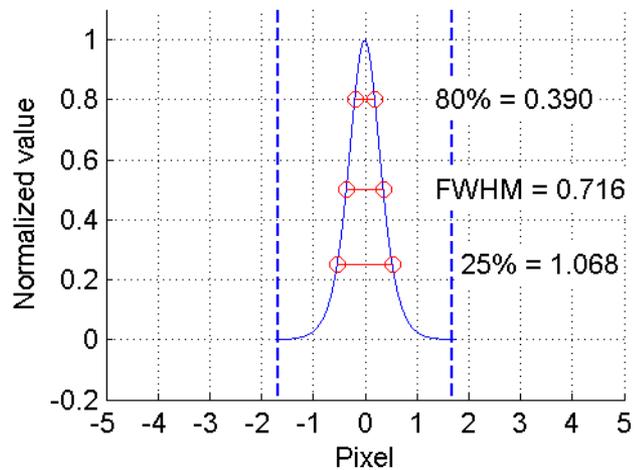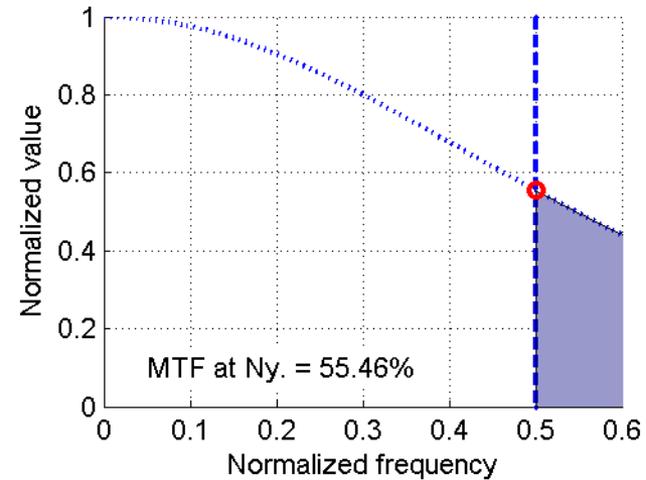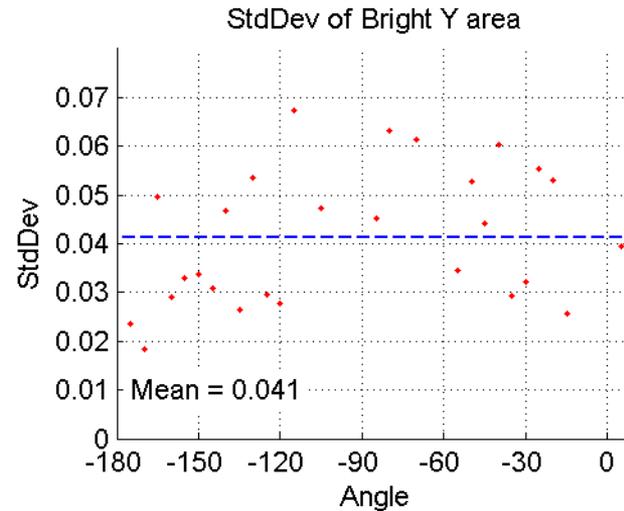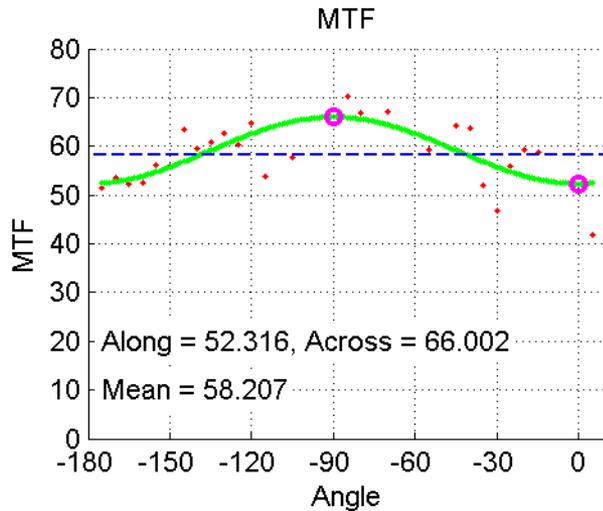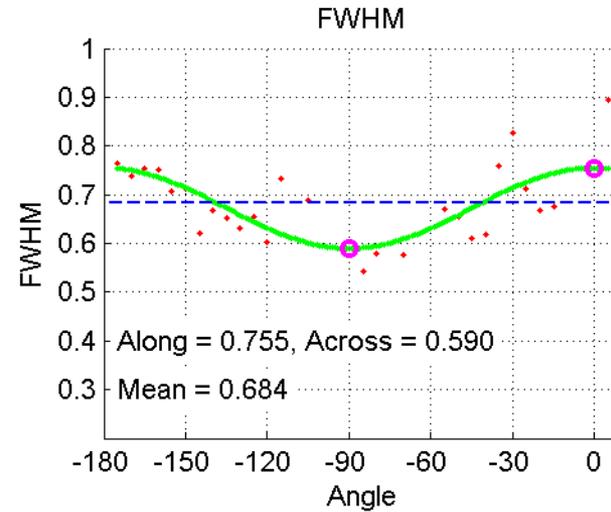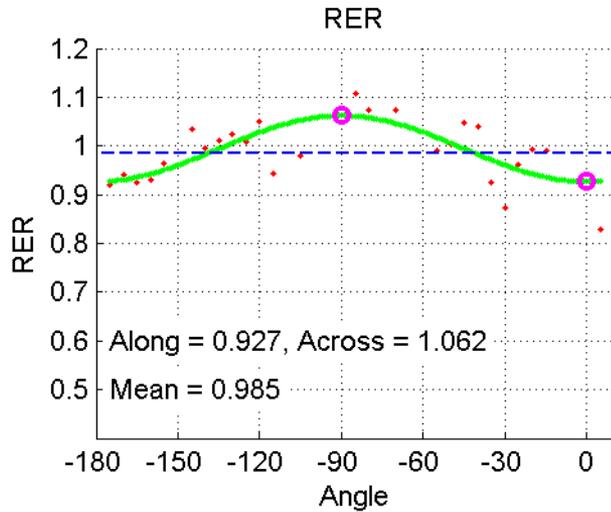
RER, FWHM, MTF (Band_1)

RER, FWHM, MTF (Band_2)
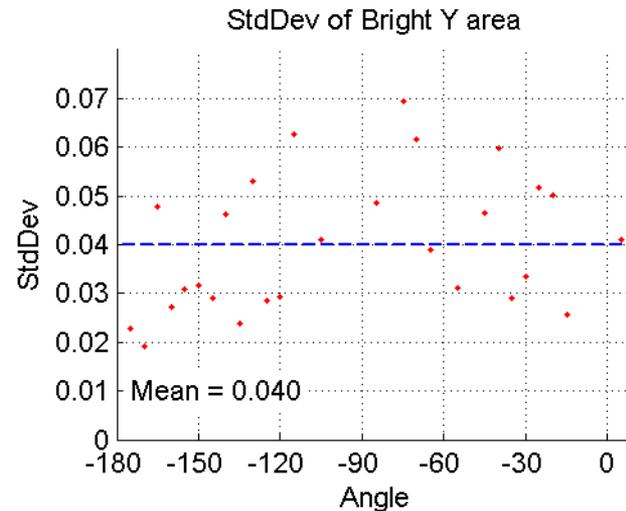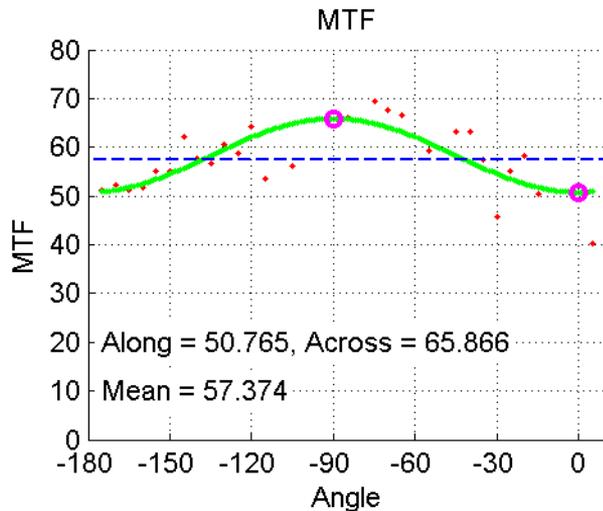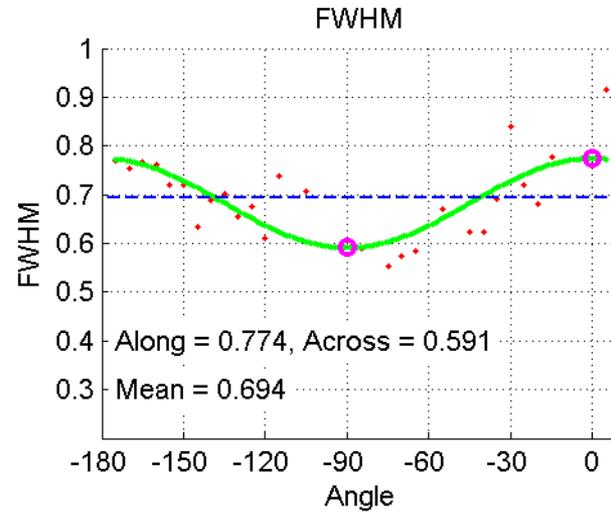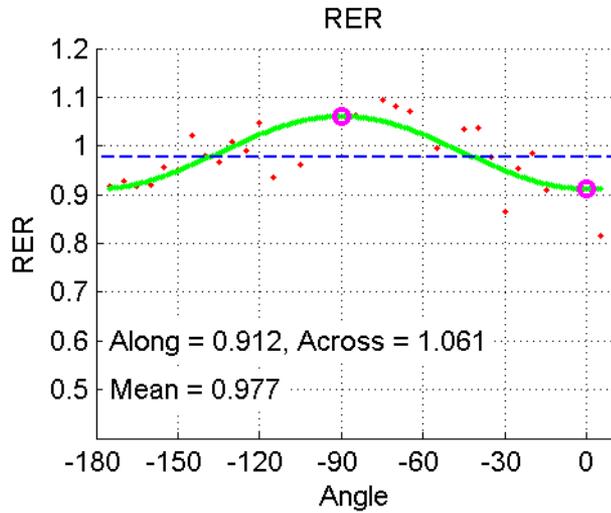
RER, FWHM, MTF (Band_3)
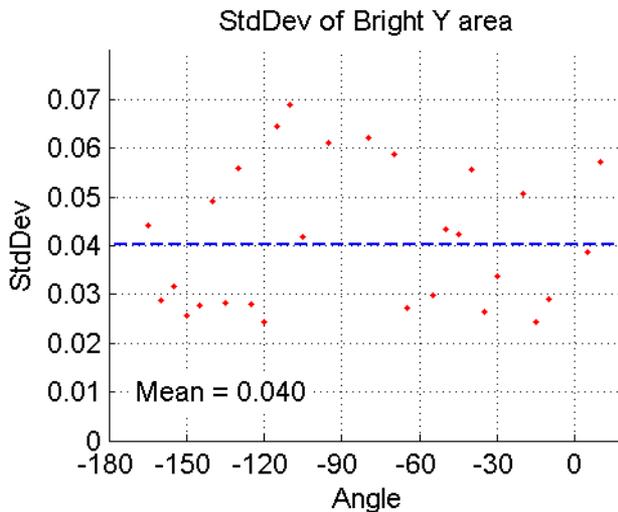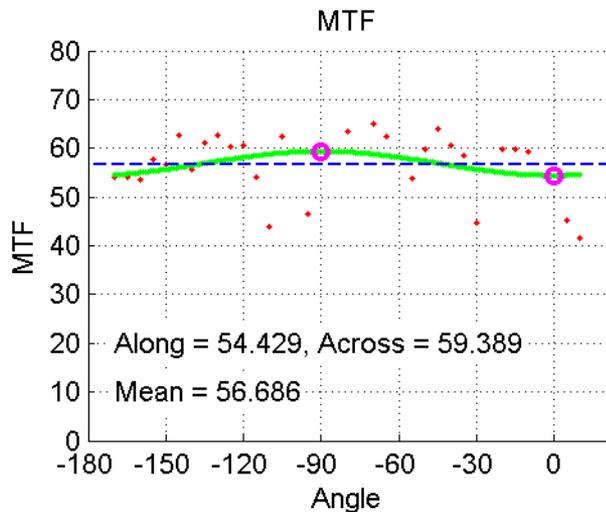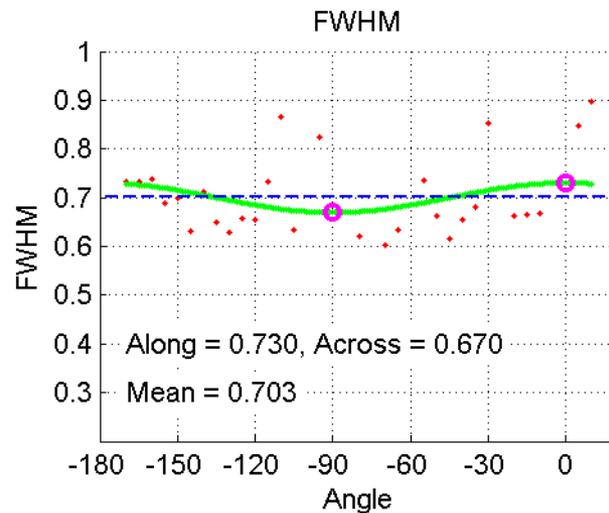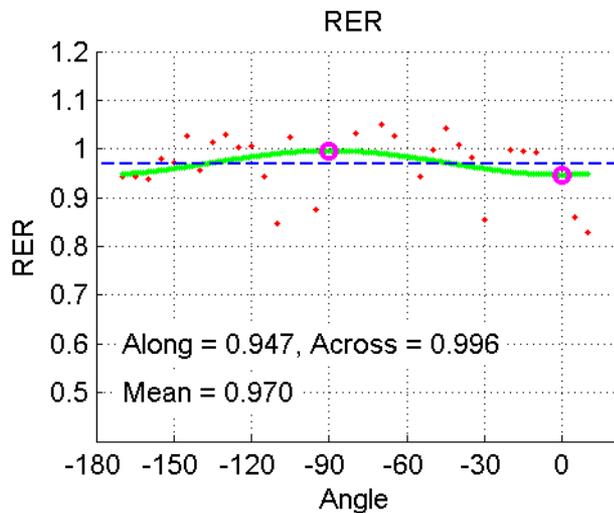
RER, FWHM, MTF (Band_4)
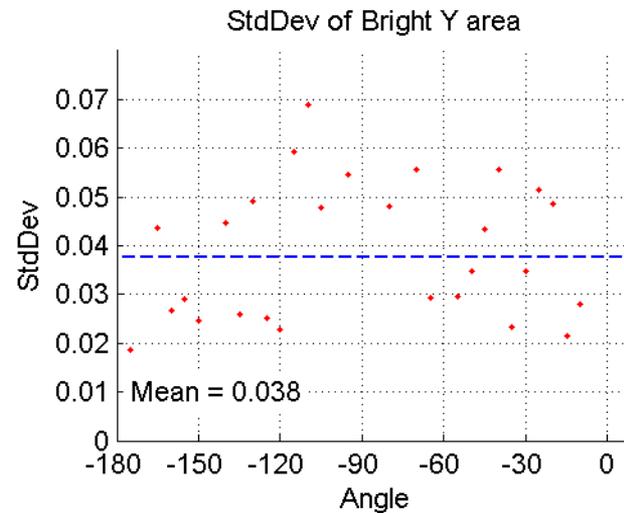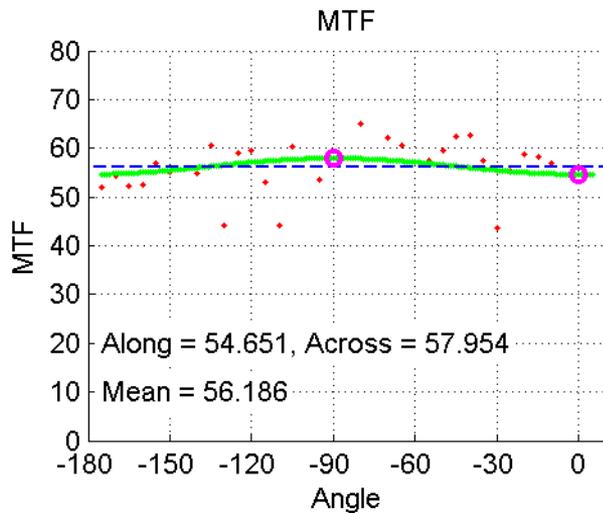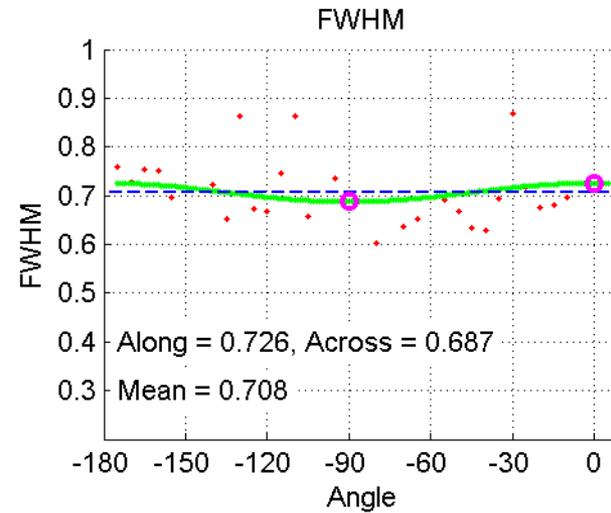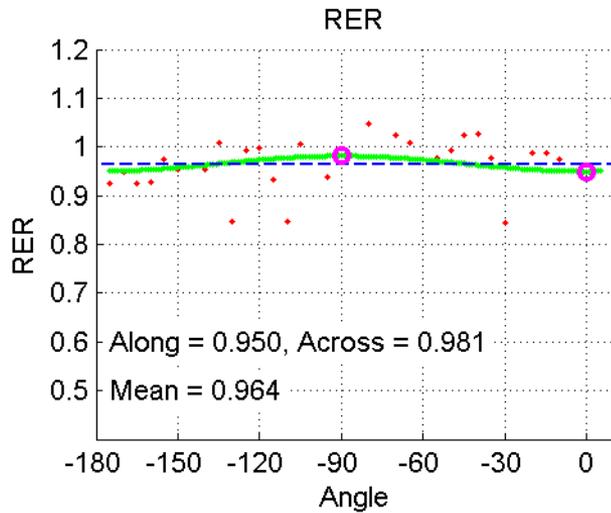
RER, FWHM, MTF (Band_5)
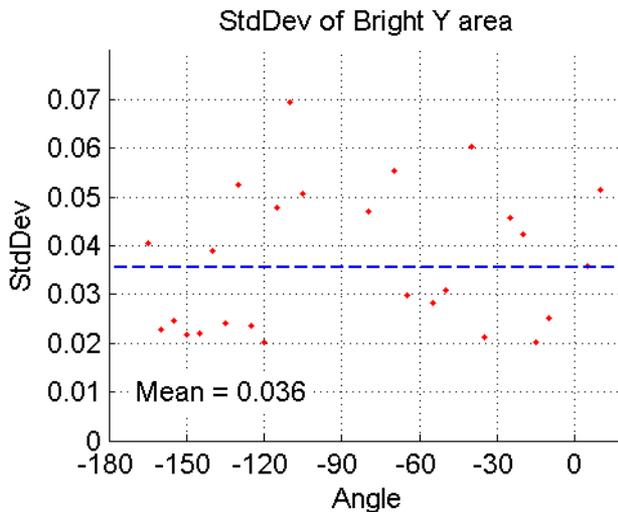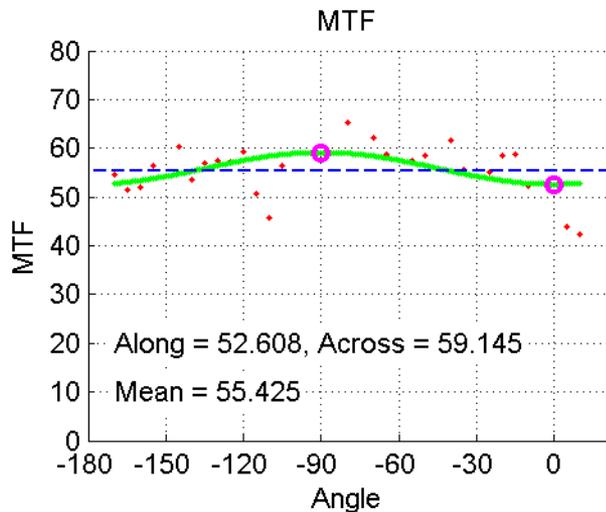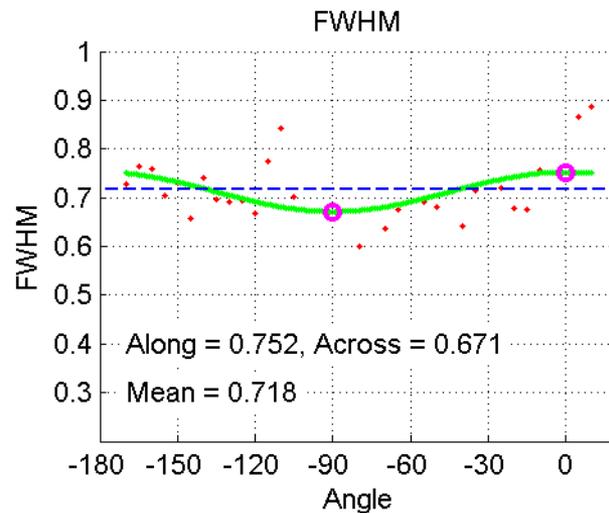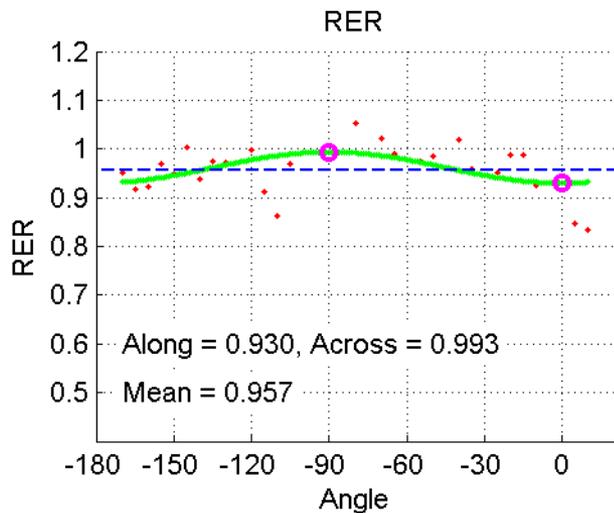
RER, FWHM, MTF (Band_6)
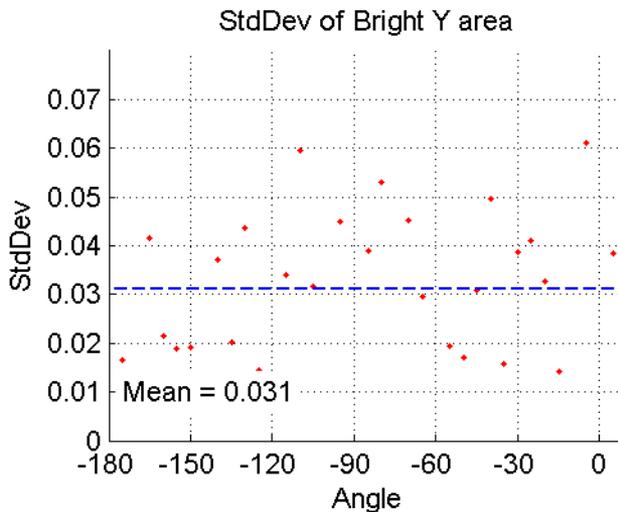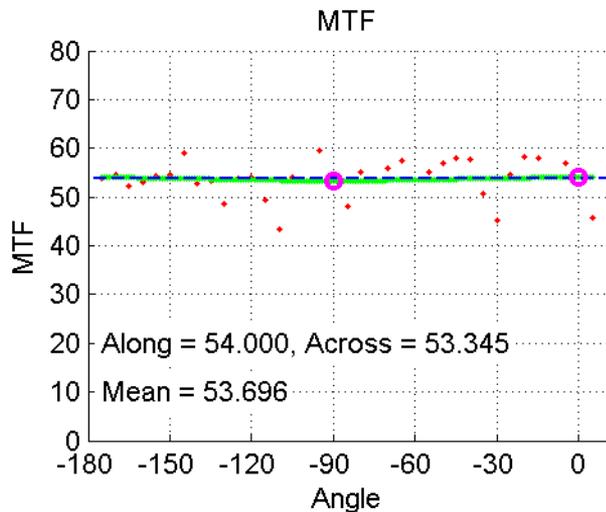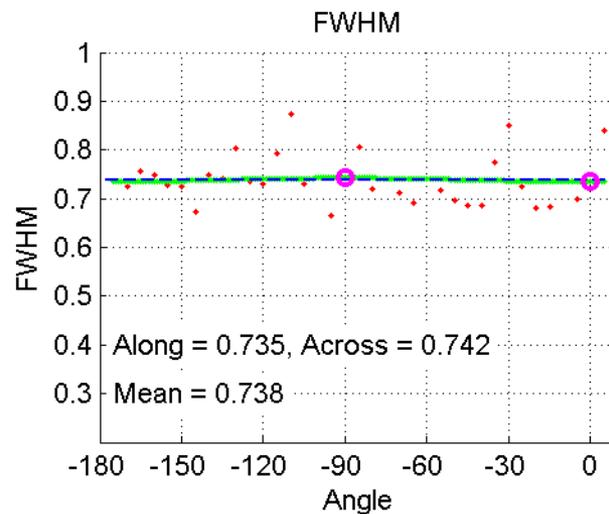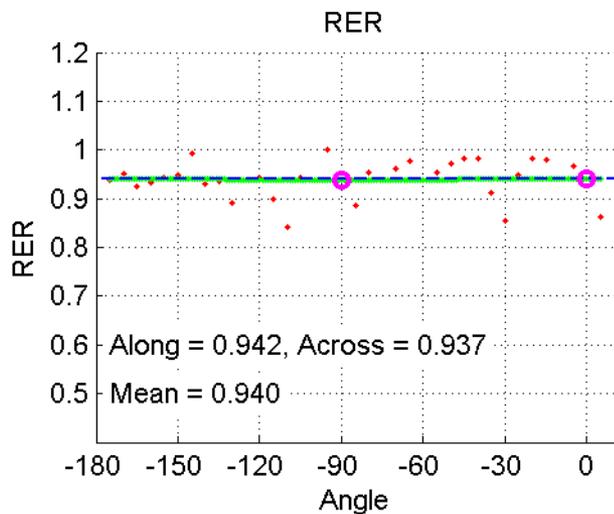
RER, FWHM, MTF (Band_7)
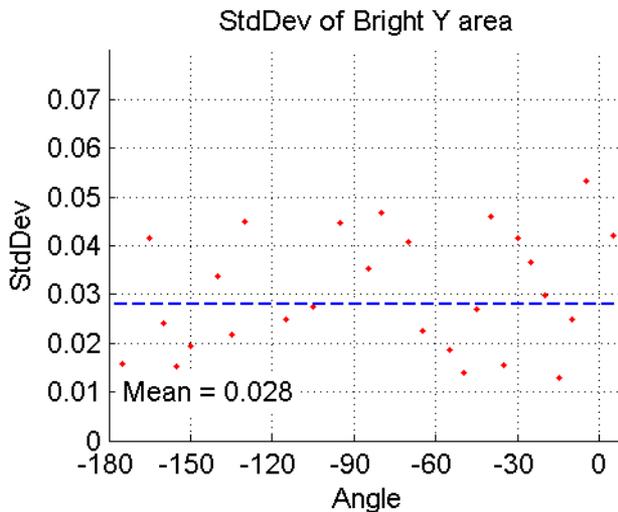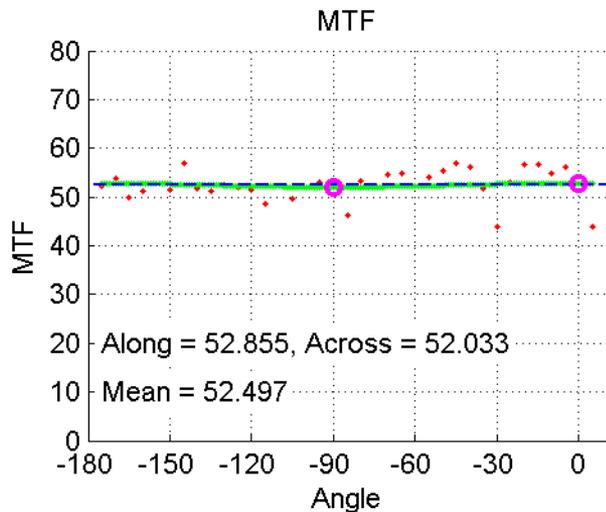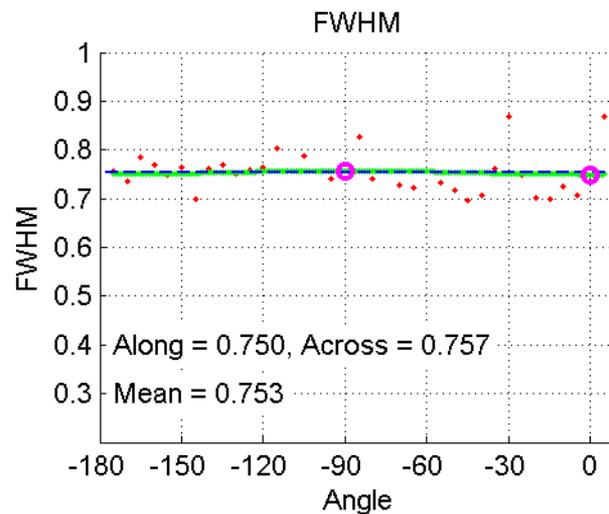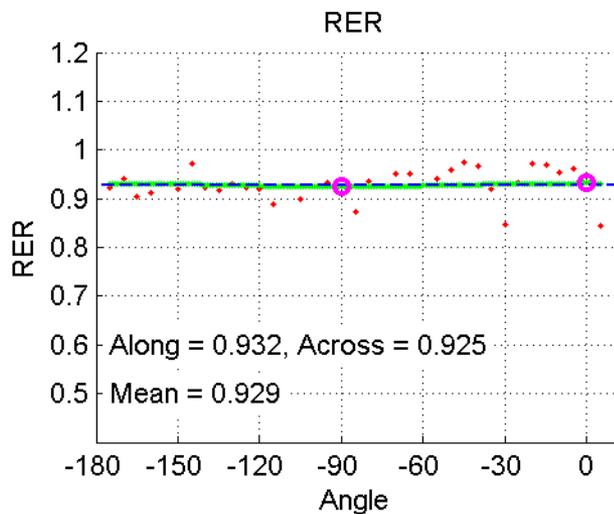
RER, FWHM, MTF (Band_8, PAN)
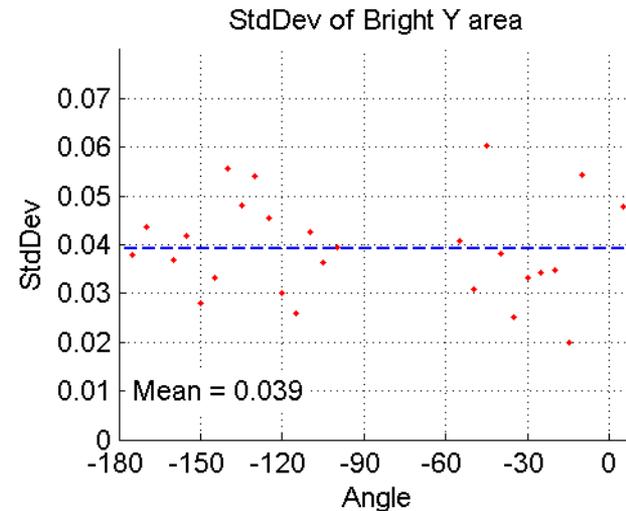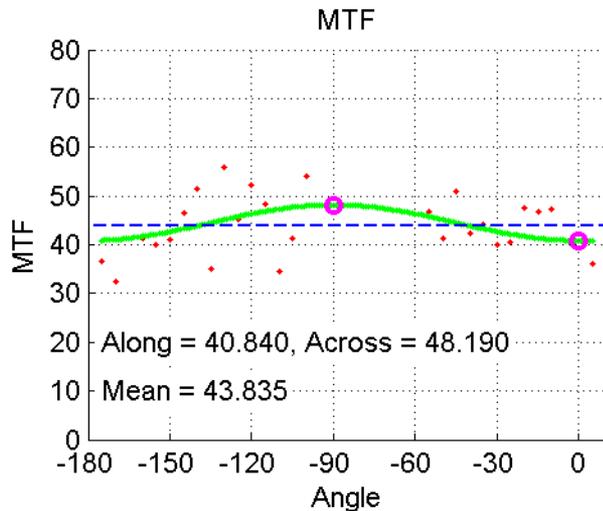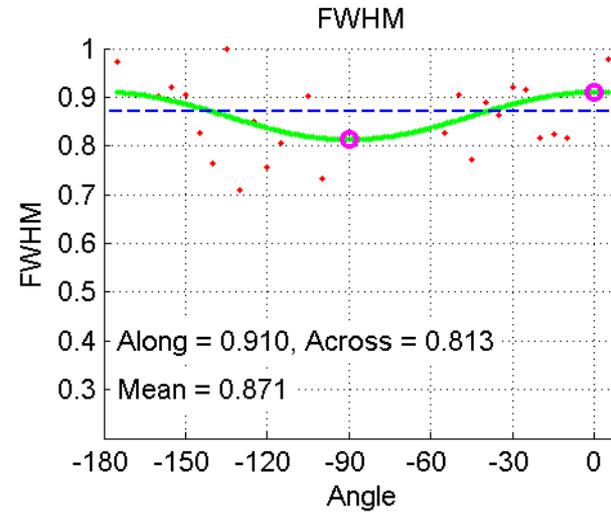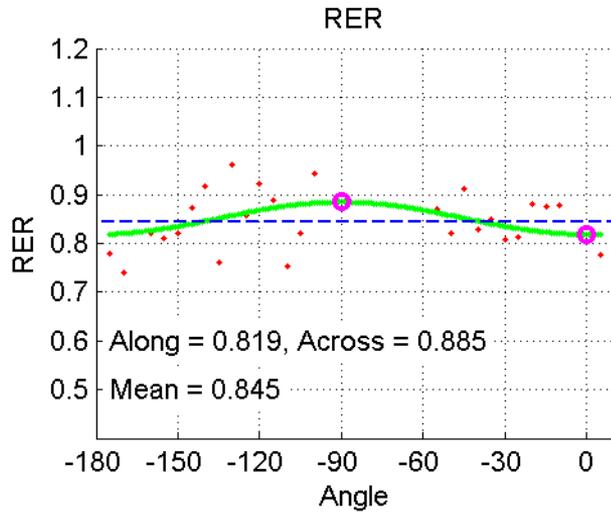
RER, FWHM, MTF (Band_9)
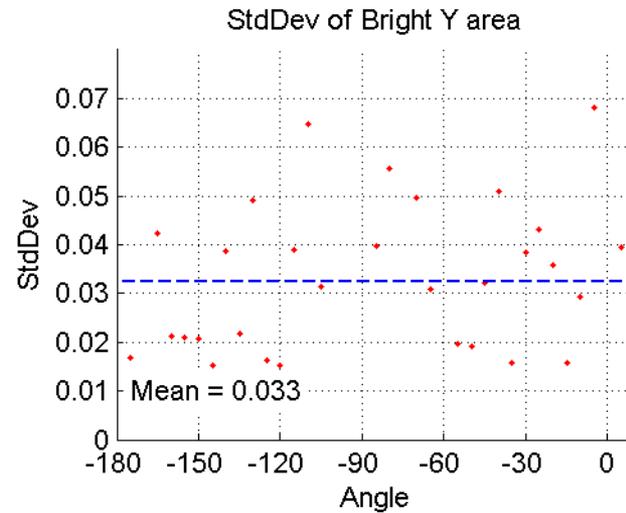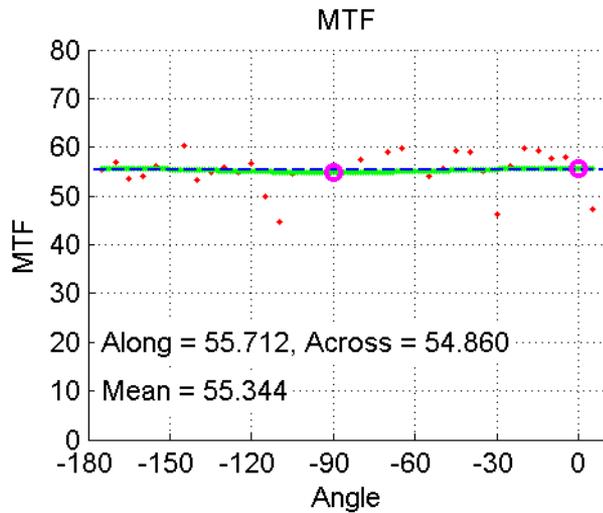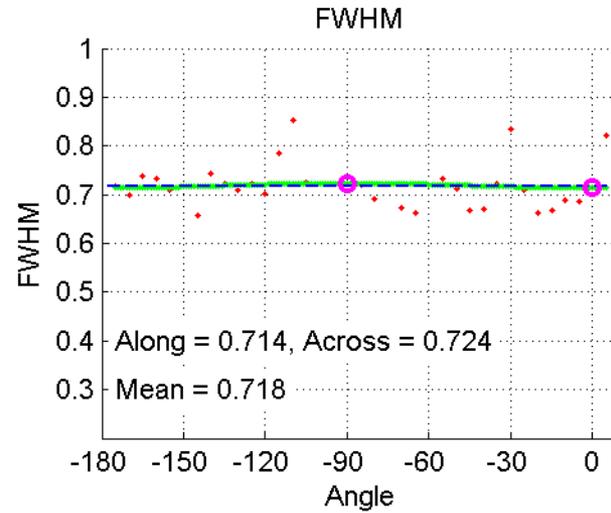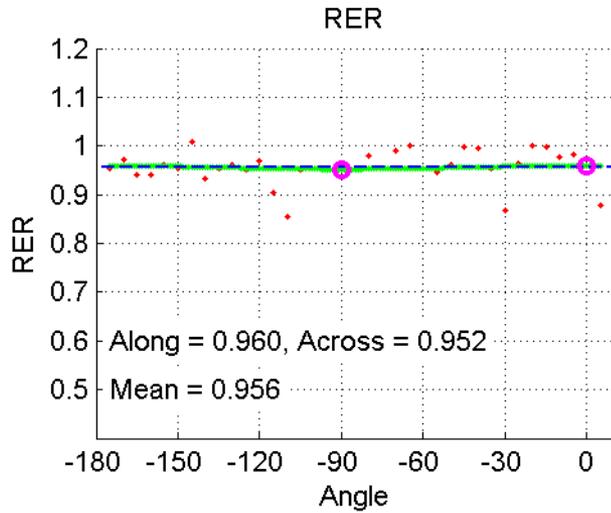
Dataset of Level 1R Lunar data

No.	Filename	SCA
1	LO800U0006422013175LGN00	8
2	LO800U1043222014076LGN00	7
3	LO800U2007202013351LGN00	8

Result of RER, FHWM, MTF

| Band	Dataset	SCA	RER			FWHM			MTF		
			mean	Along	Across	mean	Along	Across	mean	Along	Across
B1	LO800U0006422013175LGN00	8	0.985	0.927	1.062	0.684	0.755	0.590	58.21	52.32	66.00
	LO800U1043222014076LGN00	7	0.938	0.904	0.981	0.742	0.787	0.686	53.41	49.89	57.85
	LO800U2007202013351LGN00	8	0.980	0.948	1.009	0.688	0.728	0.651	57.78	54.44	60.89
	Average		0.968	0.926	1.017	0.705	0.757	0.642	56.47	52.22	61.58
B2	LO800U0006422013175LGN00	8	0.977	0.912	1.061	0.694	0.775	0.591	57.37	50.76	65.87
	LO800U1043222014076LGN00	7	0.933	0.882	0.985	0.750	0.818	0.681	52.87	47.50	58.26
	LO800U2007202013351LGN00	8	0.962	0.924	1.002	0.711	0.759	0.660	55.92	51.98	60.08
	Average		0.957	0.906	1.016	0.718	0.784	0.644	55.39	50.08	61.40
B3	LO800U0006422013175LGN00	8	0.970	0.947	0.996	0.703	0.730	0.670	56.69	54.43	59.39
	LO800U1043222014076LGN00	7	0.923	0.907	0.940	0.762	0.781	0.743	51.86	50.27	53.52
	LO800U2007202013351LGN00	8	0.963	0.953	0.972	0.709	0.722	0.696	56.05	54.99	57.10
	Average		0.952	0.936	0.969	0.725	0.744	0.703	54.87	53.23	56.67
B4	LO800U0006422013175LGN00	8	0.965	0.950	0.981	0.708	0.726	0.687	56.19	54.65	57.95
	LO800U1043222014076LGN00	7	0.925	0.897	0.958	0.759	0.797	0.715	52.07	49.08	55.46
	LO800U2007202013351LGN00	8	0.973	0.930	1.011	0.697	0.748	0.653	57.00	52.84	60.68
	Average		0.954	0.926	0.983	0.721	0.757	0.685	55.09	52.19	58.03
B5	LO800U0006422013175LGN00	8	0.957	0.930	0.994	0.718	0.752	0.672	55.42	52.61	59.14
	LO800U1043222014076LGN00	7	0.916	0.893	0.942	0.770	0.802	0.735	51.17	48.73	53.83
	LO800U2007202013351LGN00	8	0.939	0.941	0.938	0.739	0.737	0.741	53.63	53.81	53.46
	Average		0.937	0.921	0.958	0.742	0.764	0.716	53.41	51.72	55.48
B6	LO800U0006422013175LGN00	8	0.940	0.942	0.937	0.738	0.735	0.742	53.70	54.00	53.34
	LO800U1043222014076LGN00	7	0.915	0.916	0.915	0.770	0.769	0.772	51.17	51.32	51.01
	LO800U2007202013351LGN00	8	0.922	0.916	0.928	0.764	0.779	0.751	51.85	51.17	52.44
	Average		0.926	0.925	0.927	0.757	0.761	0.755	52.24	52.16	52.26
B7	LO800U0006422013175LGN00	8	0.929	0.932	0.925	0.753	0.750	0.757	52.50	52.85	52.03
	LO800U1043222014076LGN00	7	0.884	0.891	0.878	0.815	0.805	0.823	47.76	48.65	47.00
	LO800U2007202013351LGN00	8	0.925	0.943	0.908	0.758	0.735	0.780	52.11	54.05	50.26
	Average		0.913	0.922	0.904	0.775	0.763	0.787	50.79	51.85	49.76
B8 (PAN)	LO800U0006422013175LGN00	8	0.846	0.819	0.885	0.871	0.910	0.813	43.83	40.84	48.19
	LO800U1043222014076LGN00	7	0.790	0.765	0.816	0.961	1.001	0.918	37.73	35.06	40.63
	LO800U2007202013351LGN00	8	0.834	0.806	0.864	0.890	0.934	0.843	42.54	39.49	45.76
	Average		0.823	0.797	0.855	0.907	0.948	0.858	41.37	38.46	44.86
B9	LO800U0006422013175LGN00	8	0.957	0.960	0.952	0.718	0.714	0.724	55.34	55.71	54.86
	LO800U1043222014076LGN00	7	0.933	0.928	0.938	0.748	0.753	0.743	52.96	52.56	53.34
	LO800U2007202013351LGN00	8	0.938	0.956	0.922	0.742	0.719	0.763	53.47	55.39	51.65
	Average		0.943	0.948	0.937	0.736	0.729	0.743	53.92	54.55	53.28

Compare and Result of RER, FHWM, MTF

OLI	Edge Slope	GSD		RER	
		MS	PAN	MS	PAN
Specification	0.027	30	15	0.81	0.405
Measured (Jim Storey at TIM, 2013.12)	0.03054	29.934	14.932	0.914184	0.456023
Measured (Jim Storey at TIM, 2014.04)	0.02966	29.934	14.932	0.887842	0.442883

Band	RER	FWHM	MTF
1	0.968	0.705	56.47
2	0.957	0.718	55.39
3	0.952	0.725	54.87
4	0.954	0.721	55.09
5	0.937	0.742	53.41
6	0.926	0.757	52.24
7	0.913	0.775	50.79
8 (PAN)	0.823	0.907	41.37
9	0.943	0.736	53.92

# Issues & Concerns

1. **Along & Across**
   a. (X-axis) * cos(Edge line angle)
   b. (Along) Value at angle 0, 180 / (Across) Value at angle 90, 270 by 'Sine Fitting'
   c. In B6, B7 and B9, Along & Across are almost same (Is it OK?)
      a. Cause by Sine Fitting (?)
      b. Signal difference between Bands (?)
2. **SCA_7 & SCA_8**
   a. SCA_7 is smaller than SCA_8
   b. Cause by the short number of Dataset (?)
   c. Cause by scanning difference between them
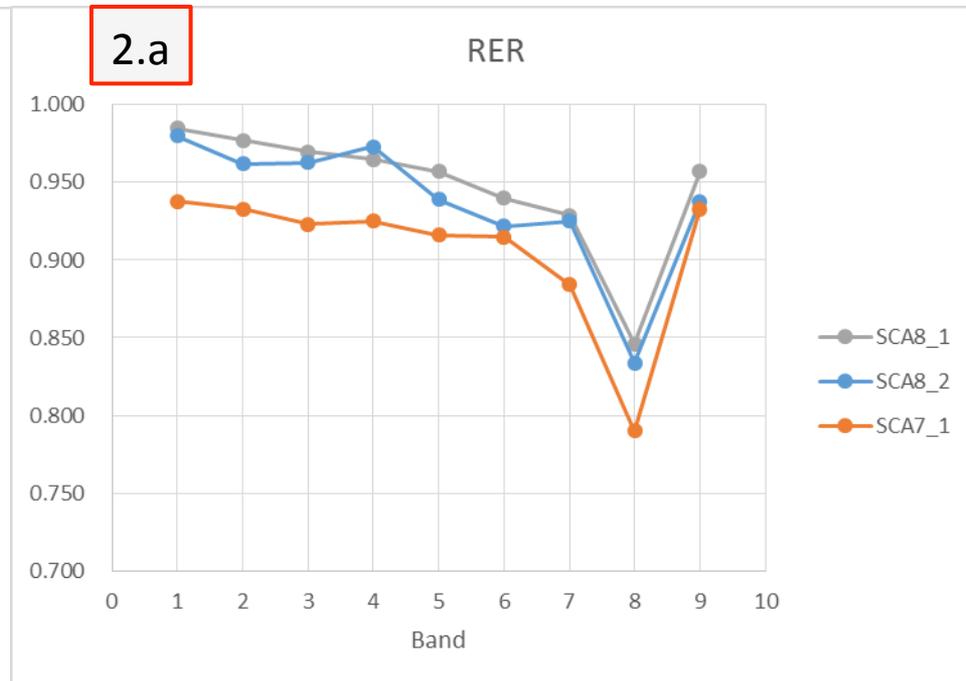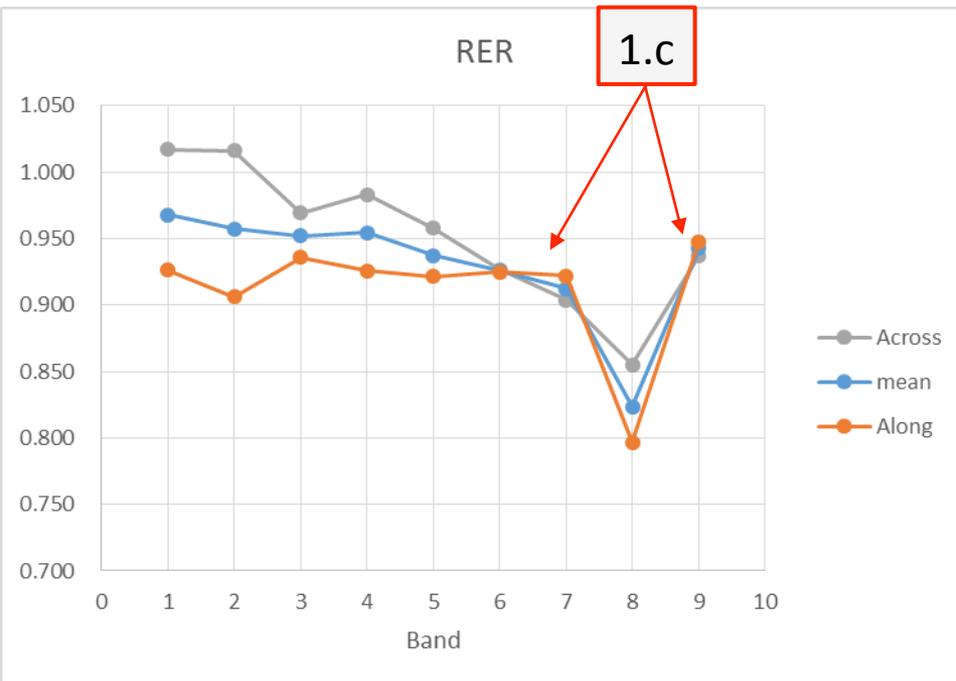
Future Work

1. **Debugging**

2. **Process, Get and Compare the result of more Level 1R Lunar data**

3. **Need More Criterions to remove the low reliable angle value**

Band_3

Along = 0.947, Across = 0.996
Mean = 0.970

Band_4

Along = 0.950, Across = 0.981
Mean = 0.964