On-orbit Spatial Characterization of IKONOS

HIGH SPATIAL RESOLUTION COMMERCIAL IMAGERY WORKSHOP

Reston, VA

Presented by

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OUTLINE

- Method Description
- Target Description
- Results
  - Panchromatic Band
    - Parking Lots
    - Blue Tarps (big and small)
    - Big Spring, TX
  - Multispectral Bands
    - Blue Tarps
- Conclusions

Method Description

- Nonparametric Model
- MTF calculation methods
  - Edge method
  - Pulse method
  - Impulse method (TBD)
- Averaging techniques
  - Spline method

- Edge method (MTF calculation method)
  - A knife edge should be chosen in an image.
  - Average the profile along the edge (ESF).
  - Differentiate the averaged profile.
  - Fourier transform and normalize.

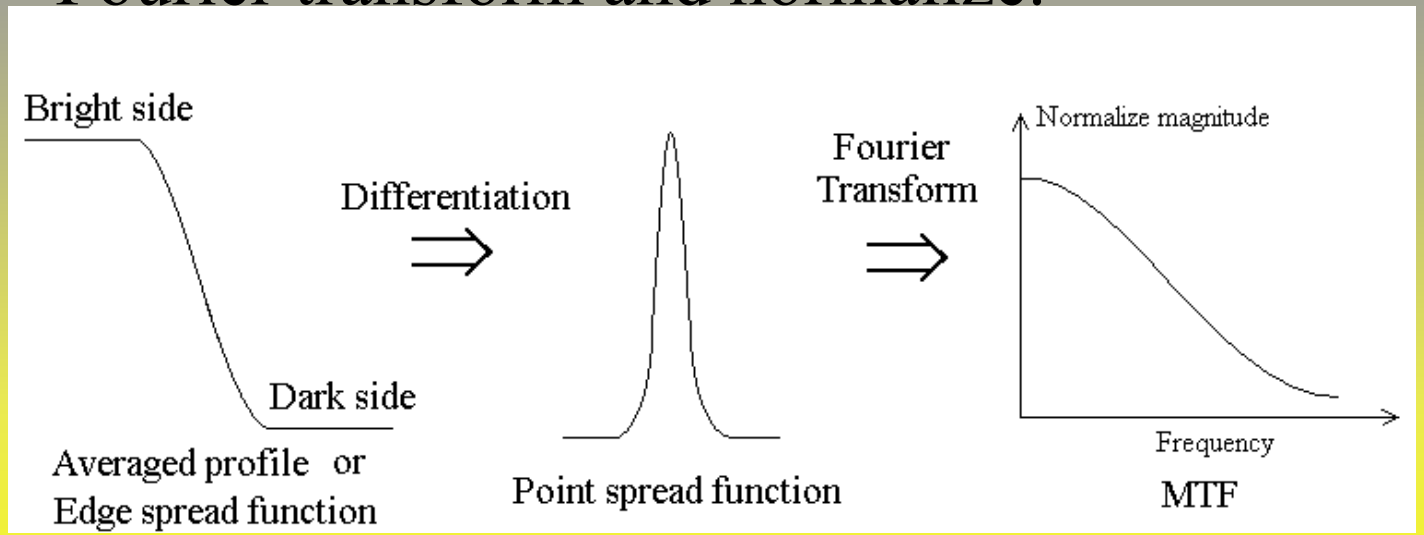


Fig 1. Edge analysis

– Edge detection

- DN values for a line as given in the data below,

0.00 0.00 0.01 0.04 0.11 0.26 0.50 0.73 0.88 0.95 0.98 1.00 1.00

- Simple digital differentiation (x[n] - x[n-1]) has been applied to detect maximum slope

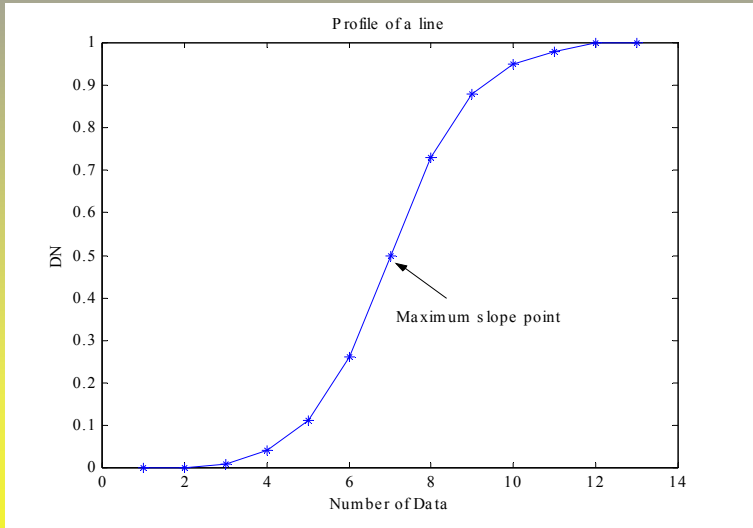


Figure 2. An example of a blurred edge

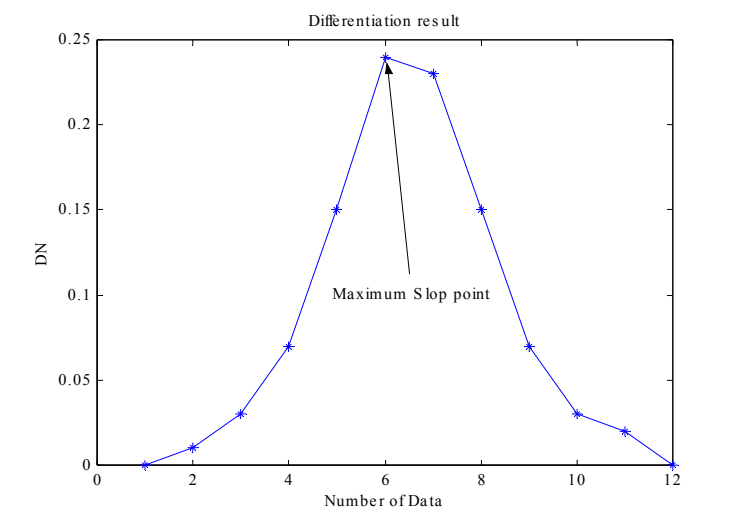


Figure 3. Result of differentiation

– Least-square fitting line for edge points

- Assumption is the edge of the target lies in a straight line.
- Any deviations from a straight line edge represent errors in the geometry of the image.
- A least-square fitting line was found through the sub-pixel edge points in Figure 4.

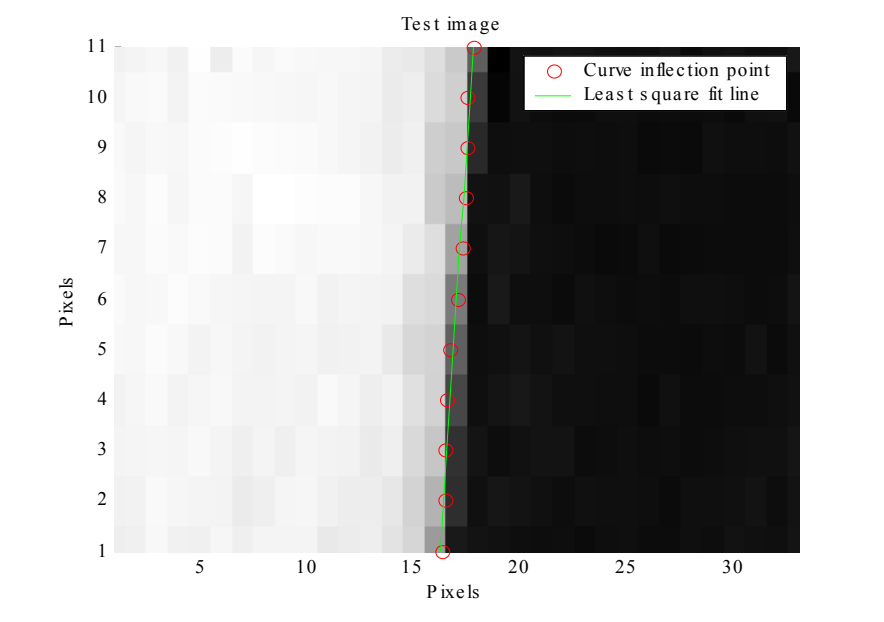


Figure 4. An example of least square fitting line

- Every usable line of the test image was splined.
- Average profile was calculated by averaging all sub-pixel points in the figures.

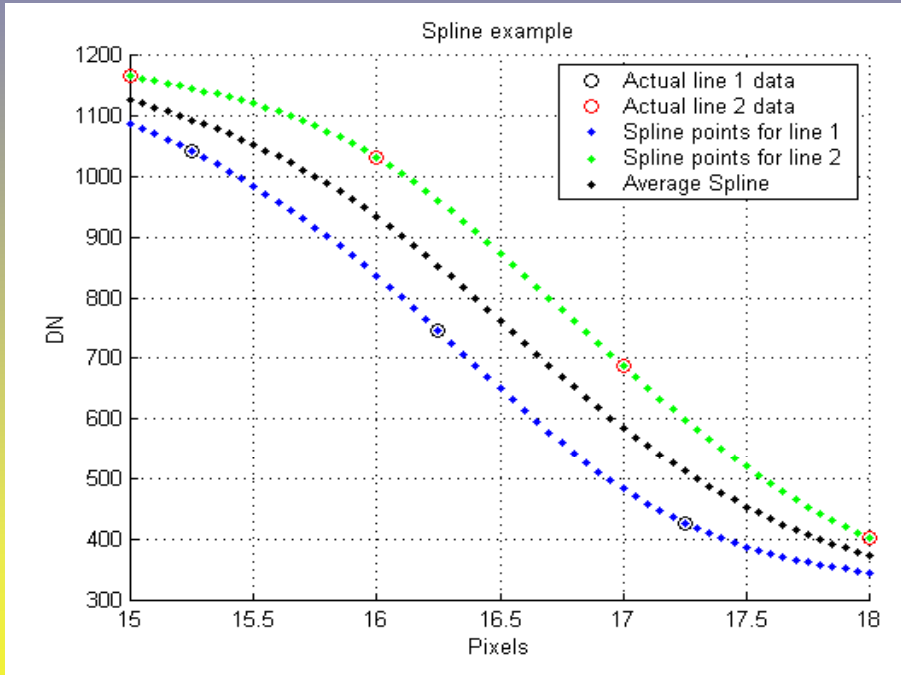


Figure 6. Averaging technique for two spline lines

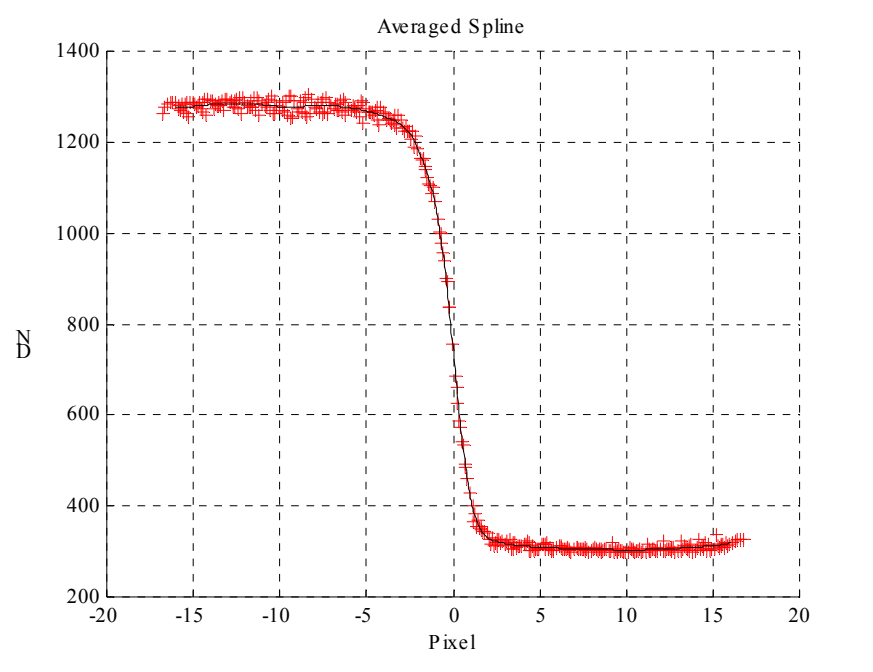


Figure 7. Average profile from 12 lines of data points

– Obtaining the Line Spread Function (LSF)

- LSF is simple differentiation of the edge spread function (ESF) which is average profile.
- LSF profile was trimmed to reduce the noise present in the uniform areas on either side of the edges

$$LSF(n) = ESF(n) - ESF(n+1).$$

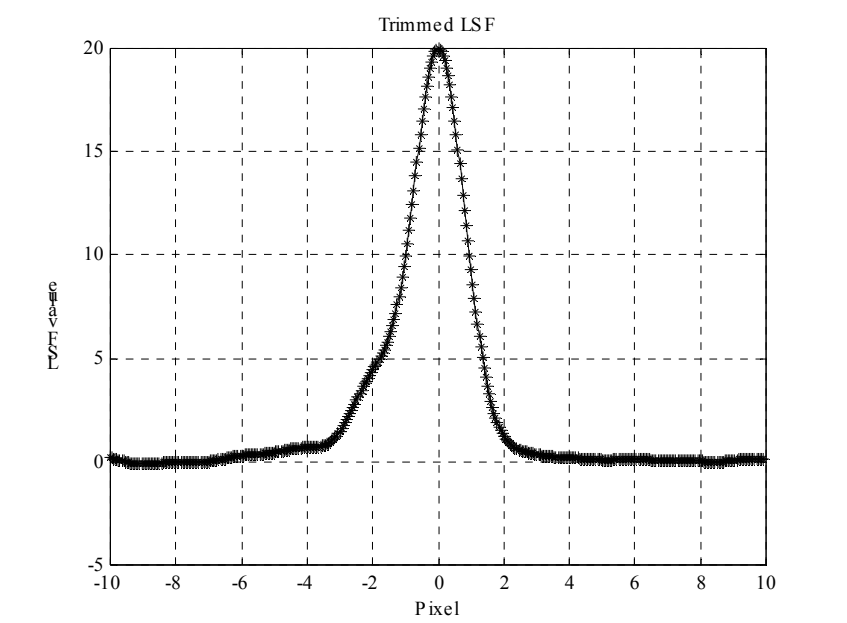


Figure 8. An example of LSF (Line Spread Function)

– MTF calculation

- Discrete Fourier transform was applied to the trimmed LSF functions.
- Magnitude function obtained and normalized.
- Nyquist Frequency value obtained.

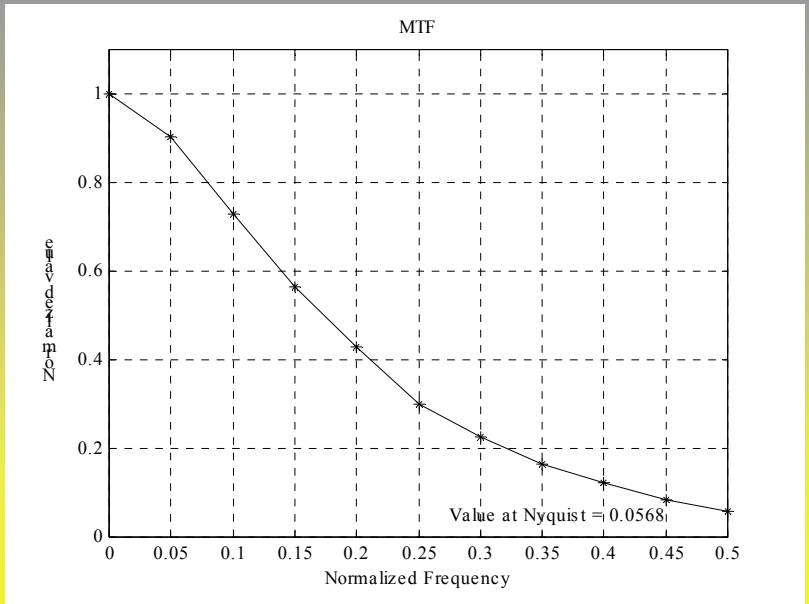


Figure 9. An example of MTF plot

- Pulse method
  - A pulse input is given to an imaging system.
  - Output of the system is the resulting image.
  - Take Fourier transform of the input and output.
  - MTF is calculated by dividing output by input.

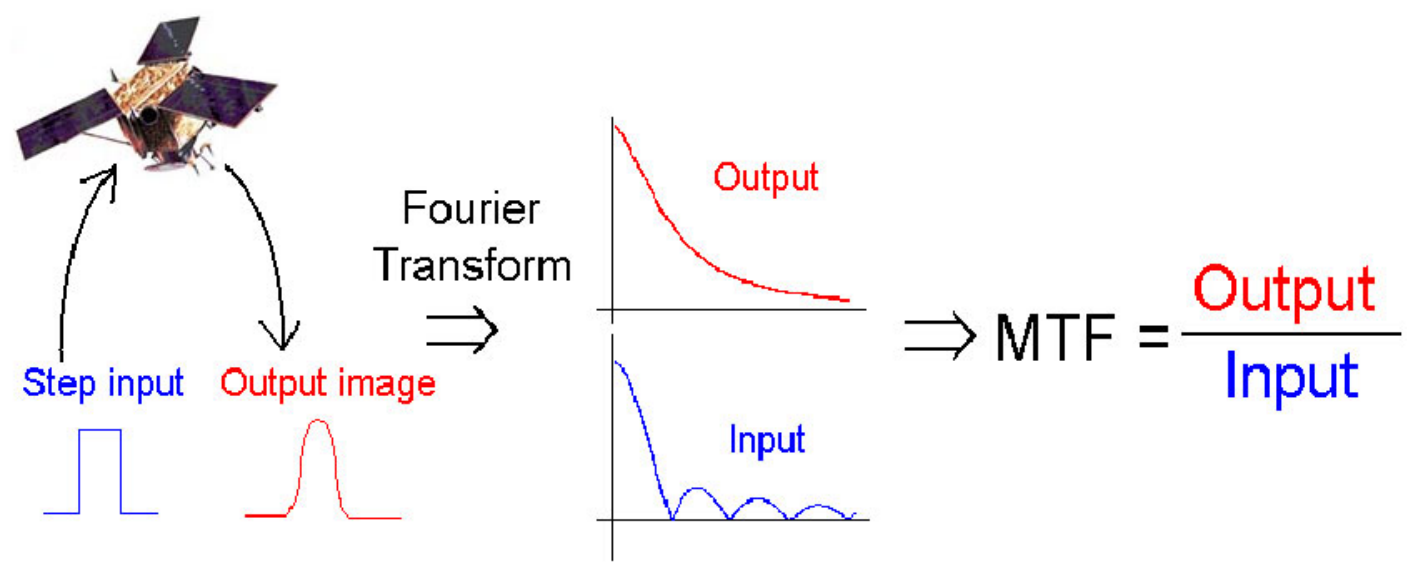


Figure 10. Pulse method

- Edge detection and least square fitting line were applied in Figure 11.
- Spline method used to get an averaged output profile in Figure 12.

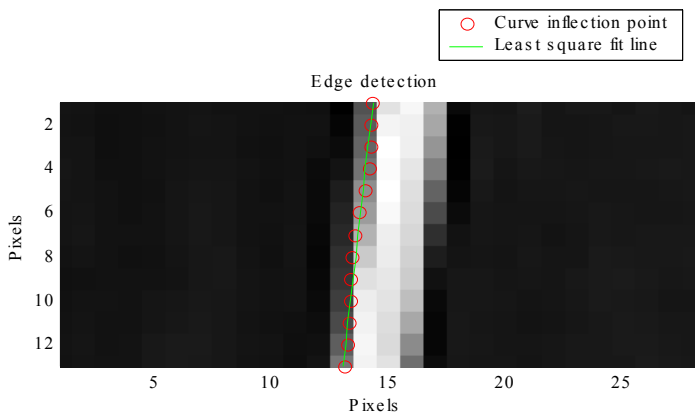


Figure 11. Edge detection and least square fitting line

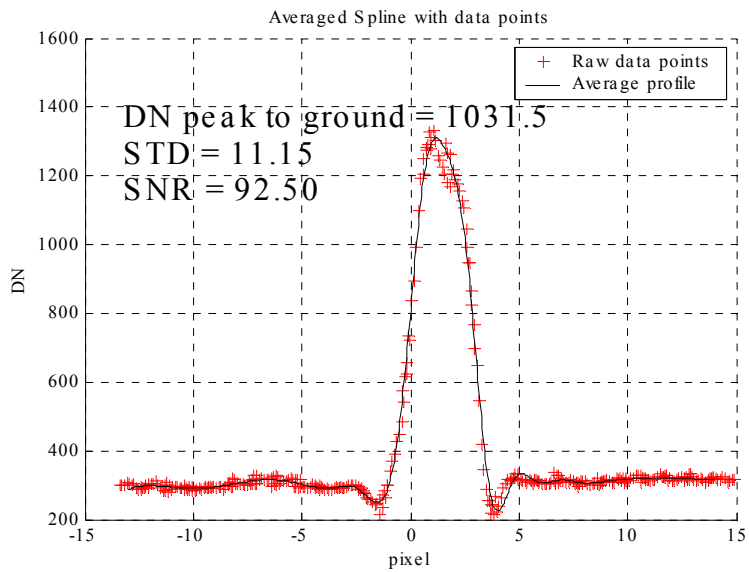


Figure 12. Average profile

- Pulse input signal is determined by width and orientation of ground target.
- Tarps width was 9 meters which corresponds to 2.25 pixels in multispectral bands in Figure 13.
- Discrete Fourier transform was applied.

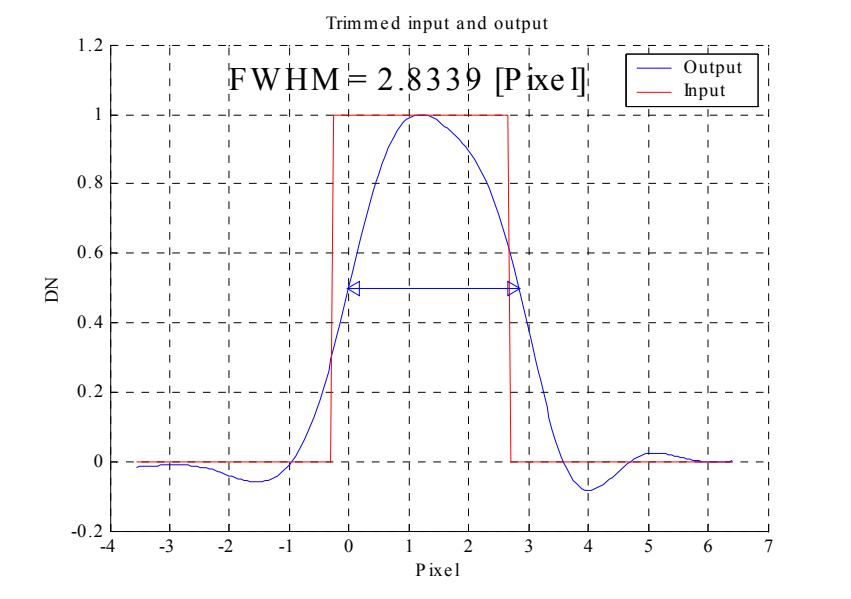


Figure 13. Input and output signals of imaging system.

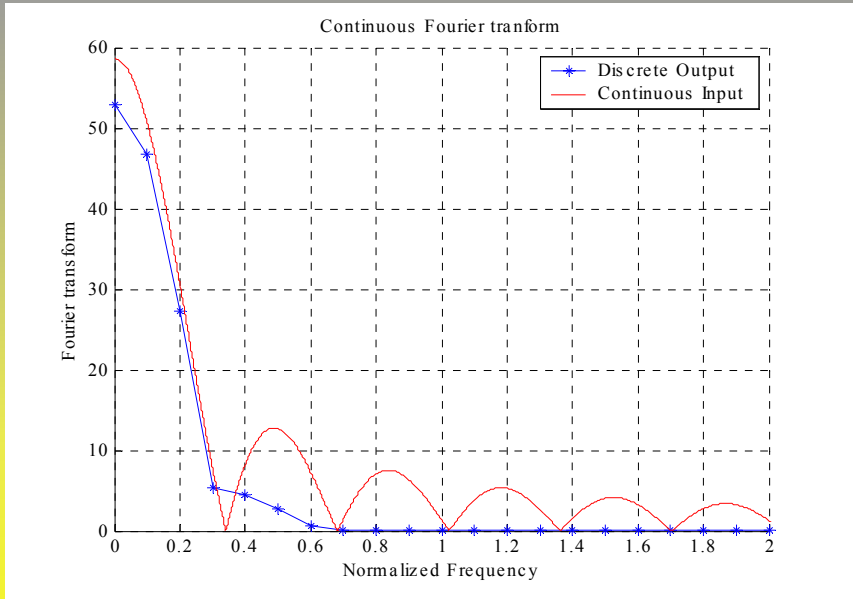


Figure 14. Fourier transform of input and output signals.

- The MTF was calculated by dividing each output value by each corresponding input value.
- The resulting MTF is normalized.
- Nyquist frequency obtained.

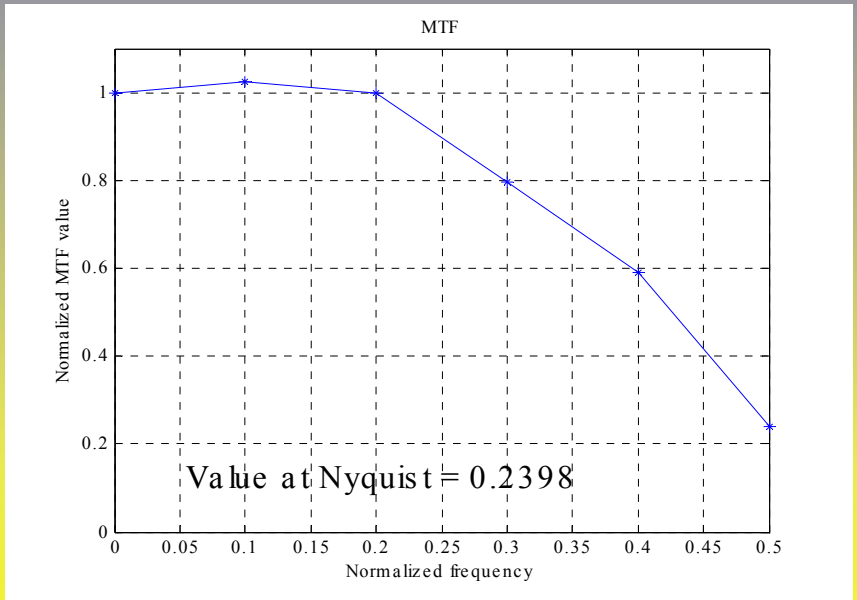


Figure 15. An example of resulting MTF plot.

- Tarp width versus Nyquist frequency
  - With the pulse method, tarp width should be carefully chosen.
  - Zero crossing points should be avoided at the desired Nyquist frequency in Figure 16.

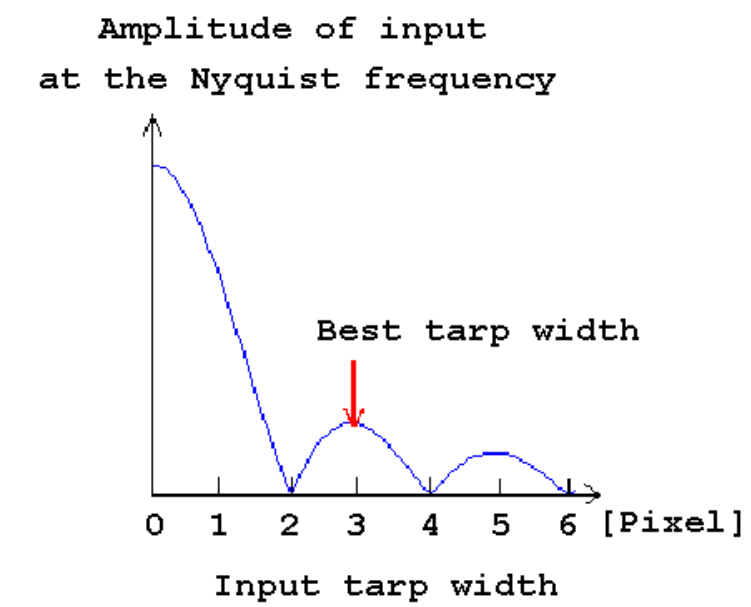


Figure 16. Nyquist frequency position on the input sinc function by the tarp width

- Impulse method
  - MTF is the normalized spatial frequency response of an imaging system.
  - The frequency response can be evaluated by applying an impulse input.

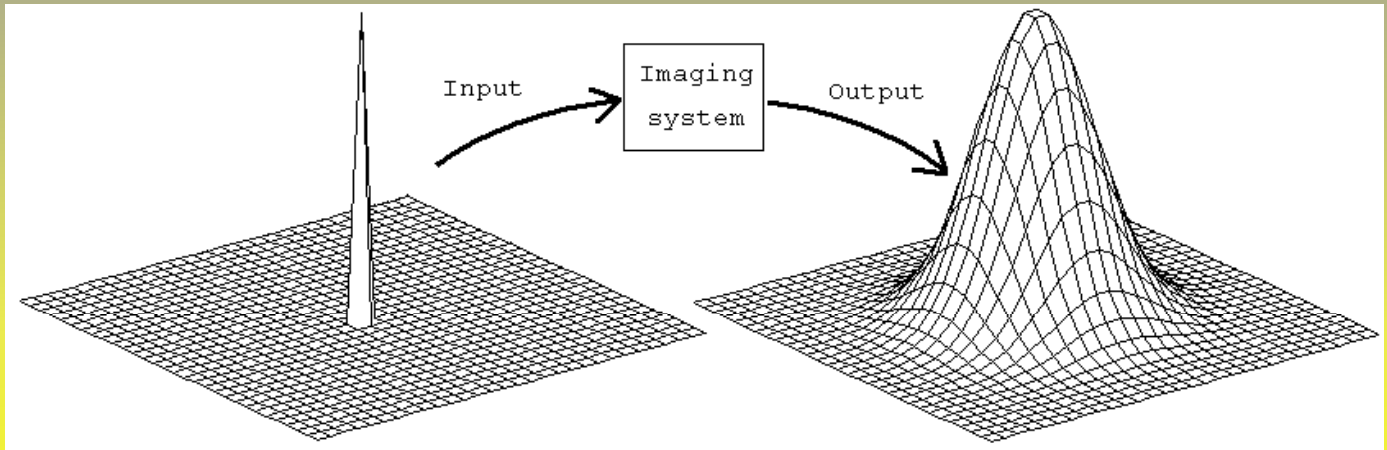


Figure 17. An example of impulse and the resulting PSF

Targets

- Brookings, SD
  - Dates: July 3, 17, 25 and Aug. 13, 2001
  - Parking lot 1 and 2
  - Blue tarps
- Big Spring, TX
  - Dates: June 22 and Aug. 5, 2001
  - Painted asphalt target

- Brookings - Parking lot 1

(a) July 3, 2001

(b) July 17, 2001

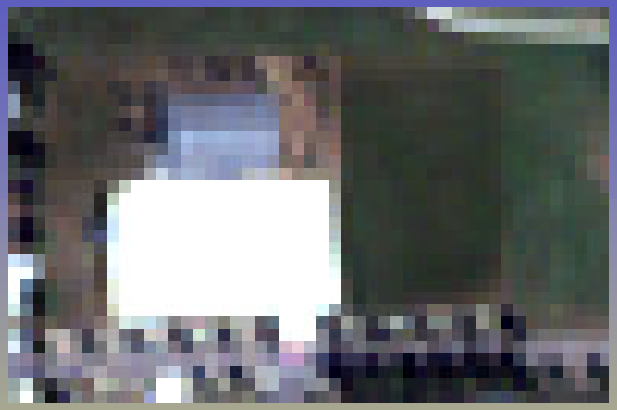
(c) July 25, 2001

(d) Aug. 13, 2001

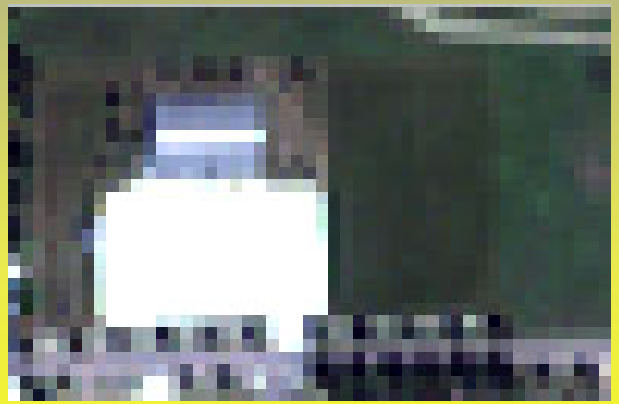
Fig 23. Brookings parking lot 1

- Brookings - Parking lot 2

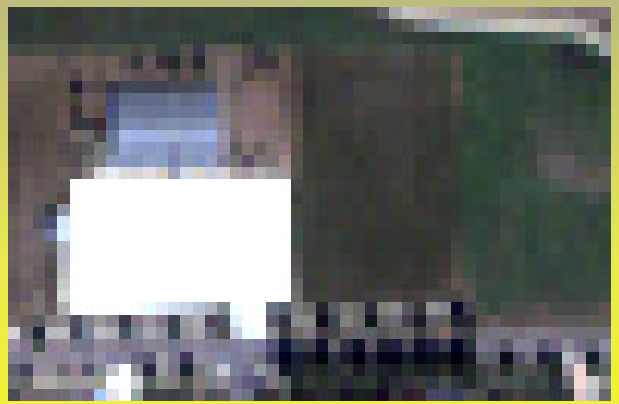
(a) July 3, 2001



(b) July 17, 2001



(c) July 25, 2001



(d) Aug. 13, 2001

Fig 24. Brookings parking lot 2

- Brookings - Blue tarps

(a) July 3, 2001

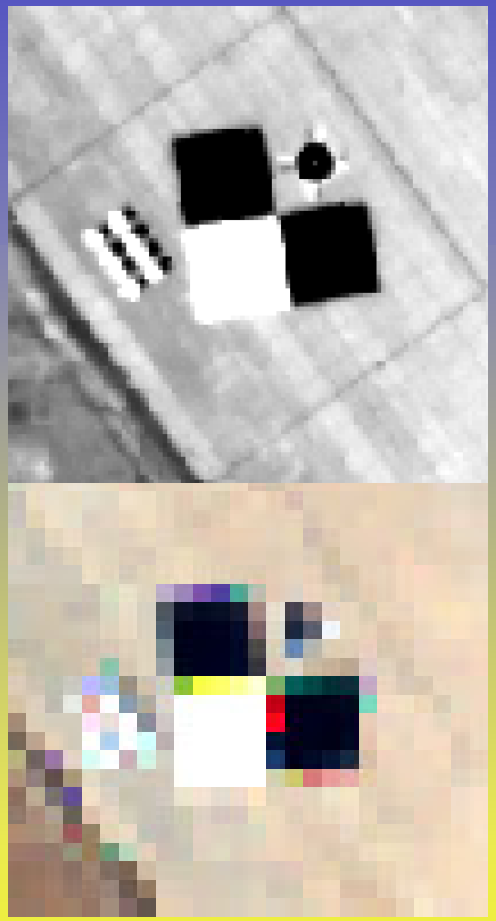
(b) July 17, 2001

(c) July 25, 2001

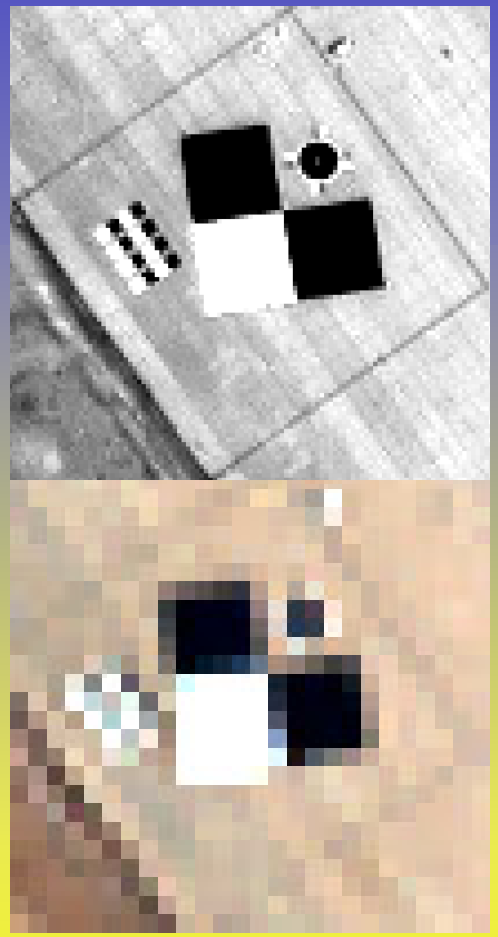
(d) Aug. 13, 2001

Fig 25. Brookings tarp target

- Big Spring - Painted concrete target



(a) June 22, 2001



(b) Aug. 5, 2001

Fig 27. Big Spring painted concrete target

- Parking lot 1 - July 3, 2001
  - Azimuth: 281.85, Elevation: 76.19

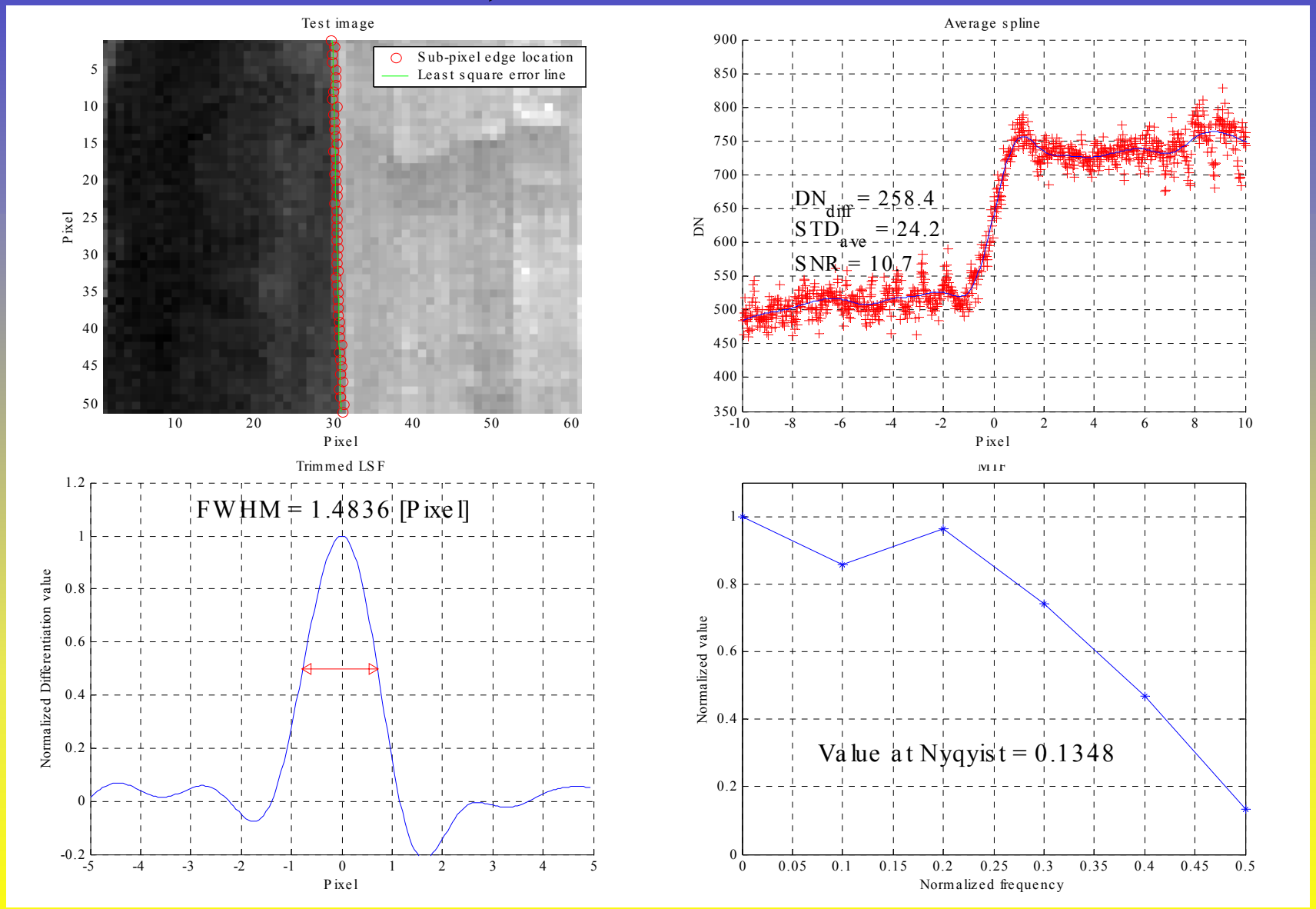


Figure 29. Parking lot 1 on July 3, 2001.

- Parking lot 1 - July 17, 2001
  - Azimuth: 289.94, Elevation: 60.80

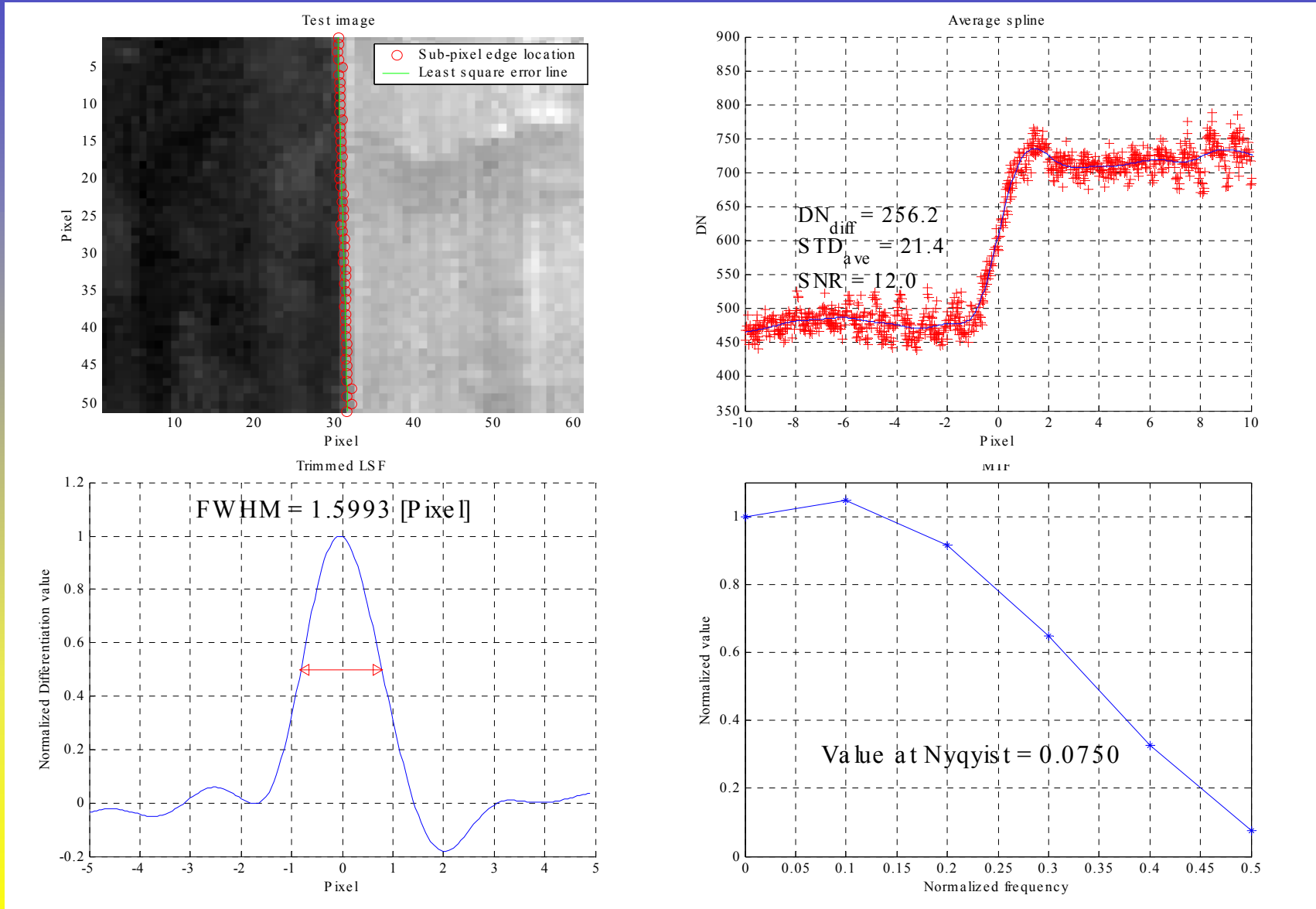


Figure 30. Parking lot 1 on July 17, 2001.

- Parking lot 1 - July 25, 2001
  - Azimuth: 269.50, Elevation: 73.20

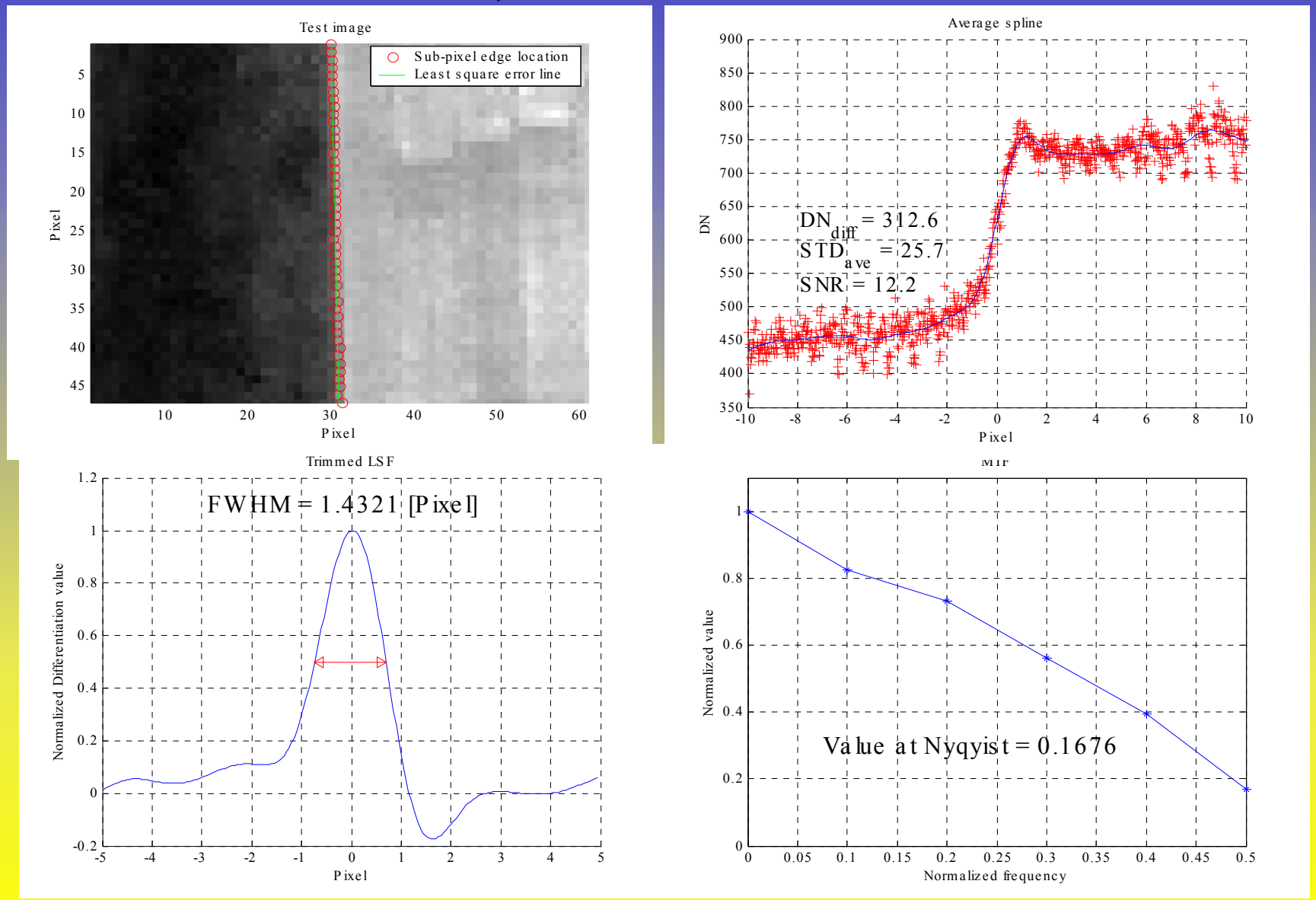


Figure 31. Parking lot 1 on July 25, 2001.

- Parking lot 1 - August 13, 2001
  - Azimuth: 353.76, Elevation: 82.54

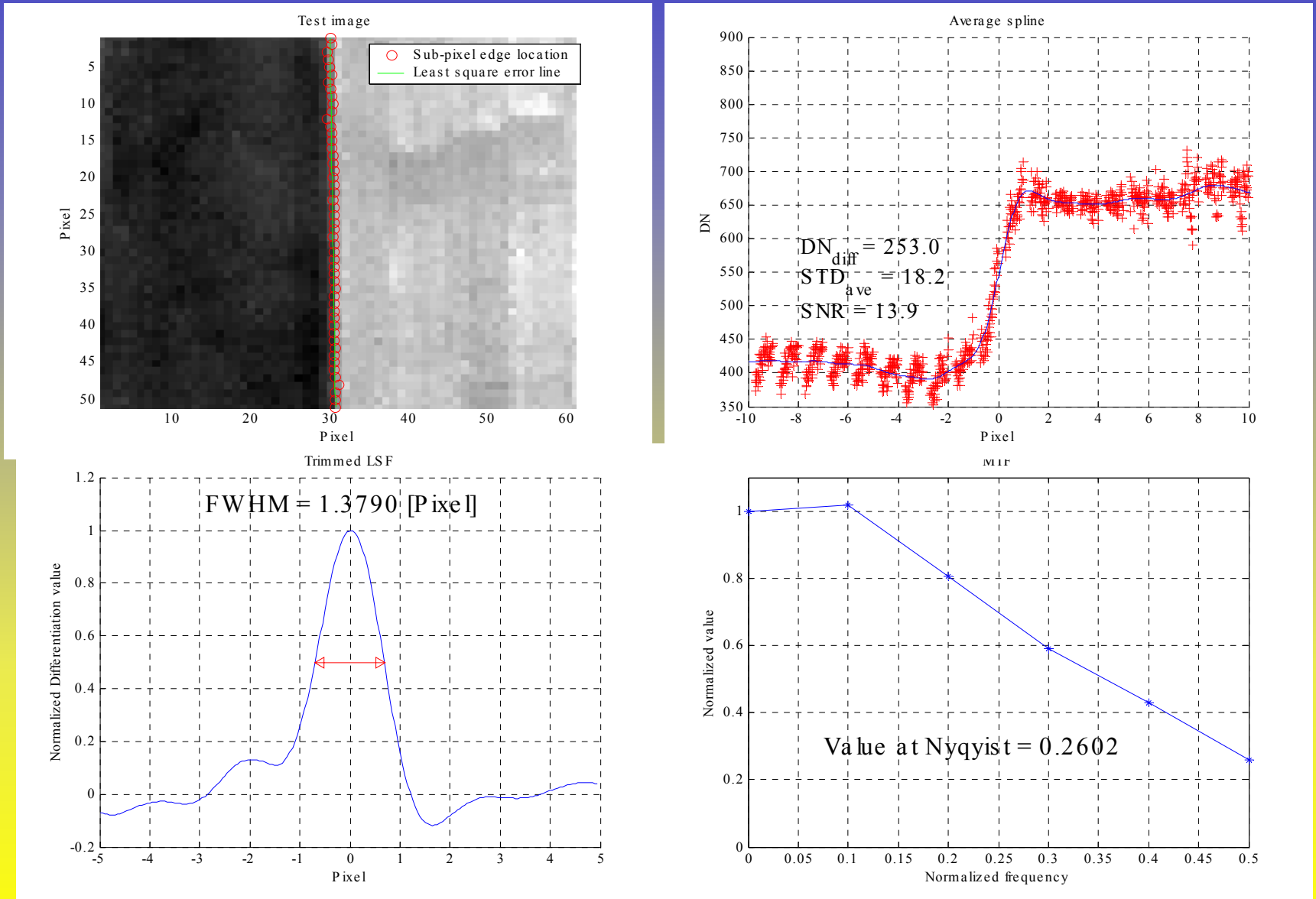


Figure 32. Parking lot 1 on Aug. 13, 2001.

- Parking lot 1 - LSF and MTF over plots

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	1.48	1.60	1.43	1.38	1.47	0.094
MTF	0.13	0.08	0.17	0.26	0.16	0.076

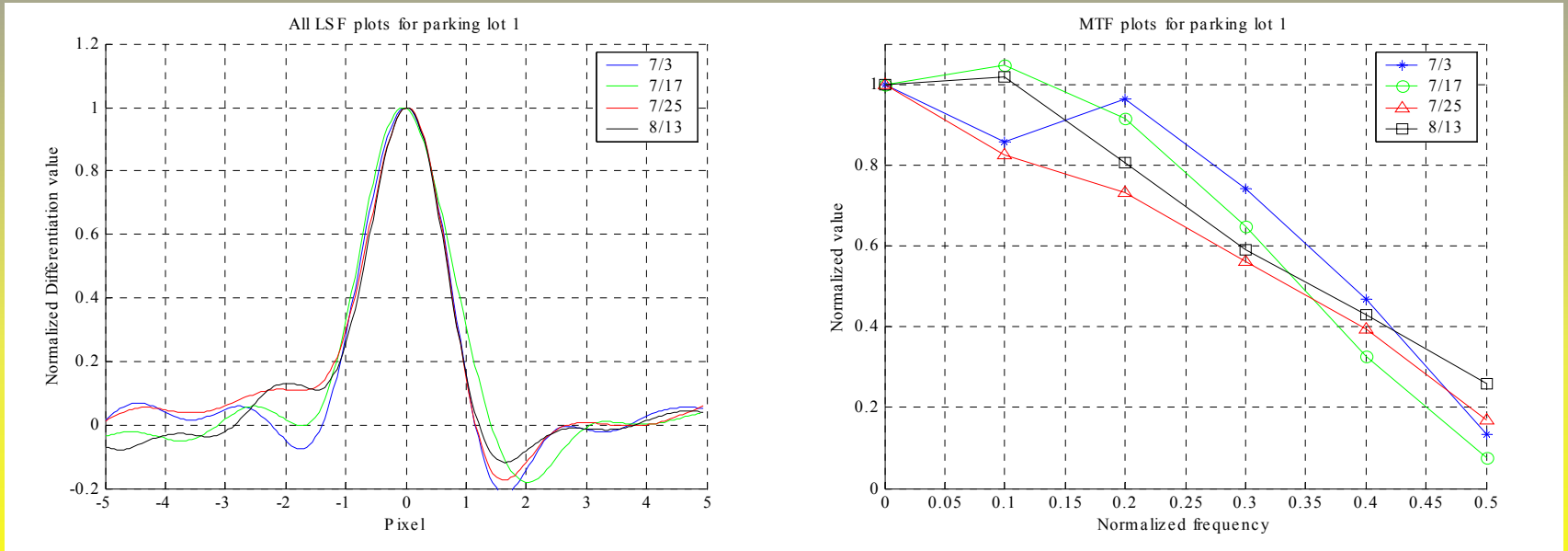


Figure 33. LSF plots for Parking lot 1.

- Parking lot 2 - LSF and MTF over plots

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	1.33	1.55	1.64	1.37	1.47	0.147
MTF	0.25	0.16	0.07	0.23	0.18	0.083

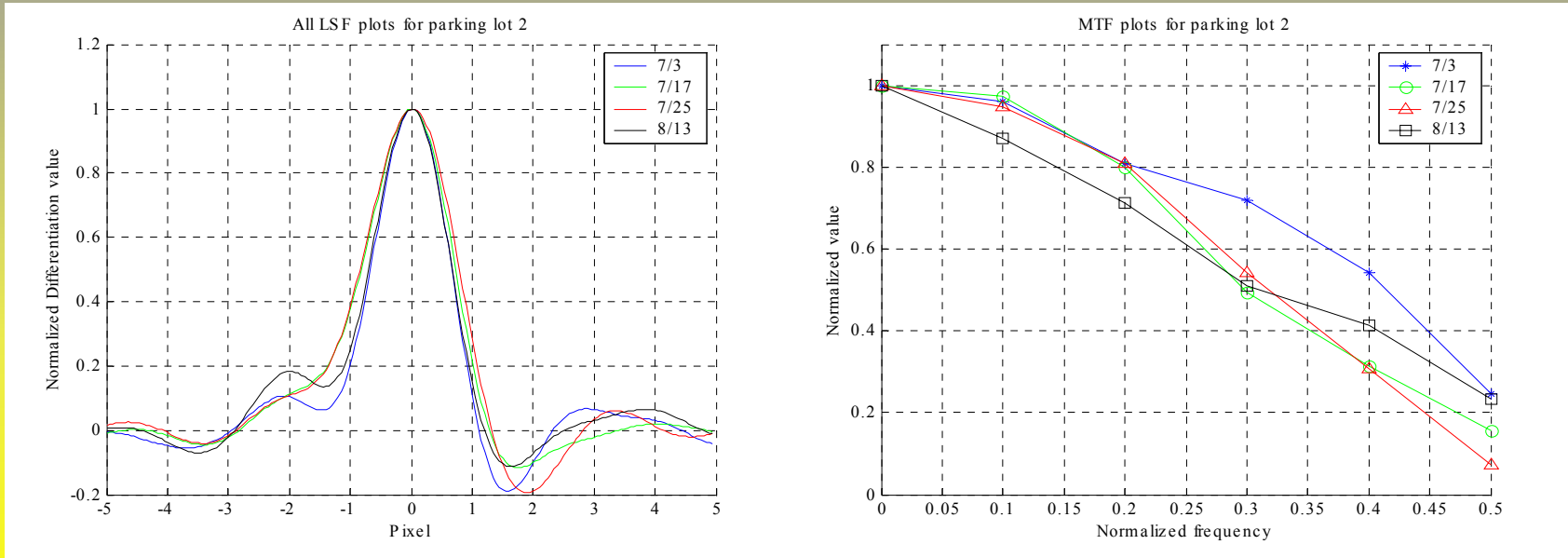


Figure 39. LSF plots for Parking lot 2.

Parking Lot Results

- Parking lot 1 - LSF and MTF

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	1.48	1.60	1.43	1.38	1.47	0.094
MTF	0.13	0.08	0.17	0.26	0.16	0.076

- Parking lot 2 - LSF and MTF

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	1.33	1.55	1.64	1.37	1.47	0.147
MTF	0.25	0.16	0.07	0.23	0.18	0.083

- Parking lot 1 and 2 - LSF and MTF plots

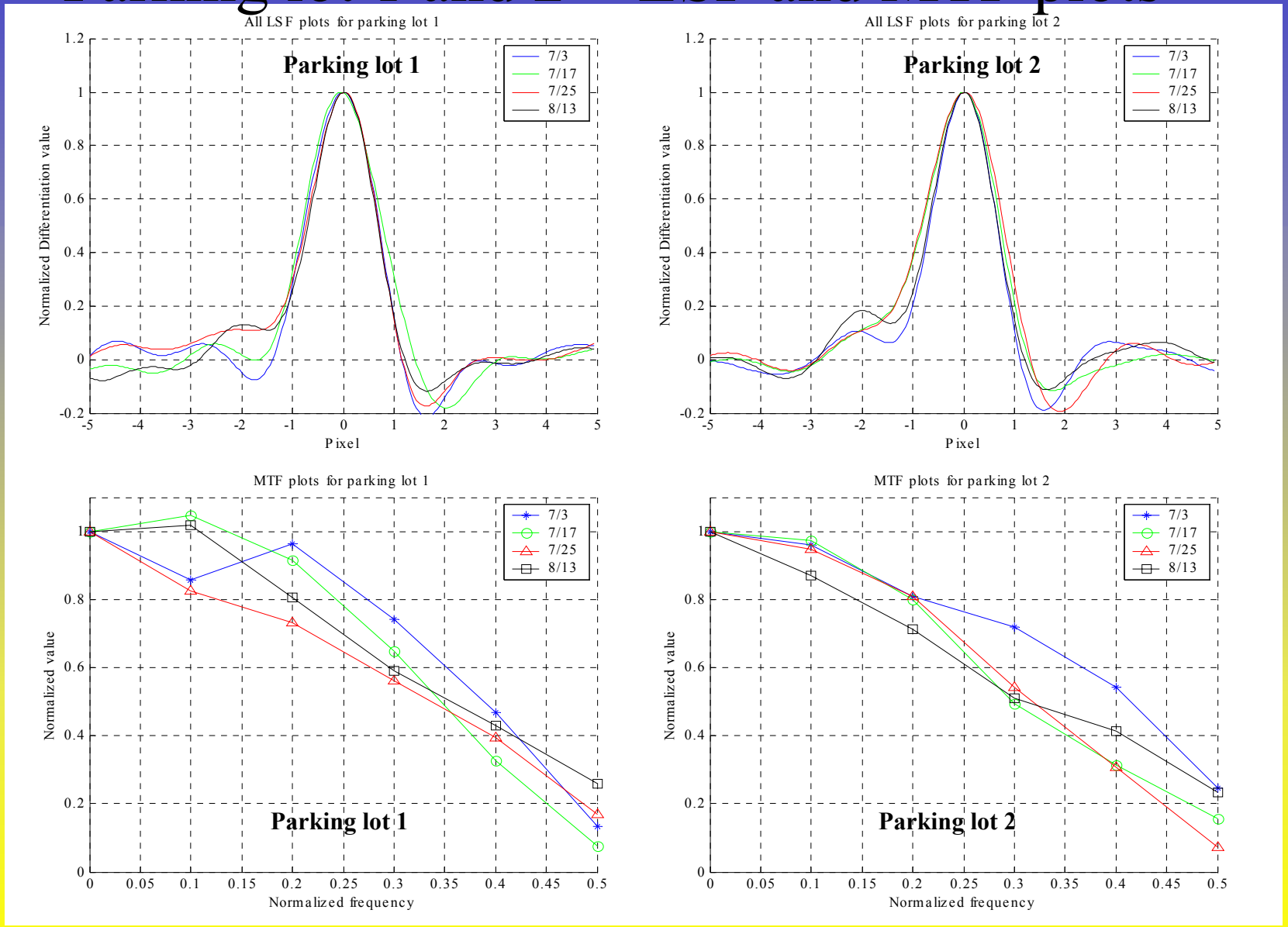


Figure 41. LSF and MTF plots for parking lot 1 and 2

- Parking lot 1 and 2 - Without MTFC

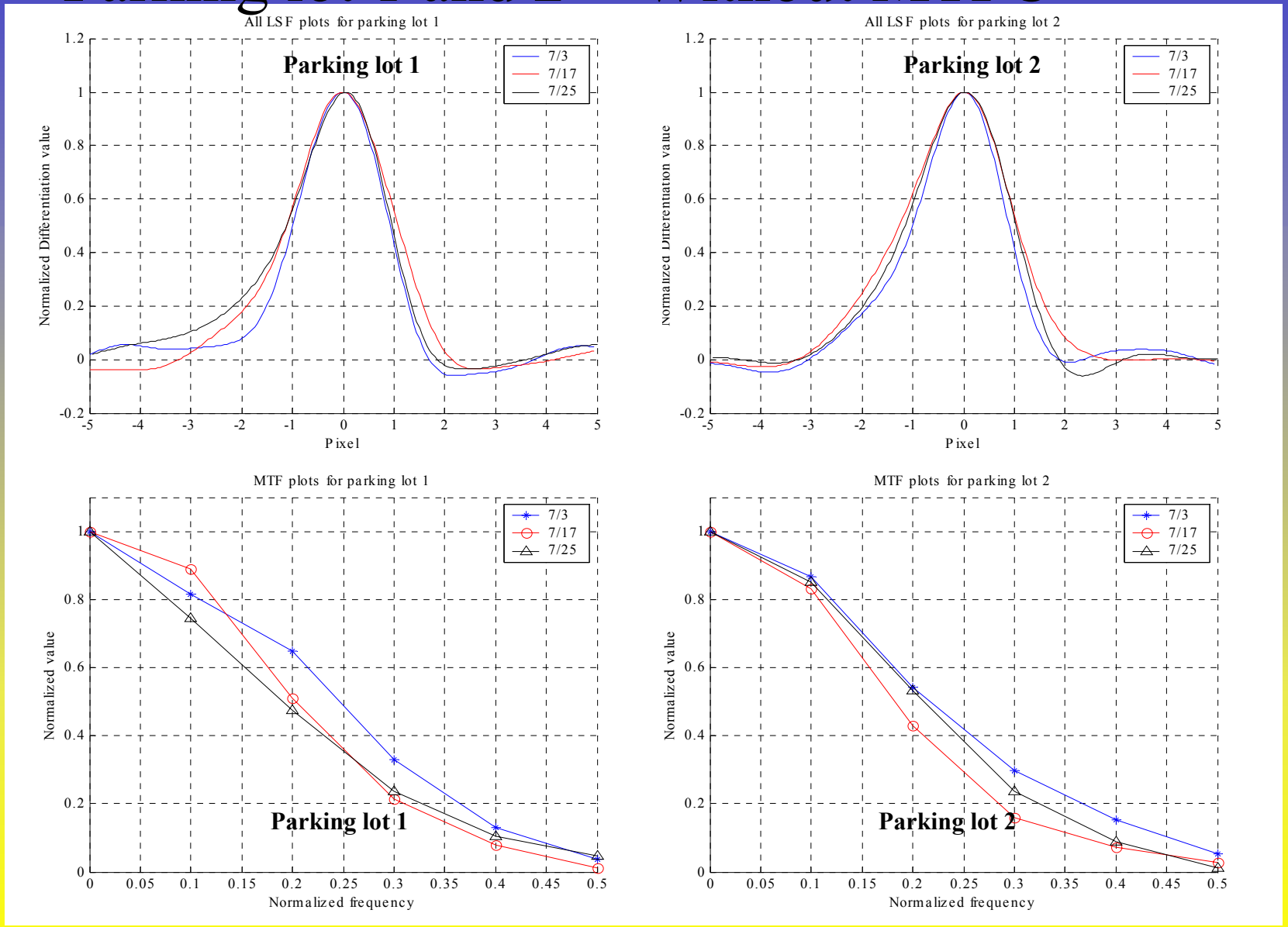


Figure 42. LSF and MTF plots for parking lot 1 and 2

- **Easting baby tarp** - July 25, 2001
  - Azimuth: 269.50, Elevation: 73.20

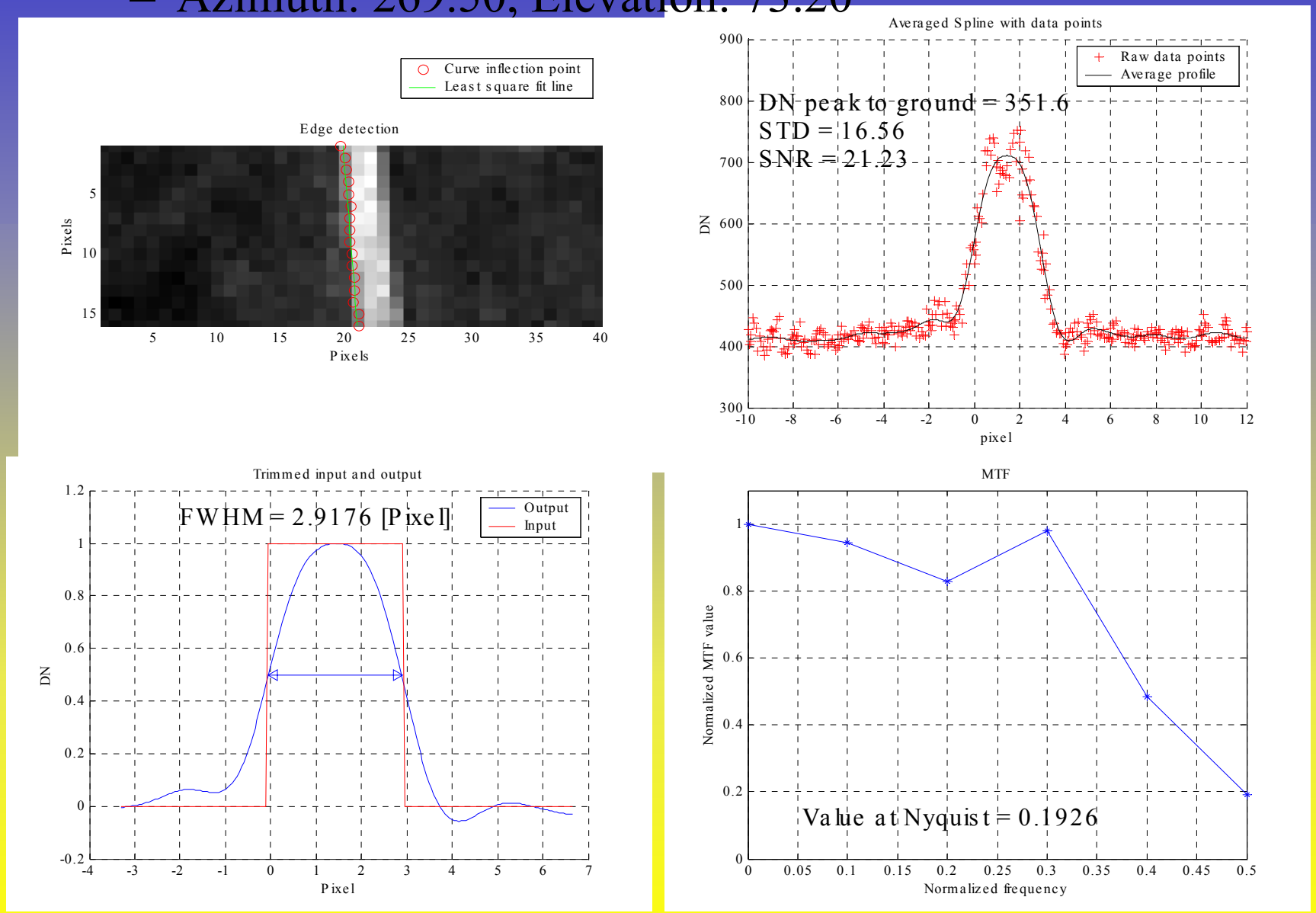


Figure 51. Easting baby tarp on July 25, 2001

- Easting direction baby tarp
  - LSF and MTF over plots

Value \ Date	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	2.84	2.92	2.97	2.91	0.039
MTF	0.15	0.19	0.16	0.17	0.024

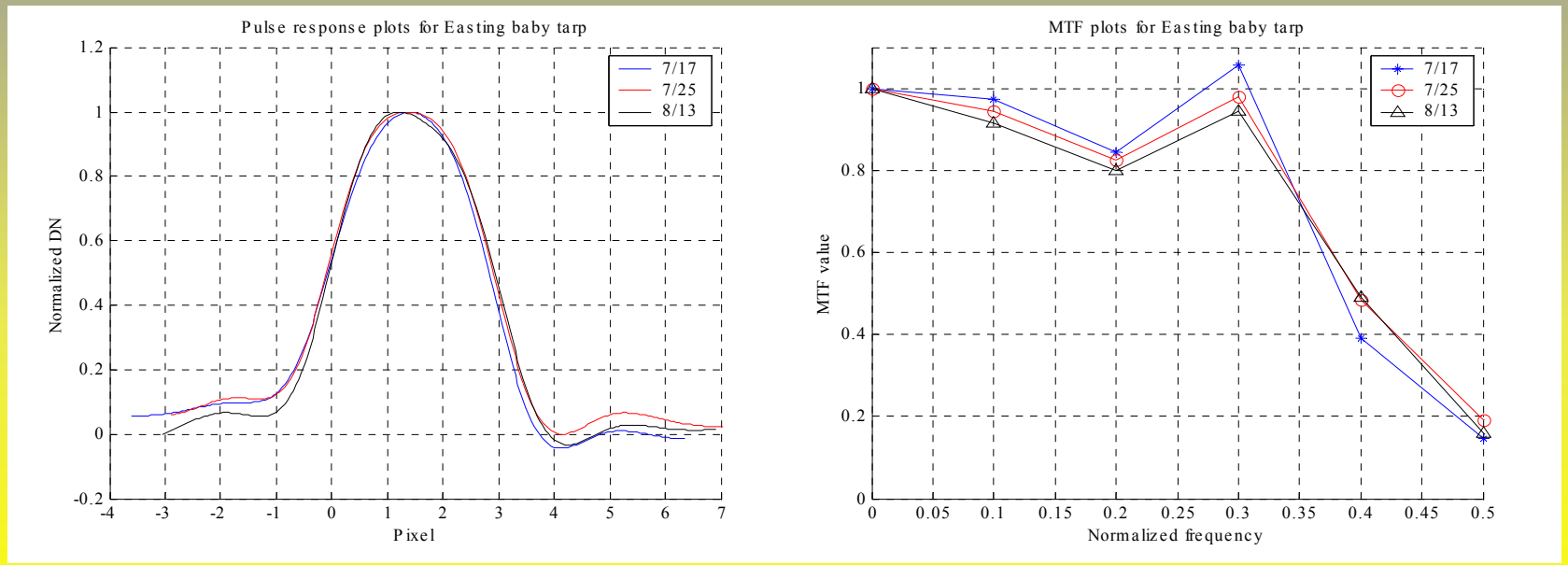
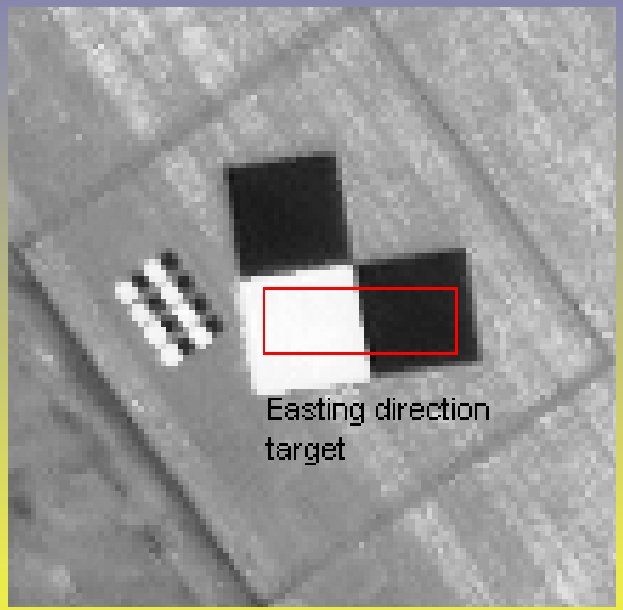
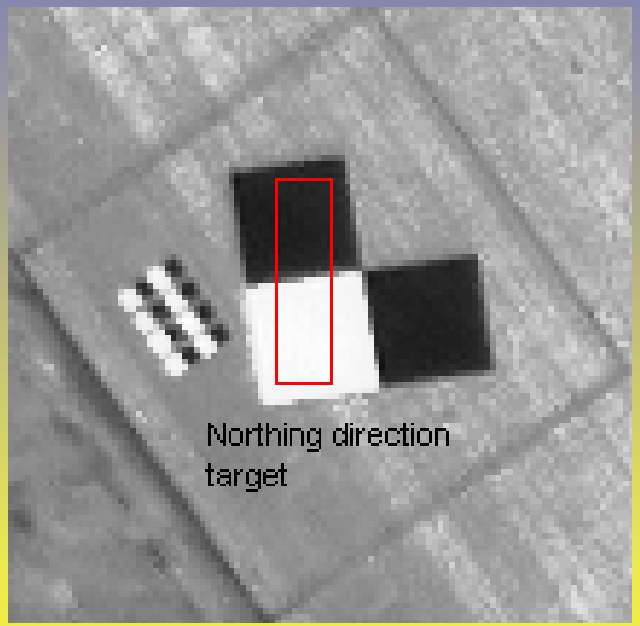


Figure 53. LSF plots for Parking lot 2.

- Big Spring painted concrete target
  - Washing date: June 21, Aug 3, Sept 25, 2001
  - Acquisition date: June 22, Aug 5, 2001



(a) Easting direction target



(b) Northing direction target

Figure 65. Big Spring painted concrete target

- Easting direction target - June 22, 2001
  - Azimuth: 234.24, Elevation: 79.66 (Cubic Convolution)

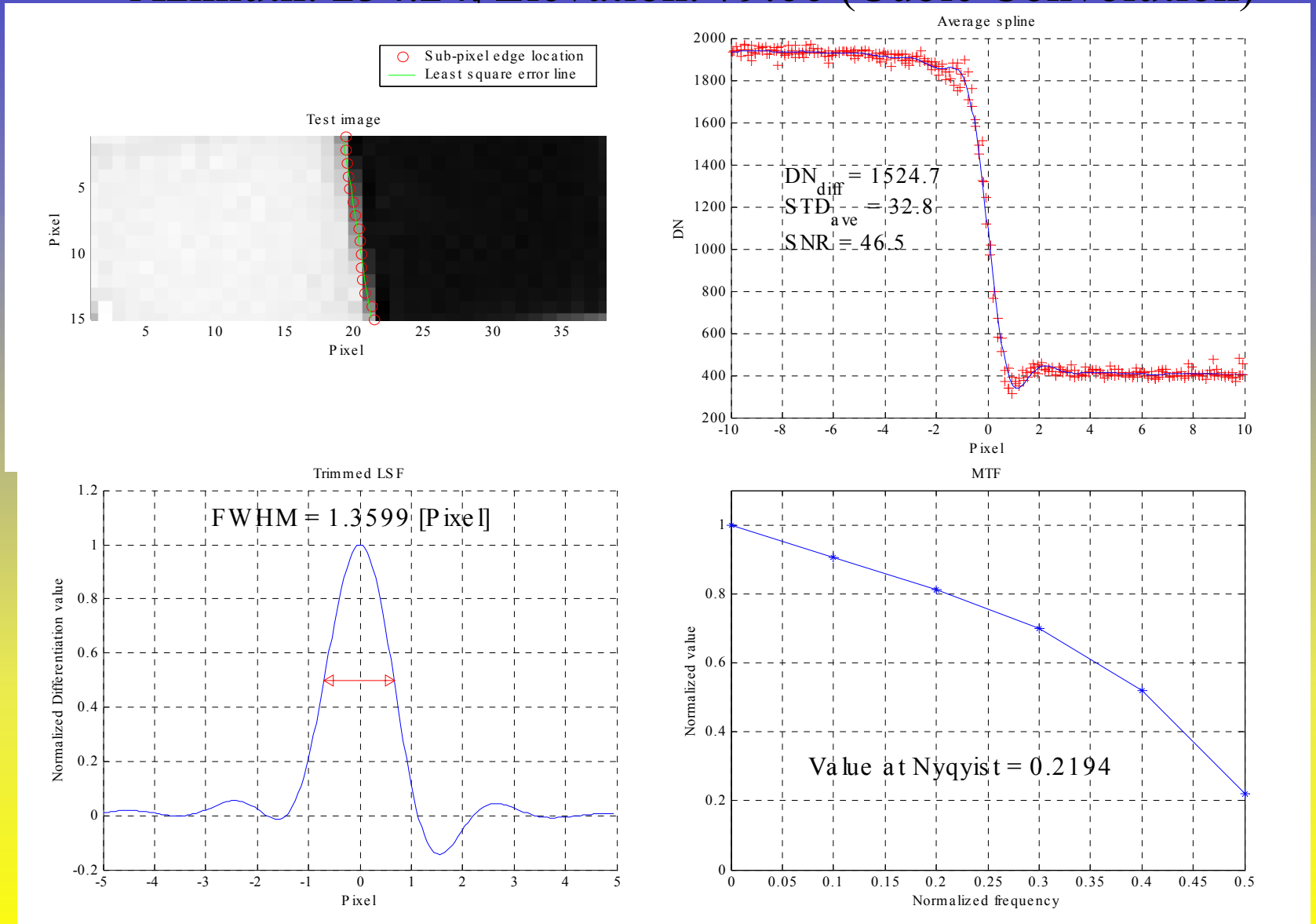


Figure 68. Big Spring Easting target on June 22, 2001.

- Northing direction target - June 22, 2001
  - Azimuth: 234.24, Elevation: 79.66 (Cubic Convolution)

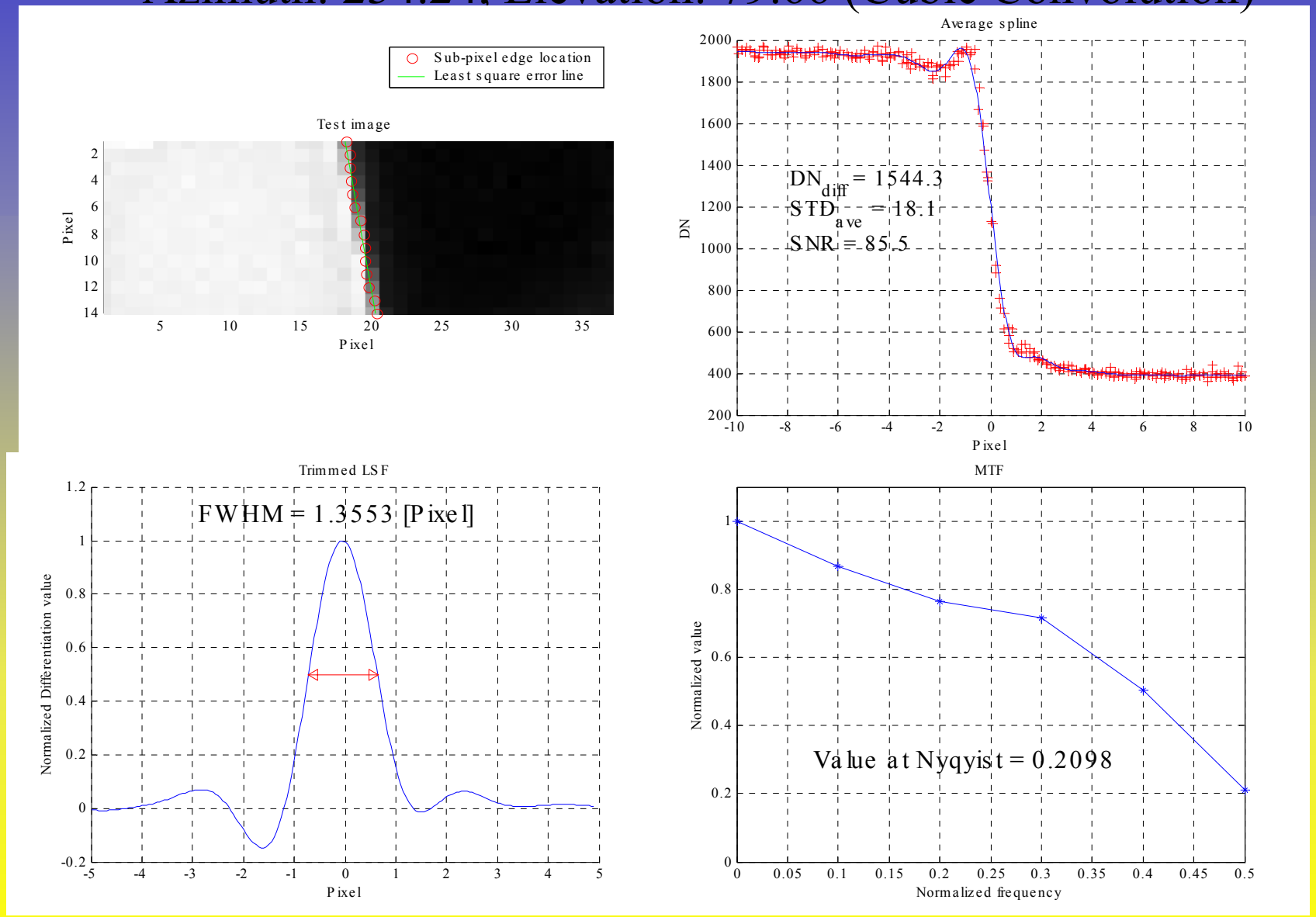


Figure 69. Big Spring Northing target on June 22, 2001.

- Big Spring painted concrete target
  - Easting direction LSF and MTF plots

Value \ Date	6/22/01			8/5/01
	Nearest Neighbor	Cubic Convolution	Cubic Convolution without MTFC	
FWHM	1.60	1.36	1.79	1.33
MTF	0.13	0.22	0.06	0.24

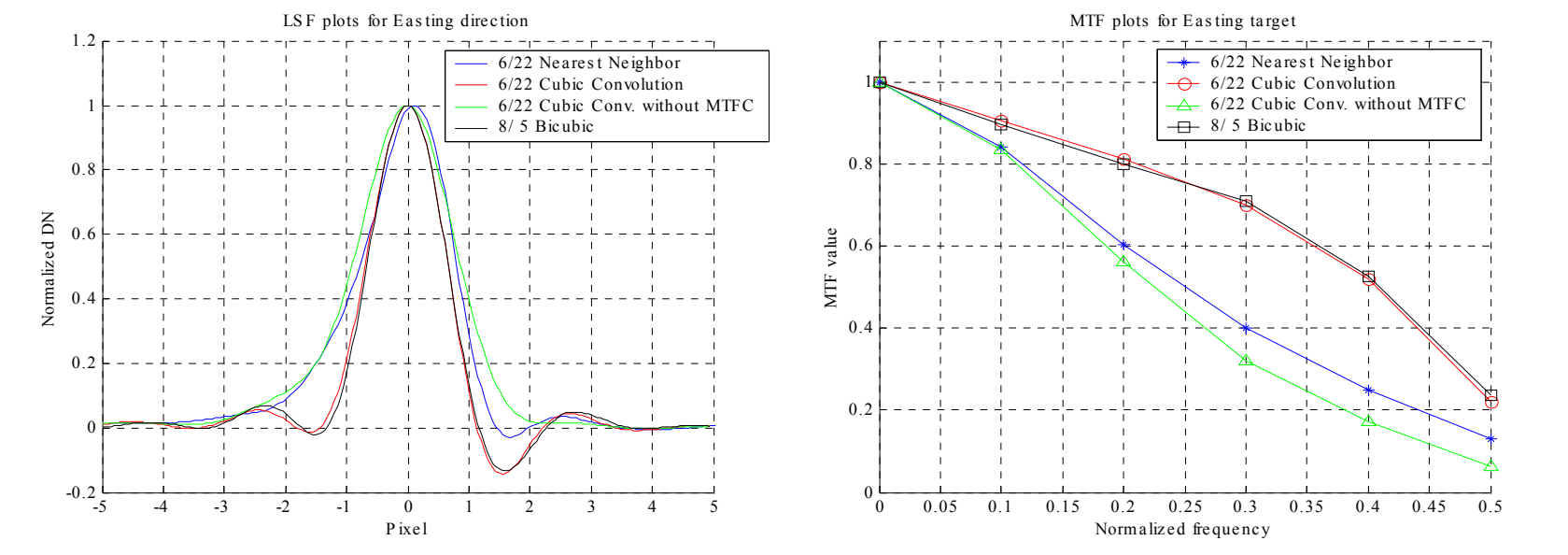


Figure 74. LSF and MTF plots for Big Spring concrete target

- Big Spring painted concrete target
  - Northing direction LSF and MTF plots

Value \ Date	6/22/01			8/5/01
	Nearest Neighbor	Cubic Convolution	Cubic Convolution without MTFC	
FWHM	1.53	1.36	1.87	1.39
MTF	0.13	0.21	0.05	0.19

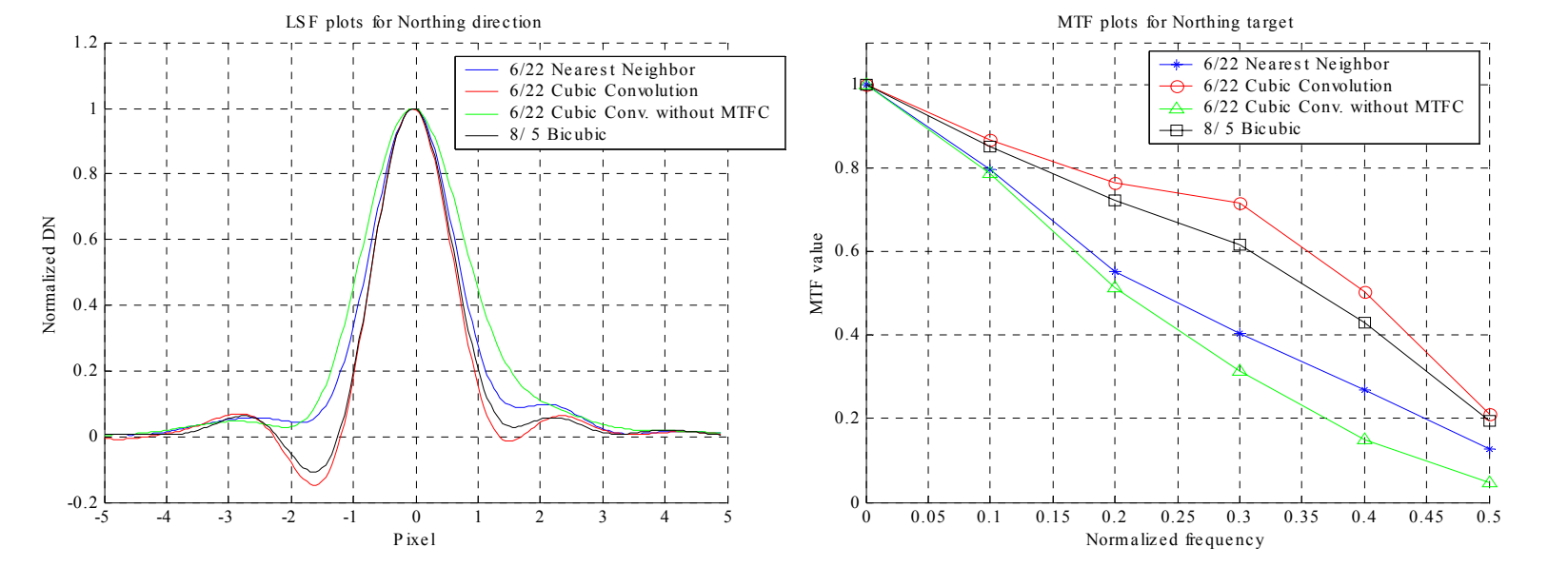


Figure 75. LSF and MTF plots for Big Spring concrete target

- **Multispectral band analysis with blue tarps**
  - Number of lines was reduced on July 3, 2001 scene.
  - Dried hay was very reflective in all bands.
  - 0.3 and 0.4 frequency points in MTF plot were very sensitive to tarp width.

July 3 2001

July 3 2001

July 3 2001

July 3 2001

Fig 81. Brookings tarp target

- Tarp target - Blue band with spline method

Aug. 13, 2001
Azimuth: 281.85
Elevation: 76.19

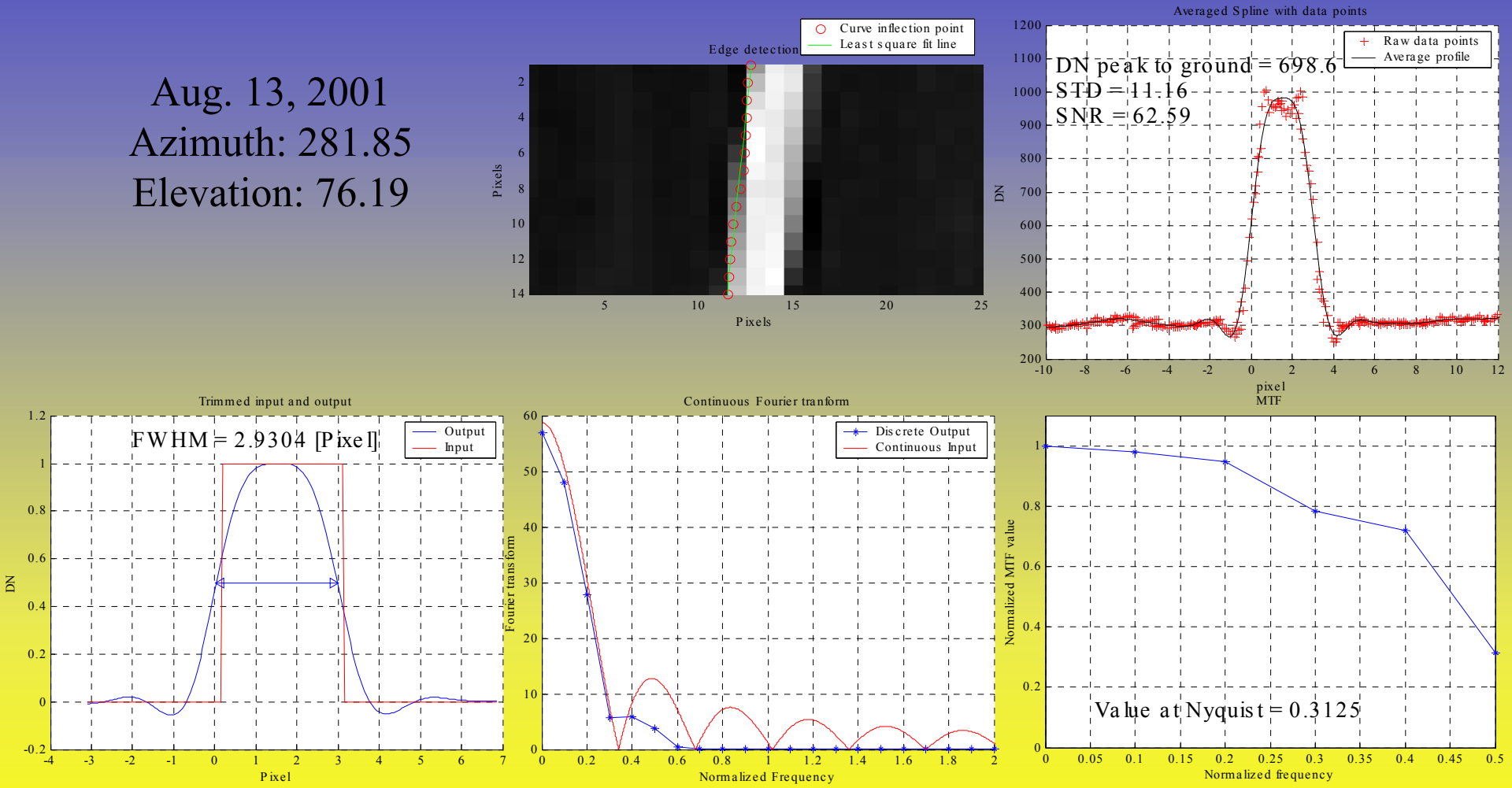


Figure 82. Blue band tarps target with spline method on Aug. 13, 2001

- Tarp target - Green band with spline method

Aug. 13, 2001
Azimuth: 281.85
Elevation: 76.19

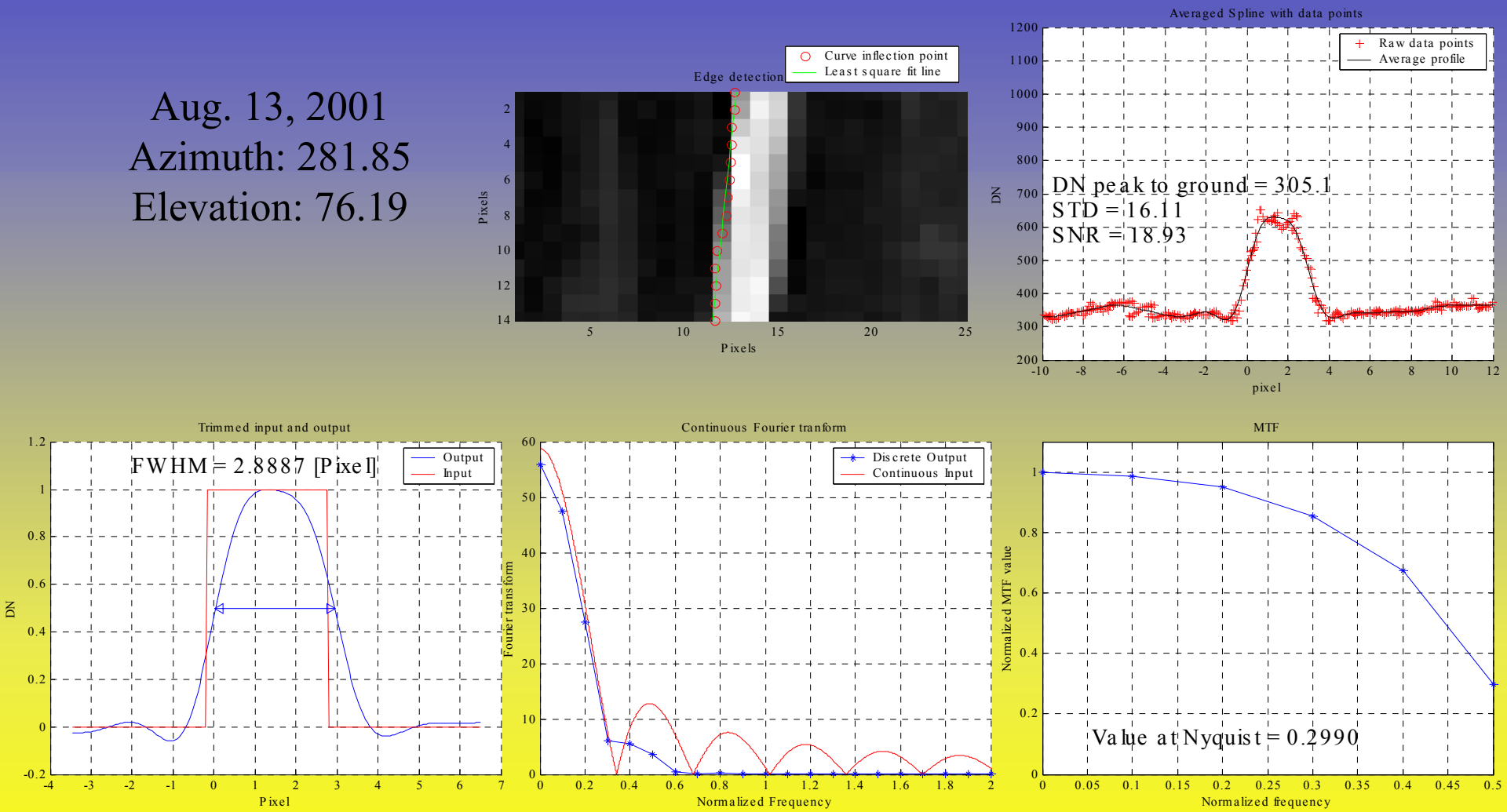


Figure 83. Green band tarps target with spline method on Aug. 13, 2001

- Tarp target - Red band with spline method

Aug. 13, 2001
Azimuth: 281.85
Elevation: 76.19

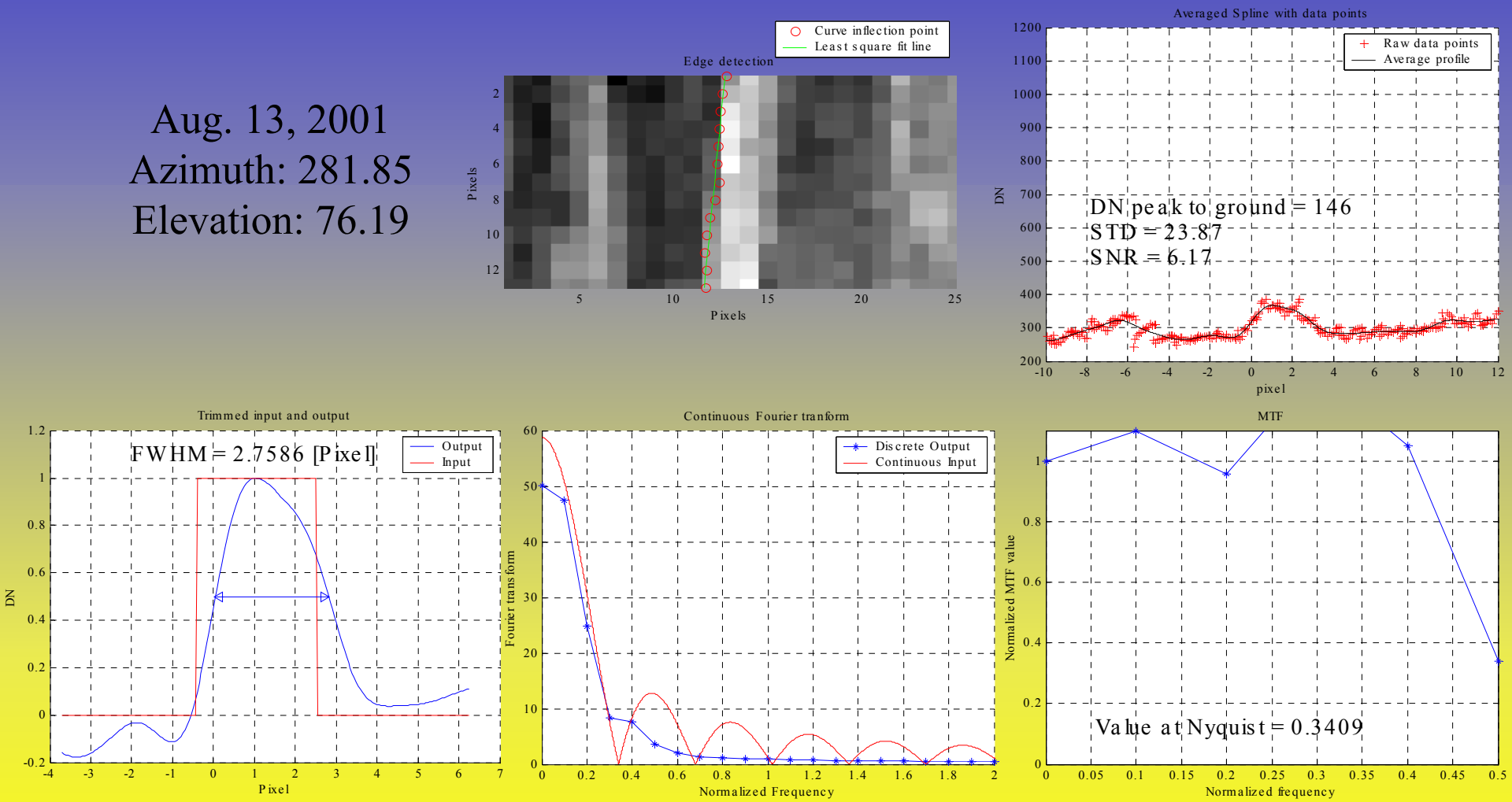


Figure 84. Red band tarps target with spline method on Aug. 13, 2001

- Tarp target - NIR band with spline method

Aug. 13, 2001
Azimuth: 281.85
Elevation: 76.19

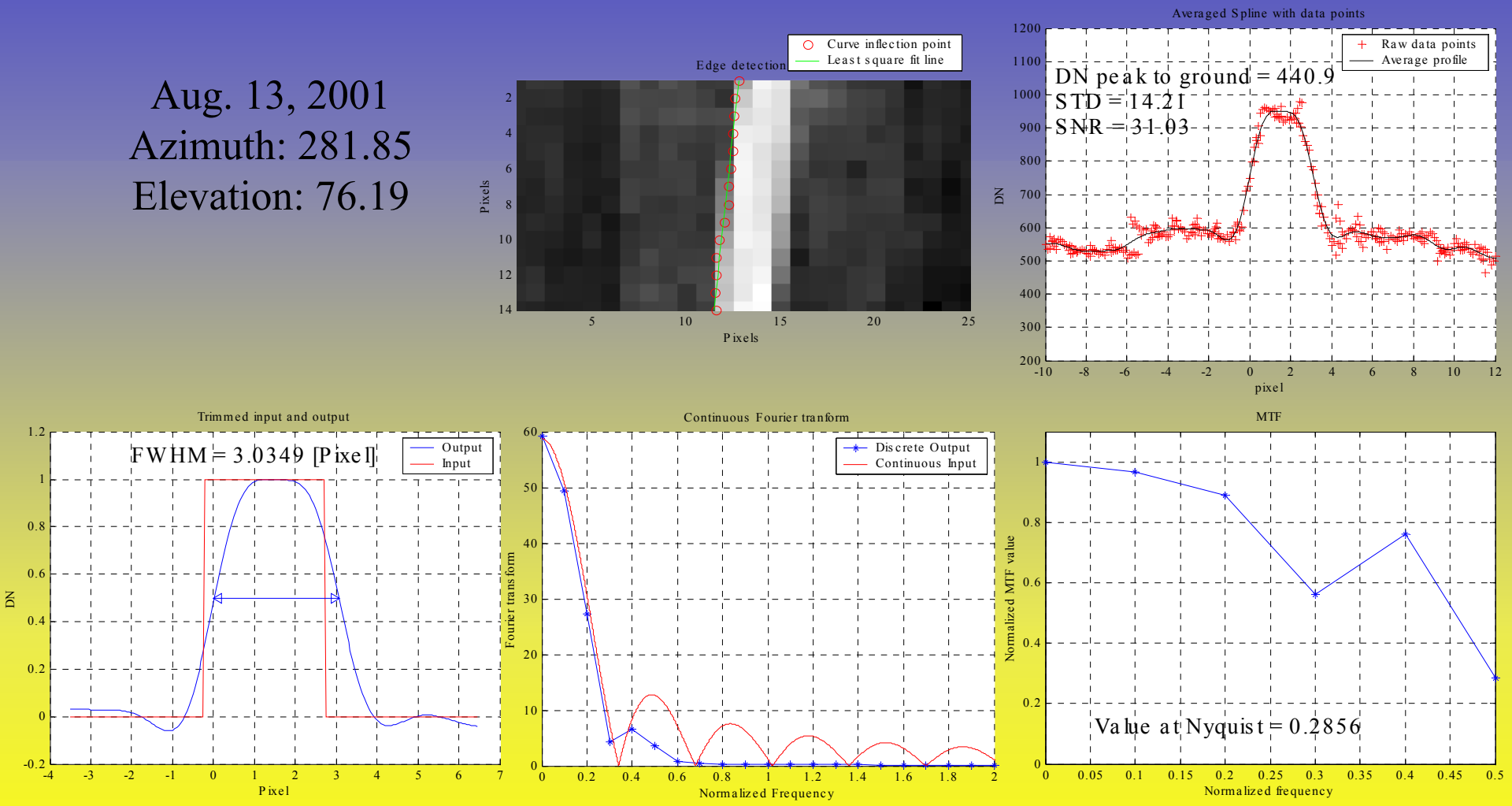


Figure 85. NIR band tarps target with spline method on Aug. 13, 2001

- Tarp target - Blue band with pulse method

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	2.73	2.83	2.78	2.93	2.82	0.085
MTF	0.31	0.24	0.22	0.31	0.27	0.048

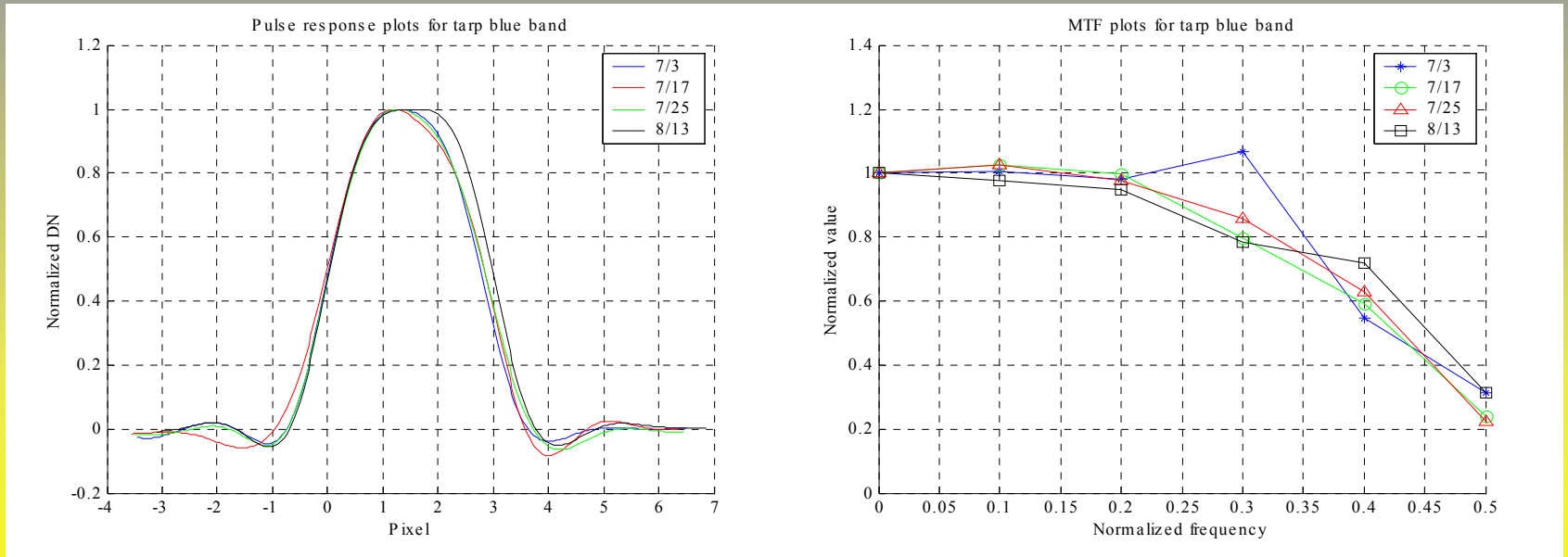


Figure 86. Blue band tarps target average plot with spline method

- Tarp target - Green band with pulse method

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	2.74	2.88	2.83	2.89	2.83	0.067
MTF	0.32	0.24	0.20	0.30	0.26	0.053

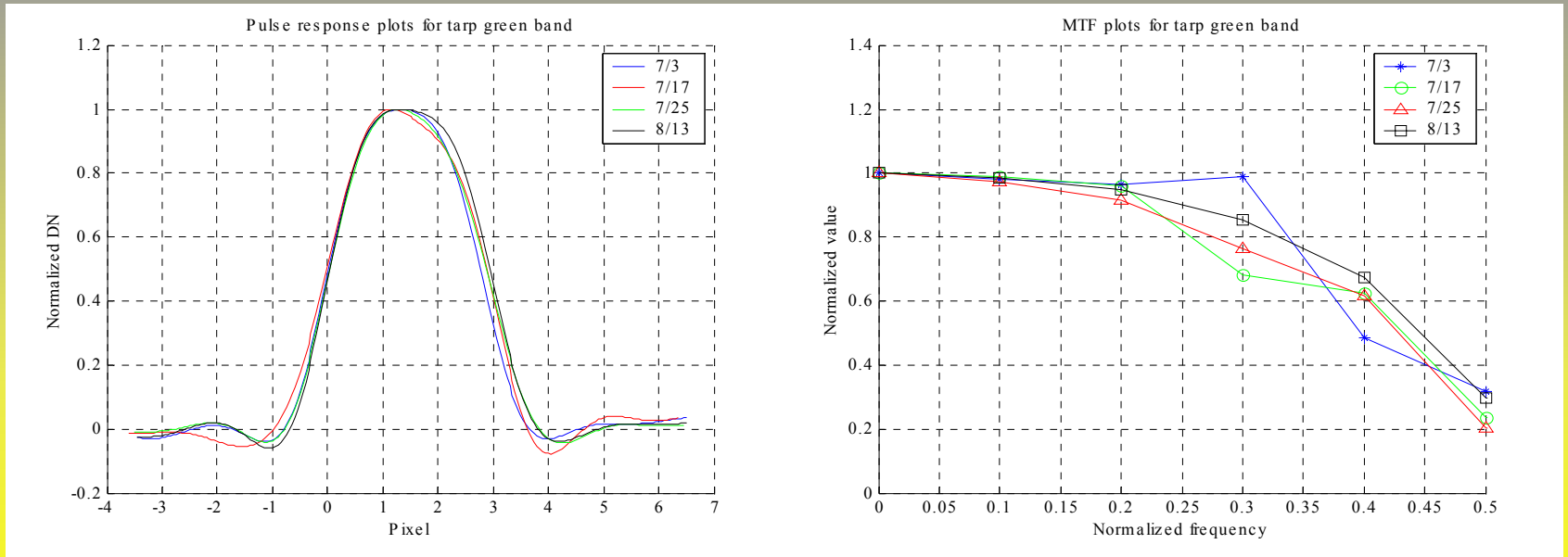


Figure 87. Green band tarps target average plot with spline method

- Tarp target - Red band with pulse method

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	2.69	2.90	2.82	2.76	2.79	0.089
MTF	0.45	0.20	0.21	0.34	0.30	0.117

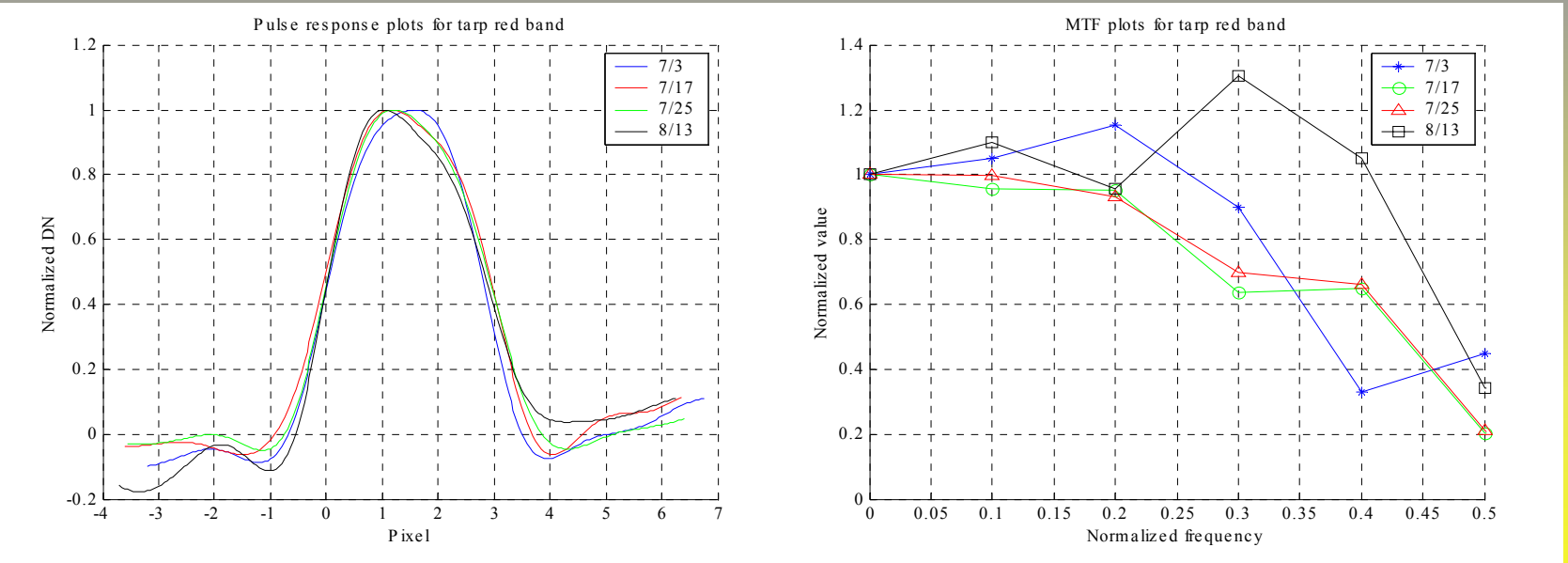


Figure 88. Red band tarps target average plot with spline method

- Tarp target - NIR band with pulse method

Value \ Date	7/3/01	7/17/01	7/25/01	8/13/01	Average	STD
FWHM	2.73	2.94	2.92	3.03	2.90	0.130
MTF	0.32	0.22	0.17	0.29	0.25	0.069

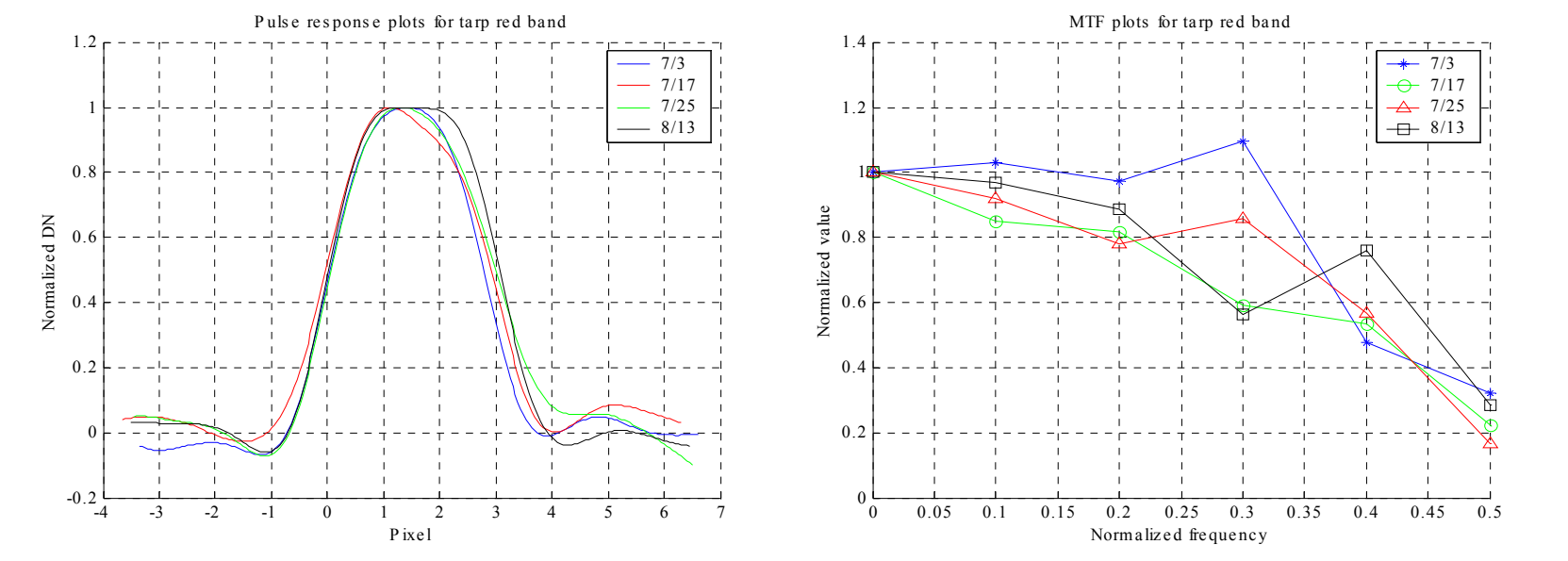


Figure 89. NIR band tarps target average plot with spline method

2000 - 2001 Comparison

MTF values at Nyquist frequency on tarp target with **multispectral** bands

	Date	Blue	Green	Red	NIR
	5/1/00	0.10	0.18	0.25	0.17
	6/30/00	0.29	0.35	0.36	0.30
Year 2000 →	Average	0.20	0.27	0.31	0.24
	7/3/01	0.31	0.32	0.45	0.32
	7/17/01	0.24	0.24	0.25	0.22
	7/25/01	0.22	0.20	0.21	0.17
	8/13/01	0.31	0.30	0.34	0.27
Year 2001 →	Average	0.27	0.26	0.30	0.25

MTF values at Nyquist frequency on Parking lot 1 and 2 with **panchromatic** band (cross track)

	Date	Parking lot1	Parking lot 2
	5/1/00	0.20	0.12
	6/30/00	0.13	0.13
Year 2000 →	Average	0.17	0.13
	7/3/01	0.13	0.25
	7/17/01	0.08	0.16
	7/25/01	0.17	0.07
	8/13/01	0.26	0.23
Year 2001 →	Average	0.16	0.18

'Baby' tarp estimate of 0.17 in the along track direction.

MTF at Nyquist frequency on **Big Spring** target with **panchromatic** band

	Date & time	Easting Dir. Target	Northing Dir. Target
	3/25/00 with 60 degree elevation	0.25	0.13
	3/25/00 with 80 degree elevation	0.26	0.11
Year 2000 →	Average	0.26	0.12
	6/11/2001	0.22	0.21
	8/5/2001	0.24	0.19
Year 2001 →	Average	0.23	0.20

Impulse method

- Convex mirrors on grass as point sources.

(a) 30″ diameter

(a) 18″ diameter

For more information, see our poster!

CONCLUSIONS

- Spatial Performance of sensor is stable and meeting specifications.
- Parking lots provide consistent target for panchromatic band. Results converging to 0.17 MTF at Nyquist.
- Big Spring Target excellent for panchromatic band with results closer to 0.22 MTF at Nyquist. Higher estimate may be largely due to better SNR.
- Multispectral band characterization consistent in the blue, acceptable in the green. MTF at Nyquist of 0.27 indicated.