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MEMORANDUM FOR PRS (In-House Publication)

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SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2003-016**
Joseph N. Beasley (AFRL/PRSO) "DSP Techniques for Positioning of Off-axis Solar Concentrators"

(Statement A)

ASME/ISEC
(Hawaii, 15-18 March 2003) **(Deadline: N/A)**

DSP Techniques for Positioning of Off-axis Solar Concentrators

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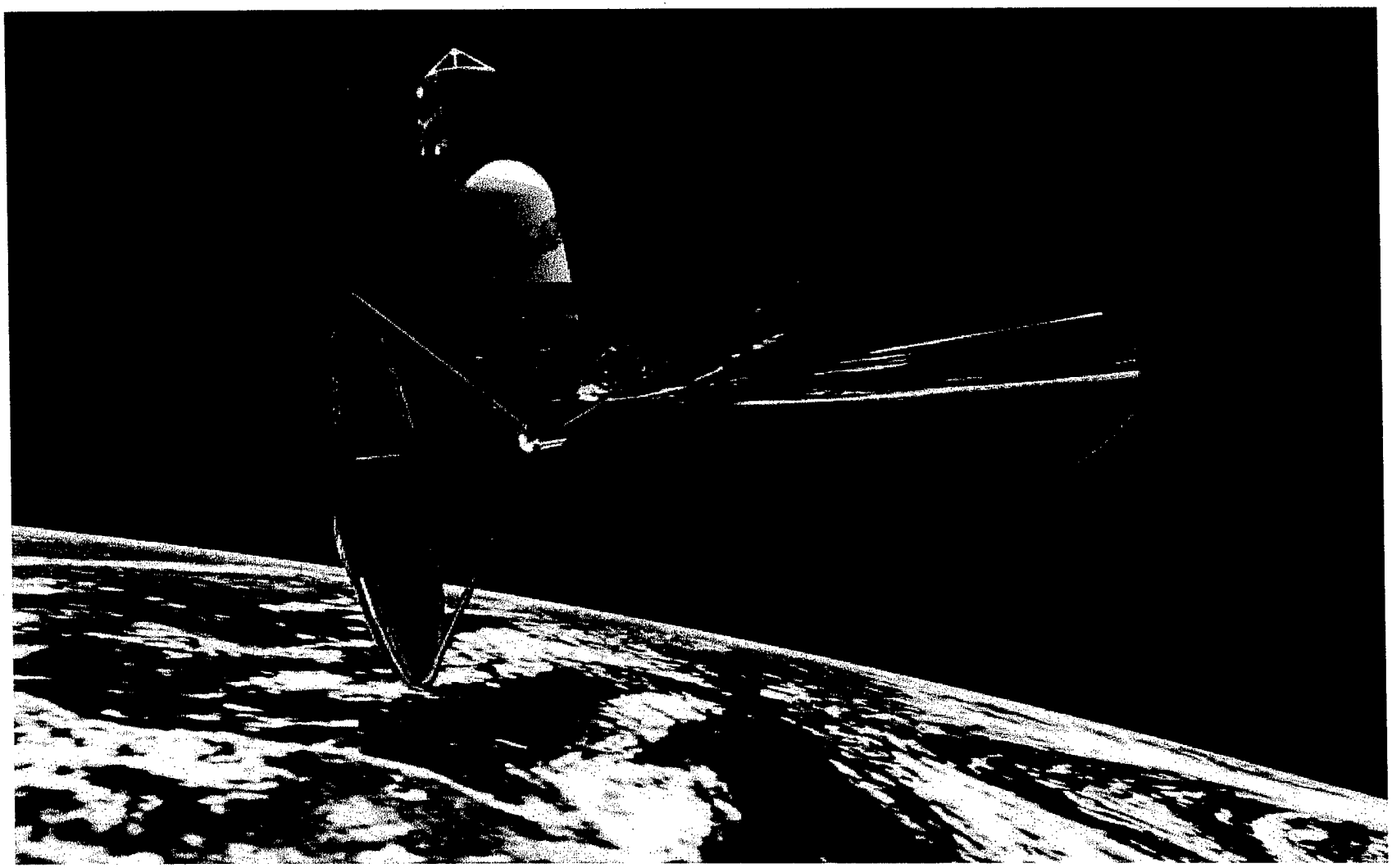
Agenda

- Introduction
- Problem Definition
- Solution Concept
- Experiment Description
- Result Presentation
- Conclusion and Future Work

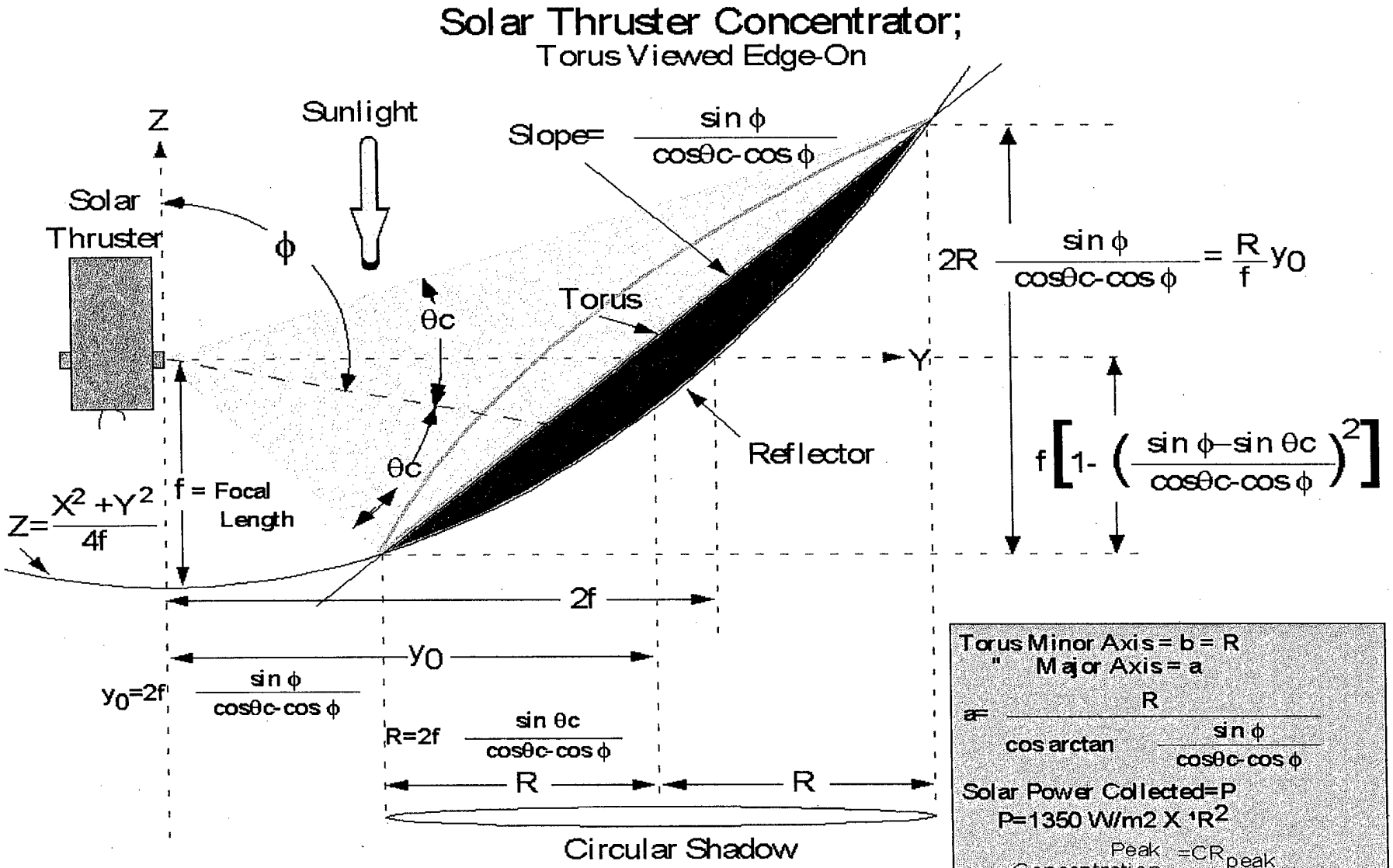
Introduction

- A major requirement for using a solar propulsion system is the the proper placement of the focal spot on the thruster absorber plane. Without proper placement of the focal spot, solar energy is not transferred to the propellant gas or at worst case, a significantly smaller proportion of the incident energy is transferred to the gas.

Solar Thermal Spacecraft Configuration

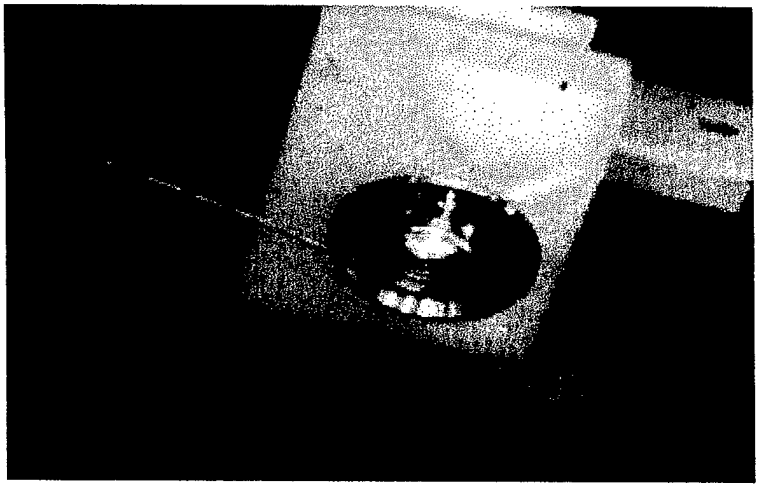


Geometry For Spacecraft



Problem

Determine location of solar focal spot on a visually complex thruster absorber and secondary concentrator. Visual complexity compounded by specular reflection from the secondary concentrator.



Problem Solution Concept

- Use Charge Coupled Device(CCD) Camera as the primary fine focus sensor. Images of the thruster are taken by the camera to be analyzed.

- Develop digital signal processing(DSP) algorithm(s) for determining focal spot position from image of thruster absorber and secondary concentrator to produce control commands for the main concentrator.

Experiment Description

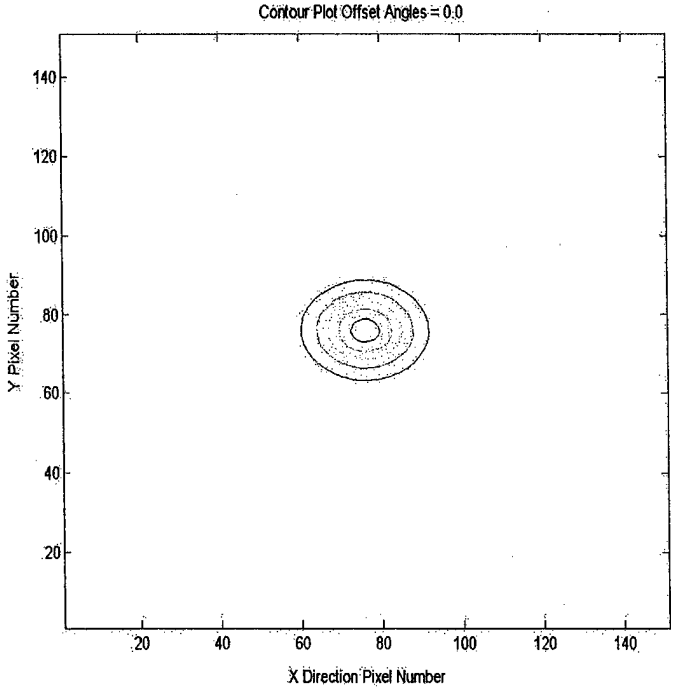
Two portions of the experiment.

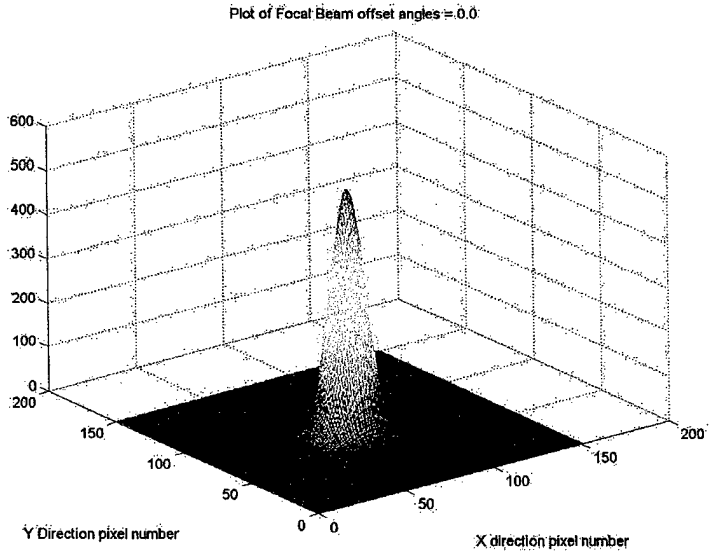
- First portion utilized data from a computer program that simulated the focal spot image from an off-axis solar concentrator.
  - Data from the program was analyzed using the 2-D Fast Fourier Transform (FFT) to see whether the coordinate location of the maximum of the focal spot intensity could be obtained.
  - Data was also analyzed using a modified Short Time Fourier Transform (STFT) to see whether the coordinate location of the maximum of the focal spot intensity could be obtained.
- Second portion will utilize real CCD images of the thruster with simulated solar light from a full scale concentrator were to be analyzed using DSP techniques.
- Second portion will also incorporate wavelet and pattern recognition methods of analyzing thruster image data.

Experiment Description(cont) Mathematics

- 1 Dimensional Fourier Transform
  - Continuous Form: $\int x(t)e^{-j2\pi ft}dt$
  - Discrete Form: $\sum f(n)e^{-j2\pi n/N*k}$ (over n)
- 2 Dimensional Fourier Transform
  - $\iint f(x,y)e^{-j(\omega x+\eta y)}dxdy$
- Short Time Fourier Transform
  - "Windowed" Fourier Transform
  - $\int w(t-\tau)f(t)e^{-j\omega t}dt$

Experiment Description(cont)
Plots of Simulated Data

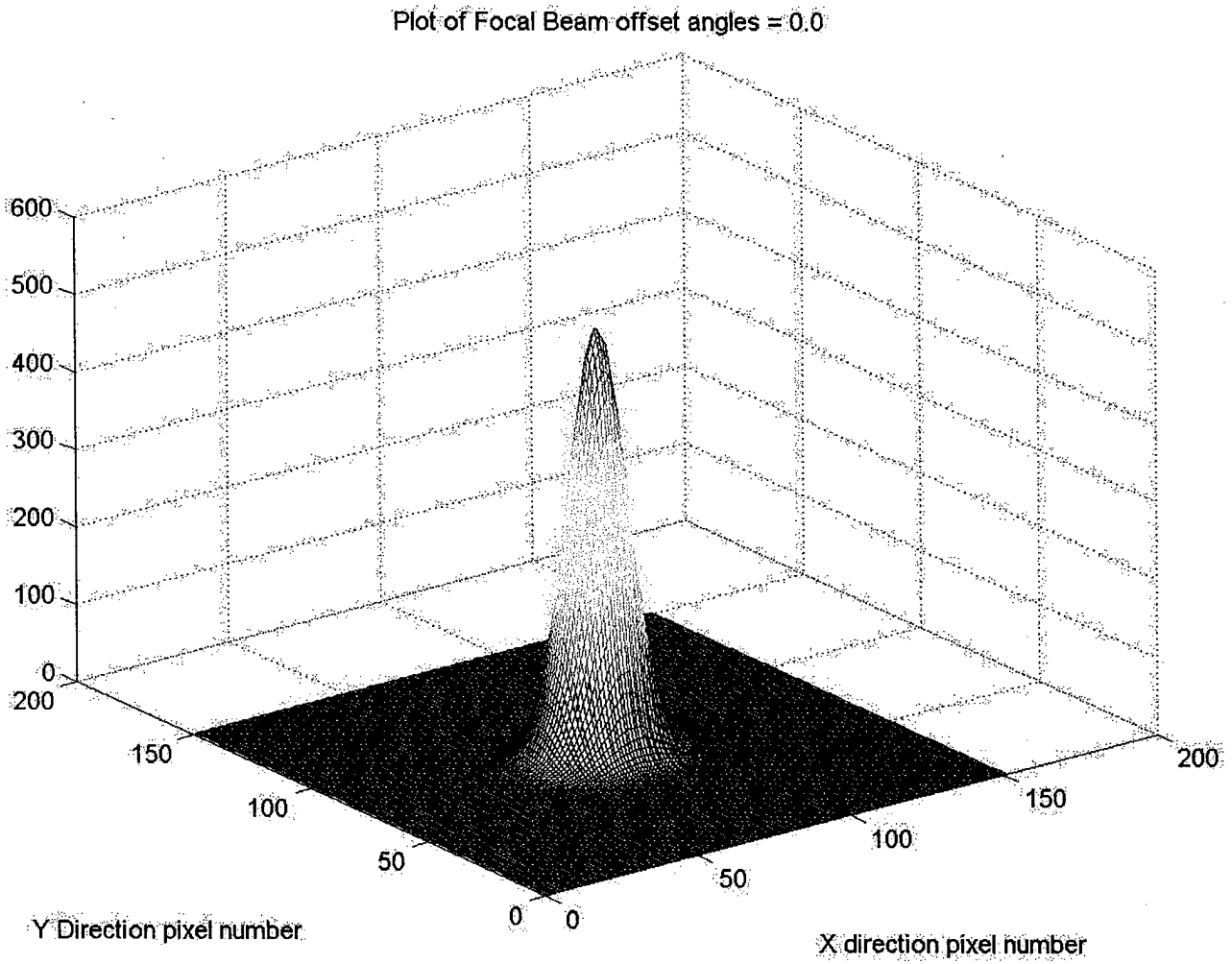




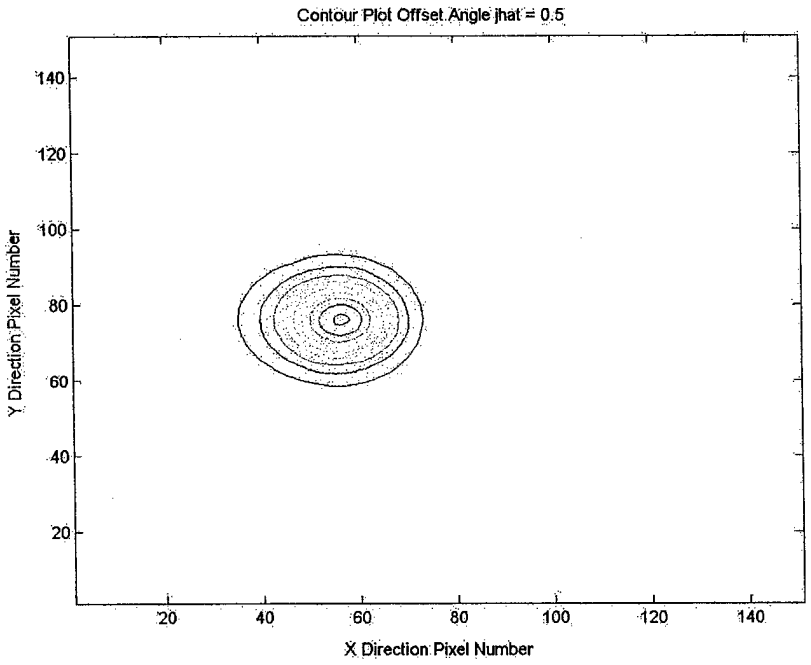
Results

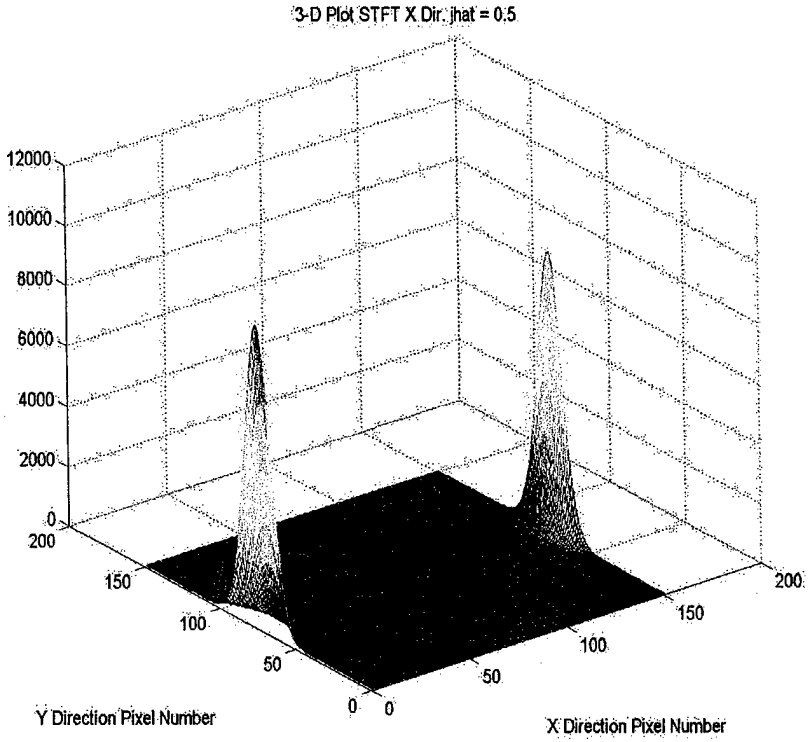
- Results from 2 D FFT limited for providing X, Y location of maximum focal spot .
- Results from 2 D STFT provides the ability to find X, Y location data useful for generating command information to the concentrators.
- Results from 2 D STFT did not indicate when the focal spot beam just changed intensity (did not move in X, Y) as when the concentrator needed to move the focal beam closer to the target or away from the target.

Results 2 D FFT

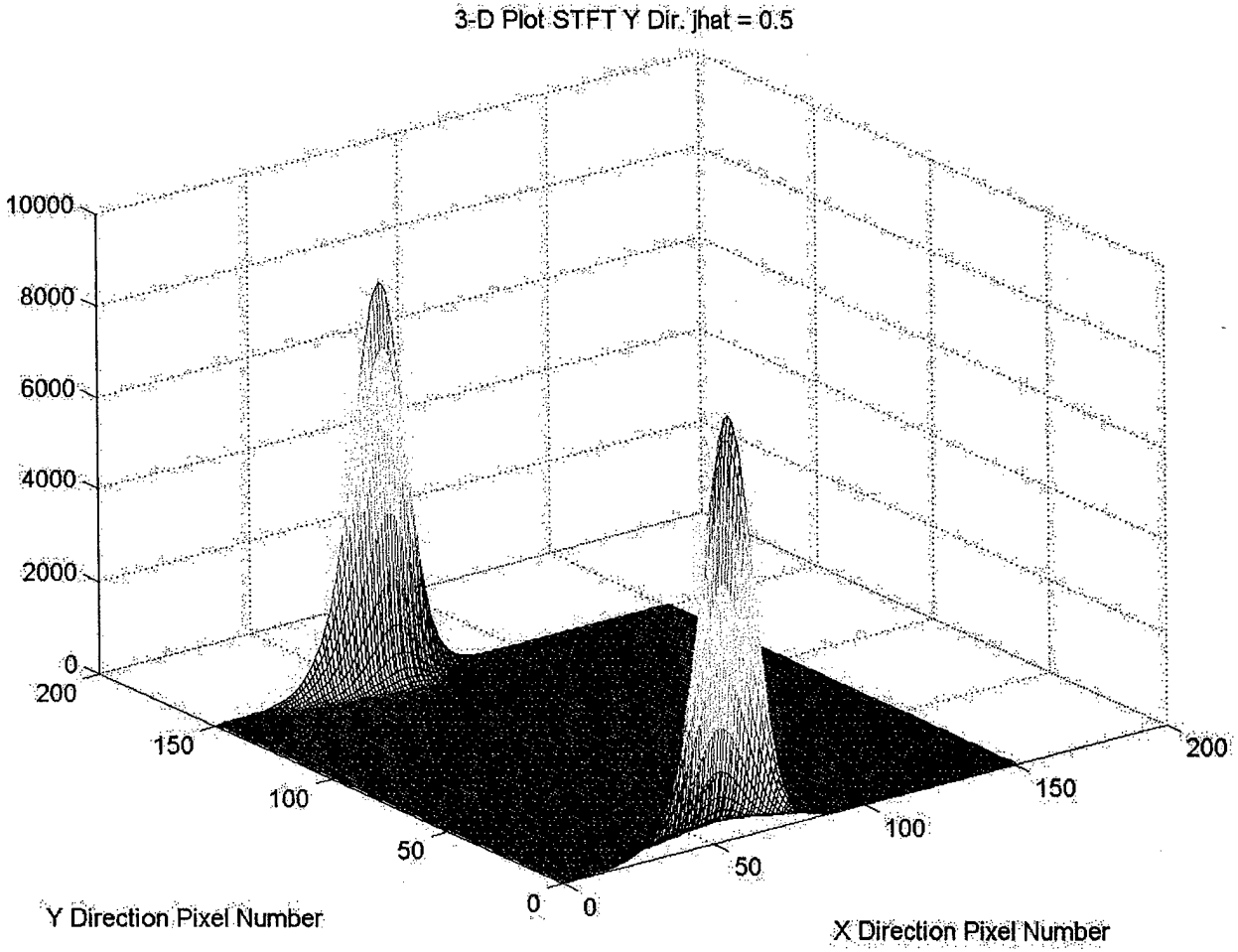


Plots STFT Data (Results)

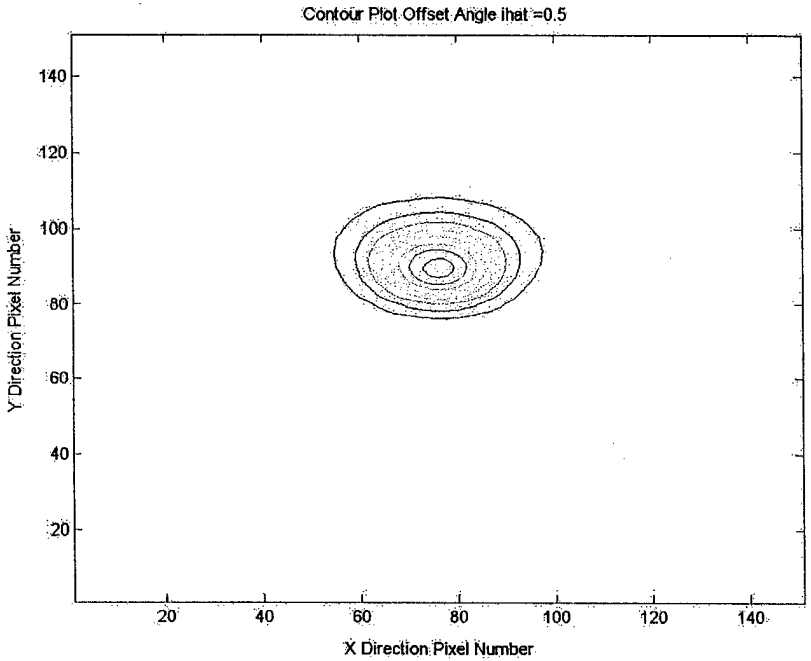


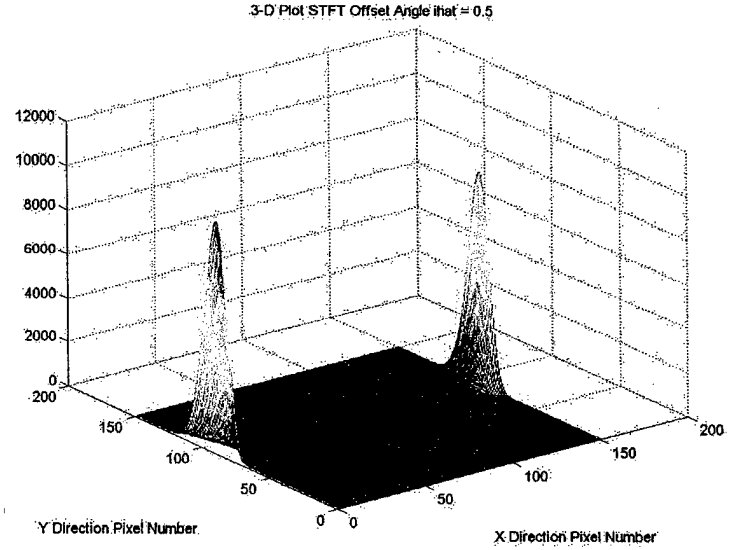


Plots STFT Data (Results cont)

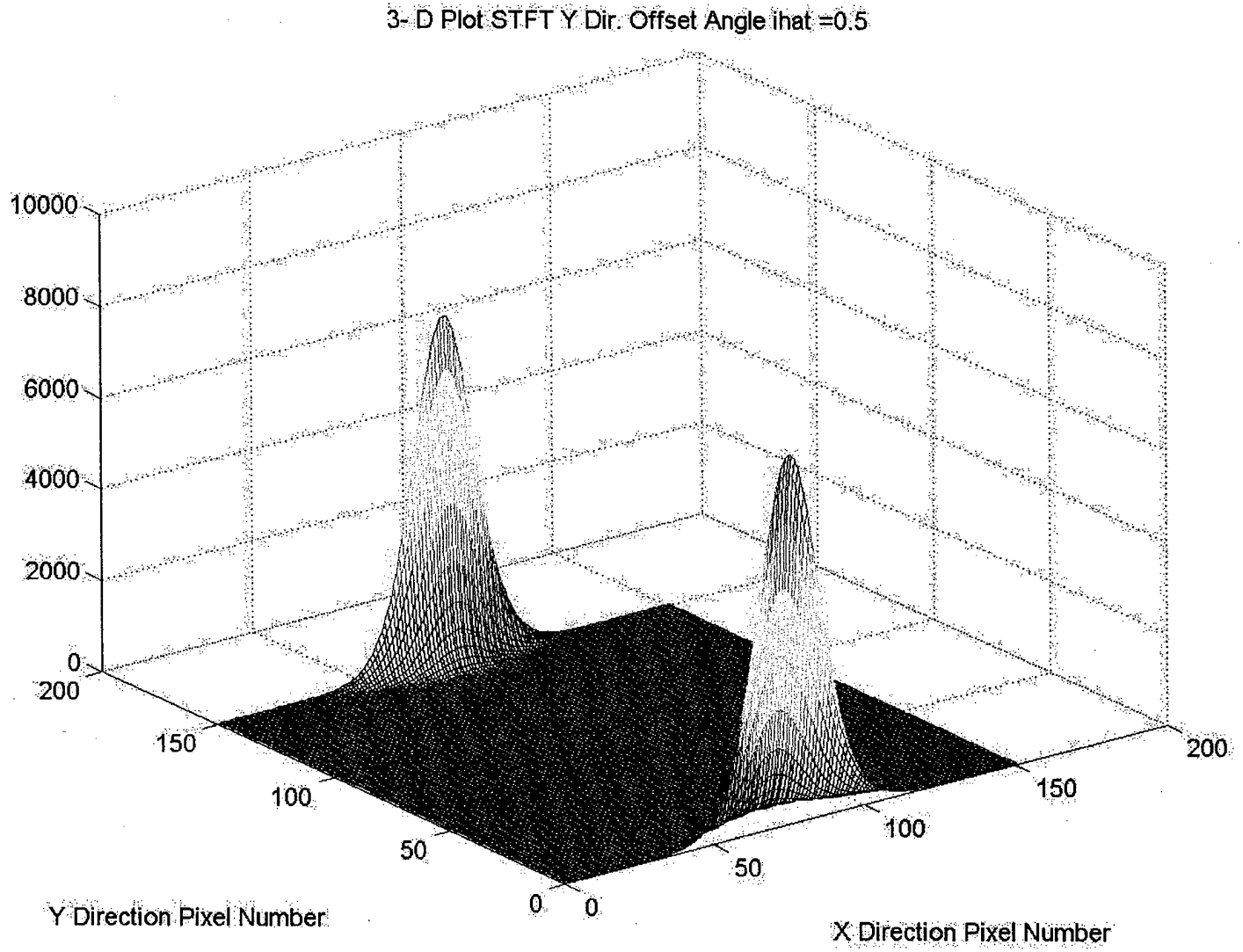


Plots STFT Data(Results cont)





Plots STFT Data(Results cont)



Conclusion and Future Work

- STFT concept works in defining current location for the focal spot in X, Y.
- Could use maximum value found in each direction (X,Y) of the STFT to determine location for the focal spot.

- Need method to determine when focal spot energy changes and not (X,Y) location.
- Need to study "real" CCD pictures of absorber and secondary concentrator.
- Investigate wavelet or multi-resolution method for focal spot location.
- Investigate pattern recognition methods in combination with wavelets for focal spot location.