Contrast Leakage as Function of Telescope Motion

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Executive Summary

- Improving model methodology to investigate radial and azimuthal contrast leakage associated with telescope Wavefront Error (WFE) Stability.

Wavefront Change over Time

- Goal is to develop methodology for deriving specification.

Caveats

- Monochromatic
- Simple model
- Band limited 4\textsuperscript{th} order Sinc\(^2\) mask
Matlab Model

Simplified integrated model:

- Telescope Aperture: can be monolithic or segmented
- Single Stage Coronagraph: can be linear \(1-\text{sinc}^2(x) \times \text{sinc}^2(y)\) or radial \(1-\text{sinc}^2(r)\) or coronagraph provided by STScI or others.
Integrated Model – Pupil Function

Pupil Function models the telescope

$$\text{Pupil}(x,y) = \text{Aper}(x,y) \times \text{Phase}(x,y) = A(x,y)e^{-i\Phi(x,y)}$$

Aperture Mask

- Can model Monolithic or Segmented Aperture
- Segments are Hexagonal
- Outer Aperture can be Hex Segment Boundary or Circle
- Hex segmentation pattern is 1, 2, … to 6 Rings.
- Can also do Central Circular Obscuration and ‘cross’ spiders

Phase defines telescope Wavefront Error

- Global Alignment: Despace (Power and Spherical), Decenter (Coma), Backplane Bending, Mount Errors, etc.
- Segment Rigid Body: Piston, Tip/Tilt
Input Phase Functions: Global Errors

PM to SM Despace: Power and Spherical

PM to SM Decenter: Coma & Tilt

PM Backplane bending

PM Mount: Trefoil
Input Phase Functions: Segment Errors

Segment Rigid Body Motion: Pistion and Tip/Tilt

Segment Decenter or Bending: Astigmatism

Segment Thermal Drift: Power

Segment Mount: Trefoil
Phase Function Perturbations

Three temporal Phase Function cases are modeled:

- Static
- Periodic
- Random

**Static** models contrast leakage for a fix amplitude of each wavefront error.

**Periodic** models contrast leakage for a wavefront error that varies sinusoidally between +/- peak amplitude values. This case represents periodic vibration such as rocking mode of a secondary mirror tower or of a primary mirror segment that is uncorrected (either no active control of active control is slow).

**Random** models motion that is not corrected by an assumed active control system.
Model Output

The model calculates Contrast Leakage:

- Photometric Noise – time and spatial averaged radial
- Systematic Noise – azimuthal varying error

We are following the definitions and methodology published by:

Photometric Noise

Photometric Noise is the time and spatial averaged radial component of the dark hole speckles. Photometric Noise is rotationally symmetric and cannot be confused for a planet. Assuming that the planet is $10E^{-10}$ contrast, Photometric Noise Contrast Leakage may be as large as $10E^{-10}$ contrast for a SNR = 1.
Systematic Noise

Systematic Noise is the component of the dark hole speckles that varies spatially after subtraction of the time-averaged radial component. This noise component can be confused for a planet. For a planet with $10^{-10}$ contrast, systematic noise should be no larger than $20\times 10^{-11}$ contrast.
Annular ROI from 1.5 to 2.5 $\lambda/D$

Photometric Noise

$\lambda/D$

-10

-5

0

5

10

-10

-5

0

5

10

-6

-8

-10

-12

-14

-16

$\lambda/D$
Sensitivity Analysis

Input pupil WFE:
  • Single Static Realization
  • Average 50 Sinusoidal Realizations
  • Average 50 Random Realizations

Quantify Contrast Leakage over ROI:
  • Average Radial
  • Azimuthal

Plot Contrast Leakage vs. Aberration Amplitude
Periodic Noise in Segmented Telescope

![Graph with data points and error bars indicating periodic noise in segmented telescope with different aberrations and noise contributions.](image)

- Segment Tip/Tilt
- Segment Power
- Segment Astigmatism
- Segment Trefoil
- Global Bend About X
- Global Power
- Global Spherical
- Global Seidel Coma
- Global Zernike Coma
## Summary for Periodic Noise in Segmented Telescope

<table>
<thead>
<tr>
<th>Segments</th>
<th>Aberration</th>
<th>WFE (nm) for 10E-10 Photometric Noise</th>
<th>WFE (nm) for 20E-11 Systematic Noise</th>
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<td>Tip / Tilt</td>
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<td>Back Plane/Mount</td>
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<td>Bend About X</td>
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</tbody>
</table>
Conclusions

Developed methodology for calculating Photometric and Systematic Contrast Leakage Noise

Will use Leakage Sensitivity to define Telescope Mechanical Motion Tolerances.