Interference Mitigation Using a Multiple Feed Array for Radio Astronomy

Chad Hansen, Karl F. Warnick, and Brian D. Jeffs
Department of Electrical and Computer Engineering
Brigham Young University
Provo, UT

J. Richard Fisher and Richard Bradley
National Radio Astronomy Observatory
Green Bank, West Virginia

July 13, 2004

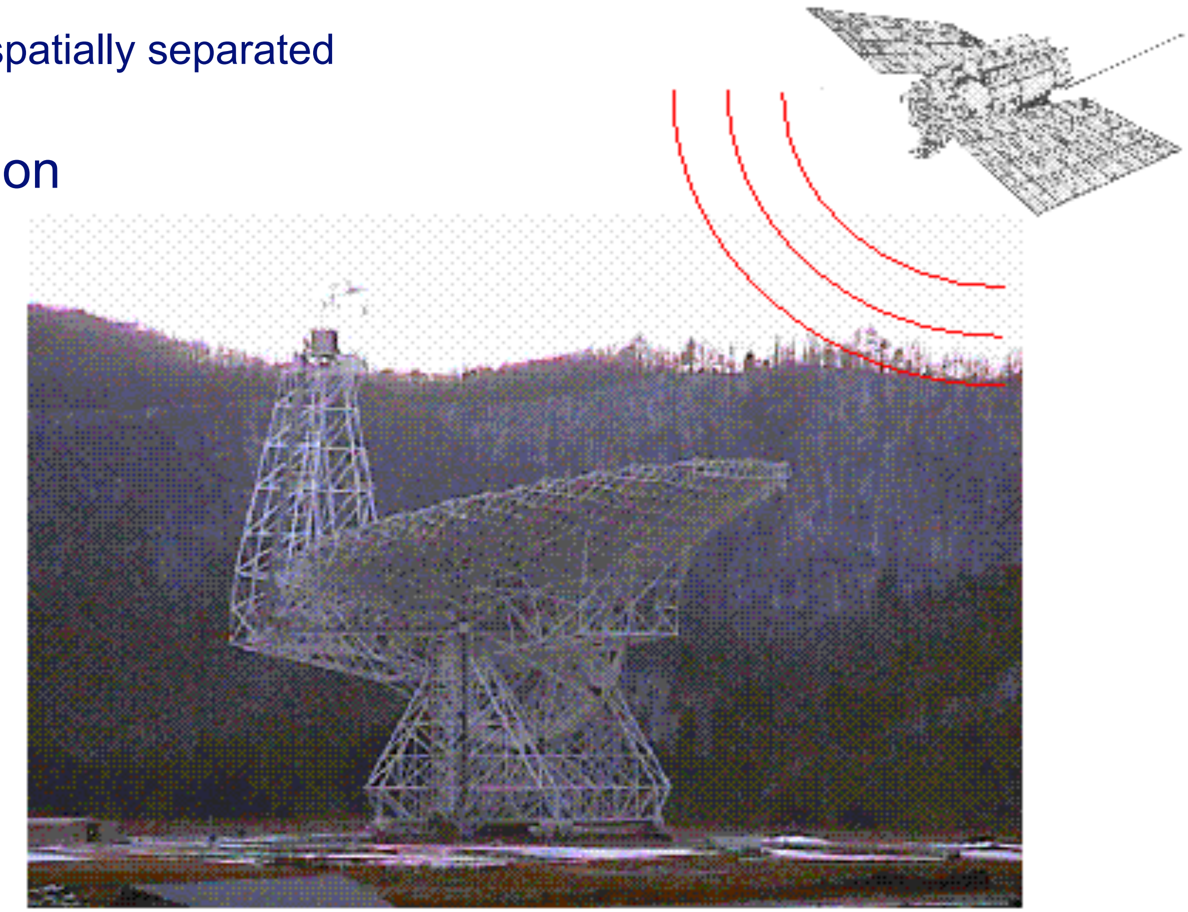
BYU
BRIGHAM YOUNG
UNIVERSITY

NRAO

RFI Mitigation

Techniques:

- Spatial filtering
  - Requires multiple spatially separated looks at interferer
- Adaptive cancellation
- Time blanking



Array Feed - Design Goals

- *High Sensitivity*
  - Sensitivity = $\frac{\text{Gain}}{\text{System Temperature}}$ ~ SNR
  - $T_{sys} = T_{receiver} + T_{spillover} + T_{Interference} + T_{atmosphere} + T_{cmb}$
- *Beam steering*
  - Beam shape control
  - Gain stability
- *RFI Mitigation*

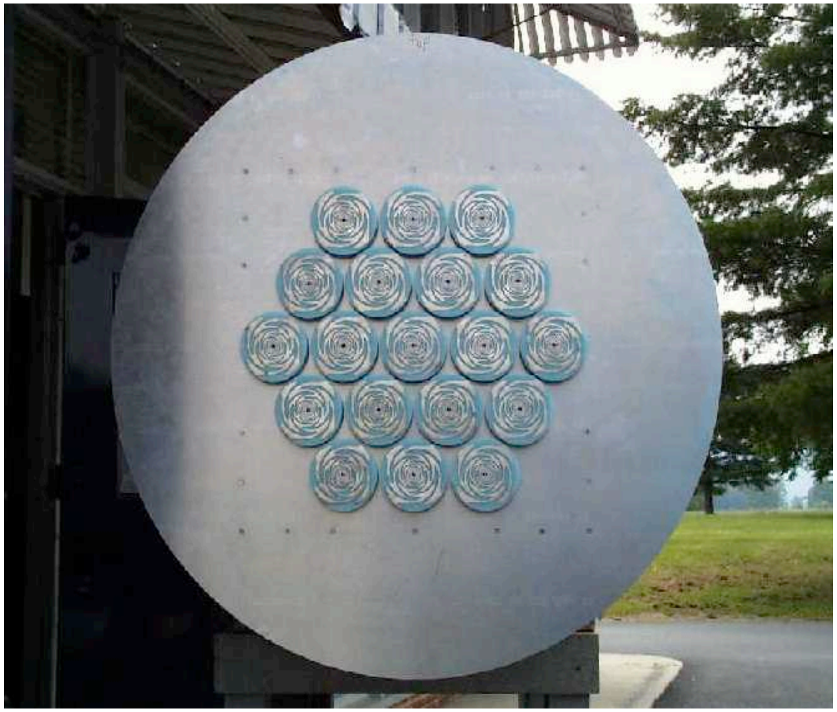
Previous Work: Array Feeds

- Most implementations: 1 feed = 1 beam

e.g: Parkes HIPASS Array – Multibeam feed.

19-element Array at NRAO

- Electrically small elements
- Hexagonal array
- Beamforming



Approach

- 25 meter paraboloid
- GRASP8 (TICRA) PTD reflector analysis software
- Array weights – three methods:
  - Conjugate field match (CFM)
  - Brute force sensitivity optimization
  - Max SNR/LCMV (beamforming + RFI nulling)
- Compare to single waveguide feed

Assumptions

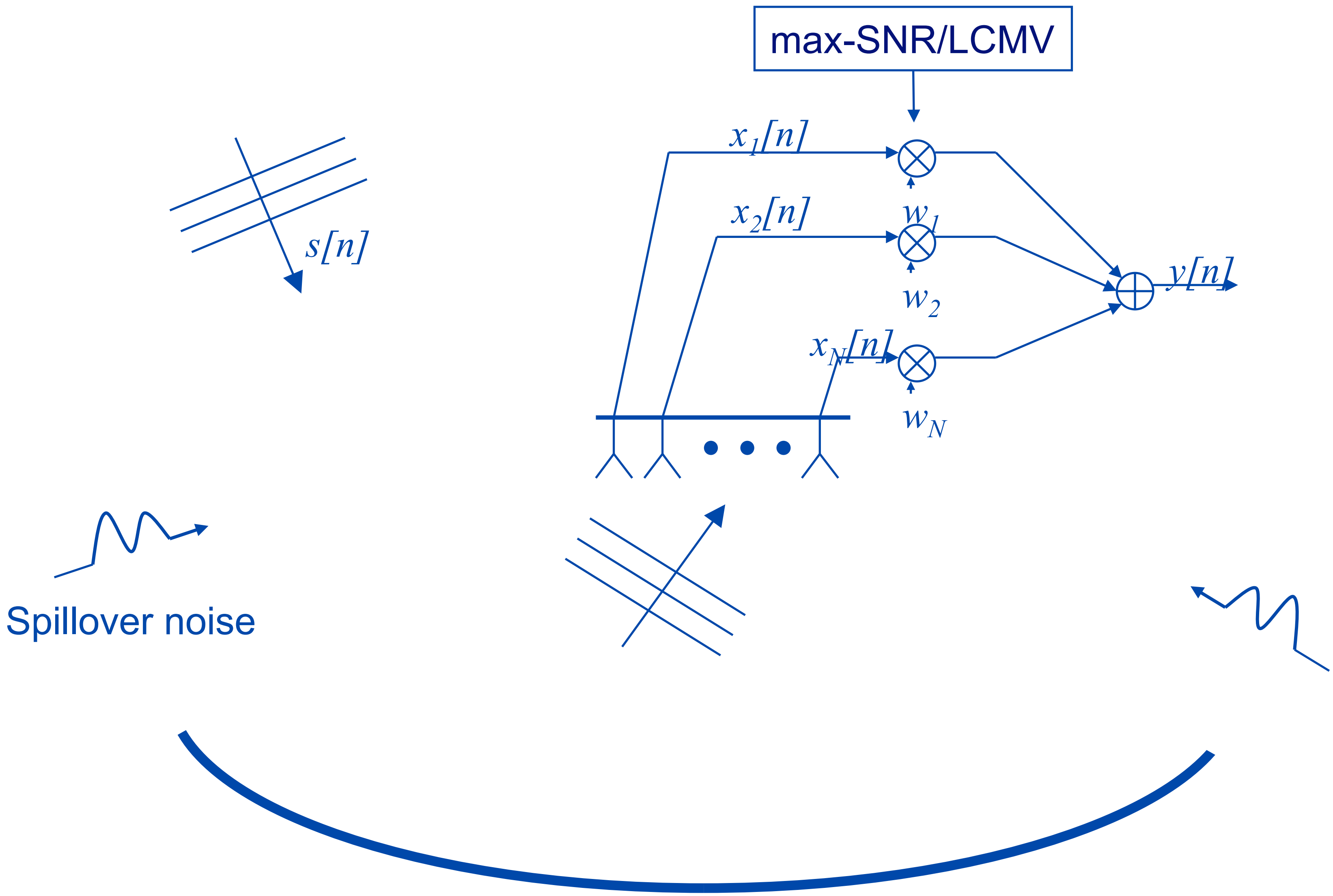
Array:

- Operating frequency: 1612 MHz
- 7 and 19-element hexagonal arrays with 0.6λ spacing
- Hertzian dipoles
- No mutual coupling between array elements
- Hemispherical element patterns

Noise model:

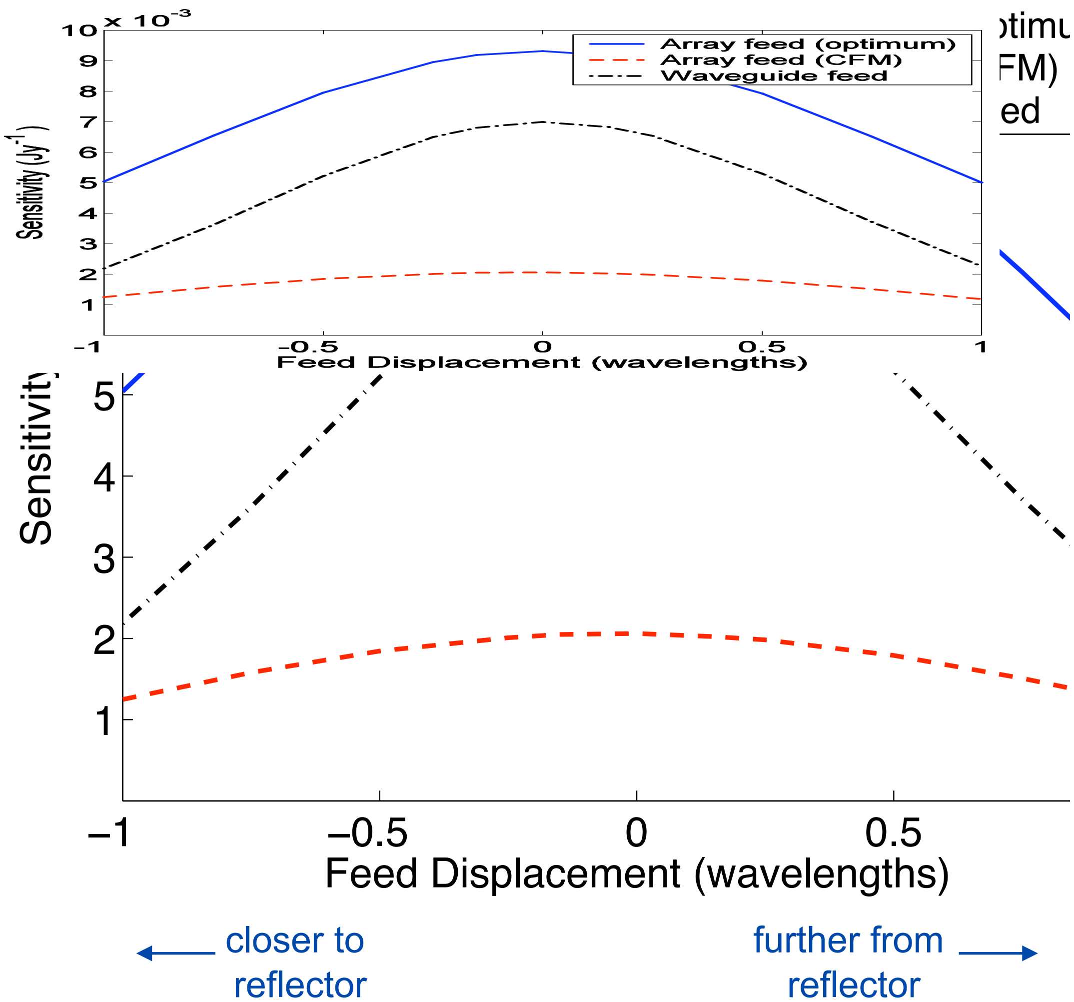
- Individual LNA noise temperature: 15 K
- Spillover noise: 300K warm ground below reflector
- Atmospheric and cosmic background noise is neglected

Interference Mitigation

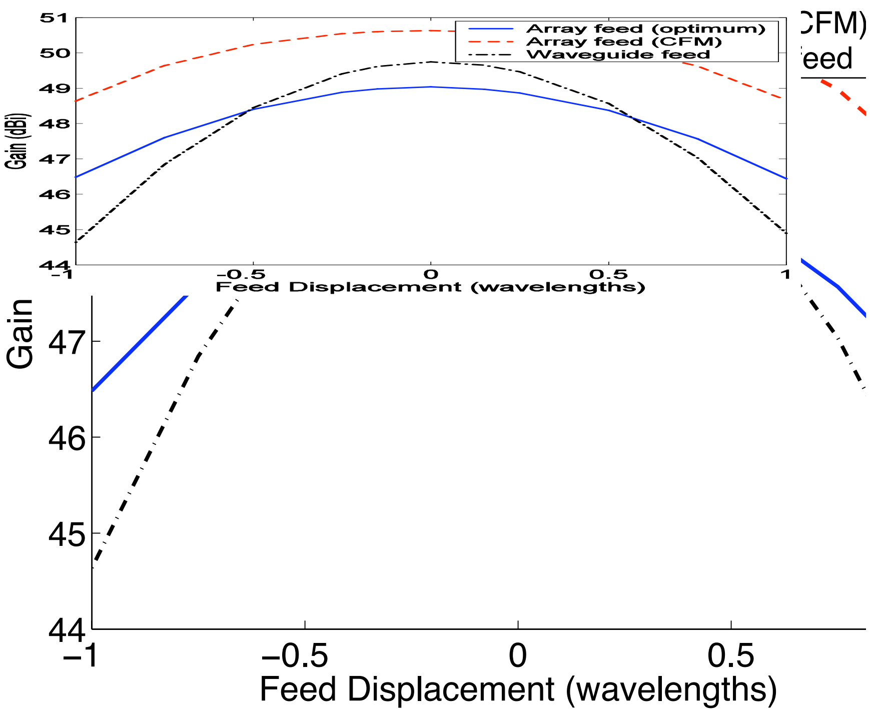


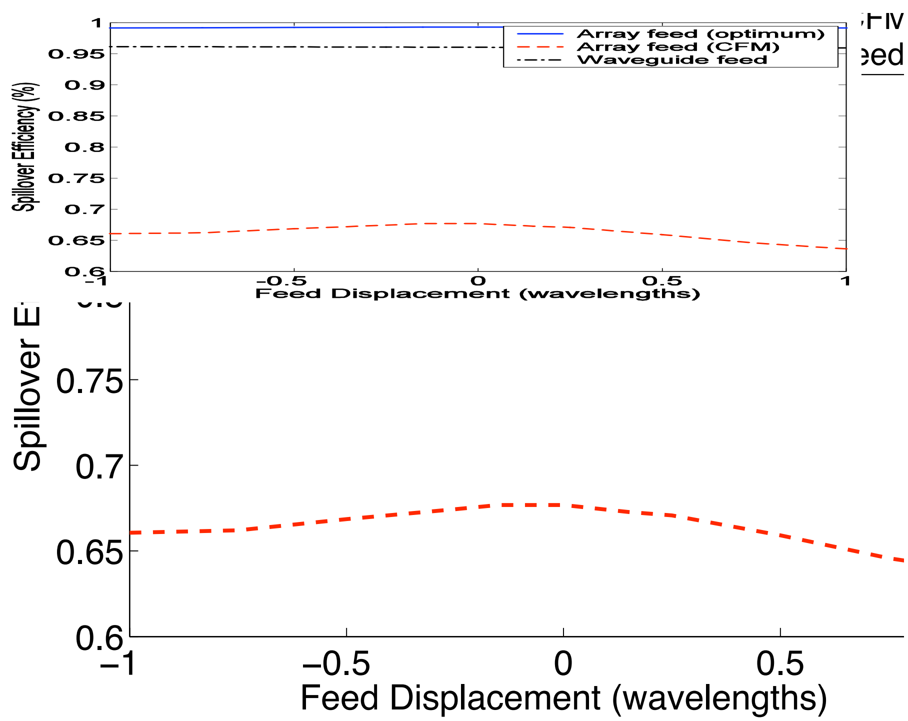
Sensitivity

- 25 meter reflector
- Boresight beam

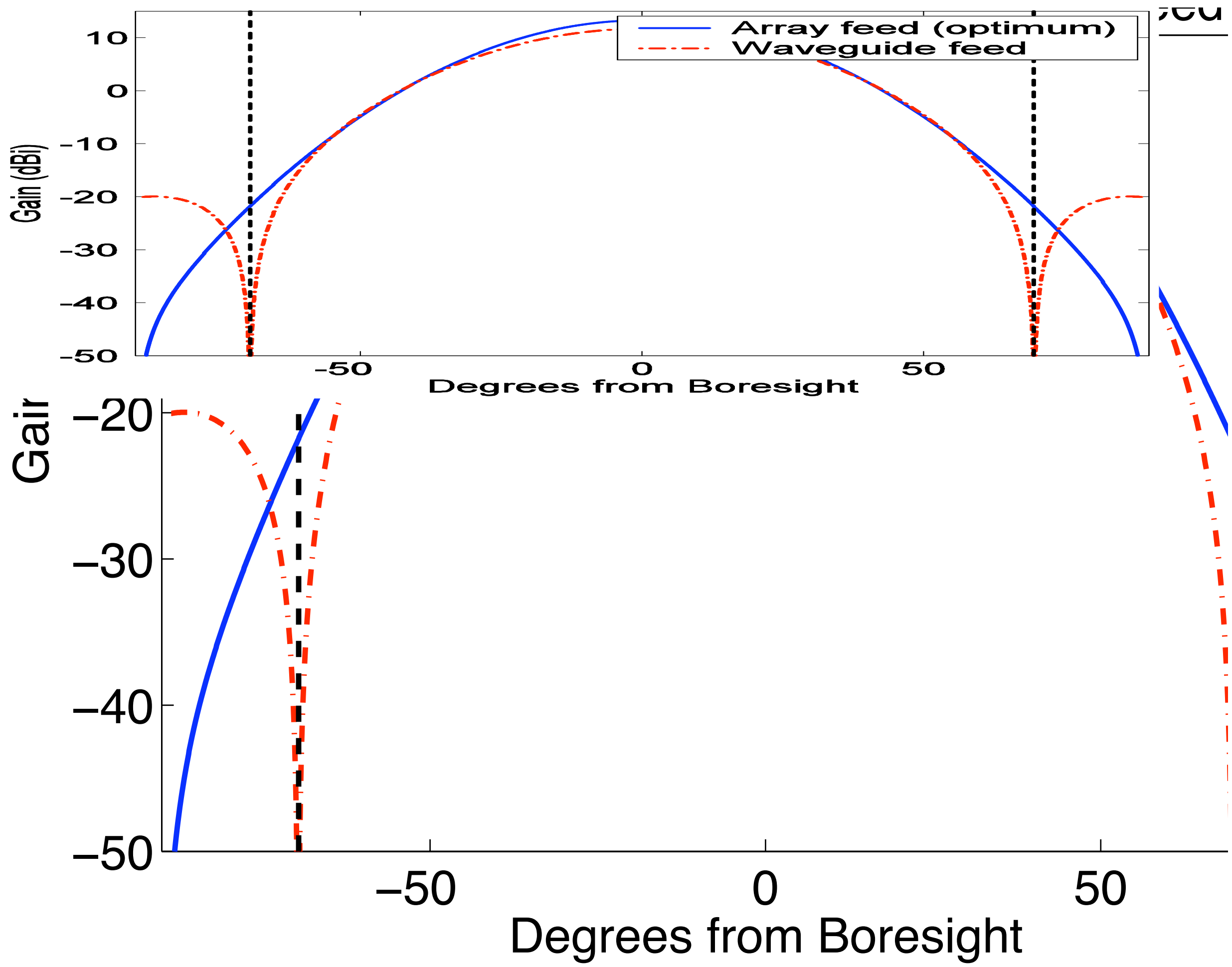


Gain and Spillover Efficiency

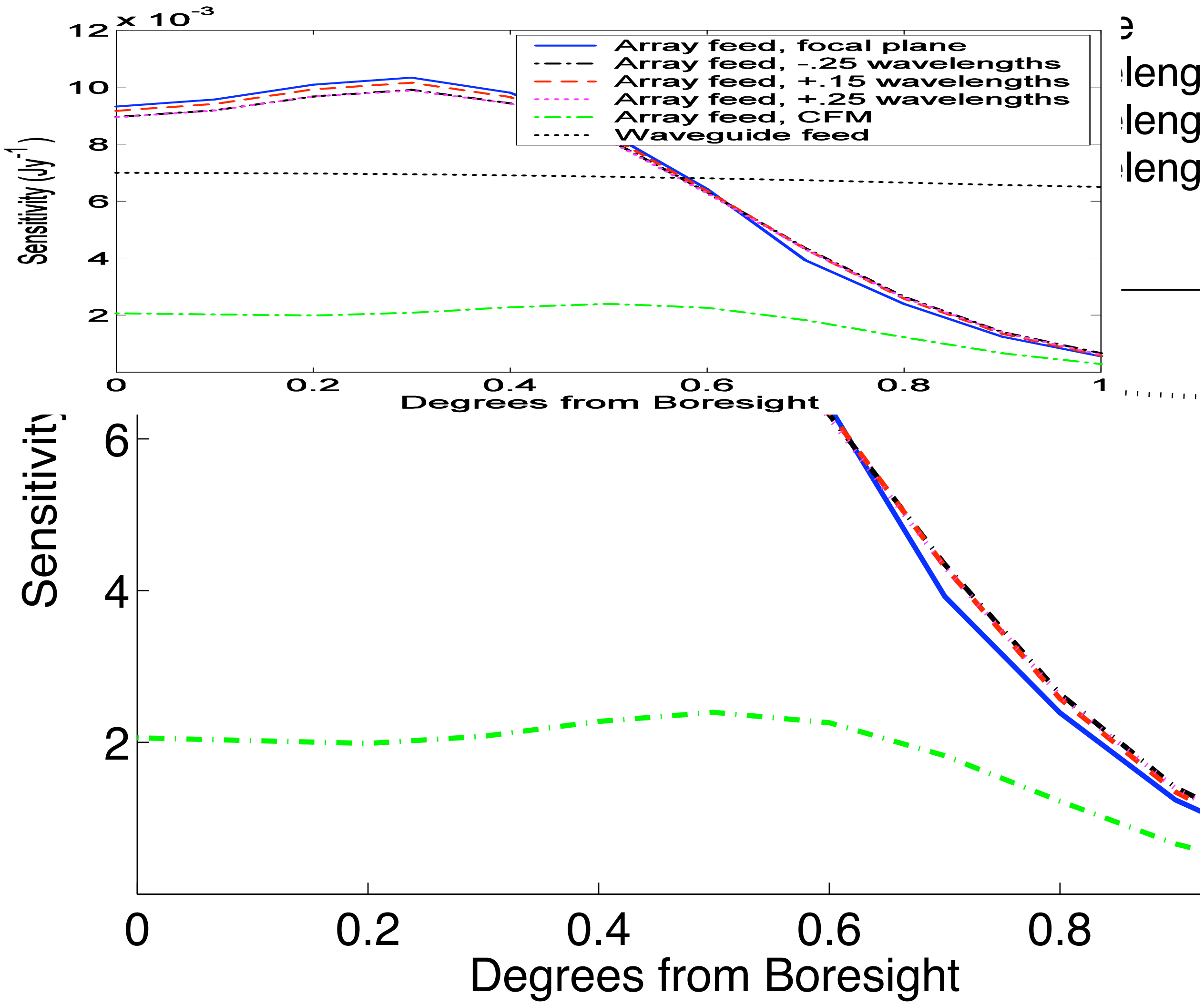




Reflector Illumination Pattern

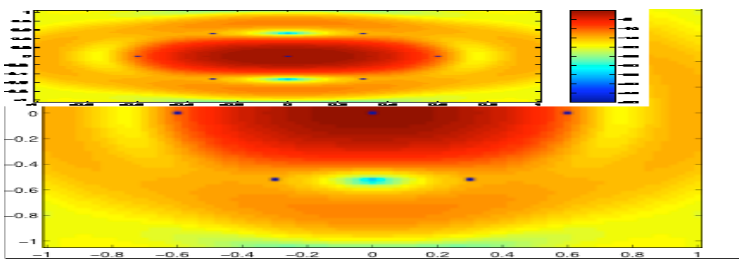


Steered Beams/Offset Feed



Focal Field Distribution

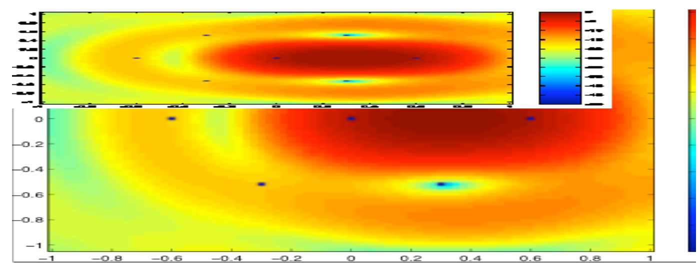
Boresight



dB

λ

Beam steered to .3˚

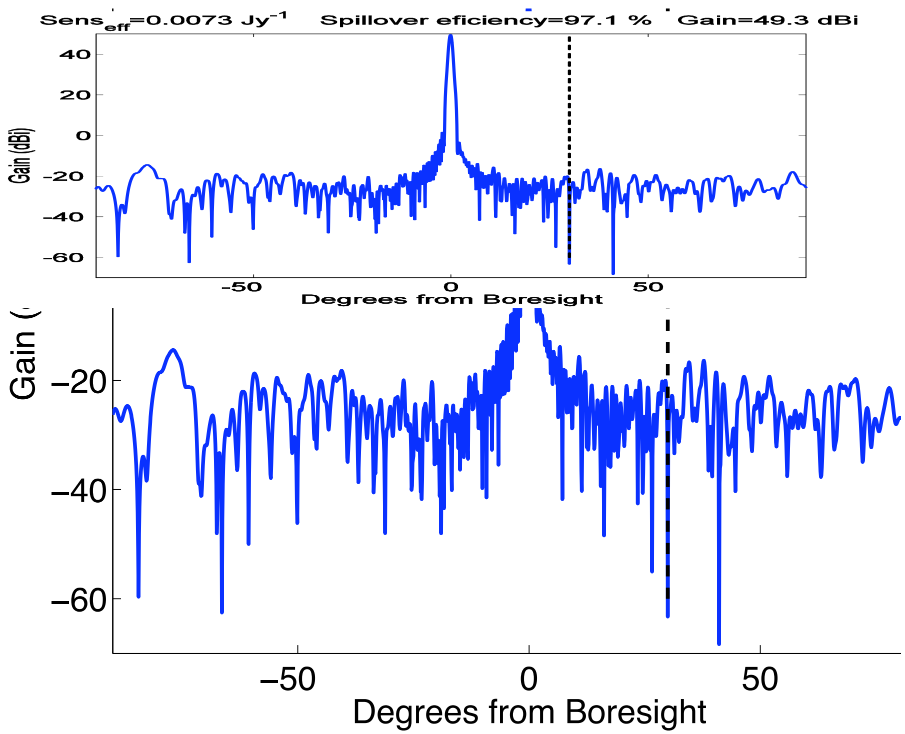


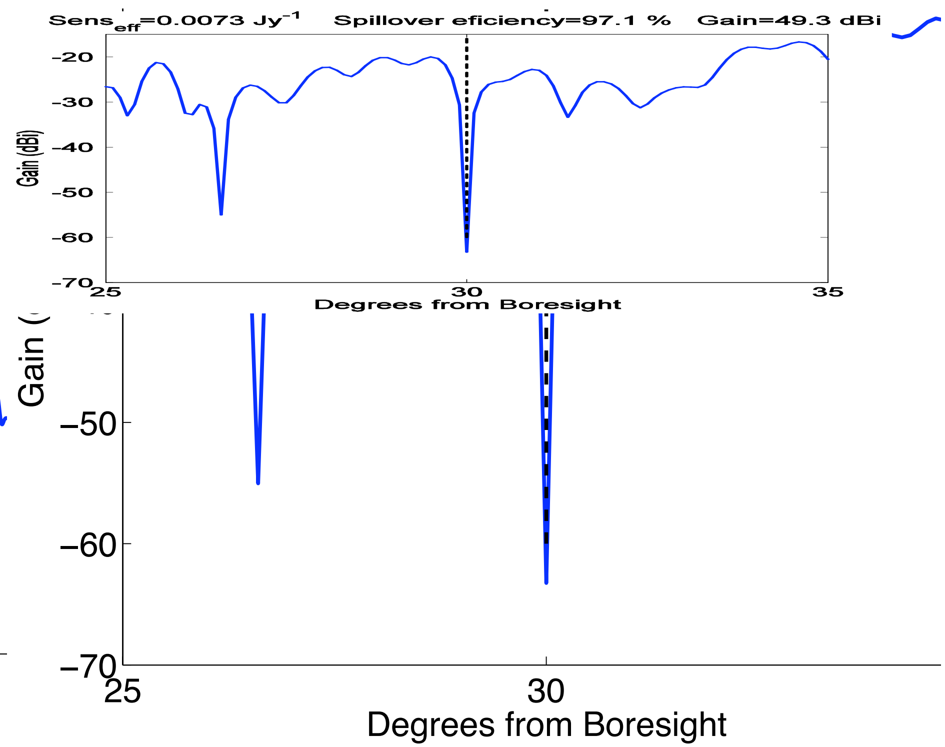
dB

λ

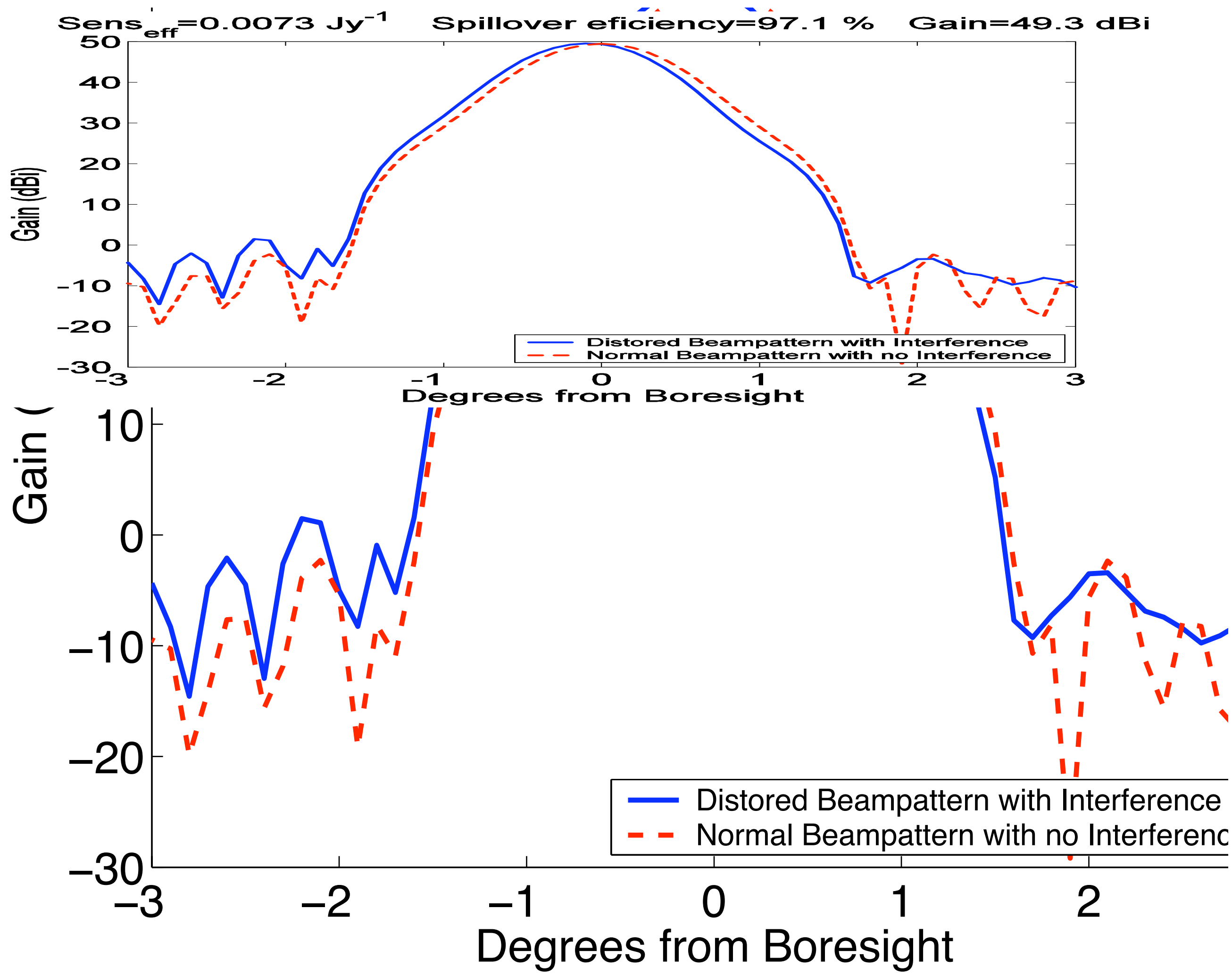
Results (7 Element Array)

Interferer at 30 degrees, INR=0 dB

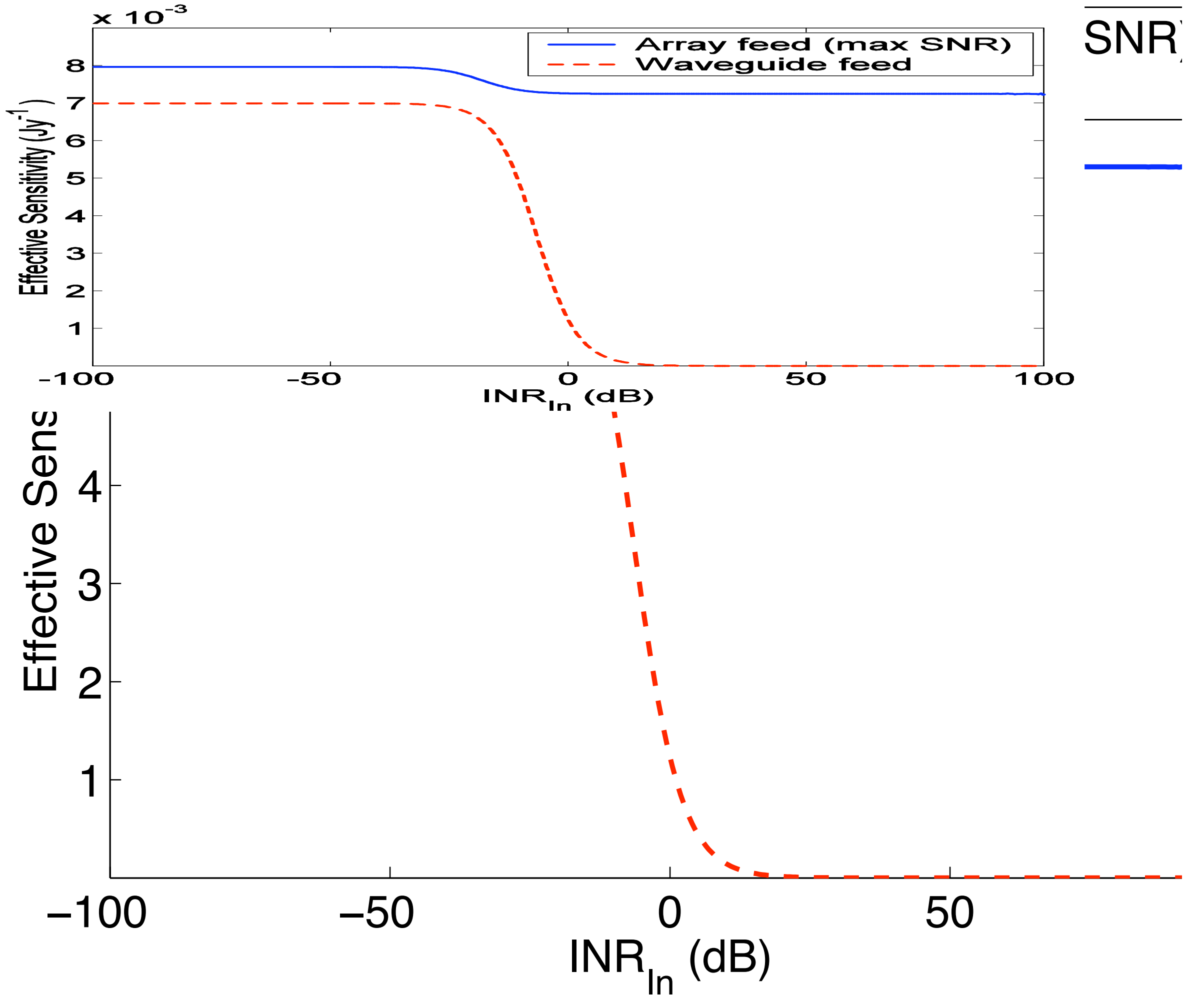




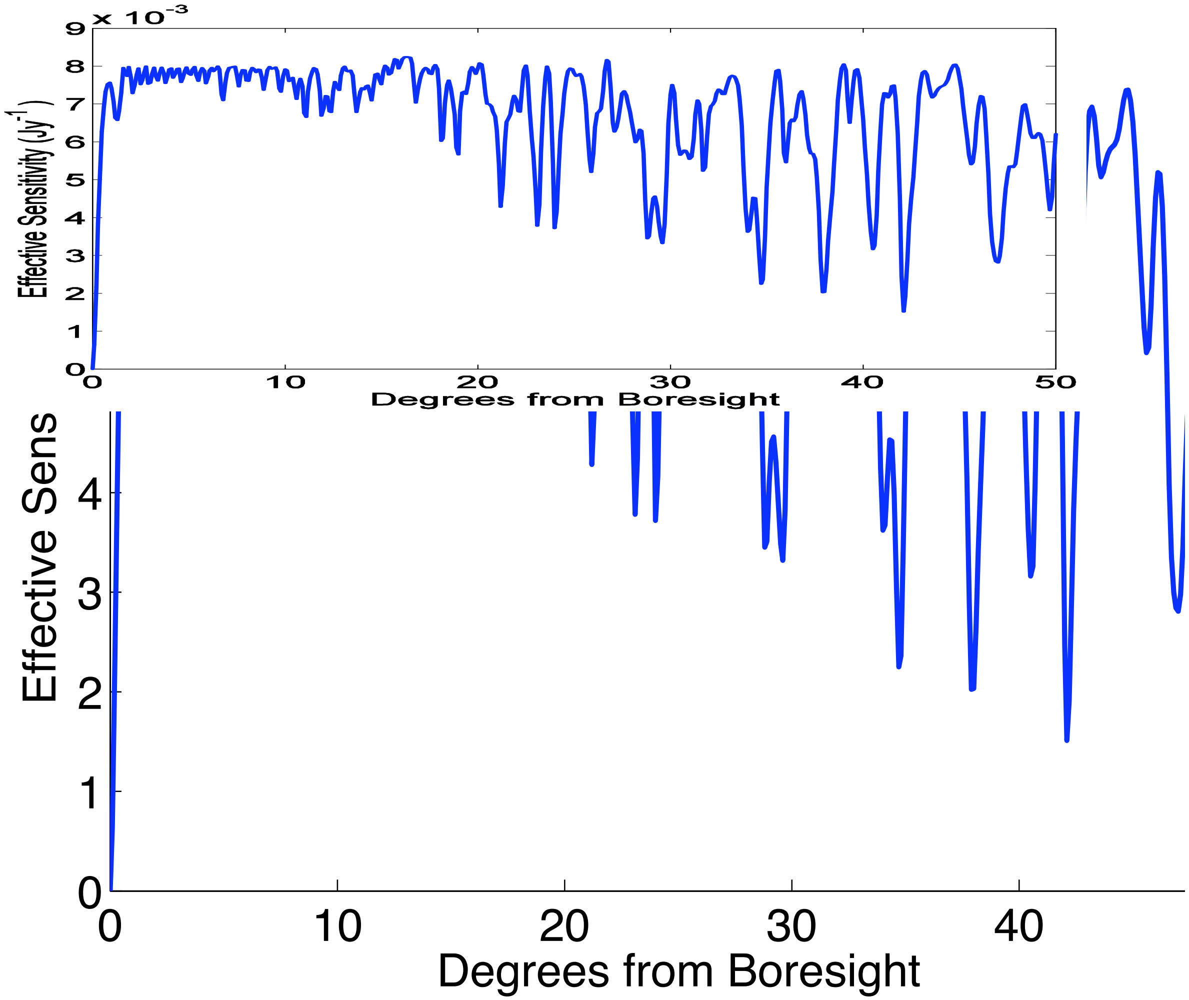
Main Beam Distortion



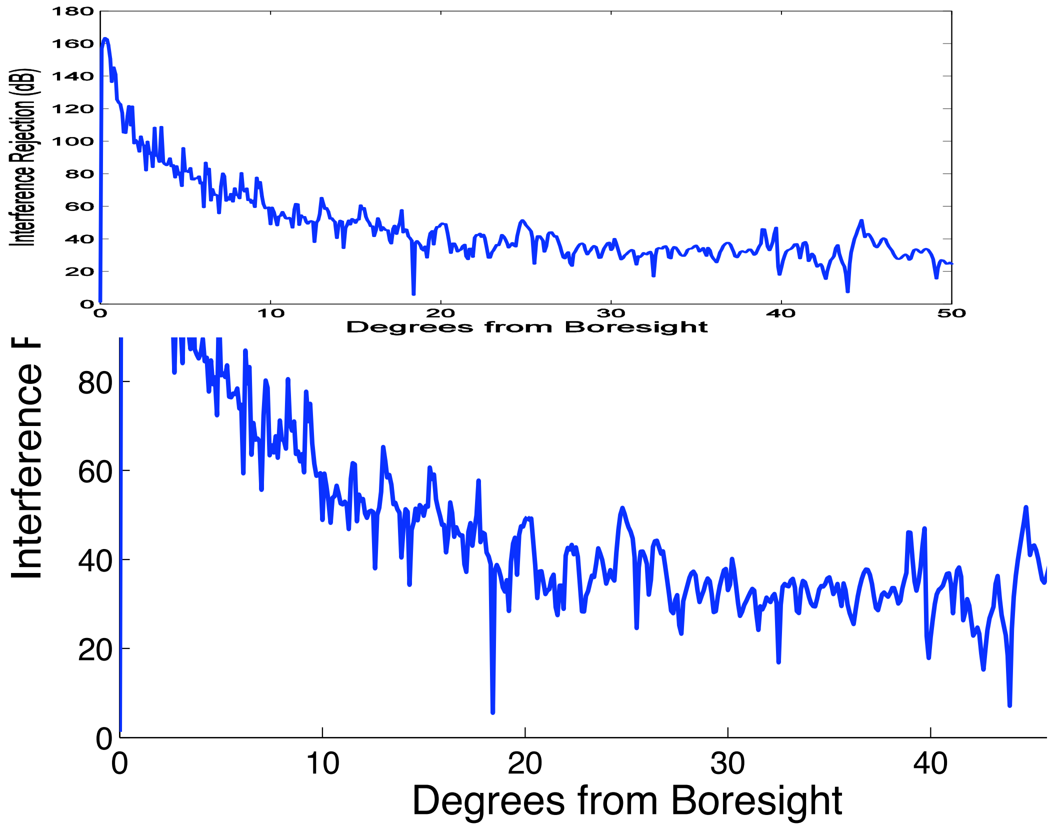
Interferer at 30 deg, INR_{In} changing



Moving Interferer



Interference Rejection



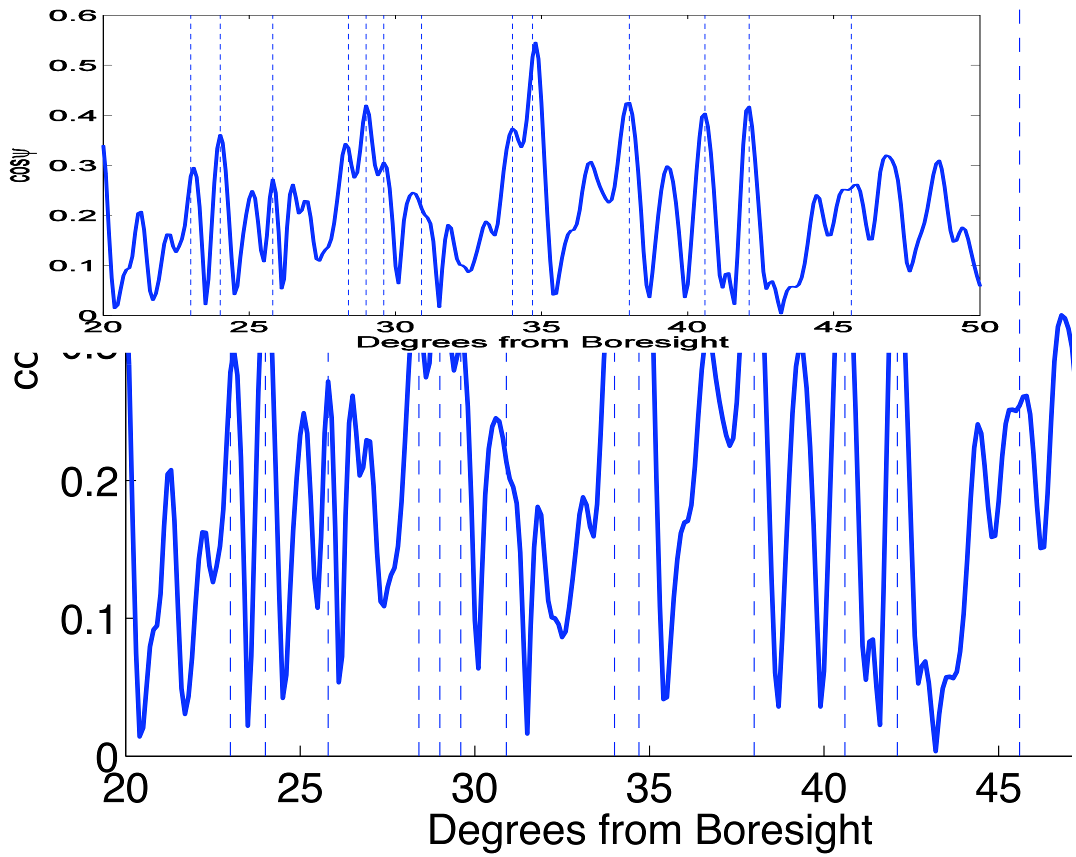
- Low sensitivity corresponds to poor spillover efficiency and gain loss

Signal/Interferer Array Responses

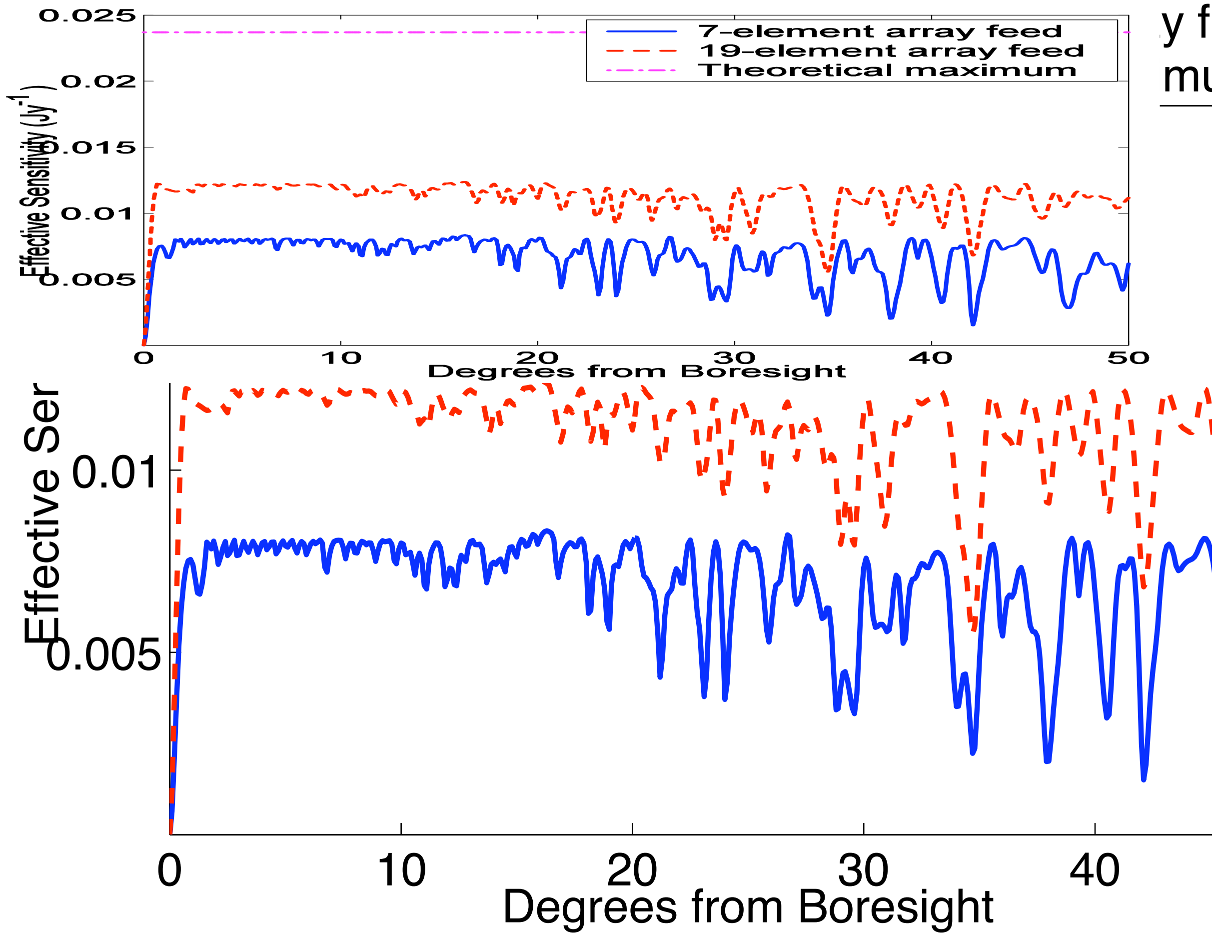
- Angle cosine between interferer and signal response vectors

- Sensitivity decreases when responses are similar

- Sensitivity loss is a grating lobe-like effect



19-element array, moving interferer

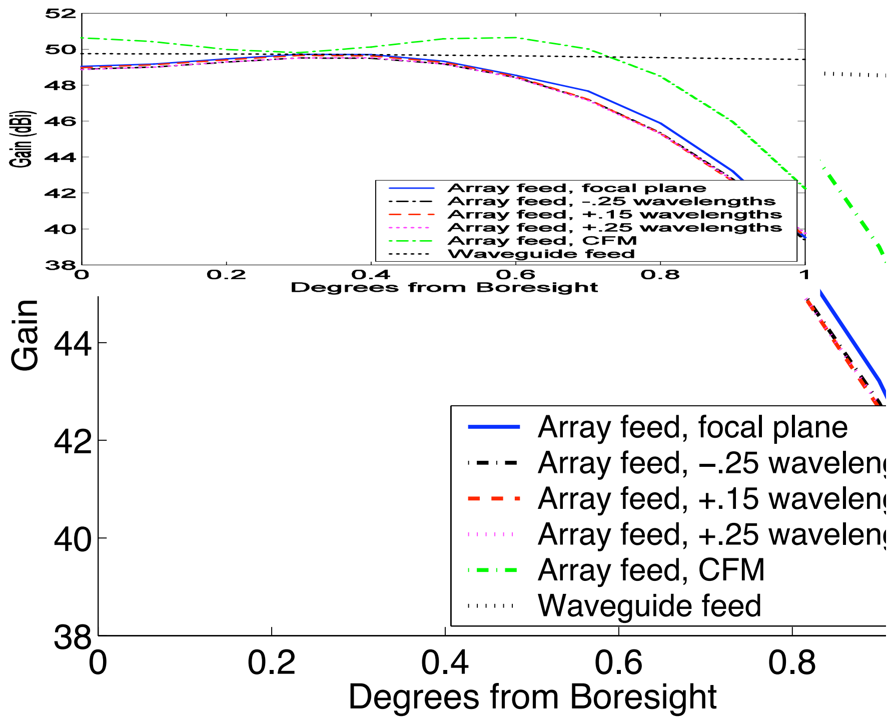


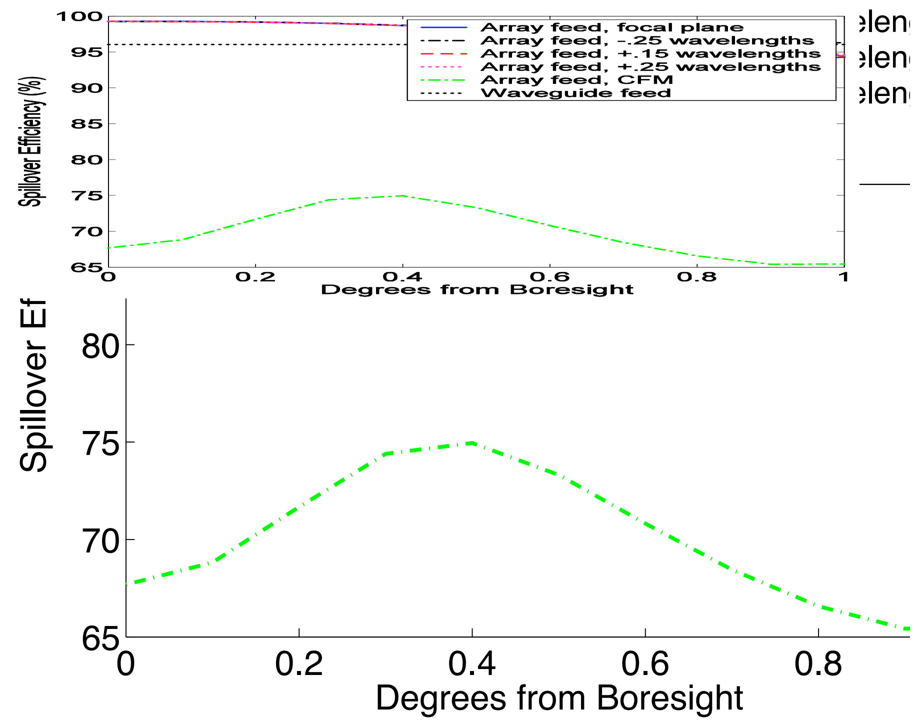
y f
mu

Conclusions

- Good sensitivity can be achieved using an array feed
- In the presence of an interferer
  - Interference at all INR levels and all angles was effectively rejected.
  - Main beam distortion occurs due to beam steering/RFI mitigation
  - Sensitivity fluctuates by a few dB with moving angle of arrival
- Future work:
  - Algorithms: beam shape control, defocusing (larger arrays)?
  - Broadband elements
  - Mutual coupling
  - Prototype…

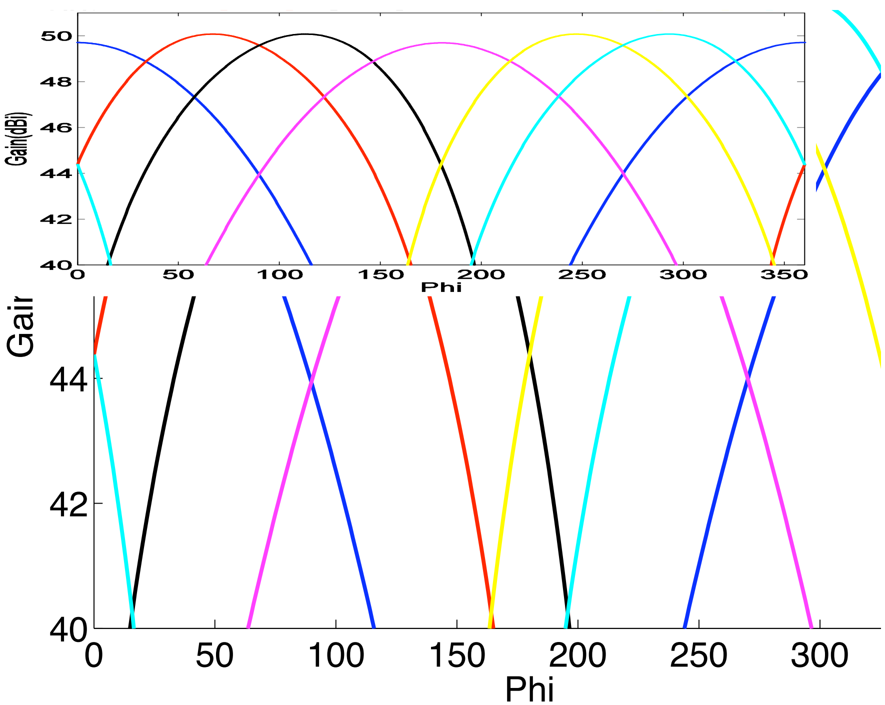
Gain and Spillover Efficiency



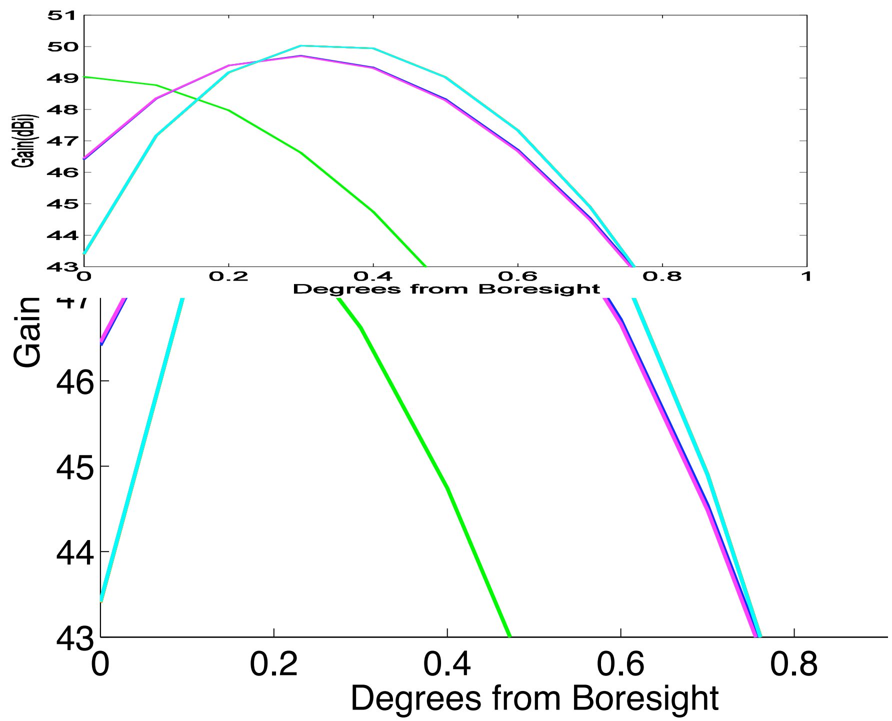


Multiple Beams

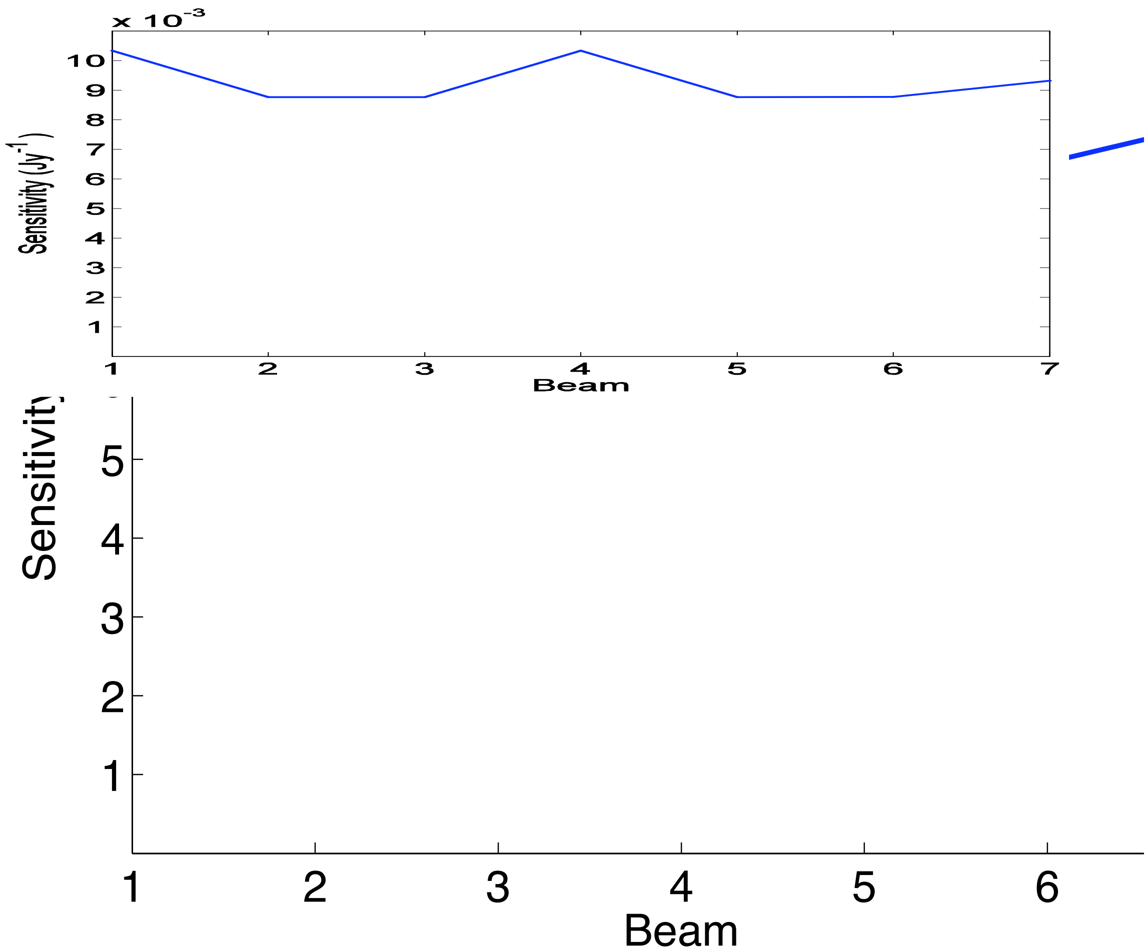
θ=.3˚



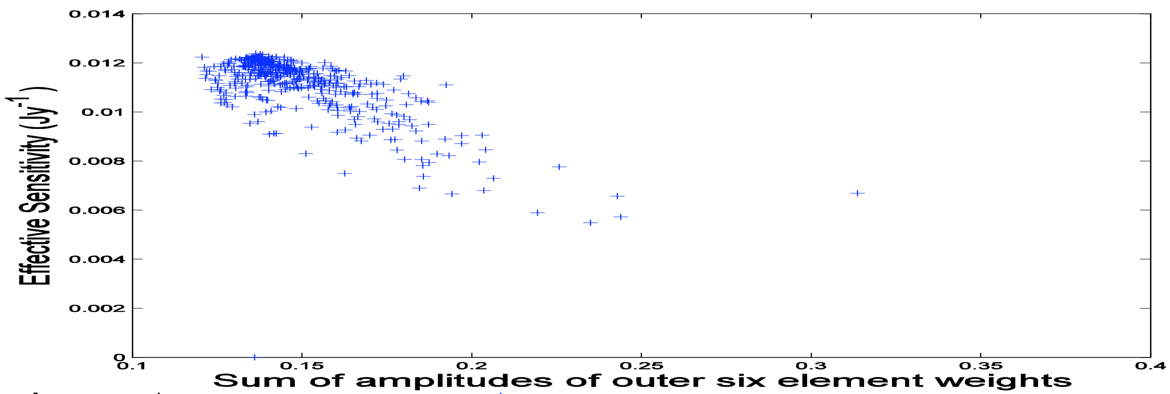
θ-cut

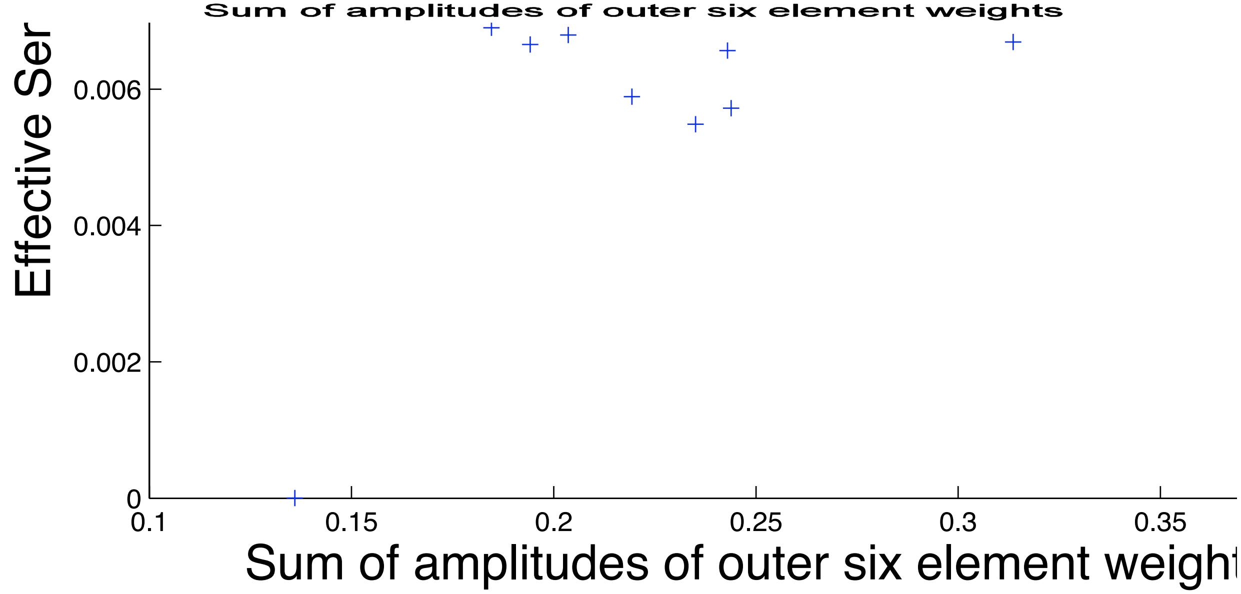


Sensitivity

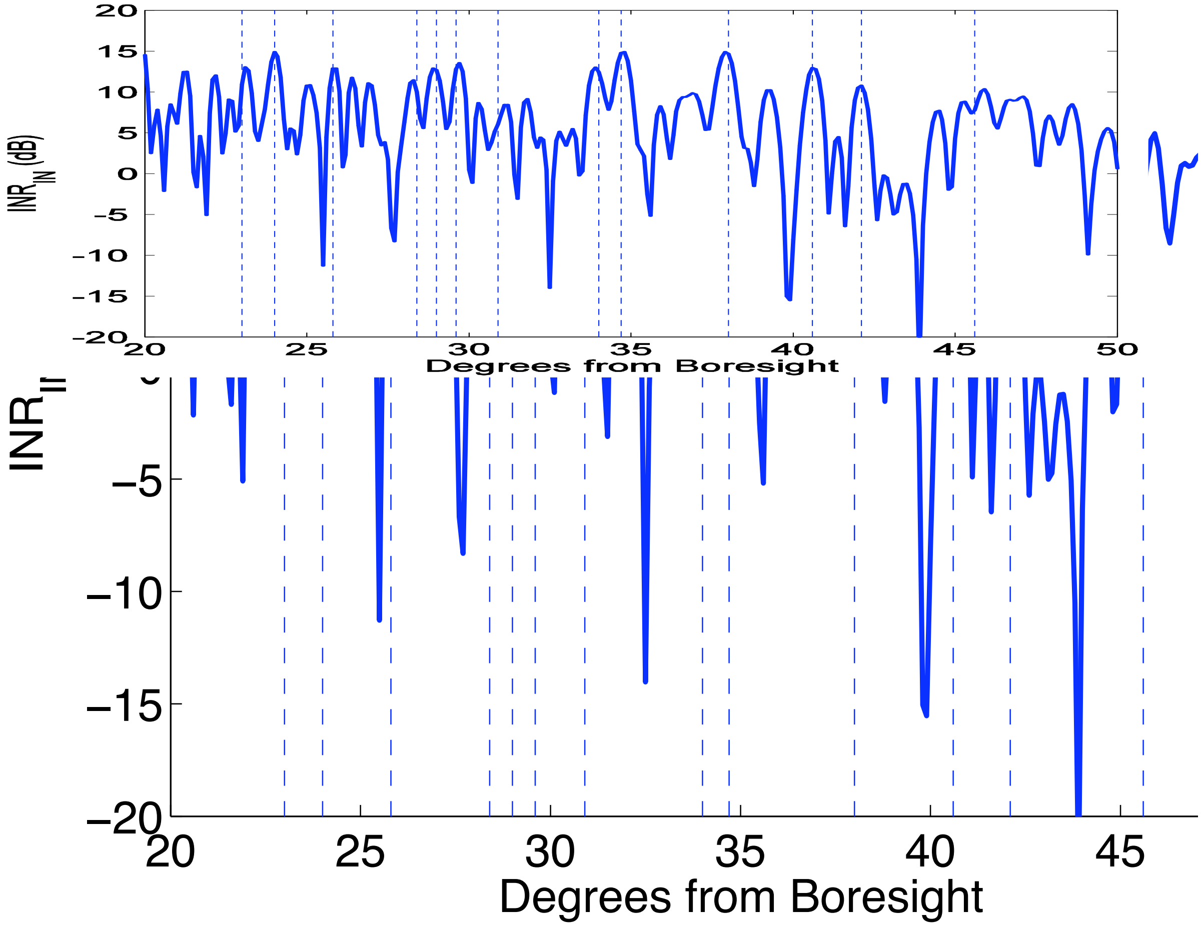


Sum of outer weights

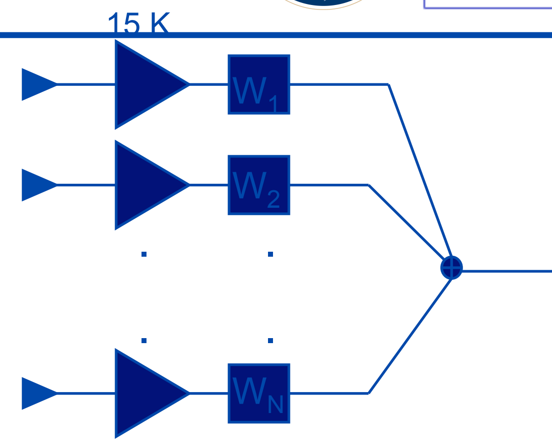




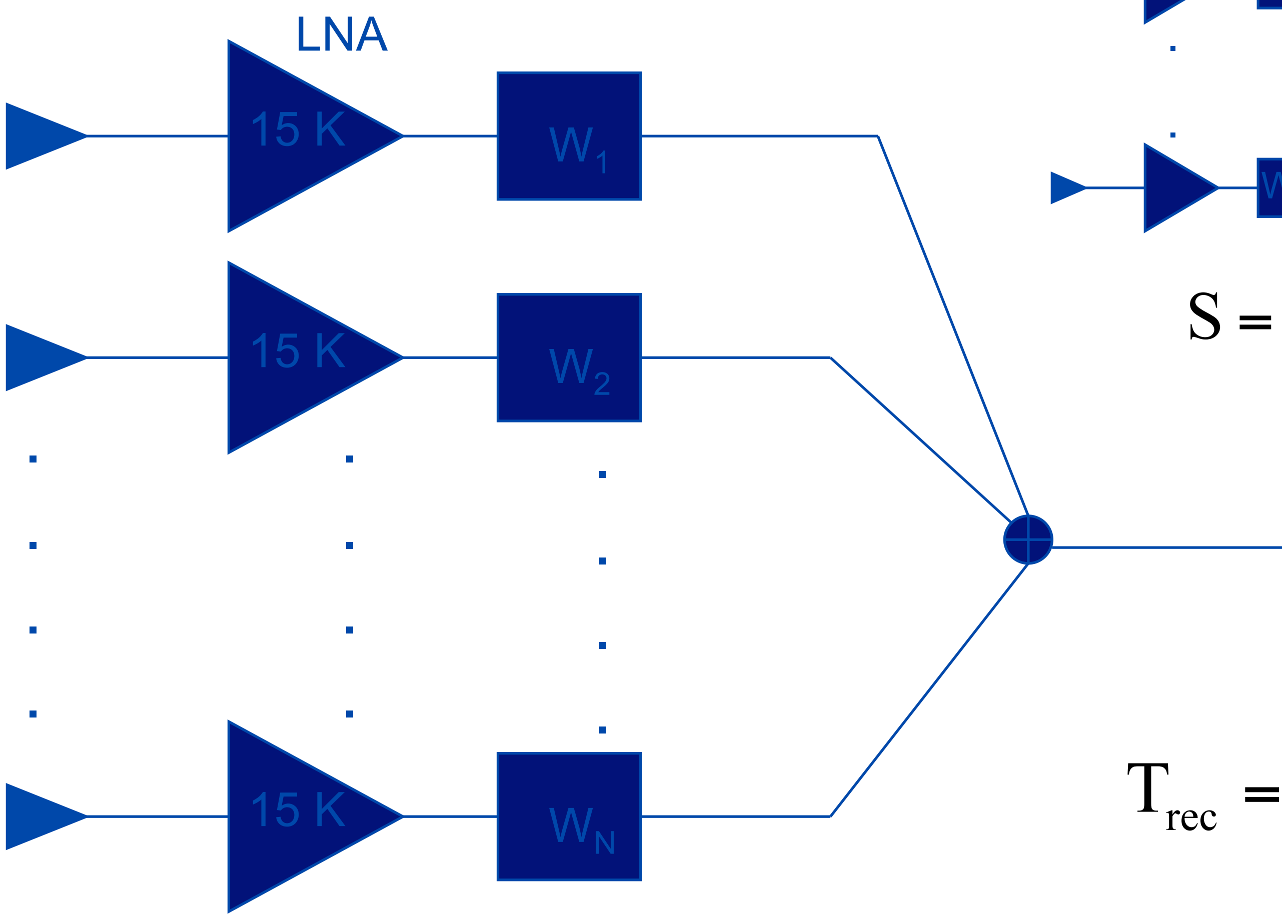
Center element, INR_{IN}



Assumptions



$$S = \frac{G}{T_{rec} + T_{spill}}$$



$$T_{rec} = \sum_{i=1}^{N} (W_i)^2 T_i$$