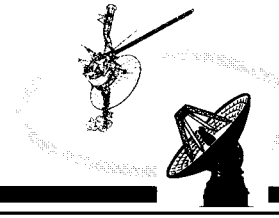


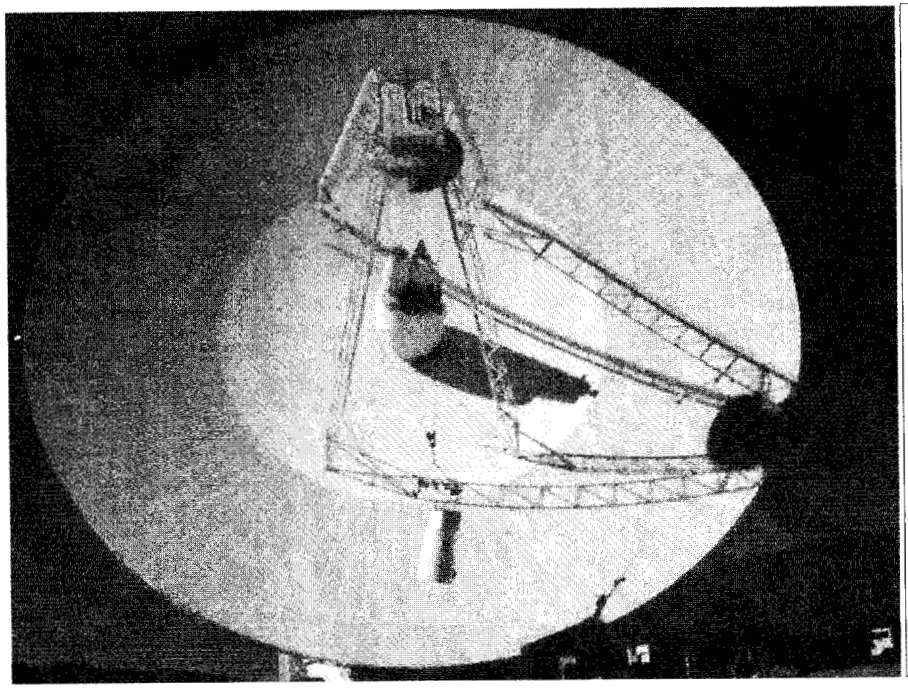
Methodology, Analysis and Experimental Study of the DFP/AFCS Systems for Compensating Gravity Distortions on the 70-meter Antenna

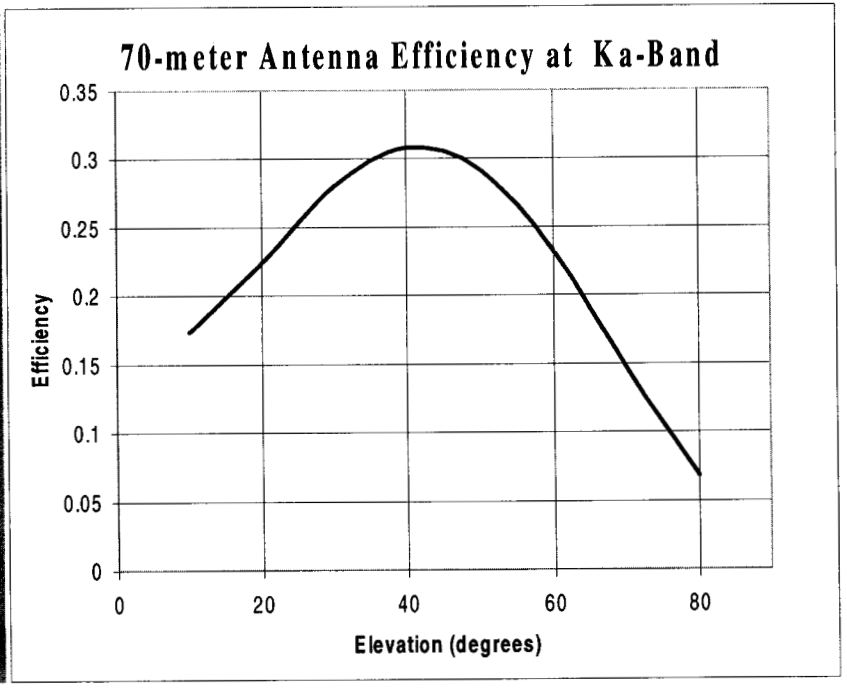
D. Rochblatt, D. Hoppe, W. Imbriale, W. Veruttipong, M. Franco, P. Richter, T. Sink (JPL)

Antenna Systems

Ka-Band DFP/AFCS Demo on the 70-M

- **A major problem for Ka-band on the 70-meter antenna is the loss in gain with elevation angle due to gravity induced structural mechanical distortions of the main reflector surface**

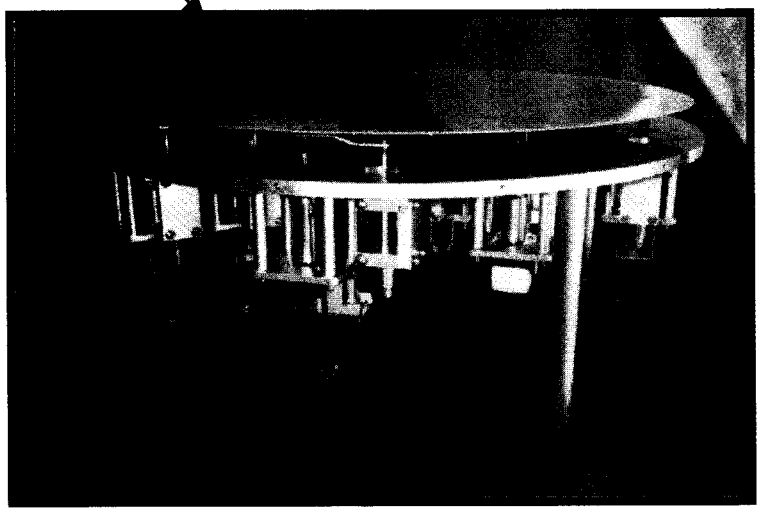




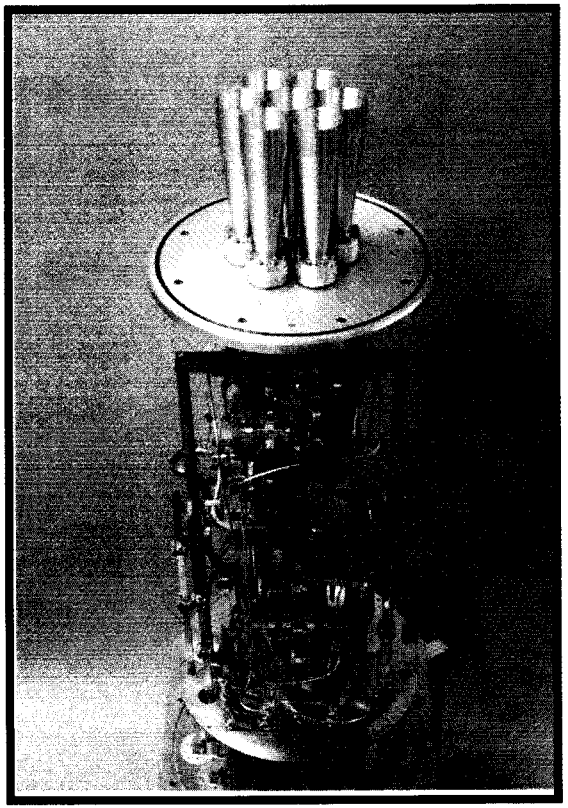
DSS-14

Ka-band Gravity Compensation Demo
Test of Two Technologies

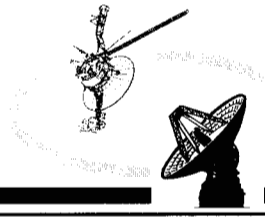
- **7 element Array Feed Compensation System (AFCS)**
- **16 actuator Deformable Flat Plate (DFP)**



DFP side view



Seven Element AFCS

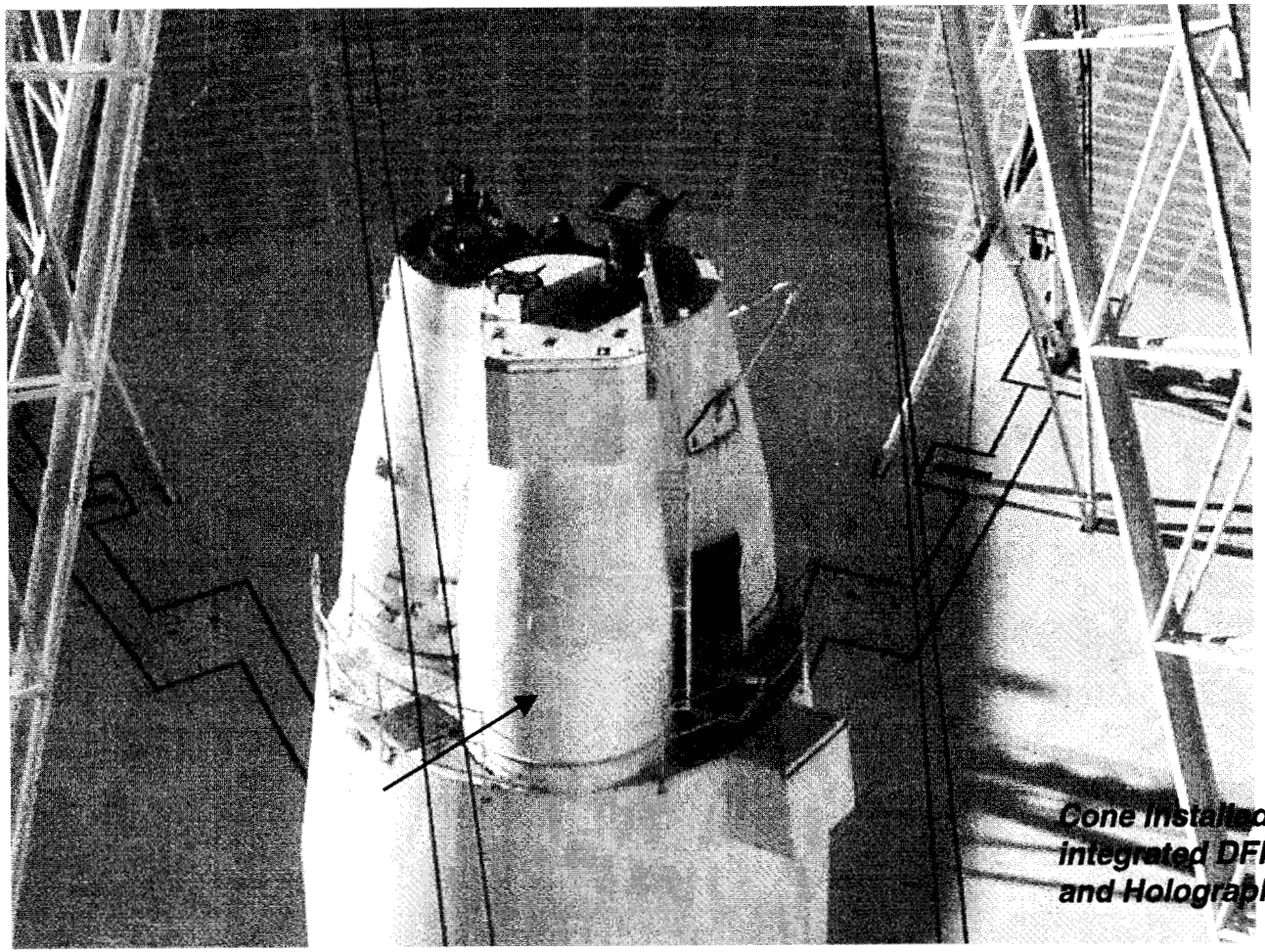


Ka-band Gravity Compensation Demo

The purpose of the demo was to evaluate the compensation and tracking performance of each technology separately, and then together in a combined system.

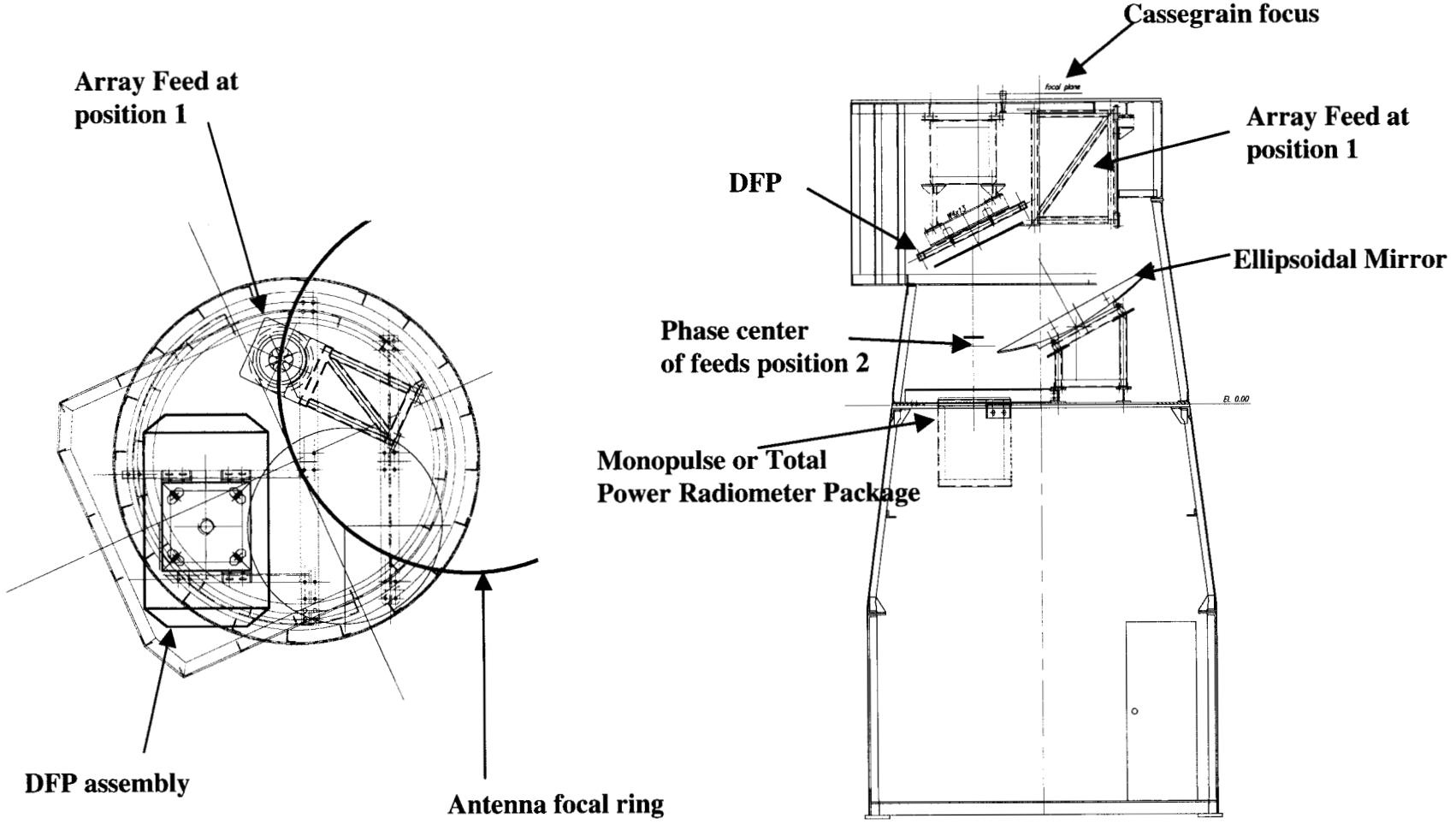
- **Both technologies compensate for the loss in gain of the 70-meter antenna at Ka-Band (32-GHz) due to gravity induced structural mechanical deformations to the main reflector surface**
- **The 7 element AFCS is a real-time compensation system that compensates for distortions due to gravity and provides closed loop pointing**
- **The 16 actuator DFP when combined with a monopulse tracking system, also provides gravity compensation and closed loop pointing**
- **Refurbished and retrofitted a feed cone with the required hardware - RF optics were designed to image the antenna cassegrain focus above the cone to a second focal position inside the cone using an ellipsoidal mirror**
- **Conducted a series of experiments between November 14, 1998 and March 1, 1999**

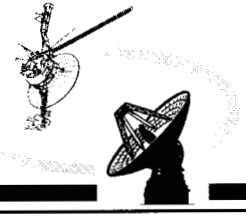
Gravity Compensation Demo Cone Installed at DSS-14 on Nov 12, 1998



Cone installed on DSS-14 with integrated DFP, AFCS, MP, TPR, and Holography

Gravity Compensation Demo Cone Mechanical Design





Steps for Calculating the DFP

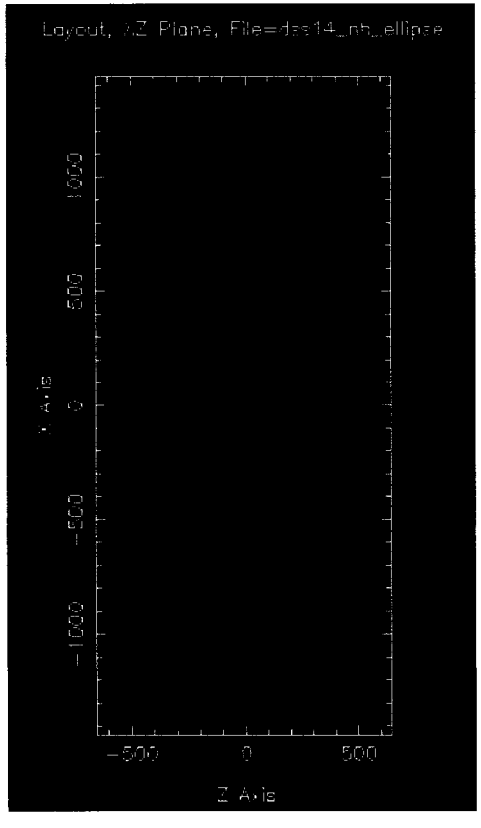
- Model the main reflector surface shape
  - based upon measured holography maps at 3 angles extended over the entire elevation range
- Use Ray optics to determine surface shape that will exactly phase compensate the distortions
- From the theoretical shape and a NASTRAN mechanical model of the plate determine the actuator positions that best fit the surface
  - This gives a model of the actual plate
- Use Physical Optics program to compute patterns and gain

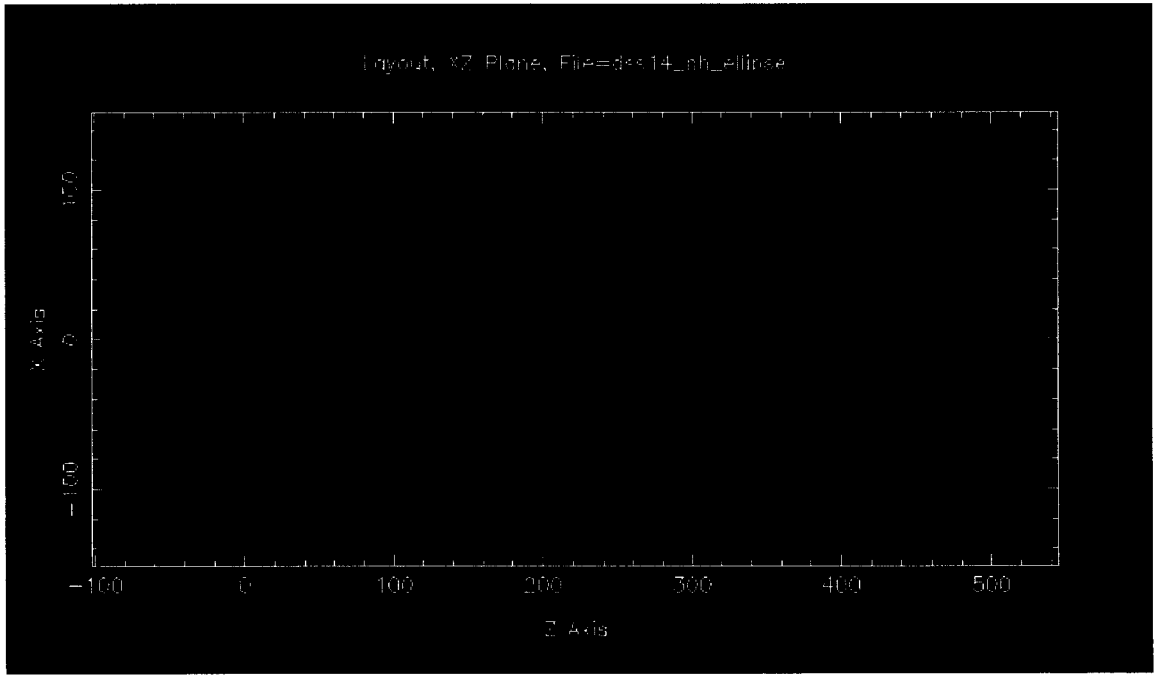
Holography (Con't)

- **DSS-14 Effective Deformation at 12.7-degrees Elevation, rms = 1.04-mm**

DFP Calibration and verification (Con't)

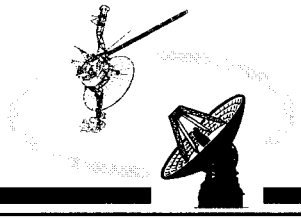
Mapping the DSS-14 effective surface deformation to the DFP position





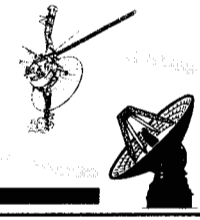
Shown: Subreflector - Cassegrain focus - Ellipsoid - DFP - Feed phase center

Shown: main, sub and Cassegrain focus



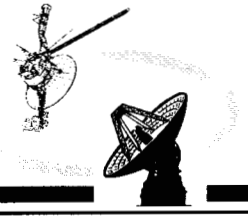
Steps for calculating the Array Feed

- Use the same main reflector surface model as the DFP
- Generate a theoretical feed model (verified by experiment)
- Use the PO program to compute the response from each feed
- Use an optimization program (or conjugate phase matching) to compute the combined pattern that gives the maximum gain



Limitations and approximations in the analysis

- The main reflector surface shape is not exactly known
- Asymmetric shape of subreflector not modeled
- Tilt angle of ellipse (off focal plane) not modeled for the DFP
- Struts not modeled

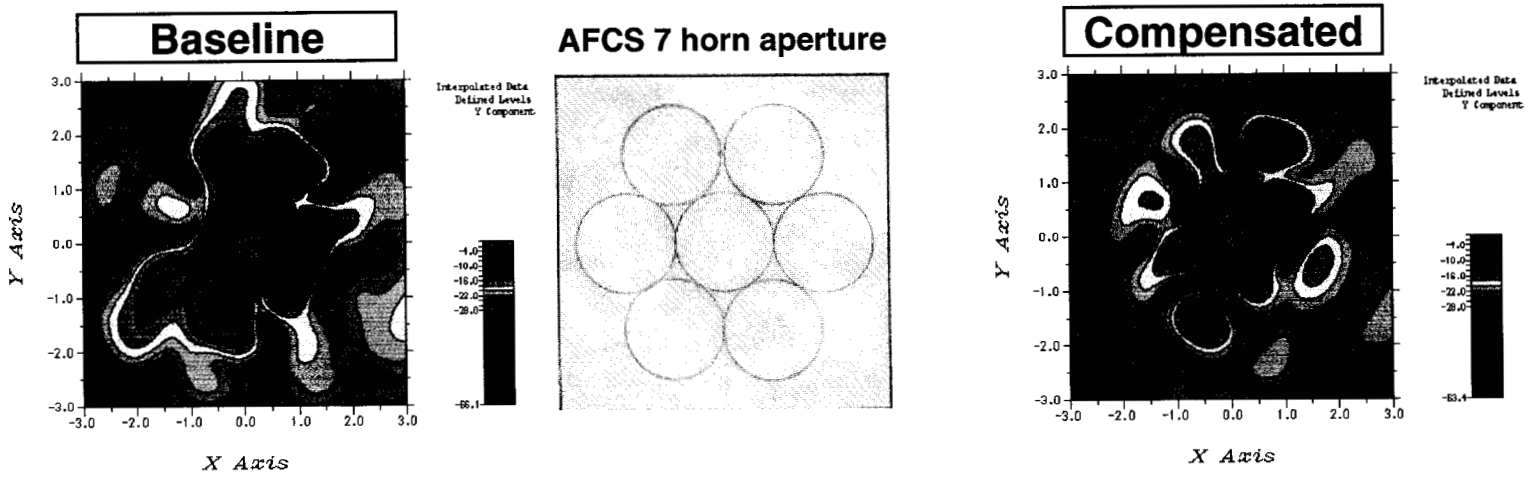


Focal Plane Fields

- The response of the antenna is a correlation of the focal plane fields created with an incident plane wave and the aperture fields of the primary horn
- The correlation gives the gain in the direction of the incident plane wave

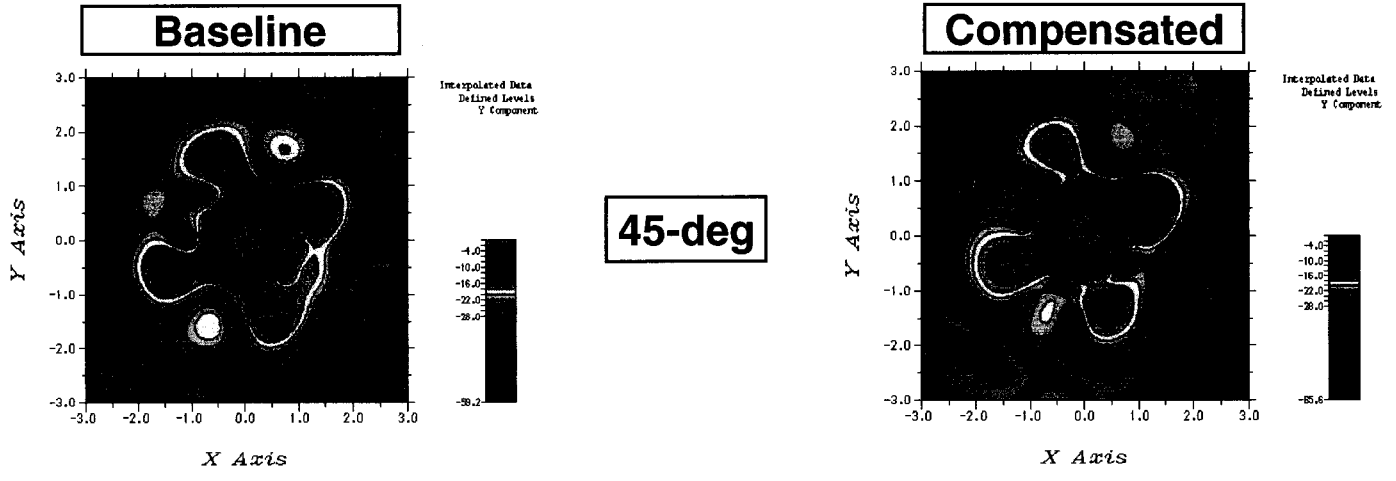
Analytical Computations of Predicted Performances

- Developed analytical computational tools to analyze all relevant parameters for both AFCS and DFP
  - Ported the Physical Optics (PO) code used to analyze the DFP and AFCS performance to a parallel computing environment using the Exemplar machine (HP / Convex SPP 2000).
  - Achieved 100X increase in computational speed in comparison with previous capability using a single PC (200 MHz Pentium).

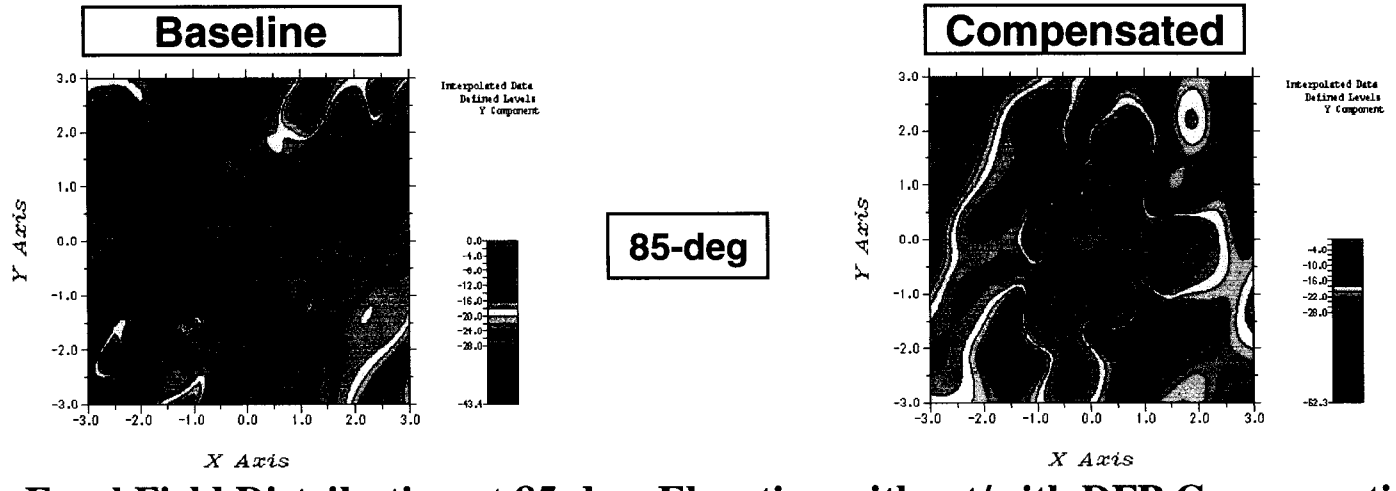


Computed Focal Field Distribution at 15-deg. Elevation without/with DFP Compensation using Holography data
NOTE: Increased Energy Concentration with DFP Compensation

Analytical Computations of Predicted Performances (Cont)



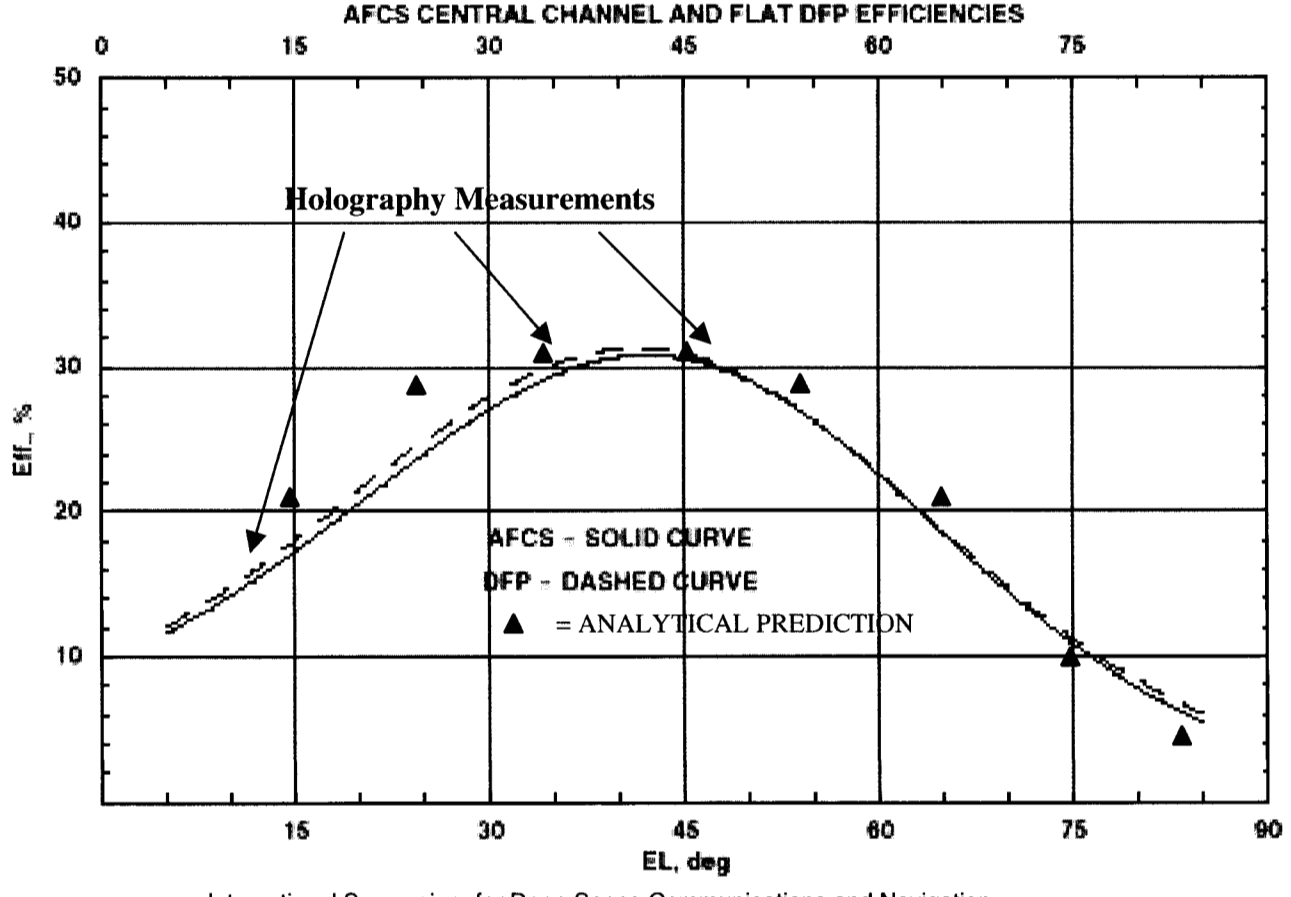
Focal Field Distribution at 45-deg. Elevation without/with DFP Compensation



Focal Field Distribution at 85-deg. Elevation without/with DFP Compensation

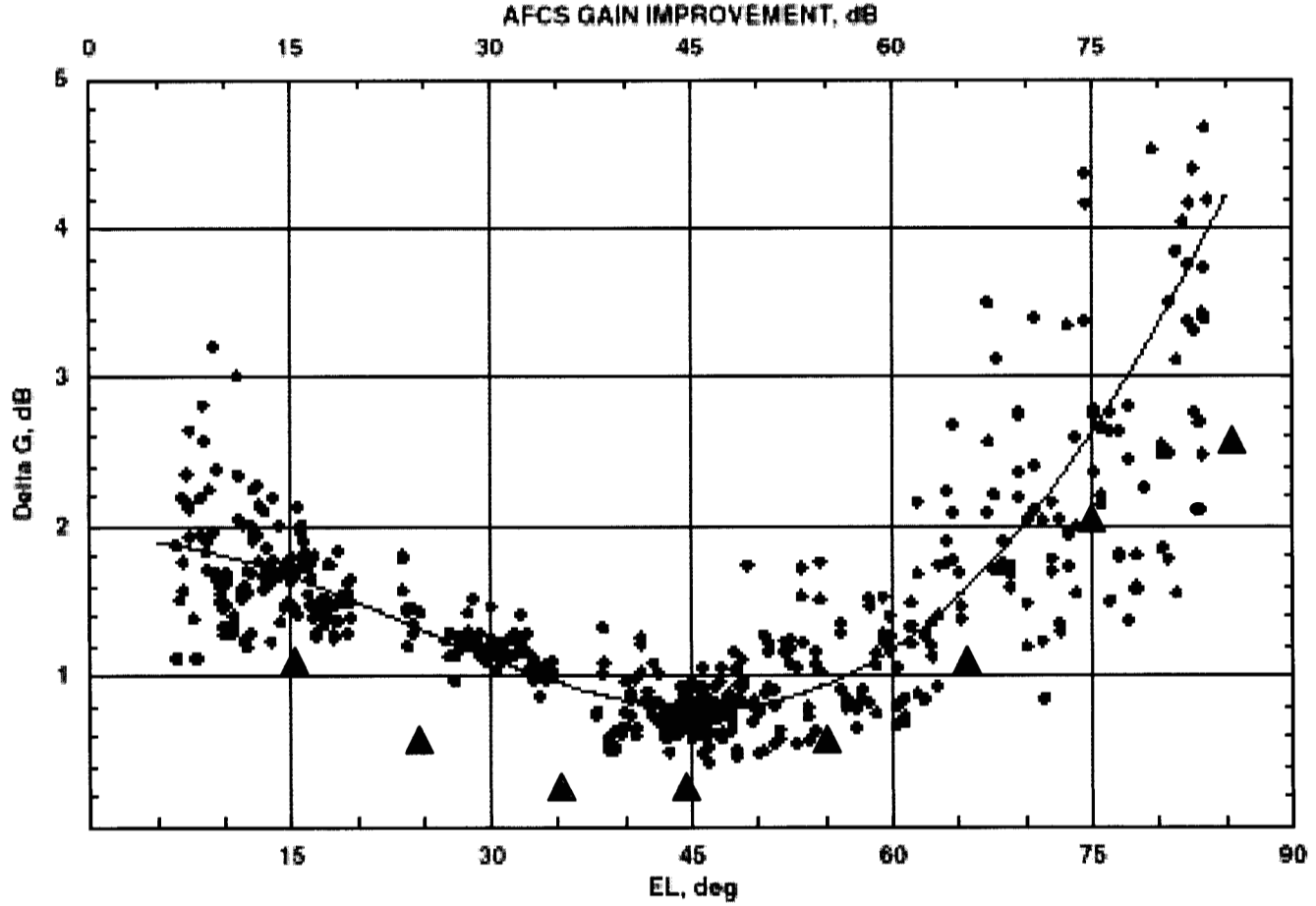
Analytical Computations of Predicted Performances (Con't)

Predicted and measured baseline performance of the 70-m antenna at Ka-Band



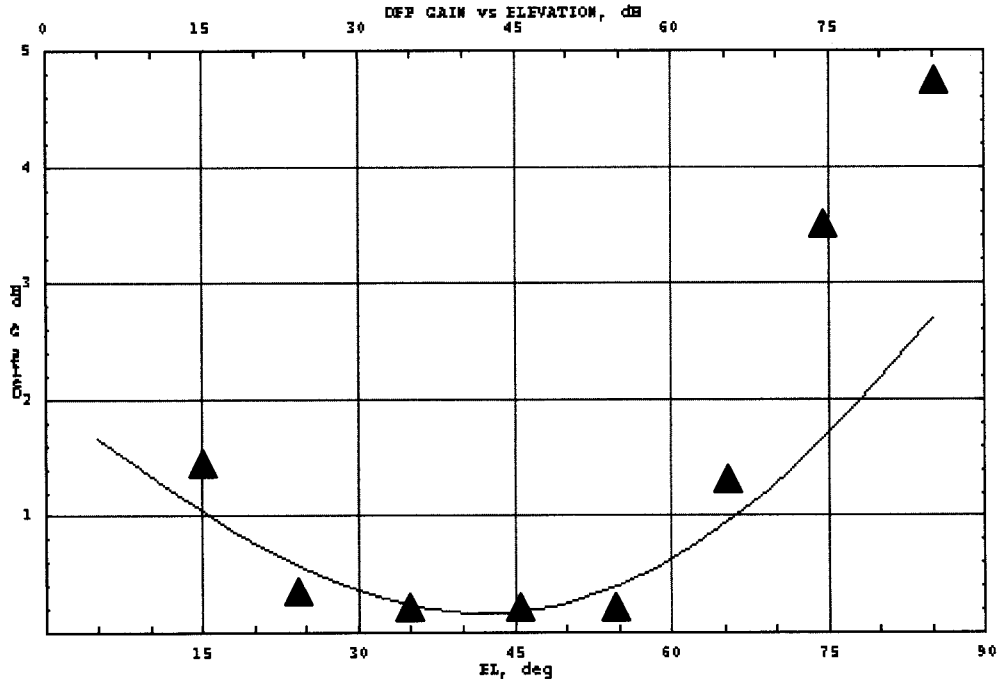
Analytical Computations of Predicted Performances (Con't)

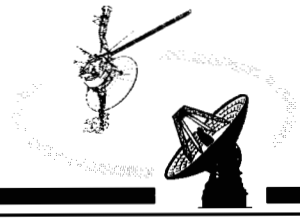
Predicted and measured AFCS compensation



Analytical Computations of Predicted Performances (Con't)

Predicted and measured DFP compensation





Statements

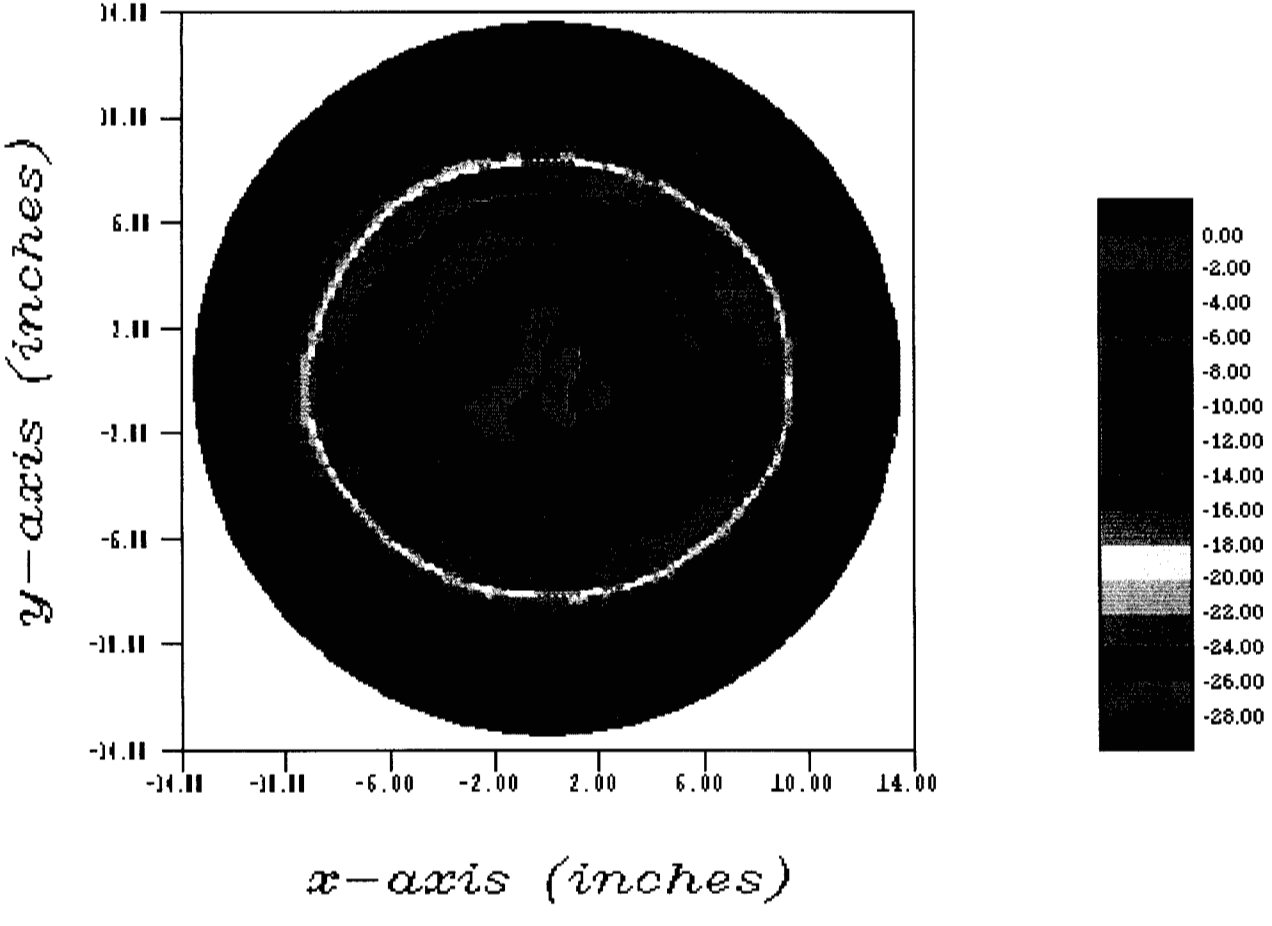
- The DFP requires an accurate description of the main reflector shape, the AFCS does not
- For the larger distortions, energy spills past the AFCS but not past the DFP
- When using the DFP, the Monopulse null points in the direction of the main beam peak
- The DFP readjusts the beam to put the peak on the mechanical boresite
  - The AFCS alone does not, but the combination DFP/AFCS does
- The current analytical model used for the main reflector shape does not contain all the distortion

Statements, Cont.

- Either system provides partial distortion compensation
- For 7 elements, the design of the current array feed is close to optimum
- Neither the number nor the placement of the DFP actuators was optimized for the 70-m antenna
- Neither the DFP nor the AFCS corrects for small errors in subreflector offset
- The combined AFCS/DFP system both analytically and experimentally does an excellent job of distortion compensation

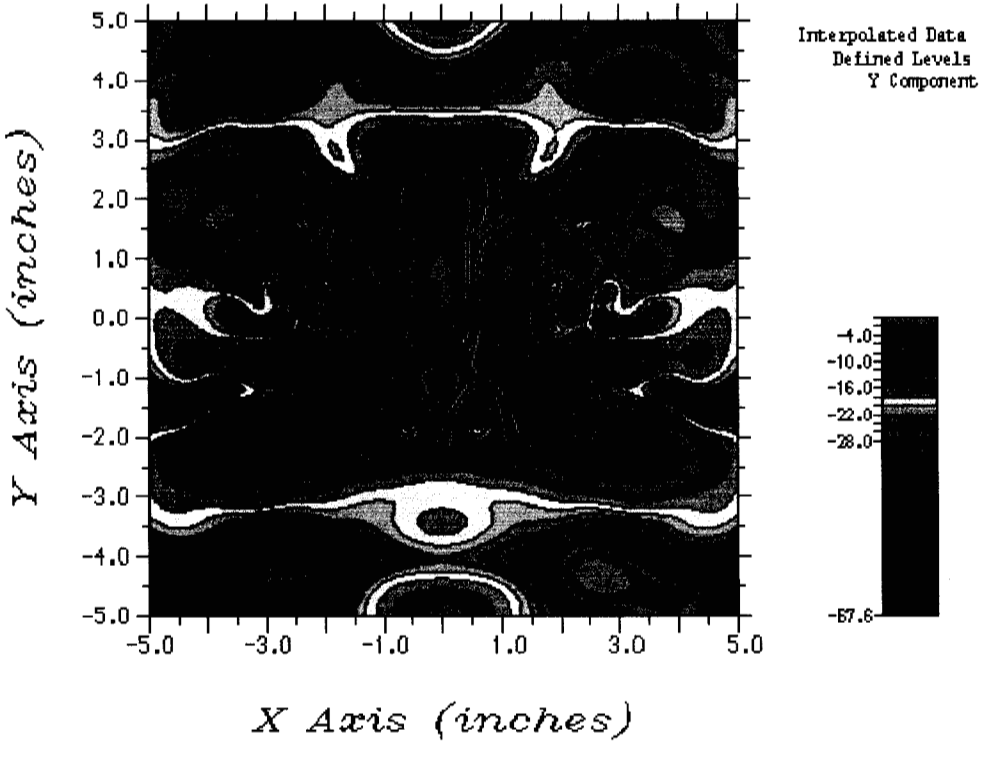
Focal Plane mode - Currents on DFP - 15° elevation

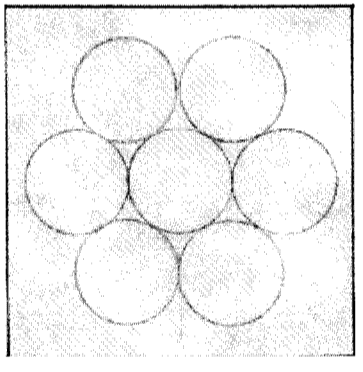
Current distribution



For large distortions energy spills past the 7 element AFCS

Focal PLane Elevation = 85 degrees

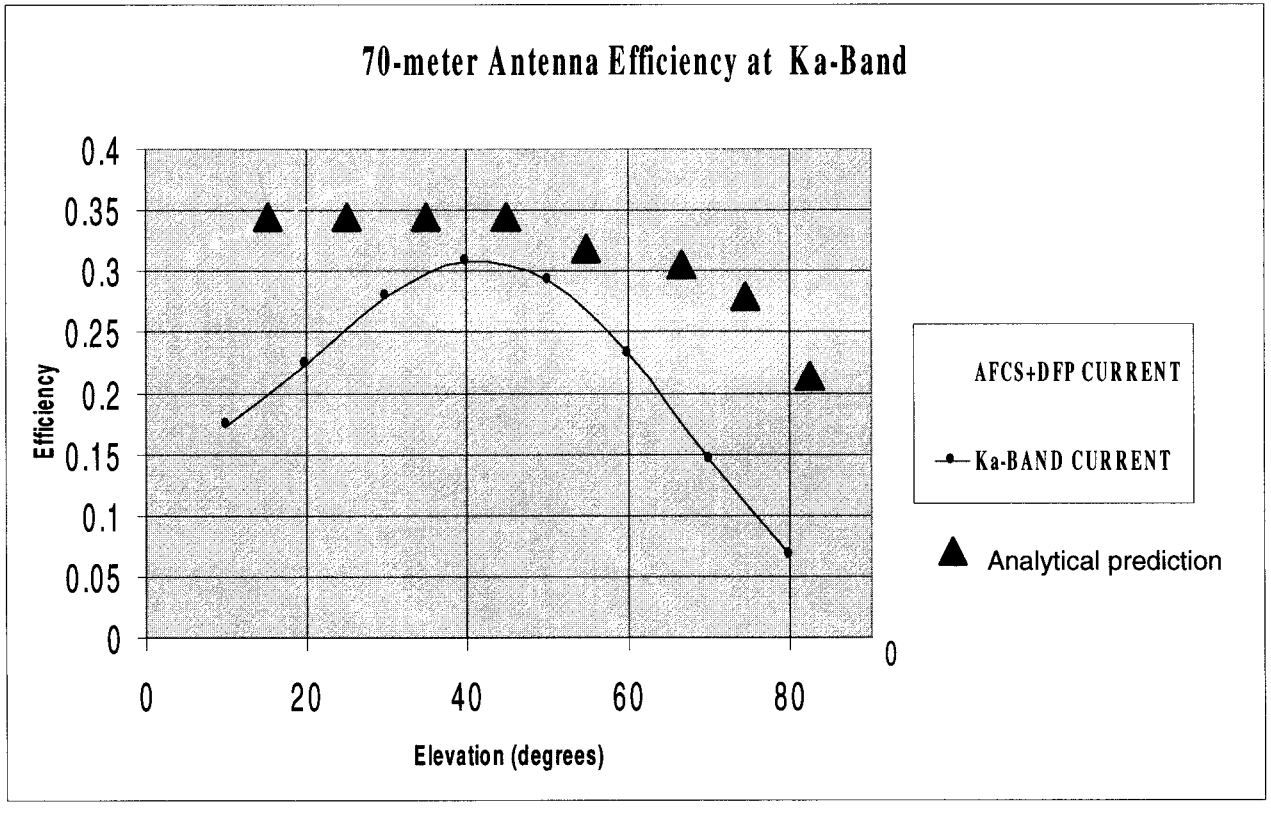


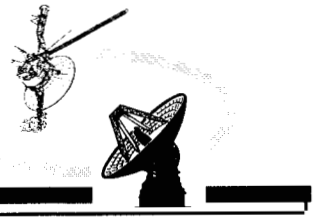


AFCS to scale

Antenna Systems

Ka-Band DFP/AFCS Demo on the 70-M





Conclusions

- Successfully demonstrated proof of concept for compensation and tracking on the DSS-14, 70-meter antenna at Ka-Band although neither systems was optimized
- The current performance of the 70-meter antenna at Ka-Band was precisely characterized
- Each candidate system demonstrated significant gravity compensation over all elevation angles
- The combined performance of the AFCS + DFP showed significant improvement relative to the performance of each individual system with nearly complete recovery at low elevation angles
- Demonstrated closed loop tracking of DS-1 Ka-Band carrier of both Monopulse and AFCS although performance was not fully characterized
- Analytical tools predictions in reasonable agreement with measurement results
- The predicted Ka-Band future performance of the 70-meter antenna here is 0.5-dB higher from the road map and can provide 10-dB gain above X-Band