N94-15578

ANALYSIS OF TOPEX LASER RETROREFLECTOR ARRAY CHARACTERISTICS

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Abstract:

The joint U.S./French TOPEX/POSEIDON mission was successfully launched on August 10, 1992 for the study of ocean height variation using microwave altimetry. Accurate determination of the satellite orbit is paramount to the determination of the above phenomenon. To accomplish this, using laser ranging, the satellite is equipped with a laser retroreflector array (LRA) around the altimeter antennae. The goal of laser ranging is to obtain precision orbits with a radial accuracy of 13 cm to the Center of Mass of the Satellite. This requires the laser range correction to the LRA reference be known at the sub-cm level and is quite a challenge considering the geometry of the LRA. Detailed studies were initiated by the TOPEX project office (Christensen) under the auspices of the CDP/DOSE project (Degnan) at Goddard Space Flight Center.

The studies included the following:

(1) Theoretical Modelling of the LRA using FFDP data and computation of Centroid tables: P. Minott/GSFC; D. Arnold/SAO

(2) Experimental measurement of the LRA trays using CW techniques: P. Minott/GSFC; Carl Gliniak/EER

(3) Pulsed experimental measurement and modelling: T. Varghese/Bendix

(4) Range Correction tables for Global SLR Tracking Configurations: T. Varghese/Bendix

(5) Data Compression using Fourier Analysis and Satellite Range Correction: A. Marshall/GSFC

This paper provides an overview of items (3) and (4).

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TOPEX LRA OPTICAL CHARACTERIZATION

- **LIDAR CROSS SECTION:** To determine optical link and therefore the photo electron yield for various tracking strategies, detection configurations.
- **TARGET SPREAD FUNCTION:** To study impact on ground ranging hardware configurations, calibration corrections, etc.
- **RANGE CORRECTION:** To deduce the range correction to determine the satellite range to LRA reference center.

LASER RANGING CORRECTIONS FOR TOPEX POD

DETERMINATION OF RANGE TO CENTER OF MASS INVOLVES THE FOLLOWING:

- Range from the station to LRA 'reflection plane'.
- Correction of the reflection plane to the LRA reference center.
- Co-ordinate transformation from LRA reference center to space-craft body-fixed coordinate system origin.
- Center of mass position co-ordinates with respect to the body fixed co-ordinate system origin.

LASER RANGING CORRECTIONS FOR TOPEX POD

FACTORS AFFECTING LASER RANGING CORRECTION

- Satellite elevation angle with respect to the ranging station
- Satellite velocity normal to the line of sight and therefore the location within the FFDP.
- Ranging hardware configuration

  a) Laser wavelength and pulsewidth
  b) Type of detection (peak, leading edge, centroid, CFD)
  c) Detector bandwidth and skew
  d) Detection threshold (spe, mpe, low/high threshold)

Very accurate determination of each of these parameters is required to obtain a laser ranging correction to 0.5 cm (1 sigma).

TOPEX CHARACTERISTICS PERTINENT TO LASER RANGING

- Circular orbit of 1336 km
  - Maximum Range ~ 2700 KM (20° Elevation)
  - Minimum Range ~ 1336 KM (90° Elevation)
- Range of velocity aberration 28-48μr
- Nadir pointing LRA - orientation of the array changes as a function of elevation angle
- LRA consist of 192 hexagonal cubes in a conical ring configuration with 128 cubes in the lower row and 64 cubes in the upper row. There are 16 trays each with 12 cubes
- Lower row diameter - 826.3mm
- Upper row diameter - 852.9mm
- Height of lower row from reference center - 88.6mm
- Height of upper row from reference center - 66.3mm
- Center of mass is away from the LRA reference center by a known distance and varies as a function of expended fuel

TOPEX CUBE CHARACTERISTICS

- **EACH HEXAGONAL CUBE HAS THE FOLLOWING FEATURES:**
  - Material - Corning fused silica #7958
  - Aperture - 38mm
  - Depth - 27.25mm
  - Dihedral Offset - 1.75 $\pm$ 0.25 arc sec
  - Refractive Index - 1.4606
  - Antireflection coating (Mg F2) for the entrance face
  - Protected silver coating for all other sides; total transmission 82%

PULSED LASER MEASUREMENT

- **OBJECTIVE: MEASURE FFDP IN THE ANNUAL REGION USING LINEARLY POLARIZED 60ps LASER PULSES AT 532 nm**
- **MEASUREMENT TECHNIQUES:**
  - Range measurements using portable standard similar to LAGEOS-2
  - Temporal mapping using:
    - (a) High speed photodiode (<10ps rise time) and a 4.5 GHz Oscilloscope
    - (b) MCP-PMT and 4.5 GHz Oscilloscope
  - Spatial intensity mapping using a CCD Camera and a Frame Grabber
- **MEASUREMENT CONFIGURATION:**
  - Single trays and individual cubes
- **ORIENTATIONS:**
  - Elevation from 0° to 40° in steps of 20°
  - Azimuth from 0° to 45° in steps of 11.25°

The elevation and azimuth here refer strictly to the laboratory setup for mounting the tray

TARGET SPREAD FUNCTION

- Although the leading edge is fairly sharp, the trailing edge is skewed and very long.
- The pulse shape is a function of elevation angle, and the position in the FFDP annulus.
- The presence of two rows of cubes arranged in the form of a conic section produces a skewed return pulse; for the leading edge the skew diminishes monotonically until the elevation reaches 40° at which time the trailing edge picks up the contribution from the upper row of cubes.
- Simulations show that if the predicted contribution from each cube is altered by a process such as thermal gradient, the resulting pulse can have significantly different temporal characteristics.
- The temporal envelope of the pulse affects the range accuracy.

SUMMARY

- Optical characterization of the LRA has been completed and a model has been established to derive the LRA optical parameters such as a Lidar Cross Section, target spread function and range correction to the LRA reference center.
- Range correction is profoundly impacted by type of detection. It is also a function of the input pulse width and the number of photo electrons used for signal definition.
- Since the range varies considerably (3-6cm) within the FFDP, the range correction has to be applied to the satellite data with the knowledge of the satellite velocity and orientation.
- Current efforts to incorporate velocity aberration and ranging instrumentation features into the data correction algorithms should provide data accuracy better than 1 cm.

Acknowledgements

The author acknowledges his deep appreciation to the following colleagues for technical assistance during the course of this project. In strictly alphabetical order, they are Steve Bucey, Christopher Clarke, Brion Conklin, Tony Mann, Tom Oldham, and Mike Selden. He is also indebted to John Degnan for various technical discussions and P. Minott for providing the far field diffraction data of the individual cubes for various orientation of the LRA.

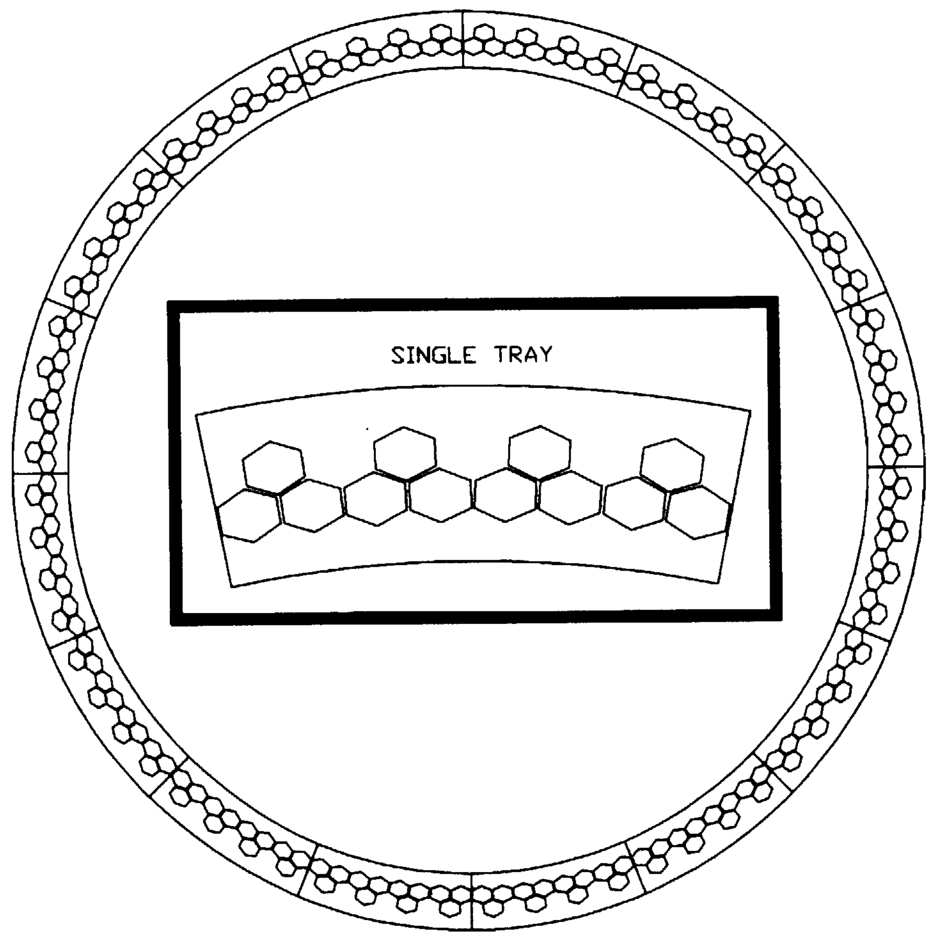


Fig. 1 ILLUSTRATION OF TOPEX LRA AND SINGLE TRAY.

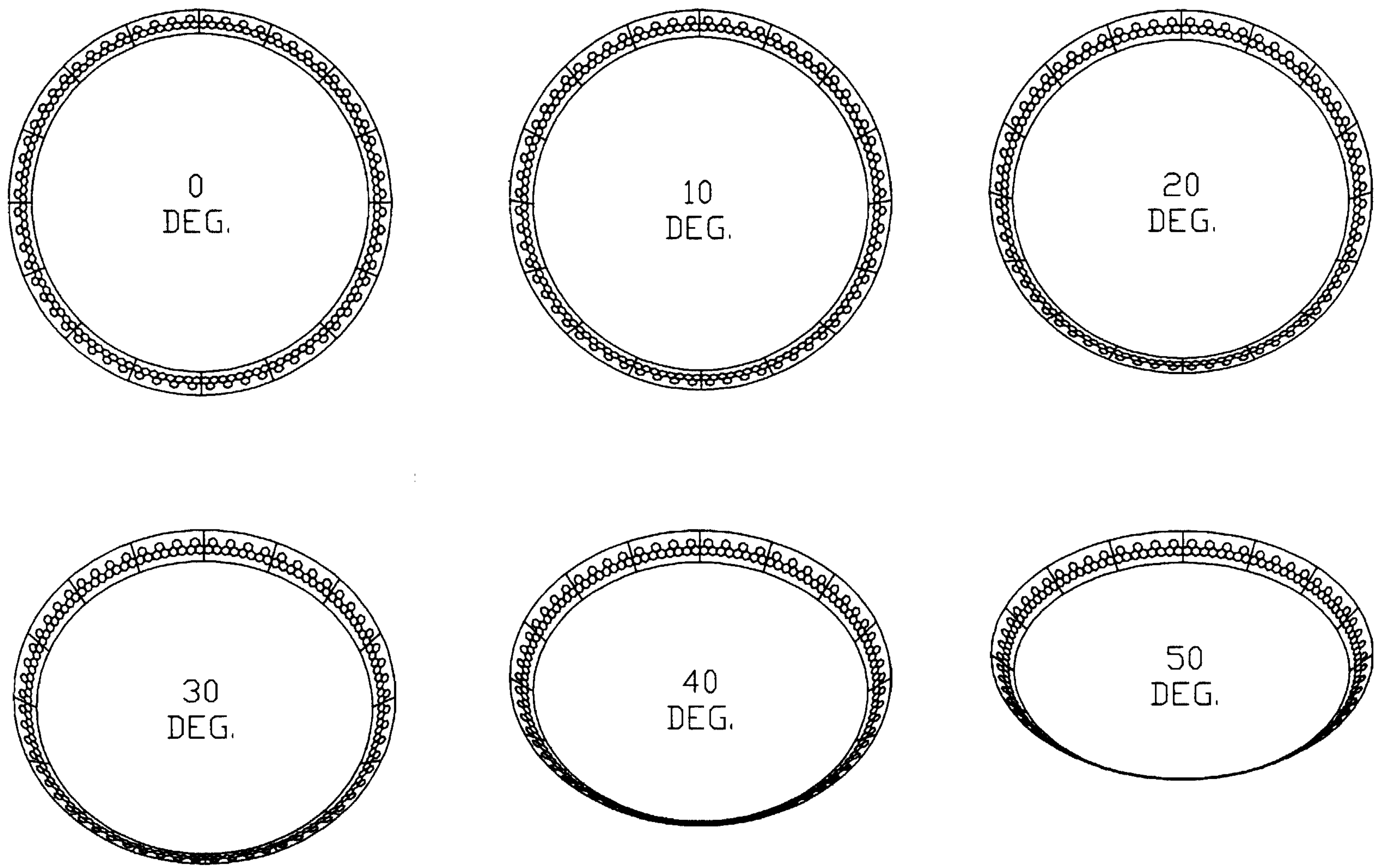
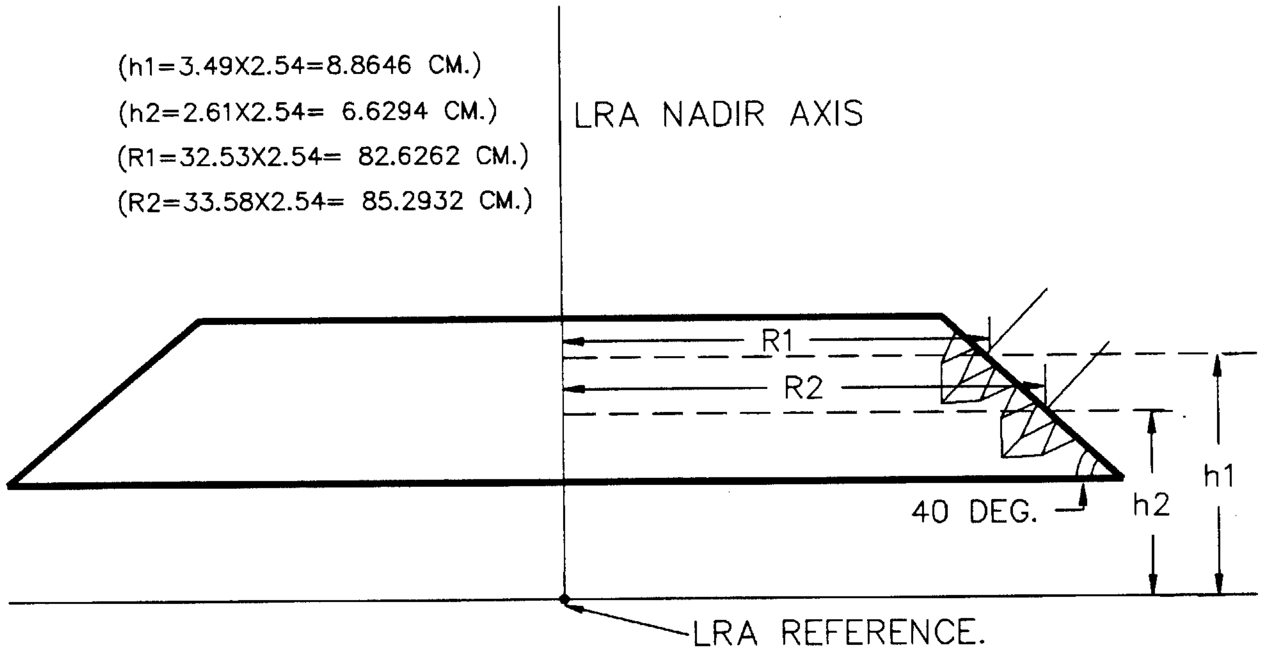


Fig. 2 LRA ORIENTATION AS A FUNCTION OF NADIR ANGLE.



h1=HEIGHT FROM THE CENTER OF THE FRONT FACE OF THE CUBE (LOWER RING; 128 CUBES) TO THE LRA REFERENCE PLANE.

h2=HEIGHT FROM THE CENTER OF THE FRONT FACE OF THE CUBE (UPPER RING; 64 CUBES) TO THE LRA REFERENCE PLANE.

R1=RADIUS (TO THE FRONT FACE OF THE CUBE) OF THE LOWER RING.

R2=RADIUS (TO THE FRONT FACE OF THE CUBE) OF THE UPPER RING.

Fig. 3 TOPEX LRA REFERENCE COORIDINATE SYSTEM.

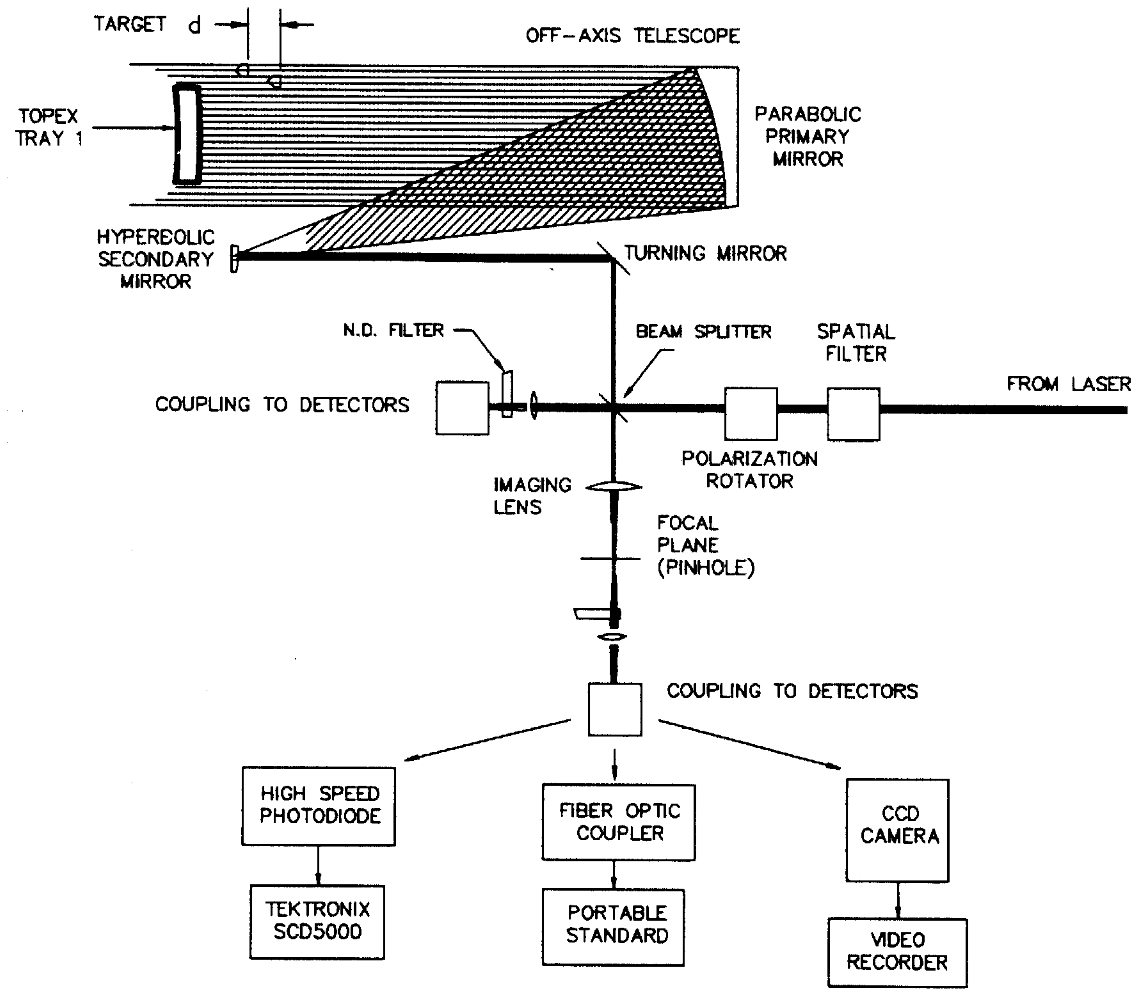


Fig. 4 OPTICAL SCEMATIC FOR TOPEX TRAY MEASUREMENT

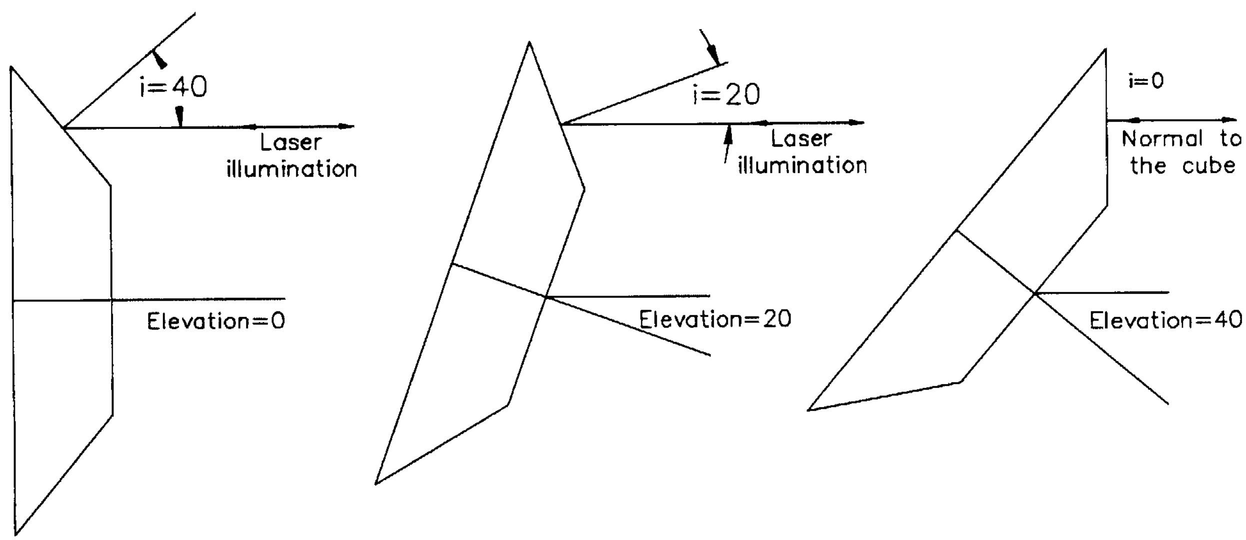


Fig. 5 LABORATORY MEASUEMENTS FOR ORIENTATIONS OF THE TOPEX TRAYS.

T/P LRA RANGE CORRECTION (RC): CFD=1250ps

INCIDENCE ANGLE=20.0; RC MIN=285.3mm; RC MAX=310.6mm

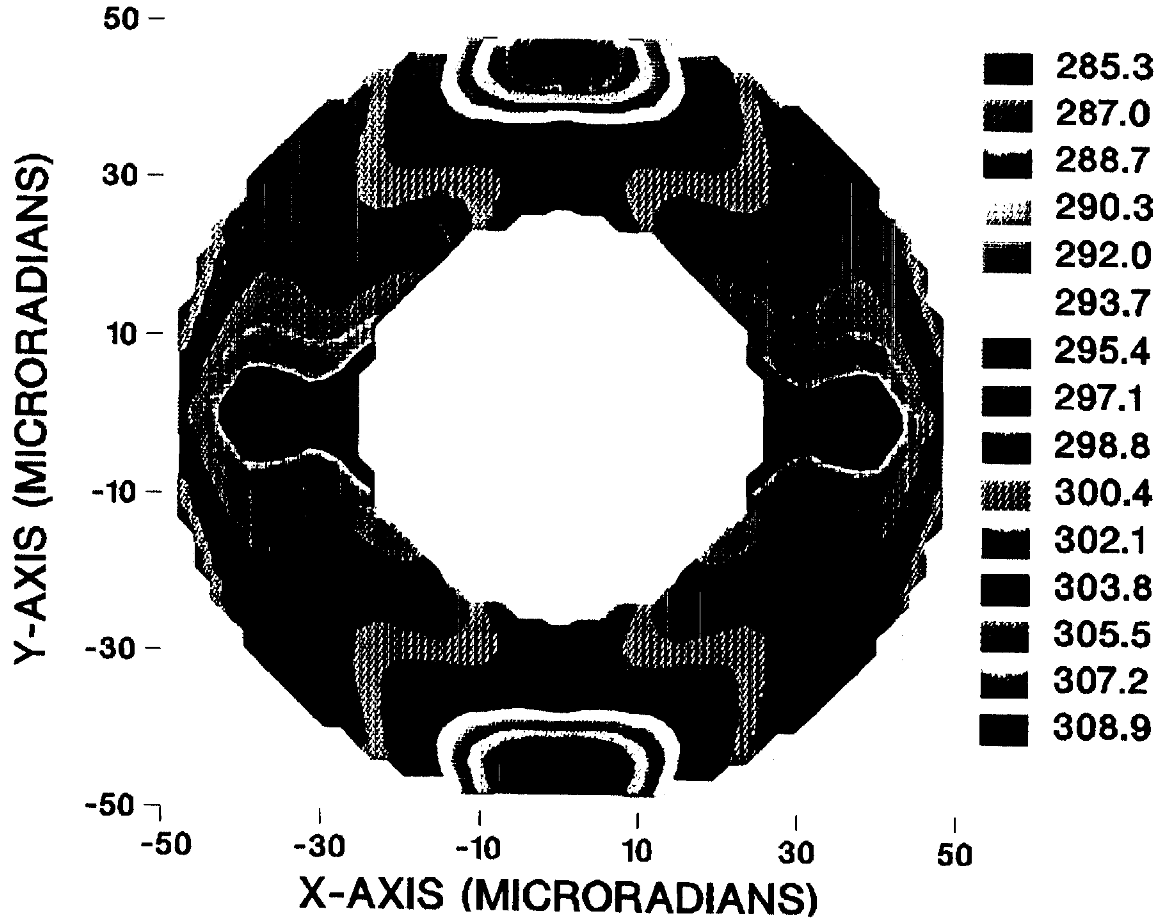


ILLUSTRATION OF THE TOPEX/POSSEIDON LRA RANGE CORRECTION FOR AN INCIDENCE ANGLE (ANGLE BETWEEN LASER LINE OF SIGHT AND NADIR) OF 20 DEGREES FOR CONSTANT FRACTION DISCRIMINATOR BASED SYSTEM. THE RANGE CORRECTION PLOTTED AS A FUNCTION OF THE VELOCITY ABERRATION SPACE SHOWS A COMPLEX PATTERN WITH A MINIMUM VALUE OF 285 MM AND MAXIMUM VALUE OF 311MM.