APPLICATION OF PUSHBROOM ALTIMETRY FROM SPACE USING LARGE SPACE ANTENNAS

C. L. Parsons and J. T. McGoogan
NASA Goddard Space Flight Center
Wallops Island, VA 23337

and

F. B. Beck
NASA Langley Research Center
Hampton, VA 23665

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OCEAN DYNAMICS FEATURES

The Earth's oceans are now known to contain dynamical features, such as currents and eddies, which have a direct correspondence to atmospheric features. Eddies and the meanderings of the major currents are mesoscale fluctuations which have analogues in the cyclones, anticyclones and fronts of our weather. Hence, it is important to develop the means to monitor their development, movement, and dissipation if we are to understand the dynamics of the oceans. One technique is to use passive infrared radiometry to map the sea surface temperature variations resulting from ocean dynamics. Figure 1 shows such an image produced by the Advanced Very High Resolution Radiometer (AVHRR); it contains the Gulf Stream flowing across the bottom of the scene and a prominent warm core ring above it.

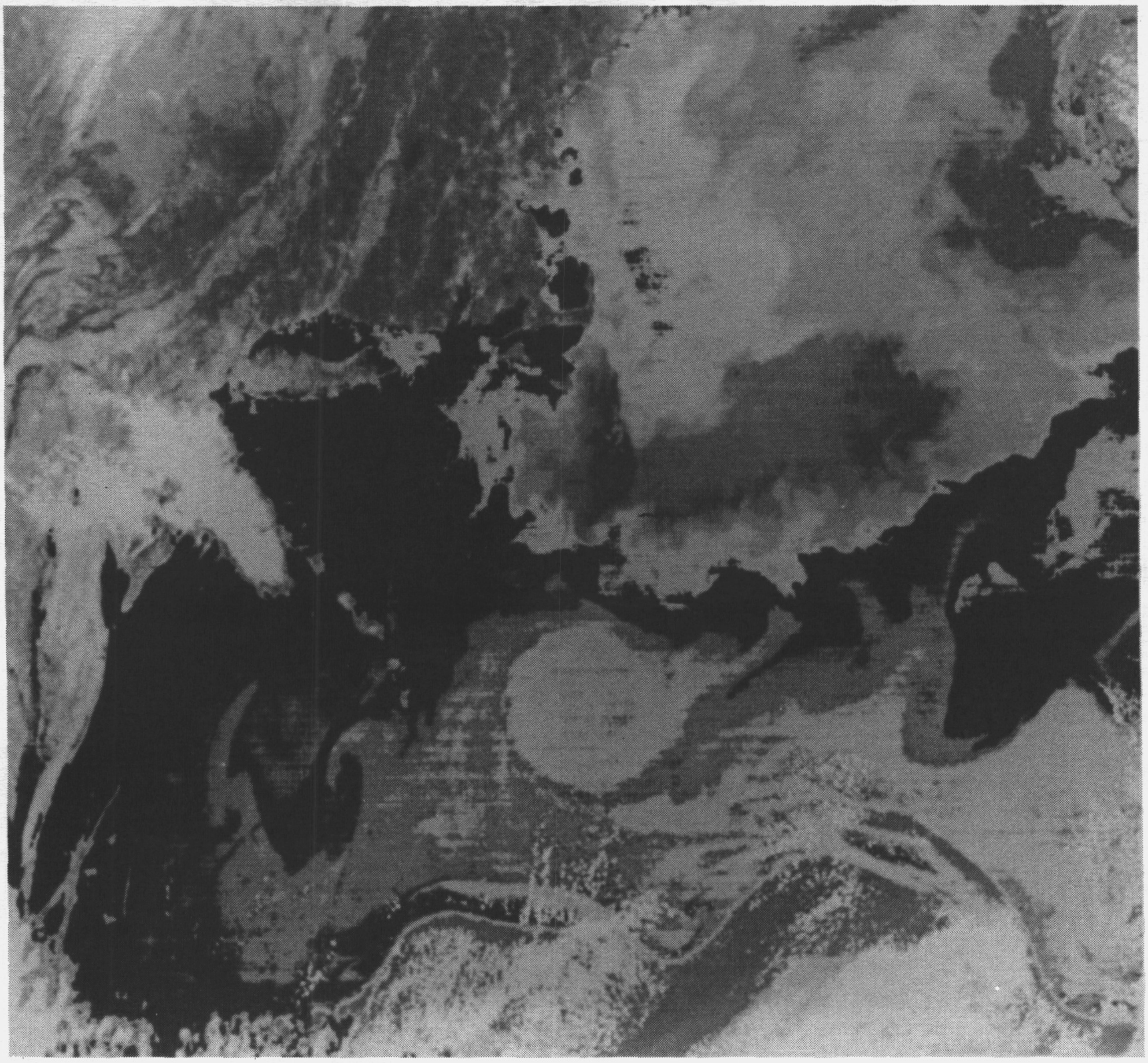


Figure 1

CONVENTIONAL ALTIMETRIC SIGNATURE OF THE GULF STREAM

In addition to sea surface temperature, the ocean can be monitored using the visible wavelengths (as in the case of the Coastal Zone Color Scanner) or microwaves. Active microwave instruments offer the potential of all-weather monitoring because they are unaffected by the atmosphere. The GEOS-3 radar altimeter produced the topographic record shown in Figure 2 as it traversed the Gulf Stream. Because this current is nearly geostrophic, the one-meter dynamic height differential between its eastern and western walls could be related directly to current velocity if the orientation of the satellite's groundtrack with respect to the current's flow axis was known. With conventional nadir-tracking altimeters such as SKYLAB, GEOS-3, and SEASAT this information is not available.

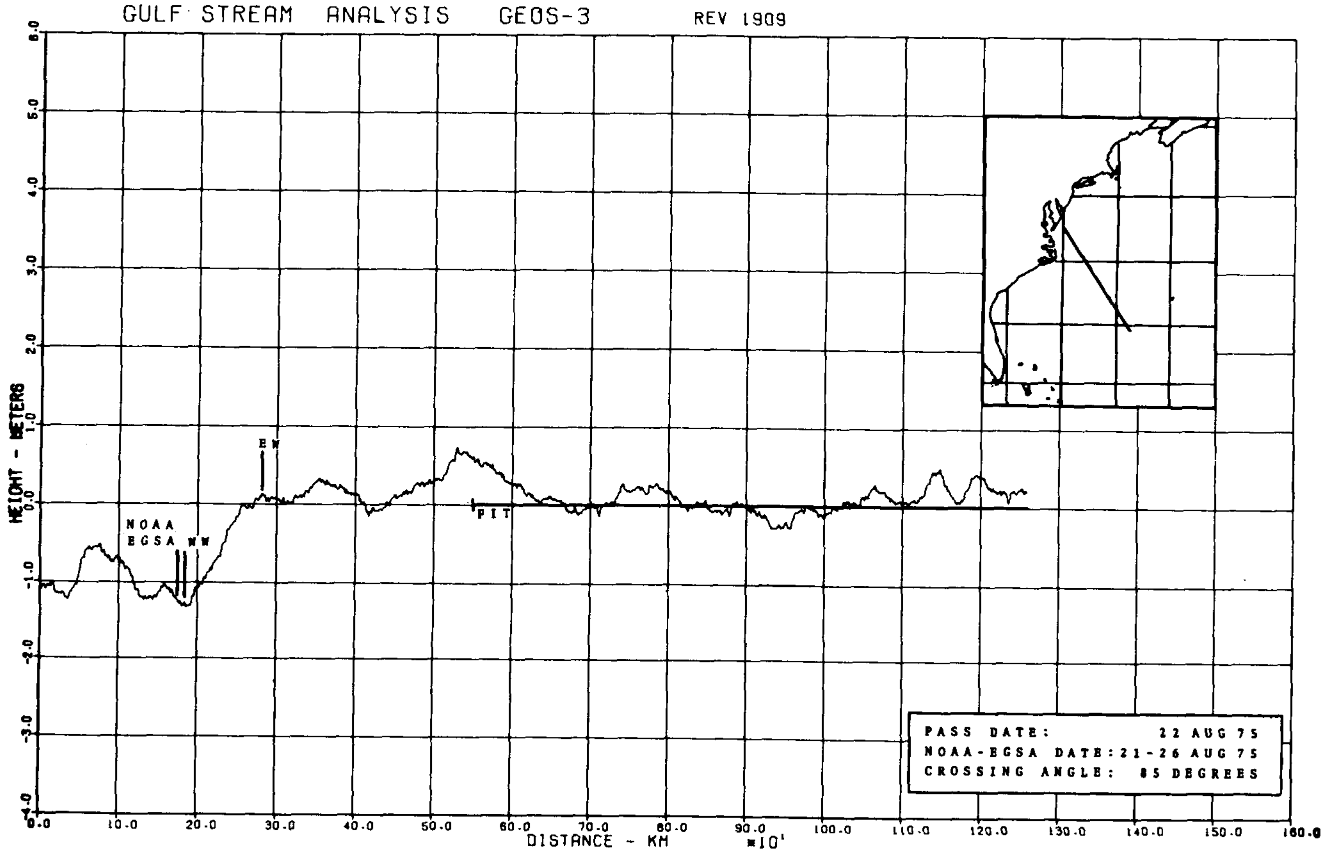


Figure 2

CAPABILITIES OF MULTIBEAM ALTIMETRY

The top of Figure 3 shows the results of a simple simulation of a five-beam altimeter raking across an eddy which has a radius of 30 km and a maximum height signature of 45 cm. The interbeam spacing at the ground is 10 km. The altimeter is assumed to have a height resolution of only 10 cm; still, the shape of the eddy is clearly detected. Using a numerical differentiation formula, these measured topographic heights can easily be used to compute velocity.

The bottom of Figure 3 shows the computed velocity pattern. A clear maximum velocity is seen at a distance of 10 km from the eddy center. This is exactly the pattern that should be observed based on the eddy model used in the simulation. By using a numerical computation of the Laplacian of the height field, the circulation of the eddy can be calculated. This "curvature" measurement is independent of the attitude of the sensor. These results are not dependent on highly sophisticated advancements in technology but only on the addition of off-nadir beams, which seems to be within reach based upon NASA Langley's 15-m antenna progress.

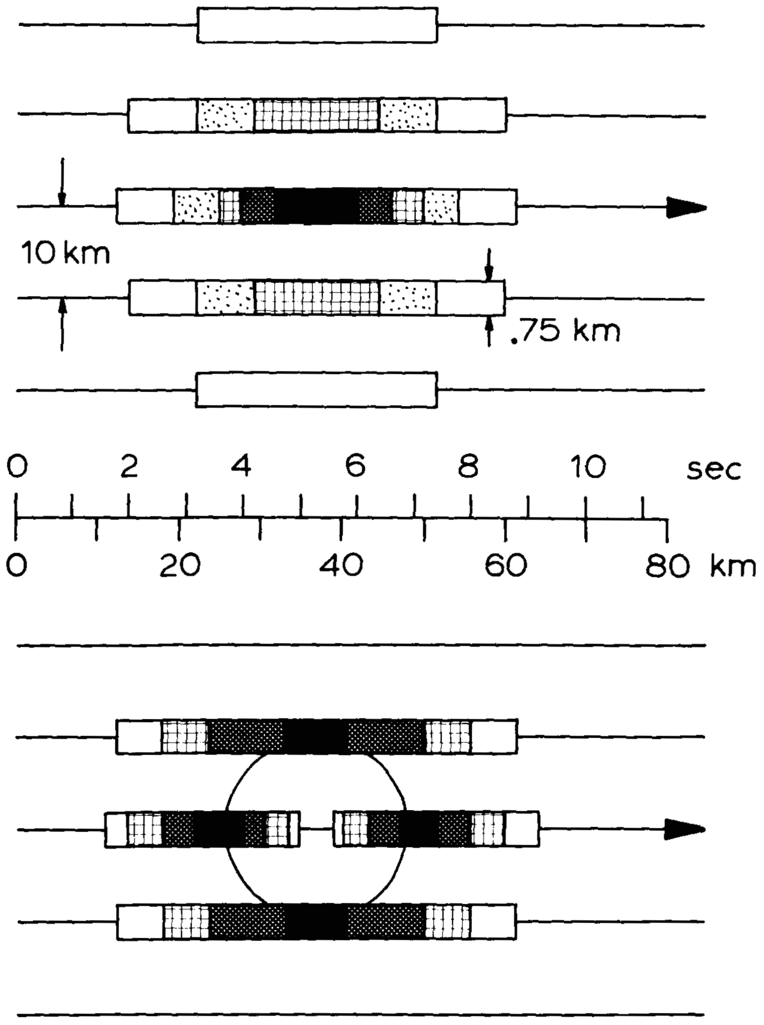


Figure 3

INTERFEROMETRIC MULTIBEAM TECHNIQUE

To do precision altimetry, a range tracker needs a sharp waveform returned from the ocean surface. Off-nadir, the waveform tends to smear and stretch. Therefore, either a large real aperture system is needed to narrow the beamwidth and hence the duration of the returned waveform, or an interferometric technique schematically shown in Figure 4 can be used. Two antenna dishes of diameter d and separated by distance D are fed from the same rf source to produce multi-lobed beams where the lobe width is set by D and the overall envelope is a function of d. In this example, each antenna has two offset feeds so that two off-nadir beams are simultaneously generated. The signal returned will show a multi-peaked response as a result of the interferometer lobe intersections on the surface.

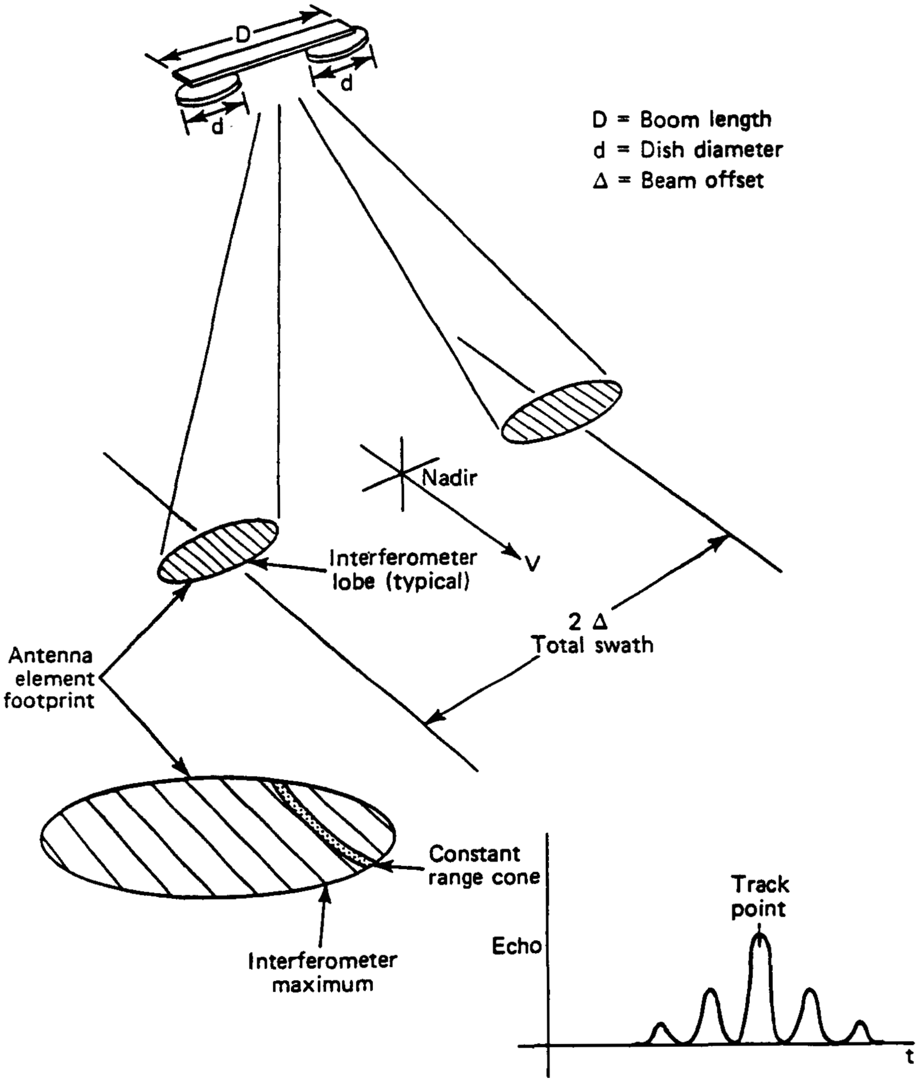


Figure 4

USE OF THE 15-METER HOOP/COLUMN ANTENNA

A cooperative study with Langley Research Center personnel has been conducted to determine the suitability of the 15-m hoop/column antenna for multibeam altimetry. Figure 5 shows an artist's view of its deployment on Shuttle. The antenna has the feature that its surface can be used in quadrants with each quadrant separately illuminated by microwave feed horns located on plates mounted to the center post. This is ideally suited for interferometry. By placing five feed horns on each of the two plates associated with opposite quadrants of the 15-m antenna, orienting them properly, and illuminating approximately 3-m-diameter spots within the two quadrants, it is possible to produce beam footprints centered at nadir ± 1.5°, and ± 3.0° off-nadir.

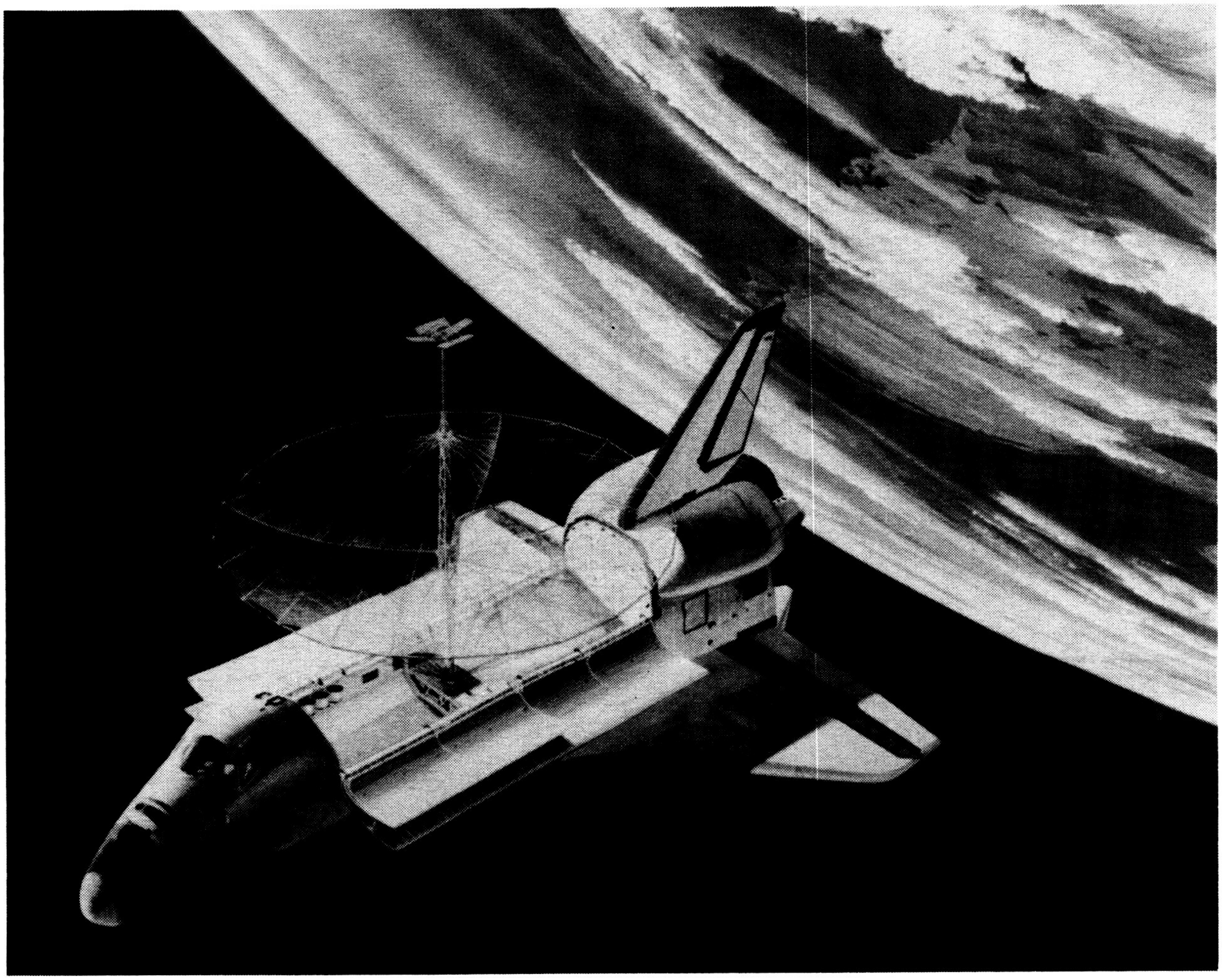
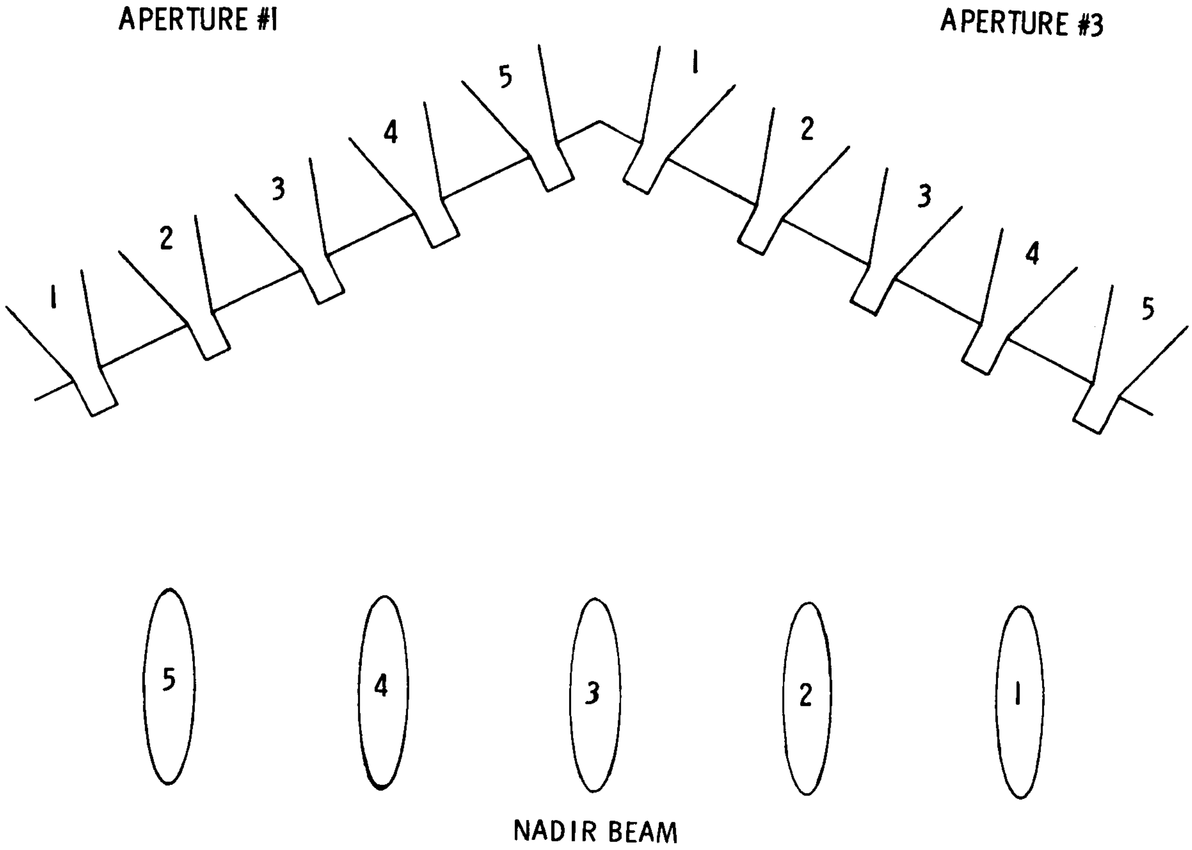


Figure 5

FEED HORN ARRANGEMENT

The arrangement of the five pairs of feed horns on the mounting plates is shown in Figure 6. This produces five footprints each of which contains 20 interference lobes.



FEED PANELS WITH ACROSS-TRACK BEAM FOOTPRINTS

Figure 6

MULTIBEAM ALTIMETER FOOTPRINT LOBE PATTERN

The envelope of the antenna pattern resulting for the -1.5° angle footprint is shown in Figure 7. The lobe structure resulting from the interference between the appropriate pair of feed horns trained on this footprint is contained within the envelope. For this antenna configuration, the lobe angular spacing is .146°, which is equivalent to a real-aperture dish diameter of 8.65 m. The gain at the center lobe of each envelope is on the order of 52 dB, which is ample for real-aperture altimetry at Shuttle altitudes.

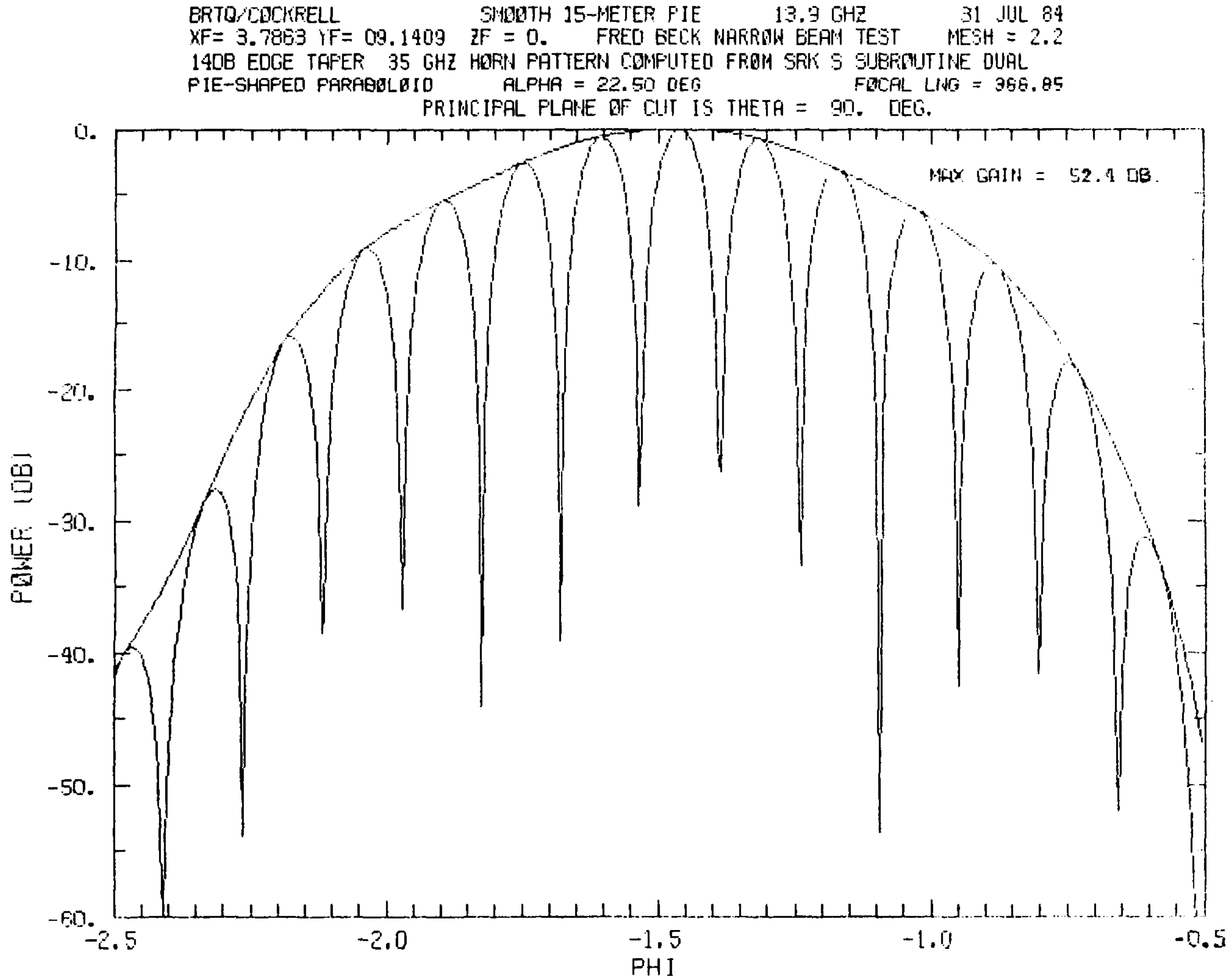


Figure 7

DATA PROCESSING TECHNIQUES

Because satellite attitude uncertainties directly translate into height measurement errors, it is crucial that pointing be known as precisely as possible. However, for a Shuttle multibeam altimetry mission that is concerned mainly with the monitoring of eddies and currents, advantage can be made of crossing arc analyses. Over a particular area of interest, an ascending orbit and a descending orbit produce 25 intersections for a 5-beam multibeam system (fig. 8). If the measured height differences at the 25 points are minimized, then the tilt will be effectively removed. For a Shuttle mission experiment incorporating a multibeam altimeter with the 15-m antenna there are no known impediments in the way of successfully measuring mesoscale ocean dynamic features for the first time.

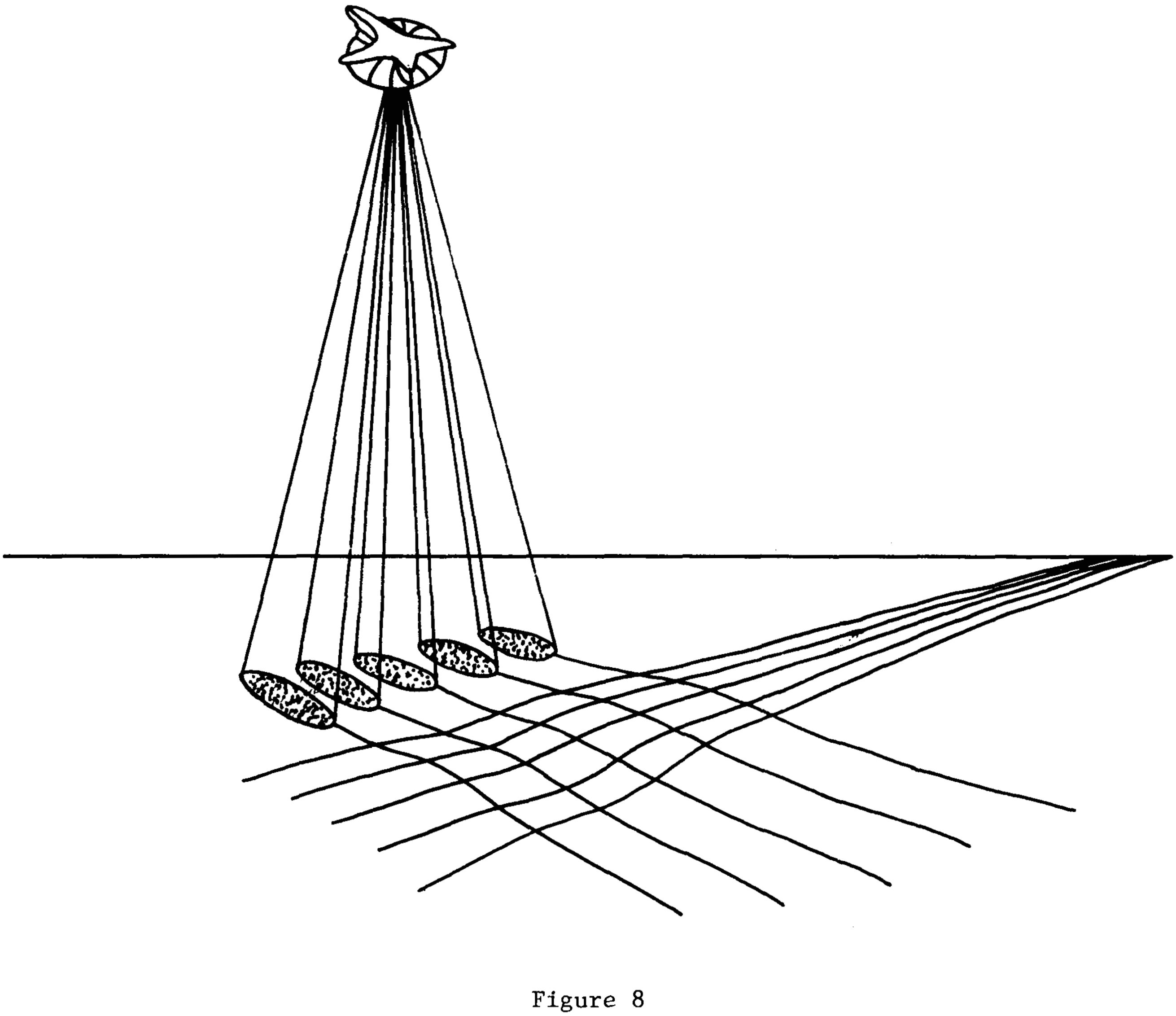


Figure 8