MAPPING FROM SHUTTLE IMAGING RADAR, SIR-B, EXPERIMENT

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ABSTRACT

The Shuttle Imaging Radar-B (SIR-B) experiment will acquire imagery at multiple incidence angles and provide digital image data. A particularly interesting area can be viewed from up to 6 different incidence angles ranging from 15° to 60°. This could obtain up to 15 different stereo-combinations. At a nominal altitude of 225 km and with an 86 km westward drift between orbits of the Shuttle, there will be 5 different combinations of base-to-height ratios from 0.38 to 1.91. By modifying the plotter software, stereomodels using SIR-B images are expected to be established on the AS11-AM analytical stereoplotter. Range resolutions of the SIR-B imagery vary from 17 m to 58 m. The azimuth resolution is 25 m. By pure photogrammetric analysis, standard errors of position measurements and elevation measurements are predicted to range from 12 m to 30 m and from 15 m to 76 m respectively, depending on the combination of different incidence angles. This indicates that National Map Accuracy Standards for maps of 1:125,000 to 1:50,000 scales can be achieved.

I. INTRODUCTION

The National Aeronautics and Space Administration (NASA) has scheduled to put the OSTA-3 experiment package on the seventeenth flight of the Shuttle Transportation System (STS-17) in August, 1984. OSTA-3 is a group of Earth observation experiments, conducted by NASA's Office of Space and Terrestrial Applications, in which the Shuttle Imaging Radar-B (SIR-B) experiment and the Large Format Camera (LFC) experiment are included. SIR-B is an experiment to continue exploring the utility of radar imaging techniques for Earth observations, i.e., to advance the current state-of-the-art of microwave remote sensing for Earth applications. It is also to explore the application of space techniques to more basic studies of the Earth's resources and its environment. SIR-B will have capabilities to digitally process the radar imagery. By mechanically tilting the antenna, a particularly interesting area can be viewed from up to 6 different incidence angles from 15° to 60°. Range resolution of SIR-B images varies from 58 m to 17 m for ranges from the near side to the far side (NASA, 1982). With all possible corrections of the radar geometry including the correction of the radar layover displacements, the SIR-B experiment may enable us to produce maps at scales of 1:125,000 to 1:50,000 which will meet the National Map Accuracy Standards. Mapping controls may be established by analytical aerotriangulation using photographs from the large format camera which is a simultaneous experiment with SIR-B in the OSTA-3 experiment on the STS-17 flight.

II. MISSION PARAMETERS AND IMAGE CHARACTERISTICS OF SIR-B EXPERIMENT

Like both Seasat and SIR-A, SIR-B will have an L-band, 23 cm wavelength synthetic aperture radar. As shown in Fig. 1, SIR-B will, for the first time, provide the ability to take multiple incidence angles at 15°, 24°, 33°, 42°, 51°, and 60° (NASA, 1982) with range resolutions of, respectively, 58.4 m, 37.1 m, 27.7 m, 22.5 m, 19.4 m, and 17.4 m. Azimuth resolution is 25 m. At a nominal altitude of 225 km and 86 km westward orbital drifts of the Shuttle, there will be 5 different combinations of

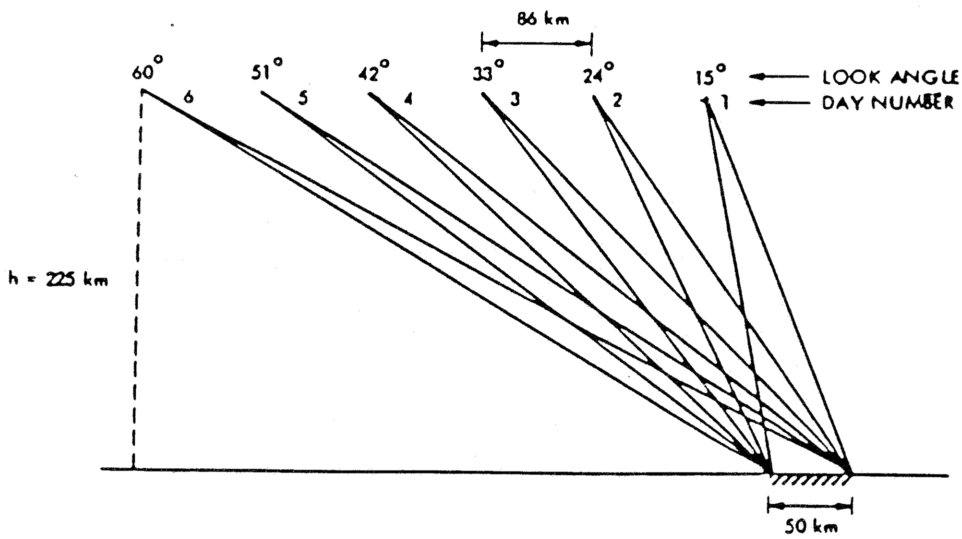

Fig. 1. Stereo configuration from multiple incidence-angle mode of SIR-B experiment.

base to height ratios (B/H). They are 0.38, 0.76, 1.15, 1.53, and 1.91 as listed in Table I. Nominal swath width ranges from 40 to 50 km. In addition to the stereo mode, SIR-B will acquire data in a mapping mode which is to continuously take images for large-scale mapping (NASA 1982). Mapping coverage is extensive from +57° to -57° of latitudes due to the 57° orbital inclination. Figure 2, for an example, is the flight-path coverage of STS-17 orbits 1 through 8.

TABLE I: Radar Stereo Parameters from SIR-B Data. Base-to-height ratios of various stereo combinations are at the upper-left half of the table, whereas lowest resolution in a stereo pair is at the lower-right half of the table. Resolutions are in meters.

INCIDENCE ANGLE		15°	24°	33°	42°	51°	60°
60°		1.91	1.53	1.15	0.76	0.38	
51°		1.53	1.15	0.76	0.38		25
42°	B/H	1.15	0.76	0.38		25	25
					Resolution(m)		
33°		0.76	0.38		27.7	27.7	27.7
24°		0.38		37.1	37.1	37.1	37.1
15°			58.4	58.4	58.4	58.4	58.4
INCIDENCE ANGLE		15°	24°	33°	42°	51°	60°

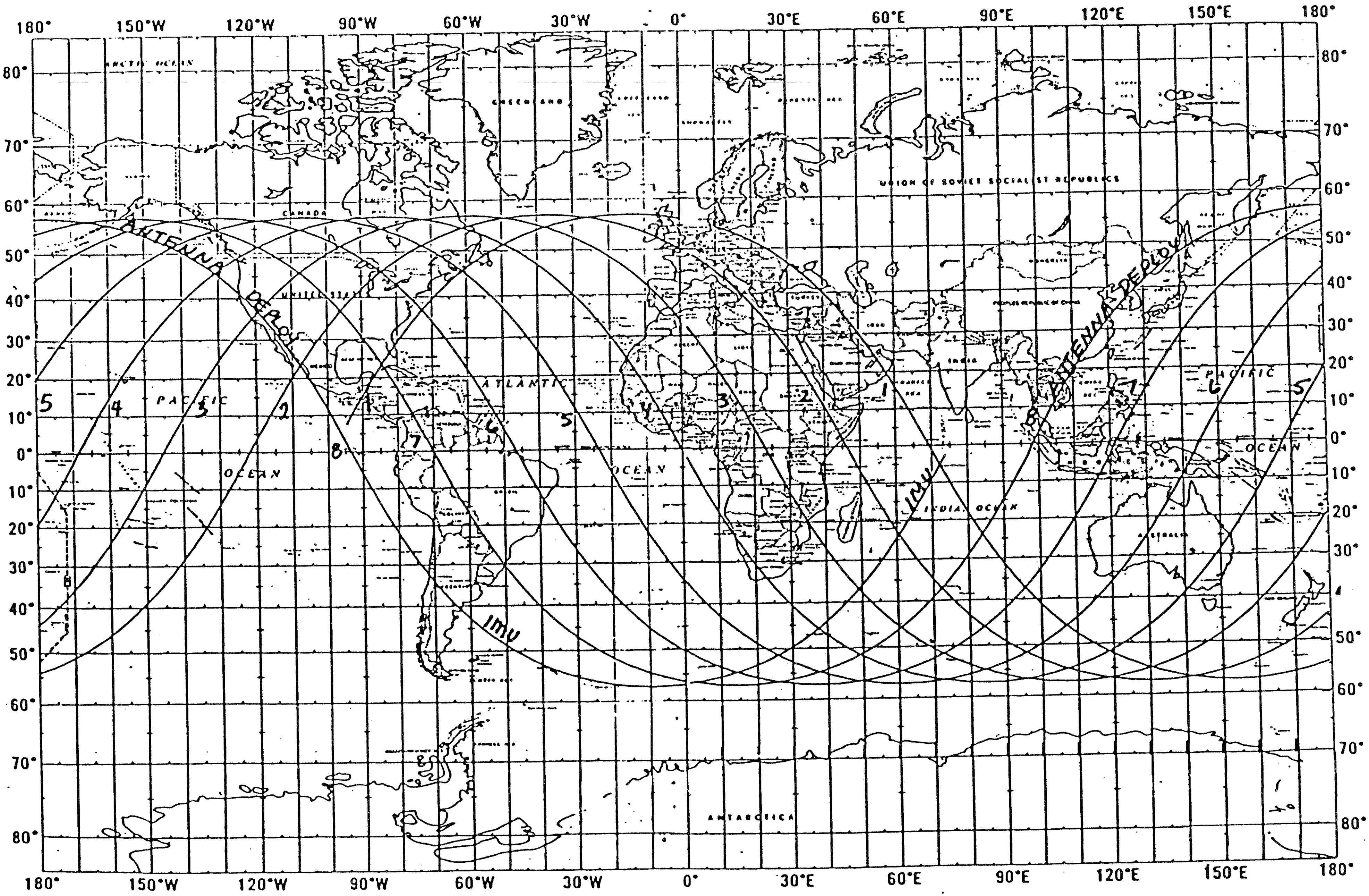

Fig. 2. Coverage example of SIR-B flight paths.

The LFC on STS-17 is a cartographic camera with a format of 230 x 460 mm. It has a 50 mm x 50 mm reseau grid. The camera focal length is 305mm with an 80 line-pair resolution (Doyle, 1982). LFC photographs will be used not only for stereo mapping, but will also be very useful for evaluating the performance results of the SIR-B experiment.

III. DATA ANALYSIS OF SIR-B IMAGES

Topographic map compilation using stereoradar images has been attempted in the mapping community in the past, but due to the uniqueness of radar geometry, which is mainly effected by its method of illumination and image formation, and radar shadow, map compilation by photogrammetric methods using side-looking radar images was not possible. For the last two decades, elevation measurements from stereo radar images have been made experimentally at various organizations. Because of limited accuracy, conceptual unfamiliarity, and lack of established procedures, no operational applications have been established.

Since 1977, the Photogrammetry Section of the Branch of Astrogeology has been continuing to conduct research and development in radar mapping for the VOIR (Venus Orbiter Imaging Radar), now VRM (Venus Radar Mapper), mission. Various experiments have been performed using radar images taken by different radar systems covering various areas in the United States (Wu, 1979, 1980a, 1980b, 1981). The results from these experiments were photo mosaic maps and establishment of stereomodels on analytical stereoplotters.

Radar imagery represents a line-scan geometry which is somewhat similar to panoramic photography except that the latter has a cylindrical geometry whereas radar imagery has layover distortion and also range scale distortion. The studies of the stereo radar mapping problem at the U. S. Geological Survey in Flagstaff have advanced to a point where the radar layover problem can be mathematically solved (Wu, 1982, 1983). The approach to compiling topographic maps from SIR-B images is to modify the existing plotter software of the panoramic photography program on the upgraded AS11-AM analytical plotter. This will enable radar stereo models to be obtained and photogrammetric measurements to be made on the plotter. As for the mapping accuracy, whether or not they will meet the National Mapping Accuracy Standards, is very difficult to predict since there are still many unknown factors with radar images. By making all possible corrections to radar geometries, including the correction of radar layover, standard errors of position measurements and elevation measurements are predicted to range, respectively, from 12 m to 30 m and from 12 m to 76 m, depending on the combination of different incidence angles used. This indicates that National Map Accuracy Standard can be met for map scales of 1:125,000 to 1:50,000.

Controls for stereo modeling may be obtained from the photographs of the large format camera which will also be included in the OSTA-3 experiment package on the STS-17 flight.

With the capability of multiple incidence angles of the SIR-B experiment, optimum radar incidence angles and optimum illumination geometries for future terrestrial and extraterrestrial missions using side-looking radar images can be determined. By pure photogrammetric analysis of the SIR-B radar images, we can predict that the optimum illumination geometries for stereo observations are, in sequence from the best to the worst: 60° & 24° (12.1 m), 60° & 33° (12.2 m), 60° & 15° (15.2 m), 51° & 24° (15.7 m), 60° & 42° (16.4 m), 51° & 33° (18.3 m), 51° & 15° (19.0 m), 42° & 24° (24.2 m), 42° & 15° (25.3 m), 60° & 51° (32.7 m), 51° & 42° (32.7 m), 42° & 33° (36.6 m), 33° & 15° (37.9 m), 33° & 24° (48.4 m), and 24° & 15° (75.9 m). Numbers in parenthesis are standard errors of elevation measurements which are derived from the radar resolution, base-to-height ratio of stereo pairs, and the plotter measurement capability.

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