THE SKYLAB RADAR ALTIMETER

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A summary of the significant hardware characteristics of the S-193 altimeter experiment portion of the 1973 SKYLAB Mission is presented. A detailed discussion of the Altimetry, Oceanographic, and Instrumentation Technology objectives are presented along with a discussion of the major experiments associated with these objectives.

INTRODUCTION

For a number of years, geodesists, oceanographers, and others have expressed an interest in the scientific possibilities of an orbiting altimeter (1-10). During recent years NASA has sponsored various studies related to the development and implementation of such a system (11-17). The basic concept which has evolved uses the orbit of the satellite as a reference from which direct radar pulse measurements are made of the vertical distance to the ocean surface - The overall objective of satellite altimetry being to synoptically map the dynamic topography of the sea surface with a precision of 10cm (7). Although, altimetry with a precision of only ±2-5 meters would perhaps be of considerable value to the earth physics community (18), the overall usefulness is largely dependent on its ability to ultimately achieve this high resolution. The present state of knowledge concerning the geoid and critical instrumentation design parameters as well as the state of precise orbit determination require that an evolutionary approach be taken. This implies that successive missions are required and that each mission should provide some significant advance in the state of the art. The SKYLAB mission is uniquely suited to be first in line to accept such a challenge.

Good spacecraft stabilization which permits using a high gain antenna and the low orbital height provide good loop gain. The permissible weight, volume, and power drain allow design of an instrument with a high degree of flexibility. This flexibility coupled with the planned low orbital eccentricity not only offers an excellent opportunity for acquisition of short arc geoidal profile information but also permits acquisition of the detailed technical information needed to improve future precision altimeter designs. This will include sensing of oceanographic and surface features, measurement of basic electromagnetic scattering characteristics, and acquisition of detailed statistical information on the characteristics of the backscattered signal. The general applications of altimetry are listed in Table 1.

Table 1

APPLICATIONS OF ALTIMETRY

- INSTRUMENTATION TECHNOLOGY
- GEODESY - REFINEMENT OF GEOID/GRAVITY MODEL
- ORBIT DETERMINATION
- OCEANOGRAPHY
- METEOROLOGY
- NAVIGATION

Some of the investigations actually planned for the SKYLAB experiment in the areas of Geodetic and Oceanographic Investigations are listed in Table 2 and 3 respectively. The Instrumentation Technology Investigations are discussed later in detail.

Table 2

GEODETIC & OCEANOGRAPHIC INVESTIGATIONS

- o GEOID MAPPING
- o TOPOGRAPHY
- o SEA STATE
- o RAIN
- o CLOUDS
- o SCATTEROMETRY
- o ALTITUDE PRECISION
- o SPATIAL DECAY TIME OF PRECISION
- o CALIBRATION

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Table 3

INSTRUMENTATION TECHNOLOGY INVESTIGATIONS

- o IMPULSE RESPONSE
- o RESOLUTION
- o σo (LOOP GAIN DESIGN)
- o STABILIZATION EVALUATION
- o CORRELATION TEMPORAL (OR SPATIAL LENGTH) MAXIMUM COMPRESSION CODE & PRF
- o PULSE COMPRESSION

INSTRUMENTATION CHARACTERISTICS

The S-193 altimeter experiment is one of three microwave experiments to be conducted aboard the 1973 SKYLAB mission. The other two experiments are the S-193 Radiometer/Scatterometer experiment and the S-194 L-Band Radiometer experiment. Since the three portions of the S-193 experiment share common R.F. circuits, the altimeter portion of the system cannot be operated simultaneously with the RADSCAT portion.

A summary of the basic electrical characteristics of the altimeter system are listed in Table 4. The flexibility of the instrument allows selection of several groups of characteristics into five basic modes of operation. These five modes are listed in Table 5 along with the pertinent characteristics of each mode.

Table 4

SKYLAB ALTIMETER ELECTRICAL CHARACTERISTICS

Transmitter type	TwT
peak power	2 Kw
PRF	250 pps
pulse code	single or dual pulse
frequency	13.9 GHz
Receiver type	coherent
IF center frequency	350 MHz
noise figure	5.5 db
pre-amplifier	tunnel diode
Antenna type	parabolic
diameter	44 inch
gain	42 db
beamwidth	1.5
Experiment Data Rate	10 K bits per sec (max)
Altimeter Signal Processor	threshold & split gate
tracking loop type	digital, 200 MHz logic
loop bandwidth	1 Hz
altitude output	32 pulse average of 2-way delay
altitude granularity	1.25 feet
acquisition time	less than 6 sec. (with initial altitude set to with ±4000 yds)
no. of sample & hold gates	8
sampling gate width	10 & 25 nsec
gate spacing	10 & 25 nsec

Sub Modes	100 nsec	10 nsec	10 nsec comp.
Rx Bandwidth	10 MHz	100 MHz	100 MHz
Altitude Noise	2 M	1.5 M	1 M
Signal to Noise Ratio	28 db	10 db	18 db
Pulse Footprint	3.5 n. miles	1.5 n. miles	1.5 n. miles

Pulse Compression	selectable
type	binary phase code
code	13 bit Barker code

Table 5

SKYLAB ALTIMETER MODES

Mode Number	Unique Features	Prime Data Sources
1. PULSE SHAPE	$.5^{\circ}$ Step Wide Bandwidth	Sample & Hold Altitude AGC
2. σo (RADAR-CROSS SECTION)	12 db Step (AGC Calibration) Antenna Positions 0°, $1/2^{\circ}$, 15.6°, 8°, 3°, 1.5°, 0°	Sample & Hold AGC
3. TIME CORRELATION	Two Pulsewidths Double Pulse Operation Spacings 1, 19.2, 17.8, 153.6, 409.6, 819.2 (Micro Seconds)	Sample & Hold Altitude
5. PULSE COMPRESSION	Three Pulsewidths 10ns 10ns (Compressed) 100ns	Sample & Hold AGC Altitude
6. NADIR ALIGNMENT	Slow Spiral Drive	AGC

The reasoning behind these five modes, or their scientific objectives, are discussed below along with their relation to altimetry and their various ground truth and calibration requirements.

Mode 1 - Waveform Experiment

The waveform experiment has been designed to collect statistical information concerning the backscattered signal, which will be used to experimentally verify the various signal models and error sources involved in both altitude and sea-state measurements. During this mode of operation, detailed pulse-by-pulse waveform information on the backscattered signal will be recorded. Each received pulse will be sampled at eight points within the received waveform with sample spacings of 10 and 25nsec for transmitted pulse lengths of 10 and 100nsec respectively. In the case of mean value waveforms which can be constructed from these measurements the square law detected signal is related to the power impulse response. Impulse response measurements are of considerable interest in the design of altimeters since the manner in which the fluctuating signal converges to a mean value strongly influences altitude tracker design and defines the degree to which surface parameters can be extracted (13, 17).

Mode 2 - Radar Cross-Section and Altimeter Experiment

This mode will provide measurement of the radar cross-section (σ^o) for land, sea, and ice returns at both normal incidence and as a function of angle up to 15 degrees off nadir. This cross-section information will be very useful in the design of future altimeters and useful for comparison purposes with the other SKYLAB experiments. Data will also be collected in this mode and analyzed to investigate the accuracy, precision and overall capability of satellite altimeters to determine mean sea level, monitor mean surface slopes, and measure small scale departure of the ocean surface from overall mean sea level.

For this mode of operation, ground truth information is especially critical.

Mode 3 - Time Correlation Experiment

In this mode a pair of pulses will be transmitted, with spacing between pulses variable from approximately 1μsec to one millisecond. Examination of the sampled return waveform data should yield the maximum PRF at which statistically independent samples of altitude data can be obtained, characteristics of the signal correlation properties as a function of surface conditions, and the maximum time interval over which the reflecting surface appears motionless and therefore suitable for use of pulse compression systems that do not contain doppler compensation.

Mode 5 - Pulse Compression Experiment

This mode consists of both 10 nanosecond uncompressed pulse operation and a 10 nanosecond phase reversal pulse compression operation using a 13 bit Barker code. Direct comparison of the two techniques will be possible, establishing the capability of phase reversal pulse compression techniques to measure detailed information on extended targets. It should be noted that 10 nanosecond altimetry (height data) cannot be obtained since the altitude tracker is designed to operate only on the 100 nanosecond pulse length. During the 10 nanosecond pulse mode the pulses are narrow-band filtered to equivalently stretch the 10nsec pulses up to 100nsec. This will not, however, affect the 10 nanosecond waveform data gathering process.

Mode 6 - Nadir Alignment Experiment

The objective of this experiment is to evaluate the feasibility and accuracy of an on-board nadir seeker to supplement or complement the normal stabilization systems required for altimeter pointing. In the nadir seeker mode the antenna is automatically moved in pitch and roll to a position at which the gated AGC control voltage is a maximum.

OPERATIONS

Present plans call for three periods of time in which the altimeter experiments can be conducted; the first two periods will be for a duration of 28 days each and the last period for a duration of 58 days. Each experiment data collection mode is expected to last approximately 3 minutes. All experimental data obtained will be stored on digital magnetic tape at a maximum rate of 10 K bits per second and returned to earth with the astronaut crews. Sufficient time exists between flights to allow some examination of the data and planning of subsequent measurements.

GROUND TRUTH

In the planned experiments, both surface and aircraft sensors will be utilized to measure parameters such as surface winds, temperature, and wave height spectrum. In addition to the nominal aircraft complement of instrumentation (nanosecond radar, laser profilometer, Stilwell photography) it is hoped that the engineering model of the SKYLAB altimeter can be installed and used for ground truth data collection.

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