JAPANESE ERS-1 TO GROUND STATION INTERFACE DESCRIPTION

REVISION 3

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PREFACE

Information herein reflects the Japanese Earth Resources Satellite-1 (JERS-1) system development status in October 1990, including result from the critical design review in July 1989 and the PFM pre-launch test in 1990.

Data acquisition and processing in the operation of ground stations are reviewed in this document. Additional information and update of parameters in this document will be provided as they become available.

Contents Page

Contents Page

Contents **Page**

Figure **Page**

Figure **Page**

Table **Page**

Table **Page**

Acronyms

AOCS ; Attitude and Orbit Control System
ASF ; Alaska SAR Facility(NASA)
BAT ; Battery Assembly
BMR ; Bubble Memory Recorder
C&DH ; Communication and Data Handling
CCD ; Charge Coupled Devices
CCT ; Computer Compatible Tape
CEOS ; Committee on Earth Observation Satellite
CNES ; Centre National d' Etudes Spatiales
CU ; Central Unit
EERS-1 ; European Remote Sensing Satellite-1
EIRP ; Equivalent Isotropic Radiated Power
EPST ; Electric Power Supply
EOC/NASDA ; Earth Observation Center/ National Space Development Agency of Japan
ESA ; European Space Agency
G/T ; Gain to Temperature ratio
GRS ; Ground Reference System
GSFC ; Goddard Space Flight Center
HDDR ; High Density Digital Recorder
HDDT ; High Density Digital Tape
INT ; Integration Hardware
JERS-1 ; Japanese Earth Resources Satellite-1
JPL ; Jet Propulsion Laboratory
JAROS ; Japan Resources Observation System Organization
LSB ; Least Significant Bit
MITI ; Ministry of International Trade and Industry
MDR ; Mission Data Recorder
MDT ; Mission Data Transmitter
MESSR ; Multispectral Electronic Self Scanning Radiometer
MMO ; Mission Management Organization
MOS-1 ;Marine Observation Satellite-1(Japanese R/S Satellite)
MSB ; Most Significant Bit
NASA ; National Aeronautics and Space Administration
NASDA ; National Space Development Agency of Japan
NOAA ; National Oceanic and Atmospheric Administration
OPS ; Optical Sensor
PCM ; Pulse Code Modulation
PCU ; Power Control Unit
PFM ; Proto-Flight Model

Acronyms

PM	; Phase Modulation
PN	; Pseudo Noise
PSK	; Phase Shift Keying
Q/L	; Quick Look
QPSK	; Quadrature Phase Shift Keying
RCS	; Reaction Control Subsystem
RHC	; Right Hand Circular
RIU	; Remote Interface Unit
RRSS	; Technology Research Association of Resources R/S System
RSP	; Reference System for Planning
S-ANT	; S-Band Antenna
SAP	; Solar Array Paddle
SAR	; Synthetic Aperture Radar
SDB	; Satellite Data Bus Subsystem
S-DIP	; S-band Diplexer
SOB	; Strap-On Booster
SPOT	; Satellite Pour l'Observation de la Terre
STA	; Science and Technology Agency (JAPAN)
SWIR	; Short Wave Infrared Radiometer
SXPDR	; USB Transponder
TCS	; Thermal Control Subsystem
VNIR	; Visible and Near Infrared Radiometer
WRS	; World Reference System

1. OUTLINE OF JERS-1 PROJECT

The Earth Resources Satellite-1(JERS-1), which is a joint project between th Ministry of International Trade and Industry (MITI) and the National Spac Development Agency of Japan (NASDA), is scheduled to be launched in th beginning of 1992 using H-I launch vehicle from Tanegashima space center.

NASDA is responsible for satellite bus development, system integration an launch, while MITI is responsible for mission instruments development. Unde MITI's supervision, RRSS(Technology Research Association of Resource Remot Sensing System) and JAROS (Japan Resources Observation System Organization) implement the development of mission instruments.

As mission instrument, the Synthetic Aperture Radar(SAR) and the Optical Sensor (OPS) will be installed in JERS-1. The SAR is active microwave imaging sensor achieving high resolution and having all-weather operation capability. The OPS is multispectral radiometer with high geometric resolution and having capability of taking stereoscopic imagery.

A wide band tape recorder, Mission Data Recorder (MDR), will also be installed on JERS-1 to obtain the data world-widely.

The mission objectives of JERS-1 are;

1) assessment of newly developed sensors and spacecraft

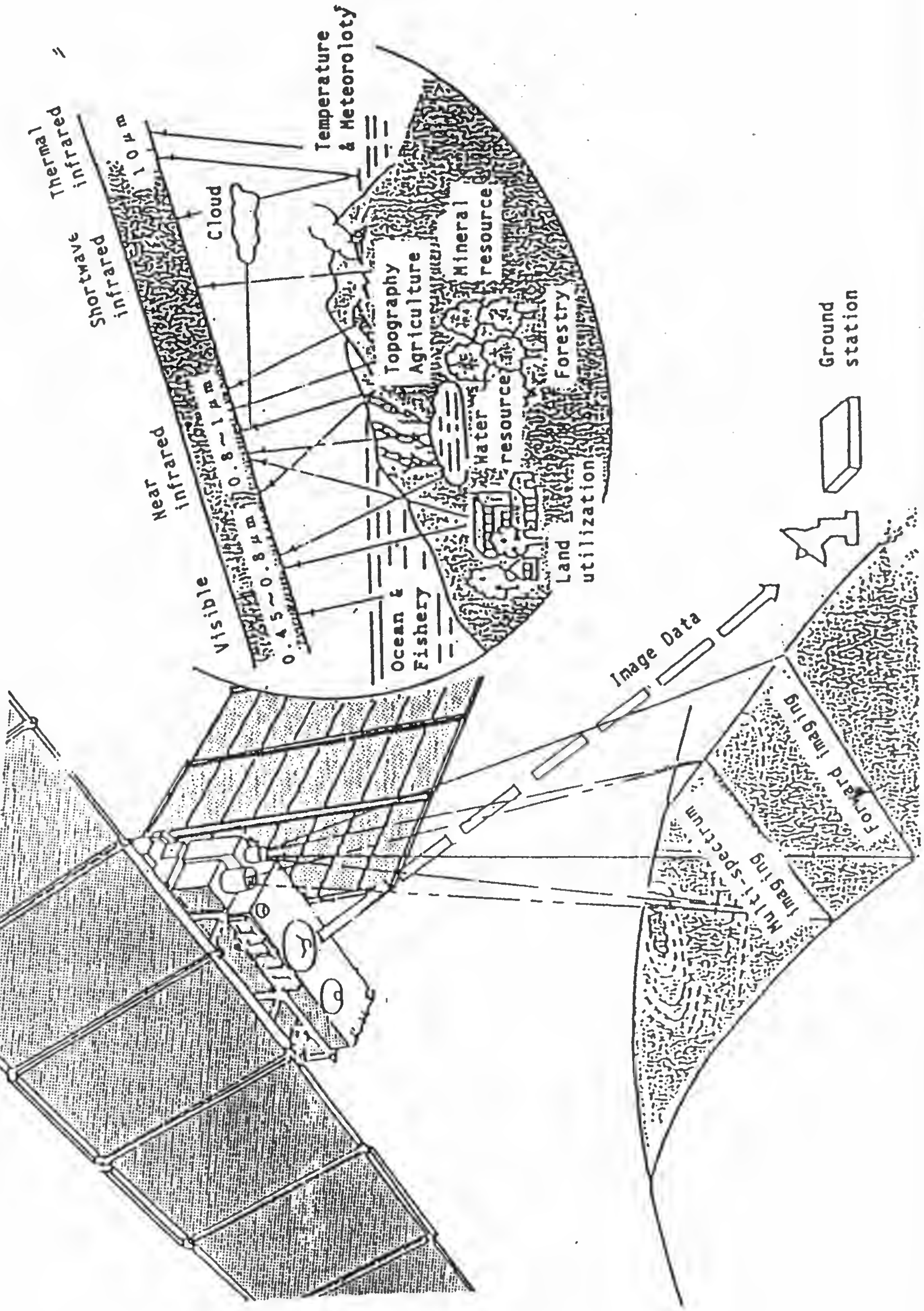
and 2) establishment of an integrated system for observing the earth, focused on earth resources, and geology, agriculture, forestry, land use, sea ice monitoring, coastal monitoring, etc.

The mission overview of JERS-1 is illustrated in Figure 1.1

The preliminary design of JERS-1 started in 1984 about three years prior to th launch of the Marine Observation Satellite-1(MOS-1). MOS-1 series is Japan' first earth observation satellites which were launched in Feb.1987 an Feb.1990. The basic design of JERS-1 started in 1986 and the Preliminar Design Review(PDR) was conducted in March 1987. In the critical design phase the Structural and Thermal Model (STM) and the Engineering Model (EM) were developed and tested, verifying mechanical and electrical design of the satellite. The Critical Design Review (CDR) was held on July 14 and 15, 1989 and the satellite design was consolidated. The Proto-Flight Model (PFM) is unde development with a launch target in the early 1992.

The data obtained by JERS-1 will be mainly received at Earth Observation Center (EOC/NASDA) which is now serving as the ground station for Landsat, MOS-1 and SPOT. Under cooperative agreement between NASA and NASDA, ASF will receive the data and provide MDR data dump service. Additionally, foreign ground stations will receive JERS-1 data in the future. From this point of view, JERS-1 expects to contribute to world-wide data applications.

Figure 1.1 The Mission overview of JERS-1



2. JERS-1 SYSTEM OVERVIEW

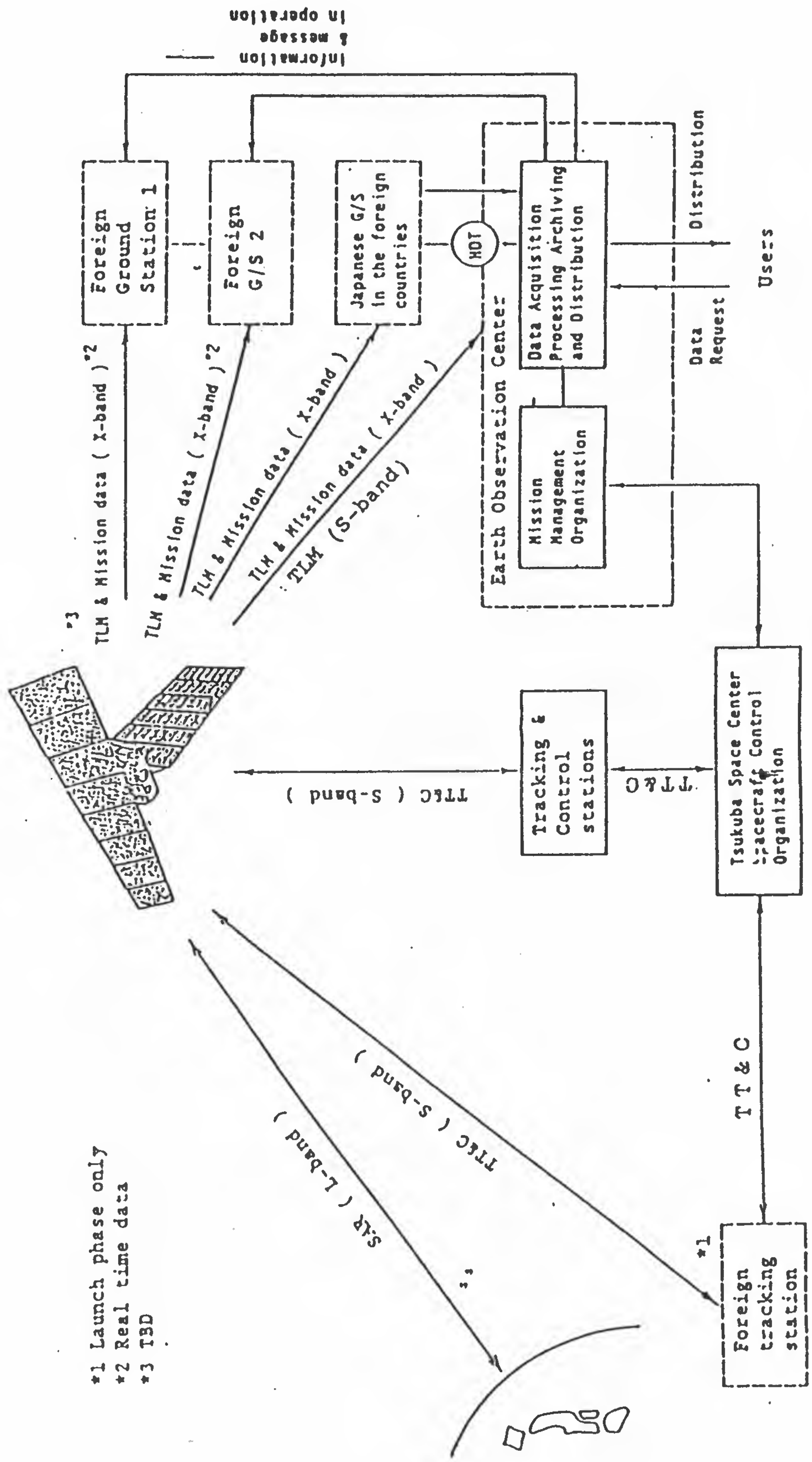
The total system of the project consists of space segment and ground segment. The ground system includes data receiving and processing facility, mission control facility, satellite tracking stations, and data analysis and distribution organizations.

And, all the mission objectives which JERS-1 loaded will be performed by many domestic ground stations cooperating with world-widely expanded foreign station, ie. in launching phase foreign tracking stations such as NASA STDN is cooperative, in operation phase, overseas and foreign ground stations will be the functions of each segments are clarified as follows and the functional block diagram of JERS-1 total system is shown in Figure.2.1

(1) space segment	JERS-1 satellite
(2) tracking and control of satellite	(1)Tsukuba Space Center (2)Tracking and Control Stations KATSUURA MASUDA OKINAWA (3)Foreign Tracking Stations
(3) data receive and processing stations	(1)Earth Observation Center in HATOYAMA (2)Foreign Ground Stations
(4) data distribution and archive stations	(1)Earth Observation Center in HATOYAMA (2)RESTEC (3)ERSDAC (4)Foreign Ground Stations
(5) mission management	MMO in earth observation center

The functional block diagram of JERS-1 total system is indicated in Figure 2.1.

Figure 2.1 The functional block diagram of JERS-1 total system



2.1 SPACECRAFT

JERS-1 employs a zero-momentum, strap-down, three-axis controlled system for high precision attitude control and also a large scale monolithic silicon based solar paddle to generate large amount of electric power necessary to conduct a two years' mission objectives.

The configuration of the JERS-1 is illustrated in Figure 2.3 and 2.4. As indicated in the figures, dimensions of the satellite bus structure are 0.92 m (Y direction) × 1.80 m (Z direction) × 3.10 m (X direction). The size of the solar paddle is 8.00 m (length) and 3.37 m (width). This solar paddle is attached to one side of the spacecraft of -Y direction and capable to generate 2053 watt in daytime at EOL(End of Life). The total weight of the spacecraft is approximately 1340 kg. JERS-1 will be launched by the second stage H-I launch vehicle the design life is 2 years.

JERS-1 satellite has several features compared with presently operated NASDA's first earth Observation Satellite, MOS-1 as follows;
(1) more precise attitude and control sensor
(2) large scale solar paddle with a capability to generate to support the satellite and mission instruments.

The subsystem of the spacecraft is shown in Figure 2.5.

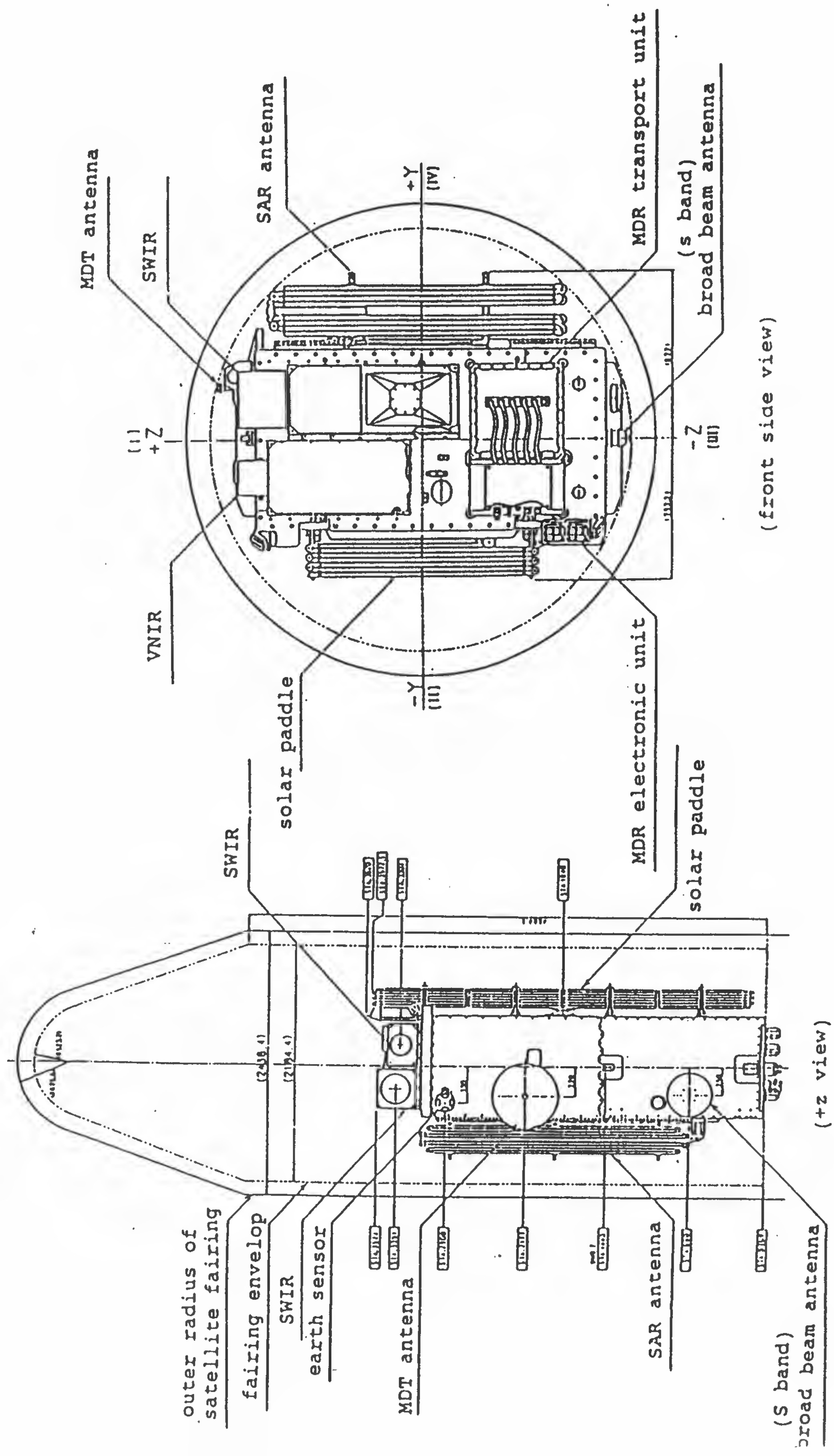


Figure 2.2 Configuration of JERS-1 at launch

Figure 2.3 Configuration of JERS-1 in orbit (1)

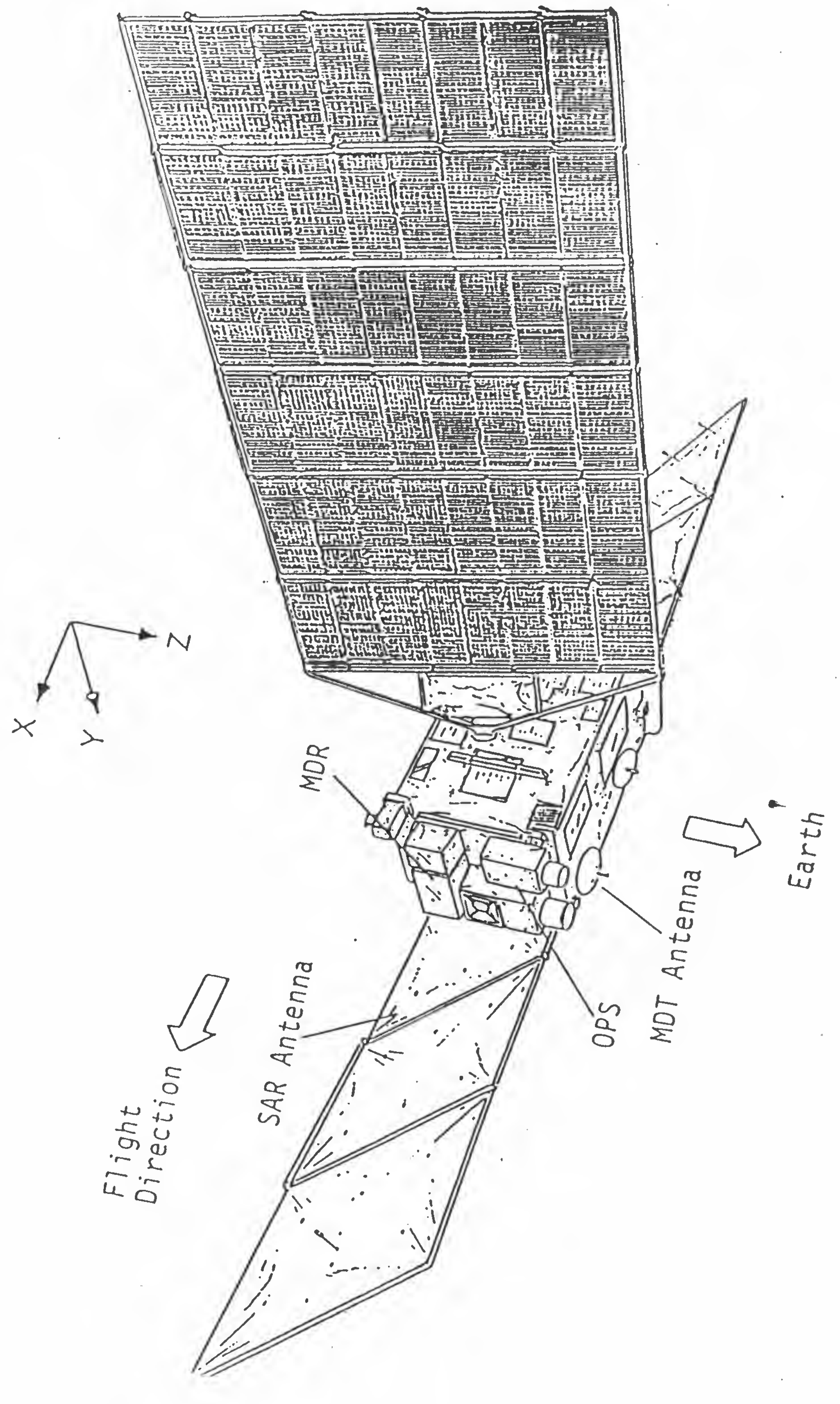


Figure 2.4 Configuration of JERS-1 in orbit (2)

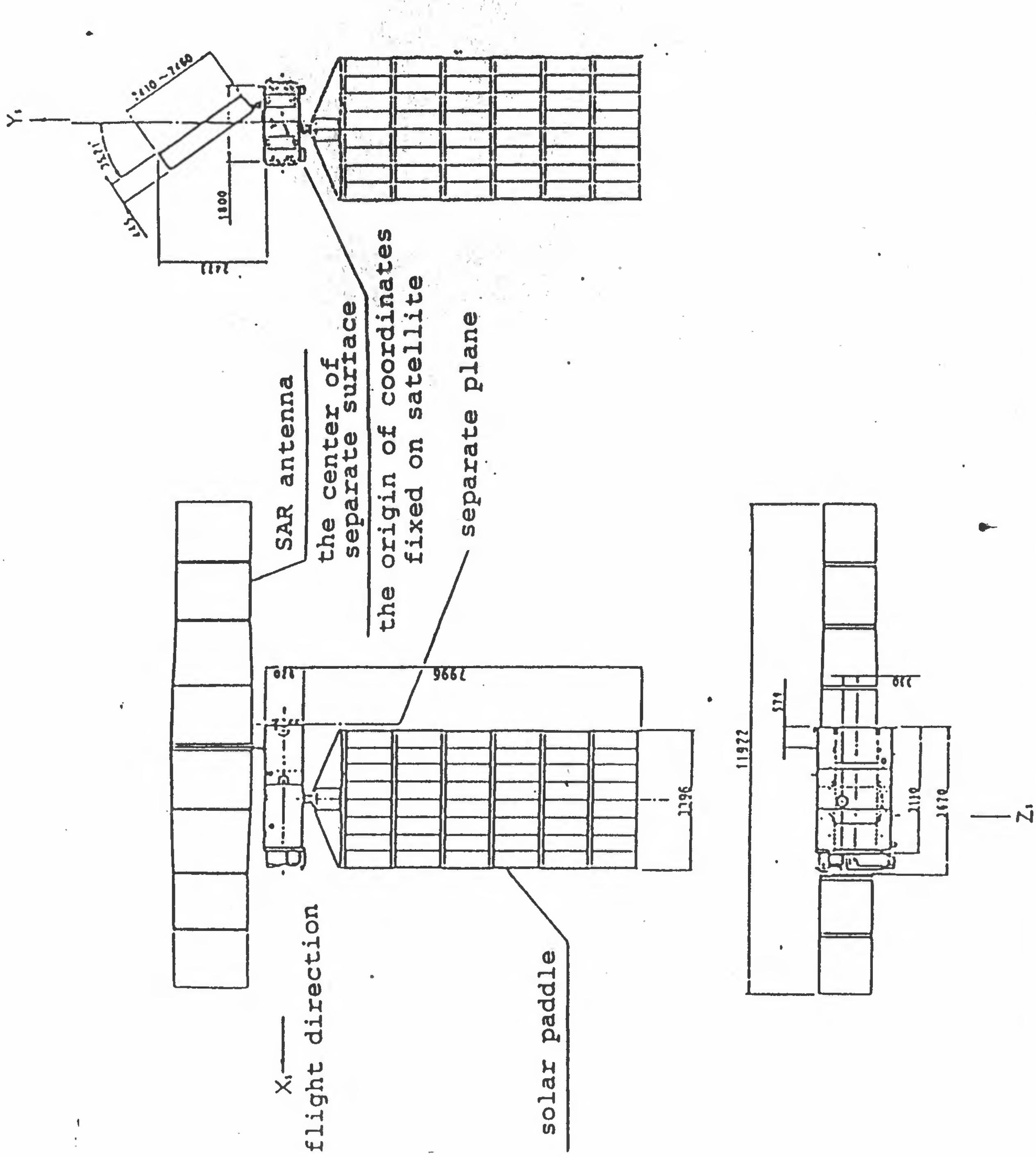


Figure 2.5 The configuration of JERS-1 Subsystem

JERS-1
Spacecraft

- Satellite Bus
  - Communication & Data Handling Subsystem (C&DH)
  - Attitude and Orbit Control Subsystem (AOCS)
  - Electric Power Subsystem (EPS)
  - Reaction Control Subsystem (RCS)
  - Structure Subsystem (STR)
  - Thermal Control Subsystem(TCS)
  - Integration Hardware Subsystem (INT)
- Mission Instrument
  - Synthetic Aperture Radar (SAR)
  - Optical Sensor (OPS)
  - Mission Data Recorder (MDR)
  - Mission Data Transmitter (MDT)

2.1.1 Coordinate Systems

The coordinate systems for JERS-1 are right-handed rectangular coordinate systems as defined in Table 2.1, Figure 2.6 and 2.7.

2.1.2 Satellite Bus System

The satellite bus system provides the mission instrument system with all the necessary services such as power, communications, attitude control, etc. it consists of the following subsystems;

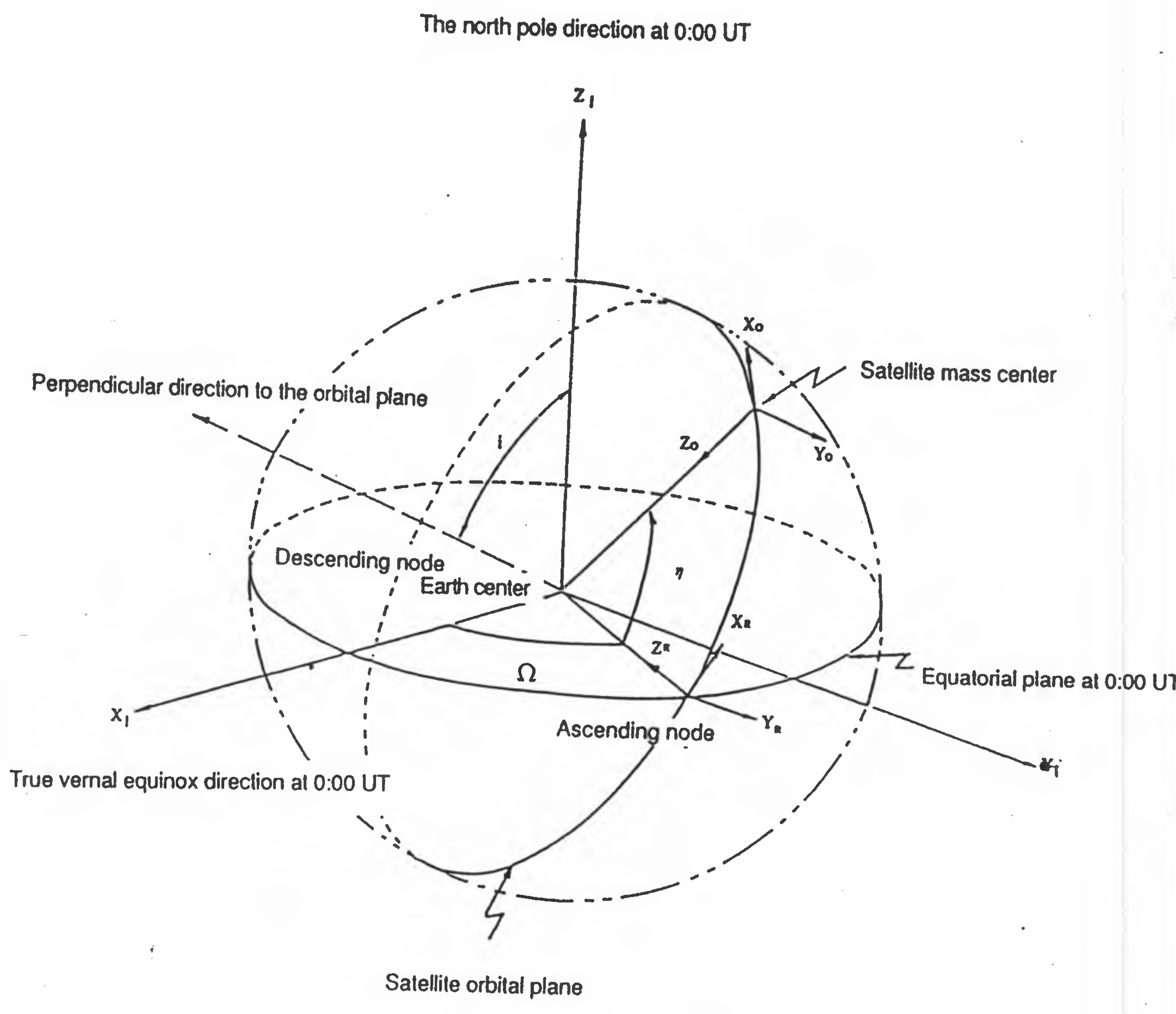
- Structural Subsystem (STR)
- Communications and Data Handling Subsystem (C&DH)
- Attitude and Orbit Control Subsystem (AOCS)
- Reaction Control Subsystem (RCS)
- Electrical Power Subsystem (EPS)
- Thermal Control Subsystem (TCS)
- Integration Subsystem (INT)

Functional block diagram of JERS-1 is shown in Figure 2.8.

Table 2.1 Definition of Coordinate Systems

Coordinate System	Symbol	Origin and Axis	Definition
Inertial Coordinate System	Φ_I	Origin X_I Y_I Z_I	Earth center Vernal equinox direction at 0:00 UT $Z_I \times X_I$ Perpendicular direction to the equatorial plane(positive to the North Pole direction)
Orbit Reference Coordinate System	Φ_R	Origin X_R Y_R Z_R	Right Ascension Equivalent to orbit coordinate system at right ascension
Orbit Coordinate System	Φ_o	Origin X_o Y_o Z_o	Satellite mass center $Y_o \times Z_o$ Opposite direction of orbital vector Earth center direction
Satellite Coordinate System	Φ_B	Origin X_B Y_B Z_B	Satellite mass center Roll axis Pitch axis Yaw axis
Satellite Fixed Coordinate System	Φ_s	Origin X_s Y_s Z_s	Crossing point of the center line of the separation section and the separation plane Parallel to respective axis of satellite coordinate system

Figure 2.6 Definition of Φ_I, Φ_R and Φ_O



Ω : Right ascension of the ascending node
i : Inclination
η : Argument of latitude

Figure 2.7 Definition of Φ_B and Φ_S

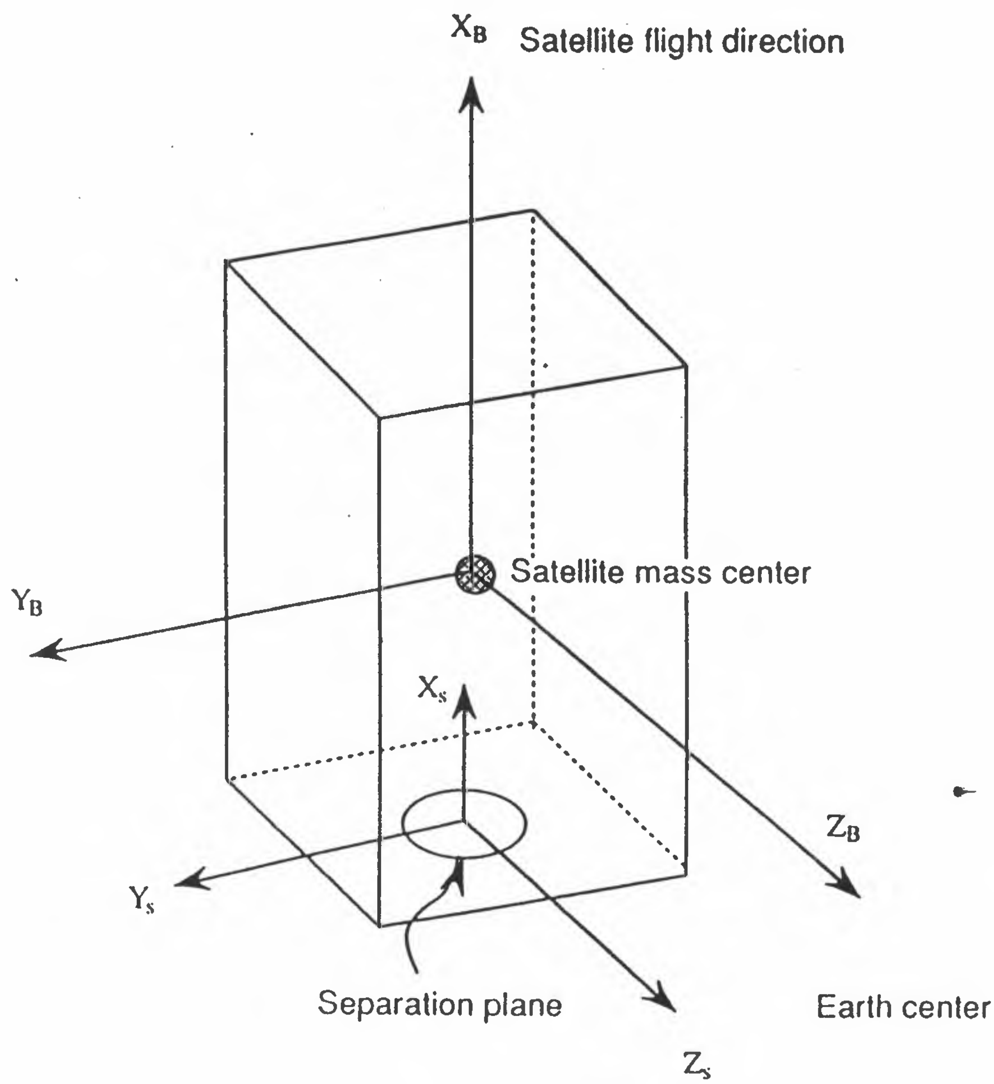
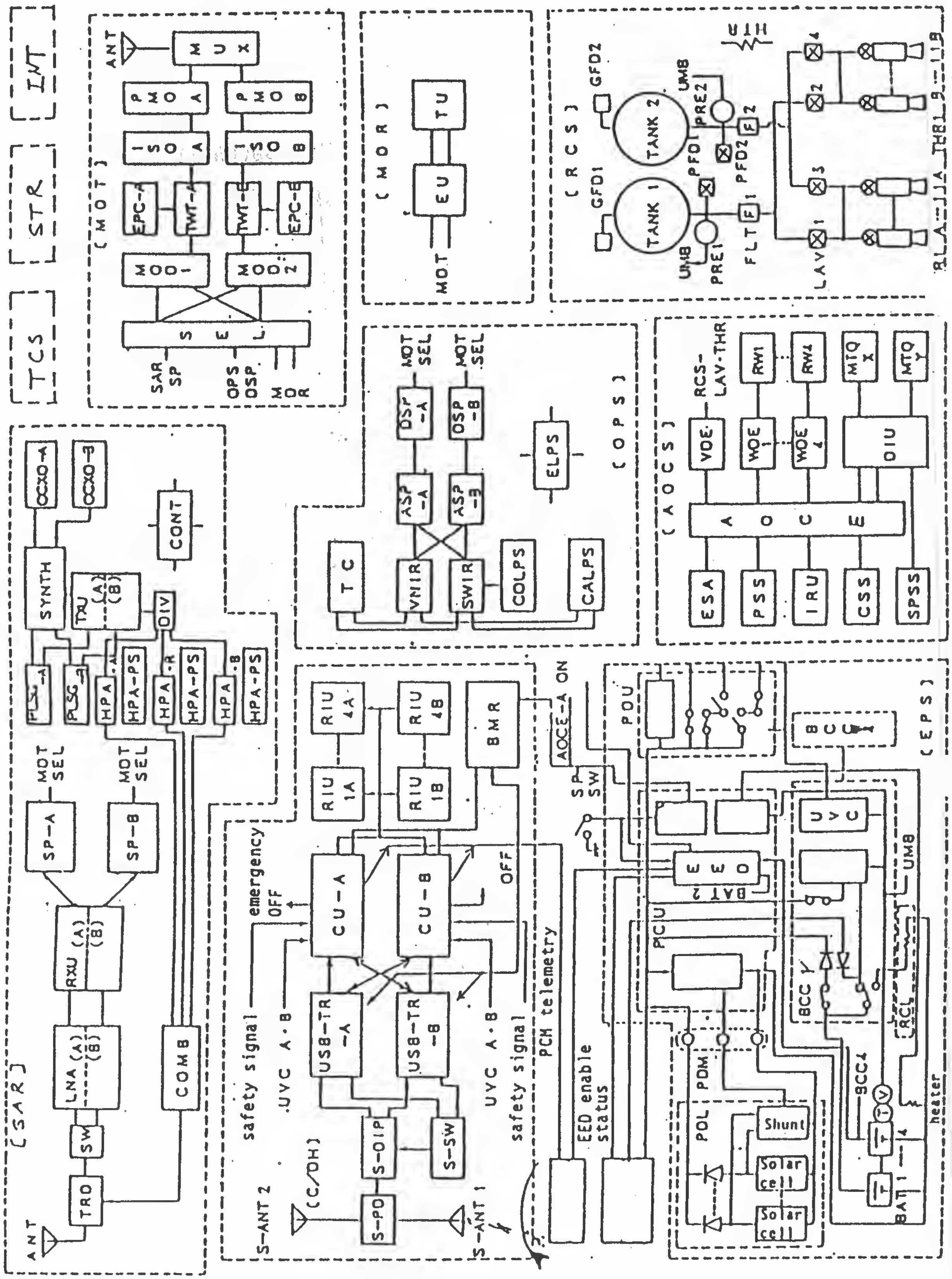


Figure 2.8 JERS-1 Functional Block Diagram



2.1.2.1 C&DH

JERS-1 performs many complex functions with large volume of command and telemetry data. The satellite adopted C&DH which is based upon Satellite Data Bus (SDB). C&DH performs the following functions:

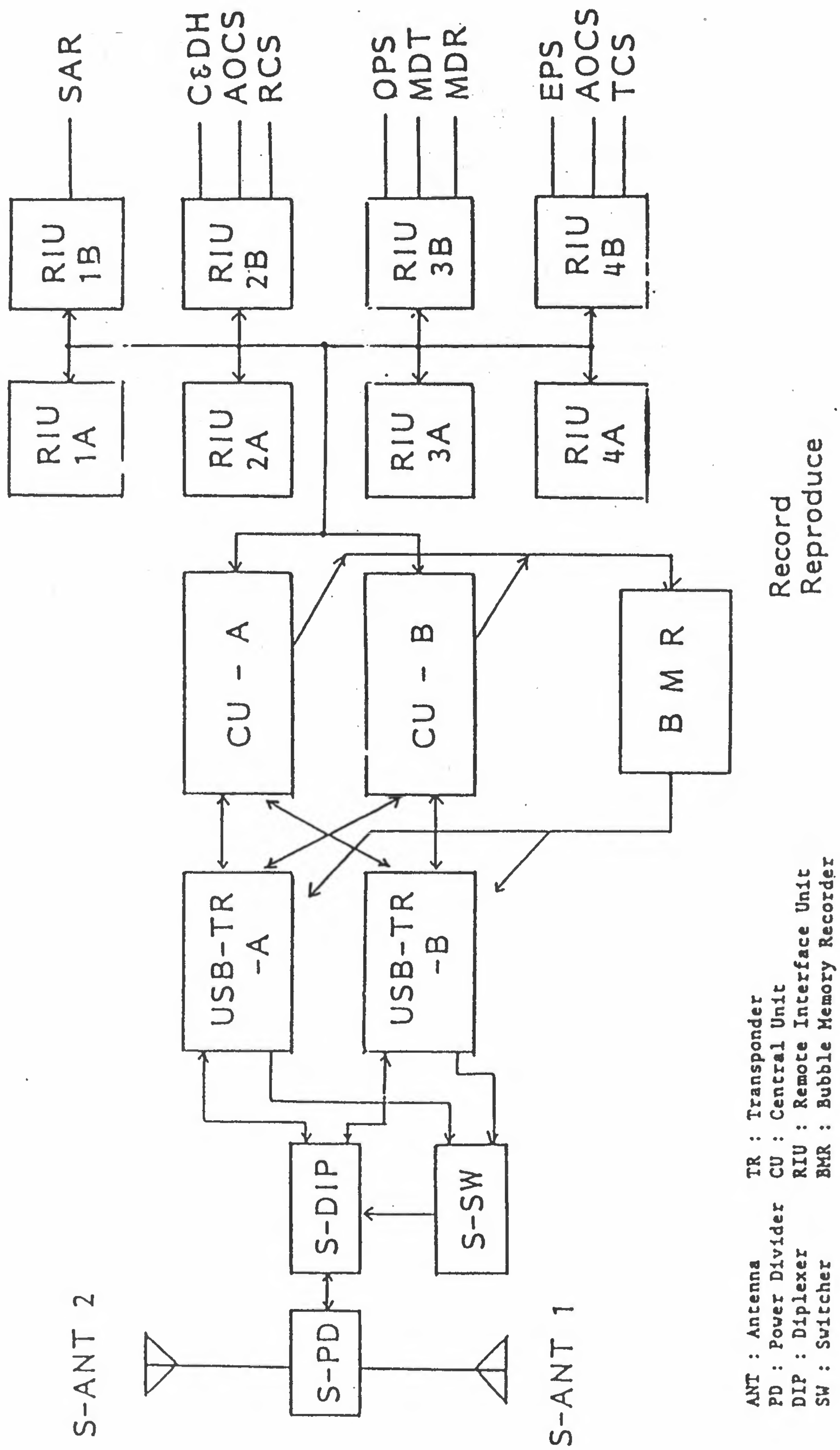
- receive, demodulate, decode, decode and execute command,
- collect and edit telemetry data,
- transmit telemetry data,
- relay ranging signal,
- supply mission instruments with telemetry data
- generate, distribute and reset spacecraft time,
- issue Light Load Mode (LLM) signal to turn off the mission instruments, detecting anomalies, etc.

C&DH functional block diagram is shown in Figure 2.9.

C&DH consists of a RF block for communications and SDB for command decoding and telemetry encoding. The RF block includes S-band antennas, diplexer and USB transponders. S-band antennas are installed on both +Z and -Z panels of satellite. S-ANT1 on +Z panel (earth panel) is a shaped broad beam antenna for normal communications with the ground, while S-ANT2 on -Z panel (anti-earth panel) is omni antenna to be used in case of contingency. Diplexer separates 2.0 GHz uplink signal from 2.2 GHz downlink signal. USB transponder's transmitting power are 17 dBm (low power mode) and 23 dBm (high power mode). In the launch phase, the high power mode is on to ensure communications link with the ground whatever the satellite attitude will be, and it will be switched to the low power mode for normal operation mode.

JERS-1's SDB consists of two Central Units (CU), eight Remote Interface Units (RIU) and four data bus lines, including a redundant system. SDB has a function of delivering command data to satellite components and collecting telemetry data from those components. CU decodes the command signal from USB transponder and addresses control bus message to one of the RIUs through the control bus line. CU also send control bus message for telemetry collection to RIUs. RIU decodes the control bus message and generates command signal to satellite component. RIU collects telemetry data from satellite component according to control message from CU and send them to CU through the reply bus line. RIU#1 supports SAR, and RIU#3 supports OPS, MDR and MDT.

Figure 2.9 Communication & Data Handling Subsystem (C&DH)



In addition to command and telemetry data handling, CU has functions of satellite time generation and delay command execution. JERS-1's CU has 256 delay command capacity.

A bubble memory recorder (BMR) was adopted to record the telemetry data outside ground station coverages. It has 16 Mbits recording capacity, including 4 Mbits endless recording area, and can record the telemetry data up to 102 min.

C&DH has, in addition, satellite protection functions in which detecting satellite attitude anomaly or bus voltage drop, it sends Light Load Mode (LLM) command to turn off the mission instruments and switch on Safety heathers. On receiving the LLM signal, BMR is turned on automatically to record telemetry data for 17 min. It will proved valuable information for failure analysis.

2.1.2.2 AOCS

JERS-1 adopted Japan's first digital, zero-momentum, strap-down, three-axis control system for the AOCS.

AOCS performs initial attitude acquisition, control of satellite orientation and stabilization, velocity increment control required to adjust the orbit, solar paddle rotation control and fault tolerance.

Features of AOCS are;

(1) Attitude data are provided by an inertial reference unit (IRU) and their errors are further corrected with an earth sensor assembly (ESA) and a precision sun sensor (PSS). Precise attitude determination is possible for three axes.
(2) Zero-momentum attitude control system employing four skewed reaction wheels (RW) and magnetic torquers (MTQ) was adopted. Together with the strap-down attitude determination by IRU, it enables precise attitude control and high attitude stability for three axes.
(3) On-board computer (OBC) in attitude and orbit control electronics (AOCE) performs computation of attitude control algorithm, data processing of sensors and actuators, fault-tolerant operations, etc. Software is stored in 16 kw ROM and 2 kw RAM and reprogrammable from the ground.

(4) Thrusters are modularized and provide unidirectional thrust to the satellite. Satellite needs to be rotated 90 deg. or 180 deg. around yaw axis in accordance with orbit control direction. Zero-momentum attitude control system has very small angular momentum, therefore it is apt for this maneuver.

The performance of AOCS is shown in Table 2.2.
AOCS's sensors and actuators are shown in Figure 2.10.

The spacecraft attitudes are obtained by gyro-based determination system, The angular rate data are sampled by IRU(Inertial Reference Unit) everv 0.125 sec., and the attitudes are estimated by integrating these rates. T drift rates of IRU gyros are periodically compensated by ESA(Earth Senso. Assembly) every 10 sec, and PSS (Precision Sun Sensor) every 5760 sec. (once every revolution over the North Pole area)

These corrections are made after filtering output data from ESA and PSS in order to avoid the satellite attitude disturbances due to abrupt changes of the sensor data. The block diagram of attitude determination system is shown in Figure 2.11.
The principle of ESA attitude measurements is shown in Figure 2.12. ESA has four quadrants, each of which consists of four detectors. ESA views the earth edge in 14μm - 16μm IR region. By comparing output data from quadrant 1 and 2, pitch angle can be estimated from output data from quadrant 3 and 4.

The principle of PSS yaw measurement is shown in Figure 2.13. PS measures azimuth angle α and elevation angle β of the sun vector. In order to detect the two angles, two coarse sensors and two fine sensors are installed with 90 degree rotation. Each sensor has slits and solar cells beneath to detect the incident angle of the incoming solar ray. When the satellite flies over the North Pole region and β becomes 0, α is equivalent to yaw attitude error.

AOCS's actuator system comprises of four skewed RWs with 20 Nm angular momentum each, consisting three out of four redundancy system, and two pairs of MTQs working in redundancy. RWs supply in normal operation mode the attitude control torques and storage capability for the residual angular momentum.

MTQs deliver wheel off-loading torques.

AOCS mode sequence is shown in Figure 2.14.

AOCE and IRU are turned on when the satellite is separated from the launch vehicle. After IRU spins up, rate dumping is performed with IRU and thrusters. When angular rate is low enough, solar paddle is deployed and, then earth acquisition, yaw acquisition are mode using IRU, ESA and thrusters. After yaw acquisition is completed AOCS proceed to normal operation mode. The above sequence will be carried out automatically.

In orbit control mode, AOCS controls continuous firing of orbit control thrusters in accordance with commands from the ground. During the thruster firing, AOCS maintains the three-axis attitude with IRU, ESA and attitude control thrusters.

AOCS operation is monitored and failures can be detected by OBC fault diagnostic program. Detecting component failure, OBC automatically switches to the redundant component. If switching to the redundant component does not solve the problem, OBC issues Safety signal to AOCS and places the satellite into sun acquisition mode, ensuring that power generation, thermal control are properly maintained.

Table 2.2 Performance of AOCS

(1) ATTITUDE CONTROL ERROR

(A) ABSOLUTE ATTITUDE (3 σ) (result of simulation test)

ROLL	:	0.12 deg	0.18 deg
PITCH	:	0.16 deg	0.17 deg
YAW	:	0.13 deg	0.15 deg

(B) ATTITUDE STABILITY (3 σ) (result of simulation test)

ROLL	:	0.7×10^{-3} deg/sec	1.1×10^{-3} deg/sec
PITCH	:	0.4×10^{-3} deg/sec	0.6×10^{-3} deg/sec
YAW	:	0.4×10^{-3} deg/sec	0.4×10^{-3} deg/sec

(2) ATTITUDE TELEMETRY DATA

(A) SAMPLING RATE (HIGH RATE MODE)

(i) ATTITUDE DATA : 2 sec

(ii) DIFFERENTIAL ATTITUDE DATA FROM IRU* : 0.5 sec
(ATTITUDE IS TO BE DETERMINED AT EVERY 0.5 SEC ON GROUND)

(B) TELEMETRY ERROR
(CAUSED BY ATTITUDE SENSOR ERROR, EPHEMERIS AND SOFTWARE ERROR, GRANULARITY OF TELEMETRY DATA, ETC.)

ROLL	:	0.09 deg
PITCH	:	0.17 deg
YAW	:	0.08 deg

* INERTIAL REFERENCE UNIT

Figure 2.10 The Arrangement of AOCS's Sensors and Actuators

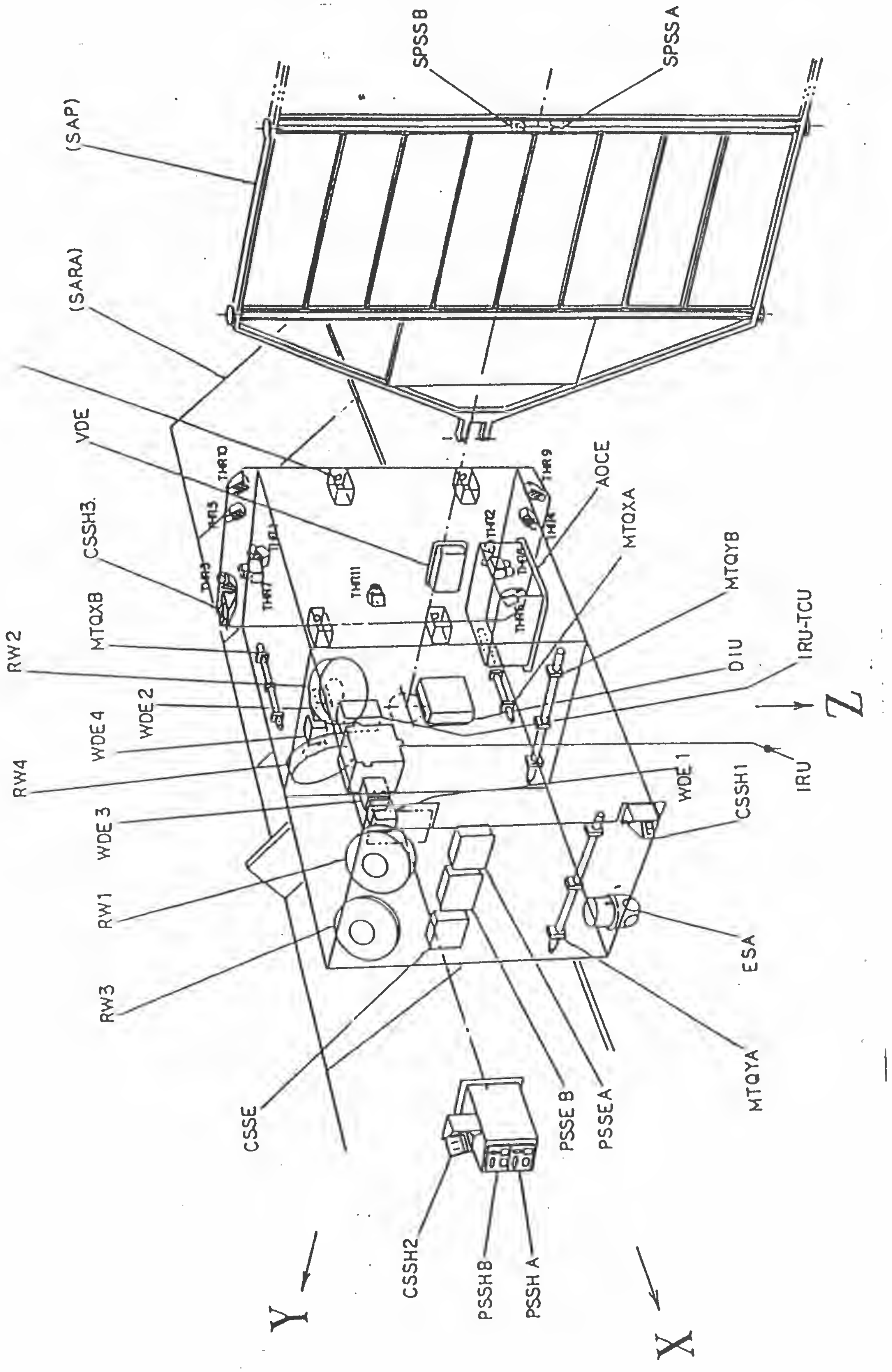


Figure 2.11 Block Diagram of Attitude Determination System

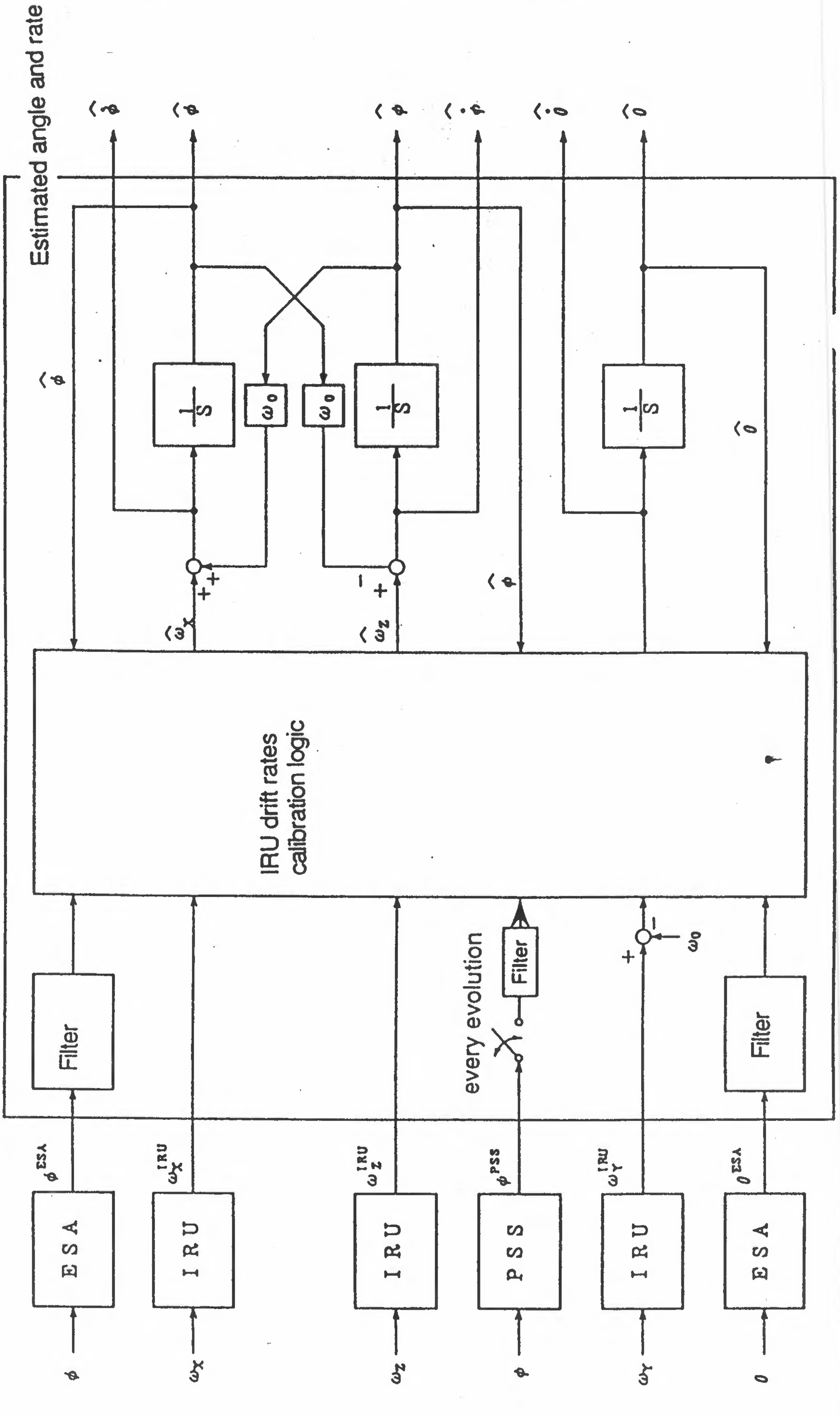


Figure 2.12 Principle of ESA Attitude Measurement

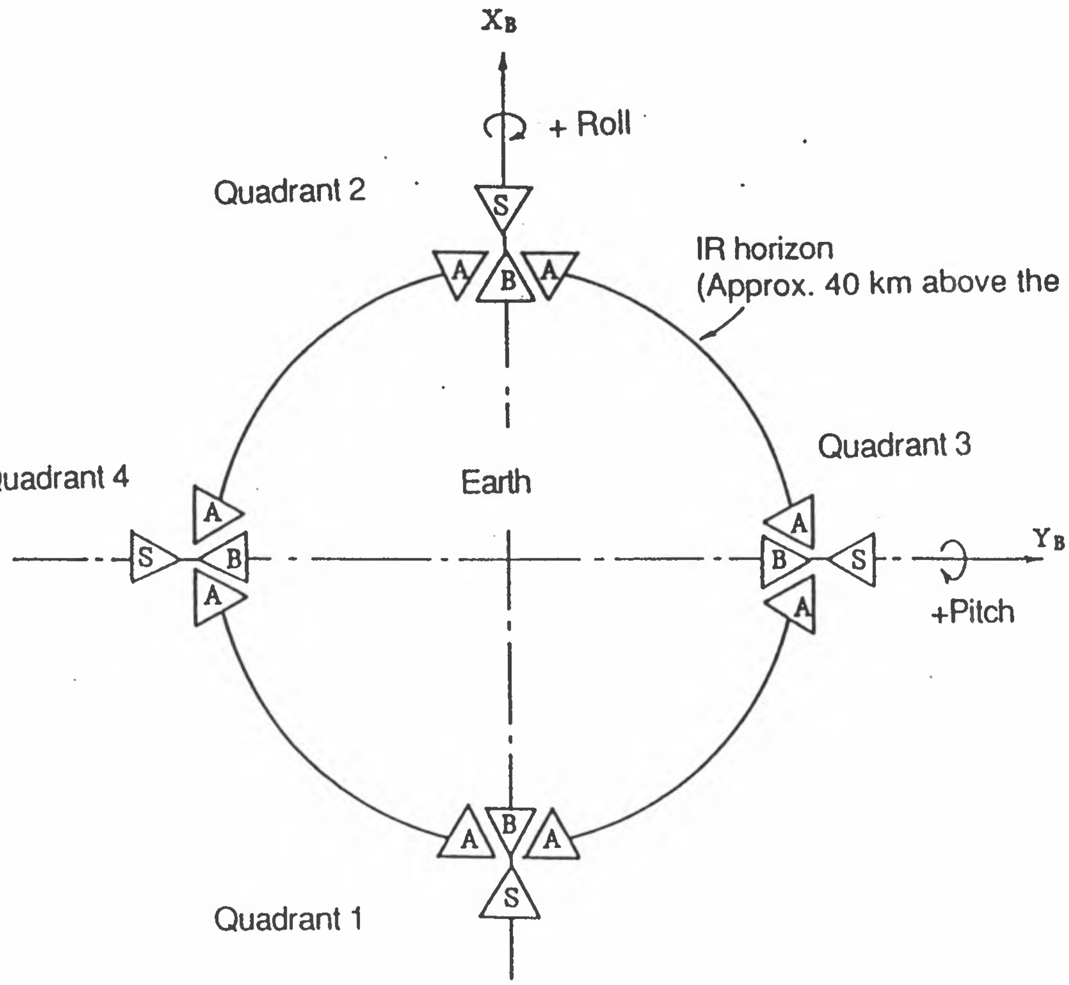


Figure 2.13 Principle of PSS Yaw Measurement

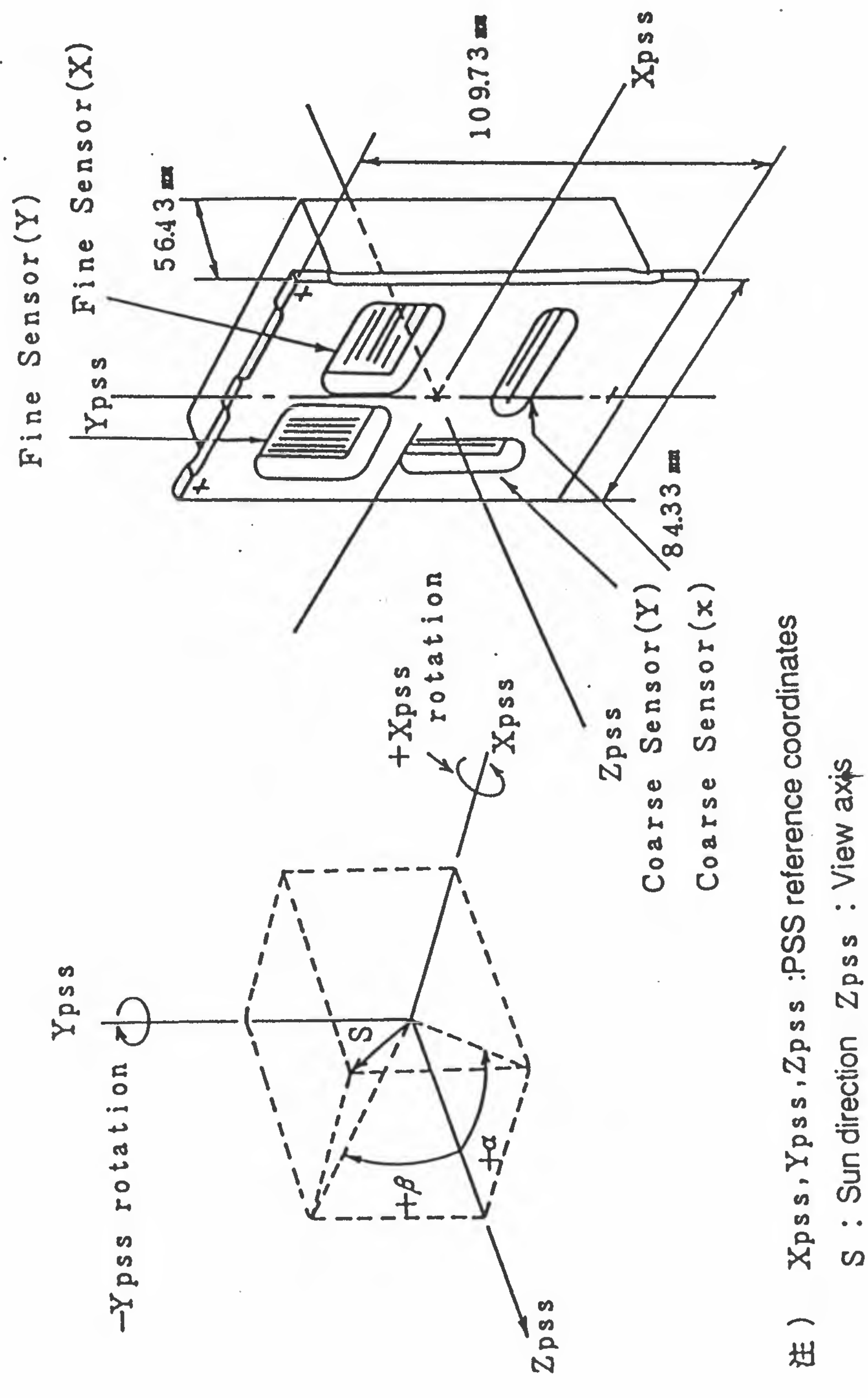
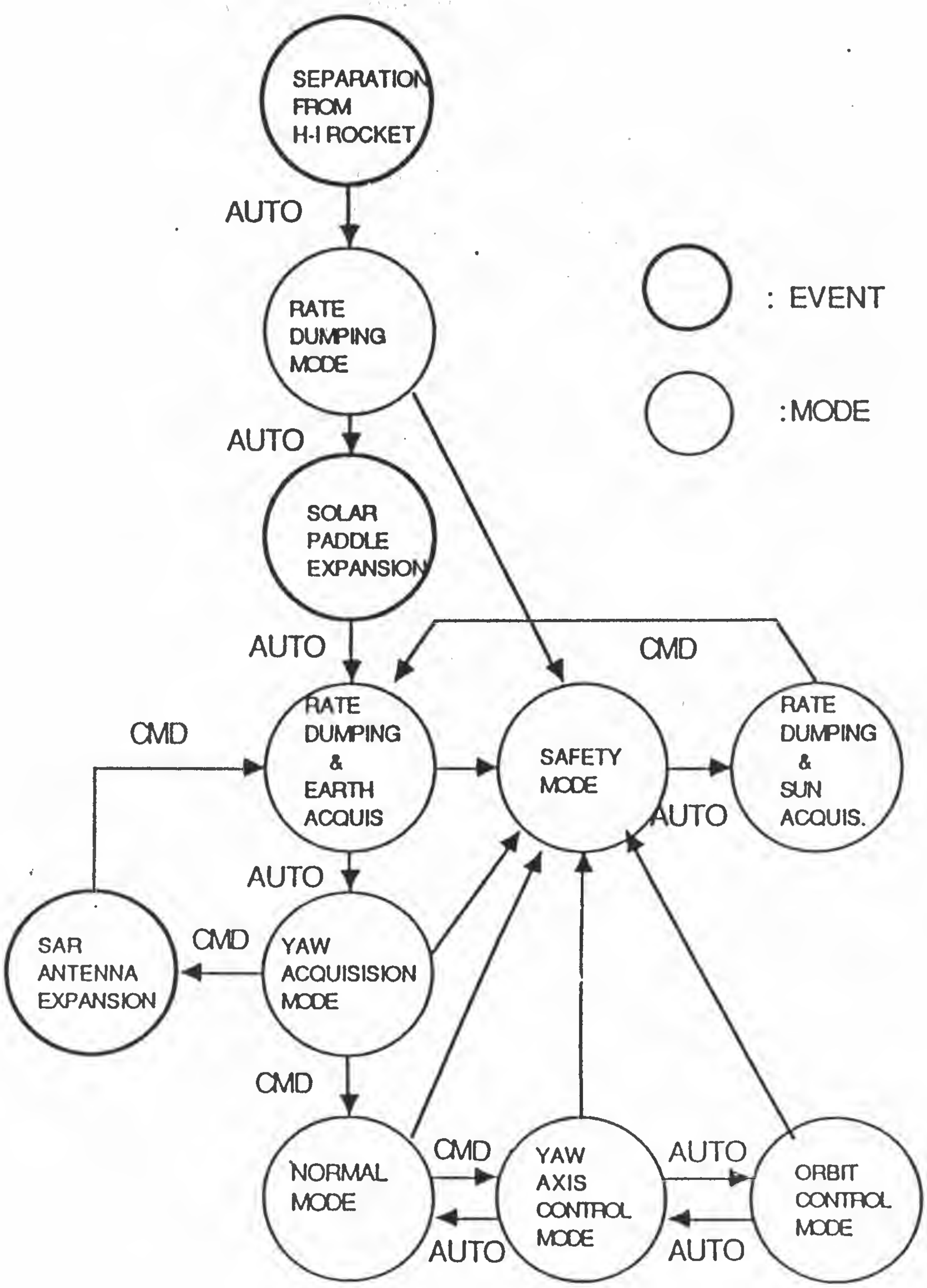


Figure 2.14 AOCS mode sequence



2.1.2.3 RCS

RCS consists of two tanks and 22 thrusters including a redundant system. The thruster use the catalytic breakdown of hydrazine, supplied from the pressurized tanks and generates 1 N thrust. In response to control signals from AOCS, RCS delivers necessary thrust for attitude acquisition, orbit control, attitude control during orbital control operations and RW unloading back-up.

2.1.2.4. EPS

High power mission instruments of JERS-1 cause large power load variatic to the satellite according to their operation profile. Long eclipse time due the low altitude makes it further difficult to maintain the power budget.

7.9 m × 3.5 m solar paddle generates 2053 w (minimum at the end of life) power in sunshine. The paddle is made of six panels and covered with 22344 Si cells with 2 cm × 4 cm size and 50 micro m thickness. A paddle drive mechanism (PDM) rotates the paddle to generate maximum power at all times.

JERS-1's power consumption in sunshine is approximately 2kw, while it drops to approximately 500 w in the eclipse. EPS adopts a regulated voltage bus system in sunshine, and, in eclipse, it switches to floating bus system. A stabilized bus system which boosts battery voltage was not employed because of its large conversion loss and internal heat dissipation. For bus voltage regulation, a digital sequential shunt is installed at the solar padd yoke to radiate heat to space, rather than inserting a series regulator in the bus line which dissipates heat inside the satellite. The digital sequential shunt also has merits of light weight, small heat dissipation, etc.

In sunlit, power from the solar paddle is regulated by power control unit (PCU), sequential shunt units (SSU) and battery charge controller (BCC) and supplied to the satellite loads through power distribution unit (PDU) at 33.6 to 35.0 regulated voltage. SSU consumes surplus power. In eclipse, discharged power from the four batteries is supplied to the satellite's loads BCC, PCU and PDU at 22.0 to 33.6 unregulated voltage.

Four BCCs control the charging current of batteries. BCC starts constant current charging at 9 A in the beginning, then reaching specified voltage given by battery's voltage-temperature control curves, switches to constant-voltage charging and the charging current tapers off. BCC has automatic charging halt/restart function to protect battery's maximum temperature, low voltage protection to prevent over-discharging, and heater temperature control of the batteries. It also provides reconditioning capability in the event of battery degradation. BCC issues under-voltage control (UVC) signal to PCU for turning off some mission instruments when it detects excessive battery voltage drops.

JERS-1 carries four Ni-Cd batteries with 22 cells 30 AH each. The satellite's large power consumption in eclipse and long eclipse time necessitate large current charging in sunlit. Charge/discharge cycles exceed 10000 times in 2 years and careful charging control is important from a viewpoint of battery lifetime management. Maximum depth of discharge (DOD) is set at 25 % in normal operation phase and 60 % in launch phase.

2.1.2.5 STR

JERS-1 is a large size box-type satellite, to which attached are two large deployable structures, i.e. solar paddle and SAR antenna, and weighs approximately 1340 Kg. Major design requirements for the structure are as follows:

(1)satellite structure with stowed solar paddle and SAR antenna needs to be housed in a launch vehicle's fairing envelope,
(2)spaces and heat dissipation areas are required for more than 140 components,
(3)the structure needs to be stiff enough for its tall configuration.

Figure 2.15 shows the JERS-1 structure breakdown. It has a size of 0.9 m x 1.8 m x 3.2 m and weight of 163 kg. The weight corresponds to 12.2 % of the total satellite mass and the figure is remarkably lower than those of earlier satellites.

JERS-1 has a composite structure which consists of CFRP frames, CFRP struts and nine aluminum honeycomb sandwich panels. The honeycomb sandwich panels carry components and also serve as structural materials. CFRP frames increase stiffness of the structure and transfer the weight load from the panels to the four attaching points with the launch vehicle. The struts are crossed to increase shear rigidity of the frame structure. The strut cross section is made of metallic matrix composite (MMC) of Al a SiC. The panel thickness is 3 cm, while 8 cm for the top panel where MDR, OPS are installed. The panels are covered with Al skins, except for two panels: top panel and anti-earth panel (lower) which are reinforced with CFRP skins.

<u>2.1.2.6 TCS</u>

TCS maintains the satellite temperature within specification from the launch to the end of mission life. Since JERS-1 carries many components with large heat dissipation and large heat load variation, TCS employs both passive and active thermal control systems. Features of TCS are as follows;

(1)OPS radiometers, MDR, RCS and batteries are fully decoupled from the satellite bus and controlled independently.

(2)SAR electronic components with large heat dissipation and heat loa variation are installed on +Y panel, where active thermal control is performed with the means of thermal louvers and heat pipes.

(3)Heaters are controlled automatically according to outer thermal environment and operation mode. When the satellite is in Safety mode, all the mission instruments are turned off and Safety heaters are turned on.

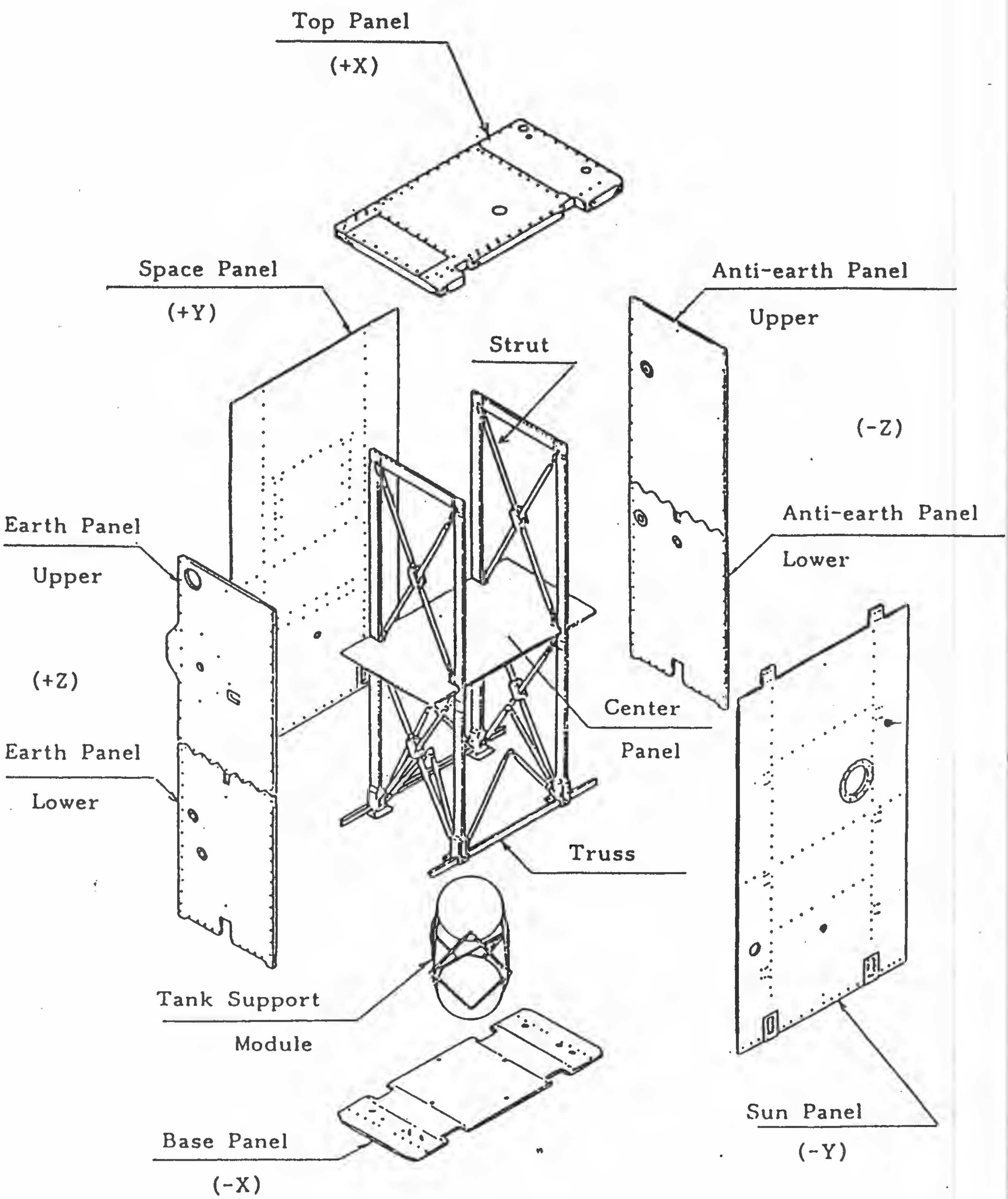
TCS is designed to cope with satellite's internal heat dissipation ranging from approximately 230 w/rev in average (Safety mode) to 573 w/rev. (SAR/OPS operation mode), and also cope with heat influx conditions due to the local mean time of 10:30 to 11:00.

Radiator area sizings were made in accordance with thermal flux density, allowed temperature ranges of each components. Total radiative areas (silver Teflon coated areas) are 3.6 square m and correspond to 20.7 % of the total satellite surface area.

Since heat dissipation efficiencies of +Y panel is high, large heat dissipating SAR components are installed on the panel and active controls with heat pipes and thermal louvers is conducted.

For low temperature, warm-up heaters, replacement heaters and Safety heaters are installed, and will be operated in accordance with outside thermal environment and operation mode.

Figure 2.15 The composition of structure system



2.1.3 Mission instruments

Mission instruments of JERS-1 consist of SAR, OPS, MDT and MDR. Details of the specification and performance characteristics of each mission equipment are described in chapter 3, 4, 5, and 6.

2.1.4 Alignment

Nominally all subsystems are aligned with the satellite coordinate system.

Misalignment between AOCS attitude reference coordinate system and the S/C coordinate system will be measured in the Proto-Flight Model test. The AOCS has a function to correct bias error in the output signal from the ESA and PSS with a command from the ground, and the misalignment will be compensated in computing the attitude data.

VNIR and SWIR are mounted on the top panel of the satellite separately. Therefore, misalignment between VNIR and the S/C coordinate system and misalignment between SWIR and the S/C coordinate system are measured independently. Interface specifications for the misalignments are set as follows:

X-axis	±0.16°
Y-axis	±0.20°
Z-axis	±0.22°

Misalignment between the radiometer optical axis and the radiometer reference system is estimated below 0.01°.

For SAR antenna misalignment with respect to the S/C coordinate system,the following interface specifications are set.

X-axis	±0.2°
Y-axis	±0.5°
Z-axis	±0.5°

2.2 GROUND SEGMENT

Ground supporting system of JERS-1 includes the tracking and control stations, data receiving and processing station, and data distribution organization.

2.2.1 JERS-1 tracking and control system

Tracking and Control Center (TACC) which is located in Tsukuba Space Center has responsibility for monitoring the health of the spacecraft and controlling the spacecraft (command transmission to JERS-1) to acquire data in accordance with mission requirements.

TACC is also responsible for maintaining JERS-1 orbit. This responsibility involves monitoring the orbit, conducting the orbit adjustment and providing orbit data with Mission Management Organization (in EOC) on routine basis. To accomplish this mission, JERS-1 tracking and control network during the operational phase is composed of Japanese Tracking and Control Stations (TACS) and TACC. In the initial operation phase the tracking and control of JERS-1 will be performed in collaboration with foreign networks such as ESA/CNES(Parth, Kourou and Kiruna) and NOAA (Fairbanks).

2.2.2 JERS-1 data acquisition and processing system

EOC/NASDA is responsible for JERS-1 data receiving and processing. At EOC/NASDA real-time data and MDR tape dump data are recorded onto High Density Digital Tape (HDDT). Quick look (Q/L) imagery of OPS is also produc in real-time and recorded on optical disk.

(1)Data receiving and recording

- Specification of High Density Digital Recorder (HDDR)

Type	: HD-96 or HD96E(Honeywell)
No. of track	: 28
Track assignment	: See Table 2.3.
Packing Density	: 33.333kbpi x 0.9
Tape Speed	: 104.35 ips

The raw data (HDDT) exchange is to conducted using this HDDR between EOC/NASDA and foreign stations.

- Specification of Optical Disk Equipment for QL

  Type : LVR-5000A(SONY)
  Input signal : NTSC
  Frame size : 640 pixel x 480 line
  Disk size : 30 cm(12inches)
  Capacity : 21000 Scenes/surface

- MDR tape dump

The data which is recorded by the on-board tape recorder (MDR) is reproduced backward (reverse reproduction) because of dispense with rewinding time of the MDR. Accordingly, the pre-processing equipment should be added for HDDR reproduction of MDR dump data.

(2)Data processing

The processed data are recorded onto digital optical disk (OD) or Computer Compatible Tape(CCT). The archiving media of EOC is OD. The product format of OPS basically resembles to that of Landsat TM and SPOT. The format of SAR is based on the recommendations of the Committee of Earth Observation Satellite (CEOS) working group.

(3)Data archiving and retrieval

The archiving of JERS-1 data is also performed at EOC/NASDA. This archiving facility employs catalog information storage for JERS-1 data as well as other Remote Sensing satellite data such as Landsat, MOS-1 and SPOT. These data can be obtained by computer from outside of EOC/NASDA.

Details of operation interfaces for foreign stations such as HDDR compatibility, Q/L interface, Catalog interface, etc. are described in JERS-1 Operation Interface Specification (HE-89033).

Table 2.3 HDDT Track assignment for JERS-1

HDDR Ch #	Tape Tr #	Contents Reading method	Recording signal
1	14	Digital	OPS or SAR data
2	16	Digital	OPS or SAR data
3	13	Digital	OPS or SAR data
4	17	Digital	OPS or SAR data
5	12	Digital	OPS or SAR data
6	18	Digital	OPS or SAR data
7	11	Digital	OPS or SAR data
8	19	Digital	OPS or SAR data
9	10	Digital	OPS or SAR data
10	20	Digital	OPS or SAR data
11	9	Digital	OPS or SAR data
12	21	Digital	OPS or SAR data
13	8	Digital	OPS or SAR data
14	7	Digital	OPS or SAR data
15	23	Digital	OPS or SAR data
16	6	Digital	OPS or SAR data
17	24	Digital	OPS or SAR data
18	5	Digital	OPS or SAR data
19	25	Digital	OPS or SAR data
20	4	Digital	OPS or SAR data
21	26	Digital	OPS or SAR data
22	3	Digital	OPS or SAR data
23	27	Digital	OPS or SAR data
24	2	Direct	IRIG-A time BNC C
25	28	FM	S band TLM BNC A
26	1	Direct	not use
-	15	-	Error Correction
-	22	-	Error Correction

2.2.3 Mission Management System

The main tasks of mission management are;

- Mission scheduling and planning
- JERS-1 mission data quick evaluation (Telemetry monitor)
- Technical information exchange with foreign stations
- Making mandatory information to operate the foreign ground station, such as orbit data, operation request, operation plan, post operation plan, etc.

The function of mission management, namely Mission Management Organization (MMO) is installed in EOC/NASDA.

The requests of data acquisition from end-users, foreign stations and investigators who participate in verification program are submitted to MMO. After that, MMO compromises these requirements and generates weekly schedule of mission operation.

The orbital information for receiving and processing in foreign stations are sent from MMO to each station using on-line system on routine basis.

Details of interface between MMO and foreign stations regarding mission scheduling and orbit data exchange are described in JERS-1 Operation Interface Specification(HE-89033).

2.3 JERS-1 ORBIT

2.3.1 Nominal orbit parameters

The JERS-1 orbit is a sun-synchronous, near-recurrent orbit. Nominal orbit parameters are summarized in Table 2.4.

Table 2.4 JERS-1 Orbit Parameters

Altitude (at the equator)	568.023 km
Semi major Axis	6946.165 km
Inclination	97.662 deg
Period	96.146 min
Eccentricity	less than 0.0015
Argument of Perigee	90 ± 30 deg
Mean Anomaly	0.0 deg
Recurrent Period	44 days
Revolution per day	15 - 1/44
Drift Direction	Westward
Drift skipping	None
Local Mean Time	10:30 - 11:00

2.3.2 JERS-1 Scene Identification

2.3.2.1 Reference System for Planning(RSP)

The Reference System for Planning is defined as the coordinate system for mission planning. This coordinate system is used in a file between EOC and TACC or between EOC and foreign ground station. General user need not know this system.
The basic idea of RSP is shown as follows;

(1) The coordinate is expressed by the Path and the set of start/end latitudes.
(2) The Path number is defined as the same concept as that of the World Reference System(WRS).
(3) The start and stop latitudes are used instead of Row number. The latitude is expressed in the range from 0 to 360 degrees. The location of 0 degree is on the ascending node.

As mentioned in section 2.3.1, recurrent period and number of revolution per day of JERS-1 are;

Recurrent period = 44 days --------------(2-1)
Number of revolution per day = 15 - 1/44 --------------(2-2)

From Eqs.(2-1) and (2-2), Total path number can be computed as Eq.(2-3).

Total path no. = (15 - 1/44)×44
= 659 --------------------------------(2-3)

In order to avoid the change from Path No.659 to Path No.1 on important part of the world ,the longitude of Path No. 659's ascending node is decided (-1.153 degree : sign (-) means west longitude).

2.3.2.2 Ground Reference System(GRS)

At first we had a plan to use the World Reference System (WRS) for the scene ID for general users. The WRS is very convenient for nadir looking sensors, but JERS-1 has OPS ,which is nadir looking sensor ,and SAR ,which has off-nadir angle. The disadvantage of this idea is the complexness of the modelization due to having two models ,and redundancies of number of grids in north and south pole region and also in the ascending paths. So the GRS,which is adopted for JERS-1, is made unique mainly parallel to the descending path without discrimination for SAR and OPS.
The requirements for the GRS are summarized as follows;
(1)To make the GRS model simple
(2)To make us imagine the sub-satellite track in the map
(3)To distribute the scene grids with nearly equal distance,all over the world

The main feature of JERS-1's GRS are shown as follows;
(1)GRS is set in only descending path to keep the uniqueness.
(2)GRS is expressed by two integers,Path and Row.
(3)To keep the distance between two grids in any regions,world is separated in 5 zones from north to south,such as north polar,north latitude,mid latitude,south latitude and south polar region. The GRS grid of each zone is independently defined.
(4)In north polar and south polar region , GRS grid is set parallel to the latitude and longitude line. To keep the grid distance nearly equal, path number is thin out. The rate of thin out is changed from 3 to 13.
(5)Central 3 zones are fully following the subsatellite track model. But in north and south latitude region, thin out of one by two paths is done.

(6)In north and south latitude region,path number is thin out and odd number is selected. So, the path 659 and 1 are continuously existing.

Each zone is described in Figure. 2.16
Details of RSP and GRS, for example how to calculate or how to use, are described in JERS-1 Operation Interface Specification(HE-89033).

Figure 2.16 Zone definition of GRS

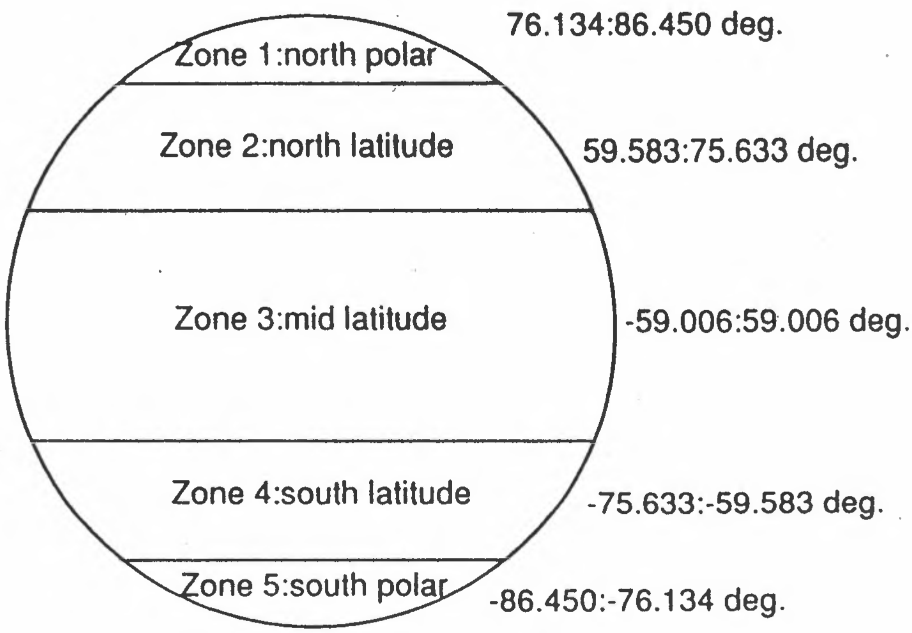


Figure 2.17 Local mean time

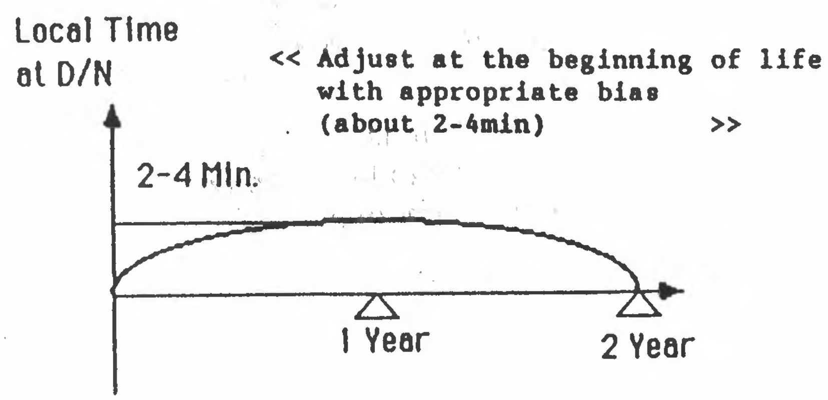


Figure 2.18 Orbit drift and altitude maneuver

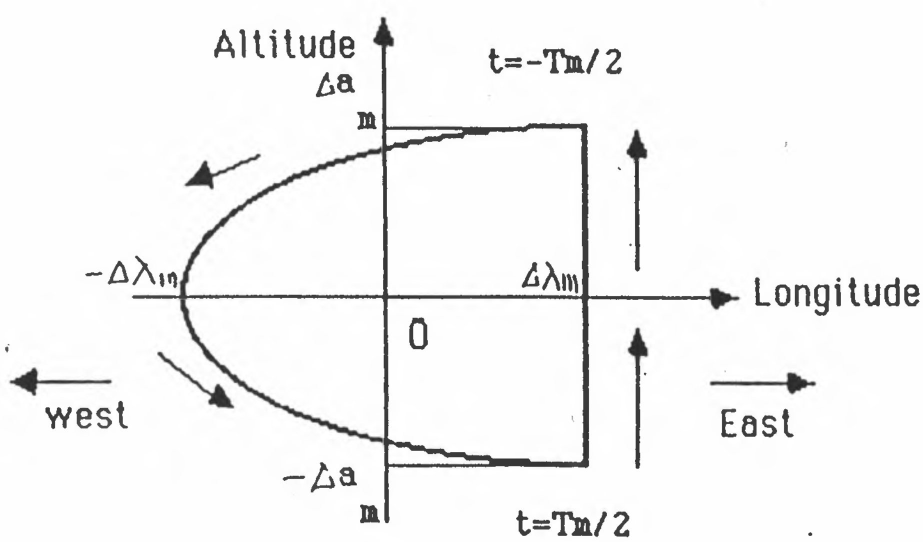
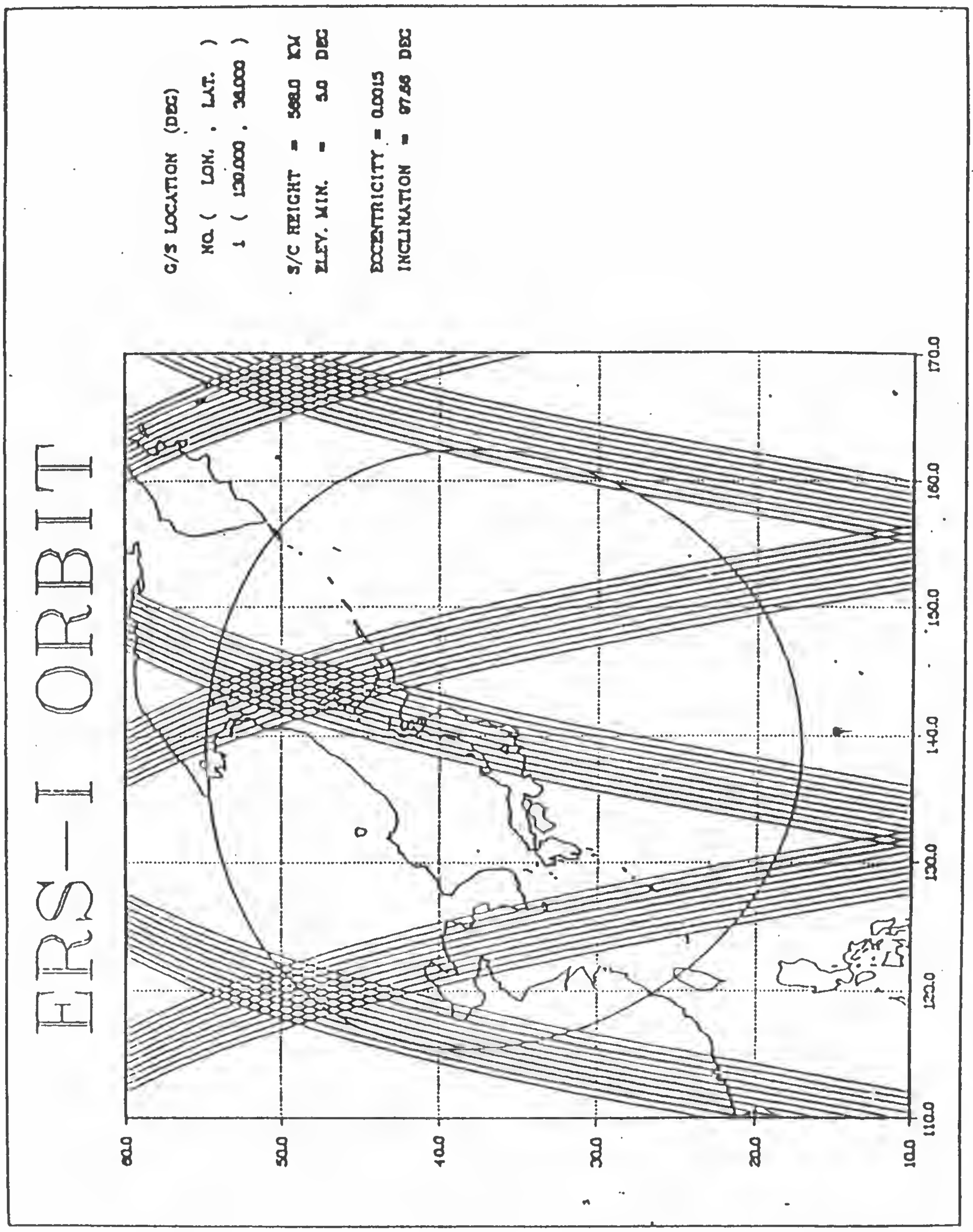


Table 2.5 Relationship between density of the atmosphere and frequency of altitude maneuver (Preliminary)

P(Kg/m3)	a(Km/day)	am(Km)	Tm(day)
1.55×10^{-12}	0.212	0.573	5.4
0.65×10^{-12}	0.089	0.371	8.3
0.18×10^{-12}	0.025	0.197	15.7

am : Target altitude bias
Tm : Frequency of altitude maneuver
a : Drop rate of semi-major axis

Figure 2.19 JERS-1 orbit



3. OPS (Optical Sensor)

3.1 General

The OPS is a multi-spectral imaging radiometer with the resolution of 18.3 m x 24.4 m on the earth. This system is composed of Visible and Near Infrared Radiometer(VNIR), Short Wave Infrared Radiometer(SWIR), and Signal processor. The both radiometers use charge-coupled devices (CCD) with 4096 elements in detector. The SWIR has Pt Silicon Schottky-Barrier type CCD.

The OPS has 4 VNIR bands (one of which is stereoscopic) and 4 SWIR bands.

OPS's high-speed observation data (30 Mbps x 2 ch) is formatted by signal processor and then sent to Mission Data Transmitter (MDT).

3.2 OPS design parameters

Major characteristics of OPS is shown in Table 3.1. VNIR consists of 4 bands with stereoscopic viewing capability. Band 4 views 15.33 deg. forward which constitutes stereoscopic observation with nadir viewing Band 3. SWIR is composed with 4 bands in shortwave infrared wavelength region. The ratio of base to height would be 0.3 which corresponds to theoretical terrain altitude estimation accuracy of about 80 m. Functional block diagram of OPS is shown in Figure 3.1. Calibration for the electronics, temperatures control unit, and active Sterling cooling system are included in the radiometer compartment. Analog output are quantized by 6 bits A/D converter then the sequential digital output are transferred to Mission Data Transmitter (MDT).

Figure 3.2 illustrates the principle of electronic scanning. As is shown in Figure 3.3, OPS is composed of two optical systems. One of them is for VNIR with stereoscopic imaging while the other is for SWIR. Figure 3.4 (1) and (2) indicate image geometry of each optical system.

On the other hand,the along track resolution can be computed using the values of the spacecraft velocity and sampling frequency (sample time per one line). One of the important factors to be considered in order to decide the value of sampling frequency is the restriction of transmission capability and/or on-board tape recorded recording capacity. Because JERS-1 system employs 6(Mbps tape recorder (See MDR specification, Section 7.2), the values o sample frequency per line and quantization level should meet the followin(equation;

$$N \times B \times P / T < 60\text{MBps} \qquad \text{------------------} \qquad (3\text{-}1)$$

where	N	:	Quantization level	(bits/pixel)
	B	:	Number of Bands = 8	(bands)
	P	:	Number of Pixels = 4096	(pixels)
	T	:	Sample frequency per line	(sec)

Based upon the trade-off study considering user requirements, the values of N=6 bits and T=3.46 msec were selected, respectively.
Consequently, the along track resolution becomes 24.4 m.

Table 3.1 Major characteristics of OPS

- OBSERVATION WAVE LENGTH

BAND	Center wavelength (μm)	Bandwidth (μm)	Dynamic range ($W/m^2 \cdot str \cdot \mu m$)
1(VNIR)	0.56 ±0.01	0.08 ±0.02	0 - 324
2(VNIR)	0.66 ±0.01	0.06 ±0.02	0 - 250
3(VNIR)	0.81 ±0.01	0.10 ±0.02	0 - 248
4(VNIR)	0.81 ±0.01(STEREO)	0.10 ±0.02	0 - 239
5(SWIR)	1.655 +0.016 -0.015	0.11 ±0.02	0 - 33.3(NOMINAL VALUE)
6(SWIR)	2.065 +0.015 -0.017	0.11 ±0.02	0 - 17.8(NOMINAL VALUE)
7(SWIR)	2.19 +0.015 -0.019	0.12 +0.02 -0.023	0 - 13.7(NOMINAL VALUE)
8(SWIR)	2.335 +0.015 -0.020	0.13 +0.022 -0.024	0 - 10.8(NOMINAL VALUE)

NOTE:Bandwidth is defined at half of peak power.Center frequency is at the center of bandwidth.

- STEREO ANGLE(VNIR) 15.33±0.21 deg (B/H=0.3)
- PIXEL NUMBER/BAND 4096
- SCANNING WIDTH 75km
- SAMPLING PERIOD 3.46 msec ± 1%
- OUTPUT DATA RATE 30Mbps × 2CH
- FIELD OF VIEW 7.55 ± 0.2 deg.
- IFOV 32.2 ± 1.0 μrad.
- RESOLUTION (cross track) = altitude × IFOV = 568.023 km × 32.2 μrad
  (along track) = s/c velocity × sampling frequency
  = 6.946 (km/sec) × 3.46 (msec)
- FOCAL LENGTH VNIR :215.3mm± 1% SWIR:310.0mm (Band 5)

Doc No : HE-88023
Revision : 2
Date : 26 OCT 90
Sheet : 3 - 4

Figure 3.1 Functional block diagram of OPS

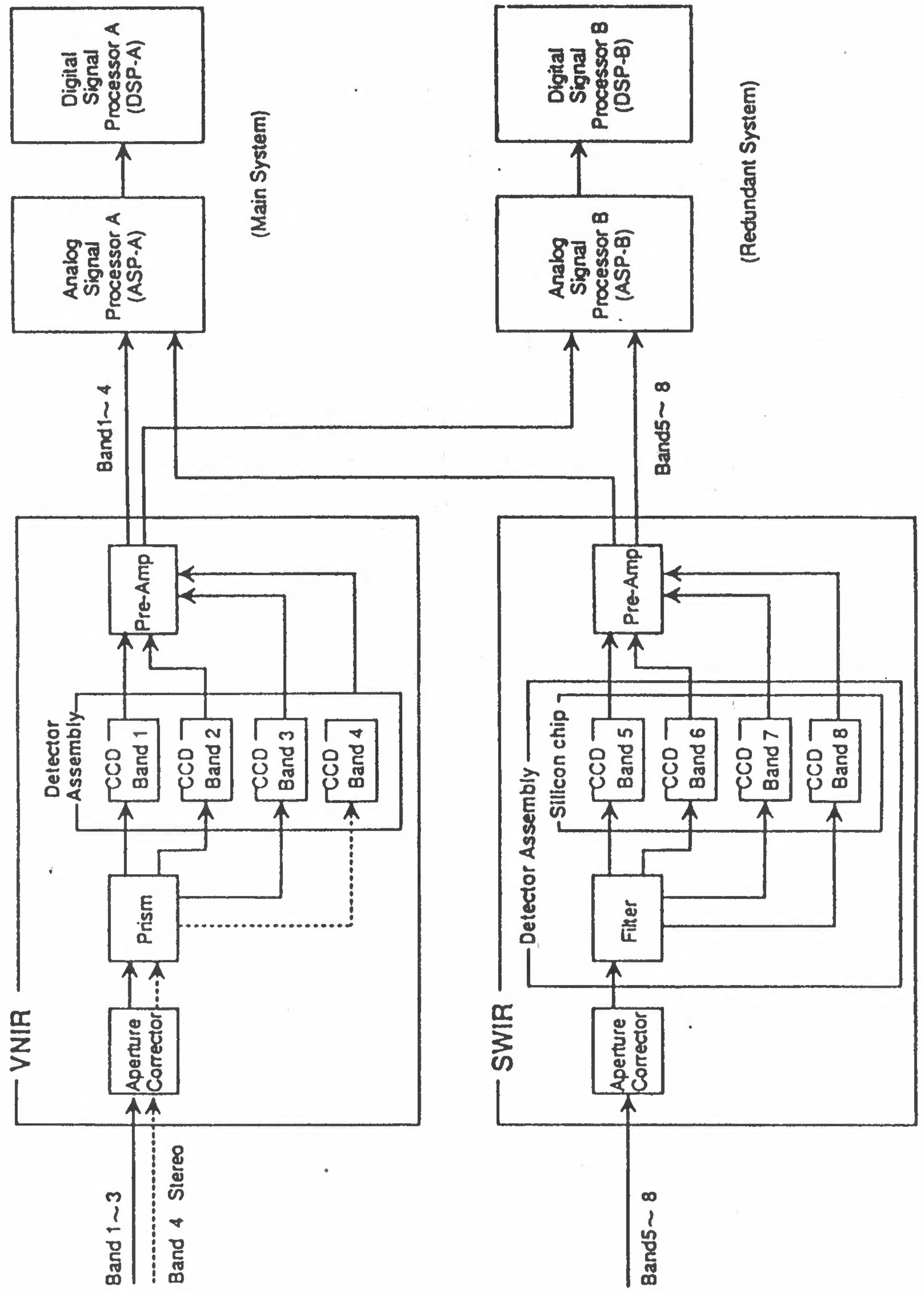
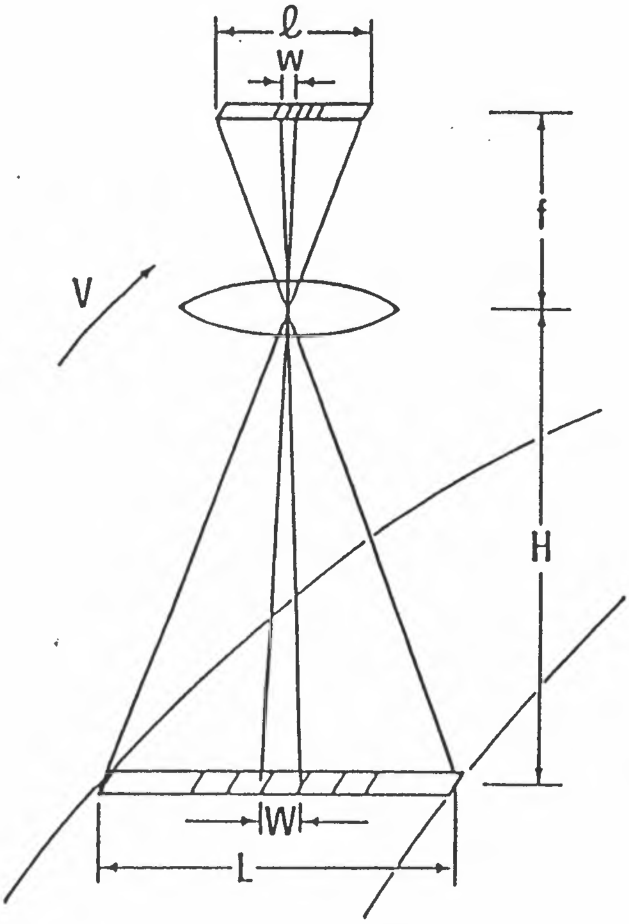


Figure 3.2 Principle of electronic scanning



H : The altitude of the satellite

v : The speed of the satellite

W : The width of one image element on the ground surface

N : The number of image elements per scanning line width

L : Ground surface scanning width ($L = N \times W$)

w : Sensor image element size

ℓ : Sensor length

f : The focal length of the optical system

$$\left(f = \frac{w}{W} \times H\right)$$

Figure 3.3 Out-look of OPS

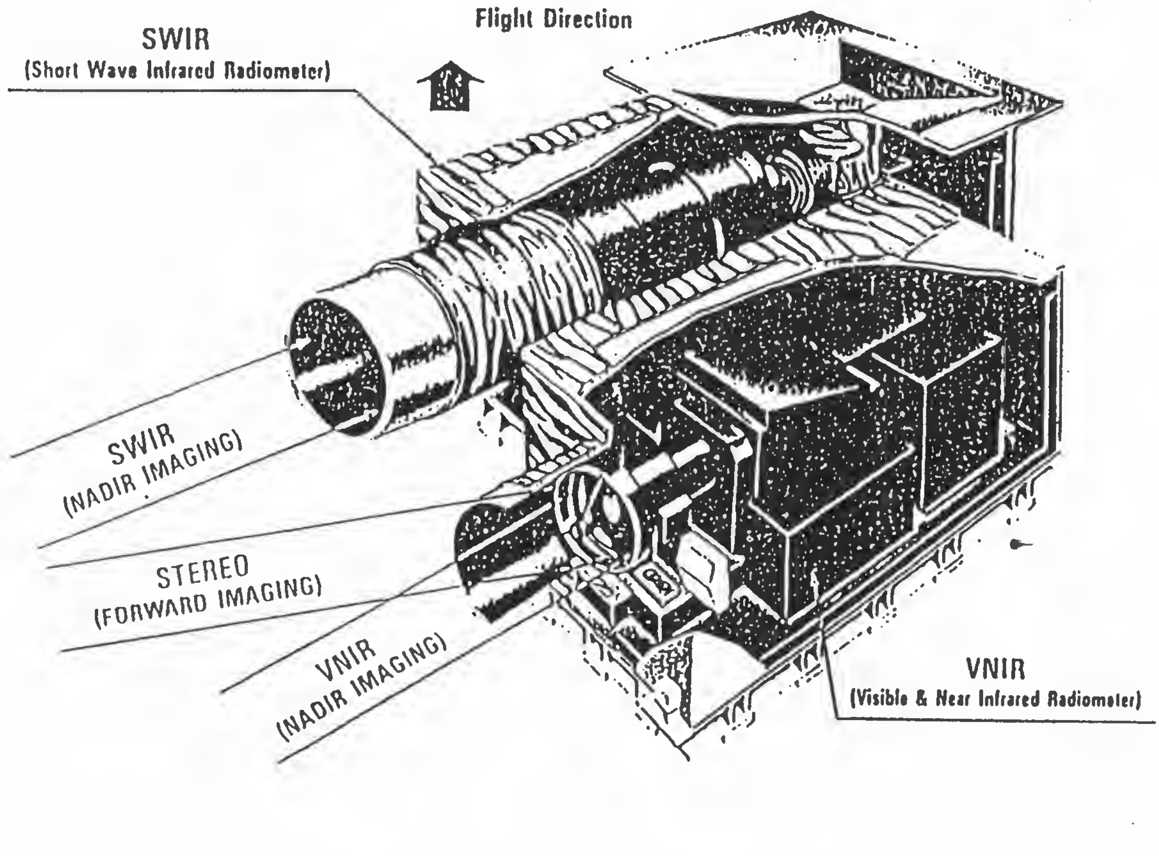


Figure 3.4 (1) VNIR Image Geometry

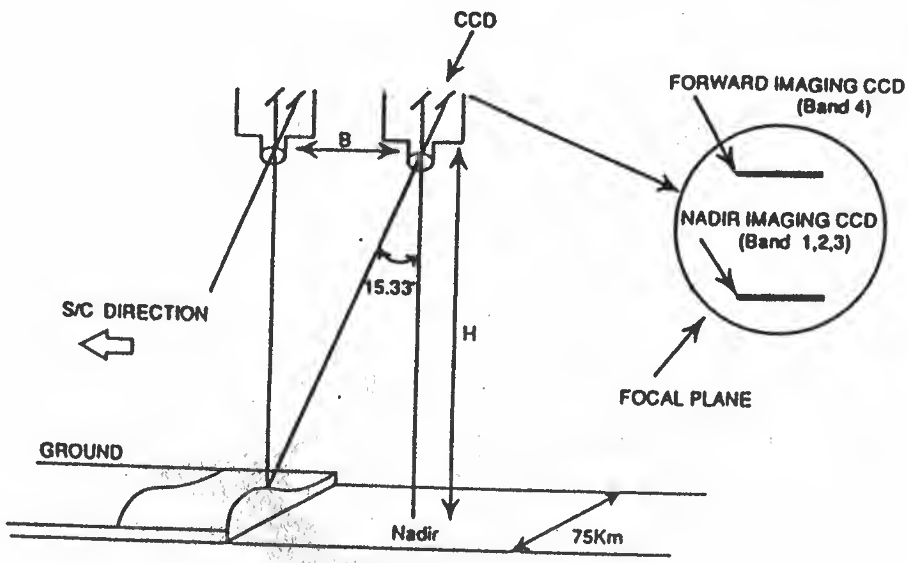
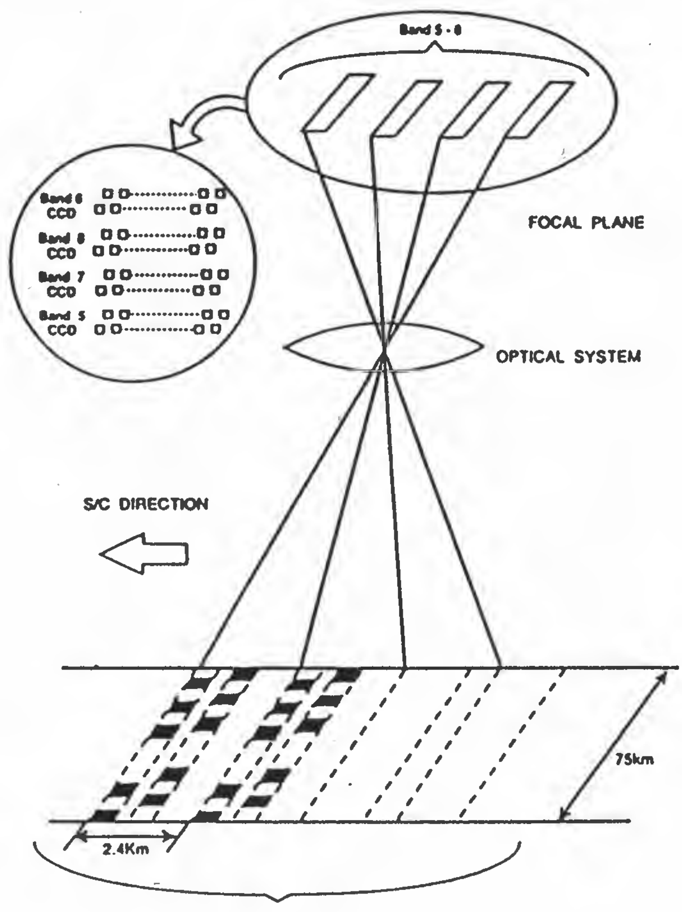


Figure 3.4 (2) SWIR Image Geometry

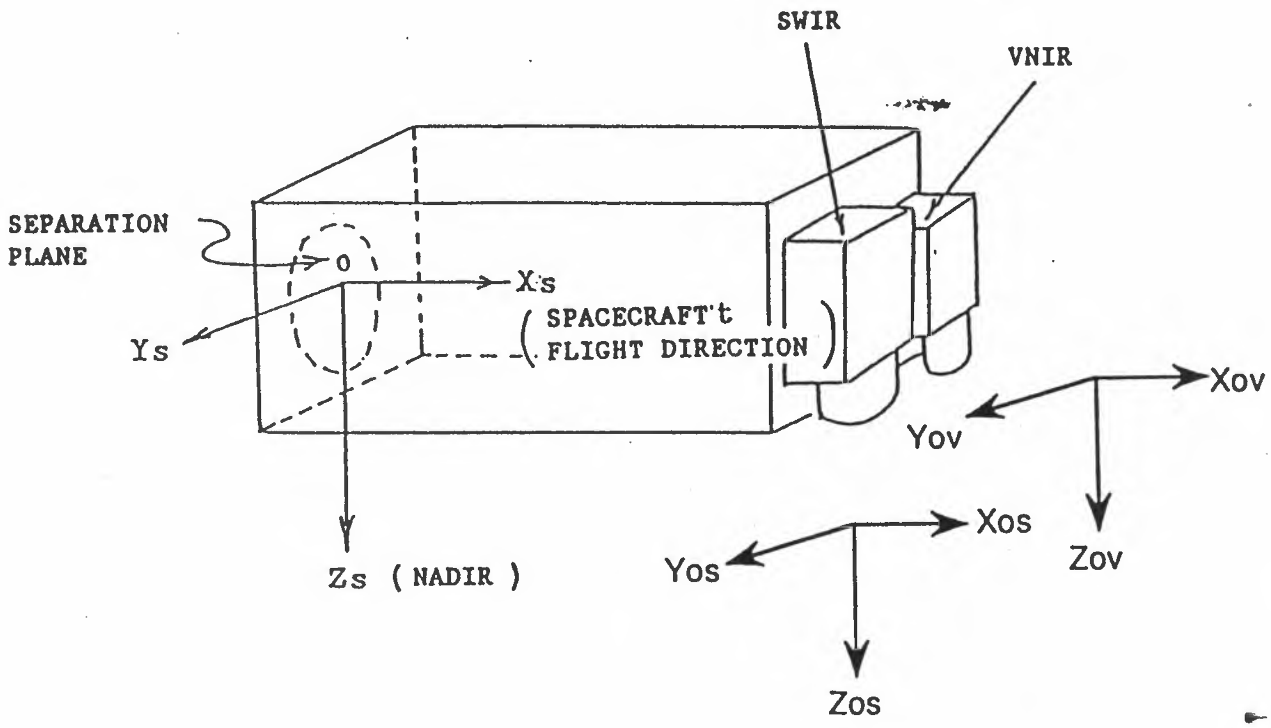


3.3 Instrument geometry

The relationship between "spacecraft body axis" and "VNIR and SWIR axis" are indicated in Figure 3.5. The alignment will be measured at proto-flight test.

Details of the information of instrument geometry will be available after the proto-flight test.

Figure 3.5 Relationship between spacecraft body axis ,VNIR axis and SWIR axis



Xs , Ys , Zs, ...SPACECRAFT BODY AXIS
Xov, Yov, Zov...............VNIR AXIS
Xos, Yos, Zos...............SWIR AXIS

3.4 Alignment

In order to perform geometric correction, it is important to know the precis viewing direction with reference to the spacecraft body coordinate systerr After proto-flight test,the alignment error of VNIR and SWIR will b measured. Figure 3.6. shows the measured error angles in preflight test.

To convert from satellite coordinate (x_s,y_s,z_s) to VNIR coordinate (x_{ov},y_{ov},z_{ov}) the following equation is adopted.

$$\begin{pmatrix} x_{ov} \\ y_{ov} \\ z_{ov} \end{pmatrix} = \begin{pmatrix} \cos\theta_y & \sin\theta_y & 0 \\ -\sin\theta_y & \cos\theta_y & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\theta_p & 0 & -\sin\theta_p \\ 0 & 1 & 0 \\ \sin\theta_p & 0 & \cos\theta_p \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_r & \sin\theta_r \\ 0 & -\sin\theta_r & \cos\theta_r \end{pmatrix} \begin{pmatrix} x_s \\ y_s \\ z_s \end{pmatrix}$$

----- (3-2)

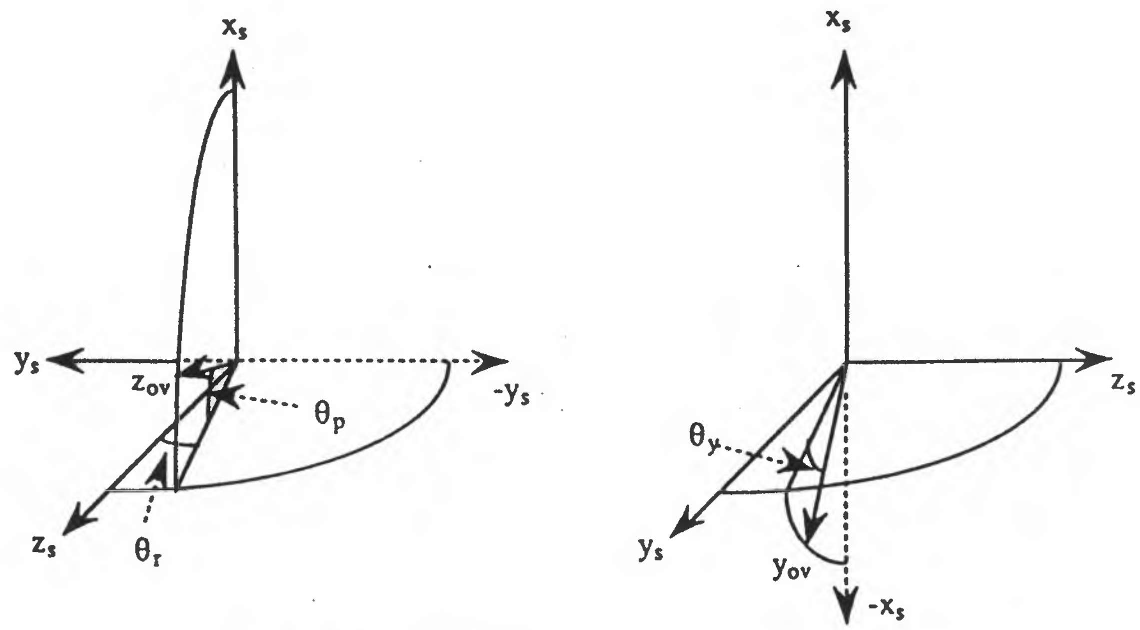
The same equation is applicable for conversion from satellite coordinate tc SWIR coordinate(x_{os},y_{os},z_{os}).

The coordinate of VNIR band 4 (x_{v4},y_{v4},z_{v4}),which is a stereo band, is made tc be rotated around the y axis of VNIR coordinate. To convert from VNIR coordinate (x_{ov},y_{ov},z_{ov}) to the band 4 coordinate,the following matrix is used.

$$\begin{pmatrix} x_{v4} \\ y_{v4} \\ z_{v4} \end{pmatrix} = \begin{pmatrix} \cos B & 0 & -\sin B \\ 0 & 1 & 0 \\ \sin B & 0 & \cos B \end{pmatrix} \begin{pmatrix} x_{ov} \\ y_{ov} \\ z_{ov} \end{pmatrix}$$

where B=15.33 deg. ----- (3-3)

Figure 3.6 Measured alignment error



x_s: Roll Axis of Satellite

y_s: Pitch Axis of Satellite

z_s: Yaw Axis of Satellite

y_{ov} :Pitch Axis of VNIR

z_{ov} :Yaw Axis of VNIR

$\theta_r, \theta_p, \theta_y$: Measured angle in pre-launch test

3.5 Geometric characteristics of OPS

The basic theories of imaging are as follows;

1) Visible Near Infrared Radiometer(VNIR); band 1 - band 3

VNIR employs the general method to scan with pushbroom technique around the nadir point by one-dimensional CCD sensor. Band 1,2 and 3 divide reflected light into prismatic spectrum according to the optics. It makes possible for each element to image the same point of field,so parallax cannot occur theoretically. Configuration of VNIR is shown in Figure 3.7.

2) Stereoscopic imaging of OPS ; band 3 and 4

As illustrated in Figure 3.4(1) stereoscopic imaging is obtained by the system which composes nadir viewing (band 3) and forward viewing (band 4) . The stereo angle is 15.33 degree, corresponding to B/H ratio of 0.3.

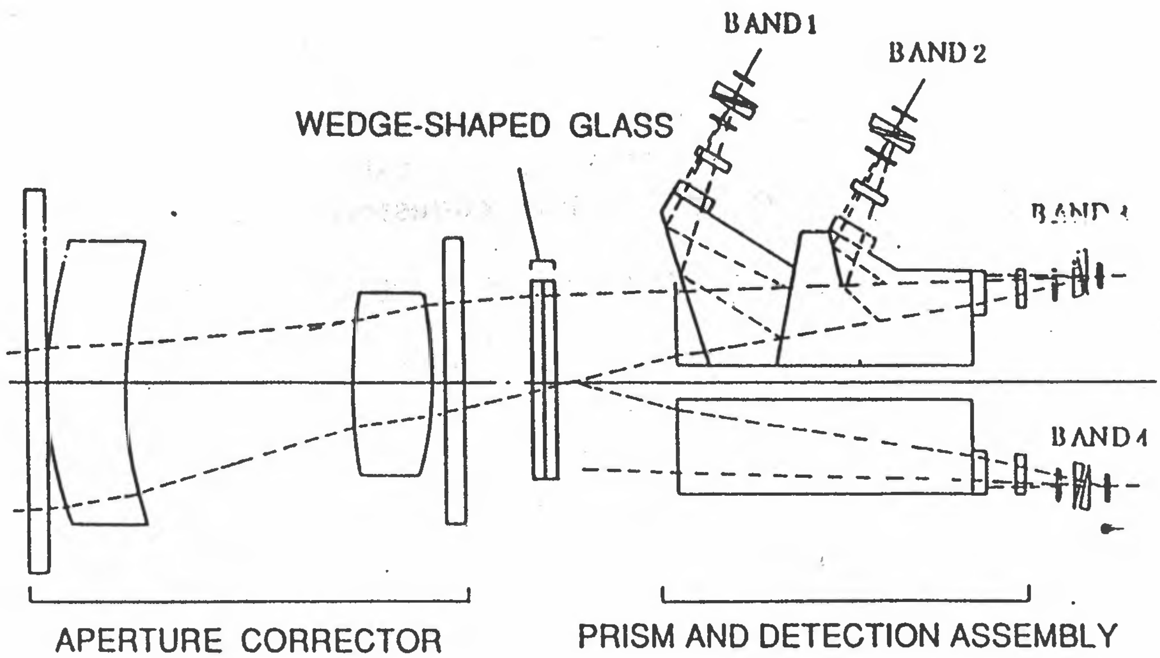
3) Short Wave-length Infrared; band 5 - 8

The CCD are arranged on the focal plane of OPS system. Each band instantaneously images different point of field. Furthermore within one band, even elements and odd elements are arranged in 2 staggered arrays as illustrated in Figure 3.8 and Figure 3.9. This arrangement causes an aberration of about one element along the satellite flight direction.

In order to perform geometric correction, the spacing of each detecting elements and observation pattern on the ground should be considered as shown in Figure 3.9(c).

From Figure 3.9(b), the distance of even and odd detecting elements from the SWIR reference optical axis can be computed and summarizes in Table 3.2.

Figure 3.7 Configuration of VNIR optical system



Doc No :	HE-88023
Revision	: 2
Date :	26 OCT 90
Sheet :	3 - 1 4

Figure 3.8 CCD array of SWIR on focal plane

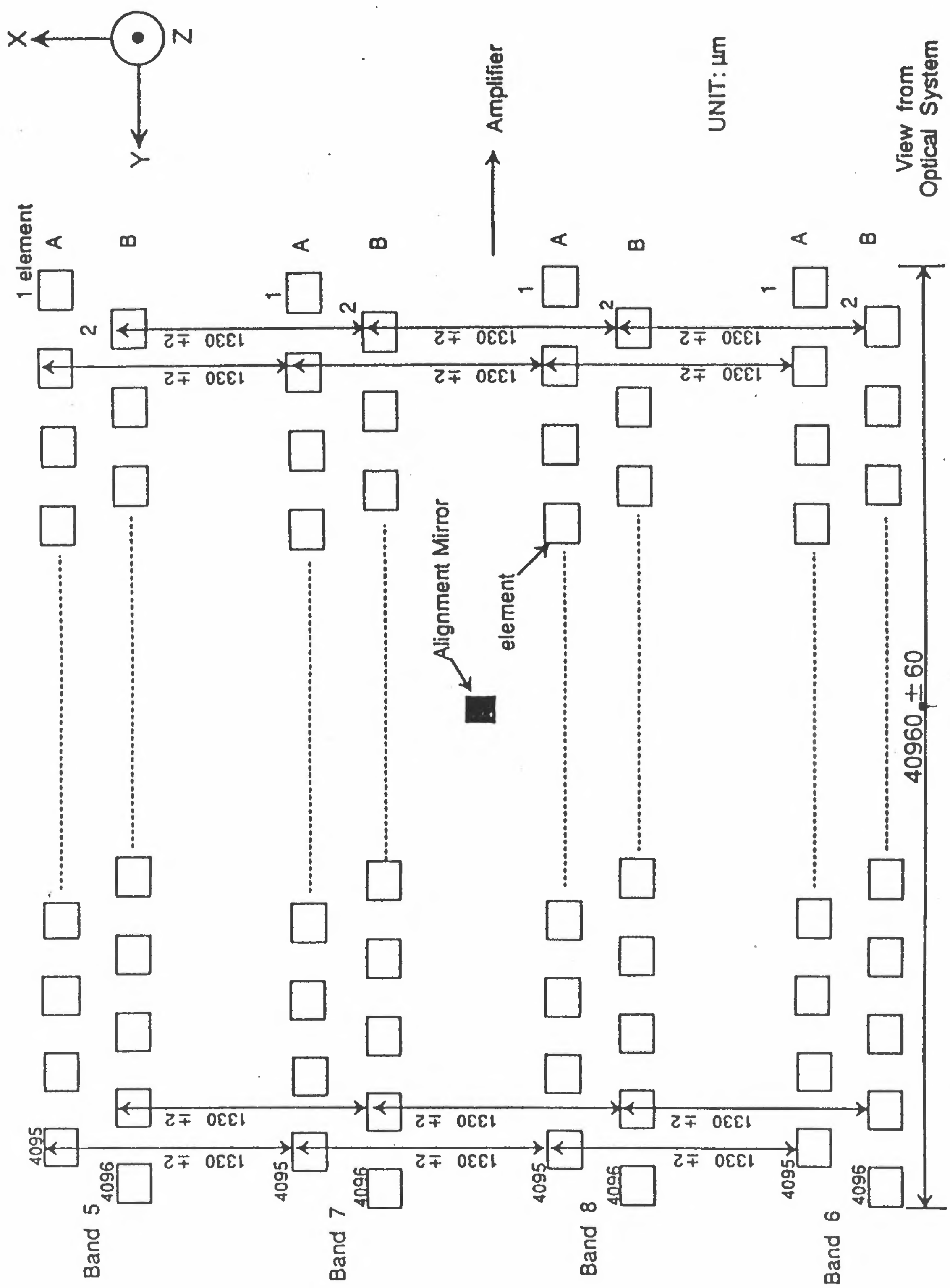
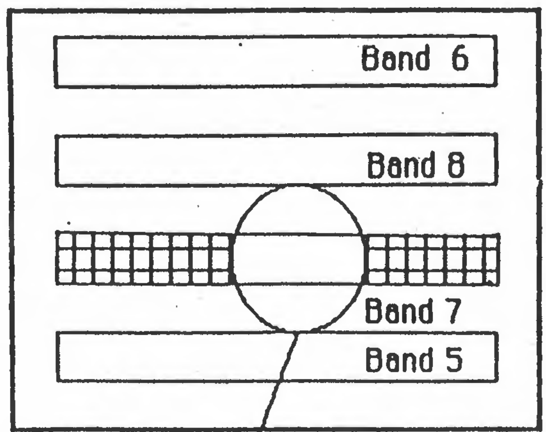


Figure 3.9 Spacing of SWIR CCD array and ground observation pattern

Figure 3.9(a) SWIR CCD array location



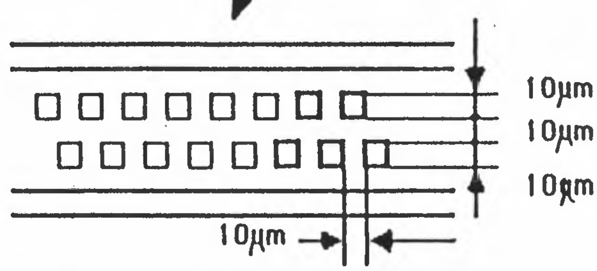


Figure 3.9(b) SWIR CCD spacing

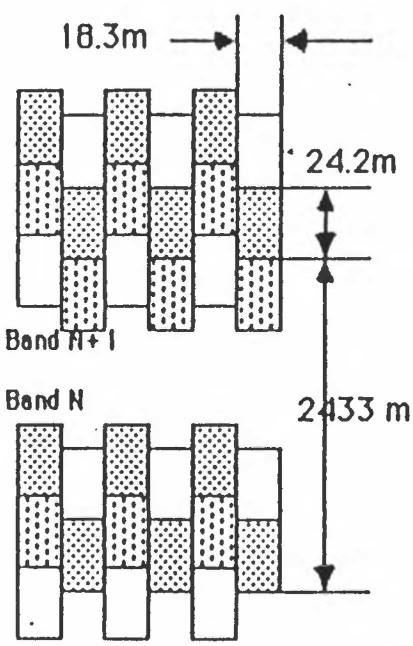


Figure 3.9(c) Observation Pattern on the ground

Table 3.2 SWIR CCD geometry(Nominal)

Band	even/odd	lx(mm)	Lx(Km)
6	even	+2.005	+3.6691
	odd	+1.985	+3.6325
8	even	+0.675	+1.2352
	odd	+0.655	+1.1986
7	even	-0.655	-1.1986
	odd	-0.675	-1.2352
5	even	-1.985	-3.6325
	odd	-2.005	-3.6691

$Lx = \{ lx \times Hs/c \}/fswir = \{ lx \times 568.023\text{Km} \}/310.4\text{mm}$

$\tan^{-1}\{ lx / fswir \} = \tan^{-1}\{ lx / 310.4 \}$

Lx : Distance from the reference point on the ground
lx : Distance from the reference point on the detector
Hs/c : Altitude of the JERS-1 spacecraft = 568.023 Km
fswir : Focal length of SWIR = 310.4 mm

3.6 OPS radiometric characteristics

3.6.1 Sensitivity and sensitivity deviation

The Sensitivity of OPS is defined for each detector element. The deviation is measured at the output of pre-amp. The sensitivity deviation of VNIR is within 20 % of the output of maximum pixel,while that of SWIR is within 48%.

3.6.2 Dynamic range

The specification of the maximum radiance of each band is listed in Table 3.3. Minimum radiance of each band is 0.

Table 3.3 Max. radiance of each band {W/(m2· str· μm)} (Specification)

Band	Rmax	Band	Rmax
1	324	5	33.3
2	250	6	17.8
3	248	7	13.7
4	239	8	10.8

When the maximum radiance is input to OPS,the output levels after A/D conversion are listed in Table 3.4.

Table 3.4 Output level at Maximum Radiance (measured)

BAND	OUTPUT LEVEL (at Max. Radiance)			
	MAIN		SUB	
	2048PIXEL	2049PIXEL	2048PIXEL	2049PIXEL
1	57	57	57	57
2	58	56	58	56
3	60	56	60	56
4	57	58	57	58
5	49	54	52	55
6	53	52	53	53
7	52	50	53	49
8	52	53	53	54

3.6.3 Signal to Noise ratio (S/N)

The signal to noise ratio at the high input level(Maximum radiance) and low input level(1/5 maximum radiance) are given in Table 3.5. The measuring point of S/N is the output of pre-amplifier , so the S/N of signal processor is not included.

Table 3.5 S/N of OPS

BAND	High Input Level				Low Input Level			
	S/N(dB) (SPEC)	S/N(dB) (Measured)		Input Radiance {W/(m²·str·μm)}	S/N(dB) (SPEC)	S/N(dB) (Measured)		Input Radiance {W/(m²·str·μm)}
		Ach	Bch			Ach	Bch	
1 Main	36	49.6	48.8	324	23	36.3	35.8	64.8
1 Sub		47.8	48.9			34.5	39.3	
2 Main	35	48.7	48.4	250	22	37.3	36.7	50.0
2 Sub		46.5	47.6			35.6	36.7	
3 Main	36	49.6	49.5	248	23	38.0	38.4	49.6
3 Sub		48.7	49.1			34.1	37.3	
4 Main	36	49.6	50.6	239	23	36.9	39.2	47.8
4 Sub		50.0	48.7			36.7	37.0	
5 Main	32	40.6	41.4	33.3	19	27.3	28.1	6.66
5 Sub		40.8	39.3			27.1	28.2	
6 Main	30	39.5	40.2	17.8	16	25.7	28.6	3.56
6 Sub		39.4	39.3			24.6	26.5	
7 Main	28	37.1	36.9	13.7	14	23.3	25.6	2.74
7 Sub		37.5	36.4			22.1	24.2	
8 Main	24	37.1	38.4	10.8	10	24.0	25.9	2.16
8 Sub		39.5	39.3			24.0	25.0	

Ach :for Odd pixels
Bch :for Even pixels
Main :Main system(ASP-A + DSP-A)
Sub :Redundant system(ASP-B + DSP-B)

3.6.4 Modulation Transfer Function

The measured value of MTF of each band is listed in Table 3.6.

Table 3.6 MTF of each band (Measured value of 2049th. pixel)

Band	MTF(at Niquist Frequency)	
	Along track	Cross track
1	16%	
2	14%	
3	17%	
4	14%	
5	24%	18%
6	19%	13%
7	21%	16%
8	20%	15%

3.6.5 Offset characteristics

Offset includes both dark current of CCD and circuit offset. The dark current generated in each CCD sensor depends on the sensor temperature , while the circuit offset is independent of the temperature.
The model of offset at the output of pre-amplifier is shown as follows;

VNIR : $V_0=V_p+V_c \cdot 2^{a \cdot (t-t_c)}$

SWIR : $V_0=V_c+a \cdot (t-t_c)$ (3-4)

where
V_0: Offset (mV)
V_P: Circuit offset (mV)
V_c: Reference voltage(mV)
a:Dark current coefficient(VNIR : $°C^{-1}$, SWIR: mV/K)
t:Temperature of detector(VNIR : °C , SWIR: K)
t_c:Reference temperature(VNIR : °C , SWIR: K)

These dark current coefficients and reference voltages are stored into the Database of the Data Processing System, and used for radiometric correction.

3.6.6 Linearity

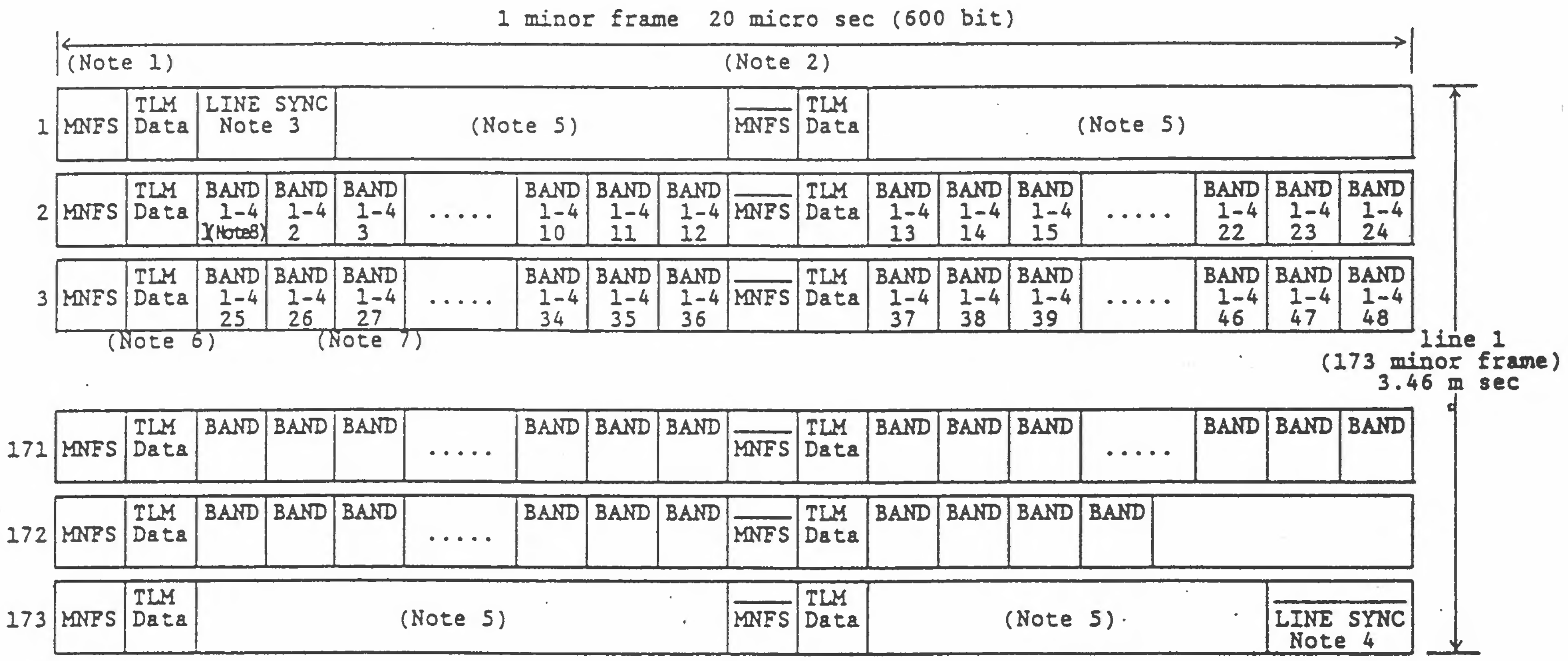
Linearity is defined at the output of pre-amplifier,so the characteristic of A/D converter isn't included. Linearity is a deviation of the relation between the input radiance and the output voltage. The specification of linearity for VNIR is within ±5% of the output level at maximum radiance,while that for SWIR is within ±13%.

3.7 Data format

The format of the major and minor frames of OPS is illustrated in Figure 3.10 (The data format in calibration mode is same as that of in normal observation mode).

As all data except minor frame synchronous signal are scrambled, it is necessary to extract the data by descrambling them on the ground.

Figure 3.10 OPS data format



note

1. Minor frame synchronous code of transmitting in real time : (10110111000)
2. Minor frame synchronous code of transmitting in reverse reproduction : (00011101101)
3. Line synchronous code of transmitting in real-time : (111110 101111 001100 110100 000000)
4. Line synchronous code of transmitting in reverse reproduction : (000000 001011 001100 111101 011111)
5. Repeating pattern of blank part of data lead : (101010 ......)
6. Bit number of TLM data is to be determined : (1 bit)
7. Bit configuration of band 1 - 4 or band 5 - 8 is as follows
8. Frame format statod above is for one channel (I ch: for VNIR), and for another channel(Q ch: SWIR), OPS has the same construction of data format in band 5 - 8.

BAND 1 or 5 (6bit)	BAND 2 or 6 (6bit)	BAND 3 or 7 (6bit)	BAND 4 or 8 (6bit)

(Note 8) (MSB fast)

3.8 Digital signal processor

Figure 3.11 shows the schematic diagram of digital multiplex system while major characteristics of digital signal processor is shown in Table 3.7.

All OPS data except for LINE SYNC,$\overline{\text{LINE SYNC}}$,MNFS,$\overline{\text{MNFS}}$ and TLM data are PN coded. Encoding is accomplished by exclusive ORing the OPS data word with a pseudo-random (PN) code as shown in Table 3.8. The PN code is stored in a PROM in the Signal Processor of OPS. The equivalent PN code is generator is shown in Figure 3.12 , in which PN code is generated from a 11 bits seed by exclusive ORing the 1st,2nd, 9th and 10th bits to form the new 11th bit. The starting pattern is all 1's. The code is reset so that the pattern repeats every four minor frames.

Note that ,since the first 7 words(42bits) of minor frames are MNFS,TLM and LINE SYNC, the first bit used in encoding is the 43th bit of the PN code.

The PN code is reset to a fixed value(1111 1111 111) for the start of scan line and for the start of every four minor frames thereafter. The PN-encoded data are transmitted to ground , most significant bit (MSB) first.

Figure 3.11 Digital multiplex system diagram

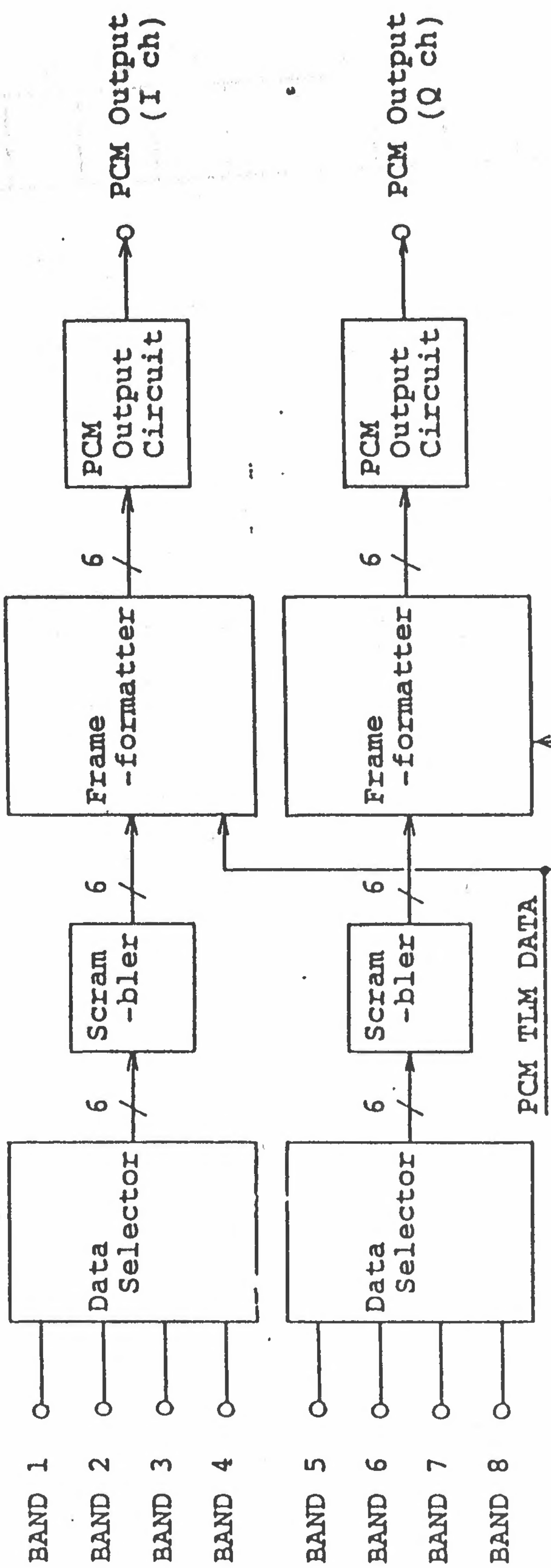


Figure 3.12 OPS scrambler

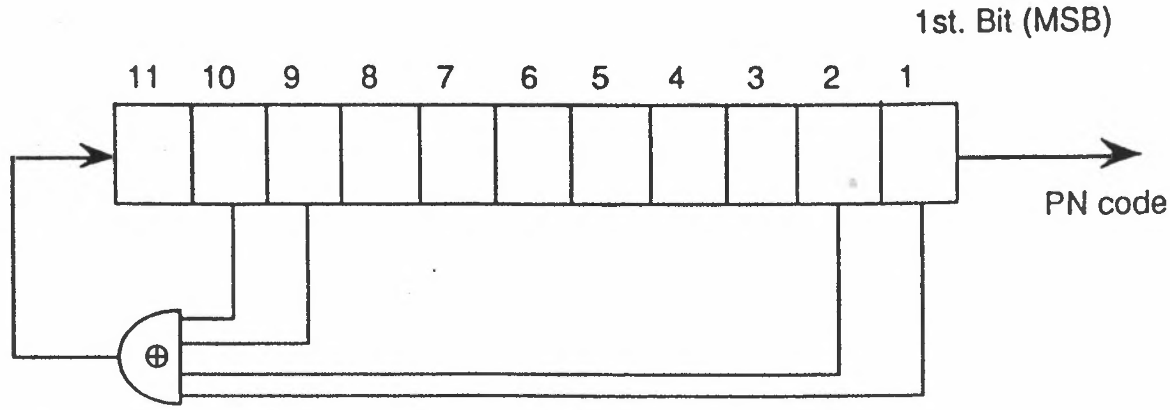


Table 3.7 Electrical Characteristics of Signal Processor

Item	Performance
Number of input bands	8
Quantization	6 bits/band
Scramble PN code	11 stages
Data rate	30 Mbps ± 1×10^{-5} /year/ch (Ich and Qch)

Table 3.8(1/3) Scramble code

Repeat " " synchronized with every 4 minor frames

24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	504	528	552	576	600	624	648	672	696	720	744	768	792
1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	1	1	1	0	0	0	0	1	1	1	1
1	0	1	0	1	1	1	0	1	0	1	0	1	0	0	0	1	1	0	1	0	0	0	1	0	0	1	0	1	1	0	1	1
1	0	1	1	1	1	1	0	1	0	1	0	1	1	0	0	0	1	0	0	1	1	0	1	1	0	1	1	0	1	1	1	1
1	0	0	0	1	1	0	1	1	0	1	1	1	0	0	1	1	1	1	1	0	0	1	0	1	0	0	1	0	1	1	1	1
0	1	0	0	1	0	0	1	0	1	0	1	1	0	1	0	0	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0	1
0	0	1	1	1	0	0	1	0	1	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0
1	0	1	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0	1	1	0	1
1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0	1	0	0	0	0	1	1	1	0	1	0	0	0	0	1	0	1
1	0	1	0	1	1	1	0	1	1	0	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0
0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0
1	1	1	1	1	0	0	1	1	0	0	1	0	0	0	1	1	0	0	1	0	1	0	0	1	1	0	0	1	1	0	1	1
0	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	1	1	0	1	0	1	0	0
0	0	1	0	0	0	1	0	0	1	0	0	0	1	1	1	0	1	1	1	0	1	0	0	0	0	0	1	0	0	0	0	1
1	1	1	0	1	1	0	0	1	1	1	1	0	1	0	0	1	1	1	0	1	1	1	0	0	1	1	0	0	0	0	0	1
1	1	1	1	1	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0	1	1	0	1
1	1	1	0	1	1	1	1	1	1	0	1	0	1	0	0	0	1	0	0	1	1	0	0	0	1	1	1	0	0	1	0	0
1	0	0	0	0	1	1	0	1	1	0	0	1	1	1	0	1	0	0	0	1	0	1	1	0	0	1	0	0	0	1	0	1
1	1	1	0	1	0	0	0	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1	0	1	1	0	0	0	0	1	0
1	0	0	0	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1	0	0	1	0	1	0	1	0	1	1	1	1	0	0
1	0	0	1	0	0	0	0	0	1	1	0	1	0	0	1	1	0	1	1	0	0	0	1	1	1	1	0	1	1	0	0	1
1	0	0	1	1	0	1	0	1	1	1	0	0	0	1	1	1	0	1	1	0	1	0	0	0	0	1	0	0	1	1	0	0
1	0	1	0	1	1	0	1	1	1	0	0	0	0	0	1	1	0	1	1	1	0	1	0	1	0	0	1	1	0	1	1	1
1	1	1	1	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	1	1	1	1
1	1	0	0	0	1	0	0	1	0	1	0	1	0	1	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	1	1	1

Table 3.8(2/3) Scramble code

816	840	864	888	912	936	960	984	1008	1032	1056	1080	1104	1128	1152	1176	1200	1224	1248	1272	1296	1320	1344	1368	1392	1416	1440	1464	1488	1512	1536	1560	1584
1	1	0	1	0	0	1	1	0	1	0	1	1	0	1	1	0	1	1	0	0	0	0	1	1	0	0	1	0	1	1	1	0
0	0	1	0	1	0	0	0	0	1	0	1	1	1	1	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	1	1	0
1	0	1	1	1	0	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	0	1	0	1	0
0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1
1	1	0	1	1	0	0	1	1	0	0	1	1	0	0	0	1	0	1	0	1	1	0	1	1	1	1	1	1	0	0	1	0
0	0	1	0	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	1	0	1	0	1
1	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	0
0	0	0	0	1	1	0	0	1	1	0	0	1	0	1	1	0	1	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0
1	1	0	0	1	0	1	0	1	1	1	1	0	1	0	1	0	1	0	1	1	0	1	0	1	1	0	1	0	1	0	1	0
0	1	0	1	0	0	1	0	1	0	0	0	0	0	1	0	1	1	1	1	1	0	0	1	0	0	1	1	1	0	1	0	1
0	0	1	0	0	1	1	0	0	1	1	1	0	0	0	0	1	1	0	0	0	1	0	1	1	0	0	0	1	1	0	1	0
0	1	1	1	0	1	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	1	1
1	0	1	1	1	1	0	1	1	0	0	0	1	1	0	0	1	1	1	0	1	1	1	1	1	0	1	0	0	1	0	1	0
1	1	1	1	0	0	1	1	0	1	0	1	0	0	1	0	0	1	0	1	1	0	0	0	1	0	1	0	0	0	1	1	1
0	1	0	0	1	1	1	0	0	1	1	1	0	1	0	1	1	0	0	1	1	1	0	0	1	1	0	1	0	0	1	1	1
0	0	1	1	0	0	0	0	1	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	0	1	1	1	1	0	1	1	1
1	1	0	1	1	0	0	0	1	0	1	1	1	1	1	1	1	0	0	0	1	0	1	1	0	1	1	0	1	0	1	1	0
1	1	1	0	1	0	1	1	0	1	0	0	1	0	0	0	1	1	0	1	0	1	1	0	0	0	1	1	1	0	1	0	1
1	0	0	1	0	0	1	1	0	1	1	1	0	0	0	1	1	0	1	0	1	0	1	1	0	1	1	0	0	0	1	0	0
0	0	0	0	1	0	1	1	0	0	1	1	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1
1	0	0	1	0	0	0	0	1	1	1	1	1	0	1	0	0	0	1	0	0	0	1	0	1	0	1	0	0	1	0	1	1
1	1	1	1	1	0	0	0	0	1	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	1	1	0	0
0	0	1	1	0	0	0	1	1	0	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1	0	1	0	1	1
1	1	1	1	0	0	1	0	1	1	1	0	0	1	1	0	1	1	1	0	1	1	0	1	0	1	1	1	1	0	0	0	1

Table 3.8(3/3) Scramble code

1608	1632	1656	1680	1704	1728	1752	1776	1800	1824	1848	1872	1896	1920	1944	1968	1992	2016	2040	2064	2088	2112	2136	2160	2184	2208	2232	2256	2280	2304	2328	2352	2376	2400	2424
1	0	0	0	1	1	0	0	0	0	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0
0	0	0	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0	1	1	0	1	0	1	1	1	0	1	1	0	1	1	0	0	1
1	0	1	0	0	1	1	1	1	1	0	1	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1
1	0	1	0	0	1	0	0	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	0	0	0	1
0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0
0	1	1	1	0	1	1	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	1	1
0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1	1	0	1	0	0
0	0	0	1	1	1	0	0	0	0	1	0	1	1	0	1	0	0	1	1	1	1	1	1	0	0	0	0	0	1	0	0	1	0	1
0	1	0	0	0	1	0	1	0	0	1	1	1	0	1	0	0	1	0	1	1	1	0	1	1	1	1	1	1	0	1	0	1	0	0
0	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	1	1	1	1	0	0	0	0	1	1	0	1	1	0	0	1	1	1	0
0	1	0	1	0	1	0	0	1	1	0	0	0	0	1	1	1	0	1	1	1	1	0	1	0	0	0	1	1	1	1	1	0	1	1
1	1	0	1	1	0	1	1	1	0	1	0	0	1	1	1	1	0	0	1	0	0	0	1	1	1	1	0	0	1	0	1	1	0	1
0	1	1	1	1	0	1	0	1	0	0	1	0	1	0	1	1	1	0	1	0	0	1	0	0	0	0	0	1	1	0	1	0	0	1
1	0	1	0	1	1	1	0	0	1	0	0	1	0	1	0	0	0	1	1	0	0	1	1	0	1	0	1	1	1	0	0	0	1	1
0	0	0	0	0	0	1	0	0	1	1	1	0	1	1	0	1	1	1	1	0	1	0	1	1	0	1	1	1	0	0	0	0	0	1
0	1	1	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	1	1	1	1	1	0	0	0	1	0	0	0	1	1	1	0	0
0	1	0	0	1	0	1	1	1	1	1	1	0	1	1	0	1	0	0	1	1	0	0	0	1	0	0	1	0	1	0	1	0	1	0
0	0	0	0	1	1	1	1	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0
0	0	1	1	1	0	0	1	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	1	0	1	0	1	0	0
1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	1	1	1	0	0	1	0	1	1	1	1	1	0	1	0	1	0	1	1	0
0	0	1	0	1	1	0	0	1	1	0	0	0	0	1	0	0	1	1	1	1	0	0	0	1	1	0	1	1	0	1	1	1	0	0
1	0	1	0	1	1	0	0	1	1	0	1	1	1	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	1	0	1	1	0	1
1	1	0	1	1	0	1	1	0	1	0	0	0	1	0	1	0	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	1	0
1	1	0	0	0	1	1	0	0	1	0	0	1	1	1	1	0	1	1	0	1	0	1	0	0	0	0	0	0	0	1	0	1	1	0

3.9 House-keeping data (HK)

Original spacecraft HK data format (from Communications and Data Handlinc Subsystem) is as follows;

1) Frame Constitution

One Major Frame	:	64	Minor Frames
One Minor Frame	:	128	Words
One Word	:	8	bits

2) Frame Rate

Major Frame	:	32	Sec/Frame
Minor Frame	:	0.5	Sec/Frame

3) Telemetry Format
   See Table 3.9

All the spacecraft telemetry data are included in OPS image data format as is shown in Table 3.10.

Table 3.9 TELEMETRY FRAME (MINOR FRAME)

0 FRAME SYNC (W0 - W2)	1	2	3	4	5 SEE NOTE	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
48	49	50	51	52 SUBCOMMUTATION (W52 - W57) <- - - - -	53	54	55	56	57 - - - - ->	58	59	60	61	62	63
64	65	66	67	68 AOCS ATTITUDE DATA (W68 - W79) <- - - - -	69	70	71	72	73	74	75	76	77	78	79 - - - - ->
80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103	104	105	106	107	108 <- - - - - OPS TELEMETRY (W108-W113)	109	110	111
112	113 - - - - ->	114	115 OPS TLM	116	117	118	119	120	121	122	123	124	125	126	127

NOTE: FRAME ID ETC.

BLANK WORDS : BUS TELEMETRY, MISSION EQUIPMENTS (OTHER THAN OPS) TELEMETRY, OR SPARE

Table 3.10 (1/3) OPS TELEMETRY LIST

NO	ITEM		WORD-FRAME-BIT
1	VNIR DETECTOR TEMP	1	W108
2		2	W109
3		3	W110
4		4	W111
5	VNIR ELEC. CAL. VOLT		W115
6	VNIR CAL LIGHT MONITOR		W54-F15(4)*
7	VNIR POWER SUPPLY VOL. +15V		W52-F29
8	VNIR POWER SUPPLY VOL. +12V		W53-F29
9	VNIR POWER SUPPLY VOL. +15V		W54-F29
10	VNIR ON/OFF		W58-F30-B7
11	VNIR FOCUS ADJ. POSITION		W56-F7
12	SWIR TEMP	1(SOPT)	W54-F22
13		2(SOPT)	W55-F22
14		3(SOPT)	W56-F22
15		4(SFAM)	W57-F22
16		5(SPS)	W56-F63
17		6	W57-F63
18		7(SRLS)	W58-F63
19		8(SRLS)	W59-F62
20		9(SRLS)	W58-F55
21	SWIR DETECTOR TEMP		W112
22	SWIR CAL LIGHT MONITOR		W55-F15(4)
23	(DELETED)		
24	SWIR ON/OFF		W58-F30-B6
25	(DELETED)		W58-F7
26	CAL. POWER SUPPLY TEMP		W53-F23
27	CAL. LIGHT SOURCE	1 ON/OFF	W59-F30-B6
28		2 ON/OFF	W59-F30-B5
29		3 ON/OFF	W59-F30-B4
30		4 ON/OFF	W59-F30-B3

Table 3.10 (2/3) OPS TELEMETRY LIST

NO.	ITEM	WORD-FRAME-BIT
31	COOLER POWER SUPPLY TEMP 1	W52-F22
32	2	W53-F22
33	COOLER SURFACE TEMP 1	W52-F15(4)*
34	2	W53-F15(4)*
35	COOLER MOUNT TEMP	W113
36	COOLER ON/OFF	W59-F63-B2
37	THERMAL CONTROL TEMP	W54-F23
38	THERMAL CONTROL A ON/OFF	W56-F14
39	B ON/OFF	W57-F14
40	THERMAL CONTROL ON/OFF	W59-F30-B0
41	ELECTRONICS POWER SUPPLY TEMP	W55-F23
42	ELECTRONICS PRIMARY POWER SUPPLY ON/OFF	W58-F30-B3
43	ELECTRONICS SECONDARY POWER SUPPLY ON/OFF	W58-F30-B2
44	ANALOG SIGNAL PROCESSOR A TEMP	W56-F23
45	ANALOG SIGNAL PROCESSOR A A/D REFERENCE VOLT 1	W52-F38
46	2	W53-F38
47	3	W54-F38
48	4	W55-F38
49	5	W56-F38
50	6	W57-F38
51	7	W58-F38
52	8	W59-F38
53	ANALOG SIGNAL PROCESSOR A POWER SUPPLY VOLT 1	W52-F39
54	2	W53-F39
55	ANALOG SIGNAL PROCESSOR A GAIN NORM/HI	W58-F30-B1
56	ANALOG SIGNAL PROCESSOR B TEMP	W57-F23
57	ANALOG SIGNAL PROCESSOR B A/D REFERENCE VOLT 1	W52-F45
58	2	W53-F45
59	3	W54-F45
60	4	W55-F45

Table 3.10 (3/3) OPS TELEMETRY LIST

NO.	ITEM		WORD-FRAME-BIT
61	ANALOG SIGNAL PROCESSOR B A/D REFERENCE VOLT	5	W56-F45
62		6	W57-F45
63		7	W58-F45
64		8	W59-F45
65	ANALOG SIGNAL PROCESSOR B POWER SUPPLY VOLT	1	W52-F46
66		2	W53-F46
67	ANALOG SIGNAL PROCESSOR B GAIN NORM/HI		W58-F30-B0
68	DIGITAL SIGNAL PROCESSOR A TEMP		W58-F23
69	DIGITAL SIGNAL PROCESSOR A POWER SUPPLY VOLT	1	W54-F39
70		2	W55-F39
71	DIGITAL SIGNAL PROCESSOR A DECODER POWER SUPPLY VOLT		W56-F39
72	DIGITAL SIGNAL PROCESSOR B TEMP		W59-F23
73	DIGITAL SIGNAL PROCESSOR B POWER SUPPLY VOLT	1	W54-F46
74		2	W55-F46
75	DIGITAL SIGNAL PROCESSOR B DECODER POWER SUPPLY VOLT		W56-F46
76	VNIR TEMP	1(VOPT)	W58-F13
77		2(VOPT)	W59-F13
78		3(VFAM)	W58-F14
79		4(VDRV)	W59-F14
80		5(VRLS)	W56-F31
81		6(VRLS)	W57-F31
82		7(VRLS)	W58-F31
83		8(VPRE)	W59-F31
84	VNIR FOCUS ADJ. ON/OFF		W58-F30-B5
85	(DELETED)		W58-F30-B4

*Fn(m) n: (MINOR)FRAME NUMBER
m: m TIMES PER MAJOR FRAME(64 MINOR FRAMES)

3.10 Calibration

The OPS has two calibration functions. One is the electric calibration and the other is the optical calibration.

The electrical calibration employs a method to supply calibration voltage to CCD ontip amplifier. This system is based on the same concept as that of used for the MESSR of MOS-1.

3.10.1 Electric calibration method

The electric calibrator performs radiometric correction as follows. The radiometer controller applies a calibration signal with voltages V1 to V4 for VNIR and V1 for SWIR to register section of each CCD sensor. The output signal goes through the register, preamplifier and signal processor. In normal operation, output signal level varies with the temperature. The electric calibration is used for gain calibration after CCD sensors. The results of preflight test are shown in Table 3.11(1) and (2). The value in each table is the average output from 1949 pixel to 2148 pixel at the Signal Processor.

Table 3.11 (1) Electric Calibration Output (Average)

BAND	Ach Average Level(Count)				Bch Average Level(Count)			
	V1	V2	V3	V4	V1	V2	V3	V4
1 Main	0.00	6.00	15.00	48.00	0.00	6.00	15.13	49.00
1 Sub	0.00	6.00	15.00	47.00	0.00	6.00	15.00	48.00
2 Main	0.00	4.00	14.00	54.00	0.00	5.00	15.24	55.58
2 Sub	0.99	4.26	14.00	53.00	0.01	5.00	15.00	54.00
3 Main	0.00	8.00	16.87	44.75	0.00	7.99	16.00	44.00
3 Sub	0.00	8.00	16.00	44.95	0.00	7.85	16.00	44.00
4 Main	0.00	9.00	16.06	40.98	0.00	9.00	17.00	42.00
4 Sub	0.00	8.00	16.00	40.00	0.00	8.00	16.00	42.00

Ach: for Odd Pixel
Bch: for Even Pixel
Main:Main system (ASP-A + DSP-A)
Sub:Redundant system (ASP-B + DSP-B)

Table 3.11 (2) Electric Calibration Output (Average)

BAND	Ach Average Level(Count)	Bch Average Level(Count)
5 Main	5.00	7.93
5 Sub	6.00	9.00
6 Main	14.04	14.95
6 Sub	14.13	14.97
7 Main	24.01	22.43
7 Sub	25.08	23.10
8 Main	30.65	31.95
8 Sub	30.67	32.53

Ach: for Odd Pixel
Bch: for Even Pixel
Main:Main system (ASP-A + DSP-A)
Sub:Redundant system (ASP-B + DSP-B)

3.10.2 Optical calibration

As shown in Figure 3.3, the mirrors for leading the internal calibration lamp light are installed in front of the optics for VNIR and SWIR. Radiance from the internal calibration lamp (Halogen lamp) is designated at a specified value. Therefore only one point calibration is available.

The followings are the concept of optical calibration.

The optical calibration of OPS is equipped in order to correct for any changes of detector responsivity and to improve radiometric performance of the image. This system consists of reference source(Cal lamp) and monitor unit of lamp level(Cal Monitor) as shown in Figure 3.13.

- The light of calibration lamp illuminate all elements of all band simultaneously.
- Calibration lamp level is not changeable(only one level) which means two points(on/off points) linear calibration.
- The system does not have a shutter which cut off the incidence of outer light source, therefore, it is restricted to operating the calibration during night time.

In order to perform radiometric calibration, output signal should be processed as shown in Figure 3.14.

First, the coefficients of G1 and G2 are determined by preflight test. The value of G2 can be monitored by electric calibration, however, it is very stable and its linearity is maintained in the normal observation mode. So, it can be said the deference between output levels of preflight and postflight under the same condition is caused by change of G1 coefficient alone. This change should be corrected by using internal light source(cal lamp).

In the calibration mode, two levels of output data from SPU can be obtained corresponding to "lamp on" and "lamp off". Using these data and processing statistically, the modified G1 coefficient is computed and applied to the actual look-up table computation for radiometric correction.In the preflight test, the values of G1, G2 and Qc will be obtained as prelaunch calibration data.

(1) Reference Light Source

VNIR'S Reference Light Source (VRLS) and SWIR'S Reference Light Source (SRLS) are for monitoring radiometric performance of the radiometer. The calibration light is lead into VNIR telescope during night time on the earth. Calibration light illuminate all detectors of all bands on the focal planes. Calibration light intensity variation is monitored by photo diode. The analog signal is converted to digital signal and sent to RIU (Remote Interface Unit).

Variation characteristics of the internal light source (Halogen lamp) depend on accuracies of the power supply source, therefore high stability calibration power source is required.

(2) Photo-diode

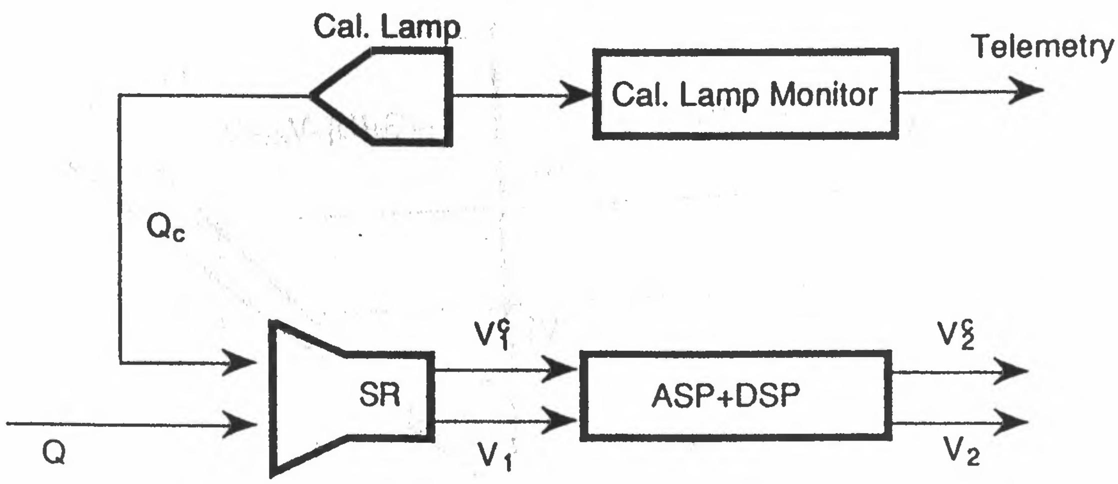
Used for monitoring Halogen lamp intensity variation employs low noise, high responsibility Si-PIN Photo-diode.

- wavelength region 400 - 1100 nm

Halogen lamp to be used as internal light source is being developed for space use.

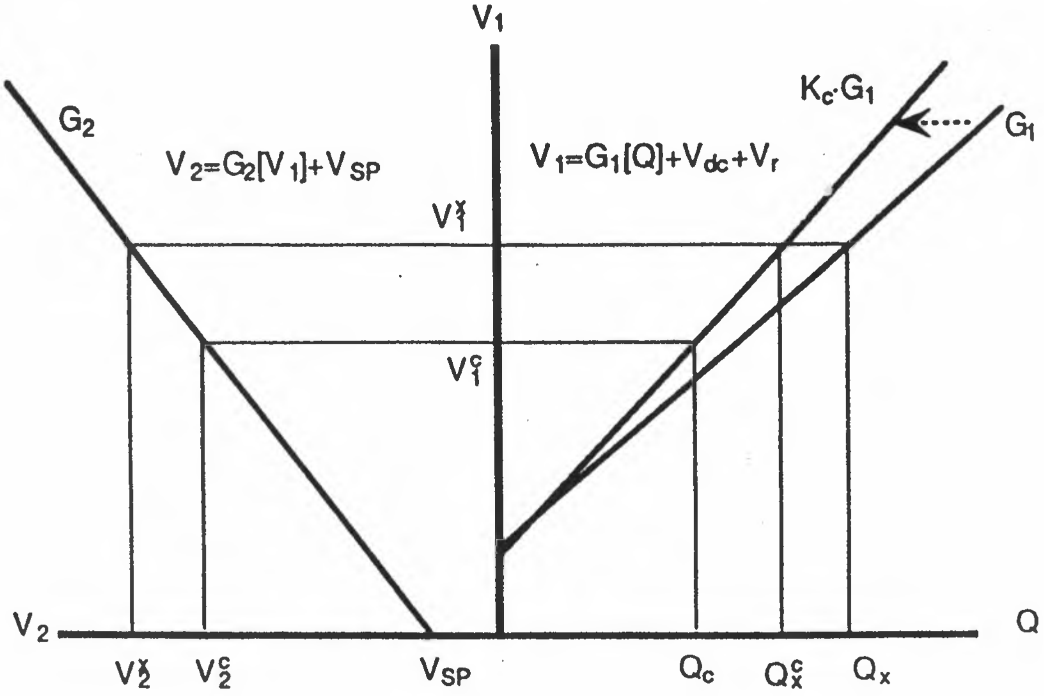
- Color temperature 3000k

Figure 3.13 Functional block diagram of OPS on-board calibrator



SR: Scanning Radiometer
ASP: Analog Signal Processor
DSP:Digital Signal Processor
V_1 : SR output (Observed)
V_1^c : SR output (Calibration)
V_2 : DSP output (Observed)
V_2^c : DSP output (Calibration)
Q :Input Illumination (Observed) {mW/(cm^2·str)}
Q_c :Input Illumination (Calibration) {mW/(cm^2·str)}

Figure 3.14 Concept of OPS on-board calibration



V_1^x : SR output (Observed)

V_1^c : SR output (Calibration)

V_2^x : DSP output (Observed)

V_2^c : DSP output (Calibration)

Q_c :Input Illumination (Calibration) {mW/(cm^2·str)}

Q_x :Input Illumination (Observed) {mW/(cm^2·str)}

Q_x^c :Calibrated Input Illumination (Observed) {mW/(cm^2·str)}

V_{dc} :Dark current

V_r :SR offset

V_{SP} :ASP+DSP offset

K_c :Calibration coefficient

Calibration Procedure

$$V_1^c = G_2^{-1}[V_2^c - V_{SP}] \qquad V_1^x = G_2^{-1}[V_2^x - V_{SP}]$$

$$K_c = \frac{G_1^{-1}[V_1^c - V_{dc} - V_r]}{Q_c} \qquad Q_x = G_1^{-1}[V_1^x - V_{dc} - V_r]$$

$$Q_x^c = \frac{G_1^{-1}[V_1^x - V_{dc} - V_r]}{K_c}$$

3.11 Operational modes

Operational modes of OPS are shown in Figure 3.15.

- All-off mode
  All parts of OPS are power off. This mode is set during launch phase or for emergency.

- Temperature control mode
  In order to control temperature of VNIR and SWIR,the thermal controller and its power source are turned on.

- Initial mode
  In addition to Temperature control mode,the Digital signal processor is turned on.

- Cooler stand-by mode
  Cool down of the Cooler is performed before SWIR observation. The power source for the Cooler is turned on.

- Observation mode
  (1) VNIR only
  The observation of VNIR is performed.
  (2) VNIR+SWIR
  The observation of VNIR and SWIR is performed.

- Lamp-1 stand-by mode or Lamp-2 stand-by mode
  The power source for calibrator and the standard lamp(Lamp-1 or lamp-2) are turned on before VNIR optical calibration.

- Lamp-3 stand-by mode or Lamp-4 stand-by mode
  The power source for calibrator and the standard lamp(Lamp-3 or Lamp-4) are turned on before SWIR optical calibration.

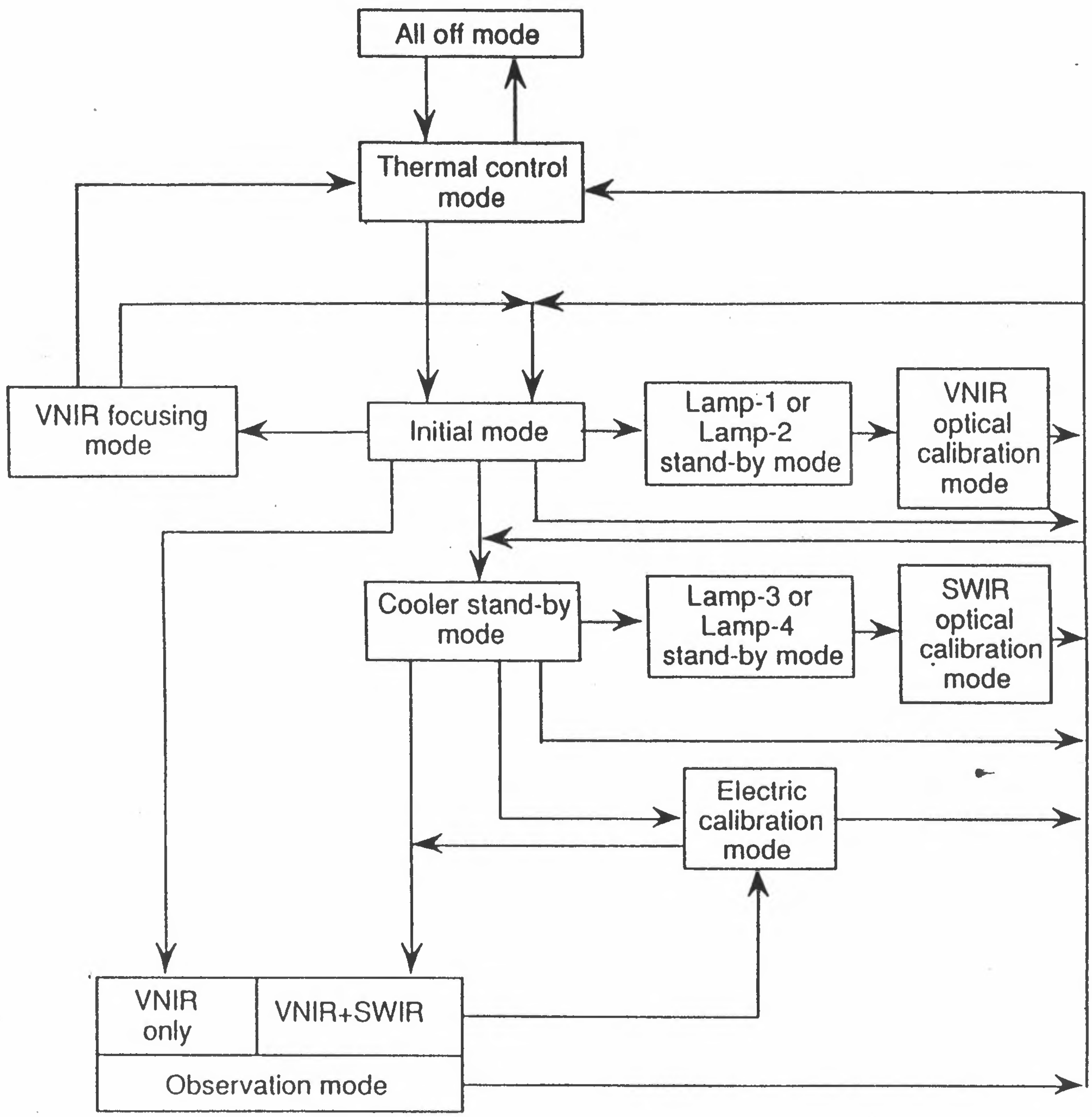
- Electric calibration mode
  Electric calibration for VNIR and SWIR is performed.

- VNIR optical calibration mode
  Optical calibration for VNIR is performed.

- SWIR optical calibration mode
  Optical calibration for VNIR is performed.

- VNIR focusing mode
  Focusing of VNIR is performed.

Figure 3.15 Operational modes of OPS



4 SAR (Synthetic Aperture Radar)

4.1 Function

SAR is composed of the following subsystems ;

- Antenna(ANT)
- Transmitter/Receiver(TRX)
- Signal Processor(SP)

The antenna is an array antenna of 1024 microstrip radiation elements of which dimensions are about 12m × 2.2m. Major function of the antenna is follows ;

- to deploy antenna on orbit.
- to radiate RF pulses to the earth.
- to receive returned RF echo from the earth.

The major function of the transmitter/receiver is as follows;

- to generate linear frequency modulated RF pulses.
- to perform coherent detection of received signal, and transmit 2 channel video signals (I ch and Q ch) to the signal processor.

The major function of the signal processor is as follows ;

- to perform A/D conversion of I and Q video signals from the transmitter/receiver.
- to transmit I channel data and Q channel data after formatting the A/D converted I and Q data and data necessary for data processing on the ground.
- to control the transmitter/receiver and the signal processor according to the command from the ground for SAR operation.

Figure 4.1 shows functional block diagram of SAR system and Figure 4.2 shows functional block diagram of signal processor.

Figure 4.1 Functional Diagram of SAR System

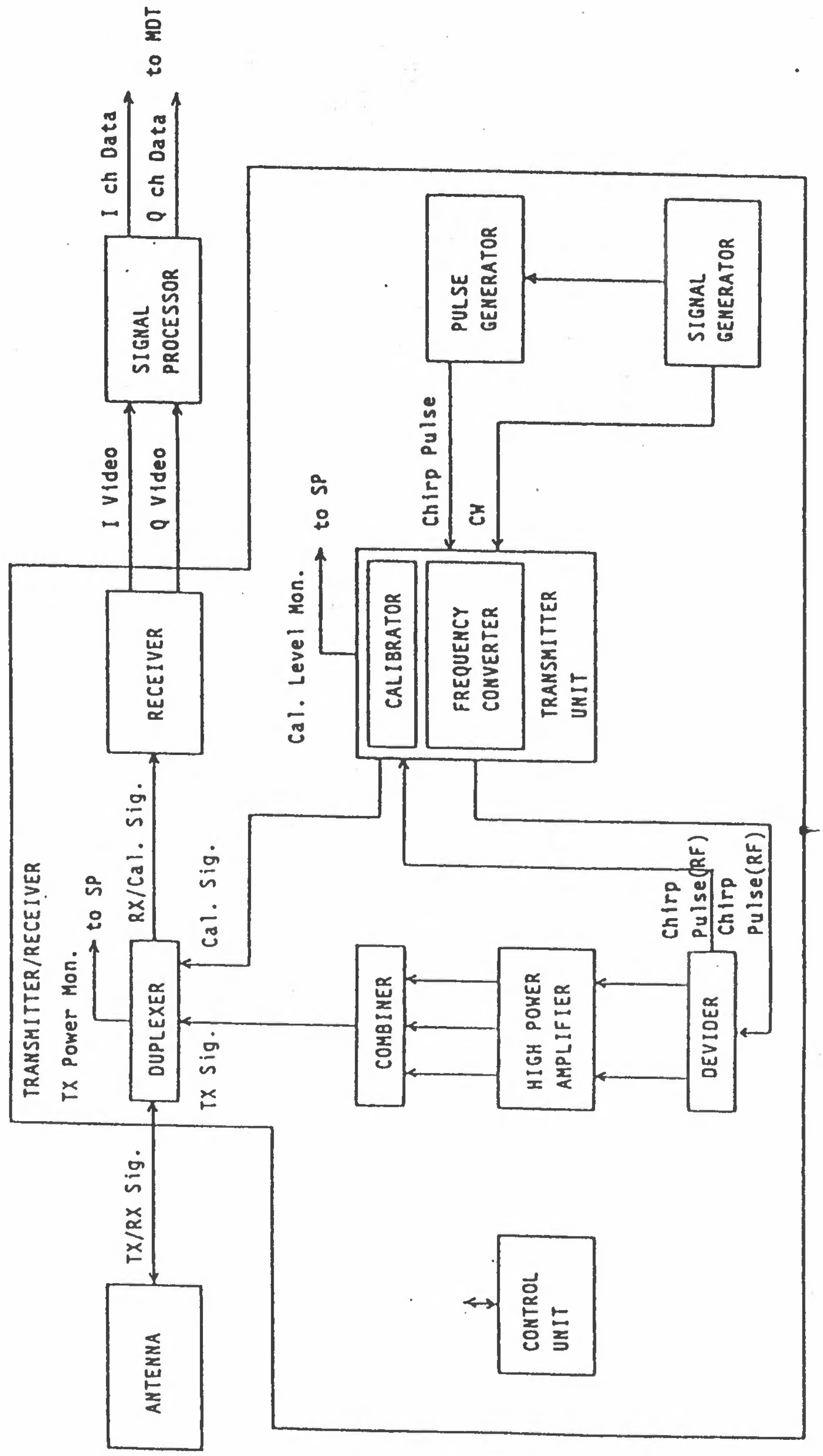
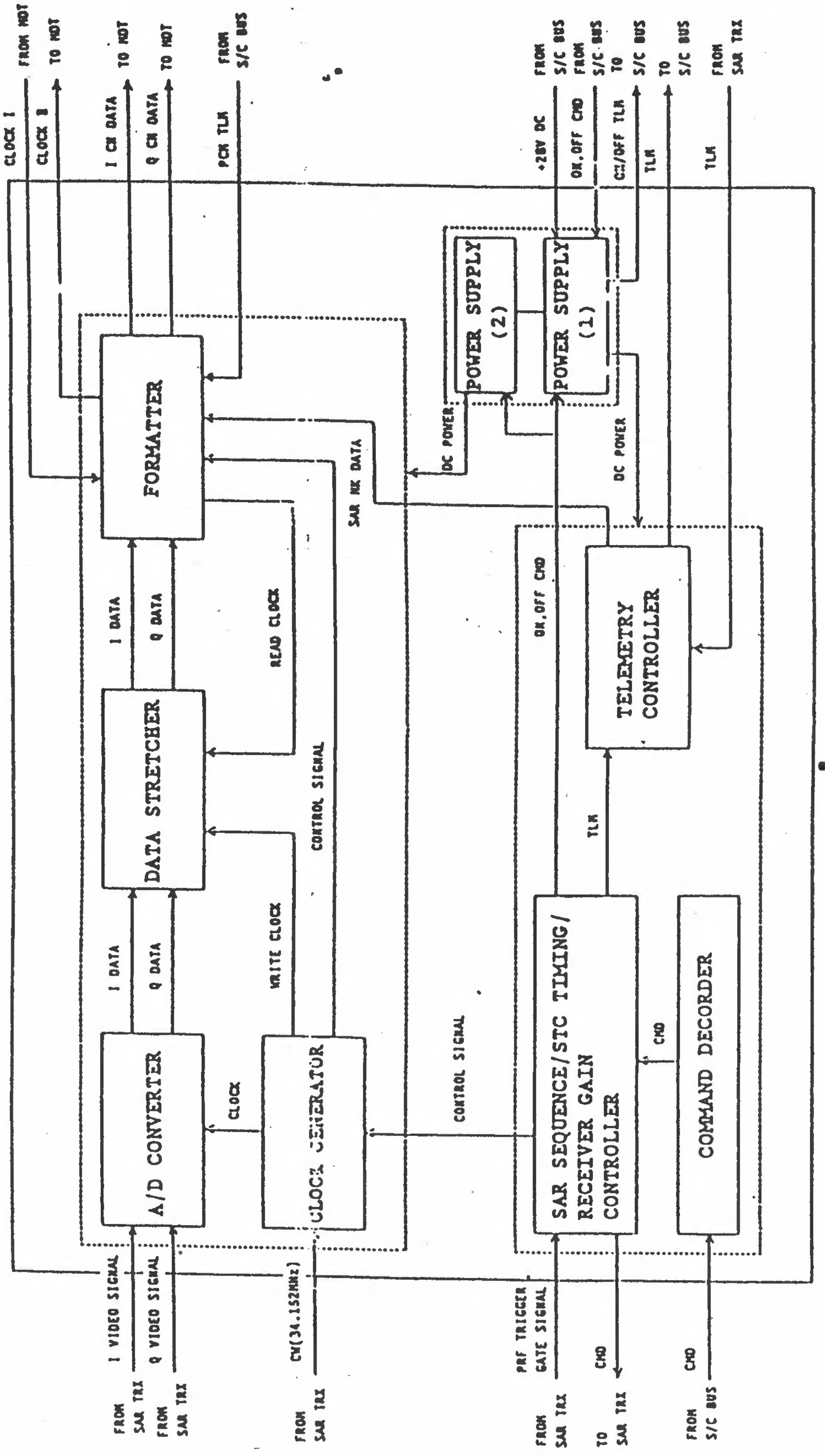


Figure 4.2 Functional Block Diagram of Signal Processor



4.2 SAR observation

4.2.1 Engineering parameters

SAR observation geometry is shown in Figure 4.3. Observation area is centered about 400Km from nadir. Full performance swath is 75 km.
Major SAR engineering parameters are shown in Table 4.1 and calculated antenna patterns are shown in Figure 4.4.

4.2.2 Operation mode

SAR has two operation modes,which are the automatic mode and the manual mode. SAR is usually operated in the automatic mode after mission check-out period. In the automatic mode,the signal processor controls operation flow automatically. SAR data sequence , which is transferred from SAR to the Mission Data Transmitter (MDT) in the automatic mode, is shown in Figure 4.5. On being transmitted as downlink data from MDT to ground, a part of the calibration data (the first portion of the cal. data before the observation data and the last portion of the cal. data after the observation data) may be lost.

In the manual mode,it is possible to set operation parameters by commands . But this mode is used only for mission check or special operation.

4.2.3 Pulse Repetition Frequency (PRF)

PRF is determined to avoid overlapping the TX pulse and the receiving echo. ERS-1's SAR can set one of five PRFs. Observation geometry is shown in Figure 4.6 and timing chart of transmitting and receiving is shown in Figure 4.7. As shown in two figures , the receiving echo must be placed between two TX pulses. So PRF must satisfy next equation.

$$\frac{n}{\frac{2R_n}{c}-T_p} < PRF < \frac{n+1}{\frac{2R_f}{c}+T_p}$$

where
R_f :range of far edge
R_n :range of near edge
T_p :pulse width
c :light speed

R_f and R_n are changed by satellite position,because the earth is ellipsoid. PRF window (Latitude vs PRF) is shown in Figure 4.8. Bold lines are possible PRFs in this figure.

Figure 4.3 SAR Observation Geometry

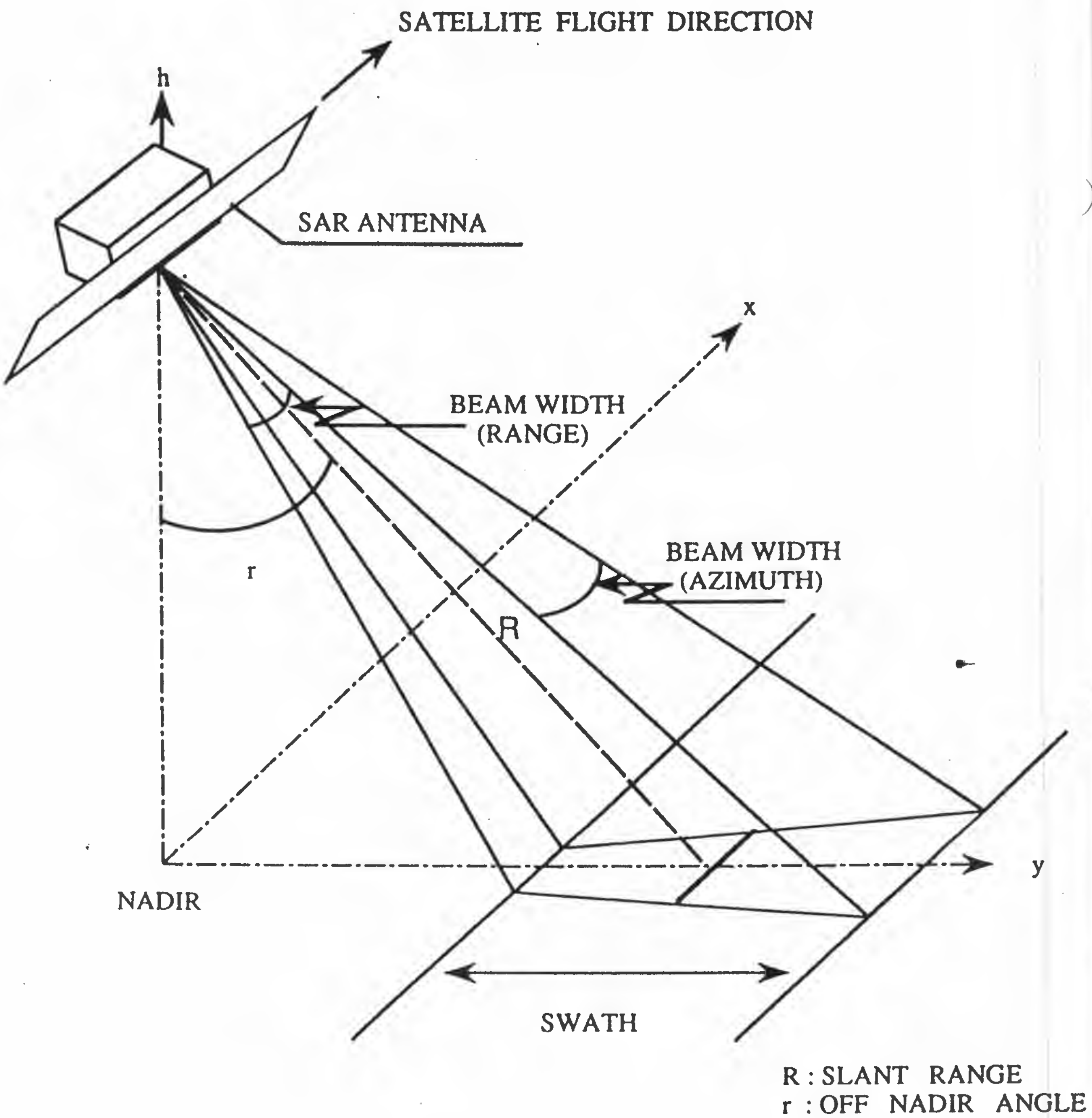


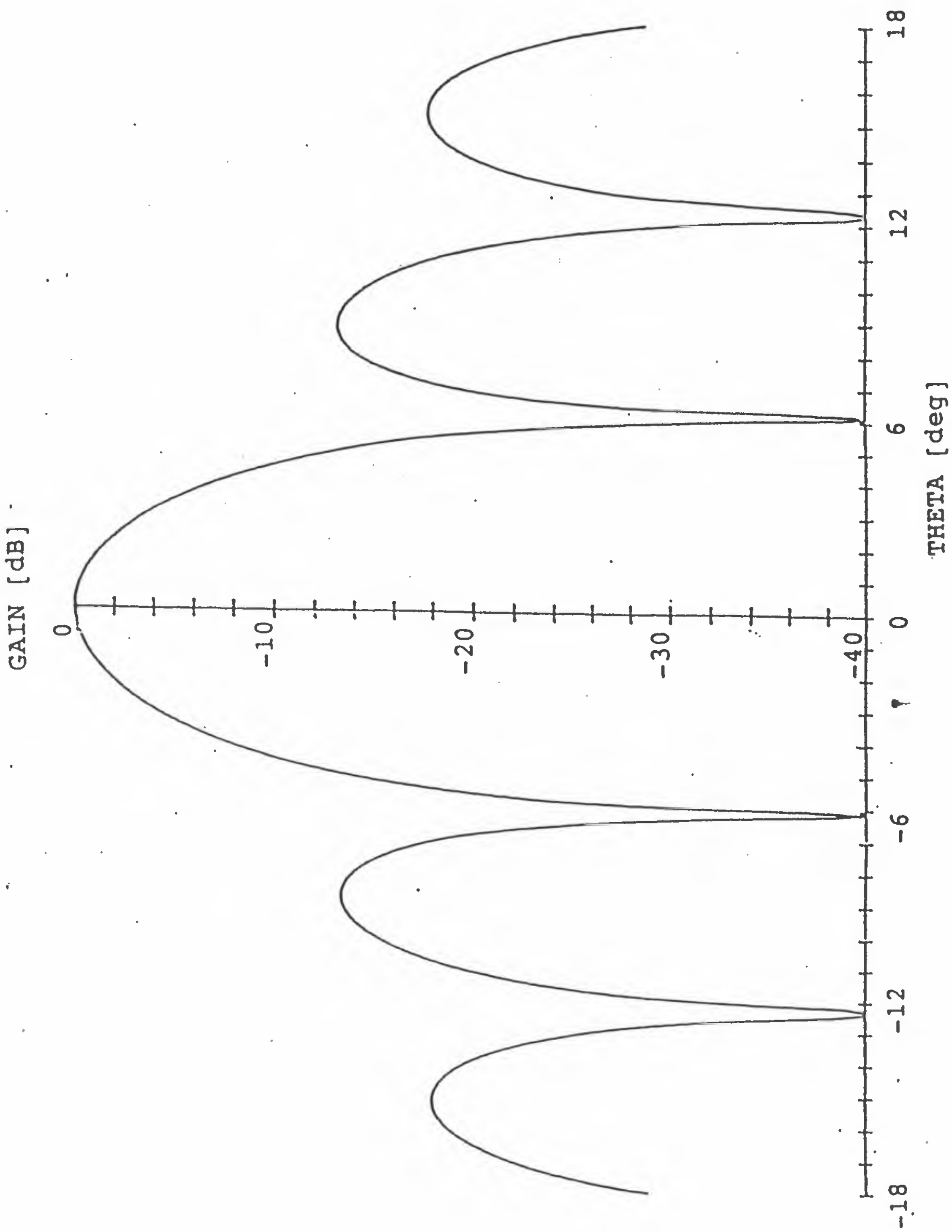
Table 4.1 SAR Parameters(1/2)

Off Nadir Angle(degree)	35 (direction of swath center) 35.21 (bore sight angle)
Swath(km)	75
Resolution	
- Range(m)	18
- Azimuth(m)	18 (3 looks)
Antenna Gain	33.5 dB MIN (at beam center)
Antenna Size(m)	2.2 × 11.92
Transmit Freq	L-Band(1275MHz±20KHz)
- Short-term Stability (at Combiner's output)	$\pm 2.6 \times 10^{-9}$ rms/5msec MAX
- Long-term Stability (at Combiner's output)	$\pm 5.0 \times 10^{-6}$ /2year MAX
Polarization	H-H
Transmitted Pulse ;	
- Type	linear down chirp
- Chirp ratio	4.286×10^{11} Hz/sec ±2.0%
- Bandwidth(MHz)	15.0 (nominal)
- Initial Freq(MHz)	1282.5
- Pulse Length(μsec)	$35^{+0.5}_{-0}$
- PRF(Hz)	1505-1606 in 25 Hz increments (1505.8, 1530.1, 1555.2, 1581.1, 1606.0)
- Noise between pulses	-90 dBm/MHz MAX
- Pulse amplitude variation	±1.0 dB
- Pulse phase variation	random 8.0 deg rss

Table 4.1 SAR Parameters(2/2)

- Peak power	1100 W MIN 1500 W MAX
Receiver gain	70 dB - 92 dB
Receiver noise figure	4.1 dB MAX
AGC time constant	64/PRF, 128/PRF
Calibration signal	
- Center frequency	1275 MHz (nominal)
- Band width	15 MHz
- variable attenuation, No. of steps	0 dB - 21 dB, 3dB steps (nominal)
- Output signal level (at Low noise amp's input)	-92 dBm - -71dBm (nominal)
A/D conversion characteristics	see Figure 4.4
Sampling Rate	17.076 MHz±1KHz
Sampling time in observation mode	360 μ sec
Sampling time in calibration mode	35 μsec
Raw Data Bit Precision	3I/3Q
Raw Data Rate(Mbps)	30 × 2 ch

Figure 4.4(1) SAR Antenna Pattern (H-plane, Range)



Doc No : HE-88023
Revision : 2
Date : 26 OCT 90
Sheet : 4 - 9

Figure 4.4(2) SAR Antenna Pattern (E-plane, Azimuth)

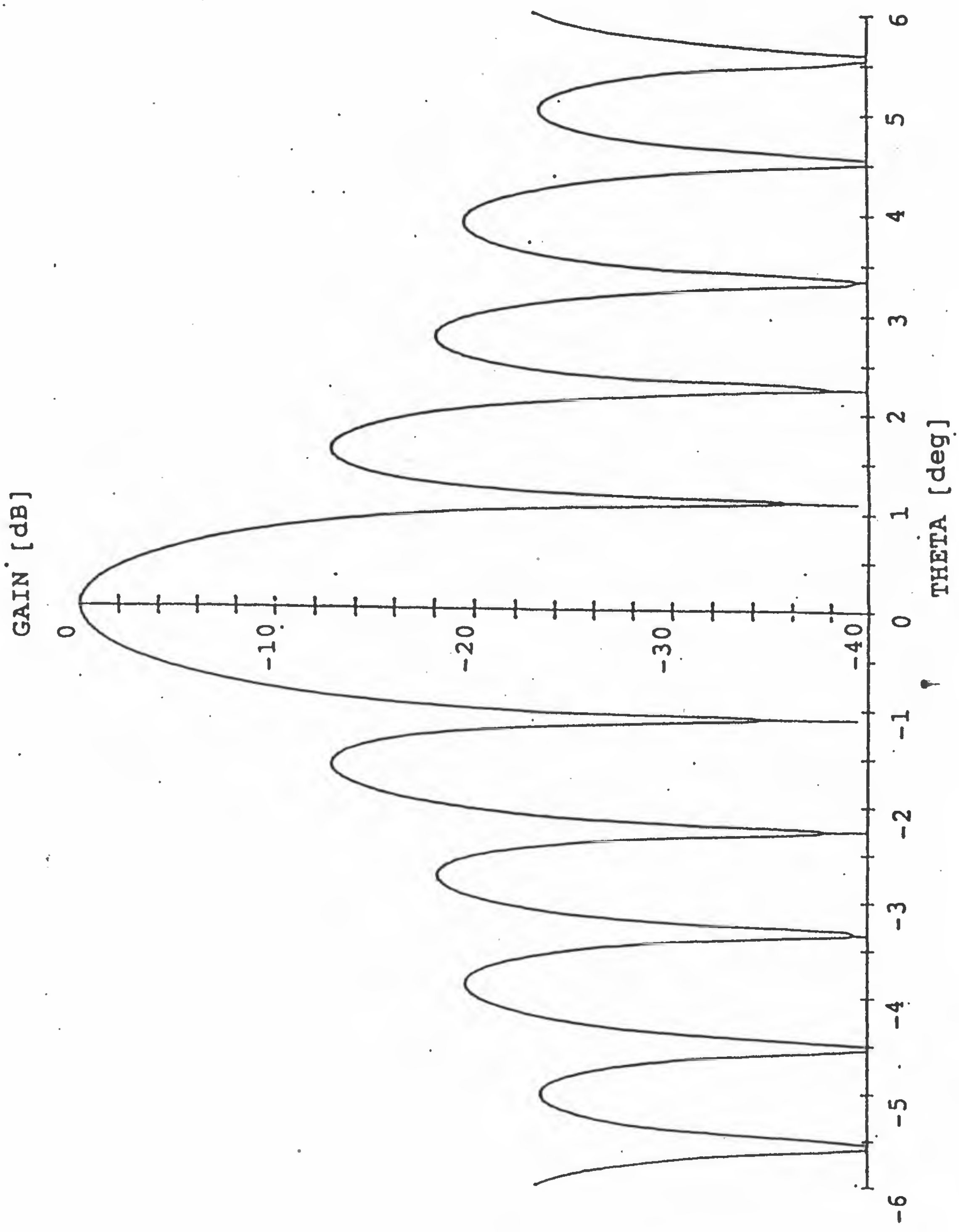


Figure 4.5 SAR Data sequence

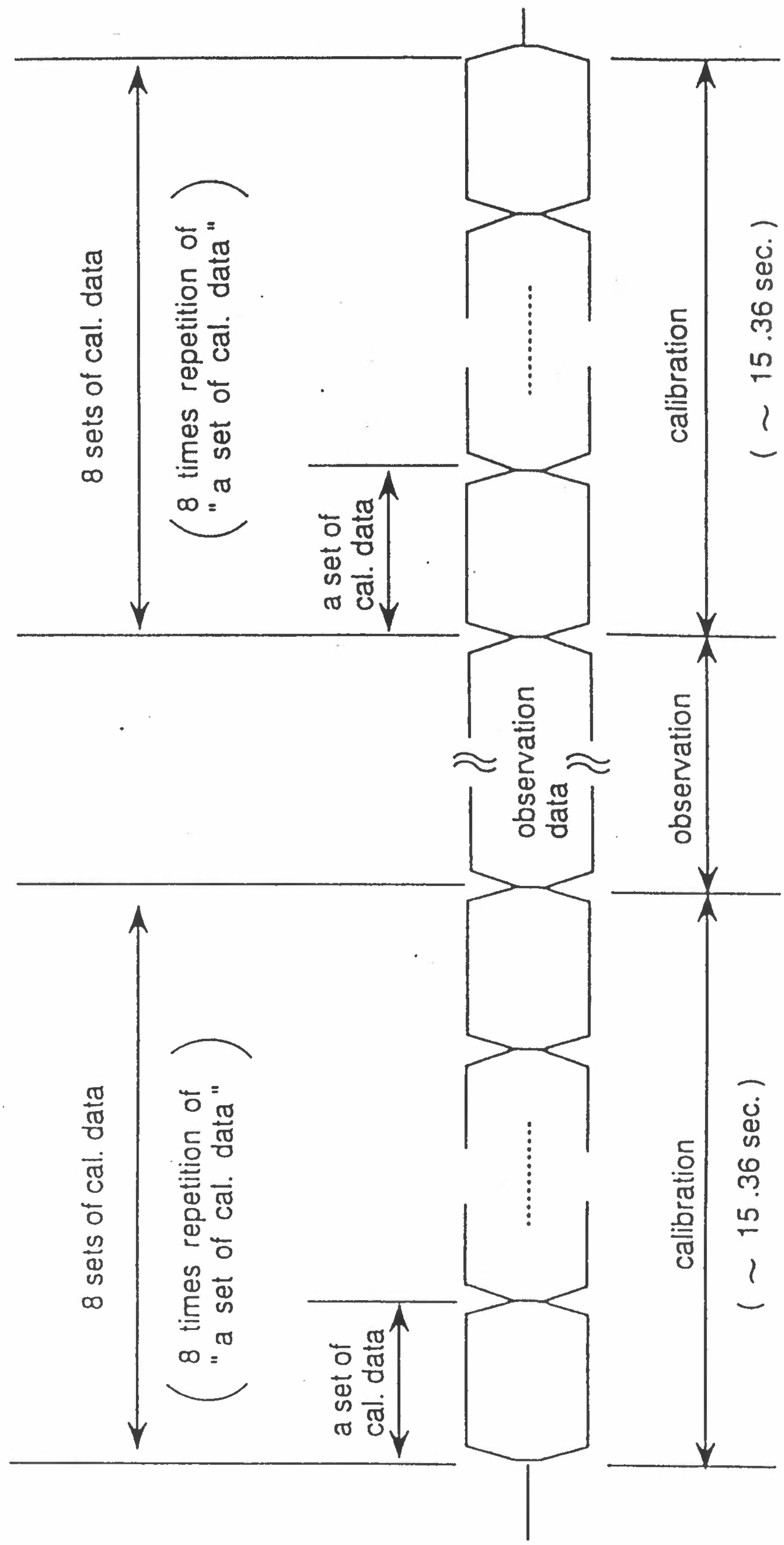


Figure 4.6 Observation Geometry

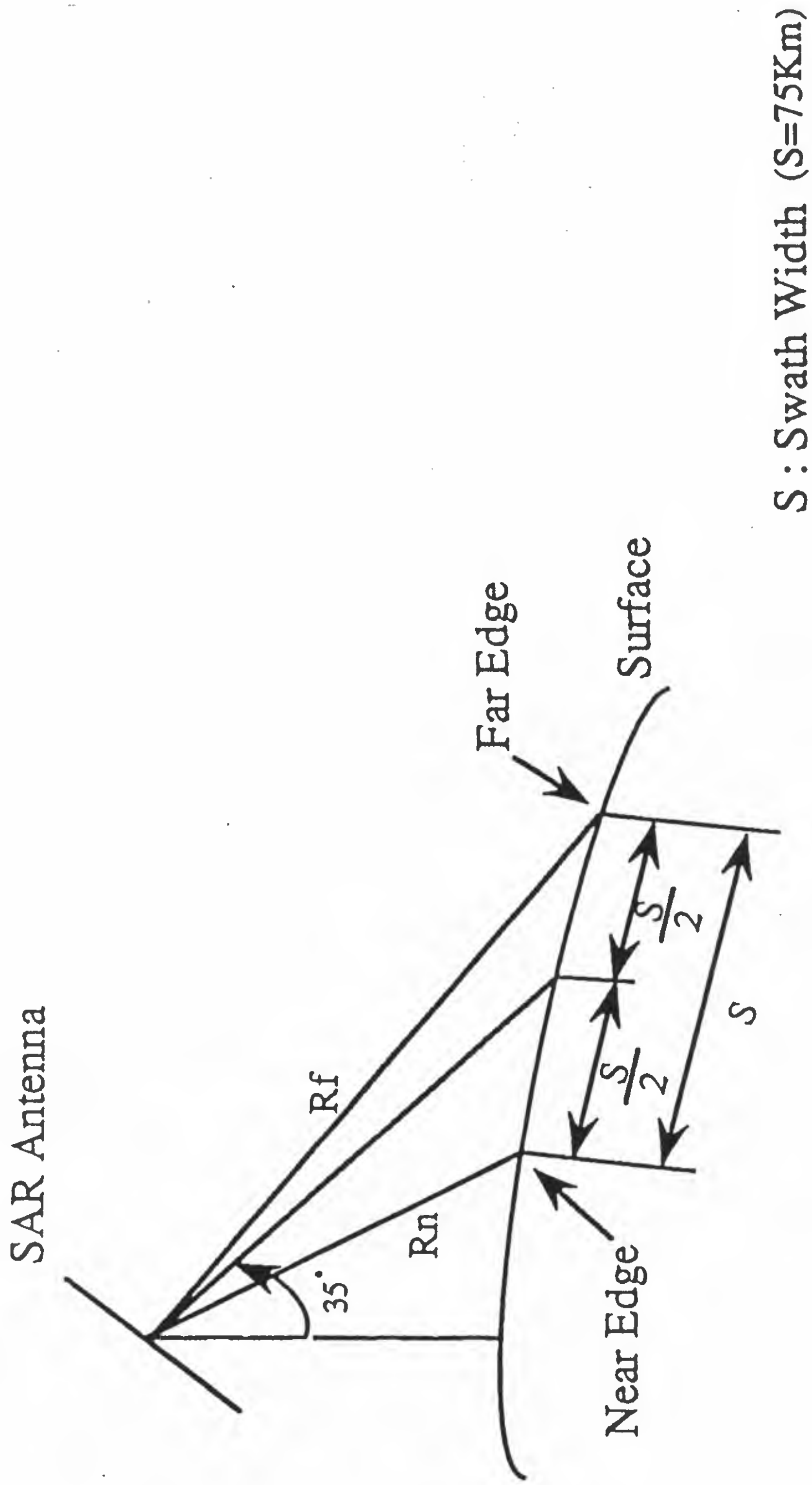
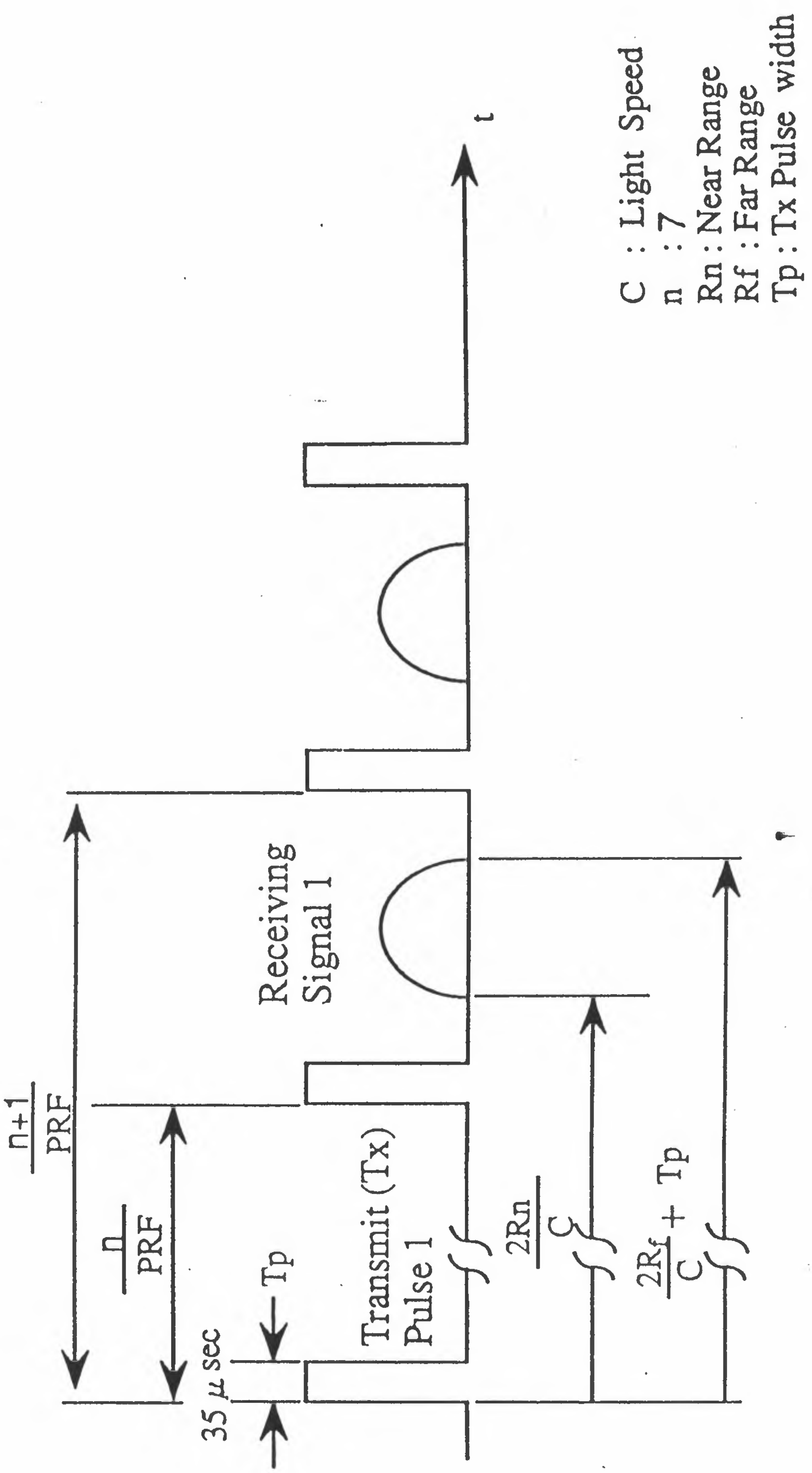
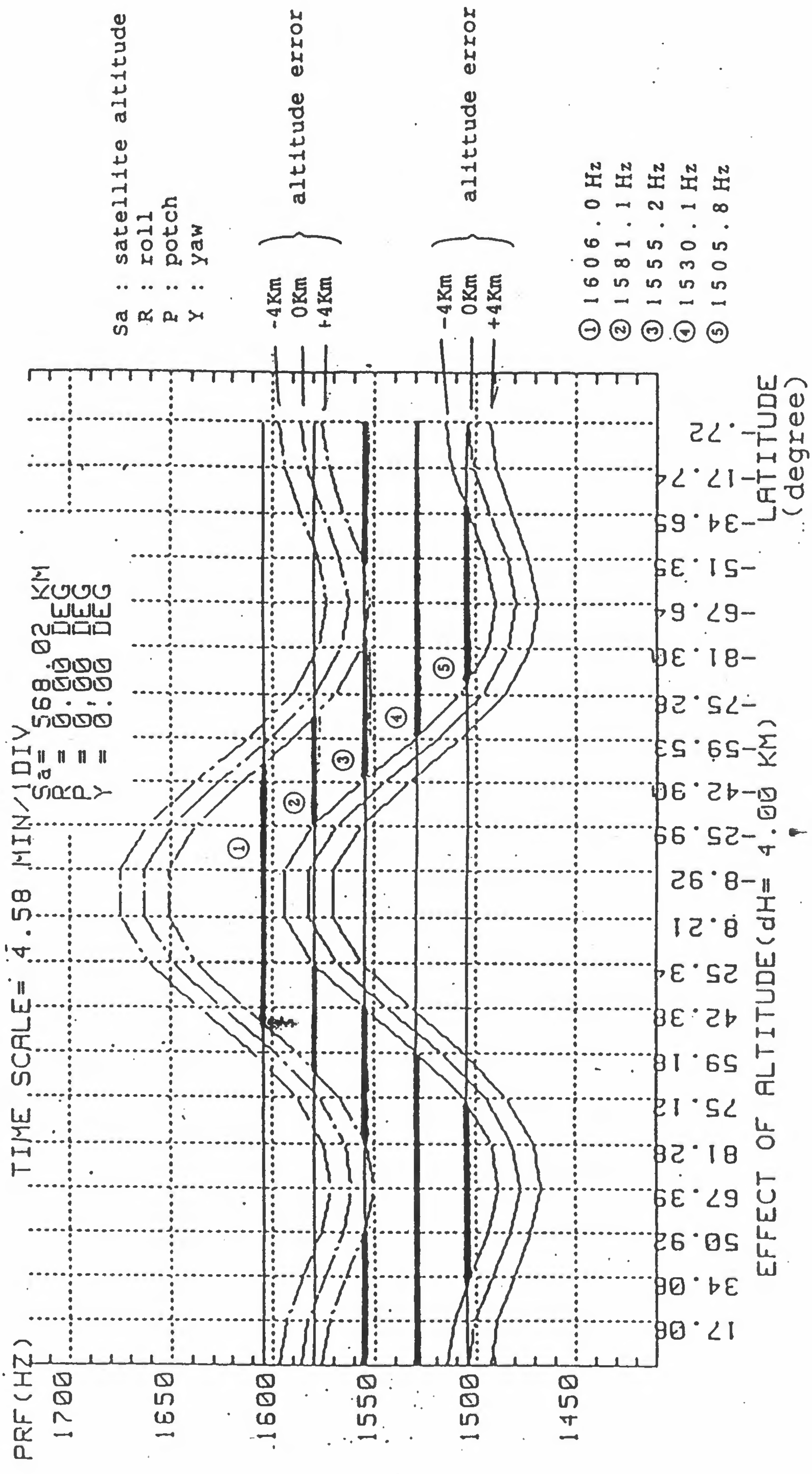


Figure 4.7 Timing Chart



Doc No :	HE-88023
Revision	: 2
Date :	26 OCT 90
Sheet :	4-13

Figure 4.8 PRF Window



4.2.4 Sensitivity Time Control (STC)

STC is adopted in order to increase dynamic range of echo data. The shape of STC curve is like reverse shape of antenna pattern. The STC curve is shown in figure 4.9. The attenuation level change completes between data samplings and takes less than 10 nsec.

The major parameters relating to the STC operation are shown in Figure 4.10 In case of normal observation, the parameters are set as shown in Table 4.2.

The STC start time is determined by the Initial STC start time and the STC start time change pattern. The STC start time changes during observation in order to fit the STC curve to the receiving time. The STC start time automatically changes every 30 seconds by 10 μsec step according to the pattern which is selected out of Figure 4.11. The tables of STC start time change pattern are given in Appendix C.

Outline of determination of STC parameters is shown in below;
Figure 4.12 describes the time variation of receiving echo during one orbit. When observation of the area denoted as A in this figure is required, an appropriate PRF is chosen. Then the STC initial start time T_0 is automatically determined according to the PRF as shown in Table 4.2. The STC start time change pattern is determined by choosing the pattern closest to the regression line of the arrival time of receiving echo on observation time in the area A.
The STC start time T_s is determined from the receiving time at the start time of observation obtained on replacing the actual curve shown in the Figure 4.12 with the STC start time change pattern chosen above.

4.2.5 Auto Gain Control(AGC)

AGC procedure is shown in figure 4.13. The detection point of receiving level is located in every receiving gate, and each size of detection point is 7μsec . The average of receiving level is calculated every 128 or 64 receiving gates. The averaging size is selected by command. The attenuator step is determined by comparing the average value with the standard value (0 dBm), and the maximum value of the attenuator step is 6 dB.

4.2.6 Analog to Digital Converter (ADC)

A/D conversion characteristics is shown in figure 4.14. ADCs for I ch and Q ch are the same circuit and have same characteristics. The input impedance of ADC is 50Ω.

Figure 4.9 STC Curve

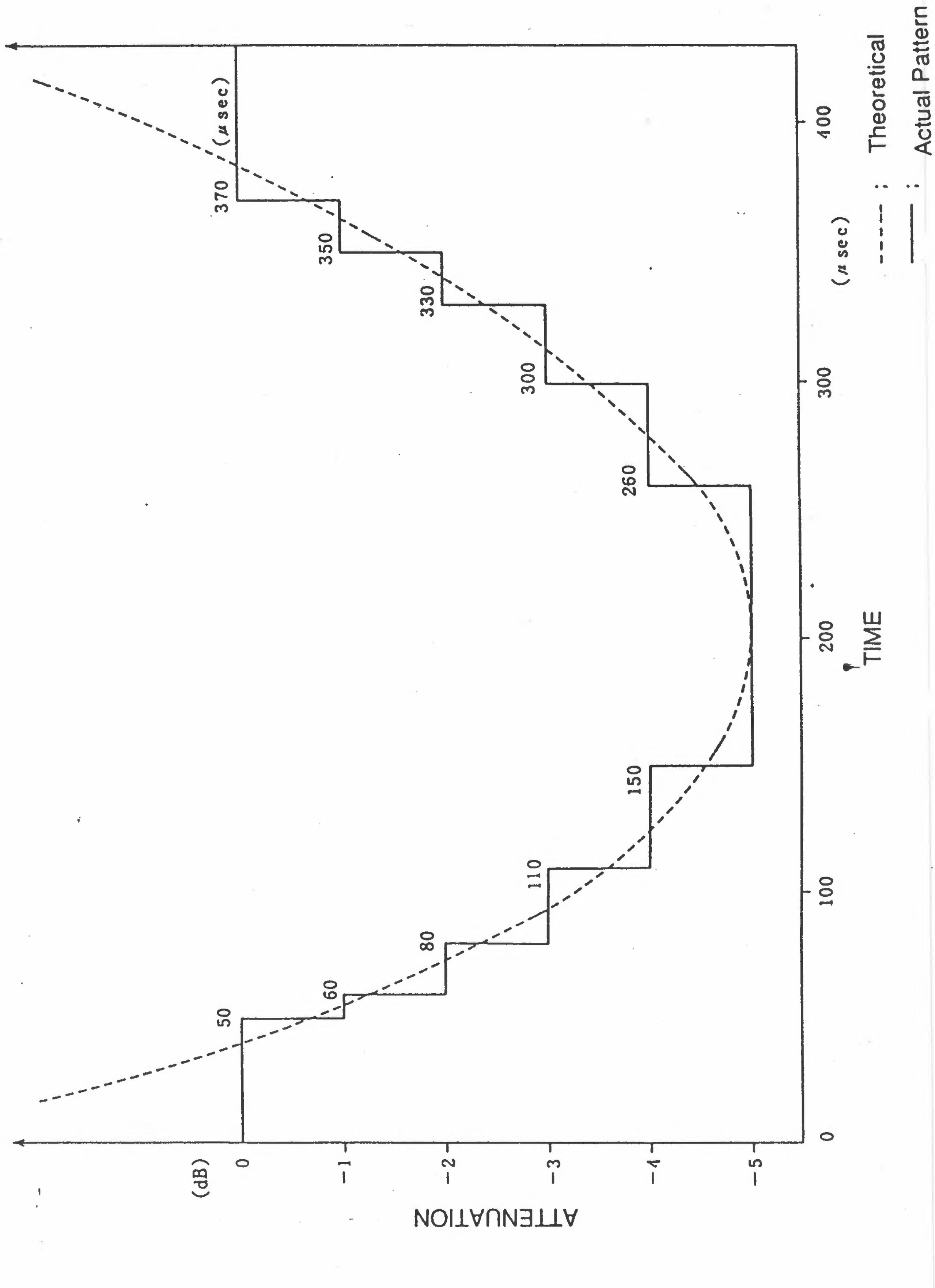


Figure 4.10. Parameters Relating to STC Operation

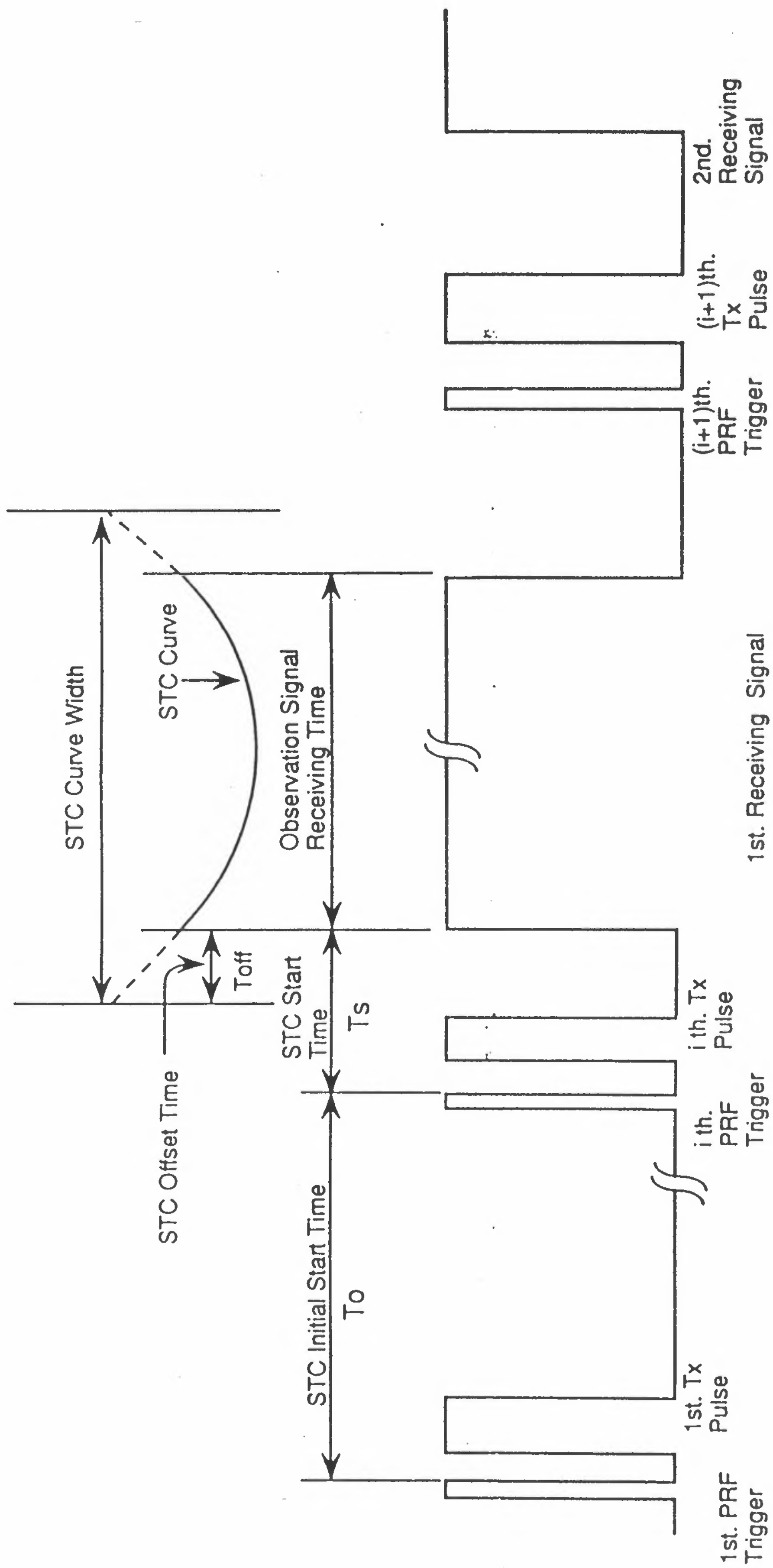


Table 4.2 Parameters Relating to STC Operation

	Calibration Mode	Observation Mode
STC curve width (T_w)	N/A	430 µsec
STC curve	N/A	see Figure 4.9
STC offset time (T_{off})	N/A	0 - 70 µsec
STC initial start time (T_0)	1/PRF	(1/PRF) × 7
STC start time (T_s)	60 µsec	60 - 300 µsec
Sampling duration	35 µsec	360 µsec

Note 1 STC curve width and STC curve are fixed.

2 PRF, STC offset time and STC start time(at observation mode) are set by command.

3 Sampling duration in the observation mode can be changed by command in range from 320 µsec to 360 µsec. But in case of normal operation ,this value is 360µsec.

Figure 4.11(1) STC Start Time Change Pattern

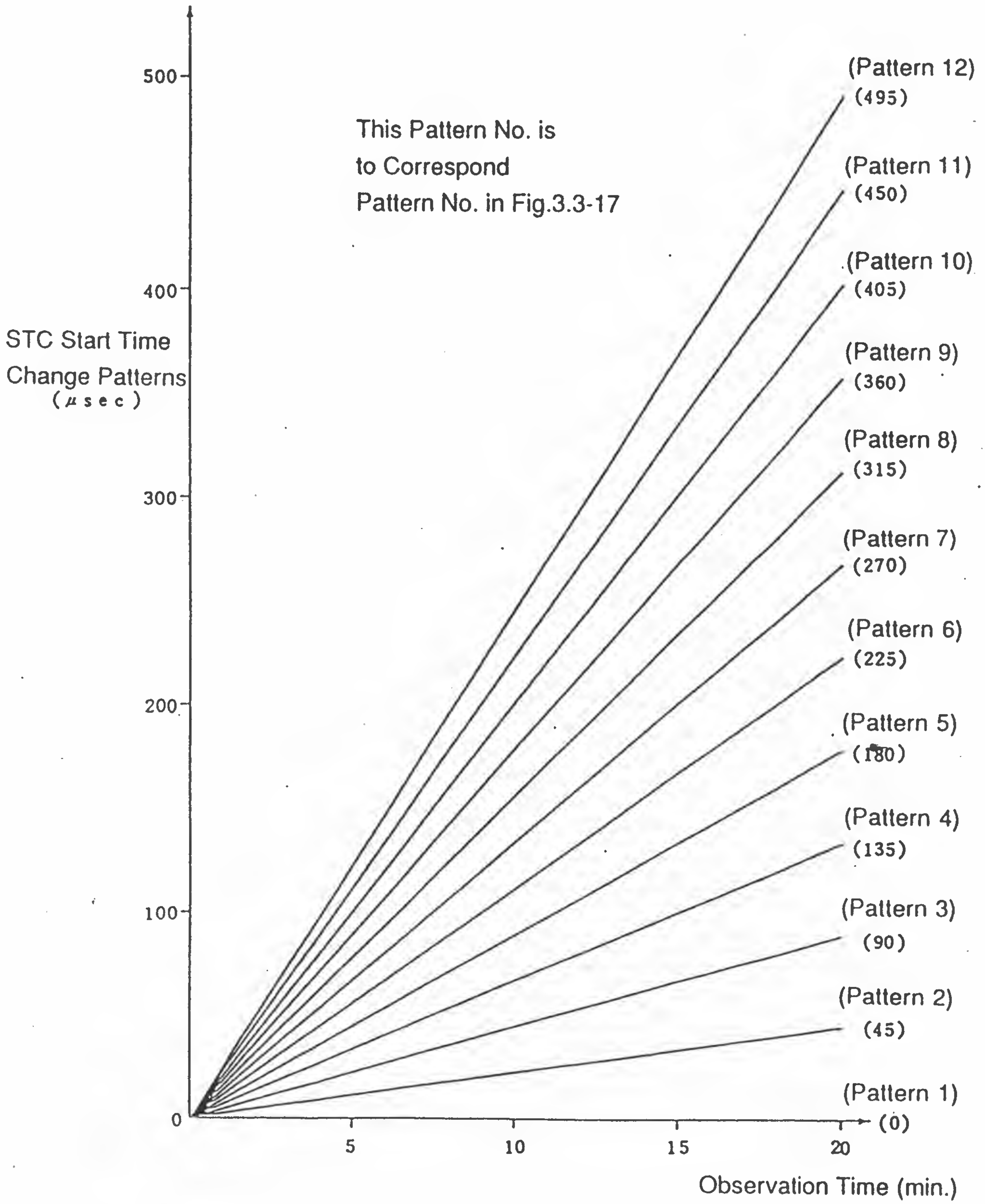


Figure 4.11(2) STC Start Time Change Pattern

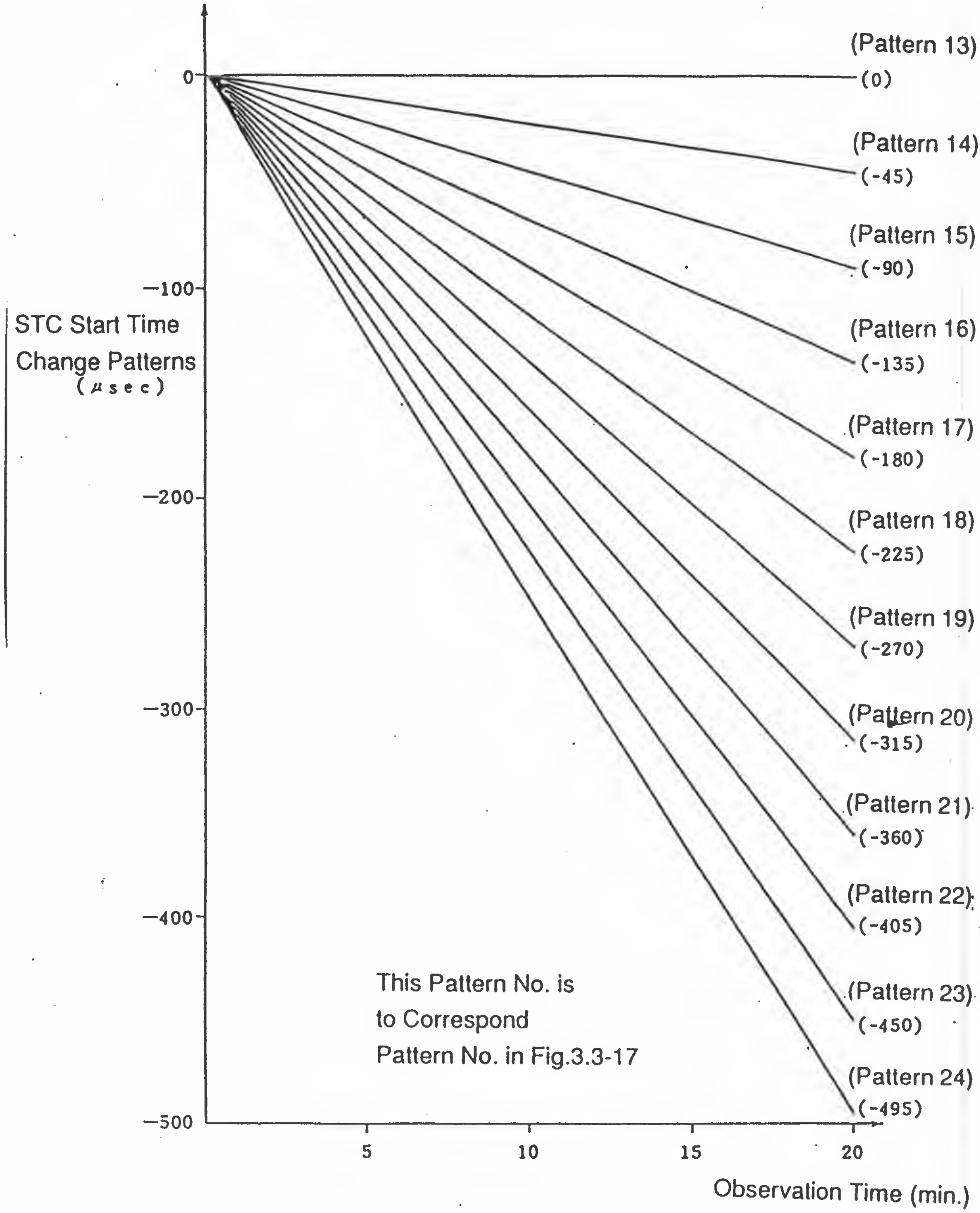


Figure 4.12 Time Variation of Receiving Echo

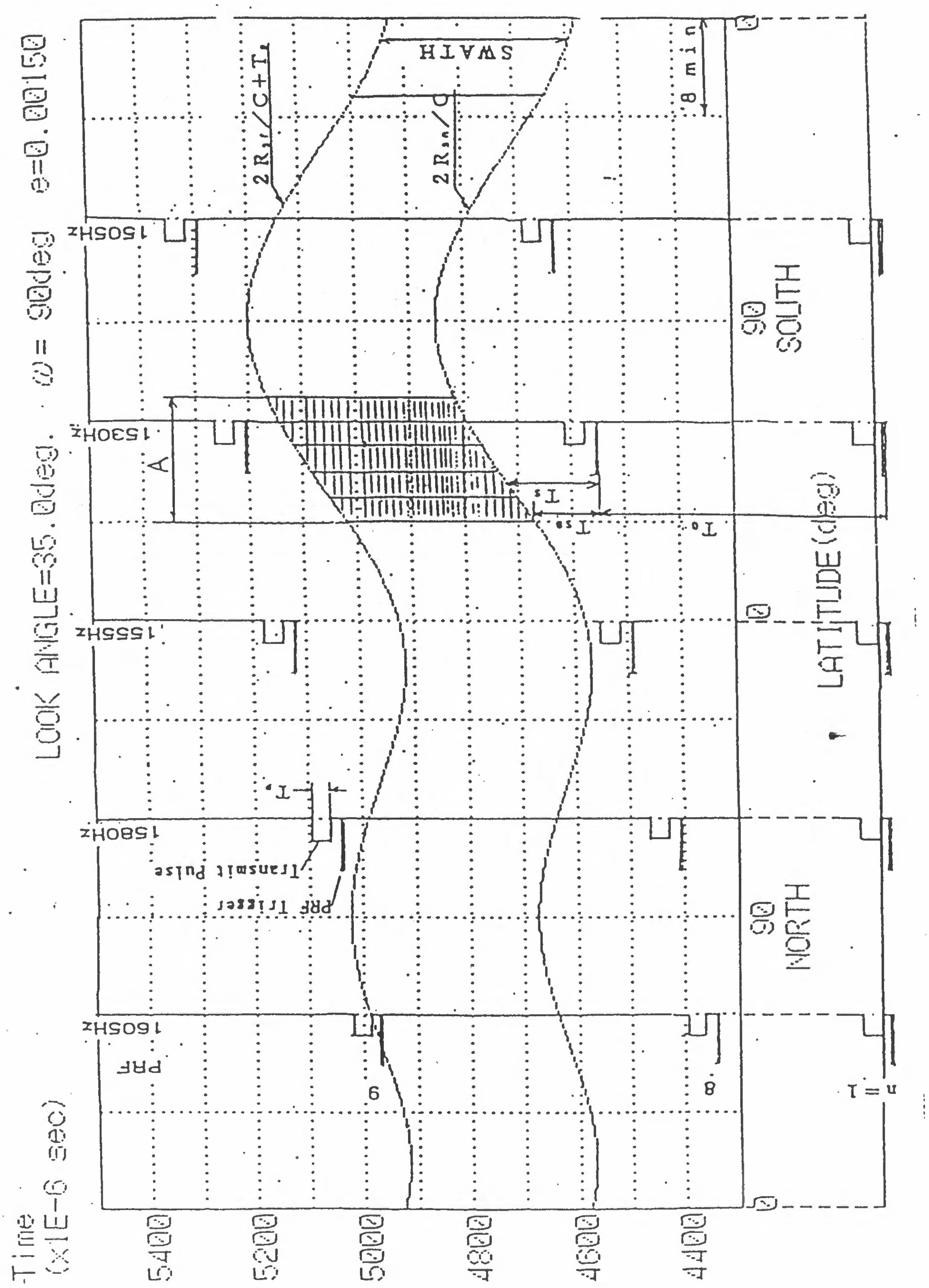


Figure 4.13 AGC Procedure

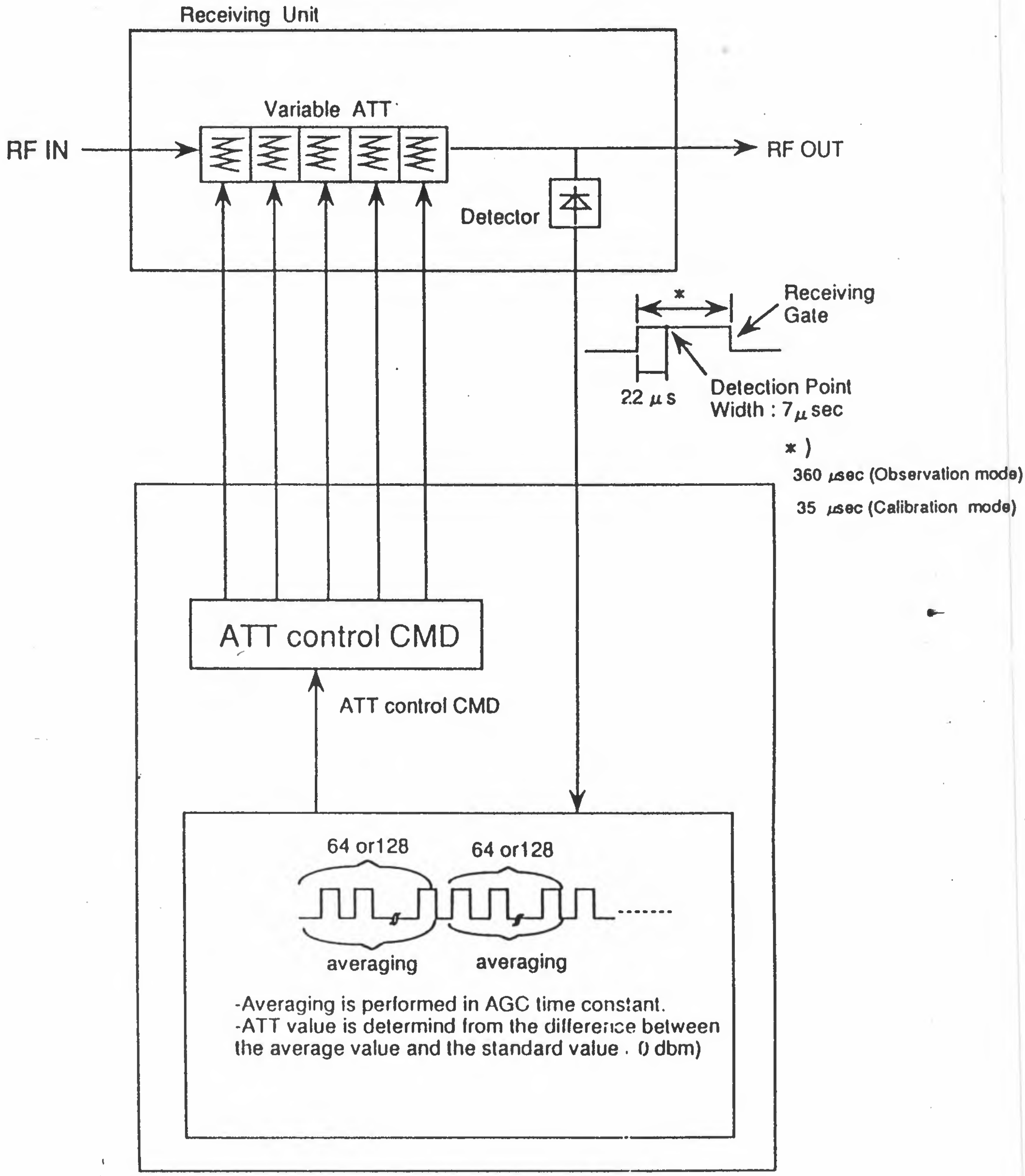
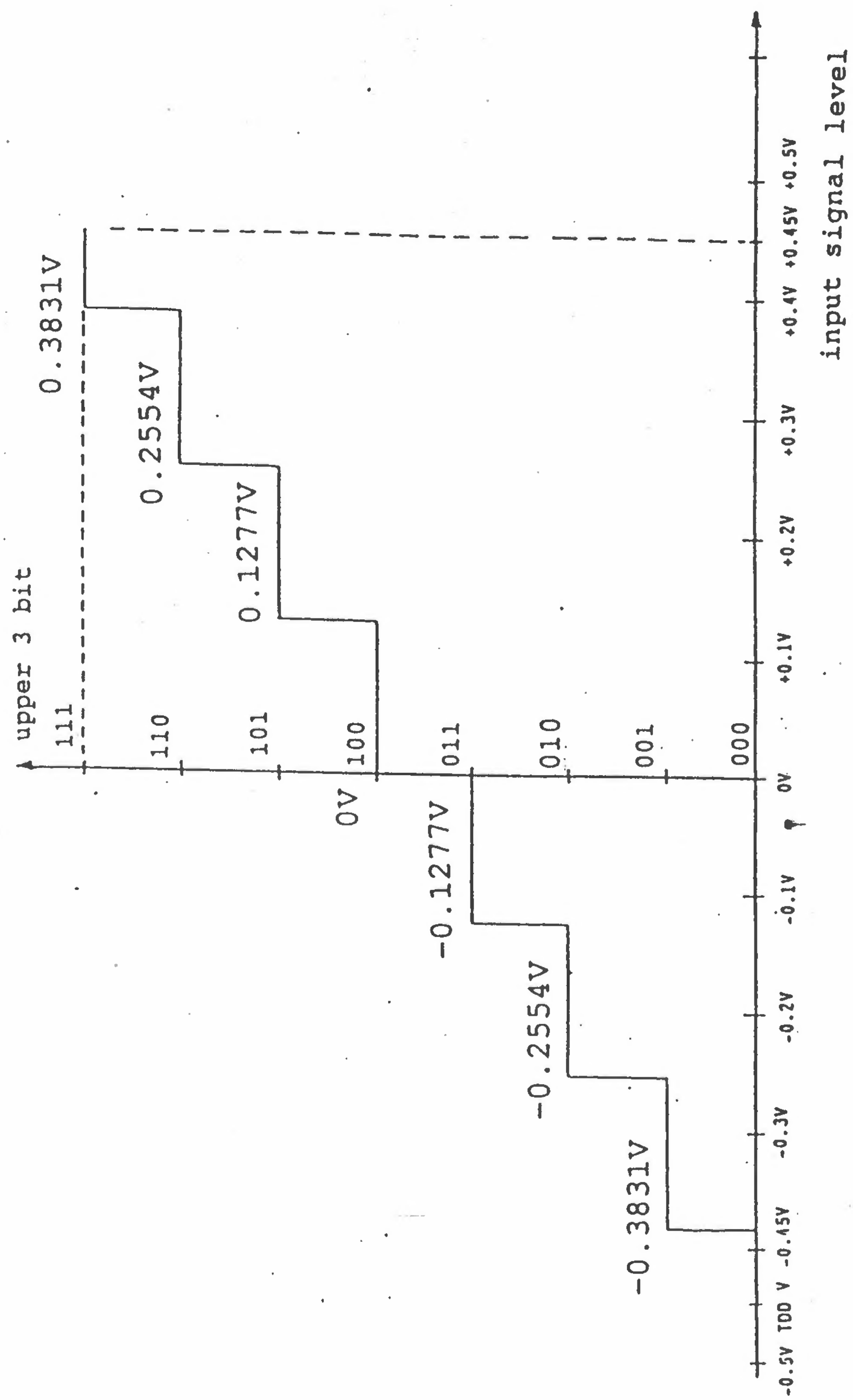


Figure 4.14 A/D Conversion Characteristics



4.3 Data format

SAR data format of calibration mode is shown in Figure 4.15 and that of observation mode is shown in Figure 4.16. SAR data format consists of four kinds of data ,which are as follows;

-Observation and Calibration data
-House Keeping(HK) data
-PCM sample data (Telemetry)
-Other data

Data length per frame varies with selected PRF out of five PRFs. I ch data and Q ch data have same timing and have the same values in HK data, Telemetry and Other data.
A/D converted I and Q data, each data rate is 17.076 Mbps x 3 (=51.2 Mbp are stretched to 30 Mbps by data stretcher to clear the input requirement of MDT.
The data stretch timing is shown in Figure 4.17 . The stretched data are output to the next formatting frame . Interleaving timing of PCM telemetry and clock data are shown in Figure 4.18.
The I ch data and Q ch data are output to MDT,where data are encoded with differential encoding scheme and modulated in QPSK as shown in Figure 4.19. On the ground ,the data are demodulated and decoded.

4.3.1 Observation and Calibration data

Observation and Calibration data are sampled data of I ch / Q ch video signal. Each quantized level is 3 bits. Nominal data length is 594 samples for calibration mode and 6144 samples for observation mode.

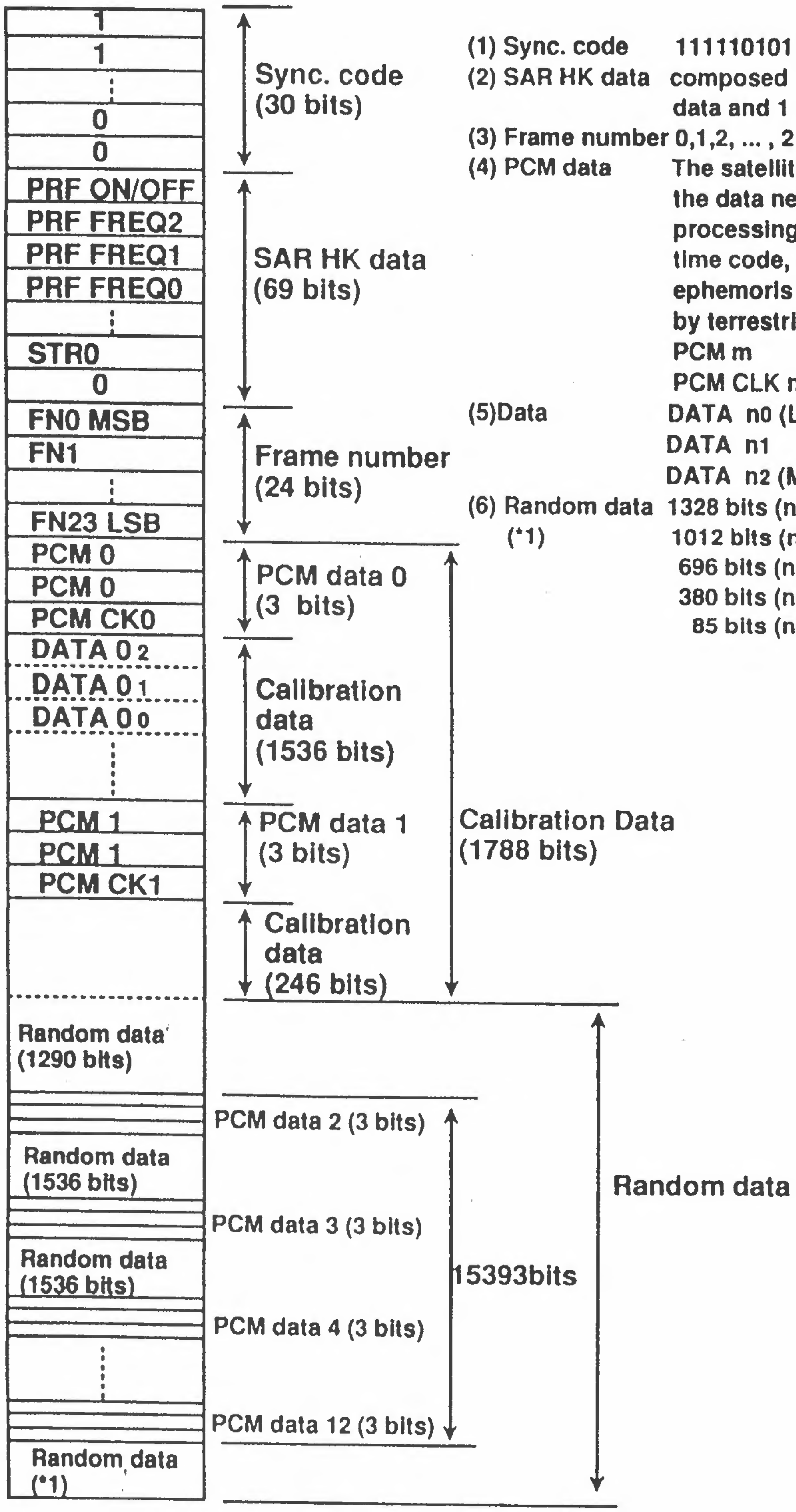
4.3.2 House Keeping (HK) data

List of SAR HK data bit definition in the automatic mode is shown in Table 4.3. HK data consist of 33 items. HK data are renewed by every PRF trigger.

4.3.3 PCM sample data (Telemetry)

PCM sample data are telemetry data that are the same as the C/DH telemetry data. Each PCM sample data consist of 2 telemetry bits and 1 clock bit. These 2 telemetry data are the same value. The timing chart of PCM data and PCM clock is shown in Figure 4.20. PCM telemetry frame is shown in Table 4.4. SAR telemetry list from S/C bus is shown in Table 4.5. Figure 4.21 shows the relationship between S/C PCM telemetry data and PCM data in SAR raw data format. All the S/C telemetry data are included in the SAR raw data. As shown in Figure 4.21, 10 times sampling during 1 bit of S/C PCM telemetry is performed. The sampling interval between the last sampling of the data format frame and the first sampling of the next frame changes according to the PRF.

Figure 4.15 SAR Raw Data Format (for Calibration Mode)



(1) Sync. code 1111101011 1100110011 0100000000

(2) SAR HK data composed of 68 bits of effective HK data and 1 bit of dummy data (0).

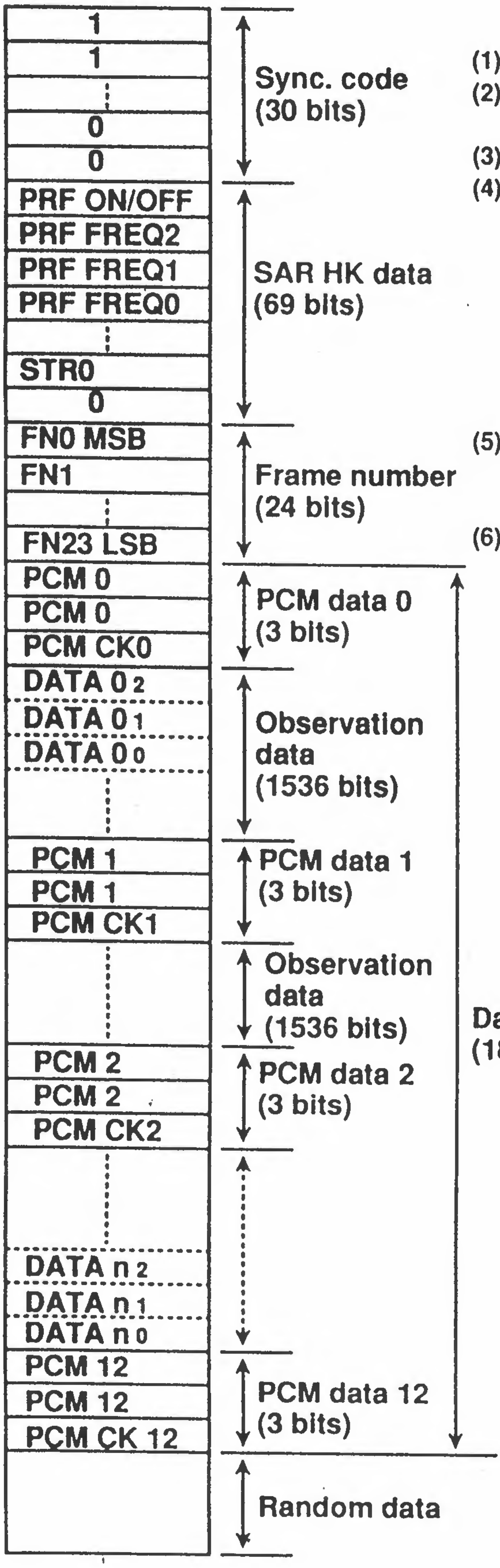
(3) Frame number 0,1,2, ... , 2^{24} -1

(4) PCM data The satellite PCM telemetry data in which the data necessary for the SAR image processing such as the attitude data, the time code, etc. are included, but no orbit ephemoris data (which will be transferred by terrestrial link).
PCM m
PCM CLK m m = 0, 1, 2, ---, 12

(5)Data DATA n0 (LSB)
DATA n1 n = 0,1,......, 593
DATA n2 (MSB)

(6) Random data (*1)
1328 bits (nominal value) at PRF=1505.8 Hz
1012 bits (nominal value) at RRF=1530.1 Hz
696 bits (nominal value) at PRF=1555.2 Hz
380 bits (nominal value) at PRF=1581.1 Hz
85 bits (nominal value) at PRF=1606.0 Hz

Figure 4.16 SAR Raw Data Format (for Observation Mode)



(1) Sync. code 1111101011 1100110011 0100000000

(2) SAR HK data composed of 68 bits of effective HK data and 1 bit of dummy data (0).

(3) Frame number 0,12, ... , 2^{24} -1

(4) PCM data The satellite PCM telemetry data in which the data necessary for the SAR image processing such as the attitude data, the time code, etc. are included, but no orbit ephemoris data (which will be transferred by terrestrial link).
PCM m
PCM CLK m m=0, 1, 2, —, 12

(5)Data DATA n_0 (LSB)
DATA n_1 n = 0,1,...., 6143
DATA n_2 (MSB)

(6) Random data 1328 bits (nominal value) at PRF=1505.8 Hz
1012 bits (nominal value) at RRF=1530.1 Hz
696 bits (nominal value) at PRF=1555.2 Hz
380 bits (nominal value) at PRF=1581.1 Hz
85 bits (nominal value) at PRF=1606.0 Hz

Figure 4.17 SP Data Stretch Timing

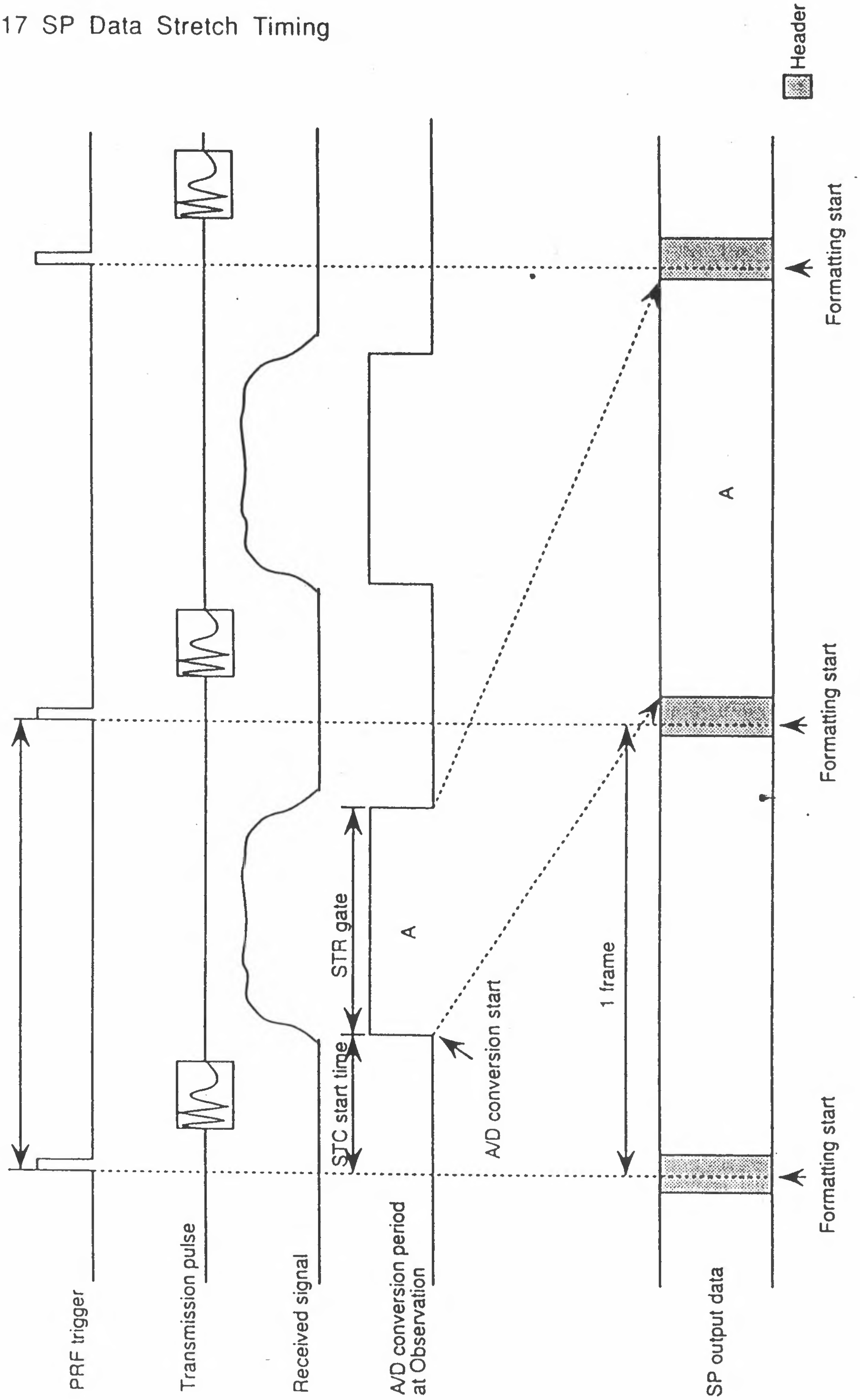


Figure 4.18 SP Data Formatting Timing

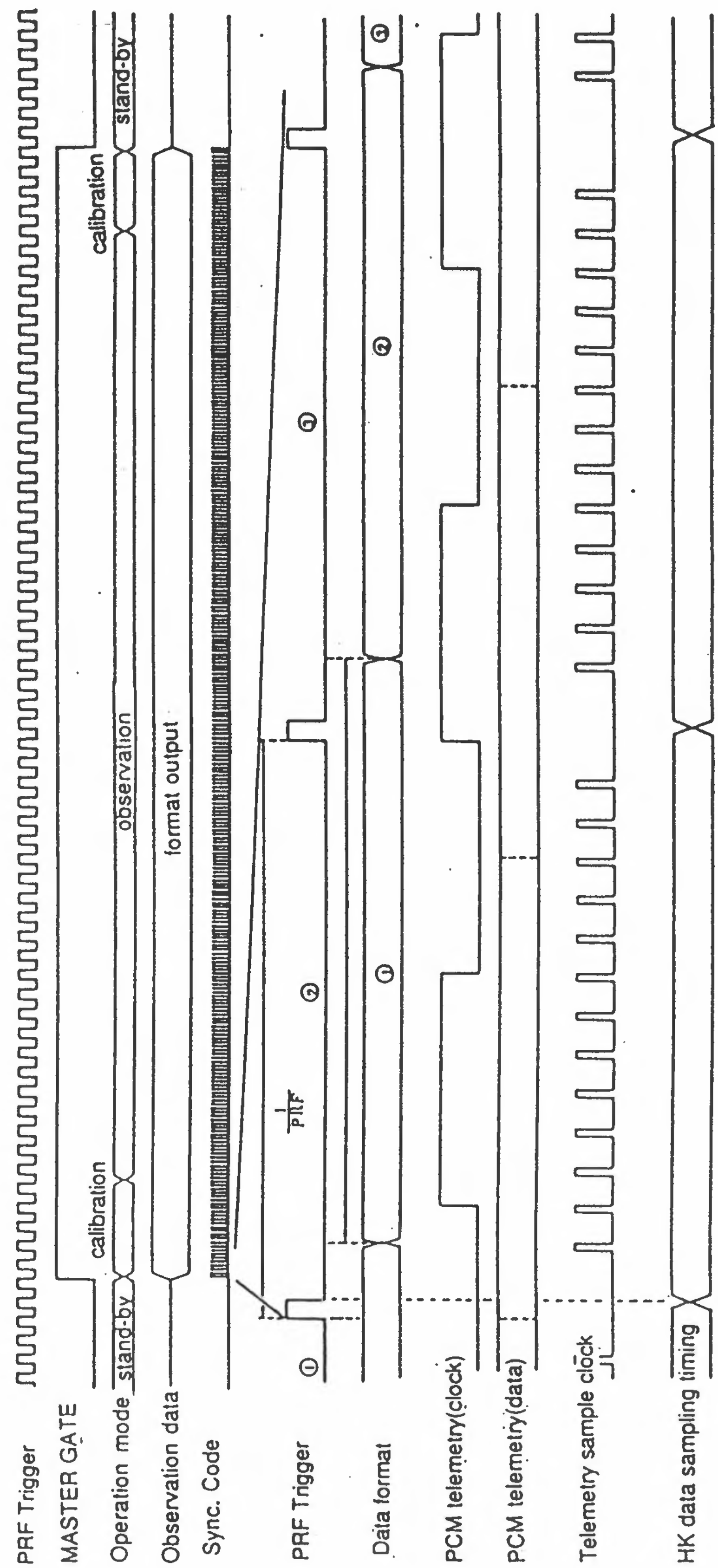
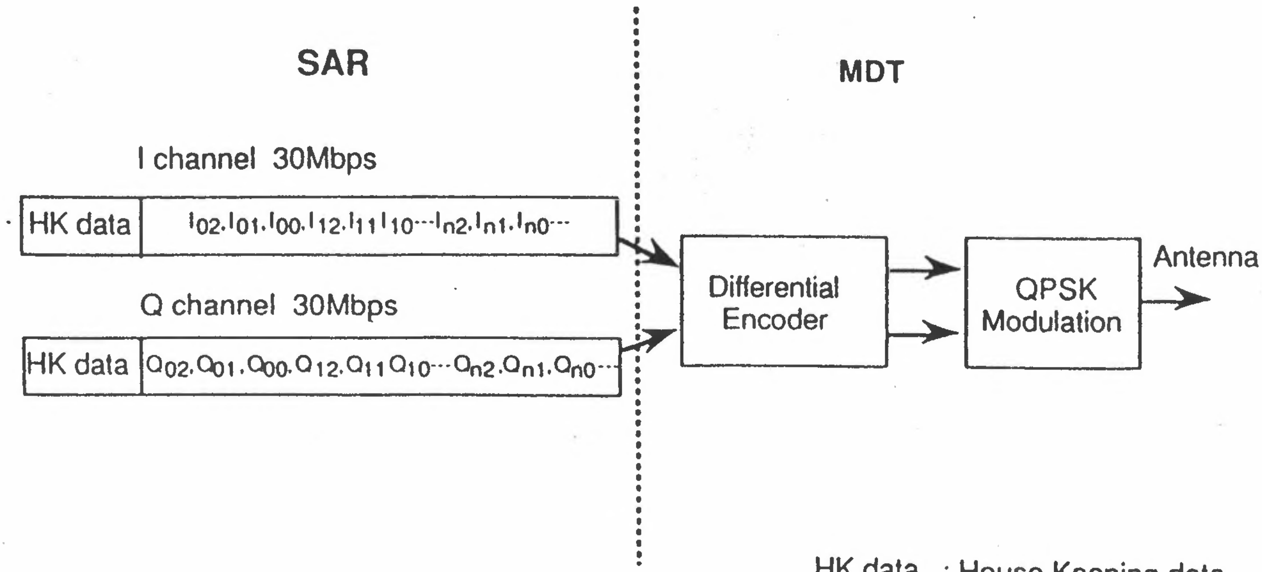


Figure 4.19 SAR Data Encoding and Modulation



HK data : House Keeping data
I_{ni} : I channel data
Q_{ni} : Q channel data

Table 4.3 (1/5) SAR HK Data Bit Definition

Bit No.	Item	Bit Definition		Remarks
1	PRF ON/OFF	1 0	ON OFF	
2~ 4	PRF	0 0 0 0 0 1 0 1 0 0 1 1 1 0 0	1505.8Hz 1530.1Hz 1555.2Hz 1581.1Hz 1606.0Hz	
5	CALIBRATION MODE ON/OFF	1 0	ON OFF	· "1" is shown at both CAL mode and OBS mode.
6	OBSERVATION MODE ON/OFF	1 0	ON OFF	· "1" is shown at OBS mode. · "0" is shown at CAL mode.
7~16	INITIAL POSITION OF STC TIME VARIATION	0 0 0 0 0 0 0 0 0 1 - - - - - 1 0 1 1 1	Pattern 1 Pattern 2 ---------- Pattern 24	· The first 5 bits represent STC START TIME CHANGE PATTERN (See Figure 4.11)
		0 0 1 0 1 0 0 1 1 0 - - - - - 1 1 1 0 1	60 μ sec 70 μ sec -------- 300 μ sec	· The last 5 bits represent INITIAL STC START TIME (See Figure 4.10)
17~21	STC START TIME	0 0 1 0 1 0 0 1 1 0 - - - - - 1 1 1 0 1	60 μ sec 70 μ sec -------- 300 μ sec	· See Figure 4.10 · effective at OBS mode. · "00000" is shown at CAL mode.

Table 4.3 (2/5) SAR HK Data Bit Definition

Bit No.	Item	Bit Definition		Remarks
22～24	STC OFFSET TIME	0 0 0 0 0 1 - - - 1 1 1	0～360 μ sec 10～370 μ sec 70～430 μ sec	· See Figure 4.10
25	AGC/MGC	1 0	AGC MGC	· effective at OBS mode. · "0" is shown at MGC mode.
26	AGC TIME CONSTANT	1 0	128/PRF 64/PRF	
27～31	AGC DATA	0 0 0 0 0 0 0 0 0 1 - - - - - 1 1 1 1 1	0dB 1dB ---- 31dB	· effective at OBS and CAL mode in AGC mode.
32～36	GAIN CONTROL STATUS (GC STA)	0 0 0 0 0 0 0 0 0 1 - - - - - 1 1 1 1 1	0dB 1dB ---- 31dB	· effective at OBS mode of MGC mode. · "00000" is shown at OBS mode of AGC mode.
37～39	STP ATT	0 0 0 0 0 1 - - - 1 1 1	0dB 3dB ---- 21dB	· effective at CAL mode. · "000" is shown at OBS mode.
40	AUTO/MANUAL	1 0	AUTO MANUAL	

Table 4.3 (3/5) SAR HK Data Bit Definition

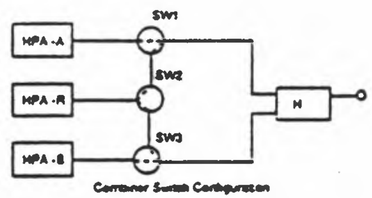
Bit No.	Item	Bit Definition		Remarks
41	OBSERVATION START/END	1 0	START END	・"1" is shown at the first CAL mode and OBS mode.
42~44	COMBINER SW1, SW2, SW3	 0 0 1 0 1 0 0 1 1 1 0 0 1 0 1 1 1 0 1 1 1	SW1 SW2 SW3 * * B A B * A B B B * * B * B B A A * A A	・* : indefinite 
45	RECEIVER SW	1 0	A or B unfixed	
46	STC CAL	1 0	CAL mode OBS. mode	
47	CAL SW	1 0	CAL mode OBS. mode	
48~49	STANDBY MODE SELECTION	0 0 0 1 1 0 1 1	EMERGENCY OFF STANDBY (1) STANDBY (2) STANDBY (3)	・"00" is shown at the first CAL mode and OBS mode.
50	CHANGE OF STATUS	1 0	MCC AGC	

Table 4.3 (4/5) SAR HK Data Bit Definition

Bit No.	Item	Bit Definition		Remarks
51	FREQUENCY SYNTHESIZER ON/OFF	1 0	ON OFF	
52	CONTROL UNIT ON/OFF	1 0	ON OFF	
53	TRANSMITTER UNIT ON/OFF	1 0	ON OFF	
54	RECEIVER UNIT ON/OFF	1 0	ON OFF	
55	SIGNAL PROCESSOR UNIT ON/OFF	1 0	ON OFF	
56	HIGH POWER AMPLIFIER POWER SOURCE A ON/OFF	1 0	ON OFF	
57	HIGH POWER AMPLIFIER POWER SOURCE B ON/OFF	1 0	ON OFF	
58	HIGH POWER AMPLIFIER POWER SOURCE R ON/OFF	1 0	ON OFF	
59	STC INITIAL START TIME	1 0	OBS. mode CAL. mode	
60	STR ON/OFF	1 0	ON OFF	

Table 4.3 (5/5) SAR HK Data Bit Definition

Bit No.	Item	Bit Definition	T_3 (μsec)	T_4 (μsec)	T_5 (μsec)	Remarks
61~68	STR STATUS	1 0 0 0 1 1 0 0	0	360	0	• "00000000" is shown in case of STR OFF.
		1 0 0 0 1 0 0 0	0	350	10	
		1 0 0 0 1 0 0 1	10	350	0	
		1 0 0 0 0 1 0 0	0	340	20	
		1 0 0 0 0 1 0 1	10	340	10	
		1 0 0 0 0 1 1 0	20	340	0	
		1 0 0 0 0 0 0 0	0	330	30	
		1 0 0 0 0 0 0 1	10	330	20	
		1 0 0 0 0 0 1 0	20	330	10	
		1 0 0 0 0 0 1 1	30	330	0	
		0 1 1 1 1 1 0 0	0	320	40	
		0 1 1 1 1 1 0 1	10	320	30	
		0 1 1 1 1 1 1 0	20	320	20	
		0 1 1 1 1 1 1 1	30	320	10	
69	SPARE	0				

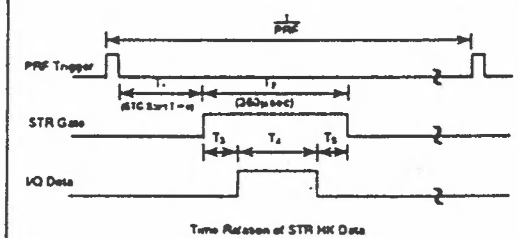


Table 4.4 TELEMETRY FRAME (MINOR FRAME)
(PCM Data from Central Unit of C&DH Subsystem)

0 FRAME SYNCH (W0 - W2)	1	2	3	4	5 SEE NOTE 1	6	7	8	9	10	11	12	13	14	15
16 SEE NOTE2 (W16-W17)	17	18 SEE NOTE 3	19 SEE NOTE	20	21	22	23	24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
48	49	50	51	52 SUBCOMMUTATION (W52 - W57) <------>	53	54	55	56	57	58	59	60	61	62	63
64	65	66	67	68 AOCS ATTITUDE DATA (W68 - W79) <------	69	70	71	72	73	74	75	76	77	78	79 ------>
80	81	82	83	84	85	86	87	88	89	90	91	92 <------	93	94	95
96 SAR TELEMETRY (W92 - W107) ------	97	98	99	100	101	102	103	104	105	106	107 ------>	108	109	110	111
112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127

NOTE: 1 FRAME ID ETC.
2 SPACECRAFT TIME DATA
3 SPACECRAFT ID ETC.

BLANK WORDS : BUS TELEMETRY, MISSION EQUIPMENTS (OTHER THAN OPS) TELEMETRY, OR SPARE

Table 4.5 (a) SAR TELEMETRY LIST
(Included in PCM Data from Central Unit of C&DH Subsystem)

NO.	ITEM	WORD-FRAME-BIT
1	SAR ANTENNA DEPLOYMENT 1 (90 deg ROTATION) LATCHUP STATUS	W57-F1(8)-B6
2	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 1	W58-F1(8)-B0
3	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 2	W58-F1(8)-B1
4	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 3	W58-F1(8)-B2
5	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 5	58-F1(8)-B3
6	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 5	58-F1(8)-B4
7	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 6	58-F1(8)-B5
8	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 7	58-F1(8)-B6
9	SAR ANTENNA DEPLOYMENT 2 (STRETCH) LATCHUP STATUS 8	58-F1(8)-B7
10	SAR ANTENNA DEPLOYMENT 2 (Inclination) LATCHUP STATUS	57-F1(8)-B7
11	SAR ANTENNA TEMPERATURE 1	W58-F4
12	SAR ANTENNA TEMPERATURE 2	W59-F4
13	SAR ANTENNA TEMPERATURE 3	W52-F5
14	SAR ANTENNA TEMPERATURE 4	W53-F5
15	SAR ANTENNA TEMPERATURE 5	W54-F5
16	SAR ANTENNA TEMPERATURE 6	W55-F5
17	SAR ANTENNA TEMPERATURE 7	W56-F5
18	SAR ANTENNA TEMPERATURE 8	W57-F5
19	SAR ANTENNA TEMPERATURE 9	W58-F5
20	SAR ANTENNA TEMPERATURE 10	W59-F5
21	OVEN CONTROLLED X'TAL OSCILLATOR-A ON/OFF	W54-F7-B5
22	OVEN CONTROLLED X'TAL OSCILLATOR-B ON/OFF	W54-F7-B4
23	PULSE GENERATOR-A ON/OFF	W54-F7-B3
24	PULSE GENERATOR-B ON/OFF	W54-F7-B2

Table 4.5 (b) SAR TELEMETRY LIST
(Included in PCM Data from Central Unit of C&DH Subsystem)

NO.	ITEM	WORD-FRAME-BIT
25	SIGNAL PROCESSOR-A TEMP	W52-F7
26	PULSE GENERATOR-A TEMP	W58-F6
27	RF OUTPUT LEVEL A	W92
28	CAL OUTPUT LEVEL A	W93
29	I VIDEO SIGNAL OUTPUT LEVEL A	W94
30	Q VIDEO SIGNAL OUTPUT LEVEL A	W95
31	SIGNAL PROCESSOR-A ON/OFF	W54-F7-B1
32	SIGNAL PROCESSOR-B TEMP	W53-F7
33	PULSE GENERATOR-B TEMP	W59-F6
34	RF OUTPUT LEVEL B	W96
35	CAL OUTPUT LEVEL B	W97
36	I VIDEO SIGNAL OUTPUT LEVEL B	W98
37	Q VIDEO SIGNAL OUTPUT LEVEL B	W99
38	SIGNAL PROCESSOR-B ON/OF	W54-F7-B0
39	HIGH POWER AMPLIFIER-A TEMP	W52-F6
40	HIGH POWER AMPLIFIER-B TEMP	W53-F6
41	HIGH POWER AMPLIFIER-R TEMP	W54-F6
42	HIGH POWER AMPLIFIER POWER SUPPLY-A TEMP	W55-F6
43	HIGH POWER AMPLIFIER POWER SUPPLY-B TEMP	W56-F6
44	HIGH POWER AMPLIFIER POWER SUPPLY-R TEMP	W57-F6
45	SERIAL DIGITAL TELEMETRY 1	W100
46	SERIAL DIGITAL TELEMETRY 2	W101
47	SERIAL DIGITAL TELEMETRY 3	W102
48	SERIAL DIGITAL TELEMETRY 4	W103
49	SERIAL DIGITAL TELEMETRY 5	W104
50	ERIAL DIGITAL TELEMETRY 6	W105
51	SERIAL DIGITAL TELEMETRY 7	W106
52	SERIAL DIGITAL TELEMETRY 8	W107

NOTE: Fn(m) n : (MINOR) FRAME NUMBER
m : m TIMES PER MAJOR FRAME(64 MINOR FRAMES)

Figure 4.20 Timing Chart of PCM data and PCM clock

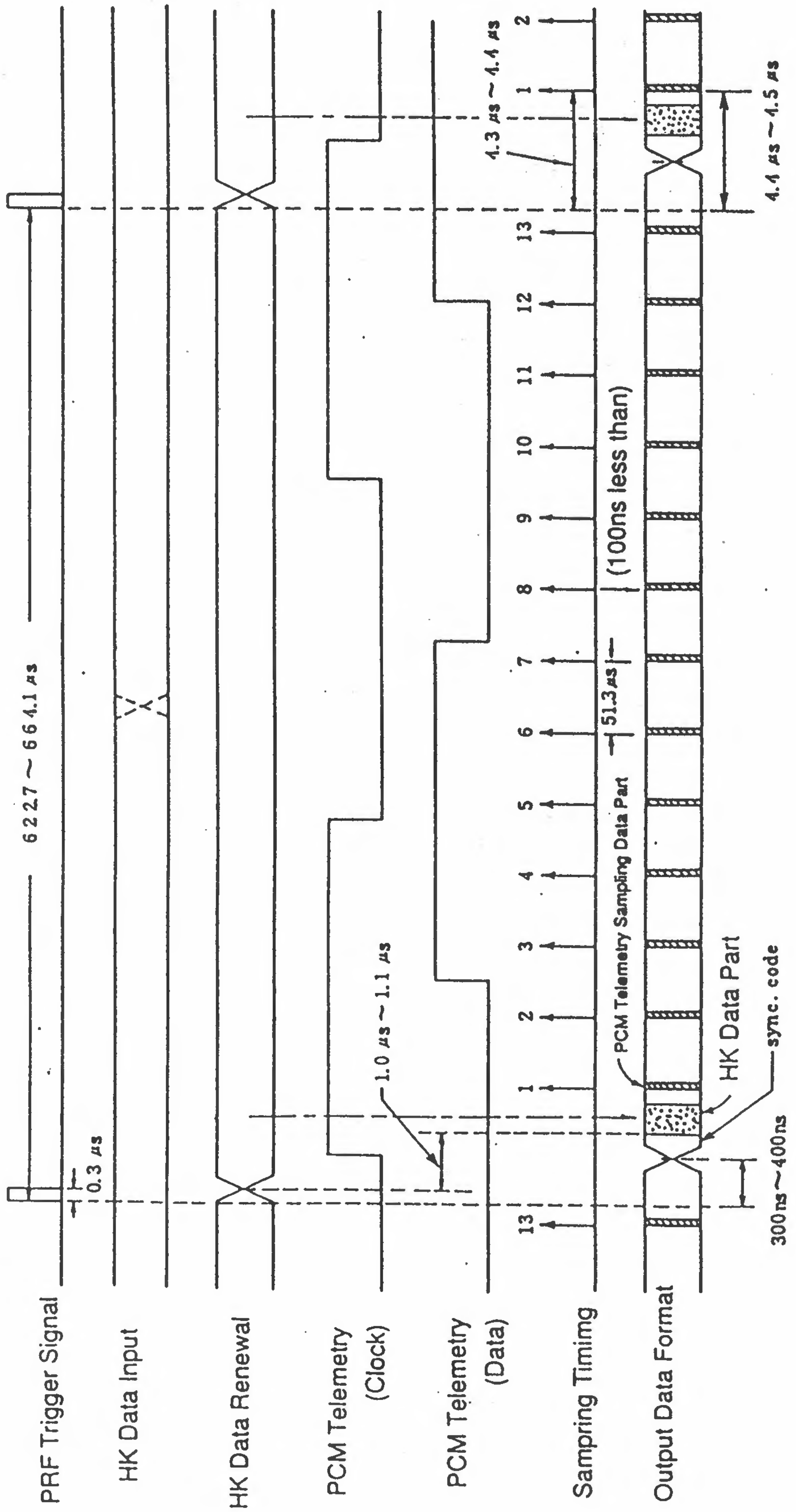
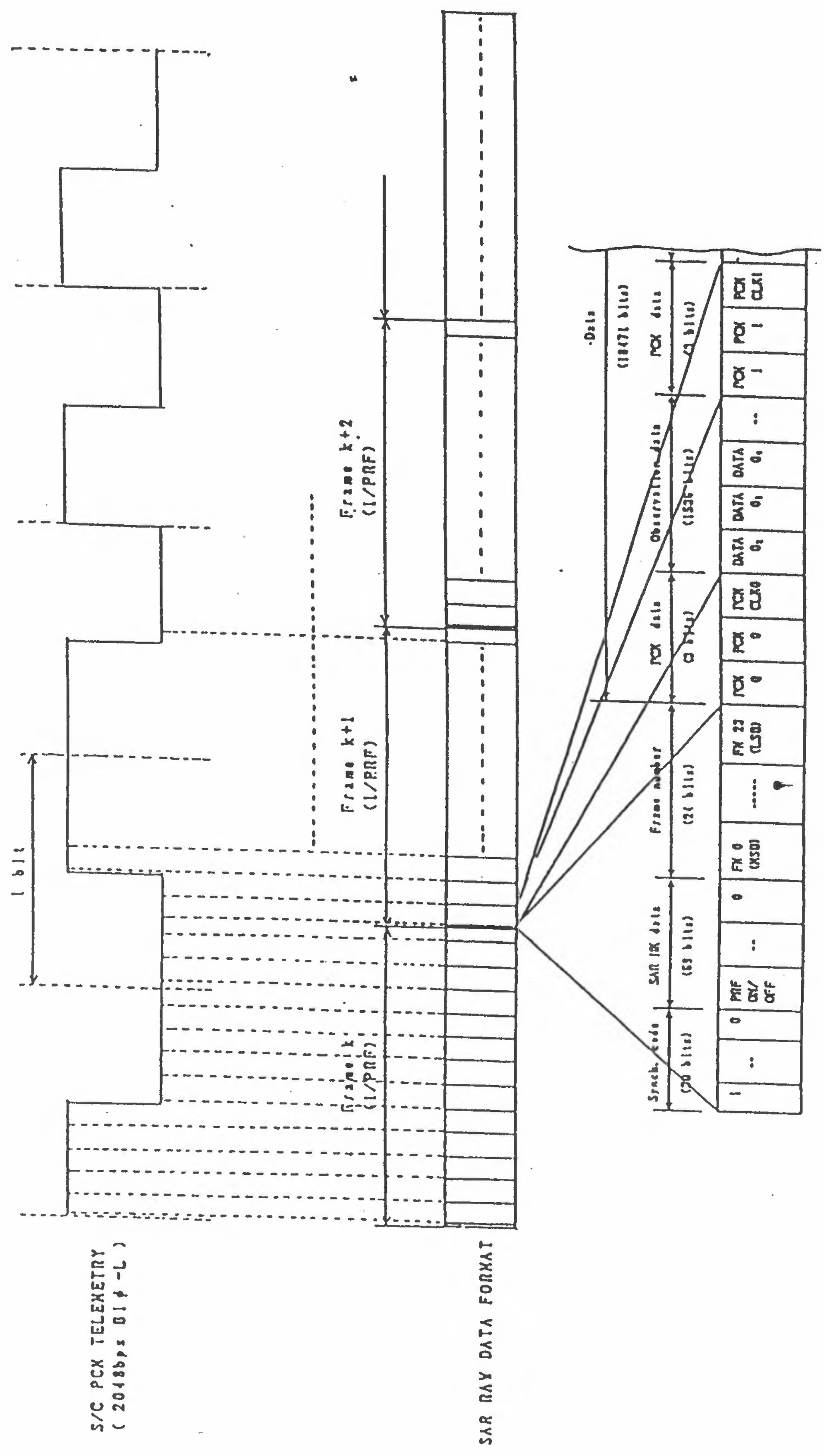


Figure 4.21 Relationship between S/C PCM Telemetry and SAR Raw Data Format



4.3.4 Other data

(1)Sync. code

Sync.code is located at the top of each frame and has 30 bits fixed pattern. The pattern is "1111101011 1100110011 0100000000". This code is used in order to detect the start of each PRF line.

(2)Frame Number

Frame number consists of 24 bits . The frame number is initialized to zero at the beginning of each observation sequence , which is composed of calibration mode at the head , observation mode at the middle , and calibration mode again at the end.
Frame number is increased by one in every PRF frame.

(3)Random Data

The bit pattern of random data in the data format is shown in Figure 4.22. The number of random bits at the end of each PRF frame is identical in I and Q channels. So I and Q channel have the same number of random bits.

Since the PRF trigger isn't synchronized to the sync. pulse from the MDT,the length of each PRF line has some fluctuation. The number of the last random bits will be changed in 3 bits range.

Figure 4.22 Random Data Bit Pattern

11111110,00011101,11100101,10010010,00000100,01001100,
8 16 24 32 40 48
01011101,01101100,00011001,10101001,11001111,01101000,
56 64 72 80 88 96
01010101,11110100,10100011,0111000
104 112 120 127

Note. -In case of calibration mode, the top 3 bits of random data are all 0.
-The last 9 bits of random data are 000000111 and this pattern is independent of PRF.

4.4 Calibration

SAR on-board Calibration is for the receiver gain calibration. Table 4.6 shows the contents of a set of calibration data. In the calibration before and after observation a set of calibration data shown in Table 4.6 repeated by 8 times as shown in Figure 4.5(SAR Data Sequence). The calibration data included in the data format are the A/D converted receiver video output which is automatic gain controlled by AGC attenuator corresponding to the receiver input level of 8 states (set up by the step attenuator as shown in Table 4.6). The status of the step attenuator and AGC attenuator are included as HK data in the data format. 21dB of the step attenuator corresponds to -92dBm of receiver(LNA) input level.

The receiver output level varies in the transient time from the step attenuator switching to reach stationary states due to AGC time constant. The variation of the receiver output level and it's duration depend on the following items;

- PRF
- timing between the step attenuator switching and the AGC attenuator switching
- AGC time constant

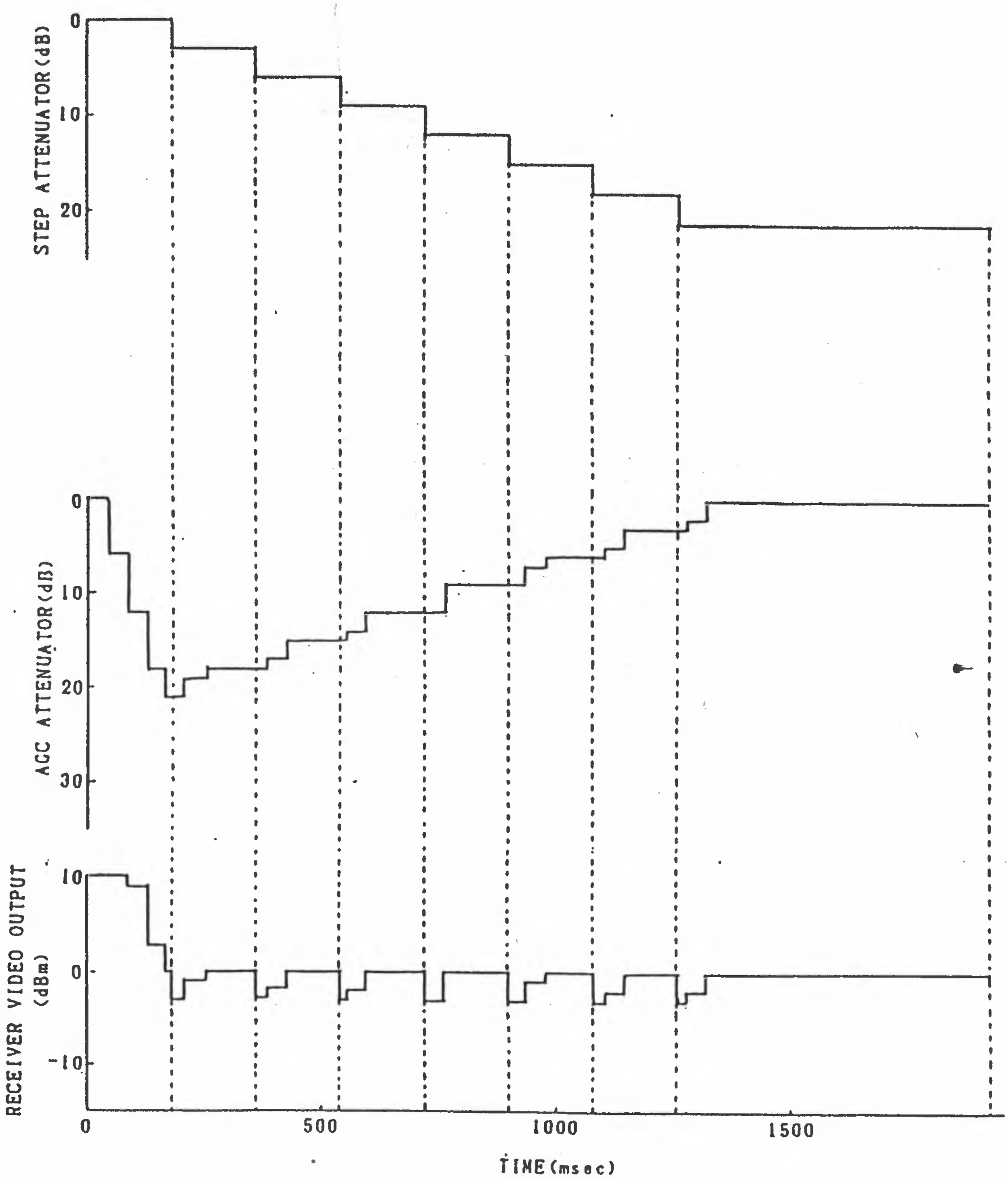
Figure 4.23 shows an example of receiver output level variation together with the related parameters in the case shown below.

- PRF=1505.8Hz
- switching timing of the step and AGC attenuators coincides at .
- AGC time constant=64/PRF

Table 4.6 SAR Calibration Data

No	Step Attenuator (dB)	Duration (msec)	AGC Attenuator (dB)	Output level of I/Q Video signal (dBm)
1	0	0 - 180		10dBm(approx.) - 0dBm(nom.) (at stationary state)
2	3	180 - 360		
3	6	360 - 540		
4	9	540 - 720		
5	12	720 - 900		
6	15	700 -1080		
7	18	1080 -1260		
8	21	1260 -1920		

Figure 4.23 An example of calibration data



4.5 Operational modes

Operational modes of SAR are described as follows;

- All-off mode
  Every part of SAR is power off. This mode is set during launch or for emergency.

- Heater mode
  Heaters of SAR antenna are turned on. This mode is used from launching to expanding antenna

- Stand-by (1) mode
  To prepare for observation , the crystal oscillator is turned on. This mode must be set 3 hours before observation.

- Stand-by (2) mode
  In addition to Stand-by (1) mode ,the pulse generator is turned on. This mode must be set 30 minutes before observation.

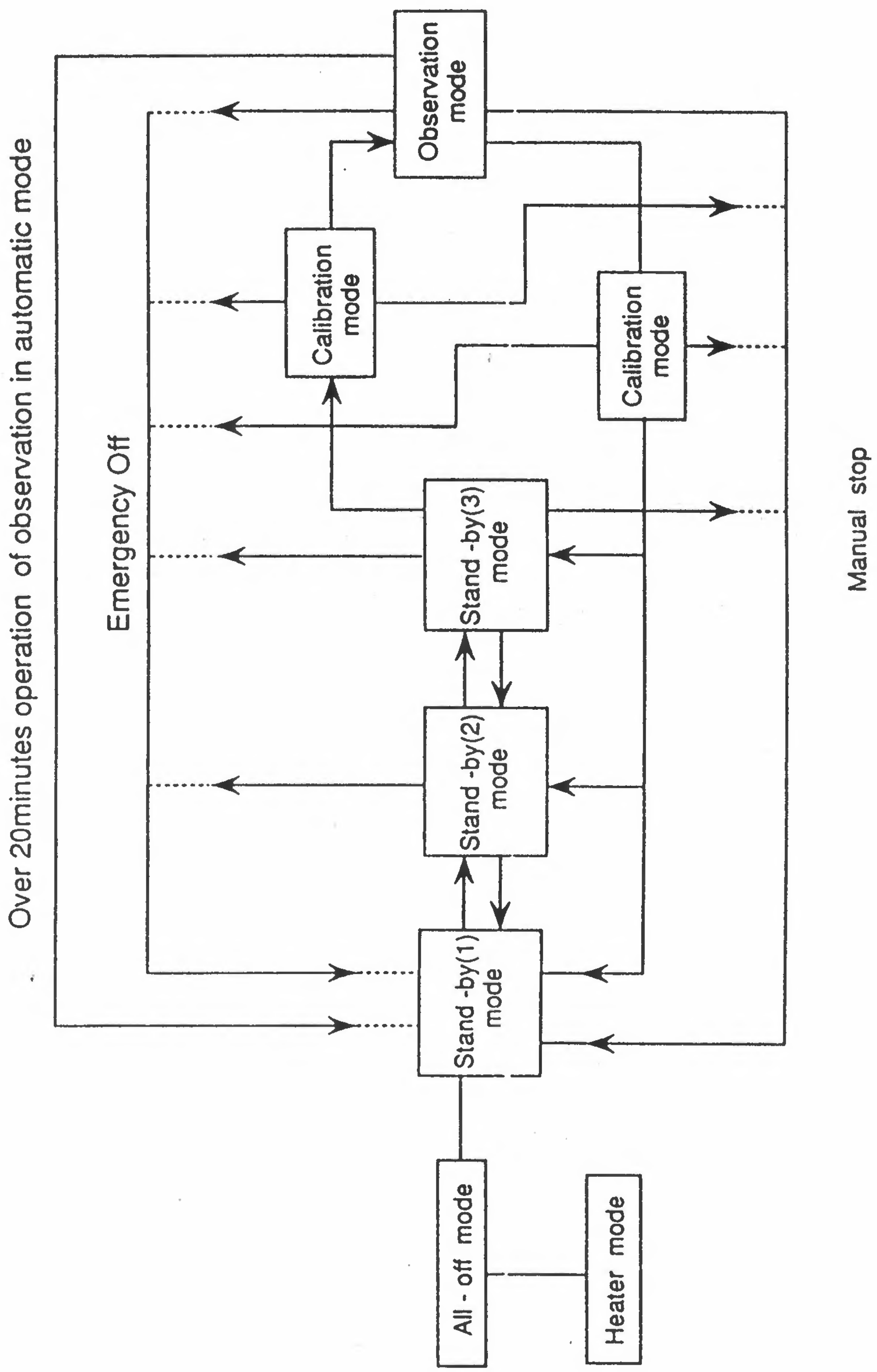
- Stand-by (3) mode
  In addition to Stand-by (2) mode ,the signal processor is turned on.

- Calibration mode
  In addition to Stand-by (3) mode, all parts except for the output amplifier are turned on. In order to collect calibration data ,this mode is set .

- Observation mode
  All parts of SAR are turned on.

The relationship of each mode is shown in Figure 4.24.

Figure 4.24 Operational modes of SAR



5. MDR (MISSION DATA RECORDER)

5.1 General

The MDR of JERS-1 is used to record and to reproduce mission sensor data whi(are observed outside of ground station coverage area. The MDR is composed electronics unit(EU), transport unit(TU) and thermal control insulator. The ma functions of this MDR are;

1) to record SAR or OPS data as digital signals of two channels (I/Q)
2) to reproduce recorded SAR or OPS data as digital signals of tw channels (I/Q)
3) to perform error correction to keep the low Bit Error Rate less tha 10^{-6}
4) to assign alternative tape track if anomaly occurs at any one of the 1 tracks (including parity) each channel (I/Q)
5) to control the temperatures of electronics unit and MDR transport un within prescribed range.

5.2 Performance

The performance characteristics of MDR are as follows;

- recording capacity : over 20 minutes
- number of channels : 2ch (I & Q)
- recording speed : 30 Mbps / ch (nominal)
- reproduction speed : 30 Mbps / ch (nominal)
- onboard storage : over 7.2×10^4 Mbits
- bit error rate : under 1×10^{-6}
- number of tracks : 40
- tape speed : 87ips
- life time
  - a) Tape running time : 2000 hours
  - b) Tape pass time : 6000 times
  - c) Start/Stop times : 20000times
  - d) Power on/off times : 20000times

- power : Max. 252 W
- transient time : under 6sec.
  data are valid 6sec after starting operatic

5.3 Operational modes

MDR reproduction is only available for EOC/NASDA and the specific forei stations.

MDR REPRODUCE ONLY	Available
MDR RECORD ONLY	Available
MDR REPRODUCE + SAR REAL	Available
MDR REPRODUCE + OPS REAL	Available
MDR REPRODUCE + VNIR REAL	Available
MDR RECORD + SAR REAL	Available
MDR RECORD + OPS REAL	Available
MDR RECORD + VNIR REAL	Available

The Operational modes are shown in Figure 5.1.

-Power off mode
All power sources are off.
-Heater mode
This mode is used for controlling temperature of EU and TU.
-Stand-by mode
EU is turned on.
-Record mode
Recording is performed.
-Reproduce mode
Reverse reproducing is performed.
-Forward wind mode
Forward winding is performed without erasing data.Tape speed is same as that of record mode.
-Reverse wind mode
Reverse winding is performed. Tape speed is same as that of reproduce mode.

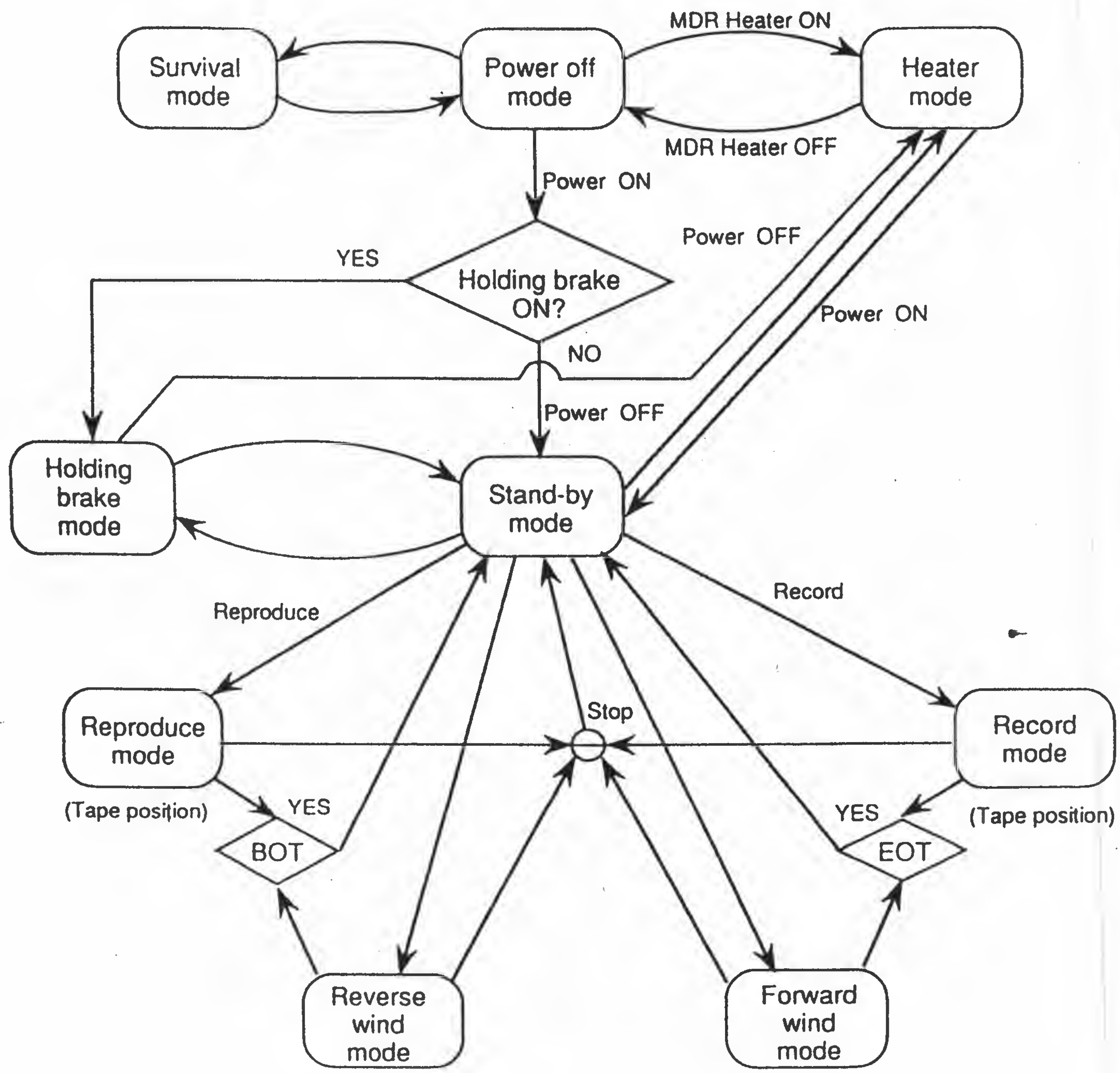
-Survival mode

Warming up EU and TU in case of getting the emergency off command. The temperature is automatically controlled.

-Holding brake mode

Putting on the brakes of tape reel for transport,storage and launch.

Figure 5.1 Operational modes of MDR



6. MDT (Mission Data Transmitter)

6.1 General

The MDT sends the real-time observation data from SAR and OPS or reproduced observation data from MDR to the ground. The block diagram of MDT is shown ir Figure 6.1.

The MDT has following functions.

(1) to receive 30 Mbps x 2ch data from 2 of SAR, OPS, and MDR originated signals. And also to send them to the ground stations.
(2) to send selected signals of SAR or OPS to MDR to record ther according to the command.
(3) to make master clock and send it to SAR,OPS and MDR.

6.2 MDT specification

(1) Carrier frequency

f_1 :8.15GHz
f_2 :8.35GHz

(2) Stability of frequency

long term :$\pm 7\times 10^{-6}$/year (max.)
short term :$\pm 7\times 10^{-8}$/sec (max.)

(3) Modulation :QPSK

(4) Bit Rate : 60 MBPS/carrier

(5) Polarization :RHCP

(6) Band width : 50 MHz (max.)

Figure 6.2 shows the output bandwidth.(measured PFM data)

Figure 6.1 MDT Simplified Block Diagram and QPSK Modulation in The Mission Data Transfer

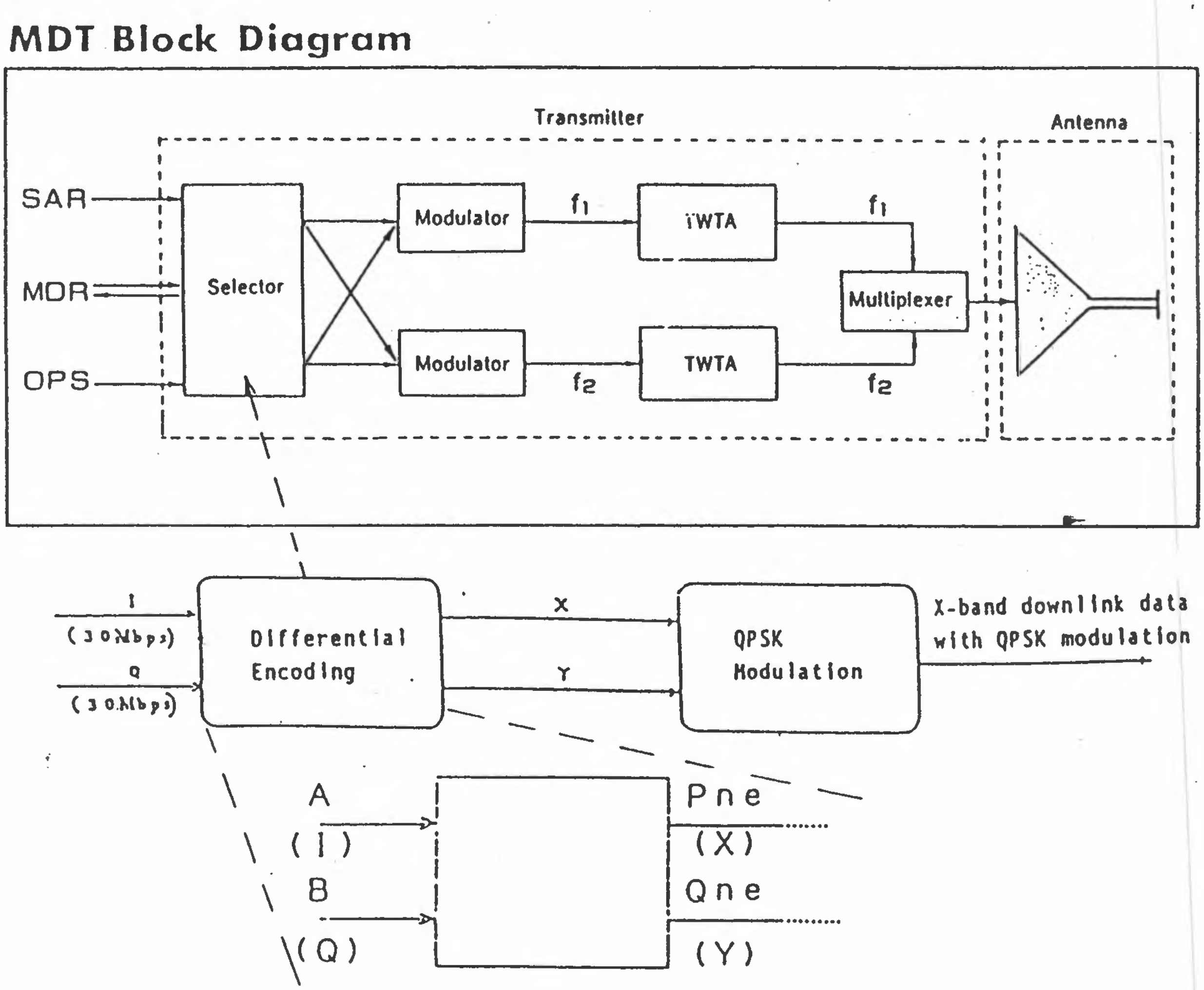
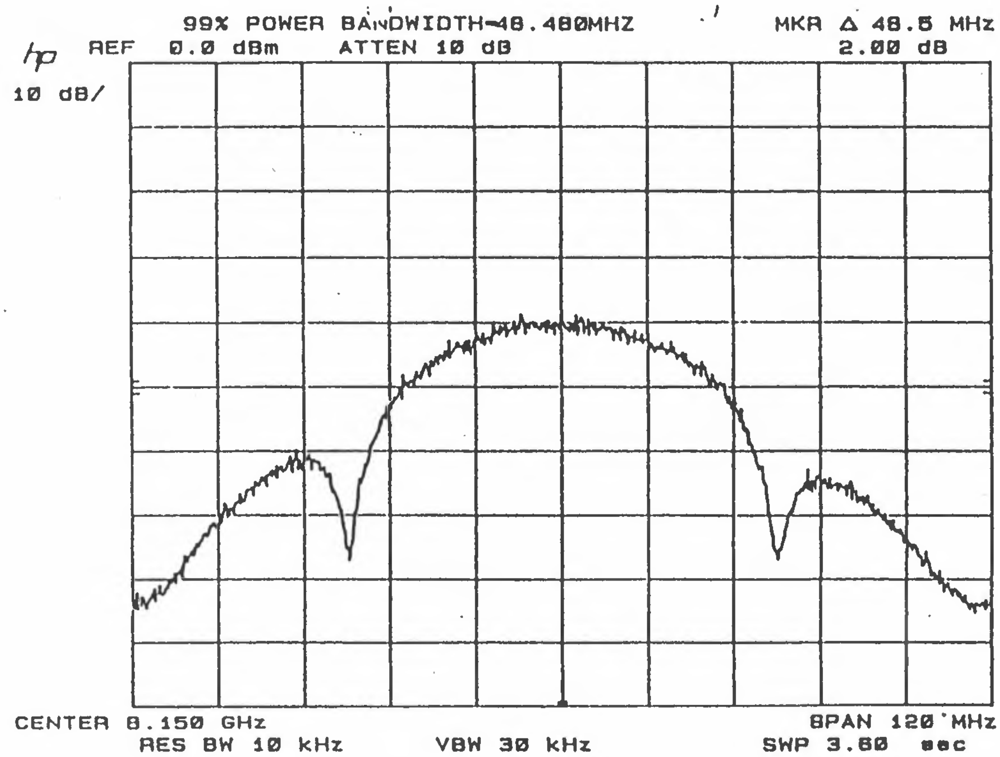
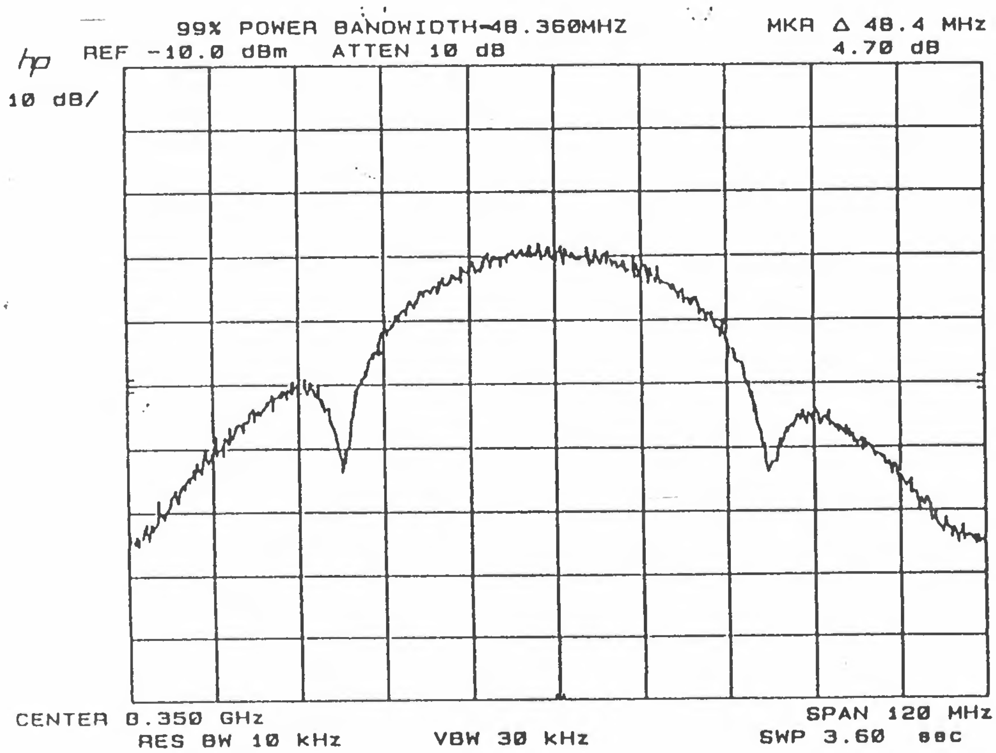


Figure 6.2 Bandwidth(measured)



8150MHz(f_1)



8350MHz(f_2)

(7) Output multiplexer characteristic :

-Filter : CHEBYSHEV (4 stages)

-Frequency : 8.15 GHz ± 1MHz

: 8.35 GHz ± 1MHz

-Insertion loss : 1.2 dB max.

-Band width of 3 dB down : 60 MHz ±3 MHz

-Power handling capability : 20 W × 2 waves

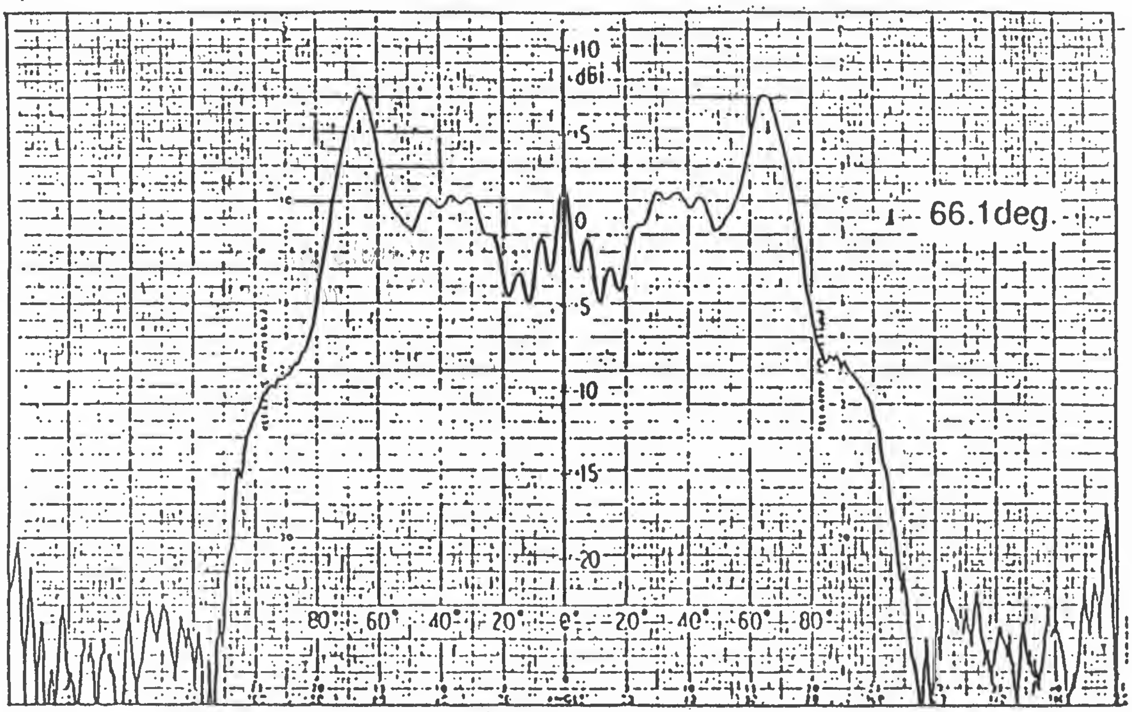
(8) Equivalent isotropic radiated power

+Z axis ± 0 deg : 32 dBm (min.)

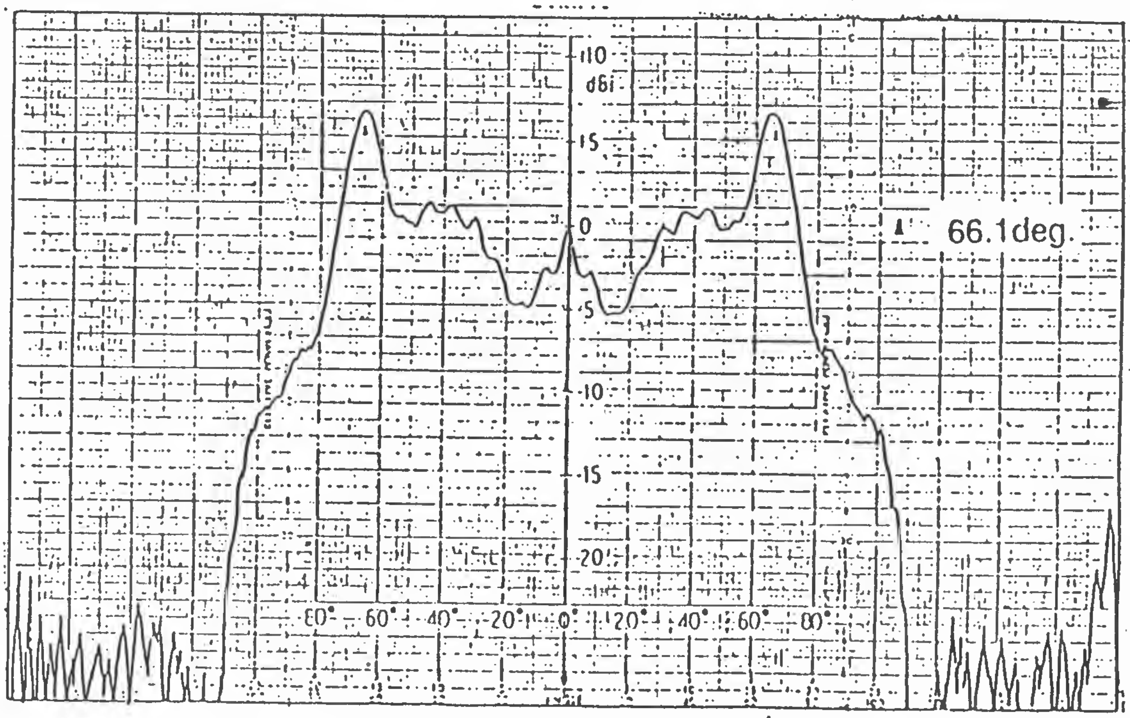
+Z axis ± 66.1 deg : 47 dBm (min.)

Figure 6.3 shows MDT Antenna Pattern(measured PFM data).

Figure 6.3 X-band Antenna Pattern(measured)



8150MHz(f1)



8350MHz(f2)

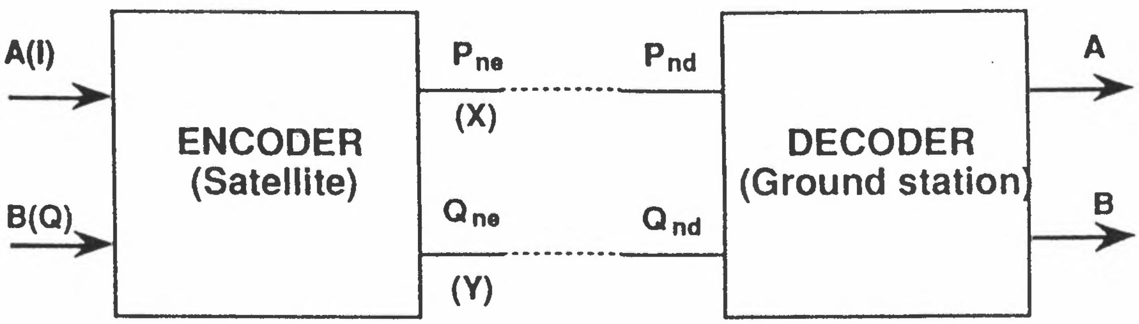
6.3 QPSK Modulation and encoding algorithm

SAR data output from signal processor includes both components of real pa and imaginaly part of radar reflection. Each values are divided into "I" and "C channel. In the OPS data stream, on the other hand, VNIR data is fed into "I channel and SWIR data is fed into "Q" channel, respectively.

Moreover data streams of "I" and "Q" channels of SAR and OPS data are encode by differential encoder and performed QPSK modulation.

The differential encoder (onboard) and decoder (at ground station) are shown ir Figure 6.4 and Figure 6.5.

Figure 6.4 Differential encoder/decorder(Logic)



Algorithm

Encoder(Satellite)

$$P_{ne}=\overline{(A_n \oplus B_n)}(A_n \oplus P_{(n-1)e})+(A_n \oplus B_n)(B_n \oplus Q_{(n-1)e})$$

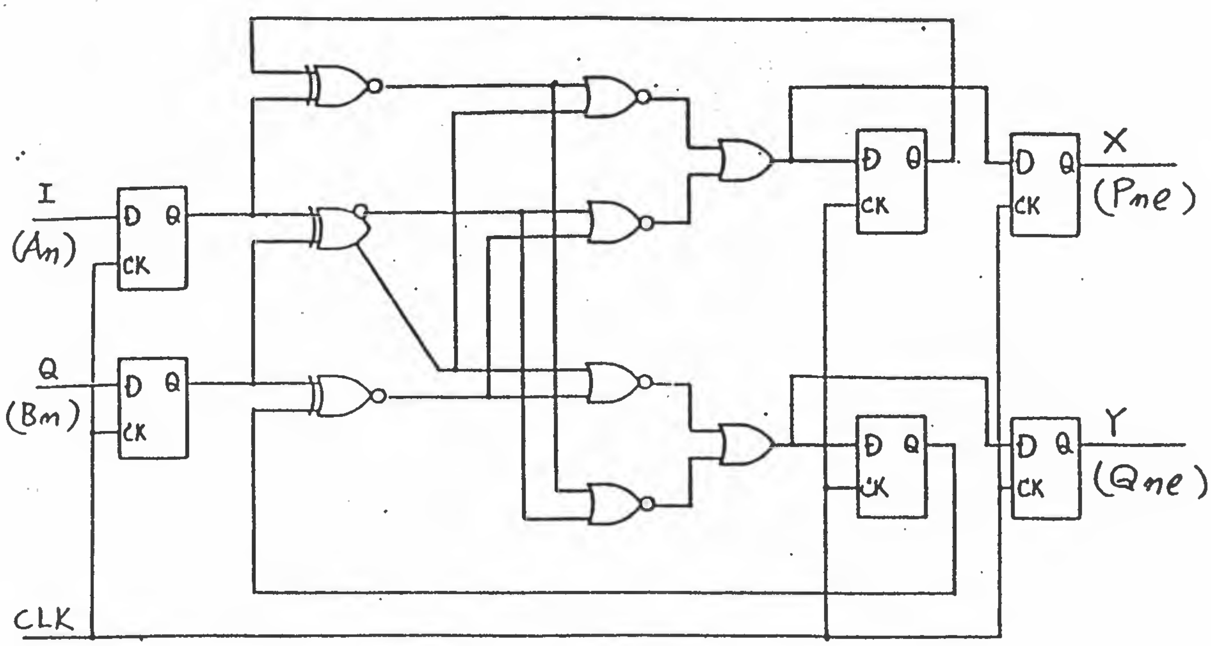
$$Q_{ne}=\overline{(A_n \oplus B_n)}(B_n \oplus Q_{(n-1)e})+(A_n \oplus B_n)(A_n \oplus P_{(n-1)e})$$

Decoder(Ground station)

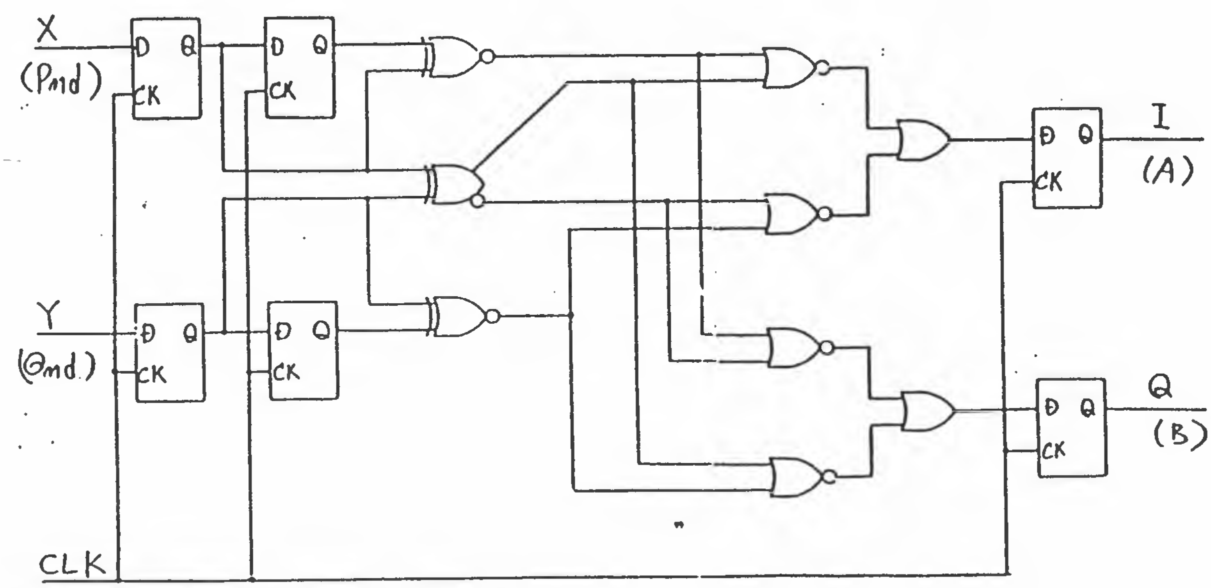
$$A=\overline{(P_{nd} \oplus Q_{nd})}(P_{nd} \oplus P_{(n-1)d})+(P_{nd} \oplus Q_{nd})(Q_{nd} \oplus Q_{(n-1)d})$$

$$B=\overline{(P_{nd} \oplus Q_{nd})}(Q_{nd} \oplus Q_{(n-1)d})+(P_{nd} \oplus Q_{nd})(P_{nd} \oplus P_{(n-1)d})$$

Figure 6.5 Differential encoder/decorder(Circuit)



(a) Encoder



(b) Decoder

6.4 Operation modes

Operation modes of MDT are shown in Figure 6.6.

-Off mode

MDT is turned off.

-TWTA pre-heat mode

The cathode heater of TWT is turned on.

-Record mode

Send SAR or OPS data to MDR.

-Single transmission mode

One of two systems (f_1 or f_2) sends data to the ground station.

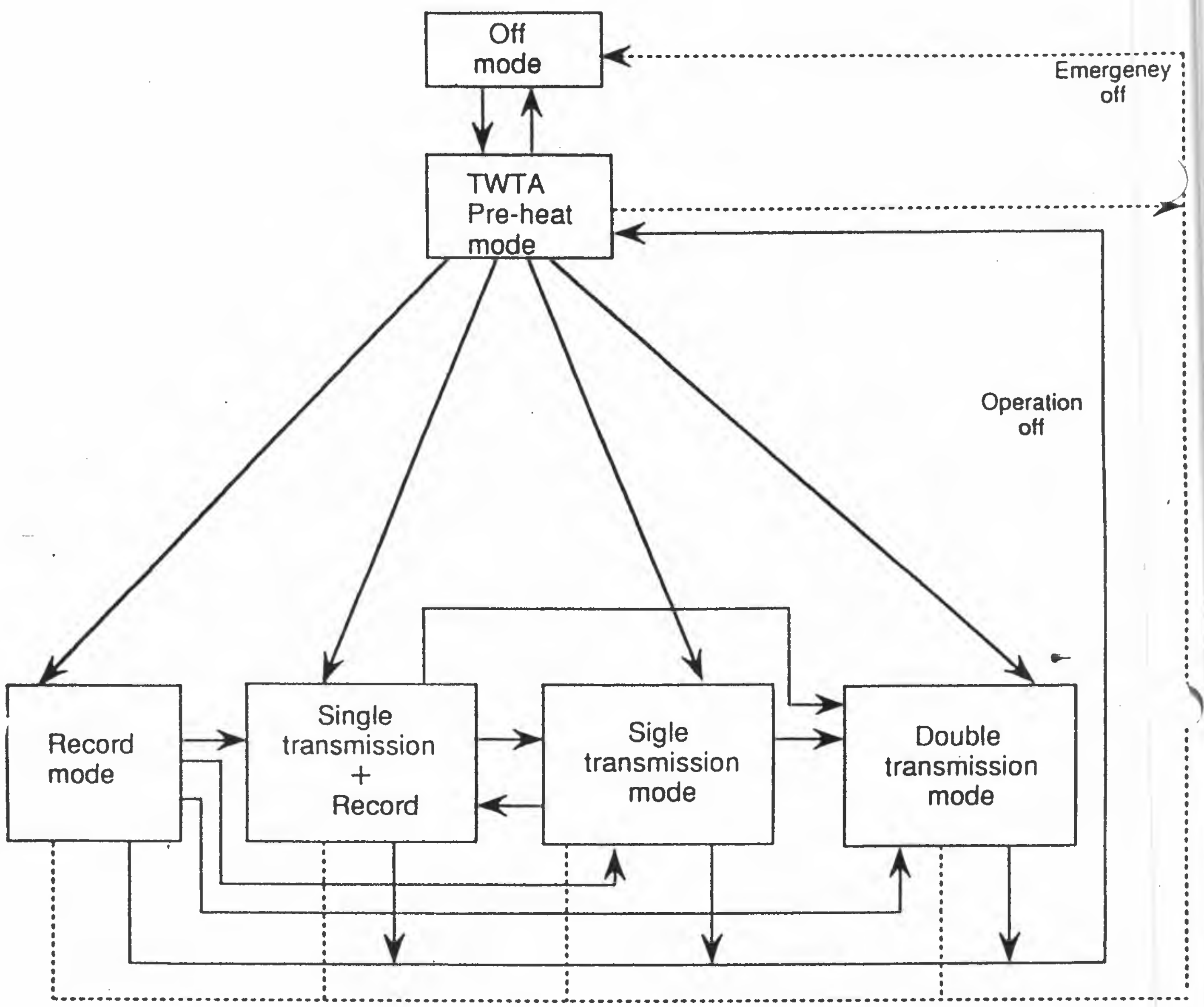
-Double transmission mode

Two systems (f_1 and f_2) send data to the ground station.

-Single transmission + Record mode

One of two systems (f_1 or f_2) sends data to the ground station and another system sends data to MDR.

Figure 6.6 Operational modes of MDT



7. TELEMETRY DATA

7.1 Real-time telemetry and stored telemetry

Real-time telemetry data are downlinked by both S-band and X-band transmitters. On the other hand, stored telemetry data are downlinked by only S-band transmitter. Note that foreign ground stations use only real-time telemetry data. PCM data format and Telemetry assignment are described in section 7.3 and 7.4 respectively.

7.2 Analog telemetry, Bi-level telemetry and Serial digital telemetry

Analog data from JERS-1 are multiplexed for transmission via S-band or X-band communication links. The multiplexed data include bi-level and serial digital telemetry data.

7.3 PCM data format

The characteristics of PCM data are summarized as follows;

- Major frame = 64 Minor frames
- Minor frame = 128 Words
- Word length = 8 Bits (B#7:MSB, B#0:LSB)
- Subcom word = 8 Words (from Word #52 to #59)
- Minor frame rate = 0.5 sec/frame
- Major frame rate = 32 sec/frame
  sync. pattern (Word #0 to #2)
- Satellite ID = 110

7.4 Telemetry assignments

Table A.1(in Appendix A) gives the word allocations for the telemetry format. Three words (i.e., words #0 to #2) are reserved for frame sync. words and two words (i.e., words #16 and #17) are reserved for spacecraft time cord data. While word #5 and word #18 is reserved for frame identification and spacecraft identification. Moreover eight words (i.e., words #52 to #59) are allocated for serial subcommutation to sample the data and twelve words (i.e., words #68 to #79) are allocated for AOCS data every minor frame. The telemetry data of mission instrument (SAR and OPS) are assigned in words #92 to #107 for SAR and words #108 to #113 and word #115 for OPS, respectively.

Table A.2 (in Appendix A)describes word assignments in detail.
Table B (in Appendix B)describes conversion table of each telemetry.

7.5 Attitude and Orbit Control System (AOCS)

AOCS has the following two telemetry modes:

- OPS stereoscopic observation mode
- AOCS health check mode

In the OPS stereoscopic observation mode, angle data and angular rate data are computed every 2 seconds and 0.5 seconds, respectively. In this mode, satellite attitude can be estimated every 0.5 second on the ground. AOCS health check mode places emphasis on sampling more AOCS status data, and attitude data and angular rate data are computed every 2 seconds only. AOCS telemetry data format (Word 68 to Word 79) in PCM telemetry data is shown in Table 7.1 for the OPS stereoscopic observation mode, and in Table 7.2 for the AOCS health check mode, respectively. The AOCS is usually operated in stereoscopic mode.

Figure 7.1 shows angle and angular rate data measured timing for the OPS stereoscopic observation mode. The accuracy of each data are as follows;

-Angle data : LSB=2^{-7}deg

-Angular rate data : LSB=2^{-14}deg/sec

Because angular rate data have higher accuracy than angle data , the attitude data should be calculated from angular rate data and angle data will be used as initial value. As shown in Figure 7.1, the position of measuring angle data is 62.5±62.5msec after S/C(spacecraft) time, while the position of measuring angular rate data is 187.5±62.5msec before S/C time.

IRU (Inertial Reference Unit) output is sampled and angular rate data $\hat{\dot{\phi}}_i$, $\hat{\dot{\theta}}_i$, $\hat{\dot{\psi}}_i$ (roll,pitch,yaw) are computed every 0.125 seconds. On the other hand, PCM telemetry frame length is 0.5 seconds. In order to match the data rates, the following calculation (averaging)is made in OBC:

$$\dot{\Phi} = \frac{1}{4}\sum_{i=1}^{4} \hat{\dot{\phi}}_i$$

$$\dot{\Theta} = \frac{1}{4}\sum_{i=1}^{4} \hat{\dot{\theta}}_i$$

$$\dot{\Psi} = \frac{1}{4}\sum_{i=1}^{4} \hat{\dot{\psi}}_i$$

In the PCM telemetry, $\dot{\Phi}$, $\dot{\Theta}$, $\dot{\Psi}$ are sent with 8 bits every 0.5 second. On the ground, relative attitude can be obtained by the following computation (example) ;

$$\Delta\theta_{TLM} = 4T_{S1}\dot{\Theta} \qquad (T_{S1}=0.125\text{sec})$$

$$\theta_{TLM} = \sum\Delta\theta_{TLM}$$

$$\theta(t) = (\theta_{TLM} \text{ smoothed})$$

where

$\Delta\theta_{TLM}$: pitch angular rate of every 0.5 sec (deg.)
θ : estimated pitch angle (deg.)

Estimated roll angle φ,yaw angle ψ are determined likely.

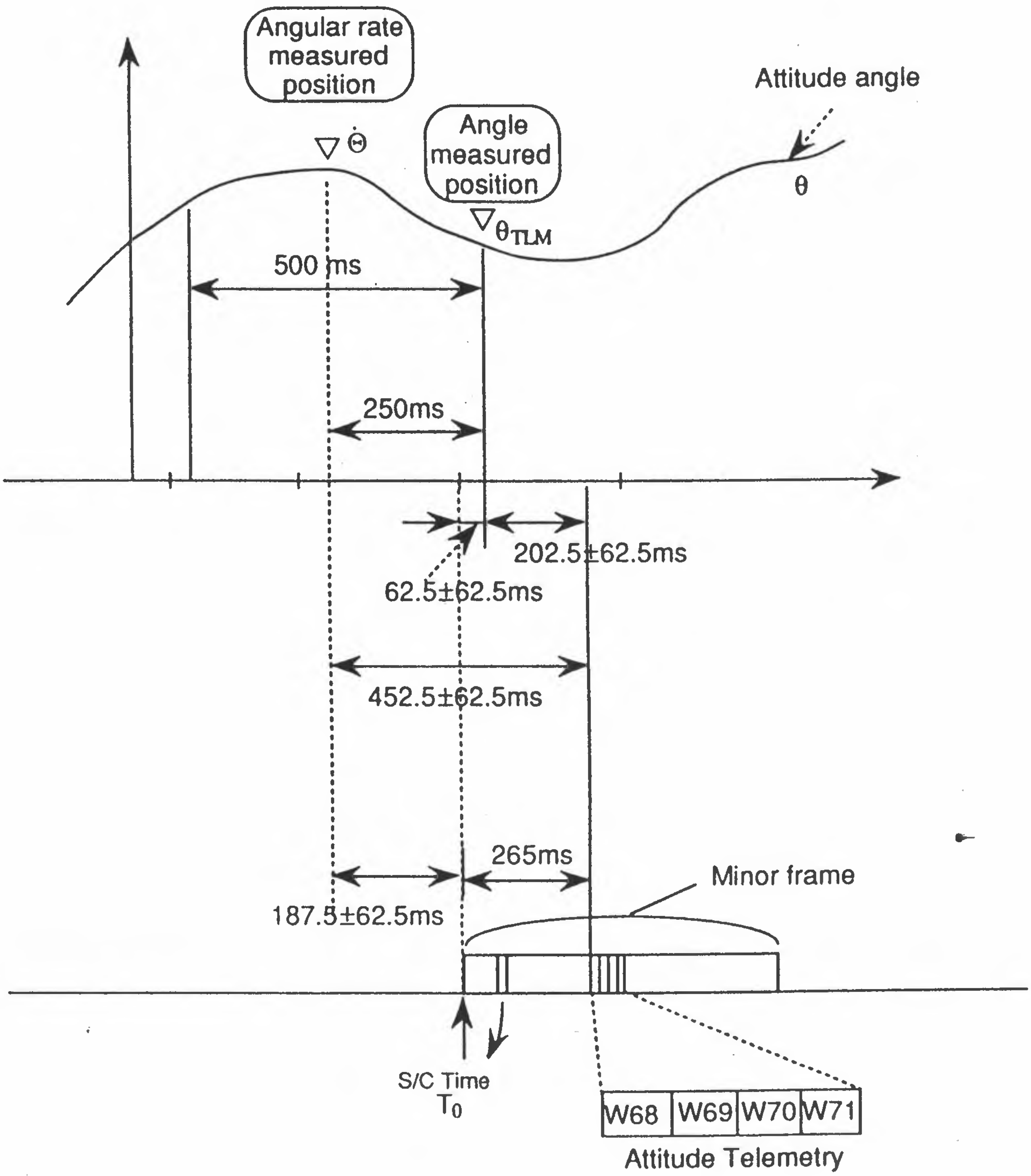
Table 7.1 OPS Stereoscopic Observation mode

Frame No.	W68	W69	W70	W71		W79
0	Roll Angular Rate	Pitch Angular Rate	Yaw Angular Rate	Roll Angle Estimation		
1				Pitch Angle Estimation		
2				Yaw Angle Estimation		
3				RW1 Angular Momentum Control Signal		
4				Roll Angle Estimation		
5				Pitch Angle Estimation		
6				Yaw Angle Estimation		
7				RW2 Angular Momentum Control Signal		
8				Roll		
9				Pitch		
10				Yaw		
11				RW3 Angular Momentum Control Signal		
12				Roll		
13				Pitch		
14				Yaw		
15				RW4 Angular Momentum Control Signal		
16						
63						

Table 7.2 AOCS Health Check mode

Frame No.	W68	W69	W70	W71		W79
0	Roll Angular Rate Measurement	Pitch Angular Rate Measurement	Yaw Angular Rate Measurement	Roll Angular Rate Estimation		
1	Roll Angle Estimation	Pitch Angle Estimation	Yaw Angle Estimation	Pitch Angular Rate Estimation		
2	Roll Angle Measurement	Pitch Angle Measurement	Thruster Mode Yaw Relative Angle Estimation	Yaw Angular Rate Estimation		
3	RW1 Angular Momentum Control Signal	RW1 Angular Momentum Control Signal	RW1 Angular Momentum Control Signal	RW1 Angular Momentum Control Signal		
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
63						

Figure 7.1 The measured position of attitude data



7.6 Spacecraft (S/C) time

7.6.1 S-band telemetry data

S/C time is contained in Word 16 and Word 17 of every frame.
Its format is shown in Figure 7.2. S/C time is generated with 32 bits. Five bits representing 2^{-1} to 2^{-5} sec. do not appear in the telemetry. Therefore S/C time has an accuracy of 2^{-5} sec.

Telemetry data formatting and satellite time are synchronized: the 1st bit of Word 0 corresponds to either 0 second or 0.5 second of S/C time (since one frame is generated every 0.5 second). S/C time increases by 1 second, therefore, the same S/C time appears in the two subsequent frames. 0 second of S/C time corresponds to the start of the first frame, and 0.5 second plus S/C time corresponds to the start of the second frame.

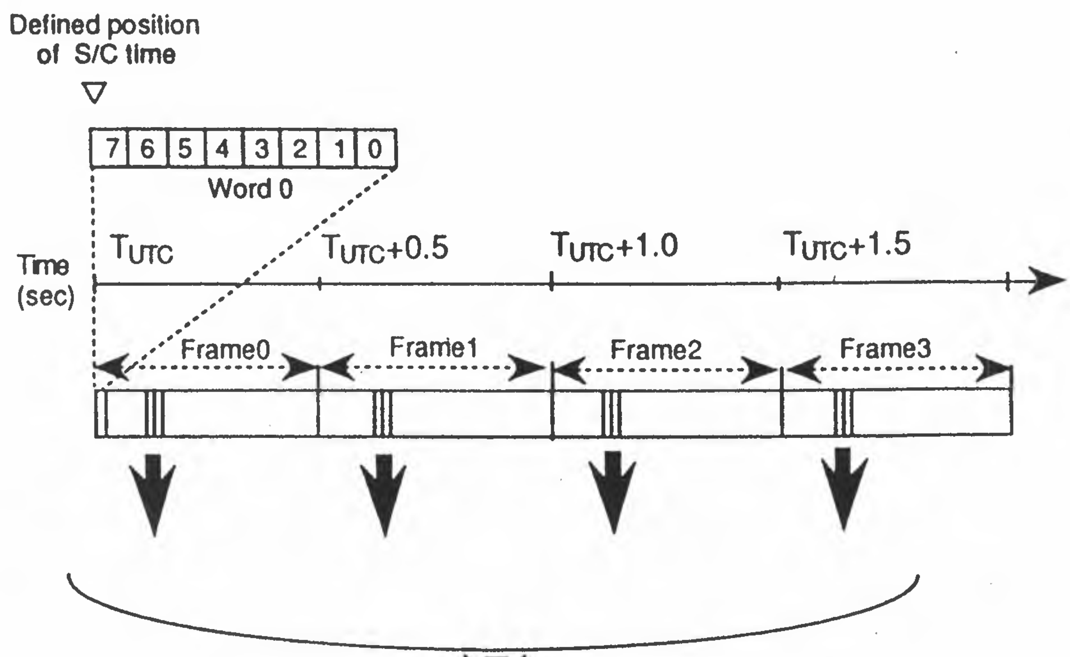
7.6.2 X-band telemetry data

C&DH provides PCM telemetry data to OPS and SAR for image correction, which are the same with S-band telemetry data.

PCM telemetry data are multiplexed with the mission data as shown in Figure 7.3.

In the ground processing, the PCM telemetry data are extracted from the mission data. In order to determined time of the mission data, the frame sync pattern of the PCM telemetry data needs to be found. Image data which contains the 1st bit of the PCM telemetry frame sync pattern, corresponds to either 0 second or 0.5 second of the S/C time is contained in the subsequent Word 16 and Word 17. If the time of the 1st bit of the PCM telemetry data is determined (therefore, time of the mission data which contain the bit) is given by multiplying with 0.49 msec.

Figure 7.2 S/C time in PCM telemetry



Word No.	16	17
Bit No.	7-0	7-0
Data	S/C time 776.7 day-4.26min.	S/C time 255 sec.-0 sec.

Frame No.	Word 16							
	7	6	5	4	3	2	1	0
F0(16)	Spare				S/C time 2^{26}-2^{24}sec.			
F1(16)	S/C time 2^{23}-2^{16}sec.							
F2(16)	S/C time 2^{15}-2^{8}sec.							
F3(16)	Spare							

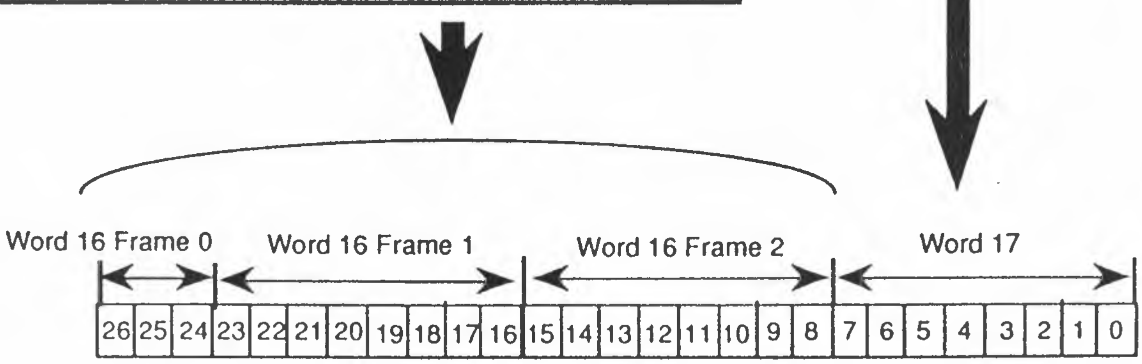
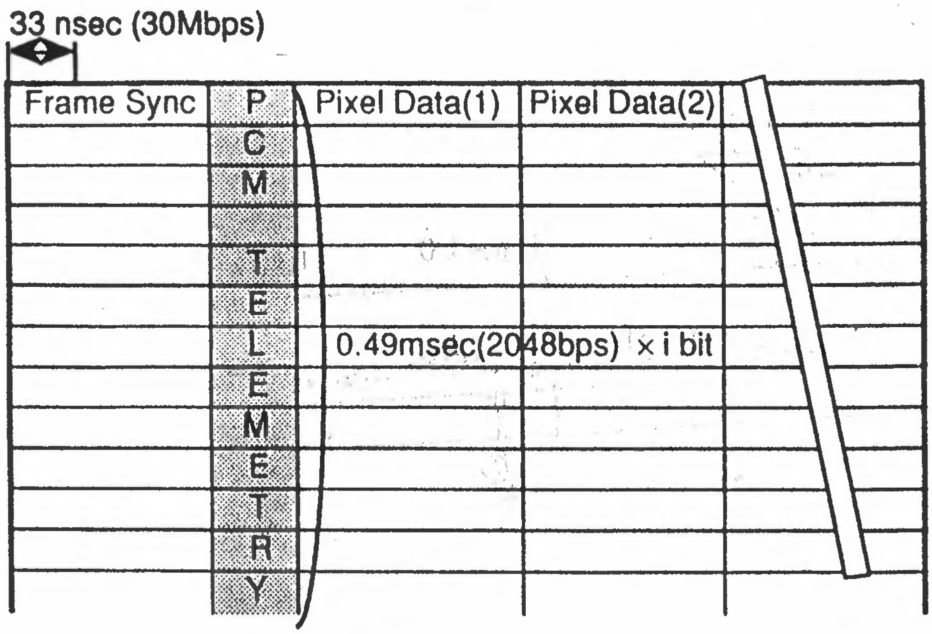


Figure 7.3 PCM telemetry data in mission data



7.6.3 S/C time correction

Time correction parameter which convert S/C time to UTC will be provided by MMO at Earth Observation Center(EOC) in operation phase.Parameters are consist of offset time and time error. Offset time represents UTC time corresponding to S/C time. Time error represents error between ground based UTC time and S/C based UTC time.
Detail information of parameters is described in JERS-1 Operation Interface Specification (HE-89033).

8. JERS-1 COMMUNICATIONS AND OPERATIONS

8.1 S-band telemetry data transmission characteristics

S-band downlink characteristics are as follows;

1) Frequency : 2220.00 MHz
2) EIRP : 9.6 dBm (EL= 5 deg)
   : 3.4 dBm (EL= 90 deg)
3) Polarization : RHC
4) S/C Antenna Pattern : See Figure 9.1
5) Real-time TLM modulation scheme

   - Modulation : PCM(Biφ-L)/PM
   - Modulation index : 0.4 Rad(O-P)
   - PCM bit rate : 2048 Bit/sec
   - Subcarrier freq : 360.448 KHz

6) Stored TLM modulation scheme

   - Modulation : PCM(Biφ-L)-PSK/PM
   - Modulation index : 1.2 Rad(O-P)
   - PCM bit rate : 32.768 Kbit/sec
   - Subcarrier freq. : 360.448 KHz

7) Ranging

   - Modulation : Tone/PM
   - Modulation index : 0.21 Rad(O-P)/Tone (coarse ranging)
     0.3 Rad(O-P)/Tone (Precision ranging)
   - Tone frequency : 500 KHz

8) Downlink spectrum bandwidth : 2220 ± 4 MHz

8.2 X-band image and telemetry data transmission

1) Frequency	:	f_1 = 8.15 GHz		
		f_2 = 8.35 GHz		
2) Bandwidth	:	50 MHz		
3) EIRP	:	32 dBm (EL=90 deg)		
		47 dBm (EL= 5 deg)		
4) Polarization	:	RHC		
5) S/C antenna characteristics	:	See Figure 6.3		
6) Modulation	:	QPSK		
Modulation code	:	OPS	NRZ-L	(image)
			NRZ-L	(telemetry)
		SAR	NRZ-L	(data)
			Biϕ-L	(telemetry)

8.3 X-band mission data transmission mode

The X-band transmit link of JERS-1 employs a QPSK modulation format for transmitting mission sensor data (real-time SAR/OPS and MDR dump data). The SAR data are usually modulated on the "I and Q" channel. For OPS ,the VNIR data are usually modulated on the "I" channel and the SWIR data are modulated on the "Q" channel.

MDR dump data are downlinked to the previously designed station. When the transmit channel does not contain any actual data, a signal is logical 0 code and is scrambled by the PN code.

8.4 Operational modes of JERS-1

Two channels of X band link is allocated each mission sensor for f_1 and f_2. The operational modes of JERS-1 are described in Table 8.1.

Table 8.1 Operational modes of JERS-1

	OPERATIONAL MODE	Availability		Used X-band Channel
		Sun lit	Eclipse	
A	SAR REAL	O	△	f1 or f2
B	OPS REAL	O	×	f1 or f2
C	VNIR REAL	O	×	f1 or f2
D	SAR REC	O	△	N/A
E	OPS REC	O	×	N/A
F	REPRO	O	O	f1 or f2
G	SAR REAL + REPRO	O	×	f1 and f2
H	OPS REAL + REPRO	O	×	f1 and f2
I	VNIR REAL + REPRO	O	×	f1 and f2
J	SAR REAL+ OPS REAL	O	×	f1 and f2
K	SAR REAL + VNIR REAL	O	×	f1 and f2
L	OPS REC+ SAR REC	O	×	f1 or f2
M	VNIR REAL + SAR REC	O	×	f1 or f2
N	SAR REAL + OPS REAL	O	×	f1 and f2

Note

OPS : VNIR + SWIR
O : Available
× : Not available
△ : Experimental base
f1 : 8150 MHz
f2 : 8350 MHz

9. RF downlink characteristics

9.1 X-band

Major specification of X-band downlink is shown in Table 9.1. Table 9.2 show link margin.

Table 9.1 Example of X-band link calculation

Item	EL = 90 deg	EL = 5 deg
Output Power (dBm)	43	43
Feed Loss (dB)	2	2
Antenna Gain (dB)	- 9	6
EIRP (dBm)	32	47
Free Space Loss (dB)	-166	-178
Atmospheric Loss(dB)	- 0.1	- 0.1
Pointing Loss (dB)	- 0.2	- 0.2
Rain Loss (dB)	- 1.2	- 3.9
G/T (dB/K)	32.9	32.3
Effective C/N0(dB.Hz)	96.0	94.9

Table 9.2 Link margin

Item	EL = 90 deg	EL = 5 deg
E/N0 (dB)	10.8	10.8
Equip. Loss (dB)	3.8	3.8
Band Width (dB.Hz)	77.8	77.8
Required C/N0 (dB.Hz)	92.4	92.4
Effective C/N0(dBHz)	96.0	94.9
Margin (dB)	3.6	2.5

9.2 S-band

Major specification of S-band downlink is shown in Table 9.3. Table 9.4 shows link margin.

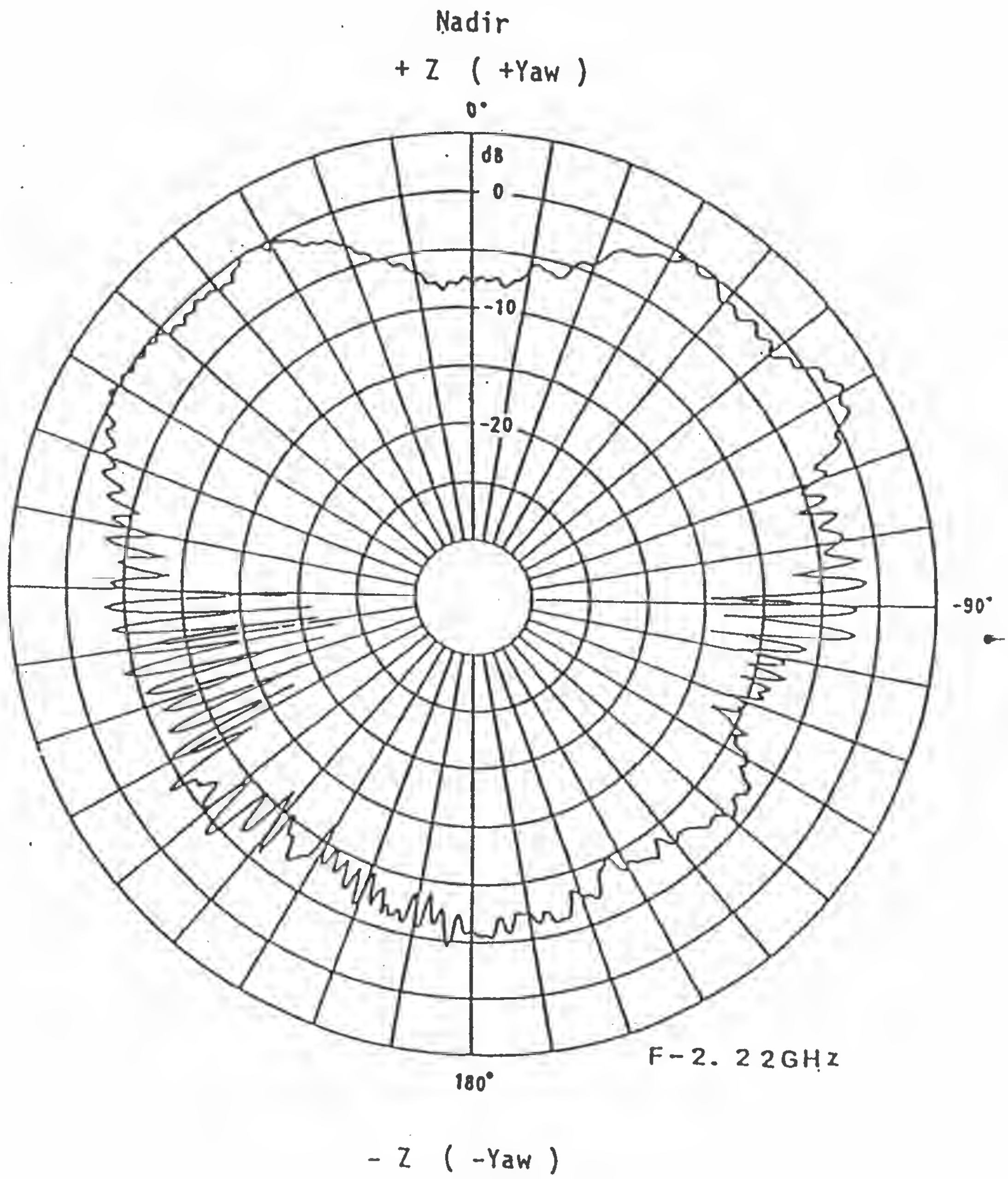
Table 9.3 Example of S band link calculation

	EL=90 deg	EL=5 deg
1) S/C EIRP (dBm)	3.4	9.6
2) Free Space loss (dB)	-154.5	-166.4
3) Miscellaneous loss (dB)	- 0.4	- 1.6
4) G. STN antenna gain (dB)	47.6	47.6
5) G. STN received power (dBm)	-103.9	-110.2
6) G. STN noise power density (dBm/Hz)	-176.0	-176.0
7) G. STN C/N0 (dB.Hz)	72.1	65.8

Table 9.4 Link margin (EL=5 deg)

Item	Carrier	Real time TLM	Playback HK Data	Ranging
Modulation Loss (dB)	4.4	1.9	4.0	17.8
Bandwidth(dB-Hz)	30.0	33.1	45.1	0.0
Required S/N (dB)	6.0	9.6	9.6	30.6
Hardware Loss (dB)	-	2.4	3.4	-
Required C/N0 (dBHzm)	40.4	57.0	62.1	48.4
Margin (dB)	25.4	8.8	3.7	17.4

Figure 9.1 S-band Antenna Pattern



Appendix-A

Table A.1 JERS-1 Telemetry List (1/ 4)

Word #	Content	Note
000	FRAME SYNC	
001	FRAME SYNC	
002	FRAME SYNC	
003	NASDA USE	
004		
005	FRAME ID (SEE TABLE A.2)	
006		
007		
008		
009		
010		
011		
012		
013		
014		
015		
016	SPACECRAFT TIME CODE	
017	SPACECRAFT TIME CODE	
018	SPACECRAFT ID	
019		
020		
021		
022		
023		
024		
025		
026		
027		
028		
029		
030		
031		
032		
033		
034		
035		

Table A.1 JERS-1 Telemetry List (2/ 4)

Word #	Content	Note
036		
037		
038		
039		
040		
041		
042		
043		
044		
045		
046		
047		
048		
049		
050		
051		
052	SUBCOMMUTATION	
053		
054		
055		
056		
057		
058		
059		
060		
061		
062		
063		
064		
065		
066		
067		
068	AOCS	
069	AOCS	
070	AOCS	

Table A.1 JERS-1 Telemetry List (3/ 4)

Word #	Content	Note
071	AOCS	
072	AOCS	
073	AOCS	
074	AOCS	
075	AOCS	
076	AOCS	
077	AOCS	
078	AOCS	
079	AOCS	
080		
081		
082		
083		
084		
085		
086		
087		
088		
089		
090		
091		
092	SAR RF OUTPUT LEVEL A	
093	SAR CAL OUTPUT LEVEL A	
094	SAR I-CHANNEL VIDEO SIGNAL LEVEL A	
095	SAR Q-CHANNEL VIDEO SIGNAL LEVEL A	
096	SAR RF OUTPUT LEVEL B	
097	SAR CAL OUTPUT LEVEL B	
098	SAR I-CHANNEL VIDEO SIGNAL LEVEL B	
099	SAR Q-CHANNEL VIDEO SIGNAL LEVEL B	
100	SAR SERIAL DIGITAL TLM 1	
101	SAR 2	
102	SAR 3	
103	SAR 4	
104	SAR 5	
105	SAR 6	

Table A.1 JERS-1 Telemetry List (4/ 4)

Word #	Content	Note
106	SAR 7	
107	SAR 8	
108	OPS	
109	OPS	
110	OPS	
111	OPS	
112	OPS	
113	OPS	
114		
115	OPS	
116		
117		
118		
119		
120		
121		
122		
123		
124		
125		
126		
127		

Table A.2 JERS-1 Telemetry Word Assignments (1/9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
52	5			SAR 13	SAR Antenna Temperature 3	PA	Table B.2	
	6			SAR 39	High Power Amplifier-A Temp	PA	Table B.3	
	7			SAR 25	Signal Processor-A Temperature	PA	Table B.11	
	15	4		OPS 33	Cooler Surface temperature 1	PA	Table B.23	
	22			OPS 31	Cooler Power Supply temperature 1	PA	Table B.23	
	29			OPS 7	VNIR Power Supply Voltage +5V	AA	5.12/255×N	
	38			OPS 45	ASP-A A/D Reference Voltage 1	AA	5.12/255×N [V]	
	39			OPS 53	ASP-A Power supply Voltage 1	AA	5.12/255×N [V]	
	45			OPS 57	ASP-B A/D Reference Voltage 1	AA	5.12/255×N [V]	
	46			OPS 65	ASP-B Power Suplly Voltage 1	AA	5.12/255×N [V]	
53	5			SAR 14	SAR Antenna Temperature 4	PA	Table B.2	
	6			SAR 40	High Power Amplifier-B Temp	PA	Table B.4	
	7			SAR 32	Signal Processor-B Temperature	PA	Table B.12	
	15	4		OPS 34	Cooler Surface temperature 2	PA	Table B.23	
	22			OPS 32	Cooler Power Supply temperature 2	PA	Table B.23	
	23			OPS 26	Calibration Power Supply temperature	PA	Table B.2	
	29			OPS 8	VNIR Power Supply Voltage +12V	AA	5.12/255×N	
	38			OPS 46	ASP-A A/D Reference Voltage 2	AA	5.12/255×N [V]	
	39			OPS 54	ASP-A Power supply Voltage 2	AA	5.12/255×N [V]	
	45			OPS 58	ASP-B A/D Reference Voltage 2	AA	5.12/255×N [V]	
	46			OPS 66	ASP-B Power Suplly Voltage 2	AA	5.12/255×N [V]	
54	5			SAR 15	SAR Antenna Temperature 5	PA	Table B.2	
	6			SAR 41	High Power Amplifier-R Temp	PA	Table B.5	
	7		0	SAR 38	Signal Processor-B ON/OFF	BL	0:OFF 1:ON	
			1	SAR 31	Signal Processor-A ON/OFF	BL	0:OFF 1:ON	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (2/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
54	7		2	SAR 24	Pulse Generator-B ON/OFF	BL	0:OFF 1:ON	
			3	SAR 23	Pulse Generator-A ON/OFF	BL	0:OFF 1:ON	
			4	SAR 22	Oven Controlled X'tal Oscillator-B ON/OFF	BL	0:OFF 1:ON	
			5	SAR 21	Oven Controlled X'tal Oscillator-A ON/OFF	BL	0:OFF 1:ON	
	15	4		OPS 6	VNIR Calibration Light Monitor	AA	5.12/255×N	
	22			OPS 12	SWIR temperature 1 (SOPT)	PA	Table B.1	
	23			OPS 37	Thermal Controller temperature	PA	Table B.4	
	29			OPS 9	VNIR Power Supply Voltage +15V	AA	5.12/255×N	
	38			OPS 47	ASP-A A/D Reference Voltage 3	AA	5.12/255×N [V]	
	39			OPS 69	DSP-A Power Supply Voltage 1	AA	5.12/255×N [V]	
	45			OPS 59	ASP-B A/D Reference Voltage 3	AA	5.12/255×N [V]	
	46			OPS 73	DSP-B Power Supply Voltage 1	AA	5.12/255×N [V]	
55	5			SAR 16	SAR Antenna Temperature 6	PA	Table B.2	
	6			SAR 42	High Power Amplifier Power Supply-A Temp	PA	Table B.6	
	15	4		OPS 22	SWIR Calibration Light Monitor	AA	5.12/255×N	
	22			OPS 13	SWIR temperature 2 (SOPT)	PA	Table B.1	
	23			OPS 41	Electric Circuit Power Supply temperature	PA	Table B.2	
	38			OPS 48	ASP-A A/D Reference Voltage 4	AA	5.12/255×N [V]	
	39			OPS 70	DSP-A Power Supply Voltage 2	AA	5.12/255×N [V]	
	45			OPS 60	ASP-B A/D Reference Voltage 4	AA	5.12/255×N [V]	
	46			OPS 74	DSP-B Power Supply Voltage 2	AA	5.12/255×N [V]	
56	5			SAR 17	SAR Antenna Temperature 7	PA	Table B.2	
	6			SAR 43	High Power Amplifier Power Supply-B Temp	PA	Table B.7	
	7			OPS 11	VNIR Focus ADJ. Position	SD	Hex notation	
	14			OPS 38	Thermal Controller A ON/OFF	AA	5.12/255×N [V]	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (3/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
56	22			OPS 14	SWIR temperature 3 (SOPT)	PA	Table B.1	
	23			OPS 44	Analog Signal Processor A(ASP-A) temperature	PA	Table B.2	
	31			OPS 80	VNIR temperature 5 (VRLS)	PA	Table B.1	
	38			OPS 49	ASP-A A/D Reference Voltage 5	AA	5.12/255×N [V]	
	39			OPS 71	DSP-A Decorder Power Supply Voltage	AA	5.12/255×N [V]	
	45			OPS 61	ASP-B A/D Reference Voltage 5	AA	5.12/255×N [V]	
	46			OPS 75	DSP-B DecorderPower Supply Voltage	AA	5.12/255×N [V]	
	63			OPS 16	SWIR temperature 5 (SPS)	PA	Table B.1	
57	1	8	6	SAR 1	SAR Antenna Deployment 1 (90 deg rotation) Latchup Status	BL	1:Non_Latch 0:Latch	
		8	7	SAR 10	SAR Antenna Deployment (Inclination) Latchup Status	BL	1:Non_Latch 0:Latch	
	5			SAR 18	SAR Antenna Temperature 8	PA	Table B.2	
	6			SAR 44	High Power Amplifier Power Supply-R Temp	PA	Table B.8	
	14			OPS 39	Thermal Controller B ON/OFF	AA	5.12/255×N [V]	
	22			OPS 15	SWIR temperature 4 (SFAM)	PA	Table B.1	
	23			OPS 56	Analog Signal Processor B(ASP-B) temperature	PA	Table B.2	
	31			OPS 81	VNIR temperature 6 (VRLS)	PA	Table B.1	
	38			OPS 50	ASP-A A/D Reference Voltage 6	AA	5.12/255×N [V]	
	45			OPS 62	ASP-B A/D Reference Voltage 6	AA	5.12/255×N [V]	
	63			OPS 17	SWIR temperature 6	PA	Table B.1	
58	1	8	0	SAR 2	SAR Antenna Deployment 2 (Stretch) Latchup Status 1	BL	1:Non_Latch 0:Latch	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (4/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
58	1	8	1	SAR 3	SAR Antenna Deployment 2 (Stretch) Latchup Status 2	BL	1:Non_Latch 0:Latch	
		8	2	SAR 4	SAR Antenna Deployment 2 (Stretch) Latchup Status 3	BL	1:Non_Latch 0:Latch	
		8	3	SAR 5	SAR Antenna Deployment 2 (Stretch) Latchup Status 4	BL	1:Non_Latch 0:Latch	
		8	4	SAR 6	SAR Antenna Deployment 2 (Stretch) Latchup Status 5	BL	1:Non_Latch 0:Latch	
		8	5	SAR 7	SAR Antenna Deployment 2 (Stretch) Latchup Status 6	BL	1:Non_Latch 0:Latch	
		8	6	SAR 8	SAR Antenna Deployment 2 (Stretch) Latchup Status 7	BL	1:Non_Latch 0:Latch	
		8	7	SAR 9	SAR Antenna Deployment 2 (Stretch) Latchup Status 8	BL	1:Non_Latch 0:Latch	
	2	2	6	SAR	SAR antenna heater ON/OFF	SD	0:OFF 1:ON	
	4		*	SAR 11	SAR Antenna Temperature 1	PA	Table B.2	
	5			SAR 19	SAR Antenna Temperature 9	PA	Table B.2	
	6			SAR 26	Pulse Generator-A Temperature	PA	Table B.9	
	7			OPS 25	deleted	SD	Binary	
	13			OPS 76	VNIR temperature 1 (VOPT)	PA	Table B.1	
	14			OPS 78	VNIR temperature 3 (VFAM)	PA	Table B.1	
	23			OPS 68	Digital Signal Processor A(DSP-A) temperature	PA	Table B.2	
	30		0	OPS 67	ASP-B Gain Normal/High	BL	0:High 1:Normal	
			1	OPS 55	ASP-A Gain Normal/High	BL	0:High 1:Normal	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (5/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
58	30		2	OPS 43	Electric Circuit Secondary Power Supply ON/OFF	BL	0:OFF 1:ON	
			3	OPS 42	Electric Circuit Primary Power Supply ON/OFF	BL	0:OFF 1:ON	
			4	OPS 85	deleted	BL	5.12/255×N	
			5	OPS 84	VNIR Focus ADJ. Circut ON/OFF	BL	0:OFF 1:ON	
			6	OPS 24	SWIR ON/OFF	BL	0:OFF 1:ON	
			7	OPS 10	VNIR ON/OFF	BL	0:OFF 1:ON	
	31			OPS 82	VNIR temperature 7 (VRLS)	PA	Table B.1	
	38			OPS 51	ASP-A A/D Reference Voltage 7	AA	5.12/255×N [V]	
	45			OPS 63	ASP-B A/D Reference Voltage 7	AA	5.12/255×N [V]	
	55			OPS 20	SWIR temperature 9 (SRLS)	PA	Table B.1	
	63			OPS 18	SWIR temperature 7 (SRLS)	PA	Table B.1	
59	4			SAR 12	SAR Antenna Temperature 2	PA	Table B.2	
	5			SAR 20	SAR Antenna Temperature 10	PA	Table B.2	
	6			SAR 33	Pulse Generator-B Temperature	PA	Table B.10	
	13			OPS 77	VNIR temperature 2 (VOPT)	PA	Table B.1	
	14			OPS 79	VNIR temperature 4 (VDRV)	PA	Table B.1	
	23			OPS 72	DSP-B temperature	PA	Table B.2	
	30		0	OPS 40	Thermal Controller B ON/OFF	BL	0:OFF 1:ON	
			3	OPS 30	Calibration Light Source 4 ON/OFF	BL	0:OFF 1:ON	
			4	OPS 29	Calibration Light Source 3 ON/OFF	BL	0:OFF 1:ON	
			5	OPS 28	Calibration Light Source 2 ON/OFF	BL	0:OFF 1:ON	
			6	OPS 27	Calibration Light Source 1 ON/OFF	BL	0:OFF 1:ON	
	31			OPS 83	VNIR temperature 8 (VPRE)	PA	Table B.1	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (6/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
59	38			OPS 52	ASP-A A/D Reference Voltage 8	AA	5.12/255×N [V]	
	45			OPS 64	ASP-B A/D Reference Voltage 8	AA	5.12/255×N [V]	
	62			OPS 19	SWIR temperature 8 (SRLS)	PA	Table B.1	
	63		2	OPS 36	Cooler ON/OFF	BL	0:OFF 1:ON	
68				AOCS	Roll Angular Rate Measurement	SD	3600*2E-14×N [DEG/hr] (CMP)	OPS Steleoscopic Observation mode
	0	16		AOCS	Roll Angular Rate Measurement	SD		AOCS helth check mode
	1	16		AOCS	Rall Angle Estimation	SD	2E-7×N [DEG] (CMP)	AOCS helth check mode
	2	16		AOCS	Rall Angle Measurement	SD	2E-5×N [DEG] (CMP)	AOCS helth check mode
69				AOCS	Pitch Angular Rate Measurement	SD	3600*2E-14×N [DEG/hr] (CMP)	OPS Steleoscopic Observation mode
	0	16		AOCS	Pitch Angular Rate Measurement	SD		AOCS helth check mode
	1	16		AOCS	Pitch Angle Estimation	SD	2E-7×N [DEG] (CMP)	AOCS helth check mode
	2	16		AOCS	Pitch Angle Measurement	SD	2E-5×N [DEG] (CMP)	AOCS helth check mode
70				AOCS	Yaw Angular Rate Measurement	SD	3600*2E-14×N [DEG/hr] (CMP)	OPS Steleoscopic Observation mode
	0	16		AOCS	Yaw Angular Rate Measurement	SD		AOCS helth check mode
	1	16		AOCS	Yaw Angle Estimation	SD	2E-7×N [DEG] (CMP)	AOCS helth check

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (7/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
								mode
71	0	16		AOCS	Rall Angle Estimation	SD	2E-7×N [DEG] (CMP)	OPS Steleoscopic Observation mode
		16		AOCS	Roll Angular Rate Estimation	SD	2E-13×N [DEG/sec] (CMP)	AOCS helth check mode
	1	16		AOCS	Pitch Angle Estimation	SD	2E-7×N [DEG] (CMP)	OPS Steleoscopic Observation mode
		16		AOCS	Pitch Angular Rate Estimation	SD	2E-13×N [DEG/sec] (CMP)	AOCS helth check mode
	2	16		AOCS	Yaw Angle Estimation	SD	2E-7×N [DEG] (CMP)	OPS Steleoscopic Observation mode
		16		AOCS	Yaw Angular Rate Estimation	SD	2E-13×N [DEG/sec] (CMP)	AOCS helth check mode
72	1	4	5	AOCS	Telemetry mode	SD	0:AOCS helth check mode, 1:OPS stereoscopic observation mode	
92				SAR 27	RF Output Level A	AA	Table B.13	
93				SAR 28	Calibrator Output Level A	AA	Table B.14	
94				SAR 29	I-Channel Video Signal Output Level A	AA	Table B.15	
95				SAR 30	Q-Channel Video Signal Output Level A	AA	Table B.16	
96				SAR 34	RF Output Level B	AA	Table B.17	
97				SAR 35	Calibrator Output Level B	AA	Table B.18	
98				SAR 36	I-Channel Video Signal Output Level B	AA	Table B.19	
99				SAR 37	Q-Channel Video Signal Output Level B	AA	Table B.20	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (8/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
100			0 - 4	SAR 45	Initial Position of STC Time Variation	SD		SAR HK 5
			5 - 7	SAR 45	PRF	SD		SAR HK 2
101			0 - 4	SAR 46	STC start time change pattern	SD		
			5 - 7	SAR 46	STC Offset Time	SD	10×N～360+10×N [μsec]	SAR HK 7
102			0 - 4	SAR 47	STC Start Time	SD		SAR HK 6
			5	SAR 47	MGC/AGC(TX/RX unit status)	SD	0:MGC mode 1:AGC mode	SAR HK 8
			6	SAR 47	AGC Time Constant	SD	0:Hi 1:Lo	SAR HK 9
			7	SAR 47	Change of Status(Selection of Optional mode)	SD	0:AGC_mode(nominal),1:MGC_mode in AUTO mode	SAR HK 20
103			0 - 4	SAR 48	MGC gain	SD	N [db]	
			5 - 7	SAR 47	Step Attenuator	SD	3×N [db]	SAR HK 12
104			0	SAR 49	AUTO/MANUAL MODE	SD	0:MANUAL 1:AUTO	SAR HK 13
			1	SAR 49	Observation START/END	SD	0:STOP 1:START	SAR HK 14
			2	SAR 49	Calbration Mode ON/OFF	SD	0:OFF 1:ON	SAR HK 3
			3	SAR 49	Observation Mode ON/OFF	SD	0:OFF 1:ON	SAR HK 4
			4	SAR 49	PRF Trigger ON/OFF	SD	0:OFF 1:ON	SAR HK 1
			5	SAR 49	STC CAL ON/OFF	SD	0:Observation mode 1:Calibration mode	
			6 - 7	SAR 49	Standby Mode Selection	SD	11:ST-3 10:ST-2 01:ST-1 00:EMR-OFF	SAR HK 19
105			0	SAR 50	Frequency Synthesizer ON/OFF	SD	0:OFF 1:ON	SAR HK 21
			1	SAR 50	Control Unit ON/OFF	SD	0:OFF 1:ON	SAR HK 22
			2	SAR 50	Transmitter Unit ON/OFF	SD	0:OFF 1:ON	SAR HK 23
			3	SAR 50	Receiver Unit ON/OFF	SD	0:OFF 1:ON	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Table A.2 JERS-1 Telemetry Word Assignments (9/ 9)

WORD	FRAME	SUBCOM.	BIT	TLM No.	SIGNAL	SIGNAL TYPE	STATUS	NOTE
105			4	SAR 50	Signal Processor Unit ON/OFF	SD	0:OFF 1:ON	SAR HK 25
			5	SAR 50	High Power Amplifier Power Source A ON/OFF	SD	0:OFF 1:ON	SAR HK 26
			6	SAR 50	High Power Amplifier Power Source B ON/OFF	SD	0:OFF 1:ON	SAR HK 27
			7	SAR 50	High Power Amplifier Power Source R ON/OFF	SD	0:OFF 1:ON	SAR HK 28
106			0 - 2	SAR 51	Combiner SW(1)/(2)/(3)	SD		SAR HK 15
			3	SAR 51	SW	SD	0:N/A 1:ON	
			4	SAR 51	CAL SW ON/OFF	SD	0:OFF 1:ON	
			5	SAR 51	STR ON/OFF	SD	0:OFF 1:ON	SAR HK 30
			6	SAR 51	Status of STC Initial Start Time setting	SD	0:Calibration mode 1:Observation mode	SAR HK 29
			7	SAR 51	Spare	SD		
107			0 - 7	SAR 52	STR Status	SD		SAR HK 31
108				OPS 1	VNIR detector temperature 1	PA	Table B.2	
109				OPS 2	VNIR detector temperature 2	PA	Table B.2	
110				OPS 3	VNIR detector temperature 3	PA	Table B.2	
111				OPS 4	VNIR detector temperature 4	PA	Table B.2	
112				OPS 21	SWIR Detector temperature	AA	Table B.26	
113				OPS 35	Cooler Mount temperature	AA	Table B.22	
115				OPS 5	VNIR Electric Calibration Voltage	AA	5.12/255×N [V]	

Sygnal Type PA:Passive Analog AA:Active Analog BL:Bi-Level SD:Sirial Digital

Appendix-B

Count value N is converted to voltage E(V) by using following equation.

$$E=\frac{5.12}{255}\times N \qquad \text{(B-1)}$$

Some tables contain the values which exceed 5.12 V. But the value is limited to 5.12 V in the telemetry.

Table B Conversion Table of Telemetry (1/ 12)

Table B. 1 Temperature Sensor Output Voltage 1

Temp (℃)	Output Voltage (V)
-31.7	9.307
-17.8	4.475
-3.9	2.296
10.0	1.241
25.0	0.675
37.8	0.419
51.7	0.259
65.6	0.166
79.4	0.110
93.3	0.075
121.1	0.038

Table B.2 Temperature Sensor Output Voltage

TEMPERATURE (℃)	Output Voltage (V)
-260.00	0.005
-240.00	0.068
-220.00	0.242
-200.00	0.467
-180.00	0.701
-160.00	0.934
-140.00	1.163
-120.00	1.389
-100.00	1.612
-80.00	1.834
-60.00	2.053
-40.00	2.270
-20.00	2.486
0.00	2.700
20.00	2.913
40.00	3.124
60.00	3.335
80.00	3.543
100.00	3.751
140.00	4.163
180.00	4.569
220.00	4.971
260.00	5.368
300.00	5.759
340.00	6.145
380.00	6.527
400.00	6.715

Table B Conversion Table of Telemetry (2/ 12)

Table B.3 SAR-HPA-A Temp

Temp (℃)	Output Voltage (v)
60	3.150
50	2.935
40	2.727
30	2.530
20	2.329
10	2.161
0	1.989
-10	1.825
-20	1.671
-30	1.524

Table B.4 SAR-HPA-B Temp

Temp (℃)	Output Voltage (v)
60	3.143
50	2.925
40	2.720
30	2.525
20	2.338
10	2.157
0	1.986
-10	1.825
-20	1.671
-30	1.523

Table B.5 SAR-HPA-R Temp

Temp (℃)	Output Voltage (v)
60	3.173
50	2.954
40	2.741
30	2.538
20	2.345
10	2.156
0	1.985
-10	1.823
-20	1.669
-30	1.527

Table B.6 SAR-HPAPS-A Temp

Temp (℃)	Output Voltage (v)
60	3.152
50	2.934
40	2.730
30	2.534
20	2.346
10	2.163
0	1.990
-10	1.827
-20	1.674
-30	1.524

Table B Conversion Table of Telemetry (3/ 12)

Table B.7 SAR-HPAPS-B Temp

Temp (℃)	Output Voltage (v)
60	3.168
50	2.948
40	2.741
30	2.542
20	2.354
10	2.174
0	2.001
-10	1.836
-20	1.683
-30	1.535

Table B.8 SAR-HPAPS-R Temp

Temp (℃)	Output Voltage (v)
60	3.123
50	2.908
40	2.703
30	2.507
20	2.321
10	2.142
0	1.974
-10	1.809
-20	1.658
-30	1.511

Table B.9 SAR-PLSG-A Temp

Temp (℃)	Output Voltage (v)
60	3.189
50	2.969
40	2.753
30	2.550
20	2.354
10	2.167
0	1.993
-10	1.827
-20	1.665
-30	1.526

Table B.10 SAR-PLSG-B Temp

Temp (℃)	Output Voltage (v)
60	3.120
50	2.904
40	2.700
30	2.503
20	2.315
10	2.137
0	1.962
-10	1.801
-20	1.650
-30	1.504

Table B Conversion Table of Telemetry (4/ 12)

Tabel B.11 SAR-SP-A Temperature

Regulation Temperature(℃)	Output Voltage (v)
-30	2.377
-28	2.392
-26	2.407
-24	2.422
-22	2.441
-20	2.461
-18	2.487
-16	2.506
-14	2.526
-12	2.546
-10	2.565
-8	2.587
-6	2.606
-4	2.627
-2	2.647
0	2.669
2	2.689
4	2.709
6	2.731
8	2.751
10	2.772
12	2.792
14	2.813
16	2.834
18	2.855
20	2.877
22	2.898
24	2.919
26	2.938
28	2.961
30	2.982
32	3.002
34	3.027
36	3.047
38	3.067
40	3.087
42	3.109
44	3.131
46	3.152
48	3.173
50	3.194
52	3.220
54	3.247
56	3.266
58	3.295
60	3.320

Table B Conversion Table of Telemetry (5/ 12)

Table B.12 SAR-SP-B Temperature

Regulation Temperature (℃)	Output Voltage (v)
-30	2.375
-28	2.390
-26	2.408
-24	2.427
-22	2.446
-20	2.468
-18	2.488
-16	2.507
-14	2.527
-12	2.547
-10	2.569
-8	2.589
-6	2.611
-4	2.630
-2	2.653
0	2.674
2	2.696
4	2.718
6	2.741
8	2.761
10	2.784
12	2.804
14	2.827
16	2.850
18	2.871
20	2.894
22	2.916
24	2.938
26	2.961
28	2.982
30	3.005
32	3.029
34	3.052
36	3.075
38	3.097
40	3.120
42	3.144
44	3.166
46	3.189
48	3.216
50	3.237
52	3.254
54	3.270
56	3.287
58	3.309
60	3.330

Table B Conversion Table of Telemetry (6/ 12)

Table B.13 Transmitting power Level Telemetry (A)

Tx Power Level (dBm)	Output Level -20℃	Telemetry +23℃	(V) +40℃
+50	0.091	0.125	0.155
+51	0.147	0.210	0.244
+52	0.229	0.319	0.356
+53	0.339	0.451	0.491
+54	0.475	0.606	0.649
+55	0.368	0.785	0.829
+56	0.855	0.979	1.033
+57	1.050	1.174	1.228
+58	1.286	1.420	1.470
+59	1.562	1.716	1.760
+60	1.879	2.063	2.098
+61	2.237	2.461	2.483
+62	2.635	2.909	2.916
+63	3.075	3.407	3.397

Table B.14 Calibration Unit Output Level Telemetry (A)

Cal. Unit Input Level(dBm)	Output Level -20℃	Telemetry +23℃	(V) +40℃
+10	1.062	1.132	1.228
+11	1.279	1.340	1.438
+12	1.540	1.591	1.690
+13	1.843	1.888	1.984
+14	2.189	2.229	2.320
+15	2.578	2.614	2.698
+16	3.010	3.044	3.118
+17	3.485	3.518	3.580
+18	4.003	4.036	4.085
+19	4.564	4.599	4.631

Table B Conversion Table of Telemetry (7/ 12)

Table B. 15 I Video Signal Output Level Telemetry (A)

I Video Signal Output (dBm)	Output Level Telemetry (V) -20℃	+23℃	+40℃
-10	1.227	1.237	1.306
-9	1.320	1.351	1.406
-8	1.443	1.489	1.530
-7	1.595	1.650	1.679
-6	1.776	1.834	1.853
-5	1.987	2.043	2.052
-4	2.228	2.275	2.276
-3	2.465	2.512	2.515
-2	2.742	2.770	2.788
-1	3.017	3.032	3.062
0	3.289	3.300	3.335
+1	3.560	3.572	3.607
+2	3.699	3.795	3.783
+3	3.848	3.935	3.951
+4	3.976	4.057	4.092
+5	4.085	4.161	4.204
+6	4.173	4.246	4.288
+7	4.242	4.313	4.344
+8	4.291	4.362	4.373

Table. B. 16 Q Video Signal Output Level Telemetry (A)

Q Video Signal Output (dBm)	Output Level Telemetry (V) -20℃	+23℃	+40℃
-10	1.207	1.306	1.271
-9	1.329	1.412	1.385
-8	1.472	1.542	1.522
-7	1.637	1.696	1.681
-6	1.822	1.873	1.861
-5	2.030	2.074	2.063
-4	2.258	2.298	2.287
-3	2.508	2.546	2.532
-2	2.780	2.818	2.798
-1	3.072	3.113	3.040
0	3.356	3.376	3.317
+1	3.639	3.639	3.630
+2	3.798	3.814	3.832
+3	3.939	3.965	3.993
+4	4.062	4.093	4.128
+5	4.166	4.198	4.236
+6	4.252	4.279	4.317
+7	4.320	4.337	4.371
+8	4.370	4.371	4.400

Table B Conversion Table of Telemetry (8/ 12)

Table B.17 Transmitting Power Level Telemetry (B)

Tx Power	Output Level Telemetry (V)		
Level (dBm)	-20℃	+23℃	+40℃
+50	0.088	0.109	0.150
+51	0.146	0.195	0.237
+52	0.232	0.303	0.348
+53	0.346	0.435	0.481
+54	0.487	0.589	0.637
+55	0.655	0.767	0.816
+56	0.856	0.964	1.022
+57	1.047	1.161	1.216
+58	1.279	1.408	1.458
+59	1.553	1.705	1.749
+60	1.869	2.053	2.088
+61	2.227	2.451	2.475
+62	2.628	2.900	2.911
+63	3.070	3.398	3.394

Table B. 18 Calibraton Unit Output Level Telemetry (B)

Cal Unit	Output Level Telemetry (V)		
Input Level (dB)	-20℃	+23℃	+40℃
+10	1.065	1.144	1.199
+11	1.283	1.352	1.403
+12	1.544	1.605	1.652
+13	1.849	1.902	1.945
+14	2.196	2.243	2.282
+15	2.587	2.629	2.664
+16	3.022	3.060	3.091
+17	3.499	3.535	3.561
+18	4.020	4.055	4.076
+19	4.584	4.619	4.636

Table B Conversion Table of Telemetry (9/ 12)

Table B. 19 I Video Signal Output Level Telemetry (B)

I Video Signal Output (dBm)	Output Level Telemetry (V)		
	-20℃	+23℃	+40℃
-10	1.188	1.261	1.288
-9	1.305	1.373	1.406
-8	1.448	1.509	1.544
-7	1.616	1.670	1.700
-6	1.809	1.855	1.877
-5	2.029	2.065	2.072
-4	2.273	2.298	2.287
-3	2.514	2.508	2.528
-2	2.777	2.800	2.809
-1	3.045	3.081	3.088
0	3.317	3.352	3.367
1	3.593	3.612	3.645
2	3.791	3.815	3.824
3	3.929	3.974	3.983
4	4.048	4.107	4.118
5	4.147	4.213	4.229
6	4.225	4.292	4.317
7	4.284	4.345	4.381
8	4.322	4.371	4.421

Table B. 20 Q Video Signal Output Level Telemetry (B)

Q Video Signal Output (dBm)	Output Level Telemetry (V)		
	-20℃	+23℃	+40℃
-10	1.143	1.250	1.298
-9	1.287	1.371	1.413
-8	1.445	1.513	1.547
-7	1.618	1.674	1.700
-6	1.804	1.856	1.872
-5	2.005	2.057	2.064
-4	2.220	2.278	2.274
-3	2.475	2.535	2.508
-2	2.766	2.795	2.815
-1	3.045	3.065	3.106
0	3.309	3.346	3.382
+1	3.561	3.636	3.642
+2	3.747	3.783	3.831
+3	3.884	3.949	3.980
+4	4.005	4.087	4.107
+5	4.107	4.197	4.210
+6	4.192	4.280	4.290
+7	4.259	4.335	4.347
+8	4.309	4.363	4.381

Table B Conversion Table of Telemetry (10/ 12)

Tabel B.21 SWIR Detector TEMPERTURE Telemetry Cal. Data (PFM)

Temperture (K)	Voltage (V)
70	4.985
75	3.7762
80	2.5674
85	1.3585
90	0.1497

Table B.22 Cooler Mount Temperture Telemetry Cal. Data (PFM)

Temperture (K)	Voltage (V)
60	0.185
70	0.815
80	1.35
90	1.84
100	2.3
110	2.73
120	3.14
130	3.52
140	3.91
150	4.29
160	4.67
170	5.03

Table B Conversion Table of Telemetry (11/ 12)

Table B.23 Passive Analog Telemetry Cal Data (PFM)

Temperature (°C)	Telemetry Voltage (V)			
	Cooler Power Source Temperature (1)	Cooler Power Source Temperature (2)	Cooler Surface Temperature (1)	Cooler Surface Temperature (2)
-30.1	4.695	4.694	4.691	4.691
-19.5	4.253	4.251	4.247	4.246
-10.0	3.760	3.760	3.756	3.753
0	3.168	3.170	3.166	3.160
+11.3	2.515	2.514	2.511	2.504
+20.3	2.033	2.032	2.029	2.022
+30.8	1.551	1.555	1.551	1.546
+40.2	1.199	1.021	1.199	1.194
+50.0	0.915	0.916	0.914	0.910
+60.0	0.692	0.639	0.692	0.688
+69.8	0.528	0.528	0.527	0.524

Table B Conversion Table of Telemetry (12/ 12)

Table B.24 Passive Analog Telemetry (Pt. Sensor) Cal. Data (Controller Tmperature)

Temperature (℃)	Voltage (V)
-40.0	2.227
-30.0	2.38
-20.0	2.488
0.0	2.703
+20.0	2.915
+25.0	2.968
+40.0	3.127
+50.0	3.232
+60.0	3.337
+80.0	3.546

Appendix-C

Table C-1 STC start time change patterns

STC Start Time Change Patterns					Class
Command bit No.					
5	6	7	8	9	
0	0	0	0	0	Pattern 1
0	0	0	0	1	〃 2
0	0	0	1	0	〃 3
0	0	0	1	1	〃 4
0	0	1	0	0	〃 5
0	0	1	0	1	〃 6
0	0	1	1	0	〃 7
0	0	1	1	1	〃 8
0	1	0	0	0	〃 9
0	1	0	0	1	〃 10
0	1	0	1	0	〃 11
0	1	0	1	1	〃 12
0	1	1	0	0	〃 13
0	1	1	0	1	〃 14
0	1	1	1	0	〃 15
0	1	1	1	1	〃 16
1	0	0	0	0	〃 17
1	0	0	0	1	〃 18
1	0	0	1	0	〃 19
1	0	0	1	1	〃 20
1	0	1	0	0	〃 21
1	0	1	0	1	〃 22
1	0	1	1	0	〃 23
1	0	1	1	1	〃 24

Table C-2 Variation of STC start time (1/4)

No.	Pattern 1 (μsec) STC Start Time	Pattern 2 (μsec) STC Start Time	Pattern 3 (μsec) STC Start Time	Pattern 4 (μsec) STC Start Time	Pattern 5 (μsec) STC Start Time	Pattern 6 (μsec) STC Start Time
1	0	0	0	0	0	0
2	0	0	0	0	0	10
3	0	0	0	10	10	10
4	0	0	10	10	10	20
5	0	0	10	10	20	20
6	0	10	10	20	20	30
7	0	10	10	20	30	30
8	0	10	20	20	30	40
9	0	10	20	30	40	50
10	0	10	20	30	40	50
11	0	10	20	30	50	60
12	0	10	20	40	50	60
13	0	10	30	40	50	70
14	0	10	30	40	60	70
15	0	20	30	50	60	80
16	0	20	30	50	70	80
17	0	20	40	50	70	90
18	0	20	40	60	80	100
19	0	20	40	60	80	100
20	0	20	40	60	90	110
21	0	20	50	70	90	110
22	0	20	50	70	90	120
23	0	20	50	70	100	120
24	0	30	50	80	100	130
25	0	30	50	80	110	140
26	0	30	60	80	110	140
27	0	30	60	90	120	150
28	0	30	60	90	120	150
29	0	30	60	90	130	160
30	0	30	70	100	130	160
31	0	30	70	100	140	170
32	0	30	70	100	140	170
33	0	40	70	110	140	180
34	0	40	70	110	150	190
35	0	40	80	110	150	190
36	0	40	80	120	160	200
37	0	40	80	120	160	200
38	0	40	80	120	170	210
39	0	40	90	130	170	210
40	0	40	90	130	180	220
41	0	50	90	140	180	230

Table C-2 Variation of STC start time (2/4)

	Pattern 7 (μsec) STC Start Time	Pattern 8 (μsec) STC Start Time	Pattern 9 (μsec) STC Start Time	Pattern 10 (μsec) STC Start Time	Pattern 11 (μsec) STC Start Time	Pattern 12 (μsec) STC Start Time
1	0	0	0	0	0	0
2	10	10	10	10	10	10
3	10	20	20	20	20	20
4	20	20	30	30	30	40
5	30	30	40	40	50	50
6	30	40	50	50	60	60
7	40	50	50	60	70	70
8	50	60	60	70	80	90
9	50	60	70	80	90	100
10	60	70	80	90	100	110
11	70	80	90	100	110	120
12	70	90	100	110	120	140
13	80	90	110	120	140	150
14	90	100	120	130	150	160
15	90	110	130	140	160	170
16	100	120	140	150	170	190
17	110	130	140	160	180	200
18	110	130	150	170	190	210
19	120	140	160	180	200	220
20	130	150	170	190	210	240
21	140	160	180	200	230	250
22	140	170	190	210	240	260
23	150	170	200	220	250	270
24	160	180	210	230	260	280
25	160	190	220	240	270	300
26	170	200	230	250	280	310
27	180	200	230	260	290	320
28	180	210	240	270	300	330
29	190	220	250	280	320	350
30	200	230	260	290	330	360
31	200	240	270	300	340	370
32	210	240	280	310	350	380
33	220	250	290	320	360	400
34	220	260	300	330	370	410
35	230	270	310	340	380	420
36	240	280	320	350	390	430
37	240	280	320	360	410	450
38	250	290	330	370	420	460
39	260	300	340	380	430	470
40	260	310	350	390	440	480
41	270	320	360	410	450	500

Table C-2 Variation of STC start time (3/4)

	Pattern 13 (μsec) STC Start Time	Pattern 14 (μsec) STC Start Time	Pattern 15 (μsec) STC Start Time	Pattern 16 (μsec) STC Start Time	Pattern 17 (μsec) STC Start Time	Pattern 18 (μsec) STC Start Time
1	0	0	0	0	0	0
2	0	0	0	0	0	−10
3	0	0	0	−10	−10	−10
4	0	0	−10	−10	−10	−20
5	0	0	−10	−10	−20	−20
6	0	−10	−10	−20	−20	−30
7	0	−10	−10	−20	−30	−30
8	0	−10	−20	−20	−30	−40
9	0	−10	−20	−30	−40	−50
10	0	−10	−20	−30	−40	−50
11	0	−10	−20	−30	−50	−60
12	0	−10	−20	−40	−50	−60
13	0	−10	−30	−40	−50	−70
14	0	−10	−30	−40	−60	−70
15	0	−20	−30	−50	−60	−80
16	0	−20	−30	−50	−70	−80
17	0	−20	−40	−50	−70	−90
18	0	−20	−40	−60	−80	−100
19	0	−20	−40	−60	−80	−100
20	0	−20	−40	−60	−90	−110
21	0	−20	−50	−70	−90	−110
22	0	−20	−50	−70	−90	−120
23	0	−20	−50	−70	−100	−120
24	0	−30	−50	−80	−100	−130
25	0	−30	−50	−80	−110	−140
26	0	−30	−60	−80	−110	−140
27	0	−30	−60	−90	−120	−150
28	0	−30	−60	−90	−120	−150
29	0	−30	−60	−90	−130	−160
30	0	−30	−70	−100	−130	−160
31	0	−30	−70	−100	−140	−170
32	0	−30	−70	−100	−140	−170
33	0	−40	−70	−110	−140	−180
34	0	−40	−70	−110	−150	−190
35	0	−40	−80	−110	−150	−190
36	0	−40	−80	−120	−160	−200
37	0	−40	−80	−120	−160	−200
38	0	−40	−80	−120	−170	−210
39	0	−40	−90	−130	−170	−210
40	0	−40	−90	−130	−180	−220
41	0	−50	−90	−140	−180	−230

Table C-2 Variation of STC start time (4/4)

STC Start Time (μsec)

No.	Pattern 19	Pattern 20	Pattern 21	Pattern 22	Pattern 23	Pattern 24
1	0	0	0	0	0	0
2	-10	-10	-10	-10	-10	-10
3	-10	-20	-20	-20	-20	-20
4	-20	-20	-30	-30	-30	-40
5	-30	-30	-40	-40	-50	-50
6	-30	-40	-50	-50	-60	-60
7	-40	-50	-50	-60	-70	-70
8	-50	-60	-60	-70	-80	-90
9	-50	-60	-70	-80	-90	-100
10	-60	-70	-80	-90	-100	-110
11	-70	-80	-90	-100	-110	-120
12	-70	-90	-100	-110	-120	-140
13	-80	-90	-110	-120	-140	-150
14	-90	-100	-120	-130	-150	-160
15	-90	-110	-130	-140	-160	-170
16	-100	-120	-140	-150	-170	-190
17	-110	-130	-140	-160	-180	-200
18	-110	-130	-150	-170	-190	-210
19	-120	-140	-160	-180	-200	-220
20	-130	-150	-170	-190	-210	-240
21	-140	-160	-180	-200	-230	-250
22	-140	-170	-190	-210	-240	-260
23	-150	-170	-200	-220	-250	-270
24	-160	-180	-210	-230	-260	-280
25	-160	-190	-220	-240	-270	-300
26	-170	-200	-230	-250	-280	-310
27	-180	-200	-230	-260	-290	-320
28	-180	-210	-240	-270	-300	-330
29	-190	-220	-250	-280	-320	-350
30	-200	-230	-260	-290	-330	-360
31	-200	-240	-270	-300	-340	-370
32	-210	-240	-280	-310	-350	-380
33	-220	-250	-290	-320	-360	-400
34	-220	-260	-300	-330	-370	-410
35	-230	-270	-310	-340	-380	-420
36	-240	-280	-320	-350	-390	-430
37	-240	-280	-320	-360	-410	-450
38	-250	-290	-330	-370	-420	-460
39	-260	-300	-340	-380	-430	-470
40	-260	-310	-350	-390	-440	-480
41	-270	-320	-360	-410	-450	-500