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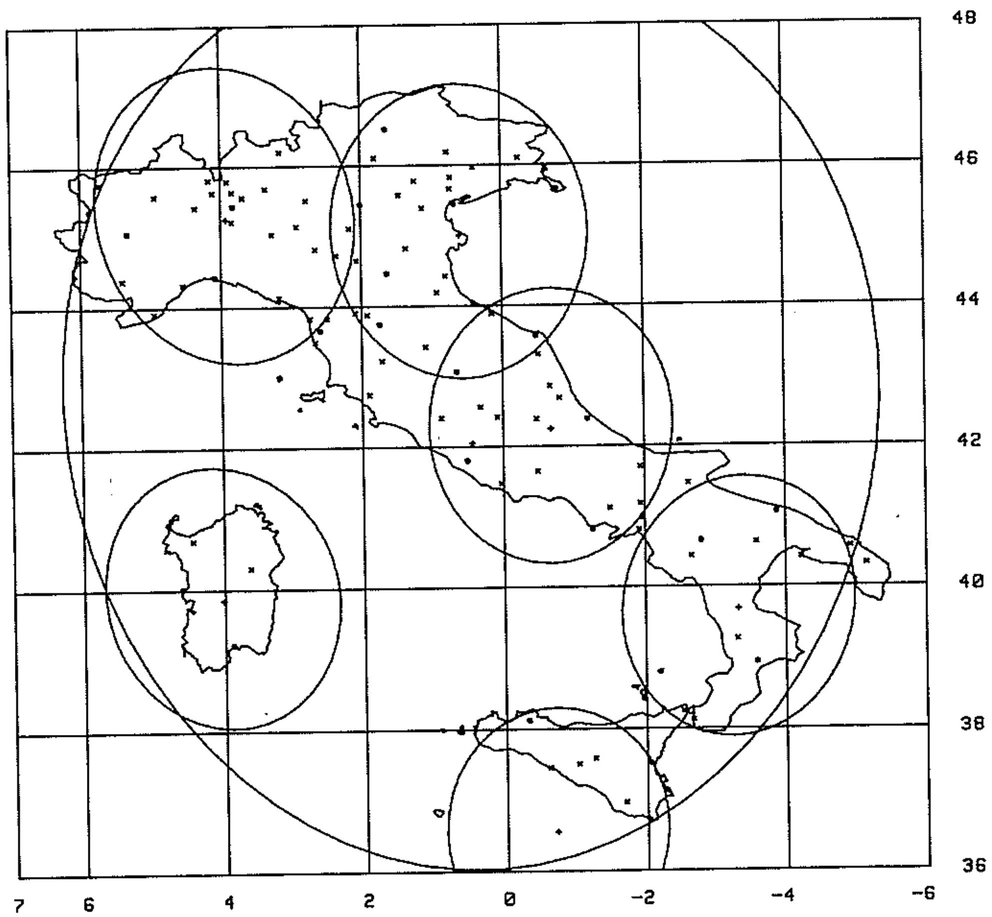

Fig. 1. Coverage of Italy by a 1.45° beam (global coverage) and by six 0.435° beams (multibeam coverage).

BS-2 Spacecraft Design

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Abstract

The Broadcasting Satellite (BS-2) is now in the design/manufacturing phase to establish the first Japanese operational domestic satellite broadcasting system using Ku-Band WARC-BS allocated frequencies. This paper presents the outline of the BS-2 spacecraft design.

1. Introduction

The development of the spacecraft was entrusted to NASDA (National Space Development Agency of Japan) by NHK (Japan Broadcasting Corporation) through TSC-J (Telecommunications Satellite Corporation of Japan) according to BS-2 contract which is awarded to Toshiba with General Electric as a major subcontractor.

There are two satellites for the BS-2 Program (Ref. 1), identical except for their assigned command/telemetry frequencies. Each will be launched by a NASDA N-II rocket from the Tanegashima Space Center and will be collocated at Japan's assigned orbital slot of 110 degrees east longitude. The first satellite (designated as BS-2a) will be launched in early 1984 while the second (BS-2b) is scheduled for a summer 1985 launch. The satellite is designed for a five year life. A propellant load to sustain a minimum of 4 years (5 year goal) of in orbit life with full north-south and east-west station keeping is planned.

2. Major Spacecraft Parameters

In orbit, either satellite is capable of broadcasting two FM color TV signals (WARC BS Channels 11 and 15) simultaneously to all of the Japanese territory including the Okinawa and Ogasawara Islands with an EIRP of at least 45.4 dBw, while the main islands will have an EIRP of at least 54.4 dBw. Each spacecraft will weigh over 680 kilograms at liftoff. On orbit, the deployed solar array will generate approximately 900 watts at the end of 5 years to support a maximum load of 785 watts. The predicted reliability at 5 years is 0.85.

3. Spacecraft Configuration

The spacecraft has inherited many components and proven design features of the Japanese Medium-scale Broadcasting Satellite for Experimental Purpose (BSE) to assure high performance and reliability. A number of improvements have also been incorporated into BS-2 .

The spacecraft configuration maximizes the mission benefits of a three-axis controlled spacecraft by providing a fixed (non-gimballed or rotating) antenna platform, large North/South-viewing equipment panels for passive heat rejection, and an oriented solar array for efficient generation of power. The spacecraft in the orbital configuration is shown in Fig. 1.

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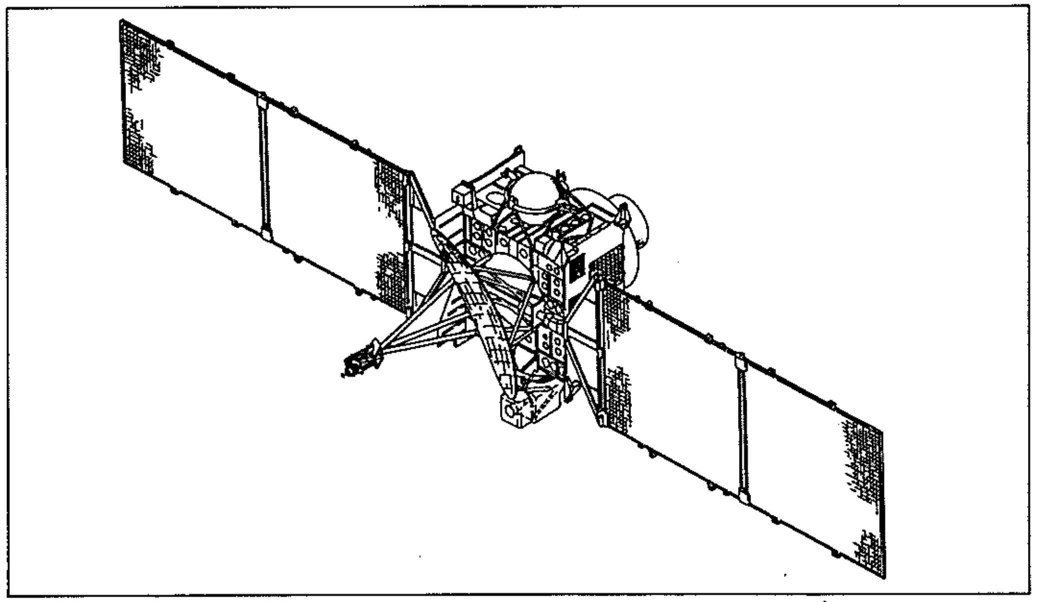

Fig. 1 BS-2 Spacecraft (Thermal Blankets Removed)

For orbital operation, the earth viewing spacecraft surface provides required fields of view for earth and monopulse sensors and antennas. The Ku-band mission antenna mounted on this platform is thermally isolated by an insulated truss to minimize temperature effects. This primary alignment surface for antenna and sensors permits the accurate pointing of the antenna RF axis to the center of the coverage area. An S-band telemetry antenna is mounted forward of the Ku-band antenna horns to minimize pattern interference from any other spacecraft element.

Solar arrays which collect solar energy are positioned outboard of the antenna by stand-off yokes. This eliminates solar cell shadowing under the worst case solar inclination conditions and precludes solar reflections onto thermal radiating surfaces. Redundant solar array drives and power takeoff assemblies are connected via a through-shaft. Either drive can power the arrays through a passive clutch, assuring redundancy as well as identical positioning of each solar array.

The equipment module is the main structural element and houses the subsystems. The primary heat generating components are mounted on the north and south viewing radiating areas. Housekeeping electronics are grouped together on the south equipment panel and the transponder subsystem electronics are mounted on the north panel. The reaction control propellant tanks are located on the east/west sides of the spacecraft at the maximum distance from the centerline to obtain a maximum moment of inertia about the thrust axis of the integral apogee motor.

For launch and the spin phase the solar array is folded down and retained on the north and south equipment panels. The spacecraft spins at 60 rpm through the transfer orbit and until shortly after apogee motor firing with a favorable inertia ratio always in excess of 1.12.

Thrusters are located to provide redundancy of all propulsion functions with minimum possible plume impingement on the vehicle. The yaw and pitch thrusters on the east and west sides support dual functions of wheel unloading and station keeping. Propellant tanks are centered at the spacecraft orbital CG plane minimizing control torque variations as the propellant is depleted.

4. Key Subsystem Summaries

Communication Subsystem

The Transponder is a frequency selective, Ku-band, single conversion rebroadcast-transponder with provision for frequency conversion of Ku-band TT&C signals to operate with S-band TT&C equipment. It is shown in Fig. 2.

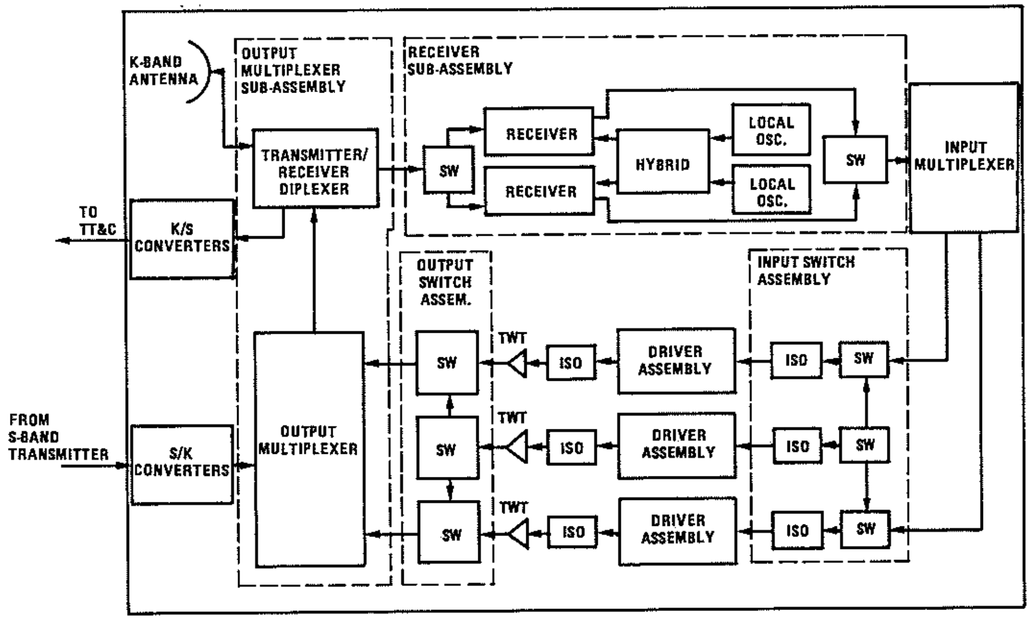

Fig. 2 Communication Subsystem Diagram

The transponder receives low level broad band TV signals at its antenna port via the satellite communications antenna. Received signals at any frequency within or between the receive frequency channel allocations are simultaneously amplified and translated downward in frequency by 2.3 GHz (nominal) in a single receiver which may be either of two redundant receivers whose local oscillator signal may be provided by either of two redundant local oscillators. The down converted signals present are separated into two transmit channel frequency allocations with channelizing filters. The channelized signals are amplified and level controlled to the desired transmit power level in separate transmitters. A redundant transmitter may be selected to level control and amplify signals in either transmit channel frequency allocation, but not both simultaneously. Transmitter output signals are recombined by means of a multiplexing filter for retransmission to the ground via the satellite communications antenna. Receive and transmit signals, which are present simultaneously at the transponder antenna port, are diplexed onto the single antenna port by means of the transmit and receive multiplexing (T/R mux) filters. The switching capability for redundant receiver, local oscillator, or transmitter selection is provided by in-line passive ferrite or hybrid devices. Redundant driver circuits for the ferrite switches are inactive and unpowered except during redundancy selection switching operations.

The transponder also receives a low level Ku-band TT&C signal at its antenna port, via the satellite communications antenna, and down converts this signal to operate with standard S-band TT&C equipment. Standard S-band transmit signals are upconverted to the TT&C Ku-band frequency, amplified, combined with the TV transmit signals, and retransmitted via the satellite communications antenna to ground TT&C receivers.

Major communication subsystem changes from BSE include the following. GaAs FET low noise amplifiers providing improved performance and reliability have replaced tunnel diode amplifiers in the 14 GHz receivers. GaAs FET amplifiers have also replaced the low level TWTA driver amplifiers. The 100 watt BSE coupled cavity TWT has been replaced by a smaller, lighter, helix type TWT supplied by Thomson CSF. The High Voltage Power Supply (HVPS) has been redesigned to operate with the helix TWT. The new HVPS has been specifically designed to produce low mechanical and electrical stress within its high voltage modules and incorporated improved potting materials. The waveguide pin diode attenuators have been redesigned as a microwave integrated circuit to provide a larger attenuation range while also saving weight. The input and output multiplexers as well as the Ku-band antenna have been redesigned to comply with the WARC Broadcasting assignments and restrictions.

Attitude Control Subsystem (ACS)

The ACS for BS-2 controls spacecraft attitude, spacecraft linear velocity and spacecraft momentum from booster separation through on-orbit pointing, including re-acquisition, if required. The spacecraft is spin stabilized through the transfer and injection modes. On-orbit control is achieved through a nominally zero-momentum, three-axis stabilization system. A passive earth sensor and monopulse sensor are used to derive roll, pitch and yaw errors with sufficient accuracy to meet the overall 0.1 degree beam pointing requirement. Redundant channels on both of these sensors assure that this accuracy will be met if a single channel failure occurs. Solar array mounted sun sensors can be used in conjunction with either an earth sensor or monopulse sensor to provide an alternate path for three axis control.

The subsystem components are identified in Fig. 3.

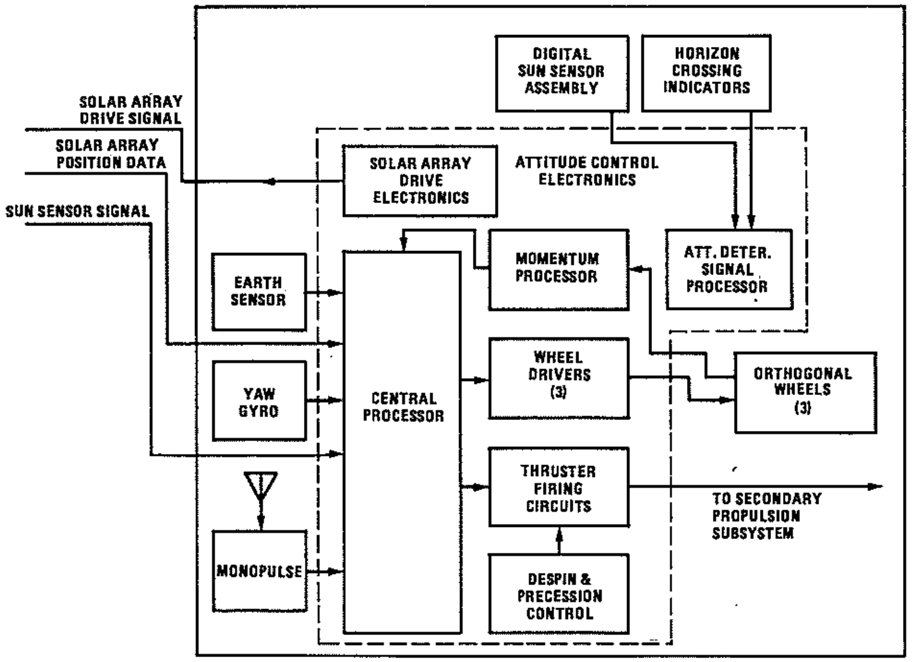

Fig. 3 Attitude Control Subsystem Diagram

Redundant secondary propul[illegible] thrusters provide a complete functional back-up to the three reaction wheels. All attitude sensors as well as the control electronics are redundant.

Three automatic features have been incorporated into the normal mode control software. The first is the availability of automatic wheel unload. The second is to continue to monitor the lock state of the monopulse sensor in on-board software, and to automatically transfer control of the spacecraft to the earth sensor for pitch and roll and sun sensors for yaw in the event of a loss of monopulse lock. The third is to interrogate the sun sensor once

a day (at noon) to calculate sun declination angle and declination angle rate. This data is used to update the memory location for sun bias when the sun sensor is used to control yaw attitude. Thus, the automatic transfer to sun sensor due to loss of monopulse lock will not require rapid uplink of current sun declination angle data. Any of these automatic features can be disabled by ground command.

Telemetry, Tracking and Command

This subsystem is shown in Fig. 4.

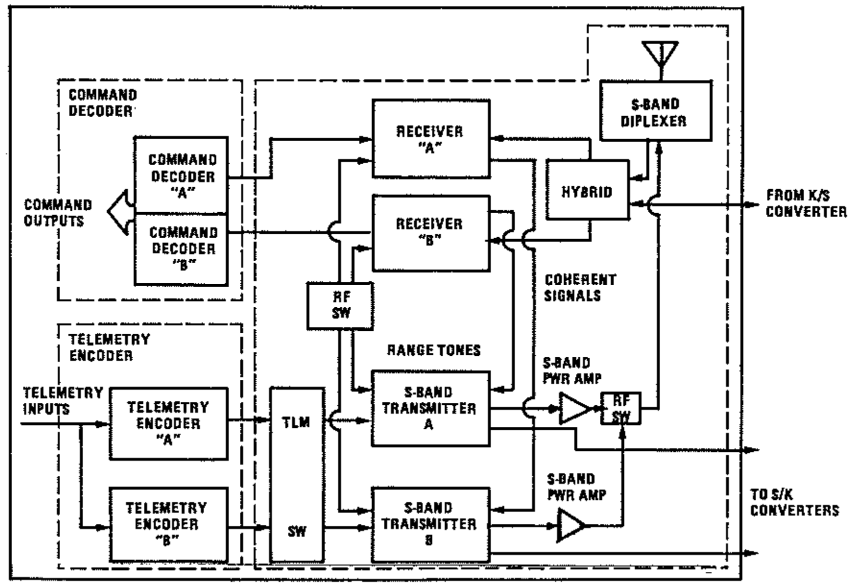

Fig. 4 Telemetry, Tracking and Control Subsystem Diagram

Two frequency bands are used. S-band links are provided for both reception and transmission during all phases of the mission starting from a pre-launch checkout period. The parameters of these links have been selected so as to provide compatibility with both the Japanese TACS and NASA-STDN. Ku-band links are established after the spacecraft has achieved the proper orientation of the Ku-band antenna and are maintained throughout the operational phase. Telemetry will be transmitted as required prior to launch and continuously on S-band after launch until Ku-band links are established. Telemetry can be transmitted on S-band, Ku-band, or both bands simultaneously after activation of the Ku-band link. Command reception capability will be provided via S-band during the pre-launch phase and until activation of the Ku-band link. Subsequently, command reception and ranging may be via either Ku-band or S-band. Simultaneous commands on both links is prohibited by ground station discipline to avoid interference at the command receivers.

The primary areas of change in the TT&C Subsystem since BSE are related to frequency selection, coherent operation, the inclusion of the capability to command S-band power amplifier deactivation and the presence of simultaneous uplinks required with two collocated satellites.

5. Other Subsystems

The other subsystems are very similar in design to those used on BSE. There have been changes, primarily in materials selection to provide for longer life and to prevent contamination of thermal and optical surfaces. Improved solar cells are used on the solar array and optical solar reflector tiles have replaced silver teflon as the primary thermal radiator surface material.

Reference

1. Y. Ueda, K. Ishibashi, and Y. Ichikawa: Operational Broadcasting Satellite Program in Japan, 1981 IAF, Rome Italy.