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THE JAPANESE MEDIUM-SCALE BROADCASTING SATELLITE FOR EXPERIMENTAL PURPOSE

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Abstruct

The Medium-Scale Broadcasting Satellite for Experimental Purpose (BSE) was planned by the Ministry of Posts and Telecommunications (MOPT) and developed by National Space Development Agency of Japan (NASDA) for the future domestic direct broadcasting satellite system,since 1974.
BSE was successfully launched from Eastern Test Range (ETR),Florida,United States, with Delta 2914 launch vehicle on April,1978.
After several precession maneuvers, Apogee Kick Motor (AKM) was fired at the third apogee and put into the drift orbit. On April 26th,BSE was stationed at the predetermined geostationary orbit position, 110 degrees east longitude.

Initial spacecraft (S/C) checkup was performed by NASDA for three months and verified that S/C equipments and operation procedures were completely acceptable.
Now,regular broadcasting experiments are performed by MOPT in cooperation with Radio Research Laboratries (RRL) and Japan Broadcasting Corporation (NHK).

This paper describes the following items attitude/orbit control mechanism,high efficiency sun oriented solar array panel and power system,and 12 GHz band broadcasting transponder constitution.

Introduction

The BSE is for experimental color television signal transmission to Japanese main land and remote islands and also is viewed as the establishement of an operational broadcasting satellite system.

Major BSE operational items are as follows:

- confirm tracking and stationkeeping technique
- data collection of three-axis zero momentum attitude control satellite and operation
- verification of antenna beam pointing accuracy (±0.2 degrees)

Also BSE mission items are as follows

- experimental picture and sound signal transmission test of broadcasting satellite system.
- experiments to evaluate performance of ground transmitter and receiver system.

BSE system parameters and S/C summary description are shown in Table 1. Also, on-orbit BSE configuration is shown in Fig.1.

Attitude Control Subsystem (ACS)

BSE has two attitude control system: one is the spin stabilized control system which is used for transfer orbit and initial part of the drift orbit, the other is the three-axis zero momentum attitude control system which is used for geostationary orbit.

ACS functional block diagram and key components are shown in Fig.2. The upper part of Fig.2 is spin stabilized attitude control elements. In the transfer orbit,spin axis attitude determination and precession maneuvers for AKM fire are required. These functions are performed by the redundant Digital Sun Sensor (DSS),Horizon Crossing Indicator (HCI), and High Thrust Engine (HTE) for precession maneuvers which has 5 lbs thrust level.

The lower part of Fig.2 is three-axis zero momentum attitude control elements. In the geostationary orbit,BSE is required to control its beam pointing within ±0.2 degrees because of its high power transponder. So,high resolution attitude sensor and sophisticated performance attitude control system are used in this system.

The specific features of BSE three-axis zero momentum attitude control system are as follows:

• same control law is used in all mission phases. (i.e. acquisition,unloading and orbit control)

• discrete time state estimate control logic.

• prevent the influence of flexible. light weight and large solar array panel to the control system.

Fig.3 shows BSE discrete time state estimator,in which,solid line is 1 second minor cycle operation and dashed line is T second update cycle operation. There are two update cycle time; 1second and 16 second.
1 second update time is used for acquisition and orbit maneuvers,and then 16 second update time used for steady state high accuracy attitude control and wheel unloading.

Discrete Time State Estimator

Each S/C control axis has a estimate position register (POS) and a estimate momentum register (MER). Basic computational cycle is as follows;

1. Compute the estimated vehicle rate using the MER and momentum wheel (TACH) feedback signal.
2. Update estimated vehicle attitude by integrating estimated vehicle rate.
3. Compute error between estimated attitude and actual sensor signal. And apply pre-determined factor to the above error.
4. Update estimated attitude with weighted error.
5. Update MER with weighted error adjusted for update period.
6. Compute thruster control logic:

   RATE CHECK: 16xMER < DB

   RATE/POSITION CHECK: 16xMER + POS<DB.

   If the left term is greater than DB (Dead Band), thruster drive signal is occured.
7. Compute new estimated vehicle rate using MER and TACH feedback.
8. Compute wheel drive signal using the above estimated rate and position signal.

The above computation cycle is repeated in all axis respectively.

Sensor Combination/Beam Pointing

Attitude control sensor combination on geostationary orbit is shown in Table 2. Combination 1 and 2 are always used. Beam pointing and rotation accuracy when combination 1 was uesd is shown in Fig.4. It can be seen that K-band (12 GHZ) beam pointing accuracy is within ±0.12 degrees and beam rotation within 0.20 degrees.

Electrical Power Subsystem (EPS)

One of the major features of BSE is sun oriented solar array panel and the Direct Energy Transfer (DET) power regulation system.

For the high power transponders (100W x 2 CH) operation,solar array panels are required to generate electrical power greater than 780 watt at worst case (end of mission).
To satisfy this power demand,solar array panel configuration was adopted, that is shown in Table 3.

Solar array panel drive circuit has two drive mode:first mode, that is regular operation mode,constant speed (0.00417 degrees/second).
Second mode, that is vernier mode,also constant speed (0.096 degrees/second), which is used for initial acquisition and to compensate for accumulated error. Solar array panel has been controlled by ground controller within ±0.5 degrees

EPS performs the following functions;

• converts solar energy to electrical power.

• regulates and distributes power to the S/C subsystem.

• stores a portion of the electrical energy in batteries for subsequent use during periods when solar energy conversion is not functioning.

EPS functional block diagram is shown in Fig.5. Power Regulation Unit (PRU) automatically maintains a nominal 28 VDC ±1% regulated power bus throughout all mission operation (i.e.transfer orbit, on-orbit and eclipse). The power regulation is accomplished by a central control in the PRU which regulates the shunt dissipators and boost converters to control the bus voltage,and the battery charge regulators to control battery charging.

When available array power exceeds the S/C needs, the central control drives shunt loads mounted on the solar array extenders which adjusts the operating point and maintains the regulated bus voltage.

As the available array power decreases in eclipse or due to degradation, PRU maintains bus voltage by a series of priority steps -- that is, switches off shunt loads turminates battery charging and turns on the boost converter to draw power from the batteries and sends a backup automatically off signal to the high power Travelling Wave Tube Amplifiers (TWTA) and north panel heaters.

Three (4 AH) nickel cadmium batteries provide energy storage for use during periods when solar energy is unavailable. The batteries are charged via separated Battery Charge Regulators (BCR) when solar array power is sufficient.

Two of the batteries are connected to the ordnance controller for activation of the electro explosive devices associated with AKM and solar array release function.

12 GHz Band Transponder Subsystem

12 GHz band broadcasting transponder is a single conversion rebroadcast transponder with provision for frequency conversion of K-band TT&C signals to operate with S-band TT&C equipment.

Fig.6 shows the frequency arrangement of BSE broadcasting transponder, and block diagram of BSE broadcasting transponder is shown in Fig. 7.

Gain allocations and diltering requirements are distributed to minimize the number of hardware elements, and to maintain margin from the non-linear points of all active element except for the 100 W TWTs.

The transmit/receive diplexer consisting of directed cavity filters routes signals between the communications anyenna and TT&C subsystem. Uplink broadcasting signals are connected to the single communications antenna port without mutual interference between transmit and receive functions. The 14 GHz switch routes received signals to either primary or redundant receiver which linearly preamplifies signals with Tunnel Diode Amplifier (TDA) in both channel A and channel B and down-converts their frequencies by 2.3 GHz using a local oscilator.

The switch provides redundancy allowing signals from either receiver to be routed to the input multiplexer, which separates signals in channel A from signals and channel B. The input switching assembly routes the channel A signal to transmitter A and the channel B signal to transmitter B, and allows either the channel A signal or channel B signal to be able to route through the redundant transmitter.

Each transmitter consists of a driver stage employing a Low Level Traveling Wave Tube Amplifier (LLTWTA) with Automatic Level Control (ALC) and a 100-watt Traveling Wave Tube Amplifier (100 W TWTA). The output switching assembly routes outputs from the two active transmitters to the output multiplexer section of the transmit/receive diplexer/output multiplexer assembly.

We have to consider the heat from 100WTWTA, from this point of view 100 WTWTAs are located on the north panel. The energy dissipated on the north panel tends to be concentrated in discrete locations on panel such as below the 100 WTWTA body. In order to distribute this heat uniformly over the panel and prevent "heat spots", heat pipes and thermal radiation fin are used.

Spacecraft antenna pattern studies have developed a coverage pattern as shown in Fig. . This multi-beam pattern provides for a rapid falloff to the westward of Japan and a wider beam to the eastward. To satisfy this requirement, three beam horn and optimum power ratio are selected.

This results in a maximum reduction of 10 dB for the remote islands of Japan. The gain reduction at the extremes of the main land is less than 4.3 dB.

Initial checkout results of the K-band transponder performance are summarized in Table 4.

Conclusion

BSE was successfully launched and K-band (12 GHz) broadcasting experiments are being conducted.

By this time, it was verified that BSE bus equipments and mission equipments had very good performance.

Reference

(1) Yoh Ichikawa., "The Results of Initial Checkup of Japanese Broadcasting Satellite for Experimental Purpose", IEEE Trans.on Broadcasting, EC-24, No.4, December '78.

FIG. 1 ON-ORBIT CONFIGURATION

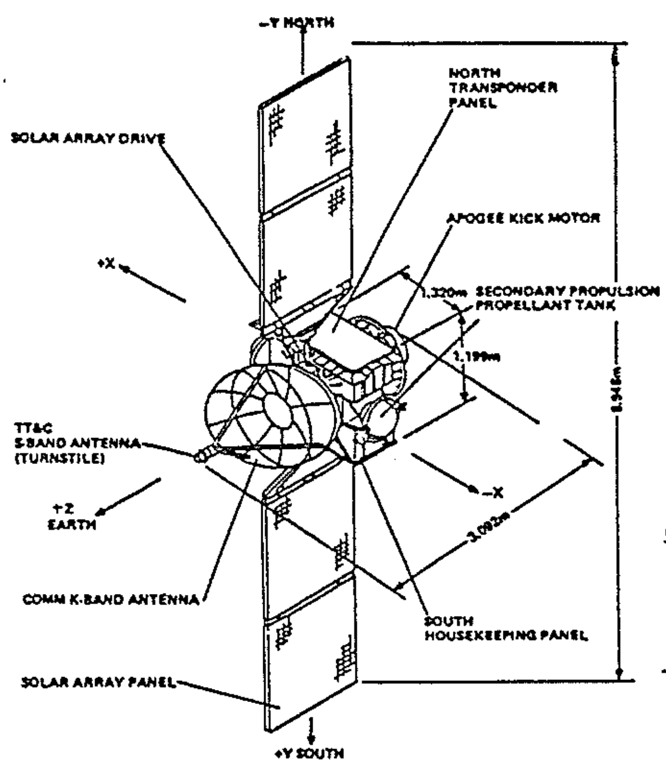

Table 1 BSE System Parameters

Satellite Location	110 East Long
Experimental Coverage	Japanese Territory
Frequency Bands	14.25 - 14.43 GHz 11.95 - 12.13 GHz
NO.of TV Channel	2 CH Color TV
Power Flux Density	Main Land >108 dEW/M² Remote Island >117 dEW/M²
System Life	3 Years
Command & Control	S-Band/K-Band
Electrical Power	1 KW
Weight	678 KG
Orbit Positioning Accuracy	± 0.1 Deg. (E-W) ± 0.1 Deg. (N-S)

Table 2 BSE Typical Sensor Combination

Combination	ROLL	PITCH	YAW
1	ES	ES	MECO
2	ES	ES	SSA
3	MP	MP	MECO
4	MP	MP	SSA

ES= Earth Sensor
MP= Monopulse Sensor
SSA= Sun Sensor Assembly
MECO= MP & ES Combination

Fig.2 ACS compoments by mission phase

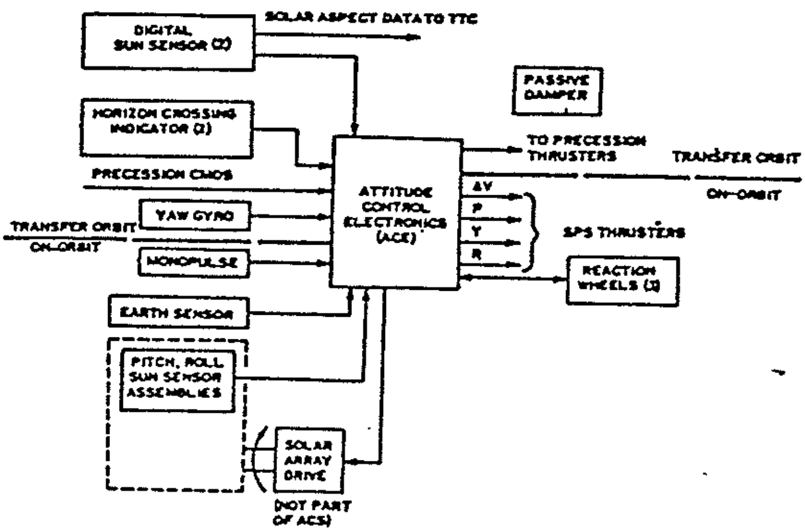

FIG. 3 DISCRETE TIME STATE ESTIMATOR

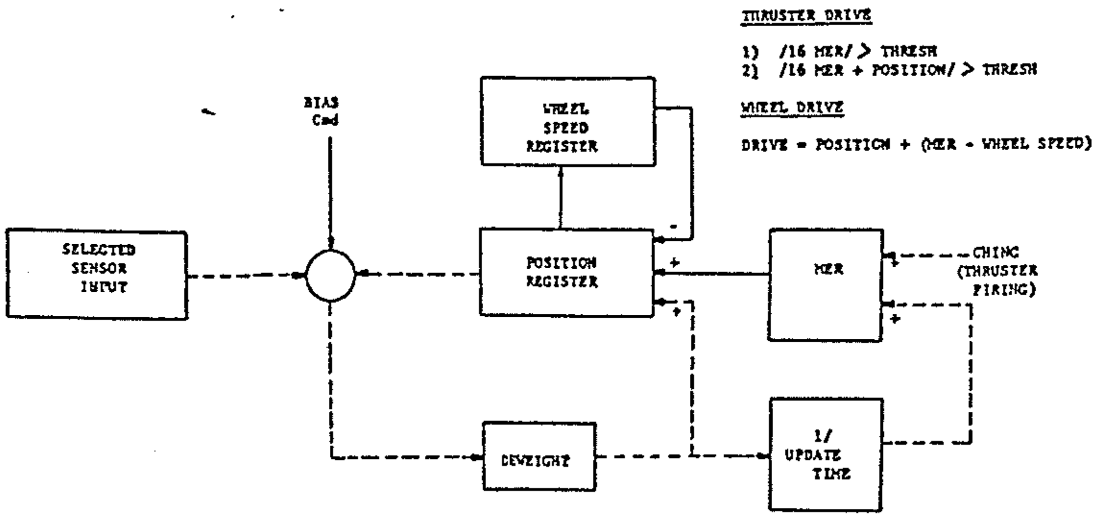

FIG. 4 ANTENNA BEAM ROTATION/POINTING

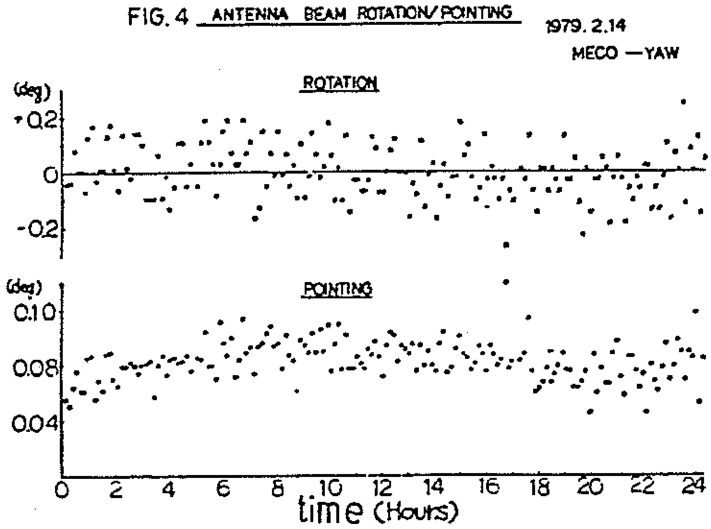

Table 3 Solar Array Design Chracț.

Solar Cell	
Cell Type	N/P Silicon
Size	20 x 40 mm
Resistivity	2 Ω-cm
Coverglass	Fused Silica
Circuit Configuration	
Series Cells	76
Parallel Cells	5
NO.of Panels	4
NO.of Solar Cells	10640
Solar Array Panel Size	
Length	1621 mm
Width	1478 mm
Total Array Panel Area	9.58 m²

FIG. 5 EPS FUNCTIONAL BLOCK DIAGRAM

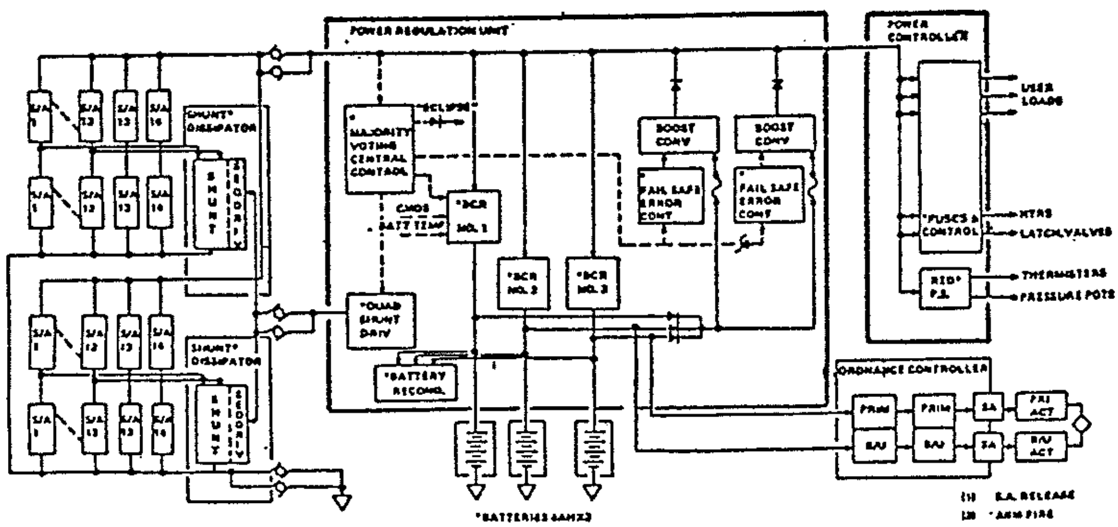

FIG.6 Frequency Arrangement for the TV Transponder

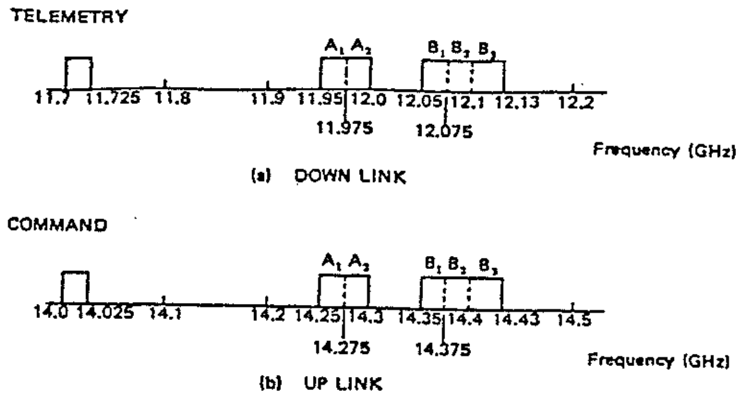

FIG.7 Block Diagram of the TV Transponder

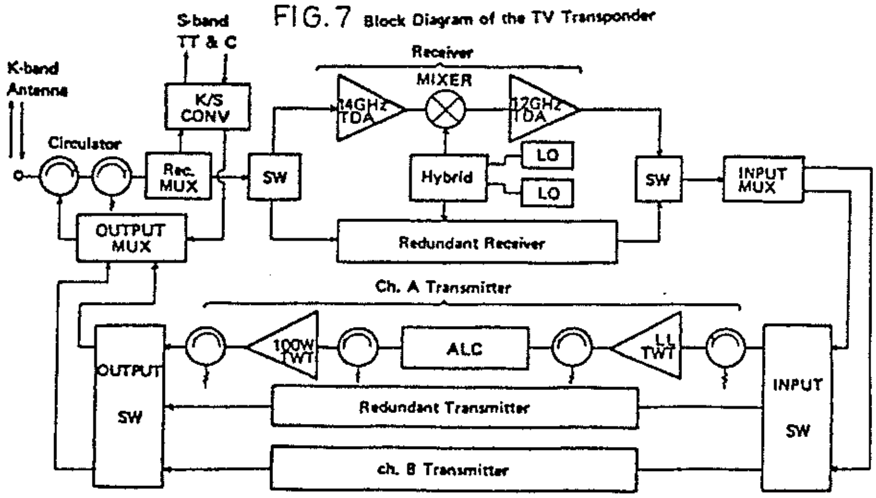

Fig. 8 K-band antenna pattern

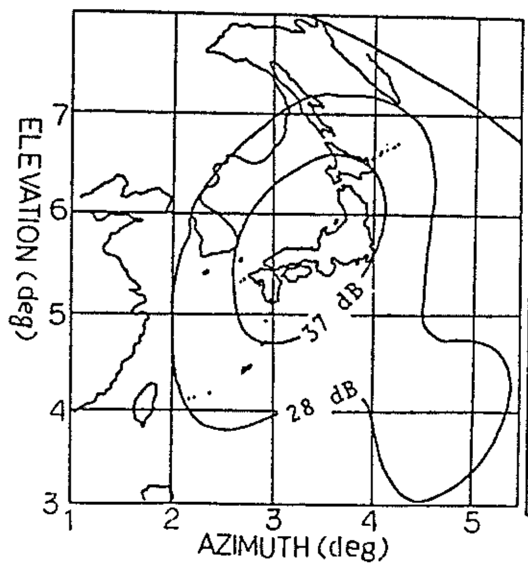

Table 4. K-Band Transponder Initial Checkup Results

Item	Requirements	Results
K-band transponder		
Output power	≥100 W	100.5 - 113.3 W
Output circuit loss	2.3 dB	(-1.9 — 1.6 dB)
Frequency response	for 50 MHz (CH A) within ± 1 dB	within ± 0.5 dB
	for 80 MHz (CH B) within ± 1 dB	within ±0.65 dB
Delay characteristic	for CH A & CH B ≤6 ns	4 ns worst case
Overall noise figure	∠8.0 dB	(6.94 dB)
Spurious	≤ -50 dB	satisfied
Intermodulation	≤ -40 dB	-41.5 — -43.0 dB
Output level variation	≤ ±1.0 dB/day	±0.8 dB/day
Output freq. variation	-≤ $\pm 5 \times 10^{-6}$ /day	4.4×10^{-7}/day
K-band antenna	for Main-Land ≥ 37 dB	≥ 37 dB(estimated)
	for Japan territory ≥ 28 dB	≥ 28 dB(estimated)

( ) : measured on ground