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**Design and Development of the Engineering Model TV Transponder
for the Medium-Scale Broadcasting Satellite for Experimental Purpose**

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Abstract

The results of the Engineering Model TV Transponder development for the Medium-Scale Broadcasting Satellite for Experimental Purpose are described. The transponder is a Ku-band single conversion rebroadcast system. Its required performance has been established through laboratory, temperature and thermal vacuum testing.

1. Introduction

The development program for the Medium-Scale Broadcasting Satellite was initiated by Ministry of Posts and Telecommunications. As a part of this program, the Engineering Model TV Transponder has been developed by Toshiba/General Electric under the guidance of NHK. This paper describes the design and developmental results obtained through assembly and testing of the engineering model.

2. Transponder Configuration

This transponder is a frequency selective, Ku-band single conversion rebroadcast transponder. It provides for simultaneous two channel TV rebroadcasting in two (channel A) and three (channel B) bands; and includes provision for frequency conversion of Ku-band TT&C signals to operate with S band TT&C equipment for support of orbit operations.

Key features of this transponder are:

- (1) Low-complexity of single conversion
- (2) Low noise figure with space-qualified TDA's
- (3) High power, high efficiency TWT's compatible with the spacecraft power system
- (4) High reliability with redundant receivers and transmitters

Waveguide interconnection was used to provide low insertion loss, high power handling capability, and reliability. This resulted in the following:

- (5) Immunity to high power radiation
- (6) High mechanical rigidity.

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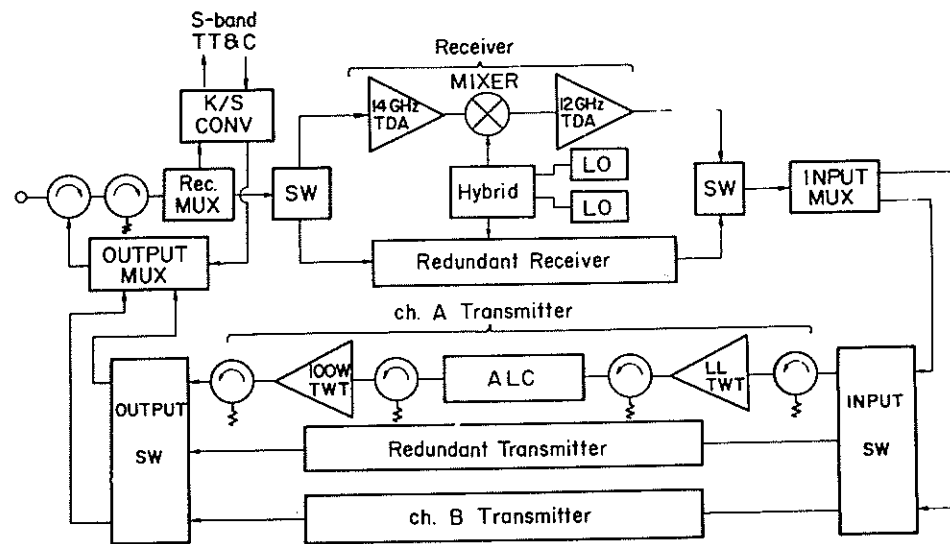


Fig. 1. Block Diagram of the TV Transponder

The functional block diagram of the transponder is shown in Figure 1. The transponder receives low level 14 GHz TV signals at its antenna port via the satellite reflector-type antenna. TV signals in two channels are simultaneously amplified and downconverted to 12 GHz in a single receiver. The TV signals are then separated into the two transmit frequency channels with channelizing filters. Each TV signal is then slaved in amplitude to ground command levels for optimum TWT drive and amplified in the transmitter chain to the specified transmit power of greater than 100 watts. Output signals are recombined with a multiplexing filter for retransmission to the ground. Receive and transmit signals are diplexed onto the single antenna port by means of a diplexing circulator in the TR diplexer/multiplexer assembly.

During the engineering model phase of development a single string receiver and transmitter chain was built and tested. Figure 2 shows the assembled engineering model transponder.

3. Detailed Description

3.1 TR Diplexer/Output Multiplexer

Waveguide junction circulators provide the TR diplexing. Multiplexing of the two TV channel outputs and the TT&C signals is performed with directional filters which consist of high-Q circular TE_{111} cavities. An unloaded-Q of 8000 has been achieved with optimally chosen cavity size and careful surface finish.

3.2 Receiver

TDA's in front of and after the broadband mixer amplify the received signals. The typical noise figure of the TDA's is 5.0 dB and the receivers survive overdrive of +10 dBm.

3.3 Transmitter

Each transmitter includes a low-level TWT and final high-power TWT. The overall transmitter gain is greater than 95 dB with the

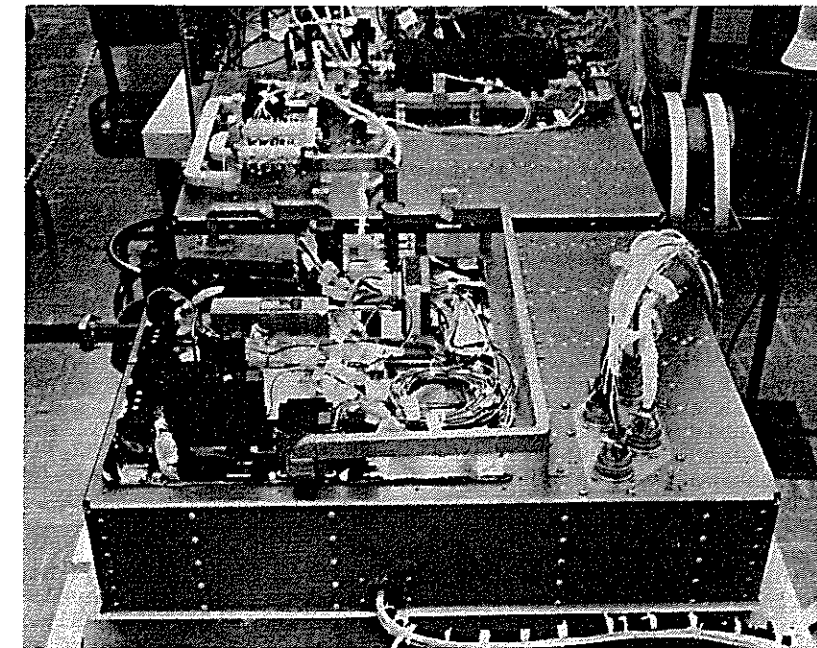


Fig. 2. Engineering Model TV Transponder

high power TWT saturated. Dedicated circuits using PIN diodes control and level the drive power into the final TWT's over the full 14 dB range of received signal strength. The final TWT's (developed by NHK) are high-power (115W typical), high-efficiency (50% typical) TWT's.

3.4 Redundancy

Full redundancy is provided for the receiver chain including independent redundant local oscillators. One for two redundancy is provided for the transmitters. The redundant transmitter may be selected for either channel with ferrite latching circulators--integrated with several junctions to each package. The latching ferrite devices are unpowered except during switching operations.

3.5 Telemetry and Command

Operation of the transponder is controlled by ground command. A sufficient number of telemetry points are allocated to monitor the channelized received power, output power, and other parameters required to allow complete performance assessment including evaluation of off-nominal conditions.

3.6 Thermal Design

The transponder mounting panel includes integral heat pipes to distribute localized thermal dissipation. This panel is located such that its outer surface forms a primary spacecraft thermal radiating surface.

4. Overall Performances

4.1 General

The overall noise figure of the transponder is less than 7 dB. Output power is high enough for good system operation. Transmit amplitude flatness is better than ± 1 dB over each of channels A and B shown in Figure 3. Group delay ripple is less than 6 nsec p-p. Overall performance of the transponder is summarized in Table 1.

This performance has been verified through laboratory bench, temperature and thermal vacuum testing.

4.2 Intermodulation (IM)

Third order IM products originating from the TDA's and high power TWT's were fully investigated under various input levels. TDA's amplify two channels of received signals simultaneously. The TWT's amplify channelized signals separately under saturated conditions where ferrite channel isolation results in low level IM products. The final stages of both 12 and 14 GHz TDA's are designed as

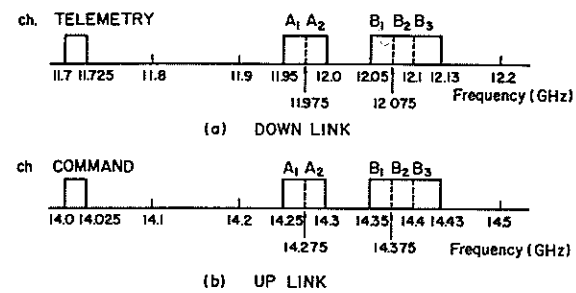


Fig. 3. Frequency Arrangement for the TV Transponder

Table 1. Performances of the TV Transponder EM

VSWR	< 1.16
NOISE FIGURE	6.4 ~ 7.3 dB
GAIN CONTROL RANGE	> 20 dB
TWT OUTPUT	> 100 W/ch.
OUTPUT CIRCUIT LOSS	< 2.0 dB
FREQUENCY RESPONSE *	< ± 0.7 dB
GROUP DELAY RIPPLE	2.9 nsec pp (ch.A) 4.1 nsec pp (ch.B)
SPURIOUS SIGNAL SUPPRESSION **	> 50 dB
THERMAL PANEL ΔT	< 5°C
POWER CONSUMPTION ***	< 610 W

* for ch.A or ch.B

** Except simultaneous operation at Ch. A₂ and B₁

*** Extrapolated for two channel operation

hybrid-coupled parallel amplifiers to reduce the IM products by 6 dB. Transmit channel isolation is provided by the channelizing filters and an arrangement of isolators to minimize the TWT-generated IM products.

With these design features, more than 50 dB suppression of IM products has been obtained for normal operating conditions of the transponder.

5. Conclusions

Development of the Engineering Model TV Transponder for the Medium-Scale Broadcasting Satellite for Experimental Purpose has been completed successfully. The feasibility of the transponder design has been demonstrated. A prototype model is presently under development.

Reference

1. S. Hayashi et al: System Design Consideration for the Broadcast Satellite, Proc. of the 10th ISTS, 1973, pp. 1091-1100.