Contents

12—RCA Satcom 3-Axis Spacecraft Experience at Geosynchronous Altitude

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Abstract

The RCA Satcom space segment presently consists of two three-axis stabilized communication satellites which have been in orbit at geosynchronous altitudes for 11 and 8 months respectively. Both satellites have experienced two eclipse seasons since the beginning of operations. Neither spacecraft hail exhibited any anomalous behavior that can be attributed to the effects of spacecraft charging. A brief discussion of the history, spacecraft characteristics and design techntques is presented.

I. HISTORY

The RCA Satcom communication satellites are owned and operated by RCA American Communications, Ihc. Under a fixed-prtce contract RCA Astro-Electronics Division developed and delivered the first flight spacecraft within

24 months. On 12 December 1975 the F-1 satellite was launched and on 15 December 1975, the apogee motor placed the satellite in its synchronous arbit. The spacecraft achieved synchronous altitude at 137° W. long. and then was commanded to drift at a 1.25° pbr day ta its position at 119° W. long. During this drift period and the time at station through commencement of commercial service on 28 February 1976, the payload support subsystems and transponder payload had successfully undergone extensive preoperational calibration and testing

On 26 March 1976, the second spacecraft was launched and also placed at 119° W. long. After verifying satisfactory performance of all payload support subsystems and that the antenna coverage patterns and the radiated power met the requirements for CONUS and Alaska, traffic was switched from F-1 to commence F-2 service bn 2 June 1976. The F-1 was commanded to drift at a 0.3° per day on June 11 to a newly assigned location at 135.80 W. as an in-orbit spare. Since the first week of August 1976, the satellites have been maintained at 135.8° W. and 119° W. for F-1 and F-2 respectively.

Before, during. and after these maneuvers all subsystems are monitored via telemetry on a continuous basis by dither or both RCA Satcom Telemetry, Tracking and Control facilities located on the East and West coasts.

2. SPACECRAFT CHARACTERISTICS

The orbital configuration of the spacecraft is shown in Figure 1. It features a three-axis stabilization system, with a fixed eondeploying antenna platform pointing to earth, and efficient power collection Via sua-oriented, flat-panel solar arrays. Housekeeping and communications equipments are mounted on North and South-facing equipment panels which are always oriented to cold space, thereby affording efficient thermal cbntrol. Earth pointing is accomplished via a bias momentum-type contrdl system which provides pitch control via a momentum wheel and magnetic torquing for yaw and roll control. The spacecraft is maintained on station via a blowdown monopropellant hydrazine reaction control system. Capability is provided for East/West and North/South drift corrections for 8 years, and €or station relocation as required.

The antenna assembly directs all 24 channels to Alaska, as well as to the lower 48 states. Hawaii can be serviced with up to 12 channels by separate offset-fed spot beams.

Frequency reuse in the 4/6 GHz bands is employed id order to establish 24 independent 34 MHz bandwidth channels within the allocated 500 MHz frequency band.

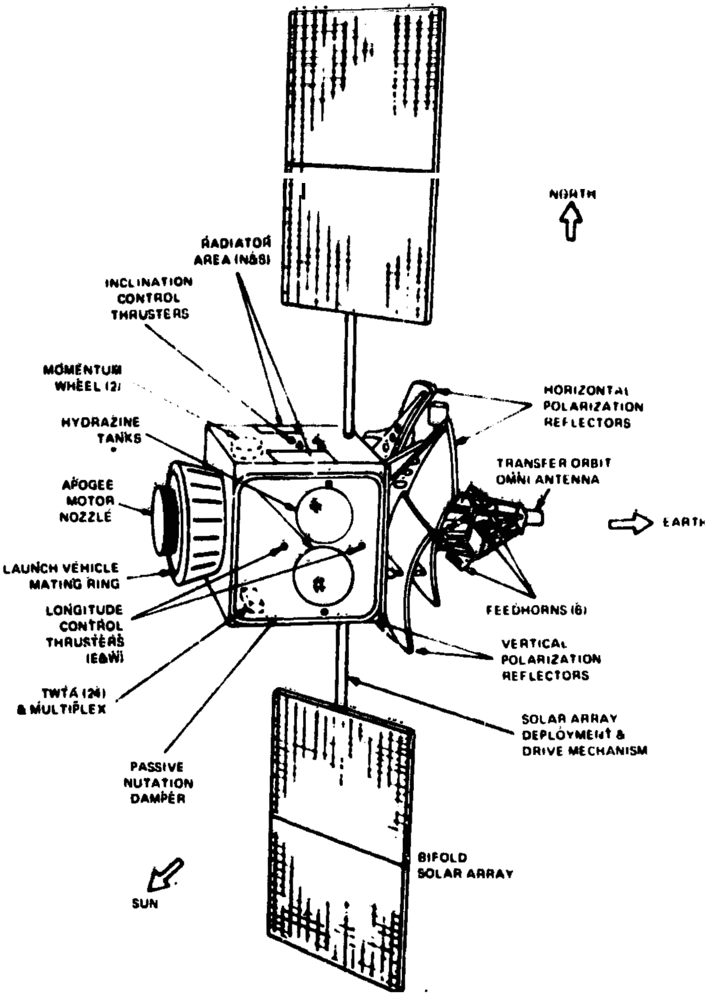

Figure 1. Orbital Configuration of the Spacecraft

The channels art? spaced on 20 MHz cehters, but are tran smitted via alter-nately horizontal add Vertical polarizations in order to isolate a 'jacent chahnels. A summary of the spacecraft performance features is given id Taule 1.

Four of the unique RCA Satcom developments which have been instrumental in achieving a 24-channel service within the weight and volume capactty of the Delta 3914 lauhch vehicle ate listed below. These developments are the keys to providing an economical high-capacity spacecraft compatible wtth low-cost Thor Delta launches.

Table 1. RCA Satcom Performance Features

Element	
Communications	
24 34-MHz channels to Conus and Alaska	Minimum EIRP 32 dBW
12 34-MHz channels to Hawaii	Minimum EIRP 26 dBW
Cross polarization isolation	Receive 33 dB Transmit 33 dB
Frequency bands	Receive 5925 to 6425 MHz Transmit 3700 to 4200 MHz
Power	550 W at end of 8 years full eclipse capability
Attitude	Pointing: ±0.19° E/W, ±0.21° N/S Stationkeeping: ±0.26° E/W. N/S Offset Pointing: 0° to ±5°
Telemetry	128 channels for operational and diagnostic information
Reliability	R = 0.5 at 17 channels for 8 years Full subsystem redundancy

(1) The Lightweight composite construction of the fixed antenna and feed assembly, which maintains accurate antenna beam alignment and requires no mechanical deployment.

(2) Microwave filters of lightweight graphite fibre epoxy composite (GFEC), which provides sufficient weight saving to make the spacecraft cotnpatible with the Delta launch vehicle.

(3) The three-axis atabilizatioh system, which provides the maximum power-to-weight ratio for spacecraft that could operate in the specified payload-power regime.

(4) High-efficiency, direct-energy-transfer power system developed for RCA Satcom and utilizing one-third of the equivalent solar cells of dual spin spacecraft minimizes the weight of the electrical power generation ahd regulation suhsystem, while maximizing efficiency.

3. SPACECRAFT CHARGING APPROACH

RCA Astro-Electronics Divison performed an in-depth study on the possibility of adverse effects on spacecraft operation at geosynchronous altitudes because of spacecraft charging as a result of the paper by Fredericks and Kendall.[1] Our understanding of the problem was furthered by discussions with Mr. R.W. Ellison of the Martin Marietta Company, Dr. D.A. McPherson of the Aerospace Corporation, and Dr. A. Rosen and Dr. G.T. Inouye of the TRW Systems Group.

The RCA Satcom spacecraft design was reexamined in light of the design practices recommended in the literature of minimize the possibilities of discharges and their effects.[1,2] The three areas that were given highest priorities were the structural design, thermal blankets and electronic interface circuitry, bearing in mtnd that any design changes made to the spacecraft had to be in consonance with the weight constraints posed by the launch of the 24 channel spacecraft on a Delta 3914. Testing was considered but not planned because of the inability to identify valid criteria of acceptability.

4. SPACECRAFT DESIGN TECHNIQUES

The principal design features incorporated into the RCA Satcom spacecraft to minimize its vulnerability to the effects of spacecraft charges are as follows

(1) The entire spacecraft is a closed body except for the apertures required for the horizon sensor, the solar array drive, and the apogee motor.

(2) Every section of the thermal blanket is grounded in two places.

(3) The outerlayer of the thermal blanket is kapton

(4) The mechanical structure, including the wrappers of all boxes, has electrical continuity.

(5) The harness wiring contains shielded twisted pairs, coaxial and triaxial cables far selected interfaces and is functionally grouped into separate bundles.

(6) The electronic interface cifcuits were designed to have high noise immunity.

5. STRUCTURAL

The almost complete closure of the spacecraft minimized the possibilities of internal differential charglng. All units on the clpacecraft have their cases grounded to the structure via electrically conductive mounting surfaces. In addition, special mounting inserts that cut ahd wedge into the honeycomb to provide goad electrical continuity were used fof all unit mountings. All structural members were designed so that electrical continuity between all sections of the spacecraft and all unit wrappers was obtained. The solar array panels were designed so that each structural section was connected together and grounded to the main spacecraft structure via the slip rihgs of the solar array drive.

6. THERMAL

Kapton was selected as the outer layer of the multilayer thermal blanket because of the improvement of its conductivity when stressed and illuminated by sunlight. In addition, each aluminized layer of the multilayer thermal blanket was grounded in two places to the main spacecraft structure. The harness from the solar array to the spacecraft is covered along the booms and in the hinge areas. The use of conductively coated solar cell cover glass or second surface mirrors was considered but rejected because of the weight penalty and its unknown radiation effects.

7. ELECTRONIC

The RCA Satcom spacecraft was initially designed with good EMC practices fbrembst in mind, with attention given to wire selection and routing in the internal harnessing. The! spacecraft harness is grouped and bundled by functioh: pbwer and power returns, signal lines arid returns. arid telemetry lines and returns. A single point ground system has been used throughout the spacecraft, with tne exception of communications equipment.

COSMOS devices were selected for the command ihterface circuitry because of their high noise immunity and relatively law useful bandwidths. Shielded twisted pairs arid coaxial cables were Used to further reduce noise sensitivity for selected interfaces. Triaxial cables werh used for clack frequencies above 100 KHz.

8. CONCLUSIONS

The performance characteristics for the communications payload and support subsystems have been analyzed and is cohtinually being monitored for evidence of anomalous behavior. Gain changes, equipment switching or other unexplained causes as experienced by other satellites at geosynchronous altitude have not been observed to date. Consequently, ria changes to the design of the RCA Satcom series of spacecraft is envisioned at this time.

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