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30/20 GHz Experimental Communications Satellite System

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30/20 GHz EXPERIMENTAL COMMUNICATIONS SATELLITE SYSTEM

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Abstract

NASA is continuing to pursue an agressive satellite communications technology development program focused on the 30/20 GHz frequency band. A review of the program progress to date is presented in the paper. Included is a discussion of the technology program status as well as a description of the experimental system concept under study. Expected system performance characteristics together with spacecraft and payload configuration details including weight and power budget is presented. Overall program schedules of both the technology development and the flight system development are included.

Introduction

NASA has reentered the arena of communications R&D. Following the program phasedown in 1973, the decision by NASA to significantly decrease its activities in R&D related to communications satellites was reviewed by many. The consensus of opinion concluded that major advances in the technology require the intervention of Government, particularly in the areas where high technical risk is involved. As a result, NASA in 1978 began the process of rebuilding its R&D activities in the satellite arena. The planning and rebuilding process was done in concert with both the system supplier industry as well as the communications service (carrier) industry. What has evolved is a broad technology development program focused on both generic technology as well as technology particularly associated with the next allocated frequency band, 30/20 GHz. The near-term technology focus pertains to 30/20 GHz systems and is the subject of this paper. NASA is currently investigating the merits and characteristics of an experimental flight system which incorporates the technology suitable for operational system applications in a form capable of being scaled from the experimental system to a commercial system in a cost-competitive manner. The experimental system requirements allow verification of component technology as well as complete system functional technology. A two-year period of experimentation is planned following launch involving both the public and private sectors as experimenters. Attainment of the program goals will provide advanced technology for increased satellite communications capabilities; will verify technical and economic feasibility of innovations for 30/20 GHz band as well as existing bands; provide reduced technical risk in the implementation of the advanced technology while assisting U.S. industry in competing in the communications satellite market with foreign sources. The program is structured to establish a good Government/industry working relationship and provide for intensive interaction within the industry to enable technology transfer to occur smoothly and efficiently. This will contribute to maintaining the U.S. technological lead in this arena.

Technology Program

The 30/20 GHz technology development program was initiated in 1980 and will continue through the development of proof-of-concept models until 1983. The objective of this focused program is to provide, through feasibility testing, the critical technology needed for advanced 30/20 GHz operational systems. The development effort is aimed at reducing the technical cost and schedule risk of the experimental flight system. All of the candidate technologies are currently under contract development with multiple awards for all critical elements except the traveling wave tube amplifier and the baseband processor. The elements included are shown in Fig. 1. To enable the effective transfer of information generated in this program all contractors are required to prepare task completion reports during the development process. These reports, as well as status reviews of each contract effort, are distributed at periodic industry briefings hosted by NASA for all interested parties. During industry briefing sessions dialogue is encouraged to aid in the transfer of information.

Experimental Flight System Concept

As a result of both in-house studies as well as contracted studies with the commercial satellite system suppliers (Ford Aerospace, General Electric, Hughes Aircraft, RCA Astro and TRW), an experiment flight system concept evolved which satisfies the major goals of the program. The communications payload incorporates significant technology advances in multibeam antennas and on-board matrix switching to facilitate interconnect among "trunking beams" on the satellite. The concept also includes two scanning beams to permit "Customer Premise Service" experiments and provides interconnection within the system with a baseband processor on the spacecraft. Low noise 30 GHz receivers and both solid state and traveling wave tube amplifiers are also included. With the focus on the technology of the communications payload, it is expected that existing spacecraft buses will be used to minimize development costs. The system concept also includes trunking diversity terminals, customer premise terminals and a master control station which provides mission, experiment and network operations. A schematic of the communications payload is shown in Fig. 2. An overall Flight/Ground System schematic is shown in Fig. 3 and Master Control Station Functions in Fig. 4.

The coverage provided by the experimental system is shown in Fig. 5. For the trunking system six spot beam (0.4 degrees) locations are provided covering New York, Washington, D. C., Cleveland and Los Angeles, with alternate sites in Houston and Tampa. Four beams can be active simultaneously with full interconnectivity among beams through the on-board matrix switch. Scanning beam coverage is confined to the eastern portion of the country plus selected sights in the west in order to evaluate the off-axis scan of the antenna system. Operational systems would provide many more spot beams as well as scanning beam coverage of the country.

Experimental System Requirements

The requirements that are common for both the Trunking System and the Customer Premise System pertain primarily to the multibeam antenna system. A spacecraft antenna system of three meters in diameter is required for the 20 GHz downlink spot beams. The use of the same antenna for the uplink or a separate two meter antenna for uplink is permitted. Low sidelobe levels are required to achieve maximum frequency reuse. The beam forming networks for both fixed and scanning beams are integrated into a common feed array.

The trunking system requirements for the spacecraft are shown in Fig. 6. Six fixed beams are required with four beams active at one time. The frequency reuse must be at least three. Maximum amplifier rf output power is 40 watts. The G/T of the system is 22 dB -°K. The burst rate on the uplink and the downlink is 256 MBPS. The implementation is Satellite Switched Time Division Multiple Access (SS-TDMA) through the IF switch matrix.

The corresponding trunking ground terminal requirements are shown in Fig. 7. A diversity site system is used with a spacing between sites of 12 kilometers. Antenna diameters of five meters are used with 400 watt uplink amplifiers. The overall G/T is 28 dB - °K. The combination spacecraft and ground terminal power systems provide 18 dB margin on the uplink and 8 dB on the downlink.

The spacecraft Customer Premise System requirements shown in Fig. 8 includes two scanning beams using separate polarizations to allow a frequency reuse of two. Interconnection is through the on-board baseband processor using a TDMA architecture. Like trunking, the amplifier maximum power is 40 watts and the G/T is 22 dB - °K. The throughput per beam is 128 MBPS with either four 32 MBPS channels per beam or one 128 MBPS channel on the uplink. The downlink rate is 256 MBPS. The mismatch between uplink and downlink is intentional with the 256 MBPS on the downlink selected to exercise the baseband processor.

An estimate of the communications payload weight and power requirements are shown in Fig. 9. The number of major components are indicated as well as the active components. The antenna system is the dominant weight element while the transmitter and baseband processor consume the greatest amount of power. The payload weight of about 190 kilograms (411 pounds) and 700 watts will require a launch vehicle capability in the SUS-D or SUS-A class in the Shuttle.

There are two classes of Customer Premise System earth terminals (see Fig. 10). A three meter system for the 32 MBPS throughput uses a 25 watt high power amplifier and provides a G/T of 24 dB - °K. The 128 MBPS system uses a five meter terminal with a 50 watt high power amplifier and provides a G/T of 28 dB - °K. Rain attenuation allowance required is 15 dB on the uplink and 6 dB on the downlink and will be provided by a combination of power margin and Forward Error Correction in the baseband processor.

The synchronization and control requirements are shown in Fig. 11. Closed loop synchronization is used with a timing accuracy of ±60 NS. Network control is through an order wire system. Trunking access requires manual setup for subframes times and switch matrix configuration. For the scanning beam system, manual setup is used for scan sequence and beam dwell time.

A typical three axis stabilized spacecraft is shown in Fig. 12 and a spinner in Fig. 13. A typical trunking terminal is shown in Fig. 14 and a Customer Premise System terminal in Fig. 15.

Experimental System Development

The planned program would initiate experimental flight system development in 1983 with a launch planned for 1987. A two-year experimental period would follow launch with an additional two years of experiments capability designed into the spacecraft system. Experimenters would be solicited through the issuance of an Announcement of Opportunity. Spacecraft time would be provided free of charge to qualified experimenters; however, ground terminals and experiment operations would be the responsibility of the experimenter as well as the preparation of reports on the experiment results. It is expected that this program would provide the necessary verification of the readiness of the critical technology elements in flight and ground systems as well as the system functional operation as it might pertain to operational service, thus enabling cost effective and spectrum conservative use of the 30/20 GHz band.

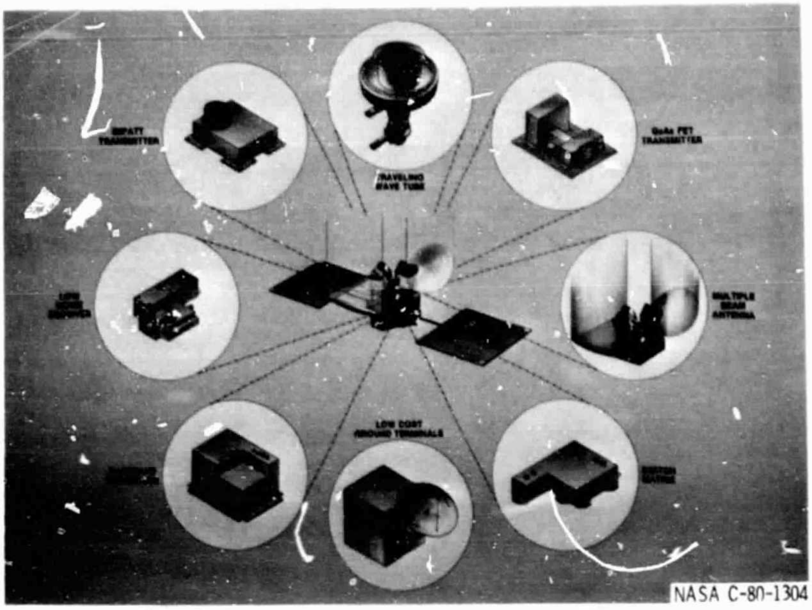

Figure 1. - 30/20 GHz communications project; technology development elements.

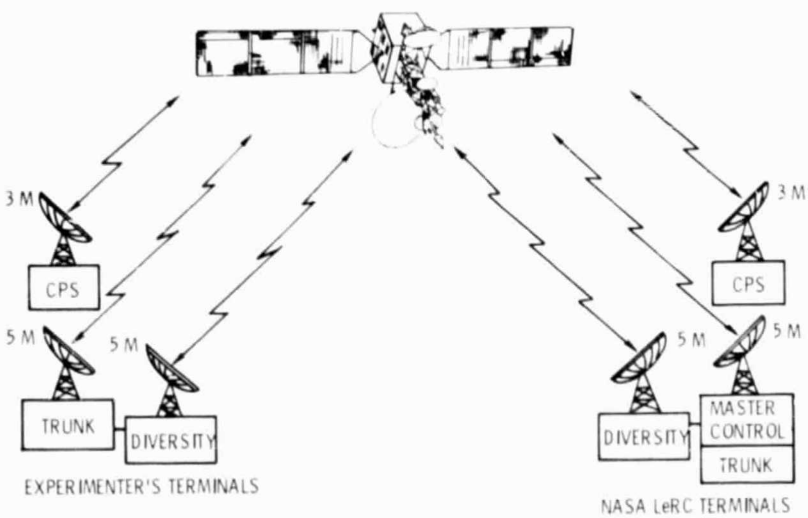

Figure 2. - Flight system schematic.

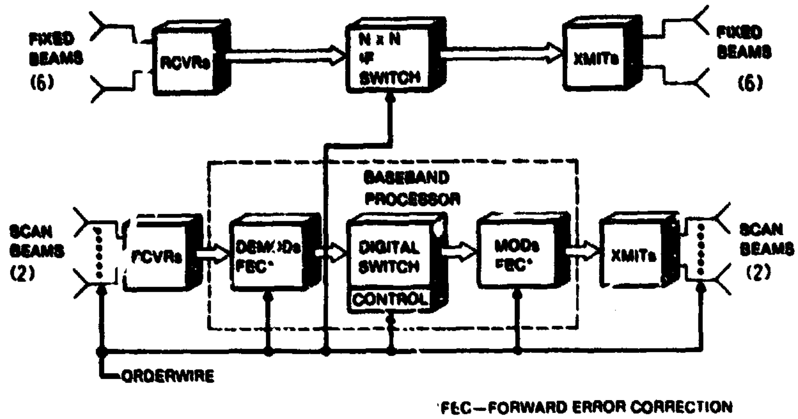

Figure 3. - Communications payload for flight system.

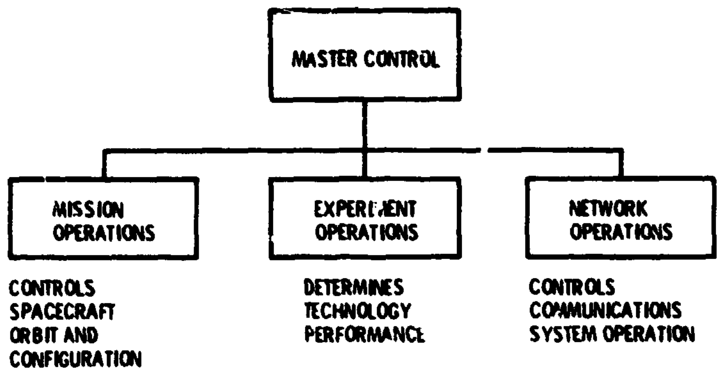

Figure 4. - Master control station functions.

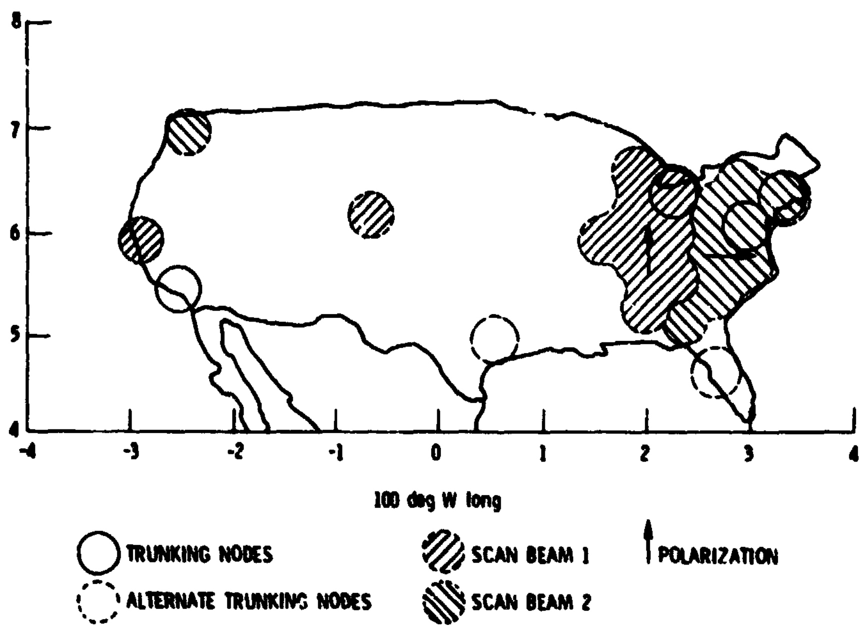

Figure 5. - Typical flight system coverage.

- SIX (6) FIXED BEAMS
- MINIMUM OF FOUR (4) ACTIVE FIXED BEAMS
  - FREQUENCY REUSE = 3
  - HPA = 40 WATTS
  - G/T = 22 db - °K
  - BURST RATE - 256 MBPS
- SS-TDMA WITH IF SWITCH MATRIX TECHNOLOGY EXPANDABLE TO 20 x 20

Figure 6. - Spacecraft trunking requirements.

- ANTENNA DIA = 5 METERS
- HPA = 400 WATTS
- G/T = 28 db - °K
- SPATIAL DIVERSITY (≥ 12 KM SPACING)
- CARRIER INTERFACE
- RAIN ATTENUATION ALLOWANCE: 18 db UPLINK/8 db DOWNLINK

Figure 7. - Trunking earth terminal requirements.

- SCANNING BEAM/BASEBAND PROCESSOR TDMA ARCHITECTURE
- TWO (2) SCANNING BEAMS
  - FREQUENCY REUSE = 2
  - HPA = 40 WATTS
  - G/T = 22 db - °K
  - THROUGHPUT/BEAM - 128 MBPS
  - CHANNELS/BEAM

    UPLINK: 4 - 32 MBPS
1 - 128 MBPS

    DOWNLINK: 1 - 256 MBPS

Figure 8. - Spacecraft CPS requirements.

EQUIPMENT	NUMBER	TOTAL WEIGHT (lb)	NUMBER ACTIVE	TOTAL POWER (W)
ANTENNA S/S	1	185	1	40
TWT'S/SSPA'S	6	90	3	337
SSDA'S	2	20	-	-
LOW NOISE RECEIVERS	6	12	4	12
AUTOTRACK	3	9	2	4
TDMA SWITCH	1	6	1	10
BBP	1	50	1	250
UPCONVERTERS	6	12	4	16
FREQ GEN + SDU	1	12	1	31
SWITCHES	25	5		
MISC (W G, ETC)		10		
TOTAL		411 lb		700 W

Figure 9. - Communications payload weight and power.

PARAMETER	32 MBPS STATION	128 MBPS STATION
ANTENNA DIAMETER (METERS)	3	5
HPA (WATTS)	25	50
G/T (db - °K)	24	28

- RAIN ATTENUATION ALLOWANCE 15 db UPLINK AND 6 db DOWNLINK (INCLUDES FEC)
- BASEBAND PROCESSOR TECHNOLOGY SCALEABLE TC GIGA-BIT SYSTEMS

Figure 10. - CPS earth terminal requirements.

- TIME ACCURACY - ±60 NS
- CLOSED LOOP SYNCHRONIZATION
- ORDER WIRE NETWORK CONTROL
- TRUNKING ACCESS
  - MANUAL SET-UP FOR SUBFRAME TIMES AND SWITCH MATRIX CONFIGURATION
- CPS ACCESS
  - MANUAL SET-UP FOR BEAM SCAN SEQUENCE AND BEAM DWELL TIME

Figure 11. - Synchronization and control requirements.

Figure 12. - Typical three axis stabilized flight spacecraft.

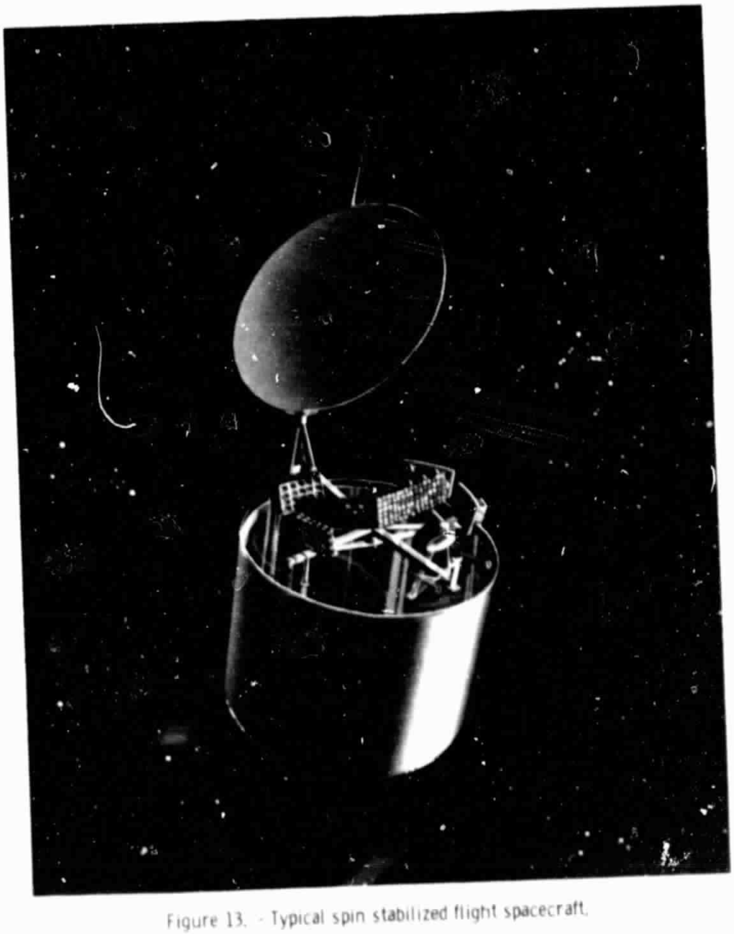

Figure 13. - Typical spin stabilized flight spacecraft.

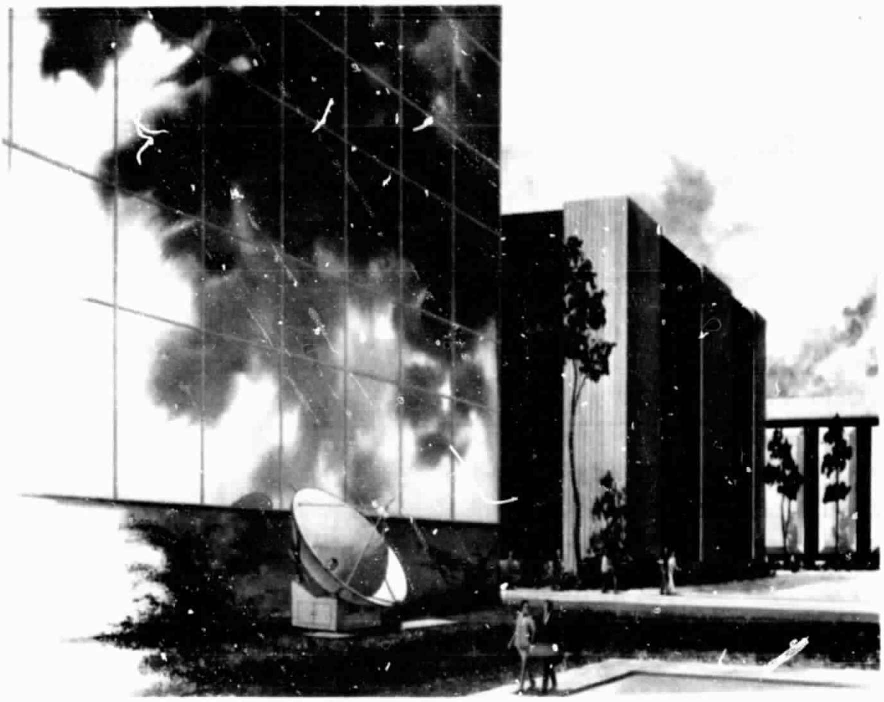

Figure 14. - Typical trunking terminal.

Figure 15. - Typical CPS terminal.