COMMUNICATIONS TECHNOLOGY SATELLITE SYSTEMS, SPACE AND GROUND SEGMENTS

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Abstract

The CTS project is a joint effort between the Communications Research Centre in Canada and the National Aeronautics and Space Administration in the United States with both nations equally sharing available spacecraft communication time. The CTS spacecraft is in synchronous orbit at 116° west longitude. General spacecraft operational characteristics are discussed with particular emphasis on communication system parameters. The associated Canadian and United States user ground terminals are reviewed with particular emphasis on wideband communications.

I. Introduction

The Communications Technology Satellite (CTS) is a joint experimental program of Canada's Department of Communications (DOC) and the United States National Aeronautics and Space Administration (NASA) to explore the application of advanced technology to satellite communications.(1) The satellite was launched on January 17, 1976 and is now being controlled from Ottawa by DOC.

There are three main technology experiments associated with the spacecraft (s/c). These include:

(a) The demonstration and flight testing of a traveling wave tube (TWT) with a power output of 200 watts and an efficiency of 50%.

(b) Flight evaluation of lightweight, flexible, extendable solar arrays with an initial total output power greater than 1.2 kilowatts.

(c) Flight evaluation of a 3-axis stabilization system on a s/c with flexible appendages.

During the two year design lifetime of the satellite, the communication time available (excepting that required for spacecraft technology experiments) will be divided equally between the United States and Canada for user communication experiments.

In Canada DOC is providing ground terminals to experimenters; this includes Federal and provincial government agencies, universities, and other groups. In the United States each experimenter (user) is responsible for providing the necessary communication ground terminals.

This paper presents information on the general s/c operational characteristics with particular emphasis on the communication system parameters. Also, the associated Canadian and United States user ground terminals are discussed with particular emphasis on wideband communications.

II. Text

CTS Spacecraft Characteristics

A drawing of CTS as it will appear in orbit is shown in Fig. 1. The s/c is greater than 17 meters long with the solar arrays extended. The two communication antennas marked SHF (super high frequency) gimballed antennas in Fig. 1 point towards the earth. Each antenna boresight is aimed at the desired location on the earth by slewing the parabolic antenna reflector about the roll and pitch axes of the s/c. Both communication antennas have only one feed horn each which is used to transmit and receive linearly polarized orthogonal signals. Each feed horn is fixed to the main body of the s/c and does not move as the antenna reflectors are slewed. The beacon antenna is also mounted to the main s/c body. It is a circular waveguide horn that transmits a right-hand circularly polarized signal to the entire area of the earth that is in view from the s/c.

A summary of the most important characteristics of CTS is given in Table I. The s/c was launched on a Thor Delta model 2914 vehicle from the Eastern Test Range and the s/c is now in a stationary orbit at 116° west longitude. The on orbit power available from the deployed solar arrays is greater than 1.2 kilowatts and should be just less than 1.0 kilowatt after two years.

The s/c attitude control pointing accuracy is $\pm$ 0.1° in pitch and roll which is one of the limiting factors on the communication antenna pointing accuracy. The s/c will be east-west station kept within $\pm$ 0.2°; however, because of weight constraints there is no propellent available for north-south station keeping and thus all ground terminals with narrow antenna beams (such as video receive stations) require antennas that can move both in azimuth and elevation. This significantly increases the cost of the wideband user terminals.

The s/c communication frequencies are 12 and 14 gigahertz for the downlink and uplink respectively. All communication signals are received and transmitted by the two parabolic SHF gimballed antennas as indicated in Fig. 2 which are 0.7 meter (28 in.) in diameter and have a nominal gain of 37 db. The total pointing error for either antenna is $\leq \pm$ 0.25°. It should be pointed out that either antenna can receive and transmit signals; however, the communication transponder is so configured that a signal received on one antenna must be transmitted by the other antenna. The transponder has two 85 megahertz bands(2) with one transponder band having a nominal output power of 200 watts and the second one 20 watts.

The frequency plan for the two transponder bands is given in Fig. 3. Also, a 200 milliwatt beacon signal is provided at a frequency of 11.7 gigahertz. However, this signal is not easily received by low cost terminals because of the low beacon power and low beacon horn gain.

The CTS communication antennas have a nominal 3 db beamwidth of 2.5°. A typical 3 db contour for a 2.5° beamwidth is shown for Alaska in Fig. 4(a). The contour for a 2.0° beamwidth is also shown. The upper left edge of the contour is determined by the 5° elevation angle line which is the location on the ground where the angle between the incoming s/c signal and the horizon is 5°. In general for elevation angles less than 5° the communication reliability may be less than desirable due to multipath effects and intervening obstacles. Three typical 3 db downlink contours for the lower 48 states are shown in Fig. 4(b) where each contour basically covers one time zone. However, at any given time only one downlink contour can be associated with the 200 watt channel and one with the 20 watt channel.

Canadian Experimenter Terminals

A summary of the important characteristics of the Canadian communication ground terminals is given in Table I. DOC will make available the following number of these terminals to be shared among experimenters:

(1) Three large terminals consisting of: Two - 3 meter transportable ground terminals and One - 9 meter Ottawa ground terminal.

(2) Sixteen small terminals consisting of: Eight - 2 meter ground terminals and Eight - 1 meter ground terminals.

The 9-meter Ottawa terminal is the largest of the terminals and is the only one which cannot be moved. The terminal is capable of providing transmission and reception of television, sound program and digital data of various rates, as well as serving as the network control for the telephony system.

The two 3-meter terminals are transportable terminals in the form of trailers and contain essentially identical communications equipment to that of the 9-meter terminal. Since they are quite readily transportable, they make available from different locations within Canada the same communications capabilities as the 9-meter Ottawa ground terminal.

The 2-meter terminals are transportable terminals primarily designed for reception of television signals relayed from any of the 3-meter or 9-meter terminals through the high power channel of the spacecraft. In addition to receiving television, they are equipped to provide one telephony channel and to transmit and receive one sound program channel.

The 1-meter terminals are small transportable terminals primarily designed for telephony applications. Each will be capable of transmitting or receiving a sound program signal.

United States User Terminals

In the United States each user is responsible for providing all terminal equipment associated with his experiment. A summary of several U.S. terminal characteristics are given in Table II. The majority of U.S. user experiments involve simultaneous two-way TV. The associated ground stations have similar characteristics to the first terminal in Table II. Another important kind of U.S. experiment involves the reception of single channel video by several ground stations and may include the transmission of return audio. These ground stations could have similar characteristics to the third terminal listed in Table II.

NASA will also have available a self-propelled simultaneous two-way TV ground station to provide broadband transmit and receive capability for short term experiments and demonstrations in various parts of the United States. This facility will have sufficient studio capability for a teacher to give a lecture or for a small group to participate in a video teleconference using the CTS s/c.

A typical FM receiver consists of an outdoor mixer down converter and an indoor intermediate frequency (IF) receiver. This receiver could provide either baseband, VHF-AM output, or both and could accommodate one or more audio sub-channels. Also, in conjunction with the outside unit a tunnel diode amplifier (TDA) or paramp would be included to improve the receiver sensitivity. Another possible type of receiver, which uses an image enhanced mixer, is also available and it does not require a preamplifier for TV reception from the s/c using the 200 W band.

A 3-meter (10 ft) parabolic antenna can be used in a TV experiment. The antenna system must have a two-axis limited motion pointing capability to accommodate the N-S and E-W movement of CTS. The antenna system is motor driven and remotely controlled from indoors.

A TV transmitting ground terminal is much more expensive than a TV receive only station because of the dominating cost of the high power amplifier, modulator-upconverter, and beacon receiver.

III. Conclusion

The CTS s/c was successfully launched on January 17, 1976 and is now on station at 116° longitude. The s/c systems have been checked out and extensive on orbit communication performance testing is nearly completed. Both U.S. and Canadian users equipment check out with the s/c has begun.

IV. References

1. Franklin, C.A. and Davison, E.H.: A High-Power Communications Technology Satellite for the 12 and 14 GHZ Bands. AIAA Paper No. 72-580. (The ion engine and liquid metal slip ring experiments listed in this report have since been deleted from the CTS program.)

2. Braun, L.D. and O'Donovan, M.V., December 1974: Characteristics of a Communications Satellite Transponder. Microwave Journal.

TABLE I. - SUMMARY OF CANADIAN SHF TERMINAL CHARACTERISTICS (12-14 GHz)

TERMINAL	PROPERTIES							
	ANTENNA			RECEIVER		SYSTEM G/T, dB/K	TRANSMITTER POWER, W	ANTENNA CONTROL
	DIAM, M	PEAK GAIN, dB 12 GHz	3 dB BEAMWIDTH, DEG	PREAMP	NOISE TEMP, K			
OTTAWA	9	58	0.2	UNCOOLED PARAMP	200	32.8	200	AUTO-TRACK
TRANSPORTABLE	3	49	.5	UNCOOLED PARAMP	200	22.8	1200	STEP-TRACK
TV RECEIVE ONLY & TWO-WAY VOICE	2	47	.7	TDA	670	16.6	20	MANUAL ADJUSTMENT
TWO-WAY VOICE	1	37	1.8	TDA	670	8.2	20	NONTRACKING

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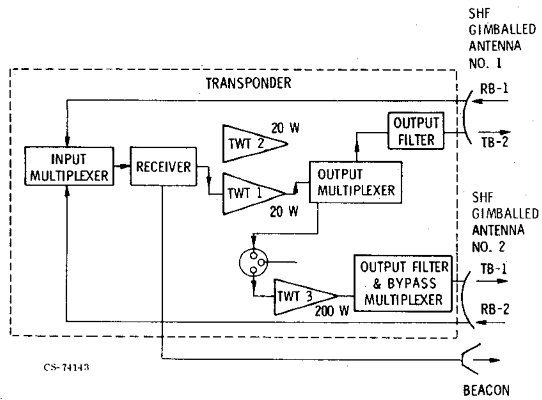

Figure 2. - SHF system configuration for primary operational mode (PM).

TABLE II. - SUMMARY OF SEVERAL U. S. SHF TERMINAL CHARACTERISTICS (12-14 GHz)

TERMINAL	PROPERTIES							
	ANTENNA			RECEIVER		SYSTEM G/T, dB/K	XMITTER POWER, W	ANTENNA CONTROL
	DIAM, M	PEAK GAIN, dB 12 GHz	3 dB BEAMWIDTH, DEG	PREAMP	TOTAL SYSTEM NOISE TEMP, K			
CLEVELAND	5	52	0.4	TDA	800	24	1250	STEP-TRACK
ROSMAN	5	53	.4	UNCOOLED PARAMP	450	26	1250	AUTO-TRACK
TV RECEIVE ONLY TWO-WAY VOICE	3	48	.6	TDA	900	18	500	REMOTE MOTOR DRIVE
TWO-WAY VOICE	1	40	1.5	TDA	900	10	20	MANUAL ADJUSTMENT
TWO-WAY VOICE	1/2	34	3.0	TDA	900	4	20	FIXED
SELF-PROPELLED	2	47	.7	UNCOOLED PARAMP	400	21	500	STEP-TRACK

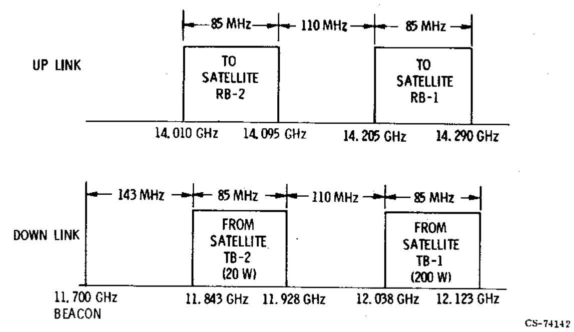

Figure 3. - SHF frequency plan, primary mode (PM).

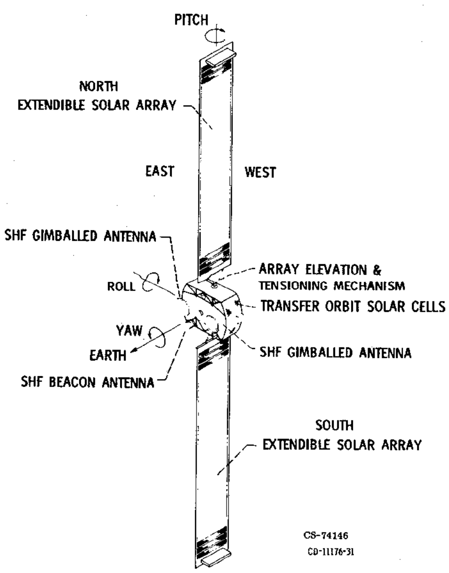

Figure 1. - CTS - on station.

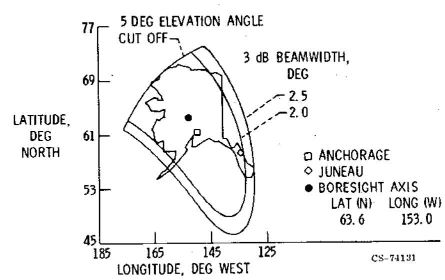

Figure 4(a). - Typical CTS antenna coverage for given boresight axis in Alaska.

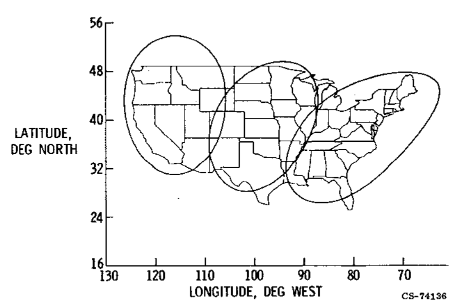

Figure 4(b). - Three typical CTS antenna coverage areas for United States (lower 48 states).