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Telesat Canada Plans for New Satellite Systems

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The Telesat Canada communications satellite system has been in commercial operation since January 1973. Three ANIK A series satellites and one ANIK B satellite have been launched successfully and some 107 earth stations are now in service. Commencing in 1981 a new series of satellites designated ANIK C will be brought into service. This paper will briefly review the considerations which led to these system plans and provide a preliminary overview of the system features and performance objectives of the proposed ANIK C satellite and associated earth stations.

Introduction

THE Telesat Canada domestic communication satellite system commenced commercial operations in January 1973. The ANIK A-1 satellite launched in November 1972 was followed by the ANIK A-2 launched in April 1973. These satellites together with an initial complement of 34 earth stations provided television distribution and telephone message services throughout Canada from coast to coast and to the northern extremities of the country.[1] Although services were provided to the more densely populated areas in the southern parts of the country, the major contribution to telecommunications in Canada was in bringing television and improved telephone services to remote communities in the far north.

Initially, analogue transmission techniques were applied throughtout the system. Later in 1973, single channel per carrier telephone message services utilizing delta-2ϕ phase shift keying (PSK) channel units were introduced and in 1976 a two-access 60 megabits per second (Mbs) Time Division Multiple Access system was brought into service.[2] In May 1975, ANIK A-3 was launched and upon execution of an in-service transfer of traffic from ANIK A-1, it took over the prime operating function of that satellite. In December 1978, ANIK B was launched and in June in 1979 the majority of traffic was transferred to it.

A brief overview of Telesat's plans for its future space segment will follow while subsequent sections of this paper will discuss planning considerations and design and performance objectives for the proposed ANIK C satellite system.

Overview of Telesat Satellite System Plans

Considering the life expectancy of the ANIK A-1 and A-2 satellites and the continuing need for services operating in the 6/4 GHz bands, it was deemed necessary to have a 6/4 GHz spacecraft available for launch in 1978. To meet this need, a contract was awarded in December 1975 for the provision of the ANIK B-1 satellite.[3] This spacecraft included not only a 6/4 GHz communications capability essentially equivalent to the ANIK A series but also a 14/12 GHz communications package. The 14/12 GHz pacakge was undertaken to provide the capability to undertake a number of pilot projects developed from the earlier successful experiments carried out under the Communications Technology Satellite (HERMES)[4] program.

During the planning of the ANIK B satellite system, Telesat could not forecast with assurance the securing of a sufficient portion of the Canadian telecommunications market to justify the major step forward to a high-capacity second generation of satellites which could operate effectively during most of the 1980's. Consequently, the ANIK B program may be considered as providing a means of continuing existing and growth services operating in the 6/4 GHz bands while having provided additional time to better assess the needs of the 1980's and to evaluate the technology available.

Early in 1976, an intensive study was undertaken of the application of communication satellite technology in Canada. This study led to a proposal that a major expansion in satellite services for telephone message traffic and television distribution be planned for the 1980's. The ANIK C satellite series and associated earth stations operating in the 14/12 GHz bands have been planned to meet this requirement. A summary of the salient features of the aforementioned satellite programs is provided in Table 1.

Planning Consideration in the ANIK C Satellite Program

In planning the ANIK C program, it was considered essential that an economy of scale be achieved in the space segment such that an expanded use of the satellite system in Canada would be encouraged. Planning focused on study of the satellite system as an integral part of the Canadian telecommunications network and this approach provided a strong base in telephone message circuit requirements from which a range of system capacities might be considered. In addition to telephone message circuit requirements, the expanded use of the satellite system for the distribution of television programming was considered to be a market with considerable potential. The forecasted requirements based on these applications appeared to be sufficient to justify a system in which economies of scale would be achievable.

Two concepts which contribute to this objective and which were incorporated into the ANIK C system were: a space segment consisting of two prime operating satellites with one in-orbit standby for service protection; and frequency reuse to provide twice the bandwidth and communications capacity in one satellite.

Economic studies encompassing spacecraft designs within the payload capability of the Delta 3914 and the Atlas Centaur launch vehicle led to the decision to maintain the spacecraft weight within the capability of the Delta 3914. Although a Space Transportation System (STS) launch was the preferred plan, a spacecraft weight within the payload capability of the Delta 3914 provided a contingency plan in the event of some unforeseen delay in STS availability. Also

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Table 1 Summary of ANIK satellite programs

Satellite	Actual or planned launch date	Frequency bands, GHz	No. of rf channels per sat.	Useable band-width per channel, MHz	EIRP per channel
ANIK A-1	Nov. 1972	6/4	12	36	34 dBW
A-2	April 1973				(2 × 8-deg beam)
A-3	May 1975				
ANIK B-1	Dec. 1978	6/4	12	36	34 dBW (2 × 8-deg beam)
		14/12	4	72	46.5 dBw (2 × 2-deg beam)
ANIK C-1	4th quarter 1981	14/12	16	54	48 dBW
C-2	1982				(1 × 2-deg beam)
C-3	1986				

contributing to system economies was a spacecraft mission life objective of eight years which provided an improvement over earlier Telesat satellites.

The 14/12 GHz bands were selected for the ANIK C system mainly to avoid earth station siting restrictions attendant upon frequency sharing with terrestrial systems in the 6/4 GHz bands. The major use of the system, which envisaged service to major cities and other relatively high population density areas, supported the need for direct access to these markets without the encumberance of terrestrial end-links to reach the desired locations.

To reduce the adverse affects of precipitation attenuation, a nominal satellite EIRP of 48 dBW per channel was specified. This level provided a reasonable compromise between spacecraft power requirements and earth station receive G/T (ratio of gain to noise temperature) values needed to achieve the desired communication system performance. To achieve this EIRP while limiting spacecraft bus power capability appropriately, 15 W travelling wave tube amplifiers (TWTA's) with four nominal 1 deg × 2 deg spot beams will be employed. Spot beam antenna coverage patterns, each of approximately one-quarter country coverage, are readily applicable to the major city telephone message traffic routing. On the other hand, television distribution requirements can sometimes be better met where one TWTA services a greater area of the country. To overcome this disadvantage, the spacecraft will be equipped with rf variable power dividers commandable from the earth. These power dividers allow the full output of a TWTA to be switched to one spot beam or an adjacent spot beam or to be equally divided between two adjacent spots. In this way, the equivalent of one-half country coverage with one TWTA can be achieved.

A spacecraft nominal G/T value of 3 dB/K will be provided with one country-wide coverage beam, as shown in Fig. 1. This receive antenna arrangement allows full flexibility in accessing any channel from any location within the service area without unduly increasing the complexity of the receive antenna system. Also, satisfactory up-link performance may be achieved with earth station high-power amplifiers not exceeding 1 kW.

A useable satellite rf channel bandwidth of 54 MHz was selected to accommodate telephone message digital transmissions of 91 Mbs (two 45 Mbs inputs). Transmission at a 91 Mbs rate rather than 45 Mbs provides economies in both the spacecraft and the earth stations. These economies result from a reduction in numbers of TWTA's and associated channelizing equipment in the spacecraft as well as a similar reduction in transmit and receive equipment at the earth stations. To improve the cost effectiveness of television transmission in the 54 MHz bandwidth, two television rf carriers sharing a single TWTA are proposed.

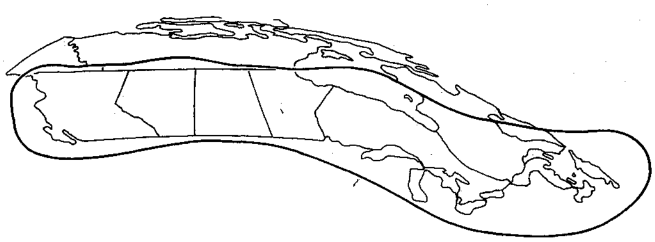

Fig. 1 ANIK C receive pattern for G/T of + 3 dB/K.

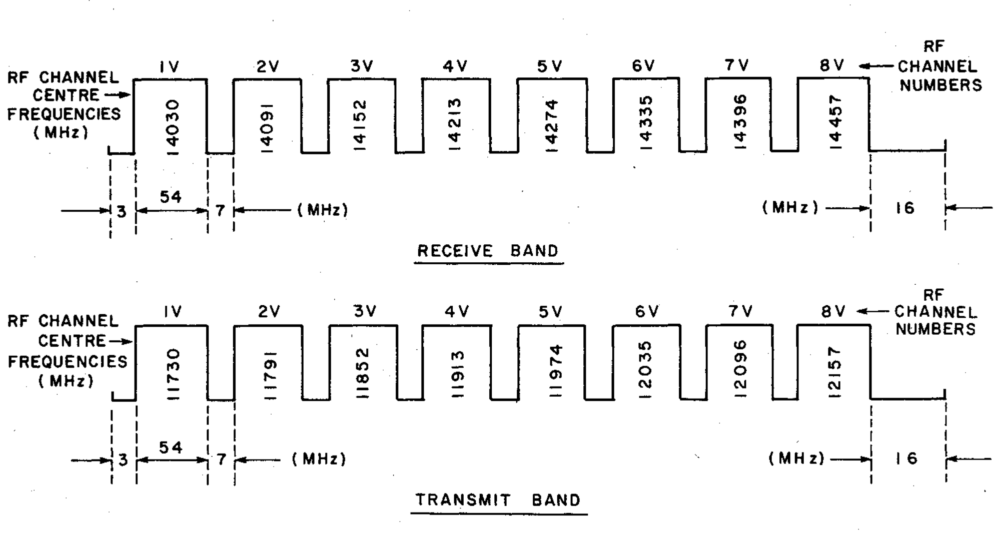

Fig. 2 ANIK C frequency plan (vertical polarization).

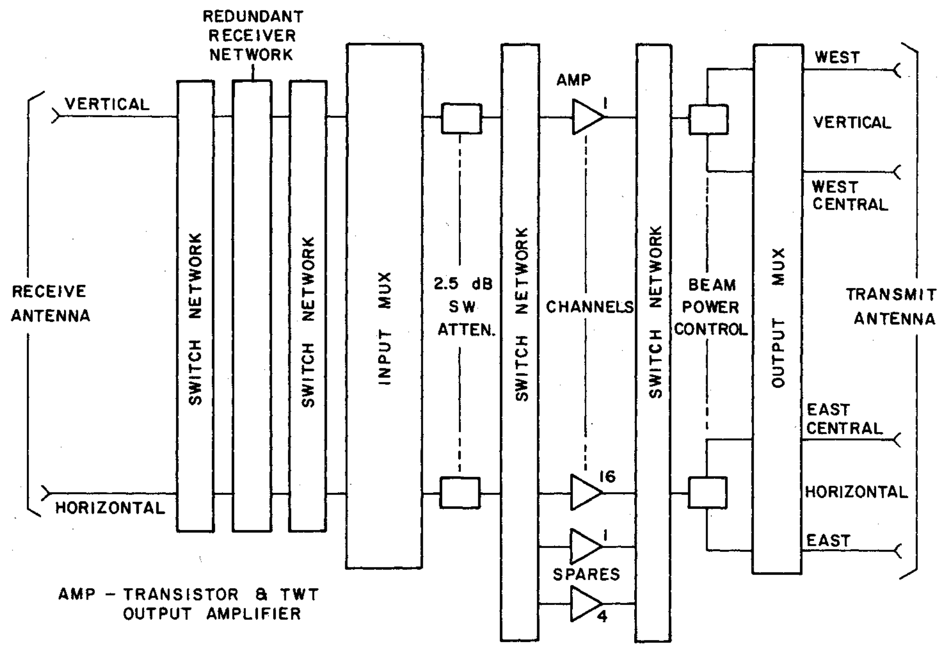

Fig. 3 ANIK C simplified functional diagram.

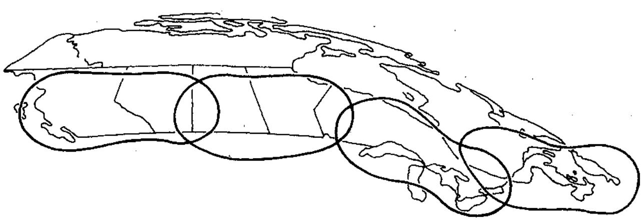

Fig. 4 ANIK C transmit pattern for EIRP of 48 dBW.

ANIK C Satellite Characteristics

The previous section of this paper discussed the planning considerations which influenced the final choice of the major satellite system characteristics. This section provides a summary of these satellite characteristics and other descriptive information on the ANIK C satellite.

The ANIK C satellite is a spin-stabilized design using the gyrostat principle and an extendible cylindrical solar cell panel to increase the available power. The weight of the satellite in transfer orbit will be approximately 2330 lb. Its dimensions have been kept suitable for a Delta 3910/PAM launch or 12% of the bay length in an STS launch.

The frequency plan of the proposed satellite is shown in Fig. 2, while Fig. 3 shows a simplified functional diagram of the communications subsystem. Figure 2 shows the vertical polarized channels which serve the western half of the country. A similar reuse of the frequency band for eight channels polarized horizontally serves the eastern half of the country. In this case the channel center frequencies are shifted upwards by 13 MHz.

It will be noted in Fig. 3 that a 2.5 dB attenuator is provided in each channel. These attenuators, commandable from the earth, allow for closer optimization of up-link performance. The 2.5 dB pad will normally be used at the beginning of satellite life and may be removed later to compensate for possible satellite gain loss. The receive and transmit antenna coverage patterns relative to the map of Canada are shown in Figs. 1 and 4, respectively.

System Interconnectivity and Traffic Patterns

Telephone message traffic will be such as to require interconnections within the coverage area of one spot beam or between any pair of spot beams. The required down-link to serve a specific location is obtained by selecting the appropriate up-link transmitting polarization, and the appropriate combination of channel frequency and rf power divider setting. As noted earlier in Fig. 3, the western half of the country and the eastern half are served respectively by vertically and horizontally polarized transmissions.

For television distribution, a similar selection of up-link frequency and polorization is made. However, rf power dividers are expected to be more often set to the split power mode so that one TWTA will serve two adjacent spot beams simultaneously.

Transmission Modes and System Performance Objectives

Several transmission modes will be utilized in the ANIK C system. In the case of telephone message traffic, all transmissions will be digital having a nominal 91 Mbs (1344 voice channels) satellite rf channel throughput. In most instances, continuous digital streams will be transmitted on a pair of rf channels to establish a two-way connection between two locations. In other instances where fewer circuits are required, a transmit location will transmit two combined 45 Mbs streams (2×672 voice channels) and these will be demultiplexed to a 45 Mbs stream at each of two received locations. Finally, although at the time of writing a firm decision has not been made, some TDMA burst transmissions

Table 2 Message performance objectives

1) Clear weather bit error rate (BER)	1×10^{-7}
2) Overall two-way availability[a] (at BER = 10^{-4})	99.95%

[a] Including 0.02% unavailability due to equipment and power outages and sun transit outages.

Table 3 Television performance objectives

	¼ Canada beam	½ Canada beam
1) Signal to noise ratio (S/N) available 99% of the time	48 dB	45 dB
2) Availability (tentative overall availability objectives)	99.92	99.58

Table 4 Earth station characteristics

Earth station type	Antenna diameter (nominal)	G/T, dB/k	Transmit EIRP,[a] dBW
Telephone message television transmit and receive	8.0 m	35.0	80-82
Television transmit	4.5-8.0 m	...	74-76
Television receive	8.0 m	29.5	...
	4.5 m	26.5	...

[a] Value required is dependent on location and shall be achieved with a 3 dB output back-off in the high power amplifiers.

may be utilized at other locations where initial traffic requirements are lower.

In the case of television transmissions, the FM-FDMA mode will be used. Two rf carriers will share a single TWTA in the satellite. Satellite filter characteristics and TWTA back-off will be carefully selected to control cross-talk between video signals and intermodulation interference power in adjacent rf channels. As noted earlier, rf power divider settings may be set to serve two spot beams simultaneously resulting in an EIRP per carrier of 39.5 dBW (48 dBW less 5.5 dB output back-off and 3 dB for power sharing between beams).

Rain attenuation in the 14/12 GHz bands is a dominant factor in the determination of expected system performance. In Canada, rain attenuation statistics have been collected and analyzed[5] and this data has been made available to Telesat for its link calculations for service to major cities across the country. Further experimental data is also being collected on rain depolarization effects. To meet performance objectives throughout the country, 12 GHz down-link fade margins of about 7 dB and 12 dB will be provided for television and telephone message traffic, respectively. Plans for the provision of up-link power control and polarization tracking at some earth stations are under consideration. All planning to date, has assumed no space diversity in the earth station network. Tables 2 and 3 provide a summary of system performance objectives for telephone and television transmissions respectively.

Earth Station Program and Characteristics

Initially there will be ten main earth stations located at major cities across the country. It is planned to bring these into commercial service in 1982. Six of these will provide telephone message and video links while an additional four stations will provide video links only. Earth stations will normally be located in downtown areas and will be rooftop mounted in close proximity to digital switching machines where possible or television operating centers in the case of video services.

Plans for television and radio program distribution services are not yet firm. However, it is proposed to establish up-links at suitable locations and receive only earth stations as required over the initial years of the sytem to meet the needs of television for broadcast networks and cable operators.

The salient features of three proposed types of earth stations are shown in Table 4. In the case of 8.0 m antennas, step-track has been specified to reduce antenna pointing errors to a tolerable level.

Space-Terrestial Interfaces and Overall System Integration

Trans-Canada Telephone System network growth in the 1980's will be largely through digital facilities. Coaxial cable,[6] digital radio relay,[7] and digital communication satellite links will be combined in the most effective way to meet telecommunication requirements. The designated interface between earth stations and terrestrial facilities will normally be at a standard level in the digital hierarchy in this country, e.g., at a multiple of the nominal 1.5 Mbs or 45 Mbs rate as appropriate for the traffic requirement. Television transmission interface points will be at video baseband, e.g., up to 4.25 MHz.

Interconnection with the digital telephone network raises a number of technical questions which require study and resolution. Among these are synchronization of digital streams, compatibility with digital switches, avoidance of double satellite hops, and provision of the most effective echo cancellers. These studies are well underway and they will be reported on elsewhere.

Conclusion

The Telesat Canada domestic satellite system will experience a major expansion in the early 1980's. The new generation of satellites, the ANIK C series and the associated earth stations will mainly accommodate this growth. Planned use of the Space Transportation System, a three satellite in-orbit space segment, and frequency reuse in the 14/12 GHz bands will provide significant economies. Increased rf channel bandwidth to 54 MHz will further contribute to both satellite and earth station economies. Earth stations located at user's premises, increased joint planning with user agencies, and integration with the Trans Canada Telephone System network are expected to stimulate and encourage use of the satellite system.

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