Canadian Broadcasting Corporation

Société Radio-Canada

Study of Operational Considerations of Feeder Links to Broadcast Satellites

D. L. Garforth, Eng.
R. S. Anderson, Eng.
W. C. Kwong, Eng.
R. Knowles
B. D. Clark, Eng.
M. Durocher, Eng.
J. F. Litchfield, Eng.

ENGINEERING HEADQUARTERS

SIÈGE DE L'INGÉNIERIE

CANADIAN BROADCASTING CORPORATION

Study of Operational Considerations

of Feeder Links to Broadcast Satellites

CBC Report No. EB-65

Engineering Headquarters Siège de l'ingénierie

checked 11/83

DOC CONTRACTOR REPORT DOC-CR-SP 83013

DEPARTMENT OF COMMUNICATIONS - OTTAWA - CANADA

SPACE PROGRAM

TITLE: Study of Operational Considerations of Feeder Links to Broadcast Satellites

AUTHORS: D. L. Garforth, Eng.
R. S. Anderson, Eng.
W. C. Kwong, Eng.
R. Knowles
B. D. Clark, Eng.
M. Durocher, Eng.
J. F. Litchfield, Eng.

Under the direction of:
J. K. MacDonald, Eng.

REPORT NO. EB-65

PREPARED BY: CANADIAN BROADCASTING CORPORATION
Engineering Headquarters
7925 Cote St. Luc Road
Montreal, Quebec, Canada
H4W 1R5

DEPARTMENT OF SUPPLY AND SERVICES CONTRACT NO: OST82-00145

DOC SCIENTIFIC AUTHORITY: Dr. Marcel Bouchard
Communications Research Centre
Shirley Bay
P.O. Box 11490, Station H
Ottawa, Ontario, Canada
K1A 8S2

CLASSIFICATION: None

DATE: March 30, 1983

March 30, 1983

CANADIAN BROADCASTING CORPORATION

(1)

Study of Operational Considerations of Feeder Links to Broadcast Satellites

CBC Report No. EB-65

DSS file no. 22 ST.36001-2-2262

This report has been prepared by:

D. L. Garforth, Eng.
R. S. Anderson, Eng.
W. C. Kwong, Eng.
R. Knowles
B. D. Clark, Eng.
M. Durocher, Eng.
J. F. Litchfield, Eng.

Under the direction of:

J. K. MacDonald, Eng.

EDITORIAL NOTE

THIS ENTIRE DOCUMENT MUST BE READ IN CONTEXT,

AS TO EXCERPT ISOLATED STATEMENTS OR SECTIONS

COULD GIVE A FALSE IMPRESSION.

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

This report presents the views of the Canadian Broadcasting Corporation concerning the requirements for feeder-link terminals operating at 17 GHz and feeding television and radio programs, and ancillary services, to a system of direct broadcast satellites operating at 12 GHz. Such a system would likely be used to provide new program services, rather than extension or replacement of existing services. The system would be configured so as to provide regional services, national services broadcast at the same clock time, and national services broadcast simultaneously. To accomplish this for television, feeder links would likely be required at twenty locations throughout Canada.

Quality and availability objectives are established such that a received picture having a quality corresponding to CCIR grade 4.5 (in the presence of noise and interference) is available 99.71% of the year (equivalent to 99% of the worst rainfall month). Two criteria for overall carrier-to-noise are considered: 12 dB and 14 dB, the latter having been suggested by the Corporation for use with multiplexed analogue component coding.

A typical feeder link would use a five-metre antenna and a 1000 watt transmitter. Site diversity is required at several locations. For each usable combination of feeder-link location and orbital position, the elevation angle and rain fade are specified. The use of transportable feeder links is proposed, primarily for regional service. These have the same parameters, except that a tracking system will likely be required to offset mechanical instability.

Audio channels will be required for 15 kHz stereophonic TV sound plus other sound and data services. Cue and control channels will be required.

The 12 GHz broadcast satellite system should be designed to accommodate a multiplexed analogue component system of coding to provide enhanced quality television. However, the increased bandwidth required for extended and high definition television could be better accommodated elsewhere in the spectrum.

The report presents an overview of the present use made by Canadian broadcasters of the satellite facilities now available in the Fixed Satellite Service. Several topics are identified which should be investigated further. A bibliography of useful documents is presented.

2.0 INTRODUCTION

Canada has been a pioneer in the use of satellites for network distribution of radio and television for the past decade. We are now equipped with a score of transponders carrying entertainment programming distribution for feeding on-air transmitters, closed circuit uses and incidental reception by individuals.

2.1 Program Distribution

This type of application, using satellites in the Fixed Satellite Service, began in the early 1970's when Anik A was first launched and used by the CBC. As transponders became more cost effective, their utilization increased to allow replacement of many terrestrial microwave services for network purposes. The distribution is primarily between the main program production and control centres across the country, which are in the principal cities.

The transponders used for this fixed-service application carry a mixture of program services ranging from the backbone distribution of CBC English and French networks, through a Northern Service program package and the CANCOM program services designed to serve the whole country, to TV Ontario and ATV-2 designed to serve parts of the country only.

2.2 Program Collection

The same channels as are used for supplying many remote over-the-air transmitters are used by CBC to deliver regional program content to the national centres for integration into the main program stream. Because of the segmented nature of such signals, they are unsuitable for inclusion in a broadcast satellite system and it is likely that they will continue to use the fixed satellite services now available in Canada.

2.3 Cable Integration

Canadian CATV systems have received programming from the Anik transponders since House of Commons broadcasts commenced in 1979. Recent additions include CANCOM's package of four programs from different TV broadcasters and pay-TV, which commenced February 1, 1983. Most cable systems are now equipped with a TVRO for the 4 and/or 12 GHz bands to receive these services.

2.4 Future System Alternatives

The technical and operational characteristics of the current Canadian broadcasting system in terms of satellite use are, therefore, clearly defined by the characteristics of the satellites available (Anik B, C and D) and the Canadian program services being carried. These services are more fully described in Appendix B of this report. These satellites use spectrum in the Fixed Satellite Service, while the broadcast satellites will be part of a broadcasting service directly to homes. These future satellites are the subject of this report.

2.4.1 Unserved Areas

One use of a broadcast satellite would be to extend coverage to those Canadians not now receiving service. This isolated population is, to some extent, increasingly being served by private satellite earth station equipment receiving CBC, CANCOM and other Canadian programs. It is unlikely that a broadcast satellite service could be justified on this basis alone.

2.4.2 Terrestrial Transmitter Replacement

It has been suggested that terrestrial transmitters could be replaced by broadcast satellites. This would seem unlikely even in the long term since services required would quickly outstrip the capacity of any satellites envisaged at this time. Additionally, such a move would largely preclude effective local and sub-regional broadcasting.

2.4.3 New Services

Although it might not be possible to enumerate new programming services at this time, it is thought that this is the logical area for broadcast satellites.

This study will consider that programming on a broadcast satellite system will not duplicate existing services. It will, however, use the experience gained by CBC over the past decade of satellite supported broadcast distribution to predict future trends toward a Canadian Broadcast Satellite system.

2.5 Proposed System

Based on the regional differences in characteristics and environment, a minimum of six service areas are required for southern Canada. Two more for the eastern and western Arctic would be ideal.

This report is based on the provision of new television program services in Canada, some providing regional service and some nation-wide service*. There are a number of possible configurations.

* This report does not use the terms "regional channels" and "national channels". Instead it describes system configurations that will provide regional and national program services.

2.5.1 Regional Service

Figure 1 illustrates a system capable of providing separate programming to each of the six coverage areas. For this example, it is assumed that these are provincial educational programs. Each satellite is fed by a feeder link located within its coverage area and each major city would have a feeder link for this purpose. There is no requirement to broadcast the regional program to any other coverage area.

For major events of regional importance, transportable feeder-link terminals would be used to originate live direct broadcasts. The primary station in the region would monitor the signal originating with the transportable terminals. In the event of failure, a standby program could be inserted by the primary station through the necessary switching operation.

2.5.2 National Service Broadcast at Same Clock Time

National broadcasting organizations will broadcast their programs throughout the country. On a regular basis, these will not be seen simultaneously as Canada has seven time zones. Instead, the programs will be seen at or near the same clock time in each time zone.

For this purpose, master feeder links would be installed at the major program centres. Each master feeder link location has one transmit beam for each satellite, which would receive the signal on its nation-wide receive antenna. Figure 2 illustrates a system in this configuration using the example of a program originating from Toronto.

2.5.3 National Service Broadcast Simultaneously

When an event of national importance, such as major sports, news, or current affairs, is to be broadcast to the entire nation simultaneously on one (or more) of the program services, other programming on that service would be pre-empted. The national program would be sent, via the Fixed Satellite Service, to the national program centre for transmission to all broadcast satellites simultaneously. As simultaneous national programming forms only a minor percentage of a regular program schedule, it will not be necessary to dedicate transponder channels for this purpose on the broadcast satellites. Figure 3 illustrates the system using the example of a national program originating from Vancouver.

The use of transportable feeder-links directly to the broadcast satellites could replace the Fixed Satellite Service for this application. However, the use of transportable feeder-links would require the ability to carry out switching of the feeder-link in such a manner as to ensure continuous video transmission from the satellite. Additional control facilities would be required on the ground to ensure continuity of service, etc.

2.6 Summary

This document will address the following topics in the context of integrating future 12 GHz broadcasting satellites for broadcasting new program services and to improve the quality of service delivered to the home:

- The operational characteristics of a major broadcasting centre capable of meeting the signal quality objectives.
- The number and most likely locations of fixed earth stations.
- The need for transportable uplink terminals, their desired operational characteristics and the extent of their use.
- The need for audio channels for broadcasting and additional channels for network cue and control, and the most desirable modulation and transponder format for these channels.
- The feasibility and desirability of using 12 GHz broadcasting satellites for the transmission of HDTV and EDTV signals.

Engineering Headquarters Siège de l'ingénierie

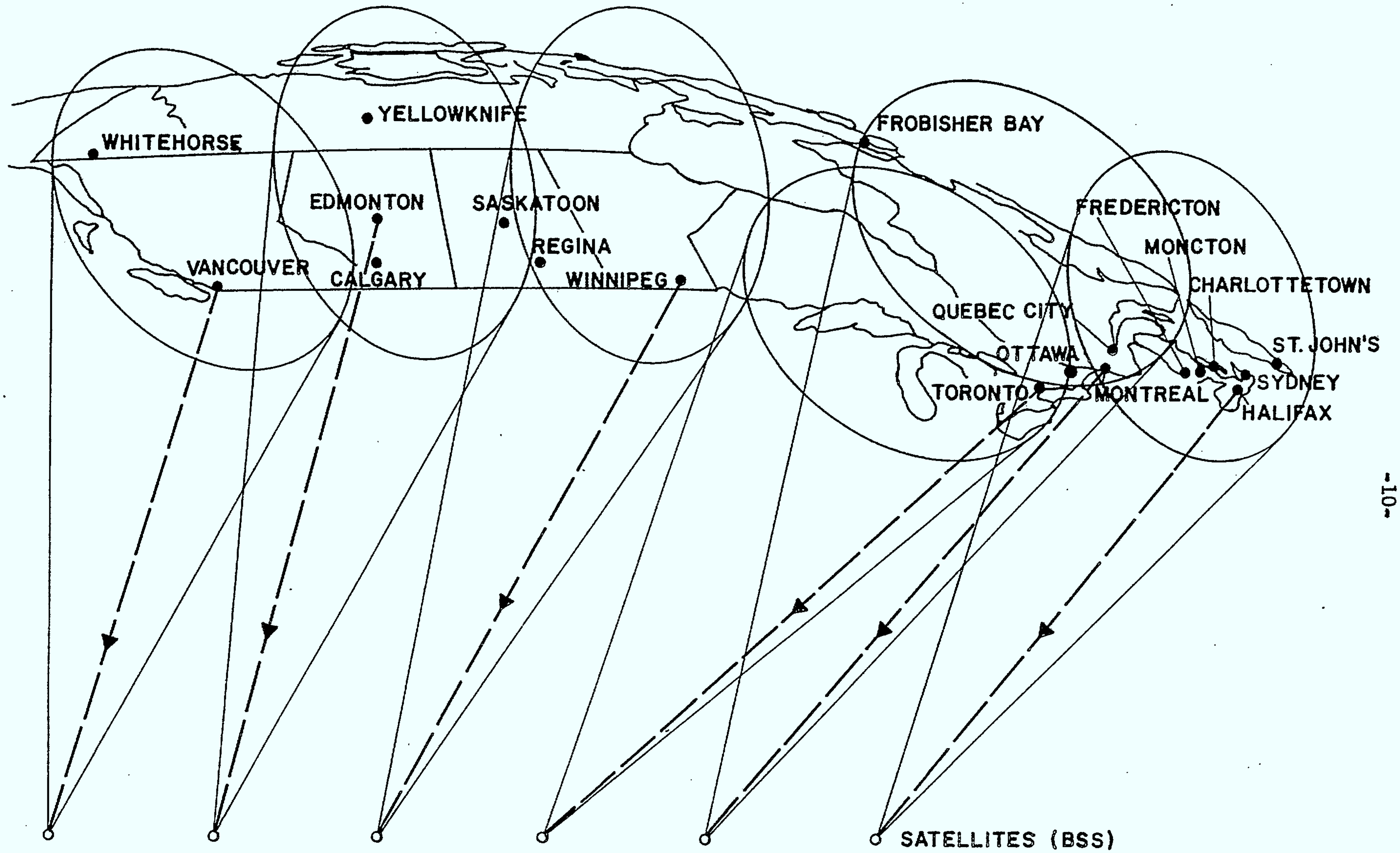

Figure 1. Program intended for one region only.

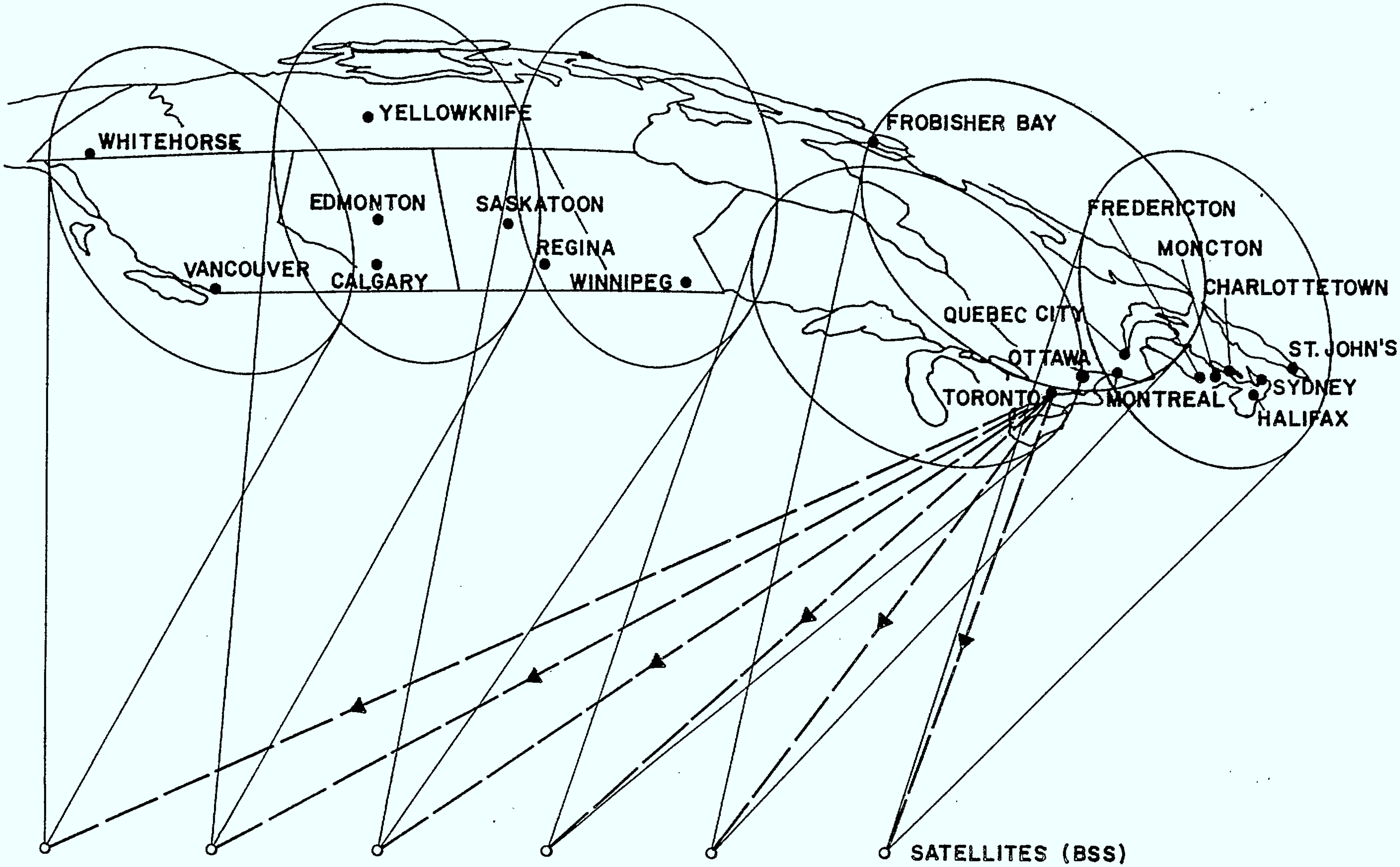

Figure 2. Program intended to be seen across the country at different times.

Engineering Headquarters Siège de l'ingénierie

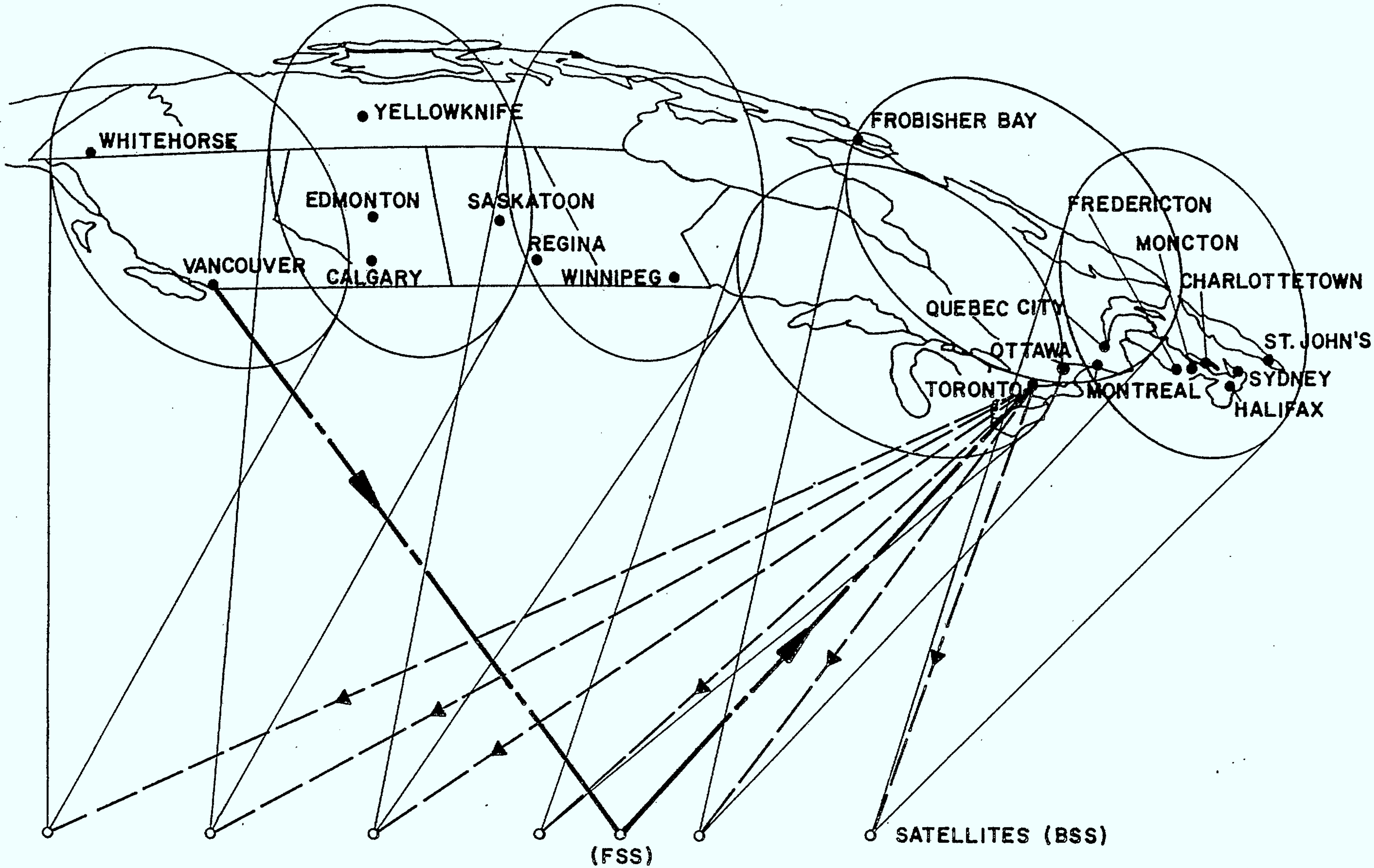

Figure 3. Program intended to be seen across the country simultanously.

3.0 THE NUMBER AND MOST LIKELY LOCATIONS OF FEEDER-LINKS

The current broadcasting systems allow transmission of program streams to areas in Canada that generally conform to the various time zones across the country. These time zones generally coïncide with provincial borders. The current centres of broadcasting activity for these various areas across the country also happen to be the major urban centres. A considerable capital investment in program origination equipment and systems has already been made in these various cities and any future broadcasting systems will more than likely originate in these same areas. The cities of interest are as follows:

* Vancouver	Quebec
* Edmonton	Moncton
Calgary	Fredericton
Saskatoon	Charlottetown
Regina	* Halifax
* Winnipeg	Sydney
Windsor	* St. John's
* Toronto	Whitehorse
Ottawa	Yellowknife
* Montreal	Frobisher Bay

All of the above centres produce significant quantities of television programming and, depending on economics, are candidates for broadcast satellite feeder-link sites. Radio might add further cities but these are not obvious at this time.

As six regional beams are being considered, one or more centres in each of the service areas fed by these beams would be equipped with feeder-link facilities. The centres most likely to be equipped are marked with an asterisk. These are the larger centres with existing talent pools and extensive production facilities.

As noted, all of the cities listed above are already actively involved in television and radio broadcasting. Many broadcasters have service areas that are extended beyond their immediate metropolitan coverage area by means of either repeaters or mini-networks. Knowing this, a number of future scenarios are possible in any given service area.

1. Any city that currently is a production centre will be a candidate for a feeder link. In some areas, several broadcasters might wish to use the broadcast satellite. Either each would have an adjacent feeder-link, or some inter-city terrestrial connections would be required. It is impossible to determine the relative costs at this point but the installation of a feeder link must be considered as an alternative to terrestrial interconnection to an existing feeder link.

2. CTV, CBC and some of the new pay-TV services are currently operating systems that involve broadcasting programs on a national scale. These organizations tend, for a number of reasons, to centralize their national program origination operations. This type of operation will continue and probably expand. As a result, in large centres, such as Halifax, Montreal, Ottawa, Toronto, Winnipeg, Edmonton and Vancouver, feeder links capable of addressing all the service beams will be required.

The physical limits imposed by orbital positioning to ensure that eclipse-caused outages occur after midnight, dictate that areas east of Quebec City may not be able to directly access the westernmost satellites. In this case, some relaying of signals originated in the east would be necessary to enable access to the westernmost satellites. This could be accomplished terrestrially, via the fixed satellite system, or by some form of direct inter-satellite communication.

The above does suggest that an organization wishing to directly access all the service area beams would be constrained from locating east of Quebec City.

The easternmost location for a satellite capable of being accessed from Vancouver, capable of providing service to the Atlantic Provinces, and having earliest onset of eclipse after midnight, is 70°W. Earliest onset of eclipse is 2357 AST, and the elevation angle for the feeder-link is 14.64°.

The westernmost location for a satellite capable of providing service to British Columbia and capable of being accessed from St. John's is 112°W. The elevation angle for the feeder-link is 11.64°. However, the earliest onset of eclipse is 2245 PST which imposes a restriction on this configuration.

4.0 FEEDER-LINK OPERATIONAL CHARACTERISTICS

4.1 Quality and Availability Objectives

The term availability is used here to express the total amount of time a system is available for use as a percentage of the total operating time. Technical quality objectives define subjective and objective performance standards to which systems are expected to conform when available for use.

Quality control programs established by broadcasters have been in operation for some time and have resulted in picture and sound quality objectives for network-connected stations.

To define technical quality, a subjective rating system is employed which takes into account a sufficient number of factors to enable a grading of between 1 and 5 to be established, a grade of 1 being the worst case. The system is fully described in CCIR recommendation 500.

The rationale for setting these subjective performance standards was based, in part, on actual performance achieved, an estimate (since substantiated) as to what could be accomplished with reasonable effort and expense, and the quality needed to satisfy TV audiences.

In addition to quality objectives, a threshold point must be established below which the signal is considered unfit for broadcast and the system carrying the service be classified as "unavailable".

Various studies have been conducted to determine quality objectives for both television and radio broadcasting. These show that a threshold point of grade 1.5 determines the availability of a system. At that quality grade, impairments are very annoying and the service would be considered unfit for broadcast.

Both broadcasters and common carriers go to great lengths to ensure that these objectives are met. In large market areas, availability objectives are typically 99.97% or better. Achieving this involves the use of redundant system components virtually throughout the entire broadcast chain coupled with automatic switchover and failure protection.

Thus:

Picture & Sound Availability Objectives		
% of time available	99.71	99.97
Quality Grade	$\geq$ 4.5	$>$1.5

A summary of the Corporation's present technical standards is shown in Appendix C. These standards pertain to the existing television service. However, we expect that standards for a broadcast satellite system should far exceed the existing standards.

For the broadcast satellite system, there are fewer factors affecting availability than in the existing broadcasting system. Rain attenuation is the major factor. If the system can be designed to accommodate all but the most severe rain fades, we would expect that the picture quality and the availability of the BSS will be better than the current broadcasting system. By definition (from the "statement of work for Canadian Broadcasting Corporation") the availability objectives will be met provided the aggregate C/I of the overall system is 30 dB for 99% of the worst month. The corresponding annual time percentage (p) is determined by:

$$p = 0.29\ p_w^{1.15} = 0.29\% \text{ of the year.}$$

Hence, the availability objective* of the system is:-

$$100\% - 0.29\% = 99.71\% \text{ of the year.}$$

The picture quality corresponding to this availability objective is Grade 4.5. With this as the basic requirement, the combined effect of noise and interference in both feeder-link and downlink connections will not cause a lesser picture quality. This implies that noise and interference will each be low enough not to mask the other and to be root-sum-square additive.

It is the opinion of CBC that these objectives meet or exceed performance currently realized in the Canadian Broadcasting Corporation's television services. We, therefore, will use them as the basis of further calculations in this report.

Assuming 18 hours per day of transmission (with no transmission after solar eclipse starts), there will be approximately 19 hours per year for which the signal will be degraded below the specified quality.

---

*In this report, availability objective for a broadcast satellite system is the percentage time of the year that the system is not degraded below the average CCIR impairment grade 4.5 due to attenuation and increase of noise on the up-path. This does not include the other causes of interruption described in CCIR report 706-1. It assumes clear-sky conditions at the receiving location.

4.2 C/N Criteria

Under the statement of work for Canadian Broadcasting Corporation, the overall signal quality for a Canadian broadcasting satellite system is C/N of 12 dB and C/I aggregate of 30 dB for 99% of the worst month.

When considering the use of Multiplexed Analogue Components (MAC) coding for television signals carried by broadcasting satellites, it has been suggested by CBC that a C/N of 14 dB will be required both for robustness of the digital sound and data channels and for freedom from truncation noise impairment for the over-deviated video. Hence, feeder-link noise budget calculations for C/N of both 12 and 14 dB are included in section 4.2.1 and 4.2.2 respectively. These calculations all assume clear weather at the receiving location.

4.2.1 Feeder-Link Noise Budget (Based on $C/N_{total} = 12$ dB)

The link equation for the feeder link of a broadcasting satellite is given by:

C/N = EIRP − Free space loss + G/T − 10 log kB
− path loss (clear-air absorption)
− rain attenuation − pointing error

Assuming:- Transmitter power (1000 watt) = 30 dBW

Feeder-link antenna = 5 m

Feeder-link antenna gain = 56.6 dBi on axis

Satellite receiving antenna beam width = $3^\circ \times 8^\circ$ (country-wide beam)

Satellite receiving antenna gain = 31 dBi on axis

Receiver noise temperature = 1500 K

Hence: EIRP = 86.6 dBW

Free space loss = 209 dB typically

G/T = −4 dB/K at edge of feeder-link service area

10 log kB = −154.8 dB (for 24 MHz)

Path loss due to clear-air absorption = 0.3 dB typically

Loss of gain due to station keeping error of 0.1° = 0 dB (as a tracking system will be used)

0.1° mispointing of 5 m dish = 1 dB

For clear-sky condition at the feeder-link location:-

$$C/N_{up} = 86.6 - 209 - 4 + 154.8 - 0.3 - 1 = 27.1 \text{ dB}$$

Given the criteria that the total system C/N must be not less than 12 dB (feeder-link and down-link), and that the feeder-link contribution must be not more than 10% (0.5 dB), the required down-link C/N would be not less than 12.5 dB.

$$\text{Therefore, } C/N_{total} = \frac{1}{\frac{1}{C/N_{up}} + \frac{1}{C/N_{down}}} = 12.3 \text{ dB}$$

Thus, there is a margin of 0.3 dB which satisfies the criterion.

For rain-fade condition at the feeder-link location:-

For this calculation a rain fade of 5 dB is assumed.

Hence,

$$C/N_{up} = 86.6 - 209 - 4 + 154.8 - 0.3 - 5 - 1 = 22.1 \text{ dB}$$

$$C/N_{total} = 12 \text{ dB}$$

Therefore, where the rain fade is expected to be 5 dB, the assumed parameters would still enable the objective to be met.

4.2.2 Feeder-Link Noise Budget (Based on $C/N_{total} = 14$ dB)

Given the criteria that the total system C/N must be not less than 14 dB (feeder-link and down-link), and that the feeder-link contribution must not be more than 10% (0.5 dB), the required down-link C/N would be not less than 14.5 dB. This could be accommodated by increasing satellite EIRP, by improving receiver G/T, or a combination of both.

With all technical parameters as stated in section 4.2.1,

For clear sky condition at the feeder-link location:-

C/N_{up} = 86.6 - 209 - 4 + 154.8 - 0.3 - 1 = 27.1 dB

C/N_{down} = 14.5 dB

Therefore,

$$C/N_{total} = \frac{1}{\frac{1}{C/N_{up}} + \frac{1}{C/N_{down}}} = 14.2 \text{ dB}$$

Thus, there is a margin of 0.2 dB which satisfies the criterion stated above.

For rain-fade condition at the feeder-link location:-

For this calculation, a rain fade of 5 dB is assumed.

Hence,
C/N_{up} = 86.6 - 209 - 4 + 154.8 - 0.3 - 5 - 1 = 22.1 dB

C/N_{down} = 14.5 dB

Therefore,
C/N_{total} = 13.8 dB

Thus, there is 0.2 dB less than the stated criterion. For areas where rain fades in the order of 5 dB or greater can occur more than 0.29% of the time, it will be necessary to compensate for rain fading. This can be accomplished by the use of a site-diversity system. However, this would involve a large capital investment and increase the system complexity.

If the G/T of the satellite receiver can be increased from -4 dB/K to -2.5 dB/K (either by improving the receiver noise temperature or increasing the receiving antenna gain) then,

C/N_{up} = 23.6 dB

C/N_{down} = 14.5 dB

Hence,
C/N_{total} = 14 dB

4.3 Site Diversity

Where rain fades exceed the values shown in table 1 (section 4.6) experience with conventional microwave systems has shown that it would not be practicable to increase EIRP sufficiently to compensate in most cases. We believe that site diversity would be required to effect any significant improvement to the availability figures. It is recommended that methodology relating to site diversity should be the subject of additional study. In addition, an examination of the depolarization effects of precipitation should be undertaken at an appropriate time.

4.4 Feeder-link Antenna

A 5 m dish is a reasonable choice for a major operational centre. The half-power beamwidth is approximately 0.24°. If the satellite position is kept within ±0.1° in the north-south and east-west directions, the maximum error will be ±0.14°. For a pointing tolerance of ±0.1°, the maximum mis-alignment of the feeder-link antenna will be 0.24°. Therefore, an auto-tracking system is required.

It is recommended that a future study of the structural adequacy of the 5 m dish to be used with various wind loading conditions is required.

4.5 Rain Regions

Figure 4 shows the rain climatic zones for Canada.

The rainfall intensities exceeded for 0.01% of the year for the various rain regions in Canada are listed below:-

Rain Region	Rain intensity (mm/h)
C	15
D	19
E	22
F	28
K	42

The rain attenuations stated in this study were based on DOC computer program "ATMOS3" and "Study of the linear or circular polarization for 12 GHz BSS" Final Report from Miller Communications Systems Ltd. Detailed information for each of the orbital positions related to the feeder-link locations is attached in Appendix A.

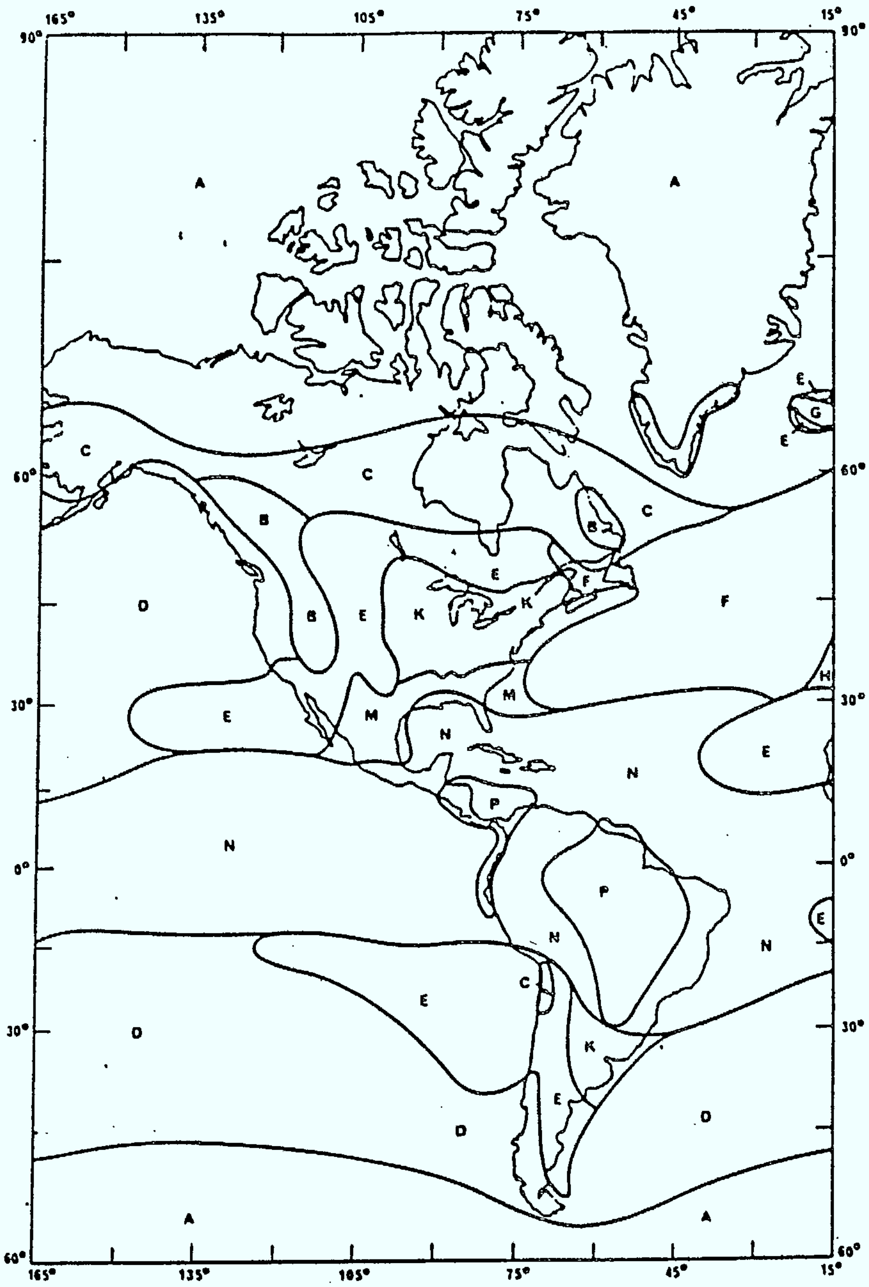

Figure 4 - Rain Climatic Zones

4.6 Elevation Angle

The minimum elevation angle (to ensure that rain attenuation of 5 dB does not occur more than 0.29% of the year) cannot be specified for an area as large as a rain region, due to the variation in ground elevation throughout each region which affects the path length through the rain cell.

For the feeder-link locations and the orbital positions (70° to 147° W) proposed in this report, if the only consideration were that rain attenuation of 5 dB must not be exceeded 1% of the worst month (i.e. 0.29% of the year), the following table would show the approximate minimum elevation angle for each of the various rain regions in Canada:-

Rain Region	Approximate Minimum elevation angle
C	2°
D	6°
E	6°
F	8°
K	16°

However, other factors must be considered. In Appendix A each feeder-link location is analyzed vis-a-vis specific orbital positions in order to determine if the following design objectives are met:-

- the elevation angle should be greater than 10° in order to avoid terrain noise;
- the elevation angle is great enough to ensure that rain attenuation of 5 dB is not exceeded 1% of the worst month (i.e. 29% of the year);
- the earliest onset of eclipse does not occur prior to midnight local time at the feeder-link location.

In this study, the lowest elevation that meets the design objectives is listed below for each rain region.

Rain Region	Lowest elevation angle (assuming no site diversity)
C	12°
D	29°
E	20°
F	15°
K	16°

Table 1 shows pertinent elevation angles for specific feeder-link locations in order to access specific satellite orbital positions.

TABLE 1

Feeder-Link Location	Rain Region	Orbital Position (1)	Potential Service Area (2)	Elevation Angle	Rain Fade Exceeded 1% of worst month (dB)	Necessity for Site Diversity
St. John's, Nfld.	F	70°W	NTZ, ATZ	32.8°	1.77	No
		105°W	NTZ to CTZ	16°	3	No
Halifax, N.S.	K	77°W	NTZ, ATZ	36.85°	2.87	No
		119°W	ATZ to MTZ	15.46°	5.29	YES
Charlottetown, PEI	F	77°W	NTZ, ATZ	35.07°	1.78	No
		119°W	ATZ to MTZ	14.41°	3.36	No
Moncton, N.B.	K	77°W	NTZ, ATZ	35.6°	2.78	No
		119°W	ATZ to MTZ	15.53°	5.03	No
Fredericton, N.B.	K	77°W	NTZ, ATZ	36.14°	2.76	No
		119°W	ATZ to MTZ	16.78°	4.8	No
Sydney, N.S.	F	77°W	NTZ, ATZ	34.4°	1.81	No
		119°W	ATZ to MTZ	12.54°	3.7	No
Frobisher Bay, NWT	C	91°W	NTZ to ETZ	15.78°	0.76	No
		112°W	NTZ to CTZ	10.19°	1.09	No
Quebec City, Que.	K	91°W	NTZ to ETZ	32.8°	2.86	No
		126°W	ATZ to MTZ	14.86°	5.07	No
Montreal, Que.	K	91°W	NTZ to ETZ	35.85°	2.94	No
		133°W	ETZ to PTZ	12.8°	6.01	YES
Ottawa, Ont.	K	91°W	NTZ to ETZ	35.58°	2.86	No
		133°W	ETZ to PTZ	13.9°	5.56	YES

TABLE 1
(Continued)

Feeder-Link Location	Rain Region	Orbital Position (1)	Potential Service Area (2)	Elevation Angle	Rain Fade Exceeded 1% of worst month (dB)	Necessity for Site Diversity
Toronto, Ont.	K	91°W	NTZ to ETZ	38.3	2.89	No
		140°W	ETZ to PTZ	12.3	6.3	YES
Winnipeg, Man.	K	105°W	NTZ to CTZ	32.3	2.54	No
		147°W	CTZ to YTZ	16.2	4.24	No
Regina, Sask.	E	119°W	ATZ to MTZ	30.61	1.26	No
		147°W	CTZ to YTZ	19.9	1.74	No
Saskatoon, Sask.	E	119°W	ATZ to MTZ	29.28	1.22	No
		147°W	CTZ to YTZ	19.73	1.65	No
Calgary, Alta.	E	119°W	ATZ to MTZ	31.4	1.21	No
		147°W	CTZ to YTZ	23.96	1.48	No
Edmonton, Alta.	E	119°W	ATZ to MTZ	28.64	1.17	No
		147°W	CTZ to YTZ	21.55	1.46	No
Yellowknife, NWT	C	119°W	ATZ to MTZ	19.23	0.68	No
		147°W	CTZ to YTZ	14.5	0.86	No
Vancouver, B.C.	D	133°W	ETZ to PTZ	32.7	1.07	No
		147°W	CTZ to YTZ	29	1.17	No
Whitehorse, Y.T.	C	147°W	CTZ to YTZ	20.45	0.69	No

Note: (1) The orbital position has been specified to ensure that solar eclipse starting time does not occur prior to midnight in any of the potential service areas.

(2) The designation of the time zones are:-

Yukon	-	YTZ
Pacific	-	PTZ
Mountain	-	MTZ
Central	-	CTZ
Eastern	-	ETZ
Atlantic	-	ATZ
Newfoundland	-	NTZ

Explanatory notes for the use of Table 1:-

e.g. Toronto, located in rain region K.

(i) The feeder link at Toronto (operating before midnight) can access the satellite located at 91°W, which would provide service to any selected area from NTZ to ETZ. The elevation angle is 38.3°, the rain fade exceeded 1% of the worst month is 2.89 dB. No site diversity is required.

(ii) The feeder link at Toronto can also access the satellite located at 140°W, which would provide service to any selected area from ETZ to PTZ. The elevation angle is 12.3°. The rain fade exceeded 1% of the worst month is 6.3 dB. In order to maintain the specified availability, site diversity is required.

4.7 Operational Characteristics

One of the objectives of feeder-link designs is to achieve the highest performance at optimal capital and operating costs. It appears that, with the minimum design feeder-link combinations of a 5 m antenna and a 1000 watt amplifier, there is little or no margin for fading at the 17 GHz frequencies involved. It is, therefore, imperative that strategies for protection of service continuity at these stations be carefully considered.

First, we can deduce that, for major national feeder-link locations, the fading is reduced by locating satellites at the eastern end of the usable arc considering eclipse after midnight in the time zone of interest. Second, it would be wise to equip the transponders with the highest performance receivers obtainable at the time design is committed. Third, we will, at some locations, require space diversity of feeder links. It is possible that, if there is more than one system user at a program origination location, common use could be made of a diversity feeder link, or each user could share the other's feeder link for this purpose.

Control systems for the transmitters in diversity protected feeder links will require careful and uniform system design and implementation. The facility interconnecting diversity locations can presumably use any current means such as buried cable, fibre optics, or microwave, provided it is carried in a frequency band not likely to suffer fading coincident with rain attenuation at 17 GHz. For separations greater than 15 km microwave would be preferable. Narrow-bandwidth control facilities, tracking systems and associated subsystems could be linked by normal metal cables in the urban infrastructure.

Installation, operation and management of large antennas is another real problem in urban areas. Public awareness of electromagnetic radiation hazards has increased, most antennas are esthetically unpleasing, and zoning bylaws make planning of feeder-link stations a very delicate business. The proposal of using separate satellites, spaced 0.4 degrees apart, with one of the two polarizations on each satellite, could in effect double the feeder-link antenna requirement.

Once planning reaches a more advanced stage, it might be possible to organize feeding patterns so as to minimize the sites requiring access to both polarizations. Additionally, all new technology systems for multibeam antennas should be explored. This could include existing torus configurations, and particular attention would be directed to power handling capability, physical placement of feed hardware, and related subjects. It is important to foresee the potential problems of high power levels at millimeter wavelengths.

5.0 TRANSPORTABLE FEEDER LINKS

Any discussion of transportable feeder links should be prefaced by an examination of current broadcast practices in order to truly assess the extent to which transportable feeder links to broadcasting satellites might be used and thus obtain an idea of their potential influence on the design and operation of broadcast satellites.

Currently, most broadcasting that is done on location "live" to air is confined to sports, political events, or special events of widespread interest. A number of elements involving some production facilities are required to enable the broadcasting of a "live" event. Whether this takes the form of "anchorman" type operations, insertion into the program of prerecorded items, or commercials, "live" programming is funnelled through an established broadcast centre prior to home delivery. At present, either terrestrial or space facilities are used to transport the remotely originated material to the centre.

Most large events that would be candidates for "live" broadcasting occur in population areas where ready access by broadcasters is available terrestrially. If the event is not intended to be broadcast "live," highly mobile equipment is generally available that can be rapidly deployed to record the event on tape for later replay.

Current mobile electronic field production equipment is both light and relatively inexpensive. Use of this gear is generally supported by centrally located editing equipment which is used to make the original material "air-worthy."

Prices currently quoted for transportable satellite feeder links preclude the use of this service for all but the most prestigious types of programs where the immediacy of "live" performance, and/or inaccessibility via normal terrestrial means, makes the use of transportable feeder links mandatory. It should be noted that the program currently is always brought back to a central location prior to onshipment to the final consumer and is not intended to be viewed by the public until final processing at the production centre has taken place.

It is conceivable that new services of educational, agricultural or other regional interest could arise where no central production area would ever exist. Programs would then originate from locations that could change on a daily, weekly or monthly basis depending on production requirements.

The size of transportable feeder links required would, of necessity, be similar to those used in permanent feeder-link installations. For certain combinations of feeder-link location and satellite orbital position, where the availability objective cannot be met without site diversity, rain attenuation will cause the signal to be degraded for short periods. This fact of life must be taken into consideration when a service of this nature is being commissioned.

Transportable feeder-link stations will, considering the need for 5 meter antennas, require a tracking system to maintain effective operation for many applications. The whole premise that such a device is easy to relocate is in contradiction to the stability required by the narrow antenna aperture. Based on the Corporation's considerable experience with transportable feeder links, it is urgently recommended that subsequent study be conducted to develop a transportable feeder-link antenna in the 5 meter class which also has the stability expected for reliable service.

In addition to the functional use for feeder-link service, a number of other services would be needed in any practicable transportable terminal. These would be at least two duplex communications circuits for technical and production intercommunications. Carriage of such circuits could be by any technique available; however, it would be useful if it were independent of the main television signal. This aspect should be studied further once design activity of transportable feeder-links is commenced.

The antenna required for this type of operation should be readily transportable from one location to another and have a reasonable setup time.

A typical transportable station, observing mobility constraints, could be constructed using a 5 m dish and a 1000 W transmitter. The EIRP would be 86.6 dBW, meaning that the system would suffer a certain degree of degradation with more than 5 dB rain fade conditions.

Rain-caused fading might have to be accepted as a potential risk in any transportable operation unless extensive, and probably expensive, means of averting it were adopted.

6.0 AUDIO AND ANCILLARY CHANNELS

6.1 Audio Channels for Broadcasting

The current television broadcasting system uses one audio channel per video signal. The bandwidth of this audio channel has traditionally been 5 kHz, although improvements in TV sets are forcing a move toward better quality. Separate tuners are now sold which allow use of standard high-fidelity audiophile equipment for TV sound listening.

In some segments of the TV distribution system, additional signals are multiplexed with the associated TV audio signal. These signals are either program channels or data channels used for cue and control purposes. The current satellite channels used by CBC are equipped for this type of operation. In this system, both the TV audio and secondary audio services are 5kHz channels.

These trends in television, spurred on by home video cassettes, new satellite-delivered music services in the United States, and increasing public consciousness, are forcing all TV audio services to full bandwidth (15kHz) high-quality audio.

Experiments and research are currently under way in the United States to specify new standards for stereo transmission of television-associated sound. While these are not totally conclusive, future broadcast satellite services should be planned with high-quality 15kHz stereo sound channels.

At present, most TV audio transmission over satellites is accomplished by analogue FM subcarrier multiplexed into the video baseband in the 5 to 8 MHz range. Equipment for this purpose is well developed, available, and inexpensive. Capacity can be extended to as many as 20 sound and data channels in current satellite systems using 36 MHz transponders.

Broadcast satellite systems soon to be implemented in Japan and Europe have been designed with digitally encoded sound channels. The Japanese will use a digital subcarrier above video which carries stereophonic 15 kHz sound or four channels of 7.5 kHz sound for multi-language transmissions, radio, etc. Europe will use a digital sound system carried by bursts of data time-division multiplexed with multiplexed analogue component video. Each blanking interval in the vision sequence allows about 10 us of data at 20 Mb/s to be sent. The resulting stream has an average rate of 2.048 Mb/s and is capable of supporting 6 or 8 high-quality sound channels.

The Canadian satellite system has been equipped to support independently sourced radio signals at the band edge of many transponders. Television feeder links are operated with power about 1 dB less than that required for transponder saturation. As a result, the transponder is sufficiently linear to relay a narrowband FM carrier located 2 MHz from the band edge and 20 dB reduced relative to the TV carrier. It is unlikely that this technique would have much application in a broadcast satellite system because bandwidth is probably too narrow.

The minimum requirement for audio in a broadcast satellite system is a 15 kHz stereophonic channel or pair of matched monaural channels for television sound, and as many other audio channels as can be developed within the transmission format selected. Comparison of analogue and digital techniques, subcarrier and SCPC schemes and various other radio related topics are beyond the scope of this report. These will require a significant amount of study before a broadcast satellite can be designed and commissioned to best serve the Canadian need.

6.2 Network Cue and Control

For operational flexibility it is likely that a network control system will be required for feeder links. The signals to effect this control function should originate from the national prime programming locations and these signals should be multiplexed into the broadcast satellite channel. Many possibilities exist for such a system, and one such is included in Appendix D.

It is envisaged that a system for the purpose of providing network cues and associated program release cues would be included in the control system. To date, little use has been made of such features in the CBC system; however, the increased demands of a broadcast satellite service would make such a cue mechanism desirable.

7.0 BROADCAST SATELLITES FOR THE TRANSMISSION OF HDTV AND EDTV SIGNALS

The advent of 12 GHz direct broadcast satellites is seen as an opportunity for improved quality of transmission as well as the rapid introduction of new services.

In order for the consumer to receive the signal, a new receive facility will be required consisting of antenna, LNA, frequency converter and demodulator. The cost of this equipment, whether designed to receive conventional video signal formats or some of the new and developing systems for increased quality or definition, would be little different.

Recent developments in analogue component schemes which can be accommodated in the bandwidth being proposed for the RARC 83 planning should certainly be evaluated in comparison with NTSC for satellite transmission. The feasibility has already been established.

For example, the Multiplexed Analogue Component (MAC) systems recently demonstrated have a better quality of picture than regular NTSC encoded television signals. The MAC systems are free from decoding artifacts such as cross-color, cross-luminance, and transmission degradations of the differential gain and phase type. These advantages qualify these systems for enhanced quality television (EQTV)*.

The other developing systems for Extended Definition Television (EDTV)** or High Definition Television (HDTV)*** are still too early in their development to evaluate in detail. As indicated in Section 4.1, however, the broadcaster has always been concerned with the quality of the signal delivered to the consumer. With the potential developments in receiver technology, e.g. large screen projection, frame stores in the receiver, the transmission system will be the weak link in the system.

While 12 GHz direct broadcast satellites could obviously be used for EDTV and HDTV transmission, it is questionable whether the planning for these satellites should be based on the bandwidth requirements for these systems. Much work remains to be done in the development of EDTV and HDTV systems, and until the systems and their bandwidth requirements are more clearly defined it is premature to plan for their transmission.

Other spectrum is allocated to satellite service in the 23 GHz band which could be developed for an EDTV or HDTV service.

---

* EQTV: Enhanced Quality Television
A television signal that can offer a better quality of signal than a regular NTSC encoded television signal.

** EDTV: Extended Definition Television
A television signal that, through digital processing, carries more detail of the picture than the present NTSC encoded television signal.

*** HDTV: High Definition Television
A television signal that carries enough detail of the picture to enable display of the picture on a large screen with good quality. Due to the increased number of scanning lines and aspect ratio, the signal requires more bandwidth and is not compatible with existing receivers.

APPENDIX A

DETAILED OPERATING PARAMETERS FOR FEEDER-LINK LOCATIONS WITH RESPECT TO SATELLITE POSITION

The following tabulations show the relationship between elevation angle, rain attenuation (CPA) and depolarization (XPD) at each of the proposed feeder-link locations.

The starting time of solar eclipse is stated in local time.

The co-polar attenuation (CPA in dB) is the value that will be exceeded 99.71% of the time.

Cross-polarization discrimination (XPD in dB) will not be lower than the value shown 99.71% of the time.

The design objectives of a feeder-link location are:-

1. Starting time of solar eclipse should be after midnight (local time).
2. The co-polar attenuation (CPA in dB) should not be greater than 5dB for 1% of the worst month (i.e. 0.29% of the year).
3. The elevation angle must not be less than 10^{o}.

For the purpose of this appendix, site diversity is not considered.

SATELLITE POSITION: 49 °W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	35.23	23:03	1.68	35.76	NO
Halifax, N.S. 44.65°N 63.62°W	K	36.53	22:33	2.88	30.65	NO
Charlottetown, PEI 46.25°N 63.13°W	F	35	22:33	1.78	35.12	NO
Moncton, N.B. 46.10°N 64.76°W	K	34.73	22:33	2.83	30.45	NO
Fredericton, N.B. 45.95°N 66.60°W	K	34.34	22:33	2.87	30.24	NO
Sydney, N.S. 46.15°N 60.18°W	F	35.77	22:33	1.76	35.4	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	16.31	21:33	0.74	41.16	NO
Quebec City, Que. 46.83°N 71.25°W	K	31.92	21:33	2.92	29.58	NO
Montreal, Que. 44.5°N 73.58°W	K	33.17	21:33	3.1	29.21	NO
Ottawa, Ont. 45.4°N 75.72°W	K	31.43	21:33	3.12	28.83	NO
Toronto, Ont. 43.65°N 79.40°W	K	31.2	21:33	3.33	28.11	NO

SATELLITE POSITION: 49°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	17.14	20:33	4.07	24.19	NO
Regina, Sask. 50.45°N 104.63°W	E	12.6	19:33	2.43	28.97	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	10.6	19:33	2.6	28.18	NO
Calgary, Alta. 51.03°N 114.17°W	E	6.68	19:33	3.6	24.76	NO
Edmonton, Alta. 53.53°N 113.28°W	E	6.3	19:33	3.47	25.09	NO
Yellowknife, NWT 62.47°N 114.37°W	C	2.4	19:33	2.89	26.83	NO
Vancouver, B.C. 49.28°N 123.12°W	D	1.6	18:33	5.48	20.44	NO
Whitehorse, Y.T. 60,72°N 135.05°W	C	–	17:33	–	–	NO

SATELLITE POSITION: 56°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	35.25	23:31	1.68	35.77	NO
Halifax, N.S. 44.65°N 63.62°W	K	38	23:01	2.81	31.26	NO
Charlottetown, PEI 46.25°N 63.13°W	F	36.34	23:01	1.73	35.68	NO
Moncton, N.B. 46.10°N 64.76°W	K	36.26	23:01	2.74	31.1	NO
Fredericton, N.B. 45.95°N 66.60°W	K	36.1	23:01	2.77	31	NO
Sydney, N.S. 46.15°N 60.18°W	F	36.75	23:01	1.73	35.8	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	17.3	22:01	0.7	41.75	NO
Quebec City, Que. 46.83°N 71.25°W	K	34.12	22:01	2.78	30.5	NO
Montreal, Que. 44.5°N 73.58°W	K	35.8	22:01	2.94	30.29	NO
Ottawa, Ont. 45.4°N 75.72°W	K	34.2	22:01	2.94	30	NO
Toronto, Ont. 43.65°N 79.40°W	K	34.45	22:01	3.11	29.44	NO

SATELLITE POSITION: 56°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	20.9	21:01	3.51	26.06	NO
Regina, Sask. 50.45°N 104.63°W	E	16.56	20:01	2	31.25	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	14.48	20:01	2.08	30.66	NO
Calgary, Alta. 51.03°N 114.17°W	E	10.84	20:01	2.65	28	NO
Edmonton, Alta. 53.53°N 113.28°W	E	10.19	20:01	2.55	28.35	NO
Yellowknife, NWT 62.47°N 114.37°W	C	5.38	20:01	1.83	31.49	NO
Vancouver, B.C. 49.28°N 123.12°W	D	6.05	19:01	3.38	25.35	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	–	18:01	–	–	NO

SATELLITE POSITION: 63°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	34.43	23:59	1.71	35.43	YES
Halifax, N.S. 44.65°N 63.62°W	K	38.56	23:29	2.78	31.49	NO
Charlottetown, PEI 46.25°N 63.13°W	F	36.8	23:29	1.72	35.87	NO
Moncton, N.B. 46.10°N 64.76°W	K	36.94	23:29	2.71	31.37	NO
Fredericton, N.B. 45.95°N 66.60°W	K	37	23:29	2.72	31.34	NO
Sydney, N.S. 46.15°N 60.18°W	F	36.84	23:29	1.73	35.85	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	17.87	22:29	0.68	42.08	NO
Quebec City, Que. 46.83°N 71.25°W	K	35.55	22:29	2.7	31.1	NO
Montreal, Que. 44.5°N 73.58°W	K	37.65	22:29	2.84	31.06	NO
Ottawa, Ont. 45.4°N 75.72°W	K	36.2	22:29	2.82	30.8	NO
Toronto, Ont. 43.65°N 79.40°W	K	37.0	22:29	2.96	30.48	NO

SATELLITE POSITION: 63°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	24.29	21:29	3.13	27.63	NO
Regina, Sask. 50.45°N 104.63°W	E	20.27	20:09	1.72	33.13	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	18.1	20:29	1.76	32.65	NO
Calgary, Alta. 51.03°N 114.17°W	E	14.82	20:29	2.13	30.48	NO
Edmonton, Alta. 53.53°N 113.28°W	E	13.9	20:29	2.04	30.82	NO
Yellowknife, NWT 62.47°N 114.37°W	C	8.17	20:29	1.36	34.56	NO
Vancouver, B.C. 49.28°N 123.12°W	D	10.42	19:29	2.45	28.77	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	-	18:29	-	-	NO

SATELLITE POSITION: 70 °W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	32.8	00:27	1.77	34.75	YES
Halifax, N.S. 44.65°N 63.62°W	K	38.17	23:57	2.8	31.32	YES
Charlottetown, PEI 46.25°N 63.13°W	F	36.37	23:57	1.73	35.7	YES
Moncton, N.B. 46.10°N 64.76°W	K	36.7	23:57	2.72	31.28	YES
Fredericton, N.B. 45.95°N 66.60°W	K	37.02	23:57	2.72	31.35	YES
Sydney, N.S. 46.15°N 60.18°W	F	36.03	23:57	1.75	35:51	YES
Frobisher Bay, NWT 63.73°N 68.55°W	C	18	22:57	0.68	42.14	NO
Quebec City, Que. 46.83°N 71.25°W	K	36.15	22:57	2.67	31.34	NO
Montreal, Que. 44.5°N 73.58°W	K	38.6	22:57	2.8	31.45	NO
Ottawa, Ont. 45.4°N 75.72°W	K	37.43	22:57	2.76	31.3	NO
Toronto, Ont. 43.65°N 79.40°W	K	38.78	22:57	2.87	31.22	NO

SATELLITE POSITION: 70 °W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	27.24	21:57	2.87	28.92	NO
Regina, Sask. 50.45°N 104.63°W	E	23.64	20:57	1.53	34.7	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	21.4	20:57	1.55	34.3	NO
Calgary, Alta. 51.03°N 114.17°W	E	18.58	20:57	1.8	32.5	NO
Edmonton, Alta. 53.53°N 113.28°W	E	17.35	20:57	1.72	32.8	NO
Yellowknife, NWT 62.47°N 114.37°W	C	10.76	20:57	1.1	36.8	NO
Vancouver, B.C. 49.28°N 123.12°W	D	14.64	19:57	1.94	31.38	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	3.23	18:57	2.6	27.9	NO

SATELLITE POSITION: 77°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	30.46	00:55	1.87	33.8	YES
Halifax, N.S. 44.65°N 63.62°W	K	36.85	00:25	2.87	30.78	YES
Charlottetown, PEI 46.25°N 63.13°W	F	35.07	00:25	1.78	35.2	YES
Moncton, N.B. 46.10°N 64.76°W	K	35.6	00:25	2.78	30.8	YES
Fredericton, N.B. 45.95°N 66.60°W	K	36.14	00:25	2.76	31	YES
Sydney, N.S. 46.15°N 60.18°W	F	34.4	00:25	1.81	34.8	YES
Frobisher Bay, NWT 63.73°N 68.55°W	C	17.7	23:25	0.69	42	NO
Quebec City, Que. 46.83°N 71.25°W	K	35.87	23:25	2.68	31.22	NO
Montreal, Que. 44.5°N 73.58°W	K	38.62	23:25	2.79	31.5	NO
Ottawa, Ont. 45.4°N 75.72°W	K	37.72	23:25	2.74	31.42	NO
Toronto, Ont. 43.65°N 79.40°W	K	39.6	23:25	2.83	31.57	NO

SATELLITE POSITION: 77°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	29.66	22:25	2.7	29.96	NO
Regina, Sask. 50.45°N 104.63°W	E	26.58	21:25	1.4	36	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	24.32	21:25	1.4	35.65	NO
Calgary, Alta. 51.03°N 114.17°W	E	22.02	21:25	1.58	34.17	NO
Edmonton, Alta. 53.53°N 113.28°W	E	20.5	21:25	1.52	34.41	NO
Yellowknife, NWT 62.47°N 114.37°W	C	13.09	21:25	0.94	38.54	NO
Vancouver, B.C. 49.28°N 123.12°W	D	18.65	20:25	1.63	33.5	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	6.36	19:25	1.72	32.1	NO

SATELLITE POSITION: 84°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's,Nfld. 47.57°N 52.70°W	F	27.5	01:23	2	8.36	YES
Halifax, N.S. 44.65°N 63.62°W	K	34.7	00:53	3	29.9	YES
Charlottetown,PEI 46.25°N 63.13°W	F	32.97	00:53	1.86	34.28	YES
Moncton, N.B. 46.10°N 64.76°W	K	33.67	00:53	2.89	30	YES
Fredericton, N.B. 45.95°N 66.60°W	K	34.4	00:53	2.86	30.26	YES
Sydney, N.S. 46.15°N 60.18°W	F	31.96	00:53	1.91	33.83	YES
Frobisher Bay,NWT 63.73°N 68.55°W	C	16.94	23:53	0.72	41.54	YES
Quebec City, Que. 46.83°N 71.25°W	K	34.7	23:53	2.75	30.74	YES
Montreal, Que. 44.5°N 73.58°W	K	37.7	23:53	2.84	31	YES
Ottawa, Ont. 45.4°N 75.72°W	K	37.1	23:53	2.77	31.16	YES
Toronto, Ont. 43.65°N 79.40°W	K	39.46	23:53	2.84	31.5	YES

SATELLITE POSITION: 84°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	31.43	22:53	2.58	30.7	NO
Regina, Sask. 50.45°N 104.63°W	E	28.98	21:53	1.3	37	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	26.74	21:53	1.3	36.74	NO
Calgary, Alta. 51.03°N 114.17°W	E	25.07	21:53	1.43	35.56	NO
Edmonton, Alta. 53.53°N 113.28°W	E	23.25	21:53	1.37	35.73	NO
Yellowknife, NWT 62.47°N 114.37°W	C	15.1	21:53	0.83	39.9	NO
Vancouver, B.C. 49.28°N 123.12°W	D	22.4	20:53	1.42	35.28	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	9.33	19:53	1.31	35	NO

SATELLITE POSITION: 91°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	24	01:51	2.22	31.02	YES
Halifax, N.S. 44.65°N 63.62°W	K	31.8	01:21	3.18	28.7	YES
Charlottetown, PEI 46.25°N 63.13°W	F	30.18	01:21	1.98	33.13	YES
Moncton, N.B. 46.10°N 64.76°W	K	31.0	01:21	3.06	28.92	YES
Fredericton, N.B. 45.95°N 66.60°W	K	31.9	01:21	3	29.2	YES
Sydney, N.S. 46.15°N 60.18°W	F	28.9	01:21	2.05	32.56	YES
Frobisher Bay, NWT 63.73°N 68.55°W	C	15.78	00:21	0.76	40.84	YES
Quebec City, Que. 46.83°N 71.25°W	K	32.8	00:21	2.86	29.94	YES
Montreal, Que. 44.5°N 73.58°W	K	35.85	00:21	2.94	30.31	YES
Ottawa, Ont. 45.4°N 75.72°W	K	35.58	00:21	2.86	30.53	YES
Toronto, Ont. 43.65°N 79.40°W	K	38.3	00:21	2.89	31	YES

SATELLITE POSITION: 91°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	32.5	23:21	2.52	31.16	NO
Regina, Sask. 50.45°N 104.63°W	E	30.77	23:21	1.25	37.82	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	28.6	23:21	1.24	37.55	NO
Calgary, Alta. 51.03°N 114.17°W	E	27.63	22:31	1.33	36.69	NO
Edmonton, Alta. 53.53°N 113.28°W	E	25.53	22:21	1.28	37.77	NO
Yellowknife, NWT 62.47°N 114.37°W	C	16.8	22:21	0.76	40.89	NO
Vancouver, B.C. 49.28°N 123.12°W	D	25.7	21:21	1.28	36.78	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	12.10	20:21	1.07	37.16	NO

SATELLITE POSITION: 98°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	20.18	02:19	2.53	29.26	YES
Halifax, N.S. 44.65°N 63.62°W	K	28.3	01:49	3.45	27.26	YES
Charlottetown, PEI 46.25°N 63.13°W	F	26.81	01:49	2.16	31.72	YES
Moncton, N.B. 46.10°N 64.76°W	K	27.76	01:49	3.32	27.56	YES
Fredericton, N.B. 45.95°N 66.60°W	K	28.79	01:49	3.25	27.94	YES
Sydney, N.S. 46.15°N 60.18°W	F	25.33	01:49	2.26	31	YES
Frobisher Bay, NWT 63.73°N 68.55°W	C	14.25	00:49	0.83	39.86	YES
Quebec City, Que. 46.83°N 71.25°W	K	30.15	00:49	3.04	28.84	YES
Montreal, Que. 44.5°N 73.58°W	K	33.24	00:49	3.1	29.24	YES
Ottawa, Ont. 45.4°N 75.72°W	K	33.26	00:49	2.99	29.58	YES
Toronto, Ont. 43.65°N 79.40°W	K	36.3	00:49	3	30.2	YES

SATELLITE POSITION: 98^{o}W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 ^{o}N 97.17^{o}W	K	32.8	23:49	2.5	31.29	NO
Regina, Sask. 50.45^{o}N 104.63^{o}W	E	31.86	22:49	1.22	38.29	NO
Saskatoon, Sask. 52.13^{o}N 106.68^{o}W	E	29.8	22:49	1.2	38.08	NO
Calgary, Alta. 51.03^{o}N 114.17^{o}W	E	29.6	22:49	1.26	37.55	NO
Edmonton, Alta. 53.53^{o}N 113.28^{o}W	E	27.27	22:49	1.21	37.55	NO
Yellowknife, NWT 62.47^{o}N 114.37^{o}W	C	18.07	22:49	0.72	41.63	NO
Vancouver, B.C. 49.28^{o}N 123.12^{o}W	D	28.58	21:49	1.18	38.02	NO
Whitehorse, Y.T. 60.72^{o}N 135.05^{o}W	C	14.57	20:49	0.92	38.84	NO

SATELLITE POSITION: 105°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	16.0	02:47	2.99	27.18	YES
Halifax, N.S. 44.65°N 63.62°W	K	24.35	02:17	3.85	25.59	YES
Charlottetown, PEI 46.25°N 63.13°W	F	23	02:17	2.41	30	YES
Moncton, N.B. 46.10°N 64.76°W	K	24.0	02:17	3.69	25.96	YES
Fredericton, N.B. 45.95°N 66.60°W	K	25.16	02:17	3.59	26.4	YES
Sydney, N.S. 46.15°N 60.18°W	F	21.34	02:17	2.56	29.28	YES
Frobisher Bay, NWT 63.73°N 68.55°W	C	12.37	01:17	0.93	38.55	YES
Quebec City, Que. 46.83°N 71.25°W	K	26.93	01:17	3.3	27.49	YES
Montreal, Que. 44.5°N 73.58°W	K	29.97	01:17	3.33	27.9	YES
Ottawa, Ont. 45.4°N 75.72°W	K	30.27	01:17	3.2	28.35	YES
Toronto, Ont. 43.65°N 79.40°W	K	33:50	01:17	3.17	29.05	YES

SATELLITE POSITION: 105°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	32.3	00:17	2.54	31.1	YES
Regina, Sask. 50.45°N 104.63°W	E	32.2	23:17	1.21	38.43	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	30.36	23:17	1.18	38.3	NO
Calgary, Alta. 51.03°N 114.17°W	E	30.93	23:17	1.22	38.11	NO
Edmonton, Alta. 53.53°N 113.28°W	E	28.39	23:17	1.18	38.04	NO
Yellowknife, NWT 62.47°N 114.37°W	C	18.91	23:17	0.69	42.1	NO
Vancouver, B.C. 49.28°N 123.12°W	D	30.86	22:17	1.12	38.99	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	16.72	21:17	0.82	40.16	NO

SATELLITE POSITION: 112°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's,Nfld. 47.57°N 52.70°W	F	11.64	03:15	3.72	24.68	NO
Halifax, N.S. 44.65°N 63.62°W	K	20	02:45	4.42	23.67	YES
Charlottetown,PEI 46.25°N 63.13°W	F	18.83	02:45	2.79	28.14	YES
Moncton, N.B. 46.10°N 64.76°W	K	19.91	02:45	4.23	24.1	YES
Fredericton, N.B. 45.95°N 66.60°W	K	21.12	02:45	4.07	24.61	YES
Sydney, N.S. 46.15°N 60.18°W	F	17	02:45	3	27.22	YES
Frobisher Bay,NWT 63.73°N 68.55°W	C	10.19	01:45	1.09	36.86	YES
Quebec City, Que. 46.83°N 71.25°W	K	23.24	01:45	3.68	25.88	YES
Montreal, Que. 44.5°N 73.58°W	K	26.18	01:45	3.67	26.32	YES
Ottawa, Ont. 45.4°N 75.72°W	K	26.72	01:45	3.5	26.86	YES
Toronto, Ont. 43.65°N 79.40°W	K	30	01:45	3.42	27.64	YES

SATELLITE POSITION: 112°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	31.07	00:45	2.6	30.59	YES
Regina, Sask. 50.45°N 104.63°W	E	31.78	23:45	1.22	38.25	NO
Saskatoon, Sask. 52.13°N 106.68°W	E	30.17	23:45	1.19	38.22	NO
Calgary, Alta. 51.03°N 114.17°W	E	31.54	23:45	1.2	38.37	NO
Edmonton, Alta. 53.53°N 113.28°W	E	28.85	23:45	1.16	38.24	NO
Yellowknife, NWT 62.47°N 114.37°W	C	19.3	23:45	0.68	42.31	NO
Vancouver, B.C. 49.28°N 123.12°W	D	32.48	22:45	1.07	39.66	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	18.50	21:45	0.75	41.16	NO

SATELLITE POSITION: 119°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	7.11	03:43	5	21.48	NO
Halifax, N.S. 44.65°N 63.62°W	K	15.46	03:13	5.29	21.43	NO
Charlottetown, PEI 46.25°N 63.13°W	F	14.41	03:13	3.36	25.87	YES
Moncton, N.B. 46.10°N 64.76°W	K	15.53	03:13	5.03	21.93	NO
Fredericton, N.B. 45.95°N 66.60°W	K	16.78	03:13	4.8	22.52	YES
Sydney, N.S. 46.15°N 60.18°W	F	12.54	03:13	3.7	24.77	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	7.76	02:13	1.34	34.64	NO
Quebec City, Que. 46.83°N 71.25°W	K	19.18	02:13	4.23	24.01	YES
Montreal, Que. 44.5°N 73.58°W	K	22	02:13	4.16	24.50	YES
Ottawa, Ont. 45.4°N 75.72°W	K	22.73	02:13	3.94	25.14	YES
Toronto, Ont. 43.65°N 79.40°W	K	26.08	02:13	3.79	25.99	YES

SATELLITE POSITION: 119°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	29.14	01:13	2.73	29.74	YES
Regina, Sask. 50.45°N 104.63°W	E	30.61	00:13	1.26	37.76	YES
Saskatoon, Sask. 52.13°N 106.68°W	E	29.28	00:13	1.22	37.84	YES
Calgary, Alta. 51.03°N 114.17°W	E	31.4	00:13	1.21	38.31	YES
Edmonton, Alta. 53.53°N 113.28°W	E	28.64	00:13	1.17	38.15	YES
Yellowknife, NWT 62.47°N 114.37°W	C	19.23	00:13	0.68	42.28	YES
Vancouver, B.C. 49.28°N 123.12°W	D	33.34	23:13	1.05	40.03	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	19.86	22:13	0.71	41.90	NO

SATELLITE POSITION: 126°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	2.5	04:11	7.74	17.01	NO
Halifax, N.S. 44.65°N 63.62°W	K	10.72	03:41	6.69	18.74	NO
Charlottetown, PEI 46.25°N 63.13°W	F	9.82	03:41	4.3	23.1	NO
Moncton, N.B. 46.10°N 64.76°W	K	10.96	03:41	6.34	19.30	NO
Fredericton, N.B. 45.95°N 66.60°W	K	12.24	03:41	5.93	20.04	NO
Sydney, N.S. 46.15°N 60.18°W	F	7.88	03:41	4.91	21.70	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	5.12	02:41	1.81	31.58	NO
Quebec City, Que. 46.83°N 71.25°W	K	14.86	02:41	5.07	21.81	NO
Montreal, Que. 44.5°N 73.58°W	K	17.5	02:41	4.88	22.41	YES
Ottawa, Ont. 45.4°N 75.72°W	K	18.42	02:41	4.57	23.15	YES
Toronto, Ont. 43.65°N 79.40°W	K	21.74	02:41	4.31	24.12	YES

SATELLITE POSITION: 126°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	26.59	01:41	2.93	28.64	YES
Regina, Sask. 50.45°N 104.63°W	E	28.76	00:41	1.32	36.97	YES
Saskatoon, Sask. 52.13°N 106.68°W	E	27.71	00:41	1.27	37.16	YES
Calgary, Alta. 51.03°N 114.17°W	E	30.51	00:41	1.23	37.93	YES
Edmonton, Alta. 53.53°N 113.28°W	E	27.75	00:41	1.2	37.76	YES
Yellowknife, NWT 62.47°N 114.37°W	C	18.69	00:41	0.7	41.98	YES
Vancouver, B.C. 49.28°N 123.12°W	D	33.41	23:41	1.05	40.06	NO
Whitehorse, Y.T. 60.72°N 135.05°W	C	20.76	22:41	0.69	42.36	NO

SATELLITE POSITION: 133°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	-	04:39	-	-	NO
Halifax, N.S. 44.65°N 63.62°W	K	5.86	04:09	9.27	15.28	NO
Charlottetown, PEI 46.25°N 63.13°W	F	5.11	04:09	6.09	19.45	NO
Moncton, N.B. 46.10°N 64.76°W	K	6.26	04:09	8.7	15.91	NO
Fredericton, N.B. 45.95°N 66.60°W	K	7.55	04:09	7.92	16.90	NO
Sydney, N.S. 46.15°N 60.18°W	F	3.13	04:09	7.37	17.49	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	2.32	03.09	2.85	26.98	NO
Quebec City, Que. 46.83°N 71.25°W	K	10.35	03:09	6.43	19.12	NO
Montreal, Que. 44.5°N 73.58°W	K	12.8	03:09	6.01	19.94	NO
Ottawa, Ont. 45.4°N 75.72°W	K	13.9	03:09	5.56	20.81	NO
Toronto, Ont. 43.65°N 79.40°W	K	17.12	03:09	5.08	21.97	NO

SATELLITE POSITION: 133°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	23.5	02:09	3.21	27.28	YES
Regina, Sask. 50.45°N 104.63°W	E	26.3	01:09	1.41	35.89	YES
Saskatoon, Sask. 52.13°N 106.68°W	E	25.55	01:09	1.35	36.2	YES
Calgary, Alta. 51.03°N 114.17°W	E	28.93	01:09	1.28	37.26	YES
Edmonton, Alta. 53.53°N 113.28°W	E	26.23	01:09	1.25	37.09	YES
Yellowknife, NWT 62.47°N 114.37°W	C	17.7	01:09	0.73	41.43	YES
Vancouver, B.C. 49.28°N 123.12°W	D	32.7	00:09	1.07	39.75	YES
Whitehorse, Y.T. 60.72°N 135.05°W	C	21.16	23:09	0.67	42.57	NO

SATELLITE POSITION: 140°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	–	05:07	–	–	NO
Halifax, N.S. 44.65°N 63.62°W	K	–	04:37	–	–	NO
Charlottetown, PEI 46.25°N 63.13°W	F	0.35	04:37	–	–	NO
Moncton, N.B. 46.10°N 64.76°W	K	1.49	04:37	13.88	11.16	NO
Fredericton, N.B. 45.95°N 66.60°W	K	2.78	04:37	12.05	12.59	NO
Sydney, N.S. 46.15°N 60.18°W	F	–	04:37	–	–	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	–	03:37	–	–	NO
Quebec City, Que. 46.83°N 71.25°W	K	5.71	03:37	8.95	15.62	NO
Montreal, Que. 44.5°N 73.58°W	K	7.97	03:37	7.96	16.87	NO
Ottawa, Ont. 45.4°N 75.72°W	K	9.16	03:37	7.2	17.92	NO
Toronto, Ont. 43.65°N 79.40°W	K	12.3	03:37	6.3	19.43	NO

SATELLITE POSITION: 140°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	20.0	02:37	3.63	25.64	YES
Regina, Sask. 50.45°N 104.63°W	E	23.3	01:37	1.54	34.56	YES
Saskatoon, Sask. 52.13°N 106.68°W	E	22.86	01:37	1.47	34.98	YES
Calgary, Alta. 51.03°N 114.17°W	E	26.72	01:37	1.36	36.30	YES
Edmonton, Alta. 53.53°N 113.28°W	E	24.14	01:37	1.33	36.14	YES
Yellowknife, NWT 62.47°N 114.37°W	C	16.29	01:37	0.78	40.6	YES
Vancouver, B.C. 49.28°N 123.12°W	D	31.2	00:37	1.11	39.13	YES
Whitehorse, Y.T. 60.72°N 135.05°W	C	21.05	23:37	0.68	42.52	NO

SATELLITE POSITION: 147°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
St. John's, Nfld. 47.57°N 52.70°W	F	-	05:35	-	-	NO
Halifax, N.S. 44.65°N 63.62°W	K	-	05:05	-	-	NO
Charlottetown, PEI 46.25°N 63.13°W	F	-	05:05	-	-	NO
Moncton, N.B. 46.10°N 64.76°W	K	-	05:05	-	-	NO
Fredericton, N.B. 45.95°N 66.60°W	K	-	05:05	-	-	NO
Sydney, N.S. 46.15°N 60.18°W	F	-	05:05	-	-	NO
Frobisher Bay, NWT 63.73°N 68.55°W	C	-	04:05	-	-	NO
Quebec City, Que. 46.83°N 71.25°W	K	1.0	04:05	14.6	10.66	NO
Montreal, Que. 44.5°N 73.58°W	K	3.1	04:05	11.93	12.69	NO
Ottawa, Ont. 45.4°N 75.72°W	K	4.4	04:05	10.4	14	NO
Toronto, Ont. 43.65°N 79.40°W	K	7.4	04:05	8.45	16.25	NO

SATELLITE POSITION: 147°W

Feeder-Link Location	Rain Region	Elevation Angle	Starting time of Solar Eclipse (hr:min)	CPA (dB)	XPD (dB)	Are design objectives met?
Winnipeg, Man. 49.9 °N 97.17°W	K	16.2	03:05	4.24	23.69	YES
Regina, Sask. 50.45°N 104.63°W	E	19.9	02:05	1.74	32.95	YES
Saskatoon, Sask. 52.13°N 106.68°W	E	19.73	02:05	1.65	33.47	YES
Calgary, Alta. 51.03°N 114.17°W	E	23.96	02:05	1.48	35.07	YES
Edmonton, Alta. 53.53°N 113.28°W	E	21.55	02:05	1.46	34.92	YES
Yellowknife, NWT 62.47°N 114.37°W	C	14.50	02:05	0.86	39.49	YES
Vancouver, B.C. 49.28°N 123.12°W	D	29.0	01:05	1.17	38.21	YES
Whitehorse, Y.T. 60.72°N 135.05°W	C	20.45	00:05	0.69	42.2	YES

APPENDIX B - PRESENT USE OF SATELLITE FACILITIES BY BROADCASTERS

Canadian Broadcasting Corporation

One channel (transponder) is used by the French network and two by the English. French language programs originate in the Maison de Radio-Canada in Montreal, travel over CBC's microwave circuits to the Telesat transmit station at Rivière Rouge and, thence, to Anik B. They are received in regional centers at six locations for time delay, if required, and integration with regional programs. These signals are also received at more than 40 remote locations for direct broadcast over transmitters. In some instances, the release time is not aligned with local time, but no economical means of local delay is yet available in isolated locations.

English network programming is originated in Toronto, carried by CBC microwave to Telesat's Allan Park station, and released in Atlantic time for broadcast in the Maritime and Newfoundland time zones directly. Western locations, except B. C., receive and delay this feed for release at correct local times. The feed is interrupted occasionally during regional origination periods for Newfoundland News. A second channel is used to send a similar program sequence at Pacific time for British Columbia and northwestern Canada, and Vancouver inserts regional news and features. At this time, in excess of 170 earth stations connect to TV transmitters and cable systems to serve the public in remote areas.

Two omnibus channels are used to gather programs from regional centres for integration with network releases and to transmit inserts of programs of special interest to limited geographic or demographic areas. For example, a sporting event might have restricted distribution rights, or certain commercial subjects (eg. beer) might have legal restrictions for certain areas.

Because of these compromises, some remote locations may not necessarily receive a perfect mix of content at the appropriate local time. There is usually a compromise in programs put on air at our northern transmitters, although we have the means to switch the earth stations remotely to our omnibus channel for special programming.

The technical details of CBC's existing satellite transmission system are as follows. The television signal frequency modulates a microwave carrier on one channel of the 6 GHz frequency band. The accompanying sound is carried over an FM subcarrier at 6.8 MHz in the video baseband. The subcarrier is modulated, in fact, with three signals - TV audio from 0-5 kHz, radio program audio between 7 kHz and 12 kHz, and a data channel from 18 kHz to 21 kHz. At the time of design and implementation in 1973, it appeared to offer a good technical solution to distributing TV audio and control with the bonus of an extra radio channel at very low cost. In practice, it has been overtaken by the need for video source flexibility, which limits the radio channel usefulness, and the desire for better quality TV sound, which the system limits to 5 kHz bandwidth.

The major shortcoming of subcarrier audio channels is that their source feeder-link location must coincide with that for the associated TV channel. It limits the usefulness of this distribution method on variable source TV distribution transponders. For this reason, another means of radio program transmission was developed. It is a low-level single-channel-per-carrier channel located near the lower edge of each transponder and referred to as Audio 4; indeed, another such carrier, referred to as Audio 5, is now being implemented. These channels can be accessed from any properly equipped earth station and are used primarily in the North to carry programming in English, French and native languages.

A new chapter has been added to CBC programming through the broadcasts of House of Commons proceedings on a daily basis. Two channels on Anik D are used to feed H.O.C. English and French programs to many cable TV headend earth stations.

The original Anik A satellites, Anik B, and Anik D, employ 6 GHz feeder links and 4 GHz down-links at relatively low power. Additionally, the 4 GHz receiving band is shared with terrestrial microwave services and it is not always possible to eliminate interference to the satellite earth station receiver. For practical purposes, the minimum earth station receive antenna size is 4.5 meters for broadcast use. Given these restrictions to individual access, another frequency band using 14 GHz for feeder links and 12 GHz for ground receive stations is allocated to satellite services.

In Canada, use of this band began with Hermes, a very powerful satellite which one could receive with a reasonable quality using antennas as small as a 60 cm - a much more manageable direct-to-home device. Joint development between the U.S.A. and Canada brought forth many active experiments in social studies, broadcasting, medicine, and interactive communications. Alas, Hermes is now history, but its place has been taken in part by Anik B, which has experimental 14/12 GHz channels installed in that spacecraft under federal government funding to continue experiments on the higher frequency band.

The 14/12 GHz channels in Anik B are about 1/10 the power of those in Hermes, so much of the direct-to-home attraction is lost. Antenna sizes have been 1.2m, 1.8m and larger, with sharing of the few available transponders by many users. It has been called semi-DBS but, in reality, only provides the opportunity in real terms for satellite to community, as one can achieve only marginal performance with the smaller earth stations.

Anik C was launched late in 1982 and provides a variety of special message and broadcast services, in particular continuing those 14/12 GHz services at present using Anik B. Unfortunately for the CBC, coverage of the whole Canadian landmass will not be possible with a single channel on Anik C. Two transponders would be needed and the limited footprints, which do not satisfactorily cover the north, and power limitations militate against small, low-cost earth stations for mass receiving.

Other Broadcasters

Generally, the southern strip of Canada has a wide variety of Canadian and U.S. signals available. As a result of the need to provide an equivalent television broadcast service in all parts of Canada, the government has licensed CANCOM to provide four Canadian TV channels to CATV systems and transmitters using the Anik satellites. Programs originate from private stations in Vancouver, Edmonton, Hamilton and Montreal, are sent via feeder links to Anik D, the same satellite as CBC House of Commons broadcasting, and are received by cable operators and communities. There is a fee for this service based upon the audience served by each operator. To date, over 250 cable operators have been authorized to become affiliates of the system, although the actual number connected is not certain. It is interesting to note that CANCOM has begun to encrypt some of its program material to eliminate unauthorized uses by operators or individuals. It is expected that over 1,200 CATV systems could eventually be part of this system. CANCOM has now applied for permission to distribute some U.S. television signals.

Another user of the Anik system is LaSette - a network dedicated to the importation, conversion and distribution of TDF 1, 2, 3 programs from France. Material is shipped on video tape to Montreal, standards converted and edited, and sent via half of one 14/12 GHz channel to more than 50 CATV systems in Quebec.

TV Ontario, and Knowledge Network in British Columbia, are using Anik C to distribute educational programming on 14/12 GHz within their provinces. Pay-TV has commenced operation on 14/12 GHz with a total of 8 signals from Anik C being carried to cable TV systems across Canada.

APPENDIX C - EXISTING TECHNICAL STANDARDS

The Corporation has issued a document summarizing the technical standards used for CBC television broadcasting. An excerpt, containing updated figures, is included in this appendix. The original document, available from CBC, is entitled "Technical Quality Standards for CBC Television Services", Development Report 4914-1, dated December 1978.

PURPOSE

A television receiver will reproduce an image whose fidelity to the image leaving the picture source depends on the extent of accumulated distortions in the delivery system linking the viewer to the program origin. Economic factors require that distortions be reduced only to that level which will result in most viewers receiving pictures which are acceptable to themselves most of the time. Since the picture signal is distorted throughout its passage to the home screen, the design engineer is required to apportion varying amounts of the overall permissible distortion to each of the many elements of the delivery chain. Knowledge of the overall distortion that is permissible comes from subjective experiments.

Relationships between the most important impairments and viewer reactions are known and, accordingly, the CBC is in a position to optimally-tailor its delivery systems to subjective goals. The purpose of this report is first to establish picture quality objectives (as seen by the viewer) for our television services and secondly to propose corresponding technical standards for the end-to-end systems (ie: camera encoder to professional receiver) to ensure picture quality objectives are met.

SUMMARY

Picture quality objectives for CBC television services proposed by Kaiser° have been reviewed in the light of extensive Quality Assurance Vehicle (QAV) data gathered since that time. This data has shown that more relaxed objectives are appropriate in order that stations might have a reasonable chance of attaining them. They are given below in terms of percentage of time (compliance) that each grade (using the C.C.I.R. five-grade quality scale) must be achieved.

Time Percentage / Stations	$\geqslant 3$	$\geqslant 4$
Group 1*	99%	65%
Group 2**	65%	-

Table 0.1 Picture Quality Objectives

These relatively modest picture quality objectives take into account the many source impairments, such as VTR banding, which may occur before a program enters the delivery system.

QAV results to date reveal that in many cases we are not meeting these objectives as yet. Meeting them will require the CBC to pay closer attention to faults both in the production and delivery of our programs.

QAV experience has shown a need to separate picture quality achieved with local programming from that of network programming. This is to permit more effective follow-up with local management after QAV audits. Accordingly, these objectives should be applied separately at each location to both types of programming.

° P. Kaiser: Tentative Overall Service Standards, Internal Memorandum, February 8, 1977.

---

* Group 1 Stations include all Network Stations.

** Group 2 Stations include all Rebroadcast Stations.

2. To meet the above objectives, the total system (i.e.: from camera encoder to professional receiver output) must be within specifications. To determine what the specifications should be, the results of numerous subjective video experiments reported in the literature have been taken into consideration. Six parameters considered as the best indices of picture quality have been assigned end-to-end values based on these experiments and tempered with practical judgment. They are as follows:

Parameter	Stations	
	Group 1	Group 2
K-Factor (%)	8	12
Weighted Signal-to-Noise (dB)	41	36
Chrom/Lum Gain Inequality (± %)	20	36
Chrom/Lum Delay Inequality (± ns)	160	250
Differential Phase (± deg)	16	24
Differential Gain (%)	23	40

Table 0.2 End-to-End Performance Specifications

It must be stressed that the above table provides tolerances for a complete end-to-end system that includes production facilities, transmitters, satellite and microwave links, etc. Clearly, any one part of the system would have a much smaller tolerance. Subjective data reported in the literature for K-factor and differential phase suggest objectives more conservative than we have chosen. Experience with the QAV has nonetheless shown that they will permit picture quality objectives to be met. In the literature they appear unnecessarily restrictive and cannot easily be realized in a practical system.

3. End-to-end parameter magnitudes given in paragraph 2, above can be used as the basis of assignment of tolerances to elements of the delivery system. This process is outside the scope of this report. Future reports will recommend allocations for system elements such as studios, links and transmitters.

APPENDIX D - CUE AND CONTROL

1.0 General

From the broadcaster's point of view, the broadcast satellite service can essentially be divided into three general categories affecting the overall cue/control concept:

a) Services provided by the broadcaster intended for general public consumption.

b) Services internal to the broadcaster, but not intended for general public use, i.e. internal feeds, collector activity, syndication, news clips, etc.

c) Services provided by non-broadcasters intended either for public or non-public consumption

This section examines cue/control requirements in the light primarily of item (a), with consideration for (b). Item (c) is outside the study.

The basic framework of a broadcast satellite cue/control system will be determined by one of two possibilities:

1) The existence of large, multi-user feeder links not owned by the broadcasters, with a common access cue/control for all users.

2) Individual broadcaster owned and operated systems independent of other users, enabling system complexity contiguous with user needs and objectives.

Item (1) will have benefits in logically governing the area of individual household receiver addressibility, to be discussed later. Item (2) is the desirable scheme in the true democratic sense and is here assumed in this report.

2.0 System Concepts

In developing an optimum concept, one must consider as wide an implementation range as possible. The following considers the range between a sophisticated national/regional control system, integrated with existing FSS, down to a no-control concept.

2.1 No Cue/Control

This concept envisions the programming as an uninterrupted stream originating from a single source. The source gathers material by whatever means and packages it for direct broadcast to the consumer.

2.1.1 Regional Origination

This alternative in the "no-control" concept realizes the regional centre as the packaging source. No transportable feeder links would be employed on the broadcast satellite service.

2.1.2 National Origination

This alternative is similar to 2.1.1 but originates from one national centre and is fed to each regional beam from that site.

2.1.3 Summary

The advantages of this "no-control" concept are:

- Not hardware/software intensive
- Permits multiple audio subcarriers since the feeder-link source is fixed
- Maintains continuous national or regional teletext/ videotex service

2.2 Cue/Control Oriented System

Cue/control is a supervisory control and data acquisition system or, in general terms, a multi-remote, single-master communication and control system. It will permit multiple source access to the broadcast satellite program stream.

The master control unit operates under manual, pre-programmed and/or computer control. It interrogates and controls various switching functions at remote terminal units over one or more communications channels. The communication is usually via some form of FSK modulation over an appropriate data-conditioned channel.

2.2.1 Regional Control

This version identifies the Regional Centres as the points of origination and control. Various feeder-link sub-regional locations and transportable units would be under exclusive control of these Regional Centres, implying individual regional cue/control data streams.

2.2.2 National Control

Same general concept as 2.2.1 but implying one single cue/control data stream parallel fed to each feeder link.

2.2.3 National/Regional Control

While essentially relegating the network control to the National Centre, this concept differs in that control is delegated to the regional feeder link for control of local transportable and sub-regional contributions. This two-level hierarchy may be necessary to relieve the Network Centre load if the regional content is a relatively high percentage of the broadcast day's programming. Both centres can operate independently or interdependently. Each centre can control certain sectors of traffic or either can assume total control of the network.

2.2.4 FSS Integration

This final complex mode integrates the existing FSS (Fixed Satellite Service) with the broadcast satellite service identified in 2.2.3. Various program sources would be available on the domestic and U. S. 6/4 satellite system. Cue/control capability would be required to configure programs for each region from all sources, including the 6/4 network.

2.2.5 Summary

The advantages of this control-oriented concept are:

- Permits multiple-source access to the broadcast satellite program stream and is thus a critical component in the implementation of a transportable-intensive operation.

- Transmit transfers will eliminate the long-haul transmission required in a "no-control" system, thus improving signal quality.

- Cue/control addressing schemes could be easily extended to provide individual household addressibility.

3.0 Cue/Control Equipment Configuration

In a cue/control concept network, there are three basic blocks, the Master Unit (be it regionally or nationally located), the Remote Terminal Units, and the Communications Equiment. Each of these has a different and distinct environment.

3.1 Master Control System

This unit contains all computer processing, communications, display and status equipment necessary to form a data network command centre, linking itself to remote feeder links via the satellite. The centre, depending on network size, requires traditional data processing as well as modern fault-tolerant transaction-type processing. Using a variety of sophisticated editors, the operator, without resorting to any software techniques, can expand, reconfigure and control all aspects of the system at every level.

3.2 Remote Terminal System

"Intelligent" remote terminals will process interrogations, commands and sequences received from the Master Control System and initiate proper action. Equipment is fundamentally of the modern process control type with multi-tasking of discrete input/outputs and fast response to real-time earth station events.

3.3 Communications Equipment

The primary requirement of a supervisory control system is the ability to time-multiplex a single communication channel to perform an unlimited number of system functions; i.e., a flexible data link rather than a discretely dedicated control channel.

3.4 Transmission Techniques

There are two ways the data channel can be carried: through the satellite (as a bandedge SCPC, vertical blanking interval, or video subcarrier channel) or via dedicated terrestrial analogue or digital circuits.

A cue/control channel sent on a subcarrier is the least expensive method, but requires either a fixed-source video or an elaborate multi-transponder safeguard system to maintain contact through feeder-link source transfers. Support circuits, i.e. backhauls, etc., are unnecessary thus offering further savings. This method would generally be undesirable in a single satellite channel system with an intensive transportable operation.

The vertical blanking interval is a possibility, but demands from other broadcast interests render it unlikely. One Canadian manufacturer of video/audio equipment utilizes the VBI to control scrambler addressing.

SCPC techniques could permit continuous duplex communication unaffected by video source transfers, but are more expensive due to the extra transmission and down conversion equipment required. Bandedge SCPC may be restricted should future transponder bandwidths be narrowed. A duplex SCPC system offers advantages over one-way control by enabling status feedback or other voice/data communications. This is seriously offset by data rate reductions due to propagation delays inherent in satellite links.

Terrestrial circuits could be employed but represent additional costs, especially if full transponders are already leased. The major advantage of this method lies in the elimination of the satellite propagation delays for full duplex data communication.

4.0 Vertical Interval Switching

Currently, network control systems provide control of the source transfer of transmission from one earth station to another, for any RF channel, with typical interruptions at the satellite of 50 milliseconds. In a collection and distribution style of system, these disruptions are not seen by the home viewer. In a direct broadcast satellite transmission they are unacceptable. It is desirable that transient-free, vertical interval switching be incorporated by future designs.

5.0 Household Addressibility

High-speed addressing and high security have been shown to be useful adjuncts in subscriber terminal equipment used for "pay per view" programming. Should this requirement be considered for a broadcast satellite system, cue/control could be merely a sub-protocol level of the overall addressing/security data stream. In this event, a nationally standardized addressing scheme encompassing cue/control, addressing, security, teletext etc., would be desirable in providing an overall electronic "mail box" system.

APPENDIX E - TOPICS FOR FUTURE INVESTIGATION

During the preparation of this report, several topics were identified which bear, directly or indirectly, on feeder-link design. In most cases these are outside the scope of this report. It is recommended that each topic be the subject of future study.

1. Structural adequacy of a 5 m feeder-link antenna.
2. Mechanically stable transportable feeder-link antenna.
3. Multiple-beam antennas for feeder-links and for reception at the satellite, including the improvement in gain and polarization discrimination, power handling capability, and physical placement of feed hardware.
4. Methodology relating to site diversity.
5. Cue and control system between the transportable and primary feeder-link stations.
6. Optimum modulation method for audio channels.
7. Investigation of feeder-link power control during rain, and its effect on C/I_{up}.
8. Effect on C/I of depolarization due to precipitation.
9. Methods of lowering the noise temperature of the satellite transponder.
10. On-board switching systems.
11. The reasonable mix of noise and interference to achieve a picture of grade 4.5 under diminished values of aggregate C/I of the overall system.

APPENDIX F - BIBLIOGRAPHY

Bouchard, M.; "Planning of feeder links to broadcasting satellites at the 1983 RARC", Satellite Systems Conference (9th), San Diego, March 1982.

Bouchard, M.; "Planning of national feeder links in multi-beam broadcasting satellite system" section 7.2, Preparatory seminar for 1983 RARC, Ottawa, May 4-8, 1981.

Card, M. L.; Palmer, J. D.; Logan K. and Lopianowski, N. M.; "Small Earth Stations for Broadcasting Satellite Systems", Journal of the SMPTE, (March 1975).

Chu, T. S.; "Microwave Depolarization of an Earth-Space Path", The Bell System Technical Journal (July - August 1980).

Day, A. G.; "Planning for DBS: A Time to Improve NTSC Picture Quality", Broadcast Technology (January/February 1983).

Department of Communications; "Atmos3", DOC computer program (print-out dated December 21, 1982).

Eaton J. L.; "Satellite Broadcasting: Slant Path Attenuation through Rain Storms", BBC Research Division Report No. 1977/7.

Ehara, Terumasa; "Prediction of Solar Eclipses by the Moon (Moon Solar Eclipses) Occurring at the Geostationary Satellite Orbit", NHK Laboratories notes.

Independent Broadcasting Authority; "Satellites for Broadcasting", IBA Technical Review No. 11, (July 1978).

International Telecommunications Union; "Conference Preparatory Meeting for RARC-83" sections 3 and 5.

Kinik, J. and Fox, F. J.; "A Network Control System for Television Distribution by Satellite", Journal of the SMPTE, (March 1975).

Lo, G. J. P. and Bouchard, M.; "Broadcasting Satellite Technology", Section 5.1, Preparatory Seminar for 1983 RARC on broadcast satellite planning principles and Methodology, May 4-8, 1981, Ottawa, Canada.

Lin, S.H.; Bergmann, H. J.; and Pursley, M. V.; "Rain Attenuation on Earth-Satellite Paths - Summary of 10-Year Experiments and Studies", The Bell System Technical Journal (Feb. 1980).

Mertens, H.; "Satellite Broadcasting - Design and Planning of 12-GHz Systems", European Broadcasting Union Tech. 3220-E (March 1976).

Roscoe, O. S.; "Direct Broadcast Satellites - the Canadian Experience", Satellite Communication (Aug. 1980).

Siocos, C. A.; "Broadcasting Satellite Service: Minimum Elliptical Beam Determination", Journal of the SMPTE, (Mar. 1975).

Siocos, C. A.; "Broadcasting-Satellite Coverage - Geometrical Consideration", IEEE Transactions on Broadcasting Vol. BC-19 (Dec. 1973).

Siocos, C. A.; "The CCIR and Broadcasting from Satellites - A Brief Review", International Communication Conference, Boston (1979).

Siocos, C. A.; "Broadcasting Satellites Power Blackouts from Solar Eclipses due to the Moon", IEEE Transactions on Broadcasting Vol. BC-27 No. 2 (June 1981).

Waki, Kimihiko; Katayama, Masanoku; and Sonoda, Shoji; "Operational Broadcasting Satellite in Japan", IEEE Transactions on Broadcasting Vol. BC-28, No. 4 (December 1982).

Weda, Seiki, and Yoshida, Ryo; "Switching Control System for Access to a Broadcast Satellite from Multiple Earth Stations", IEEE Transactions on Broadcasting Vol. BC-28 No. 4 (Dec. 1982).

STUDY OF OPERATIONAL CONSIDERATIONS
OF FEEDER LINKS TO BROADCAST SATEL-
LITES.