FINAL REPORT
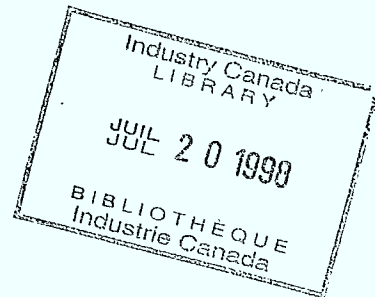
A STUDY OF CANADIAN EHF COMMUNICATION

REQUIREMENTS AND TECHNOLOGY

DEVELOPMENT

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**CANADIAN ASTRONAUTICS LIMITED**

**FINAL REPORT**

**A STUDY OF CANADIAN EHF COMMUNICATION**

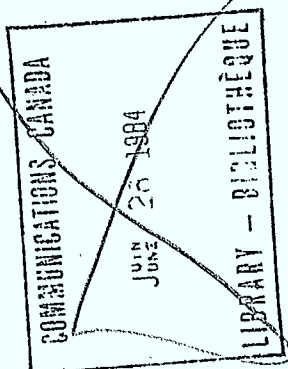**REQUIREMENTS AND TECHNOLOGY**

**DEVELOPMENT**

Prepared for:   Department of Communication, Space Planning

DOC Scientific Authority:  J. Carson
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September 1983

EHF FINAL REPORT

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## DEPARTMENT OF COMMUNICATIONS - OTTAWA - CANADA

## SPACE PROGRAM

TITLE:  A STUDY TO DETERMINE THE REQUIREMENT FOR, AND AREAS OF, TECHNOLOGICAL DEVELOPMENT OF EHF SATELLITE COMMUNICATIONS SYSTEMS IN CANADA

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SECTION 1

INTRODUCTION

and

SUMMARY OF FINDINGS

## 1.1 INTRODUCTION

This report presents the final results of "A Study of Canadian EHF Communication Requirements and Technology Development", performed for the Space Planning Department, Department of Communications.

The initial goals of the study were:

i)   to establish the projected requirements for an EHF satellite system for Canada,

ii)  to identify alternative technologies to EHF satellite communications,

iii) to model an EHF communication system for Canada,

iv)  to develop an EHF mission model,

v)   to specify operational modes,

vi)  to investigate the State-of-the-Art of EHF developments.

During the course of the study, in agreement with the scientific authority, the activity undertaken in (iii), (iv) and (v) above were reduced, while additional effort was undertaken in areas (i), (ii), and (vi). As a result of this shift in direction of emphasis, the report has ended with a format as is demonstrated pictorially in Figure 1.1-1. As the figure shows, the report is divided into five major sections:

- Section 1, which contains the Introduction to the Report.

- Section 2, which addressed the Global state-of-the-art developments in EHF technology.

- Section 3, in which suppliers or potential suppliers of EHF equipment or components are identified and their capabilities discussed.

Sections 2 and 3 present an overview of Global EHF advancements and potentials and together provide the reader a preparation for the major portion of the report, the Canadian EHF Survey, comprising Sections 4 and 5 as follows:

- Section 4, which reports the findings, extensive analysis and market survey of the Canadian Communications Industry. Chapter 4.1.1 describes the Canadian Demographic Model to the year 2000 upon which the market survey is predicted. Chapters 4.1.2 to 4.1.5 describe the Commercial market and Military and Scientific Markets. Chapters 4.1.1 through 4.1.5 collectively serve to establish the Demand Side of the Canadian Communications market equation. Chapters 4.2.1 through 4.2.3, establish the Supply Side of the Canadian Communications market equation by respectively defining the Satellite capacity, the Terrestrial Capacity and the potential for Fibre Optics Capacity within Canada to the year 2000.

Chapter 4.3, using the Demand and Supply predictions of Chapters 4.1 and 4.2, addresses the market potential for EHF services within Canada. In this chapter, the capacity for Canadian Suppliers to meet Canadian and Global needs is also covered.

- Section 5, in which a Mission Model for EHF is discussed.

The report has been formatted according to the above division of subject matter. Each section ends (where applicable) with a list of references called up within the preceeding section. There are two Appendices to the report, which are located after the text of the Section 5.

Canadian Astronautics Limited wishes to thank the Department of Communications for the opportunity to develop this report on the potential markets, requirements and technology development of EHF systems.

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CANADIAN
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**Figure 1.1-1  Report Structure**

SECTION 2

GLOBAL EHF SYSTEMS SURVEY

## 2.0  GLOBAL EHF SYSTEMS SURVEY

### 2.1  INTRODUCTION

The development of EHF satellite systems is surveyed on a global basis in this chapter. The studies done by other countries, their technology development, delineated in the following chapter, are later used as benchmarks in deriving a possible Canadian EHF mission model. An attempt will be made here to uncover the driving forces for the commitment to use EHF frequencies in these countries, and any problems that might have been encountered in the development of their systems. One of the major obstacles, of course, has been the lack of reasonably priced subsystems and components that meets the required specifications. An assessment of the EHF technology development and the current "state-of-the-art", with an aim to identifying potential areas of opportunity for Canadian industry, is deferred until the next chapter.

This survey of global systems is based mainly on a literature survey of various technical journals and conference proceedings. Further telephone contacts were made with various people in the respective administrations.

EHF or millimeter waves, with their advantages spelled out in later chapters, have been viewed as relatively new and developing technology with many potential applications. But some of the attendant difficulties, such as the cost required for technology development has kept millimeter waves, as some believe it will always be, "just around the corner". However, the past five or six years have witnessed increasing levels of interest in the development and use of the EHF spectrum [1-25]. This active interest has been spurred by the concern that the capacity of the lower frequency bands (4/6 GHz, 12/14 GHz) and the geostationary orbit space might be used up in the not-too-distant future. Military considerations and specific purpose applications have also accelerated this interest.

The major countries or administrations which are considering EHF spectrum use are Italy, Japan, the USA and the European Space Agency (ESA). No information is available on the Russian or Communist Block Countries' activities, hence any possible EHF systems there are not addressed.

| PROJECT | FREQUENCIES | LAUNCH DATE | |
|---|---|---|---|
| US ATS-V/VI | 32/30, 20 GHz | 1970 | Experimental |
| LES 8/9 | 38/36 GHz | 1976 | Experimental Military |
| MILSTAR | 44/20 | 1987/88 | Military |
| ACTS | 30/20 | 1987/88 | Experimental |
| FLEETSAT VII | 44/20 | 1988 | Proto-operational Military |
| JAPANESE ETS-II(KIKU-2) | 35/32 GHz | 1977 | Experimental |
| CS I ("SAKURA") | 30/20 GHz | 1977 | Experimental |
| CS II | 30/20 GHz | 1983 | Communication – Commercial |
| ECS | 34.5 GHz | 1977 | Experimental |
| ITALIAN ITALSAT | 30/20 GHz<br>50/40 GHz | 1987 | Domestic Communication Propagation Expts. |
| SWEDISH "TRUCKSAT" ON TELE-X SATELLITE | 30/20 GHz | 1986 | 30/20 GHz Technology Experiments |
| ESA'S LSAT | 30/20 GHz | 1986 | Experimental |
| UK SKYNET | 44/7 GHz | 1986 | Experimental Military |
| CANADA'S MSAT | 44/22 GHz | 1986 | Experimental Military |

Table 2.1  Global EHF Satellite Projects

Some of the major existing and planned EHF satellite programs are tabulated in Table 2.1. From this table it is apparent that most of the satellites launched up to now, or currently planned, are of an experimental nature. The table also illustrates the active role played by Military satellites, which normally acts as a catalyst in technology development in many areas. The following section describes the existing millimeter wave satellite systems, followed by a section describing the systems that are planned in the near future (up to about 10 years from now).

## 2.2 PRESENT SYSTEMS

Perhaps the earliest satellites equipped with millimeter wave capability were the American ATS-V and ATS-VI satellites. These satellites served primarily the purpose of propagation experiments at various frequencies. The ATS-V had an uplink of 32 GHz, and a 15 GHz beacon on-board the spacecraft as a source. On ATS-VI, in addition to a 4/6 GHz payload, the spacecraft had on-board beacons, one at 20 GHz and the other at 30 GHz, for use in propagation experiments. The U.S. COMSTAR satellite had two downlink beacons at 19 GHz and 29 GHz, respectively. All of these satellites were used extensively by Ippolito of NASA and on NASA-sponsored programs to amass data, aimed at a better understanding of EHF propagation properties. The data were used as inputs to generate suitable propagation models, including rain models [15].

As a precursor to their interest in higher-frequency communication satellites the Italians launched the Sirio experimental satellite in 1977. This 18/12 GHz satellite was used mainly for propagation and communication experiments.

The Japanese realized early the potential of using the relatively narrow beams of EHF to serve their geographically small country. The Ministry of Posts and Telecommunications (MOPT) has proceeded with the program for millimeter wave satellite communications, in addition to other lower-frequency pre-operational communication and broadcasting experimental

satellites, since 1967. Their concerted effort in this area will make Japan the first country to utilize EHF satellites for communications.

## 2.2.1 THE JAPANESE SYSTEMS

The geographic and demographic characteristics of Japan has prompted MOPT to commit themselves to the use of satellite communications in the EHF band. Japan consists of a series of islands, which are highly mountainous, forcing most of its large population to be concentrated in only 30% of the country. Thus, a high population density is found especially on the Pacific Metropolitan Belt, the industrialized western part of Japan. The result is that there is a severe crowding of the various communication systems in this area. The 4/6 GHz band is heavily used by terrestrial links, such that the C-band ground stations for satellite communications are already experiencing problems of interference from the terrestrial systems. The 7/8 GHz band is allocated for mobile satellite communications, including maritime and aeronautical. The Ku band (12/14 GHz) is being used for satellite communications but has been assigned to broadcast satellites. (The Japanese medium-scale Broadcast Satellite for Experimental Purpose, BSE, was launched successfully on April 8, 1978.) The ever-increasing clamour for more capacity could not, therefore, be satisfied by using C or Ku bands due to interference problems. Attention was then focused on the hitherto unoccupied, hence interference-free, EHF band. Propagation considerations, especially rainfall, has kept the frequency as low as possible within the EHF band, i.e., 30/20 GHz was chosen for initial experiments. It is hoped that the use of this band will remove the smaller islands' dependence on the unreliable shortwave radio for contact with the main island.

Besides the Ku-band Medium-Scale Broadcast Satellite for Experimental Purpose (BSE or YURI), the Radio Research Laboratories (RRL) of MOPT has three EHF programs:

- The Medium Capacity Communication Satellite for Experimental Purpose (CS), also named SAKURA.

- The Engineering Test Satellite Type II (ETS-II) [ KIKU-2] .

- The Experimental Communication Satellite (ECS).

The first satellite on the Japanese program was ETS-II, which was launched on February 23, 1977, attaining its position in a geostationary orbit at 130° E on March 5. This was the first geosynchronous satellite launched by the Japanese National Space Development Agency (NASDA), using their N-launch vehicle, from Tanegashima Space Centre. The main purpose of ETS-II was to acquire the experience of launching geostationary satellites using the N-launch vehicle. The RRL/MOPT conducted EHF propagation experiments, using a 34.5 GHz beacon on-board ETS-II, to study the viability of EHF Satellite Communications. Two other beacons at 1.7 GHz and 11.5 GHz were also provided.

A 28 cm parabolic antenna made of graphite epoxy with an aluminium surface was used for experiments at 34.5 GHz. The propagation experiment transmitter consisted of a 17.76 MHz crystal oscillator, multiplied to get 34.52626 GHz. In addition, this carrier could, by means of a ground command, be 100% amplitude modulated by a 300 Hz rectangular wave.

The main feature of the ground station was a modified Cassegrain 10 m diameter antenna with a four reflector beam-guide feed. An rms surface roughness of about 0.25 mm (0.0098 in.) was obtained at 45° elevation, with a measured gain of 69.7 dB at 34.5 GHz. A tracking capability of 1/10 of the antenna beamwidth (0.05°) was reported. The receiver has a direct downconverter to 1.7 GHz, located right under the antenna feed to minimize losses. ETS-II obtained valuable propagation data under various weather

conditions; up to 7000 h of test time data was recorded. Rain margins of 4 dB and 19.5 dB were found necessary to assure 99% and 99.9% link reliability, respectively, at 34.5 GHz [9].

The ECS satellites are experimental in nature, and are designed to develop the necessary technology and data acquisition techniques necessary for the establishment of satellite communications using EHF. The transponders were designed and developed by RRL/MOPT and the Nippon Telegraph and Telephone Public Corporation (NTT). RRL and NTT were to work in cooperation with Kokusai Denshin Denwa Co. Ltd. (KDD) to carry out experiments with ECS. The initial launch was scheduled for 1979 using NASDA's N-launch vehicle. Another was rescheduled for 1980. Both launches of ECS (ECS I and II) failed.

ECS had a dual K/C band of frequencies; 35 GHz and 6 GHz for uplinks, and 32 GHz and 4 GHz for downlinks. The K-band centre-fed parabolic reflector antenna used a honeycomb construction with graphite-fibre reinforced plastic (GFRP) face skins over aluminium for thermal stability. The gain was 33 dB at 35 GHz and 32 dB at 32 GHz. The satellite G/T was -4.8 dB/K and the EIRP was 64.5 dBm. Two K-band earth stations were built: a main station with a 10 m antenna and 120.5 dBm EIRP and a substation with a 7 m antenna and 117.5 dBm EIRP. The 10 m C-band earth station had an EIRP of 106.5 dBm and a G/T of 29.2 dB/K.

The K- and C-band transponders used a common IF so that they can be cross-strapped, by command, to give any of the four operational modes. IF bandwidths of 10 MHz, 40 MHz and 120 MHz were selectable by ground command. One of the ECS experiments was to study site diversity for satellite communications. The main ground station was accompanied by a substation about 50 km away connected with a terrestrial wideband communication link. Each of these had a 10 m diameter modified Cassegrain antenna, as in ETS-II. Helium gas cooled low noise parametric amplifiers with 165 K noise temperature at 32 GHz were used, for a total G/T of about 42.7 dB/K. FDM/FM and 64 kb/s QPSK SCPC communication test equipment were being used.

The Japanese Medium Capacity Communication Satellite (CS) [Sakura] was launched on December 15, 1977, and placed on a geostationary orbit at 135° E. CS (Sakura) was the world's first EHF (30/20 GHz) experimental communication satellite system and was designed to provide experience with operation of an EHF communication satellite. The commercial version CS-2 is scheduled for launch in 1983. Further, it was designed to acquire additional propagation data to supplement those from ETS-II.

The CS satellite is spin stabilized and has 8 transponders, two at C-band (4/6 GHz) and six at K-band (30/20 GHz) and has mechanically despun antennas. Each transponder has 200 MHz bandwidths with output powers of 34 dBm for K-band channels and 35 dBm for the C-band channels. One of the K-band transponders was built by NTT. The K-band antenna is a 33 dB gain antenna, shaped to have a pattern covering the Japanese mainland. The antenna was supplied by Mitsubishi Electric Corporation of Japan.

A variety of earth stations ranging in size, from small stations with 2 m antennas to the main stations with 13 m antennas, were involved in testing a realistic operational configuration. The earth stations and the various experiments carried out are listed in Table 2.2, reprinted from Ref. 26. Typical parameters of a small K-band earth station are as follows:

- Frequency        30/20 GHz
- G/T        21.3 dB/K
- EIRP        56.3 dBW
- Transmission        FM-SCPC
  Δ MOD.-PSK.SCPC
- Antenna        Cassegrain 2 m
  Gain 53.3/50.3 dBi
- HPA        IMPATT
  2 W output power
- LNA        FET
  750 K noise temperature

The large earth station has a 500 W K-band transmitter and is equipped with a helium-cooled parametric amplifier with a noise temperature of 50 K at the receiver front end.

2-8

| STATION | ANTENNA | Experiments | LOCATION | ORGAN |
|---------|---------|-------------|----------|-------|
| Main Fixed Earth Station | 13 m(K-band) 10 m(C-band) | Telephone (FDM, TDMA) Television (FM, PCM-PSK) SCPC SSRA (Spread Spectrum Random Access) Propagation Satellite operation and control | Kashima (Ibaraki) | RRL |
| Yokosuka Fixed Earth Station | 11.5 m(K-band) 12.8 m(C-band) | Telephone (FDM, TDMA) Television (FM, TDMA) CPFSK* Propagation Satellite operation and control | Yokosuka | YECL |
| Sendai Fixed Earth Station | 11.5 m(K-band) (Offset Cassegrain) | Telephone (FDM, TDMA) Television (FM) Propagation | Sendai | YECL |
| Transportable Earth Station | 11.5 m(C-band) | Telephone (TDMA) Television (TDMA) | Hachijo Island | YECL |
| SCPC Earth Terminal | 2 m(K-band) | Telephone (SCPC) Propagation | Yamagawa (Kagoshima) | RRL |
| Field Strength Measuring Terminal | 2 m(K-band) | Propagation | Wakkanai | RRL |
| Small Transportable Earth Station | 2.7 m(K-band) Vechile-mounted | Telephone (FDM) | ——— | YECL |
| Small Transportable Earth Station | 3 m(C-band) Vehicle-mounted | Telephone (FDM) or Television (FM) | ——— | YECL |
| Field Strength Measuring Terminal | 3 m(K-band) | Propagation | Sugita (Yokohama) | YECL |

* CPFSK = Continuous Phase Frequency Shift Keying

Table 2.2  Earth Stations of CS Program

## 2.2.2 THE LES 8/9 SATELLITES

The Lincoln Experimental Satellites (LES) are a series of satellites designed to demonstrate various critical technologies, notably for the military. LES-8/9 is a basic modification of the LES-7 spacecraft but has communication payloads in the K-band (38/36 GHz), in addition to the military UHF band. Full-scale operation of advanced technologies for strategic communications links has been demonstrated. The operation of the $C^3$ system with jam-resistance and a certain measure of survivability was of prime concern. Low data rate links joining command posts and force elements, and moderate data rate links used among command posts were successfully demonstrated. Most of the command posts were also mobile.

The LES-8/9 consists of two satellites launched on the same launcher in March 1976. The unique feature of these spacecraft is the use of radioisotope thermoelectric generators (RTGs) instead of solar arrays. The satellites are in a quasi-circular orbit, with an inclination of approximately 25°, such that the subsatellite points traced a figure 8 daily. LES 8 was placed over the Pacific Ocean, while LES 9 was placed over North America. The two satellites are linked by a K-band intersatellite link. The satellites are stabilized to ±0.1° around the pitch and roll axes, and ±0.6° around the yaw axis. Among the various antennas on-board are an 18-inch K-band dish with a movable planar reflecting plate for beam steering, and a square-aperture pyramidal horn with 9.5° beamwidth for up and downlinks. The dish is used for crosslinking between the two spacecraft but the reflecting plate can be used to steer the beam towards the earth, should the need for a high gain uplink arise. The gain for the dish was 42.6 dBi to the 24.4 dBi of the horn. A transmit power of 0.5W is available for both the crosslink and the downlink. The spacecraft are equipped with full signal-processing capability, such that the UHF and EHF links can be cross-coupled. All solid-state electronics were used.

## 2.3 PLANNED SYSTEMS

Although there are several planned military systems which are expected to utilize EHF, our emphasis here shall be mainly on communication systems.

### 2.3.1 The Japanese EHF Development Plans

The Communications Satellite for Experimental Purpose (Sakura) was a success, exceeding its design life of 3 years. As a follow-on to this, Japan will launch the world's first commercial EHF communication satellite in 1983. This program, designated CS-2, will have two satellites, CS-2a and CS-2b, both launched into a geostationary orbit by NASDA's N-rocket from Tanegashima Space Centre. CS-2a will be placed at 130° E longitude and CS-2b at 135° E.

The transponder will be very similar to CS-1, with 2 C-band channels and 6 K-band (30/20 GHz) channels. The K-band channels each have 130 MHz bandwidth. The full transponder was designed by NEC of Japan. An one meter diameter antenna with 35 dB gain shaped to cover the main island was built by Mitsubishi Electric Corporation. The satellite G/T will be -5 dBi/K at the edge of coverage. The ground station incorporates a 2 kW RF power output HPA. The system will use a mix of SCPC-FDMA and TDMA at 60 Mb/s.

Besides the operational CS-2, Japan will continue on its experimental satellites ECS-II to test out various advanced satellite system concepts. For example, experiments are already under way for a K-band Satellite-Switched TDMA (SS-TDMA) [2].

The major problem encountered in the Japanese program was that related to severe rain attenuation. The SCPC transmitter system presented some problems due to the high RF frequency and the relatively low information rate; designing a band shaping filter with a time-bandwidth product, BT = 1 was quite a challenge.

## 2.3.2  The U.S. EHF Systems

NASA let out several contracts in the late 1970's to perform a thorough market study on telecommunication traffic potential, including voice, video and data for the time period of 1980-2000.  Further, an estimate was made of the satellite communication market capture.  Although there were differences in the actual numbers estimated by the different companies, e.g. Western Union [10a] and ITT [10b], the studies all concluded that the satellite traffic demand will exceed the capacity of the C and Ku bands sometime in the 1990's, and higher frequencies will have to be resorted to.  S. Fordyce of NASA estimates that, by the year 2000, there will be a demand of 2700 equivalent 36 MHz transponders (27).  By reducing C-band satellite separation to 3° and applying the Ku band fully, the domestic satellite capacity is expected to be somewhere around 1200 equivalent 36 MHz transponders.  The remaining 1500 may be provided by the use of 30/20 GHz satellites, with the advantage of 2.5 GHz of available spectrum for commercial use.

In the light of this, NASA has been conducting several conceptual studies for a Ka-band satellite system, capable of interconnecting large metropolitan areas, which generate significant volumes of intercity message and data traffic.  Several programs are under way, aimed at developing the technology necessary for a wideband communication satellite operating near 30/20 GHz.  Such technologies include:  techniques for spectrum conservation through multiple frequency reuse;  consideration of paraboloid reflectors, lens antennas, or phased arrays, to generate multiple narrow beams;  solid-state satellite transmitters and low-noise amplifiers;  on-board switching and signal processing; and satellite compatibility with earth stations of moderate size and cost.

An Advanced Communications Technology Satellite (ACTS) is currently planned for launch somewhere around 1987-88 to verify the critical technologies.  All proof-of-concept tests, for the various subsystems contracted to over 20 U.S. companies, are expected to be completed by 1983.

The ACTS satellite covers the continental U.S. and may also provide coverage of Alaska and Hawaii. Both fixed and scanning beams are planned, with each beam being about 0.3° beamwidth or covering a spot about 115 miles across. The spatial isolation of the beams allows frequency reuse, achieving an expected throughput of 150,000 equivalent voice circuits. Two types of service are provided: trunking service using fixed beams, and Customer Premise Service using relatively inexpensive earth stations, served by both the fixed beam and scanning beams.

The satellite message switching planned for this mission will allow interconnectivity without the usual ground based distribution network, and hence, can result in system savings. A Master Control Terminal will handle all scheduling, message switching, etc.

Means to combat the expected rain outage for the trunking terminals include transmission rate reduction, site diversity with antennas, at least 10 km apart, and brute-force methods, such as automatic power augmentation of the signal. For the CPS, burst rate reduction and forward error correction (FEC) codes may be used.

A typical scenario considered by NASA has 40 spot beams; 18 fixed ones with a total traffic of 6 Gb/s, and 22 scanning beams for CPS. The total CPS traffic in fixed and scanning beams is about 4 Gb/s.

The spacecraft antenna would be an offset-fed reflector using folded optics. The feedhorn assembly consists of a bank of switches, power dividers and phase shifters used to form the various beams. An on-board microprocessor controls the switches, power dividers and phase shifters to provide the scanning beams. Two types of on-board switching are being considered. One is IF switching, at 3-8 GHz, using an nxn microwave switch matrix (MSM) controlled by a MSM controller. The other is a baseband processor and switch for use with the CPS traffic. This requires complete demodulation and remodulation of data. The design life of the spacecraft is 10 years, which places severe reliability constraints on all on-board components, including TWTs, GaAs FET's or IMPATT's. Further, the low-noise specification for 5 dB noise figure is expected to be quite a challenge.

Apart from the ACTS satellite the U.S.'s activity in the EHF is mainly for military application. The planned Navy's FLTSATCOM has an EHF ("Applique Package") operating in 43-45 GHz band for secure anti-jam application. Both TACSATCOM II and DSCS-III-U, which will be launched in the 1990's, will make use of EHF packages, among others, and the Air Force's Milstar will use EHF for $C^3$ strategic force modernization.

## 2.3.3 THE ITALIAN SYSTEM

Italy has committed itself to the use of 30/20 GHz systems. Estimates made in 1979 predicted a satellite traffic of about 150,000 voice channels by the year 2000 [20]. Assumptions made in this forecast were that one sixth of the traffic pertaining to links shorter than 500 km, and one-third of traffic from links in excess of 500 km, would be sent via satellite. Thus, a total satellite bandwidth of 4.2 GHz would be required with Digital Speech Interpolation. Hence, frequency reuse is indicated. According to G. Perrotta of Selenia, data is at its inception in Italy and no reliable forecasts exist. Very preliminary studies for HDTV points to about 5 channels. Also 3-6 video conferencing channels may be expected.

An EHF preoperational domestic communication satellite is now planned for launch in 1987. Phase B contracts totalling $17.8 million were awarded to Italian manufacturers, with Campagnia Nazionale Satelliti (CNS) as the prime contractor, and Selenia making the communication payload.

The satellite, ITALSAT, will have a capacity of 50,000 2-way simultaneous voice circuits operating at 30/20 GHz, which will also be used for emergency communication during natural disasters. Use of 20 and 44 GHz bands is also being preliminarily considered for military use. The satellite also carries a 50/40 GHz payload with a 1 W output power designed for propagation experiments. A 3.3° circular beam covering most of Western Europe is required. For the 30/20 GHz, two 1.95 m multibeam antennas with three spot beams each for a total of six spots (each 0.4° wide) are base-lined, as well as an Italy coverage beam for point-to-multipoint communication. The satellite is however, equipped with three redundant

transponders with 250 MHz channel bandwidth, and on-board processing, including demodulation regeneration and remodulation, to allow on-board speed conversion and baseband switching. A satellite switched TDMA (SS-TDMA) type of operation at 120 Mb/s QPSK continuous mode with one ground terminal per transponder is envisaged. However, there is one optional 360 Mb/s regenerative transponder. The system is used purely for high density non-hierarchical point-to-point communication, i.e., between compartment centres. An operational system is expected in 1992.

## 2.3.4 EUROPEAN AND OTHER SYSTEMS

The European Space Agency (ESA) has been planning the launch of the Large-capacity Satellite (L-SAT), now scheduled for launch in 1986. This is an experimental satellite carrying a hybrid payload at 12/14 GHz and 30/20 GHz. The 30/20 GHz transponder will permit experiments with this new band, which is believed will be widely used by the 1990's. Planned missions include inter-university teleconferencing and tele-education; general teleconferencing services, intercity telephone links; broadband links for real-time, very-long-baseline radio astronomy interferometry; and second-generation specialized services systems. Two independently-steerable transmit/receive spot-beam antennas with 0.6° beamwidths are planned on-board. For narrowband transmission experiments, a small earth terminal with a 2.5 m diameter antenna and 200 W transmitted RF power will be used [28].

The Swedish Space Corporation has plans to conduct experiments using 30/20 GHz technology and mobile communications ("Trucksat") on Sweden's Tele-X satellite, which is scheduled for launch in 1986. However, the future of this trial is not certain due to shortage of funds, and depends on possible financing by the U.K. and France who have expressed interest.

In addition to these communication experiments, military use of EHF in Europe may materialize in the 1990's. The U.K. will be launching an experimental military satellite (SKYNET), in 1986 using 44 GHz in the uplink and 7 GHz in the downlink.

INTELSAT is planning on using 33/23 GHz intersatellite links (ISL), since satellite-to-satellite link transmission requires no fade margin (the only problem might be occasional sun outages). Some development of equipment has already started under various contracts. These include a Hughes 10 W TWTA at 23 and 33 GHz, GE's wideband FM modem, frequency converters, and IF amplifiers by NEC, and 2-3 dB noise figure FET by Plessey.

## 2.3.5 TERRESTRIAL SYSTEMS

A few terrestrial communication links have been developed at the EHF band, both in Europe and the U.S. For example, Plessey in the U.K. was experimenting with short-range 60 GHz links as early as 1978. Norden of the U.S. developed 5 EHF radios operating at 36-38.6 GHz and 60 GHz band. Some of these are hand-held radios with full duplex voice capability up to 40 km and half duplex video or data transmission up to 13 km. AIL has also developed 60-70 GHz tranceivers tunable through the absorption band, which will provide transmission of FM signals containing voice, data and video in a full-duplex operation, where warranted. The transmitter power is 100 mW and the antenna beamwidth 5°. Japan's EHF terrestrial facilities include an 18 GHz 274 Mb/s QPSK digital radio system with a channel capacity of 4032, a 400 Mb/s QPSK system at 20 GHz using an all-solid-state repeater system, and repeaters spaced at 3 km is also operational. Further, by 1978, NTT and Fujitsu had developed a guided millimeter wave line system for 800 Mb/s in the 40-80 GHz range.

## 2.4  GLOBAL TECHNOLOGY DEVELOPMENT PROGRAMS

In the past, there have not been any significant millimeter-wave developments, largely due to the difficulty of developing a new technology and the concomitant cost.  Companies felt that a viable market did not exist to justify investment in the technology and the potential system developers did not plan millimeter wave systems because no components were available.  In some cases, system developers had to build their own major components.  However, the military's and communications' push into the millimeter waves have resulted in technology development programs on a larger scale.  The biggest development program is perhaps that of the US Department of Defense (DOD), one to develop technology and components suitable for MILSATCOM at EHF.  DOD has funded many companies to develop TWTs and other sources, receivers, flight hardware, etc.  All these have, however, been directed solely to U.S. companies.  NASA has a similar program on the ACTS, whereby they have awarded contracts to several companies to develop techniques and components for EHF SATCOM.

The Japanese are quickly acquiring the expertise to the point where all their satellites would be built exclusively by Japanese companies. For example, the CS-2 transponder is wholly NTT built.  Likewise, all the contracts on ITALSAT has been awarded to Italian companies, although a fair amount of subcontracting is expected.

A few companies have carried on their own in-house development programs to acquire marketable capabilities.  Among these are Siemens, Hughes, AIL, Microwave Associates, AEL, Thomson-CSF, Raytheon and Watkins-Johnson.  As more companies are convinced that millimeter waves have finally come of age and that the market exists, there will be more and more development programs with the eventual proliferation of components and lowering of costs.

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SECTION 3

COMPONENTS AND SUBSYSTEM SUPPLIERS SUMMARY

## 3.0  COMPONENTS AND SUBSYSTEM SUPPLIERS SUMMARY

### 3.1  INTRODUCTION

One of the objectives of this study is to survey the current state of technology available for EHF frequencies and identify the technologies critical to the implementation of an EHF satellite communication system. The technology assessment methodology starts with existing satellite communication architectures and studies, and identifies the major subsystems and the required performance characteristics. An examination of the technology base determined from operational systems, current research and development programs of manufacturers, and projections of future development, leads us to identify critical areas of technology development. An extensive literature survey of conference proceedings, trade journals and manufacturer advertisements, etc., was conducted and augmented by telephone conversations with various manufacturers.

The assessment in this survey is limited to communication systems. However, it should be mentioned that technology for remote sensing radiometry, radio astronomy, and microwave interferometry, seems to be quite mature, since it has preceded communications. Advances have also been made in other areas such as radar and military ECM, ECCM and ESM. All these areas share similar state-of-the-art technology and considerable technology borrowing may occur.

### 3.2  EHF TECHNOLOGY

Since we are considering communications systems only, the major problem becomes one of the fade margin required during inclement weather, especially rain. Since these margins increase with frequency, communications systems would operate in the lowest band available in the EHF spectrum, which is 30/20 GHz. Components at 45 GHz shall be considered, where necessary, mainly because most military systems tend to use this band, and 60 GHz will be assessed for intersatellite link (ISL) applications. (It should be noted, however, that INTELSAT is planning on using 23/33 GHz ISL's.)

### 3.2.1 APPLICABLE SUBSYSTEMS AND COMPONENTS

A simplified block diagram of a satellite communication system is depicted in Figure 3.2-1. This diagram shows the major subsystems required. The baseband processor, which may include frequency hopping, etc., and the modem and codec are not considered in the assessment as they are similar to those used with lower frequency satellite systems, i.e., they are not RF frequency dependent. It may be mentioned, though, that with increased available bandwidth at EHF, higher bit rates may be transmitted requiring higher-speed modems than currently available. The switching matrix shown may include processing as in the case of a regenerative system. The subsystems can be classified into the following three types:

1) RF subsystems,
2) Antennas, and
3) On-board switching and processing.

Each of these subsystems is treated in a separate subsection.

In addition to these major subsystems, other miscellaneous components should be considered. These include filters, coaxial connectors waveguide components such as hybrids, twists, bends, rotary joints, circulators, and ferrite products. A careful look at numerous manufacturers' catalogs indicates that these are generally available up to about 40 GHz. Beyond 40 GHz, the number of suppliers decreases. Alpha Industries, Varian, TRW and Hughes Aircraft Co., among others, manufacture active and passive devices at frequencies above 40 GHz [1,2].

An important consideration in a study of this nature has to be the necessary test equipment. These include spectrum analysers, network analysers, frequency meters, power meters, sweep generators, phase shifters, and attenuators. Test equipment is prolific up to 18 GHz but beyond that only a few suppliers are available up to 26 GHz. Some of this is direct operating but some is by frequency extension using peripheral equipment, e.g., downconverting to below the 18 GHz range. Suppliers include Hewlett

Packard, Hughes, Polarad, Tektronix, Systron Donner, Wiltron and Watkins Johnson. Hughes (their 1983 Catalog [1]) is the most notable supplier of test equipment above 26 GHz extending all the way to the W-band (75-110 GHz), mainly because they are heavily involved in millimeter-wave research and development.

## 3.2.2 TECHNOLOGY FACTOR

Three technology related considerations have to be made in assessing the various components. The first is the frequency dependence of most subsystems. Most components have performance which decreases as the frequency increases. The low noise amplifiers have a temperature which is frequency dependent, varying as the square root of frequency for mixers and $f^{3/2}$ for parametric amplifiers, where f is the operating RF frequency. The high power amplifiers (HPA's) have powers (P) which generally obey the relationship $Pf^2$ = constant; in the solid-state amplifier the active region is proportional to the square of the wave length $(\lambda^2)$, whereas the electron beam area of a TWT is proportional to $\lambda^2$. Further frequency dependence appears in attenuation. For a rectangular waveguide, the loss in dB, varies as $f^{3/2}$ for constant length, and varies as the square root of frequency, if dimensions are scaled with the wavelength. The rain attenuation is approximately proportional to the square of frequency $(f^2)$.

Frequency limitation occurs for FETs and helix TWTs. The low-noise FET amplifier is frequency limited to about 30 GHz in the near term and with low-cost MIC fabrication in the far term this limit may be extended to 40 GHz. The power FET has similar limits of 30 GHz and 40 GHz in the near and far terms for reproducible cost-effective devices, while the high power slow-wave helix TWT is limited to 40 GHz.
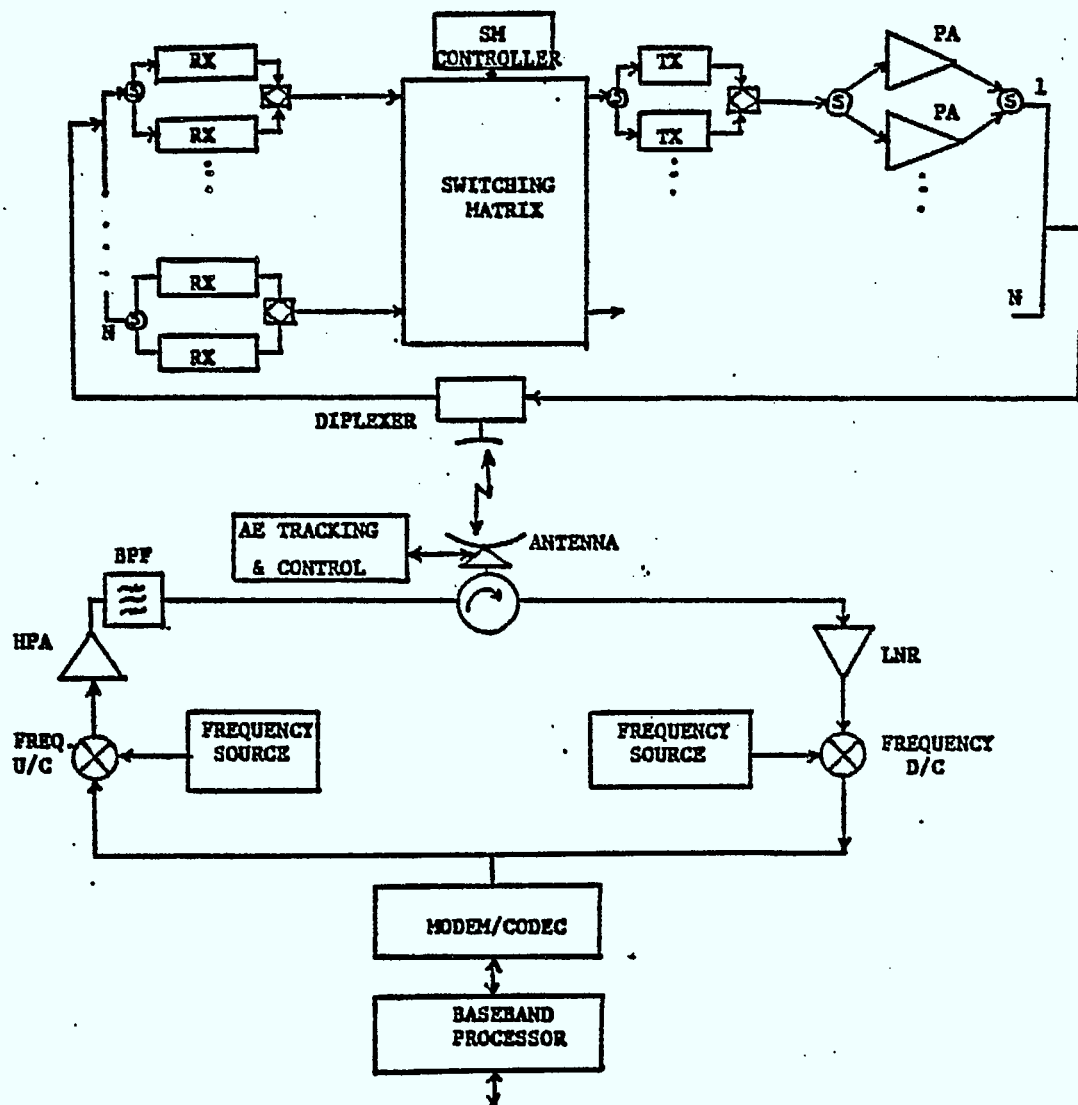
Figure 3.2-1  Equipment Configuration

Certain implementation factors have also to be taken into account. Increase in frequency requires tighter tolerances making fabrication more difficult, and hence, a lower yield. The gain, efficiency and output power are reduced, due to losses in the active devices. To get a given power from a TWT with increasing frequency would require a higher operating voltage and more difficult beam focussing and thermal design, such that one might have to change from air to liquid cooling or from periodic permanent magnet (PPM) focussing to electromagnetic focussing which is heavier and consumes lots of power. For solid-state devices, parasitic effects worsen with increasing frequency. Increasing frequency requires better antenna surface tolerances and tracking accuracy if the antenna dimensions are kept constant, and may lead to more complex tracking systems. For optimum performance, higher frequency antennas may require radomes for protection against the weather. The most logical use of the EHF band is for high data rate communications from point-to-point, i.e. between major cities. This requires smaller beam widths, large antennas, in terms of wavelengths, and therefore more accurate pointing and tracking.

## 3.3 RF SUBSYSTEMS

### 3.3.1 LOW-NOISE RECEIVERS

The satellite receiver is a crucial element in the performance of the system. The noise figure (NF) of the low-noise receiver impacts the earth station transmitter and antenna. A lowering of the noise alleviates the demand on transmitted power and antenna size. A few dB decrease in the satellite receiver NF will mean lower demands on the receiving earth station and can result in significant system dollar savings, since there would be a large number of earth stations. The overall bandwidth of the receiver is also an important consideration. A factor to be borne in mind while considering low-noise receivers is the relative importance of its noise compared to other sources. For the satellite receiver, the antenna sees the noise temperature of the warm earth, i.e., 290 K. This in itself is a noise figure of 3 dB and obviates the need to reduce receiver temperatures drastically. The sky noise temperature of EHF ground terminals varies according to the elevation angle and rain conditions, ranging from about 20 K for 90 degree elevation angle at 20 GHz to a maximum of 275 K during heavy rain. Thus there would be no need for ground terminal receivers with noise temperatures below around 150 K as they would not significantly improve system noise performance.

The design goals for NASA's Advanced Communication Technology Satellite (ACTS) [30] for example are:

- NF                        5 dB
- RF amplifier gain         20 dB
- IF                        3-8 GHz
- Operating bandwidth       27.5-30 GHz

Three types of low-noise receiver systems are available: low-noise mixer/IF transistor amplifier combination, parametric amplifier which may be cooled or uncooled, and low-noise amplifier with a FET preamplifier.

The broadband mixer/IF amplifier combination is probably the simplest receiver form. A critical factor here is the mixer conversion loss since the overall noise figure is a product of the conversion loss and the IF amplifier noise figure. Values of about 2-3 dB conversion loss are possible, and by using GaAs MESFETs as the IF amplifiers, NF's of about 1 dB at 4 GHz are obtainable. Broadband mixers/IF amplifier combinations with about 2 GHz IF are currently available with noise figures of about 5 dB and 7 dB for 30 GHz and 44 GHz respectively. With image-enhanced mixers, noise figures of 4 dB and 5.5 dB are available. Further reduction in NF would require cooled parametric amplifiers (paramps) for the IF with the concomitant increase in cost.

Parametric amplifiers may be used for ground terminals. The operating temperature dictates the noise temperature obtainable. Uncooled paramps (temperature ≃ 313 K) can achieve noise figures of 3.5 dB at 30 GHz and 4.5 dB at 44 GHz. Improvements to 2 dB and 3.5 dB respectively are expected in the near future. An example, listed in Table 3.1 along with other low-noise receivers, is the LNR 37 GHz receiver composed of a paramp followed by a mixer and IF amplifier (paraconverter) with a noise figure of 4 dB. Lower noise figures are obtainable by use of thermo electrically-cooled and cryogenically-cooled paramps. Thermoelectrically-cooled paramps can achieve noise figures of close to 2 dB at 30 GHz and 3 dB at 44 GHz. Cryogenically-cooled paramps can achieve noise figures around 1 dB, but such low noise figures are are not needed as mentioned earlier.

3-7

FET's offer lower noise temperatures, and with their solid-state MIC fabrication techniques they can be low cost and more reliable. Also with solid devices, there is a potential of integration. (For example in R&D labs, the entire receiver front end-RF amplifier, mixer, and oscillator - has been integrated on a single piece of gallium arsenide. NF's of 3.0 dB or lower are currently available at 18 GHz. At 30 GHz, Hughes has a 6 dB noise figure FET amplifier with 6 dB gain using a 0.5 $\mu$m gate length. Table 3.1 indicates that activity in FET amplifiers, especially GaAs FETs, is picking up. A lot of effort is concentrated on reducing the gate length to 0.25 $\mu$m or less. A GaAs FET with a noise figure of 5 dB at 30 GHz is now available from Avantek. Estimated GaAs FET optimized performance would yield a NF of 1.5 dB at 20 GHz and 2.3 dB at 30 GHz [3].

The critical elements for receiver development will be the production of reliable and reproducible 4 GHz GaAs FET IF amplifier, and the 30 GHz GaAs FETs for the RF amplifiers. Development of mixer devices with enhanced image response characteristics will also be a challenge. It should be noted that the noise figure of 5 dB is quite demanding and its achievement will require critical technology.

3.3.2 TRANSMITTERS

In both the uplink and downlink, it is desirable to maximize the EIRP which depends on RF transmitter power and the antenna gain. Since the satellite antenna gain is limited by other considerations such as coverage area, the RF power amplifier must have as much power as possible. In the uplink, we want to maximize transmitted power in order to achieve a suitable signal-to-noise ratio at the satellite. It is apparent, therefore, that the high power amplifier would probably be the most costly and critical subsystem. The power achievable depends on the gain, efficiency, mass and reliability of the particular amplifier, which in turn depend on the type of devices (thermionic or solid-state) and technology used. Efforts to achieve extremely high powers (peak as well as CW) have continued. For example, in the 1970s, Russian researchers at Gorki State University developed ejection cyclotron maser tubes (gyromontron oscillators with quasi-CW powers of up to 60 k W), and Varian has claimed 200 kW at 289 Hz using gyroklystron oscillators [4].

For most satellite communication transmitters, three types of amplifiers can be used: the travelling-wave tube (TWT), IMPATT diodes and GaAs FETs. These are considered next. Klystron amplifiers will be considered as well, but in lesser detail.

## Table 3.1 Receiver Suppliers

| MANUFACTURER | FREQUENCY (GHz) | GAIN (dB) | NOISE FIGURE (dB) | |
|---|---|---|---|---|
| Harris Corp. | 20 | 26 | 5 Goal | MESFET LNA (4 stages) |
| Rockwell Int'l | 20 | | | AMP. D/C |
| GTE Telecom (Italy) | 30 | 35 | 4.6 | PARAMP PREAMP |
| ITT | 30/44 | 06 (RF-to-IF) | 3.8 | GaAsFET LNA |
| LNR | 37 | | 4 (440 K) | Paraconverter |
| Hughes | 29<br>30<br>38 | 6.9<br>6<br>7 | 3.7<br>6<br>5.5 | FET AMP 0.25 μm gate MESFET |
| Plessey | 23/33<br>27 | <br>5 | 2-3<br>3.6 | FET for INTELSAT's ISL 0.3 μm gate MESFET |
| Toshiba | 30 | 5 | 4 | GaAs MESFET ($\frac{1}{4}$μ GATE) |
| | 29 | 10 | 7.5 | GaAs FET |
| NEC | 32 | 30 | 1.4 | Cryogenically Cooled Paramp |
| COMTECH Labs | 20 | | 3 | Paramp |
| AIL | 36 | | 3.8 | Paramp - Experimental |
| Fujitsu | 30 | | 4.5 | Paramp - Experimental |

### 3.3.2.1  TWT Amplifiers

Travelling-wave tubes are thermionic devices which have typically wide bandwidths and are capable of operation over the entire downlink band. They provide sufficient power for one TWT to be used for each downlink beam. TWTs are capable of multiple power levels which facilitates efficient and adaptive power budgeting and control.  They also claim an adequate efficiency, such that one amplifier can be used to amplify more than one channel at a time.

An example of state-of-the-art requirements is NASA's design goal which calls for a 10 year life TWT with an efficiency of 35-40% capable of operation in a multi-power mode from 7.5 W to 75 W RF power output and operation over a bandwidth of 3.5 GHz.  The critical elements in the TWT development of this type are the low-loss helix structure, the design of electron-beam focussing components and reduction of signal distortion.  Such a high power operation mode at 20 GHz for 10 years is unprecedented and the reliability will be a critical issue.

A survey of manufacturers of ground segment TWTA's showed about half a dozen manufacturers capable of EHF TWT tube production.  These are listed in Table 3.2.  For higher powers, coupled-cavity TWT's as opposed to helix-types are used.  The efficiencies shown are for the TWT tube only. Considerable effort is being expended by various companies to improve TWT cost, performance and producibility.  These include "diamond turning" techniques and "ferruleless" circuits by Hughes, the "folded waveguide" concept of Raytheon, the "Helix In Guide Hybrid (Hightron)" of Litton, and Varian's "Comb-Quad" and "Tunneladder" [5] .  By incorporating depressed collectors, the efficiency of a TWT is increased.  The problem of heat removal from the helix tends to limit available power of a PPM focussed helix tube.  Higher powers, may call for PM focussing to enable liquid cooling to be applied to the tube body.  In Table 3-2, the focussing is done by PPM except where exception is noted.  Powers in the order of a few kilowatts will be available in the far term.

Table 3.2   EHF Ground Segment TWT Suppliers

| MANUFACTURER | FREQUENCY (GHz) | OUTPUT POWER (W) | EFFICIENCY (%) | GAIN (dB) | BANDWIDTH (GHz) | |
|---|---|---|---|---|---|---|
| HUGHES | 30 | 200 | 25 | 36 | 1.0 | Liquid Cooled Air Cooled |
| | 37.4 | 100 | 25 | 45 | 2.0 | Air Cooled |
| | 44 | 250 | 25 | 50 | 2.0 | Liquid Cooled Air Cooled |
| SIEMENS | 30 | 1200 | 25 | 43 | 2.0 | Liquid Cooled |
| | 37.4 | 1000 | 25 | 41 | 1.5 | Liquid Cooled |
| | 44 | 500 | 24 | 43 | 2.0 | Liquid Cooled |
| | 44 | 150 | 27 | 40 | 2.0 | Air Cooled |
| TOSHIBA | 30 | 400 | 16 | 41 | 1.0 | Air Cooled (Solenoid focused) |
| NEC | 29 | 27 | 20 | 40 | 2.0 | Conduction Cooling |
| | 30 | 700 | | 42 | 2.5 | Forced Air Cooled. (Solenoid focused) |
| | 35 | 600 | | 45 | 2.5 | Forced Air Cooled. (Solenoid focused) |
| VARIAN | 35 | 30 kW(peak) | 20 | 35 | | Coupled Cavity |
| RAYTHEON | 44 | 148 (225 max) | | 41 | | Air Cooled |
| | Q-band | 80 | | | | Proposed |

**Table 3.3   EHF Space Segment TWT Suppliers**

| MANUFACTURER | FREQUENCY (GHz) | OUTPUT POWER (W) | EFFICIENCY (%) | GAIN (dB) | BANDWIDTH (GHz) | |
|---|---|---|---|---|---|---|
| HUGHES | 20 | 4 | 17 | 50 | 1.0 | Flight Qualified on CS-I |
| | 20 | 7.5/75 | 30-50 | 30 | 3.5 | In Development |
| | 23/33 | 10 | 37 | 43 49 | | INTELSATs ISL |
| | 60 | 5 | 14 | 38 | 0.1 | |
| THOMSON CSF | 20 | 15 | 33 | 51 | 1.0 | Developed |
| WATKINS - JOHNSON | 20 | 25 | 40 | 50 | 1.0 | Developed |
| AEG TELEFUNKEN | 20 | 22 | 38 | 50 | 3.0 | Developed |

Table 3.3 shows the space segment TWT suppliers identified. Although some of the tubes listed have been space qualified, it should be noted that only the Hughes 4 W tube has flown (on the Japanese CS I). However, Thomson CSF has had flight experience at Ku band with INTELSAT V. For 30 GHz tubes, current densities exceeding the 0.2 A/cm$^2$ available now with oxide cathodes, may be required. This may call for programmable power supplies since the current densities decrease with time for fixed operating parameters. Dispenser or impregnated cathodes may have to be used which are more costly.

Technology projections for TWT amplifiers for both space segment and ground segments are summarized below:

## SPACE SEGMENT

|           |                 | 20 GHz    | 40 GHz   |
|-----------|-----------------|-----------|----------|
| Near Term | Helix           | 20-40 W   | 10-20 W  |
| Far Term  | Helix           | 70-100 W  | 15-50 W  |
|           | Coupled-cavity  | 200 W     | 100 W    |

## GROUND SEGMENT TWTS

|           |               | 30 GHz    | 45 GHz    |
|-----------|---------------|-----------|-----------|
| Near Term | Air Cooled    | 400-500 W | 150-200 W |
|           | Liquid Cooled | 1 kW      | 500-700 W |
| Far Term  | Air Cooled    | 700 W     | 300 W     |
|           | Liquid Cooled | 1.5 kW    | 900 W     |
| Near Term | Solenoid      | 2 kW      | 1 kW      |
| Far Term  | Solenoid      | 20 kW     | 8 kW      |

To summarize, TWT development for both ground and space segments is continuing and the necessary tubes for 20/30 GHz seem available. The critical issue, however, remains the demonstration of reproducible, reliable and affordable tubes.

### 3.3.2.2 Solid-State Amplifiers

Although TWT's have been used for high power production at high frequencies, solid-state amplifiers are developing fast as an alternative to TWT's. The attractive features are the greater reliabilities expected, lightweight and potential low cost. Another advantage is the potential of integration. However their efficiencies are somewhat lower than that of TWT's. Both diodes and transistors are considered. Solid-state power amplifiers are readily available up to X-band and considerable activity is going on up to 40 GHz.

Many diode types are available such as GUNN, BARITT, TRAPATT, and IMPATT. They are all used for different applications, but for power amplifiers, the IMPATT is used since it is the most powerful CW diode source. The Silicon IMPATT, which uses avalanche multiplication to create negative resistance effect, can be used up to very high frequencies. For example, Hughes has developed a 217 GHz phase-locked IMPATT oscillator for low noise applications. A power of 15 mW at an efficiency of 0.5% was obtained [6]. Silicon IMPATT devices were used in the LES 8/9 as amplifiers in the K-band downlink and cross-link transmitters at 38 GHz. GaAs IMPATT's, which have higher DC-to-RF efficiency than silicon devices, are gaining more widespread use.

IMPATT diode transmitters have lower power and bandwidth than TWT's, and hence, only one transmitter can be used for a single channel. Thus, combiners are needed to obtain the required power level. Although they have somewhat lower efficiencies than TWT's, they have the advantage of potentially higher reliability. Typical requirements of IMPATT's for EHF are:

- Bandwidth       0.5 GHz
- Individual device power level       4-6 Watts
- Combining (4 or 6 way) for a total of       20 Watts
- Composite amplifier gain       30 dB
- Operational efficiency       $\approx$ 20%
- Design life       10 years

The critical technology here is the development of the 4-6 W IMPATT devices themselves; currently only 2-3 watt devices are available. Also, the efficient combining network without excessive signal loss will be critical, as will the high power and frequency operation of these devices over 10 years.

LNR Communications, Inc., has a contract with the Air Force Wright Aeronautical Lab. to develop a 20 GHz GaAs IMPATT diode amplifier having 20 Watts CW power with at least 1 GHz bandwidth. An overall gain of 30 dB is targetted by use of 20 GHz FET driver modules and IMPATT power modules.

Table 3.4 lists the currently available IMPATT amplifiers in the frequency band of interest. Note the decreased efficiency compared to TWT's (Table 3-3). It is clear that a lot more development has to be done before IMPATT's can be readily used as amplifiers. Estimates of near-term projection (5 years) indicate a possibility of 8 W at 20 GHz and 2 W at 40 GHz.

IMPATT amplifiers at 60 GHz have been developed by Hughes, TRW and NEC. For example, NEC has a silicon IMPATT operating at 50-70 GHz with an output power of 0.3 W and DC-RF efficiency of 6% and Hughes has an IMPATT operating at 50-70 GHz with an output power of 0.2 W. Hughes is also developing a laboratory model of 7% efficient, 60 GHz silicon IMPATT with a power of 1.0 W. TRW has a 1 W 60 GHz IMPATT amplifier with a gain of 14 dB and is developing a 2 W 60 GHz IMPATT amplifier with a gain of 17 dB [12].

GaAs FET power amplifiers offer more ease of combining and linear amplification than IMPATTS. They also generally have higher efficiencies and wider bandwidths and lower noise figures. The power capability of a FET decreases rapidly with frequency above 20 GHz because the required gate width becomes small. Due to device impedance matching problems, parasitic problems also increase. To increase the power output, a power combining approach must be adopted.

Table 3.4  IMPATT Diode Suppliers

| MANUFACTURER | FREQUENCY (GHz) | OUTPUT POWER (W) | GAIN (dB) | EFFICIENCY | |
|---|---|---|---|---|---|
| LNR | 20 | 1.25 - 1.5 | | 11-15 | |
| | 20 | 20 | 30 | | 1 GHz bandwidth (under development) |
| VARIAN | 18 - 23 | 0.3 | | 3.5 | |
| HUGHES | 26.5 - 40 | 0.2 | | | |
| | 40 - 50 | 0.2 | | | |
| | 43.5 - 45.5 | 1.5 | | 10 | ILO* |
| | 40 | 1.7 | | 12 | LABORATORY |
| RAYTHEON | 33.5 | 2.5 | | 18.6 | LABORATORY (GaAs) |
| | 41.6 | 1.1 | | 15.1 | LABORATORY (GaAs) |
| NEC | 18 - 25 | 1.5 | | 10 | |
| | 35 - 50 | 0.5 | | 8 | |
| MIT | 38 | 0.5 | | • | LES 8/9 Cross-link and downlink |
| TRW | 37.3 | 5.0 | | 33 | Used Combiners |
| | 38.1 | 5.0 | | 30 | |
| | 41 | 10.0 | | 33 | Under Development *12 diodes combined |
| MOTOROLA | 44.5 | 1.0 | | 10 | ILO |

* Injection-locked oscillator

GaAs FET transmitters are currently capable of about ¼-½ watt in the 20 GHz downlink band. They have sufficient bandwidth and linearity to permit amplification of multiple channels by one transmitter. The key design parameter based on NASA's ACTS program are:

- Bandwidth                    2.5 GHz
- Individual device power  0.25-1 W
- Combined power           6-7.5 W
- Efficiency                    15-20%
- Sufficient linearity for multicarrier operation.

The device development itself is a critical issue, especially in large numbers and with reproducible characteristics. Power combiners will be another critical area.

Table 3.4a summarizes the GaAs FET power amplifier devices being developed by various companies. It is apparent that suppliers for these devices are few and much more activity is needed. It is estimated that in the near term (5 years), GaAs FET's with output powers of 2 W at 20 GHz and 0.5 W at 40 GHz will be available.

Table 3.4a  GaAs FET Suppliers

| MANUFACTURER | FREQUENCY (GHz) | OUTPUT POWER (W) | GAIN (dB) | EFFICIENCY % |
|---|---|---|---|---|
| TI | 19<br>20 | 7.5 (16 stage amp.)<br>0.45<br>(1.0 W Goal) | 30 | 30 |
|  | 25 | 0.2 |  |  |
| TRW | 20 | 4.0 | 34 | 10 |
| MSC | 20 | 0.5<br>(1.0 W Goal) | 3.55 | 13 |
| HUGHES | 18 | 1.0 |  |  |
|  | 40 | 5 mW |  |  |
| FUJITSU | 20 | 0.7 |  |  |
|  | 23 | 1.0 |  |  |
| MITSUBISHI | 30 | 0.1 |  |  |

### 3.3.2.3  Klystron Amplifiers

Klystron amplifiers are thermionic devices that are particularly noted for high power applications. Their peak output powers range from milliwatts to megawatts with average output powers between 1 to 100 kilowatts. Their power gain ranges from 3 to 90 dB. Klystron amplifiers operate primarily in the frequency bands between UHF and 100 GHz but are capable of operation above 100 GHz.

The first tubes to sucessfully demonstrate the principle of klystrons were reflex klystrons developed in the late 1930's. During World War II, reflex klystrons underwent major development resulting from their applications as local oscillators in radar receivers. Development work on klystron amplification began following the war and has progressed to the point where klystron amplifiers are commonly employed for amplification of microwave signals.

Although klystron amplifiers produce a lot of power, they suffer from one major constraint for their applications in the EHF band, they have a problem with obtaining sufficient percentage bandwidth. A comparison of instantaneous bandwidths between klystron amplifiers and TWTAs illustrates this limitation. TWTAs, as discussed in section 3.3.2.1, have bandwidths ranging from 1.0 to 3.0 GHz, with 2.0 GHz as a typical value. Klystron amplifiers, operating in the EHF band, presently have bandwidths of 30, 50, and 150 MHz. There is at least an order of magnitude difference in bandwidths between the two types of amplifiers. The bandwidth may be improved by the use of extended interaction amplifiers (EIA) with a special output circuit distributed over a considerable distance. Further, klystron amplifiers also suffer from a lack of frequency agility. To alter the center frequency of the klystrons require each cavity to be retuned separately.

The tendency has been to use TWTAs for communications in the EHF band, particularly when large bandwidths are required, such as when spread spectrum is considered. Also, TWTAs are capable of multiple power levels, allowing efficient and adaptive power budgeting and control. The effort to improve TWTA in the communications industry is quite considerable and was treated in greater detail in section 3.3.2.1.

A survey of manufacturers of klystron amplifiers showed there were only a couple of companies with products in the EHF band. The companies were Varian and NEC. Table 3.5 lists the available klystron amplifiers and their characteristics for these two companies.

Other noted manufacturers, such as Philips and English Electric Valve (EEV) concentrate on the UHF band, while others, such as Thomson-CSF, ITT, GE, and Raytheon do not manufacture klystron amplifiers above X band (~ 10 GHz). Hughes, Varian and Raytheon are placing their efforts into improving TWTAs instead. The lack of companies manufacturing klystron amplifiers in the EHF band once again reinforces the points that TWTAs are better suited for communications in the EHF band.

Table 3.5  EHF Klystron Amplifiers Suppliers

| MANUFACTURER | FREQUENCY (GHz) | OUTPUT POWER (W) | GAIN (dB) | BANDWIDTH (MHz) | COMMENT |
|---|---|---|---|---|---|
| VARIAN | 18 ‑ 26 | 1000 | 50 | 50 (1 dB) | L, A |
|  | 26 ‑ 36 | 1000 | 50 | 30 | L, B |
| NEC | 27.5 ‑ 29.0 | 450 | 43 | 150 | FA, PM |
|  | 28.7 ‑ 30.1 | 450 | 43 | 150 | FA, PM |
|  | 29.6 ‑ 31.0 | 450 | 43 | 150 | FA, PM |
|  | 27.5 ‑ 29.0 | 150 | 45 | 50 | FA, PM |
|  | 28.7 ‑ 30.1 | 150 | 45 | 50 | FA, PM |
|  | 29.6 ‑ 31.0 | 150 | 45 | 50 | FA, PM |

COOLING:            FA = FORCED AIR

                    L = LIQUID

FOCUSSING MAGNET:   PM = PERMANENT MAGNET

                    A = VYW ‑ 7808

                    B = VA ‑ 1928

## 3.4  ANTENNAS

EHF is particularly suited to operation with spot beams.  For satellite systems it is of paramount importance to get as much EIRP as possible in order to achieve a suitable link availability.  Since EIRP depends on amplifier output power and the antenna gain, it is important to maximize the antenna gain.  However, the size of the antenna is usually determined by other factors than gain alone, i.e., the size of the spot beams required.  Multiple beam antennas with low side lobes are required for frequency reuse and can be used for either fixed or scanning beams.  Beamwidths of 0.3° or less are typical at EHF.  Studies in Europe and the U.S.A. have shown that a good way to produce widely separated spot beams at 20/30 GHz is to use a special feed network and a dual-reflector antenna system.  The main antenna reflector diameter is in range of 2.7 to 3.7 m.  The minimum gain is 52 dB [Reference 19, Section 2.2].  The antenna gain obtainable is limited by surface accuracy of a reflector antenna as well as the antenna tracking accuracy.  This fundamental gain limitation is considered in the following subsection.  A typical spacecraft antenna is a paraboloid reflector with an off-axis feed and uses folded optics.  The feed horn assembly consists of a bank of switches, power dividers and phase shifters, which can be varied by an on-board microprocessor to effect beam scanning.  NASA's requirements for the antenna include:

- Gain                                       53 dBi
- Beamwidth                             0.35 °
- Sidelobe level                         40 dB below mainlobe
- Isolation between beams         > 30 dB at same frequency
- Beam-to-beam switching time < 0.5 μ S

The design of the reflector surface with sufficient surface tolerance, and the suitable beam forming components are considered the critical elements.

### 3.4.1 FUNDAMENTAL ANTENNA GAIN LIMITATIONS

Paraboloid antennas are typical at these frequencies and shall be used here. It shall also be assumed that the antenna aperture is at least 10 wavelengths in diameter (0.15 m at 20 GHz).

The gain (G) of a paraboloidal antenna is given by:

$$G = \eta \left(\frac{\pi D}{\lambda}\right)^2 \qquad (3.3.1)$$

where $\lambda$ = wavelength

and $\eta$ the overall antenna efficiency which includes effect of surface errors, block loss, spillover loss and aperture illumination efficiency.

Surface accuracy, which is determined by technology capability, limits the absolute antenna gain achievable. Equation (3.3.1) can be modified to include surface errors as follows:

$$G = \eta \left(\frac{\pi D}{\lambda}\right)^2 \ e^{-\left(\frac{4\pi\varepsilon}{\lambda}\right)^2} \qquad (3.3.2)$$

where $\varepsilon$ is the rms deviation of the reflector surface from ideal.

$\eta$ is the efficiency not including surface error effects.

The loss in gain due to surface errors is then:

$$\Delta G = -685.8 \left(\frac{\varepsilon}{\lambda}\right)^2 \ dB \qquad (3.3.3)$$

This gain loss is shown in Figure 3.3.1 for 20 GHz, 30 GHz and 44 GHz.

From the figure, it is seen that to obtain a gain loss of less than 1 dB, the surface accuracy must be less than 0.025 in for 20 GHz, 0.017 in for 30 GHz and 0.01 for 44 GHz.

For small antennas (diameters less than 4 ft.) surface accuracies of 0.025 in. area available with standard stamping or spinning techniques, 0.012 in. accuracies are possible with precision spinning or molding, and 0.005 in. if machine casting or molding technique is used. Hence from Figure 3.4.1, very low gain losses can be achieved if the correct manufacturing process is used.

For larger antennas, the antenna is fabricated from panels which introduces several factors contributing to surface accuracy. These include manufacturing factors, and environmental factors (gravity, wind loads, thermal gradients). The surface accuracy varies with the antenna diameter. A linear approximation is often used; i.e. $\epsilon = KD$

Hence

$$G = \eta \left(\frac{\pi D}{\lambda}\right)^2 e^{-\left(\frac{4\pi KD}{\lambda}\right)^2} \tag{3.3.4}$$

The gain loss is $\Delta G = -685.8 \, K^2 \left(\frac{D}{\lambda}\right)^2$ dB

Figure 3.4.2 illustrates the fundamental gain limitations of the antenna due to surface accuracy. As the diameter increases for a given value of K, the gain reaches a maximum value and then decreases. The maximum gain is 4.34 dB below what could be achieved if no surface errors were present.
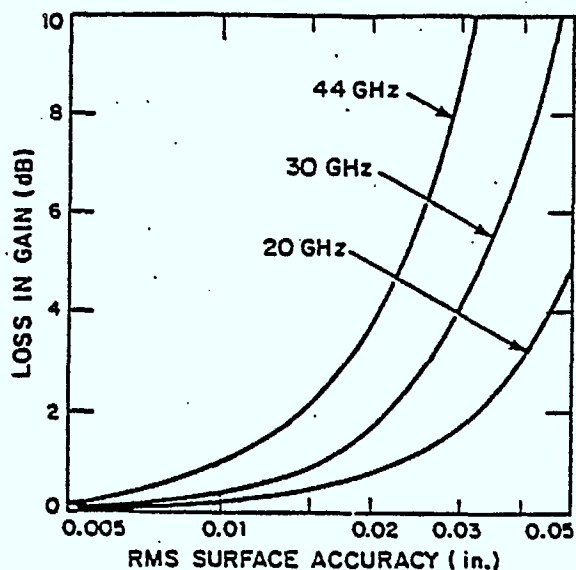
Figure 3.4.1  Antenna Gain Loss as a Function oF Surface
Accuracy (From Reference 32)
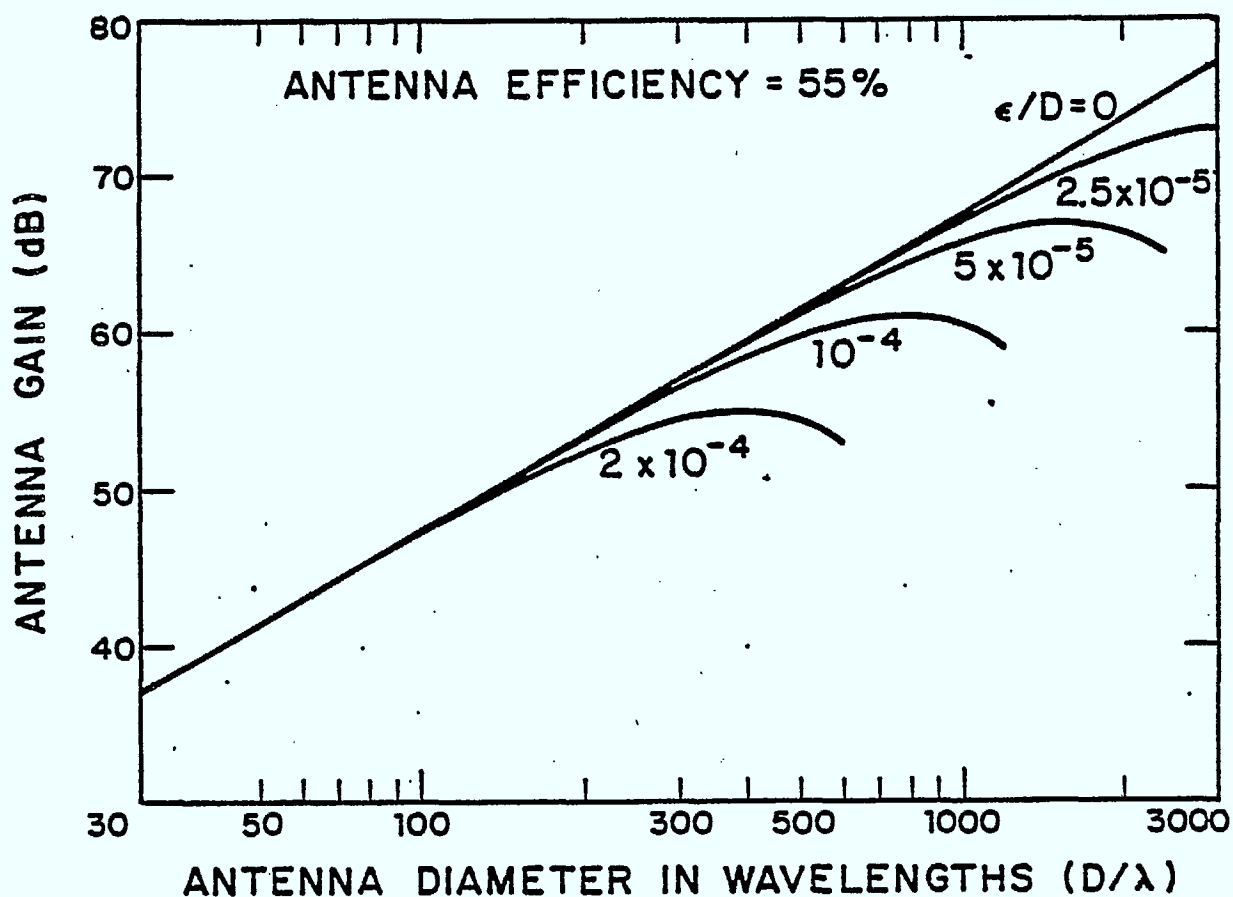


Figure 3.4.2  Antenna Gain Limitations Due To Antenna Surface
Accuracy (From reference 33)

Antennas with surface accuracy to diameter ratio $\epsilon/D = 10^{-4}$ are readily available. The best commercially available antennas have an $\epsilon/D$ ratio of about $5 \times 10^{-5}$. Better ratios are available with special techniques. For example Mitsubishi Electronic Company built an 11.5 m antenna with an rms surface accuracy of 0.17 mm ($\epsilon/D = 1.5 \times 10^{-5}$) for a ground station to communicate with CS-1.

Antenna tracking accuracy causes a reduction in the realizable gain due to the resulting pointing error. The gain of a parabolic reflector incorporating the tracking accuracy $\Delta\Theta$ is given by:

$$G = \eta \left(\frac{\pi D}{\lambda}\right)^2 e^{-2.76\left(\frac{\Delta\Theta}{\Theta_3}\right)^2} \qquad (3.3.5)$$

where $\Theta_3$ is the 3 dB antenna beamwidth

The loss in gain is $\Delta G = -11.99 \left(\frac{\Delta\Theta}{\Theta_3}\right)^2$ dB.

For a loss of 1.5 dB, the tracking error must be $\cong 0.35\, \Theta_3$.

The 3 dB beamwidth for a parabolic reflector is given by:

$$\Theta_3 = \frac{70\lambda}{D}$$

which yields:

$$\Delta G = -\left(\frac{\Delta\Theta}{20.15}\ \frac{D}{\lambda}\right)^2 \text{ dB.} \qquad (3.3.6)$$

From (3.3.6) it can be seen that for a fixed tracking accuracy, and antenna diameter, the antenna gain loss increases as the square of frequency. Hence, if we want to operate with the same antenna at a higher frequency, the tracking accuracy must be improved in order not to suffer further gain losses. Figure 3.4-3 depicts the antenna gain limitations due to tracking accuracies [33]. The curves show that for a given tracking accuracy, the achievable gain in the direction of the satellite reaches a maximum value as the antenna diameter increases, and drops as the antenna diameter increases further.

Tracking accuracy depends on a number of factors including the tracking technique used, wind loading, gravitational and thermal effects. Accuracies of the order of 0.5° are considered typical for mobile terminals using open-loop tracking techniques, while for a satellite 0.2° is typical. If sequential scanning tracking method is used, however, as in LES 8/9 antenna, an accuracy of 0.05° can be achieved. The use of monopulse tracking further improves the tracking accuracy of mobile antennas to 0.1°, whereas with fixed ground antennas, 0.02° can be obtained. Radomes may be used to prevent effects of windload on tracking and surface accuracies. This may incur a small radome transmission loss.

## 3.4.2 AVAILABLE ANTENNAS

Several different types of antennas may find application in EHF including the parabolic antenna, the lens antenna, and the phased array antenna. For the ground segment, the parabolic antenna will most likely be used. Several manufacturers have catalogs listing EHF parabolic antennas, e.g., the TECOM catalog. The space segment may use parabolic reflectors, horns, shaped beam reflectors, arrays and multiple-beam antennas (MBA). For example, the Japanese 30/20 GHz CS satellite uses a shaped horn reflector built by Mitsubishi. The MIT's LES 8/9 spacecraft employed dual-reflector antennas at 36/38 GHz. The use of phased arrays is being examined by the U.S. Air Force.

Table 3.6 lists existing EHF antennas as well as those under development. Multiple beam antennas with both fixed and scanning spot beams as well as the requisite sidelobe levels will require quite a sophisticated design. MBA's can be either reflectors, phased arrays, or lens. Tradeoffs of gain, bandwidth, weight, and complexity have to be made.
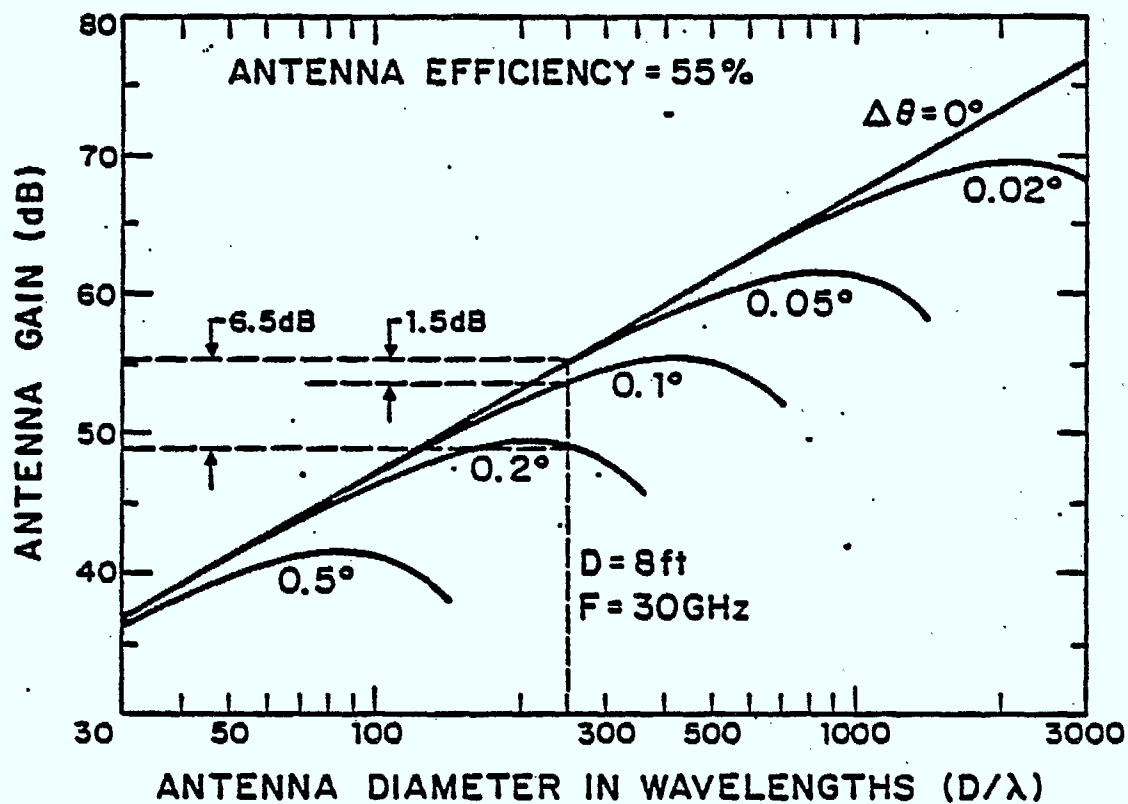
Figure 3.4-3  Antenna Gain Limitations Due To
Antenna Tracking Accuracy (Ref. 33)

Table 3.6  EHF Antenna System Supplier

| MANUFACTURER | FREQUENCY (GHz) | TYPE | GAIN (dBi) | EFFICIENCY (%) | |
|---|---|---|---|---|---|
| ROCKWELL INT'L | 20.7/44.5 | Offset Dual Reflector | 35.1/41.7 | 73 | Surface tolerance < 0.005" |
| | 44 | Lens | 34.8 | 55 | 37 beam |
| MITSUBISHI | 20/30 | Shaped Horn Reflector | 33 | | Flown on "CS"I |
| | 20/30 | Dual Reflector Multi-beam | 51.6 | | 4 beams of 0.35° width |
| | 19/29 | Offset Cassegrain Reflector for Ground Terminals | 66.3/69.5 | 70 | 11.5 m diameter 0.17 mm rms surface error |
| FORD AEROSPACE | 20/30 | Dual MBA Reflectors | 54 (Fixed) 52 (Scanning) | | 24 beams 0.3° wide -30 to -40 dB SL |
| BELL AEROSPACE | 42.5-45.5 | | 45.8 | | -12 dB SL, 26 in. dia. Dual-band SHF/EHF |
| MIT | 44 | Adaptive Nulling Antennas | | | |
| | 21/45 | Dual Frequency Feed | | | |
| | 36/38 | Parab. Refl./Horn | 42.6 dish 24.4 horn | | Used in LES 8/9 0.002" surface tolerance |
| GTE | 44/20 | Feed System | | | |
| HARRIS CORP. | | Pseudo-Mono pulse Tracking Feed & Scanner | | | |
| TRW | | S/C Multi-beam Antenna | | | |
| USAF* | 44 | Phased Array Antenna | | | |
| BALL AEROSPACE | 20 | | 17.3 | 45 | |
| TECOM | 18-26 26-40 | Parab. dish | 31-34 34-37 | | 14 in. diameter ≃ 3° beamwidths |
| NOSC* | 44 | Lens 6.9" Diameter | 34.52 | 41.6 | |

*not actually a supplier.

## 3.5  ON-BOARD SWITCHING AND PROCESSING

Since multiple spot beams are expected to be used, on-board switching is called for to provide the necessary interconnectivity. This space switch can be combined with different access methods to exploit satellite resources in an efficient manner to satisfy virtually any form of traffic requirement. Two types of switching are distinguished – IF switching for trunk traffic, and baseband processing and switching for use with customer premise terminals.

### 3.5.1  RF SWITCH

A possible IF switch consists of an nxn matrix of solid-state switch elements, where n is the number of input and output channels. One or more switches can be activated in a row allowing one input channel to be connected to several output channels. The switching action is controlled by the Master Control Terminal (MCT) via special control circuits. The switching element consists of a dual-gate GaAs FET and couplers to transfer the IF signal from a row to a column of the matrix. The switch matrix under development for NASA has the following characteristics:

- IF                                          3-8 GHz
- 20 x 20 matrix, i.e.,                        400 switch elements
- Data rate switchable                         > 1 Gb/s
- End-to-end loss                              < 15 dB
- Switching time                              ≃ 10 ns
- Channel-to-channel isolation 40 dB
- Design life                                  10 years
- Light weight and low power consumption

The critical technology includes development of the GaAs FET switch/amplifier device, broadband couplers and the switching control circuit, plus packaging and integration of the switch matrix.

Ford Aerospace and GE are developing SS-TDMA IF switch matrices for NASA. Intelsat has made a decision to use SS-TDMA in their Intelsat VI and has let a contract to NEC to develop a reliable SS-TDMA switch.

## 3.5.2 BASEBAND PROCESSOR

The most probable access method of the future for EHF is TDMA. Satellite-switched TDMA has been billed as the ultimate objective for satellite communications. Satellite signal regeneration (processing) as opposed to IF switching is advantageous especially if the link is uplink power limited such as in a military system. The uplink noise, jamming and interference is removed at the satellite and is not retransmitted on the downlink, hence noise accumulation does not occur like in the IF switch systems. Thus BBP SSTDMA systems can lead to superior performance. A saving of 3 dB or more in signal-to-noise ratio, may be obtained, compared to the RF processor. Further, by use of LSI in the baseband processor, the switch can be light compared to the heavier IF microwave switch elements. A further advantage is that associated with signal format change and speed conversion. Since the baseband data stream is available at the satellite, a modulation technique that optimizes the downlink may be used irrespective of the uplink modulation i.e. the uplink and downlink can be optimized separately. For example DQPSK may be used on the uplink since it does not require carrier recovery, while QPSK, which is more power efficient is used on the downlink. Various data speeds may be used in the different downlinks thus requiring bit-rate conversion on board. This allows the use of different size earth terminals thus making the system truly flexible.

In the proposed NASA ACTS system for example, the baseband processor (BBP) is required to switch messages among a network of about 2000 customer premise service (CPS) terminals. It has to demodulate and decode the uplink signal down to digital data, store these data in memory and then switch them digitally to downlink channels. The data are re-coded and remodulated. The BBP can switch individual voice messages from any location to any other location within the fixed or scanned beams, and thus, eliminate the message distribution on the ground. This "switchboard-in-the-sky" concept can lead to significant system cost saving. The key required technologies include:

- fast acquisition burst demodulator for the 27.5 - 550 Mb/s rate
- high-speed digital circuitry (27 Mb/s)
- high reliability (10 year design life)

Critical elements include the low-power, high-speed LSI demodulator, serial-to-parallel converters, Forward Error Correction Code decoders and the digital routing switch. Motorola is developing a BBP and spaceborne switch under contract with NASA. The ITALSAT system will use BBP and Selenia and GTE are developing a baseband switching matrix and demodulators.

## 3.6   CANADIAN EHF CAPABILITY

### 3.6.1   PRESENT INDUSTRY CAPABILITIES

Canadian industry, like those in other countries, has never been quite convinced that a viable market for EHF components and subsystems does exist.  They have been reading and hearing for the past 15 years or so that millimeter-wave technology is "just around the corner".  To develop the necessary millimeter-wave technology requires a considerable cost investment and industry has to be quite sure that a large market exists to justify their investment.  In our interview with Canadian industry, some companies said that although they feel they have EHF capability, they do not see any substantial market beyond the MSAT project.

In other countries, development has been spurred by government projects such as the NASA ACTS, the Japanese MOPT CS program and Italy's National Space Plan.  Other development has been by large companies such as Hughes, Siemens, Watkins Johnson, with large R&D budgets.  Most Canadian companies do not have large R&D budgets to start in-house EHF development programs.  The R&D portion of Canadian companies is typically 5-15% of sales.  Military contracts have helped tremendously to evolve EHF capability in the U.S., for example the MIT's LES 8/9 satellites with EHF payloads was DOD supported.  In Canada, a limited number of government contracts, mainly DND-related have been completed by Canadian industry or are in progress. Andrew Antenna Company constructed a 6 ft. diameter dish antenna for the CRC ground terminal to communicate with LES 8/9 satellites.  They are also currently developing a 20/44 GHz feed for DOC to go on the MSAT spacecraft. ComDev has experience with RF components, waveguide filters, couplers and ferrite devices at EHF, and are building up a surface acoustic wave (SAW) capability.  They have had contracts to supply components for the Japanese Broadcast Satellite and are currently building components for L-SAT satellites at 20 and 30 GHz.

Varian Canada is well recognized in the development and manufacturing of millimeter-wave Extended Interaction Klystron (EIK) and also produce mm wave Reflex Klystrons. They have had considerable success in selling these to the U.S. government agencies, laboratories, and also in Europe. They also produce a variety of EHF radars. Varian is one of the companies that expects a substantial market for their products in the next 5 to 10 years.

Canadian Astronautics Limited's Electronic Warfare Group is developing wideband VCO in the 18-40 GHz range for their Tactical Signal Simulator (TASS). They are also studying the requirements of expanding the operating frequency of the TASS to 100 GHz.

Universities, although not potential manufacturers per se, are doing research in millimeter wave area. At the University of Toronto they are carrying out DREO-funded studies on 20/44 GHz space communications emphasizing antennas. They are developing multi-beam antennas with beam steering and adaptive null steering. The University of Ottawa has developed a mmW receiver front end (mixer) and has been involved in fin-line techniques. Further they are developing cavity-stabilized millimeter-wave sources (LO) and modulators. The University of Manitoba is also involved in analytical and computer program studies for the Defence Research Establishment (DRE) and CRC.

Another area where Canadian Industry is involved, although not strictly EHF but will be required along with the use of EHF, is in signal processing. A number of companies have capabilities in this area. Examples include MDA who are doing work on spread-spectrum and digital signal enhancement, and Canadian Marconi who have a DND contract on spread-spectrum applications.

Further, CRC is testing a 16 km terrestrial EHF link from CRC to Kingsmere in the Gatineau Hills to test weather effects on an EHF link. This will provide valuable information since in a satellite earth link, most of the attenuation (absorption) occurs in the short distance through the earth's atmosphere. In addition, CRC is studying self-adapting variable bit-rate modems to allow the information rate through a small terminal to be continuously adjusted during inclement weather such as in the presence of rain downpours. This might prove to be an effective way to combat outages due to rain. The alternative is to use site diversity which incurs cost penalties.

## 3.6.2  PROJECTED CAPABILITY

A survey of Canadian industry capability and potential at EHF was done.  Although a few companies expressed optimism about the future existence of a market for EHF, most companies were doubtful as to the existence of a viable market outside such programs as MSAT.

There was a general consensus based on remarks from Industry that the Canadian Government should encourage industry to pursue development of EHF based communication systems as this will help them capture their fair share of the market especially in the joint U.S.-CANADA military programs. Military EHF programs were considered the most likely application of EHF.

There appears to be the necessary Industry base to build on for development of EHF subsystems or components.  A number of companies have sufficient capability at C and Ku band that may be extended to EHF. Table 3.7 lists a number of companies that are representative of Canadian Industry potential capability and the most probable potential areas.  There is a notable lack of activity in solid-state device development, with the exception of SED who are developing solid-state low-noise RF devices at SHF, and could possibly extend to EHF.  A number of companies can probably develop capability through a transfer of technology from their parent companies in the U.S., but it is felt that with enough incentive, more Canadian-produced technology may be available.

Table 3.7   Potential Canadian Suppliers

|  | ANTENNAS | RF DEVICES COMPONENTS | PROCESSING/ SWITCHING | EARTH STATIONS |
|---|---|---|---|---|
| ANDREW ANTENNA | P(E) | | | |
| ANTECH | P | | | |
| CAL | | P | | P |
| CAN. MARCONI | | P | P(E) | |
| COMDEV | | E | P | |
| DTL | | | P | |
| M. ASSOC. | P | | | |
| MDA | | | P | P |
| MILLER COMM. | | | P | |
| MITEC ELECT. | | P | | |
| PACIFIC MICROTEL | | | | P |
| RAYTHEON | | P | | P |
| SED | | P | | P |
| SPAR | P | P | | P |
| U. OF T.* | E | | | |
| VARIAN | | P | | |

P − Potential

E − Existing

* − Not actually a supplier

### 3.6.3 POTENTIAL AREAS FOR CANADIAN INDUSTRY DEVELOPMENT

On the global market, most countries are adopting a parochial view whereby they try to limit contracts on their programs to companies in their countries. Only in cases where there is a definite lack of capability within their industry would they consider allowing foreign competitors and even then they would most probably go with the "proven" manufacturers. It is therefore forecasted that Canadian Industry will not capture any significant global EHF market. However, some local market will exist in the future, and something has to be done right now in order to prepare for it when it arrives and prevent losing to other countries even in local markets. It is clear, however, that Canadian Industry will require Government encouragement and financial assistance to develop the requisite EHF capability, and international reputation and to promote international sales.

It is considered a poor business to develop device and component capability such as GaAs FET's etc., and it might be more advisable to buy devices from the U.S. and develop subsystems. Canadian Industry should have the capability to produce all aspects of ground terminals. Development of RF subsystems is considered an area where some effort should be directed. Canada has a large number of microelectronic companies and it is expected that Canada can become a major supplier of processing electronics. On-board processing is an area that should be actively developed in the light of present capability. Some capability should be developed to exploit the already existing base of analysis and fabrication of antennas.

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SECTION 4

SURVEY OF COMMUNICATION REQUIREMENTS

BY

CIVIL, MILITARY, AND SCIENTIFIC COMMUNITIES

## 4.1 CANADIAN DEMAND SIDE

### 4.1.1 DEMOGRAPHIC DATA AND FORECASTING

#### 4.1.1.1 Introduction

Prior to proceeding with traffic volume projections of Canadian telecommunications up to the year 2000, it is important to study several variables whose trends could influence our projections. These variables are: i) population, ii) the number of Canadian households, and iii) the Gross National Product (GNP). The population is of course the main driver for the demand of telecommunications. When combined with the trends in the number of households and the settlement pattern in Canada, the demand and provision of video service and telephone usage can be correlated. The population growth trend, when considered with the trend of the GNP, can be used to forecast business telephone and data requirements. Although the GNP decreased in 1982, the 1983 economic recovery is predicted to continue through the year 2000.

The following text is intended to familiarize the reader with the growth rates and trends of the above variables. The growth trends for population and the number of Canadian households are averages of four plausible scenarios produced by Statistics Canada. The growth trend for Canada's GNP was obtained through trend line analysis. All the trends show a declining rate of growth with respect to time.

What follows is a brief description of these analyses. The supporting data for this chapter may be found in Appendix A to this report.

#### 4.1.1.2 Population

The four population scenarios produced by Statistics Canada, [1] are illustrated in Figure 4.1.1-1. These scenarios, based on the June 1,1976 Census, were generated under four different sets of assumptions; accounting for fertility rates, and international and interprovincial migration patterns.

The average annual growth rate (over five year intervals) used to project the population to the year 2000 is shown in Figure 4.1.1-2. The overall trend is a declining rate of growth as Canadians tend towards smaller families. The average scenario shows the growth rate dropping from 1.20% in 1981 to 0.86% in 1991, and then to 0.68% by 2001. It is interesting to note that Woods Gordon [2], favours Statistics Canada's fourth projection - their most pessimistic scenario. Our average scenario is more optimistic. It tracks Statistics Canada's third projection while riding slightly above it.
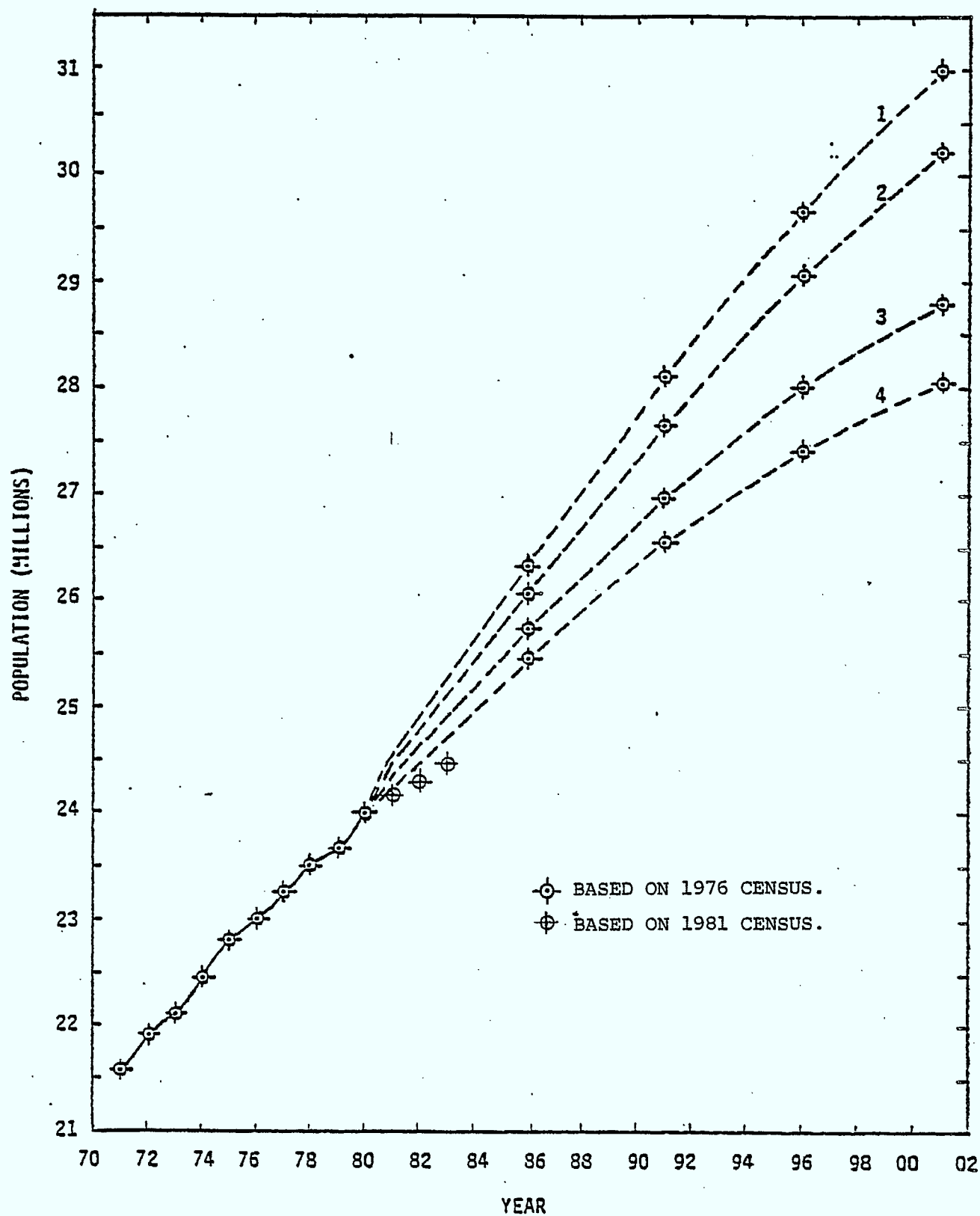
Figure 4.1.1-1  Canadian Population
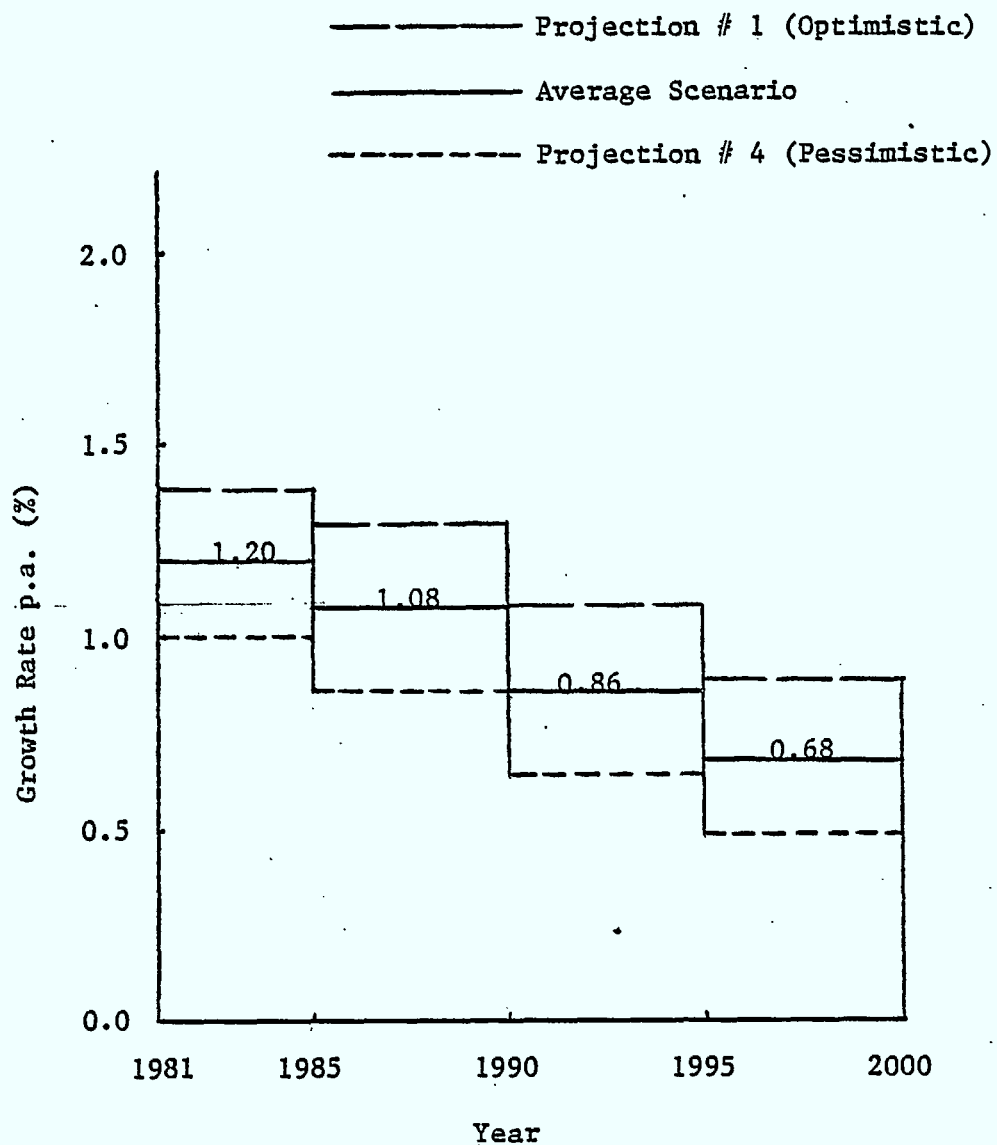
Figure 4.1.1-2   Average Annual Growth – Population

### 4.1.1.3 Number of Canadian Households

Statistics Canada, [1], also produced four projections for the number of Canadian households. The four different sets of assumptions considered factors like marital status and size of families. But as opposed to the population projections, which used the 1976 Census, these were based on the Census of 1971. These four scenarios are shown in Figure 4.1.1-3.

The growth trend in the number of Canadian households, being partially driven by the trend in population, declines with respect to time, but drops more rapidly than with population. The average scenario shows a drop from 2.40% in 1981 to 1.19% in 1991, and then down to 1.17% by the year 2001. The higher initial growth rate of the number of households is attributable to the young people of the baby boom, as they become of age. Once the baby boom effect passes through, the rate of decline starts to level out as depicted by the projections during the 1990's.

Figure 4.1.1-4 illustrates the assumed annual growth rates, over five year intervals, of Statistics Canada's most optimistic and pessimistic scenarios, accompanied by an average scenario.
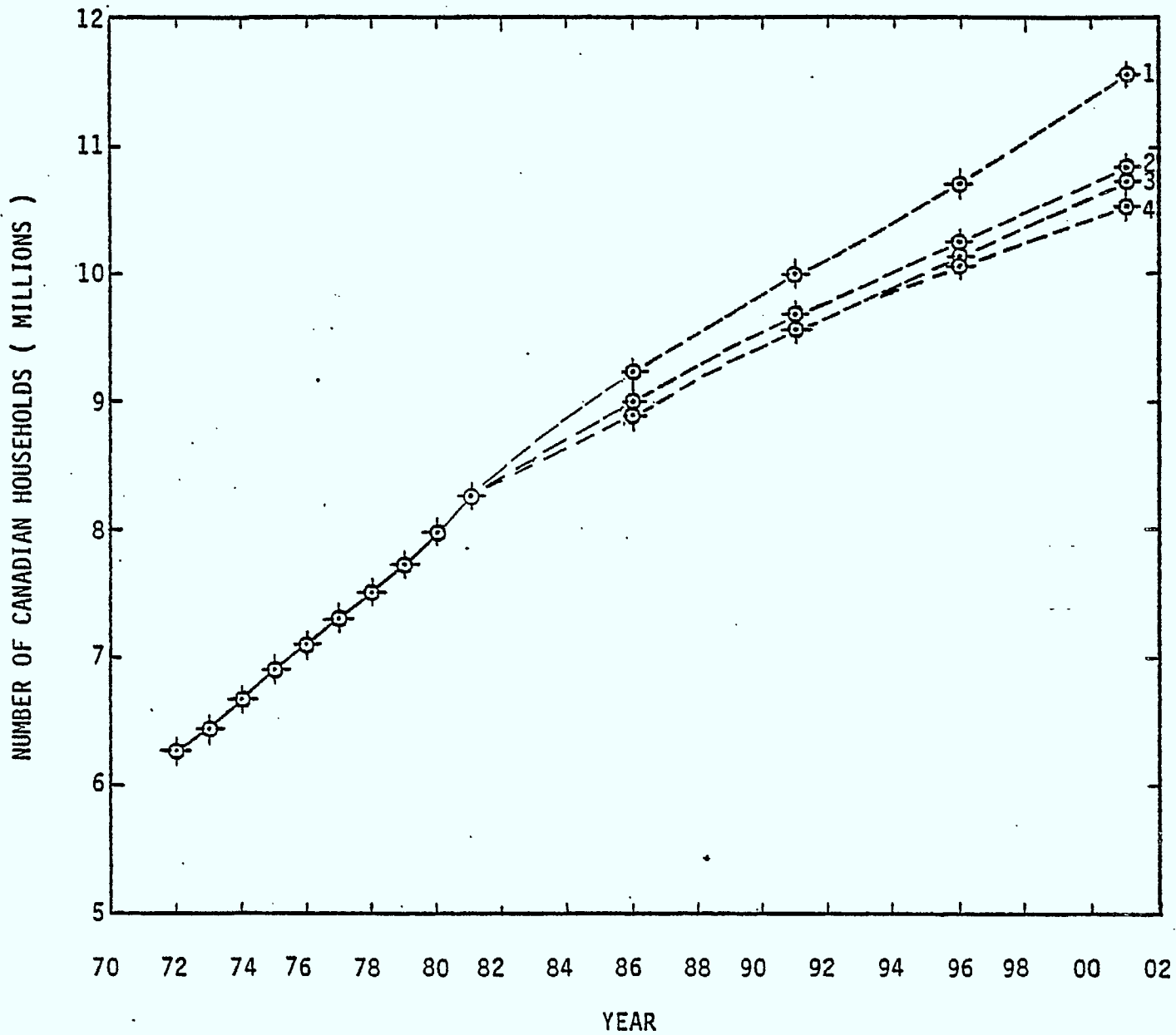
Figure 4.1.1-3  Number of Canadian Households (1972-2001)
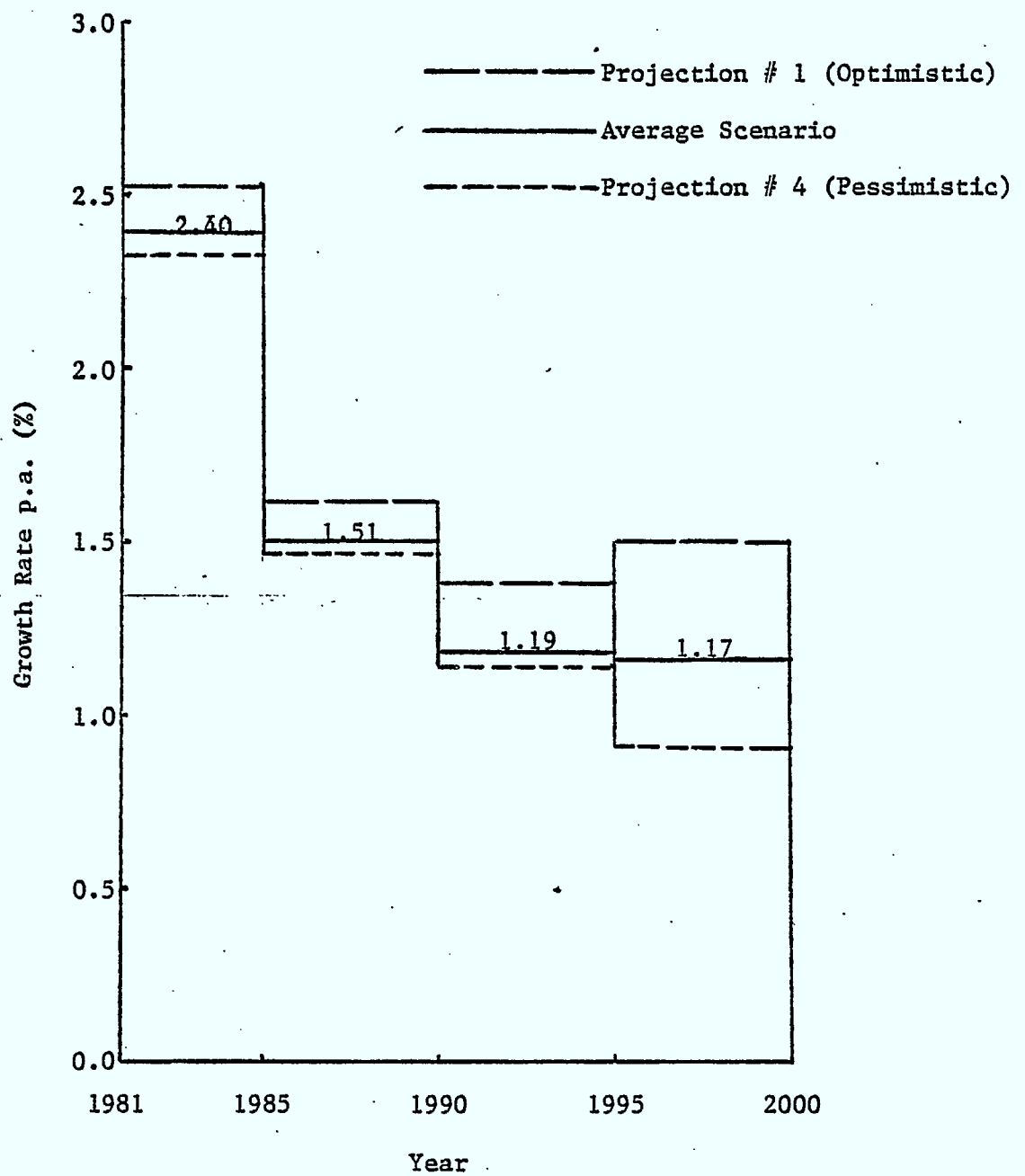
Figure 4.1.1-4  Average Annual Growth - Households

## 4.1.1.4  Gross National Product

The projection of Canada's GNP was produced using trend line analysis. The GNP figures between 1970 and 1980, in constant 1971 dollars, were used [1]. The 'best line' possessed a correlation figure of 0.9865 for the given data and had an annual increase of 4228 million constant 1971 dollars. This best fit line is illustrated in Figure 4.1.1-5.

Translating the constant annual monetary increase into annual compounded growth rate, over five year intervals, yields a declining growth trend. The growth rate drops from 3.59% in 1980 to 2.29% in 1990, and then down to 2.05% by the year 2000.
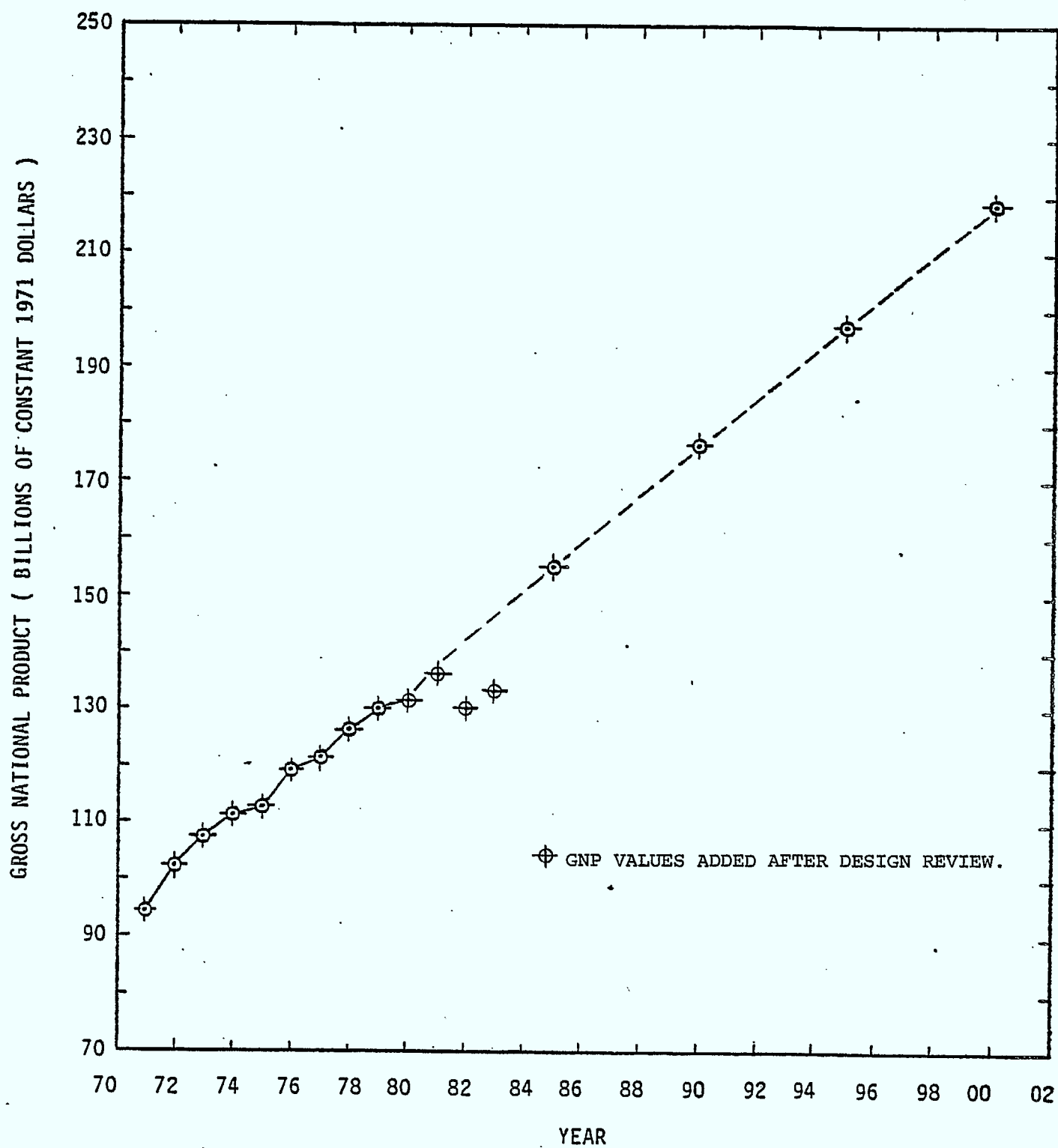
Figure 4.1.1-5  Gross National Product (1970-2000)

## 4.1.1.5  Summary of Forecasting

For convenience, the projected figures for the population, number of Canadian households and GNP (in five year intervals) are tabulated together in Table 4.1.1-1.  The compounded annual growth rates assumed for the projections of the three factors are listed in Table 4.1.1-2.  Finally, the growth rates found in Table 4.1.1-2 are drawn on Figure 4.1.1-6.  All three factors show decreasing annual growth rates.  These forecasts show a continuing increase in the Gross National Product, in constant dollars, per unit of population, that is the forecaset is for continued growth in the real wealth of Canada through to the year 2000.

Table 4.1.1-1  Projected Population, Households
and GNP Figures (1980-2000)

| YEAR | POPULATION ('000) | HOUSEHOLDS ('000) | GNP IN MILLIONS OF CONSTANT 1971 DOLLARS |
|---|---|---|---|
| 1980 | 23,936 | 7,970 | 130,160 |
| 1985 | 25,407 | 8,973 | 155,294 |
| 1990 | 26,809 | 9,671 | 176,434 |
| 1995 | 27,982 | 10,260 | 197,574 |
| 2000 | 28,946 | 10,874 | 218,714 |
| RATIO 2000/1980 | 1.21 | 1.36 | 1.68 |

Table 4.1.1-2  Assumed Average Annual Growth Rates for
Population, Households and GNP Projections
(1980-2000)

| TIME INTERVAL | POPULATION GROWTH (%) | HOUSEHOLD GROWTH (%) | GNP GROWTH (%) |
|---|---|---|---|
| 1980-1985 | 1.20 | 2.40 | 3.59 |
| 1985-1990 | 1.08 | 1.51 | 2.59 |
| 1990-1995 | 0.86 | 1.19 | 2.29 |
| 1995-2000 | 0.68 | 1.17 | 2.05 |
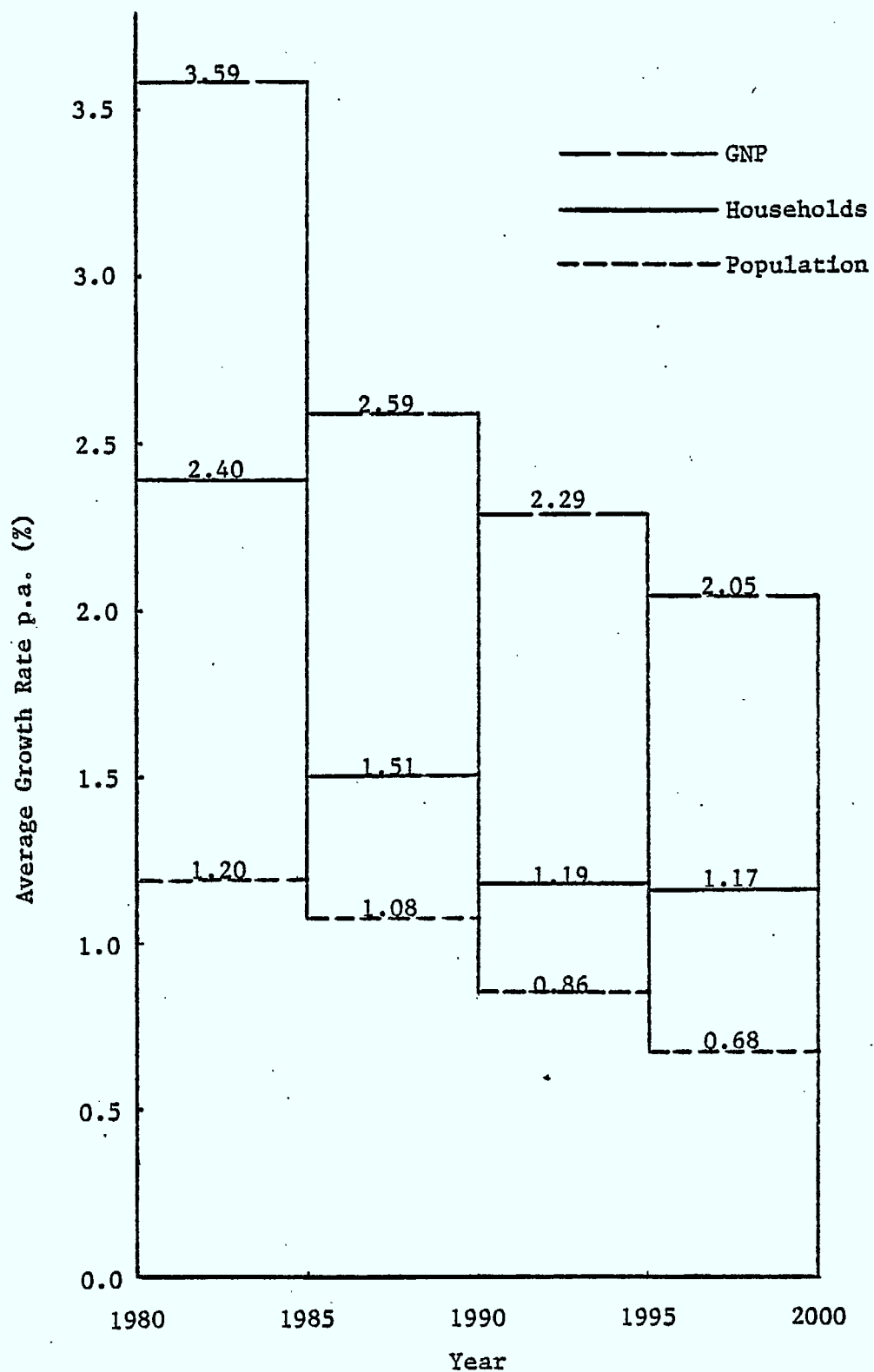
Figure 4.1.1-6  Assumed Growth Rates For Population, Households and GNP Projections (1980-2000)

## 4.1.2  VOICE SERVICE REQUIREMENTS

### 4.1.2.1  Introduction

Throughout history, man's desire and need to exchange ideas and information has driven him to continually develop better methods of communications. Each development has enabled him to communicate, in a variety of ways, with more people, more quickly and over greater distances then before. One such development occured in March 1876 and revolutionized the telecommunications industry. Its effect was so profound that it would be extremely difficult for us to live without it today. This development was, of course, Alexander Graham Bell's invention - the telephone.

As we enter the Information Age, Canada is equipped with one of the best telecommunications networks in the world. In 1980, there were over 16.5 million telephones connected to this network - enough to rank fourth in the world for the number of telephones per capita. With an average of one telephone for every two people, this network is truly extensive. In fact, 98% of all the Canadian households had at least one telephone in 1980.

Our dependence on the telephone is astounding. There were approximately 26 billion calls made in 1980, that is an average of 1624 calls per telephone annually. Of these 95% were local calls, while 5% were long distance telephone calls. In this study our interests lie in the long distance calls, where an EHF fixed communications satellite system could provide the service cost effectively.

Forming the backbone of Canada's telecommunications network is a co-operative of telephones companies, known as the TransCanada Telephone System (TCTS). Its primary responsibility is to provide Canada with long distance telephony, video, and data communications. Since its establishment in 1931, TCTS's membership has grown to consist ten large Canadian telecommunications carriers. These organizations are Telesat Canada, Bell Canada, British Columbia Telephone, Alberta Government Telephone, Saskatchewan Telecommunications, Manitoba Telephone System, The New Brunswick Telephone Company, Maritime Telegraph & Telephone Company Limited, The Island Telephone Company, and Newfoundland Telephone Company Limited. The first three companies are under the regulations of the CRTC.

The competitor to TCTS, in national telecommunications, is CNCP Telecommunications. CNCP acts as a carrier for some telephone companies and maintains its livelihood through data communication services. It has been estimated, that about 60% of CNCP's total revenues is derived from data communications, while the corresponding figure is 3% or 4% for TCTS [3,4]. CNCP is under the regulations of the CRTC.

There are also other Telcos, but they have not been mentioned as our involvement with them will be slight. A list of the major telephone and telecommunications carriers in Canada may be found in Appendix B.

There are numerous services offered by the telephone companies, the following section will consider the three primary services. These are:

A) Message Telephone Service (MTS),
B) Wide Area Telephone Service (WATS), and
C) Private Lines.

The former two services are public services and their traffic volumes will be dealt with concurrently.

### 4.1.2.2  Message Telephone Service (MTS) and Wide Area Telephone Service (WATS) Traffic Volumes

#### 4.1.2.2.1  Introduction

This section deals with the determination of the public telephone traffic volume. The services which generate this traffic volume are the Message Telephone Service (MTS) and the Wide Area Telephone Service (WATS), i.e., everything except Private Line Service. There follows a description of the services listed under MTS and WATS, which are based on the classifications of message rate voice services by the Canadian Telecommunications Carriers Association (CTCA) [4]. While description of equivalent CNCP services has not been included, this is not considered to be significant in this context since the purpose is to give the reader a feel for the characteristics of the MTS and WATS services and not to describe the full array of message rate voice services available.

The Message Telephone Service (MTS) is the normal telephone service to which most Canadians have become accustomed. The mainstream of long distance MTS is the Direct Distance Dialing service (DDD) which offers residential and business telephone subscribers access to almost any other subscribers on the telephone network on a dial-up basis. Access to the remainder of the network may be attained through operator assistance. Once the two parties are connected, a single 4 kHz voice circuit is dedicated to their use for the duration of the call.

Traffic volume under Multicom I is also included. Multicom I allows the subscriber to access up to ten other designated subscribers on the DDD network through one digit dialing. The single digit activates an appropriate automatic dialer which calls the desired party. Voicecom I and II traffic are also included.

The Wide-Area Telephone Service (WATS) offers special rates for bulk one-way telephone service. There are two forms of WATS-INWATS and OUTWATS. INWATS allows customers from specific WATS zones to call in without being charged. INWATS service is identified by the Zenith 800 number. OUTWATS, on the other hand, allows the subscriber to make only outgoing calls to specified WATS zones. WATS charges are based on the accumulative toll call time per month and the WATS zones that are accessed. The time factor is additionally broken down into less than or greater than 160 hours of usage.

The public telephone traffic volume also encompasses international long distance calls.

4.1.2.2.2  The Toll Telephone Traffic Model

The toll telephone traffic network in Canada is a complex and extensive communictions grid that provides numerous links to most Canadian communities.

It is the purpose of this section to derive the numbers of long distance calls, the duration of these calls, and finally the number of voice circuits required for calls which are over distances of greater than 300, 400 and 500 miles, during periods of peak utilization. Rather than attempt a comprehensive and undoubtedly complex analysis of traffic on the actual network the authors have used a statistical approach to develop the necessary information. The methodology is described in Section 4.1.2.2.3. The three distance values of 300, 400 and 500 miles were selected to correspond to maximum, average and minimum scenarios respectively. In the final analysis, in Section 4.3, the amount of traffic captured by satellites will vary with the distance.

The final calculated values for the number of voice circuits are not intended to represent the actual number of voice circuits at any specific physical point in the telephone network. Rather the values are measures of the predicted voice traffic that could logically be carried by satellites.

4.1.2.2.3 Methodology

There follows the methodology employed to determine the public voice traffic volume, up to the year 2000. A detailed flow diagram to illustrate the methodology is shown in Figure 4.1.2.-1. The final objective of this exercise is to ascertain the number of voice circuits required to accomodate the long distance voice traffic volume.

The standard practice for designing such a multiple trunk line is to design for the "normal" worst case usage, i.e., during the peak hour. Extraordinarily heavy duty traffic loads, typical of those on holidays or national emergencies, are normally absorbed by secondary trunk lines. Therefore, the traffic contribution of an extraordinary demand will not be considered in this study.

The volume of telephone traffic is the product of two factors:

  i)  the number of toll call attempts during the peak hour; and
  ii)  the time duration of the toll call attempts.

The next four sections will provide an in-depth breakdown of the analysis. Paragraph 4.1.2.2.4 derives the peak hour toll call attempts from Statistics Canada data. The raw data are in the form of completed annual toll call statisitics. To start, the annual statistics were projected up to the year 2000. It is known that the peak hour traffic occurs on weekdays, hence the next step was to eliminate the weekend toll calls. By assuming there are 250 business weekdays in a year, the number of toll calls completed on an average business weekday was then calculated. Next, the number of toll calls completed during the peak hour was determined predicated on a certain percentage of the weekday total.

The analysis to this point only accounts for completed calls. However, unsuccessful calls also require circuit usage and their contribution to the traffic demand must be considered as well. Thus, the final step was to apply an estimated successful/unsuccessful call ratio to obtain the peak hour toll call attempts.

Paragraph 4.1.2.2.5 describes the time duration of toll call attempts in terms of the connect time and holding time for both successful and unsuccessful calls are discussed.

Paragraph 4.1.2.2.6 combines the results of the two preceeding paragraphs to determine the toll telephone traffic volume and then translate it into voice circuit requirments. The portion of these toll voice circuits which are dedicated for national toll traffic is isolated and identified in paragraph 4.1.2.2.7.

It should be noted that the inclusion of unsuccessful toll calls increases the required number of voice circuits by 3% to 5% in the model. Hence, the impact due to unsuccessful toll calls, while not being large, is significant.
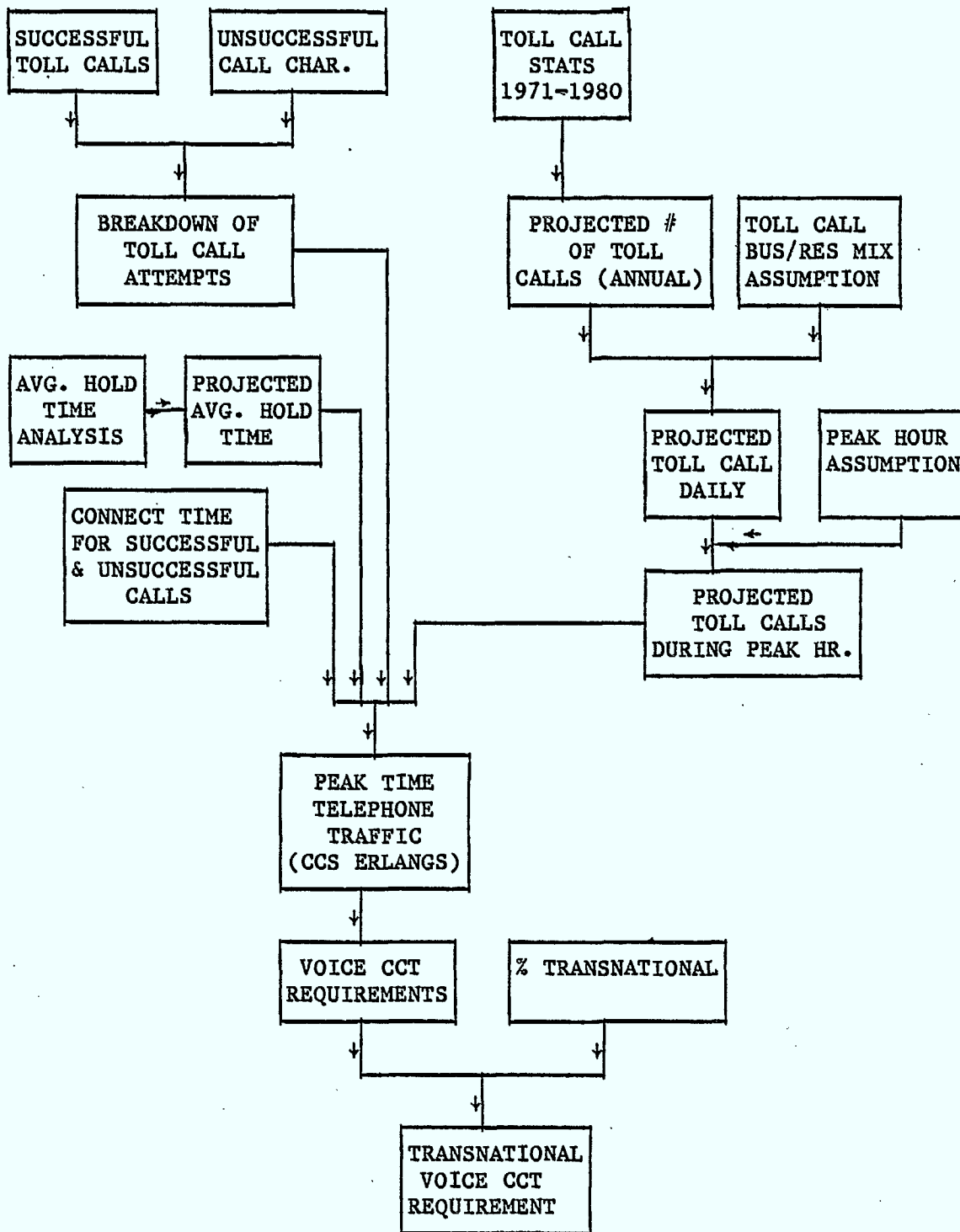
```
┌─────────────┐   ┌─────────────┐        ┌─────────────┐
│ SUCCESSFUL  │   │UNSUCCESSFUL │        │ TOLL CALL   │
│ TOLL CALLS  │   │CALL CHAR.   │        │ STATS       │
│             │   │             │        │ 1971-1980   │
└──────┬──────┘   └──────┬──────┘        └──────┬──────┘
       │                 │                      │
       └────────┬────────┘                      │
                │                               │
         ┌──────┴──────────┐           ┌────────┴──────────┐  ┌─────────────┐
         │ BREAKDOWN OF    │           │ PROJECTED #       │  │ TOLL CALL   │
         │ TOLL CALL       ├───┐       │ OF TOLL           │  │ BUS/RES MIX │
         │ ATTEMPTS        │   │       │ CALLS (ANNUAL)    │  │ ASSUMPTION  │
         └─────────────────┘   │       └────────┬──────────┘  └──────┬──────┘
                               │                │                    │
  ┌──────────┐  ┌──────────┐   │                └─────────┬──────────┘
  │ AVG. HOLD │  │PROJECTED│   │                          │
  │ TIME      ├─▶│AVG. HOLD│   │                 ┌────────┴────────┐  ┌─────────────┐
  │ ANALYSIS  │  │TIME     │   │                 │ PROJECTED       │  │ PEAK HOUR   │
  └───────────┘  └─────────┘   │                 │ TOLL CALL       │  │ ASSUMPTION  │
                               │                 │ DAILY           │  │             │
  ┌──────────────┐             │                 └────────┬────────┘  └──────┬──────┘
  │ CONNECT TIME │             │                          │◀─────────────────┘
  │ FOR SUCCESSFUL│            │                 ┌────────┴──────────┐
  │ & UNSUCCESSFUL│            │                 │ PROJECTED         │
  │ CALLS        │             │                 │ TOLL CALLS        │
  └──────────────┘             │                 │ DURING PEAK HR.   │
                               │                 └───────────────────┘
            ▼  ▼  ▼  ▼
         ┌─────────────┐
         │ PEAK TIME   │
         │ TELEPHONE   │
         │ TRAFFIC     │
         │ (CCS ERLANGS)│
         └──────┬──────┘
                │
         ┌──────┴──────┐        ┌─────────────────┐
         │ VOICE CCT   │        │ % TRANSNATIONAL │
         │ REQUIREMENTS│        │                 │
         └──────┬──────┘        └────────┬────────┘
                │                        │
                └───────────┬────────────┘
                            │
                  ┌─────────┴────────┐
                  │ TRANSNATIONAL    │
                  │ VOICE CCT        │
                  │ REQUIREMENT      │
                  └──────────────────┘
```

Figure 4.1.2-1

4.1.2.2.4  Determination of Peak Hour Toll Call Attempts

The objective of this portion of the analysis is to ascertain the number of toll call attempts, which would be made during the hour of peak usage in the network on a typical weekday, between the years 1980 and 2000. The final product was the result of a disassembly process.

The first step of the process was to project the number of completed annual telephone toll calls over the period 1980 - 2000. Three methods were attempted, which are described below.

The first method employed a linear-regression analysis of the historical data between 1971 and 1980 (derived from Statisitics Canada Catalogue 56-203). The fit for this data yielded a correlation of 0.996. Figure 4.1.2-2 is a plot of the historical data and shows the straight line used in the fit. The fit indicates a constant annual growth of 90 million long distance telephone calls per year which corresponds to a declining compounded annual growth from 4.7% (1985-1990) to 3.8% (1990-1995) to 3.2% (1995-2000). The projected total annual number of toll calls, to the year 2000, is tabulated in Table 4.1.2-1. These projected growth rates are much lower than the average growth rate of 10% p.a. exhibited by the historical data. Hence, it was decided not to use linear-regression.

The second method used assumed a constant percentage growth of 10% p.a., derived from the historical data. This growth rate is considerably greater than the projected growth in population and the GNP. The projected number of annual toll calls are also tabulated in Table 4.1.2-1 and shown in Figure 4.1.2-2. This method was not used, since it implied perpetual growth and forecasted extremely high values in the latter years of the century.

The third method, which was chosen for the model, consisted of creating a scenario which considered several factors. These included declining growth rates in population and households, market saturation in the 1990's, historical growth rates, the one possibility of reduced long distance tariffs in the future, and the fact that growth was neither linear nor exponential. The forecasted figures, along with the assumed growth rates for the scenario, are depicted in Table 4.1.2-1 and Figure 4.1.2-2.
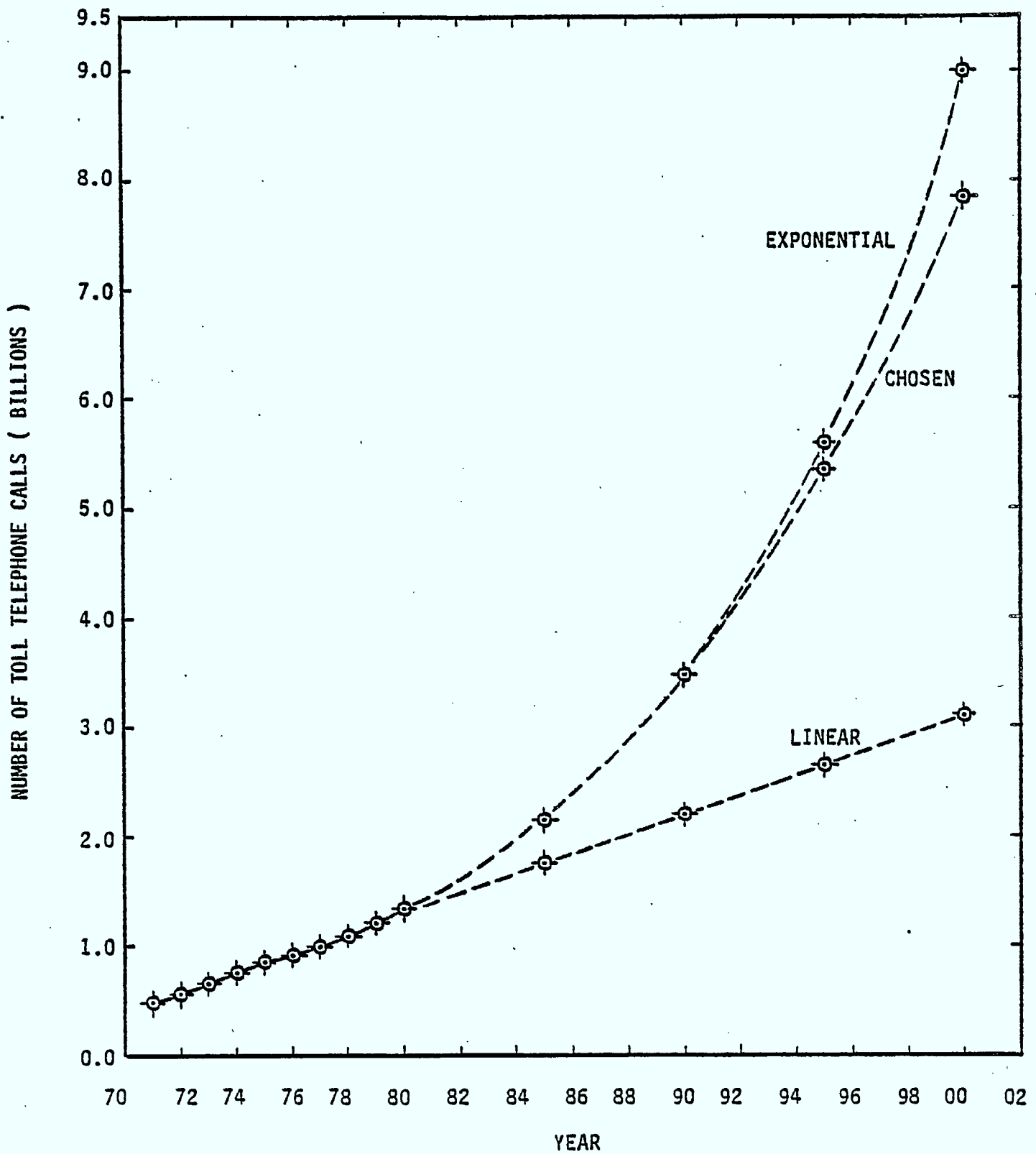
Figure 4.1.2-2  Number of Toll Calls vs. Time

## Table 4.1.2-1: Forecasted Total Number of Annual Toll Calls Completed Annually (1980-2000)

| YEAR | FORECASTED TOTAL NUMBER OF ANNUAL TOLL CALLS (MILLIONS) | | | AVERAGE ANNUAL GROWTH RATE OF CHOSEN SCENARIO FOR TIME INTERVAL STARTING |
|------|------------------------|---------------------|--------------------|----------|
|      | LINEAR REGRESSION | EXPONENTIAL GROWTH | CHOSEN SCENARIO |          |
| 1980 | 1340 | 1340 | 1340 | 10% p.a. |
| 1985 | 1749 | 2158 | 2158 | 10% p.a. |
| 1990 | 2202 | 3476 | 3476 | 9% p.a.  |
| 1995 | 2655 | 5598 | 5348 | 8% p.a.  |
| 2000 | 3108 | 9015 | 7858 |          |

The next step was to arrive at the number of toll calls made on an average weekday. Thus, the following assumptions were made, based on information gathered from the ITT 30/20 GHz study [5].

1) That all business toll calls are made on the 250 workdays of the year;

2) That residential toll calls data may be broken down as follows:
   i) 10% of calls made during times when the 60% discount is in effect, i.e., weekends and early morning hours
   ii) 80% are made during times when the 35% discount is in effect, i.e., 6 p.m. to midnight
   iii) 10% are made during business hours with no discount; and

3) The business/residential toll call mixture for the period of interest is:

| TIME INTERVAL | % OF ANNUAL TOLL CALLS | |
|---------------|----------|-------------|
|               | BUSINESS | RESIDENTIAL |
| 1980-1989 | 54 | 46 |
| 1990-2000 | 57 | 43 |

Applying these assumptions, the weekend toll calls were eliminated and then the remainder was divided by 250 to obtain the number of toll calls made during an average weekday. The number of calls during an average weekday is equal to: the total number of annual calls x $(1.0-.46x.1) \div 250$. The results are listed in Table 4.1.2-2. These figures show a large increase in the per capita use of the telephone as shown in Table 4.1.2-2. Even the linear regression predicts an increase in per capita use of the long distance telephone call.

Table 4.1.2-2: Forecasted Number of Toll Telephone Calls
Completed During Average Weekday (1980-2000)

| YEAR | FORECASTED NUMBER OF CALLS DURING AVG. WEEKDAYS (THOUSANDS) |
|------|---------------------------------------------------------------|
| 1980 | 5113 |
| 1985 | 8235 |
| 1990 | 13306 |
| 1995 | 20472 |
| 2000 | 30080 |

The percentage of daily toll calls made during peak hours of an average weekday has been estimated by Brackett (Ref.6) and by Martin (Ref. 7). These references were the only sources of traffic time distribution found. From data in Ref. 6, page 96 the peak demand can be calculated at 8.26% of the total daily calls. In reference 6 it had been assumed that the demand between 12 midnight and 7 a.m. was zero. The authors regard this as unrealistic and have assumed an average hourly demand of 12.9 per hour (90/7) for this 7 hour period. The distribution is as follows:

| Time Period | Traffic | Percent |
|---|---|---|
| MIDNIGHT – 7 a.m. | 90 | |
| 7 – 8 | 40 | |
| 8 – 9 | 70 | |
| 9 – 10 | 95 | |
| 10 – 11 | 100 | 8.26 |
| 11 – 12 | 80 | |
| NOON – 1 p.m. | 50 | |
| 1 – 2 | 75 | |
| 2 – 3 | 100 | 8.26 |
| 3 – 4 | 90 | |
| 4 – 5 | 90 | |
| 5 – 6 | 90 | |
| 6 – 7 | 60 | |
| 7 – 8 | 50 | |
| 8 – 9 | 40 | |
| 9 – 10 | 40 | |
| 10 – 11 | 25 | |
| 11 – MIDNIGHT | 25 | |

From Figure 15.1, Ref. 7, the peak demand is 14.1% of the total daily calls. The peak hour, according to both sources occurs between 10 am and 11 am. A second peak of approximately the same magnitude occurs between 2 and 3 p.m. The 8.26% figure is used to calculate the minimum peak demand. An increase of 25% upon the 14.1 percent figure, i.e. 17.6% is used to calculate maximum "busy" day peak demand. The average peak was calculated using the median of the 8.26% and the 14.1% values.

**Table 4.1.2-3: Forecasted Number of Toll Telephone Calls Completed During The Peak Hour Of An Average Weekday (1980-2000)**

| YEAR | PROJECTED TOLL CALLS DURING PEAK HOUR ('000) | | |
|---|---|---|---|
| | MINIMUM | MAXIMUM | AVERAGE |
| 1980 | 422 | 900 | 572.7 |
| 1985 | 680 | 1449 | 922.3 |
| 1990 | 1099 | 2342 | 1490.3 |
| 1995 | 1691 | 3603 | 2292.9 |
| 2000 | 2485 | 5294 | 3369.0 |

In order to model the actual voice circuit usage, unsuccessful toll calls must be accounted for as well as successful calls. Two statistical analyses performed by personnel at Bell Laboratories, [8] [9], indicate that 70.7% and 69.0% of toll calls attempts are successful. An additional source James Martin, [7] , estimates the success rate to be 68%. The analyses done by Bell Laboratories were more extensive; and hence, a success rate of 70% will be adopted for this model. The effect of the unsuccessful toll calls will be applied in paragraph 4.1.2.2.5.

4.1.2.2.5 Asssumptions for Time Duration of Toll Call Attempts

To complete the model, the time duration for which toll call attempts, whether successful or not, occupy the voice circuits must be accounted for. This time duration was separated into connect and holding time.

One of the previous Bell Lab analyses, [8], found the average connect time for a successful and an unsuccessful toll call attempt to be 26.6 and 48.8 seconds, respectively. It is interesting to see that the author, K.S. Liu, has included the connect time of additional attempts resulting from an unsuccessful response on the first attempt. ITT, in their report, [5], used a 45 second time for unsuccessful calls. Our model employed the values generated by K.S. Liu, i.e., 27 and 49 seconds.

Once the two parties are connected, the time for which the circuit is occupied is known as the holding time. This is the time for which the customer is charged. A study [10] provides a breakdown of toll calls, made in the Bell network, by mileage band, duration and total charge minutes during 1975. This data has been reprinted as Table 4.1.2-4. Analysis of this data yielded an average holding time of 322 seconds. ITT, [5], has estimated that the average holding time will increase by 30 seconds per decade. An increase of 15 seconds every five years was used in our model. The projected average holding time assumed is listed in Table 4.1.2-5. As a comparison, ITT assumed an initial average holding time of 360 seconds, in 1980, for their study.

Table 4.1.2-4  Estimated Long Distance Messages (All Types)
According to Distance and Duration - Bell Canada, [10]
(on the annual basis - in millions)
Duration in Charged Minutes

| Rate Mileage | 1 min. | 2 min. | 3 min. | 4 min. | 5 min. | 6 min. & Over | Total Min. Charged | % of Total Min. Charged |
|---|---|---|---|---|---|---|---|---|
| 0- 10 | 6.4 | 3.5 | 2.0 | 1.2 | 0.9 | 3.4 | 71.0 | 2.7 |
| 11- 14 | 12.4 | 7.1 | 4.1 | 2.6 | 1.7 | 5.9 | 125.3 | 4.8 |
| 15- 22 | 24.6 | 15.2 | 9.4 | 6.1 | 4.2 | 15.2 | 303.8 | 11.5 |
| 23- 30 | 15.1 | 10.0 | 6.5 | 4.4 | 3.1 | 11.8 | 222.3 | 8.4 |
| 31- 40 | 13.4 | 9.3 | 6.3 | 4.4 | 3.2 | 12.8 | 231.9 | 8.8 |
| 41- 50 | 7.6 | 5.5 | 3.9 | 2.7 | 2.0 | 8.6 | 151.9 | 5.8 |
| 51- 60 | 6.1 | 4.6 | 3.3 | 2.4 | 1.8 | 8.0 | 138.2 | 5.2 |
| 61- 80 | 6.5 | 5.0 | 3.7 | 2.7 | 2.1 | 10.0 | 169.0 | 6.4 |
| 81-100 | 4.2 | 3.3 | 2.5 | 1.8 | 1.5 | 7.3 | 123.9 | 4.7 |
| 101-130 | 5.4 | 4.1 | 3.1 | 2.4 | 1.9 | 9.7 | 163.2 | 6.2 |
| 131-160 | 3.5 | 2.6 | 2.0 | 1.5 | 1.2 | 6.3 | 106.3 | 4.0 |
| 161-200 | 2.1 | 1.7 | 1.4 | 1.1 | 0.9 | 5.0 | 83.6 | 3.2 |
| 201-250 | 3.8 | 2.9 | 2.3 | 1.7 | 1.4 | 8.4 | 142.8 | 5.4 |
| 251-300 | 1.5 | 1.2 | 0.9 | 0.7 | 0.6 | 4.1 | 68.2 | 2.6 |
| 301-400 | 5.9 | 4.6 | 3.7 | 2.9 | 2.3 | 13.6 | 229.7 | 8.7 |
| 401-500 | 1.5 | 1.2 | 1.0 | 0.7 | 0.6 | 4.0 | 67.7 | 2.6 |
| 501-Over | 4.3 | 3.5 | 2.9 | 2.5 | 2.2 | 14.7 | 237.8 | 9.0 |
|  | 124.1 | 85.3 | 59.0 | 41.8 | 31.6 | 148.8 | 2636.6 | 100.0 |

Table 4.1.2-5:  Forecasted Average Holding Time Duration (1980-2000)

| YEAR | AVERAGE HOLDING TIME (SEC) |
|---|---|
| 1980 | 337 |
| 1985 | 352 |
| 1990 | 367 |
| 1995 | 382 |
| 2000 | 397 |

4.1.2.2.6  Determination of MTS and WATS Traffic Volume and Required Voice Circuits

With a complete model, the telephone traffic volume may be calculated.  The telephone traffic demand may be expressed as:

$$TT = (STC)(CTSC + HT) + (UTC)(CTUC)$$

where   TT = total telephone traffic volume in call-seconds

STC = successful toll calls during peak hour

UTC = unsuccessful toll calls during peak hour

CTSC = average connect time for successful toll call

CTUC = average connect time for unsuccessful toll call

HT = average holding time for successful toll call

But UTC = $(\frac{1}{.70} - 1)$ STC, based on a 70% success call rate.

∴ TT = STC $(27 + HT + (\frac{1}{.70} - 1)(49))$,

or TT = STC $[48 + HT]$                                                     (1)

Using equation (1), and the data in Table 4.1.2-3 the projected telephone traffic volume during the peak hour up to the year 2000 was calculated and is tabulated in Tables 4.1.2-6 to 4.1.2-8.  To compute the number of voice circuits required to satisfy the traffic volume, statistical queuing formulae were used.  These formulae, developed by A.K. Erlang, determine the number of circuits required given:

i)   the traffic volume, i.e., calls x time duration,

ii)  the grade of service required, and

iii) the number of trunks grouped together to form the line.

The traffic volume has already been extensively dealt with. The grade of service specifies the maximum percentage of calls which may be lost or delayed for any reason and is often expressed as a decimal number between zero and one. A typical system has a grade of service of 0.01 and this was the value used in this model. This means that one call in 100 may be "blocked".

The third factor is one of efficiency. As the number of trunks grouped together to form a line increase, probability dictates that more customers may be served with the same grade of service. This is referred to as "packing efficiency". A group size of 100 trunks has been used in this model. Larger group sizes were not used since the gain in "packing efficiency" is slight for group sizes above 100 trunks. A group size of 100 trunks would optimize both the flexibility and packing efficiency of the network.

Erlang tables, such as those found in [11], are often used to perform the conversion of the traffic volume into voice circuits. For a grade of service of 0.01, the capacity of the 100 trunk group is 84 Erlangs. An Erlang is equivalent to 3600 call-seconds, i.e., one 4 KHz voice channel occupied for one hour.

Table 4.1.2-6:  Forecasted Minimum Toll Telephone Traffic
and Duplex Voice Circuit Requirement during the
Peak Hour, for Years Between 1980 and 2000.

| MINIMUM | | |
|---|---|---|
| TELEPHONE TRAFFIC | | DUPLEX VOICE CCT REQ'D ('000) |
| YEAR | in $1 \times 10^6$ cs | ERLANGS |
| 1980 | 162 | 45000 | 53.6 |
| 1985 | 272 | 75556 | 89.9 |
| 1990 | 456 | 126667 | 150.8 |
| 1995 | 727 | 201444 | 240.4 |
| 2000 | 1106 | 307222 | 365.7 |

* CS = Call - seconds

Table 4.1.2-7:   Forecasted Maximum Toll Telephone Traffic and
Duplex Voice Circuit Requirement during the
Peak Hour, for the years between 1980 and 2000.

| | MAXIMUM | | |
| --- | --- | --- | --- |
| | TELEPHONE TRAFFIC | | DUPLEX VOICE CCT REQ'D |
| YEAR | in 1 x 10$^6$ cs* | ERLANGS | ('000) |
| 1980 | 347 | 96389 | 115 |
| 1985 | 580 | 161111 | 192 |
| 1990 | 972 | 270000 | 321 |
| 1995 | 1544 | 430278 | 512 |
| 2000 | 2356 | 654444 | 779 |

Table 4.1.2-8:   Projected Average Toll Telephone Traffic and
Voice Circuit Requirement during the
Peak Hour, for the years between 1980
and 2000.

| | AVERAGE | | |
| --- | --- | --- | --- |
| | TELEPHONE TRAFFIC | | DUPLEX VOICE CCT REQ'D |
| YEAR | in 1 x 10$^6$ cs* | ERLANGS | ('000) |
| 1980 | 220.5 | 61247 | 72.9 |
| 1985 | 368.9 | 102786 | 122.0 |
| 1990 | 618.5 | 171798 | 204.5 |
| 1995 | 985.9 | 273874 | 326.0 |
| 2000 | 1499.2 | 416446 | 495.8 |

*cs = call-seconds

4.1.2.2.7  Projection of Voice Circuits Required by a Trans National Canada
            Telephone Network

        To determine the number of voice circuits that could logically be
carried by satellite it was assumed that the toll call distances would be
greater than 300, 400, and 500 miles for the maximum, average and minimum
scenarios respectively.  The distance of 300 miles does not remove traffic
high density corridors such as Toronto-Ottawa, Toronto-Montreal etc.
Traffic in such high density corridors could be handled by an EHF satellite
link.  However the satellite portion of the market between 300 and 500 miles
is expected to be relatively low because of competing ground links.  This is
particularly true in view of the rapid development of fibre optics.  The
percentage of toll calls in the three scenarios are obtained from
Table 4.1.2-4 and are 20.3%, 11.6% and 9%.

        Using these figures, the projected number of voice circuits required
by a telephone network crossing the nation was calculated and has been
summarized in Table 4.1.2-9.  These forecasted voice circuits represents the
total long distance demand which potentially could be captured by satellite
communications.  The actual portion which is carried by satellite will be
determined in Section 4.3.


            Table 4.1.2-9  Forecasted Number of Duplex Voice Circuits
                           Required by a Trans National Telephone Network
                           during the Peak Hours (1980-2000)

| | NUMBER OF VOICE CIRCUITS (000s) REQUIRED TO CARRY TELEPHONE CALLS OVER DISTANCES GREATER THAN 300 MILES | | |
|---|---|---|---|
| YEAR | MINIMUM | MAXIMUM | AVERAGE |
| 1980 | 4.8 | 23.3 | 8.46 |
| 1985 | 8.1 | 39.0 | 14.15 |
| 1990 | 13.6 | 65.2 | 23.72 |
| 1995 | 21.6 | 103.9 | 37.82 |
| 2000 | 32.9 | 158.1 | 57.51 |

### 4.1.2.3  Private Line Telephone Service Traffic Volume

The treatment of the requirements for private line service was different than that of the public telephone traffic requirements. The reason lies in the fact that private line demand is not dependent on traffic volume but rather upon the necessity to provide dedicated links.

The use of revenue data was considered for the analysis but was not adopted on the basis that it does not reflect the true situation. Also the nature of private line tariffs is extremely complicated since it is a function of the number of leased lines and the length of the links. These factors make it practically impossible to dismantle the private line revenues into its components. Hence, revenue data was not used in the forecasting exercise. It also proved to be difficult to get actual data on the existing numbers of private lines. The estimates below would include private lines, utilization by governments, Crown corporations, military, police and companies.

It was assumed that the number of private lines is a fixed percentage of the MTS and WATS total traffic volume. The magnitude of the percentage was estimated from information from the 30/20 GHz Fixed Communications Systems studies performed by ITT [5] and Western Union [12], in the U.S., for NASA. Table 4.1.2-10 shows the percentage of the total projected voice circuits which are used as private lines in the U.S. The average of these percentages are also listed in the table. However, consultation with various experts in telephony has led the authors to the conclusion that these values are high, the United States has more private lines than Canada. In Canada the percentage is closer to 20% of the total number of voice circuits, or 25% of WATS + MTS.

> Private lines = .2 Total
> WATS + MTS =   .8 Total
> Private lines = .25 (WATS + MTS)

For minimum, average and maximum cases percentages of 22, 23.5 and 25 were used. Using these values and Table 4.1.2-9, the forecasted numbers of voice circuits required on private lines to carry long distance calls over distances greater than 300, 400 and 500 miles for maximum, average and minimum cases respectively are determined. These figures do not represent the actual physical number of private lines.

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Table 4.1.2-10   Ratio of Private Lines to Total
Voice Circuits (percent)

| YEAR | ITT | W.U. | AVERAGE |
|------|------|------|---------|
| 1980 | 17.6% | 40.7% | 29.2% |
| 1990 | 18.1% | 37.8% | 28.0% |
| 2000 | 22.6% | 33.5% | 28.0% |

Table 4.1.2-11   Forecasted Number of Duplex Voice Circuits
Required as Private Lines (1980-2000)

| YEAR | FORECASTED NUMBER OF VOICE CIRCUITS REQUIRED TO CARRY LONG DISTANCE TELEPHONE TRAFFIC OVER DISTANCES GREATER THAN 500, 400 AND 300 MILES ('000) | | |
|------|------------------------|------------------------|------------------------|
| | MINIMUM > 500 MILES | MAXIMUM· > 300 MILES | AVERAGE > 400 MILES |
| 1980 | 1.0 | 5.8 | 1.99 |
| 1985 | 1.8 | 9.8 | 3.32 |
| 1990 | 3.0 | 16.3 | 5.57 |
| 1995 | 4.8 | 26.0 | 8.89 |
| 2000 | 7.2 | 39.5 | 13.51 |

### 4.1.2.4  Summary of Voice Circuit Requirements (1980-2000)

The summary of the voice circuit requirements between 1980 and the year 2000 are presented in six tables.  Table 4.1.2-12 to 4.1.2-14 summarize the MTS + WATS, private line and the total voice circuit requirements for the three scenarios:  i) minimum, ii) maximum and iii) average.

Table 4.1.2-12 Forecasted Number of Duplex Voice Circuits
Required Under Minimum Scenario for Long
Distance Calls over 500 Miles (1980-2000)

| YEAR | MINIMUM NUMBER OF DUPLEX VOICE CIRCUITS REQUIRED ('000) | | |
|------|-------------|--------------|-------|
|      | MTS & WATS | PRIVATE LINE | TOTAL |
| 1980 | 4.8 | 1.0 | 5.8 |
| 1985 | 8.1 | 1.8 | 9.9 |
| 1990 | 13.6 | 3.0 | 16.6 |
| 1995 | 21.6 | 4.8 | 26.4 |
| 2000 | 32.9 | 7.2 | 40.1 |

Table 4.1.2-13  Forecasted Number of Duplex Voice Circuits
Required Under Maximum Scenario for Long
Distance Calls over 300 Miles (1980-2000)

| YEAR | MAXIMUM NUMBER OF DUPLEX VOICE CIRCUITS REQUIRED ('000) | | |
|------|-------------|--------------|-------|
|      | MTS & WATS | PRIVATE LINE | TOTAL |
| 1980 | 23.3 | 5.8 | 29.1 |
| 1985 | 39.0 | 9.8 | 48.8 |
| 1990 | 65.2 | 16.3 | 81.5 |
| 1995 | 103.9 | 26.0 | 129.9 |
| 2000 | 158.1 | 39.5 | 197.6 |

Table 4.1.2-14   Forecasted Number of Duplex Voice Circuits Required
Under Average Scenario for Long Distance Calls over
400 Miles (1980-2000)

| YEAR | AVERAGE OF DUPLEX VOICE CIRCUITS REQUIRED ('000) | | |
|------|------------|--------------|-------|
| | MTS & WATS | PRIVATE LINE | TOTAL |
| 1980 | 8.46 | 1.99 | 10.45 |
| 1985 | 14.15 | 3.32 | 17.47 |
| 1990 | 23.72 | 5.57 | 29.29 |
| 1995 | 37.82 | 8.89 | 46.71 |
| 2000 | 57.51 | 13.51 | 71.02 |

### 4.1.3 DATA TRANSMISSION SERVICES REQUIREMENT

#### 4.1.3.1  Introduction

The following section will address the data transmission services requirements.  The data services are divided into two major categories.  The first comprises message/record services, such as TWX/Telex, facsimile and electronic mail, while the second category comprises services related to computer communications, i.e., terminal to computer or computer to computer traffic requirments.

Data services, when carried over digital transmission facilities, are extremely efficient.  Thus, in spite of high data rates, the data transmission services requirement is expected to be much lower than that of the telephone and video broadcast.

#### 4.1.3.2  Message/Record Services

This section deals with the traffic contributions generated by message related data services, i.e., TWX/Telex, facsimile and electronic mail.  Related services, such as telegrams, cablegrams and money orders, will not be considered due to either their declining usage or their insignificant contribution to the traffic volume.

#### 4.1.3.2.1  TWX/Telex

TWX and Telex are the teletypewriter service networks provided by TCTS and CNCP, respectively.  Both are low speed transmission services and operate on their own switched circuit network on a dial-up basis. Interconnections to other international teletypewriter networks are also available.  The differences in the services lie in their transmission speeds and character coding.  TWX uses ASCII code and is capable of transmitting 100 words per minute.  Telex, on the other hand, operates on a five level ITA No. 2 Code at 66 words per minute.  Depending on the length of the message, one service is less expensive than the other due to the difference in transmission rates and the nature of the tariffs.

The data traffic volume attributed to TWX/Telex was determined by projecting the teletypewriter population to the year 2000 and multiplying it by the average usage, i.e., the number of bits/year, of a typical terminal.

The population of TWX terminals between 1971 and 1980, is shown in Table 4.1.3-1 and Figure 4.1.3-1. The compounded growth rate of the total number of teletypewriters, over the 10 year period, was a 2.1% p.a. Most of this growth was attributable to connections onto circuit switched teletypewriter exchanges which saw a 3% p.a. growth rate over the decade. Connections onto private lines grew at 1.4% p.a. over the decade.

The authors were unable to obtain similar data on Telex from CNCP, because CNCP regards this information as confidential. However a count of the number of Telex addresses in the 1983 directory shows 65,000 listed terminals. There are a considerable number of unlisted numbers, for example, transmit only terminals are not listed. The number of unlisted terminals may be 20 to 50% of the listed terminals. The number of TWX terminals in 1983 is 14,000 while the estimated number of telex terminals is about 100,000.
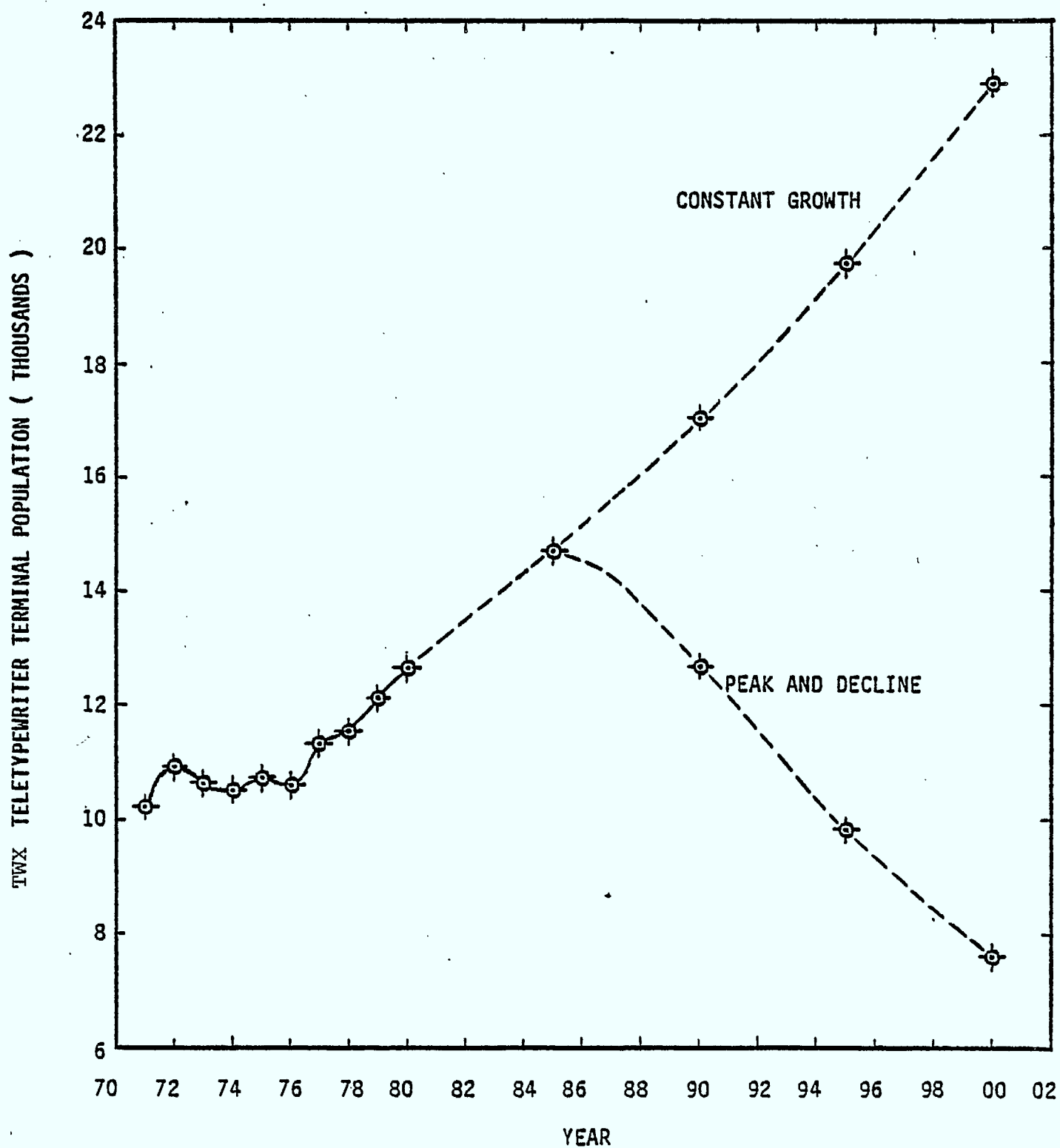
Figure 4.1.3-1TWX TELETYPEWRITER TERMINAL POPULATION (1971-2000)

Table 4.1.3-1   TWX (TCTS) Teletypewriter Population (1971 - 1980)

| YEAR | TELETYPEWRITERS CONNECTED TO | | |
|------|---------------|--------------|-------|
|      | PRIVATE LINES | TTY EXCHANGE | TOTAL |
| 1971 | 5773 | 4484 | 10257 |
| 1972 | 5752 | 5187 | 10939 |
| 1973 | 5427 | 5211 | 10638 |
| 1974 | 5225 | 5286 | 10511 |
| 1975 | 5382 | 5382 | 10764 |
| 1976 | 5323 | 5286 | 10609 |
| 1977 | 6258 | 5099 | 11357 |
| 1978 | 6518 | 5034 | 11552 |
| 1979 | 6356 | 5803 | 12159 |
| 1980 | 6640 | 604r | 12681 |
| GROWTH RATE 1971-80 | 1.4% | 3.0% | 2.1% |

Source:   Statistics Canada; Telephone Statistics; Catalogue 56-203; 1971-80.

It is expected that the total volume of TWX/Telex messages will continue to increase with respect to time; however, teletypewriter population will not. A. D. Little has forecasted that teletypewriter population will peak in 1985 and then decline thereafter. ITT, agrees with this forecast [5] and predicts a growth rate of ~3% p.a. for the second half of the 1980's and a ~5% p.a. for the 1990's. Figure 4.1.3-2 illustrates the forecast made by ITT. This trend reflects the substitution effect of more efficient future services, especially electronic mail, for the transmission of image-free messages. Table 4.1.3-2 shows the total projected teletypewriter population (telex and TWX) in Canada using ITT's growth rate assumptions. A growth rate of 3% p.a. was assumed for the first half of the 1980's.

To convert the projected number of teletypewriters into data traffic volume, the conversion factor of 28.8 kilobits/day was used. [5], [13]. This conversion factor was the product of the following assumptions:

i)   virtually all usage of the TWX/Telex networks occurs during the 250 business day in a year,
ii)  a typical terminal transmits five message per business day,
iii) a typical message contains 120 words,
iv)  a word consists of 6 characters, and
v)   each character consists of 8 bits.

(The figure of 8 bits per character was derived from using 7 and 5 information bits for TWX and Telex, respectively [5]. This produces an average of 6 information bits per character. Allowing two bits for start-stop and parity bits yields a total of 8 bits per character.)

∴ DAILY DATA TRAFFIC PER TELETYPEWRITER = 5 msg/day
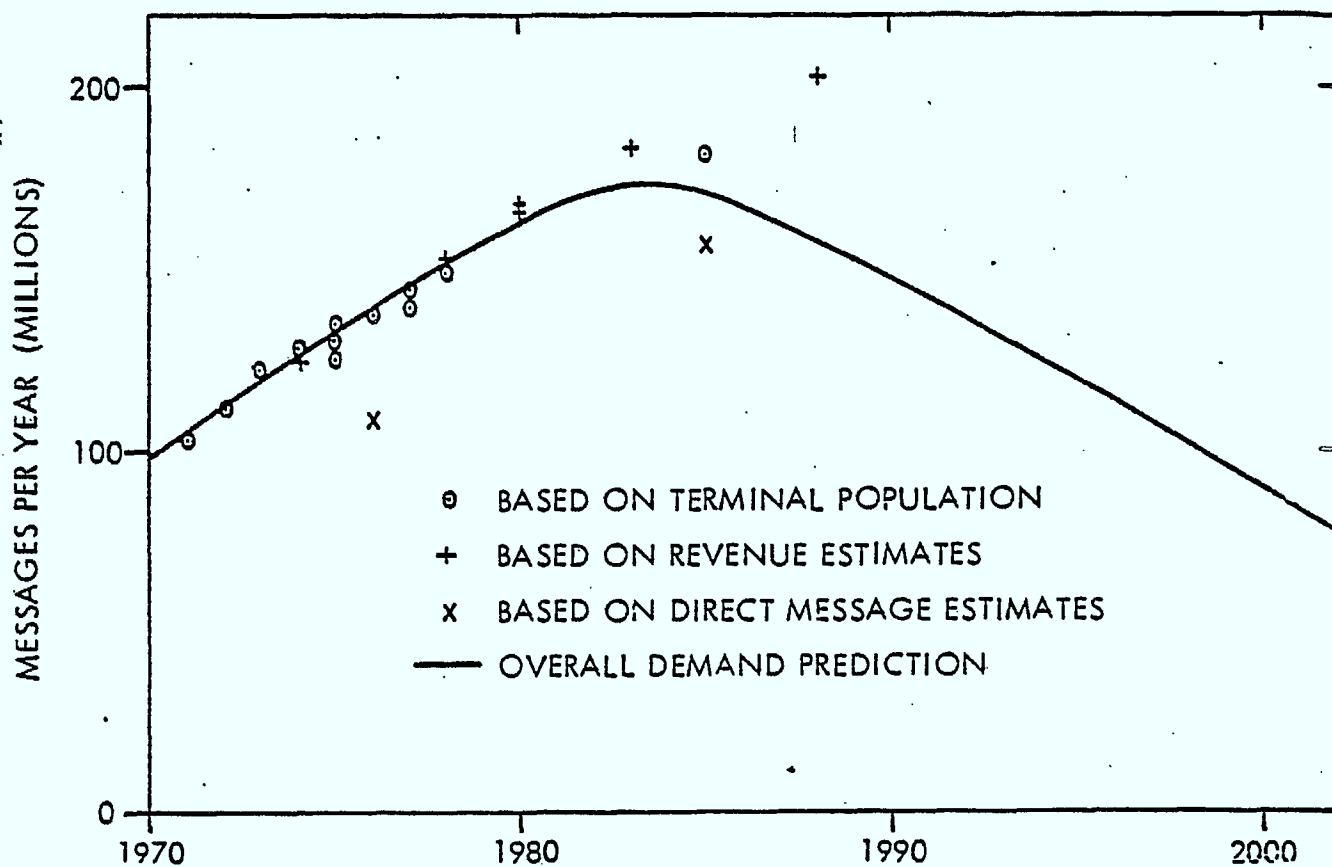x 120 words/msg x 6 char/word x 8 bits/char.
= 28.8 kb/day.

Figure 4.1.3-2 ITT Forecast Of TWX/Telex Messages Per Year [5]

Table 4.1.3-2  Total Teletypewriter Population(1980 - 2000)

| YEAR | NUMBER OF TELETYPEWRITERS | | |
|------|---------------------------|---|---|
|      | CONSTANT GROWTH SCENARIO | PEAK AND DECLINE SCENARIO | DIFFERENCE |
| 1980 | 103,260 | 103,260 | 0 |
| 1985 | 119,700 | 119,700 | 0 |
| 1990 | 138,770 | 103,260 | 35,510 |
| 1995 | 160,880 | 79,900 | 80,980 |
| 2000 | 186,500 | 61,830 | 124,670 |

Table 4.1.3-3 illustrates the projected data traffic volume due to TWX/Telex. Discussions with Bell Canada personnel yielded an estimate that 18% of the daily traffic on private and WATS occurred during the peak hour. This value is higher than that used for telephone usage and reflects the predominantly business usage of these lines. This is also one case for TWX/Telex. Thus, it has been assumed that 18% of the daily TWX/Telex traffic volume occurs during the peak hour.

ITT, in their report, [5], estimated that 80% of TWX/Telex traffic qualified as long distance traffic, i.e., over 200 miles. In the absence of any opposing data, this assumption has been adopted for this report. The long distance peak hour traffic is tabulated in the third column of Table 4.1.3-3.

Table 4.1.3-3  Forecasted Long Distance TWX/Telex Traffic
Data Rate Requirements Volume (1980-2000)

| YEAR | DAILY TRAFFIC Mbits/day | PEAK HOUR DATA RATE kbps | PEAK HOUR DATA RATE kbps |
|------|------------------------|--------------------------|--------------------------|
| 1980 | 2974 | 148.7 | 119.0 |
| 1985 | 3447 | 172.4 | 137.9 |
| 1990 | 2974 | 148.7 | 119.0 |
| 1995 | 2301 | 115.1 | 92.1 |
| 2000 | 1781 | 89.1 | 71.2 |

4.1.3.2.2  Facsimile

Facsimile machines are used for electronic transmission of an image for reproduction purposes.  Pictures, graphics and printed matter are prime candidates for facsimile transmission.  The page to be transmitted is scanned line-by-line, the information is encoded, transmitted, and then decoded and printed at the receiving station.  The resolution desired determines the number of scan lines required per page.  The greater the resolution, the greater the number of scan lines.

First generation facsimile devices were mechanical in nature and operated at slow speeds, typically two to six minutes per page.  The maximum transmission speed is limited by the maximum speed of the rotating drum employed in many of these machines.  First generation facsimile represent a large portion of the total facsimile population and are particularly applicable to low volume usage requirements.

Second generation facsimile have been developed.  The rotating drums have been replaced by flat-bed scanning, and document feeders have been added; thus, enabling higher operating speeds.  Medium speed facsimile can handle a page in one to two minutes, while a high speed facsimile can transmit a page in less than a minute.

Data compression techniques are another important feature of second generation facsimile.  One page of 8½"x11" paper consists of approximately 935,000 bits of information in uncompressed form. [12].  With data compression techniques, a page can be reduced to between 150,000 to 200,000 bits.  For high resolution reproduction, 450,000 bits per page, after data compression, would be a very reasonable figure.  There is a trend to increase the resolution of the transmitted page in the future.  To accommodate this trend, it has been assumed that a page transmitted, by facsimile, comprises an average of 300,000 bits.

The approach to determine the data traffic volume due to facsimile transmission will be similar to that used for the TWX/Telex analysis. Firm information on the installed base of facsimile is virtually non-existent. R. W. Hough and Associates Ltd., [14], has made an estimate of this number for the period between 1975 and 1985. Figure 4.1.3-3 and Table 4.1.3-4 illustrates their estimate.

Western Union, has estimated a 13% p.a. growth rate for facsimile machines in the U.S. between 1980 and 1990 [12]. ITT, predicted a similar growth rate of 12% p.a. for the same period and that during the 1990's, there would be a 10% p.a. growth rate [5]. This study uses 13% p.a. for the 1980's, and 10% p.a. for the following decade.

For comparison purposes, Table 4.1.3-4 lists the reports' estimate of Canada's installed facsimile base along with that of ITT's and Western Union for the U.S. ITT's and Western Union's forecasts agrees to within 10% of each other. If the basic rule-of-thumb of 10:1 for U.S. versus Canadian data is applied, the reports' forecast parallels the U.S. predictions, but with a five-year time lag.
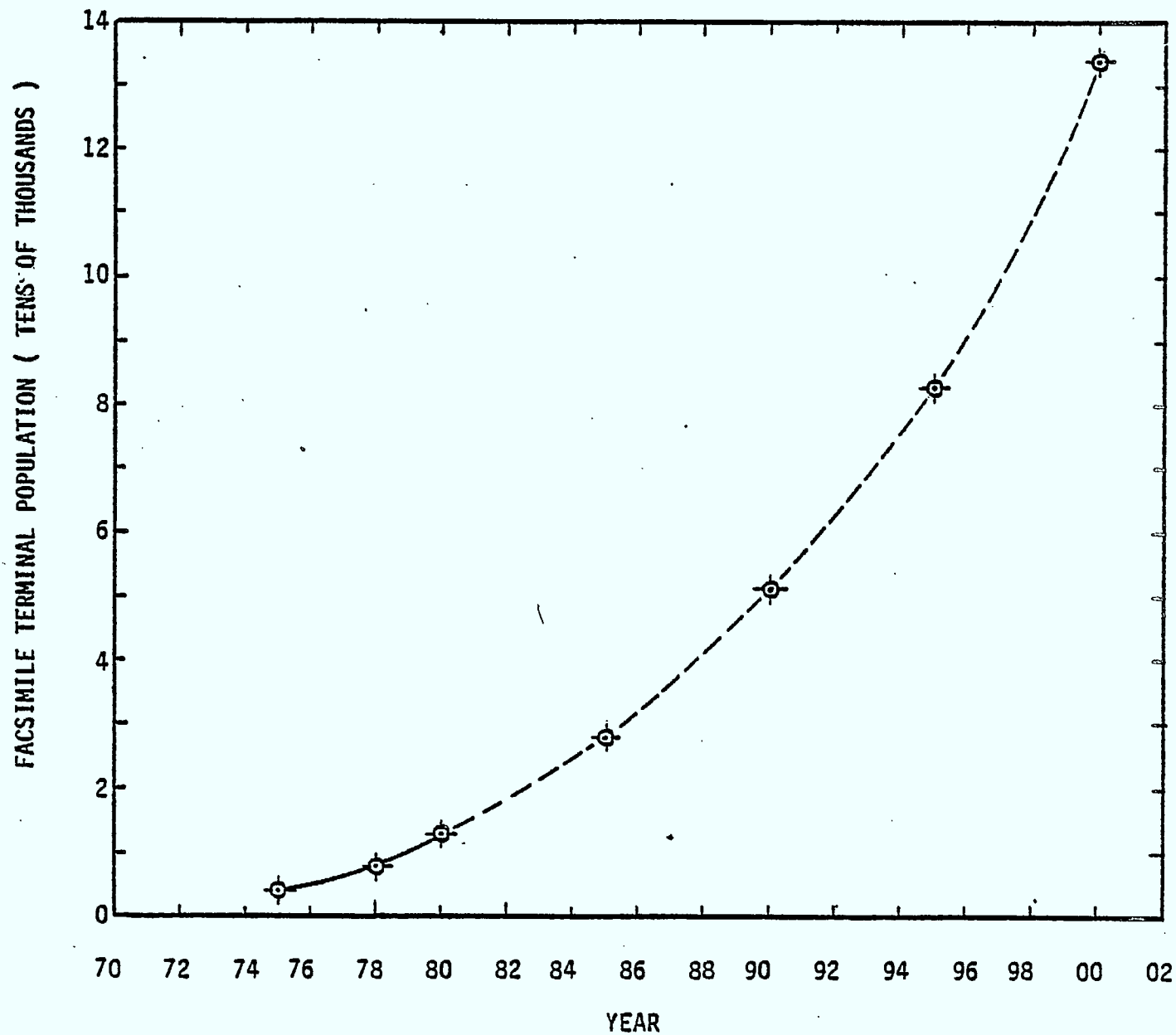
Figure 4.1.3-3  Facsimile Estimates and Forecasts Units
Installed In Canada, 1975-2000

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### Table 4.1.3-4  Facsimile Population (1975 - 2000)

| YEAR | R. W. HOUGH | ITT | W.U. |
|------|------------|------|------|
| 1975 | 4,000 | | |
| 1978 | 8,000 | | 185,800 |
| 1980 | 13,000 | 290,000 | 238,400 |
| 1985 | 28,000 | 511,000* | 444,700 |
| 1990 | 51,600 | 901,000 | 829,300 |
| 1995 | 83,100 | 1,451,000** | |
| 2000 | 133,800 | 2,340,000 | |

*   Assumes 12% p.a. Growth Rate

** Assumes 10% p.a. Growth Rate

This correlation ends with the installed base of facsimile, however, since their estimates of the daily traffic volume per terminal are completely different, as illustrated by Table 4.1.3-5.

The Western Union estimates were determined via a weighted average methodology. Table 4.1.3-6 depicts the facsimile population by type and usage, as assumed by Western Union [12]. The low speed machines were considered as first generation, while the medium and high speed machines were second generation. A typical page on these machines comprise 150,000 bits. The special purpose facsimile is used for high resolution graphics transmission at an average of 450,000 bits per page. The results of this exercise are tabulated in Table 4.1.3-5.

ITT, on the other hand, made the following assumptions on facsimile usage [5]:

A) i) a typical terminal will transmit 1300 pages/year, or 5.2 pages/day, in the 1980's;

   ii) a typical terminal will transmit 2600 pages/year, or 10.4 pages/day, in the 1990's; and

B) a typical page comprises 300,000 bits, reflecting the desire for a higher resolution reproduction.

As for the estimates used for this report it was decided to follow ITT's assumptions [ 5 ] . However, the doubling of the number of transmitted pages in the 1990's seemed rather abrupt. Thus, in this report ITT's increase was halved, i.e., a typical terminal would transmit 2600 pages/year or 10.4 pages/day by the year 2000, as shown in Table 4.1.3-6a.

The data traffic volume attributable to facsimile transmission over the next two decades on a daily, peak hour, and peak hour long distance basis are tabulated in Table 4.1.3-7. The peak hour traffic volume assumes even distribution of the daily traffic volume over the 8 hours in a normal business day. The percentage of long distance traffic in column 3 of Table 4.1.3-7 were based on ITT's estimates.

Table 4.1.3-5  Comparison of Daily Traffic Volume Estimates,
Generated by a Typical Facsimile Terminal by U.S. EHF Studies
(bits/day/terminal)

| YEAR | WESTERN UNION | ITT | CAL |
|------|---------------|-----|-----|
| 1978 | $1.57 \times 10^6$ | | |
| 1980 | $1.32 \times 10^6$* | $1.56 \times 10^6$ | $1.56 \times 10^6$ |
| 1990 | $1.27 \times 10^6$ | $3.12 \times 10^6$ | $2.34 \times 10^6$ |
| 2000 | | $3.12 \times 10^6$ | $3.12 \times 10^6$ |

* Linear Interpolation

Table 4.1.3-6  Facsimile Population by Type and Usage as Assumed by
Western Union [12]

| TYPE | 1978 | | | 1990 | | |
|------|------|------|------|------|------|------|
| | POP. | % POP | USAGE | POP. | % POP | USAGE |
| LOW SPEED | 167,000 | 90 | 3.8 pg/day | 717,000 | 86 | 3.8 pg/day |
| MED. SPEED | 3,400 | 1.8 | 12 pg/day | 13,900 | 1.7 | 12 pg/day |
| HIGH SPEED | 5,400 | 2.9 | 12 pg/day | 78,200 | 9.4 | 21.6 pg/day |
| SPECIAL | 10,000 | 5.3 | 40 pg/day | 20,200 | 2.4 | 40 pg/day |
| TOTAL | 185,800 | | | 829,300 | | |

Table 4.1.3-6a  Pages Transmitted per Day per Terminal

| YEAR | PAGES/DAY/TERMINAL |
|------|--------------------|
| 1980 | 5.2 |
| 1985 | 5.2 |
| 1990 | 7.8 |
| 1995 | 7.8 |
| 2000 | 10.4 |

Table 4.1.3-7   Forecasted Facsimile Traffic Data Rate
Requirements (1980-2000)

| YEAR | DAILY TRAFFIC* Gbits/day | PEAK HOUR DATA RATE Mbps | PERCENT THAT GOES LONG DISTANCE | PEAK HOUR LONG DISTANCE DATA RATE Mbps |
|------|--------------------------|--------------------------|--------------------------------|----------------------------------------|
| 1980 | 20.3 | 0.70 | 35 | 0.25 |
| 1985 | 43.7 | 1.52 | 35 | 0.53 |
| 1990 | 120.7 | 4.19 | 50 | 2.10 |
| 1995 | 194.5 | 6.75 | 50 | 3.38 |
| 2000 | 417.5 | 14.5 | 60 | 8.70 |

* Daily Traffic = pages per day x No. of terminal (R.W. Hough) x 300,000

### 4.1.3.2.3  Electronic Mail

Over the past decade, electronic mail has been a subject of major discussion throughout the world.  There are advantages in transmitting business mail electronically.  The most obvious one is the speed in which a letter could be sent, reliably, over that of the conventional postal system. The time saved translates into financial savings and increased office efficiency.  As the business world proceeds with office automation, and in light of the potential advantages, the development of electronic mail systems into the office of the future appears inevitable.

This process has already begun in Canada.  In 1976-1977, the Canada Post Office introduced its electronic mail service, Telepost.  Since its inauguration, the service has grown steadily.  During 1978-79, over 400,000 Telepost messages were sent over the leased CNCP facilities [15].  This number increased to 658,989 transmitted messages in 1979-80.  In competition against Telepost, the Computer Communications Group (CCG) of TCTS has planned the introduction of Teletex in late 1982.  Teletex would allow communicating word processors and electronic memory typewriters to transmit a business letter locally, nationally or internationally in about 10 seconds.

The contribution of electronic mail to data traffic was considered in two components.  These components are the electronic mail capture of "conventional" mail and Telex/TWX messages.

### 4.1.3.2.3.1  Telex/TWX Message Capture

In Section 4.1.3.2.1, it was noted that part of the TELEX/TWX message data traffic volume will be transmitted as electronic mail.  The captured data traffic volume was determined by calculating the difference in teletypewriter population between the two growth scenarios in Table 4.1.3-1 (linear vs peak and decline growth), and multiplying by the estimated traffic generated by an average teletypewriter.  Table 4.1.3-8 tabulates the captured TELEX/TWX message data traffic.

Table 4.1.3-8    Projected Electronic Mail Data Traffice Through TELEX/TWX
Message Capture (1980 - 2000)

| YEAR | DAILY TRAFFIC Mbits/day | PEAK HOUR DATA RATE kbps | PEAK HOUR LONG DISTANCE DATE RATE kbps |
|------|-------------------------|--------------------------|----------------------------------------|
| 1980 | 0 | 0 | 0 |
| 1985 | 0 | 0 | 0 |
| 1990 | 1023 | 51.3 | 40.7 |
| 1995 | 2332 | 116.4 | 93.6 |
| 2000 | 3590 | 179.1 | 143.3 |

4.1.3.2.3.2  Conventional Mail Capture

The methodology adopted to determine the data traffic resulting from electronic transmission of conventional mail was to project Canada Post Office (CPO) mail statistics to the year 2000 based on the existing 1971-80 database [15]. The percentage of mail which could be captured was then estimated. Finally, the number of pieces of mail was converted into data traffic by assuming average number of bits contained in a piece of mail.

Table 4.1.3-9 and Figure 4.1.3-4 depict the historical and projected growth of the volume of originating First Class mail. What Figure 4.1.3-4 illustrates is that there was a declining annual growth rate between 1971 and 1975. A linear fit of this data yields a correlation factor of 0.9986. The volume of originating First Class mail grew at an average of 197.3 million pieces annually over the five year period. However, an airline strike in 1976 brought an end to the trend. A partial recovery was established in 1977 only to be eliminated by a postal strike in 1978. Since 1978, the original trend seems to have reappeared but exhibits a faster decline in its annual growth rate. This was probably the result of mail volume lost to couriers or alternative services from the postal service interruptions. The projection of mail volume to the year 2000 was based on the data from 1978 to 1980. The correlation of the linear fit to this data was 0.9918. The average annual growth over five year periods were 3.5% p.a. (1980-1985), 3.0% p.a. (1985-1990), 2.6% p.a. (1990-1995), and 2.3% p.a. (1995-2000). The projection may be optimistic in light of the postal rate increases in 1982.
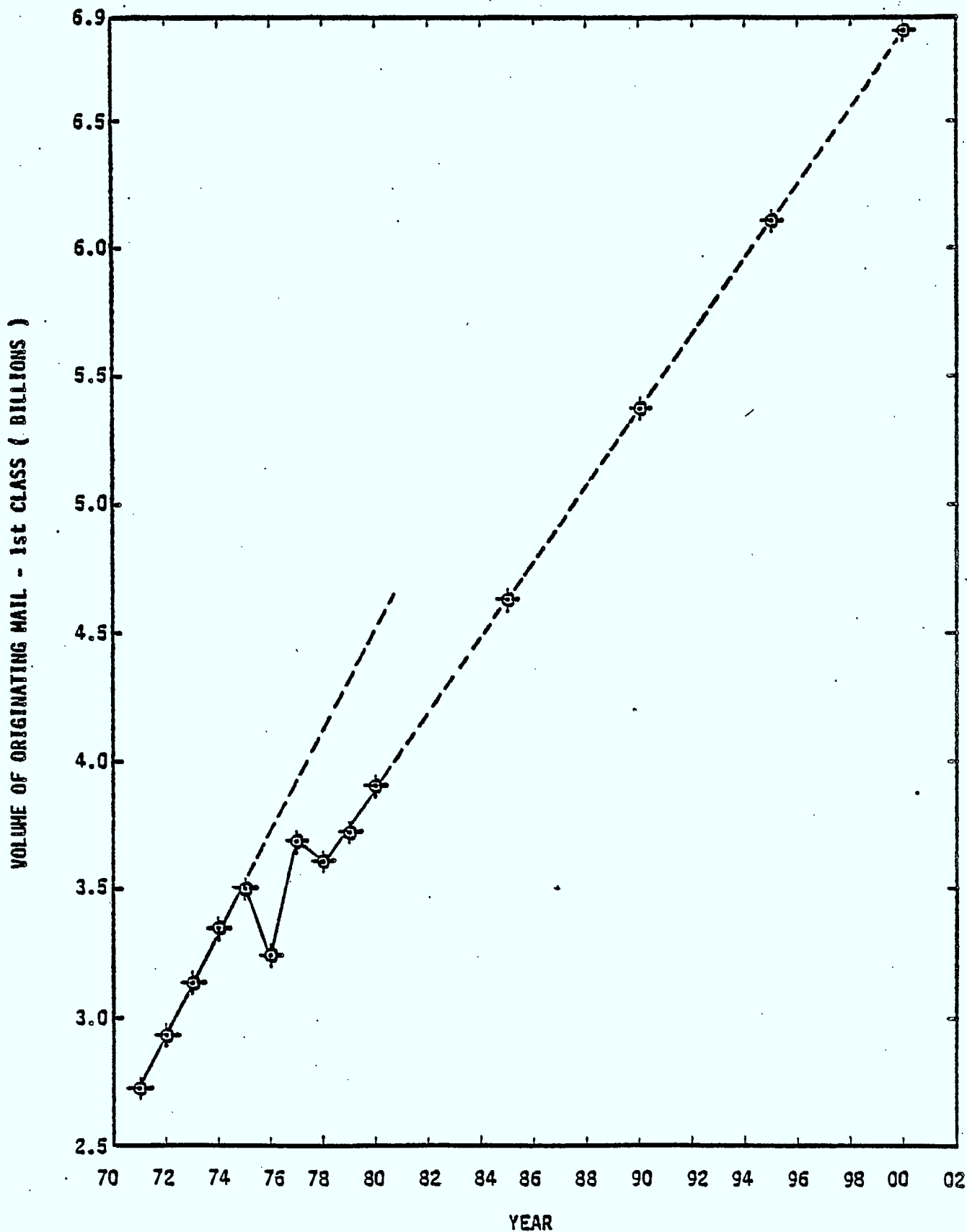
Figure 4.1.3-4   Growth of First Class Mail

**Table 4.1.3-9  Volume of Originating Mail - 1$^{st}$ Class (1971 - 1980)
(In Millions) [ 15]**

| YEAR | 1$^{st}$ CLASS | TOTAL | % OF TOTAL | PER CAPITA VOLUME |
|------|---------------|-------|-----------|-------------------|
| 1971 | 2723 | 4553 | 59.8 | 128 |
| 1972 | 2936 | 4713 | 62.3 | 136 |
| 1973 | 3141 | 4751 | 66.1 | 144 |
| 1974 | 3347 | 5074 | 66.0 | 151 |
| 1975 | 3504 | 5316 | 65.9 | 156 |
| 1976 | 3244 | 4941 | 65.7 | 142 |
| 1977 | 3687 | 5804 | 63.5 | 159 |
| 1978 | 3610 | 5965 | 60.5 | 153 |
| 1979 | 3725 | 6056 | 61.5 | 157 |
| 1980 | 3906 | 6409 | 60.9 | 163 |

It should be noted at this point that electronic mail will never fully replace our present postal system. Table 4.1.3-10, shows the breakdown of originating mail by type, for the fiscal year ending in 1974, used to determine the potential electronic mail market [16]. Parcels, considered as fourth class mail, will obviously be unaffected. Advertising mail (third class), on the other hand, would be an excellent market. However, most advertisements are local in nature and even national advertisement would require only a single transmission to each desired city to serve as a master. Hence, although advertisement via electronic mail will occur, its contribution to long distance data traffic would be negligible. Second class mail, such as magazines and newspapers, will be electronically transmitted in the future, not as eletronic mail but rather as a DBS service, like Telidon. Thus, the potential market exists only in first class mail.

Table 4.1.3-10 also lists the anticipated percentage of electronic mail capture. It is estimated that eventually 34% of the first class mail volume will be replaced by electronic mail. Assuming it takes twenty years to reach market saturation, Table 4.1.3-11 illustrates the projected data traffic due to the capture of conventional mail.

The factor of 102,750 bits/piece of mail used to convert the pieces of mail into bits/year was derived as follows:

i)   one digital page contains 32640 bits, i.e., 8.5 x 8 lines/inch x 6 inches x 10 char/inch x 8 bit/char.

ii)  one digital page has a fill factor of 80%.

iii) one facsimile page contains 450,000 bits.

iv)  one out of every ten pages is a facsimile page.

iv)  an average page contains 74376 bits, i.e., 0.9 x 32640 x 0.80 + 0.1 x 450,000.

vi)  an average business letter comprises 1.5 pages of information, i.e., 102,750 bits.

Taking this process one step further, one may assume that half of the letters are sent during the 8 business hours on each of the 250 business days in a year. Thus the long distance electronic mail data traffic is 50% of the transmission capacity required during the normal business hour.

It can be seen that the contribution due to Telex/TWX is negligible, and is roughly three orders of magnitude lower than that of conventional mail. Thus, Table 4.1.3-11 also represents the total forecasted electronic mail data traffic over the next two decades.

Table 4.1.3-10 Volume of Originating Mail by Type 1973 - 1974 [16]

| TYPE | CLASS | % of TOTAL | % OF 1st CLASS MAIL | % CAPTURED OF THIS TYPE OF MAIL | % CAPTURE TIMES % 1st CLASS |
|---|---|---|---|---|---|
| Transaction (cheques, bills, statements, purchase orders, etc.) | 1st | 40 | 60 | 40 | 24.0 |
| Personal Correspondence | 1st | 13 | 20 | 0 | 0 |
| Business Correspondence | 1st | 9 | 14 | 50 | 7.0 |
| Government Correspondence | 1st | 4 | ·6 | 50 | 3.0 |
| Magazines & Newspapers | 2nd | 9 | | | |
| Advertising | 3rd | 23 | | | |
| Parcels | 4th | 1 | | | |
| TOTAL | | 100 | 100 | — | 34.0 |

Table 4.1.3-11  Projected Electronic Mail Data Traffic Through Capture of
Conventional Mail (1980 - 2000)

| YEAR | ANNUAL VOLUMES 1st CLASS MAIL (MILLIONS) | % CAPTURE 1st CLASS | DAILY EM DATA TRAFFIC $10^9$ BITS/DAY | PEAK HOUR DATA RATE Mbps | LONG DISTANCE PEAK HOUR DATA RATE Mbps |
|------|------|------|------|------|------|
| 1980 | 3906 | 0 | 0 | 0 | 0 |
| 1985 | 4635 | 7 | 133.4 | 4.6 | 2.3 |
| 1990 | 5375 | 17 | 187.8 | 6.5 | 3.3 |
| 1995 | 6115 | 27 | 338.3 | 11.8 | 5.9 |
| 2000 | 6855 | 34 | 479.0 | 16.6 | 8.3 |

| YEAR | VOLUME 1st CLASS MAIL PER CAPITA | PEAK HOUR DATA RATE PER CAPITA (Mbps) |
|------|------|------|
| 1980 | 163 | 0 |
| 1985 | 182 | .091 |
| 1990 | 200 | .123 |
| 1995 | 219 | .211 |
| 2000 | 237 | .287 |

4.1.3.3  Computer Communications Data Traffic

The following section discusses the contributions of computer communications to the total data traffic volume.  Computer communications, due to the nature of its' services, (such as database transfers and remote job entries) has always generated more data traffic than the message/record services described in the preceeding section.  In Section 4.1.3.4, it can be seen that computer communications represents roughly 85% of the total data traffic volumes.

Computer communications has exhibited a substantial growth over the last few years.  This trend is expected to continue until the latter part of this decade when saturation will be reached.  This growth is attributable to reduction in the costs of "smart" terminals, microcomputer and minicomputers. Smart terminals are typically multi-functional user-programmable CRTs.  They have shown increased market penetration because of two reasons: i) their substitution of older, outdated terminals which had almost no user-programmable capabilites, and ii) their acceptance as powerful and flexible tools.  Likewise, micro and minicomputers are gaining in popularity.  They represent an economical form of limited computing power that fits into the trend towards distributed processing and remote time-sharing.  Although these terminals tend to reduce the amount of data transmitted by use of some preliminary processing; their capabilities induce manipulation of data that was unthought of in the past, and hence, their use results in the transmission of more data bases.

The two components of computer communications are terminal to computer, and computer to computer.  Services generating terminal to computer traffic are usually interactive in nature, operating in an inquiry/response mode.  Examples of such services are air-line reservations, on-line banking, inventory control and credit verification.  While the services possess the majority of terminals active in computer communication they generate only a volume of data which is not of great significance to this study.  Since there are interactive services, the terminals are connected to low speed data line in order to be ecomomically feasible, and hence are limited to low data rate. Fortunately, most of the services are not hindered by low data rates.

Traffic generated by point of sales (POS) terminals, automatic sensoring and metering systems are not included. These services produce a low volume of data, and more importantly, are local in nature. Thus, their impact need not be assessed.

The second component , computer to computer traffic is not as well known because our exposure to it is minimal. Distributed processing and electronic funds transfer (EFT) are the major contributors of computer to computer traffic. Distributed processing implies the creation or modifications of local data bases which are transferred to other processors, via high speed lines. On the other hand, EFT traffic is generated by clearing house operations. A cheque is estimated to contain 1000 bits of information in the account number, bank and the funds to be transferred [17]. With the large volume of cheques which are cleared, the data traffic contribution of EFT is significant.

Computer to computer throughput traffic will not be considered. This applies primarily to dataspace application in which a processor is used to retransmit data from another  processor. In other words, only originating computer to computer data will be treated.

4.1.3.3.1  Network Configurations

Prior to embarking on the analysis, it is worthwhile to consider the applications, and transmission line requirements of current configurations of computer communications networks. In their survey, Price Waterhouse, [19] identified the following four configurations:

    i)   single node-interactive;
    ii)  single node-remote batch;
    iii) multi-centre network with central processing; and
    iv)  mixed network

These networks will now be discussed.

The first network configuration is an interactive single node or star network. The network consists of numerous terminals scattered across the country, all connected to a central computer, typically a medium or large scale mainframe. Airline reservations, on-line banking, on-line entry, inventory control, and credit checking applications are characteristic of this configuration. The terminals are normally real-time and highly interactive, although time-sharing systems are also used to a lesser extent. The amount of data sent is low and occurs randomly. As a result of this, low to medium speed (150 to 2400 bps) lines are employed with regional multiplexers and concentrator stations to optimize line usage.

The single node remote batch system network used by the service bureaus is the second configuration. This network comprise remote batch terminals or minicomputers connected to a very large central computer, such as an IBM 370/165. The access lines may be leased or dial-up, but due to the heavy throughput requirements the lines have high speed capabilities, typically 2400 to 19200 bps. The central computers are located in Toronto, Ottawa and Calgary.

A multi-center network with central processing is a third configuration. This network would be used by institutions with very heavy daily processing loads, such as the major banks, and would consist of several small computing centers connected to a large central computer complex. Data is collected at the smaller centers and perhaps, processed or concentrated before being transmitted to the central computer. Files are updated at the central computer and then sent back to the smaller centers for distribution. The central complex is usually located in Toronto, Montreal, Calgary, Edmonton or Vancouver.

A fourth configuration is a mixed system, where the network has more than one major node. Connecting the nodes are high speed lines, capable of handling at least 9.6 kbps. In the majority of cases, 19.6 or 50 kbps data lines are employed. Characteristic usage of this network includes computer to computer transmissions, high speed file transfer, processing load sharing, and backup and redundancy support functions. This network is used by large institutions within banking, resource, transportation and utility industries that have several major operational centers across the country.

4.1.3.3.2  Sources of Reference

The database for this analysis was formulated from three major sources.  The first is the annual Canadian Computer Census by the Canadian Information Processing Society (CIPS), [18] .  Detailed raw data is provided in the census but the data requires refining to make it useable.  Some summary tables are included, giving a breakdown of the computer installation, by province and rental class.

The second source is Datacom '76, Results of a Survey of Computer/Communications Facts and Opinions, by Price Waterhouse and R. W. Hough, [19] .  Eighty-eight major data communications users were contacted, of which 74 responded.  Eight of the 74 respondents chose to express their opinions rather than to provide data.

· A sample size of 74 companies is by no means as comprehensive as the CIPS Cencus; however, these companies represent the major players in their respective industries and provides an excellent insight into the nature of computer communications.  A breakdown of the industrial respondents showed there were 21 financial institutions, 11 service bureaus, 6 resource comapnies, 17 manufacturing companies, 10 transportational utility companies, and 9 wholesaler/retailers.

The assets of the financial institutions totalled $80 billion, roughly 60% of the assets of the Financial Post's Top 50 Financial Institutions.  The industrial companies represent 40% of the sales of Financial Post's Top 100 Industrials, with total sales of $30 billion.  The wholesalers/retailers have total sales of $8 billion, equivalent to 35% of the sales of the Financial Post's Top Merchandisers.  The service bureaus have been estimated to have contributed about 35% of the industry's revenues.  The respondents owned plants located across Canada to provide nationwide coverage.

Some of the finding of the Datacom '76 survey provides an interesting insight into the characterisitcs of computer communications [19] . A partial list of their findings are given below:

i) "92% of the data communications circuits used by the respondents are low to medium speed (2400 bits per second or less), but a very large amount of traffic flows through the small percentage of lines which are high speed."

ii) "On-line banking, video display, teletype and point-of-sale terminals, all of which are low speed, interactive devices, comprise 92% of the terminals in use. Only 5% of the terminals are remote batch, but these transmit 73% of the data communications traffic."

iii) "Computer Communications traffic in Canada is large and growing. The respondents transmit and receive some 4.9 billion characters per day. This traffic is highly concentrated geographically. Virtually all of it flows to and from computer centres in six cities - Toronto, Montreal, Ottawa, Calgary, Edmonton and Vancouver. Toronto computer centres alone account for 67%of the traffic flow."

iv) "Computer service bureaus are large contributors to data communications traffic, accounting for 42% of the volume reported in the this survey."

The third source is "The EDP Guide - Computer Communications", volumes 1 and 2, by R. W. Evans Associates Ltd., [20]. The report considers the many facets of computer communications. The common carriers, their network configurations, the telecommunications market, and the computer communications market in Canada are among the topics discussed in detail.

#### 4.1.3.3.3 Data Traffic Analysis

The survey performed by Price Waterhouse, [19], on computer communications has detail and breakdowns of the number of terminals and data traffic generated by industry and type of terminal. Their results are shown in Tables 4.1.4-12 and 4.1.4-13. Thus, the methodology used to forecast computer/communications data traffic was to apply anticipated growth rates to the Price Waterhouse statistics.

Since Price Waterhouse's statistics were derived from a limited database, the figures were scaled up to represent the full industry in 1976. The scalars employed were based on the shares the companies contributed to their respective industries' total assets. This point had been discussed at the beginning of this subsection. Hence, a scalar of $(.60)^{-1}$ or 1.67 was used for the financial industry. Resources, manufacturing and transportation utilities were adjusted by a multiplier of 2.5. The remaining industries, i.e. service bureaus and wholesale/retail, used a factor of 2.86. Table 4.1.4-14 illustrates the adjusted figures. It was assumed a character comprised 10 bits, 8 for information and 2 for overhead.

Growth rates were then applied to project these figures up to the end of the century. Table 4.1.4-15 lists the assumed growth rates used, based on terminal type. The rates used by the reports were the general concensus of CAL's estimates, R. W. Evans, CIPS, ITT and other sources, [5, 18, 20, 21].

The forecasted computer/communications data traffic volume is shown in Table 4.1.4-16. The average annual growth rates per half decade periods up to the year 2000 are 21.9%, 16.4%, 11.7% and 10.0%. This translates into an average annual growth rate of 14.9% p.a. over the next 20 years, a very reasonable estimate.

The number of terminals, listed in Table 4.1.4-13, were also adjusted. The results is shown in Table 4.1.4-17. From this table, the total number of terminals was 41854. This value was low when compared to the 50,422 and 55,400 terminals estimated by R. W. Evans, [22] and R. W. Hough, [14], respectively. Averaging these three estimates yielded 49225 terminals connected in 1976. From this, three scenarios were generated: i) minimum, ii) average and iii) maximum. The previously calculated figure (41854) was adopted as the minimum scenario. The average and maximum scenarios were obtained through scaling the minimum scenario by 49225/41854 = 1.176 and 55400/41854 = 1.324. Table 4.1.4-18 summarizes the forecasts for each of the three scenarios.

All that was required to complete the analysis was to estimate the amount of long distance traffic. Price Waterhouse, [19], also provided a breakdown of the origin and destination of the surveyed traffic volume. This has been reprinted as Table 4.1.4-19. Local traffic accounted for 47.3% of the transmitted data. Removing the links which would be handled using terrestrial facilities, Ottawa, Montreal and Toronto, it was determined that 32.0% of the traffic would be long distance. Table 4.1.4-20 lists the long distance traffic forecasted for the three scenarios.

Table 4.1.4-12  1976 Data Communications Traffic by Industry and Type of Terminal (Millions of Characters Per Day) (54 Companies Reporting) [19]

| | Remote Batch | CRT | TTY | Other Terminals | Computer to Computer | Industry Total |
|---|---|---|---|---|---|---|
| Financial | 270.4 | 81.1 | 24.1 | 121.2 | 182.0 | 678.8 |
| Service Bureaus | 2,018.7 | 0.4 | 28.3 | -- | -- | 2,047.4 |
| Resource | 512.1 | 142.7 | 9.0 | 6.6 | -- | 670.4 |
| Manufacturing | 304.6 | 28.5 | 4.9 | 28.1 | 45.9 | 412.0 |
| Transportation and Utilities | 236.7 | 323.5 | 13.3 | 251.6 | 23.8 | 848.9 |
| Wholesale/Retail | 197.3 | 7.3 | 1.1 | 6.8 | -- | 212.5 |
| Total for type of terminal | 3,539.8 | 583.5 | 80.7 | 414.3 | 251.7 | 4,870.0 |
| Percent of Grand Total | 72.7% | 12.0% | 1.7% | 8.5% | 5.2% | |

Table 4.1.4-13  1976 Terminals by Type and Industry [19]

| | Remote Batch | Video (CRT) | TTY | Other | Total |
|---|---|---|---|---|---|
| Financial Institutions | 50 | 549 | 635 | 8,997 | 10,231 |
| Service Bureaus | 580 | 24 | 1,524 | -- | 2,128 |
| Resource | 109 | 50 | 73 | 104 | 336 |
| Manufacturing | 119 | 550 | 197 | 960 | 1,826 |
| Transportation and Utilities | 41 | 3,705 | 828 | 139 | 4,713 |
| Wholesale/Retail | 66 | 44 | 20 | 404 | 534 |
| | 965 | 4,922 | 3,277 | 10,604 | 19,768 |

Table 4.1.4-14  Adjusted 1976 Data Communications Traffic by Industry and Type of Terminals. (In Megabits per day)

| | Remote Batch | CRT | TTY | Other Terminals | Computer to Computer | Industry Total |
|---|---|---|---|---|---|---|
| Financial | 4,507 | 1,352 | 402 | 2,020 | 3,033 | 11,314 |
| Service Bureaus | 57,677 | 11 | 809 | - | - | 58,497 |
| Resource | 12,803 | 3,568 | 225 | 165 | - | 16,761 |
| Manufacturing | 7,615 | 713 | 123 | 703 | 1,148 | 10,302 |
| Transportation and Utilities | 5,918 | 8,088 | 333 | 6,290 | 595 | 21,224 |
| Wholesale/Retail | 5,637 | 209 | 31 | 194 | - | 6,071 |
| Total for Type of Terminal | 94,157 | 13,941 | 1,923 | 9,372 | 4,776 | 124,169 |
| Percent of Grand Total | 75.8% | 11.2% | 1.6% | 7.6% | 3.8% | 100% |

Table 4.1.4-15  Assumed Growth Rates by Type of Terminals

| | TERMINAL TYPE | | | | |
|---|---|---|---|---|---|
| Time Interval | Batch | CRT | TTY | OTHERS | COMPUTER TO COMPUTER |
| 1976-1980 | 34% | 42% | 10% | 35% | 24% |
| 1980-1985 | 20% | 30% | 5% | 15% | 20% |
| 1985-1990 | 15% | 20% | 5% | 15% | 15% |
| 1990-1995 | 10% | 15% | 5% | 15% | 10% |
| 1995-2000 | 10% | 10% | 5% | 10% | 10% |

Table 4.1.4-16   Forecasted Data Communications Data Rate by Type of
Terminal for 1980 - 2000 Period in Mbps During Peak Hour

| TIME | TERMINAL TYPE | | | | | TOTAL | GROWTH RATE p.a. |
|------|---------------|---|---|---|---|-------|------------------|
|      | REMOTE BATCH | CRT | TTY | OTHERS | COMPUTER TO COMPUTER | | |
| 1980 | 10.54 | 1.97 | 0.10 | 1.08 | 0.39 | 14.1 | |
| 1985 | 26.23 | 7.31 | 0.13 | 3.30 | 0.98 | 38.0 | 21.9% |
| 1990 | 52.76 | 18.19 | 0.16 | 8.21 | 1.96 | 81.3 | 16.4% |
| 1995 | 84.97 | 36.58 | 0.21 | 16.52 | 3.16 | 141.4 | 11.7% |
| 2000 | 136.84 | 58.91 | 0.26 | 26.60 | 5.09 | 227.7 | 10.0% |
| | | | | | | | 14.9% |

Table 4.1.4-17   Adjusted 1976 Terminals by Type and Industry

| | REMOTE BATCH | VIDEO (CRT) | TTY | OTHER | TOTAL |
|---|---|---|---|---|---|
| Financial Institutions | 84 | 915 | 1,059 | 14,995 | 17,053 |
| Service Bureaus | 1,658 | 69 | 4,355 | -- | 6,082 |
| Resource | 273 | 125 | 183 | 260 | 841 |
| Manufacturing | 298 | 1,375 | 493 | 2,400 | 4,566 |
| Transportation and Utilities | 103 | 9,263 | 2,070 | 348 | 11,784 |
| Wholesale/Retail | 189 | 126 | 58 | 1,155 | 1,528 |
| | 2,605 | 11,873 | 8,218 | 19,158 | 41,854 |

Table 4.1.4-18   Forecasted Data Communications Data Rate for
1980-2000 Period in Mbps During Peak Hour

| TIME | MINIMUM SCENARIO (Mbps) | AVERAGE SCENARIO (Mbps) | MAXIMUM SCENARIO (Mbps) |
|------|------|------|------|
| 1980 | 14.1 | 16.6 | 18.7 |
| 1985 | 38.0 | 44.7 | 50.3 |
| 1990 | 81.3 | 95.6 | 107.6 |
| 1995 | 141.4 | 166.3 | 187.2 |
| 2000 | 227.7 | 267.8 | 301.5 |

LOCATION OF COMPUTER CENTRE

| Terminal Location | Vancouver | Calgary | Edmonton | Winnipeg | London | Toronto | Ottawa | Montreal | Halifax | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| N.W.T./Yukon | .016 | | .026 | | | .002 | | | | .040 |
| Vancouver/Victoria | .455[1] | .002 | .022 | | | .160 | | .073 | | .692 |
| B.C. Other | 1.190 | 1.472 | .051 | | .015 | 2.273 | .002 | .031 | | 5.034 |
| Calgary/Alberta South | .014 | 2.110[1] | 2.905[2] | | .004 | 3.317 | .105 | .016 | | 8.471 |
| Edmonton/Alberta North | .031 | .673[2] | .041[1] | | .006 | .881 | .004 | .132 | | 1.768 |
| Regina/Saskatchewan | | .049 | .020 | .024 | .002 | 2.487 | .004 | .073 | | 2.659 |
| Winnipeg/Manitoba | .054 | .415 | .008 | .073[1] | .006 | 2.102 | .006 | 1.996 | | 4.660 |
| Thunder Bay/Northern Ontario | | | | .031 | .008 | 1.196 | .165 | .099 | | 1.499 |
| Windsor/London/Sarnia | .004 | | .002 | .002 | .014[1] | 1.291 | .205 | .086 | | 1.608 |
| Hamilton/Niagara Penn. | .004 | | | | .010 | 2.135[2] | .002 | .016 | | 2.167 |
| Toronto/Kitchener/Barrie | .215 | | .002 | .051 | .059 | 32.280[1] | .341[2] | .789[2] | | 33.737 |
| Cornwall/Eastern Ontario | | | | | .004 | .218 | | .535 | | .757 |
| Ottawa/Hull | .021 | | | | .006 | 3.257[2] | 6.452[1] | .138[2] | | 9.876 |
| Montreal Area | .173 | | .002 | .016 | .016 | 9.460[2] | 1.044[2] | 5.803[1] | | 16.516 |
| Quebec City | .002 | | | | | .487 | .055 | .202 | | .748 |
| Quebec Other | | | | | | .656 | .222 | .628 | | 1.504 |
| New Brunswick | | | | | .004 | .479 | .006 | .081 | .043 | .613 |
| Prince Edward Island | | | | | | .021 | | .004 | | .025 |
| Newfoundland | | | | | | .176 | | .083 | .012 | .271 |
| Nova Scotia | | | | | .006 | 1.790 | .036 | .282 | .041[1] | 2.155 |
| U.S.A. | .080 | | .028 | .024 | | 1.715 | 2.108 | .536 | | 4.491 |
| Europe | | | | | | .437 | | .120 | | .557 |
| Asia | | | | | | .010 | | | | .010 |
| Mexico & South America | | | | | | .132 | | | | .132 |
| Africa | | | | | | | | | | |
| TOTAL | 2.259 | 4.721 | 3.087 | .221 | .160 | 66.962 | 10.759 | 11.723 | .096 | 100.00 |

Table 4.1.4-19 Origin and Destination of Computer Communications

Traffic Volumes ( Percent Distribution )   [19]

Isolation:
Level 1 = 52.7% L.D.
Level 2 = 32.0% L.D.

4-70

Table 4.1.4-20   Forecasted Long Distance Data Communications Data Rate
for 1980-2000 Period in Mbps During Peak Hour

| TIME | MINIMUM SCENARIO (Mbps) | AVERAGE SCENARIO (Mbps) | MAXIMUM SCENARIO (Mbps) |
|------|-------------------------|-------------------------|-------------------------|
| 1980 | 4.5  | 5.3  | 6.0  |
| 1985 | 12.1 | 14.3 | 16.1 |
| 1990 | 26.0 | 30.6 | 34.4 |
| 1995 | 45.3 | 53.2 | 59.9 |
| 2000 | 72.9 | 85.7 | 96.5 |

## 4.1.3.4  Summary of Data Services Requirments

A summary of the data rates required during the peak hour for long distance transmission for the average scenario is shown in Table 4.1.3-21. Computer communiations is by far the driving force behind the data service demand, generating roughly 85% of the total data traffic. This can be seen in Table 4.1.3-22. On the other hand, Telex/TWX traffic provides a negligible contribution. Facsimile traffic is forecasted to double about every five years and represent about 8.5% of the total traffic at the end of the century. Electronic mail is expected to increase rapidly over the next few years and will generate as much data traffic as fascimile machines by the end of the century.

The authors are not predicting an explosive increase in data communications; although the predicted per capita data transmission is 5 times higher in the year 2000 than in 1985. There are several reasons for this conservative prediction. The increasing capabilities and decreasing costs of micro, mini and small main frame computers makes it more economical to do data processing locally. The newer computers have large memories that can contain large data bases that were previously available only on large main frame machines. There are also specialized data base processing units that can be located in local offices of the major users. The main company computer needs to send only instructions to these data base processors which will then do the required processing and produce reports for local use.

Electronic mail will probably be transmitted in off-peak hours when the link costs are lower, and link utilization is low.

Table 4.1.3-21   Summary Table of Data Rates Required During The Peak
Hour For Long Distance Transmission (1980 - 2000) in Mbps

| SERVICE CATEGORY | YEAR | | | | |
|---|---|---|---|---|---|
| | 1980 | 1985 | 1990 | 1995 | 2000 |
| Telex/TWX | 0.12 | 0.14 | 0.12 | 0.09 | 0.07 |
| Facsimile | .25 | .53 | 2.10 | 3.38 | 8.70 |
| Electronic Mail | 0 | 2.3 | 3.3 | 5.9 | 8.3 |
| Computer Communications | 5.3 | 14.3 | 30.6 | 53.2 | 85.7 |
| TOTAL | 5.67 | 17.27 | 36.12 | 62.6 | 102.77 |
| TOTAL PER CAPITA bps/person | .23 | .68 | 1.34 | 2.27 | 3.55 |

Table 4.1.3-22   Summary Table of The Percentage Of Data Communications
Traffic Volume By Service Category (1980 - 2000)

| SERVICE CATEGORY | YEAR | | | | |
|---|---|---|---|---|---|
| | 1980 | 1985 | 1990 | 1995 | 2000 |
| Telex/TWX | 2.1% | 0.8% | 0.33% | 0.16% | 0.068% |
| Facsimile | 4.4% | 3.1% | 5.8% | 5.4% | 8.5% |
| Electronic Mail | 0.0% | 13.3% | 9.1% | 9.5% | 8.1% |
| Computer Communications | 93.5% | 82.8% | 84.7% | 85.7% | 83.4% |

## 4.1.4 VIDEO AND AUDIO BROADCAST SERVICE REQUIREMENTS

### 4.1.4.1 Introduction

The demand for video and radio broadcasting services was previously thought to be the main driver in the future demand for EHF bandwidth. Recent regulatory decisions in Canada and the United States have transformed the broadcasting field into a dynamically evolving telecommunications service. The introduction of a single service type has the potential of using large quantities of bandwidth, as evidenced by the four 36 MHz satellite RF channels requirement of CANCOM in the extension of services to the remote and underserved communities in Canada. The large variety of potential services indicates significant demand for bandwidth in the future. However, it is felt that the multitude of services can be provided with state-of-the-art technology, as will be shown later in the report.

Probably the most important factor in the decision process is that of regulatory policy. The types and quantity of services to be provided, is the service desirability and introduction date, the financial and feasibility for support of the new service and the impact on existing services will be subject to regulatory influence which must be taken into account if a realistic projection of video and radio broadcasting services is to be obtained.

This section will discuss the following video and broadcasting services under the influence of economics, technology and regulatory policies:

i)    network broadcast - national and provincial
ii)   tele-education
iii)  extension of television services to remote and underserved communities
iv)   pay television
v)    services viable under a direct broadcast system, and
vi)   video conferencing.

## 4.1.4.2 Network Television Broadcast

Two national commercial television networks are available in Canada. These are the Canadian Broadcasting Corporation (CBC) and the Canadian Television Network (CTV). On a provincial basis, Global Communications Limited and Atlantic Television System Limited (ATV-2) provide broadcast services to southern Ontario and Maritimes, respectively. In addition, two other broadcast services, Les Télé-Diffusiers Associés (TVA) and La Société d'Edition et de Transcodage de la Télévision Etrangère Ltée (la Sette), provide coverage to Québec. The following text will describe these networks in greater detail and discuss their future video demand requirements.

### 4.1.4.2.1 Canadian Broadcasting Corporation (CBC)

The CBC was created by an act of Parliament on November 2, 1936, [23]. Its mandates, as cited in Section 3(g) of the Broadcast Act 1967-68, [24], are to:

i) "be a balanced service of information, enlightenment for people of different ages, interests and tastes covering the whole range of programming in fair proportion"

ii) "be extended to all parts of Canada as public funds become available"

iii) "be in English and French, serving the special needs of geographic regions, and actively contributing to the flow and exchange of cultural and regional information and entertainment"

iv) "contribute to the development of national unity and provide for a continuing expression of Canadian identity"

The initial service provided by the CBC was radio coverage to 49% of the public [23]. It was not until 1952 that television service commenced.

By March 31, 1982, the CBC network comprised 60 television stations (27 CBC owned and 33 private affiliates), 112 radio stations (68 CBC owned and 44 private affiliates) and 8 shortwave transmitters (including private affiliated stations), [25]. Its combined coverage, i.e., English and French, is 99.4% for AM radio, 74.6% for FM stereo and 99.1% for television [25].

To fulfill its requirement to broadcast to all Canadians, the CBC has constructed an intricate space and terrestrial distribution system. Forming the backbone of the terrestrial segment is a trans-Canada microwave network, which is in most part leased from TCTS and CNCP. Along with its other landlines, the network extends over 85,000 kilometers throughout Canada and is capable of serving 96.6% of the Canadian population, [23]. To serve the remaining population, and to facilitate the distribution of programming to its ten regional centers, the CBC has leased **ten 6/4 GHz satellite transponders** from Telesat's Anik B and D1. Leasing costs in 1982, are in the order of $16 million and $17 million for the terrestrial and space segments respectively [26].

Each of the two satellites supplies five unprotected transponders to CBC. Primary network broadcasts, such as the English networks and regional north-Atlantic and Pacific release, and the Eastern French network, are handled through Anik B. News gathering services occupy the remaining two transponders on this satellite. With Anik D1, two transponders have been designated for House of Commons broadcasts - English and French, with another three for future services. Prior to the launch of Anik D1, in August of 1982, these services were carried by Anik A2 and A3, which had been co-located at the same orbital slot.

In "Touchstone for the CBC" (1977), two new television services had been proposed. CBC-2 and Télé-2 were the two services that would offer Canadians commercial-free programming in both English and French. With Pay-TV achieving a premiere in early 1983, CBC believe that these services would partially offset the influx of foreign programming. Table 4.1.4-1 shows the percentage of television viewing time dedicated towards domestic and foreign programs. Note that in 1980, 69.8% of English language television viewing time was spent on foreign programs; most of this was during prime time. For

Table 4.1.4-1  Percentage Distribution of Viewing Time by Origin of Program
and Station [27]

| ALL ENGLISH TV STATIONS | | | | | | ALL FRENCH TV STATIONS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1967 | 1972 | 1976 | 1978 | 1980 | | 1967 | 1972 | 1976 | 1978 | 1980 |
| 78.4% | 77.6% | 74.9% | 74.7% | 71.0% | Percent Viewing of Canadian Stations | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| 21.6% | 22.4% | 25.1% | 25.3% | 29.0% | Percent Viewing of American Stations | N/A | N/A | N/A | N/A | N/A |
| 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| 29.1% | 34.4% | 28.9% | 30.5% | 30.2% | Percent Viewing of Canadian Programs | 58.7% | 66.4% | 64.8% | 54.2% | 61.4% |
| | | | | | Percent Viewing of Non-Canadian Programs | | | | | |
| 49.3% | 43.2% | 46.0% | 44.2% | 40.8% | • On Canadian TV Stations | 41.3% | 33.6% | 35.2% | 45.8% | 38.6% |
| 21.6% | 22.4% | 25.1% | 25.3% | 29.0% | • On American TV Stations | N/A | N/A | N/A | N/A | N/A |
| 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

N/A = Not Applicable (i.e. there are no French-language American TV stations)

French language television, the situation was not as severe, only 38.6% of the viewing time went to foreign programming. In either case, Canadians spent a fair percentage of the time viewing foreign programming.

Programming on CBC-2/Télé-2 would be repeats of the best programs of the regular CBC networks supplemented with some new programming. The services would be predominately Canadian content. An eventual goal of 75% to 80% Canadian content was established by the CBC. CBC-2/Télé-2 would immediately double CBC's available prime time and allow more in depth coverage or discussion of the arts, sciences and current events.

The services would call for a minimum of three satellite TV channels; one for Télé-2 and two for CBC-2 with Atlantic and Pacific releases. Initially satellite-to-cable distribution would be used to deliver the services to cable subscribers equipped with converters. In time, coverage would be extended to remote communities. Another distribution method that was contemplated was to use Anik C in a DBS capacity.

The cost for the two services was relatively low at $30 million (1981 $). As a comparison, the present English and French television programming costs $450 million annually (1981 $) [28].

The application for licensing CBC-2/Télé-2, earlier this year, had been declined by the CRTC on the basis of lack of funds and possibly eliminating the chance for Pay-TV's lively arts C-Channel to establish itself.

Summarizing the CBC's requirement for satellite TV channels; the corporation presently uses seven channels. This basic requirement will remain unaltered up to the year 2000. Future services, such as CBC-2/Télé-2, will be established by 1987 or earlier, depending on the availability of funding and the viability of C-Channel. This means a minimum of three additional satellite TV channels around 1985. Radio broadcasts with all-Canada coverage may be incorporated into these three TV channels.

Due to the fact that CBC normally leases unprotected channels from Telesat, additional channels have been required to ensure the provision of the essential services or to be available for future services. Norman Nault, Coordinator in Distribution Planning estimates that there would be a requirement of 15 TV channels by 1992. Our projection would see 13 TV channels by 1985 and 14 TV channels by 1995.

4.1.4.2.2  Canadian Television Network (CTV)

The CTV network is Canada's oldest private television network. When it was established in 1961, it comprised eight private stations servicing 2.5 million households. The network grew to 18 stations by 1975 and broadcasted to some 5.5 million households or 87% of the viewing audience [29]. Today, it is the most extensive network after the CBC, with 27 program originating stations and 246 rebroadcasting stations, for a total of 273 transmitters (as of December 31, 1981) [27].

The mandate of the CTV network is "to operate in Canada as the national alternative English language service, a national network program service in the public interest. Such service will be varied, balanced and designed in concept to serve the national interest comprising a balanced mix of the elements of information, public service, the arts and entertainment" [29].

In terms of satellite transponders requirement, CTV has been using CBC's future service transponder on an interim basis since January of 1981 [30]. It is envisaged a requirement of one satellite TV channel by 1985, for CTV, for news gathering and program distribution. An additional channel may be required by 1990 to accomodate growth in the network.

CTV will not require satellite TV channels to distribute its programming to those whom do not presently receive the service. Instead, it is probable that a separate company, such as CANCOM, will provide this link.

### 4.1.4.2.3  Global Communications Limited (GLOBAL)

Since its' establishment in July of 1972, Global has been providing television service to southern Ontario through its network of six transmitters (one originating and five rebroadcasting) [27]. The network also sells its programming to four television stations in Western Canada. It is unlikely that Global will require any satellite TV channel, although it is a prime candidate for a DBS service or for extension of services to the remote and underserved communities. Global had filed an application to the CRTC to extend its network service across Canada in April of 1981. In its decision (81-257) the CRTC denied the application. The forecast is a requirement of one Anik D TV channel between now and the end of the century.

### 4.1.4.2.4  Les Télé-Diffuseurs Associés (TVA)

Since its inauguration in 1971, TVA has grown from three stations to 15 transmitting stations; of which, six originate programming and nine are for rebroadcasting. The network provides commercial French language television to the provice of Quebec. In 1979, its services were accessable by 98.0% of the population in Quebec.

Similar to CTV, TVA has been using one TV channel on Anik A3, for program distribution, on an interim basis, since January 1981. Based on this fact, we have assumed that TVA will require one satellite TV channel up to the year 2000. There is a possibility that this service be implemented as a DBS service in the future.

### 4.1.4.2.5  Atlantic Television System Limited (ATV-2)

On April 14, 1981, in decision 81-253, the CRTC licensed Atlantic Television Systems Limited (ATV-2) to broadcast via satellite, network television services to cable companies, in the Maritimes, Newfoundland and the Eastern Arctic. ATV-2 will provide a commercial television service similar to current over-the-air television services. Its service will comprise educational (20%), news, public affairs and general entertainment programming. ATV-2 is owned by CHUM Limited of Toronto, which holds the CTV network license for the Atlantic region.

ATV-2 has been given priority cable carriage to ensure it has the revenue base to survive. The network is expected to start service in early 1983. Coverage is provided using the east spot of an Anik C satellite. The forecasted demand for ATV-2 is one satellite TV channel from 1983 to the year 2000.

4.1.4.2.6  La Société d'Édition et de Transcodage de la
                    Télévision Etrangère Ltée (la Sette)

        La Société d'Édition et de Transcodage de la Télévision Etrangère
Ltée, or la Sette, is a consortium formed by the Québec government and a
group of CATV companies.  La Sette offers taped programs from France as an
alternate French-language in Québec.  The program package is a selection of
programs provided by three French television networks.  The programs are
taped in Paris and then flown to Canada.

        The transmitting station for la Sette, is located in Montreal, and
has been disseminating the program package via satellite to Québec CATV
distributors since September 15, 1980.  Originally, part of an Anik B 12/14
GHz transponder was used but the service has been transferred to Anik C3.
Negotiations are also underway to provide an all-Canada coverage.  It is
forecast there will be a requirement of two Anik C TV channels between now
to the end of the century to continue this service.

4.1.4.3  Tele-Education

        Currently, there are four provincial educational television networks
in Canada.  The networks are:

    i)    the Knowledge Network of the West Communications Authority
          (Knowledge Network) of British Columbia;

    ii)   the Alberta Educational Communications Corporation (ACCESS)

    iii)  the Ontario Educational Communications Authority (OECA); and

    iv)   the Québec Broadcasting Bureau (Radio-Québec).

There follows a description of these four networks in more detail, and a
discussion on future tele-educational services.

4.1.4.3.1  Knowledge Network of the West Communications Authority
           (Knowledge Network)

The Knowledge Network began its operation in January, 1981. As a DOC pilot project, it distributed programming via the 12/14 GHz segment of Anik B to cable served communities in British Columbia, Yukon, the Mackenzie Delta in the Northwest Territories, and to limited regions in Western Alberta. Within 18 months, the network could be accessed by more than 82% of the population in British Columbia.

The network provides a full range of educational and informative programs for viewers of all ages. Approximately 62% of these programs are Canadian; of which half are produced in British Columbia. A further 25% of the programs are British productions, while American originated programs comprise the remaining share [ 31] .

The network is funded primarily by two provincial sources; the Ministry of Education and the Ministry of Universities, Science and Communications. Together, they provided 83% of the $2.8 million budget for 1981-82 [ 31] . The remainder came from accumulated interest and user fees.

As for transponder requirements, the Knowledge Network has recently signed an agreement with Telesat for the use of one TV channel at a cost of $945,000 a year. It is very likely the network will lease another channel in the near future. Thus, the forecast is two TV channels on an Anik C satellite from 1985 through to the year 2000.

4.1.4.3.2  Alberta Educational Communications Corporation (ACCESS)

In 1973, ACCESS was established by the Government of Alberta to provide educational television broadcasting to the province. ACCESS programming is also part of DOC's pilot projects using the 12/14 GHz portion of Anik B. Upon termination of the pilot project, ACCESS will move its service onto Anik C. Hence, a requirement of one Anik C TV channel up to the year 2000 is forecasted.

### 4.1.4.3.3 Ontario Educational Communications Authority (OECA)

The OECA was established as a Crown Corporation in 1970 to provide programming to all levels of education in Ontario. Its services are a part of the programming in DOC's pilot projects being carried on the 12/14 GHz portion of the Anik B satellite. It is expected that OECA will continue providing its services using Anik C after the termination of the pilot project. Hence, forecasts are for a requirement of one Anik C TV channel from now to the end of the century.

### 4.1.4.3.4 Québec Broadcasting Bureau (Radio-Québec)

Radio-Québec was established as a public corporation, in 1969, to provide radio and television services to Québec and to produce educational programming. Service, in 1978, was assessible by 85% of Québec's population. The forecast for Radio-Québec is one satellite TV channel from now to the year 2000.

### 4.1.4.3.5 Future Tele-Education Services

There exists a desire to form a full Canada coverage tele-education network through provincial or regional networks. To this end, two new regional networks are anticipated to begin operation in the near future. Saskatchewan Media/Manitoba will supply educational services to the two remaining prairie provinces. The maritime provinces have yet to establish their network. Both new networks are expected to provide their services via Anik C.

The feasibility and usefulness of real-time Tele-education has already been proven through experiments on CTS. One such experiment was the exchange of curriculum between Stanford University in the United States and Carleton University in Ottawa, Canada.

Normally one satellite TV channel would be required for each signal being transmitted; however, if reduced rate video is used, it is possible to fit two or three signals over the same channel. Reduce rate video will match the required bandwidth in accordance to the rate of change of the image. Such a method is ideal for Tele-education, due to the slow motion of the image. Also, it allows the lecturer to use several teaching aids simultaneously, especially if it is not possible to lease only part of a transponder.

The multiplexing scheme may be implemented either in analogue or digital. The digital method requires a high bit rate and 'flash' analog-to-digital converter. Implementation costs would be in the neighbourhood of $150,000. Traditional analogue multiplexing methods are more cost efficient and only cost about $10,000 [32].

The potential demand would be extremely large considering the number of educational institutions in Canada, probably anywhere from 30 to 100 channels. But to be realistic, it would be very difficult for most institutions to justify such a cost when their existing budgets are so tight and will continue to be so in the future.

What will likely happen is that non real-time university credit courses will be offered on cable television. CATV offers a cost effective distribution system with a well established customer base. To combine this with a low tuition fee, video taped courses could prove to be a profitable venture. The courses offered will be distributed locally or regionally and thus, distribution requirements should not be demanding. Long distance transmissions could be handled at night when the traffic volume is low and rates are less expensive. It is envisaged that the previously mentioned télé-education networks will make the service part of their repetoire.

A small increase in satellite transponder requirement is expected to be generated in order to supply this service. The forecasted demand is for three satellite TV channels for 1985 and 1990, increasing to four TV channels for 1995 and 2000.

4.1.4.4 <u>Extension of Service to Remote and Underserved Communities</u>

4.1.4.4.1 Introduction

Television service in remote communities of Canada has been less than desirable, with only 49.7% of rural households receiving three or less different television channels, [33]. In an attempt to rectify the situation and to fulfil section 3(e) of the Broadcasting Act, [34] (to broadcast to all Canadians in English and French) the CRTC assembled the Therrien Committee in January of 1981, to look into the extension of services to remote and underserved communities. Their report, entitled "The 1980's: A Decade of Diveristy ～ Broadcasting, Satellites and Pay-TV" made 41 recommendations [34]. Among the recommendations were:

> RECOMMENDATION 1: "The CRTC should immediately call for licence applications for the delivery, in remote and underserved areas, of a range of Canadian satellite television services that would be attractive to Canadian audiences."

> RECOMMENDATION 3: "Immediate action should be taken to ensure that the national radio services be made available in all parts of Canada as soon as possible."

> RECOMMENDATION 4: "Canada must fulfil its obligation to provide opportunity for its native peoples to preserve the use of their languages and foster the maintenance and development of their own particular cultures through broadcasting and other communications."

### 4.1.4.4.2  CANCOM

A direct result of the study was the approval of the application by Canadian Satellite Communications Inc. (CANCOM) for a network licence to distribute television and radio broadcasting services on April 14, 1981. Services carried by CANCOM includes "CHAN-TV Vancouver, CITV-TV Edmonton, CHCH-TV Hamilton, CFQM-FM Moncton, CKAC and CITE-FM Montreal,CKO-FM-2 Toronto, CIRK-FM Edmonton and CFMI-FM Vancouver and two native language radio signals." [35] . CANCOM is also expected to distribute native television programming on a part-time basis. Originally, CANCOM had proposed to provide French-language television programming through Télémedia Communications Ltée. (TCTV); however, the CRTC believes that TVA should provide this service instead of TCTV. The signals will be scrambled for security and for regional isolation of program services. The consortium shall receive a maximum monthly charge of $4.00 from each subscriber of the local distributors.

The services to be provided by CANCOM generates a requirement for 4 satellites TV channels. Discussions with Peter Norman of Satellite Services Business Development at Telesat Canada has confirmed that 4 channels on Anik D1 have been leased by CANCOM. Another channel will be required for TVA, and there is a distinct possibility that an additional channel will be required in the near future, since it was pointed out in CRTC decison 81-252 that no Altantic television programming has been provided. CANCOM has made a commitment to add such a service once it becomes available.

CANCOM has recently submitted an application to add four American TV stations (ABC, CBS, NBC, PBS) to its package. The application was heard on November 23, 1982 and was approved. Provision of these services will commence in early 1983.

CANCOM's competitors to provide this service consisted of Conestaga Satellite Services Limited of Kentville, Nova Scotia, Norcom Telecommunications Limited of Kenora, Ontario, and Northstar Home Theatre Inc. of Mississauga, Ontario. Their proposals had been denied on the basis that excessive competition would snuff out the project. Thus, it would be safe to say that no new competing services would be offered until the next decade. New services at that time would not likely be network television but rather new DBS video services instead. Ten TV channels are projected to be required by 1985.

### 4.1.4.4.3 Newfoundland Broadcasting Company Limited (NTV)

On recommendation of the Therrien Committee, a license was granted to the Newfoundland Broadcasting Company Limited (NTV) to extend CTV network services to the remote and underserved communities in the Newfoundland and Labrador area. The CTV affililiate selected was CJON-TV of St. John's, Nfld. The service is part of a two year experiment on Anik B conducted at no charge to NTV. Upon completion of the experiment, it is expected NTV will continue its service using the east spot of an Anik C satellite or be carried as part of the CANCOM service on the Anik D satellite.

### 4.1.4.5 Pay Television

After almost a decade of effort to establish the regulatory policies for pay television (Pay-TV), the CRTC announced its decision (Decision CRTC 82-240) concerning this issue on March 18, 1982. It was in 1972 when Rogers Cable Limited of Toronto first filed its application to the CRTC to supply five Pay-TV channels - three movie and two information channels. At that time, the application was deferred due to the lack of policies on the matter.

In brief, CRTC's Pay-TV policy objectives are to strengthen the Canadian broadcasting system through supplying complementary television services to existing ones and to provide a greater diversity of programming.

Part of the revenues would be fed back into the system to obtain or create new high quality Canadian productions. These objectives were derived from Recommendation 28 of the report, "The 1980's: A Decade of Diversity - Broadcasting, Satellites and Pay-TV", by the Committee on Extension of Service to Northern and Remote Communities.

Six licences were issued in Decision CRTC 82-240, two for national and four for regional services . National services consisted of a general interest and a specialty (performing arts) service. Three of the regional services were general interest, and covered Atlantic, Central and Western Canada. The remaining regional service is planned to provide multilingual programming. The rationale for this system was that the national and regional service would each provide programs reflecting the needs of its respective audience, but yet would permit competition to each other on common programming; and thus, a greater diversity of programs would result. Rather than describing each license separately, Table 4.1.4-2 summarizes the licenses, their coverage, services offered and distribution requirements.

To summarize the known current Pay-TV channel requirement, there is a demand for ten TV channels on Anik C3. The trend is to increase Canadian content from 30% to 50% by January of 1986. The cost for each service is about $15 to individual subscribers.

The impact of Pay-TV is anything but certain, and its impact will depend greatly upon its cost to the consumers and the method by which the services are marketed over the next couple of years. Pay-TV services began in February 1983, and the acid test of its viability will take place during the first couple of years of operation. Without the benefit of past history on which to base a projection, the next best solution is to look at marketing surveys and base a projection on the estimated demand. However, prior to doing this, a brief look at the growth of the cable industry will provide the reader a greater insight into the projections.

### Table 4.1.4-2  Summary of Pay-TV Licences

| LICENSEE | SERVICES | COVERAGE AND DISTRIBUTION |
|---|---|---|
| First Choice Canadian Communications Corp.<br><br>First Choice | -general interest<br>-english and french<br>-service 24 hrs/day,7days/wk.<br>-30% Canadian content 50% by Jan. 1986<br>-first run films | -four TV channels on Anik C<br>-two east, two west spot beams<br>-unscrambled, populated Canada |
| Lively Arts Market Builders Inc. (LAMB)<br><br>C Channel | -specialty, ie., performing arts<br>-42 hrs/wk of CDN and foreign performing arts programming<br>-30% Canadian content, 40% by Jan. 1986 | -two TV channels on Anik C - one east, one west spot beam<br>-scrambled, populated Canada |
| Alberta Independent Pay Television (ALLARCO)<br><br>Super Channel- Alberta | -general interest<br>-24 hrs/day of CDN and foreign english programming<br>-70% films, 30% mix of sports, comedy, musicals<br>-30% Canadian Content, 50% by Jan. 1986<br>-100% of profit to go to CDN productions | -one TV channel on Anik C - west spot<br>-scrambled, Alberta |
| Ontario Independent Pay Television<br><br>Super Channel- Ontario | -general interest<br>-24 hrs/day of CDN and foreign english programming<br>-70% films, 30% mix of sports, comedy, musicals<br>-30% Canadian content, 50% by Jan. 1986<br>-100% of profit to go to CDN productions | -one TV channel on Anik C - east central spot<br>-scrambled, Ontario |
| Star Channel Services Ltd.<br><br>Star Channel | -general interest<br>-47 hrs/wk of CDN and foreign programming<br>-predominately English<br>-films, varieties, music specials, documentaries<br>-30% Canadian content, 50% by Jan. 1986 | -one TV channel on Anik C - east spot<br>-scrambled, Atlantic Region |
| World View Television Limited<br><br>World View | -multilingual - Chinese, Japanese, Italian, Scandinavian, East Indian, etc.<br>-92 hrs/wk<br>-60% Canadian content | -assume one TV channel on Anik C - west spot |

An analysis of Cable TV statistics would give the general impression that the industry is nearing market saturation. Table 4.1.4-3 lists the major statistics from the cable industry. Reference [33] estimates there are approximately 1.4 million rural households. With 6.1 million out of 7.8 million households presently wired for cable, this would suggest that only smaller communities remain to be wired. Since these new operations are not as profitable, there will be a declining growth rate in the number of households being wired for cable. In 1980, 95.3% of the households in licensed areas had access to Cable TV. This figure drops to 78.2% when the total number of households are considered. Of the households with access to Cable TV, 70.5% subscribed to the service. However, if all Canadian households are considered, then only 55.1% of all the households subscribe to the service.

Proceeding onto the demands for Pay-TV, Table 4.1.4-4 summarizes the interest in Pay-TV for various market surveys. The trend for acceptance of Pay-TV has increased with time. Crop's survey showed 27% of the public would be likely subscribe to a Pay-TV service at $9/month. Nielson-Ferns found the percentage to be 51%, in 1981, for a Pay-TV service costing $10/month. The latter demand is considered to be too high because their Pay-TV model used was similar to the United States model. In any case, with 55% of all Canadian households subscribing to cable, there definitely is a market for Pay-TV.

With respect to demand sensitivity of prices, the Neilson-Ferns survey found that demand rapidly declined once the charge for the service exceeded $12/month in 1981. Proposed Pay-TV services will each cost about $15/month at the outset in 1983. The cable companies have been pushing for a tiered rate system. With this system, packages of one, two or three Pay-TV services, in addition to the regular subscription, would be available at a reduced price. Though this may make the services appear more reasonable, the fact that the services may be slightly overpriced should be taken into consideration.

## Table 4.1.4-3  Cable Television Statistics [36]

| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | % Growth '75-'80 |
|---|---|---|---|---|---|---|---|
| Direct Subscribers (in millions) | 2.2 | 2.4 | 2.7 | 3.1 | 3.4 | 3.6 | 10.4% |
| Indirect Subscribers (in millions) | .63 | .65 | .64 | .65 | .69 | .70 | 2.1% |
| Total Subscribers (S) (in millions) | 2.8 | 3.1 | 3.4 | 3.7 | 4.1 | 4.3 | 9.0% |
| Households Passed (HP) (in millions) | 4.3 | 4.6 | 4.9 | 5.5 | 5.9 | 6.1 | 7.2% |
| Households in Licenced Area(HL) (in millions) | 4.6 | 4.9 | 5.3 | 5.8 | 6.2 | 6.4 | 6.8% |
| Total Households (TH) (in millions) | 6.7 | 6.9 | 7.0 | 7.3 | 7.6 | 7.8 | 3.1% |
| % Households Subscribing (S/TH) | 41.8 | 44.9 | 48.6 | 50.7 | 53.9 | 55.1 | |
| % Households with Access(HP/TH) | 64.2 | 66.7 | 70.0 | 75.3 | 77.6 | 78.2 | |
| Market Penetration (S/HP) | 65.1% | 67.4% | 69.4% | 67.3% | 69.5% | 70.5% | |
| Franchise Penetration (HP/HL) | 93.5% | 93.9% | 92.5% | 94.8% | 95.2% | 95.3% | |

Table 4.1.4-4  Demand for Pay-TV - Comparison of Different Surveys [ 37]

| INTEREST IN/LIKELIHOOD OF MONTHLY SUBSCRIPTION TO PAY CHANNEL | CROP 1977* ($8/Mth) | COMPLAN 1979** ($8/Mth) | CROP 1980* ($9/Mth) | Nielson-Ferns 1981*** ($10/Mth) |
|---|---|---|---|---|
| Very Interested/ Very Likely | 3% | 16% | 10% | 18% |
| Fairly Interested/ Likely | 8% | 17% | 17% | 33% |
| Not Too Interested/ Fairly Unlikely | 21% | 19% | 13% | 21% |
| Not at All Interested/ Very Unlikely | 54% | 48% | 56% | 27% |
| Don't Know/No Answer | 13% | 1% | 5% | 2% |
| Note:   Total may not add exactly to 100% due to rounding | | | | |

| | |
|---|---|
| * | Sponsored by CRTC; All regions of Canada.  All day service. |
| ** | Sponsored by CCTA; All regions of Canada.  All day service. |
| *** | Sponsored by Toronto Star and Torstar Ltd.; Edmonton, Montreal and Toronto only.  Prime-Time only |

Also related to pricing is just how many systems can the public afford and desire. This point was commented upon by Commissioners Gagnon and Grace about decision CRTC 82-240. They expressed concern that Canada's sudden transition from having no Pay-TV to a full Pay-TV system, with national, regional and multilingual services, would exceed the actual demand for Pay-TV.

Another point to consider is that the CRTC is calling for two additional regional Pay-TV services, i.e., British Columbia and Québec to complete regional coverage across Canada.

Up to this point, the U.S. Pay-TV model has been deliberately avoided in our projection for Pay-TV services. The Canadian Pay-TV system, because of the regulations on Canadian content will not follow a growth like that of the United States. However, we can investigate their Pay-TV services to see why they have been successful. Knowing their success formula should help us to determine what Canadian Pay-TV needs to provide in order to remain viable. Table 4.1.4-5 lists the major U.S. Pay-TV program distributors and Figure 4.1.4-1 illustrates their shares in the market. The two big distributors are Home Box Office (HBO) and Showtime. Their market captures are 60% for HBO and 16% for Showtime. Both offer premier movies as the main draw, supplemented by entertainment specials. HBO goes one step further to add sports to its repertoire . Table 4.1.4-6 provides a breakdown of HBO programming. From this, the conclusion may be drawn that commercial-free movies is the success factor behind Pay-TV in the U.S.

Projecting the channel requirement for Pay-TV under the present state of affairs is extremely difficult. We believe there exists a demand for a national Pay-TV service, such as First Choice. Starting with only 30% Canadian content, and hence an abundance of movies, the service should show an excellent growth rate in the first couple of years. Market saturation should be reached within three years. Canadians can probably just support two Pay-TV services, so as long as there is a full regional network, a competitor to First Choice will not be approved by the CRTC. The earliest we might see a third movie/entertainment service would be in 1995. The year 2000 would probably be more reasonable.

### Table 4.1.4-5  Major Pay-TV Program Distributors [37]

As of December 1980

| NAME | SUBSCRIBERS (000) | SATELLITE DELIVERED |
|------|------------------|---------------------|
| Home Box Office | 6,237 | Yes, Satcom I |
| Showtime | 1,625 | Yes, Satcom I |
| Movie Channel | 566 | Yes, Satcom I |
| National STV-Chartwell | 416 | No |
| Self-Booked Systems | 322 | No |
| Cinemax | 201 | Yes, Satcom I |
| PRISM | 189 | No |
| Home Theatre Network | 151 | Yes, Satcom I |
| SelecTV | 107 | No |
| Wometco Home Theatre | 95 | No |
| National STV - Oak | 90 | No |
| Theta | 71 | No |
| Starcase | 63 | No |
| Rainbow | 53 | Yes, Comstar D-2 |
| Showbiz | 43 | No |
| Galavision | 30 | Yes, Satcom I |
| National STV - Buford | 27 | No |
| Optical Systems | 18 | No |
| Continental Cinevue | 17 | No |
| American TV & Communications | 15 | No |
| Limelight | 13 | No |
| Showcase | 9 | No |
| Others | 31 | |
| TOTAL | 10,389 | |

### Figure 4.1.4-1 [37]

SHARE OF MARKET FOR PAY TV DISTRIBUTORS [37]

As of December 1980
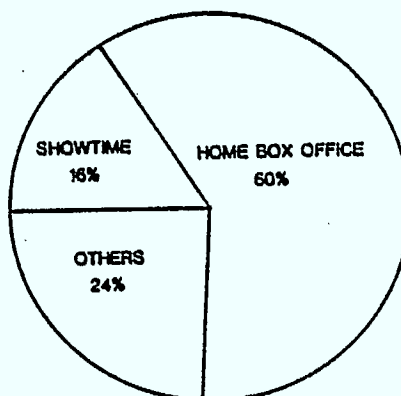
Table 4.1.4-6  Analysis of HBO Programming - May 1980 [ 37]

| TYPES OF PROGRAM | FIRST PLAYS | | REPEATS | |
|---|---|---|---|---|
| | NO. OF TITLES | HOURS OF PROGRAMMING | NO. OF TITLES | HOURS OF PROGRAMMING |
| Movies* | 20 | 37:25 | 32 titles (92 plays) | 172:05 |
| Sports | 8 | 7:30 | 6 titles | 11:00 |
| Variety/Entertainment | 7 | 7:00 | 8 titles | 23:30 |
| Documentaries | 3 | 2:30 | 3 titles | 6:30 |
| Promotional Programs | 2 | 1:00 | 2 titles | 2:00 |
| TOTALS | 40 | 55:25 | 51 titles (138 plays) | 215:05 |

\* As can be seen, movies predominate -- 58.82% of the number of different titles shown, and occupy 77.45% of the total time.  Further, 82.1% of the time devoted to movies is occupied with repeat showings.

The regional Pay-TV services will follow a gradual growth trend. As Canadian television productions become more abundant and of better quality, the services will see their markets grow. Market saturation will be reached in six or seven years. We will see two regional services added in the near future, requiring two more Anik C3 TV channels, primarily as a result of CRTC policy.[1]

The C-Channel will see a very limited market, mainly because of its specialized service. There just is not that much interest in the arts. The service will have quite a struggle to stay alive.

Thus, the projected demand for PAY TV will be twelve 12/14 GHz television channels from 1983 to the year 2000. Two further 12/14 GHz TV channels will be added by 1990, one for multilingual services in Ontario and an adult programming channel. The latter will require authorized access to the service, either through a key or a numerical code. By 1995, two 12/14 GHz TV channels will join the existing nework as future services.

## 4.1.4.6  Services Viable Under a Direct Broadcasting System

### 4.1.4.6.1  Introduction

The evolution of a direct broadcast satellite (DBS) from concept to reality continues to progress as program requirements become identified, the necessary technology developed, and the funds required are made available. The concept of a DBS has received critical review throughout the world, particluarly in Japan, United States, Western Europe and Canada. The experiments of the US/Canadian Communication Technology Satellite (CTS) have proven the feasibility of direct-to-home broadcasting and has demonstrated the potential of its services. Direct-to-home broadcast offers a couple of

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[1] One of these services, Télévision de l'est Canada (TVEC), has recently acquired a license. Likewise, a B.C. Pay-TV service (AIM) has been licensed to provide service in the very near future.

resources which present fixed satellite services does not provide. It allows direct access to each person within the country via satellite. There is a large amount of bandwidth available which is not allocated for specific uses such that they cannot be altered. These two primary features allows a flexibility in service development unparallelled by existing frequency bands.

Services evolving under a DBS environment will be driven by the needs of its audience, i.e., their culture, language and interests, as opposed to technology of the system. The characteristics of a direct-to-home broadcasting system makes it ideal for network and Pay-TV services; however, since these services were discussed earlier, only alternative services will be considered in this section.

4.1.4.6.2 Audio Services

In a previous CAL study for DOC on alternate services on a direct broadcast satellite, reference [32], two audio services, i.e., FM superstations and radio networks, were isolated as possible DBS services.

A FM superstation would offer national coverage through a network of regional broadcasts to compensate for the time zones. Programming content will have to be general interest in style, independent of geographical location, but news may be on the regional level. Analysis of Statistics Canada data, in the report, shows that Ontario and Québec to be well served in English and French FM service, respectively. Québec, B.C., Manitoba and perhaps Alberta were considered as adequately served, while Saskatchewan and the Maritimes were underserved. It was estimated that 8 FM stations are the most any one major urban center can support. However, a more realistic forecast would be 2 FM stereo superstations per beam starting in 1990.

Whether superstations will be able to obtain licences is another matter. Superstations are presently against CRTC policy and the establishment of such stations could decimate smaller radio stations.

A second service is the distribution of audio commercials, and syndicated news program material. Potential users include Broadcast News, CKO All News Radio Network, File-Media Communications Ltd., CFCF Radio, Standard Broadcasting and Maclean-Hunter. The demand forecast would be for three or four 15 KHz channnels. Once again the question of whether such a service will be allowed by the CRTC arises.

As one can see, the bandwidth requirements for audio services are almost negligible. There is always the possibility that they will use subcarriers in satellite transponders carrying other services. The maximum overall demand would be one RF channel starting in 1985.

### 4.1.4.6.3 Narrowcasting

Narrowcasting is provision of a television service to a small or select audience. A prime example of its application is to provide special courses geared towards selected professional groups. The courses may be made interactive by establishing a telephone link between the student and the professor.

O. Roscoe, Director of the Space Planning Branch at DOC, estimates that one satellite TV channel will be required starting in 1985. This demand will increase by one channel for every five years to give a requirement of four satellite TV channels by the year 2000.

His estimate was based on the following assumptions:

i) 60 hours of service per year for each profession;
ii) service will be provided to 15 professions;
iii) the English version of the services will be geared towards three regions: the Atlantic, Ontario and the West; and
iv) one French version of each service is required.

Hence, each version of a service requires 900 hours per year. With four versions, the total requirement is 3600 hours per year. This translates to one satellite TV channel used for about 14.5 hours on each of the 250 working days in a year.

### 4.1.4.6.4  Telidon – a Teletext and Videotex System

When we think of Telidon, we think of teletext and videotex. The primary difference between these two computer systems is that teletext is a one-way system while videotex is a two-way system. Teletext system enables the user to select and display pages of alpha-numeric data on a television screen. The user; however, does not have the capability to communicate with the computer, other than database access. In a videotex system, the user is capable of both communicating with the computer and database access.

Telidon teletext signals are carried in the vertical blanking interval (VBI) of the NTSC video signal. Under this scheme, it is possible to transmit 4.33 kilobits of information per frame for an effective data rate of 129.8 kbps, [32]. If an entire video frame is used, instead of the VBI, then the effective transmission rate is 3.24 Mbps. Hence, an increase of 25 times in the data rate.

The authors forecast the need for one satellite TV channel, prior to 1985, for the dissemination of Telidon. The authors forecast that the demand will remain at one satellite TV channel up to the year 2000.

### 4.1.4.6.5  High Definition Television (HDTV)

Up to now, we have seen two stages of television technology, i.e., the development of monochromatic and colour TV. High definition television (HDTV) will represent the third generation of this technology. What it offers, over its predecessors, is a higher resolution picture. HDTV should quadruple the amount of detail available on existing television receivers. To do this, HDTV will use at least 1100 scan lines, roughly double the number used in the world's three major standards: NTSC, PAL and SECAM. NTSC is the acronym for the National Television Systems Committee, the standard used on the North American continent and Japan. In Europe and Brazil, PAL or Phase Alternation Line is used, while the standard in France and the Soviet Union is SECAM or Séquentiel Coleur Avec Mimoire. Presently, NTSC and PAL use 525 and 625 scan lines, respectively.

High definition television is still in the early stages of development with international standards and regulations still to be clearly defined. It is also dependent upon other technological development, such as digital broadcast equipment; wideband analogue and digital video tape recorders (VTR's); large, wide screen television receiver and direct broadcast satellites. In any case, it is unlikely that HDTV will appear in retail stores prior to the end of this decade. However, as HDTV gains momentum, the distribution of HDTV compatible programming will demand more bandwidth and wider bandwidth video channels. The following text will look at the hurdles encountered by HDTV along with some of the developments in progress.

The major hurdles encountered in HDTV are the bandwidth requirements, incompatibility with existing standards and the cost of a system. These difficulties were identified in a study performed by the Society of Motion Picture and Television Engineers (SMPTE) in an attempt to define international HDTV standards. On the list of desirables was a high resolution picture, with an aspect ratio greater than 4:3, that was comparable to 35 mm films. The signal should be compatible with NTSC, PAL and SECAM, and digital video signal techniques should be used wherever possible to minimize the costs of future systems.

With the thoughts in mind, SMPTE produced the following recommendations:

i) A frame should comprise 1100 scan lines, with a target of 1500 lines per frame in the future;

ii) An interlace pattern at 30 frames-per-second should be used;

iii) The aspect ratio (i.e. horizontal to vertical length) of the display should exceed 5:3, preferably 2:1.

iv) The chrominance portion of the signal should be transmitted separately from the luminance portion.

v) For a 1100 lines-per-frame raster, the bandwidth for the luminance and chrominance should be 20 MHz and 7 MHz, respectively.

The study group, [38], however, was not overly optimistic of attaining full compatibility with present standards, as indicated by the statement:

"The transition from the existing public color service to such
an improved HDTV color service would, it seems, be fraught
with so many political, social and economic impediments that
it might never succeed in attracting a sufficient audience to
justify the heavy costs of its development."

The fifth recommendation by the SMPTE study group gives an indication
of the bandwidth required for a HDTV channel. Without compression and
aspect ratio techniques, the baseband video signal for HDTV will occupy
27 MHz. This is approximately four times greater than the 6 MHz required by
a NTSC TV channel or the 7 to 8 MHz channel of the PAL and SECAM systems.

N. Mokhoff, [39], calculated the data rate needed to digitize a HDTV
signal. Such a signal would have a bandwidth between 22 and 44 MHz,
depending on the horizontal blanking interval and the aspect ratio chosen.
Considering the best case, i.e. a bandwidth of 22 MHz, a minimum sampling
frequency of 44 MHz would be required according to Nyquist's criterion. If
the luminance channel had 256 quantization levels or 8 bit resolution, then
the minimum data rate for a monochromatic signal was calculated to be 352
Mbps (i.e. 44 MHz x 8 bps). For a color signal, the rate was estimated to
be over 700 Mbps, if each of the two chrominance channels had 6 bit
resolution and transmission was performed via time-division multiplexing.
Hence for a color signal with an aspect ratio of 5:3, the data rate was
about 800 Mbps, once the bits for control functions were added, considerably
more than the 88.6 to 228 Mbps required to digitize an existing TV signal.

The SMPTE study group also identified three potential applications
for HDTV:

i)   the projection of television programs in theatres;

ii)  the production of motion pictures; and

iii) in the home.

It is envisioned that HDTV will make its introduction through the first two
applications, where the customer base is large enough to justify the high
capital cost of a HDTV system. HDTV could also provide the special

attraction needed by theatres to compete successfully against the growing array of home entertainment services. A viable HDTV system for theatres may not be too far off. For example, Sony Corporation, in 1981, demonstrated a close circuit HDTV system with 1125 lines, using a high-definition three-tube camera and a VTR [39]. However, it must be realized that much development work still remains in cameras, projection systems, VTR's, digital converters and processors. Development in cameras with the required luminance and chrominance bandwidths, and signal-to-noise ratio is under way. NHK of Japan has broadcast camera tubes with up to 1600 lines of resolution. Much of the equipment used in Sony's HDTV demonstration was based on development work performed by NHK since 1968. Meanwhile, development at Thomson CSF of France has lead to a camera that is flat to 10 MHz.

Once a direct broadcast satellite service is established, transponders may be used to distribute films directly to theatres, thus eliminating film costs. However, the economic feasibility of this system must be considered in greater detail because differences in time zones will have to be taken into account. This implies the use of an additional transponder or tape and delay. A more important consideration is that the resolution is only comparable to that of 35 mm film. What advantages does a HDTV system really give the consumer over the present system and do they justify the system's implementation costs?

The economic viability of HDTV will depend on wide acceptance in the home entertainment market. Cost of new receivers and converters will be a major element in acceptance of HDTV. Receiver technology is not foreseen as a problem, 1024 line, raster scan colour display monitors for computer applications are available now.

A large, wide display will be one of the major selling features of HDTV. Efforts to produce a large display are coming from companies like RCA, Bell Laboratories, Texas Instruments, NHK, sharp, Burroughs, Lucitron, and Westinghouse. These efforts include modifications of electron-beam scanning devices, improvements to projection system and development of solid state displays. A 50 inch display that is only 4 inches thick is being developed by RCA and may be available to the consumer by 1990. The display is comprised of modules mounted side-by-side which are scanned by three electron beams deflected at right angles to the screen.

Due to the wide bandwidth required by a HDTV signal, there will undoubtedly be efforts made to minimize the cost related to signal transmission through signal compression. The tendency has been to focus on analogue compression techniques for the near future and then to progress to digital in the long term. The design of these converters will be technically challenging, particularly if the signal has to be transmitted in the 6-8 MHz bandwidth of the established VHF and UHF bands. Usage of a higher frequency band would relax this restriction. The real challenge, though, would be to produce them inexpensively. If a HDTV receiver is to compete on the television market, it would be priced at not more than 150% of a standard color TV receiver.

A third difficulty is what capabilities should a HDTV receiver possess. Ideally, it should be capable of receiving current television and HDTV signals. To make it only HDTV compatible would detract from its marketability. Some progress has been made as to the implementation of direct broadcast satellites services to individual homes. In the U.S., several applications have been submitted to the FCC. One of these proposals, submitted by the CBS, has expressed the intention of transmitting HDTV services, in addition to current television service via a DBS.

On the other side of the ocean, a field trail of a HDTV-FM DBS system at 12 GHz has been performed by NHK and the Ministry of Posts and Telecommunications of Japan. The system's specifications are depicted in Table 4.1.4-7. It is important to note that a total of 105 MHz bandwidth was used in the experiment.

It is envisaged that domestic HDTV receivers may be available in 1990 at the earliest. Due to their price and the fact they will be replacing aging color TV receivers, HDTV will follow a slow market penetration curve. The rate of penetration will be greatly influenced by the quality and quantity of entertainment services available on HDTV.

There are numerous difficulties which must be hurdled before HDTV is implemented. The uncertainties of these parameters make it extremely difficult to predict the market impact of HDTV. It is felt that the requirements for the extra wide bandwidth or extra high data rates of a HDTV system could be met by the incorporation of a direct broadcast satellite into the Canadian satellite community. Because of the large bandwidth required by HDTV it would be a "natural" application for an EHF satellite link.

## Table 4.1.4-7  Satellite HDTV-FM Transmission
### (Reference [40], Table 11)

|                                      | LUMINANCE         | CHROMINANCE       |
|--------------------------------------|-------------------|-------------------|
| Carrier Frequency                    | 12.0875 GHz       | 11.9625 GHz       |
| Video Bandwidth                      | 20 MHz            | 6.5 MHz           |
| Type of Modulation                   | FM                | FM                |
| Frequency Deviation                  | 40 MHz            | 12 MHz            |
| Radio Frequency Bandwidth            | 80 MHz            | 25 MHz            |
| S/N Ratio (Unweighted)               | 42.5 (38.6) dB    | 44.5 (40.6 dB     |
| C/N Ratio (99% of time)              | 16.7 (12.8) dB    | 22 (18.1) dB      |
| Receiving Antenna Diameter           | 2.5 m (1.6 m)     |                   |
| Receiver Noise Temperature           | 660 K             |                   |
| Satellite Transmitting Antenna Gain  | 37 dB             |                   |
| Satellite Transmitter Power          | 100 W             | 100 W             |

## 4.1.4.7  Videoconferencing

Providing an accurate estimate of the demand of videoconferencing will be no simple task. The service is still relatively new and how well it performs on the market still remains to be seen. Some fairly gross assumptions have been made to arrive at estimated demand. The future of videoconferencing looks promising, if AT&T's new Picturephone Meeting Service (PMS) is any indication. The PMS centre in New York is booked 85% of the time and the service is obviously satisfactory because 70% of the customers have used PMS before, [5]. PMS is an attractive alternative to travel, especially when the meetings are short, say of 1-2 hour duration, or when there are many attendees (more than two per party) or if the distance to be travelled is far.

The attitude of the customers towards videoconferencing will affect how fast PMS will penetrate the market. In a study by Bell Canada, it was found 37% of the 9619 travelling businessmen surveyed wanted to decrease their amount of travelling, while 15% desired an increase and 48% were happy with their present amount of travel. Thus, at least one third of the people surveyed would be interested in videoconferencing.

Marketing consultants have also estimated the potential usage of different conferencing modes. Table 4.1.4-8 shows their estimates. In our opinion, the latter two estimates by FSI and Dayton Research Institute did not consider the option of audio with graphic support so their estimates of demand for teleconferencing are both optimistic; and will not be considered. From the table, if we average out the estimates, then 47% of the conferences are suitable for face-to-face meetings, 12% for videoconferencing and 41% for audio teleconferencing with graphic support. The estimate by Systems Strategy of 2% for video with audio support seems to be out of line, if this figure is ignored then the average for video with audio support becomes 13.3%. So although videoconferencing is an impressive exchange medium, its rate of substitution is not extremely high. Audio teleconferencing with graphic support; however, appears to be a more likely substitution for face-to-face meeting. Audio teleconferencing is less expensive than video conferencing and requires much less bandwidth. The technology to transmit data to a CRT connected with a telephone also exists. It is expected videoconferencing will be accepted first by large corporations and the government. Small companies or conferences with only a few attendees will use audio teleconferencing with graphic support.

Table 4.1.4-8  Suitability of Various Conference Modes [ 5]

| | Face-to-Face Meetings | Teleconferencing | |
| --- | --- | --- | --- |
| | | Video with Audio Support | Audio with Graphics Support |
| SBS - Project Prelude | | Some | |
| Systems Strategy Dept. BPO | 59% | 2% | 39% |
| Stanford Research Institute | 47% | 8% | 45% |
| Xerox | 50% | 9% | 41% |
| Bell Labs | 50% | 10% | 40% |
| NYU Alternate Media Centre | 50% | 10% | 40% |
| James Martin | 40% | 20% | 40% |
| UK Communications Study Group | 34% | 23% | 43% |
| Average | 47.1% | 11.7%* | 41.1% |
| Future Systems Inc. | 62.5% | 37.5% | - |
| Dayton Research Institute | 50% | 50% | - |

* If the Systems Strategy Dept BPO figure of 2% is omitted the average becomes 13.3%.

To determine the videoconferencing transponder requirements, a model was constructed with the knowledge or assumptions of the number of long distance videoconferences, conference durations, signal bandwidth requirements, and traffic load distributions. A significant portion of the modelling was to forecast the number of long distance videoconferences, which was assumed to be proportional to the number of enplanements. Estimates of the number of conferences per trip and the realizable percentage of videoconfercing capture were also integrated into the forecast. The subsequent text describes this modelling in greater detail.

The initial procedure was to forecast the number of enplanements to the end of the century. Table 4.1.4-9 and Figure 4.1.4-2 illustrate the results of linear regression analysis of Statistics Canada data. The fit yielded a correlation factor of 0.9630. With a linear fit, a declining growth rate has been implied. The annual growth rates, for the next 20 years, in half decade intervals, are 4.1%, 3.8%, 3.2% and 2.7%. These figures are considerably larger than projected population or GNP growth. Therefore minimum and mid-range growth scenarios were created based on projected population and GNP data. The number of conferences generated through airplane trips was then calculated using the the following assumptions [5] :

i)   half the number of enplanements to account for round trip travel;

ii)  business passengers represent 40% of the enplanements;

iii) an average of 2.7 conferences are held per trip; and

iv)  on the average people travel from 2 different destinations to each business meeting.

Based on Table 4.1.4-8. it was estimated videoconferences could capture 13.3% of all conferences and the acceptance of videoconferencing followed the replacement rates depicted in Table 4.1.4-10. The computed number of videoconferences is shown in Table 4.1.4-10 as well. The conversion from annual to daily videoconferences assumes 250 working days per year. The number of conferences is given by:

$$N_c = N_e \text{ x .5 x .4 x 2.7 x .5}$$

where $N_e$ is the number of enplanements.

The number of video conferences that could potentially be carried on Canadian satellites is given by:

$$N_V = N_c \text{ x .133}$$

Table 4.1.4-9   Number of Enplanements Annually (1971-2000)

| YEAR | NUMBER OF ENPLANEMENTS (MILLIONS) | | |
|------|---------|---------|---------|
|      | MINIMUM | AVERAGE | MAXIMUM |
| 1971 |         |         | N/A     |
| 1972 |         |         | N/A     |
| 1973 |         |         | 15.33   |
| 1974 |         |         | 17.16   |
| 1975 |         |         | 16.25   |
| 1976 |         |         | N/A     |
| 1977 |         |         | 18.89   |
| 1978 |         |         | 20.06   |
| 1979 |         |         | 22.77   |
| 1980 | 23.9    | 23.9    | 23.97   |
| 1985 | 25.4    | 28.5    | 29.27   |
| 1990 | 26.8    | 32.4    | 35.24   |
| 1995 | 27.9    | 36.4    | 41.22   |
| 2000 | 28.9    | 40.3    | • 47.19 |

N/A = not available
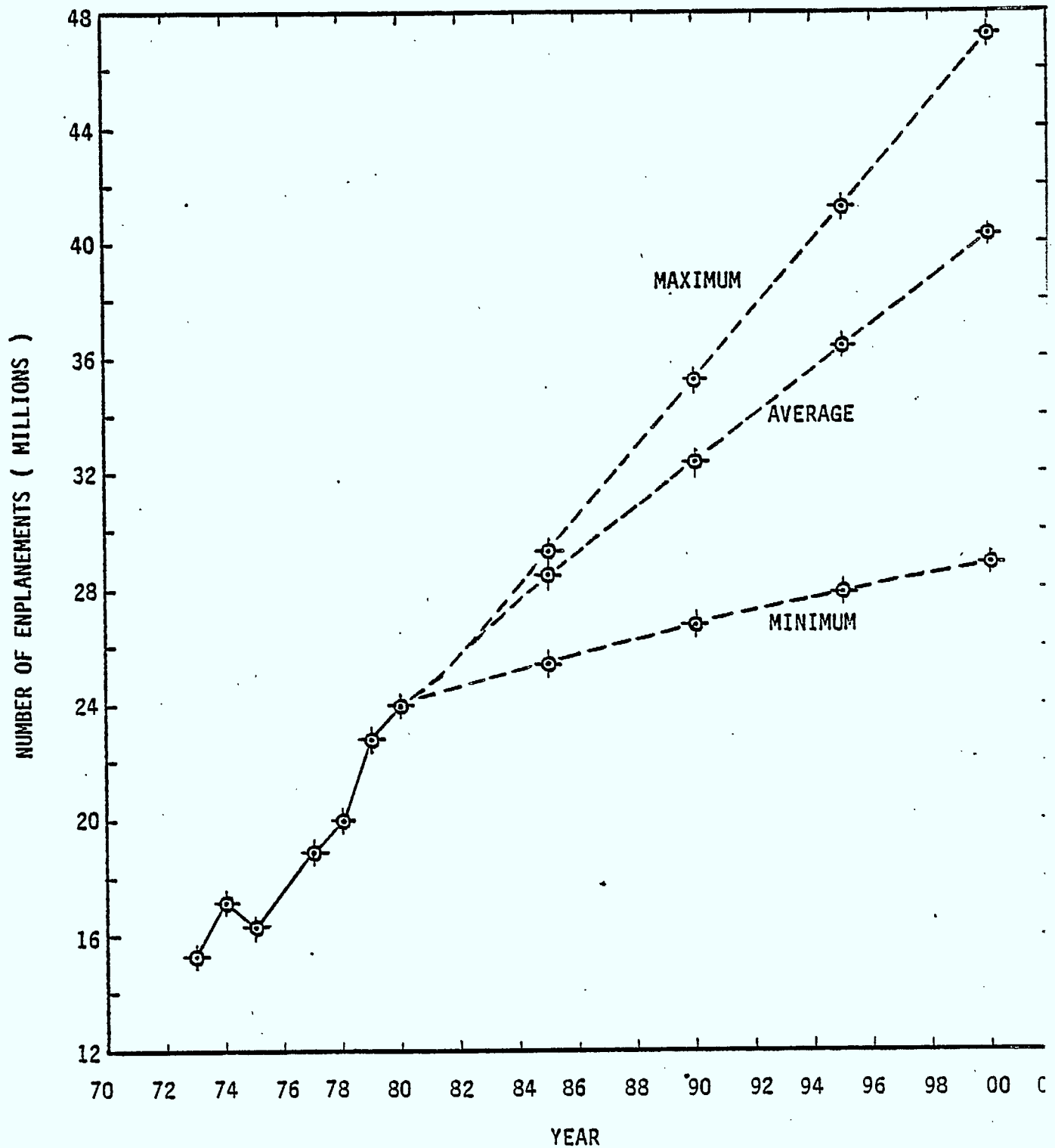
Figure 4.1.4-2  NUMBER OF ENPLANEMENTS (1973-2000)

To estimate the numbers of videoconferences that would be carried by satellites a set of values for percentage capture by satellites was selected as shown on Table 4.1.4-10. The relationship between minimum, average and maximum cases were taken as 9, 11.6, 20.3; i.e. the same as for toll telephone traffic. Because the authors do not foresee a very rapid increase in demand and the accompanying development of satellite based technology, the percentages for 1985 were 4.5%, 5.8% and 10.15%. These figures were increased linearly to 18%, 23.2% and 40.6% by the year 2000.

To estimate the peak hour demand it was assumed that transponders would be lused for 12 hours per day and that the peak demand would be 1.5 times the 12 hour average.

Video compression techniques will be used for successful videoconferencing because costs must be considerably lower than full rate television. AT&T is reportedly ready to offer a videoconference service that uses their DS-1 lines which has a data rate of 1.544 Mbps [Ref. 70]. A standard 36 MHz transponder will carry data at a rate of 60.6 Mbps. If the transponders can be utilized to 75% of maximum capacity then 30 one-way or 15 two-way videoconferences could be carried on each transponder. Table 4.1.4-11 summarizes transponder requirements.

Table 4.1.4-10   Forecast of Number of Videoconferences (1980-2000)

| YEAR | NUMBER OF CONFERENCES ($N_C$) ANNUALLY ($10^6$) | | | POTENTIAL NUMBER OF VIDEOCONFERENCES ($N_V$) ANNUALLY ($10^3$) | | | ESTIMATE OF PERCENTAGE CAPTURE BY SATELLITES | | | REALIZABLE NUMBER OF TWO-WAY VIDEOCONFERENCES CARRIED BY SATELLITE ANNUALLY ($10^3$) | |
|------|------|------|------|------|------|------|------|------|------|-----------|-------------------------|
| | MIN. | MID. | MAX. | MIN. | MID. | MAX. | MIN. | MID. | MAX. | MID-VALUE | PEAK HOURS DEMAND |
| 1980 | 6.47 | 6.47 | 6.47 | 861 | 861 | 861 | — | — | — | — | — |
| 1985 | 6.86 | 7.70 | 7.90 | 912 | 1024 | 1051 | 4.5 | 5.8 | 10.15 | 59.4 | 29.7 |
| 1990 | 7.24 | 8.75 | 9.51 | 963 | 1164 | 1265 | 9.0 | 11.6 | 20.3 | 135.0 | 67.5 |
| 1995 | 7.53 | 9.83 | 11.13 | 1001 | 1308 | 1504 | 13.5 | 17.4 | 30.45 | 227.6 | 113.8 |
| 2000 | 7.80 | 10.88 | 12.74 | 1037 | 1447 | 1694 | 18.0 | 23.2 | 40.6 | 335.7 | 167.8 |

Table 4.1.4-11   Videoconferencing Transponder Requirement (1980-2000)

| YEAR | TRANSPONDERS REQUIRED | | | NO. OF 2-WAY CONFERENCES PER TRANSPONDER |
|------|---------|-----------|---------|------------------|
| | MINIMUM | MID-VALUE | MAXIMUM | |
| 1980 | — | — | — | — |
| 1985 | 2.1 | 3.0 | 5.3 | 10 |
| 1990 | 2.9 | 4.5 | 8.6 | 15 |
| 1995 | 4.5 | 7.6 | 15.3 | 15 |
| 2000 | 6.2 | 11.2 | 22.9 | 15 |

4.1.4.8  Summary of Video and Audio Broadcast Requirements

A summary of the video and audio broadcast requirements, by service type, is listed in Table 4.1.4-12.  Network television broadcast has the greatest demand with 21 satellite TV channels by the year 2000.  Roughly 2/3 of this demand is from the CBC.  The major growth in this category will occur during the next few years.

Pay television shows the second greatest demand with 16 satellite TV channels by the year 2000.  All these Pay-TV services have been introduced recently and new services are not anticipated until the latter part of this decade.

Videoconferencing will rank third in demand by the end of the century.  It exhibits the fastest rate of growth amongst all the categories because its demand is more business driven rather than population driven.

Extension of services to remote communities and tele-education are forecasted to have similar requirements with 10 and 9 satellite TV channels, respectively.  Both services are presently being established and hence, further expansion will occur during the next five years or so.  Virtually no growth has been predicted in the next decade, once the services have matured.

DBS relative services have been predicted to have the lowest demand at the end of the century with 6 satellite TV channels.  Growth is evenly distributed over the latter 15 year period, once the initial services are introduced.  Narrowcasting comprises most of this demand.

Table 4.1.4-13 depicts the projected satellite TV channel requirements according to frequency bands.  The major demand over the next 17 years is for channels in the 12/14 GHz band.  The drivers for this demand are videoconferencing, narrowcasting and future Pay-TV services.

Minimum, average and maximum values were not provided for TV because the potential services were identified and simply counted.  The figures given tend to be a maximum scenario because all foreseen services were included.

Table 4.1.4-12  Projected Satellite TV Channels Required
Between 1983 and 2000, by Service Type

| SERVICE CATEGORY | FREQ. BAND (GHz) | PROJECTED A SATELLITE TV CHANNELS REQUIRED | | | | |
|---|---|---|---|---|---|---|
| | | 1983 | 1985 | 1990 | 1995 | 2000 |
| 1) NETWORK: | | | | | | |
| CBC | 4/6 | 10 | 13 | 13 | 14 | 14 |
| CTV | 4/6 | INTERIM USE OF 1 | 1 | 2 | 2 | 2 |
| GLOBAL | 4/6 | - | 1 | 1 | 1 | 1 |
| TVA | 4/6 | INTERIM USE OF 1 | 1 | 1 | 1 | 1 |
| ATV-2 | 12/14 | 1 | 1 | 1 | 1 | 1 |
| LA SETTE | 12/14 | 1 | 2 | 2 | 2 | 2 |
| TOTAL | | 14 | 19 | 20 | 21 | 21 |
| 2) TELE-EDUCATION: | | | | | | |
| KNOWLEDGE NTWK | 12/14 | 1 | 2 | 2 | 2 | 2 |
| ACCESS | 12/14 | DOC PILOT PROJECT | 1 | 1 | 1 | 1 |
| TVO/OECA | 12/14 | | 1 | 1 | 1 | 1 |
| RADIO-QUÉBEC | 12/14 | - | 1 | 1 | 1 | 1 |
| FUTURE SERVICES | 12/14 | 2 | 3 | 3 | 4 | 4 |
| TOTAL | | 5 | 8 | 8 | 9 | 9 |
| 3) EXTENSION OF SERVICE: | | | | | | |
| CANCOM | 4/6 | 8 | 10 | 11 | 11 | 11 |
| NTV | 12/14 | DOC PILOT PROJECT 1 | 1 | 1 | 1 | 1 |
| TOTAL | | 9 | 11 | 12 | 12 | 12 |
| 4) PAY TELEVISION: | | | | | | |
| FIRST CHOICE (ENG) | 12/14 | 2 | 2 | 2 | 2 | 2 |
| FIRST CHOICE (FR) | 12/14 | 2 | 2 | 2 | 2 | 2 |
| SUPERCHANNEL (ALTA) | 12/14 | 1 | 1 | 1 | 1 | 1 |
| SUPERCHANNEL (ONT) | 12/14 | 1 | 1 | 1 | 1 | 1 |
| STAR CHANNEL | 12/14 | 1 | 1 | 1 | 1 | 1 |
| C CHANNEL | 12/14 | 2 | 2 | 2 | 2 | 2 |
| WORLD VIEW | 12/14 | 1 | 1 | 1 | 1 | 1 |
| FUTURE SERVICES | 12/14 | 2 | 2 | 4 | 6 | 6 |
| TOTAL | | 12 | 12 | 14 | 16 | 16 |
| 5) ADDITIONAL DBS RELATED: | | | | | | |
| AUDIO | 4/6 | - | 1 | 1 | 1 | 1 |
| NARROWCASTING | 12/14 | - | 1 | 2 | 3 | 4 |
| TELIDON | 12/14 | - | 1 | 1 | 1 | 1 |
| HDTV | 12/14 | N/A | N/A | N/A | N/A | N/A |
| TOTAL | | - | 3 | 4 | 5 | 6 |
| 6) VIDEOCONFERENCING* | 12/14 | - | 3 | 5 | 8 | 12 |

Table 4.1.4-13  Projected Satellite TV Channels Required
Between 1983 and 2000, by Frequency Band

| FREQUENCY BAND (GHz) | PROJECTED SATELLITE TV CHANNELS REQUIRED | | | | | |
|---|---|---|---|---|---|---|
| | 1983 | 1985 | 1990 | 1995 | 2000 | |
| 4/6 (ANIK C) | 20 | 27 | 29 | 30 | 30 | |
| 12/14 (ANIK D) | 20 | 29 | 34 | 41 | 46 | |
| TYPE OF ANIK SATELLITES REQUIRED | 2C+D | 2C+2D | 3C+2D | 3C+2D | 3C+2D | BAND |
| CHANNELS AVAILABLE TO OTHER USERS | 0 | 13 | 11 | 10 | 10 | 4/6 |
| | 12 | 3 | 14 | 7 | 2 | 12/14 |

4.1.5  POTENTIAL CANADIAN MILITARY AND SCIENTIFIC REQUIREMENTS

4.1.5.1  Introduction

The information included in this section of the report regarding the potential Canadian Military use of EHF systems is the view of the authors and in no way does it constitute DND policy or requirements.

The expanding use of commercial satellite communication systems which includes diverse services, such as data, voice, Pay-TV, etc., is sharing the spotlight with a burgeoning marketplace for military satellite communications at least on the global scene [41-52]. However, satellite communications is only one possible medium of communication. Operational defence communication systems typically include a mix of different transmission media. In addition to satellite, there is line-of-sight communications, troposcatter, land and submarine cable, high and low-frequency (HF/LF) systems, leased circuits, allied systems, and civil transmission media.

Military systems have a relatively low spectrum use compared to commercial communication systems and the two are developing with different technical emphases. Commercial systems are almost entirely motivated by revenue and profit, such that moving to a different frequency band for example will be governed purely by capacity and economic considerations.

On the other hand, military systems have the requirements of physical and functional (electronic) survivability and maintainability in all aspects of $C^3$ (Command, Control and Communication) for which there is no civilian counterpart. Interoperability is also a major concern for military systems. This includes intersystem communication where a terminal designed for one system is able to use a second system, e.g. an allied system, and intrasystem communication whereby terminals of one system can communicate with one another by using a second system. Military systems could provide service to large (tactical) mobile terminals, with their unique requirements, and respond to rapid reconfiguration, i.e., terminals are

deployed and set up in new areas and must be accommodated in the existing networks or newly defined ones, all in a very short time. In addition there is a large inhomogeneity in the user types (different terminal sizes, data rates, etc.). This in turn requires a priority access discipline including absolute preempt capability. Due to their nature, especially in war time, military systems are very intolerant of asset outage or incorrect transmission. Hence, they are required to have very low error rates. Some networks will need to have world wide coverage thus requiring satellite constellations with crosslinking.

Other requirements include automated message handling of both voice and data, and flexibility of the systems to interface with a variety of computers. Further, since military systems procurement takes a long time, terrestrial equipment supporting the communication network should be easily adaptable to changes in the satellite environment.

Another military requirement, and it is important in every $C^3$ system, is a measure of jamming resistance. In the antijamming (AJ) environment, the satellite itself is often the primary target of attack. AJ measures include spread spectrum (SS) techniques, such as direct sequence (DS) or pseudo noise (PN), and frequency hopping (FH), to mitigate the effects of jamming; however, SS does lead to the use of large bandwidths. The vulnerability of the satellite to jamming makes the uplink power limited, in contrast to commercial satellites which are primarily downlink power limited. Other techniques are available, including complex antennas with adaptive nulling to suppress jamming from discrete locations; this complexity also distinguishes military satellite systems from commercial systems.

Finally, a military system must have a low probability of intercept (LPI) to prevent $C^3$ information from being detected by unintended receivers. Here, LPI is a generic term covering low probability of reception as well, and may be achieved by a variety of mechanisms including antenna directivity, low signal overshoot, SS techniques and signal encryption.

The salient system characteristics (subject to tradeoffs since they all cannot be met) of a viable military satellite communication system include:

### Terrestrial Terminals

- Many small terminals used on mobile platforms and a few fixed ones (strategic).
- Low uplink EIRP.
- Low G/T.
- Multiple access capability and a common signalling format.
- Secure communication ⁓ directional antennas, SS capability.
- Variable interface to operate independent of existing constraints of terrestrial communication systems, i.e., translate between network format and constraints of existing systems.
- "Band diversity" ⁓ it is forecast that as the military moves into new bands, existing bands will be preserved. Some terminal types will have to possess the capability to operate in more than one band, e.g. through modular add⁓ons.
- As inexpensive as possible, particularly in the case of expendible terminals.

### Satellite

- High gain, narrow beam receive antenna (High G/T).
- High EIRP.
- Multiple narrow beams to provide gain and spatial discrimination ⁓ may be single beam with rapid switching.
- Adaptive (steerable) nulling for jamming suppression.
- On⁓board processing including SS demodulation, data demodulation and remodulation, coding/decoding, deinterleaving, switching and downlink reformatting.
- DAMA control.

- Spacecraft transponder with high efficiency, e.g. FDM on uplink, TDM on downlink.
- Satellite crosslinks to provide hidden operation or world-wide network without multiple terrestrial relays, thus reducing enemy jamming opportunity.

Further discussion is presented in Paragraph 4.1.5.2.1 on meeting this wide spectrum of requirements.

Besides the military applications considered, EHF waves are used in radio astronomy, atmospheric study, remote sensing of the earth using radiometry etc., and other scientific applications. These are treated in Section 4.1.5.3.

Selection of particular EHF bands for military and scientific use is based on international and regional frequency allocations, the available bandwidth, competing services vying for the same spectrum resource, propagation effects, the unique requirement of the military and the current and projected state of the technology and development. The Canadian Frequency allocations for EHF satellite service, which conform to WARC-79 general allocations [53] are given in Table 4.1.5-1 from 18 GHz to 60 GHz.[1] This table includes allocations for radio astronomy and Earth Exploration in addition to fixed and mobile satellite services allocations. The candidate bands for military EHF satellite communication, based on matching required characteristics to the attributes of the allocated bands, are:

- 30/20 GHz band. A bandwidth of 1.5 GHz is available for fixed satellite services
- 43.5-47 GHz. This band is allocated for mobile satellite service
- 50/40 GHZ. A 1 GHz uplink and downlink bandwidth is available.

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[1] EHF spectrum is usually defined as the band of frequencies between 30 GHz and 300 GHz. However, we have extended the lower end to include the 18-20 GHz band since it is usually paired with either 30 GHz or 40 GHz and many of the technologies employed are similar. The upper end is often limited to 60 GHz, since no expansion of satellite communications above this frequency is forecast for at least 20 years.

The most likely pairings, for the reasons given below, for uplink and downlink are 30/20 GHz, 43.5-45.5/40 GHz or 43.5-45.5/20 GHz, and 50/40 GHz. 30 GHz and 44 GHz are preferred to 50 GHz for uplink mainly because of the larger bandwidth allocation at the lower frequencies, the reasonably well-developed technology base, and the lower atmospheric attenuation. 20 GHz downlink will probably be used more frequently than 40 GHz primarily because of problems with obtaining high-enough RF power on-board the satellite at 40 GHz, even though this entails a higher uplink to downlink frequency ratio than 44/40 GHz operation. For intersatellite links 60 GHz is almost definitely the choice, particularly considering the additional bandwidth available compared to 32-33 GHz.

Table 4.1.5-1  Frequency Allocations for EHF Satellite Service

| Frequency Band (GHz) | Service |
|---|---|
| 18.6 - 18.8 | Earth Exploration-Satellite Fixed Satellite (Space-to-Earth) Space Research (passive) |
| 18.8-19.7 | Fixed Satellite (Space-to-Earth) |
| 19.7-20.2 | Fixed-Satellite, Mobile Satellite (space-to-Earth) |
| 20.2-21.2 [1] | Fixed Satellite, Mobile Satellite (space-to-Earth) |
| 21.2-21.4 | Earth Exploration Satellite, Space Research (Passive) |
| 22.21-22.5 (23.6-24) | Earth Exploration, Space Research (Passive), Radio Astronomy |
| 22.55-23 23-23.55 | Inter-Satellite |
| 24.05-24.25 | Earth Exploration Satellite (Active) |
| 27-27.5 | Fixed Satellite (Earth-to-Space) Earth Exploration-Satellite (space-to-space) |
| 27.5-29.5 | Fixed Satellite (Earth-to-Space) |
| 29.5-30 30-31 [1] | Fixed-Satellite (Earth-to-Space) Mobile-Satellite (Earth-to-Space) |
| 31.3 -31.8 | Earth Exploration, Space Research (Passive), Radio Astronomy |
| 32-32.3 32.3-33 | Intersatellite |
| 36-37 | Earth Exploration (Passive), Space Research (Passive) |
| 37.5-39.5 | Fixed-Satellite (space-to-Earth) |
| 39.5-40.5 | Fixed-Satellite (Space-to-Earth), Mobile-Satellite (Space-to-Earth) |
| 40.5-42.5 | Broadcasting-Satellite |
| 42.5-43.5 | Fixed-Satellite (Earth-to-Space), Radio Astronomy (Earth-to-Space) |
| 43.5-47 | Mobile-Satellite |
| 47.2-50.2 | Fixed-Satellite (Earth-to-Space) |
| 50.4-51.4 | Fixed-Satellite (Earth-to-Space), Mobile-Satellite (Earth-to-Space) |
| 54.25-58.2 59-64 | Inter-Satellite |

(1)  Government use only

### 4.1.5.2 Military Systems

### 4.1.5.2.1 Military Systems Characteristics

Some of the military satellite communications system requirements described in Paragraph 4.1.5.1 can be met by judicious choice of the operating frequency. Increased military use of the higher frequency bands is a possibility since their commitment to secure and survivable $C^3$ will give rise to a need for increased spectrum resources. As mentioned earlier the use of spread spectrum techniques to achieve jam resistance is at a cost of large bandwidths. The jamming margin, $(\frac{J}{S})$ or processing gain of such a system is given by:

$$\frac{J}{S} = \psi \ (\frac{W}{R}) \ (\frac{1}{E_b/N_o}) \tag{1}$$

where   J is the jammer power

   S is the transmitted signal power

   $\psi$ is the space spreading factor

   W is the requisite bandwidth

   R is the transmitted data rate, and

   $E_b/N_o$ is the energy per bit-to-noise density ratio.

It is evident from (1) that bandwidth is the parameter of greatest potential for jamming margin. Since there is considerably more bandwidth allocated at EHF frequencies (more than 1 GHz bandwidth) than at UHF or SHF, it is clear that EHF offers tremendous promise for jam-resistant military communications and an increase in the cost exchange ratio [54], or the proportionately higher cost borne by a jammer to counter an AJ mechanism, compared with the cost to the jammed system to implement the AJ mechanism.

Operation at EHF will also produce a significant reduction in the probability of intercept from that achievable at UHF or SHF. The maximum detectability range, $L_d$, i.e., the distance within which an intruder must locate his terminal in order to intercept, varies with frequency [42] as :

$$L_d \, \alpha \ \frac{1}{f^{3/2}} \tag{2}$$

Hence, the maximum detectability range for an interceptor is 7 times smaller at 30 GHz than it would be at 8 GHz or 13 times smaller at 44 GHz than at 8 GHz. Comparing with UHF say at 400 MHz, the detectability range advantage of operation at 30 GHz is 650! The inherent data scrambling and power spreading of SS, over a wide bandwidth, making the signal resemble random noise, further improves LPI operation. The short wavelengths of EHF, compared with UHF and SHF, result in better antenna discrimination and spatial resolutions which improves adjacent channel and intentional interference rejection, and nulling antenna system performance. The increased gain and narrower beamwidths achievable with reasonably small EHF apertures, are suited to mobile platforms which have limited capabilities to accommodate terminal weight, power and dimensions. This allows cheaper terminal antennas than possible at SHF, and since there would be many (small) users, an overall system cost decrease is realizable.

In addition to the AJ processing gain advantage mentioned above, the potential ElRP advantage of interference sources, accidental or otherwise, is reduced by the fundamental limit on the maximum RF power and antenna gain that can be produced thus allowing the user closer parity with interference. The RF output power of an electron beam tube varies inversely as the square of frequency, and the antenna gain loss due to surface accuracy and tracking error both increase with frequency (see Section 3.4.1).

One sobering fact that has to be considered along with the laudatory properties of EHF, is the substantially increased propagation attenuation experienced by EHF waves in inclement weather. Rain is the dominant cause of atmospheric attenuation and this attenuation increases with frequency, see Figure 4.1.5.2-1 [55]. The probability of significant rainfall is less than 10%; hence, for required availabilities of over 90%, rain margins must be allowed or appropriate measures such as adaptive error-correcting codes, and space diversity invoked to mitigate the deterioration of performance. The cost of these have to be traded-off against AJ and LPI advantages. However, a 60 GHz intersatellite link (ISL) can be operated with little attenuation, and yet be protected from interference or detection from the surface of the earth, due to the high attenuation in the space-earth path.
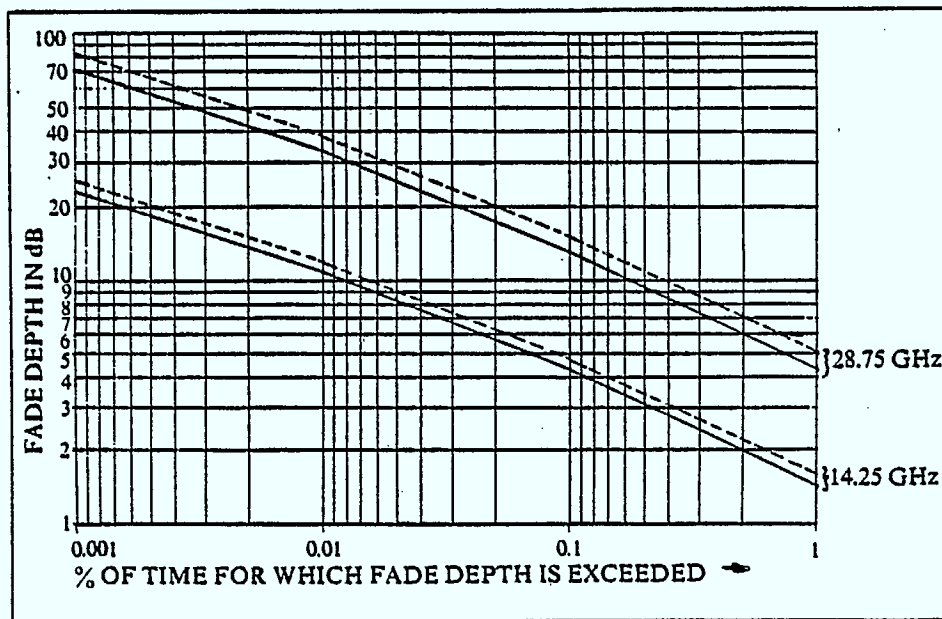
Figure 4.1.5.2-1
Example of rain attenuation at 28 GHz and 14 GHz. Note differential
fading between polarizations: ——horizontal; —— vertical.
The curves shown are computed from a point on earth having a latitude
of 50° and longitude equal to that of the geostationary satellite and
for a rain rate $R_{001}$ of 45 mm/hr.

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At polar latitudes, very low elevation angles are subtended by the earth terminal local horizon and geostationary earth orbit (GEO). Signal amplitude fading and sky noise are expected to be serious problems for low elevation angle communications. Non-GEO systems may be required to provide communications service at high latitudes at EHF frequencies.

Aside from the use of EHF for military satellite communications, EHF may be used for terrestrial-based point-to-point secure military communications including ship-to-ship and battlefield communications. Bands near 22 GHz and 60 GHz have been suggested for terrestrial covert communication precisely because of the water-vapour and oxygen absorption peaks. Any spurious signal is severely attenuated beyond a certain distance, i.e., signal overshoot is limited.

There is a multitude of potential non-communications military applications of EHF waves, which stem from three basic properties of EHF. The three basic properties are:

1)  Propagation losses are relatively low in selected atmospheric windows. Further, these losses are much lower than those encountered while using optical or infrared waves.

2)  Reasonable resolutions are obtainable from small dimension apertures (hence lower weight), the resolution being proportional to $\frac{\lambda}{\iota}$, where $\lambda$ is the wavelength and $\iota$ the physical dimension. This is especially important where vehicles are required to disguise their operation; a large antenna is difficult to disguise.

3)  Tactical targets have significant radar cross-sections ($\sigma$) at these frequencies.

The radar and electronic counter measures (ECM) applications generally have the common requirement of relatively short range (10's or 100's of kilometers) compared with communications applications (100's to 10000's of kilometers), and vary in frequency from about 35 GHz to 300 GHz. Some of these potential applications are listed below without detailed explanation:

- Radar e.g.:
    - Surveillance including target detection, identification and classification.

    - High resolution imagery including airborne and spaceborne platforms.

    - Navigation including terrain following and avoidance, anti-collision, and landing aids.

    - Fire/weapons control.

    - Active missile guidance (on board).

- ECM e.g.:
    - Fire/weapons control including target designators and illuminators, and beam riders for missile guidance.

    - Electronic support measures (ESM) including radar warning receivers (RWR).

4.1.5.2.2  Canadian Military Systems

There is very limited information available on the Canadian military requirements in general and military satellite communications in particular. This stems from the classified nature of some material which makes it unavailable for a study of this nature, and the lack of any articulated DND policy on satellite communications. It can only be inferred that there is some perceived potential in EHF and SATCOM in general, based on the fact that DND is supporting MSAT (interested in a 44/20 GHz package), is purchasing or planning to purchase radios to interoperate with the US, and is supporting experiments at CRC on the Shirley Bay-Kingsmere terrestrial EHF link. Whenever any information was obtained, it was purely as a personal opinion. Hence, information included in this report or possible scenarios suggested are our own views based on these personal opinions and our interpretation of them and in no way constitutes DND policy.

The Canadian Forces have four major roles[1] :

- Surveillance and protection of our sovereign territory and coastlines.

- Defence of North America in co-operation with U.S. Forces.

- Fulfillment of such NATO commitments as may be agreed upon.

- Performance of such international peacekeeping roles as [ Canada] may from time-to-time assume.

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[1] Defence 1975:  Department of National Defence publication.

In addition, the military in other countries, notably the U.S.A., fulfills an additional role of acting as an initiator and leader for technology development by industry. The Canadian military could also be fulfilling this role in a more concerted way as this would lead to a symbiotic relationship where both DND and industry would benefit.

The Canadian military has then a formidable task in fulfilling its roles in view of the wide geographical area to be covered. Modern command, control, communications and intelligence ($C^3 I$) capability is badly needed to provide AJ and robustness to the operation of the deployed forces in the defence of North America and surveillance of the sea lanes. The current high frequency (HF) long-range communications systems are easily intercepted and would be ready targets in a hostile situation. The addition of UHF, SHF and EHF systems, including satellite systems, with the HF systems in a supplementary role, would enhance survivability of the communications network.

Communications needs are usually differentiated as strategic and tactial. Strategic covers fixed unit communications between the major command centres, backhaul links, and defence data communications. Strategic communications now depend largely on commercial carriers. This is not very desirable for reasons of reliability and survivability and therefore a back-up or alternate route, preferrably under military control, should be provided for the major command links and the interface links to our major allies.

Tactical communications refers to communications involving the actual deployed forces and their support, and therefore, depends on on the forces' configuration. The number and requirements of communication links in a certain place may change very rapidly in an active situation. The communications terminals may be fixed, transportable or mobile. Mobile terminals, which can be airborne, vehicle-borne or shipborne, may be capable of full communications while in motion. Others, classified as transportable, may be signalled while in motion but must come to a halt and be deployed for full communications. Some vehicle-borne and manpack terminals are typical of this. Tactical systems are classed according to their force or command assignment - Air Tactical, Maritime Tactical, and Land Tactical (combat units).

Regarding strategic applications, it is clear that without a detailed knowledge of the number of formations and the traffic volumes, it will not be possible to estimate the military impact on EHF systems forecasting. For example, there are seven command headquarters plus CFE, perhaps 20 major bases and 50 smaller units such as radar and communications squadrons, with perhaps three-quarters of these in Canada and the rest overseas. The vast variety of data rates and the channel usage of these formations and units is so diverse as to make modelling the communications network extremely difficult. Similar conclusions can be drawn for tactical applications. Although we have numbers of ships, aircraft, squadrons, bases, vehicles and formations, we are again faced with a wide diversity of data rates and traffic volume.

Information on the non-communication aspects of the Canadian military, which include ECM and ECCM, weapons guidance, surveillance, radar, and ESM, is even more difficult to obtain. We shall hence not dwell on this topic. Suffice it to say that terminal guidance systems and ship defence systems will probably go up to millimeter range to exploit resolution and better firing accuracy available here. There appears to be a joint Canada/US interest on electronic warfare (EW) work in the EHF band. DREO has contracts out for low millimeter wave frequency halvers and for EHF GHz oscillators (TWTs and Klystrons). However, our interest in EW is not mainly for requirements (capacity) but stems from the commonality of equipment with communications. Mixers can be used for both, coherent sources (oscillators) for radar are similar to communications ones except that one emphasizes fast tuning while the other stresses low noise. Peak pulse power is a criterion in radar whereas in communications it is the average power.

### 4.1.5.2.3  Foreign Military Systems

Other countries, such as the UK and the USA, have acquired defense systems which are operational and utilise a variety of transmission media. In the free world, the US is perhaps the most advanced.

The US strategic systems include the National Military Command System (NMCS) which consists of the National Military Command Centre (NMCC), the Alternate National Military Command Centre (ANMCC) and the National Emergency Airborne Command Post (NEACP) with interconnecting telecommunications; the Worldwide Military Command and Control System (WWMCCS); the Minimum Essential Emergency Communications Network (MEECN) which utilises frequency bands from ELF to SHF; and the general-purpose Defense Communications Systems which embrace all the long-haul point-to-point assets of the Army, Navy, Marine Corps, and Air Force. The tactical systems include programs such as the Joint Tactical Communication Program (TRI-TAC), Combat Net Radio primarily close to the Forward Edge of the Battle Area (FEBA), and satellite communications. A variety of bands from HF to SHF are in use via several media such as cable, line of sight radio relays, and troposcatter systems, and link encryption frequency is utilized.

Extensive use of military satellite communications (MILSATCOM) has been made in the US and more systems are planned. For example, as early as 1962, the communications satellite SYNCOM II served a seagoing ship, the USN Kingsport [48]. The Lincoln Labs of MIT have had several experimental satellites such as LES-5, LES-6, LES-8/9, which have aided greatly in the development of MILSATCOM. LES 8/9 have successfully demonstrated the possibility of using EHF (38/36 GHz) and intersatellite links. The present Defense Satellite Communication System (DSCS-II) uses SHF. The DSCS-III System using UHF and SHF, adaptive antenna beam steering and frequency hopping (FH) is scheduled for the early 1980's and will provide better jam resistance and increased capacity. Its upgrade DSCS-III-U will be operated at 30/20 GHz probably with nulling antennas. The GAPFILLER (UHF) and FLTSAT (UHF/SHF), will be complemented by the UHF/SHF LEASATS in 1983. A follow up of TACSATCOM-1, which used UHF/SHF, will be the planned TACSATCOM-II in the

1990's which will utilize EHF with on-board processing and antenna nulling [56]. AFSATCOM with a number of satellites (including FLTSAT, DSCS and LEASAT) in geostationary and elliptical orbits serves the nuclear capable forces. The Air Force's MILSTAR will provide $C^3$ strategic force modernization. This will use four geostationary satellites over the East and West Pacific, Indian Ocean, and the Atlantic, as well as two highly inclined elliptical orbits to cover the polar regions. It is expected to be nuclear and antilaser hardened and will serve the US strategic nuclear and all theatre forces with two-way EHF comunications on a survivable basis [52]. This vigorous activity of the US military in the area of satellite communications is expected to continue well into the future.

The NATO Integrated Communications Systems (NICS), initiated in 1970, is providing modern communications meeting the entire military and political requirements. The NATO communications network includes, among others, the NATO Phase III satellite program, SATCOM III consisting of three geosynchronous satellites launched in 1976, 1977 and 1978. These use encrypted data, forward error correcting codes and QPSK modulation.

The U.K. has been active with operational military satellites since 1969 with the launch of SKYNET I(A), an SHF satellite. It and SKYNET II(B) employed a spread spectrum multiple access (SSMA) scheme, and provided communications capabilities to strategic and tactical forces including maritime mobile terminals. SKYNET IV, currently being procured for a 1986 launch, will offer UHF/SHF/EHF services with an EHF uplink around 44 GHz coupled to an SHF 7 GHz downlink. As well, the U.K. is actively engaged in EHF military earth terminal development. Figure 4.1.5.2-2 (from reference [57]) shows an advanced portable manpack terminal built for the British Army by Ferranti Electronics; it is believed to operate in the 30/20 GHz bands.

# One-man satellite terminal

A compact terminal for satellite use has been developed for the British Army by Ferranti Electronics Microwave Division. Designed to be operated by one person, the unit for field use weighs only 16 kg and fits into a folding carrying frame. Included are the receiver, transmitter, antenna, battery, keyboard, printer and an integral microprocessor for message storage, encoding, display, frequency synthesis and alarm monitoring. The transmitter uses a 2.5 Watt FET amplifier. Using a wide beamwidth antenna makes satellite acquition relatively easy with only a compass, signal strength meter and inclinometer, all included with the set.



*The portable terminal for satellite communication, designed by the UK's Royal Signals and Radar Establishment and developed by Ferranti Electronics Microwave Division, can be deployed and in contact with a base station within two minutes.*

**Figure 4.1.5.2-2   UK Army Transportable EHF Terminal**

## 4.1.5.2.4  Potential Future Canadian Military Requirements

While the roles of the Canadian military are expected to remain as they are for the foreseeable future, and the need for advanced technology systems and hardware is widely advocated, the absence of a definitive policy towards the use of space, and the capital limitations of the DND, make it very difficult to forecast specific Canadian military requirements for the next 20 years.  It is the authors opinion that, with Canadian military commitments domestically, continentally and abroad, creating a significant geographical challenge, and an equally significant compatibility and interoperability challenge, that advanced technology electronics systems will be needed to support major weapons systems and force deployments, particularly in the field of communications.

Regarding EHF technology, it is certain that the Canadian military will require some capability in this band in the future because both our allies and adversaries are developing the band to exploit its capabilities. As noted earlier, the EHF band provides the exceptionally wide bandwidths considered necessary for AJ and LPI schemes.  Also as noted, the EHF band offers some propagation problems such as high absorption, high path loss and severe fading at low elevation angles.  The latter area is one recommended by a number of those interviewed as an area requiring further research, and given Canada's strong expertise in low elevation angle propagation phenomena, Canada should take the lead.  In conjunction with this, Canada might profitably consider taking on the system development of a military satellite communications system offering secure robust service in the high latitude and polar regions of North America and Europe on behalf of ourselves and our allies.

The move to very complex military spacecraft systems employing active AJ and LPI schemes in turn leads to the need for complex on-board processors for spacecraft, and compatible processors for ground terminals. This is another area in which Canada will require systems and hardware, and in which their procurement costs might be offset by developing systems for domestic use that can be sold internationally to our allies. While such systems do not have the "EHF" label on them, there is expected to be a strong association between the new military EHF systems and advanced processors.

Another area of technology related to AJ and LPI is antennas. Complex beam steering and null steering antennas will be required, including active aperture antennas, i.e. those with the RF components distributed about the aperture itself. While such antennas will be a definite requirement for military spacecraft, the associated technology will be directly applicable to commercial spacecraft, including non-communications systems, e.g. remote sensing, navigation.

Survivability of the space segment is a very strong requirement for the current and future generations of military satellite systems, not only for communications. Nuclear and laser hardening is being actively persued (DSCS III and MILSTAR) and requirements are being prepared for protection from charged particle beams and other future weapons. In Canada, only the military has an interest in this area. If Canadian industry is to have an opportunity to build Canadian systems or to compete to build U.S. or other allied subsystems, it will require Canadian military support to develop a Canadian industrial capability. At present, the U.S. hardening specifications are not released in requests for proposals, and Canadian companies attempting to supply to the U.S. market would be "shooting in the dark". Canada cannot continue to rely on domestic communications satellites, particularly in times of tension. It will ultimately be necessary to acquire the capability for secure, robust and survivable communications, and again, there may be an opportunity to offset acquisition costs by funding Canadian development of systems for domestic use that can also be sold to our allies.

It is understood that DND is considering funding some spacecraft EHF development work on M-SAT, and is planning some extensive EHF propagation experiments in the Ottawa area. While the military is without a specific policy on the use of space, and while a requirements quantification is beyond the scope of this study, some recommendations can nevertheless be offered based on the collection of expert opinion gathered during the interviews. The focus here will mainly be in the area of military satellite communications because it seems to be on the threshold of Canadian-funded EHF technology development.

The military could most usefully exploit EHF technology to provide tactical communications, employing wideband (SS) secure services. Strategic links could be more economically supplied using the SHF bands, while still providing secure robust communications. In advance of EHF tactical terminal availability to operational forces, it would likely be necessary to procure UHF systems, and here the development emphasis should be on small, rugged, severe environment antennas, high power amplifiers, and baseband subsystems (microprocessors, frequency synthesizers). In making the transition from UHF to EHF for tactical communications, the military should consider retaining the capability to communicate in the UHF band as a supplement to EHF communications.

The baseband equipment mentioned above may have some commonality with that being developed for M-SAT. This leads to another recommendation, and that is, components (sources, filters, mixers, etc.) in which Canada has, or is developing, a capability, are required in all the previously mentioned technology development areas. For example, components developed for use on radiation hardened spacecraft and ground equipment, have a direct use in the commercial satellite industry, and not just communications, and may have further spin-offs, such as non-space military and civil electronics systems protection, personnel dosimetry, and medical radiation therapy. As another example, RF components developed for EHF purposes may be suitable as IF components for higher frequency systems such as laser inter-satellite links.

In summary, while the military requirements are not specifically defined, there is, nonetheless, a need on the part of the Canadian military to use EHF technology just to interoperate with our allies. Some specific areas have been noted where military support is needed to establish or strengthen the Canadian industrial capability, in return for offset benefits that will accrue through foreign sales.

### 4.1.5.3 Scientific Requirements

Apart from military applications, other non-commercial uses of millimetre wavelengths exist. These are mostly of scientific nature and are being actively pursued by universities and government departments. Systems falling into this (scientific) classification may consist of space-to-earth data transmission for spaceborne research payloads related to remote sensing of the earth, geophysical applications, and stellar mapping.

To try and uncover the present and planned Canadian activity in this area, we made several contacts with scientists at the National Research Council (NRC), the department of Energy, Mines and Resources (EMR), and various Canadian Universities.

### 4.1.5.3.1 Radio Astronomy

There is generally great interest in Canada in this area. A major application here is the observation of various sources in the sky and mapping them at different frequencies. By observing the molecular spectral lines, emitted from space, a large amount of information can be gathered. Astrophysical information gathered this way includes information about the dynamics temperatures and densities involved, measurement of distances using the technique of statistical parallax, and the chemical and radiation environment of interstellar clouds.

Some of the spectral lines involved in radio astronomy fall directly in the frequencies that this study is addressing; such as the lines of water vapour and ammonia (22-24 GHz), and silicon oxide ($S_i0$) line at 43 GHz. More than 80 spectral lines have been detected in the interstellar space between 20 and 50 GHz from several molecules. Between 50 and 69 GHz the atmospheric absorption has prevented ground-based observations. Molecular lines have been detected all the way up to 492 GHz and the numbers are continually growing.

For spectral line work, a constant _percentage_ bandwidth is required. At 20 GHz, a bandwidth typically of 20 MHz would be required while at 100 GHz, the required bandwidth is more like 200 MHz i.e. a percentage bandwidth of 0.1 to 0.2%.

Technology developed for communications at EHF may be expected to find application for radio astronomy. However, the stringent performance requirements of radio astronomy subsystems, notably the receiver, must be taken into account. Astronomy signals are extremely weak; for example, a signal having a signal-to-noise ratio, $S/N = -30dB$ is considered strong, and $S/N = -60$ dB are possible. Hence, the receiver must have extremely low-noise characteristics, with system noise temperatures of the order of 50 K at 20 GHz. Parametric amplifiers cooled to about 20 K are often used. Masers also find frequent use in good low-noise astronomy receivers. Above 40 GHz, receivers in use are almost exclusively cooled mixers but other types are entering the field. Antennas for this use are required to have high gains (high angular resolutions) and are hence large with accurate surface tolerance - the telescope at Algonquin Park has a 46 metre diameter antenna; Japan has a 45 metre diameter telescope and 10 m diameter interferometer. Hence communication receivers and antennas, even at the requisite frequencies, would not be applicable to radio astronomy. However, they would form a technology base from which to develop astronomy equipment. On the other hand, EHF communication manufacturers would be able to greatly benefit from the equipment developed for radio astronomy.

In Canada, spectroscopy and other astronomy research is going on actively, but projects are hampered by shortage of funds. NRC currently has a 19-24 GHz cooled parametric amplifier receiver and a maser at 20 GHz tunable over 20-26 GHz is being built and is expected to be ready by fall of 1983. A 9 mm (31-34 GHz) receiver is in use on the telescope. The front end (cooled mixer) of this receiver is being constructed at the University of Toronto. A 43 GHz receiver (probably a low-noise reflecting-type maser developed by MIT) is expected within $1\frac{1}{2}$ years. In the long-term plans, NRC, hopes to improve the antenna to enable operation to extend to over 100 GHz from the present $\approx 30$ GHz. This will entail antenna resurfacing. Such operation would enable the observation of the carbon monoxide (CO) line at 115 GHz. If approved, this should be ready in three or four years. NRC, together with university astronomers across Canada, is also actively trying to realize the Canadian Long Baseline Array (CLBA) project which would, with its 8 antennas, be the most powerful telescope in the world. One receiver would cover the water vapour line at 22 GHz and perhaps go up to 24 GHz. The University of British Columbia Department of Physics is doing astronomical observations in the 80-115 GHz range with a telescope of 4.6 m diameter.

Outside Canada, a lot of developmental work is going on in the USA, notably at the Bell Labs, Caltech and Berkeley. Germany and France have jointly established an institute of millimeter-wave radio astronomy at Grenoble. Japan is busily outfitting its new 45 m telescope for use up to 120 GHz.

Radio astronomy is very active in the millimeter wave region and will become even more so as the very powerful new Japanese 45 m telsecope mentioned above comes into full operation, followed by the 30 m German telescope in Spain, the French interferometer, the British telescope in the Canary Islands and the new 12 m, more precise telescope to replace the existing 11 m telescope on Kitt Peak in the USA.

From Table 4.1.5-1 a total bandwidth of 2.2 GHz has been allocated to radio astronomy from 18 GHz to 64 GHz. There is a further bandwidth allocation totalling 17.3 GHz between 64 and 120 GHz for a total of 19.5 GHz between 28 GHz and 120 GHz, and 33.7 GHz between 120 and 275 GHz. It is difficult to assess what the total bandwidth used for radio astronomy will be up to the year 2000. The total bandwidth however, is not a significant parameter here since frequency allocations are different from those of communications. What is significant is that an overlap of technology does exist between communication and astronomy, for example, waveguides, filters, etc., and one can draw from the other.

The CLBA would produce the largest data for transmission to research centres. Each of the eight sites could transmit 96 Mb/s in real time. In addition, each site is linked to the central control facilty via a dedicated 9.6 kb/s line for command and telemetry. Hence there is a potential of 786 Mb/s of raw data and 76.8 kb/s of command and telemetry data. However, financial constraints led to a decision to record the 768 Mb/s of raw data on tape instead. Hence the data from CLBA is expected to be negligible.

## 4.1.5.3.2  Remote Earth Monitoring

Electromagnetic waves are often used for remote sensing of the earth for such applications as natural resource monitoring, gathering meteorological and oceanographic information, sea-ice mapping for navigation in polar regions, etc. Both active and passive techniques are used depending on application. Active devices include radar and scatterometers which depend on backscattering of the electromagnetic waves that they transmit. Due to the long distances involved, even for low-earth orbit satellites (and since the waves have to travel twice the distance to the earth), active sensors would require more power than is possible to generate using current state-of-the-art at EHF. Most space-based radars will be frequency-limited to L band (eg. Seasat) and C-band (eg. Radarsat).

Passive sensors include optical (visible and Infrared), and microwave radiometers. A multitude of potential uses of space-based radiometry have been suggested and many developed in the past decade or two. These include the monitoring of phenomena in the lower and upper regions of the atmosphere, observation of surface features over ocean, land, and ice regions and many more. In radiometry, passive sensors measure the radiometric temperature of objects such as ships or land vehicles, or terrain for mapping. This is related to the emissivity of the radiating object as well as to its thermal and brightness (reflecting) temperature. The radiation from the object suffers interference from undesired background radiation. Narrow antenna beams minimize this interference and increase resolution and object contrast. EHF frequencies would therefore be suitable, since with small-size antennas narrow beam widths can be obtained, and the wide bandwidth affords greater sensitivity.

Canada does not have its own earth sensing satellite, and the Federal Department of Energy, Mines and Resources (EMR) is persuing the possibility of acquiring one. Canada is interested in launching Radarsat, a remote sensing satellite, probably in the early 1990's. This would carry a C-band synthetic aperture radar (SAR) as the primary sensor for sea-ice monitoring and a secondary sensor, either a scatterometer (ocean winds etc) or a visible-infrared (VIR) instrument primarily for land resources use. Data of the order

100-200 Mb/s will be downlinked from the satellite to earth stations possibly at X-band. Further, data from the processing stations (eg. Shoe Cove) will have to be transmitted to central locations (eg. Ottawa). These, however, could be at a considerably lower data rate. The total data rate for Radarsat is estimated at 300 Mb/s (from Radarsat to the receiving earth stations) over two or three separate main downlink data channels of less than 150 Mb/s each, as opposed to housekeeping telemetry channels in the order of kilobits per second. Other RADARSAT-type of data are under active consideration for reception in Canada. These include data from the European ERS-1 spacecraft which carries a C-band radar, and the French SPOT spacecraft with pushbroom-type multispectral scanners named high-resolution visual (HRV) [58].

Other countries have been active in remote sensing, and have used the capabilities of frequencies in the 20-60 GHz range for sensing data [59] as opposed to using these frequencies for data transmission. This has included planetary exploration (Mariner 2 in 1962 which measured the surface temperature of Venus using 15.8 and 22.2 GHz), and earth sensing. A variety of antenna types both scanning and nonscanning have been used. The non-scanning antennas include: Russian Cosmos 384 nadir viewing parabolic antenna (22.2, 37 GHz) in 1970, and the US Nimbus 5 microwave spectrometer (NEMS) with 5 nadir viewing lens-loaded horns (22.2, 31.4, 53.6, 54.9, 58.8 GHz) in 1972. The scanning antennas are either mechanically or electronically scanned. The mechanically scanned ones are usually for lower frequencies but rotating mirrors have been used, eg. Nimbus 6 Scanning Microwave Spectrometer (SCAMS) with three rotating hyperbolic mirrors (22.2, 31.6, 52.8, 53.8, 55.4 GHz channels) in 1975, the dual rotating mirrors on Tiros N Microwave Sounding Unit (MSU) (channels at 50.3, 53.7, 55.0, 57.9 GHz) in 1978, and the single rotating mirror of Block 5D satellite seven-channel microwave temperature sounder (SSM/T) (50.5, 53.2, 54.3, 54.9, 58.4, 58.8 and 59.4 GHz) also in 1978. Electronically scanned antennas include the Electronically Scanning Microwave Radiometer (ESMR) on Nimbus 5 (19.3 GHz) and Nimbus 6 (37 GHz) and the Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus 7 and Seasat (6.6, 10.7 18, 21, 37 GHz) both in 1978. The above radiometers have been used for various applications such as measuring water vapour content, liquid water

content, rain rate and temperature profile in the atmosphere; sea temperature, sea-ice concentration and classification; and snow cover and soil moisture. Resolutions ranging from 200 to 16 km have been obtained and swath widths from 180 to 3000 km have been scanned.

It appears that earth sensing technology is quite mature and currently available. Developments will continue to improve resolutions. Larger antennas and more sensitive receivers will greatly improve present capabilities.

4.1.5.3.3 Geophysical and Other Scientific Applications

The department of Energy, Mines and Resources is involved in several areas of geophysical research, such as geophysical survey with applications for positioning, Atlantic geosun sensing, ship navigation survey, geodetic survey etc. Using geophysical and geochemical data, maps for various applications are plotted.

Geophysical work uses very low frequencies (audio range), except for visible frequency applications. Natural and Magnetic frequencies are much lower. The highest frequency used is in the range of 20 kHz. However, the earth scientists collect reasonably large amounts of data which is typically in the north or remote fields. These data then have to be transmitted to the major centres for analysis. Data from the north and other research regions can be transmitted to the satellite in a global beam, then beamed to a major centre (say Ottawa) via a narrow spot beam. It is conceivable that the global beam could be in the C or Ku-band whereas the spot beam might be an EHF one. The elevation angle at Ottawa is sufficiently high for the link not to experience severe fades. Also some of the scientific data collected requires very accurate timing. A high-speed data line could be used. In addition, if such a transmission facility for scientific data were available, Canada may be able to sell its services to American users.

Other scientific applications include medical video and other tele-health applications. These were considered in the section dealing with video data. In order to estimate the amount of data transmitted by scientific community the authors examined several potential applications. For example, RADARSAT, earth resources satellites, weather satellites, and emergency planning. While these programs can generate large amounts of data, the baseline designs are structured to transmit their raw data directly to a ground station or central collection point. Data is processed at this site, before being distributed. Investigations have established that in such a design the rate of transmission of processed data is one to two orders of magnitude less than the raw data. It is the processed data that would be transmitted through the satellite network. Given the fact that the potential applications will not be mature until the late 1980's to early 1990's and given that processed data rates will not be as high as first thought, it is the authors' estimation that scientific demand will not exceed one ANIK channel, which is equivalent to 90 Mb/s. In the summary we have allocated one video channel for transmission of scientific data in 1990 and two channels in 1995 and 2000.

### 4.1.5.4  Summary of Total Government Requirements

As explained in Section 4.1.5.2.4, it is very difficult to forecast specific Canadian military traffic requirements for the next 20 years. Some of the military traffic is carried by the common carriers and is hence included in the voice traffic in Section 4.1.2. The total military traffic is low compared to commercial traffic and would not by itself be any significant factor in the move towards EHF. As mentioned earlier, it is the unique military requirements, particulary jam resistance and low probability of intercept, rather than capacity per se, that will call for the use of EHF.

Scientific use is allocated its own share of the spectrum and thus will not influence communications development. Nevertheless, some of the data collected by the scientific community need to be transmitted using normal comunications channels. Based on discussions with EMR, users, radioastromers, et al., it is estimated that by the year 2000, the total data rate requirements from all the scientific community will be approximately 90 Mb/s. This estimate will be combined in Section 4.3, with estimates from Sections 4.1.1 to 4.1.4 to yield the total Canadian telecommunication traffic estimate.

## 4.2 CANADIAN SUPPLY SIDE

### 4.2.1 SPACE SEGMENT

In Canada, a domestic telecommunications network linking the entire country via satellite is provided solely by Telesat Canada. Since the launch of Anik A, in November 1972, Telesat Canada has to date accumulated a total of six spacecraft positioned in geostationary orbits. Four more satellites are scheduled to be flown by October 1985. Of the six in orbit spacecraft, only four are currently capable of providing services. These are the ANIKS A3, B1, and the newly launched C3 and D1. Anik A1 and A2 had fullfilled their design life and have, just recently, been retired. Figure 4.2-1 shows the launch schedule and design life for the Anik A through D series.

The new generation of Telesat satellites, the Anik C's and D's, are designed to meet the existing and projected market demands from various users. The 6/4 GHz Anik D series are replacement satellites for the three Anik A's, the last of which is expected to be out of service by early 1984 and for Anik B, scheduled to be retired by 1986. The Anik C series, operating at 14/12 GHz, are designed to meet the expanded market demand growth in the late 1980's and early 1990's. In addition, existing services currently provided by the 14/12 GHz portion of the Anik B will also be adopted by the Anik C's when Anik B reaches end of life in 1986.

ANIK LAUNCH SCHEDULES AND DESIGN LIFE
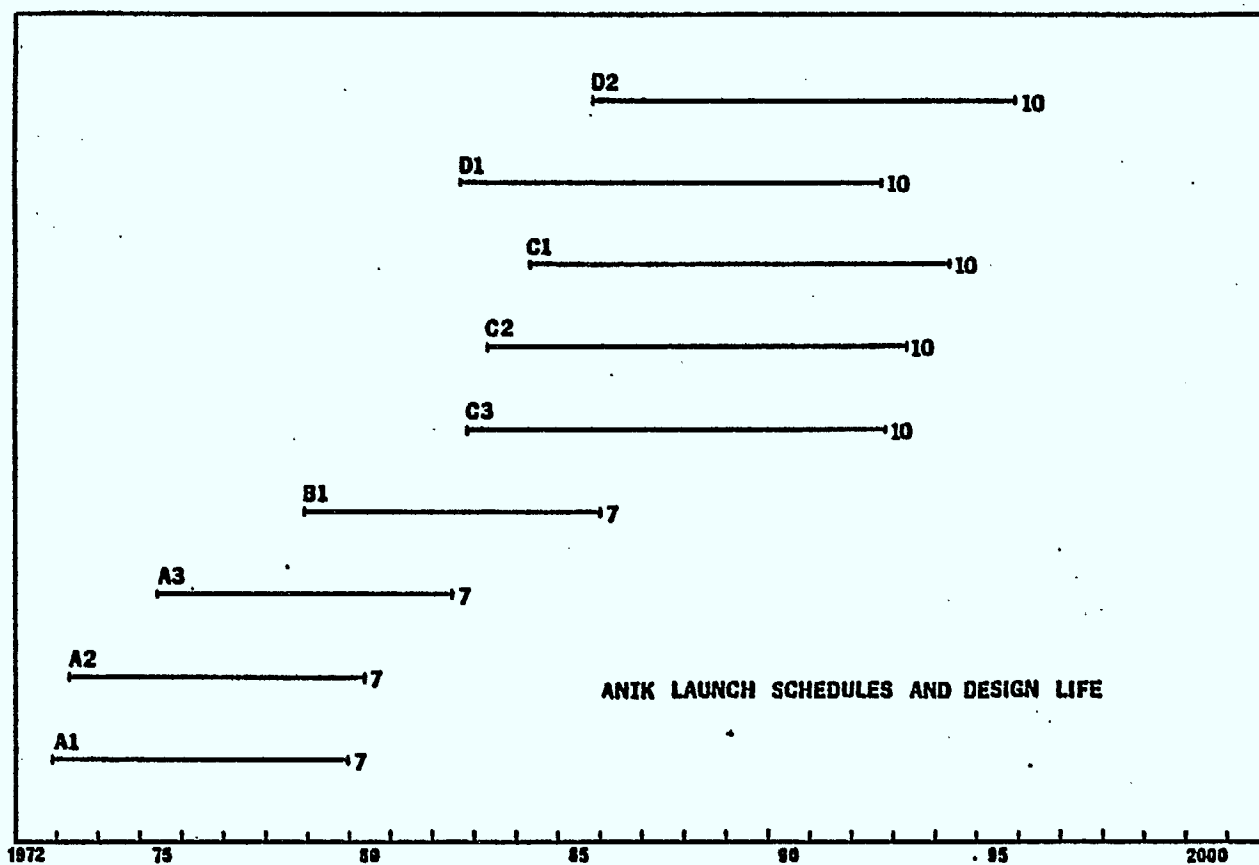
Figure 4.2 -1

### 4.2.1.1  COMMUNICATION CAPACITY OF THE ANIKS

The communication capacity of the Anik, as it evolved from the original A series to the current C and D series, had increased many fold within a relatively short time frame of ten years. By the year 1984, the Anik C and D will have a total combined usable bandwidth of 4032 MHz as opposed to that of 1080 MHz provided by the three Anik A's. This growth demonstrates the increasingly higher demand for information distribution and exchange on a national scale, where the country-wide coverage by satellite is most feasible.

The 6/4 GHz communication systems are categorized into heavy, medium and thin route message facilities. In the heavy route traffic, each RF channel is capable of handling 960 one-way multiplexed voice circuits, frequency modulated single access. In the medium density message traffic, each RF channel can operate under one of two modes. These are a) frequency modulation, frequency division multiple access (FM/FDMA) or b) pulse code modulation, time division multiple access (PCM/TDMA). In each case, up to 200 two-way voice circuits can be carried using FDMA, and up to 300 (two-way) in the TDMA mode. The thin route message facility operates under single channel per carrier mode (SCPC/FDMA). In this case each voice circuit modulates an RF carrier using phase shift keying (PSK) with delta encoding technique and up to 360 two-way circuits can be carried in one satellite transponder.

The 14/12 GHz transponder in Anik C has a bandwidth of 54 MHz. Unlike the 36 MHz in Anik A and D, and the 72 MHz in the 14/12 portion of Anik B, the Anik C channel can accomodate two television signals plus two radio programmes. The digital data handling capability of the Anik C transponder is two DS-3 bit streams at a composite rate of 91 Mbps using QPSK modulation. The equivalent telephony capacity is 1344 one-way voice channel per transponder. Table 4.2-1 summarizes the overall communication capacity performance of the Aniks.

### 4.2.1.2 ANIK CAPACITY IN YEAR 2000

The Anik C's and D's which are to be launched in the early to mid 1980's, are designed for a minimum mission life of eight years with an expected life of ten years. Replacement satellites in the form of Anik E and Anik F operating in the C and Ku bands will be required, at the mid 1990 time frame, to take over the existing traffic carried by Aniks C & D. At the same time, inspection of the satellite communication growth trend from the early 1970's to late 1980's will strongly indicate higher market demands from more satellite transponders. To this end, it is not unreasonable to assume that two or even three more satellites will be required for the Canadian service. Furthermore, depending on the feasibility and state of technology in high frequency development (EHF), the additional system may be envisaged as one of hybrid type. With a concept similar to that of the Anik B, the new system may carry a secondary payload consisting of a 30/20 GHz transponder. The hybrid satellite, in addition to supplying the excess demand using the C (or Ku) band primary payload, can at the same time be employed to investigate operationally new 30/20 GHz applications. High Definition Television (HDTV), which demands a wide bandwidth for operation (app. 100 MHz), is one such service that can be experimentally explored with such a system.

However, in the foreseeable future, the established domestic satellite communication system will still be centred on the C and Ku bands. Until such time that capacity of these bands is saturated, it will neither be likely nor economically feasible to have full operation of a complete 30/20 GHz system. The cost impact, especially upon the ground segment end of the system, will be so significant that unless drastic changes in demand occur, a 30/20 GHz system will only be playing a secondary role at the most to the frequency bands presently in use.

Table 4.2-1  Anik Communication Capacity Summary

| Anik Series | Freq. (GHz) | No. of Transponders (RF Channels) | | RF Channel Bandwidth (MHz) | Total Useable Bandwidth (MHz) | Communication Capacity (Per RF Channel) |
| | | Total on-board | At any given time | | | |
|---|---|---|---|---|---|---|
| A | 6/4 | 12 | 10 | 36 | 360 | 960 FM/FDM one-way voice channels or 1 TV signal |
| B | 6/4 | 12 | 10 | 36 | 360 | same as Anik A |
| | 14/12 | 4 | 2 | 72 | 144 | Nominal 2, or maximum 3 TV signals |
| C | 14/12 | 20 | 16 | 54 | 864 | 91 Mbps using QPSK, or 1344 voice channels, or 2 TV signals plus 2 radio programs |
| D | 6/4 | 24 | 20 | 36 | ⁺720 | 60 Mbps, or 960 one-way heavy route, or 200 two-way FDMA/FM, or 300 two-way TDMA, or 360 two-way SCPC voice circuits |

To evaluate the total communication capacity for which the C and Ku band transponders alone can provide for Canada, the following assumptions have been made:

- future satellite orbital slots in the geostationary orbit that have been assigned to CANADA are listed in Table 4.2-2.

- the satellite will have capability and capacity similar to those of Anik C and Anik D; and

- mutual inter-/intra-system interference will not exist by virture of employing planning schemes such as spatial separation, frequency reuse, and polarization discrimination.

Using these assumptions, approximations for maximum capacity available in the C and Ku band satellite system have been derived as shown in Table 4.2-3 in terms of usable bandwidth.

As a further illustration of this derived communication capacity, the usable bandwidth is translated to equivalent "information units", as shown it Table 4.2-4.

Table 4.2-2  Orbit Position Allocations for Canada

|   | ORBIT LOCATION | FREQUENCY |
|---|---|---|
| 1 | 117.5°W | 12/14 |
| 2 | 112.5 | 12/14 |
| 3 | 111.5 | 4/6 |
| 4 | 110 | 12/14 |
| 5 | 108 | 4/6 |
| 6 | 107.5 | 12/14 |
| 7 | 104.5 | 4/6 |

Table 4.2-3   Communication Capacity for C and Ku Band System
with all Allocated Orbit Slots Occupied

|  | C (6/4 GHz) | Ku (14/12 GHz) |
|---|---|---|
| Bandwidth per RF transponder (MHz) | 36 | 54 |
| Number of transponders per satellite | 20 | 16 |
| Total bandwidth per satellite (MHz) | 720 | 864 |
| Total number of satellites in orbit | 3 | 4 |
| Total usable bandwidth per operation band (MHz) | 2160 | 3456 |
| Total usable bandwidths in system (MHz) | 5616 ||

Table 4.2-4   Equivalent Information Units Per Usable Bandwidth

|  | Total Usable Bandwidth (MHz) | Voice Circuits | Television Channels | Data Rate (Mbps) (QPSK) |
|---|---|---|---|---|
| C Band | 2160 | 57,600 | 60 | 3,640 |
| Ku Band | 3456 | 92,160 | 128 | 5,824 |
| System Total | 5616 | 149,760 | 188 | 9,463 |

## 4.2.2  TERRESTRIAL NETWORKS

### 4.2.2.1  Existing Facilities

Long-haul transmission facilities in Canada are managed and operated by TCTS and CNCP. Unlike the U.S., Canada's long-haul facilities are almost all terrestrial microwave radio operating in the 4, 6 and 8 GHz frequency bands. There is a trend, in Canada, to replace all existing analog long-haul facilities with digital facilities since the digital terminal costs are less than analog and it is cheaper to terminate a digital switch with a digital facility.

The TCTS long-haul facility consists mainly of two routes, across Canada, mainly made up of TD-2 analog microwave radio and DRS-8 digital microwave radio over-built on the existing TD-2 facilities.

The TD-2 radio, operating in the 4 GHz band, can provide ten working and two protection channels using interstitial frequency plans. Each TD-2 RF channel, although originally designed to carry approximately 500 VF channels, can be modified to carry 1200 VF channels by applying new technologies to certain critical areas.

The DRS-8 radio, operating in the 8 GHz band, was designed to become the standard long-haul transmission facility to meet growth requirements on the high density toll traffic routes in the 1980's. The system, with crosspolarization, can grow to an ultimate capacity of eleven working and one protection channel. Each DRS-8 RF channel is capable of transmitting two DS-3 channels (91.040 Mb/s) or an equivalent of 1344 VF channels.

The total traffic carrying capacity of the TCTS long-haul network assuming the two routes (TCTS and Interprovincial) equipped with TD2 and DRS-8 radios is summarized below:

TD-2    4 GHz

10 RF channels @ 1200 VF channels = 12,000 ccts
for 2 routes                       = 24,000 ccts

DRS-8    8 GHz

11 RF channels @ 1344 VF channels = 14,784 ccts
for 2 routes                       = 29,568 ccts
_____

    TOTAL CAPACITY            = 53,568 ccts

In addition to the above capacities, TCTS uses DUV (data under voice) techniques to augment its digital carrying capabilities on its analog facilities. This technique normally inserts a 1.544 Mb/s T1 stream in the unoccupied lower baseband of the TD-2 analog radio. TCTS's dataroute facilities have implemented this technique on three TD-2 RF channels.

Assuming the above, the TCTS network date transmission capability is:

Data Capacity

3 x 1.544 Mb/s = 6.176 Mb/s

The CNCP long-haul facilities consist of a main route of analog microwave radio operating in the 6 GHz band. The band can provide seven working and one protection channel. Assuming each channel can carry 1800 VF channels, the total capacity is:

Total Capacity = 1800 x 7 = 12,600 ccts.

### 4.2.2.2  Future Facilities

Various systems are under investigation by the telephone companies to meet the traffic demands in the 1985-1990 time frame. Two digital radio systems are being examined for long-haul transmission, operating in a unified 4 GHz digital band and a lower 6 GHz digital band.

The unified 4 GHz digital radio system utilizes both the lower and upper 4 GHz bands for a total bandwidth of 1200 MHz or twenty-eight 40 MHz RF channels. The system carries 2688 voice channels on each RF channel combining four DS-3 rate channels into a bit rate of about 182 Mb/s.

The unified 4 GHz route will be determined by the 4 GHz TD-2 analog radio route and is presumed to be implemented as an overbuild and share the route structure with DRS-8. In order to achieve implementation of the unified 4 GHz digital radio system the existing analog radio system (TD-2) in the lower 4 GHz would be abandoned in planned multi-stage manner by transferring traffic initially onto DRS-8 and ultimately turning up the unified 4 GHz digital radio in stages.

The system is assumed not to use cross-polarization of the RF channels. Therefore the system is expected to grow to thirteen working channels and one protection channel. The total capacity is:

#### Unified 4 GHz

| | |
|---|---|
| 13 RF channels @ 2688 VF channels | = 34,944 ccts |
| for 2 routes | = 69,888 ccts |

The lower 6 GHz band has provision for a total bandwidth of 500 MHz and is plausable for eight two-way RF channel frequency assignment. It is expected that this band would not be allocated for a totally digital use in the foreseable future, therefore, for interference reasons, two DS-3 channels for RF channel is the most likely assignment in light of expected long-term analog use. The ultimate capacity without cross-polarization will probably be seven working channels and one protection channel providing 9408 VF channels.

Lower 6 GHz

    7 RF channels @ 1344 =     9,408 ccts
    for 2 routes          =   18,816 ccts

In summary, the total available capacity from terrestrial networks is provided below:

| | |
|---|---|
| DRS-8 | 29,568 ccts |
| Unified 4 GHz | 69,888 ccts |
| Lower 6 GHz | 9,408 ccts |
| TOTAL | 108,864 ccts |

It should be noted that the effective circuit capacity can be increased if the use of more efficient speech transmission techniques such as DSI (digital speech interpolation) and low-bit rate speech encoding is introduced in the network. During our discussions with telephone industry personnel, it was felt that more efficient techniques could effectively increase capacity by approximately 50%.

## 4.2.3  FIBRE OPTICS COMMUNICATIONS CAPACITY

### 4.2.3.1  Introduction

The technology of fibre optics, after twelve years of research and development, had emerged from the laboratory to become an agressive competitor to existing commercial systems.  The technology and applications are developing very rapidly and have already found establishment in certain segments of the telecommunication industry.  Because of its inherent capability to carry vast amounts of information, fibre optics will present an increasing challenge to the existing terrestrial and satellite microwave systems.  It will complement, if not totally replace, those service areas where conventional systems are either stretching the limit of their capability, or are just not cost or performance effective.  Several countries, including Canada, have experimental and prototype optics comunications networks with plans for expansion into operational systems [60 to 64].  The most attractive application for fibre optics links is a relatively short high density route such as the Quebec City to Windsor, or Boston to Washington communication corridors.  The use of fibre optics on long distance links is also attractive.  AT&T plans to include single mode fibre optics lines in the next trans-atlantic cable (TAT8), due for completion in 1988 [61].  Fibre optics will have a very significant impact on the demand for satellite communications.  In a recent evaluation of the impact of fibre optics on demand for satellite transponders in the year 2000, the Space WARC reduced estimates of the number of necessary transponders by 30% [65].

### 4.2.3.2  System Elements

A fibre optics transmission system has three major elements:  the optical fibre, the transmitter, and the receiver.

The fibre is a dielectric waveguide within which light propagates by way of total internal reflection.  Performance of a fibre is graded by attenuation (dB/km) and pulse broadening (ns/km).  Typical performance of a current production, multi-mode, high graded longwave fibre (1300 nanometers

(nm)) is about 1 dB/km in attenuation, and .7 ns/km in dispersion. For shortwave fibre (840 nm), 4 dB/km and 2.5 ns/km are representative values [66]. Single mode fibers are much superior to multimode fibers in terms of channel capacity; data rates as high as 400 Mbps with repeaters spaced at 30 km have been demonstrated in field trials [61]. In typical multimode systems, data rates are up to 140 Mbps with repeaters spaced at about 7 km [60]. The planned trans-atlantic cables will use single mode fibre.

The optical transmitter contains a driver and a light source. The two types of light sources used in fibreoptic systems are light emitting diode (LED) and injection laser. The LED is less expensive, more reliable, and has longer life. The injection laser has higher radiated power, greater usable bandwidth, and much smaller linewidth. For most applications, LED is adequate and is more economical. In system applications where a high data rate is a requirement, injection laser must be used since the wide LED linewidth (35 nm as opposed to 2 nm in injection laser) limits the transmission rate due to higher material dispersion.

At the receiver end, a solid state photo diode is used for reception of the light signal. Silicon photodiodes, which are reliable and inexpensive, are widely used. In situations where sensitive, high performance is required, higher cost avalanche photo detectors (APD) are preferred.

Other components included in a fibreoptics transmission link are regenerators, connectors, splicers, and couplers. The regenerators act like repeaters in the terrestial microwave system. Light signals transmitted through a long route may become contaminated due to the pulse broadening effect. Regenerators are inserted at the appropriate spacing along the route so that a clean signal may be reconstructed for transmission downstream. A typical link calculation presented in Table 4.2.3-1 shows the derivation of repeater span length.

### 4.2.3.3  System Application

The choice of a telecommunciation system to satisfy a particular demand is highly dependent on a combination of geography, capacity and application, while consideration must be given to the system's reliability and expandability.  The reason for popular acceptance of fibreoptics communication is that it possesses the potential to meet most of the above system requirements.  Some of the inherent characteristics which are most attractive in fibre optics are listed in Table 4.2.3-2.

An established application of fibreoptics communication system is to replace copper wires and coaxial cables in high capacity data links between central offices.  The key feature is the dependence of attenuation upon modulation bandwidth of the two transmissions.

Optical fibre has a constant attenuation of a few dB/km over the modulation bandwidth, whereas the attenuation of a coaxial cable is approximately 60 dB/km at 400 MHz and increases roughly as the square root of frequency. This non-linearity restricts the extensive application of high data rate transmission in coaxial cable systems.

Table 4.2.3-1  Link Calculation Of A Typical Fibre Optics Transmission

| Link Parameters | 840 nm | 1300 nm |
|---|---|---|
| Launch Power | -3.0 dBm | -3.0 dBm |
| Connector 2 @ 2 dB | -4.0 dB | -4.0 dB |
| Extinction Ratio | -2.0 dB | -2.0 dB |
| Contingency | -8.0 dB | -8.0 dB |
| Effective Launched Power | -17.0 dBm | -17.0 dB |
| Receiver Sensitivity | -51.0 dBm | -40.0 dB |
| Span Length Margin | 34.0 dB | 23.0 dB |
| | | |
| Fibre Loss | 2.5 dB/km | 1.0 dB/km |
| Splice Loss | .35 dB/km | .35 dB/km |
| Span Length Loss | 2.85 dB/km | 1.35 dB/km |
| | | |
| Span Length | 11.0 km | 17.0 km |

* Receiver sensitivity is assumed at BER = $10^{-10}$.

Table 4.2.3-2  Advantages of Optical Fibre

| CHARACTERISTICS | ADVANTAGES |
|---|---|
| • Large Bandwidth | • high channel capacity<br>• high data transmission rate<br>• low cost per channel |
| • Dielectric | • electrical isolation<br>• immune to interference and radiation<br>• resistiant to tapping; hence system security |
| • Small Size, Light Weight | • space and weight saving<br>• ease for installation |
| • Terrestrial | • ease of expansion to meet demands<br>• ease of maintenance and repair<br>• ease of upgrading to take advantage of new technologies<br>• rate of expenditures can be adjusted to budget and demand constraints |

Currently, the more competitive market trend for fibre optics is to provide local network distribution and to carry high density data and voice traffic over busy routes for point-to-point transmission. In the terrestial micro-wave system, a typical separation between repeaters is about 40 km. In addition to maintaining the line-of-sight contact, the repeater sites must also be located on adequately high ground such that the theoretical first Fresnel zone can be cleared for proper wave transmission. In situations where distance and terrain geography make it impractical to install a microwave system, fibre optics communication will be the prime alternative system. In current multimode optical links repeaters are typically 8 km apart. However in field trial systems using single mode fibre repeaters were 30 km apart and laboratory demonstrations have shown remarkably high data rates over long fibres, 420 Mbps over an 84 km fibre, without repeaters [61]. Because of the high data rate and point to point nature of the fibre optics, it is much more competitive with foreseen EHF applications than with the wide area coverage supplied by 4/6 and 12/14 services. However, it is expected that fibreoptics will penetrate every communication market segment except in areas where only thin route is in demand, or in communication systems which are highly distributive and/or mobile in nature.

In a study on the comparative costs of satellite, fibre optics and microwave radio communications [67], Future Systems Inc have identified domains where one or other technology has a cost advantage Tables 4.2.3-3 and 4.2.3-4 summarize these relative domains.

An inspection of both tables reveals that a fibreoptics system is most cost competitive when providing network service to compact areas where high traffic density is desired. The trend also predicts that with the anticipated lowering of cost of system implementation, fibreoptics systems will certainly become a replacement of terrestial microwave systems, which in relative scale has reached the saturation stage of development. Fibreoptics systems will certainly decrease the traffic on exisitng communications spacecraft and will reduce the demand for expanded high density service that could be provided by EHF. Fibre optics will provide very strong competition to EHF spacecraft in the distance range of 300 to 500 miles.

This section of the EHF study is just a thumbnail sketch of the future of fibre optics.

A useful adjunct to this report would be a detailed analysis of the future development of fibre optics communications and its impact on alternate modes.

Table 4.2.3-3    Comparison Of Most Cost Effective Coverage Range
For Competitive Communication Systems (ref 67)

| CHANNEL CAPACITY | | F.O.T. VS SAT | | F.O.T. VS T.M.S. | | T.M.S. VS SAT | |
|---|---|---|---|---|---|---|---|
| | | F.O.T | SAT | F.O.T. | T.M.S. | T.M.S. | SAT |
| 24 | C | < 45 km | > 45 km | – | All Range | < 350 km | > 350 km |
| | A | – | All Range | – | – | < 40 km | > 40 km |
| 120 | C | < 255 km | > 255 km | < 30 km | > 30 km | < 710 km | > 710 km |
| | A | < 25 km | > 25 km | – | – | – | All Range |
| 480 | C | < 360 km | > 360 km | < 70 km | > 70 km | < 950 km | > 950 km |
| | A | < 40 km | > 40 km | – | – | – | All Range |

Channel = one way telephone voice circuit with 4 kHz bandwidth or 64 kbps capacity.

C    = conventional satellite

A    = advanced satellite – has an on-board switching, improved transmission performance and uses multiple spot beams for frequency reuse.

F.O.T.    Fibre Optics Transmission System

T.M.S.    Terrestrial Microwave System

SAT    Satellite Communication System

Table 4.2.3-4  Summary Of Feasible Coverage Range For Communication
System

| CHANNEL CAPACITY | | F.O.T. | T.M.S. | SAT |
|---|---|---|---|---|
| 24 | C | – | < 350 km | > 350 km |
| | A | – | < 40 km | > 40 km |
| 120 | C | < 30 km | > 30 km <br> < 710 km | > 710 km |
| | A | – | – | All Range |
| 480 | C | < 70 km | > 70 km <br> < 950 km | > 950 km |
| | A | < 40 km | – | > 40 km |

## 4.3   DETERMINATION OF EHF REQUIREMENTS IN CANADA

### 4.3.1   INTRODUCTION

This section will answer the question ~ Is there a need to use the EHF band in Canada between now and the year 2000?

### 4.3.2   METHODOLOGY

Since our primary interest lies in the space segment the analysis performed deals with the demand and supply of Canadian satellite resources.

The first procedure of the analysis was to consolidate the commercial, military and scientific demands derived in Section 4.1.2 to 4.1.5. It was decided to convert all the services' demands into data rate equivalents in bits per second (bps), because in the near future all traffic carried by satellite will be in digital format.

To these demands, satellite capture ratios were applied to isolate the space segment requirements. The transponder loading efficiency for video signals were also included. The final demand was then matched against the available supply to determine whether there was a surplus or shortfall in supply, and hence a need or not for EHF band resources.

This methodology was applied to the average scenario since it provides a reasonable forecast. A worst case was also considered by performing the same analysis to the maximim demand scenario.

### 4.3.3   CONSOLIDATION OF TELECOMMUNICATIONS DEMAND

As mentioned earlier, the telecommunications demand comprised commercial, military and scientific demands. In Section 4.1.5, it was pointed out that total military traffic is low compared to the commercial traffic. In addition, some of the current traffic is carried by the common carriers and hence is included in the commercial telecommunications demand. In light of this, we can say the military demand has been incorporated.

Table 4.3.3-1 shows the voice and data components of the commercial demand under the average scenario. In satellite communications, a transponder may be dedicated to carry one-way voice signals, either incoming or outgoing. Hence, to convert a 4 kHz full duplex voice circuit into bits per second, a conversion factor of 128 kbps per duplex voice circuit was used. This assumes there are two one-way voice signals, each digitized at a rate of 64 kbps.

To isolate the portion of the total demand for voice traffic to be carried via satellite, a capture ratio of 20% was used for traffic over distances greater than 500 miles. This figure was obtained in consultation with personnel at TCTS. This accounts for route diversity, restrictions due the inherent time delay of satellite communications, echoing and the limitations of using only a single hop. To account for the expected penetration of fibre optics into the market the satellite capture percentage for distances between 300 and 400 miles was assumed to be only 10%, and between 400 and 500 miles was assumed to be 15%. Values for voice traffic shown in Tables 4.3.3-1, 4.3.3-2, 4.3.3-5 and 4.3.3-6 were calculated from data in 4.1.2.2 through 4.1.2.4. Inefficiencies in channel utilization would bring the demand figures up, however techniques are available now to increase the number of voice circuits per channel up to the 5000 circuits per 36 MHz transponder. Therefore no utilization factor was applied.

The time utilization of a transponder that is carrying data that originated at a computer or teletype terminal or in a facimile machine is low. Estimates in the ITT 30/20 GHz study (Ref. 5, page 116) show utilization factors between 35% and 40%. New techniques for packetization of data will tend to increase the channel utilization. A utilization factor of 25% was applied to the digital data and the capture by satellite was estimated to be 20%.

Table 4.3.3-3 depicts the video portion of the commercial demand. A digitization rate for a single video channel of 42 Mbps is regulated. The video channel requirements have been categorized by frequency band. To account for transponder loading, the C-band signals (4/6 GHz) have been adjusted to use 60.6 Mbps, i.e., the full transponder. For the Ku-band signals (12/14 GHz), a full 54 MHz (91 Mbps) transponder can accomodate two video signals. Hence, the Ku-band signals were adjusted to use 45.5 Mbps each.

Table 4.3.3-1 Forecasted Satellite Capture of Voice and Data
Portion of Commercial Demand (1980-2000) in Mbps:
Average Scenario

| YEAR | FORECASTED VOICE AND DATA DEMAND | | | VOICE AND DATA SATELLITE CAPTURED DEMAND | | |
|------|----------------|----------------|----------------|----------------|----------------|----------------|
| | VOICE a | DATA b | TOTAL | VOICE .189a | DATA .8b | TOTAL |
| 1980 | 1338 | 5.7 | 1343 | 253 | 4.6 | 258 |
| 1985 | 2236 | 17.2 | 2253 | 422 | 13.4 | 435 |
| 1990 | 3749 | 36.0 | 3785 | 708 | 28.8 | 737 |
| 1995 | 5979 | 62.5 | 6042 | 1129 | 50.0 | 1179 |
| 2000 | 9091 | 102.7 | 9194 | 1716 | 82.2 | 1798 |

Table 4.3.3-2 Forecasted Satellite Capture of Voice and Data
Portion of Commercial Demand (1980-2000) in Mbps:
Maximum Scenario

| YEAR | FORECASTED VOICE AND DATA DEMAND | | | VOICE AND DATA SATELLITE CAPTURED DEMAND | | |
|------|----------------|----------------|----------------|----------------|----------------|----------------|
| | VOICE a | DATA b | TOTAL | VOICE .151a | DATA .8b | TOTAL |
| 1980 | 3725 | 6.5 | 3731 | 563 | 5.2 | 568 |
| 1985 | 6246 | 19.1 | 6265 | 946 | 15.3 | 961 |
| 1990 | 10432 | 40.0 | 10472 | 1581 | 32.0 | 1613 |
| 1995 | 16627 | 77.9 | 16705 | 2523 | 62.3 | 2585 |
| 2000 | 25293 | 113.6 | 25406 | 3836 | 90.8 | 3927 |

Table 4.3.3-3 Forecasted Satellite Capture of Video Portion of
Commercial Demand (1980-2000) in Mbps

| YEAR | FORECASTED VIDEO DEMAND calculated at 42 Mbps/channel | | | SATELLITE CAPTURED VIDEO DEMAND | | |
|------|----------------|----------------|----------------|----------------|----------------|----------------|
| | C-Band | Ku-Band | TOTAL (Mbps) | C-Band 60.6 Mbps/C | Ku-Band 45.5 Mbps/C | TOTAL (Mbps) |
| 1983 | 840 | 840 | 1680 | 1212 | 910 | 2122 |
| 1985 | 1134 | 1218 | 2352 | 1636 | 1319 | 2955 |
| 1990 | 1218 | 1428 | 2644 | 1757 | 1547 | 3304 |
| 1995 | 1260 | 1722 | 2982 | 1818 | 1865 | 3683 |
| 2000 | 1260 | 1932 | 3192 | 1818 | 2093 | 3911 |

All that remains to be considered are the scientific requirements for satellite links. From Section 4.1.5, it was estimated that, for the average scenario, the demand would be 100 Mbps (1990), 200 Mbps (1995) and 200 Mbps (2000). It is conceivable that in a maximum demand scenario, the demand would be 200 Mbps (1990), 400 Mbps (1995), amd 400 Mbps (2000).

Table 4.3.3-4 lists the numbers of satellites which could be put in place for a maximum scenario.

Table 4.3.3-5 summarizes the total telecommunication requirements for the average scenario.

The supply of satellite resources was described in Section 4.2. By the end of 1985, it is expected that the three Anik Cs and the two Anik Ds will provide an in-orbit capacity of 6792 Mbps. Full utilization of the parking orbits available to Canada would provide a maximum capability of 9.463 Gbps. Under an average scenario, it can be seen from Table 4.3.3-5 that the supply exceeds the projected demand.

To ensure the maximum scenario demand could be met a similar analysis was performed. Table 4.3.3-6 summarizes the demand under the maximum case scenario. Once again, it can be seen that the supply exceeds the demand, but projected supply and demand are fairly close.

Table 4.3.3-4  Number of ANIK Satellites in Orbit, Number of Transponders and Available Bandwidth, Maximum Scenario

| YEAR | SATELLITES | TRANSPONDERS @ BW (MHz) | TOTAL BW (MHz) | TOTAL Mbps |
|------|------------|-------------------------|----------------|------------|
| 1980 | A3 + B1 | 20 @ 36 + 2 @ 72 | 864 | 1454 |
| 1985 | 3C + 2D | 40 @ 36 + 48 @ 54 | 4032 | 6792 |
| 1990 | 3C + 3D | 60 @ 36 + 48 @ 54 | 4752 | 8004 |
| 1995 | 4C + 3D | 60 @ 36 + 64 @ 54 | 5616 | 9463 |
| 2000 | 4C + 3D | 60 @ 36 + 64 @ 54 | 5616 | 9463 |

Table 4.3.3-5  Forecasted Total Satellite Telecommunications Demand
Under an Average Scenario (1980-2000)

| YEAR | COMMERCIAL | | SCIENTIFIC & MILITARY (Mbps) | TOTAL DEMAND (Mbps) | FORECASTED SUPPLY (Mbps) | POSSIBLE SATELLITE CONFIGURATION+ |
|------|-----------------------|--------------|---|---|---|---|
|      | VOICE & DATA (Mbps) | VIDEO (Mbps) | | | | |
| 1980 | 258  | 846   | -   | 1104 | 1454 | A3 + B1 |
| 1985 | 435  | 2955* | -   | 3390 | 5700 | 2C + 2D |
| 1990 | 737  | 3304  | 100 | 4141 | 6792 | 3C + 2D |
| 1995 | 1179 | 3683  | 200 | 5062 | 6792 | 3C + 2D |
| 2000 | 1798 | 3911  | 300 | 6009 | 6792 | 3C + 2D |

*The increase between 1980 and 1985 is due to Pay TV, Educational TV,
and CANCOM

+Refer to Table 4.1.4-13

Table 4.3.3-6  Forecasted Total Satellite Telecommunications
Demand Under The Maximum Scenario (1980-2000)

| YEAR | COMMERCIAL | | SCIENTIFIC & MILITARY (Mbps) | TOTAL DEMAND (Mbps) | FORECASTED SUPPLY (Mbps) |
|------|-----------------------|--------------|---|---|---|
|      | VOICE & DATA (Mbps) | VIDEO (Mbps) | | | |
| 1980 | 568  | 846*  | -   | 1414 | 1454 |
| 1985 | 961  | 3092  | -   | 4053 | 6792 |
| 1990 | 1613 | 3486  | 200 | 5299 | 8004 |
| 1995 | 2585 | 4047  | 400 | 7032 | 9463 |
| 2000 | 3927 | 4411  | 400 | 8738 | 9463 |

*The 2 - 14/12 channels on ANIK B plus 10 - 4/6 channels used by the CBC.

Prior to drawing our final conclusions, the impact of terrestrial network traffic spillover and compression techniques should be reviewed. Earlier discussions on terrestrial facilities estimated that saturation of these networks is not expected prior to the year 2000. Thus, little if any, traffic is expected to spill over the terrestrial networks. Further, new competing technologies, in particular fibre optics, could potentially reduce the traffic carried by the space segment by a considerable amount (Ref. 65 and 68).

Compression techniques will also reduce the requirements of space resources. Video compression techniques are currently under development and are showing good progress. It is expected that a compression ratio of 2:1 for full video will be achieved and implemented by 1990. With video requirements generating over half of the overall satellite traffic, the impact would be substantial. Compression techniques, such as DSI, for terrestrial facilities also threatens to reduce satellite traffic. However, their impact will be limited by TCTS policy. What DSI ensures is that no terrestrial spillover traffic will be created through postponing the saturation of the terrestrial network.

The slow acceptance of teleconferencing has spurred development of video compression techniques that promise to reduce the costs significantly. AT&T is reportedly ready to market a videoconferencing service that uses only 1.544 Mbps [70]. Widergren Communications reported development of a system that utilizes only 56 Kbps, (Ref. 69).

In light of these discussions, the conclusion of this analysis is that there is no demand for an EHF system prior to the year 2000.

## 4.4  COMPARISON OF DATA FROM THE ITT [5] AND WESTERN UNION [12] REPORTS

This section presents comparisons of the data in the reports by ITT and Western Union, for the U.S. traffic demand, and the data in this report. Rather than compare only the final figures on total Megabits per second transmitted by satellites or the total number of transponders the authors have gone back to the basic traffic demand figures in the three reports. For purposes of comparison all traffic numbers have been converted to a common unit of Mbps.

### 4.4.1  DATA FROM ITT

The peak hour voice service projections in Table 2.1-20 of the ITT report are listed in Table 4.4.1-1.

### Table 4.4.1-1  Voice Traffic Demand

| YEAR | DUPLEX VOICE CIRCUITS MILLIONS | EQUIVALENT Mbps (128 Kbps/circuit) | THIS REPORT | |
|------|-------------------------------|-----------------------------------|-------------|---------|
| | | | AVERAGE | MAXIMUM |
| 1980 | .35 | 44,800 | 1,338 | 3,686 |
| 1990 | .84 | 107,500 | 3,749 | 10,304 |
| 2000 | 1.58 | 202,200 | 9,091 | 24,986 |

Table 4.4.1-1 also provides the comparable figures in this study.

The summary of Video service demands are given in Table 2.2-17 of the ITT report and are reproduced in Table 4.4.1-2 with conversions to Mbps.

Table 4.4.1-2  Summary of Video Demand

| SERVICE | UNITS | 1980 | 1990 | 2000 |
|---------|-------|------|------|------|
| Network TV[1] | Video Channels | 10 | 12 | 16 |
| | Mbps | 606 | 727 | 970 |
| CATV[2] | Channels | 35 | 50 | 60 |
| | Mbps | 1,592 | 2,275 | 2,730 |
| Videoconference[3] | Conferences per year | 5,000 | 830,000 | 3,100,000 |
| | Mbps | 18 | 2,012 | 7,514 |
| Education[2] | Channels | 15 | 165 | 500 |
| | Mbps | 683 | 7,508 | 22,750 |
| Health & Public Affairs[2] | Channels | 0 | 25 | 50 |
| | Mbps | 0 | 1,138 | 2,275 |
| TOTAL | Mbps | 2,899 | 13,660 | 36,239 |
| This Report Average Scenario | Mbps | 846 | 3,304 | 3,911 |
| Maximum | Mbps | 846 | 3,486 | 4,411 |

(1)  Conversion factor 60.6 Mbps/channel

(2)  Conversion factor 45.5 Mbps/channel

(3)  Conversion factors 1980 $\dfrac{(\text{Conferences/year}) \times 1.5 \times 60.6}{250 \times 10 \times 10}$

1990 & 2000 $\dfrac{(\text{Conferences/year}) \times 1.5 \times 60.6}{250 \times 10 \times 15}$

The data service traffic demand provided in Table 2.3-19 of the ITT report are listed in Table 4.4.1-3.

**Table 4.4.1-3  Data Service Traffic Demand**

| SERVICE | UNITS | 1980 | 1990 | 2000 |
|---------|-------|------|------|------|
| Message | Tera bits/year | 41 | 3,232 | 4,284 |
| Traffic | Mbps[1] | 8.5 | 673 | 893 |
| Computer | Tbpy | 175 | 612 | 2,063 |
| Traffic | Mbps | 36.5 | 127 | 430 |
| Narrowband | Tbpy | 9 | 362 | 1,074 |
| Conferencing | Mbps | 7.6 | 75 | 224 |
| Totals | Mbps | 52.6 | 875 | 1,547 |
| Total without Conferencing | Mbps | 45 | 800 | 1,323 |
| This Report Average | | 5.7 | 36 | 103 |
| Maximum | | 6.5 | 40 | 114 |

(1) Conversion factors $\text{Mbps} = \dfrac{\text{Tbpy} \times 1.5 \times 10^{-6}}{250 \times 8 \times 3600}$

It appears that conferencing has been counted twice by ITT once under videoconferencing and once under Narrowband conferencing. Therefore in the final comparisons (Section 4.4.3) narrowband conferencing has been ignored.

4.4.2  DATA FROM WESTERN UNION

The net longhaul traffic forecast from Table II-14 of the Western Union report are listed in Table 4.4.2-1.

Table 4.4.2-1  Voice Traffic Demand

| YEAR | HALF VOICE CIRCUITS THOUSANDS | EQUIVALENT Mbps 64 Kbps/circuit | THIS REPORT | |
|------|------|------|------|------|
| | | | AVERAGE | MAXIMUM |
| 1980 | 2,099 | 134,300 | 1,338 | 3,686 |
| 1990 | 5,315 | 340,160 | 3,749 | 10,304 |
| 2000 | 13,771 | 881,340 | 9,091 | 24,986 |

The baseline Video Service as provided in Table II-16 of the Western Union report are listed in Table 4.4.2-2.

## Table 4.4.2-2  Summary of Video Demand

| SERVICE | UNITS | 1980 | 1990 | 2000 |
|---|---|---|---|---|
| Network TV | Channels | 45 | 52 | 59 |
| | Mbps | 2,250[1] | 2,236[2] | 2,419[3] |
| CATV | Channels | 79 | 91.2 | 99.4 |
| | Mbps | 3,950 | 3,922 | 4,075 |
| Occasional Video | Channels | 29 | 46.8 | 48 |
| | Mbps | 1,450 | 2,012 | 1,968 |
| Teleconference | Channels | 23 | 103.6 | 242 |
| | Mbps | 1,150 | 4,455 | 9,922 |
| Interactive Home | Channels | 0 | 0 | 9.5 |
| Video | Mbps | 0 | 0 | 390 |
| Total | Mbps | 8,800 | 12,625 | 18,774 |
| This Report Average | Mbps | 846 | 3,304 | 3,911 |
| Maximum | Mbps | 846 | 3,486 | 4,411 |

(1) Conversion factor for all services 1 channel = 50 Mbps in 1980.

(2) Conversion factor for all services 1 channel = 43 Mbps in 1990.

(3) Conversion factor for all services 1 channel = 41 Mbps in 2000.

The net long haul traffic forecast for Data taken from Table II-7 of the Western Union Report are listed in Table 4.4.2-3.

**Table 4.4.2-3  Data Service Traffic Demand**

| SERVICE | UNITS | 1980 | 1990 | 2000 |
|---|---|---|---|---|
| Data Transmissions | Terabits/year | 888 | 4,799 | 20,893 |
| | Mbps | 185 | 999 | 4,353 |
| Electronic Mail | Terabits/year | 124 | 1,734 | 4,568 |
| | Mbps | 26.8 | 361 | 952 |
| EFTS/POS | Terabits/year | 27 | 216 | 1,178 |
| | Mbps | 5.6 | 45 | 245 |
| Miscellaneous | Terabits/year | 40 | 208 | 914 |
| | Mbps | 8.3 | 43 | 190 |
| Total | Mbps | 226 | 1,448 | 5,740 |
| This Report Average | Mbps | 5.7 | 36 | 103 |
| Maximum | Mbps | 6.5 | 40 | 114 |

$$\text{Conversion Factor Mbps} = \frac{\text{Tbpy} \times 1.5 \times 10^6}{250 \times 8 \times 3600}$$

## 4.4.3  SUMMARY

The traffic demands derived from the ITT, Western Union and this report are summarized in Table 4.4.3-1.

### Table 4.4.3-1  Comparison of Predicted Traffic Demands

| TRAFFIC TYPE | REPORT | DEMAND (Mpbs) | | |
|---|---|---|---|---|
| | | 1980 | 1990 | 2000 |
| Voice | ITT | 44,800 | 107,500 | 202,200 |
| | WU | 134,300 | 340,160 | 881,340 |
| | CAL (Avg) | 1,338 | 3,749 | 9,091 |
| | (Max) | 3,686 | 10,304 | 24,986 |
| Video | ITT | 2,899 | 13,660 | 36,239 |
| | WU | 8,800 | 12,625 | 18,774 |
| | CAL (Avg) | 846 | 3,304 | 3,911 |
| | (Max) | 846 | 3,486 | 4,411 |
| Data | ITT | 45 | 800 | 1,323 |
| | WU | 226 | 1,448 | 5,740 |
| | CAL (Avg) | 5.7 | 36 | 103 |
| | (Max) | 6.5 | 40 | 114 |
| TOTALS | ITT | 47,744 | 121,960 | 239,762 |
| | WU | 143,326 | 354,233 | 905,854 |
| | CAL (Avg) | 2,189 | 7,089 | 13,105 |
| | (Max) | 4,538 | 13,830 | 29,511 |

There are considerable differences in the traffic demands predicted by ITT and Western Union.  Canadian Astronautics' maximum scenario values are approximately 1/10th of the ITT, about the value one would expect based on our relative population size.

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SECTION 5

CANADIAN EHF MISSION MODEL

## 5.0 CANADIAN EHF MISSION MODEL

### 5.1 MISSION MODEL

Based on the results of our study, it appears that Canadian Communication traffic demand will not be sufficient to impell satellite systems towards EHF. Present (ANIK B, C and D) satellites along with additional satellites at C and Ku band to occupy fully the available orbital slots, plus the use of appropriate frequency reuse techniques, will meet all foreseen traffic for the next two decades, except in the unlikely event that video conferencing services demand grow at a phenomenal rate. Fibre optics communication will probably have come of age by then and offer severe competition. Some special services, such as military needs for robust anti-jam systems with low probability of intercept and perhaps some scientific uses, may be best served by EHF. Such services, however, cannot by themselves provide economic justification for development of EHF technology in Canada. A decision based on factors other than cost effectiveness would have to be made to have an EHF satellite serve such needs.

The capacity of an EHF satellite far exceeds present Canadian communication traffic needs. It is estimated that a single EHF satellite could replace a number of lower frequency satellites, since a single EHF transponder could carry 10% of Canadian Traffic by the year 2000. It must be remembered however that EHF would not provide adequate services to some areas, such as the extreme north, due to high attenuations associated with low elevation angles and narrow beamwidths. Also the cost of such a system would be significantly higher than that of present systems. In any scenario where the advantages of EHF could be put to best use the satellite would be relatively very expensive compared to an ANIK or even a CTS type.

However, if an EHF communication satellite were to be launched, it might open up new horizons and push the communications industry into drastic changes of perspective. The available capacity could open up new markets

for new and presently unforeseen demands much in the same way as did the
14/12 GHz band on CTS and Anik B. It is expected that the satellite could
be best used for the following services:

- military systems
- High Definition Television (HDTV)
- Spot beam point-to-point communications
- High date rate scientific data transfer, e.g.
  Canadian Long Baseline Array (CLBA)
- Emergency Planning

These services would be well suited to an EHF system, since they
share a common characteristics of high data rate, high spatial resolution
and large bandwidth. An EHF capability might also stimulate cross border
markets although politics will definitely be a factor here. There might be
a possibility for a Canada - U.S. combined effort in EHF. In short, an EHF
satellite would provide far more capacity than Canadian needs, and the U.S.
market (if it could be tapped) could be a catalyst for the establishment of
one. However, the United States' plans for their own EHF system, the ACTS,
are well under way.

The system architecture to satisfy Canadian needs might involve
multiple spot beams and on-board switching. SS-TDMA would most likely be
used. To serve all areas, a few spot beams might be scanned. This might
prove complex and costly, and furthermore, provide poor service in the
north. A potential solution would be to use a dual frequency band satellite
with EHF spot beams covering the main centre and a global beam at C or Ku
band to provide service to the north, etc. On-board switching equipment,
multiple beam antennas and on-board power sources will be critical
techniques required to fulfill these missions.

The need, if any, for such a satellite is most likely to occur in the
21st century. By the time Canadian need for EHF comes along, global EHF
technologies will have come of age and components will be readily available
at relatively low cost. If Canadian technology has to be used, availability
of components might be doubtful unless development is started very soon.

## 5.2  REGULATORY POLICIES

The significance of governmental regulatory policies  upon the
Canadian Communications Industry cannot be over stated.  In terms of the
development of satellite systems, government policy decisions have been
crucial to the inception, technological advance and traffic (and hence
revenue) loading of present and planned satellite systems.  The effect of
deregulation, of course, depends upon the extent to which deregulation is
applied.  As can be seen from the recent decision to allow private reception
of satellite signals, and of the acceptance by Telesat Canada of the
practice of uplinking to a satellite from a source not controlled by
Telesat, the previously strict regulation of satellite communications is
being partially relaxed.  While, it is not anticipated that the industry
will ever become totally deregulated, it is not possible for the authors to
anticipate the extent to which regulation will continue to be applied in the
future.

The rationale and figures derived in the main body of the report
assume that there will be no fundamental change in the regulatory conditions
in force at the time of writing.

In order to evaluate the effects of deregulation, it was decided to
investigate what fundamental changes in the market, as applicable to
satellite communications in general and EHF systems in particular, would
take place if total deregulation were to occur.  In this fashion, the reader
will be able to understand the directions in which deregulation will direct
the requirements for EHF in the extreme case.

In the author's opinion, the effects of total deregulation will be as
follows:

1)  The common carriers will move to load the terrestrial system to
    its maximum cost effective usage by off-loading their traffic
    from Telesat's satellite systems.

2) There will be a substantial push towards –

   a) Fibre optics systems for short haul traffic corridors and for local distribution.
   b) Capacity enhancing techniques to better utilize available bandwidth.
      e.g. Digital Speech Interpolation (DSI)

It is expected in such a scenario that Telesat would be forced to reduce its rates and/or expand the nature of its services within Canada and expand into the United States market or else it would have to maintain a substantial number of unused channels. In either case, the need for more capacity, especially capacity in the amounts as can be expected to be provided by an EHF system, will not be present. In the longer haul, Telesat may move to recover its competitive position by the launch of an EHF system in which vast capacity becomes available for the cost of a single launch. (Note that an EHF transponder is expected to provide bandwidth an order of magnitude greater than C or K band existing systems). However, the development of such a system to the operational level would take approximately seven to eight years from the time that the deregulated scenario is accepted. Delays of this kind lead the authors to assume that, even in the very unlikely event that total deregulation occured, any EHF system considered acceptable at that time would suffer a substantial delay until such time as the existing systems moved towards saturation, and from the results of this study services available at 6/4 and 14/12 will not saturate until after the year 2000.

From the above scenario, it can be seen that the effects of deregulation upon EHF will be to reduce the need for such a system, and hence to delay its development.

APPENDIX A


DEMOGRAPHIC DATA


AND FORECASTING

## TABLE OF CONTENTS

Table A-1  Population, Households and GNP (1970-2000)

| Year | POPULATION ('000) | HOUSEHOLDS ('000) | GNP IN MILLIONS OF CONSTANT 1971 DOLLARS | GNP (M$) POPULATION ('000) |
|------|-------------------|-------------------|------------------------------------------|----------------------------|
| 1970 | 21,297 |       | 88,390   | 4.15 |
| 1971 | 21,568 |       | 94,450   | 4.38 |
| 1972 | 21,821 | 6,272 | 100,248  | 4.59 |
| 1973 | 22,095 | 6,463 | 107,812  | 4.88 |
| 1974 | 22,446 | 6,685 | 111,678  | 4.98 |
| 1975 | 22,800 | 6,904 | 113,005  | 4.96 |
| 1976 | 22,993 | 7,109 | 119,249  | 5.19 |
| 1977 | 23,258 | 7,298 | 121,762  | 5.24 |
| 1978 | 23,483 | 7,506 | 126,281  | 5.38 |
| 1979 | 23,672 | 7,731 | 130,115  | 5.50 |
| 1980 | 23,936 | 7,970 | 131,675  | 5.44 |
| 1981 | 24,342[1] | 8,282 | 136,114 | 5.59 |
| 1982 | 24,634[2] | N/A | 130,069 | 5.28 |
| 1983 | 24,890[2] | N/A | 133,152[3] | 5.35 |
| 1985 | 25,407 | 8,973  | 155,294 | 6.11 |
| 1990 | 26,809 | 9,671  | 176,434 | 6.58 |
| 1995 | 27,982 | 10,260 | 197,574 | 7.06 |
| 2000 | 28,946 | 10,874 | 218,714 | 7.56 |

[1] From 1981 Census
[2] Estimated Population based on 1981 Census
[3] Projected GNP at second quarter of 1983, seasonally adjusted at annual rate

## Table A-2  Population Projections

| | PROJECTION ('000) | | | |
|---|---|---|---|---|
| YEAR | 1 | 2 | 3 | 4 |
| 1981 | 24,574 | 24,441 | 24,338 | 24,205 |
| 1986 | 26,331 | 26,055 | 25,716 | 25,440 |
| 1991 | 28,092 | 27,662 | 26,975 | 26,549 |
| 1996 | 29,643 | 29,050 | 27,993 | 27,412 |
| 2001 | 30,981 | 30,221 | 28,794 | 28,054 |

## Table A-3  Projected Population Growth Rates

| YEAR | ANNUAL GROWTH RATE (%) | | | | |
|---|---|---|---|---|---|
| INTERVAL | 1 | 2 | 3 | 4 | AVERAGE |
| 1971-76* | 1.29 | 1.29 | 1.29 | 1.29 | 1.29 |
| 1976-81** | 1.34 | 1.23 | 1.14 | 1.03 | 1.19 |
| 1981-1986 | 1.39 | 1.29 | 1.11 | 1.00 | 1.20 |
| 1986-1991 | 1.30 | 1.20 | 0.96 | 0.86 | 1.08 |
| 1991-1996 | 1.08 | 0.98 | 0.74 | 0.64 | 0.86 |
| 1996-2001 | 0.89 | 0.79 | 0.57 | 0.46 | 0.68 |

\* Historical

\*\* Historical and Projected

## Table A-4  Household Projections

| YEAR | PROJECTION ('000) | | | |
|------|------|------|------|------|
|      | 1    | 2    | 3    | 4    |
| 1981 | 8,146  | 8,019  | 7,931  | 7,927  |
| 1986 | 9,234  | 9,020  | 8,904  | 8,897  |
| 1991 | 10,008 | 9,696  | 9,586  | 9,569  |
| 1996 | 10,725 | 10,263 | 10,150 | 10,085 |
| 2001 | 11,561 | 10,862 | 10,739 | 10,553 |

## Table A-5  Projected Household Growth Rates

| YEAR INTERVAL | ANNUAL GROWTH RATE (%) | | | | |
|------|------|------|------|------|------|
|      | 1    | 2    | 3    | 4    | AVERAGE |
| 1976-1981 | 3.38 | 3.05 | 2.82 | 2.81 | 3.02 |
| 1981-1986 | 2.54 | 2.38 | 2.34 | 2.34 | 2.40 |
| 1986-1991 | 1.62 | 1.46 | 1.49 | 1.47 | 1.51 |
| 1991-1996 | 1.39 | 1.14 | 1.15 | 1.06 | 1.19 |
| 1996-2001 | 1.51 | 1.14 | 1.13 | 0.91 | 1.17 |

APPENDIX B

# Characteristics of Major Canadian Telephone
# and Telecommunications Carriers

| COMPANY | AFFILIATION | OWNERSHIP | TYPE OF CORPORATION | REGULATION | PRINCIPAL TERRITORY |
|---|---|---|---|---|---|
| Bell Canada | TCTS | Private | Investor-owned | Federal | Ontario and Québec |
| British Columbia Telephone | TCTS | Private | Investor-owned | Federal | British Columbia |
| CNCP Telecommunications | | Private/ Public | Crown corporation/ Investor-owned | Federal | Canada |
| Teleglobe Canada | TCTS*** | Public | Crown Corporation | Federal** | International/Overseas |
| Telesat Canada | .TCTS | Private/ Public | Investor-owned**** | Federal | Canada |
| NorthwesTel | | Public | CNR-owned | Federal | North West Territories |
| Terra Nova Telecommunications | | Public | CNR-owned | Federal | Newfoundland |
| Alberta Government Telephones | TCTS | Public | Crown Corporation | Provincial | Alberta |
| Saskatchewan Telecommunications | TCTS | Public | Crown Corporation | Provincial* | Saskatchewan |
| Manitoba Telephone System | TCTS | Public | Crown Corporation | Provincial | Manitoba |
| Maritime Telegraph and Telephone | TCTS | Private | Investor-owned | Provincial | Nova Scotia |
| New Brunswick Telephone | TCTS | Private | Investor-owned | Provincial | New Brunswick |
| Québec-Téléphone | | Private | Investor-owned | Provincial | Québec |
| Newfoundland Telephone | TCTS | Private | Investor-owned | Provincial | Newfoundland |
| Télébec | | Private | Investor-owned | Provincial | Québec |
| Island Telephone | TCTS | Private | Investor-owned | Provincial | Prince Edward Island |
| Northern Telephone | | Private | Investor-owned | Provincial | Ontario |
| edmonton telephones | | Public | Municipally-owned | Municipal | Edmonton |

CRTC-regulated carriers are indicated with bold lettering.
TCTS = TransCanada Telephone System.

Source: Telecommunications Directorate, CRTC.

* Reports to the Provincial Minister of Communications, rather than to a regulatory agency.
** Reports to the Federal Minister of Communications, rather than to the CRTC.
*** Non-voting associate member.
**** An incorporated company owned by the Government of Canada and the major telephone companies.

MAJOR TELEPHONE COMPANIES IN CANADA

Shaded areas show parts of Canada where CRTC-
regulated companies provide telephone service.

MAJOR TELEPHONE COMPANIES IN CANADA

1. Newfoundland Telephone Company
2. Terra Nova Telecommunications
3. Maritime Telegraph and Telephone Company
4. The Island Telephone Company
5. The New Brunswick Telephone Company
6. Télébec
7. Québec Téléphone
8. Téléphone du Nord de Québec
9. Bell Canada
10. Northern Telephone
11. Ontario Northland Telecommunications
12. Manitoba Telephone System
13. Saskatchewan Telecommunications
14. Alberta Government Telephones
15. edmonton telephones
16. British Columbia Telephone
17. NorthwestTel
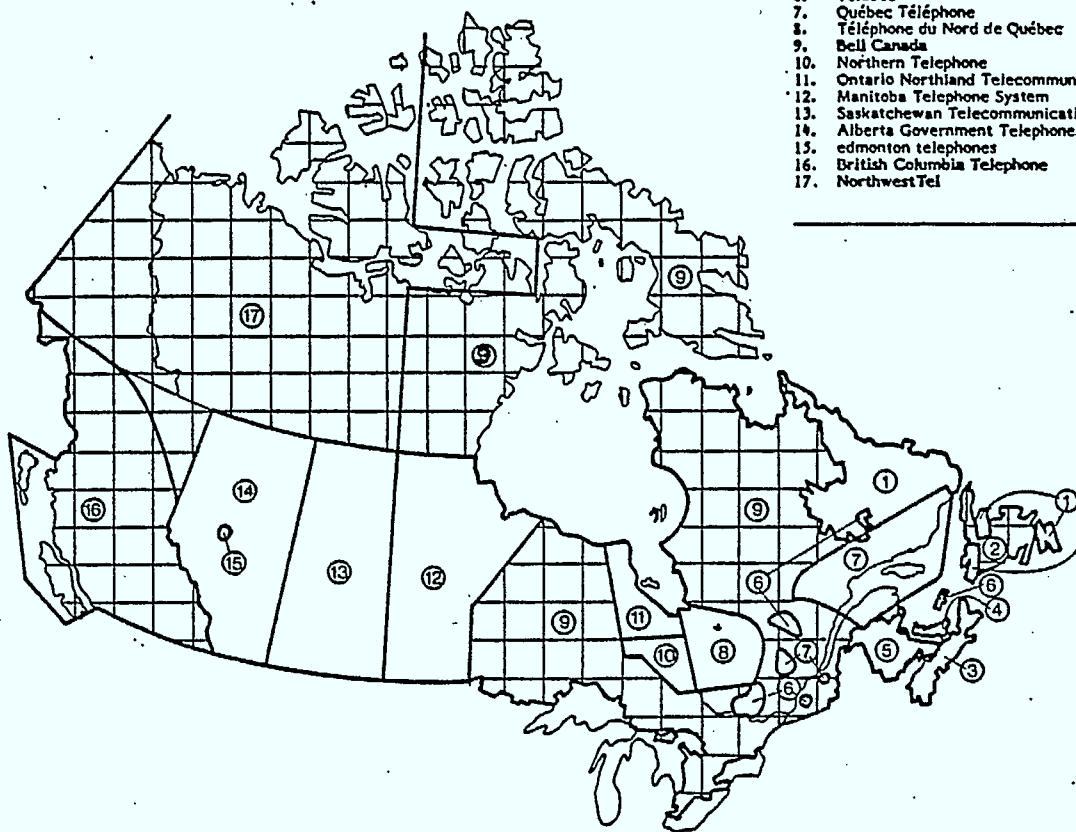
SOURCE:    STATISTICAL INFORMATION CENTER; CRTC FACTS DIGEST ON
           BROADCASTING AND TELECOMMUNICATIONS IN CANADA; CRTC,
           OTTAWA; JANUARY 1982

A STUDY OF CANADIAN EHF COMMUNICATION
REQUIREMENTS AND TECHNOLOGY DEVELOPMENT

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