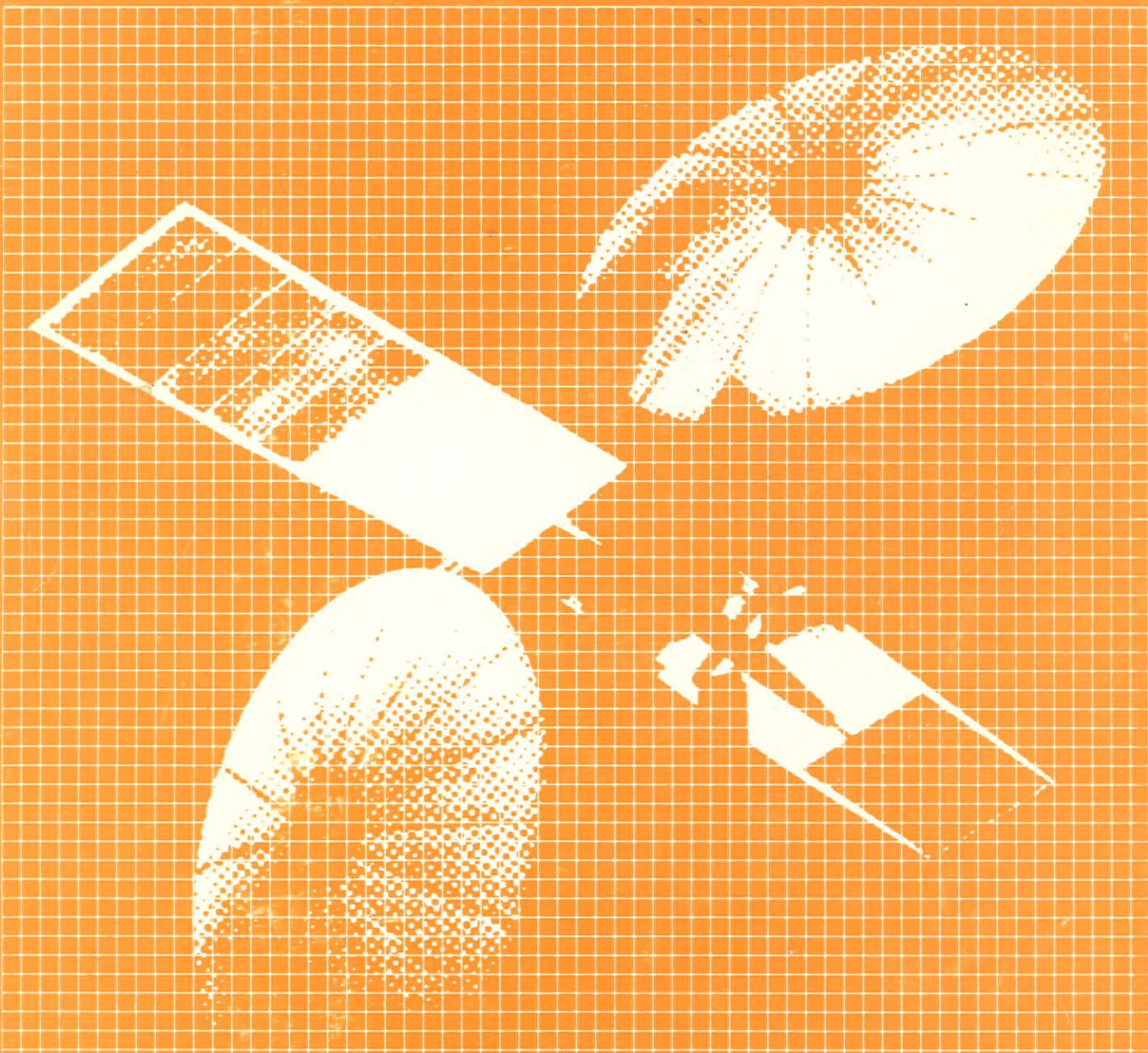
MOBILE COMMUNICATIONS SATELLITE (MSAT)

Communications Research Centre
Department of Communications
Shirley Bay, Ontario

Commuincations System Concept Document

MSAT NO. 2001 Issue A

Government of Canada
Department of Communications
Gouvernement du Canada
Ministère des Communications



MSAT

Canada

MOBILE COMMUNICATIONS SATELLITE (MSAT)

Communications Research Centre
Department of Communications
Shirley Bay, Ontario

Commuincations System Concept Document

MSAT NO. 2001 Issue A

MOBILE COMMUNICATIONS SATELLITE (MSAT)

Communications Research Centre
Department of Communications
Shirley Bay, Ontario

MSAT REQUIREMENTS DOCUMENT | MSAT NO. 2001

DATE 2 March 1983 | ISSUE A

TITLE: MSAT Communications System Concept Document

APPLICABILITY: MSAT Demonstration Satellite

Prepared by:

J.D.B. Kent
Systems Manager

Reviewed by:

H.R. Raine
Space Segment Manager

J.A. Nicholson
Ground Segment Manager

P.M. Boudreau
MSAT Program Manager

Approved by:

J.L. McNally
Project Manager

Released by:

R.W. Breithaupt
Program Director

MOBILE COMMUNICATIONS SATELLITE (MSAT)

Communications Research Centre
Department of Communications
Shirley Bay, Ontario

MSAT REQUIREMENTS DOCUMENT

MSAT NO. 2001

CHANGE RECORD

DATE: 83/03/02

ISSUE		CHANGE			REMARKS
LTR.	DATE	NO.	DATE	AUTHORITY	
0	82/06/04				Preliminary version, issued as MSAT #4 (interim), for information pending review and approval.
0	83/02/01				Revised preliminary, unissued.
P1	83/02/11				Amended for Approvals.
P2	83/02/28				Amended to delete 400 MHz Service.
A	83/03/02				Approved issue.

TABLE OF CONTENTS

Tables:

Figures:

Annexes:

Controlled Distribution:

1.0 USER REQUIREMENTS

1.1 Introduction

This document details the communication system concept for the communication services to be provided on the demonstration mobile satellite (MSAT) system. The Department of National Defence (DND) communication system concept is classified and contained in a separate document. For completeness, unclassified elements of the DND system where they impact on this concept document are included.

As a result of early collaboration between DOC and the United States National Aeronautics and Space Administration (NASA) on the feasibility of providing satellite service to mobile terminals, a cooperative venture between these two parties is planned for the remainder of the program. The details of this arrangement are contained in a draft, "ARRANGEMENT CONCERNING MOBILE SATELLITE COMMUNICATIONS COOPERATION BETWEEN THE UNITED STATES NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND THE DEPARTMENT OF COMMUNICATIONS OF CANADA." Where agreements impact on the Canadian system design, they are included in this document.

The information contained in this document is based on research and development carried out at the Communications Research Centre (CRC) and Phase A studies conducted under contract by Canadian industry for the Department of Communications (DOC). The bibliography contains a list of these study reports which can be made available for amplification where necessary.

MSAT is a geostationary satellite scheduled for launch in 1987 to be positioned at a nominal longitude of 106.5°W. It will provide public; mobile radio service (MRS), mobile telephone service (MTS) and data service (DS) to mobile and transportable terminals operating in the 821-825 MHz and 866-870 MHz bands. In addition, service from remote data collection platforms (DCP's) is planned to fixed locations.

The demonstration system will be used in Canada to establish actual system parameters, confirm operational characteristics of development terminals and conduct a post launch communications program involving experiments and interim commercial service, to build up a user community for the operational system planned for service in 1994. An initial user complement of 700 terminals has been assumed in projecting the traffic growth. In the event of an early satellite anomaly a spare spacecraft could be ready for launch 15 months after a decision to proceed has been made.

The primary concern of this document is the translation of user communication requirements into technical parameters that can be used to establish a baseline communication system concept for MSAT. These parameters then can be used to size the space segment communications payload and establish the ground segment. The user population, service types and community of interest are based on Phase A studies; however, complete flexibility, within the constraints of satellite power and available bandwidth is maintained to trade off service types and test new concepts.

1.2 Communications Requirement

This section contains the communications requirements for the demonstration MSAT system and includes:

- Types of Service
- Grade of Service (GOS)
- Traffic Estimates
- User Community of Interest
- Quality of Service
- Performance Requirements
- Coverage Requirements

1.3 Mobile Radio Service

Mobile Radio Service (MRS) provides voice communication between mobile users, base stations, other mobiles and gateway stations. Direct access to the switched-telephone-network (STN) is not provided. Circuits are half duplex and will be voice activated or push to talk. Channels will be pooled for the majority of users with assignments based on trunk availability at the time of service request. Dedicated channels will be provided for large user groups who will time share the channel in accordance with normal terrestrial MRS operation. Dedicated channels will be UHF to UHF or UHF to SHF Base stations and any signalling necessary will be included in the user terminals. In all cases, user groups will form subnetworks within the overall MRS network and may only be able to access members of their own group.

The following modulation and coding techniques are being investigated to determine their suitability and cost for use in the MRS:

- Pitch Excited Linear Predictive Coding (PELPC) with differential minimum shift keying (DMSK)

- Amplitude Companded Single Sideband (ACSSB)

The channel quality for MRS under faded conditions will, in terms of equivalent noise, be not greater than 65.0 dBrnCO for 99% of the time, subsequently referred to as field quality. For vocoded speech the minimum articulation index will be 0.6.[1] This service is not designed to be tandemed to other trunks; if this is done a degradation in overall quality will result. Data at 2.4 kb/s using the DMSK modem can be carried in the MRS; however, the error rate under fully faded conditions may not be adequate for some users and power adjustment may be necessary. User experience in proper siting of the mobile terminal should result in acceptable performance using nominal mobile power.

The expected user population for the demonstration period (1987-94) assuming an initial 595 users for the MRS is shown in Table 1.1 and plotted on Figure 1.1.

---

[1]Kryster, Karl D., Methods for the Calculation and use of the Articulation Index, J. Acoust. Soc. Am. 34., 1689-1697.

1.3 (cont'd)

The user community of interest for equal traffic division between beams is shown in Table 1.2 and the busy hour (BH) traffic intensity based on 0.0155 Erlangs per user is given in Table 1.3. The Grade of Service (GOS) at satellite end of life (EOL) is P.10 corresponding to 10% blockage and trunk groups are sized in accordance with the Erlang B formula.

Mobile terminals must be low cost, lightweight and robust with a high mean time between failure (MTBF). Terminals operating in the pooled channel mode must be able to operate on all assignable channels and be compatible with the demand assignment multiple access (DAMA) and network signalling protocols. Terminals operating on dedicated channels need only operate on their assigned channels and be compatible with their base station signalling protocol. The mobile terminal antenna must provide gain at the satellite elevation angle, be omni-directional in azimuth and discriminate against low angle signals. Terminal frequency control must be adequate to permit operation with 5 kHz channel spacing.

1.4 Mobile Telephone Service

Mobile Telephone Service (MTS) provides voice communications between mobile users, other mobiles and gateway stations. Direct access to and from the STN is provided at the gateway station in a manner transparent to the users. Circuits are full duplex and will be voice activated. All satellite MTS channels will be pooled by beam and assigned to users based on their availability at the time of service request. Signalling and supervision (push button dialing, dial tone, busy signal, etc.) at the mobile unit will be similar to that used in the proposed cellular system. A numbering plan for the mobile units will be necessary; however, signalling from mobiles to addresses in the STN will use the same number as in the terrestrial network.

NBFM modulation compatible with the proposed cellular system will be used and channel quality under faded conditions into the STN will, in terms of equivalent

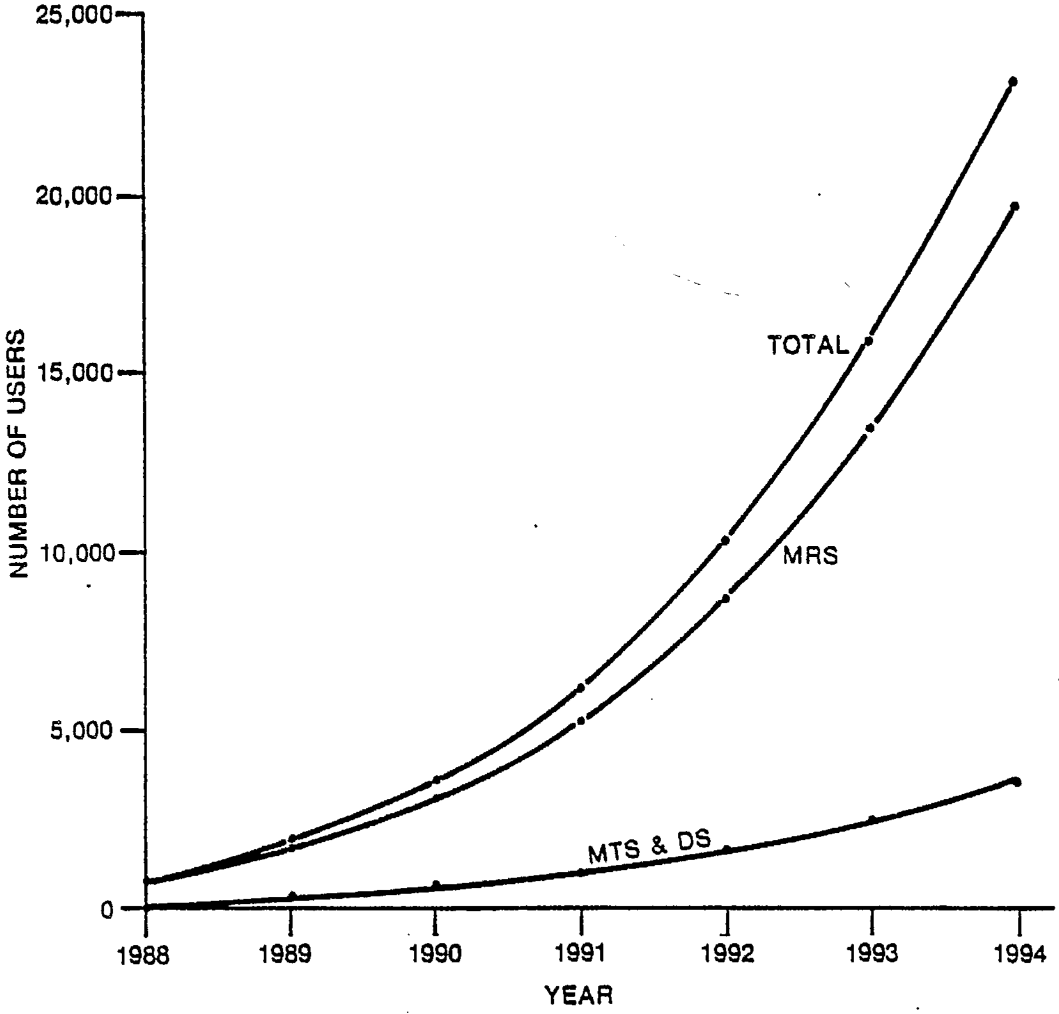


Figure 1.1

Expected MRS - MTS/DS User Population - Demonstration Period

TABLE 1.1

MSAT EXPECTED MRS MARKET PENETRATION

YEAR ENDING	MSAT MRS USERS
1988	595
1989	1,615
1990	3,060
1991	5,270
1992	8,670
1993	13,430
1994	19,635

TABLE 1.2

MRS COMMUNITY OF INTEREST

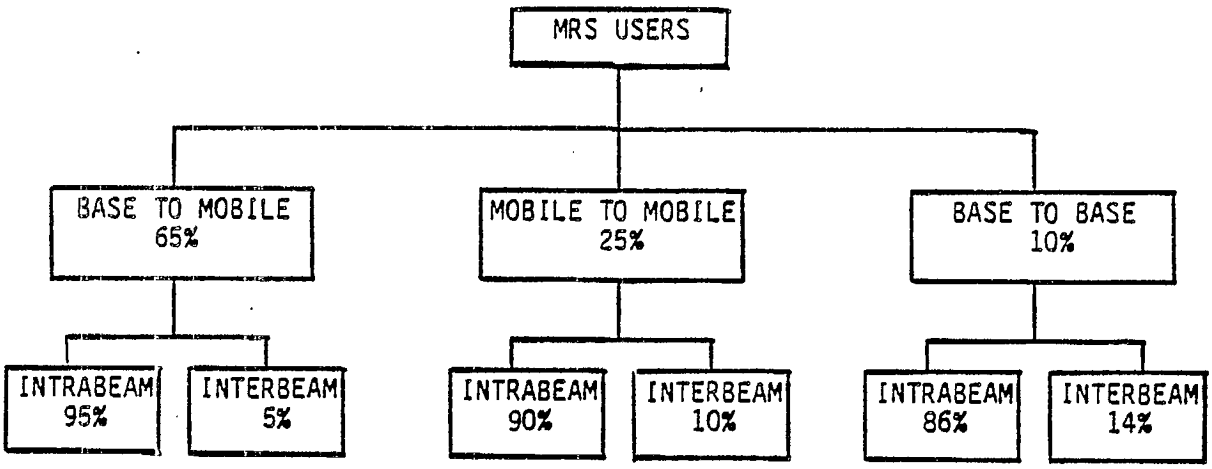


TABLE 1.3

MRS TRAFFIC DISTRIBUTION

BUSY HOUR TRAFFIC INTENSITY

(0.0155 BH Erlangs/User)

TABLE 1.3(a) - BASE TO MOBILE

YEAR ENDING	INTRABEAM BH ERLANGS/BEAM	INTERBEAM BH ERLANGS/BEAM
1988	1.40	0.07
1989	3.86	0.20
1990	7.32	0.39
1991	12.61	0.66
1992	20.75	1.09
1993	32.14	1.69
1994	46.98	2.47

Table 1.3(b) - MOBILE TO MOBILE

YEAR ENDING	INTRABEAM BH ERLANGS/BEAM	INTERBEAM BH ERLANGS/BEAM
1988	0.52	0.06
1989	1.41	0.16
1990	2.67	0.30
1991	4.59	0.51
1992	7.56	0.84
1993	11.71	1.30
1994	17.12	1.90

TABLE 1.3 (cont'd)

MRS TRAFFIC DISTRIBUTION

BUSY HOUR TRAFFIC INTENSITY

(0.0155 BH Erlangs/User)

TABLE 1.3(c) - BASE TO BASE

YEAR ENDING	INTRABEAM BH ERLANGS/BEAM	INTERBEAM BH ERLANGS/BEAM
1988	0.20	0.03
1989	0.54	0.09
1990	1.02	0.17
1991	1.76	0.29
1992	2.89	0.47
1993	4.48	0.73
1994	6.54	1.07

1.4 (cont'd)

noise, be not greater than 62.0 dBrnCO for 99% of the time, subsequently referred to as toll quality. Signals from the STN to the mobile user under faded conditions will provide a channel quality, in terms of equivalent noise, not greater than 75.0 dBrnCO for 99% of the time. Preemphasis will be used and the subjective signal to noise ratio will be enhanced by the use of compandors.

The expected user population for the demonstration period assuming 105 users at the start of the first year of service for MTS is given in Table 1.4 and plotted on Figure 1.1. The user community of interest for equal traffic between beams and the BH traffic intensity is given in Tables 1.5 and 1.6. The GOS at satellite end of life is P. 10.

Mobile terminals must be low cost, lightweight and robust with a high MTBF. Terminals must be capable of operating on all channels assigned to the MTS and be compatible with the DAMA and network protocols. The mobile terminal antenna must provide gain at the satellite elevation angle, be omni-directional in azimuth and discriminate against low angle signals. If it is cost effective, terminals should be interoperable with MSAT and the proposed cellular system.

1.5 Data Service

The results of the Phase A studies did not indicate a large requirement for the Data Service (DS); however, subsequent information indicates that this requirement could expand considerably. For the demonstration system sizing, DS is included as a supplement to the MTS with usage on the MRS subject to the constraints of channel power allocation and the fade margin for voice service. When more information is available, adjustments can be made within the constraints of power and spectrum availability to provide the required capability. MTS terminals will be capable of operating in both the data and voice modes. Special codecs and displays for data operation will be necessary and the switch over from voice to data will take

TABLE 1.4

MSAT EXPECTED MTS AND DS MARKET PENETRATION

YEAR ENDING	MSAT MTS AND DS USERS
1988	105
1989	285
1990	540
1991	930
1992	1530
1993	2370
1994	3465

TABLE 1.5

MTS AND DS COMMUNITY OF INTEREST

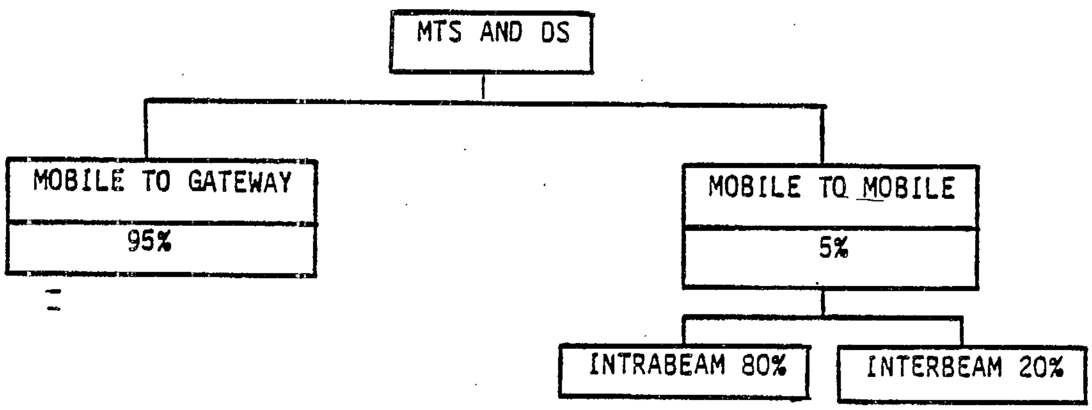


TABLE 1.6

MTS AND DS TRAFFIC DISTRIBUTION

BUSY HOUR TRAFFIC INTENSITY

(0.0155 BH Erlangs/User)

YEAR ENDING	MOBILE TO GATEWAY BH ERLANGS/BEAM	MOBILE TO MOBILE BH ERLANGS/BEAM	
		INTRABEAM	INTERBEAM
1988	0.39	0.02	
1989	1.05	0.04	0.01
1990	1.99	0.08	0.02
1991	3.42	0.14	0.04
1992	5.63	0.24	0.06
1993	8.72	0.37	0.09
1994	12.76	0.54	0.13

1.5 (cont'd)

place after signalling is completed and both parties are off hook.

The data module should operate at 2.4 kb/s with a bit error rate (BER) not greater than 1 in 106 over the satellite channel. Error detection and correction(EDC) can be used to achieve this performance; however, an automatic repeat request (ARQ) type system should not be utilized. Buffering for 300 words or 2400 bytes of data should be provided at the mobile terminal. The data module should be robust with a high MTBF. The display should able to be read easily with the high ambient light levels encountered in vehicle operation.

1.6 Data Communications Platform Service

The Data Communications Platform (DCP) service will be provided in the 821-825 MHz uplink band and received at gateways or the CCS on the 11.65-11.70 GHz downlink. Specific details are not available at present. When this service is defined, a tradeoff in MRS or MTS spectrum will be made.

1.7 SHF/SHF Service

A requirement exists to link gateways and the CCS for orderwires, signalling and network management purposes. A total of 12 channels shared between the gateways and the CCS in a FDMA mode have been allocated to meet this requirement. These channels will be spaced 30 kHz and have an uncoded BER of at least 1 in 10^6 for data up to 4.8 kb/s and a carrier to noise density ratio (C/N_0) of at least 54 dB-Hz for voice.

1.8 Connectivity

In order to meet the various traffic distributions outlined previously,

1.8 (cont'd)

certain constraints must be placed on the number of paths available to the user through the satellite. For the MTS and DS, all mobile traffic will be routed to the serving gateway, UHF to SHF. The low density mobile to mobile service will be double hop within a beam for intrabeam traffic and double hop via or in conjunction with the destination gateway for interbeam traffic. For MRS, all mobile to mobile and base to base intrabeam traffic and 50% of the base to mobile intrabeam traffic will be UHF to UHF. The remaining 50% of the base to mobile intrabeam traffic will be UHF to SHF via gateways or SHF base stations. All interbeam traffic will be double hop via, or in conjunction with, the destination gateway. The required connectivity is summarized in Table 1.7, based on EOL requirements.

1.9 Coverage

Canada coverage, including territorial waters and the 200 mile limit, down to an elevation angle to the satellite of 0° (Figure 1.3) is required for all services. For operation north of the 10° contour special antennas will be necessary due to the relatively low angle of elevation from these areas to the satellite. Four overlapping beams in Canada (as shown in Figures 1.2 and 1.3) provides the necessary coverage, segregates the user population into regional groupings and permits frequency reuse among the Eastern and Western beams. Two US beams and use of two equivalent NBFM channels from the Western Canadian beam for Alaska provides the necessary US coverage.

1.10 Eclipse Capability

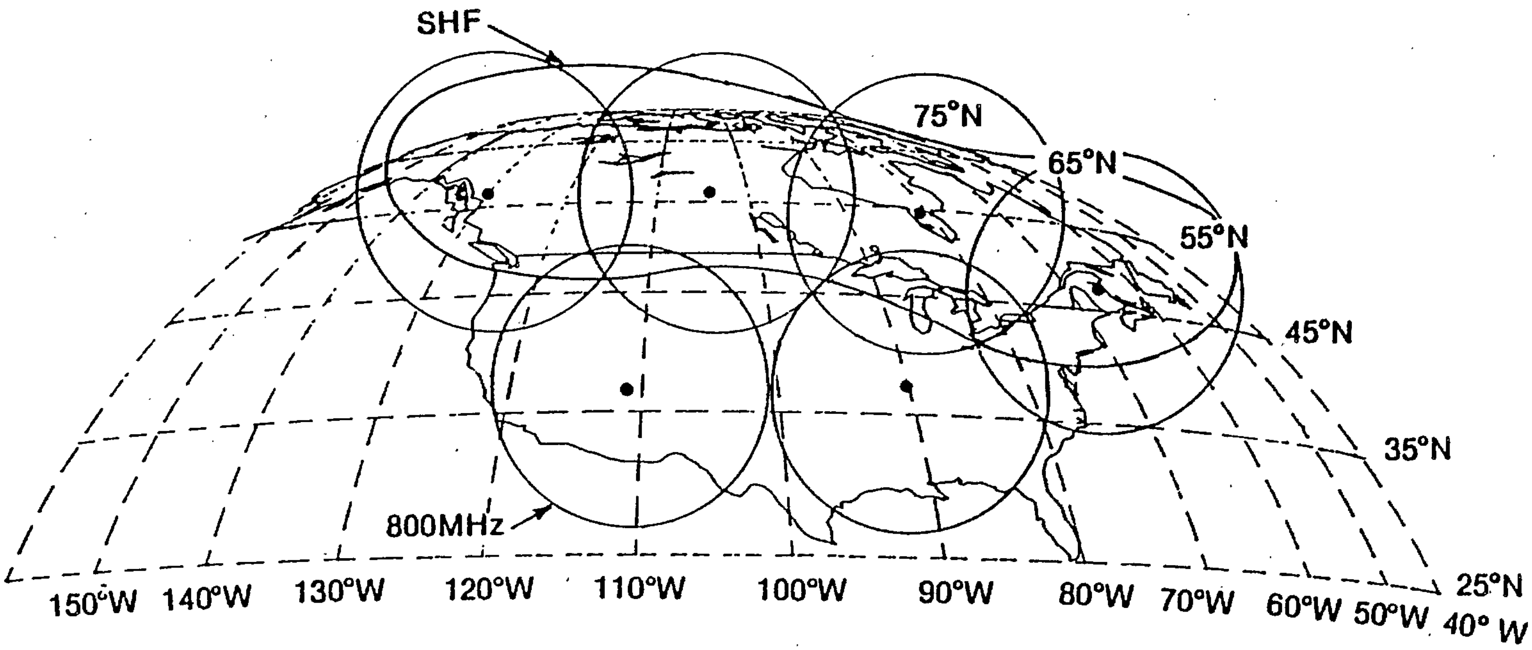
The satellite should be capable of providing 25% of the nominal beam loading during an eclipse. The nominal beam loading is considered to be the busy hour loading for each beam adjusted for a GOS of P.10 during eclipse conditions. The eclipse period is forecast to occur during relatively light loading conditions on the communication subsystem, resulting in little degradation in service to most users.

TABLE 1.7

TRANSPONDER CONNECTIVITY/BEAM

	UHF to SHF		UHF to UHF	
Service	Traffic Intensity Erlangs	Traffic Channels	Traffic Intensity Erlangs	Traffic Channels
MTS and DS	14.10	17*		
MRS	34.37	36*	47.16	48

* Includes double hop requirement.



MSAT COVERAGE
FIGURE 1.2

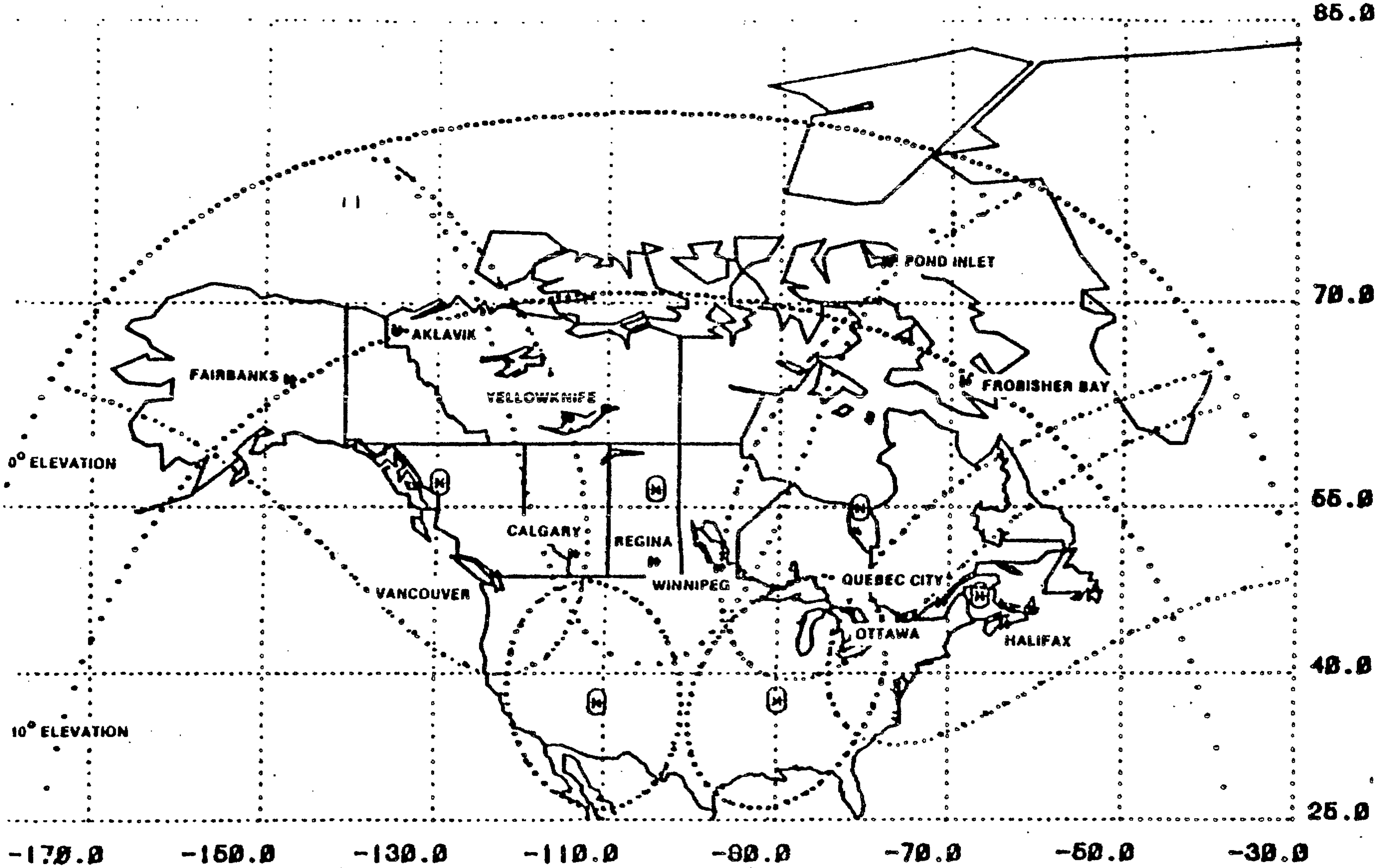


Figure 1.3

MSAT 800 MHz BEAM FOOTPRINTS

2.0 COMMUNICATIONS ARCHITECTURE

2.1 The communication paths through the satellite and extension into the terrestrial network have been designed to meet the user communication requirements outlined in Section 1, and to provide the necessary connectivity between network nodes to control the system. The system is flexible in that call routing can be changed to meet specific user needs. The purpose of this section is to detail the various links within the system and explain how they are combined to meet overall objectives. Considerations is only given to operation within the four Canadian UHF footprints and the SHF backhaul; however, operation within the US is expected to be similar within the coverage constraints.

2.2 The connectivity of the terminals and channelization of the satellite within the mobile communication system are:

2.2.1 Mobile Radios and UHF Base Stations

These terminals uplink to the satellite in the band 821-825 MHz and receive on the satellite downlink in the 866-870 MHz band. The transmit and receive frequency are paired and offset by 45 MHz.

2.2.2 Gateways, CCS and SHF Base Stations

These terminals uplink to the satellite in the 13.20-13.25 GHz band and receive on the satellite downlink in the 11.65-11.70 GHz band. The transmit and receive frequency are paired and offset by 1.55 GHz.

2.2.3 Satellite

The satellite receives UHF uplinks in the four beams (1 MHz assignment per beam) in the 821-825 MHz band and transponds the received signal to four unique 1 MHz assignments in the 11.65-11.70 MHz downlink band. A portion of the UHF uplink in

2.2.3 (cont'd)

each beam is also transponded to the 866-870 MHz satellite downlink and provides the UHF-UHF path. Note that this is only provided within a beam and no UHF-UHF translation is provided between beams. The satellite receives on the SHF uplink 13.20-13.25 GHz and transponds the beam assignment to 1 MHz slots in the UHF downlink in the 866-870 MHz band. A segment of the SHF uplink is directly transponded to the 11.65-11.70 GHz band which provides the SHF-SHF cross strap. The beam coverage for the UHF and SHF is shown in Figure 1.2 and the channelization in Figure 2.1

2.2.4 Terrestrial

Direct connections from gateways to the STN are provided for the MTS via trunks between the Gateways and a Telco class 4/5 office. Dedicated lines are also planned from gateways to dispatch offices to permit terrestrial system access for MRS users in the vacinity of the gateway stations. Interconnection of gateways and the CCS by dedicated trunks or via switched facilities will be implemented as necessary.

2.3 Call Routing

Call routing within each beam of the MSAT System is the responsibility of the gateway stations which are controlled by the DAMA system. Gateways may be interconnected terrestrially for interbeam calls, and via SHF-SHF satellite links for signalling information exchange and network management purposes. Overall, system control is exercised by the CCS which utilizes information forwarded from gateways and satellite telemetry to monitor the communication traffic flow, reconfigure the network or take other corrective action to maintain network integrity. Figure 2.2 outlines the control hierarchy and information flow. If the DAMA is contained within the gateway, it will assign and monitor 800 MHz channels in the UHF beam in which they are located.

The forward link is established between the gateway or SHF base stations and the mobile terminal, uplinked at SHF and downlinked at UHF. As the SHF footprint

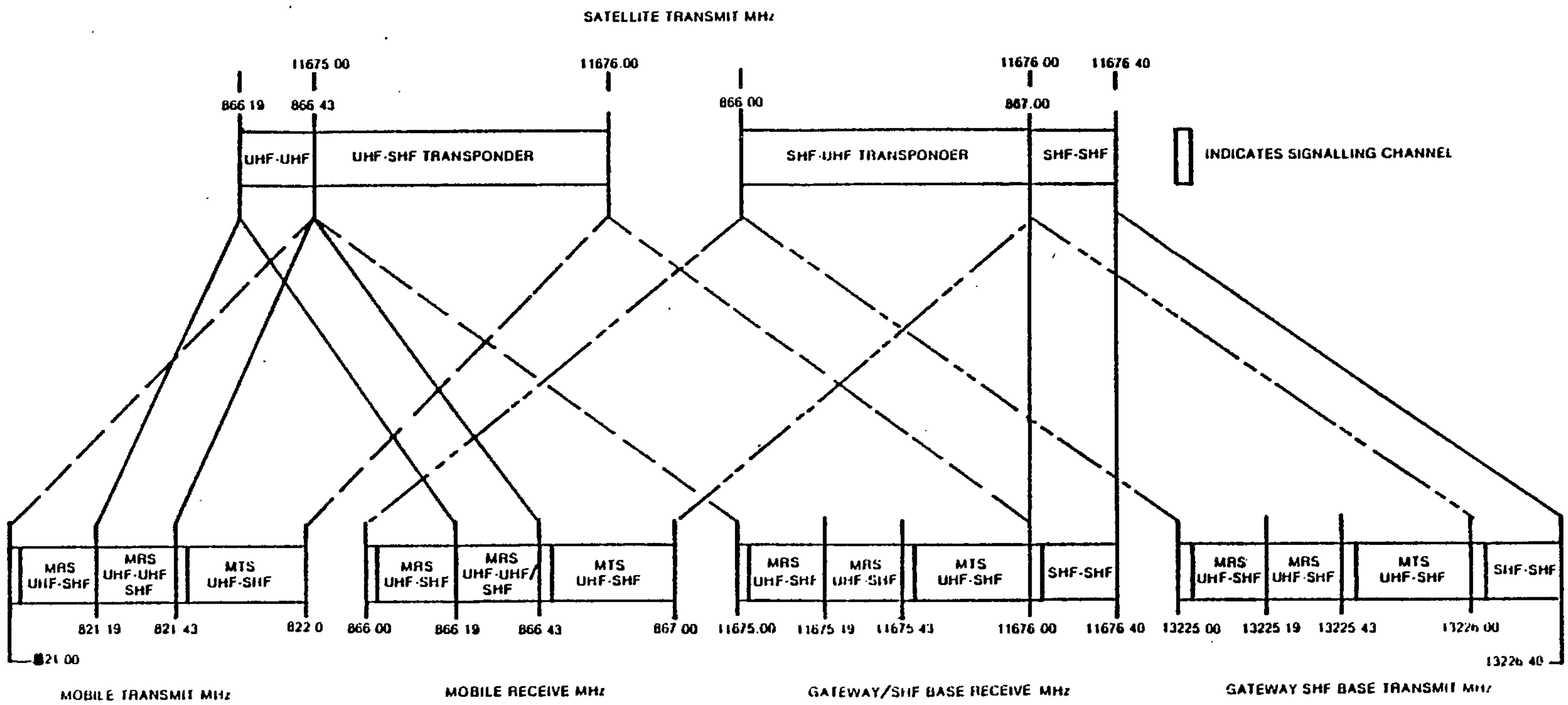


Figure 2.1

MSAT CHANNELIZATION

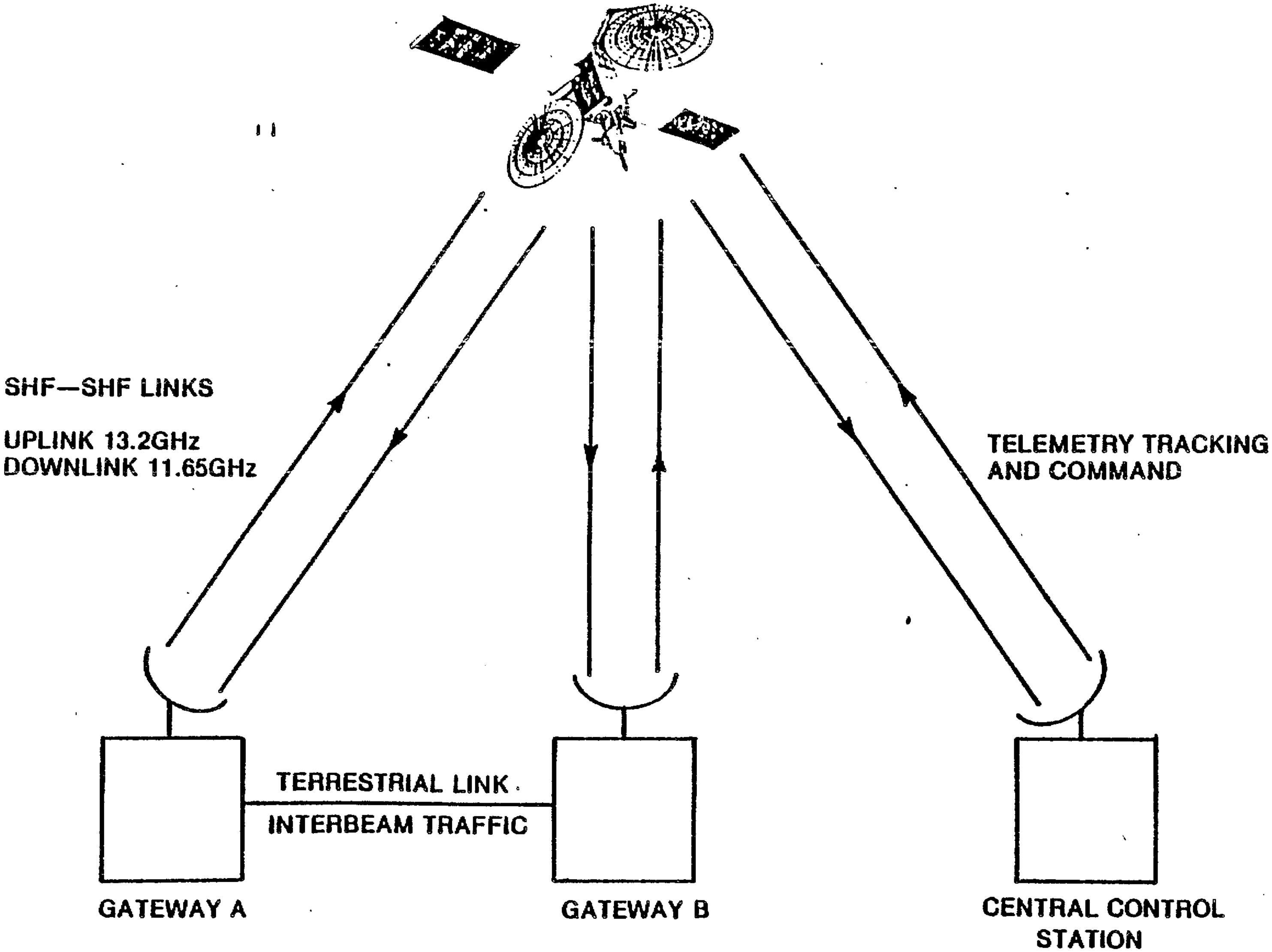


Figure 2.2

MSAT CONTROL HIERARCHY

2.3 (cont'd)

covers all gateways and SHF bases, they may access any UHF channel in the system. The return link from the mobile to the gateway is uplinked at UHF and downlinked at SHF which restricts the mobile to access into the 1 MHz UHF beam allocation within which it resides (neglecting overlap areas). However, its transponded SHF downlink can be received at all gateway or SHF base stations. Figure 2.3 illustrates the UHF/SHF path through the satellite.

Mobile/UHF base to mobile/UHF base calls may be established on the UHF cross strap for intrabeam calls or double hop via a gateway for either intrabeam or interbeam calls. Figure 2.4 and 2.5 illustrates these connections.

All accesses at 800 MHz will use FDMA. Because of the geographic separation of the Western and Eastern Canadian 800 MHz footprints, spectrum will be simultaneously assigned to users in the two beams. By appropriate interconnection in the satellite in the UHF/SHF mode, the UHF bandwidth of each beam is translated to a unique portion of the backhaul SHF bandwidth. Thus even where a UHF frequency is reused in separate footprints, each of the channels is uniquely addressable in the SHF backhaul signal by any of the gateway stations.

The MSAT 800 MHz communications systems is being designed to permit the simultaneous operation of mobiles utilizing any of three modulation/coding schemes. NBFM, compatible with the proposed terrestrial 800 MHz cellular system, will permit the evaluation of terminals capable of switching between terrestrial and satellite mobile telephone service. The ACSSB system will test the feasibility of this potentially high voice quality, bandwidth efficient, wide dynamic range technique. Digitally-coded voice also shows very good long term potential although current LPC codecs cannot provide toll quality voice at 2.4 Kbps. As LPC represents a maturing technology, there is a good probability that toll quality will be available at rates as low as 2.4 Kbps during the demonstration period and this rate has been selected for the digital codec. Voice security can easily be implemented using this technique.

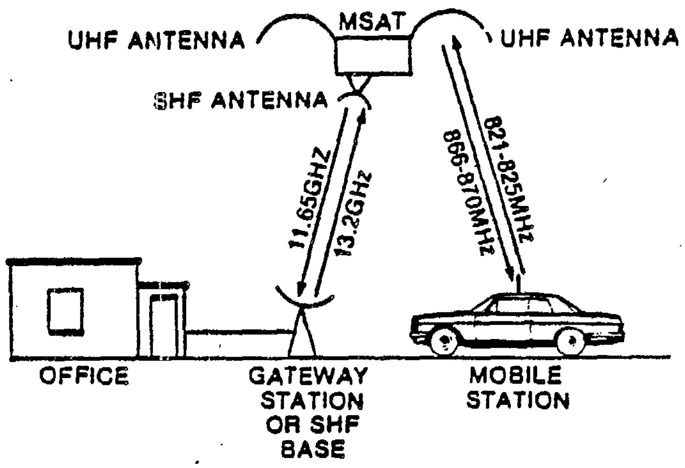


Figure 2.3

SHF/UHF 800 MHz SERVICE

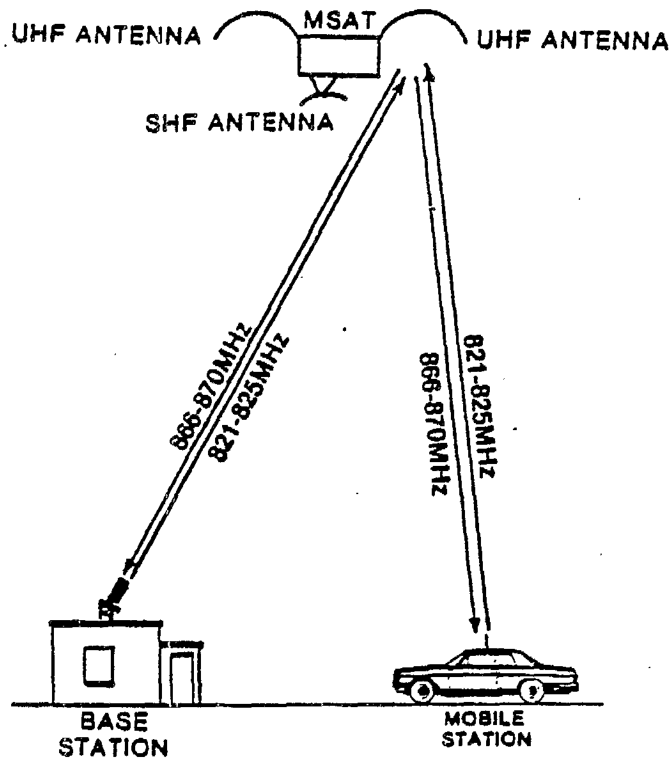


Figure 2.4

UHF/UHF 800 MHz SERVICE

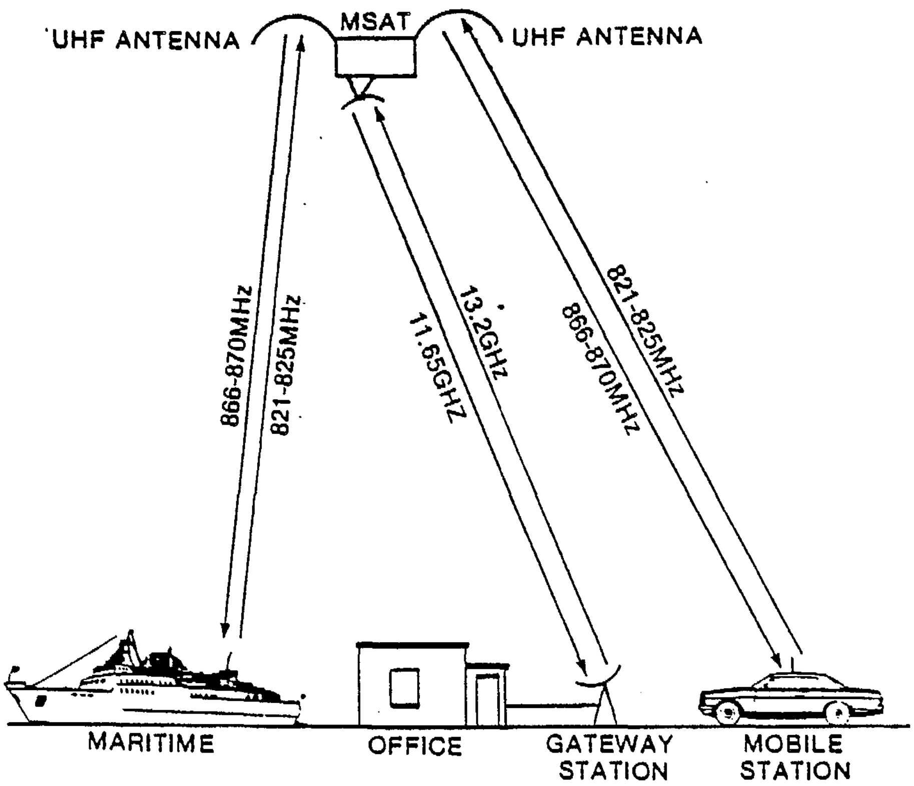


Figure 2.5

INTER-BEAM 800 MHz SERVICE

3.0 FREQUENCY REQUIREMENTS

The frequency requirements for the MSAT Demonstration system (excluding the DND requirements) are as given in Table 3.1.

Table 3.1

FREQUENCY REQUIREMENTS MSAT DEMONSTRATION SYSTEM

MRS, MTS & DS uplink from mobile, DCP uplink	821 - 825 MHz
MRS, MTS and DS downlink to mobile	866 - 870 MHz
Gateways and SHF base stations uplink	13.20 - 13.25 GHz
Gateways and SHF base stations downlink	11.65 - 11.70 GHz
Telemetry Tracking and Command uplink	2.090 GHz
Telemetry Tracking and Command downlink	2.270 GHz

4.0 PROPAGATION

4.1 Mobile Links in the 800 MHz Band

The two most important propagation factors to be considered for mobile communications in the 800 MHz band are fading due to multipath and shadowing by terrain obstacles. Rain attenuation is not significant in this band and the effects of Faraday polarization plane rotation are avoided by the use of circular polarization. Ionospheric scintillation can cause some small losses at locations near the equator and at high latitudes at certain times of the year; however, for most applications its effects can be neglected. Each service has its own unique propagation characteristics which will be described in more detail.

4.1.1 Land Mobile Service

In urban areas measurements have indicated that line-of-sight shadowing is so frequent that diffuse scattering from buildings becomes the main propagation mode, resulting in large propagation margins being necessary. Margins greater than 30 dB are required for coverage 90% of the time over 90% of the locations.[2] The MSAT system is not designed for operation in this environment.

In suburban and rural areas where direct line-of-sight conditions are more usual, diffuse multipath reflections from the ground and nearby objects coupled with shadowing by trees and other obstacles are the factors which determine the necessary margin. It has been determined that, under line-of-sight conditions, the multipath signal is typically from 10 to 13 dB below the line-of-sight signal. The received signal level variations are modelled very accurately by the Nakagami-Rice distribution function.

Shadowing by terrain obstacles such as trees is modelled by the log-normal distribution. Experiments have indicated that foliage provides a mean attenuation of

[2] CCIR, SG-8, Document 8/91, 11 August 1980.

4.1.1 (cont'd)

about 0.3 dB/m in the 800 MHz band. Where shadowing is continuous and for elevation angles in the range 15-20°, the long-term mean attenuation is 7 dB with a standard deviation of about 6 dB. Further work is in progress at CRC to establish a model of the channel fading characteristics under various terrain and elevation angles. These parameters will be determined for several environmental categories such as: four-lane highway, highway through improved terrain, highway through unimproved terrain, etc. This will enable determination of an accurate value for the propagation margin to the mobile. The goal is to provide reliable service for 99% of the time.

The link margins for the MSAT 800 MHz part of the UHF-SHF, SHF-UHF links are:

	Return Link	Forward Link
NBFM	13 dB to Minimum Quality	5 dB to Toll Quality
ACSSB	5 dB to Toll Quality	5 dB to Toll Quality
DMSK/PELPC	13 dB to Minimum Quality	13 dB to Minimum Quality

4.1.2 Maritime Mobile Service

For this service of multipath is more severe. The effects of shadowing by the ship's superstructure are in general much less than the shadowing problem in the land mobile case. The net result is that it can reasonably be assumed that about the same power level will be required from the satellite to the ship as in the land mobile case. To give a single figure for the propagation margin is not feasible, as this varies with elevation angle and antenna discrimination characteristics (i.e. both directivity and polarization factors).

If only directivity discrimination against multipath is assumed, then to provide an adequate signal at the maximum fade depth under smooth-sea conditions (worst case) an antenna gain of 11 dB is required for NBFM service.[3] This allows for

3 Canadian Astronautics Ltd., "A Study of MSAT Shipborne Antennas", DOC Contractor Report, DOC-CR-SP-82-002.

4.1.2 (cont'd)

operation down to five degrees elevation and includes a small margin for shadowing, pointing errors and a 2 dB allowance for ionospheric scintillation at high latitudes. It should be noted that the use of a land-mobile vehicle antenna which could discriminate in both directivity and polarization against low angle-of-arrival multipath signals may be feasible, and will be evaluated as part of the channel modelling task at CRC.

4.2 Backhaul Links in the 11/13 GHz Bands

The gateway stations will be located so that the elevation angle to the satellite is in the region of 30°. The main excess path loss in the 11/13 GHz band is due to rain attenuation. This has been characterized and for 99% availability, 2.7 dB and 2.1 dB margins are included, with tropospheric absorption contributing 0.3 dB, resulting in a total propagation margin of 3.0 dB and 2.4 dB at 13 GHz and 11 GHz, respectively.

4.3 Mobile and Transportable Antennas

Annex B indicates the types of antennas being considered for mobile and transportable terminals.

5.0 DAMA AND NETWORK MANAGEMENT

5.1 General

In order to make maximum use of the satellite trunks, they will be pooled within beams, by type of service (MRS or MTS), except for dedicated channel MRS users. These users will require interconnect among other users within their own community of interest which will be one of the functions of the DAMA system. The DAMA system must therefore identify incoming user demands for service, route the call, make the interconnection and return the trunk to the pool at call termination. As the MTS and MRS have different calling rates, holding times per call and interconnect requirements, two separate systems are planned sharing the same processor and switching matrix, with each system being optimized for its service characteristics.

The DAMA system will consist of the DAMA controller and the mobile radio DAMA processor which will interact via the demand and assignment channels to exchange information on the call processing. The system must:

- Ensure that users are interconnected only to other prescribed users and that channel spacing and modulation type are compatible.
- Know the status of users within their own beam and have access to information on users within other beams.
- Route and supervise interbeam and intrabeam calls via the UHF-SHF and UHF-UHF links including double hop, if necessary.
- Make efficient use of the demand and assignment channels with a minimum hand shaking to counter satellite propagation delays.
- Automatically repeat or correct signalling messages corrupted by message overlap or fading.
- Provide the necessary traffic information required by the network management system.

5.1 (cont'd)

- Be capable of being expanded to accommodate the increased users and number of gateways in an operational system.

Previous studies have indicated that the DAMA system can be distributed to gateways with each gateway controlling channel assignment and switching in its beam area. In the demonstration system, with Canada wide coverage of the SHF backhaul a master gateway could be used with a single processor controlling the switching matrices of slave gateways. A decision on a centralized or distributed system will be made based on technical and financial considerations. If a centralized system approach is taken, the master gateway, Network Management System (NMS) and CCS could be colocated.

5.2 Mobile Telephone Service

Mobile telephone users must be capable of originating and receiving calls to and from other mobile telephone users and STN subscribers. Signalling will be automatic and the gateway interface will be transparent to the user. The gateway will process all calls, provide numbering conversion, maintain a subscriber list, store billing information and interface the MSAT protocols with the STN requirements Supervisory signals (called party busy, not available, ringing, etc.) will be generated at the mobile terminal and controlled by the DAMA processor. As far as possible, compatibility with the terrestrial cellular system is desirable.

5.3 Mobile Radio Service

Mobile radio users must be capable of originating and receiving calls to and from other mobile subscribers, UHF and SHF base stations and its serving gateway; however, access can be restricted to members of the users group. The DAMA processor must process intrabeam and interbeam calls, maintain a subscriber list and classmarking, store billing information, control mobile subscriber supervisory

5.3 (cont'd)

signals and exchange information with other beam processors. The mobile terminal DAMA module must generate the supervisory signals, respond to commands received via the assignment channel and process information for the demand channel. The MRS numbering plan must accommodate expansion to an operational system but be flexible enough to provide abbreviated dialing to members of a user group.

5.4 Network Management System

The Network Management System (NMS) must optimize system utilization, store and analyze network data, reconfigure the network for overload conditions or subsystem failures and maintain a current network status log. Status information will be fed to the NMS from gateway stations via the SHF-SHF links and from the satellite telemetry data forwarded from the CCS. Historical logs as necessary will be kept for future analysis. Commands (load shedding, user beam allocation, etc.) to the gateways will be forwarded via the SHF-SHF link. Requests for transponder reconfiguration (gain settings, UHF-UHF routing, etc.) will be sent to the CCS. Systemwide alarm status will be maintained. The NMS may be colocated with the CCS or master gateway depending on technical and financial factors.

6.0 COMMUNICATION SYSTEM DESCRIPTION

6.1 Communications Concept

The 800 MHz services will operate in a single channel per carrier frequency division multiple access (SCPC/FDMA) mode. The accesses are all translated on the mobile uplink in the 821-825 MHz band to six unique 1 MHz slots in the 11.65-11.70 GHz band. The gain in this path is adjustable and is optimized for NBFM. Gateways operating to a mobile will uplink in the 13.20-13.25 GHz which is translated to the beams unique 1 MHz allocation in the 866-870 MHz band. As gateways operate in the Canada wide SHF footprint they can access all UHF beams while the mobile can only access the UHF beam footprint in which it is located, or in two beams if in an overlap area. This Canada wide coverage of the gateways enables them to interconnect two mobiles, in different beams via a UHF-SHF-SHF-UHF connection. In the MRS UHF crossstrap, 240 KHz of the mobile uplink band is filtered and translated 45 MHz to the UHF downlink. The gain in the this path is adjustable over 20 dB in 1 db steps, with the gain setting being optimized for DMSK/PELPC.

In the SHF crossstrap direct translation with a 1.55 GHz offset is used. The gain in this path is also adjustable and will be set for the most stringent requirement of the services carried (NBFM voice or DATA). Figure 2.1 illustrates these interconnections.

6.1.1 Modulation, Source Coding, Channel Quality Considerations

6.1.1.1 MRS & MTS Services

The three modulation and access techniques used in the MRS and MTS are FDMA/NBFM, FDMA/DMSK/PELPC and FDMA/ACSSB. The satellite and gateway stations will be designed to allow different combinations of the signals to operate simultaneously through the UHF/SHF and UHF/UHF transponders.

6.1.1.1 (cont'd)

The system is designed to provide at least a specific minimum voice quality only for a certain percentage of locations and time. Typically 99% of the time quality will exceed the specified minimum value. Certain conditions will tend to augment voice quality, such as mobile operation near beam centre, or with clear line-of-sight to the satellite, or in off-peak hours. On the other hand a vehicle operating at beam edge in a region with significant path shadowing at peak traffic time will likely suffer sub-minimum quality for significantly greater than 1% of the time. It should be noted however that in most situations with shadowing, the major part of a conversation will be good quality, with only occasional, short signal dropouts. It is expected that the user will rapidly gain experience in the fading characteristics of the environment he is operating in, and take measures to optimize the radio path.

For the terrestrial cellular systems, 10.5 KHz peak deviation, 2:1 companded FM; a C/N_0 of 53 dB-Hz has been shown to provide toll quality, while 45 dB-Hz provides a minimum acceptable quality. Using the criteria for margins stated in para. 4.1.1, the unfaded C/N_0 requirement on the return link will be 58 dB-Hz and 56.3 dB-Hz on the forward link. These criteria provide a 13 dB fade margin to minimum quality on the return link, and a 13.9 dB fade margin to minimum quality on the forward link.

Based on an 8 dB E_b/N_0 providing a 10^{-3} BER and 5 dB providing a 2 x 10^{-2} BER for DMSK, with these two error rates providing full and minimum quality respectively with LPC codecs, then for PELPC at 2.4 Kbps data rate the C/N_0 requirements translate to 42 and 39 dB-Hz. The unfaded C/N_0 with 13 dB margin on the return link becomes 52.0 dB-Hz, while that on the forward link becomes 49.4 dB-Hz.

Only preliminary results are available for ACSSB; tests are underway at CRC to refine the values of C/N_0 requirements for toll and minimum quality. Values which are considered conservative are a C/N_0 of 48 dB-Hz for toll quality and 33 dB-Hz for minimum quality where the "C" represents the average power of the carrier. The unfaded C/N_0 with margin on the return link becomes 53 dB-Hz while that on the forward link becomes 51.3 dB-Hz. These result in fade margins of

6.1.1.1 (cont'd)

21.0 and 20.0 dB for the return and forward link respectively. Figure 6.1 illustrates the channel performance under fading conditions.

6.2 Space Segment Parameters

In this section, parameters of the space segment which impact on the communication system design will be considered and specified. As some parameters are interactive, values for discussion will be drawn from section 7, where the total link performance is evaluated based on the need to achieve specific communications performance.

6.2.1 Spacecraft Antenna and Feed Systems

To meet the coverage requirements shown in Figure 1.2 multiple horn feeds, dual band feeds and beam forming networks are required for the different antenna systems. Due to the irregular patterns of some antennas, EOC gain is specified for the footprints.

6.2.1.1 800 MHz Antenna System

Two 9.14 m aperature, offset-fed parabolic reflectors fed by individual horns for the Canadian Western and Eastern beams and multihorn feeds and a beam forming network for the Canadian interior beams and the US beams are used. Figure 6.2 illustrates the feed arrangement for the 800 MHz and 400 MHz systems. Losses associated with the 800 MHz feed system are summarized in Table 6.1. Right-hand circular polarization will be used for the 4 Canadian beams and left-hand circular polarization for the 2 US beams.

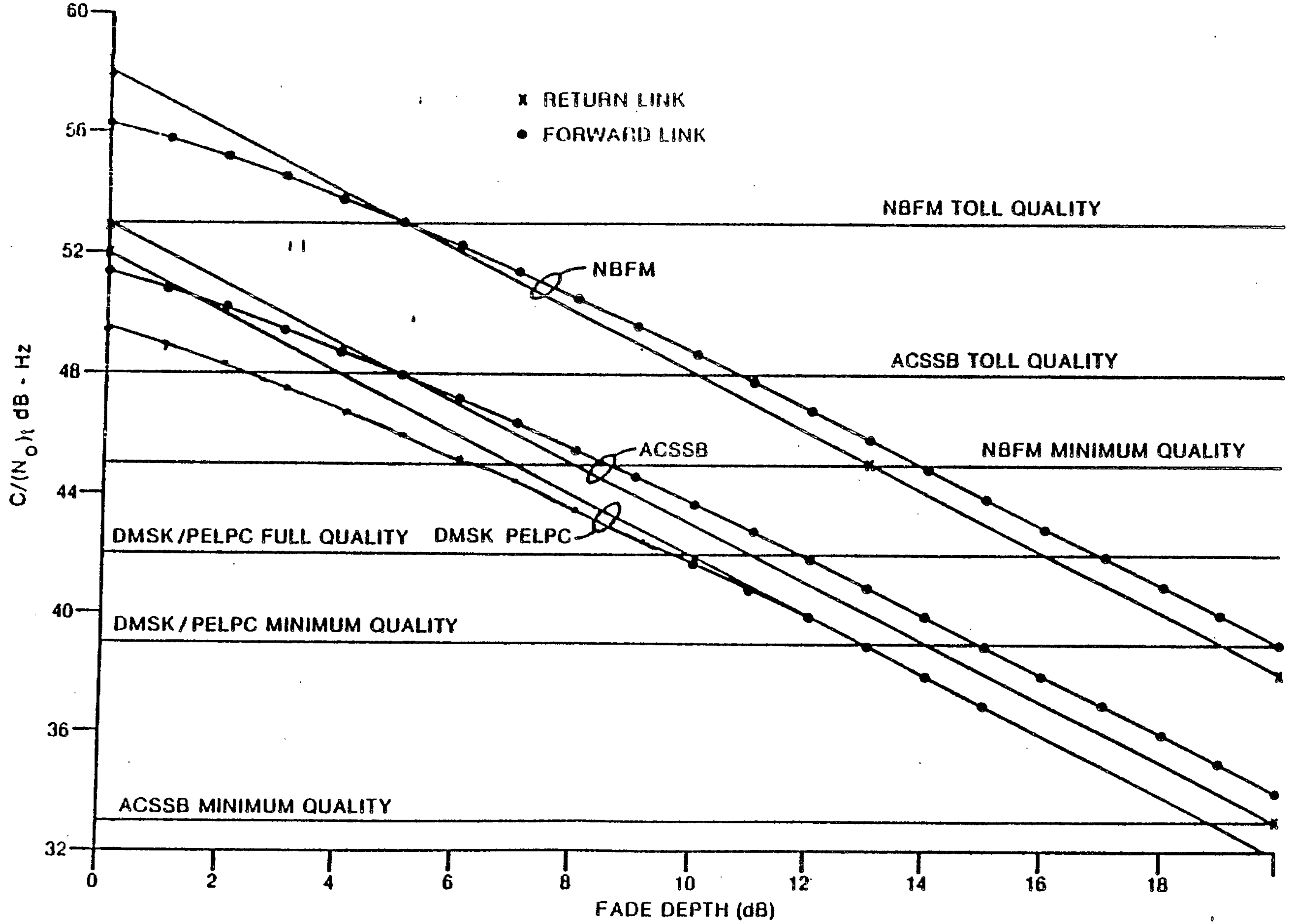


Figure 6.1

FADING PERFORMANCE OF DIFFERENT MODULATION SCHEME

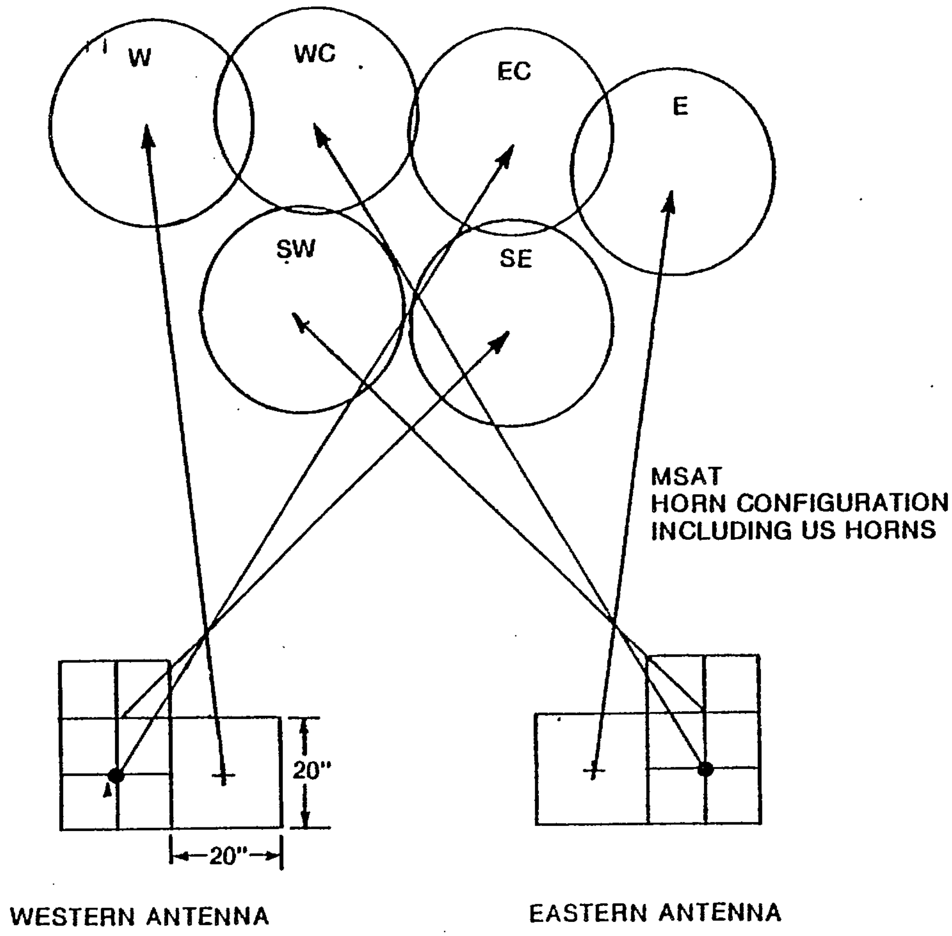


Figure 6.2
MSAT UHF FEED CONFIGURATION

Table 6.1

SATELLITE 800 MHz FEED SYSTEM LOSSES

LOSSES	EASTERN & WESTERN CANADIAN BEAMS		INTERIOR CANADIAN & US BEAMS	
	TRANSMIT 868 MHz	RECEIVE 823 MHz	TRANSMIT 868 MHz	RECEIVE 823 MHz
Edge of Coverage Gain in dB	32.5	32.0	33.0	32.5
Cabling Loss in dB	0.7	0.7	0.7	0.7
Redundancy Switch Loss in dB	0.2	0.2	0.2	0.2
Duplexer Loss in dB	0.8	1.4	0.8	1.4
Beam Forming Network Loss in dB	-	-	0.5	0.5
Polarizer Loss in dB	0.2	0.2	0.2	0.2
Margin in dB	0.5	0.5	0.5	0.5
Net Antenna EOC Gain in dB	30.1	29.0	30.1	29.0

6.2.1.1 (cont'd)

The G/T_s of the receive systems can be derived from the antenna gains specified above at edge of coverage, and from the system temperature T_s, referred to the antenna, given in the following formula:

$$T_s = T_a + ((1 - L)/L)T_o + (1/L)T_r$$

where T_a is the antenna noise temperature in degrees K.

T_r is the receiver noise temperature referred to the LNA input in degrees K.

T_o is the temperature of the loss elements in degrees K.

L is the loss (as a decimal fraction) between the antenna terminals and the LNA

$$L = 10^{-0.1L_r}$$

L_r is the loss in dB between the antenna terminals and the LNA.

A 1.5 dB noise figure is used for the 800 MHz receiver, giving

T_r = 120°K. For L_r = 3.0 dB, L = 0.50. With $T_o = T_a$ = 290°K, T_s=818°K or 29.1 dBK.

For G = 32.0 dB, G/T_s = 2.9 dB/K, without including an allowance for pointing loss.

For the 13 GHz receiver a 4 dB noise figure is used with input losses of 1.5 dB and $T_o = T_a$ = 290°K, T_s = 29.1 dBK. With an antenna gain at EOC of 29 dB,

$$G/T_s = -0.1 \text{ dB/K}.$$

An allowance of 0.5 dB degradation in C/N_o is allocated to all sources of IM interference and spurious signals for 800 MHz service signals passing through the satellite. Some of the major sources are discussed later in this section with an indication of their impact on satellite parameters.

6.2.1.1 (cont'd)

No margin is recommended for pointing errors of the satellite antennas on the demonstration satellite. North-South movement of the satellite antenna will have some effect on the gain as seen from the small triangles above and below the regions of footprint overlap (Figure 1.2); however, service from the northern triangle will likely be only from transportable terminals or units with higher antenna gain and little shadowing loss. Intermodulation in the satellite will constrain the amount that the downlink carrier, to these terminals can be reduced below the power required to a mobile; thus the signals to a transportable will generally be well above minimum quality. Service to the southern triangle will be to terminals with a reduced path loss and a higher elevation angle to the satellite than the value assumed in the EOC areas: this improvement should compensate for the possibility of up to 1 dB loss of antenna gain due to satellite motion.

6.2.2 Uplink and Satellite Contribution to Forward $C/(N_o)_t$ at 800 MHz UHF/SHF Mode

On the forward path, it is desirable to make the uplink and satellite noise contribution to the overall noise budget minor in relation to the power critical downlink. A practical allocation is to limit the satellite contribution, C/I_o (intermodulation (IM), interbeam interference, spurii, etc.) to a reduction in overall C/N_o of 0.5 dB resulting in:

$$C/I_o = C/(N_o)_t - 10 \text{ Log } (1 - 10^{-0.05})$$

$$C/I_o = C/(N_o)_t + 9.6 \text{ dB}$$

Using the same value for the uplink $(C/N_o)_u = C/I_o)$, the percentage noise allocation becomes; uplink 11%, satellite 11% and downlink 78% or 9.6 dB, 9.6 dB and 1.1 dB above $C/(N_o)_t$.

6.2.2 (cont'd)

Since it is required to demonstrate toll quality with up to a 5 dB fade for NBFM and ACSSB, the noise parameters must be specified with respect to full quality $(C/N_o)t$ of 53 dB-Hz and 48 dB-Hz respectively resulting in the following noise allocations under faded conditions.

GATEWAY TO MOBILE

	5 dB FADE TO TOLL QUALITY				FADE DEPTH TO MINIMUM QUALITY		
	$(C/N_o)u$ dB-Hz	C/I_o dB-Hz	$(C/N_o)d$ dB-Hz	$(C/N_o)t$ dB-Hz	$(C/(N_o)d$ dB-Hz	Fade dB	$(C/(N_o)t)$ dB-Hz
NBFM	62.6	62.6	54.1	53.0	45.2	13.9	45.0
ACSSB	57.6	57.6	49.1	48.0	33.1	21.0	33.0

(Note: The requirement for all ACSSB channels to provide toll quality with up to a 5 dB fade may be relaxed when a better assessment of the overall quality is available).

The above figures are based on the assumption that the satellite input power is constant and that thermal noise is the dominant contributor on the uplink.

The previous noise allocation is straight forward for NBFM and ACSSB as both have a 5 dB downlink fade to full quality; however, the DMSK/PELPC is faded 13 dB to minimum quality, and to maintain the same ratios a different transponder gain would be necessary. This is unacceptable and the transponder gain is set for the analog requirement and the DMSK/LPC budgets adjusted while maintaining the same interference allocation. This results in a noise allocation of 2.1% and 2.1% and

6.2.2 (cont'd)

95.8% at minimum quality, corresponding to 16.7, 16.7 and 0.2 dB above the total noise budget. The effect of the common transponder gain is to increase the SHF EIRP and reduce the UHF EIRP.

6.2.3 800 MHz Return Link Allocations, UHF/SHF Mode

In order to keep the cost of the mobile as low as possible and consistent with available devices, a limit of 10 dBW maximum has been established for the mobile transmitter PA power output. This represents a maximum EIRP of 13 dBW for the NBFM mobile transmitter. Using the same criteria as previously established for satellite degradation of 0.5 dB with respect to the overall C/N_0, which represents 11% of the link noise budget, values of 59% and 30% are allotted to the uplink and downlink, respectively. This result in $C/(N_0)_u = C/(N_0)_t + 2.3$ dB; $C/I_0 = C/(N_0)_t + 9.6$ dB; and $C/(N_0)_d = C/(N_0)_t + 5.2$ dB.

6.2.4 SHF Backhaul Parameters

With reasonable care in the design of the satellite backhaul receiver, its contribution to the C/N_0 degradation of a transponded signal should be negligible compared to the other sources of degradation. The satellite backhaul transmitter, however, presents a more difficult design problem. Feeding into this transmitter will be a host of signals; DCP and EPIRB signals at 400 MHz, a widely varying number of 800 MHz signals which individually are fading, SHF/SHF cross-strap signals, and 800 MHz data signals. Even with these services grouped to ensure that low-order IM is from like services, the selection of the TWTA operating point will have a critical effect on intermodulation interference on this return link. The TWTA design will be the responsibility of the spacecraft supplier; who must ensure that its contribution to total link C/N_0 degradation must only be a fraction of the 0.5 dB transponder allowance.

6.2.5 Intermodulation, Frequency Reuse and Adjacent Channel Interference at 800 MHz

The various modulation techniques have differing sensitivities to co-channel energy and will, because of their different carrier levels and characteristics, cause differing levels of interference when they mix in a non-linearity. In addition to the above, the return link will have a different (and more difficult) specificaion for co-channel interference than will the forward link. The result is a very complex matrix of interference specifications.

Beginning with the effect of link direction, the major factor here is whether or not the interference fades when the signal fades. In the forward direction (to the mobile), the sources of co-channel energy (IM and sidelobe energy from frequency reuse in another beam) originate from the same location as the desired signal; i.e. the satellite. Thus both signal and interference will fade simultaneously and equally. The protection ratio for the forward UHF link is thus equal to the allowed C/I for this source of interference for the modulation utilized.

On the return link however, the sources of UHF interference are other mobiles reusing the same assignment and being received through sidelobes of the desired beam.In this case the interferers and the desired signal will fade independently. The worst case would be all reuse channels active and unfaded, with the desired signal fully faded. A more practical scenario would have fewer than the full set of reuse channels active, due to less than full assignment and to voice activation of uplink carriers. Although either the desired or interfering carriers can be at beam centre or at edge of beam, this factor will not be considered here. The conclusion is that the protection ratio for side-lobe interference on the return link will have to be about 13 dB higher than the C/I which would be allocated to this source of interference in the absence of fading.

For the digital services, DMSK modulation is planned. It is relatively bandwidth efficient (e.g. compared to PSK) and has good spectral control of energy spilling into adjacent channels. Differential detection will be used as it is much simpler to realize than coherent detection and has some advantages in fast acquisition and recovery from fades, however there will be a larger implementation

6.2.5 (cont'd)

loss with the differential technique. Experiments have shown that a coherent MSK detector's sensitivity to co-channel interference is about the same as to an equal power of white noise. A differential detector of MSK is expected to act similarly, unless the interference source has a coherence period which bridges more than a bit period of the desired signal. In order to control the level of co-channel interference from frequency reuse, it is expected that similar services would guarantee that the co-channel interference from frequency reuse would have a coherence period equal to the desired signal, and that the interfering source power level was the same as the desired source. Co-channel energy from intermodulation, however, could have the characteristics of any of the source signals.

In the critical return link (in terms of antenna sidelobe energy from frequency reuse) the digital modulation would require the total sidelobe interference to be significantly below the fully-faded desired signal. If the interference can be treated as noise, and if 1 dB of link degradation can be ascribed to this source, the interference would have to be 6 dB below noise level or about 14 dB below signal level for a fully-faded signal. For a single interference source this would require sidelobes down at least 27 dB from the main lobe. This severe a sidelobe specification is probably not realizable. If the probability of a 13 dB fade and the simultaneous presence of an interferer is a rare event, one could probably relax the voice quality requirement from "full" to "minimum" during this occurance. This would allow the interference power to equal the noise power (i.e. a 3 dB S/N degradation) at 8 dB below the fully-faded carrier. The resultant sidelobe specification would now be 21 dB for a single interference source, which is much more realizable.

Experiments with NBFM have shown that, where the desired and interfering signals are co-channel and fade simultaneously, it is sufficient that the interfering signal be maintained 8 dB below the desired signal. At this point there is a noticable, but acceptable degradation in voice quality. If this quality is also acceptable for the satellite system, and the 8 dB protection must be provided for a fully-faded signal, then the antenna sidelobes for a single interferer would have to be at least 21 dB below the main lobe.

6.2.5 (cont'd)

It has been stated that the required C/I to maintain toll quality for ACSSB was a peak signal to peak interference ratio of 17 dB. Measurements to substantiate this will be undertaken at CRC. In the critical return link ACSSB would require the total sidelobe interference to be 17 dB below the fully faded desired signal. For a single interference source this would require sidelobes down greater than 30 dB from the main lobe. Again these sidelobe levels are too severe, and would only be necessary if full quality must be maintained. Until measurements are made it will not be possible to estimate the tolerable co-channel interference for a degraded ACSB signal at the bottom of a fade. It should be noted that both NBFM and ACSSB can demodulate some types of interference as intelligible audio, which is much more objectionable than noise.

Summarizing the interference problem on the UHF uplink from antenna sidelobes and frequency reuse, it appears that ACSSB is likely more sensitive than NBFM or digital modulation, with the latter two requiring sidelobes 21 dB below mainlobe for a single interferer for acceptable degradation in voice quality at the bottom of a fade. It should be noted that IM on the SHF backhaul (or UHF downlink for cross-strapped channels) will also add degradation to the total return link and must be factored in. This is discussed later in this section.

On the UHF forward link, as stated earlier, the mainlobe desired signal will track the sidelobe interfering signals in a fade. The sidelobe specifications from this source would be much less severe than with the return link; hence the return link values will be the determining ones.

Intermodulation interference from the UHF power amplifier will be the largest contributor to co-channel degradation on the forward link, and hence must receive amajor share of any degradation allowance. Specifying the IM as a fraction of the total noise plus interference budget at minimum quality (i.e. at the bottom of a downlink fade) would provide unacceptable quality in the absence of a fade (i.e. interference would equal or exceed noise for NBFM or ACSSB). To avoid this problem, IM interference is specified at the full quality point on the forward link.

6.2.5 (cont'd)

In the digital modulation case, a budget of 0.5 dB link degradation has been allotted for all sources of spurious signals on the satellite. This implies, for a C/I_0 of 55.7 dB-Hz and a bit rate of 33.8 dB-Hz, that the contribution of the spurri be at least 21.9 dB below E_b. If the UHF power amplifier IM is allocated half this allowance, its products must have a spectral density at least 24.9 dB below E_b. Assuming the mobile receiver noise bandwidth is equal to the digital bit rate, the ratio of carrier power to integrated IM over the receive bandwidth will need to be 24.9 dB minimum.

For NBFM, the contribution to the toll $C/(N_0)_t$ of 0.5 dB from sources other than thermal noise gives a C/I_0 of 62.6 dB-Hz. Allowing IM from the power amplifier one half this allowance makes C/IM_0 = 65.6 dB-Hz. Assuming a noise bandwidth of 27 kHz, the minimum requirement for C/IM is 21.3 dB for NBFM.

For ACSSB, with a C/I_0 of 57.6 dB-Hz, allowing one half this allowance to IM gives a C/IM_0 of 60.6 dB-Hz. For an assumed receiver noise bandwidth of 3.0 kHz, the minimum requirement for C/IM is 25.8 dB.

The above numbers for C/IM now need to be translated into a general IM specification for the satellite power amplifier. What complicates this conversion is the variety of carrier levels and spectral content which will be present in the UHF power amplifier. Taking NBFM as the 0 dB reference, PELPC channels will be -6.9 dB in power, and ACSSB will be -5.0 dB. The digital channels will have almost a flat spectrum across their bandwidth. NBFM with a low audio input signal level can appear like an unmodulated carrier, while with full modulation it is fairly flat in spectrum. ACSB with its "whitening" preemphasis will look fairly flat across its channel, but with widely-varying signal amplitude.

One operational feature which may simplify the IM design is that of grouping similar services together in the downlink UHF amplifier passband. With this grouping, the dominant low-order IM will fall on services of a similar power level. Based on this factor and on the fact that larger carriers will experience a greater

6.2.5 (cont'd)

non-linearity in the amplifier, it will be assumed that a two-tone, third order IM specification of 20.8 dB utilizing two carriers each 3.5 dB higher than a nominal NBFM signal will be an adequate specification for the P.A. It should be noted that, except in the most-constrained version of MSAT, two carriers will not bring the down-link UHF amplifier anywhere near saturation. To properly assess the nonlinearity the PA will have to be loaded with multiple signals, simulating a full peak-hour loading, with the two tones being part of the total signal environment.

Adjacent channel interference must also be controlled. The specification for a satellite system will be much less severe than for a terrestrial mobile system. The terrestrial system must account for a transmitter which is located close to a receiver being on a channel adjacent to the channel being used by a distant transmitter. Adjacent channel energy specifications 60 to 80 dB below the assigned channel are typical. In the satellite case, all adjacent channels originate from the same distance. Again the worst case is on the UHF uplink where the desired signal may be faded by 13 dB while the adjacent signals are unfaded. If a severe specification is assumed; i.e. that an adjacent channel signal (assumed to be similar in type to the desired signal) contributes no more than 0.1 dB degradation to link performance, then the adjacent channel spillover must be at least 16.4 dB below noise level in the desired channel for a single interferer and 19.4 dB for two interferers (i.e. both adjacent channels are assigned).

Using the fully-faded level (13 dB) on the desired channel on the return link with noise bandwidths as stated above, the adjacent channel spillover integrated across the desired channel must be at least 37.6 dB below the unfaded interfering adjacent carrier level for DMSK/LPC, 33.1 dB in the NBFM case, and 37.6 dB in the ACSSB case.

6.2.6 UHF/UHF Cross-Strap for the 800 MHz Service

The UHF-UHF cross-strap consists of a broad band UHF receiver with

6.2.6 (cont'd)

commandable gain of 20 dB in 1 dB steps cross connected to the UHF power amplifier. The gain setting is used to set the PA power level for the different operating conditions as the satellite load changes with the number of users.

The effect of an uplink fade on a fixed gain transponder is to reduce the $(C/N_0)_u$, the C/I_0, and consequently the $(C/N_0)_d$. A downlink fade on the other hand only reduces the $(C/N_0)_d$. To illustrate the significance of an uplink fade on overall link performance, consider a mobile - mobile link using DMSK/PELPC. Assuming that a clear line of sight uplink signal at boresight will drive the satellite UHF PA to the same level as a SHF unfaded uplink, then a 13 dB uplink fade will result in a $C/(N_0)_t$ of 36.4 dB-Hz which is below minimum quality. The maximum uplink fade under the above conditions to minimum quality is 10.4 dB. A downlink fade of 13 dB results in minimum quality.

The mobile EIRP is fixed in relation to the UHF-SHF requirements; therefore when operating in the UHF-UHF mode, a mobile signal at the UHF PA input at EOC will on an average be 1.5 dB below the SHF signal resulting in a 1.5 dB reduction in C/I_0 and downlink power for the mobile terminal. This factor is included in the mobile UHF-UHF link budgets given in Table 7.1. The net effect is a reduction in the overall margin. Figure 6.3 illustrates the combinations of uplink and downlink fades that result in minimum quality.

Table 7.1 shows the expected performance for different cross-strap terminal operation. Note that the margins assumed vary for the different examples and that the services with wider differences between full and minimum quality fare better in the cross-strap mode.

Some assumptions made in Table 7.1 are:

a) The unfaded C/I_0 in the satellite the C/I_0 on the feeder-transponder signal. As the UHF uplink carrier is reduced due to fading, the C/I_0 falls equally.

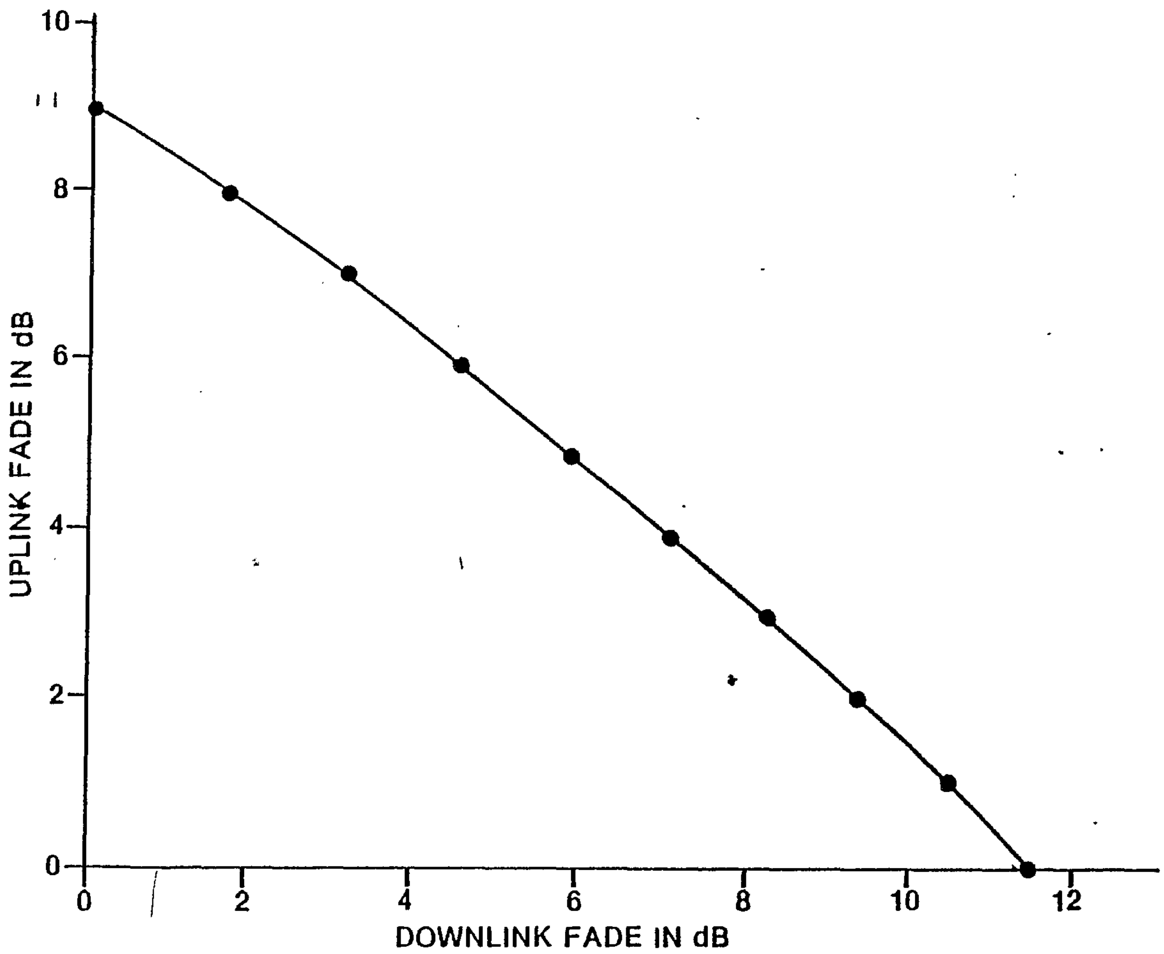


Figure 6.3
FADE DEPTH TO MINIMUM QUALITY
MOBILE/MOBILE - DMSK/PELPC

6.2.6 (cont'd)

b) A base unit operates with a 6 dB higher antenna gain than a mobile and with good circularity. The base EIRP is adjusted to equal the mobile EIRP less the 0.5 dB ellipticity margin (i.e. provides the same signal at the satellite). The base receive C/N_0 is 6.5 dB higher than the mobile due to the higher antenna gain and lack of ellipticity loss.

c) For a base station link, a 0 dB margin is assumed as shadowing and multipath fading should be absent. Margins are otherwise adjusted first on the critical uplink up to a minium of 13 dB, then on the downlink to result in at least minimum quality. Other combinations of up and down link fades can be utilized, but the above should present the worst case effect of fading.

6.2.7 SHF/SHF Cross-Strap

The SHF-SHF cross strap will carry a mixture of NBFM voice and data channels for information exchange between gateways and the CCS. The actual bandwidth and data rates necessary for these links will be established during Phase B. For planning purposes twelve 30 KHz channels (27 KHz noise bandwidth) are assumed with an overall $C/(N_0)_t$ = 54 dB-Hz. Using a noise allocation of 19%, 11% and 70% for the uplink, satellite and downlink results in $C/(N_0)_u$ = 61.3 dB-Hz, C/I_0 = 63.6 dB-Hz and $C/(N_0)_d$ = 55.5 dB-Hz.

6.2.8 Satellite Oscillator Stability

Phase noise in the satellite translation oscillators is one of the sources of degradation which will contribute to the total 0.5 dB signal degradation in $C/(N_0)_t$ due to the satellite. The allocation to this source will be left to the

6.2.8 (cont'd)

satellite designers. One of the signal parameters required in arriving at this allocation for the digital modulations is the 2400 bps bit rate which must be carried by the transponders.

For the NBFM, 800 MHz services, the translation oscillator specification will need to be in terms of degradation to a 10.5 KHz peak deviation 2:1 companded FM signal. Any translation oscillator degradation to an AM signal for the ACSSB service will need to be in terms of a 3.0 KHz-wide 4:1 companded, SSBAM signal.

Several options exist for realization of the long term stability of the translation frequency. The most straightforward is to utilize a reference oscillator with sufficient stability over the lifetime of the satellite. A drift of much less than 1 part in 10^7 per year would be required for this approach. A second option is to have a reference oscillator whose frequency can be corrected by ground command, where the oscillator stability is sufficiently high that corrections are required relatively infrequently. A third option for those services uplinking or downlinking through a gateway station is to apply an offset at the gateway to correct not only for the satellite oscillator drift (assuming moderate values), but also for the doppler offset due to the satellite motion. The 800 MHz service, total frequency offset error, including that due to the mobile oscillator, should be no greater than 500 Hz. Allowing half of this to the UHF/SHF translation on a backhauled channel (or half to each mobile in a UHF/UHF channel), means the net translation error should be less than 3 parts in 10^8.

6.2.9 800 MHz Power Amplifier Head-Room

The 800 MHz power amplifier in the satellite will be carrying simultaneously a variety of frequency and amplitude modulated signals of various amplitudes. The number of channels assigned will vary with time, assigned channel signals

6.2.9 (cont'd)

with appear and disappear with voice activation, and various carrier combinations will result in short-term peaks in total signal power. The above effects make the specification of the power amplifier difficult, particularly when coupled with a need to operate the power amplifier in a linear fashion to control the levels of intermodulation.

With a power-limited satellite having a relatively constrained capacity per beam, there are significant advantages to being able to transfer capacity between beams for short periods of time to service a peak demand in one beam. What has been considered is that sufficient headroom would be provided for each beam's power amplifier to supply the nominal (all assignable channels assigned) service assignment with a specified maximum level of intermodulation. If the demand for service in one beam exceeded its nominal assignment and other beams had less than full assignment, a temporary overassignment of the one beam would be made under control of the NMS. Under the overassigned condition the major effects would be that the intermodulation level would increase over the specified value in that beam, and the PA power dissipation would increase. Since the overassignment would generally only be a small fraction of the nominal assignment, these effects should not appreciably affect performance and only occur at the end of the satellite's planned service life.

The power supply and biassing of the satellite UHF power amplifiers will need to account for the various load variations and for the need to provide for head room for protection against intermodulation. The intermodulation specification is considered in section 6.2.4.

6.2.10 Voice Activation and Push to Talk

In the power-limited demonstration satellite system, the satellite capacity is significantly increased if channel carriers are removed during voice pauses in a conversation. In the forward link of the duplex MTS sesrvice and the backhauled

6.2.10 (cont'd)

MRS service this function can be performed by voice detection circuitry at the gateway station, assuming the analog voice signal is provided to the gateway (special provisions may be required where voice is digitized at a point remote from the gateway).

In the MRS service, an added advantage of mobile and base station transmitter push-to-talk is that the mobile's duplexer can be replaced with a much simpler T-R switch. For MRS service on a UHF cross-strap, push-to-talk will permit shared operation on one pair of channels (one uplink, one down-link) for the two connected stations or for the network of stations on a party-line interconnection.

ACSSB has power reduction in the absence of voice as an inherent part of the modulation process. A pilot tone, which will be approximately 10 dB below the peak power, is the residual transmit power level with voice absent. FM and PELPC digital transmitters will need tospecifically remove the carrier with voice absent.

For standard telephone useage, studies have shown that an average speaker on a duplex circuit is silent 60% of the conversation period; i.e. is talking only 40% of the period. If the off-hook to on-hook rather than the conversation period is used as a reference, the active voice percentage drop to around 25% for DDN calls. The MTS service on MSAT will likely follow telephone statistics, suggesting a 40% voice activity factor for the conversation period as being a reasonable assumption.

For the MRS service the selection of a voice activity factor is more complex.For those users operating in a voice activate mode in a common channel on UHF/UHF cross-strap, if each user (of a pair) is active 40% of the time, the channel will have voice present 80% of the time. Statistics for voice activity on a dispatch operation as might be used on MSAT are not yet available. If the dispatch channels are demand-assigned, the voice activity may be almost 100% for the typical 20 second message (once the assignment procedure is completed). For a fixed-assigned channel, loadings up to 50% have been suggested for some operations.

6.2.11 Redundancy Requirements

Although the early phases of the first generation MSAT will concentrate on communications experiments, later phases will see a build-up of pre-operational service to customers. A base of 23,000 mobiles is expected at the end of service life. In order for these customer goals to be achieved, some guarantee of service from the satellite must be provided. Due to program fiscal restraint it is not planned that an in-orbit spare satellite will be launched but that a replacement satellite could be available for launch 15 months after an early major failure in the first satellite. With this in mind, reliability goals, service priority ranking, and redundancy interconnect philosophy for the satellite must be carefully specified to maximize end-of-life service capability.

6.2.12 Spacecraft UHF NFBM Requirements Summary

The spacecraft UHF NFBM requirements are summarized as follows:

a) EIRP/NBFM Channel at EOC 868 MHz 37.4 dBW with a power flux density of -118.4 dBW/m2 at the SHF receive antenna.

b) G/T at EOC at 823 MHz 2.9 dB/°K.

BEAM	BORESIGHT	EOC*	
#1 Western Canada/Alaska	57.1°N	60.1°N	156.7°W
	129.8°W	70.8°N	120.3°W
		49.6°N	139.4°W
		56.8°N	112.4°W
		43.1°N	129.5°N
		47.4°N	113.0°N
#2 West Central Canada	56.5°N	70.2°N	125.5°W
	104.4°W	69.2°N	80.6°W
		56.0°N	119.4°W
		55.3°N	89.7°W
		47.2°N	114.6°W
		46.7°N	95.5°W

6.2.12 (cont'd)

#3	Eastern Central Canada	54.9°N	69.6°N	83.3°W
		80.9°W	58.8°N	54.6°W
			56.3°N	95.7°W
			48.5°N	71.8°W
			46.9°N	96.7°N
			42.2°N	81.7°N
#4	Eastern Canada	47.3°N	62.0°N	59.3°W
		66.4°W	46.5°N	44.1°W
			51.9°N	78.6°W
			39.1°N	61.0°W
			43.4°N	84.3°W
			34.8°N	71.4°W
#5	Western US	37.1°N	46.3°N	119.7°W
		111.0°N	47.7°N	106.0°W
			36.3°N	120.9°W
			38.4°N	101.0°W
			32.2°N	118.9°W
			34.0°N	101.7°W
#6	Eastern US	37.3°N	46.6°N	94.8°W
		90.2°W	40.1°N	77.9°W
			38.3°N	100.3°W
			31.8°N	83.1°W
			33.8°N	100.3°W
			28.8°N	87.0°W

* EOC is defined as the 33.0 dBic contour at 868 MHz for beams 2, 3, 5 and 6 and the 32.5 dBic contour for beams 1 and 4.

c) The overall degradation introduced by the satellite (Intermodulation, spurii, co-channel interference, etc.) shall not be greater than a reduction of 0.5 dB in overall $C/(N_0)_t$.

6.3 Ground Segment Parameters

System parameters are provided here for the SHF gateway station, the base station, the various 800 MHz mobile terminals, and the DCP and EPIRB terminals. Most numbers are not hard; i.e. they are subject to possible refinement if improvements are made (such as in the mobile antenna), or can be modified in tradeoffs (eg. the SHF dish size). However, the link equations of section 7.0 are based on the parameters provided below.

6.3.1 800 MHz Terminal

6.3.1.1 800 MHz Vehicular Terminal

Recent measurements by DOC Research Branch of 800 Mhz non-thermal noise have been used in establishing the noise budget. These measurements were made utilizing a drooping dipole mobile antenna (see Annex B) prototype with about 5 dB discrimination against signals arriving from angles of 0° and below. Taking values from 5 sites ranging from a "noisy" expressway location to a "quiet" rural area, and utilizing antenna temperatures which were exceeded less than 10% of the time, an average value of 220°K antenna temperature was obtained.

The loss between the antenna terminals and the receive LNA will be a function of earth station type. Duplex stations will suffer a higher loss due to the larger rejection requirement of the receive filter. Stations which require longer separations between the antenna and LNA will suffer a larger cabling loss. Without being too specific as to its apportionment, a median loss of 1 dB will be assumed for the link analysis.

LNA noise figures over the narrow bandwidth of the 800 MHz service can be made smaller than 1 dB; however, these low values might result in a significant cost penalty in device cost or assembly. Until a more definite value becomes available from an earth station manufacturer, a 2 dB noise figure (or 170°K noise temperature) will be assumed.

6.3 Ground Segment Parameters

System parameters are provided here for the SHF gateway station, the base station, the various 800 MHz mobile terminals, and the DCP and EPIRB terminals. Most numbers are not hard; i.e. they are subject to possible refinement if improvements are made (such as in the mobile antenna), or can be modified in tradeoffs (eg. the SHF dish size). However, the link equations of section 7.0 are based on the parameters provided below.

6.3.1 800 MHz Terminal

6.3.1.1 800 MHz Vehicular Terminal

Recent measurements by DOC Research Branch of 800 Mhz non-thermal noise have been used in establishing the noise budget. These measurements were made utilizing a drooping dipole mobile antenna (see Annex B) prototype with about 5 dB discrimination against signals arriving from angles of 0° and below. Taking values from 5 sites ranging from a "noisy" expressway location to a "quiet" rural area, and utilizing antenna temperatures which were exceeded less than 10% of the time, an average value of 220°K antenna temperature was obtained.

The loss between the antenna terminals and the receive LNA will be a function of earth station type. Duplex stations will suffer a higher loss due to the larger rejection requirement of the receive filter. Stations which require longer separations between the antenna and LNA will suffer a larger cabling loss. Without being too specific as to its apportionment, a median loss of 1 dB will be assumed for the link analysis.

LNA noise figures over the narrow bandwidth of the 800 MHz service can be made smaller than 1 dB; however, these low values might result in a significant cost penalty in device cost or assembly. Until a more definite value becomes available from an earth station manufacturer, a 2 dB noise figure (or 170°K noise temperature) will be assumed.

6.3.1.1 (cont'd)

The overall system noise temperature, referred to the antenna, is calculated as per paragraph 6.2.

For T_a = 220°K, T_o = 290°K, T_r = 170°K,
Then T_s = ~~509~~°K (27.1 dBK) referred to the antenna terminals.
512

For a RHC-polarized vehicular antenna gain of 4 dBi, the receive G/T is -23.1 dB/K. Assuming a 1 dB loss between the transmitter and the antenna, the EIRP requirements of section 7.0 leads to transmitter powers of 2.0 to 8.1 watts for DMSK/PELPC to NBFM.

6.3.1.2 800 MHz Field Portable Terminal

It is possible the antenna noise temperature of the field portable terminal will be less than that of the vehicular terminal, but a conservative approach is to assume the same value; i.e. Ts of 27.1 dBK. With a 10 dBi antenna gain, low axial ratio, and proper siting to avoid shadowing and multipath, the field portable terminal will experience much better communications reliability than the vehicular terminal. The 10 dB antenna gain increases the receive G/T to -17 dB/K. A good axial ratio removes the need for an antenna ellipticity margin. Good antenna siting reduces the propagation margin requirement to less than 1 dB.

It is assumed that, in order to preserve a realistic intermodulation environment, signals of a given service type will pass through the satellite at the same level, irrespective of the terminal type from which they originate. On the return uplink from a field portable terminal, the EIRP would be adjusted to be 0.5 dB less than from the vehicular terminal (to account for the lack of an ellipticity loss). The field portable signal at the satellite would appear at a level equal to the unfaded signal from a mobile; i.e. well above toll quality.

On the forward downlink the field portable not only avoids any fading loss or ellipticity loss, but also has a 6 dB better G/T. The downlink contribution to overall forward link performance becomes very small. Table A.23 shows a typical link table for PELPC service, utilizing satellite C/I_0 and feeder $C/(N_0)_u$

6.3.1.2 (cont'd)

values from the vehicular tables A.16 and A.18. As can be seen, the link qualities are significantly above toll and are primarily limited by the feeder or satellite components. On links operating from the far north, a 2 dB propagation allowance may be prudent, but this has little effect on the overall link quality if included. Tables for the other services are not included as they follow the above trend, with performance significantly above that which can be guaranteed on the vehicular terminal.

6.3.1.3 800 MHz Ship Terminal

As is described in section 4.1.2, the most likely antenna for this service is a motion-stabilized unit with a gain of about 11 dBi. The ship G/T would thus be at least 8 dB higher than the vehicular terminal, assuming a lower antenna noise which will reduce the Ts by at least 1 dB below the vehicular value.

Section 4.1.2 also mentions the difficulty of assigning single values for propagation margins. As a result of the complexity of presentation, and the need for further study, specific link tables will not be included in this document. Suffice it to say that, operating with uplink and downlink EIRP's of the vehicular service, quality of performance should meet or exceed that of the vehicular terminal.

6.3.2 Gateway Station

A 5M antenna has been assumed as a compromise between earth station cost and satellite-SHF EIRP. Dual linear polarized feed will be required along with provision for duplex operation. A boresight gain of 54.2 dB is required at 13.2 GHz and 53.1 dB at 11.65 GHz with an antenna pointing loss at 0.5 dB for both systems.

A receive-LNA noise figure of 2 dB is required. This, in conjunction with a 0.7 dB line and filter loss and a 50°K sky noise results in a 24.8 dBK system noise temperature. Using the 53.1 dB gain figure, the G/T is 28.3 dB/K.

6.3.2 (cont'd)

With a transmit gain of 54.2 dB the EIRP/channel figures of section 7, range from 44.1 to 37.2 dBW which indicates that TWTA's in the 100 watt range will be required for a full-service satellite at 10 dB backoff. It has been assumed that this TWTA back-off will ensure that uplink intermodulation is significantly below intermodulation generated in the satellite, and can be neglected in the link analysis. It should be noted that all gateways will provide energy at the satellite across the full backhaul bandwidth and that addition of uplink noise and spurii will occur. Uplink power control will be required at gateways to ensure that under unfaded conditions the uplink power is reduced to limit the UHF downlink to the faded values given in Table 7.2, Link Budget Summary.

6.3.3 Base Station

A UHF base station will have the characteristics of the field portable terminal described in section 6.3.1.2. An SHF base station would have characteristics similar to the gateway station of section 6.3.2 except for having the capacity for only one or a small number of channels.

6.3.4 Margin for Antenna Ellipticity

The satellite 800 MHz antenna will provide an axial ratio of 2 dB or better for the complete coverage area. For vehicular mobile antennas a 4 dB axial ratio at the minimum elevation angle of 15° appears achievable; this, in conjunction with the satellite antenna ellipticity, results in a 0.5 dB polarization loss. For transportable antennas, either helical or flat spiral (attache case), axial ratios of 2 dB or better have been measured resulting in a negligible polarization loss.

6.4 Operational Characteristics of Central Control Station

The role of the CCS is very dependent on the DAMA system chosen for each of the services and the location of the NMS. As the DAMA systems are still under study, their characteristics are not yet finalized. For the demonstration system, it is possible the gateway stations will not be manned (unless through co-location with another manned establishment). It is therefore likely the CCS, which will be manned, will include the NMS and it may also have the resident intelligence for all channel assignment processes, using gateways as simple remote transceivers and switches. Decisions on the degree of centralization of the DAMA, method of inter-gateway communication, mobile unit monitoring, satellite frequency offset control, etc., are presently under study.

6.5 Operational Characteristics of Gateway Stations

The gateway stations perform the function of local control of the assignment of channels for the 800 MHz services in a UHF beam, monitoring terminal performance in that beam, providing switched telephone network interconnect for calls requiring terrestrial interconnect in the geographic area of the gateway, and providing SHF feeder links for those calls to the satellite.

To perform these functions the gateway must have and be able to carry out the following functions:

- SHF antenna and transmitter/receiver to provide the feeder link to MSAT and order wire links to the CCS and other gateways.

- Transmit/receive channel units to allow modulation/demodulation of those signals required for control, demand assignment, or monitoring of channels and services for which the gateway is responsible including the capability to operate on SHF assignments to other beams.

6.5 (cont'd)

- Channel units are required for those services desiring terrestrial interconnection via the gateway to the STN and are also required for double-hop services utilizing the gateway as a relay point. Channel units must be capable of being operated on any of the assignable frequencies, under remote computer control; however specific units will likely be tailored for only one of the possible modulation techniques.

- Data regeneration for DMSK/LPC and data double hop circuits.

- A DAMA system function (under local or remote control) for the assignment of 800 MHz satellite channel capacity on demand and for the assoicated signalling and supervision required.

- Provide the necessary terrestrial interfaces to the STN, including signalling, call charging and accounting, voice activation, voice coding (for digital services), echo suppression, etc.

- Provide monitoring services for the 800 MHz assignments at SHF to ensure correct performance of mobile stations.

- Provide the necessary traffic and status information to the NMS.

- Provide any other necessary functions associated with the satellite services

6.6 Operational Characteristics of Base Stations

The primary function of a base station is to provide a local access to MSAT for service to a specific set of MRS users. These stations will operate under DAMA control and will request channels, as required, from the responsible gate-way station (except where the base station is operating on pre-assigned channels).Automatic interconnection to the STN will not normally be provided.

6.6 (cont'd)

Both UHF and SHF base stations are planned with the base station operating at UHF being implemented at much less cost and complexity than an SHF base station. For a single-channel UHF base station, the equipment required would be essentially the same as a field-portable terminal. For multiple-channel operation, more complex equipment would be required to allow FDMA from the base.

7.0 COMMUNICATION SYSTEM DESIGN DETAILS

This section contains MSAT link budget summaries in Tables 7.1 through 7.5 for the DCP, EPIRB and 800 MHz service as well as the SHF/SHF and UHF/UHF cross-strap, based on parameters discussed in the various subsections of 6.0. Detailed link budgets are contained in Annex A. The noise performance of the various links were calculated from the following equations:

$$\frac{1}{10C/(N_o)t/10} = \frac{1}{10(C/(N_o)u/10} + \frac{1}{10(C/(N_o)d/10} + \frac{1}{10(C/I_o)/10}$$

where: C/N_o = the ratio of carrier power to the spectral density of noise (dB-Hz)

C/I_o = the ratio of carrier power to the spectral density of interference (dB-Hz)

u, d and t refer to uplink, downlink and total link, respectively

$$C/N_o = EIRP - L - M + G/T + 228.6$$

EIRP = effective isotropic radiated power (dBW) per channel

L = free space loss (dB)

M = link margin (dB)

G/T = receiving system figure of merit (dB/K)

TABLE 7.1

MSAT LINK BUDGET SUMMARY-800 MHz UHF/UHF SERVICES

		DMSK/PELPC			ACSSB		
		M - M	M - B	B - M	M - M	M - B	B - M
UPLINK (Ref. Annex A Table)		(A.19)	(A.21)	(A.23)	(A.11)	(A.13)	(A.9)
Frequency	MHz	823	823	823	823	823	823
Power/Channel	dBW	3.1	3.1	-3.4	4.1	4.1	-2.4
EIRP/Channel	dBW	6.1	6.1	5.6	7.1	7.1	6.6
Space Loss	dB	182.8	182.8	182.8	182.8	182.8	182.8
Propagation Margin	dB	9.0	11.3	0.0	13.0	18.3	0.0
Polarization Loss	dB	0.5	0.5	0.0	0.5	0.5	0.0
Receive G/T	dB/°K	2.9	2.9	2.9	2.9	2.9	2.9
Faded $C/(N_o)_u$	dB-Hz	45.3	43.0	54.3	42.3	37.0	55.3
Faded C/I_o	dB-Hz	45.3	43.0	54.3	42.3	37.0	55.3
Faded $C/((N_o)_u + I_o)$	dB-Hz	42.3	40.0	51.3	39.3	34.0	52.3
DOWNLINK (Ref. Annex A Table)		(A.20)	(A.22)	(A.24)	(A.12)	(A.14)	(A.10)
Frequency	MHz	868	868	868	868	868	868
Faded Power/Channel	dBW	-10.1	-12.4	-1.1	-13.1	-18.4	-0.1
Unfaded Power/Channel	dBW	-1.1	-1.1	-1.1	-0.1	-0.1	-0.1
Faded EIRP/Channel	dBW	20.0	17.7	29.0	17.0	11.7	30.0
Unfaded EIRP/Channel	dBW	29.0	29.0	29.0	30.0	30.0	30.0
Space Loss	dB	183.3	183.3	183.3	183.3	183.3	183.3
Propagation Margin	dB	0.0	0.0	11.4	4.5	0.0	18.6
Polarization Loss	dB	0.5	0.0	0.5	0.5	0.0	0.5
Receive G/T	dB-°K	-23.1	-17.1	-23.1	-23.1	-17.1	-23.1
$C/(N_o)_d$	dB-Hz	41.7	45.9	39.3	34.2	39.9	33.1
$C/(N_o)_t$	dB-Hz	39.0	39.0	39.0	33.0	33.0	33.0

M - Mobile
B - Base

Table 7.2

MSAT LINK BUDGET SUMMARY-SHF/UHF & UHF/SHF SERVICES

		NBFM (Link)		ACSSB (Link)		DMSK/PELPC(Link)	
		Return	Forward	Return	Forward	Return	Forward
UPLINK (Ref. Annex A Table)		(A.1)	(A.3)	(A.5)	(A.7)	(A.15)	(A.17)
Frequency	GHz	0.823	13.225	0.823	13.225	0.823	13.225
Power/Channel	dBW	9.1	-8.1	4.1	-13.1	3.1	-15.0
EIRP/Channel	dBW	12.1	44.1	7.1	39.1	6.1	37.2
Space Loss	dB	182.8	206.5	182.8	206.5	182.8	206.5
Atmospheric Loss	dB	0.0	0.3	0.0	0.3	0.0	0.3
Margin	dB	13.0	2.7	5.0	2.7	13.0	2.7
Polarization Loss	dB	0.5	0.0	0.5	0.0	0.5	0.0
Pointing Loss	dB	0.0	0.5	0.0	0.5	0.0	0.5
Receive G/T	dB/°K	2.9	-0.1	2.9	-0.1	2.9	-0.1
Faded $C/(N_0)_u$	dB-Hz	47.3	62.6	50.3	57.6	41.3	55.7
Faded C/I_0	dB-Hz	54.6	62.6	57.6	57.6	48.6	55.7
Faded $C/((N_0)_u + I_0)$	dB-Hz	46.6	59.6	49.6	54.6	40.6	52.7
DOWNLINK (Ref. Annex A Table)		(A.2)	(A.4)	(A.6)	(A.8)	(A.16)	(A.18)
Frequency	GHz	11.675	0.868	11.675	0.868	11.675	0.868
Faded Power/Channel	dBW	-25.9	7.3	-22.9	2.3	-31.9	0.4
Unfaded Power/Channel	dBW	-12.9	10.0	-17.9	5.0	-18.9	3.1
Faded EIRP/Channel	dBW	1.6	37.4	4.6	32.4	-4.4	30.5
Unfaded EIRP/Channel	dBW	14.6	40.1	9.6	35.1	8.6	33.2
Space Loss	dB	205.4	183.3	205.4	183.3	205.4	183.3
Atmospheric Loss	dB	0.3	0.0	0.3	0.0	0.3	0.0
Margin	dB	2.1	5.0	2.1	5.0	2.1	13.0
Pointing Losses	dB	0.5	0.0	0.5	0.0	0.5	0.0
Polarization Loss	dB	0.0	0.5	0.0	0.5	0.0	0.5
Receive G/T	dB/°K	28.3	-23.1	28.3	-23.1	28.3	-23.1
$C/(N_0)_d$	dB-Hz	50.2	54.1	53.2	49.1	44.2	39.2
$C/(N_0)_t$	dB-Hz	45.0	53.0	48.0	48.0	39.0	39.0

Table 7.3

MSAT LINK BUDGET SUMMARY-SHF/SHF CROSS-STRAP

UPLINK (Ref. Annex A Table)		(A.25)
Frequency	GHz	13.20 - 13.25
EIRP/Channel	dBW	42.8
Space Loss	dB	206.5
Propagation Margin	dB	3.0
Transmit Antenna Pointing Loss	dB	0.5
$C/(N_0)_u$	dB-Hz	61.3
Satellite Receive G/T	dB/°K	-0.1
C/I_0	dB-Hz	63.6
DOWNLINK (Ref. Annex A Table)		**(A.26)**
Frequency	GHz	11.65 - 11.70
EIRP/Channel	dBW	6.9
Space Loss	dB	205.4
Propagation Margin	dB	2.4
Receive Antenna Pointing Loss	dB	0.5
Receive G/T	dB/K	28.3
$C/(N_0)_d$	dB-Hz	55.5
Total Link $C/(N_0)_t$	dB-Hz	54.0

ANNEX A

- CONTENTS -

MSAT LINK BUDGET DETAILS

TABLE A.1 MSAT LINK BUDGET DETAIL

MOBILE TO SATELLITE

Modulation NBFM; 30 kHz Channel Spacing, 27 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power			9.1 dBW
2.	Transmit Circuit Loss			1.0 dB
3.	Transmit EIRP			12.1 dBW
4.	Losses			196.3 dB
	a. Free Space Loss		182.8 dB	
	b. Multipath & Shadowing Loss		13.0 dB	
	c. Polarization Loss		0.5 dB	
5.	Gains			36.0 dB
	a. Transmit Antenna EOC		4.0 dB	
	b. Receive Antenna EOC		32.0 dB	
6.	Received Signal Power/Channel			-152.2 dBW
7.	Receiving Circuit Loss		3.0 dB	
	a. Polarizer	0.2 dB		
	b. Duplexer	1.4 dB		
	c. Cable	0.7 dB		
	d. Redundancy Switch	0.2 dB		
	e. Beam Forming Network	0.5 dB		
8.	Receiving System Temperature			29.1 dBK
	a. Receiver NF		1.5 dB	
	b. Receiver Noise Temperature	$= 290\ (10^{0.15}-1) = 120°K$		
	c. Loss Element Temperature	$= 290°K$		
	d. Antenna Noise Temperature	$= 290°K$		
	e. System Noise Temperature	$= 290 + 290(10^{0.3}-1) + 10^{0.3}x120 = 818°K$		
9.	G/T EOC			2.9 dB/°K
10.	Boltzmann's Constant			-228.6 dBW/Hz°K
11.	Receive System Noise Density			-199.5 dB-Hz
12.	$(C/N_o)_u$			47.3 dB-Hz
13.	C/I_o			54.6 dB-Hz
14.	$C/((N_o)_u + I_o)$			46.6 dB-Hz

TABLE A.2 MSAT LINK BUDGET DETAIL

SATELLITE TO GATEWAY

Modulation NBFM; 30 kHz Channel Spacing, IF BW 27 kHz
Frequency 11.65 - 11.70 GHz

1.	a. Transmit Power/Channel (unfaded uplink)		-12.9 dBW
	b. Transmit Power/Channel (faded uplink)		-25.9 dBW
2.	Transmit Circuit Loss		1.5 dB
3.	a. Transmit EIRP/Channel (unfaded uplink)		14.6 dBW
	b. Transmit EIRP/Channel (faded uplink)		1.6 dBW
4.	Losses		208.3 dB
	a. Free Space Loss	205.4 dB	
	b. Receive Antenna Pointing Loss	0.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.1 dB	
5.	Gains		82.1 dB
	a. Transmit Antenna EOC	29.0 dB	
	b. Receive Antenna Gain	53.1 dB	
6.	Received Signal Power/Channel		-153.6 dBW
7.	Receiving Circuit Loss	0.7 dB	
3.	Receiving System Temperature		24.8 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature = $290(10^{0.2}-1) = 170°K$		
	c. Loss Element Temperature = 290°K		
	d. Antenna Noise Temperature = 50°K		
	e. System Noise Temperature = $50 + 290(10^{0.07}-1)+10^{0.07}\times170$ = 300°K		
9.	G/T		28.3 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-203.8 dB-Hz
12.	$(C/N_o)d$		50.2 dB-Hz
13.	$C/((N_o)u+I_o)$		46.6 dB-Hz
14.	$C/(N_o)t$		45.0 dB-Hz

TABLE A.3 MSAT LINK BUDGET DETAIL

GATEWAY TO SATELLITE

Modulation NBFM; 30 kHz Channel Spacing, 27 kHz IF BW
Frequency 13.20 - 13.25 GHz

1.	Transmit Power/Channel		-8.1 dBW
2.	Transmit Circuit Loss		2.0 dB
3.	EIRP/Channel		44.1 dBW
4.	Losses		210.0 dB
	a. Transmit Antenna Pointing Loss	0.5 dB	
	b. Free Space Loss	206.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.7 dB	
5.	Gains		83.2 dB
	a. Transmit Antenna Gain	54.2 dB	
	b. Receive Antenna EOC Gain	29.0 dB	
6.	Received Signal Power/Channel		-136.9 dBW
7.	Receiving Circuit Loss	1.5 dB	
8.	Receiving System Temperature		29.1 dBK
	a. Receiver NF	3.0 dB	
	b. Receiver Noise Temperature	$= 290(10^{0.3}-1) = 289°K$	
	c. Loss Element Temperature	$= 290°K$	
	d. Antenna Noise Temperature	$= 290°K$	
	e. System Noise Temperature	$= 290 + 290(10^{0.15}-1) + 10^{0.15} \times 289$ $= 818°K$	
9.	G/T		-0.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-199.5 dB-Hz
12.	$(C/N_o)_u$		62.6 dB-Hz
13.	C/I_o		62.6 dB-Hz
14.	$C/((N_o)_u + I_o)$		59.6 dB-Hz

TABLE A.4 MSAT LINK BUDGET DETAIL

SATELLITE TO MOBILE

Modulation NBFM; 30 kHz Channel Spacing, IF BW 27 kHz
Frequency 866-870 MHz

1. Transmit Power		7.3 dBW
2. Transmit Circuit Loss		2.4 dB
a. Polarizer	0.2 dB	
b. Duplexer	0.8 dB	
c. Cable	0.7 dB	
d. Redundancy Switch	0.2 dB	
e. Beam Forming Network	0.5 dB	
3. Transmit EIRP		37.4 dBW
4. Losses		188.8 dB
a. Free Space Loss	183.3 dB	
b. Fade Margin	5.0 dB	
c. Polarization Loss	0.5 dB	
5. Gains		36.5 dB
a. Transmit Antenna EOC Gain	32.5 dB	
b. Receive Antenna EOC Gain	4.0 dB	
6. Received Signal Power/Channel		-147.4 dBW
7. Receiving Circuit Loss	1.0 dB	
8. Receiving System Temperature		27.1 dBK
a. Receiver NF	2.0 dB	
b. Receiver Noise Temperature	$= 290(10^{0.2}-1) = 170°K$	
c. Loss Element Temperature	$= 290°K$	
d. Antenna Noise Temperature	$= 220°K$	
e. System Noise Temperature	$= 220 + 290(10^{0.1}-1)+10^{0.1}\times 170$ $= 509°K$	
9. G/T		-23.1 dB/°K
10. Boltzmann's Constant		-228.6 dBW/Hz°K
11. Receive System Noise Density		-201.5 dB-Hz
12. $(C/N_0)d$		54.1 dB-Hz
13. $C/((N_0)u+I_0)$		59.6 dB-Hz
14. $C/(N_0)t$		53.0 dB-Hz

TABLE A.5 MSAT LINK BUDGET DETAIL

MOBILE TO SATELLITE

Modulation ACSSB; 5 kHz Channel Spacing, 3 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power		4.1 dBW
2.	Transmit Circuit Loss		1.0 dB
3.	Transmit EIRP		7.1 dBW
4.	Losses		188.3 dB
	a. Free Space Loss	182.8 dB	
	b. Multipath & Shadowing Loss	5.0 dB	
	c. Polarization Loss	0.5 dB	
5.	Gains		36.0 dB
	a. Transmit Antenna EOC	4.0 dB	
	b. Receive Antenna EOC	32.0 dB	
6.	Received Signal Power/Channel		-149.2 dBW
7.	Receiving Circuit Loss	3.0 dB	
	a. Polarizer 0.2 dB		
	b. Duplexer 1.4 dB		
	c. Cable 0.7 dB		
	d. Redundancy Switch 0.2 dB		
	e. Beam Forming Network 0.5 dB		
8.	Receiving System Temperature		29.1 dBK
	a. Receiver NF	1.5 dB	
	b. Receiver Noise Temperature	$= 290\,(10^{0.15}-1) = 120°K$	
	c. Loss Element Temperature	= 290°K	
	d. Antenna Noise Temperature	= 290°K	
	e. System Noise Temperature	$= 290 + 290(10^{0.3}-1) + 10^{0.3}\times 120$ = 818°K	
9.	G/T EOC		2.9 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-199.5 dB-Hz
12.	$(C/N_0)_u$		50.3 dB-Hz
13.	C/I_0		57.6 dB-Hz
14.	$C/((N_0)_u + I_0)$		49.6 dB-Hz

TABLE A.6 MSAT LINK BUDGET DETAIL

SATELLITE TO GATEWAY

Modulation ACSSB; 5 kHz Channel Spacing, IF BW 3 kHz
Frequency 11.65 - 11.70 GHz

1.	a. Transmit Power/Channel (unfaded uplink)		-17.9 dBW
	b. Transmit Power/Channel (faded uplink)		-22.9 dBW
2.	Transmit Circuit Loss		1.5 dB
3.	a. Transmit EIRP/Channel (unfaded uplink)		9.6 dBW
	b. Transmit EIRP/Channel (faded uplink)		4.6 dBW
4.	Losses		208.3 dB
	a. Free Space Loss	205.4 dB	
	b. Receive Antenna Pointing Loss	0.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.1 dB	
5.	Gains		82.1 dB
	a. Transmit Antenna EOC	29.0 dB	
	b. Receive Antenna Gain	53.1 dB	
6.	Received Signal Power/Channel		-150.6 dBW
7.	Receiving Circuit Loss	0.7 dB	
8.	Receiving System Temperature		24.8 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature	$= 290(10^{0.2}-1) = 170°K$	
	c. Loss Element Temperature	$= 290°K$	
	d. Antenna Noise Temperature	$= 50°K$	
	e. System Noise Temperature	$= 50 + 290(10^{0.07}-1) + 10^{0.07} \times 170 = 300°K$	
9.	G/T		28.3 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-203.8 dB-Hz
12.	$(C/N_o)_d$		53.2 dB-Hz
13.	$C/((N_o)_u+I_o)$		49.6 dB-Hz
14.	$C/(N_o)_t$		48.0 dB-Hz

TABLE A.7 MSAT LINK BUDGET DETAIL

GATEWAY TO SATELLITE

Modulation ACSSB; 5 kHz Channel Spacing, 3 kHz IF BW
Frequency 13.20 - 13.25 GHz

1.	Transmit Power/Channel		-13.1 dBW
2.	Transmit Circuit Loss		2.0 dB
3.	EIRP/Channel		39.1 dBW
4.	Losses		210.0 dB
	a. Transmit Antenna Pointing Loss	0.5 dB	
	b. Free Space Loss	206.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.7 dB	
5.	Gains		83.2 dB
	a. Transmit Antenna Gain	54.2 dB	
	b. Receive Antenna EOC Gain	29.0 dB	
6.	Received Signal Power/Channel		-141.9 dBW
7.	Receiving Circuit Loss	1.5 dB	
8.	Receiving System Temperature		29.1 dBK
	a. Receiver NF	3.0 dB	
	b. Receiver Noise Temperature	$= 290(10^{0.3}-1) = 289°K$	
	c. Loss Element Temperature	$= 290°K$	
	d. Antenna Noise Temperature	$= 290°K$	
	e. System Noise Temperature	$= 290 + 290(10^{0.15}-1) + 10^{0.15} \times 289$ $= 818°K$	
9.	G/T		-0.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-199.5 dB-Hz
12.	$(C/N_0)_u$		57.6 dB-Hz
13.	C/I_0		57.6 dB-Hz
14.	$C/((N_0)_u + I_0)$		54.6 dB-Hz

TABLE A.8 MSAT LINK BUDGET DETAIL

SATELLITE TO MOBILE

Modulation ACSSB; 5 kHz Channel Spacing, IF BW 3 kHz
Frequency 866-870 MHz

1.	Transmit Power		2.3 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		32.4 dBW
4.	Losses		188.8 dB
	a. Free Space Loss	183.3 dB	
	b. Fade Margin	5.0 dB	
	c. Polarization Loss	0.5 dB	
5.	Gains		36.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	4.0 dB	
6.	Received Signal Power/Channel		-152.4 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature = $290(10^{0.2}-1)$ = 170°K		
	c. Loss Element Temperature = 290°K		
	d. Antenna Noise Temperature = 220°K		
	e. System Noise Temperature = $220 + 290(10^{0.1}-1) + 10^{0.1} \times 170$ = 509°K		
9.	G/T		-23.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density (8+10)		-201.5 dB-Hz
12.	$(C/N_0)_d$		49.1 dB-Hz
13.	$C/((N_0)_u + I_0)$		54.6 dB-Hz
14.	$C/(N_0)_t$		48.0 dB-Hz

TABLE A.9 MSAT LINK BUDGET DETAIL

UHF-UHF BASE TO MOBILE

BASE TO SATELLITE

Modulation ACSSB; 5 kHz Channel Spacing, 3.0 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power			-2.4 dBW
2.	Transmit Circuit Loss			1.0 dB
3.	Transmit EIRP			6.6 dBW
4.	Losses			182.8 dB
	a. Free Space Loss		182.8 dB	
	b. Multipath and Shadowing Margin		0.0 dB	
	c. Polarization Loss		0.0 dB	
5.	Gains			42.0 dB
	a. Transmit Antenna Gain		10.0 dB	
	b. Receive Antenna EOC Gain		32.0 dB	
6.	Received Signal Power/Channel			-144.2 dBW
7.	Receiving Circuit Loss		3.0 dB	
	a. Polarizer	0.2 dB		
	b. Duplexer	1.4 dB		
	c. Cable	0.7 dB		
	d. Redundancy Switch	0.2 dB		
	e. Beam forming Network	0.5 dB		
8.	Receiving System Temperature			29.1 dBK
	a. Receiver NF		1.5 dB	
	b. Receiver Noise Temperature $= 290(10^{0.15}-1)$	= 120°K		
	c. Loss Element Temperature	= 290°K		
	d. Antenna Noise Temperature	= 290°K		
	e. System Noise Temperature $= 290 + 290(10^{0.30}-1) + 10^{0.3} \times 120$	= 818°K		
9.	G/T			2.9 dB/°K
10.	Boltzmann's Constant			-228.6 dBW/Hz°K
11.	Receive System Noise Density			-199.5 dB-Hz
12.	$C/(N_0)_u$			55.3 dB-Hz
13.	C/I_0			55.3 dB-Hz
14.	$C/((N_0)_u + I_0)$			52.3 dB-Hz

TABLE A.10 MSAT LINK BUDGET DETAIL

UHF-UHF BASE TO MOBILE

SATELLITE TO MOBILE

Modulation ACSSB; 5 kHz Channel Spacing, IF BW 3.0 kHz
Frequency 866-870 MHz

1.	Transmit Power		-0.1 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		30.0 dBW
4.	Losses		202.4 dB
	a. Free Space Loss	183.3 dB	
	b. Multipath and Shadowing Margin	18.6 dB	
	c. Polarization Loss	0.5 dB	
5.	Gains		36.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	4.0 dB	
6.	Received Signal Power/Channel		-168.4 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature $= 290(10^{0.2} - 1) = 170°K$		
	c. Loss Element Temperature $= 290°K$		
	d. Antenna Noise Temperature $= 220°K$		
	e. System Noise Temperature $= 290 + 290\ (10^{0.1} - 1) + 10^{0.1} \times 170 = 509°K$		
9.	G/T =		-23.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/H
11.	Receive System Noise Density		-201.5 dB-Hz
12.	$C/(N_o)_d$		33.1 dB-Hz
13.	$C/((N_o)_u + I_o)$		52.3 dB-Hz
14.	$C/(N_o)_t$		33.0 dB-Hz

TABLE A.11 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO MOBILE

MOBILE TO SATELLITE

Modulation ACSSB; 5 kHz Channel Spacing, 3 kHz IF BW
Frequency 821-825 MHz

1. Transmit Power — 4.1 dBW

2. Transmit Circuit Loss — 1.0 dB

3. Transmit EIRP — 7.1 dBW

4. Losses — 196.3 dB
   a. Free Space Loss — 182.8 dB
   b. Multipath & Shadowing Loss — 13.0 dB
   c. Polarization Loss — 0.5 dB

5. Gains — 36.0 dB
   a. Transmit Antenna EOC — 4.0 dB
   b. Receive Antenna EOC — 32.0 dB

6. Received Signal Power/Channel — -149.2 dBW

7. Receiving Circuit Loss — 3.0 dB
   a. Polarizer — 0.2 dB
   b. Duplexer — 1.4 dB
   c. Cable — 0.7 dB
   d. Redundancy Switch — 0.2 dB
   e. Beam Forming Network — 0.5 dB

8. Receiving System Temperature — 29.1 dBK
   a. Receiver NF — 1.5 dB
   b. Receiver Noise Temperature $= 290\,(10^{0.15}-1) = 120^\circ K$
   c. Loss Element Temperature $= 290^\circ K$
   d. Antenna Noise Temperature $= 290^\circ K$
   e. System Noise Temperature $= 290 + 290(10^{0.3}-1) + 10^{0.3}\times 120$ $= 818^\circ K$

9. G/T EOC — 2.9 dB/°K

10. Boltzmann's Constant — -228.6 dBW/Hz°K

11. Receive System Noise Density — -199.5 dB-Hz

12. $(C/N_o)u$ — 42.3 dB-Hz

13. C/I_o — 42.3 dB-Hz

14. $C/((N_o)u + I_o)$ — 39.3 dB-Hz

TABLE A.12 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO MOBILE

SATELLITE TO MOBILE

Modulation ACSSB; 5 kHz Channel Spacing, IF BW 3.0 kHz
Frequency 866-870 MHz

1.	Transmit Power		-13.1 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		17.0 dBW
4.	Losses		188.3 dB
	a. Free Space Loss	183.3 dB	
	b. Multipath and Shadowing Margin	4.5 dB	
	c. Polarization Loss	0.5 dB	
5.	Gains		36.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	4.0 dB	
6.	Received Signal Power/Channel		-167.3 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature $= 290(10^{0.2} - 1) = 170°K$		
	c. Loss Element Temperature $= 290°K$		
	d. Antenna Noise Temperature $= 220°K$		
	e. System Noise Temperature $= 290 + 290\ (10^{0.1} - 1) + 10^{0.1} \times 170 = 509°K$		
9.	G/T		-23.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/H
11.	Receive System Noise Density		-201.5 dB-Hz
12.	$C/(N_0)_d$		34.2 dB-Hz
13.	$C/((N_0)_u + I_0)$		39.3 dB-Hz
14.	$C/(N_0)_t$		33.0 dB-Hz

TABLE A.13 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO BASE

MOBILE TO SATELLITE

Modulation ACSSB; 5 kHz Channel Spacing, 3 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power			4.1 dBW
2.	Transmit Circuit Loss			1.0 dB
3.	Transmit EIRP			7.1 dBW
4.	Losses			201.6 dB
	a. Free Space Loss		182.8 dB	
	b. Multipath & Shadowing Loss		18.3 dB	
	c. Polarization Loss		0.5 dB	
5.	Gains			36.0 dB
	a. Transmit Antenna EOC		4.0 dB	
	b. Receive Antenna EOC		32.0 dB	
6.	Received Signal Power/Channel			-162.5 dBW
7.	Receiving Circuit Loss		3.0 dB	
	a. Polarizer	0.2 dB		
	b. Duplexer	1.4 dB		
	c. Cable	0.7 dB		
	d. Redundancy Switch	0.2 dB		
	e. Beam Forming Network	0.5 dB		
8.	Receiving System Temperature			29.1 dBK
	a. Receiver NF		1.5 dB	

b. Receiver Noise Temperature $= 290\ (10^{0.15}-1) = 120°K$
c. Loss Element Temperature $= 290°K$
d. Antenna Noise Temperature $= 290°K$
e. System Noise Temperature $= 290 + 290\ (10^{0.3}-1) + 10^{0.3} \times 120$
$= 818°K$

9.	G/T EOC	2.9 dB/°K
10.	Boltzmann's Constant	-228.6 dBW/Hz°K
11.	Receive System Noise Density	-199.5 dB-Hz
12.	$(C/N_o)_u$	37.0 dB-Hz
13.	C/I_o	37.0 dB-Hz
14.	$C/((N_o)_u + I_o)$	34.0 dB-Hz

TABLE A.14 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO BASE

SATELLITE TO BASE

Modulation ACSSB; 5 kHz Channel Spacing, IF BW 3.0 kHz
Frequency 866-870 MHz

1.	Transmit Power		-18.4 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		11.7 dBW
4.	Losses		183.3 dB
	a. Free Space Loss	183.3 dB	
	b. Multipath and Shadowing Margin	0.0 dB	
	c. Polarization Loss	0.0 dB	
5.	Gains		42.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	10.0 dB	
6.	Received Signal Power/Channel		-161.6 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature $= 290(10^{0.2} - 1)$ $= 170°K$		
	c. Loss Element Temperature $= 290°K$		
	d. Antenna Noise Temperature $= 220°K$		
	e. System Noise Temperature $= 290 + 290\ (10^{0.1} - 1) + 10^{0.1} \times 170$ $= 509°K$		
9.	G/T		-17.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/H
11.	Receive System Noise Density		-201.5 dB-Hz
12.	$C/(N_0)_d$		39.9 dB-Hz
13.	$C/((N_0)_u + I_0)$		34.0 dB-Hz
14.	$C/(N_0)_t$		33.0 dB-Hz

TABLE A.15 MSAT LINK BUDGET DETAIL

MOBILE TO SATELLITE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, 2.4 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power			3.1 dBW
2.	Transmit Circuit Loss			1.0 dB
3.	Transmit EIRP			6.1 dBW
4.	Losses			196.3 dB
	a. Free Space Loss		182.8 dB	
	b. Multipath & Shadowing Loss		13.0 dB	
	c. Polarization Loss		0.5 dB	
5.	Gains			36.0 dB
	a. Transmit Antenna EOC		4.0 dB	
	b. Receive Antenna EOC		32.0 dB	
6.	Received Signal Power/Channel			-158.2 dBW
7.	Receiving Circuit Loss		3.0 dB	
	a. Polarizer	0.2 dB		
	b. Duplexer	1.4 dB		
	c. Cable	0.7 dB		
	d. Redundancy Switch	0.2 dB		
	e. Beam Forming Network	0.5 dB		
8.	Receiving System Temperature			29.1 dBK
	a. Receiver NF		1.5 dB	
	b. Receiver Noise Temperature	$= 290\ (10^{0.15}-1) = 120°K$		
	c. Loss Element Temperature	$= 290°K$		
	d. Antenna Noise Temperature	$= 290°K$		
	e. System Noise Temperature	$= 290 + 290(10^{0.3}-1) + 10^{0.3} \times 120$ $= 818°K$		
9.	G/T EOC			2.9 dB/°K
10.	Boltzmann's Constant			-228.6 dBW/Hz°K
11.	Receive System Noise Density			-199.5 dB-Hz
12.	$(C/N_0)_u$			41.3 dB-Hz
13.	C/I_0			48.6 dB-Hz
14.	$C/((N_0)_u + I_0)$			40.6 dB-Hz

TABLE A.16 MSAT LINK BUDGET DETAIL

SATELLITE TO GATEWAY

Modulation DMSK/PELPC; 5 kHz Channel Spacing, IF BW 2.4 kHz
Frequency 11.65 - 11.70 GHz

1.	a. Transmit Power/Channel (unfaded uplink)		-18.9 dBW
	b. Transmit Power/Channel (faded uplink)		-31.9 dBW
2.	Transmit Circuit Loss		1.5 dB
3.	a. Transmit EIRP/Channel (unfaded uplink)		8.6 dBW
	b. Transmit EIRP/Channel (faded uplink)		-4.4 dBW
4.	Losses		208.3 dB
	a. Free Space Loss	205.4 dB	
	b. Receive Antenna Pointing Loss	0.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.1 dB	
5.	Gains		82.1 dB
	a. Transmit Antenna EOC	29.0 dB	
	b. Receive Antenna Gain	53.1 dB	
6.	Received Signal Power/Channel		-159.6 dBW
7.	Receiving Circuit Loss	0.7 dB	
8.	Receiving System Temperature		24.8 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature	$= 290(10^{0.2}-1) = 170°K$	
	c. Loss Element Temperature	= 290°K	
	d. Antenna Noise Temperature	= 50°K	
	e. System Noise Temperature	$= 50 + 290(10^{0.07}-1)+10^{0.07}x170$ = 300°K	
9.	G/T		28.3 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-203.8 dB-Hz
12.	$(C/N_o)d$		44.2 dB-Hz
13.	$C/((N_o)u+I_o)$		40.6 dB-Hz
14.	$C/(N_o)t$		39.0 dB-Hz

TABLE A.17 MSAT LINK BUDGET DETAIL

GATEWAY TO SATELLITE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, 2.4 kHz IF BW
Frequency 13.20 - 13.25 GHz

1.	Transmit Power/Channel		-15.0 dBW
2.	Transmit Circuit Loss		2.0 dB
3.	EIRP/Channel		37.2 dBW
4.	Losses		210.0 dB
	a. Transmit Antenna Pointing Loss	0.5 dB	
	b. Free Space Loss	206.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.7 dB	
5.	Gains		83.2 dB
	a. Transmit Antenna Gain	54.2 dB	
	b. Receive Antenna EOC Gain	29.0 dB	
6.	Received Signal Power/Channel		-143.8 dBW
7.	Receiving Circuit Loss	1.5 dB	
8.	Receiving System Temperature		29.1 dBK
	a. Receiver NF	3.0 dB	
	b. Receiver Noise Temperature	$= 290(10^{0.3}-1) = 289°K$	
	c. Loss Element Temperature	$= 290°K$	
	d. Antenna Noise Temperature	$= 290°K$	
	e. System Noise Temperature	$= 290 + 290(10^{0.15}-1) + 10^{0.15} \times 289$ $= 818°K$	
9.	G/T		-0.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-199.5 dB-Hz
12.	$(C/N_0)_u$		55.7 dB-Hz
13.	C/I_0		55.7 dB-Hz
14.	$C/((N_0)_u + I_0)$		52.7 dB-Hz

TABLE A.18 MSAT LINK BUDGET DETAIL

SATELLITE TO MOBILE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, IF BW 2.4 kHz
Frequency 866-870 MHz

1.	Transmit Power		0.4 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		30.5 dBW
4.	Losses		196.8 dB
	a. Free Space Loss	183.3 dB	
	b. Fade Margin	13.0 dB	
	c. Polarization Loss	0.5 dB	
5.	Gains		36.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	4.0 dB	
6.	Received Signal Power/Channel		-162.3 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature	$= 290(10^{0.2}-1) = 170°K$	
	c. Loss Element Temperature	= 290°K	
	d. Antenna Noise Temperature	= 220°K	
	e. System Noise Temperature	$= 220 + 290(10^{0.1}-1)+10^{0.1} x 170$ = 509°K	
9.	G/T		-23.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-201.5 dB-Hz
12.	$(C/N_o)d$		39.2 dB-Hz
13.	$C/((N_o)u+I_o)$		52.7 dB-Hz
14.	$C/(N_o)t$		39.0 dB-Hz

TABLE A.19 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO MOBILE

MOBILE TO SATELLITE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, 2.4 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power			3.1 dBW
2.	Transmit Circuit Loss			1.0 dB
3.	Transmit EIRP			6.1 dBW
4.	Losses			192.3 dB
	a. Free Space Loss		182.8 dB	
	b. Multipath & Shadowing Loss		9.0 dB	
	c. Polarization Loss		0.5 dB	
5.	Gains			36.0 dB
	a. Transmit Antenna EOC		4.0 dB	
	b. Receive Antenna EOC		32.0 dB	
6.	Received Signal Power/Channel			-154.2 dBW
7.	Receiving Circuit Loss		3.0 dB	
	a. Polarizer	0.2 dB		
	b. Duplexer	1.4 dB		
	c. Cable	0.7 dB		
	d. Redundancy Switch	0.2 dB		
	e. Beam Forming Network	0.5 dB		
8.	Receiving System Temperature			29.1 dBK
	a. Receiver NF		1.5 dB	
	b. Receiver Noise Temperature	$= 290\,(10^{0.15}-1) = 120°K$		
	c. Loss Element Temperature	$= 290°K$		
	d. Antenna Noise Temperature	$= 290°K$		
	e. System Noise Temperature	$= 290 + 290(10^{0.3}-1) + 10^{0.3}\times120 = 818°K$		
9.	G/T EOC			2.9 dB/°K
10.	Boltzmann's Constant			-228.6 dBW/Hz°K
11.	Receive System Noise Density			-199.5 dB-Hz
12.	$(C/N_o)_u$			45.3 dB-Hz
13.	C/I_o			45.3 dB-Hz
14.	$C/((N_o)_u + I_o)$			42.3 dB-Hz

TABLE 20 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO MOBILE

SATELLITE TO MOBILE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, IF BW 2.4 kHz
Frequency 866-870 MHz

1.	Transmit Power		-10.1 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		20.0 dBW
4.	Losses		183.8 dB
	a. Free Space Loss	183.3 dB	
	b. Multipath and Shadowing	0.0 dB	
	c. Polarization Loss	0.5 dB	
5.	Gains		36.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	4.0 dB	
6.	Received Signal Power/Channel		-159.8 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature $= 290(10^{0.2} - 1) = 170°K$		
	c. Loss Element Temperature $= 290°K$		
	d. Antenna Noise Temperature $= 220°K$		
	e. System Noise Temperature $= 290 + 290\,(10^{0.1} - 1) + 10^{0.1} \times 170 = 509°K$		
9.	G/T		-23.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/H
11.	Receive System Noise Density		-201.5 dB-Hz
12.	$C/(N_0)_d$		41.7 dB-Hz
13.	$C/((N_0)_u + I_0)$		42.3 dB-Hz
14.	$C/(N_0)_t$		39.0 dB-Hz

TABLE A.21 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO BASE

MOBILE TO SATELLITE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, 2,4 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power			3.1 dBW
2.	Transmit Circuit Loss			1.0 dB
3.	Transmit EIRP			6.1 dBW
4.	Losses			194.6 dB
	a. Free Space Loss		182.8 dB	
	b. Multipath & Shadowing Loss		11.3 dB	
	c. Polarization Loss		0.5 dB	
5.	Gains			36.0 dB
	a. Transmit Antenna EOC		4.0 dB	
	b. Receive Antenna EOC		32.0 dB	
6.	Received Signal Power/Channel			-156.5 dBW
7.	Receiving Circuit Loss		3.0 dB	
	a. Polarizer	0.2 dB		
	b. Duplexer	1.4 dB		
	c. Cable	0.7 dB		
	d. Redundancy Switch	0.2 dB		
	e. Beam Forming Network	0.5 dB		
8.	Receiving System Temperature			29.1 dBK
	a. Receiver NF		1.5 dB	
	b. Receiver Noise Temperature	$= 290\ (10^{0.15}-1) = 120°K$		
	c. Loss Element Temperature	$= 290°K$		
	d. Antenna Noise Temperature	$= 290°K$		
	e. System Noise Temperature	$= 290 + 290(10^{0.3}-1) + 10^{0.3}\times 120 = 818°K$		
9.	G/T EOC			2.9 dB/°K
10.	Boltzmann's Constant			-228.6 dBW/Hz°K
11.	Receive System Noise Density			-199.5 dB-Hz
12.	$(C/N_0)_u$			43.0 dB-Hz
13.	C/I_0			43.0 dB-Hz
14.	$C/((N_0)_u + I_0)$			40.0 dB-Hz

TABLE A.22 MSAT LINK BUDGET DETAIL

UHF-UHF MOBILE TO BASE

SATELLITE TO BASE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, IF BW 2.4 kHz
Frequency 866-870 MHz

1.	Transmit Power		-12.4 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		17.7 dBW
4.	Losses		183.3 dB
	a. Free Space Loss	183.3 dB	
	b. Multipath and Shadowing	0.0 dB	
	c. Polarization Loss	0.0 dB	
5.	Gains		42.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	10.0 dB	
6.	Received Signal Power/Channel		-155.6 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature $= 290(10^{0.2} - 1)$	= 170°K	
	c. Loss Element Temperature	= 290°K	
	d. Antenna Noise Temperature	= 220°K	
	e. System Noise Temperature $= 290 + 290\ (10^{0.1} - 1) + 10^{0.1} \times 170$	= 509°K	
9.	G/T		-17.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/H
11.	Receive System Noise Density		-201.5 dB-Hz
12.	$C/(N_0)_d$		45.9 dB-Hz
13.	$C/((N_0)_u + I_0)$		40.0 dB-Hz
14.	$C/(N_0)_t$		39.0 dB-Hz

TABLE A.23 MSAT LINK BUDGET DETAIL

UHF-UHF BASE TO MOBILE

BASE TO SATELLITE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, 2.4 kHz IF BW
Frequency 821-825 MHz

1.	Transmit Power			-3.4 dBW
2.	Transmit Circuit Loss			1.0 dB
3.	Transmit EIRP			5.6 dBW
4.	Losses			182.8 dB
	a. Free Space Loss		182.8 dB	
	b. Multipath and Shadowing Margin		0.0 dB	
	c. Polarization Loss		0.0 dB	
5.	Gains			42.0 dB
	a. Transmit Antenna Gain		10.0 dB	
	b. Receive Antenna EOC Gain		32.0 dB	
6.	Received Signal Power/Channel			-145.2 dBW
7.	Receiving Circuit Loss		3.0 dB	
	a. Polarizer	0.2 dB		
	b. Duplexer	1.4 dB		
	c. Cable	0.7 dB		
	d. Redundancy Switch	0.2 dB		
	e. Beam forming Network	0.5 dB		
8.	Receiving System Temperature			29.1 dBK
	a. Receiver NF		1.5 dB	
	b. Receiver Noise Temperature $= 290(10^{0.15}-1)$ $= 120°K$			
	c. Loss Element Temperature $= 290°K$			
	d. Antenna Noise Temperature $= 290°K$			
	e. System Noise Temperature $= 290 + 290(10^{0.30}-1) + 10^{0.3} \times 120$ $= 818°K$			
9.	G/T			2.9 dB/°K
10.	Boltzmann's Constant			-228.6 dBW/Hz°K
11.	Receive System Noise Density			-199.5 dB-Hz
12.	$C/(N_0)_u$			54.3 dB-Hz
13.	C/I_0			54.3 dB-Hz
14.	$C/((N_0)_u + I_0)$			51.3 dB-Hz

TABLE A.24 MSAT LINK BUDGET DETAIL

UHF-UHF BASE TO MOBILE

SATELLITE TO MOBILE

Modulation DMSK/PELPC; 5 kHz Channel Spacing, IF BW 2.4 kHz
Frequency 866-870 MHz

1.	Transmit Power		-1.1 dBW
2.	Transmit Circuit Loss		2.4 dB
	a. Polarizer	0.2 dB	
	b. Duplexer	0.8 dB	
	c. Cable	0.7 dB	
	d. Redundancy Switch	0.2 dB	
	e. Beam Forming Network	0.5 dB	
3.	Transmit EIRP		29.0 dBW
4.	Losses		195.2 dB
	a. Free Space Loss	183.3 dB	
	b. Multipath and Shadowing	11.4 dB	
	c. Polarization Loss	0.5 dB	
5.	Gains		36.5 dB
	a. Transmit Antenna EOC Gain	32.5 dB	
	b. Receive Antenna EOC Gain	4.0 dB	
6.	Received Signal Power/Channel		-162.2 dBW
7.	Receiving Circuit Loss	1.0 dB	
8.	Receiving System Temperature		27.1 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature $= 290(10^{0.2} - 1) = 170°K$		
	c. Loss Element Temperature $= 290°K$		
	d. Antenna Noise Temperature $= 220°K$		
	e. System Noise Temperature $= 290 + 290\,(10^{0.1} - 1) + 10^{0.1} \times 170 = 509°K$		
9.	G/T		-23.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/H
11.	Receive System Noise Density		-201.5 dB-Hz
12.	$C/(N_0)_d$		39.3 dB-Hz
13.	$C/((N_0)_u + I_0)$		51.3 dB-Hz
14.	$C/(N_0)_t$		39.0 dB-Hz

TABLE A.25 MSAT LINK BUDGET DETAIL

SHF-SHF

GATEWAY TO SATELLITE

Modulation NBFM; 30 kHz Channel Spacing, IF BW 27 kHz
Frequency 13.20-13.25 GHz

1.	Transmit Power/Channel		-9.4 dBW
2.	Transmit Circuit Loss		2.0 dB
3.	EIRP/Channel		42.8 dBW
4.	Losses		210.0 dB
	a. Transmit Antenna Pointing Loss	0.5 dB	
	b. Free Space Loss	206.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.7 dB	
5.	Gains		83.2 dB
	a. Transmit Antenna Gain	54.2 dB	
	b. Receive Antenna EOC Gain	29.0 dB	
6.	Received Signal Power/Channel		-138.2 dBW
7.	Receiving Circuit Loss	1.5 dB	
8.	Receiving System Temperature		29.1 dBK
	a. Receiver NF	3.0 dB	
	b. Receiver Noise Temperature $= 290(10^{0.3}-1) = 289°K$		
	c. Loss Element Temperature $= 290°K$		
	d. Antenna Noise Temperature $= 290°K$		
	e. System Noise Temperature $= 290 + 290(10^{0.15}-1) + 10^{0.15} \times 289 = 818°K$		
9.	G/T		-0.1 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-199.6 dB-Hz
12.	$(C/N_0)_u$		61.3 dB-Hz
13.	C/I_0		63.6 dB-Hz
14.	$C/((N_0)_u + I_0)$		59.3 dB-Hz

TABLE A.26 MSAT LINK BUDGET DETAIL

SHF-SHF

SATELLITE TO GATEWAY

Modulation DMSK; 30 KHz Channel Spacing, IF BW 27 KHz
Frequency 11.65 - 11.70 GHz

1.	a. Transmit Power/Channel (unfaded uplink)		-17.9 dBW
	b. Transmit Power/Channel (faded uplink)		-20.6 dBW
2.	Transmit Circuit Loss		1.5 dB
3.	a. Transmit EIRP/Channel (unfaded uplink)		9.6 dBW
	b. Transmit EIRP/Channel (faded uplink)		6.9 dBW
4.	Losses		208.3 dB
	a. Free Space Loss	205.4 dB	
	b. Receive Antenna Pointing Loss	0.5 dB	
	c. Atmospheric Loss	0.3 dB	
	d. Rain Margin	2.1 dB	
5.	Gains		82.1 dB
	a. Transmit Antenna EOC Gain	29.0 dB	
	b. Receive Antenna Gain	53.1 dB	
6.	Received Signal Power/Channel		-148.3 dBW
7.	Receiving Circuit Loss	0.7 dB	
8.	Receiving System Temperature		24.8 dBK
	a. Receiver NF	2.0 dB	
	b. Receiver Noise Temperature = $290(10^{0.2}-1)$ = 170°K		
	c. Loss Element Temperature = 290°K		
	d. Antenna Noise Temperature = 50°K		
	e. System Noise Temperature = $50 + 290(10^{0.07}-1) + 10^{0.07} \times 170$ = 300°K		
9.	G/T		28.3 dB/°K
10.	Boltzmann's Constant		-228.6 dBW/Hz°K
11.	Receive System Noise Density		-203.8 dB-Hz
12.	$(C/N_o)_d$		55.5 dB-Hz
13.	$C/((N_o)_u + I_o)$		59.3 dB-Hz
14.	$C/(N_o)_t$		54.0 dB-Hz

ANNEX B MOBILE & TRANSPORTABLE ANTENNAS

- CONTENTS -

Figures

ANNEX B

B.1.0 Mobile and Transportable Antennas

Several types of mobile and transportable antennas will be required to provide the range of services envisaged for MSAT. The planned transmit band for MSAT ground terminals is 821-825 MHz and the receive band is 866-870 MHz. A 6% bandwidth capability will be required if one antenna is used for both transmit and receive functions. Right-hand circular polarization (in the direction of propagation the rotation of the electric field vector in a transverse plane is clockwise) will be used in both cases. Each application area requires a different antenna type due to the different operating and propagation characteristics.

B.2.0 Land-Mobile Antennas

B.2.1 Vehicle Antennas

The choice of antenna pattern for vehicular use is affected by several factors:

- the need to maximize the gain over an elevation angle range of about 15 to 35 degrees.

- the need for omnidirectional (or automatically optimized) azimuth coverage.

- the need to discriminate against interfering signals such as ignition noise and multipath.

Initial investigations have shown that by providing a gain fall-off below 15 degrees elevation, a reduction of up to 5 dB can be obtained in the effective antenna noise-temperature due to ignition noise and ground (black-body) radiation.

B.2.1 (cont'd)

The performance goal is a single-antenna system with a minimum gain of 4 dB at all azimuth angles over an elevation range of 15 to 35 degrees. The axial ratio is to be no greater than 4 dB over the elevation range.

Development work on antenna systems is continuing and some of the suitable antenna elements which have been investigated to date are:

Drooping Turnstile Antenna: this is a crossed-dipole antenna where the dipole elements are declined at 45° below the horizontal, providing better coverage and axial ratio at lower elevation angles. The size of this antenna is about 20 cm high and 12 cm diameter. A disadvantage is that the antenna must be mounted at a critical height above a ground-plane. To ensure adequate performance for most users, it would be necessary to provide a small ground plane as an integral part of the antenna.

Truncated Conical Log-Spiral: by using a four-arm spiral on a cone with opposite arms connected together and the two pairs fed in antiphase, a conical radiation pattern is obtained. The direction of maximum radiation in the elevation plane is determined by the spiral angle on the cone. It was found necessary to use at least three-quarters of a turn for each arm to get a good pattern and low axial ratio. The resulting antenna was 30 cm high and 25 cm in diameter at the base. This antenna will operate with or without a ground plane.

Backfire Quadrifilar Helix: fed at the top with the same phasing as used for the turnstile antenna, the quadrifilar helix also produces a suitable radiation pattern. Of the prototypes investigated, the minimum size which gave reasonable performance was 3.5 cm diameter and 60 cm high. Smaller sizes have an excessive dissipative loss. This antenna will also operate with or without a ground-plane.

Antenna Arrays: the use of an array of several antennas to provide directivity in the aximuth plane could greatly improve performance. Automatic control of phasing would be required to provide maximum gain in the appropriate direction.

B.2.2 Field-Portable Antennas

For this application, the main emphasis is on portability and ease of erection. The antenna can be sited to avoid line-of-sight shadowing and can be aligned in the satellite direction. A gain of 10 dBi will reduce the transmit power required from the ground terminal while retaining a broad enough beamwidth (50°) that alignment is not too critical. At the same time, reasonable discrimination will be obtained against environmental interference and multipath. Two versions of the portable antenna are desirable: one of a lighter construction which could be set up and used for a short while in an attended situation. The second version would be of heavier construction suitable for deployment in an unattended situation for several months.[1]

Light-Duty Antenna: a "suitcase" type antenna consisting of a two-element planar array would be suitable for this application. The individual printed-circuit elements could be two-arm planar spirals mounted over a suitable cavity. An investigation has shown that such an antenna can be constructed with overall dimensions of 50 x 25 x 6 cm.

Heavy-Duty Antenna: for this application there are several suitable types. An investigation of the horn-cavity antenna was carried out in some detail. This has the shape of a truncated cone of 47 cm maximum diameter and 23 cm deep. It is somewhat smaller than the alternative short-backfire antenna and also has low sidelobe levels (-20 dB). The printed-circuit feed can easily be protected by a plastic sheet radome across the front of the antenna.

B.2.3 Ship Antennas

Because of the severe multipath problem for this service, high antenna gains are necessary to discriminate against multipath signals. In order to provide toll-quality service under smooth-sea conditions (worst-case), an antenna gain of 11 dBi

[1] Andrew Antenna Co. Ltd., "A Study to Develop Antennas for the MSAT Transportable Terminals", DOC Contractor Report, DOC-CR-SP-82-003.

B.2.3 (cont'd)

is required.[2] To maintain antenna pointing accuracy, smaller ships will need a passive stabilization system for the antenna, to maintain the pointing direction within 7.5 degrees. The azimuth control will be derived from the ship's gyro-compass system, with corrections by peaking manually when required. For the antenna element, the horn-cavity antenna investigated for field-portable use would be suitable. The size and gain are appropriate and the antenna can easily be made weatherproof.

B.2.4 Antenna Patterns

Antenna patterns for various antennas tested are shown in Figures B1 - B3.

2 Canadian Astronautics Ltd., "A Study of MSAT Shipborne Antennas", DOC Contractor Report, DOC-CR-SP-82-002.

ELEVATION PATTERN

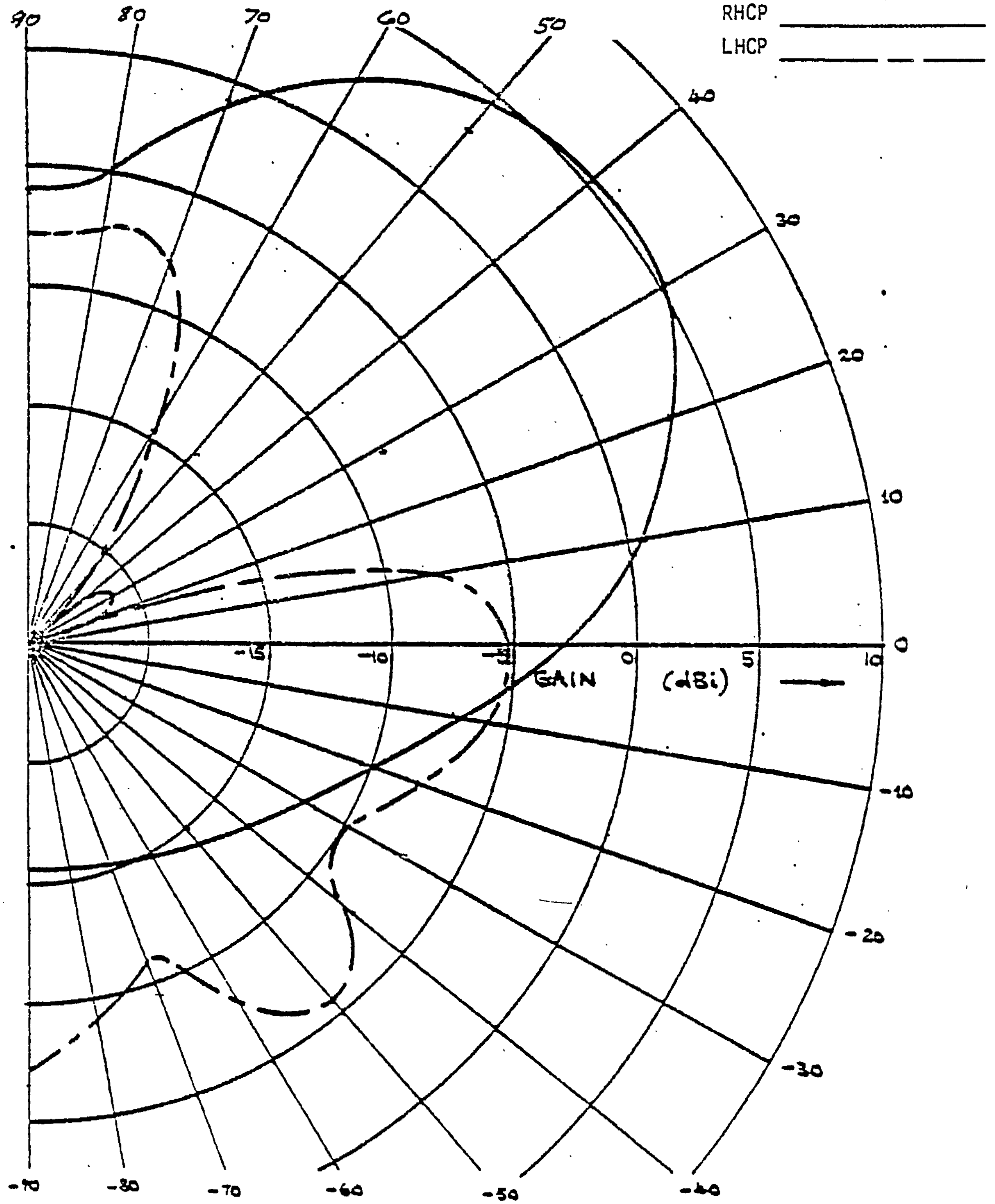


Figure B.1

CROSSED DROOPING DIPOLE ANTENNA (870 MHz)

ELEVATION PATTERN

RHCP ————

LHCP — — —

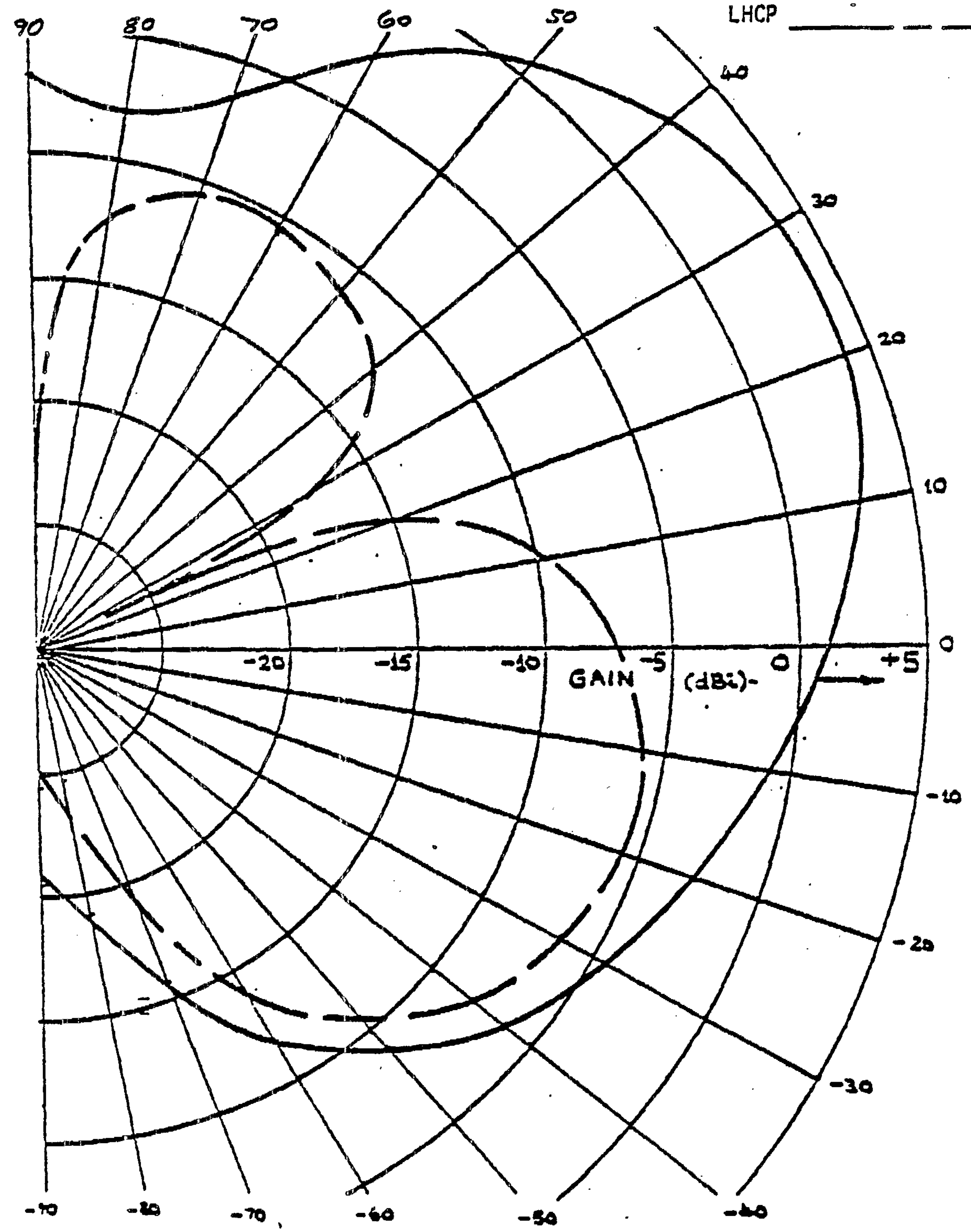


Figure B.2 CONICAL LOG-SPIRAL ANTENNA (HALF-WAVE BALUN. NO GROUND PLANE. 870 MHz)

ELEVATION PATTERN

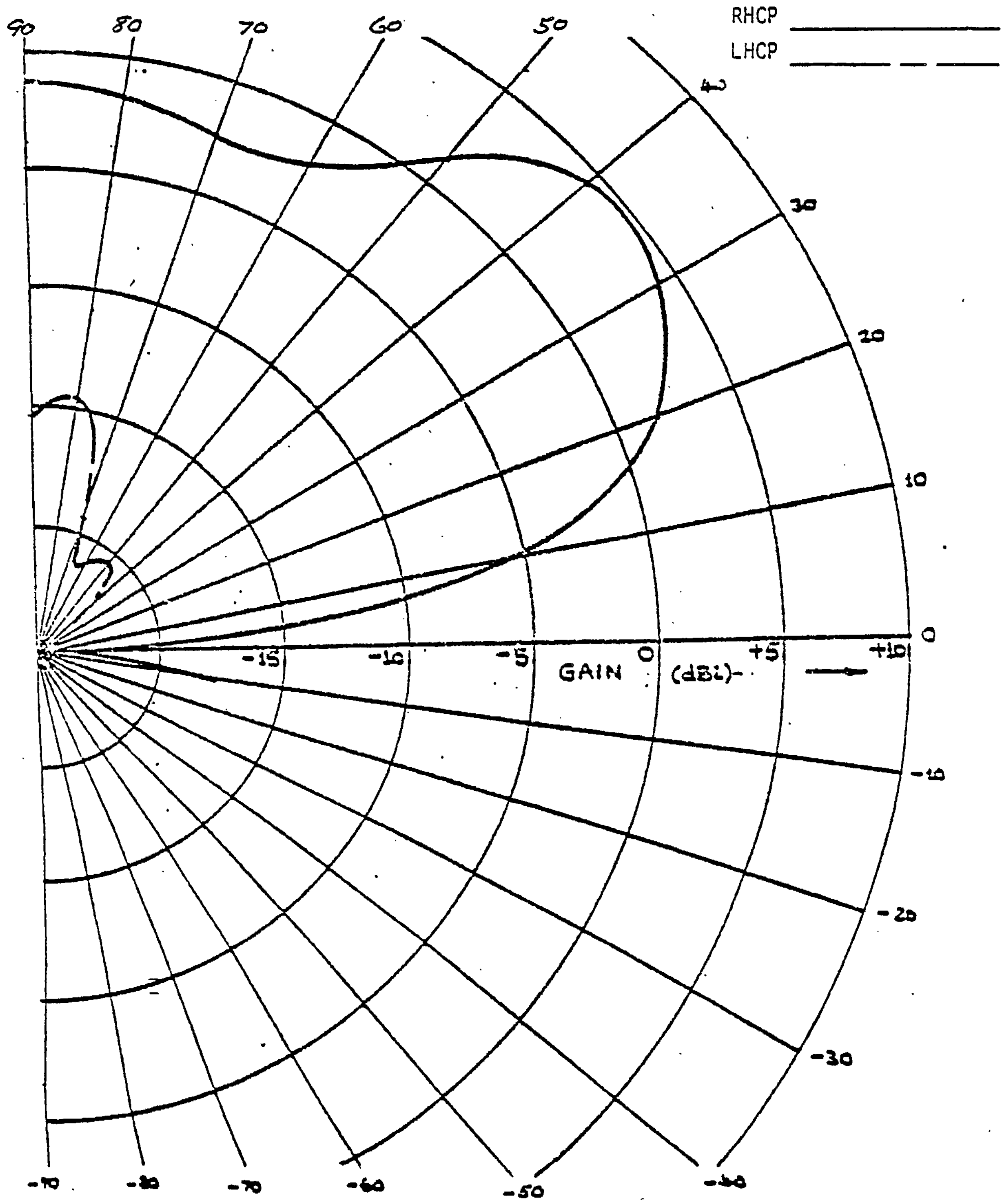


Figure B.3 BACKFIRE QUAD. HELIX ANTENNA (MODEL 2)
(HALF-WAVE BALUNS (50 UNBAL. TO 200 BAL.) 870 MHz)

ANNEX C BIBILOGRAPHY

1. "User Requirements for a Mobile Satellite System Operating in the 806-890 MHz Band", Vol. I - Report, Vol. II - Tables and Appendicies, Woods Gordon Management Consultants, Toronto, Ontario, September, 1981, DOC-CR-SP-81-025.

2. "MSAT Commercial Viability Study" Intel Consultants Ltd., Ottawa, Ontario, March, 1982, DOC-CR-SP-81-046.

3. "User Cost Benefit Study for a Mobile Satellite Radio System", Systemhouse Ltd., Ottawa, Ontario, April 1982, DOC-CR-SP-81-028.

4. "MSAT Canadian Demonstration Spacecraft - Report and Baseline Performance Document", SPAR (SSD), Ste.-Anne-de-Bellevue, Quebec, December, 1981, DOC-CR-SP-81-047A.

5. "Executive Summary, MSAT Spacecraft Conceptual Design Studies", SPAR Aerospace Ltd., Ste.-Anne-de-Bellevue, Quebec, December 1981, DOC-CR-SP-81-047B.

6. "Development of Configuration Software for the Demonstration Mobile Communications Satellite", J.K. Kendall Consultants Ltd., Mississauga, Ontario, July 1981, DOC-CR-SP-81-037.

7. Update of COMSATMOD Program, (Software only), Canadian Astronautics Ltd., Ottawa, Ontario, November, 1981.

8. MUSAT Transportable Antenna, Andrew Antenna Co., Whitby, Ontario, DOC-CR-SP-81-012.

9. MSAT Transportable Antenna Study, Andrew Antenna Co., Whitby, Ontario, January, 1982, DOC-CR-SP-82-003.

10. A Study of MSAT Shipborne Antennas, Canadian Astronautics Ltd., January, 1982, DOC-CR-SP-82-002.

11. "MSAT Gateway Station Study - Canadian Option". SED Systems Ltd., Saskatoon, Sask., October 28, 1981, DOC-CR-SP-81-049A.

12. "A Study of the MSAT Central Control Station Requirements", SED Systems Ltd., Saskatoon, Sask., November 27, 1981, DOC-CR-SP-81-050.

13. MSAT Mobile Terminal Study, ADGA Ltd., Ottawa, Ontario, April, 1982, DOC-CR-SP-82-034.

14. Mission and Operational Analysis, Telesat Canada, Ottawa, Ontario, DOC-CR-SP-82-005.

15. System Availability Study for MSAT, Telesat Canada, Ottawa, Ontario, DOC-CR-SP-82-006.

16. Study of the Application of TDMA for MSAT, Miller Communications Systems Ltd., Kanata, Ontario, March, 1982, DOC-CR-SP-82-011.

17. "A Study of Intersystem Interference in the 806-890 MHz-Band", Canadian Astronautics Ltd., Ottawa, Ontario, September 1981, DOC-CR-SP-81-045.

18. General Functional Requirements for the Ground Segment S/C Real Time Computing System (SRTCS) for MSAT. GasTOPS Ltd., Ottawa, Ontario, June 12, 1981, DOC-CR-SP-81-031.

19. General Functional Requirements for the Ground Segment Real-Time Simulation (RTS) system for MSAT. GasTOPS Ltd., Ottawa, Ontario, June 12, 1981, DOC-CR-SP-81-032.

20. General Functional Requirements for the Ground Segment S/C Test and Integration Computing System (STICS) for MSAT. GasTOPS Ltd., Ottawa, Ontario, June 12, 1981, DOC-CR-SP-81-033.

21. "Executive Summary of an MSAT Ground Segment Computer Study" (Report), GasTOPS Ltd., Ottawa, Ontario, June 12, 1981, DOC-CR-SP-81-044A.

22. MSAT Ground Segment Computer Study, GasTOPS Ltd., Ottawa, Ontario, June 12, 1981, DOC-CR-SP-81-044B.

23. Demonstration MSAT Ground Segment Computing Requirements Survey, GasTOPS Ltd., Ottawa, Ontario, March 1982, DOC-CR-SP-82-014.

24. Demonstration MSAT Ground Segment Computing Requirement Study, GasTOPS Ltd., Ottawa, Ontario, March 1982, DOC-CR-SP-82-015.

25. "An Analysis of Alternative Systems for Development of Mobile Satellite Services". Vol. 1 - Report, Vol. 2 - Appendices. Canadian Astronautics Ltd., Ottawa, Ontario, December 1981, DOC-CR-SP-82-009.

26. (Study of Application of Vector Quantization to Residually-Excited Linear Predictive Coding), University of Sherbrooke, Quebec, March 1982, DOC-CR-SP-82-021.

27. Configuration Options for the Demonstration MSAT, SPAR Aerospace, DOC-CR-SP-82-004A, -004B, -004C.

ISSUE P2 CHANGE ____ MSAT NO. 2001

Controlled Distribution

NAME	NO.
Altman, S.P./DSM	1
Andean, J.D./Systems	1
Athanassiadis, D./Post-Launch Comm. Program Mgr.	2
Boudreau, P.M./Program Manager	1
Breithaupt, R.W./Program Director	1
Caswell, R.D./Bus Manager	1
Forster, B.D./SSC/Contractor Manager	1
Hindson, W.D./Communications Processing Systems	1
Heal, J.A./Project Office Manager	1
Huck, R.W./Mobile Systems Studies	1
Jeffrey, Major G.I./DND Payload Manager	6
Kent, J.D.B./Systems Manager	1
Maynard, L.A./DSS	1
McNally, J.L./Project Manager	1
Nicholson, J.E./Ground Segment Manager	1
Palfreyman, M./DSE	1
Raine, H.R./Space Segment Manager	1
Tennuci, J.E./Product Assurance Manager	1

FILES: Project Office - MSAT 6970-13-5-1	5
SPARES	50

MOBILE COMMUNICATIONS SATELLITE (MSAT) : COMMUNICATIONS SYSTEM CONCEPT DOCUMENT