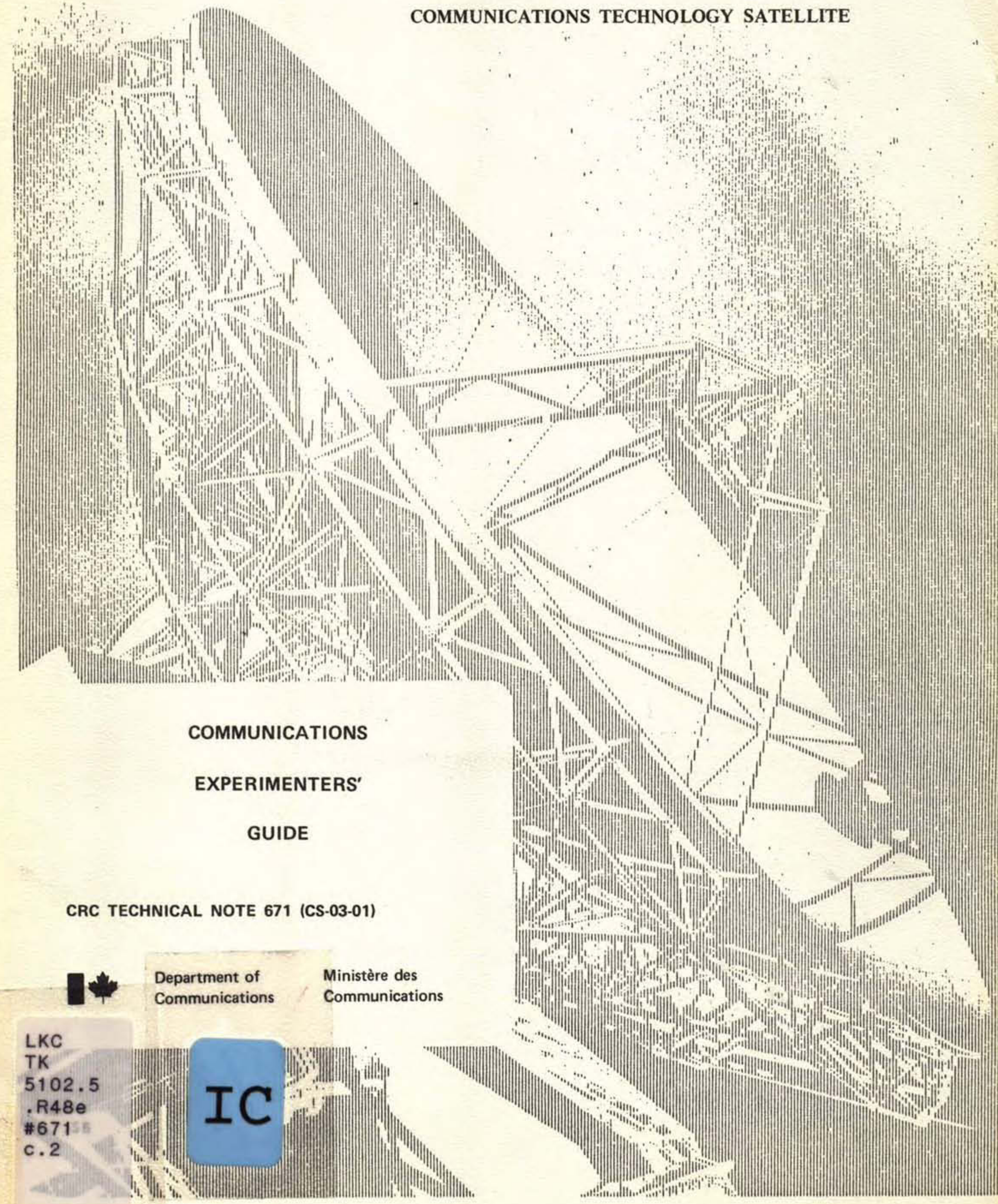
COMMUNICATIONS TECHNOLOGY SATELLITE



COMMUNICATIONS EXPERIMENTERS' GUIDE

CRC TECHNICAL NOTE 671 (CS-03-01)

Department of Communications
Ministère des Communications

OTTAWA

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COMMUNICATIONS RESEARCH CENTRE

DEPARTMENT OF COMMUNICATIONS
CANADA

COMMUNICATIONS EXPERIMENTERS' GUIDE
COMMUNICATIONS TECHNOLOGY SATELLITE

by

R.W. Huck

(Space Applications Branch)

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1. INTRODUCTION

The Communications Technology Satellite (CTS) is a joint experimental program of the Canadian Department of Communications and the United States National Aeronautics and Space Administration to explore the application to communications of advanced satellite technology. It is planned to launch the experimental satellite in December 1975. In addition to the development and flight testing of advanced spacecraft sub-systems, both countries will carry out an experimental program in communications using the satellite. The U.S. and Canada have agreed to share the use of the satellite for communications experiments on a 50-50 basis.

One of the main technology experiments on CTS will be the testing of a 200 watt, high-efficiency, travelling-wave tube operating at a frequency of 12 GHz. The RF output power will be significantly greater than that provided by an existing spacecraft.

Prior to 1971, the only frequency bands allocated for satellite communications were below 9 GHz. Bands at 4 and 6 GHz are being used extensively in international systems such as INTELSAT, and are also used by Telesat Canada for the Canadian domestic satellite system. These bands are allocated on a primary basis to, but shared with equality by, the Fixed-Satellite (communications satellite) and the Fixed (terrestrial) Services, and are subject to sharing constraints and power flux density limits by international agreement.

In July of 1971, the I.T.U. World Administrative Radio Conference on Space Telecommunications allocated a number of new frequency bands to the space services. The CTS will transmit in the band allocated at 11.7 - 12.2 GHz and receive in the band at 14.0 - 14.5 GHz.

There is no power flux density limit imposed on satellite transmissions at 12 GHz and, therefore, the development of high e.i.r.p. satellites is appropriate to this frequency band.

Although the 12 GHz band is not allocated exclusively to space services, terrestrial services, by international agreement, may be introduced only after the elaboration and approval of plans for space services to ensure compatibility of the use of the band within each country. In fact, the ability to locate ground stations close to the user, by avoiding coordination problems often encountered in the lower frequency shared bands, may be one of the more important features of the use of the band by domestic systems with large numbers of terminals. In Region 2, which comprises North and South America, use of the 12 GHz band by space services is limited to domestic systems. It is allocated to the Broadcasting-Satellite Service as well as the Fixed-Satellite Service.

Communications experiments using CTS will be aimed primarily at exploring those applications that take particular advantage of the use of the 12 GHz band and the high satellite e.i.r.p. Ground station development within the CTS program will tend to concentrate on terminals having small diameter antennas which can be located close to the user. The satellite and ground terminals will be particularly suitable for technological and social experiments in the areas of:

1) Television broadcasting to remote communities.

2) Interactive educational or instructional television to remote communities with a telephony quality return channel.

3) Two-way television between communities.

4) Sound broadcasting.

5) Two-way telephony.

6) Teleconferencing.

7) Medical consultation and biomedical telemetry from remote locations.

8) Data links.

9) Wideband distribution.

This guide has been prepared to provide a document on the technical and operational aspects of the CTS satellite, the associated ground terminals and the communications capabilities of the combined system. Its purpose is to assist experimenters in detailed planning of their individual experiments and to specify some of the divisions of responsibilities between the Department of Communications and the experimenter, with regard to the operational implementation of their communication experiments within the CTS program. The satellite itself and each of the types of ground terminals are described in detail.

The interfaces in the ground terminals where experiments access the CTS system are specified. The ground terminals have been designed to provide, wherever feasible, the communications requirements desired by the experimenters.

Included in this document is a description of the basic services provided by the satellite and the associated ground terminals. These basic services, such as television, telephony and sound program, can be combined in various manners, most of which are described, to implement different experiments. It is important that each experimenter be fully cognizant of the operating limitations of the satellite and ground terminals as described herein.

2. COMMUNICATIONS APPLICATIONS

2.1 COMMUNICATIONS SYSTEM CAPABILITIES

2.1.1 Satellite

As a prelude to a discussion of the communications capabilities of the combined system of the spacecraft with its associated ground terminals, it is necessary to introduce briefly some of the characteristics of the spacecraft itself. A more detailed description is provided in Section 4.

The spacecraft will be launched into the geostationary satellite orbit and will be located nominally in the plane of the earth's equator, at 116°W longitude, approximately due south of Banff, Alberta at an orbital radius of approximately 35,886 km (22,300 miles). From this location, any part of the North American continent is visible, with the possible exception of some of the islands or portions of islands located near the north pole.

Figure 2.1 illustrates some of the communications characteristics of the spacecraft. On board the spacecraft there are two steerable antennas and a transponder. Signals received by one antenna at 14 GHz are amplified by the transponder, frequency translated and transmitted at 12 GHz from the second antenna.

Two communications channels are provided in the CTS transponder. As illustrated in Figure 2.1, any suitably equipped ground terminal in Area 1 can send a communication signal via the spacecraft transponder to any terminal in Area 2 through one of the channels. A return link from any terminal in Area 2 can be established via the second channel of the transponder to any terminal in Area 1. It is not possible, however, to send a signal from some location within one beam coverage area, through the spacecraft and back to the same coverage area unless the second antenna is pointed such that the beam coverage areas of both antennas are coincident or a double hop through one of the large terminals is used. Limitations in the capabilities of the terminals and the types of communications signals will be discussed later.

Two relatively narrow-beam steerable antennas, with a beamwidth of 2.5°, are provided, with the result that the coverage area for each of the antennas is limited and is certainly much less than Canada-wide. Since all of Canada cannot be covered simultaneously, a capability of service to any part of Canada then requires that the spacecraft antennas be steerable. Details on coverage areas provided by these spot beams are given in Section 4.3.

The two antennas are remotely steerable by ground command to accommodate the pointing requirements established for each experimenter. For this reason, it is necessary for the experimenter to indicate the precise location of his ground terminals to CRC such that the beams can be properly oriented.

Movement of the antennas on the spacecraft involves transmitting command signals from a spacecraft control terminal located at the Communications Research Centre. Each time the antennas are moved, other than for minor pointing corrections, it is necessary to allow a short period of time to restabilize the spacecraft. Consequently, changes in pointing requirements during any experimenter's daily allotted time will be discouraged.

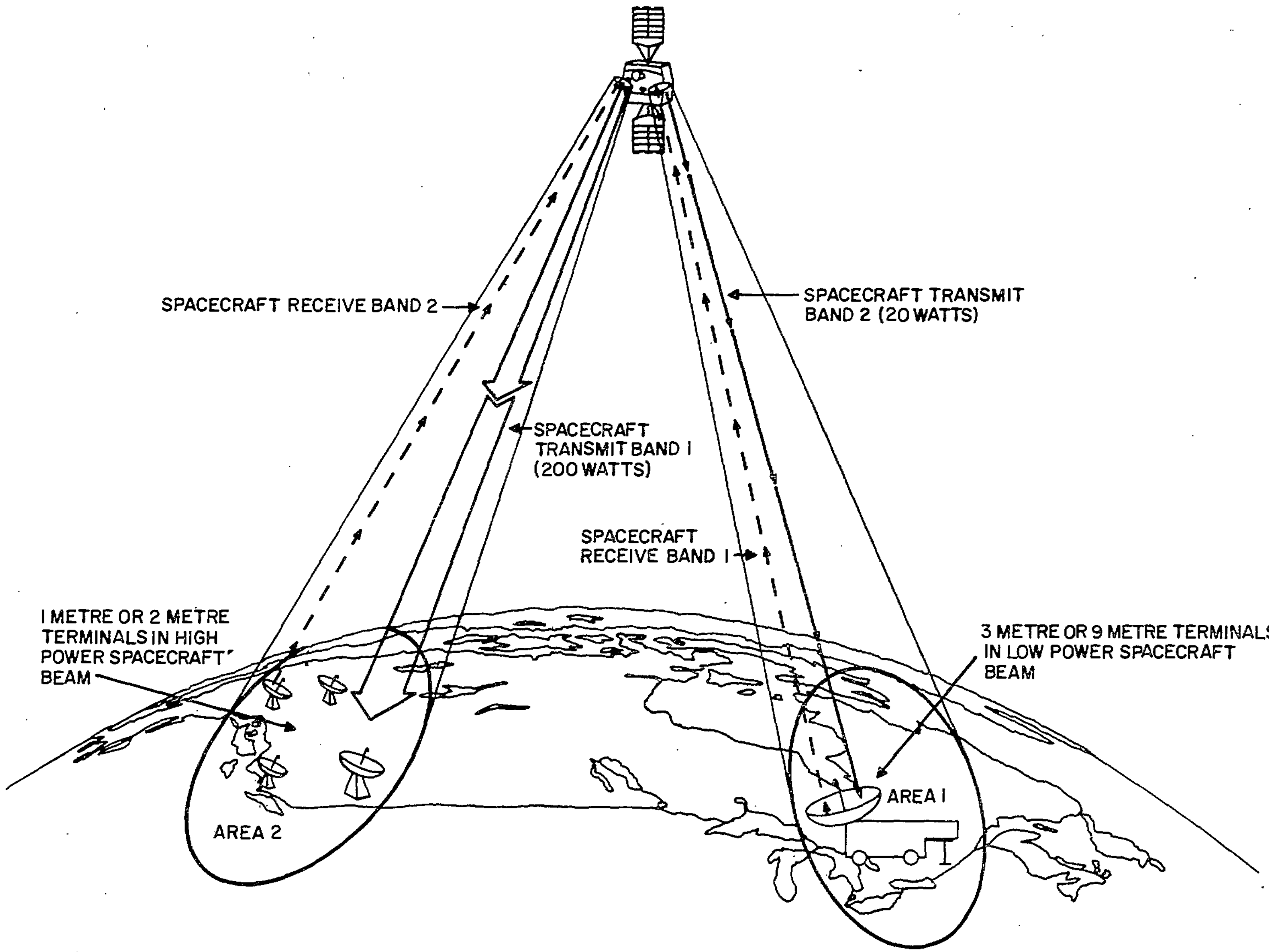


Figure 2.1. CTS Communications Characteristics

One of the unique features of the spacecraft transponder is that one of the two communication channels is equipped with a high power transmitter of 200 watts, compared with 20 watts for the second. This permits the satellite to operate in a broadcast mode where one relatively large station can broadcast through this channel to any number of smaller stations within the coverage area of the high power beam. The technical requirements of the ground terminals, and consequently the cost, are reduced considerably from the case of receiving the same quality of signal from the low power channel.

2.1.2 Ground Terminals

The Department of Communications has reviewed the approved experiments to evaluate the technical requirements of the ground terminals to be used with the spacecraft. Under the constraints of the communications capabilities of the spacecraft and the financial resources available, CRC has specified and initiated procurement for a complement of ground terminals to meet the requirements of the experimenters.

DOC/CRC will make available the following terminals to be shared among experimenters:

1) Three large terminals consisting of:

   2 3-metre transportable ground terminals

   1 9-metre Ottawa ground terminal

2) Sixteen small terminals consisting of:

   8 2-metre ground terminals

   8 1-metre ground terminals.

The 9-metre Ottawa terminal is the largest of the terminals and, in fact, is the only one which cannot be moved. The terminal has a 9.14 metre (30 ft) diameter antenna mounted on a pedestal. Some of the communications equipment is located in an antenna cabin mounted on the pedestal directly behind the main reflector. Near the antenna is an operations building which contains the remainder of the communications equipment and a control console for the antenna. From this building, control of the entire terminal is provided. The terminal will be capable of providing transmission and reception of television, sound program and digital data of various rates, as well as serving as the network control for the telephony system.

The two 3-metre terminals are transportable terminals in the form of trailers. They each have a 3.05 metre (10 ft) diameter antenna and contain essentially identical communications equipment to that of the 9-metre terminal. Since they are quite readily transportable, they make available from different locations within Canada the same communications capabilities as the 9-metre Ottawa ground terminal.

The 2-metre terminals are transportable terminals primarily designed for reception of television signals relayed from any of the 3-metre or

9-metre terminals through the high power channel of the spacecraft. They consist of a 2.13 metre (7 ft) diameter antenna with associated communications equipment. In addition to receiving television, they are equipped to provide one telephony channel and to transmit and receive one sound program channel. Limitations on the simultaneous use of these capabilities will be discussed later in this section.

The 1-metre terminals are small transportable terminals primarily designed for telephony applications. They consist of a 0.81 metre (32 inches) diameter antenna and associated communications equipment. Each will be equipped for telephony and, in addition, provide a capability of transmitting or receiving a sound program signal.

2.1.3 Available Communications Capabilities

In accordance with the requirements of the experimenters and the technical characteristics of the spacecraft, the terminals have been designed to provide several specific communications capabilities. These capabilities, described below, form the basic modes of operation of the complete system. Table 2.1 summarizes the inter-terminal communications capabilities. It should be noted that the table does not imply simultaneous operation.

The terminals, with their respective capabilities, have been designed specifically to make use of the unique feature of the 200W high power transmitter of the spacecraft. For this reason, in almost all cases, the small terminals will be located in the high power beam coverage area of the spacecraft while the large terminals will be in the low power beam coverage area. This should be understood in the descriptions for the basic modes of operation which follow.

2.1.3.1 TV Broadcast

Each of the three large terminals is equipped to broadcast television to any number of 2-metre terminals. The TV broadcast consists of one NTSC color video channel accompanied by up to three audio channels. The audio channels are all equivalent in performance. An experimenter may choose to use any or all of the channels and transmit any audio signal compatible with channel characteristics.

The large terminals are equipped to accept the TV video and audio signals at baseband frequencies. The outputs of TV cameras and video tape recorders are typically at baseband. At the receiving end, the video and audio signal outputs of the 2-metre terminals are at baseband as well.

It is the responsibility of the experimenter to provide all TV video and audio production and monitor equipment and to interface with the transmitting and receiving terminals at baseband. The experimenter must ensure that all signals and interconnections are compatible with the terminal. Consequently, the experimenter must provide, as necessary to meet his requirements, TV cameras, microphones, audio amplifiers, video tape recorders, cabling, microwave links to remote location, etc., for the transmit end. Similarly, at the 2-metre receiving terminal, he must provide, as required, a video and audio distribution system, cables, TV receivers, etc.

TRANSMIT

RECEIVE	9 METRE	3 METRE	2 METRE	1 METRE
9 METRE	———	TV with 3 Audio Ch. or IF Interface Ch.*	One Telephony Ch. or IF Interface Ch.* or Sound Program (if equipped with optional SPTU)***	One Telephony Ch. or Sound Program Ch. (if equipped with SPTU)***
3 METRE	TV with 3 Audio Ch. or IF Interface Ch.*	TV with 3 Audio Ch. or IF Interface Ch.*	One Telephony Ch. or IF Interface Ch.* or Sound Program Ch. (if equipped with SPTU)***	One Telephony Ch.
2 METRE	Any pair of: TV with 3 Audio Ch. One Telephony Ch. Sound Program Ch. (if equipped with optional SPRU)** or IF Interface Ch.*	Any pair of: TV with 3 Audio Ch. One Telephony Ch. Sound Program Ch. (if equipped with optional SPRU)** or IF Interface Ch.*	One Telephony Ch. or One Sound Program Ch. (if Tx has SPTU*** and Rx has SPRU**) only when using a 9 or 3 metre NCT in double-hop mode.	One Telephony Ch. or One Sound Program Ch. (if Tx has SPTU*** and Rx has SPRU**) only when using a 9 or 3 metre NCT in double-hop mode.†
1 METRE	One Telephony Ch. and Sound Program Ch. (if equipped with optional SPRU)**	One Telephony Ch. and Sound Program Ch. (if equipped with optional SPRU)**	One Telephony Ch. or One Sound Program Ch. (if Tx has SPTU*** and Rx has SPRU**) only when using a 9 or 3 metre NCT in double-hop mode.	One Telephony Ch. or One Sound Program Ch. (if Tx has SPTU*** and Tx has SPRU**) only when using a 9 or 3 metre NCT in double-hop mode.†

* IF Interface Ch. is an 85 MHz (1 dB) channel at an IF of 735 MHz suitable for connection of high speed digital data modems.

** SPRU - Sound Program Receive Unit

*** SPTU - Sound Program Transmit Unit

† Sound Program from a 1 metre to a 1 metre or 2 metre terminal requires a 9 metre network control terminal.

NOTE: The services described between terminals are not necessarily simultaneous services.

Table 2.1. Interterminal Communications Capabilities of CTS Ground Terminals

Since the received signals at the 2-metre terminals are made available to the experimenter at baseband, the experimenter will be required to process the signals to be compatible with the distribution system employed. For example, although a baseband signal can be fed directly to a video monitor, it cannot be connected to the antenna input of a normal commercial TV receiver. Normal TV receivers can be used, however, by one of two methods. A suitably skilled TV technician can connect to the baseband amplifier inputs for both the videc and audio signals in the circuitry of the TV receiver and adjust the signal amplitudes to suit the particular TV set. Alternately, a TV remodulator can be purchased which remodulates the baseband video and audio on a RF carrier to make it compatible with the antenna inputs of the receiver. For example, one such device, called a color RF adapter, remodulates the baseband signal on a carrier such that it can be received on channel 3 or channel 4 of a standard TV set. Some video tape recorders employ built-in devices of this sort such that a standard color TV set can be used to display the output of the recorder.

2.1.3.2 Telephony

A telephony system has been designed to permit a two-way interconnection of telephone quality between any of the small terminals. However, single-hop telephony communications, via the satellite, between any pair of small terminals is not possible. Such communication requires a double-hop through the satellite with a large terminal in the loop configured as a Network Control Terminal (NCT). The NCT is always located at the centre of the spacecraft low power beam. Although this may seem more complicated than a simple single-hop mode, there are a number of reasons for taking the two-hop approach for CTS. These are:

1) it simplifies the small terminal design;

2) each small terminal has a unique frequency assignment and therefore channel switching at the small terminal is not required;

3) channel switching is accomplished by a semi-automatic switching system located at the NCT;

4) the RF power requirement for the small terminals is less than with single-hop because of the specific characteristics of the CTS transponder;

5) a pilot carrier is required for frequency control and this is provided by the NCT;

6) telephony capability can be maintained if the 200 watt high power tube in CTS fails and only a back-up 20 watt tube is left.

The telephony system will likely be widely used by experimenters. It is imperative that the experimenter, in planning his experiment, be fully cognizant of the technical limitations and operational requirements of the system including each type of ground terminal. A detailed description of the system follows, concluding with the limitations imposed on it in terms of equipment availability and operational requirements.

The telephony system has been designed to allow a telephony quality two-way link between:

1) pairs of 1-metre terminals;

2) pairs of 2-metre terminals;

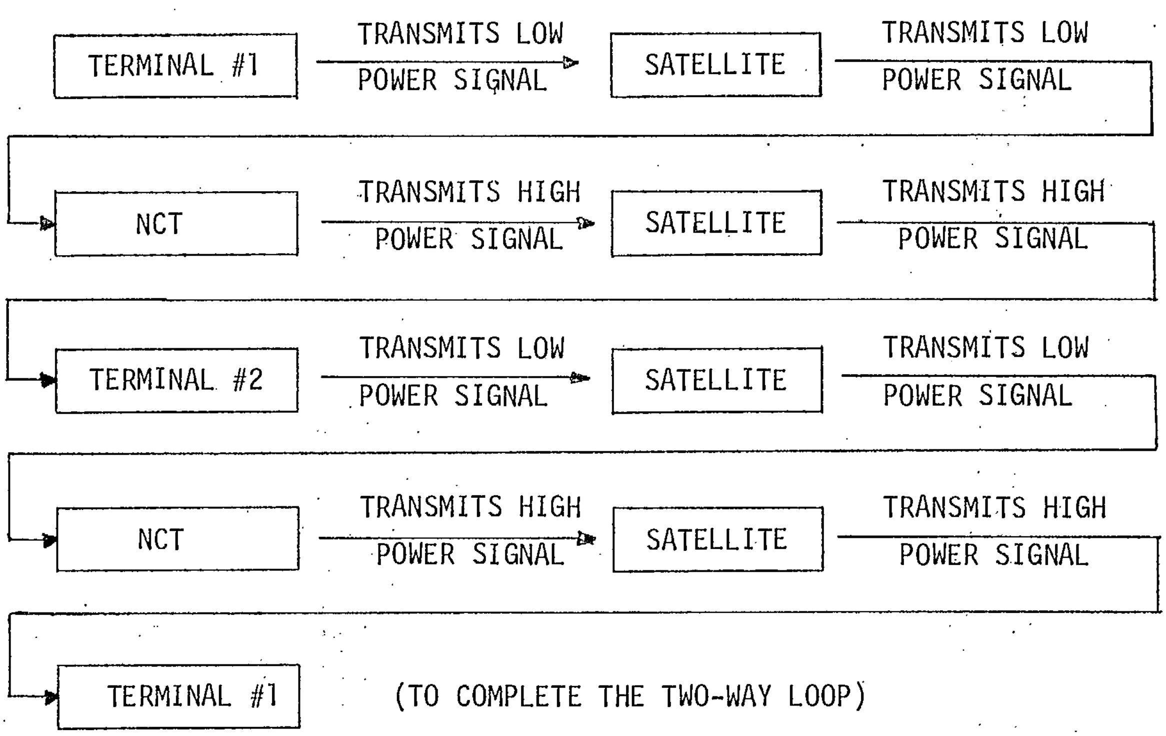
3) any 1-metre and any 2-metre terminal in pairs;

4) a small terminal and the large terminal acting as the NCT.

In addition, a conference network can be established interconnecting a maximum of nine small terminals, an operator at the NCT and an additional external input at the NCT.

In order to operate the telephony system, the participating small terminals must lie within the high power beam of the spacecraft. In addition, one of the large terminals must be centred on the low power beam and this terminal will act at the NCT for the telephony system. It is important to appreciate that under no circumstances can a small terminal communicate with another small terminal directly via the satellite. In every case, an NCT must be involved to relay the signals between the participating small terminals. Figure 2.2 illustrates the sequence in which a call between two terminals is established in the two-hop scheme used.

The sequence proceeds as follow:



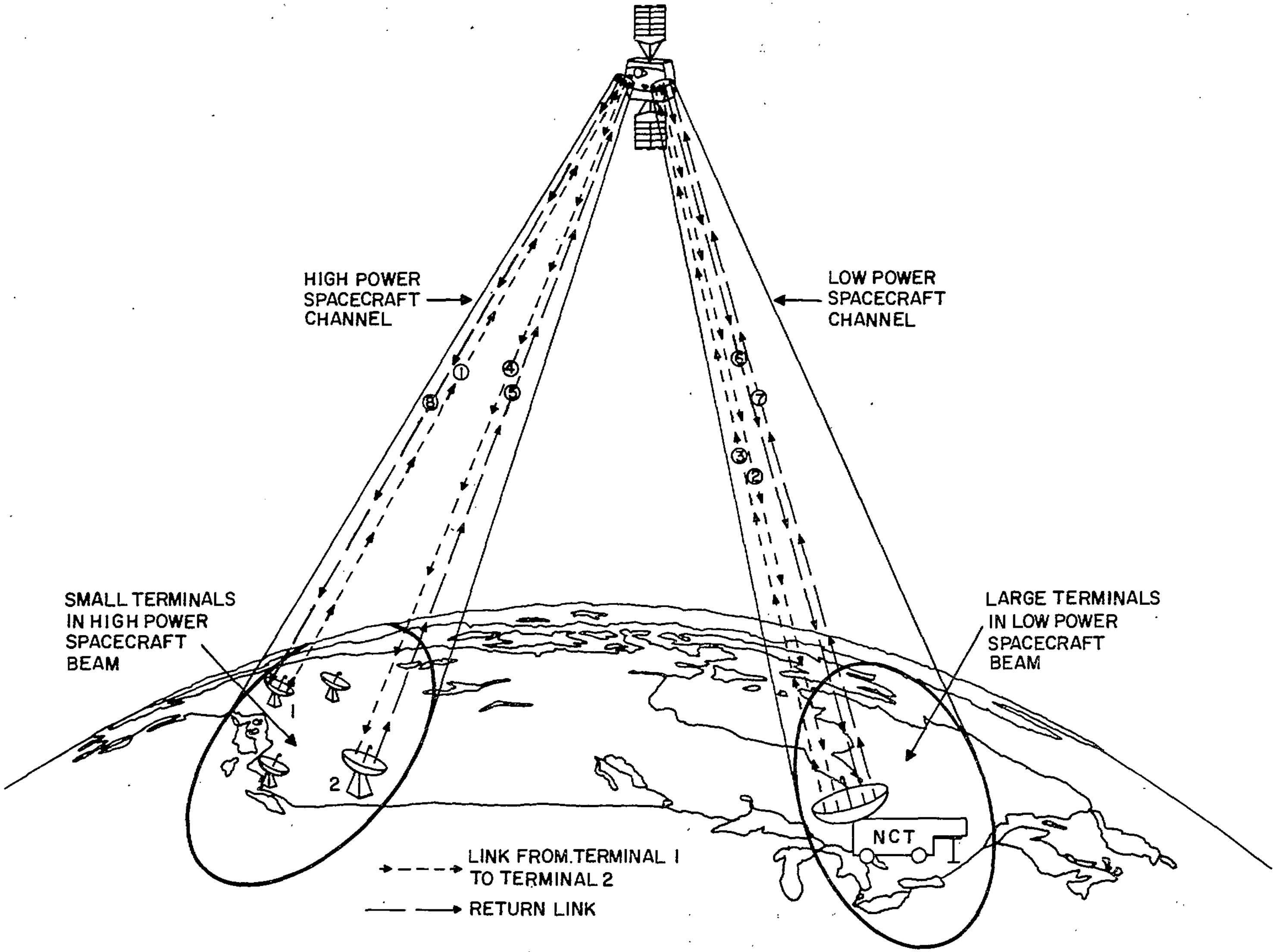


Figure 2.2. Signalling Requirements for the Telephony System

Each of the small terminals transmits and receives on its own unique assigned frequency. To place a call from one terminal to another requires that the NCT receives at the frequency assigned to Terminal #1 and transmits at the frequency assigned to Terminal #2. This requires the use of one channel unit or one modem (modulator-demodulator) in the NCT. A return link, establishing the two-way capability, requires, in the same manner, a second channel unit. Switching is automatically provided at the NCT to allow any one participating small terminal in the high power beam of the spacecraft to call any other participating small terminal in the same beam. The NCT simply switches to the appropriate modem assigned to the terminal. A second pair of terminals can simultaneously achieve interconnection in an identical manner. This can continue up to the limit of either participating terminals or available channel units in the NCT. It is important to note that although the NCT can simultaneously transmit signals to (or receive signals from) several terminals, each individual terminal is frequency tuned to receive only the one signal directed to it from the NCT.

The NCT is equipped with an automatic switching system which, like the terrestrial system, allows a party at one terminal to selectively call a specific second terminal. This is accomplished at the originating terminal by the use of the touch-tone dial in the standard telephone set accompanying each terminal. The originator simply dials the desired terminal and the NCT makes the necessary interconnections to provide the two-way link, provided, of course, that terminal is not busy.

With the use of the NCT, conferencing calls can be readily established involving several terminals, and, if desired, an operator at the NCT and an external input at the NCT. A maximum of two independent conferences can be simultaneously handled by the NCT. The applications and operation of a teleconferencing system is described below in Section 2.2.4.

Of prime importance to the experimenter is a realization of the limitations to system capacity. Up to a maximum of nine channel units can be accommodated by each NCT. This means that up to nine small terminals can be involved in two-way telephone communications under the control of the NCT at any time.

In addition to the nine terminals, two more parties can be simultaneously included into the network. Both of these lines are available at the NCT and consist of an operator interface and an external input interface. Consequently, any terminal can talk to an operator at the NCT or a party on the external input utilizing only one channel unit since only a single hop is necessary to talk between the NCT and a small terminal. For a two-way link between two small terminals, two hops are required through the satellite, with two passages through the NCT and consequently two channel units are required.

The combinations of how the channel units can be used to maximum capacity vary, depending upon the requirements of the experimenters. For example:

1) a two-way telephone link can be established between four pairs of 1 or 2-metre terminals for a total of eight terminals with a ninth terminal carrying on a two-way conversation with an operator at the NCT;

2) five terminals and an operator at the NCT can be involved in a teleconference while, at the same time, two two-way conversations can occur between two pairs of terminals for a total of 9 terminals.

Although each NCT can handle up to nine channel units, this number will not necessarily be available. CRC have purchased a total of 18 units to be shared between the three NCT's. CRC will ensure, however, that a sufficient number of channel units will be available at the NCT used by the experimenter to accommodate the small terminals that have been assigned to that particular experimenter.

In addition to the limited number of channel units, the following restrictions apply:

1) No direct communication, via the spacecraft, is possible between small terminals. In every case, the involvement of an NCT is required.

2) A small terminal cannot establish a telephony connection to a large terminal unless that terminal is acting as its NCT.

3) Links by the telephony system cannot be established between two large terminals. The terminals will not be equipped with the telephony equipment necessary to provide this capability. There are, however, possible ways of providing a two-way link by use of other equipment included in the large terminals. For example, the audio channels associated with the TV can be used to provide a two-way link. However, care must be exercised to ensure that all interface requirements, described in Section 3, are met and that the spacecraft antennas are pointing in the appropriate directions.

Some experimenters may wish to use the telephony channel for signals other than voice communication. Examples could be teletype, facsimile, telemetry compatible with telephone channel capacities, etc. In this case, it is the responsibility of the experimenter to provide all the necessary equipment beyond the telephone set supplied with the terminals and to ensure that the CTS telephone system is capable of supporting the form of modulation utilized by this equipment. Such equipments can be interfaced with the terminals either through telephone acoustic couplers supplied by the experimenter or, more appropriately, through connection to a line interface provided specifically for this purpose. The experimenter must ensure that all interface requirements for the appropriate terminals are met.

In some applications, an experimenter may wish to use the external input at the NCT to tie into the terrestrial telephone system. In addition, the experimenter might wish that the small terminals tie into the local telephone systems. To do this requires, by law, the involvement of the local telephone companies. The CTS telephony system differs from the terrestrial system and an interface must be provided.

First, the CTS system is a 4-wire system which eliminates the need for echo suppressors in the ground terminals provided no terminal is connected to the terrestrial telephone system. The terrestrial system generally uses a two wire scheme which results in echoes in the satellite circuit if echo suppressors are not used. Interfacing to terrestrial telephone systems will therefore require that the telephone company provide an echo suppressor designed for geostationary satellite links and suitable electronic hardware to convert from the four wire to a two wire system. Most telephone companies should be aware of and have available the necessary equipment. However, if an experimenter wishes to use this capability, he should consult, at an early stage, with the local telephone company concerned.

Second, for reasons of economy and simplicity, the dialing system employed by the CTS telephony system is not compatible with the terrestrial system. Consequently, the intervention of an operator is required at the external telephone connection interface to assist in the interconnection of calls with the local telephone system. The operator, equipped with a touch-tone dialer, can set up calls within the CTS system at the request of the caller on the terrestrial system. Once the requested connection has been established, the operator then must patch in the terrestrial line. Calls originating within the CTS system can be tied into the terrestrial system in a similar manner.

Procurement of the equipment required to interface with the terrestrial telephone system is the responsibility of the experimenter. This would involve, primarily, making suitable arrangements with the local telephone companies.

2.1.3.3 Sound Program

A capability will exist to transmit a sound program signal between terminals as described below. This signal is a wideband, high fidelity signal equivalent to that broadcast by commercial FM radio stations and is suitable for transmission of music. It is a monaural signal, however, as opposed to stereo. It is useful to draw a distinction between this signal and the signals supplied by the telephony system. The telephony system provides only a telephone quality channel and, as such, is narrow band (300-3400 Hz for telephone compared with 50 Hz to 15,000 Hz for sound program).

1) Transmission From Large to Small Terminals

CRC has purchased eight sound program receive units which are designed to plug into any of the small terminals. These receivers can provide a high fidelity, one way sound program channel from a large terminal to as many as eight small terminals. In addition to broadcast of high fidelity program material, this signal can be used to transmit data, facsimile, teletype or any other signal compatible with the channel.

An interface panel is available both at the originating station and the receiving station to connect in experimenter equipment at baseband. These interfaces are described in Section 3 and it remains the responsibility of the experimenter to ensure that his equipment is compatible.

The small terminals are equipped with an amplifier such that if the program is to be used close to the terminal only a loud-speaker need be provided. All other equipment required to produce and distribute the program must be supplied by the experimenter. This includes, as required, studio microphones, tape recorders, distribution amplifiers, etc.

As in the case of the telephony system, several restrictions apply in the use of this service. All the small terminals have been designed to attain sufficient frequency stability for both the telephony and sound program systems by means of a pilot carrier. This requires that a special carrier be broadcast via the satellite by the NCT. Consequently, all small terminals receiving a sound program signal must be under the control of the NCT transmitting it. The implications are as follows:

a) A sound program signal cannot be transmitted between two large terminals.

b) The small terminals must all be located in the high power beam of the spacecraft and the NCT in the low power beam.

It should be noted that, in the case of sound program, the signal is transmitted in a broadcast mode to all small terminals located in the high power beam which are equipped with the sound program receive unit. It occupies a single predetermined frequency band such that all terminals receive on the same frequency as opposed to a unique frequency provided to each terminal for the telephony system.

2) Transmission From Small to Large Terminals

CRC has purchased three sound program transmit units which are designed to plug into any of the small terminals. These transmit units permit the origination of high fidelity, monaural, sound programs from small terminals. In addition, this channel can be used for data, facsimile, teletype, or any other signal compatible with the channel. Used in conjunction with the capability described above in (1) this service will allow the relay of high fidelity signals from a small terminal located in the high power spacecraft beam to other small terminals located within the same beam via the spacecraft and NCT in the same two-hop mode employed for telephony.

Again, this transmitting capability is subject to several restrictions. For reasons described above, the transmitting terminals must be under the control of a NCT, implying the following limitations:

a) The transmitting terminal must be in the high power beam of the spacecraft and the NCT in the low power beam.

b) No direct communication between small terminals via the satellite is possible. All signals must be relayed by the NCT.

c) Sound program transmission between two large terminals is not possible. However, an essentially equivalent service of slightly less capacity (10 kHz bandwidth instead of 15 kHz) is available through the use of an audio channel associated with the television system, provided they are not already in use by the experimenter.

d) Sound program signals can be transmitted from a 2-metre to a large terminal providing the large terminal is acting as its NCT. Sound program signals from a 1-metre terminal can only be transmitted to the 9-metre, located at the centre of the low power beam, provided the 9-metre terminal is acting as the NCT for that 1-metre terminal.

e) The sound program transmit units all transmit at the same frequency. Consequently, although three units are available, only one of the terminals equipped with the radio program transmit units under the control of the same NCT can transmit at any time.

f) Telephony and sound program transmission cannot occur simultaneously from the same small terminal. Attaching the optional sound program transmit unit to any of the small terminals requires disconnecting the telephony transmit unit and connecting the sound program transmit unit. It should be noted that a small terminal simultaneously can receive a telephony signal and transmit a sound program signal, however, the telephony signal will be one-way receive only. In order to provide this simultaneous service, the telephony connection through the NCT must first be established. This requires that the telephony transmit unit be connected into the IF interface to provide the necessary signalling to establish the connection. Then the telephony transmit unit may be disconnected and replaced by the sound program transmit unit, thus permitting simultaneous sound program transmission and telephony reception. To release the connection of the telephony channel at the end of the experiment, the telephony transmit unit must again be connected into the IF interface in place of the sound program transmit unit. Then, it is only necessary to hang up the telephone handset and the signal required to release the connection at the NCT will be transmitted.

g) It is possible at the NCT to patch sound program signals into the telephony system, or vice versa. However, the signal transmission qualities will, of course, be determined by the telephony channel since it is the lowest quality.

2.1.3.4 Simultaneous Operation

Although the capabilities described in Section 2.1.3.3 are available on an individual basis, many experimenters will no doubt wish to use some combinations of the basic services provided. This section briefly indicates what can be provided at the same time. Any unique requirements should be discussed with CRC. Section 2.2, following this, will describe some special applications.

With each of the services operating within the channel and terminal constraints described, Table 2.2 summarizes the 4 different combinations of services that can be simultaneously provided to different terminals, using the equipment supplied. Not included are special cases involving transmission of digital data. For most digital experiments either the telephony or sound program channel can be used. Otherwise the experimenter may require exclusive use of one or both of the satellite channels.

			SATELLITE CHANNELS		
Case 1:	3 Metre or 9 Metre Terminals	*Television + Telephony →	200 W Channel	→ Television + Telephony	2 Metre or 1 Metre† Terminals
		← Telephony+Sound Program	20 W Channel	← Telephony+Sound Program**	
Case 2:	3 Metre or 9 Metre Terminals	*Television+Sound Program →	200 W Channel	→ Television+Sound Program	2 Metre or 1 Metre† Terminals
		← Telephony+Sound Program	20 W Channel	← Telephony+Sound Program**	
Case 3:	3 Metre or 9 Metre Terminals	*Telephony+Sound Program →	200 W Channel	→ Telephony+Sound Program	2 Metre or 1 Metre† Terminals
		← Telephony+Sound Program	20 W Channel	← Telephony+Sound Program**	
Case 4:	3 Metre or 9 Metre Terminals	***Television →	200 W Channel	→ Television	3 Metre or 9 Metre Terminal
		← Television	20 W Channel	← Television	

NOTES:

* Television, Telephony and Sound Program cannot all be transmitted simultaneously.

** Each of the small terminals can transmit only one signal at any time; either telephony or sound program. In addition, of a group of terminals transmitting simultaneously, only one can transmit sound program. However, it can be any one of the group. The remainder each transmit their own assigned telephony channel.

*** For simultaneous two-way television, telephony or sound program cannot be included. However, there are 3 audio channels associated with each TV channel which could be used for additional audio interconnection.

† One metre terminals cannot receive Television and can transmit sound program only to the 9 metre NCT.

Table 2.2. Simultaneous Signal Capabilities

2.2 APPLICATIONS

2.2.1 General

Having reviewed the technical réquirements as reported in experimenters' proposals, several specific applications have been identified.

One of the potential problems common to several of the applications involves the generation of echoes where simultaneous audio transmission and reception is required through the use of microphones and loud-speakers. Section 2.2.8 describes some possible difficulties that could arise, depending on the manner in which the experimenter implements his audio circuit.

2.2.2 Voice Interactive Television

The 3-metre or 9-metre NCT transmits TV to 2-metre terminals. The 2-metre terminals can provide a return link via a telephone channel. If interaction between 2-metre terminals is required instead of or in addition to a simple return link to the NCT, this can be provided through the telephony system. An alternate approach to providing interaction among the small terminals, including an instructor at the TV transmitting terminal, would be to equip the instructor with earphones to hear all questions or conversation on the telephony conference circuit and to reply over the TV audio channel. As noted in Section 2.2.8, the telephony conference circuit should not be patched directly to the TV audio channel since this would cause any speech originating from a 2-metre terminal in the telephone channel being received by that same terminal over the TV audio channel with a one-half second delay. This echo would cause confusion.

2.2.3 Two-way Television

All the large terminals are equipped to transmit and receive television in either of the two spacecraft RF channels. With the final design configuration of the terminals, simultaneous two-way television is possible between two 3-metre terminals or a 3-metre terminal and a 9-metre terminal. It must be noted that telephony or sound program channels cannot be provided between these same terminals.

2.2.4 Telephone Conferencing

Conference networks, involving a NCT and small terminals, can be arranged with the telephony system. It should be emphasized that the restrictions applicable to the individual telephony channels described above in Section 2.1.3.3 apply to the utilization of that same system in this mode.

Conferencing calls can be arranged either from the NCT or from any one of the participating small terminals. With automatic switching provided in the NCT a party wishing to establish a conference call simply dials the other parties to be included in the conference. In addition to the small terminals, an operator at the NCT and the terrestrial telephone system, tied in by a special external input/output interface at the NCT, can be included.

The NCT has a capability of operating with two simultaneous independent conference networks. Each conference network can be established independently by any of the participating terminals or by the NCT through the operator's telephone. If desired, the operator's telephone can be used to establish both conferences by setting up one conference, dropping out, and setting up the second. The operator can then participate in the second conference. If, at the same time, a participant is also required at the NCT in the first conference, the external input/output interface can be used to patch an experimenter-owned telephone into the first conference to provide this capability.

As described previously in Section 2.1.3.3, the number of small terminals simultaneously participating in telephone conferences is limited by available equipment at the NCT to nine terminals. This limitations is not affected by inclusion of the terrestrial telephone system or an operator at the NCT.

2.2.5 High Speed Data

An interface has been made available in the 9, 3 and 2-metre terminals to allow an experimenter to connect in special modulation and demodulation equipment necessary to transmit and receive high speed data. The channel provided for this application is an 85 MHz (1 dB) bandwidth channel centred on an intermediate frequency (IF) of 735 MHz. Details of the channel are provided in Section 3.

It is the responsibility of the experimenter wishing to use this channel to evaluate his own requirements and ensure that they are compatible with the capabilities of the spacecraft and the terminals. This includes not only interfacing, but a complete communications link analysis to ensure that the spacecraft and terminals can support the experiment. If necessary, CRC can provide additional details to those experimenters who wish to evaluate specific applications of this channel.

The high IF interface in both transmit and receive chains is available in 9-metre, 3-metre and 2-metre terminals. The 9-metre and 3-metre terminals can receive and transmit in either RF spacecraft channel. Only 1 of the 2 metre terminals is so equipped. The remaining 2-metre terminals all receive via the high power spacecraft channel and transmit via the low power spacecraft channel.

Typical uses of this channel would generally involve data rates which could not be supported by the telephony, sound program or the TV channels, or specific modulation processes incompatible with the FM modulation used in those channels. Examples are:

1) 65 Mbps with 2 phase DPSK from a 9-metre to 3-metre and 2-metre terminals in the high power spacecraft channel;

2) 60 Mbps with Fast FSK modulation from a 3-metre to a 9-metre terminal in the low power spacecraft channel;

3) 62.5 Mbps with CPSK modulation from a 3-metre to a 9-metre terminal or vice versa; etc.

2.2.6 Low Speed Data

Low speed data applications would generally involve the use of the telephony system to provide transmissions of telemetry, teletype, etc.. Use of the telephony system for special data applications is, of course, subject to all the operating characteristics of the telephony system described in Section 2.1.3.2.

It is the responsibility of the experimenter to ensure that all equipment interfaces with the terminals required to transmit and receive his signals are compatible with the interface and channel characteristics. The telephony channels are essentially equivalent in their characteristics to those of the terrestrial telephone system. Consequently, as a general rule, if special equipment supplied by the experimenter can be used over terrestrial telephone lines, then it can be used with CTS. Care must be taken, however, to ensure operation within the terminal configuration described for the telephony system. (For example, a transmitting terminal cannot hear its own transmission return from the spacecraft.) The interface and channel characteristics are described in Section 3.

All the equipment required at both the receiving and transmitting terminals beyond the terminal interfaces available to experimenters must be provided by the experimenter. This includes, as required, cabling, teletypes, teletype modems, baseband telemetry transmitters and receivers compatible with telephone channels, etc.. A two-way switch would be useful to switch between the telephone set and the externally connected equipment (e.g., data modem, telemetry set, etc.). This would allow the experimenter to first establish the link by dialing with the telephone set in the normal mode and then, once established, to switch over to the external equipment.

It should be noted that these channels should be treated as regular telephone channels in that teletypes cannot be directly connected to the interface without the intermediary use of teletype modems. Teletype modems, of course, condition the outputs of teletypes such that they are suitable for transmission over telephone lines. In addition the output of the telephone line must then be reconditioned to be suitable for teletype input.

2.2.7 Facsimile and Slow Scan Television

The telephony system can also be used for transmission and reception of facsimile and slow scan television. Once again, the experimenter must ensure that equipment used with the terminal is compatible with the interface and the channel characteristics. The experimenter must also work within the operational characteristics of the telephony system described in Section 2.1.3.2. In addition, all equipment external to the terminals must be provided by the experimenter.

2.2.8 Potential Problems of Audio Feedback

One of the difficulties associated with communicating via a geostationary satellite is that it takes about 1/4 second for the communications signal to travel from a ground terminal through the satellite and back down to a second ground terminal. If, by some mechanism of acoustical feedback, the received audio signal at the second terminal was to be retransmitted via the satellite to the first, it would appear at the first terminal delayed about 1/2 second from the originating signal. This echo would cause confusion and is unacceptable for a simultaneous two-way experiment involving audio signals.

The CTS telephony system, operated on its own, has been designed to circumvent this problem by using a four wire interface instead of the standard two wire interface used in local distribution for terrestrial telephone systems. A four wire interface permits separation of transmit and receive signals. In addition, the standard handset provides sufficient isolation between the receive speaker and the transmit microphone such that sound propagating from the handset speaker to the microphone is negligible.

Feedback problems could occur and, in fact, could become quite severe in cases where audio channels other than the telephony system described above are used for simultaneous intercommunication. Examples are voice interactive television described in Section 2.2.2 above, two-way television described in Section 2.2.3 above, and use of speakers and microphones (instead of the telephone handset) for the telephony system.

In voice interactive television, it is presumed that a teacher or moderator will be located at the TV originating terminal, using the NCS of that terminal for control of the telephony system. If the teacher's speech is transmitted through an open microphone over a TV audio channel and the discussion on the telephony conference circuit is output via a speaker in the same room as the microphone, potential feedback problems occur. It is obvious that if there is sufficient acoustical coupling between the microphone and the speaker the telephony conference would be fed into the TV audio channel. Thus, speech transmitted in a telephony channel from a small terminal to the NCT would re-appear at that same small terminal in the TV audio channel with a 1/2 second delay. This, of course, is an unacceptable situation. For this reason, it was suggested in Section 2.2.2 that the teacher at the NCT receive the telephony conference by means of headphones such that a sufficient amount of acoustical isolation between the telephony system and the TV audio channel could easily be achieved.

A further difficulty arises in that at the same TV receiving terminal the TV audio could feasibly be coupled into the telephony channel such that the TV audio signal re-appears at the TV transmitting terminal in the telephony channel with a 1/2 second delay. This, again, is unacceptable.

Two-way television and the telephony system have the same potential feedback problems wherever open speakers and microphones are used in the same room for reception and transmission of TV audio or telephony signals.

If feedback is sufficiently severe, the familiar problem of oscillations between the speaker and microphone could occur resulting in a loud high-pitched squeal at the speaker output. The acoustical echo as described above and the high pitched squeal could render useless both the TV audio channels and the telephony system.

The extent to which these problems may impose restrictions upon the operational implementation of the experiment is not an easily determined quantity and has to be analyzed by each experimenter for his particular requirements. It is imperative that in situations where speakers and microphones are employed in the same room particular emphasis should be placed on the design of the room acoustics. It is estimated that to ensure the echo returning to the transmitting terminal be imperceptible, the isolation between the speaker and microphone at the receiving terminal must be a minimum of 40 dB. Consequently, for severe problems, it may be necessary to consider the use of "push-to-talk" microphones that simultaneously disconnect the speakers during the time the microphone is engaged. In the case of the telephony system, echo suppressors have been specifically designed to eliminate this problem. Echo suppressors for use with geostationary satellite links are available through most major telephone companies. In choosing an echo suppressor, it is important to appreciate that the telephony system is a two-hop system where the echo delay between the small and large stations is one-half second and between two small stations is approximately one second. Basically, the function of an echo suppressor is to disconnect the microphone at the receiving terminal upon sensing the presence of a voice signal in its receiver.

It is obvious from the above discussion that it is not sufficient for an experimenter to plan his method of audio distribution for simultaneous transmission and reception without giving considerable thought to problems of feedback.

3. GROUND TERMINALS

3.1 GENERAL

The Communications Research Centre will have a complement of ground terminals which will be made available to experimenters to conduct the CTS communications experimental program. This section describes these terminals in terms of capabilities, configuration, electronic performance, user interfacing, site requirements and operational requirements.

The terminals that will be available to experimenters include the following:

1) one 9-metre Ottawa ground terminal

2) two 3-metre transportable ground terminals

3) eight 2-metre ground terminals

4) eight 1-metre ground terminals.

In general most experimenters will interface with the terminals at baseband with such signals as TV video and audio, telephony, and sound program. An Intermediate Frequency interface is available to permit interfacing of special digital modulation and demodulation equipment.

TV or sound program origination, monitoring, or distribution equipment (e.g., TV cameras, tape recorders, TV receivers, etc.) are not supplied as part of the ground terminals and are the responsibility of the experimenters. The interfacing of the telephony and sound program inputs and outputs of the terminals to telephone or other systems, if required, will be the responsibility of the experimenters.

Similarly, interfacing experimenter's modems at the IF interface will be the responsibility of the experimenter. In all cases, the experimenter must ensure that any external equipment connected into the interfaces of the terminals is compatible with the terminal equipment and meets all interface requirements.

3.2 NINE-METRE OTTAWA GROUND TERMINAL

3.2.1 General

This terminal is the largest of the terminals to be provided for CTS experiments. It is permanently installed at the Communications Research Centre, Shirley Bay, Ottawa. The terminal will be equipped for all types of signals envisaged for the CTS experiments, including television transmission and reception and sound program transmission and reception. In addition, it will have the necessary equipment to act as a network control terminal for the telephony system.

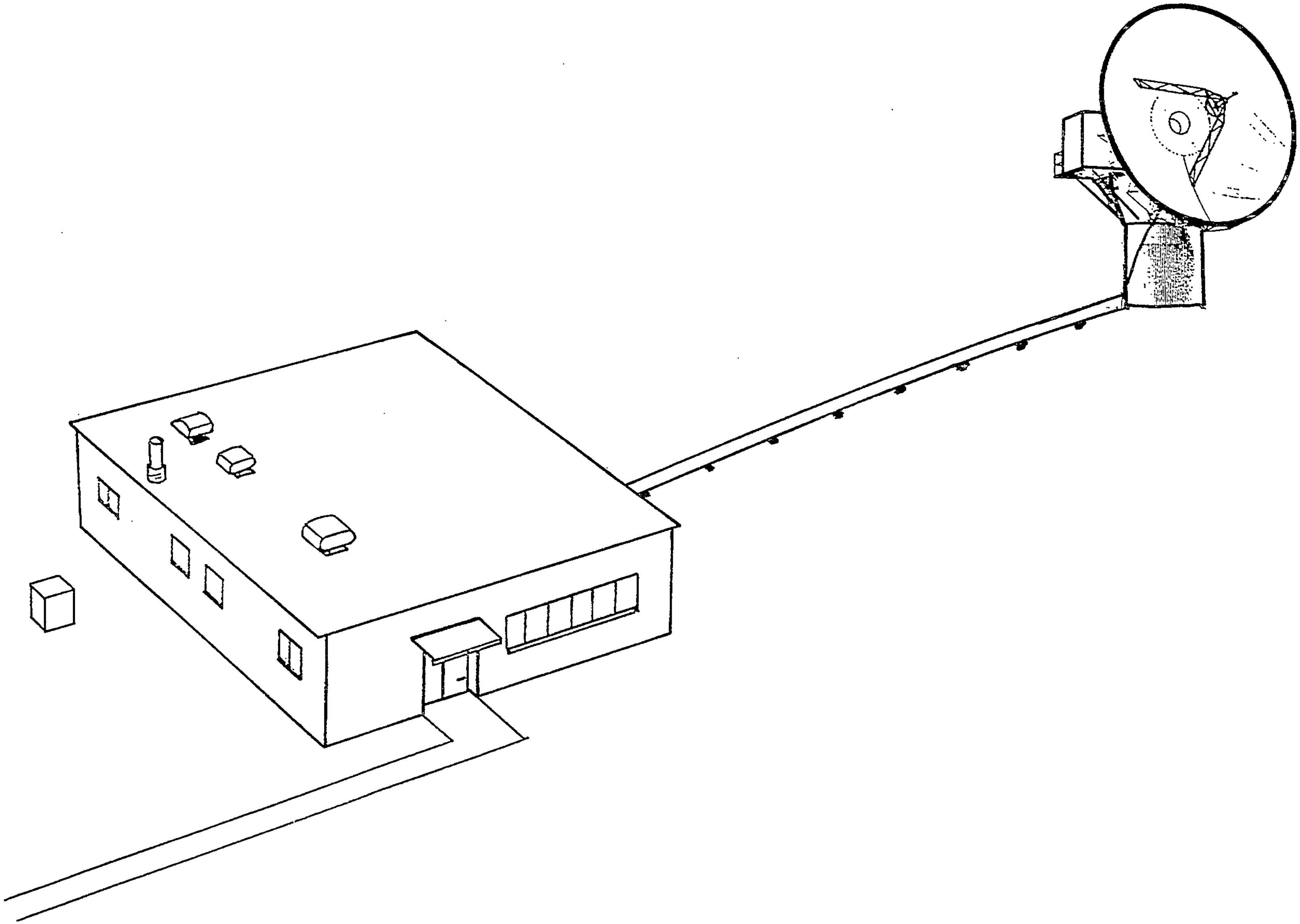


Figure 3.1. 9-Metre Ottawa Ground Terminal

As illustrated in Figure 3.1, the terminal is composed of two major parts; an antenna and a control building. The antenna is made up of a 9.14 metre (30 ft) parabolic reflector mounted on a completely steerable pedestal. Located behind the main reflector of the antenna is an electronics equipment cabin. The control building is situated approximately 30 metres (100 ft) from the antenna with a cable run connecting the two. The control building contains the operating console for the antenna and some of the ground communications equipment. The complete terminal is operated from the control building. All interfacing of experimenter's equipment is to be done at the communications equipment racks within the control building.

3.2.2 Signal Types and Interfaces

Patch panels and connection panels are provided within the communications equipment racks located inside the control building to permit experimenters to interface with the terminal. This section describes the available signal types and the interface characteristics in detail. The experimenter must deliver his signals to and from these interfaces and consequently must provide all necessary cabling, terrestrial links, etc. It is the responsibility of the experimenter to ensure that all signals and equipment connected into the interfaces are compatible with the terminal.

3.2.2.1 Transmit

1) Television

One television signal including 0, 1, 2 or 3 television audio channels can be transmitted to 2-metre or 3-metre terminals.

a) Video channel interface

impedance:	75 ohms unbalanced
connector:	BNC female type on baseband interface patch panel
bandwidth:	30 Hz to 4.2 MHz
level:	1.0 volt peak-to-peak for the composite video. A video clamping amplifier is available with the capability of providing equalization of at least 610 metres (2000 ft) of type RG-11/U cable or equivalent.

b) Audio channel interface

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jacks on the internal patch panel
bandwidth:	50 Hz to 10 kHz

test-tone level: + 10 dBm for a 1 kHz full load test-tone.

nominal program level: 0 Vu

2) Sound Program

One sound program signal can be transmitted to 1 or 2-metre terminals equipped with the optional sound program receive unit. Sound program signals *cannot* be transmitted to 3-metre terminals. Also sound program can be transmitted only to those 1 or 2-metre terminals using the 9-metre terminal as the NCT.

a) Sound program interface

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack on a patch panel in the telephony equipment rack.
bandwidth:	50 Hz to 15 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

3) Telephony

Up to a maximum of nine 1 or 2-metre terminals may simultaneously intercommunicate within the telephony system under the control of the network control provided by the 9-metre terminal. Normally, since a total of only 18 interchangeable channel units are provided to be shared among the two 3-metre and the 9-metre terminals, nine channels units will not be available. CRC will ensure, however, that sufficient channel units will be provided to the appropriate NCT to accommodate all small terminals assigned to operate under the control of that NCT.

Since, for the telephony system, the 9-metre terminal is equipped to operate as a Network Control Terminal only, two-way voice service (or sound program service) between either 3-metre terminal and the 9-metre terminal is not possible.

Switching required to complete telephone interconnections, between any of the small terminals is achieved in the network control automatically. Consequently, at the 9-metre terminal, only two interface connections will normally be available to the experimenter. These include an operator input and output and an external voice input and output for the telephony system. In addition to these two connections, an interface panel is located in the telephony equipment which permits separate access to any of the inputs and outputs of the telephony modems and the sound program modem. These interfaces will not normally be available to experimenters. If any experimenter requires the use of these interfaces, arrangements should be made with CRC to discuss the technical details.

The interfaces have the following characteristics:

a) Operator interface

An interface is provided for the operator to control the telephony system. From here an operator can connect with any of the 1 or 2-metre terminals or can establish conference calls among the 1 or 2-metre terminals, including himself. The interface consists of a telephone set equipped with a touch-tone dial which plugs into the telephony equipment. The telephone set can be remoted by means of a 30 metre (100 ft) cable supplied by CRC.

b) External voice input/output interface

This interface is provided to connect to a terrestrial voice circuit. Use of this facility requires special interconnections to be made by the terminal operator.

interconnection:	transmit pair of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced
connector:	spade lug type terminals located in the telephony equipment
test-tone level at interface:	-13 dBm for 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface TLP:	-16 TLP nominal
nominal speech level for an average talker:	-32 Vu
dynamic range:	50 dB
data or facsimile nominal signal level:	-29 dBm

c) Telephone channel interface in baseband interface patch panel

In addition to the above interfaces, there are individual channel interfaces available in the telephony equipment at the baseband interface patch panel. As previously mentioned, these points are not normally available to experimenters without prearrangement with CRC. One possible use of this interface is interconnection of facsimile or data modems. The interface is as follows:

interconnection:	transmit pairs of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced

connector:	telephone type tip, ring and sleeve jack in the baseband interface patch panel located in the telephony equipment cabinet
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	-13 dBm for 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface TLP:	-16 TLP nominal
nominal speech level for an average talker:	-32 Vu
dynamic range:	50 dB
data or facsimile nominal signal level:	-29 dBm at interface point

4) IF Interface

An IF interface with a bandwidth of 85 MHz will be available for special signal applications. Experimenters wishing to use this facility should contact CRC to discuss specific requirements. The interface characteristics are as follows:

IF frequency:	735 MHz
bandwidth (1 dB):	85 MHz
impedance:	50 ohms unbalanced
connectors:	TNC connectors located on internal IF connection panel
signal level (max):	-7 dBm (+0, -2 dB) for transmitter output saturation at 200W
IF to RF gain:	60 dB (+2, -0 dB)

3.2.2.2 Receive

1) Television

One television signal including 0, 1, 2 or 3 television audio channels can be received from a 3-metre terminal.

a) Video channel interface

impedance:	75 ohms unbalanced
connector:	BNC female type on internal patch panel
bandwidth:	30 Hz to 4.2 MHz
level:	1.0 volt peak-to-peak for the composite video. A video clamping amplifier is available with the capability of providing equalization for at least 610 metres (2000 ft) of type RG-11/U cable or equivalent.

b) Audio channel interface

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jacks on the internal patch panel
bandwidth:	50 Hz to 10 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

2) Sound Program

One sound program signal can be received from a small terminal equipped with the optional sound program transmit unit provided the 9-metre terminal is the telephony system network control for the transmitting small terminal. Note that a sound program signal cannot be received from either of the 3-metre terminals.

a) Sound program interface

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack on a patch panel in the telephony equipment rack
bandwidth:	50 Hz to 15 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

3) Telephony

Up to a maximum of 9 simultaneous telephone channels can be received, from each of any small terminal. The restrictions for the transmit interface described above apply here as well.

a) Operator interface

The operator interface is described above in the transmit Section 3.2.2.1.

b) External voice input/output interface

interconnection:	transmit pair of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced
connector:	spade lug type terminals located in the telephony equipment
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	+10 dBm for a 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface TLP:	+7 TLP nominal
nominal speech level for an average talker:	-9 Vu
dynamic range:	50 dB
nominal signal level for data or facsimile:	-6 dBm

c) Telephone channel interface in baseband interface patch panel

interconnection:	receive pair of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack located in telephone equipment rack
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	+10 dBm for a 1 kHz full load test-tone
interface TLP:	+7 TLP nominal
nominal speech level for an average talker:	-9 Vu
dynamic range:	50 dB

data or facsimile nominal signal level:	-6 dBm

4) *IF Interface*

IF frequency:	735 MHz
bandwidth (1 dB):	85 MHz
impedance:	50 ohms unbalanced
connectors:	TNC connectors on internal IF connection panel
RF to IF gain:	70 dB (+2, -0 dB)
attenuation range:	0 to 20 dB in 5 dB steps.

3.2.3 Operation and Maintenance

Operation and maintenance of the 9-metre terminal will be the responsibility of CRC. An operating crew will be monitoring terminal operation during the time an experimenter is using the terminal.

3.2.4 Environmental Requirements

Both the antenna-mounted equipment cabin and the control building are heated and air conditioned. Equipment in both areas must be capable of operating in ambient temperatures between 18.3°C (65°F) and 26.7°C (80°F) and surviving in temperatures from -34.4°C (-30°F) to 37.8°C (100°F).

3.2.5 Terminal Characteristics

This section is provided primarily for information to those experimenters interested in more technical details of the 9-metre terminal. A brief description of the major terminal characteristics and a block diagram description of terminal operation is provided.

The major terminal characteristics are defined by the two following parameters:

1) system G/T: 32.9 dB

2) e.i.r.p. 81.7 dBW

Figure 3.2 is a block diagram of the terminal's communications equipment. The basic equipment is essentially identical to that provided for the 3-metre terminals.

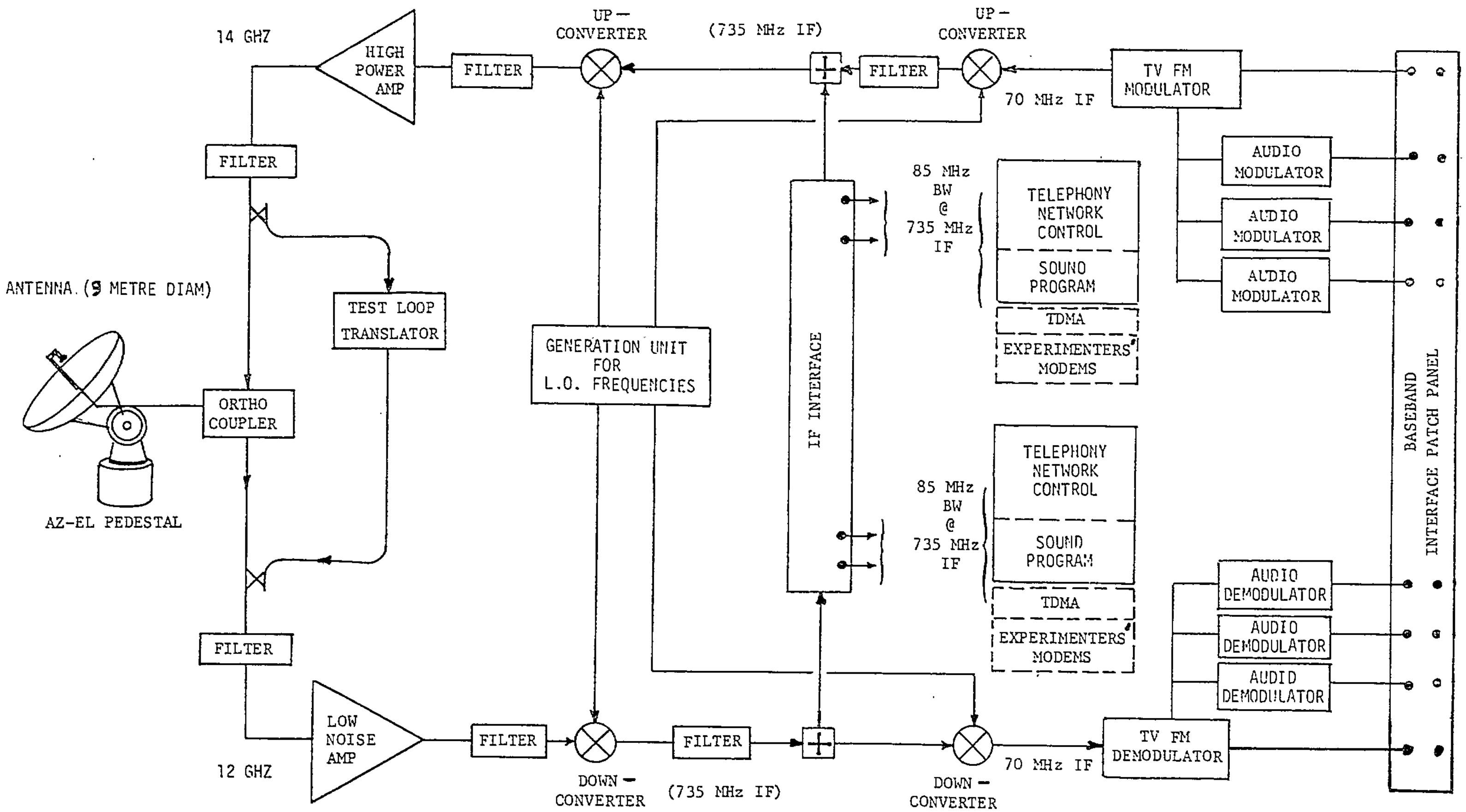


Figure 3.2. Block Diagram of 9-Metre Terminal Equipment

An experimenter can interface with the terminal at three locations depending upon the specific requirements of the experiment. These include a baseband interface patch panel for TV video and audio, a baseband patch panel for the telephony system, and an IF interface connection panel. The details of these interfaces have been described above. The telephony system interfaces with the terminal equipment at the high IF interface and has baseband interfaces for the telephony channel units and the sound program modem associated with it.

With reference to Figure 3.2, the following signal flow occurs. Up to three TV audio channels are each frequency modulated onto a preassigned subcarrier located, in the frequency spectrum, just above the video baseband. These signals are mixed with the TV video baseband and frequency modulated onto a 70 MHz IF carrier. The 70 MHz is then converted to the appropriate RF frequency for final transmission by a two stage up-conversion process. A high IF of 735 MHz is used. From the IF interface connection panel signals can be injected into the transmit path. In fact, this is where the telephony and sound program signals are introduced into the terminal transmit path. Highly stable frequency sources are used in the up-conversion.

After up-conversion, the signals go into a 200 watt TWT amplifier whose output goes through an orthocoupler to the antenna. The orthocoupler permits the antenna to simultaneously transmit and receive signals. The last stage of up-conversion and the 200 watt TWT are located in the antenna cabin while the remainder of the up-link equipment is in the control building.

On the receive side, from the orthocoupler the received signals are filtered, then amplified by a low noise amplifier. Two stage down-conversion is used to convert from RF to 735 MHz, then to 70 MHz. Again an interface is available at the 735 MHz IF. For a TV signal, the 70 MHz is then demodulated. The audio subcarriers are filtered off and each separately demodulated. The baseband signals are available in the baseband interface patch panel. The low noise amplifier and the first stage of down-conversion are located in the antenna cabin. A 55 metre (180 ft) cable at the 735 MHz IF connects to the remainder of the down-link equipment in the control building.

A test loop translator is provided to connect, with suitable attenuation, from the transmit RF to the receive RF for purposes of testing and aligning the terminal communications equipment.

The local oscillator frequencies used in the up and down-converters are sufficient in number to permit the terminal operator to independently select either RF transmit band or either RF receive band.

The following parameters summarize the characteristics of the 9-metre terminal subsystems. Much of the electronic communications equipment is identical to that of the 3-metre terminals with the major exception of the high power amplifier in the transmitting chain. It should be noted that parameters quoted are performance specifications yet to be confirmed by actual measurement. The actual values are expected to be somewhat better even though the performance specifications will provide the full quality desired.

Antenna:	9.14 metre (30 ft) diameter parabolic reflector with Cassegrainian horn-reflector feed. With the attached mode coupler, the feed system is dual linear orthogonally polarized in the RF transmit and receive communications channels, and circularly polarized to receive the beacon signal transmitted by the spacecraft. Polarization angle is continuously adjustable over a range of ±95°. Transmit gain referred to transmitter output is 58.7 dB. Receive gain referred to input of low noise amplifier is 57.4 dB.
Antenna Mount:	Elevation over azimuth pedestal remotely steerable ±300° from North in azimuth and -2° to +92° in elevation. Remote position indicators with resolution to 0.01°.
Antenna Tracking:	Three tracking options are available; manual, program track under the control of a computer, and fully automatic tracking on the spacecraft beacon signal.
Transmitter:	200 watt Travelling Wave Tube amplifier which covers both RF transmit bands.
Low Noise Amplifier:	Parametric amplifier followed by a tunnel diode amplifier to provide an input noise temperature of 217° Kelvin. 500 MHz instantaneous bandwidth.
Up-converter:	Two stage with low IF at 70 MHz and high IF at 735 MHz. RF transmit band selection provided at final stage of up-conversion from 735 MHz to RF.
Transmit Chain (from IF interface to antenna):	40 dB bandwidth less than 350 MHz. IF to RF gain of 60 dB (+2, -0 dB) at saturated output power level with gain attenuators set to zero. Gain is continuously adjustable from 0 to -30 dB.

Gain stability greater than ±0.5 dB/24 h

Gain slope less than ±0.1 dB/MHz in either transmit band with limit of ±1 dB over full 85 MHz band.

Gain ripple less than 1 dB peak-to-peak.

Down-converter:

Two stage with high IF at 735 MHz and low IF at 70 MHz. RF receive band selection provided at first stage of down-conversion between RF and 735 MHz.

Receive chain (from antenna to IF interface):

Can receive either RF receive band

1 dB minimum instantaneous bandwidth is 85 MHz for either channel with input signal levels from receiver noise level to -90 dBW.

RF to IF gain of 70 dB (+2, -0 dB) with gain attenuators set to zero. Gain is adjustable from 0 to -20 dB in 5 dB steps.

Gain stability greater than +0.5 dB/24 h

Gain slope less than ±0.05 dB/MHz within either receive band with limit of +1 dB over full 85 MHz band.

Gain ripple less than 1 dB peak-to-peak.

Dynamic range from receiver noise level to an input signal level of -90 dBW.

Television video channel characteristics and performance:

(Description includes combined modulator and demodulator unless otherwise stated.)

Frequency modulation.

Designed for NTSC color video with bandwidth 30 Hz to 4.2 MHz plus 0 to 3 audio subcarriers at 5.14 MHz, 5.41 MHz and 5.79 MHz.

Video frequency response relative to 0.0 dB at 10 kHz is within ±0.7 dB at 30 Hz and 4.2 MHz.

Deviation of video on 70 MHz carrier variable from ±2.5 MHz to ±12 MHz peak with 1% linearity over ±15 MHz. Normally set to ±6 MHz peak.

Deviation of each audio subcarrier on 70 MHz carrier variable from ±0.5 MHz to ±1.5 MHz peak. Normally set to ±0.99 MHz peak.

Video pre-emphasis and de-emphasis in accordance with CCIR Rec. 405-1, Vol. 4, Part 1, New Delhi, 1970 for 525 line TV.

Video noise weighting in accordance with CCIR Rec. 421-2, Vol. 5, Part 2, New Delhi, 1970, Annex 3, Note 1.

Gain stability ±2% per hour and ±5% per day for transmission between large terminals and ±2% per hour and ±5% per day for the demodulator only in the small terminals.

Signal-to-noise ratio 49 dB minimum in non-faded conditions, expressed as the ratio of the 1 volt peak-to-peak 761.6 kHz test-tone to the rms weighted noise above 10 kHz, including the effects of de-emphasis.

Envelope delay response at 3.58 MHz not to exceed ±60 nsec relative to that at 15 kHz for transmissions between large terminals and ±80 nsec relative to that at 15 kHz for the demodulator only in the small terminals.

Audio to video crosstalk: intermodulation products in the band 30 Hz to 4.2 MHz not to exceed -50 dB with respect to a full load 1 V 15 kHz test-tone in the video channel for transmissions between large terminals and for the demodulator only in the small terminals.

Differential gain: variations of burst amplitude with video level, expressed as a percentage of reference burst to amplitude, not to exceed 5% for average picture levels from 10% to 90% for transmissions between large terminals and 15% for the demodulator only in the small terminals.

Differential phase: phase variations of the color burst at each level from 10% to 90% average picture level not to exceed 3° for transmissions between large terminals and 4° for the demodulator only in the small terminals.

Field time waveform distortion as measured by tilt of a field rate display of a standard window test signal not to exceed ±5% with unclamped signal and ±1% for clamped signal for transmissions between large terminals and for the demodulator only in the small terminals.

Line time waveform distortion as measured by tilt of a line rate display of a standard window test signal not to exceed ±1.5% for transmission between large terminals and ±3% for the demodulator only in the small terminals.

Short time waveform distortion, as measured with a standard 2T sine-squared pulse of 0.25 μsec half amplitude duration, will have a K-factor not exceeding 2% for transmission between large terminals and 2% for the demodulator only in the small terminals.

Television audio channel characteristics and performance:

Three modems are provided to frequency modulate sub-carriers at 5.14 MHz, 5.41 MHz and 5.79 MHz with deviation variable from ±40 kHz to ±100 kHz peak for a +10 dBm rms, 1 kHz test-tone. Normally set to ±60 kHz peak.

Audio pre-emphasis and de-emphasis to have a 75 micro-second RC time constant.

Signal-to-noise ratio 50 dB minimum in non-faded conditions, expressed as the ratio of the +10 dBm rms 1 kHz test-tone to the rms weighted noise, including the effects of de-emphasis.

Audio noise weighting in accordance with CBC standard program weighting.

The specifications for the audio channels given below apply to transmissions *between* large terminals, including contributions of both the modulator and the demodulator, and to the demodulator *only* for the small 2-metre receiving terminals.

Gain stability within ±0.5 dB over 24 hours.

Gain frequency response within ±1 dB from 70 Hz to 8 kHz and the response at 10 kHz within 3 dB of that at 1 kHz.

Harmonic distortion measured with a 1 kHz test-tone not to exceed 2%.

Video-to-audio crosstalk not to exceed -50 dB with respect to +10 dBm rms audio test-tone level.

Audio-to-audio crosstalk not to exceed -50 dB with respect to +10 dBm rms audio test-tone level.

Sound program channel characteristics (and performance):

(Defined for one-way transmission between a NCT and a small terminal, and vice versa, such that the combined performance of the modulator and demodulator is given.)

FM modulation

Pre-emphasis and de-emphasis use a standard 75 μsec time constant.

Signal-to-noise ratio 52 dB minimum in non-faded conditions, expressed as the ratio of the +10 dBm rms 1 kHz test-tone to rms weighted noise, including the effects of de-emphasis.

Gain stability ±0.2 dB per day and ±1 dB per six months.

Gain frequency response measured relative to a 1 kHz tone at -20 dBm in a continuous envelope

50 - 1000 Hz	+1 dB, -4 dB
100 - 10,000 Hz	+1 dB, -1 dB
10,000 - 15,000 Hz	+1 dB, -4 dB

Linearity over a dynamic range of +10 dBm to -40 dBm to be better than ±1 dB for a 1 kHz tone.

Total harmonic distortion measured with a 1 kHz +10 dBm rms test-tone not to exceed 2%.

Intelligible crosstalk between telephony channels and the sound program channel not to exceed -60 dBm.

Single frequency interference less than -60 dBm measured in a 10 Hz bandwidth in the band 30 Hz to 20 kHz.

Telephony channel performance: (Defined for one-way transmission between a NCT and a small terminal, and vice versa, such that the combined performance of the modulator and demodulator is given.)

FM modulation.

Signal-to-noise ratio at discriminator output 33 dB minimum for each telephone channel, in non-faded conditions, expressed as the ratio of the 1 kHz +3 dBm0 full load test-tone at input interface to unweighted noise, not including de-emphasis.

Gain stability better than ±0.2 dB per day and ±1 dB per six months.

Gain frequency response measured relative to a 1000 Hz tone at -10 dBm0 is within a continuous envelope having the following limits:

300 Hz to 500 Hz	+1 dB,	-6 dB
500 Hz to 600 Hz	+1 dB,	-4 dB
600 Hz to 2400 Hz	+1 dB,	-3 dB
2400 Hz to 3000 Hz	+1 dB,	-6 dB
3000 Hz to 3600 Hz	+1 dB,	-11 dB

Pre-emphasis to provide a frequency response of +6 dB per octave in the band 300 Hz-3400 Hz with corresponding de-emphasis in demodulator.

Compandor Characteristics: 2 dB:1 dB compression ratio, 55 dB dynamic range, nominal 2 msec attack time, less than 22.5 msec recovery time, audio band 300 Hz to 3400 Hz.

Envelope delay is within the following limits relative to a 1800 Hz test-tone at a level of -12 dBm0:

1000 Hz to 3600 Hz not to exceed 300 μsec
800 Hz to 2800 Hz not to exceed 500 μsec
600 Hz to 3000 Hz not to exceed 1500 μsec

Linearity over a dynamic range of 0 dBm0 to −50 dBm0 better than ±1 dB for a 1 kHz test-tone.

Total harmonic distortion measured with a 1 kHz test-tone at a level of +3 dBm0 not to exceed 5%.

Intelligible crosstalk between telephony channels or between telephony channels and the sound program channel not to exceed −65 dBm0.

Single frequency interference less than −65 dBm0 measured in a 10 Hz bandwidth in the band 30 Hz to 15 kHz.

Echo performance: isolation between direct voice input and direct voice output to be greater than 60 dB.

3.3 THREE-METRE TRANSPORTABLE GROUND TERMINAL

3.3.1 General

This terminal is a self contained transportable terminal that will provide most of the services provided by the 9-metre Ottawa ground terminal for applications where it is not feasible nor desirable to use the Ottawa terminal. It will be usable for TV broadcast transmission or reception and will be equipped to provide network control for telephony operation with smaller terminals.

Two terminals are being purchased with both terminals configured in the form of the trailer illustrated in Figure 3.3. The trailers are towable for highway transport and can also be transported by rail, semi-trailer truck, and Hercules aircraft. They can be installed and operated by not more than two men.

The trailers are "fifth-wheel" type, towable by a 3/4 ton truck equipped with a suitable hitch and brake system. The truck will be provided by CRC for transportation purposes. Figure 3.4 illustrates the layout and design. The outside trailer dimensions are 9.45 metres (31 ft) total in length, 2.56 metres (8.4 ft) in width, and 2.69 metres (8.83 ft) in height. The front 2.13 metres (7 ft) of the trailer forms the hitch area where, above the hitch, the air conditioner and other assorted equipment are located. In Figure 3.4, an area is shown to be allocated for storage of an electrical generator. While on site, this area will normally be available as usable space inside the terminal.

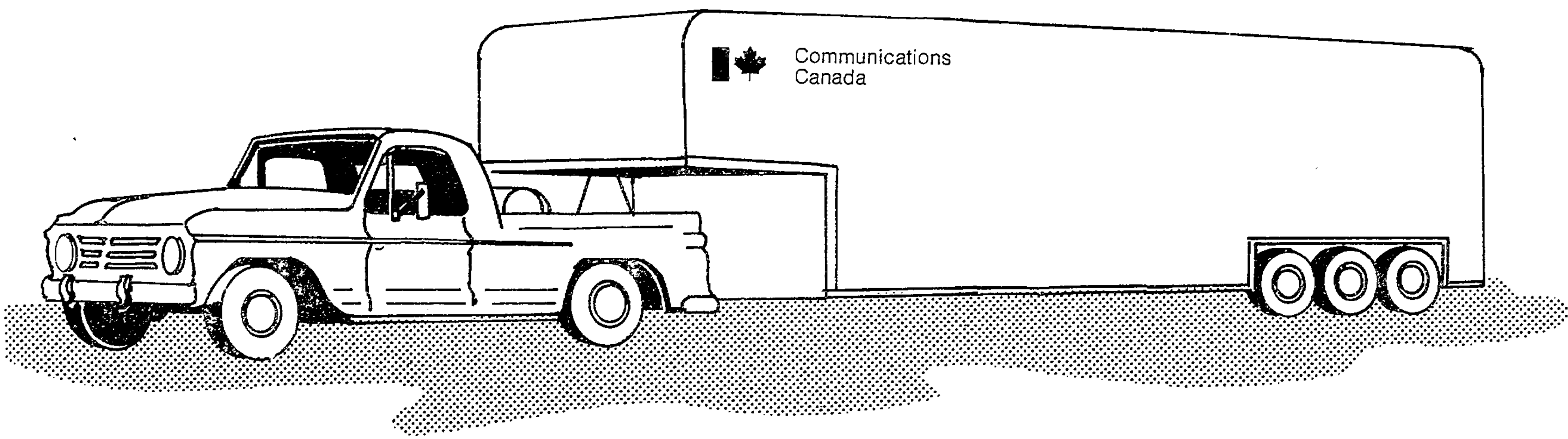


Figure 3.3. 3-Metre Terminal in Road Transport Mode

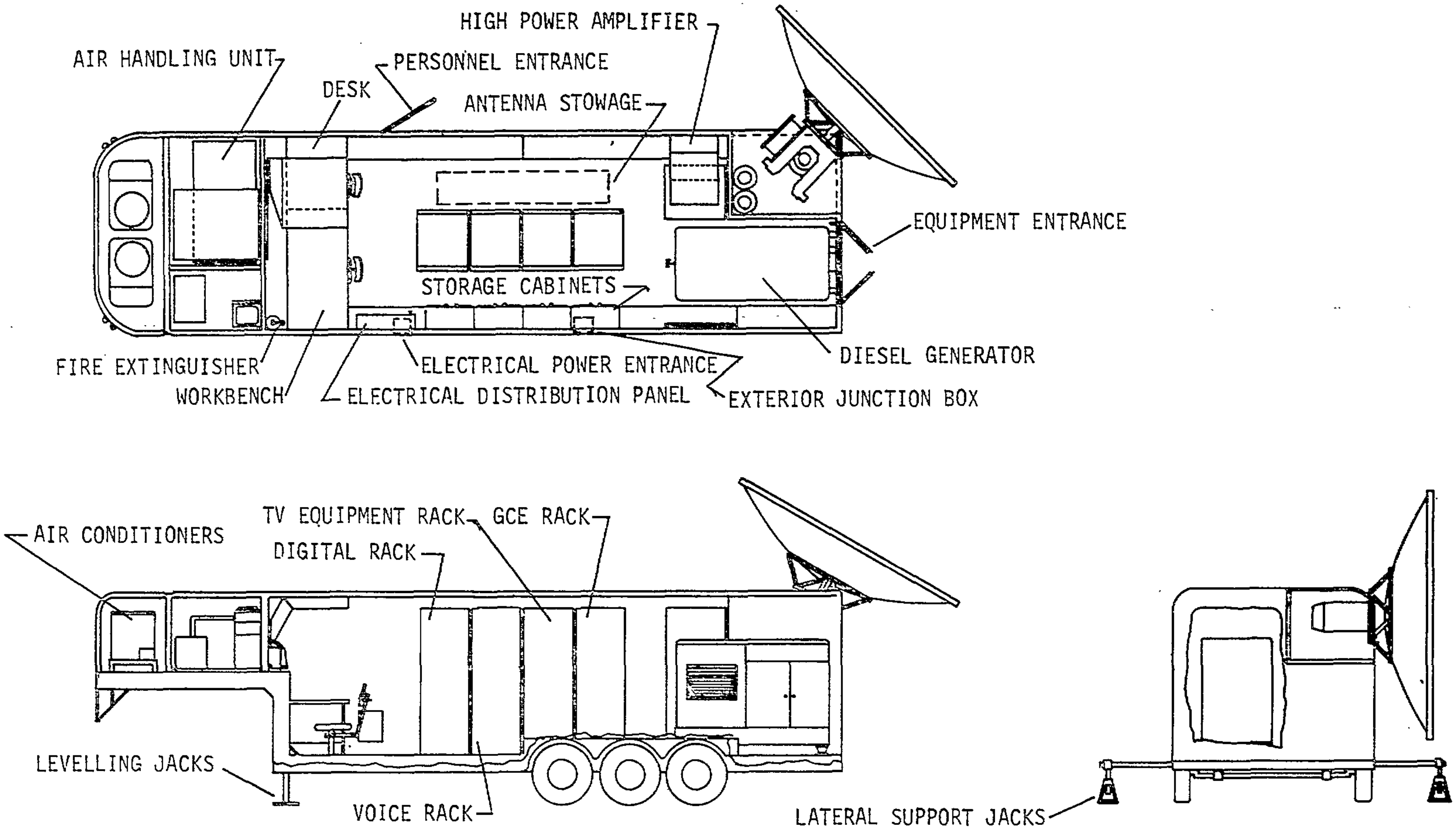


Figure 3.4. 3-Metre Terminal Layout

One of the terminals has been specially configured such that the communications equipment racks inside the trailer and the antenna with its associated mount can be removed from the trailer and packaged in sufficiently small pieces to permit transport by an aircraft as small as a Twin Otter. This is intended to allow operation of a 3-metre terminal from regions so remote that they are inaccessible by means other than small aircraft.

The configuration, referred to as the small aircraft transport configuration, is illustrated in Figure 3.5. In this configuration, the trailer is not available to house any of the equipment. Consequently, the equipment is separated into two parts. A platform is provided on which is mounted a small 1.8 m x 1.8 m x 2.0 m (6 ft x 6 ft x 6.5 ft) high weather-proof hut as well as the antenna assembly. The hut will contain the terminal equipment that is required to be located in proximity to the antenna. The remaining portion of the terminal is intended to be housed in a weatherproof, environment controlled building provided by the experimenter. This, for example, could be the building from which productions are to be originated. The equipment is interconnected by cables 30 metres (100 ft) in length thus limiting the distance between the two portions of the terminal to 30 metres (100 ft). Control and monitoring of the terminal equipment will be done from the equipment located in the experimenter's building by CRC operating personnel. The experimenter will, of course, be responsible for control and monitoring his own equipment connected into the terminal interfaces.

In the small aircraft transport configuration, the terminal equipment to be transported is estimated to weigh approximately 2270 Kg (5000 lbs) in total. The terminal equipment is packaged into approximately twenty packages of varying sizes with individual weights ranging from 45 Kg (100 lbs) to 136 Kg (300 lbs).

3.3.2 Signal Types and Interface Requirements

A weather proof interface junction box will be provided on the exterior of the trailer. In general, it is expected that an experimenter will interface at this point by running lines from his equipment housed elsewhere. It will be the experimenter's responsibility to deliver all signals to and from this junction box. This requires that all necessary cabling be provided by the experimenter.

Space within the trailer is very limited. However, in special circumstances, it may be possible to locate a small amount of user equipment within the trailer. In this case, interface with the terminal equipment can be made at internal patch panels located in the terminal equipment racks. Should such requirements arise, they will have to be dealt with on a case by case basis.

When the terminal has been moved onto a site in the small aircraft transport configuration, the trailer, and consequently the exterior junction box, will not be available. Interfacing to the terminal equipment is provided by the patch panels located in the communications equipment racks which are to be housed in the experimenter's facilities. Again, it is the responsibility of the experimenter to deliver signals to and from this patch panel. This requires that all necessary cabling to connect into the patch panel be provided by the experimenter.

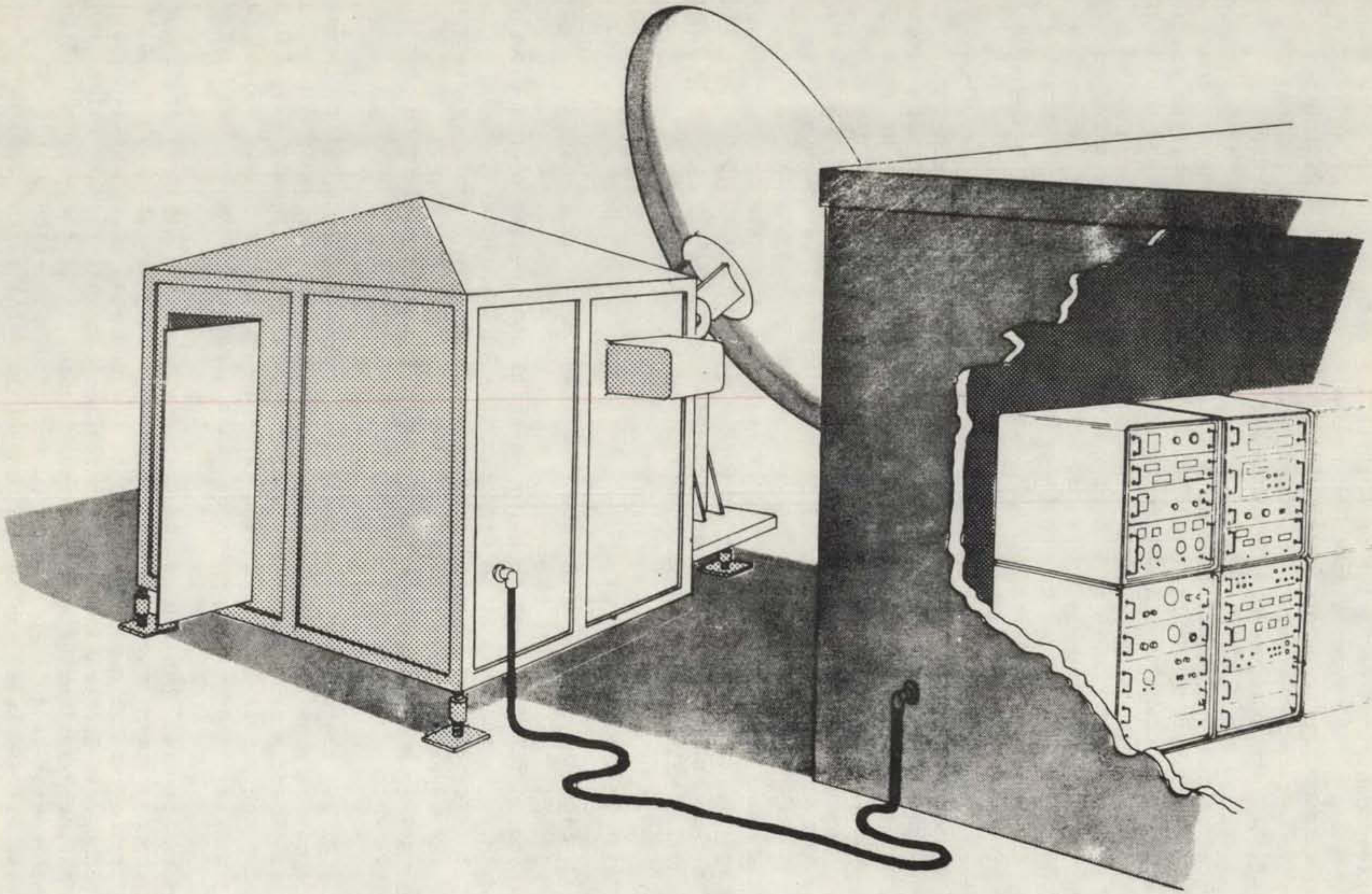


Figure 3.5. 3-Metre Terminal in Small Aircraft Transport Configuration

The following signal types will be accommodated. The inter-terminal transmission capability is also given. In the standard mode of operation for TV broadcast, sound program and telephony network control, the spacecraft low power beam must be centred on the terminal. All electrical parameters of the interfaces are identical to these given for the 9-metre terminal.

3.3.2.1 Transmit

1) Television

One television signal including 0, 1, 2 or 3 television audio channels can be transmitted to 2-metre terminals, the 9-metre terminal, or the other 3-metre terminal.

a) Video channel interface

impedance:	75 ohms unbalanced
connector:	BNC female type on exterior junction box or on internal patch panel
bandwidth:	30 Hz to 4.2 MHz
level:	1.0 volt peak-to-peak for the composite video. A video clamping amplifier is available with the capability of providing equalization of at least 610 metres (2000 ft) of type RG-11/U cable or equivalent.

b) Audio channel interface

impedance:	600 ohms balanced
connector:	spade lug type terminals in the exterior junction box and telephone type tip, ring and sleeve jacks on the internal patch panel.
bandwidth:	50 Hz to 10 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

2) Sound Program

One sound program signal can be transmitted to small terminals equipped with an optional sound program receive unit. The sound program is controlled in the same manner as the telephony system and cannot be transmitted to the second 3-metre terminal or the 9-metre terminal. Also, sound program signals can be transmitted only to those small terminals using the transmitting 3-metre terminal as the NCT.

a) Sound program interface

impedance:	600 ohms balanced
connector:	spade lug type terminals located in the exterior junction box or a telephone type tip, ring and sleeve jack on a patch panel in the telephony equipment rack.
bandwidth:	50 Hz to 15 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

3) Telephony

Up to a maximum of nine small terminals may simultaneously intercommunicate within the telephony system under the control of the network control provided by one 3-metre terminal. Normally, since a total of only 18 interchangeable channel units are provided to be shared among the two 3-metre and the 9-metre terminals, nine channel units will not be available. CRC will ensure, however, that sufficient channel units will be provided to the appropriate NCT to accommodate all small terminals assigned to operate under the control of that NCT.

Since, for the telephony system, each 3-metre terminal is equipped to operate as an NCT only, the terminals are not equipped to permit two-way voice service (or sound program transmission or reception service) between two 3-metre terminals or a 3-metre terminal and the 9-metre terminal.

Switching required to complete telephone interconnection between any of the small terminals is achieved in the network control automatically. Consequently, at the 3-metre terminals, only two interface connections will normally be available to the experimenter. These include an operator input and output and an external voice input and output for the telephony system. In addition to these two connections, an interface panel is located in the telephony equipment which permits separate access to any of the inputs and outputs of the telephony modems and the sound program modems. These interfaces will not normally be available to experimenters. If any experimenter requires the use of these interfaces, arrangements should be made with CRC to discuss the technical details.

The interfaces have the following characteristics.

a) Operator interface

An interface is provided fo the operator to control the telephony system. From here an operator can connect with any of the 1 or 2-metre terminals or can establish conference calls among the 1 or

2-metre terminals, including himself. The interface consists of a telephone set equipped with a touch-tone dial which plugs into the telephony equipment. The telephone set can be remoted by means of a 30 metre (100 ft) cable supplied by CRC.

b) External voice input/output interface

This interface is provided to connect to a terrestrial voice circuit. Use of this facility requires special interconnections to be made by the terminal operator.

interconnection:	transmit pair of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced
connector:	spade lug type terminals located in the exterior junction box or in the telephony equipment
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	-13 dBm for a 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface TLP:	-16 TLP nominal
nominal speech level for an average talker:	-32 Vu
dynamic range:	50 dB
nominal signal level for data or facsimile:	-29 dBm at interface point

c) Telephone channel interface in baseband interface patch panel

In addition to the above interfaces, there are individual channel interfaces available in the telephony equipment at the baseband interface patch panel or by special arrangement, at the exterior junction box. As previously mentioned, these points are not normally available to an experimenter without pre-arrangement with CRC. One possible use of this interface is interconnection of facsimile or data modems. The interface is as follows:

interconnection:	transmit pairs of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack in the baseband interface patch panel located in the telephony equipment cabinet.

bandwidth:	300 Hz to 3400 Hz
test-tone level:	-13 dBm for 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface point:	-16 TLP nominal
nominal speech level (at interface) for an average talker:	-32 Vu
dynamic range:	50 dB
data or facsimile nominal signal level:	-29 dBm at interface point

4) IF Interface

An IF interface with a bandwidth of 85 MHz will be available for special signal applications. An experimenter wishing to use this facility should contact CRC to discuss specific requirements. The interface characteristics are as follows:

IF frequency:	735 MHz
bandwidth (1 dB):	85 MHz
impedance:	50 ohms unbalanced
connectors:	TNC connectors located in exterior junction box or on internal IF connection panel
signal level (max):	-0.8 dBm (+0, -2 dB) for transmitter output saturation at 1.2 kW
IF to RF gain:	60 dB (+2, -0 dB)

3.3.2.2 Receive

1) Television

One television signal including 0, 1, 2, or 3 television audio channels can be received from a 9-metre terminal or the second 3-metre terminal.

a) Video channel interface

impedance:	75 ohms unbalanced
connector:	BNC female type in exterior junction box or on internal patch panel

bandwidth:	30 Hz to 4.2 MHz
level:	1.0 volt peak-to-peak for the composite video. A video clamping amplifier is available with the capability of providing equalization for at least 610 metres (2000 ft) of type RG-11/U cable or equivalent.

b) Audio channel interface

impedance:	600 ohms balanced
connector:	spade lug type terminals in the exterior junction box or telephone type tip, ring and sleeve jacks on the internal patch panel
bandwidth:	50 Hz to 10 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

2) Sound Program

One sound program signal can be received from a 2-metre terminal equipped with the optional sound program transmit unit, provided the 3-metre terminal is the telephony system network control for the transmitting 2-metre terminal. Note that a sound broadcast signal cannot be received from the second 3-metre, the 9-metre or 1-metre terminals.

a) Sound program interface

impedance:	600 ohms balanced
connector:	spade lug type terminals located in the exterior junction box or on a terminal strip in the telephony equipment rack
bandwidth:	50 Hz to 15 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

3) Telephony

Up to a maximum of 9 simultaneous telephone channels can be received, one from each of any small terminal. The restrictions for the transmit interface described above apply here as well.

a) Operator interface

The operator interface is described above in the Transmit Section 3.3.2.1.

b) External voice input/output interface

interconnection:	transmit pair of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced
connector:	spade lug type terminals located in the exterior junction box or in the telephony equipment
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	+10 dBm for a 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBM)
interface TLP:	+7 TLP nominal
nominal speech level for an average talker:	-9 Vu
dynamic range:	50 dB
nominal signal level for data or facsimile:	-6 dBm

c) Telephone channel interface in baseband interface patch panel

interconnection:	receive pair of voice-frequency 4-wire telephone cable
impedance:	600 ohms balanced
connector:	spade lug type terminals in exterior junction box or telephone type ring, and sleeve jack located in two-way voice equipment rack
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	+10 dBm for a 1 kHz full load test-tone
interface TLP:	+7 TLP nominal
nominal speech level for an average talker:	-9 Vu

dynamic range:	50 dB
data or facsimile nominal signal level:	-6 dBm

4) *IF Interface*

IF frequency:	735 MHz
bandwidth (1 dB);	85 MHz
impedance:	50 ohms unbalanced
connectors:	TNC connectors located in exterior junction box or on the internal IF connection panel
RF to IF gain:	70 dB (+2, -0 dB)
attenuation range:	0 to 20 dB in 5 dB steps.

3.3.3 Site Requirements and Installation

The experimenter shall assume all responsibility for the selection and preparation of the sites for the 3-metre terminals. Having approved the selected site, CRC will apply for a licence to operate the terminal on the site. The terminal itself will be licenced separately. The experimenter will be asked to assist by providing detailed information on sites such as precise location in terms of latitude, longitude, and altitude, proximity of airports or radar stations, horizon angles for the surrounding terrain, etc.. After the necessary information has been provided, CRC will be responsible to ensure that the terminals are licenced to operate at the site.

CRC can provide the experimenter with the azimuth and elevation angles of the spacecraft from the experimenter's site when latitude, longitude and altitude have been determined. Azimuths will be provided with respect to true north. If the experimenter uses a magnetic compass while evaluating the site for spacecraft visibility and terminal maneuverability, he must compensate for the magnetic declination at the particular site. Magnetic compasses will generally not be adequate in densely built-up areas or regions likely to produce magnetic anomalies. In this case the assistance of a professional surveyor is recommended. Latitude and longitude of a site can generally be determined to a sufficient accuracy from topographical survey maps. Magnetic declination charts and topographical survey maps are available to the public from the Map Distribution Office, Surveys and Mapping Branch, Department of Energy, Mines and Resources, 615 Booth Street, Ottawa, K1A 0E9. Latitude and longitude of a site must be given to an accuracy of 5 minutes.

Figure 3.6 illustrates the terminal set up on a typical site. The site must be selected in accordance with several requirements:

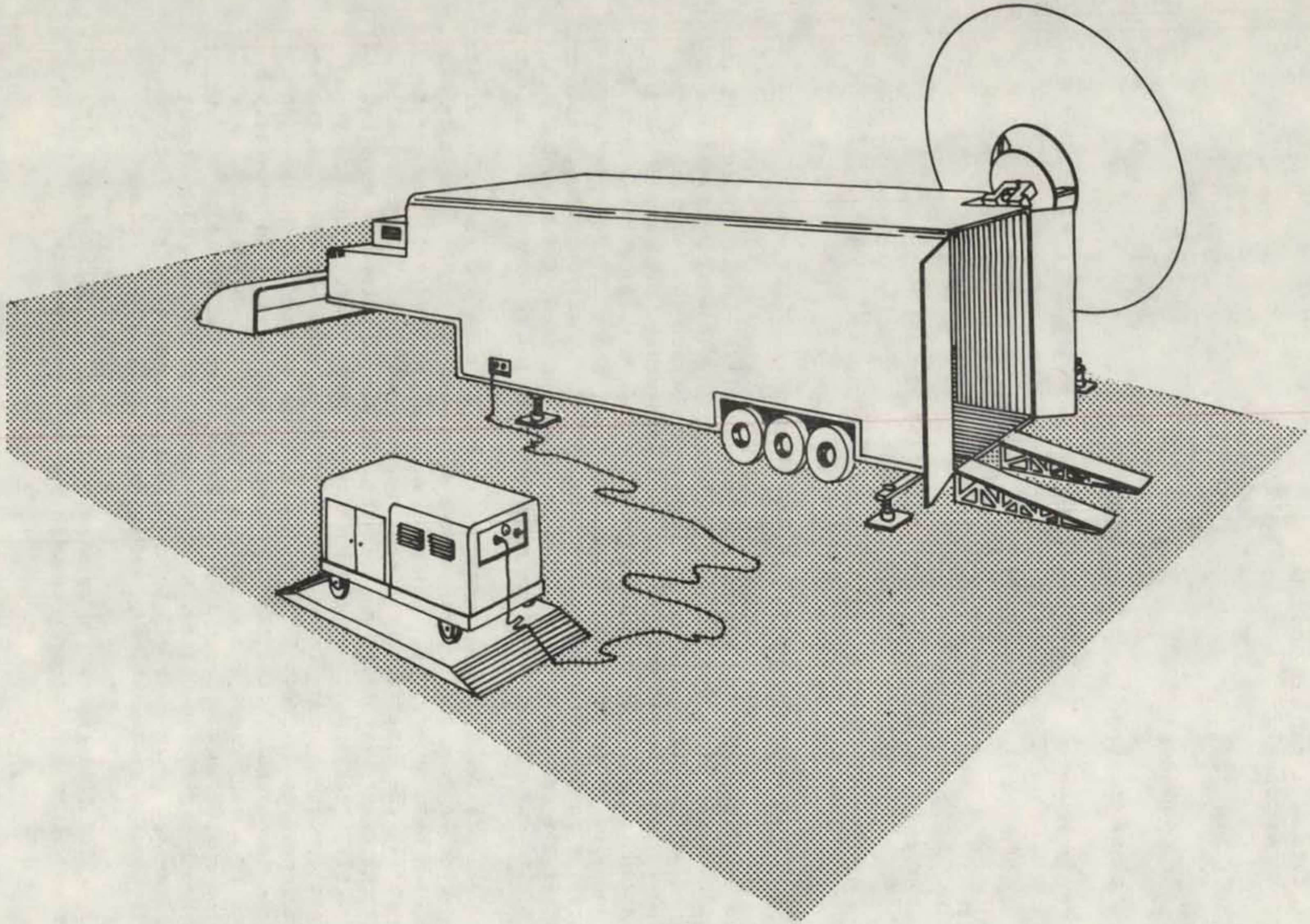


Figure 3.6. 3-Metre Terminal on Site

1) The trailers of the 3-metre terminals will come equipped with foot pads and levelling jacks and should be capable of installation on any reasonable soil, gravel, paved, etc., surface with a minimum of site preparation. The site should be cleared, be reasonably level with less than a 5% grade, and have a bearing strength of not less than 14,650 Kg per square metre (3000 lbs per square foot). The total weight of the terminal is estimated to be approximately 6800 Kg (15,000 lbs). If necessary, a security fence should be provided for radiation protection and for the physical protection of the terminal. A reasonable access road should be available to the site.

2) The site must be selected such that a clear line of sight to the spacecraft is available. It must be clear of obstacles within a 10° cone of the nominal line of sight. In addition the site must have sufficient room to maneuver the trailer so that it lies with the front of the trailer pointing 135° counter-clockwise to the satellite line of sight. Figure 3.7 illustrates the required geometry. This requirement arises because the antenna is located on the rear corner of the trailer and cannot point along the longitudinal or the transverse axis of the trailer.

3) The experimenter is responsible to ensure that an electrical service outlet is available on the site if local commercial electrical power is to be used. In locations where commercial electrical power is not available an electrical generator must be provided. CRC will have one generator available for this purpose. The power requirements and respective responsibilities of CRC and the experimenter are described in Section 3.3.4.

4) Grounding for the electrical power source, whether it be commercial or the generator, must be provided by the experimenter to the requirements of the local site.

The terminal will be installed on the site by the CRC operating crew. However, the experimenter must have the services of a qualified electrician to connect the commercial electrical power to the terminal. If installation occurs during the winter, the experimenter is responsible to clear the site of snow sufficient to maneuver the terminal into position.

The experimenter will be responsible for providing an azimuth reference on the site such that when the terminal is set up, the azimuth angle of the spacecraft can be readily determined to an accuracy of ±0.5°. The specific requirements for this azimuth reference are dependent upon the characteristics and location of each individual site. Consequently, it is expected that these specific requirements can be coordinated with CRC at the time of CRC approval of the site. For example, in cases of a cleared, open site with no surrounding obstacles to create magnetic anomalies, a magnetic compass would suffice to provide sufficient accuracy to lay an azimuth reference line. In densely built-up areas it may be more suitable to provide a bearing from a reference point on the site to a nearby visible land mark by use of city engineering drawings which contain the site and an aximuthal reference.

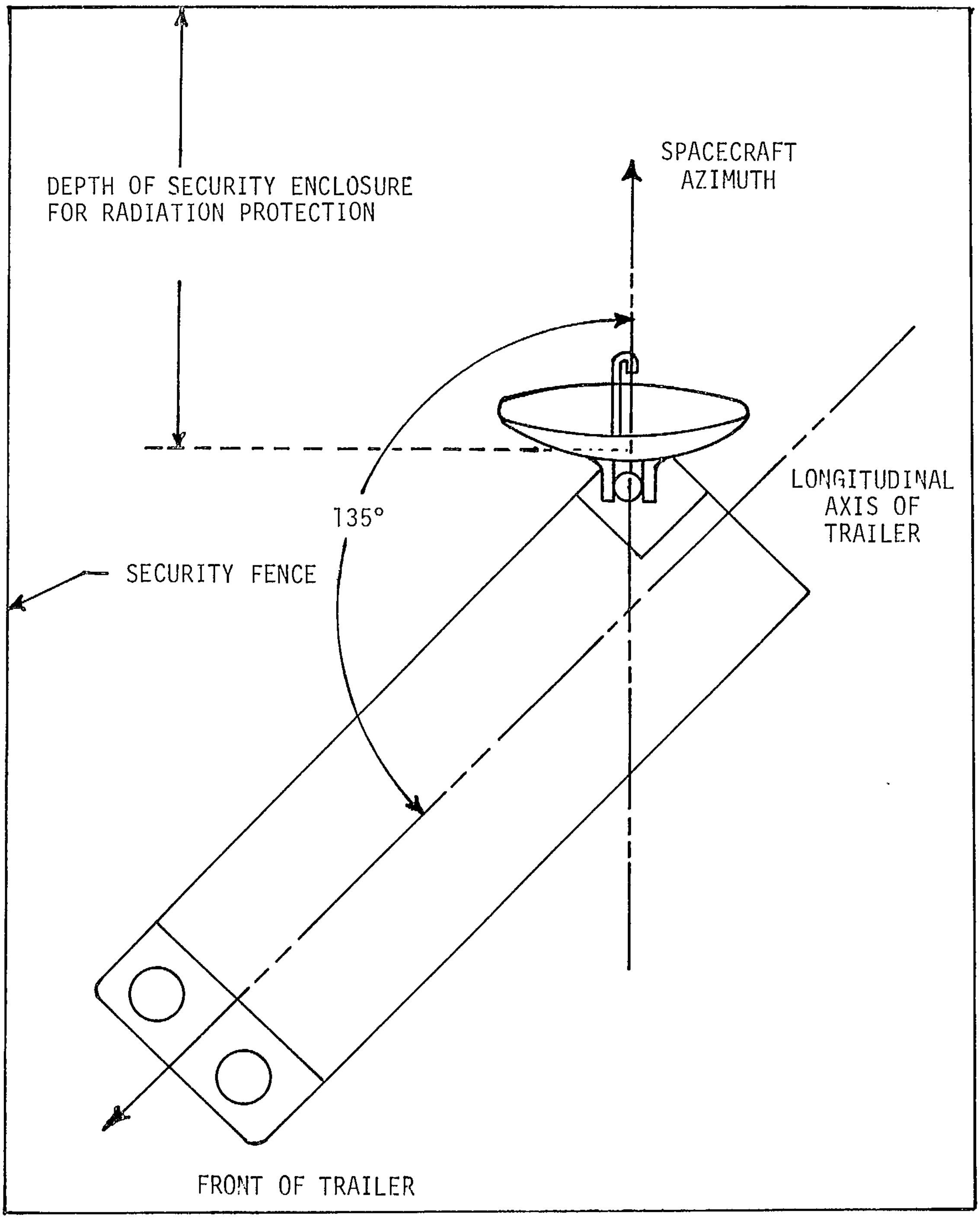


Figure 3.7. 3-Metre Terminal Orientation on Site Locations

Setting-up and dismantling the terminal in the trailer configuration can be accomplished by the two-man operating crews provided by CRC. Dismantling in preparation for transport requires an estimated 4 hours of time to disassemble and package the antenna and secure all equipment for transport. Set-up at the next site requires an estimated 8 hours for antenna assembly, locating and acquiring the satellite, and system checkout.

In the small aircraft transport configuration, facilities must be provided by the experimenter to house the equivalent of three and one-half racks of equipment. Rack dimensions are approximately 1.8 metres (6 ft) high, 0.6 metres (25 inches) wide and 0.8 metres (30 inches) deep. The weight of the 3-1/2 racks together is estimated to be approximately 454 Kgs (1000 lbs). (In the actual configuration, each rack consists of two transit cases stacked one upon the other). To permit proper operation of the terminal the temperature of the room containing this equipment must be maintained between 18.3°C (65°F) and 26.7°C (80°F) by means of heating and, if necessary, air conditioning. An estimated maximum of 5 kW will be dissipated by the equipment to be housed in the experimenter's facilities.

Setting-up and dismantling the terminal in the small aircraft transport configuration requires more effort than in the case of the trailer mode. The terminal must be broken down to be packaged in sufficiently small pieces to be carried on a Twin Otter aircraft. The experimenter will be asked to assist in this task. Movement of this terminal during an experiment, particularly in this configuration, is discouraged.

The power levels capable of being transmitted by the 3-metre terminal are sufficiently high to present an RF radiation hazard to personnel in the beam of the antenna. Consequently, the experimenter is required to select and protect the site such that persons are prevented from entering areas where the radiation level is too high. Allowable exposure to RF radiation is generally accepted to be power densities of 10 mW/cm^2 for short exposure and 1 mW/cm^2 for indefinite exposure. Calculations indicate, however, that maximum power densities of 64 mW/cm^2 occur at a distance of 82.3 metre (270 ft) along the boresight of the antenna. Maximum power density right at the antenna is 32 mW/cm^2 and, in the far field, at 130.5 m (428 ft) along the boresight, 1.6 mW/cm^2. Radiation density directly beside the antenna, resulting from spillover from the feed, could be as high as 1.25 mW/cm^2. Directly behind the antenna all radiation density is less than the acceptable level of 1 mW/cm^2.

It is evident from the above discussion that suitable precautions, such as a security fence, must be taken to ensure that personnel do not accidentally walk into the beam. Fencing on the site must be arranged such that the terminal can still be easily maneuvered to point the antenna along the satellite look angle. Figures 3.7 and 3.8 illustrate a suitable arrangement. Figure 3.9 is a graph which shows recommended distances to extend an enclosed area from the trailer to provide a 3.05 metre (10 ft) beam clearance assuming the immediate surrounding terrain is horizontal. Curves are also shown for terrain that has a +5% slope and a -5% slope.

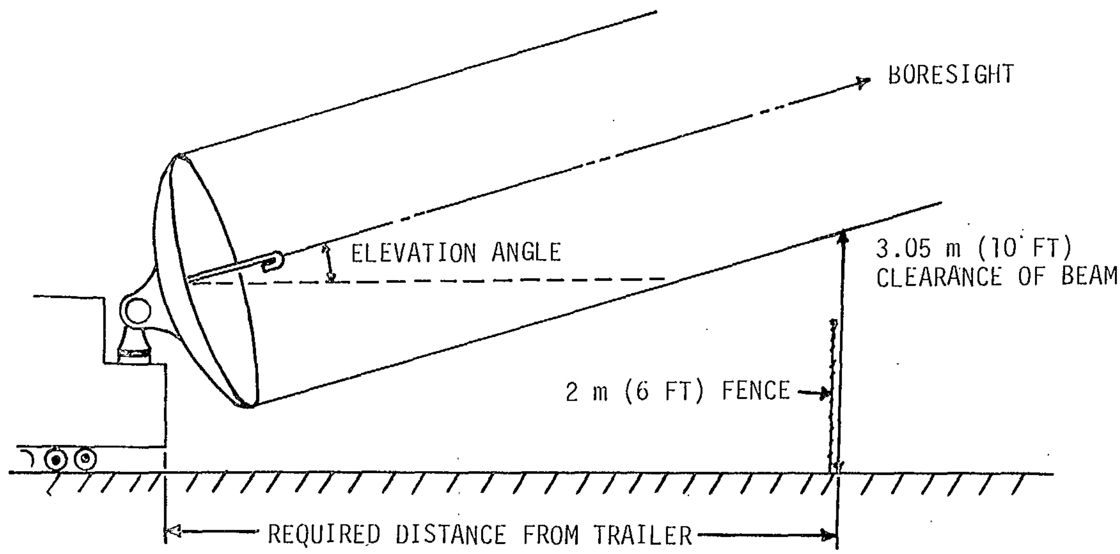


Figure 3.8. Protection From Radiation Hazards

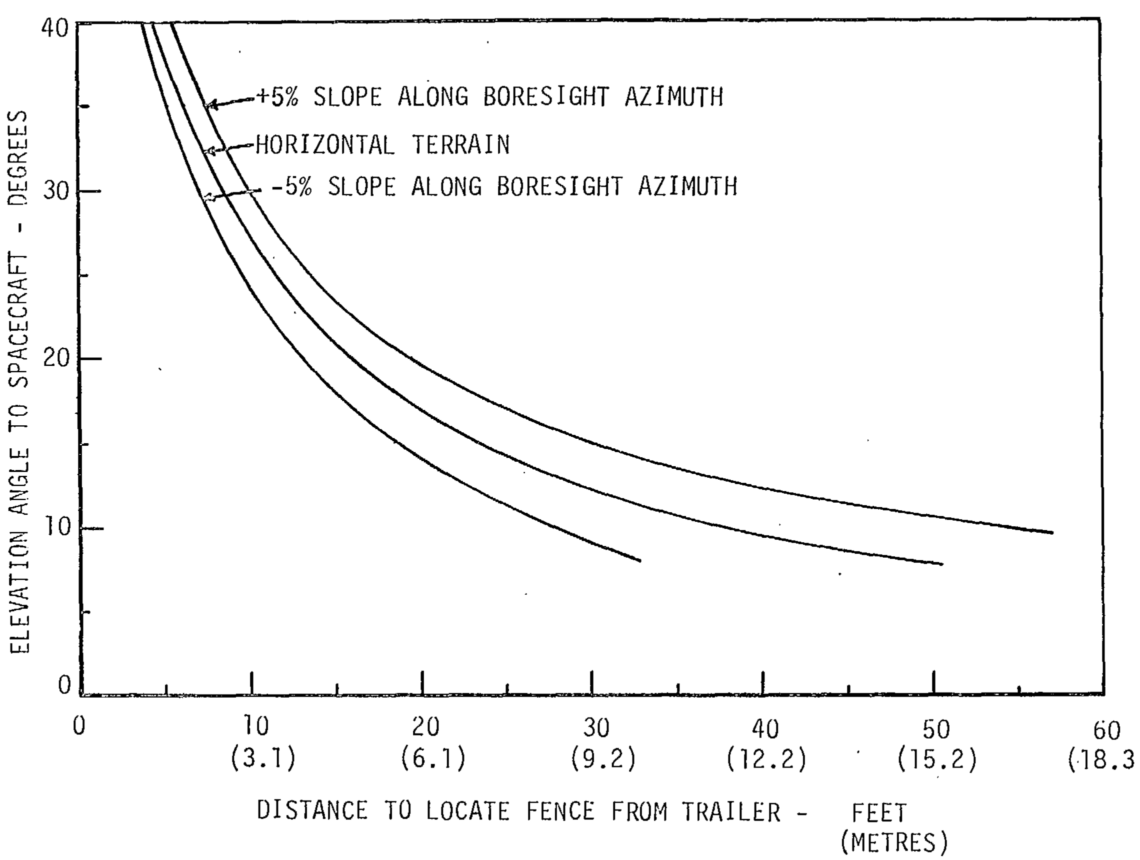


Figure 3.9. Depth of Safety Enclosure as a Function of Elevation Angle

3.3.4 Power

It is desirable to operate the terminal from locally available electrical power sources whenever possible. The terminal will be equipped to operate from a 240/120 volt ±15%, single phase, 60 Hz ±2%, three wire service at a maximum rate of 25 kW (32 KVA with a 0.8 PF). In the small aircraft transport configuration this maximum required capacity reduces to an estimated 16.5 kW (20.5 KVA) due to the fact that air conditioners required to cool the trailer will not be necessary in this configuration. With the exception of the air conditioners, the terminal is designed to operate with primary power frequency fluctuations of ±5 Hz. Whether or not the air-conditioners can tolerate this fluctuation has yet to be determined by the prime contractor. It should be noted that in addition to this capacity the experimenter will be expected to provide lighting, heating and, if necessary, air-conditioning for his own building in which some of the terminal equipment is installed. It is the responsibility of the experimenter to provide a service of this capacity on the site, subject to all the local electrical code regulations. The experimenter must arrange for the services of a qualified electrician to complete the electrical connections to the terminal when it arrives at the site and to disconnect when it leaves. The costs incurred for these services and the actual costs of the electrical energy must be borne by the experimenter.

One portable diesel-electric generator is being purchased to be shared between the two 3-metre terminals. This generator can be used in areas where local power is not available, or if available, not suitable for the terminals.

The generator is manufactured by John Deere and has the following characteristics:

Generating capacity:	30 kW (37.5 KVA)
Voltage:	240/120 V Single Phase
Regulation (voltage):	±2%
Regulation (frequency):	±1.5 Hz
Dimensions (estimated):	1.8 m long x 0.84 m wide x 1.32 m high (71 in x 33 in x 52 in)
Weight:	1225 Kg (2700 lbs)
Fuel:	#2 diesel, consumed at approximately 11.8 litres/h (2.6 gal/h) at full generating capacity.

It may be necessary to run the generator continuously during cold weather. This would be required to keep the terminal heated as well as prevent difficulties of cold weather starting. The requirement is entirely dependent upon local weather conditions. It is the responsibility of the experimenter to ensure an adequate fuel supply is available and delivered to the site. Fuel costs will be borne by the experimenter.

Transporting the generator when the terminal is moved in the trailer configuration, is accomplished simply by loading the generator onto the trailer. In the small aircraft transport configuration, movement of the generator is considerably more difficult. Exact dimensions of the generator complete with mounted wheels are not yet available from the contractor. It appears, though, that the generator cannot be transported by Twin Otter aircraft and the services of a larger aircraft, such as a DC-3, may become necessary. The capacity available from this generator is not required in the small aircraft configuration and it may be possible to rent a smaller capacity generator more readily transported by air.

3.3.5 Operation and Maintenance

Operation and maintenance of the 3-metre terminals will be the responsibility of CRC. An operating crew will be monitoring terminal operation during the time experimenters are using the terminal.

3.3.6 Environmental Requirements

The 3-metre terminals are equipped with heating and air conditioning to maintain internal temperatures within the range 18.3°C (65°F) to 26.7°C (80°F), under the operating outside environmental limits indicated below. Experimenter's equipment that may be installed temporarily in the terminal trailers must be designed to the operational and survivable environment limits indicated below. In the small aircraft transport configuration, the experimenter must supply heating and, if necessary, air conditioning in the building, designated by the experimenter to contain the terminal equipment, to a temperature range of 18.3°C (65°F) to 26.7°C (80°F) for proper terminal operation. The heat dissipation of the terminal equipment inside the experimenter's facilities is estimated to 5 kW. The operating environment limits given below are those limits within which the terminals have been designed to operate with no degradation in performance below the required qualities. The survivable environment limits are those limits which the equipment is designed to survive without damage or without degradation to performance for subsequent operation.

	OPERATIONAL	SURVIVABLE
Temperature:	-45.6°C (-50°F) to 35°C (95°F)	-51°C (-60°F) to 40.6°C (105°F)
Relative Humidity:	5% to 100%	5% to 100%
Rain:	0.75 cm (0.3 in)/5 min	1.25 cm (0.5 in)/5 min
Snow (Average):	2.8 m (110 in)/year	4.1 m (160 in)/ year
Snow (Max. Rate):	0.51 m (20 in)/24 h	0.64 m (25 in)/24 h
Ice:	1.27 cm (0.5 in)	2.54 cm (1 in)
Wind (Average):	48.3 Km/h (30 mi/h)	-
Wind (Gusts):	72.5 Km/h (45 mi/h)	177 Km/h (110 mi/h)

3.3.7 Transportation

In the trailer configuration, the normal mode of transport will be by towing or by flat bed railway car or flat bed truck. CRC will provide the towing vehicle. For rapid long distance moves, the terminal is air transportable by a Lockheed Hercules aircraft. However, air transport is very costly and consequently should be used only where other means of transport are not available or cannot meet the schedule requirements.

One of the 3-metre terminals can be configured into a small aircraft transport mode. In this mode, the electronics, antenna and antenna pedestal are simply removed from the trailer and packaged separately in sufficiently small pieces to fit onto a Twin Otter or similar aircraft. In total, approximately 20 packages will have to be transported, each weighing in the range of 45 Kg (100 lbs) to 135 Kg (300 lbs). The total equipment weight is presently estimated to be 2270 Kg (5000 lbs) (excluding the diesel-electric generator).

The electronic equipment is presently configured into 10 cases with sizes generally being 0.91 m (36 in)H x 0.64 m (25 in)W x 0.76 m (30 in)D. Each of the cases is equipped with four handles for hand carrying by up to four men if required.

The packaging of the antenna, antenna pedestal, support platform and hut has not yet been defined by the contractor. However, the size restrictions of the Twin Otter apply to these as well.

A Twin Otter aircraft is not large enough to carry the complete complement of equipment in one trip. It is estimated a minimum of three trips will be required. Additional trips may be required, depending on non-stop flight distance, since weight of fuel can be traded off with cargo weight.

CRC will be responsible for installation of the terminal on the site. When the small aircraft transport mode is used, the experimenter will be expected to provide vehicles and man power to haul the terminal packages between the air strip and the site and to assist in setting up the terminal.

Experimenters will be asked to make arrangements for and bear certain portions of the cost of transportation. It is expected that CRC will provide transportation between major centres while the experimenter will bear the cost of moving the terminal between these major centes and the terminal sites.

3.3.8 Terminal Characteristics

This section is provided primarily for information to those experimenters interested in more technical details of the terminals. A brief description of the major terminal characteristics and a block diagram description of terminal operation is provided.

The major terminal characteristics are defined by the two following parameters: (These are minimum specified values).

1) System G/T: 22.8 dB

2) e.i.r.p.: 79.5 dBW

Figure 3.10 is a block diagram of the terminal's communications equipment. An experimenter can interface with the terminal at four locations depending upon the specific requirements of the experiment. These include the exterior junction box mounted on the outside of the trailer, an internal baseband interface patch panel for TV video and audio, a baseband patch panel for the telephony and sound program systems, and an IF interface connection panel. The details of these interfaces have been described above. The telephony system interfaces with the terminal equipment at the high IF interface and has baseband interfaces for the telephony channel units and the sound program modem associated with it.

With reference to Figure 3.10, the following signal flow occurs. Up to three TV audio channels are each frequency modulated onto a preassigned subcarrier located, in the frequency spectrum, just above the video baseband. These signals are added to the TV video baseband, then frequency modulated onto a 70 MHz IF carrier. The 70 MHz is then converted by a two stage up-conversion process to the appropriate RF frequency for final transmission. A high IF of 735 MHz is used. From the IF interface connection panel, signals can be injected into the transmit path. In fact, this is where the telephony and sound program signals are introduced into the terminal transmit path. Highly stable frequency sources are used in the up-conversion.

After up-conversion the signals go into a 1.2 kW klystron amplifier whose output goes through an orthocoupler to the antenna. The orthocoupler permits the antenna to simultaneously transmit and receive signals.

On the receive side, from the orthocoupler the received signals are filtered and then amplified by a low noise amplifier. A two stage down-conversion is used to convert from RF to 735 MHz, then to 70 MHz. Again an interface is available at the 735 MHz IF. For a TV signal, the 70 MHz is then demodulated. The audio subcarriers are filtered off and each separately demodulated. The baseband signals are available in the internal baseband interface patch panel and in the exterior junction box.

A test loop translator is provided to connect, with suitable attenuation, from the transmit RF to the receive RF for purposes of testing and aligning the terminal communications equipment.

The selection of local oscillator frequencies used in the up and down-converters will permit the terminal operator to independently select either RF transmit band or either RF receive band.

The following parameters summarize the characteristics of the terminal subsystems. Much of the electronic communications equipment is identical to that of the 9-metre terminal. A major difference, however, occurs in the high power amplifier in the transmitting chain. The baseband equipment is essentially identical. For the characteristics of the TV video and audio channels, the sound program channel, and the telephony channels, the reader is referred to Section 3.2.4. It should be noted that parameters quoted are performance specifications yet to be confirmed by actual measurement.

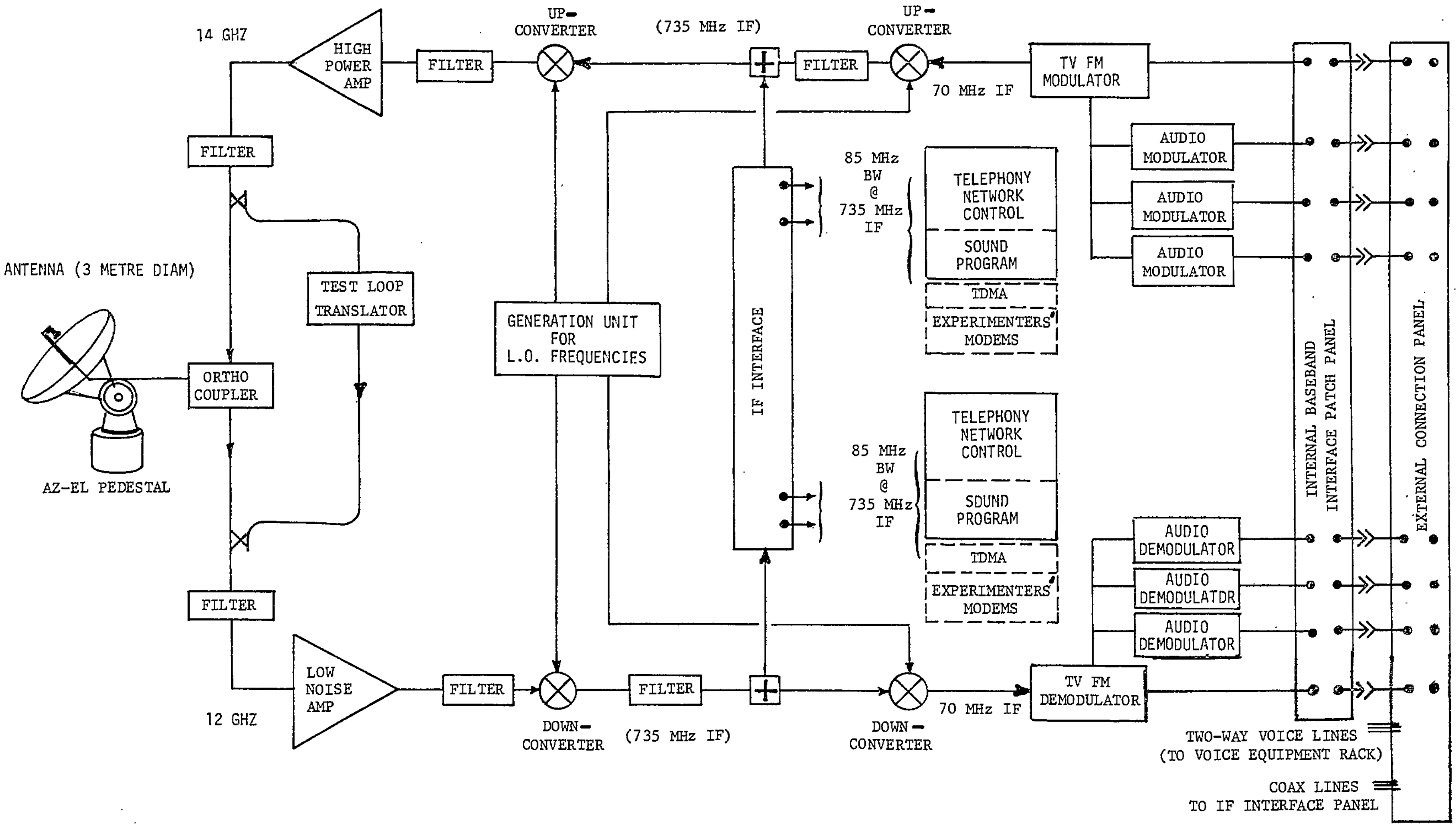


Figure 3.10. 3-Metre Transportable Ground Terminal

The actual values may be better. If the experimenter requires more detailed specifications for his own system evaluation than is provided here, CRC can furnish this upon request.

Antenna:	3.05 metre (10 ft) diameter parabolic reflector with dual orthogonal linear polarized focal point feed at 12 GHz and 14 GHz. Transmit gain - nominally 50.3 dB Receive gain - nominally 48.8 dB
Antenna Mount:	Elevation over azimuth pedestal remotely steerable ±35° in azimuth and 0-90° in elevation. Remote position indicator with resolution of 0.1°.
Antenna Tracking:	Step-track on spacecraft beacon signal strength with step period of 1 second and step size of 0.044°.
Transmitter:	1.2 kW (minimum) klystron amplifier with 85 MHz bandwidth. In order to change transmit RF frequency band, the klystron tube requires changing. Electrical prime power requirement: 12 KVA, 240V, single phase, 60 Hz.
Low noise amplifier:	Combination parametric amplifier followed by a tunnel diode amplifier to provide an input noise temperature of 217° Kelvin with overall system input noise temperature at paramp input flange of 340° Kelvin. 500 MHz instantaneous bandwidth.
Up-converter:	Two stage with low IF at 70 MHz and high IF at 735 MHz. RF transmit band selection provided at final stage of up-conversion from 735 MHz to RF.
Transmit chain (from IF interface to antenna):	Can transmit in either RF transmit band. 1 dB instantaneous bandwidth of 85 MHz for either RF channel, with output power levels between 0 and saturation.

	40 dB bandwidth less than 350 MHz
	IF to RF gain of 60 dB (+2, −0 dB) at saturated output power level with gain attenuators set to zero. Gain is continuously adjustable from 0 to −30 dB.
	Gain stability greater than ±0.5 dB/24h
	Gain slope less than ±0.1 dB/MHz in either transmit band with limit of ±1 dB over full 85 MHz band.
Down-converter:	Two stage with high IF at 735 MHz and low IF at 70 MHz.
	RF receive band selection provided at first stage of down-conversion between RF and 735 MHz.
Receive chain (from antenna to IF interface):	Can receive either RF receive band
	1 dB minimum instantaneous bandwidth is 85 MHz for either channel with input signal levels from receiver noise level to -90 dBW.
	RF to IF gain at 70 dB (+2, -0 dB) with gain attenuators set to zero. Gain is adjustable from 0 to -20 dB in 5 dB steps.
	Gain stability greater than ±0.5 dB/24 h
	Gain slope less than ±0.5 dB/MHz within either receive band with limit of ±1 dB over full 85 MHz band.
	Dynamic range from receiver noise level to an input signal level of -90 dBW.

3.4 TWO-METRE GROUND TERMINAL

3.4.1 General

This terminal is intended to provide television reception plus a single telephony channel. In addition, by connection of the optional sound program transmit unit (SPTU) and/or sound program receive unit (SPRU), the terminal can transmit or receive the sound program channel.

Eight of these terminals are being purchased. The terminals are configured as illustrated in Figure 3.11. They are designed to be used near the building provided by the experimenter. The antenna and antenna mount can

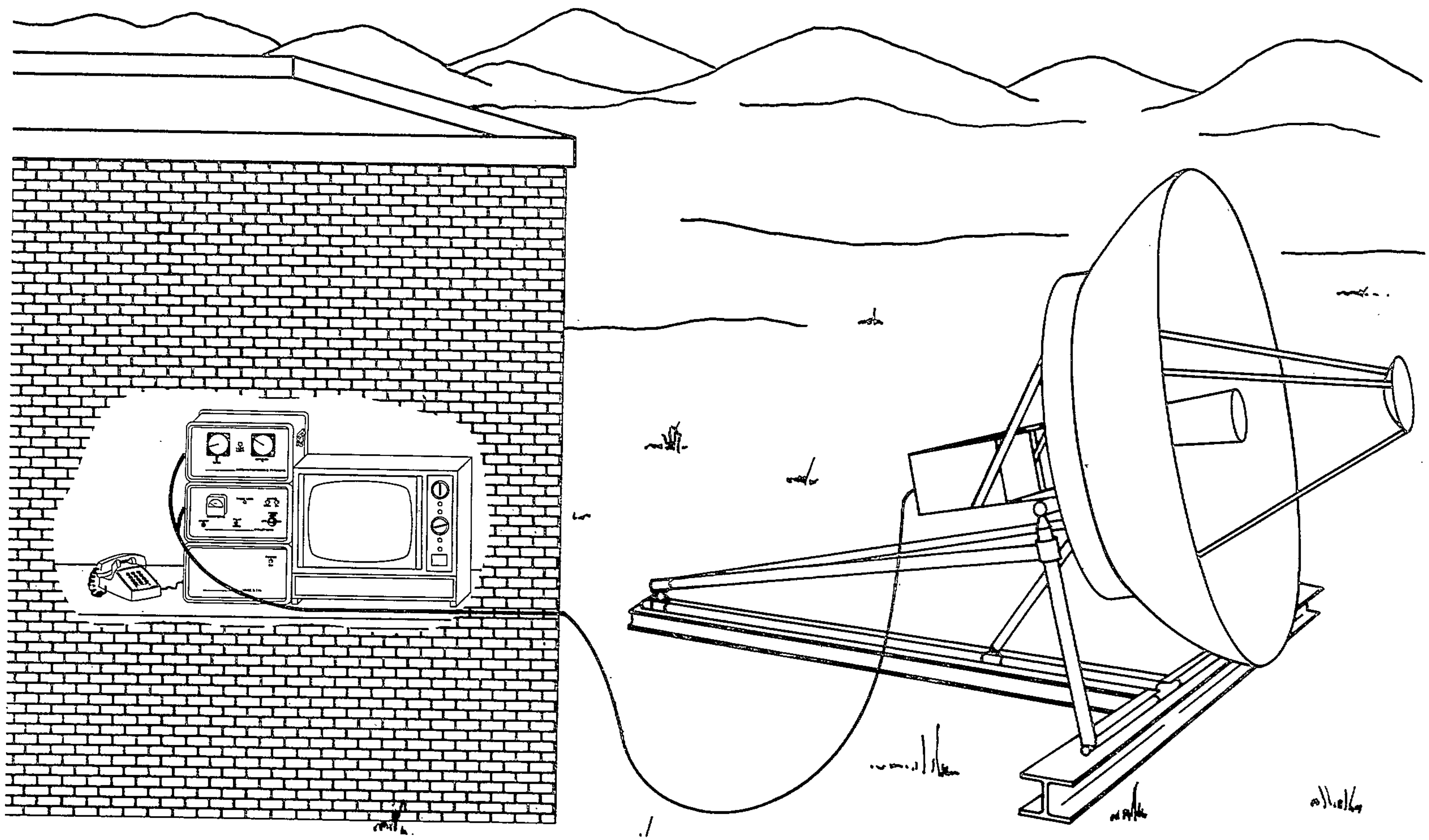


Figure 3.11. 2-Metre Ground Terminal

be installed either on the roof of the building or on the ground near the building. Associated near the antenna is a weatherproof electronics equipment package containing the high frequency components of the terminal. This package is interconnected by means of cables to an indoor unit which is composed of packages containing some terminal electronics, the interface panels and operating controls. This indoor unit would be installed inside the experimenter's building. Interconnecting cables are provided to allow separations between the indoor and outdoor units of up to 30.5 metres (100 ft).

The terminal can be broken into several small pieces for transport purposes which can be easily handled for setting-up or dismantling by two men.

3.4.2 Signal Types and Interface Requirement

Patch panels and connection panels are provided on the electronic packages located in the experimenter's building to allow the experimenter's equipment to interface with the terminal.

This section describes the available signal types and the interface characteristics in detail. The experimenter must deliver his signals to and from these interfaces and, consequently, must provide all necessary cabling, terrestrial links, etc.. It is the responsibility of the experimenter to ensure that all signals and equipment connected into the interfaces are compatible with the terminal.

3.4.2.1 Transmit

1) Telephony

The 2-metre terminal is capable of transmitting voice over one telephone channel. Two interfaces are available for this signal. A standard telephone set is included as part of the terminal equipment to provide an acoustic interface. In addition, a direct input into the telephony channel unit is provided on the baseband interface patch panel.

a) Telephone set

The telephone set is a standard desk-top telephone, equipped with a touch tone dial. The telephone set is equipped with a 3.05 metre (10 ft) cord. As an option the experimenter can remote the telephone set with a CRC supplied 30.5 metre (100 ft) extension cable.

Equipment such as facsimile, data modems, etc., designed with acoustic couplers for connection to terrestrial telephones can be connected to this telephone in an identical manner.

b) Direct telephone channel unit input on the baseband interface patch panel

This input provides a hard wire connection for the transmit lines of special equipment to be interfaced with the terminal. This includes, for example, facsimile, telewriters, slow scan television, data modems, etc.. When the telephone set is being used, the telephone interface unit, which is part of the terminal equipment, is plugged into the same connectors on this interface. Consequently, the above equipment cannot be simultaneously connected. The interface has the following characteristics:

connection:	telephone type tip, ring and sleeve jack
impedance:	600 ohms balanced
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	-13 dBm for a 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface TLP:	-16 TLP nominal
nominal speech level for an average talker:	-32 Vu
dynamic range:	50 dB
data or facsimile nominal signal level:	-29 dBm
gain adjust:	an amplifier is provided, for the transmit chain, which can be patched into the input of the telephony channel unit. This amplifier provides a ±6 dB gain, continuously adjustable, and is designed to handle the facsimile, data, speech signals, etc., listed above.

2) *Sound Program*

One sound program signal can be transmitted to a 3-metre or 9-metre terminal providing that terminal is acting as the NCT for the transmitting 2-metre terminal. This capability requires the use of the optional sound program transmit unit. In order to transmit sound program, the transmit telephony channel unit must be disconnected and the sound program transmit unit connected in its place. This is accomplished through patch connections on an IF interface described below. The input interface to the sound program transmit unit has the following characteristics:

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack located on an interface panel in the sound program transmit unit
bandwidth:	50 Hz to 15,000 Hz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu
gain adjust:	baseband input continuously adjustable ±6 dB.

3) IF Interface

A high IF interface patch panel is available in the 2-metre terminal. This patch panel is provided for very specific applications which would not normally involve most experiments. The description is provided here, however, for those who do have a specific interest. The interface characteristics are as follows:

IF frequency:	735 MHz
bandwidth (1 dB):	85 MHz
impedance:	50 ohms unbalanced
connectors:	TNC female connectors
signal level (max):	-10 dBm for transmitter output saturation.

3.4.2.2 Receive

1) Television

One TV video channel with 0 to 3 TV audio channels can be received from a 3-metre or 9-metre terminal.

a) Video channel interface

impedance:	75 ohms unbalanced
connector:	BNC female located on the TV baseband interface patch panel
bandwidth:	30 Hz to 4.2 MHz
level:	1 volt peak-to-peak for the composite video.

b) Audio channel interface

impedance:	600 ohms balanced
connector:	spade lug type with screw terminals
bandwidth:	50 Hz to 10 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu

2) Telephony

As indicated in Section 3.4.2.1 (1) two interfaces are available to an experimenter and can be used in accordance with his requirements. A standard telephone set is included as part of the terminal equipment to provide the acoustic interface. In addition, a direct output from the telephony channel unit is provided on the baseband interface patch panel.

a) Telephone set

This telephone set is, as described above, a standard desk-top telephone equipped with a touch tone dial.

b) Direct telephone channel unit output on the baseband interface patch panel.

This output provides a hard wire connection for the receive lines for special equipment to be interfaced with the terminals. When the telephone set is being used, the telephone interface unit, supplied as part of the terminal equipment, is plugged into this interface into the same connectors which would otherwise be used by the special equipment. This interface has the following characteristics:

connector:	telephone type tip, ring and sleeve jack
impedance:	600 ohms balanced
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	+10 dBm for a 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface TLP:	+7 TLP nominal
nominal speech level for an average talker:	-9 Vu
dynamic range:	50 dB

nominal signal level for data or facsimile:	-6 dBm
gain adjust:	An amplifier is provided for the receive chain which can be patched into the output of the telephony channel unit. This amplifier provides a ±6 dB gain continuously adjustable, and is designed to handle the facsimile, data or speech signals listed above.

3) Sound Program

A 2-metre terminal can receive the sound program channel transmitted from the 9-metre or 3-metre terminal which is acting as the NCT for the 2-metre terminal. This requires that the receiving 2-metre terminal be equipped with the optional sound program receive unit. On this unit, two interfaces are available; which can be used simultaneously; a standard output interface and a speaker interface.

a) Standard output interface

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack located on an interface panel in the sound program receive unit
bandwidth:	50 Hz to 15 kHz
test-tone level:	+10 dBm for a 1 kHz full load test-tone. A variable gain amplifier is provided to adjust signal level at output by ±6 dB
nominal program level:	0 Vu.

b) Speaker interface

impedance:	suitable to drive a speaker of 4 to 16 ohm impedance
connector:	pair of spade lug type terminals
bandwidth:	50 Hz to 15 kHz
power output:	10 watts into an 8 ohm load. A volume control is provided on the exterior of the sound program receive unit.

4) IF Interface

A high IF interface is provided with the following characteristics:

IF frequency:	735 MHz
bandwidth (1 dB):	85 MHz
impedance:	50 ohms unbalanced
connectors:	TNC female connectors
RF to IF gain:	the gain from the antenna port to the output port on the high IF interface patch panel is 70 dB (+2, -0 dB). Consequently, signal levels at the IF interface depend upon received signal strengths and signal characteristics.

3.4.3 Site Requirements and Installation

The experimenter shall assume all responsibility for the selection and preparation of the sites for the 2-metre terminals. Having approved the selected site, CRC will apply for a licence to operate the terminal on the site. The terminal itself will be licenced separately. The experimenter will be asked to assist by providing detailed information on sites such as precise location in terms of latitude, longitude and altitude, proximity of airports or radar stations, horizon angles for the surrounding terrain, etc.. After the necessary information has been provided, CRC will be responsible for ensuring that the terminals are licenced to operate at the site.

CRC can provide the experimenter with the azimuth and elevation angles of the spacecraft from the experimenter's site when the experimenter determines the latitude, longitude and altitude of the site. Azimuths will be provided with respect to true north. If the experimenter uses a magnetic compass while evaluating the site for spacecraft visibility he must compensate for the magnetic declination at the particular site. Magnetic compasses will generally not be adequate in densely built-up areas or regions likely to produce magnetic anomalies. In this case the assistance of a professional surveyor is recommended. Latitude and longitude of a site can generally be determined to a sufficient accuracy from topographical survey maps. Magnetic declination charts and topographical survey maps are available to the public from the Map Distribution Office, Surveys and Mapping Branch, Department of Energy, Mines and Resources, 615 Booth Street, Ottawa, K1A 0E9. Latitude and longitude of a site must be given to an accuracy of 5 minutes.

The site must be selected in accordance with several requirements:

1) Sites for the antenna can be selected either on the roof of buildings or on the ground near the experimenter's building. The site should be cleared, reasonably level and have a sufficient bearing strength to support the weight of the antenna and the outdoor electronics. The equipment itself is estimated to weigh approximately 280 Kg (620 lbs). Installation requirements are discussed below. The experimenter is responsible for the physical protection of the terminal.

2) The site must be selected such that a clear line of sight to the spacecraft is available. It must be clear of obstacles within a 10° cone centred on the line-of-sight.

3) The experimenter is responsible to ensure that an electrical service outlet is available on the site if local commercial electrical power is available. If commercial electrical power is not available, the experimenter must arrange to acquire a suitable portable electrical generator.

It is the responsibility of the experimenter to provide adequate foundations for mounting the antenna and all equipment and structures associated with the antenna. Design details for the antenna structures have not yet been worked out by the contractor and consequently are not available at this time. However, once these become available, CRC will provide design details of possible foundations which the experimenter can use for mounting the antenna. The type of foundation applicable to the experimenter depends, of course, on the selected site characteristics (e.g., roof top, pavement, field, etc.). The mount designs which will be provided are presently envisaged to be of four different types:

1) Wooden rails and ground anchors

   This concept would require the placement of wooden rails, suitably oriented, in accordance with the requirements of the antenna structure, to which the antenna structure would be bolted. The rails themselves would be secured to the ground by means of ground anchors.

2) Bolting to suitable existing structures

   The antenna structure may be bolted directly to existing structures provided those structures have sufficient strength to withstand the antenna weight and the wind loads on the antenna.

3) Weighted down platforms

   Platforms can be used, suitably designed to accept the antenna structure, which can be weighted down to secure firmly the antenna in the presence of wind loading.

4) Concrete pads

   Concrete pads can be designed to which the antenna structure can be bolted.

The mountings are to be provided and installed by the experimenter and in each case must be aligned properly with the look angle of the spacecraft. Spacecraft look angles will be provided by CRC for the individual sites. However, the experimenter must provide the necessary surveying to orient the mount properly with respect to the look angle. This can be accomplished, in certain cases, by means of a magnetic compass, or, in areas not suitable for magnetic compasses, by a gyroscopic compass or by astronomical survey techniques. Any surveyor should be able to provide the required reference line.

The orientation of the particular mount selected by the experimenter with respect to the look angles, as well as the required accuracy, will be given in the detailed plans to be provided by CRC.

CRC will be responsible for the installation, check-out and removal at the site for each 2-metre terminal assigned to the experimenter. It is expected that each experimenter will not require any one terminal to be located at more than one site during his experiment. Any relocation of terminals during any given experiment will be carried out only with the approval of CRC. It will be the responsibility of the experimenter and will only be considered in special cases.

The experimenter will be asked to provide some assistance in the installation and removal of the terminal. This would involve, depending upon specific site requirements, perhaps one man and a vehicle, such as a 1/2 ton truck, suitable for hauling the equipment. Terminal installation and check-out is expected to take approximately 8 hours in good weather conditions. An additional two hours is required for terminal check-out at the beginning of the experimenter's first time allocation for the spacecraft.

Radiation densities in the beam of the antenna are not expected to exceed the safe levels for human exposure. However, sufficient precautions should be taken to ensure that, when transmitting, access to the antenna is prevented, and that long periods of exposure to persons in the beam of the antenna be avoided. Radiation levels between the antenna feed and the sub-reflector, within the structure of the antenna, will exceed safe levels.

3.4.4 Power

It is the responsibility of the experimenter to provide adequate electrical power to operate the terminal. The terminal requires an estimated 700 watts, 120 volts ±15%, 60 Hz ±10% single phase, three wire service to run the terminal electronics and can be simply plugged into a standard 3 pronged household type utility outlet (15 amp.). For severe cold weather operation, heaters have been installed in the outdoor electronic boxes, which could require an additional 1750 watts. The design details of this additional requirement are still under consideration. The exact power requirement will be available after detailed terminal design is complete.

If commercial electrical power is not locally available sufficiently close to the site location, the experimenter must arrange to acquire a portable electrical generator with the power capacity and characteristics quoted above. Typical generators, which would meet this requirement, weigh in the order of 27-36 Kg (60-80 lbs), have a gasoline consumption rate in the order of 4.6 litres (1 gallon) per 5 to 6 hours at full load and are approximately 0.03-0.04 cubic metres (1 to 1.5 cubic feet) in size.

3.4.5 Operation and Maintenance

Once the terminal has been installed, the experimenter will be expected to operate the terminal. To assist the experimenter in this task, CRC will be prepared to conduct a training session at CRC in Ottawa, shortly after launch of the spacecraft, for one or two persons designated by the experimenter. In addition, at the completion of the terminal installation at a particular site, the installer will provide a demonstration of the operational aspects of the terminal.

One of the operational requirements of the 2-metre terminal is to adjust the pointing of the antenna to achieve reception of maximum signal strength (see Section 4.4). The spacecraft, although geostationary, moves more or less cyclically over a 24 hour period relative to beam centre of the 2-metre terminal. To ensure maximum performance from the terminal at all times requires that every hour the operator observe a signal strength meter and adjust the antenna pointing by means of remote control to maximize signal strength. The remote controls and meter will be available with the electronics equipment supplied in the indoor unit.

After the terminal has been set up and properly aligned by the CRC set-up crew, acquisition of the spacecraft requires the use of azimuth and elevation remote position readouts and the remote controlled positioners provided with the terminal. The experimenter may be required to conduct a search for the satellite over a range of up to ±4° in elevation and azimuth. A table of look angles calculated for various times during the day will be provided for guidance, if this proves to be necessary.

Although the present tracking method to be provided with the terminal is manual, requiring an operator to peak up the signal strength, CRC is presently investigating the possibility of procurement of an automatic step-track unit. The step-track system would automatically follow the motion of the satellite such that maximum signal strength is received at all times.

Maintenance of the 2-metre terminals will be the responsibility of CRC. Maintenance personnel will be available to maintain, troubleshoot and repair the terminals. In some cases, experimenters who have trained electronics technicians may be asked, if a failure occurs, to do very simple established procedures to attempt to determine the cause of failure and avoid delays in unnecessary travel or in acquiring, from a central stores, the necessary replacement part. Otherwise, all maintenance will be provided by CRC. The outage time of a terminal due to equipment failure may be one-half day to 2 weeks depending upon the location.

3.4.6 Environmental Requirements

The 2-metre terminals are being designed to operate and survive within the environmental limits specified below. Part of the terminal, consisting of electronics packages referred to as the indoor units, are to be installed in shelters or buildings to be supplied by the experimenter.

The operating environment limits given below are those limits within which the terminals will operate with no degradation in performance below the required values. The survivable environment limits are those limits which the equipment will survive without damage or without degradation to performance for subsequent operation.

The operational limits for the indoor units are:

Temperature:	4.4°C (40°F) to 35°C (95°F)
Relative Humidty:	5% to 75%
Altitude:	Sea level to 3050 metres (10,000 ft)

Listed below are the operational limits for the remainder of the terminal equipment and the survivable limits for the complete terminal, including the indoor unit. The experimenter will be required to clear snow from the antenna reflector and beam-path to prevent excessive signal attenuation.

	OPERATIONAL	SURVIVABLE
Temperature:	-45.6°C (-50°F) to 35°C (95°F)	-51°C (-60°F) to 40.6°C (105°F)
Relative Humidity:	5% to 100%	5% to 100%
Rain:	0.75 cm (0.3 in)/5 min	1.25 cm (0.5 in)/5 min
Snow (Average):	2.8 m (110 in)/year	4.1 m (160 in)/year
Snow (Max. Rate):	0.51 m (20 in)/24 h	0.64 (25 in)/24 h
Ice:	0.64 cm (0.25 in)	1.27 cm (0.5 in)
Wind (Average):	48.3 Km/h (30 mi/h)	-
Wind (Gusts):	72.4 Km/h (45 mi/h)	177 Km/h (110 mi/h)
Altitude:	Sea level to 3048 m (10,000 ft)	9144 m (30,000 ft)

3.4.7 Transportation

For transporting the terminal from one site to the next, between experiments, the terminal breaks down into sufficiently small pieces to be easily handled by one or two men. The terminal is tentatively designed by the contractor to break down into approximately 9 or 10 packages. The largest piece will be the major portions of the main reflector which will be the 1.67 metre (66 in) diameter parabolic dish weighing approximately 54 Kg (120 lbs) (excluding packaging). The antenna subreflector assembly will be contained in a package estimated to be 0.9 metre x 0.9 metre x 0.8 metre (3 ft x 3 ft x 2.5 ft) weighing approximately 27 Kg (60 lbs) (excluding packaging). An additional package 0.5 metre x 0.5 metre x 0.9 metre (1.5 ft x 1.5 ft x 3 ft) weighing an estimated 23 Kg (50 lbs) (excluding packaging) will contain the feed horn assembly for the antenna. Structural members of the antenna mount, the longest being 1.9 metres (75 in), make up the remaining pieces for the antenna subsystem. In addition to these, there will be 5 packages of electronics equipment each 0.51 metre x 0.91 metre x 0.25 metre

(20 in x 20 in x 10 in) and weighing in the order of 23-27 Kg (50-60 lb) including transit cases. Interfacility cables, in 30 metre (100 ft) lengths, and a few miscellaneous parts complete the pieces required to be transported. The total terminal weight is expected to be approximately 300 Kg (650 lbs), excluding special shipping boxes.

Transportation will generally be by road and air freight. In general, CRC will be responsible for transportation between major centres while the experimenter will be responsible for moving the terminals between these major centres and the terminal sites.

3.4.8 Terminal Characteristics

This section is provided primarily for information to those experimenters interested in the more technical details of the terminals. A brief description of the major terminal characteristics, as they are known to date, and a block diagram description of terminal operation is provided.

The major terminal characteristics are defined by the two following parameters: (these are specified minimum values)

1) System G/T: 16.6 dB

2) e.i.r.p. 60.5 dBW

Figure 3.12 is a block diagram illustration of the terminal's communications equipment. Experimenters can interface with the terminal at several points depending upon the specific requirements of the experiment. These include the high IF interface patch panel, TV patch panel, the baseband interface patch panel for the telephony system, the baseband patch panel of the sound program transmit unit (if available at the terminal), the baseband patch panel of the sound program receive unit (if available at the terminal) and a low IF interface patch panel.

With reference to Figure 3.12 the following signal flow occurs. At the telephony baseband interface patch panel, the telephone set plugs into a telephone interface unit which, in turn, patches, at the panel, into the transmit side of the telephony channel unit. Hard wire connection of equipment other than the telephone (e.g., telewriter, facsimile, data modems, etc.) is expected to be done directly at the input patch connections of the telephony channel unit. A ±6 dB gain amplifier is provided which can be patched into the baseband circuit to adjust gain. The telephony channel unit frequency modulates the baseband voice signal onto a low IF. The IF is unique to each terminal since there are fixed channel assignments with the frequencies for all terminals equipped for telephony varying from 100.17 MHz to 101.36 MHz with spacings of 70 kHz. The output appears on the low IF interface patch panel.

With signals obtained from its own baseband patch panel, the sound program transmit unit frequency modulates a carrier of frequency 98.42 MHz. The output of this unit also appears on the low IF interface patch panel. At this point, either the telephony channel unit or the sound program transmit unit is patched into the first stage of a two stage up-conversion. Both signals cannot be accommodated simultaneously.

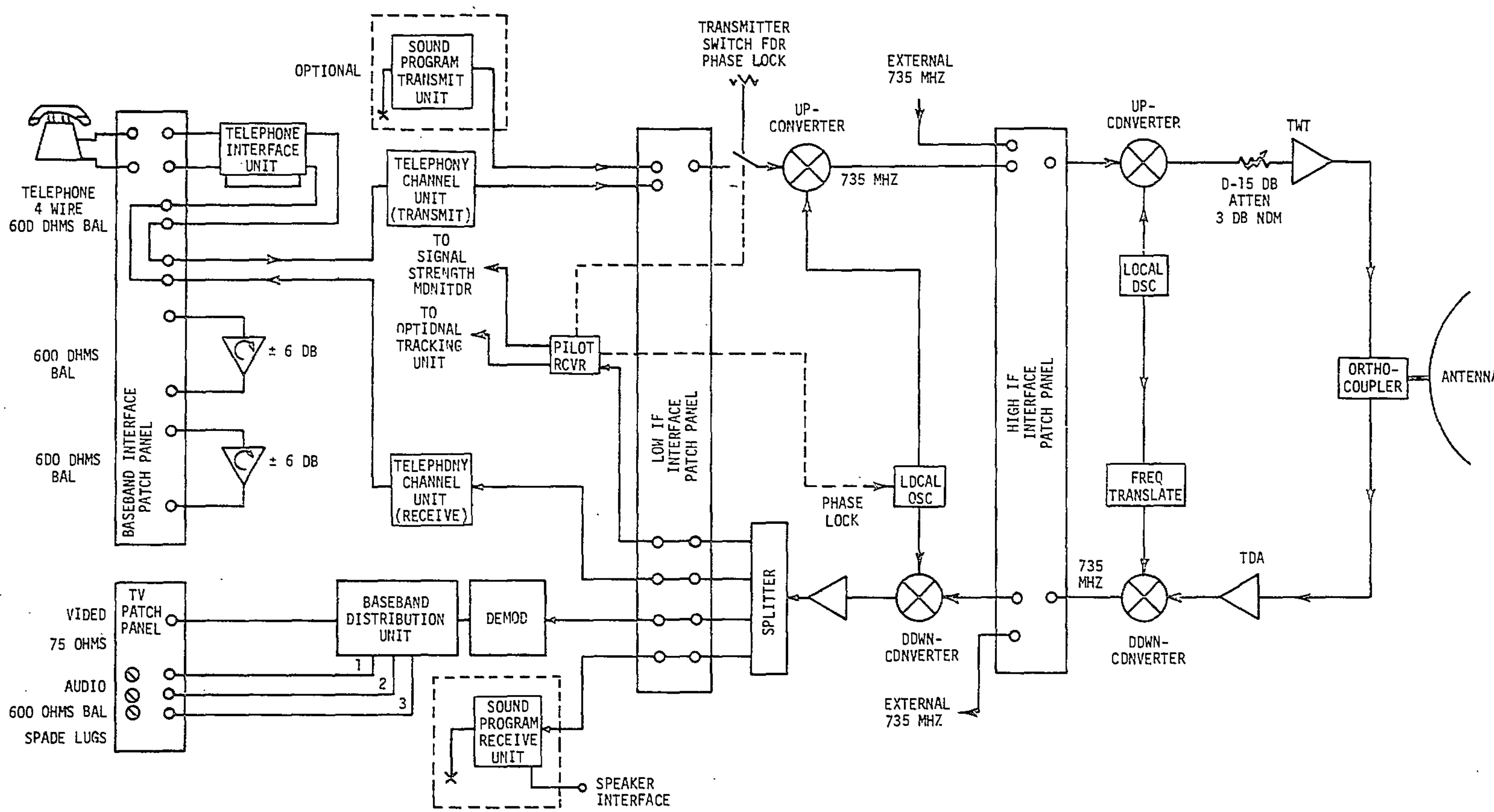


Figure 3.12. Block Diagram of 2-Metre Terminal Equipment

The first stage of up-conversion converts the signals to a nominal IF of 735 MHz with the output appearing on a high IF interface patch panel. This signal or an external signal can then be patched to the second stage of up-conversion which converts to the low spacecraft RF channel. A TWT power amplifier then amplifies the signal for final output via an orthocoupler to the antenna. Seven of the eight terminals transmit in the lower frequency spacecraft RF channel. Only one of the 2-metre terminals can transmit in either the higher or the lower channel.

On the receive side, the signal at the receive port of the orthocoupler is amplified by a low noise tunnel diode amplifier. The first stage of a two stage down-converter converts the RF to a 735 MHz high IF signal which is made available on the high IF interface patch panel. With one exception, seven 2-metre terminals are equipped to receive only the high spacecraft RF channel. One terminal is equipped to receive either channel.

At the high IF interface patch panel, the signal can be patched either to external equipment or to the second stage of down-conversion. This stage converts to a low IF where a power splitter splits the signal and feeds it to four connectors appearing on the low IF interface patch panel. These four low IF signals are:

1) Television (video and 0 to 3 audio channels) at an IF of 70 MHz;

2) Pilot carrier at a frequency of 97.16 MHz;

3) Sound program at a frequency of 98.42 MHz;

4) Telephony at a unique frequency, for each terminal, in the range of 100.17 MHz to 101.36 MHz;

At the IF interface patch panel, each of the signals is patched to its respective demodulator. The pilot carrier transmitted by the NCT is used to establish a frequency reference to eliminate drift of the local oscillators used in the second stage of down-conversion. This reduces the drift of the signal frequencies with respect to the channel filters.

The television receiver demodulates the video and three audio channels from a 70 MHz IF carrier. The baseband outputs are available on a TV patch panel.

The receive side of the telephony channel unit demodulates the particular telephony channel assigned to the terminal. The baseband output appears at a baseband interface patch panel, where a ±6 dB gain amplifier can be patched in, and where hard wire connections to external equipment such as telewriters, data modems, etc., can be made. When the telephone handset is being used, the telephony channel unit output is patched into a telephone interface unit required for use with the telephone set.

The fourth received signal is for the optional sound program receive unit. The signal is frequency demodulated by the sound program receive unit and made available to the experimenter at a patch panel on the unit.

The antenna uses a high efficiency shaped reflector with a Cassagrainian feed system. The antenna structure, on which the reflector and feed are supported, has been designed to permit remote steering of ±4° in elevation and azimuth about pre-set nominal pointing angles. The pre-set azimuth angle is determined by the orientation of the antenna mount, while the pre-set elevation angle is determined by manual adjustment of the antenna structure.

The following parameters summarize the characteristics of the terminal subsystems. With the exception of the antenna and the television receiver, the equipment is identical to that of the 1-metre terminal. For detailed characteristics of the TV video and audio channels, the sound program channel and the telephony channel, the reader is referred to Section 3.2.4. If the experimenter requires more detailed specifications for his own system evaluation than is provided here, CRC can furnish this upon request.

Antenna:	2.13 metres (7 ft) diameter shaped parabolic reflector with Cassagrainian dual orthogonal linearly polarized feed. Transmit gain nominally 48.4 dB Receive gain nominally 47.0 dB
Antenna mount:	Elevation over azimuth structure remotely steerable at least ±4° in azimuth and ±4° in elevation about a pre-set elevation angle in the range 0° to 90°.
Antenna tracking:	manual steering to peak up received signal strength. (Step-track is being investigated by CRC.)
Transmitter:	20 watt travelling wave tube amplifier.
Low noise amplifier:	Tunnel diode amplifier with an input noise temperature of 670°K to provide an overall system noise temperature of 766°K in clear weather at an elevation angle of 5°.
Up-converter:	Two stage with low IF nominally centred on 70 MHz and high IF at 735 MHz.
Transmit chain (from high IF interface to antenna):	All 2-metre terminals but one can transmit only in the low RF spacecraft channel. The 1 dB instantaneous bandwidth of 85 MHz for input power levels between -10 dBm and saturation of the output power amplifier.

	IF to RF gain sufficient to saturate 20 watt TWT amplifier with a 0.1 mW signal at IF interface.
	Gain variable from +3 to -15 dB about nominal setting.
	Gain slope less than 0.1 dB/MHz with maximum of 1.0 dB over the full 85 MHz channel.
	Gain ripple less than 1.0 dB peak-to-peak.
	Gain stability not to exceed ±0.5 dB/24 h
Down-converter:	Two stage with high IF at 735 MHz and low IF nominally centred on 70 MHz.
Receive chain (from antenna to IF interface):	All 2-metre terminals except one can receive only the high RF spacecraft channel.
	1 dB instantaneous bandwidth is 85 MHz.
	70 dB (+2, -0 dB) RF to IF gain.
	Gain slope less than 0.5 dB/MHz with maximum of 1.0 dB over the full 85 MHz channel.
	Gain ripple less than 1.0 dB peak-to-peak.
	Dynamic range from receiver noise level to an input signal level of -95 dBW at the antenna receive port.

3.5 ONE-METRE GROUND TERMINAL

3.5.1 General

This terminal is intended to provide a single telephony channel. In addition, by connection of the optional sound program transmit unit and/or sound program receive unit, the terminal can transmit or receive the sound program channel.

Eight of these terminals will be available for experimenter's use. The terminals are presently configured as illustrated in Figure 3.13, although the design is still under review. They are designed to be used near the building provided by the experimenter. The antenna and antenna mount can be installed either on the roof of the building or on the ground near the building. Associated with the antenna is a weatherproof electronics equipment

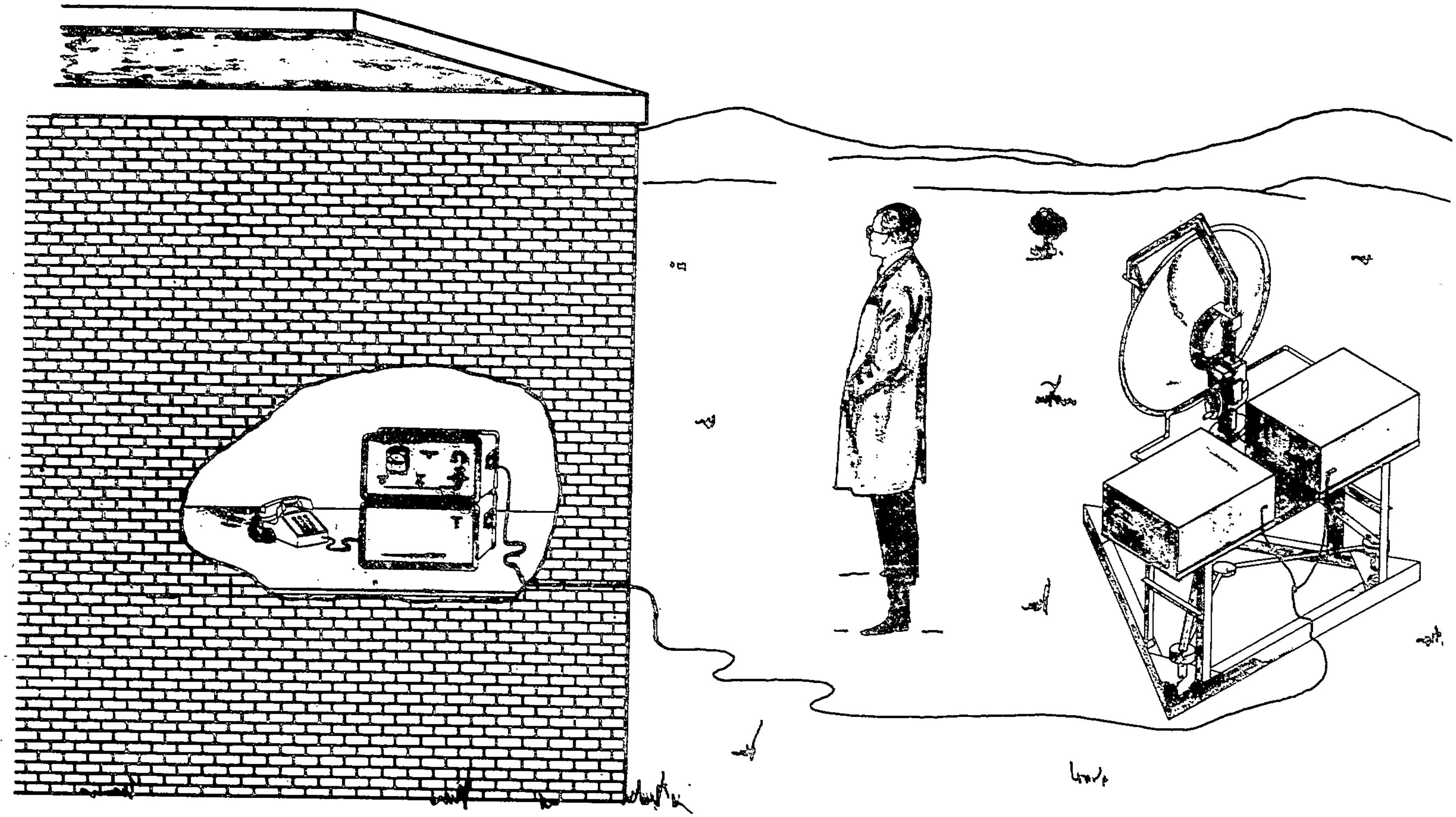


Figure 3.13. 1-Metre Terminal

package containing the high frequency components of the terminal. This package is interconnected by means of cables to an indoor unit which is composed of packages containing some terminal electronics, the interface panels and operating controls. This indoor unit would be installed inside the experimenter's building. Interconnecting cables are provided to allow separations between the indoor and outdoor units of up to 30.5 metres (100 ft).

The terminal can be broken into several small pieces for transport purposes which can be easily handled for setting-up or dismantling by two men.

3.5.2 Signal Types and Interface Requirement

Patch panels and connection panels are provided on the electronic packages located in the experimenter's building to allow the experimenter's equipment to interface with the terminal.

This section describes the available signal types and the interface characteristics in detail. The experimenter must deliver his signals to and from these interfaces and consequently must provide all necessary cabling, terrestrial links, etc. It is the responsibility of the experimenter to ensure that all signals and equipment connected into the interfaces are compatible with the terminal.

3.5.2.1 Transmit

1) Telephony

The 1-metre terminal is capable of transmitting voice for one telephone channel. Two interfaces are available for this signal. A standard telephone set is included as part of the terminal equipment to provide the acoustic interface. In addition, a direct input into the telephony channel unit is provided on the baseband interface patch panel.

a) Telephone set

The telephone set is a standard desk-top telephone, equipped with a touch tone dial. The telephone set is equipped with a 3.05 metre (10 ft) cord. As an option the experimenter can remote the telephone set with a CRC supplied 30.5 metre (100 ft) extension cable.

Equipment such as facsimile, data modems, etc., designed with acoustic couplers for connection to terrestrial telephones can be connected to this telephone in an identical manner.

b) Direct telephone channel unit input on the baseband interface patch panel

This input provides a hard wire connection for the transmit lines of special equipment to be interfaced with the terminal. This includes, for example, facsimile, telewriters, slow scan television, data modems, etc. When the telephone set is being used, the telephone interface unit, which is part of the terminal equipment, is plugged into the same connectors on this interface. Consequently, the above equipment cannot be simultaneously connected. The interface has the following characteristics:

connection:	telephone type tip, ring and sleeve jack
impedance:	600 ohms balanced
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	-13 dBm for a 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is +3 dBm)
interface TLP:	-16 TLP nominal
nominal speech level for an average talker:	-32 Vu
dynamic range:	50 dB
data or facsimile nominal signal level:	-29 dBm
gain adjust:	An amplifier is provided, for the transmit chain, which can be patched into the input of the telephony channel unit. This amplifier provides a ±6 dB gain, continuously adjustable, and is designed to handle the facsimile, data, speech signals, etc. listed above.

2) Sound Program

One sound program signal can be transmitted to a 9-metre terminal only providing that terminal is acting as the NCT for the transmitting 1-metre terminal. This capability requires the use of the optional sound program transmit unit. In order to transmit sound program, the transmit telephony channel unit must be disconnected and the sound program transmit unit connected in its place. This is accomplished through patch connections on an IF interface described below. The input interface to the sound program transmit unit has the following characteristics:

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack located on an interface panel in the sound program transmit unit
bandwidth:	50 Hz to 15,000 Hz

test-tone level:	+10 dBm for a 1 kHz full load test-tone
nominal program level:	0 Vu
gain adjust:	baseband input continuously adjustable ±6 dB.

3) IF Interface

An IF interface patch panel is available in the 1-metre terminal. This patch panel is provided for patching in the sound program transmit unit in place of the telephony channel unit and for test points for terminal maintenance.

3.5.2.2 Receive

1) Telephony

As indicated in Section 3.5.2.1 (1) two interfaces are available to an experimenter and can be used in accordance with his requirements. A standard telephone set is included as part of the terminal equipment to provide an acoustic interface. In addition, a direct output from the telephony channel unit is provided on the baseband interface patch panel.

a) Telephone set

This telephone set is, as described above, a standard desk-top telephone equipped with a touch tone dial.

b) Direct telephone channel unit output on the baseband interface patch panel.

This output provides a hard wire connection for the receive lines of special equipment to be interfaced with the terminals. When the telephone set is being used, the telephone interface unit, supplied as part of the terminal equipment, is plugged into this interface into the same connection which would otherwise be used by the special equipment. This interface has the following characteristics:

connector:	telephone type tip, ring and sleeve jack
impedance:	600 ohms balanced
bandwidth:	300 Hz to 3400 Hz
test-tone level at interface:	+10 dBm for a 1 kHz full load test-tone (test-tone level at zero transmission level point (TLP) is ±3 dBm)
interface TLP:	+7 TLP nominal

nominal speech level for an average talker:	-9 Vu
dynamic range:	50 dB
nominal signal level for data or facsimile:	-6 dBm
gain adjust:	An amplifier is provided for the receive chain which can be patched into the output of the telephony channel unit. This amplifier provides a ±6 dB gain continuously adjustable, and is designed to handle the facsimile, data or speech signals listed above.

2) Sound Program

A 1-metre terminal can receive the sound program channel transmitted from the 9-metre or 3-metre terminal which is acting as the NCT for the 1-metre terminal. This requires that the receiving 1-metre terminal be equipped with the optional sound program receive unit. On this unit, two interfaces are available which can be used simultaneously, a standard output interface and a speaker interface.

a) Standard output interface

impedance:	600 ohms balanced
connector:	telephone type tip, ring and sleeve jack located on an interface panel in the sound program receive unit
bandwidth:	50 Hz to 15 kHz
test-tone level at interface:	+10 dBm for a 1 kHz full load test-tone. A variable gain amplifier is provided to adjust signal level at output by ±6 dB.
nominal program level:	0 Vu.

b) Speaker interface

impedance:	suitable to drive a speaker of 4 to 16 ohm impedance
connector:	pair of spade lug type terminals.

3) IF Interface

An IF interface patch panel is provided in the 1-metre terminal at which point the IF signal is patched into the receive portion of the telephony channel unit, the pilot receiver unit and the sound program receive unit.

3.5.3 Site Requirements and Installation

The experimenter shall assume all responsibility for the selection and preparation of the sites for the 1-metre terminals. Having approved the selected site, CRC will apply for a licence to operate the terminal on the site. The terminal itself will be licenced separately. The experimenter will be asked to assist by providing detailed information on sites such as precise location in terms of latitude, longitude and altitude, proximity of airports or radar stations, horizon angles for the surrounding terrain, etc.. After the necessary information has been provided, CRC will be responsible to ensure that the terminals are licenced to operate at the site.

CRC can provide the experimenter with the azimuth and elevation angles of the spacecraft from the experimenter's site when the experimenter determines the latitude, longitude and altitude of the site. Azimuths will be provided with respect to true north. If the experimenter uses a magnetic compass while evaluating the site for spacecraft visibility, he must compensate for the magnetic declination at the particular site. Magnetic compasses will generally not be adequate in densely built-up areas or regions likely to produce magnetic anomalies. In this case, the assistance of a professional surveyor is recommended. Latitude and longitude of a site can generally be determined to a sufficient accuracy from topographical survey maps. Magnetic declination charts and topographical surveys maps are available to the public from the Map Distribution Office, Surveys and Mapping Branch, Department of Energy, Mines and Resources, 615 Booth Street, Ottawa, K1A 0E9. Latitude and longitude of a site must be given to an accuracy of 5 minutes.

The site must be selected in accordance with several requirements:

1) Sites for the antenna can be selected either on the roof of buildings or on the ground near the experimenter's building. The site should be cleared, reasonably level and have a sufficient bearing strength to support the weight of the antenna and the outdoor electronics. For winter operation, the outdoor equipment, including the antenna, must be kept clear of snow. The equipment itself is estimated to weigh approximately 95 Kg (210 lbs). Installation requirements are discussed below. The experimenter is responsible for the physical protection of the terminal.

2) The site must be selected such that a clear line of sight to the spacecraft is available. It must be clear of obstacles within a 10° cone centred on the line-of-sight.

3) The experimenter is responsible to ensure that an electrical service outlet is available on the site if local commercial electrical power is available. If commercial electrical power is not available the experimenter must arrange to acquire a suitable portable electrical generator.

It is the responsibility of the experimenter to provide an adequate mounting base for mounting the antenna and all equipment and structures associated with the antenna. Design details for the antenna structures have not yet been worked out by the contractor and consequently are not available at this timé. However, once these become available, CRC will provide design details of possible mounting bases which the experimenter can use for mounting the antenna. The type of mounting base applicable depends, of course, on the selected site characteristics (e.g., roof top, pavement, etc.). It is expected that these mounting requirements will be very simple and, indeed, it has yet to be determined whether prior preparation of mounting bases is even required. If they are required they may take the form of planks or rails, etc., perhaps weighted down with sandbags or equivalent.

The mountings are to be provided and installed by the experimenter and in each case must be aligned properly with the look angle of the spacecraft. Spacecraft look angles will be provided by CRC for the individual sites. However, the experimenter must provide the necessary surveying to orient the mount properly with respect to the look angle. This can be accomplished, in certain cases, by means of a magnetic compass, or, in areas not suitable for magnetic compasses, by a gyroscopic compass or by astronomical survey techniques. Any surveyor should be able to provide the required reference line. The orientation of the particular mount selected by the experimenter with respect to the look angles, as well as the required accuracy, will be given in the detailed plans to be provided by CRC.

CRC will be responsible for the installation, check-out, and removal at the site for each 1-metre terminal assigned to the experimenter. It is expected that each experimenter will not require any one terminal to be located at more than one site during his experiment. Any relocation of terminals during any given experiment will be carried out only with the approval of CRC. It will be the responsibility of the experimenter and will only be considered in special cases. Relocation of a terminal requires that the terminal be broken down into the transport mode to prevent damage from occurring.

At least two of the terminals are being designed to be used in a field portable mode of operation such that they can be transported with a field party and used to provide communications for short periods. Although, these terminals will be capable of being readily transported from site to site, they will still require dismantling prior to moving. At the new site, the experimenter will be required to set up the terminal, point it in the proper direction to acquire the spacecraft signals and operate it on his own.

The experimenter will be asked to provide some assistance in the installation of the terminal and removal of the terminal at the end of the experiment. This would involve, depending upon specific site requirements, perhaps one man and a vehicle, such as a 1/2 ton truck, suitable for hauling the equipment. Terminal installation and check-out is expected to take no more than 3 to 6 hours, depending upon local conditions.

3.5.4 Power

It is the responsibility of the experimenter to provide adequate electrical energy to operate the terminal. The terminal requires an estimated 460 watts, 120 volts, ±15%, 60 Hz ±10% single phase, three wire service to run the terminal electronics and can be simply plugged into a standard 3 pronged household type utility outlet (15 amp). For severe cold weather operation, heaters have been installed in the outdoor electronics boxes which could require an additional 1750 watts. The design details of this additional requirement are still under consideration. The exact power requirement will be available after detailed terminal design is complete.

If commercial electrical energy is not locally available sufficiently close to the site location, the experimenter must arrange to acquire a portable electrical generator with the power capacity and characteristics quoted above. Typical generators, which would meet this requirement weigh in the order of 27 to 36 Kg (60 to 80 lbs), have a gasoline consumption rate in the order of 4.6 litres (1 gallon) per 5 to 6 hours at full load and are approximately 0.03 to 0.04 cubic metres (1 to 1.5 cubic feet) in size.

3.5.5 Operation and Maintenance

Once the terminal has been installed, the experimenter will be expected to operate the terminal. To assist the experimenter in this task, CRC will be prepared to conduct a training session, at CRC in Ottawa, shortly after launch of the spacecraft, for one or two persons designated by the experimenter to operate these terminals. In addition, at the completion of the terminal installation at a particular site, the installer will provide a demonstration of the operational aspects of the terminal.

It should be noted that of all the terminals designed for operation with CTS, this is the only one which does not require tracking or periodic adjustment of pointing angles. The terminals are simply installed, pointing at the nominal spacecraft position. The beamwidth of the antenna is sufficiently large to cover the complete range of expected spacecraft motion.

Radiation densities in the beam of the antenna are not expected to exceed the safe levels for human exposure. However, sufficient precautions should be taken to ensure that, when transmitting, access to the antenna is prevented and that long periods of exposure to persons in the beam of the antenna be avoided. Radiation levels between the antenna feed and the reflector, within the structure of the antenna, will exceed safe levels.

Maintenance of the 1-metre terminals will be the responsibility of CRC. Maintenance personnel will be available to maintain, troubleshoot and repair the terminals. In some cases, experimenters who have trained electronics technicians may be asked, if a failure occurs, to do very simple established procedures to attempt to determine the cause of failure and avoid delays in unnecessary travel time or in acquiring, from a central stores, the necessary replacement part. Otherwise, all maintenance will be provided by CRC. The outage time of a terminal due to equipment failure may be one-half day to 2 weeks depending upon the location.

3.5.6 Environmental Requirements

The 1-metre terminals are being designed to operate and servive within the environmental limits specified below. Part of the terminal, consisting of electronics packages referred to as the indoor units, are to be installed in shelters on buildings to be supplied by the experimenters.

The operating environment limits given below are those limits within which the terminals will operate with no degradation in performance below the required values. The survivable environment limits are those limits which the equipment will survive without damage or without degradation to performance for subsequent operation.

The operational limits for the indoor units are:

Temperature:	4.4°C (40°F) to 35°C (95°F)
Relative Humidity:	5% to 75%
Altitude:	Sea level to 3048 metres (10,000 ft)

Listed below are the operational limits for the remainder of the terminal equipment and the survivable limits for the complete terminal, including the indoor unit.

	OPERATIONAL	SURVIVABLE
Temperature:	-45.6°C (-50°F) to 35°C (95°F)	-51°C (-60°F) to 40.6°C (105°F)
Relative Humidity:	5% to 100%	5% to 100%
Rain:	0.75 cm (0.3 in)/5 min	1.25 cm (0.5 in)/5 min
Snow (Average):	2.8 m (110 in)/year	4.1 m (160 in)/year
Snow (Max. Rate):	0.51 m (20)/24 h	0.64 (25 in)/24 h
Ice:	0.64 cm (0.25 in)	1.27 cm (0.5 in)
Wind (Average):	48.3 km/h (30 mi/h)	-
Wind (Gusts):	72.4 km/h (45 mi/h)	177 km/h (110 mi/h)
Altitude:	sea level to 3048 m (10,000 ft)	9144 m (30,000 ft)

The operational and survivable environment limits on the two field portable terminals are identical to those above except that for terminal operation the permissible wind load on the entire terminal is reduced to 40.2 km/h (25 mi/h).

3.5.7 Transportation

For transporting the terminal from one site to the next, between experiments, the terminal breaks down into sufficiently small pieces to be easily handled by one or two men. When the terminal is being used in the field portable mode it is still necessary to dismantle the terminal for transport. The configuration for the terminal has not yet been finalized by the contractor. However, it is estimated that the complete terminal would break down into 8 or 9 separate pieces. The antenna, complete with feed, will likely be packaged in a 1.1 m x 1.1 m x 0.6 m (3.5 ft x 3.5 ft x 2 ft) package with total weight in the order of 11 Kg (25 lbs) (excluding case). A tripod mount for the antenna is expected to occupy a package 1.2 m x 0.3 m x 0.3 m (4 ft x 1 ft x 1 ft) with total weight of approximately 9 Kg (19 lbs) (excluding case). A package of 0.6 m x 0.6 m x 0.5 m (2 ft x 2 ft x 1.5 ft) weighing about 10 Kg (23 lbs) (excluding case) will contain waveguide and antenna hardware. An equipment stand to support the two outdoor electronics packages will be packaged in a box 1.5 m x 0.6 m x 0.3 m (5 ft x 2 ft x 1 ft) and weigh an estimated 10 Kg (22 lbs) (excluding the case). The antenna base, weighing approximately 16 Kg (35 lbs) (excluding the case) will be packaged in a box 1.5 m x 0.3 m x 0.3 m (5 ft x 1 ft x 1 ft). Four 0.5 m x 0.5 m x 0.3 m (20 in x 20 in x 10 in) packages will contain the terminal electronics equipment, two for outdoor electronics and two for indoor electronics. The outdoor packages will weigh approximately 27 Kg (60 lbs) each and the indoor packages approximately 23 Kg (50 lbs) each including the transit cases. Some additional packaging will be required to contain miscellaneous terminal components including interconnecting cables and the telephone hand set. The total terminal weight, excluding shipping boxes, is estimated to be 160 Kg (350 lbs).

Transportation will generally be by road and air freight. Experimenters will be asked to make arrangements for and bear certain portions of the cost of transportation. It is expected that CRC will be responsible for transportation between major centres while the experimenter will bear the cost of moving the terminals between these major centres and the terminal sites.

3.5.8 Terminal Characteristics

This section is provided primarily for information to those experimenters interested in the more technical details of the terminals. A brief description of the major terminal characteristics, as they are known to date, and a block diagram description of terminal operation is provided.

The major terminal characteristics are defined by the two following parameters: (These are the minimum specified values as specified at beam edge.)

1) System G/T 5.2 dB

2) e.i.r.p. 48.0 dBW

Figure 3.14 is a block diagram illustration of the terminals communications equipment. Experimenters can interface with the terminal at several points depending upon the specific requirements of the experiment. These include the baseband interface patch panel for the telephony system, the baseband patch panel of the sound program transmit unit (if available at the terminal), the baseband patch panel of the sound program receive unit (if available at the terminal) and a low IF interface patch panel.

With reference to Figure 3.14, the following signal flow occurs. At the telephony baseband patch panel, the telephone set plugs into a telephone

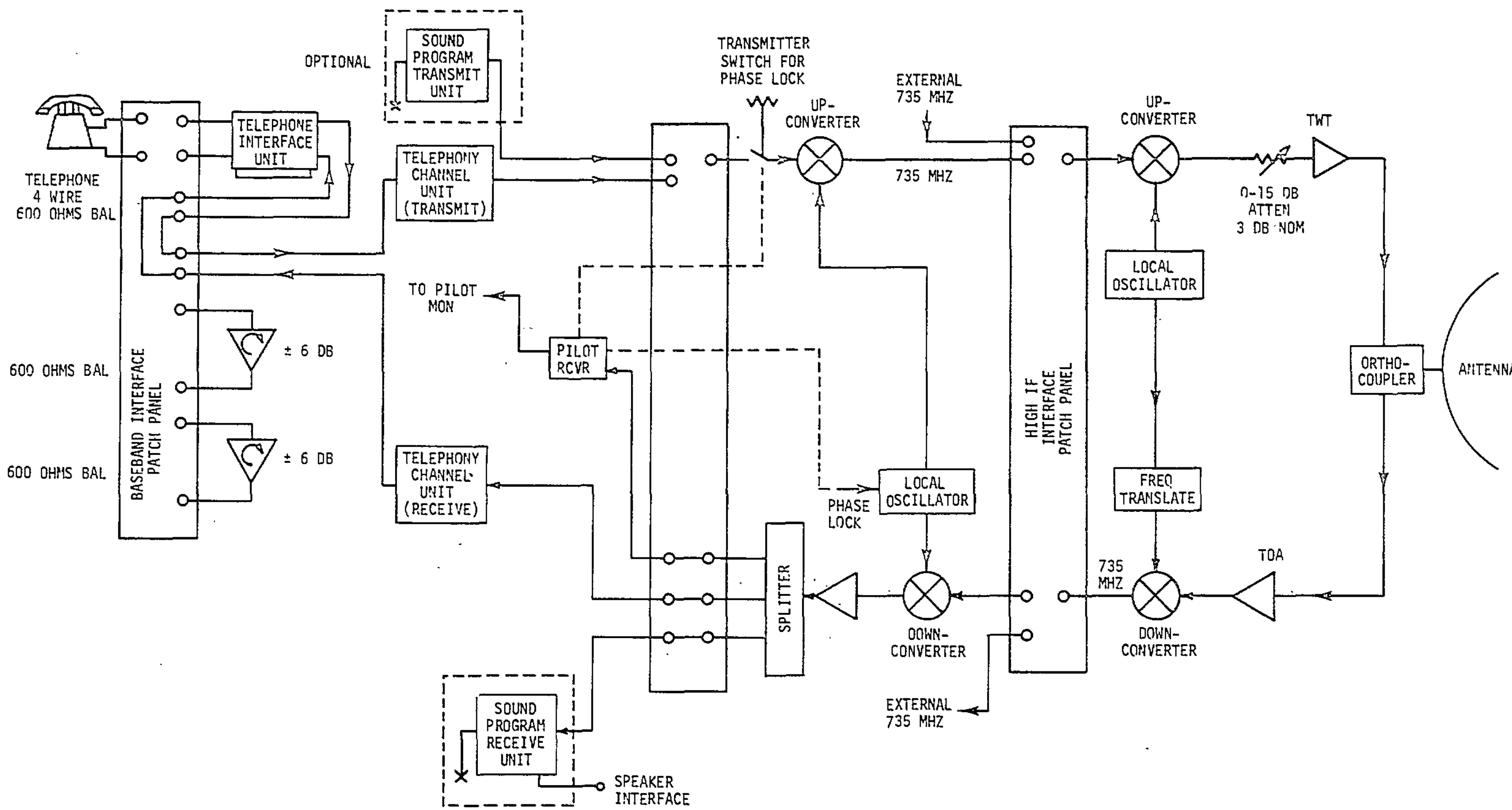


Figure 3.14. Block Diagram of 1-Metre Terminal Equipment

interface unit which, in turn, patches, at the panel, into the transmit side of the telephony channel unit. Hard wire connection of equipment other than the telephone (e.g., telewriter, facsimile, data modems, etc.) is expected to be done directly at the input patch connections of the telephony channel unit. A ±6 dB gain amplifier is provided which can be patched into the baseband circuit to adjust gain. The telephony channel unit frequency modulates the baseband voice signal onto a low IF. The IF is unique to each terminal since there are fixed channel assignments with the frequencies for all terminals equipped for telephony varying from 100.17 MHz to 101.36 MHz with spacings of 70 kHz. The output appears on the low IF interface patch panel.

With the signals obtained from its own baseband patch panel, the sound program transmit unit frequency modulates a carrier of frequency 98.42 MHz. The output of this unit also appears on the low IF interface patch panel. At this point, either the telephony channel unit or the sound program transmit unit is patched into the first stage of a two stage up-conversion. Both signals cannot be accommodated simultaneously.

The first stage of up-conversion converts the signals to a nominal IF of 735 MHz. This signal is connected to the second stage of up-conversion which converts to the low spacecraft RF channel. A TWT power amplifier then amplifies the signal for final output via an orthocoupler to the antenna. All 1-metre terminals are equipped to transmit in the low RF spacecraft channel only.

On the receive side, the signal at the receive port of the orthocoupler is amplified by a low noise tunnel diode amplifier. The first stage of a two stage down-converter converts the RF to a 735 MHz high IF signal. All 1-metre terminals are equipped to receive only the high spacecraft RF channel.

The high IF signal is connected to the second stage of down-conversion. This stage converts to a low IF where a power splitter splits the signal into three paths with connectors appearing on a low IF interface patch panel. These three low IF signals are:

1) Pilot carrier at a frequency of 97.16 MHz;

2) Sound program at a frequency of 98.42 MHz;

3) Telephone at a unique frequency, for each terminal, in the range of 100.17 MHz to 101.36 MHz.

At the IF interface patch panel each of the signals is patched to its respective demodulator. The pilot carrier, transmitted by the NCT is used to establish a frequency reference to eliminate drift of the local oscillators used in the second stage of down conversion. This reduces the drift of the signal frequencies with respect to the channel filters.

The receive side of the telephony channel unit demodulates the particular telephony channel assigned to the terminal. The baseband output appears at a baseband interface patch panel, where a ±6 dB gain amplifier can be patched in, and where hard wire connections to external equipment such as telewriters, data modems, etc., can be made. When the telephone handset is being used, the telephony channel unit output is patched into a telephone interface unit required for use with the telephone set.

The third received signal is for the optional sound program receive unit. The signal is frequency demodulated and made available to the experimenter at a patch panel on the unit.

The antenna uses a parabolic reflector with a focal point feed system. It will be mounted on a specially designed mount which will be provided with a limited range of pointing adjustment.

The following parameters summarize the characteristics of the terminal subsystems. With the exception of the antenna, the equipment is essentially identical to that of the 2-metre terminal. Note, however, that a TV demodulator is not supplied with this terminal. For detailed characteristics of the sound program channel and the telephony channel, the reader is referred to Section 3.2.4. If the experimenter requires more detailed specifications for his own system evaluation than what is provided here, CRC can furnish this upon request.

Antenna:	0.81 metre (32 in) diameter parabolic reflector with dual orthogonal linearly polarized focal point feed. Transmit gain nominally 39.2 dB Receive gain nominally 37.8 dB
Antenna mount:	Mechanical mount to provide manual pointing adjustment over a range of 0° to 60° in elevation with a fine adjustment of ±4° in both elevation and azimuth.
Antenna tracking:	No tracking required. With antenna initially pointed in the proper direction, the 1-metre antenna beamwidth covers the full expected motion of the spacecraft.
Transmitter:	20 watt travelling wave tube amplifier. Transmit chain gain variable 0 to -15 dB Normally set to -3 dB.
Low noise amplifier:	Tunnel diode amplifier with an input noise temperature of 670°K to provide an overall system noise temperature of 766°K in clear weather at an elevation angle of 5°.
Up-converter:	Two stage with low IF nominally centred on 70 MHz and high IF at 735 MHz.
Down-converter:	Two stage with high IF at 735 MHz and low IF nominally centred on 70 MHz.

4. SPACECRAFT

4.1 GENERAL

The Communications Technology Satellite will be launched from the NASA Test Range in Florida on an advanced three-stage Thor-Delta launch vehicle and placed in the geostationary satellite orbit at 116° west longitude. The design lifetime in orbit is two years. When on station, a momentum wheel and reaction control jets, operated in conjunction with earth and sun sensors, will stabilize the spacecraft in three axes so that the communications antennas always face the earth. The spacecraft orientation accuracy will be ±0.1° in pitch and roll, ±1.1° in yaw. Beam pointing with respect to any selected point on the earth will be maintained to an accuracy of ±0.2°. There will be no north-south station keeping. The launch window and launch profile will be tailored as much as possible within the schedule and payload constraints to maximize the fraction of time during the two year mission that the orbit inclination is 0.65° or less. This time period should begin 3 to 6 months after launch. The east-west thrusters of the Reaction Control system will be used to keep the east-west deadband to ±0.2°. Power will be supplied to the spacecraft by two solar sails measuring approximately 16.5 m (54 ft) tip-to-tip which will be unfurled in orbit. Figure 4.1 is a sketch of the spacecraft.

The satellite will be controlled from a telemetry, tracking and command station located near Ottawa. The configuration of the spacecraft communications system can be varied (select operational modes, adjust transponder gains and point spacecraft antennas) in accordance with experiment requirements. Monitoring of spacecraft systems operation will be continuous.

A major technology experiment on the spacecraft is the use of a 200 watt high efficiency (>50%) TWT which, in combination with a transponder package and antenna system, will be capable of relaying communications signals between suitably located ground terminals. The antenna system consists of two fully gimballed antennas with a beamwidth of 2.5°. Either antenna can be commanded to point anywhere in the Western Hemisphere and can be used to relay communications signals in both directions simultaneously.

The spacecraft will also carry a beacon transmitter at 11.7 GHz operating into an earth coverage antenna for use as a tracking aid and for propagation measurements.

4.2 TRANSPONDER

A simplified schematic diagram of the spacecraft communications package, illustrating the primary and a secondary mode of operation, is shown in Figure 4.2(a) and (b). Figure 4.3 is a more detailed schematic showing the major components in the spacecraft transponder. The transponder portion consists of a receiver, frequency translator and three TWT's. The frequency plan for the transponder is shown in Figure 4.4. In the primary mode (PM1), signals received by antenna 1 in receive band 1 (RB1) are frequency translated and transmitted in transmit band 1 (TB1) by the 200 watt TWT through antenna 2 to remote ground terminals (RB1 to TB1). Simultaneously, signals may be

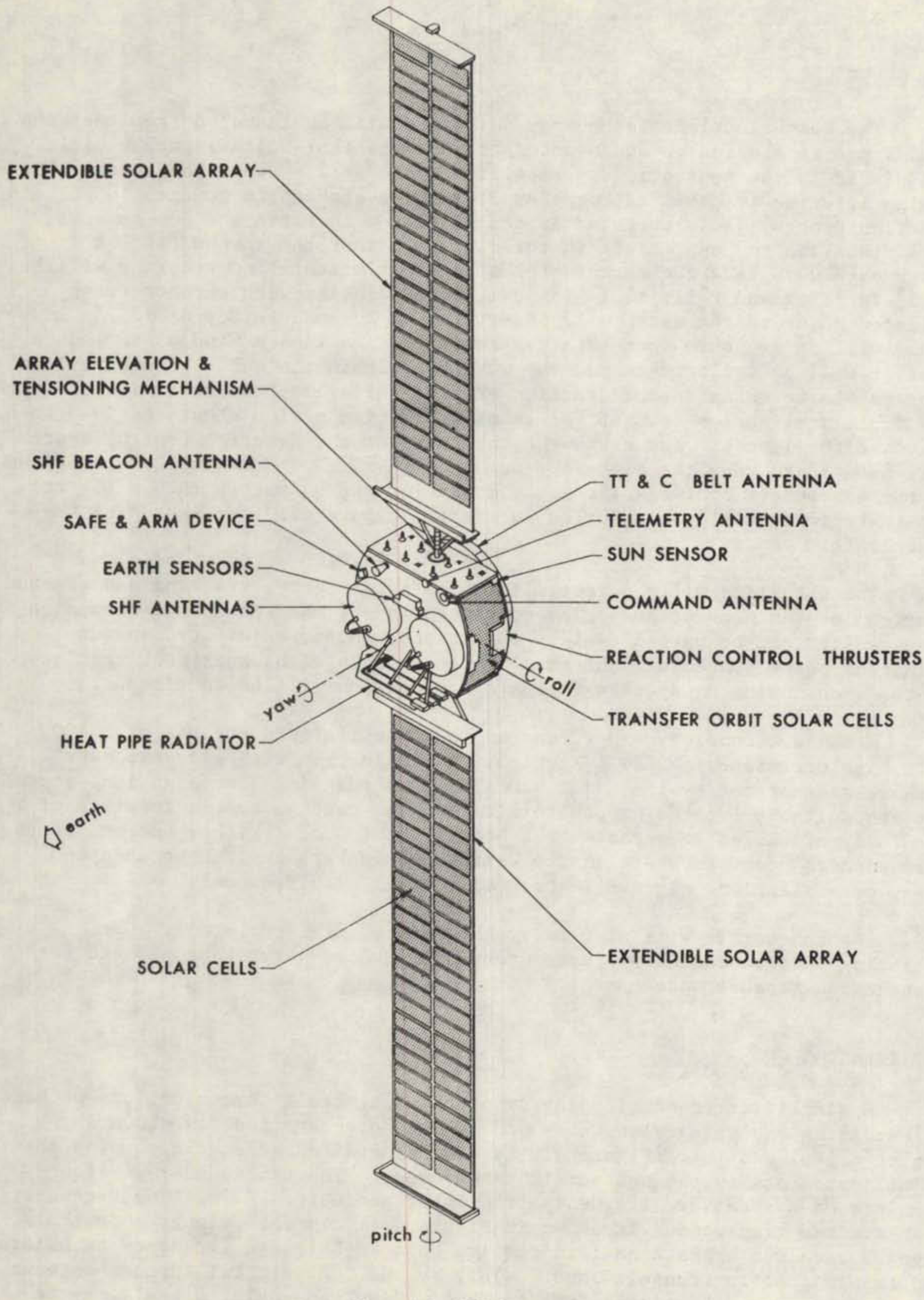


Figure 4.1. CTS Spacecraft

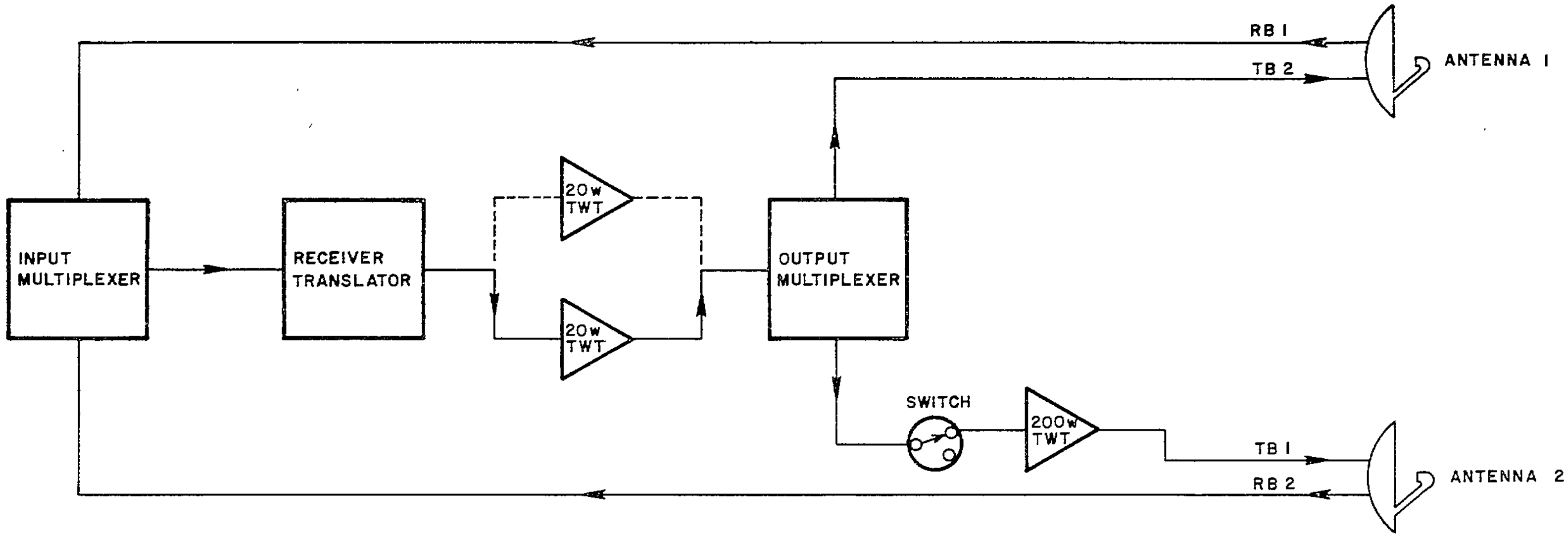


Figure 4.2(a). SHF Transponder — Primary Mode

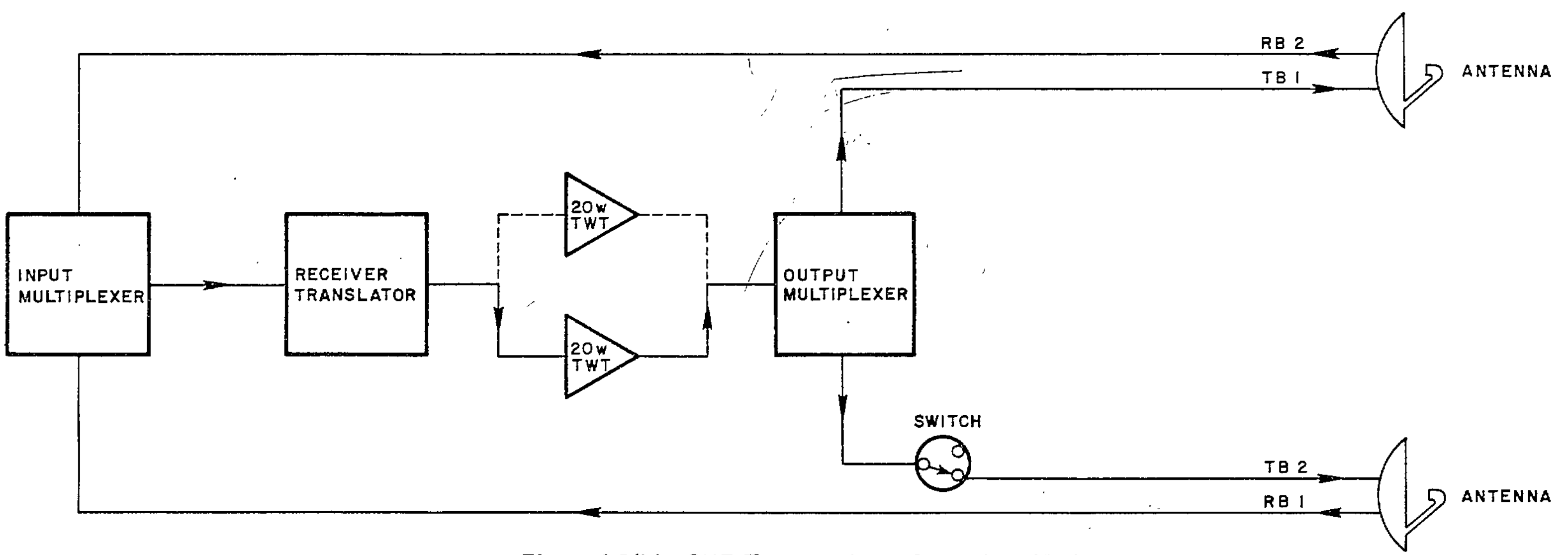


Figure 4.2(b). SHF Transponder — Secondary Mode

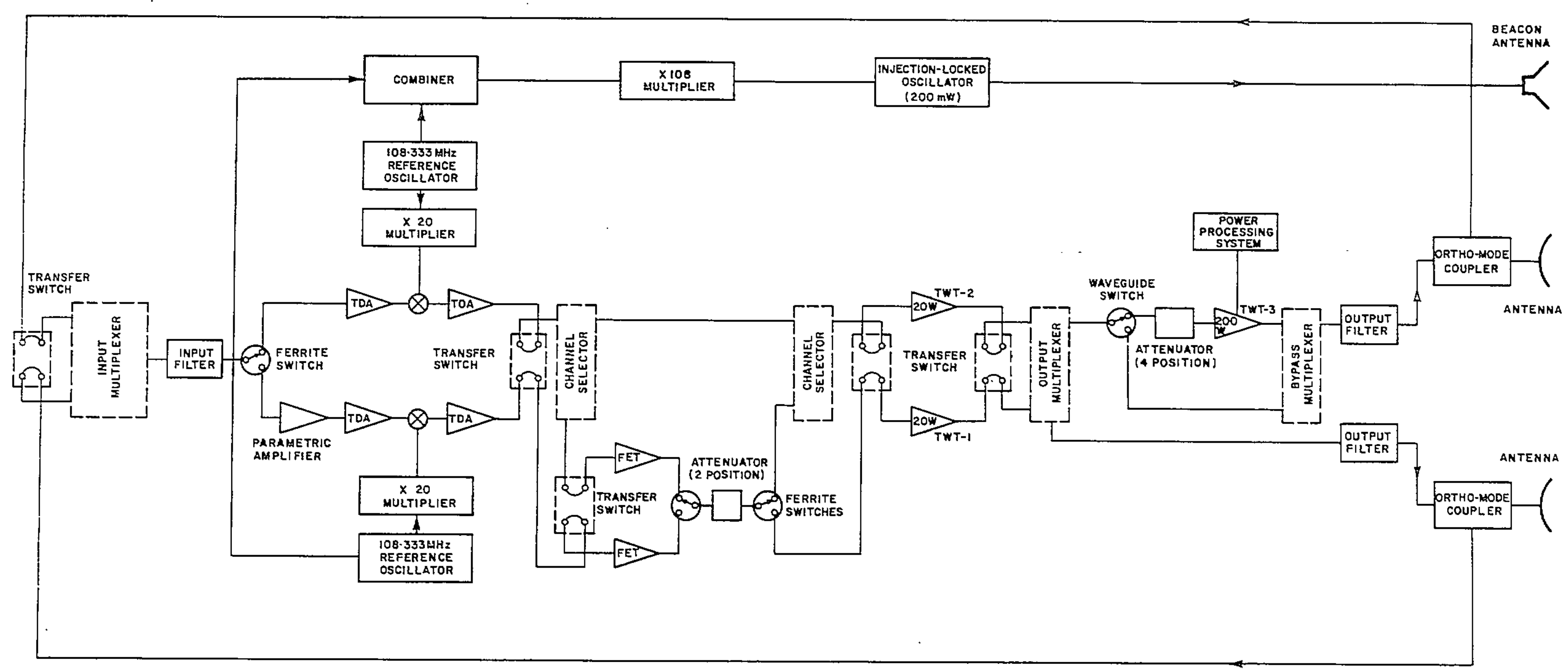


Figure 4.3. SHF Transponder

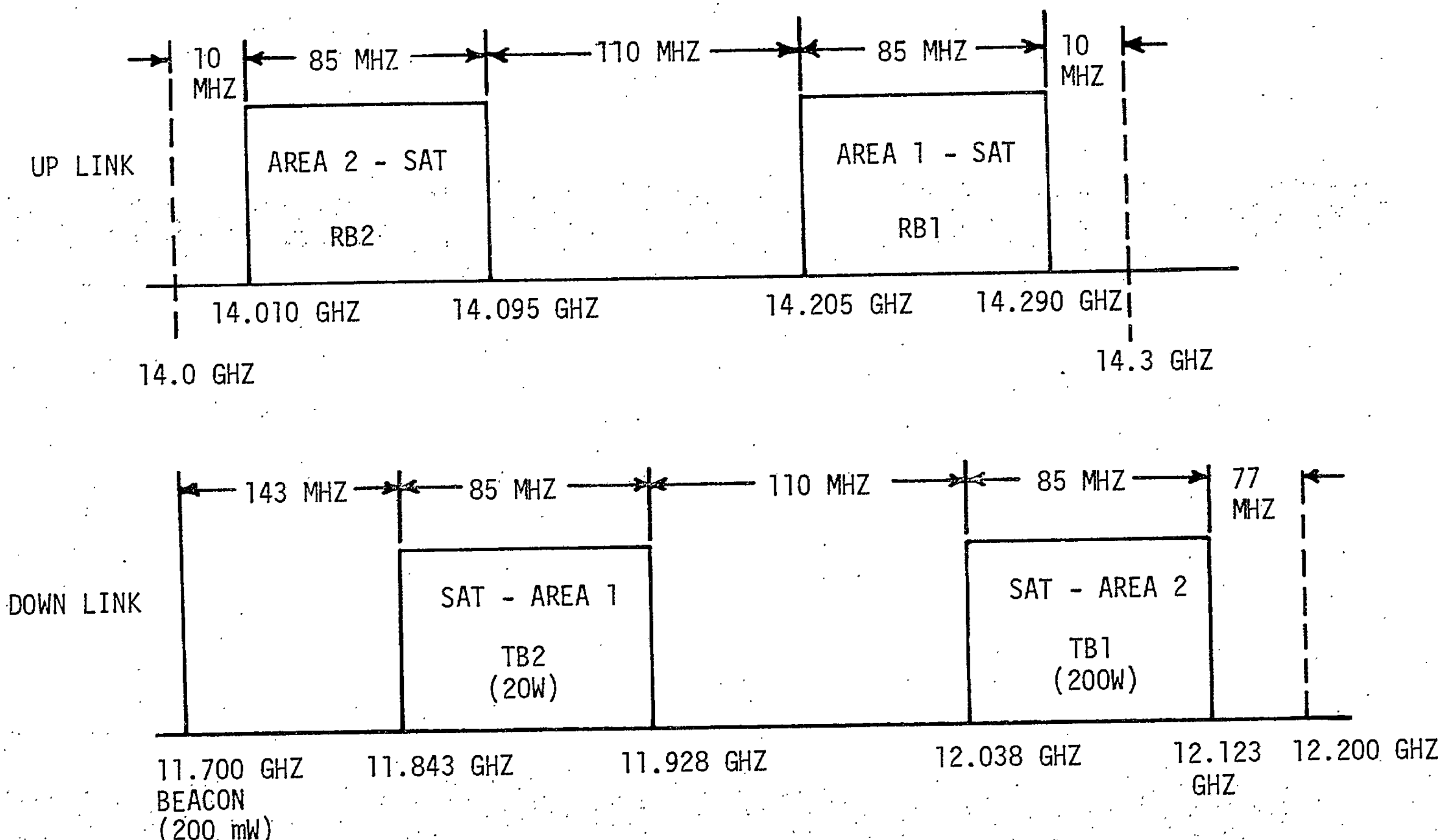


Figure 4.4. SHF Frequency Plan

received from remote ground terminals by antenna 2 in receive band 2 (RB2), frequency translated and transmitted in transmit band 2 (TB2) by the 20 watt TWT through antenna 1 (RB2 to TB2).

In the event of failure of either the experimental 200 watt TWT or the 20 watt TWT, the transponder can be reconfigured to maintain a reduced communications capability. If the 200 Watt TWT fails, the 20 watt TWT can be used to bypass the 200 watt TWT. This constitutes the secondary mode of operation. The maximum transmitter power is thus reduced to 20 watts. If the 20 watt TWT fails, the second 20 watt TWT can be switched in to operate in either the primary or secondary mode described above. These modes are summarized in Table 4.1. Note that in the secondary mode, a total of 20 watts is available and must be shared between TB1 and TB2.

TABLE 4.1

Transponder Operating Modes

	PRIMARY MODE		SECONDARY MODE	
	TB1	TB2	TB1	TB2
Max Transmit Power	200 W	20 W	20 W	20 W
Antenna	2	1	1	2

The transponder is equipped with two switch selectable low noise RF receiver amplifiers. A parametric amplifier is provided which amplifies both receive bands. This amplifier will normally be used for all communications applications. As a back-up to the parametric amplifier, a tunnel diode amplifier, with a noise figure approximately 3 dB higher, can be switched in.

An additional feature of the transponder is that it transmits a right-hand circularly polarized CW beacon signal at 11.7 GHz. This signal is derived directly from the translation oscillator and can be used to monitor its frequency drift. In addition, the beacon signal is convenient for use by the large terminals for spacecraft tracking. The e.i.r.p. for the beacon signal is a minimum of 11.5 dBW within a 10.5° cone centred at 20°N latitude and 105°W longitude.

The following table, Table 4.2, summarizes the specifications of the spacecraft transponder and antennas.

The frequency plan of the communications signals received and transmitted by the spacecraft transponder is determined by the ground terminals. Similarly the band selected for use through the transponder, i.e., RB1 to TB1 or RB2 to TB2, is determined by the ground terminals operating within

TABLE 4.2

Transponder and Antenna Specifications

Receive Band 1 (RB1)	14.205 - 14.290 GHz	
Receive Band 2 (RB2)	14.010 - 14.095 GHz	
Transmit Band 1 (TB1)	12.038 - 12.123 GHz	
Transmit Band 2 (TB2)	11.843 - 11.928 GHz	
Polarization* (Transmit and Receive)	Linear, orthogonal	
Transmit Antenna Gain (Boresight) (at reference plane)	36.3 dB	
Reduction in Transmit Gain ($\pm 1.25^{o}$ off boresight)	2.7 dB	
Filter Loss TB1 (200 W)	0.85 dB	Between output of TWT and Reference Plane
Filter Loss TB2 (20 W)	1.0 dB	
Filter Loss TB1 (20 W in SM)	1.8 dB	
Filter Loss TB2 (20 W in SM)	2.3 dB	
Receive Antenna Gain (Boresight) (at reference plane)	36.2 dB	
Reduction in Receive Gain ($\pm 1.25^{o}$ off boresight)	3.0 dB	
Gain RB1 to TB1 (at reference plane)	122 dB** nominal (saturated gain)	
Gain Stability RB1 to TB1 (initial tolerance, temperature, lifetime)	Nominal ± 4 dB (not including 200 W TWT)	
Gain RB2 to TB2 (at reference plane)	114 dB*** nominal (small signal gain)	
Gain Stability RB2 to TB2 (initial tolerance, temperature, lifetime)	nominal ± 4 dB	
Gain RB1 to TB1 (secondary mode)	114 dB*** nominal (small signal gain)	
Gain Selection	By ground command	
Gain Flatness (not including 200 W TWT)	± 0.75 dB over centre 68 MHz ∓ 1 dB over 85 MHz (RB1 to TB1) ∓ 1.25 dB over 85 MHz (RB2 to TB2)	
Receiver Noise Temperature (at reference plane) with		
Parametric Amplifier	1000^{o} Kelvin	
Tunnel Diode Amplifier	2000^{o} Kelvin	

Estimated System Noise Temperature (at reference plane) with	
Parametric Amplifier	1315° Kelvin
Tunnel Diode Amplifier	2315° Kelvin
Conversion Oscillator Frequency Stabilities (at 2.1666666 GHz)	better than $\pm 1 \times 10^{-5}$ over useful life of spacecraft; better than $\pm 1 \times 10^{-6}$/month Noise and spurious less than:
	2 Hz RMS in band 300-3400 Hz
	4 Hz RMS in band 100-15,000 Hz
	500 Hz RMS in band 15,000 Hz - 5 MHz

* *The transmit polarization vector is aligned to the pitch axis ±0.5°, i.e., vertical, when viewed from earth at satellite longitude. The receive polarization is aligned to the roll axis ±0.5°, i.e., horizontal, when viewed from earth at satellite longitude.*

** *Step attenuators can be switched in on ground command to reduce saturated gain to 117 dB. Two additional 5 dB steps of attenuation can be switched in. However, saturation of the transponder is not then possible.*

*** *A step attenuator can be switched in on ground command to reduce small signal gain to 110 dB.*

constraints described in Section 3.0. With reference to a 70 MHz IF which can be converted up to the centre of either RF band, the frequency plan for the communications signals is given in Table 4.3 for the low IF. In addition, the RF frequencies are provided. Wideband digital signals will be transmitted at band centre.

4.3 SPACECRAFT ANTENNA COVERAGE

The spacecraft antennas are gimballed so that they can be aimed at any point on the earth's surface that is visible from the satellite. Figures 4.5, 4.6 and 4.7 show the coverage obtained for a typical set of boresight aiming points. The contours represent the areas within which at least half of the peak incident satellite power will be received, taking into account the worst case of predicted satellite motion.

Figure 4.5 shows how the spacecraft antennas might be aimed to permit the Ottawa terminal to transmit signals to ground terminals in Central Canada, using the 200 watt tube. The return link to Ottawa would use the 20 watt tube.

Since the spacecraft antennas are independently gimballed, their coverage patterns may be superimposed. This is illustrated in Figure 4.6. Here, a terminal in, say, Quebec, could transmit via the 200 watt tube to ground terminals in most of the Province of Quebec, with a return link via the 20 watt tube. Note that a terminal in the region that is common to both beams could receive its own transmission if it were capable of receiving in

TABLE 4.3

Communication Signals Frequency Plan

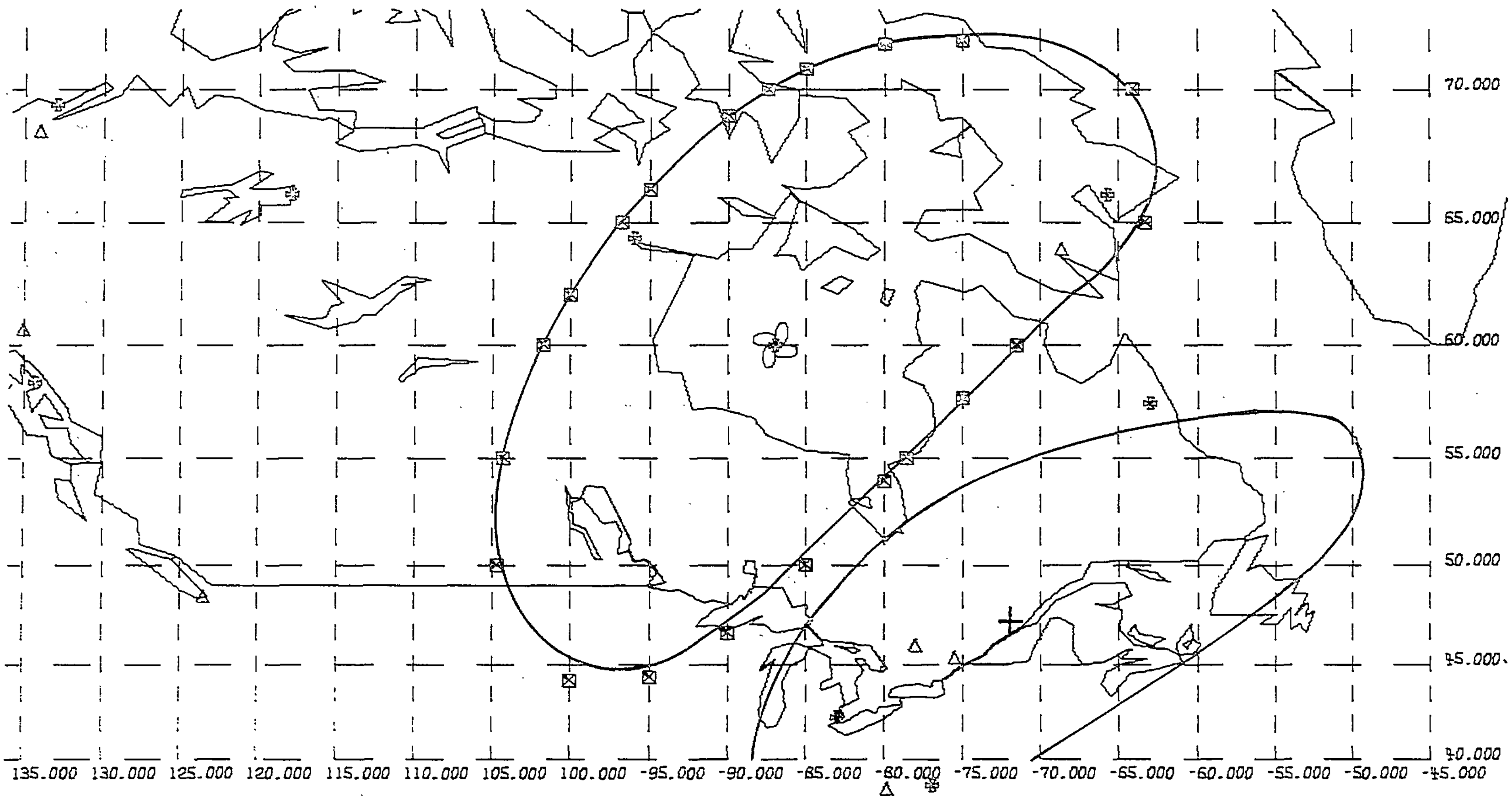
SIGNAL	LOW IF (MHz)	RB1 (GHz)	RB2 (GHz)	TB1 (GHz)	TB2 (GHz)
Television (with 3 Audio Ch)	70	14.2471666	14.0521666	12.0805000	11.8855000
Sound Program	98.42	14.2755866	14.0805866	12.1089200	11.9139200
CW Pilot (for telephony)	97.16	14.2743266	-	12.1076600	-
Telephony Chs. (70 kHz Spacing)					
#1	100.17	14.2773366	14.0823366	12.1106700	11.9156700
#2	100.24	14.2774066	14.0824066	12.1107400	11.9157400
#3	100.31	14.2774766	14.0824766	12.1108100	11.9158100
#4	100.38	14.2775466	14.0825466	12.1108800	11.9158800
#5	100.94	14.2776166	14.0826166	12.1109500	11.9159500
#6	100.52	14.2776866	14.0826866	12.1110200	11.9160200
#7	100.59	14.2777566	14.0827566	12.1110900	11.9160900
#8	100.66	14.2778266	14.0828266	12.1111600	11.9161600
#9	100.73	14.2778966	14.0828966	12.1112300	11.9162300
#10	100.80	14.2779666	14.0829666	12.1113000	11.9163000
#11	100.87	14.2780366	14.0830366	12.1113700	11.9163700
#12	100.94	14.2781066	14.0831066	12.1114400	11.9164400
#13	101.01	14.2781766	14.0831766	12.1115100	11.9165100
#14	101.08	14.2782466	14.0832466	12.1115800	11.9165800
#15	101.15	14.2783166	14.0833166	12.1116500	11.9166500
#16	101.22	14.2783866	14.0833866	12.1117200	11.9167200
#17	101.29	14.2784566	14.0834566	12.1117900	11.9167900
#18	101.36	14.2785266	14.0835266	12.1118600	11.9168600

both of the down-link bands. This is the only example illustrated where "loop" testing of this kind is possible and this can only be done with the 3-metre and 9-metre terminals.

The situation of Figure 4.7 is similar to that of Figure 4.5, except that the appropriate ground terminals are assumed to be in, say, Newfoundland and British Columbia.

4.4 SPACECRAFT MOTION

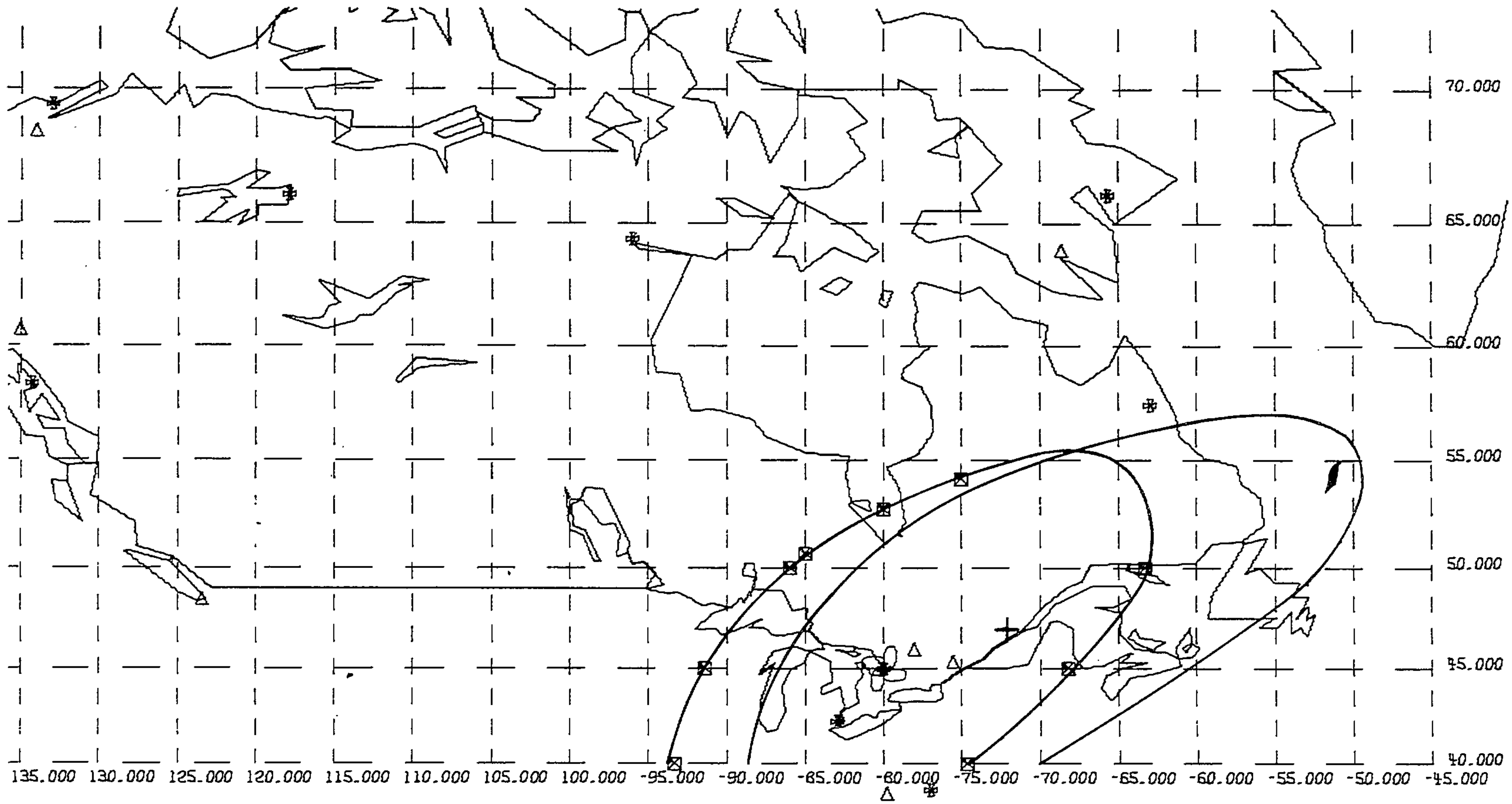
The CTS is nominally geostationary, but all geostationary satellites require some form of station-keeping system to maintain their positions to some specified accuracy. CTS will use reaction jets to maintain its position at 116°W longitude within ±0.2° in the east-west direction. Current plans call for orbit injection with a nominal bias in-orbit inclination of 0.9°. As



COVERAGE DIAGRAM FOR 3 dB CONTOURS

SATELLITE LONGITUDE = 116.0° W

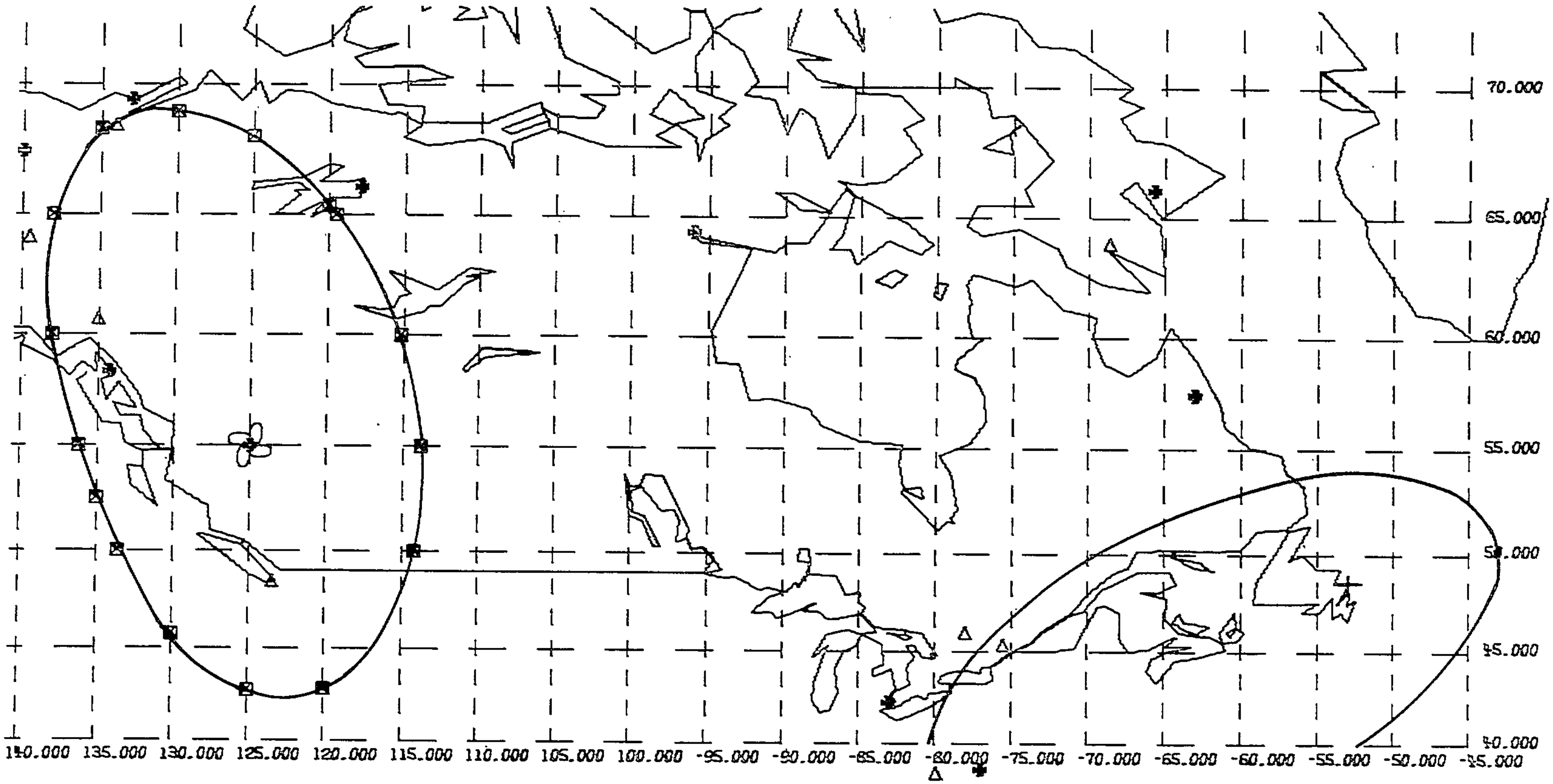
Figure 4.5. Area Coverage Diagram



COVERAGE DIAGRAM FOR 3 dB CONTOURS

SATELLITE LONGITUDE = 116.0° W

Figure 4.6. Area Coverage Diagram



COVERAGE DIAGRAM FOR 3 dB CONTOURS

SATELLITE LONGITUDE = 116.0° W

Figure 4.7. Area Coverage Diagram

stated in Section 4.1, it is hoped to keep orbit inclination below 0.65° during most of the mission. In this case, the spacecraft will have an initial daily north-south motion of ±0.65°. The orbit inclination should decrease during the first year of operation and, depending on the launch node, may become nearly zero resulting in correspondingly small daily north-south excursions. The advantage of using a satellite with limited motion is, of course, that it permits the use of fixed, non-tracking ground antennas.

Figure 4.8 gives an example of a possible path described by the satellite during a 24 hour period as seen by a ground station at Ottawa. The crosses give the satellite position at hourly intervals. The exact path described by the satellite will be a complex one dependent on many factors and it will change with time. At present, one can only predict that the satellite will lie within an inclined rectangular box having a width of about 0.47° and a length of about 1.4° as seen from Ottawa assuming an inclination of 0.65°. Considering launch dispersions, this length could be slightly larger at beginning of life. The angle of the major axis of this rectangle with respect to the local vertical will depend on the geographical position of the ground station and the exact parameters of the satellite orbit.

In order to examine the tracking requirements for ground antennas, a 3 dB contour for the 1-metre ground terminal antenna and 1 dB contours for a 2-metre ground terminal antenna at 12 GHz are shown as solid lines on Figure 4.8. The small circles are for a 2-metre antenna and the large circle for a 1-metre antenna. Based on the assumptions used in deriving Figure 4.8, a non-tracking 2-metre antenna will provide between 2 and 8 hours of operation during a day, depending on the desired operating times. A non-tracking 1-metre antenna provides full 24 hour coverage.

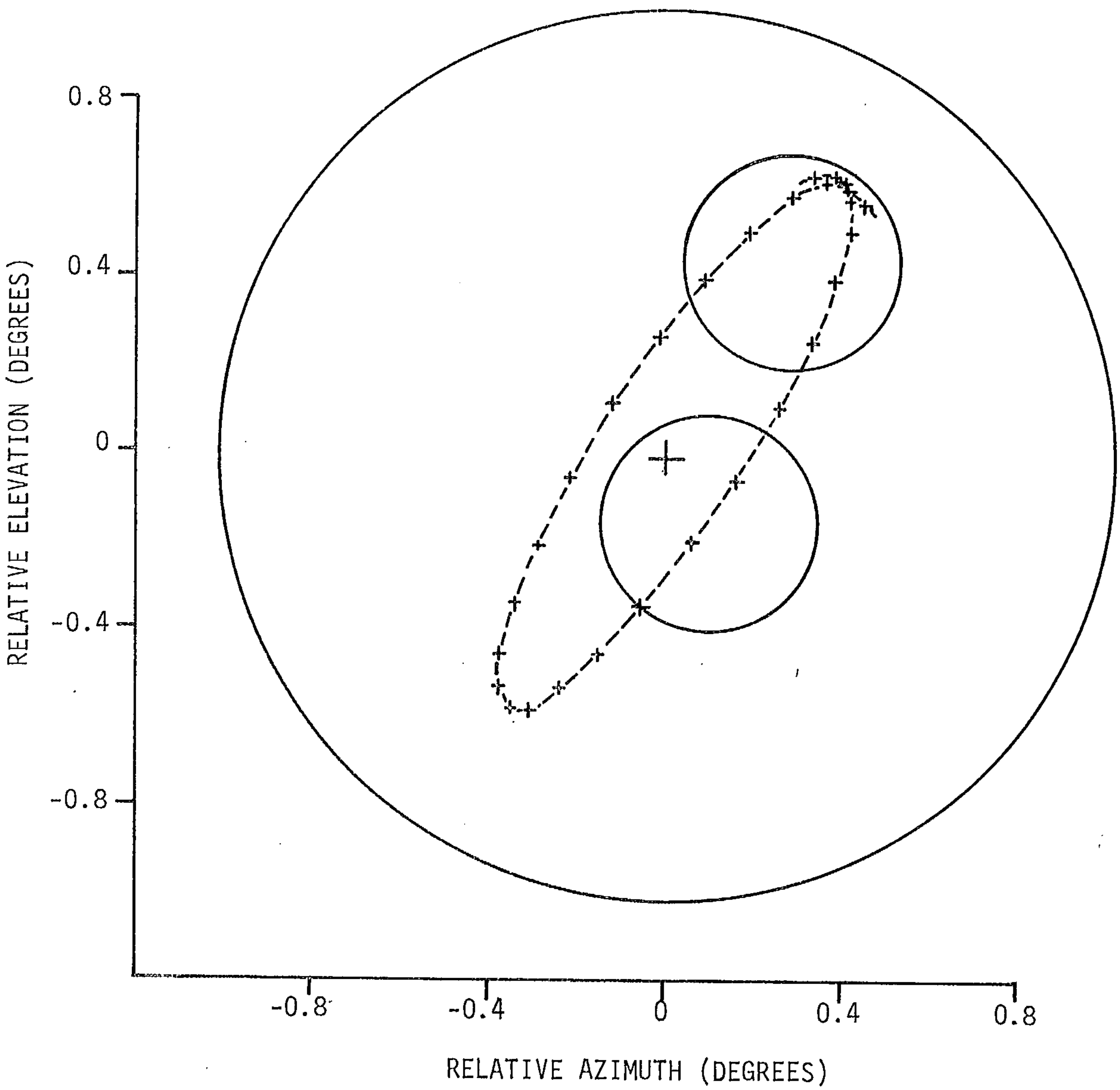


Figure 4.8. Daily Satellite Motion

5. COMMUNICATIONS LINK ANALYSIS

5.1 GENERAL

This section is provided to show the experimenter examples of link calculations which were computed for various communications signals. These calculations were used in planning the communications services to be provided by CTS and for the subsequent design of the associated ground terminals.

5.2 LINK ANALYSIS

In determining performance of a satellite communications system, it is necessary to calculate signal-to-noise ratios at the output of receive terminals from data on terminal characteristics (antenna, power out, noise temperature, etc.), transponder characteristics, transmission path losses, and signal parameters (deviation, bandwidth, etc.). Some typical link calculations for CTS are given in this section as examples for those readers familiar with such analyses. The values given in the following tables were obtained from a computer program. Therefore, an attempt to add up the values as given may result in a small discrepancy in the answer because of round-off.

The examples given are for the transponder in a low gain mode with a paramp front end, which gives best performance by minimizing uplink noise. In the highest gain position, ground transmit power are reduced at the expense of increased uplink noise and, hence, reduced performance. The calculations also change and performance is reduced if the TDA is substituted for the paramp in the transponder front end. Normally this will only be done if the paramp fails.

The examples given are also for single signals only. The calculations may change with multiple signals present because of small-signal gain suppression in the nonlinear channel.

The C/N and S/N ratios given are non-faded values. These are reduced by the amount of a fade due to propagation effects. The margin above threshold for these non-faded values is shown, and for most cases, this is more than the minimum estimated propagation margin required to be above threshold for 99.9% of the time. This is also shown.

The calculation of baseband performance uses the equations:

1) FM Signal

$$SNR = 10 \log \frac{3}{2} + WP - IM + 20 \log \frac{\Delta f}{f_m} - 10 \log f_m + \frac{C}{N_o}$$

$$BW = 2 f_m \left(CRF + \frac{\Delta f}{f_m} \right)$$

where:

- SNR - rms test-tone to rms weighted noise ratio
- WP - weighting and de-emphasis factor
- Δf - peak deviation
- f_m - top baseband frequency
- IM - implementation loss (for non-ideal demodulator, degradation due to oscillator phase noise and intermodulation noise for narrow band signals)
- C/N_o - carrier-to-noise density ratio
- BW - receiver filter bandwidth
- CRF - equals 1, if Carson Rule bandwidth is used.

2) FMTV With Subcarriers

$$SNR_V = 10 \log \frac{3}{2} + 20 \log \left[(2\sqrt{2}) \frac{100}{140} \right] + WP - IM$$

$$+ 20 \log \frac{\Delta f_v}{f_v} - 10 \log f_v + \frac{C}{N_o}$$

$$SNR_A = 10 \log \frac{3}{4} + WP - IM + 20 \log \Delta f_c + 20 \log \Delta f_a$$

$$- 30 \log f_a - 20 \log f_{sc} + \frac{C}{N_o}$$

$$BW = 2(\Delta f_v + N\Delta f_c + f_b)$$

where:

- SNR_V - peak-to-peak video (excluding sync-tip) to rms weighted noise ratio
- SNR_A - rms audio test-tone to rms weighted noise ratio
- Δf_v - peak video deviation
- f_v - video baseband

Δf_c - peak carrier deviation by a subcarrier

Δf_a - peak subcarrier deviation by audio

f_a - audio baseband

N - number of subcarriers

f_b - total baseband (video plus subcarriers)

3) Digital PSK

$$\frac{E_b}{N_o} = \frac{C}{N_o} - IM - 10 \log R$$

where

E_b/N_o - energy per bit to noise density ratio

R - bit rate

IM - implementation loss due to demodulator performance and effect of nonlinear channel

5.2.1 TV Signal

Two examples are given in Tables 5.1 and 5.2. These are:

1) From a 3 m terminal in Ottawa to a 2 m terminal in the North at a 5° elevation angle.

   Spacecraft Antenna Beams

   - one centred on Ottawa 3 m terminal
   - 2 m terminal at edge of second beam.

   Transponder Channel

   - 200 W, 117 dB saturated gain
     122 dB small-signal gain
   - paramp front end.

   Spacecraft Position

   - 116°W longitude
   - at its most southerly excursion for 0.65° inclination

2) From a 3 m terminal in Saskatchewan to a 3 m terminal in Quebec.

This is the return link for a two-way TV application. The other direction would be similar to (1) above through the high power channel.

Spacecraft Antenna Beams

- centred on both terminals.

Transponder Channel

- 20W, 105 dB saturated gain
  110 dB small-signal gain
- paramp front end.

5.2.2 Sound Program

The example given in Table 5.3 is from the 9 m Ottawa Terminal to a 1 m terminal in the North at a 5° elevation angle.

Spacecraft Antenna Beams

- one centred on Ottawa 9 m terminal

- 2 m terminal at edge of second beam.

Transponder Channel

- 200W, 117 dB saturated gain
  122 dB small-signal gain
- paramp front end.

5.2.3 Telephony

Examples are given for both directions in Tables 5.4 and 5.5.

1) From a 3 m terminal in the North

Spacecraft Antenna Beams

- one centred on 3 m terminal
- 1 m terminal at edge of second beam.

Transponder Channel

- 200W, 117 dB saturated gain
  122 dB small-signal gain
- paramp front end.

2) From a 1 m terminal in the North to a 3 m terminal in Ottawa

Transponder Channel

- 20 W, 105 dB saturated gain
  110 dB small-signal gain
- paramp front end.

5.2.4 Digital PSK

The example given in Table 5.6 is from the 9 m terminal in Ottawa to a 2 m terminal in Manitoba.

6. ACKNOWLEDGEMENT

The author wishes to acknowledge the many helpful suggestions contributed by members of the Space Applications staff in the preparation of this document. In particular, J.W.B. Day provided a review of the entire document as well as the material of Section 5.

CTS CALCULATION:A TV BROADCAST 3 AUDIO SC SIGNAL FROM A 10' TERMINAL IN OTTAWA AT BEAM CENTER
1458 DEC 20,'74 (03 DEC 74 09) TO A 7' TERMINAL IN THE NORTH AT EDGE OF COVERAGE
SATELLITE INCL. SOUTH NON-LIN. TWT 200.0W GAIN 117.0-122.0DB PAMP MODES 2,3=1,1

UPLINK			DOWNLINK		
RF CHANNEL BANDWIDTH	KHZ	.2977E 05	GAIN(TO OUTPUT OF FILTER)	DB	118.2
GROUND TRANSMIT POWER	WATTS	629.4	SATELLITE TWT POWER	WATTS	198.6
TRANSMIT LINE LOSS	DB	1.000	OUTPUT FILTER LOSS	DB	.8500
GROUND ANTENNA GAIN	DB	50.12	SATELLITE ANTENNA GAIN	DB	36.30
ANTENNA POINTING LOSS	DB	1.763	ANTENNA OFF-AXIS LOSS	DB	2.701
FREE SPACE LOSS	DB	207.3	FREE SPACE LOSS	DB	206.3
ATMOSPHERIC ATTENUATION	DB	.1848	ATMOSPHERIC ATTENUATION	DB	.7547
SATELLITE ANTENNA GAIN	DB	36.20	GROUND ANTENNA GAIN	DB	47.04
ANTENNA OFF-AXIS LOSS	DB	.7358E-01	ANTENNA POINTING LOSS	DB	1.086
RECEIVED CARRIER LEVEL	DBW	-96.06	RECEIVED CARRIER LEVEL	DBW	-105.4
SATELLITE SYSTEM TEMP.	DEG.K	1315.	GROUND SYSTEM TEMP.	DEG.K	1096.
C/N UPLINK	DB	26.61	C/N DOWNLINK	DB	18.07

C/N TOTAL LINK	DB	17.50
MARGIN ABOVE THRESHOLD	DB	6.771
MINIMUM PROPAGATION MARG.	DB	3.296
% OF TOTAL NOISE IN DOWNLINK		87.73
TOTAL LINK TEMPERATURE	DEG.K	1249.

FM SIGNAL

WEIGHTED S/N	DB	49.00	BASEBAND FREQUENCY	KHZ	4200.
WEIGHTING&DEEMPHASIS	DB	13.00	PEAK DEVIATION	KHZ	6953.
IMPLEMENTATION LOSS	DB	1.000	CARSON RULE FACTOR		1.000
THRESHOLD MARGIN	DB	1.000	RF CHANNEL BANDWIDTH	KHZ	.2977E 05

SUBCARRIER

NO. OF SUBCARRIERS		3.000	TOTAL VIDEO BASEBAND	KHZ	5900.
WEIGHTED AUDIO S/N	DB	53.00	PEAK DEVIATION-AUDIO	KHZ	60.00
WEIGHTING&DEEMPHASIS	DB	2.800	DEVIATION-SUBCARRIER	KHZ	988.8
IMPLEMENTATION LOSS	DB	1.000	PEAK DEVIATION-VIDEO	KHZ	6019.
HIGHEST SUBCARRIER	KHZ	5790.	POWER-BANDWIDTH FACTOR		1.334
AUDIO BASEBAND	KHZ	10.00	SUBCARRIER C/N	DB	22.41

Table 5.1

CTS CALCULATION:A TV BROADCAST 3 AUDIO SC SIGNAL FROM A 10' TERMINAL IN SASKATCHEWAN AT BEAM CENTER
1254 JAN 31,'75 (03 DEC 74 09) TO A 10' TERMINAL IN QUEBEC AT BEAM CENTER
SATELLITE INCL. SOUTH NON-LIN. TWT 20.0W GAIN 105.0-110.0DB PAMP MODES 2,3=1,1 99.

UPLINK			DOWNLINK		
RF CHANNEL BANDWIDTH	KHZ	.2977E 05	GAIN(TO OUTPUT OF FILTER)	DB	109.1
GROUND TRANSMIT POWER	WATTS	250.4	SATELLITE TWT POWER	WATTS	10.20
TRANSMIT LINE LOSS	DB	1.000	OUTPUT FILTER LOSS	DB	1.000
GROUND ANTENNA GAIN	DB	50.12	SATELLITE ANTENNA GAIN	DB	36.30
ANTENNA POINTING LOSS	DB	1.763	ANTENNA OFF-AXIS LOSS	DB	.6658E-01
FREE SPACE LOSS	DB	207.3	FREE SPACE LOSS	DB	206.0
ATMOSPHERIC ATTENUATION	DB	.1625	ATMOSPHERIC ATTENUATION	DB	.1780
SATELLITE ANTENNA GAIN	DB	36.20	GROUND ANTENNA GAIN	DB	48.49
ANTENNA OFF-AXIS LOSS	DB	.7358E-01	ANTENNA POINTING LOSS	DB	1.250
RECEIVED CARRIER LEVEL	DBW	-99.97	RECEIVED CARRIER LEVEL	DBW	-113.6
SATELLITE SYSTEM TEMP.	DEG.K	1315.	GROUND SYSTEM TEMP.	DEG.K	320.0
C/N UPLINK	DB	22.70	C/N DOWNLINK	DB	15.21

C/N TOTAL LINK	DB	14.50
MARGIN ABOVE THRESHOLD	DB	3.771
MINIMUM PROPAGATION MARG.	DB	3.420
% OF TOTAL NOISE IN DOWNLINK		84.88
TOTAL LINK TEMPERATURE	DEG.K	377.0

FM SIGNAL

WEIGHTED S/N	DB	46.00	BASEBAND FREQUENCY	KHZ	4200.
WEIGHTING&DEEMPHASIS	DB	13.00	PEAK DEVIATION	KHZ	6953.
IMPLEMENTATION LOSS	DB	1.000	CARSON RULE FACTOR		1.000
THRESHOLD MARGIN	DB	1.000	RF CHANNEL BANDWIDTH	KHZ	.2977E 05

SUBCARRIER

NO. OF SUBCARRIERS		3.000	TOTAL VIDEO BASEBAND	KHZ	5900.
WEIGHTED AUDIO S/N	DB	50.00	PEAK DEVIATION-AUDIO	KHZ	60.00
WEIGHTING&DEEMPHASIS	DB	2.800	DEVIATION-SUBCARRIER	KHZ	988.8
IMPLEMENTATION LOSS	DB	1.000	PEAK DEVIATION-VIDEO	KHZ	6019.
HIGHEST SUBCARRIER	KHZ	5790.	POWER-BANDWIDTH FACTOR		1.334
AUDIO BASEBAND	KHZ	10.00	SUBCARRIER C/N	DB	19.41

Table 5.2

CTS CALCULATION:A FM SOUND PROGRAM SIGNAL FROM A 30' TERMINAL IN OTTAWA AT BEAM CENTER
0936 DEC 18,'74 (03 DEC 74 09) TO A 3' TERMINAL IN THE NORTH AT EDGE OF COVERAGE
SATELLITE INCL. SOUTH NON-LIN. IWT 200.0W GAIN 117.0-122.0DB PAMP MODES 2,3=1,1

UPLINK			DOWNLINK		
RF SIGNAL BANDWIDTH	KHZ	200.0	GAIN(TO OUTPUT OF FILTER)	DB	121.9
GROUND TRANSMIT POWER	WATTS	1.251	SATELLITE TWT POWER	WATTS	12.02
TRANSMIT LINE LOSS	DB	1.000	OUTPUT FILTER LOSS	DB	.8500
GROUND ANTENNA GAIN	DB	59.66	SATELLITE ANTENNA GAIN	DB	36.30
ANTENNA POINTING LOSS	DB	.1916	ANTENNA OFF-AXIS LOSS	DB	2.701
FREE SPACE LOSS	DB	207.3	FREE SPACE LOSS	DB	206.3
ATMOSPHERIC ATTENUATION	DB	.1848	ATMOSPHERIC ATTENUATION	DB	.7547
SATELLITE ANTENNA GAIN	DB	36.20	GROUND ANTENNA GAIN	DB	38.00
ANTENNA OFF-AXIS LOSS	DB	.7358E-01	ANTENNA POINTING LOSS	DB	2.573
RECEIVED CARRIER LEVEL	DBW	-112.0	RECEIVED CARRIER LEVEL	DBW	-128.1
SATELLITE SYSTEM TEMP.	DEG.K	1315.	GROUND SYSTEM TEMP.	DEG.K	1132.
C/N UPLINK	DB	32.44	C/N DOWNLINK	DB	16.94

C/N TOTAL LINK	DB	16.82
MARGIN ABOVE THRESHOLD	DB	6.934
MINIMUM PROPAGATION MARG.	DB	4.390
% OF TOTAL NOISE IN DOWNLINK		97.25
TOTAL LINK TEMPERATURE	DEG.K	1164.

FM SIGNAL

WEIGHTED S/N	DB	52.00	BASEBAND FREQUENCY	KHZ	15.00
WEIGHTING&DEEMPHASIS	DB	9.600	PEAK DEVIATION	KHZ	85.00
IMPLEMENTATION LOSS	DB	2.500	CARSON RULE FACTOR		1.000
THRESHOLD MARGIN	DB	.0000	RF SIGNAL BANDWIDTH	KHZ	200.0

Table 5.3

CTS CALCULATION: A FM TELEPHONY CHANNEL SIGNAL FROM A 10' TERMINAL IN OTTAWA AT BEAM CENTER
0937 DEC 18, '74 (03 DEC 74 09) TO A 3' TERMINAL IN THE NORTH AT EDGE OF COVERAGE
SATELLITE INCL. SOUTH NON-LIN. TWT 200.0W GAIN 117.0-122.0DB PAMP MODES 2,3-1,1

UPLINK			DOWNLINK		
RF SIGNAL BANDWIDTH	KHZ	33.00	GAIN(TO OUTPUT OF FILTER)	DB	122.0
GROUND TRANSMIT POWER	WATTS	1.730	SATELLITE TWT POWER	WATTS	1.309
TRANSMIT LINE LOSS	DB	1.000	OUTPUT FILTER LOSS	DB	.8500
GROUND ANTENNA GAIN	DB	50.12	SATELLITE ANTENNA GAIN	DB	36.30
ANTENNA POINTING LOSS	DB	1.763	ANTENNA OFF-AXIS LOSS	DB	2.701
FREE SPACE LOSS	DB	207.3	FREE SPACE LOSS	DB	206.3
ATMOSPHERIC ATTENUATION	DB	.1848	ATMOSPHERIC ATTENUATION	DB	.7547
SATELLITE ANTENNA GAIN	DB	36.20	GROUND ANTENNA GAIN	DB	38.00
ANTENNA OFF-AXIS LOSS	DB	.7358E-01	ANTENNA POINTING LOSS	DB	2.573
RECEIVED CARRIER LEVEL	DBW	-121.7	RECEIVED CARRIER LEVEL	DBW	-137.7
SATELLITE SYSTEM TEMP.	DEG.K	1315.	GROUND SYSTEM TEMP.	DEG.K	1132.
C/N UPLINK	DB	30.55	C/N DOWNLINK	DB	15.14

C/N TOTAL LINK	DB	15.02
MARGIN ABOVE THRESHOLD	DB	5.529
MINIMUM PROPAGATION MARG.	DB	4.414
% OF TOTAL NOISE IN DOWNLINK		97.21
TOTAL LINK TEMPERATURE	DEG.K	1165.

FM SIGNAL

WEIGHTED S/N	DB	33.00	BASEBAND FREQUENCY	KHZ	3.400
WEIGHTING&DEEMPHASIS	DB	.0000	PEAK DEVIATION	KHZ	9.100
IMPLEMENTATION LOSS	DB	2.200	CARSON RULE FACTOR		2.176
THRESHOLD MARGIN	DB	.0000	RF SIGNAL BANDWIDTH	KHZ	33.00

Table 5.4

CTS CALCULATION:A FM TELEPHONY CHANNEL SIGNAL FROM A 3' TERMINAL IN THE NORTH AT EDGE OF COVERAGE
0942 DEC 18,'74 (03 DEC 74 09) TO A 10' TERMINAL IN OTTAWA AT BEAM CENTER
SATELLITE INCL. SOUTH NON-LIN. TWT 20.0W GAIN 105.0-110.0DB PAMP MODES 2,3-1,1

UPLINK			DOWNLINK		
RF SIGNAL BANDWIDTH	KHZ	33.00	GAIN(TO OUTPUT OF FILTER)	DB	110.0
GROUND TRANSMIT POWER	WATTS	12.90	SATELLITE TWT POWER	WATTS	.1289E-01
TRANSMIT LINE LOSS	DB	1.260	OUTPUT FILTER LOSS	DB	1.000
GROUND ANTENNA GAIN	DB	39.46	SATELLITE ANTENNA GAIN	DB	36.30
ANTENNA POINTING LOSS	DB	3.661	ANTENNA OFF-AXIS LOSS	DB	.6658E-01
FREE SPACE LOSS	DB	207.8	FREE SPACE LOSS	DB	205.9
ATMOSPHERIC ATTENUATION	DB	.9539	ATMOSPHERIC ATTENUATION	DB	.1462
SATELLITE ANTENNA GAIN	DB	36.20	GROUND ANTENNA GAIN	DB	48.49
ANTENNA OFF-AXIS LOSS	DB	3.001	ANTENNA POINTING LOSS	DB	1.250
RECEIVED CARRIER LEVEL	DBW	-129.9	RECEIVED CARRIER LEVEL	DBW	-142.5
SATELLITE SYSTEM TEMP.	DEG.K	1315.	GROUND SYSTEM TEMP.	DEG.K	320.0
C/N UPLINK	DB	22.33	C/N DOWNLINK	DB	15.91

C/N TOTAL LINK	DB	15.02
MARGIN ABOVE THRESHOLD	DB	5.529
MINIMUM PROPAGATION MARG.	DB	4.583
% OF TOTAL NOISE IN DOWNLINK		81.42
TOTAL LINK TEMPERATURE	DEG.K	393.0

FM SIGNAL

WEIGHTED S/N	DB	33.00	BASEBAND FREQUENCY	KHZ	3.400
WEIGHTING&DEEMPHASIS	DB	.0000	PEAK DEVIATION	KHZ	9.100
IMPLEMENTATION LOSS	DB	2.200	CARSON RULE FACTOR		2.176
THRESHOLD MARGIN	DB	.0000	RF SIGNAL BANDWIDTH	KHZ	33.00

Table 5.5

CTS CALCULATION:A SINGLE DIGITAL PSK SIGNAL FROM A 30' TERMINAL IN OTTAWA AT BEAM CENTER
1256 JAN 31,'75 (03 DEC 74 09) TO A 7' TERMINAL IN MANITOBA AT EDGE OF COVERAGE
SATELLITE INCL. SOUTH NON-LIN. TWT 200.0W GAIN 117.0-122.0DB PAMP MODES 2,3=1,1 99.

UPLINK			DOWNLINK		
RF CHANNEL BANDWIDTH	KHZ	.8500E 05	GAIN(TO OUTPUT OF FILTER)	DB	117.9
GROUND TRANSMIT POWER	WATTS	52.61	SATELLITE TWT POWER	WATTS	199.8
TRANSMIT LINE LOSS	DB	1.000	OUTPUT FILTER LOSS	DB	.8500
GROUND ANTENNA GAIN	DB	59.66	SATELLITE ANTENNA GAIN	DB	36.30
ANTENNA POINTING LOSS	DB	.1916	ANTENNA OFF-AXIS LOSS	DB	2.701
FREE SPACE LOSS	DB	207.3	FREE SPACE LOSS	DB	205.8
ATMOSPHERIC ATTENUATION	DB	.1848	ATMOSPHERIC ATTENUATION	DB	.1214
SATELLITE ANTENNA GAIN	DB	36.20	GROUND ANTENNA GAIN	DB	47.04
ANTENNA OFF-AXIS LOSS	DB	.7358E-01	ANTENNA POINTING LOSS	DB	1.086
RECEIVED CARRIER LEVEL	DBW	-95.73	RECEIVED CARRIER LEVEL	DBW	-104.2
SATELLITE SYSTEM TEMP.	DEG.K	1315.	GROUND SYSTEM TEMP.	DEG.K	1096.
C/N UPLINK	DB	22.39	C/N DOWNLINK	DB	14.72

C/N TOTAL LINK	DB	14.03
MARGIN ABOVE THRESHOLD	DB	4.200
MINIMUM PROPAGATION MARG.	DB	2.128
% OF TOTAL NOISE IN DOWNLINK		85.39
TOTAL LINK TEMPERATURE	DEG.K	1284.

PSK SIGNAL

E/NO	DB	12.20	BIT RATE	KB/S	.6500E 05
IMPLEMENTATION LOSS	DB	3.000	RF CHANNEL BANDWIDTH	KHZ	.8500E 05

Table 5.6

CRC DOCUMENT CONTROL DATA

1. ORIGINATOR: Space Applications Branch

2. DOCUMENT NO: CRC Technical Note No. 671

3. DOCUMENT DATE: February 1975

4. DOCUMENT TITLE: Communications Experimenters' Guide
   Communications Technology Satellite

5. AUTHOR(s): R.W. Huck

6. KEYWORDS: (1) CTS
   (2) Experimenters'
   (3) Guide

7. SUBJECT CATEGORY (FIELD & GROUP: COSATI)

   17 Navigation, Communications, Detection, and Countermeasures

   17 02 Communications

8. ABSTRACT:

This Technical Note describes the technical and operational aspects of the CTS satellite, the associated ground terminals, and the communications capabilities of the combined system. Its purpose is to provide information to experimenters needed in the detailed planning of their individual experiments and to specify some of the divisions of responsibility between the Department of Communications and the experimenter.

9. CITATION:

Government of Canada Gouvernement du Canada