M-SAT PHASE A EXTENSION

CANADIAN DEMONSTRATION SPACECRAFT

REPORT AND BASELINE PERFORMANCE DOCUMENT ADDENDUM

TASK 3 M-SAT

G-STAR WITH ONLY COMMERCIAL MOBILE PAYLOAD

DEMONSTRATION MISSION

REPORT REF. NO. DOC-CR-SP-82-004-~~B~~C

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TABLE OF CONTENTS

1.0 PURPOSE

2.0 APPLICABLE DOCUMENTS

3.0 SYSTEM DESCRIPTION

- 3.1 System Concept
- 3.2 Coverage Pattern
- 3.3 Frequency Plan
- 3.4 Traffic Capability
- 3.5 Demographic Distribution

4.0 TRADE-OFFS

- 4.1 One Reflector Versus Two
- 4.2 With and Without NSSK
- 4.3 Solar Array Shadowing

5.0 SPACE SEGMENT DESCRIPTION

- 5.1 General
- 5.2 Launch Vehicle Interface
- 5.3 Mission Scenario

6.0 SUBSYSTEM DESCRIPTION

- 6.1 Antenna Subsystem
- 6.2 Transponder Subsystem
- 6.3 Bus Subsystems

7.0 SPACECRAFT SYSTEM BUDGETS

- 7.1 Spacecraft Mass and Power Budgets
- 7.2 Payload Mass and Power Breakdown

1.0 PURPOSE

The purpose of this document is to define the performance of a Canadian Demonstration M-SAT using a G-STAR derivative Bus launched on a delta class launch vehicle (2770 lbs into transfer orbit) and carrying only a high UHF payload. The preferred configuration is assumed to be without North South stationkeeping. Under trade-offs a parallel configuration using North-South stationkeeping for 7 years is presented.

This volume is an addendum to the main phase A report. Some sections of the report are essentially unchanged in which case reference is made to the phase A report.

2.0 APPLICABLE DOCUMENTS

The following documents are applicable to and form part of this report. In general, only those sections are applicable which are specifically referenced herein, however, the documents provide considerable background material which is essential for understanding the satellite system.

(1) M-SAT Canadian Demonstration Spacecraft Report and Baseline Performance Document, Volumes I and II.

Report Ref. # : DOC-CR-SP-81-047-A
Contract # : OST-00133
Contract File #: 15ST 36100-0-0768

(2) M-SAT PHASE A EXTENSION, TASK 1 CANADIAN DEMONSTRATION SPACECRAFT - L-SAT BUS' ADDENDUM TO PHASE A REPORT.

REPORT REF. # : DOC-CR-SP-82-004-B
CONTRACT # : OST81-00181
CONTRACT FILE #: 15ST36001-1-3040

(3) M-SAT PHASE A EXTENSION, TASK 2 CANADIAN OPERATIONAL SPACECRAFT-L-SAT BUS' ADDENDUM TO PHASE A REPORT.

REPORT REF. # : DOC-CR-SP-82-004-B
CONTRACT # : OST81-00181
CONTRACT FILE # : 15ST36001-1-3040

3.0 SYSTEM DESCRIPTION

3.1 System Concept

The system concept is for a commercial mobile only payload sized to fully load an RCA G-STAR Bus with 2770 lbs capability into transfer orbit.

The communications system is unchanged from the baseline, and is described by figure 3.4-1 (a) of the phase A report except that the backhaul frequency band is changed to 14/12 GHz.

3.2 Coverage Pattern

The coverage pattern is identical to that in the baseline. It is reproduced here as figure 3.2-1. There are four beams provided by a single 30 foot reflector. The overlapping beams are provided by sharing horns between beams using a transponder beam forming network.

3.3 Frequency Plan

The high UHF frequency plan is identical to that of the baseline. The 4 MHz band is divided into four 1 MHz subbands with one subband assigned to each of the four beams. Frequency reuse is not incorporated. The polarization is right hand circular on both uplink and downlink, identical to that used on the baseline.

3.4 Traffic Capability

Table 3.4-1 summarizes the number of assignable channels for the complete spacecraft in both sunlight and eclipse and for both narrow band FM and Pitch Excited LPC. The calculation was carried out assuming that the same transponder was fully loaded with NBFM in one case and LPC in the other. A mix of traffic is conceptually possible but no intermediate cases have been worked out.

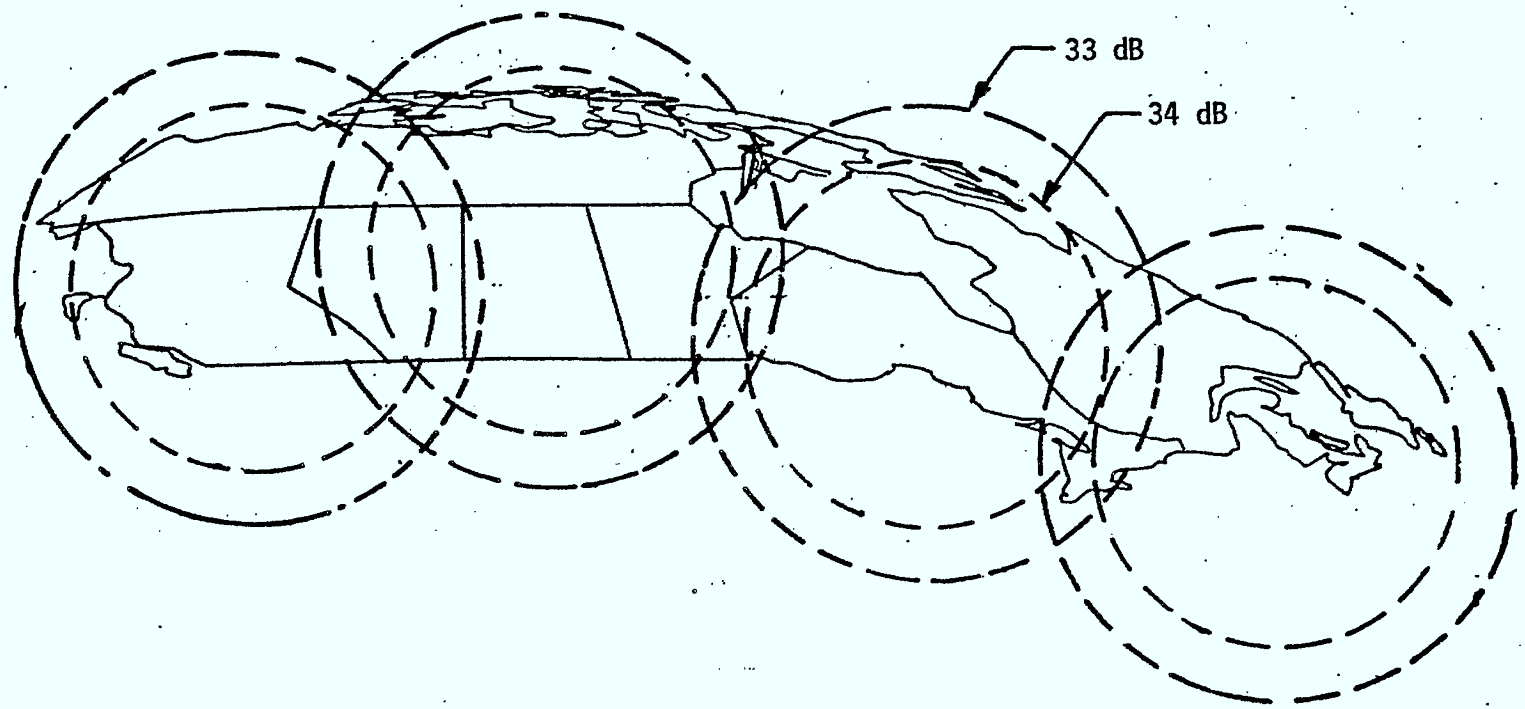


Figure 3.2-1 Coverage Patterns for High UHF Antenna with 30 Ft. Reflector

TABLE 3.4-1 G-STAR DEMONSTRATION MODEL-USER ESTIMATE

	TOTAL CHANNELS	CHAN/BEAM	TRAFFIC ER/BEAM	NUMBER OF USERS/BEAM	TOTAL NUMBER OF USERS
Sunlight					
NBFM	44	10	7	560	
		10	7	560	
		12	9	720	
		12	9	720	2560
PELPC	218	35	33	2640	
		35	33	2640	
		57	57	4560	
		91	95	7600	17440
Eclipse					
NBFM	11	2	0.6	48	
		2	0.6	48	
		3	1.3	104	
		4	2.1	168	368
PELPC	88	14	11	880	
		14	11	880	
		23	21	1680	
		37	35	2800	6240

3.0 SYSTEM DESCRIPTION (CONT'D)

The total number of users, assuming LPC with an EIRP of 33.7 dBW, 10% blockage and .0125 Erlangs per user, is 17440. This equals the Woods Gordon projection to the year 1992 which is approximately the time frame when an operational M-SAT would have to be launched.

The above traffic capability is based on the assumption that no North-South stationkeeping is used. It should be noted that RCA has not confirmed that the power level required to provide this capacity can be made available.

3.5 Demographic Distribution

The breakdown of the number of users is made on the basis of the coverage pattern of figure 3.2-1 and is listed in table 3.5-1. This table also lists the number of channels per beam required to service 70,000 users across Canada. The number of channels per beam has been reduced to 27.2% resulting in the peak and total number of channels matching the calculated values of table 6.2-1 as well as the number of users per beam and total number of users matching that given in table 3.4-1 for LPC traffic. Table 3.5-1 therefore, is the basis on which the peak number of channels per beam and total channels on the spacecraft have been assigned.

TABLE 3.5-1 ESTIMATE OF DEMOGRAPHIC DISTRIBUTION

	No. of Users	Beam Total	Traffic Erlangs/ Beam	Ch/Beam	Percent. Capacity Of Beam	Demo.Model Ch/Beam	Busy Hr.? Traffic Er/Beam	Number Of Users
Beam 1		11,120	139.0	130.0	16.2%	35	33	2640
B.C.	8446							
Yukon	134							
N.W.T.	40							
Alta.	2500							
Beam 2		10,975	137.2	128.2	16.0%	35	33	2640
Alta.	2590							
Sask.	5425							
Man.	2839							
N.W.T.	121							
Beam 3		18,477	231.0	211.3	26.3%	57	57	4560
Ont.	18077							
N.W.T.	100							
Quebec	300							
Beam 4		29,428	367.8	332.5	41.5%	91	95	7600
Quebec	17739							
Ont.	2000							
Nfld.	3318							
N.S.	2787							
N.B.	3200							
P.E.I.	384							
Canada TOTAL	70,000		875	802	100%	218	218	17440

4.0 TRADE-OFF STUDIES

4.1 One Reflector Versus Two

The one reflector version was selected entirely on the basis that it was impossible to stow two reflectors and two feeds within the Delta shroud. Thus the high UHF transponder reflector and feed are identical except in power to the baseline described in the phase A report. This includes the transponder beam forming with all the attendant phase and amplitude stability problems of the power amplifiers and low noise amplifiers.

4.2 With or Without North-South Stationkeeping (NSSK)

Calculation of the channel capacity is given in table 4.2-1 for full NSSK and in table 4.2-2 for no NSSK. There is a significant increase in total number of channels without NSSK increasing from 26 to 44 for NBFM and from 147 to 218 for PELPC.

There appear to be no significant penalties in the space segment with antenna pointing corrected by on-board control of the momentum wheels. This gives fine pointing control which can be programmed to cycle on a daily basis.

On the ground, the gateway stations must be equipped with a tracking capability but the mobiles are unchanged. Because of the small number of gateway stations, the required tracking capability is not a large penalty to pay for such increase in capacity.

TABLE 4.2-2 RCA G-STAR WITH NO NSSK

(PREFERRED CONFIGURATION)

Coding Type		NBFM	PELPC
Antenna Diameter	m	9.15	9.15
	ft	30	30
Number of Beams		4	4
Edge EIRP	dBw	39.7	33.7
Antenna Gain (including cable loss)	dB	32	32
Pointing and Imbalance Allowance	dB	1.75	1.75
Transponder RF power/	dBw	9.45	3.45
Output Circuit Loss	dB	1.3	1.3
HPA RF Output/Channel	dBw	10.75	4.75
	watts	11.9	3.0
Max. Conversion Efficiency		.27	.27
Voice Activation		Yes	Yes
BFN		Yes	Yes
Max. No. of Active Ch/Beam	N_{BA}	10.9	43.2
Max. No. of Assignable Ch/Beam	N_{APB}	12	92
Total Number of Active Channels	N_{TA}	23.9	94.8
Total Number of Assignable Channels	N_{ASS}	44	218
Max. RF Power per Amp	watts	129.7	129.7
Max. DC Power per Amp	watts	480.4	480.4
Max. DC Power for 5 Amps	watts	1338	1338
Remainder of Transponder	watts	69	69
Total DC Power to Trans Transponder	watts	1407	1407
Number of Active Channels in Eclipse		10.5	41.6
Number of Assignable Channels in Eclipse		11	88
Total DC Power in Eclipse	watts	942	942
Unit Weight of HPA & EPC	Kg	8.44	8.44
Total Weight of 8 Units	Kg	67.5	67.5

TABLE 4.2-1 RCA G-STAR WITH FULL NSSK

10% POWER AND WEIGHT MARGIN

Coding Type		NBFM	PELPC
Antenna Diameter	m	9.15	9.15
	ft	30	30
Number of Beams		4	4
Edge EIRP	dBw	39.7	33.7
Antenna Gain (including cable loss)	dB	32	32
Pointing and Imbalance Allowance	dB	1.75	1.75
Transponder RF Power/Ch	dBw	9.45	3.45
Output Circuit Losses	dB	1.3	1.3
HPA RF Power/Channel	dBw	10.75	4.75
	watts	11.9	3.0
Max. Conversion Efficiency		.27	.27
Voice Activation		Yes	Yes
BFN		Yes	Yes
Max.No. of Active Ch/Beam	N_{BA}	7	28
Max.No. of Assignable Ch/Beam	N_{APB}	7	54
Total Number of Active Channels	N_{TA}	16.6	65.8
Total Number of Assignable Channels	N_{ASS}	26	147
Max. RF Power Per Amp	watts	83.3	83.3
Max. DC Power Per Amp	watts	308.5	308.5
Max. DC Power for 5 Amps	watts	903	903
Remainder of Transponder	watts	69	69
Total DC Power to Transponder	watts	972	972
Number of Active Channels in Eclipse		7	27.8
Number of Assignable Channels in Eclipse		7	54
Total DC Power in Eclipse	watts	638	638
Unit Weight of (HPA & EPC)	Kg	5.64	5.64
Total Weight of 8 (HPA & EPC) s	Kg	45.1	45.1

4.0 TRADE-OFF STUDIES (CONT'D)

4.3 Solar Array Shadowing

The Woods Gordon Survey has analyzed the air time of the current 1981 population of non-metropolitan mobiles. The variation of air time with time of year, day of the week and hour of the day has been analyzed. The heaviest usage months are July and August which are 20% over the yearly average. The heaviest day is Friday which is 25% over the yearly average and the heaviest hour of the day is between 8 and 9 am which is 77% over the yearly average. Thus the worst hour of a Friday in July or August is 2.66 times the yearly average (see figure 4.3-1).

The present population of non-metropolitan mobiles is not distributed the same way as the guide line user population. The guide line user population was based on a manipulation of present rural population without any reference to the activities of this population.

On the other hand, by canvassing the users the Woods Gordon survey found 38% of existing mobiles in B.C. and the Yukon compared to 12.25% in the guide line user population.

The Woods Gordon survey plotted the air time during the day against the clock time without considering that the clocks in different parts of the country are different. The air time spreads out over a longer period of time if satellite local time is used. By moving the satellite away from the region of greatest user activity then the peak can be shifted earlier or later in the day. Thus for the guideline population with greatest useage in the east the satellite should be moved west. This causes the heavy eastern traffic to appear early in satellite local time and reduce the afternoon traffic load. In this case it is best to have the antenna on the west side which then shadows the array in the afternoon.

4.0 TRADE-OFF STUDIES (CONT'D)

Figure 4.3-2 shows the integrated traffic normalized to 100% and the maximum reduction by shadowing for an antenna on the west side and also for an antenna on the east side. With the antenna on the west side and shadowing in the afternoon, the full expected traffic can be supported even with maximum shadowing allowance. With the antenna on the east side, the early morning traffic exceeds the power available when the maximum shadowing effect is considered.

If the payload is such that two large antennas are required, then shadowing will occur in both the morning and afternoon and the optimum satellite orbital slot would balance the morning and afternoon shadowing.

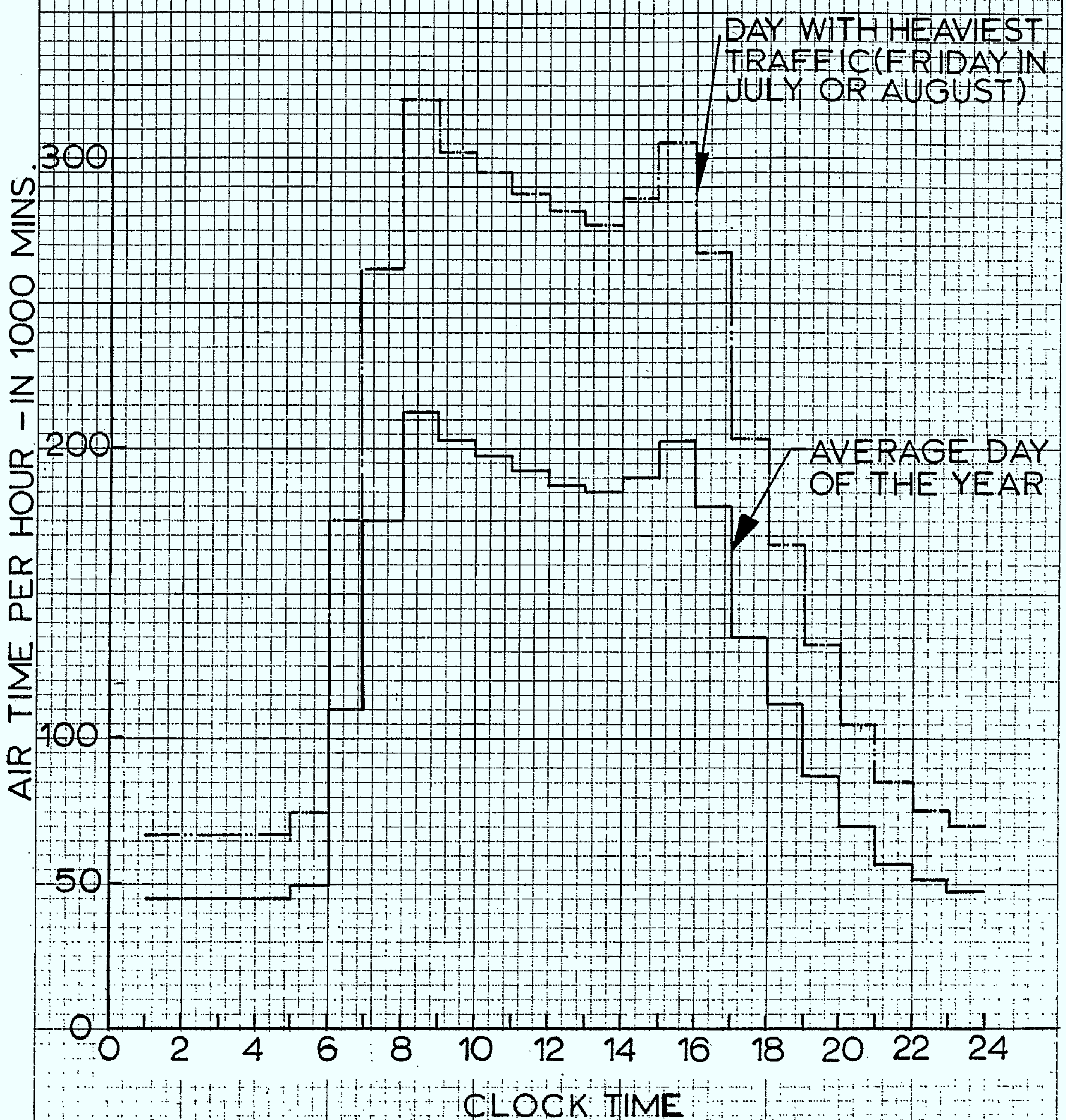


FIG.4.3-1 WOODS GORDON SURVEY RESULTS FOR 1981 POPULATION

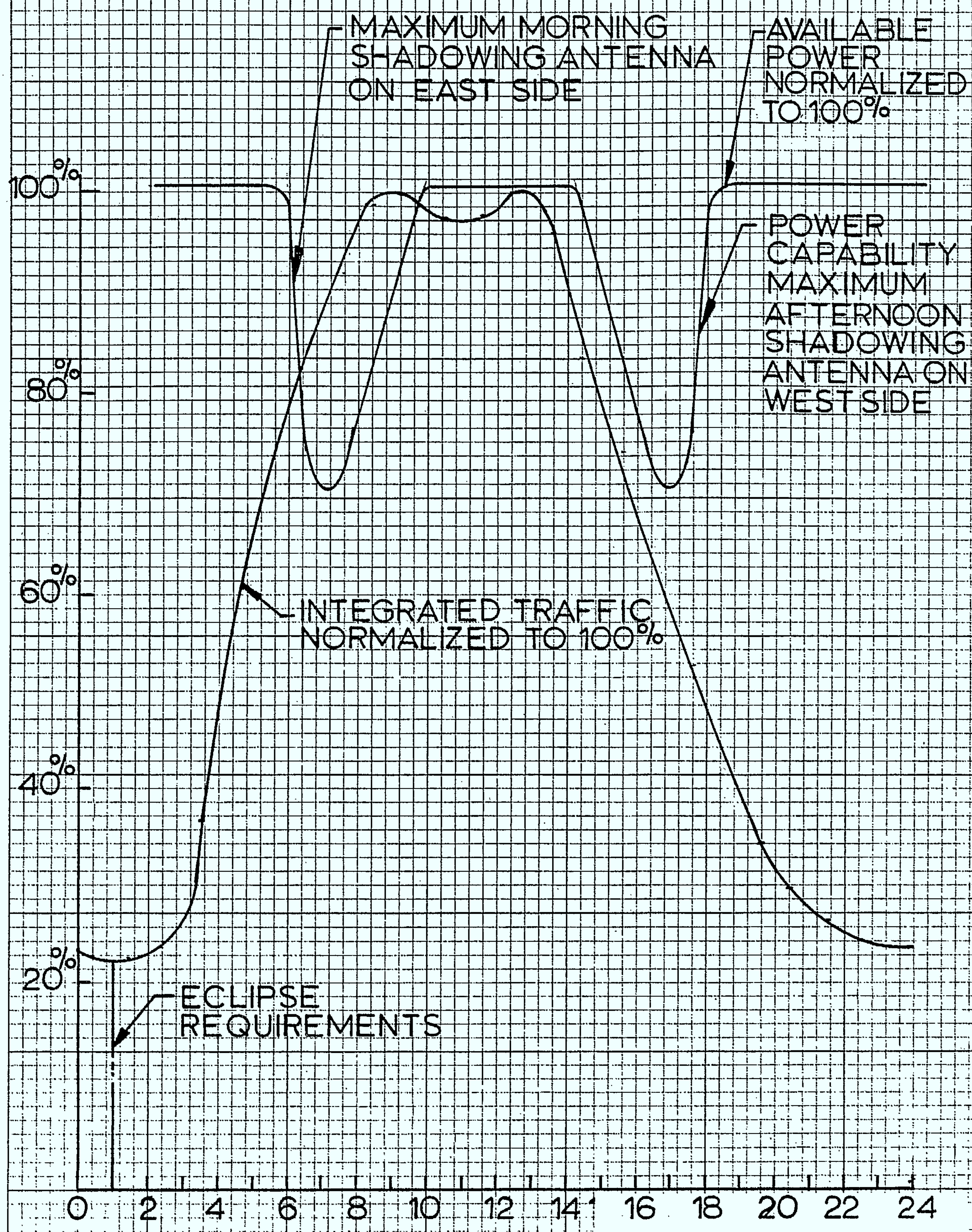


FIG.4.3-2 SATELLITE LOCAL TIME (WEST CENTRAL BEAM)

5.0 SPACE SEGMENT DESCRIPTION

5.1 General

The high UHF only demonstration M-SAT spacecraft has been configured utilizing the Advanced RCA 2770 lbs bus (G-STAR) and one 30 ft reflector due to Delta envelope limitations for stowing two 30 ft reflectors. The beam coverage is identical to that used in the Phase A baseline design. The repeater is electrically identical to that of Phase A except that assemblies have been distributed over the North and South panels in an approximately equal power dissipation manner.

Description of the overall spacecraft design configuration designated AX-4, is provided in section 6.0 of this report.

5.2 Launch Vehicle Interface

The spacecraft is compatible with the Delta 3920 Launch Vehicle. The stowed configuration, as shown in drawing number 2611798, is designed to fit within the Delta dynamic payload envelope. The spacecraft will also fit within a standard Ariane III dual launch fairing or the lower half of the Ariane IV dual launch "unsymmetrical" fairing. The spacecraft can also be accommodated on STS, mounted horizontally on a Pam-D cradle.

The spacecraft weight is well within the capability of the Delta 3920/Pam-D launch vehicle, as shown in section 7.0.

5.3 Preliminary Mission Scenario

For a Delta 3920 launch, the mission sequence will be as follows:

- Ignition of first stage engine and solid motors
- Lift off
- Solid motor burnout, and separation sequence

5.0 SPACE SEGMENT DESCRIPTION (CONT'D)

5.3 Preliminary Mission Scenario (Cont'd)

- Main engine cutoff
- Vernier engine cutoff
- Stage I-II separation
- Second stage ignition
- Jettison fairing
- Second stage engine cutoff
- Coast
- Start PAM sequencing system
- Reorientation to PAM firing attitude
- Fire spin rockets
- Stage II-PAM separation
- PAM ignition
- PAM burnout
- PAM/spacecraft separation
- Fire tumble system YO weight bolt cutters
- Acquisition by ground station
- Command and telemetry system checkout
- Monitor spacecraft status
- Reorientation to AMF attitude
- 1st Apogee - preburn velocity correction
- Possible reorientation
- Nth apogee - fire apogee motor
- Reorientation to post-AMF ΔV Attitude
- Post-AMF ΔV correction
- Reorientation to equitorial normal
- Despin
- Sun and Earth acquisition
- Solar array deployment
- Reflector boom deployments
- Reflector deployment/orientation
- Feed deployment
- East/west drift to station
- On-station operations

6.0 SUBSYSTEM DESCRIPTION

6.1 Antenna Subsystem

The antenna feed and reflector are identical with the high UHF baseline antenna described in section 6.1.2 of the phase A report. It consists of a wrap-rib mesh reflector approximately 10 meters in diameter to provide the required 9.15 meter diameter aperture the mesh is gold plated molybdenum wires. The feed assembly consists of an assembly of circularly polarized horns as shown in figure 6.1-1. Four horns are excited simultaneously to form one beam and four beams are formed by having a 50% over lap with the horns of the adjacent beam.

The support system for the reflector has been modified to ease the stowage problem. The support linkage is mounted to the front of the reflector hub rather than the back. Thus the support arm is in front of the reflector rather than behind and provides some blockage of the aperture. This will increase the side lobe levels but this is not considered detrimental since the frequency spectrum is not being reused in the demonstration model.

The far field pattern of the antenna is shown in figure 3.2.1 showing a worst case edge gain of 32.5dB. A half dB is allowed for combining and cable loss to the transponder interface port at the duplexer input terminal giving a net antenna gain of 32 dB.

6.2 Transponder Description

The transponder block diagram is shown in figure 6.2-1. The transponder is the same as that of the baseline except that it is now divided into two parts with one mounted on the North panel and the other part mounted on the South panel.

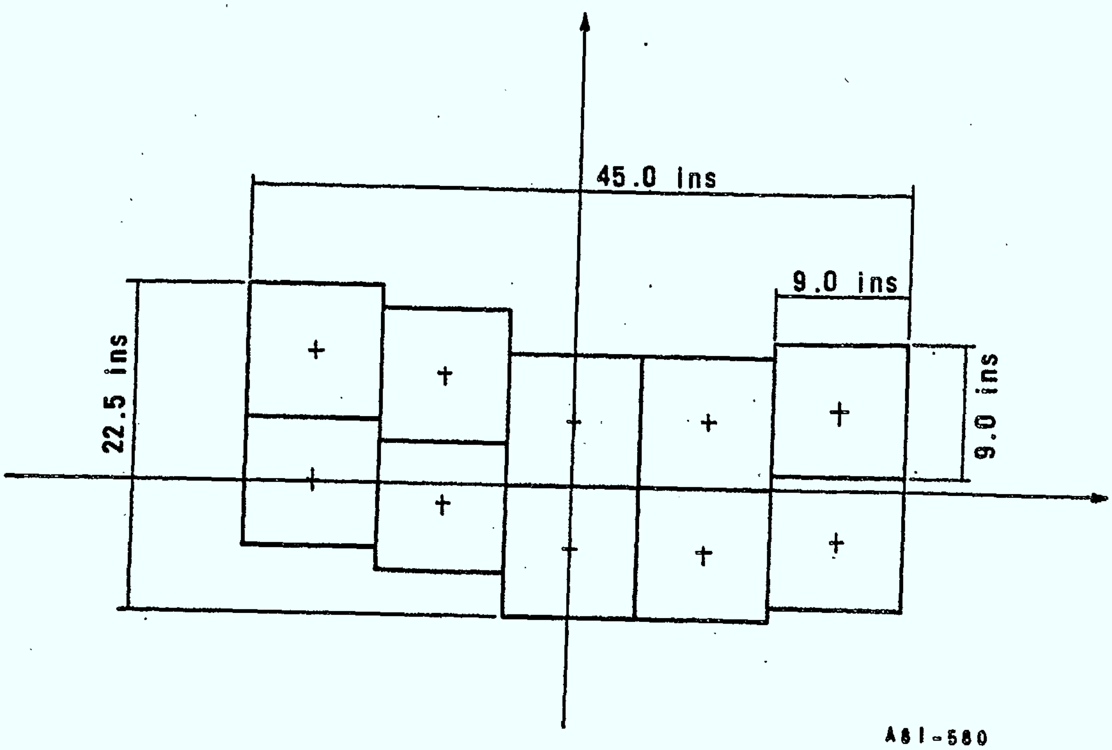


Figure 6.1-1 High UHF Miltiple Feed Horn Assembly
for an Antenna with F/D = .625

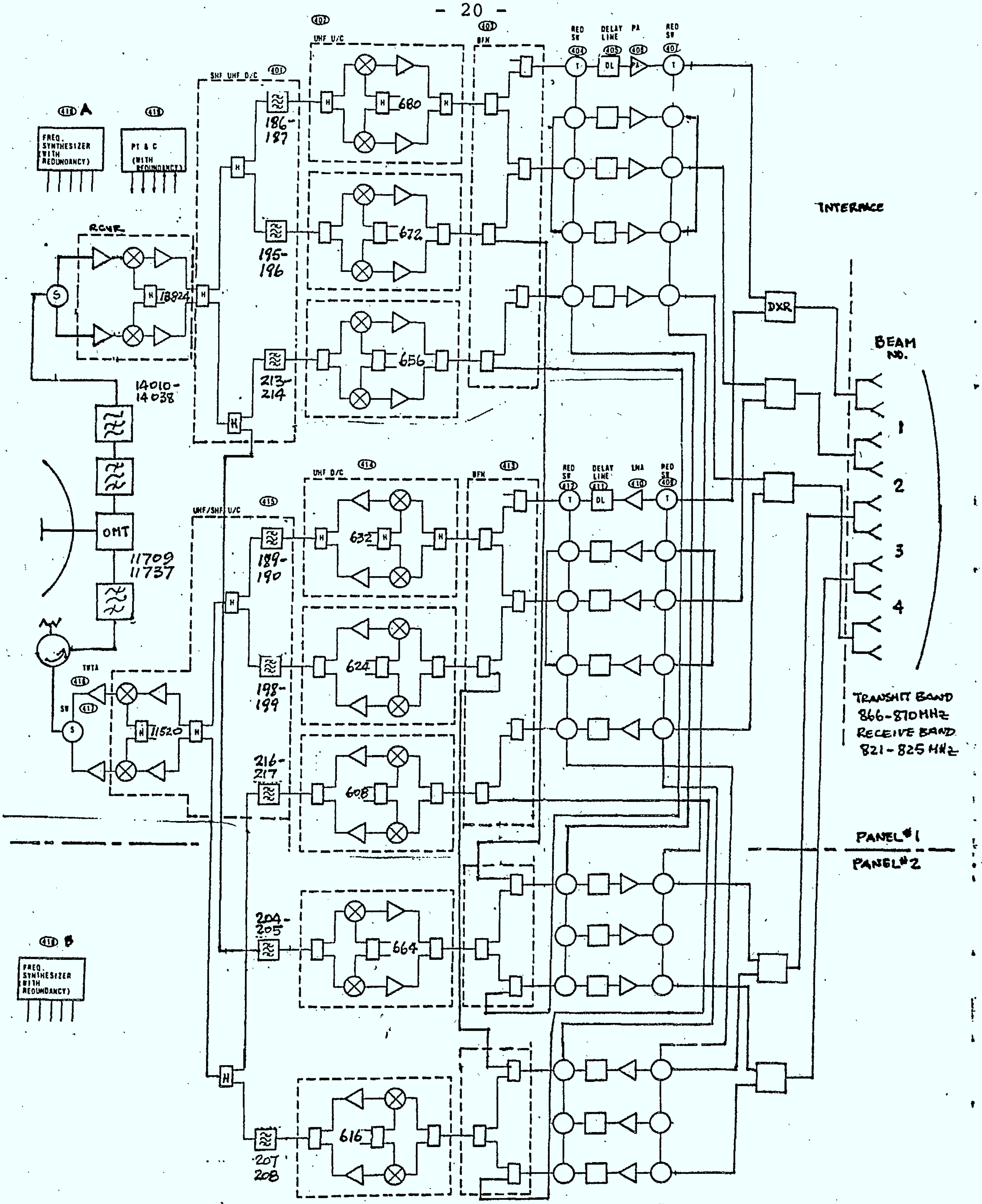


Figure 6.2-1 COMMERCIAL MOBILE REPEATER ON RCA 2770 LB BUS

6.0 SUBSYSTEM DESCRIPTION (CONT'D)

6.2 Transponder Description (cont'd)

There are five amplifiers to feed the five horn pairs hence an uneven split of power dissipation is imposed on the design. Further, a two amplifier failure mode could exist whereby four amplifiers would have to be operational on one panel and only one on the other. From sun input considerations it would be preferable to mount the higher dissipation part of the transponder on the North panel. The power dissipation for each panel is presented in Table 6.2-1.

The two halves of the transponder come together at the beam forming network (BFN). Since the line lengths have to be equalized, the BFN is preferably located in an intermediate location such as the underside of the antenna deck. A detailed layout and trade-off is required to determine the optimum position for the various units of the transponder.

The use of a transponder BFN introduces the problems of phase and gain stability of both the power amplifiers and the low noise amplifiers. Phase and amplitude imbalance between horns as a minimum can result from the following factors:

a) Variation with temperature of the amplifiers
b) Variation with temperature difference between amplifiers
c) Variation with life both active and standby
d) Variation with drive level (power amplifiers only)
e) Initial setting errors
f) Variation with temperature of the switched phase shifters
g) Variation with life of the switched phase shifters
h) Variation between settings with time and temperature of the switched phase shifters

TABLE 6.2-1 ESTIMATE OF PA POWER DISSIPATION BASED ON DEMOGRAPHIC DISTRIBUTION OF TABLE 3.5-1

<table>
<tr><th rowspan="2">BEAM NO. WEST TO EAST</th><th colspan="2">ASSIGNABLE CHANNELS</th><th rowspan="2">EQUIVALENT ACTIVE CHANNELS PER AMP</th><th colspan="2">NORMAL OPERATION</th><th colspan="2">TWO AMPLIFIERS FAILED MODE</th></tr>
<tr><th>PER BEAM</th><th>PER AMP</th><th>NORTH PANEL</th><th>SOUTH PANEL</th><th>NORTH PANEL</th><th>SOUTH PANEL</th></tr>
<tr><td rowspan="2">Beam 1</td><td rowspan="2">35 (16%)</td><td>35(8%)</td><td>7.6(8%)</td><td>145.3</td><td></td><td>145.3</td><td></td></tr>
<tr><td rowspan="2">70(16%)</td><td rowspan="2">15.2(16%)</td><td rowspan="2">189.0</td><td rowspan="2"></td><td rowspan="2">189.0</td><td rowspan="2"></td></tr>
<tr><td rowspan="2">Beam 2</td><td rowspan="2">35 (16%)</td></tr>
<tr><td rowspan="2">92(21%)</td><td rowspan="2">19.9(21%)</td><td rowspan="2"></td><td rowspan="2">216.1</td><td rowspan="2">216.1</td><td rowspan="2"></td></tr>
<tr><td rowspan="2">Beam 3</td><td rowspan="2">57 (26%)</td></tr>
<tr><td rowspan="2">148(34%)</td><td rowspan="2">32.2(34%)</td><td rowspan="2"></td><td rowspan="2">286.9</td><td rowspan="2"></td><td rowspan="2">286.9</td></tr>
<tr><td rowspan="2">Beam 4</td><td rowspan="2">91 (42%)</td></tr>
<tr><td rowspan="2">91(21%)</td><td rowspan="2">19.9(21%)</td><td rowspan="2">216.1</td><td rowspan="2"></td><td rowspan="2">216.1</td><td rowspan="2"></td></tr>
<tr><td></td><td></td></tr>
<tr><td>TOTALS</td><td>218 (100%)</td><td>(100%)</td><td>94.8(100%)</td><td>550.4</td><td>503.0</td><td>766.5</td><td>286.9</td></tr>
</table>

6.0 SUBSYSTEM DESCRIPTION (CONT'D)

6.2 Transponder Description (cont'd)

The transponder is a double conversion type similar to that selected for the baseline demonstration model. This allows the use of all the UHF bandwidth without having to subtract bandwidth for filter guard bands. It seems fairly certain that bandwidth will be a restriction at least in an operational system so the double conversion transponder is used.

The backhaul frequency has been changed from the military band at 7/8 GHz. 14/12 GHz has been selected for the purpose of providing weight and power estimates. This is the same band selected for the earlier operational system design but the trade-off performed then is only partially valid. A single all Canada backhaul beam is used requring one redundant receiver. All the frequency segments in the UHF bands are stacked in frequency and translated to the 14/12 GHz band for transmission to/from the gateway stations.

The detailed frequency plan is given in Table 6.2-2. In the forward path, the 14 GHz receive signal is translated to an IF frequency in the vicinity of 200 MHz where the band is separated into four segments for the four UHF beams. The four frequency segments are then translated by different local oscillator frequencies to the appropriate location in the 866-870 MHz band. In the return path, the uplink signals at 821-825 MHz are translated to an IF frequency also in the region of 200 MHz where the frequency segments are multiplexed together and translated to 12 GHz for transmission to the gateway station.

All local oscillator frequencies are selected so that they can be derived from a common master oscillator. A simplified block diagram is given in figure 6.2-2 indicating how this might be done. A detailed study is required to determine the optimum method of deriving the various L.O. frequencies.

TABLE 6.2-2 DETAILED FREQUENCY PLAN FOR THE HIGH UHF TRANSPONDER

FORWARD PATH

14 GTH UPLINK	L.O.	IF FILTER BANDS	L.O.	TRANSMIT BAND
14010-14038	13824	186 - 187	680	866.0 - 867.0
	(288 x 6 x 8)	195 - 196	672	867.0 - 868.0
		204 - 205	664	868.0 - 869.0
		213 - 214	656	869.0 - 870.0

RETURN PATH

UHF RECEIVE	L.O.	IF FILTER BANDS	L.O.	12 GHz DOWNLINK
821 - 822	632	189 - 190	11520	11709 - 11737
822 - 823	624	198 - 199	(288 x 5 x 8)	
823 - 824	616	207 - 208		
824 - 825	608	216 - 217		

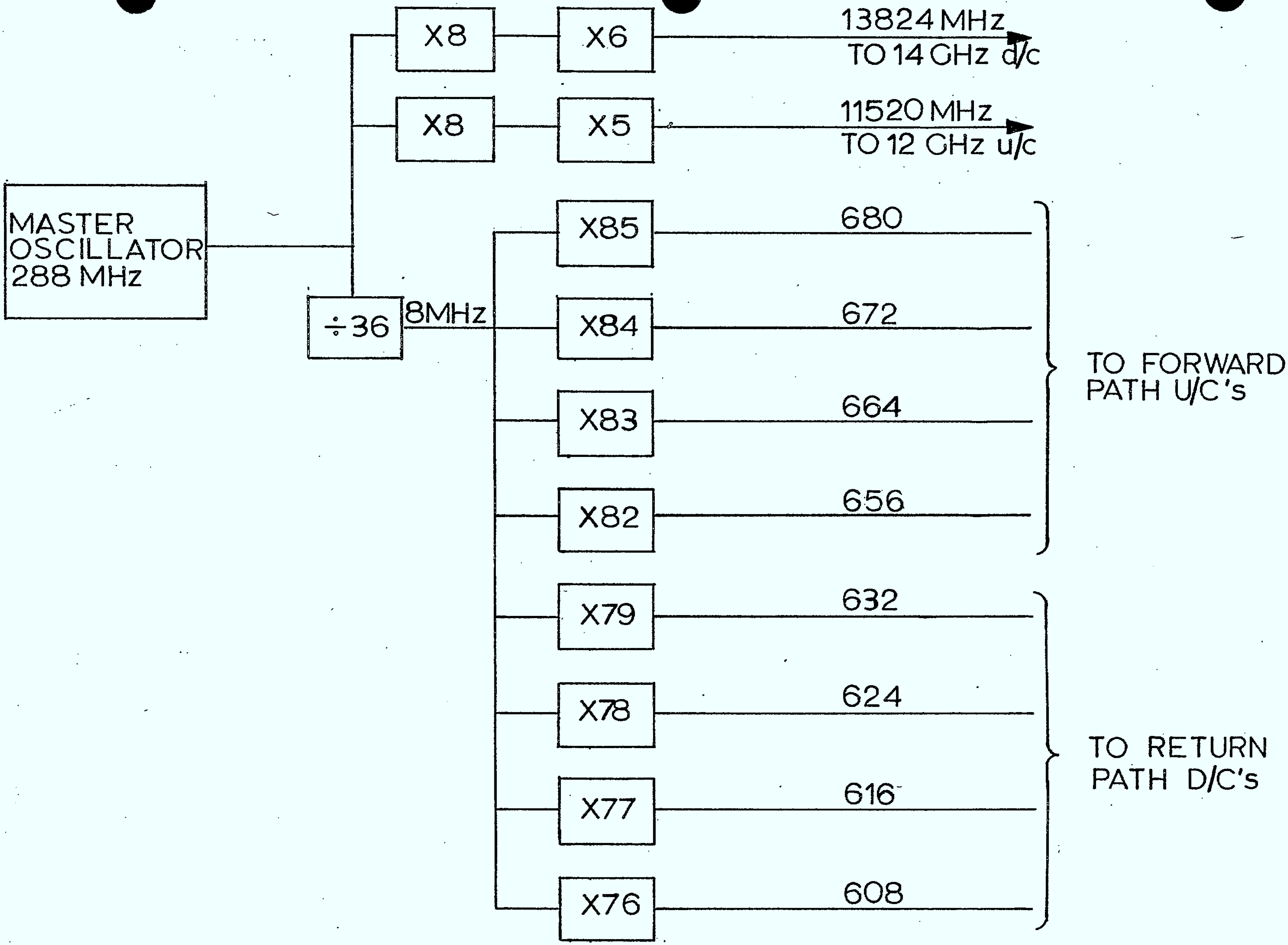


FIG. 6.2-2 SIMPLIFIED BLOCK DIAGRAM OF A POSSIBLE LOCAL OSCILLATOR SOURCE.

6.0 SUBSYSTEM DESCRIPTION (CONT'D)

6.3 Bus Changes

6.3.1 General

Two M-SAT/G-STAR Configurations are considered in this section. The preferred configuration has an increased payload mass and has no north/south stationkeeping propellant. The Bus changes outlined herein are based on limited information that is presently available. The extent of these changes, and the ability of the Bus to accommodate them, has not been confirmed by RCA at this time.

6.3.2 Changes to Basic G-STAR Bus to Accommodate the Preferred Configuration

The baseline G-STAR spacecraft will require additional structural strengthening and stiffening local to the wrap rib reflector boom attachment and feed assembly mounting fitting. Additional solar array panels will be required to provide 1560 watts to the payload and additional thermal doublers and second-surface minors will be required to handle the increased thermal loads. RCA have not confirmed the potential capacity in this regard. A reduction in eclipse operation of the high UHF payload from 100% to 25% will result in a reduction in battery weight, and some RCS tankage may be removed to reduce overall system weight due to the elimination of north-south stationkeeping. A larger momentum wheel may be required to compensate for greater disturbance torques, and the earth sensor assemblies must be relocated to the east edge of the earth facing panel. A detailed analysis of the effects of plume impingement and solar torques on the configuration will be required to evaluate the on-station fuel requirement and the trade-offs between the proposed solar sail and additional momentum wheel capacity and/or additional magnetic

6.0 SUBSYSTEM DESCRIPTION (CONT'D)

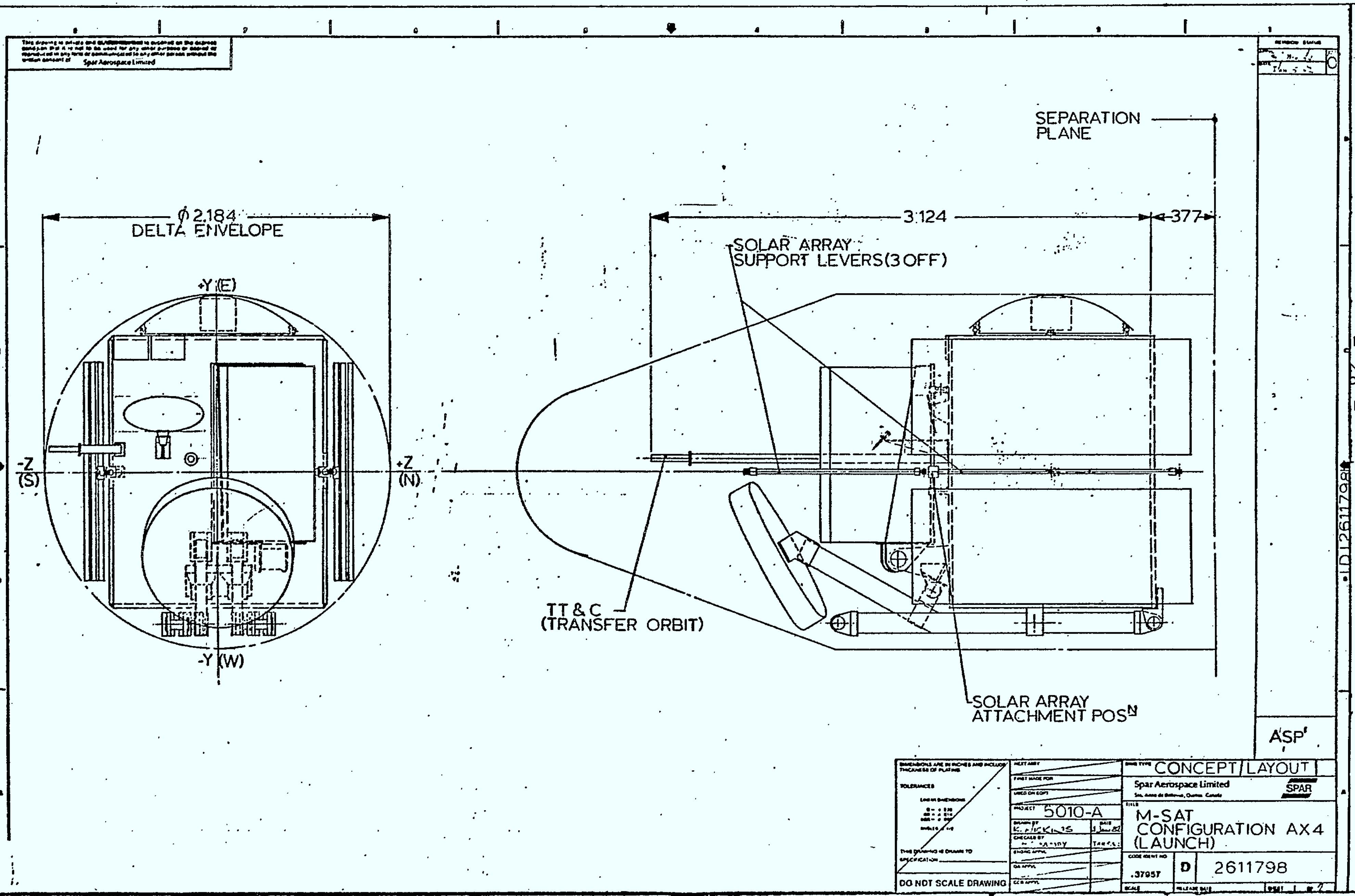
6.3.2 Changes to Basic G-STAR Bus to Accommodate the Preferred Configuration (cont'd)

torquers. Finally, the on-station Ku band TT & C system must be routed through the backhaul antenna, and new omni antenna assemblies are required. A mission-specific attitude control system will be required to achieve M-SAT pointing requirements, and to cope with the flexibility of the large deployable structures and potential plume impingement effects.

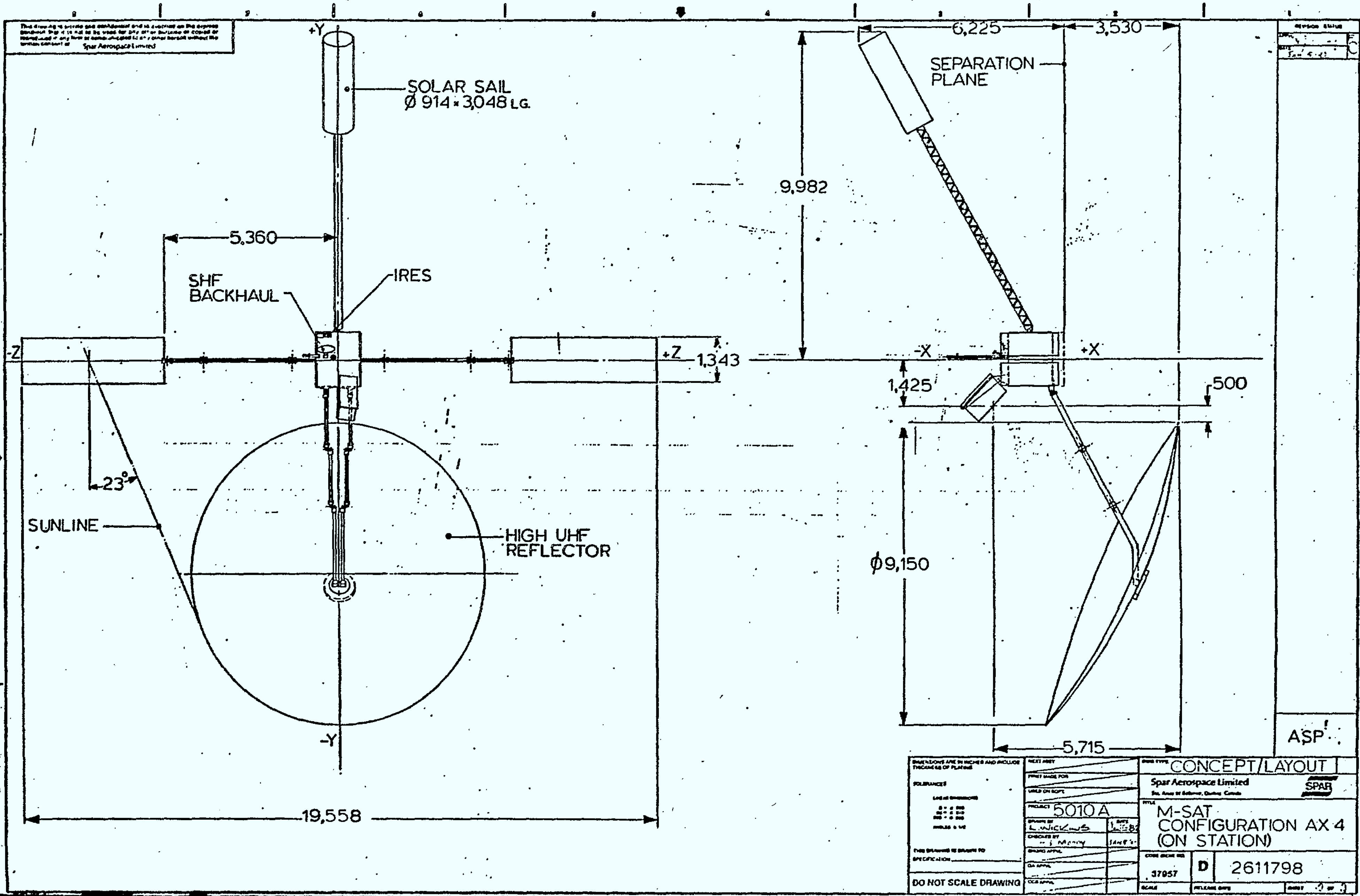
6.3.3 Changes to Basic G-STAR to Accommodate the Alternate Configuration

The alternate M-SAT/G-STAR configuration retains the requirement for north-south stationkeeping and thus the baseline G-STAR RCS system. The reduced payload on this configuration will require passive thermal subsystem redesign but no significant increase in overall thermal rejection capacity, and no significant changes to the power subsystem and solar array assemblies. With these exceptions, the changes identified in paragraph 6.3.2 above will be required. Overall, this configuration requires significantly fewer major modifications.

The stowed and deployed configuration drawings are shown in SPAR drawing number D2611798 sheet 1 and sheet 2 respectively. These drawings show the spacecraft with the standard G-STAR solar array required by the alternate rather than the augmented solar array required by the preferred configuration. This is because no information was forthcoming from the bus supplier concerning the feasibility of augmenting the solar array.



SEPARATION PLANE
ϕ 2.184
DELTA ENVELOPE
3.124
377
SOLAR ARRAY SUPPORT LEVERS(3 OFF)
+Y (E)
-Z (S)
+Z (N)
-Y (W)
TT & C (TRANSFER ORBIT)
SOLAR ARRAY ATTACHMENT POSN
CONCEPT LAYOUT
Spar Aerospace Limited
SPAR
PROJECT 5010-A
M-SAT CONFIGURATION AX4 (LAUNCH)
D 2611798
DO NOT SCALE DRAWING
D 2611798


+Y
SOLAR SAIL
Ø 914 × 3,048 LG.
5,360
SHF
BACKHAUL
IRES
-Z
+Z
1,343
23°
SUNLINE
HIGH UHF
REFLECTOR
-Y
19,558
6,225
3,530
SEPARATION
PLANE
9,982
-X
+X
1,425
500
ϕ9,150
5,715
ASP
CONCEPT/LAYOUT
Spar Aerospace Limited
SPAR
PROJECT 5010 A
L. WICKENS
DO NOT SCALE DRAWING
M-SAT
CONFIGURATION AX 4
(ON STATION)
37057
D
2611798

7.0 SPACECRAFT SYSTEM BUDGETS

7.1 Spacecraft Mass and Power Budgets

The spacecraft level mass budget is given in Table 7.1-1. Configuration 1 represents the budget of a redesigned G-STAR where north-south stationkeeping fuel has been traded for larger power subsystem to supply 1560 w for payload use and larger payload weight for increased traffic capacity. This configuration has been based on redesign trade off assumptions derived from existing published data which have not been confirmed by the Bus supplier. Due to the large extent of the required redesign, a significant risk exists in the eventual fit of the payload as depicted in this report. Configuration 2 represents the budget of a slight redesign of G-STAR still including 7 years of north-south stationkeeping fuel and power requirements increased to 1070 w for payload use. Both configurations have been based on eclipse operation of 25% capacity of the high UHF link with the associated battery capacity reduction included.

Information required to produce a spacecraft power budget is not available for this bus. The power requirement budgets for sunlight and eclipse operation of the payload are presented in 7.2.

The various assumptions made for the required reconfiguration of the G-STAR to carry the payloads of configuration 1 and 2 are contained in the adjusted mass and power envelopes presented in Figure 7.1-1. The basic bus is capable of carrying 156 kg of payload and provide 1000 w DC power to the payload.

7.0 SPACECRAFT SYSTEM BUDGETS (CONT'D)

7.1 Spacecraft Mass and Power Budgets (Cont'd)

Fuel off loading has been assumed as 13.6 kg per year for each year of operation without north-south stationkeeping. The assumed power to mass trade-off factor has been 7.3 w of DC power per kg. This figure is assumed to contain all the weight required in the change of the power subsystem for 100% eclipse operation capability. For reduced eclipse operation (25% capacity in this case) the weight reduction for batteries is assumed to be 1 kg per 30 Wh of battery capacity (based on nickel hydrogen batteries operated to 60% DOD).

7.2 Payload Mass and Power Breakdown

The transponder weight and power breakdown is presented in Table 7.2-3 for the preferred configuration of no NSSK and in Table 7.2-4 for the configuration with 7 years of NSSK. A comparison of the payload required weight and power for both cases of with and without NSSK is given in Tables 7.2-1 and 7.2-2. Antenna weight breakdown is given in Table 7.2-5.

TABLE 7.1-1 HIGH UHF DEMONSTRATION MODEL (G-STAR WITH DELTA/ PAM-D LAUNCH)

WEIGHT SUMMARY (kg)

Subsystem	Config'n. 1 (No NSSK)	Config'n. 2 (7 year NSSK)
Repeater	122.3	93.6
Antennas		
30 ft. Wrap Rib	56.3	56.3
Backhaul	2.7	2.7
T & C	1.8	1.8
Solar Sail	8.2	8.2
Platform		
Structure	64.9	64.9
Thermal	15.5	15.5
Attitude Control	32.2	32.2
Power	194.7	133.1
TT & C	27.1	27.1
Propulsion	28.8	28.8
Spacecraft Dry Mass	554.5	464.2
Propellant and Pressurant	13.7	108.8
Akm and Akm Expendables	608.6	608.6
Margin on dry spacecraft mass	93.2 (16.8%)	88.4 (19.0%)
Launch Weight	1270	1270

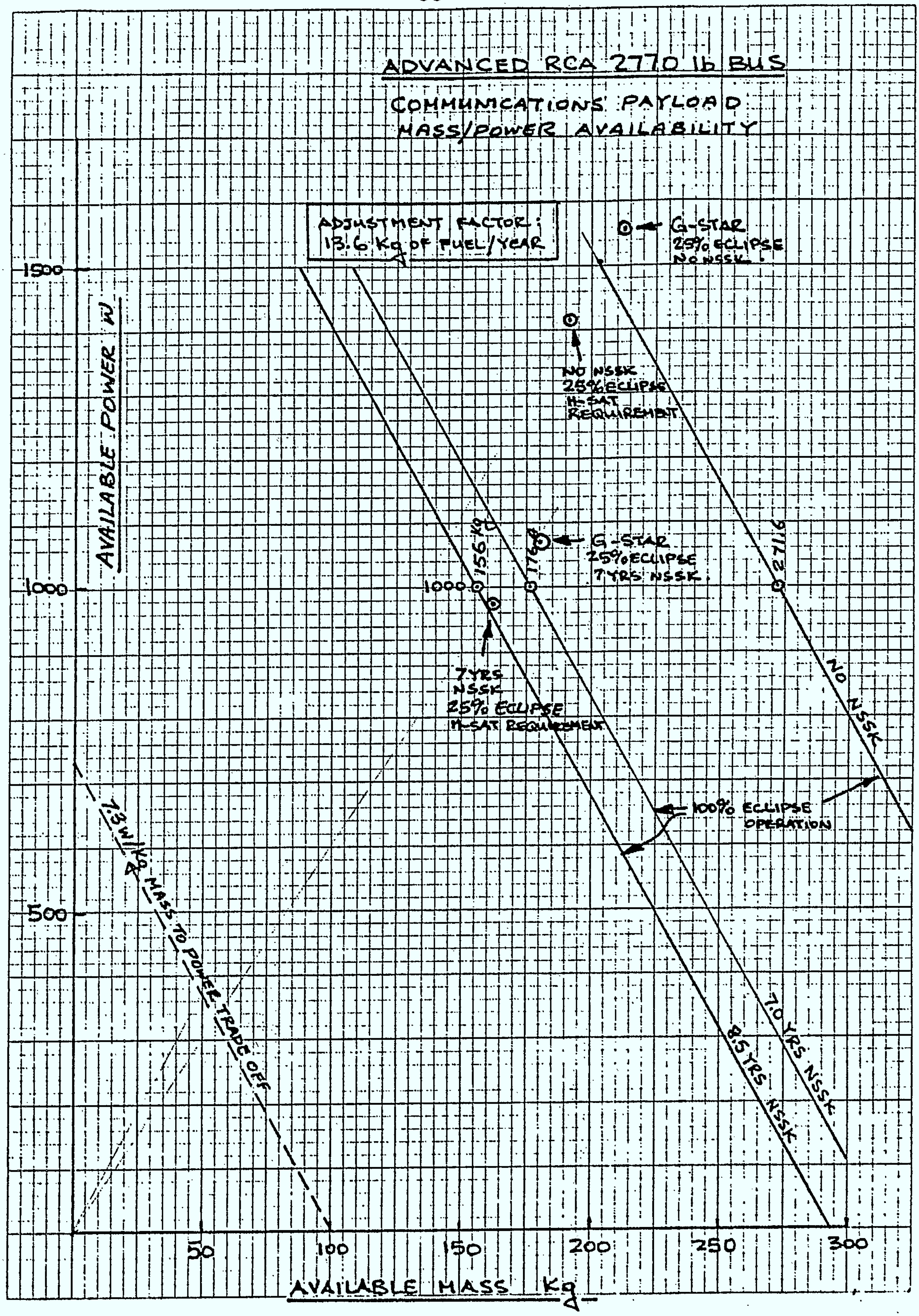


Figure 7.1-1 Payload Mass and Power Envelope of RCA G-STAR

TABLE 7.2-1 COMMERCIAL MOBILE PAYLOAD ON RCA G-STAR BUS

(PREFERRED CONFIGURATION)

General Notes:

1. Eclipse operation power based on 25% of the NBFM channels being active.
2. Capacity (assignable channels):

	Sunlight	Eclipse
NBFM	44	11
PELPC	218	88

3. 4 Beams with on board beam forming network.
4. No NSSK.

Repeater	Mass (Kg)	Sunlight DC Power (w)	Eclipse DC Power (w)
High UHF with Ku Band Backhaul	122.3	1407.3	941.8
Antennas			
30 ft. wrap rib	56.3		
Backhaul	2.7		
T & C	1.8		
Solar Sail	8.2		
TOTAL	191.3	1407.3	941.8
G-STAR capability (No NSSK and batteries reduced by 15.5 Kg for 25% eclipse operation)	213.5	1560	1050
MARGIN	+11.7%	+10.9%	+11.5%

TABLE 7.2-2 COMMERCIAL MOBILE PAYLOAD ON RCA G-STAR BUS

(ALTERNATE CONFIGURATION)

General Notes:

1. Eclipse operation power based on 25% of the NBFM channels being active.
2. Capacity (assignable channels):

	Sunlight	Eclipse
NBFM	26	7
PELPC	147	54

3. 4 Beams with on-board Beam forming network.
4. Full NSSK for 7 years.

Repeater	Mass (Kg)	Sunlight DC Power (w)	Eclipse DC Power (w)
High UHF with Ku Band Backhaul	93.6	971.9	638.4
Antennas			
30 ft. wrap rib	56.3		
Backhaul	2.7		
T & C	1.8		
Solar sail	8.2		
TOTAL	162.6	971.9	638.4
G-STAR Capability (7 yrs NSSK and batteries reduced by 13.3 Kg for 25% eclipse operation)	180.1 Kg	1070 w	720
MARGIN	+10.8%	+10.1%	+12.8%

TABLE 7.2-3 MASS AND POWER BREAKDOWN OF THE HIGH UHF REPEATER

(44 NBFM CHANNELS WITH VOICE ACTIVATION)
(PREFERRED CONFIGURATION)

ITEM	UNIT NAME	Quantity Per S/C	Unit Mass (kg)	Total Mass (kg)	Total DC Power (W)	Total Dissip. (W)
401	SHF/UHF D/C	1	0.54	0.54	1.8	1.8
403/413	IF BFN (Tx & Rx)	2	0.22	0.44	-	-
404/412	RED'Y SWITCH	2 SETS	0.25	0.50	0.6	0.6
405/411	DELAY LINE	-	-	-	-	-
402	UHF U/C	4	0.41	1.64	9.6	9.6
406	UHF PA & EPC	8	8.44	67.52	1338.1	1053.7
407/409	RED'Y SWITCH	2 SETS of 8	0.14	2.24	Pulsed	10.6
408	DUPLEXER	5	0.68	3.40	-	29.3
410	UHF PREAMP	8	0.18	1.44	1.8	1.8
415	UHF/SHF U/C	1	0.47	0.47	0.4	0.4
414	UHF D/C	4	0.30	1.20	1.5	1.5
416	SHF TWTA (10W)	2	3.0	6.00	35	27
417	W/G SWITCH	1	0.64	0.64	Pulsed	-
418A	FREQ. SYNTH.	1	1.30	1.30	5.5	5.5
419	PWR TLM/CMD UNIT	1	2.27	2.27	5.4	5.4
418B	FREQ. SYNTH.	1	1.10	1.10	4.0	4.0
420	BRACKETRY/ HARDWARE	SET	-	0.91	-	-
421	CABLING & WIRE HARNESS	SET	-	10.0	-	-
	HEAT SPREADER PLATES	SET	-	19.2	-	-
	LOW NOISE AMPS	1	0.54	0.54	3.6	3.6
	RECEIVE BPF	1	0.23	0.23	-	-
	RECEIVE BSF	1	0.23	0.23	-	-
	TRANSMIT BPF+LPF	1	0.36	0.36	-	-
	OUTPUT ISOLATOR	1	0.07	0.07	-	-
	TOTAL			122.25	1407.3	1154.8

TABLE 7.2-4 MASS AND POWER BREAKDOWN OF THE HIGH UHF REPEATER

(26 NBFM CHANNELS WITH VOICE ACTIVATION)
(ALTERNATE CONFIGURATION)

ITEM	UNIT NAME	Quantity Per S/C	Unit Mass (kg)	Total Mass (kg)	Total DC Power (W)	Total Dissip. (W)
401	SHF/UHF D/C	1	0.54	0.54	1.8	1.8
403/413	IF BFN (Tx & Rx)	2	0.22	0.44	-	-
404/412	RED'Y SWITCH	2 SETS	0.25	0.50	0.6	0.6
405/411	DELAY LINE	-	-	-	-	-
402	UHF U/C	4	0.41	1.64	9.6	9.6
406	UHF PA & EPC	8	5.64	45.12	902.7	705.2
407/409	RED'Y SWITCH	2 SETS of 8	0.14	2.24	Pulsed	10.6
408	DUPLEXER	5	0.68	3.40	-	29.3
410	UHF PREAMP	8	0.18	1.44	1.8	1.8
415	UHF/SHF U/C	1	0.47	0.47	0.4	0.4
414	UHF D/C	4	0.30	1.20	1.5	1.5
416	SHF TWTA (10W)	2	3.0	6.00	35	27
417	W/G SWITCH	1	0.64	0.64	Pulsed	-
418A	FREQ. SYNTH.	1	1.30	1.30	5.5	5.5
419	PWR TLM/CMD UNIT	1	2.27	2.27	5.4	5.4
418B	FREQ.SYNTH.	1	1.10	1.10	4.0	4.0
420	BRACKETRY/ HARDWARE	SET	0.91	0.91	-	-
421	CABLING & WIRE HARNESS	SET	10.0	10.0	-	-
	HEAT SPREADER PLATES	SET	-	12.9	-	-
	LOW NOISE AMPS	1	0.54	0.54	3.6	3.6
	RECEIVE BPF	1	0.23	0.23	-	-
	RECEIVE BSF	1	0.23	0.23	-	-
	TRANSMIT BPF+LPF	1	0.36	0.36	-	-
	OUTPUT ISOLATOR	1	0.07	0.07	-	-
	TOTAL			93.55	971.9	806.3

TABLE 7.2-5 ANTENNA WEIGHT BREAKDOWN

1.	HIGH UHF ANTENNA		56.3 Kg
	- Wrap rib reflector, 30 ft aperture	18.2Kg	
	- Deployment boom with hinges and spring dampers	17.3Kg	
	- Reflector tie-down brackets and pyros	2.7Kg	
	- Feed horn array, hinge, spring damper	13.6Kg	
	- Coax lines (6-off @ 48 in)	2.7Kg	
	- Feed tie-down brackets & pyros	0.9Kg	
	- Feed thermal blankets	0.9Kg	
		56.3Kg	
2.	SHF PRIMARY ANTENNA		2.7 Kg
	- 15 in. diameter reflector	0.9Kg	
	- Horn plus waveguide feed	0.2Kg	
	- Tower	1.4Kg	
	- Thermal hardware	0.2Kg	
		2.7Kg	
3.	T&C ANTENNAS WITH COAX LINES AND SUPPORT POSTS (2-OFF):		1.8 Kg
4.	SOLAR SAIL		8.2 Kg
	- Mast element, 9 in. x 33 ft.	1.4Kg	
	- Stowage, tie-down, release mechanisms,etc.	4.5Kg	
	- 10 ft x 3 ft Kapton solar sail	2.3Kg	
		8.2Kg	