HUGHES
Space and Communications Group
GOVERNMENT ELECTRONICS SYSTEMS DIVISION

HS256C-1045-0061

FINAL REPORT

FOR THE
HIGH RESOLUTION MICROWAVE SPECTROMETER SOUNDER (HIMSS) INSTRUMENT PROGRAM

APPENDIX : TRMM STUDY

AN INSTRUMENT FOR NASA'S

TROPICAL RAINFALL MEASURING MISSION

APRIL 1991

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HIGH RESOLUTION MICROWAVE SPECTROMETER SOUNDER (HIMSS)

FINAL REPORT

APPENDIX : TRMM STUDY
(A RADIOMETER FOR NASA'S TROPICAL RAINFALL MEASURING MISSION)

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SUBMITTED TO:

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

BY:

HUGHES

SPACE AND COMMUNICATIONS GROUP
GOVERNMENT ELECTRONICS SYSTEMS DIVISION

HS256C-1045-0061

TRMM

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CONCEPTUAL DESIGN REVIEW

RADIOMETER
FOR THE

TROPICAL RAINFALL MEASURING MISSION (TRMM)

GODDARD SPACE FLIGHT CENTER
JANUARY 1991

FINAL REVIEW AGENDA

9:00 INTRODUCTION	T. SMITH/E. LOBL
9:15 RADIOMETER CONCEPT/ REQUIREMENTS/ PERFORMANCE	E. LOBL
10:00 ANTENNA SUBSYSTEM	R. WITTE
10:30 RECEIVER SUBSYSTEM	S. BAGGETT
10:45 SIGNAL PROCESSING SUBSYSTEM	J. CASTRO
11:00 POWER SUBSYSTEM	M. ZWANG
11:10 STRUCTURES, MECHANISMS AND CONTROLS	C. STAMMERJOHN
11:30 QUESTION PERIOD AND WRAP-UP	
12:00 LUNCH	
1:00 CAD ROOM TOUR	
1:30 HARDWARE TOUR: SSM/I THERMAL/MASS MODEL, BAPTA	

TRMM RADIOMETER CONCEPT OVERVIEW

The TRMM radiometer defined during this study meets the intent of the requirements listed in Appendix B.

In order to reduce development and production costs and risks, the TRMM radiometer concept is derived from the architecture of the Special Sensor Microwave/Imager (SSM/I) built for the Defense Meteorological Satellite Program (DMSP). Much of the actual hardware is taken or readily modified from SSM/I hardware. The management approach for the TRMM program also benefits from our experience on the SSM/I Program.

TRMM RADIOMETER CONCEPT OVERVIEW

- TRMM RADIOMETER MEETS THE INTENT OF ALL REQUIREMENTS

- BASELINE CONCEPT DERIVED DIRECTLY FROM SPECIAL SENSOR MICROWAVE/IMAGER (SSM/I)

- TRMM RADIOMETER CONCEPT REPRESENTS LOW RISK APPROACH
  - SSM/I FLIGHT HERITAGE
  - NO CRITICAL TECHNOLOGY ISSUES
  - REALISTIC COSTS AND SCHEDULES

TRMM RADIOMETER CONCEPT BASELINE

TRMM Radiometer is a total power, conically scanning radiometer. Calibration is performed every scan (using the same path that the scene data uses) thus accounting for any changes that might occur from scan to scan.

The advantage that TRMM has over SSM/I is the additional 10 GHz channels. These data will provide sea surface temperature data, an important parameter in understanding the dynamics of the atmosphere.

TRMM RADIOMETER CONCEPT BASELINE

- TRMM RADIOMETER HAS THE SSM/I REFLECTOR, MULTI-FREQUENCY HORN, TIE-DOWN POINTS AND DEPLOYMENT; BAPTA, BAPTA CONTROL ELECTRONICS AND MECHANISMS; RECEIVERS (19 TO 85 GHz), COLD SKY REFLECTOR, POWER SUPPLY AND MOMENTUM WHEEL ASSEMBLY.

- THE MODIFIED OR NEW ELEMENTS ARE: 10GHz HORN AND RECEIVERS, SIGNAL PROCESSING UNIT, AND WARM CALIBRATION LOAD

RADIOMETER HERITAGE

Most TRMM radiometer components are similar to SSM/I. The new 10 GHz horn has its heritage from other Hughes programs. The 10 GHz receiver will have the SSM/I type architecture, with the appropriate local oscillator and the specified bandwidth.

The Signal Processing unit will provide the same function as the SSM/I digital unit. The two reasons for redesigning the unit are obsolete parts and new technology.

RADIOMETER HERITAGE

SUBSYSTEM	HERITAGE
ANTENNA	REFLECTOR, HORN, COLD LOAD:SSM/I 10 GHz HORN: NEW
RECEIVER	19, 22, 37 & 85 GHz RECEIVERS: SSM/I 10 GHz RECEIVER: SSM/I ARCHITECTURE
SIGNAL PROCESSING	UNIT FUNCTIONS:SSM/I UNIT DESIGN: NEW
POWER	ENTIRE POWER SUBSYSTEM: SSM/I
MECHANISMS & CONTROLS	ALL: SSM/I
STRUCTURES	ALL: SSM/I, LARGER SPINNING SECTION

PRELIMINARY SPECIFICATIONS AND PERFORMANCE

The performance of the TRMM radiometer baseline concept are compared to the specification transmitted in Appendix B of the Statement of Work.

The TRMM concept has fewer channels (9) than specified (14). Hughes believes that these 9 channels will meet the intent of the TRMM mission requirements. All the other specifications listed are met by the proposed baseline concept.

PRELIMINARY SPECIFICATIONS AND PERFORMANCE

PARAMETER	BASELINE	SPECIFICATION	COMMENTS
NUMBER OF CHANNELS	9	14	EXTRA CHANNELS CAN BE ADDED AS OPTIONS
RECEIVER TYPE	HETERODYNE WITH REJECTION BAND AROUND LO FREQUENCY	DIRECT DETECTION, OR HETERODYNE WITH REJECTION BAND AROUND LO FREQUENCY	
NADIR ANGLE	46 DEGREES	46 DEGREES	
NADIR ANGLE STABILITY		0.05 DEGREES	
ACTIVE SCAN ANGLE	+/-70° FROM TRACK	+/-70° FROM TRACK	
BEAM CENTER CO-REGISTRATION	<2.5 KM ALONG SCAN <1 KM CROSS SCAN	<3 KM GOAL	
LIFETIME	> 3 YEARS	3 YEARS	
RELIABILITY	>0.8	0.8	

PRELIMINARY SPECIFICATIONS AND PERFORMANCE (CONTINUATION)

The mass and data rate performance have a large margin when compared to the Appendix B Specifications.

The antenna performance is met at all frequencies, except at the highest frequency. More details in the antenna subystem description.

PRELIMINARY SPECIFICATIONS AND PERFORMANCE(CONTINUATION)

PARAMETER	BASELINE	SPECIFICATION	COMMENTS
MAXIMUM MASS, Kg	70.3	88	
MAXIMUM DATA RATE, KBPS	8.5	30	DATA RATE INCREASES WITH SOME OPTIONS
PONTING ERROR	0.15 ° ACROSS SCAN 0.20 ° ALONG SCAN	0.2 ° ACROSS SCAN 0.3 ° ALONG SCAN	
TEMPERATURE ACCURACY, °	< 1.5	1.5	
CALIBRATION STRATEGY	EVERY SCAN THROUGH EARTH-OBSERVATION FEEDS 5 SAMPLES	EVERY SCAN THROUGH EARTH-OBSERVATION FEEDS 4 SAMPLES	
MINIMUM REQUIRED ANTENNA PERFORMANCE%	SEE ANTENNA SECTION	>92 AT ALL FREQUENCIES EXCEPT 90 GHz >90 AT 90 GHZ	THIS REQUIREMENT MET WITH THE SEPARATE FEEDS OPTION

PRELIMINARY SPECIFICATIONS AND PERFORMANCE (CONTINUATION)

This table shows the baseline concept channel frequencies and the correspondent specification. Three of the center frequencies are different. In the baseline the SSM/I channels were kept unchanged in order to minimized the final cost of the TRMM radiometer.

PRELIMINARY SPECIFICATIONS AND PERFORMANCE(CONTINUATION)

PARAMETER	BASELINE		SPECIFICATION		COMMENTS
RF CHANNELS	FREQUENCY, POLARIZATION	TEMPERATURE RESOLUTION	FREQUENCY, POLARIZATION	TEMPERATURE RESOLUTION	
	85.5 V (1)	0.7	90 V (2)	0.7	SPECIFICATION CAN BE ACHIEVED WITH SEPARATE HORN OPTION
	85.5 H (1)	0.7	90 H (2)	0.7	
	37 V (1)	0.4	37 V (2)	0.7	
	37 H (1)	0.4	37 H (2)	0.7	
	22.23 V	0.5	21 V	0.7	
	-	-	21 H	0.7	
	19.35 V	0.5	18 V	0.7	
	19.35 H	0.5	18 H	0.7	
	10.65 V	0.5	10.65 V	0.7	
	10.65 H	0.5	10.65 H	0.7	

SOME UNSPECIFIED PARAMETERS PERFORMANCE
(CONTINUATION)

PARAMETER	BASELINE	SPECIFICATION	COMMENTS
MOMENTUM COMPENSATION, N m	0.226 x axis 0.0057 y&z axes		SSM/I SPECS
IMBALANCE:			
STATIC, N m	0.2		SSM/I SPECS
DYNAMIC, Kg m^2	0.0035		
HEAT TRANSFER (RADIATIVE & CONDUCTIVE), W	< 10		

TORQUE DISTURBANCE
STATIC IMBALANCE ANALYSIS

SOURCE	STATIC IMBALANCE (IN-LB) SSM/I SN 005	STATIC IMBALANCE (IN-LB) HIMSS DESIGN*	HIMSS RATIONALE
MRC READOUT ERROR	0.330	0.100	MRC SPEC.
BEARING RUNOUT	0.291	0.060	2 ARC SEC. CONING 0.0003 in. BEARING PLAY
TILT & ECCENTRICITY	0.201	N/A	ELIMINATED BY CLOCKING BAPTA DURING BALANCING
GATE LINK LOCATION	0.021	0.021	
WATER LOSS IN ORBIT	0.031	0.062	2X SSM/I VALUE(TBD)
GRAVITY EFFECT	0.003	0.090	.003 in. REFLECTOR OFFLOAD ERROR ESTIMATE
DEPLOYMENT REPEATABILITY	0.156	0.148	0.01° HINGE REPEATABLILTY
THERMAL BLANKET INSTALLATION	0.140	0.280	2X SSM/I VALUE(TBD)
I) RSS OF UNCERTAINTIES	±0.529	±0.355	
II) 3σ MEASUREMENT VARIATION	±0.08	±0.08	SSM/I VALUE(TBD)
II) RSS OF I & II	±0.535	±0.364	
IV) STATIC IMBALANCE (MEASURED)	±0.1	±0.1	SSM/I VALUE(TBD)
V) TOTAL STATIC IMBALANCE	0.1±0.535	0.1±0.364	
VI) WEIGHT OF SENSOR, LB	85	209	
MAXIMUM STATIC OFFSET, IN (V/VI)	0.0075	0.0022	
SPECIFIED STATIC OFFSET,IN	0.013	TBD	

*(11/27/89 update)

REFERENCE NO. 891127-ADC-5

1 in lb = 0.113 Nm

TORQUE DISTURBANCE

DYNAMIC IMBALANCE ANALYSIS

SOURCE	DYNAMIC IMBALANCE (LB-IN^2) SSM/I SN 005	DYNAMIC IMBALANCE (LB-IN^2) HIMSS DESIGN*	HIMSS RATIONALE
BEARING RUNOUT	2.45	2.10	2 ARC SEC. CONING 0.0003 in. BEARING PLAY
TILT & ECCENTRICITY	2.51	N/A	ELIMINATED BY CLOCKING BAPTA DURING BALANCING
GATE LINK LOCATION	0.26	0.26	
WATER LOSS IN ORBIT	0.61	2.4	4X SSM/I VALUE(TBD)
GRAVITY EFFECT	0.06	8.60	.003 in. REFLECTOR OFFLOAD ERROR ESTIMATE
DEPLOYMENT REPEATABILITY	3.53	14.8	0.01° HINGE REPEATABLILTY
THERMAL BLANKET INSTALLATION	0.61	2.4	4X SSM/I VALUE(TBD)
BALANCE WEIGHT INSTALLATION	1.00	4.0	4X SSM/I VALUE(TBD)
I) RSS OF UNCERTAINTIES	±5.16	±18.03	
II) 3σ MEASUREMENT VARIATION	±3.67	±3.67	SSM/I VALUE(TBD)
III) RSS OF I & II	±6.33	±18.4	
IV) DYNAMIC IMBALANCE (MEASURED)	1.54	1.54	SSM/I VALUE(TBD)
V) TOTAL DYNAMIC IMBALANCE	1.54±6.33	1.54±18.4	(0.0059 kg m^2 max)
MAXIMUM DYNAMIC IMBALANCE, LB-IN^2 (KG-M^2)	7.87 (0.0023)	20.0 (0.0059)	
SPECIFIED DYNAMIC IMBALANCE, LB-IN^2	12	TBD	

*(11/28/89 update)

REFERENCE NO. 891207-ADC-5b

$1\ \text{lb in}^2 = 2.93 \times 10^{-4}\ \text{kg m}^2$

TRMM

DATA HANDLING REQUIREMENTS

(BASELINE)

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SPIN RATE:	44 RPM
SPIN PERIOD:	1.37 SEC
ACTIVE SCAN ANGLE:	140 DEGREES
ACTIVE SCAN PERIOD:	0.53 SEC

VIDEO DATA

CH FREQ, GHz	QTY	INT TIME, mSEC	SAMPLES/SCAN
10.7	2	5.8	184
19.4	2	5.8	184
22.2	1	5.8	92
37	2	5.8	184
85.5	2	5.8	184
			828

CALIBRATION DATA

CH FREQ, GHz	COLD SAMPLES	WARM SAMPLES	POLARIZATION	TOTAL
10.7	5	5	2	20
19.4	5	5	2	20
22.2	5	5	1	10
37	5	5	2	20
85.5	5	5	2	20
				90

GAIN DATA	9
STATUS TELEMETRY	18
PACKET HEADER	36

TOTAL WORDS	981
TOTAL BITS	11772
AVERAGE BIT RATE	8.6 KBPS

BLOCK DIAGRAM

The TRMM radiometer consists of 5 major subsystems: the antenna subsystems, the receiver subsystem, the signal processing subsystem, the power subsystem, and the structures and mechanisms and controls subsystem.

The reflector and feedhorns collect RF energy emitted by the Earth which is then conducted to the receiver subsystem via coaxial cables and waveguide. In the receiver, the signals from the 9 baseline channels are amplified, downconverted, reamplified, and detected.

The signal processing subsystem multiplexes the channels and performs an analog-to-digital conversion. The resulting science data are multiplexed with instrument telemetry data and then read out to the spacecraft. Commands from the spacecraft are routed to the signal processing unit for distribution within the TRMM radiometer.

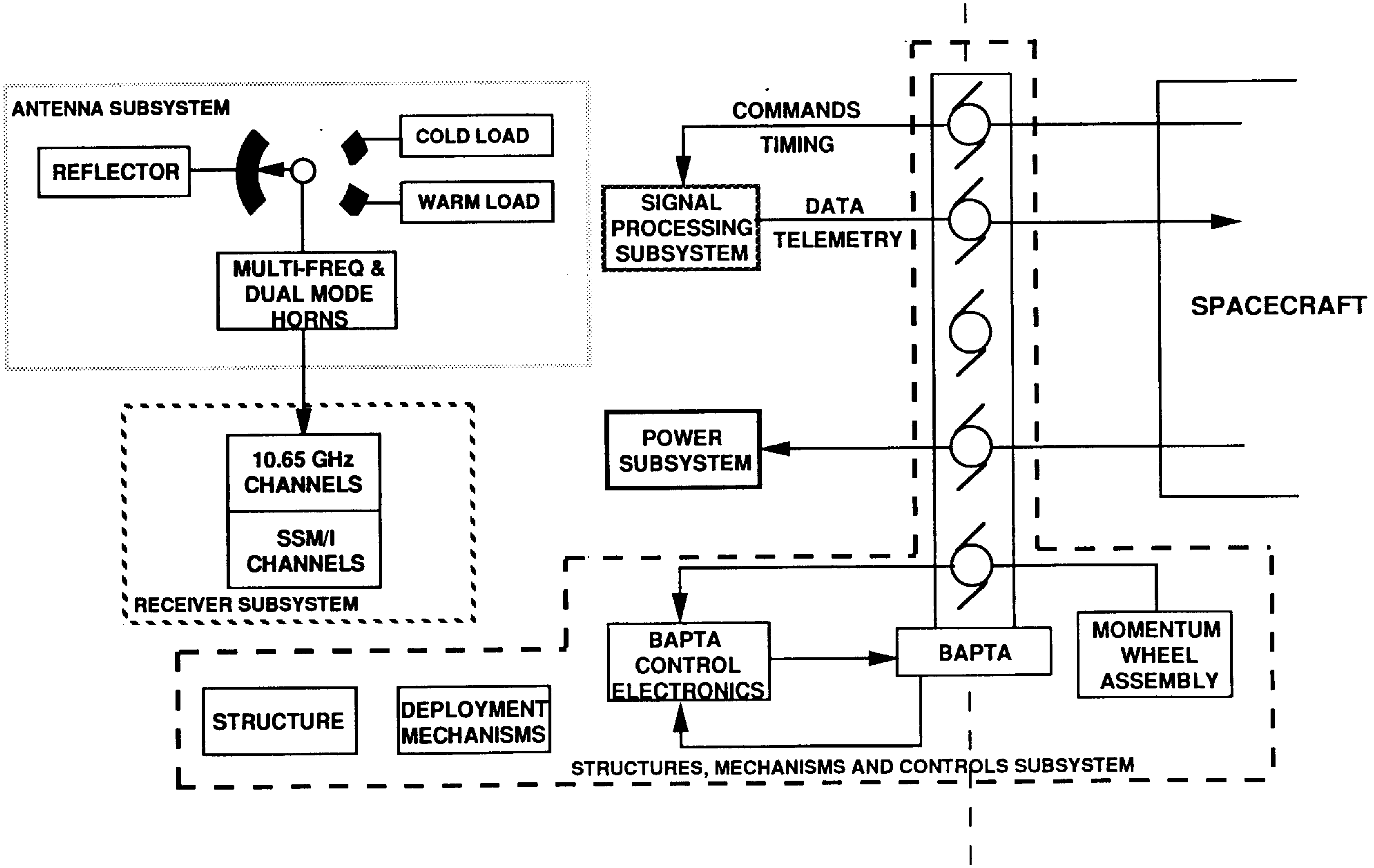
The spun compartment is supported and spun by the bearing and power transfer assembly (BAPTA). The BAPTA motor speed is controlled by the BAPTA control electronics (BCE). The angular momentum of the spun section is compensated by the momentum wheel assembly (MWA). The combined angular momentum of the spun section and MWA is maintained equal to zero by the BCE.

Power for all electronics and motors is provided by the power subsystem.

TRMM

BLOCK DIAGRAM

HUGHES



TRMM MASS AND POWER BUDGETS

The TRMM radiometer mass is 63.9 kg. Most of these data are actual values from SSM/I. A 10% contingency is included.

The power consumption estimate is 49.8 watts. This includes a 10% contingency.

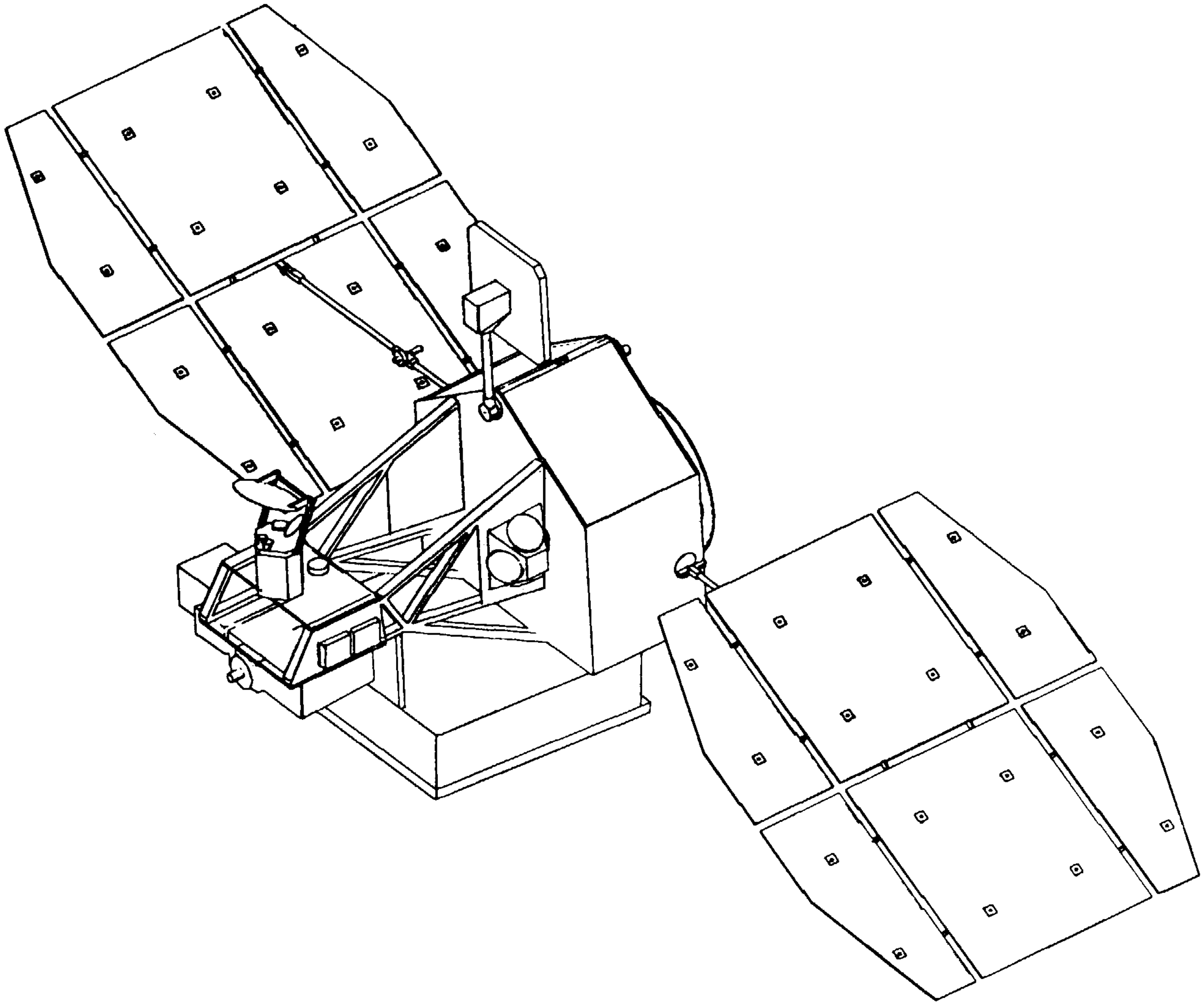
TRMM MASS AND POWER BUDGETS

	MASS, Kg	POWER, Watts
ANTENNA SUBSYSTEM	8.2	--
RECEIVER SUBSYSTEM	12.2	17.3
SIGNAL PROCESSING	2.4	2.1
STRUCTURES AND MECHANISMS	15.6	--
BAPTA AND BCE	12.3	5.5
MOMENTUM WHEEL	9.1	15.0
POWER SUBSYSTEM	2.1	5.4
BALANCE WEIGHTS	2.0	--
SUBTOTAL	63.9	45.3
CONTINGENCY (10%)	6.4	4.5
TOTAL	70.3	49.8

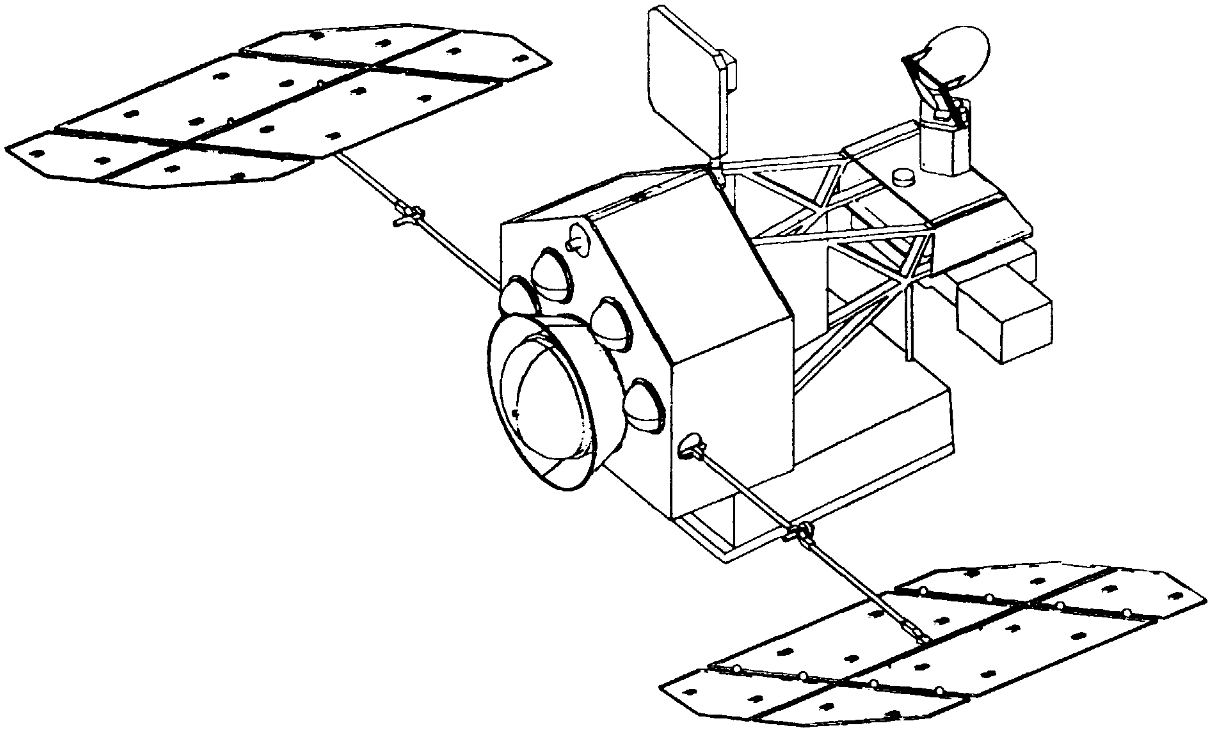
ANTENNA SUBSYSTEM

TASK MANAGER
R. WITTE

TRMM SPACECRAFT



TRMM SPACECRAFT



TRMM

TRMM SPACECRAFT

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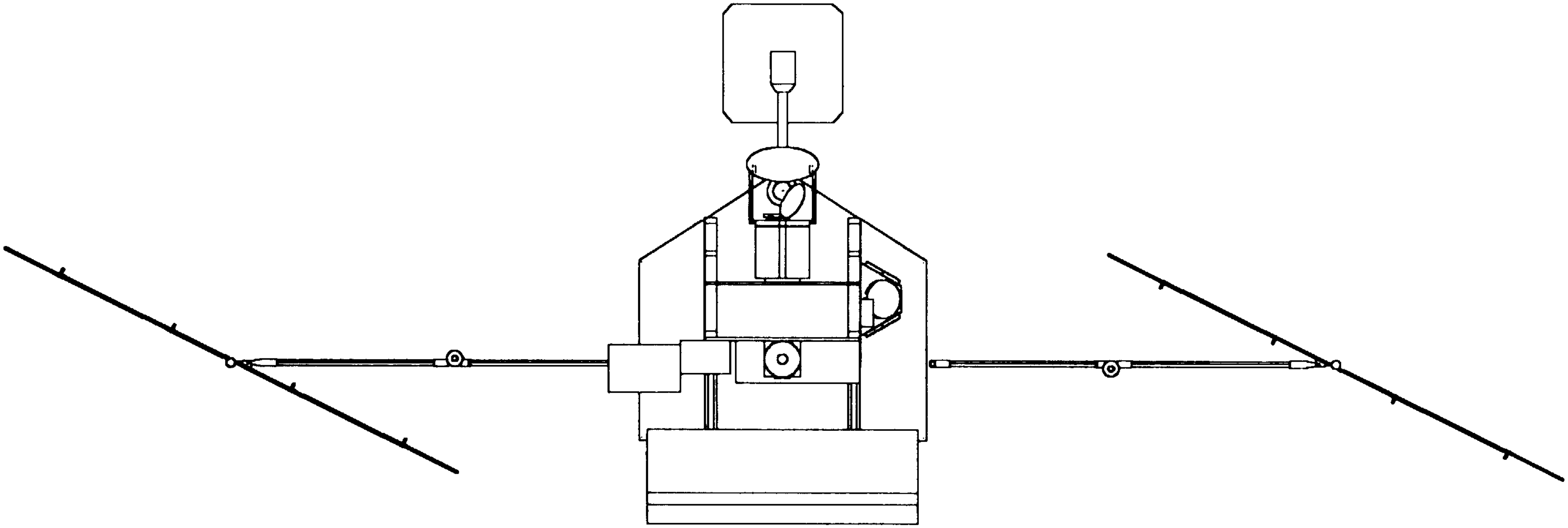

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TRMM SPACECRAFT

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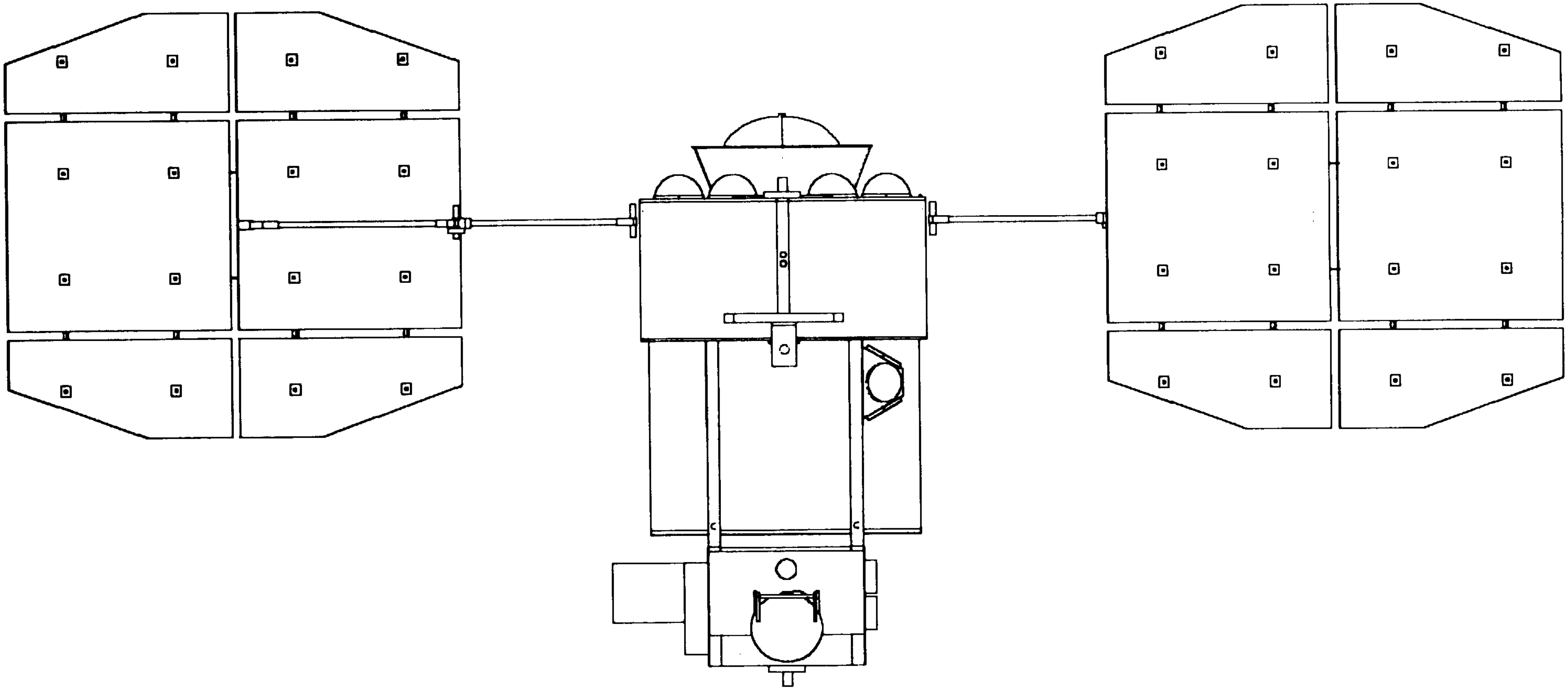
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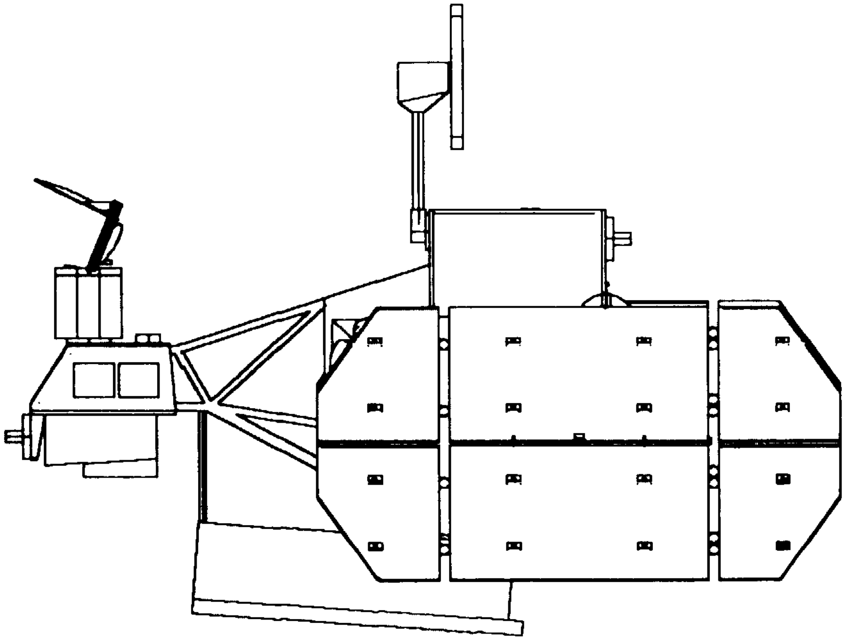
TRMM SPACECRAFT



ANTENNA SUBSYSTEM ELEMENTS

The antenna system is comprised of four major groups which all work in concert with each other. An offset, parabolic reflector is designed to capture the microwave energy radiated from the earth and direct it to a multi-frequency feed system. The system accepts microwave energy at several widely spaced discrete frequencies and with dual, orthogonal linear polarizations. For calibration of the system a cold sky reflector and warm load assembly are interposed between the main reflector and feed cluster on every revolution of the antenna to present known and controlled temperatures to the feeds.

ANTENNA SUBSYSTEM ELEMENTS

- REFLECTOR
- FEEDHORN ARRAY:
  - SSM/I HORN AND A SEPARATE 10.65 GHz HORN
- COLD CALIBRATION LOAD (COLD SKY REFLECTOR)
- WARM CALIBRATION LOAD

SSM/I - TRMM COMPARISON

The antenna requirements and goals for the TRMM radiometer are very close to the performance achieved on the seven Hughes manufactured SSM/I antennas. The table compares SSM/I to the proposed antenna for TRMM. A significant difference in requirements is the 10.65GHz lowest frequency for TRMM. The lowest frequency for SSM/I was 19.35GHz.

The SSM/I has both vertical and horizontal ports for all but the 21GHz band. A major redesign would be required to add a horizontal polarization port so it is proposed to omit this polarization from the 21GHz TRMM requirement.

SSM/I - TRMM COMPARISON

PARAMETER	SSM/I	TRMM	CHANGES
VIEW ANGLE	± 51°	±70°	RELOCATE WARM LOAD AND COLD SKY REFLECTOR
REFLECTOR DIAMETER, M	0.6	0.6 BASELINE (1.0 OPTION)	NO CHANGE NEW STRUCTURE, STOW/DEPLOY, NEW DESIGN, DRAWINGS, QUAL
FREQUENCY RANGE, GHz	19.35 - 85.5	10.65 - 85.5 (90)	ADDED A 10.65 GHz HORN (RETUNE SSM/I HORN FOR OPTION FREQUENCIES)
FEED HORN	SINGLE MULTI-FREQUENCY	1 MULTI-FREQUENCY 1 SINGLE FREQUENCY	REDESIGN SPINNING STRUCTURE, RECEIVER/WAVEGUIDE LAYOUT, BRACKETS FOR NEW HORN
WARM LOAD	1.5 cm PYRAMID HT 10.7 cm x 12.4 cm	2.5 cm PYRAMID HT 10.7 cm x 13.2 cm	PYRAMID HEIGHT SCALED FOR 10.65 GHz PERFORMANCE SMALL CHANGE IN SIZE
COLD SKY REFLECTOR	17.3 cm x 19.3 cm APERTURE 8.4 cm FOCAL LENGTH	SAME AS SSM/I	NO CHANGE

FEED SYSTEM

Hughes proposes a minimal impact approach from SSM/I to satisfy the TRMM goals. The TRMM feed system would use the present SSM/I multi-frequency feed at the reflector focus with a 10.65GHz dual mode horn mounted next to the SSM/I feed. The approach has been chosen to minimize the feed cost and the impact on the cold sky reflector and warm load sizes. The SSM/I feed horn and the 10.65GHz feed horn are different types of horns. The SSM/I horn is a very broadband corrugated wall horn called a scalar horn. The scalar feed radiation pattern beamwidth is controlled primarily by the flare angle of the horn and is essentially independent of the aperture size. However, in order to support the necessary fields for the broadband performance, the aperture size of the scalar horn must be several wavelengths in diameter at the lowest frequency. The 4 inch SSM/I horn aperture size is 6.5 wavelengths at 19.35GHz. To redesign the scalar horn to operate at 10.65GHZ would require the aperture diameter to grow to 7.2 inches, almost double the SSM/I aperture size. Therefore, the warm load and cold sky reflector sizes would also almost double in order to accommodate the larger horn. On the other hand, the aperture diameter of the dual mode horn is required to be only 2.84 wavelengths at 10.65GHz, 3.15 inches. The aperture diameter is smaller than the SSM/I scalar horn at the lower 10.65GHz and with the same radiation pattern beamwidth. The dual mode horn can support 10% frequency bandwidth and possesses excellent beam symmetry, low cross polarization and low sidelobes which is an ideal feed for a radiometer reflector system. The advantage of the add-on dual mode 10.65GHz horn is quite evident.

There are some small differences between the desired TRMM frequencies and those for SSM/I between 18 and 90GHz. Modification of the SSM/I multi-frequency scalar horn to accommodate the TRMM frequencies requires changing the rejection/pass filters used in the feed output ports. This modification to the SSM/I feed is possible with minimal non-recurring design to modify the filters and empirically resolve possible interactions between the various ports.

The SSM/I has both vertical and horizontal ports for all but the 21GHz band. A major redesign would be required to add a horizontal polarization port so it is proposed to omit this polarization from the 21GHz TRMM requirement.

TRMM

Feed System

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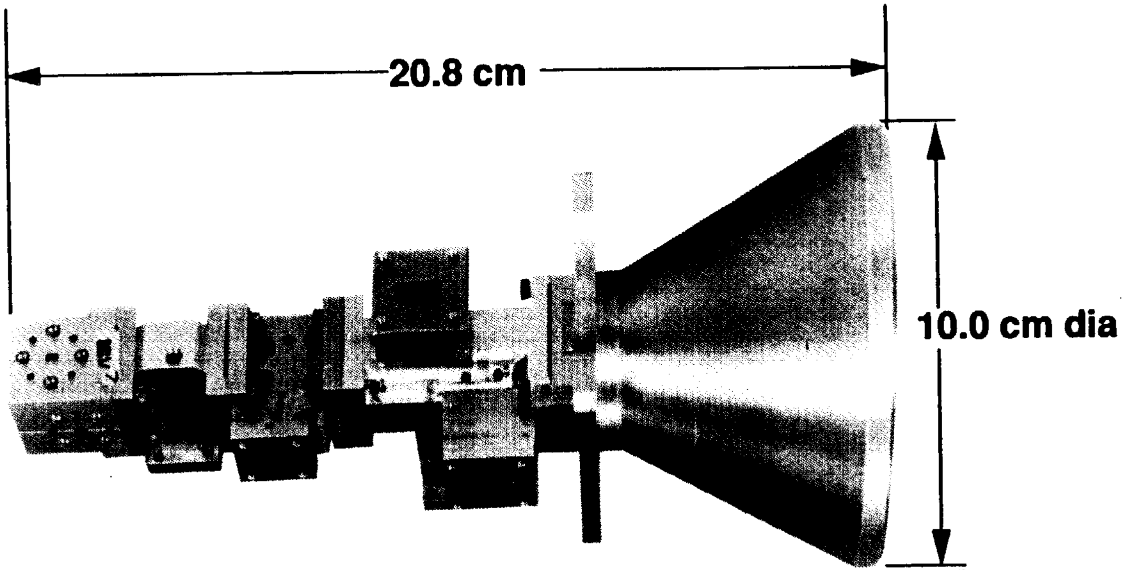

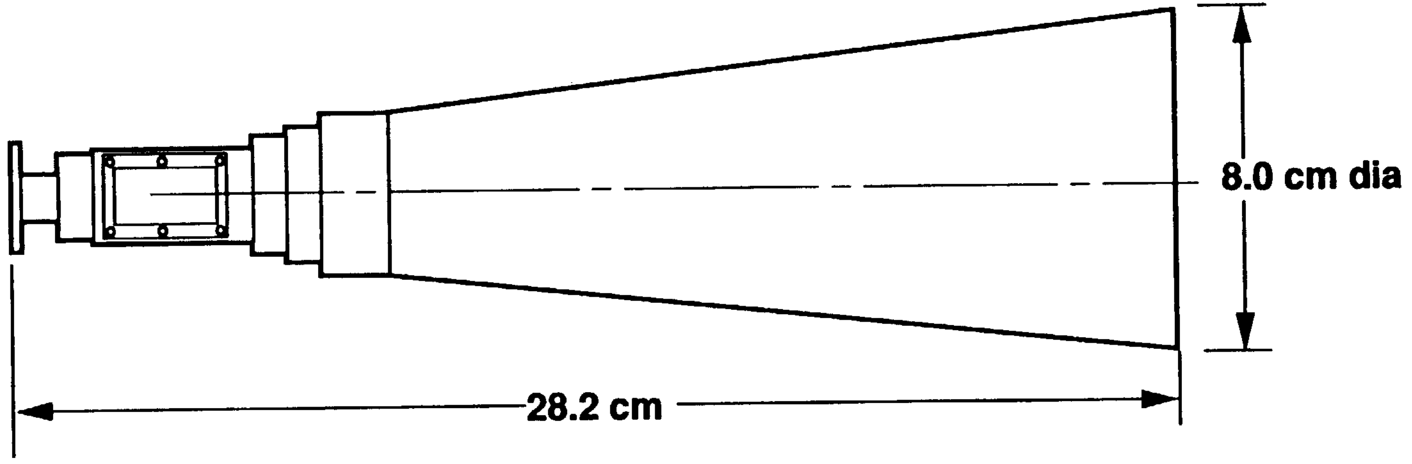

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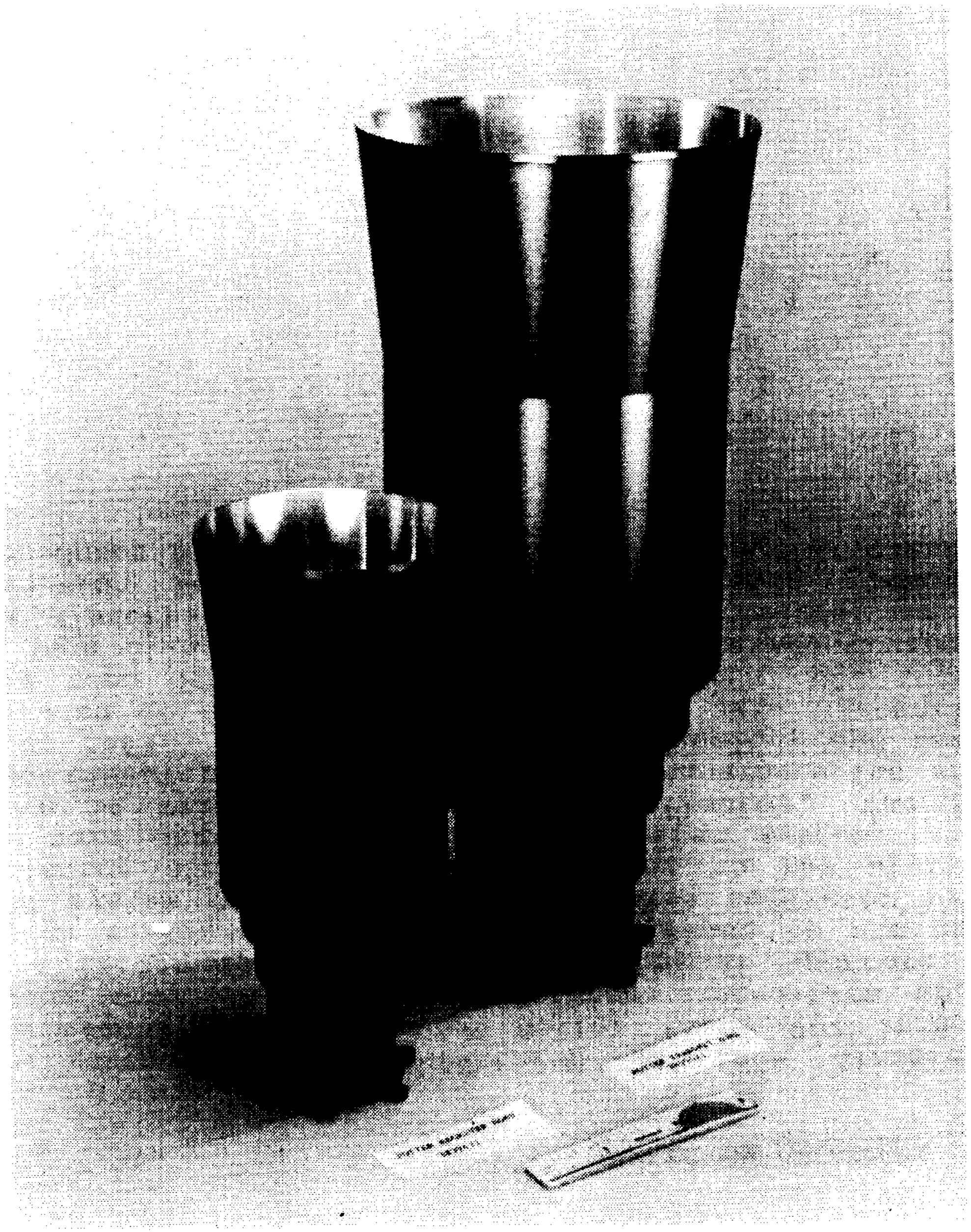
DUAL MODE HORNS

Hughes Aircraft has extensive design experience in dual mode horns; transmit and receive feeds arrays (see figure) for Intelsat VI and SAP395; global coverage horns for Intelsat VI (C-Band), Leasat (X-Band), UHF Follow-On (X-Band) and EHF Band.



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Dual Mode Horns

TRMM

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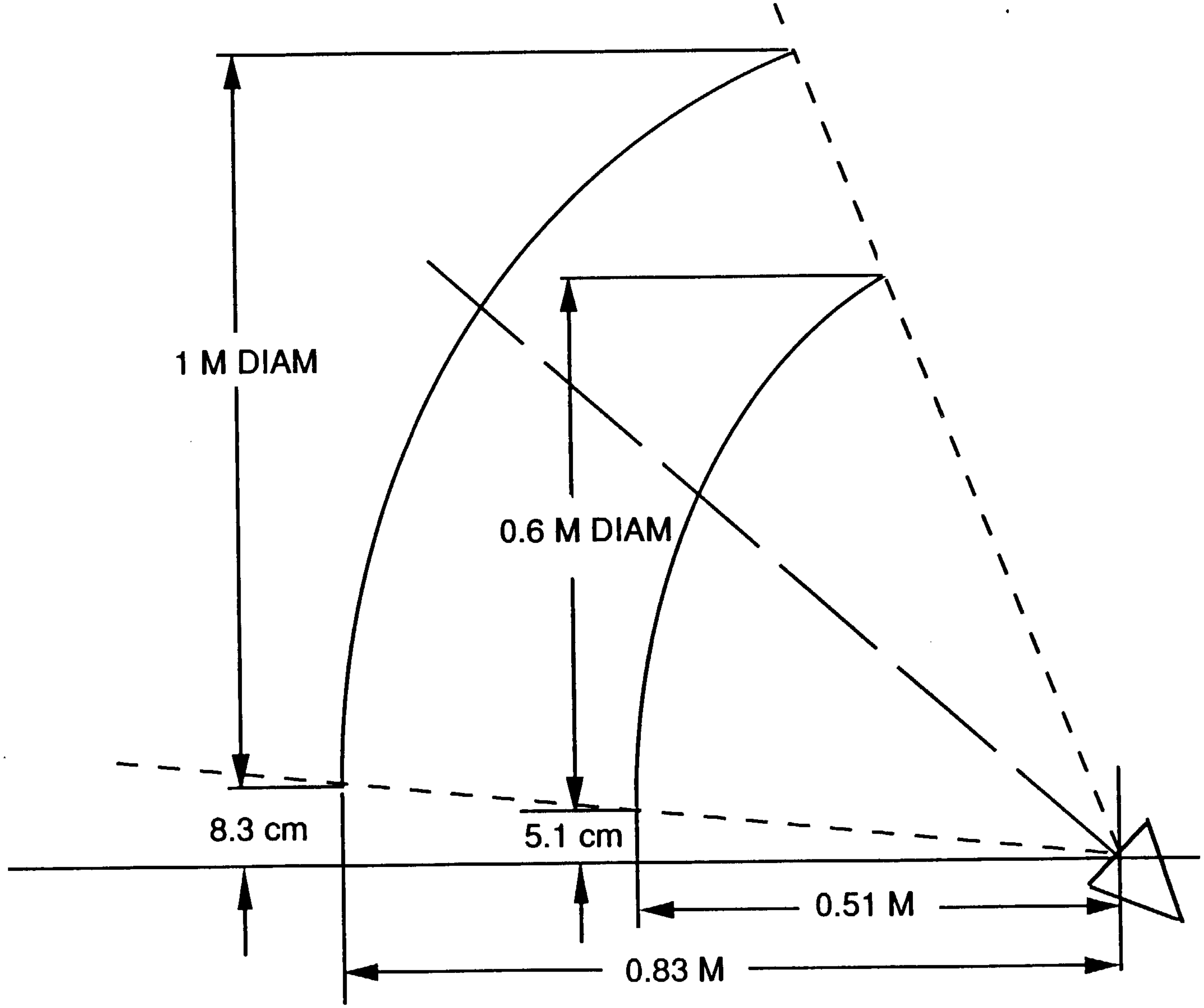
REFLECTOR GEOMETRY

The seven Hughes Manufactured 24 inch diameter SSM/I graphite reflectors consistently have achieved better than .002 inch RMS surface tolerances which causes only small beam efficiency degradation up to 90GHz. The consideration of a larger reflector up to 1 meter in aperture diameter does not present any design risks. A minimum design approach to the antenna is shown where the same feed system can be used for any size reflector by scaling the focal length and reflector offset dimension according to the aperture size in order to present the same angular geometry to the feed system. A 1 meter aperture diameter is shown in relation to the SSM/I reflector. The Hughes Antenna Systems Product Line (ASPL) has been designing and manufacturing space borne composite reflectors since 1961. The design, process technology and facilities have been continuously upgraded to the current state of the art. Recently two new graphite reflectors have been designed and manufactured with .002 inch RMS surfaces in 36 inch and 44 inch diameter apertures. Low temperature curing autoclave processes, graphite low distortion mandrels, and humidity control are features employed to achieve precesion reflectors. In-house precision photogrammetry is part of Hughes procedures for measuring reflector surface characteristics.

REFLECTOR GEOMETRY



WARM LOAD PYRAMID DIMENSIONS

Hughes proposes to scale the SSM/I pyramid dimensions to shift the SSM/I reflectivity performance down to the 10.65GHz frequency for TRMM. The proposed dimensions are shown. Because of the large physical aperture of the SSM/I multi-frequency scalar horn the reflection effects from approximately 50 of the pyramids will be integrated at any given time in the calibration period so the high frequency performance of the redesigned warm load for TRMM can be expected to have low reflectivity.

TRMM

WARM LOAD PYRAMID DIMENSIONS

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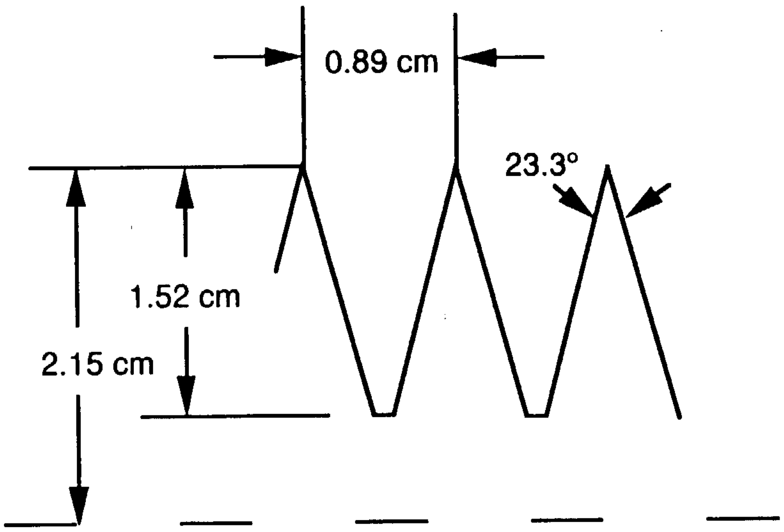
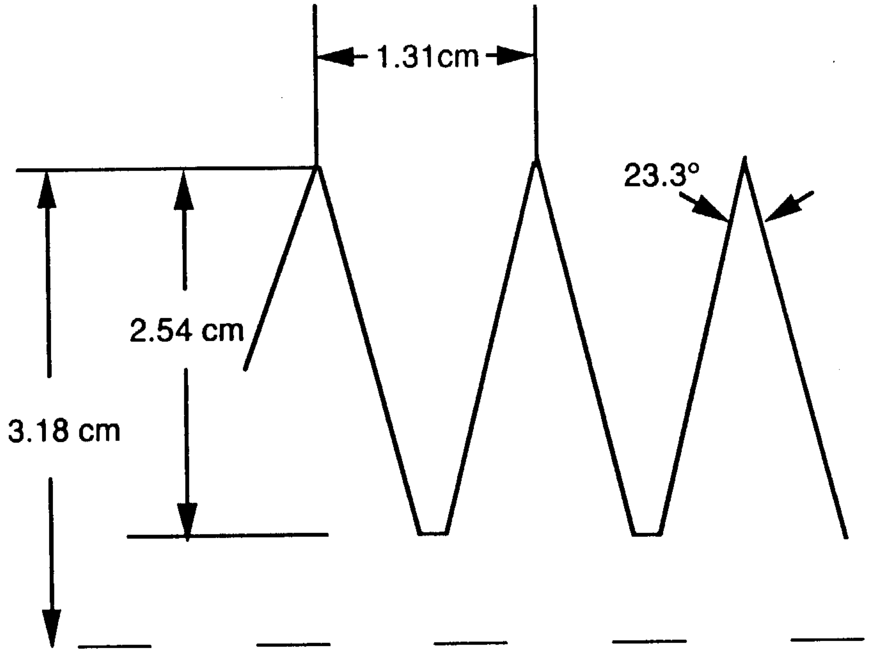


a) SSM/I (19 GHz MIN)



b) TRMM (10.65 GHz MIN)

SSM/I WARM LOAD (HERITAGE)

The SSM/I warm load as shown was designed to have low reflectivity from 19.35 to 85.5GHz. At 10.65GHz it could be expected to degrade although it was never measured below 19.35GHz. The degradation would be due to two possible features of the load design. The first is that the pyramid dimensions become significantly smaller in terms of wavelengths. In fact, the SSM/I pyramid height would be very close to one wavelength at 10.65GHz. The second design feature is the absorption in the dissipative coating which is less at 10.65GHz due to lower attenuation factor and smaller thickness in wavelengths.

TRMM

SSM/I Warm Load

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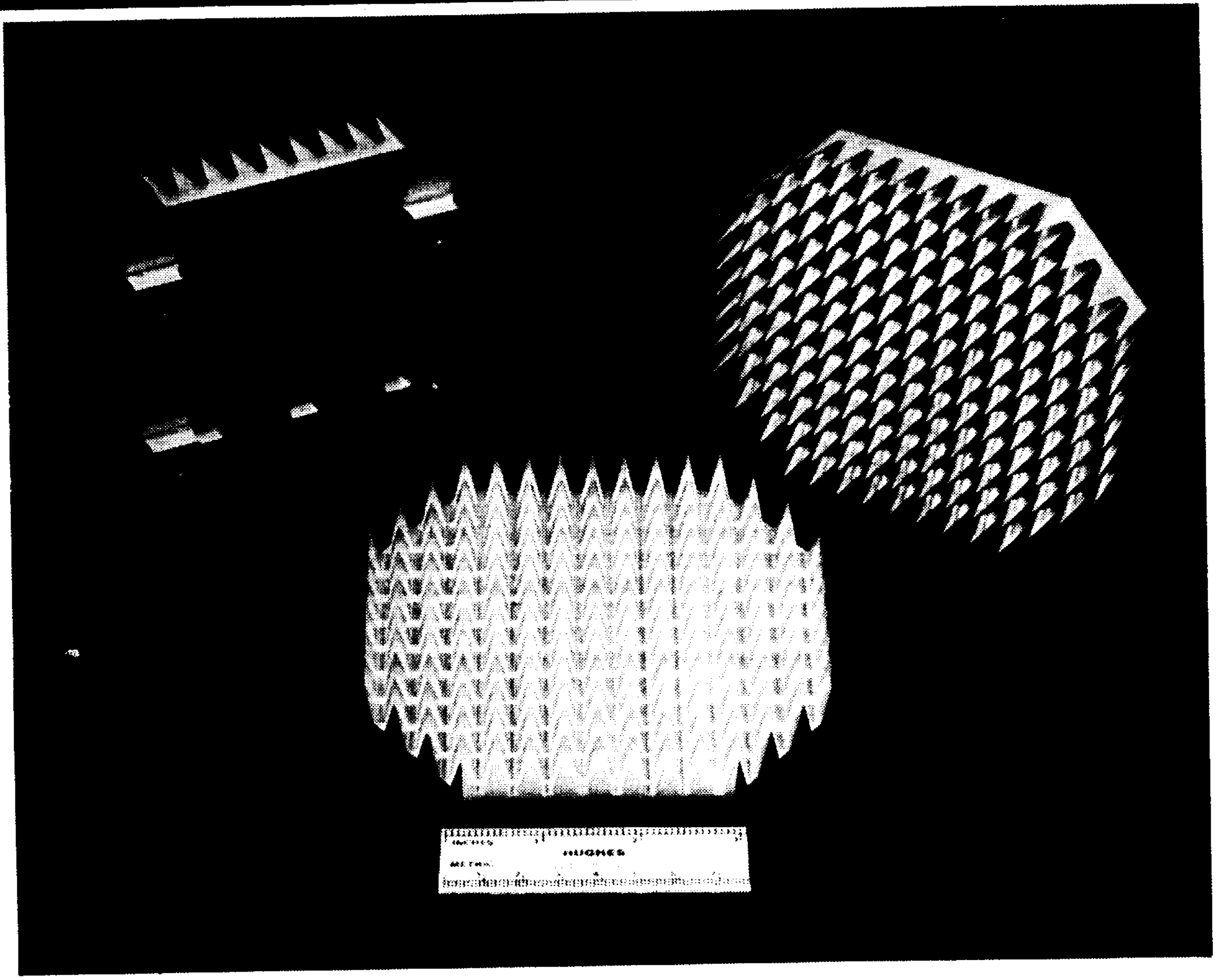

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COLD SKY REFLECTOR

The additional 10.65GHz horn has a smaller aperture diameter than the SSM/I horn and therefore it is anticipated that the SSM/I Cold Sky Reflector as shown can be used without modification. The radiation pattern at 10.65GHz, however, is expected to be broader and require a larger clear field of view to space than SSM/I. The placement of the cold sky reflector depends on the platform geometry while also being somewhat limited due to the wide ±70° scan range of the radiometer.

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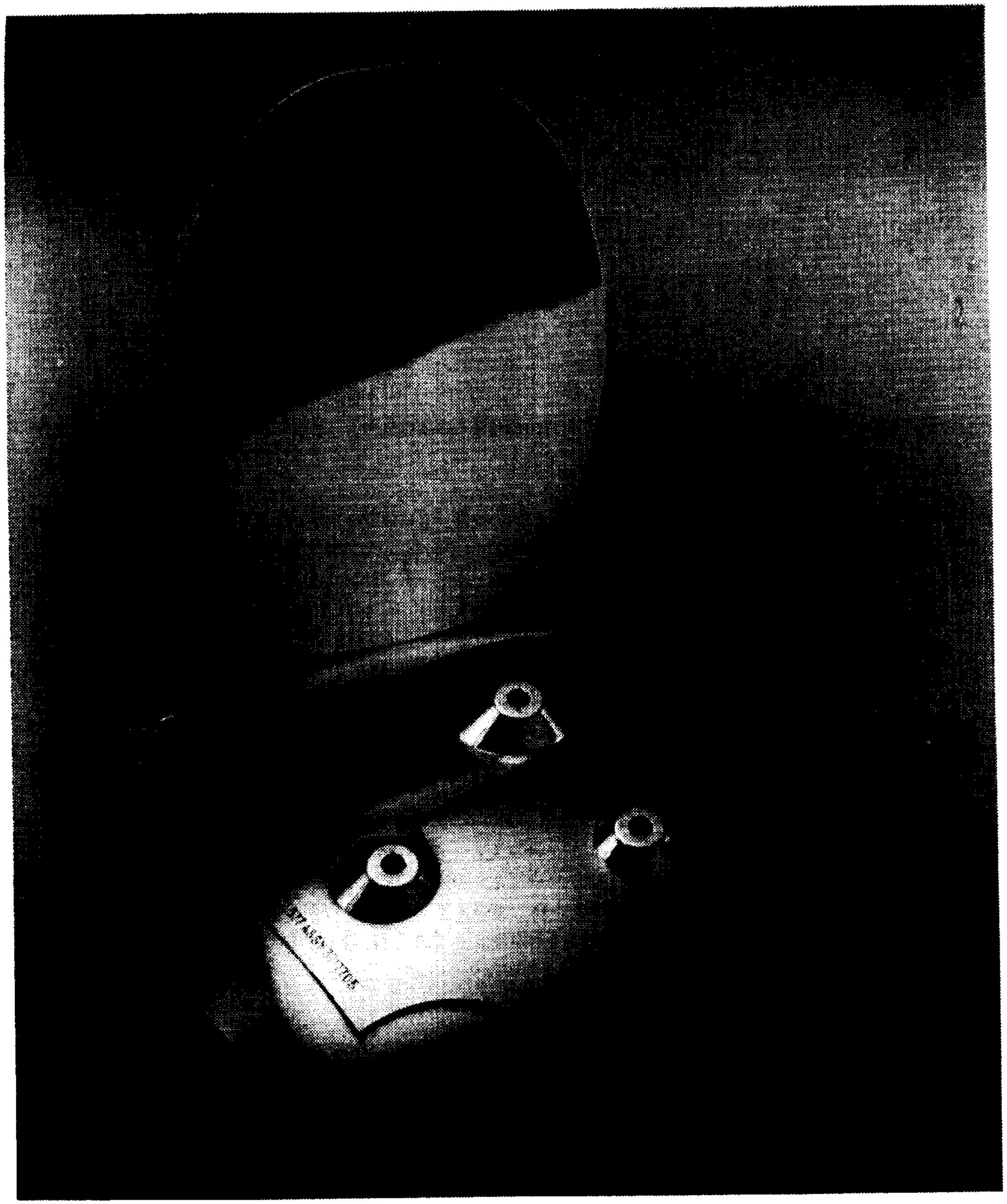


HUGHES

SSM/I Cold Sky Reflector

902500-3

TRMM

2180-2007

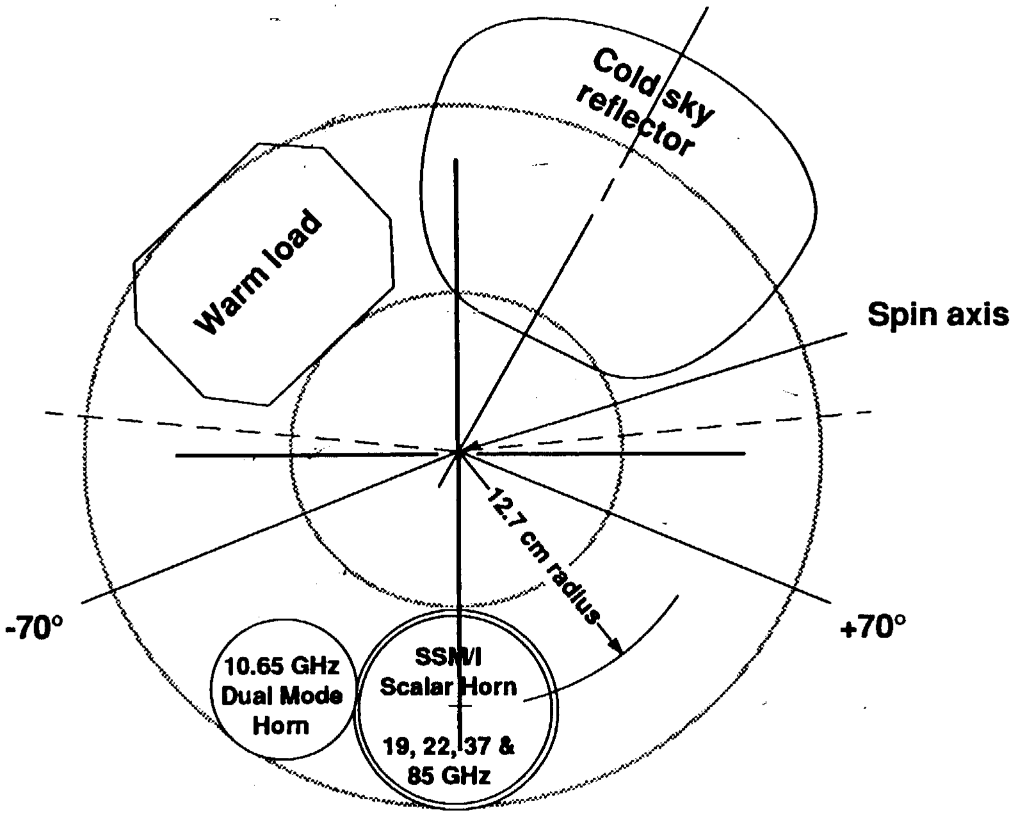
CALIBRATION LOADS AND ROTATING FEED LOCUS

The antenna subsystem receives microwave energy from earth. At an instant in time only the energy from a particular footprint is desired. The antenna pattern is required to minimize the collection of microwave energy from the earth outside of the footprint and from any other source such as the spacecraft and other payloads. As the spacecraft is moving relative to the earth, the footprint is also swept transverse to the velocity direction by rotating the antenna about the nadir axis allowing the beam to collect energy over a ±70° arc of the earth's surface. The calibration of the system is dependent upon the antenna to alternately collect energy solely from a cold and warm source of known and controlled temperatures.

For calibration of the system a cold sky reflector and warm load assembly are interposed between the main reflector and feed cluster on every revolution of the antenna to present known and controlled temperatures to the feeds.

The accompanying figure shows the elements as viewed from the main reflector looking down the spin axis.

Calibration Loads and Rotating Feed Locus



BEAM EFFICIENCY ESTIMATE FOR 10.65GHz

Because the 10.65GHz horn is laterally displaced from the reflector focal axis and has some axial defocusing due the phase center being near the horn aperture plane there will be some degradation to beam efficiency.

These effects have been analyzed by computer simulation to show that the predicted beam efficiency will exceed 90% allowing for imperfections in the reflector and feed alignment as shown in the table.

BEAM EFFICIENCY ESTIMATE FOR 10.65 GHz

THEORETICAL		0.9180
REFLECTOR SURFACE TOLERANCE	RANDOM	0.9995
	SYSTEMATIC	1.0000
STRUCTURE DEFLECTION		1.0000
FEED ERRORS		0.9993
POLARIZATION MISALIGNMENT		0.9988
PREDICTED		0.9160

10.65GHz CONTOUR PATTERN PLOT

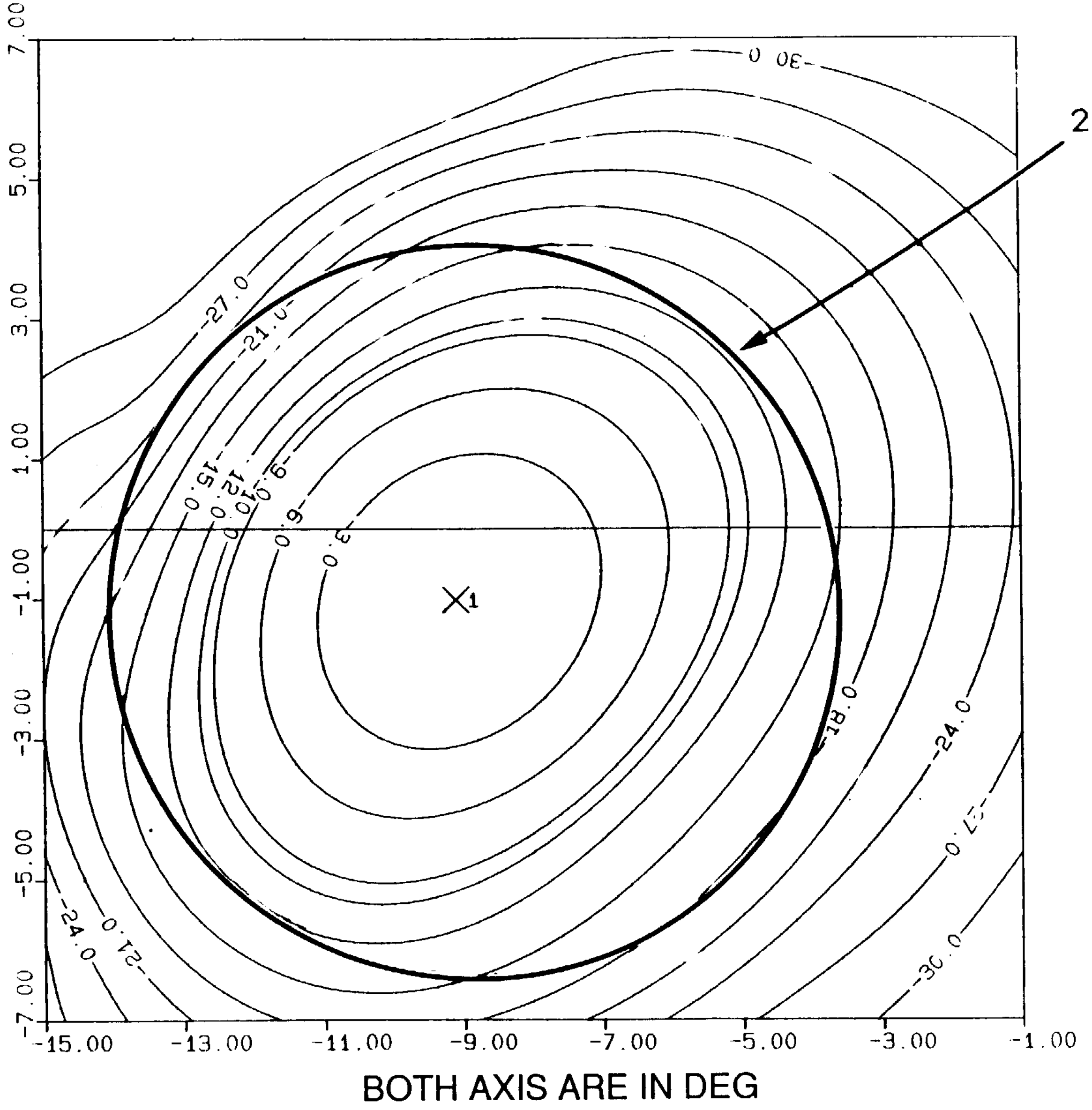
Because the 10.65GHz horn is laterally displaced from the reflector focal axis and has some axial defocusing due the phase center being near the horn aperture plane there will be some degradation to beam efficiency.

The computed pattern shows the effects of the defocusing in the figure. The equal-potential field contours are plotted and the 2.5-times-the-average 3dB beamwidth circle superimposed. The computed beam efficiency including these defocusing effects is 91.8 percent

TRMM

SSM/I MAIN REFLECTOR 10.65 GHz CONTOUR PATTERN PLOT

HUGHES



2.5 times the average 3dB beamwidth

BEAM EFFICIENCY

The antenna requirements and goals for the TRMM radiometer are very close to the performance achieved on the seven Hughes manufactured SSM/I antennas.

The TRMM beam efficiency goal is 92% at 10.65, 18, 21, and 37GHz and 90% at 90GHz.

The accompanying table summarizes and compares the SSM/I and TRMM beam efficiency data with the recommended specifications for the proposed TRMM antenna.

A little margin between the predicted and recommended beam efficiency specification values is needed to accommodate possible interaction between the feeds and measurement tolerances.

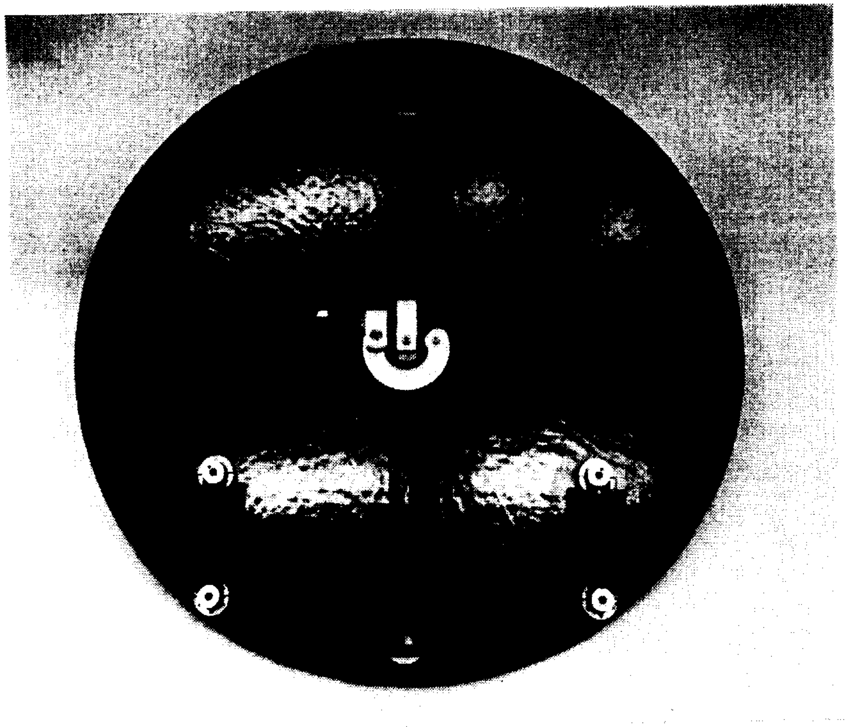
BEAM EFFICIENCY

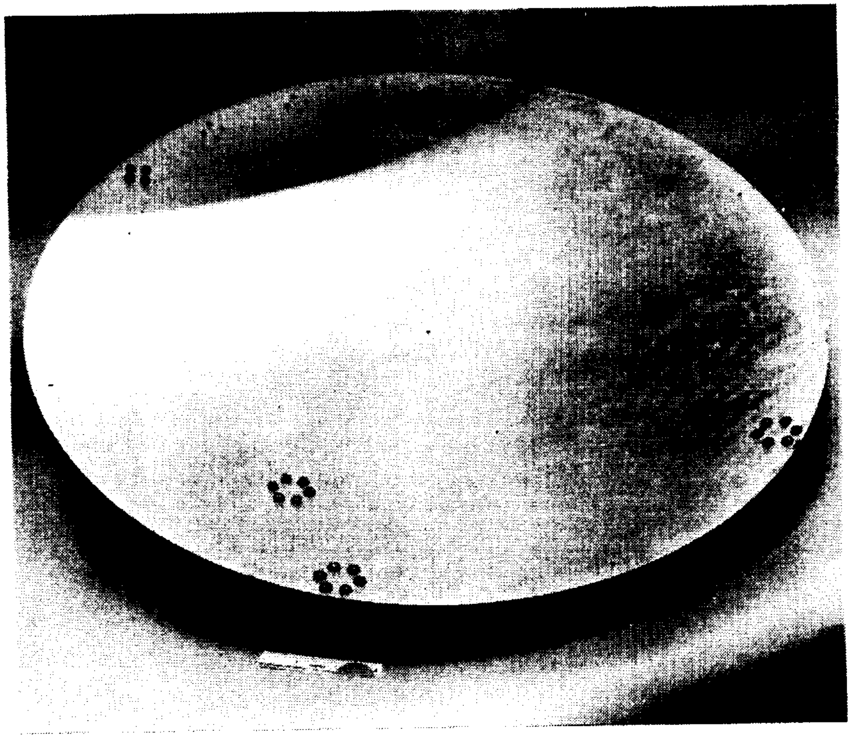
SSM/I			TRMM			
FREQUENCY GHz	MEASURED %	SPECIFICATION %	FREQUENCY GHz	PREDICTED % *	GOAL %	RECOMMENDED SPECIFICATION, % *
---	---	---	10.65	91	92	90
19.35	95	90	18	95	92	92
22.235	94	90	21	94	92	92
37	92	90	37	92	92	90
85.5	88	87	90	88	90	87

* ASSUMES 1) NO INTERACTION BETWEEN THE TWO HORNS (POSSIBLE BEAM EFFICIENCY DEGRADATION)

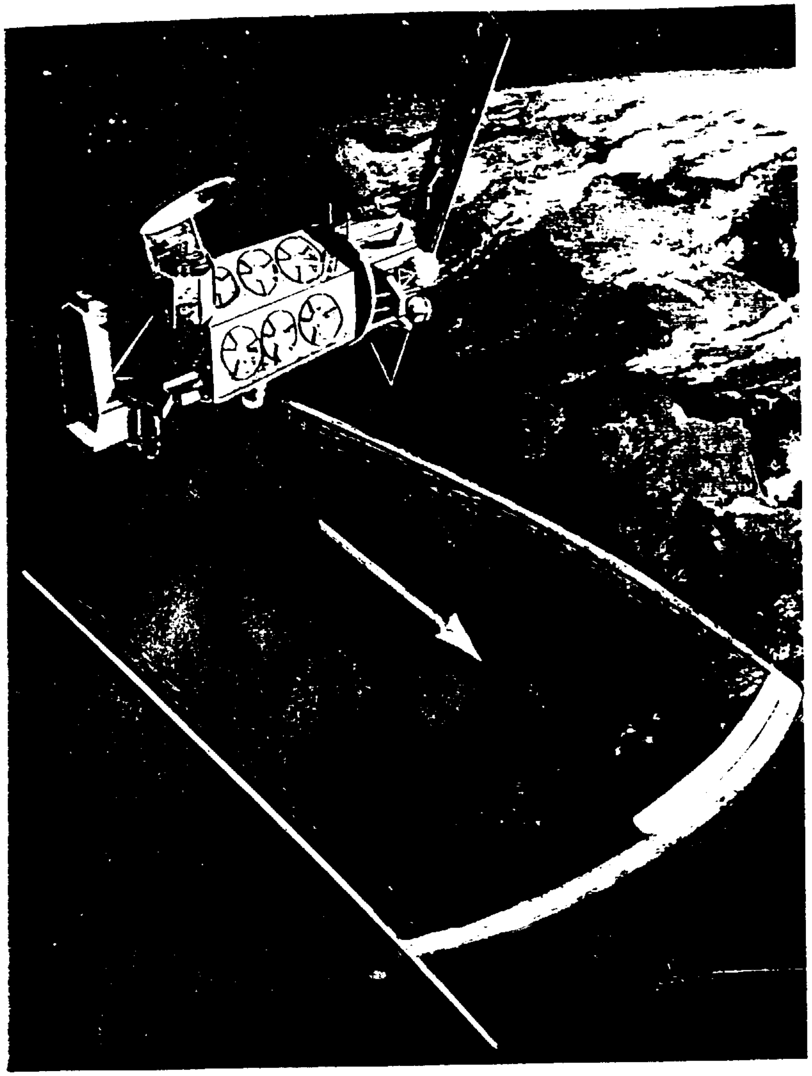
2) RETUNING THE SSM/I HORN DOES NOT AFFECT THE BEAM EFFICIENCY

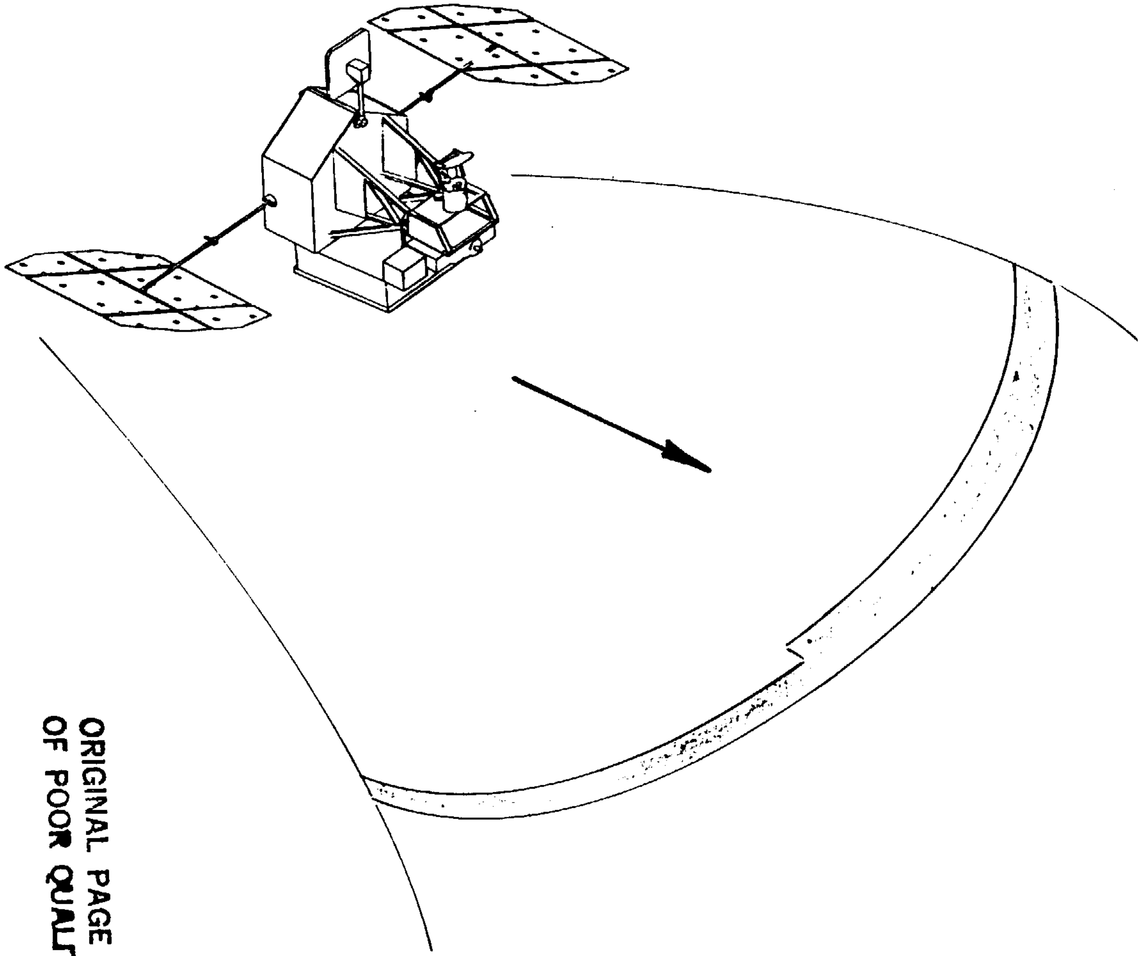
SSM/I Reflector





SPACECRAFT COMPARISON OF TRMM TO SSM/I COLD SKY REFLECTOR VIEW DIFFERENCES





COLD SKY REFLECTOR TASKS ACCOMPLISHED

- DETERMINED CLEAR FIELD OF VIEW REQUIREMENTS
    - NEAR FIELD RADIATION PATTERN COMPUTATIONS
    - CAD GENERATED SPACECRAFT/PAYLOAD LAYOUTS
    - 2 COLD SKY REFLECTOR GEOMETRIES

- ANALYZED FOR SPACECRAFT INTERFERENCE TO RADIATION PATTERN
    - CAD GENERATED FIELDS OF VIEW
    - 2 COLD SKY REFLECTOR GEOMETRIES

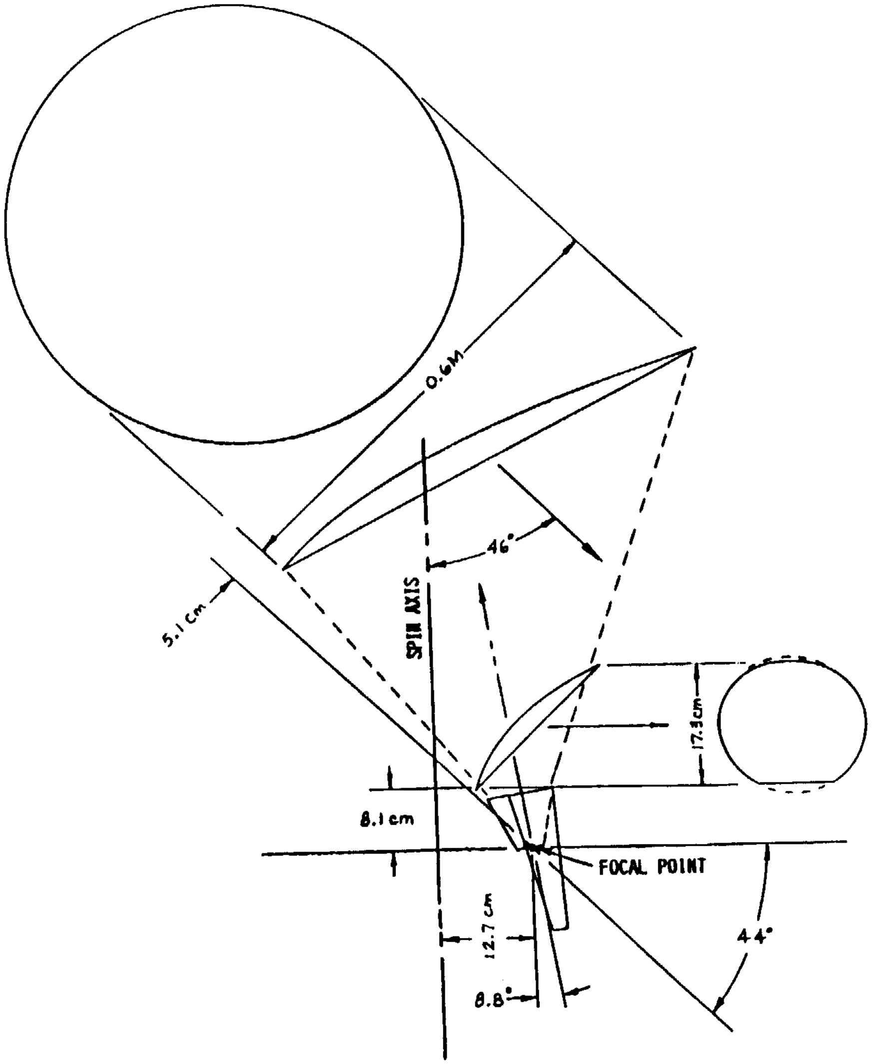
COLD SKY REFLECTOR PERFORMANCE REQUIREMENTS

- ALL NEAR FIELD RADIATION PATTERN LEVELS GREATER THAN - 25 dB BELOW THE PATTERN PEAK ARE TO HAVE A CLEAR FIELD OF VIEW (THIS CRITERIA COMMENSURATE WITH THE 2.5x3dB BEAMWIDTH CRITERIA FOR DEFINING BEAM EFFICIENCY)

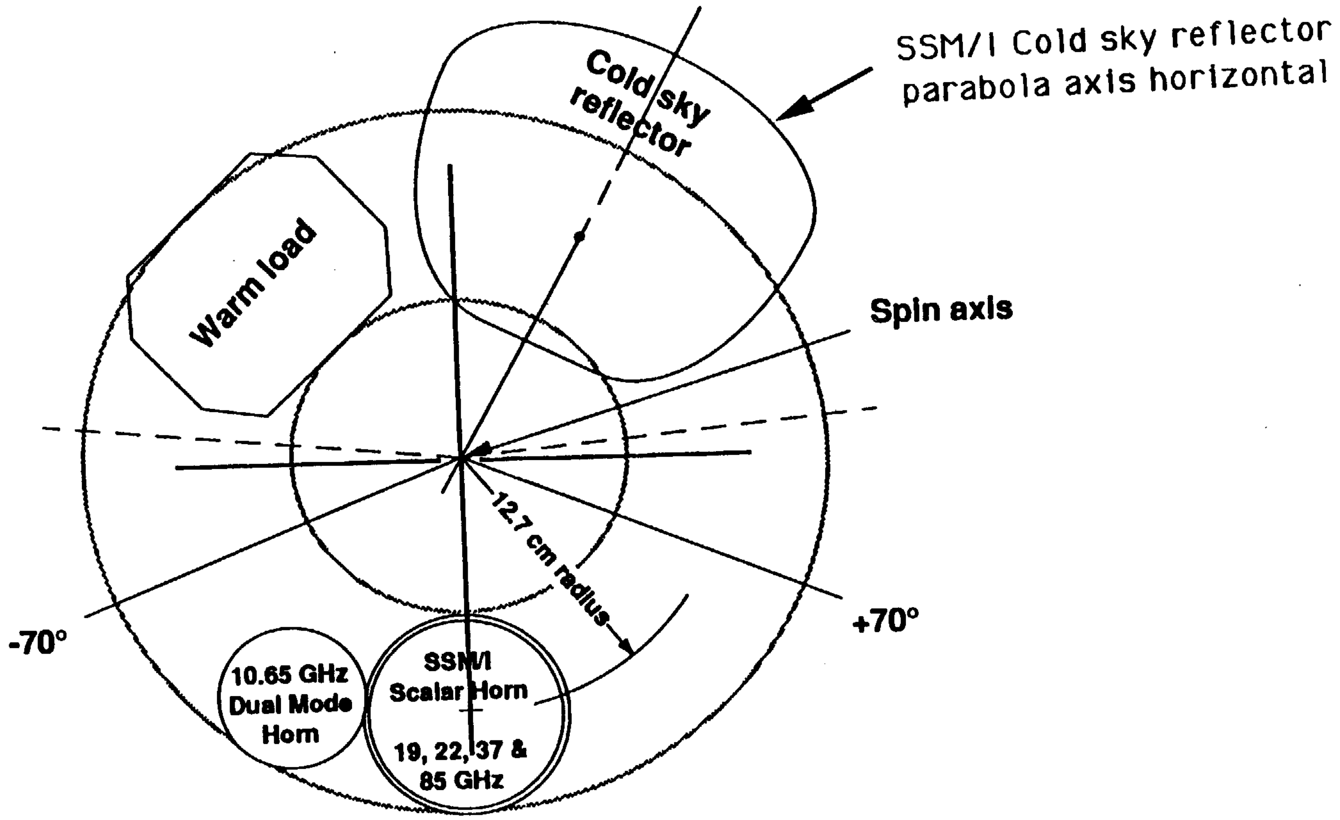
- THE COLD SKY REFLECTOR BLOCKS THE FEED FROM THE MAIN REFLECTOR OVER AN 8 DEGREE FEED MOTION SECTOR

- THE SPINNING MAIN REFLECTOR STRUCTURE MUST PHYSICALLY AND ELECTRICALLY CLEAR THE COLD SKY REFLECTOR

SSM/I MAIN AND COLD SKY REFLECTOR GEOMETRIES



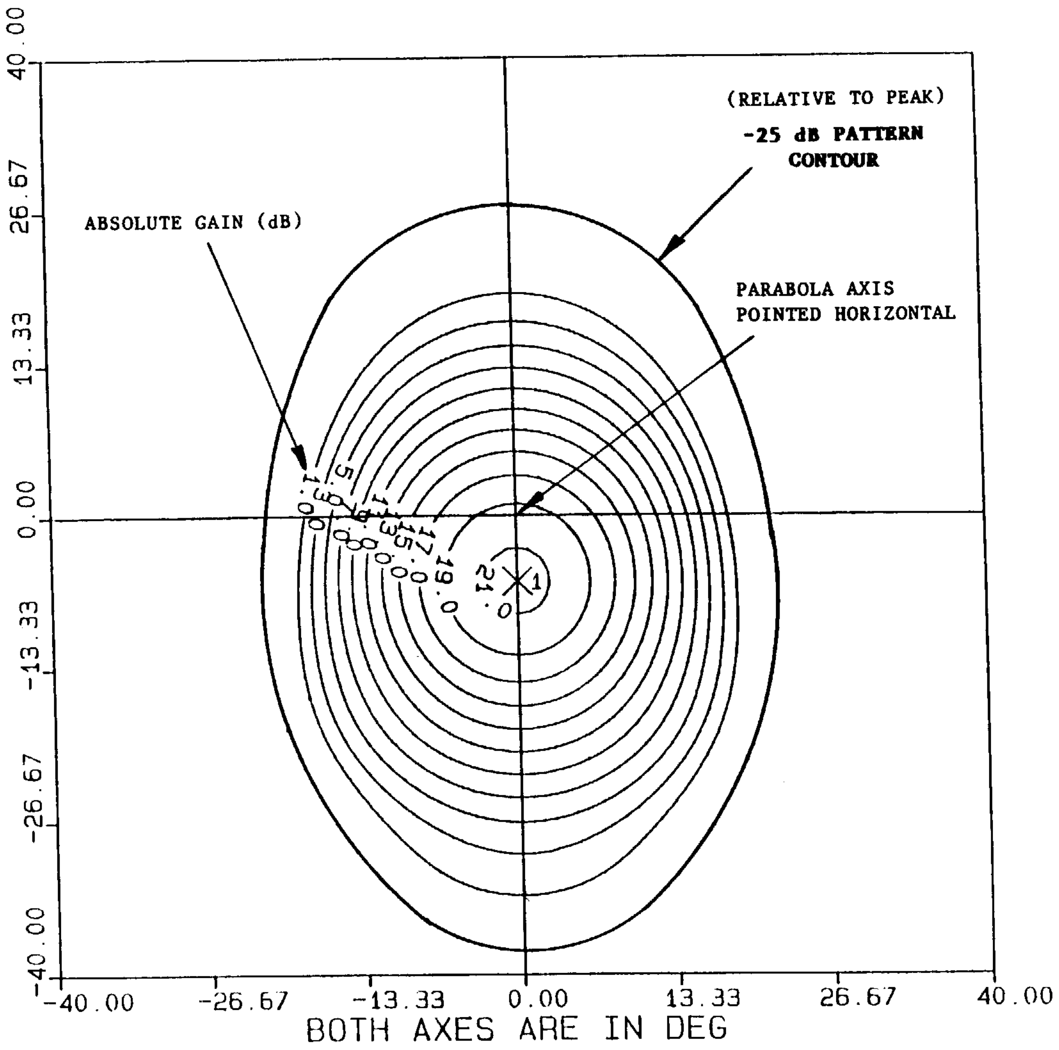
CALIBRATION LOADS AND ROTATING FEED LOCUS



TRMM

SSM/I COLD SKY REFLECTOR 10.65GHz, HORIZONTAL POLARIZATION CONTOUR PLOT

HUGHES



(RELATIVE TO PEAK)

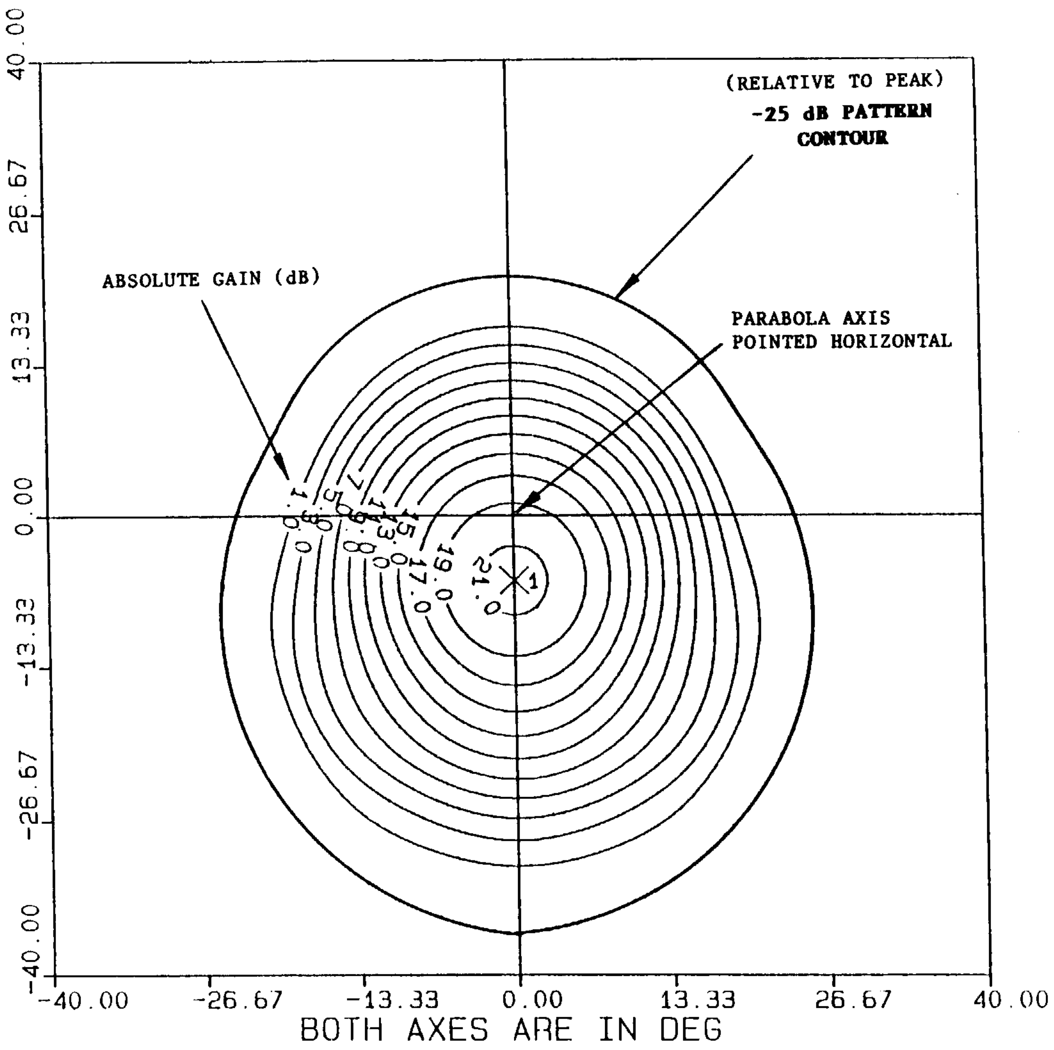
-25 dB PATTERN CONTOUR

PARABOLA AXIS POINTED HORIZONTAL

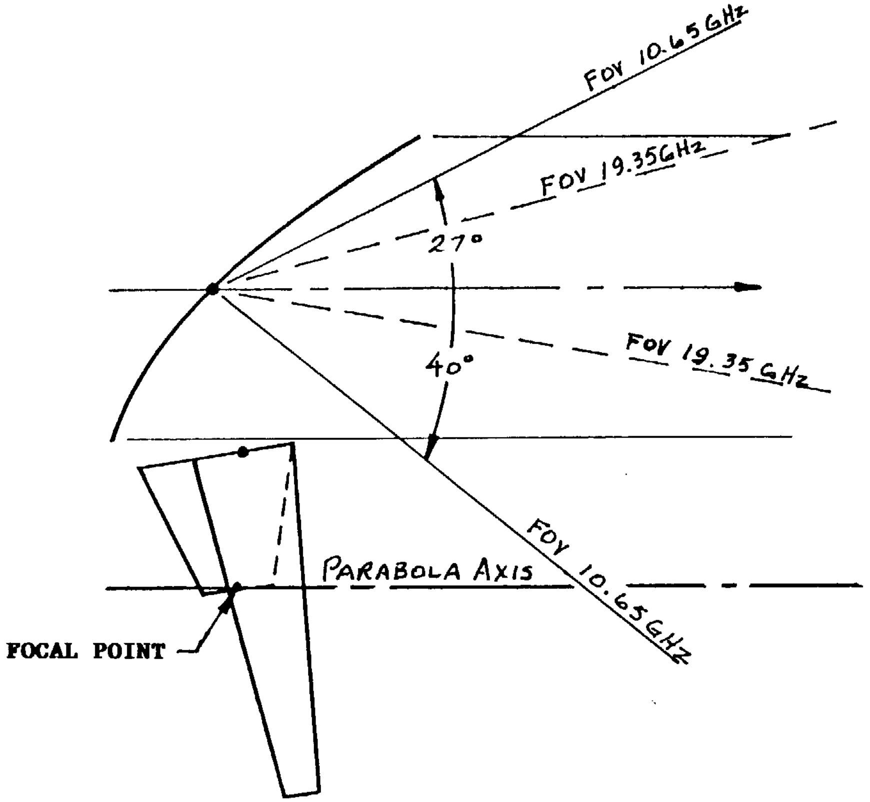
ABSOLUTE GAIN (dB)

BOTH AXES ARE IN DEG

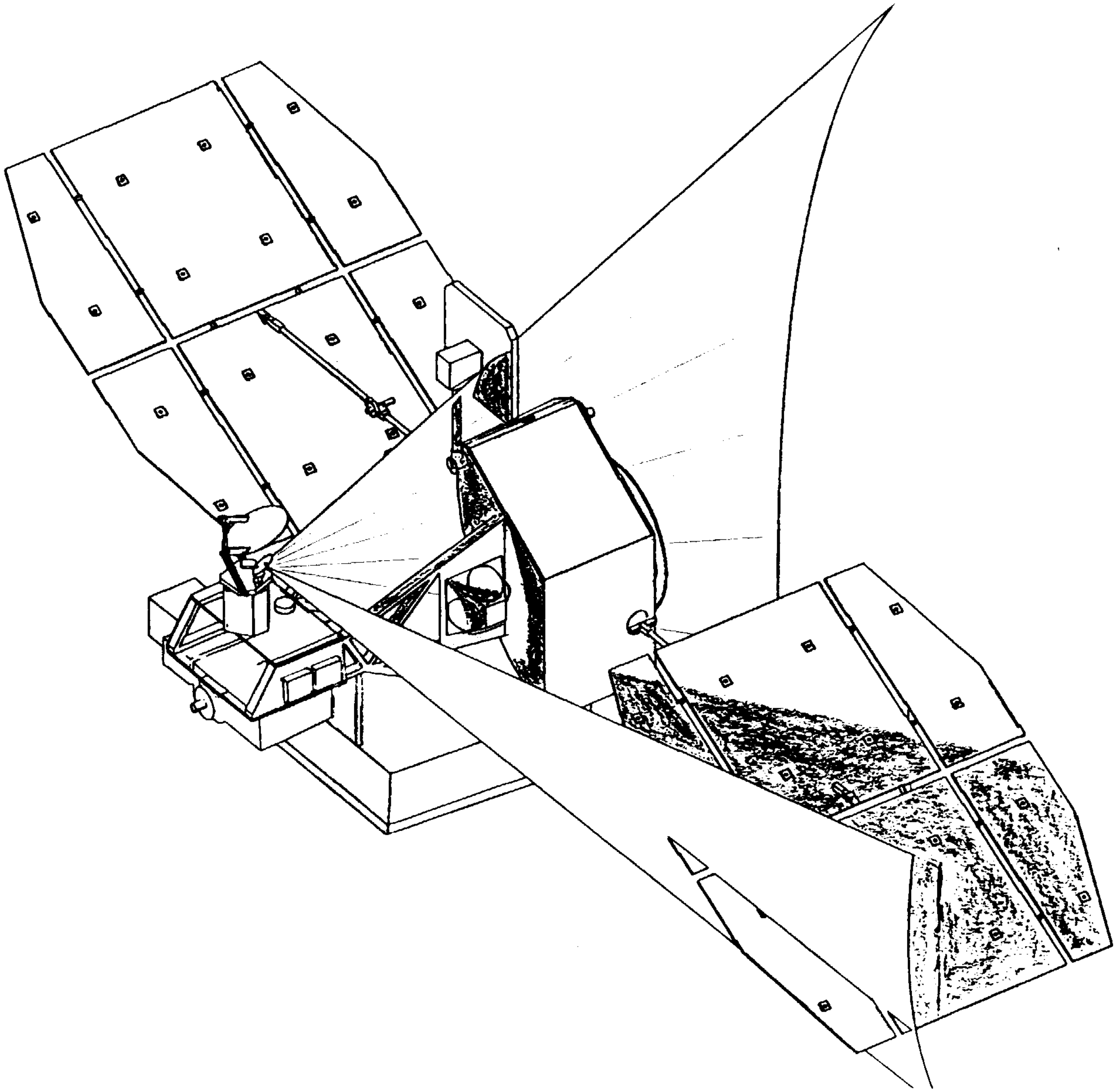
SSM/I COLD SKY REFLECTOR 10.65GHz, VERTICAL POLARIZATION CONTOUR PLOT



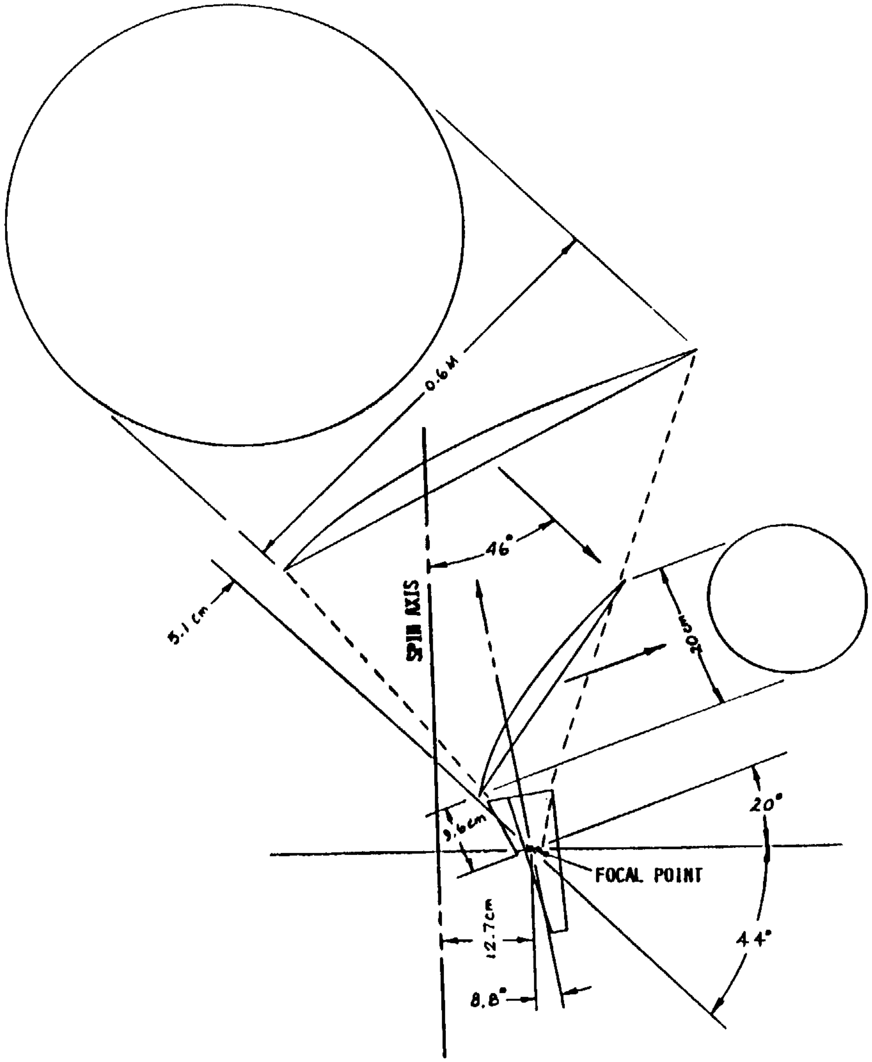
SSM/I COLD SKY REFLECTOR
CLEAR FIELD OF VIEW REQUIREMENTS
- 25 dB PATTERN CONTOURS



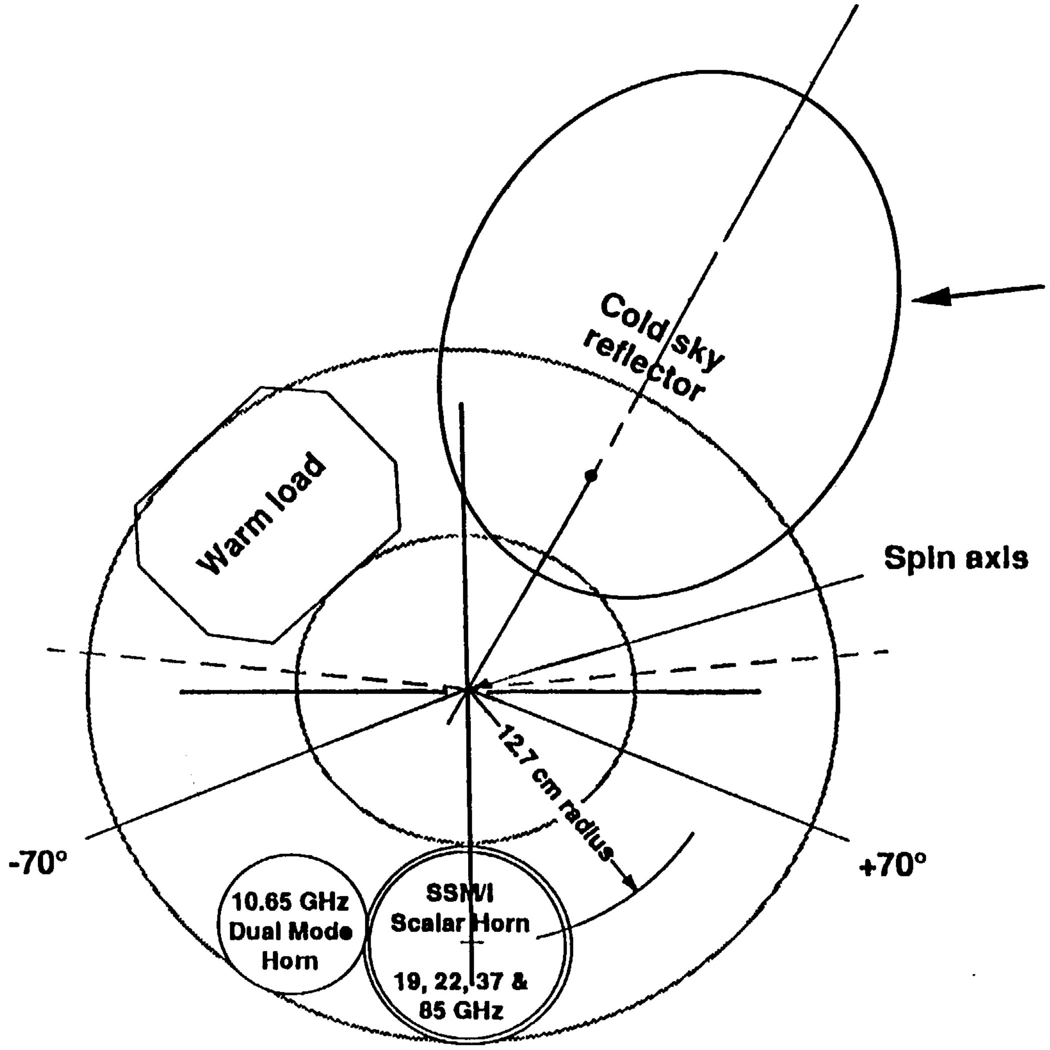
SSM/I Cold Sky Reflector 10.65 GHz Field of View Spacecraft Impingement



SSM/I MAIN AND NEW COLD SKY REFLECTOR GEOMETRIES



CALIBRATION LOADS WITH NEW COLD SKY REFLECTOR



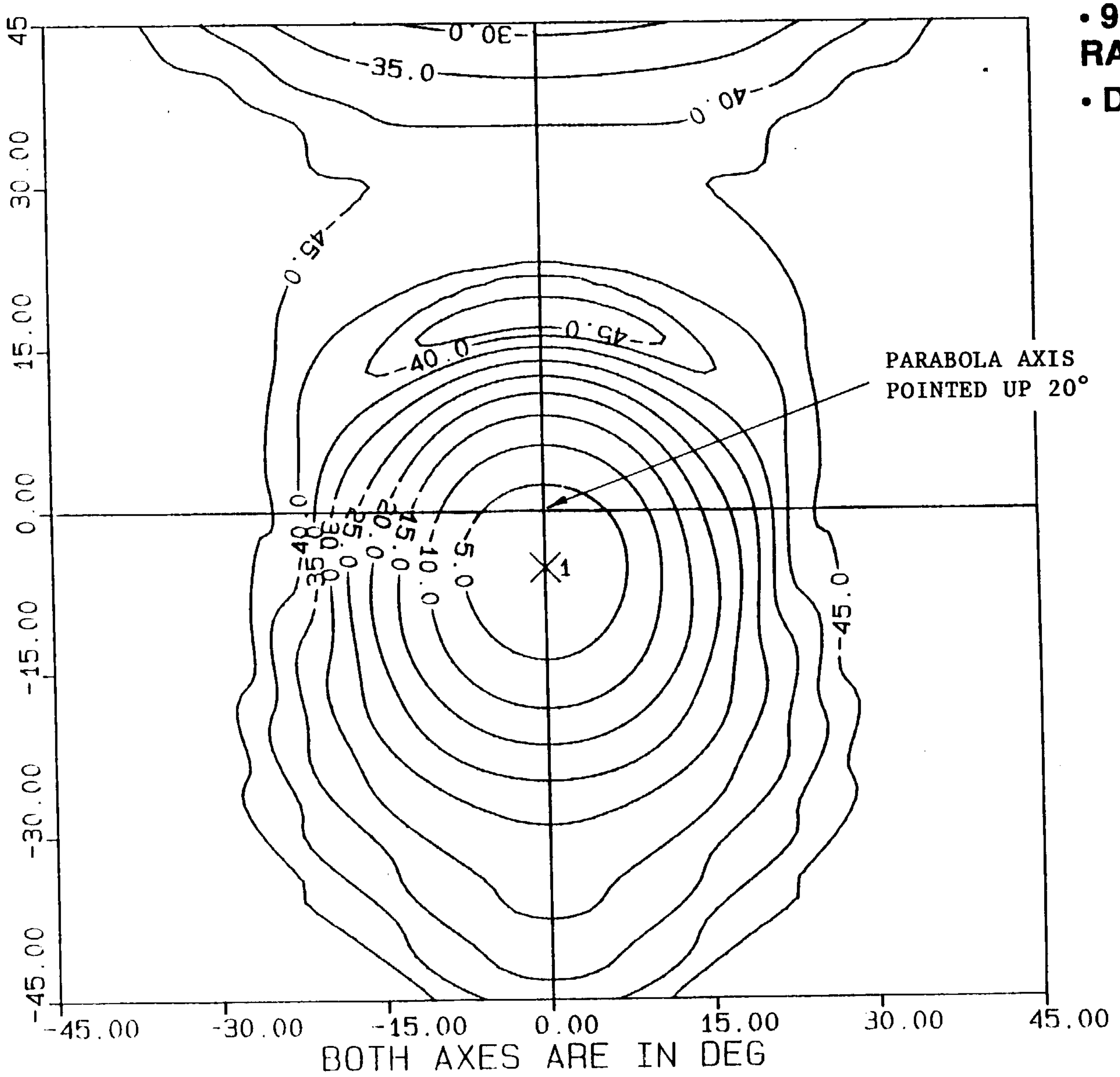
New cold sky reflector parabola axis up 20°

TRMM

NEW COLD SKY REFLECTOR
10.65GHz, HORIZONTAL POLARIZATION
CONTOUR PLOT

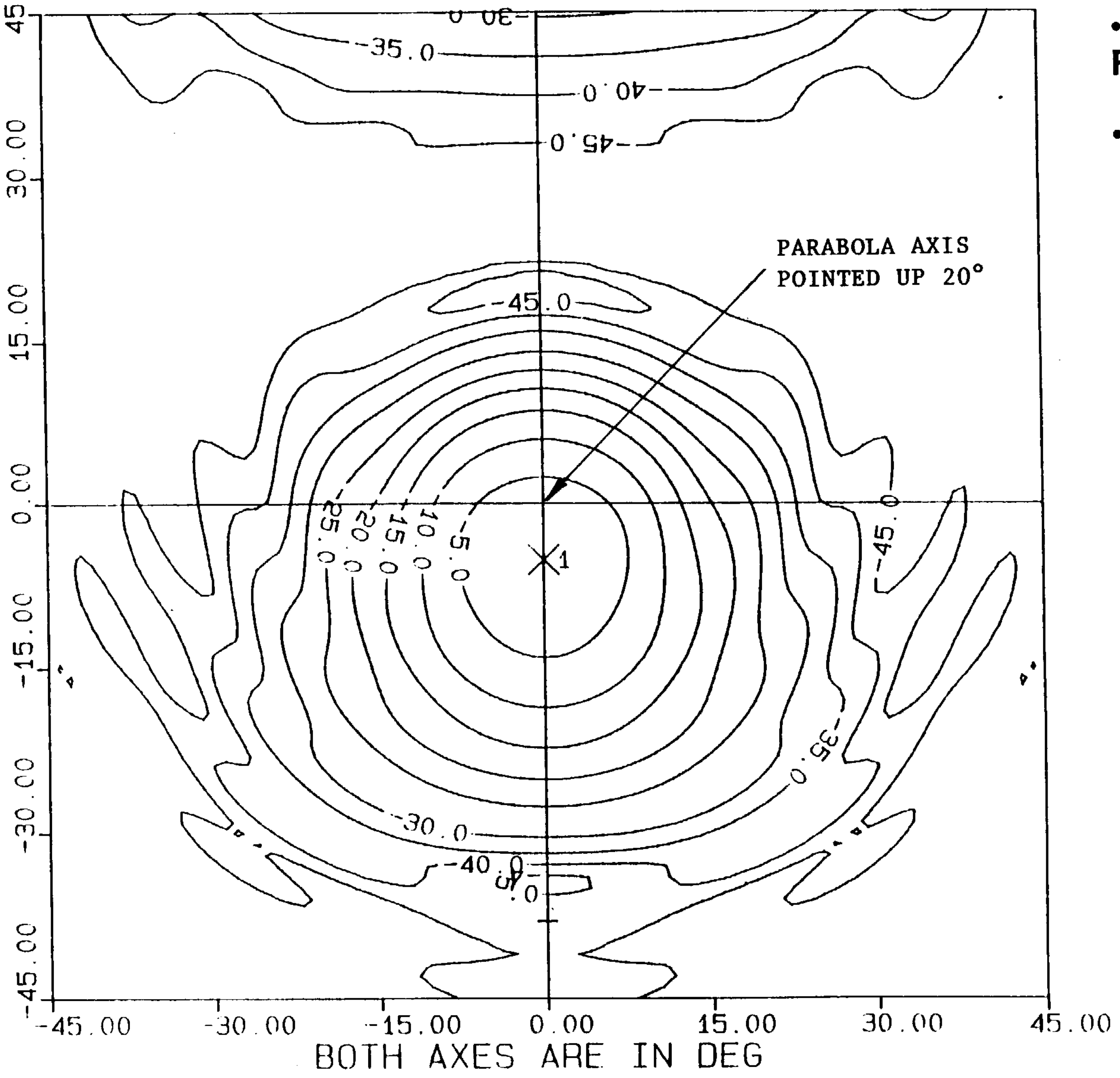
HUGHES

- 90"NEAR FIELD RADIATION PLOT
- DISPLACED DUAL MODE FEED


PARABOLA AXIS
POINTED UP 20°

NEW COLD SKY REFLECTOR 10.65GHz, VERTICAL POLARIZATION CONTOUR PLOT

- 90"NEAR FIELD RADIATION PLOT
- DISPLACED DUAL MODE FEED

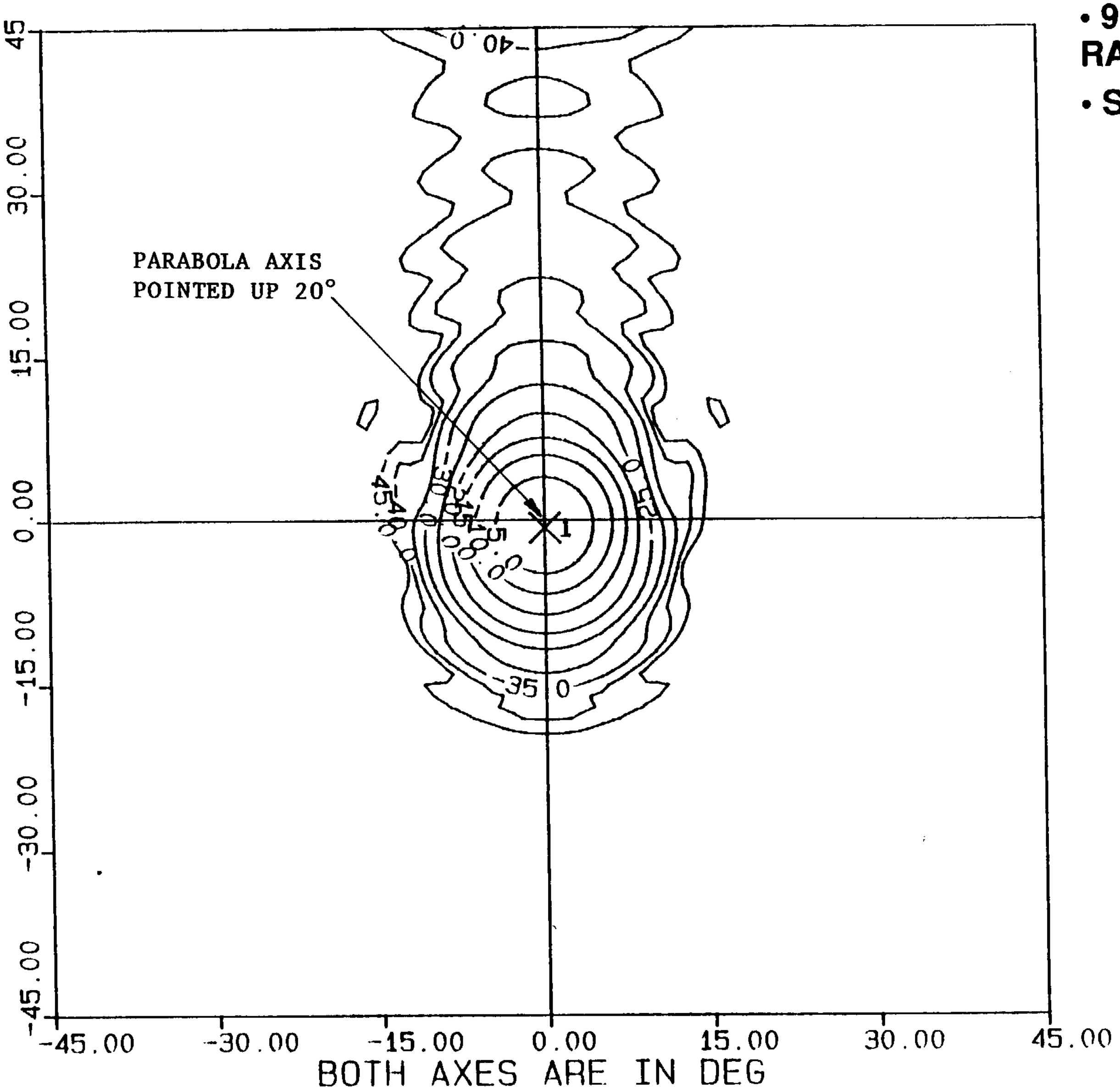


TRMM

NEW COLD SKY REFLECTOR
19.35GHz, HORIZONTAL POLARIZATION
CONTOUR PLOT

HUGHES

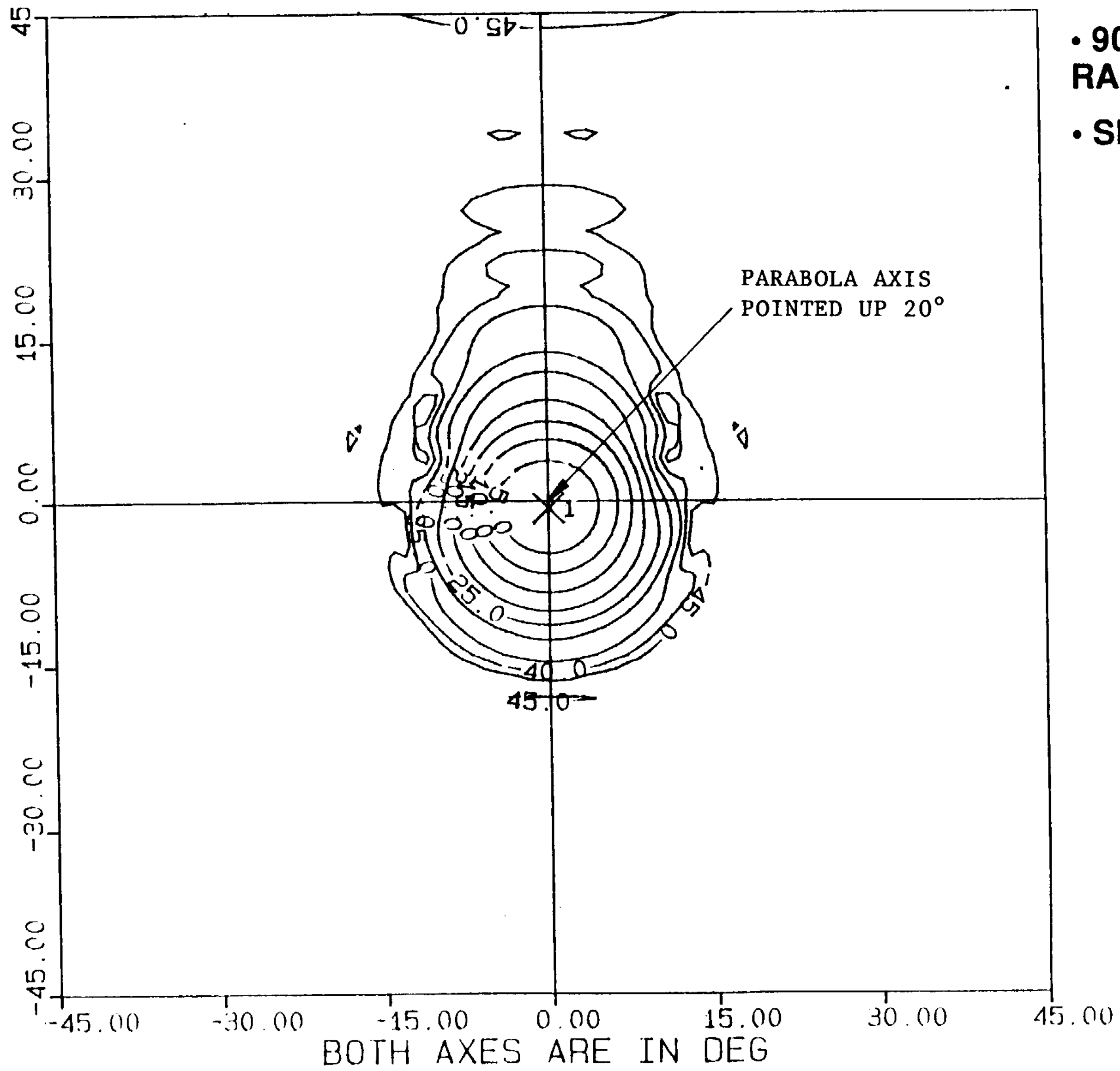
- 90"NEAR FIELD RADIATION PLOT
- SIMULATED SSM/I FEED



TRMM

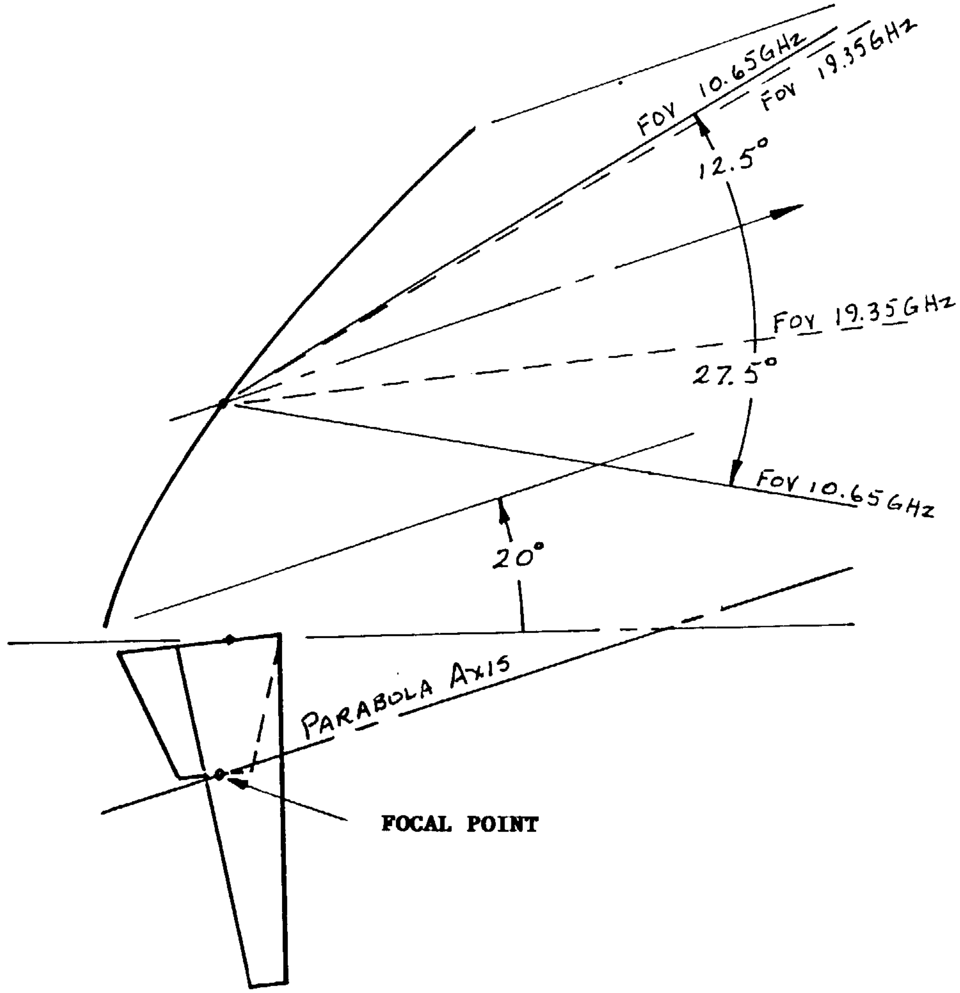
NEW COLD SKY REFLECTOR
19.35GHz, VERTICAL POLARIZATION
CONTOUR PLOT

HUGHES

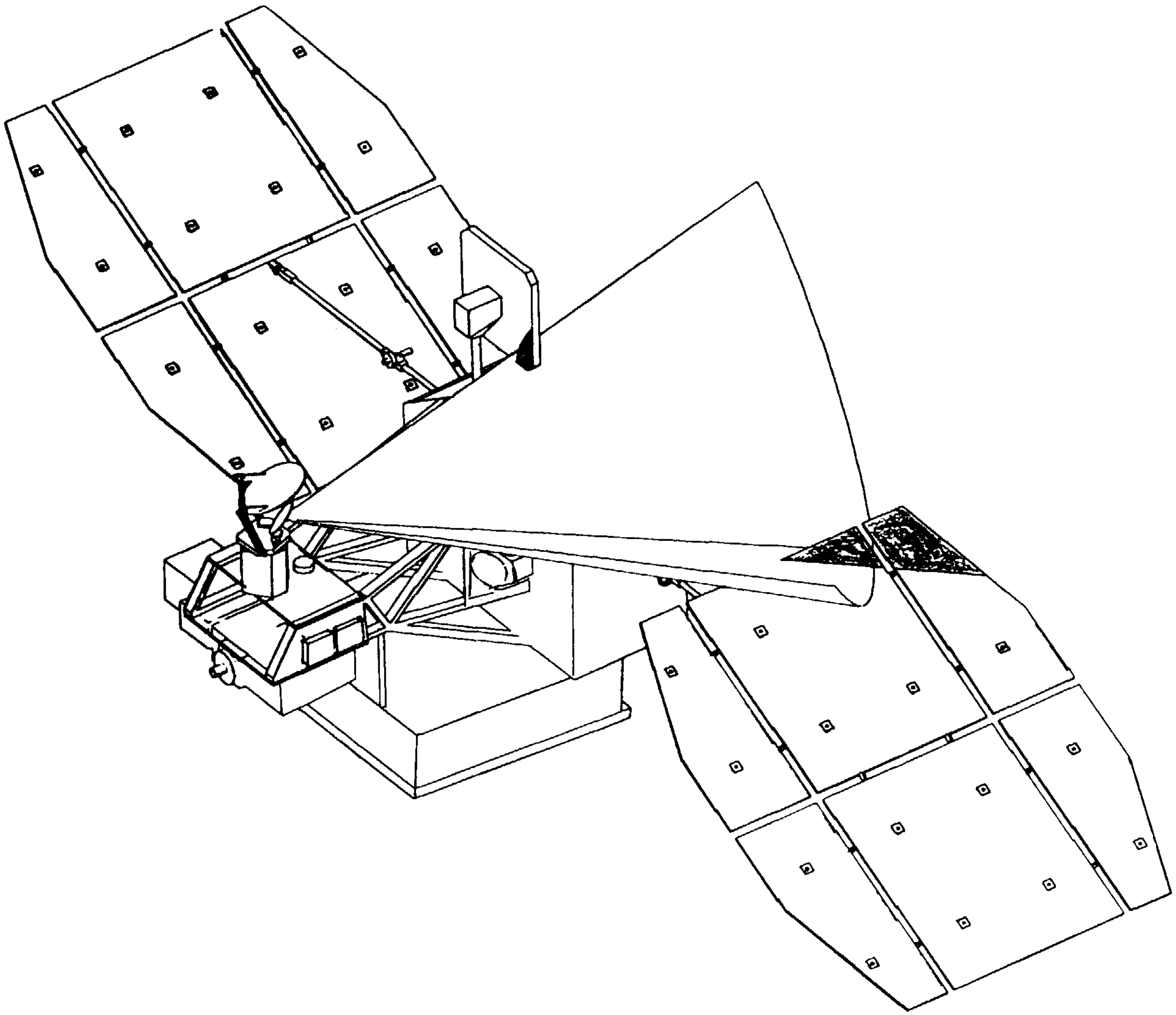


- 90"NEAR FIELD RADIATION PLOT
- SIMULATED SSM/I FEED

NEW COLD SKY REFLECTOR - AXIS TILTED UP 20° CLEAR FIELD OF VIEW REQUIREMENTS - 25 dB PATTERN CONTOURS



New Cold Sky Reflector 10.65 GHz Field of View Spacecraft Impingement



COLD SKY REFLECTOR ANANLYSIS CONCLUSIONS

- 10.65 GHz RADIATION PATTERNS DETERMINE THE WIDEST FIELD OF VIEW REQUIREMENTS WITH A DOWNWARD POINTING BIAS

- THE SPACECRAFT BODY IS IN THE FAR FIELD OF THE COLD SKY REFLECTOR AT 10.65 GHz AND 19.35 GHz

- THE SSM/I COLD SKY REFLECTOR APPROACH HAS MAJOR SPACECRAFT BODY RADIATION INTERFERENCE TO THE CLEAR FIELD OF VIEW REQUIREMENTS

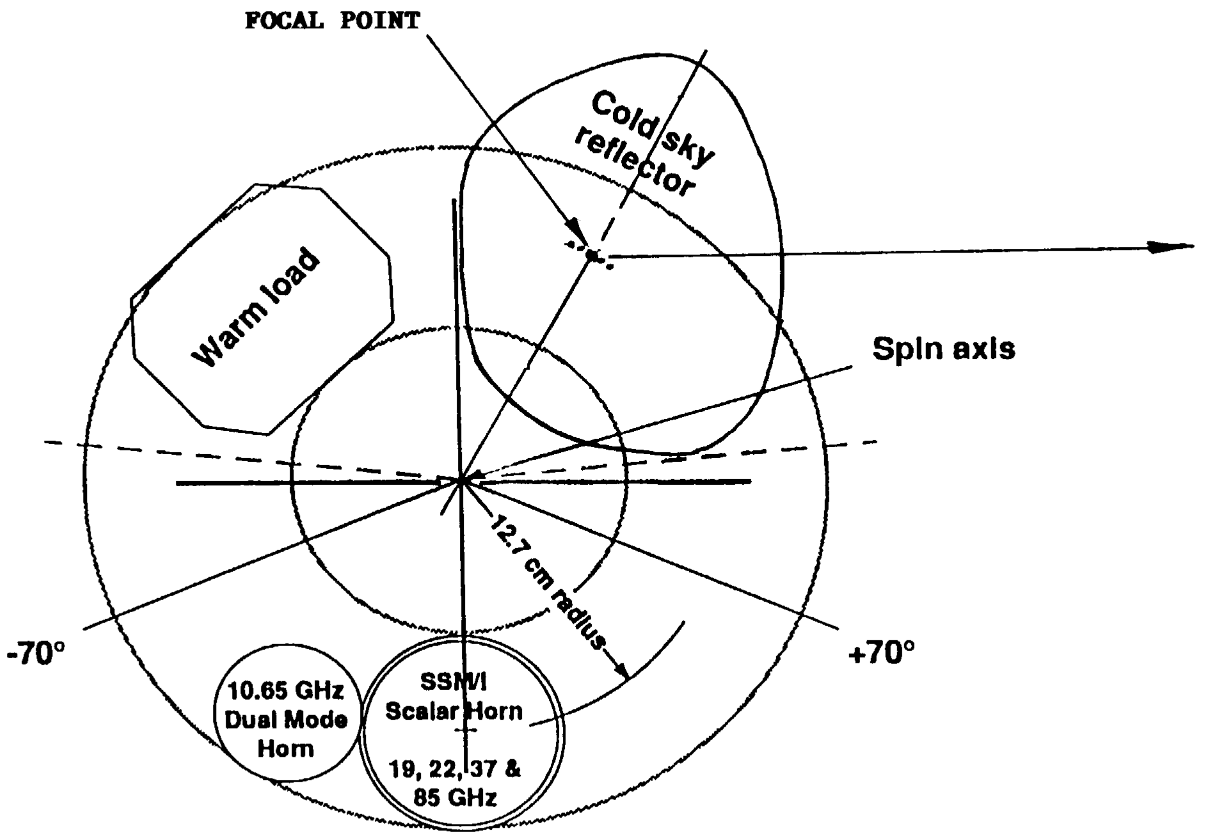
- A NEW COLD SKY REFLECTOR DESIGN IS REQUIRED

- FURTHER STUDIES REQUIRED

TRMM

SSM/I COLD SKY REFLECTOR SKEWED FROM THE RADIAL DIRECTION (SIDE LOOKING)

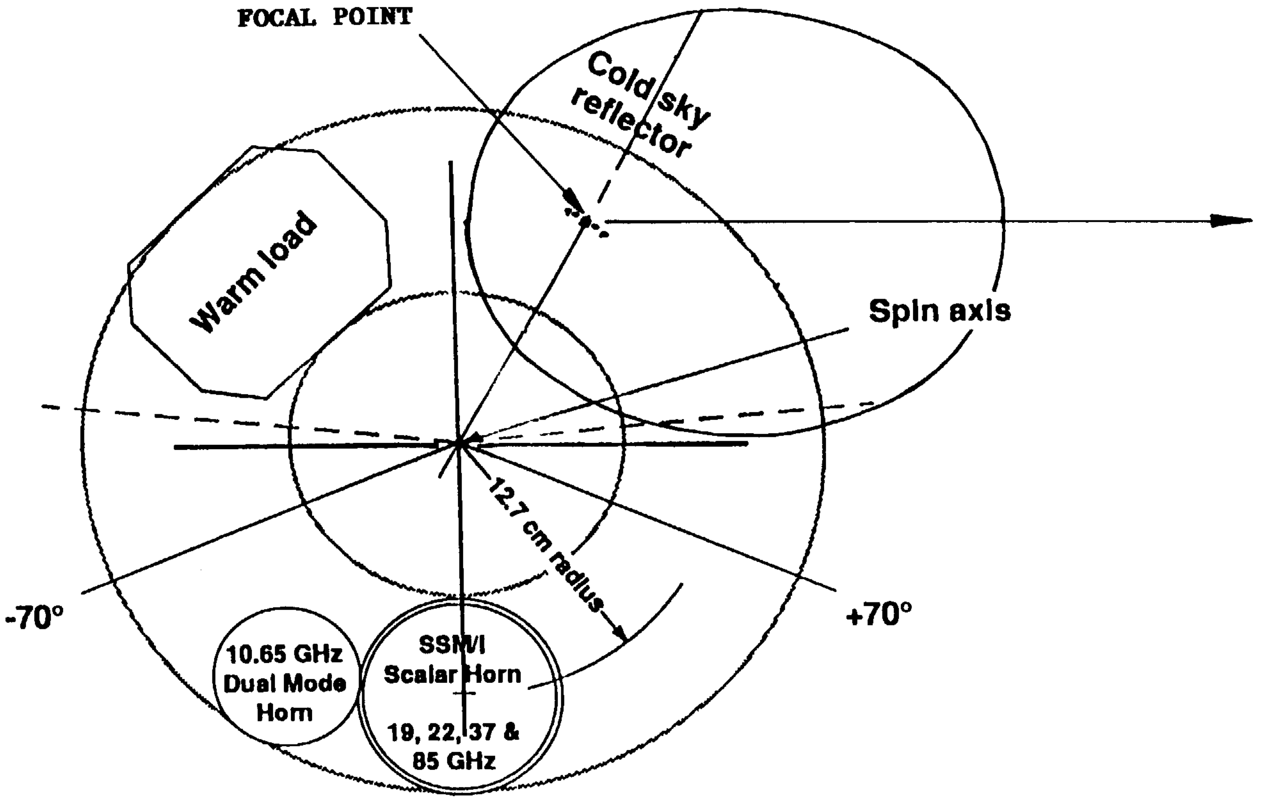
HUGHES



TRMM

NEW COLD SKY REFLECTOR - AXIS TILTED UP 20° SKEWED FROM THE RADIAL DIRECTION (SIDE LOOKING)

HUGHES



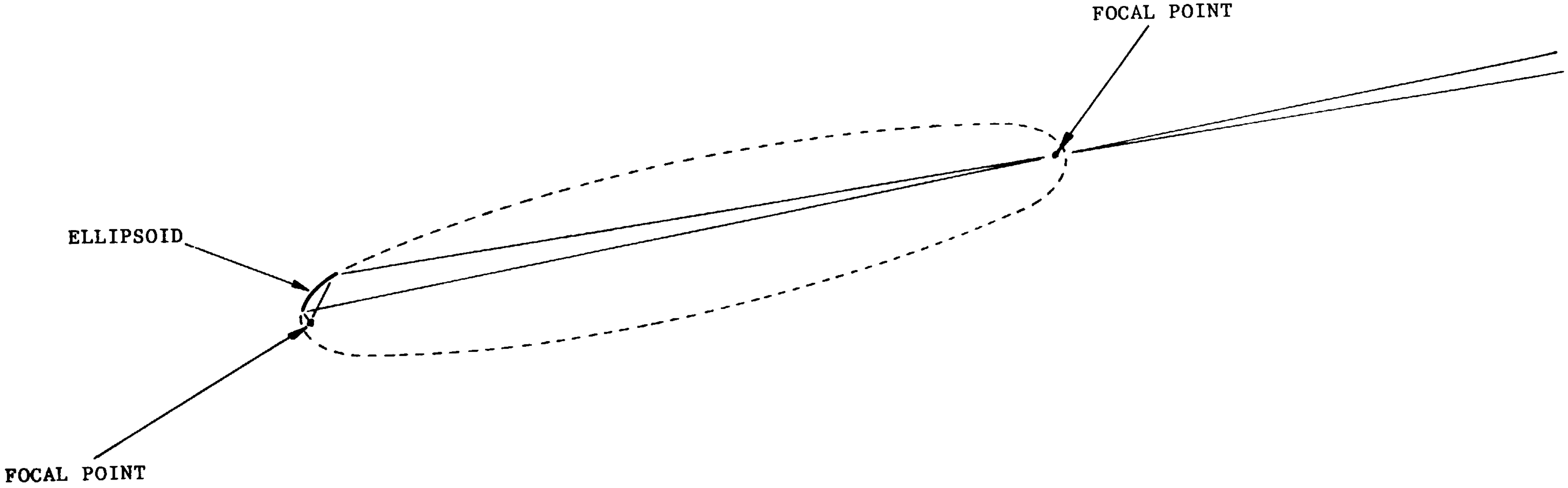
NEW COLD SKY REFLECTOR CONCEPTS

- OFFSET PARABOLOID WITH AXIS POINTING UP - RELATIVELY LOW RISK - ANALYSIS SHOWS MAJOR IMPROVEMENT

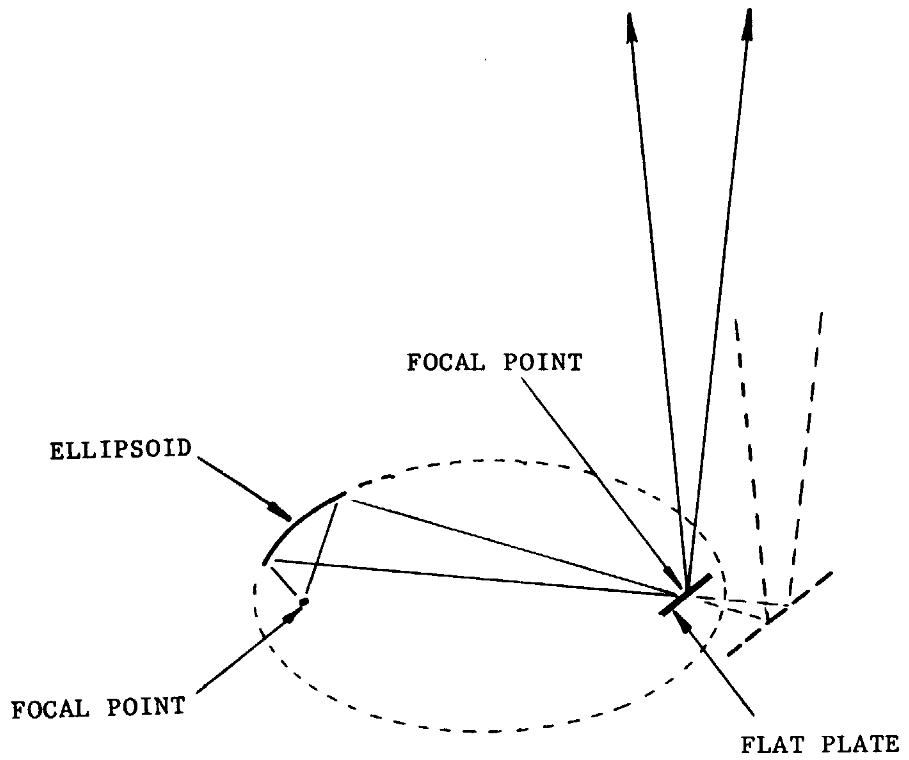
- OFFSET PARABOLOID AXIS SKEWED FROM THE RADIAL DIRECTION AND POSSIBLY TILTED UP AS WELL - FEED MOTION DURING THE 8° CALIBRATION PERIOD TAKES ON A COMPLEX RELATIONSHIP TO THE PARABOLA FOCAL PLANE - CONCERN ABOUT BEAM SCANNING IN AZIMUTH AND ELEVATION PLANE THAT MAY CAUSE TOO LARGE OF A CLEAR FIELD OF VIEW AND ALSO SEE THE MAIN REFLECTOR SUPPORT STRUCTURE

- OFFSET ELLIPSOID TO PRODUCE A SECOND FOCAL REGION IN THE REGION OF THE SPACECRAFT BODY AND SOLAR PANELS FOR IMPROVED CLEARANCE

ELLIPSOIDAL COLD SKY REFLECTOR CONCEPT



ELLIPSOIDAL COLD SKY REFLECTOR CONCEPT



RECEIVER SUBSYSTEM

TASK MANAGER
S. BAGGETT

RECEIVER SUBSYSTEM ELEMENTS

The Receiver Subsystem has major elements: The Mixer-Preamplifier-Local oscillator (MPL) and the Detector Electronics Units (DEU).

The MPL receives the energy from the antenna, downconverts it to IF, and then amplifies it before it is being transferred to the DEUs. The downconversion is done with a balanced mixer and a GUNN local oscillator.

The DEU detects the IF energy from the MPL, with a square law detector, amplifies this signal (with a variable gain amplifier) before it is integrated and sent to the signal processing unit for A/D conversion and transfer to the spacecraft.

RECEIVER SUBSYSTEM ELEMENTS

- MIXER - PREAMPLIFIER - LOCAL OSCILLATOR (MPL)
    - INPUT ISOLATOR
    - BALANCED MIXER / PREAMPLIFIER
    - IF AMPLIFIER
    - GUNN LOCAL OSCILLATOR

- DETECTOR ELECTRONICS UNIT (DEU)
    - SQUARE LAW DETECTOR
    - VARIABLE GAIN AMPLIFIER
    - OFFSET AMPLIFIER
    - INTEGRATOR

RECEIVER SUBSYSTEM REQUIREMENTS

Listed here are the requirements from Appendix B of the SOW as well as some SSM/I requirements. For example, the RF bandwidth and the radiometric accuracy are SSM/I requirements. These assumptions were needed in order to be able to generate cost and schedule estimates.

TRMM

RECEIVER SUBSYSTEM REQUIREMENTS

HUGHES

PARAMETER	CHANNEL CENTER FREQUENCY, GHz				
	10.65	19.35	22.235	37.0	85.5
POLARIZATION	V & H	V & H	V	V & H	V & H
RF BANDWIDTH, MHz	400	480	480	1800	2800
RADIOMETRIC, ACCURACY, K	1.5	1.5	1.5	1.5	1.5
DELTA T, K	0.7	0.7	0.7	0.7	0.7
SCENE TEMPERATURE, K	150	300	300	300	300
INTEGRATION TIME, ms	5.8	5.8	5.8	5.8	5.8

RECEIVER SUBSYSTEM BLOCK DIAGRAM

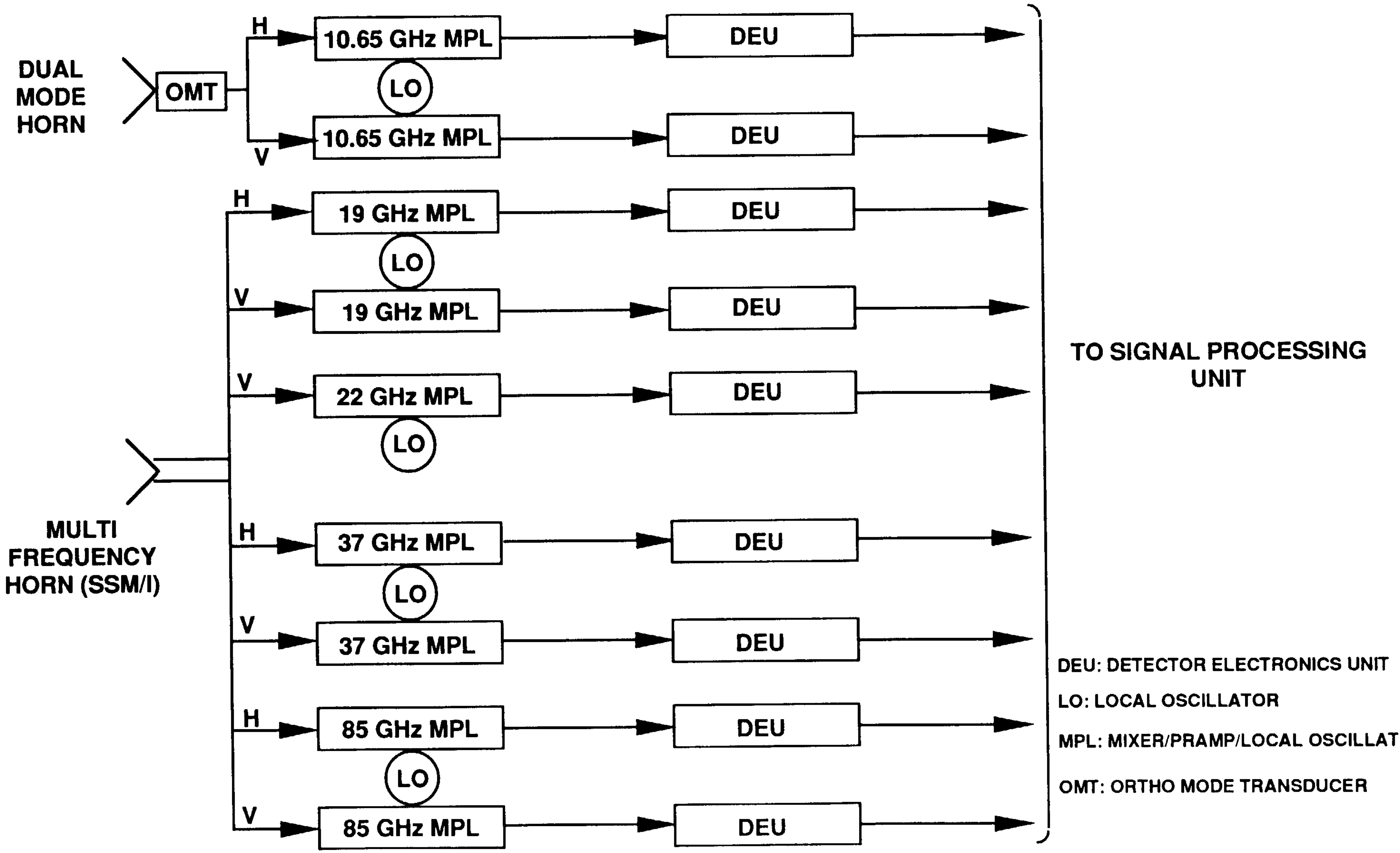
The RF block diagram is a conventional hetrodyne receiver. A multi-frequency horn supplies the horizontal and vertical polarized energy to the receiver input. The desired RF spectrum is selected by filters and down converted to a convenient IF frequency. Detection is performed by a diode detector and the resulting signal is amplified and transferred to the signal processing unit.

A separate dual mode feed and 2 receiver chains are required for the additional 10.65 GHz channels.

TRMM

RECEIVER SUBSYSTEM BLOCK DIAGRAM

HUGHES



DEU: DETECTOR ELECTRONICS UNIT

LO: LOCAL OSCILLATOR

MPL: MIXER/PRAMP/LOCAL OSCILLATOR

OMT: ORTHO MODE TRANSDUCER

RECEIVER SUBSYSTEM TRADES

Heterodyne vs. Direct Detection

Historically, radiometer receivers have been implemented using a heterodyne architecture. The received microwave energy is frequency translated and detected at the lower frequency. Receivers at frequencies below about 8 GHz can also be implemented using direct detection. Direct detection does not require a frequency translation process. The required RF spectrum is selected by a filter, amplified and applied directly to the detector. TRMM has chosen the heterodyne approach because it offers the best combination of reliability and proven performance.

RECEIVER SUBSYSTEM TRADE

HETERODYNE VS. DIRECT DETECTION

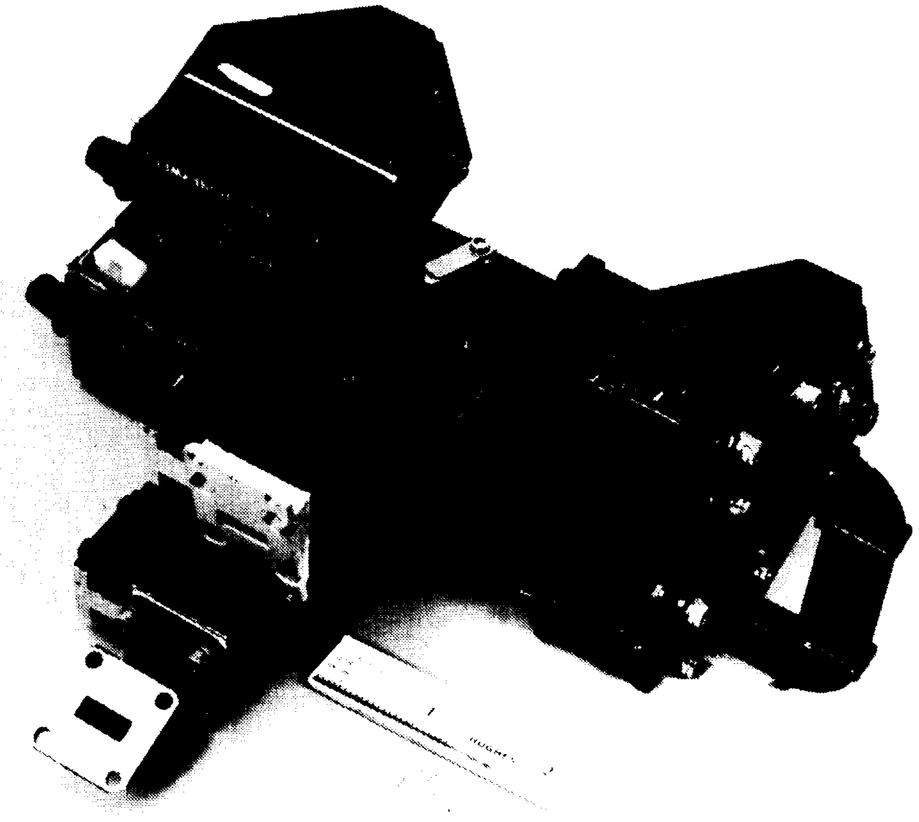
	HETERODYNE	DIRECT DETECTION
HARDWARE	LOCAL OSCILLATORS, MIXERS, <5GHz DETECTORS	DETECTOR @ RF FREQUENCY
WEIGHT/POWER	LOCAL OSCILLATORS REQUIRE RIPPLE FREE POWER	SAVE WEIGHT AND POWER
DETECTOR	FLIGHT HERITAGE, DOCUMENTED LINEARITY	NOT SPACE QUALIFIED, NEEDS LINEARITY VERIFICATION

RECOMMENDATION: USE HETERODYNE APPROACH

TRMM

SSM/I 19 GHz Mixer-Preamplifier-Local Oscillator (MPL)

HUGHES



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902500-4

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SIGNAL PROCESSING SUBSYSTEM

TASK MANAGER
J. CASTRO

SIGNAL PROCESSING SUBSYSTEM ELEMENTS

The Signal Processing Subsystem consists of a sigle non-redundant Signal Processing Unit. The major elements of this unit are an analog multiplexer, an analog-to-digital converter, and an application specific integrated circuit (ASIC).

The analog multiplexer performs time-division sampling of all science data from the Receiver Subsystem and analog instrument status.

The analog-to-digital converter performs a 12 bit conversion of each analog sample received from the analog multiplexer and transfers the resulting digital data to the ASIC.

The ASIC is a custom VLSI (very large scale integration) circuit which performs all the logic timing and control functions for the unit. It is implemented with silicon-on-sapphire CMOS technology and manufactured at Hughes' Microelectronics Technology Center in Carlsbad, California.

SIGNAL PROCESSING SUBSYSTEM

ELEMENTS

- ANALOG MULTIPLEXER
    - 9 VIDEO DATA CHANNELS
    - 9 CONDITIONED TEMPERATURE DATA
- ANALOG-TO-DIGITAL CONVERTER
- APPLICATION SPECIFIC INTEGRATED CIRCUIT (ASIC)
    - INSTRUMENT TIMING AND CONTROL
    - DATA PACKET FORMATING
    - CRYSTAL OSCILLATOR
    - RAM AND PROM

SIGNAL PROCESSING SUBSYSTEM REQUIREMENTS

The Signal Processing Subsystem is required to perform over a three year service life. Total radiation dose at the internal semiconductor chips is expected to be less than 10,000 rads (Si) for this life-time and orbit. Components used in the Signal Processing Unit design can generally tolerate dose levels one-to-two orders of magnitude greater than this.

A key set of Signal Processing Subsystem requirements relate to video data processing. The subsystem is required to multiplex 9 differential data channels from the Receiver Subsystem. Each video data sample is converted to a 12 bit digital word and temporarily stored within the Signal Processing Unit during each scan. The stored data are then formatted and transferred to the spacecraft. In addition to video science data, the Signal Processing Subsystem is required to process commands and telemetry.

The Signal Processing Subsystem generates a number of clock signals for use by the Power Subsystem and BAPTA (Bearing and Power Transfer Assembly) Control Electronics. A reference clock is provided to the Power Subsystem to synchronize the DC-to-DC converters contained in that subsystem. Other timing signals provided for BAPTA control Electronics use include a 30 Hz spin reference frequency, a 3 kHz modulation synchronization frequency, and a 15 kHz clock.

TRMM

SIGNAL PROCESSING SUBSYSTEM

REQUIREMENTS

HUGHES

- 3 YEARS LIFE
- RADIATION DOSE < 10000 RADS
- INTERFACE WITH OPTICAL INTERFACE UNIT
- TELEMETRY AND COMMAND PROCESSING
- PROVIDE CLOCK TO THE BAPTA CONTROL ELECTRONICS UNIT AND POWER SUPPLY
- VIDEO DATA PROCESSING
    - MULTIPLEX DATA CHANNELS AND TELEMETRY
    - VARIABLE GAIN CONTROL: 16 LEVELS
    - 12 BIT DIGITIZATION
    - DATA STORAGE
    - DATA FORMATTING FOR OUTPUT TO SPACECRAFT

SIGNAL PROCESSING UNIT BLOCK DIAGRAM

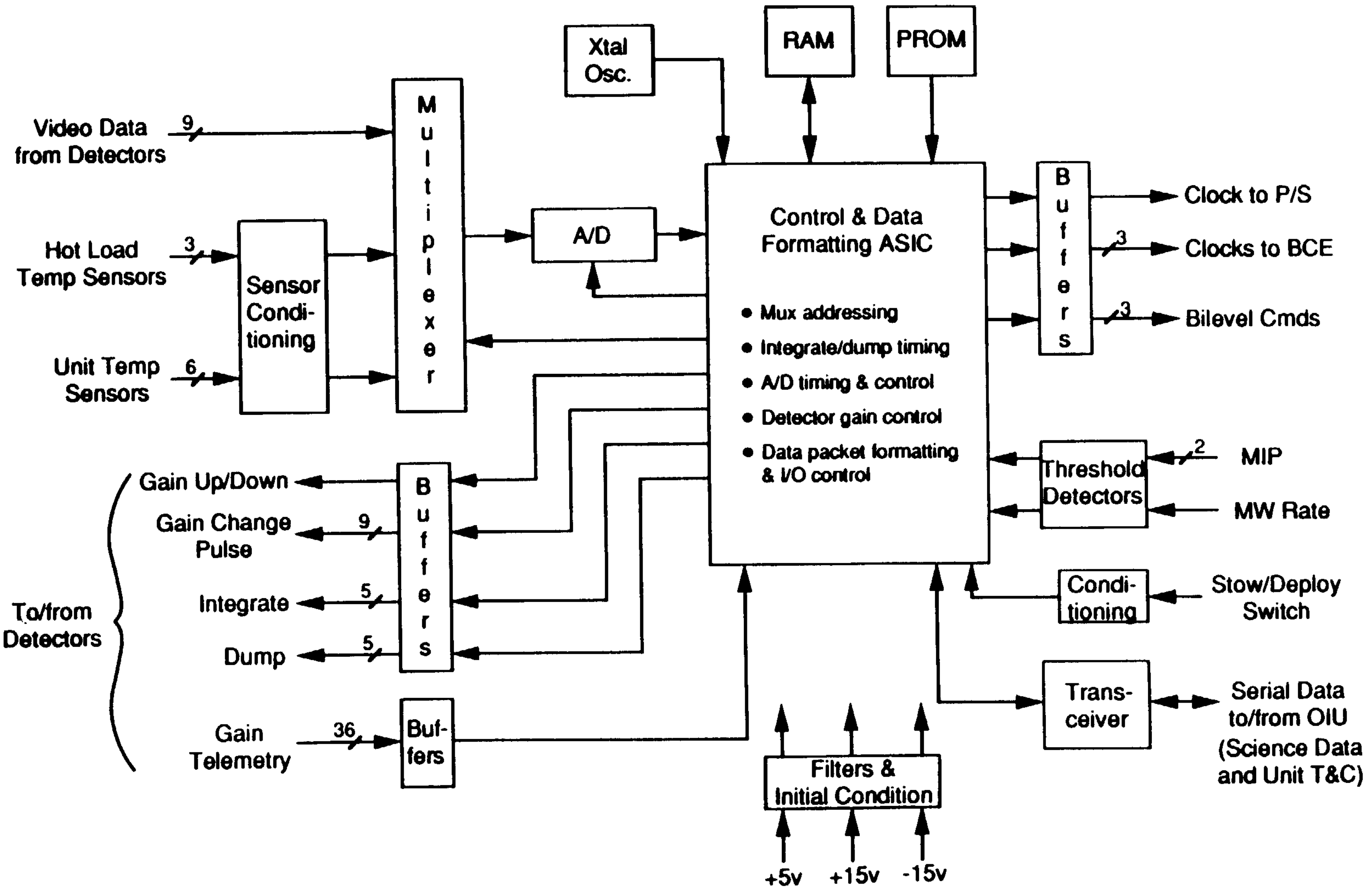
This chart shows a block diagram of the Signal Processing Unit. Outputs from the Receiver Subsystem are time division multiplexed to a 12-bit analog-to-digital converter. Other analog data representing instrument status, warm load platinum temperature sensors, antenna deployment angle, and an internal Signal Processing Unit reference voltage and thermistor are also multiplexed and digitized.

Timing and control for the entire unit is implemented in a single ASIC (application specific integrated circuit). Input data sampling sequences and output formatting parameters are stored in PROM (programmable read-only memory). Sampled and digitized science and status data are temporarily stored in RAM (random access memory) prior to being read out on the MIL-STD-1553B payload science data bus for transfer to the spacecraft.

The Signal Processing Unit Processes and decodes serial commands received from the spacecraft. The Signal Processing Unit uses the serial commands to generate up to eight discrete command outputs for use by other TRMM subsystems.

The MIP (Master Index Pulse) signal is received from the BAPTA (Bearing and Power Transfer Assembly) and used to determine the start of each picture scan. The Signal Processing Unit generates clock signals for use by the BCE (BAPTA Control Electronics) and the Power Subsystem.

SIGNAL PROCESSING UNIT
BLOCK DIAGRAM



SIGNAL PROCESSING SUBSYSTEM INTERFACES

There are internal interfaces, between the SPU and the other radiometer (spinning) units, and the external interfaces, going thru the slip rings to the spacecraft and the despun part of the radiometer.

The internal interfaces are:

a) With the DEUs for temperature, gain and video data, as well as control of the integration and gain information.

b) The power supply provides power and temperature telemetry and receives commands and a 15 KHz clock.

c) The BAPTA Control Electronics (BCE) provides telemetry and receives two clocks.

d) The BAPTA provides the Master Index Pulse (MIP) as well as its temperature telemetry.

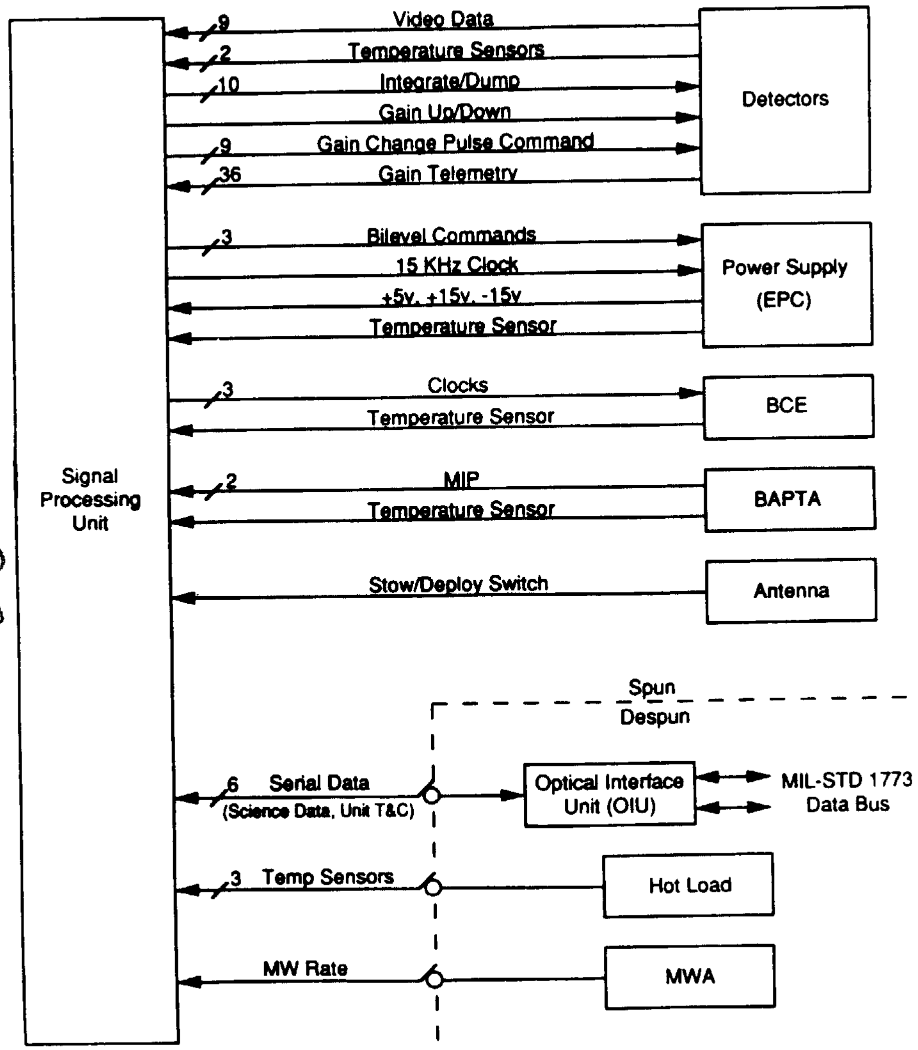
e) Telemetry indicating the position of the reflector during deployment is provided by a microswitch mounted on the antenna.

The interface with the despun warm (hot) load and the momentum wheel assembly are telemetry data on the temperature of the calibration load and on the spin rate of the momentum wheel.

The science data and some of the unit telemetry is transmitted to the spacecraft via an Optical Interface Unit (OIU).

HUGHES

SIGNAL PROCESSING SUBSYSTEM INTERFACES



TRMM

DESIGN CHANGES FROM SSM/I

The architecture of the TRMM signal processing subsystem is derived from the SSM/I program. Signal processing techniques used are similar to those used on SSM/I except that these techniques are implemented in an application specific integrated circuit (ASIC) rather than through use of a microprocessor as was done on SSM/I.

Where appropriate, circuit functions used on previous Hughes programs are proposed for TRMM. One example is the analog multiplexer which is implemented with 16-channel CMOS monolithic circuits used on numerous Hughes programs including HS261, the multimission bus (MMB), and HS601. Another example is the faster analog-to-digital converter which uses hybrid technology and has previously been used on Hughes' HS601 programs.

The TRMM spacecraft uses a single MIL-STD-1773 data bus. The SPU interfaces with this bus to transmit the science data and to receive commands.

DESIGN CHANGES FROM SSM/I

- FASTER A/D CONVERTER TO ACCOMMODATE HIGHER DATA RATE
  - COMPONENT USED ON HS601
- SINGLE APPLICATION-SPECIFIC INTEGRATED CIRCUIT REPLACES THE 1802 MICROPROCESSOR AND THE MSI LOGIC
  - HIGHER RELIABILITY BY REDUCING THE UNIT EQUIVALENT PART COUNT
  - FLEXIBILITY RETAINED BY STORING KEY TIMING PARAMETERS IN PROM
  - LOWER COST
- SINGLE MIL-STD 1773 DATA BUS INTERFACE REPLACES THE OLS AND SPACECRAFT INTERFACES
  - REQUIRES NEW OPTICAL INTERFACE UNIT DESIGN
  - SCIENCE DATA MULTIPLEXED WITH TELEMETRY DATA

MICROPROCESSOR/ASIC TRADE STUDY

A trade-off study has been conducted to consider use of a microprocessor versus a hard-wired logic controlled system. The conclusion reached from this study is that the hard-wired logic approach is more optimum for the TRMM application. The microprocessor chip set considered in the trade study implements the MIL-STD-1750A architecture. Additional interface logic implemented on an ASIC (application specific integrated circuit) would be required to support the microprocessor. On the other hand, all the required logic functions could be implemented on a single ASIC, thus reducing the Signal Processing Unit's parts count. The microprocessor approach requires additional PROM (programmable read-only memory) to store the software as "firmware", thus increasing power consumption by 0.5 watt. Reliability is higher for the single ASIC approach due to lower parts count. The most significant disadvantage of the microprocessor approach is the added software development cost.

TRMM

MICROPROCESSOR/ASIC TRADE STUDY

HUGHES

CONSIDERATION	MICROPROCESSOR	ASIC
PARTS COUNT	3-CHIP SETS	ONE ASIC
POWER	PROM >1 WATT	PROM <0.5 WATT
RELIABILITY	HIGH (4 VLSI CHIPS)	VERY HIGH (1 VSLI CHIP)
COST	HIGH FLIGHT S/W DEVELOPMENT COST	NO FLIGHT S/W

RECOMMENDATION: USE THE ASIC

DIGITAL INTERFACE
ACTION ITEM RESPONSE

- MARK FLANEGAN OF GSFC WAS CONTACTED REGARDING THE 1553B - 1773 INTERFACE

- *SCI* IS DEVELOPING A SPACE QUALIFIED 1553B - 1773 ASSEMBLY CALLED A 'TERMINAL'; THIS ASSEMBLY WILL BE PART OF THE OIU

- PRELIMINARY SIZE AND POWER SPECIFICATIONS WERE OBTAINED FROM *SCI*

- NEED MORE DETAIL INFORMATION ON THE *SCI* TERMINAL AND SPACECRAFT POWER BUS INTERFACE

POWER SUBSYSTEM

TASK MANAGER
M. ZWANG

POWER SUBSYSTEM ELEMENTS

The TRMM Power Subsystem consists of 3 power subsystem modules:

Receiver DC/DC converter, Signal Processing DC/DC converter, and the Post Regulator Unit. The two DC/DC Converters are housed in a single chassis. The Post Regulator Unit contains 6 linear post-regulators in addition to two command controlled switches for the BAPTA Heater and the BAPTA Motor.

POWER SUBSYSTEM ELEMENTS

- DC/DC CONVERTER UNITS:
  - RECEIVER (1)
  - SIGNAL PROCESSING (1)
- POST-REGULATORS:
  - GUNN LOCAL OSCILLATOR (5)
  - DETECTOR ELECTRONICS UNITS (1)
- SWITCHES:
  - BAPTA HEATER (1)
  - BAPTA MOTOR (1)

TRMM - SSM/I COMPARISON

The differences between the TRMM and the SSM/I power supplies are minimal. There is one extra post regulator to accommodate the new LO, at 10.65 GHz, and 25% more power consumed by the two new channels.

TRMM - SSM/I COMPARISON

TRMM POWER SUBSYSTEM IS FUNCTIONALLY THE SAME AS SSM/I

DIFFERENCES:

	TRMM	SSM/I
LO POST-REGULATORS	5	4
RECEIVER POWER	125% OF SSM/I	-

POWER SUBSYSTEM BLOCK DIAGRAM

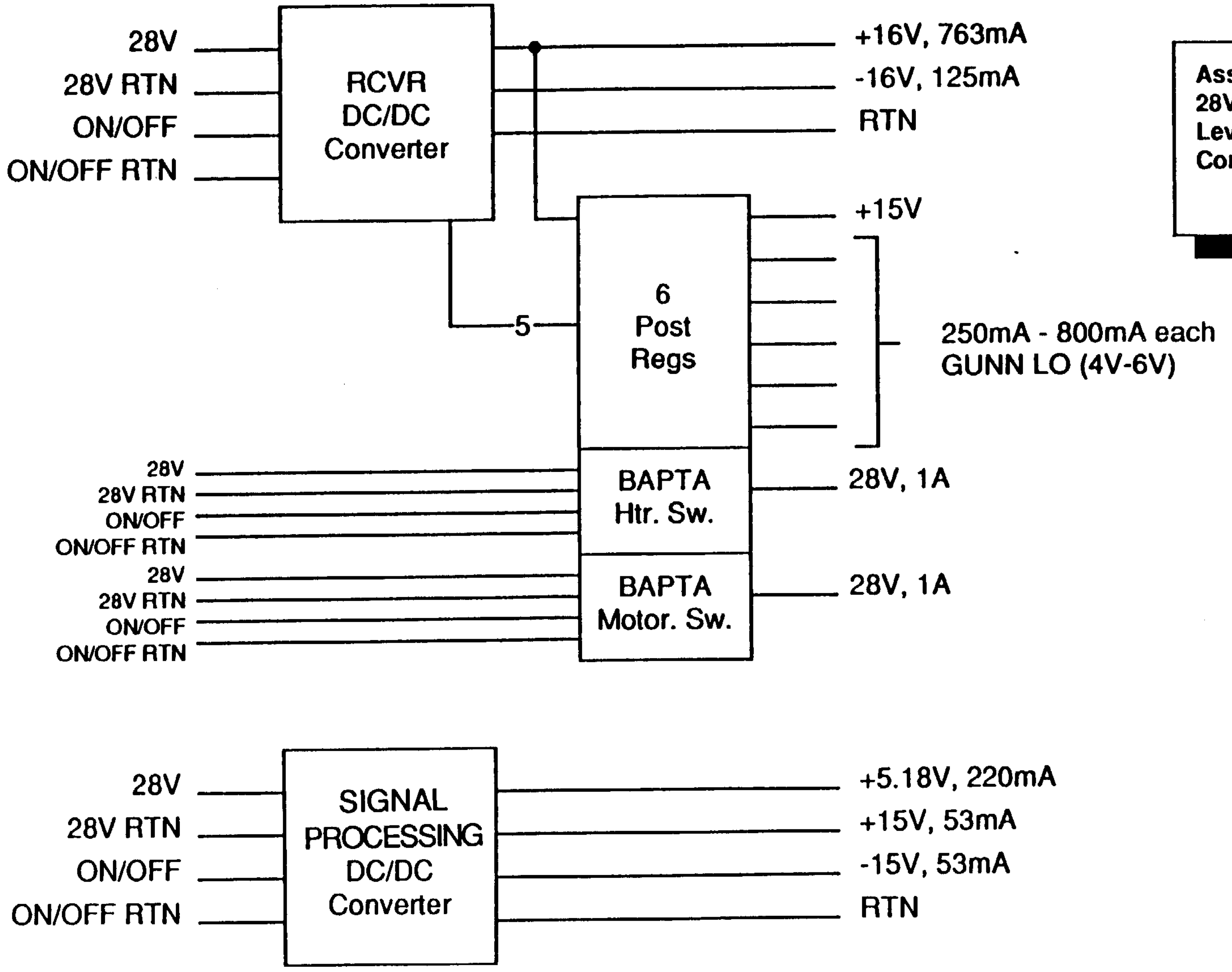
A 28V bus power is provided continuously to the DC/DC converters and switches. A level command to the Signal Processing DC/DC Converter turns the unit on. The Signal Processing Unit is enabled to send commands to the Receiver DC/DC Converter, and BATPA motor or heater switches.

The Post Regulator unit contains five adjustable post regulators for the GUNN LOs and one +15V post regulator for the receiver detector electronics.

TRMM

POWER SUBSYSTEM BLOCK DIAGRAM

HUGHES



Assumptions:
28V is ±2%
Level commands Logic 1 ≥ 4V
Converters sync to 15kHz clock

CHANGES TO RECEIVER POWER SUPPLY

The receiver power supply will have to be able to provide the extra power needed by the 10 GHz channels. The changes are in the magnetics of the converter, and in the current limit circuit of the preregulator.

The 5 LOs will be using 4 taps on the DC/DC converter.

CHANGES TO RECEIVER POWER SUPPLY

- MODIFICATIONS TO THE RECEIVER DC/DC CONVERTER (TO HANDLE MORE POWER)
    - REDESIGN MAGNETICS
    - MODIFY PREREGULATOR CURRENT LIMIT
- PROVIDE 4 TAPS ON THE DC/DC CONVERTER FOR ALL THE LO POST-REGULATORS

POWER SUBSYSTEM ESTIMATED POWER REQUIREMENTS

Listed here are the SSM/I and the estimated TRMM power requirements. The only changes occur because of the additional two receivers, and thus the receiver power supply will provide the extra power.

POWER SUBSYSTEM ESTIMATED POWER REQUIREMENTS

	VOLTAGE	SSM/I	ESTIMATED TRMM
RECEIVER POWER SUPPLY	+16V	610mA	763mA
	-16V	100mA	125mA
	+15V	80mA	100mA
	POST-REGS	250 TO 800mA x4	250 TO 800mA x5
SIGNAL PROCESSING POWER SUPPLY	+5.18V	220mA	220mA
	+15V	53mA	53mA
	-15V	53mA	53mA

STRUCTURES, MECHANISMS AND CONTROLS SUBSYSTEM

TASK MANAGER
C. STAMMERJOHN

STRUCTURES, MECHANISMS AND CONTROLS SUBSYSTEM ELEMENTS

Listed here are the elements of the structures, mechanisms and control subsystem. They are: The Bearing And Power Transfer (BAPTA), BAPTA Control Electronics (BCE), Momentum Wheel Assembly (MWA) (includes the momentum wheel and the electronics controlling it), Antenna Deployment Mechanism (ADM) and the Radiometer Deployment Mechanism (RDM).

STRUCTURES, MECHANISMS AND CONTROLS SUBSYSTEM ELEMENTS

ELEMENT	CONTENTS/FUNCTION
BEARING AND POWER TRANSFER ASSEMBLY (BAPTA)	SPIN MOTOR, POSITION ENCODER, POWER AND SIGNAL SLIPRINGS
BAPTA CONTROL ELECTRONICS (BCE)	CONTROLS SPIN RATE, INTERFACES WITH MWA
MOMENTUM WHEEL ASSEMBLY (MWA)	COMPENSATES THE SENSOR ANGULAR MOMENTUM
ANTENNA DEPLOYMENT MECHANISM (ADM)	MULTI-RATE, FLUID FILLED ROTARY DAMPER CONTROLLING THE REFLECTOR DEPLOYMENT
RADIOMETER DEPLOYMENT MECHANISM (RDM)	MULTI-RATE, FLUID FILLED ROTARY DAMPER CONTROLLING THE RADIOMETER DEPLOYMENT

STRUCTURES, MECHANISMS AND CONTROL SUBSYSTEM ELEMENTS (CONT)

Other miscellaneous elements of this subsystem are: The calibration load assembly (the structure only), pyrotechnics, harness, thermal blankets and the function of mechanical integration, mass properties, spin balance and vibration. The SSM/I program was set up this way, and the program ran smoothly. The rationale was that this subsystem is responsible for the mechanisms and controls which is a major part of the radiometer, and thus the staff would be very knowledgeable integrating and testing the radiometer.

STRUCTURES, MECHANISMS AND CONTROLS SUBSYSTEM ELEMENTS (CONT)

ELEMENT	CONTENTS/FUNCTION
CALIBRATION LOAD ASSEMBLY	DESPUN STRUCTURE FOR THE TWO CALIBRATION LOADS
PYROTECHNICS	REDUNDANT PIN PULLER PYRO DEVICES FOR RADIOMETER AND REFLECTOR DEPLOYMENTS
HARNESS	
THERMAL BLANKETS	
MECHANICAL INTEGRATION MASS PROPERTIES, SPIN BALANCE AND VIBRATION	

TRMM - SSM/I COMPARISON

As mentioned before, all mechanisms and controls are the same as SSM/I. The changes neeeded are in the structure of the rotating compartment to accommodate the new horn and new receivers.

The changes in the BCE are minimal component changes due to the higher spin rate.

TRMM - SSM/I COMPARISON

	SSM/I	TRMM
ANTENNA STRUCTURE AND DEPLOYMENT	4 BAR LINKAGE 2 STAGE	SAME
RADIOMETER DEPLOYMENT MECHANISM	FLUID DAMPED	SAME, SIZE TBD
BAPTA	TITANIUM	SAME
BAPTA CONTROL ELECTRONICS	ANALOG	SAME, COMPONENT CHANGES DUE TO HIGHER SPIN RATE
SENSOR STRUCTURE		REDESIGN REQUIRED TO ACCOMMODATE NEW HORN AND RECEIVERS

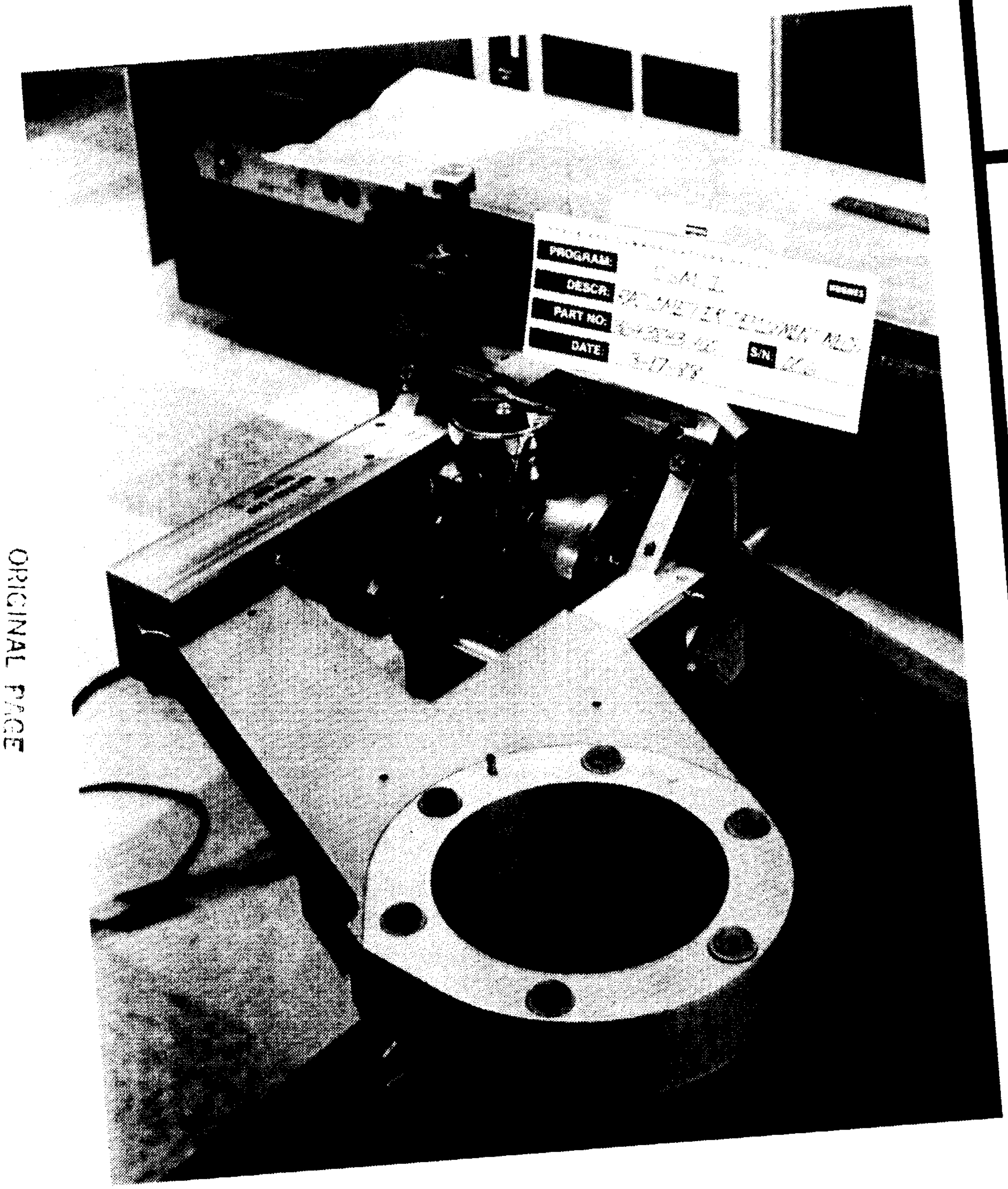
MOMENTUM WHEEL CHARACTERISTICS

This table shows the characteristics of the proposed momentum wheel for the TRMM mission, purchased from Bendix.

MOMENTUM WHEEL CHARACTERISTICS

MOMENTUM RANGE	SSM/I 2.2 - 3.0 FT-LB-SEC	*TRMM 4.0 - 6.0 FT-LB SEC
OVERALL WEIGHT	19 LBS	20 LBS
MOTOR TYPE	A.C. TYPE	SAME AS SSM/I
BEARINGS	R-8	R-10
ELECTRONICS	EXISTING	SAME AS SSM/I
WHEEL DIAMETER	9 INCHES	12 INCHES
COST	$400K/WHEEL (QTY 4)	$500K (ONE WHEEL)
BENDIX PRINTS, DOCUMENTS	EXISTING	SAME AS SSM/I
POWER CONSUMPTION	10 WATTS	15 WATTS (APPROX.)

(* COBE/GODDARD WHEEL)



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HUGHES

SSM/I Radiometer Deployment Mechanism (RDM)

TRMM

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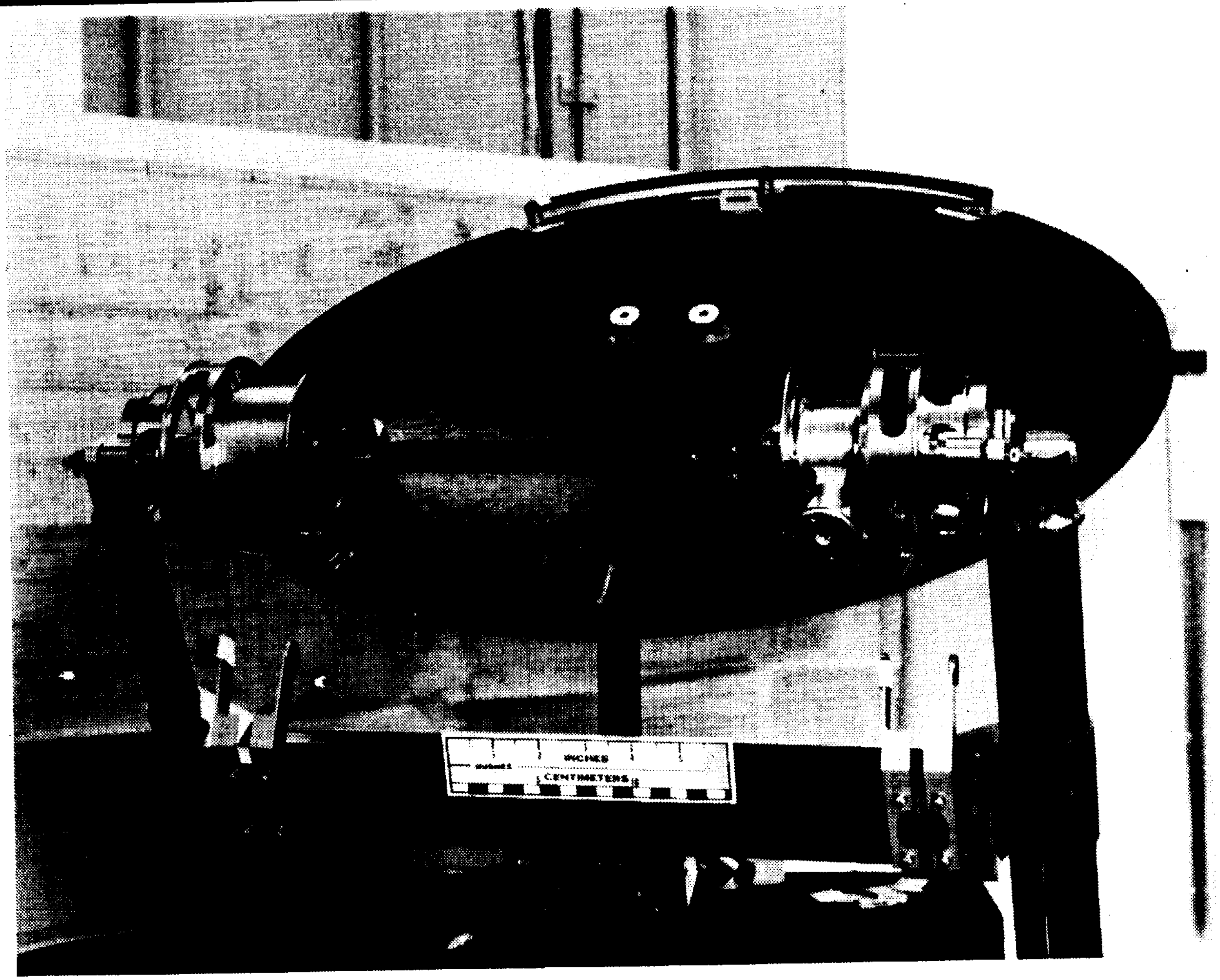
TRMM

SSM/I Antenna Deployment Mechanism (ADM)

HUGHES



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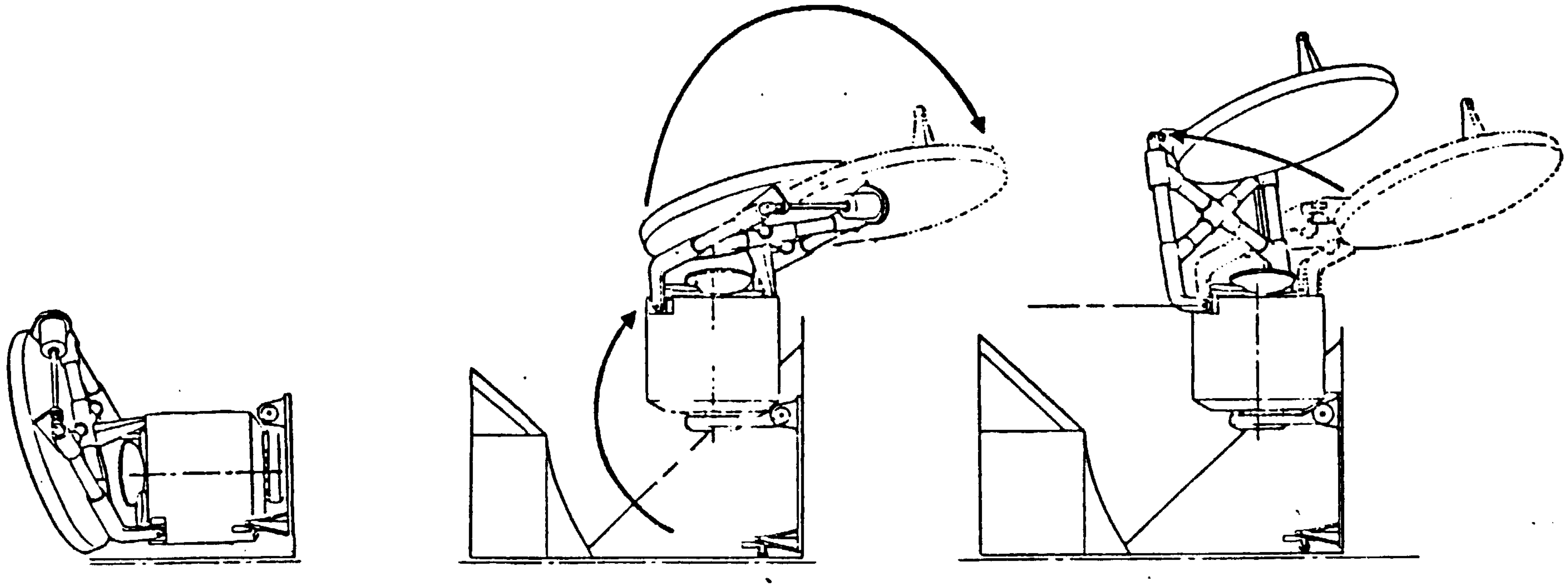
SSM/I DEPLOYMENT SCHEME



a) STOWED

b) SENSOR DEPLOYMENT AND ANTENNA ROTATION

c) ANTENNA TRANSLATION TO FINAL POSITION

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