AAP DATA RELAY TERMINAL DESIGN STUDY

SECOND PROGRESS REPORT

Contract No. NASW-1982 for NASA Headquarters

In the period subsequent to the first Design Review, which took place on 13 October 1969, the effort was directed towards completing several tradeoff studies and the establishment of a terminal baseline design. During this period, the work effort initiated by McDonnell-Douglas Aircraft Corporation (MDAC) for integrating the Data Relay Terminal (DRT) into the Saturn Workshop (SWS) was terminated when it was established by NASA that the DRT would not be incorporated into the SWS. As a result, it was not possible to reach final agreement with MDAC on details of attaching the DRT to the SWS, and two possible DRT configurations have been included in the baseline design. The principal differences between the two configurations are in the length and layout of the antenna boom, and the location at which the boom is attached to the SWS.

It was established that communications via the DRT would employ one carrier on the up-link (MCC/H to SWS) and two carriers on the down-link (SWS to MCC/H). It was also established that the simultaneous transmission of multiple low-data-rate digital telemetry signals would be accomplished by digital multiplexing into a single data stream at 72Kbps.

Design Review No. 2, covering Performance Requirements and the DRT Baseline Design, was held at Hughes, El Segundo, on 15 December 1969. The material covered in this design review is summarized in the attached set of charts which were presented at the design review.

The period covered by this report is from 14 October 1969 through 16 December 1969, inclusive.

HUGHES AIRCRAFT COMPANY

L M Gould by H.H.

Leon M. Gould
Program Manager

AAP DATA RELAY TERMINAL DESIGN STUDY

FOR NASA HEADQUARTERS UNDER CONTRACT NO. NASW - 1982

DESIGN REVIEW NO 2

PERFORMANCE REQUIREMENTS

PRELIMINARY DESIGN CONCEPT

12-15-69

AGENDA

1	REQUIREMENTS REVIEW	GOULD
2	BLOCK DIAGRAM OF DATA RELAY TERMINAL	REICHE
3	LINK POWER BUDGETS AND CARRIER SPREADING	WINTERBOTTOM
4	DIGITAL SIGNAL MULTIPLEXING	FLEARY
5	ANTENNA TRACKING	STOKES
6	LINK ACQUISITION	STOKES
7	PHYSICAL CONFIGURATION, POWER, WEIGHT	MILLIKEN
8	THERMAL DESIGN	MC GRATH
9	ANTENNA DESIGN	CARNEGIS
10	ANTENNA POSITIONING	TOWNSEND

LINK REQUIREMENTS

UPLINK - VOICE OR VOICE + COMMAND

DOWNLINK - VOICE OR VOICE + TELEMETRY A, B, OR C

VOICE: - T T/N $\geq$ 20 dB (WITH CLIPPING)

- PRIORITY ON BOTH LINKS

COMMAND: - 2 KHz SINE WAVE SUPERIMPOSED ON 1 KHz SINE WAVE

- 10^{-6} BER

TELEMETRY: - 10^{-4} BER ON ANY CHANNEL

CHANNEL A	51.2 KBPS
B	72 KBPS
C	1.6 + 4.0 + 2 x 5.12 + (5.12 OR 5.76) (ASSUMED ALL ASYNCHRONOUS)

CARRIER FREQUENCIES

OPERATE ON EITHER OF TWO ADJACENT TRANSPONDER CHANNELS FROM GROUP OF CHANNELS 9-12

LINK TRADEOFFS

NUMBER OF CARRIERS:	UPLINK: 1
	DOWNLINK: 2
DOWNLINK MODULATION:	DIGITAL MULTIPLEXING OF TM CHANNEL C
	FM FOR VOICE
	BI PHASE FOR DATA
SPECTRUM SPREADING:	UPLINK: PROBABLY NOT REQUIRED
	DOWNLINK: REPEATER BANDWIDTH
	INADEQUATE TO ACHIEVE CCIR RECOMMENDATION

ORBITAL AND STABILIZATION CONSTRAINTS

NOMINAL AAP/SWS ORBIT

ALTITUDE - 220 N MI (CIRCULAR)

INCLINATION - 35^0 (35^0 TO 55^0)

ORIENTATION RELATIVE TO SUN OR EARTH - ARBITRARY

AAP/SWS ATTITUDE

SUN INERTIAL MODE:

X (LONGITUDINAL) AXIS IN ORBIT PLANE
Z AXIS (SOLAR PANELS) TOWARD SUN

UNCERTAINTY (ATM)

PITCH OR YAW	$\pm$ 4 ARC MIN (3σ)
ROLL	$\pm$10 ARC MIN (3σ)
RATES	TBD

ALLOWABLE REACTION WITH SWS

50 FOOT-POUNDS

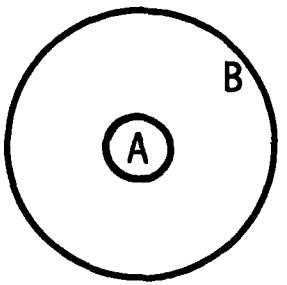
500 FOOT-POUND-SECONDS

ANTENNA/ANTENNA POSITIONING CONSTRAINTS

ANTENNA - 15' DIA RIGID PARABOLA WITH CASSEGRAINIAN FEED

MOUNTING LOCATION - AFT END OF SWS

BOTH CENTER (A) AND
OFFSET (B) LOCATIONS UNDER CONSIDERATION



ACQUISITION

AUTOMATIC, WITH COMPUTER ASSIST
MANUAL BACK UP MODE

TRACKING

AUTOMATIC, WITHOUT COMPUTER ASSIST

COMPUTER ASSIST

REAL TIME COMPUTER AT MCC
- *UPDATING ON BOARD COMPUTER*
- PROGRAM UPLINK TRANSMISSION

ON BOARD COMPUTER
- ACQUISITION POINTING COMMANDS ($\pm 5^0$)
- GENERATE ACQUISITION SCAN PATTERN

TRADE-OFFS

OPERATIONAL CONTINUITY
- MINIMIZE INTERRUPTIONS CONSISTENT WITH MOMENTUM REACTION CONSTRAINTS AND EFFICIENT UTILIZATION OF POWER

INTERFACES

AAP/SWS

LOCATION: OUTBOARD AT AFT END OF SWS, EXCEPT FOR CONTROL PANEL AND BASEBAND PROCESSING UNIT, WHICH SHALL BE INBOARD.

CONFIGURATION:

STOWED - WITHIN THE SEPARATION ENVELOPE SPECIFIED BY SWS CONTRACTOR

DEPLOYED - SHALL NOT INTERFERE WITH THERMAL RADIATORS ON AFT END OF SWS

O AND M TO BE COORDINATED WITH MDAC

POWER:

28 V DC BUS (25 TO 30 V)

TRANSIENTS - 100 V SPIKES, 10 μSEC DURATION
- LOAD SWITCHING 22 TO 33 V WITH RECOVERY TIME OF 1 SEC

THERMAL: THERMAL CONTROL OF OUTBOARD TERMINAL EQUIPMENT SHALL BE INDEPENDENT OF SWS

T & C: HARDWIRE (50-100 PAIRS)

LOADS: PRELIMINARY STRUCTURAL DESIGN CRITERIA FROM MDAC (HAC REPORT NO. 2222.3/1035)

INTERFACES (Con't)

AAP/ATM

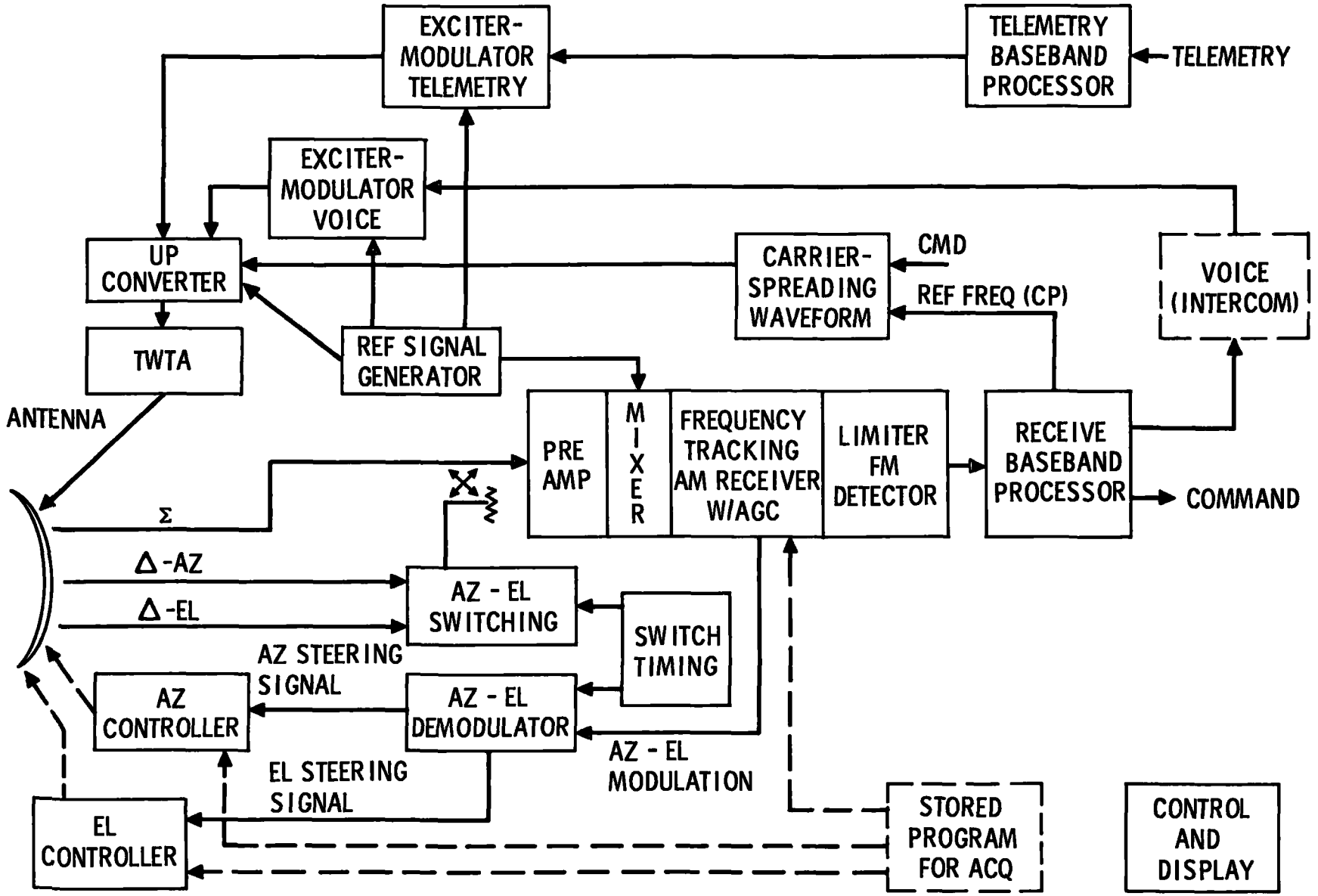
ON BOARD COMPUTER - ACQUISITION POINTING AND SCANNING COMMANDS

- DETAILS TBD

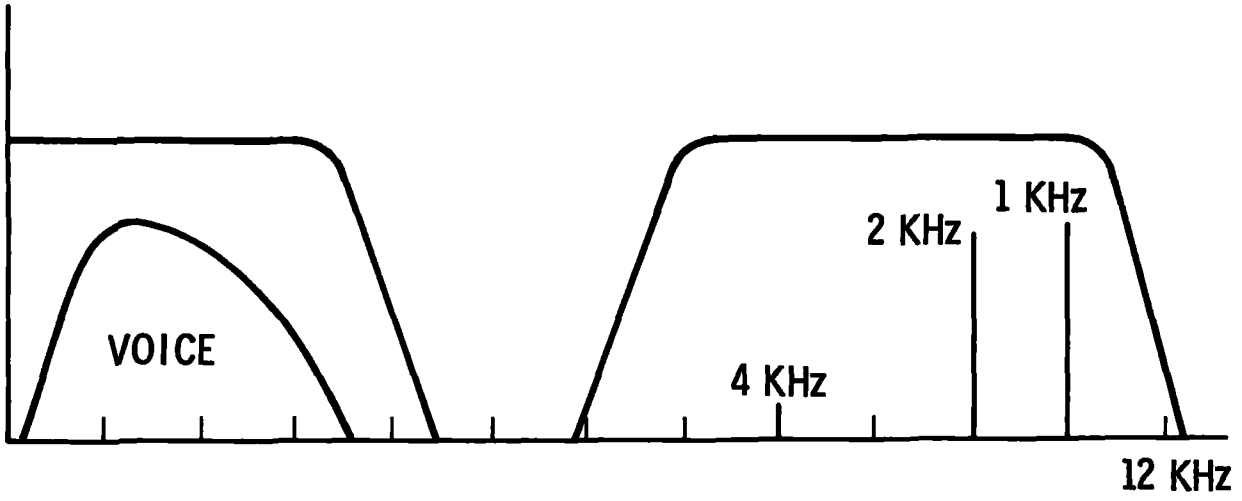
INTELSAT IV

- NO MODIFICATIONS FOR THIS APPLICATION
- PERFORMANCE DATA PROVIDED BY HAC
- CHANNEL ALLOCATED TO THIS APPLICATION SHALL BE FROM CHANNELS 9 THROUGH 12, WITH ADJACENT CHANNEL FROM SAME GROUP DESIGNATED AS BACKUP
- SPECIFIC CHANNEL DESIGNATIONS TO BE PROVIDED BEFORE HARDWARE IMPLEMENTATION

OWS MICROWAVE TERMINAL



UP LINK - SINGLE CARRIER COMMAND AND VOICE MULTIPLEXING



ASSUMED:

1. GEMINI COMMAND WAVEFORM REQUIRES ROUGHLY THE EQUIVALENT OF A VOICE CHANNEL.
2. 20 dB TT/N WILL MEET REQUIREMENTS OF BER = 10^{-6}.

RETAIN COHERENCY OF 1 AND 2 KHz WAVEFORM THROUGH MUX AND DEMUX BY COHERENT TRANSLATION

1 VS 2 CARRIERS - UPLINK

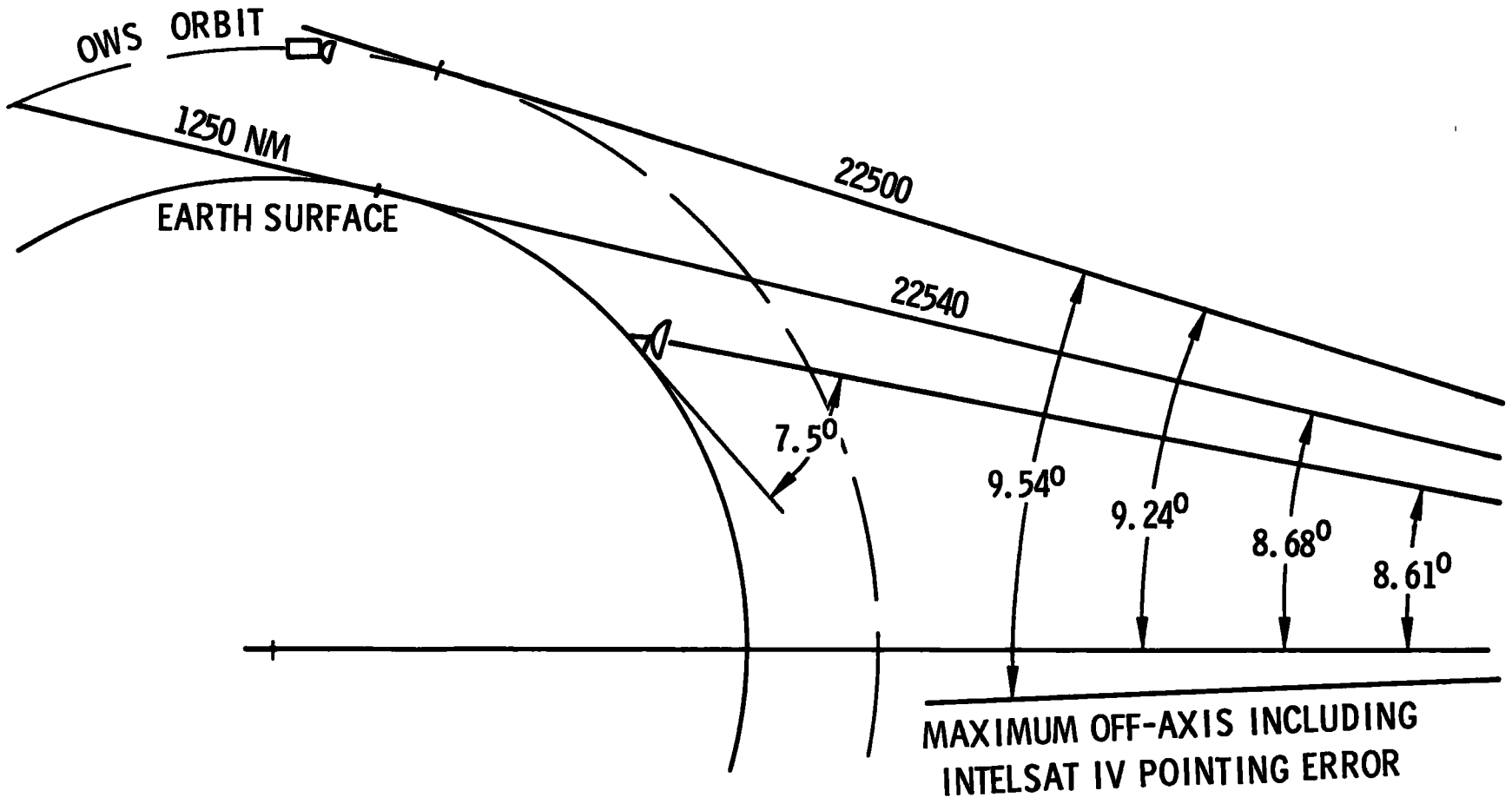
2 CARRIERS	-	MINIMUM REQUIRED RF BW/POWER (INTELSAT IV)
	-	2 DEMODS AT OWS
1 CARRIER	-	SMALL INCREASE IN POWER DUE TO LARGER OCCUPIED BW
	-	1 DEMOD + 1 DEMUX ON OWS
	-	ALL UPLINK POWER AVAILABLE FOR OWS ACQUISITION
	-	CONTINUOUS PRESENCE OF COMMAND SIGNAL AIDS CARRIER SPREADING DURING VOICE PAUSE
SELECTION	-	1 CARRIER

1 VS 2 CARRIERS - DOWNLINK

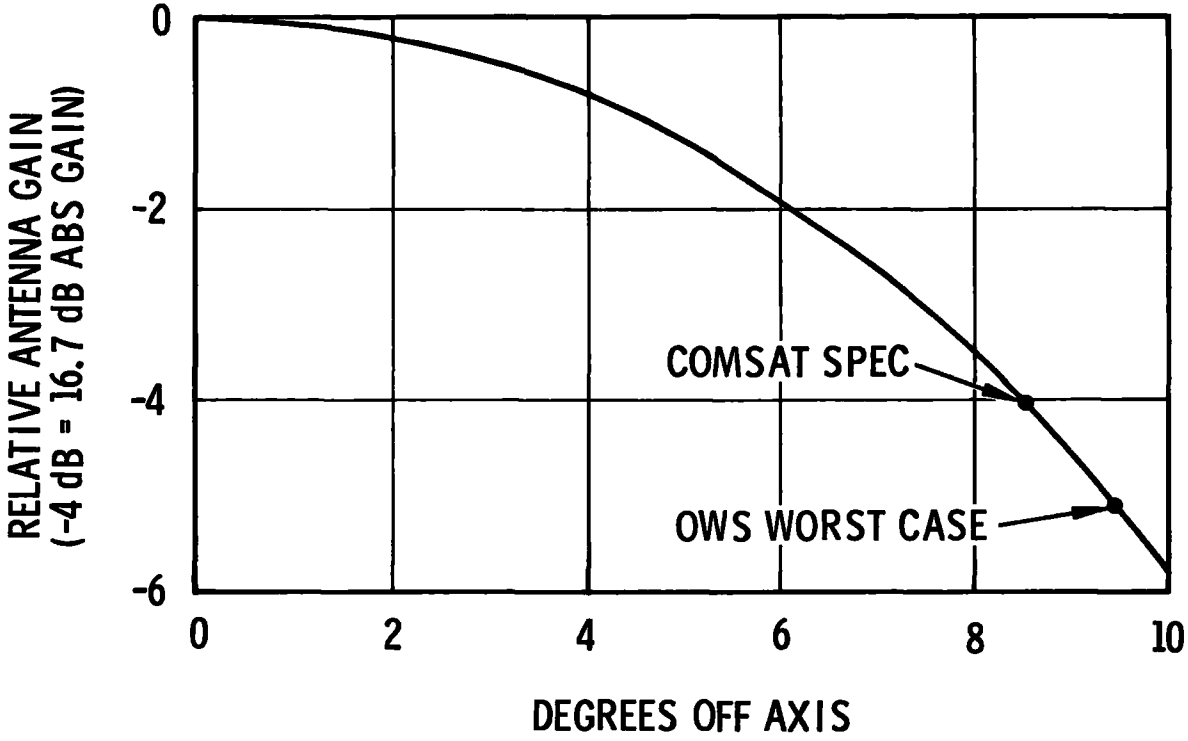
2 CARRIERS	-	REQUIRES LESS RF POWER IN SPITE OF MULTICARRIER LOSS
	-	2 MODULATOR/EXCITERS IN OWS
1 CARRIER	-	POOR MIX OF VOICE + DATA REQUIRES EXCESS BANDWIDTH AND/OR COMPLEX MULTIPLEXING
	-	REQUIRED MUX MORE EXPENSIVE THAN ADDITIONAL MODULATOR
SELECTION	-	2 CARRIERS

LINK GEOMETRY

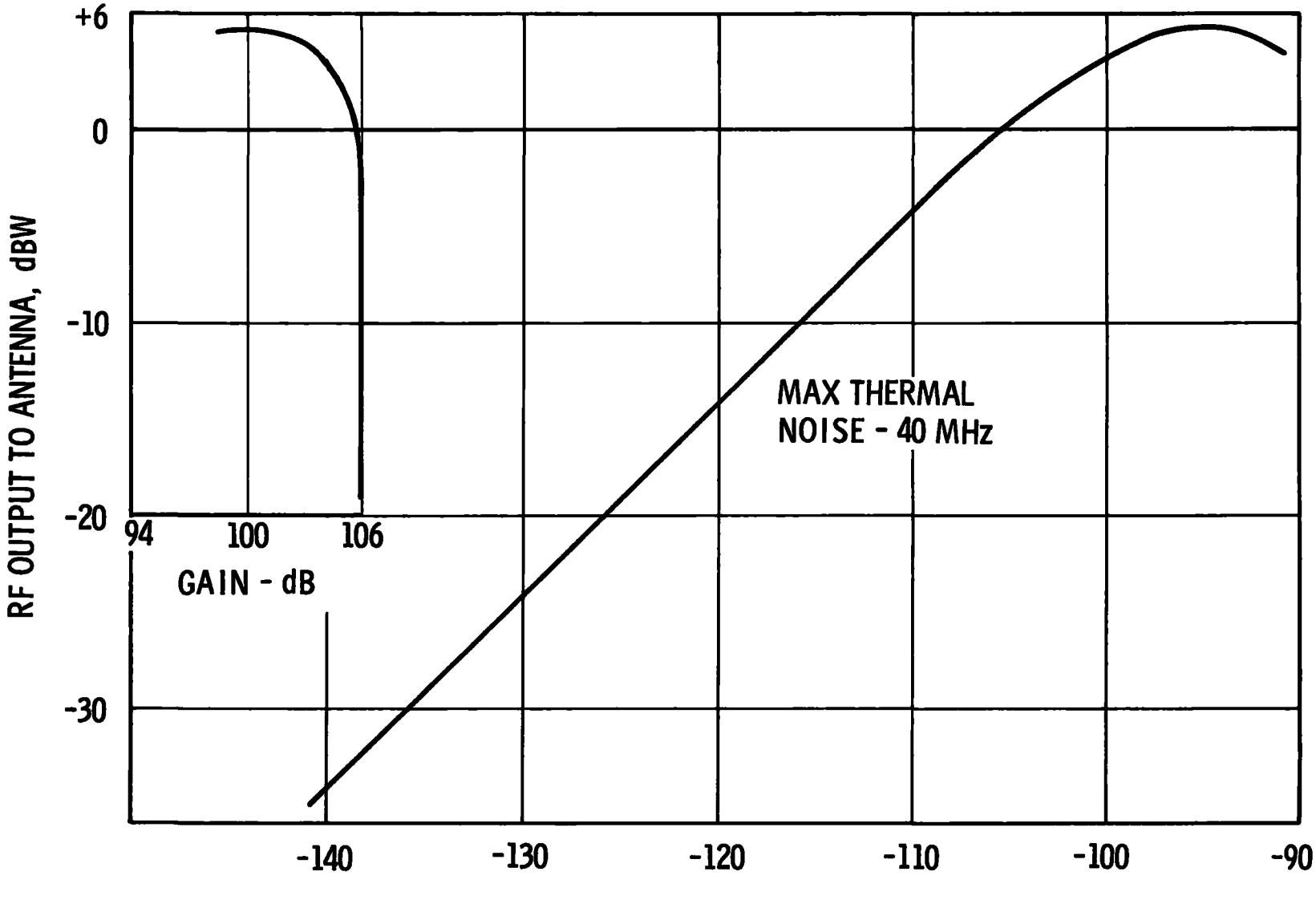
BOTH RANGE LOSS AND INTELSAT IV ANTENNA
GAINS ARE FUNCTIONS OF THE GEOMETRY



INTELSAT IV EARTH COVERAGE ANTENNA PATTERN



INTELSAT IV TRANSFER CHARACTERISTIC



UPLINK POWER BALANCE

MULTIPLEXED VOICE + 1KB/S COMMAND, FM

EARTH STATION RF OUTPUT	18.1 WATTS
INTELSAT IV RF OUTPUT	+0.4 DBW
C/N REQUIRED	10.0 DB
C/N OBTAINED	12.4 DB
MARGIN	+2.4 DB

UPLINK POWER CONTROL REQUIRED TO COMPENSATE FOR WEATHER

DOWNLINK WORST CASE POWER BALANCE

	3.1 KHz VOICE, FM	72 KB/S, BI-PHASE
SWS RF OUTPUT	2.3 W	14.2 W
INTELSAT IV RF OUTPUT	-30.7 dBW	-22.8 dBW
C/N REQUIRED	10.0 dB	10.4 dB
C/N OBTAINED	8.4 dB	8.8 dB
MARGIN	-1.6 dB	-1.6 dB

1) WEATHER CONDITION CORRESPONDS TO EARTH STATION G/T LOSS OF 6 dB

2) ASSUMED INTELSAT IV POINTING ERROR OF 0.3°

3) OCCURS AT WORST ORBIT GEOMETRY WHEN READY TO TRANSFER LINK TO OTHER INTELSAT IV

DOWNLINK POWER FLUX DENSITY AT SURFACE OF EARTH

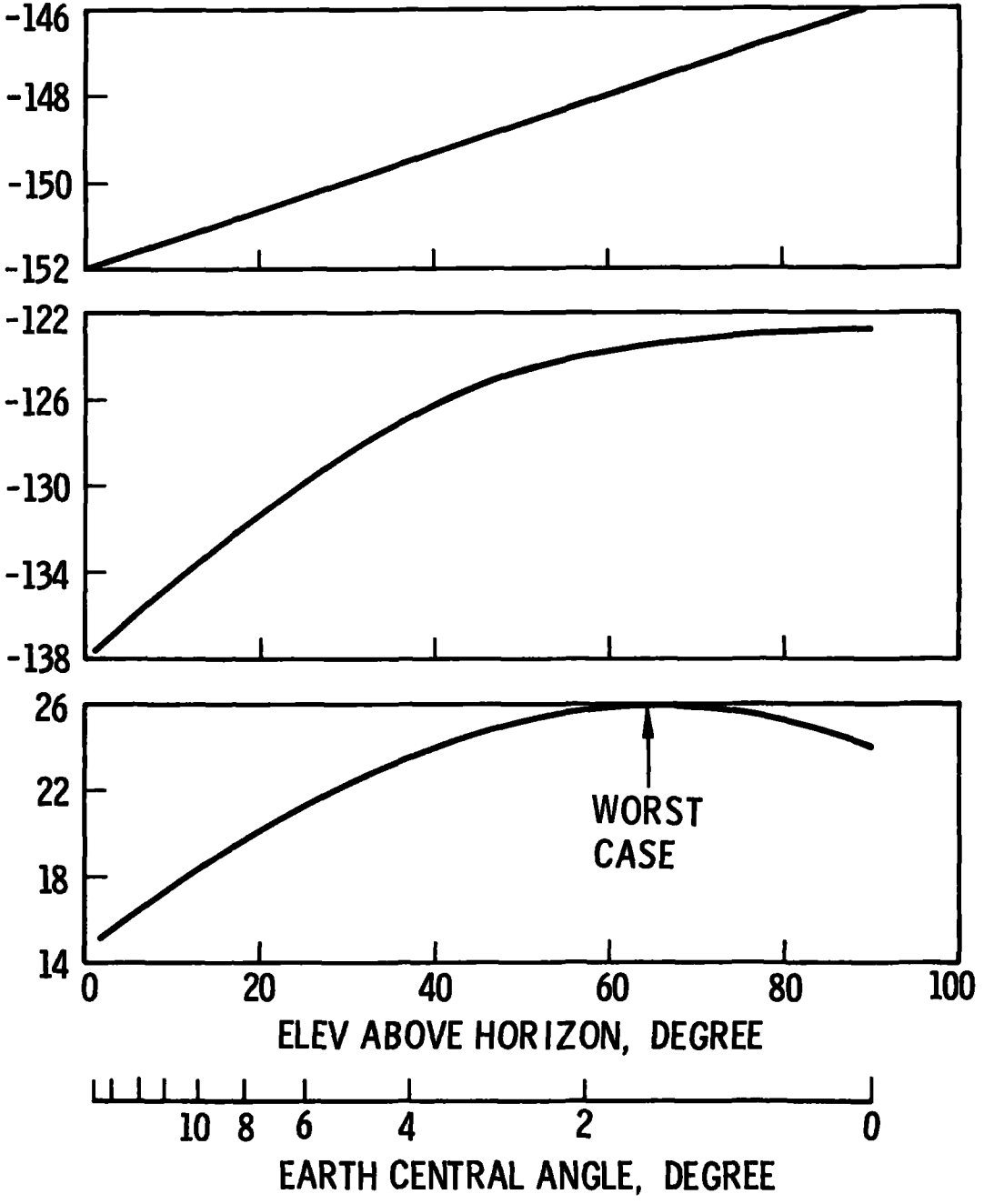
CCIR REG 358-1

MAX INCIDENT PWR FLUX-DENSITY
$dBw/M^2/4$ KHz

INCIDENT POWER VS SLANT RANGE
dBw/M^2

220 NM ORBIT
ISOTROPIC OWS ANT
EIRP = 0 dBw

PROTECTION REQUIRED
dB/dBw



DOWNLINK POWER FLUX DENSITY AT SURFACE OF EARTH

PROTECTION REQUIRED FOR WORST-CASE PATH GEOMETRY	26 dB/dBw
ADDEND FOR ON-AXIS EIRP	59 dBw
PATTERN DISCRIMINATION BY OWS ANTENNA ($>10^0$ OFF-AXIS)	-35 dB
ADDITIONAL PROTECTION REQUIRED	50 dB
MAXIMUM REDUCTION IN POWER FLUX DENSITY ATTAINABLE BY CARRIER SPREADING FULL CHANNEL BANDWIDTH	-39 dB
DEFICIT	11 dB

POSSIBLE IMPLEMENTATION:

APPLY TRIANGULAR WAVEFORM (WITH ROUNDED CORNERS)

f_m = 4 KHz (= OUT-OF-VOICEBAND UPLINK CP)

f = $\pm$16 MHz PEAK

DOWNLINK 5-CHANNEL MULTIPLEXING REQUIREMENT

5 BIT STREAMS :

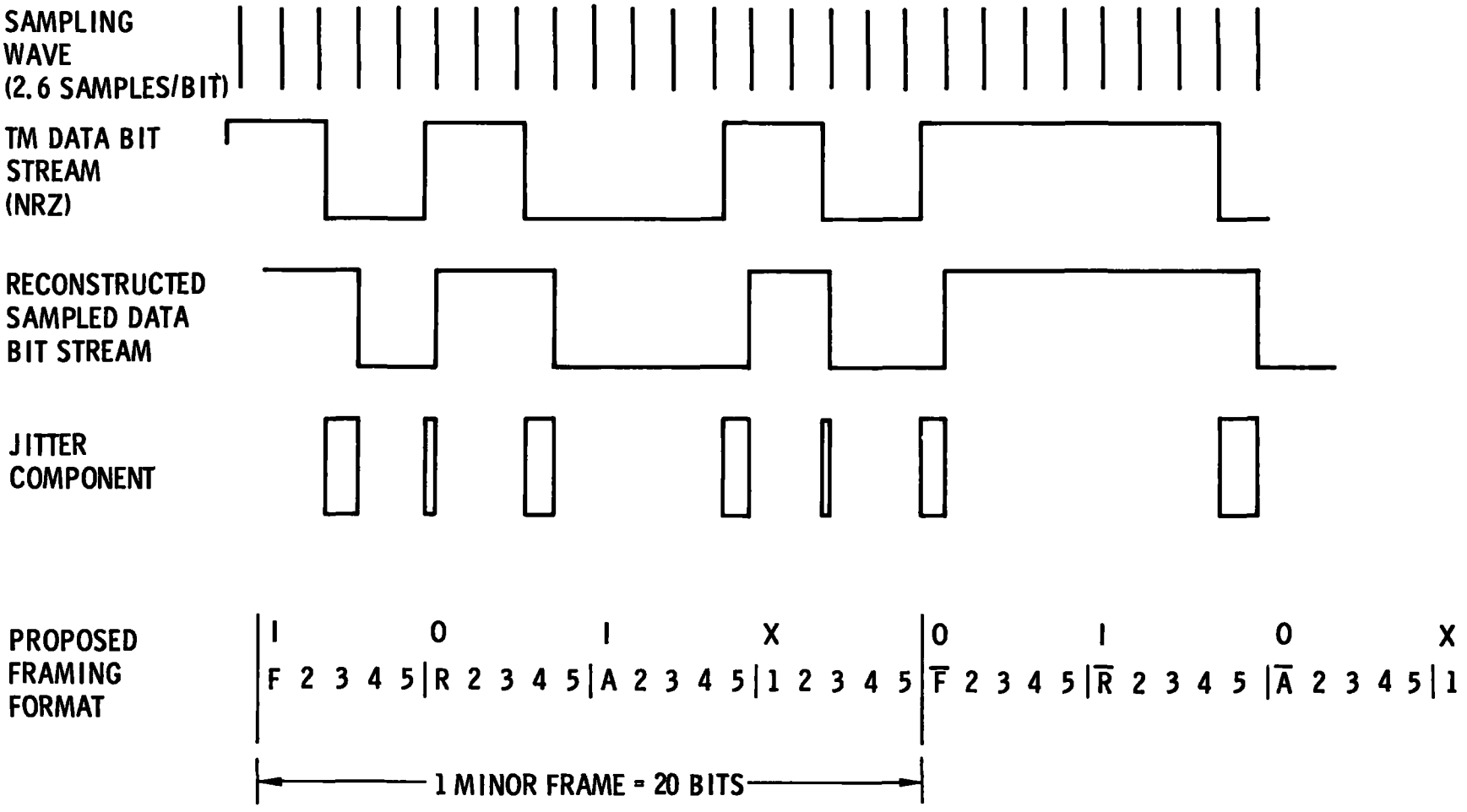
1.6 KBPS
4.0 KBPS
5.12 KBPS
5.12 KBPS
5.12 OR 5.76 KBPS

MAX COMPOSITE INFORMATION CONTENT = 21.6 KBPS

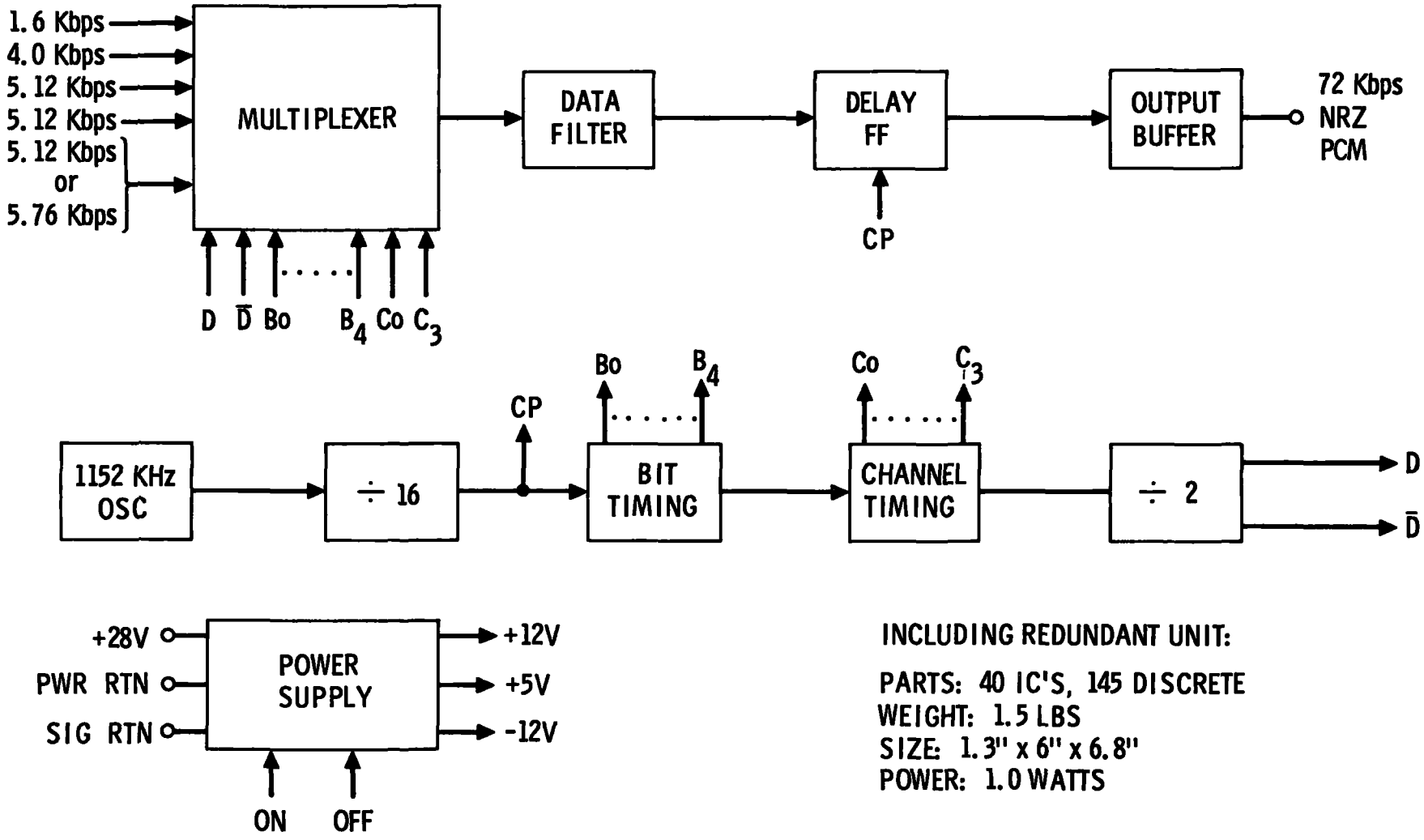
MULTIPLEXER DESIGN OBJECTIVE :

--COMBINE THESE 5 BIT STREAMS INTO SINGLE BIT STREAM NOT EXCEEDING 72 KBPS.

SAMPLING FRAME FORMAT



DIGITAL ENCODER



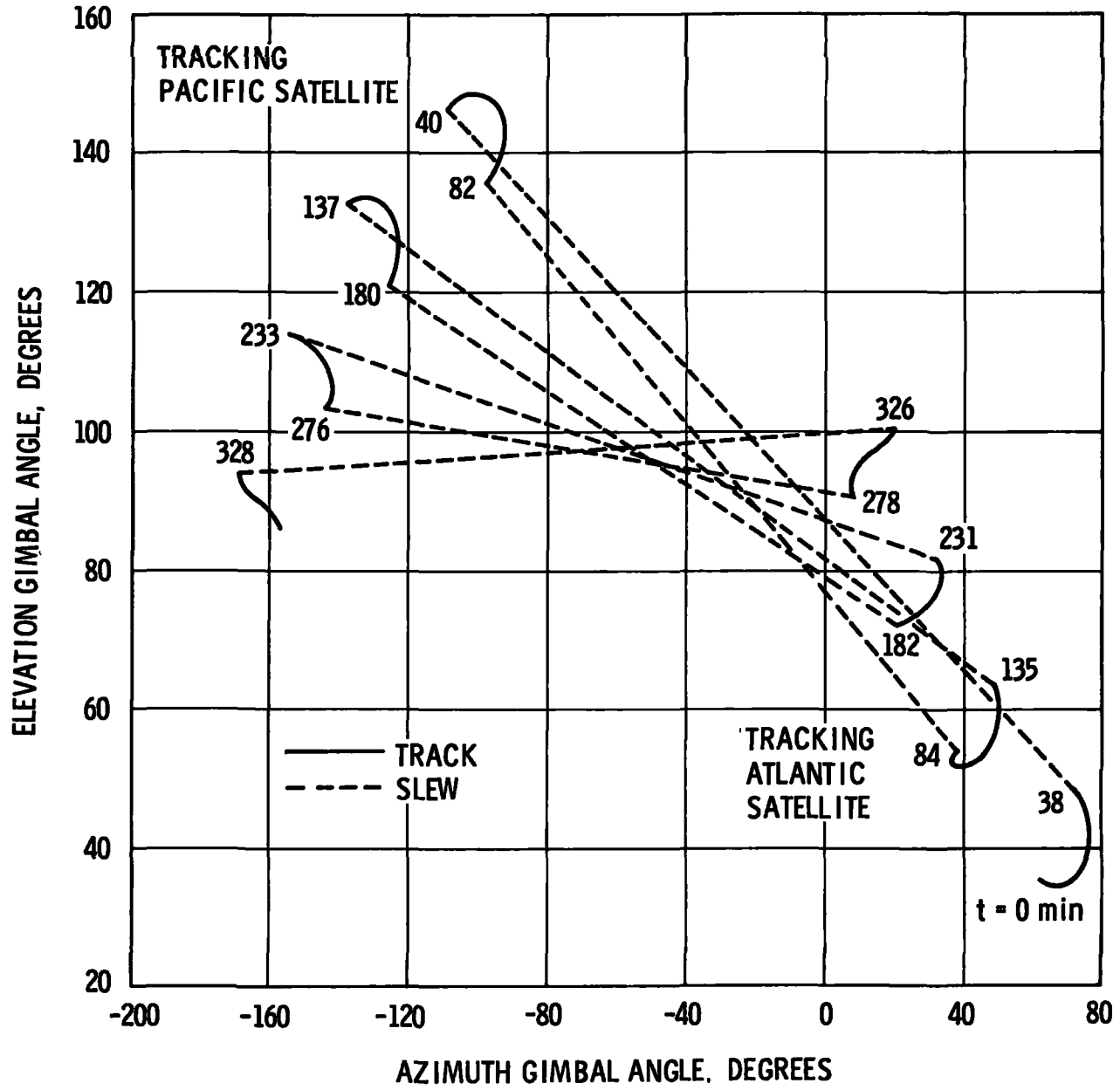
INCLUDING REDUNDANT UNIT:

PARTS: 40 IC'S, 145 DISCRETE
WEIGHT: 1.5 LBS
SIZE: 1.3" x 6" x 6.8"
POWER: 1.0 WATTS

ENCODER PERFORMANCE SUMMARY

CHANNEL NUMBER	BIT RATE (Kbps)	SAMPLE PER BIT	MAX JITTER (% OF BIT)
1	1.6	2.25	± 22.2
2	4.0	3.6	± 13.9
3	5.12	2.82	± 17.7
4	5.12	2.82	± 17.7
5	5.76 OR 5.12	2.5 OR 2.82	± 20.0 OR 17.7

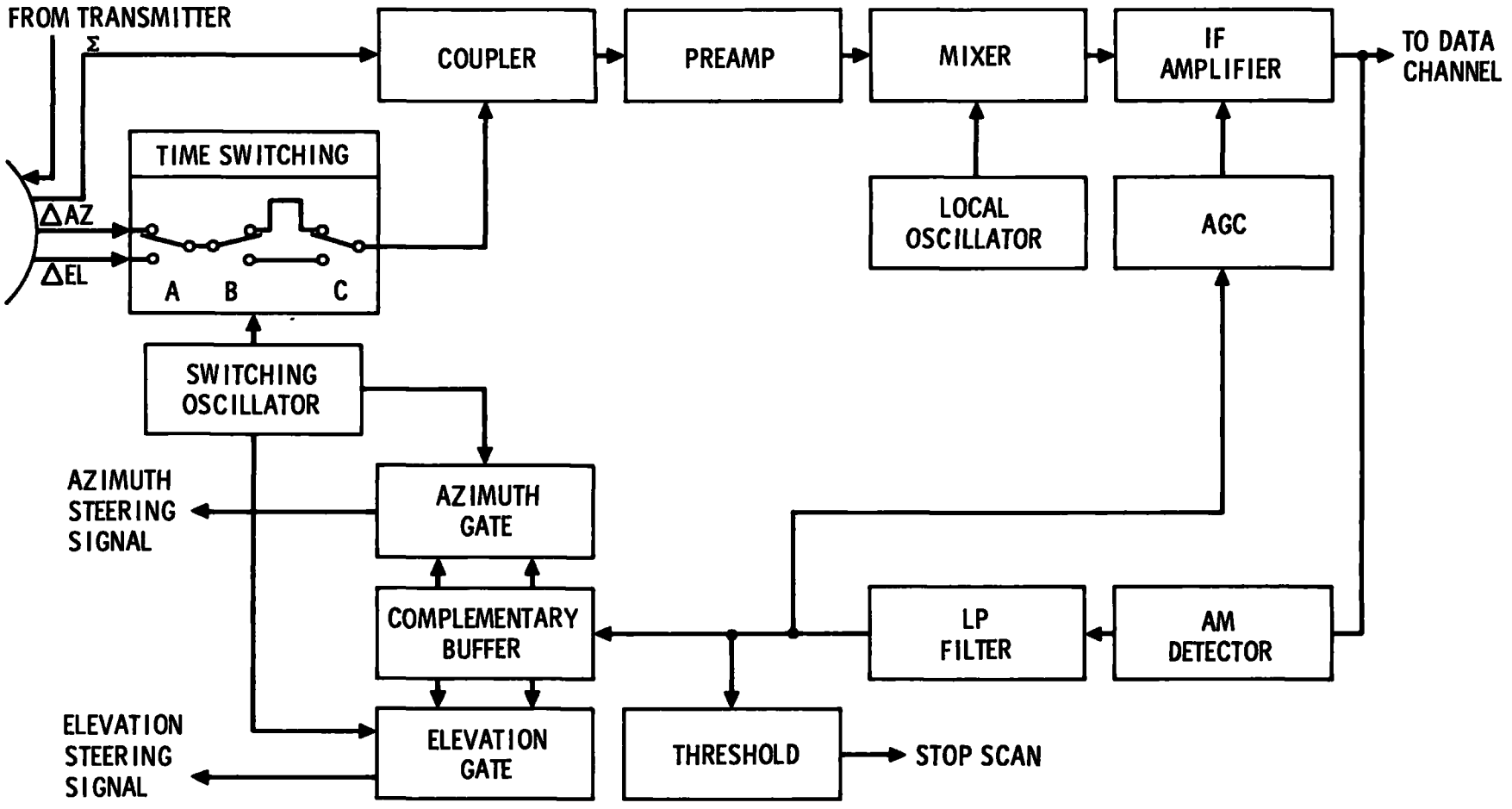
TYPICAL TRACKING PATHS FOR ORIENTED SPACECRAFT



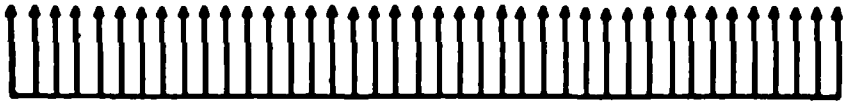
TRACKING PARAMETERS

INTELSAT ERP	13 dBw
IF BANDWIDTH	50 KHz
SERVO BANDWIDTH	1 RADIAN/SEC
SUM CHANNEL NOISE TEMP	1258^{0} K
RECEIVE ANTENNA GAIN	42.3 dB
RECEIVE BEAMWIDTH	1 DEGREE
3 SIGMA THERMAL NOISE ERROR	0.008 DEGREES

TIME-SHARED MONOPULSE CONCEPT



TIME DIVISION MONOPULSE VECTOR DIAGRAM



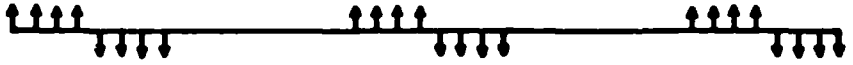
a) SUM CHANNEL

b) AZIMUTH ERROR SIGNAL

c) ELEVATION ERROR SIGNAL

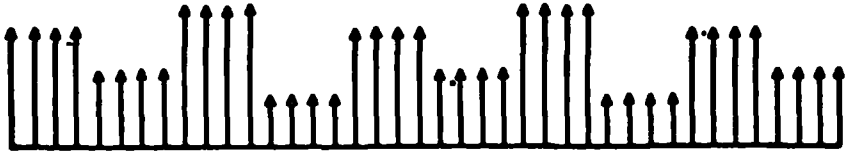
d) AZIMUTH CHANNEL AFTER SWITCH A

e) ELEVATION CHANNEL AFTER SWITCH A



f) AZIMUTH CHANNEL AFTER SWITCHES B AND C

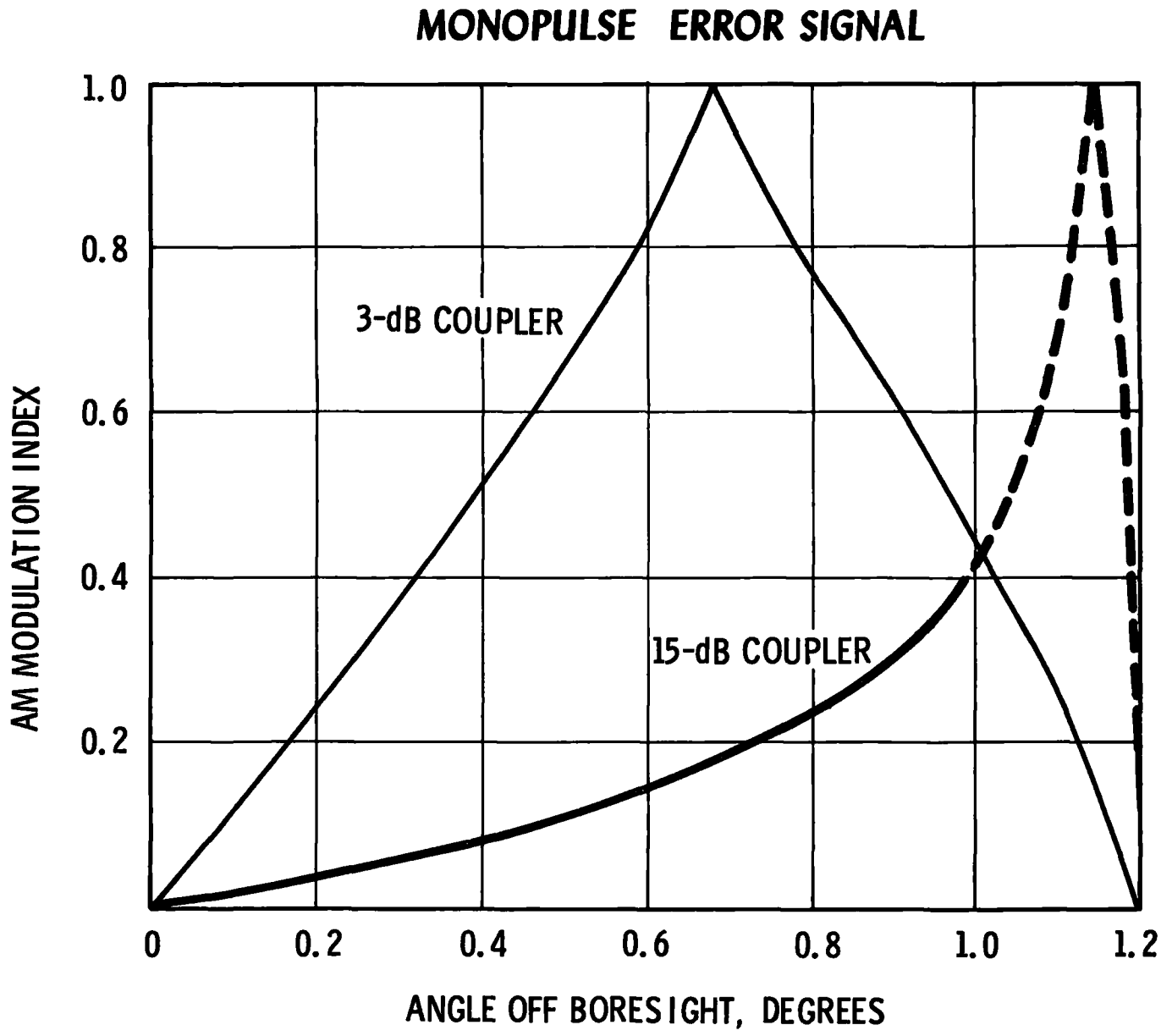
g) ELEVATION CHANNFL AFTER SWITCHES B AND C



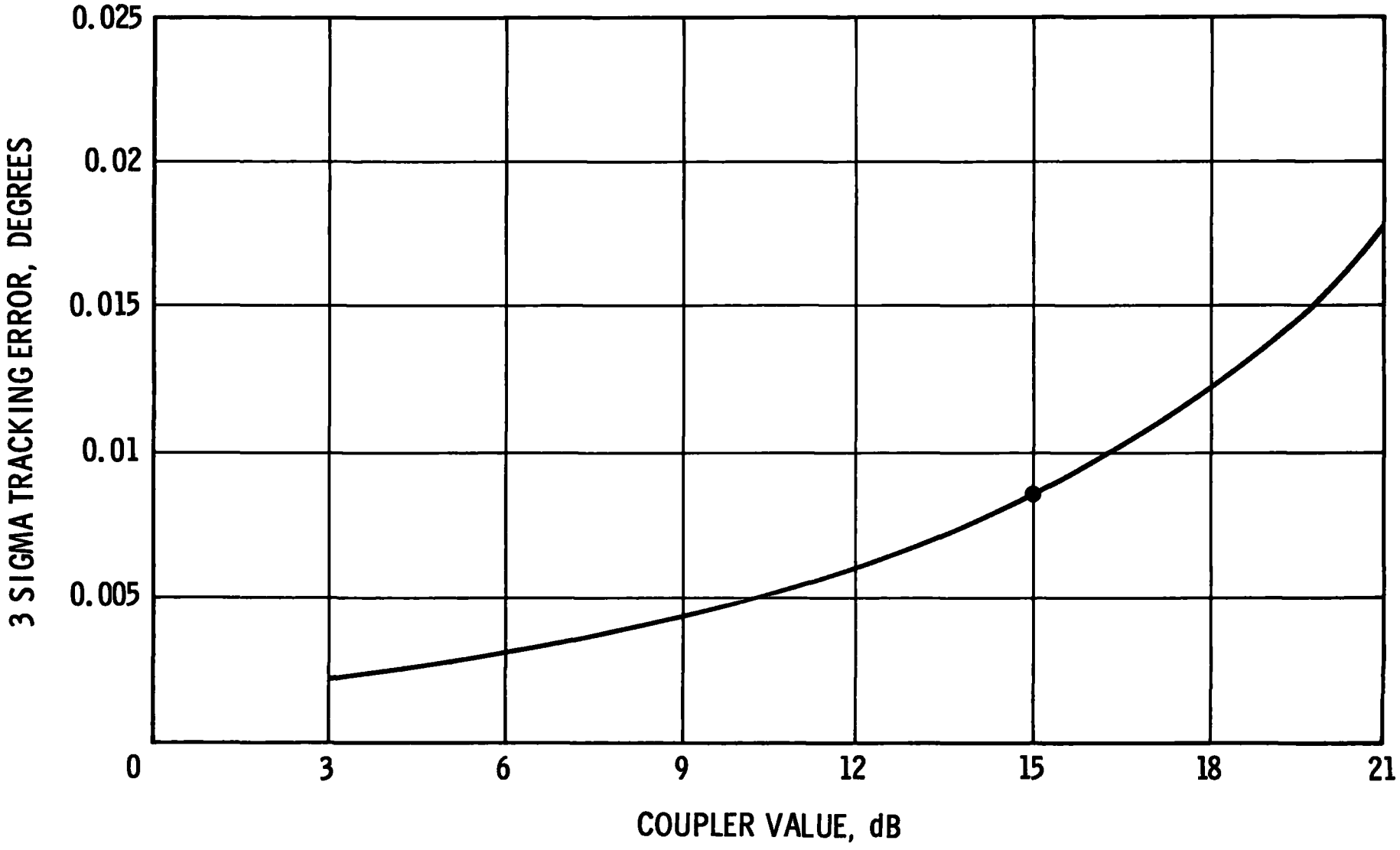
h) AZIMUTH AND ELEVATION CHANNEL ADDED TO SUM CHANNEL

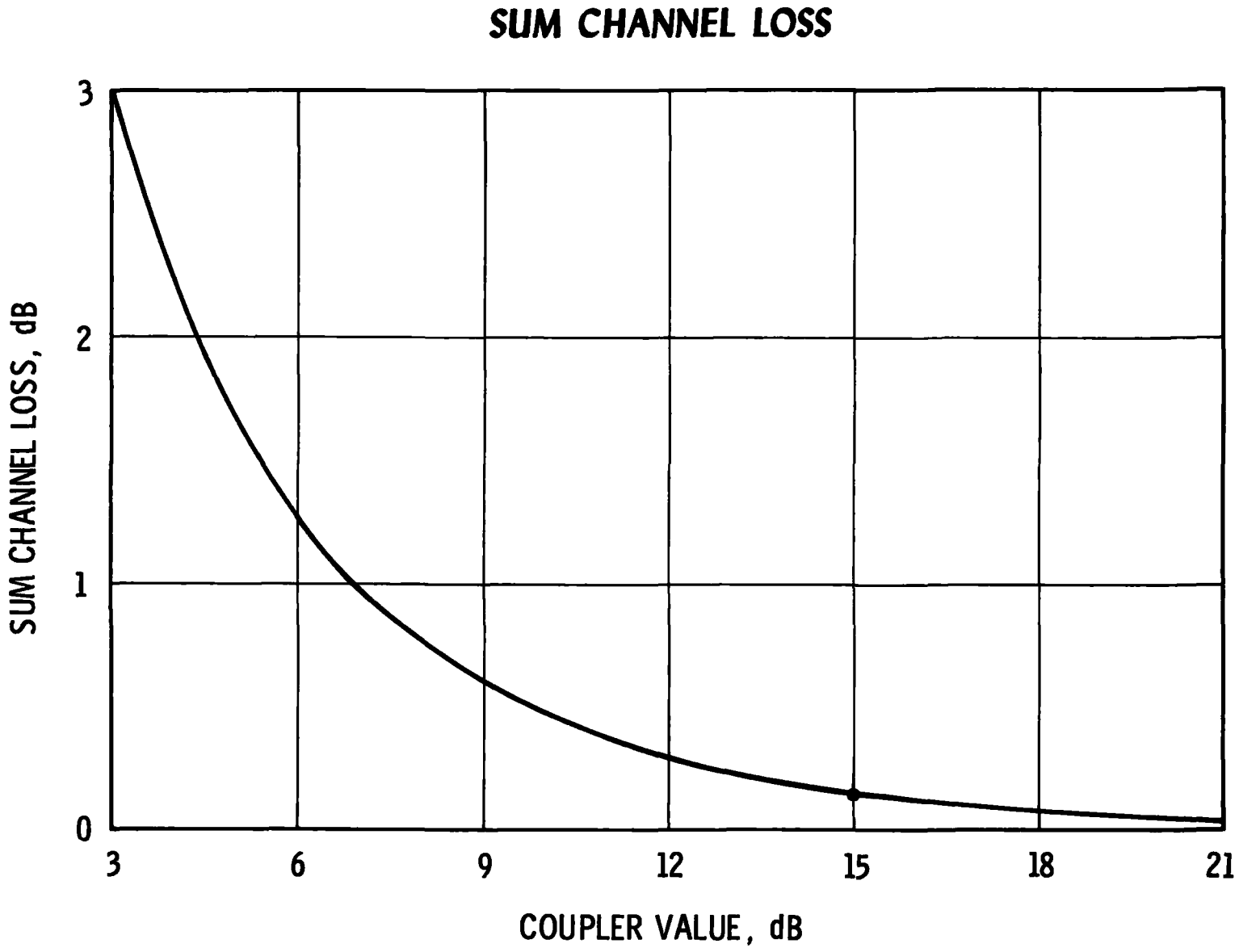
ADVANTAGES AND DISADVANSAGES OF TRUE MONOPULSE AND TIME SHARED MONOPULSE

	TRUE MONOPULSE	TIME SHARED MONOPULSE
ADVANTAGES	● BEST THERMAL NOISE PERFORMANCE FOR TRACKING AND COMMUNICATION LINK	● LESS HARDWARE ● PHASE AND AMPLITUDE BALANCE NOT REQUIRED
DISADVANTAGES	● REQUIRES THREE CHANNELS ● REQUIRES AMPLITUDE AND PHASE TRACKING BETWEEN CHANNELS AS A FUNCTION OF FREQUENCY AND TEMPERATURE	● SLIGHT DEGRADATION IN TRACKING AND COMMUNICATION LINK PERFORMANCE DUE TO COUPLING


MONOPULSE ERROR SIGNAL
1.0
0.8
0.6
0.4
0.2
AM MODULATION INDEX
3-dB COUPLER
15-dB COUPLER
0
0.2
0.4
0.6
0.8
1.0
1.2
ANGLE OFF BORESIGHT, DEGREES

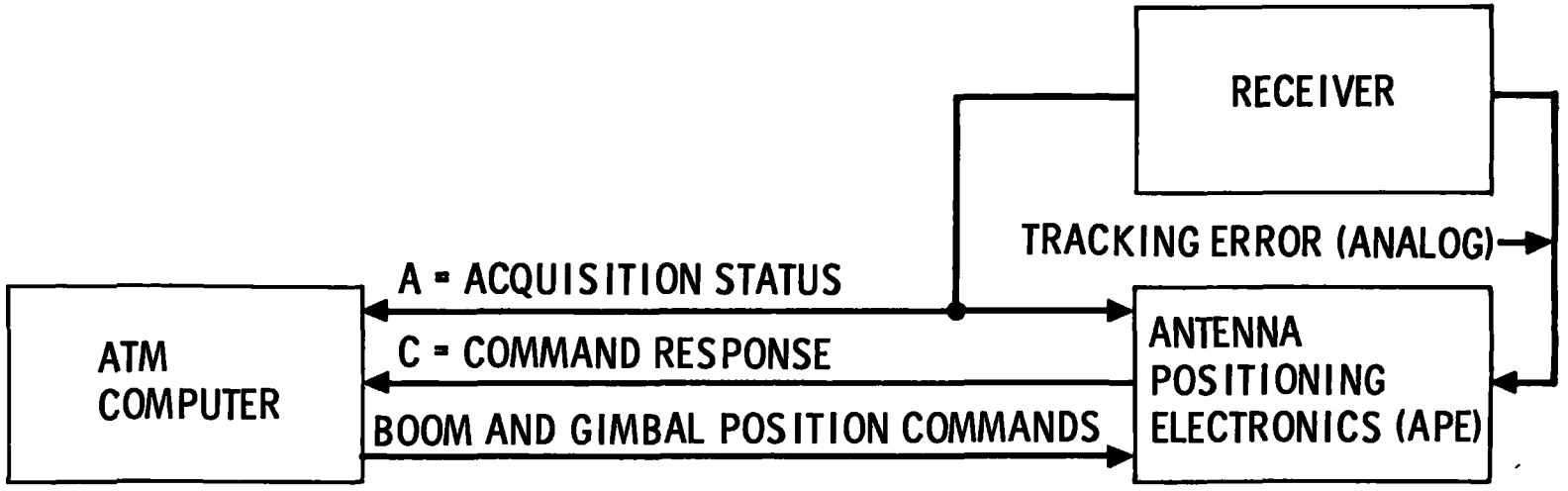
THERMAL NOISE TRACKING ERROR




SUM CHANNEL LOSS
SUM CHANNEL LOSS, dB
3
2
1
0
3
6
9
12
15
18
21
COUPLER VALUE, dB

ACQUISITION PROCEDURE

- UPON LOSS OF TRACK ($A \rightarrow \bar{A}$) COMPUTER ISSUES DESIRED BOOM AND GIMBAL POSITION COMMANDS. COMMAND RECEIPT IS ACKNOWLEDGED BY TRANSITION $C \rightarrow \bar{C}$
- WHEN RESPONSE IS COMPLETE, AS INDICATED BY $\bar{C} \rightarrow C$, NEW POSITIONS COMMANDS ARE ISSUED (SCAN PATTERN)
- WHEN RECEIVER ACQUIRES ($\bar{A} \rightarrow A$), COMPUTER IS RELEASED AND APE TRANSFERS TO TRACK MODE



ACQUISITION COMPUTATIONS

- NOMINAL POSITION COMMAND

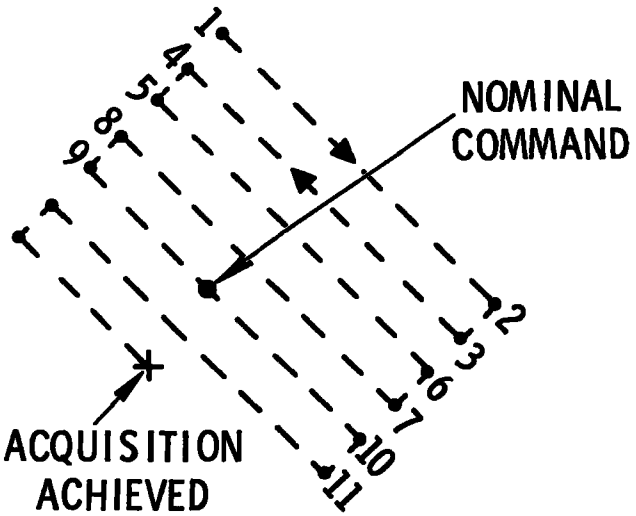
$$AZ = \text{ARCTAN } C_1/C_3$$

$$EL = \text{ARCTAN } \frac{C_1 \text{ SIN (AZ)} + C_3 \text{ COS (AZ)}}{C_2}$$

WHERE $\overline{C} = (C_1, C_2, C_3)$ IS THE VECTOR DIRECTED FROM SWS TO INTELSAT IV IN COORDINATES CENTERED AT SWS AND ORIENTED TO THE GIMBAL MOUNT (BOOM POSITION AND PROPER QUADRANTS FOR AZ AND EL DETERMINED BY AZ - EL SPACE MASK)

- SCAN GENERATION

ACTUAL POSITION COMMANDS ARE SEQUENCE OF POINTS IN SCAN PATTERN



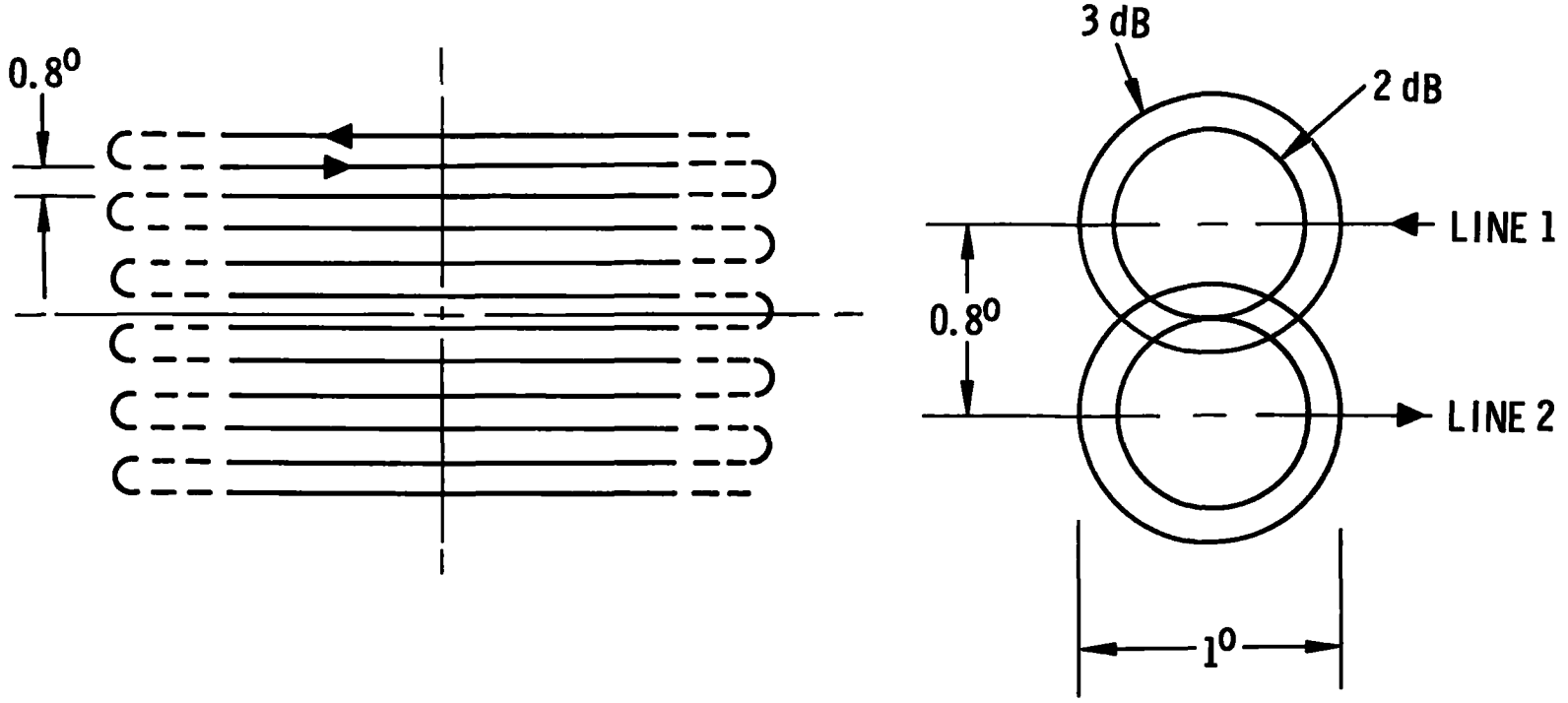
INITIAL ACQUISITION POINTING ERRORS

ERROR	ANGLE, ARCMINUTES		
	PITCH	YAW	ROLL
SPACE STATION ATTITUDE	4	4	10
SPACE STATION THERMAL DEFLECTION	16	16	0
SLEW MECHANISM	3	3	3
BOOM ALIGNMENT	3	3	3
BOOM THERMAL DEFLECTION	0	18	18
GIMBAL POSITION	3	3	3
ANTENNA THERMAL DEFLECTION	9	9	9
ANTENNA BORESIGHT	5	5	5
MONOPULSE PHASE	5	5	5
RELAY SATELLITE ORBITAL POSITION	2	2	2
MAXIMUM SUM ERROR	50	68	58
EXPECTED RMS ERROR	21	28	24

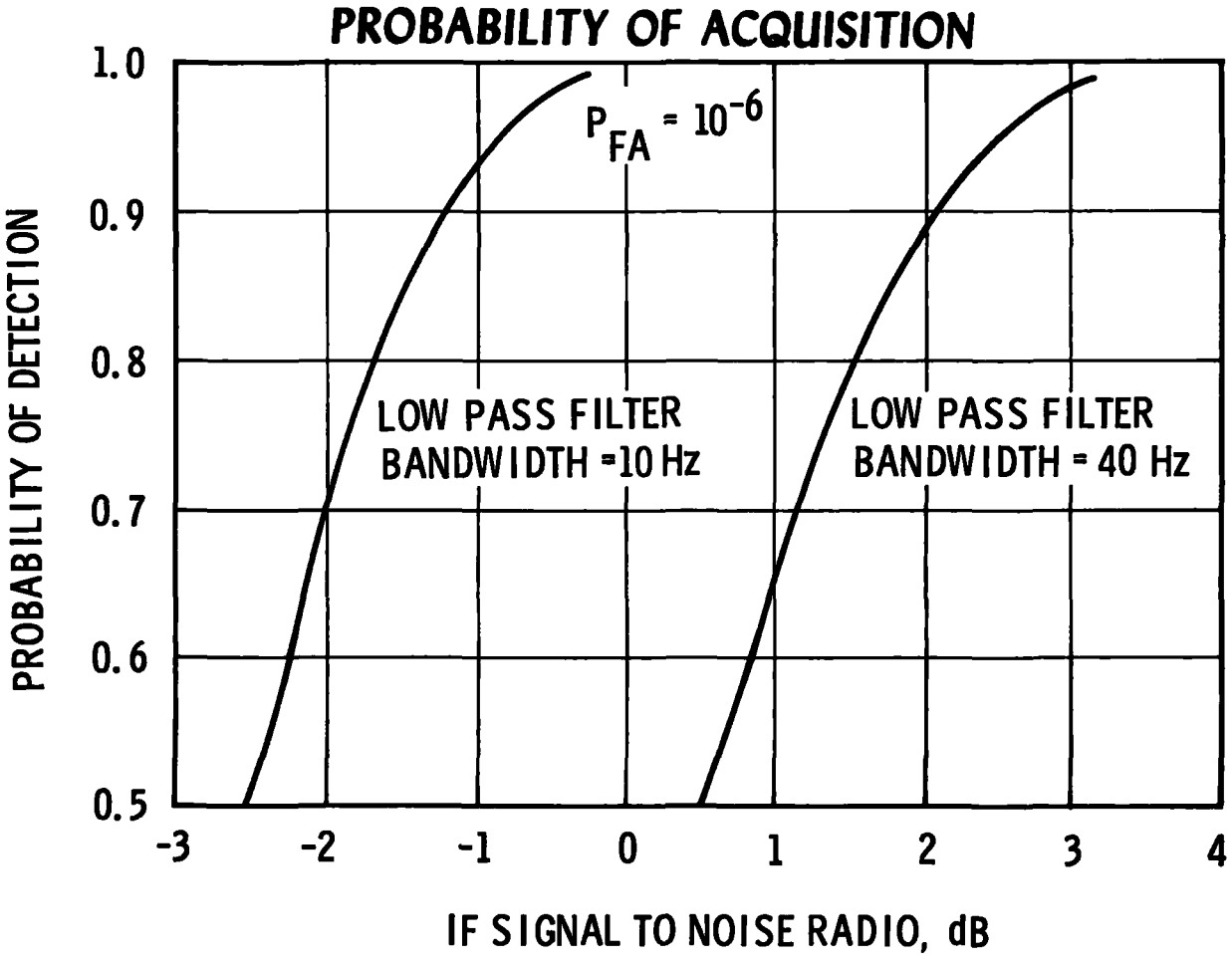
ACQUISITION PARAMETERS

PROBABILITY OF ACQUISITION	0.99
SCAN SECTOR	10^0 X 10^0
TYPE OF SCAN	RASTER
LINE SEPARATION	0.8^0
POINTING LOSS	3 dB
NUMBER OF ANGLE BINS	144
MAXIMUM ACQUISITION TIME	$\simeq$1 MIN
IF SIGNAL TO NOISE RATIO	3.2 dB

ACQUISTION SCAN PATTERN



UNCERTAINTY AREA = 10^0 x 10^0
SCAN RATE = 150^0/min
TIME PER LINE = 4-6 sec
NUMBER OF LINES = 12
MAXIMUM ACQUISITION
TIME = 48-72 sec

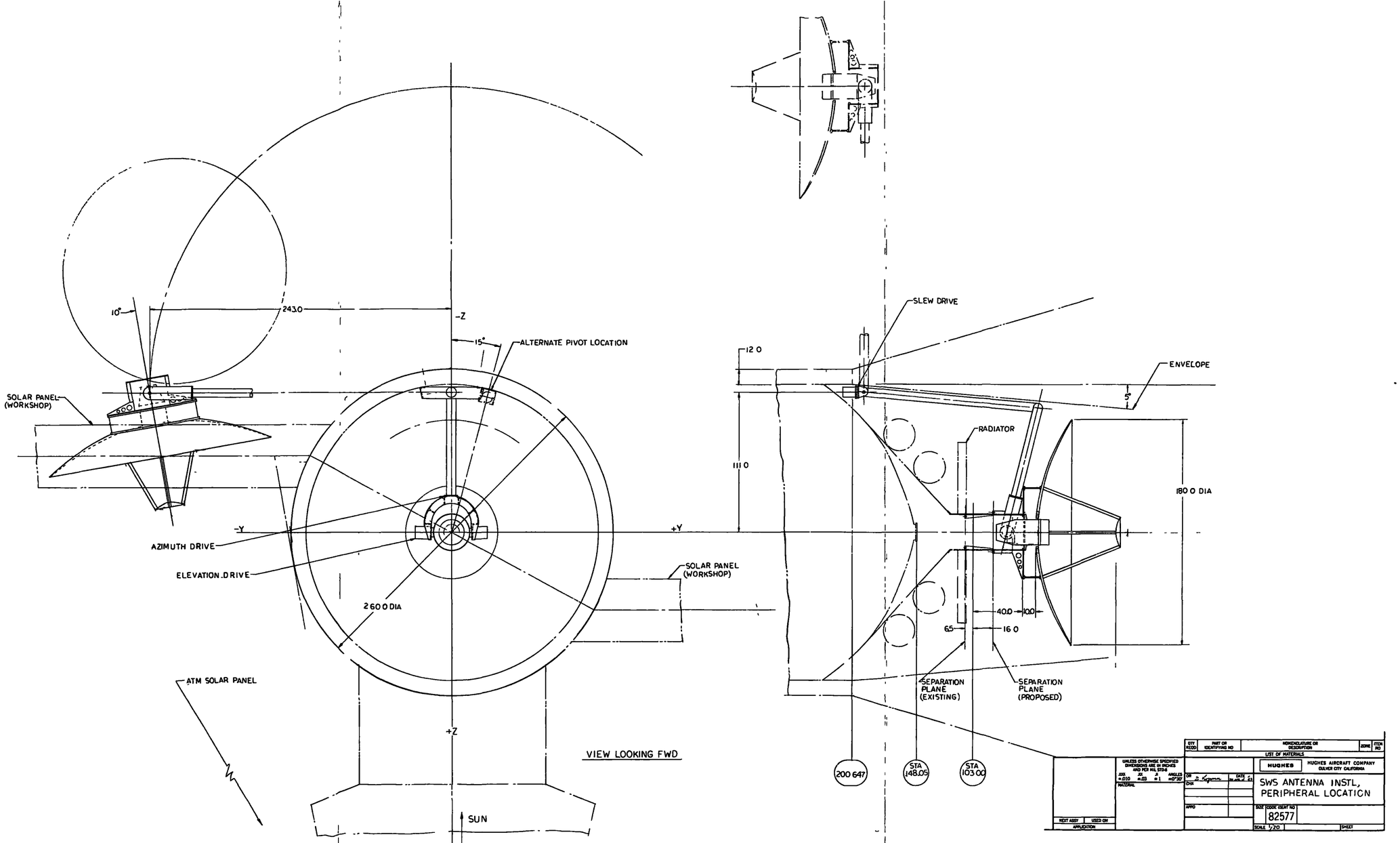


$$P_{ACQ} = \frac{Pd}{K P_{FA}} \left[1 - (1 - P_{FA})^{K}\right] = 0.99$$

Pd = 0.99

K = NUMBER OF ANGLE BINS = 144

$P_{FA} = 10^{-6}$



QTY REQD	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	ZONE	ITEM NO
		LIST OF MATERIALS		

HUGHES — HUGHES AIRCRAFT COMPANY, CULVER CITY, CALIFORNIA

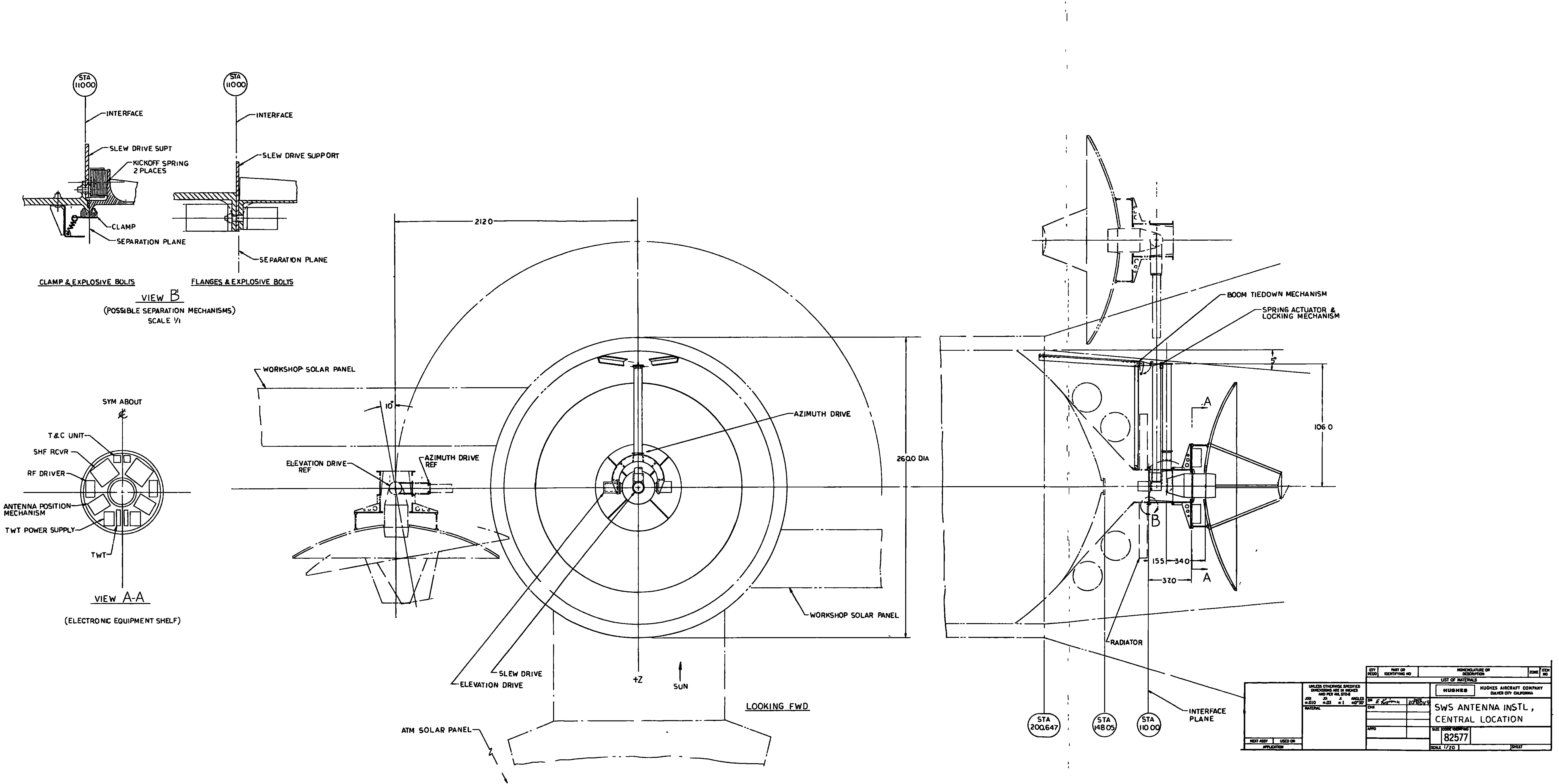
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND PER MIL STD-8
XXX ±.010 XX ±.03 X ±1 ANGLES ±0°30'
MATERIAL

DR R. Nguyen DATE 6-63
CHK
APPD

NEXT ASSY | USED ON
APPLICATION

SWS ANTENNA INSTL, PERIPHERAL LOCATION

SIZE CODE IDENT NO 82577
SCALE 1/20 SHEET


STA 110.00
INTERFACE
SLEW DRIVE SUPT
KICKOFF SPRING 2 PLACES
CLAMP
SEPARATION PLANE
CLAMP & EXPLOSIVE BOLTS
SLEW DRIVE SUPPORT
FLANGES & EXPLOSIVE BOLTS
VIEW B
(POSSIBLE SEPARATION MECHANISMS)
SCALE 1/1
SYM ABOUT ℄
T&C UNIT
SHF RCVR
RF DRIVER
ANTENNA POSITION MECHANISM
TWT POWER SUPPLY
TWT
VIEW A-A
(ELECTRONIC EQUIPMENT SHELF)
WORKSHOP SOLAR PANEL
212.0
10°
ELEVATION DRIVE REF
AZIMUTH DRIVE REF
AZIMUTH DRIVE
260.0 DIA
SLEW DRIVE
ELEVATION DRIVE
+Z
SUN
LOOKING FWD
ATM SOLAR PANEL
BOOM TIEDOWN MECHANISM
SPRING ACTUATOR & LOCKING MECHANISM
5°
A
106.0
B
15.5
34.0
37.0
RADIATOR
STA 200.647
STA 148.05
STA 110.00
INTERFACE PLANE
QTY REQD
PART OR IDENTIFYING NO
NOMENCLATURE OR DESCRIPTION
ZONE
ITEM NO
LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND PER MIL STD-8
.XXX ±.010
.XX ±.03
.X ±.1
ANGLES ±0°30'
MATERIAL
HUGHES
HUGHES AIRCRAFT COMPANY
CULVER CITY CALIFORNIA
DR
DATE 20 NOV 9
CHK
APPD
SWS ANTENNA INSTL,
CENTRAL LOCATION
SIZE
CODE IDENT NO
82577
SCALE 1/20
SHEET
NEXT ASSY
USED ON
APPLICATION

ELECTRICAL POWER REQUIREMENTS

SUBSYSTEM/ITEM		POWER (WATTS)
COMMUNICATIONS SUBSYSTEM		118
COMMUNICATIONS RECEIVER	8	
TRACKING RECEIVER	5	
BASEBAND PROCESSOR	3	
FREQUENCY REFERENCE	10	
CONTROL PANEL	2	
TRANSMITTER	90	
ANTENNA POSITIONING SUBSYSTEM*		42
AZIMUTH CONTROL	21	
ELEVATION CONTROL	21	
NOMINAL POWER REQUIREMENTS		160

* INTERMITTENT LEVEL OF 52 WATTS FOR ANTENNA SLEWING OR BOOM REPOSITIONING

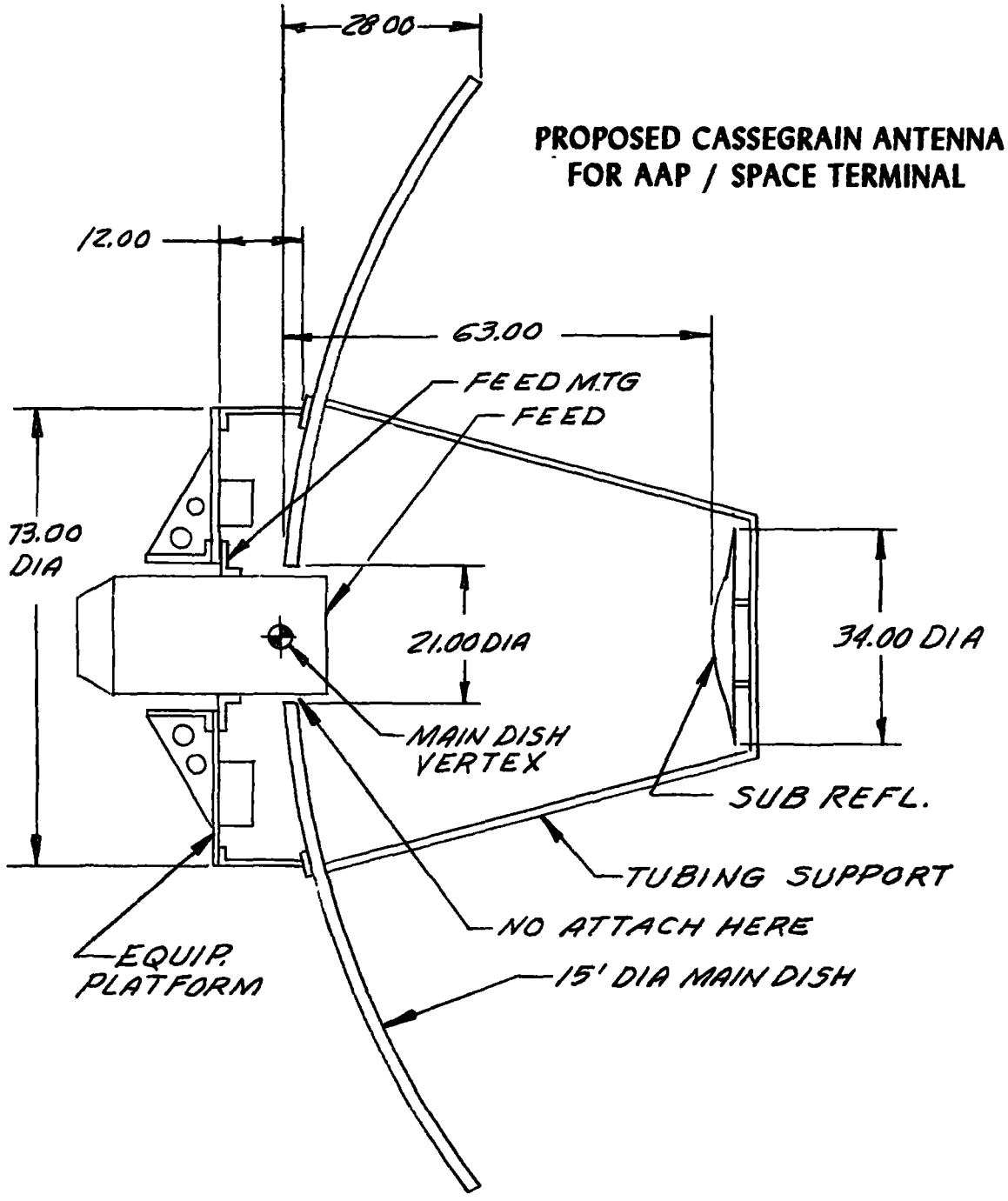
SATURN WORKSHOP TERMINAL
PRELIMINARY ESTIMATED WEIGHTS

ITEM	WEIGHT, POUNDS	
COMMUNICATION SUBSYSTEM		100
COMMUNICATIONS RECEIVER (2)	20	
TRACKING RECEIVER	10	
TRANSMITTER (2)	42	
DIPLEXER AND CIRCUITS	2	
BASEBAND PROCESSOR (2)	6	
CONTROL PANEL	10	
FREQUENCY REFERENCE GENERATOR (2)	10	
ANTENNA (15 FT DIAMETER)		209
MAIN REFLECTOR	160	
SUB REFLECTOR	14	
FEED	35	
ANTENNA POSITION CONTROL		125
ANTENNA POSITIONER (2)	66	
BOOM POSITIONER	33	
SERVO CONTROLLER (2)	16	
CREW CONTROL AND DISPLAY	10	

ITEM	WEIGHT, POUNDS	
WIRE HARNESS		50
EQUIPMENT WIRING	25	
POWER LEADS	10	
SIGNAL LEADS	15	
STRUCTURE		175
EQUIPMENT SUPPORT	105	
DEPLOYMENT BOOM	60	
SEPARATION MECHANISM	10	
THERMAL CONTROL		20
INSULATION BLANKETS	10	
PAINT AND FINISHES	10	
CONTINGENCY (10%)		71
TOTAL TERMINAL WEIGHT		750

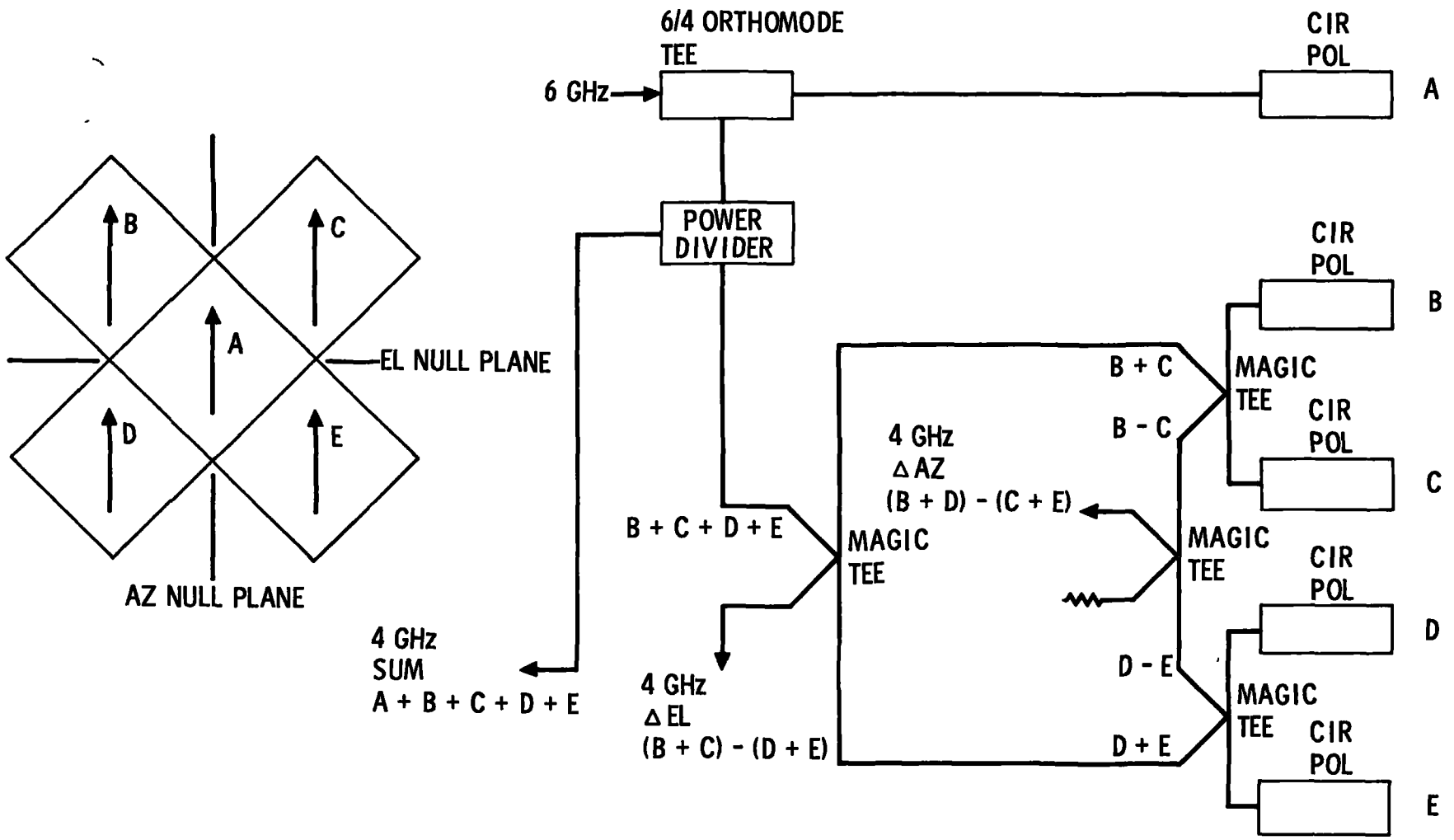
THERMAL CONTROL SUMMARY

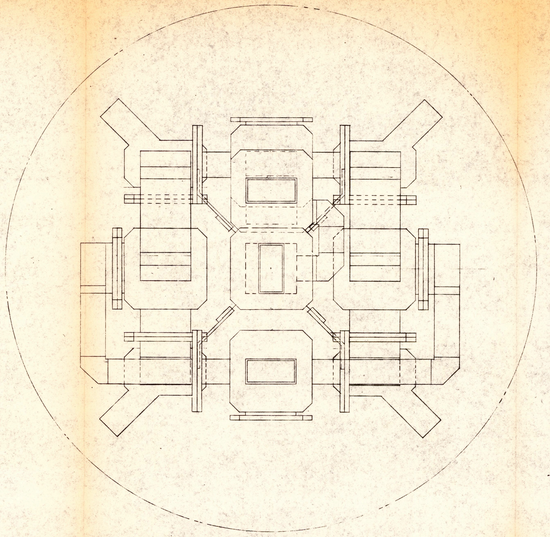
COMPONENT	THERMAL DESIGN	CONTROL REQUIREMENTS	PREDICTED TEMPERATURES		
			DESCRIPTION	MAX	MIN
ELECTRONICS PACKAGE	BLACK RADIATOR (α * = 0.96 = 0.85) 30 LAYERS OF SI	OPERATIONAL = 0/+100 SURVIVAL = -40/+140	POWER ON POWER OFF (BORESIGHT POINTED AT SUN)	95^{0}F 0	45^{0}F -20
ANTENNA • DISH	BOTH SIDES BLACK	ACCEPTABILITY OF BULK TEMPERATURES AND ΔT'S DETERMINED BY STRESS AND DISTORTION ANAL	GRADIENT ^{0}F/in BULK TEMP ΔT = ACROSS DISH THRU CORE	50 180 225 30	$\approx$ -90 $\approx$ $\approx$
• FEED STRUTS	ASSUMED BLACK FOR WORST CASE ΔT'S		BULK TEMP ΔT BETWEEN ST.	190 225	-150 $\approx$
GIMBAL ASSY	ASSUMED BLACK FOR WORST CASE ΔT'S	-200^{0}F TO $+200^{0}$F	BULK TEMP	+150	-90



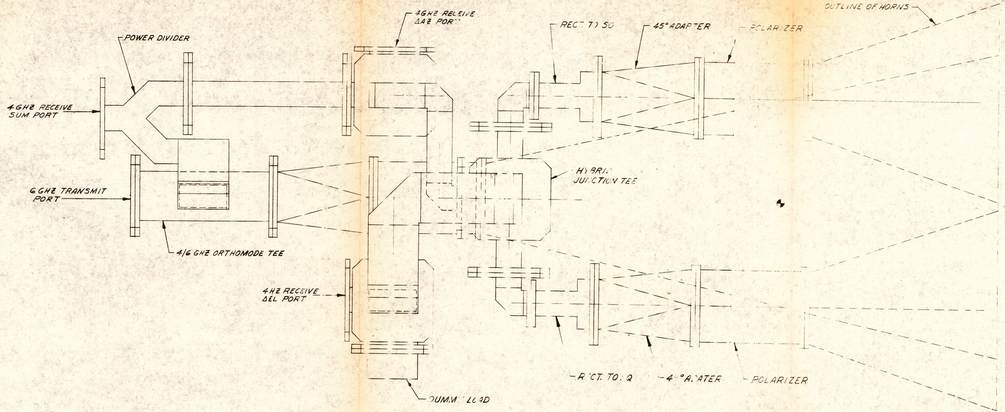
PROPOSED CASSEGRAIN ANTENNA FOR AAP / SPACE TERMINAL

FIVE - HORN RF FEED CIRCUITRY

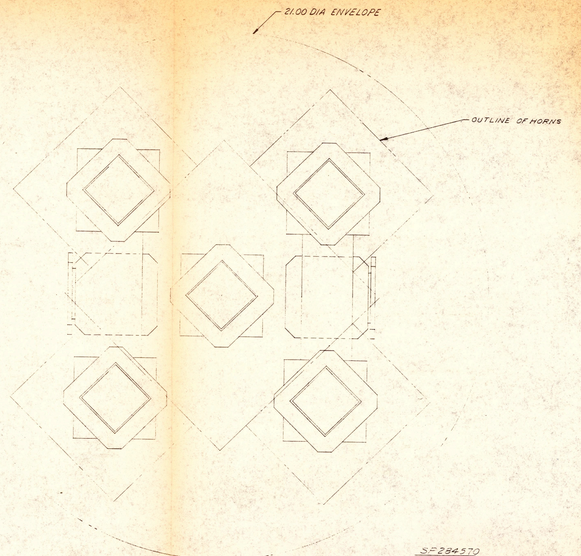




REAR VIEW

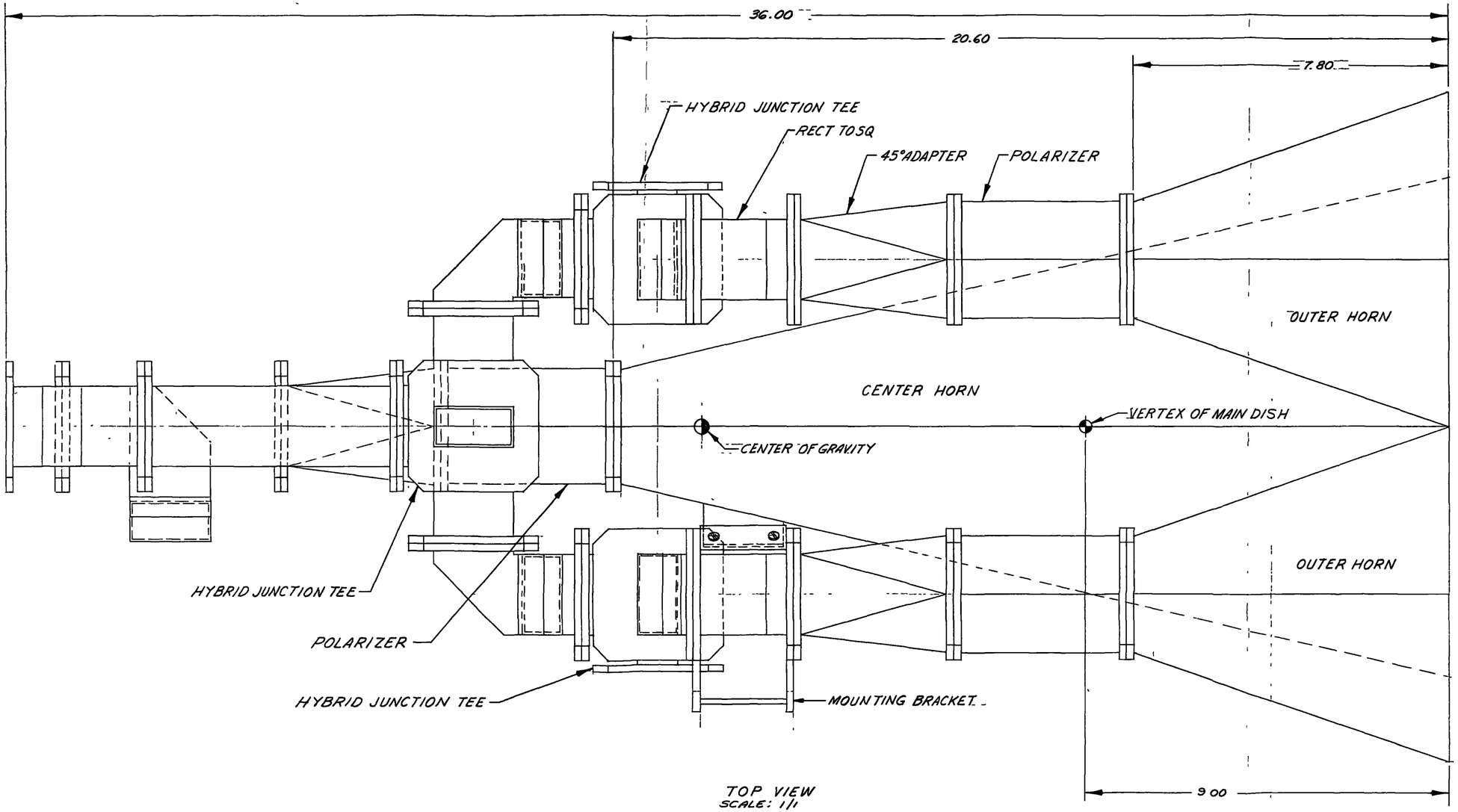


SIDE VIEW



FRONT VIEW

SP 284570
PROPOSED ANTENNA FEED LAYOUT
ARP SPACE TERMINAL
SCALE 1/1 DATE 3 DEC 1969
SHEET 1 OF 2



TOP VIEW
SCALE: 1/1

SP 284570
PROPOSED ANTENNA FEED LAYOUT
AAP SPACE TERMINAL
DATE 9 DEC 1969
SHEET 2 OF 2

EXPECTED PERFORMANCE CASSEGRAIN ANTENNA

PARAMETER	TRANSMIT	RECEIVE
FREQUENCY, MHz	6350 ± 38	4120±38
POLARIZATION	LHCP	RHCP
GAIN (SUM-BEAM PEAK), dB	45.8	42.3
ELLIPTICITY, dB	2.0	2.0
SIDELOBE LEVEL (SUM), dB		
MAX (1ST)	< -16	< -16
$5^0 < \theta < 10^0$	< -30	———
$\theta > 10^0$	< -35	———
SUM PEAK-TO-DIFFERENCE PEAK, dB	———	6.0
MONOPULSE NULL DEPTH, dB (REF TO SUM PEAK)	———	>35
BEAMWIDTH (3 dB) DEGREES	0.65	1.00

ANTENNA LOSS BUGET AND EXPECTED GAINS , dB SUM PEAK

PARAMETER	FREQUENCY, MHz	
	6350 ± 38	4120 ± 38
AREA GAIN	49.6	45.9
LOSSES		
APERTURE EFFICIENCY	1.0	0.9
SPILLOVER	0.7	0.7
HYPERBOLOID BLOCKAGE	0.5	0.5
STRUT (HYPERBOLOID SUPPORT) BLOCKAGE	0.2	0.2
REFLECTOR RMS SURFACE ERROR (σ_M = 0.040 inch, σ_S = 0.015 inch)	0.4	0.2
REFLECTOR THERMAL DISTORTION	0.3	0.3
RF CIRCUIT (2 MAGIC TEES, 4 ft W/G POLARIZER, POWER DIVIDER, 6/4 OMT)	0.4	0.5
CROSS-POLARIZED POWER	0.3	0.3
TOTAL	3.8	3.6
EXPECTED GAIN	45.8	42.3

ANTENNA DESIGN DETAILS

MAIN REFLECTOR: (HONEYCOMB SANDWICH CONSTRUCTION)

- FOUR PLIES 112 PREPREG COVERS
- 1.5 INCH THICK ALUMINUM FLEXCORE
- ONE PLY METALLIZED DACRON MESH (RF REFLECTOR)
- SYNTACTIC FOAM FILL AT 21 IN., 60 IN., AND 180 IN., IN DIAMETERS
- STEEL INSERTS FOR MTG RING AND QUADRIPOD

SUBREFLECTOR:

- APPROXIMATELY 30 PLIES 112 PREPREG
- VDA REFLECTIVE SURFACE
- FOUR MOUNTING BOSSES ON BACKSIDE

QUADRIPOD:

- 1 INCH DIAMETER EPOXY GLASS TUBES; UNIDIRECTIONAL GRAPHITE FIBER STIFFENERS

PRELIMINARY STRESS AND STIFFNESS ANALYSIS

FOR QUASI-STATIC CONDITION 25G LONG.+►25G LAT

MAXIMUM COMPRESSIVE FACESHEET STRESS LESS THAN 5,000 PSI

- PREDICTED 2-SIGMA ALLOWABLE BASED ON SIMILAR CONFIGURATIONS ON OTHER HAC PROGRAMS

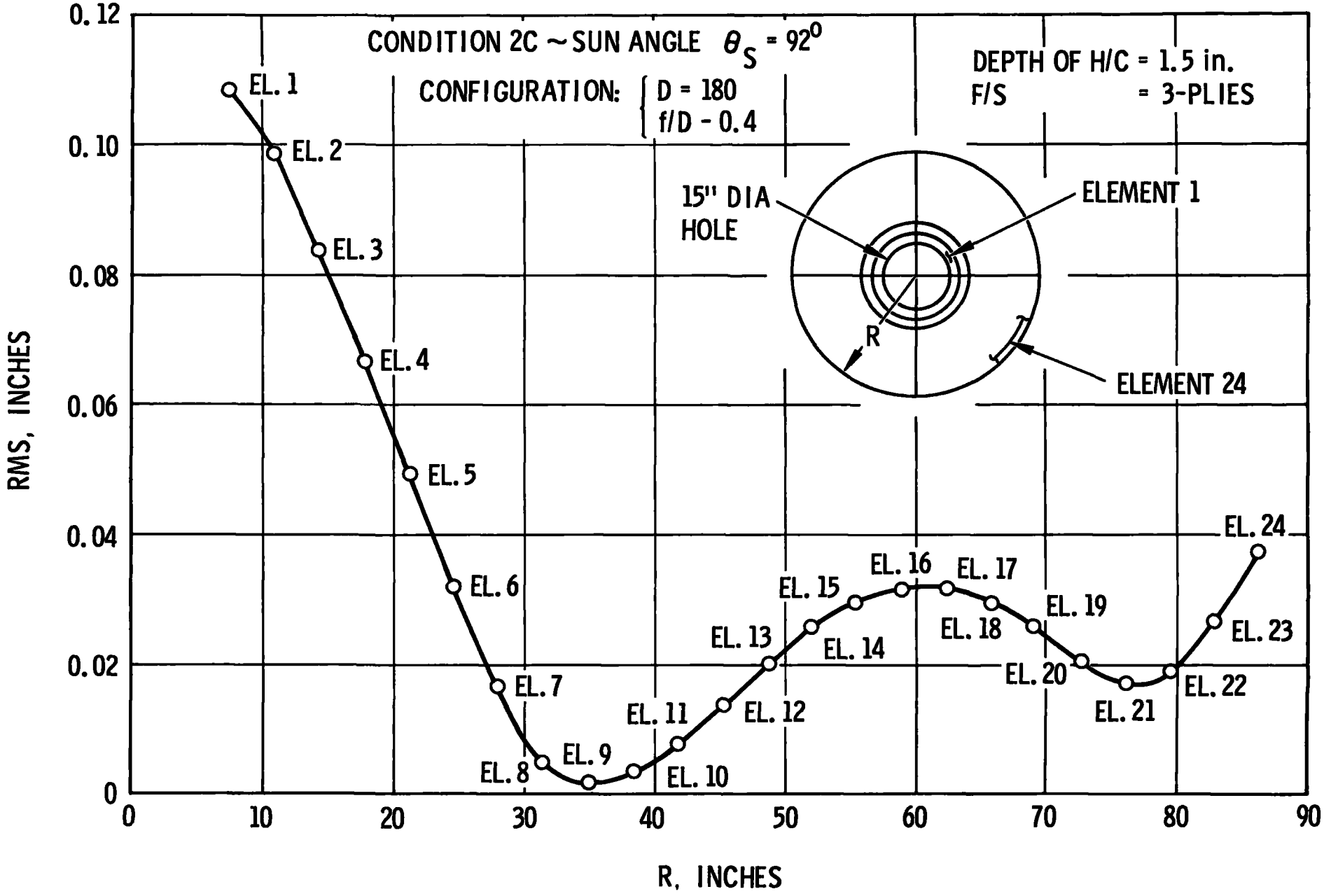
  10,000 PSI

$$MS = \frac{10,000}{5,000} - 1 = 1.0$$

- LOCAL REINFORCEMENT AT REACTION POINTS TO MINIMIZE STRESSES

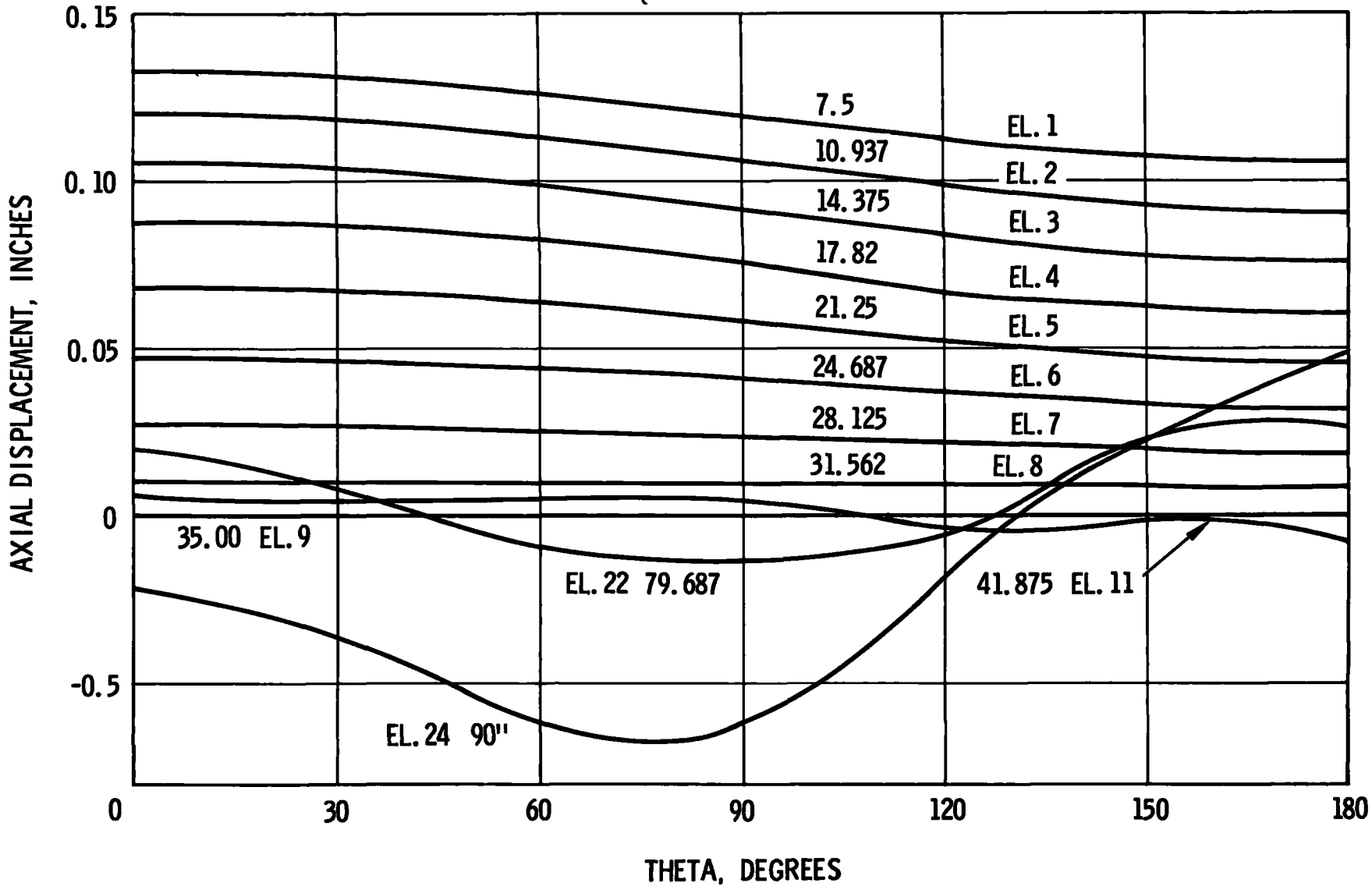
- FUNDAMENTAL FREQUENCY OF ANTENNA PREDICTED TO BE GREATER THAN 20.0 CPS

RMS OF RING ELEMENTS (1 TO 24) VERSUS DISTANCE FROM CENTERLINE



DISPLACEMENTS VERSUS AZIMUTH ANGLES OF ELEMENTS

CONDITION 2C ~ SUN ANGLE $\theta = 92^0$
CONFIGURATION { D = 180 IN. DEPTH H/C = 1.5 IN.
f/D = 0.40 FS = 3-PLIES



MAIN REFLECTOR FABRICATION SEQUENCE

(16 TON MEEHANITE MOLD ON A SPECIAL CART
FOR LAYUP AND CURING OPERATIONS)

1 CLEAN TOOL SURFACE
2 APPLY RELEASE AGENT
3 CUT 112 EPOXY GLASS PREPREG CLOTH AND METALLIZED DACRON MESH TO PATTERN; ONE INCH OVERLAP ON ALL JOINTS, WARP DIRECTION OF PREPREG ROTATED 45^{0} ON EACH PLY
4 APPLY TWO PLIES PREPREG TO TOOL SURFACE
5 APPLY ONE PLY METALLIZED DACRON MESH
6 APPLY TWO PLIES PREPREG
7 CUT HONEYCOMB FLEX-CORE TO PATTERN
8 FIT CORE PIECES TO TOOL, APPLY FOAMING ADHESIVE TAPE BETWEEN CORE SEGMENT JOINTS, FASTEN CORE PIECES AND TAPE TOGETHER WITH ALUMINUM CLIPS

(CONTINUED)

MAIN REFLECTOR FABRICATION SEQUENCE (Cont')

9	FILL REQUIRED AREAS OF CORE CELLS WITH SYNTACTIC FOAM
10	APPLY FOUR PLIES PREPREG
11	APPLY VACUUM BAG OVER ASSEMBLY
12	EVACUATE BAG TO 20 INCHES OF Hg OR MORE
*13	CURE IN OVEN FOR THREE HOURS AT 325-350^{0}F. (CURE TIME TO START WHEN MOLD SURFACE REACHES 325^{0}F)
14	COOL IN OVEN, UNDER VACUUM PRESSURE, TO 200^{0}F OR LESS
15	REMOVE VACUUM BAG, REMOVE EXCESS MATERIAL, AND TRIM EDGES TO PRINT
16	REMOVE DISH FROM TOOL WITH VACUUM LIFT
17	DRILL HOLES IN FOAMED AREA OF THE DISH TO ACCEPT STRUCTURAL ATTACHMENT INSERTS, BOND INSERTS IN PLACE WITH EPOXY ADHESIVE (ROOM TEMPERATURE CURE)

*THE CURE OVEN WILL BE TESTED TO DETERMINE THE TIME-TEMPERATURE HISTORY OF THE 16 TON MOLD. IF NECESSARY, STRIP HEATERS WILL BE APPLIED TO THE UNDERSIDE OF THE MOLD

ANTENNA POSITIONERS

- ELEVATION AND AZIMUTH DRIVES FOR ACQUISITION AND TRACKING
- BOOM DRIVE TO MOVE ENTIRE TERMINAL FROM 0^0 POSITION TO THE 180^0 POSITION
- ACCEPT COMMANDS TO REPOSITION AT HIGH RATE
- CORRECT CONTINUOUSLY TO ERROR SIGNAL INPUT
- PROVIDE POSITION READOUT

POSITIONER REQUIREMENTS

● GIMBAL POSITION	ELEVATION	0 TO 200^0
	AZIMUTH	0 TO 380^0
	BOOM	0 TO 180^0
● RATES	TRACK ON EL AND AZ	0 TO 1.5^0/MIN
	SLEW ON ALL AXES	180^0 < 2 MIN (150^0/MIN)
● ACCURACY	TRACKING TO	±0.05^0
	SLEW	± 0.20^0
● TEMPERATURES	GIMBALS	-90^{0}F TO +150^{0}F SINKS
	ELECTRONICS	0^{0}F TO +100^{0}F OPERATING
		-65^{0}F TO +140^{0}F NON-OPERATING
● WEIGHT	33 LBS FOR EACH DRIVE - 3 PER VEHICLE	
	9 LBS FOR EACH CONTROL ELECTRONICS - 2 PER VEHICLE	
● POWER	23.5 TO 28.5 VDC	
	30 WATTS TIME AVERAGE	
	80 WATTS PEAK WORST CASE	
● BRAKE	MAINTAIN POSITION WITH POWER OFF SYSTEM	
● POSITION READOUT	PROVIDE GIMBAL SHAFT POSITION IN BINARY WORD	
● RELIABILITY	SAFETY MARGINS COMPATIBLE WITH MANNED SYSTEMS	

POSITIONER REQUIREMENTS (Con't)

● LOAD PROPERTIES	APPROX 550 LBS EL AND AZ INERTIA 310 SLUG-FT^2 BOOM < 20 FT LENGTH
● LIFE	112 DAYS IN SPACE 2 BOOM SWEEPS PER DAY 2 GIMBAL SLEWS PER ORBIT (92 MINUTE) CONTINUOUS TRACKING
● GROUND TEST	BEARINGS TO WITHSTAND FULL LOADS INCL COUNTER BALANCE GIMBALS TO OPERATE WITH 14 FT - LB UNBALANCE TO ALLOW FOR SIMPLIFIED COUNTER BALANCE SYSTEM
● COMMANDS	ACQUISITION MODE - SLEW TO PRESENT POSITION INDICATED BY BINARY WORD TRACK MODE - 10 VOLT/DEGREE ERROR SIGNAL FOR EL AND AZ GIMBALS
● COST	COMMONALITY OF COMPONENTS MINIMIZE COST BY UTILIZATION OF COMMON ENGINEERING MATERIALS AND QUALIFIED DESIGNS

MOTOR TYPE

SELECTION	ADVANTAGES	DISADVANTAGES
HIGH SPEED 2 ϕ AC	HIGHLY DEVELOPED LOW SLEW	REQUIRES AC POWER FORM REQUIRES EXTRA GEARS AND BEARINGS REQUIRES BRAKE
BRUSHLESS DC SERVO	LINEAR SPEED/TORQUE HIGH EFFICIENCY	COMPLEX COMMUTATION LIMITED SIZE AVAILABILITY REQUIRES BRAKE
BRUSH DC SERVO	LOW TRACK POWER LARGE SELECTION LINEAR SPEED/TORQUE	HIGH SLEW POWER BRUSH LUBRICATION WEAR PHENOMENON REQUIRES BRAKE
VARIABLE RELUCTANCE STEPPER	HIGH PULSE RATE NO BRUSHES HIGH EFFICIENCY ALLOWS OPEN LOOP POSITIONING	LIMITED SIZE AVAILABILITY HIGH PEAK CURRENT REQUIRES BRAKE
PERMANENT MAGNET STEPPER	POWER OFF HOLDING TORQUE NO BRUSHES ALLOWS OPEN LOOP POSITIONING SPACE QUALIFIED VENDOR	LIMITED PULSE RATES HIGH PEAK CURRENT REQUIRES COMMUTATION FOR LARGE INERTIA

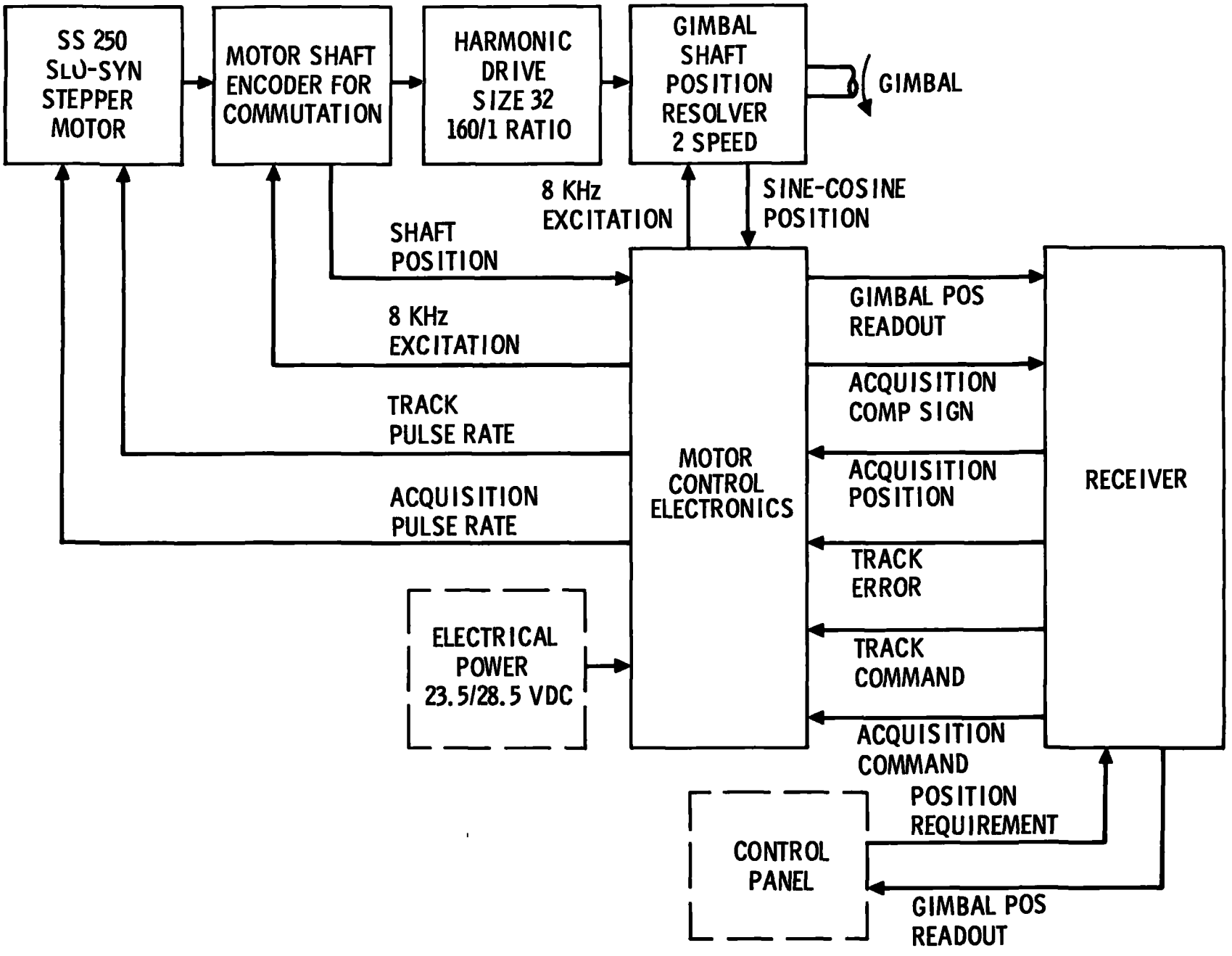
MOTOR TRADE-OFF

	SLO-SYN STEPPER SS-250	INLAND D. C. BRUSH T-2950	SIZE 23 2 ϕ 400 $\sim$ SERVO MOTOR
MOTOR STALL TORQUE FT - LB	1.17	1.20	0.047
CURRENT AT SLEW ROOM TEMP	1.22 a	2.9 a	1.2 a
CURRENT AT TRACK (0.4 ^{0}/MIN AVG)	0.14 a 10% DUTY	0.06 a	0.6 a
AVG CURRENT 90% TRACK	0.25 a	0.34 a	0.66 a
WEIGHT - MOTOR ONLY	6.50 LB COMPLETE	2.15 LB FRAMELESS	1.80 LB MOTOR
ADDITIONAL DRIVE ELEMENTS	0	2.00 LB FRAME	2.00 LB 2 STAGE SPUR GEAR
POWER OFF BRAKE	29 FT - LB	0.02 FT - LB	LOW

DRIVE TRAIN SELECTION

REQUIREMENT	HARMONIC DRIVE	GEARS
160/1 RATIO	1 STAGE	4 STAGES
WITHSTAND MOTOR STALL 140 FT-LB	320 FT-LB CAPACITY	LARGE GEARS
NO. TEETH IN CONTACT	MANY WITH SURFACE CONTACT	1.6 WITH LINE CONTACT
BACKLASH	$\simeq 0$	LARGE
TEMPERATURE -90^0 TO $+150^0$F	MoS_2 POWDER	BONDED MoS_2
WEIGHT	2.5 LB	HIGH
RELIABILITY	LOW PARTS COUNT	HIGH PARTS COUNT

POSITIONER SUBSYSTEM BLOCK DIAGRAM



ORIGINATOR NAME _____

ORIGINATOR SEQUENCE NO. _____ MASTER JOB NO. _____ ART NO. ____

HUGHES

HUGHES AIRCRAFT COMPANY
SPACE SYSTEMS DIVISION

This graphic layout sheet is for preparing rough input for finished artwork, or if neatly done, final art for inexpensive Thermofax vu-graph transparencies. Lettering will meet minimum requirements if printed to fill the blue guidelines (note example). A superior "communication aid" will result if lettering is readable and if you (1) let your visual function as an audience aid by exposing the message rather than functioning simply as speaker notes, (2) use graphic symbols whenever possible to express your ideas and (3) delete all data not pertinent to your message

PROPOSALS AND PUBLICATIONS
VISUAL AID GRAPHIC FRAME
For Visualizing Charts, Slides and Vu-Graphs
11839SS

SPECIAL ART INSTRUCTIONS:

TORQUE BUDGET

ELEVATION & AZIMUTH DRIVES	FLIGHT TRACK	GD TEST TRACK	FLIGHT SLEW	GD TEST SLEW
CABLES AND BEARINGS	19.7	20.7	19.7	20.7
ONE STEP WIND-UP	139.0	139.0	0	0
UNBALANCED MOMENT	0	168.0	0	168.0
ACCELERATION	0	0	8.3	8.3
TOTAL REQUIRED	158.7	327.7	28.0	197.0
TORQUE AVAILABLE WORST CASE	884.0	884.0	605.0	605.0
TORQUE MARGIN	5.6/1	2.7/1	21.6/1	3.10/1
BOOM DRIVE				
CABLES AND BEARINGS	TRACK NOT		19.7	20.7
UNBALANCED MOMENT	REQUIRED		0	168.0
ACCELERATION	ON BOOM		68.0	68.0
TOTAL REQUIRED			87.7	256.7
TORQUE AVAILABLE WORST CASE			605.0	605.0
TORQUE MARGIN			6.9/1	2.36/1

NOTE: ALL TORQUE VALUES ARE IN INCH-POUNDS

POWER USEAGE

CURRENT

WINDING TEMPERATURE	-90°F	116°F	225°F
MOTOR CURRENT PEAK - AMPS	2.0	1.4	1.0
ELECTRONICS STANDBY - AMPS	0.4	0.4	0.4
ELECTRONICS SLEW ADDITION - AMPS	0.7	0.7	0.7
TOTAL AMPS	3.1	2.5	2.1

POWER - SLEW ONE AXIS

23.5 V BUS	73 WATTS	59 WATTS	49 WATTS
26.0 V BUS	80 WATTS	65 WATTS	54 WATTS
28.5 V BUS	88 WATTS	71 WATTS	60 WATTS

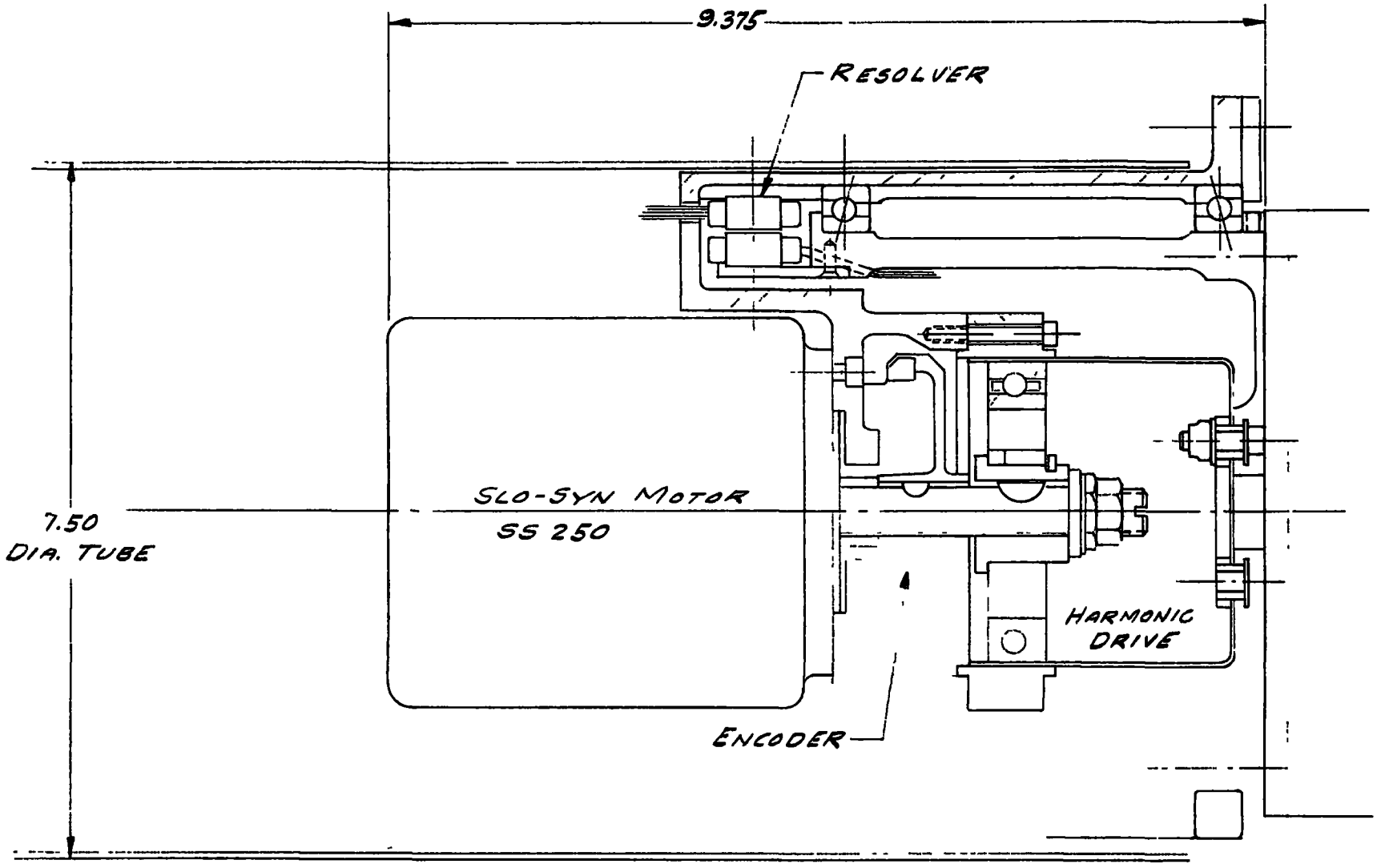
POWER TRACK 0.4°/MIN		ONE AXIS	TWO AXIS
MOTOR - MEAN TEMPERATURE	1.4 a X 10% DUTY =	0.14 a	0.28 a
ELECTRONICS STANDBY		0.40 a	0.40 a
ELECTRONICS DRIVE ADDITION	0.7 a X 10% DUTY =	0.07 a	0.14 a
		0.61 a	0.82 a

POWER - 26 V BUS	16 WATTS	21 WATTS
POSITIONER SYSTEM (90% TRACK, 10% SLEW)		26 WATTS

DIRECT SHAFT READOUT INSTRUMENT

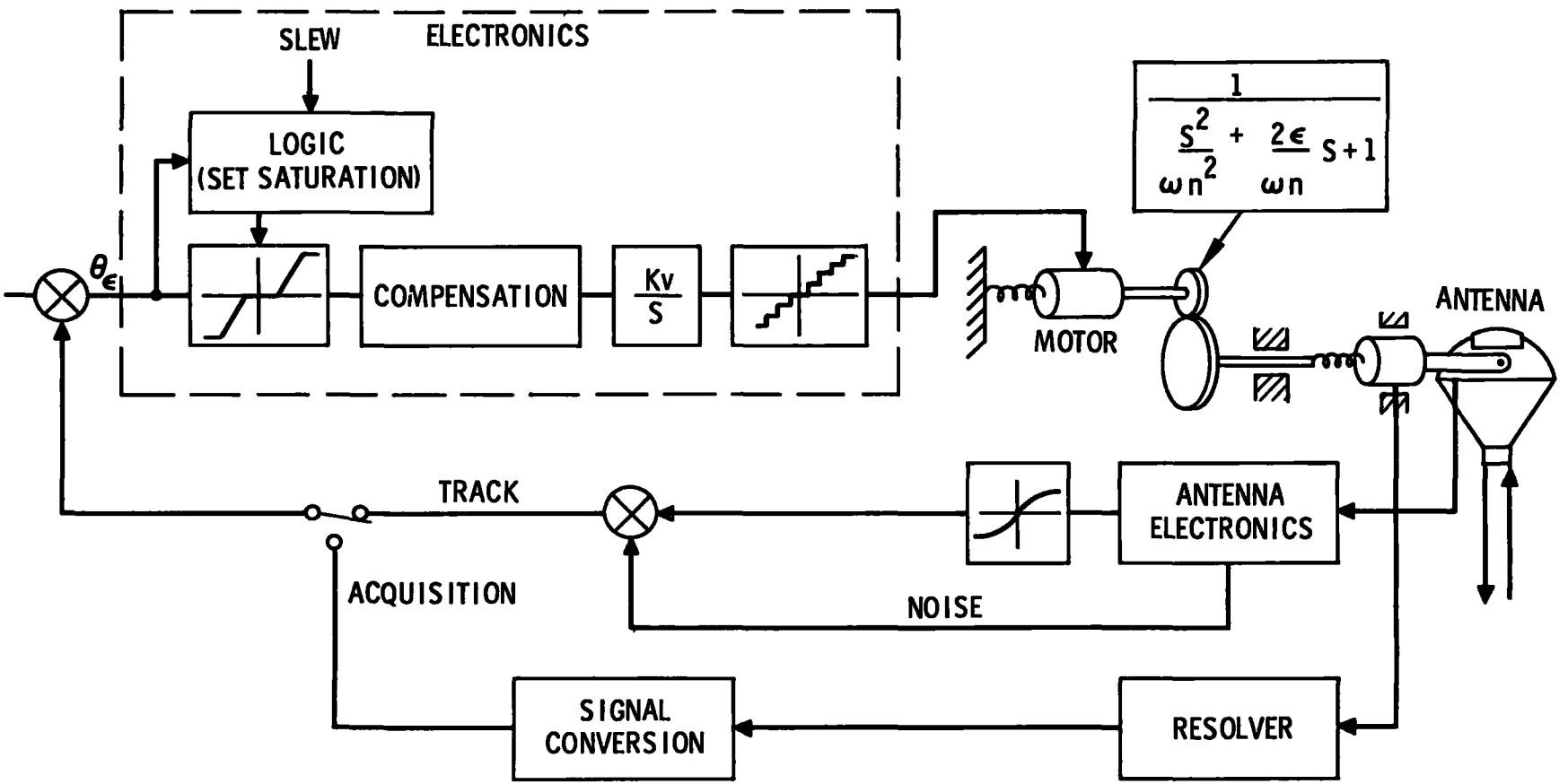
PROPERTY	DIGISEC OPTICAL	RESOLVER-2 SPEED AMER ELECTRONICS	MAGNETIC V SCAN ENCODER-LIBRASCOPE
ACCURACY	0.017^{0}	0.20^{0}	0.10^{0}
INPUT POWER	6.7 WATTS 2 DC VOLTAGES	0.1 WATT 10 VOLT 5 KHz	1.0 WATT
OUTPUT FORM	BINARY WORD	SINE-COSINE	MAGNETIC STATE OF ELEMENTS
ENVIRONMENTAL ADAPTION	REDESIGN FOR VAC USE. CONTAINS ELECTRONIC COMPONENTS TEMP LIMITING	NO PROBLEM FOR TEMP OR VAC	CONTAINS INTERNAL GEARS AND BEARINGS
WEIGHT EFFECT PER POSITIONER	18 LBS	BASE LINE	BASE LINE TO - 1 LB
COST THRU VEHICLE 1 MECH	80 K	BASE LINE	+ 30 K
COST THRU VEHICLE 1 ELECTRONICS	-115 K	BASE LINE	- 30 K
	TOTAL COST - 35 K	0	0
RISK	OUTSIDE VENDER DEVELOP FOR SPACE	LOWEST NO NEW DEVELOP.	CHANGE LUBE FOR INTERNAL MECH AND HAC GEAR DRIVE

ANTENNA POSITIONING DRIVE ASSEMBLY



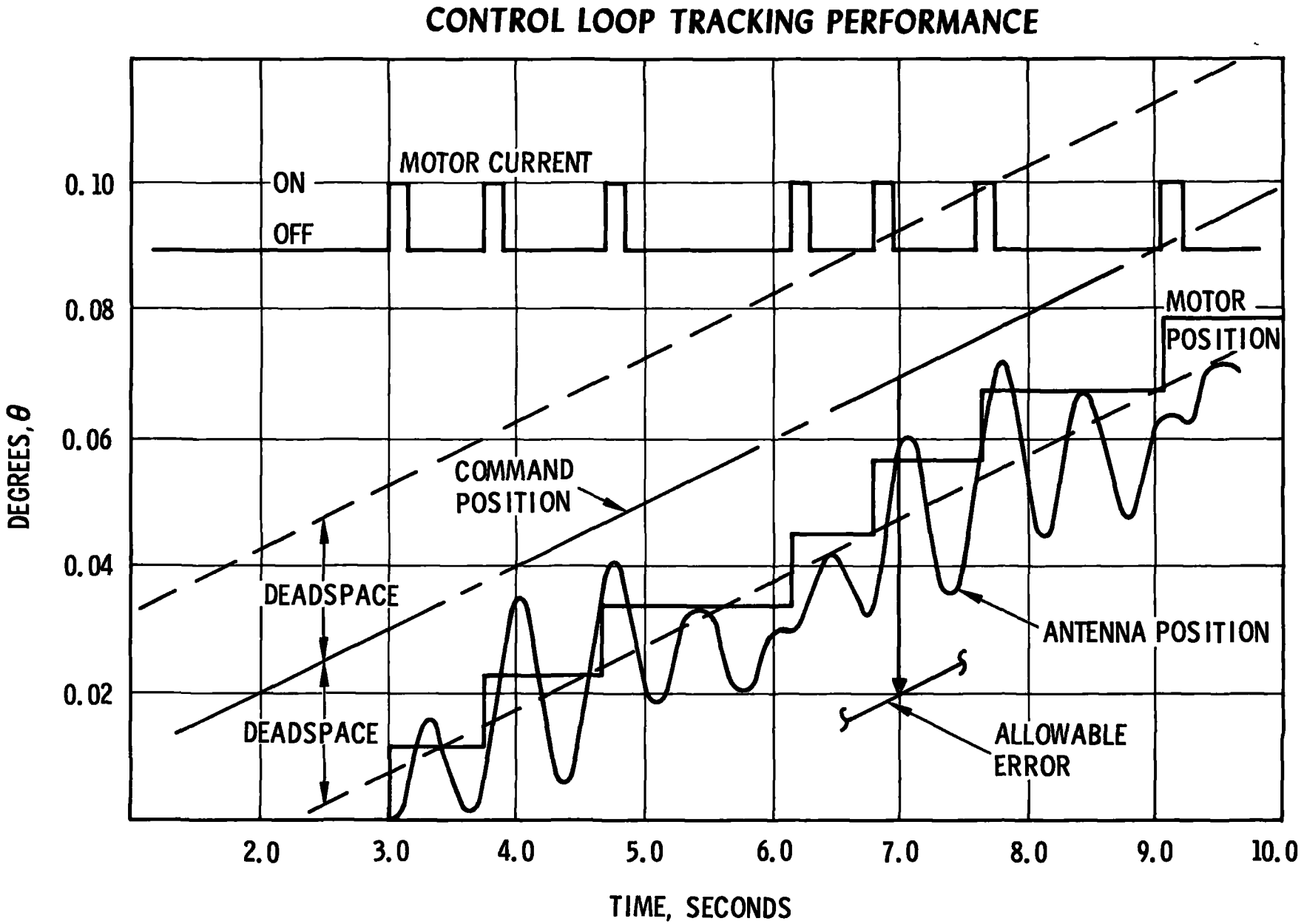
POSITIONER CONTROL LOOP

BLOCK DIAGRAM

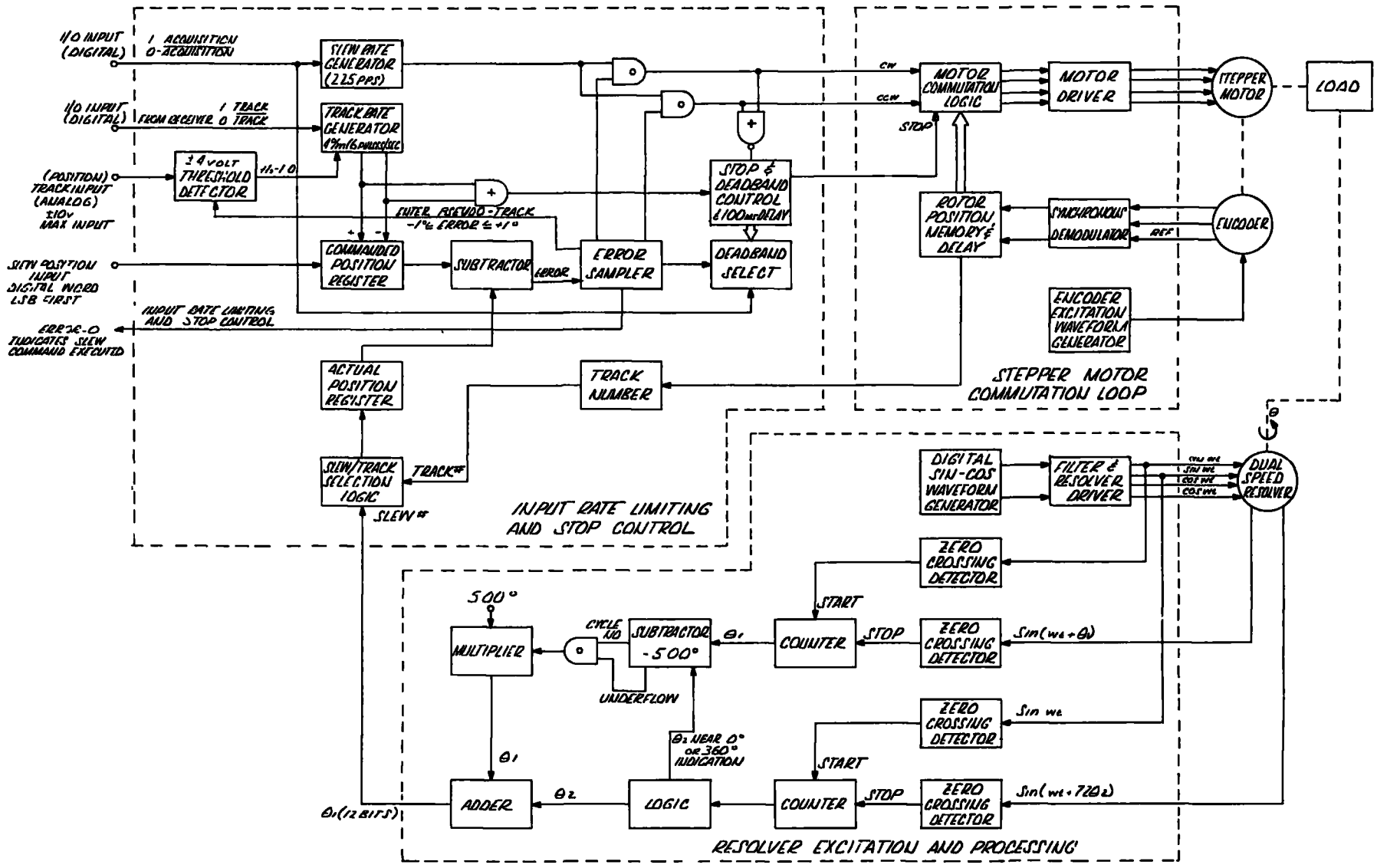


POSITIONER CONTROL LOOP PARAMETERS

PARAMETER	VALUE	CALCULATION	COMMENTS
(1) FORWARD LOOP GAIN Kv	1.0^0/SEC/DEG	$\frac{3^0/\text{MIN} \times \frac{1}{60}}{0.05^0}$	MINIMUM = $\frac{\text{ERROR}}{\text{MAX EXPECTED RATE}}$ MAXIMUM MUST ALLOW GAIN MARGIN
(2) DEAD SPACE	$\pm 0.02^0$	> 0.016	MUST BE GREATER THAN 1σ NOISE LEVEL TO MINIMIZE OSCILLATIONS
(3) BANDPASS	~ 1 RAD/SEC	ALLOW NO. 1 BUT $< \frac{\omega_n \text{ STRUCTURE}}{10}$	SAME AS COMMENT FOR NO. 1 (AS LOW AS POSSIBLE)
(4) COMPENSATION	$\frac{1}{0.5S + 1}$	$>$BANDPASS $< \frac{\omega_n \text{ STRUCTURE}}{5}$	ALLOWS ROLL OFF AT STRUCTURAL FREQUENCY (DETAILED STUDY REQUIRED AT HARDWARE STAGE)
(5) RATE SATURATION	4^0/MIN TRACKING 150^0/MIN SLEW		WANT MAXIMUM TRACKING RATE LOW TO CONTROL TRANSIENTS
(6) TORQUE LIMIT	50 FT NO.		VEHICLE REQUIREMENT


CONTROL LOOP TRACKING PERFORMANCE
MOTOR CURRENT
ON
OFF
0.10
0.08
0.06
0.04
0.02
DEGREES, θ
MOTOR POSITION
COMMAND POSITION
DEADSPACE
DEADSPACE
ANTENNA POSITION
ALLOWABLE ERROR
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME, SECONDS

ANTENNA POSITIONER ELECTRONICS



POSITIONER AREAS FOR FUTURE STUDY

1. ELECTRONIC IMPLEMENTATION OF SLEW DECELERATION
2. ELECTRONIC IMPLEMENTATION OF RESOLVER A TO D CONVERSION
3. INVESTIGATE BRUSH ENCODERS FOR GIMBAL SHAFT ANGLE
4. MECHANISATION OF CONTROL LOOP COMPENSATION
5. TORQUE AND IMPULSE LIMITING INTO VEHICLE
6. RELIABILITY ASSESSMENT