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[redacted]
Sheet count 122
P-118 Unit 10
COPY 1

CARRIE
PHASE I
FINAL REPORT

NATIONAL SECURITY INFORMATION
UNAUTHORIZED DISCLOSURE
SUBJECT TO CRIMINAL SANCTIONS

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16 JULY 1990

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Approved for Release: 2024/08/06 C05098301

AIL Systems Inc.
Subsidiary of Eaton Corporation
Commack Road
Deer Park, New York 11729

TO: [redacted]
Director, [redacted]
SAFSP

FROM: [redacted]

DATE: 16 July 1990

The use of special purpose payloads to meet emerging intelligence requirements in a cost/schedule effective manner has added a new dimension to our overhead collection assets.

In anticipation of this new dimension, AIL Systems has been focusing on being a quality, quick-reaction, cost-effective supplier for the past five years. We are anxious to begin working on the payload portion of the CARRIE program and I personally commit that all of the required resources will be available on a timely basis to insure the success of this program.

[redacted]
Director
Advanced Technology & Systems

INDEX

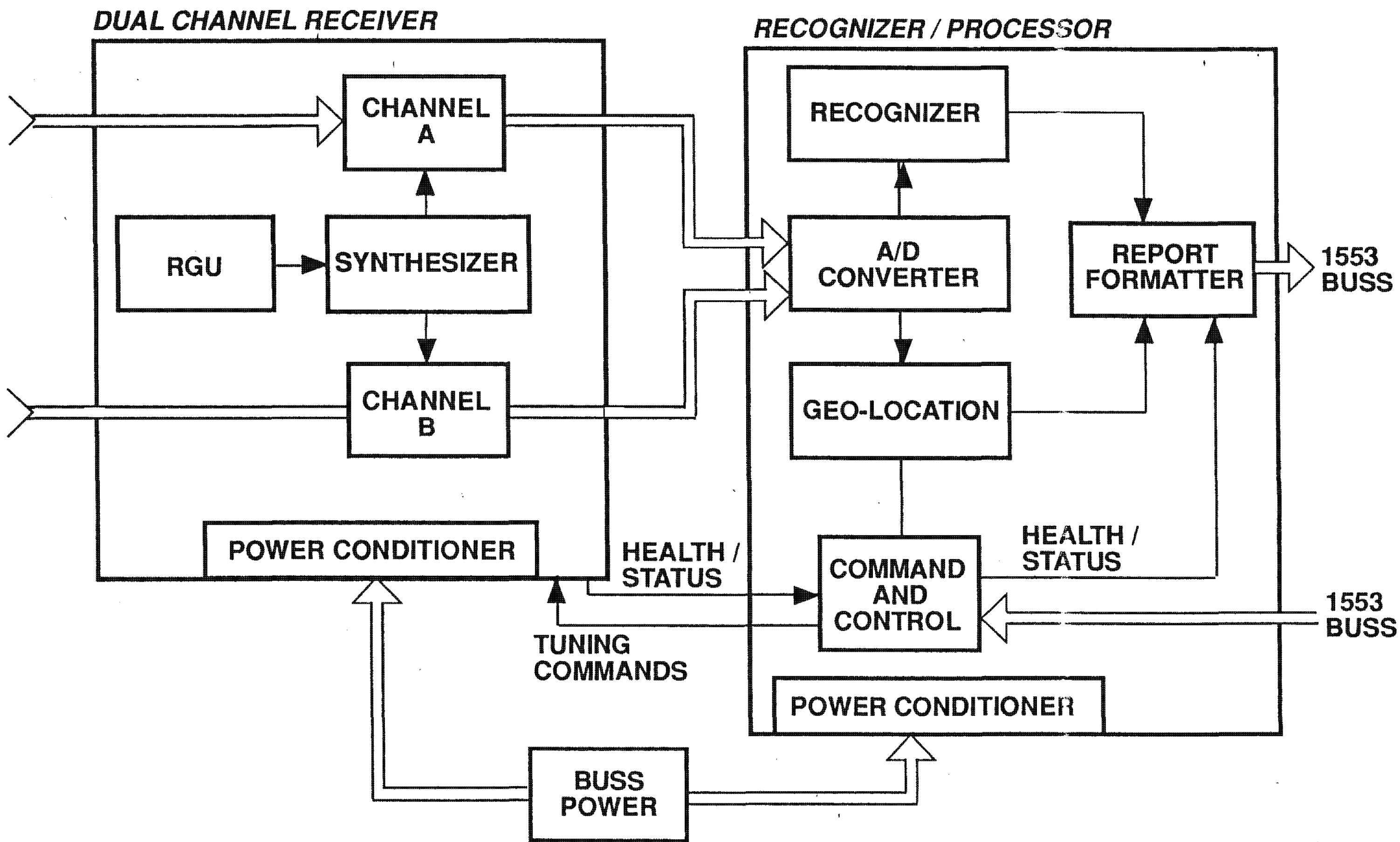
1.0 MISSION

MISSION OBJECTIVES

- PROVIDE TACTICAL COMMUNICATIONS MAPPING OF SOI'S
- DETECT, CATEGORIZE, LOCATE
- COMPATIBLE WITH EXISTING TERMINALS
- LOW RISK APPROACH

~~SECRET~~/

FUNCTIONAL INTERFACE DIAGRAM



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2.0 SYSTEM REQUIREMENTS

C05098301

SYSTEM REQUIREMENTS

- FREQUENCY RANGE: 100 - 500 MHZ
  [redacted]

- GEOLOCATION [redacted]
  MANY [redacted]

- PRE-DETECTION ON A TASKED BASIS

- DIRECTED SCAN & GENERALIZED SEARCH

SIGNAL LEVEL REQUIREMENTS

ITEM	LOSS	CUMMULATIVE SIGNAL LEVEL	COMMENT
kT		- 114 dBm	1 MHz REFERENCE
BANDWIDTH	-10dB	- 124 dBm	100 kHZ
NOISE FIG	5dB	- 119 dBm	
SNR	10dB	- 109 dBm	FM THRESHOLD
ANT GAIN	- 3dB	- 112 dBm	CIRCULAR POL
POL LOSS	3dB	- 109 dBm	ANY LINEAR

PEAK OF BEAM REQUIRES -109 dBm LINEAR POLARIZATION

EMITTER ERP REQUIREMENTS
PROVIDES -109 dBm AT BORESIGHT

FREQUENCY MHZ	ALT n mi	PATH LOSS dB	NADIR ERP dBm	-6 dB ** ERP dBm
100	275	126.6	16.6	22.6
200	275	132.6	22.6	28.6
300	275	136.1	26.1	32.1
400	275	138.6	28.6	34.6
500	275	140.6	30.6	36.6

** ANTENNA GAIN - PATH LOSS = - 6 dB FROM NADIR

ERROR BUDGET
INTERFEROMETER SYSTEM

PHASE NOISE		
MIN SIGNAL	12 DB	
INTEGRATION PER DWELL	16 DB	
	28 DB	2.3 DEGS
PHASE QUANTIZATION		
8 BITS		0.4 DEGS
PHASE MISTRACK		
ANTENNAS		5.0 DEGS
RCVR		N/A
RSS		5.5 DEGS

LOCATION UNCERTAINTY
INTERFEROMETER SYSTEM

<u>NADIR</u> <u>40 DEG ELEVATION</u>

D/LAMBDA=0.5

ONE SIGMA

SEMIMAJOR AXIS

SEMIMINOR AXIS

ERROR BUDGET ANALYSIS

AN ANALYSIS OF THE ERROR BODGET
INCLUDING ALLOCATION OF SPACECRAFT
CAN BE FOUND IN APPENDICES B AND D

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ERROR BUDGET ITEMS NOT CONSIDERED

- TOPOLOGICAL ERRORS
  THIS REQUIES STORING OF TOPOLOGICAL DATA
- ATMOSPERIC/IONOSHERIC CORRECTION
  LIMITING COLLECTION TO 40 DEG ELEVATION
  LIMITS MAGNITUDE OF CORRECTION
  MAY NOT BE NECESSARY

RELIABILITY CONSIDERATIONS

1 RELIABILITY PROGRAM

A reliability program will be developed to meet the Buyer's requirements. The reliability program will be implemented so that the equipment is designed, developed, and manufactured to meet the equipment specifications. It will encompass reliability requirements, reliability tasks, and schedules for control of such tasks. The following is a description of detailed reliability elements to assure an effective reliability program.

2 RELIABILITY IMPLEMENTATION PROCEDURES

A Reliability Implementation Procedure will be generated by the Program Reliability Leader. This procedure defines the reliability related tasks to be performed by other groups assigned to the program. In this manner, the contractual requirements of the Reliability Plan are transmitted as instructions, techniques, controls, and responsibility to assure that the reliability requirements are fulfilled. This procedure includes workmanship standards, design requirements, method of parts selection and requests for additional parts, derating requirements, design review requirements, malfunction reporting requirements, and other information as required.

3 RELIABILITY ANALYSIS

X.3.1 Reliability Prediction. The Seller will prepare a reliability analysis which predicts the probability of mission success for all Seller-supplied equipment. The analysis will consist of an assessment of piece part failure rates calculated in accordance with MIL-HDBK-217. The reliability prediction will include the following: Reliability block diagram, mathematical models, and conditions applied.

3.2 Failure Mode and Effects Analysis (FMEA). The Seller will prepare and submit an FMEA. The analysis will also identify all single point failures. The primary objective will be to eliminate single point failures. When this is not possible, all effort will be directed to minimizing the effects through the use of greater derating, fault tolerant features, and compensating provisions.

3.3 Stress/Derating Analysis. A circuit stress analysis will be performed to determine that the part derating requirements are met. Design engineering will supply the actual stress levels and Reliability engineering will supply electrical and thermal ratings to assure that the design is adequately derated.

In addition, the design will be analyzed for potential failures due to part characteristic drift with time. Reliability engineering will supply any part characteristics drift data to aid in the analysis.

3.4 Radiation. From the beginning of the design phase, Radiation engineers will be involved with the Design engineers. Parts approval by Radiation Parts engineering shall be required for all devices used. Radiation and Reliability engineers shall review on an ongoing basis the application, expected shielding and any radiation impacts on the electrical performance and also participate at internal design reviews. In addition, the Seller will provide any necessary information at Program Reviews and formal reports or data items in support of PDR and CDR.

3.4.1 Design Considerations. This program will be designed to survive and perform to its requirements after having been exposed to a cumulative integrated total dose of 10×10^3 Rads external to the unit.

The devices most susceptible to radiation are the active devices, i.e., transistors, diodes, and microcircuits. The passive devices have little or no susceptibility at the housing attenuated levels.

3.4.2 Radiation Data. In order to assist Design engineering in the application of parts in the radiation environment, a Radiation Summary Total Dose Data List will be generated for this program. This data list contains all parts which are affected by radiation. The list will also include, for each item, information regarding vendor, the total dose level at which the item is affected, the specific parameter and resulting effect, and the source of the information.

3.4.3 Testing. Since sufficient radiation information is not available on all parts regarding device performance in the expected radiation environment, testing shall be performed on those parts. Testing shall be on 5 samples with at least 1 control sample IAW MIL-STD-883 Method 1019, but minimum dose rate requirement will not be required.

For those parts which require testing, the Seller is anticipating using ICS Radiation Laboratory. This vendor has been used in support of needed radiation testing on other programs. Their technical support and turnaround time were satisfactory and consistent with the hardware assembly schedule requirements.

3.4.4 Radiation Analysis. All affected parts will be analyzed to verify performance in the specified radiation environment. The total effects on sensitive device parameters will be combined with temperature and end of life effects by an rms or reciprocal of the sum of the reciprocals formulas. This will be compared to the circuit design tolerance for this parameter. The ratio of total dose level used in the calculations to the device expected dose shall be the margin.

The present housing designs are typically 40-50 mils aluminum. A preliminary review indicates that additional shielding may be required for radiation susceptible parts. The amount of extra shielding would depend on the part, its application, and details of the housing; eg. subcovers or other materials within the housing. A detailed analysis will be performed during the design phase.

3.5 Failure Reporting and Analysis. Failure reporting and analysis will be performed on all failures of deliverable equipment occurring on qualification or flight hardware.

During end item qualification or acceptance testing, in the event of failure, the test will stop and the hardware setup will remain in place. All troubleshooting, removal of hardware or any other action will require concurrence from Reliability and/or Quality Assurance engineers. All activity shall be documented in accordance with the malfunction reporting procedure.

All data and supporting analysis shall be submitted in accordance with data requirements. Existing company procedures and forms shall be used to satisfy the data item requirements. Malfunction reporting, analysis, and corrective action is detailed in Seller Policy and Procedure Bulletin Volume 22-709.

A copy of all malfunction reports will be submitted to Quality Assurance. Problems that are directly related to workmanship will be referred to Quality Assurance for corrective action. The results of Quality Assurance action are returned to Reliability for inclusion in the Malfunction Report.

3.5.1 Failure Summaries. Summaries and requests for corrective action will be generated by Reliability personnel. Reports will be submitted as required by the Statement of Work.

3.5.2 Failure Analysis Facilities. Analysis of part failures will be conducted in the Seller's facility utilizing either the Reliability Laboratory, Materials Laboratory, and/or Central Research Laboratory. These laboratories are equipped to perform diversified testing and measuring techniques, x-ray and microscopic analysis, including scanning electron microscope (SEM) evaluation, sectioning and disectioning techniques as applied to failure analysis of parts.

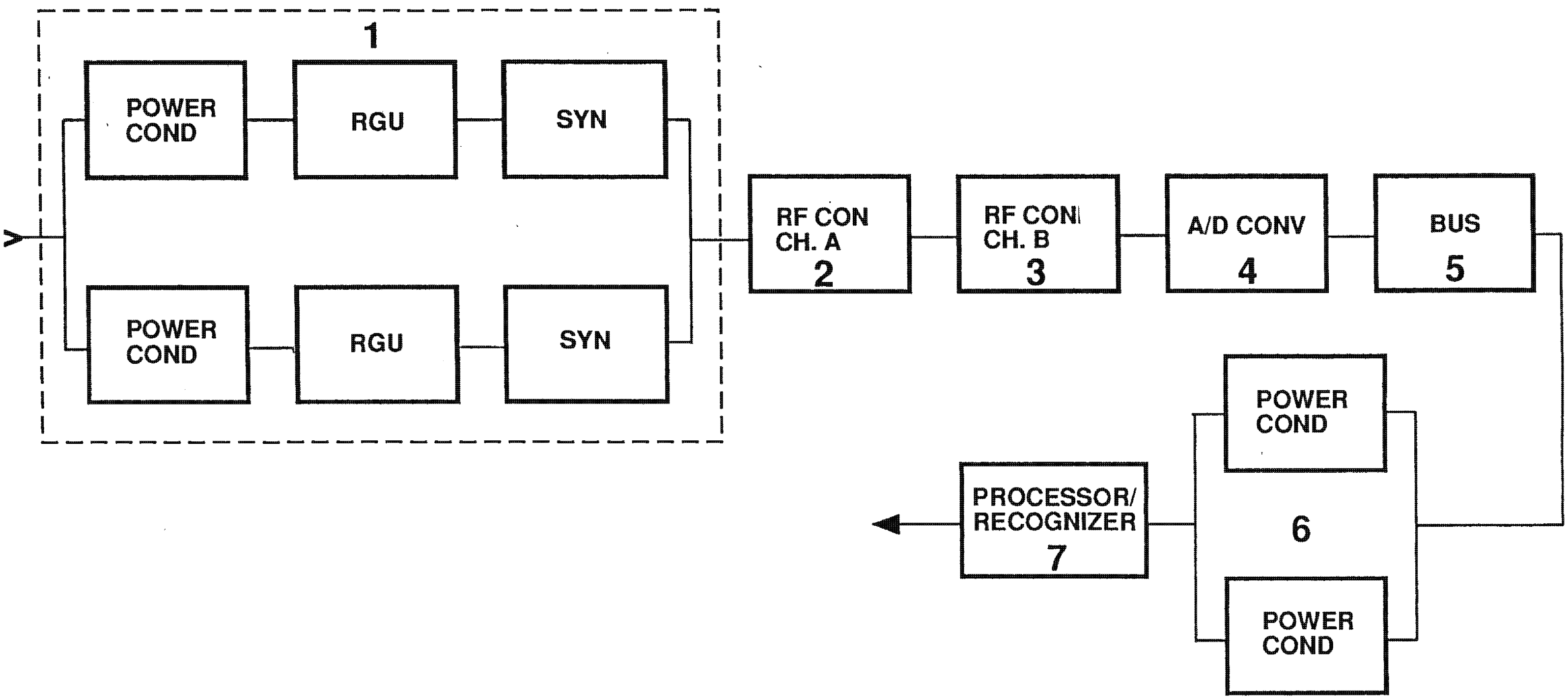
4 PARTS, MATERIALS AND PROCESSES (PMP)

The Seller will conduct a PMP Control Program that complies with Buyer requirements. Existing PMP documentation will be used to the fullest. These documents shall be reviewed and revised whereever necessary to conform to the current program requirements. All required documentation and supporting information will be submitted for Buyer review and approval.

4.1 PMP Selection and Standardization. A PMP Control Program will be implemented to standardize the number and types of PMP used in deliverable equipment. The program developed will assure selection of reliable PMP for long life spacecraft applications. The Seller will generate an initial Parts Selection List.

Use of nonstandard parts will be compliant with the Buyer's screening, acceptance, and qualification requirements.

RELIABILITY BLOCK DIAGRAM



RELIABILITY PREDICTION

BLOCK	FAILURE RATE	PROBABILITY OF SUCCESS 1 YR.	PROBABILITY OF SUCCESS 2 YR.	MIL 217 REV
1	*	.984	.944	C
2	3.127	.973	.947	E
3	3.127	.973	.947	E
4	3.032	.974	.948	E
5	5.000	.957	.916	D
6	*	.995	.981	D
7	3.033	.974	.948	E

$$R_s(t) = R_1(t) \times R_2(t) \ldots R\ (t) = \prod_{i=1}^{\eta} R\, i(t)$$

WHERE

$R\,i(t)$ = RELIABILITY OF THE i^{th} BLOCK

η = NUMBER OF BLOCK INTHE SYSTEM

TIME (t)	Ps
1 YEAR	.842
2 YEAR	.684

FUTURE PREDICTIONS

- ACTUAL DESIGNS WILL REFLECT LOWER STRESS LEVELS
- "S" AND "JTXV" QUALITY LEVEL PARTS CAN BE USED IN CRITICAL AREAS.
- ACTUAL PARTS COUNT WILL BE USED (NO CONTINGENCY FACTOR)
- MIL-HDBK-217 REV. E WILL BE USED FOR PDR / CDR
- THERMAL ANALYSIS WILL REFLECT INDIVIDUAL PART TEMPERATURES.

RADIATION EVALUATION

- PARTS WITH TOTAL DOSE TOLERANCE IN [redacted] RANGE WILL BE ACCEPTABLE
- SEU ENVIRONMENTS WILL REQUIRE CAREFUL ATTENTION TO DEVICE TYPE, CIRCUIT DESIGNS, AND EQUIPMENT PERFORMANCE
- BULK DAMAGE FROM HIGH ENERGY PROTONS DOES NOT APPEAR TO BE A DESIGN INFLUENCE
- SOME ITEMS HAVE BEEN IDENTIFIED FOR REPLACEMENT WITH RAD HARDENED DEVICES

THERMAL DESIGN

The AIL Dual Channel Receiver (37W) and Receiver Processor (28W) will be mounted to a Spacecraft Mounting Plate controlled within the range of -10° C to $+50^{\circ}$ C. This equipment will be completely enclosed within a multi-layer insulation blanket to eliminate temerature excursions caused by transient external heat fluxes.

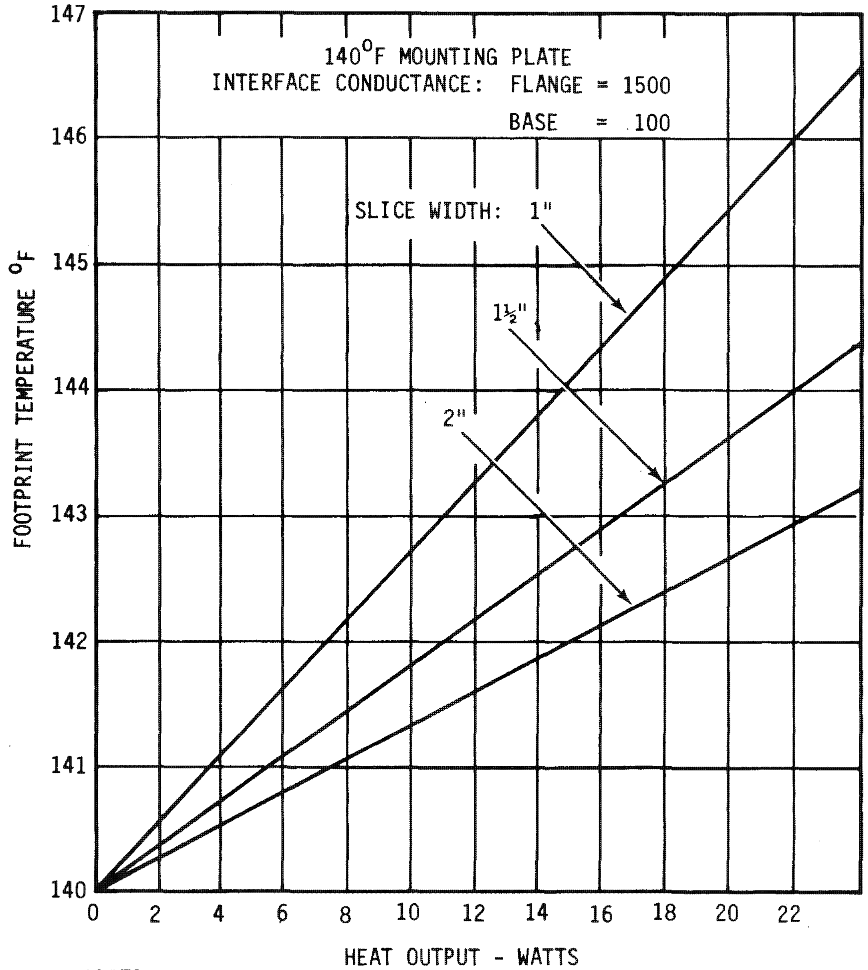
The design objective is to limit all IC junctions to 125° C for a Qual Test condition of 60° C (140° F) mounting Plate.

The packaging configuration will be in the form of machined aluminum slices. Figure 1 shows footprint temperatures (on the slice side of the mounting interface) for various slice widths and power dissipations.

Figure 2 shows the highest average web temperature vs. slice width and power dissipation for a 0.065 inch thick web.

Based on analysis from a similr program, Table I lists sub-assembly dissipations, hottest IC junction temperatures and the IC junction to slice mounting surface temperature difference. These values are thought to be typical for the "slice" type of construction. Specific IC junction temperatures for this program will depend on individual IC dissipation, θ_{jc} and location within the slice. However based upon past experience, the 125° C junction limit will be achieved.

FOOTPRINT TEMPERATURE VS POWER



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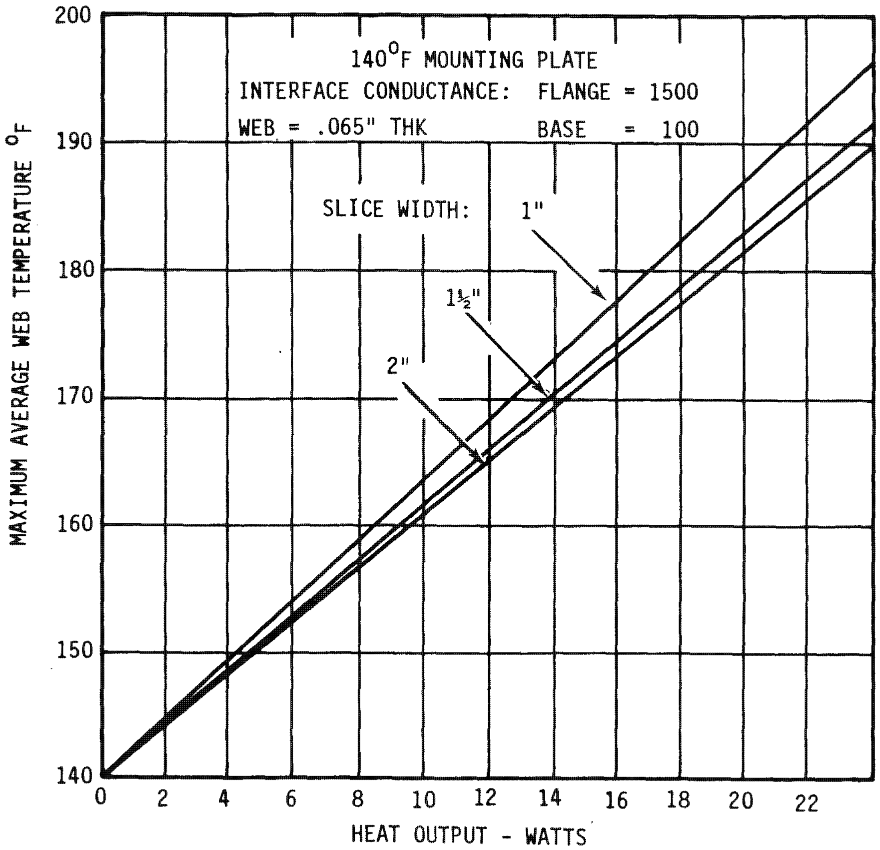
MAXIMUM AVERAGE WEB TEMPERATURE VS POWER



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TYPICAL THERMAL PARAMETERS

SUBASSY TYPE	HEAT DISSIPATION (WATTS)	HOTTEST IC JUNCTION (C)	JUNCT. TO MTG SURFACE T (C)
AMPLIFIER	1.89	114.5	54.5
	1.77	103.3	43.3
	1.49	102.1	42.1
	0.60	92.1	32.1
	0.42	90.6	30.6
AMPLIFIER	0.28	93.3	33.3
SWITCH	0.21	82.8	22.8
SWITCH	0.10	111.9	51.9
1.1" SLICE	4.7	108.4	48.4
1.25"	6.7	111.9	51.9
1.5"	3.9	112.1	52.1
2.0"	8.1	98.8	38.8
	4.5	89.3	29.3
2.0"	3.5	79.2	19.2
2.5"	7.7	103.7	43.7
	5.0	94.2	43.2
2.5"	3.0	100.3	40.3

TABLE I

3.0 ANTENNA SUBSYSTEM

The Antenna Subsystem has seen several evolutions from the original concept of CROSSED DIPOLES with a ground plane. After initial meetings with our Associate Contractor concerning this concept we both undertook configuration studies of different antenna types. The first type studied was a crossed Log Periodic which although met the envelope constraints, did not provide adequate Phase Tracking across the frequency band of interest. The next configuration studied was a deployable Log Conical Spiral, which although met all electrical requirements provided risk in the development of the deployment mechanism. These configurations were forwarded to you for review and concurrence, and per your direction we have focused solely on Bi-directional Spirals to meet system and mission requirements.

Although our original recommendation was to procure the log conical spirals from another supplier, since your direction to utilize flat spirals we have re-evaluated our decision, and as a known quality supplier of this type of antenna we will be fabricating the antennas and deployment mechanism in-house. The following section provides details on three low risk deployment concepts which we have evaluated.

The final choice of deployment mechanism will be chosen after further study by AIL and our Associate Contractor. The results of this study will be presented to you and will be directed toward insuring a low risk approach.

ANTENNA REQUIREMENTS

PARAMETER	SPECIFICATION
FREQUENCY COVERAGE	100 - 500 MHZ
POLARIZATION	CIRCULAR
BEAMWIDTH	80° + / - 8° NOMINAL AT 3 DB POINT
PATTERN RATIO	0 DB
GAIN	NOMINAL 3 DB @ BS
PHASE TRACK	5° RMS BETWEEN SET OVER FREQUENCY
WEIGHT	12 # MAX INCLUDING DEPLOYMENT BOOMS
SIZE	CONSISTENT WITH VEHICLE SHROUD AND SATELLITE CONSTRAINTS

3.0 ANTENNA SUBSYSTEM

3.1 DF Concept

The platform DF antenna subsystem is a phase matched pair of non-cavity backed flat spiral antennas arrayed in an linear interferometer configuration. See Figure 3-1. Resolution of angle of arrival (AOA) ambiguities over the 5 to 1 operating bandwidth is achieved by utilizing the variable projection of the interferometer baseline provided by the spinning platform. The antennas provide circularly symmetric beams about 80° wide in fore and aft directions normal to the spiral face. Polarization is circular of one sense in the forward direction and circular of the opposite sense in the aft direction. Antenna element concept details, expected performance, and mechanical design are provided in the following paragraphs.

3.2 Antenna Element Concept

The antenna elements of the DF interferometer are two-armed flat spirals without the usual cavity backing. As such, they will receive bidirectionally instead of unidirectionally but can be used unambiguously in an interferometer configuration, provided simultaneous frequency identical signals are not incident from both forward and aft directions. Since simultaneity is highly unlikely, the backing cavity, which normally would require that the spirals themselves by deployable, can be eliminated with the only penalty being a potential increase in AOA error due to reduced discrimination against spacecraft scattered signals. To quantify and minimize this effect by optimized antenna positioning, scale model measurements including both antennas and the platform will be conducted during the first quarter of the program. To prohibit additional AOA error from pattern degradation caused by coaxial feed line interference in the vicinity of the spiral face , each spiral will be excited by the "infinite balun" arrangement shown in Figure 3-2. This configuration provides a balanced to unbalanced transmission line transformer of virtually unlimited bandwidth while making the center feed of the spiral effectively disappear by configuring it as a integral part of the filament structure. To improve the impedance, circular polarization and phase tracking performance of the spirals, a resistive terminating band will be provided at the outside edge of each antenna.

3.3 Antenna Element Electrical Performance

The gain performance of the spiral elements of the DF interferometer is limited at the low end of the frequency band by the outside electrical diameter selected for the spiral. For best performance this diameter should be equal or greater than about 0.375 λ_L. In contrast, gain performance at the upper end of the band is governed by the inside electrical diameter of the spiral which should be equal or less than about 0.125 λ_H. Using these guidelines for the diameters, the electrical performance of the spiral elements of the interferometer over its 5:1 frequency band is estimated as follows for a 44" diameter spiral:

Gain vs. Frequency

FREQUENCY (MHZ)	GAIN (DBI)
100	+ 3 *
200	+ 3.5
300	+ 3.5
400	+ 3.2
500	+ 3.1

* Note: -3 db if 36" diameter is used, -17 db if 24" diameter is used.

Half Power Beamwidth

$80^\circ \pm 8^\circ$, bidirectional pencil beams.

<u>Polarization</u>

Circular, maximum axial ratio 3 db over the half power beamwidth.

SWR (Relative to a Zo of 50)

2.5:1

Element to Element Phase Tracking

5° RMS electrical, over the half power beamwidth.

FIGURE 3-1

ROTATING INTERFEROMETER CONCEPT

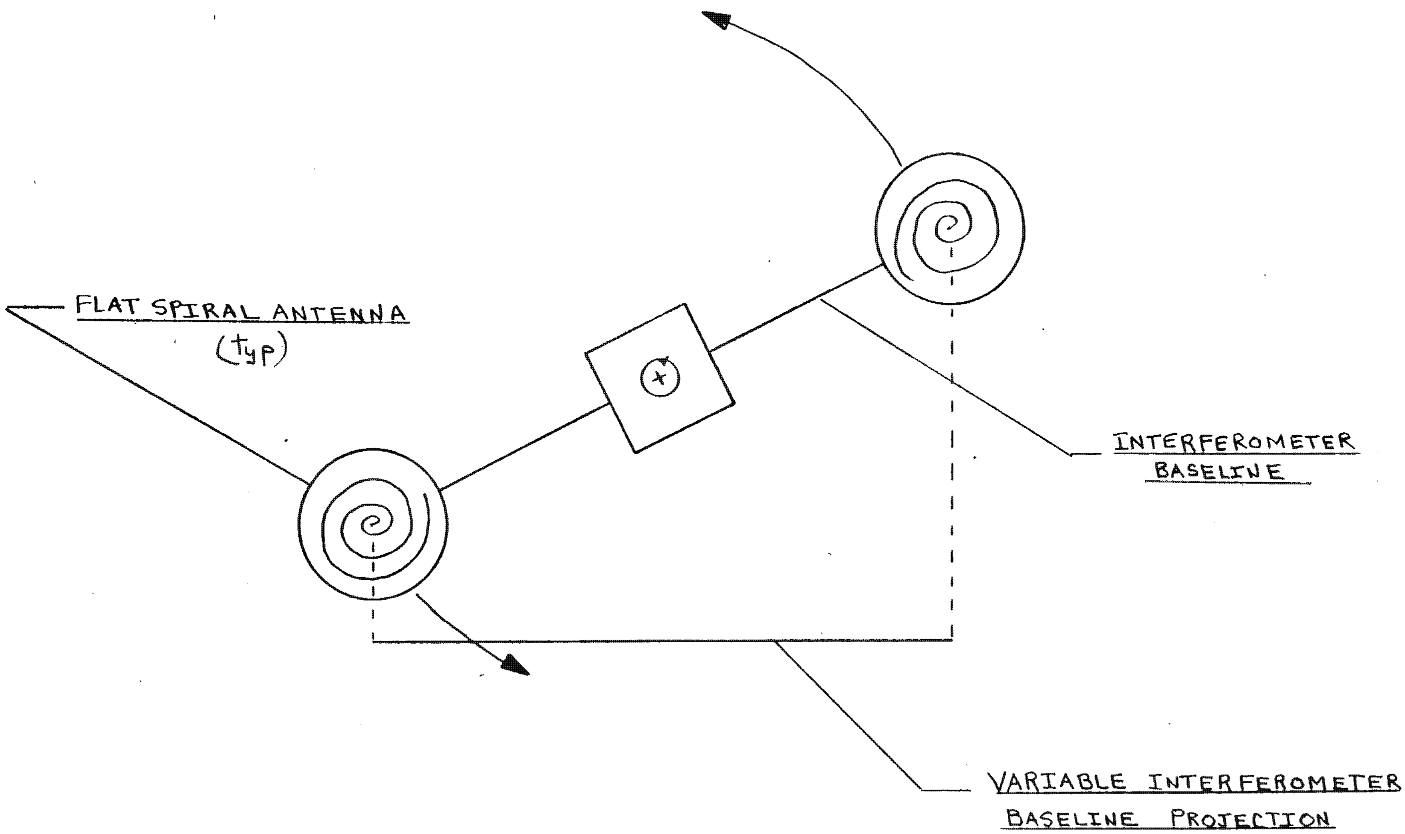
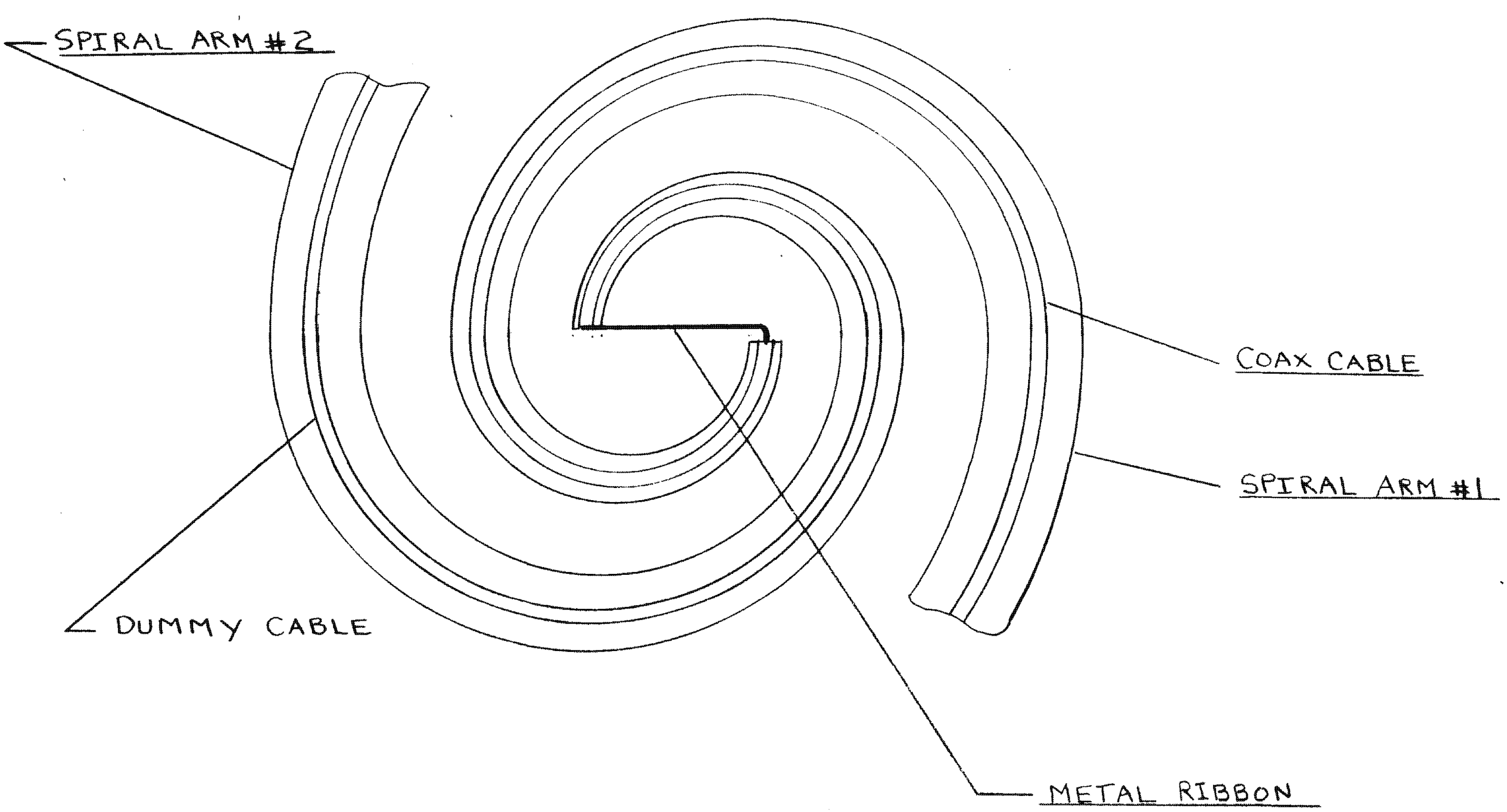


FIGURE 3-2

SPIRAL ANTENNA FEED CONFIGURATION



3.4 Mechanical Design

Each spiral antenna element of the interferomter will be etched on the metallized side of 44" diameter, 1/4" thick honeycomb panel consisting of two .010" thick polyimide-quartz skins sandwiching a low dielectric constant glass-polyimide honeycomb core. Metallization will be two ounce (.0028") copper from which a complementary two filament logarithmic spiral (growth rate $\sim$ .012) will be etched. To excite the spiral a low loss, coaxial cable will be soldered to one of the filaments and run in from the outside edge to one side of a terminal pair located at the spiral center. The feed arrangement is then completed by soldering the center conductor of the cable to the opposite filament terminal. For symmetry purposes a dummy coaxial cable (same diameter but with no center conductor) will be soldered to and run along the opposite filament to its outside edge. To complete the circuit, a thin ring of deposited resistive material at the outside edge of the spiral will connect the opposing filament/cables together.

ANTENNA CONCEPT NO 1

GENERAL ANTENNA CONFIGURATION

The antenna elements consist of copper spirals adhesively bonded to light weight Hexcel type honeycomb dielectric panels 1/4 " thick. The copper radiating element is on one surface only , but the aperture can radiate equally well in both directions perpendicular to the spiral face, since the honeycomb panel is transparent at the frequencies of interest.

As shown in Figure 1A the spiral antenna discs are 44" in outer diameter to provide maximum gain, while still allowing ample sway space from the 46"-50" diameter vehicle walls in the stowed position. Smaller diameter antennas can, of course, be easily accommodated if the gain is not required.

In the deployed position the spacing between the centers of the two antennas is 72", which allows electrical resolution of interferometer ambiguities, as well as providing at least a 2" spacing between the payload and each spiral disc. This 2" spacing permits an unobstructed view for the antenna aft, in addition to the clear forward view. The hinge point for the erection of each antenna is geometrically located at this 2" point.

STOWED ANTENNA DESCRIPTION

Figure 1A depict the stowed position of the two antenna elements. As pointed out above, they are hinged at the 2" points outboard of the payload. In the stowed position they are analogous to two hands touching only at the finger tips, in the "church steeple" position. In this analogy the wrists are at the hinge points. The tips of the discs are separated by a small foam elastic snubber to prevent vibration damage during launch.

Each hinge point contains the erecting force device which can be either be a simple spring or a gear motor. In either case a locking pin would prevent inadvertent deployment during ground or launch conditions. This deployment locking pin would be either squib or solenoid retracted upon command from the payload. AIL has made satellite deployable boom antennas of this type previously which were successful in deployment and operation.

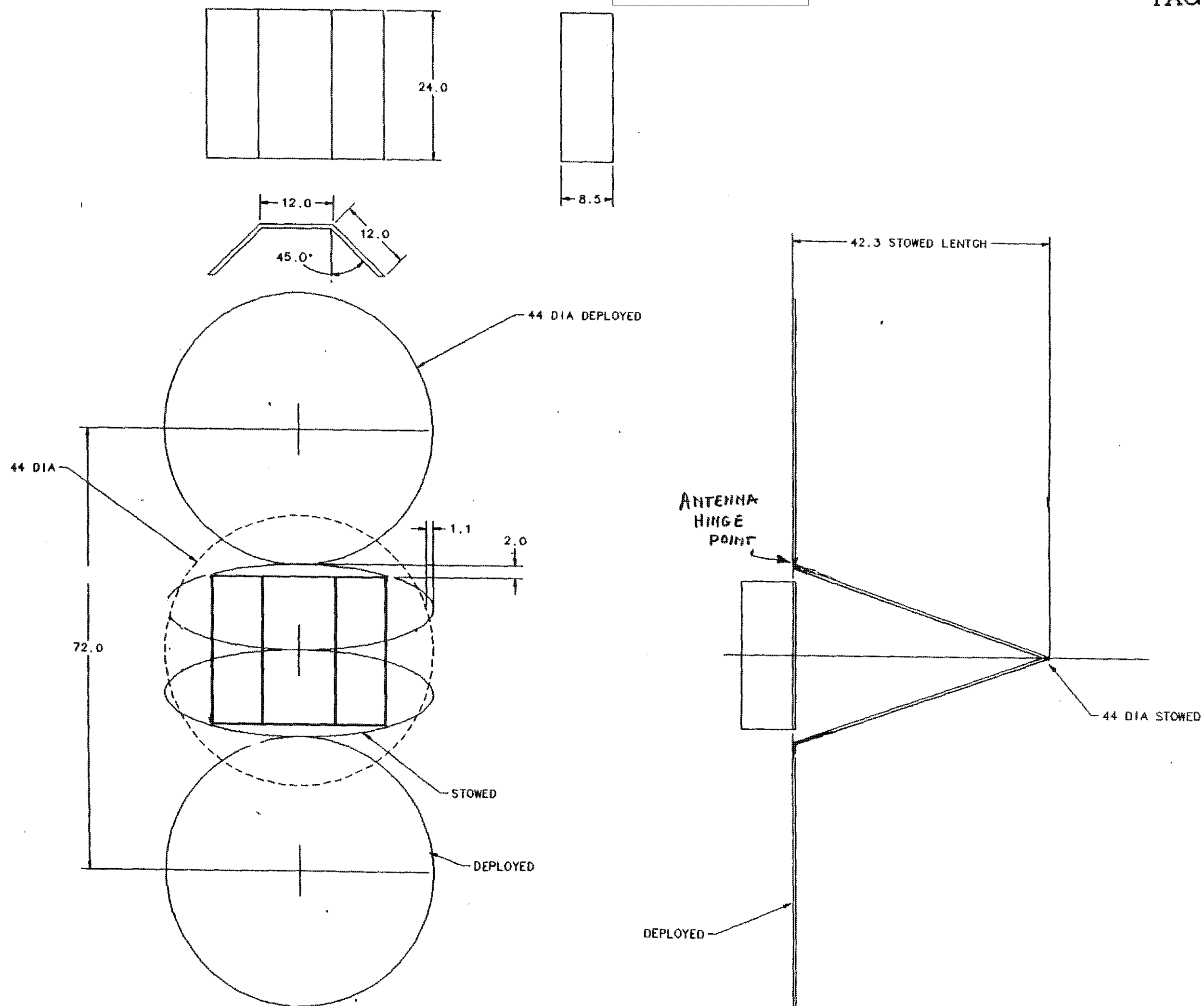
DEPLOYED ANTENNA DESCRIPTION

Upon receipt of the deployment command the antenna locking pins would be retracted from each antenna hinge point, and each antenna would swing open 90° to the deployed coplanar position. The panels would lock in this position, and micro switches would verify that each of the antennas was fully deployed. In the deployed position the apertures are essentially coplanar with the front of the payload.

OVERALL OBSERVATIONS

Concept Number 1 is a simple straight forward approach. The non-complex hinge point results in the antenna aperture plane flush with the payload forward surface hinge

The "church steeple" stowed position of the configuration uses the conical nose cone area volume to a depth of only 42.3".



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ANTENNA CONCEPT NO 2

GENERAL ANTENNA CONFIGURATION

As in Concept No 1, the antenna elements consist of copper spirals adhesively bonded to light weight Hexcel type honeycomb dielectric panels 1/4 " thick. The copper radiating element is on one surface only , but the aperture can radiate equally well in both directions perpendicular to the spiral face, since the honeycomb panel is transparent at the frequencies of interest.

As shown in Figure 2A the spiral antenna discs are 44" in outer diameter to provide maximum gain, while still allowing ample sway space from the 46"-50" diameter vehicle walls in the stowed position. However in this concept the antennas are supported on 14" dielectric material standoffs that are transparent to the antenna.

As in Concept 1, the deployed position the spacing between the centers of the two antennas is 72", as well as providing at least a 2" spacing between the payload and each spiral disc. This 2" spacing permits an unobstructed view for the antenna aft, in addition to the clear forward view. The hinge point for the erection of each antenna is geometrically located at this 2" point.

The difference in this concept from that of Concept 1 is that the plane of the antenna spiral apertures is now located 14" forward of the pay load, providing isolation for the antennas from the metallic effect of the payload.

STOWED ANTENNA DESCRIPTION

Figure 2A depict the stowed position of the two antenna elements. As pointed out above, they are hinged at the 2" points outboard of the payload. In the stowed position they are analogous to two hands with palms fully touching, in the "Bali Dancer Prayer" position. In this analogy the elbows are at the hinge points. The entire faces of the discs are parallel and separated by a small foam elastic snubbers at the periphery to prevent vibration damage during launch.

As in concept 1, each hinge point contains the erecting force device which can be either be a simple spring or a gear motor. In either case a locking pin would prevent inadvertent deployment during ground or launch conditions. This deployment locking pin would be either squib or solenoid retracted upon command from the payload.

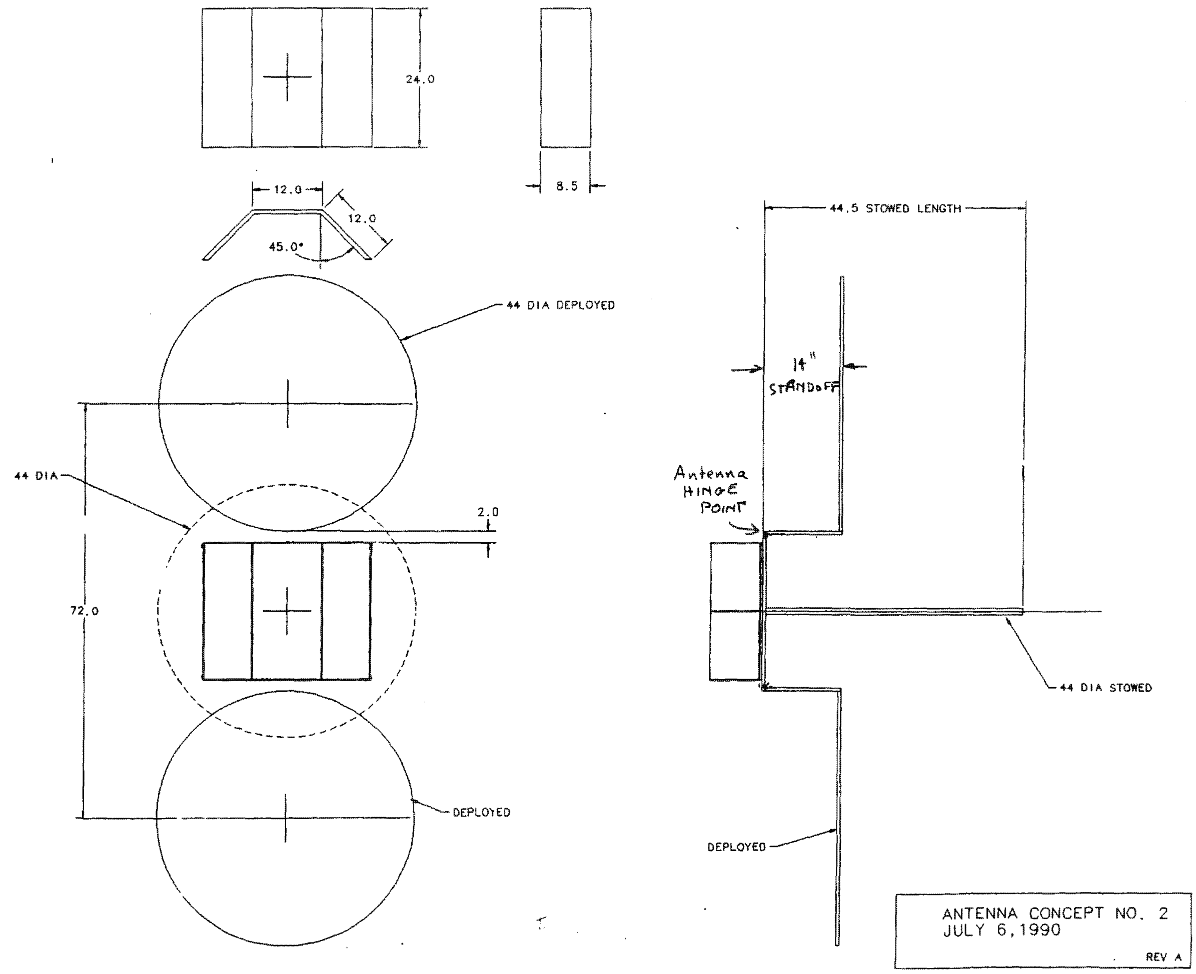
DEPLOYED ANTENNA DESCRIPTION

Upon receipt of the deployment command the antenna locking pins would be retracted from each antenna hinge point, and each antenna would swing open 90° to the deployed coplanar position.The plane of the antennas is forward of the payload. The panels would lock in this position, and micro switches would verify that each of the antennas was fully deployed.

OVERALL OBSERVATIONS

Concept No 2 offers the same simple straight forward approach for deployment that Concept No 1 employs. In this case however, the hinge arm results in the antenna aperture plane located 14" forward of the payload , with desirable isolation advantages.

The "Bali Dancer" stowed position of this configuration uses the conical nose cone area volume to a depth of 44", which is only slightly larger than Concept 1.


24.0
12.0
12.0
45.0°
8.5
44 DIA DEPLOYED
44 DIA
2.0
72.0
DEPLOYED
44.5 STOWED LENGTH
14"
STANDOFF
Antenna
HINGE
POINT
44 DIA STOWED
DEPLOYED
ANTENNA CONCEPT NO. 2
JULY 6,1990
REV A

ANTENNA CONCEPT NO 3

GENERAL ANTENNA CONFIGURATION

As in Concept No 1 and 2 the antenna elements consist of copper spirals adhesively bonded to light weight Hexcel type honeycomb dielectric panels 1/4 " thick. The copper radiating element is on one surface only , but the aperture can radiate equally well in both directions perpendicular to the spiral face, since the honeycomb panel is transparent at the frequencies of interest.

As shown in Figure 3A the spiral antenna discs are 44" in outer diameter to provide maximum gain, while still allowing ample sway space from the 46"-50" diameter vehicle walls in the stowed position. However in this concept the antennas are supported on two separate pivot points, and are stowed parallel to the face of the payload, similar to two "pizzas"stacked on the payload face. The antennas deploy by swinging outward parallel to one another on the pivot axes.

Similar to Concepts 1&2, in the deployed position the spacing between the centers of the two antennas is 72"

STOWED ANTENNA DESCRIPTION

Figure 3A depict the stowed position of the two antenna elements. As pointed out above, they are pivoted at 36" points outboard of the payload. In the stowed position they are analogous to two stacked "pizzas". The entire faces of the discs are parallel and separated by small foam elastic snubbers at the periphery to prevent vibration damage during launch.

In this concept , each pivot point contains the rotating force device which can be either be a simple spring or a gear motor. In either case a locking pin would prevent inadvertent deployment during ground or launch conditions. This deployment locking pin would be either squib or solenoid retracted upon command from the payload.

DEPLOYED ANTENNA DESCRIPTION

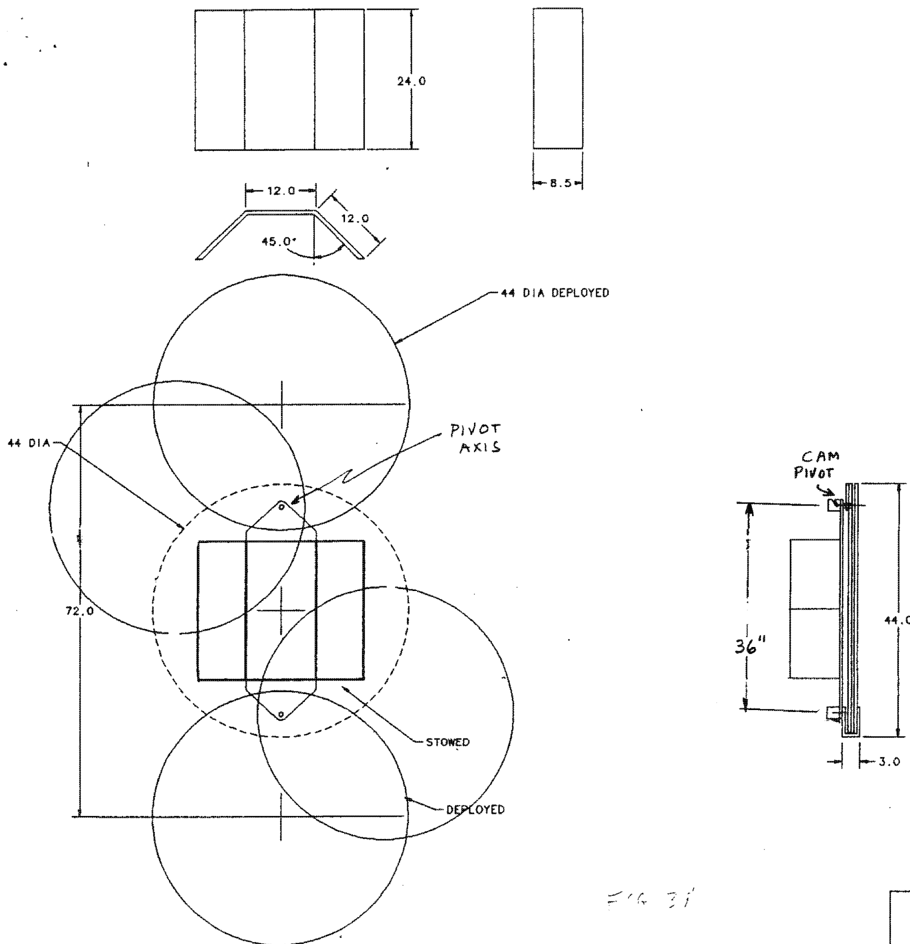
Upon receipt of the deployment command the antenna locking pins would be retracted from each antenna pivot point, and the antennas would swing open 180° to the deployed coplanar position. The plane of the antennas is essentially coplanar with the payload The panels would lock in this position, and micro switches would verify that each of the antennas was fully deployed.

As shown in figure 3A one antenna is stowed behind the other prior to deployment. In order to establish absolute coplanarity of both antennas after deployment, the pivot axle for the lower antenna will have a cam thread such that when it rotates 180°, it will move up axially to position the face of the lower antenna parallel with the other antenna. This is analagous to a threaded bolt in a nut. When the bolt is rotated 180° it moves longitudinally 1/2 a thread length.

OVERALL OBSERVATIONS

Concept No 3 offers the advantage of a very compact stowed height. This configuration only projects 3"into the nose cone area volume, which is substantially less than Concepts 1 or2. This would allow other vehicle payloads to be longer longitudinally if required.

One minor shortcoming of this design is that in this approach the pivot and the support structure for the pivot are in the field of view of the antenna aperture, 4" in from the outer diameter. To the extent that these components are made of non metallic materials they will have minimum impact on the antennas, and then only at the very high end of the frequency band.



ANTENNA CONCEPT NO. 3
JULY 6,1990
REV A

4.0 DUAL CHANNEL RECEIVER

DUAL CHANNEL RECEIVER

4.1 BASIS OF DESIGN

THE DUAL RECEIVER/LO GENERATOR TOPOLOGY AND FUNCTIONAL CONFIGURATION (REF FIG 4-1) HAS BEEN DERIVED FROM A DESIGN WHICH IS CURRENTLY IN PRODUCTION AT AIL FOR THE ALQ-161 PROGRAM, WITH MORE THAN 100 SYSTEMS PRODUCED TO DATE. THIS UNIT, THE BAND 1-3 RECEIVER, WAS ITSELF DERIVED FROM AN EARLIER DESIGN INTENDED FOR A SPACE BORN APPLICATION.

THE RECEIVER, WHOSE FUNCTIONAL CHARACTERISTICS ARE GIVEN IN SECTION 4.3, IS A FOUR CONVERSION RECEIVER COVERING A FREQUENCY RANGE FROM 100 TO 500 MHZ. THE OUTPUTS FROM THE RF SECTION ARE IF SIGNALS WITH A 100 KHZ BANDWIDTH AT A 2 MHZ CENTER FREQUENCY.

THE PRIMARY MODIFICATIONS TO THE BAND 1-3 ARCHITECTURE REQUIRED TO IMPLEMENT THE CURRENT REQUIREMENTS IS TO: (A) ELIMINATE THE LOG/DISCRIMINATOR DETECTION FUNCTIONS FROM THE RF SECTION, (B) ADDING A FORTH CONVERSION TO ACCOMODATE THE PROPOSED DETECTION SCHEME, AND (C) IMPLEMENTING THE FINE FREQUENCY STEPPING IN THE SECOND CONVERSION. IN ADDITION, BY SUBSTITUTING CERTAIN COMPONENTS WITH LOWER POWER, HIGHER EFFICIENCY TYPES, THE SYSTEM WOULD BENEFIT IN REDUCTIONS IN SIZE/WEIGHT/POWER FROM THE EXISTING PRODUCTION HARDWARE.

4.2 FUNCTIONAL DESCRIPTION

THE RECEIVER/LO GENERATOR SECTION IS HOUSED IN FOUR DOUBLE SIDED ASSEMBLYS, ONE DUAL RECEIVER CHAIN, ONE DUAL REFERENCE GENERATOR UNIT (MAIN & REDUNDANT), ONE DUAL SYNTHESIZER UNIT (MAIN & REDUNDANT), AND ONE DUAL POWER CONDITIONER (MAIN & REDUNDANT). FIGURES 4-2,4-3,4-4 AND 4-5 SHOW THE FUNCTIONAL BLOCK DIAGRAM OF THESE UNITS (EXCEPT FOR POWER COND.) AND FIGURE 4-6 SHOWS THE OUTLINE DIMENSIONS FOR THE OVERALL SECTION, WITH REPRESENTATIVE INTERFACE AND MOUNTING APPROACHES. FIG 4-7 SHOWS THE INTERNAL STRUCTURE OF A TYPICAL DUAL SIDED ASSEMBLY (OR "SLICE") INTENDED FOR SPACE APPLICATION.

A FOUR CONVERSION SUPERHETERODYNE RECEIVER APPROACH HAS BEEN SELECTED TO MAXIMIZE SPURIOUS REJECTION AND PROVIDE THE REQUIRED FREQUENCY COVERAGE AND SELECTIVITY AS WELL AS SUFFICIENT SENSITIVITY TO MEET OVERALL MISSION OBJECTIVES. SYNTHESIZED LO SIGNAL GENERATION IS CHOSEN TO PROVIDE THE SPECTRAL PURITY AND COHERENCY REQUIRED BY SYSTEM PERFORMANCE OBJECTIVES.

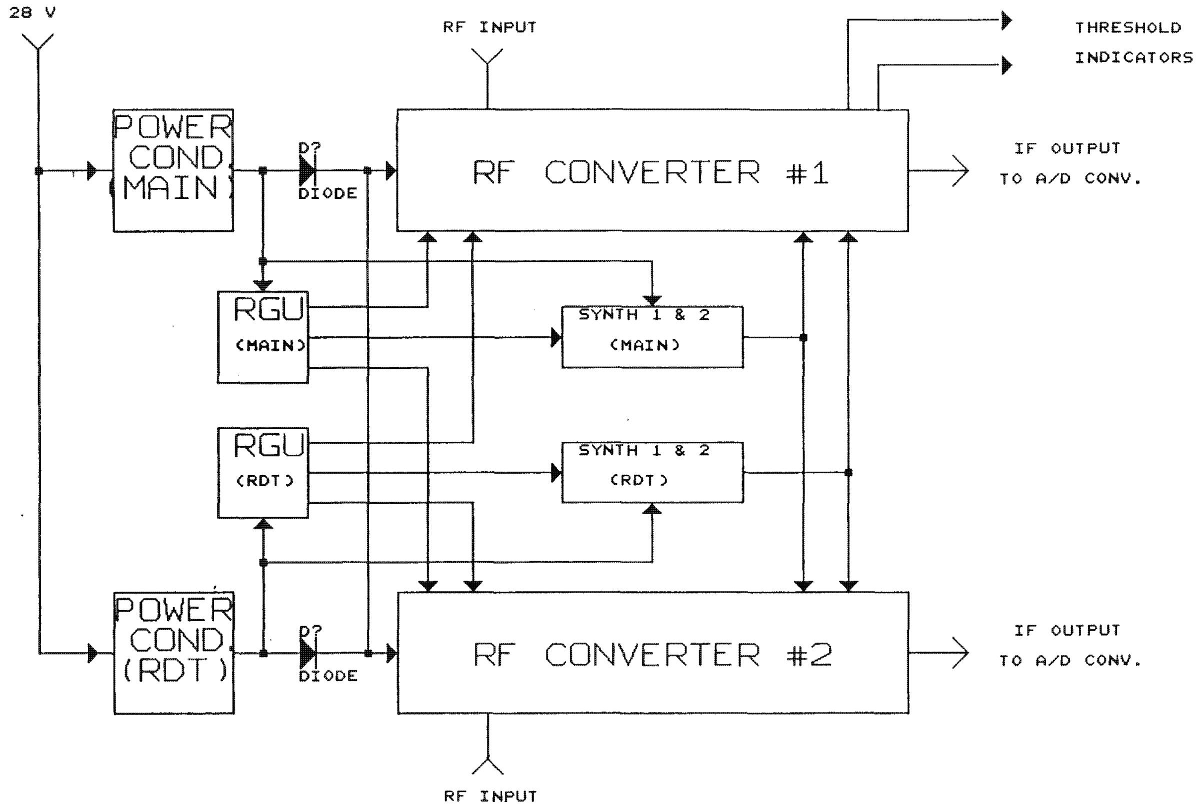


FIGURE 4-1
SYSTEM FUNCTIONAL BLOCK DIAGRAM

4.2.1 RECEIVER OPERATION

THE RECEIVER'S PERFORMANCE WAS ANALYZED USING A COMPUTER PROGRAM WHERE BY ENTERING EACH COMPONENTS RF PARAMETERS (I.E. GAIN, NF, K FACTOR), THE PROGRAM WILL SIMULATE THE OVERALL SYSTEM PERFORMANCE. THE OUTPUT OF THIS PROGRAM IS SHOWN IN TABLE 4-1.

THE RECEIVER CHAIN FUNCTIONAL BLOCK DIAGRAM IS SHOWN IN FIGURE 4-2, AND WILL BE USED TO DESCRIBE THE RF TO IF SIGNAL FLOW AND CONDITIONING.

THE FRONT-END OF THE RF CONVERTER CONTAINS A BANDPASS FILTER, FL1, WHICH PRIVIDES SPURIOUS REJECTION PRIOR TO AMPLIFICATION AND UPCONVERTING. AMPLIFIERS AR1 AND AR2 PROVIDE SIGNAL GAIN AND ARE THE PRIMARY FACTOR IN SETTING OVERALL RECEIVER NOISE FIGURE. AMPLIFIERS IN THIS FREQUENCY RANGE ARE AVAILABLE AS EITHER PURCHASED ITEMS TO MIL 883 LEVEL B OR CURRENTLY PRODUCED "IN-HOUSE" UNITS QUALIFIED TO LEVEL S FOR MAJOR SPACE BORN SYSTEMS. WITH AMPLIFIER NOISE FIGURES IN THE RANGE OF 2 TO 3 DB, AN OVERALL SYSTEM NOISE FIOGURE OF LESS THAN 5 DB IS READILY ACHIEVABLE. THE FINAL CHOICE OF AMPLIFIERS WILL BE BASED ON SYSTEM SENSITIVITY REQUIREMENTS VS SIZE/WEIGHT/POWER TRADE-OFFS.

FOLLOWING THE AMPLIFIERS, THE INPUT SIGNAL IS UPCONVERTED TO 1900 MHZ WITH AN IF BANDWIDTH OF 40 MHZ ,NOMINALLY. THIS PROVIDES BANDPASS ISOLATION BETWEEN SIGNALS AND LO'S, YET IS SUFFICIENTLY WIDE SUCH THAT ITS CONTRIBUTION TO BASEBAND FLATNESS IS NEGLIGIBLE. THE LO FOR THIS CONVERSION IS THE SYNTHERSIZER #1, COVERING A RANGE OF 2000 TO 2400 MHZ, IN 2 MHZ STEPS.

THE FIRST IF SECTION PROVIDES FILTERING AND AMPLIFICATION PRIOR TO THE SECOND CONVERSION WHICH IS A DOWNCONVERSION TO 498 MHZ. THE LO FOR THIS CONVERSION IS ACCOMPLISHED VIA A SECOND SYNTHESIZER, COVERING A RANGE OF 2397 TO 2399 MHZ, IN 50 KHZ STEPS.

THE SECOND IF SECTION, WHICH IS 10 MHZ WIDE, PROVIDES FILTERING AND AMPLIFICATION PRIOR TO A DOWNCONVERSION TO 22 MHZ. THE FILTER, WHICH WILL BE IMPLEMENTED USING A SURFACE ACOUSTIC WAVE (SAW) DEVICE, IN THIS SECTION PROVIDES BANDPASS ISOLATION BETWEEN SIGNALS AND LO'S, AND SPURIOUS REJECTION OF THE 2X2 MIXER PRODUCT. THE LO FOR THIS CONVERSION IS ACCOMPLISHED VIA A FIXED REFERENCE LO AT 520 MHZ.

TWO TONE TEST POWER LEVELS ARE –54 dBm AND –54 dBm

COMPONENT		STAGE NF	CUM NF	STAGE GAIN	CUM GAIN	KFT	IM/SIG RATIO
CAB	XXX	1.0	1.000	-1.0	-1.0		
BPF	FL1	0.8	1.800	-0.8	-1.8		
AMP	AR1	2.8	4.600	23.3	21.5	-26.0	-91.0
AMP	AR2	3.5	4.613	13.0	34.5	-48.0	-87.0
CPL	HY1	1.0	4.613	-1.0	33.5		
PAD	AT1	6.0	4.615	-6.0	27.5		
MIX	M1	8.0	4.629	-8.0	19.5	-24.0	-77.0
PAD	AT2	4.0	4.655	-4.0	15.5		
BPF	FL2	1.0	4.666	-1.0	14.5		
AMP	AR3	6.7	4.855	11.5	26.0	-42.0	-98.0
MIX	M2	8.0	4.874	-8.0	18.0	-24.0	-80.0
PAD	AT3	2.0	4.887	-2.0	16.0		
BPF	FL3	1.0	4.896	-1.0	15.0		
AMP	AR4	3.5	4.951	13.0	28.0	-48.0	-100.0
MIX	M3	8.0	4.963	-8.0	20.0	-24.0	-76.0
PAD	AT5	0.0	4.963	0.0	20.0		
BPF	FL4	1.0	4.966	-1.0	19.0		
AMP	AR5	3.5	4.988	13.0	32.0	-48.0	-92.0
MIX	M4	8.0	4.992	-8.0	24.0	-24.0	-68.0
BPF	FL5	1.0	4.994	-1.0	23.0		
AMP	AR6	3.5	5.002	13.0	36.0	-48.0	-84.0

IM/SIG COHERENT SUM	-60.16 dB
IM LEVEL	-114.16 dBm
NOISE FIGURE	+ 5.00
NUMBER OF ELEMENTS	21

TABLE 4-1

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY

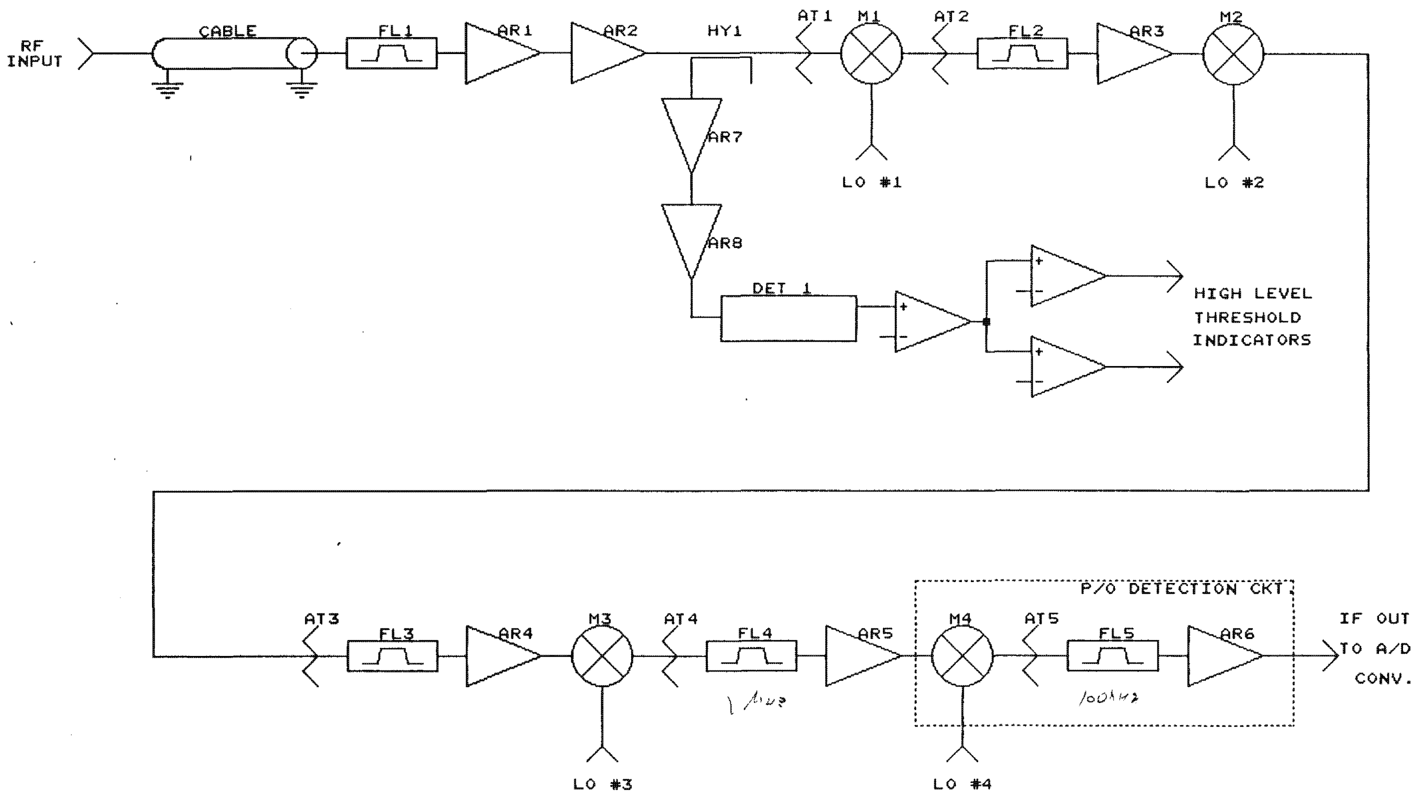


FIGURE 4-2
BLOCK DIAGRAM - RF CONVERTER

THE THIRD IF SECTION, WHICH IS 1 MHZ WIDE, FILTERS,AMPLIFIES AND MIXES THE THIRD IF WITH A FIXED 20 MHZ REFERENCE TO DERIVE THE FINAL BASEBAND FREQUENCY OF 2 MHZ. THE FINAL IF BANDWIDTH OF 100 KHZ IS SET BY FL5, WHICH WILL BE IMPLEMENTED USING A CRYSTAL FILTER. FOLLOWING THE FILTER, AMPLIFIER AR6 PROVIDES GAIN TO THE IF SIGNAL TO SET THE OUTPUT LEVEL TO THE DETECTION CIRCUITRY WHICH FOLLOWS THE RECEIVER.

IN ORDER TO DETECT THE PRESENCE OF UNWANTED SIGNALS, THE RECEIVER WILL INCLUDE A DETECTION PATH WHICH IS COUPLED OFF THE CONDUCTION PATH PRIOR TO THE FIRST CONVERSION. THIS DETECTION PATH, WHICH INCLUDES TWO RF AMPLIFIERS, ONE DETECTOR AND THREE VIDIO AMPLIFIERS, WILL GENERATE INFORMATION TO THE SYSTEM REGARDING THE INCOMING SIGNAL STRENGTH. THIS INFORMATION, WHICH IS PROCESSED BY THE CPU WILL USED TO CONFIGURE THE RECEIVER TO THE APPROPRIATE SETTINGS.

4.2.1.1 DESIGN IMPLEMENTATION

THE RF CONVERTER SHALL BE IMPLEMENTED USING A NUMBER OF CURRENTLY PRODUCED "IN-HOUSE" ASSEMBLIES QUALIFIED TO LEVEL S FOR MAJOR SPACE BORN SYSTEMS. MANY OF THESE ASSEMBLIES HAVE BEEN PRODUCED IN QUANTITIES GREATER THAN 200 UNITS USED ON ALQ-161 PROGRAM (B1-B), AND ARE NOW CONSIDERED EASILY MANUFACTURABLE AND LOW RISK. IN PARTICULAR, THE SURFACE ACOUSTIC WAVE DEVICES (SAW), AIL IS ONE OF THE PIONEERS IN SAW FILTER DEVELOPMENT AND HAS PRODUCED OVER 3000 UNITS FOR THE B1-B PROGRAM ALONE.

CERTAIN COMPONENTS SUCH AS AMPLIFIERS,MIXERS AND COUPLERS, WHICH BY THEIR NATURE MUST BE CUSTOMIZED APPLICATION SPECIFIC DEVICES TO ACHIEVE PERFORMANCE, ARE READILY AVAILABLE FROM VARIOUS VENDORS WITH WHOM AIL HAS HAD EXPERIENCE, TO EITHER MILITARY OR HIGH RELIABILITY REQUIREMENTS. IN ADDITION TO PERFORMANCE AND RELIABILITY, THESE PARTICULAR VENDORS CAN PRODUCE PRODUCTS MORE COST EFFECTIVELY THAN AIL, RESULTING IN A LOWER OVERALL SYSTEM COST CONSISTANT WITH THE PROPOSED BUDGET.

4.2.2 LO GENERATION SECTION

THE LO GENERATION SCHEME, WHOSE FUNCTIONAL BLOCK DIAGRAM IS SHOWN IN FIGURE 4-3,4.4, AND 4.5, IS COMPOSED OF TWO SYNTHESIZERS AND ONE REFERENCE GENERATOR. THE SYNTHESIZERS PROVIDE THE FIRST (COURSE STEP) AND SECOND (FINE STEP) LO'S TO THE RECEIVER CHAINS, AND THE REFERENCE GENERATOR PROVIDES THE REQUIRED COMBLINE AND REFERENCE LINES TO THE SYNTHESIZERS. BOTH THE SYNTHESIZER AND REFERENCE GENERATOR PROPOSED DESIGNS ARE DIRECT OUT-GROWTHS OF THE BAND 1-3 RECEIVER TOPOLOGY, CONCEPT, DESIGN AND PRODUCTION HARDWARE.

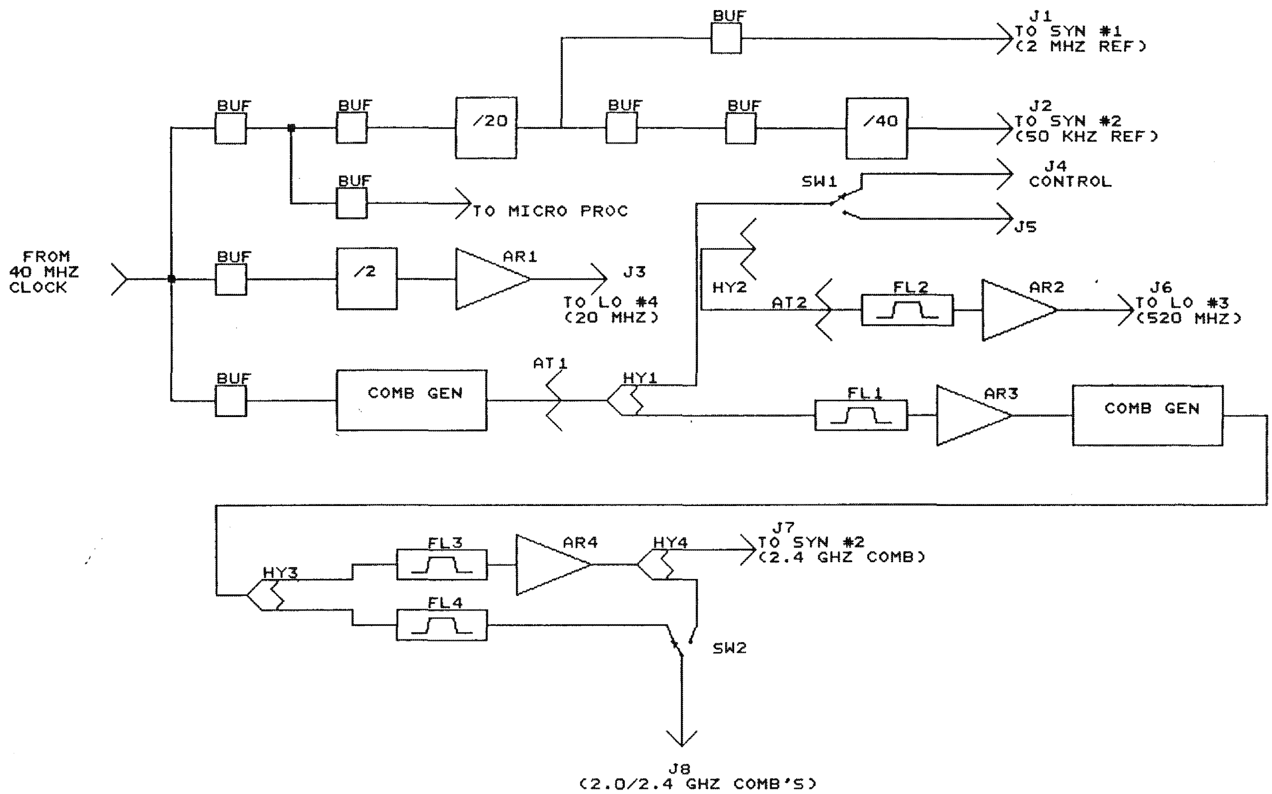
2.2.2.1 REFERENCE GENERATOR

ALL REQUIRED FREQUENCIES ARE DERIVED COHERENTLY FROM AN EXTERNAL 40 MHZ REFERENCE WHOSE STABILITY AND SPECTRAL PURITY PERFORMANCE IS COMMENSURATE WITH SYSTEM ACCURACY, NOISE, AND SENSITIVITY REQUIREMENTS. THE 40 MHZ SIGNAL IS BUFFERED AND TAPPED OFF TO DIVIDE BY 20 CIRCUITRY TO GENERATE THE 2 MHZ REFERENCE FREQUENCY, AND THEN BUFFERED AND DIVIDED BY 40 TO GENERATE THE 50 KHZ REFERENCE FREQUENCY FOR THE SYNTHESIZERS.

THE 2.0/2.4 GHZ COMBLINES ARE GENERATED FROM THE 40 MHZ CRYSTAL OUTPUT VIA TWO STAGES OF MULTIPLICATION. THE FIRST SRD MULTIPLIER GENERATES A 40 MHZ COMBLINE OUT OF WHICH THE 400 MHZ COMB AND THE 520 MHZ LO (LO #3) IS SELECTED BY FILTERING. TWO STAGES OF FILTERING AND BUFFERING AMPLIFICATION ARE USED TO SUPPRESS THE UNWANTED COMBLINES. THE RESULTANT 400MHZ SIGNAL IS AMPLIFIED BY CLASS C AMPLIFIER (FOR HIGH EFFICIENCY) AND SRD MULTIPLIED TO CREATE A 400 MHZ COMBLINE. THE DESIRED 2.0 AND 2.4 GHZ LINES ARE THEN FILTERED, POWER SPLIT, AND SELECTED TO BE SENT TO EACH SYNTHESIZER.

THE FINAL LO (LO #4) IS GENERATED BY BUFFERING AND DIVIDING BY 2 THE 40 MHZ CRYSTAL OUTPUT.

ALL OF THE COMPONENTS REQUIRED FOR THE REFERENCE GENERATOR CHAIN ARE CURRENTLY AVAILABLE AS MILITARY QUALIFIED HARDWARE AND ARE IN PRODUCTION AT EITHER AIL OR OUTSIDE VENDORS FOR ONGOING PROGRAMS.



FIRURE 4-3
BLOCK DIAGRAM - RGU

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY

4.2.2.2 SYNTHESIZERS

TWO SYNTHESIZERS ARE PROPOSED TO GENERATE THE REQUIRED LO SIGNALS FOR THE RECEIVED SIGNAL PATH CONVERSIONS. THE FIRST, SYNTH. #1 PROVIDES LO #1 TO THE FIRST CONVERSION MIXER, AND TUNES THE INPUT RF BANTHWIDTH IN 2 MHZ STEPS. THE SECOND, SYNTH #2 PROVIDES LO #2 TO THE SECOND CONVERSION MIXER AND TUNES THE 2 MHZ IF BANTHWIDTH GENERATED BY THE FIRST CONVERSION IN 50 KHZ STEPS, TO INSURE THE CAPABILITY TO CAPTURE THE SIGNAL OF INTEREST'S ENTIRE BANDWIDTH WITHIN THE 100 KHZ BANDWIDTH OF THE RECEIVERS FINAL IF. BOTH OF THESE SYNTHESIZERS ARE PROPOSED AS SIMPLIFIED VERSIONS OF THE UNITS CURRENTLY IN PRODECTION AT AIL, AND WILL USE MANY OF THE MILITARY QUALIFIED HYBRIDS AND ASSEMBLIES EMPLOYED IN THE EXISTING SYNTHESIZER.

AS SHOWN IN THE BLOCK DIAGRAM OF FIGURE 2.3 AND 2.4, BOTH SYNTHRSIZERS ARE CONCEPTUALLY THE SAME. THE LO SIGNAL IS GENERATED BY AN S-BAND, VCO FOR SYNTH #1 OR DRO FOR SYNTH #2, AMPLIFIED TO THE DESIRED LEVEL, AND POWER SPLIT TO PROVIDE BOTH THE RECEIVER LO SIGNALS AND A COUPLED SIGNAL TO THE PHASE LOCK LOOP CIRCUITRY. THE COUPLED SIGNAL IS MIXED WITH THE 2.0 OR 2.4 GHZ COMBLINE SELECTED FROM THE REFERENCE GENERATOR TO GENERATE AN IF SIGNAL OF 200 TO 400 MHZ FOR SYNTH #1, OR IS MIXED WITH THE FIXED 2.4 GHZ REFERENCE GENERATOR OUTPUT TO GENERATE A 1 TO 3 MHZ IF SIGNAL FOR SYNTH #2. THE IF SIGNALS ARE THEN DIGITALLY FREQUENCY DIVIDED BY PROGRAMMABLE DIVIDERS (THE DIVIDE-BY NUMBER BEING CONTROLLED BY THE 9-BIT PARALLEL TUNING WORD) BY EITHER 100 TO 200 TO PRODUCE A 2 MHZ SIGNAL (SYNTH #1), OR BY 20 TO 60 TO PRODUCE A 50 KHZ SIGNAL (SYNTH #2). THESE SIGNALS ARE DIGITALLY PHASE LOCKED TO THEIR RESPECTIVE 2 MHZ OR 50 KHZ REFERENCE SIGNALS, WITH THE RESULTANT ERROR SIGNAL BEING CONDITIONED BY THE LOOP FILTERS AND TUNING DRIVERS TO PROVIDE THE REQUIRED TUNING VOLTAGE TO THE VCO'S. AS SHOWN IN THE BLOCK DIAGRAM, SYNTH #1 ALSO REQUIRES COARSE PRETUNING OF THE VCO AND LOOP GAIN ADJUSTMENT DUE TO ITS WIDER TUNING RANGE.

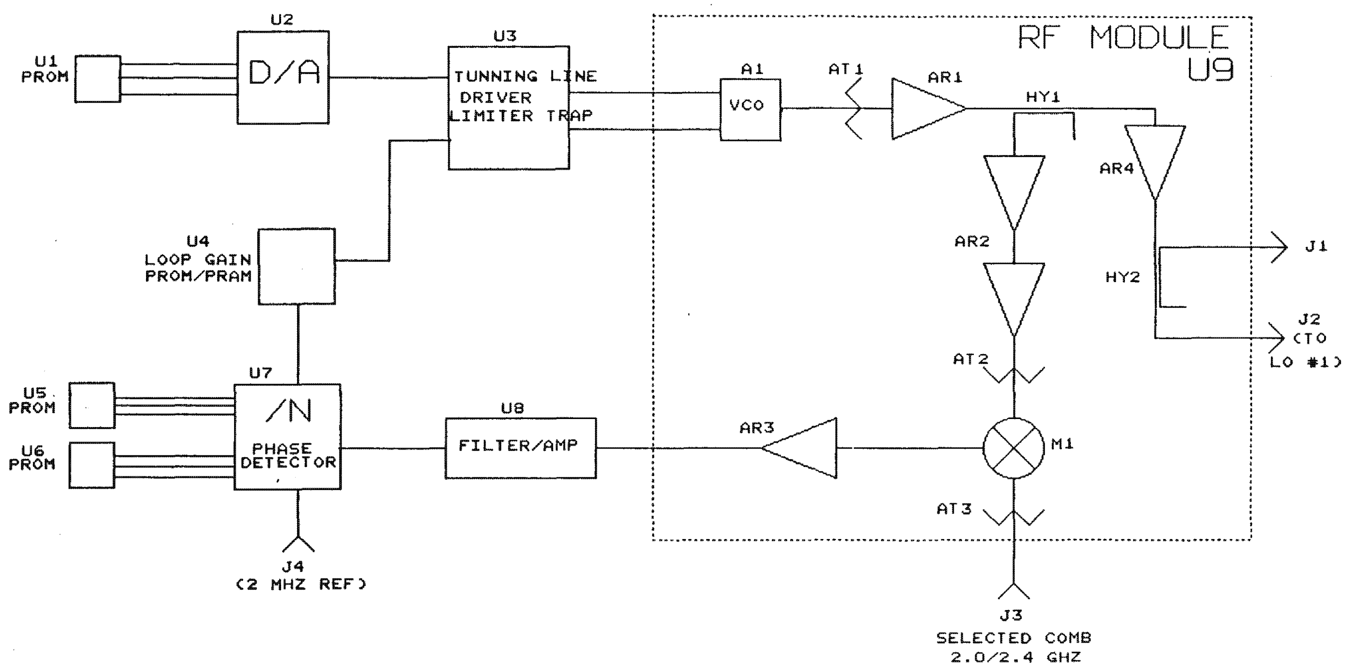


FIGURE 4-4
BLOCK DIAGRAM - SYNTHESIZER #1

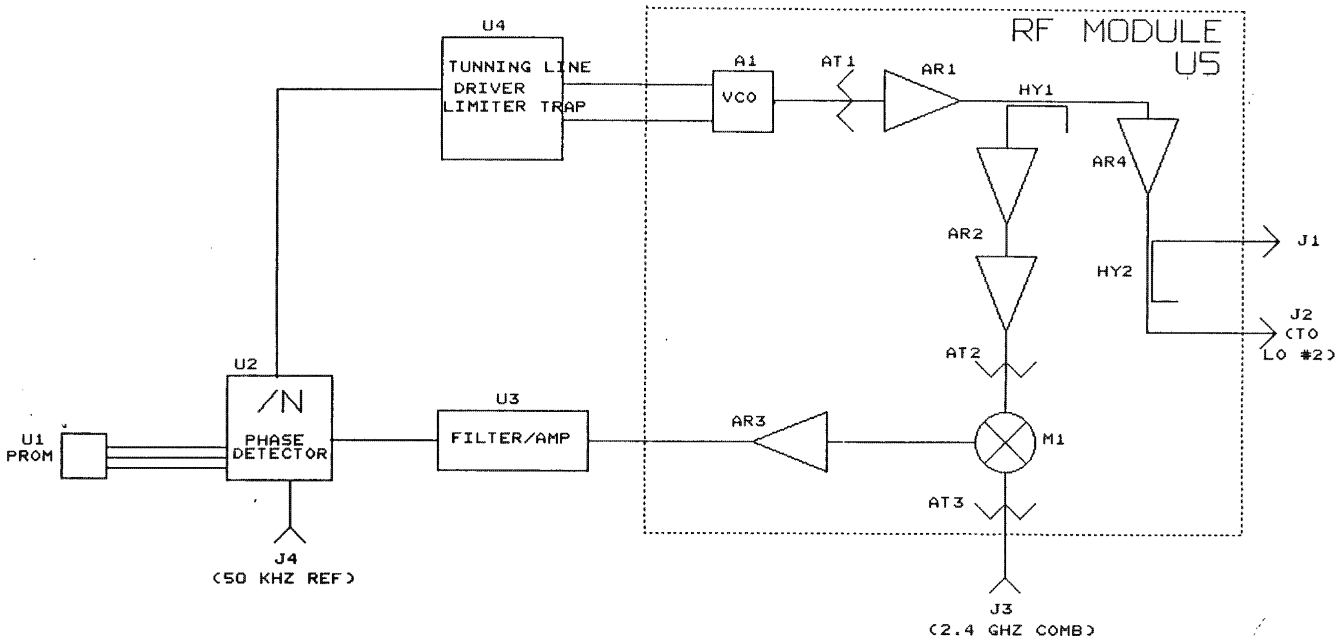


FIGURE 4-5
BLOCK DIAGRAM - SYNTHESIZER #2

FIGURE 4-6 DUAL CHANNEL RECEIVER OUTLINE

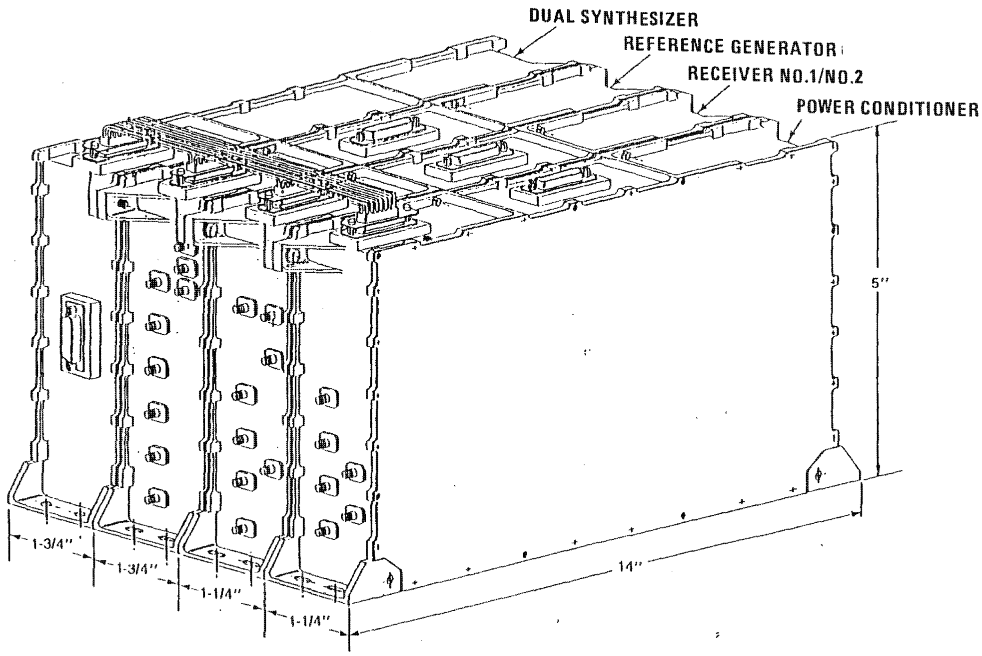
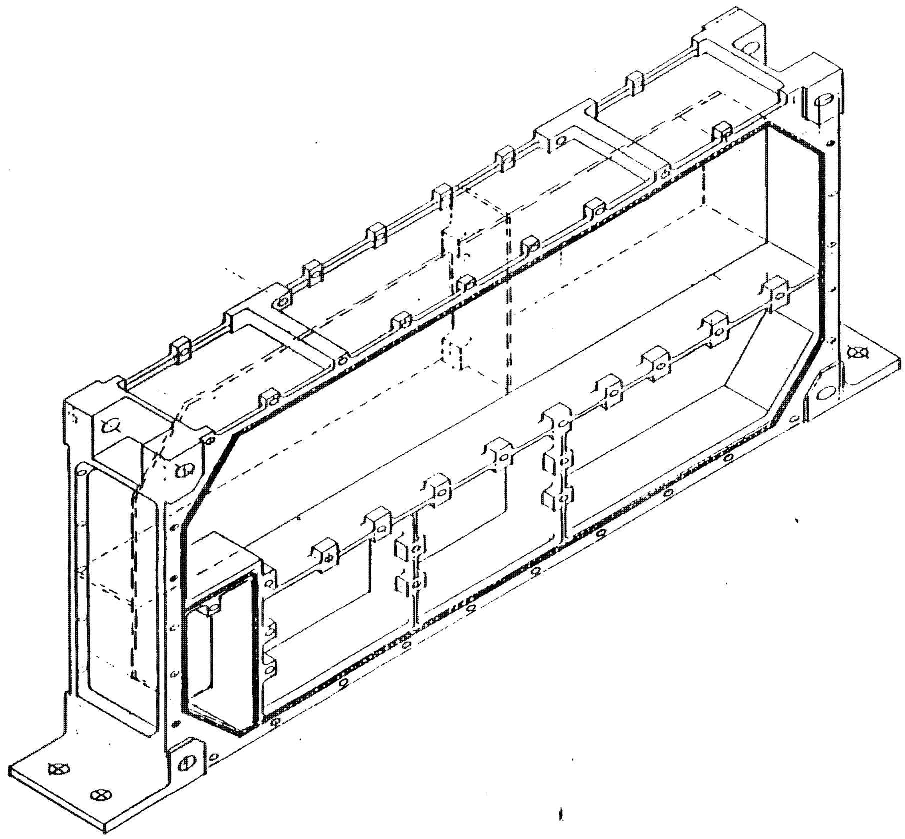


FIGURE 4-7 TYPICAL DUAL-SIDED CHASSIS LAYOUT



RECEIVER PERFORMANCE

PARAMETER	PERFORMANCE
FREQUENCY	100 TO 500 MHZ
IF BANDWIDTH	100 KHZ
NOMINAL GAIN	+ 36 DB
NOISE FIGURE	5 DB
LINEAR DYNAMIC RANGE	70 DB
SPUR FREE DYNAMIC RANGE	50 DB
LO STEP SIZE	50 KHZ
LO SETTLING TIME	2 MS
GAIN COMPRESSION @ INPUT POWER	1 DB @ -34 DBM
THIRD ORDER INTERCEPT POINT	+ 12 DBM
WEIGHT	25 # MAX
DC POWER	40 WATTS MAX

POWER CONDITIONER

The Power Conditioner generates the Payload required DC regulated voltages from the Spacecraft primary + 28 Volt$_{dc}$ Buss. Each Power Conditioner will be contained in it's own shielded, filtered slice. Referring to the Power Conditioner block diagram, all input and output lines to and from the Power Conditioner will pass through wall mounted feedthrough EMI filters which provide high frequency attenuation of conducted susceptibility and emissions. The input buss may be fused, if desired, before passing through these filters, with high reliability sub-miniature fuses.

The circuit topology is that of a pulse-width modulated, push-pull. DC-DC convertor, whose transformer secondary windings are sized to provide the desired DC output voltages, when rectified and filtered. The most critical DC output, in terms of regulation is sensed by an error amplifier and fed back, via an opto-isolator to the pulse-width modulator to achieve the desired regulation.

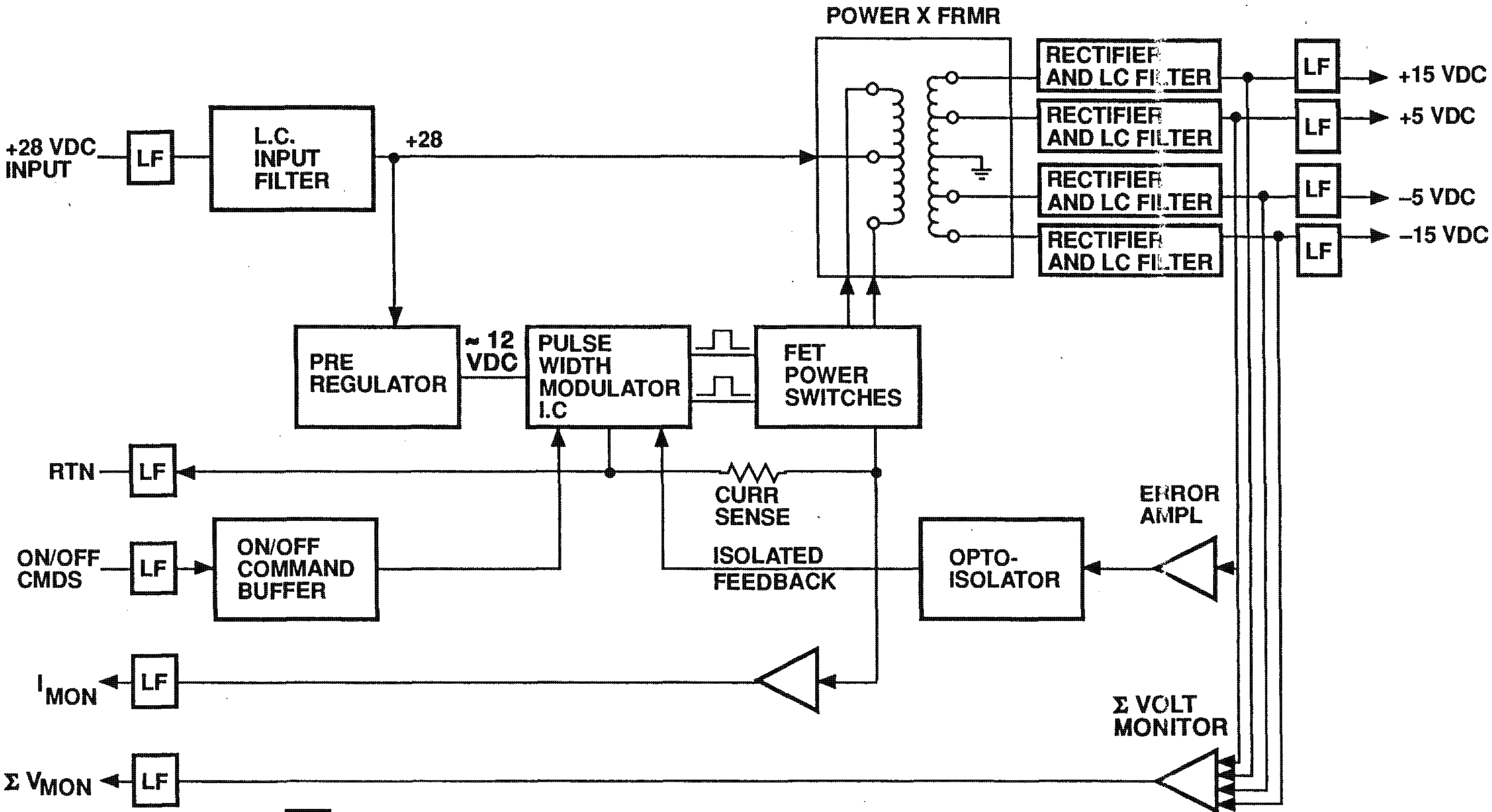
The switching frequency is chosen to achieve the optimum compromise between minimum transformer and filter component sizes and highest circuit efficiency, and will be in the 30 KHZ to 50 KHZ range.

The Power Conditioner is capable of being commanded ON/OFF via a low level pulse, TTL or suitable signal. In the OFF state only a low (< 20ma) standby current is drawn from the input buss.

In addition, health status circuitry such as the input current and summed output voltage monitors, will be provided as shown in the block diagram.

All the circuitry described abov has been built and successfully operated in several spaceborne systems with similar environmental and operational requirements.

TYPICAL POWER CONDITIONER BLOCK DIAGRAM



LF = FEEDTHRU LINE FILTER

HANDLE VIA BYEMAN CONTROL SYSTEM ONLY

POWER CONDITIONER

- INPUT BUSS : +28 V DC +/- 4 V
- CW CONDUCTED SUSCEPTIBILITY PER MIL-STD-461 NOTICES
- ASSUMES CW RIPPLE CONTAINED WITHIN 24 V TO 32 V ENVELOPE
- LOADS ON BUSS

RECEIVER	38 WATTS
PROCESSOR	17 WATTS
	----
	65 WATTS

5.0 PROCESSOR-RECOGNIZER

5.0 PROCESSOR SECTION

The five processor functions are defined in the first chart. The primary processing functions are the interference determination, geolocation, and recognition. In order to understand the relationship of these functions, an operational overview will be interspersed with functional descriptions.

The initial processing determines the presence of interference. If the frequency channel(bandwidth) contains only one signal, or multiple signals where one is greatly above the power level of the other(s), the geolocation is measured and recognition performed. This is important since many of the expected intercepts will contain co-channel interference. This approach eliminates performing recognition on co-channel interference and possibly outputting an erroneous report. It also optimizes the report quantity. The two channel system is transformed to the frequency domain by 128 point FFT's after the data is digitized at a 250KSPS rate. A 2 x 2 matrix operation (or solving a quadratic equation) serves to provide data for interference determination. This function uses 4 sets of data spaced about 100ms apart to insure that false results are precluded. The same data is used to determine the principal phase. The full 30 sets of data taken during one spin are used to reconstruct the sine wave formed due the spin action on the incoming phase front from the desired signal.

The recognition process integrates a number of 1024 point FFT's to sample data over a 70 ms period. The output of the FFT is demodulated by an FM unit. Another FFT on the resultant baseband decides if there is signal at the tones and/or in the designated channels. Standard pattern criteria for recognition, used by NSA for years, will be implemented.

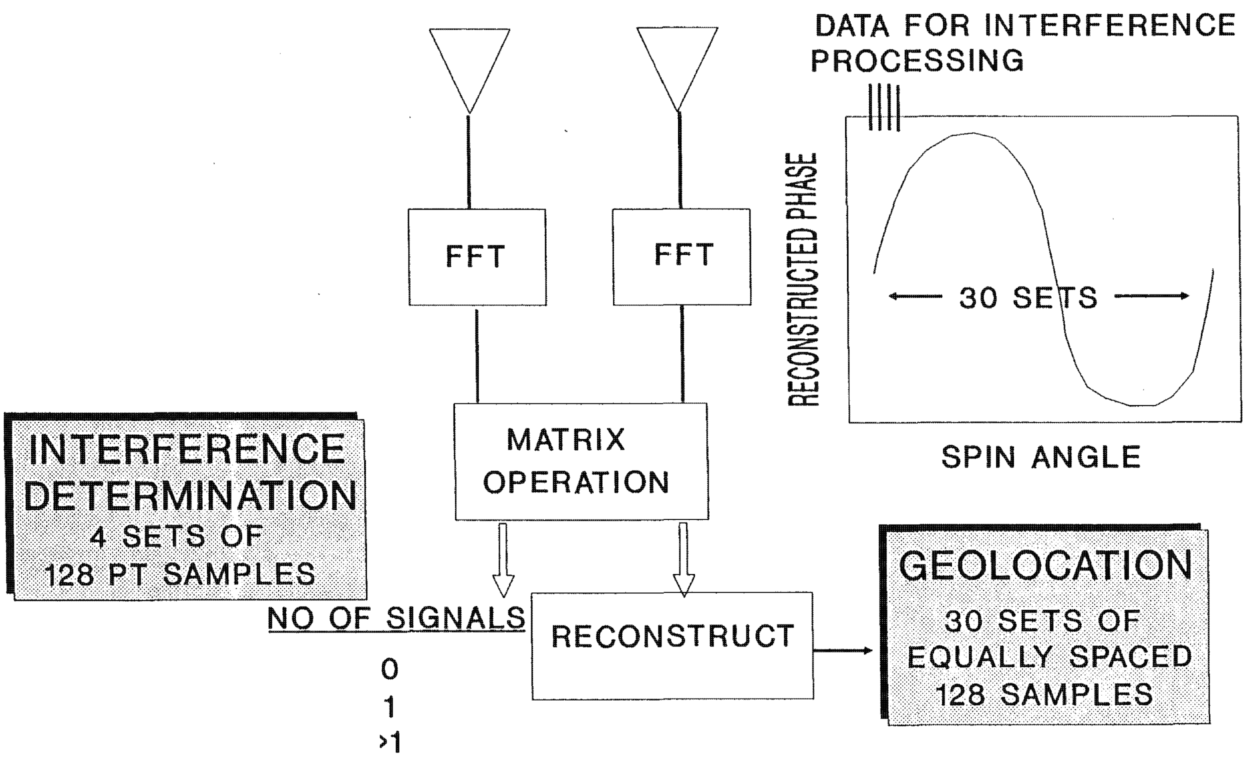
Since the interference determination finds clean data to perform recognition, it is appropriate to consider a scheme were other frequencies are examined for interference while a clean frequency is being processed. The Receiver Tuning chart illustrates this approach. While one, two, or three signals are being processed during a single spin, up to ten others from the preprogrammed coverage list are examined for interference. In this way, the list of channels to intercept are intelligently used to avoid collecting data when interference is a problem. In the Typical Timeline chart, this is shown. In the lowest portion of the chart, one full spin is shown with 30 geolocation samples for each of three signals is collected. Three long samples are taken for the recognition. In the first four frames, shown in the second line of picture, additional data is examined to determine co-channel interference. The receiver is rapidly frequency switched to achieve this concept, taking less than 2 ms to switch frequency after each 0.512 ms dwell to collect samples for the interference determination and geolocation processes.

Our processor concept uses a TI TMS320C30 chip to provide the computing power needed for these functions. As shown on the Processor Concept chart, it is supplemented by functions. The TI chip was selected for its overall performance margin as shown in the DSP Benchmarks. The specific processor design is shown in a chart entitled Digital Processor Block Diagram.

PROCESSOR FUNCTIONS

- INTERFERENCE DETERMINATION
  DERIVATIVE OF ASF ALGORITHMS
- GEOLOCATION
  RECONSTRUCTION OF SINE WAVE
- RECOGNITION
  STANDARD PATTERN MAPPING
- REPORTING
  TADIXS-B INTERCEPT REPORTS
  ACTIVITY REPORTS
  PRE-D SNAPSHOT
- SYSTEM CONTROLS
  CONFIGURATION, RCVR TUNING
  HOUSEKEEPING

PROCESSING FUNCTIONS



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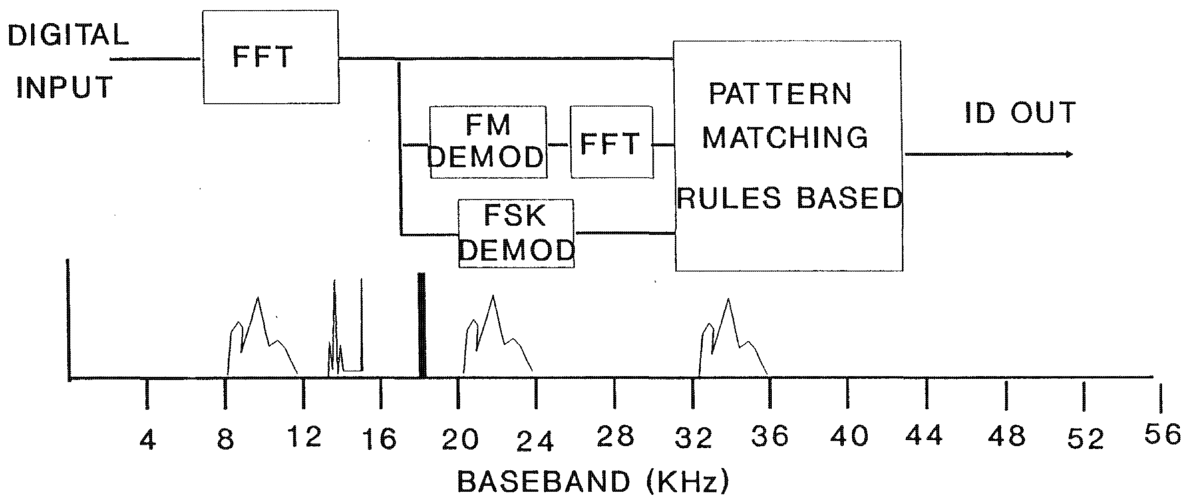
RECOGNITION FUNCTION



FM/FDM
RECOGNITION CRITERIA

TONE LOCATION
RF FREQUENCY
CHANNEL ACTIVITY

FSK RECOGNITION
CRITERIA

RF FREQUENCY
BAUD
MARK SPACE SEPARATION

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY

SECRET/[redacted]

RECEIVER TUNING

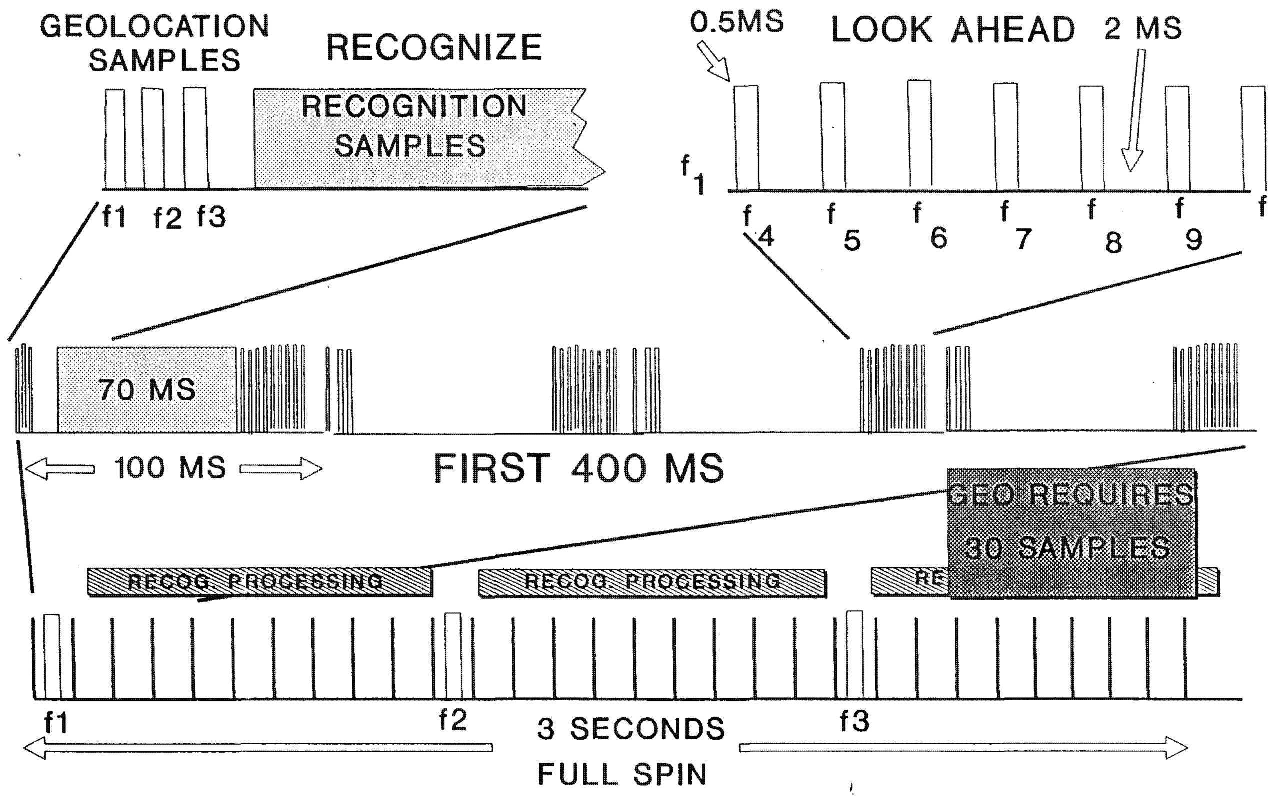
FREQ LIST	SPIN 1		SPIN 2		SPIN 3		SPIN 4		SPIN 5	
	COLLECT	LOOK AHD	COL	L A	COL	L A	COL	L A	COL	L A
120.2	X									
120.6		X								
121.0		X								
121.4		X	X							
121.8		X								
122.2		X								
122.6		X								
123.0		X	X							
123.4		X								
123.8		X	X							
124.2		X		X						
135.4				X	X					
130.8				X	X					
131.2				X						
140.0				X	X					
140.4				X						
140.8				X			X			
141.2				X			X			
141.6				X			X			
141.8								X		
142.2								X	X	
142.6								X		
143.0								X		
143.4								X		
143.8								X		
145.2								X		
145.6								X		
147.0								X		
147.4										X
147.8										X

SMART SCAN COVERS LARGER FREQ RANGE IN LESS TIME

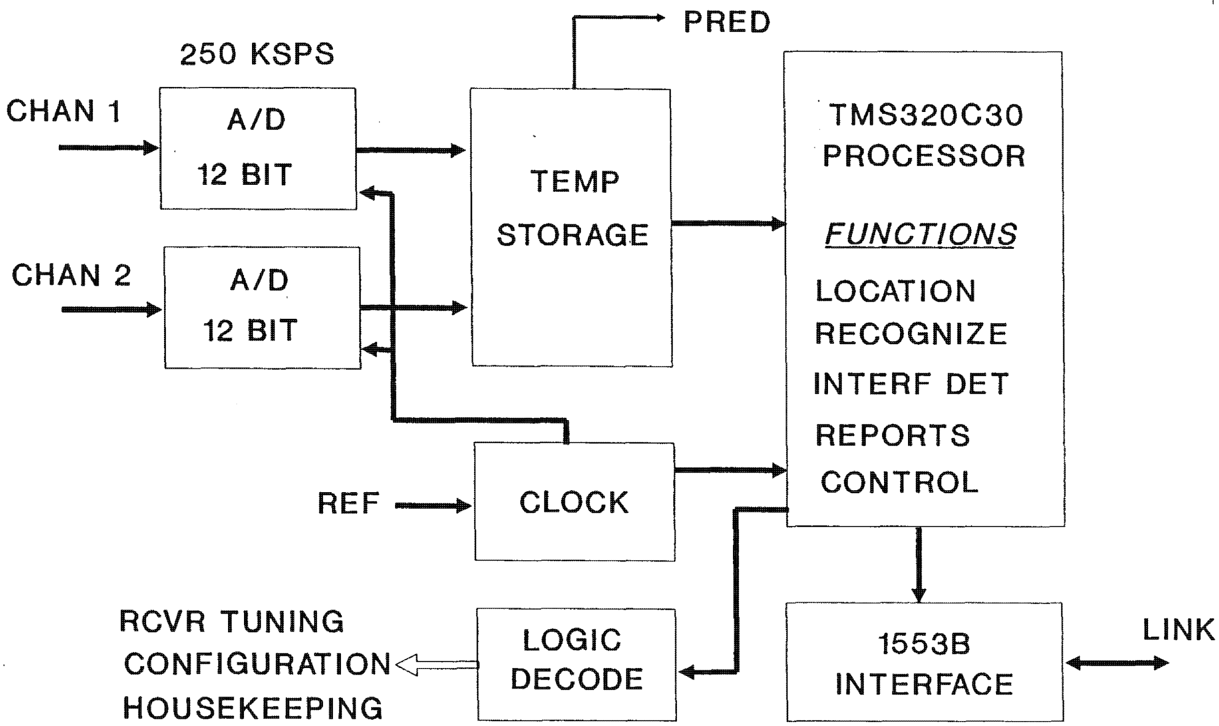
INTERFERENCE >70%

HANDLE VIA BYEMAN CONTROL SYSTEM ONLY

TYPICAL PROCESSOR TIMELINE
LOOK AHEAD FUNCTION



PROCESSOR CONCEPT



DSP BENCHMARKS

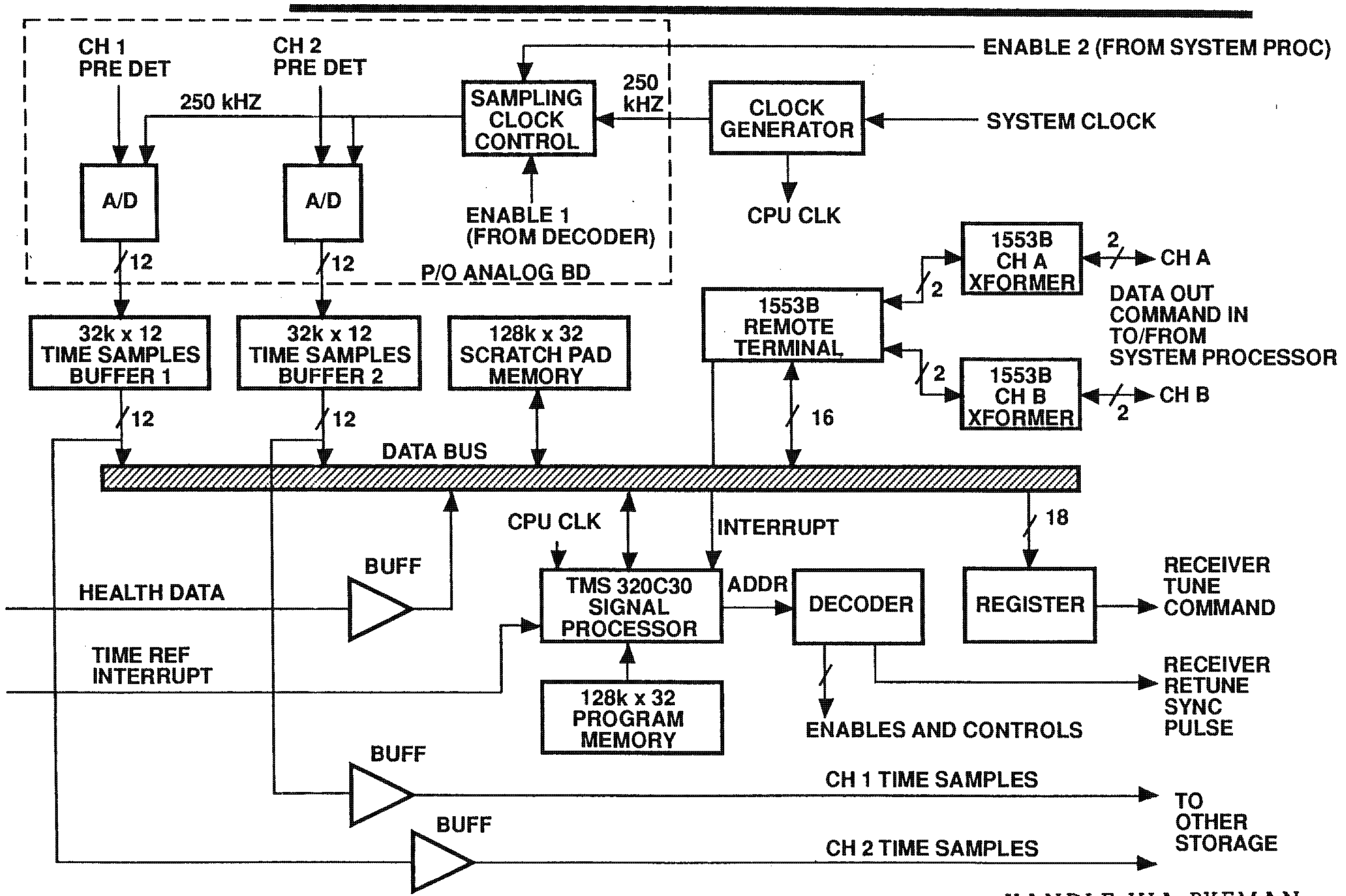
32 BIT FLOATING POINT

TYPE	TECH-NOLOGY	POWER DISS.	INSTR. CYCLE	1K COMPL FFT	FIR FILTER	AVAIL-ABILITY
ADI's ADSP21000	1 MICRON CMOS	2.5W	50 ns	1.3 ms	50 ns PER TAP	?
MOTOROLA'S DSP96002	1 MICRON CMOS	1.5W	60 ns	1.2 ms	60 ns PER TAP	SAMP PR. 3Q
AT & T's WEDSP32C	0.75 M CMOS	.75W	80 ns	2.8 ms	80 ns PER TAP	PROD
NEC's uPD77240	<1 M CMOS	1.5W	90 ns	7.5 ms	98.4 ns PER TAP	SAMP 3Q
TEXAS INST. TMS320C30-33	1.0 M CMOS	1.25 W	60 ns	2.36 ms	60 ns PER TAP	PROD

TI TMS320C30 CHIP BEST IN STANDALONE OPERATION

MIL SPEC VERSION AVAILABLE FOR THIS EFFORT

DIGITAL PROCESSOR BLOCK DIAGRAM



Software for the processor is defined in the Family tree, consisting of 6000 Lines of Code. In addition, charts are provided for the geolocation and Message Assembly functions. Geolocation is performed in the typical manner for a spinning interferometer with some mathematical short cuts to reduce processing without sacrifice of accuracy. Navigation and attitude is added to the raw geolocation number so that output reports are complete. The message assembly shows emitter reports to the TADIXS-B format, BITE reports, Activity history reports, and change reports. In addition to TADIXS-B reports, the raw phase data can be returned to CONUS, provided this option is commanded. THe report size is equal to the 256 bit TADIXS-B report length.

Option 1 called for the deletion of on board processing. This was modified to perform the interference determination on board and only send down data when one signal is present. Use of the interference determination results in just 27 Kilobytes per intercept. Given 300 intercepts per a 15 minute readin, a storage capacity of 5.1 Mbyte is needed. This implies about 6 readin periods if the on board storage was 32 MBytes. The following table defines storage requirements.

STORAGE REQUIREMENTS

On Board Processing

Tadixs-B Rpt 256 bits	=	32 Bytes	
30 sets phase data	=	30 Bytes	64 Bytes/Intercept
1000 Intercepts / orbit		64 KBytes	
12 Orbits / day		960 KBytes	1MByte Storage

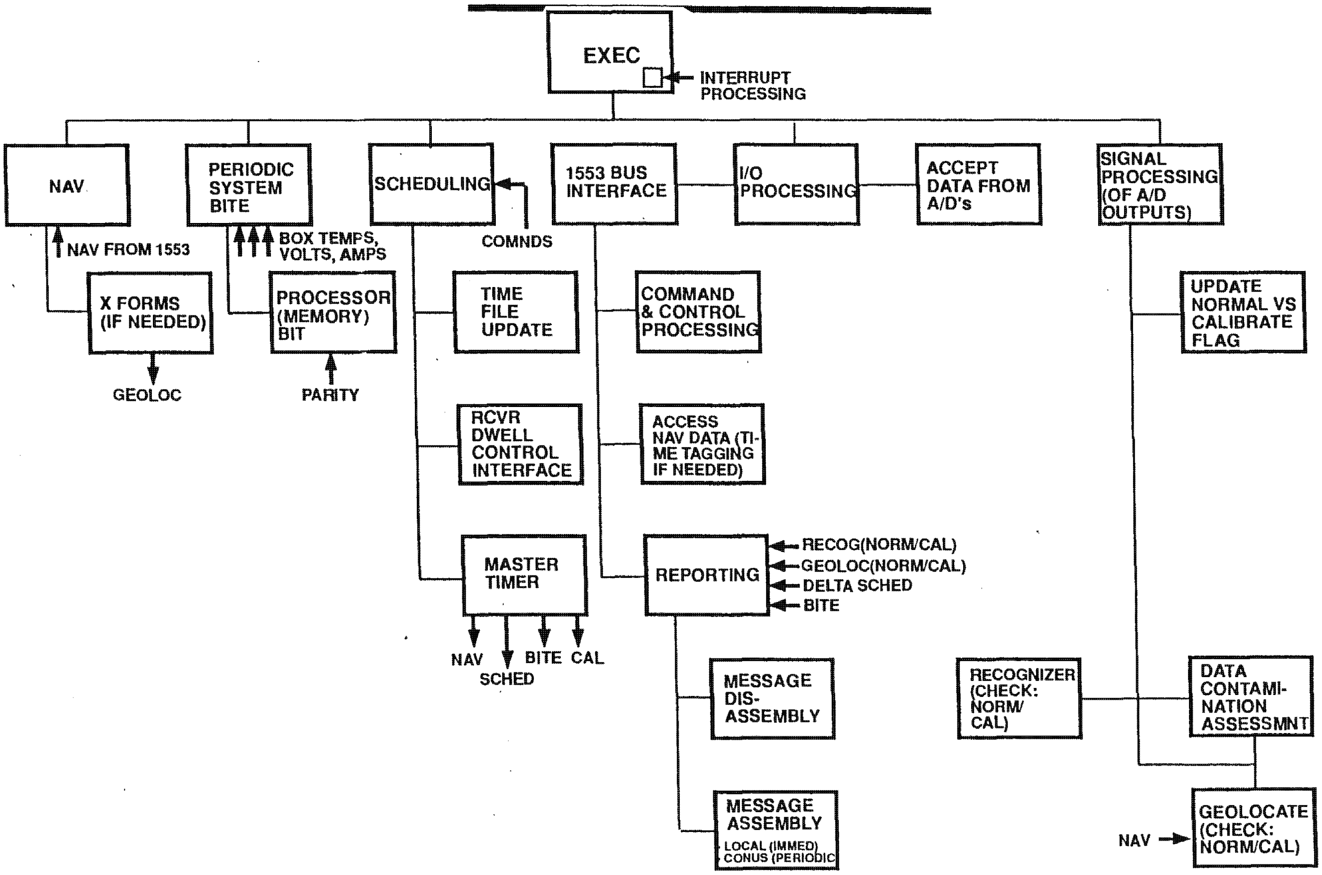
Ground Processing Only

30 sets phase data	=	30 Bytes	
Block of Pre-D 50 ms @ 4us Sample rate			18.75 KBytes
	12 bits resolution		
		Total Data set	= 19 KBytes
1000 intercepts / orbit			19 Mbytes

Practically, the average is 500 intercepts/orbit = 9.5MBytes

IF ADD 32 MBytes STORAGE,,COLLECT > 3 ORBITS

S/W FAMILY TREE



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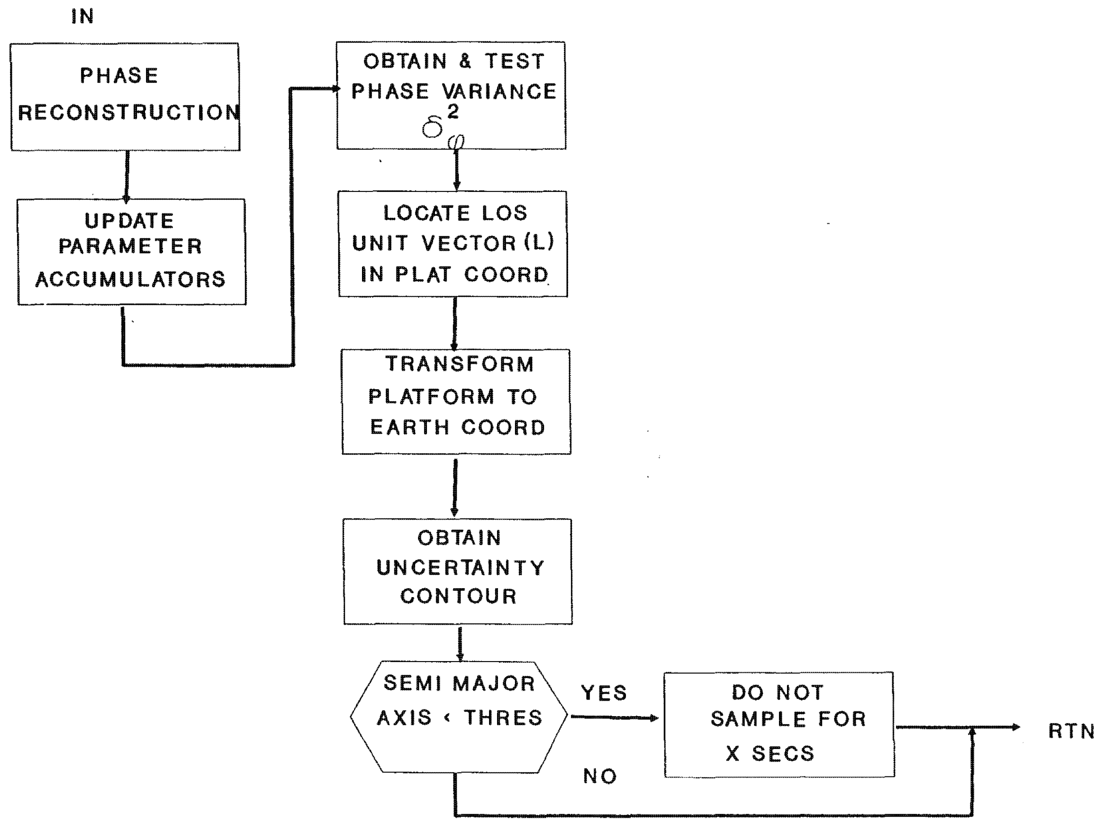
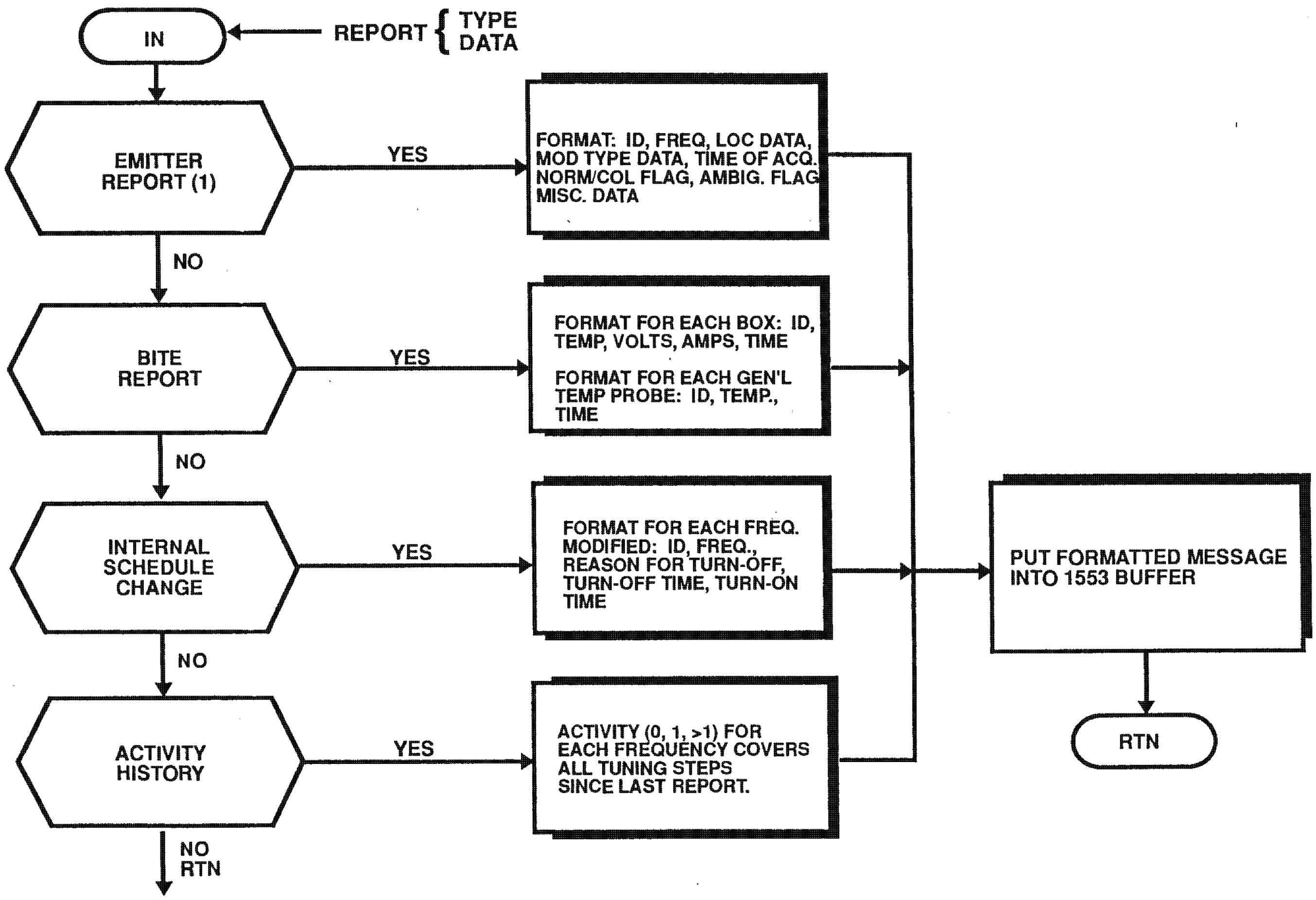
GEOLOCATION SOFTWARE

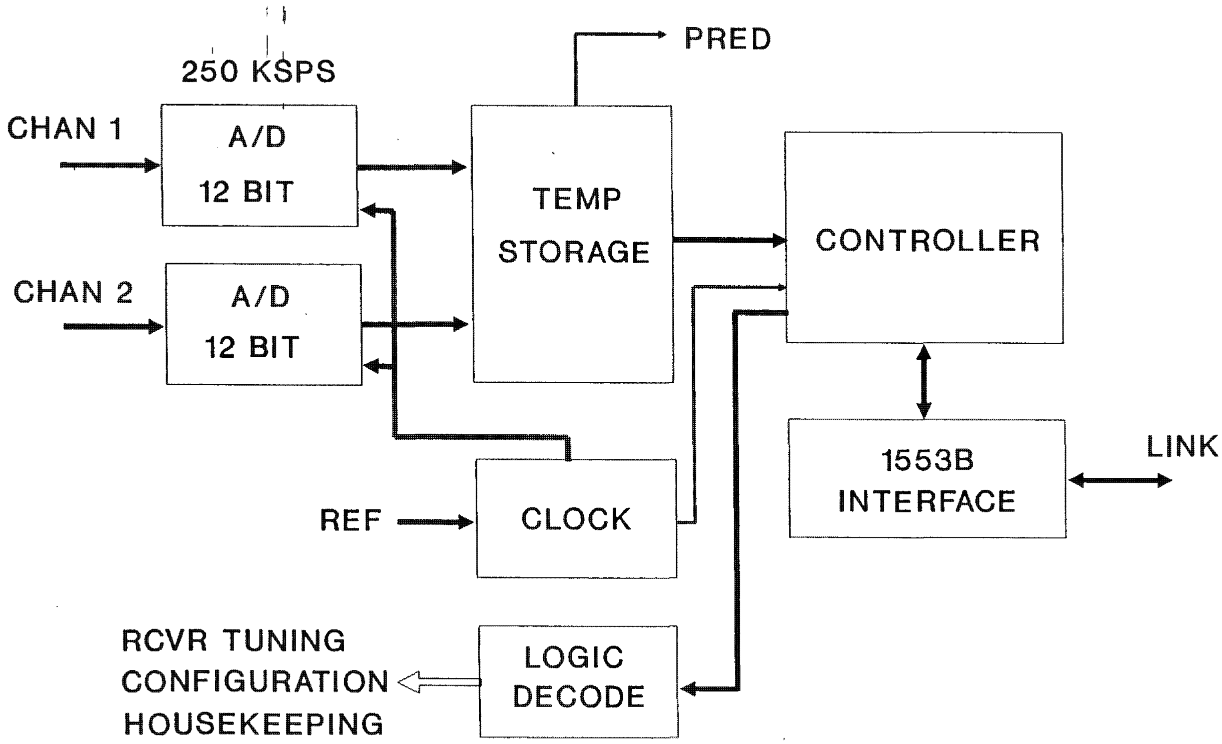


MESSAGE ASSEMBLY

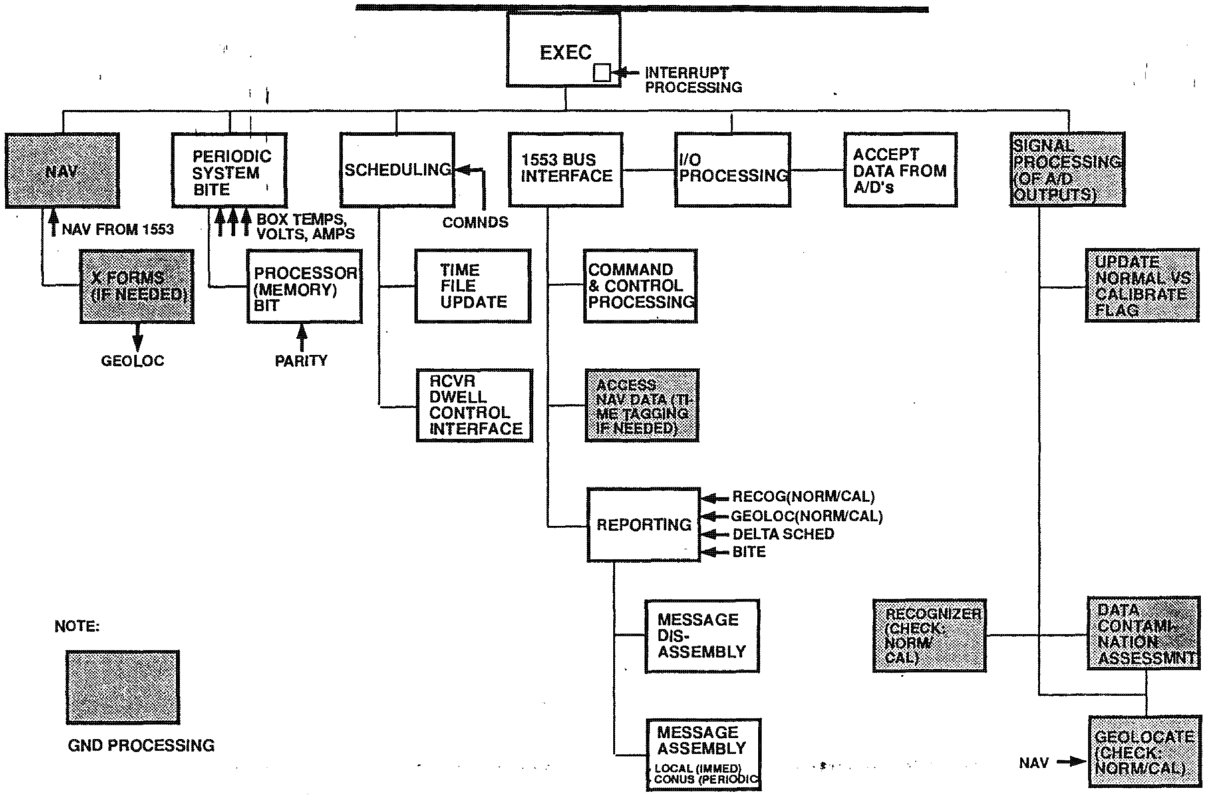


NOTE: (1) THIS MAY BE THE REPORT ON NORMALLY ACQUIRED EMITTER OR ON AN ACQUISITION OF A CALIBRATION EMITTER. THE LATTER WILL BE TAGGED AS A CALIBRATION REPORT.

PROCESSOR CONCEPT
OPTION 1



S/W FAMILY TREE *OPTION 1*



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DIGITIZER

The digitizing function is accomplished by two identical A/D Converter circuits, one for each channel. The analog inputs are digitized and stored in registers where they are read by the CPU which treats the registers as memory locations.

Each A/D Converter circuit consists of a signal conditioning circuit, a sample and hold circuit, an analog to digital converter circuit, and a storage register. The signal conditioning circuit matches the signal levels and impedances of the receiver outputs and the sample and hold inputs. The sample and hold circuit ensures that the full analog bandwidth of the input signal and the full capability of the A/D Converter are maintained. The A/D Converter receives the output of the sample and hold circuit, digitizes it and sends it to the storage registers. This output register is then read by the CPU. The control signals for the sample and hold circuit, the A/D Converter, and the storage register originate from a timing circuit on the CPU board.

HEALTH/STATUS MONITORING

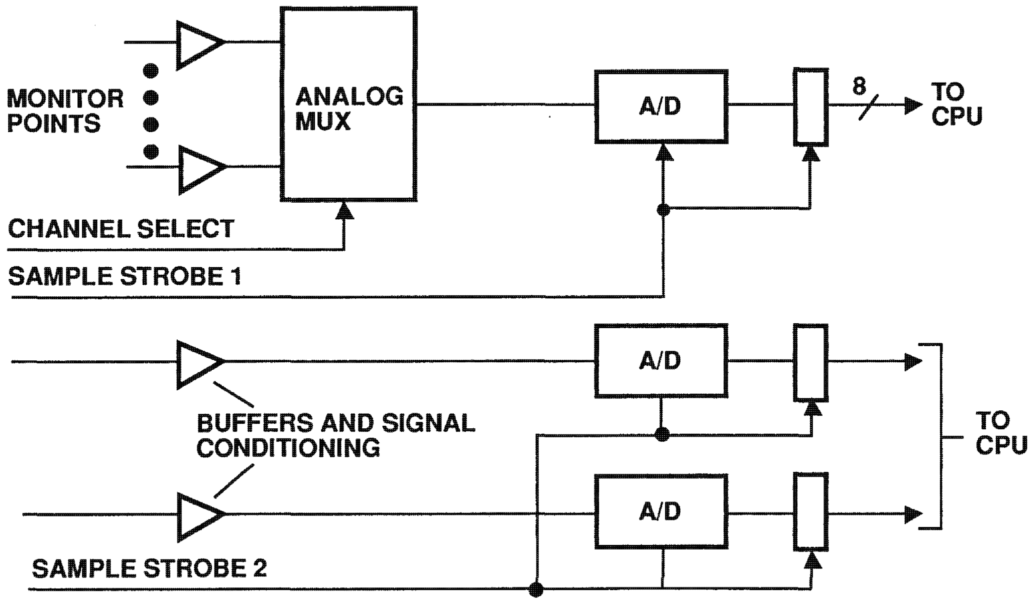
The Health/Status monitoring function is accomplished by the monitor point circuit. This circuit monitors test point outputs, digitizes the voltages at these points, and makes them available to the CPU, via a storage register.The CPU treats this register as a memory location. The parameters monitored include:

Synthesizer 1 out of lock indicator
Synthesizer 2 out of lock indicator
Power supply output voltages
Processor O.K. indicator

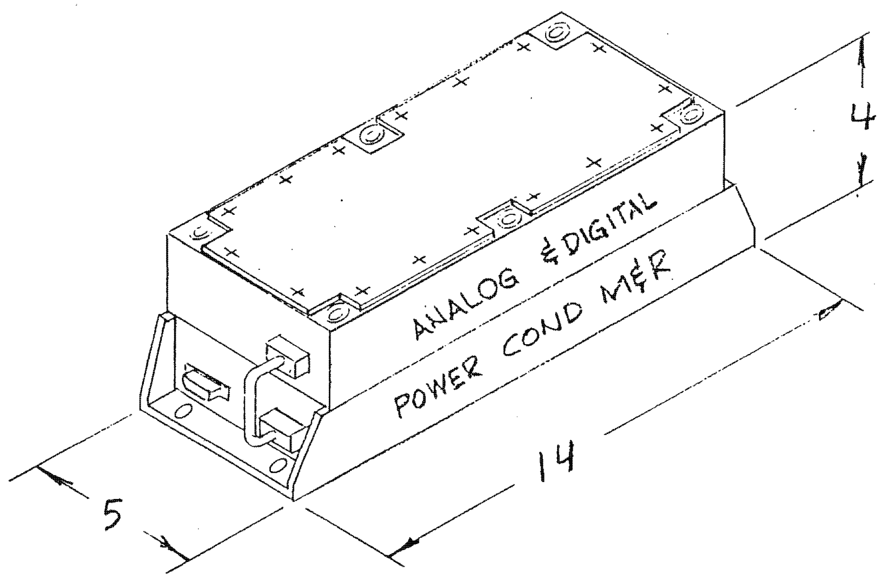
Spares inputs are provided to allow additional monitor points if required.

The monitor point circuit consists of signal conditioning circuits, an analog multiplexer, an Analog to Digital Converter, and an output register. The signal conditioning circuits adjust the signal levels prior to entry to the analog mux. This is done so as to provide a constant input range to the A/D Converter despite the varying voltage levels of the monitor points. No sample and hold circuit is required between the mux and the A/D Converter since all the monitor points consist of D.C. voltages. The output of the A/D Converter is applied to the CPU via a storage register. The CPU treats each input to the mux as a memory location. In operation the LSB's of the CPU address lines are used to address the mux and the MSB's are decoded to enable the storage register. All control signals originate from a timing circuit on the CPU board.

ANALOG CIRCUIT BOARD



RECOGNIZER/PROCESSOR OUTLINE



6.0 GEOLOCATION

6.0 GEOLOCATION AND INTERFERENCE

Geolocation and Interference determination functions are based on previously demonstrated AIL experiencce as shown in the chart. Both topics are explained in the following charts. [redacted] characteristics. The taking of 30 set of samples, each of 128 points, results in a 16 dB integration to aid in the effective SNR [redacted] The phase reconstruction is performed on the fly because frequency domain data is utilized, which is simpler than performing calculations after all data is collected.

An example of phase reconstruction shows the raw phase angle versus spin angle. When reconstructed, a single sine wave is expected as seen in the right hand graph. Since motion occurs during the spin, errors as shown in the chart, Motion Compensation, occur which can be correted by a look-up table in the processor. Location uncertainty is shown for nadir, with expected operationalong the 5 degree path.

Interference Determination is based on a correlation coeficient calculated from both channels. The last chart shows the No Interference case and one with interference. In the former, all data approaches a value of 1, whereas the presence on interference reduces the value substantially below 1. By examining four sets of data, we avoid the sometimes erroneous readings that occur due to the spin. All 4 readings must be near 1 for there to only be one signal present.

GEOLOCATION & INTERFERENCE OVERVIEW

GEOLOCATION

INTERFEROMETER ALGORITHMS DEVELOPED FOR SR-71 AND AN/ALR-77 SYSTEMS

OPERATIONALLY DEPLOYED FOR OVER 20 YEARS

INTERFERENCE DETERMINATION

ADAPTIVE SPATIAL FILTER TECHNIQUE

INTERFERENCE EASILY DETERMINED FROM ARRAY

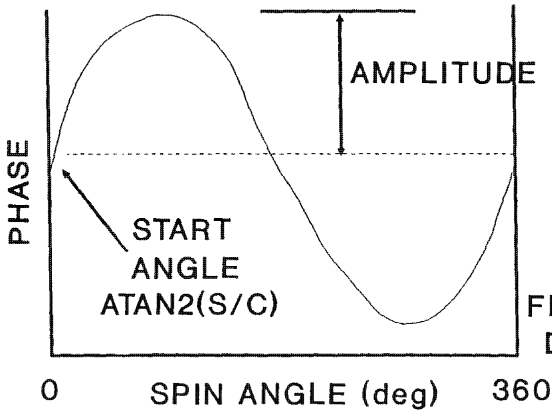
COMBINING BOTH CAPABILITIES YIELDS SIMPLE "ON-THE-FLY" GEOLOCATION FOR OBP

ALGORITHM SIMPLIFED BY SPIN

- NAVIGATION/ATTITUDE NOT REQUIRED ON EACH DWELL
  MID SPIN REPORT SUFFICES
- INERTIA INTERFEROMETER ARM POSITION NOT REQUIRED ON EACH DWELL
- [redacted]
  H/W SIMPLIFIED i.e. RCVR PHASE TRACK NOT REQUIRED
- PLATFORM MOTION COMPENSATED VIA LOOK-UP TABLE

PHASE RECONSTRUCTION

- PRINCIPAL PHASE FROM ARGUEMENT OF CROSS CORRELATION TERM
- TIME BANDWIDTH OF 40 (128 SAMPLES) PROVIDES 16 DB INTEGRATION PER DWELL
- INTEGRATION REDUCES DWELLS PER SPIN TO 30
- INTEGRATION OF DWELL SAMPLES ALLOWS ON-THE-FLY PHASE RECONSTRUCTION

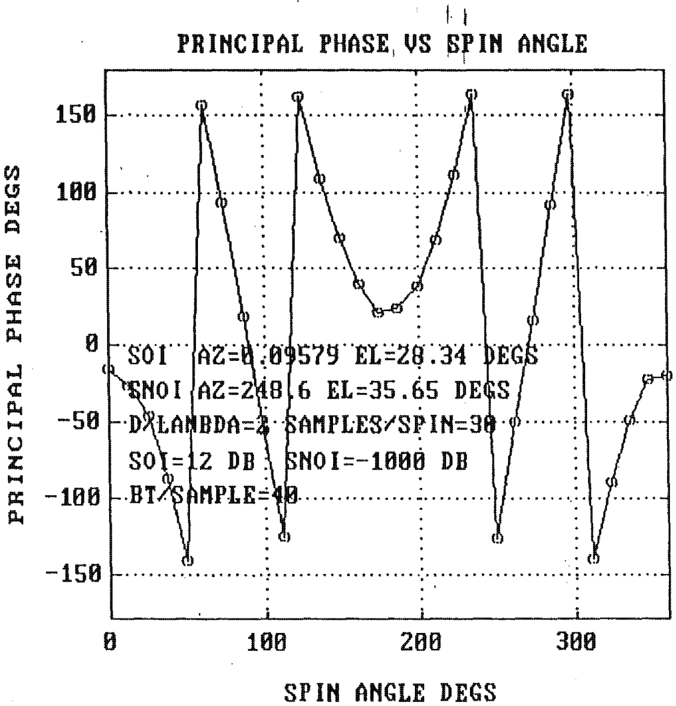


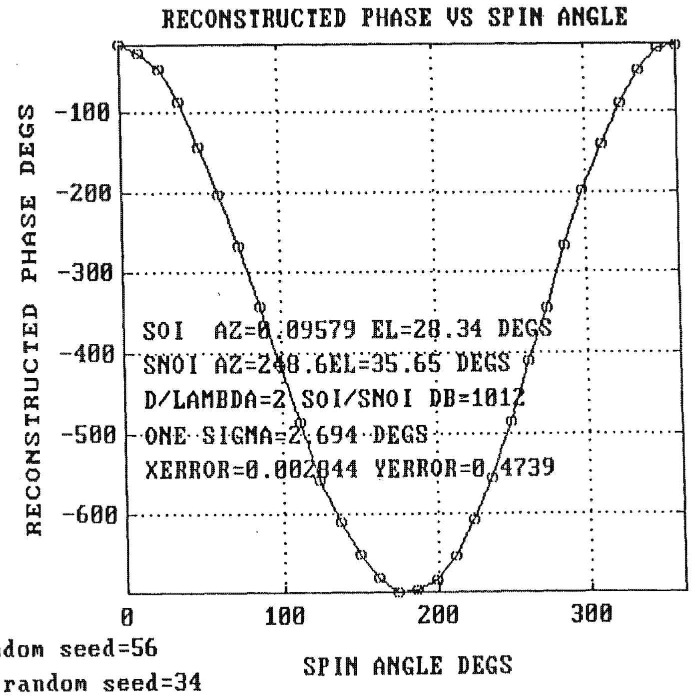
FROM DFT

AMP = SQRT(S^2 +C^2)
= 360 * D/L *SIN (EL ANG)

C= AMPL OF COSINE
S = AMPL OF SIN

EXAMPLE OF PHASE RECONSTRUCTION





phase random seed=56
location random seed=34

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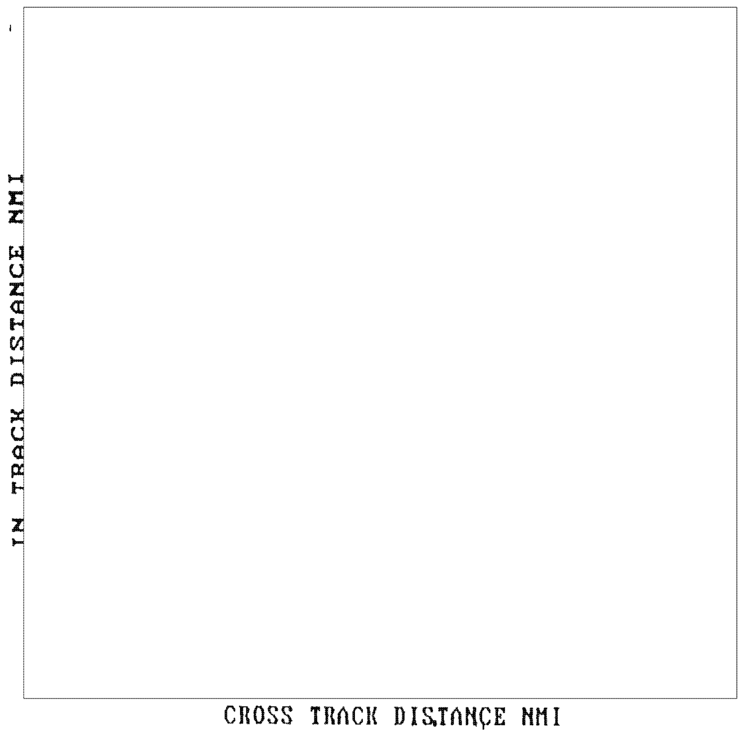
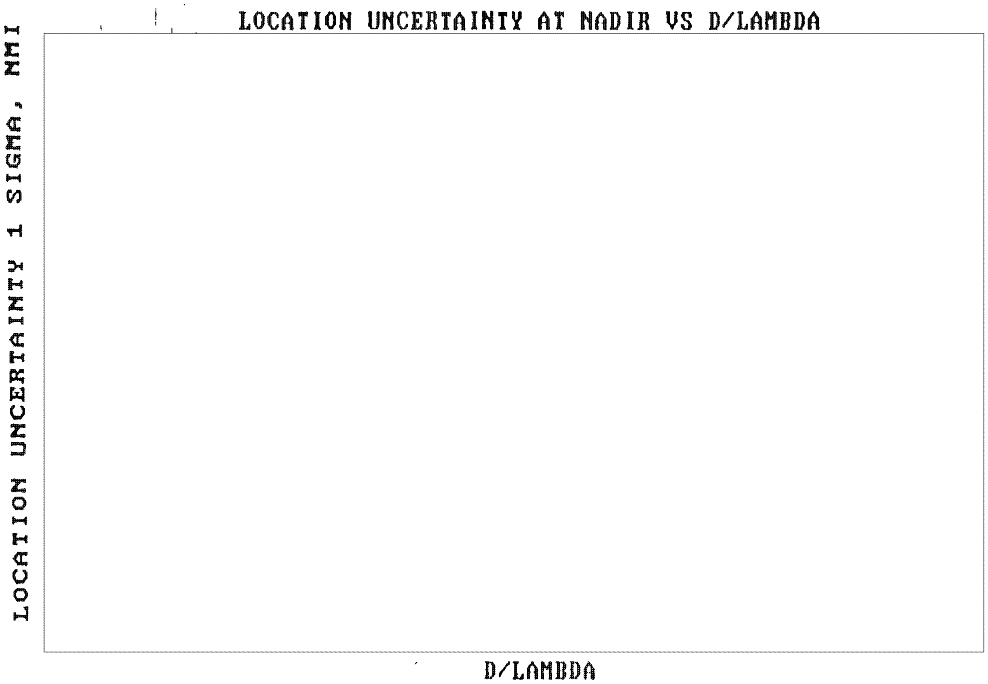
MOTION COMPENSATION

- PLATFORM MOTION DURING COLLECTION CAN BE COMPENSATED FOR BY SIMPLE LOOK UP TABLE



LOCATION UNCERTAINTY AT NADIR



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NORMALIZED SEMIMAJOR AXIS

NORMALIZED SEMIMAJOR AXIS CONTOURS

IN TRACK DISTANCE NMI

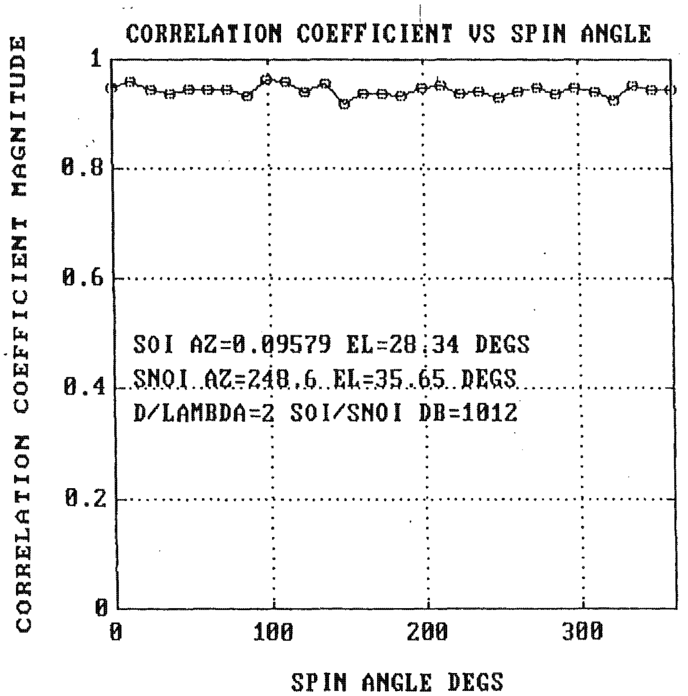
CROSS TRACK DISTANCE NMI

INTERFERENCE DETERMINATION

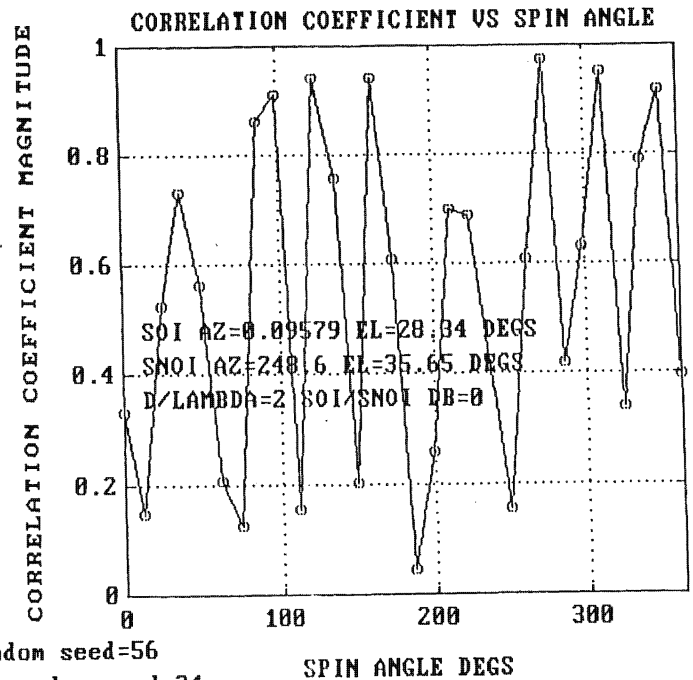
- TWO ELEMENT INTERFEROMETER IS TWO ELEMENT ADAPTIVE ARRAY
- EACH DWELL = 40 TIME BANDWIDTH PRODUCTS
- COMPUTE 128 FFT FOR EACH CHANNEL
- FORM 2 X 2 COVARIANCE MATRIX
- COMPUTE EIGENVALUES (LMAX & LMIN)
  or
  CROSSCORRELATION COEFFICIENT (CCC)
- INTERFERENCE PRESENT LMIN > THRESHOLD
  CCC < THRESHOLD

INTERFERENCE DETERMINATION

NO INTERFERENCE



WITH INTERFERENCE



phase random seed=56
location random seed=34

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7.0 PHYSICAL DESCRIPTION

MECHANICAL PACKAGING CONCEPT

The electronic hardware for the CARRIE Program consists of two assemblies, a Dual Channel Receiver and the Processor-Recognizer Assembly.

The Dual Channel Receiver consists of four (4) modular sub-assemblies which provide the following functions:

- o Dual RF Converter
- o Dual Synthesizer (Main & Redundant)
- o Reference Generator (Main & Redundant)
- o Power Conditioner (Main & Redundant)

Each of the above listed functions is packaged in an individual "slice" housing which is then separately assemblied and tested. The individual slices are then integrated to form the Dual Channel Receiver.

The basic chassis design for the four (4) sub-assemblies is a machined slice housing. This machined slice housing technique has been successfully used on many space qualified systems fabricated by AIL. The slices are securely fastened to one another by bolts to form a rigid assembly meeting the specific dynamic, thermal, and EMI environments.

The machined slice housing allows for the type of joint design necessary for efficient thermal conductivity and structural rigidity. All of the slices are machined from a solid block of 6061-t6 alluminum with walls, gussets and web thickness sized appropriately with the structural, thermal, EMI and fabrication requirements. Mounting flanges for each slice are machined to a prescribed .120 inch thickness and are designed to afford ample structural continuity to the housing shear walls. All of the slice housings are machined with a center wall forming an "I" beam cross-section. The walls are configured so that each slice is independently shear resistant against loading directed along the assembly's Y and Z axis. The shear walls also assure adequate strength and rigidity of the unit between mounting flanges. The center walls will be provided with ribs to further stiffen the unit and minimize out of plane (X axis) deflection and transmissibilities. Each side of the slice housing has a machined groove to accept a spiral type metal gasket. The slice covers, are non-structural, and when fastened in place complete an EMI type seal for each required assembly.

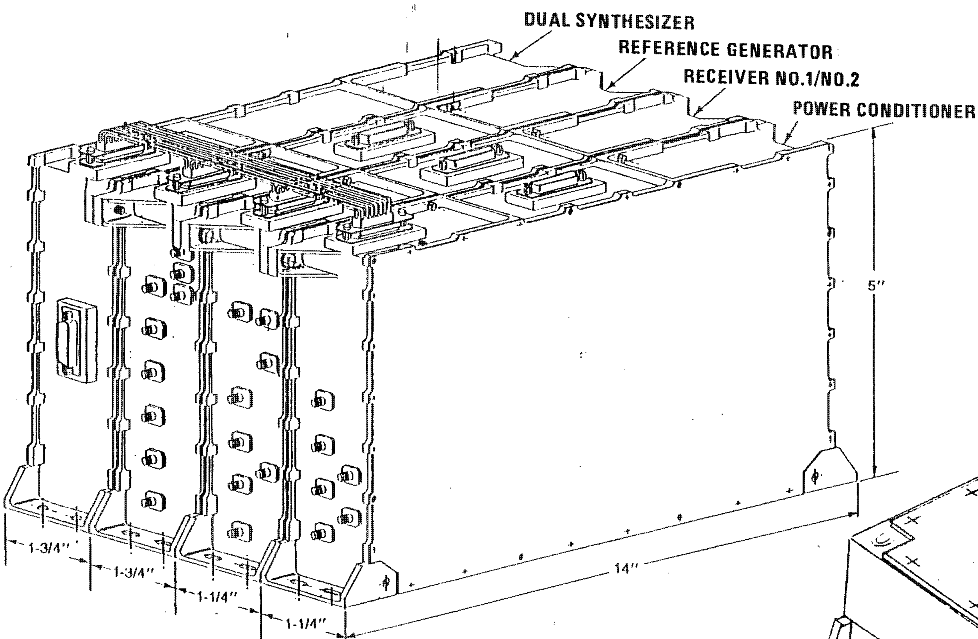
The Processor-Recognizer Assembly consists of two (2) modular sub-assemblies to provide the following functions:

- o Analog and Digital Subassembly
- o Power Conditioner (Main and Redundant)

These sub-assemblies also the same machined slice technique as described above.

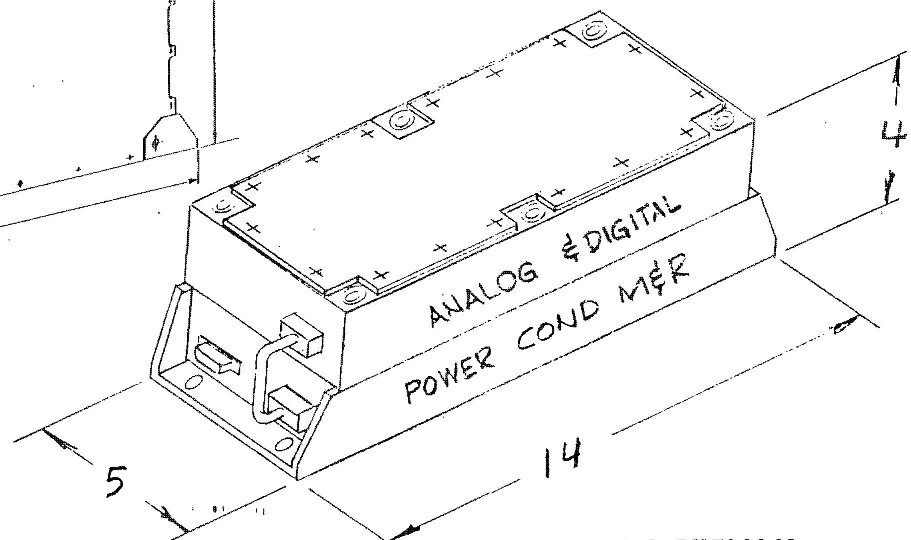
~~SECRET~~/[redacted]

UNIT PHYSICAL CHARACTERISTICS



RECEIVER/SYNTHESIZER
21.2 #

PROCESSOR
10.2 #



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~~SECRET~~/[redacted]

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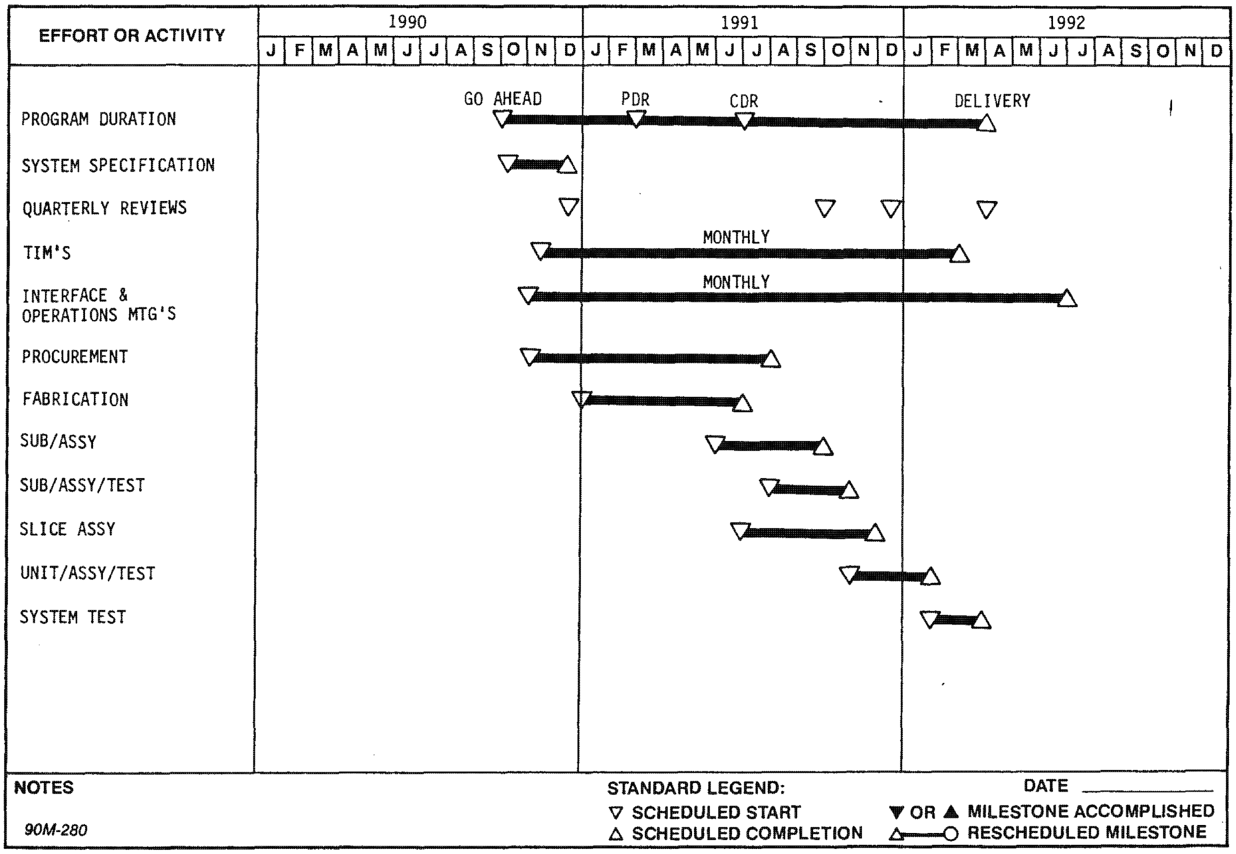
• 8.0 PROGRAMMATICS

The Special Programs Department of AIL Systems has a proven record in the management of Programs requiring focused Management to insure full compliance with all contractual requirements including performance, schedule and cost. It is our approach to dedicate an experienced task force for the duration of the program, which reports directly to AIL Management. As explained in the introductory letter from [redacted] the director of Advanced Technology and Systems, AIL is firmly committed to the successful development and operational deployment of this system. AIL has formed a team of proven Technical, Administrative, and Management capability to meet all requirements of this innovative and challenging program. As shown in the attached Organization Chart [redacted] has been designated as the Program Manager, and brings to the position over twenty five years of experience in Byeman related programs. Assisting [redacted] as Deputy Program Manager is [redacted] who will also assume responsibility for Interface Control between the Payload and the Spacecraft, and all Test and Integration phases of the program.

Each of the principal task areas are managed by experienced individuals who will report directly to the Program Manager for their areas of expertise. Reporting to the Engineering Manager, [redacted] are members of the functional Engineering Groups, each of whom has had extensive experience in the design of Space Qualified Hardware for Byeman related programs.

Page Denied

Attached is a Level I schedule for the CARRIE program, which although aggressive, is success oriented and realizable. In order to insure the schedule success of the program, lower level schedules (Level II and III) will be prepared by the individuals responsible for the Antenna Subsystem, Dual Channel Receiver, and Processor-Recognizer. Progress against these schedules will then be monitored at weekly staff meetings between the Program Manager and the functional managers. This will insure that difficulties are identified and resolved in a timely manner. The Level II and III schedules will be updated monthly using a computer based schedule monitoring program. These updates will be available at the monthly Program Reviews.



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9.0 APPENDICES

Approved for Release: 2024/08/06 C05098301

APPENDICES

- A INTERFERENCE DETECTION
- B LINE OF SIGHT IN PLATFORM
- C ELECTRICAL PHASE RECONSTRUCTION
- D ERROR ANALYSIS AT NADIR
- E ATE DESIGN APPROACH

Appendix A

Interference Detection

For the recognition function and for reliable geolocation it is necessary that the presence of interference be detected. The two element interferometer is also a two element adaptive array and state of the art adaptive array techniques can be used. For these techniques to work well a sufficient amount of integration at each dwell is required. For initial planning purposes a time-bandwidth product of 40 was selected. This in effect assures 40 independent samples per dwell. If we assume an IF bandwidth of 100 KHZ then a time duration of 0.4 millisecs is required for the dwell. With a spin of 20 rpm (120 degs/sec) the platform rotates 0.048 degs spatially. Assuming a maximum d/lambda of 5 the change in electrical phase during the 0.4 millisec dwell is 0.9 degs electrical. This is not considered a problem in interference detection. From the FFT outputs for each channel the elements of the covariance matrix can be computed. In what follows the expected values of the covarinace matrix (M) will be used to compute the expected cross-correlation function. Let

S=SOI power
I=SNOI power
Ts=SOI principal phase difference
Ti=SNOI principal phase difference.
N=thermal noise

From these the expected elements of the covariance matrix are

$M(1,1)=M(2,2)=S+I+N$
$M(1,2)=S*\exp(j*Ts)+I*\exp(j*Ti)$
$M(2,1)=\mathrm{conjugate}(M(1,2))$.

The expected cross-correlation function (r) is

$$r=\mathrm{sqrt}(S^2+2*S*I*\cos(dT)+I^2)/(S+I+N)$$

where $dT=Ts-Ti$

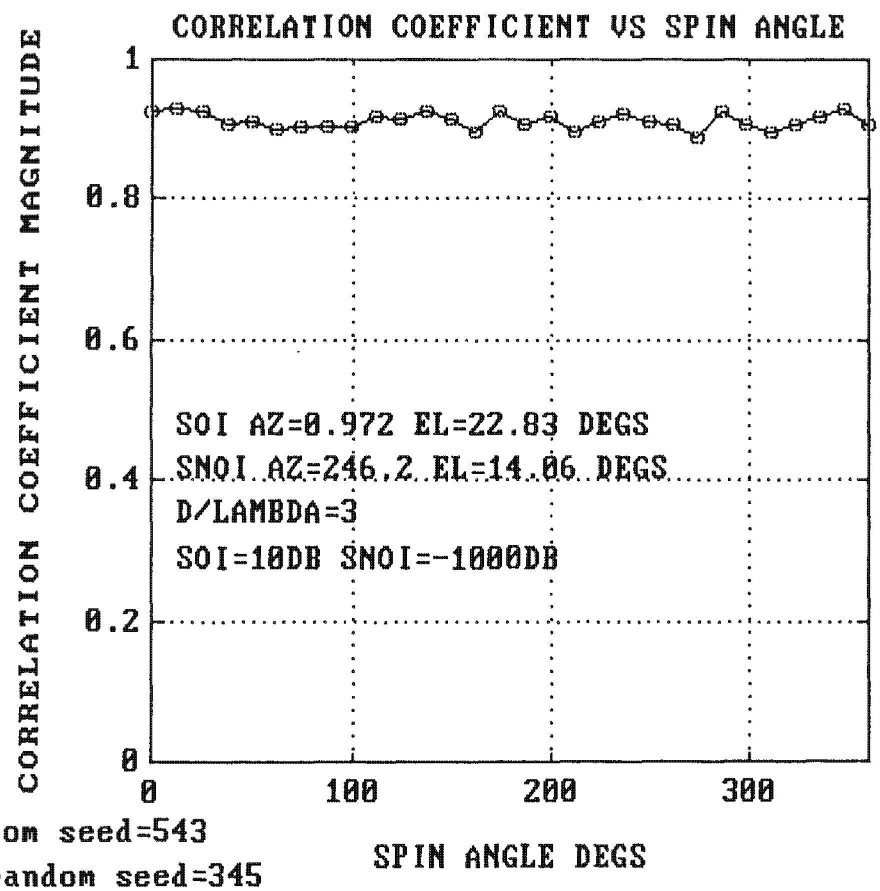
There are two spatially positions of the interferometer when the angle of arrival of the SOI and SNOI are the same. Ignoring platform motion, these two positions are 180 degs apart. At these positions

$$r=(S+I)/(S+I+N)$$

and the system can not detect the presence of an interferer. As the platform spins the angles of arrival change and the difference of the phase differences dT is no longer zero. Now the system is able to threshold to detect an interferer. It is possible that on the first dwell of the spin dT was zero. It should not be assumed, based on the first dwell for this

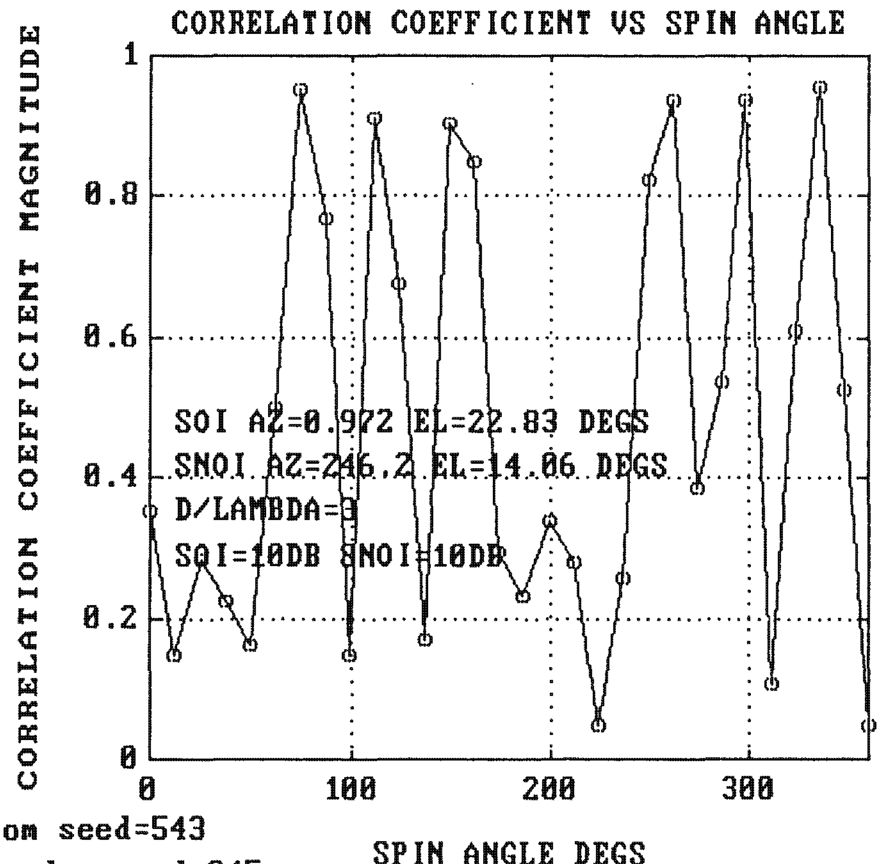
case, that there is no interference. To avoid this situation the following rule has been set up in the processor, if the first four dwells in the spin pass threshold there is no interference. Figure A-1 shows the plot of the cross-correlation function versus spin angle. The left side is for a 10 dB SOI with no interference. The right hand side is for the addition of a SNOI of 10 dB. As can be seen there is no problem in detecting the interference case. The wiggles in the SOI only case are due to finite integration. Notice in the right hand plot that there are indeed two positions 180 degs apart where r is high enough to be taken as a no interference case.

FIGURE A-1
(LEFT FIGURE)



phase random seed=543
location random seed=345

FIGURE A7
(RIGHT FIGURE)



phase random seed=543
location random seed=345

Appendix B

Line of Sight in Platform

In the absence of vehicle motion the expected reconstruction of electrical phase versus spin angle is a sinusoid. The period of the spin is known from the attitude sensing system. The amplitude of the sinusoid relates to frequency or wave length and elevation angle with respect to the spin axis. The relationship is

$$\text{Amp}=2*\pi d/\lambda \sin(\varepsilon)$$

where d=phase center spacing

λ =wave length

ε =elevation angle

The starting phase of the sinusoid gives the azimuth with respect to the vehicle coordinates. Directly estimating amplitude and starting angle results in a non-linear estimation procedure. It is simpler to consider the sinusoid as consisting of a sine wave and a cosine wave. This results in a linear estimation procedure which is nothing more than a Discrete Fourier Transform. For reasons that will be explained later the phase bias associated with the phase reconstruction will also be estimated. The necessary parameters are estimated from

$$\text{minimize} \sum_{i=1}^{N-1} \left(\phi_i - C_i^t E\right)^2$$

where ϕ_i =reconstructed phase at time ti

$C_i^t\ [\sin(\omega t_i)\ \ \cos(\omega t_i)\ \ 1]$

A=amplitude of sine wave

B=amplitude of cosine wave

ϕbias=phase bias

ω = spin period

$E^t = [A\ \ B\ \ \phi\text{bias}]$

Taking the necessary derivatives and solving

$$E = \left(\sum c_i c_i^t\right)^{-1} T$$

$$T = \sum \phi_i C_i$$

Assuming the samples are equally spaced in time for one spin

$$\sum c_i c_i^t = \begin{bmatrix} N/2 & & 0 \\ & N/2 & \\ 0 & & N \end{bmatrix}$$

Then

$$A = \sum \phi_i \sin(w_0 t_i) / (N/2)$$

$$B = \sum \phi_i \cos(w t_i) / (N/2)$$

$$\phi_{\text{bias}} = \sum \phi_i / N$$

In the presence of random phase errors $(\sigma\phi)$ the uncertainties are

$$\sigma_A^2 = \sigma\phi^2/(N/2) \qquad \cancel{\sigma_{AB} = 0}$$

$$\sigma_B^2 = \sigma\phi^2/(N/2) \qquad \sigma\phi^2_{BIAS} = \sigma\phi^2/N$$

The amplitude of the total sinusoid is

$$Amp^2 = A^2 + B^2$$

and the uncertainty is

$$\sigma^2_{Amp} = \sigma\phi^2/(N/2)$$

The starting phase (β) is

$$\tan\beta = A/B$$

and the uncertainty is

$$\sigma_\beta^2 = \sigma\phi^2 / \left(\frac{N}{2} * Amp^2\right) = \frac{\sigma\phi^2}{(N/2)} * \frac{1}{(2\pi d/\lambda \sin(\varepsilon))^2}$$

The uncertainty in elevation is

$$\sigma_E^2 = \frac{\sigma_\phi^2}{(N/2)} * \frac{1}{\left(2\pi d/_\lambda \cos(E)\right)^2}$$

The expected phase uncertainty associated with the estimation is

$$\sigma_\phi^2 = \left(\Sigma \phi_i^2 - \tau^t E\right) / _{N-3}$$

Appendix C

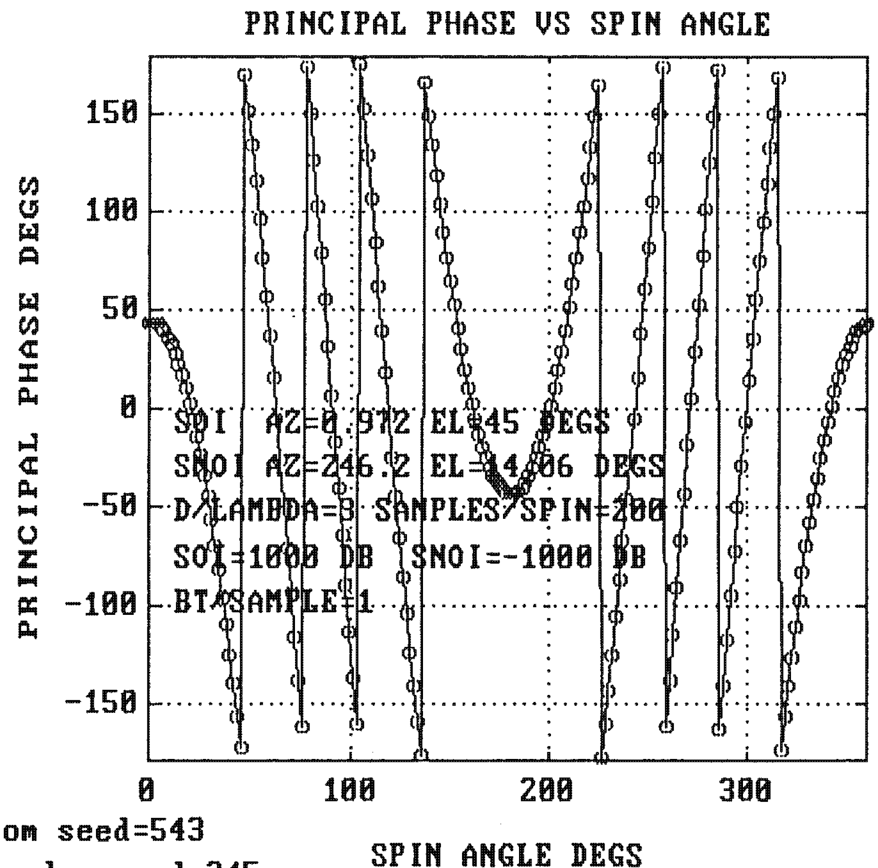
Electrical Phase Reconstruction

A significant procedure for eventual on board processing is to phase reconstruct on the fly. This eliminates the need for storage and allows the geolocation, at least with respect to the vehicle, to be done on the fly. To do reconstruction on the fly requires that enough samples be taken on each phase lobe so that the transitions from lobe to lobe can be detected. This permits the correct number of 360 degs to be added to the principal phase to phase reconstruct. As discussed in Appendix B the geolocation is contained in the resulting sinusoid and does not depend on the phase bias present. This means that phase reconstruction can start on the first principal phase reading without regard to the ensuing bias that will occur.

At 500 MHz and with the largest spacing currently envisioned the d/lambda is 3. It is anticipated that the system will not report out locations that are out of main beam of the antenna pattern. For analysis purposes an elevation of 45 degs is used in what follows. Figure C-1 is a plot of the principal phase for the above conditions ignoring noise, the SOI has been artificially set to 1000 dB and the SNOI artificially set to -1000 dB. Two hundred equally spaced samples have been assumed. The phase lobes are easily identified. Figure C-2 is a plot of the phase reconstruction. No problems are encountered. For Figure C-3 the number of samples has been reduced to 30 per spin and the principal phase plot looks different from figure C-1. The phase reconstruction for the 30 sample case is shown in Figure C-4. Comparing Figure 2 with Figure 4 shows that the phase reconstruction with 30 samples has been successful. Figures 5 and 6 show the case for a SOI of 10 dB. As can be seen the system will properly reconstruct the phase. In the above a phase jump, in magnitude, of 180 degs has been used as a threshold in detecting phase lobe jumps.

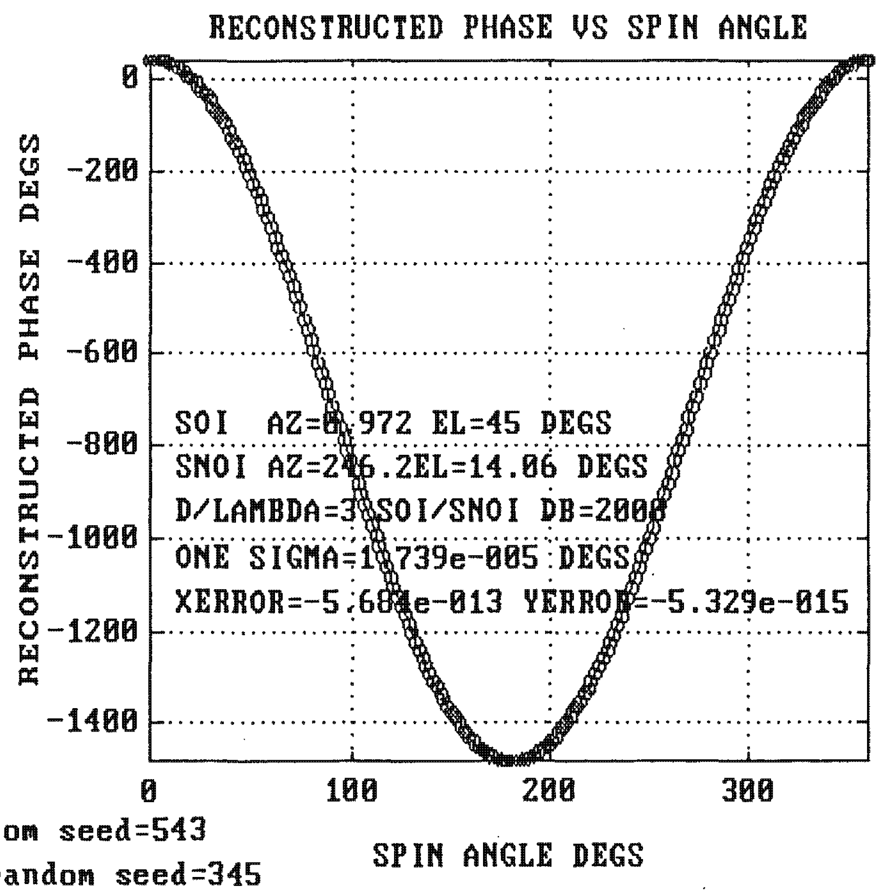
Admittedly the examples did not include phase mistrack errors which will add to the principal phase variations. These effects, if significant, may require more samples per spin. This can be settled once the antenna data is available. Based on antenna mistrack error models there does not appear to be any significant problems in doing phase reconstruction on the fly.

FIGURE C-1



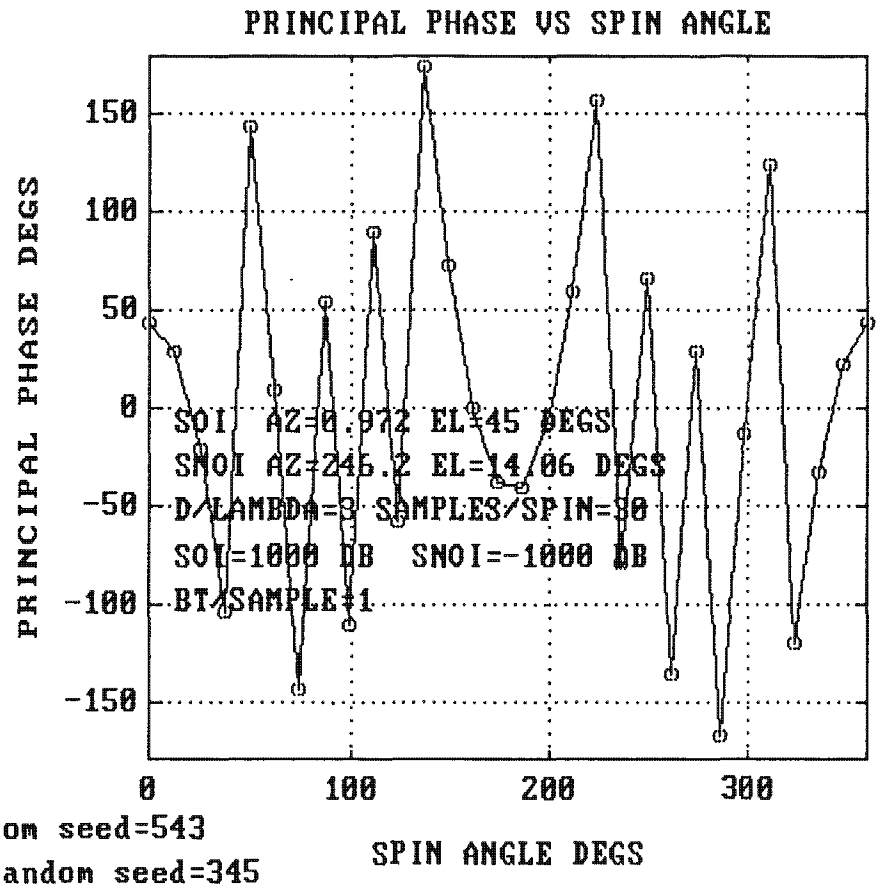
phase random seed=543
location random seed=345

FIGURE C-2



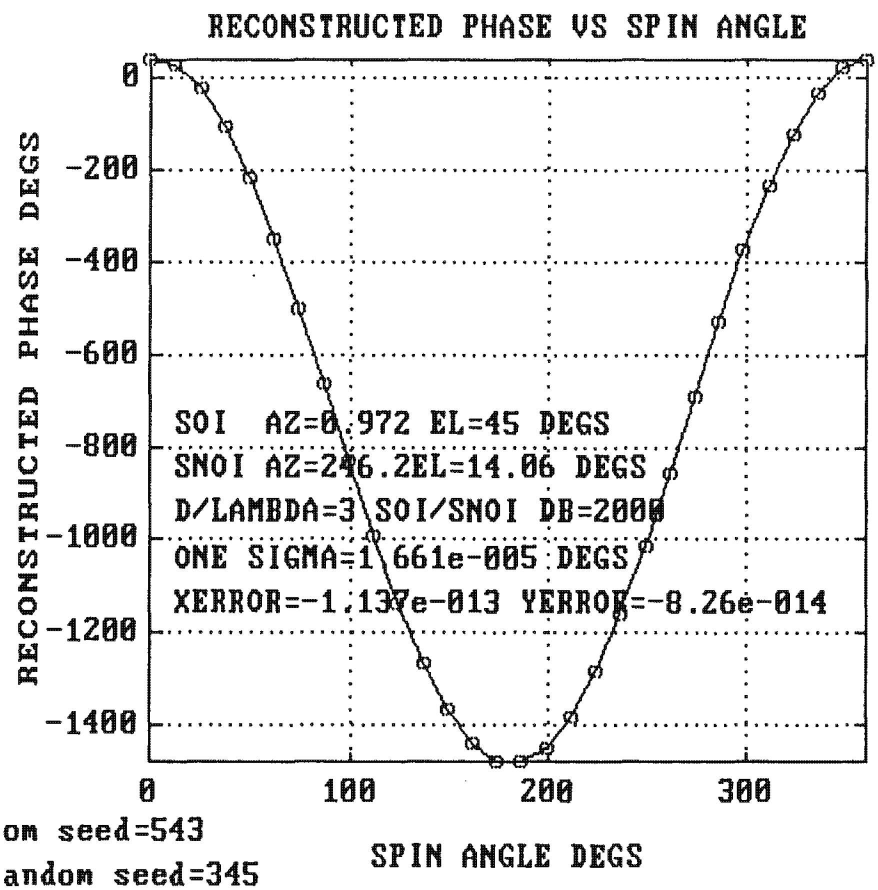
phase random seed=543
location random seed=345

FIGURE C-3



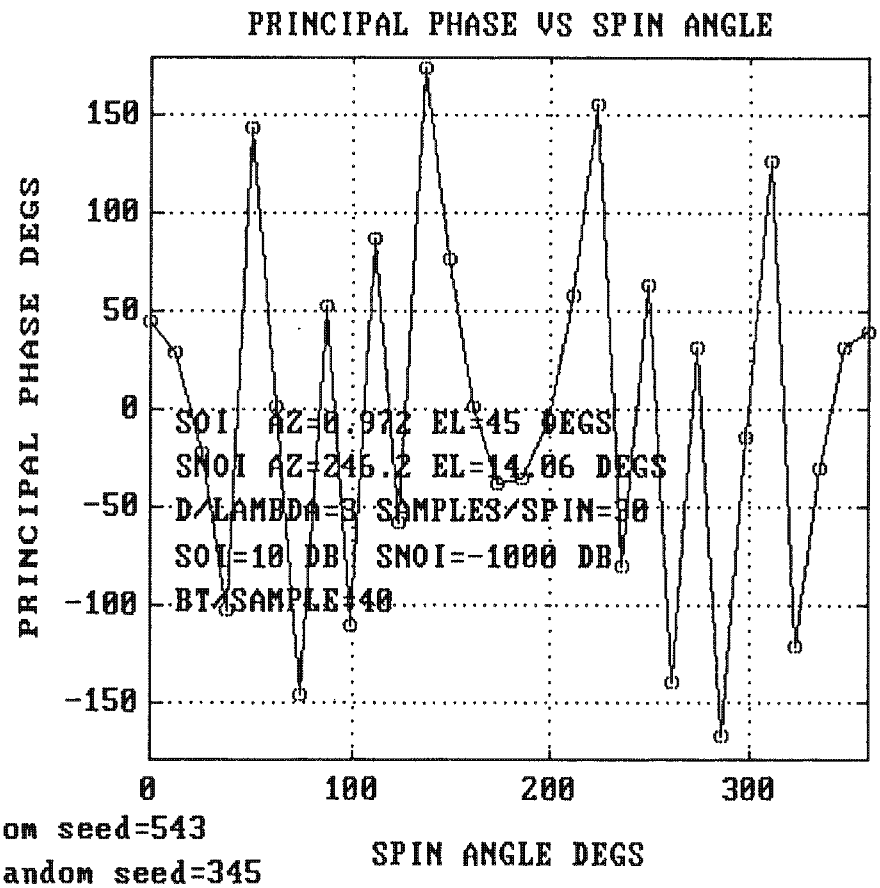
phase random seed=543
location random seed=345

FIGURE C-4



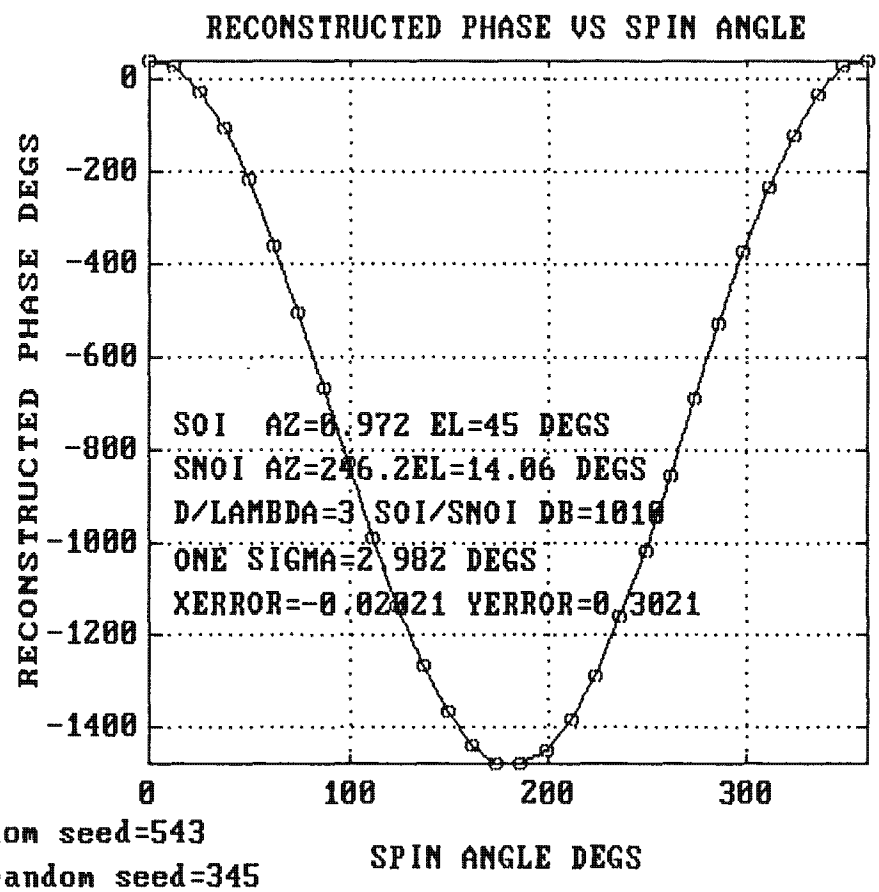
phase random seed=543
location random seed=345

FIGURE C-5



phase random seed=543
location random seed=345

FIGURE C-6



phase random seed=543
location random seed=345

Appendix D

Error Analysis at Nadir

For this analysis it is assumed that the spin axis is along the orbit radius, a nadir pointing position. The interferometer error budget is given in Table D-1.

Table D-1
Interferometer Error Budget

Item	1 sigma phase
Phase Noise	
Minimum signal 10 dB	
Integration	
per Dwell 16 dB	2.3 degs
Phase Quantization	
8 bits	0.4 degs
Phase Mistrack	
Antennas	5.0 degs
RCVR	n/a
RSS	5.5 degs

Using a d/lambda of 0.5 (low end) and 30 samples per spin the elevation uncertainty at nadir (see Appendix B) is

$$\sigma_\varepsilon^2 = \frac{\sigma_\phi^2}{(M/2)} * \frac{1}{(2\pi d/\lambda \cos(\varepsilon))^2}$$

The error budget for the spacecraft has not been firmed up at the present time. Present indications give an error budget as in Table D-2.

Table D-2
Spacecraft Error Budget

Item	1 sigma
Ephemeral	1 nmi
Attitude	0.1 degs
Start angle	0.1 degs

At nadir the semi major axis is [redacted] RSSing this with the interferometer contribution gives a semi-major axis of [redacted] at nadir, well within requirements.

APPENDIX E

ATE DESIGN APPROACH

1.0 TEST CONCEPT

The current concept for PAYLOAD Automatic Test Equipment (ATE) is shown in FIGURE E-1. This equipment configuration will permit the payload to be tested with a signal simulation scenario similar to that encountered during actual operation. This will be accomplished by providing inputs to the Dual Channel Receiver similar to those received from the Antenna Subsystem when an emitter is present within the field of view.

2.0 FUNCTIONAL DESCRIPTION

The Signal Simulation portion of the ATE consists of three (3) signal generators (SG1-SG#). Each signal generator simulates a potential Signal of Interest (SOI) which can be routed to the Payloads RF inputs. The signal generators (SG1 and SG2) are each capable of being modulated with simultaneous FM and AM modulation. In addition generator SG3 is capable of providing simultaneous AM, FM, Pulse and Phase modulation and can be used to simulate co-channel interference.

In order to simulate the phase offset normally provided by an emitter as the Spacecraft moves across the target area, each signal generators' RF output is divided into two equal signals using a zero (0) degree RF hybrid. The RF signal from one arm of the hybrid is then fed through a digitally controlled phase shifter assembly. The Phase Shifter is an 8 bit device which provides 1.4 degrees per bit control of the RF signal. RF signal level is controled directly by the signal generators and can be varied between +13 DBm and -120 DBm.

The phase adjusted signals from each generator are combined into a single RF output via HY5, a zero degree three way hybrid. This combined signal is then supplied to the Payload at input B. A similar path is also used for the reference signal using HY4 to input A of the Payload.

The final test scenario will be run from a software routine over the HP-IB. This routine will vary the frequency and power level of the generators. In addition the phase shifters will be varied to simulate different emitter locations.

After processing by the Payload Processor the data will be output to the CPU in Mission Report Format. This report will be compared to calculated emitter type and locations based on the known values of the generators and the simulated navigation data tables and operational commands supplied to the Payload via the 1553 Buss. The 1553 Buss data emulates the Spacecraft Command and Navigation data.

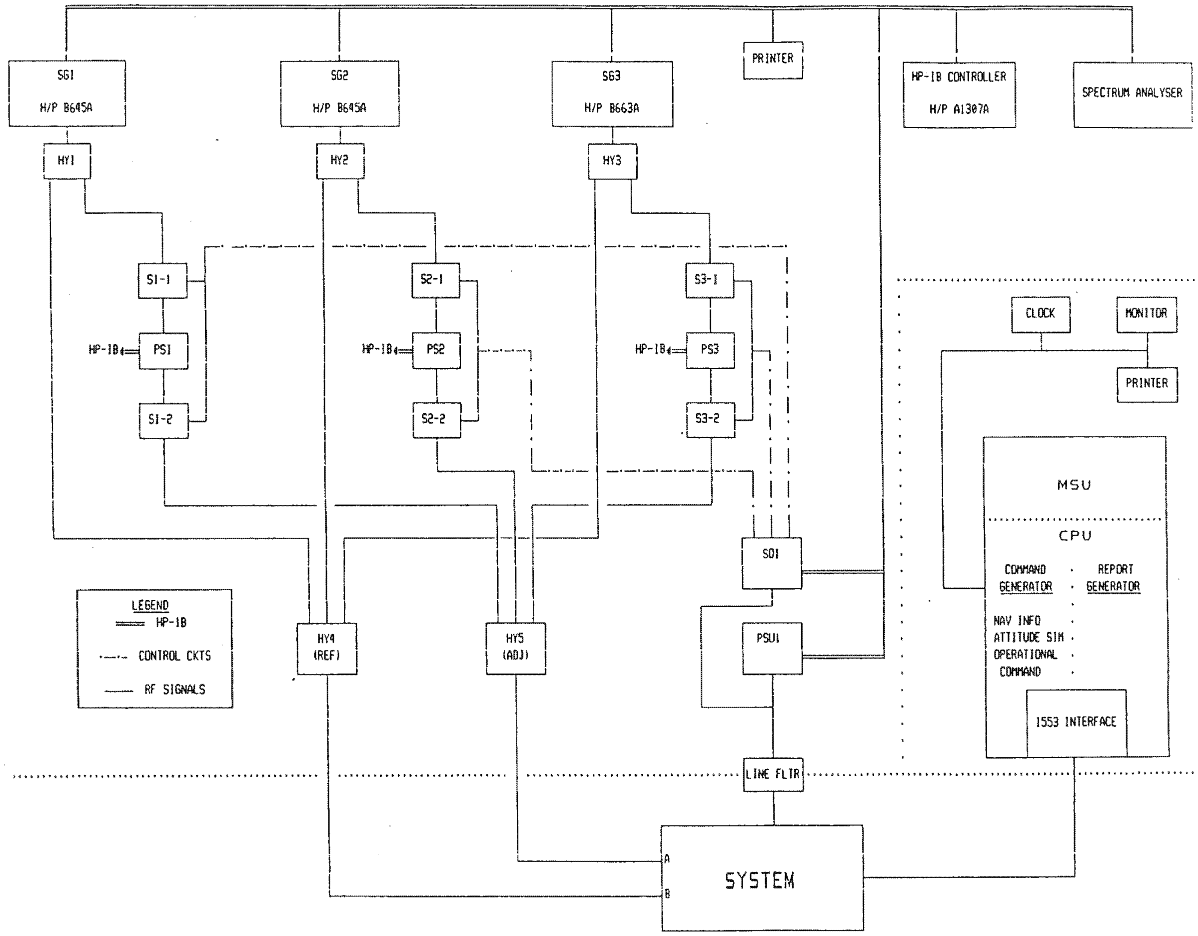


FIGURE E-1
SIMULATED SIGNAL TEST SETUP

HANDLE VIA BYEMAN
CONTROL SYSTEM ONLY