This Reliability Prediction was prepared by Motorola's Government Electronics Division as required under the Bendix/Motorola subcontract SC-0721 for the ALSEP program.

The ALSEP Redundant Command Receiver is a solid state receiver with active redundancy that may be used to receive either PM or PM-FM type signals. This receiver includes two identical electrically separate receivers, consisting of an rf converter, and IF and Audio Amp, and a power isolator. Each receiver (A and B) is a dual conversion super heterodyne receiver with a center frequency of 2119 MHZ. In addition, the Redundant Command Receiver has an rf power divider referred to as an rf coupler and a selection circuit referred to as an audio combiner.

There was a reliability design goal of .998 for a two-year mission on the lunar surface. The predicted reliability (based on the FACI-configuration) is .99795 in format 1 and .99786 in format 2. These predictions were based upon an expected temperature of 45°C.

The telemetry was considered non-mission essential and failure modes resulting in only the loss of telemetry were not considered in the reliability calculations.

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Document No: 3875/038

Reference: ARD-439, Para 6.13

14 August 1970

Reliability Prediction For
ALSEP Redundant
Command Receiver
BxA Part Number 2345147

"Preliminary - The Bendix Corporation Aerospace Systems Division Approval Pending"

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Contract Number: NAS 9-5829

Subcontract Number: SC-0721

APPLICATION		REVISIONS			
NEXT ASSEMBLY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
			"Preliminary - The Bendix Corporation Aerosapce Systems Division Approval Pending"	8/14/70	
		A	Revised to FACI Configuration	11/30/70	

REV STATUS	REV	A	A				A		A	A	A	A		A	A	A	A			
OF SHEETS	SHEET	1	2	3	4	5	6	7	8	9	10	11		A1	A2	A3	A4	A5	A6	A7

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FOR PARTS LIST SEE

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES AND END USE. FOR TOLERANCES SEE NOTE

DR BY Ronald W. King

CHK BY

MFG

PROJ NO.

MATERIAL:

CONTR NO.

RELEASE NOTICE

APPROVED DATE

APPROVED DATE

MOTOROLA INC.
Government Electronics Division
8201 EAST McDOWELL ROAD
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Reliability Prediction For
ALSEP Redundant Command Receiver
BxA Part Number 2345147
Document No. 3875/038

SIZE	CODE IDENT NO.	DWG. NO.
A	94990	

SCALE | | SHEET 1 OF

V-1-B-199H-100A-3/69 DWG FORMAT

Table of Contents

1.0 INTRODUCTION:

A reliability prediction was performed on the ALSEP Redundant Command Receiver for Bendix Aerospace Systems. The prediction complied with the requirements of Task 4 of the Reliability Program Plan for the ALSEP Redundant Command Receiver (Motorola Document No. 3875/001 Revision A, dated 30 April 1970).

This report is considered a final reliability prediction submitted to fulfill the requirements of the CDR.

The configuration of the design used for this analysis is as detailed in the Assembly Parts List dated 30 Nov. 1970 and the following revisions of the schematics:

Schematic Name:	Schematic Number	Revision
IF and Audio	63-P11349B	D
RF Converter	63-P11377B	B
Interconnection Diagram	63-P11356B	C

These revisions of the schematics have been submitted to Bendix under separate cover and are, therefore, not included in this report.

2.0 REQUIREMENTS:

The reliability requirement is a design goal of .998 for a 2-year mission of lunar surface operation.

Telemetry was considered non-mission essential and failure modes resulting in only the loss of telemetry were not considered in the reliability calculations.

Audio A, Audio B, CSPA, and CSPB were not considered mission essential except as used within the Command Receiver to provide a selected audio output.

Piecepart drift failure modes were not considered mission essential except in critical tolerance circuits.

An environmental K-factor of 1.0 was used for lunar surface operation. Reliability predictions were based upon an expected temperature of 45°C.

3.0 SUMMARY OF ANALYSIS AND CONCLUSIONS:

The reliability of the Redundant Command Receiver for a two year (17520 hours) lunar surface mission is .99795 for for format 1 and .99786 for format 2, as compared with the design goal of .998.

The reliability equation is essentially composed of three terms: Probability of success with 0 failures, probability of success with 1 failure, and the probability of 2 failures which represents system failure.

For Format 1:	For Format 2:
$P_S(0) = .91709$	$P_S(0) = .91489$
$P_S(1) = .08087$	$P_S(1) = .08297$
$P_F(2) = .00204$	$P_F(2) = .00214$

The predicted reliabilities of .9980 (format 1) and .9979 (format 2) indicate that the apportioned design goal of .998 will be met by the Redundant Receiver. Although some aspects were taken into account, the total effect of the comprehensive reliability program cannot be adequately accounted for in a prediction. The reliability program consists of the following:

1) All pieceparts are screened to the maximum reliability level,
2) All pieceparts are applied in accordance with a conservative derating guide,

3) A PAA has been performed to assure that no part application problems remain,

4) An FMECA has been performed to assure that single-point-failure areas have been recognized and minimized,

5) A closed loop failure reporting and corrective action program,

6) Taking the most severe result into account in the case of questionable failure modes,

7) Taking special precautions with critical parts, e.g. in the case of the RF receptacle, a serial element, a right-angled adaptor has been incorporated to reduce the necessary number of matings, thereby decreasing the probability of inducing failure modes.

4.0 ANALYSIS DETAILS

4.1 FUNCTIONAL DESCRIPTION:

The ALSEP Redundant Command Receiver is a solid state receiver with active redundancy that may be used to receive either PM (format 1) or PM-FM (format 2) type signals.

The Redundant Command Receiver includes two identical electrically separate receivers, consisting of an RF converter, an IF and Audio Amp, and a power isolator. Each receiver (A and B) is a dual conversion superheterodyne receiver with a center frequency of 2119 MHz. In addition, the Redundant Command Receiver has an RF power divider referred to as an RF coupler and a selection circuit referred to as an audio combiner. The overall block diagram is shown in Figure 1.

The RF input power is provided to the receiver through a single RF connector interface and is divided by a power divider and applied to receivers A and B. The local oscillator injection for each converter is provided from a crystal oscillator at 110.9631 MHz. Selectivity is provided by a 3-pole preselector preceeding the mixer, a 3-pole filter in the first IF, and a 5-pole filter following the second mixer. Integrated circuits are used in the receiver for most of the IF gain and the subcarrier and audio circuitry. After amplification and gain leveling, a limiter and a Travis discriminator circuit are used to demodulate the receiver signal. After the first discriminator, the signal is processed in accordance with the format selected and then proceeds to the active filter output amplifier, which provides a narrow post detector bandwidth to reduce output audio noise.

A narrow band detector is used to recognize and indicate the presence of a 1 KHz synchronizing tone. The filter has a noise bandwidth of approximately 100 Hz. The output of the detection circuit is a bi-level signal, identified as a Command Signal Presence Indicator (CSP). The CSP is used within the audio combiner circuitry to implement the redundancy switch for switching from receiver A to receiver B.

The Redundant Command Receiver is designed to receive modulated signals in either of two types of modulation designated as format 1 or format 2. The format is selected by means of appropriate connections in the wiring harness external to the receiver.

The modulating signals are constructed as follows:
Digital data is bi-phase modulated onto a 2 KHz subcarrier and a 1 KHz synchronizing tone is added. This combination then constitutes the composite audio signal and is used in either format. In format 1, the composite audio signal is phase modulated directly onto the S-band carrier at 3 radians peak. In format 2, the composite audio signal is frequency modulated onto a 70 KHz subcarrier at 5 KHz peak deviation.

After the first discriminator in the IF and Audio Module of the receiver, the signal processing is dependent upon the format. In format 1 operation, an integrator having a corner frequency of approximately 80 Hz is used to restore the original composite audio form. This is necessary because the received PM signal is demodulated by a FM discriminator. The output amplifier is combined with an active filter to provide a narrow post-detection bandwidth to reduce the output audio noise.

In format 2 operation, the first discriminator output is the 70 KHz subcarrier with its frequency modulation. This signal is further processed through an Integrator (corner frequency of 30 KHz), a limiter, and a pulse counting discriminator. The composite audio signal from the discriminator goes to the active filter output amplifier.

The implementation of redundancy in this receiver is a major design characteristic. Figure 2 shows the reliability model for the Redundant Command Receiver. Both receivers A and B are operating during the mission. When the CSP from receiver A indicates the presence of a command signal from the output of receiver A, receiver A is selected by the audio combiner. When CSP does not appear, either due to failure of A or due to no command signal, then receiver B will be selected.

All single point failure modes have been eliminated through the use of part redundancy, except the RF input receptacle which is a contractually specified interface. All functions, except telemetry, have redundant pin connections within the multipin connector.

4.2 RELIABILITY BLOCK DIAGRAM:

A system summary of the failure mode, effects, and criticality analysis (Document No. 3875/035) is contained in Appendix A. The subassembly failure modes were grouped according to the criticality of those failure modes. The failure rates (%/1000 hours) are itemized in the Reliability Model Code column for those failure modes considered mission essential and for those included in the reliability block diagram. The reliability block diagram is shown in Figure 2. Failure rates were obtained from Motorola's R&C Special Memorandum Number 188 for each part application (electrical stress) and at 45°C. The serial portion of the audio combiner and the multipin connector have a negligible failure rate due to the part and pin redundancy within each.

A simplified reliability block diagram may be constructed by combining the serial elements of the receiver. That reliability block diagram is shown in Figure 3 for each format.

4.3 LOGIC DIAGRAM AND MATH MODEL:

A logic diagram and a math model are shown in Figure 4. The math model was based upon a mission time of 17520 hours.

4.4 MULTIPLE FAILURE PROBABILITY:

The reliability of the multipin connector and the serial portion of the audio combiner were assumed negligible (R = 1.0) due to pin and part redundancy within the block. Figure 5 shows that this assumption is valid for the serial portion of the audio combiner.

The multiple failure probabilities were calculated as follows:

For Format 1:

$P_S(0) = R_1 R_2 R_3 = (.99974) (.95661) (.95894)$

$= .91709$

$P_S(1) = R_1 (1-R_2) R_3 + R_1 R_2 (1-R_3)$

$= (.99974) (.04339) (.95894) + (.99974) (.95661) (.04106)$

$= .08087$

$P_F(2) = 1- \left[P_S(0) + P_S(1)\right] = 1-.99792$

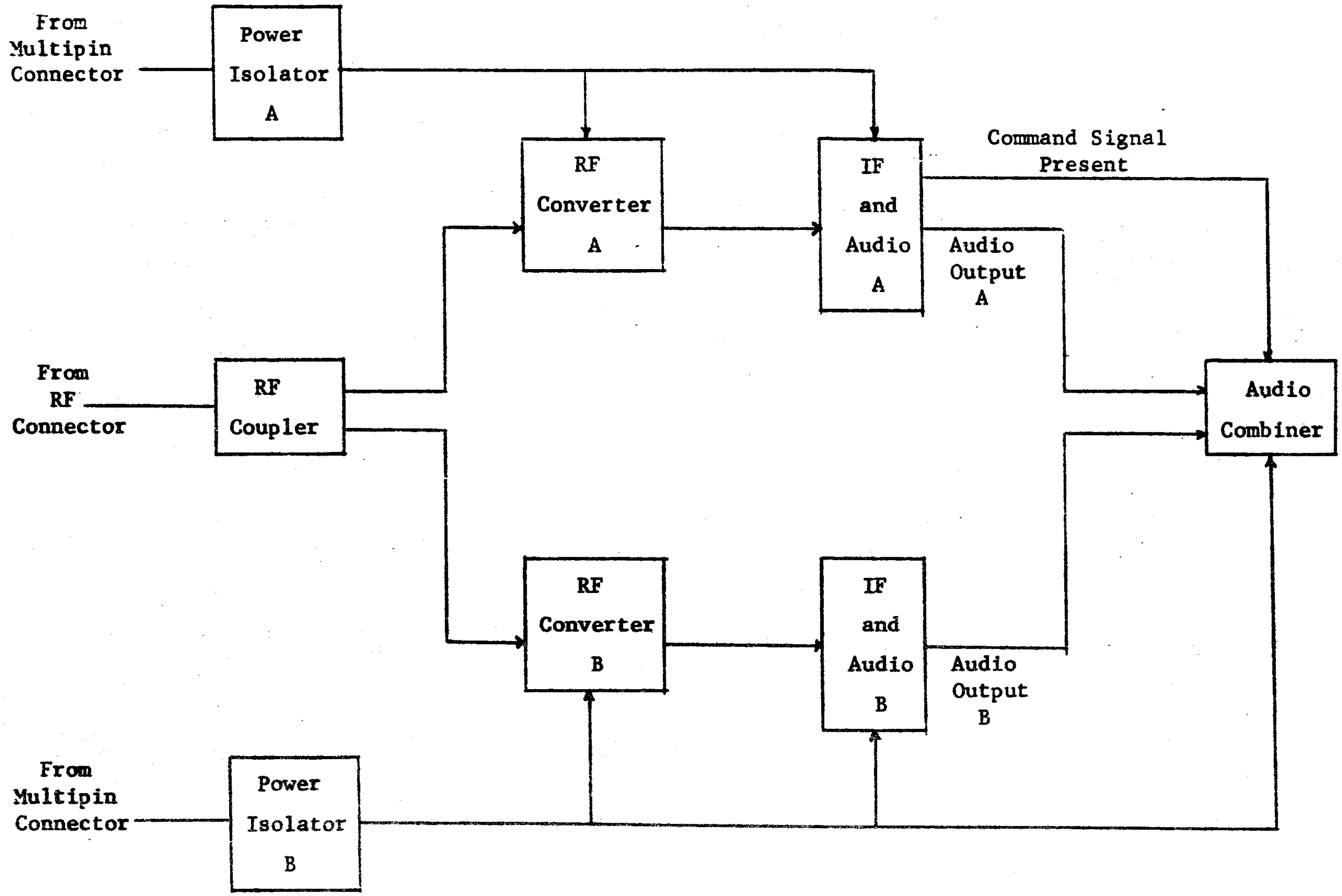
$= .00204$

For Format 2:

$P_S(0) = .91489$

$P_S(1) = .08297$

$P_F(2) = .00214$



<u>Figure 1</u>

ALSEP Redundant Command Receiver

Functional Block Diagram

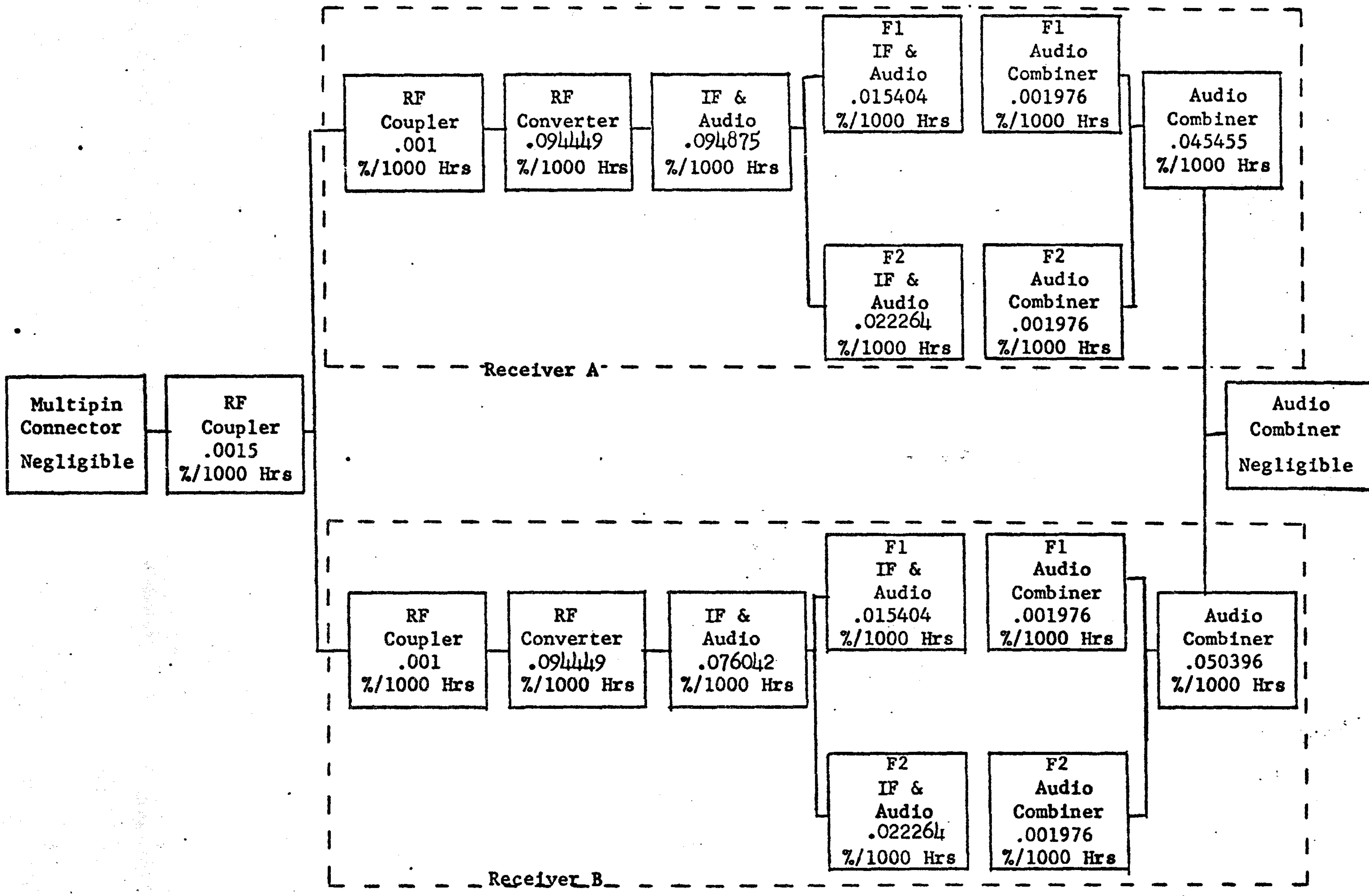
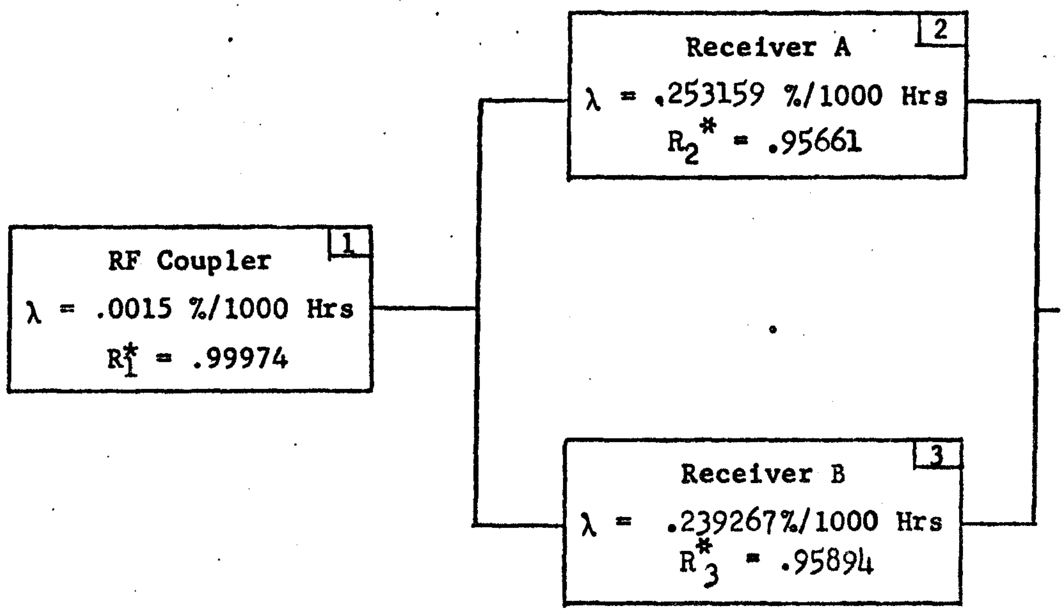
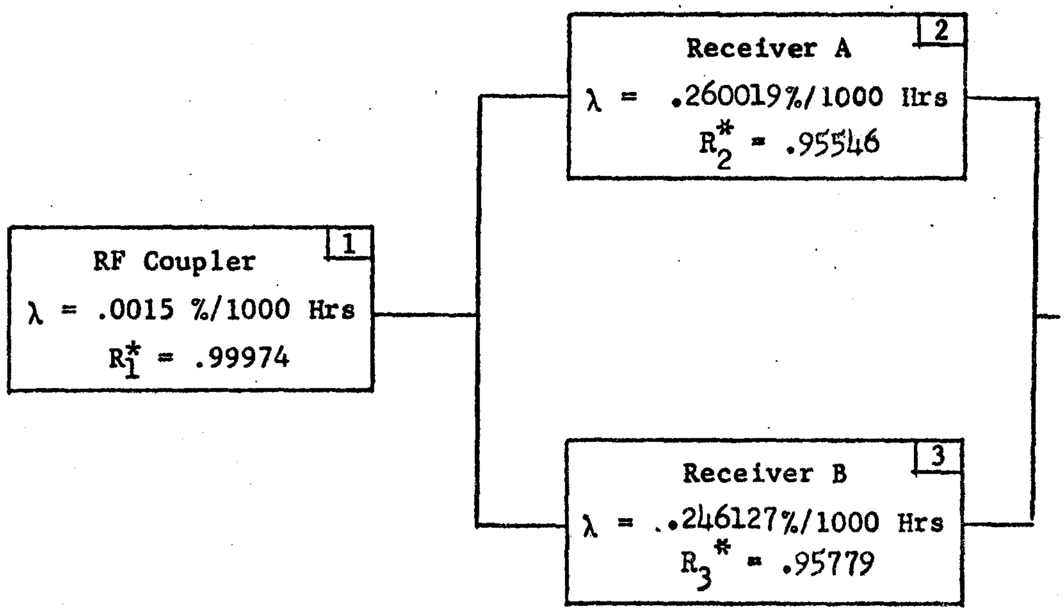


Figure 2

ALSEP Redundant Command Receiver Reliability Block Diagram



FORMAT 1



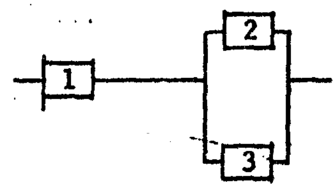
FORMAT 2

$^{*}R = \exp[-\lambda(17520 \text{ Hours})]$

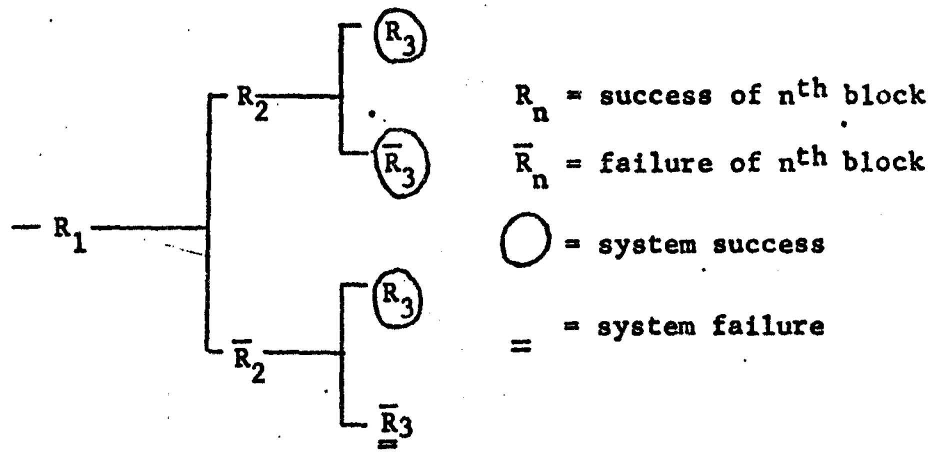
<u>Figure 3</u>

Simplified Reliability Block Diagram

Reliability Block Diagram:



Reliability Logic Diagram:



Math Model:

FORMAT 1 $R = R_1 R_2 R_3 + R_1 R_2 \bar{R}_3 + R_1 \bar{R}_2 R_3$

$= R_1 R_2 [R_3 + \bar{R}_3] + R_1 \bar{R}_2 R_3$

$= R_1 [R_2 + (1 - R_2) R_3]$

$= [.99974] [.95661 + .04339 (.95894)]$

$= .99795$

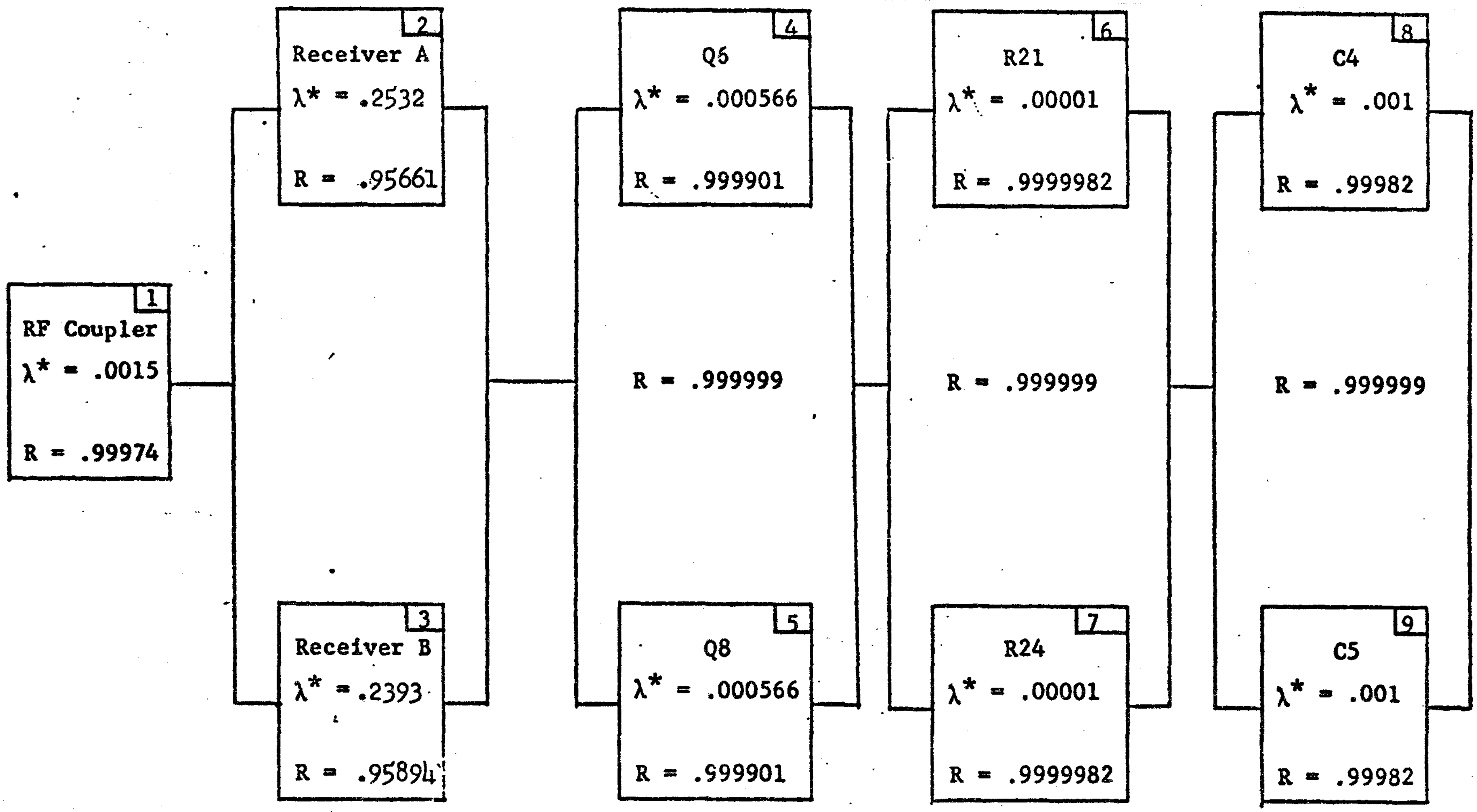
FORMAT 2 $R = R_1 [R_2 + (1 - R_2) R_3]$

$= [.99974] [.95546 + (.04454) (.95779)]$

$= .99786$

<u>Figure 4</u>

Logic Diagram and Math Model



*%/1000 Hrs

FORMAT 1

<u>Figure 5</u>

Reliability Block Diagram Including Part Redundancy

APPENDIX A

FMECA Sheets

APPENDIX A IS ON FILE WITH ORIGINAL MOTOROLA DOCUMENT #3875/038