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MULTIFREQUENCY MICROWAVE RADIOMETER (MFMR)

L-BAND MODIFICATION

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Prepared by

Lockheed Electronics Company, Inc.
Houston Aerospace Systems Division
Houston, Texas

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for

EXPERIMENTS SYSTEMS DIVISION

LYNDON B. JOHNSON SPACE CENTER

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L-BAND MODIFICATION

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PREFACE

This document was prepared by Lockheed Electronics Company, Inc., Houston Aerospace Systems Division, under contract NAS-9-12200, Job Order 44-965, and was issued at the Lyndon B. Johnson Space Center, Houston, Texas in accordance with Action Document Number 44-965-018. Acknowledgment is made to S. C. Reid of the Lockheed Electronics Company for preparing this report and to B. J. Doehring and C. H. Solie for their assistance.

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1.0 INTRODUCTION

1.1 Objective

It has been determined by laboratory and flight tests and through consultation with scientific users that the Multifrequency Microwave Radiometer (MFMR) is inadequate in its ability to accurately measure radiometric brightness temperature. This report describes the redesign of the L-Band part of the MFMR to provide an instrument with improved sensitivity and accuracy.

1.2 Background

The MFMR was procured as an Earth Resources Aircraft Program Sensor in 1967. Since that time, it has been used with varying degrees of success as an operational aircraft instrument. As a result of its usage several specific design deficiencies have been uncovered which have lead to this redesign effort.[1]

1.3 Summary

The redesign of the L-Band MFMR results in elimination of the design deficiencies known to have existed in the Radiometer System. Considerable improvement in system accuracy and resolution can be expected as shown in the analyses in Sections 2 and 5.

2.0 SYSTEM CONSIDERATIONS

2.1 Sensitivity

The sensitivity of a microwave radiometer, as defined by Moore[2] is "the RMS minimum detectable antenna temperature variation". This limit of the temperature resolution of the radiometer is given by Hach[3] for the case of an AGC stabilized Dicke Radiometer similar in design to the one employed in the L-Band receiver. The expression given by Hach can be simplified to the form given in equation (1) below, since the AGC integration time used is greater then 100 times the signal integration time.

$$\Delta T_{RMS} = \left(\frac{(T_H + T_r)^2 + (T_c + T_r)^2 + 2(T_B' + T_r)^2}{2B\tau} \right)^{1/2} \qquad (1)$$

where T_H is the Hot Reference Temperature

T_c is the Cold Reference Temperature

T_r is the Receiver Noise Temperature

T_B' is the equivalent observed Brightness Temperature

B is the Pre-Detection Bandwidth

τ is the Post-Detection Signal Integration Time

Application of equation (1) to the modified L-Band system indicates theoretical resolutions of 0.5° K to 0.7° K for brightness temperatures from 50° K to 450° K.

2.2 Accuracy

The major contributing factors to the absolute accuracy limitation of a radiometer are: those measurement uncertainties associated with radome, antenna and transmission line losses, the mismatch loss uncertainties due to the unknown phase of the finite interface VSWR's, the accuracy of the determination of the receiver transfer characteristics and the receiver gain stability.

Reduction of the uncertainty in the measurement of radome loss can be accomplished by use of the techniques described by Seidel and Stelried[4] and in the measurement of antenna loss by the technique described by Paris.[5]

The obvious method for reduction of mismatch loss uncertainties is to provide minimum interface VSWR's. To this end, the antenna, transmission line and the receiver designs require VSWR of less than 1.1:1.

To accurately determine the receiver transfer characteristic a two-point reference noise generator technique will be used to calibrate the radiometer receiver. To insure that the calibration remains valid, accurate internal reference noise generators are used to provide the Dicke reference temperature and the AGC reference temperature.

The receiver is gain stabilized by use of an AGC loop which is controlled by the two fixed reference temperatures.

The receiver is thus insensitive not only to receiver gain changes, but also to fluctuations of other relevent receiver parameters, such as, thermal noise, bandwidth and square-law detector sensitivity.

2.3 Gain Distribution

To establish the gain distribution of the receiver, the initial consideration is to provide input levels to the square-law detector over its linear operating range. From testing of the detector to be used, the optimum power level into the detector has been determined to be -30 dBm. To provide this level, the required predetection gain for a 3 dB noise figure, 27 MHz bandwidth preamplifier is 70 dB.

Since the detector sensitivity is 1 mv/μw the output of the detector for a -30 dBm input signal is 1 mv. To provide a nominal output voltages in the range of 4 volts the processor gain would have to be about 4000 times (72 dB). The exact value of this gain will be optimized at time of test. The AGC voltage provides approximately 6 dB of gain control in a variable gain amplifier to compensate for gain changes in either the pre-detection or post-detection amplifiers.

The Signal Flow Analysis diagrams are contained in Appendix A.

3.0 IMPLEMENTATION

3.1 Antenna

The antenna to be used is a low-profile planar array which is sealed in an environmental radome. The array is constructed from a single sheet of copper-clad polyolefin which is etched to form the dipole radiators and feedlines. The etched sheet is center fed by a balanced-line to coaxial-line transition. The sheet is sandwiched between two layers of closed cell polyurethene foam and is backed by a reinforced aluminum ground plane. The front of the array is closed with a protective radome of fiberglass. Additional fiberglass skins are bonded to the sides of the structure to provide an enviornmental seal. The antenna is being purchased from Airborne Instruments Laboratories of Melville, L. I., New York, who has provided similar antennas for S-194 and the Mississippi Test Facility.

The specification for the antenna is included in Appendix B.

3.2 Receiver

A block diagram of the modified L-Band Receiver is shown in figure 1.

The radiometric temperature from the antenna is applied to the L-Band Receiver where it is switched by a Dicke Switch at a 500 Hz rate. The reference temperature input

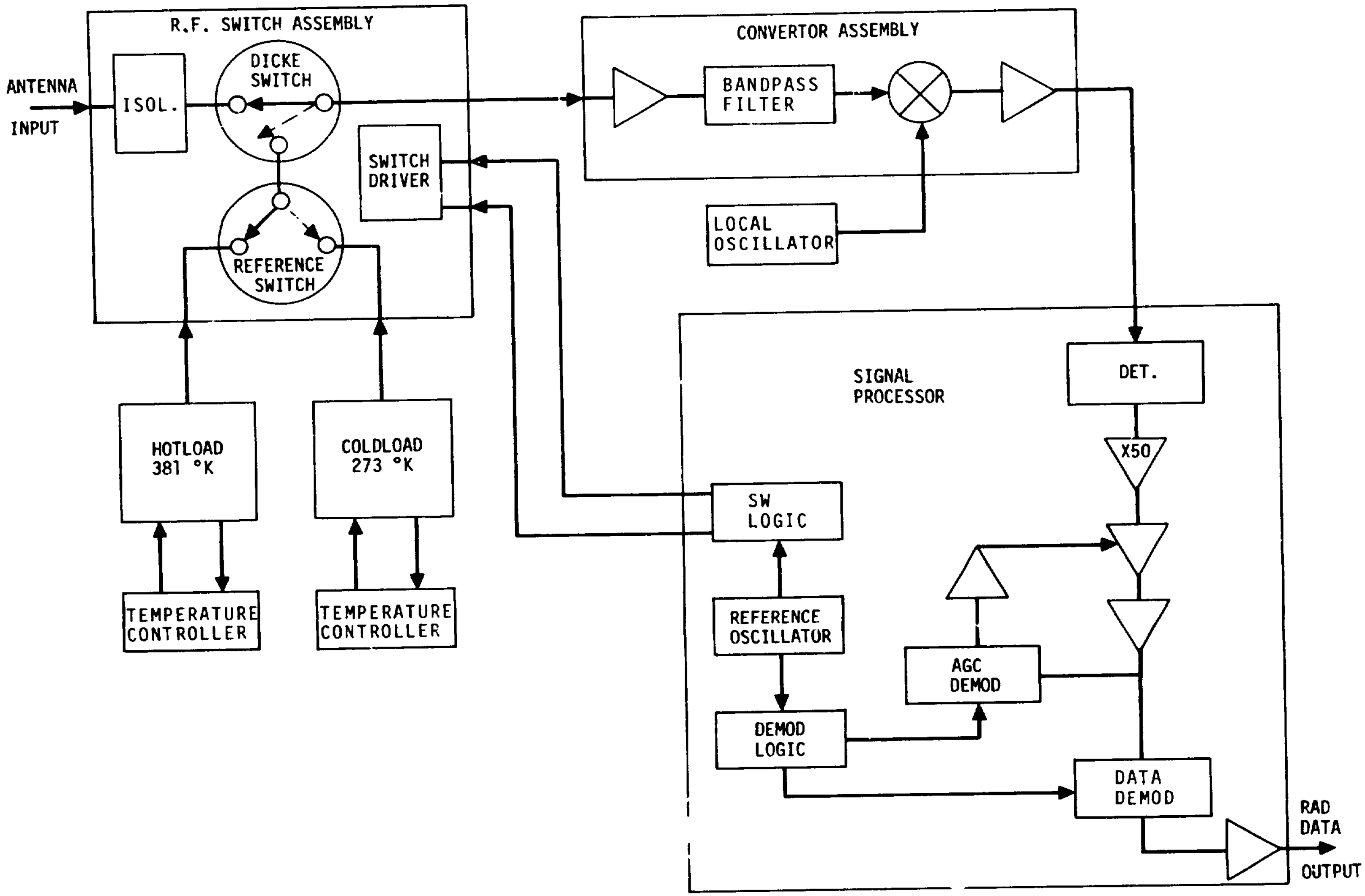

Figure 1. — MFMR L-band RCVR block diagram.

to the Dicke Switch (the alternate input) is switched by the Reference Switch at a 250 Hz rate between calibrated Hot and Cold Reference Loads.

The Dicke Switch, the Reference Switch and their switch drivers are contained in the R. F. Switch Assembly. The intregral switch approach used provides for optimum matching of components to obtain the desired high isolation, low loss and low VSWR required to meet the sensitivity, stability and accuracy requirements of the L-Band Receiver.

The specifications for the Switch Assembly are included in Appendix B. The Switch Assembly used has been purchased from Electromagnetic Sciences Laboratory of Atlanta, Ga. who has provided similar switches for the Nimbus E five-channel Radiometer System.

Hot (381° K) and Cold (273° K) Reference Loads are alternately switched by the Reference Switch to provide the Reference Temperature input. These loads provide an accurate and stable reference signal to the radiometer system. The specifications for the loads and their temperature controllers are included in Appendix B. They are being purchased from Airborne Instruments Laboratories of Melville, L. I., New York, who has provided many similar calibrated temperature sources to NASA and industry.

The low level noise signal output of the switch assembly is applied to the input of the Converter Assembly.

The Converter Assembly consists of a low noise preamplifier, a bandpass filter, an image rejection mixer and an

I. F. Amplifier. The input signal is amplified by 70 dB, down-converted to 60 MHz and bandwidth limited to 27 MHz in the Converter Assembly. The specification for the Converter Assembly is contained in Appendix B. It is being purchased from Amplica, Inc. of Westlake Village, California as an integral unit. The use of a combined R. F. Amplifier - Filter - Mixer - I. F. Amplifier provides for optimum design of the Reveiver Front End and eliminates the normally inherent front end interface problems.

The Local Oscillator signal required for frequency conversion in the mixer is obtained from a solid state oscillator retained from the original design. The effects of L. O. to Mixer mismatch are minimized by the use of a 10 dB attenuator at the mixer input.

The 60 MHz I. F. Signal from the Converter Assembly is applied to the Signal Processor where it is first square-law detected by an Aertech DX 872 Tunnel Diode Detector and them amplified and synchronously demodulated. The specification for the tunnel diode detector is included in Appendix B. The expected signal level applied to the square-law detector is from -33 dBm to -25 dBm, a level well within the square-law range of the detector.

The detected square-wave modulated noise signal is applied to the audio circuits (See figure 2 for block diagram) in the Signal Processor where it is amplified by a low noise Fairchild UA 739 I. C. whose gain is Automatic Gain Controlled (AGC) about a nominal value of times 5,000. The signal is then phase inverted, buffered and applied to the Data and AGC Synchronous Demodulators where

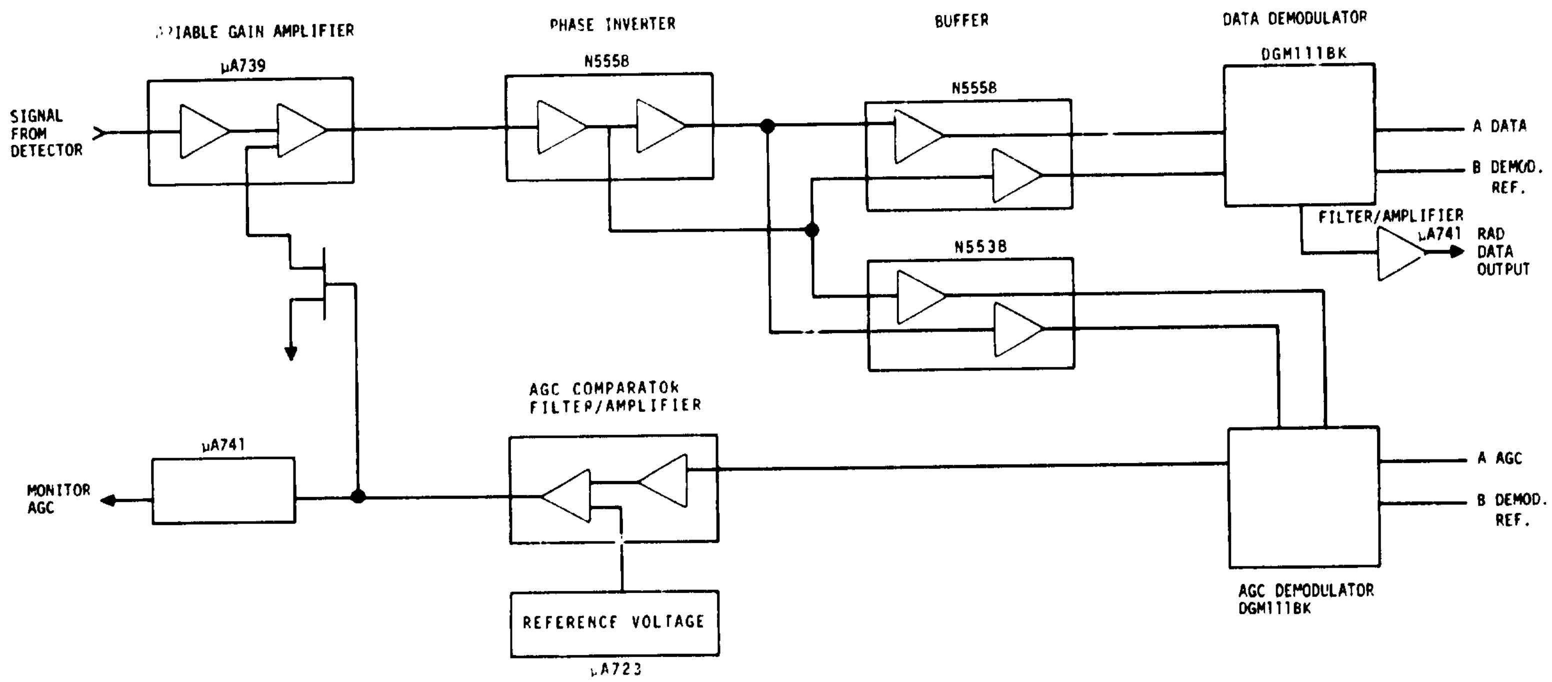

Figure 3. — Signal processor block diagram.

it is compared with the synchronous reference signals from the logic circuits. The output signal of the Data Demodulator is filtered, amplified, baseline offset by a Fairchild μA 741 I. C. and delivered as radiometer data output of the Receiver. The output signal of the AGC Demodulator is filtered, amplified and compared to a stable reference before being fed back to the variable gain amplifiers.

The logic circuits (see figure 3 for logic diagram) in the Signal Processor provide the switching signals for the R. F. Switch Assembly and the Synchronous Demodulators in the audio circuits of the Signal Processor Assembly. A MC 4024 I. C. acts as a 1 kHz Reference Oscillator which is the source of all L-Band Receiver timing signals. The 500 kHz and 250 Hz R. F. Switch signals are divided down from the 1 kHz signal by an I. C. and gated by the switch logic prior to application to the R. F. Switch Assembly. A demodulator blanking signal is also developed to prevent demodulator operation during R. F. Switch transfer time. The blanking signal together with the mode command signals from the Control Panel and the 500 Hz and 250 Hz timing signals is applied to the demodulator logic for development of synchronous demodulator timing signals. Figures 4 through 7 illustrate the timing sequences provided by the logic circuits in the system operational modes.

The layout of the Receiver components within the existing enclosure is shown in figure 8. The R. F. Switch Assembly, Converter Assembly and Reference Loads are located so that the R. F. cables are of minimum length. Low loss and low VSWR OSM connectors and semi-rigid 0.141 cable are used throughout the Receiver.

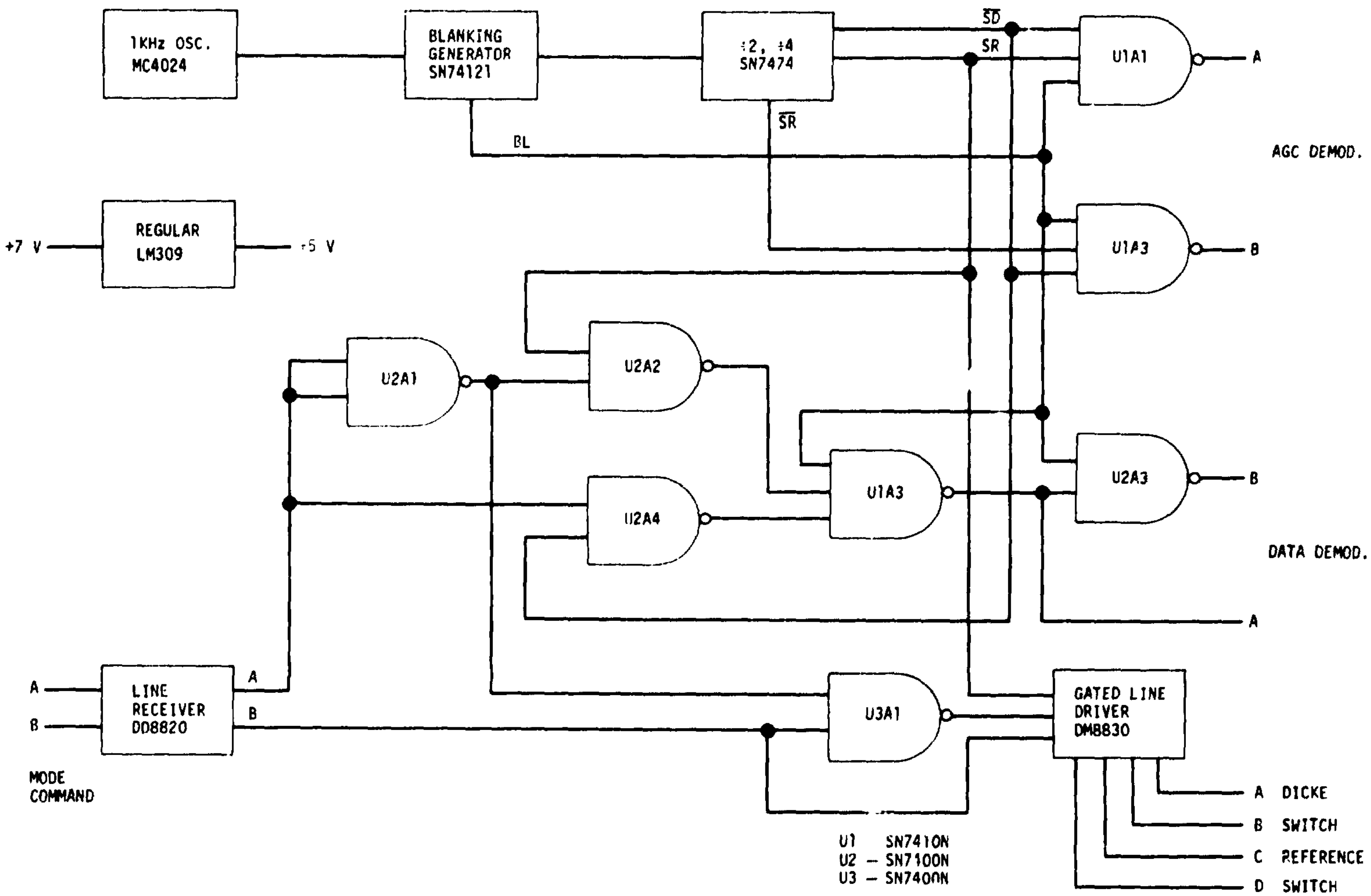

Figure 3. — Logic diagram.

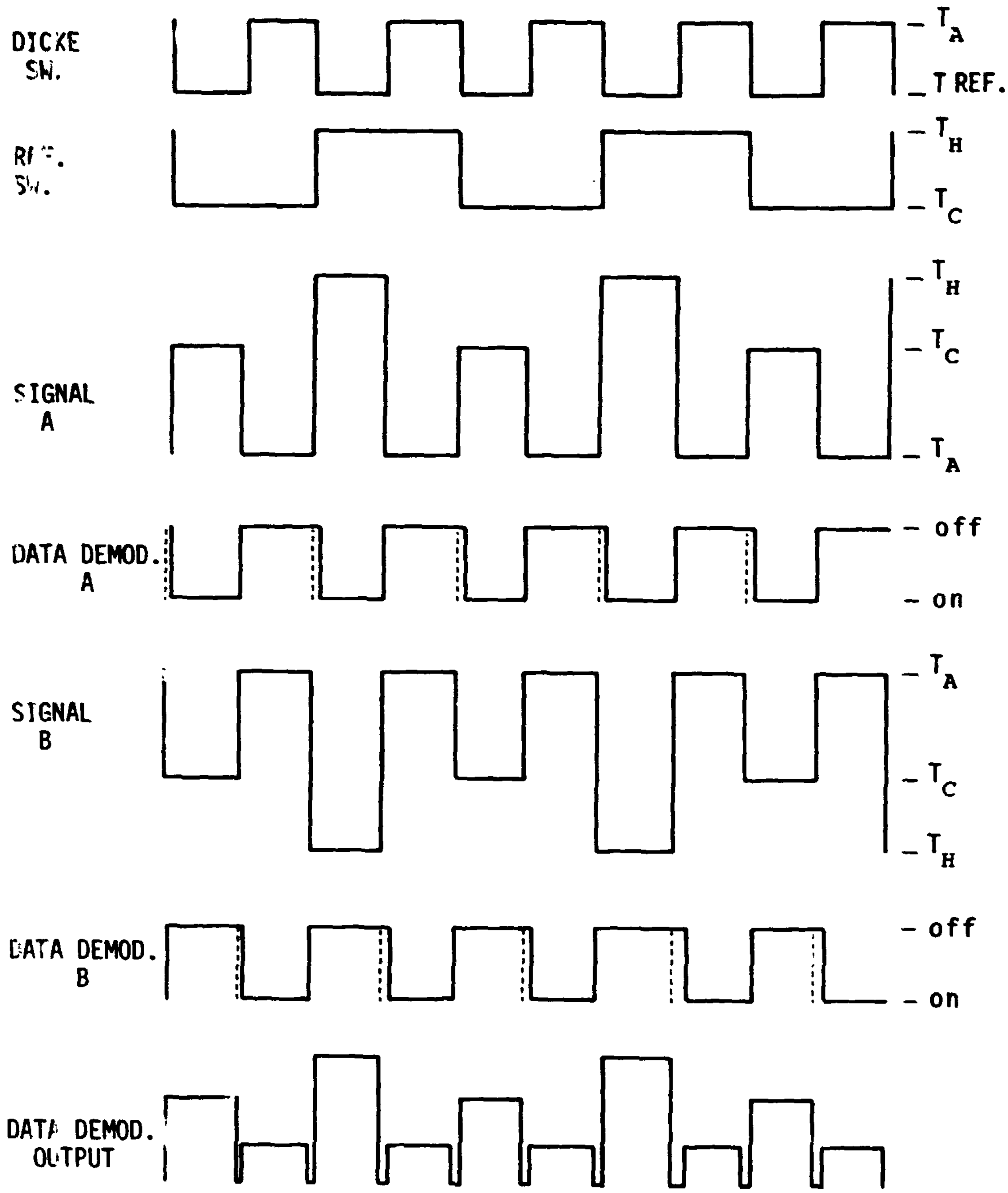

Figure 4. – Operate mode data demodulation timing chart.

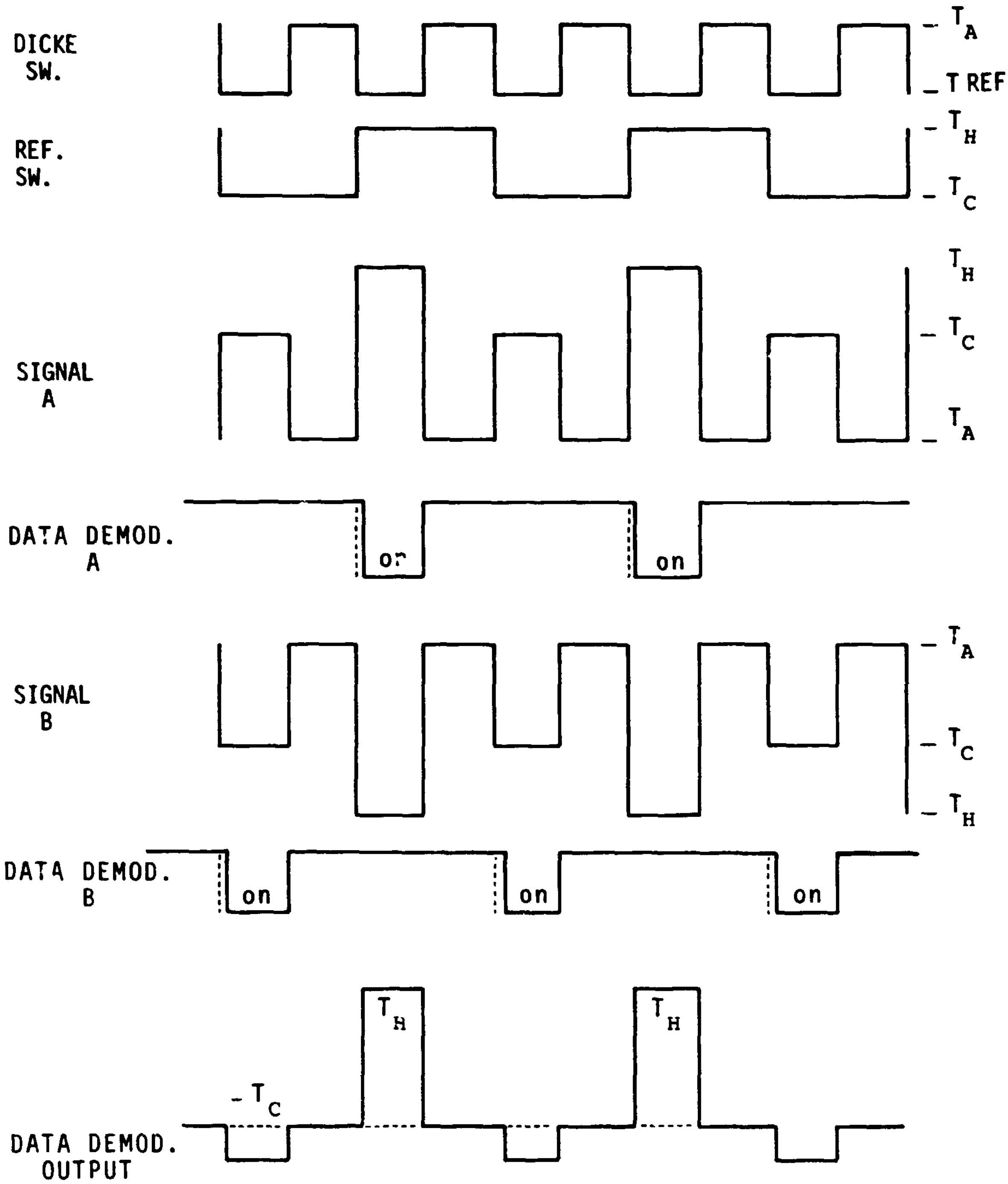

Figure 5. — Calibrate mode data demodulation timing chart.

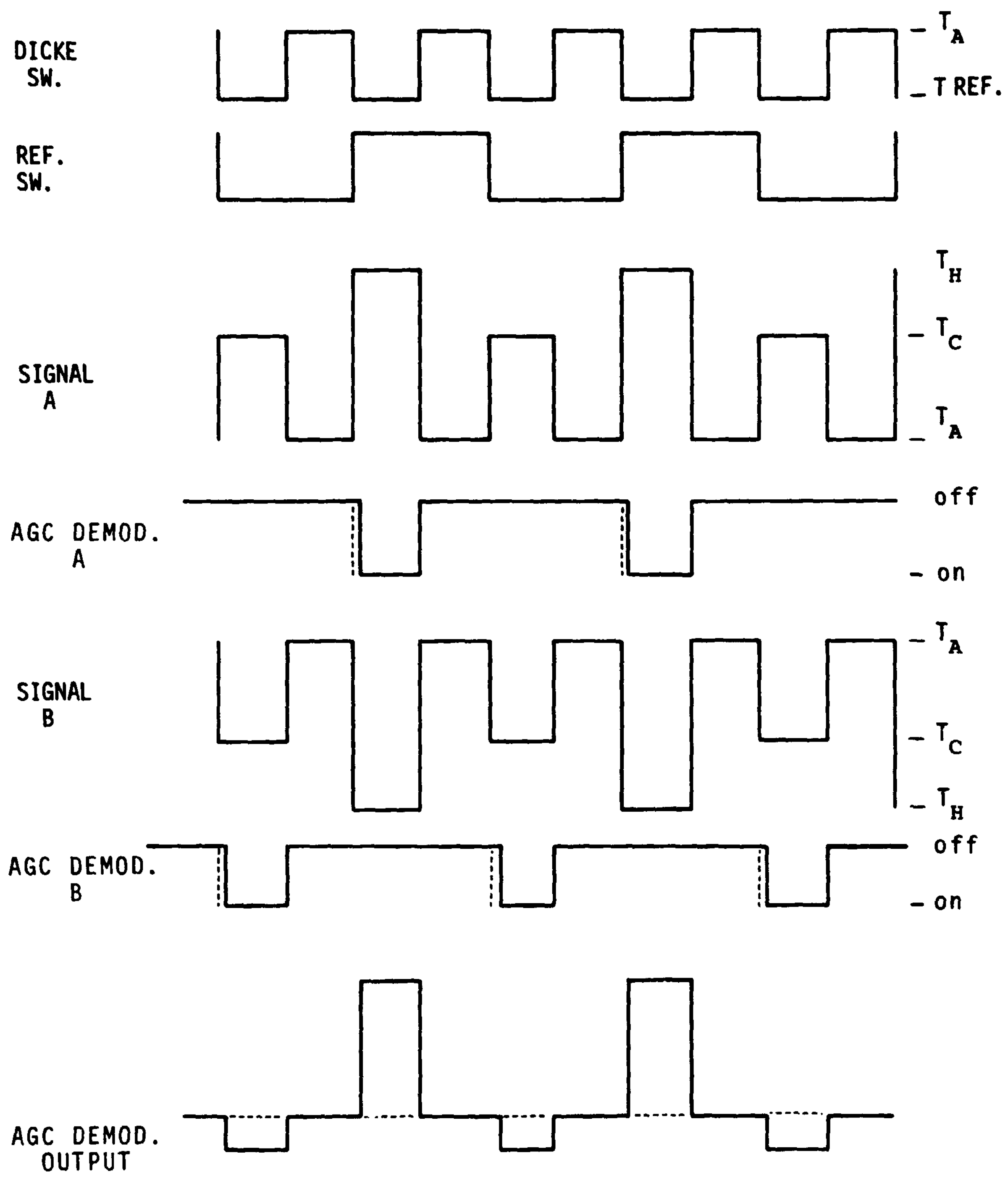

Figure 6. — Operate mode AGC demodulation timing chart.

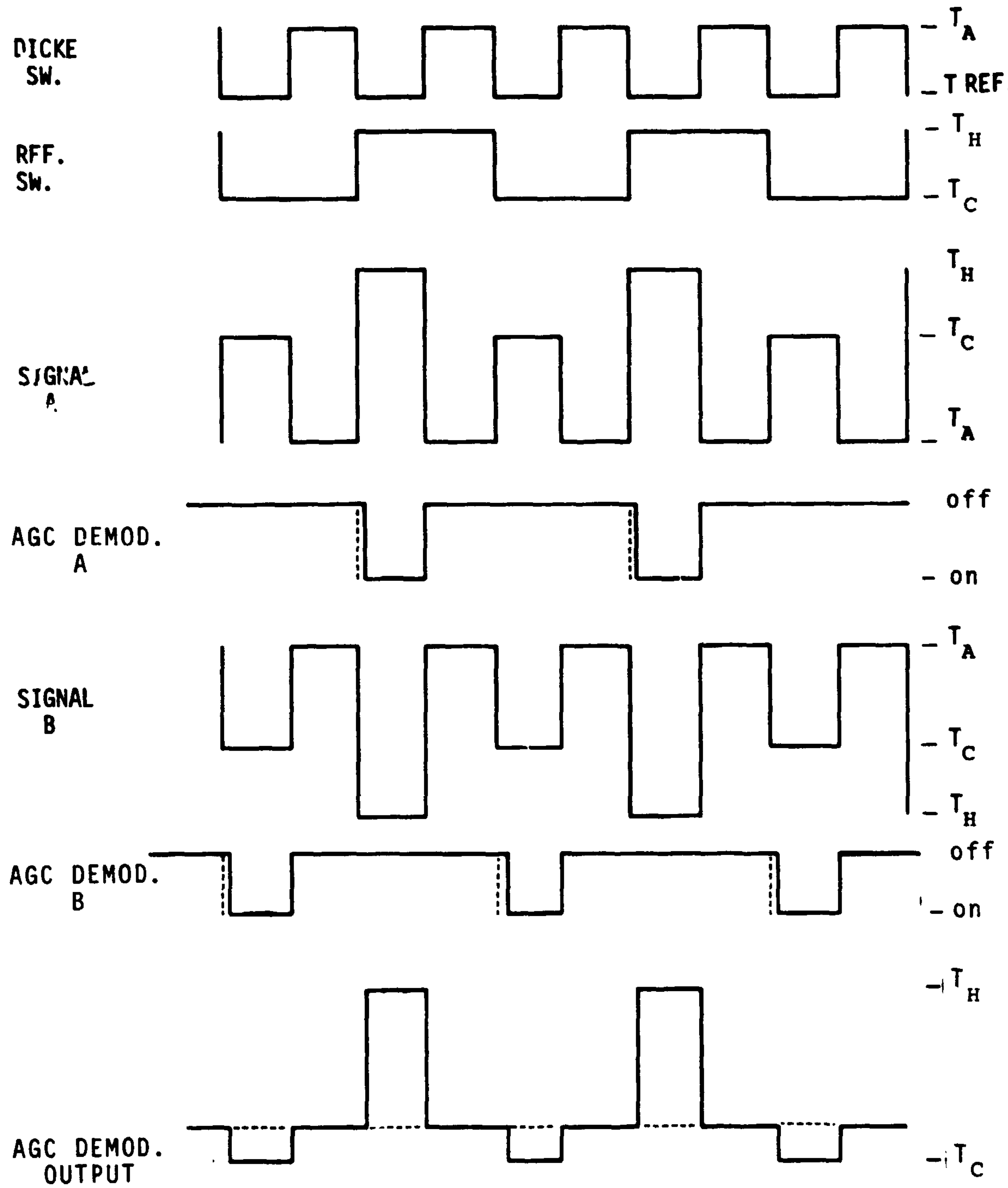

Figure 7. – Calibrate mode AGC demodulation timing chart.

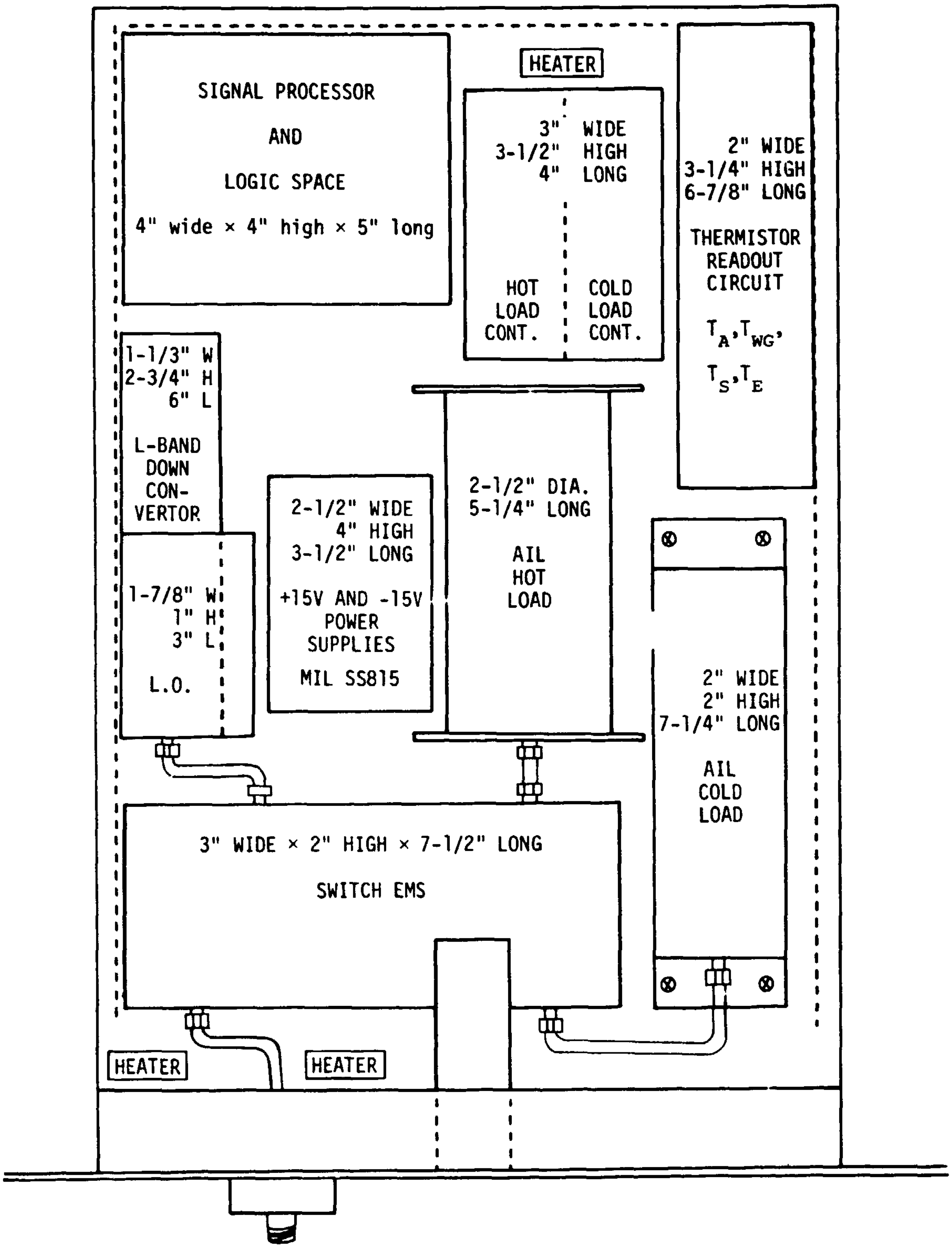

Figure 8. — MFMR receiver layout.

Heaters will be located so as to provide a stable temperature for the critical R. F. components. Thermistor temperature sensors are located on the R. F. Switch Assembly, the Hot Load and the Cold Load to provide accurate temperature information for data reduction.

4.0 CALIBRATION EQUATION

The block diagram of the radiometer receiver is shown in figure 1. The Dicke Switch position is alternately changed from the equivalent observed radiometric temperature, input T_B', to either of two fixed reference temperatures, T_H or T_C. During one period, τ, of the Dicke Switch T_B' is observed two times and both T_H and T_C are each observed once. The converter assembly with a gain, G, a bandwidth, B, and a Noise Temperature, T_r, applies this switched signal to a square-law detector with a sensitivity, η.

The square-law detector output voltage can be described by:

$$v(t) = kBG\eta \begin{Bmatrix} T_C + T_r & 0 \le t \le \frac{\tau}{4} \\ T_B' + T_r & \frac{\tau}{4} \le t \le \frac{\tau}{2} \\ T_H + T_r & \frac{\tau}{2} \le t \le \frac{3\tau}{4} \\ T_B' + T_r & \frac{3\tau}{4} \le t \le \tau \end{Bmatrix} \qquad (2)$$

where $v(t)$ is the output voltage as a function of the period τ .

k is Boltzmann's constant.

B is the pre-detection bandwidth.

G is the pre-detection gain.

η is the detector sensitivity.

This voltage is amplified by a variable gain amplifier and synchronously demodulated by the (ta and AGC demodulators. The synchronous detector outputs can be written:

$$V_{AGC} = \frac{kBGng_0 g_{agc}}{4} [T_H - T_c] \tag{3}$$

$$V_{data} = \frac{kBGng_0 g_{data}}{4} [T_H + T_c - 2T'_B] \tag{4}$$

where g_0 is controlled voltage gain, g_{agc} is agc gain, and g_{data} is data gain.

From equation (3)

$$g_0 = \frac{4V_{AGC}}{kBGng_{agc}[T_H - T_c]} \tag{5}$$

substituting in equation (4) for g_0 results in:

$$V_{data} = V_{agc}\left(\frac{g_{data}}{g_{agc}}\right)\left(\frac{T_H + T_c - 2T'_B}{T_H - T_c}\right) \tag{6}$$

An offset d.c. level E_{0B} is added to V_{data} and from laboratory calibration the values of $\left(V_{agc}\,\frac{g_{data}}{g_{agc}}\right)\left(\frac{1}{T_H - T_c}\right)$, defined as S and (T_H+T_c) defined as T'_R can be determined. Thus E_{0A}, the radiometer output can be written:

$$E_{0A} = S[T'_R - 2T'_B] + E_{0B} \tag{7}$$

Laboratory calibration to obtain accurate values for S and T'_R is accomplished using secondary standard radiometric noise generators (RNG). The output voltage is measured using these known inputs and is expressed as follows:

$$E_{OA(CL)} = S[T'_R - 2T_{cL}] + E_{OB} \quad (8)$$

$$E_{OA(HL)} = S[T'_R - 2T_{HL}] + E_{OB} \quad (9)$$

$$E_{OA(CL)} - E_{OA(HL)} = -S[2T_{cL} - 2T_{HL}] \quad -(9)$$

$$S = \frac{E_{OA(CL)} - E_{OA(HL)}}{2[T_{HL} - T_{cL}]} \quad (10)$$

$$E_{OA(CL)} + E_{OA(HL)} = S[2T'_R - 2T_{cL} - 2T_{HL}] + 2E_{OB} \quad (8) + (9)$$

$$E_{OA(CL)} + E_{OA(HL)} - 2E_{OB} = 2S[T'_R - T_{cL} - T_{HL}]$$

$$\left(\frac{E_{OA(CL)} + E_{OA(HL)} - 2E_{OB}}{2S}\right) + (T_{cL} + T_{HL}) = T'_R \quad (11)$$

From equation (7):

$$E_{0A} = S[T'_R - 2T'_B] + E_{0B}$$

$$E_{0A} - E_{0B} = ST'_R - 2ST'_B$$

$$2ST'_B = ST'_R - E_{0A} + E_{0B}$$

$$T'_B = \frac{T'_R + \dfrac{E_{0B} - E_{0A}}{S}}{2} \qquad (12)$$

and from the expression for an observed temperature through losses:

$$T'_B = \frac{T_B}{L_R L_A L_L} + \frac{(L_R - 1)T_R}{L_R L_A L_L} + \frac{(L_A - 1)T_A}{L_A L_L} + \frac{(L_L - 1)T_L}{L_L} \qquad (13)$$

$$T_B = L_R L_A L_L T'_B - (L_R - 1)T_R - (L_A - 1)T_A L_R - (L_L - 1)T_L(L_A L_R) \qquad (14)$$

where T_B is the observed brightness temperature, and T'_B is the equivalent brightness temperature.

Assuming values for:

L_R = 0.325 dB (1.10786) , T_R = 280° K (Radome Loss)

L_A = 0.5 dB (1.122) , T_A = 290° K (Antenna Loss)

L_L = 0.2 dB (1.0423) , T_L = 300° K (Line Loss)

Results in:

$$T_B = 1.3\ T'_B - 85.2 \tag{15}$$

substituting equation (12) into (15) we get:

$$T_B = 1.3\left[\frac{T'_R + \frac{E_{OB} - E_{OA}}{S}}{2}\right] - 85.2 \tag{16}$$

Assigning values of $T_B = 50°$ K providing an E_{OA} of 4.5 V; and assigning $T_B = 450°$ K providing an E_{OA} of 0.5 V results in a value for E_{OB} of 1.615 volts.

5.0 ERROR ANALYSES

In the discussion that follows, radiometric accuracy is defined as the probable error in the determination of the equivalent brightness temperature seen by the radome of the system. Denoting the total probable error of the quanity Y, by PEY, and the probable error of the quanity Y due to the probable error in one of the parameters Xi that composes Y, by PEY/Xi we have:

$$PEY/Xi = PEX_i \left|\frac{\partial Y}{\partial X_i}\right| \tag{17}$$

and

$$PEY = \left[\sum_i \left(PEX_i \left|\frac{\partial Y}{X_i}\right|\right)^2\right]^{1/2} \tag{18}$$

Since we desire to determine the probable error in the measurement of the observed brightness temperature T_B , the probable error of each of its constituent components must first be defined. The errors c n be divided according to their sources as follows: R. F. Component Uncertainty errors, Calibration errors and Electronics errors.

The errors due to R. F. Component Uncertainties that will be considered are: radome, antenna and line losses and temperatures. The observed brightness temperature can be expressed as:

$$T_B = L_R L_A L_L [S'(E_{OA} - E_{OB}) + T_R']$$

$$- (L_R - 1)T_R - (L_A - 1)L_R T_A - (L_L - 1)L_R L_A T_L \qquad (19)$$

Taking $\frac{\partial T_B}{\partial (\ )}$ of equation (19) results in:

$$\frac{\partial T_B}{\partial L_R} = L_A L_L [S'(E_{OA} - E_{OB}) + T_R' - T_L]$$

$$+ L_A(T_L - T_A) + (T_A - T_R) \qquad (20)$$

$$\frac{\partial T_B}{\partial L_A} = L_R L_L [S'(E_{OA} - E_{OB}) + T_R' - T_L] + L_R(T_L - T_A) \qquad (21)$$

$$\frac{\partial T_B}{\partial L_L} = L_R L_A [S'(E_{OA} - E_{OB}) + T_R' - T_L] \qquad (22)$$

$$\frac{\partial T_B}{\partial T_R} = -(L_R - 1) \qquad (23)$$

$$\frac{\partial T_B}{\partial T_A} = -(L_A - 1)L_R \qquad (24)$$

$$\frac{\partial T_B}{\partial T_L} = -(L_L - 1)L_R L_A \qquad (25)$$

Uncertainties in the phases of VSWR's at the antenna-line interface and at the line-receiver interface will be treated as uncertainties in mismatch loss and will be combined as an additional error source. Using the expected values for the parameters and evaluating (20) through (25) results in the values for $\frac{\partial T_B}{\partial(\ )}$ tabulated in Table I.

TABLE I.- VALUES FOR $\frac{\partial T_B}{\partial(\ )}$

	Old Ant. $T_B = 100$	Old Ant. $T_B = 350$	New Ant. $T_B = 100$	New Ant. $T_B = 350$
$\left\lvert\frac{\partial T_B}{\partial L_R}\right\rvert$	262	36	197	29
$\left\lvert\frac{\partial T_B}{\partial L_A}\right\rvert$	193	36	193	36
$\left\lvert\frac{\partial T_B}{\partial L_L}\right\rvert$	248	33	186	27
$\left\lvert\frac{\partial T_B}{\partial T_R}\right\rvert$	.11	.11	.11	.11
$\left\lvert\frac{\partial T_B}{\partial T_A}\right\rvert$	.55	.55	.13	.13
$\left\lvert\frac{\partial T_B}{\partial T_L}\right\rvert$	.07	.07	.05	.05

Calibration errors are the result of the radiometric accuracy of the calibration source and the mismatch uncertainty associated with differences in source impedance between the calibration source and the actual system. Since the sources to be used have a radiometric accuracy of 1° K and a source VSWR of 1.05:1 the calibration error is 2° K.

The electronics errors are the result of resolution of the radiometer and the associated data system. Both the radiometer resolution and the least significant bit of the data system are approximately 1/2° K thus the electronics error is 1° K. Table II is a tabulation of the error sources and the resultant system accuracy.

TABLE II.– ERROR SOURCES AND RESULTANT SYSTEM ACCURACY

$$\left(PE\left|\frac{\partial T_B}{\partial(\ )}\right|\right)^2$$

Uncertainty	PE	Old Ant. $T_B \to 100$	Old Ant. $T_B \to 350$	New Ant. $T_B \to 100$	New Ant. $T_B \to 350$
Radome Loss	±.05 dB	27.4	0.5	16	0.4
Antenna Loss	±.05 dB	15	0.5	15	0.5
Line Loss	±.01 dB	1	–	0.5	–
Radome Temp.	±1° K	–	–	–	–
Ant. Temp.	±1° K	1	1	1	1
Line Temp	±1° K	–	–	–	–
Ant./Line VSWR	(1.5:1)	372	13	2.5	0.1
Line/RCVR VSWR	(1.1:1)	0.2	–	0.2	–
Calibration	2° K	4	4	4	4
Receiver	1° K	1	1	1	1
$\sum$		421.6	20.0	40.2	7.0
PE T_B(°K)		20.5	4.5	6.4	2.7

6.0 REFERENCES

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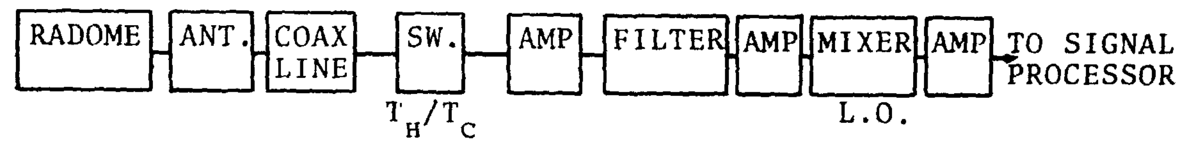
APPENDIX A

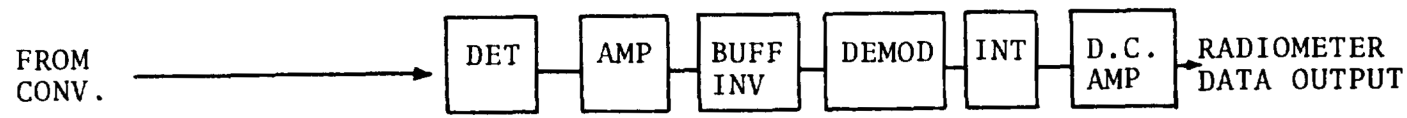
SIGNAL FLOW ANALYSIS DIAGRAMS

FOR THE MFMR L-BAND MODIFICATION



		RADOME	ANT.	COAX LINE	SW.	AMP	FILTER	AMP	MIXER	AMP	TO SIGNAL PROCESSOR
Center Freq.	MHz	1413.6							60	60	60
3 dB B.W.	MHz	—	—	—	—	100	27	100	60	60	27
Gain (Loss)	dB	(.325)	(.5)	(.2)	(.8)	20	(4)	20	(6)	40	—
VSWR		—	1.1:1	1.1:1	1.1:1	1.1:1	—	—	—	—	—
Isolation	dB	—	—	—	30	—	—	—	30	—	—
Operating Temp.	°K	280	290	300	328						
Component Noise Fig.	dB	—	—	—	—	2.8	—	3	6	3	—
System Temp.	°K			450	—	290	—	—	—	—	—
Noise Power Max. (450 T_A)	dBM				-95.8	—	—	—	—	—	-25.8
Noise Power Min. (50 T_A)	dBM				-98.3	—	—	—	—	—	-28.3
Noise Voltage (Max.)	mv										
Noise Voltage (Min.)	mv										

Signal Flow Analyses Diagram



		DET	AMP	BUFF INV	DEMOD	INT	D.C. AMP	RADIOMETER DATA OUTPUT
Center Freq.	Hz	60 MHz 500						
3 dB B.W.	kHz	27 MHz 10	10	10				
Gain (Loss)	dB	—	72	0	—	—	5	—
Voltage Gain		—	4000	1	—	—	1.765	—
$T_R + T_H$	mV	2.455	—	9.82V	—	—	—	—
$T_R + T_C$	mV	2.138	—	8.552V	—	—	—	—
Noise Voltage Max. (450 T_A)	mV	2.630	—	-10.52V	—	Volts -.667	—	0.5
Noise Voltage Min. (50 T_A)	mV	1.479	—	-5.916V	—	Volts +1.635	—	4.5
η	mV/μV	1/1						

Signal Flow Analysis Diagram (Concluded)

APPENDIX B

TECHNICAL SPECIFICATIONS FOR THE PURCHASED SUBASSEMBLIES USED IN THE MFMR L-BAND MODIFICATION

TECHNICAL SPECIFICATION FOR A L-BAND ANTENNA

1.0 SCOPE

This specification sets forth the requirements for a Low Loss L-Band Antenna to be used as part of an Aircraft Microwave Radiometer System.

2.0 ELECTRICAL REQUIREMENTS

2.1 Frequency Band - 1.400 to 1.427 GHz

2.2 VSWR - $\leq$ 1.1:1 over frequency band

2.3 Beam Efficiency - 90% min.

2.4 Beam Width (3db) - $\leq 17^{\circ}$

2.5 Beam Width (null to null) $\leq 42^{\circ}$

2.6 Sidelobe Level $>$ 20db below main beam peak

2.7 Cross Polarization Level $>$ 30 db below linear polarized main beam

2.8 Insertion Loss - 0.5 db (max)

2.9 Polarization - Vertical linear

3.0 MECHANICAL REQUIREMENTS

3.1 Weight - $\leq$ 40 pounds

3.2 Depth - $\leq$ 5 inches

3.3 Envelope Dimensions - per DWG # SLE-39103063

3.4 Temperature Sensors - The antenna will contain a temperature sensor mounted so as to monitor the temperature of the antenna loss and shall be either part #YSI 44011 or YSI 15135 manufacturered by Yellow Springs Instrument Company, Yellow Springs, Ohio.

3.5 R.F. Connector - A female type N connector shall be used.

4.0 ENVIRONMENTAL REQUIREMENTS

4.1 Temperature: Non-operate - $-62^{\circ}C$ to $+68^{\circ}C$

Operate - $-50^{\circ}C$ to $+50^{\circ}C$

4.2 Altitude: Sea Level to 30,000 feet

4.3 Humidity: up to 100% relative humidity.

4.4 Vibration: per MIL-E-5400K, Curve 1 except acceleration level to be ± 2.5 g peak.

4.5 Shock: 10 g's each axis, duration of 11 m seconds.

5.0 TEST REQUIREMENTS

The antenna specified herein shall be tested for conformance to the requirements of Paragraph 2. The testing shall be monitored and verified by the Vendor's Quality Assurance Representative and may be monitored by the purchaser or his representative. Conformance to the requirements of Paragraph 4 need not be demonstrated by the vendor, however, shall be guaranteed by the vendor.

6.0 DELIVERABLE DATA

Deliverable data as a minimum shall consist of the test plan and test results of Paragraph 5.

TECHNICAL SPECIFICATIONS FOR L-BAND LOW NOISE DOWN CONVERTER

1.0 SCOPE

This specification sets forth the requirements for an L-Band Low Noise Frequency Down Converter Assembly. The Converter Assembly shall be an integral unit and shall consist of an RF limiter, an RF amplifier, a bandpass filter, a mixer and an IF amplifier with variable gain. The RF bandwidth shall be developed by the RF amplifier and the bandpass filter and prior to the mixer input.

2.0 ELECTRICAL SPECIFICATIONS (for ambient temperature of +50°C ± 2.0°C).

2.1. R.F. Center Frequency: 1.4135 GHz ± 0.5 MHz

2.2 R.F. Bandwidth (-3db points): 27 MHz minimum.

2.3 R.F. Bandwidth (-60db points): 36 MHz maximum.

2.4 R. F. Input Power Protection: 100 watts peak minimum and 1 watt average minimum from 0.5 GHz to 4.0 GHz.

2.5 Noise Figure (R.F. input to IF output): 3.0 db maximum.

2.6 VSWR (Input and Output): 2:1 maximum.

2.7 R.F. to I.F. Gain: Adjustable from 65 db to [illegible]

2.8 Ambient Temperature Gain Changes: R.F. to I.F. Gain changes not to exceed .06 db/°C temperature change.

2.9 L.O. Frequency Input Requirements: 1.4735 GHz ± 0.5 MHz.

2.10 L.O. Input Power Requirements: +3.0 DBm to + 5.0 DBm.

2.11 I.F. Center Frequency: 60 MHz.

2.12 Image Rejection: 60 db minimum.

2.13 I.F. Bandwidth: (-1.0 db points) 36 MHz minimum.

2.14 I.F. Output Power: +5 DBm minimum at 1 db compression point.

2.15 D. C. Power Requirements: +15 VDC at 60 Ma maximum.

3.0 MECHANICAL

3.1 Size (excluding connectors) not to exceed 6" x 1-1/2" x 2-3/4".

3.2 R.F. connectors shall be Type SMA female.

4.0 ENVIRONMENTAL

4.1 Non-Operating Temperatures: The unit shall be capable of withstanding non-operating temperature extremes of -60°C to + 70°C.

4.2 Operating Temperature: The unit shall be capable of operating in temperature extremes of -30°C to + 70°C.

4.3 Operating Altitude: The unit shall be capable of operating in pressures of sea level to 30,000 feet.

4.4 Non-Operating Humidity: The unit shall be capable of withstanding 100% humidity conditions.

4.5 R.F.I. Shielding: R.F.I. shielding shall be incorporated.

4.6 Operating Vibration: The unit shall be capable of operating while subjected to the vibration requirements of Curve I of MIL-E-5400K (latest revision) except maximum level to be ± 2.5 g peak.

5.0 TEST REQUIREMENTS

The L-Band Low Noise Down Converter shall be tested for compliance to the electrical specifications of Paragraph 2.0. The testing shall be monitored and verified by the vendor's Quality Assurance representative. Conformance to the environmental requirements of Paragraph 4.0 will be certified by the vendor.

6.0 DELIVERABLE DATA

Deliverable Data as a minimum shall consist of the test results of Paragraph 5.0 and mechanical and electrical drawings required for installation, electrical interfacing, and maintenance.

1.0 SCOPE

This specification sets forth the requirements for an L-Band Low Loss Switch Assembly for use in an Airborne Radiometer System. The Switch Assembly shall be an integral unit and shall consist of a fixed isolator and two latching junction circulators with associated drivers.

Mechanical and electrical drawings, sufficient for installation and electrical interfacing, shall be supplied as deliverable items.

2.0 ELECTRICAL SPECIFICATIONS (For Ambient Temperature of $+50^{o}C \pm 2.0^{o}C$):

2.1 Center Frequency: 1.4135 GHz

2.2 Bandwidth (-3db points): 72 MHz minimum

2.3 Insertion Loss (with 50 ohm load impedance and termination VSWR per Table 1):

2.3.1 Input to Output: 0.7 db maximum

2.3.2 Load 1 to Output: 0.8 db maximum

2.3.3 Load 2 to Output: 0.8 db maximum

2.4 Isolation (with 50 ohm load impedance and termation VSWR per Table 1):

2.4.1 Input to Output: 25 db minimum

2.4.2 Load 1 to Output: 50 db minimum

2.4.3 Load 2 to Output: 50 db minimum

2.4.4 Load 1 to Load 2: 25 db minimum

2.5 Voltage Requirements:

2.5.1 +28.0 VDC ± 0.1 VDC at 750 Ma maximum

2.5.2 +5.2 VDC ± 0.2 VDC at 100 Ma maximum

2.6 Switch Rate:

2.6.1 Switch 1 shall be capable of switching at a 500 Hz rate.

2.6.2 Switch 2 shall be capable of switching at a 250 Hz rate and synchronous with Switch 1.

2.7 Switching Time: 50 usec. maximum.

2.8 Trigger Requirements: Switches shall be capable of being triggered from +5.0 V logic.

3.0 MECHANICAL

3.1 Size (excluding connectors): Not to exceed 2" high by 3" wide by 7-1/2" long.

3.2 Connectors: R. F. connectors shall by Type SMA female.

3.3 Connector location: R.F. connector location shall be similar to Figure 2.

4.0 ENVIRONMENTAL

4.1 Non-Operate Temperature: The unit shall be capable of withstanding non-operate temperature extremes of -60°C to +70°C.

4.2 Non-Operating Humidity: The unit shall be capable of withstanding 100% humidity conditions.

4.3 Operating Temperature: The nominal operating temperature shall be +50°C ± 2.0°C.

4.4 Operating Altitude: The unit shall be capable of operating in pressures of sea level to 30,000 feet.

4.5 Operating Vibration: The unit shall be capable of operating while subjected to the vibration requirements of Curve I of MIL-E-5400K, (latest revision) except maximum level to be ± 2.5 g. peak.

5.0 TEST REQUIREMENTS

The L-Band R.F. Switch Assembly shall be tested for compliance to the electrical specifications of Paragraph 2.0. The testing shall be monitored and verified by the vendor's Quality Assurance representative. Conformance to the environmental requirements of Paragraph 4.0 will be certified by the vendor.

6.0 DELIVERABLE DATA

Deliverable Data as a minimum shall consist of the test results of Paragraph 5.0 and mechanical and electrical drawings required for installation and interfacing.

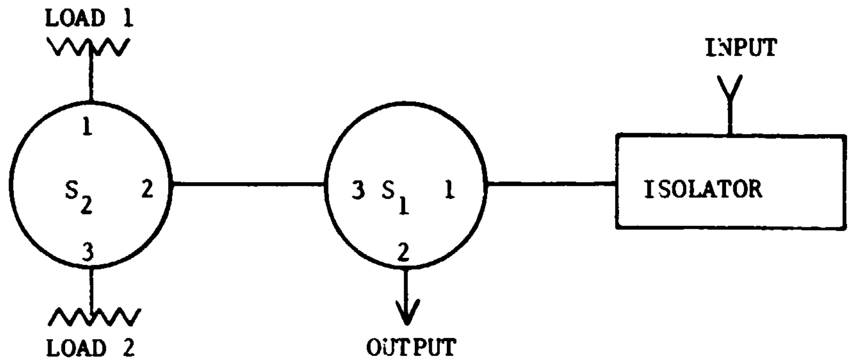


FIGURE 1

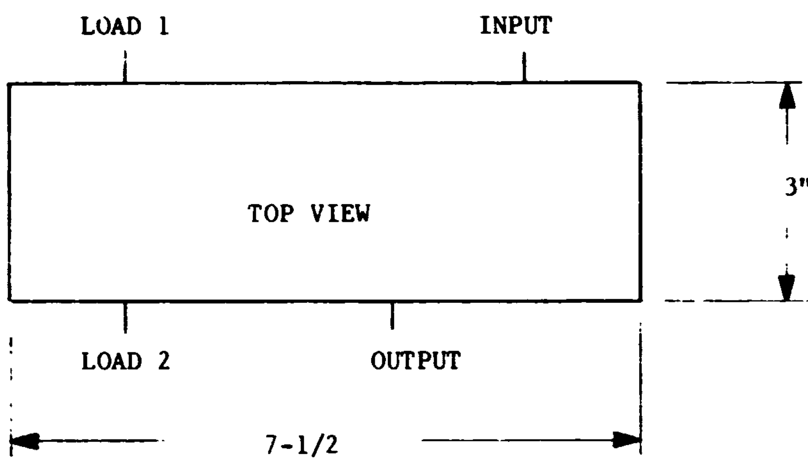


FIGURE 2

TERMINATING VSWR (50 ohm IMPEDANCE)

PORT	VSWR (MAX)
INPUT	2:1
OUTPUT	2:1
LOAD 1	1.1
LOAD 2	1.1

TABLE 1

1.0 SCOPE

This specification sets forth the requirements for hot and cold temperature, Reference Noise Generators for use in an Airborne L-Band Radiometer System as radiometric temperature standards. Each RNG (Reference Noise Generator) shall consist of a temperature controlled 50 ohm termination and an associated controller and temperature read-out.

Mechanical and electrical drawings, sufficient for installation and interfacing, are required as deliverable items.

Calibration tables for conversion of thermometric temperature to radiometric temperature are required as deliverable items.

2.0 ELECTRICAL

2.1 Center Frequency: 1.4135 GHz

2.2 Output Impedance: 50 ohms

2.3 VSWR: 1.10 maximum from 1.3 GHz to 1.5 GHz

2.4 Thermometric Temperature:

2.4.1 Hot RNG: $381^{\circ}K$ nominal

2.4.2 Cold RNG: $273^{\circ}K$ nominal

2.5 Thermometric Accuracy: $\pm 0.1^{\circ}K$

2.6 Thermometric Stability: $0.05^{\circ}K$ peak to peak

2.7 Radiometric Temperature Accuracy: $\pm 0.25^{\circ}K$

2.8 Power Requirements:

2.8.1 Hot RNG: 28.0 $\pm$ 0.2 VDC at 125 ma maximum

2.8.2 Hot RNG Controller: +15.0 $\pm$ 0.1 VDC at 25 ma maximum and -15.0 $\pm$ 0.1 VDC at 25 ma maximum

2.8.3 Cold RNG: +14.0 $\pm$ 0.2 VDC at 2.5 amps maximum

2.8.4 Cold RNG Controller: +15.0 $\pm$ 0.1 VDC at 25 ma maximum and -15.0 $\pm$ 0.1 VDC at 25 ma maximum.

2.9 Thermometric Temperature Monitor Output: The output shall be in the range of 0 to + 5 VDC.

2.10 Temperature Stabilization Time: The time required for temperature stabilization, when the ambient temperature is +50°C, shall not exceed 30 minutes.

3.0 MECHANICAL

3.1 Size

3.1.1 Hot RNG: 2-1/2 inches wide by 2-1/2 inches high by 5-1/2 inches long maximum.

3.1.2 Cold RNG: 2 inches wide by 2 inches high by 7 inches long maximum.

3.1.3 Hot RNG Controller: 1 inch high by 3-1/2 wide by 4 inches long maximum.

3.1.4 Cold RNG Controller: 1 inch high by 3-1/2 inches wide by 4 inches long maximum.

3.2 Weight

3.2.1 Hot RNG: 1-1/2 lbs maximum

3.2.2 Cold RNG: 2-1/4 lbs. maximum

3.2.3 Hot RNG Controller: 1/2 lb. maximum.

3.2.4 Cold RNG Controller: 1/2 lb. maximum.

3.3 R. F. Connectors: The RF Connectors shall be type SMA female.

4.0 ENVIRONMENTAL

4.1 Non-Operating Temperature: The units shall be capable of withstanding non-operating temperature extremes of -60°C to +70°C.

4.2 Non-Operating Humidity: The unit shall be capable of withstanding 100% humidity conditions.

4.3 Operating Temperature: +50°C $\pm$ 2.0°C.

4.4 Operating Altitude: The unit shall be capable of operating in pressures of sea level to 30,000 feet.

4.5 Operating Vibration: The unit shall be capable of operating while subjected to the virbation requirements of Curve I of MIL-E-5400K (latest revision) except maximum level to be $\pm$ 2.5 g peak.

5.0 TEST REQUIREMENTS

The L-Band Hot and Cold RNG and their associated controllers shall be tested for compliance to the electrical specifications of Paragraph 2.0 with the exception of Paragraph 2.7 which may be verified by calculations. The testing shall be monitored and verified by the vendor's Quality Assurance representative. Conformance to the environmental requirements of Paragraph 4.0 will be certified by the vendor.

6.0 DELIVERABLE DATA

Deliverable Data as a minimum shall consist of the test results of Paragraph 5.0, mechancial and electrical drawings necessary for installation and interfacing, and calibration tables for conversion of thermometric temperature to radiometric temperature.

SPECIFICATIONS FOR A TUNNEL DIODE DETECTOR

1.0 SCOPE

This specification sets forth the requirements for a Tunnel Diode Detector.

2.0 ELECTRICAL REQUIREMENTS

2.1	Input Frequency:	45 MHz – 75 MHz
2.2	Voltage Sensitivity:	K = 1000 $^{MV}/_{MW}$
2.3	Figure of Merit:	M > 100
2.4	Flatness:	±0.1 db
2.5	VSWR:	1.5:1 (Max)
2.6	Polarity:	Negative
2.7	1 db Compression Open Circuit:	-18 dbm (Min)
2.8	Bias:	None
2.9	D. C. Return:	Internal
2.10	Video Bandwidth:	DC to 10 KHz

3.0 MECHANICAL REQUIREMENTS

3.1	Input Connector:	OSM Plug
3.2	Output Connector:	OSM Jack
3.3	Total Length:	1-3/8"
3.4	Body Diameter:	5/16"