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TASK 60 TEST REPORT

EVALUATION OF IRIG-A 21 CHANNEL CONSTANT BANDWIDTH FM MULTIPLEXER FOR SHUTTLE DEVELOPMENT FLIGHT INSTRUMENTATION

MAY 1974

JOHNSON SPACE CENTER
HOUSTON, TEXAS [redacted]

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

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APPROVED BY

N. B. Farmer
Head, Astrionics Programs Office

Ralph S. Sawyer
Chief, Tracking and Communications Development Division

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EVALUATION OF IRIG-A 21 CHANNEL CONSTANT BANDWIDTH FM MULTIPLEXER FOR SHUTTLE DEVELOPMENT FLIGHT INSTRUMENTATION

PREPARED BY

5-23-74
C. M. Haddick, Principal Engineer
Lockheed Electronics Company, Inc.

APPROVED BY

LEC	NASA
for 5/23/74 W. J. Shannahan, Supervisor Astrionics Projects Section	C. L. Ritterhouse Astrionics Programs Office
for L. R. Watkins, Manager Tracking and Communications Systems Department	N. B. Farmer, Head Astrionics Programs Office

Prepared By
Lockheed Electronics Company, Inc.
For
Tracking and Communications Development Division

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FIGURE

ABBREVIATIONS AND ACRONYMS

BW	Bandwidth
CBW	Constant Bandwidth
DR	Deviation Ratio
EMR	Electro-Mechanical Research, Inc.
FM	Frequency Modulation
FS	Full Scale
IRIG	Inter-range Instrumentation Group
LPF	Low Pass Filter
SNR	Signal-to-Noise Ratio
THD	Total Harmonic Distortion
V	Volt
VCO	Voltage-Controlled Oscillator
Ch	Channel
Discr.	Discriminator
Freq.	Frequency
Hz	Hertz (Cycles Per Second)
Lab	Laboratory
MHz	Megahertz (Million Cycles Per Second)
Osc	Oscillator
Ref.	Reference
Sel.	Selector
Vdc	Volts Direct Current
dB	Decibel

dBm	Decibels Referred to 1 Milliwatt
dc	Direct Current
i.f.	Intermediate Frequency
kHz	Kilohertz (Thousand Cycles Per Second)
mV	Millivolt
max	Maximum
pk-pk	Peak-to-Peak
rf	Radio Frequency
rms	Root Mean Square
vs	Versus

TASK 60 TEST REPORT
EVALUATION OF IRIG-A 21 CHANNEL
CONSTANT BANDWIDTH FM MULTIPLEXER
FOR
SHUTTLE DEVELOPMENT FLIGHT
INSTRUMENTATION

1.0 SUMMARY

A frequency modulated (FM) multiplexer, consisting of 21 IRIG-A constant bandwidth (CBW) voltage-controlled oscillators (VCO's) was tested to determine its suitability for use in multiplexing 21 data signals which have frequency ranges of dc to 2 kHz. Tests* were performed with the composite signal, consisting of the mixed outputs of the 21 VCO's connected directly to a set of subcarrier discriminators, with the signal recorded on magnetic tape and played back through the discriminators (discr.), and with the signal transmitted by a frequency-modulated (FM) S-band radio frequency (rf) transmitter to a FM receiver and through the subcarrier discriminators.

The tape recording tests included test conditions where tape speed flutter was induced to determine the reduction in flutter noise which can be obtained by the tape speed compensation equipment.

The rf transmission test included transmitting the composite signal at a nominal rf received signal of -73 dBm

*These tests were performed in the Tracking and Communications Development laboratories as Shuttle-in-line, Task 60B, wideband studies and evaluation.

and at rf levels of -83 and -86 dBm. The level of -73 dBm is the estimated minimum equivalent signal level which will be received from the Shuttle vehicle at a slant range of 5 degrees.

1.1 VCO PERFORMANCE TESTS

These tests were performed with the VCO signals connected directly to the discriminators. The tests included measurement of peak-to-peak (pk-pk) noise with dc signals applied to the VCO's, distortion with sine wave signals applied to the VCO's, crosstalk between received data signals, and phase error between the received data signals.

The worst case test results are summarized as follows:

Peak-to-peak noise:	0.6% FS at DR=2
	3.9% FS at DR=1
Distortion:	0.65% at DR=2
	3 0% at DR=1
Crosstalk:	2.8% at DR=1
Phase Error:	19° at 2.0 kHz (DR=1)
	10.1° at 1.0 kHz (DR=1)
	18.4° at 1.0 kHz (DR=2)
	5.6° at 0.5 kHz (DR=2)

1.2 RECORDED TESTS

The multiplexer composite signal consisting of the VCO output signals was recorded on an intermediate bandwidth recorder at a tape speed of 60 inches per second. The recorded data were played back through the subcarrier discriminators to determine data signal degradation caused by the recording process. Recordings were also made with induced tape speed flutter. The worst case test results are summarized as follows:

No recorder flutter:

pk-pk noise	1.8% FS at DR=2	
	6.0% FS at DR=1	
distortion	1.0% at DR=2	
	3.3% at DR=1	

2.4% flutter:

pk-pk noise	2.3% FS at DR=2
	7.0% FS at DR=1
distortion	1.95% at DR=2
	4.1% at DR=1

4.5% flutter:

pk-pk noise	2.5% FS at DR=2
	8.0 FS at DR=1
distortion	4.1% at DR=2
	5.5% at DR=1

These results show that the tape speed compensation equipment is effective in reducing noise on the data signals that would be caused by uncompensated tape speed flutter.

The significantly higher values of distortion measured with induced flutter are caused by frequency modulation of the data signals that results from the induced flutter. The tape speed compensation equipment does not correct the changes in data signal frequency which is caused by the recorder flutter.

1.3 RF TRANSMISSION TESTS

The worst case test results are summarized as follows.

	DR=1		DR=2	
Received rf level	Percent Distortion	Noise, % FS pk-pk	Percent Distortion	Noise, % FS pk-pk
-73 dBm	3.0	7.0	0.71	1.2
-83 dBm	–	8.0	–	1.4
-86 dBm	–	8.5	–	1.5

The relatively high peak-to-peak noise level of 7.0 to 8.5 percent of full scale was measured on the data signal obtained from channel 14A (120 kHz center frequency) at a deviation ratio of 1. These values were measured with the VCO frequency set to high and low bandedges. The noise measured with the VCO set at center frequency was 1.5 percent of full scale. At a received rf level of -73 dBm, the maximum peak-to-peak noise measured on the other channels was 4.5 percent of full scale; at a received level of -86 dBm, the maximum noise on the other channels was 6.0 percent of full scale. The high noise levels measured on channel 14A is caused by interference from a 120 kHz reference signal in the 120 kHz translator. This interference can be significantly reduced by the use of a transmitter which has a lower deviation sensitivity, so that the VCO signals could be set to higher values. Such a transmitter was not available when these tests were performed.

The rf level of -86 dBm was determined to be the minimum usable level with the available test equipment. This level produces a calculated receiver i.f. section signal-to-noise ratio of 13 dB.

1.4 COMPARISON OF TEST RESULTS

The worst case noise and distortion measurements for the test nominal recording and transmission test configurations are summarized in table I to indicate the degradation caused by the recording and transmission processes.

TABLE I. — COMPARISON, NOISE AND DISTORTION MEASUREMENTS

Test Condition	% Distortion	Noise, % FS pk-pk	% Distortion	Noise, % FS pk-pk
	DR=1		DR=2	
VCO signals direct to discriminators	3.0	3.9	0.65	0.6
VCO signals recorded	3.3	6.0	0.86	1.8
VCO signals transmitted, rf level -73 dBm	3.0	7.0	0.71	1.2

2.0 INTRODUCTION

Tests were performed to evaluate the performance of a frequency modulation data signal multiplexer which consists of 21 IRIG-A constant bandwidth voltage-controlled oscillators.

2.1 MULTIPLEXER DESCRIPTION

The multiplexer contains VCO's, mixer amplifiers, translators, and a reference oscillator manufactured by Sonex, Inc. The multiplexer consists of 21 IRIG-A channel CBW VCO's, Sonex part number TEX-3007MD; five mixer amplifiers, Sonex part number TEX-3207MD; three translators, Sonex part number TEX-3802; and one 240 kHz reference oscillator, Sonex part number TEX 3402A.

The 21 VCO signals are developed from one group of IRIG CBW VCO's, consisting of channels 1A through 6A, and three groups of IRIG CBW VCO's, each consisting of channels 1A through 5A. The composite output of the group of 1A through 6A VCO's is connected directly to the final mixer amplifier. The frequencies of the groups of 1A through 5A VCO's are translated up to obtain the channel 7A through 21A VCO frequencies. Channels 7A through 11A are obtained by using a 120 kHz translating frequency; channels 12A through 16A are obtained by using a 160 kHz translating frequency; and channels 17A through 21A are obtained by using a 200 kHz translating frequency.

Each of the groups of VCO's is mounted in a separate chassis with a mixer amplifier. The three translators, the reference oscillator, and the final summing amplifier are mounted in a separate chassis.

The peak frequency deviation of the IRIG-A channels is 2 kHz. Each of the VCO's can be modulated by a 2 kHz data signal if a deviation ratio (DR) of 1 is used. The deviation ratio is defined as $DR = \frac{F_d}{F_m}$, where F_d is the VCO peak frequency deviation and F_m is the maximum frequency of the data signal. The VCO deviation ratio is determined by the cut-off frequency of the low pass filter used at the output of the FM subcarrier discriminator which recovers the data signal. In general, the quality of the received data signal is increased as the deviation ratio is increased. The IRIG-A channel VCO's can be used to transmit 1 kHz data signals with a deviation ratio of 2.

2.2 TEST DESCRIPTION

The purpose of the evaluation tests was to determine the accuracy which can be expected when the IRIG-A VCO's are used to multiplex 21 data signals in the range of 0 to ? kHz. In addition, the multiplexer output signal was recorded on a magnetic tape recorder and transmitted by a S-band FM telemetry transmitter to determine the data signal degradation which would be caused by the recording and transmission processes.

Static (dc) signals obtained from a precision laboratory power supply, and dynamic (sine wave) signals obtained from laboratory sine wave oscillators were used as simulated data signals. The simulated data signals were connected to the inputs of the FM multiplexer VCO's. Electro-Mechanical Research, Inc. (EMR) model 4150 FM subcarrier discriminators were used to demodulate the composite FM multiplex signals to recover the multiplexed data signals.

An EMR model 4059 detranslator was used to translate the IRIG channels 7A through 21A signals down to three groups of 1A through 5A signals. The detranslator develops translating frequencies of 120 kHz, 160 kHz, and 200 kHz from an external 240 kHz reference signal. The 240 kHz reference frequency obtained from the multiplexer was supplied to the detranslator during the tape recording tests to facilitate tape speed compensation.

The data signals, recovered at the output of the discriminators, were measured using an oscilloscope, a voltmeter, and a total harmonic distortion analyzer to determine the degree of data signal degradation which is caused by the multiplexing, recording, and transmission process. Phase delay measurements were also made to determine how accurately different data signals can be time-correlated when the signals are multiplexed.

3.0 DISCUSSION

3.1 VCO PERFORMANCE TESTS

The FM multiplexer, the simulated data signals, and the test equipment were connected as shown in figure 3-1. Static data signal noise, dynamic data signal distortion, channel-to-channel phase error, and crosstalk measurements were made with the multiplexer output connected directly to the discriminators.

3.1.1 Static Noise Tests

Peak-to-peak noise at the outputs of the subcarrier discriminators was measured with static data signals of 0, 2.5, and 5.0 applied to the VCO signal inputs. These measurements were made using VCO deviation ratios of 1 and 2. The measurements expressed as percentages of full scale are given in table II.

The maximum peak-to-peak noise on the received data signals measured for a data signal deviation ratio of 1 was 1.3 percent of full scale for an input signal of 2.5 Vdc (VCO center frequency); the maximum peak-to-peak noise measured with input signals of 0 Vdc (VCO low bandedge) and 5.0 Vdc (VCO high bandedge) was 3.9 percent.

The value of 3.9 percent was measured for channel 6A with the VCO frequency set to high bandedge (5.0 Vdc data signal). The noise measured for channel 7A with the same input signal was 3.5 percent of full scale. The

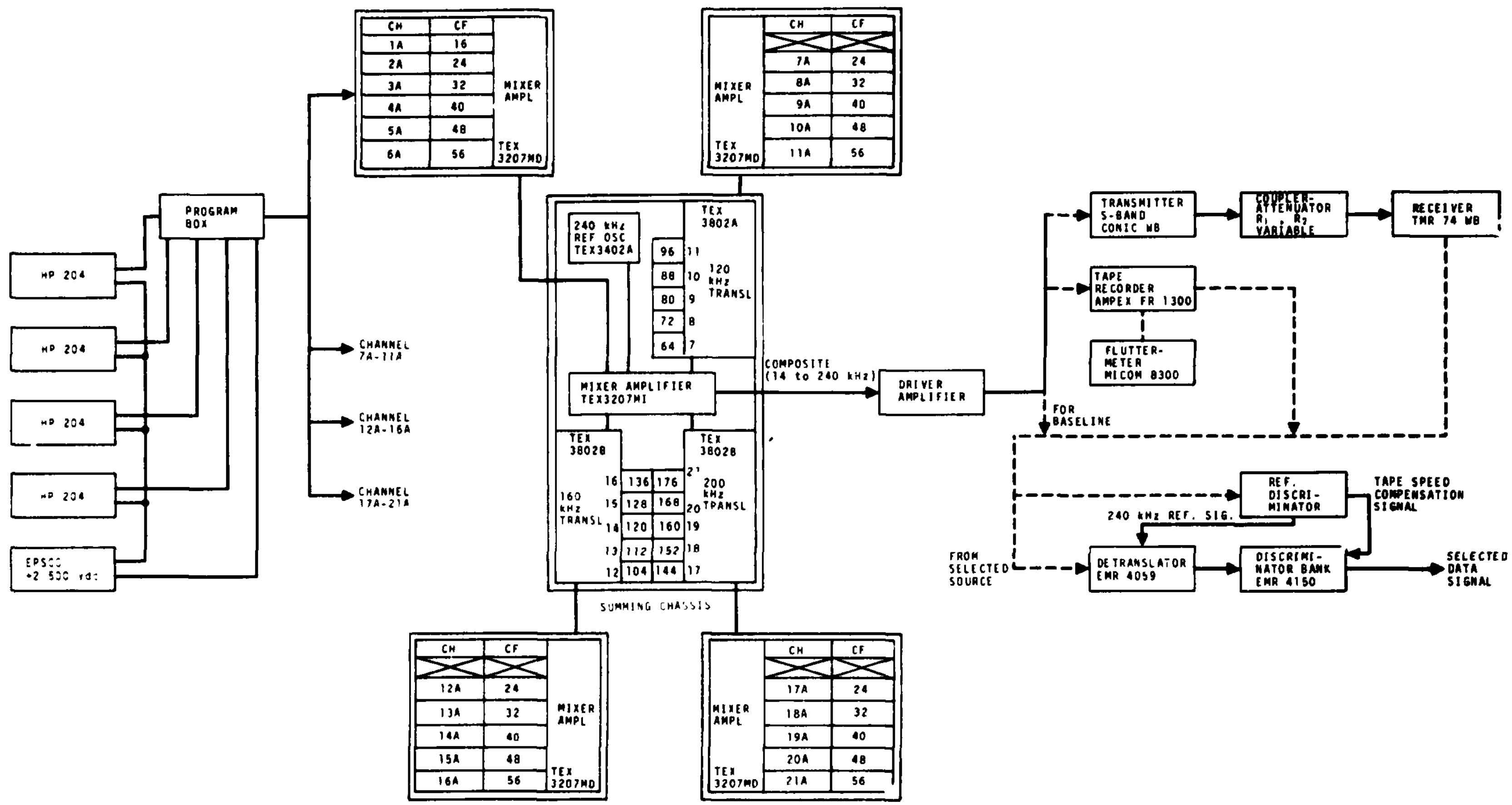


Figure 3-1. — Block diagram of laboratory 21 channel constant bandwidth multiplexer evaluation tests.

TABLE II. – STATIC DATA SIGNAL NOISE, pk-pk PERCENT OF FULL SCALE

VCO Channel	0 Vdc	2.5 Vdc	5.0 Vdc	0 Vdc	2.5 Vdc	5.0 Vdc
	Noise, % FS pk-pk					
	DR=1			DR=2		
1A	1.8	1.3	1.7	.5	.4	.5
2A	1.8	1.3	1.7	.4	.4	.5
3A	1.5	.8	1.4	.4	.3	.3
4A	1.8	1.1	1.8	.4	.4	.6
5A	1.6	1.0	1.7	.3	.4	.5
6A	1.3	.9	3.9	.5	.4	.4
7A	1.3	.9	3.5	.5	.3	.4
8A	1.5	1.0	1.7	.3	.4	.6
9A	2.0	.9	1.7	.4	.4	.4
10A	1.8	.9	1.8	.4	.4	.5
11A	1.3	.9	1.4	.3	.3	.4
12A	1.6	.9	1.6	.4	.3	.4
13A	1.5	1.1	1.8	.5	.4	.6
14A	2.6	.9	2.8	.4	.3	.4
15A	1.2	.8	1.3	.3	.3	.3
16A	1.5	1.0	1.4	.3	.3	.4
17A	.9	.6	1.3	.3	.2	.2
18A	.9	.6	1.0	.2	.2	.2
19A	2.3	.8	2.4	.3	.4	.5
20A	.9	.6	.9	.2	.2	.2
21A	1.0	.6	.8	.3	.2	.3

relatively high noise levels for these two channels are caused by mutual interference between the two VCO signals. Channel 7A is obtained by translating a 56 kHz VCO signal to obtain a signal which has a frequency of 64 kHz. The translation causes a 180 degree change in the deviation sensitivity of the resulting signal. When a 5.0 Vdc signal is applied to both channel 6A and channel 7A, the channel 6A VCO frequency is at high bandedge and the channel 7A VCO frequency, obtained by translation, is at low bandedge. The frequency separation between the two VCO's is minimum for this condition so that maximum crosstalk occurs.

The noise on the data signals measured for channels 14A (120 kHz) and 19A (160 kHz) with 0 Vdc and 5.0 Vdc data signals were also relatively high. With the input signal set to 5.0 Vdc, 2.8 percent was measured on channel 14A and 2.4 percent was measured on channel 19A. The higher noise levels on these channels is caused by feed-through of the 120 kHz translation signal from the 120 kHz translator, and feed-through of the 160 kHz translation signal from the 160 kHz translator. The noise levels measured are not considered excessive but do show the necessity of suppressing the translation signal at the outputs of the translators.

The maximum peak-to-peak noise on the received data signals measured at a deviation ratio of 2 was 0.4 percent for an input signal of 2.5 Vdc; the maximum peak-to-peak noise measured with input signals of 0 and 5.0 Vdc was 0.6 percent. The use of a deviation ratio of 2 eliminated the data signal degradation which occurred on channels 6A, 7A, 14A, and 19A when a data signal deviation ratio of 1 was used.

3.1.2 Dynamic Data Signal, Harmonic Distortion

Sine wave data signals were applied to the VCO's. Recovered data signal total harmonic distortion was measured at the subcarrier discriminator outputs. The measurements were made using VCO deviation ratios of 1 and 2.

The results of the measurements are given in table III.

The maximum total harmonic distortion measured for a data signal deviation ratio of 2 was 0.65 percent. The maximum total harmonic distortion measured for a data signal deviation ratio of 1 was 3.0 percent.

The distortion analyzer filters out the data signal fundamental component and provides a measure of the remaining content of the data signal. This measurement gives an indication of noise and crosstalk contained in the received data signal.

3.1.3 Phase Error, Channel-to-Channel

A single sine wave data signal was connected in parallel to the inputs of all VCO's. The difference in phase between the recovered data signals was measured at the output of the subcarrier discriminators for data signal frequencies of 2.0, 1.0, and 0.5 kHz. Measurements were made using 2 kHz low pass filters (DR=1) and 1 kHz low pass filters (DR=2). The measured values of phase errors are given in table IV.

TABLE III. – DYNAMIC DATA SIGNAL, PERCENT TOTAL HARMONIC DISTORTION, SYSTEM BASELINE TEST

VCO Channel	Data Signal Freq, Hz	Data	VCO Channel	Data Signal Freq, Hz	Data
% THD			% THD		
DR=1			DR=2		
1A	2000	1.85	1A	1000	0.34
2A	1900	2.40	2A	900	0.33
3A	1800	2.65	3A	800	0.58
4A	1750	2.55	4A	750	0.52
5A	2000	2.60	5A	1000	0.49
6A	1900	2.25	6A	900	0.33
7A	1800	2.75	7A	800	0.32
8A	1900	2.65	8A	900	0.58
9A	2000	2.30	9A	1000	0.37
10A	1750	2.65	10A	750	0.58
11A	1800	2.65	11A	800	0.28
12A	1750	2.40	12A	750	0.32
13A	1800	3.00	13A	800	0.56
14A	1900	2.30	14A	900	0.52
15A	2000	2.65	15A	1000	0.47
16A	1750	2.70	16A	750	0.38
17A	2000	2.50	17A	1000	0.23
18A	1750	2.75	18A	750	0.55
19A	1800	2.55	19A	800	0.65
20A	1900	2.40	20A	900	0.31
21A	2000	1.85	21A	1000	0.24

TABLE IV. - DYNAMIC DATA SIGNAL, CHANNEL-TO-CHANNEL PHASE ERROR, SYSTEM BASELINE TEST

VCO Channel	Freq 2.0 kHz, degrees	Freq 1.0 kHz, degrees	Freq 1.0 kHz, degrees	Freq 0.5 kHz, degrees
	DR=1		DR=2	
1A-2A	-14.5	-6.9	-8.4	5.6
2A-3A	-7.8	-2.8	-11.8	-2.5
3A-4A	+2.0	-1.2	+4.6	0
4A-5A	-11.5	-3.8	-8.7	-1.5
5A-6A	+7.5	+2.4	-2.7	-.7
6A-7A	+5.5	+2.8	+14.1	+4.3
7A-8A	-3.7	-1.7	-7.7	-3.0
8A-9A	+2.2	+1.4	-5.1	-.3
9A-10A	+6.0	+3.0	+18.4	+3.6
10A-11A	+9.0	+[illegible].5	-9.0	0
11A-12A	-6.5	-5.8	-3.3	-3.0
12A-13A	-12.5	-4.2	+.6	-.5
13A-14A	+2.5	+1.6	+9.3	+1.9
14A-15A	+6.0	+3.3	-2.4	+1.0
15A-16A	+10.5	+4.1	+13.2	+2.4
16A-17A	-18.1	-7.7	-12.2	-4.3
17A-18A	-4.5	-2.1	-8.2	-3.2
18A-19A	+2.7	+1.8	-5.0	-.1
19A-20A	+5.7	+2.8	+18.3	+3.6
20A-21A	+9.0	+4.0	-9.1	- 2
1A-7A	-18.7	-10.0	-13.2	-5.5
1A-12A	-12.5	-7.0	-10.2	-4.1
1A-17A	-19.0	-10.1	-18.0	-5.6

The maximum phase shift measured between channels is as follows:

Data Signal Frequency (kHz)	Maximum Phase Shift (degrees)
DR=1	
2.0	-19 (Ch 1A to Ch 17A)
1.0	-10.1 (Ch 1A to Ch 17A)
DR=2	
1.0	+18.4 (Ch 9A to Ch 10A)
0.5	-5.6 (Ch 1A to Ch 2A and Ch 1A to Ch 17A)

3.1.4 Crosstalk, Channel-to-Channel

A 5 V pk-pk sine wave data signal was applied in turn to channels 6A, 11A, 16A and 21A. A 2.5 Vdc data signal was applied to the remaining VCO's. The peak-to-peak noise on the received data signals obtained from the remaining VCO's was measured to determine the amount of crosstalk caused by the sine wave signals. The crosstalk measurements were performed for a data signal deviation ratio of 1 with a sine wave signal frequency of 2.0 kHz. The results of the crosstalk measurements are given in table V.

The test results indicate that most of the crosstalk occurs on the VCO's adjacent to the VCO which is modulated by the sine wave signal. The worst case crosstalk increased the noise on the unmodulated VCO's from 0.9 to 2.8 percent peak-to-peak.

TABLE V. – CHANNEL-TO-CHANNEL CROSSTALK TEST

Crosstalk Condition	Noise, % FS pk-pk				
	DR=1				
Channel	Basic Noise	6A	11A	16A	21A
1A	1.3	1.2	1.2	1.2	1.2
2A	1.3	1.0	1.1	1.3	1.2
3A	.8	.8	.9	.9	.8
4A	1.1	1.3	1.2	1.2	1.2
5A	1.0	2.8	1.0	.9	.9
6A	.9	Signal	1.0	1.0	.9
7A	.9	2.8	1.3	1.3	1.3
8A	1.0	1.0	1.1	1.0	.9
9A	.9	1.0	1.0	1.0	1.0
10A	.9	1.4	2 8	1.3	1.3
11A	.9	.8	Signal	1.1	1.0
12A	.9	.9	2.6	1.0	1.0
13A	1.1	1.8	1.5	1.7	1.7
14A	.9	.9	1.2	1.0	1.0
15A	.8	.8	.8	2.4	.9
16A	1.0	1.3	1.3	Signal	1.3
17A	.6	.7	.7	2.4	.7
18A	.6	.8	.6	.7	.8
19A	.8	.9	.9	.9	.9
20A	.6	.6	.6	.6	2.2
21A	.6	.7	.6	.6	Signal

The crosstalk measurements were made with the unmodulated VCO's set at their center frequencies. The crosstalk on an unmodulated VCO will increase as the frequency of the VCO is moved toward the frequency of an adjacent VCO.

3.2 RECORDING TESTS

The output of the FM multiplexer was recorded on an Ampex FR 1300 magnetic tape recorder at a recorder speed of 60 inches per second, using direct record-playback electronics. The recorded tape was played back with the reproduced signal connected to the subcarrier discriminators to determine the degradation in data signal quality caused by the tape recording process. The FM multiplexer, simulated data signals, and test equipment were connected as shown in figure 3-1.

The recorder normal record level was set to 1.0 Vrms, i.e., a 1.0 Vrms sine wave signal produces 1.0 percent third harmonic distortion on the tape. Each of the VCO levels was set to a nominal value of 70 mVrms; the 240 kHz tape speed reference signal was set to a nominal value of 140 mVrms. The tape speed reference signal was set 6 dB higher than the VCO signals to ensure that a relatively clean signal would be available for providing tape speed and tape flutter compensation for the recorded data signals during tape playback. The VCO and reference signal levels were chosen such that the composite recorded signal would have a nominal peak-to-peak value of 2.8 volts when the signal was observed using an oscilloscope.

Prior to recording the FM multiplexer signal, recorder slot noise measurements were made relative to the normal record level. A wave analyzer with 3.0 kHz filter bandwidth was used to make the measurements. The measured signal-to-noise ratios are listed in table VI. The measured noise was used to obtain an indication of the noise in a 1.0 kHz and a 2.0 kHz bandwidth over the frequency range of the recorder. These values are also listed in table VI. The data signal-to-noise ratio will depend on the tape noise levels; the results obtained for the tests reported here can be used to predict the performance of a different recorder only if the signal-to-noise characteristics of the recorders are the same.

3.2.1 Static Data Signal Noise

The output of the FM multiplexer was recorded with 0, 2.5, and 5.0 Vdc data signals applied to the VCO's. The recorded tape was played back, and the reproduced signal was connected to the subcarrier discriminators. The peak-to-peak noise on the recovered data signals was measured. Measurements were made using deviation ratios of 1 and 2. Measured values expressed as percentages of full scale are given in table VII.

With a data signal deviation ratio of 1.0, the maximum peak-to-peak noise for a 2.5 Vdc data signal was 3.5 percent; the maximum peak-to-peak noise was 6.0 percent for 0.0 and 5.0 Vdc data signals.

TABLE VI. – TAPE RECORDER SLOT NOISE DATA

Frequency, (kHz)	Measured SNR, 3.0 kHz BW	Calculated SNR	
		2.0 kHz BW	1.0 kHz BW
10	57	58.8	61.8
20	67	68.8	71.8
40	67	68.8	71.8
80	67	68.8	71.8
100	65	68.8	69.8
175	64	65.8	68.8
240	63	64.8	67.8

TABLE VII. – STATIC DATA SIGNAL NOISE, pk-pk PERCENT OF FULL SCALE, RECORDED DATA TEST

VCO Channel	0 Vdc	2.5 Vdc	5.0 Vdc	0 Vdc	2.5 Vdc	5.0 Vdc
	Noise, % FS pk-pk					
	DR=1			DR=2		
1A	4.0	2.8	3.5	1.4	1.0	1.8
2A	3.5	2.5	3.5	1.1	1.0	1.1
3A	3.5	2.4	3.5	1.2	1.0	1.2
4A	4.0	2.5	4.0	1.3	1.3	1.2
5A	4.0	2.5	4.0	1.3	1.2	1.3
6A	4.0	2.8	6.0	1.4	1.4	1.5
7A	4.5	2.8	6.0	1.4	1.3	1.5
8A	4.5	3.0	5.0	1.5	1.3	1.5
9A	5.0	3.0	5.0	1.5	1.3	1.5
10A	5.0	3.0	5.0	1.5	1.3	1.6
11A	5.0	3.0	5.0	1.5	1.4	1.5
12A	5.0	3.0	6.0	1.5	1.5	1.7
13A	5.0	3.5	5.5	1.5	1.5	1.8
14A	6.0	3.3	6.0	1.6	1.5	1.8
15A	6.0	3.4	5.5	1.7	1.5	1.7
16A	6.0	3.5	5.5	1.7	1.5	1.7
17A	5.5	3.4	6.0	1.7	1.6	1.8
18A	5.5	3.4	6.0	1.6	1.5	1.7
19A	6.0	3.4	6.0	1.7	1.5	1.8
20A	6.0	3.2	6.0	1.8	1.5	1.7
21A	6.0	3.2	6.0	1.7	1.6	1.7

With a data signal deviation ratio of 2.0, the maximum peak-to-peak noise for a 2.5 Vdc data signal was 1.6 percent; the maximum peak-to-peak noise for 0.0 and 5.0 Vdc data signals was 1.8 percent.

3.2.2 Static Data Signal Noise With Induced Tape Recorder Flutter

Tape recorder flutter levels of 2.42 and 4.5 percent were induced by placing adhesive tape on the recorder capstan. Static data signals were recorded and played back as described in section 3.2.1. The measured values of noise on the data signals, expressed as percentages of full scale, are given in table VIII.

A comparison of the test results listed in table VIII and those listed in table VII (no induced flutter) shows that the induced flutter increases the peak-to-peak noise on the received data signals. With 2.42 percent flutter and a deviation ratio of 2, the worst case noise was increased from 1.8 percent to 2.3 percent; with a deviation ratio of one, the worst case noise increased from 6.0 percent to 7.0 percent. With 4.5 percent flutter and a deviation ratio of 2, the worst case noise increased from 1.8 percent to 2.5 percent; with a deviation ratio of 1, the worst case noise increased from 6.0 percent to 8.0 percent.

3.2.3 Dynamic Data Signal Harmonic Distortion

The output of the FM multiplexer was recorded with sine wave data signals applied to the VCO's. The recorded

TABLE VIII. – PLAYBACK STATIC DATA SIGNAL NOISE, pk-pk PERCENT OF FULL SCALE, WITH TAPE RECORDED FLUTTER, RECORDED DATA TEST

VCO Channel	0 Vdc	2.5 Vdc	5.0 Vdc	0 Vdc	2.5 Vdc	5.0 Vdc
	Noise, % FS pk-pk					
	DR=1			DR=2		
	2.42% Flutter					
1A	4.0	2.5	4.0	1.3	1.0	1.3
2A	4.3	2.5	4.0	1.3	1.0	1.2
3A	4.3	2.4	4.5	1.3	1.0	1.3
4A	4.5	2.7	4.5	1.4	1.2	1.4
5A	4.5	2.7	4.5	[illegible]	1.2	1.4
6A	5.0	2.8	6.5	1.7	1.4	1.5
7A	5.0	3.0	7.0	1.7	1.4	1.7
8A	5.5	3.0	5.5	1.7	1.4	1.5
9A	5.5	3.0	5.5	1.7	1.3	1.6
10A	5.5	3.3	5.5	1.7	1.4	1.7
11A	5.5	3.3	5.5	1.7	1.4	1.6
12A	5.5	3.4	6.0	1.8	1.5	2.0
13A	6.0	3.8	6.0	1.9	1.5	2.0
14A	6.0	3.5	6.0	2.0	1.5	1.8
15A	6.0	3.5	6.0	2.0	1.5	1.8
16A	6.5	3.7	6.0	2.0	1.5	1.8
17A	6.5	3.7	6.5	2.2	1.6	2.0
18A	6.5	3.8	6.0	2.0	1.6	1.8
19A	7.0	3.7	7.0	2.3	1.7	1.9
20A	7.0	3.7	6.0	2.3	1.6	2.0
21A	7.0	3.7	6.0	2.2	1.5	1.8

VCO Channel	0 Vdc	2.5 Vdc	5.0 Vdc	0 Vdc	2.5 Vdc	5.0 Vdc
	Noise, % FS pk-pk					
	DR=1			DR=2		
	4.5% Flutter					
1A	4.0	2.8	4.0	2.0	1.2	1.6
2A	4.0	2.6	4.0	1.4	1.2	1.3
3A	4.5	2.7	4.0	1.4	1.3	1.4
4A	4.5	2.8	4.0	1.5	1.4	1.4
5A	5.0	3.0	4.0	1.6	1.4	1.5
6A	5.5	3.4	7.0	2.0	1.7	1.8
7A	6.0	3.5	7.0	2.0	1.8	1.8
8A	6.0	3.5	5.0	1.8	1.7	1.8
9A	6.0	3.6	5.0	2.0	1.6	1.7
10A	6.0	3.6	5.0	2.0	1.7	1.8
11A	6.0	3.6	5.0	2.0	1.6	1.7
12A	7.0	3.8	5.5	2.4	1.8	2.0
13A	7.0	4.0	5.5	2.4	2.0	2.5
14A	8.0	4.0	6.0	2.5	1.7	1.8
15A	7.0	4.0	5.5	2.4	1.8	1.8
16A	7.5	4.0	5.5	2.4	1.8	2.0
17A	8.0	4.0	5.5	2.5	2.0	2.0
18A	7.5	4.4	5.5	2.4	1.8	2.0
19A	8.0	4.4	6.0	2.5	1.8	2.0
20A	7.5	4.2	5.5	2.4	1.7	1.8
21A	7.5	4.0	5.5	2.4	1.7	1.8

tape was played back with the reproduced signal connected to the subcarrier discriminators. The total harmonic distortion of the recovered data signals was measured. Measurements were made using deviation ratios of 1 and 2. The measured values are given in table IX.

The maximum distortion measured at a data signal deviation ratio of 2 was 0.86 percent; the maximum distortion measured at a deviation ratio of 1 was 3.3 percent. The measured values provide an indication of the crosstalk and tape noise contained in the data signals.

3.2.4 Dynamic Data Signal Harmonic Distortion With Induced Tape Recorder Flutter

Tape recorder flutter levels of 2.42 and 4.5 percent were induced by placing adhesive tape on the recorder capstan. Sine wave data signals were recorded and played back as described in section 3.2.3. The measured values of total harmonic distortion are given in table X.

The values listed in table X compared with those in table IX (no induced flutter) show that the induced flutter causes a significant increase in the data signal distortion. With 2.42 percent flutter, the maximum distortion for a deviation ratio of 2 was 1.95 percent; the maximum distortion at a deviation ratio of 1 was 4.1 percent.

With 4.5 percent induced flutter, the maximum distortion for a deviation ratio of 2 was 4.1 percent; the maximum distortion at a deviation ratio of 1 was 5.5 percent.

TABLE IX. – PLAYBACK DYNAMIC DATA SIGNAL, PERCENT TOTAL HARMONIC DISTORTION, RECORDED DATA TEST

VCO Channel	Data Freq, kHz	Data
% THD		
DR=1		
1A	2.0	2.1
2A	1.9	2.6
3A	1.8	2.9
4A	1.75	2.8
5A	2.0	2.8
6A	1.9	2.55
7A	1.8	2.9
8A	1.9	2.95
9A	2.0	2.6
10A	1.75	3.0
11A	1.8	3.0
12A	1.75	2.8
13A	1.8	3.3
14A	1.9	2.7
15A	2.0	3.0
16A	1.75	3.1
17A	2.0	2.9
18A	1.75	3.3
19A	1.8	3.0
20A	1.9	3.0
21A	2.0	2.45

VCO Channel	Data Freq, kHz	Data
% THD		
DR=2		
1A	1.0	.56
2A	.9	.49
3A	.8	.69
4A	.75	.66
5A	1.0	.66
6A	.9	.55
7A	.8	.53
8A	.9	.71
9A	1.0	.61
10A	.75	.74
11A	.8	.55
12A	.75	.58
13A	.8	.73
14A	.9	.70
15A	1.0	.72
16A	.75	.61
17A	1.0	.58
18A	.75	.76
19A	.8	.86
20A	.9	.76
21A	1.0	.60

TABLE X. - PLAYBACK DYNAMIC DATA SIGNAL, PERCENT TOTAL HARMONIC DISTORTION, WITH TAPE RECORDED FLUTTER, RECORDED DATA TEST

VCO Channel	Data Freq, kHz	% THD	Data Freq, kHz	% THD
	2.42% Flutter			
	DR=1		DR=2	
1A	2.0	2.9	1.0	1.8
2A	1.9	3.3	.9	1.8
3A	1.8	3.6	.8	1.8
4A	1.75	3.5	.75	1.8
5A	2.0	3.4	1.0	1.9
6A	1.9	3.3	.9	1.75
7A	1.8	3.5	.8	1.75
8A	1.9	3.7	.9	1.85
9A	[illegible]	3.3	1.0	1.7
10A	1.75	3.8	.75	1.65
11A	1.8	3.7	.8	1.7
12A	1.75	3.5	.75	2.0
13A	1.8	4.1	.8	1.9
14A	1.9	3.5	.9	1.95
15A	2.0	3.7	1.0	1.95
16A	1.75	3.8	.75	1.8
17A	2.0	3.6	1.0	1.85
18A	1.75	4.1	.75	1.9
19A	1.8	3.7	.8	1.95
20A	1.9	3.6	.9	1.9
21A	2.0	3.2	1.0	1.85

VCO Channel	Data Freq, kHz	% THD	Data Freq, kHz	% THD
	4.5% Flutter			
	DR=1		DR=2	
1A	2.0	4.7	1.0	3.5
2A	1.9	[illegible]	.9	3.7
3A	1.8	5.1	.8	3.6
4A	1.75	4.9	.75	3.6
5A	2.0	5.0	1.0	3.7
6A	1.9	5.0	.9	3.7
7A	1.8	5.1	.8	3.6
8A	1.9	5.2	.9	3.8
9A	2.0	4.9	1.0	3.9
10A	1.75	5.2	.75	3.8
11A	1.8	5.2	.8	3.7
12A	1.75	5.0	.75	3.8
13A	1.8	[illegible]	.8	3.9
14A	1.9	[illegible]	.9	4.0
15A	2.0	5.2	1.0	4.0
16A	1.75	5.1	.75	3.7
17A	2.0	5.2	1.0	4.1
18A	1.75	5.4	.75	3.9
19A	1.8	5.2	.8	4.0
20A	1.9	5.2	.9	4.1
21A	2.0	4.8	1.0	4.1

The tape recorder flutter causes frequency modulation of the data signals as well as frequency modulation of the VCO signals. The frequency modulation of the data signal cannot be corrected by the tape speed compensation equipment available. The distortion measured is essentially a measure of the sidebands around the data signals which are produced by the frequency modulation.

3.3 TRANSMITTED TESTS

The output of the FM multiplexer was used to frequency modulate a S-band rf transmitter. The transmitter output was connected through attenuators to a S-band FM receiver. Adjustable attenuators were used to allow control of the received power levels. The received FM multiplexer signal was connected to the subcarrier discriminators to determine the degradation in data signal quality caused by the transmission process.

The FM multiplexer, simulated data signals, and test equipment were connected as shown in figure 3-1.

The levels of the channel 10A through channel 21A VCO's were set to produce a transmitter FM modulation index of 0.7. The levels of channels 1A through 9A were set to produce a minimum transmitter deviation of 61 kHz per channel to reduce interference on these channels caused by the higher frequency VCO's. The resulting peak transmitter deviation produced by the composite signal was 1657 kHz. The FM receiver i.f.

bandwidth used was 3.3 MHz. The overall signal-to-noise ratio for each VCO channel is obtained from the following equation.

$$\text{SNR} = 10 \log 3/4 \ \frac{F_D}{F_M}^2 (\text{DR})^2 \ \frac{B_{IF}}{B_D} + \text{SNR}_R \ \text{dB}$$

where F_D is the transmitter frequency deviation produced by the VCO signal, F_M is the VCO frequency, DR is the VCO deviation ratio, B_{IF} is the receiver i.f. bandwidth, B_D is the data signal low pass filter bandwidth, and SNR_R is the signal-to-noise ratio in the receiver i.f. section.

For a data signal deviation ratio of 2, the calculated minimum data signal-to-noise ratio is as follows:

$$\text{SNR} = 10 \log 3/4 \ (0.7)^2 \ (2)^2 \ \frac{3300}{1} + \text{SNR}_R$$

$$= 36.8 + \text{SNR}_R \ \text{dB}$$

For a data signal deviation ratio of 1, the calculated minimum SNR is

$$\text{SNR} = 10 \log 3/4 \ (0.7)^2 \ (1)^2 \ \frac{3300}{2} + \text{SNR}_R$$

$$= 27.8 + \text{SNR}_R \ \text{dB}$$

The tests were performed at received power levels of -73, -83, and -86 dBm. Tests were attempted at a received power level of -89 dBm; this power level results in a calculated receiver i.f. section signal-to-noise ratio of

10 dB. However, frequent FM noise spikes occurred at the output of the data signal low pass filter at a received power level of -89 dBm. When the power level was increased to -86 dBm, the spikes became relatively infrequent and the received data signals were considered to be usable.

The calculated data signal-to-noise ratios (rms-to-rms) for the test received power levels are as follows:

Received power (dBm)	Calculated SNR, dB DR=1	DR=2
-73	53.8	62.8
-83	43.8	52.8
-86	40.8	49.8

The value of -73 dBm is estimated to be the minimum level which will be received from the Shuttle vehicle at a slant range of 5 degrees. The use of a 10-watt transmitter is assumed. This power level includes a factor to account for the differences in system noise temperatures between the test receiver and the receiver which would be used to receive the signal from the Shuttle vehicle.

3.3.1 Static Data Signal Noise

The peak-to-peak noise on the recovered data signals was measured at the outputs of the subcarrer discriminators with 0, 2.5, and 5 Vdc data signals applied to the VCO's. The measurements were made with received rf power levels of -73, -83 and -86 dBm, and with VCO deviation ratios of 1 and 2. The measured values are given in table XI.

TABLE XI. - STATIC DATA SIGNAL NOISE, pk-pk PERCENT OF FULL CALE

VCO Channel	0 Vdc	2.5 Vdc	5.0 Vdc	0 Vdc	2.5 Vdc	5.0 Vdc
	Noise, % FS pk-pk					
	DR=1			DR=2		
	rf Level = -73 dBm					
1A	4.5	2.0	4.5	1.0	.8	1.0
2A	4.5	2.5	4.5	1.0	1.0	1.2
3A	4.0	1.7	4.0	.6	.5	.8
4A	4.5	2.5	4.5	.8	.9	1.2
5A	3.5	1.6	4.0	.6	.6	.8
6A	3.5	1.6	6.0	.8	.6	.7
7A	3.0	1.3	5.5	.8	.6	.8
8A	3.0	1.8	4.0	.7	.6	.9
9A	3.5	2.0	4.0	.6	.6	.6
10A	3.0	1.5	3.5	.7	.6	.9
11A	3.0	1.6	3.0	.6	.6	.6
12A	2.5	1.7	3.5	.6	.5	.6
13A	2.5	1.5	2.8	.6	.5	.9
14A	7.0	1.5	7.0	.8	.5	.9
15A	2.0	1.5	3.0	.4	.4	.6
16A	2.0	1.1	1.8	.4	.4	.6
17A	1.6	1.0	1.8	.4	.4	.5
18A	1.6	1.2	2.0	.4	.4	.4
19A	2.0	1.0	2.4	.4	.4	.6
20A	2.0	.8	1.6	.4	.3	.4
21A	1.6	.8	1.7	.4	.3	.4

VCO Channel	0 Vdc	2.5 Vdc	5.0 Vdc	0 Vdc	2.5 V
	Noise, % FS pk-pk				
	DR=1			DR-	
	rf Level = -83 dBm				
1A	4.0	2.0	4.0	.9	.
2A	4.5	2.2	4.4	1.0	1.
3A	4.0	1.7	4.0	.7	.
4A	4.5	2.8	4.4	.8	.
5A	4.0	1.8	3.5	.8	.
6A	4.0	1.8	5.5	.9	.
7A	3.5	1.8	5.5	.9	.
8A	3.5	2.4	4.0	.9	.
9A	3.8	2.2	4.0	.9	
10A	3.9	2.0	4.0	1.0	
11A	3.5	2.2	3.8	1.0	
12A	3.4	2.0	3.8	1.0	
13A	3.2	2.2	3.8	1.0	
14A	7.5	2.3	8.0	1.2	
15A	3.0	2.0	3.4	.9	
16A	3.0	2.0	3.0	.8	
17A	2.8	1.6	3.0	.9	
18A	2.8	2.0	.0	.6	
19A	3.2	2.0	3.5	.8	
20A	2.8	1.8	3.0	.6	
21A	2.8	1.8	2.8	.8	

FOLDOUT FRAME

NOISE, pk-pk PERCENT OF FULL SCALE, TRANSMITTED DATA SHEET

2.5 Vdc	5.0 Vdc	0 Vdc	2.5 Vdc	5.0 Vdc
Noise, % FS pk-pk				
DR=1		DR=2		
rf Level = -83 dBm				
2.0	4.0	.9	.7	1.0
2.2	4.4	1.0	1.0	1.2
1.7	4.0	.7	.6	.9
2.8	4.4	.8	.9	1.2
1.8	3.5	.8	.7	.9
1.8	5.5	.9	.7	.9
1.8	5.5	.9	.7	1.0
2.4	4.0	.9	.8	1.0
2.2	4.0	.9	.8	1.0
2.0	4.0	1.0	.9	1.4
2.2	3.8	1.0	.9	1.1
2.0	3.8	1.0	.9	1.1
2.2	3.8	1.0	.9	1.2
2.3	8.0	1.2	.8	1.2
2.0	3.4	.9	.8	1.0
2.0	3.0	.8	.8	1.0
1.8	3.0	.9	.8	1.0
2.0	3.0	.6	.8	.9
2.0	3.5	.8	.8	1.0
1.8	3.0	.6	.8	.9
1.8	2.8	.8	.8	.9

VCO Channel	0 Vdc	2.5 Vdc	5.0 Vdc	0 Vdc	2.5 Vdc	5.0 Vdc
	Noise, % FS pk-pk					
	DR=1			DR=2		
	rf Level = -86 dBm					
1A	4.0	2.0	4.0	1.0	.8	1.1
2A	4.5	1.8	4.5	1.0	1.1	1.2
3A	4.0	2.0	4.0	.8	.7	1.0
4A	4.0	3.0	4.5	1.0	1.1	1.4
5A	3.5	2.0	4.0	.9	.8	1.1
6A	3.5	2.4	6.0	1.1	1.0	1.1
7A	4.0	2.4	6.0	1.2	1.0	1.2
8A	4.0	2.8	4.0	1.2	1.2	1.3
9A	4.0	2.8	4.0	1.2	1.1	1.2
10A	4.0	2.8	4.5	1.3	1.2	1.5
11A	4.0	2.8	4.0	1.3	1.2	1.4
12A	4.0	3.0	4.5	1.3	1.2	1.4
13A	3.5	2.8	4.0	1.3	1.2	1.5
14A	8.0	2.6	8.5	1.4	1.2	1.5
15A	4.0	2.8	4.0	1.2	1.1	1.4
16A	4.0	2.7	4.0	1.2	1.1	1.3
17A	3.5	2.6	4.0	1.2	1.2	1.2
18A	3.5	2.8	4.0	1.2	1.1	1.2
19A	4.0	2.7	4.5	1.2	1.1	1.3
20A	3.5	2.6	3.5	1.2	1.1	1.2
21A	3.5	2.6	3.5	1.2	1.1	1.3

The signal-to-noise equations given in section 3.3 show that the FM transmitter deviation produced by each of the VCO signals should be proportional to the frequency of the VCO in order to obtain equal signal-to-noise ratios for each of the VCO's. When the VCO signal levels are set to produce transmitter deviation which is proportional to the VCO frequency, the lower frequency VCO's signal levels must be set to relatively low values and are subject to interference from intermodulation signals which may be produced by the higher frequency VCO's. When this occurs, it may be necessary to set the lower frequency VCO levels to a minimum value.

The FM transmitter used provided a frequency deviation sensitivity of 12.2 mVrms per kHz. In order to provide a reasonable transmitter FM modulation index of 0.7 per VCO, it was necessary to set the level of the highest frequency VCO at 10 mVrms. If a constant FM modulation index per VCO was used, the level of the channel 1A VCO would be 0.92 mVrms. It was necessary to increase the minimum VCO level to 5.0 mVrms in order to reduce the data signal noise levels to the values listed in table XI.

The VCO signal output levels for channels 1A through 9A were set to 5.0 mVrms. The VCO signal levels for channels 10A through 21A were set to produce a transmitter FM modulation index of 0.7 per VCO. When the VCO's are operated at low signal levels, the signals are subject to interference from extraneous signals, such as the translating signals which are present in the multiplexer. The 120 kHz translation signal caused 7.0 percent of full scale peak-to-peak noise on the channel 14A (120 kHz center frequency VCO when the data signal was set to 0 Vdc or 5.0 Vdc. Reduced data signal noise levels for the lower frequency VCO's could be obtained if a transmitter were used which had a lower deviation sensitivity.

3.3.2 Dynamic Data Signal Distortion

Sine wave data signals were applied to the VCO's. The total harmonic distortion of the recovered data signals was measured. Measurements were made with a received power level of -73 dBm with VCO deviation ratios of 1 and 2. The measured values are given in table XII. The measured values indicate the noise and crosstalk content of the data signals.

TABLE XII. – DYNAMIC DATA SIGNAL, PERCENT TOTAL HARMONIC DISTORTION, TRANSMITTED DATA TEST

VCO Channel	Data Freq, kHz	-73 dBm
	% THD	
	DR=1	
1A	2.0	2.0
2A	1.9	2.75
3A	1.8	2.8
4A	1.75	2.85
5A	2.0	2.65
6A	1.9	2.4
7A	1.8	2.8
8A	1.9	2.75
9A	2.0	2.35
10A	1.75	3.0
11A	1.8	2.65
12A	1.75	2.5
13A	1.8	3.0
14A	1.9	2.4
15A	2.0	2.6
16A	1.75	2.75
17A	2.0	2.4
18A	1.75	2.9
19A	1.8	2.6
20A	1.9	2.4
21A	2.0	1.85

VCO Channel	Data Freq, kHz	-73 dBm
	% THD	
	DR=2	
1A	1.0	.44
2A	.9	.48
3A	.8	.64
4A	.75	.58
5A	1.0	.55
6A	.9	.47
7A	.8	.43
8A	.9	.66
9A	1.0	.51
10A	.75	.71
11A	.8	.45
12A	.75	.48
13A	.8	.64
14A	.9	.57
15A	1.0	.57
16A	.75	.45
17A	1.0	.44
18A	.75	.64
19A	.8	.48
20A	.9	.58
21A	1.0	.41

4.0 CONCLUSIONS

The test results indicate that the 21 channel IRIG-A VCO's can be used to satisfactorily multiplex 21 data signals which have frequency ranges of dc to 2 kHz. The results indicate that the quality of the received data signals depends on the data signal deviation ratio used, i.e., the frequency range of the signals which are to be multiplexed. The VCO channels were tested with deviation ratios of 1 (dc to 2 kHz data signal frequency range) and 2 (dc to 1 kHz data signal frequency range). The quality of the received data signals is considerably better when a deviation ratio of 2 is used. The narrower data signal low pass filter associated with a deviation ratio of 2 decreases the noise contained with the data signal and reduces the interference caused by channel-to-channel crosstalk. When some data signal degradation can be tolerated, a data signal deviation ratio of 1 can be used to double the frequency range capacity of the multiplexer.

4.1 VCO PERFORMANCE

The tests were performed with the multiplexer output connected directly to the discriminators to obtain baseline performance data, so that any performance degradation caused by the recording and transmission processes could be determined. The maximum data signal noise measured with the FM multiplexer connected directly to the discriminators was 3.9 percent peak-to-peak. The maximum value was measured for VCO channel 6A with a 5.0 Vdc input signal and a data signal deviation ratio of 1.

The noise levels measured for channels 6A and 7A with a 5.0 Vdc data signal applied to both VCO's is caused by mutual crosstalk between the VCO's. Since the channel 7A VCO signal is obtained by translation, a 5.0 Vdc input signal produces a low bandedge frequency, while a 5.0 Vdc input signal applied to channel 6A produces a high bandedge frequency. The two VCO signal frequencies are as near as possible to each other and a maximum crosstalk condition exists when a 5.0 Vdc data signal is applied simultaneously to both VCO's.

The data signal noise levels measured for channels 14A (120 kHz) and 19A (160 kHz) at a deviation ratio of 1 were higher than the noise measured on channels other than channels 6A and 7A (ref. table II). The noise measured on these channels was caused by interference produced by the 120 kHz and 160 kHz multiplexer translators. The noise levels are not considered excessive but do show the possibility that the interference could be worse on these channels if the suppression of the translating frequency at the translator output is inadequate.

The data signal distortion measurements and the crosstalk measurements made at a data signal deviation ratio of 1 show that crosstalk between the channels can be expected. The data signal distortion measurements were made with all VCO's simultaneously modulated by full scale sine wave data signals. The data signal frequencies were made unequal so that crosstalk signals could not be coherent with the data signal on a particular VCO channel. The maximum data signal distortion was 3.0 percent. This value was measured for channels 13A and 18A at a deviation ratio of 1. The crosstalk is inherent and can be reduced effectively only by increasing the spacing between the VCO frequencies or by increasing the deviation ratio. The maximum data signal distortion was 0.65 percent when the deviation ratio was increased to 2.

The channel-to-channel phase error tests were made by applying a single signal to all the VCO's and by measuring the phase difference between the signals at the discriminator data signal low pass outputs. The maximum phase shift between channels was 19 degrees for a data signal frequency of 2.0 kHz; the phase shift decreased in approximate proportion to the signal frequency as the data signal frequency was decreased, and was a maximum of 5.6 degrees at a data signal frequency of 0.5 kHz. Phase shift calibration of the channels would be required if the time correlation between data signals must be more accurate than that which is indicated by the measured phase errors.

4.2 RECORDING TESTS

Test results indicate that some degradation in data signal quality will occur due to tape noise (ref. tables IX through XII). However, the degradation is minimal and the test results are considered to be satisfactory. The peak-to-peak noise measured with dc data signals was a maximum of 1.8 percent when a data signal deviation ratio of 2 was used; the peak-to-peak noise was a maximum of 6.0 percent when a deviation ratio of 1 was used. The total harmonic distortion measured with sine wave signals on all VCO channels was a maximum of 0.86 percent when a data signal deviation ratio of 2 was used; the maximum distortion was 3.3 percent when a deviation ratio of 1 was used.

The tests which were performed with induced tape speed flutter levels of 2.42 and 4.5 percent show that the flutter noise can be reduced effectively by the tape speed compensation equipment. The 4.5 percent flutter level increased the peak-to-peak noise from a maximum of 6.0 percent (no recorder flutter) to a maximum of 8.0 percent when a data signal deviation ratio of 1 was used, and from a maximum of 1.8 percent (no recorder flutter) to a maximum of 2.5 percent when a deviation of 2 was used. A significant increase in data distortion was found when flutter was induced. The recorded sine wave data signals are frequency modulated by the recorder flutter. The distortion measured increased because of the sidebands around the data signals which are caused by the frequency modulation. Tape speed compensation equipment which would eliminate frequency modulation of the data signals is not available. The distortion measured at a deviation ratio of 1 increased from 3.3 percent (no flutter) to a maximum of 5.5 percent when 4.5 percent flutter was induced.

4.3 RF TRANSMISSION TESTS

The test results show that the 21 IRIG-A VCO channels can be transmitted satisfactorily using a S-band rf transmitter, and that standard FM signal-to-noise ratio calculations can be made to predict the data signal signal-to-noise ratio that will be experienced for a particular receiver rf power level.

For a received power level of -73 dBm, (estimated minimum value which would be received from the Shuttle vehicle), the maximum peak-to-peak noise level was 1.2 percent for a deviation ratio of 2 and 7.0 percent for a deviation ratio of 1. Additional tests were performed with the received rf level decreased to levels which are near the receiver threshold. Although data obtained at the lower rf levels are degraded by the receiver noise, the degradation is not severe, and the data obtained with the received rf level set to -86 dBm is considered to be acceptable.

While the test results are considered satisfactory, it was necessary to set the VCO output signals at relatively low levels to obtain reasonable transmitter frequency deviation, and the signals were subject to interference from extraneous signals, such as those generated in the multiplexer translators. The test results could be improved if a transmitter with a lower frequency deviation sensitivity were used. This would allow the VCO signal levels to be raised so that the signals would be less susceptible to interference.

APPENDIX A

TASK 60 TEST PROCEDURE
EVALUATION OF TWENTY-ONE "A" CHANNEL CONSTANT BANDWIDTH FM MULTIPLEXER

EE-5-73-103

TASK 60 TEST PROCEDURE
EVALUATION OF TWENTY-ONE "A" CHANNEL CONSTANT BANDWIDTH FM MULTIPLEXER

APPROVAL:

Astrionics Programs Office ______________________
Charles L. Ritterhouse

Astrionics Programs Office ______________________
Norman B. Farmer

February 1974

EE-5-73-103

TASK 60 TEST PROCEDURE
EVALUATION OF TWENTY-ONE "A" CHANNEL CONSTANT BANDWIDTH FM MULTIPLEXER

PREPARED BY

2-25-74

C. E. Coe, Cognizant Engineer
Astrionics Projects Section

APPROVED BY

2-26-74

W. J. Shannahan, Supervisor
Astrionics Projects Section

L. R. Watkins, General Department Manager
Tracking and Communications Systems Department

Prepared By

Lockheed Electronics Company, Inc.

For

Astrionics Programs Office
Tracking and Communications Development Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

February 1974

LEC-1801
Shuttle

CONTENTS

FIGURES

Figure		Page

TASK 60 TEST PROCEDURE
EVALUATION OF TWENTY-ONE "A" CHANNEL
CONSTAND BANDWIDTH FM MULTIPLEXER

1.0 INTRODUCTION

The tests described in this procedure are for evaluating a 21-channel constant bandwidth (CBW) FM Multiplexer. They are conducted to provide typical data and operating characteristics of the translated system of "A" channels, which are located at center frequencies of 16 to 176 kHz.

Sonex, Inc. voltage controlled oscillators (VCO's), and mixer amplifiers are mounted remotely and are cable connected to the summing chassis which contains the reference oscillator, translators and final mixer. (See figure 1-1.) The VCO modulation package is contained as part of the task 60 breadboard. External test equipment includes the data signal simulators or stimuli to the VCO's. The FR 1300 simulates an onboard recorder configuration; the wideband (2272.5 MHz, 10 watt) transmitter, also on the task 60 breadboard, provides the rf transmission mode for the CBW. Evaluation test equipment is primarily contained in the development flight instrumentation (DFI breadboard ground support equipment (GSE) and a CBW detranslator/discriminator rack assembly.

The static tests at center and bandedge frequencies provide noise data for worst case conditions. Dynamic simulation of the VCO's to both bandedges gives a representation of total harmonic distortion. This procedure treats the two tests independently. Both recorded and transmitted data will be taken for the two basic types of tests.

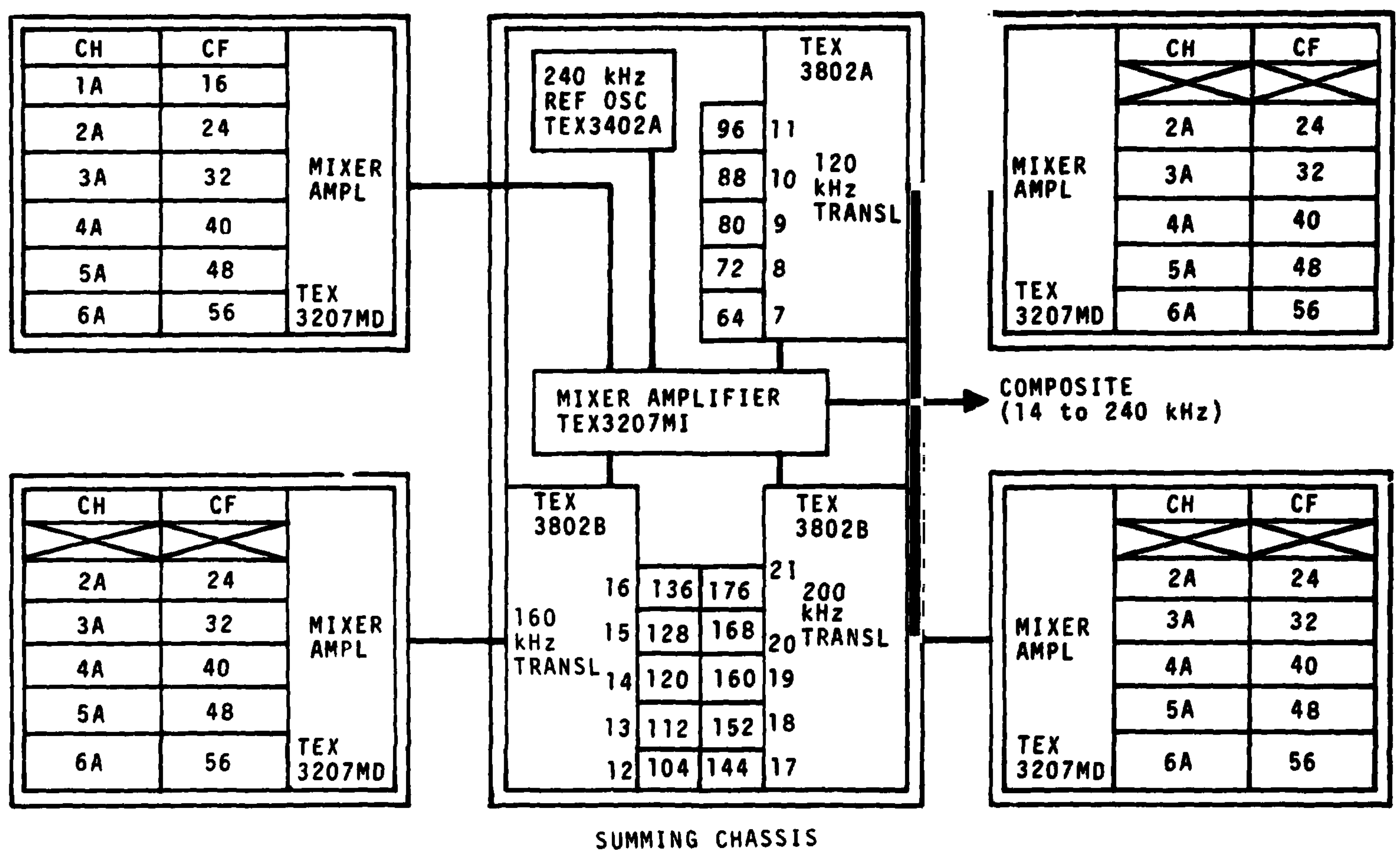


Figure 1-1.-DFI-CBW "A" channel modulation package configuration.

Previous CBW modulation tests (Ref. EE-5-73-501, Task 60 Initial CBW Modulation System Test Report) indicated that adequate signal quality could be obtained with a transmitter deviation of 0.7, a total peak deviation of 504 kHz for the 12 channel, six translated system. Therefore, this deviation factor will be used in these tests for comparison.

Both static and dynamic tests will be performed using an instrumentation recorder, intermediate [illegible]dwidth (300 Hz to 300 kHz), and an rf receiver (3300 kHz I[illegible]).

Tests will be conducted at modulation indexes of 1 and 2, where:

Mod index 1 – 2 kHz low pass filters (LPF) are installed in data discriminators.

Mod index 2 – 1 kHz filters are installed in data discriminators.

The equipment list sheet should be maintained throughout these tests. The test equipment and procedure may be modified at the discretion of the test conductor in order to obtain the required data. Test configuration and signal path data sheets are to be maintained to supplement the procedural figures.

2.0 STATIC STIMULATION NOISE TEST

2.1 CALIBRATION

Basic Method.— Calibrate the oscilloscope and discriminators so that 100 mV deflection on the oscilloscope will indicate 1 percent. This is accomplished using the TM calibrator and adjusting each discriminator output for ±5 Vdc at bandedges and 0 Vdc at center frequency.

Alternate Method.— Apply +2.5 Vdc stimulus to all VCO's on the modulation package. Set the discriminators for 0 Vdc as read on the oscilloscope. Vary stimulus to +5 Vdc and adjust discriminator output for a +5 Vdc response as read on the oscilloscope. Repeat, using 0 Vdc. Repeat these steps as often as needed to establish a ±5 Vdc from bandedge to bandedge as indicated on the oscilloscope. Perform calibration on each discriminator to be used.

2.2 RECORDER SETUP

Using the Ampex FR1300 operations manual, ensure that recorder direct-record/reproduce amplifiers are set up for 60 ips. Check record level by measuring the third harmonic level with a wave analyzer. With a flutter meter, measure the nominal recorder flutter characteristic. Perform a frequency response check for these CBW test frequencies, measure the signal-to-noise ratio, and record on data sheet A-7. Perform tape and recorder slot noise measurements per data sheet instructions (A-7 and A-8).

2.3 SYSTEM BASELINE DATA

Performance check of VCO's and mixers shall have been performed previously with the special 21-channel chassis prior to these tests. CBW test system and support equipment baseline noise is measured and recorded according to the following steps. See figure 2-1.

1. Apply +2.5 Vdc stimulus to all VCO's by setting the Epsco Power Supply to +2.5 Vdc.
2. Set the composite package output using a wave analyzer. Monitor the mixer amplifier output, and adjust each data VCO for 0.070 Vrms and the 240 kHz reference oscillator component for 0.140 Vrms. Ensure that the 2 kHz filters are in the discriminators. Record data on sheets A-11 through A-14.
3. Using the Tektronix oscilloscope, monitor the discriminator output and record the peak-to-peak noise levels in percent for each channel. Repeat test with Epsco set at +5 Vdc (upper bandedge) and 0 Vdc (lower bandedge).
4. Monitor the bandpass filter of each discriminator using the Beckman counter, and record frequencies for each of the following conditions:

   0 Vdc stimulus

   +5 Vdc stimulus

   +2.5 Vdc stimulus

   NOTE: Wideband amplifier (HP 467A) is required to raise signal levels to the triggering level of counter.

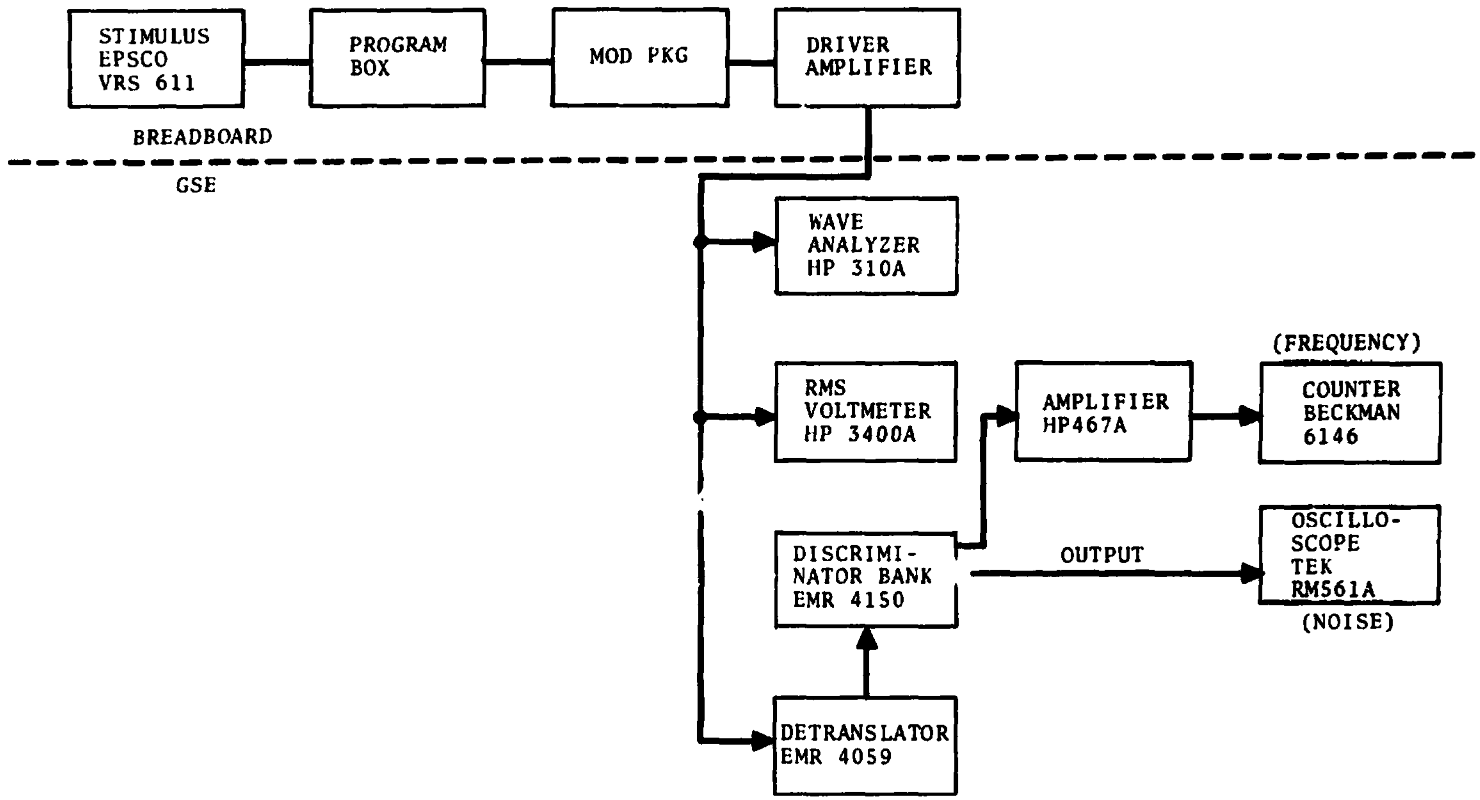


Figure 2-1. – Static test baseline.

5. Repeat the above with 1 kHz filters for MI = 2; a repeat of step 4 is not required.

2.4 RECORDED DATA

Configure the Ampex FR1300 and test equipment as described in figure 2-2.

2.4.1 Recording Procedure

NOTE: Mod package set per baseline test.

1. Set stimulus (Epsco) for +2.5 Vdc.
2. Verify that VCO and reference levels are per baseline test, and that 1 kHz filters are installed in the data discriminators.
3. Read and record composite signal amplitude prerecording using HP 3400 for true rms and oscilloscope for peak-to-peak volts.
4. Record data with stimulus (Epsco) set for 0 Vdc, +2.5 Vdc and +5 Vdc. Record sufficient data at each point to allow for making measurements of percent noise and frequency for each VCO on playback.
5. Play back recording, making measurement of percent noise, frequency of each VCO and reference, composite signal (rms) and peak-to-peak. Record on data sheet A-15.
6. Induce approximately 2.5 percent flutter on tape recorder.

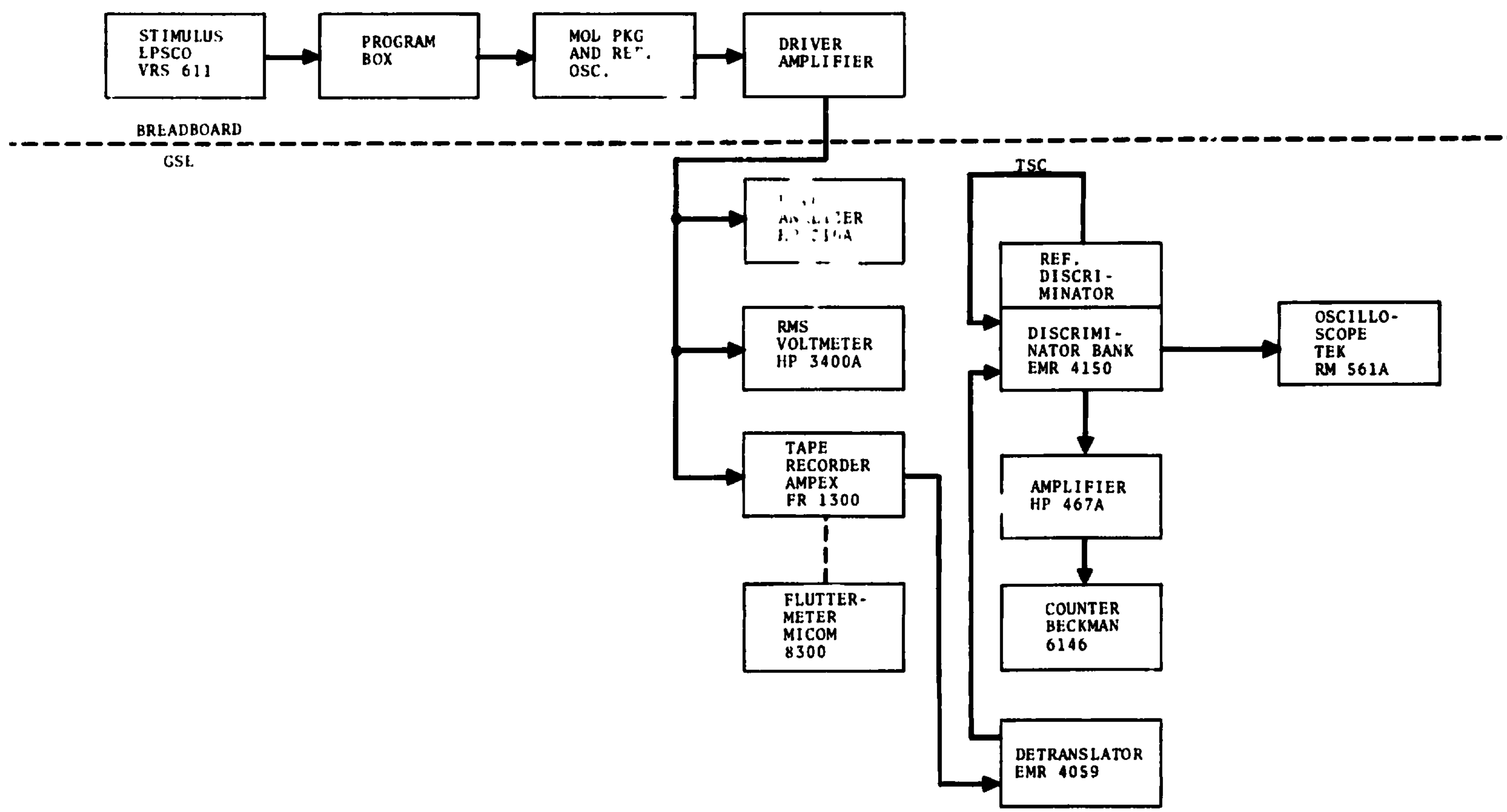


Figure 2-2. – Recorded data test.

NOTE: Flutter shall be induced by adding tape to the capstan and repeating measurements of tape recorder flutter until conditions of steps 6 and 9 are met.

7. Measure percent flutter on tape recorder, test frequency 50 kHz, bandpass 2 to 5 kHz, PK switch at 2σ.

8. Repeat steps 4 and 5. Record on data sheet A-16.

9. Induce approximately 5 percent flutter on tape recorder. Measure per step 7.

10. Repeat steps 4 and 5. Record on data sheet A-17.

11. Change discriminator filters to 2 kHz and play back the recordings made in steps 5, 8, and 10. Record the data on sheets A-18, 19 and 20.

2.5 TRANSMITTED DATA

2.5.1 Preliminary Steps

1. Connect equipment as described in figure 2-3.

2. Set up modulation package preemphasis according to the deviation schedule (appendix sheet A-10). Measure and record the VCO levels, the composite rms, and peak-to-peak voltage at the transmitter input. Disable the mod package 240 kHz reference frequency.

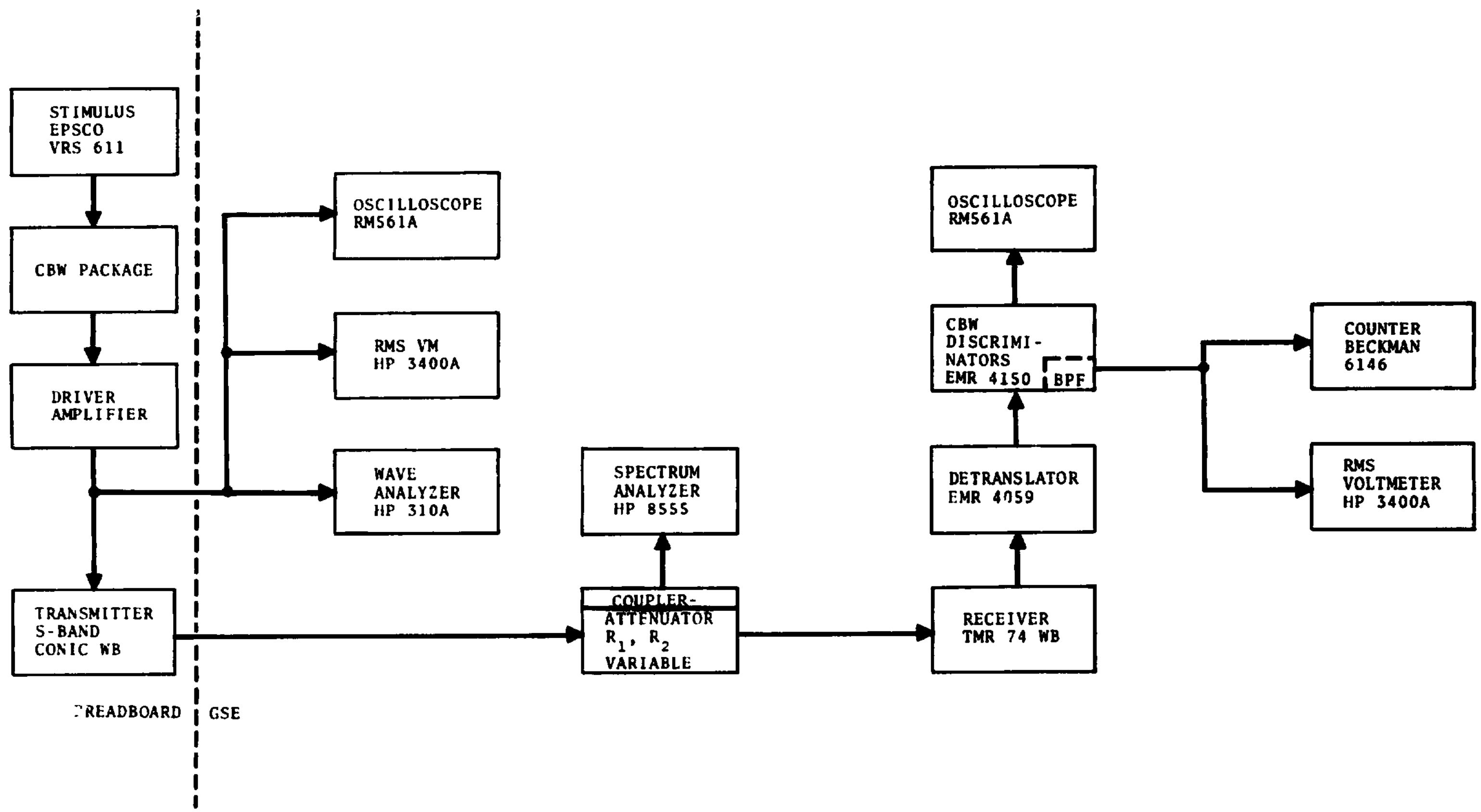


Figure 2-3. — Transmitted data test.

3. Set up TMR74 receiver for 3300 kHz IF bandwidth and 250 kHz video bandwidth.

4. Configure rf components per appendix sheet A-9. Apply power to the Conic transmitter and measure the power level at the 20 dB power attenuator output. Reconnect per figure 2-3 and measure power at the cable end to the receiver, with both R_1 and R_2 set to zero. Subtract these two numbers and add 20 dB for the fixed path loss. Measure power level at the -30 dB sampling port of the first coupler. To this measurement add 50 dB, thus giving the transmitter power. Perform calculations for variable attenuator settings for the total received power per the rf setup and calibration data sheet A-9.

5. Complete the cabling between the Conic transmitter, the rf attenuator, coupler, and receiver. Apply modulation to the transmitter, dial maximum attenuation, then apply transmitter power. Readjust rf attenuator corresponding to the first rf level on the appendix data sheet A-9.

6. Ascertain that 2 kHz filters are installed (MI = 1).

2.5.2 Transmitting Procedure

1. Read and record percent noise and VCO frequency for each channel, with rf level set for -73 dBm. Record data on sheets A-21, 22 and 23.

2. Reset attenuators corresponding to -83 dBm.
   Repeat step 1, except for frequency measurement.
3. Reset attenuators corresponding to -86 dBm.
4. Repeat step 1, except for frequency measurement.
5. Install discriminator 1 kHz filters (MI = 2).
6. Repeat steps 1 through 4. Record data on sheets
   A-24, 25 and 26.

3.0 DYNAMIC STIMULATION DISTORTION TESTS

3.1 PRELIMINARY STEPS

The equipment shall be configured as shown in figure 3-1. Signal generators (oscillators) are set to dynamically stimulate the CBW subcarrier oscillators according to the following:

CBW dynamic test signals

1. Discriminator MI = 1 (2 kHz Filters)

CH 1A, 5A, 9A, 15A, 17A, 21A	=	2.0 kHz
CH 2A, 6A, 8A, 14A, 20A	=	1.9 kHz
CH 3A, 7A, 11A, 13A, 19A	=	1.8 kHz
CH 4A, 10A, 12A, 16A, 18A	=	1.75 kHz

2. Discriminator MI = 2 (1 kHz Filters)

CH 1A, 5A, 9A, 15A, 17A, 21A	=	1.0 kHz
CH 2A, 6A, 8A, 14A, 20A	=	0.9 kHz
CH 3A, 7A, 11A, 13A, 19A	=	0.8 kHz
CH 4A, 10A, 12A, 16A, 18A	=	0.75 kHz

3.2 CALIBRATION

Reference the tape recorder, transmitter, receiver and rf path setups in the previous static tests. No changes are required. VCO output amplitudes must be checked with only the +2.5 Vdc stimulus applied to their inputs.

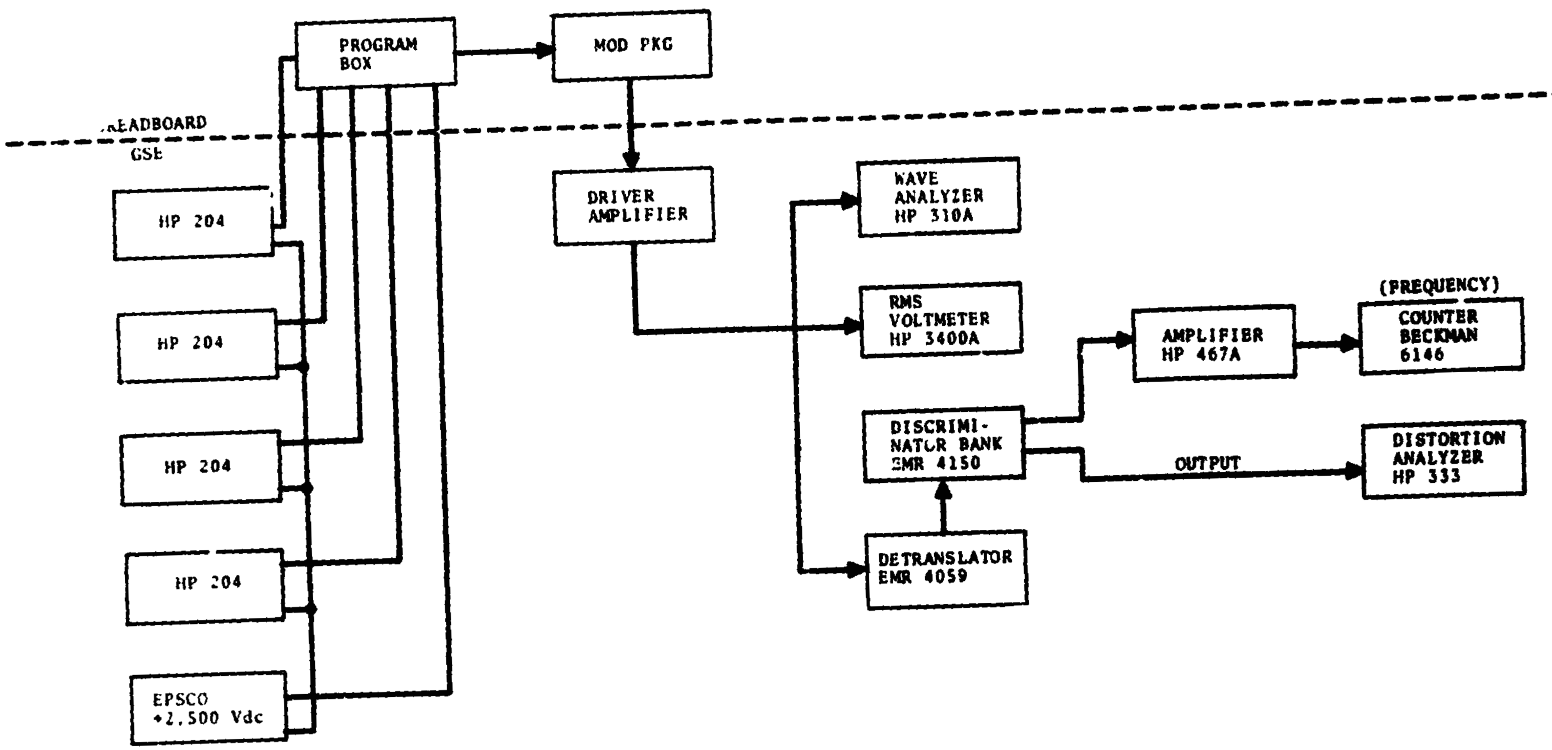


Figure 3-1. – Dynamic test baseline.

3.3 SYSTEM BASELINE DATA

Using the DFI breadboard and GSE, set up the equipment as shown in figure 3-2. External oscillators will be required as well as a harmonic distortion analyzer.

3.3.1 Baseline Data

1. Set up bias power supply for (+) 2.5 Vdc, into common VCO input for VCO center frequency adjustment. Record data on sheet A-27.
2. With the wave analyzer, measure and reset VCO levels to 70 mV and reference to 140 mV.
3. Connect bias supply to the oscillators as shown; enable the 240 kHz reference oscillator.
4. Set oscillators to the above frequencies for MI = 1 with dial accuracy; set output levels to 5 V pk-pk, using the oscilloscope. Reference paragraph 3.1 for frequencies and distribution.
5. Ensure that discriminators contain 2 kHz filters.
6. Read and record on the data sheet the total harmonic distortion (THD) for each of the discriminator channel outputs. Record on data sheet A-27.
7. Change discriminator filters to 1 kHz and test frequencies for MI = 2; repeat steps 6 and 7. Record on data sheet A-27.

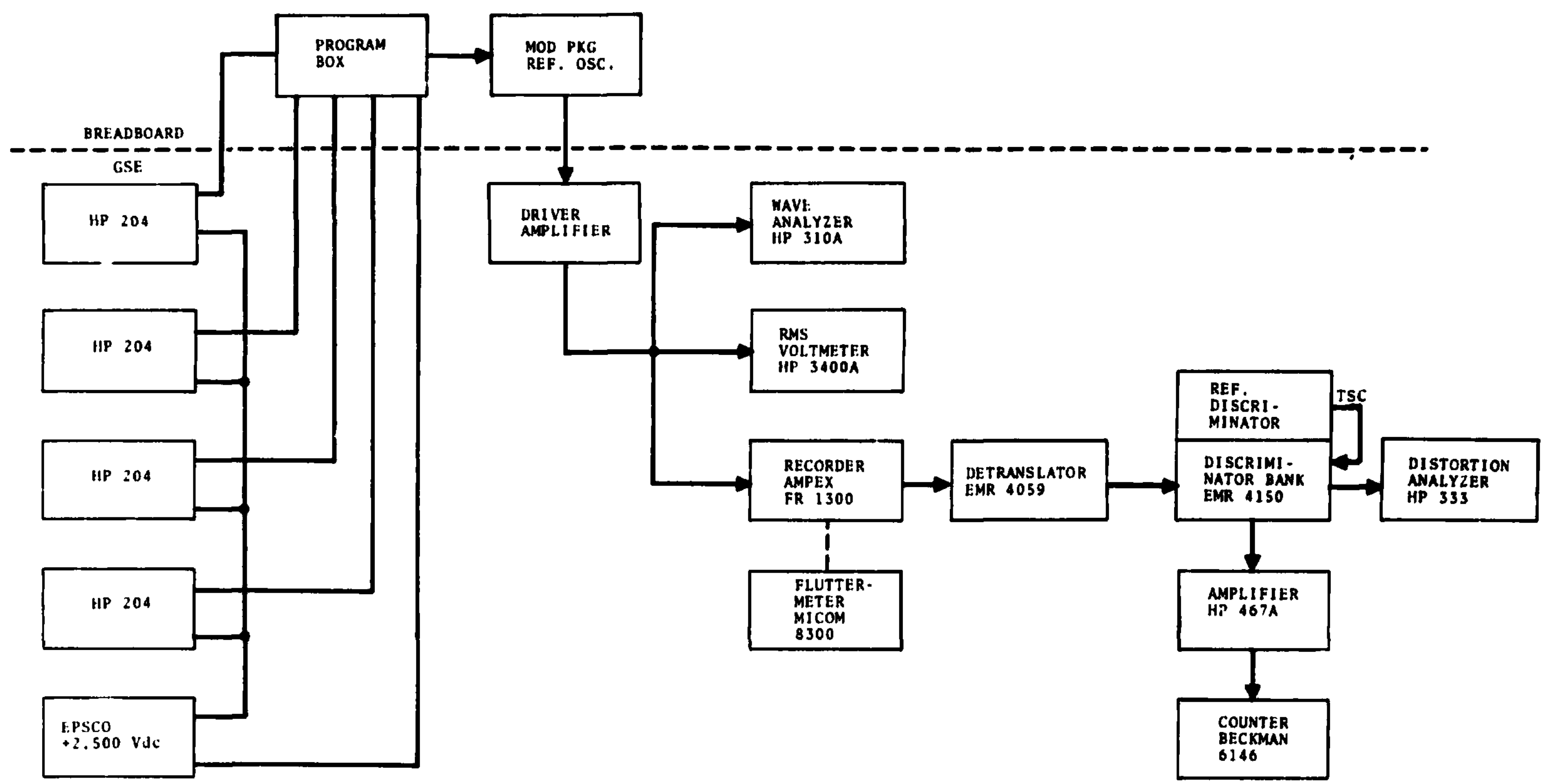


Figure 3-2. — Recorded data test.

3.3.2 Interchannel Crosstalk

Obtain basic noise data from sheet A-13, and use in obtaining the crosstalk component.

1. Stimulate channel 6A with 2 kHz, 5 V pk-pk, and measure the percent noise on each of the remaining channel outputs. Record on data sheet A-32.

2. Stimulate, in turn, channel 11A, 16A, and 21A; and repeat measurements as per step 1. Record data on sheet A-32.

3.3.3 Interchannel Phase

Assuring setup of VCO outputs for recording levels, simultaneously apply a test signal to two channels, per sheet A-33. The test signal amplitude shall be 5 V peak-to-peak. With a phase meter measure the adjacent channels' phase lead or lag. Record data on sheet A-33.

1. Perform the measurement with test signal at 2 kHz and with 2 kHz LPF's.

2. Change signal frequency to 1 kHz, and repeat.

3. Change to 1 kHz LPF's and repeat.

4. Reduce signal to 500 Hz and repeat measurement.

3.4 RECORDED DATA

Change equipment setup to include the Ampex FR1300 between the mod package and the detranslator discriminators, as in the static tests previously run. See figure 2-1.

1. Read and record the composite signal amplitude, volts peak-to-peak, and volts rms.
2. Record data with oscillators set to 5 V pk-pk, and record sufficient data to allow time for THD measurements on each channel.
3. Play back recording, measuring the THD for each channel through 1 kHz discriminator filters (MI = 2). Record data on sheet A-28.
4. Rewind tape and change filters to 2 kHz and reset oscillator frequencies. Then play back recording, measuring the individual channel's THD.
5. Use same equipment as in the paragraphs above. Add tape to the recorder capstan to provide ≈2 percent flutter. Repeat steps 1 through 4. Record data on sheet A-29.
6. Repeat step 1 above, but change tape to provide ≈5 percent flutter. Record data on sheet A-30.

3.5 TRANSMITTED DATA

3.5.1 Preliminary Steps

Configure CBW system per figure 3-3, and perform checks to assure rf path setup per section 2.5.1. Disable the 240 kHz reference oscillator.

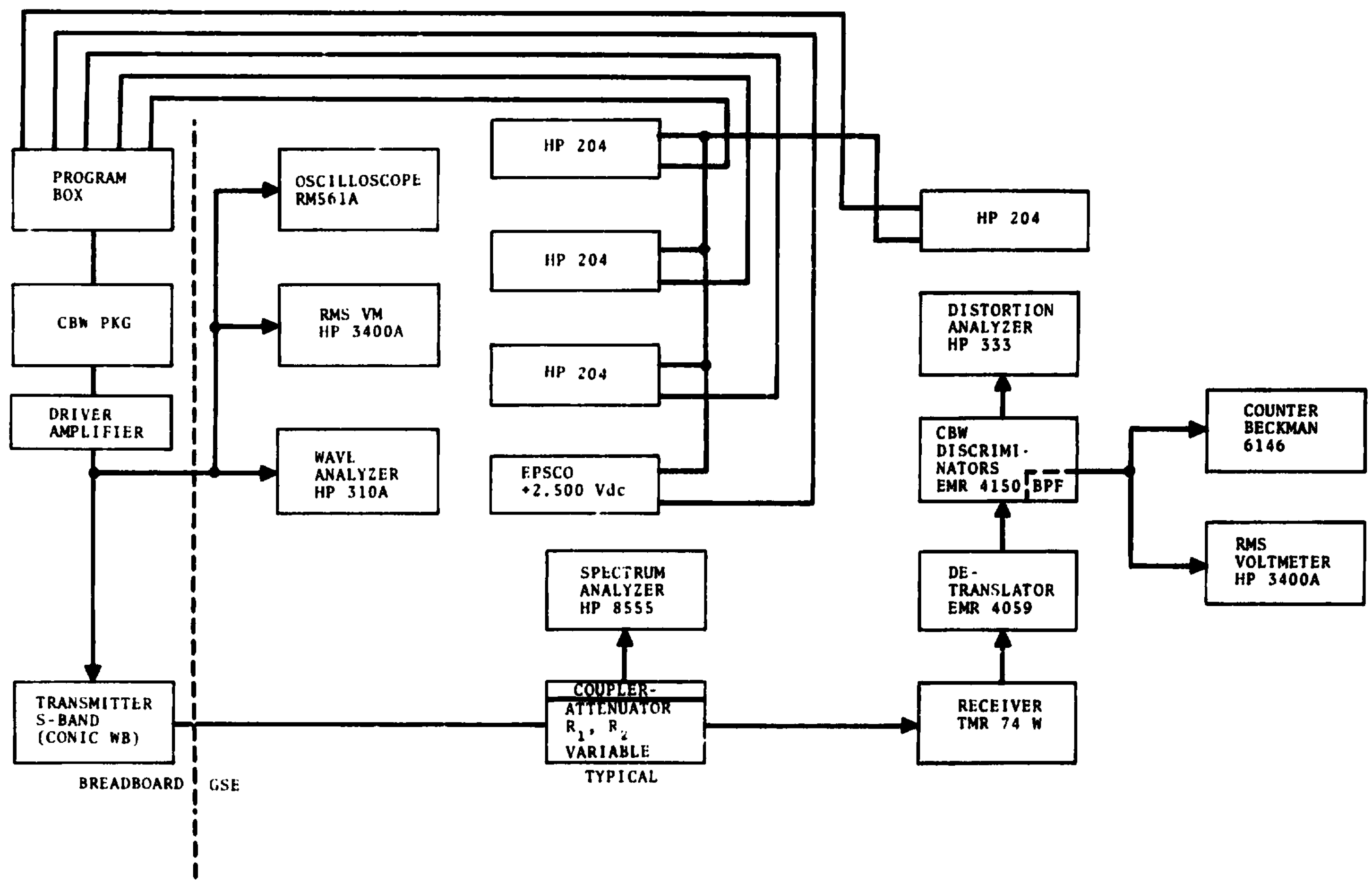


Figure 3-3. – Transmitted data test.

3.5.2 Transmitting Procedure

1. With the rf level set for -73 dBm, read and record the test signal frequencies and measure the total harmonic distortion (THD) for each channel. The test signals are set up for MI = 1 data. Record data on sheet A-31.
2. Install discriminator 1 kHz filters; repeat step 1 with the MI = 2 test signal frequencies.

APPENDIX A

DATA SHEETS

CONTENTS

21- "A" CHANNEL CBW

PAGE NO. 1

TEST NUMBER | SHEET OF | TEST PROCEDURE NO. | PROCEDURE SECTION NO.

RECORDED BY 5-16-74 [signature]

APPROVED BY [signature]

TYPE OF TEST AND DATA OUTPUT POINT

EQUIPMENT LIST

EQUIPMENT NOMENCLATURE	MODEL	MFR S/N	NASA S/N
Phasemeter	329 B, P/I AZ	Action	77424
Wave Analyzer	310A	H-P	87428
Frequency Counter	5245	H-P	82267
Digital Voltmeter	8300A	Fluke	87049
Distortion Analyzer	333A	H-P	63452
Time Code Generator	9300	Datum	99200
Power Meter	432B	H-P	89324
Power Supply	36-15A	Sorenson	35384
Receiver	TMR-74	DEI	84099
RF Tuner	TU-74-5A	DEI	84100
FM Demod. - WB	D-74-EW	DEI	84101
DC Power Source	VRS 611	Epsco	58084
Oscillator #1	204B	H-P	79354
Oscillator #2	204B	H-P	39941
Oscillator #3	5000	K-H	87682
Oscillator #4	142	Wavetek	82973
Oscilloscope	RM561	Tek.	89101
Time Base	3B3	Tek.	89103
Dual Trace Amplifier	3A72	Tek.	63556
Tape Recorder	FR1300	Ampex	73391
True RMS Voltmeter	3400A	H-P	90710
Universal Tunable Discriminator	410-01	EMR	99625
Flutter Meter	8300	Mincom	78347

REMARKS:

LEC FORM 142 (AUG 69) NASA — MSC

21-"A-CHANNEL CBW'			PAGE NO. 2
TEST NUMBER	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO.	
RECORDED BY 5-16-74 H.C. Bynley	TYPE OF TEST AND DATA OUTPUT POINT		
APPROVED BY CM Haddin	EQUIPMENT LIST		

EQUIPMENT NOMENCLATURE	MODEL	MFR S/N	NASA S/N
Spectrum Analyzer	141T	H-P	87852
RF Tuner	8556A	H-P	90339
IF	8552B	H-P	87581
1. Discriminator	4150	EMR	98124
Low Pass Filter	4157-02	EMR	2554
Channel Selector	4151-01	EMR	3071
2. Discriminator	4150	EMR	98855
Low Pass Filter	4157-02	EMR	2952
Channel Selector	4151-01	EMR	3073
3 Discriminator	4150	EMR	98863
Low Pass Filter	4157-02	EMR	2974
Channel Selector	4151-01	EMR	3077
4 Discriminator	4150	EMR	98856
Low Pass Filter	4157-02	EMR	2951
Channel Selector	4151-01	EMR	3079
5. Discriminator	4150	EMR	98861
Low Pass Filter	4157-02	EMR	2973
Channel Selector	4151-01	EMR	3082
6 Discriminator	4150	EMR	98865
Low Pass Filter	4157-02	EMR	2955
Channel Selector	4151-01	EMR	3086
7. Discriminator	4150	EMR	98854
Low Pass Filter	4157-02	EMR	2945

REMARKS.

[illegible]

21-"A" CHANNEL CBW		PAGE NO. 3
TEST NUMBER	SHEET OF	TEST PROCEDURE NO / PROCEDURE SECTION NO.
RECORDED BY 5-16-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT	
APPROVED BY CM Hadddrick	EQUIPMENT LIST	

EQUIPMENT NOMENCLATURE	MODEL	MFR S/N	NASA S/N
7 Channel Selector	4151-01	EMR	3074
8 Discriminator	4150		98866
Low Pass Filter	4157-02		2950
Channel Selector	4151-01		3075
9 Discriminator	4150		98862
Low Pass Filter	4157-02		2944
Channel Selector	4151-01		3078
10 Discriminator	4150		98859
Low Pass Filter	4157-02		2947
Channel Selector	4151-01		3083
11 Discriminator	4150		98125
Low Pass Filter	4157-02		2949
Channel Selector	4151-01		3084
12 Discriminator	4150		98864
Low Pass Filter	4157-02		2935
Channel Selector	4151-01		3072
13 Discriminator	4150		98860
Low Pass Filter	4157-02		2946
Channel Selector	4151-01		3076
14 Discriminator	4150		98858
Low Pass Filter	4157-02		2936
Channel Selector	4151-01	EMR	3080
Group Detranslator	4059	EMR	98117

REMARKS: Ref. Unit 98119 & 98118

2.1 "A" CHANNEL CBW		PAGE NO. 4
TEST NUMBER 2.2	SHEET OF	TEST PROCEDURE NO / PROCEDURE SECTION NO.
RECORDED BY T.C. Brinkley	TYPE OF TEST AND DATA OUTPUT POINT FR 1300 RECORD/PLAYBACK SET-UP 60 ips	
APPROVED BY [illegible signature]		

INPUT: freq 1 kHz, level 1.0 Vrms

OUTPUT: level (kHz BPF) 0 dB, 3rd Harmonic -40 dB

RECORDER NOMINAL FLUTTER 0.24 %

TRACK 4 USED FOR SET-UP DATA.

REMARKS: OSCILLATOR SN 74587, ANALYZER N 63542, FLUTTERMETER SN 78347

① ANALYZER BPF-BW = N/A kHz

NASA — MSC

21- "A" CHANNEL CBW

PAGE NO. 5

TEST NUMBER 2.2 | SHEET OF | TEST PROCEDURE NO. | PROCEDURE SECTION NO.

RECORDED BY: R.C. Brinkley

APPROVED BY: W.M. Haddick

TYPE OF TEST AND DATA OUTPUT POINT: TAPE RECORDER SET-UP

Slot noise - After routine set up, i.e., for 1 Vrms and 1% third harmonic, erase tape.
- Short data channel input and assure proper output loading and connect to 3 kHz BPIF Wave Analyzer.
- Operate the recorder at ips.
- Measure and record the noise floor level for:

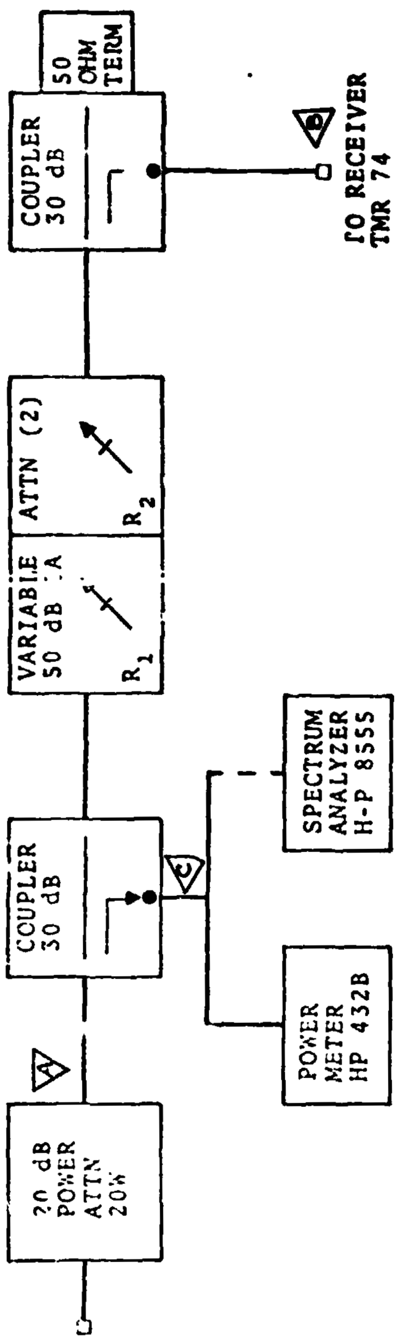
Freq. kHz	Level Sig.	Level Noise
10	-8dB	-65dB
20	-8dB	-75dB
40	-8dB	-75dB
80	-8dB	-75dB
100	-8dB	-73dB
200	-6dB	-70dB
400	-4dB	-67dB

REMARKS: This measurement may be used to adjust the recording levels of the subcarriers.

LEC FORM 142 (AUG 69) NASA — MSC

2i- "A" CHANNEL C.B.W.	PAGE NO. 6

TEST NUMBER 2.5.1.2	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO.
RECORDED BY H. C. [signature]	TYPE OF TEST AND DATA OUTPUT POINT	
APPROVED BY [signature]	RF SETUP AND CALIBRATION	



Power meas at A +20.2 dBm ; at B -13.5 dBm ; at C -10.1 dBm

$P_t = C + 50 = +39.9$ dBm; EPL = A-B $(R_1 = R_2 = 0)$

$\therefore R_1 + R_2 = P_t - EPL - TRP$ for TRP's of -73 dBm, -83 dBm, -86 dBm

$R_1 + R_2$ SET	TRP
59.5 dB	73 dBm
69.5	83
72.5	86

LEC FORM 92 (MAY 68)

21 - "A" CHANNEL CBW

PAGE NO. 7

TEST NUMBER 2.5.1 | SHEET OF | TEST PROCEDURE NO | PROCEDURE SECTION NO

RECORDED BY 5-14-74 N.C. Byerley

APPROVED BY [signature]

TYPE OF TEST AND DATA OUTPUT POINT

RF DEVIATION SCHEDULE

CH	f_c	kHz	mVrms	CH	f_c	kHz	mVrms
1A	16	61.0	5.0	12A	104	72.8	5.97
2A	24	61.0	5.0	13A	112	78	6.39
3A	32	61.0	5.0	14A	120	84	6.88
4A	40	61.0	5.0	15A	128	89	7.29
5A	48	61.0	5.0	16A	136	95	7.79
6A	56	61.0	5.0	17A	144	101	8.26
7A	64	61.0	5.0	18A	152	106	8.69
8A	72	61.0	5.0	19A	160	112	9.18
9A	80	61.0	5.0	20A	168	118	9.67
10A	88	61.6	5.05	21A	176	123	10.1
11A	96	67.2	5.5				
				TOTAL		156.6	

REMARKS XMTR SENS. = 12.2 kHz/mVrms

LEC FORM 91 (MAY 68) NASA — MSC

"A" CHANNEL CBW		PAGE NO. 5
TEST NUMBER 2.3-4	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO STATIC
RECORDED BY 5-9-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT	
APPROVED BY [signature]	S.C. FREQUENCY BASELINE UNTRANSLATED	

CHANNEL	LBG	C	HBE
1A	14006	16026	18023
2A	22006	24015	26013
3A	30004	32010	34015
4A	38003	40008	42003
5A	45996	48006	50008
6A	54020	56016	57999
7A	54005	56010	58008
8A	46003	48012	50013
9A	38016	40031	42035
10A	29997	32001	34001
11A	21994	24003	26005
12A	54010	56020	58022
13A	46017	48027	50028
14A	38009	40021	42023
15A	29990	31997	33998
16A	22007	24013	26008
17A	54003	56018	58020
18A	46007	48019	50021
19A	38009	40018	42017
20A	30005	32014	34017
21A	22000	24007	26005

PACKAGE
COMPOSITE OUTPUT
.340 Vrms
2.8 Vpk-pk

LEC FORM 92 (MAY 68)

NASA — MSC

"A" CHANNEL CBW

PAGE NO. 7

TEST NUMBER 2.3-4	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO STATIC
RECORDED BY 5-9-74 N.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT S.C. FREQUENCY BASELINE TRANSLATED	
APPROVED BY [signature]		

CHANNEL	LBG	C	HBE
1A	14006	16026	18023
2A	22006	24015	26013
3A	30004	32010	34015
4A	38003	40008	42003
5A	45996	48006	50008
6A	54020	56016	57999
7A	54003	56007	58006
8A	46001	48010	50011
9A	38013	40027	42033
10A	29995	31996	33998
11A	21991	23999	26001
12A	54017	56027	58028
13A	46026	48035	50035
14A	38016	40027	42027
15A	29998	32004	34004
16A	22013	24019	26014
17A	54000	56015	58017
18A	46004	48015	50018
19A	38005	40015	42014
20A	30002	32010	34014
21A	21996	24004	26002

LEC FORM 92 (MAY 68)

NASA — MSC

"A" CHANNEL CBW

PAGE NO. 10

TEST NUMBER 2.3-3	SHEET OF	TEST PROCEDURE NO. / PROCEDURE SECTION NO STATIC
RECORDED BY 5-10-74 N.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT	% NOISE BASELINE MI = 1
APPROVED BY [signature]		

CHANNEL	LBE	C	HBE
1A	1.8	1.3	1.7
2A	1.8	1.3	1.7
3A	1.5	.8	1.4
4A	1.8	1.1	1.8
5A	1.6	1.0	1.7
6A	1.3	.9	3.4
7A	1.3	.9	3.5
8A	1.5	1.0	1.7
9A	2.0	.9	1.7
10A	1.8	.9	1.8
11A	1.3	.9	1.4
12A	1.6	.9	1.6
13A	1.5	1.1	1.8
14A	2.6	.9	2.8
15A	1.2	.8	1.3
16A	1.5	1.0	1.4
17A	.9	.6	1.3
18A	9	.6	1.0
19A	2.3	.8	2.4
20A	.9	.6	.9
21A	1.0	.6	.8

RECORDER COMPOSITE OUTPUT
.340 Vrms
2.8 Vpk-pk

"A" CHANNEL CBW

PAGE NO. 11

TEST NUMBER 2.3-3	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO STATIC
RECORDED BY 5-10-74 [illegible]	TYPE OF TEST AND DATA OUTPUT POINT % NOISE	BASELINE MI=2
APPROVED BY [illegible]		

CHANNEL	LBE	C	HBE
1A	.5	.4	.5
2A	.4	.4	.5
3A	.4	.3	.3
4A	.4	.4	.6
5A	.3	.4	.5
6A	.5	.4	.4
7A	.5	.3	.4
8A	.3	.4	.6
9A	.4	.4	.4
10A	.4	.4	.5
11A	.3	.3	.4
12A	.4	.3	.4
13A	[illegible]	.4	.6
14A	.4	.3	.4
15A	.3	.3	.3
16A	.3	.3	.4
17A	.3	.2	.2
18A	.2	.2	.2
19A	.3	.4	.5
20A	.2	.2	.2
21A	.3	.2	.3

"A" CHANNEL CBW	PAGE NO. 12

TEST NUMBER 2.4.1-5	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO. STATIC
RECORDED BY 5-10-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT	
APPROVED BY [signature]	RECORDED % NOISE MI = 1	

CHANNEL	S.C. FREQ. @ C	LBE	C	HBE	
1A	16025	4.0	2.8	3.5	71
2A	24007	3.5	2.5	3.5	70
3A	32000	3.5	2.4	3.5	70
4A	39996	4.0	2.5	4.0	70
5A	47995	4.0	2.5	4.0	71
6A	55999	4.0	2.8	6.0	69
7A	56000	4.5	2.8	6.0	70
8A	47996	4.5	3.0	5.0	69
9A	40019	5.0	3.0	5.0	70
10A	31986	5.0	3.0	5.0	70
11A	23992	5.0	3.0	5.0	70
12A	56011	5.0	3.0	6.0	70
13A	48020	5.0	3.5	5.5	68
14A	40013	6.0	3.3	6.0	70
15A	31989	6.0	3.4	5.5	69
16A	24009	6.0	3.5	5.5	70
17A	56006	5.5	3.4	6.0	71
18A	48000	5.5	3.4	6.0	70
19A	39999	6.0	3.4	6.0	69
20A	31999	6.0	3.2	6.0	70
21A	23994	6.0	3.2	6.0	70

RECORDER COMPOSITE OUTPUT .346 VRMS [illegible] V pk-pk

240 kHz Ref. Level .140 Vrms

"A" CHANNEL CBW	PAGE ! /.3

TEST NUMBER 2.4.1-8	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO
RECORDED BY 5-13-74 H.C. Bradley APPROVED BY VM Haddock	TYPE OF TEST AND DATA OUTPUT POINT % NOISE RECORDED ≈ 2.5 % FLTR MI = 1	

CHANNEL	S.C. FREQ @ C	LBE	C	HBE	
1A	15942	4.0	2.5	4.0	
2A	23887	4.3	2.5	4.0	
3A	31835	4.3	2.4	4.5	
4A	39793	4.5	2.7	4.5	
5A	47750	4.5	2.7	4.5	
6A	55707	5.0	2.8	6.5	
7A	55726	5.0	3.0	7.0	
8A	47750	5.5	3.0	5.5	
9A	39818	5.5	3.0	5.5	
10A	31824	5.5	3.3	5.5	
11A	23876	5.5	3.3	5.5	
12A	55733	5.5	3.4	6.0	
13A	47785	6.0	3.8	6.0	
14A	39812	6.0	3.5	6.0	
15A	31829	6.0	3.5	6.0	
16A	23889	6.5	3.7	6.0	
17A	55731	6.5	3.7	6.5	
18A	47761	6.5	3.8	6.0	
19A	39798	7.0	3.7	7.0	
20A	31841	7.0	3.7	6.0	
21A	23874	7.0	3.5	6.0	

RECORDER OUTPUT (COMPOSITE) [illegible] Vrms [illegible] Vpk-pk

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"A" CHANNEL CBW			PAGE NO. 14
TEST NUMBER 2.4.1-10	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO	
RECORDED BY 5-13-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT % NOISE RECORDED ≈ 5.0% FLTR MI = 1		
APPROVED BY [signature]			

CHANNEL	S.C. FREQ @ C	LBE	C	HBE	
1A	15887	4.0	2.8	4.0	
2A	23802	4.0	2.6	4.0	
3A	31724	4.5	2.7	4.0	
4A	39652	4.5	2.8	4.0	
5A	47528	5.0	3.0	4.0	
6A	55441	5.5	3.4	7.0	
7A	55458	6.0	3.5	7.0	
8A	47515	6.0	3.5	5.0	
9A	39621	6.0	3.6	5.0	
10A	31667	6.0	3.6	5.0	
11A	23753	6.0	3.6	5.0	
12A	55430	7.0	3.8	5.5	
13A	47537	7.0	4.0	5.5	
14A	39611	8.0	4.0	6.0	
15A	31662	7.0	4.0	5.5	
16A	23763	7.5	4.0	5.5	
17A	55432	8.0	4.0	5.5	
18A	47507	7.5	4.4	5.5	
19A	39588	8.0	4.4	6.0	
20A	31673	7.5	4.2	5.5	
21A	23748	7.5	4.0	5.5	

RECORDER COMPOSITE OUTPUT .3/C VRMS 2.7 Vpk-pk

LEC FORM 92 (MAY 68) NASA — MSC

"A" CHANNEL CBW

PAGE NO. 15

TEST NUMBER	SHEET OF	TEST PROCEDURE NO. / PROCEDURE SECTION NO.
2.4.1-5		

RECORDED BY 5-10-74 H.C. Byerley

APPROVED BY [illegible signature]

TYPE OF TEST AND DATA OUTPUT POINT: % NOISE RECORDED

MI = 2

CHANNEL	S.C. FREQ @ C	LBE	C	HBE	
1A		1.4 *	1.0 *	1.8 *	
2A		1.1	1.0	1.1	
3A		1.2	1.0	1.2	
4A		1.3	1.3	1.2	
5A		1.3	1.2	1.3	
6A		1.4	1.4	1.5	
7A		1.4	1.3	1.5	
8A		1.5	1.3	1.5	
9A		1.5	1.3	1.5	
10A		1.5	1.3	1.6	
11A		1.5	1.4	1.5	
12A		1.5	1.5	1.7	
13A		1.5	1.5	1.8	
14A		1.6	1.5	1.8	
15A		1.7	1.5	1.7	
16A		1.7	1.5	1.7	
17A		1.7	1.6	1.8	
18A		1.6	1.5	1.7	
19A		1.7	1.5	1.8	
20A		1.8	1.5	1.7	
21A		1.7	1.6	1.7	

* [illegible] DISCRIMINATOR

"A" CHANNEL CBW	PAGE NO. 16

TEST NUMBER 2.4.1-3	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO.
RECORDED BY 5-13-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT	
APPROVED BY [signature]	% NOISE RECORDED x 2.5% FLTR MI = 2	

CHANNEL	S.C. FREQ. @ C	LBE	C	HBE	
1A		1.3*	1.0*	1.3*	
2A		1.3	1.0	1.2	
3A		1.3	1.0	1.3	
4A		1.4	1.2	1.4	
5A		1.4	1.2	1.4	
6A		1.7	1.4	1.5	
7A		1.7	1.4	1.7	
8A		1.7	1.4	1.5	
9A		1.7	1.3	1.6	
10A		1.7	1.4	1.7	
11A		1.7	1.4	1.6	
12A		1.8	1.5	2.0	
13A		1.9	1.5	2.0	
14A		2.0	1.5	1.8	
15A		2.0	1.5	1.8	
16A		2.0	1.5	1.8	
17A		2.2	1.6	2.0	
18A		2.0	1.6	1.8	
19A		2.3	1.7	.9	
20A		2.3	1.6	2.0	
21A		2.2	1.5	1.8	

* 410-01 DISCRIMINATOR

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"A" CHANNEL CBW	PAGE NO. 17

TEST NUMBER 2.4.1-10	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO.
RECORDED BY 5-14-74 N.C. Byerley		TYPE OF TEST AND DATA OUTPUT POINT % NOISE RECORDED ≈ 5.0% FLTR MI=2
APPROVED BY [illegible]		

CHANNEL	S.C. FREQ @ C	LBE	C	HBE	
1A		2.0 *	1.2 *	1.6 *	
2A		1.4	1.2	1.3	
3A		1.4	1.3	1.4	
4A		1.5	1.4	1.4	
5A		1.6	1.4	1.5	
6A		2.0	1.7	1.8	
7A		2.0	1.8	1.8	
8A		1.8	1.7	18	
9A		2.0	1.6	1.7	
10A		2.0	1.7	1.8	
11A		2.0	1.6	1.7	
12A		2.4	1.8	2.0	
13A		2.4	2.0	2.5	
14A		2.5	1.7	1.8	
15A		2.4	1.8	1.8	
16A		2.4	1.8	2.0	
17A		2.5	2.0	2.0	
18A		2.4	1.8	2.0	
19A		2.5	1.8	2.0	
20A		2.4	1.7	1.8	
21A		2.4	1.7	1.8	

* [illegible] DISCRIMINATOR

LEC FORM 92 (MAY 68) NASA — MSC

"A" CHANNEL CBW	PAGE NO. 18
TEST NUMBER 2.5.2-1	SHEET OF
TEST PROCEDURE NO. / PROCEDURE SECTION NO STATIC	
RECORDED BY 5-15-74 H.C. Byerley	APPROVED BY [signature]
TYPE OF TEST AND DATA OUTPUT POINT: % NOISE TRANSMITTED	MI = 1

RF LEVEL = -73dBm

CHANNEL	S.G. FREQ @ C	LBE	C	HBE
1A	16030	4.5	2.0	4.5
2A	24016	4.5	2.5	4.5
3A	32014	4.0	1.7	4.0
4A	40013	4.5	2.5	4.5
5A	48017	3.5	1.6	4.0
6A	56018	3.5	1.6	6.0
7A	56032	3.0	1.3	5.5
8A	48014	3.0	1.8	4.0
9A	40034	3.5	2.0	4.0
10A	32003	3.0	1.5	3.5
11A	24008	3.0	1.6	3.0
12A	56039	2.5	1.7	3.5
13A	48045	2.5	1.5	2.8
14A	40031	7.0	1.5	7.0
15A	32008	2.0	1.5	3.0
16A	24020	2.0	1.1	1.8
17A	56031	1.8	1.0	1.8
18A	48022	1.8	1.2	2.0
19A	40013	2.0	1.0	2.4
20A	32017	2.0	.8	1.6
21A	24004	1.6	.8	1.7

"A" CHANNEL CBW		PAGE NO. 19
TEST NUMBER 2.5.1-2	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO. STATIC
RECORDED BY 3-15-74 H.C. Byerly	TYPE OF TEST AND DATA OUTPUT POINT % NOISE TRANSMITTED MI = 1	
APPROVED BY WM Haddick		

RF LEVEL = -33 dBm

CHANNEL	S.G. FREQ @ C	LBE	C	HBE
1A		4.0	2.0	4.0
2A		4.5	2.2	4.4
3A		4.0	1.7	4.0
4A		4.5	2.8	4.4
5A		4.0	1.8	3.5
6A		4.0	1.8	5.5
7A		3.5	1.8	5.5
8A		3.5	2.4	4.0
9A		3.8	2.2	4.0
10A		3.8	2.0	4.0
11A		3.5	2.2	3.8
12A		3.4	2.0	3.8
13A		3.2	2.2	3.8
14A		7.5	2.3	8.0
15A		3.0	2.0	3.4
16A		3.0	2.0	3.0
17A		2.3	1.8	3.0
18A		2.8	2.0	3.0
19A		3.2	2.0	3.5
20A		2.8	1.8	3.0
21A		2.8	1.8	2.8

"A" CHANNEL CBW

PAGE NO. 20

TEST NUMBER 2.5.1-3	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO STATIC
RECORDED BY 5-15-74 H.C. Buckley	TYPE OF TEST AND DATA OUTPUT POINT % NOISE TRANSMITTED MI = 1	
APPROVED BY [signature]		

RF LEVEL = -86 dBm

CHANNEL	S.G. FREQ @ C	LBE	C	HBE
1A		4.0	2.0	4.0
2A		4.5	1.8	4.5
3A		4.0	2.0	4.0
4A		4.0	3.0	4.5
5A		3.5	2.0	4.0
6A		3.5	2.4	6.0
7A		4.0	2.4	6.0
8A		4.0	2.8	4.0
9A		4.0	2.8	4.0
10A		4.0	2.8	4.5
11A		4.0	2.8	4.0
12A		4.0	3.0	4.5
13A		3.5	2.8	4.0
14A		8.0	2.6	8.5
15A		4.0	2.8	4.0
16A		4.0	2.7	4.0
17A		3.5	2.6	4.0
18A		3.5	2.8	4.0
19A		4.0	2.7	4.5
20A		3.5	2.6	3.5
21A		3.5	2.6	3.5

"A" CHANNEL CBW	PAGE NO. 21

TEST NUMBER 2.5.1-1	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO STATIC
RECORDED BY 5-15-74 H.C. Brierley	TYPE OF TEST AND DATA OUTPUT POINT % NOISE TRANSMITTED MI = 2	
APPROVED BY [signature]		

RF LEVEL = -73 dBm

CHANNEL	S.G. FREQ @ C	LBE	C	HBE
1A		1.0 *	.8 *	1.0 *
2A		1.0	1.0	1.2
3A		.6	.5	.8
4A		.8	.9	1.2
5A		.6	.6	.8
6A		.8	.6	.7
7A		.8	.6	.8
8A		.7	.6	.9
9A		.6	.6	.6
10A		.7	.6	.9
11A		.6	.6	.6
12A		.6	.5	.6
13A		.6	.5	.9
14A		.8	.5	.9
15A		.4	.4	.6
16A		.4	.4	.6
17A		.4	.4	.5
18A		.4	.4	.4
19A		.4	.4	.6
20A		.4	.3	.4
21A		.4	.3	.4

LEC FORM 92 (MAY 68) NASA — MSC

"A" CHANNEL CBW	PAGE NO. 22
TEST NUMBER 2.5.1-2	SHEET OF
TEST PROCEDURE NO.	PROCEDURE SECTION NO. STATIC
RECORDED BY 5-15-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT % NOISE TRANSMITTED MI = 2
APPROVED BY [signature]	

RF LEVEL = -83 dBm

CHANNEL	S.G. FREQ @ C	LBE	C	HBE
1A		.9 *	.7 *	1.0 *
2A		1.0	1.0	1.2
3A		.7	.6	.9
4A		.8	.9	1.2
5A		.8	.7	.9
6A		.9	.7	.9
7A		.9	.7	1.0
8A		.9	.8	1.0
9A		.9	.8	1.0
10A		1.0	.9	1.4
11A		1.0	.9	1.1
12A		1.0	.9	1.1
13A		1.0	.9	1.2
14A		1.2	.8	1.2
15A		.9	.8	1.0
16A		.8	.8	1.0
17A		.9	.8	1.0
18A		.6	.8	.9
19A		.8	.8	1.0
20A		.6	.8	.9
21A		.8	.8	.9

* [illegible] DISCRIMINATOR

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"A" CHANNEL CBW			PAGE NO. 23
TEST NUMBER 2.5.1-3	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO STATIC	
RECORDED BY 5-15-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT % NOISE TRANSMITTED MI = 2		
APPROVED BY [signature]			

RF LEVEL = -86dBm

CHANNEL	S.G. FREQ @ C	LBE	C	HBE
1A		1.0 *	.8 *	1.1 *
2A		1.0	1.1	1.2
3A		.8	.7	1.0
4A		1.0	1.1	1.4
5A		.9	.8	1.1
6A		1.1	1.0	1.1
7A		1.2	1.0	1.2
8A		1.2	1.2	1.3
9A		1.2	1.1	1.2
10A		1.3	1.2	1.5
11A		1.3	1.2	1.4
12A		1.3	1.2	1.4
13A		1.3	1.2	1.5
14A		1.4	1.2	1.5
15A		1.2	1.1	1.4
16A		1.2	1.1	1.3
17A		1.2	1.2	1.2
18A		1.2	1.1	1.2
19A		1.2	1.1	1.3
20A		1.2	1.1	1.2
21A		1.2	1.1	1.1

"A" CHANNEL CBW			PAGE NO. 24
TEST NUMBER 3.3.1	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO. DYNAMIC	
RECORDED BY 5-13-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT DISTORTION. — BASELINE		
APPROVED BY [signature]			

CHANNEL	DATA FREQ (Hz) 5 V pk-pk	S.C. RECORD LEVEL	% THD MI=1	% THD MI=2	
1A	1.77 Vrms	71	1.85	.34	
2A	↑	70	2.40	.33	
3A		70	2.65	.58	
4A		70	2.55	.52	
5A		71	2.60	.49	
6A		69	2.25	.33	
7A		70	2.75	.32	
8A		69	2.65	.58	
9A		70	2.30	.37	
10A		70	2.65	.58	
11A		70	2.65	.28	
12A		70	2.40	.32	
13A		68	3.00	.56	
14A		70	2.30	.52	
15A		69	2.65	.47	
16A		70	2.70	.38	
17A		71	2.50	.23	
18A		70	2.75	.55	
19A		69	2.55	.65	
20A	↓	70	2.40	.51	
21A	1.77 Vrms	70	1.85	.24	

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"A" CHANNEL CBW	PAGE NO. 25

TEST NUMBER 3.4.3	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO. DYNAMIC
RECORDED BY 5-13-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT DISTORTION — RECORDED	
APPROVED BY [signature]		

CHANNEL	DATA FREQ (Hz)	% THD MI = 1	% THD MI = 2
1A	1998	2.1	.56
2A	1899	2.6	.49
3A	1799	2.9	.69
4A	1748	2.8	.66
5A	1998	2.8	.66
6A	1899	2.55	.55
7A	1799	2.9	.53
8A	1899	2.95	.71
9A	1998	2.6	.61
10A	1748	3.0	.74
11A	1799	3.0	.55
12A	1748	2.8	.58
13A	1799	3.3	.73
14A	1900	2.7	.70
15A	1998	3.0	.72
16A	1748	3.1	.61
17A	1998	2.9	.58
18A	1748	3.3	.76
19A	1799	3.0	.86
20A	1900	3.0	.76
21A	1998	2.45	.60

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"A" CHANNEL CBW

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TEST NUMBER 5.4.5

SHEET OF

TEST PROCEDURE NO.

PROCEDURE SECTION NO. DYNAMIC

RECORDED BY 5-14-74 H.C. Buckley

APPROVED BY [signature]

TYPE OF TEST AND DATA OUTPUT POINT

DISTORTION — RECORDED

% 2.5 % FLTR

.242% FLUTTER

CHANNEL	DATA FREQ (Hz)	% THD MI=1	% THD MI=2
1A	1989	2.9	1.8
2A	1892	3.3	1.8
3A	1789	3.6	1.8
4A	1743	3.5	1.8
5A	1990	3.4	1.9
6A	1892	3.3	1.75
7A	1790	3.5	1.75
8A	1892	3.7	1.85
9A	1990	3.3	1.7
10A	1744	3.8	1.65
11A	1789	3.7	1.7
12A	1743	3.5	2.0
13A	1789	4.1	1.9
14A	1893	3.5	1.95
15A	1991	3.7	1.95
16A	1743	3.8	1.8
17A	1990	3.6	1.85
18A	1744	4.1	1.9
19A	1790	3.7	1.95
20A	1892	3.6	1.9
21A	1991	3.2	1.85

RECORDER OUTPUT
COMPOSITE SIGNAL
2.7 V pk-pk
.290 V rms

LEC FORM 92 (MAY 68)

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"A" CHANNEL CBW

PAGE NO. 27

TEST NUMBER 3.4.6	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO. DYNAMIC
RECORDED BY 5-14-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT	DISTORTION — RECORDED ±5.0 % FLTR
APPROVED BY		

4.5% FLUTTER

CHANNEL	DATA FREQ (Hz)	% THD MI = 1	% THD MI = 2
1A	1980	4.7	3.5
2A	1882	4.9	3.7
3A	1785	5.1	3.6
4A	1732	4.9	3.6
5A	1980	5.0	3.7
6A	1882	5.0	3.7
7A	1784	5.1	3.6
8A	1882	5.2	3.8
9A	1980	4.9	3.9
10A	1730	5.2	3.8
11A	1785	5.2	3.7
12A	1731	5.0	3.8
13A	1784	5.5	3.9
14A	1882	5.0	4.0
15A	1980	5.2	4.0
16A	1730	5.1	3.7
17A	1980	5.2	4.1
18A	1730	5.4	3.9
19A	1785	5.2	4.0
20A	1882	5.2	4.1
21A	1980	4.8	4.1

RECORDER OUTPUT
COMPOSITE SIGNAL
3.3 V pk-pk
.41 Vrms

LEC FORM 92 (MAY 68)

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"A" CHANNEL CBW

PAGE NO. 28

TEST NUMBER 3.5

SHEET OF

TEST PROCEDURE NO.

PROCEDURE SECTION NO.

RECORDED BY 5-15-74 H.C. Bydelley

TYPE OF TEST AND DATA OUTPUT POINT DISTORTION - TRANSMITTED

APPROVED BY C.M. Haddick

CHANNEL	DATA FREQ (Hz) MI=1	% THD MI=1	% THD MI=2
1A	1999	2.0	.44
2A	1900	2.75	.48
3A	1802	2.8	.64
4A	1750	2.85	.58
5A	1999	2.65	.55
6A	1900	2.4	.47
7A	1802	2.8	.43
8A	1900	2.75	.66
9A	1999	2.35	.51
10A	1750	3.0	.71
11A	1802	2.65	.45
12A	1750	2.5	.48
13A	1801	3.0	.64
14A	1900	2.4	.57
15A	1999	2.6	.57
16A	1750	2.75	.45
17A	1999	2.4	.44
18A	1750	2.9	.64
19A	1802	2.6	.48
20A	1900	2.4	.58
21A	1999	1.85	.41

LEC FORM 92 (MAY 68)

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"A" CHANNEL CBW	PAGE NO. 29

TEST NUMBER 3.3.2	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO DYNAMIC
RECORDED BY 5-13-74 H.C. Buckley	TYPE OF TEST AND DATA OUTPUT POINT CROSSTALK –	
APPROVED BY [signature]		

CHANNEL	MI=1 BASIC NOISE	MI=1	MI=1	MI=1	MI=1
1A	1.3	1.2	1.2	1.2	1.2
2A	1.3	1.0	1.1	1.3	1.2
3A	.8	.8	.9	.9	.8
4A	1.1	1.3	1.2	1.2	1.2
5A	1.0	2.8	1.0	.9	.9
6A	.9	SIGNAL	1.0	1.0	.9
7A	.9	2.8	1.3	1.3	1.3
8A	1.0	1.0	1.1	1.0	.9
9A	.9	1.0	1.0	1.0	1.0
10A	.9	1.4	2.8	1.3	1.3
11A	.9	.8	SIGNAL	1.1	1.0
12A	.9	.9	2.6	1.0	1.0
13A	1.1	1.8	1.5	1.7	1.7
14A	.9	.9	1.2	1.0	1.0
15A	.8	.8	.8	2.4	.9
16A	1.0	1.3	1.3	SIGNAL	1.3
17A	.6	.7	.7	2.4	.7
18A	.6	.8	.6	.7	.8
19A	.8	.9	.9	.9	.9
20A	.6	.6	.6	.6	2.2
21A	.6	.7	.6	.6	SIGNAL

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"A" CHANNEL CBW	PAGE NO. 30

TEST NUMBER 3.3.1	SHEET OF	TEST PROCEDURE NO. PROCEDURE SECTION NO. DYNAMIC
RECORDED BY 5-13-74 H.C. Byerley	TYPE OF TEST AND DATA OUTPUT POINT	INTERCHANNEL PHASE
APPROVED BY [signature]		

CHANNELS	2 kHz LPF PHASE 2 kHz Sig. DEG.	2 kHz LPF PHASE 1 kHz Sig. DEG.	1 kHz LPF PHASE 1 kHz Sig. DEG.	1 kHz LPF PHASE 0.5 kHz Sig. DEG.
1A-2A	-14.5	-6.9	-8.4	-5.6
2A-3A	-7.8	-2.8	-11.8	-2.5
3A-4A	+2.0	-1.2	+4.6	0
4A-5A	-11.5	-3.8	-8.7	-1.5
5A-6A	+7.5	+2.4	-2.7	-.7
6A-7A	+5.5	+2.8	+14.1	+4.3
7A-8A	-3.7	-1.7	-7.7	-3.0
8A-9A	+2.2	+1.4	-5.1	-.3
9A-10A	+6.0	+3.0	+18.4	+3.6
10A-11A	+9.0	+4.5	-9.0	0
11A-12A	-6.5	-5.8	-3.3	-3.0
12A-13A	-12.5	-4.2	+.6	-.5
13A-14A	+2.5	+1.6	+9.3	+1.9
14A-15A	+6.0	+3.3	-2.4	+1.0
15A-16A	+10.5	+4.1	+13.2	+2.4
16A-17A	-18.1	-7.7	-12.2	-4.5
17A-18A	-4.5	-2.1	-8.2	-3.2
18A-19A	+2.7	+1.8	-5.0	-.1
19A-20A	+5.7	+2.8	+18.3	+3.6
20A-21A	+9.0	+4.[illegible]	-9.1	-.2
1A-7A	-18.7	[illegible]	-13.2	5.5
1A-12A	-12.5	[illegible]	-10.2	4.1
1A-17A	19.0	-10.1	-18.0	-5.6