N4
75
Copy 1
56

Report No. FAA-NA-75-56

FAA WJH Technical Center
00090590

AIRCRAFT COMMUNICATIONS INTERFERENCE TESTS

Jack Bernstein

NAS
LIBRA
APR 6 '76

MARCH 1976

FINAL REPORT

Document is available to the public through the
National Technical Information Service
Springfield, Virginia 22151

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

Technical Report Documentation Page

1. Report No. FAA-NA-75-56	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle AIRCRAFT COMMUNICATIONS INTERFERENCE TESTS		5. Report Date March 1976
		6. Performing Organization Code
7. Author(s) Jack Bernstein		8. Performing Organization Report No. FAA-NA-75-56
9. Performing Organization Name and Address Federal Aviation Administration National Aviation Facilities Experimental Center Atlantic City, New Jersey 08405		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 062-222-000
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington D.C. 20590		13. Type of Report and Period Covered Final April 1975 - May 1975
		14. Sponsoring Agency Code
15. Supplementary Notes		

NAFEC LIBRARY APR 6 '76

16. Abstract

This report covers tests conducted to determine the possible causes of interference to aircraft very high frequency (vhf) voice communications resulting from transmissions from the vhf digital data link system operating onboard the same aircraft.

Tests were conducted to determine aircraft vhf antenna isolation and vhf receiver response. The tests show that isolation depends on the physical positioning of the antennas on the airframe and that existing isolation (found to be as little as 23 dB) can realistically cause interference or quieting between transceivers even though they are operating at different frequencies up to 4 MHz apart. It was also found that transceiver design affects the rejection of undesired received signals.

It was recommended that maximum isolation be maintained between aircraft antennas, receiver design be optimized for rejection of undesired signals, and cockpit communications discipline be used.

17. Key Words Interference Aircraft Communications Antenna Isolation VHF Communication	18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia, 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	17	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Purpose	1
Background	1
DISCUSSION	1
General	1
Aircraft Antenna Isolation Tests	1
Laboratory Receiver Tests	2
SUMMARY OF RESULTS	6
CONCLUSIONS	13
RECOMMENDATIONS	13
REFERENCE	13

LIST OF ILLUSTRATIONS

Figure		Page
1	Test Aircraft (N377) VHF Antenna Placement	3
2	Antenna Loss Test Configuration	3
3	Laboratory Test Configuration	6
4	Laboratory Receiver Tests (4 Pages)	9

LIST OF TABLES

Table		Page
1	Antenna Power Measurements--Ground Test	4
2	Antenna Power Measurements--Flight Test	5
3	Coupling Loss	7
4	Average Antenna Signal Coupling	8
5	Summary Results of Laboratory Tests	8

INTRODUCTION

PURPOSE.

Aircraft and laboratory tests were conducted to determine the cause of very high frequency (vhf) voice communications interference resulting from transmissions from the vhf digital data link system operating on board the same aircraft and to cite possible corrective action.

BACKGROUND.

During the course of conducting vhf data link tests, it was found that certain vhf voice channels used by the aircraft crew had an audio interference. At the request of the Systems Research and Development Service (SRDS) Communication Division, this problem was investigated to determine its cause. Limited tests at that time indicated that the interference was due to data link transmissions. This interference was also noted during digital communication flight tests conducted by the United Kingdom (reference 1). Even though data link made the problem apparent, it was found through initial probing-type tests that voice transmissions also caused receiver interference or quieting.

DISCUSSION

GENERAL.

Aircraft antenna isolation measurements and laboratory receiver response measurements were made to determine the possible cause of data link interference to the aircraft's vhf communications. Ground and airborne test measurements were made to determine the degree of isolation between the four communications antennas on the test aircraft. Laboratory measurements were made to determine receiver response to various continuous wave (CW) and modulated signals. Aircraft antenna isolation measurements were made with CW signal only, as this signal represents optimum transmitter spectrum and therefore would present minimum interference. Laboratory tests were made to determine the degradation of receiver performance, if any, due to modulation and signal level variation, as well as with CW signals.

AIRCRAFT ANTENNA ISOLATION TESTS.

Ground and airborne antenna isolation tests were made on the National Aviation Facilities Experimental Center (NAFEC) test aircraft, N377, a Grumman 159 Gulfstream. This aircraft has four communications antennas, three of which are Collins type 37R-2 vhf antennas, located at stations 237 top, 279.5 bottom, and 485.5 bottom; and one of which is a Collins type 37R-2U vhf/uhf antenna at station 376.5 top. The station number refers to the distance in inches

that the antenna is located from the nose of the aircraft. Figure 1 shows the placement of these antennas on the test aircraft, N377. Of the aircraft's four antennas, the forward ones, at stations 237 top and 279.5 bottom, are used for the aircraft's vhf communications systems.

For the isolation measurements, a Bendix RTA-43A transceiver, in the CW transmit mode, was used, working into a General Radio GR-874-GA variable attenuator prior to feeding, in turn, each of the four aircraft antennas. On the receiving end of any one of the three remaining antennas, a Hewlett-Packard H.P.3406A broadband sampling voltmeter was used to measure the received power level in decibels at 1 milliwatt (dBm). The test equipment configuration used is shown in figure 2. The transmitter was sequentially tuned to 118.15 MHz, 126.15 MHz, and 134.7 MHz, and the power transmitted into antenna 1 at each of these frequencies was measured with the sampling voltmeter, taking into account the loss through the General Radio GR-874-GA attenuator. These frequencies are at the low, mid, and high band of the vhf communication spectrum. The measured pad losses follow:

Frequency	Loss
118.15 MHz	51.8 dBm
126.15 MHz	50.0 dBm
134.7 MHz	48.3 dBm

The voltmeter was then connected to each of the remaining three antennas, and the received power was recorded in dBm. The procedure was repeated using antenna 2 as the transmitting antenna, then antenna 3, and finally antenna 4. For each case, the remaining three antennas were used as the receiving antennas. This sequence was conducted under the following three conditions:

1. The aircraft was located on the NAFEC ramp. The aircraft was connected to ground power, and the power cart was positioned at a 45° angle to the aircraft, with the aircraft door closed. (The 45° angle was used to minimize reflections off the power cart.)

2. The aircraft was on the NAFEC ramp, employed its own power, and the door was closed. (NOTE: For ease in making test measurements, only antennas 1 and 2 were used for transmitting; antennas 1, 2, and 3 were used for receiving.)

3. A local visual flight rules (VFR) flight was conducted to confirm ground measurements.

The resultant antenna coupling measurements are shown in tables 1 and 2.

LABORATORY RECEIVER TESTS.

Laboratory tests were conducted to determine receiver response to CW and modulated signals across the vhf communications frequency band (118 MHz to 136 MHz).

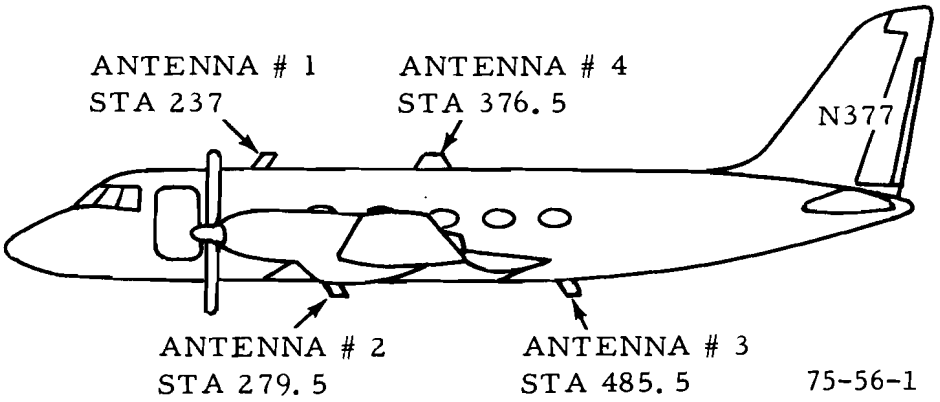


FIGURE 1. TEST AIRCRAFT (N377) VHF ANTENNA PLACEMENT

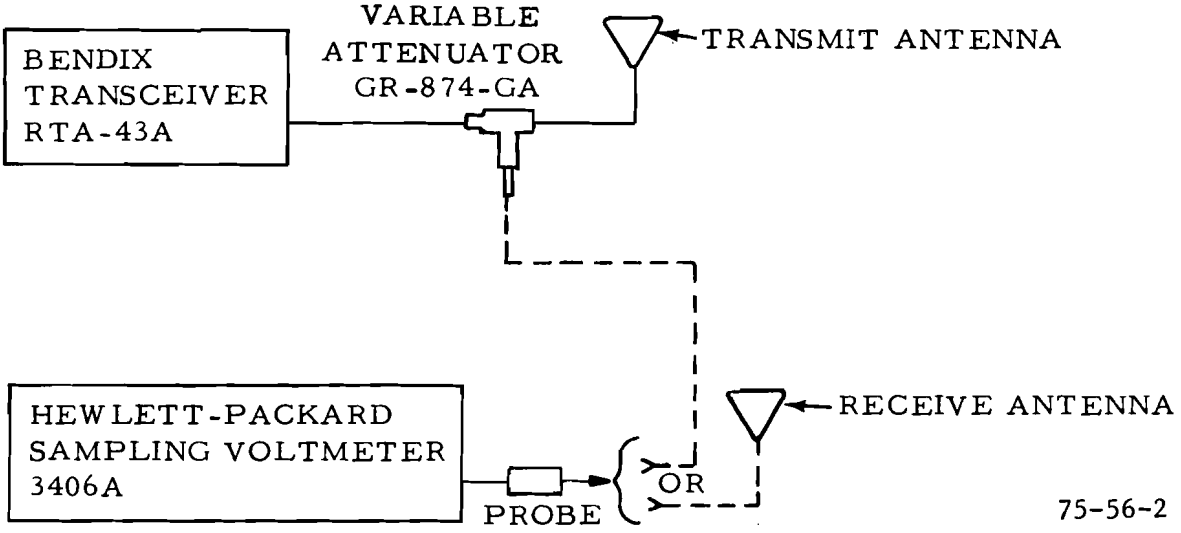


FIGURE 2. ANTENNA LOSS TEST CONFIGURATION

TABLE 1. ANTENNA POWER MEASUREMENTS--GROUND TEST

	Frequency in MHz	Power Into TX Ant. (in dBm)	Power From Receiving Antenna (in dBm) 1	2	3	4	Test Condition (see below)
Test 1							
Antenna 1	118.15	+48.3		+9.2	>+23*	+3.4	1
	126.15	+47.6		+7.6	>+23*	+7.2	1
	134.7	+44.7		+9	>+23*	+3.3	1
Test 2							
Antenna 2	118.15	+48.8	+10		+5	>+23*	1
	126.15	+48.2	+9		+1	>+23*	1
	134.7	+46.3	+3.5		-0.8	>+23*	1
Test 3							
Antenna 3	118.15	+47.3	+20.6	+4.2		+8.7	1
	126.15	+47	+20.6	+3		+14.5	1
	134.7	+47.4	+18.4	-4		+11.5	1
Test 4							
Antenna 4	118.15	+49.8	+3	>+23*	+12		1
	126.15	+46.4	+4.1	>+23*	+14.6		1
	134.7	+48	+0	+22.7	+12.3		1
Test 5							
Antenna 1	126.15	+47.5		+7	>+23*		2
	134.7	+47.3		+8	+18.6		2
Test 6							
Antenna 2	126.15	+48.2	+8.8		+2.6		2
	134.7	+46.3	+6.4		-0.2		2

TEST CONDITION.

1. Aircraft located on NAFEC ramp, used ground power. Aircraft power cart located at 45° angle to aircraft, with aircraft door closed.

2. Aircraft located on NAFEC ramp, using its own power. Aircraft door closed.

NOTE:

*The H.P.3406A broadband sampling voltmeter will not read higher than 23 dBm.

TABLE 2. ANTENNA POWER MEASUREMENTS--FLIGHT TEST

	Frequency in MHz	Power Into TX Ant. (in dBm)	Power From Receiving Antenna (in dBm) 1	2	3	4	Test Condition (see below)
Test 1							
Antenna 1	118.15	+48.3		+9	+22	+3	3
	126.15	+47.4		+9.5	>+23*	+4.8	3
	134.7	+47.3		+9.5	+20.2	0	3
Test 2							
Antenna 2	118.15	+48.8	+10		+ 5.8	>+23*	3
	126.15	+47.8	+11.3		- 2.0	>+23*	3
	134.7	+45.7	+7.0		- 1.5	>+23*	3
Test 3							
Antenna 3	118.15	+47.3	+21.8	+4		+10	3
	126.15	+46.8	>+23*	-3.5		+16	3
	134.7	+47.3	+20	+1		+15	3
Test 4							
Antenna 4	118.15	+47.8	+4.5	>+23*	+12		3
	126.15	+47	+14.8	>+23*	+15.8		3
	134.7	+47.5	+1	>+23*	+15		3

Test Condition

3. Local VFR Flight

NOTE:
*The H.P.3406A broadband sampling voltmeter will not read higher than 23 dBm.

These tests were made with available transceivers; a Collins 51X2, a Collins 618M2B, and a King 9100 transceiver. The Collins 51X2 is the same type as that used for vhf communication in the test aircraft N377. It also represents an earlier generation model of the transceivers in use today. The 618M2B conforms to Aeronautical Radio, Inc. (ARINC) 546 characteristic, while the 9100 meets ARINC 566A characteristic and represents the latest state-of-the-art in transceiver design.

The test equipment was connected as shown in figure 3. The Hewlett-Packard H.P.8660 test generator was varied in frequency from 118 MHz to 136 MHz at 0-dBm CW, 0-dBm 80-percent modulation at 1 kHz, 0-dBm 80-percent modulation at 5 kHz, 9.5-dBm CW, 9.5-dBm 80-percent modulation at 1 kHz, and 9.5-dBm 80-percent modulation at 5 kHz, while the receivers under test were sequentially tuned to 122 MHz, 126.15 MHz, and 132 MHz. The resultant automatic gain control (AGC) output of the receiver under test was recorded on a Hewlett-Packard/Mosely X-Y plotter.

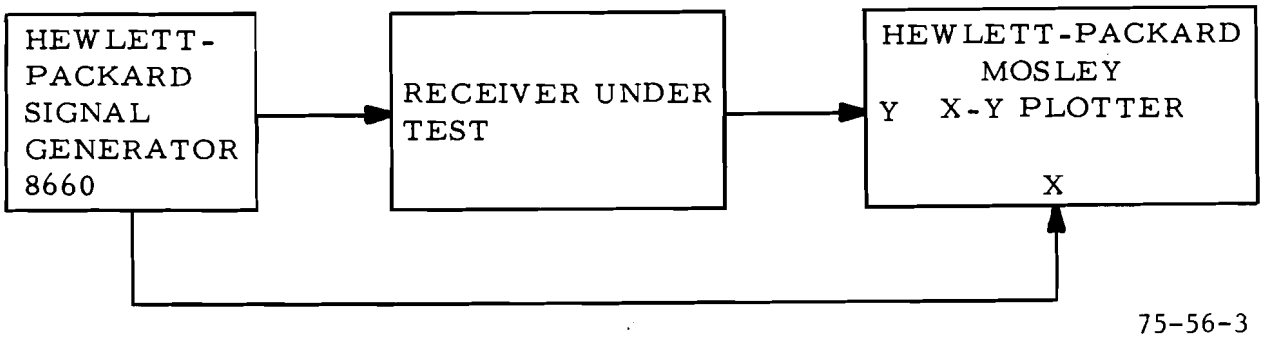


FIGURE 3. LABORATORY TEST CONFIGURATION

SUMMARY OF RESULTS

The coupling losses in dBm between the various combinations of aircraft antennas are shown in table 3. By averaging the vhf coupling loss measurement obtained at the three frequencies used (118.15 MHz, 126.15 MHz, and 134.7 MHz) and the three aircraft test conditions for the various antenna combinations, the results shown in table 4 are obtained. These results show that the maximum signal coupling exists between antennas 1 and 3, and 2 and 4, while minimum signal coupling exists between antennas 1 and 4, and 2 and 3. In terms of the position of antennas on the airframe, maximum coupling is found between the upper front and lower rear, and the lower front and upper rear, while minimum signal coupling exists between the upper or lower antennas. In addition, the maximum signal coupling is approximately 23 dB, and minimum signal coupling is approximately 45 dB.

Results of the laboratory receiver tests are shown in figure 4 and are summarized in table 5. This information shows that regardless of the carrier frequency, the Collins 618M2B and King 9100 performed similarly, but the Collins 51X2 was different, in that its response was degraded to a greater degree in terms of dB rejection and bandwidth of susceptibility. The results also show that a signal level less than -87 dB to -50 dB may not be detected, because an adjacent transmitter may have already established this level or a greater one in the receiver--the level being dependent upon the receiver characteristics. Such was the case when receiver quieting occurred during data link flight tests. These levels are not the worst case and represent only an average value.

TABLE 3. COUPLING LOSS

TX Antenna	Frequency in MHz	Coupling Loss (in dBm) Receiving Antennas 1	2	3	4	Test Condition (see below)
1	118.15		39.1	24.9	44.9	1
1	118.15		39.3	26.3	45.3	3
1	126.15		40.0	24.6*	40.4	1
1	126.15		40.5	24.5*		2
1	126.15		38.4	25.4	44.4	3
1	134.7		35.7	21.5	41.4	1
1	134.7		39.3	28.7		2
1	134.7		37.8	27.1	47.3	3
2	118.15	38.8		43.8	25.8*	1
2	118.15	38.8		43.0	25.8*	3
2	126.15	39.2		47.2	25.2*	1
2	126.15	39.4		45.6		2
2	126.15	36.5		49.8	24.8*	3
2	134.7	42.8		47.1	23.3*	1
2	134.7	39.9		46.5		2
2	134.7	38.7		47.2	22.7*	3
3	118.15	26.7	43.1		38.6	1
3	118.15	26.5	42.9			1
3	118.15	25.5	43.3		37.3	3
3	126.15	26.4	44.0		32.5	1
3	126.15	26.4	44.0		32.5	1
3	126.15	23.8*	50.3		30.8	3
3	134.7	29.0	51.4		35.9	1
3	134.7	27.3	46.3		32.3	3
4	118.15	46.8	26.8*	37.8		1
4	118.15	45.3	26.8*	37.8		3
4	126.15	42.3	23.4*	31.8		1
4	126.15	32.2	24.0*	31.8		3
4	134.7	45.0	25.3	35.7		1
4	134.7	46.5	24.5*	32.5		3

TEST CONDITIONS.

1. Aircraft on NAFEC ramp with external power cart parked at 45° to aircraft, with aircraft door closed.

2. Aircraft on NAFEC ramp using aircraft power, with aircraft door closed.

3. Local VFR flight.

NOTES:

*These values are approximate, as the calculations used to obtain them involved a value greater than the maximum value of the sampling voltmeter (23 dB).

FAA WJH Technical Center
00090590

TABLE 4. AVERAGE ANTENNA SIGNAL COUPLING

Antenna Combination	Average Coupling (in dB)
1 to 2	40
1 to 3	25
1 to 4	42
2 to 1	39
2 to 3	45
2 to 4	23
3 to 1	26
3 to 2	45
3 to 4	34
4 to 1	44
4 to 2	24
4 to 3	33

TABLE 5. SUMMARY RESULTS OF LABORATORY TESTS

Test Condition		TRANSCEIVER Collins 51X2	Collins 618M2B	King 9100
0-dBm, CW	122 MHz	77 to 63 dB ± 1.75 MHz	87 to 75 dB ± 1 MHz	82 to 79 dB ± 1 MHz
0-dBm, CW	126.15 MHz	77 to 67 dB ± 1.5 MHz	82 to 68 dB ± 1 MHz	80 to 70 dB ± 1 MHz
0-dBm, CW	132 MHz	77 to 62 dB ± 2.0 MHz	85 to 70 dB ± 1 MHz	83 to 80 dB ± 1 MHz
0-dBm, 1 kHz 80% MOD	126.15 MHz	77 to 67 dB ± 1.5 MHz	82 to 70 dB ± 1 MHz	80 to 65 dB ± 1 MHz
0-dBm, 5 kHz 80% MOD	126.15 MHz	77 to 67 dB ± 1.5 MHz	82 to 68 dB ± 1.5 MHz	80 to 70 dB ± 1 MHz
9.5-dBm, CW	126.15 MHz	79 to 60 dB ± 4.0 MHz	83 to 60 dB ± 4.0 MHz	82 to 60 dB ± 4.0 MHz
9.5-dBm, 1 kHz 80% MOD	126.15 MHz	80 to 60 dB +4 to -3 MHz	87 to 60 dB ±4.0 MHz	82 to 58 dB +4 to -3 MHz
9.5-dBm, 5 kHz 80% MOD	126.15 MHz	80 to 50 dB +4 to -3 MHz	87 to 60 dB ±3.5 MHz	82 to 60 dB +4 to -3 MHz

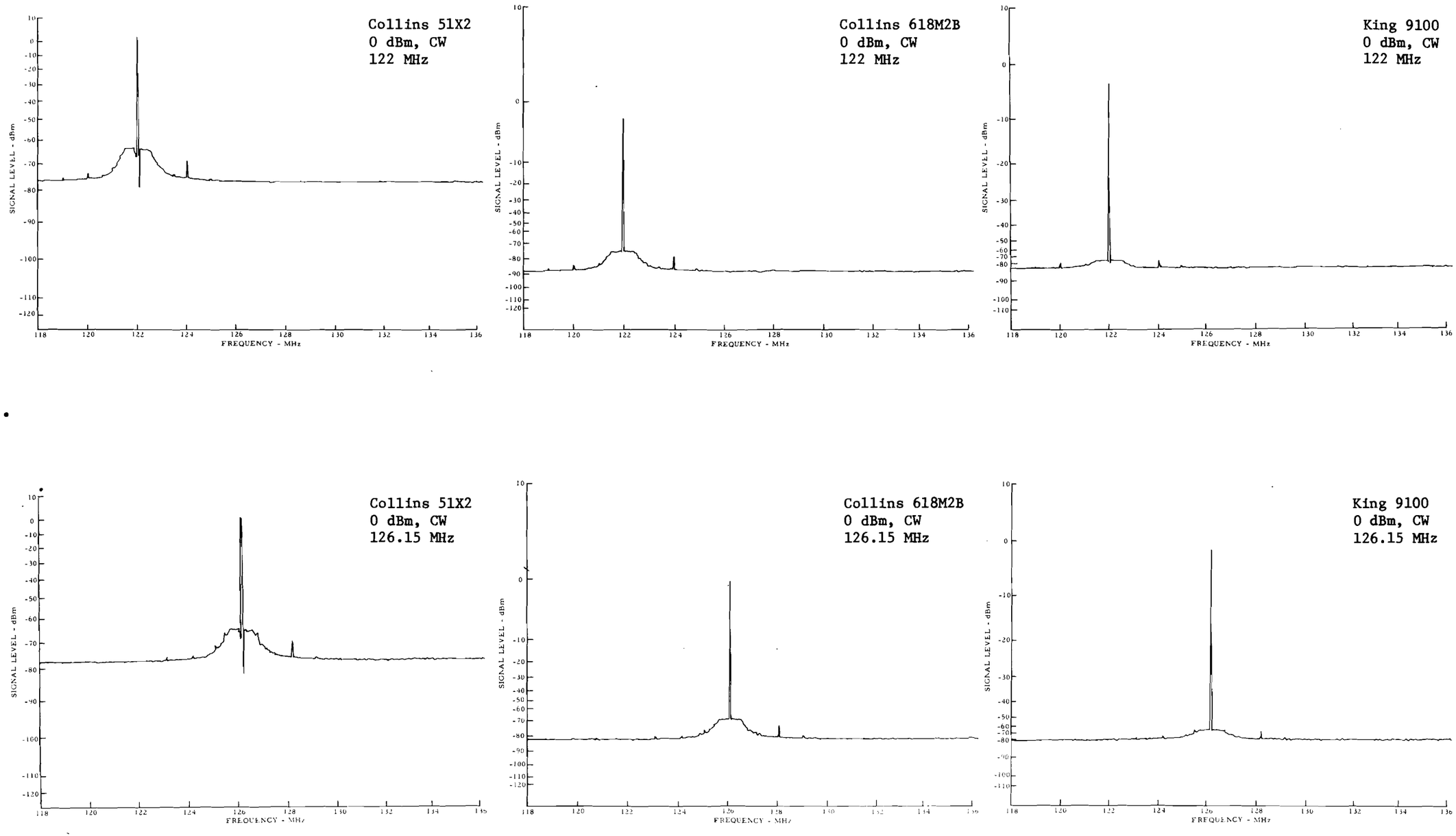
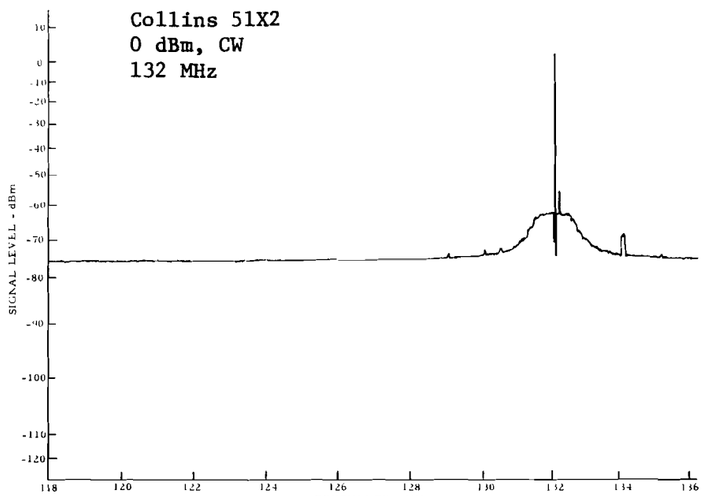
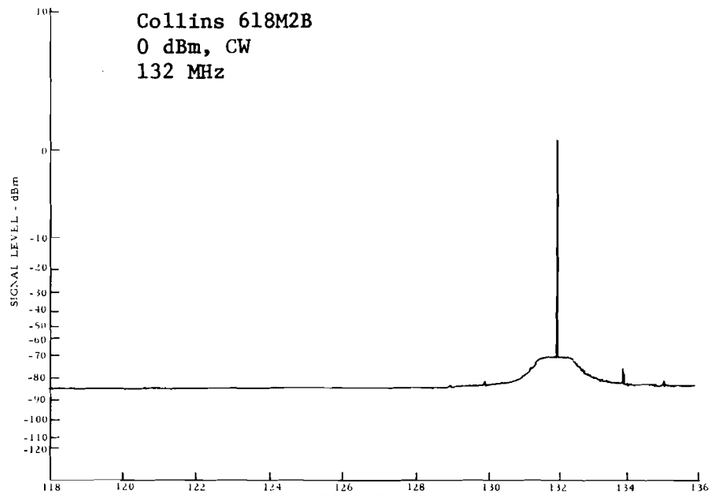
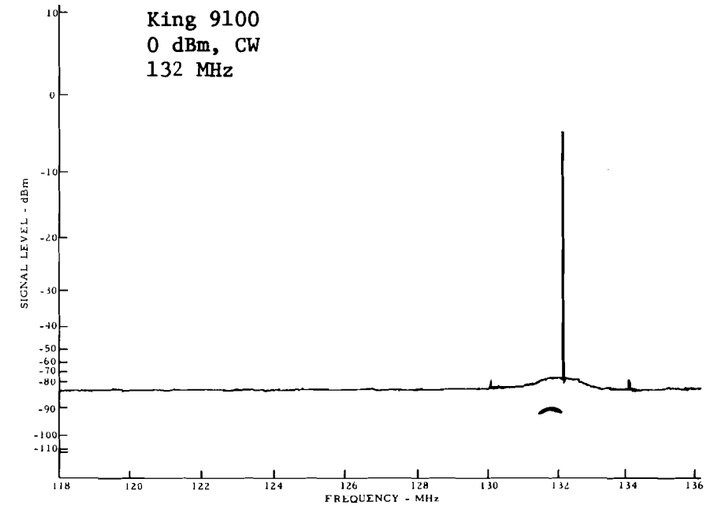
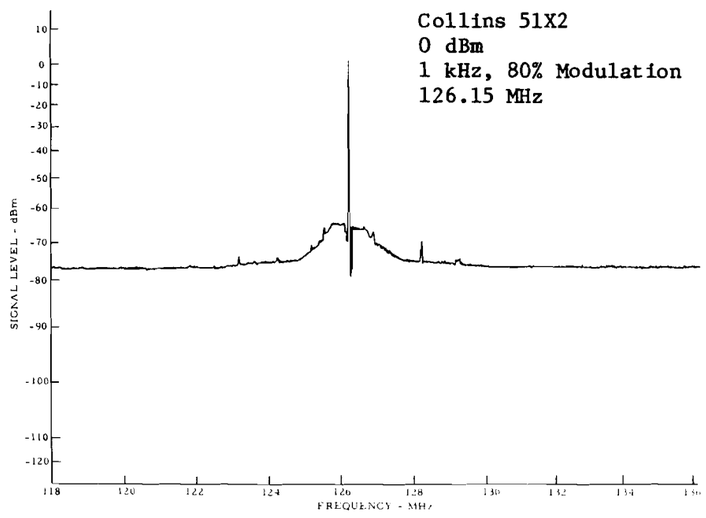


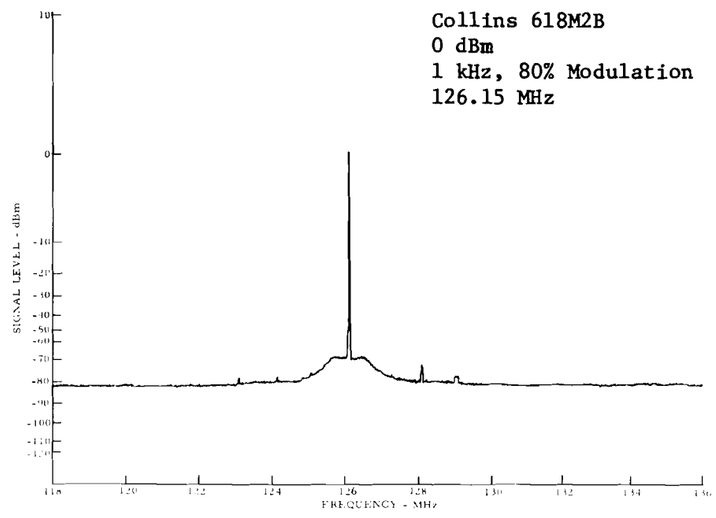
FIGURE 4. LABORATORY RECEIVER TESTS (Sheet 1 of 4)











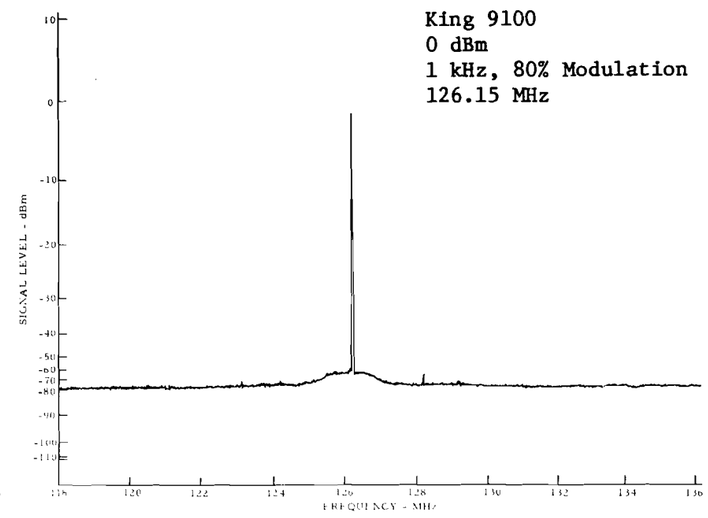
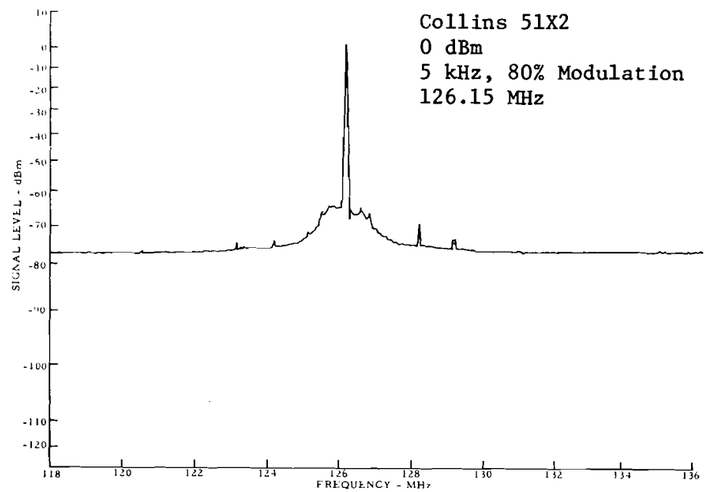
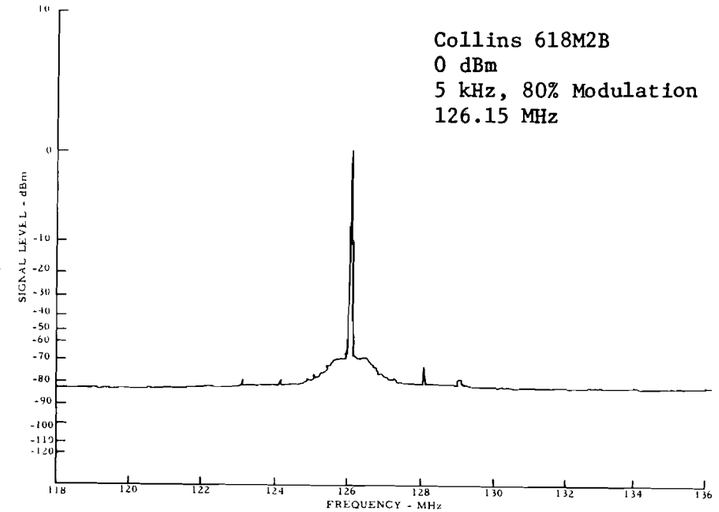
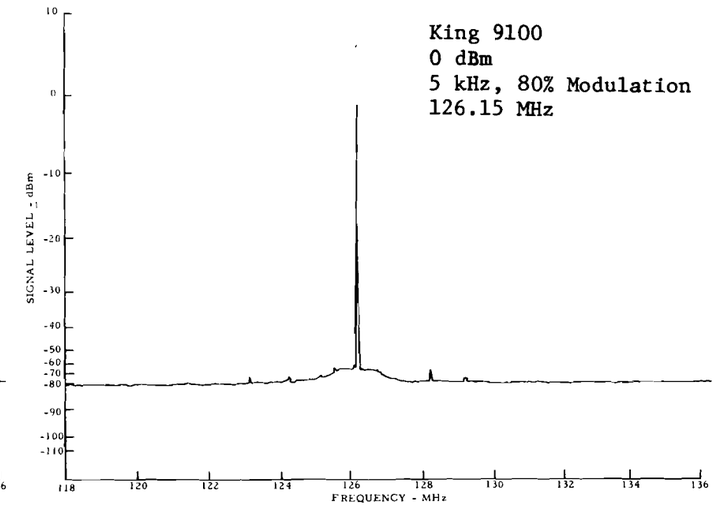
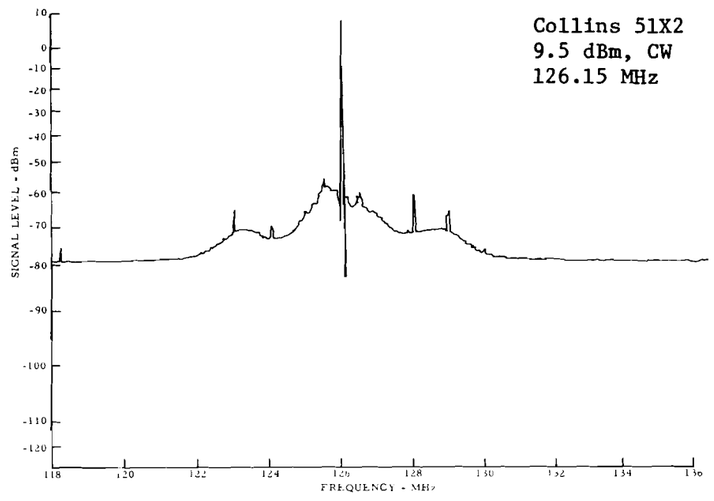


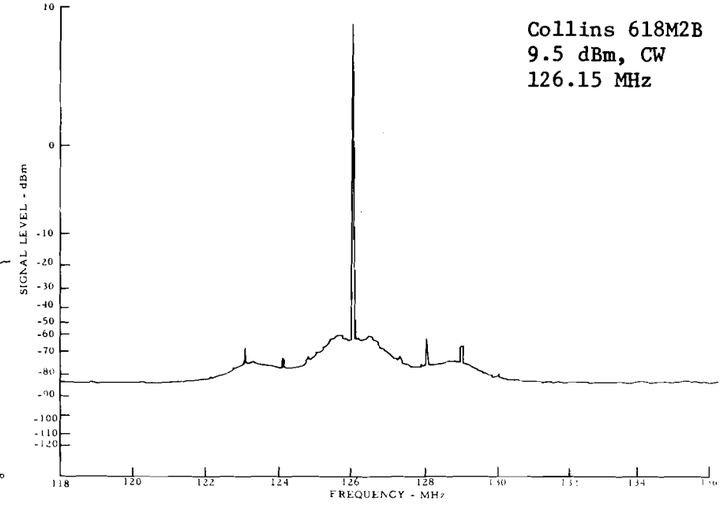
FIGURE 4. LABORATORY RECEIVER TESTS (Sheet 2 of 4)











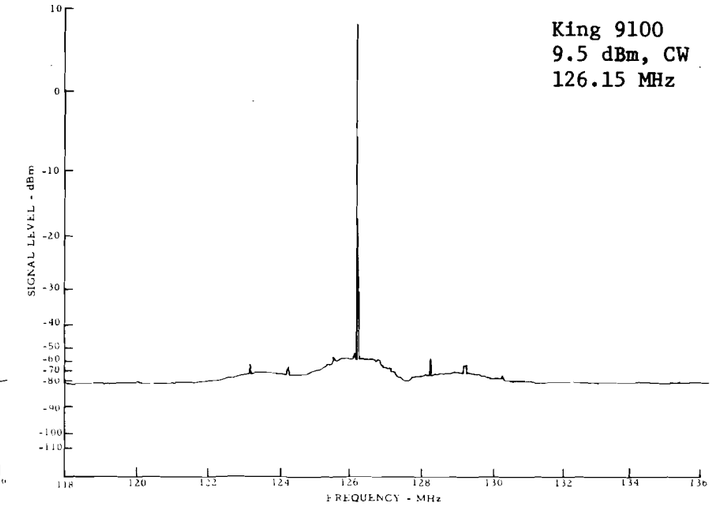
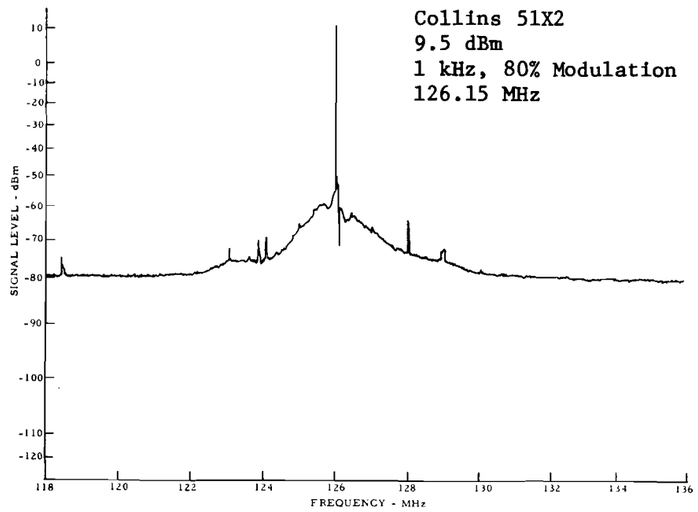
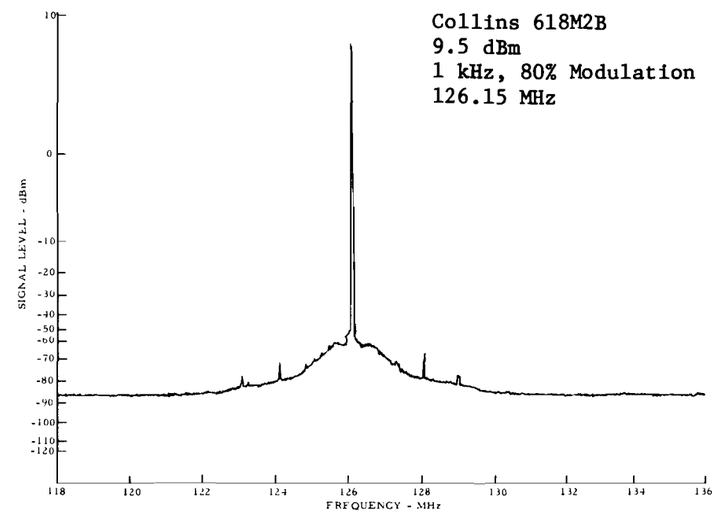
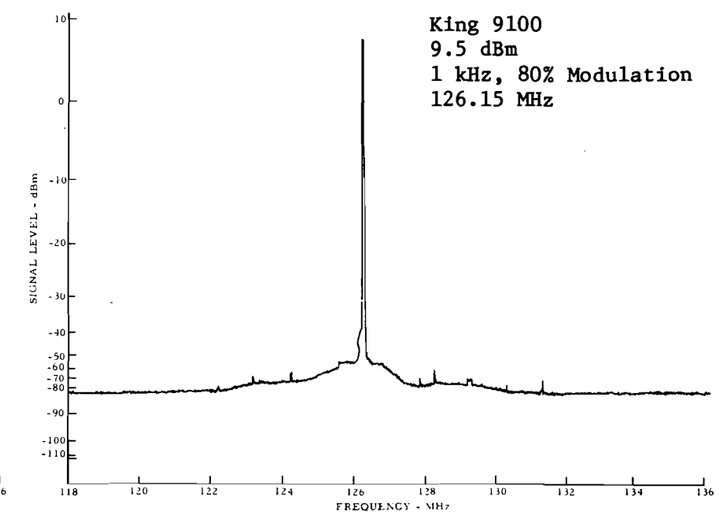
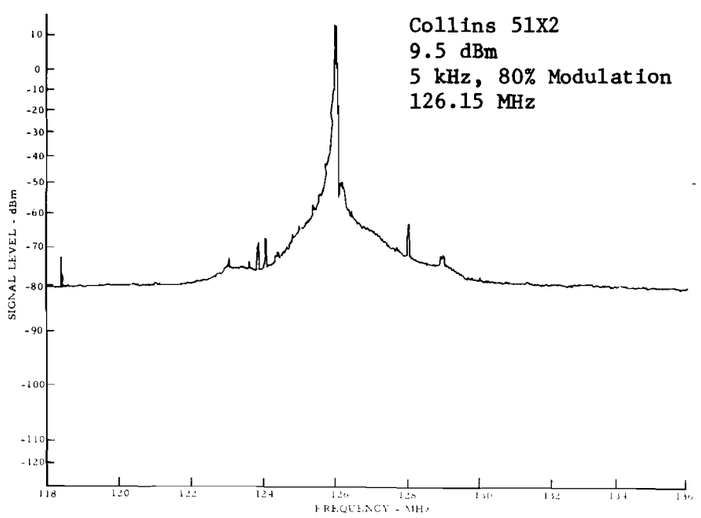


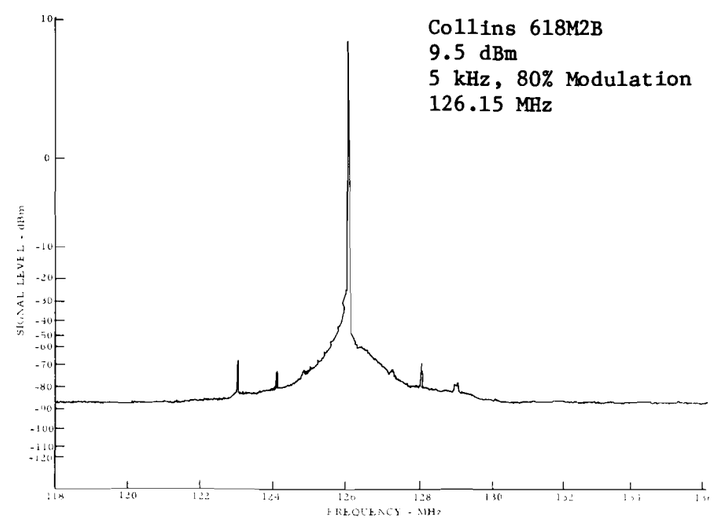
FIGURE 4. LABORATORY RECEIVER TESTS (Sheet 3 of 4)











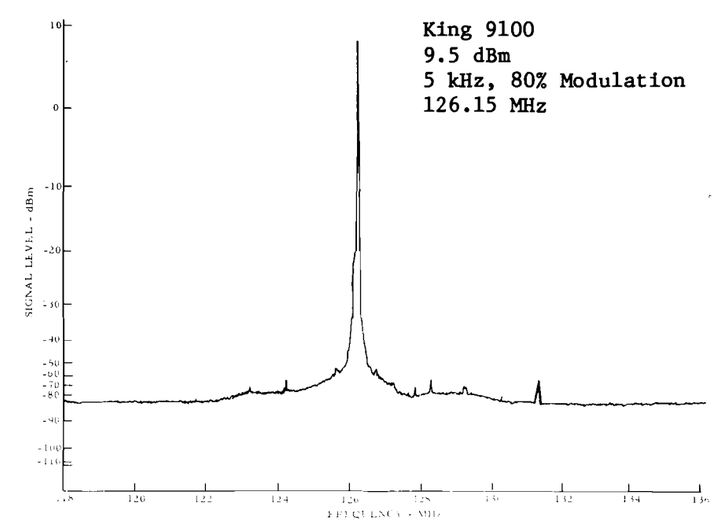


FIGURE 4. LABORATORY RECEIVER TESTS (Sheet 4 of 4)

CONCLUSIONS

It is concluded that:

1. The isolation between certain antenna combinations on the test aircraft is small (less than 23 dB) and results in interference or quieting between transceivers, even though there is frequency separation.

2. The isolation between antennas depends upon their physical positioning on the aircraft, and for the test aircraft, the maximum isolation (45 dB) is not sufficient to prevent interference.

3. Transceiver design affects the rejection of undesired received signals such that operation within a bandpass of 1 MHz is the best case and 4 MHz is the worst case.

RECOMMENDATIONS

It is recommended that:

1. For maximum isolation, aircraft communications antennas be separated by the largest lateral distance possible.

2. Receiver design be optimized for rejection of maximum undesired signal levels experienced in any particular aircraft installation.

3. Cockpit communications discipline be used so as to have one, and only one transmitter operating at a time if the physical size of the aircraft precludes antenna lateral separation.

4. Isolation measurements of proposed aircraft communication antenna locations be made to minimize the "self-caused" interference problem.

5. If digital communication is implemented, frequency assignment consideration should be made such that simultaneous use of voice and digital transmission is not precluded aboard the same aircraft.

REFERENCE

1. Braybrook, L. J. and Bowes, K. G., Air-Ground Digital Data Transmission Tests in the VHF Aeromobile Band, International Civil Aviation Organization, Automated Digital Data Interchange Panel, Working Group No. 1: Eleventh Meeting, London, Agenda, Item 7, November 5 - 8, 1974.