LABORATORY TESTS OF VOR SIGNAL INTERFERENCE RATIOS

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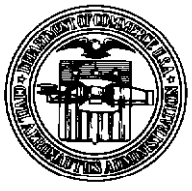

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LABORATORY TESTS OF VOR SIGNAL INTERFERENCE RATIOS

SUMMARY

This report presents the results of tests conducted at the Technical Development and Evaluation Center of the Civil Aeronautics Administration to determine the interference between signals of different levels from either VOR or ILS stations operating on the same or adjacent channels These tests also indicate the action of the flag alarm in different types of receivers when the received signal is subjected to interference from other VOR or ILS stations

INTRODUCTION

A major problem in the establishment of adequate very-high-frequency omnirange (VOR) and instrument landing system (ILS) facilities in the United States is the reduction of interference between them Minimum interference is obtained through careful selection of frequencies with respect to facility location In general the greater this geographical separation is, the closer their frequencies may be

The range of a VOR station is approximately proportional to the line-of-sight distance from the station The present-day trend for scheduled airlines is to fly at higher altitudes, which increases the usable range of a VOR facility but also increases the likelihood of interference between stations

The airline types of navigation receivers have an alarm circuit which will cause a flag to show on the course deviation indicator whenever the VOR or ILS facility fails, whenever the received signal strength is insufficient for reliable receiver operation, or whenever certain receiver components fail The flag alarm, however, may not indicate bearing errors resulting from interference by other VOR or ILS signals, as will be shown in this report

EQUIPMENT AND TESTS

A series of laboratory tests was conducted at the Center in order to determine interference ratios under the following conditions

1 Two VOR stations operating on the same frequency
2 Two VOR stations operating on frequencies 100 kilocycles per second (kc) apart
3 Two VOR stations operating on frequencies 200 kc apart
4 One VOR and one ILS localizer operating on the same frequency
5 One VOR and one ILS localizer operating on frequencies 100 kc apart
6. One VOR and one ILS localizer operating on frequencies 200 kc apart

These tests were conducted on the following types of receivers that were available at the Center

1 Collins Type 51R-2
2. Bendix Type MN-85BA
3 Aircraft Radio Corporation Type ARC-15A
4 National Aeronautical Corporation NARCO Omnigator VTR-1

The following general test equipment setup and procedure were used during these tests

The output of each of two Boonton Type 211 signal generators was connected through a six-decibel (db) pad to the input of the receiver being tested

Two audio generators, Collins Type 479S, were used to modulate the signal generators with omnirange and ILS audio tones

The output of both signal generators was adjusted to 500 microvolts (μv) and fed to the receiver being tested The variable phase of the desired signal (hereafter referred to as No 1 signal) was set to 0°, and the bearing selector dial of the undesired signal (hereafter referred to as No. 2 signal) was adjusted so that it would produce maximum error in the receiver output This error appeared at 257° and 78°

The No 1 signal level was held constant, while the No 2 signal level was varied in direct ratios above (+db) and below (-db) the No 1 signal The receiver input expressed in μv, as shown in the tabulations, is that voltage which appeared across the antenna terminals of the receiver being tested and is equal to one-half the output of the test set

1 TWO VOR STATIONS OPERATING ON THE SAME FREQUENCY

Procedure

The two test sets were operating as two VOR stations and were separated approximately 1500 cycles per second (cps) in frequency The variable phase of No 2 signal

was normally between 250° and 265° for maximum error The flag current in the Collins and Bendix receivers was adjusted for 220 microamperes (μa) on each of the reference and variable channels. The ARC-15A and NARCO receivers have no adjustment for flag current Two flag movement loads were used in the test setup and totaled 500 ohms The flag current tabulated in Tables I, IV, and V is the current through only one of the 1000-ohm flag movements.

Comments

a The signal input level of the desired signal (No 1) did not materially affect the bearing error in the Collins and Bendix receivers. However, in the ARC-15A and NARCO receivers the desired level did affect the bearing error at ratios less than -10db

b. The Bendix and ARC-15A receivers provided usable bearing indications (1° or less of error) at interference ratios of -14 db or more The Collins receiver required a ratio of -17 db, and the NARCO required greater than -16 db ratio

c The information given in Table I indicates that the flag will not be visible although the errors may be as high as 14° in the ARC-15A, as high as 8° in the Collins 51R-2, and as high as 6 6° in the Bendix The basis for this statement is the requirement that the flag shall be visible when the flag current is 250 μa or less The low flag current in the ARC-15A with input of 5μv is attributed to low sensitivity of the receiver

2. TWO VOR STATIONS OPERATING ON FREQUENCIES 100 KC APART

Procedure

The procedure for this test was the same as for Test No 1, except that the No 2 signal (the undesired signal) was tuned 100 kc above the No 1 signal and then 100 kc below

TABLE I

EFFECTS CAUSED BY TWO VOR STATIONS ON THE SAME FREQUENCIES

No 2 Signal Ratio	No 1 Signal Input Levels					
	5 μv		500μv		5000 μv	
(decibels)	Error (degrees)	Flag Current (μa)	Error (degrees)	Flag Current (μa)	Error (degrees)	Flag Current (μa)
Collins 51R-2						
- 6.0	8.1	260	7 9	275	7 7	280
- 9 5	4 3	270	3 3	290	3 3	295
-14 0	2.4	275	1 1	300	1 2	305
-20 0	0.5	280	0 3	305	0 2	315
-26 0	0.0	285	0 1	310	0.0	320
Bendix MN-85BA						
- 6 0	6 2	268	6 6	286	6 3	298
- 9 5	2 6	276	2.7	300	2 5	310
-14 0	0 8	280	0 9	306	1.0	316
-20.0	0.0	285	0 3	310	0 2	320
-26.0	0 0	285	0 2	310	0 0	320
ARC-15A						
- 6 0	9 7	170	11.0	260	14.0	320
- 9 5	1.9	200	2 8	295	4.0	340
-14 0	0.2	220	0 2	320	0 5	380
-20 0	-	-	-	-	0 1	400
NARCO VTR-1						
- 6 0	11 7	-	11 5	-	12 2	-
- 9 5	4 1	-	4 1	-	4 3	-
-14 0	1 3	-	1 2	-	1 5	-
-20.0	0.8	-	0 5	-	0 5	-

TABLE II

ERRORS CAUSED BY TWO VOR STATIONS SEPARATED BY 100 KC

No 2 Signal Ratio (decibels)	No 1 Input Signal Levels: 5 μv Frequency 100 kc Higher (degrees)	5 μv Frequency 100 kc Lower (degrees)	500 μv Frequency 100 kc Higher (degrees)	500 μv Frequency 100 kc Lower (degrees)	5000 μv Frequency 100 kc Higher (degrees)	5000 μv Frequency 100 kc Lower (degrees)
ARC-15A						
- 6 0	0 0	0 0	0 0	3 4	0 0	3 0
- 9 5	-	-	0 0	1 16	0 0	1 0
-14 0	-	-	0 0	0 0	0 0	0 0
NARCO VTR-1						
- 6 0	0 0	3 3	4.8	1 3	3 6	1 3
- 9 5	0 0	1 8	2 1	0 5	1 7	0 6
-14 0	0 0	0 3	0 8	0 0	0 7	0 0

Collins 51R-2
Bendix MN-85BA

No interference or bearing error was noted on either receiver with inputs less than +60 db above the desired signal level

it The results are shown in Table II

Comments

a The Collins and Bendix receivers did not indicate any errors from an interfering signal spaced 100 kc away and less than 60 db above the desired signal

b The ARC-15A was not affected by adjacent channel interference when the interfering signal was -9 5 db or more below the desired signal level

c The NARCO was not affected by adjacent channel interference when the interfering signal was -13 db or more below the desired signal level

3. TWO VOR STATIONS OPERATING ON FREQUENCIES 200 KC APART

Procedure

The procedure was the same as for Test No 1 except that the No 2 signal was tuned 200 kc above the No 1 signal and then 200 kc below it The results are shown in Table III

TABLE III

ERRORS CAUSED BY TWO VOR STATIONS SEPARATED BY 200 KC

No 1 Signal Input Level	No. 2 Signal Ratio for 1° of Error: Frequency 200 kc Higher (decibels)	Frequency 200 kc Lower (decibels)
NARCO VTR-1		
5 μv	+33 0	+17 0
500 μv	+14 0	+24 0
5000 μv	+17 0	+ 8 5

Collins 51R-2
Bendix MN-85BA

No interference or bearing error was noted on either receiver with inputs less than +80 db above the desired signal level

ARC-15A

No interference or bearing error was noted at inputs less than +20 db above desired signal levels of 5, 500, and 5000 μv.

TABLE IV

EFFECTS CAUSED BY THE SIGNALS OF AN UNDESIRED ILS STATION ON THE SAME FREQUENCY AS A VOR STATION

No 2 Interfering ILS Signal Level Ratio (decibels)	No 1 Desired VOR Signal Input Level					
	5 μv		500 μv		5000 μv	
	Error (degrees)	Flag Current (μa)	Error (degrees)	Flag Current (μa)	Error (degrees)	Flag Current (μa)
Collins 51R-2						
- 6 0	0 32	255	0 6	280	0 6	285
-14 0	0 0	280	0 0	310	0 2	310
Bendix MN-85BA						
- 6 0	0 24	270	-	-	0 5	285
-14.0	0 0	280	-	-	0 2	310
ARC-15A						
- 6.0	0 7	210	-	-	2 4	300
- 9 5	0 0	270	-	-	0 9	335
-14 0	-	-	-	-	0 6	385
NARCO VTR-1						
- 6 0	3.0	-	3 5	-	4 0	-
- 9 5	2 0	-	2 5	-	3 0	-
-14 0	0.7	-	1 0	-	1 0	-
-20.0	0.3	-	0 4	-	0 4	-

4 ONE VOR AND ONE ILS OPERATING ON THE SAME FREQUENCY

Procedure

Two separate tests were conducted under these conditions in which VOR was designated as the desired signal and ILS as the undesired In the first test the No 1 signal (the desired one) was a standard VOR signal on 114 9 megacycles (Mc) and the No 2 an ILS signal on 114 9 Mc In the second test the No 1 signal was a standard ILS signal on 110 1 Mc and the No 2 a VOR signal on approximately the same frequency The radio-frequency (rf) differences were approximately 1500 cps Results are shown in Tables IV and V

Comments

a An ILS interfering signal that is 6 db or more below the desired VOR signal did not cause a VOR course error greater than 0 6° in the Collins or Bendix receivers

b The ARC-15A receiver provided a usable VOR bearing at low signal inputs (5 μv) when the interfering ILS signal was approximately -9 5 db or at the higher (5000 μv) input levels of -14 db or more

c The NARCO receiver provided a usable VOR bearing when the interfering ILS signal was -14 db or more at all signal levels

d When the VOR was the desired signal and the ILS signal was the interfering one (-6 db), there was no indication by the flag alarm of any interference in the Collins and Bendix receivers, although the Collins may have 0 6° error and Bendix 0 5°

e A VOR interfering signal -6 db or more below the desired ILS signal did not cause an on-course error in the Collins or Bendix receivers, although it changed the course sensitivity by approximately 1 0°

f The ARC-15A receiver indicated an ILS on-course error of approximately 0 15° when the VOR interfering signal was -20 db below the desired signal

g The ILS flag alarm in the Collins, Bendix, and ARC receivers indicated interference was present when the VOR interfering signal level was less than -6 db below the desired signal

h A heterodyne tone was audible and increased in volume as the ratio between signals was decreased.

TABLE V

EFFECTS CAUSED BY THE SIGNALS OF AN UNDESIRED VOR STATION ON THE SAME FREQUENCY AS AN ILS STATION

No 2 Interfering VOR Signal Level Ratio (decibels)	No 1 Desired ILS Signal Input Level: 5 μv On-Course Error (degrees)	5 μv Course Sensitivity (degrees)	5 μv Flag Current (μa)	500 μv On-Course Error (degrees)	500 μv Course Sensitivity (degrees)	500 μv Flag Current (μa)	5000 μv On-Course Error (degrees)	5000 μv Course Sensitivity (degrees)	5000 μv Flag Current (μa)
Collins 51R-2									
- 6	0 0	7 15	215	0 0	6 35	250	0 0	6 0	265
-14	0 0	5 85	275	0 0	5 35	310	0 0	5 1	325
Infinite	0 0	5 63	290	0 0	5 30	315	0 0	5 0	332
Bendix MN-85BA									
- 6	0 0	8 65	195	0 0	7 8	217	0 0	7 15	227
-14	0 0	6 5	265	0 0	5 85	290	0 0	5 36	305
-20	0 0	6 1	282	0 0	5 5	310	0 0	5 0	327
Infinite	0 0	6 0	285	0 0	5 25	320	0 0	5 0	330
ARC-15A									
- 6	0 23		180	0 0			0 0		
-14	0 2		215	0 0			0 0		
-20	0 15		230	0 0			0 0		
-26	0 05		235	0 0			0 0		
NARCO VTR-1									
- 6	0 04			0 06			0 08		
- 9 5	0 02			0 03			0 04		
-14	0 0			0 0			0 02		

5 ONE VOR AND ONE ILS LOCALIZER OPERATING ON FREQUENCIES 100 KC APART

Procedure

The procedure was the same as for Test No 4, except that the interfering signal was 100 kc above and below the desired signal

Comments

When the VOR was the desired signal and the ILS the undesired, the Collins and Bendix receivers did not indicate any bearing error when the ILS signal level was less than +60 db above that of the VOR The ARC-15A and NARCO receivers did not indicate any bearing error with ILS signal input levels of less than +20 db above the VOR signal

When the ILS was the desired signal and the VOR was the undesired, the Collins and Bendix receivers did not indicate any on-course error when the VOR signal level was less than +60 db above that of the ILS The NARCO and ARC-15A receivers did not indicate any on-course error when the VOR signal level was less than +6 db above the desired ILS level When the undesired VOR signal was greater than +6 db above the ILS, the TO-FROM indicator in the NARCO receiver was deflected

6 ONE VOR AND ONE ILS LOCALIZER OPERATING ON FREQUENCIES 200 KC APART

Procedure

The procedure was the same as for Test No 4, except that the interfering signal was 200 kc above and below the desired one

Comments

Any interfering signal that was less than +60 db above the desired one and spaced 200 kc above or below the desired channel did not cause any course error when the Collins or Bendix receivers were used An

interfering signal of +35 db or less did not cause course error when using an ARC-15A receiver An interfering signal of +26 db or less did not cause course errors when using the NARCO receiver

CONCLUSIONS

1 Flag Alarm

The flag alarm will not indicate VOR bearing errors caused by a co-channel interfering signal that is -6 db or more below the level of the desired signal These errors could be as high as 8° for the Collins, 6 6° for Bendix, and 14° for ARC-15A receivers, respectively.

2 VOR Interfered by Another VOR Signal

The level of an undesired VOR signal that is on the same frequency channel as the desired one must be -14 db below the desired level in order to provide usable bearing indication with 1° or less of error with either the Bendix or the ARC-15A receivers The interfering signal must be -17 db for the Collins receiver or -16 db for the NARCO receiver to produce 1° of error or less For 100-kc separation between the two VOR signals, no indication of errors will be noted on the Collins or Bendix receivers when the undesired signal level is +60 db or less, when it is -9 5 db or more on the ARC-15A, or when it is -13 db or more on the NARCO receivers For 200-kc separation between the two VOR signals, no indication of errors will be noted on the Collins or Bendix receivers when the undesired signal level is +80 db or less, when it is +20 db or less on the ARC-15A, or when it is +8 5 db on the NARCO receivers

3 VOR Interfered by ILS Signal

An ILS interfering signal which is -6 db below the VOR signal and on the same frequency channel will cause VOR bearing error of approximately 0 6° in the Collins and Bendix receivers, a 2 4° error in the ARC-15A, and 4 0° error in the NARCO receivers.

4 ILS Interfered by VOR Signal

A VOR interfering signal which is -6 db below the ILS signal and on the same frequency channel will not cause an on-course error in the Collins or Bendix receivers but decreases the course sensitivity approximately 20 per cent It will cause an on-course error of about 0 23° in the ARC-15A and of approximately 0 04° in the NARCO receivers

5 Desired Signal Input Level

The bearing error caused by an interfering signal whose level is changed in direct ratio to the desired signal is not materially affected by any receiver when the desired signal level is varied from 5 to 5000 μv

6 Aural Output

When any two signals (ILS or VOR) are on the same channel, a heterodyne tone is audible at all times and increases in volume as the ratio (db) between the signals is decreased

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