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Selectivity Tests of Tunable VOR Receivers

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by

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SELECTIVITY TESTS OF
TUNABLE VOR RECEIVERS

SUMMARY

This report presents the results of tests conducted at the CAA Technical Development Center to determine the tolerable limits for interfering signals between VOR stations and between a VOR and a localizer station. Data are presented for each of three different tunable receivers commonly used in private aircraft.

INTRODUCTION

The CAA Office of Air Navigation Facilities requested that tests be conducted at the Technical Development Center (TDC) to determine limits of tolerable interfering signal levels between VOR stations and between VOR and localizer stations when using Lear, Aircraft Radio Corporation (ARC), and National Aeronautical Corporation (NARCO) receivers.

Tests for the following combinations of conditions were requested:

1. Two VOR stations having a frequency separation of 0 to 10 kc.

2. Two VOR stations having frequency separations of 100, 200, and 300 kc.

3. One VOR and one localizer having a frequency separation of 100 kc.

For each of the above combinations, it was desired to determine the levels of interfering signal for various levels of desired signal which will cause 1° error, 2° error, "just-audible" signal, and an "objectionable audio signal." These were to be determined at the phase relation between the audio signals of the desired and the interfering stations which causes the greatest interference.

EQUIPMENT AND METHODS

Figure 1 is a block diagram of the equipment which was set up in the receiver laboratory for these tests. An audio oscillator and amplifier were used to furnish power of adjustable frequency (approximately 59.9 cps) to the motor of one of the Collins 479S generators in order to provide a continuously changing phase relation between desired and interfering audio signals. This would produce automatically the phase conditions which would cause the greatest bearing error.

Voice band-pass filters were used on the tape reproducer and on the low-frequency receiver outputs to filter out noises not normal to the speech channel of a VOR. The low-frequency receiver was tuned to the local low-frequency range for the continuous weather broadcast. The recording on the reproducer consisted of weather broadcasts. Stable co-channel signal frequency differences were obtained by operating both r-f generators by crystal control. By means of an adjustable trimmer in the crystal circuit of one oscillator, its frequency could be adjusted up to 10 kc from normal. The cathode-ray oscilloscope and

Hew t-Packard audio oscillator were used to determine when the frequency diff ence was of the desired value, as well as to move a signal frequency a known amount for use in obtaining selectivity data. Large frequency differences such as 100 kc, 200 kc, and 300 kc were obtained by operating one of the r-f generators as a master oscillator.

The course deviation indicator was a 40-microampere, zero-center meter sufficiently fast-acting to follow the rate of phase variation previously stated The percentage modulation indicator was used to check modulation levels of both desired and undesired signal sources. The levels of desired signals indicated on the charts in this report are voltages at the receiver input terminals. Except as indicated on Fig. 31, observations were made by TDC personnel. Any reference to the level of an interfering signal is to be interpreted as a ratio in db to the desired signal. The phrase, "objectionable audio interference," is intended to mean a level of interference which is distracting, or which might reduce intelligibility of voice or identification on a desired signal. A level of interference which is not objectionable will be referred to as the "just-audible" signal.

TESTS

Figures 2, 3, and 4 show that the tolerable ratio of undesired to desired signal for a 1° error limit remains almost constant through the range of desired signal levels tested. At the frequency difference of 30 cps, all three receivers tolerate approximately the same level of interfering signal.

Figures 5, 6, and 7 depict the same conditions as Figs 2, 3, and 4 except with a 2° error limit. The 30-cps frequency difference is the limiting factor, with only slightly more tolerance than with a 1° error limit. The probability of co-channel stations being nearly 30 cps in frequency difference is small, however.

Figures 8, 9, and 10 show interfering signal tolerance for three levels of desired signal with 1-, 2-, and 3-channel separations when the limit of tolerable interference is 1° error. Co-channel data from Figs. 2, 3, and 4 also are shown as far as practicable on the above figures Figures 11, 12, and 13 are similar to Figs. 8, 9, and 10 except for the 2° error limit.

Figures 14, 15, and 16 show the decrease or increase in tolerance to an interfering signal depending upon whether receiver detuning is toward or away from the interfering frequency. Figures 17, 18, and 19 show slightly more tolerance with the 2° error limit. Otherwise, conditions are the same.

Figures 20, 21, 22, and 23 indicate ratios of undesired to desired signal which cause just-audible interference during co-channel operation Results are given for three levels of desired signals. Figures 21 and 22 are results obtained with the same receiver by two different observers.

Figures 24, 25, 26, and 27 point up a tolerance for higher levels of interfering signal if the frequency separation is about 5 kc. This refers to objectionable audio interference while navigation error effects would occur at lower levels of interfering signal.

Figures 28, 29, and 30 show just-audible interference as established by three observers. These are for the intermediate level of desired signal.

Figures 31, 32, and 33 show limits of interference ratios which give objectionable audio interference as interpreted by several observers.

It will be noted in Figs. 34, 35, 36, 37, 38, and 39 that the stronger desired signal will allow less relative level of interfering signal than does a lower level of desired signal.

Figures 40 through 45 show the effect of receiver detuning upon the allowable relative level of undesired to desired signal for just-audible interference and for objectionable audio interference of signals from nearby channels insofar as aural effects are concerned. When the interference is limited to that which causes a 1° error in azimuth, the aural effects will be below an objectionable level.

Figures 46, 47, and 48 show the over-all selectivity curves for the three types of receivers tested. A 5-microvolt unmodulated signal at resonance was taken as a reference. The automatic volume control (AVC) voltage thus obtained was held constant for other frequencies by increasing the input signal level as required.

Figures 49, 50, and 51 show the over-all audio response of the three types of receivers tested. The receiver output was measured as the audio frequency was varied. The r-f generator modulation level was held constant at 30 per cent.

Table I shows the data obtained for a VOR interfering with a localizer The limiting criterion was to be a 0.3° course error. With the ARC receiver, course width doubled before a 0.3° course error was experienced; therefore, that condition was taken as a limit for the ARC receiver.

Table II shows the data obtained for a localizer interfering with a VOR. Here also the ARC receiver gave double course width before the limiting azimuthal error was experienced.

Table III is a compilation of the more critical or limiting values for interference between two VOR's and between a VOR and a localizer.

CONCLUSIONS

It is concluded that, for all three receivers tested, based on the condition of using the minimum level of the interfering signal:

1. For two VOR's on the same channel, the level of the undesired VOR signal must be at least 44.5 db below the desired VOR signal level to permit operation with less than 1° error when the frequency separation of the two VOR stations is 30 cps. When the frequency separation is 5,000 cps, the level of the undesired signal must be at least 24.5 db before it causes a 1° error.

2. For two VOR's separated by 100-, 200-, and 300-kc with the receivers properly tuned, the level of the undesired signal at 100-kc separation must be at least 12.5 db below the desired signal level. At 200- and 300-kc separations, the undesired signal level must not be more than 24 db and 30 db above the desired signal, respectively, to permit operation with less than 1° error.

3. For interference by a localizer at 100-kc separation, the level of the localizer signal must be less than the level of the VOR signal to permit operation with less than 1° error.

4. For localizer interference by a VOR at 100-kc separation, the level of the VOR signal must not be more than 8 db above the localizer signal to avoid objectionable audio interference.

TABLE I

VOR INTERFERING WITH LOCALIZER

Ratio in DB of Undesired/Desired Signal for Three Levels of Desired Signal

Type Receiver	Limiting Criterion	VOR Frequency Separation -100 kc 500 uv	50 uv	5 uv	VOR Frequency Separation +100 kc 500 uv	50 uv	5 uv
ARC	Double Course Width	+15.6	+14.0	+20.0	+13.1	+20.8	+21.6
NARCO	0.3° Error	+10.9	+16.9	+23.5	+20.0	+21.6	+27.6
ARC	Just-Audible Interference	+ 1.6	+ 7.2	+15.6	+ 2.9	+14.0	+18.6
NARCO	Just-Audible Interference	0.0	+ 6.0	+15.6	+ 6.0	+12.0	+23.5
ARC	Objectionable Audio Interference	+10.9	+ 9.5	+16.9	+ 9.5	+18.1	+18.6
NARCO	Objectionable Audio Interference	+ 6.0	+ 8.0	+16.9	+12.0	+15.6	+26.0

TABLE II

LOCALIZER INTERFERING WITH VOR

Type Receiver	Limiting Criterion	Ratio in DB of Undesired/Desired Signal for Three Levels of Desired Signal					
		Loc. Frequency Separation -100 kc			Loc. Frequency Separation +100 kc		
		500 uv	50 uv	5 uv	500 uv	50 uv	5 uv
ARC	Double Course Width	+18.1	+22.9	+25.1	+18.1	+19.1	+24.1
NARCO	1° Error	+ 1.6	+ 2.9	+ 9.5	+ 8.0	+10.6	+18.1
Lear	1° Error	+ 0.9	+ 1.6	+ 8.0	+ 1.6	0.0	+14.0
NARCO	2° Error	+ 5.1	+ 9.0	+13.1	+14.0	+15.6	+23.5
Lear	2° Error	+20.0	+16.9	+14.0	+20.0	+16.9	+20.0
ARC	Just-Audible Interference	+ 4.1	+14.0	+20.0	+ 4.1	+ 9.5	+12.0
NARCO	Just-Audible Interference	- 2.2	+ 3.5	+ 7.8	+ 6.0	+14.0	+28.0
Lear	Just-Audible Interference	-10 5	- 4.4	+ 2.9	- 8.0	- 4.4	+ 3.5
ARC	Objectionable Audio Interference	+ 8.0	+19.1	+20.0	+ 8.0	+14.0	+13.1
NARCO	Objectionable Audio Interference	+ 6.0	+10.9	+20.0	+14.0	+20.0	+29.5
Lear	Objectionable Audio Interference	+ 6.0	+ 3.5	+ 9.5	+ 6.0	+ 3.5	+ 9.5

TABLE III

PARTIAL TABULATION OF TEST RESULTS

Two VOR's - 1° Error - Desired Signal Level 50 uv - Maximum Acceptable Level in DB of Interfering Station (Lowest Level Observed)

Type Receiver	Frequency Separation 30 cps	1000 cps	5000 cps	100 kc		200 kc		300 kc
ARC	-43	- 7.5	-14.5	+ 9	+ 6*	+38	+39*	+45
NARCO	-44.5	-17	-21	- 4.5	- 5*	+31.5	+25*	+52
Lear	-43	-22	-24.5	-12.5	-14*	+24	+17*	+30.5

Receiver detuned 10 kc where indicated by *, otherwise tuned to resonance.

Two VOR's - Objectionable Audio Interference - Desired Signal Level 50 uv - Maximum Acceptable Level in DB of Interfering Station (Lowest Level Observed)

Type Receiver	Frequency Separation 100 cps	1000 cps	5000 cps	100 kc		200 kc		300 kc
ARC	-38.5	-39.3	-13	+14	+12*	+46	+48*	+46
NARCO	-20	-41	-15	+ 6	0*	+40	+34*	+60
Lear	-22	-45	-26	- 6	- 6*	+32	+23*	+42

Receiver detuned 10 kc where indicated by *; otherwise tuned to resonance.

Localizer - VOR Interference
100-KC Separation - Desired Signal Level 50 uv - Maximum Acceptable Level in DB of Interfering Station (Lowest Level Observed)

Type Receiver	Localizer Interfering with VOR: 1° Error or Double Course Width		Localizer Interfering with VOR: Objectionable Audio Interference	VOR Interfering with Localizer: Either .3° Error or Double Course Width		VOR Interfering with Localizer: Objectionable Audio Interference
ARC	+19	x	+14	+14	x	+9
NARCO	+ 3	@	+10.5	+17	#	+8
Lear	0	@	+ 3			

x - Double Course Width; @ - 1° Error, # - .3° Error

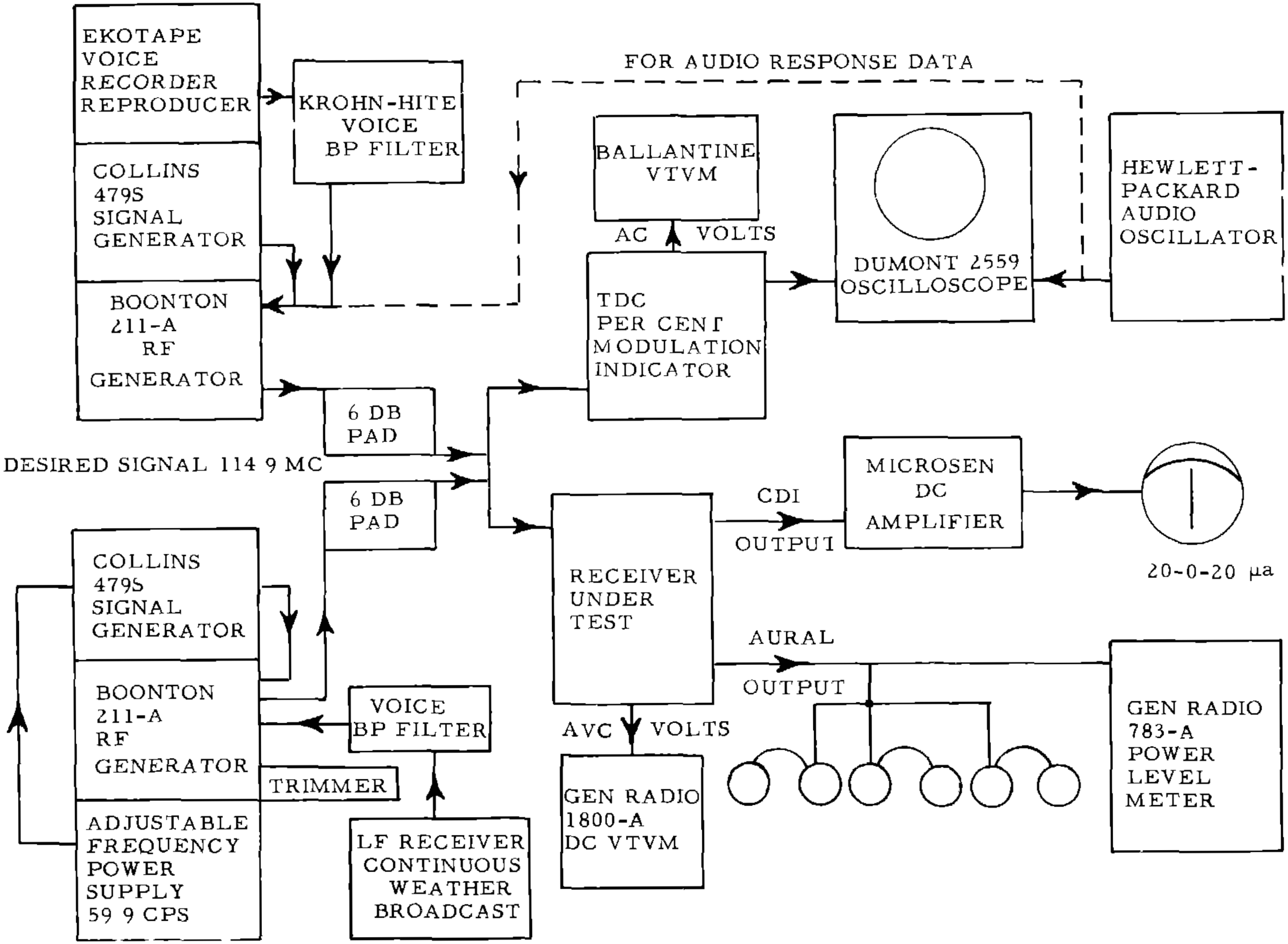

FIG 1 BLOCK DIAGRAM OF THE EQUIPMENT

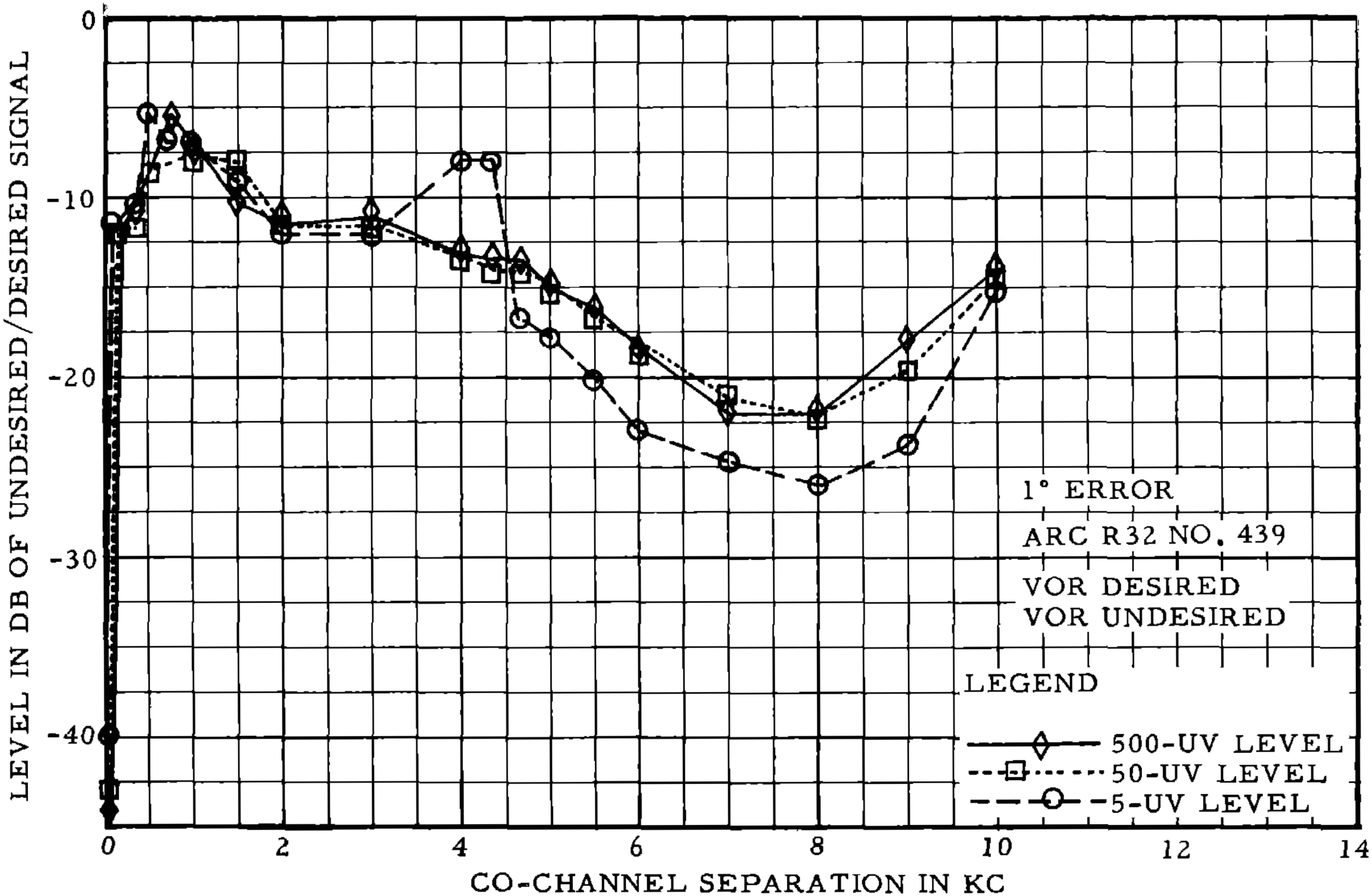

FIG. 2 1° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 10 KC) FOR ARC RECEIVER

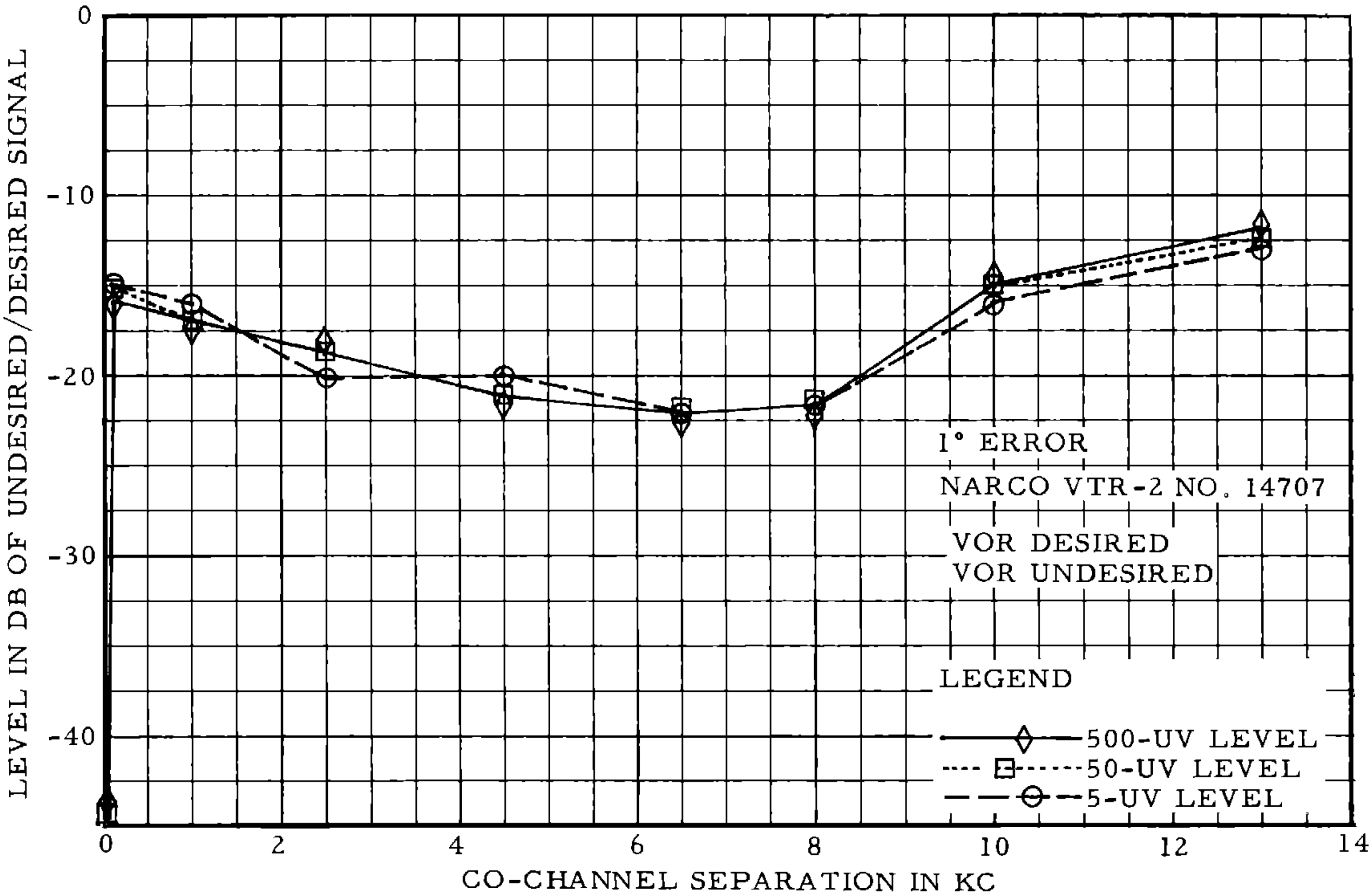

FIG. 3 1° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 13 KC) FOR NARCO RECEIVER

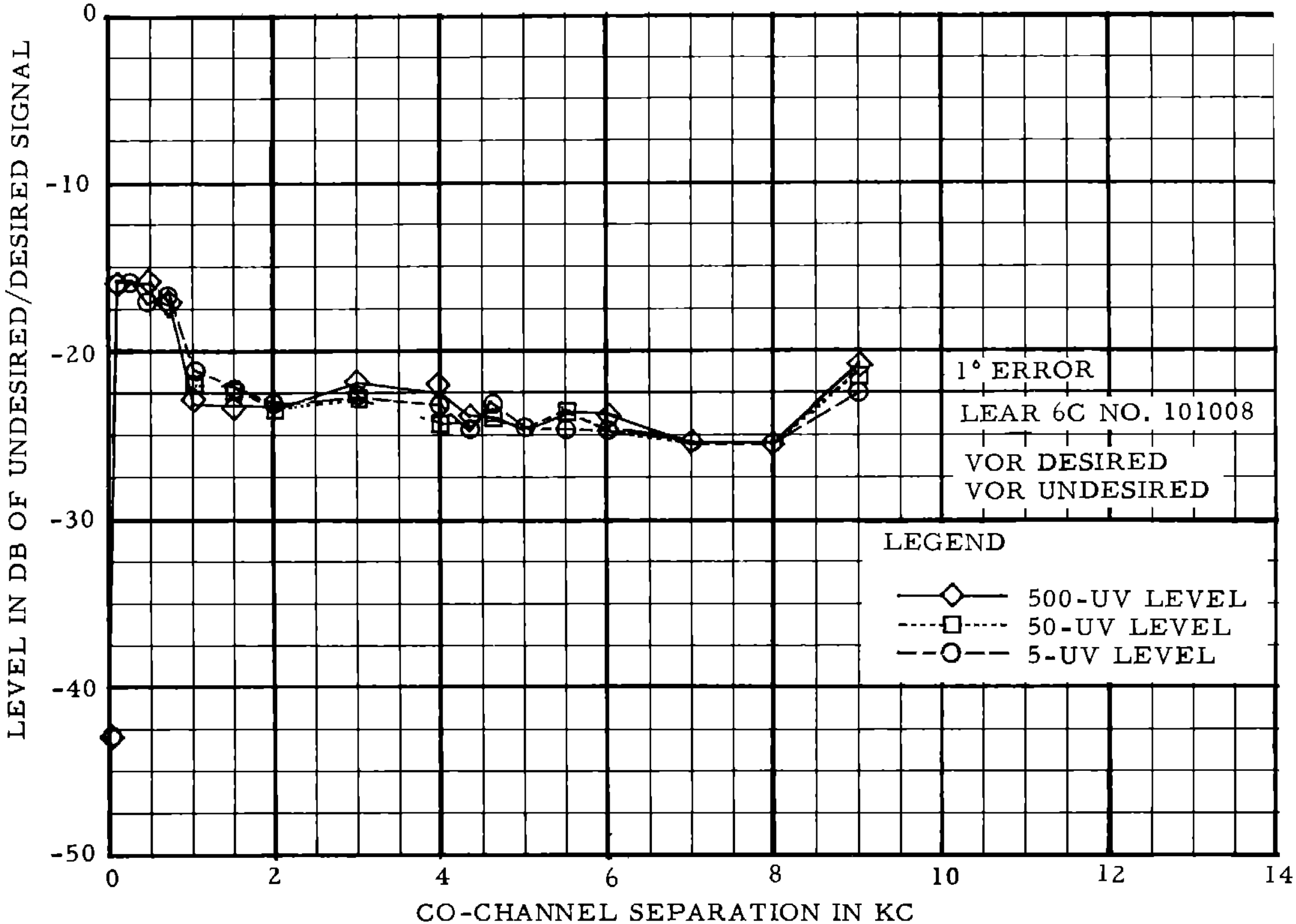

FIG. 4 1° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR LEAR RECEIVER

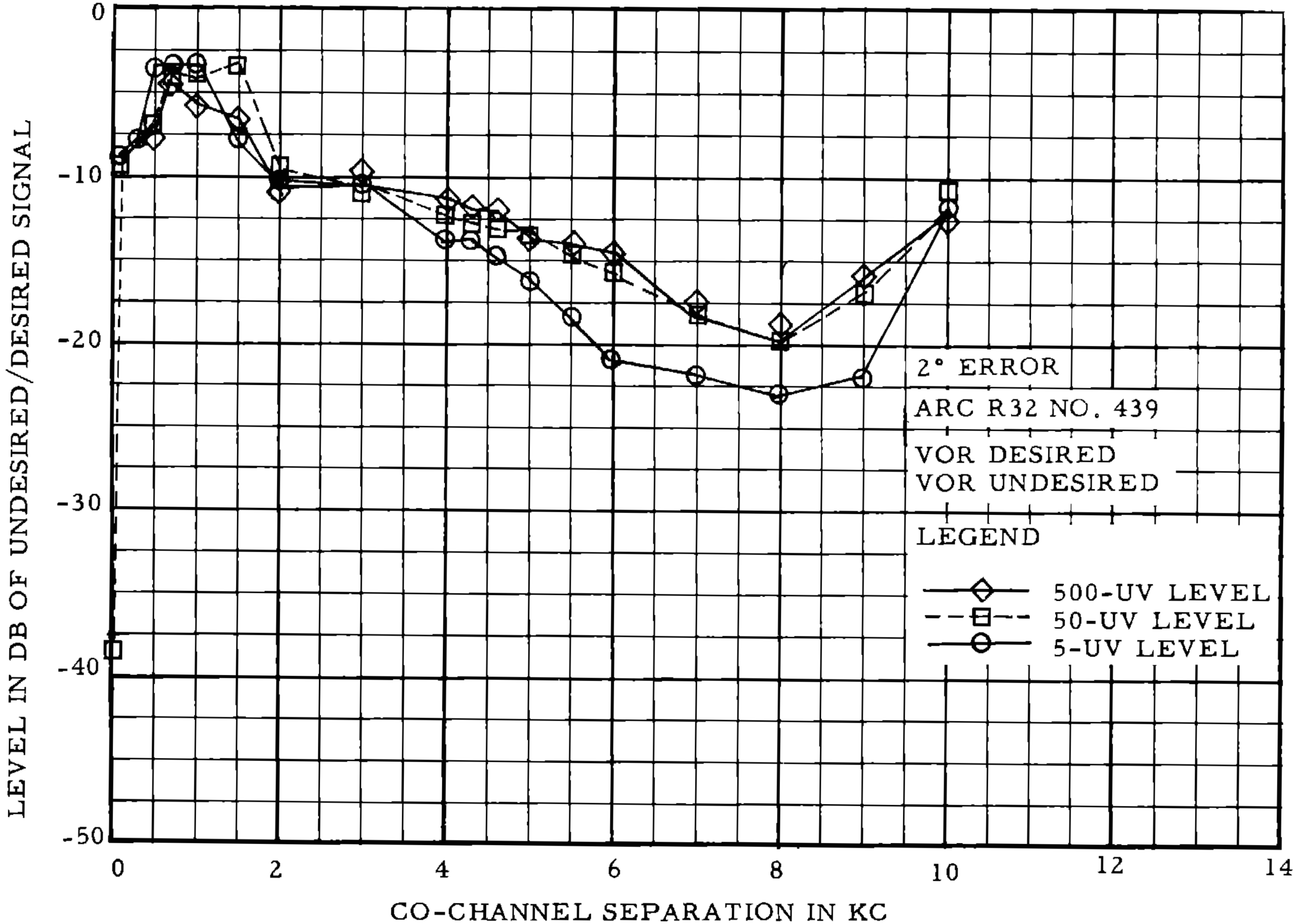

FIG. 5 2° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 10 KC) FOR ARC RECEIVER

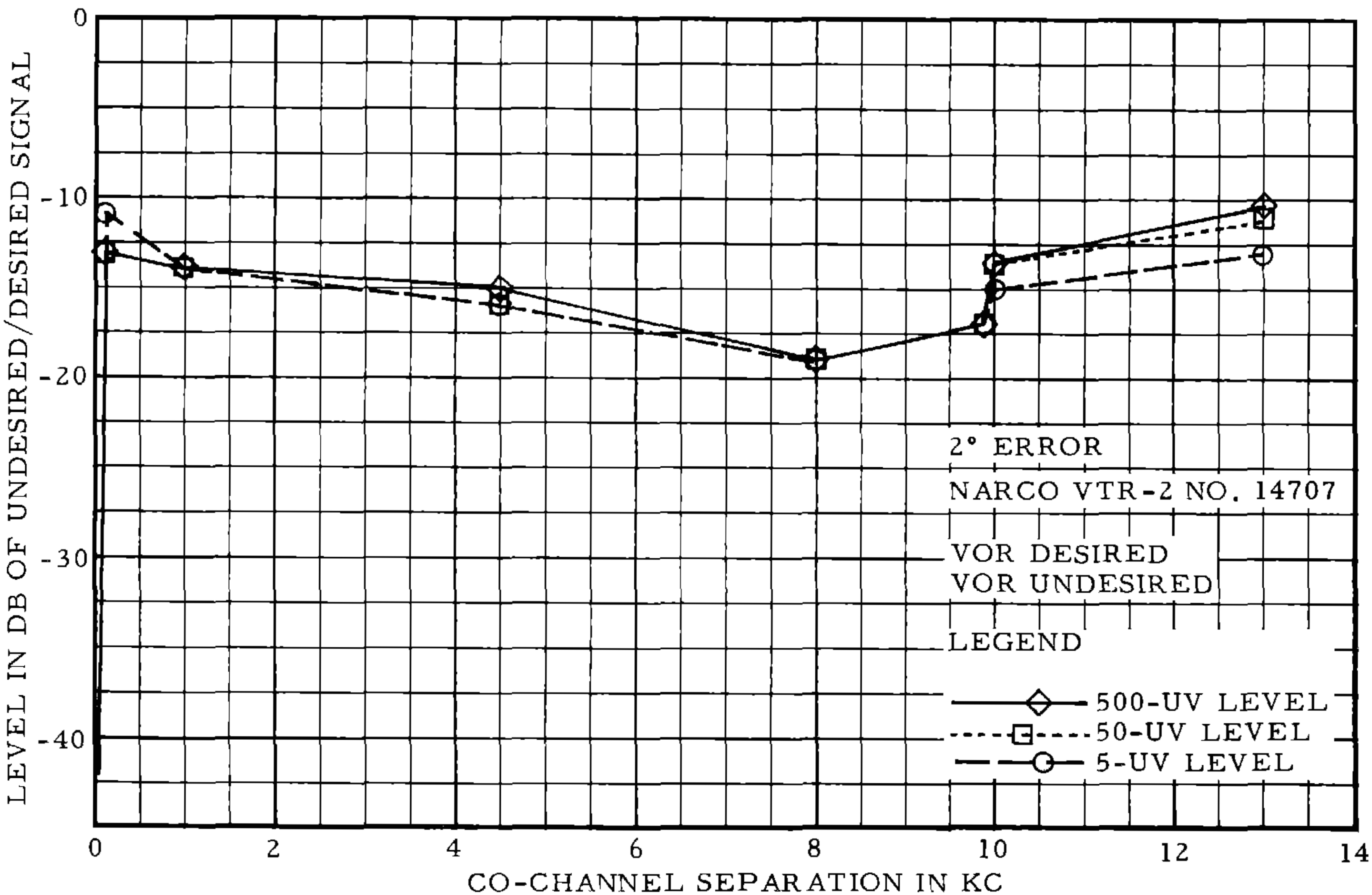

FIG. 6 2° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 13 KC) FOR NARCO RECEIVER

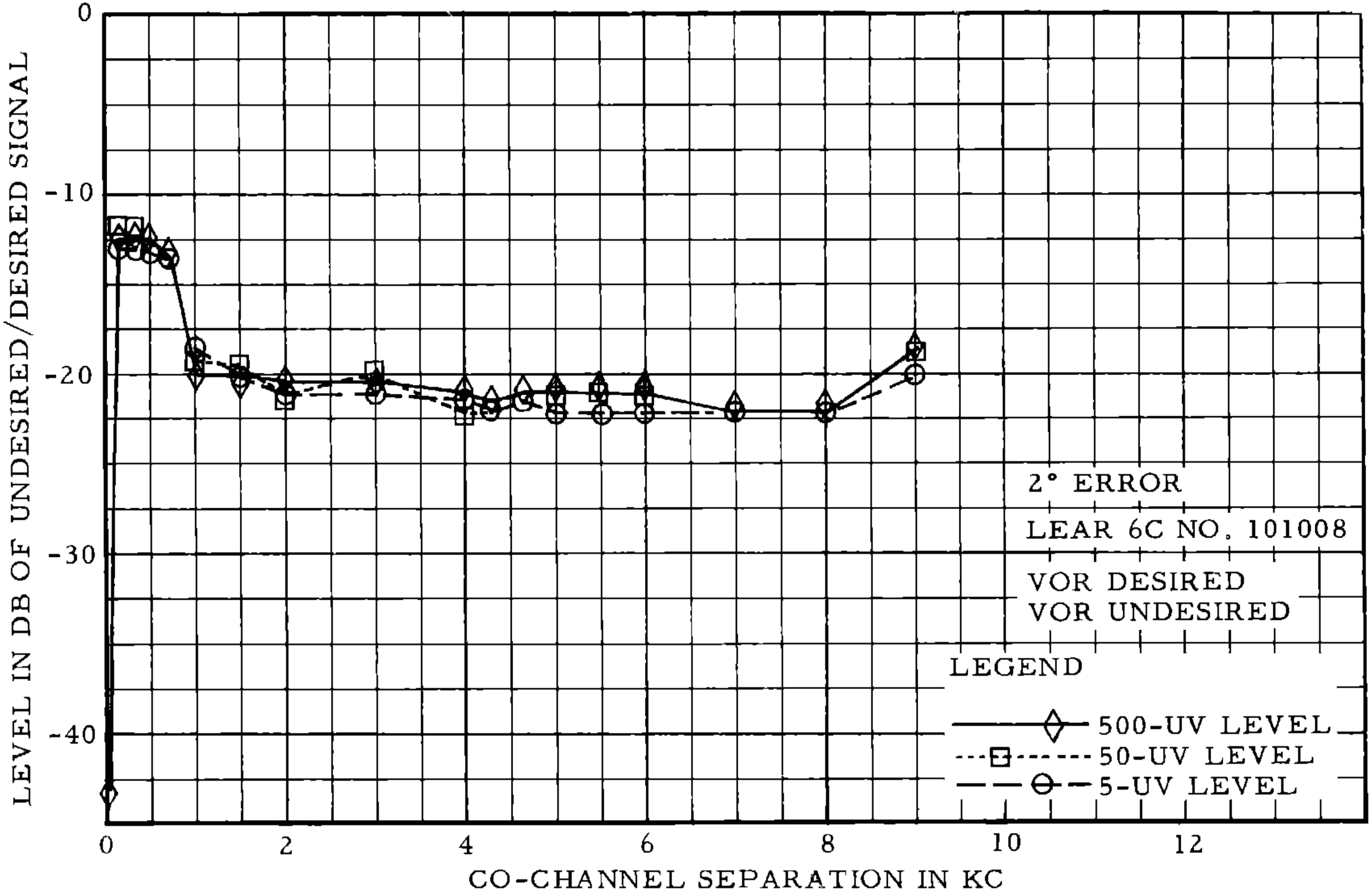

FIG. 7 2° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR LEAR RECEIVER

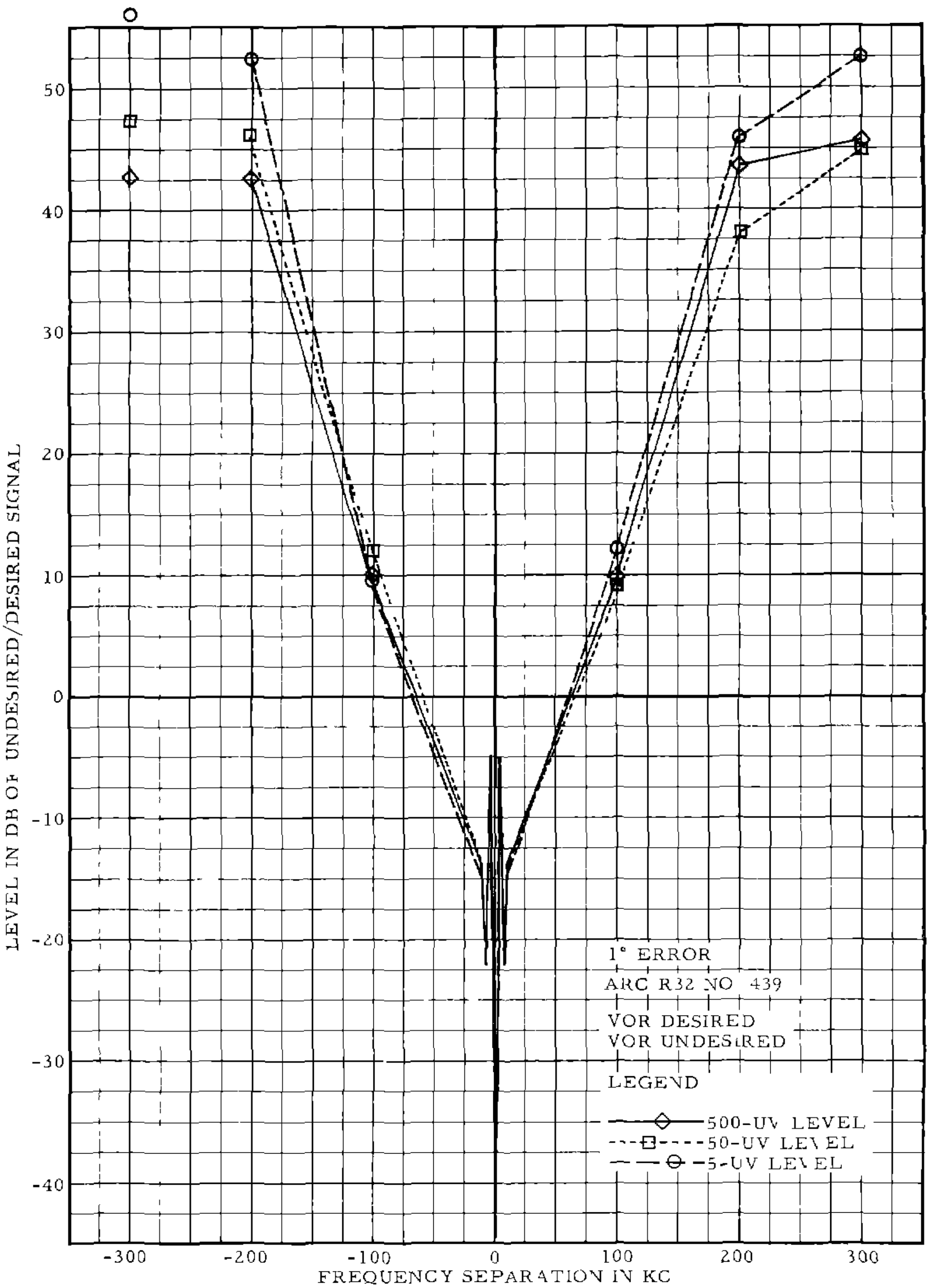

FIG 8 1° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR ARC RECEIVER

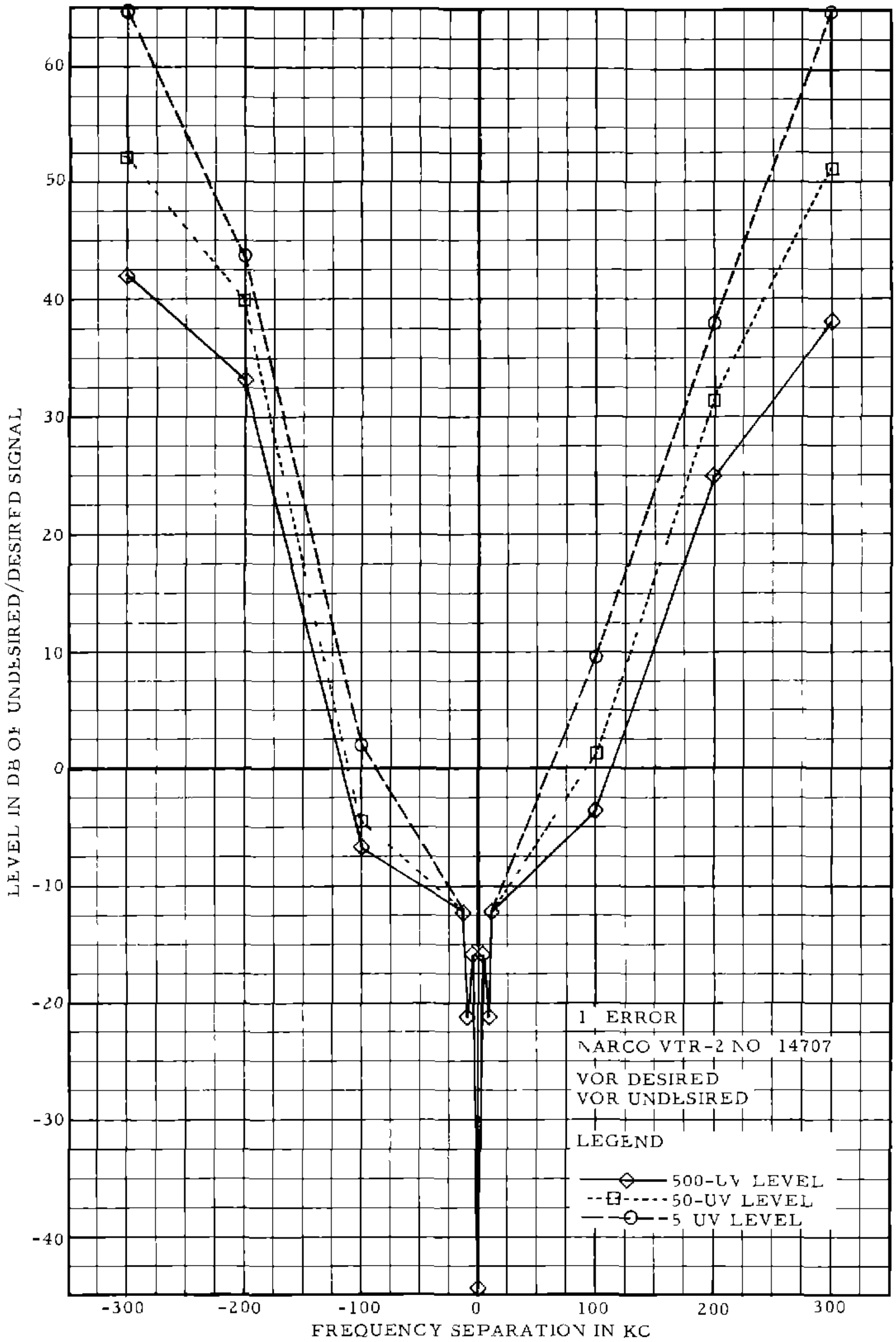

FIG 9 1° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR NARCO RECEIVER

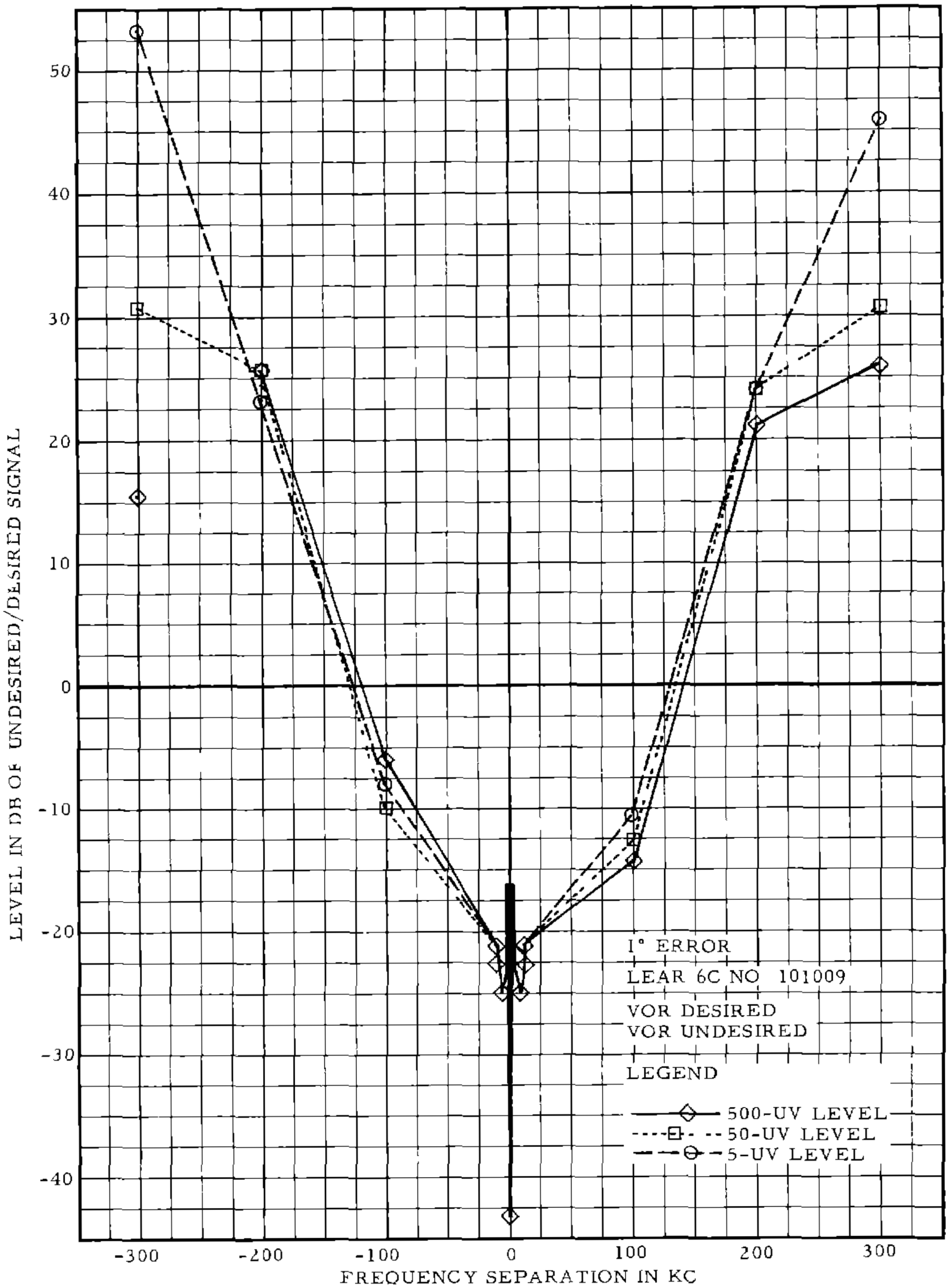

FIG 10 1° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR LEAR RECEIVER

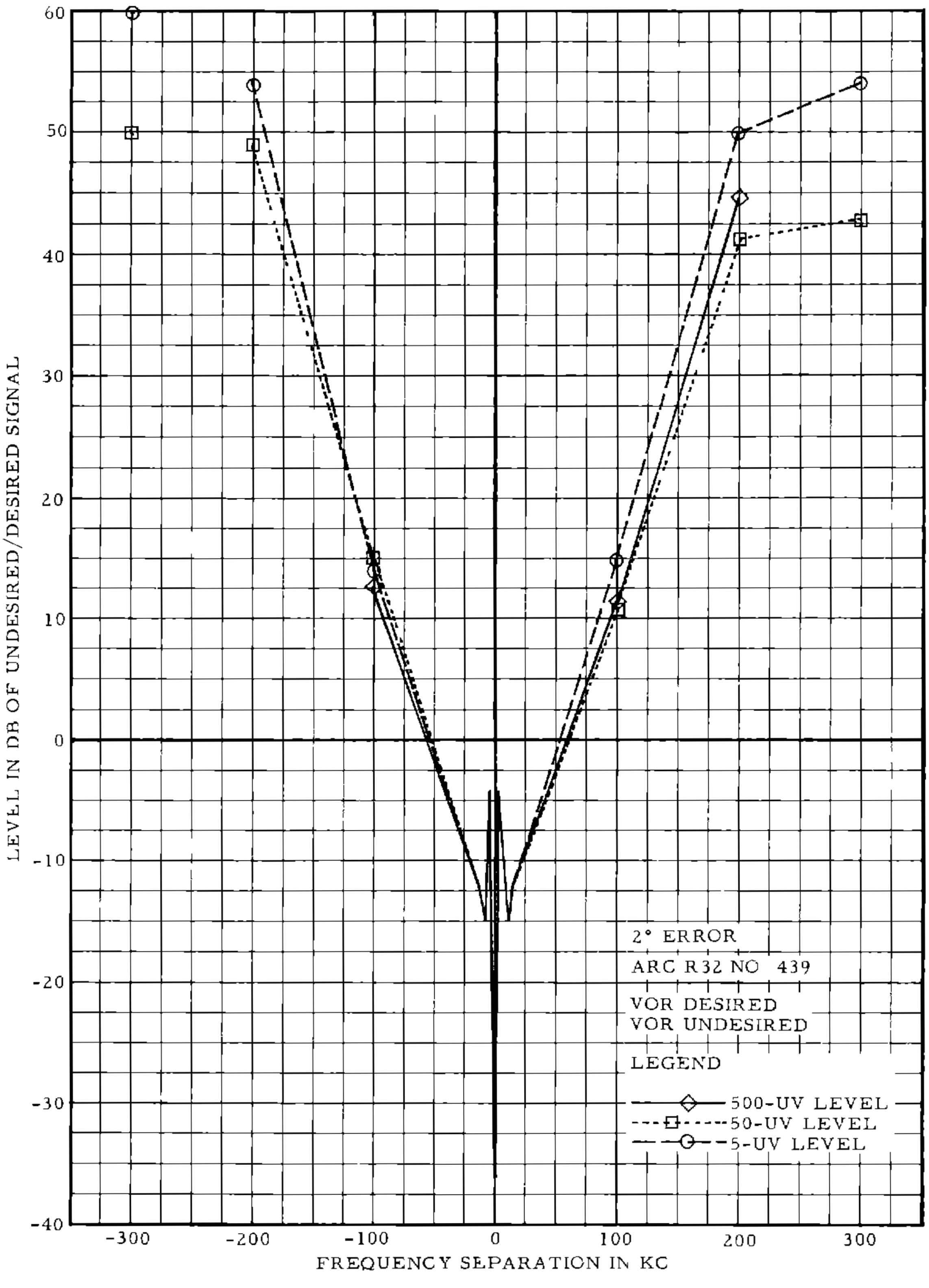

FIG 11 2° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR ARC RECEIVER

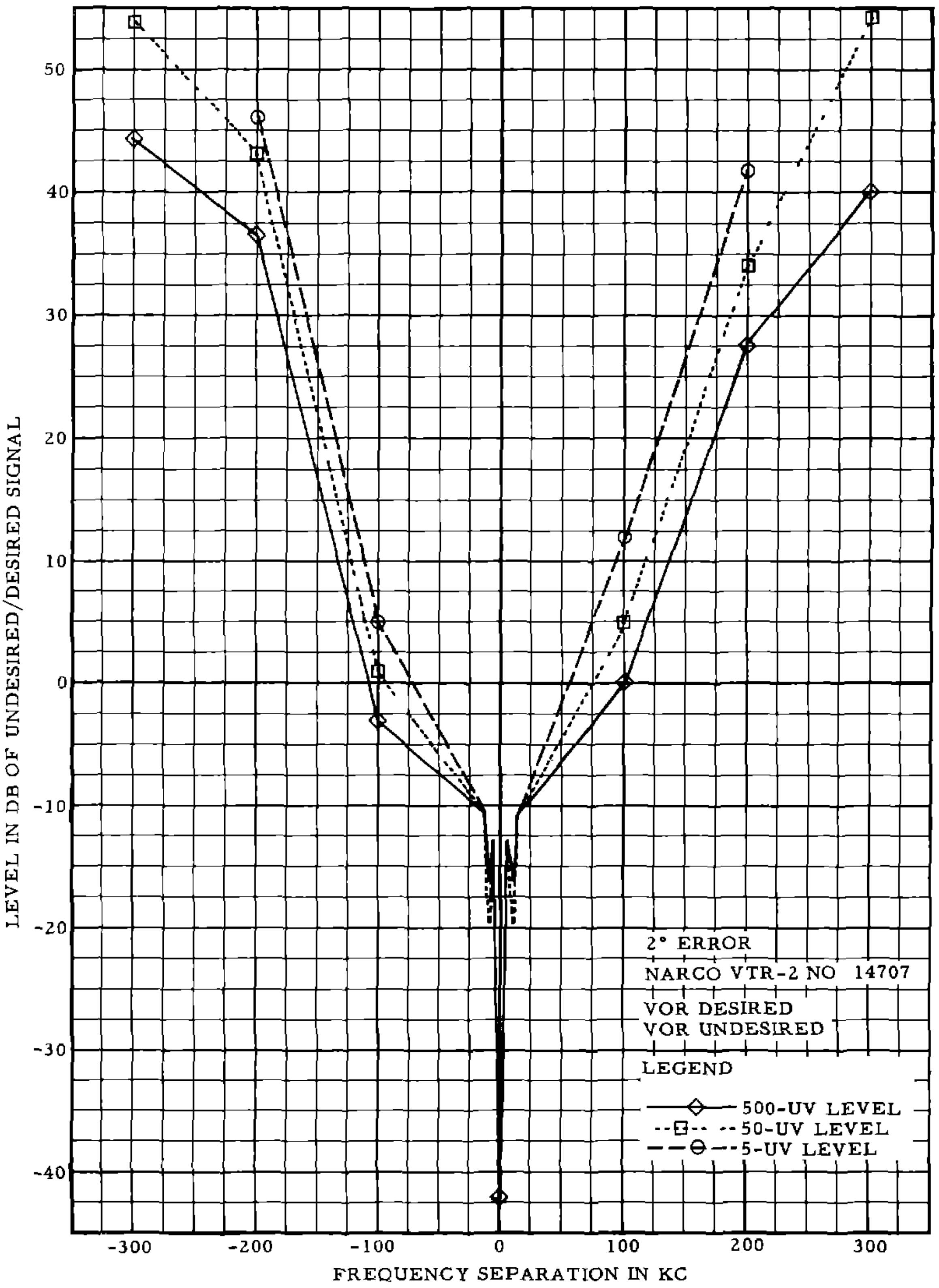

FIG 12 2° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR NARCO RECEIVER

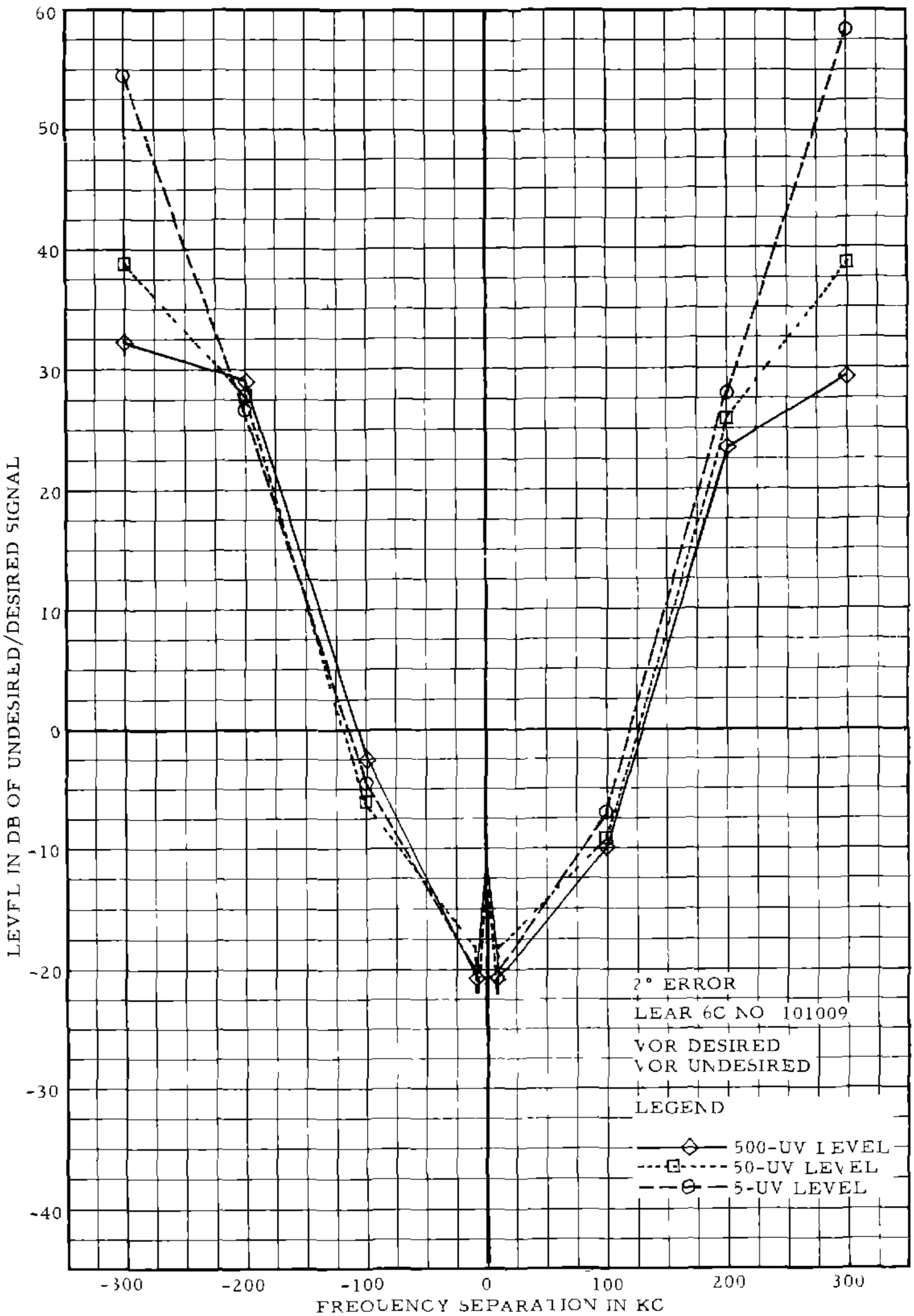

FIG 13 2° ERROR INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR LEAR RECEIVER

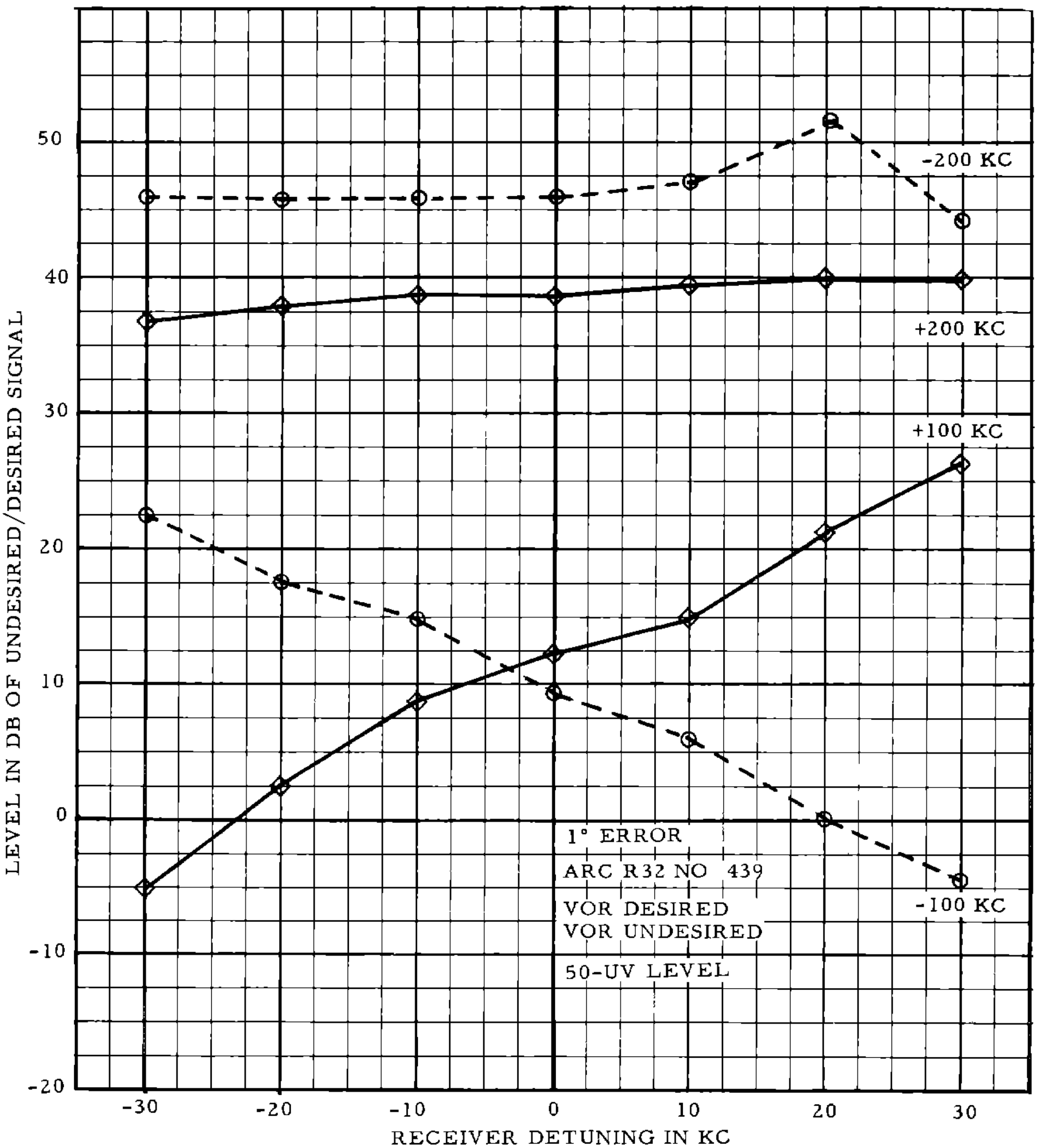

FIG 14 1° ERROR INTERFERENCE VERSUS ARC RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

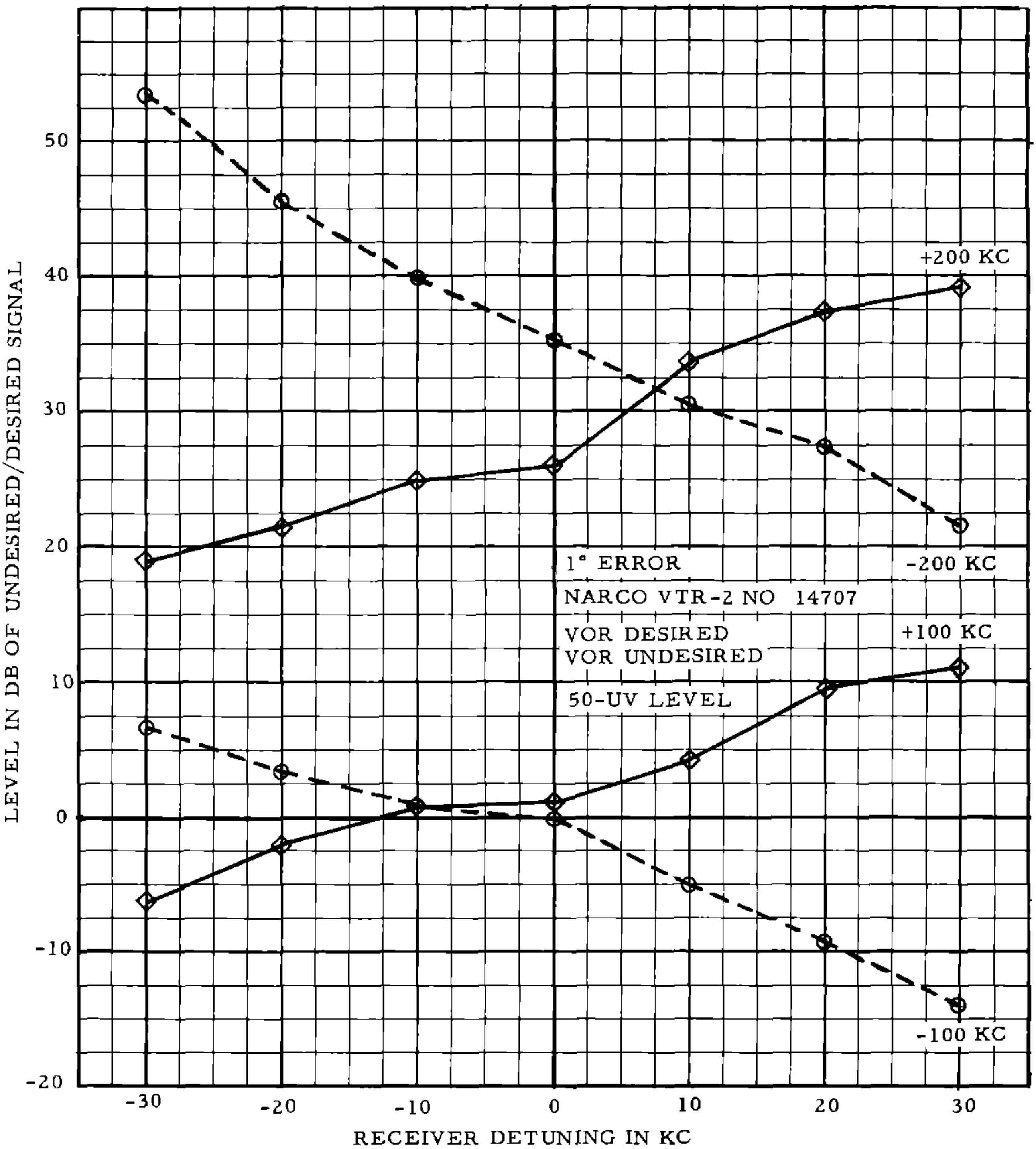

FIG 15 1° ERROR INTERFERENCE VERSUS NARCO RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

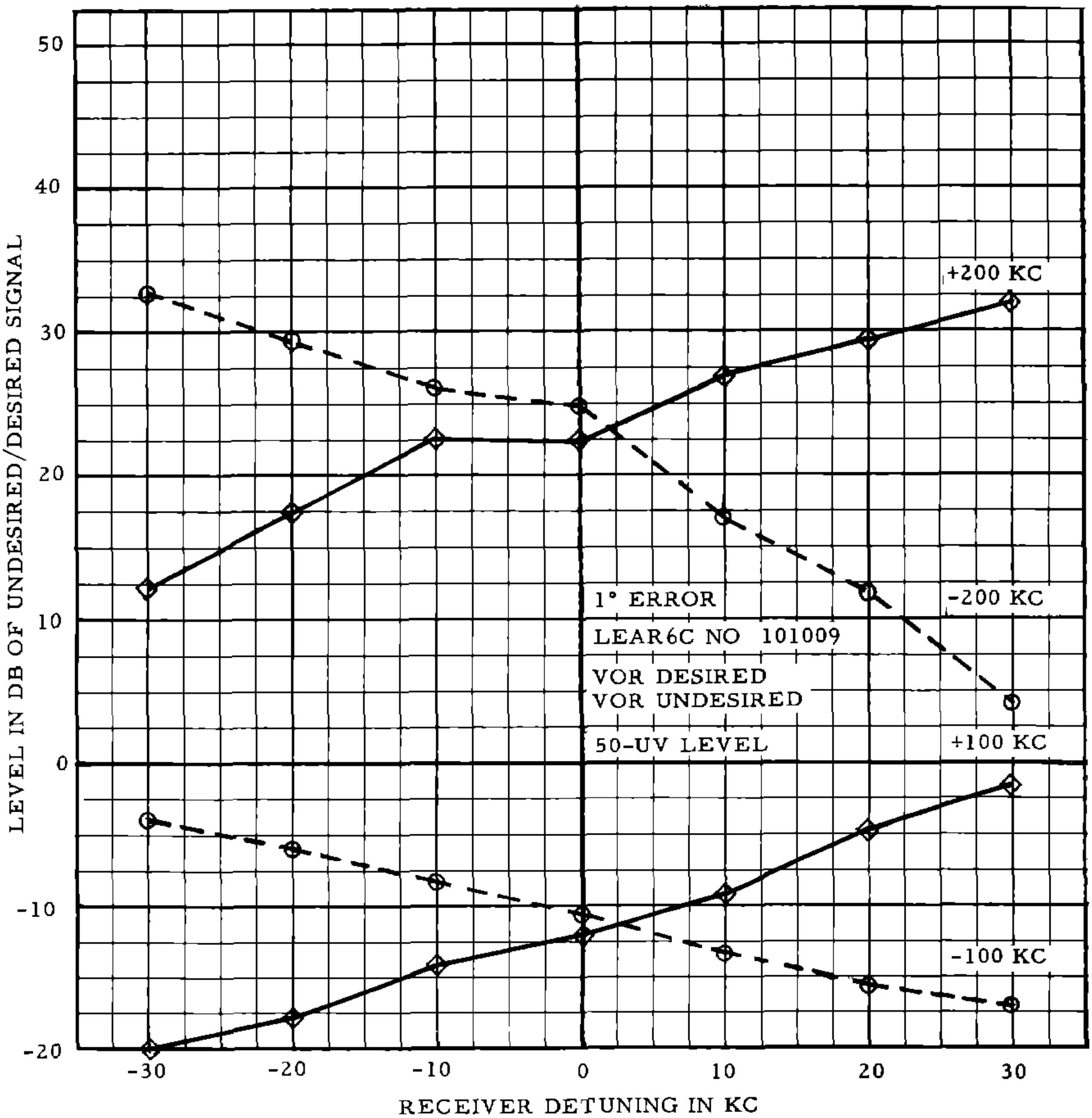

FIG 16 1° ERROR INTERFERENCE VERSUS LEAR RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

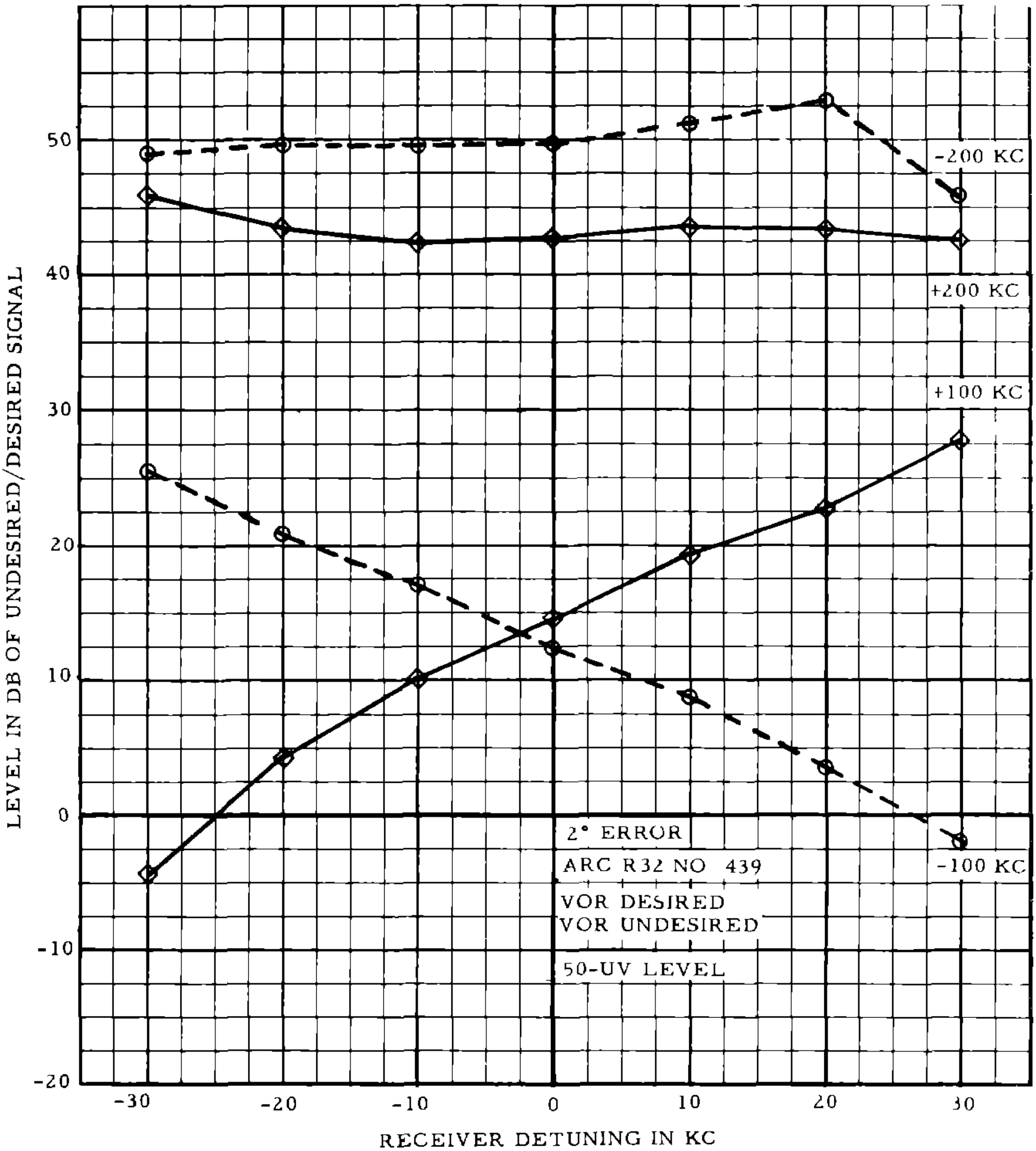

FIG 17 2° ERROR INTERFERENCE VERSUS ARC RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

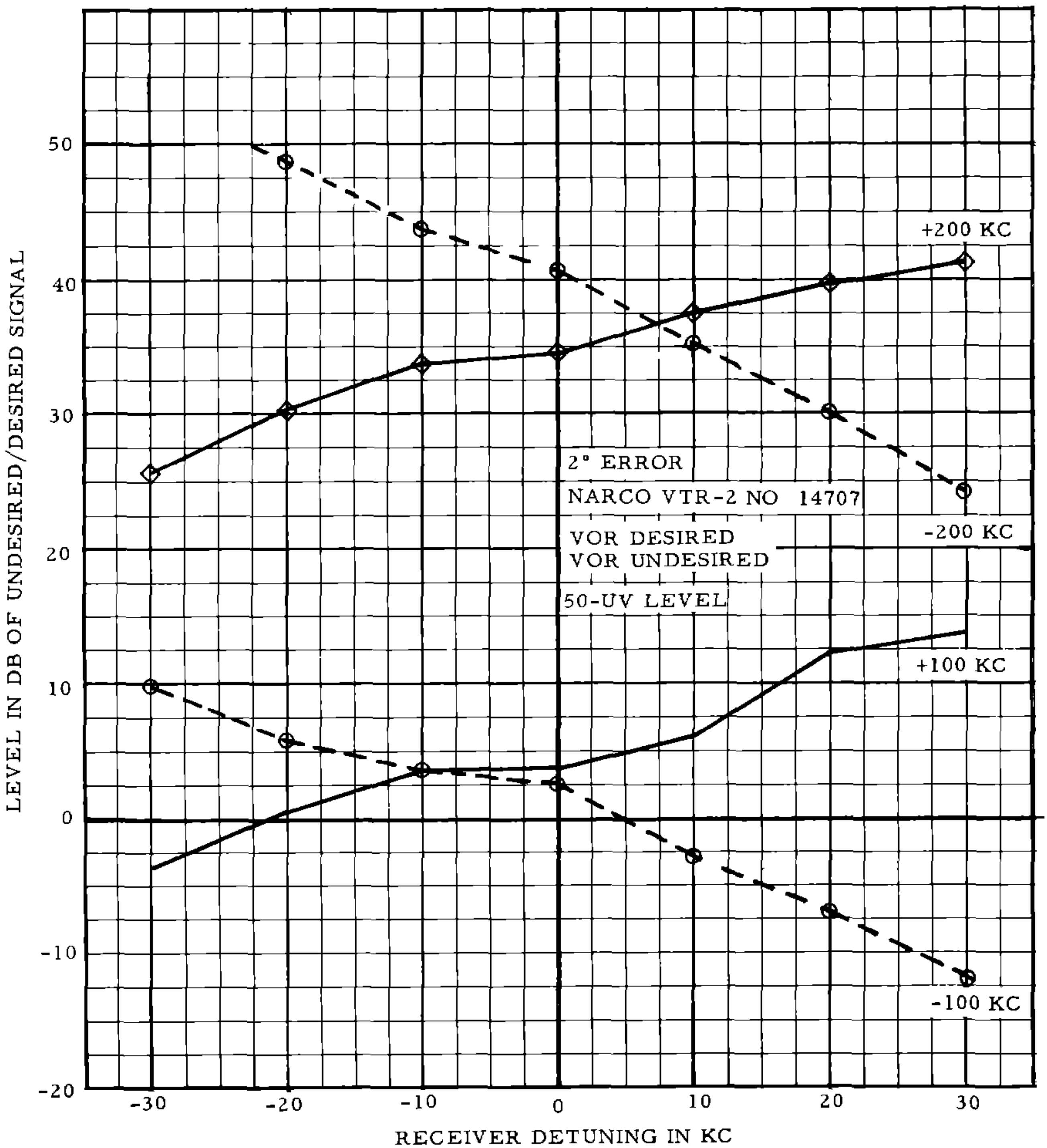

FIG. 18 2° ERROR INTERFERENCE VERSUS NARCO RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

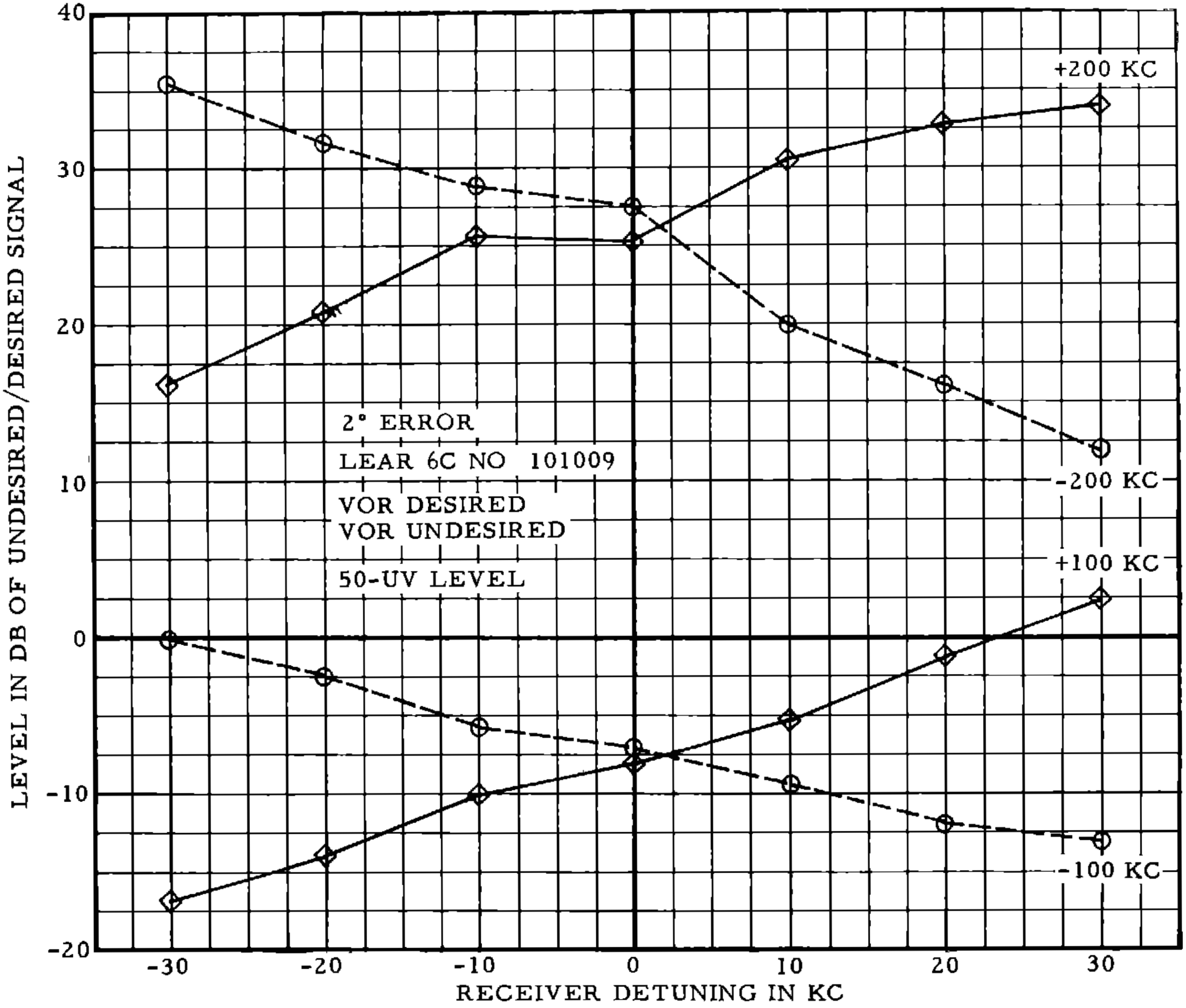

FIG. 19 2° ERROR INTERFERENCE VERSUS LEAR RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

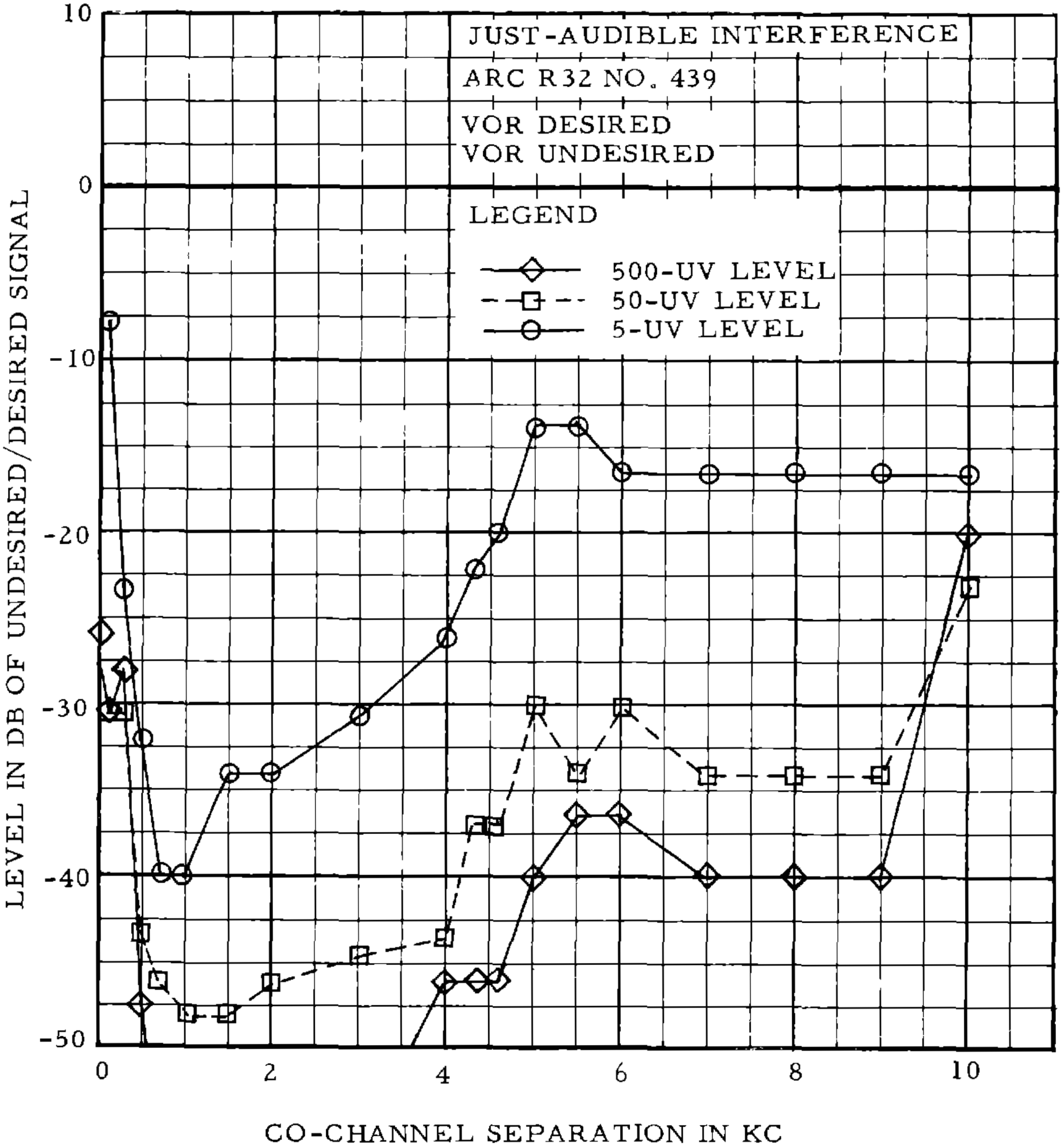

FIG. 20 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 10 KC) FOR ARC RECEIVER

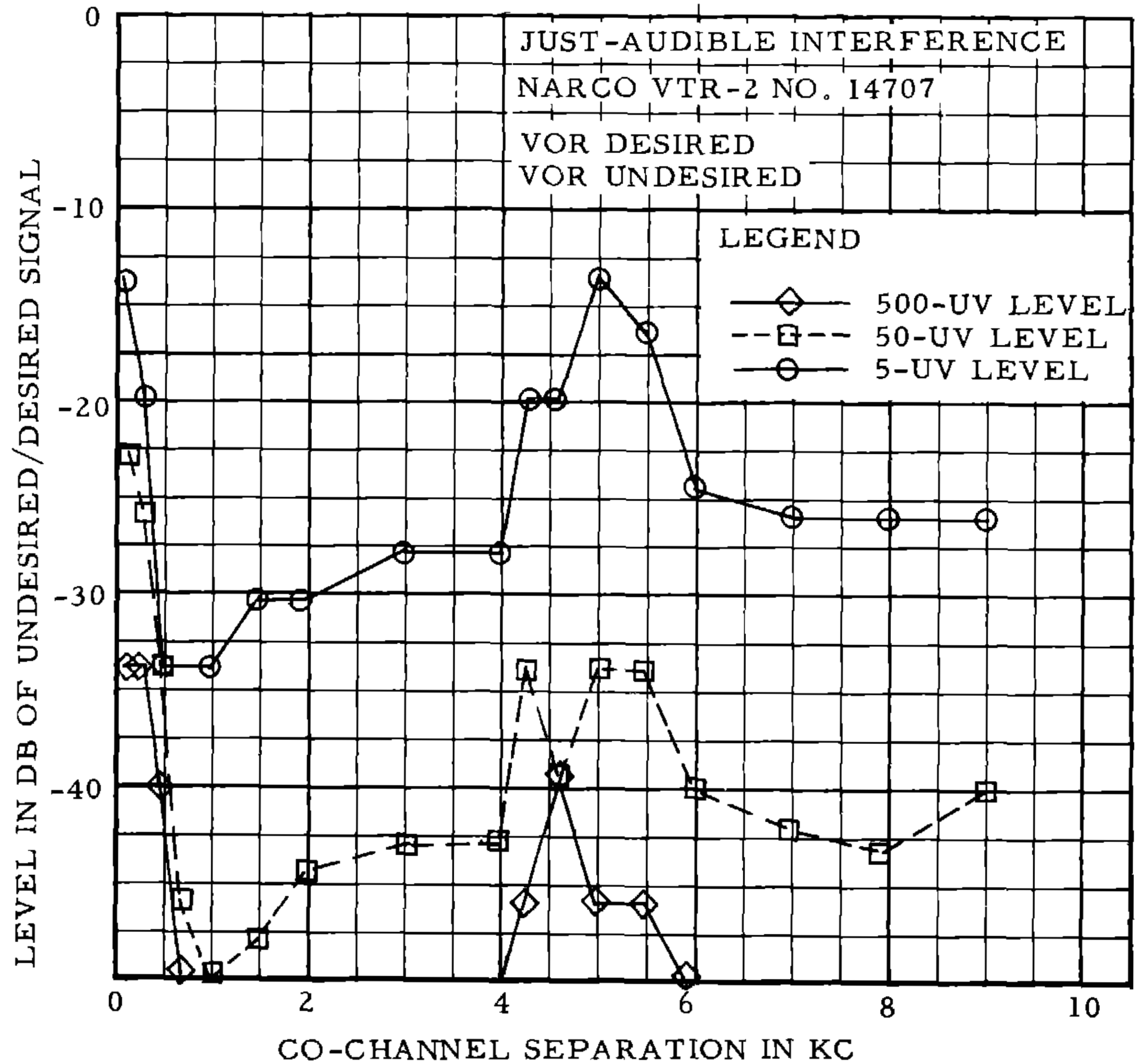

FIG. 21 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR NARCO RECEIVER - OBSERVER A

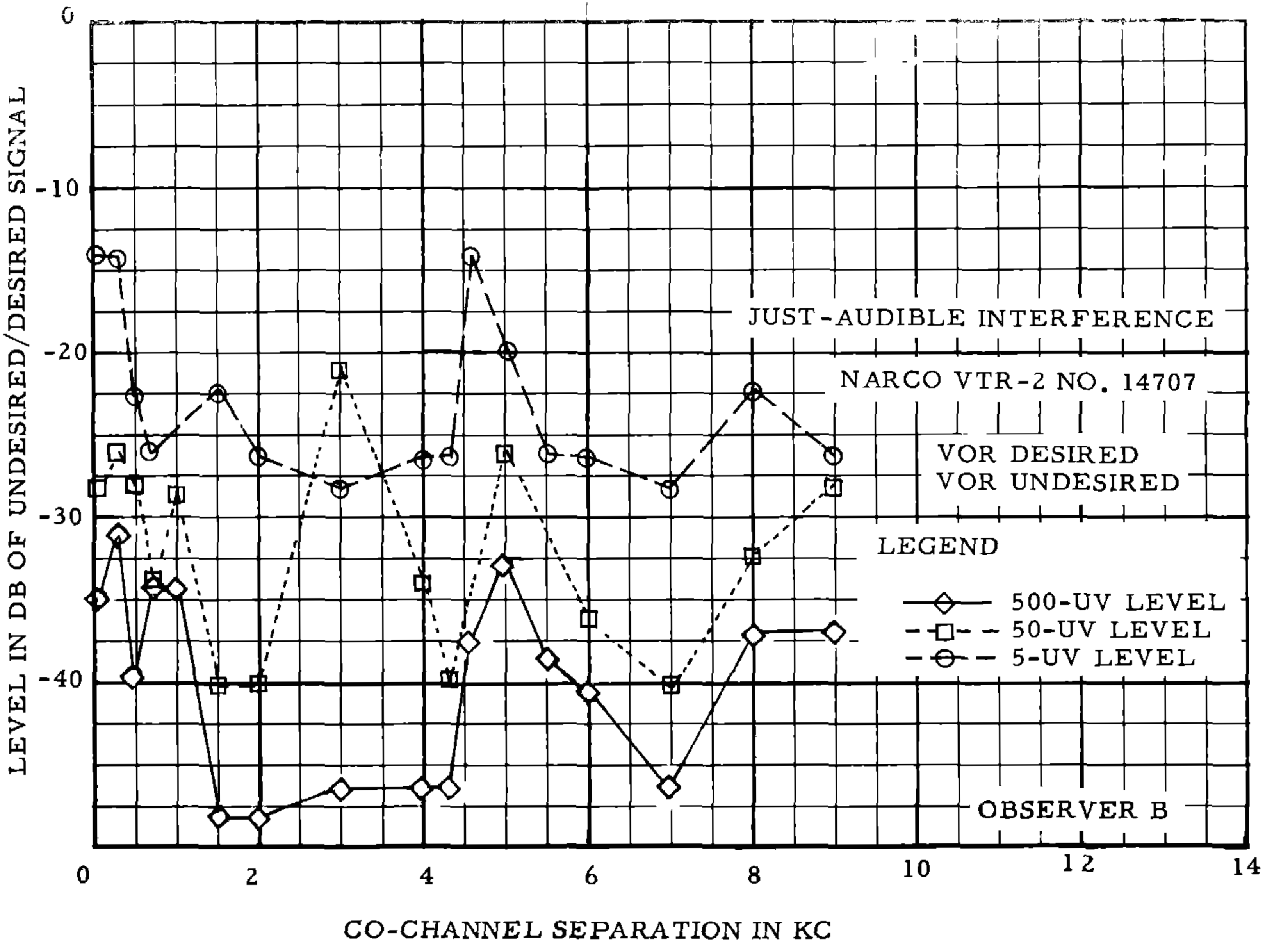

FIG. 22 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR NARCO RECEIVER - OBSERVER B

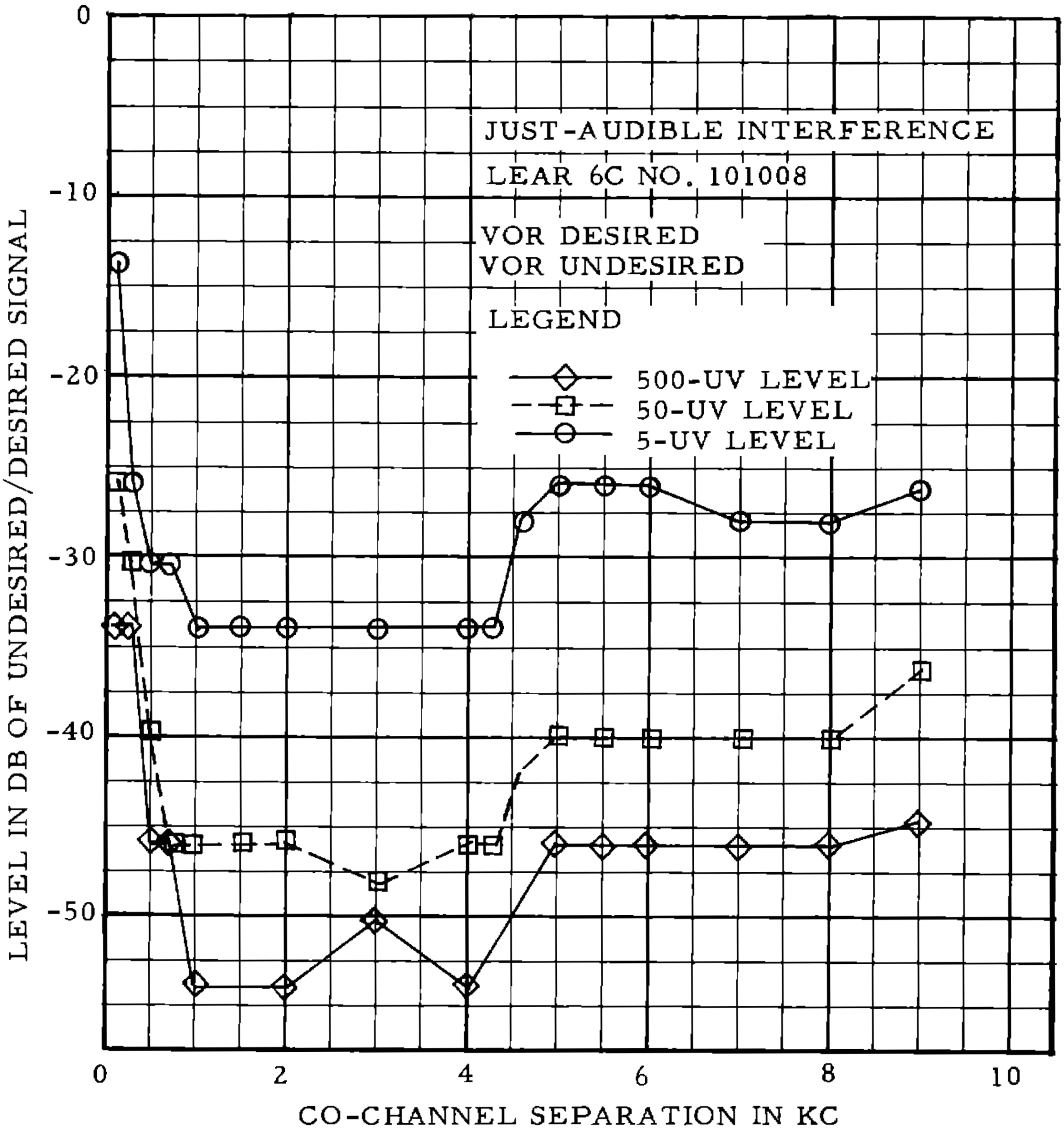

FIG. 23 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR LEAR RECEIVER

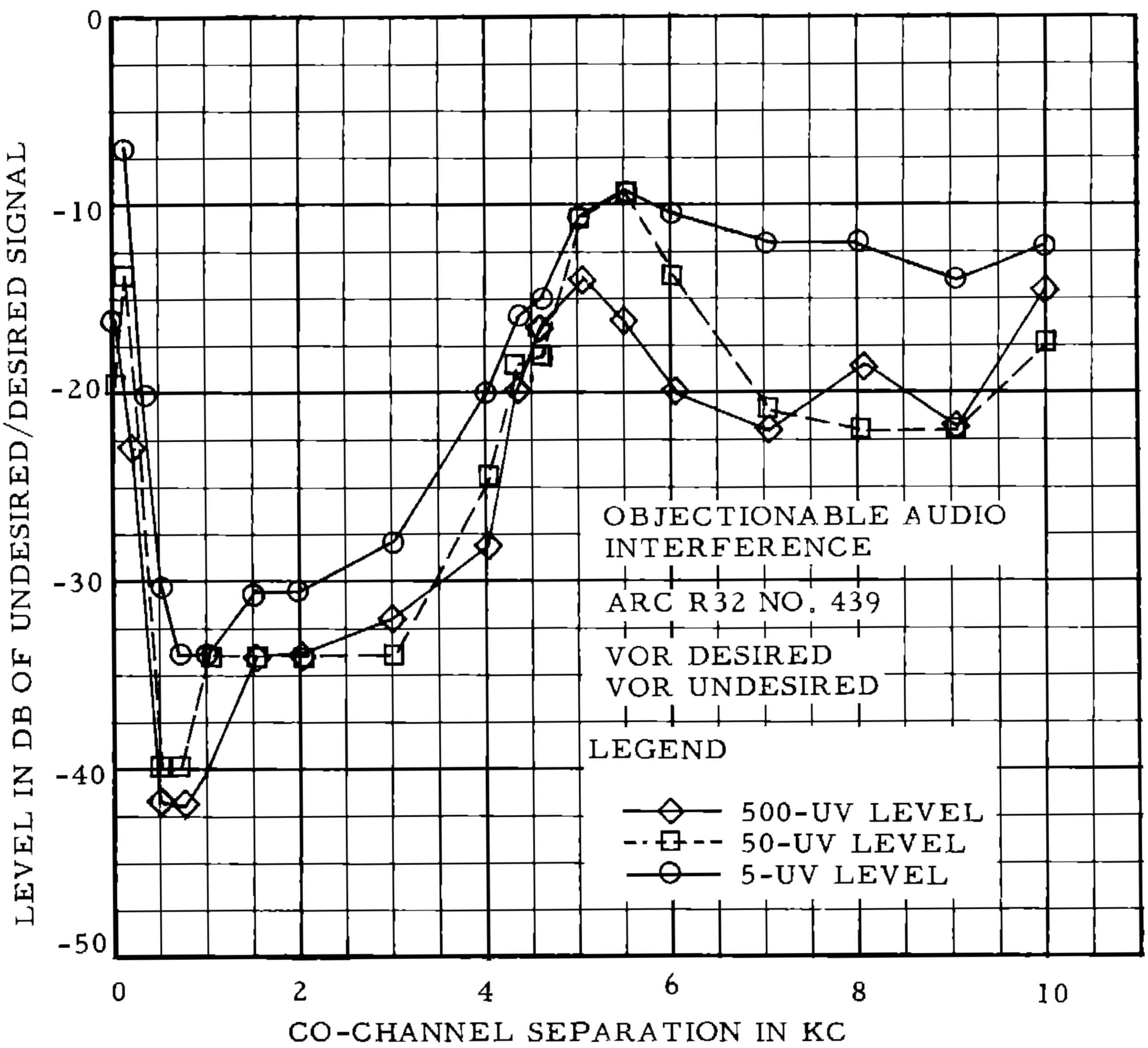

FIG. 24 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 10 KC) FOR ARC RECEIVER

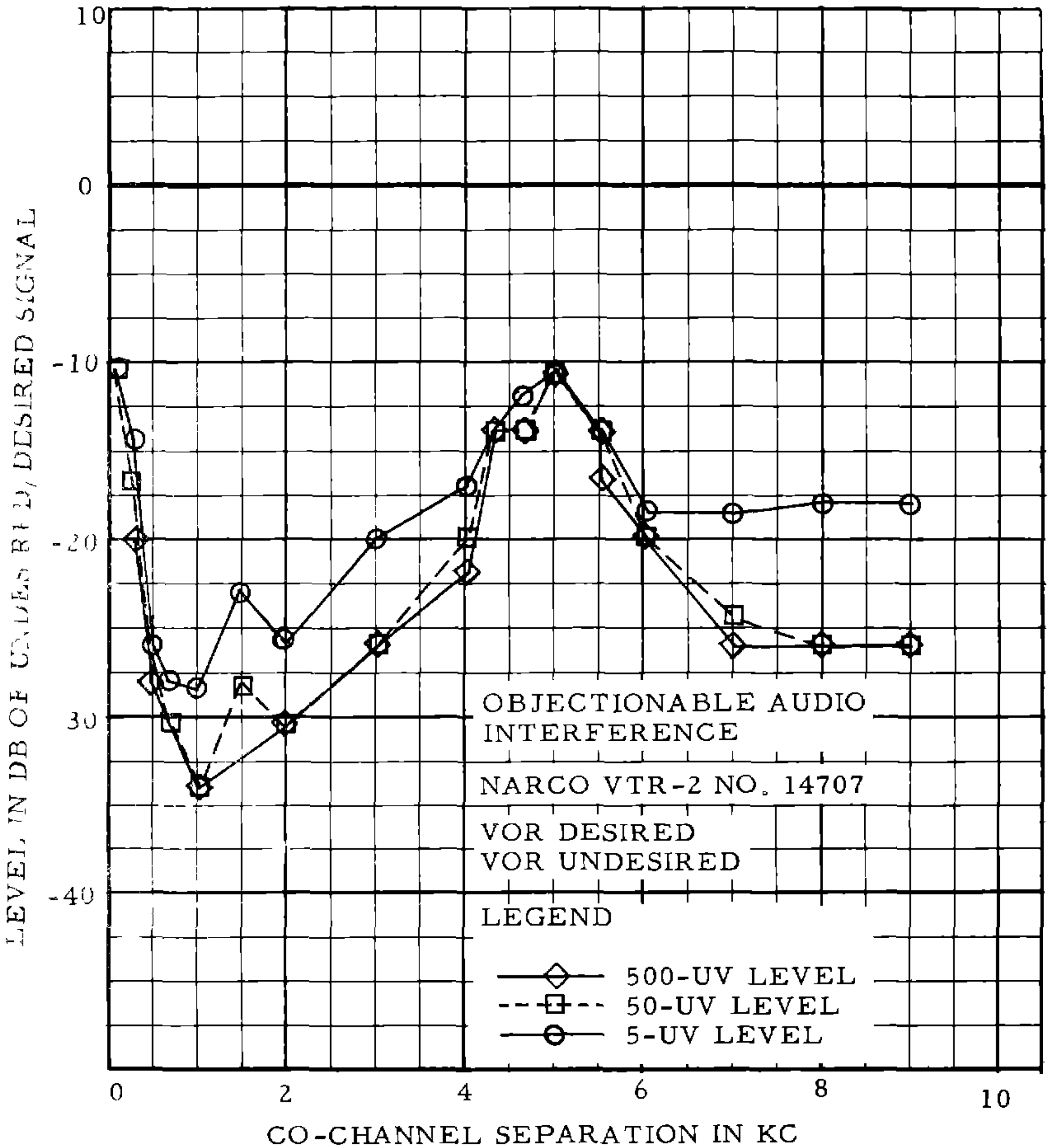

FIG. 25 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR NARCO RECEIVER - OBSERVER A

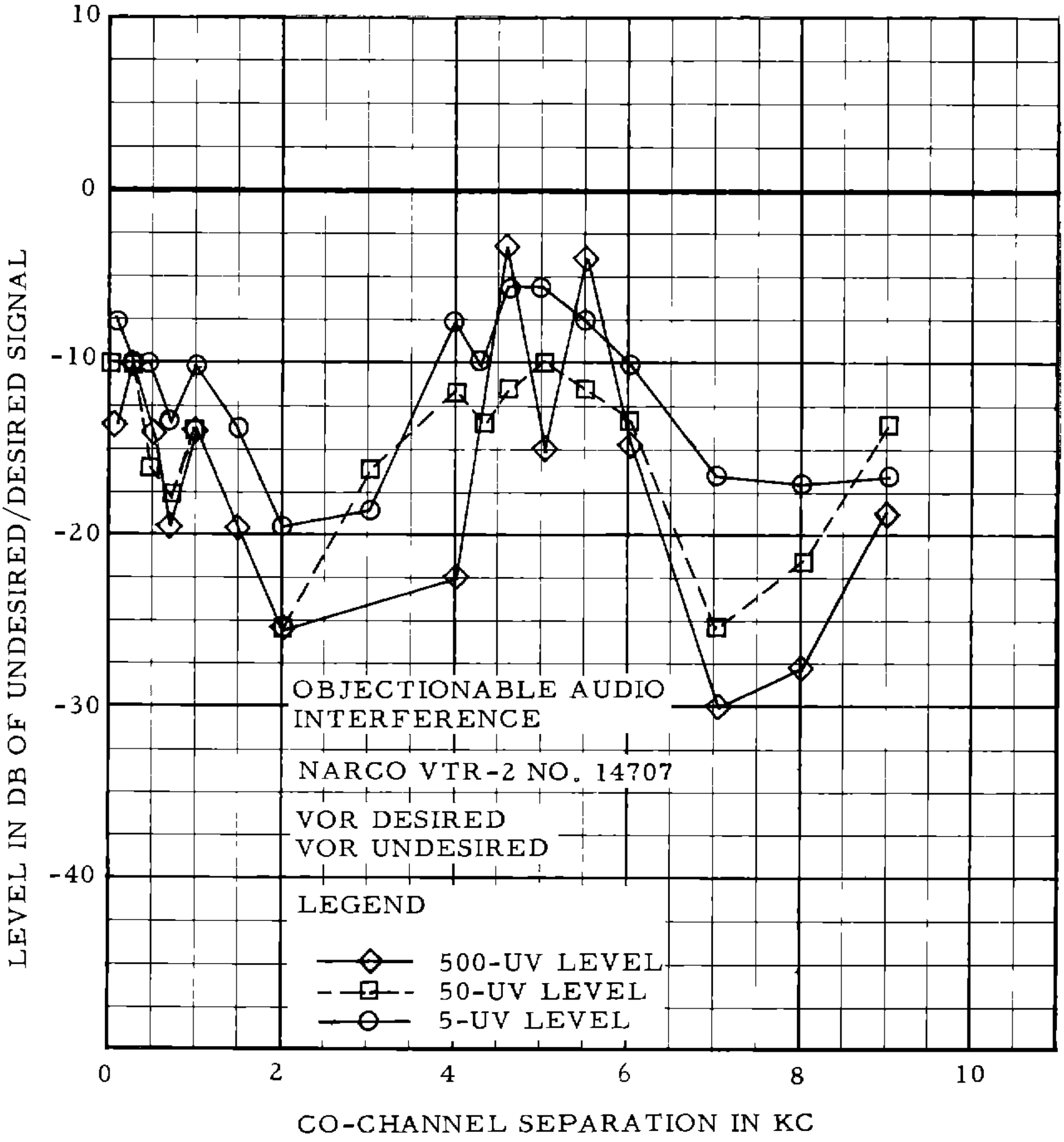

FIG 26 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR NARCO RECEIVER - OBSERVER B

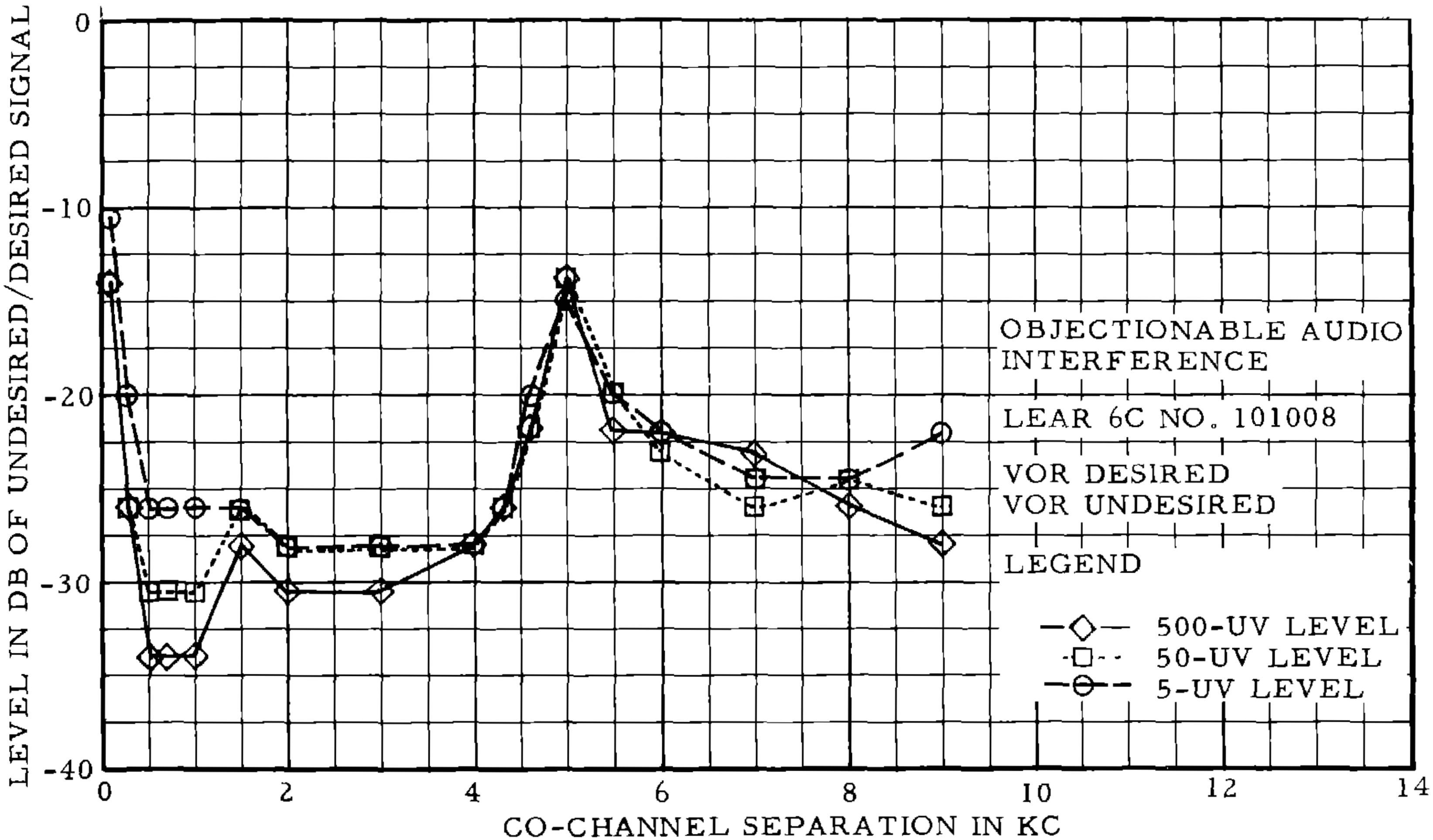

FIG. 27 OBJECTIONABLE AUDIO INTEREFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR LEAR RECEIVER

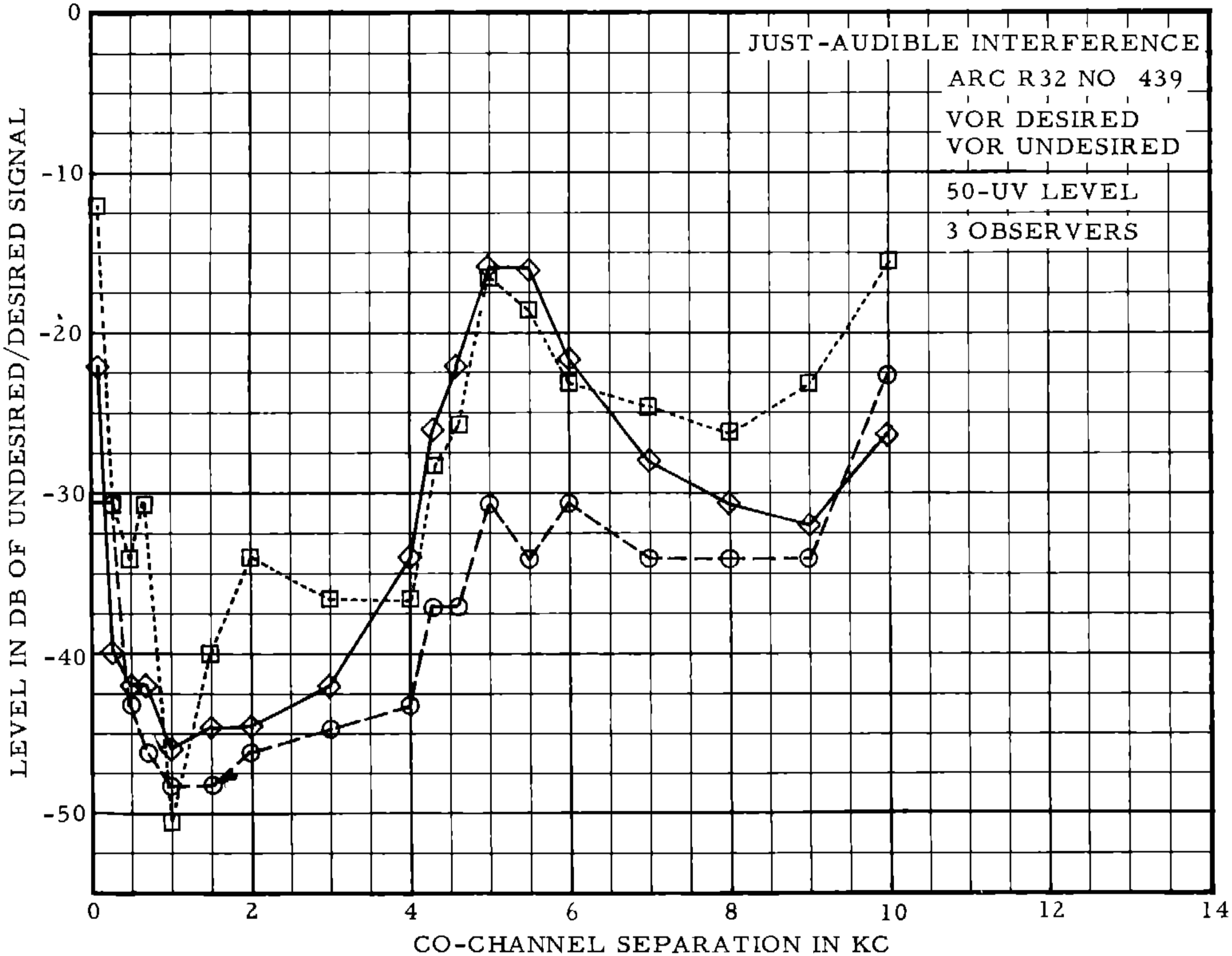

FIG. 28 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 10 KC) FOR ARC RECEIVER - THREE OBSERVERS

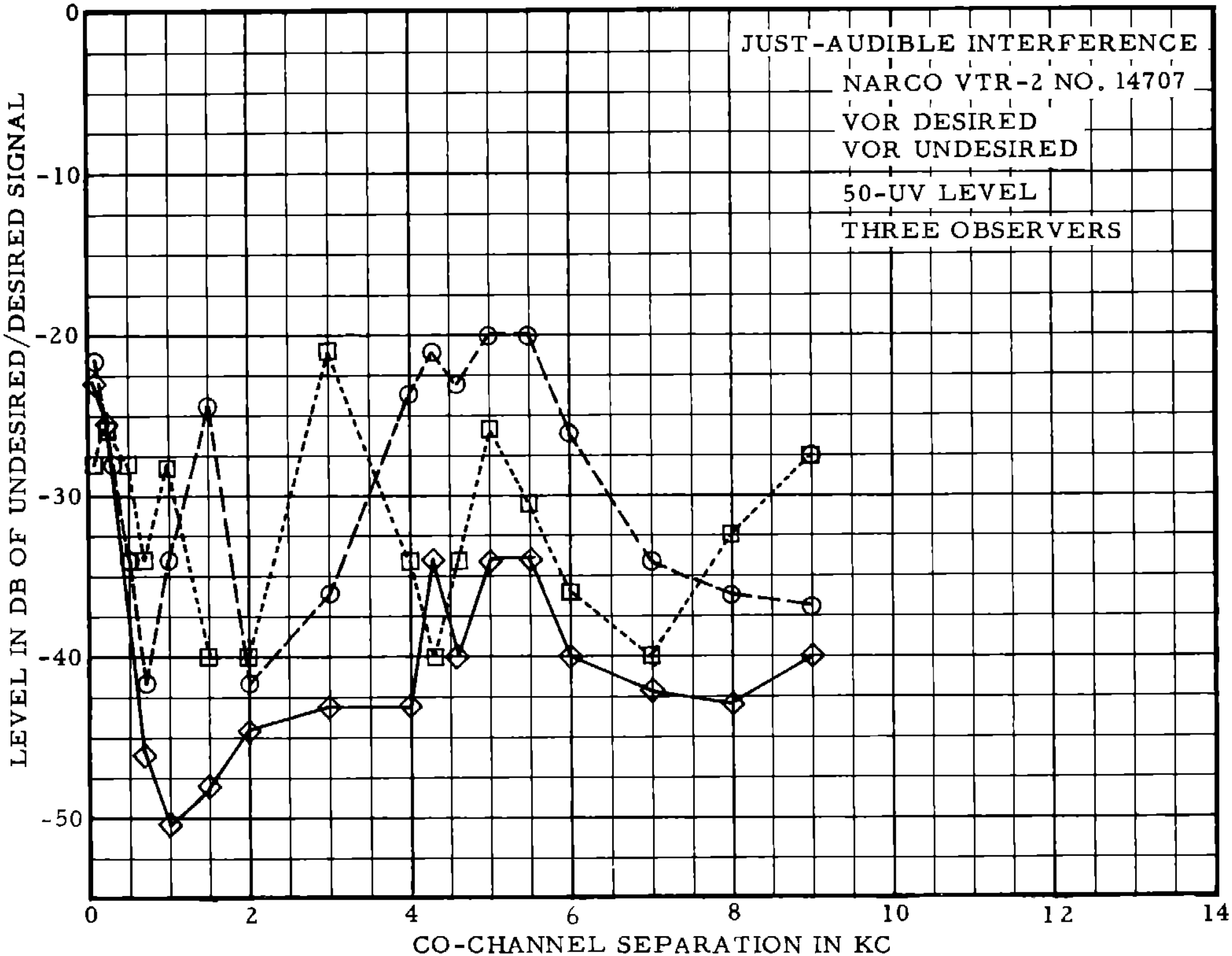

FIG. 29 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR NARCO RECEIVER - THREE OBSERVERS

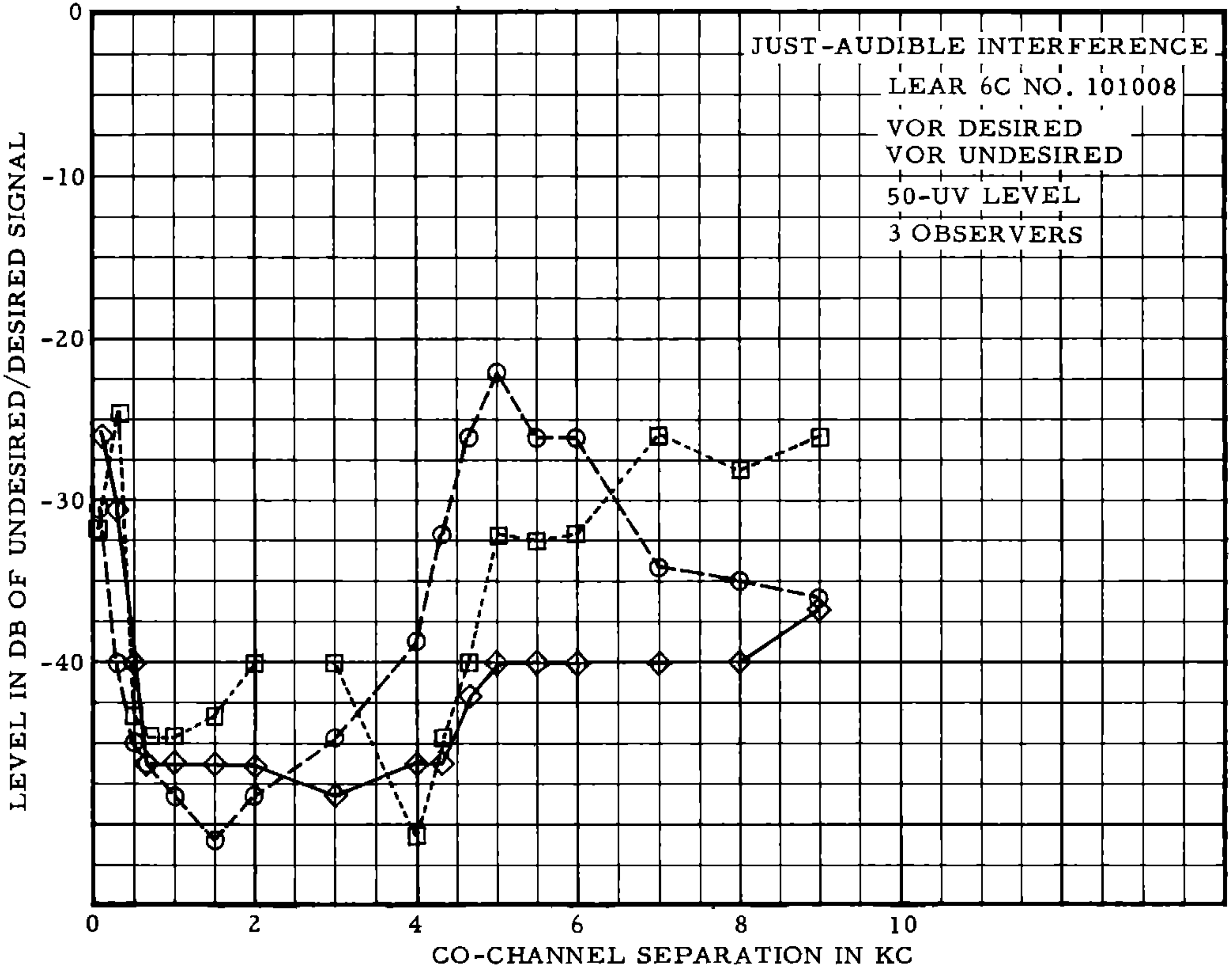

FIG. 30 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR LEAR RECEIVER - THREE OBSERVERS

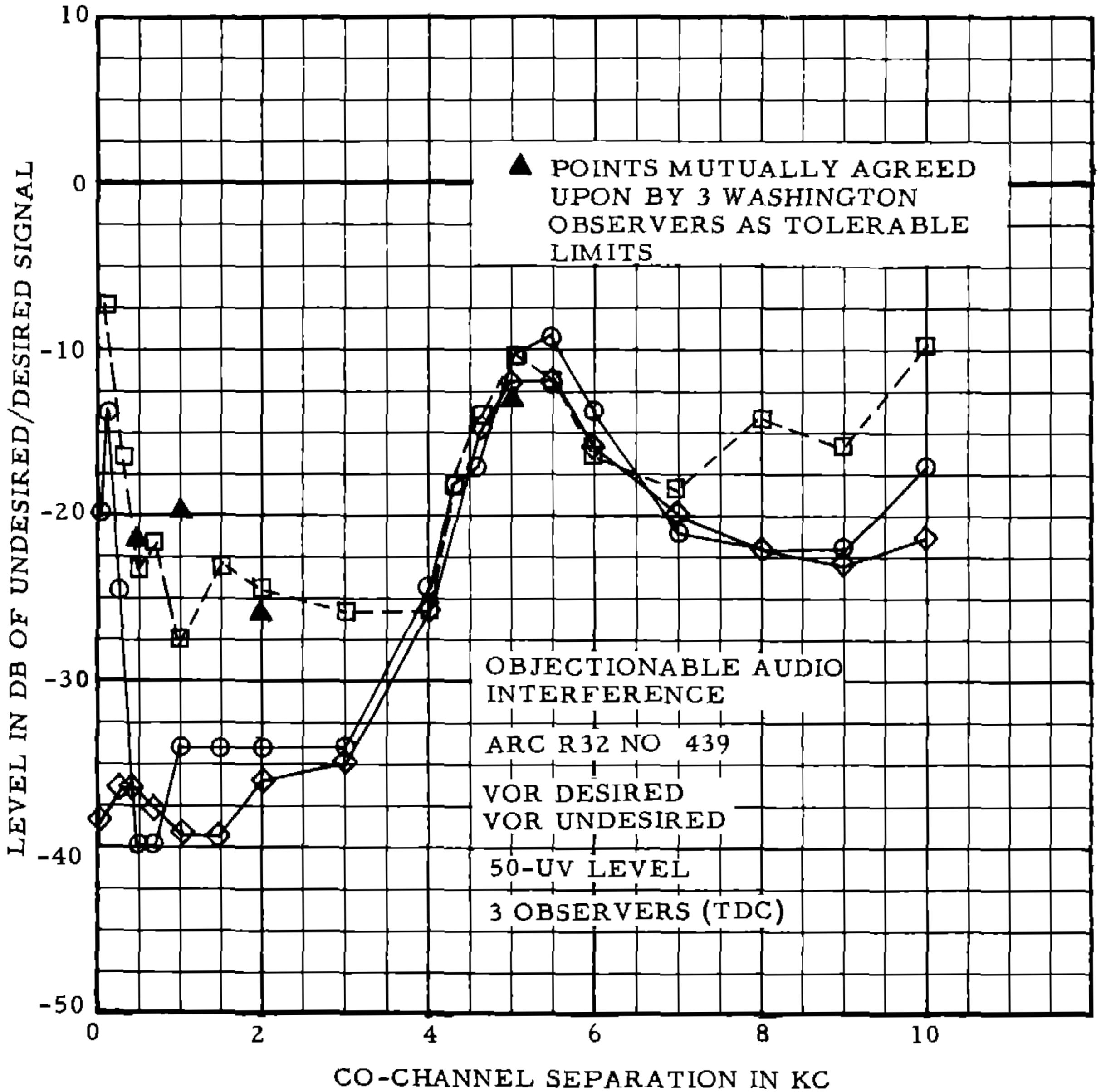

FIG. 31 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 10 KC) FOR ARC RECEIVER - SIX OBSERVERS

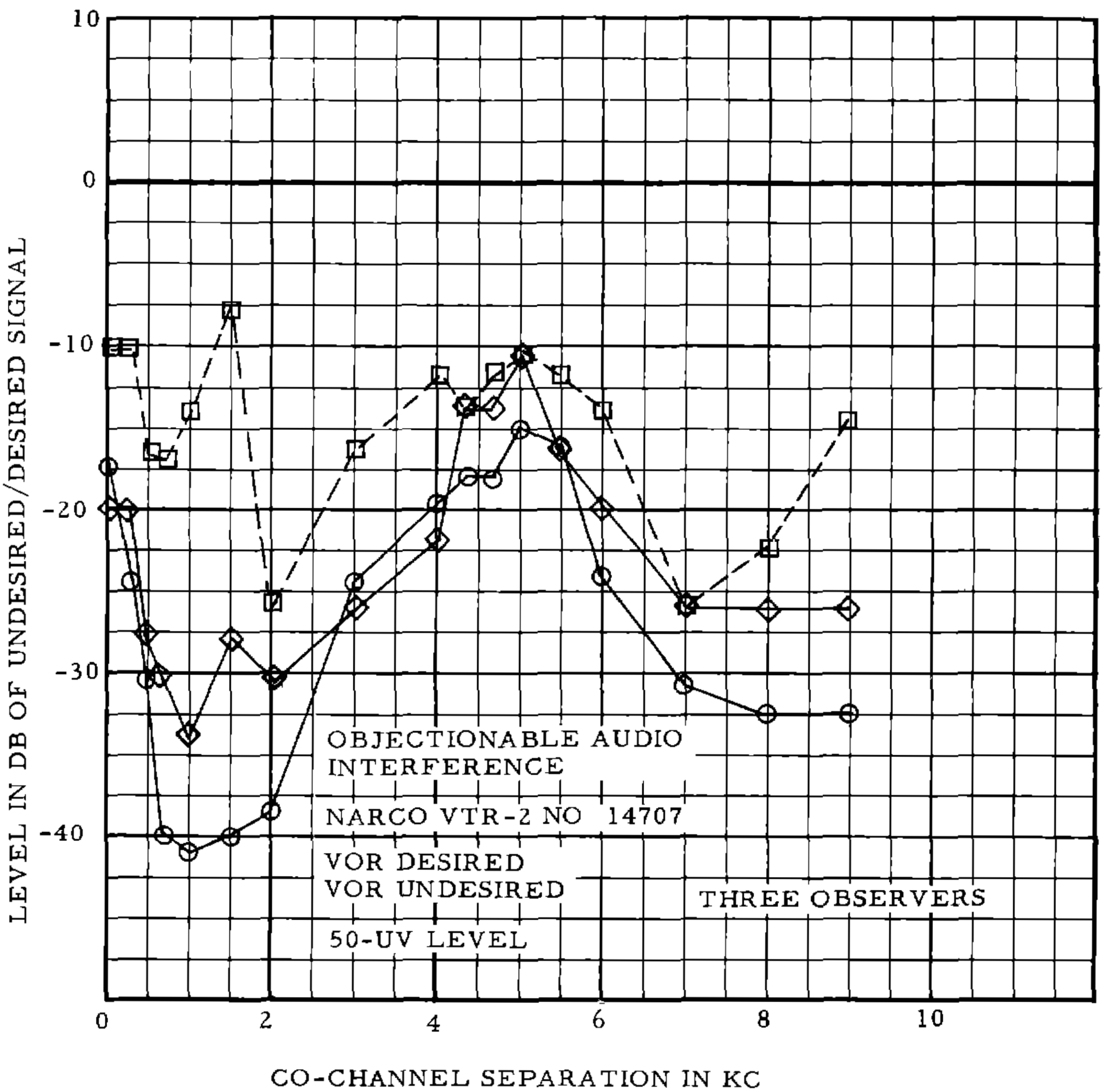

FIG 32 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 9 KC) FOR NARCO RECEIVER - THREE OBSERVERS

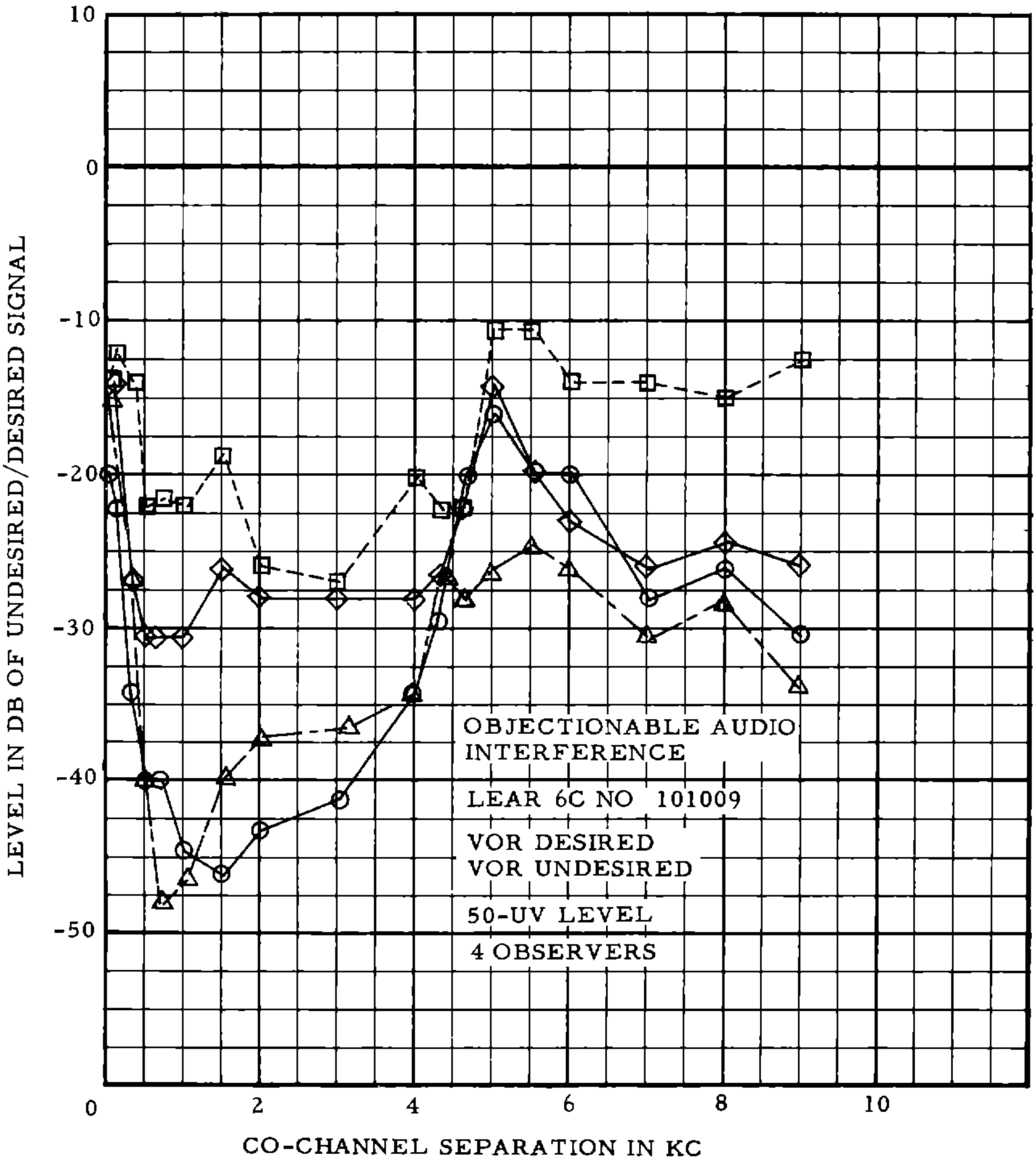

FIG 33 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR LEAR RECEIVER - FOUR OBSERVERS

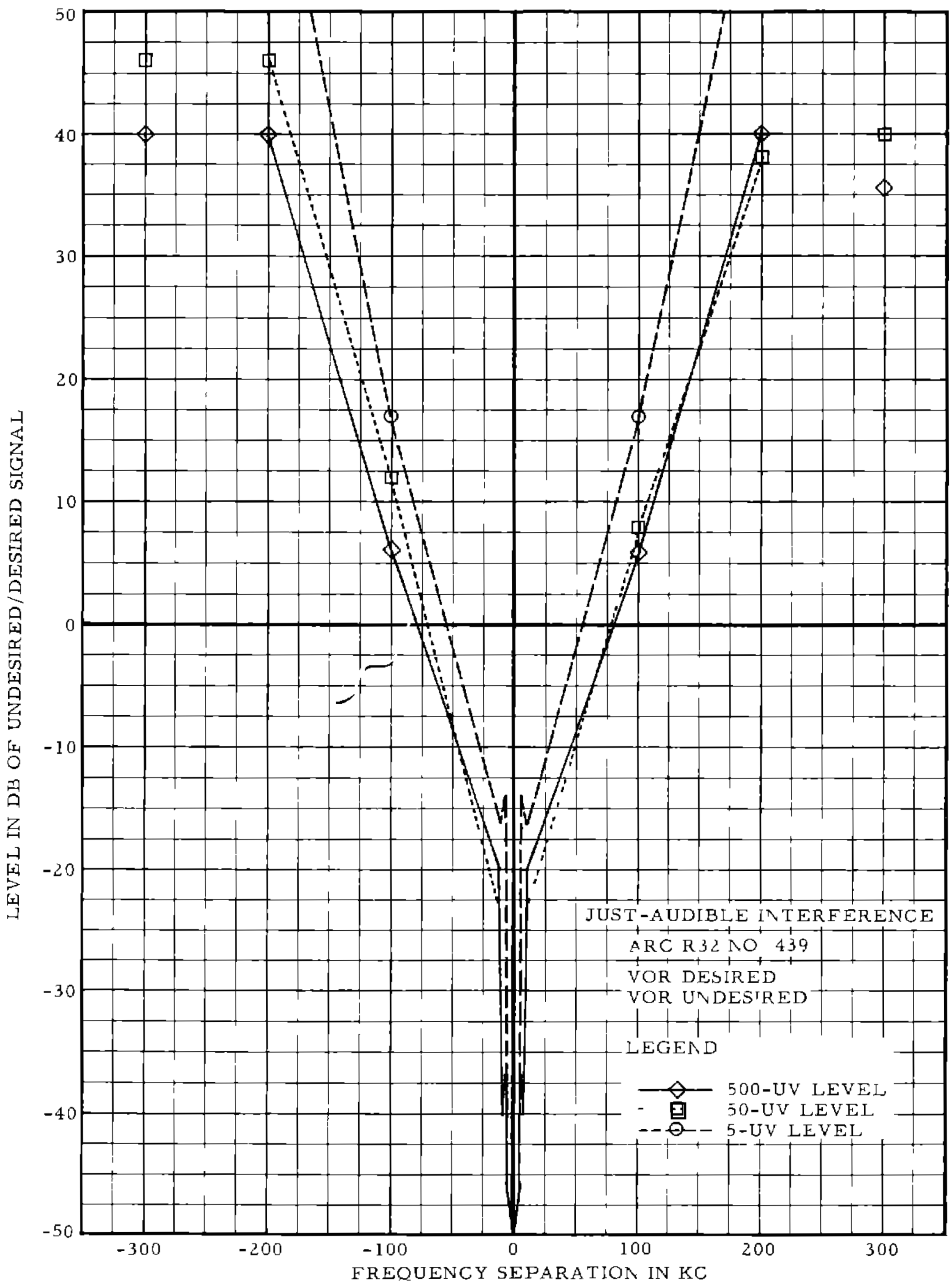

FIG 34 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR ARC RECEIVER

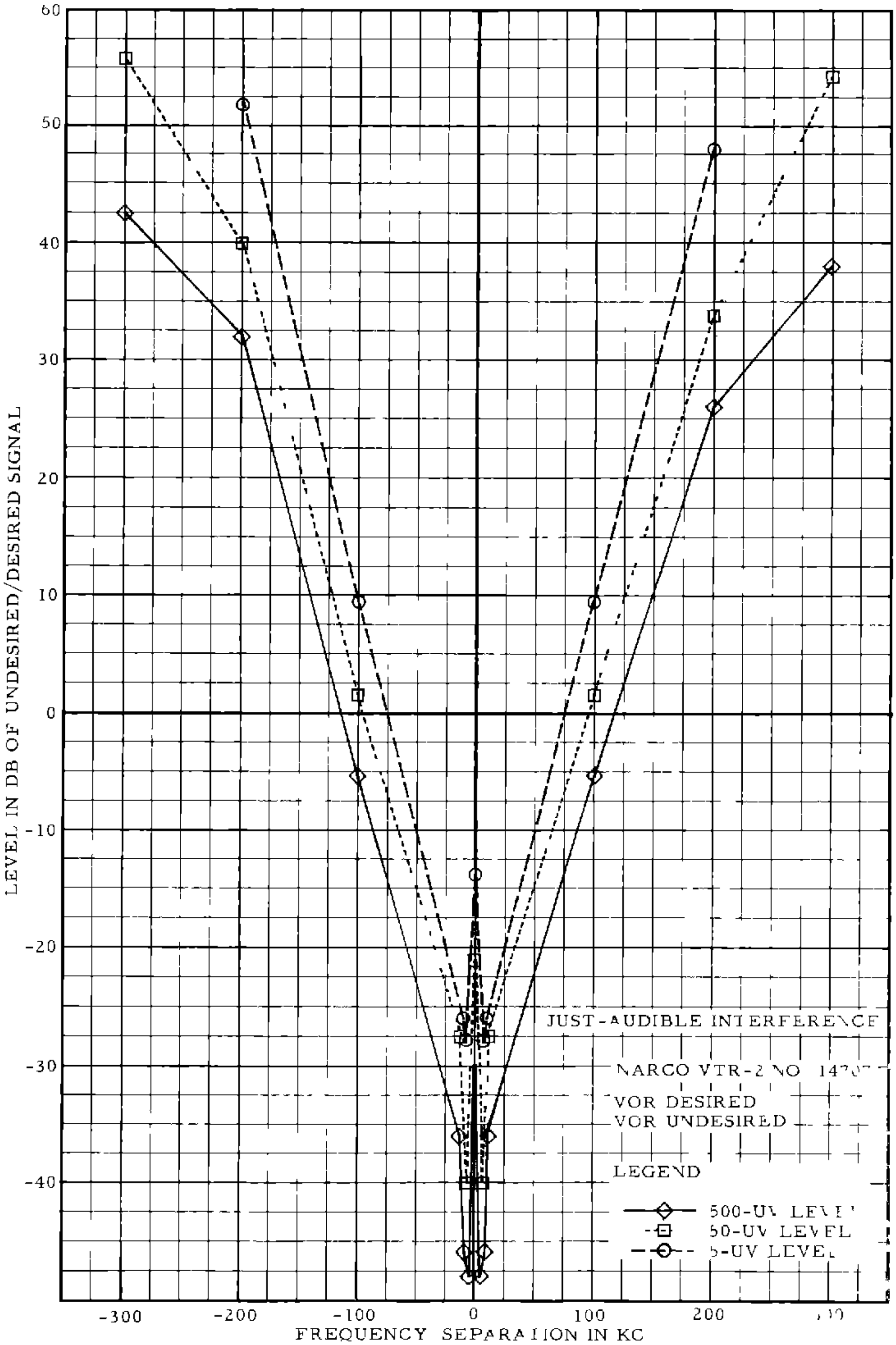

FIG 35 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR NARCO RECEIVER

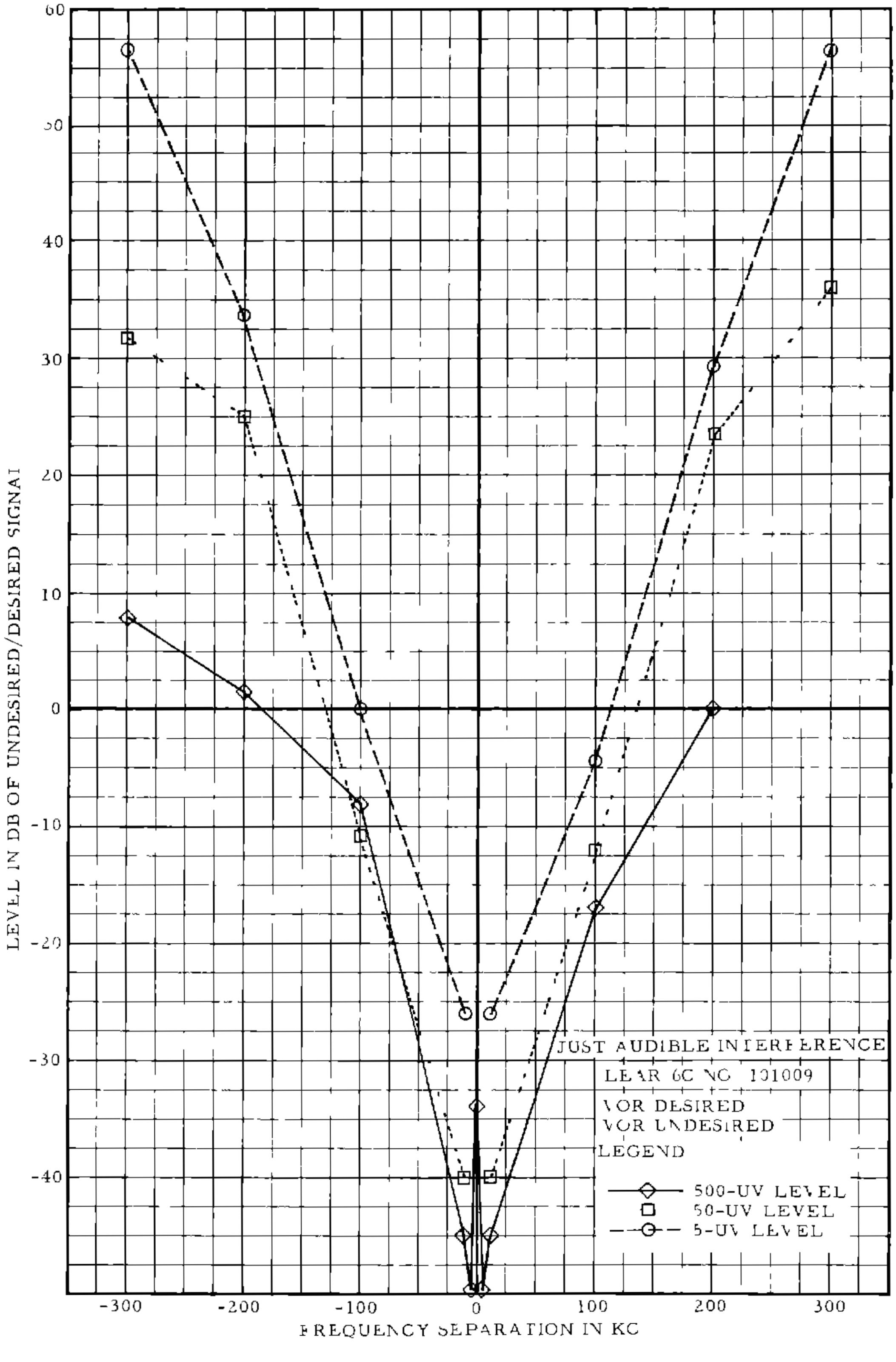

FIG 36 THRESHOLD AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR LEAR RECEIVER

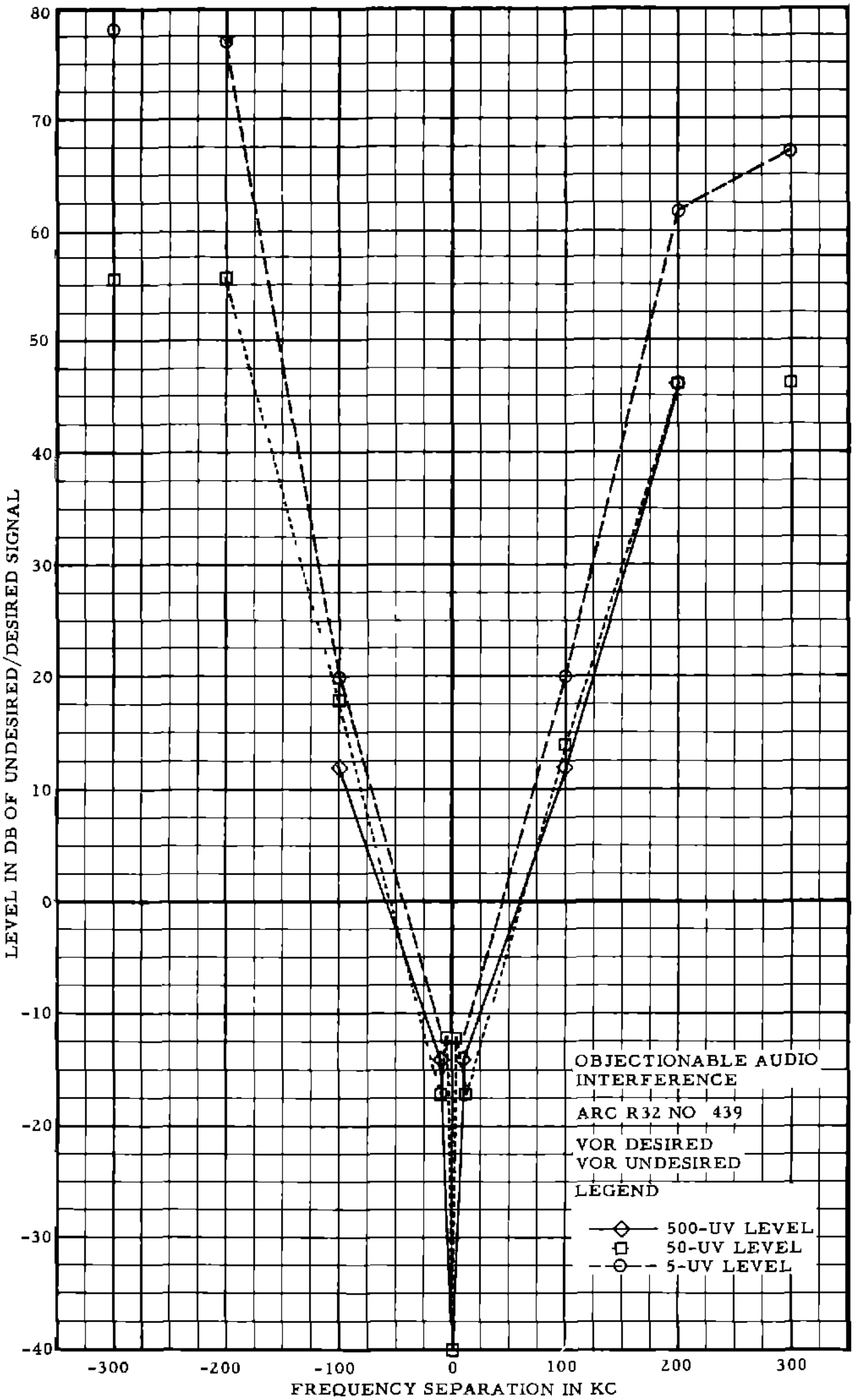

FIG 37 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR ARC RECEIVER

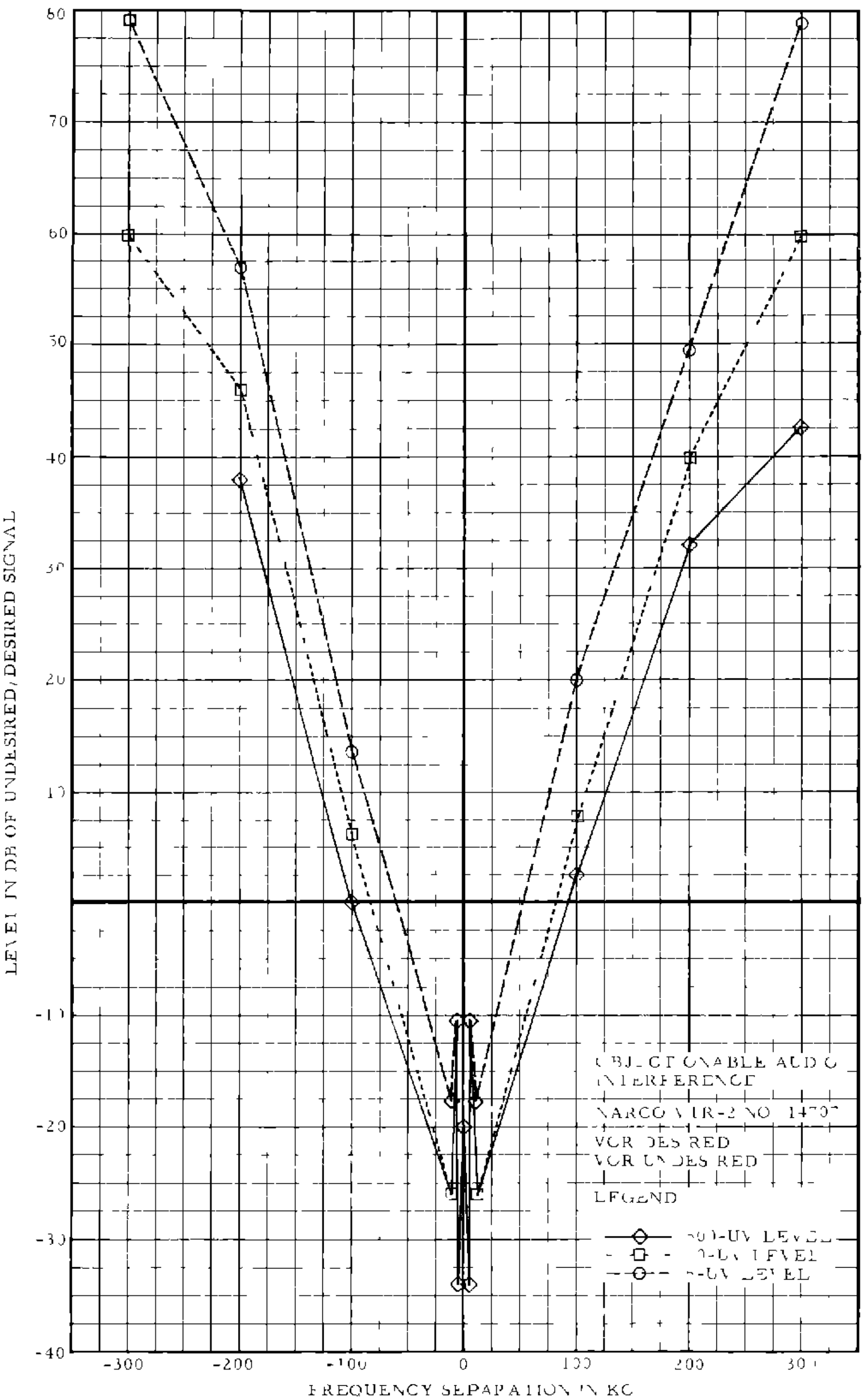

FIG. 38 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR NARCO RECEIVER

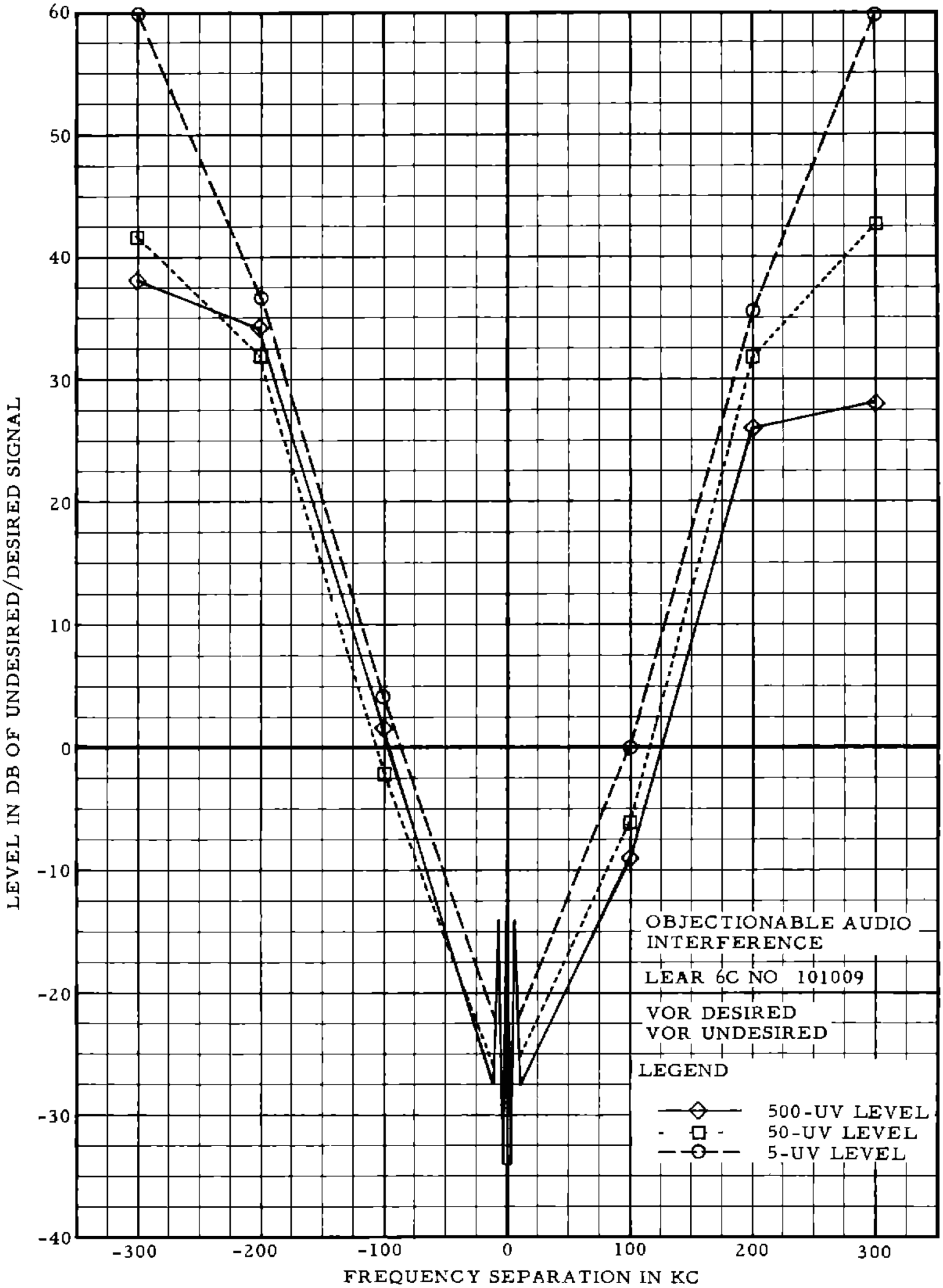

FIG 39 OBJECTIONABLE AUDIO INTERFERENCE VERSUS FREQUENCY SEPARATION (0 - 300 KC) FOR LEAR RECEIVER

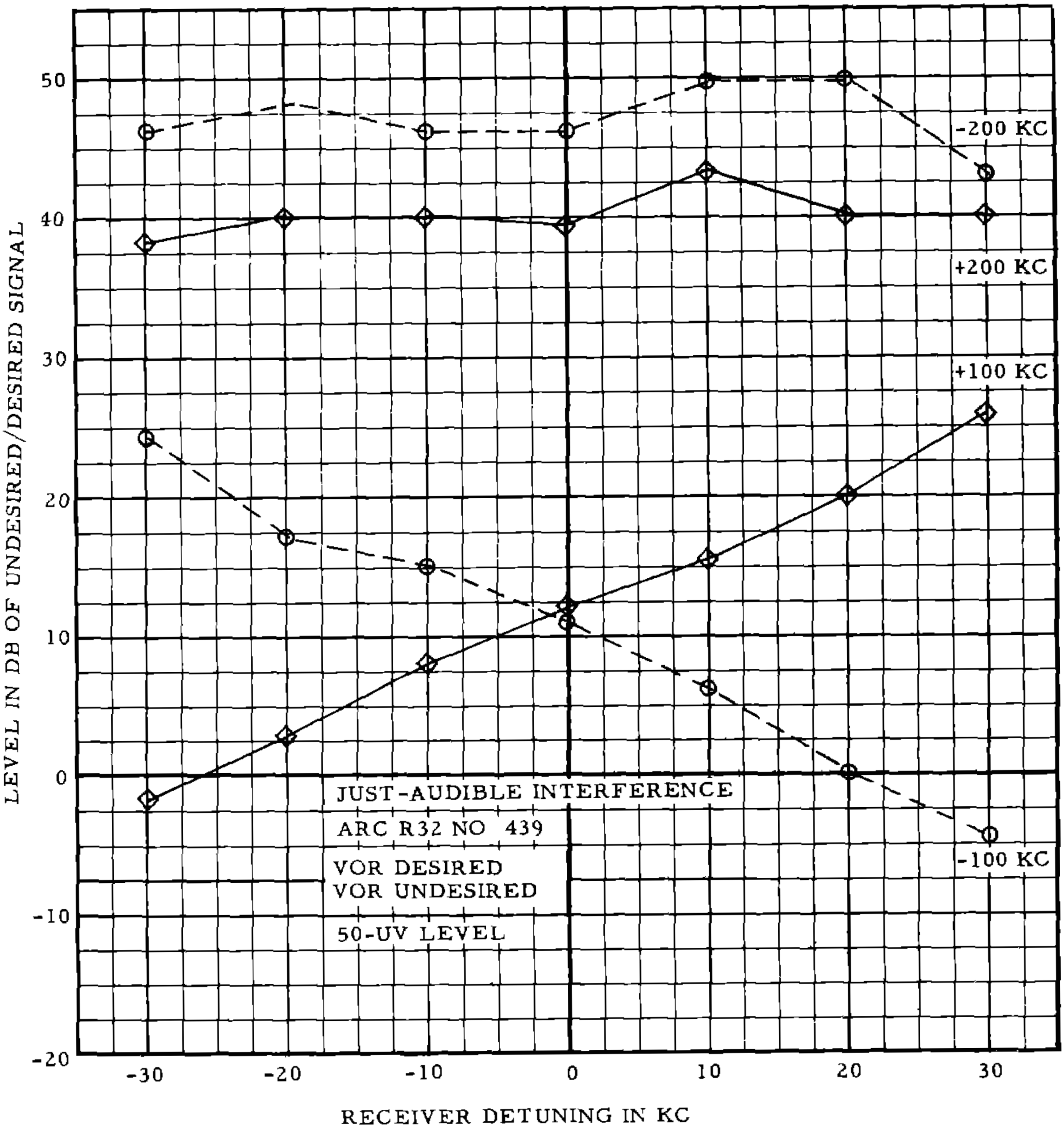

FIG. 40 THRESHOLD AUDIO INTERFERENCE VERSUS ARC RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

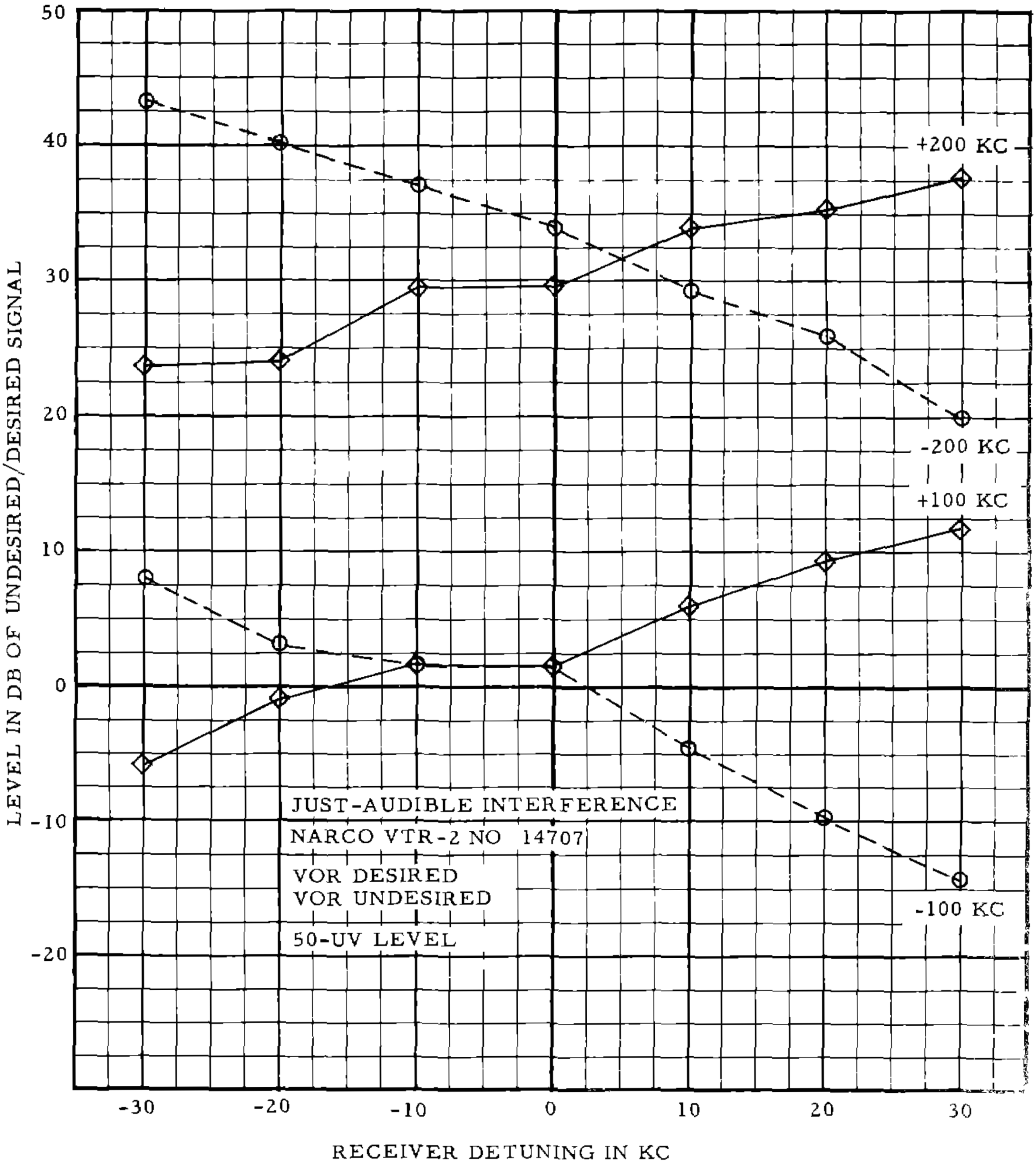

FIG 41 THRESHOLD AUDIO INTERFERENCE VERSUS NARCO RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

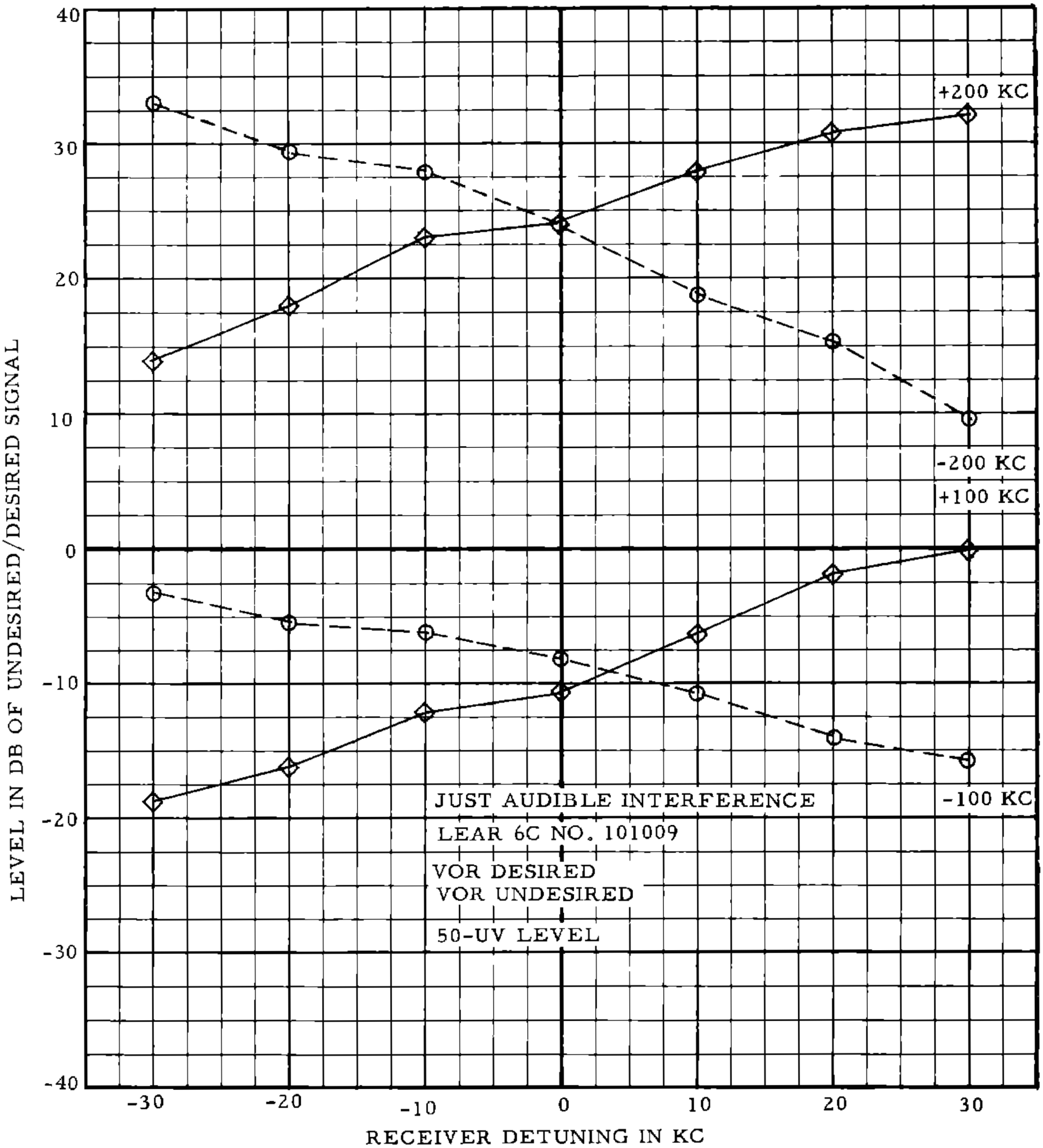

FIG 42 THRESHOLD AUDIO INTERFERENCE VERSUS LEAR RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

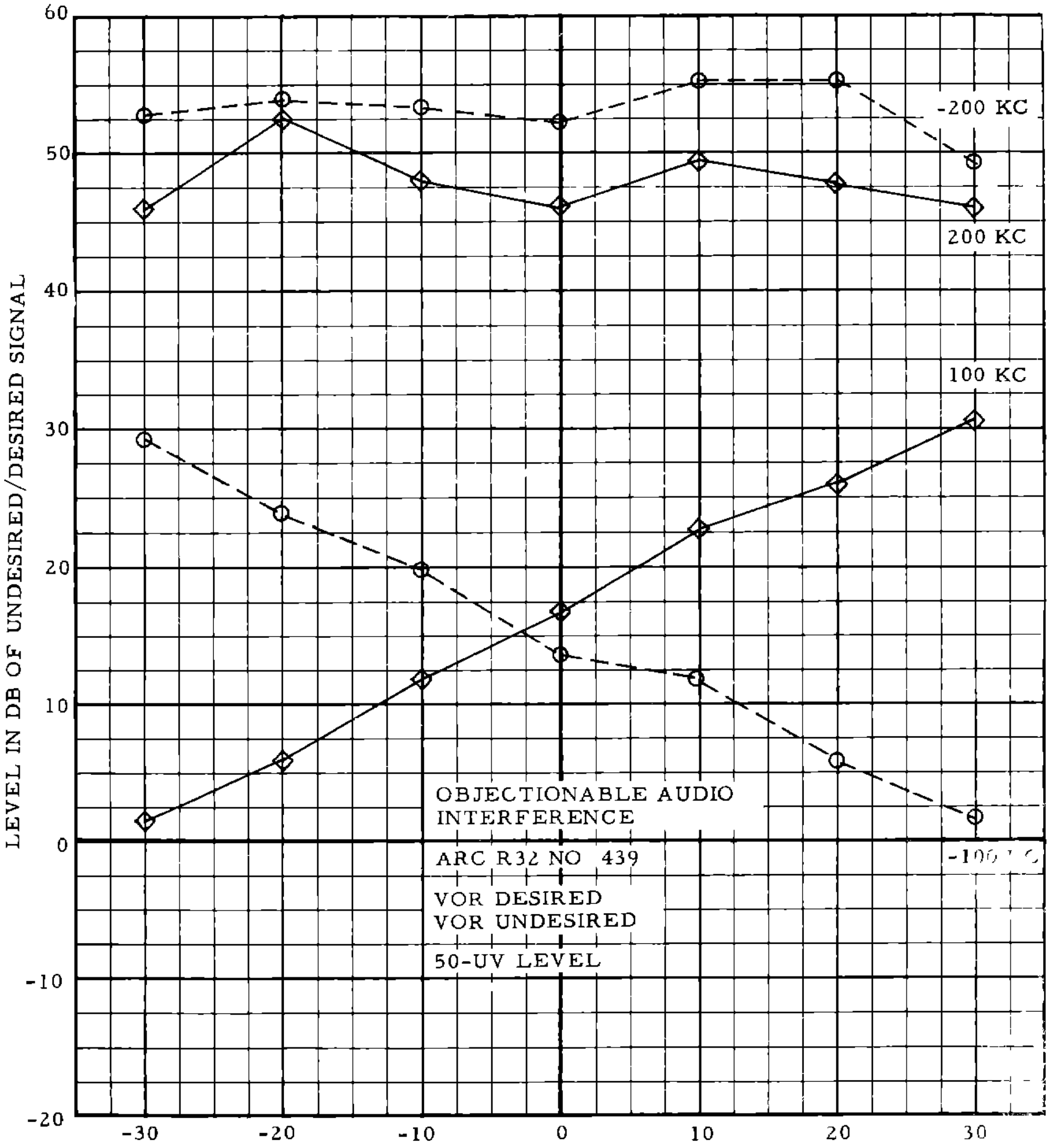

FIG 43 OBJECTIONABLE AUDIO INTERFERENCE VERSUS ARC RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

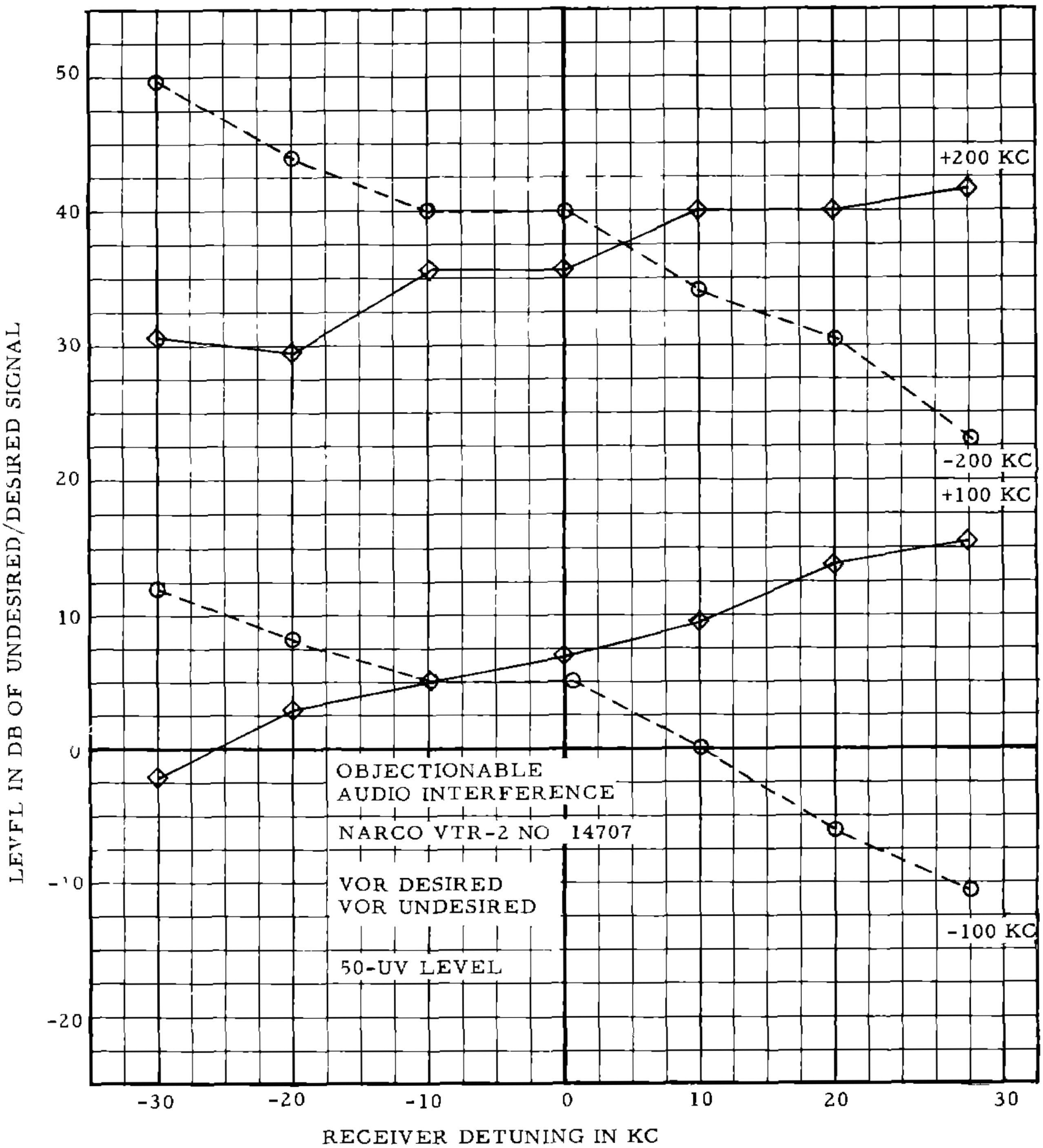

FIG 44 OBJECTIONABLE AUDIO INTERFERENCE VERSUS NARCO RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

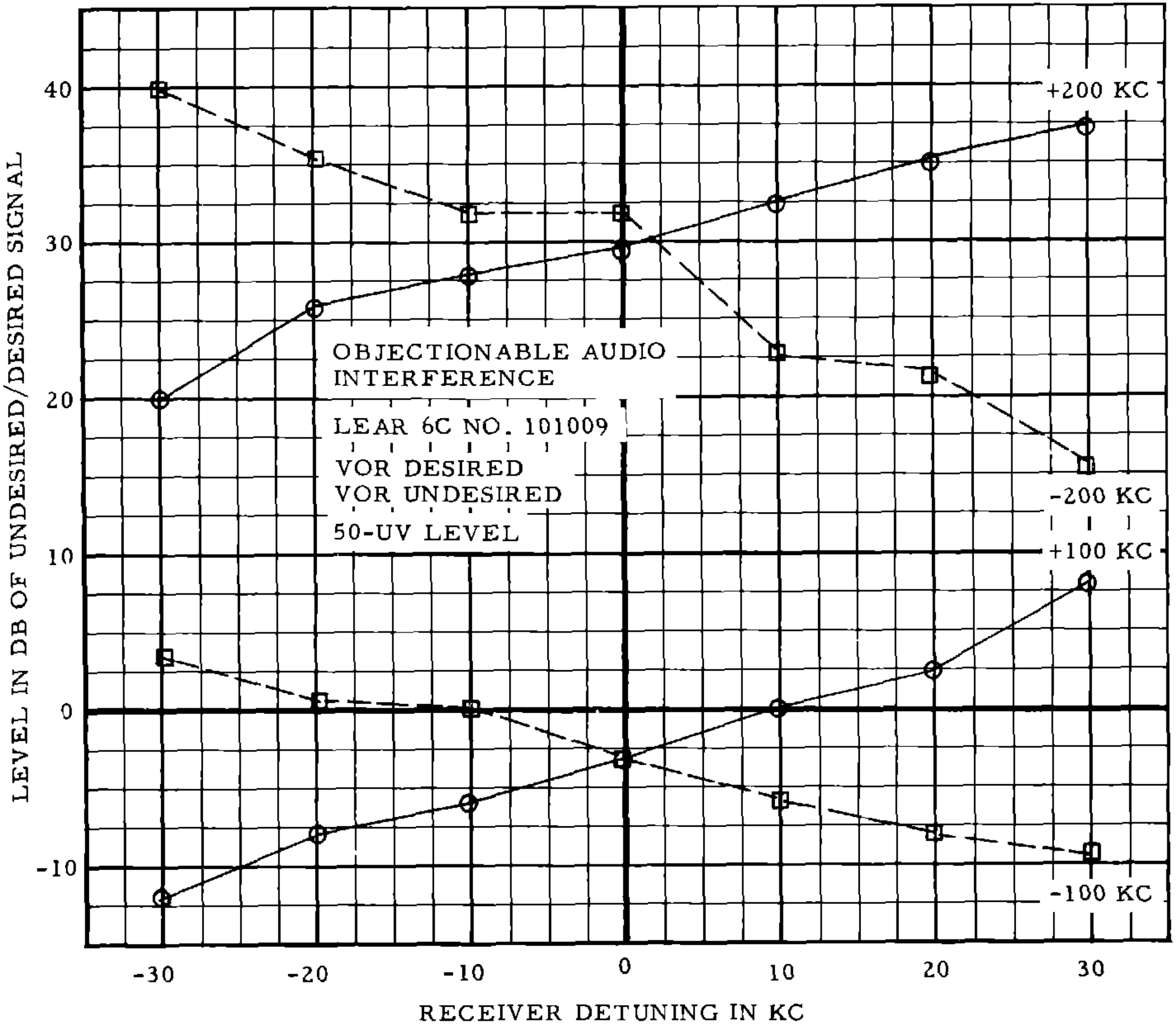

FIG. 45 OBJECTIONABLE AUDIO INTERFERENCE VERSUS LEAR RECEIVER DETUNING FOR ONE- AND TWO-CHANNEL SEPARATIONS

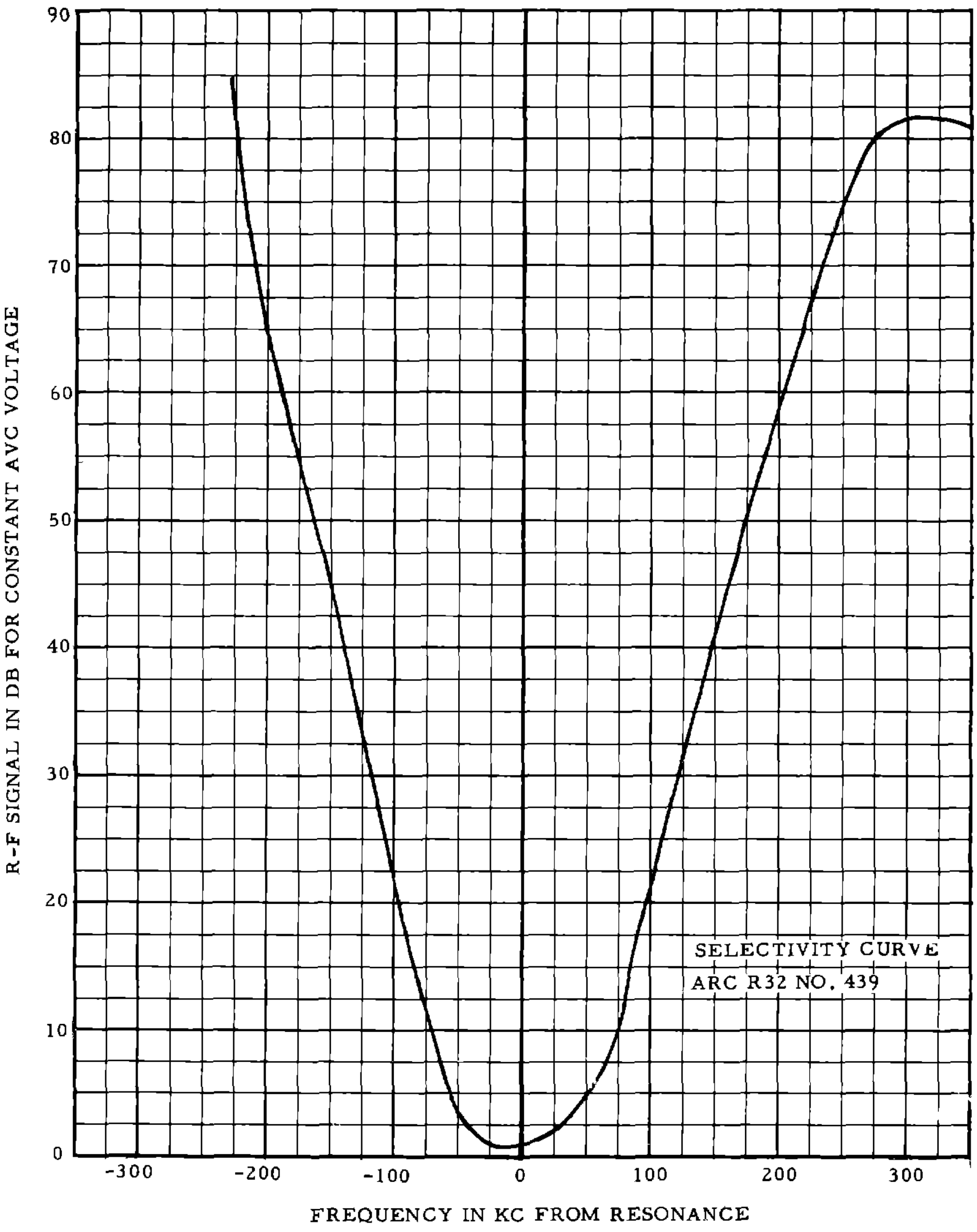

FIG 46 SELECTIVITY CURVE FOR ARC RECEIVER

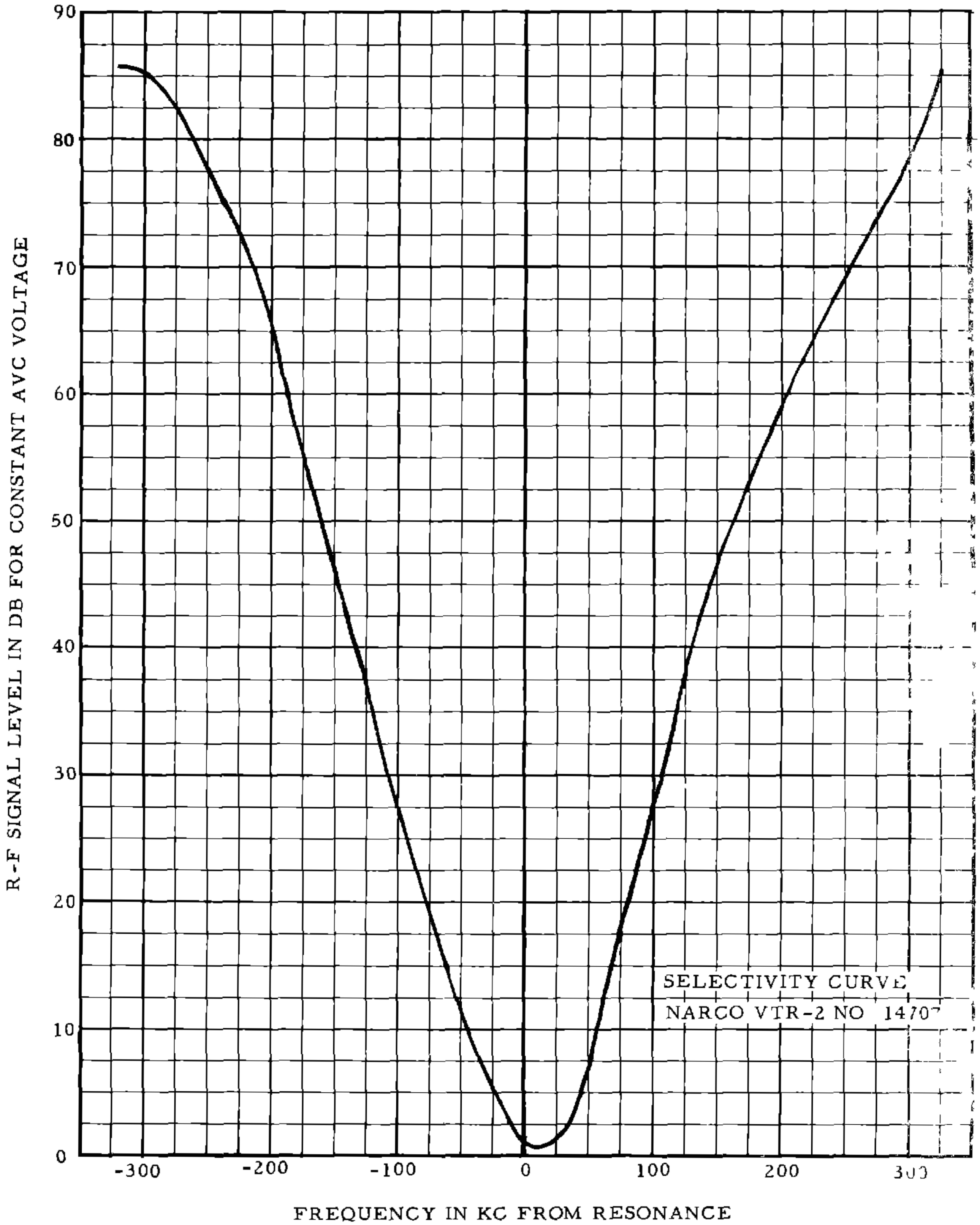

FIG 47 SELECTIVITY CURVE OF NARCO RECEIVER

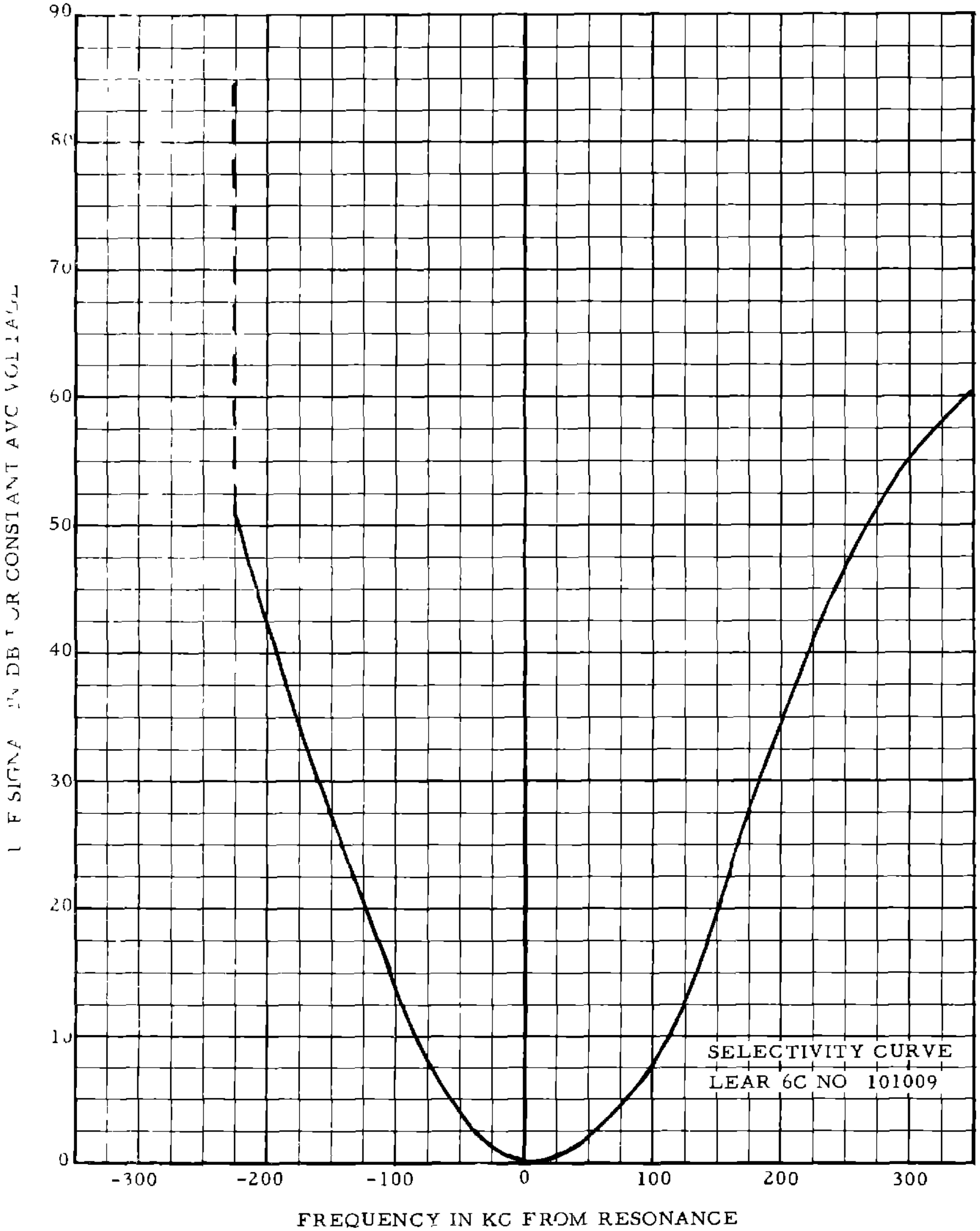

FIG -8 SELECTIVITY CURVE OF LEAR RECEIVER

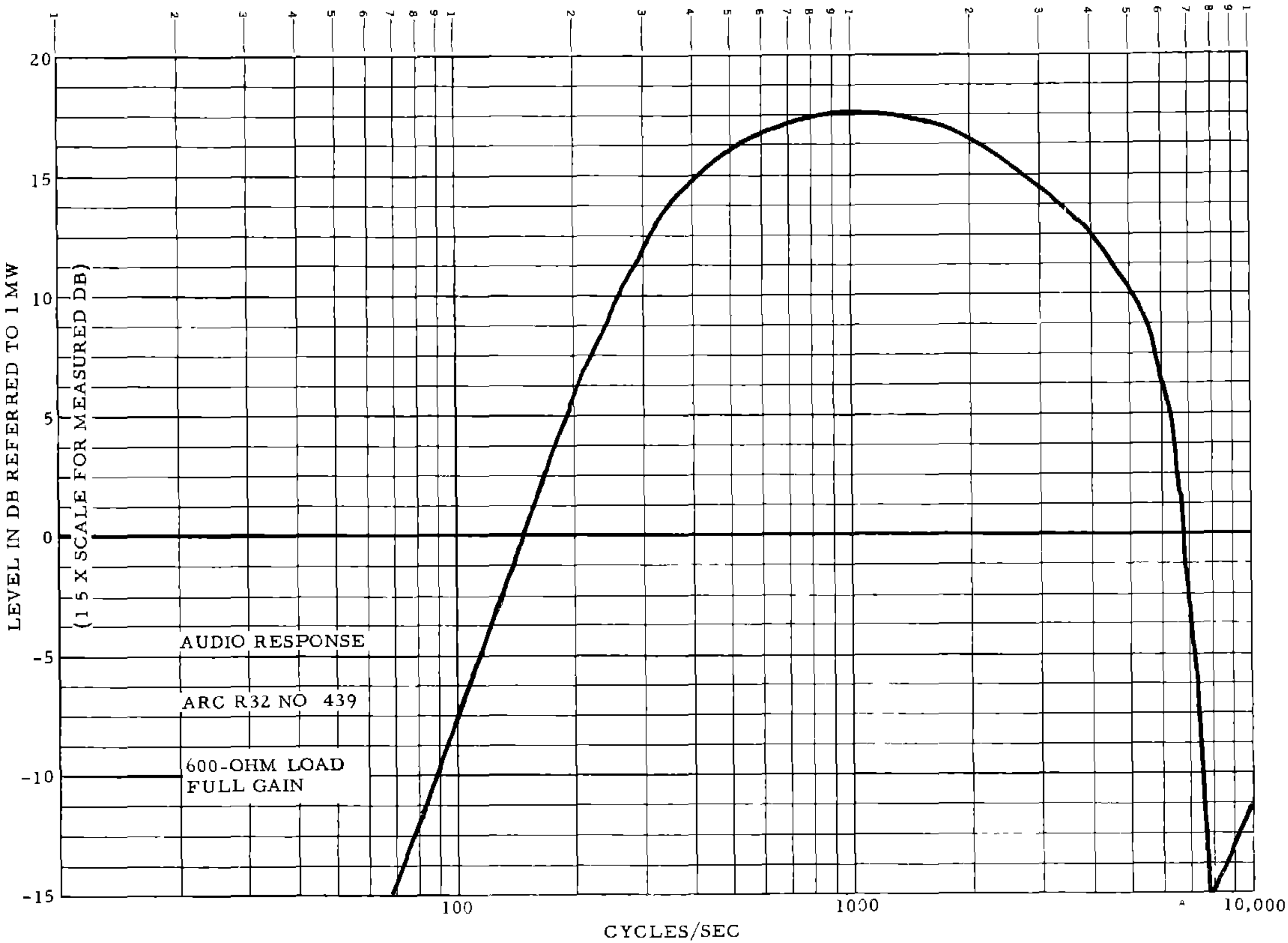

FIG 49 AUDIO RESPONSE CURVE OF ARC RECEIVER

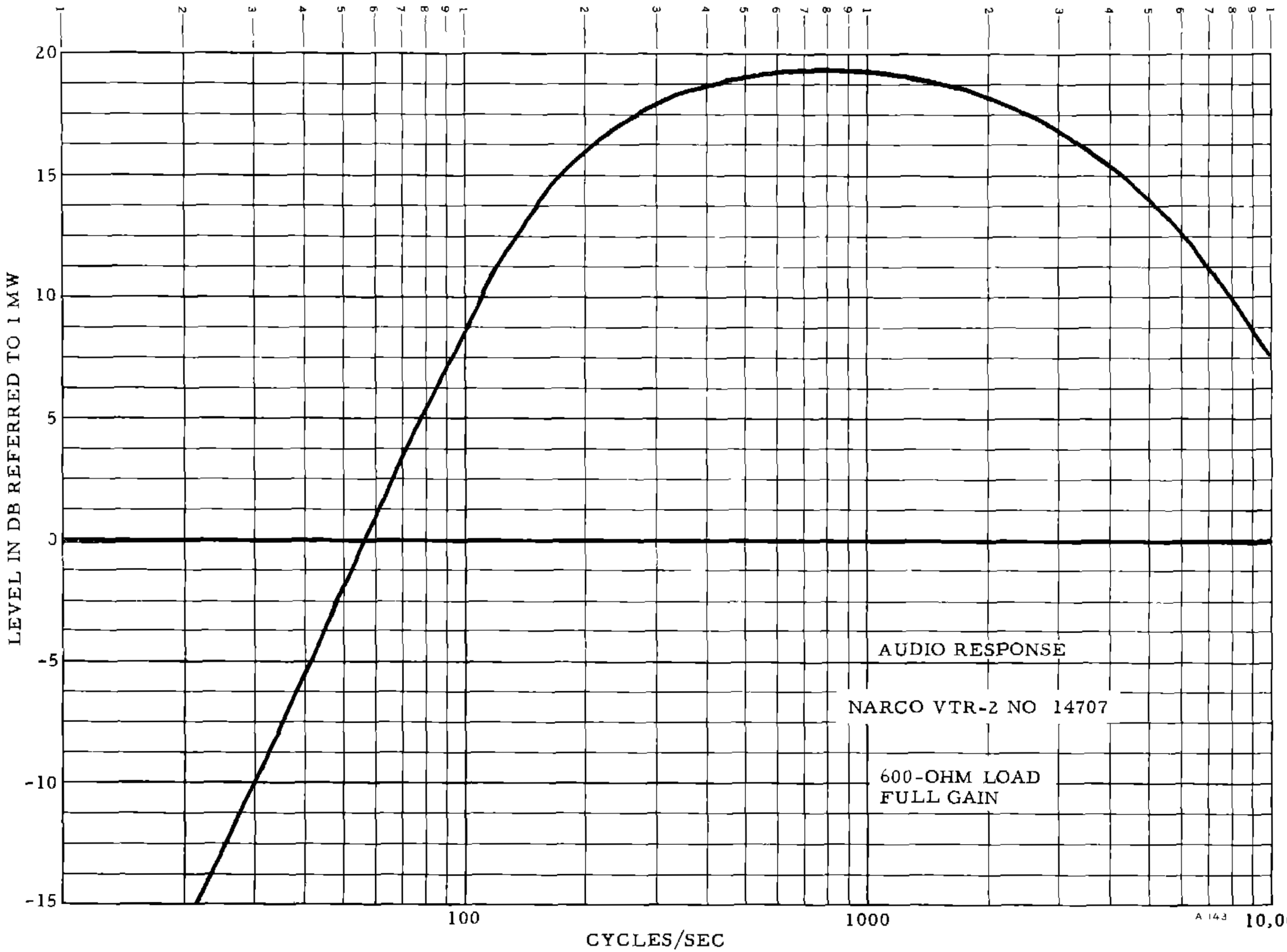

FIG 50 AUDIO RESPONSE CURVE OF NARCO RECEIVER

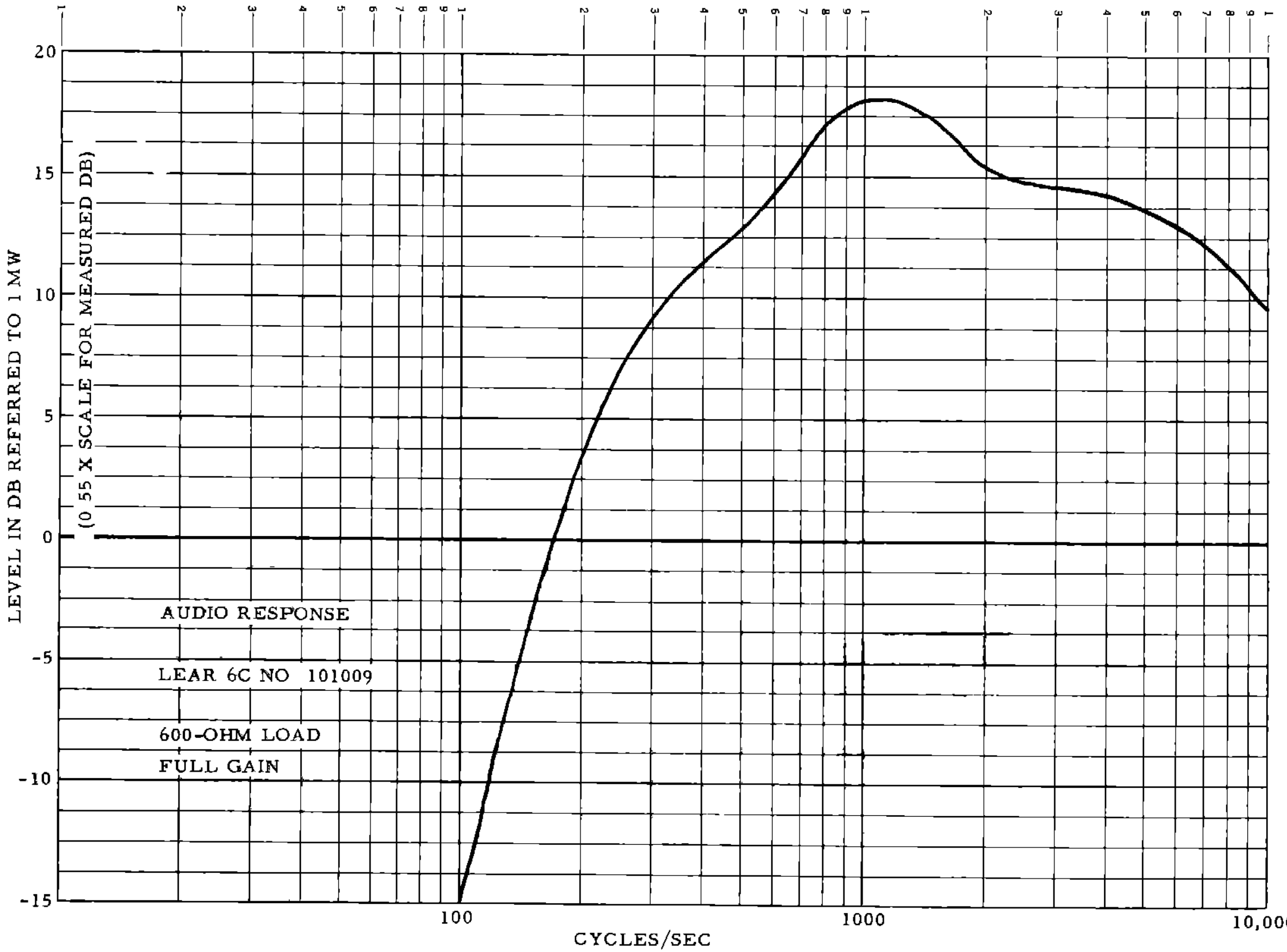

FIG 51 AUDIO RESPONSE CURVE OF LEAR RECEIVER