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2027

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A COMPARISON OF OMNIDIRECTIONAL AND ROTATING DIRECTIONAL ANTENNAS FOR INTERCEPT

[Unclassified Title]

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[redacted]

February 25, 1957

[redacted]

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ABSTRACT

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With the completion of an intercept probability computer it has become possible to determine the probability of intercept for a given receiver working against a given transmitter. Considering an AN/WLR-1 intercepting the lower beam of an AN/CPS-6B radar, it has been found that a high performance omnidirectional antenna would be a better intercept antenna than the AN/SLR-2 direction-finding antenna rotated at high speed. While this conclusion applies quantitatively only to this one case, the computed data suggests that development of omnidirectional microwave intercept antennas should be pursued, and that provisions should be made for the installation of these antennas with the AN/WLR-1 system.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problems R06-07 and R06-02
Projects NR 417-000 and NR 417-002
NE 071-240 and NE 071-240-3
BuShips Problems S-1255-3 and S-1702

Manuscript submitted February 19, 1957

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A COMPARISON OF OMNIDIRECTIONAL AND ROTATING DIRECTIONAL ANTENNAS FOR INTERCEPT

NRL Report 4612[1] describes a digital analyzer which in conjunction with a system simulator can be used to compute the probability of countermeasures interception. Recently the system simulator has been completed and will be described in detail in a forthcoming formal report. However, the results of a problem computed as a check on the over-all operation of the two computors are of such general interest that it has been deemed desirable to publish them in this format.

The problem is a comparison of an omnidirectional and a rotating direction-finding antenna as intercept antennas for a modern intercept receiver. The intercept receiver has been assumed to be an AN/WLR-1. The two antennas that are being compared are a hypothetical omnidirectional antenna of gain 4 db below isotropic and an AN/SLR-2 direction-finding antenna. The transmitter assumed for this case is the AN/CPS-6B. The AN/WLR-1 is a high-speed mechanically tuned superheterodyne microwave receiver. At S-band it scans a 2-kMc band with its 20-megacycle IF bandwidth once every two seconds. It is probably capable of recording a single intercepted pulse although in this simulation two pulses were assumed necessary for recognition.

The AN/CPS-6B is a 750-kw, long-range, V-beam radar with a high-gain antenna of narrow beamwidth.[2] In these computations the transmitter antenna was assumed to be rotating at 5 rpm. The receiver direction-finding antenna was assumed to be rotating at 300 rpm.[3] Figures 1 thru 14 show for various arbitrary attenuations 5 db apart the probability of intercept versus waiting time. In these graphs, the solid line represents the performance with the AN/SLR-2 antenna and the broken line represents the performance with the omnidirectional antenna. In Fig. 1, which represents a strong signal, the probability of intercept rises to unity in two seconds for both antennas. Here

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1) Wald, B., "The Computation of the Probability of Countermeasures Interception" NRL Report 4612 (~~Conf.~~) 5 Oct 1955

2) The antenna pattern was provided by A. T. Waterman, Jr. of the Electronics Research Laboratory, Stanford University. It is interesting to note that this is one of the few microwave antennas whose 360° pattern is known. The lack of 360° antenna patterns is the most serious problem faced in the prediction of intercept receiver performance.

3) The pattern of the AN/SLR-2 antenna was measured by Mr. John Ihnat of this Laboratory.

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the signal is so strong that it is necessary for the receiver to search its band only once to be sure of receiving the transmitted signal. In Fig. 2, 5 db below Fig. 1, the probability of intercept still rises to unity in two seconds for the omnidirectional antenna, but only to nine tenths for the direction-finding antenna. This may be interpreted as saying that ten percent of the time a null of the direction-finding antenna is pointed at the transmitter, at the time the receiver crosses the signal frequency. In Figs. 3, 4 and 5, each 5 db below its predecessor, the omnidirectional antenna still is capable of receiving any part of the transmitted signal pattern and its probability rises linearly to unity in two seconds; however the curve for the direction-finding antenna becomes flatter and flatter as a larger proportion of its nulls become incapable of receiving the transmitted pattern. In Fig. 6, the curve for the omnidirectional antenna begins flattening. Now the signal is so weak that the omnidirectional antenna is not capable of receiving quite all of the transmitted signal pattern. In Figs. 7 and 8 this situation continues. In Figs. 9 and 10, the omnidirectional antenna's margin of superiority over the direction-finding antenna has been reduced. This reflects the fact that at these signal levels the omnidirectional antenna is capable of receiving only the peaks of the transmitted signal pattern. In Figs. 11, 12, 13 and 14, therefore, the direction-finding antenna is superior to the omnidirectional antenna. In Figs. 15 to 17, however, it may be seen that the omnidirectional antenna has not suffered as much in the reduction of signal level as has the direction-finding antenna. This reflects the fact that the omnidirectional antenna is still waiting for the major lobe of the transmitted pattern but that the df antenna must have a coincidence of its major lobe with the major lobe of the transmitted pattern in order to deliver a signal above threshold to the receiver.

Figures 1 thru 17 are cross plotted on Figs. 18, 19 and 20 which represent the waiting time to reach a given intercept probability versus signal strength. Referring to Fig. 19 as representative of these cross plots, it may be seen that for high signal strengths the omnidirectional antenna is superior but only by a relatively unimportant margin as it reaches fifty percent probability only a few seconds before the direction-finding antenna. For intermediate signal strengths the direction-finding antenna is superior by a margin of about 20 seconds. For weak signals the omnidirectional antenna reaches fifty percent probability several minutes before the direction-finding antenna. For still weaker signals, which the omnidirectional antenna is incapable of receiving, the direction-finding antenna will reach fifty percent probability in finite time but in a time so long as not to be of tactical interest. Thus it may be seen that for the antennas assumed in these plots the choice of antennas is dictated by the signal strength of the transmitted signal whose interception probability is to be optimized.

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It should be reemphasized here that these computations were made on the basis of an omnidirectional antenna of gain of 4 db below isotropic. Recent work in this Branch has indicated that it is possible to construct an omnidirectional antenna whose gain at low angles of elevation is 6 db above isotropic. Figure 19 therefore, has been replotted in Figs. 21 and 22 for omnidirectional antennas of gain 1 and 6 db above isotropic. It may be seen that the +6 db omnidirectional antenna is superior to the direction-finding antenna as an intercept antenna for all signal levels.

Figure 23 replots the information of Figs. 19 and 20 on a range versus probability-of-intercept basis. The transmitting antenna is assumed to be elevated 100 feet and the receiving antenna 10 feet. This might be representative of a submarine approaching a low coast. The receiver was assumed to have a threshold of -85 dbm[4] for certain recognition and -89 dbm for a .50 probability of recognition. On this basis, the arbitrary attenuation scale was converted to range, utilizing published information on microwave attenuation.[5]

Inspection of Fig. 23 reveals that at least for this case the omnidirectional antenna's margin of superiority is considerable in an operational sense. Although these conclusions apply only to the AN/CPS-6B transmitter, they are suggestive enough to indicate that the development of suitable omnidirectional antennas for use with AN/WLR-1 should be pursued and that installations of the AN/WLR-1 should include an omnidirectional antenna.

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4) This figure was supplied by Mr. Nicholas R. Garafolo of this Laboratory on the basis of operator tests. He will publish the complete results of these tests in the near future.

5) Norton, Rice, & Vogler, "The Use of Angular Distance in Estimating Transmission Loss" Proceedings of the IRE 43:10 p. 1488, October 1955.

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[redacted] [redacted]

the signal is so strong that it is necessary for the receiver to search its band only once to be sure of receiving the transmitted signal. In Fig. 2, 5 db below Fig. 1, the probability of intercept still rises to unity in two seconds for the omnidirectional antenna, but only to nine tenths for the direction-finding antenna. This may be interpreted as saying that ten percent of the time a null of the direction-finding antenna is pointed at the transmitter, at the time the receiver crosses the signal frequency. In Figs. 3, 4 and 5, each 5 db below its predecessor, the omnidirectional antenna still is capable of receiving any part of the transmitted signal pattern and its probability rises linearly to unity in two seconds; however the curve for the direction-finding antenna becomes flatter and flatter as a larger proportion of its nulls become incapable of receiving the transmitted pattern. In Fig. 6, the curve for the omnidirectional antenna begins flattening. Now the signal is so weak that the omnidirectional antenna is not capable of receiving quite all of the transmitted signal pattern. In Figs. 7 and 8 this situation continues. In Figs. 9 and 10, the omnidirectional antenna's margin of superiority over the direction-finding antenna has been reduced. This reflects the fact that at these signal levels the omnidirectional antenna is capable of receiving only the peaks of the transmitted signal pattern. In Figs. 11, 12, 13 and 14, therefore, the direction-finding antenna is superior to the omnidirectional antenna. In Figs. 15 to 17, however, it may be seen that the omnidirectional antenna has not suffered as much in the reduction of signal level as has the direction-finding antenna. This reflects the fact that the omnidirectional antenna is still waiting for the major lobe of the transmitted pattern but that the df antenna must have a coincidence of its major lobe with the major lobe of the transmitted pattern in order to deliver a signal above threshold to the receiver.

Figures 1 thru 17 are cross plotted on Figs. 18, 19 and 20 which represent the waiting time to reach a given intercept probability versus signal strength. Referring to Fig. 19 as representative of these cross plots, it may be seen that for high signal strengths the omnidirectional antenna is superior but only by a relatively unimportant margin as it reaches fifty percent probability only a few seconds before the direction-finding antenna. For intermediate signal strengths the direction-finding antenna is superior by a margin of about 20 seconds. For weak signals the omnidirectional antenna reaches fifty percent probability several minutes before the direction-finding antenna. For still weaker signals, which the omnidirectional antenna is incapable of receiving, the direction-finding antenna will reach fifty percent probability in finite time but in a time so long as not to be of tactical interest. Thus it may be seen that for the antennas assumed in these plots the choice of antennas is dictated by the signal strength of the transmitted signal whose interception probability is to be optimized.

FIGURE 2
(Attn. 90db)

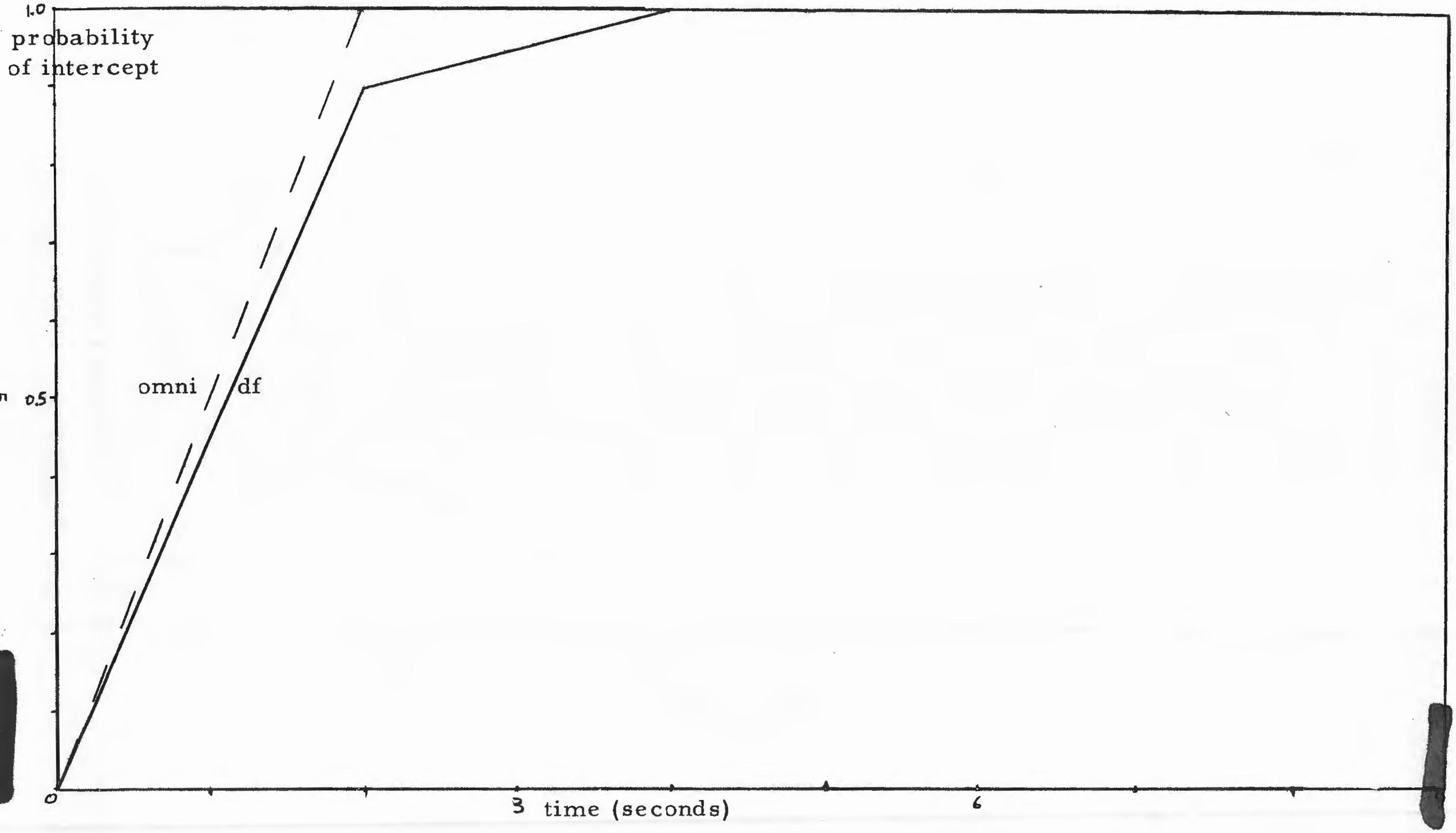

FIGURE 3
(Attn. 95db)

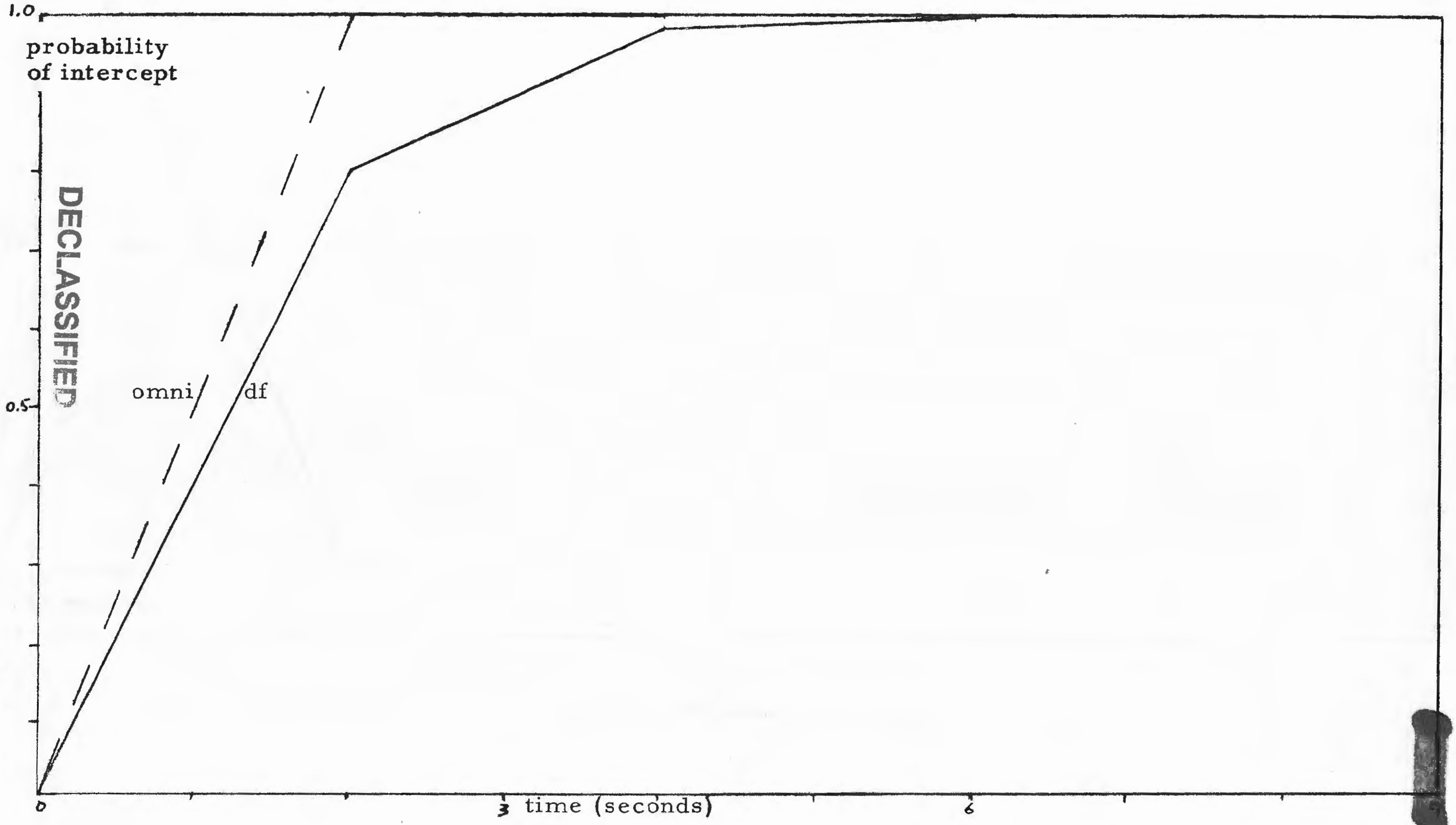

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FIGURE 4
(Attn. 100db)

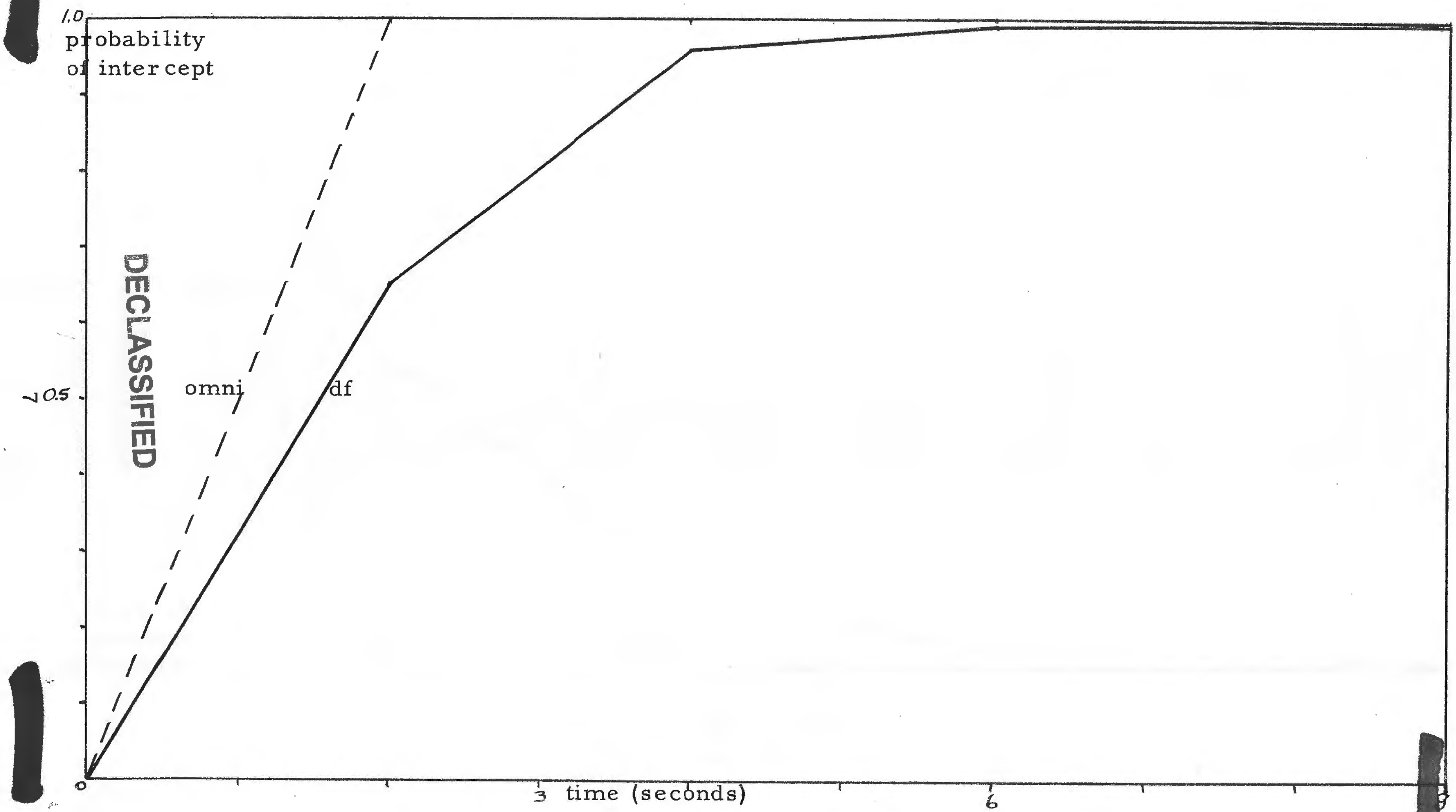


FIGURE 5
(Attn. 105db)

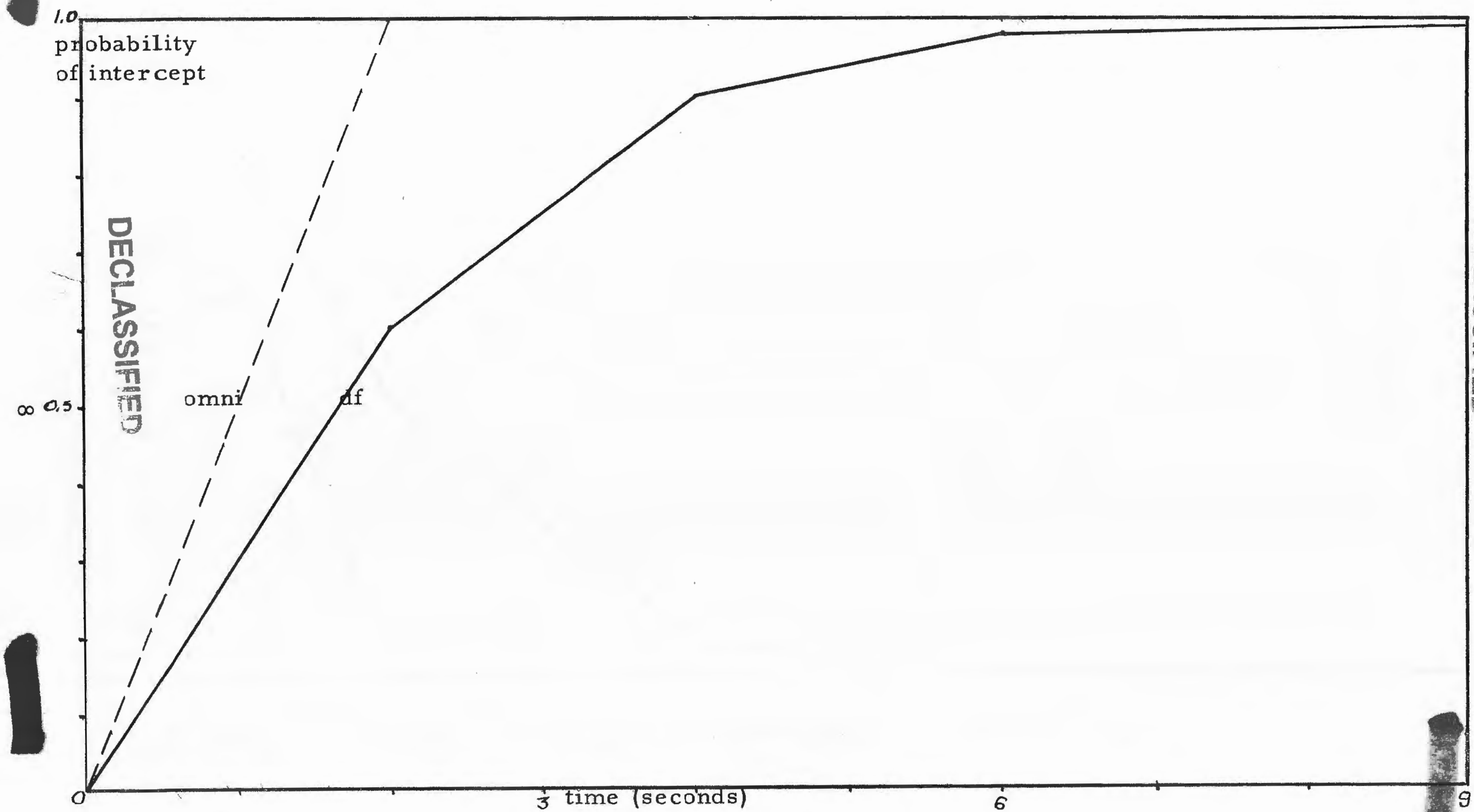
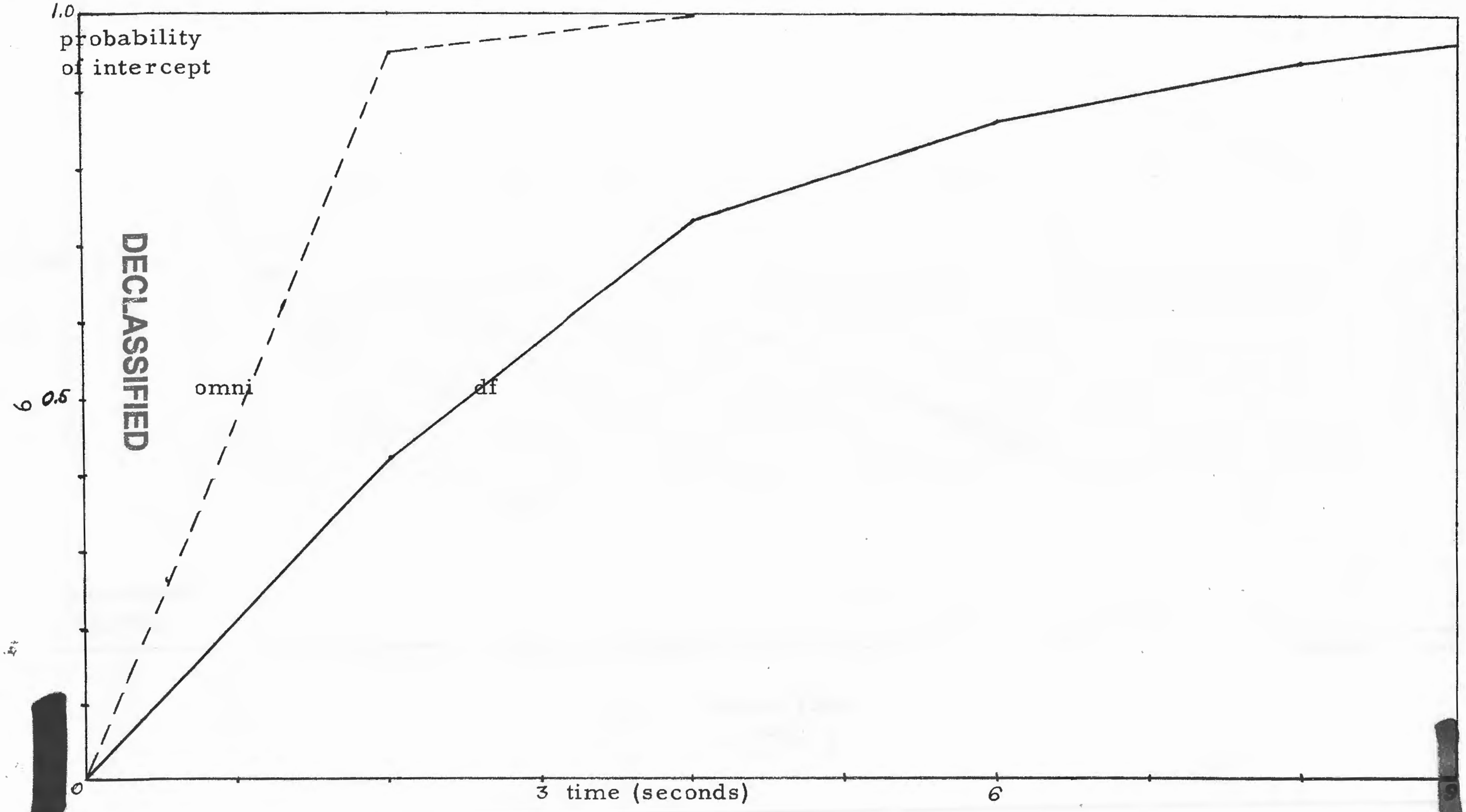


FIGURE 6
(Attn. 110 db)



[redacted]

FIGURE 7
(Attn. 115db)

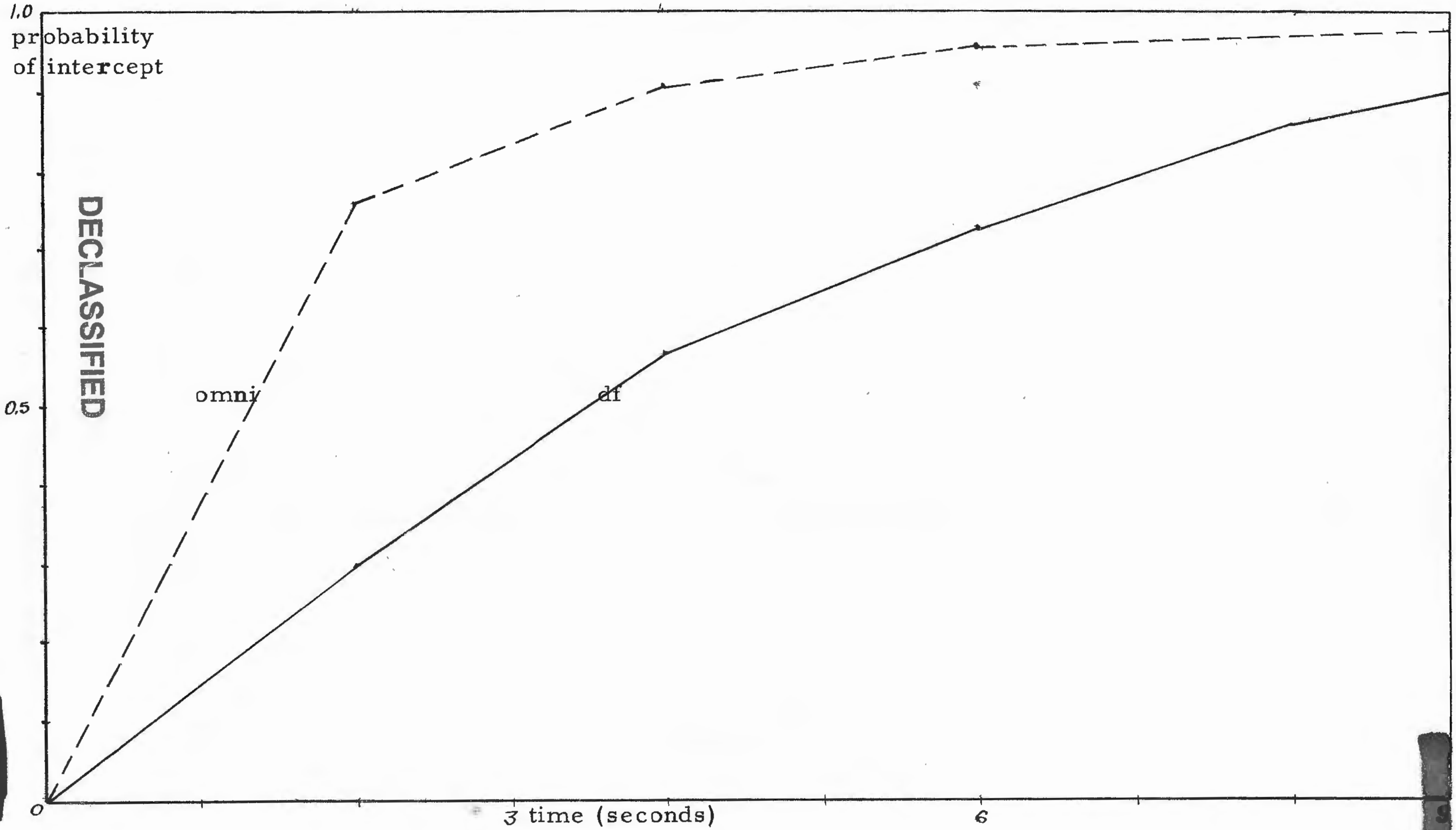


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FIGURE 8
(Attn. 120db)

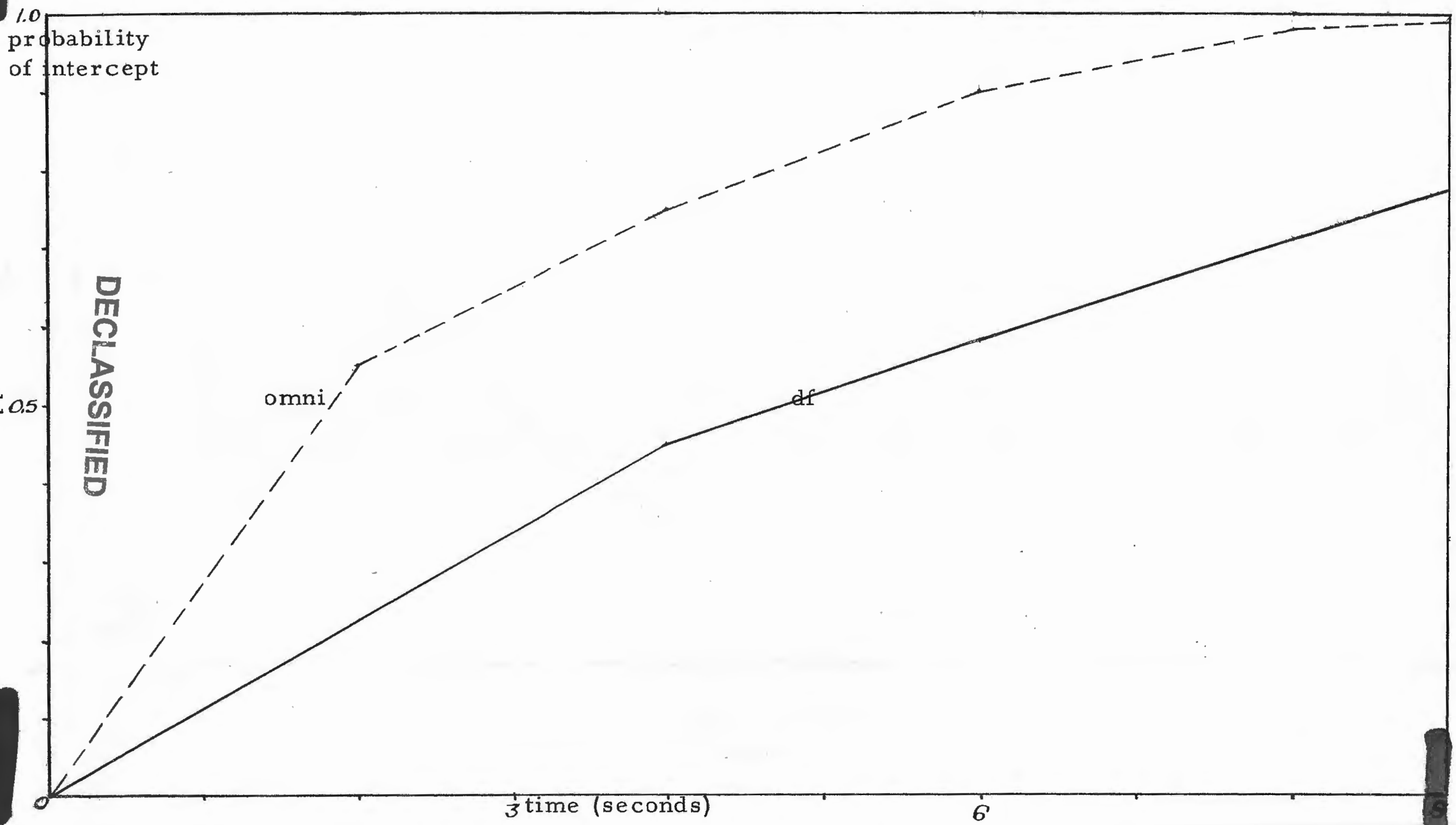

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FIGURE 9
(Attn. 125db)

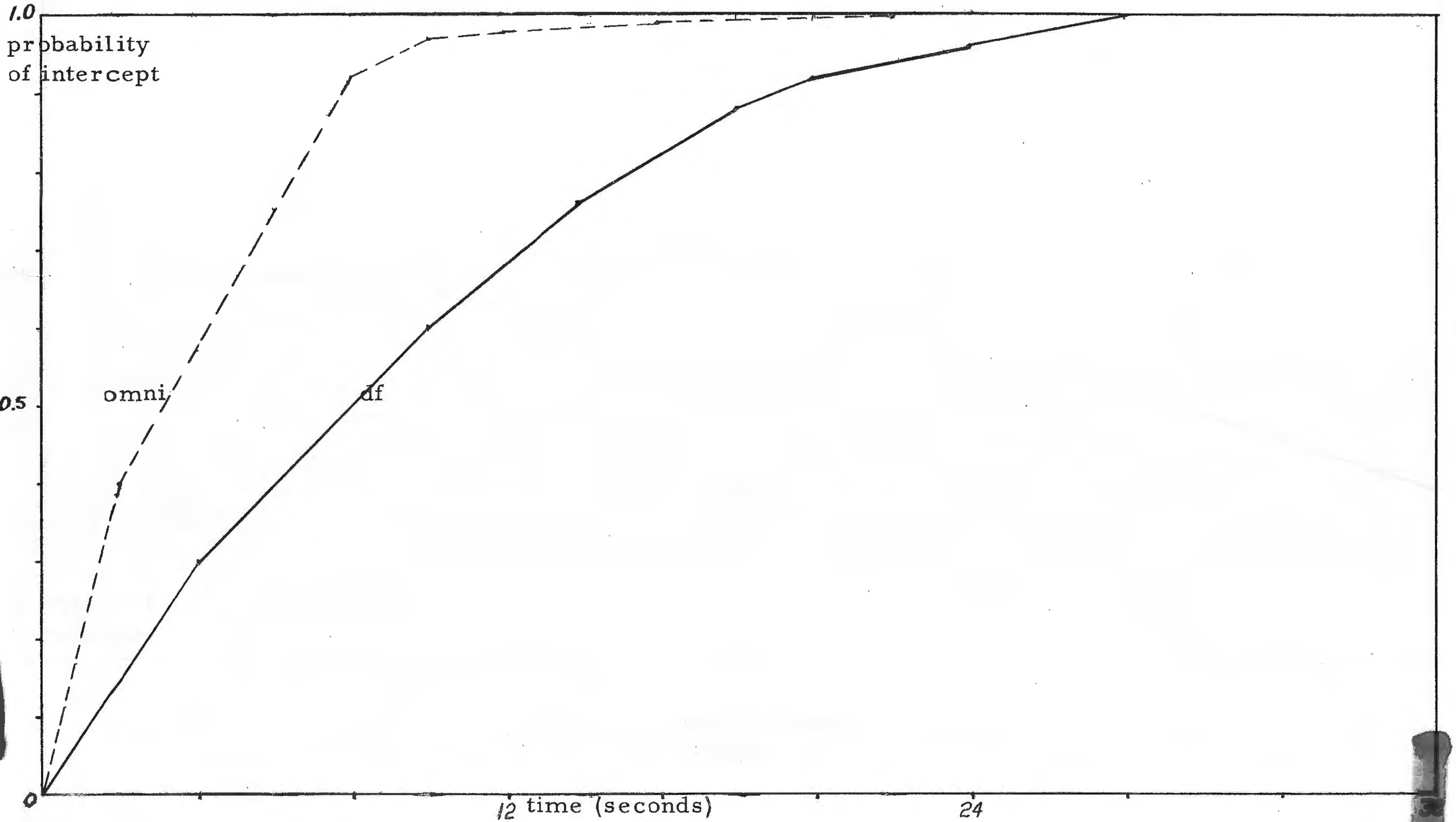

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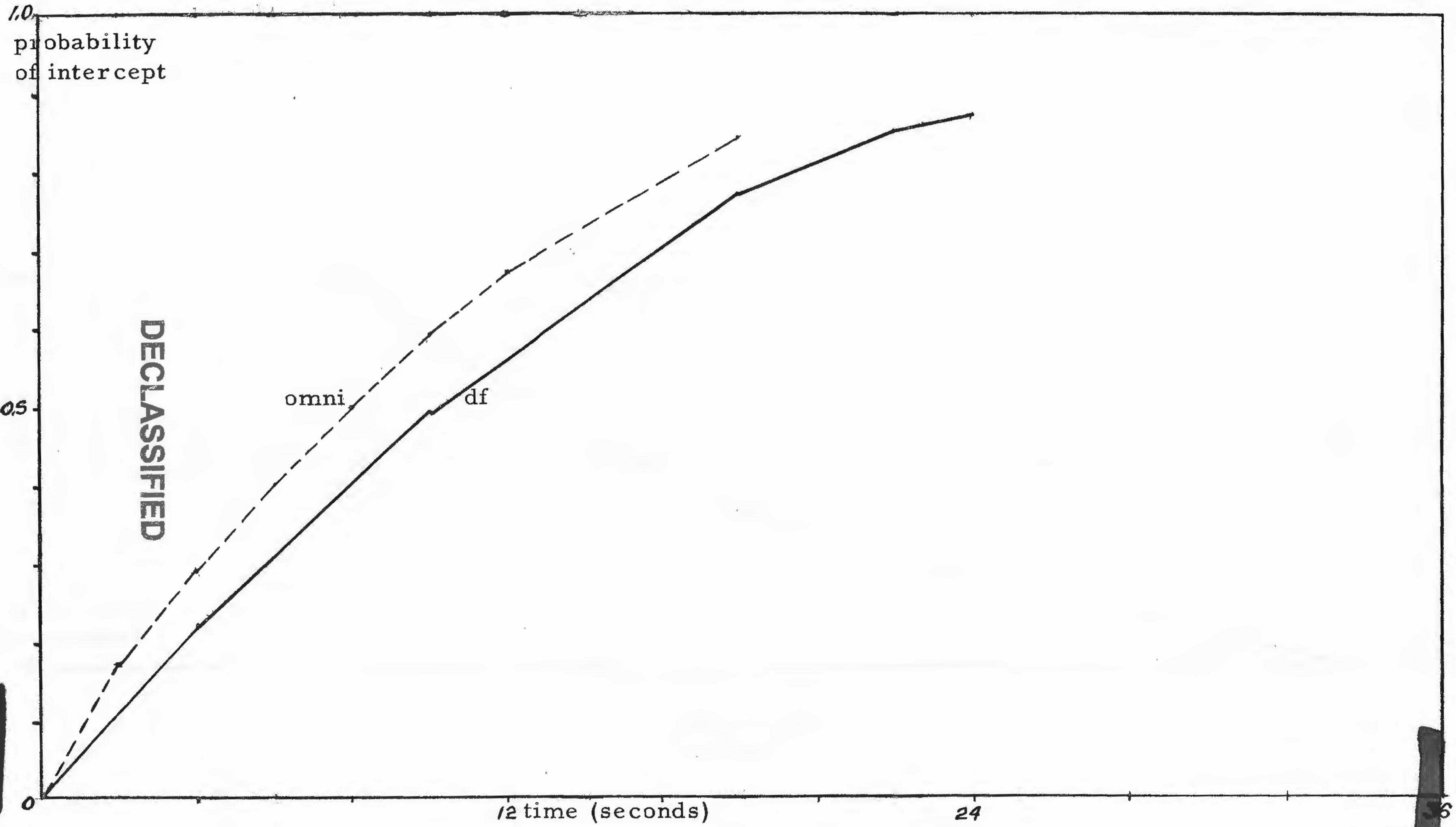
FIGURE 10
(Attn. 130db)



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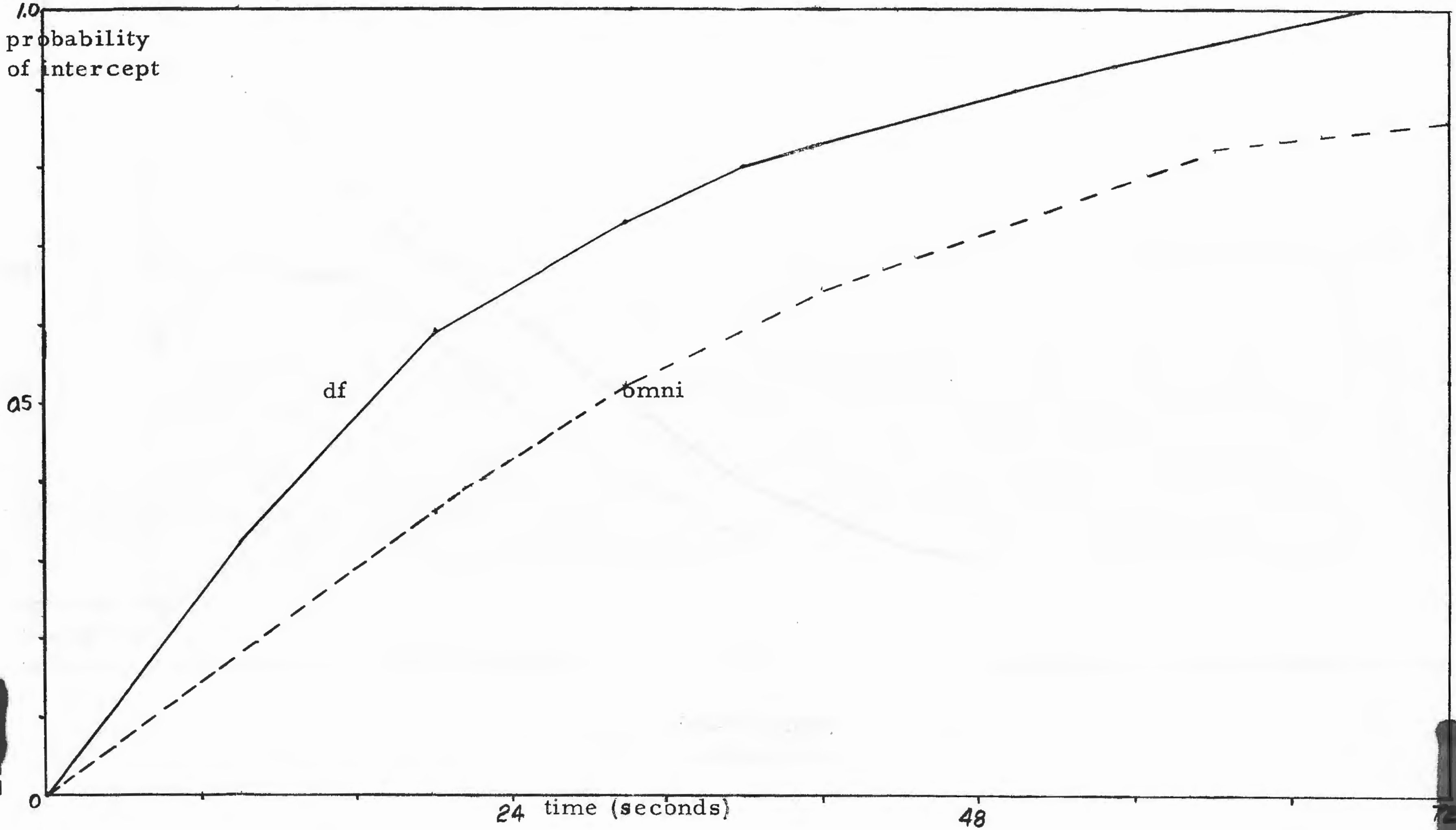
[redacted] [redacted]

FIGURE 11
(Attn. 135db)



[redacted]T [redacted]

FIGURE 12
(Attn. 140db)

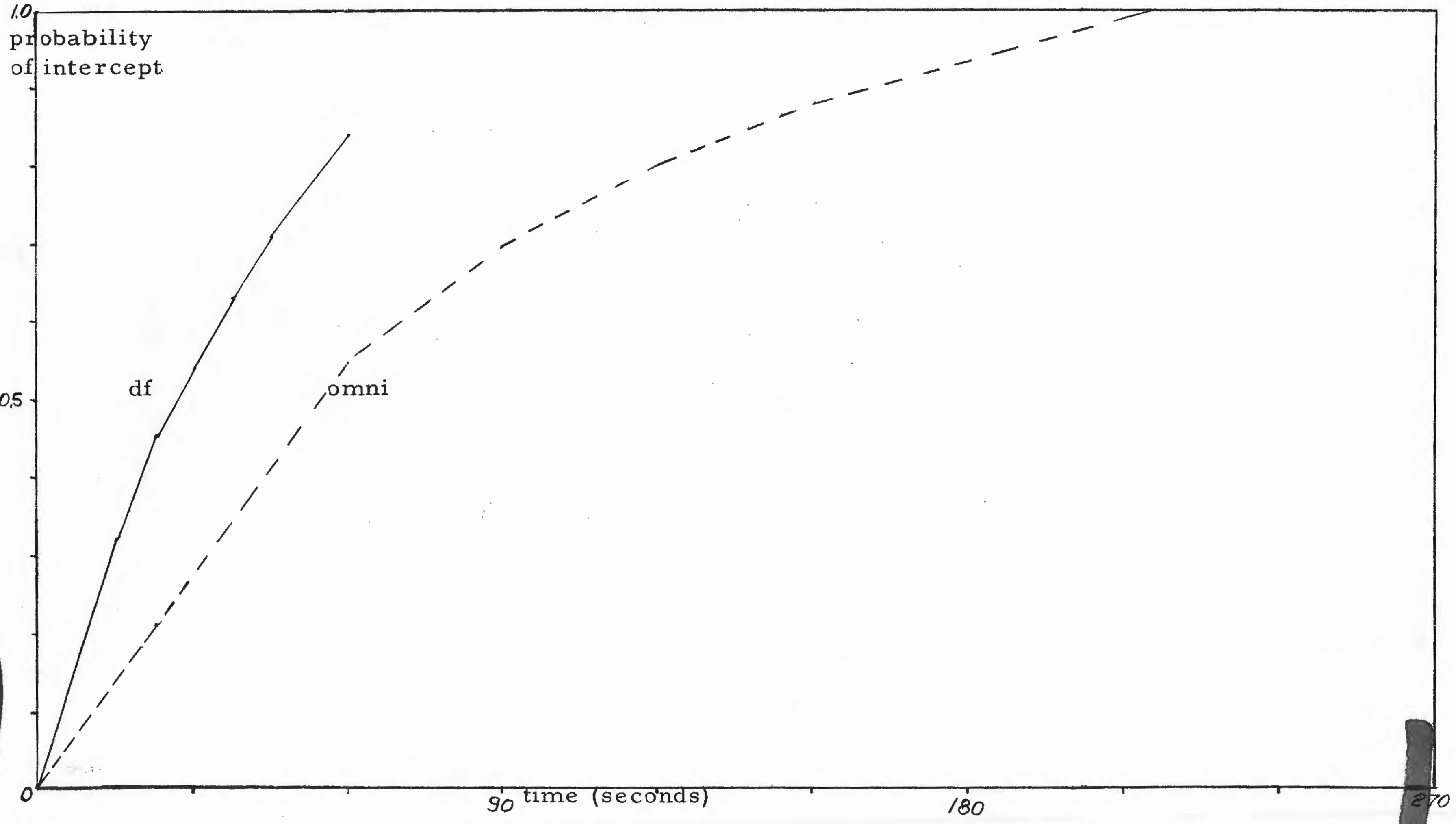


FIGURE 12
(Attn. 140db)

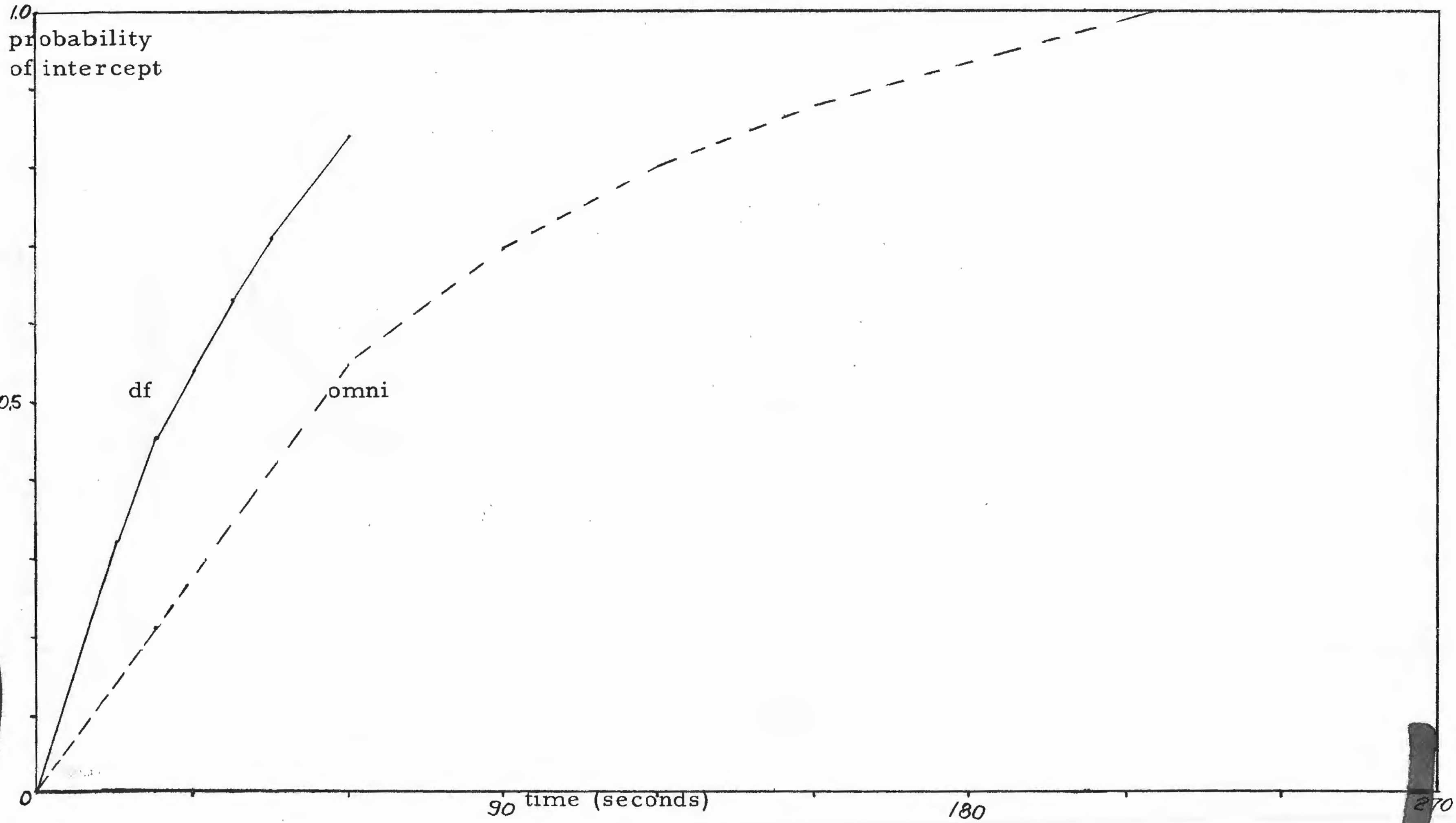
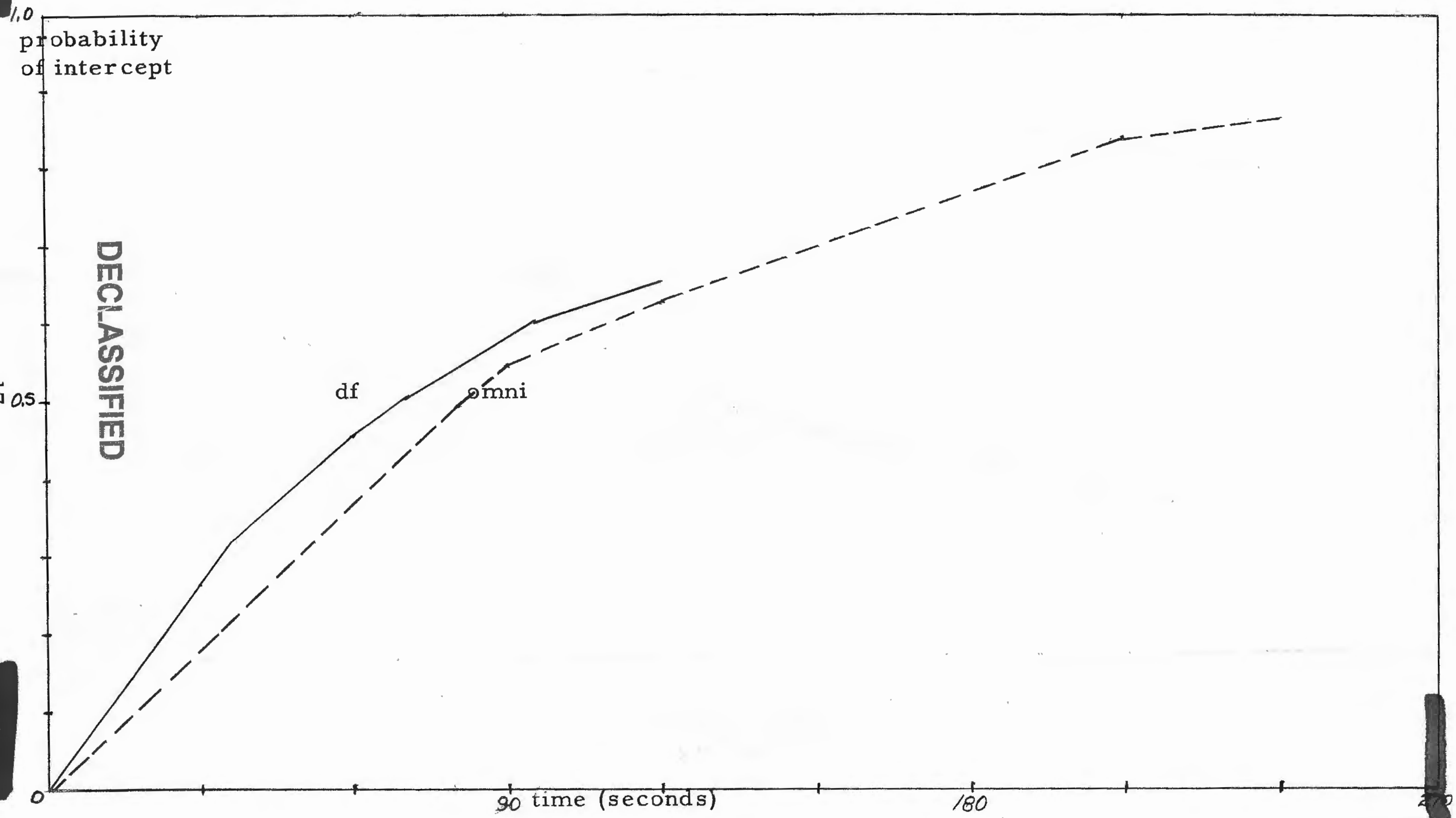


FIGURE 14
(Attn. 150db)



[redacted]

FIGURE 15
(Attn. 155db)

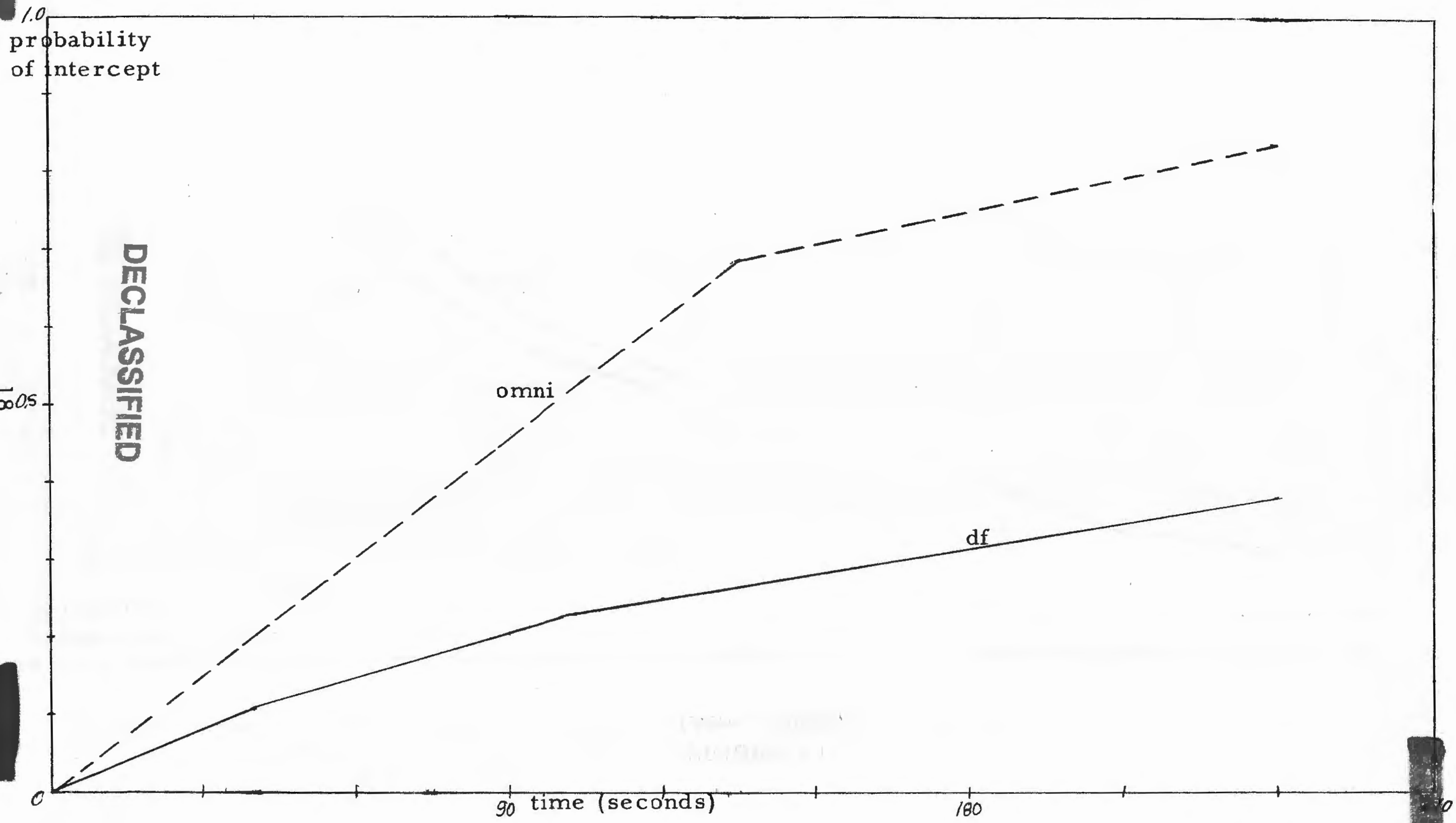


FIGURE 16
(Attn. 160db)

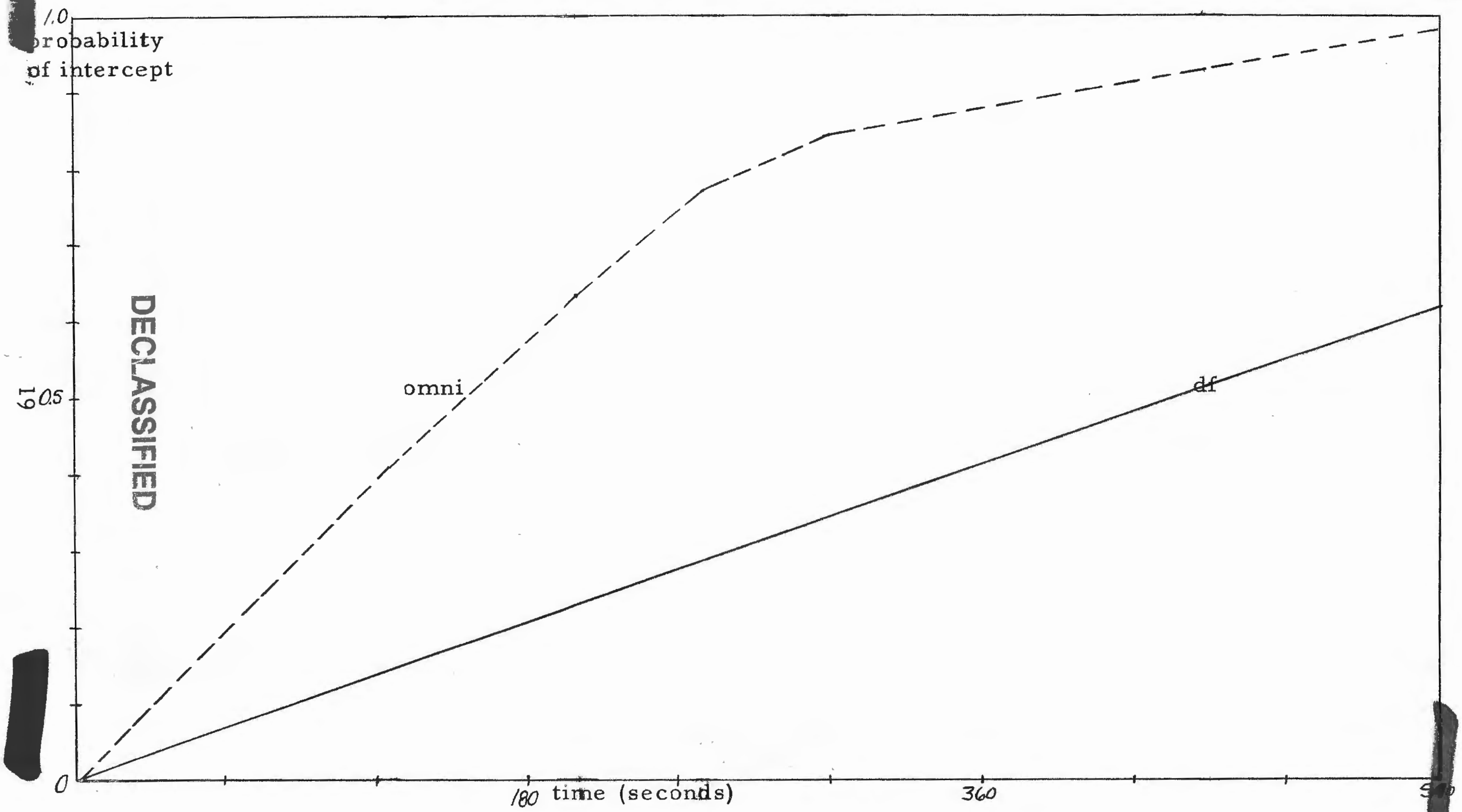


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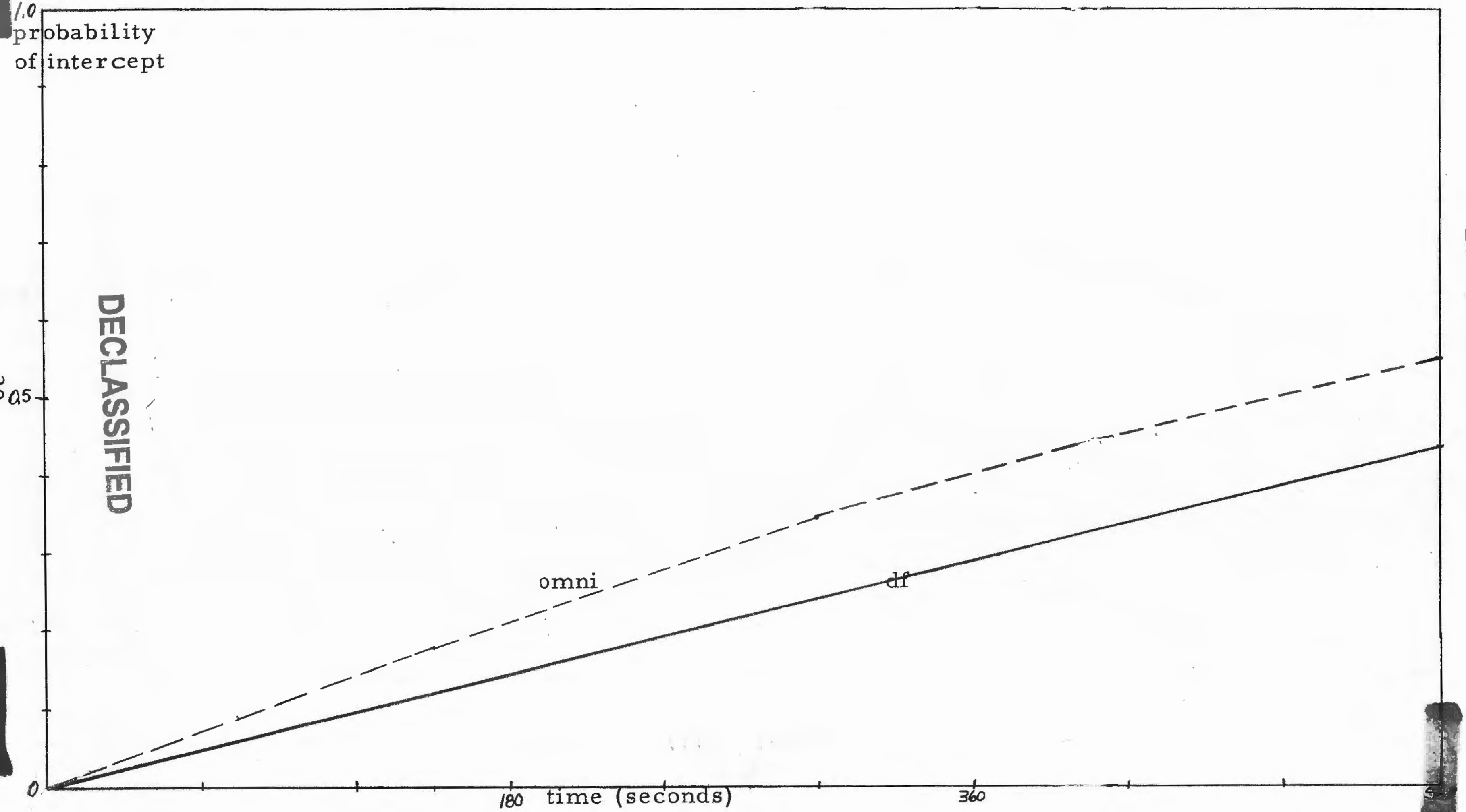
FIGURE 17
(Attn. 165db)



[redacted] [redacted]

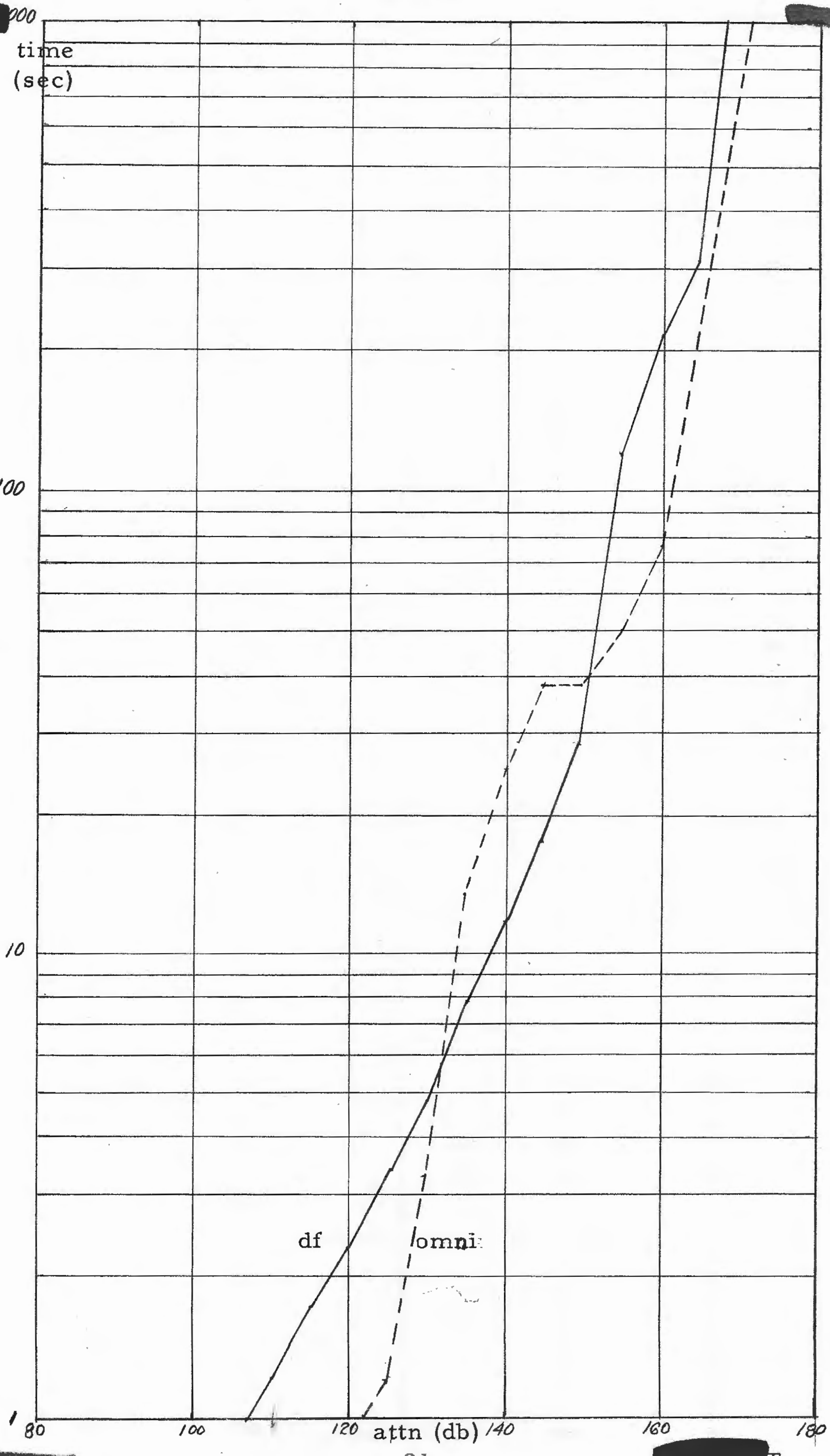


FIGURE 18
Waiting time for 0.25 prob. of int.

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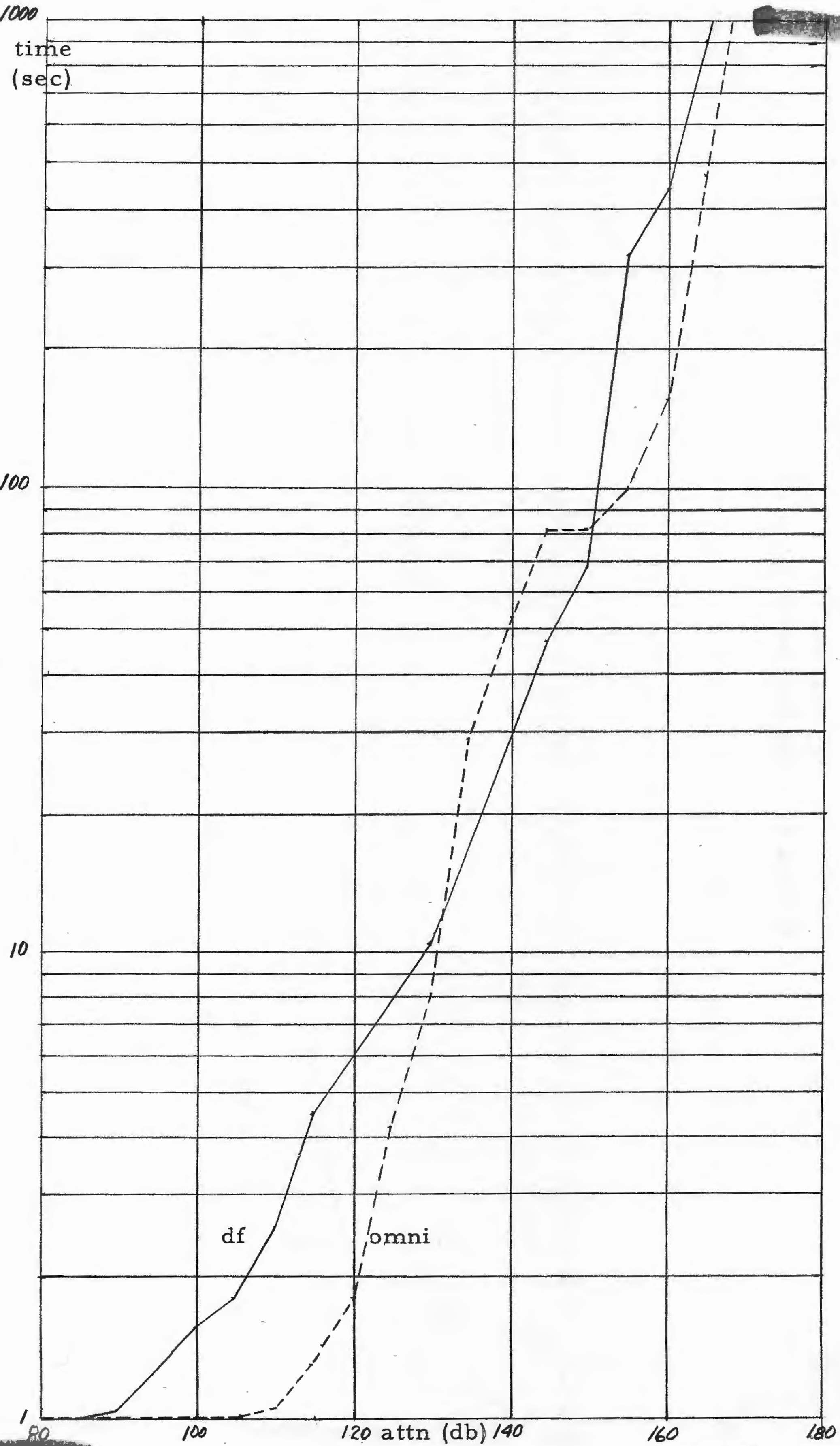

FIGURE 19
Waiting time for 0.50 prob. of int.

[redacted]

[redacted]

[redacted] [redacted]

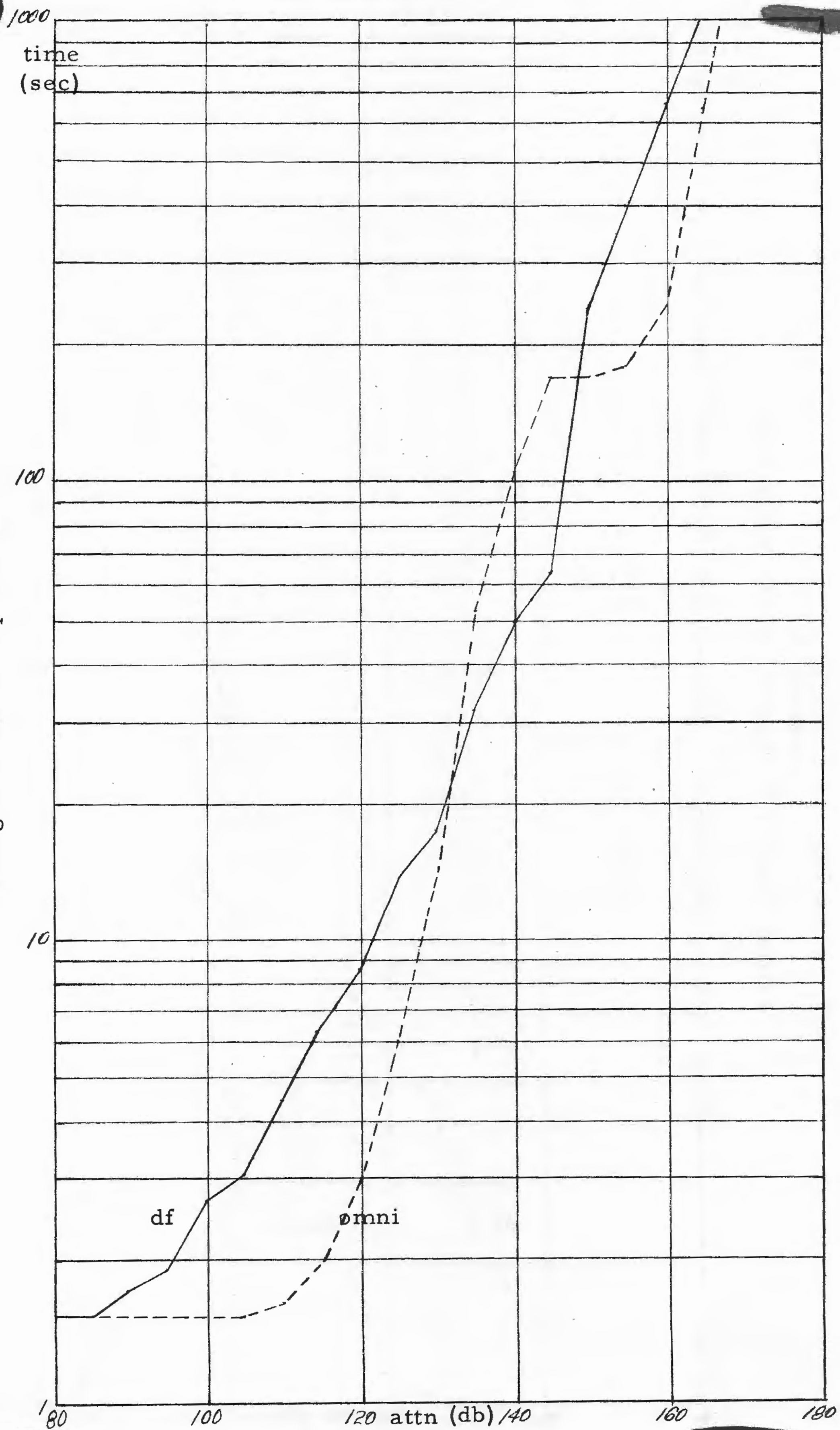

FIGURE 20
Waiting time for 0.75 prob. of int.

[redacted] [redacted]

[redacted]T [redacted]

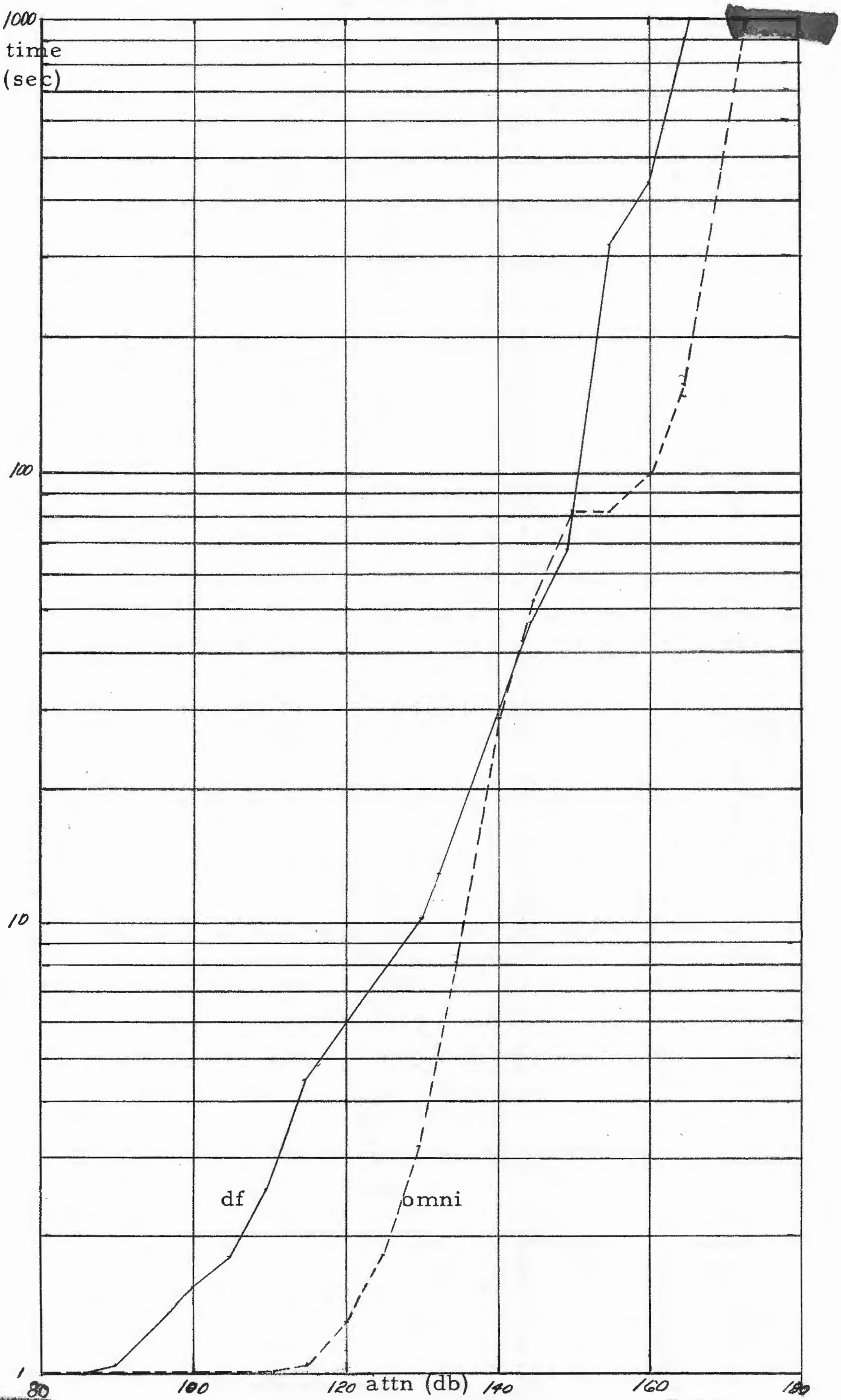

FIGURE 21
Waiting time for 0.50 prob. of int. (omni +1 db)

[redacted] [redacted]T

[redacted] DECLASSIFIED [redacted]

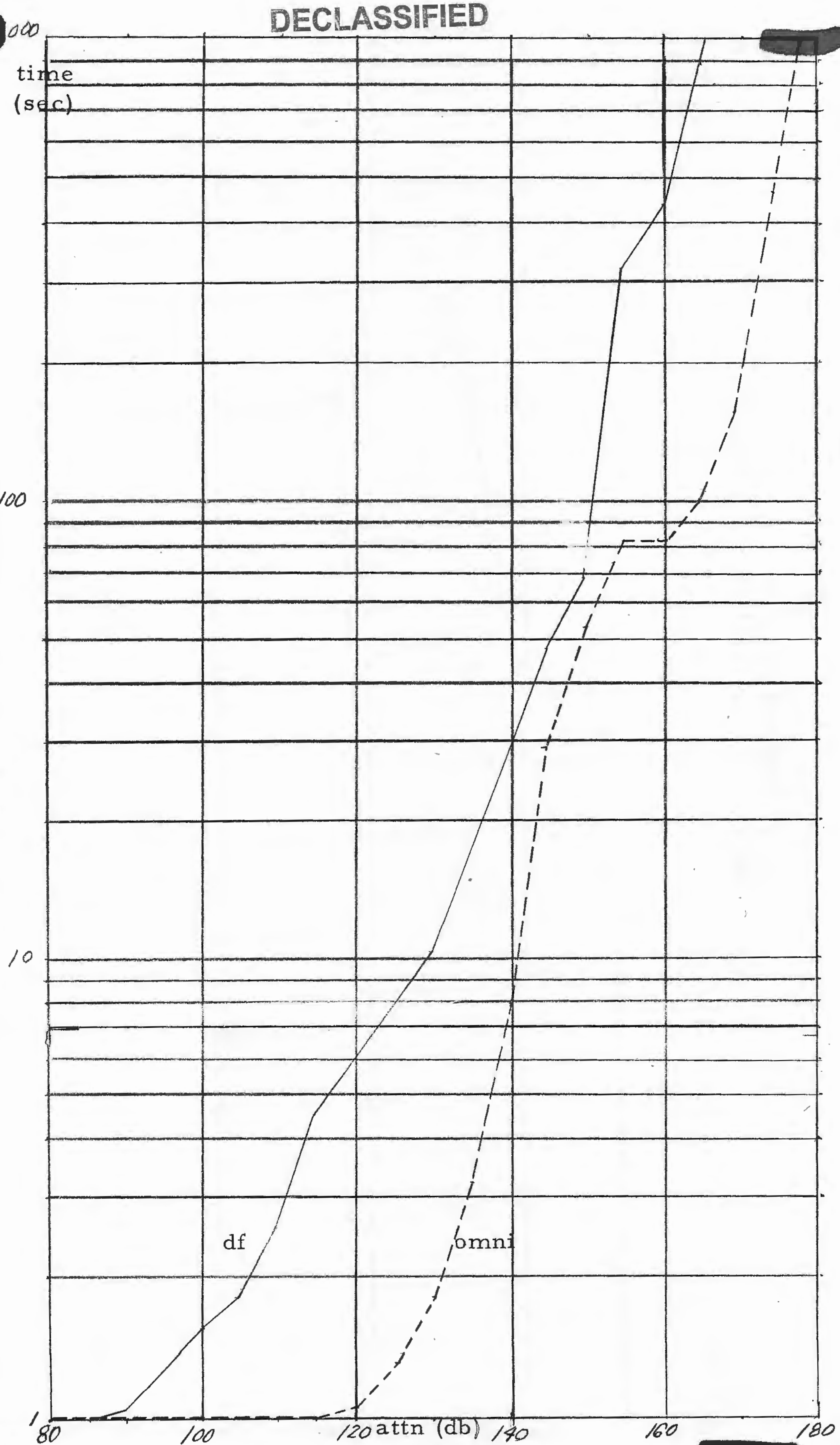

FIGURE 22
Waiting time for 0.50 prob. of int. (omni +6 db)

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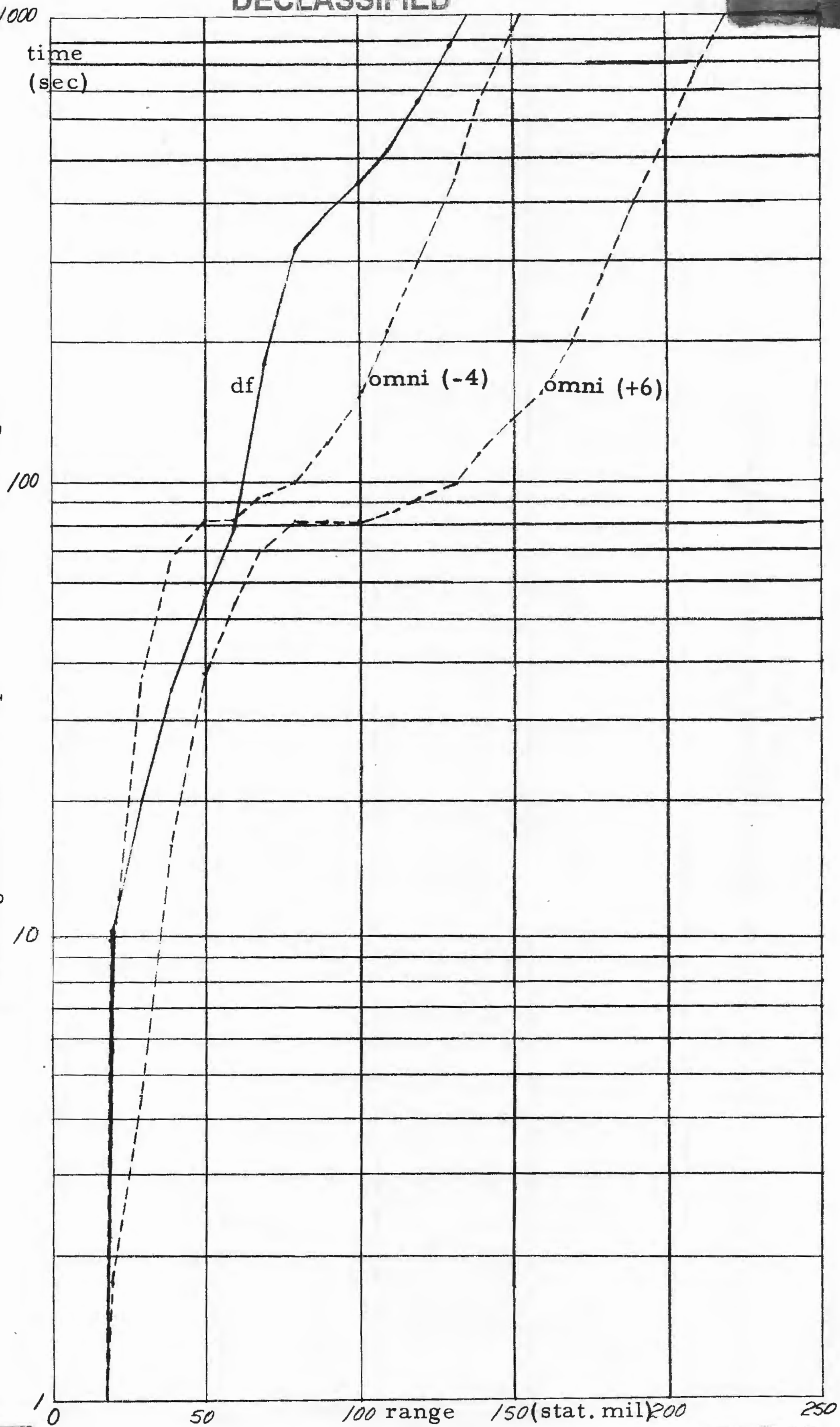

FIGURE 23
Waiting time for 0.50 prob. of int. vs. range

	Copy No.
CNO	
Attn: Code Op-371C	1 - 2
Code Op-314	3
Code Op-347	4
Code Op-30GT	5 - 6
Code Op-555C	7
Code Op-316	8
Code Op-302T-7	9
Code Op-922F2 (ONI)	10
ONR	
Attn: Code 460	11 - 12
Code 427	13
Code 931	14
BuShips	
Attn: Code 840 (10 cys)	15 - 24
BuAer	
Attn: AV-42 (5 cys)	25 - 29
BuOrd	
Attn: Code ReSl	30 - 31
USNADC, Johnsville, Pa.	
Attn: Code EL-95	32
USNEL, San Diego	
Attn: Library	33
USNAMTC, Pt. Mugu, Calif.	34
CO, USN School, Electronics Technician, USN Training Center, Great Lakes, Ill.	35 - 36
OCSigO	
Attn: Ch. Res. & Dev. Div., SIGEB-C	37 - 38
DSCD, Hq., USAF, Directorate of Res. & Dev.	
Attn: AFDRD-EL-2	39 - 40
CG, Air Proving Ground, Eglin AFB	
Attn: Electronics Branch, Operational Test Div.	41 - 42
SCEL, Fort Monmouth, N. J.	
Attn: Dir., Countermeasures Div.	43
Chief of Staff, Air Force, Pentagon	
Attn: AFOAC-E	44
AFDRD-SC-3	45