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VLBA ELEMENT OPERATING PROBABILITY USING VLA RELIABILITY DATA

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This memorandum defines Optimum Reliability, and discusses the VLA reliability experience as related to the VLB array, VLBA element operating probability, and gives a Summary of results. It is assumed that the VLB array will be of modular design and its modules will be typical of modules used in the VLA. This simple analysis will provide some data to allow operating system trade-off vs the "Suggested Number of Spare Modules for the VLB Array" by A.R. Thompson in his memorandum (VLBA Number 53) date January 7, 1982.

I Optimum Reliability

Deciding what type of system provides the minimum total life cost concerns basically the following extreme design approaches:

a) A system design that requires a large number of spare units. This approach has a high maintenance and repair cost with the added cost of equipment unable to operate.

b) A highly reliable system with its high design cost and more expensive component cost.

c) These two approaches will most likely be comparable in total life cost. The minimum total life cost lies somewhere in between and therefore is the Optimum Reliability Point. This optimum reliability point reflects a moderate initial design and component cost and a reasonable (small) number of spares and reduced maintenance and repair cost. The total life cost

of these two approaches is depicted graphically in Figure 1.

II VLA Reliability Experience as Related to the VLB Array

If we assume the 10 element VLB array is of similar design to the 27 element VLA design and that Critical Modules (A critical module if failed would put the whole element out of operation) can be cross shipped from the Central Maintenance Station or a secondary distribution station to a site in 24 hrs or less.

Then based on the above assumptions we can use the VLA experience to predict the VLBA reliability.

a) Probability of Failure [1] of an array element is given by

$$P = \frac{MTTR+T_A}{MTBF}$$

where

P = probability of failure

MTTR = Meantime To Repair

T_A = Access Time

MTBF = Mean Time Between Failures

For the VLA and VLBA the MTTR is small compared to T_A. Then we can simplify P to

$$P = \frac{T_A}{MTBF}$$

The average access time for the VLA is 12 hours. The average access time for the VLBA could be in the range 29 to 43 hours with an average of 36 hours as shown in Table I.

Then $P_{(VLBA)}$ becomes

$$P_{(VLBA)} = P_{(VLA)} \times \frac{T_{A\ (VLBA)}}{T_{A\ (VLA)}}$$

Using the VLA Summary of Downtime for 1981 we can predict the downtime for the VLBA. (See Appendix I). For example, for T_A(VLBA) = 24 hours.

$$\text{Critical Modules } P_{(VLBA)} = 1.54 \times \frac{24}{12} = 3.08\%$$

$$\text{Total System } P_{(VLBA)} = (1.54 + 1.69)\ \frac{24}{12} = 6.46\%$$

III VLBA Element Operating Probability. We can relate $P_{(VLBA)}$ to the probability of >N Antennas Operating [1] by the probability of "P_k" of "K" failures in an "N" element array. P_k is given by the binomial distribution.

$$P_K = \frac{N!}{K!\ (N-K)} \times P^K \times (1-p)^{N-K}$$

This binomial distribution for a 10 element array is shown in Figure 2 and 3. From Figure 2 and 3 we can see that for a $P_{(VLBA)}$ calculated for T_A of 0.5, 1, 2 and 3 day the operational probability will be as shown in TABLE II, and Figures 4, 5 and 6.

Access times of 1 to 2 days appear to provide a reasonable operational goal.

IV Summary

a. It is beyond the scope of this memorandum to assign costs to >N elements operating and the associated lost data and the cost trade-off for reliability vs design cost to predict the curve shown in Figure 1.

b. All critical modules do not have to be stocked at each site.

c. The shipping time of 24 hours can be reduced to 12 hours in special cases while a compromise of critical module spares kept at the site would improve the reliability at an additional total life cost.

d. A cost trade-off study of critical module size and weight Vs shipping cost should be under taken.

e. Design considerations for equipment safety vs critical modules should be considered i.e. capability of manually or automatically driving the antenna to the stow position with a defective antenna control unit.

f. System performance without a cryogenic system operating or one frequency band not operating for a short period of time should be considered. All of the above items and other considerations will determine the total life cost and therefore the optimum reliability.

JC/bg

REFERENCES

1) VLA Reliability and Maintenance

An Early Look

Balister, Fisher, Pyane and Weinreb

VLA Electronics Memorandum #165

2) VLA Summary of Downtime for 1981

Table I

Average Access Time (T_A) For Two Possible VLBA Sites

Site Location	Trouble occurs	Module Transportation Schedule*				
		LV Socorro**	Arr Alb	Arr Airport Near Site	Installed** At Site	Access Time
Anchorage Al	0500	0900	1100	2300	1200	31
	1700	0900	1100	2300	1200	43
Bishop CA	0500	0900	1100	0800	1000	29
	1700	0900	1100	0800	1000	41

Average Access Time (T_A) = 36

* Module Transportation Schedule was arrived at using official Airline Guide - North American Edition.

** 1. Working Hours

Assume each site work 0800 to 1700 Local Standard Time

2. Times

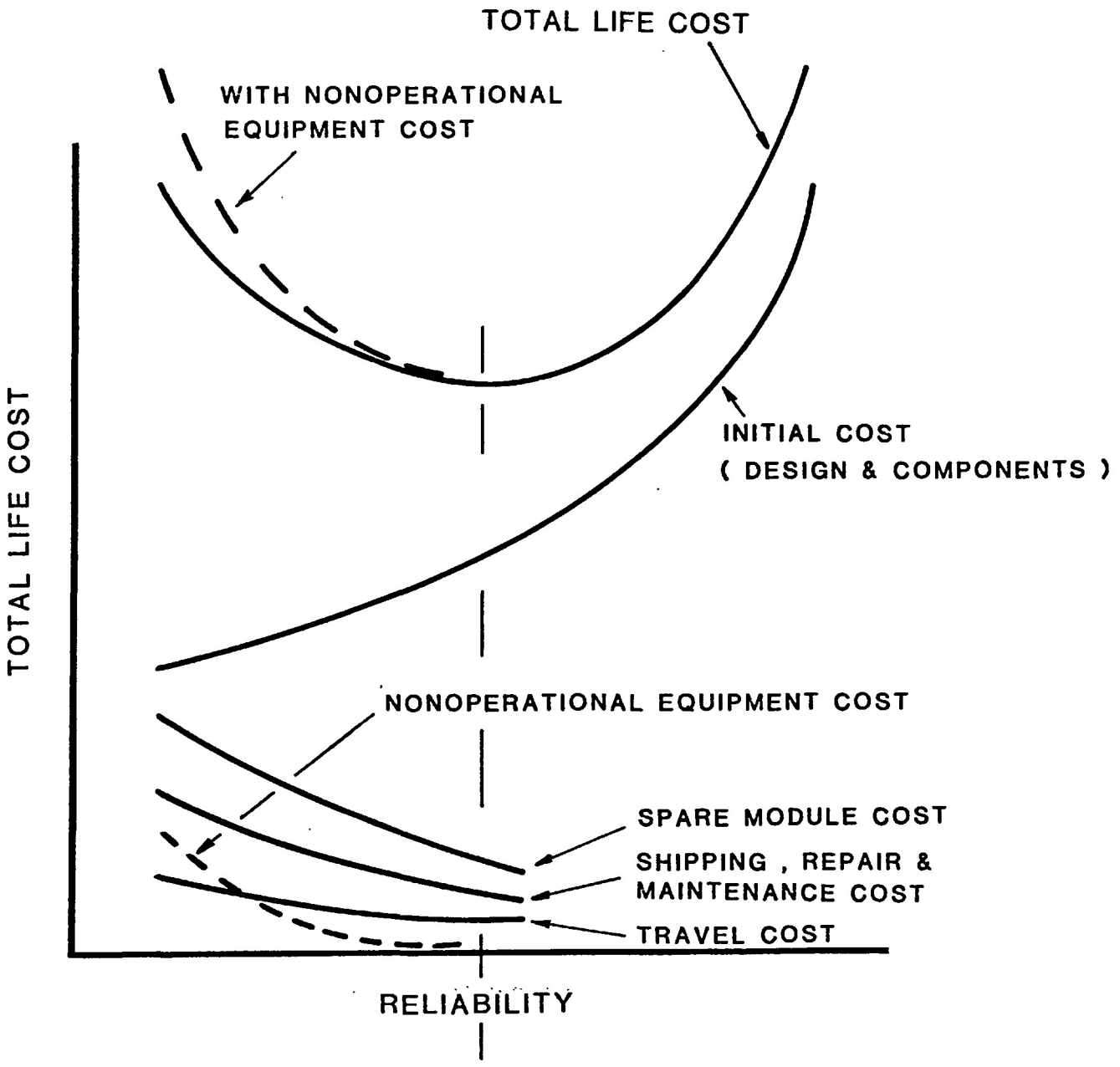
All Times listed are Mountain Standard Time for Alaska/Hawaii Standard Time Subtract 3 hours for Pacific Standard Time Subtract 1 hour.

TABLE II

PROBABILITY OF >N ANTENNAS

OPERATIONAL

>N		SYSTEM OPERATING CONDITION							
		SOME DEGRADATION				COMPLETE OPERATION			
	T_A=	0.5	1	2	3	0.5	1	2	3
10		85	74	53	38	72	52	25	11
9		98.9	96.2	87	76	96.2	87	62	39
8		99.95	99.7	97.8	94	99.68	97.6	86.5	69
7		>99.99	99.8	99.7	98.9	99.98	99.7	96.8	85



TOTAL LIFE COST vs RELIABILITY

FIGURE 1

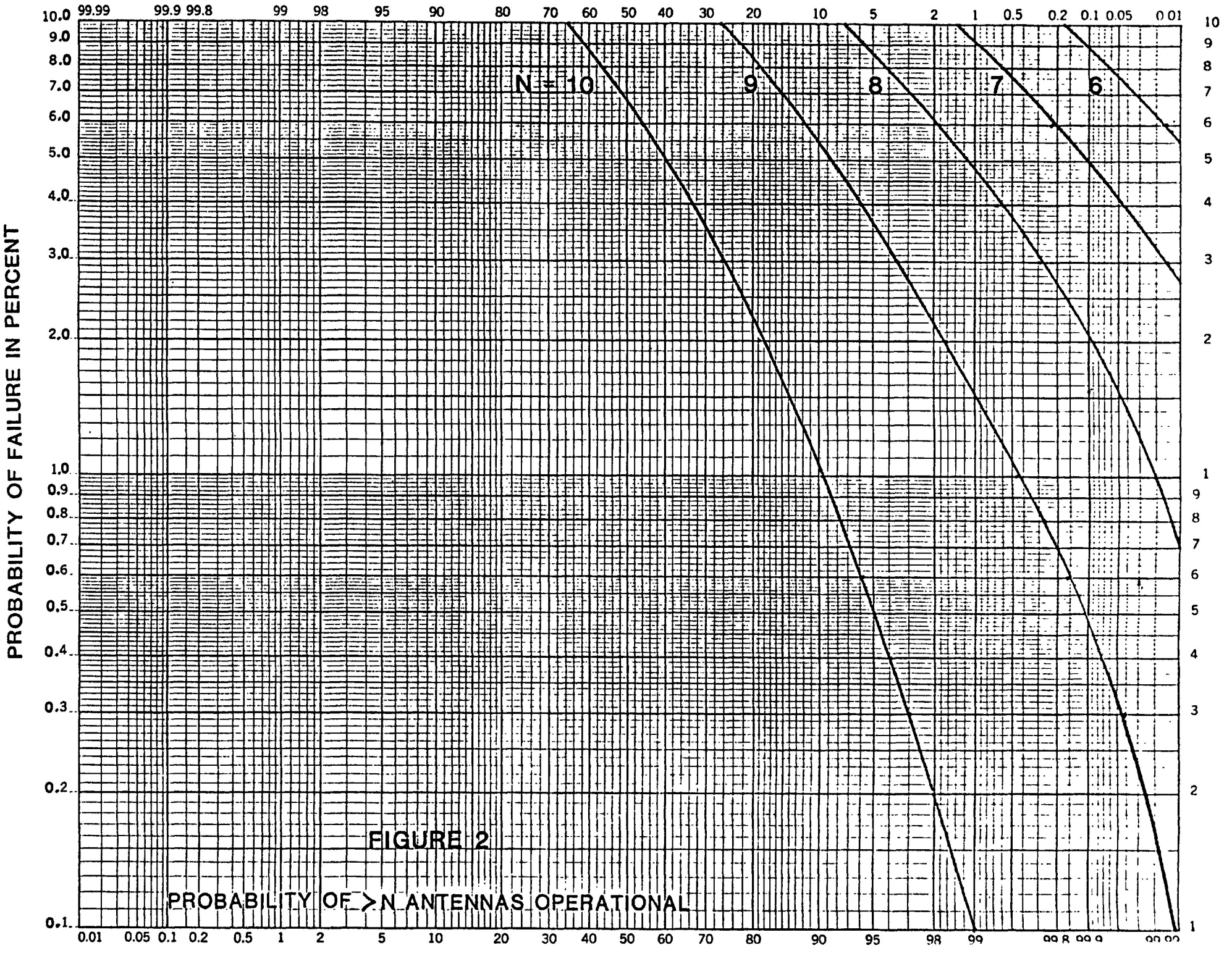


FIGURE 2

PROBABILITY OF ≥N ANTENNAS OPERATIONAL

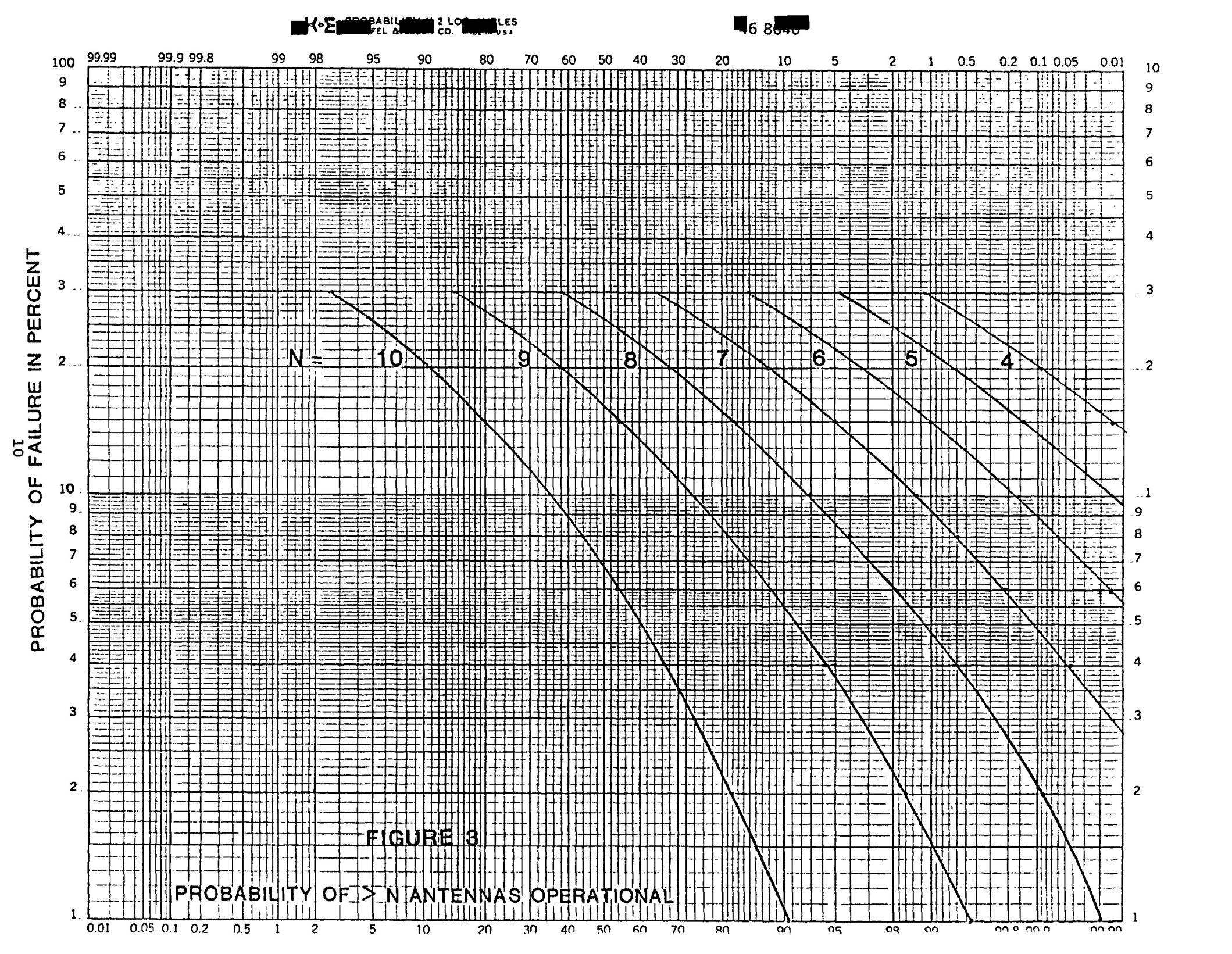
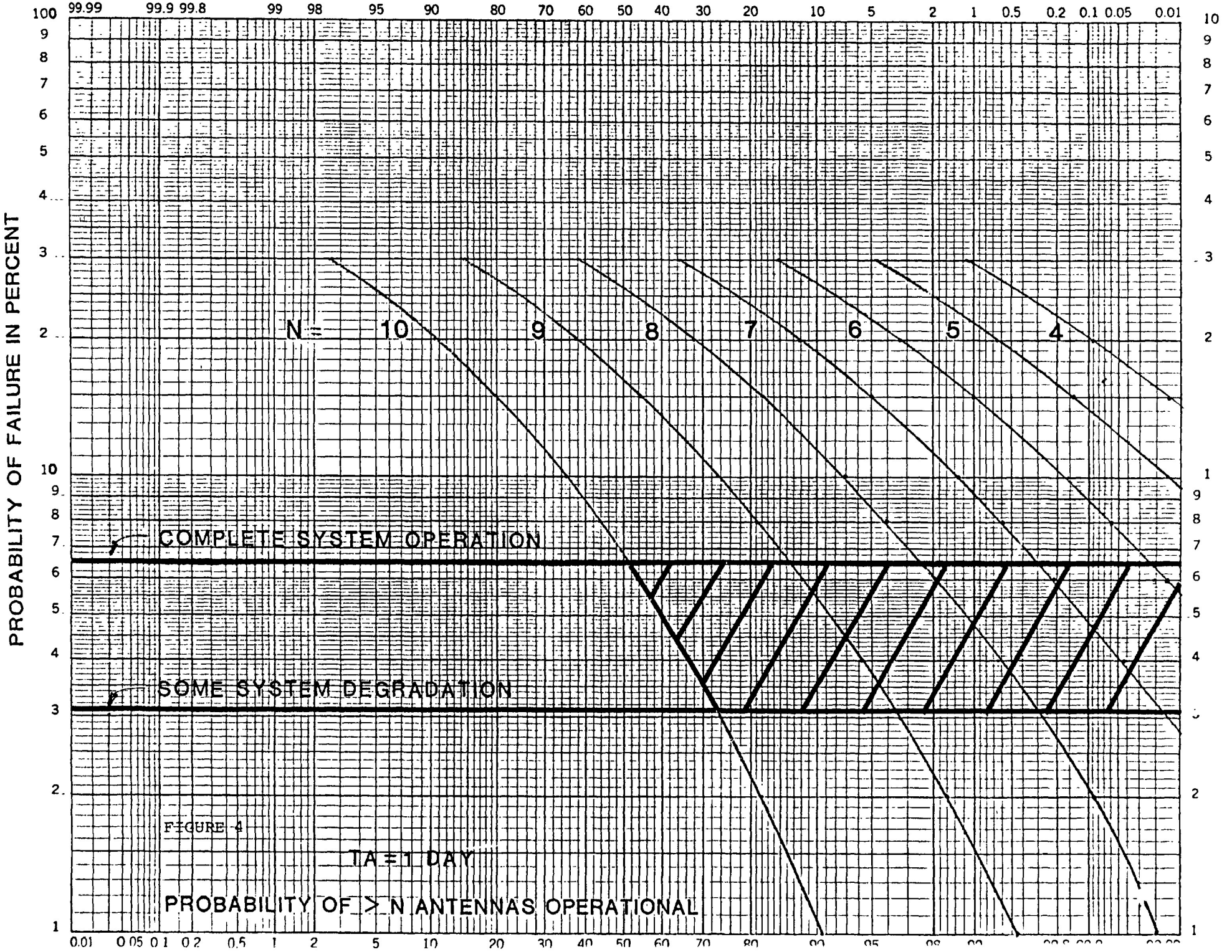

PROBABILITY OF FAILURE IN PERCENT
OR
PROBABILITY OF > N ANTENNAS OPERATIONAL
N = 10
9
8
7
6
5
4
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01

FIGURE 3



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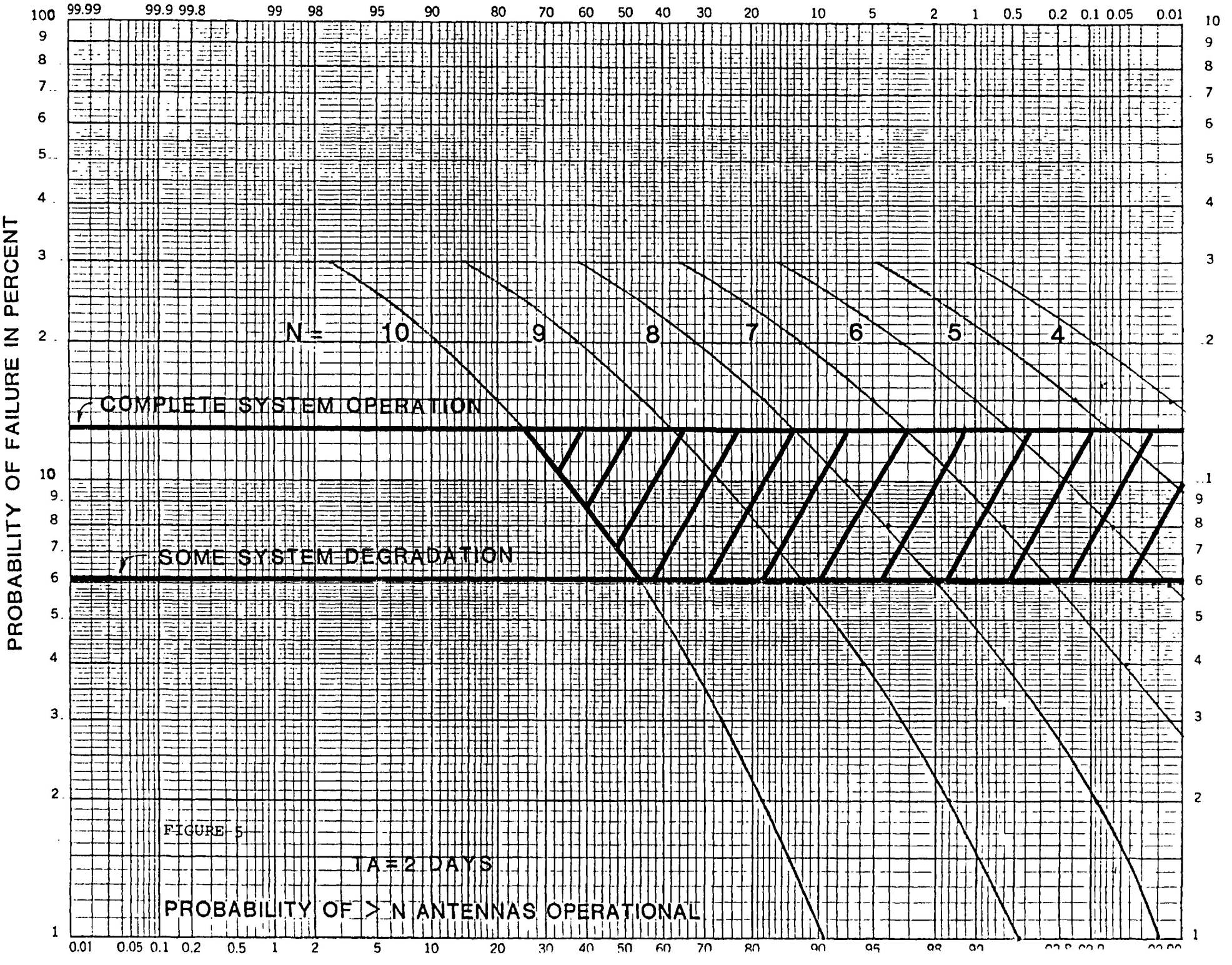

FIGURE 5

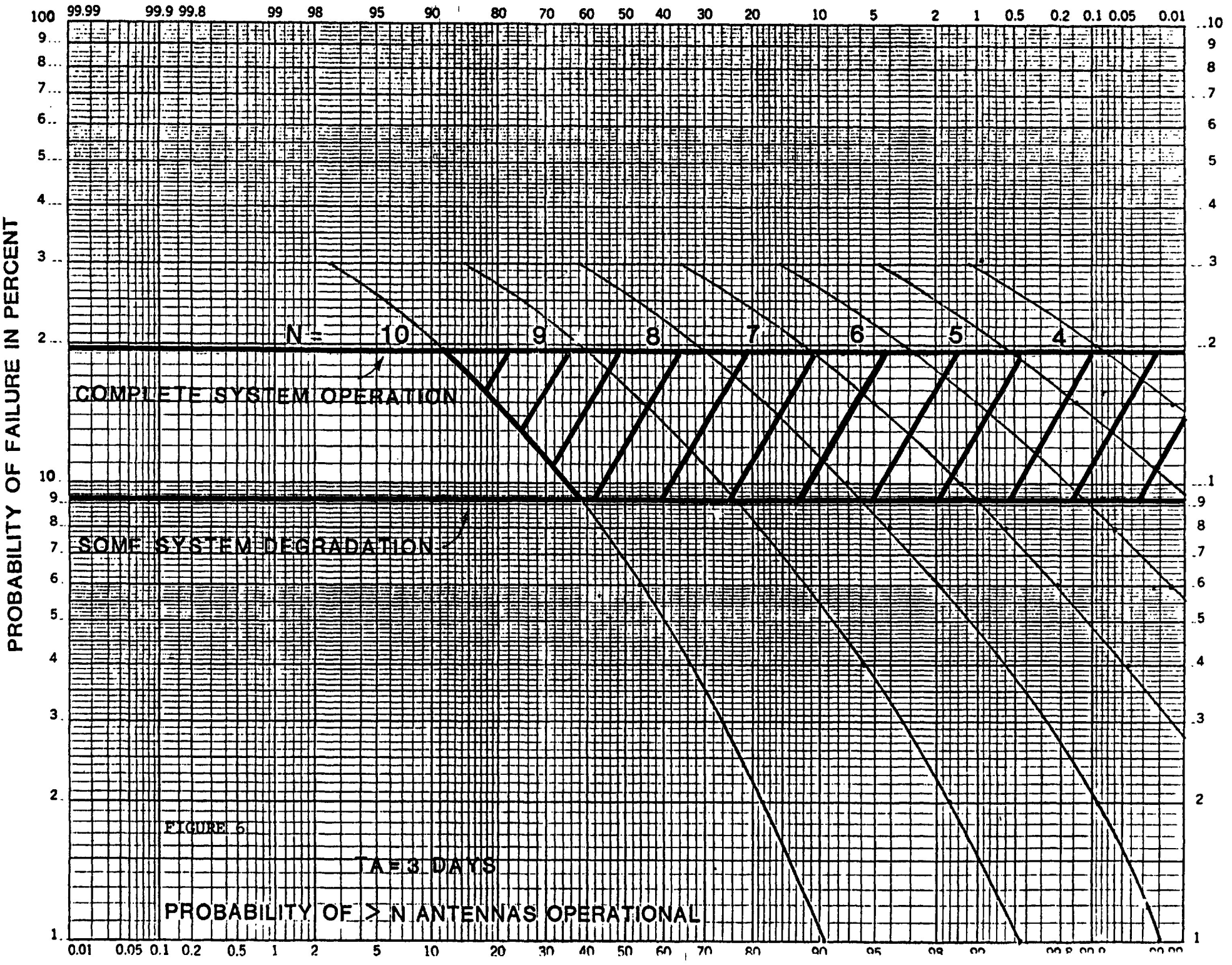
PROBABILITY OF FAILURE IN PERCENT
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98
N = 10 9 8 7 6 5 4
COMPLETE SYSTEM OPERATION
SOME SYSTEM DEGRADATION
TA = 3 DAYS
PROBABILITY OF ≥ N ANTENNAS OPERATIONAL

FIGURE 6

Appendix I

The VLA Downtime Summary for the year 1981 was reviewed and used to define the critical and non-critical areas. The critical are defined as that area that will remove the whole element (Antenna System) from operation. The results of this review is shown in TABLE I of this Appendix.

APPENDIX I
TABLE I
DOWNTIME BREAKDOWN
BY SUB-SYSTEM OR CATEGORY

SUB-SYSTEM OR CATEGORY	TOTAL VLA %	VLBI CRITICAL	VLBI NON-CRITICAL	REMARKS
ANTENNA MECHANICAL	0.24	0.24		
ANTENNA ELECTRICAL	0.34	0.34		
FRONT END COOLED	0.46		0.46	System will operate but not on all Frequencies
FRONT END UNCOOLED	0.39		0.39	System will operate but not on all Frequencies
CRYOGENICS	0.35		0.35	System will operate but with degraded performance
MONITOR AND CONTROL	0.38	0.19	0.19	Monitor not as critical as control
FOCUS/ROTATION	0.11		0.11	Present system being redesigned.
WAVEGUIDE	0.01			Not required VLBI
L.O. ANTENNA	0.19	0.19		
L.O. CENTRAL	0.05	0.05		
IF TRANSMISSION	0.03			Not require VLBI
IF RECEIVERS & SAMPLERS	0.06		0.06	
DELAY AND MULTIPLIER	0.27			Off Line for VLBI
COMPUTER HARDWARE	0.40	0.40		
OTHER HARDWARE	0.02		0.02	
HU-ERROR	0.13	0.13		
SOFTWARE	1.41			Manpower priority can be fixed
WEATHER	0.29			Not the same at each site
POWER	0.20			Not the same at each site
UNSCHEDULED TEST	0.01		0.01	
P/M, RETRO, EXP MODULES	0.10		0.10	
TOTAL	5.44	1.54	1.69	