Land Mobile Satellite Transmission Measurements at 869 MHz

A Comparison of Error Probabilities for Various Message Block Durations and Fade Margins as a Function of Vegetation Shadowing.

by

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1. Introduction

In order to give vehicles travelling in rural areas of the United States access to the telephone network, a Land Mobile Satellite System (LMSS) is being planned. A previous report (Vogel,1985) described an experiment which made use of a balloon borne transmitter in order to simulate LMSS transmissions. The received signal power and phase at 869.5 MHz were recorded in a mobile van as it followed the balloon across eastern Texas, Louisiana, Mississippi and into Alabama.

The data presented previously have now been analyzed for the probability that the received signal level dropped below a threshold during short time blocks of various durations and the conditional probability that such an event would reoccur after a given delay. If it is assumed that a fade threshold crossing of even 1 msec would produce an error in the transmission, then the derived quantities can be considered error probabilities.

Extensive tables and graphs are presented with the results from the analysis. They can be used to devise communication strategies which will provide improved link availability in the presence of vegetation shadowing.

2. The Data Base

The data were collected at elevation angles from 30 to 50 degrees at normal highway speeds (from 10 mph up) with a crossed drooping dipole receiving antenna. They were analyzed for three categories of vegetation shadowing:

1) None

This group includes data collected over a cumulative driving distance of 45.5 miles (75 km) at an average speed of 51.7 mph with a standard deviation of 8.6 mph. No shadowing by roadside trees occurred, but signal blockage due to highway overpasses is included.

2) Infrequent

This group includes data collected over a cumulative driving distance of 16.6 miles (27 km) at an average speed of 53.7 mph with a standard deviation of 5.5 mph. Shadowing by roadside trees occurred for less than half the time during any one minute.

3) Frequent

This group includes data collected over a cumulative driving distance of 32.1 miles (53 km) at an average speed of 47.4 mph with a standard deviation of 7.9 mph. Shadowing by roadside trees occurred for more than half the time during any one minute.

2. Analysis Procedure

The data were originally recorded on analog tape and then sampled and digitized at a rate of 1,000 samples per second. The digitizing program stored the data in files, each of which contained 63 records of 1.024 seconds duration. Computing overhead resulted in a sampling gap of 22 milliseconds between each record and of several seconds between each file. A shadowing classification was made for each file.

The analysis was made for time block durations of 25, 50, 75, 100, 125 and 150 milliseconds. Each class of data was converted to a contiguous record of signal level minima with respect to the line-of-sight level during consecutive 25 milliseconds. For simplification only 40 such values were obtained for each 1.046 sec sample plus gap record, resulting in a contraction of 46 milliseconds for each second. Similarly, files in each classification group were concatenated even if they were not contiguous in time. This procedure resulted in three representative data files on which the analysis was performed. The simplifications made should have a negligible effect on the outcome for the type of delay considered.

Thresholds were 3, 6, 9, 12 and 15 dB below the line-of-sight level. It should be noted that this level was estimated a posteriori from the data by averaging the mean level of several one second records in each file for

which a low variance and a high signal level indicated that no shadowing was present.

The quantities calculated were error probabilities and conditional error probabilities, i.e. the probabilities that given an error occurred, one would again occur after a delay of 1 to 6 blocks or of 1 to 5, 10, 20, 40, 80 or 160 seconds.

3. Results

The error probabilities for the three classes, depending on the signal level threshold and the time block duration, are given in Tables 1,2 and 3. Without vegetation shadowing, the probabilities for thresholds from -6dB are below .5 percent and are only weakly dependent upon the time block duration. For the infrequent class, the probabilities for the larger thresholds are actually below those for the no shading class. This is due to the fact that the "none" class contained more highway overpasses than the "infrequent" class. A similar trend has already been observed in the power level distribution functions given in the previously mentioned report. The error probabilities are quite high for the "frequent" class, from 55% at a threshold of -3dB and 150 msec time blocks to 3.7% at -15dB and 25 msec, respectively.

Tables 4 to 6 give the conditional error probabilities. Even for the "none" class a -3dB threshold is clearly insufficient and there is a strong correlation for short delays. After 4 seconds the probability of a repeated error is very small. Curiously, it increases again, albeit to a low value, in the delay range of 20 and 40 seconds. At an average speed of about 24 meters per second, this implies that some shadowing occurrs with a periodicity of about .5 to 1 km. A similar effect can be observed in the infrequent shadowing results but does not appear or is masked in the frequent shadowing data. For this class after a delay of about 20 seconds not much more error decorrelation occurrs.

For convenience, graphs have been included (Figs.1 through 33) which allow for an easier comparison of the dependence of the error probabilities on the various parameters.

The first three repeat the information presented in Tables 1 through 3. One can see that for no or infrequent shadowing there is a large decrease in error probabilities when increasing the fade margin from 3 to 6 dB. In all cases the error probability increases as the time block length varies from

25 to 150 msec. The same can not be said about the conditional probabilities. For the 25 msec blocks, these tend to be larger at the very short delays. This is probably related to the scale size of the individual shadowing objects. For the frequent shadowing case, most delay gain is achieved after about 20 to 40 seconds. After that the error probabilities decrease only by a few percent as the delay is increased to 160 seconds.

Reference

Vogel, W. J., "Land Mobile Satellite Transmission Measurements at 869 MHz: Selected Results from the Dedicated Stratospheric Balloon Experiment of November 12 and 13, 1984," MSAT-X Report 106, Jet Propulsion Laboratory, Pasadena, Ca, 12 April 1985

TABLE 1

Probablities in percent that the received signal power at 869.5 MHz was ever below the line-of-sight level by 3 to 15 dB during time blocks of 25 to 150 msec. The values are derived from balloon measurements with **no vegetation shadowing** over a cumulative driving distance of 45.5 miles at an average speed of 51.7 mph.

Level	Time Block Duration - msec					
dB	25	50	75	100	125	150
-3	2.54	3.38	3.99	4.48	4.91	5.30
-6	0.32	0.34	0.35	0.37	0.39	0.40
-9	0.29	0.31	0.33	0.34	0.36	0.37
-12	0.26	0.28	0.30	0.31	0.33	0.34
-15	0.24	0.27	0.29	0.30	0.32	0.33

TABLE 2

Probablities in percent that the received signal power at 869.5 MHz was ever below the line-of-sight level by 3 to 15 dB during time blocks of 25 to 150 msec. The values are derived from balloon measurements with **infrequent vegetation shadowing** over a cumulative driving distance of 16.6 miles at an average speed of 53.7 mph.

Level	Time Block Duration - msec					
dB	25	50	75	100	125	150
-3	6.39	9.23	11.37	13.12	14.59	15.87
-6	0.71	0.96	1.16	1.34	1.50	1.65
-9	0.24	0.33	0.40	0.47	0.53	0.58
-12	0.15	0.19	0.23	0.26	0.29	0.33
-15	0.10	0.13	0.15	0.18	0.20	0.22

TABLE 3

Probablities in percent that the received signal power at 869.5 MHz was ever below the line-of-sight level by 3 to 15 dB during time blocks of 25 to 150 msec. The values are derived from balloon measurements with **frequent vegetation shadowing** over a cumulative driving distance of 32.1 miles at an average speed of 47.4 mph.

Level	Time Block Duration - msec					
dB	25	50	75	100	125	150
-3	39.91	45.44	48.91	51.45	53.45	55.13
-6	21.95	26.10	28.68	30.46	31.81	32.90
-9	12.26	16.17	18.82	20.82	22.42	23.75
-12	6.73	9.67	11.91	13.72	15.24	16.54
-15	3.70	5.71	7.38	8.81	10.06	11.19

TABLE 4

Conditional probabilities in percent: Given the received signal power at 869.5 MHz was ever below the line-of-sight level by 3 to 15 dB during time blocks of duration 25 to 150 msec, that during a like time block after a delay of 1 time block to 160 seconds the same level would again be crossed. The values are derived from balloon measurements with **no vegetation shadowing** over a cumulative driving distance of 45.5 miles at an average speed of 51.7 mph.

Level	Time Block Duration - msec						Delay
dB	25	50	75	100	125	150	
-3	66.95	62.92	66.63	65.21	64.06	62.64	1 Block
-6	94.85	42.42	46.55	51.81	49.69	57.56	1 Block
-9	94.64	43.51	46.97	46.06	50.33	58.51	1 Block
-12	92.77	37.36	41.22	45.82	44.55	53.36	1 Block
-15	87.13	26.61	40.55	45.19	44.42	52.97	1 Block
-3	64.59	64.48	63.85	61.75	63.34	65.07	2 Blocks
-6	90.20	47.79	52.34	60.13	60.12	78.98	2 Blocks
-9	89.28	48.09	46.97	59.26	61.64	60.64	2 Blocks
-12	86.75	42.13	45.21	53.92	56.90	56.84	2 Blocks
-15	80.53	41.23	44.66	52.99	52.11	54.16	2 Blocks
-3	63.10	59.75	61.85	63.22	64.73	67.39	3 Blocks
-6	85.78	53.61	59.47	61.19	72.60	72.89	3 Blocks
-9	84.45	48.09	57.87	57.87	74.28	74.68	3 Blocks
-12	81.63	46.07	54.79	58.99	76.03	67.05	3 Blocks
-15	76.57	45.32	53.97	55.58	76.67	67.70	3 Blocks
-3	62.98	64.44	65.43	65.00	67.46	65.60	4 Blocks
-6	81.37	53.61	62.36	73.56	65.85	55.80	4 Blocks
-9	79.62	51.65	58.60	75.23	58.31	56.81	4 Blocks
-12	76.51	44.10	53.99	76.96	58.11	56.15	4 Blocks
-15	72.28	43.27	50.41	72.99	53.85	56.77	4 Blocks

Table 4 Level dB	Conditional Probabilities / No Shadowing Time Block Duration - msec 25	50	75	100	125	150	Delay
-3	62.23	61.99	64.70	68.61	65.01	66.67	5 Blocks
-6	76.96	58.28	74.61	62.05	54.40	52.26	5 Blocks
-9	74.80	58.78	60.53	58.33	55.21	41.49	5 Blocks
-12	71.08	55.62	56.38	58.23	51.82	42.69	5 Blocks
-15	67.00	50.29	56.44	53.77	52.36	38.48	5 Blocks
-3	61.40	64.37	64.46	68.71	66.85	68.23	6 Blocks
-6	72.55	58.28	74.61	55.44	51.94	40.86	6 Blocks
-9	69.97	53.94	75.79	52.78	41.24	28.51	6 Blocks
-12	65.66	54.78	68.09	52.15	37.53	23.20	6 Blocks
-15	61.72	50.88	68.49	52.73	38.21	23.28	6 Blocks
-3	48.37	52.13	52.96	53.23	53.36	53.33	1 Second
-6	10.05	10.02	10.02	10.02	10.02	10.02	1 Second
-9	9.92	9.92	9.93	9.95	9.98	10.00	1 Second
-12	9.64	9.55	9.57	9.62	9.69	9.74	1 Second
-15	9.24	9.06	9.04	9.09	9.18	9.26	1 Second
-3	45.18	48.26	48.49	48.39	48.21	47.99	2 Seconds
-6	6.37	6.29	6.24	6.18	6.34	6.48	2 Seconds
-9	6.43	6.36	6.30	6.25	6.21	6.38	2 Seconds
-12	5.72	5.62	5.59	5.57	5.57	5.57	2 Seconds
-15	5.94	5.85	5.75	5.71	5.71	5.70	2 Seconds
-3	42.79	45.47	45.92	46.10	46.15	46.21	3 Seconds
-6	0.74	0.93	1.56	2.13	2.66	3.14	3 Seconds
-9	0.00	0.25	0.73	1.39	2.00	2.55	3 Seconds
-12	0.00	0.00	0.00	0.76	1.45	2.09	3 Seconds
-15	0.00	0.00	0.00	0.26	0.99	1.66	3 Seconds
-3	39.81	42.60	43.03	43.15	43.22	43.14	4 Seconds
-6	0.00	0.00	0.00	0.00	0.00	0.00	4 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	4 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	4 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	4 Seconds

Table 4 Level dB	Conditional Probabilities / No Shadowing Time Block Duration - msec 25	50	75	100	125	150	Delay
-3	38.48	41.27	41.59	41.23	40.84	40.45	5 Seconds
-6	0.00	0.00	0.00	0.00	0.00	0.00	5 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	5 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	5 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	5 Seconds
-3	30.02	31.58	31.43	31.36	31.20	31.04	10 Seconds
-6	0.00	0.00	0.00	0.00	0.00	0.00	10 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	10 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	10 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	10 Seconds
-3	18.67	19.97	19.65	19.36	19.19	19.13	20 Seconds
-6	0.00	0.00	0.22	0.43	0.61	0.79	20 Seconds
-9	0.00	0.00	0.00	0.23	0.44	0.64	20 Seconds
-12	0.00	0.00	0.00	0.25	0.48	0.70	20 Seconds
-15	0.00	0.00	0.00	0.26	0.50	0.71	20 Seconds
-3	4.31	5.45	6.35	7.00	7.55	8.00	40 Seconds
-6	0.00	0.00	0.22	0.43	0.61	0.79	40 Seconds
-9	0.00	0.00	0.00	0.23	0.44	0.64	40 Seconds
-12	0.00	0.00	0.00	0.00	0.24	0.46	40 Seconds
-15	0.00	0.00	0.00	0.00	0.25	0.48	40 Seconds
-3	3.53	4.01	4.59	5.09	5.49	5.93	80 Seconds
-6	0.00	0.00	0.00	0.00	0.00	0.00	80 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	80 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	80 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	80 Seconds
-3	6.88	9.30	10.54	11.14	11.48	11.69	160 Seconds
-6	0.00	0.00	0.00	0.00	0.00	0.00	160 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	160 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	160 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	160 Seconds

TABLE 5

Conditional probabilities in percent: Given the received signal power at 869.5 MHz was ever below the line-of-sight level by 3 to 15 dB during time blocks of duration 25 to 150 msec, that during a like time block after a delay of 1 time block to 160 seconds the same level would again be crossed. The values are derived from balloon measurements with **infrequent vegetation shadowing** over a cumulative driving distance of 16.6 miles at an average speed of 53.7 mph.

Level	Time Block Duration - msec						Delay
dB	25	50	75	100	125	150	
-3	55.44	41.73	51.17	55.64	62.81	63.99	1 Block
-6	64.44	17.33	20.46	30.70	35.97	40.16	1 Block
-9	66.97	13.10	15.17	23.08	23.83	29.34	1 Block
-12	70.77	21.43	18.81	29.31	26.72	31.51	1 Block
-15	71.74	25.42	21.74	18.99	37.08	44.44	1 Block
-3	49.09	46.44	54.72	57.30	64.00	68.05	2 Blocks
-6	52.06	20.37	35.71	32.89	35.37	47.76	2 Blocks
-9	48.62	16.55	21.91	31.25	38.72	45.95	2 Blocks
-12	52.31	19.05	32.67	36.21	39.69	37.67	2 Blocks
-15	63.04	25.42	44.93	50.63	55.06	52.53	2 Blocks
-3	46.63	46.66	52.24	59.11	64.84	64.70	3 Blocks
-6	46.67	27.17	29.92	40.60	41.04	45.05	3 Blocks
-9	42.20	22.07	29.78	40.38	51.91	47.49	3 Blocks
-12	47.69	38.10	39.60	42.24	44.27	30.14	3 Blocks
-15	52.17	25.42	55.07	58.23	33.71	31.31	3 Blocks
-3	45.44	53.44	55.89	62.18	59.91	65.18	4 Blocks
-6	41.90	31.38	34.94	39.09	44.03	41.25	4 Blocks
-9	39.45	24.83	42.70	45.67	43.83	26.25	4 Blocks
-12	41.54	38.10	45.54	32.76	30.53	28.08	4 Blocks
-15	41.30	50.85	62.32	34.18	25.84	9.09	4 Blocks

Table 5 Conditional Probabilities / Infrequent Shadowing							
Level	Time Block Duration - msec						Delay
dB	25	50	75	100	125	150	
-3	43.40	43.45	59.89	57.64	62.43	65.52	5 Blocks
-6	37.46	20.84	41.70	42.79	40.75	37.18	5 Blocks
-9	33.03	33.79	45.51	44.71	27.23	46.33	5 Blocks
-12	32.31	45.24	38.61	31.03	27.48	41.10	5 Blocks
-15	34.78	61.02	30.43	26.58	8.99	24.24	5 Blocks
-3	41.26	48.92	57.66	61.47	60.26	63.85	6 Blocks
-6	33.65	29.98	39.19	36.91	37.61	29.72	6 Blocks
-9	29.36	33.79	28.09	27.88	46.38	34.75	6 Blocks
-12	29.23	51.19	27.72	26.72	40.46	13.70	6 Blocks
-15	32.61	61.02	27.54	8.86	23.60	20.20	6 Blocks
-3	27.21	36.43	42.24	46.45	49.58	52.01	1 Second
-6	3.81	5.39	6.95	8.05	8.96	10.04	1 Second
-9	0.00	0.00	0.00	0.00	0.00	0.00	1 Second
-12	0.00	0.00	0.00	0.00	0.00	0.00	1 Second
-15	0.00	0.00	0.00	0.00	0.00	0.00	1 Second
-3	21.95	31.65	37.84	42.11	45.15	47.51	2 Seconds
-6	3.81	5.15	6.37	7.38	8.51	9.23	2 Seconds
-9	0.92	2.07	2.81	3.37	3.83	4.25	2 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	2 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	2 Seconds
-3	19.31	28.71	34.79	38.98	42.23	44.83	3 Seconds
-6	1.90	2.81	3.67	4.19	4.93	5.70	3 Seconds
-9	0.92	1.38	1.69	1.92	2.13	2.32	3 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	3 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	3 Seconds
-3	16.08	25.21	31.30	35.37	38.31	40.67	4 Seconds
-6	1.27	2.58	2.90	3.36	3.88	4.21	4 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	4 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	4 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	4 Seconds

Table 5 Conditional Probabilities / Infrequent Shadowing							
Level	Time Block Duration - msec						Delay
dB	25	50	75	100	125	150	
-3	16.40	24.48	29.90	33.94	36.76	38.91	5 Seconds
-6	1.27	2.11	2.51	3.02	3.43	3.93	5 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	5 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	5 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	5 Seconds
-3	12.39	19.04	23.59	26.42	28.39	30.09	10 Seconds
-6	1.27	1.41	1.35	1.51	1.64	1.90	10 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	10 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	10 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	10 Seconds
-3	9.97	15.89	19.98	23.17	25.53	27.47	20 Seconds
-6	0.32	0.47	0.97	1.34	1.64	2.04	20 Seconds
-9	0.00	0.00	0.00	0.00	0.43	0.77	20 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	20 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	20 Seconds
-3	12.82	17.29	20.31	22.37	24.09	25.49	40 Seconds
-6	3.81	4.68	5.21	5.37	5.67	5.97	40 Seconds
-9	1.83	2.07	2.25	2.40	2.98	3.09	40 Seconds
-12	0.00	0.00	0.00	0.86	1.53	2.05	40 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	40 Seconds
-3	5.02	7.51	9.5	11.45	13.13	14.66	80 Seconds
-6	0.00	0.23	0.58	0.67	0.75	0.81	80 Seconds
-9	0.00	0.00	0.00	0.00	0.00	0.00	80 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	80 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	80 Seconds
-3	13.20	17.83	20.73	23.02	24.87	26.41	160 Seconds
-6	2.22	3.28	4.05	4.36	4.48	4.48	160 Seconds
-9	0.00	0.00	0.00	0.48	0.85	1.16	160 Seconds
-12	0.00	0.00	0.00	0.00	0.00	0.00	160 Seconds
-15	0.00	0.00	0.00	0.00	0.00	0.00	160 Seconds

TABLE 6

Conditional probabilities in percent: Given the received signal power at 869.5 MHz was ever below the line-of-sight level by 3 to 15 dB during time blocks of duration 25 to 150 msec, that during a like time block after a delay of 1 time block to 160 seconds the same level would again be crossed. The values are derived from balloon measurements with **frequent vegetation shadowing** over a cumulative driving distance of 32.1 miles at an average speed of 47.4 mph.

Level	Time Block Duration - msec						Delay
dB	25	50	75	100	125	150	
-3	86.13	81.33	82.85	84.44	85.22	86.60	1 Block
-6	81.08	72.39	75.55	78.99	81.60	82.58	1 Block
-9	68.15	57.57	62.88	65.94	70.49	73.98	1 Block
-12	56.22	42.21	52.53	56.95	60.19	63.90	1 Block
-15	45.75	30.82	40.87	45.80	48.72	50.47	1 Block
-3	83.06	81.52	82.66	84.53	86.65	87.46	2 Blocks
-6	75.15	71.43	76.14	80.03	82.70	84.31	2 Blocks
-9	57.83	57.40	63.35	70.36	72.70	76.25	2 Blocks
-12	43.04	45.86	53.37	54.90	61.02	67.77	2 Blocks
-15	31.27	34.01	39.99	40.99	48.69	57.09	2 Blocks
-3	82.24	80.91	83.49	85.41	86.59	87.95	3 Blocks
-6	73.22	71.76	78.22	81.83	82.02	85.12	3 Blocks
-9	54.73	56.48	65.78	68.30	73.57	77.36	3 Blocks
-12	38.86	44.97	50.68	59.02	63.90	68.32	3 Blocks
-15	27.94	32.79	35.79	48.12	51.53	58.33	3 Blocks
-3	81.78	81.23	84.60	85.47	87.49	89.10	4 Blocks
-6	71.73	72.54	78.57	80.83	84.24	83.26	4 Blocks
-9	52.93	59.21	63.86	71.49	75.04	77.57	4 Blocks
-12	36.59	41.30	52.85	59.11	63.84	68.41	4 Blocks
-15	26.09	31.65	42.39	46.18	51.17	57.84	4 Blocks

Table 6 Conditional Probabilities / Frequent Shadowing							
Level	Time Block Duration - msec						Delay
dB	25	50	75	100	125	150	
-3	81.16	82.06	84.55	86.20	87.79	86.47	5 Blocks
-6	70.33	73.92	77.50	82.75	82.44	82.08	5 Blocks
-9	51.00	59.85	67.06	72.62	74.54	74.87	5 Blocks
-12	35.45	42.75	54.12	59.25	65.12	66.11	5 Blocks
-15	24.54	28.20	42.16	47.34	52.70	55.77	5 Blocks
-3	80.50	82.78	83.80	86.30	85.80	87.59	6 Blocks
-6	68.85	75.45	79.99	80.65	80.54	83.89	6 Blocks
-9	49.20	59.28	67.25	70.01	72.83	76.85	6 Blocks
-12	33.25	42.44	53.90	60.51	62.65	64.64	6 Blocks
-15	23.39	31.77	41.61	49.50	50.97	53.71	6 Blocks
-3	70.65	75.36	77.63	79.13	80.33	81.33	1 Second
-6	54.92	62.24	66.37	68.98	70.79	72.15	1 Second
-9	38.01	47.19	52.79	56.67	59.67	62.07	1 Second
-12	24.90	33.85	39.89	44.24	47.75	50.70	1 Second
-15	15.61	22.44	27.88	32.27	35.88	39.21	1 Second
-3	66.20	71.02	73.54	75.18	76.46	77.56	2 Seconds
-6	50.37	57.43	61.25	63.66	65.34	66.61	2 Seconds
-9	33.64	42.35	47.77	51.58	54.46	56.77	2 Seconds
-12	21.12	29.27	34.91	39.11	42.64	45.55	2 Seconds
-15	13.04	19.13	23.92	28.00	31.40	34.41	2 Seconds
-3	63.15	68.07	70.65	72.40	73.78	74.96	3 Seconds
-6	47.66	54.54	58.20	60.41	62.00	63.23	3 Seconds
-9	32.05	40.51	45.63	49.26	52.13	54.35	3 Seconds
-12	20.15	27.90	33.06	36.89	40.13	42.86	3 Seconds
-15	12.91	19.01	23.70	27.44	30.67	33.34	3 Seconds
-3	60.83	66.05	68.72	70.49	71.89	73.02	4 Seconds
-6	44.45	51.03	54.64	57.02	58.73	60.06	4 Seconds
-9	30.15	37.55	42.43	45.94	48.64	50.79	4 Seconds
-12	19.13	26.35	31.12	34.72	37.69	40.17	4 Seconds
-15	12.66	18.11	22.21	25.62	28.70	31.37	4 Seconds

Table 6 Conditional Probabilities / Frequent Shadowing							
Level	Time Block Duration - msec						Delay
dB	25	50	75	100	125	150	
-3	59.23	64.23	66.88	68.63	70.05	71.16	5 Seconds
-6	42.38	48.97	52.74	55.11	56.83	58.14	5 Seconds
-9	27.95	35.65	40.46	43.95	46.60	48.72	5 Seconds
-12	17.44	24.31	29.11	32.84	35.79	38.29	5 Seconds
-15	10.98	16.07	20.25	23.67	26.63	29.11	5 Seconds
-3	54.10	59.03	61.62	63.42	64.80	65.94	10 Seconds
-6	37.80	44.38	47.95	50.19	51.77	52.99	10 Seconds
-9	22.87	30.37	35.04	38.41	41.16	43.36	10 Seconds
-12	14.21	20.65	25.08	28.43	31.17	33.58	10 Seconds
-15	8.88	13.59	16.96	19.80	22.47	24.89	10 Seconds
-3	48.03	53.43	56.50	58.65	60.37	61.81	20 Seconds
-6	31.43	37.57	41.00	43.20	44.75	45.94	20 Seconds
-9	18.28	24.96	29.40	32.59	35.06	37.06	20 Seconds
-12	10.55	15.66	19.54	22.81	25.44	27.69	20 Seconds
-15	6.01	9.58	12.51	14.83	17.03	19.06	20 Seconds
-3	46.53	51.90	54.97	57.16	58.93	60.38	40 Seconds
-6	30.24	36.14	39.32	41.37	42.87	44.01	40 Seconds
-9	17.56	23.90	27.94	30.97	33.37	35.34	40 Seconds
-12	9.81	14.98	18.83	21.88	24.34	26.49	40 Seconds
-15	5.82	8.94	11.83	14.41	16.53	18.45	40 Seconds
-3	45.47	50.94	54.14	56.40	58.18	59.71	80 Seconds
-6	29.33	34.91	37.84	39.61	40.87	41.77	80 Seconds
-9	17.76	23.67	27.50	30.35	32.57	34.33	80 Seconds
-12	10.07	14.67	18.07	21.00	23.35	25.39	80 Seconds
-15	5.87	9.42	12.14	14.56	16.59	18.40	80 Seconds
-3	47.99	53.08	55.92	57.92	59.42	60.67	160 Seconds
-6	29.97	35.79	38.99	41.03	42.54	43.72	160 Seconds
-9	16.93	22.65	26.47	29.24	31.53	33.36	160 Seconds
-12	8.87	13.26	16.83	19.73	22.11	24.18	160 Seconds
-15	4.80	7.83	10.37	12.62	14.58	16.38	160 Seconds

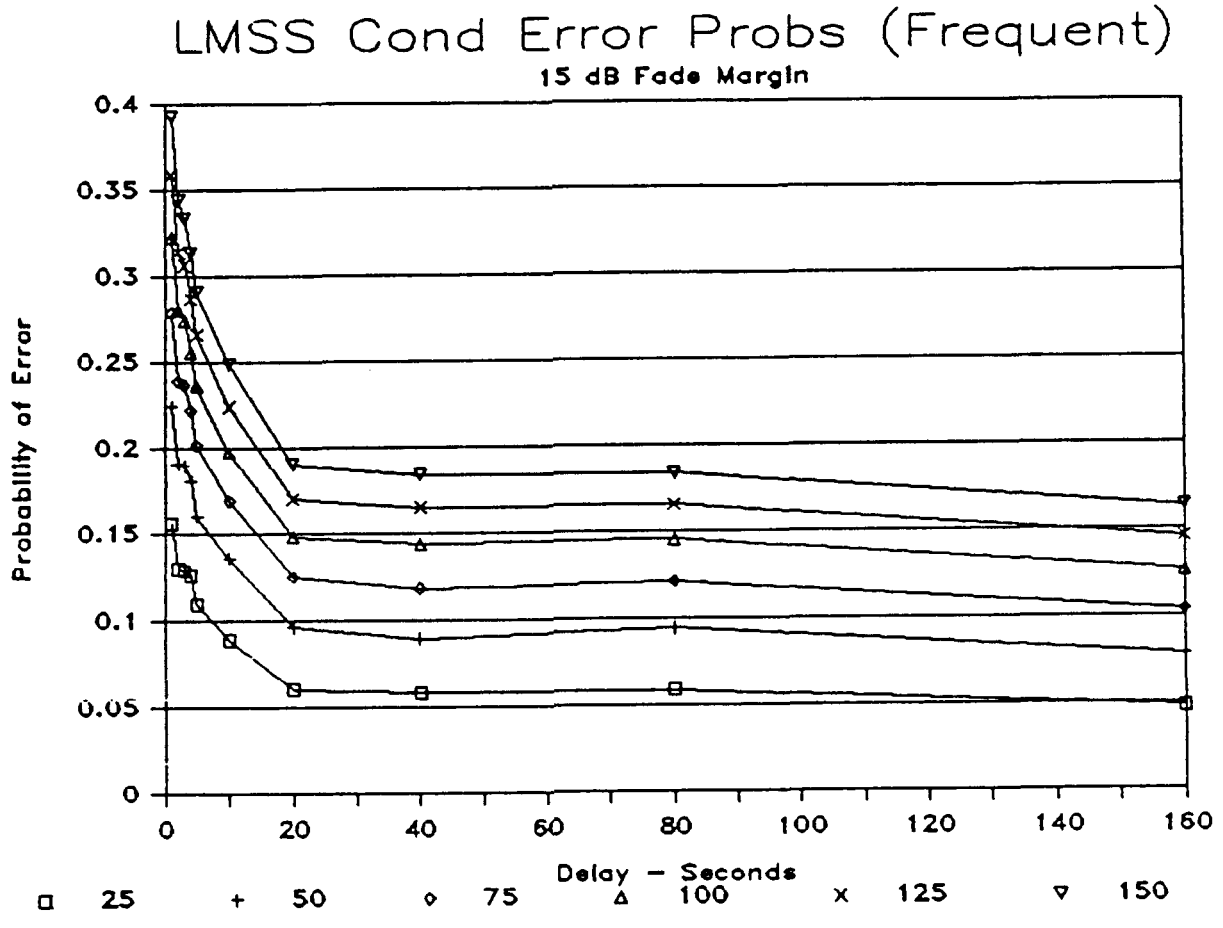
LMSS Cond Error Probs (Frequent)
15 dB Fade Margin
Probability of Error
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 1

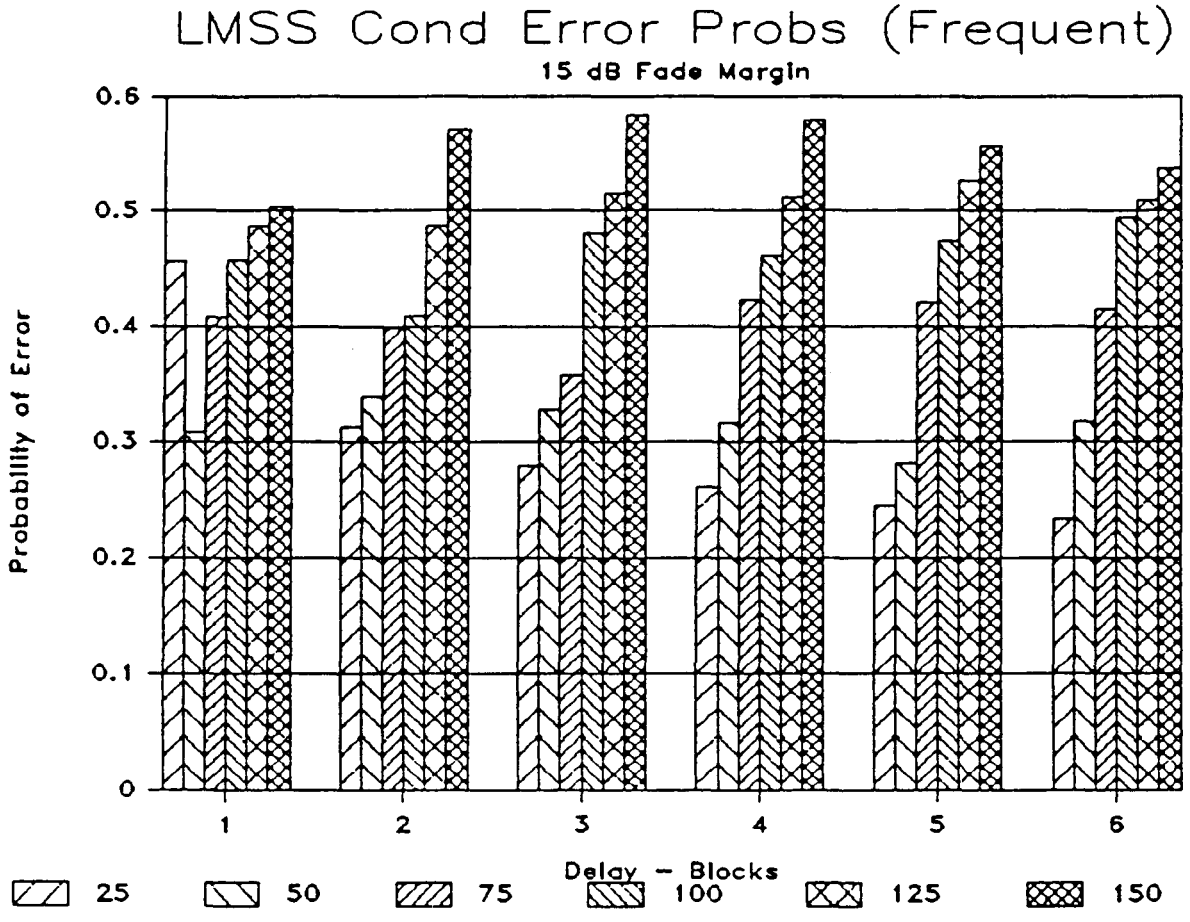
LMSS Cond Error Probs (Frequent)
15 dB Fade Margin
Probability of Error
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 2

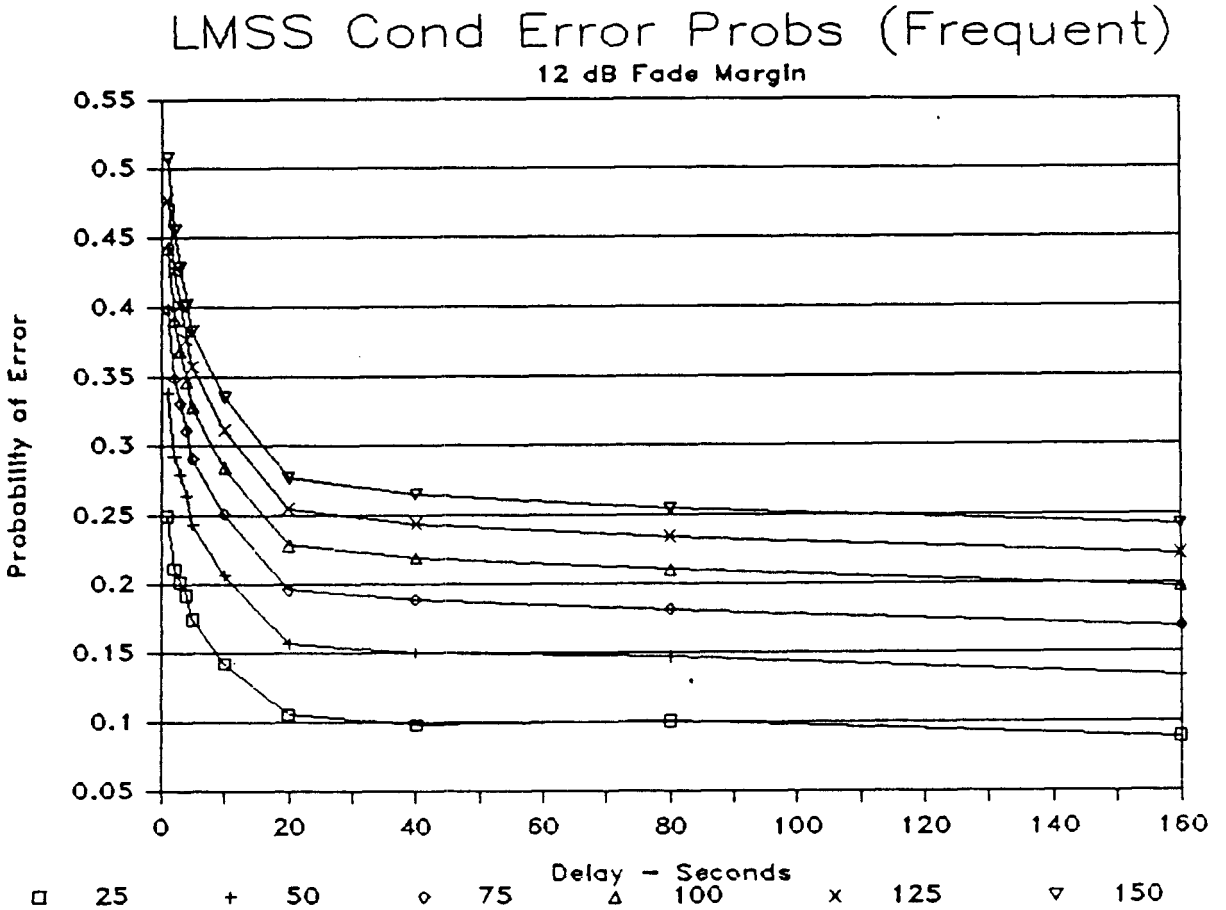
LMSS Cond Error Probs (Frequent)
12 dB Fade Margin
Probability of Error
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 3

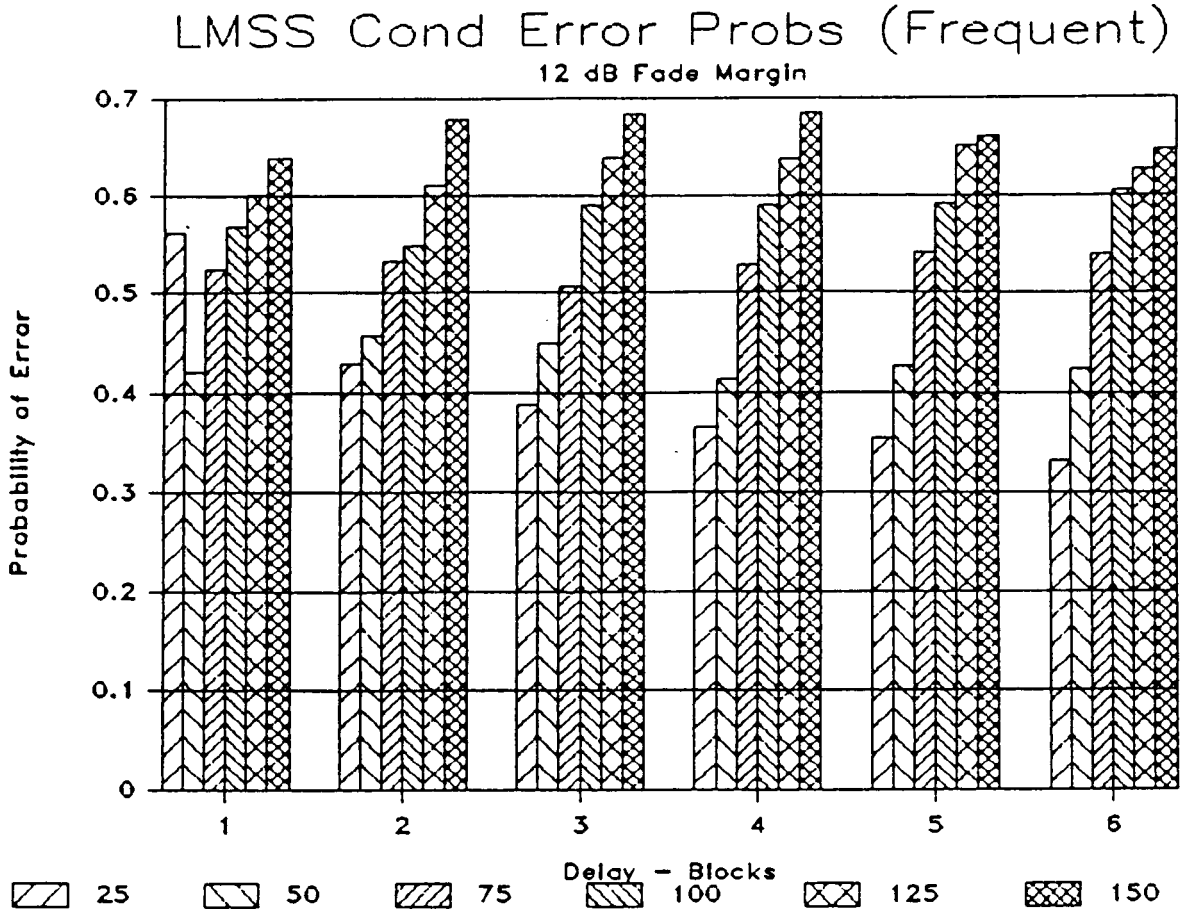
LMSS Cond Error Probs (Frequent)
12 dB Fade Margin
Probability of Error
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 4

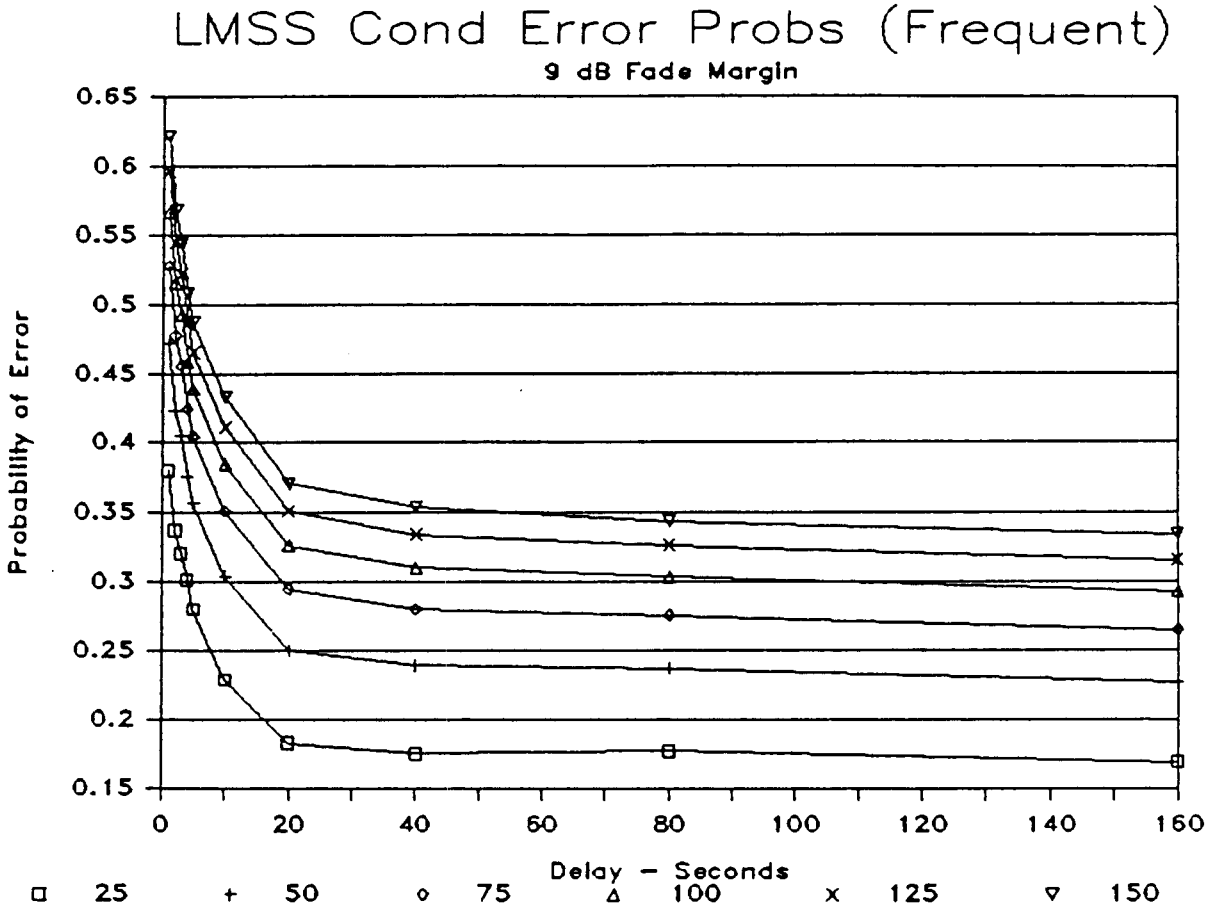
LMSS Cond Error Probs (Frequent)
9 dB Fade Margin
Probability of Error
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0
20
40
60
80
100
120
140
160
Delay – Seconds
□ 25
+ 50
◇ 75
△ 100
x 125
▽ 150

Figure 5

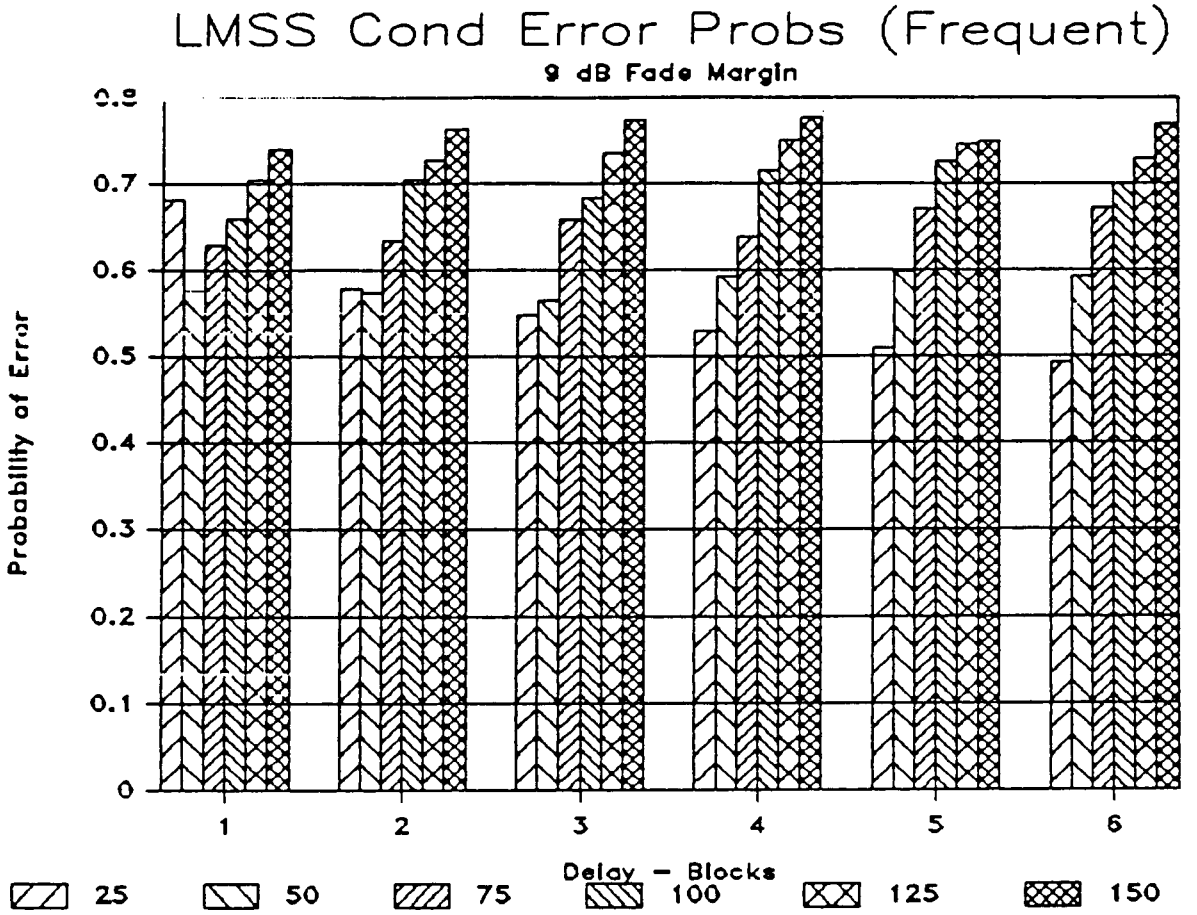
LMSS Cond Error Probs (Frequent)
9 dB Fade Margin
Probability of Error
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 6

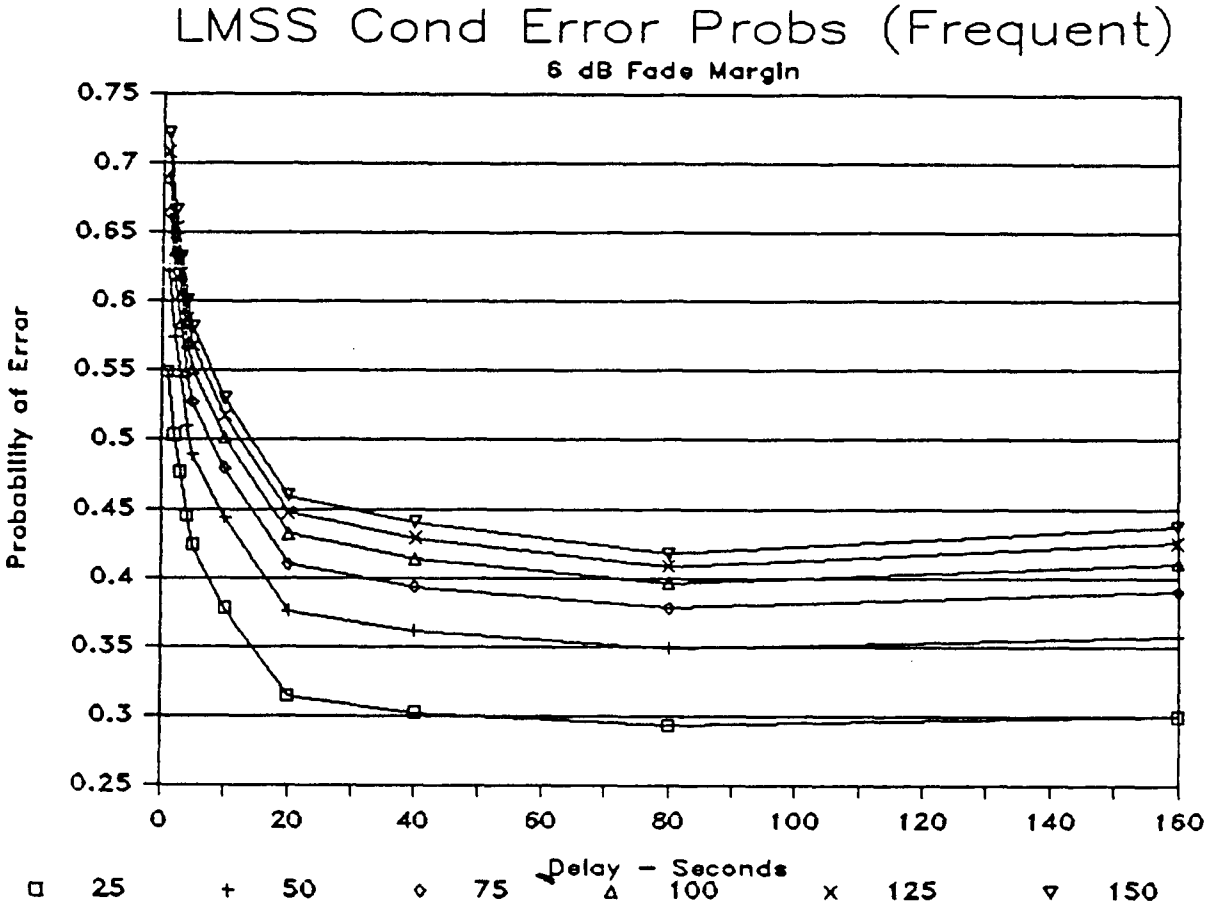
LMSS Cond Error Probs (Frequent)
6 dB Fade Margin
Probability of Error
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 7

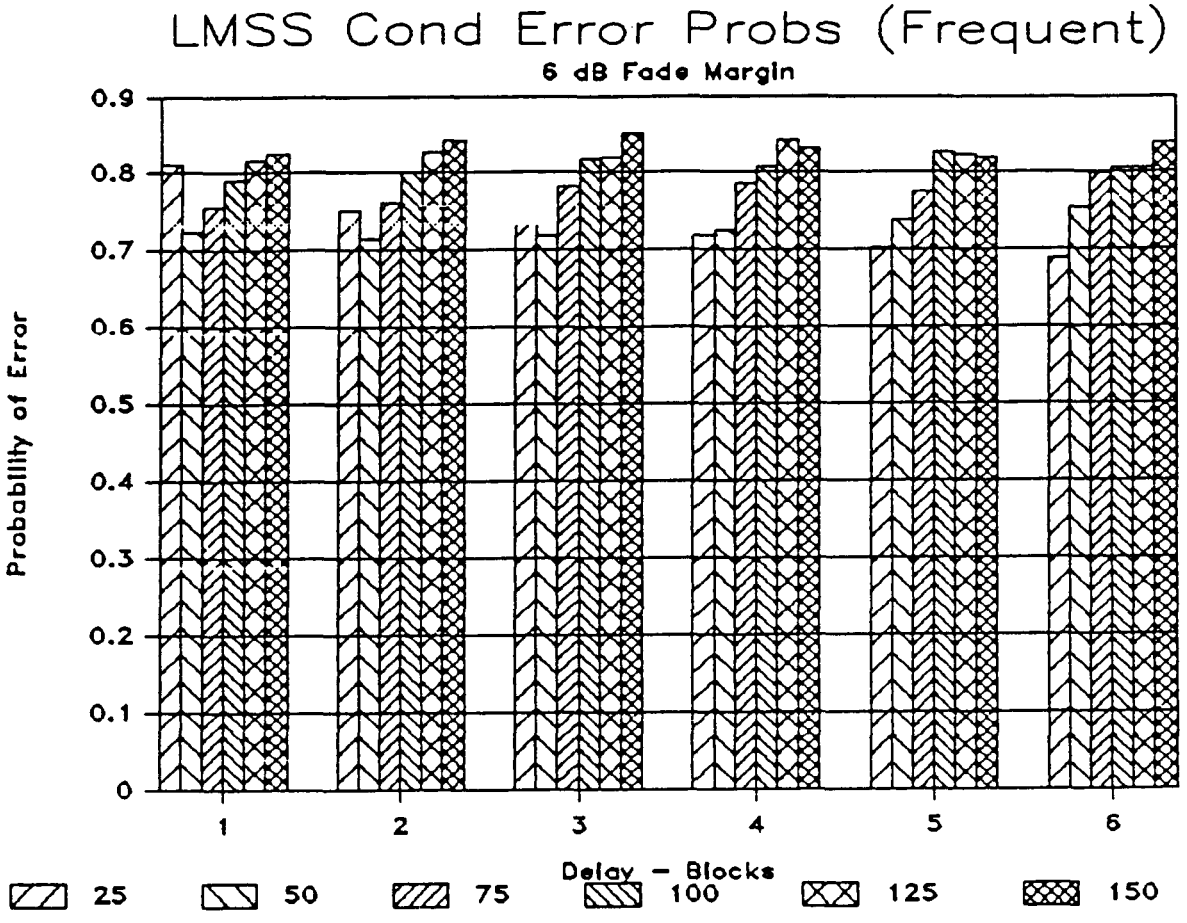
LMSS Cond Error Probs (Frequent)
6 dB Fade Margin
Probability of Error
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 8

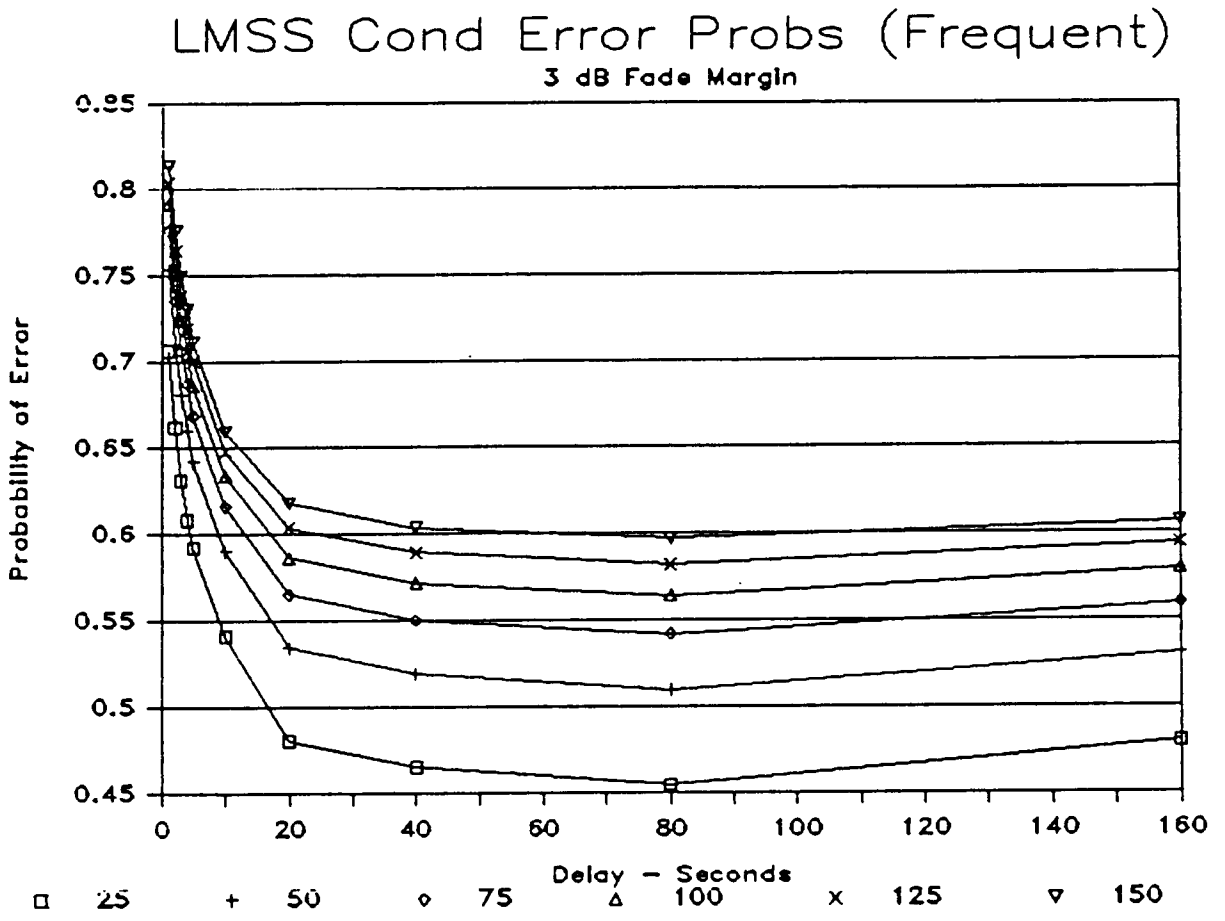
LMSS Cond Error Probs (Frequent)
3 dB Fade Margin
Probability of Error
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 9

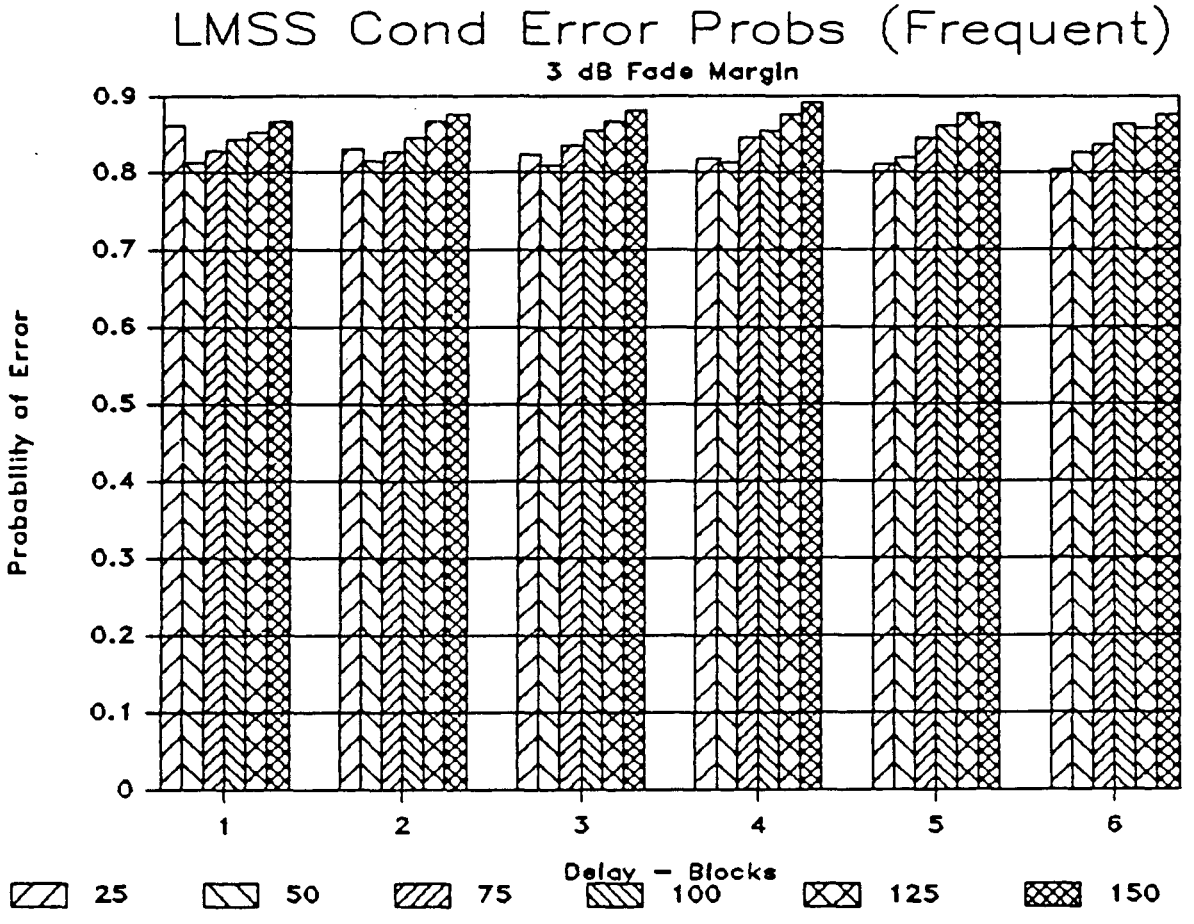
LMSS Cond Error Probs (Frequent)
3 dB Fade Margin
Probability of Error
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 10

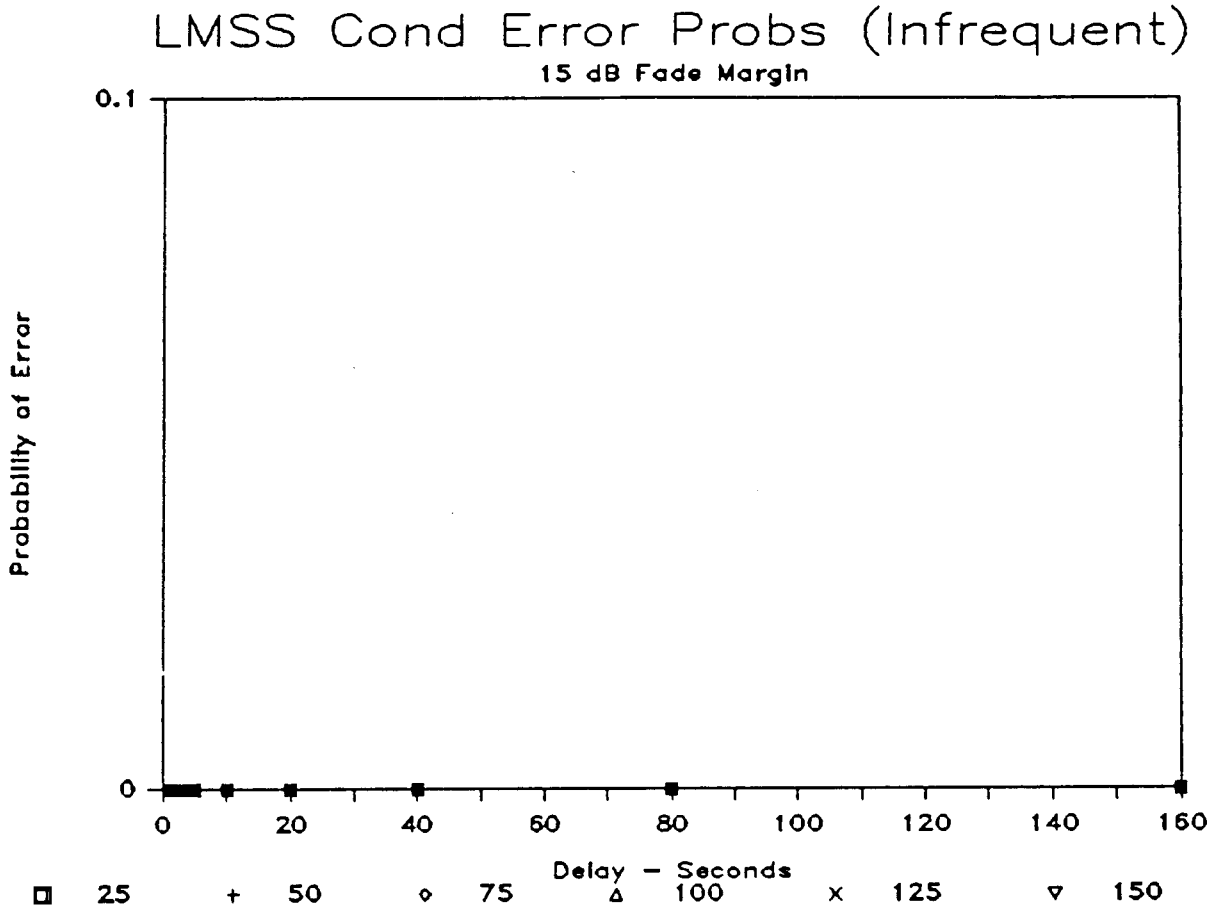
LMSS Cond Error Probs (Infrequent)
15 dB Fade Margin
0.1
0
Probability of Error
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 11

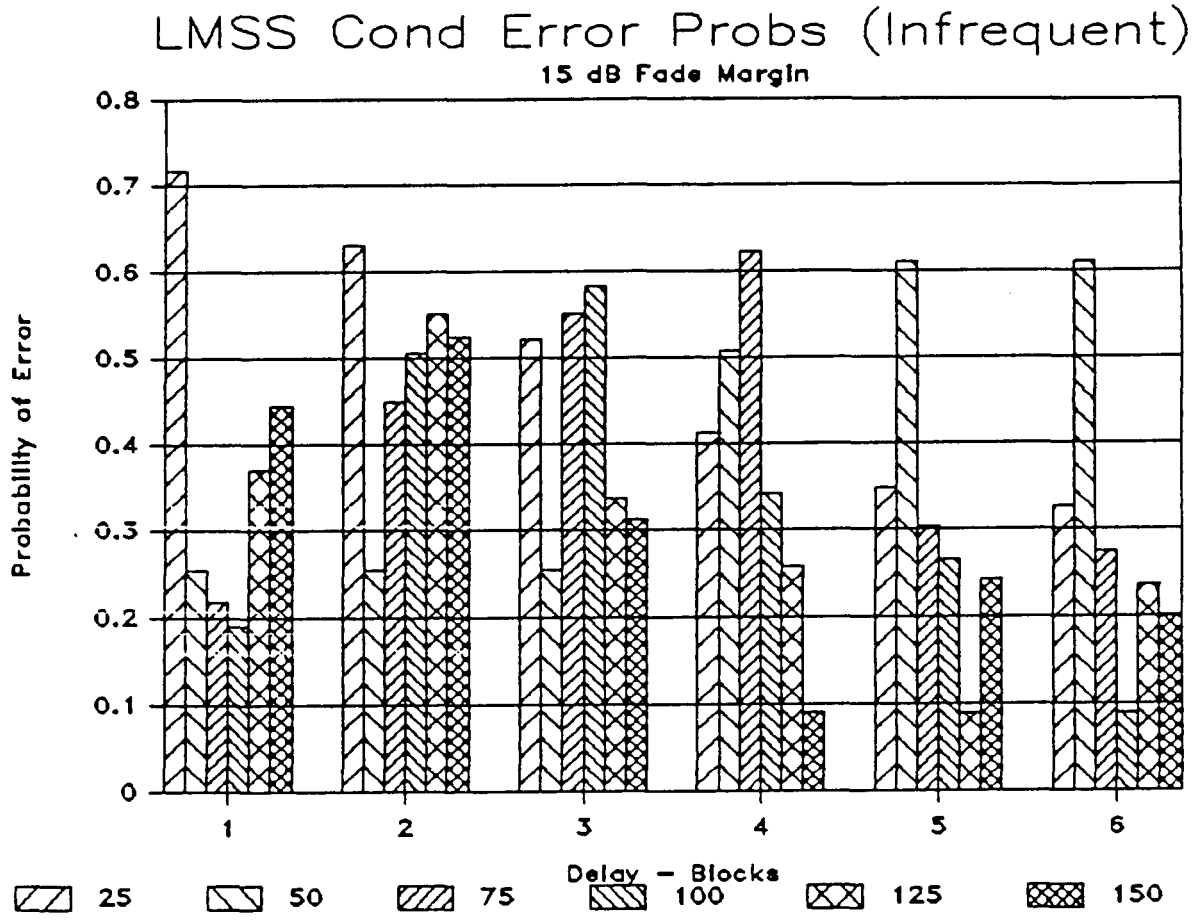
LMSS Cond Error Probs (Infrequent)
15 dB Fade Margin
Probability of Error
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 12

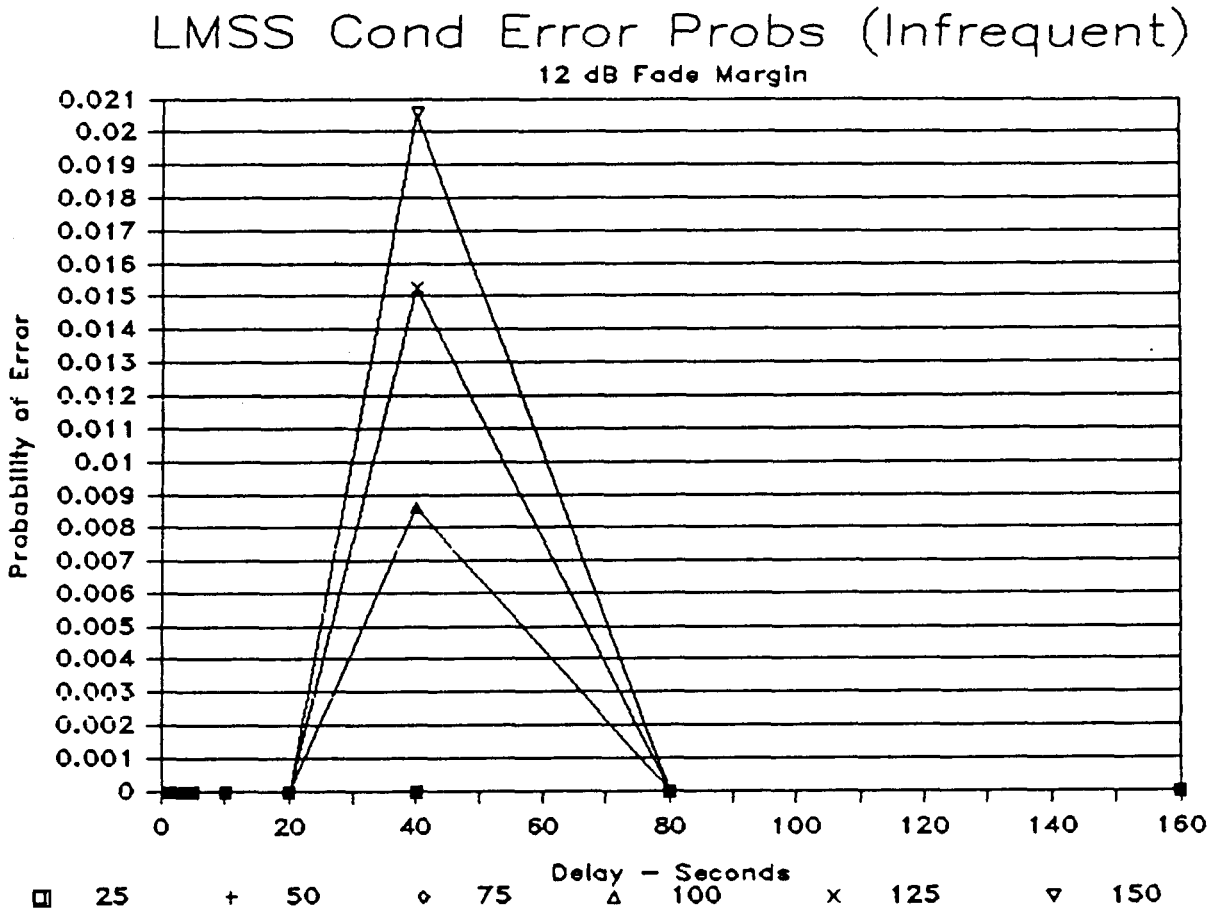
LMSS Cond Error Probs (Infrequent)
12 dB Fade Margin
Probability of Error
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
20
40
60
80
100
120
140
160
Delay – Seconds
25
50
75
100
125
150

Figure 13

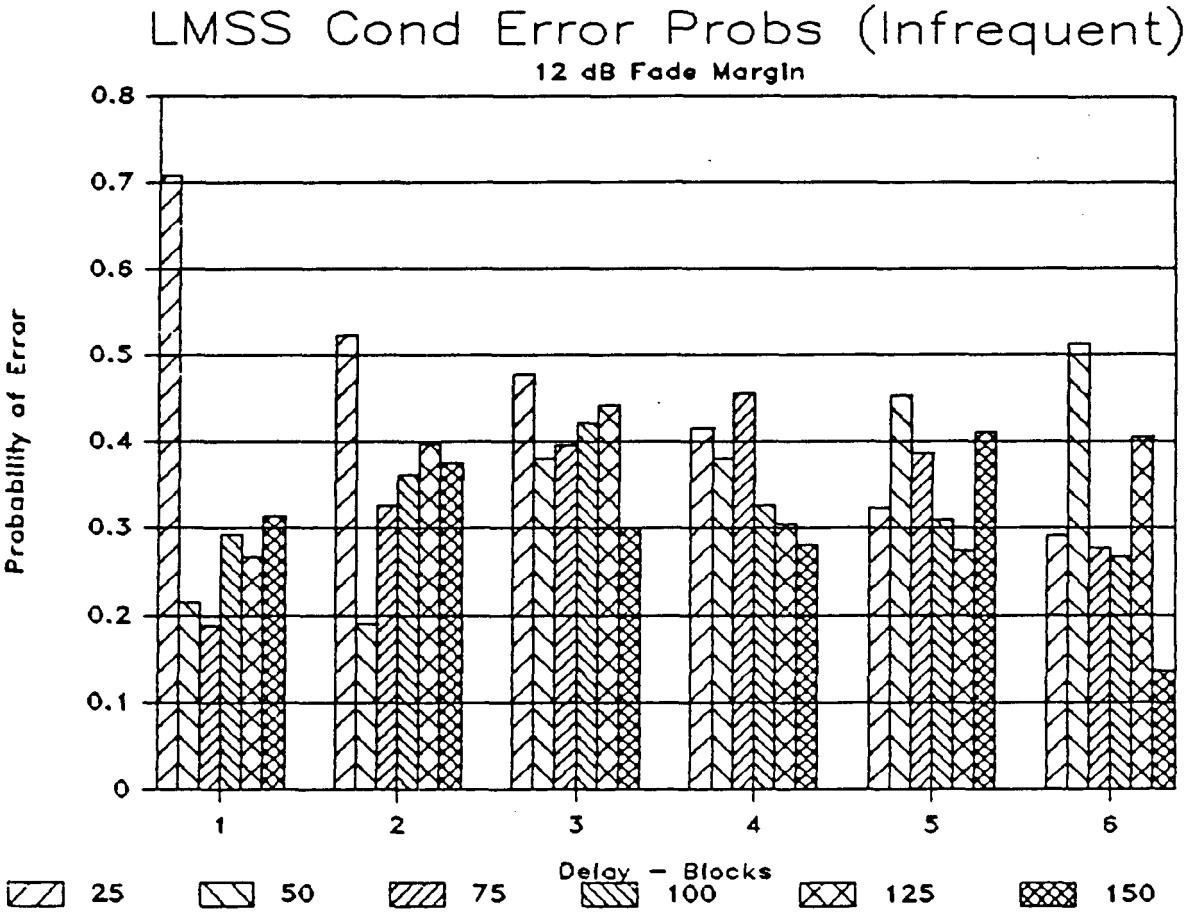
LMSS Cond Error Probs (Infrequent)
12 dB Fade Margin
Probability of Error
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 14

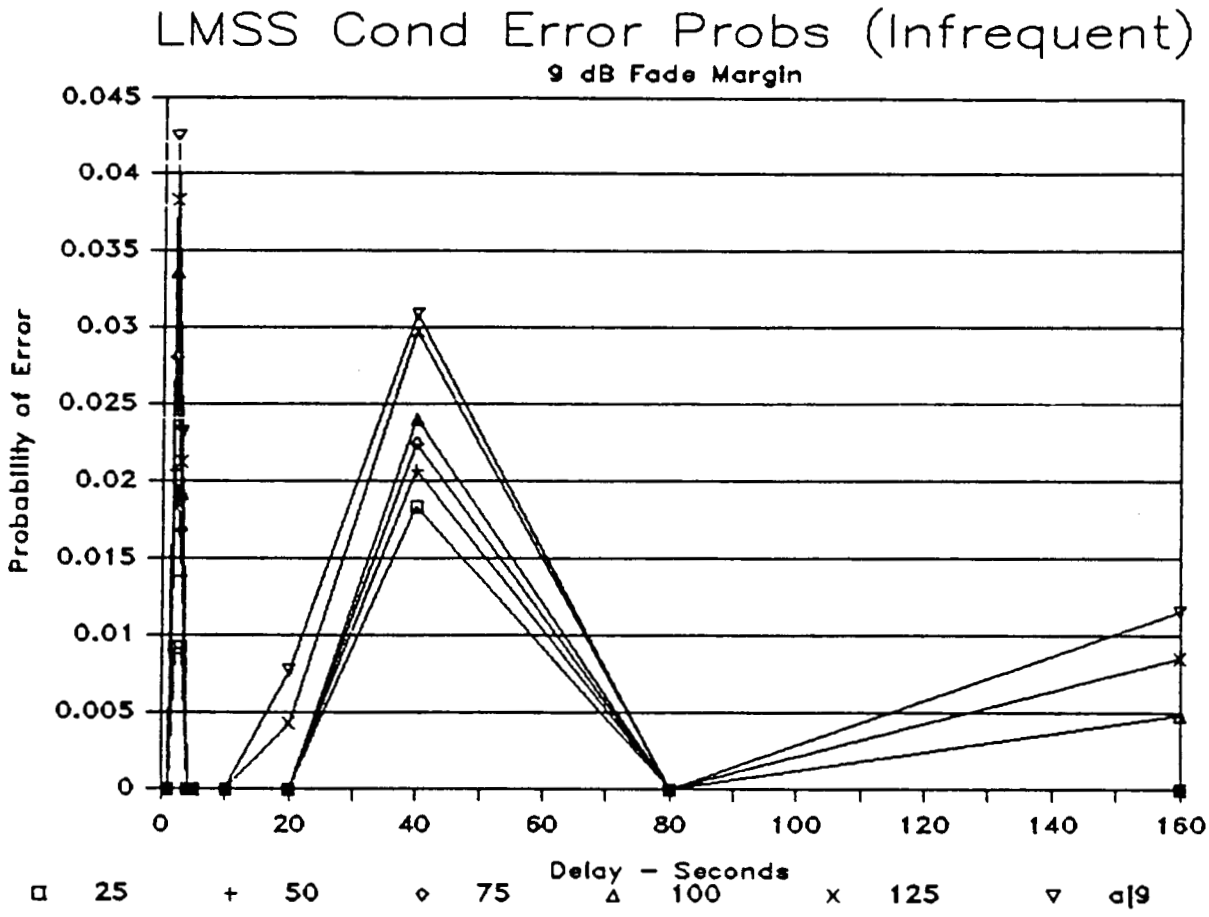
LMSS Cond Error Probs (Infrequent)
9 dB Fade Margin
Probability of Error
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
9

Figure 15

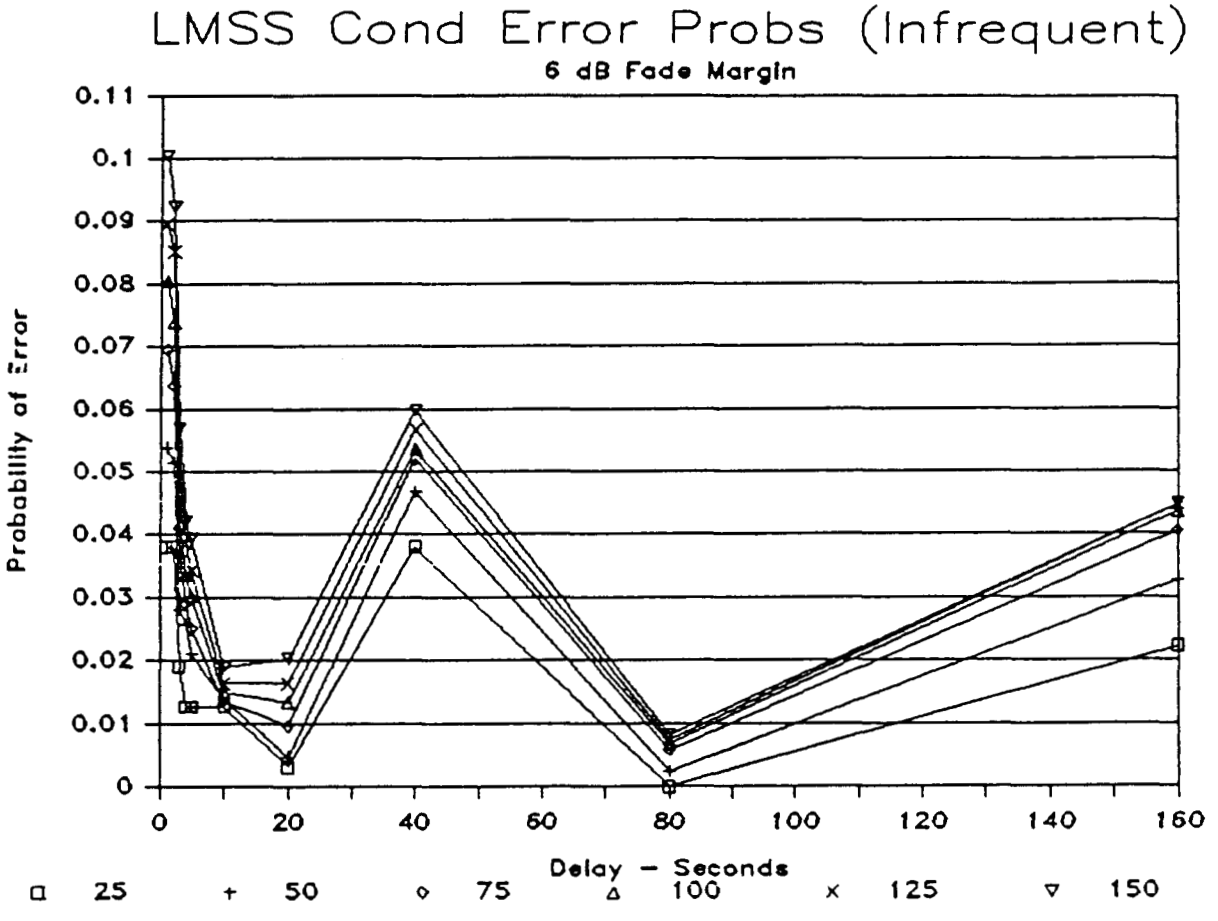

Figure 17

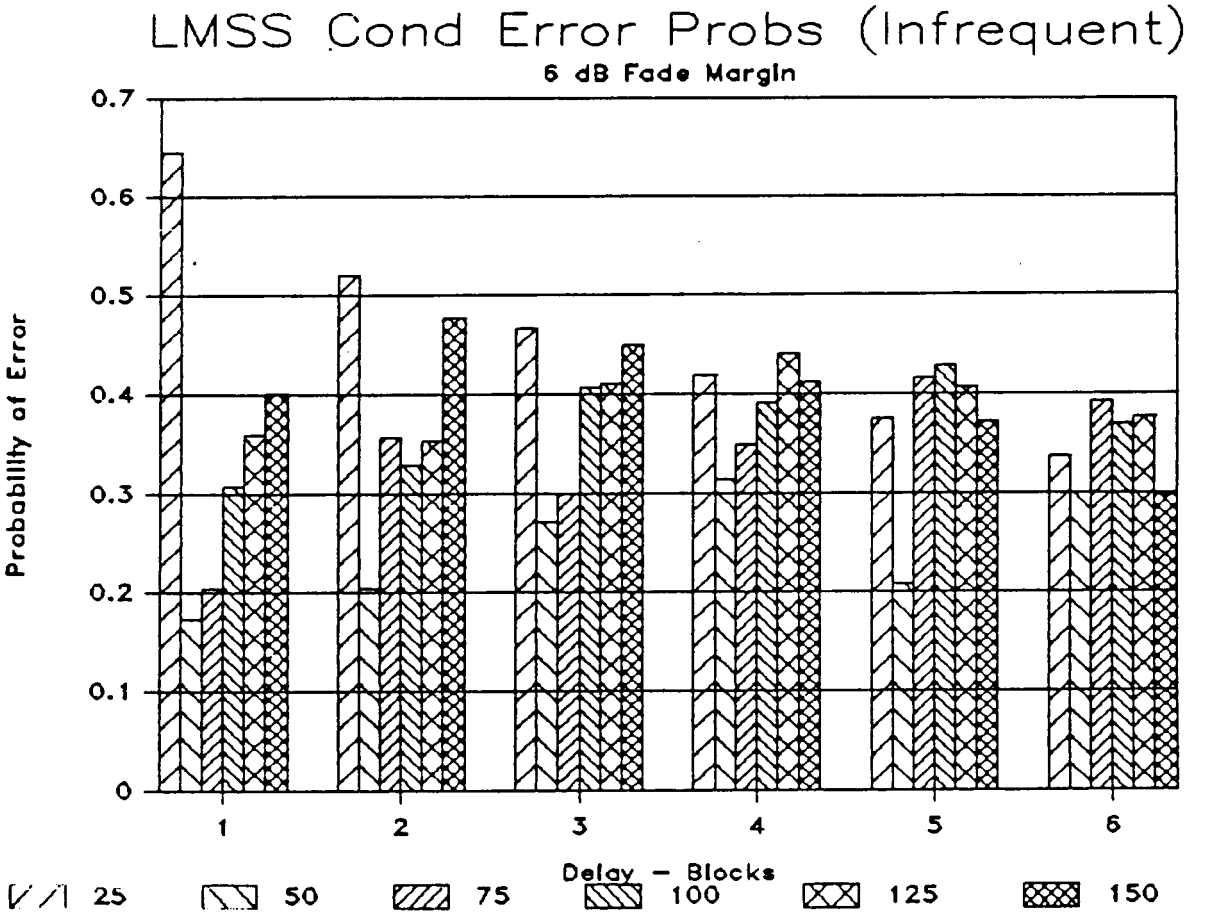
LMSS Cond Error Probs (Infrequent)
6 dB Fade Margin
Probability of Error
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 18

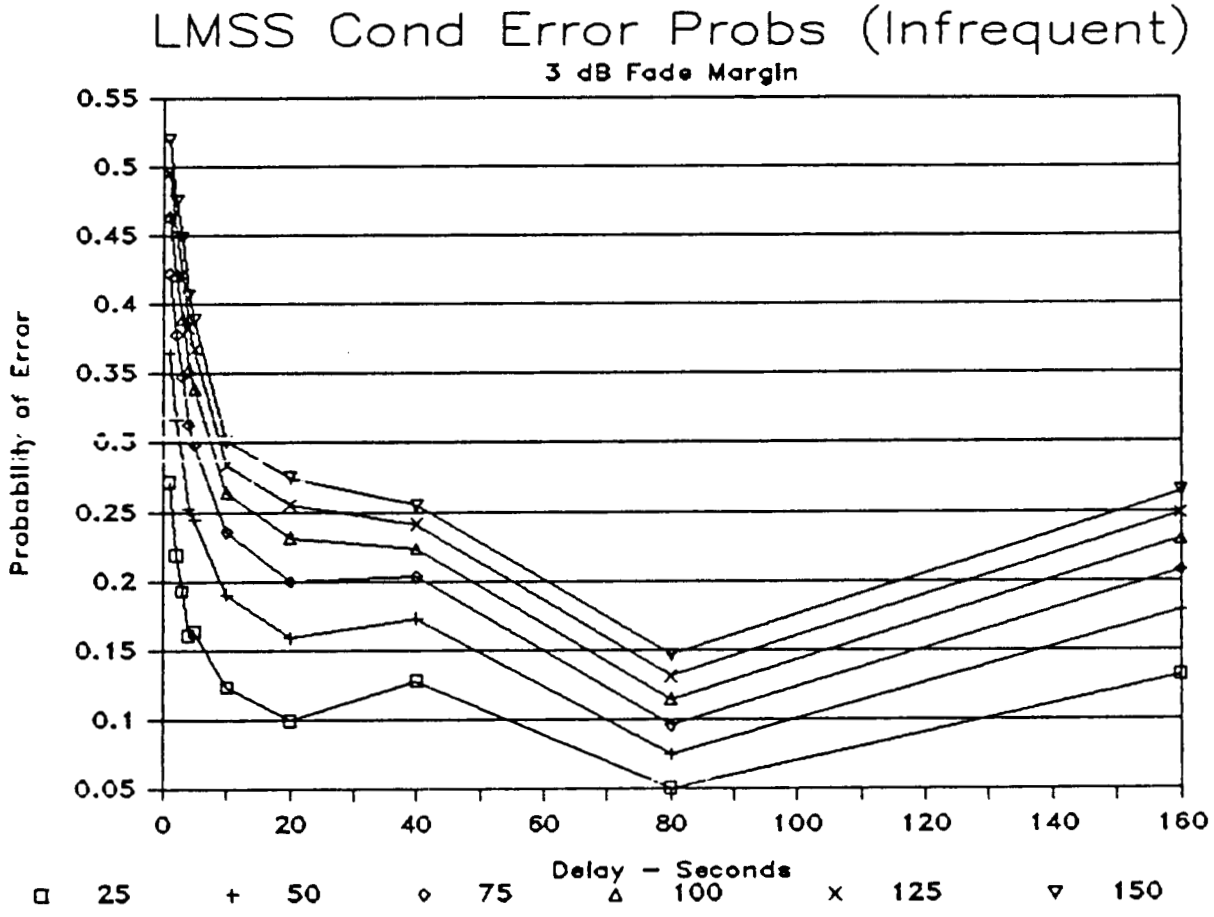
LMSS Cond Error Probs (Infrequent)
3 dB Fade Margin
Probability of Error
0.55
0.5
0.45
0.4
0.35
0.25
0.2
0.15
0.1
0.05
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 19

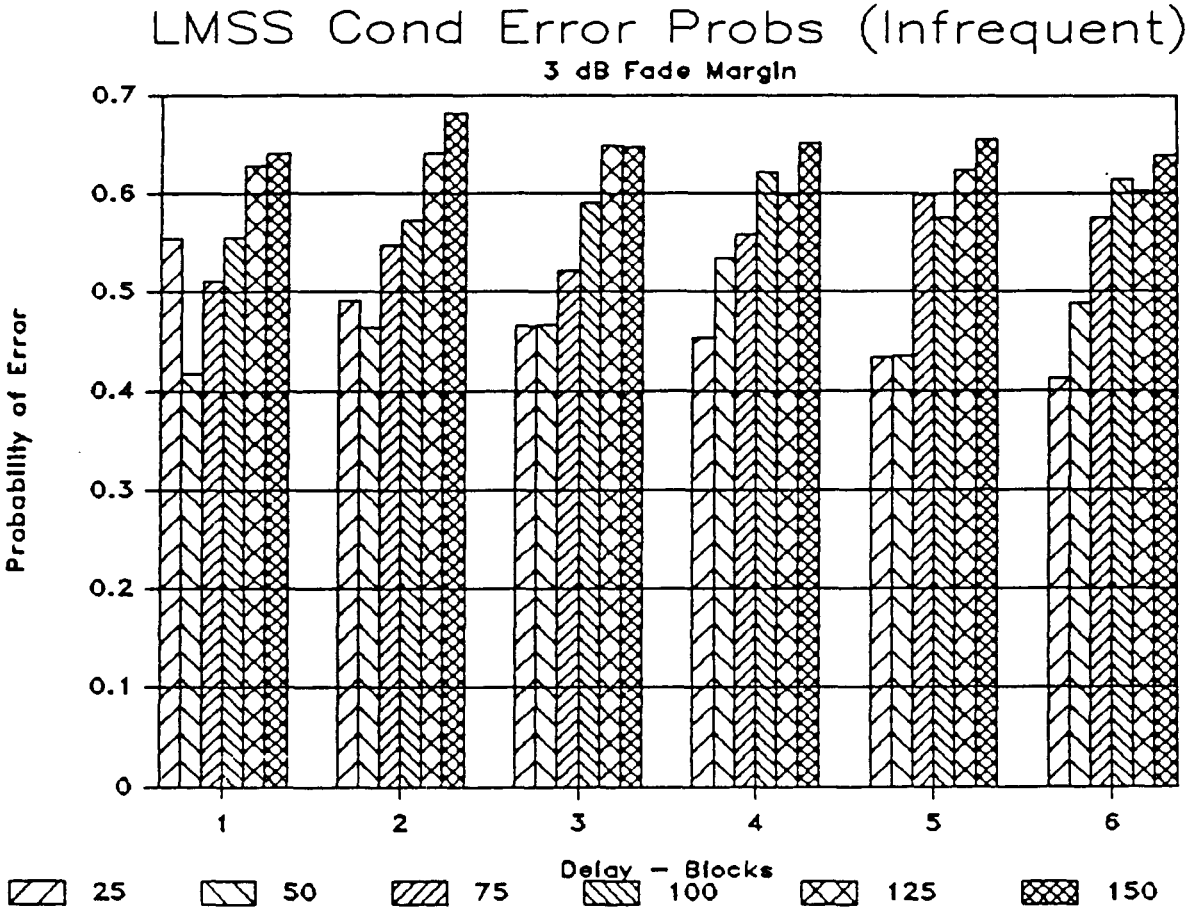
LMSS Cond Error Probs (Infrequent)
3 dB Fade Margin
Probability of Error
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 20

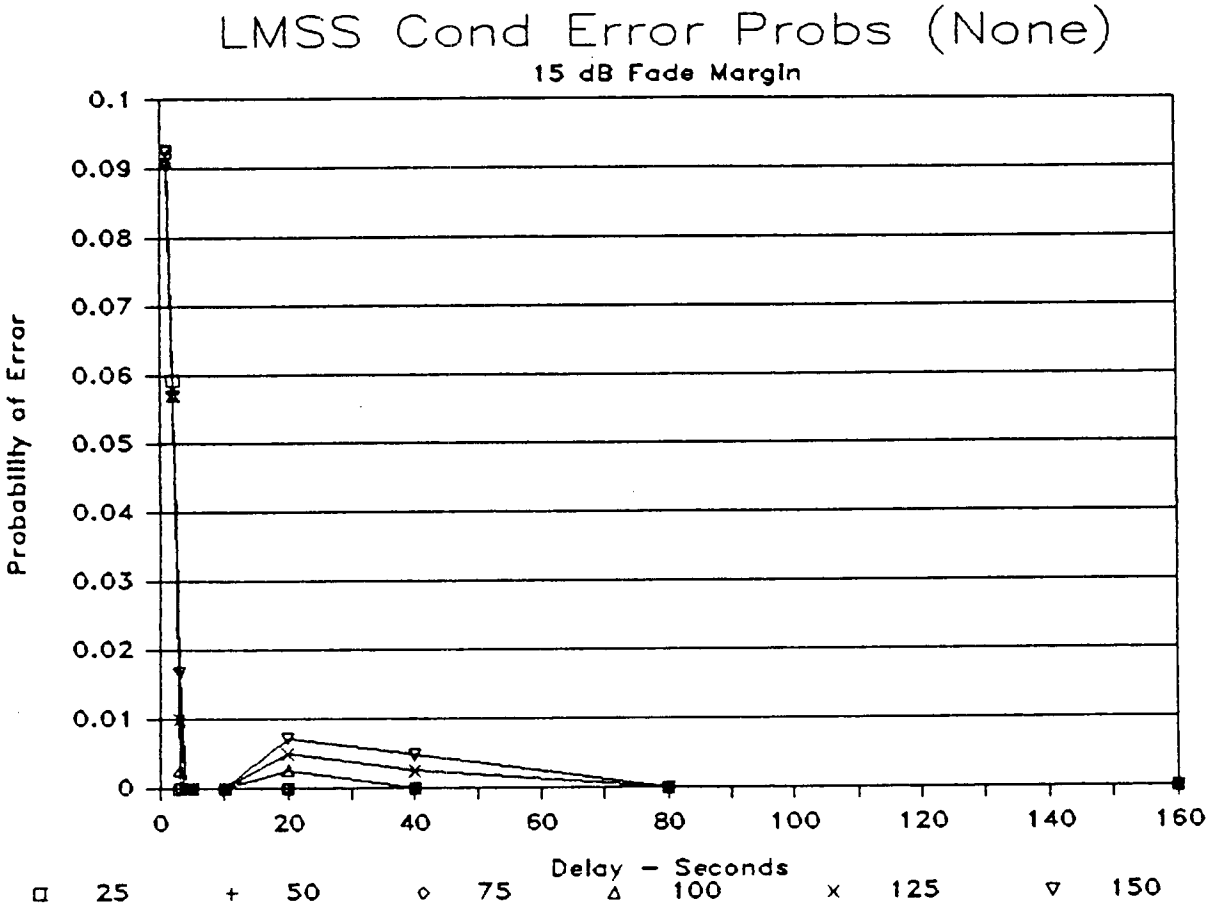
LMSS Cond Error Probs (None)
15 dB Fade Margin
Probability of Error
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 21

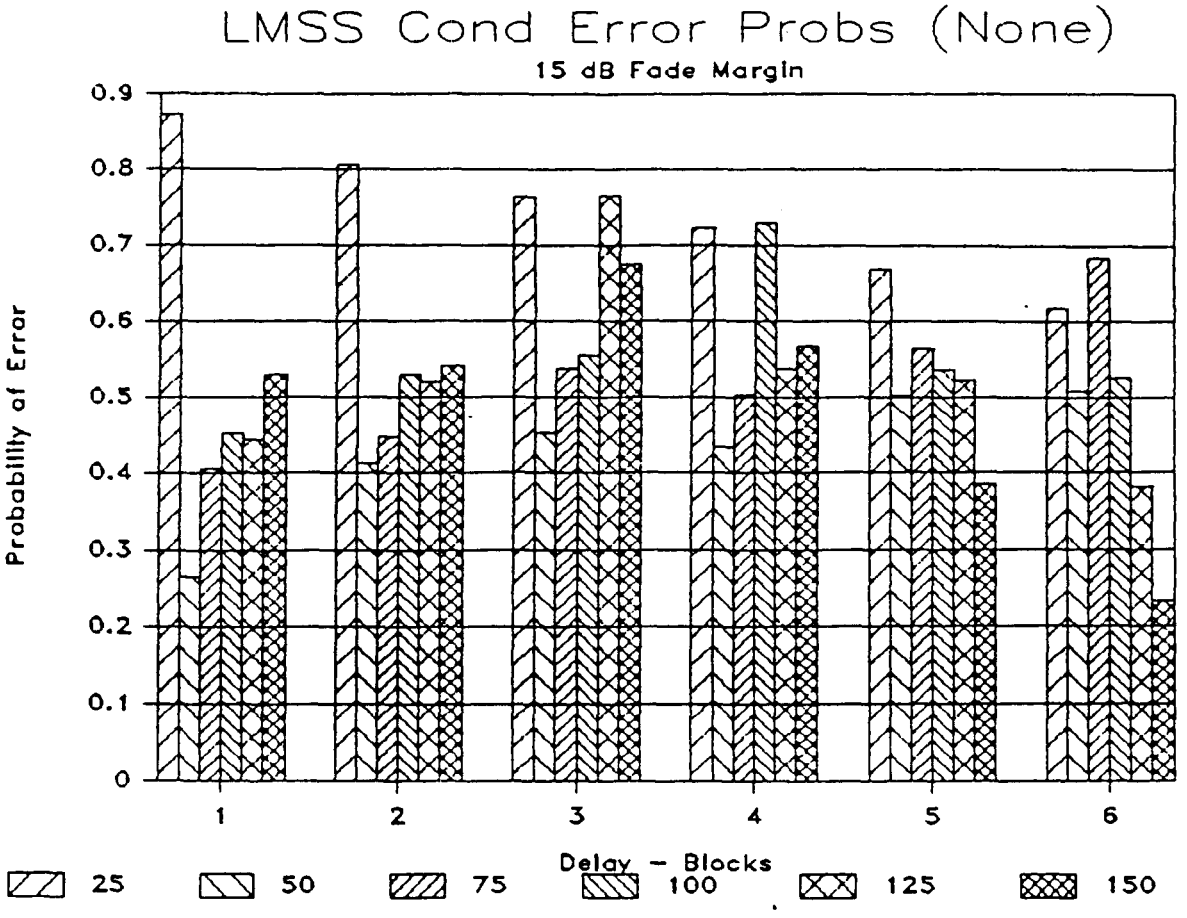
LMSS Cond Error Probs (None)
15 dB Fade Margin
Probability of Error
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 22

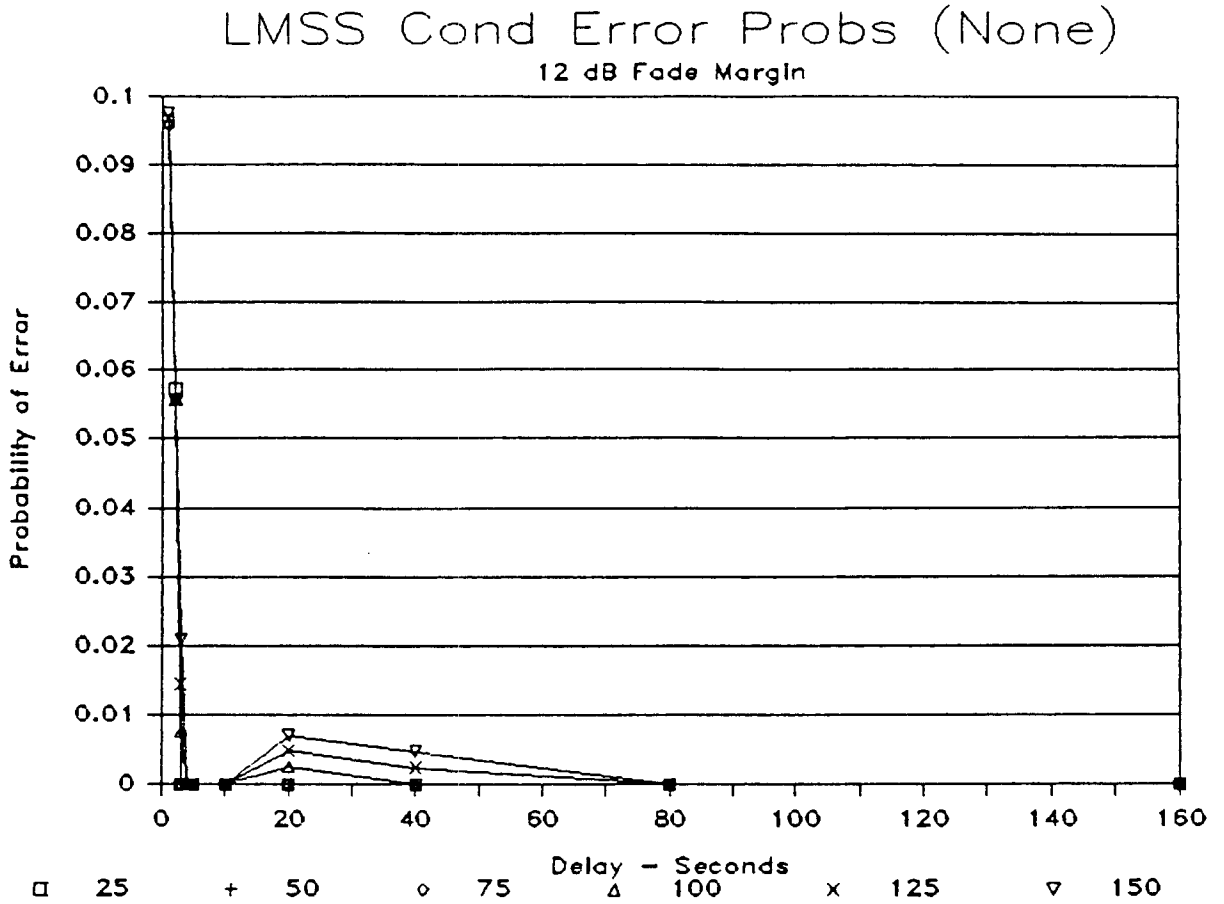
LMSS Cond Error Probs (None)
12 dB Fade Margin
Probability of Error
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 23

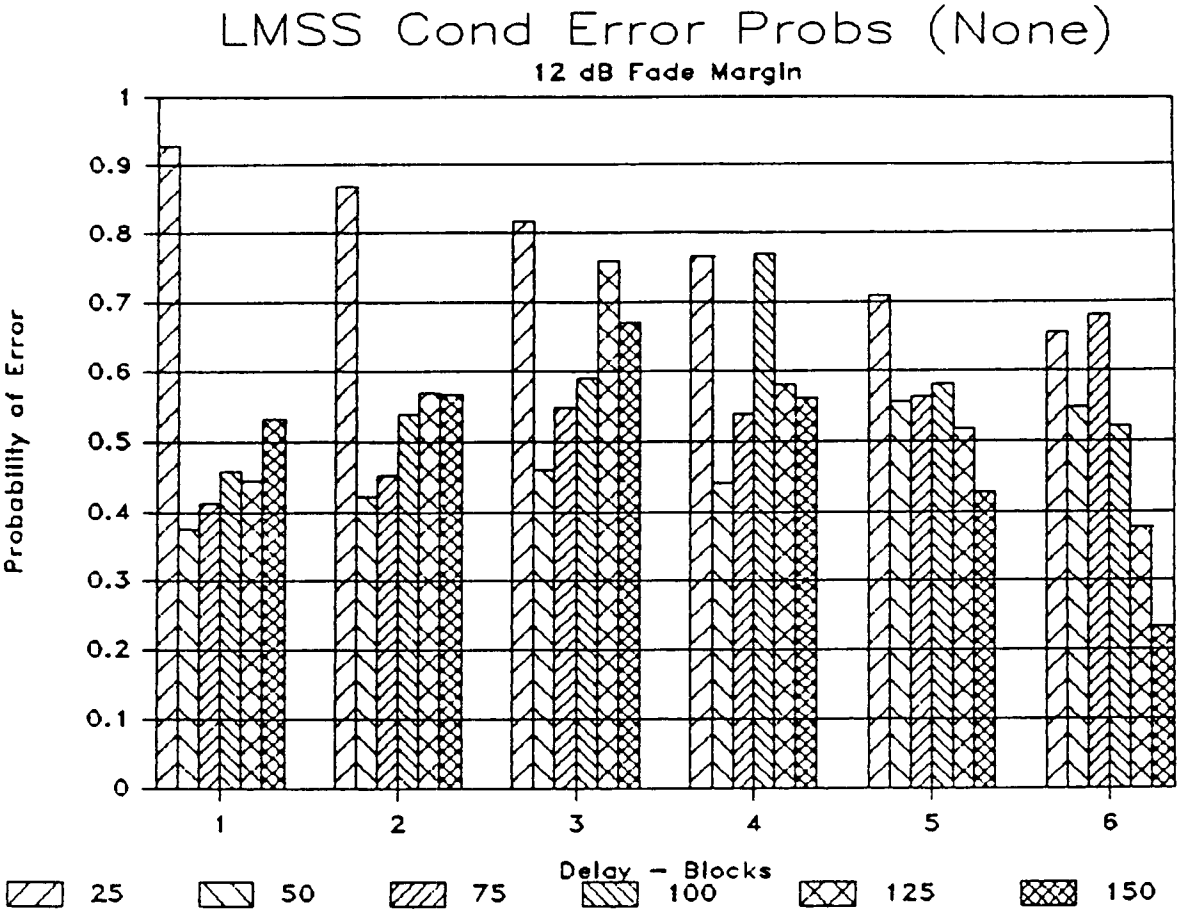
LMSS Cond Error Probs (None)
12 dB Fade Margin
Probability of Error
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 24

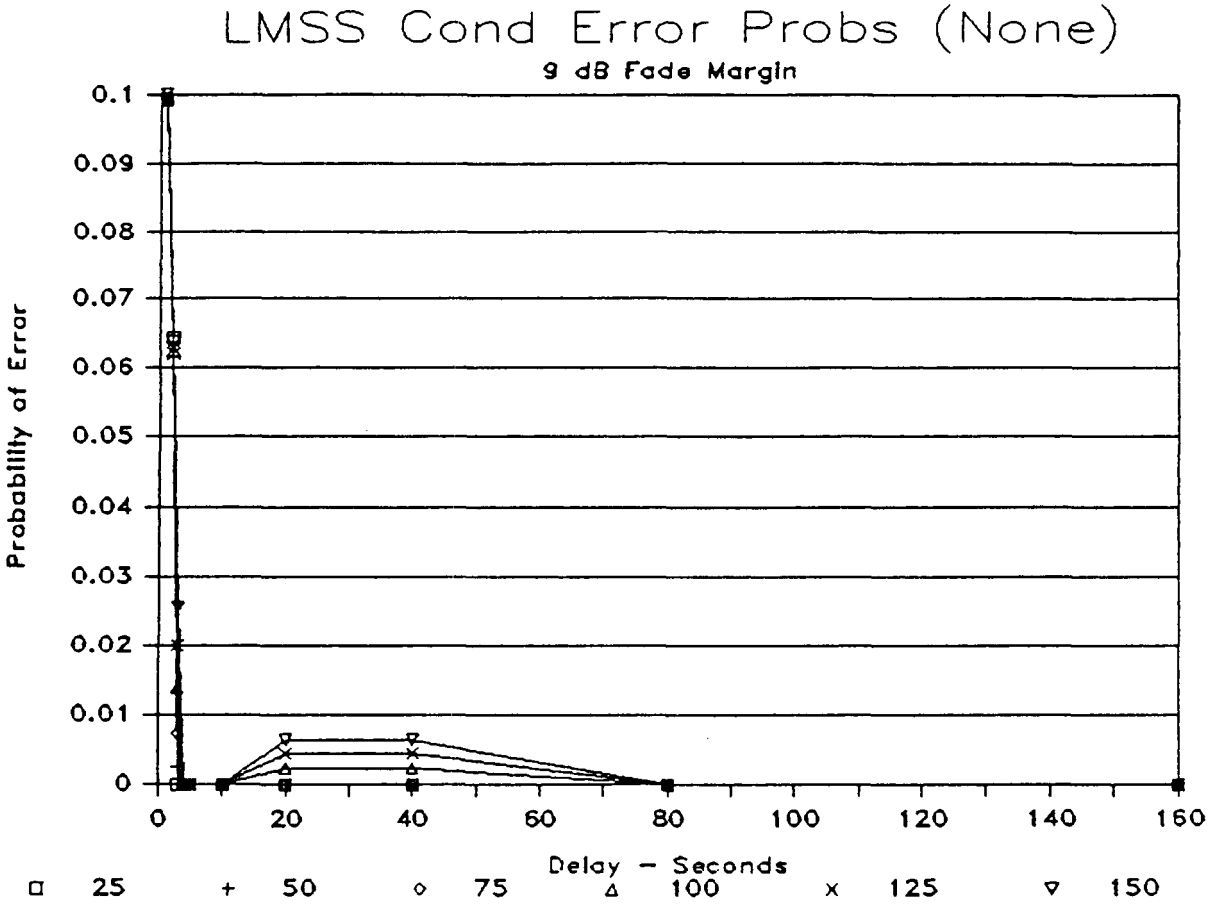
LMSS Cond Error Probs (None)
9 dB Fade Margin
Probability of Error
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
Delay - Seconds
□ 25
+ 50
◇ 75
△ 100
× 125
▽ 150

Figure 25

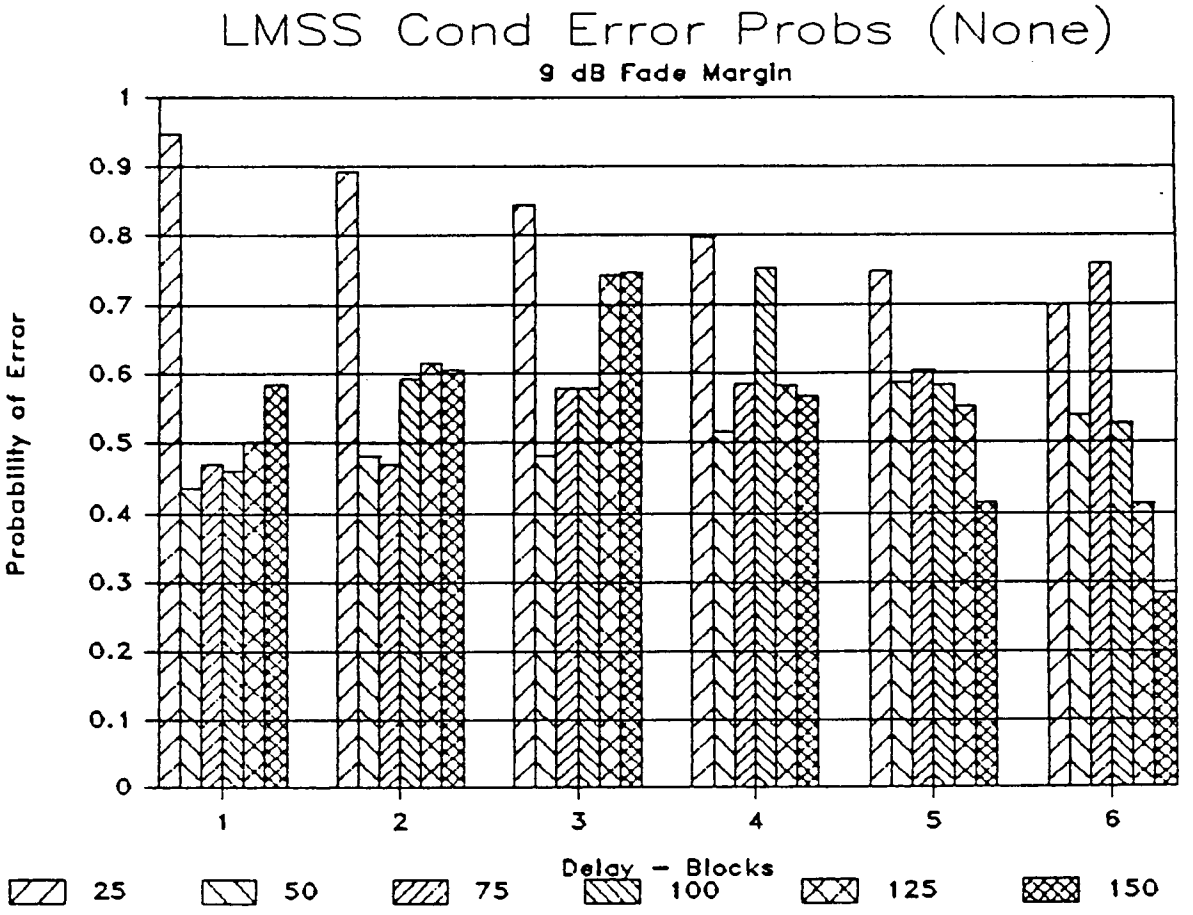
LMSS Cond Error Probs (None)
9 dB Fade Margin
Probability of Error
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 26

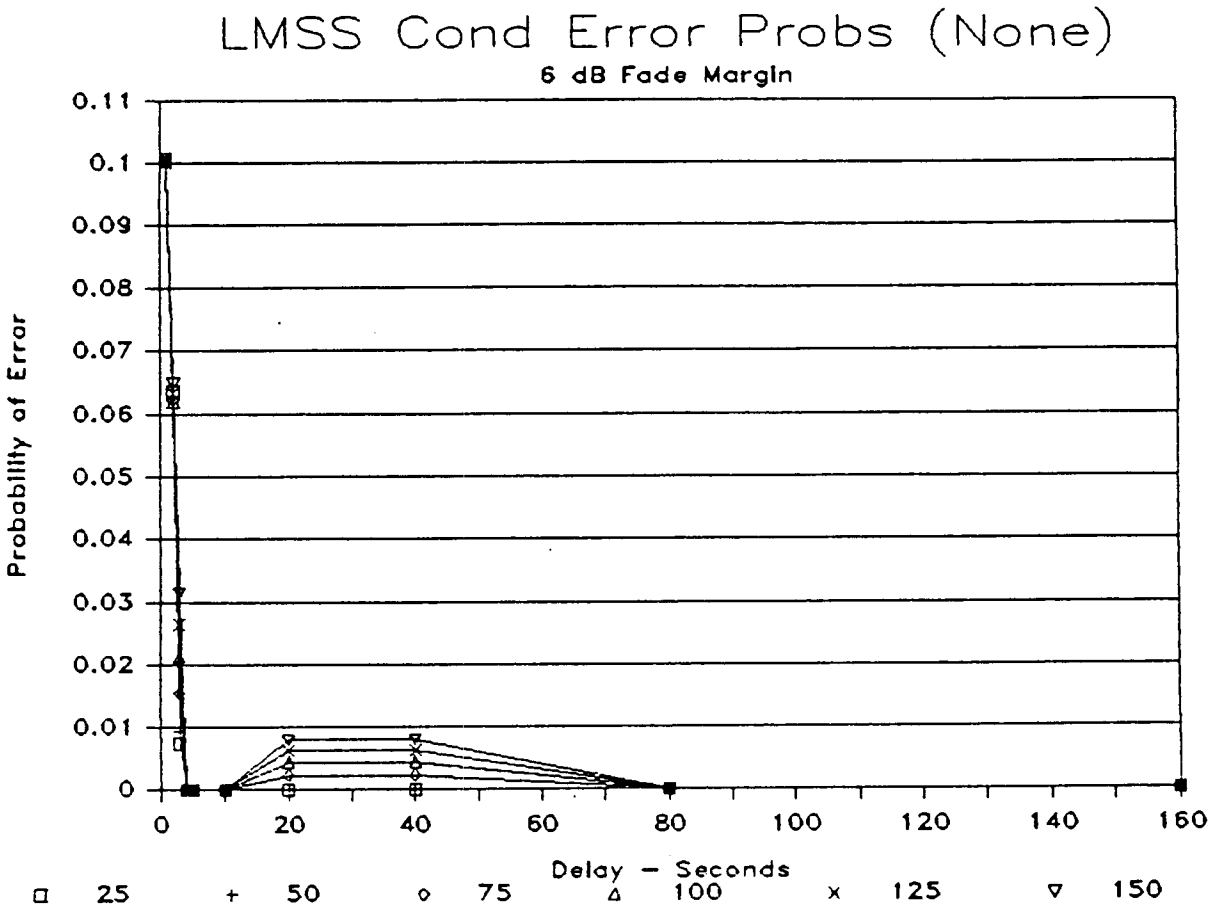
LMSS Cond Error Probs (None)
6 dB Fade Margin
Probability of Error
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
Delay - Seconds
□ 25
+ 50
◇ 75
△ 100
x 125
▽ 150

Figure 27

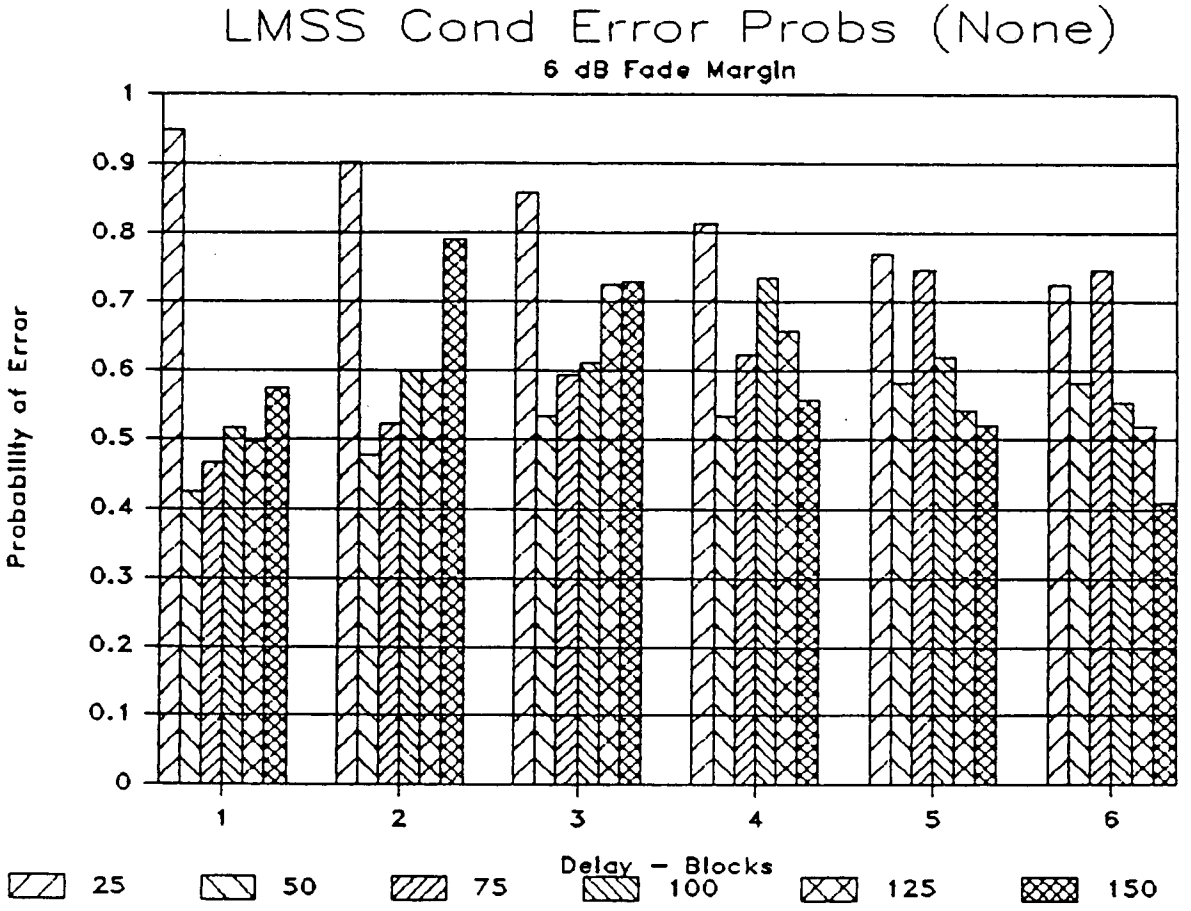
LMSS Cond Error Probs (None)
6 dB Fade Margin
Probability of Error
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 28

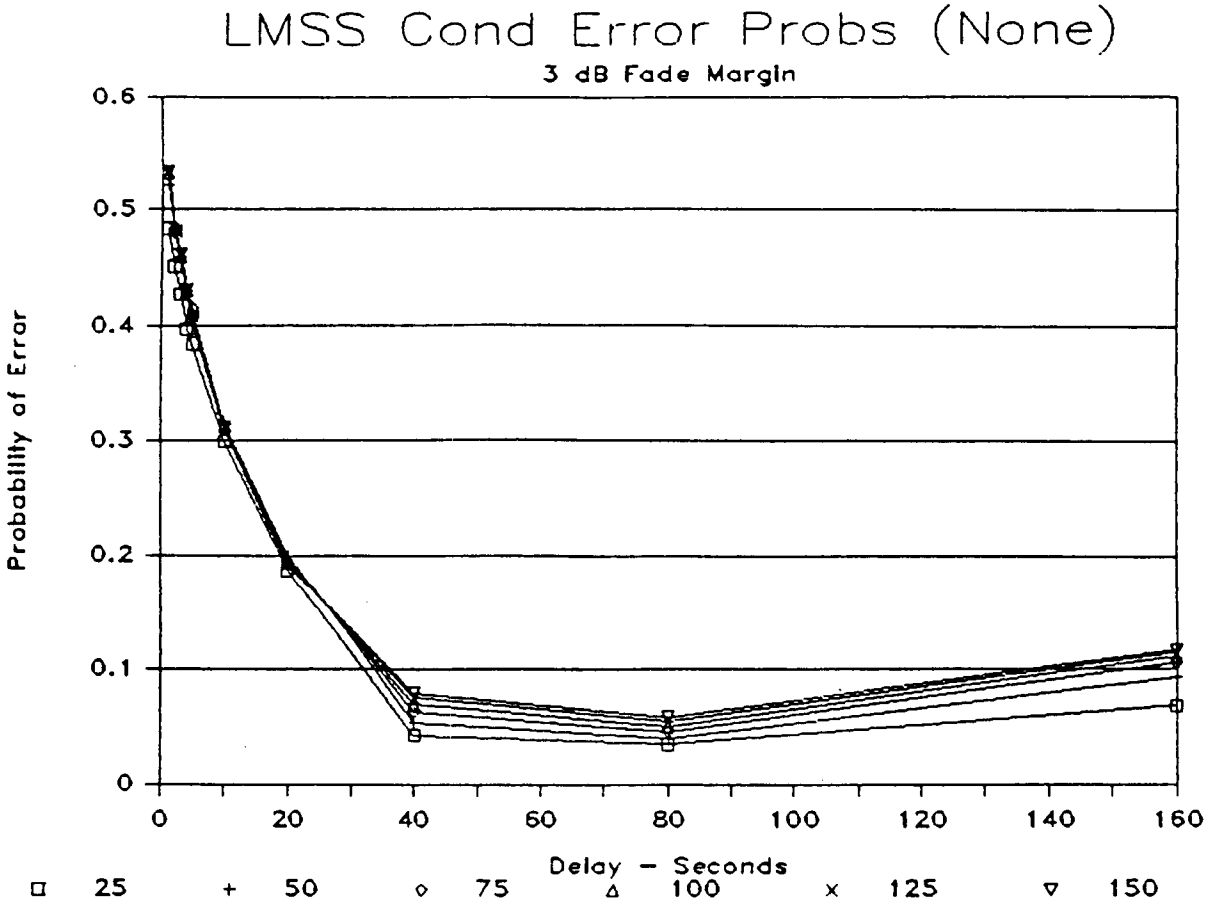
LMSS Cond Error Probs (None)
3 dB Fade Margin
Probability of Error
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140
160
Delay - Seconds
25
50
75
100
125
150

Figure 29

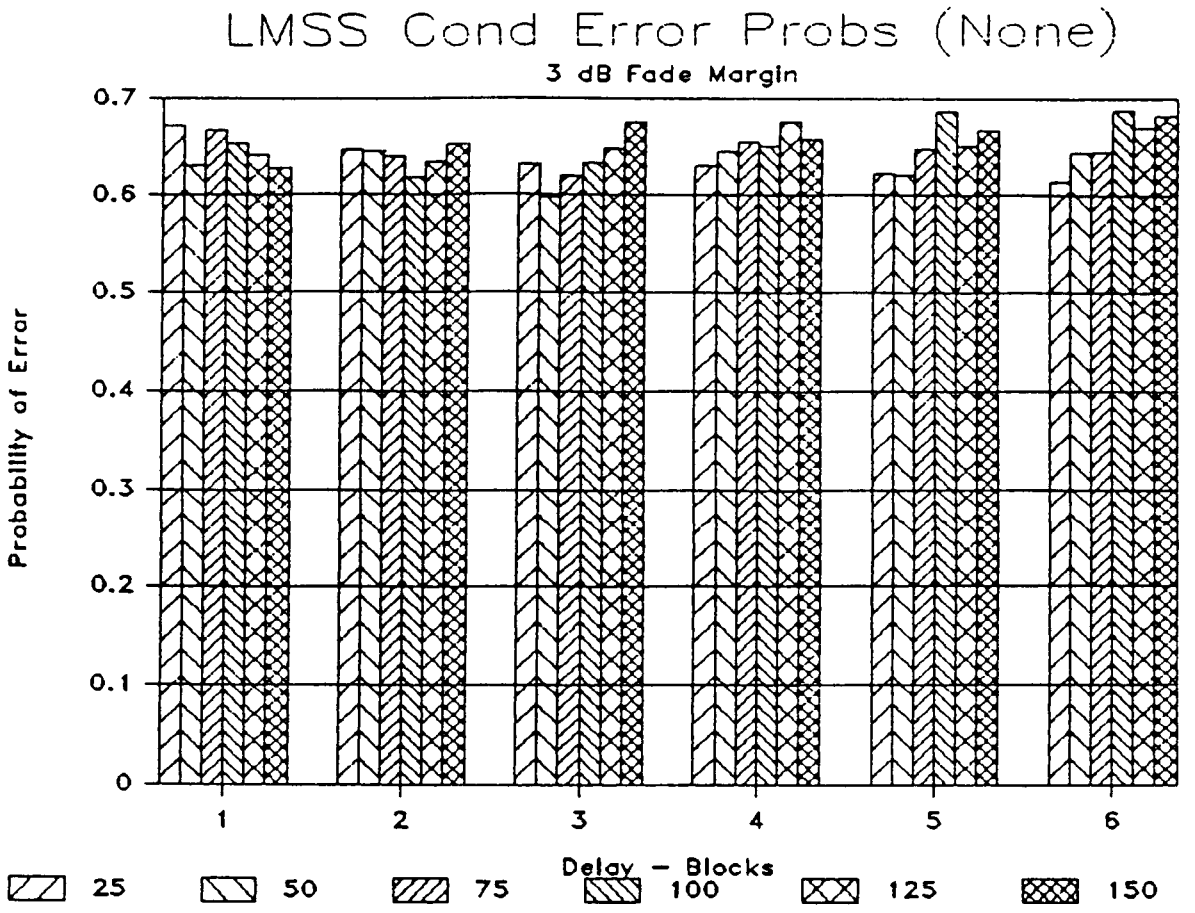
LMSS Cond Error Probs (None)
3 dB Fade Margin
Probability of Error
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Delay - Blocks
25
50
75
100
125
150

Figure 30

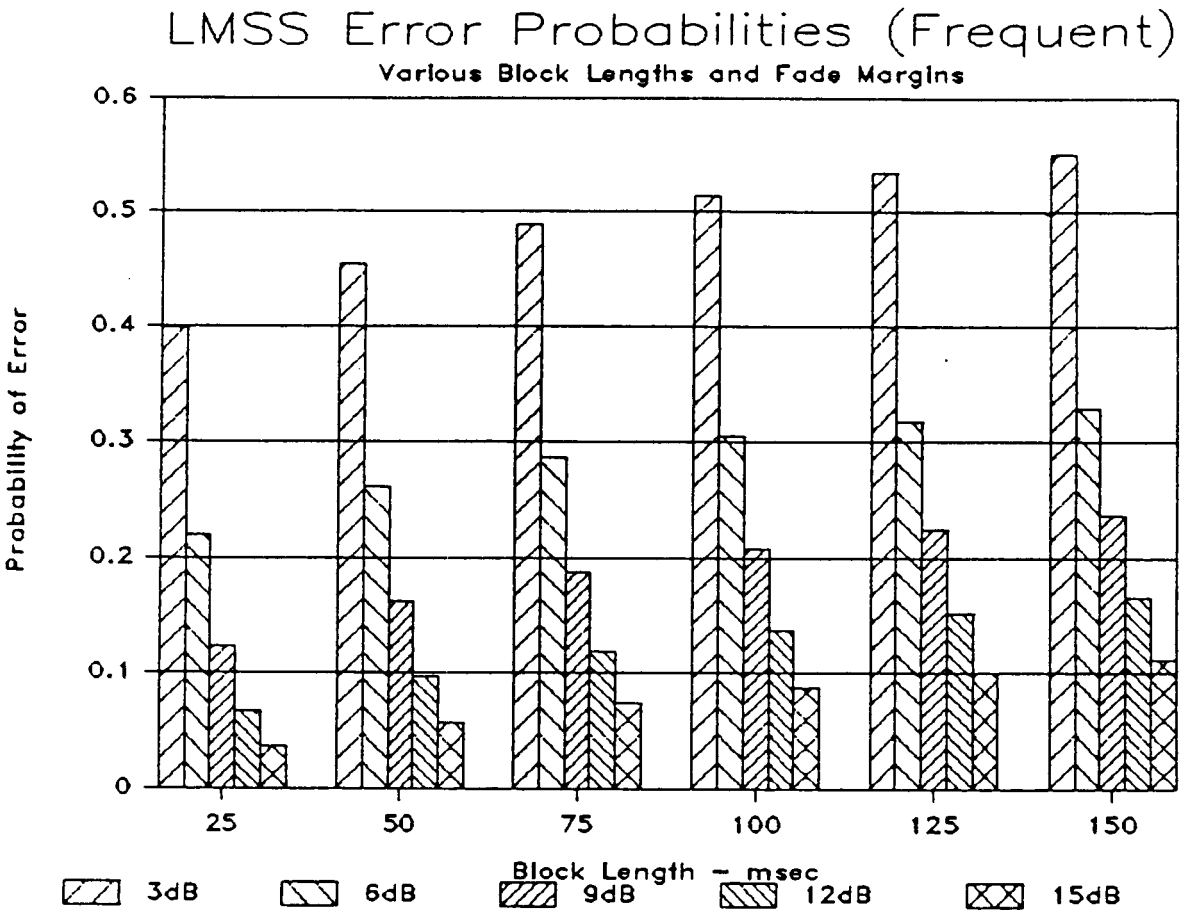
LMSS Error Probabilities (Frequent)
Various Block Lengths and Fade Margins
Probability of Error
0.6
0.5
0.4
0.3
0.2
0.1
0
25
50
75
100
125
150
Block Length - msec
3dB
6dB
9dB
12dB
15dB

Figure 31

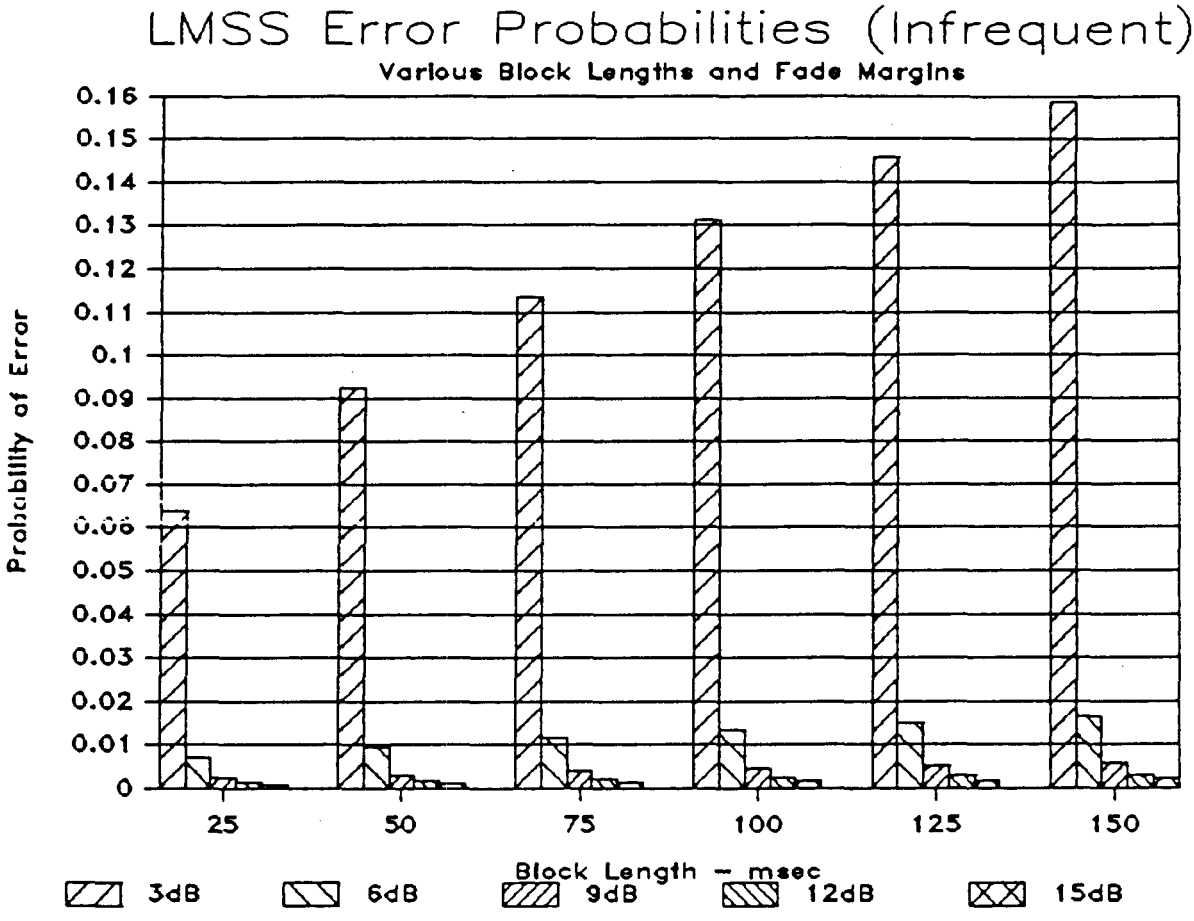
LMSS Error Probabilities (Infrequent)
Various Block Lengths and Fade Margins
Probability of Error
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
25
50
75
100
125
150
Block Length - msec
3dB
6dB
9dB
12dB
15dB

Figure 32

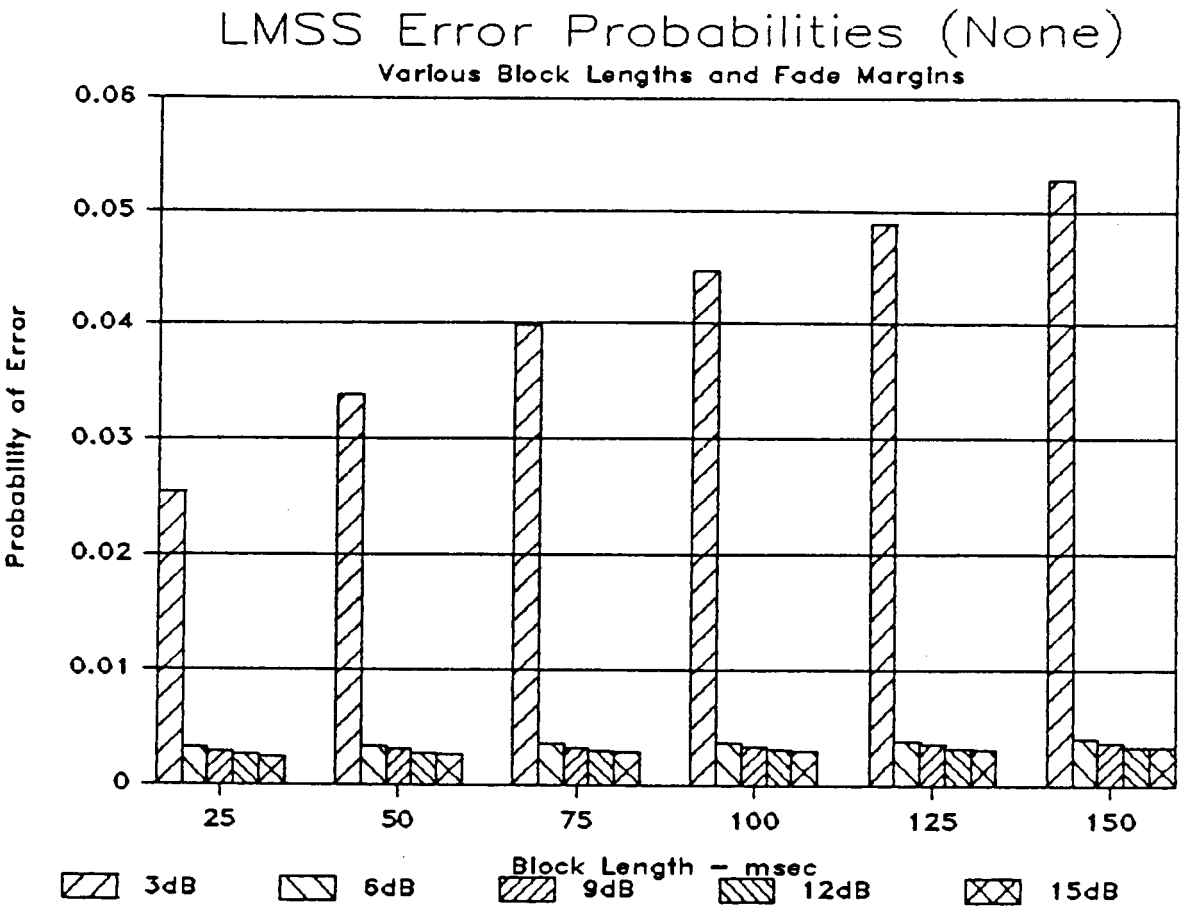
LMSS Error Probabilities (None)
Various Block Lengths and Fade Margins
Probability of Error
0.06
0.05
0.04
0.03
0.02
0.01
0
25
50
75
100
125
150
Block Length – msec
3dB
6dB
9dB
12dB
15dB

Figure 33