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ASS Note 48
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SOME SATELLITE SIMULATION RESULTS

I. INTRODUCTION

In this note we report some simulation results for the slotted ALOHA satellite channel with a large number of small users (Model I in ASS Note 39) and the FCFS reservation scheme (see ASS Note 38 by L.G. Roberts). The simulation models are based upon the following assumptions:

(1) no random noise errors (the satellite channel has perfect information feedback);

(2) new messages are generated independently from Poisson distribution(s);

(3) all ground stations have the same round-trip propagation delay R.

Note that in assumption (2), only the newly generated packets are derived independently from a Poisson distribution; any collisions, random retransmissions and queueing are accounted for in the simulations. Message delays are obtained by time-stamping messages at the time of their creation.

In general, our simulation results indicate the following:

(1) Under "stable" conditions experimental results agree very well with analytic results (in ASS Notes 38 and 39) thus lending validity to approximations and assumptions made in the mathematical derivations.

(2) The slotted ALOHA channel with a large number of small users can become unstable even though the input rate to such a channel is significantly below 1/e. The FCFS reservation scheme depends upon using a fraction of the satellite channel in the ALOHA mode for making reservations and thus is subject to the same effects of instability. Some simple scheme is necessary to monitor the channel traffic and apply controls whenever unstable conditions are detected.

We are currently studying the dynamic behavior of the slotted ALOHA channel and will report our findings in a future note.

II. The Slotted ALOHA Simulations

A start-up period of a few hundred slots is allowed (depending on individual runs) before statistics are gathered to compute the average values for throughput rate S, traffic rate G, traffic distribution and average packet delay D. In addition to the above long-term average values, average values for the corresponding variables are also computed for all consecutive periods of 200 slots. These will be referred to as the short-term averages and they portray the approximate dynamic behavior of the channel. If during a run, all the short-term average values for the traffic rate are below 1, such a run is designated to be a "stable" run.*

"Stable" runs

In Figures 1 and 2 we plot simulation data for "stable" runs together with analytic results for S, G and D. Note the excellent agreement between analytic results and simulation data in almost all cases. In Figures 3-4, we show the comparisons between the probability density function for traffic arrivals obtained by simulation (from "stable" runs) and the Poisson density with the same average rate. Recall in ASS Note 17, it was shown that as $K \to \infty$ the traffic arrivals are Poisson distributed. Note in the figures that for K=15, the agreement is very good; even for K=5, the traffic density still approximates a Poisson density very well.

"Unstable" runs

In Figures 5-10, we show situations when during the runtime of a simulation the ALOHA channel becomes unstable (i.e. the average channel traffic rate increases as the throughput rate decreases). In Fig. 5, we see that for K=5, the channel traffic rate quickly diverges despite the fact that the input rate = 0.325 and is less than the theoretical maximum of 0.347 corresponding to G=1 (see Fig. 1). In Fig. 6 we see that increasing K to 7 enables the channel to accommodate the input rate of 0.325. The channel becomes unstable temporarily but regains stability without any external controls. Similar situations are shown in Figures 7 and 8 for a channel input rate of 0.35 and values of K equal to 15 and 40. In Fig. 9, we see that with K=2, the channel becomes unstable for an input rate as low as 0.25. Referring to Fig. 1, for K=2 the channel has a theoretical maximum throughput rate S_{MAX}=0.295. In Fig. 10, we see that if the input rate is reduced to 0.2, the channel traffic does not diverge. Thus the maximum input rate an ALOHA channel can accommodate is considerably less than $S_{MAX}(K)$ obtained by having the channel traffic rate G=1.

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* The same run can still become unstable if the runtime is increased.

III. FCFS Reservation Simulations

Program features and assumptions

The scheduling algorithm used in this simulation is the same as outlined by L. G. Roberts in ASS Note 38 with minor differences. The channel is slotted such that for every M slots used for reserved data there is one slot for ALOHA traffic (including reservation requests). Each such ALOHA slot is further divided into V small slots. When there is no reserved data, the channel is switched into the ALOHA mode in which all the slots are used for ALOHA traffic. As soon as a reservation request was successful and the corresponding data packets are ready to transmit, the channel is switched back into the MIXED mode with only 1 ALOHA slot (containing V small slots) for every M data slots. Such a scheme is particularly useful when the input data contain a lot of multipacket messages.

In the simulations, we shall assume the following:

(1) number of ground stations = 10;

(2) roundtrip propagation delay R = 10;

(3) input data arrive at σ messages/slot and consist of equal number of single packet and 8-packet messages such that the average message length = 4.5 packets and the average data input rate S = 4.5σ packets/slot;

(4) V = 6.

The simulation program can accept message length distributions other than the one in (3) above. The above assumptions are made to coincide with Roberts' so that we can compare the simulation results here with his analytic results. To specify the simulation completely, we need the following further assumptions:

(5) message arrivals generated in the same slot for a given station are lumped together as a single message;

(6) the random retransmission interval K in the ALOHA channel is assumed to be equal to V=6 so that every blocked ALOHA packet will randomize its retransmission over all the small slots in a single ALOHA slot (this assumption was made for the ease of programming and has been generalized in the simulation program to allow K to be multiples of V);

(7) newly generated ALOHA packets will also randomize their transmissions over all the small slots within an ALOHA slot rather than transmitting in the first available small slot.

In all of our simulations, the ALOHA traffic in the channel consists of only the reservation requests. In this case, the channel performance is expected to be slightly better than Roberts' analytic results since he included in the ALOHA traffic acknowledgement messages. The simulation program does not provide for the generation of acknowledgement messages. However, it does provide for the generation of arbitrary ALOHA packets at some specified Poisson rate to use the ALOHA portion of the channel in addition to the reservation request packets.

Comparison of analytic and simulation results

In Fig. 11, we show the tradeoffs between throughput and delay for the FCFS reservation scheme with M=5. E[block delay] is the average message delay for both single and eight-packet messages. It includes both the ALOHA delay for the reservation request packet and the queueing delay in waiting for the reserved data slots. The analytic results for this tradeoff are taken from Fig. 2 in ASS Note 38. We see that the analytic and simulation results agree quite well. The simulation results give a slightly better channel performance than the analytic results because the simulations did not include the use of the ALOHA portion of the channel by acknowledgement packets. Hence the ALOHA packet delays are smaller because of the lower utilization. When the data input rate S is small, the difference in the two curves is negligible since the ALOHA portion of the channel is lightly utilized in both cases. In Fig. 12, we show the average throughput rate, traffic rate and packet delay for the ALOHA portion of the channel as a function of the data rate S.

Delay and stability considerations in determining M

What fraction f of the satellite channel is for the use of ALOHA traffic? The answer is f = 1-S where S is the input data rate. Thus f is not a function of M! If given S, our main concern is the average message delay, it seems to suggest the use of as large a value of M as possible since the ALOHA utilization does not depend on M whereas the FCFS queueing delay decreases as M increases. However, although the ALOHA utilization is independent of M, increase in the value of M gives rise to the following limitations. If we telescope our attention only on the ALOHA slots, the variance of the input process of the ALOHA channel increases as M increases. As a result the average ALOHA packet delay increases due to the larger variance. In addition, the variance of the traffic in the ALOHA channel is directly proportional to the variance of the input. As the variance of the traffic increases, the ALOHA channel becomes less stable! Since a stable ALOHA channel is necessary for acceptable reservation delays, too large a value of M cannot be used.

In Figs. 13 and 14, we show the channel performance for values of M other than 5. From the simulation data M=7 gives the best performance. In Figs. 15 and 16 we show situations when the ALOHA channel under a high data input rate becomes "unstable" for values of M equal to 7 and 10.

IV. Further comments

Operating policies

The operation of a slotted satellite channel in both the ALOHA mode and the FCFS reservation mode requires constant monitoring of the ALOHA channel traffic and the use of external controls (or built-in local SIMP policies) to reduce the channel input data rate and/or increase the random retransmission interval K to offset fluctuations in the channel traffic. From the simulation results, a minimum operating value for K is about 15. (Note in Fig. 2 that the delay curve corresponding to K=15 is quite near the optimum). At the same time, the average channel traffic rate G should be kept below 0.7.

An estimate for G

An estimate for G can be obtained by counting the number of empty slots in the ALOHA channel during an appropriate interval. The fraction of empty slots $f_0 \cong e^{-G}$ (see Figs. 3 and 4). Hence the estimate is

$$G \cong -\ln(f_0)$$

Final remarks

Both simulation programs are written in PL/I. Typical runs on the UCLA-CCN IBM 360/91 require approximately 3 CPU seconds execution time each for 10,000 slots of the FCFS reservation simulation and 4000 slots of the slotted ALOHA simulation.

ACKNOWLEDGEMENTS

The author would like to thank E. Walton who coded the FCFS reservation simulation and J. Spencer who coded the slotted ALOHA simulation.

Fig. 1 Throughput as a Function of ALOHA Channel Traffic

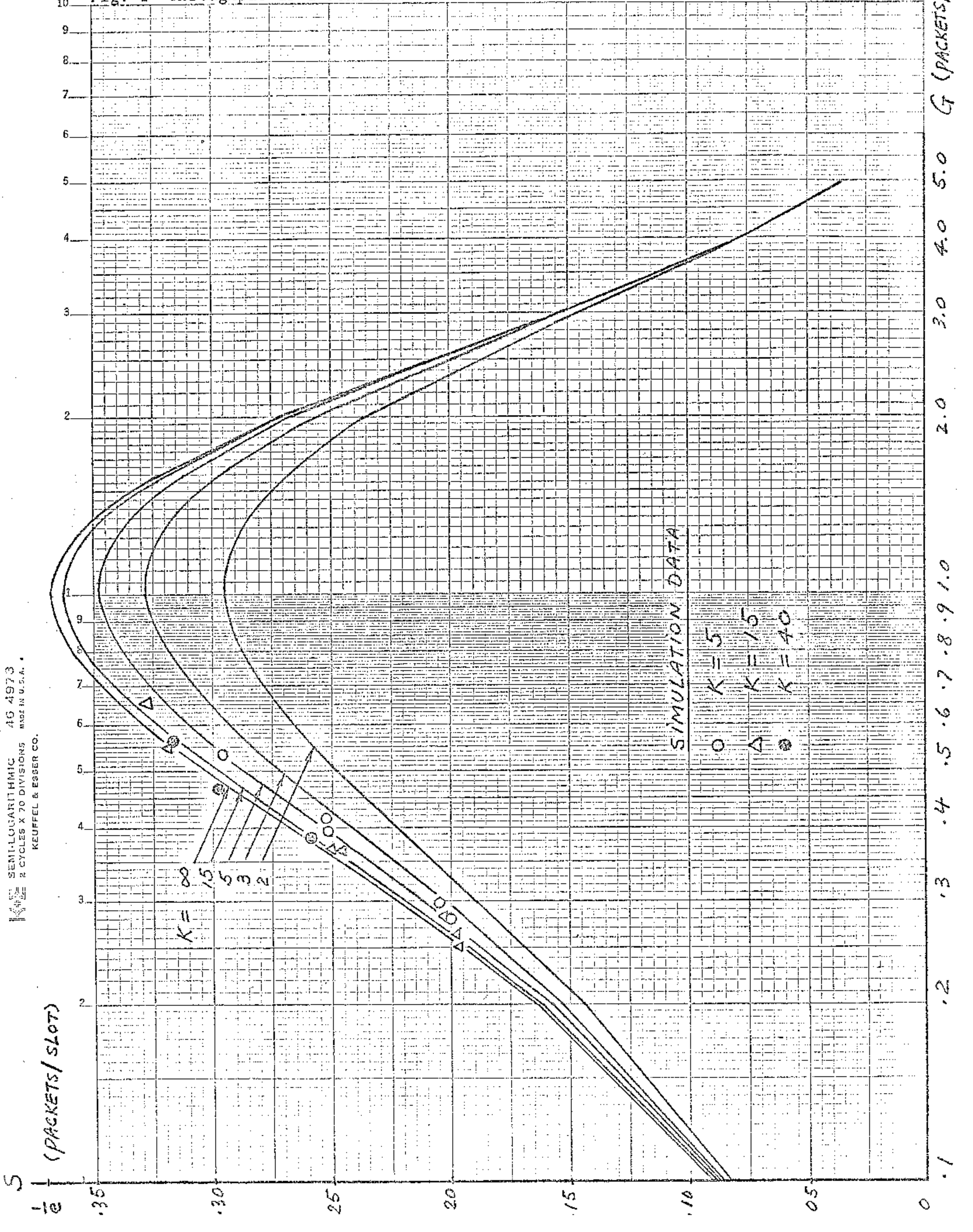
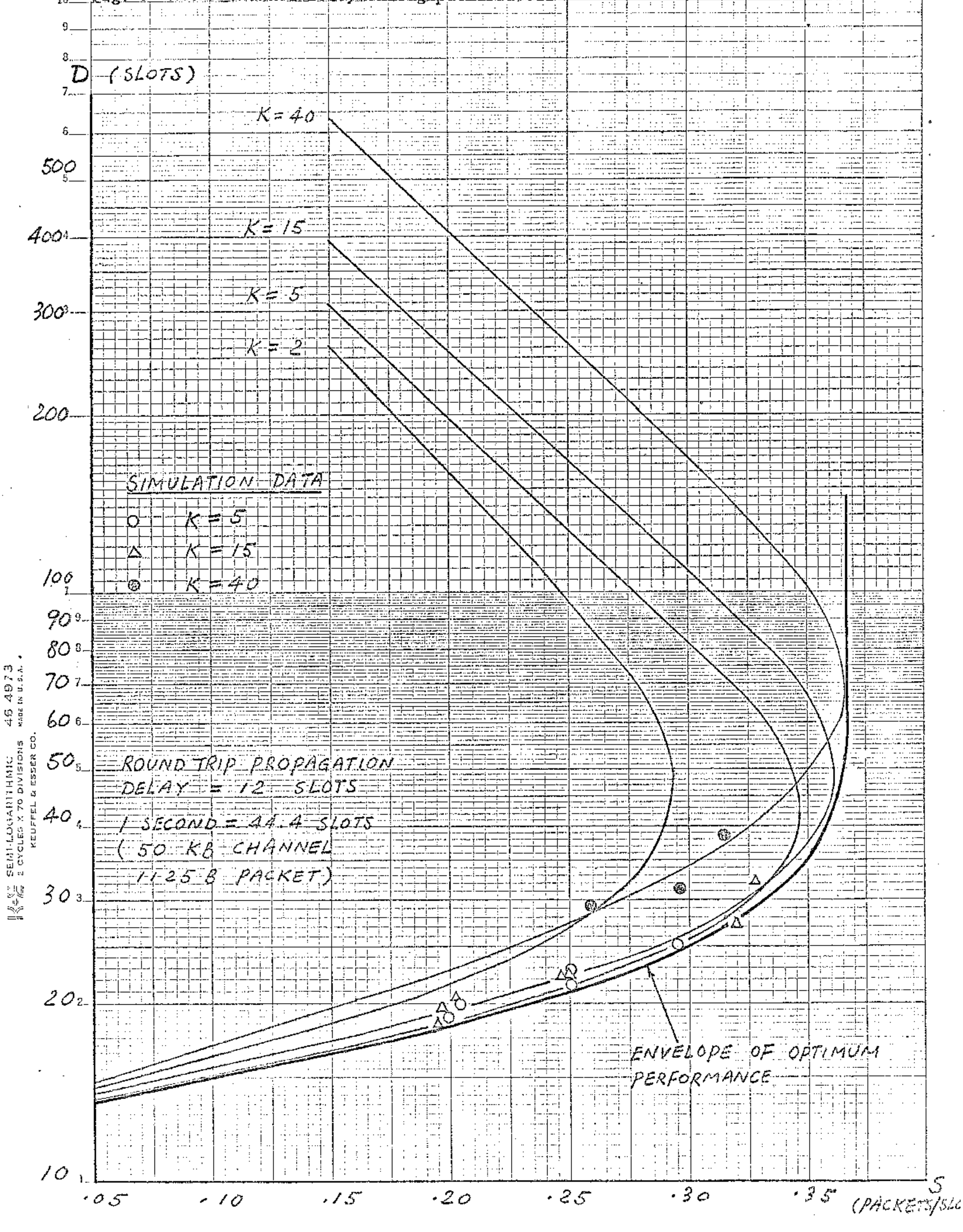


Fig. 2 ALOHA Channel Delay-Throughput Tradeoff



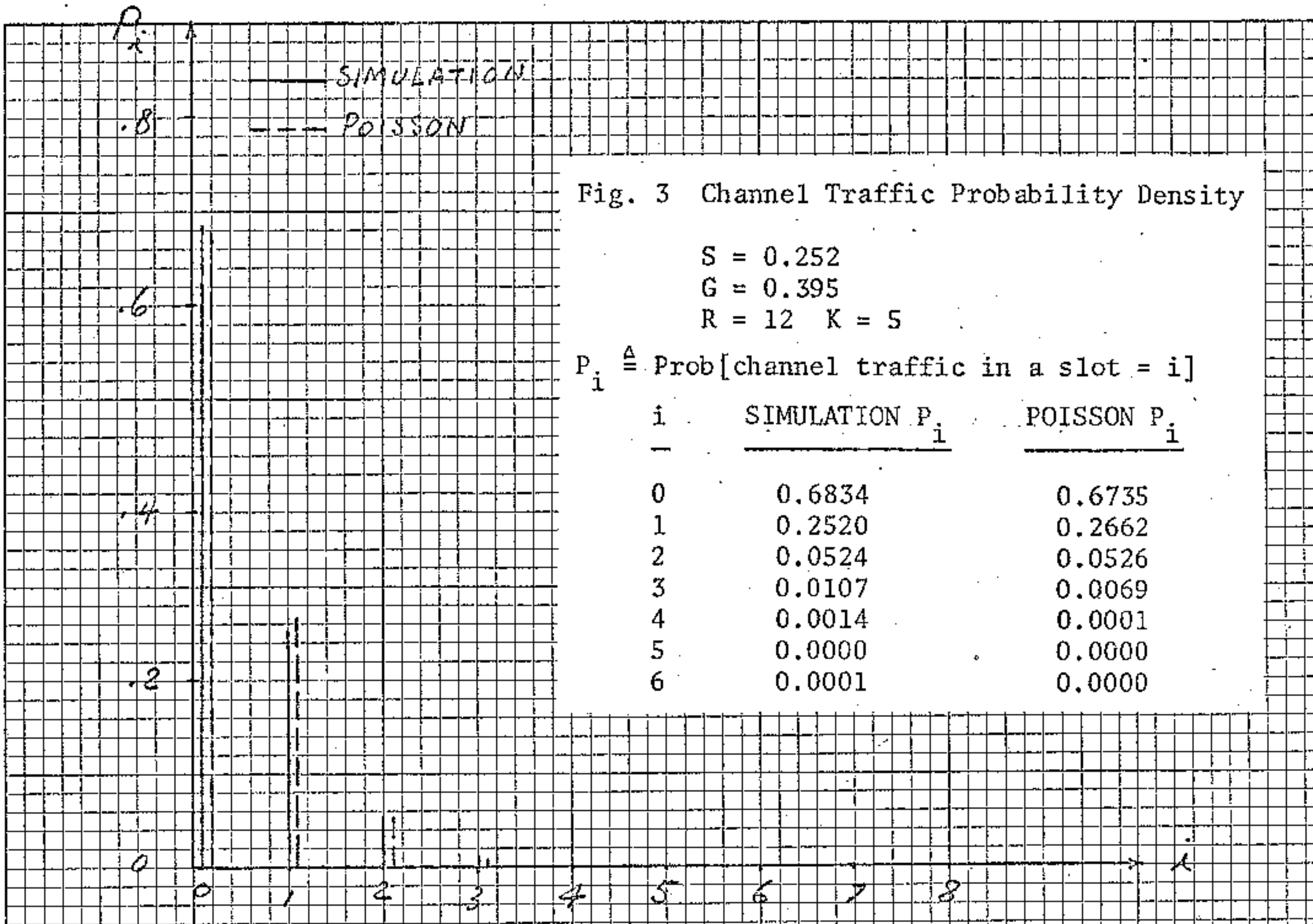


Fig. 3 Channel Traffic Probability Density

S = 0.252
G = 0.395
R = 12 K = 5

$P_i \triangleq$ Prob[channel traffic in a slot = i]

i	SIMULATION P_i	POISSON P_i
0	0.6834	0.6735
1	0.2520	0.2662
2	0.0524	0.0526
3	0.0107	0.0069
4	0.0014	0.0001
5	0.0000	0.0000
6	0.0001	0.0000

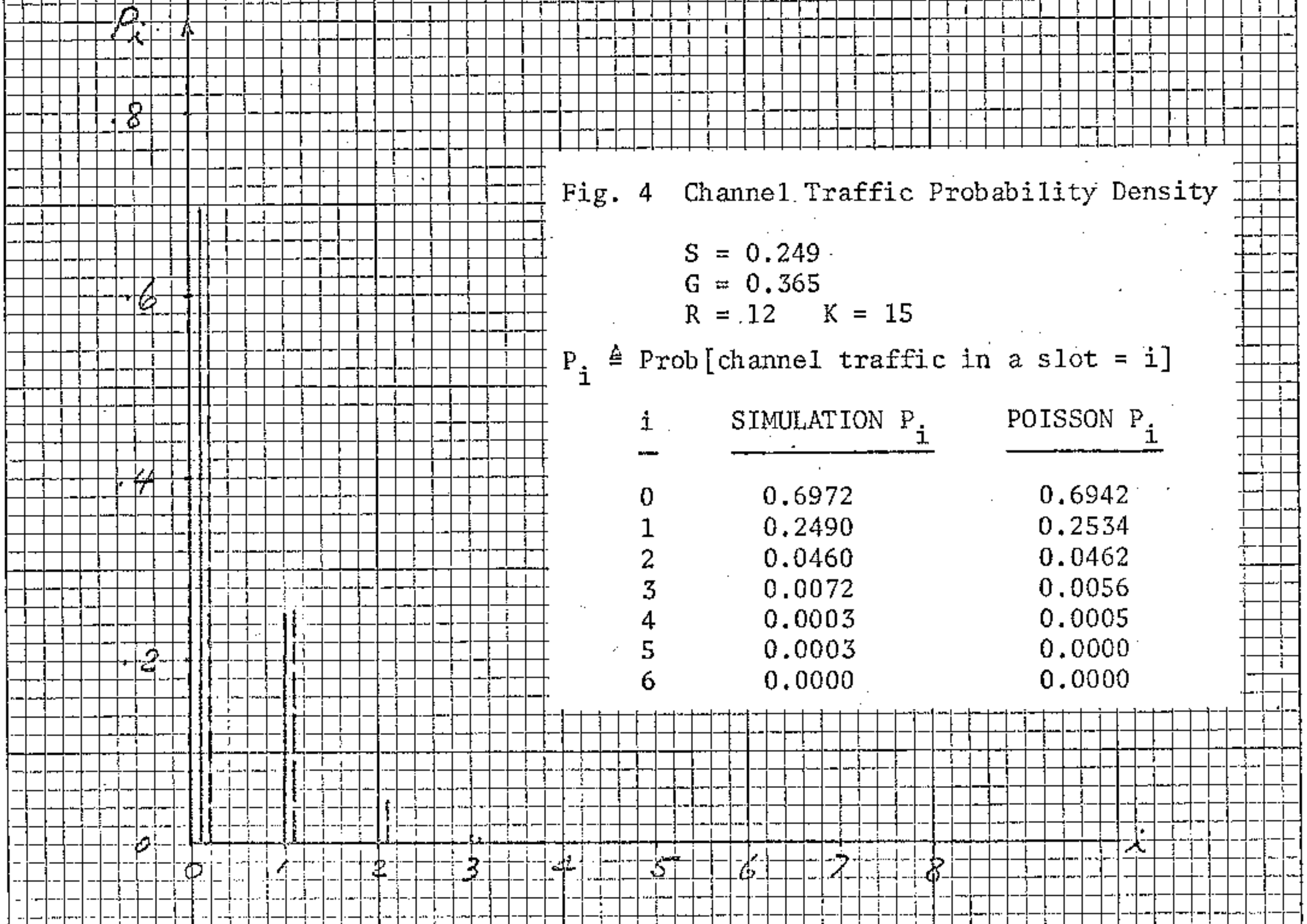


Fig. 4 Channel Traffic Probability Density

S = 0.249
G = 0.365
R = 12 K = 15

$P_i \triangleq$ Prob[channel traffic in a slot = i]

i	SIMULATION P_i	POISSON P_i
0	0.6972	0.6942
1	0.2490	0.2534
2	0.0460	0.0462
3	0.0072	0.0056
4	0.0003	0.0005
5	0.0003	0.0000
6	0.0000	0.0000

Fig. 5 Dynamic Behavior of a Slotted ALOHA Channel

```
INPUT PARAMETERS   => => =>
     INPUT RATE = 0.325
     PRØPAGATIØN DELAY =  12
     K =    5
     RUN TIME =  4000
     SEED =      64783
     AVERAGE VALUES IN  200 TIME SLØT PERIØDS
```

TIME PERIØD	THRØUGHPUT RATE= S	TRAFFIC RATE= G	PACKET DELAY= D	FRACTIØN ØF TIME CHANNEL EMPTY
1 = 200	0.315	0.490	20.143	0.600
201 = 400	0.315	0.840	38.635	0.455
401 = 600	0.300	0.735	22.450	0.530
601 = 800	0.250	1.920	67.180	0.195
801 = 1000	0.190	3.175	121.526	0.045
1001 = 1200	0.020	5.535	151.750	0.005
1201 = 1400	0.000	9.805	0.000	0.000
1401 = 1600	0.000	14.590	0.000	0.000

```
LØNG TERM STATISTICS =>=>=>=>=>=>=>

TIME FØR LØNG TERM STATS =
```

Fig. 6 Dynamic Behavior of a Slotted ALOHA Channel

INPUT PARAMETERS => => =>

INPUT RATE = 0.325
PROPAGATION DELAY = 12
K = 7
RUN TIME = 4000
SEED = 64783
AVERAGE VALUES IN 200 TIME SLOT PERIODS

TIME PERIOD	THROUGHPUT RATE= S	TRAFFIC RATE= G	PACKET DELAY= D	FRACTION OF TIME CHANNEL EMPTY
1 = 200	0.315	0.455	19.714	0.620
201 = 400	0.310	0.685	27.903	0.525
401 = 600	0.365	0.860	35.562	0.425
601 = 800	0.325	0.930	39.446	0.405
801 = 1000	0.300	0.765	34.283	0.500
1001 = 1200	0.320	1.490	66.484	0.255
1201 = 1400	0.350	1.135	50.700	0.305
1401 = 1600	0.285	1.230	66.579	0.365
1601 = 1800	0.395	1.370	47.886	0.240
1801 = 2000	0.375	1.000	53.587	0.385
2001 = 2200	0.335	0.645	28.701	0.530
2201 = 2400	0.345	0.760	31.565	0.475
2401 = 2600	0.330	0.895	26.955	0.445
2601 = 2800	0.330	1.130	60.712	0.345
2801 = 3000	0.285	0.480	29.860	0.625
3001 = 3200	0.325	0.560	23.062	0.570
3201 = 3400	0.325	0.730	33.708	0.505
3401 = 3600	0.320	0.640	30.750	0.540
3601 = 3800	0.275	0.485	22.691	0.625
3801 = 4000	0.300	0.560	29.517	0.590

LONG TERM STATISTICS =>=>=>=>=>=>=>

THROUGHPUT = 0.325
TRAFFIC = 0.840
IDLE SLOTS = 0.464
AVERAGE DELAY = 38.292

TIME FOR LONG TERM STATS = 4000

Fig. 7 Dynamic Behavior of a Slotted ALOHA Channel

INPUT PARAMETERS => => =>
INPUT RATE = 0.350
PROPAGATION DELAY = 12
K = 15
RUN TIME = 4000
SEED = 39276
AVERAGE VALUES IN 200 TIME SLOT PERIODS

TIME PERIOD	THROUGHPUT RATE= S	TRAFFIC RATE= G	PACKET DELAY= D	FRACTION OF TIME CHANNEL EMPTY
1 - 200	0.330	0.510	17.924	0.595
201 - 400	0.370	0.605	30.892	0.530
401 - 600	0.360	0.860	32.764	0.425
601 - 800	0.340	0.840	43.147	0.435
801 - 1000	0.315	1.415	58.889	0.250
1001 - 1200	0.380	1.260	72.066	0.260
1201 - 1400	0.325	0.455	37.215	0.610
1401 - 1600	0.355	0.480	20.803	0.590
1601 - 1800	0.275	0.405	20.600	0.665
1801 - 2000	0.360	0.560	27.528	0.550
2001 - 2200	0.330	0.430	18.561	0.620
2201 - 2400	0.310	0.545	22.065	0.580
2401 - 2600	0.335	0.840	44.866	0.455
2601 - 2800	0.320	0.705	34.703	0.500
2801 - 3000	0.325	1.085	43.815	0.350
3001 - 3200	0.310	1.715	67.161	0.180
3201 - 3400	0.105	3.255	147.143	0.050
3401 - 3600	0.015	5.910	220.333	0.000
3601 - 3800	0.000	9.155	0.000	0.000
3801 - 4000	0.000	12.400	0.000	0.000

LONG TERM STATISTICS =>=>=>=>=>=>=>

THROUGHPUT = 0.270
TRAFFIC = 2.259
IDLE SLOTS = 0.371
AVERAGE DELAY = 41.287

TIME FOR LONG TERM STATS = 3800

Fig. 8 Dynamic Behavior of a Slotted ALOHA Channel

INPUT PARAMETERS => => =>
INPUT RATE = 0.350
PROPAGATION DELAY = 12
K = 40
RUN TIME = 4000
SEED = 43961
AVERAGE VALUES IN 200 TIME SLOT PERIODS

TIME PERIOD	THROUGHPUT RATE= S	TRAFFIC RATE= G	PACKET DELAY= D	FRACTION OF TIME CHANNEL EMPTY
1 = 200	0.325	0.525	28.508	0.580
201 = 400	0.345	0.850	32.478	0.430
401 = 600	0.350	1.265	81.043	0.310
601 = 800	0.365	1.255	92.151	0.280
801 = 1000	0.410	1.015	84.220	0.335
1001 = 1200	0.385	0.880	48.143	0.395
1201 = 1400	0.395	0.665	49.519	0.485
1401 = 1600	0.295	0.610	35.566	0.555
1601 = 1800	0.365	0.720	52.753	0.490
1801 = 2000	0.385	0.610	35.000	0.515
2001 = 2200	0.325	0.565	39.723	0.565
2201 = 2400	0.270	0.710	43.407	0.545
2401 = 2600	0.365	0.960	55.370	0.385
2601 = 2800	0.365	0.985	81.137	0.365
2801 = 3000	0.360	0.525	47.750	0.565
3001 = 3200	0.310	0.670	35.952	0.530
3201 = 3400	0.285	0.540	47.807	0.595
3401 = 3600	0.390	0.890	52.308	0.395
3601 = 3800	0.360	0.775	44.875	0.460
3801 = 4000	0.420	1.055	60.702	0.310

LONG TERM STATISTICS =>=>=>=>=>=>=>

THROUGHPUT = 0.355
TRAFFIC = 0.818
IDLE SLOTS = 0.448
AVERAGE DELAY = 54.505

TIME FOR LONG TERM STATS = 3800

Fig. 9 Dynamic Behavior of a Slotted ALOHA Channel

INPUT PARAMETERS => => =>
INPUT RATE = 0.250
PROPAGATIØN DELAY = 12
K = 2
RUN TIME = 4000
SEED = 39276
AVERAGE VALUES IN 200 TIME SLØT PERIØDS

TIME PERIØD	THRØUGHPUT RATE= S	TRAFFIC RATE= G	PACKET DELAY= D	FRACTIØN ØF TIME CHANNEL EMPTY
1 - 200	0.265	0.370	17.849	0.685
201 - 400	0.245	0.555	24.061	0.630
401 - 600	0.240	0.785	34.188	0.565
601 - 800	0.265	1.035	54.849	0.475
801 - 1000	0.215	1.010	42.581	0.555
1001 - 1200	0.165	1.965	35.788	0.405
1201 - 1400	0.130	3.010	86.615	0.300
1401 - 1600	0.035	5.710	20.857	0.065
1601 - 1800	0.000	9.760	0.000	0.000
1801 - 2000	0.000	13.025	0.000	0.000

LØNG TERM STATISTICS =>=>=>=>=>=>=>

TIME FØR LØNG TERM STATS =

Fig. 10 Dynamic Behavior of a Slotted ALOHA Channel

INPUT PARAMETERS => => =>
INPUT RATE = 0.200
PROPAGATION DELAY = 12
K = 2
RUN TIME = 4000
SEED = 44854
AVERAGE VALUES IN 200 TIME SLOT PERIODS

TIME PERIOD	THROUGHPUT RATE= S	TRAFFIC RATE= G	PACKET DELAY= D	FRACTION OF TIME CHANNEL EMPTY
1 = 200	0.185	0.310	22.081	0.765
201 = 400	0.170	0.280	21.853	0.775
401 = 600	0.185	0.605	31.892	0.650
601 = 800	0.210	0.600	48.333	0.630
801 = 1000	0.195	0.555	28.385	0.660
1001 = 1200	0.225	0.365	29.778	0.715
1201 = 1400	0.185	0.615	24.324	0.635
1401 = 1600	0.200	1.430	70.475	0.375
1601 = 1800	0.155	1.240	80.258	0.505
1801 = 2000	0.205	0.725	102.488	0.600
2001 = 2200	0.145	0.790	43.310	0.610
2201 = 2400	0.265	0.935	59.868	0.485
2401 = 2600	0.220	0.815	39.091	0.565
2601 = 2800	0.270	0.730	50.426	0.580
2801 = 3000	0.165	0.175	19.455	0.830
3001 = 3200	0.185	0.360	16.649	0.730
3201 = 3400	0.230	0.635	32.435	0.605
3401 = 3600	0.215	0.585	40.535	0.645
3601 = 3800	0.185	0.405	34.162	0.725
3801 = 4000	0.225	0.405	23.800	0.690

LONG TERM STATISTICS =>=>=>=>=>=>=>

THROUGHPUT = 0.205
TRAFFIC = 0.669
IDLE SLOTS = 0.623
AVERAGE DELAY = 43.945

TIME FOR LONG TERM STATS = 3400

Fig. 11 FCFS Reservation: Comparison of Simulation and Analytic Results

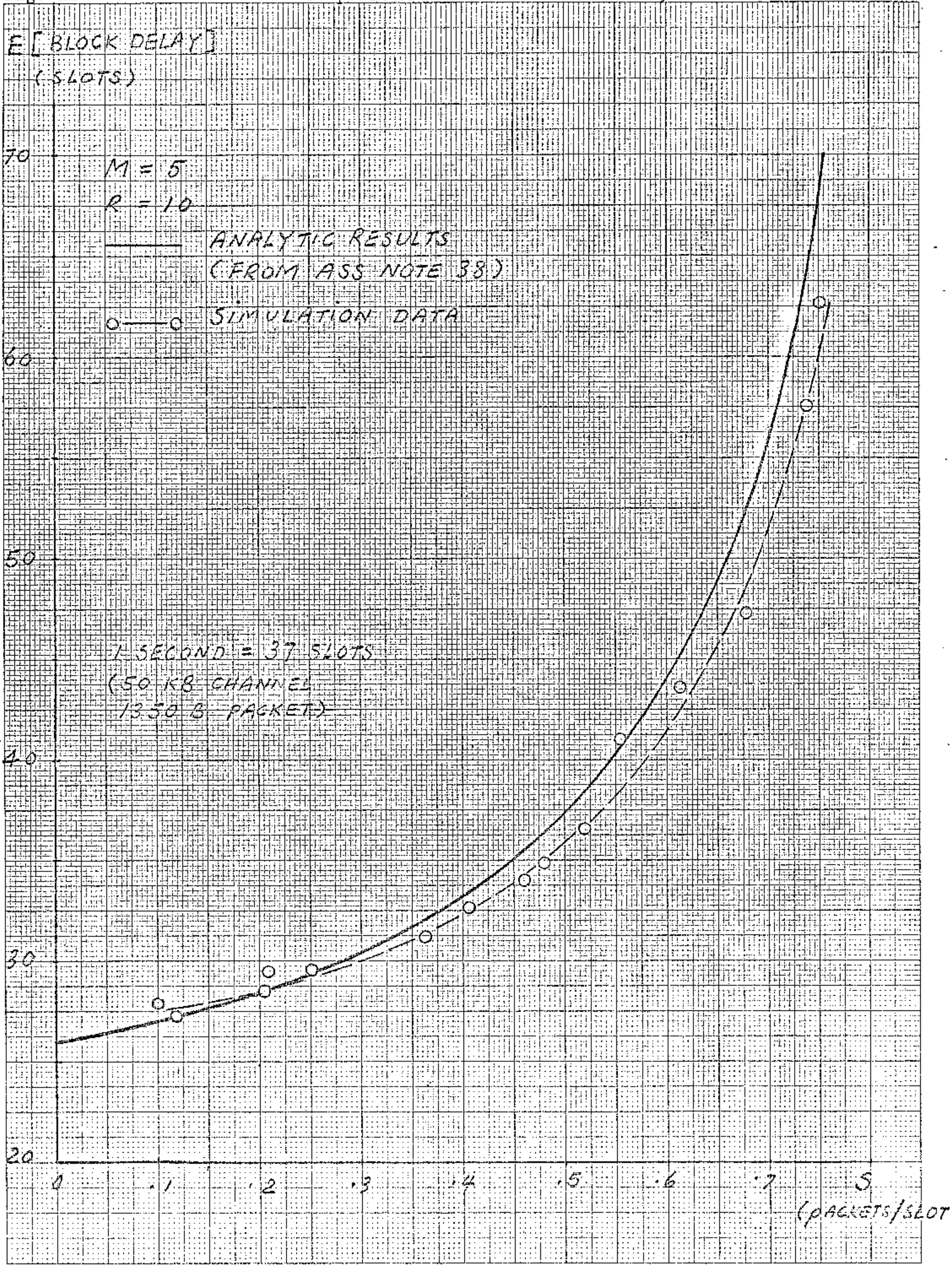


Fig. 12 Simulation Results: The ALOHA Channel for Reservation Requests

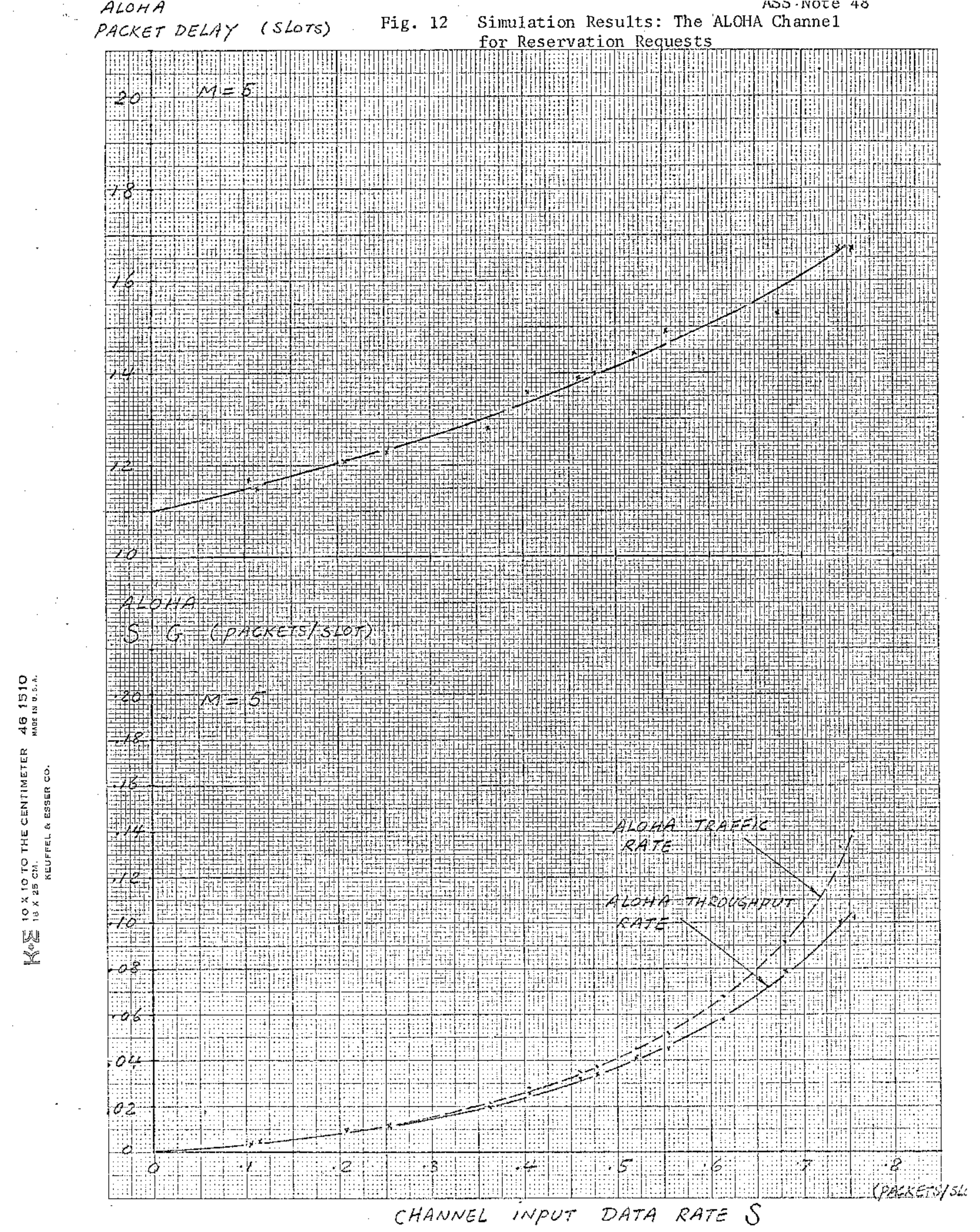


Fig. 13 FCFS Reservation: Simulation Results for Different Values of M

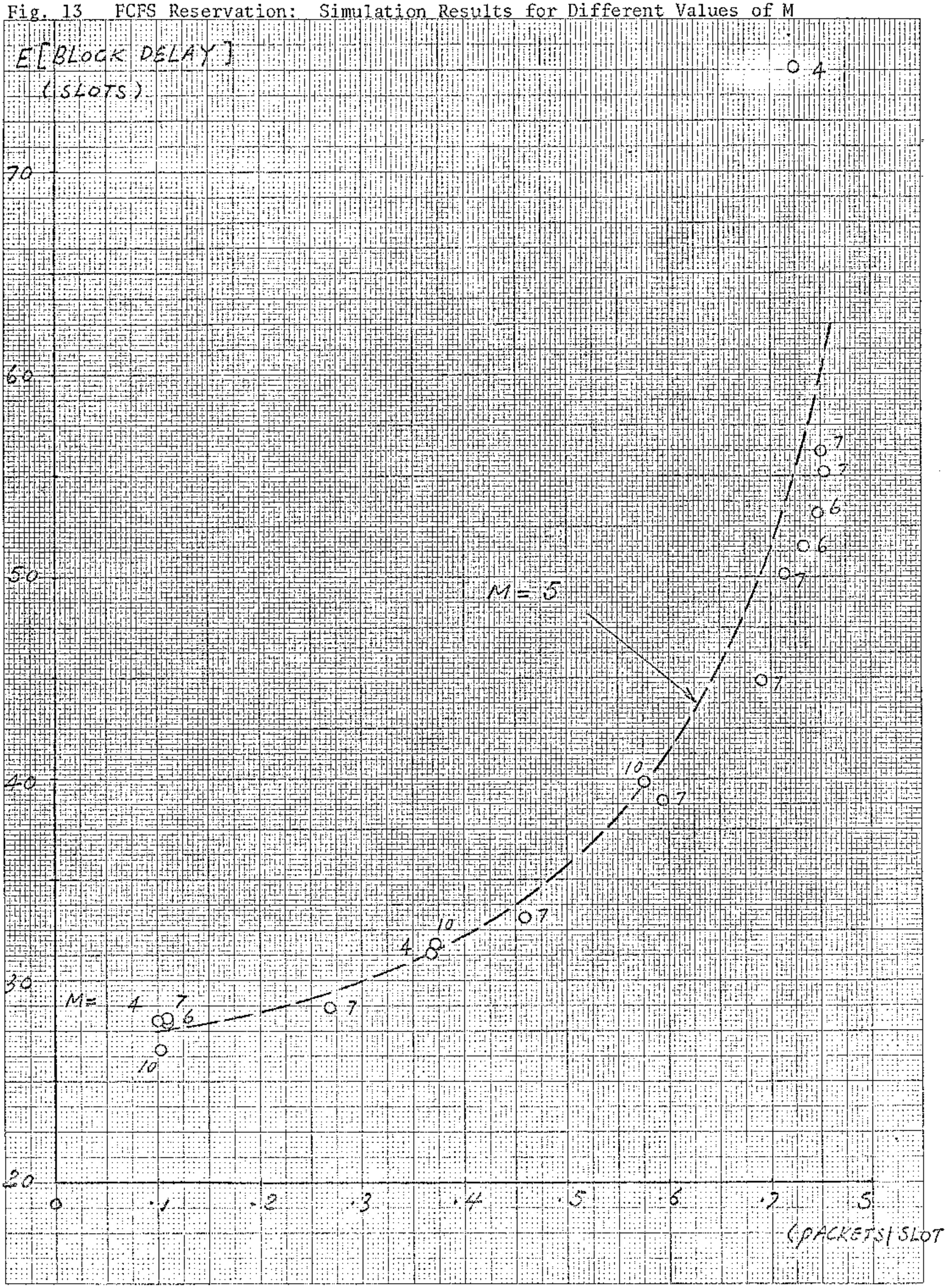


Fig. 14 Simulation Results for Different Values of M: The ALOHA Channel for Reservation Requests

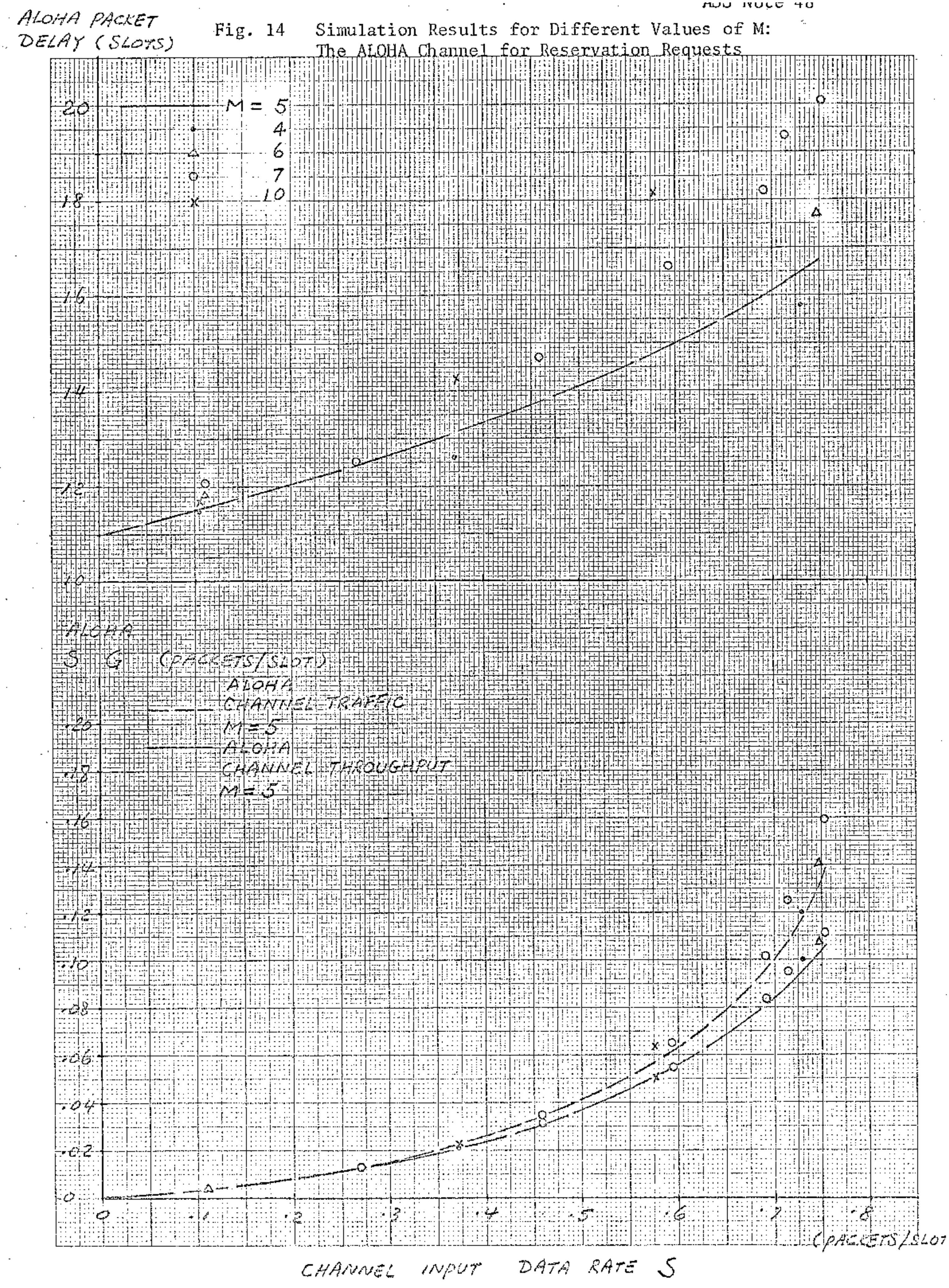


Fig. 15 FCFS Reservation: Unstable ALOHA Channel

M = 7
Total channel input data rate = 0.75 packets/slot
Round-trip propagation delay R = 10 slots
K = 6
V = 6
No. of ground stations = 10
Period for short-term statistics = 200

SHORT-TERM STATISTICS FOR PERIODS OF 200 SLOTS BEFORE SIMULATION BLOWS UP:

```
*** AVERAGE DELAYS BETWEEN SLOTS      5427 AND      5627
 AVERAGE RESERVATION DELAY IS        34.522
 TOTAL RESERVATION DELAY IS      794.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        23.000
 AVERAGE BLOCK DELAY IS        73.650
 TOTAL BLOCK DELAY IS      1573.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        20.000
 AVERAGE ALOHA UTILIZATION IS        0.044
 ALOHA TRAFFIC AVERAGE IS        0.998
 DATA TO TOTAL SLOTS RATIO IS        0.565

*** AVERAGE DELAYS BETWEEN SLOTS      5628 AND      5828
 AVERAGE RESERVATION DELAY IS        81.444
 TOTAL RESERVATION DELAY IS      1466.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        18.000
 AVERAGE BLOCK DELAY IS        93.200
 TOTAL BLOCK DELAY IS      1864.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        20.000
 AVERAGE ALOHA UTILIZATION IS        0.030
 ALOHA TRAFFIC AVERAGE IS        1.096
 DATA TO TOTAL SLOTS RATIO IS        0.519

*** AVERAGE DELAYS BETWEEN SLOTS      5829 AND      6029
 AVERAGE RESERVATION DELAY IS        12.400
 TOTAL RESERVATION DELAY IS      248.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        20.000
 AVERAGE BLOCK DELAY IS        27.529
 TOTAL BLOCK DELAY IS      468.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        17.000
 AVERAGE ALOHA UTILIZATION IS        0.023
 ALOHA TRAFFIC AVERAGE IS        0.591
 DATA TO TOTAL SLOTS RATIO IS        0.270

*** AVERAGE DELAYS BETWEEN SLOTS      6030 AND      6230
 AVERAGE RESERVATION DELAY IS        12.278
 TOTAL RESERVATION DELAY IS      221.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        18.000
 AVERAGE BLOCK DELAY IS        30.500
 TOTAL BLOCK DELAY IS      671.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        22.000
 AVERAGE ALOHA UTILIZATION IS        0.026
 ALOHA TRAFFIC AVERAGE IS        1.352
 DATA TO TOTAL SLOTS RATIO IS        0.435
```

STATISTICS FOR THE WHOLE RUN:

```
*** TOTAL DELAYS BETWEEN SLOTS        0 AND      6260
 AVERAGE RESERVATION DELAY IS        33.260
 TOTAL RESERVATION DELAY IS      33460.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS      1006.000
 AVERAGE BLOCK DELAY IS        77.453

 TOTAL BLOCK DELAY IS      77685.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS      1003.000
 AVERAGE ALOHA UTILIZATION IS        0.100
 ALOHA TRAFFIC AVERAGE IS        0.553
 DATA TO TOTAL SLOTS RATIO IS        0.731
```

Fig. 16 FCFS Reservation: Unstable ALOHA Channel

M = 10

Total channel input data rate = 0.75 packets/slot

Round trip propagation delay R = 10 slots

K = 6

V = 6

No. of ground stations = 10

Period of short-term statistics = 200

SHORT-TERM STATISTICS FOR PERIODS OF 200 SLOTS BEFORE SIMULATION BLOWS UP:

```
*** AVERAGE DELAYS BETWEEN SLOTS  7638 AND  7838
 AVERAGE RESERVATION DELAY IS        23.129
 TOTAL RESERVATION DELAY IS       717.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        31.000
 AVERAGE BLOCK DELAY IS         41.222
 TOTAL BLOCK DELAY IS      1113.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        27.000
 AVERAGE ALOHA UTILIZATION IS          0.058
 ALOHA TRAFFIC AVERAGE IS          0.086
 DATA TO TOTAL SLOTS RATIO IS          0.560

*** AVERAGE DELAYS BETWEEN SLOTS  7839 AND  8039
 AVERAGE RESERVATION DELAY IS        32.515
 TOTAL RESERVATION DELAY IS      1073.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        33.000
 AVERAGE BLOCK DELAY IS         57.824
 TOTAL BLOCK DELAY IS      1966.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        34.000
 AVERAGE ALOHA UTILIZATION IS          0.177
 ALOHA TRAFFIC AVERAGE IS          0.441
 DATA TO TOTAL SLOTS RATIO IS          0.850

*** AVERAGE DELAYS BETWEEN SLOTS  8040 AND  8240
 AVERAGE RESERVATION DELAY IS        31.696
 TOTAL RESERVATION DELAY IS       729.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        23.000
 AVERAGE BLOCK DELAY IS         58.643
 TOTAL BLOCK DELAY IS      1642.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        28.000
 AVERAGE ALOHA UTILIZATION IS          0.066
 ALOHA TRAFFIC AVERAGE IS          0.793
 DATA TO TOTAL SLOTS RATIO IS          0.715

*** AVERAGE DELAYS BETWEEN SLOTS  8241 AND  8441
 AVERAGE RESERVATION DELAY IS        11.400
 TOTAL RESERVATION DELAY IS       228.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        20.000
 AVERAGE BLOCK DELAY IS         32.211
 TOTAL BLOCK DELAY IS       612.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        19.000
 AVERAGE ALOHA UTILIZATION IS          0.037
 ALOHA TRAFFIC AVERAGE IS          1.259
 DATA TO TOTAL SLOTS RATIO IS          0.555

*** AVERAGE DELAYS BETWEEN SLOTS  8442 AND  8642
 AVERAGE RESERVATION DELAY IS        16.360
 TOTAL RESERVATION DELAY IS       409.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS        25.000
 AVERAGE BLOCK DELAY IS         32.042
 TOTAL BLOCK DELAY IS       769.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS        24.000
 AVERAGE ALOHA UTILIZATION IS          0.038
 ALOHA TRAFFIC AVERAGE IS          1.578
 DATA TO TOTAL SLOTS RATIO IS          0.450
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STATISTICS FOR THE WHOLE RUN:

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*** TOTAL DELAYS BETWEEN SLOTS       0 AND  8701
 AVERAGE RESERVATION DELAY IS        24.980
 TOTAL RESERVATION DELAY IS     33998.000
 NUMBER OF RESERVATION SAMPLES THIS TIME PERIOD IS      1361.000
 AVERAGE BLOCK DELAY IS         49.568
 TOTAL BLOCK DELAY IS     67363.000
 NUMBER OF BLOCK SAMPLES THIS TIME PERIOD IS      1359.000
 AVERAGE ALOHA UTILIZATION IS          0.085
 ALOHA TRAFFIC AVERAGE IS          0.287
 DATA TO TOTAL SLOTS RATIO IS          0.624
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