Ground Communications Facility 50-kbps Wideband Data Error Rate Test

J. P. McClure
SFOF/GCF Development Section

During June 1971 a seven-day wideband data error test was conducted between the SFOF Communications Terminal and the NASCOM Madrid Switch Center.

The test, which was run at 50 kbps, was conducted to determine both long-term and fine-grained error data for a wideband circuit comparable to those expected to be used to support Mariner Venus-Mercury 1973. The test was quite successful.

Long-term end-to-end error rates of 6×10^{-5} or better were measured in both directions. The hourly and 5-min error distributions indicate that the errors are grouped into bursts (as expected). The majority of the time the error rate is substantially less than the average.

I. Introduction

During the period June 8–14, 1971, a lengthy wideband data test was conducted between the SFOF Communications Terminal at JPL and the NASCOM Madrid Switch Center adjacent to DSS 61.

The test, which was run at 50 kbps, had two purposes; (1) to determine the error rates of a circuit generally comparable to those expected to be used in support of *Mariner* Venus-Mercury 1973 (MVM'73), and (2), to determine the statistical distribution of the errors. The test was quite successful and the resulting data satisfies both needs.

This article reports the measured error rates and the long-term (5-min to 1 day) error distributions. The fine-grained error statistics data are presently being reduced and will be reported in the future.

II. Test Configuration and Procedure

The configuration used for the test is shown in Fig. 1. Circuit GW 58619, provided by NASCOM, used 303C data sets operating synchronously at 50 kbps. The routing of this American Telephone and Telegraph circuit is not known nor are the facilities from which it was derived. The 303C data set requires substantially all of a 48 kHz passband; hence, a group bandwidth was used.

At Goddard Space Flight Center the continental circuit was connected to an overseas group circuit GW 58530, again using 303C data sets. The GSFC interconnection was at the direct current sides of the data sets, thus providing digital regeneration of the signal at this point. The routing of the overseas circuit via Comsat to the Madrid switch is shown on Fig. 1.

Test data consisted of the 2047-bit pseudo-random pattern generated by Frederick Electronic Company Model 600 test sets. At each receive location the pseudo-random pattern was also synchronized and compared against the standard pattern by Frederick 600 (F600) sets.

The bit-error pulse outputs generated by the Frederick 600's were handled in various ways depending on the location. At GSFC modified F600's outputted a pulse each time a bit error occurred and, on a separate line, simultaneously outputted a pulse each time a block error was detected. For this test the F600 block size was set to 600 bits, thus a block error output pulse occurred each time a set of 600 bits contained one or more errors. Printer-punch-recorders (PPRs) were used to accumulate either bit or block error counts for 5-min periods and then destructively print out the total. The PPR also punched a paper tape containing the same data as was printed. A TTY printout from the paper tape was the prime data for analysis.

At the Madrid switch center a modified F600 was used to drive two PPRs, one each for bit and block error counts.

At the SFOF Communications Terminal a conventional F600 was used. Block error data were obtained through use of a programmable block error counter (PBEC) set to produce error pulses for each 600-bit block. On two occasions the data received at the SFOF was routed to a computer for logging on magnetic tape. This recorded data will be reduced to determine the fine-grained error distribution.

The test configuration used, i.e., 303C data sets with regeneration at GSFC, closely approximates the expected configuration to be used for *Mariner* Venus-Mars 1973. One difference is anticipated, namely that a Western Electric Company 303B data set will be used operationally instead of the 303C used in this test. The 303C uses nearly a full 48-kHz group channel to handle 50 kbps whereas a 303B uses somewhat more than a half-group to support 28.5 ± kbps. The two data sets (and their associated modems) have only minor differences. Both use the same modulation scheme (binary vestigial side band amplitude modulation) and detection process.

NASCOM/GSFC served as the test conductor. Though the period June 8 through June 14, 1971 (Days 159 through 165) was used, the test was not conducted continuously. The overseas circuit (GW 58530) was diverted several times for operational purposes (voice/data channels). Channel outages occurred and on occasions the test was not restarted until the next day. A total of approximately 99 h of inbound data to JPL was recorded and about 98 h of outbound data was obtained at Madrid. GSFC recorded a total of 179 h in both directions.

III. Test Results and Preliminary Analysis

When data circuits fail they sometimes do so abruptly. Other times they slowly degenerate with the error rate increasing accordingly. In error rate tests it is always difficult to decide when the error rate is bad enough to declare the line "out", and thus not include subsequent errors in the totals. In this analysis the circuit was generally considered to have failed when the 5-min error rate exceeded 10^{-3}. The circuit was considered restored when the rate fell back below 10^{-3}.

The measured data and resulting error rates for the total period are shown in Table 1.

Tables 2 through 5 show the same information on a per-day basis. Several observations can be made regarding the table data:

(1) Day-to-day error rate variations of 20 to 1 were experienced (Table 1, Col. 3).

(2) In total, Madrid-to-JPL showed a lower error rate than Madrid-to-GSFC, an impossibility. Examination of hourly and 5-min data indicates numerous times when JPL recorded fewer errors than GSFC-inbound. An instrumentation error is suspected as the cause of these anomalies. Operator error, though possible, does not appear plausible.

(3) Madrid's simultaneous recording of bit and block errors makes it possible to derive the average number of error bits in an error block. This value, K, ranges from 26 to 116 on a daily basis, with a long term average of 62.4. With numerous assumptions one could conclude that the average burst length should be about 128 bits long. Actual burst length data must await the reduction of the magnetically recorded data.

(4) On a daily basis there appears to be some correlation between the performance of the inbound and outbound portions of the end-to-end circuit. On

four days the BER slope was the same, and on two days it differed.

Figure 2 is a representative logarithmic plot of the hourly end-to-end bit errors in each direction. No diurnal trend is evident, and no significant correlation between the inbound and outbound direction is evident. As in high speed data, the error counts range over wide limits, typically three orders of magnitude or more.

Figures 3 and 4 are bar chart plots of the hourly distribution of bit-error rates. For instance, Fig. 3 shows that on the Madrid-to-JPL circuit there were five 1-hour intervals when the hourly error rate ranged between 2×10^{-6} and 4×10^{-6}. The median M value is marked on each figure, this being the value below and above which there are an equal number of intervals. The average bit-error rate A is also shown.

The span between the median and the average plainly shows how much effect a few "bad" hours can have on the average. In the Fig. 3 case there were few hours with really poor error rates and as a result the median and average values are close. In contrast, Fig. 4 shows a wider spread due to several hours with heavy errors. Restated, the figures indicate that the majority of the time the error rate is well below the average. Despite this satisfying fact, the overall system design must be capable of handling the higher rate intervals.

Figures 5 and 6 are also plots of the bit-error rate distribution; however, these figures are based on 5-min intervals, the maximum resolution available. Most noteworthy is the large number of intervals having no errors. In all cases the median value is significantly lower than the equivalent hourly median rate. Both of these observations simply verify what the raw data show, i.e., performance on a 5-min interval can range from very bad to the very best. Despite the wide interval over which the errors range, each figure has a definite non-zero peak in the 10^{-5} to 10^{-6} area.

IV. Conclusions

If the 1973 wideband configuration is implemented in the planned manner we may expect operational bit error rates of 6×10^{-5} or better, measured on a long-term basis. The errors will be bunched, with the error rates showing wider variations as the sample interval becomes shorter. The majority of the time the error rate will be substantially less than the average.

Table 1.

	Bit test hours	Bit error rate	Block test hours	Block error rate (600 bits)
Madrid to GSFC (Overseas leg)	117.24	3.66×10^{-5}	2.58	11.9×10^{-4}
Madrid to JPL (End-to-end)	85.0	1.83×10^{-5}	14.42	6.04×10^{-4}
JPL to GSFC (Continental leg)	55.2	2.72×10^{-5}	4.0	14.6×10^{-4}
JPL to Madrid (End-to-end)	97.67	5.95×10^{-5}	99.58	5.69×10^{-4}

Table 2. Results (inbound) Madrid to GSFC

Madrid to GSFC						
Day	Bits			Blocks (600 bit)		
	Hours	Errors	Bit error rate $\times 10^{-5}$	Hours	Block errors	Block error rate $\times 10^{-4}$
159	–	–	–	2.58	922	11.9
160	8.83	50411	3.17	–	–	–
161	20.16	52964	1.45	–	–	–
162	20.0	225717	6.26	–	–	–
163	24.0	35446	0.82	–	–	–
164	24.0	20737	0.48	–	–	–
165	20.25	387770	10.77			
TOTAL	117.24	773045	3.66	2.58	922	11.9

Table 3. Results (inbound)—Madrid to JPL

Madrid to JPL						
Day	Bits			Blocks (600 bit)		
	Hours	Errors	Bit error rate $\times 10^{-5}$	Hours	Block errors	Block error rate $\times 10^{-4}$
159	–	–	–	1.92	553	9.59
160	2.25	7504	1.85	–	–	–
161	4.25	21430	2.80	12.5	2058	5.48
162	17.75	101724	3.18	–	–	–
163	24.0	49810	1.15	–	–	–
164	24.0	45842	1.06	–	–	–
165	12.75	53924	2.34	–	–	–
TOTAL	85.00	280234	1.83	14.42	2611	6.04

Table 4. Results (outbound)—JPL to GSFC

JPL to GSFC						
Day	Bits			Blocks (600 bit)		
	Hours	Errors	Bit error rate $\times 10^{-5}$	Hours	Block errors	Block error rate $\times 10^{-4}$
159	–	–	–	4.0	1756	14.6
160	9.5	28501	1.66	–	–	–
161	14.7	169061	6.38	–	–	–
162	20.0	55268	1.53	–	–	–
163	11.0	18334	0.92	–	–	–
164	–	–	–	–	–	–
165	–	–	–	–	–	–
TOTAL	55.2	271164	2.72	4.0	1756	14.6

Table 5. Results (outbound)—JPL to Madrid

JPL to Madrid							
Day	Bits			Blocks (600 bit)			K
	Hours	Errors	Bit error rate $\times 10^{-5}$	Hours	Block errors	Block error rate $\times 10^{-4}$	
159	–	–	–	–	–	–	
160	9.75	64917	3.69	9.33	1381	4.93	45
161	14.00	225352	8.94	14.58	2024	4.62	116
162	13.92	308934	12.32	15.00	3284	7.29	101
163	24.00	217359	5.03	24.00	2150	2.98	101
164	24.00	157100	3.63	24.00	5157	7.15	30
165	12.00	73811	3.41	12.67	3019	7.93	26
TOTAL	97.67	1047473	5.95	99.58	17015	5.69	62.4

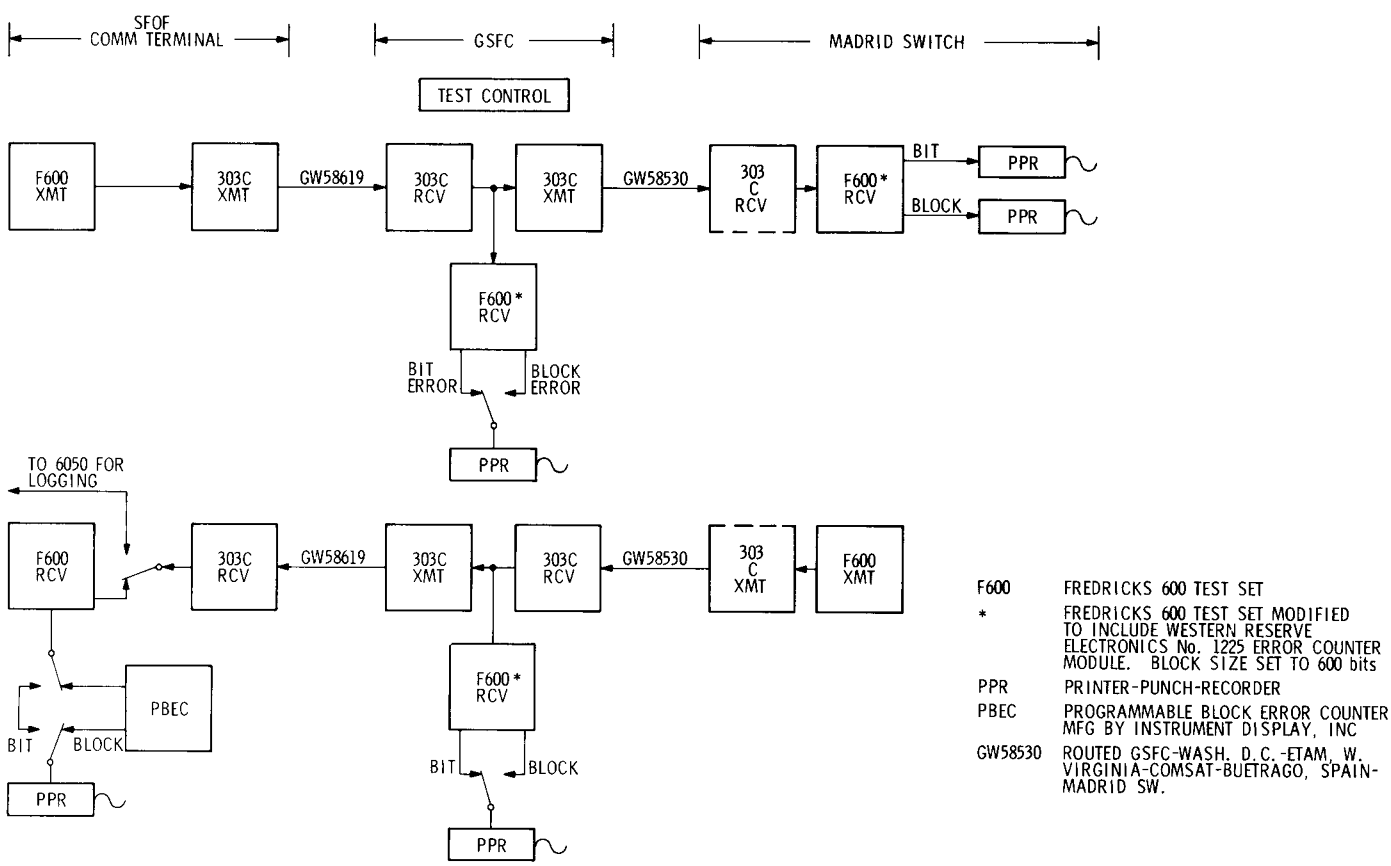

Fig. 1. 50-kbps Wideband test configuration, June 1971

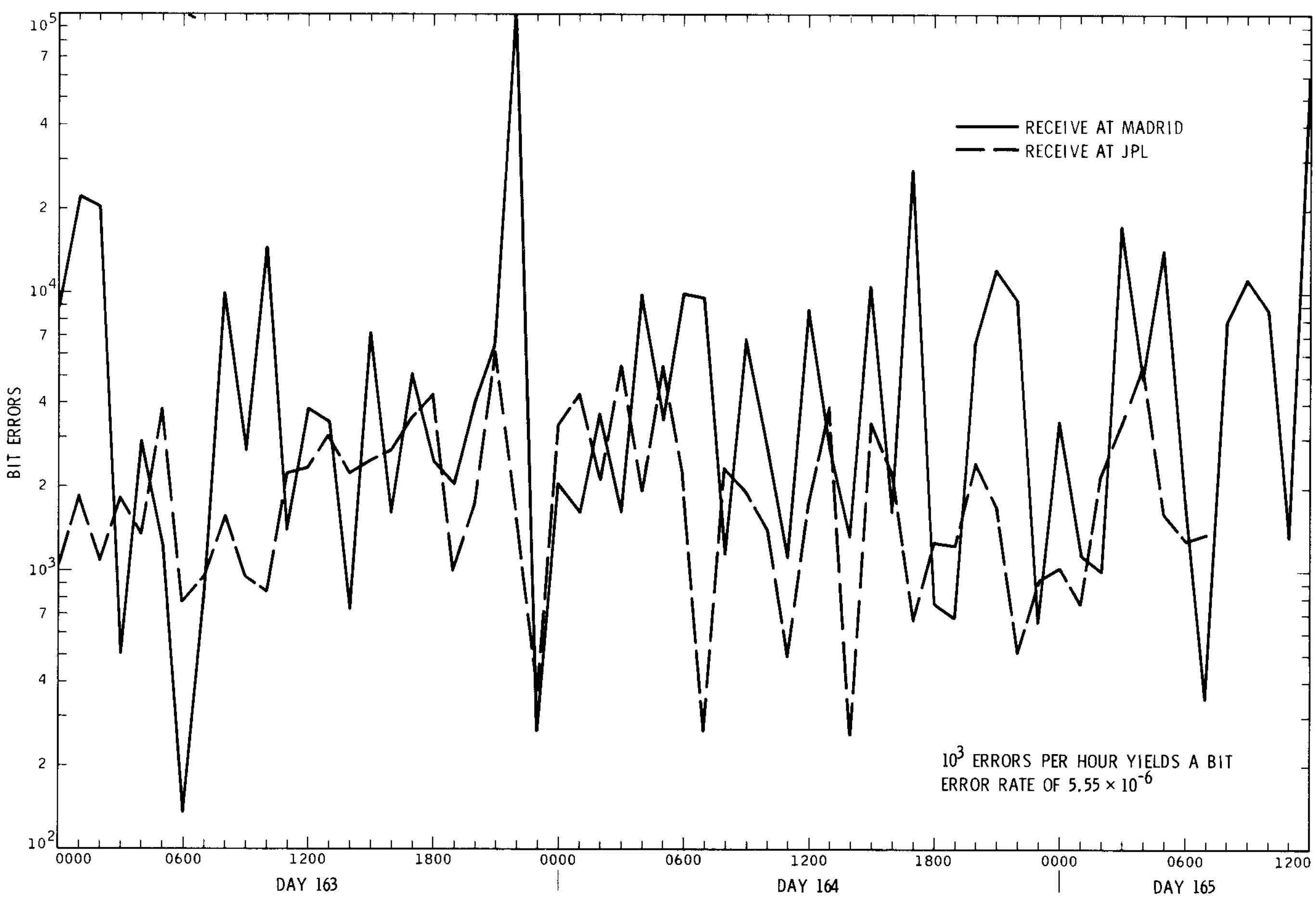

Fig. 2. Bit errors per hour

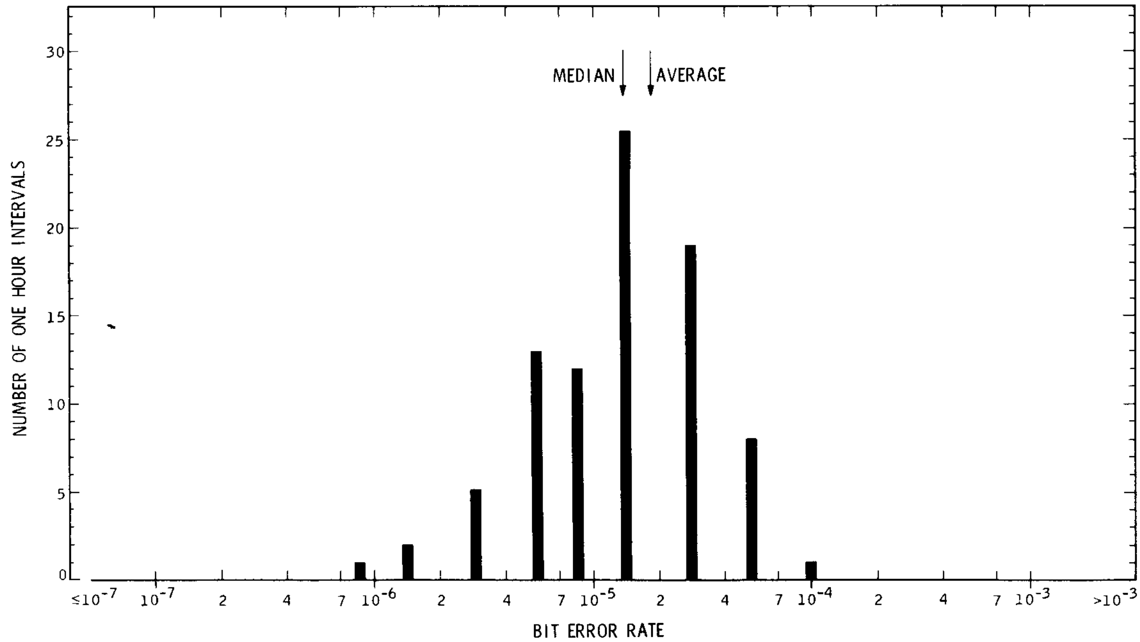

Fig. 3. Bit-error rate distribution (hour basis) Madrid to JPL

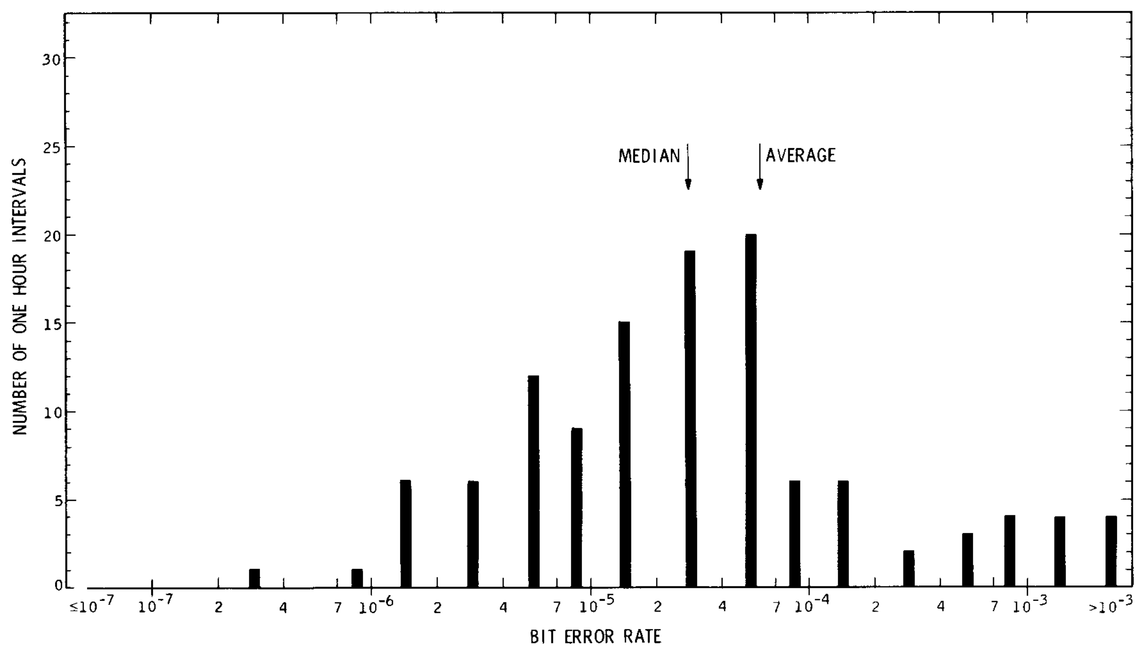

Fig. 4. Bit-error rate distribution (hour basis) JPL to Madrid

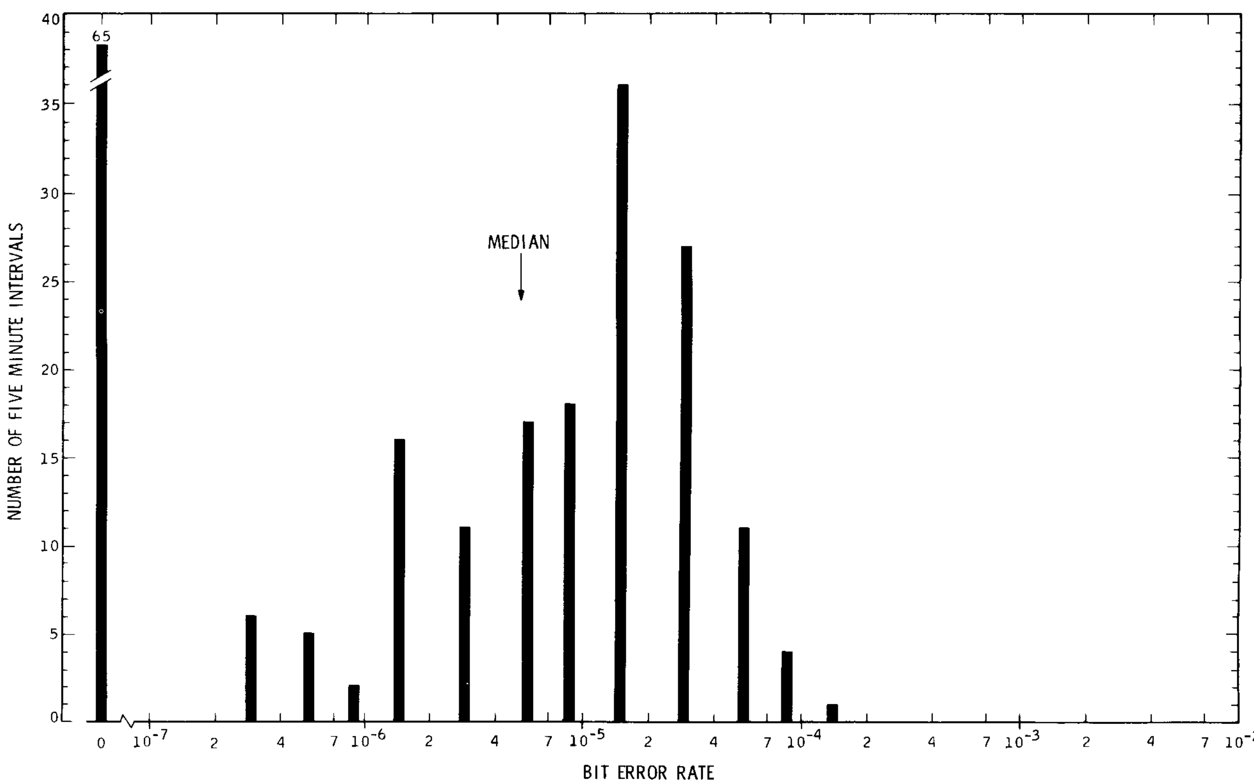

Fig. 5. Bit-error distribution (5-min. basis) Madrid to JPL

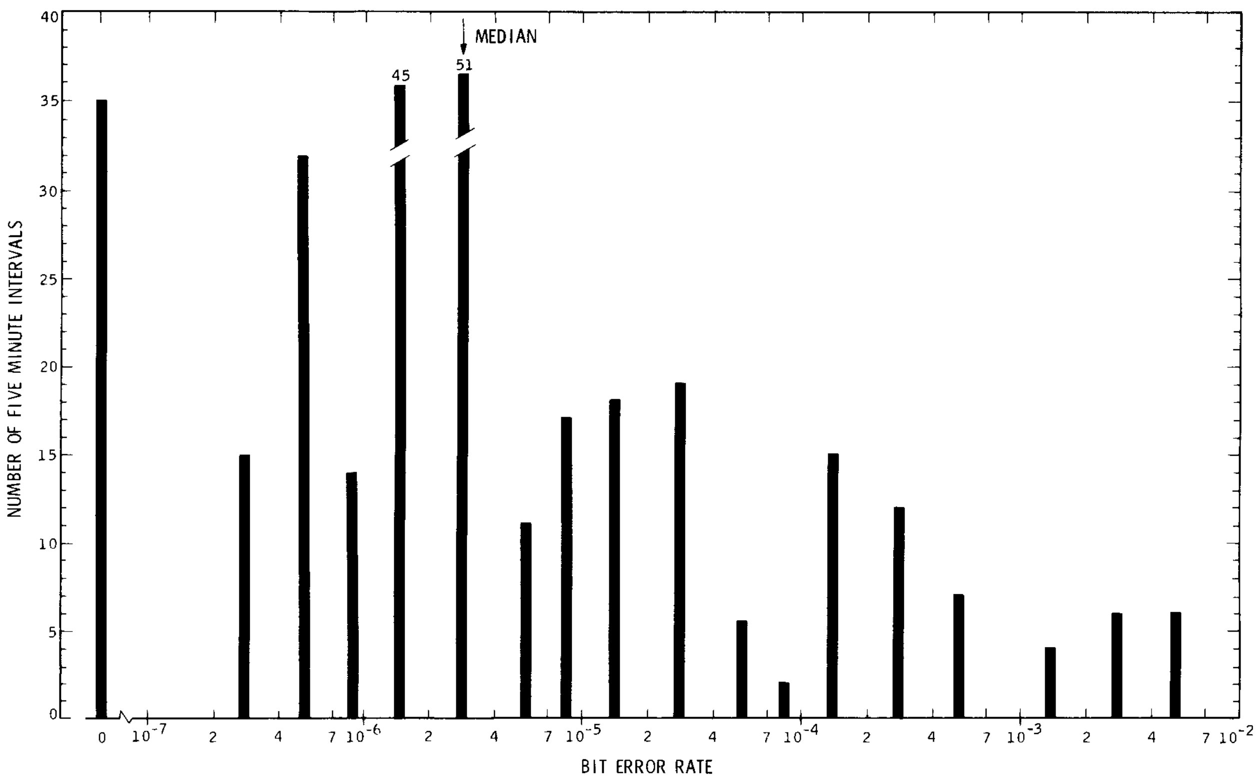

Fig. 6. Bit-error distribution (5-min. basis) JPL to Madrid