NASA Technical Memorandum 107345
Globecom Paper S32.1

ATM Quality of Service Parameters at 45 Mbps Using a Satellite Emulator: Laboratory Measurements

William D. Ivancic
Lewis Research Center
Cleveland, Ohio

and

Eric A. Bobinsky
Terasphere
Berea, Ohio

Prepared for
Globecom '97
sponsored by the Institute of Electrical and Electronics
Engineers (IEEE) Communications Society
Phoenix, Arizona, November 4–8, 1997

National Aeronautics and
Space Administration

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William D. Ivancic
National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio 44135

Eric A. Bobinsky
Terasphere, Berea, Ohio 44017

ABSTRACT: Results of 45–Mbps DS3 intermediate-frequency loopback measurements of asynchronous transfer mode (ATM) quality of service parameters (cell error ratio and cell loss ratio) are presented. These tests, which were conducted at the NASA Lewis Research Center in support of satellite-ATM interoperability research, represent initial efforts to quantify the minimum parameters for stringent ATM applications, such as MPEG–1 and MPEG–2 video transmission. Portions of these results were originally presented to the International Telecommunications Union's ITU–R Working Party 4B in February 1996 in support of their Draft Preliminary Recommendation on the Transmission of ATM Traffic via Satellite.

Introduction

Asynchronous transfer mode (ATM) quality of service parameters, including severely errored cell block ratio, cell loss ratio, and cell error ratio obtained in a 45–Mbps DS3 intermediate data rate (IDR) loopback configuration are presented. These tests were conducted at the NASA Lewis Research Center in support of ongoing satellite-ATM interoperability research.

Test Equipment and Procedures

Tests were conducted with the following hardware:

- EFData SDM–9000 IDR modem (provided by AT&T Bell Laboratories)
- Adtech AX/4000 ATM Traffic Generator/Analyzer
- Hewlett-Packard HP 3708A noise test set
- Adtech SX/14 Data Channel Simulator

ATM cell streams were generated by the Adtech AX/4000 unit (which is compliant with ITU recommendations G.826 and G.703) equipped with a 44.736–Mbps North American physical layer convergence procedure (PLCP) DS3 interface operating in a C-bit parity framing format with a nominal ATM cell bit rate of approximately 40 Mbps at 100-percent bandwidth utilization.

The bit pattern generated for the cell stream by the AX/4000 was set to a bit-repetition cycle (length) of $2^{23} - 1$ bits. For these tests, a cell block was arbitrarily chosen to be 100 cells, and the threshold for a severely errored cell block ratio was five errored cells.

The ATM DS3 stream was degraded at the output of the IDR modulator by injecting random, gaussian noise generated by the HP 3708A at an intermediate frequency of 70 MHz (Fig. 1). For this test, the control variable was the signal-to-noise ratio (E_b/N_0) set at the HP 3708A, which ranged from 5.0 to 9.0 dB. The EFData modem was configured for the quadrature phase shift keying (QPSK) modulation format with a three-fourths convolutional forward error correcting code. A large number of trials were conducted at each E_b/N_0 setting. Results presented reflect typical experimental runs (deviation between trials was negligible).

Note that for these particular experiments the Adtech SX/14 Data Channel Simulator was operated in a pass-through (delay) mode and did not contribute any random or systematic errors to the data stream. Also note that the Adtech AX/4000 DS3 ATM line cards operate only in ATM header error-detection mode. Thus, single errors in the ATM header are not corrected. Instead, the ATM cell is dropped, resulting in cell loss. The IDR modem uses convolutional coding, which

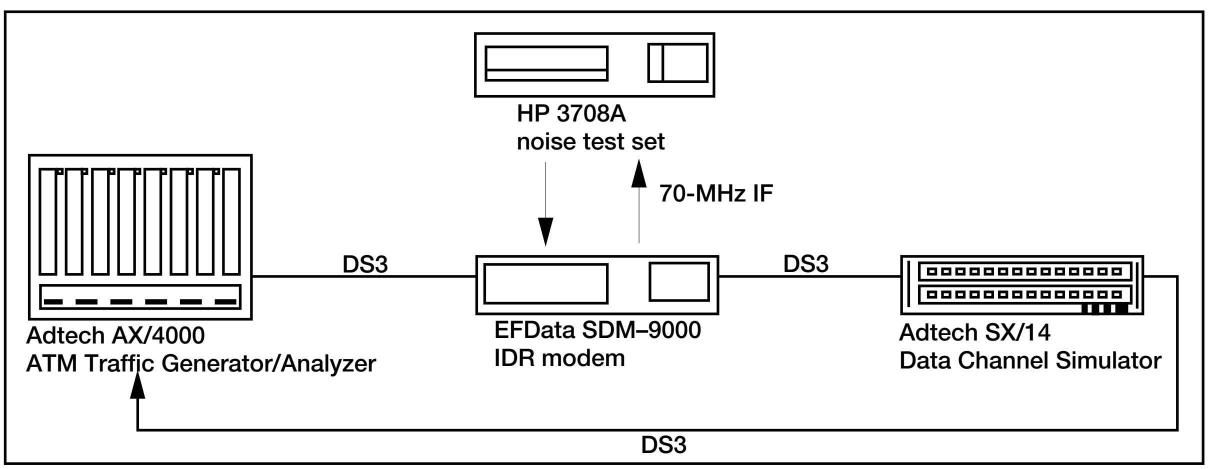

Figure 1.—Intermediate-frequency (IF) loopback configuration showing Adtech AX/4000 DS3 asynchronous transfer mode (ATM) line cards.

produces a burst of errors when the amount of error in the received data exceeds the capability of the code. Thus, the inability of the Adtech AX/4000 DS3 line cards to correct single errors is not considered significant.

Results

Table I reflects measurements of ATM severely errored cell block ratio, cell loss ratio, and cell error ratio as functions of desirable E_b/N_0 as set at the HP 3708A noise test set. Figure 2 indicates the same results geographically as a plot of error ratio versus E_b/N_0.

Columns 5 through 7 of Table I reflect the bit error rate (BER) as measured at the ATM stream terminus (AX/4000) and at the SDM–9000 modem, along with the measured E_b/N_0 at the modem. The "Number out of sequence" column indicates irreconcilable errors in the sequence number portion of the test packets. These errors are most likely to occur at low E_b/N_0 settings. The "Number of resynchronizations" column indicates how often a burst error in the $2^{23} - 1$ bit pattern was large enough to cause the test equipment to initiate a new pattern acquisition search. Each E_b/N_0 test was performed for a different length of time. For low E_b/N_0 settings, the test runs were relatively short, on the order of a few minutes. However, for high E_b/N_0 settings, tests were run either until at least 100 errors were counted or for at least one hour. The particular 9.0 dB E_b/N_0 test shown in Table I occurred over a weekend (2+ days). It is believed that a power line surge occurred during this test when portions of NASA's computer facilities where shutting down. This is substantiated by the high severely errored cell block ratio measurement. Other test runs at the 9.0 E_b/N_0 setting did not exhibit the high severely errored cell block ratio and resynchronization readings.

TABLE I.—QUALITY OF SERVICE PARAMETERS MEASURED AT 45 Mbps

Signal-to-noise ratio measured at HP 3708A noise test set, E_b/N_0	Severely errored cell block ratio	Cell loss ratio	Cell error ratio	Bit error rate measured at Adtech AX/4000	Bit error rate measured at EFData modem	Signal-to-noise ratio measured at EFData modem, E_b/N_0	Number out of sequence	Number of resynchronizations
5.0	6.0113×10^{-2}	4.6903×10^{-3}	1.6476×10^{-2}	3.0829×10^{-3}	$>1.0\times10^{-3}$	4.3	17	6945
5.5	5.5323×10^{-3}	1.1125×10^{-3}	4.6065×10^{-3}	7.2861×10^{-4}	5.0×10^{-4}	4.8	0	2394
6.0	1.1221×10^{-3}	2.6895×10^{-4}	1.1216×10^{-3}	1.7183×10^{-4}	8.7×10^{-5}	5.4	1	913
6.5	3.4092×10^{-4}	5.6695×10^{-5}	2.6771×10^{-4}	3.6528×10^{-5}	2.5×10^{-5}	5.9	0	267
7.0	1.2348×10^{-5}	9.1380×10^{-6}	5.4582×10^{-5}	6.1549×10^{-6}	5.7×10^{-6}	6.4	0	74
7.5	1.0000×10^{-99}	2.0047×10^{-6}	8.5537×10^{-6}	1.2213×10^{-6}	8.7×10^{-7}	6.9	0	15
8.0	1.0000×10^{-99}	1.7238×10^{-7}	1.5514×10^{-6}	1.2432×10^{-7}	2.5×10^{-7}	7.4	0	4
8.5	1.0000×10^{-99}	1.0850×10^{-7}	2.4413×10^{-7}	5.7464×10^{-8}	6.2×10^{-8}	7.9	0	4
9.0	9.2440×10^{-9}	6.6853×10^{-9}	2.3065×10^{-8}	3.4513×10^{-9}	1.0×10^{-10}	8.4	0	124

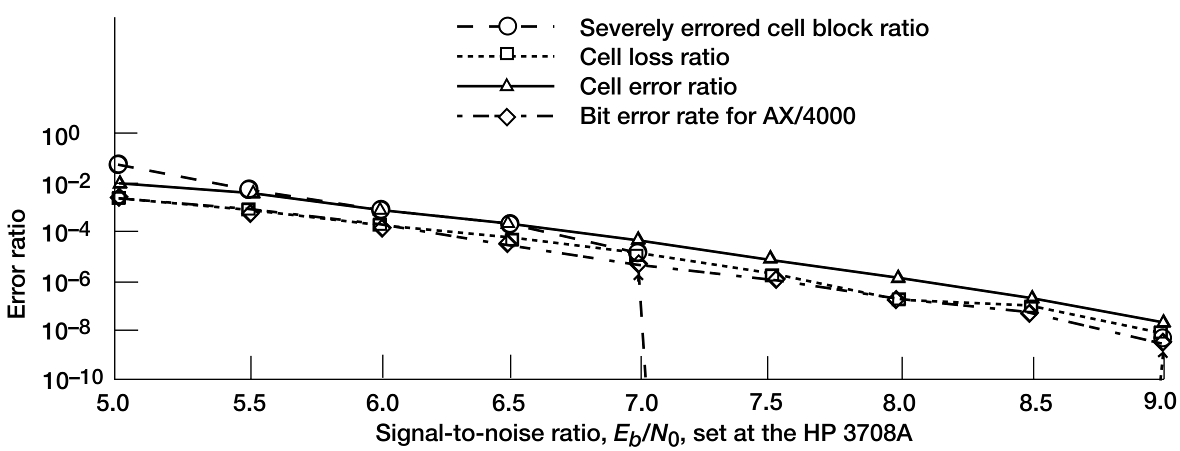

Figure 2.—Asynchronous transfer mode (ATM) DS3 radiofrequency loopback. Bit-repetition length, $2^{23} - 1$ bits; bad headers are withheld.

Discussion

As shown previously by Eutelsat [1] in similar tests conducted for 34–Mbps plesiochronous digital hierarchy (PDH), the cell loss ratio over the IDR link is approximately proportional to the bit error rate, although some differences have been observed, which likely result from the use of different test equipment and 34–Mbps, instead of 45–Mbps, PDH framing. The results presented here appear to validate this conclusion for IDR for DS3 (in C-bit parity mode using PLCP). These results pertain to basic IDR (per Intelsat IESS–308 Rev. 7A) and do not include the optional IDR Reed-Solomon outer code.

The results presented here indicate that the requirements for all classes of ATM service, as proposed in the International Telecommunications Union's ITU–T Draft Recommendation I.356,[1] may not be accommodated by transmission services designed to just comply with ITU–T Recommendation G.826, such as the IDR service as specified in Tables 2 and 3 in reference [2]. For certain classes of ATM, it will be necessary to augment the error performance of the basic IDR service through the use of the optionally specified Reed-Solomon outer codec or other link enhancer schemes. The results presented here do not include such performance-enhancing techniques. Preliminary tests have shown the efficacy of these link-enhancing techniques in ATM network applications [3].

A closely related consideration is the fact that the methods for predicting system performance contained in ITU–R S.1062, *Allowable Error Performance for a Hypothetical Reference Digital Path Operation at or Above the Primary Rate*, were developed for systems operating at frequencies below the Ka band. Since a number of broadband Ka band systems are either planned or under development, S.1062 (or any subsequent performance recommendation) must apply to the Ka band. To that end, NASA is planning to develop data that will extend (or validate) the current methods contained in S.1062 to Ka band frequencies. Figure 3 illustrates the satellite link availability requirements as contained in ITU–R S.1062 with the ATM current and proposed quality of service requirements of ITU–T I.356, *B–ISDN ATM Layer Cell Transfer Performance*. Notice that an order of magnitude or more improvement may be needed to meet the quality of service requirements for stringent telecommunication applications such as compressed data and video. Also note that as the quality of service requirements increase, the link availability decreases.

Future Work

NASA conducted these tests in preparation for investigating the quality of service requirements for stringent ATM applications, namely MPEG–1 and MPEG–2 (Moving Pictures

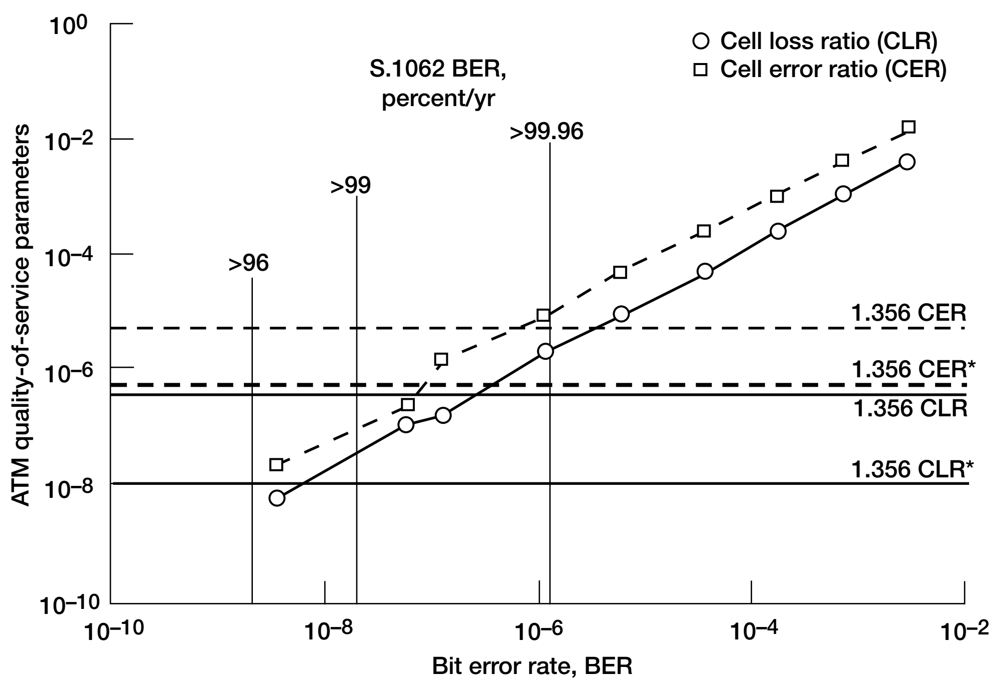

Figure 3.—Asynchronous transfer mode CER and CLR results for 45-Mbps intermediate data rate (IDR) modem without the Reed–Solomon code compared with results for ITU Recommendation S.1062 and proposed ITU Draft Recommendation 1.356. (*More stringent values will be used for further study of the current draft of 1.356.)

[1]As agreed to at the ITU–T Study Group 13 Rapporteur's meeting held in Lannion, France, November 13–17, 1995.

Experts Group) video streams with DS3 and synchronous optical network (SONET) synchronous transfer signals—level 1 (STS–1, 51.84 Mbps) and synchronous transfer signals—level 3 (STS–3, 155.52 Mbps) transmission over bursty error channels. Clearly, a bursty channel will likely have a nonproportional impact on encoded ATM streams, and MPEG–2, in particular. In addition, bursty channels offer a large number of functional options, the choice of which may dramatically affect the choice of minimal quality of service parameters.

To help resolve such issues, NASA is developing a set of tests for MPEG–2 video to present to the ITU. Industry consensus seems to be that MPEG–2 video applications, in particular, will prove to be the applications most sensitive to ATM channel errors.

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1. Eutelsat: Effect of Error Bursts in the Transmission of Framed ATM Cell Streams Over Satellite. ITU–R Doc. 4B/48–E, Jan. 1995.
2. IDR Performance. Intelsat Earth Station Standard IESS–308 (Rev. 7A), p. 36A.
3. Chitre, D.M.; and Faris, F.: Interoperability of Satellite and Terrestrial Networks: Challenges and Solutions. AIAA Paper 96–1129–CP, 1996.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1997	Technical Memorandum

4. TITLE AND SUBTITLE

ATM Quality of Service Parameters at 45 Mbps Using a Satellite Emulator: Laboratory Measurements

5. FUNDING NUMBERS

WU–632–50–5A

6. AUTHOR(S)

William D. Ivancic and Eric A. Bobinsky

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135–3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E–10649

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM–107345
Globecom Paper S32.1

11. SUPPLEMENTARY NOTES

Prepared for the Globecom '97 sponsored by the Institute of Electrical and Electronics Engineers (IEEE) Communications Society, Phoenix, Arizona, November 4–8, 1997. William D. Ivancic, NASA Lewis Research Center, and Eric A. Bobinsky, Terasphere, 343 W. Bagley Road, Suite 405, Berea, Ohio 44017. Responsible person, William D. Ivancic, organization code 5610, (216) 433–3494.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 17

This publication is available from the NASA Center for AeroSpace Information, (301) 621–0390.

12b. DISTRIBUTION CODE

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14. SUBJECT TERMS

ATM; Quality of service; ITU; Satellite communications

15. NUMBER OF PAGES

6

16. PRICE CODE

A02

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	