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BASIC GUIDELINES FOR APPLICATION OF PERFORMANCE STANDARDS TO COMMISSIONING OF DCS DIGITAL CIRCUITS

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FOREWORD

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This document provides performance requirements for use in commissioning DCS Transmission Subsystems. It is applicable to cable, microwave, and satellite transmission subsystems.

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EXECUTIVE SUMMARY

This engineering publication provides guidance to engineers and managers who are involved in the specification and testing of digital circuit performance for the Defense Communications System. The parameters and their values are given for the commissioning of digital circuits, together with general recommendations for test and acceptance.

This engineering publication is one of three documents that provide guidance in the area of digital circuit performance. MIL-STD-188-323 provides digital performance standards which apply to the design of digital transmission systems. DISAC 300-175-9 provides performance standards for both analog and digital circuits during operation and maintenance (O&M). EP 1-92 covers the area of commissioning of digital circuits and the testing required to accept these circuits. This EP explains the difference between the design, commissioning, and O&M performance standards, as applied to either a commercial or military system.

Requirements are given in terms of the same performance parameters as used for design and O&M, namely, bit errors, availability, bit count integrity, delay, and jitter. For each parameter, a definition is given (in some cases there are different and even conflicting definitions), a performance level is given for DCS circuits, and guidance is given for testing techniques and duration.

The performance parameters and values given herein have been used in DCS upgrades, so that a comparison can be made of actual performance observed during commissioning with the values given here. Such a performance comparison is made here for circuits in both European and Pacific regions; data rates from DS-0 (64 kb/s) to DS-3 (44.736 Mb/s) are included in this comparison.

Finally, the commercial standards which were used collectively to determine the appropriate performance standards for DCS circuits are included in an appendix.

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I. INTRODUCTION

The purpose of this publication is to provide technical guidance to personnel involved in the specification and commissioning of transmission systems which are to be integrated into the Defense Communications System (DCS). This publication should therefore be used in preparing performance specifications, statements of work, TSO/TSRs, project test plans and test procedures for system acceptance testing. This publication refers to several other documents used in the design, specification, and testing of transmission resources in the DCS, such as MIL-STD-188-323, DISAC 300-175-9, and CCITT/CCIR recommendations, and interprets those documents for use in the specification and commissioning of DCS circuits.

This publication interprets the requirements of military and commercial standards, and provides guidance for applying those documents to the actual specification and commissioning of DCS links. This publication specifically provides the derivation of requirements for Government-owned and leased line-of-sight (LOS), satellite, and cable transmission systems. System parameters covered are error performance, system availability, transmission delay, jitter, and bit count integrity. The document provides guidelines for testing the systems in the proper manner to demonstrate the required performance.

In the past DISA has used a myriad of documents in the specification of performance for procurement and commissioning. The traceability of these specifications is sometimes difficult. Thus this publication should allow the user to come to one document for performance requirements for initial test and acceptance testing of digital DCS circuits. To facilitate its use this publication contains an extensive bibliography of other documents used by both military and commercial organizations for the same purpose. To maintain its currency, this publication will be updated as necessary to keep up with changing standards.

The user of this publication may use all or part of the performance criteria contained herein. In some cases, other parameters may be necessary to adequately specify a particular system or service or to be compatible with foreign carriers and manufacturers. To meet the needs for a particular statement of work or specification, some modification of the performance parameters included herein may also be necessary. The reader should consider these performance parameters as general guidelines which may be changed to meet a particular system requirement.

II. BACKGROUND

Military and commercial standards organizations have drawn up or studied transmission performance standards for several applications which must be understood before proceeding. These standards generally fall into one of three categories: design criteria, commissioning standards, and operation and maintenance standards. For example, the CCITT in Recommendation G.102 distinguishes and explains standards in these three areas of performance standards. In the following paragraphs, descriptions and applications will be given for design criteria, commissioning standards, and maintenance standards, together with a look at other DoD and commercial documents used as performance standards which are therefore relevant to this publication.

A. Design Criteria.

Design criteria provide performance standards for the design of systems by engineers. In the design of any system, there are always a set of parameters which indicate performance to be achieved for the selected design. These performance parameters are similar to those used for commissioning and maintenance standards, but with different intentions. Here the intended use is the selection of certain design parameters, such as transmit power, antenna size, or receiver sensitivity, based on performance criteria for an end-to-end circuit. The degradations which cause an outage, i.e. a condition in which the performance standards are not met, can be described by statistics and models of the various sources of degradation. These sources of degradation would include radio fading, frequency interference, and equipment failure, to name a few. However, those sources of outage which cannot be described by statistics or models are not included, such as human error or acts of God. Thus, we say that design standards are based on optimum operating conditions and may therefore be unrealistic for actual field performance. The resulting choice of design parameter values, say the transmit power, will allow the performance standards to be met only if the system behaves as predicted by statistics and models. Since no system behaves in the field exactly as analysis would predict, these design standards are inappropriate for actual commissioning or operating conditions.

A common method used to derive these design standards is to formulate a hypothetical reference circuit as was done in MIL-STD-188-323 [1]. This approach allows the system designer to base performance standards on some reference, usually a quasi-worst case length circuit. In this way, the designer ensures that all actual circuit designs will meet the performance standards. In practice, no circuit or system looks exactly like the hypothetical reference circuit, so that actual performance standards on real circuits must account both for non-ideal behavior of a communications system and the unique makeup of that circuit.

B. Commissioning Standards

The conditions encountered for real circuits and systems installed in the field may vary considerably from the idealized assumptions made for the hypothetical reference circuits. Therefore allowances have to be made for the unique makeup of the actual system and the likelihood of degradation beyond predicted values.

The values selected for commissioning standards represent the minimum acceptable performance when conducting tests for the initial commissioning of DCS circuits or systems. However, commissioning tests must be performed during periods of normal operating conditions, since time does not permit tests to be conducted over all operating conditions. It is expected that actual per-

performance will exceed commissioning standards for most of the time. When performance degrades significantly below the commissioning standards, or below O&M operational monitoring thresholds maintenance actions are required.

C. Operating and Maintenance Standards

In service, the performance of a circuit or system may deteriorate because of aging, extreme environmental conditions, non-catastrophic failures, and the like. The design and commissioning standards are selected to give a margin of protection against these forms of degradation such that there is satisfactory performance when the circuit or system is in service. Operating and maintenance (O&M) standards are the minimally acceptable performance thresholds beyond which the customer no longer has satisfactory service. Hence some maintenance action is required when these limits are exceeded. The circuit or system is removed from service and remedial action is taken to restore performance.

In the DCS, operating and maintenance standards are used by O&M personnel in monitoring, troubleshooting, testing, and correcting deficiencies. In DISAC 300-175-9 [2], standards are given for both analog and digital circuits, links, and multilinks, in the form of technical parameters and their thresholds. Circuit parameters apply end-to-end, while link and multilink parameters apply technical control to technical control.

TSO/TSR's normally use DCS Parameter Codes described in DISAC 300-175-9 for initially specifying user services. Although DCS Parameter Codes are not used explicitly in this document, the test parameters and parameter thresholds found in this document may be used in writing TSO/TSR's for purposes of specifying initial testing and acceptance criteria. O&M thresholds established for DCS Parameter Code parameters in DISAC 300-175-9 will still be used for routine O&M and out-of-service testing. Detailed guidance for the preparation and formatting of TSO/TSR's is provided in DCAC 310-65-1 [17].

D. DoD and Commercial Standards

The Department of Defense (DoD) has developed its own performance requirements and standards for the purpose of designing, procuring, and operating DoD communication systems. MIL-STD-188-323 provides performance standards for the design of digital transmission systems used in either Government-owned or leased systems. Thus MIL-STD-188-323 is meant for use <u>by engineers</u> in designing new systems; however, it is not intended for use by maintenance personnel when testing operational systems, nor for the testing and commissioning of new systems. DISA has developed a circular, DISAC 300-175-9, for use by maintenance personnel for in-service monitoring and out of service testing and trouble shooting of operational systems. This new publication, JIEO EP 1-92, is intended to provide guidance to those who write specifications for procurement or implementation of systems and for those personnel involved in initial testing and commissioning of new digital systems. This guidance is based on the requirements of MIL-STD-188-323, and thus reflects the performance which should be obtained with a new system designed to

MIL-STD-188-323 standards. JIEO EP 1-92 shall be used in conjunction with MIL-STD-188-323.

Various commercial organizations and standards bodies have also developed, and are continuing to develop, a body of documentation which provides for the specification of commercial systems. This work is being performed by international governmental standards bodies and commercial organizations, such as the International Telephone and Telegraph Consultative Committee (CCITT), the International Radio Consultative Committee (CCIR), the American National Standards Institute (ANSI), the International Telecommunications Satellite Consortium (INTELSAT), the Telecommunications Industries Association (TIA, formerly Electronic Industries Association (EIA)), and the Institute of Electrical and Electronic Engineers (IEEE), among others.

Although these standards bodies publish performance standards useful for inclusion in design, and commissioning standards, the establishment of minimally acceptable user performance thresholds is normally not within their purview. Also, these standards normally use differing performance parameters, parameter definitions, and parameter thresholds since they are intentionally geared towards narrowly focused telecommunications services. The standards developed by DoD for the provisioning of telecommunications services attempt to cover the broad spectrum of services which are currently available or are under development.

In addition, individual companies, such as AT & T, MCI, and Sprint publish information describing the performance which their systems can provide. This performance may differ from that recommended by the standards bodies. A short synopsis of commercial standards as they currently relate to digital telecommunications performance parameters is provided in Appendix A. These standards which are used for in-service monitoring and out of service testing and troubleshooting are left to the commercial carrier or end user to specify.

The Department of Defense leases a substantial portion of its telecommunication requirements, particularly within the United States. Future capital expenditure budget constraints may cause even more of the DCS to be leased. Therefore, it is appropriate to bring DCS performance requirements in line with commercial standards, to the maximum extent consistent with military constraints. This has been done for MIL-STD-188-323 and DISAC 300-175-9, and is also done in this publication.

E. Testing and Test Equipment

Test equipment which can be used in the commissioning of digital transmission systems are currently manufactured by a number of different vendors. Care should be used in specifying the proper test equipment to ensure that parameters outlined in this document and in DISAC 300-175-9 are properly measured. Standards developed by the various bodies outlined above and in Appendix A are often arrived at independently and may or may not use the same definitions as are used by test equipment manufacturers. Likewise test equipment manufacturers usually include a wealth of parameter measurements for which this document has no usable parameter threshold.

A common example of this confusion is encountered in the measurement of the DCS digital parameter Loss of Bit Count Integrity (LBCI) or Mean Time to Loss of Bit Count Integrity (MTTLBCI) (see definitions in Section III.c.1). Many manufacturers of digital test equipment provide for the measurement of "Synch Losses", "Clock Slips", and "Pattern Slips". All three parameters have been used in the past to indicate (rightly or wrongly) an indication of LBCI or MTTLBCI. However, from the definitions of these parameters by the test equipment manufacturer only the "Pattern Slip" parameter has a definition which is compatible with this document for measuring LBCI or MTTLBCI. Likewise, this document is not intended to provide thresholds for Synch Losses and Clock Slips solely because they are parameters which are available on commercial test equipment.

III. DERIVATION OF REQUIREMENTS

Here a list of performance parameters is developed for the specification and commissioning of DCS circuits, with each parameter first defined, then interpreted for DCS circuits, and finally given a recommended test period. A general set of guidelines to follow in the test of these parameters is given in Figure 1. Specific test procedures, however, are not included in this publication, but can be found in DCAC 310-70-1, Volume II, Supplement 1 [3].

The specific values given herein are based on performance specifications used for both terrestrial and satellite transmission systems. These performance specifications are in turn based on industry standards where applicable and on military requirements where necessary. Some users will require different performance (probably more stringent) than cited here, but the same approach to commissioning tests will hold independent of the specified values. Both individual link and end-to-end performance requirements are given herein, since DCS circuits may span only a single link or several links or even an international distance. All specifications apply to both leased and government-owned circuits. It is recognized, however, that these specifications will not cover all applications in the DCS. For example, in some cases there will be foreign PTT standards to be followed. In other cases additional parameters may have to be given not covered herein. For the large majority of DCS circuits, however, these specifications should suffice.

A. Error Performance

1. Definitions

The following is a list of the most popular choices of parameters used to characterize error performance:

(1). Error Free Seconds (EFS) or Error Seconds (ES): percentage or probability of one-second error measurements that are error free (EFS) or in error (ES).

Test for total time T_{TOTAL} seconds

Count the number of whole-second intervals that the circuit is unavailable, i.e. $T_{UNAVAIL}$, defined as periods of 10 or more seconds with a BER $\geq 10^{-3}$. Calculate the available time, T_{AVAIL}, and the fraction of availability, F_{AVAIL}

$$T_{AVAIL} = T_{TOTAL} - T_{UNAVAIL}$$

$$F_{AVAIL} = \frac{T_{TOTAL} - T_{UNAVAIL}}{T_{TOTAL}}$$

Within T_{AVAIL} seconds count the number of one-second intervals that contain at least one error (N_{ES}). Calculate the fraction of errored seconds, F_{ES} as

$$F_{ES} = \frac{N_{ES}}{T_{AVAIL}}$$

Within T_{AVAIL} seconds count the number of losses of bit count integrity (N_{BCI}) and calculate the mean time to loss of BCI T_{BCI} as

$$T_{BCI} = \frac{T_{AVAIL}}{N_{BCI}}$$

Note: For circuits meeting Availability criteria found in this document, $T_{AVAIL} \simeq T_{TOTAL}$. This fact is most useful when using test equipment which only measure N_{BCI} over the time interval T_{TOTAL} to calculate the approximate T_{BCI}.

Figure 1. FLOWCHART OF DCS COMMISSIONING TESTS FOR AVAILABILITY AND ERROR PERFORMANCE

(2) Average Bit Error Rate (BER): ratio of errored bits to the total bits transmitted in some time interval.

(3) Degraded Minutes (DM): percentage or probability of one-minute measurements that have a $BER \geq 10^{-6}$.

(4) Severely Errored Seconds (SES): percentage or probability of one-second measurements that have $BER \geq 10^{-3}$.

(5) Residual Bit Error Rate (RBER): the remaining bit error rate which results when bursty error events are subtracted out from overall testing results (See Appendix A.3.3).

More than one of these error parameters may be used in specifying performance, as done by the CCITT and CCIR. However, use of more than one parameter will complicate design or test procedures, since calculated or measured values of these parameters depends on the distribution of errors which is time varying. One parameter may be the most stringent for a particular link or time, while another parameter will be more stringent for a different link or time. Consequently, a single parameter has been selected for DCS applications. This is the same approach used in MIL-STD-188-323. It is recognized, however, that in some applications more than one error parameter may be appropriate in specifying DCS circuit performance.

Average BER is perhaps the widest known of error performance statistics yet poses severe difficulties when performing long term testing (longer than a few minutes) such as encountered in initial testing and acceptance testing. These difficulties occur due to the general statistical nature of errors in digital communications channels. Errors in digital channels tend to occur in clumps or bursts where large numbers of errors are generated in short periods of time. For testing of high-speed digital circuits (i.e. > 64 kbps) an error event of this nature need only last for a few seconds to destroy the average BER statistic for a test which has run for many hours or days, even though the remaining period is virtually error free. Thus it is desirable to factor out these burst error types of events for initial test and acceptance of new digital services. It is for this reason that no unconditional average BER standards or recommendations are made by commercial and international standards organizations for long term testing of high data rate digital services.

The use of RBER can therefore be considered as a candidate for initial test and acceptance testing. As specified in CCIR recommendation 634-1 the RBER is defined as the average bit error rate after the worst (fading periods) BER intervals have been discarded. The CCIR definition is based on 15-min BER measurements over a 30 day period with the discarding of 50% of the 15-min intervals containing the worst BER measurements, and using the remaining 15-min intervals to calculate the RBER. Unfortunately definitions, thresholds, and methods for measuring RBER as defined by the CCIR/CCITT are at best provisional and require extended testing periods (30 days) in order to make a proper evaluation. Shortening the test period to 72 hours would substantially limit the ensemble of 15 minute samples from which RBER statistics are calculated and could tend to make results unreliable.

Another approach to the measurement of RBER is taken by some Test Equipment manufacturers is to exclude all measurements for severely errored seconds when computing the average bit error rate. This parameter, known as (BER-SES), effectively eliminates burst errors (BER > 10^{-3}) from the final error rate calculation and can be a useful measurement tool for examining the Residual Error Rate characteristics of digital circuits. This is especially true for circuits which are under test for much shorter periods of time than required by the CCIR/CCITT (i.e. 30 days). However, the lack of bona fide standards or thresholds for either definition of RBER make their use in this document undesirable.

Out of the many possible choices for error parameter, the error-free second (EFS) is the standard used for DCS error performance standards. Its advantages include (1) EFS is the industry-wide standard in the United States; (2) all modern bit error rate test equipment provide for its measurement; (3) design of links and systems is facilitated; and (4) testing for commissioning and troubleshooting is easy. The end-to-end ES objective can be prorated on a mileage basis to yield link or section performance objectives. Conversely, individual ES contributions can be added to give the total ES performance end-to-end.

The most significant drawback to the use of EFS or ES is that it is difficult to translate performance allocations from one bit rate to another. By comparison, SES and DM are based on BER and therefore their number remains the same for different bit rates. For the ES or EFS parameters, the scaling between bit rates is complex and depends on the distribution of errors which is link and time dependent. Such a translation requires knowledge of the error behavior for the particular link, but such data is not generally available. Since we lack the necessary data base from which to derive such a relationship, we have adopted the relationships used by industry and have verified the resulting values by comparison with actual field data, as described below.

2. DCS Error Performance

The errored second performance allocation for commissioning of DCS circuits is given in Table I. The basis for these commissioning standards is a collection of industry publications on error performance [4,5,6,7,8]. These industry standards describe performance promised to the customer. Each circuit is tested to ensure that standards are met or exceeded before the circuit is commissioned. Thus these industry standards have the same use as DCS commissioning standards. In fact, these same standards have already been used by DISA in a variety of specifications for transmission services. The error performance standards which have been published by industry at this point in time are limited to standard rates of DS-0 (64 kb/s), DS-1 (1.544 Mb/s), DS-2 (6.312 Mb/s), and DS-3 (44.736 Mb/s). In general, as the rate increases, the percentage of error-free seconds will decrease for a fixed bit error rate on a given transmission channel. This relationship holds because of the simple fact that there are more bits which can be in error as the bit rate increases. Hence the mileage-based standards shown in Table I reflect higher performance for low rates and vice versa. The range of rates covered by Table I is an extension over the industry standards which are limited to the standard rates listed above. The methodology used to develop Table I was based on the argument that the industry objective given for a particular rate should be met by any rate up to that standard rate. Thus, for example, the objective given for DS-0 should be met by any rate between 0 and DS-0. The resulting three ranges cover any rate anticipated in the DCS.

DATA RATE (R)	LINK ALLOCATION		END-TO-END ALLOCATION	
	TERRESTRIAL[1]	SATELLITE	CONUS	OCONUS[2]
$0 < R \leq 64$ kb/s	$1-(6.250 \times 10^{-7})D$	0.997	0.997	0.985
64 kb/s $< R \leq 6.312$ Mb/s	$1-(7.292 \times 10^{-6})D$	0.965	0.965	0.965
6.312 Mb/s $< R \leq 44.736$ Mb/s	$1-(2.083 \times 10^{-5})D$	0.90	0.90	0.90

1. D is the link distance in kilometers
2. This allocation applies to any non-satellite connection or to a single satellite link. For a double satellite connection, this allocation should be squared. If there are terrestrial tails used to extend satellite connectivity, a terrestrial allocation should be added to the given allocation.

TABLE I. ERROR-FREE SECOND PERFORMANCE FOR COMMISSIONING OF DCS CIRCUITS

For each of the three ranges of data rates, there are both link and end-to-end commissioning standards shown. Link allocations are given on a distance basis for terrestrial links (line-of-sight microwave or cable), so that the distance of the link affects the allocation. For satellite links and end-to-end allocations, the error-free second performance is independent of distance. The CONUS end-to-end allocations are based on industry standards [4,5,6,7,8] (see Appendix A). The terrestrial link allocations have been derived from the CONUS allocations by prorating the end-to-end allocation down to an allocation per kilometer, assuming a worst-case distance of 4800 km in the CONUS circuit. Note that the resulting terrestrial link allocation for 64 kb/s agrees with MIL-STD-188-323. The satellite link allocation has been set equal to the CONUS allocation, since one satellite link could be used to satisfy any length circuit in CONUS. The OCONUS end-to-end allocations were also based on industry standards but for international circuits [9]. For any end-to-end circuit involving multiple links, the user of this publication has two choices in allocating performance: (1) adding the per-link error-second allocations (or multiplying the error-free second allocations) using the appropriate terrestrial or satellite allocations, or (2) applying the end-to-end allocation using the appropriate CONUS or OCONUS allocation. Thus the end-to-end allocations should be considered the limiting allocation, i.e., no sum of link allocations should be worse than the end-to-end allocation. All of these allocations should in fact be considered worst case; if better performance is available from some existing carrier or service, those performance allocations may be used.

Some applications, particularly satellite communications, may require other error parameters to be specified, either in addition to or in lieu of error-second rate. If bit error rate is to be used, it is recommended that either (or both) degraded minutes or severely errored seconds be included, since these are standard forms of BER specification and measurement. For terrestrial applications, the CCITT and CCIR specifications (see Appendix A, paragraphs 3.1 and 3.3) give end-to-end BER specifications which can be allocated on a per kilometer basis by dividing the end-to-end allocation by the total distance of the hypothetical reference circuit. (Note: the CCITT and CCIR specifications are equivalent when reduced to a per unit distance allocation.) For satellite applications, CCIR Recommendation 614 (see Appendix A, paragraph 3.7) or INTELSAT specifications (see Appendix A, paragraphs 3.4 and 3.5) should be used. Table II lists degraded minutes (DM) and severely errored second (SES) objectives, for the same link and end-to-end allocations as Table I. These objectives are based on the commercial standards given in Appendix A, and may be used to supplement or replace the error-free second performance required in Table I.

ERROR PARAMETER[1]	LINK ALLOCATION		END-TO-END ALLOCATION	
	TERRESTRIAL[2]	SATELLITE	CONUS	OCONUS
Degraded Minutes	< 0.004 (D/2500)	≤ 0.02	< 0.1	< 0.1
Severely Errored Seconds	< 0.00054 (D/2500)	≤ 0.0003	< 0.002	< 0.002

1. Both degraded minutes and severely errored seconds have allocations which are independent of data rate. Values are expressed as the fraction of the test interval in which the anomaly occurs.
2. D is the link distance in kilometers

TABLE II. DEGRADED MINUTES AND SEVERELY ERRORED SECONDS FOR COMMISSIONING OF DCS CIRCUITS

3. <u>Testing</u>

The CCIR and CCITT recommend a 30 day test period for verification of error performance. However, for the commissioning of circuits in the DCS, such a lengthy period would be prohibitive in cost. A test period of 72 hours is recommended. Such a test period will include diurnal variations but obviously not seasonal variations.

B. Availability

1. <u>Definition</u>

As is the case with other test parameters a variety of definitions for availability currently exist. For the design of DCS systems, unavailability (defined as 1-A, A = availability) is defined as an outage of 60 or more seconds in which the BER is 10^{-4} or worse. This definition is used in MIL-STD-188-323 to facilitate link and system design, specifically to distinguish propagation effects, which rarely exceed one minute in duration, from equipment failures, which nearly always exceed one minute before restoration.

However, for the commissioning of circuits where leased as well as government-owned systems are employed, the CCIR and CCITT definition is more appropriate. Both the CCIR and CCITT define unavailability as an outage of 10 or more seconds where the BER is 10^{-3} or worse. Use of this definition will facilitate the use of standard test sets which can automatically test and record unavailability per the CCIR and CCITT definition. This latter CCIR/CCITT definition of availability is what is used throughout this document for availability parameter thresholds.

2. <u>DCS Availability Standards</u>

The allocation of availability for commissioning of DCS circuits is shown in Table III. Like the error performance allocation, the availability allocation is based on published standards to the extent that they exist, for bit rates of DS-0, DS-1, DS-2, and DS-3 [1,4,5,6,7,8]. We have extended these industry and military specifications to include any data rates between 0 and DS-3. The basis for these allocation fractions is that lower rate circuits, below 1.544 Mb/s, will include first level multiplex and possibly low speed submultiplex; higher rate circuits, from 1.544 Mb/s to 6.312 Mb/s, will not include low speed or first level multiplex; and the highest rate circuits, between 6.312 Mb/s and 44.736 Mb/s, will include neither low speed, first, or second level multiplex. This difference in equipment is key to availability since in general lower level multiplex does not include redundancy but higher level multiplex does include redundancy. Therefore, lower level multiplex reliability limits the availability possible at rates below 1.544 Mb/s. The specified values shown in Table III apply to most DCS circuits. However, certain users will require higher availability, typically 0.9999, which may complicate commissioning tests by extending the test period necessary to verify the availability.

The only existing industry standards which deal with commissioning standards for availability apply only to CONUS circuits [4,5,6,7,8], and we have used those standards for the CONUS circuits in Table III. For all other circuits, i.e., both link and OCONUS, we have used MIL-STD-188-323 as the basis. Specifically, for rates below 1.544 Mb/s, availability standards found in MIL-STD-188-323 directly apply. For the higher rates the standards have been derived by removing appropriate multiplex equipment from the equipment tables found in Appendix D of MIL-STD-188-323 and recalculating the availability. Note that availability is not a function of distance for any of the link allocations, but that by definition a link contains no repeaters, i.e., a link is considered point-to-point. For any end-to-end circuit involving multiple links, the user of this publication has two choices in allocating availability performance: (1) multiplying the per link allocations using the appropriate terrestrial or satellite allocations, or (2) applying the end-to-end allocation using the appropriate CONUS or OCONUS allocation. Thus the end-to-end allocations should be considered the limiting allocation, i.e., no product of link allocations should be worse than the end-to-end allocation. All of these allocations should in fact be considered worst case; if better performance is available from some existing carrier or service, those performance allocations may be used.

3. Testing

The CCIR and CCITT both recommend 30 days for testing of availability, but such a test length would be prohibitively expensive for DCS circuit commissioning. Like the error performance tests recommended above, a 72 hour test period is recommended which can be conducted concurrently with the error performance tests.

During commissioning tests, all other performance standards described herein apply only to periods of availability, as shown in Figure 1. Thus, errored

DATA RATE (R)	LINK ALLOCATION			END-TO-END ALLOCATION	
	LINE-OF-SIGHT	FIBER OPTIC	SATELLITE	CONUS	OCONUS
$0 < R \leq 64$ kb/s	0.999753	0.999785	0.994958	0.99	0.987
64 kb/s $< R \leq 6.312$ Mb/s	0.999896	0.999928	0.995101	0.997	0.988
6.312 Mb/s $< R \leq 44.736$ Mb/s	0.999926	0.999958	0.995131	0.997	0.988

TABLE III. AVAILABILITY PERFORMANCE FOR COMMISSIONING OF DCS CIRCUITS seconds and losses in BCI recorded during a period of unavailability should be edited from the final measured data. Bit error rate test sets allow such a distinction to be made between availability and other performance measures.

C. BIT COUNT INTEGRITY

1. Definition

Bit count integrity (BCI) is defined as the preservation of the number of bits transmitted in an interval of time. If one or more bits is either added or subtracted in a given interval of time, a loss of bit count integrity occurs which will cause loss of synchronization in digital transmission equipment.

2. DCS Bit Count Integrity Performance

BCI performance is defined in terms of the mean time to loss of BCI (MTTLBCI) or the number of losses of BCI (LBCI) in a fixed testing interval. The corresponding standards found in industry are given in terms of mean time to timing slips, and these specifications tend to be more relaxed than DCS requirements. For example, current CCITT Recommendation G.822 calls out a requirement for not more than five (5) slips per day for a global hypothetical reference circuit. DCS requirements must be more stringent because of the use of encryption, especially secure voice. Unencrypted circuits will experience only a momentary "click" with a timing slip, typically just the time required for any multiplexers affected to regain synchronization. For encrypted circuits, however, a timing slip causes a bigger outage because of the need to resynchronize the crypto equipment before multiplex can be resynchronized. For terrestrial circuits this may result in a one to two second service interruption of data users or dropping of switched voice calls. Likewise, for digital circuits traversing satellite paths this service interuption may extend to between 4 and 5 seconds due to the effects of path delay. Many encrypted circuits are rekeyed daily, which also can cause a loss of BCI on a periodic basis. As a consequence, we have adopted 24 hours as the mean time to loss of BCI on all end-to-end circuits.

Table IV provides the commissioning standards for loss of BCI for DCS circuits traversing links, CONUS, and OCONUS. For circuits operating at DS-0 rates or below, performance allocations are based on MIL-STD-188-323. Previous commissioning specifications for BCI performance have also used MIL-STD-188-323. The assumption made in this use of the military standard is that during commissioning tests, timing of the circuit(s) is based on the DCS Timing Subsystem or a Stratum 1 Clock (which are essentially equivalent). If this assumption is not true for a particular circuit test, then the values given in Table IV are invalid and must be changed to match the accuracy and stability of the timing subsystem in use. A guide to calculations of slip rate (e.g. loss of BCI) as a function of clock parameters and bit rate is given in references [10,11]. The link allocation values given in Table IV for higher bit rates were derived by removing lower level multiplex from the equipment count corresponding to a 64 kb/s circuit and using a fraction of the new equipment count to the old equipment count to obtain a prorated calculation.

The rationale for this approach is that each equipment has a built-in buffer which is subject to loss of BCI due to overflow or underflow, so that fewer equipments will mean proportionally fewer losses of BCI. The end-to-end allocations for higher rates are simply an extension of the MIL-STD-188-323 (and previous specifications) to any other rate, so that the allocation remains 24 hours regardless of bit rate.

DATA RATE (R)	LINK ALLOCATION		END-TO-END ALLOCATION	
	TERRESTRIAL	SATELLITE	CONUS	OCONUS
$0 < R \leq 64$ kb/s	2688	71	24	24
64 kb/s $< R \leq 6.312$ Mb/s	3046	78	24	24
6.312 Mb/s $< R \leq 44.736$ Mb/s	5077	97.6	24	24

TABLE IV. MEAN TIME TO LOSS OF BCI (HOURS) PERFORMANCE FOR COMMISSIONING OF DCS CIRCUITS

3. Testing

Test sets have only been recently available that are capable of directly measuring LBCI events. Often, older digital test equipment provide a capability to monitor the interruption of digital services through the use of such parameters as Synch Loss, and Clock Slip, which, depending on the manufacturer, may have widely varying definitions and interpretations. Many of these parameters measure only high error rate conditions or combinations of high error rate conditions with LBCI events. LBCI events themselves may not be directly and discretely detected. Thus it is imperative that those performing commissioning tests make certain that the definitions of the vendor test parameter exactly match that which is used in this document for Loss of Bit Count Integrity.

The procedure used to test for losses of bit count integrity, specified in [3], distinguishes between a burst of errors and a true loss of BCI. A burst of errors may cause a BERT to lose synchronization, which may appear as a loss of BCI but is in fact due to a high error rate causing a loss in the required correlation between the received pattern and the expected pattern. As indicated in Figure 1, losses of BCI should be counted only during periods of availability. Furthermore, crypto resets should not be included in the count of BCI losses.

The CCITT recommends a 30 day test period for the testing of slip rate specifications. Again, for DCS circuit commissioning, 30 days would be a prohibitive time and so a 72 hour test is recommended, to be done concurrently with the availability and error performance tests. Clearly a 72 hour test is insufficient to yield a measure of mean time to loss of BCI with any confidence. Hence the contractor should also demonstrate by analysis that BCI performance requirements will be met. This analysis should include effects of clocks and, if applicable, propagation delay variations (e.g., satellite doppler).

D. DELAY

1. Definition

The transmission delay of any circuit is the transit time of the transmitted information between the end points of the circuit. Total delay in a circuit is a function of propagation time (path distance and media dependent), buffering, and and filter delay (for a voice circuit). Propagation delay is independent of data rate, while buffering delay is inversely proportional to the data rate. The specification and test for delay is important to voice and interactive data users because of the waiting time effect.

2. DCS Delay Performance

The delay values shown in Table V are the maximum allowed values due to the sum of propagation delay and signalling processing. The terrestrial link allocations assume that propagation delay is negligible, that the lowest speed circuits may include filtering delay, and that higher speed circuits incur delay only from other signal processing such as buffers for synchronization and multiplexing. The satellite link and OCONUS end-to-end allocations are dominated by the satellite delay for one and two links, respectively. The CONUS allocation is based on an all-terrestrial circuit; if satellite transmission were used to satisfy a CONUS circuit, the satellite link allocation should be used. All of the delay allocations given here are based on MIL-STD-188-323 and other DCS performance specifications.

DATA RATE (R)	LINK ALLOCATION		END-TO-END ALLOCATION	
	TERRESTRIAL	SATELLITE	CONUS	OCONUS
$0 < R \leq 64$ kb/s	5	300	150	600
64 kb/s $< R \leq 6.312$ Mb/s	2	300	125	600
6.312 Mb/s $< R \leq 44.736$ Mb/s	2	300	125	600

TABLE V. DELAY PERFORMANCE IN MSECS FOR COMMISSIONING OF DCS CIRCUITS

3. Testing

Standard bit error rate test sets included a method of measuring delay. Resolution of the measurement should be to 0.1 millisecond. The time interval to be measured can be of transmitted and received data, pseudorandom patterns, or some other user selected signals. If using a pseudorandom pattern, the length of the pattern must exceed the maximum expected delay. To minimize the test time, one should use the minimum usable pattern length, found as (data rate) x (maximum expected delay). For example, to make a delay measurement of 1.544 Mb/s over a satellite link with maximum delay of 300 milliseconds, the pattern length should be 463,200 bits; a $2^{19}-1$ pattern having length 524,287 bits is the minimum usable length pattern for this case.

E. JITTER

1. Definition

Jitter is defined as a short-term variation of the transition instant from its intended position or time. Longer-term variation of the transition is sometimes called wander. Jitter can cause several forms of degradation, from bit errors to loss of synchronization, so that it must be carefully controlled in a digital communications system.

2. DCS Jitter Performance

Jitter can be specified for both digital transmission equipment and for circuits (or for networks). The CCITT has provided recommendations for both equipment and networks in their G.700 and G.800 series recommendations. The MIL-STD-188-323 specifications for jitter apply only to equipment and are taken directly from the appropriate CCITT recommendations. The jitter specifications of MIL-STD-188-323 are used to verify equipment performance but are not appropriate for network (circuit) performance testing. For the commissioning of circuits, the G.800 series recommendations on network limits are used here, both G.823 for the European hierarchy and G.824 for the North American hierarchy [12,13]. The network (here interpret network as circuit) limits on jitter and wander found in G.823 and G.824 are discussed below and specified in Tables VI and VII and Figures 2 and 3.

(a) Limits on Jitter

Specification and control of maximum values of output jitter at network interfaces are necessary to enable interconnection of digital transmission components (multiplex, cross-connect, media) to form the end-to-end circuit. These limits should be met regardless of the number or type of transmission components which make up the circuit. These limits shown in Table VI and Table VII are intended to be compatible with the jitter tolerance specifications as found in other parts of the CCITT Recommendations (G.700 series) or in MIL-STD-188-323. The values given in Tables VI and VII and measurement configuration given in Figure 2 are limited to only the North American and European rates; values for other rates are under study.

(b) Limits on Wander

Wander is usually characterized by the time error it causes. Actual magnitude of wander depends on propagation delay variations and on clock performance parameters such as initial accuracy and instability. Specifications for wander are necessary to control the rate of buffer slips,

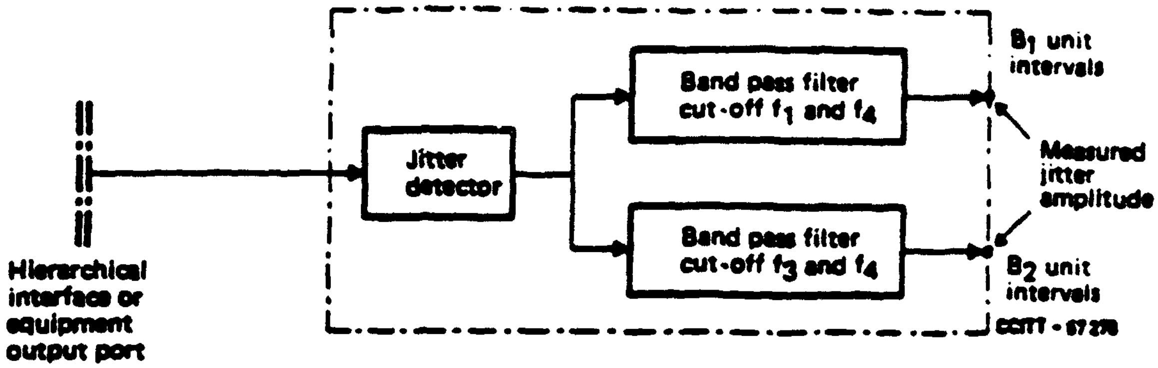

FIGURE 2. MEASUREMENT ARRANGEMENTS FOR OUTPUT JITTER FROM A HEIRARCHICAL INTERFACE OR AN EQUIPMENT OUTPUT PORT (CCITT REC G.823 and G.824)

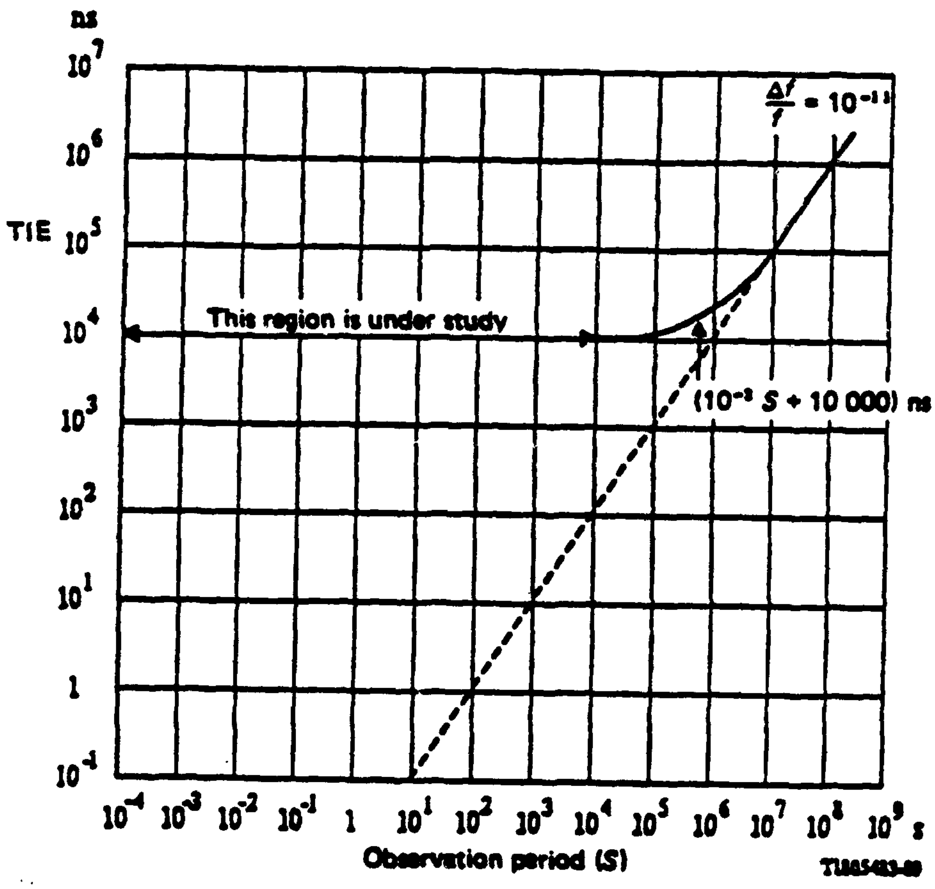

FIGURE 3. PERMISSIBLE MAXIMUM TIME INTERVAL ERROR (MTIE) VERSUS OBSERVATION PERIOD S FOR THE OUPUT OF A NETWORK NODE (CCITT REC. G. 823 AND G. 824)

	Network limit (UI peak-to-peak)		Band-pass filter having a lower cut-off frequency f_1 or f_3 and a minimum upper cut-off frequency f_4		
Digital rate (kbit/s)	B_1	B_2	f_1 (Hz)	f_3 (kHz)	f_4 (kHz)
1 544	5.0	0.1 (Note)	10	8	40
6 312	3.0	0.1 (Note)	10	3	60
32 064	2.0	0.1 (Note)	10	8	400
44 736	5.0	0.1	10	30	400
97 728	1.0	0.05	10	240	1 000

UI Unit Interval.

Note – This value requires further study.

TABLE VI. MAXIMUM OUTPUT JITTER ALLOWED FOR 1.544 MB/S HIERARCHY.
(CCITT REC. G. 824)

Parameter value / Digit rate (kbit/s)	Network limit		Measurement filter bandwidth		
			Band-pass filter having a lower cutoff frequency f_1 or f_3 and an upper cutoff frequency f_4		
	B_1 unit interval peak-to-peak	B_2 unit interval peak-to-peak	f_1	f_3	f_4
64 (Note 1)	0.25	0.05	20 Hz	3 kHz	20 kHz
2 048	1.5	0.2	20 Hz	18 kHz (700 Hz)	100 kHz
8 448	1.5	0.2	20 Hz	3 kHz (80 kHz)	400 kHz
34 368	1.5	0.15	100 Hz	10 kHz	800 kHz
139 264	1.5	0.075	200 Hz	10 kHz	3500 kHz

Note 1 – For the codirectional interface only.

Note 2 – The frequency values shown in parenthesis only apply to certain national interfaces.

Note 3 – UI = Unit Interval:

TABLE VII. MAXIMUM OUTPUT JITTER ALLOWED FOR 2.048 MB/S HIERARCHY
(CCITT REC. G. 823)

which cause loss of BCI. The maximum time interval error (TIE) over a period of S seconds shall not exceed ($10^{-2}S + 10000$) ns for values of S greater than 10^4. For values of $S < 10^4$, the maximum TIE is under study by the CCITT [12, 13]. The resultant specification is illustrated in Figure 3.

3. Testing

Testing of jitter is to be done at a hierarchical interface or equipment output port as shown in Figure 2. The jitter detector shown in Figure 2 is available in off-the-shelf test equipment. More information on test methodology for jitter is found in CCITT Recommendation 0.171.

IV. COMMISSIONING STANDARDS VS OBSERVED FIELD RESULTS

Table VIII compares observed results from field tests of DCS circuits with the commissioning standards given in this publication. A variety of circuit types and configurations are shown, including single and multiple links, rates from DS-0 to DS-3, and circuits from both Europe and the Pacific. Results for three performance parameters are given: unavailability, errored seconds, and mean time to loss of BCI.

Performance of the European circuits was measured for a one-year period as part of a long-term evaluation sponsored by DCA and conducted by ITS [14,15]. These circuits exhibited marginal performance, with three of the six circuits failing to meet the availability objective; four of the six failing to meet errored second standards; but all six circuits meeting the BCI standards. It should be noted, however, that these commissioning standards were not in place at the time these circuits were commissioned, nor were these links designed to MIL-STD-188-323 standards.

The Pacific circuits shown in Table VIII passed all commissioning standards, with the test period being typical of those used for actual commissioning tests [16]. These circuits were more recently commissioned than the European circuits, were designed with more current procedures, and are composed of more modern equipment. Using state-of-the-art equipment and design, it is therefore expected that future circuit commissioning will meet the standards stated herein.

V. CONCLUSIONS

This engineering publication has provided guidance for the test and acceptance of DCS digital circuits. These commissioning standards compliment earlier standards developed for the design, and operation and maintenance of digital transmission systems. With this publication, DoD departments, agencies, and contractors can apply consistent standards to the commissioning of DCS circuits. DCS systems designed via design criteria contained in MIL-STD-188-323 will meet the commissioning standards contained herein. Likewise, O&M standards such as DISAC 300-175-9 should be met by any circuit which is commissioned with standards contained herein.

PATH TYPE	DATA RATE	DISTANCE (KM)	NUMBER OF LINKS	MEASUREMENT INTERVAL	UNAVAILABILITY (FRAC.)		ERRORED-SECONDS (FRAC.)		MEAN TIME TO BCI LOSS (HRS)	
					Objective	Observed	Objective	Observed	Objective	Observed
LINDERHOFE-FELDBERG LOS TANDEM	DS-0	234	4	1 YEAR	9.88E-4	1.49E-3 (F)	1.46E-4	2.87E-3 (F)	672	
BOCKSBERG-KOETERBERG LOS	DS-0	72	1	1 YEAR	2.47E-4	4.42E-4 (F)	4.5 E-5	1.54E-3 (F)	2688	
KOETERBERG-ROTHWESTERN LOS	DS-0	51	1	1 YEAR	2.47E-4	2.63E-4 (F)	3.19E-5	2.05E-5	2688	
ROTHWESTERN-SCHWARZENBORN LOS	DS-0	56	1	1 YEAR	2.47E-4	1.15E-4	3.5 E-5	4.33E-5 (F)	2688	
SCHWARZENBORN-FELDBERG LOS	56 KB/S	99	1	1 YEAR	2.47E-4	2.80E-5	6.19E [illegible]	5.40E-5	2688	
LINDERHOFE-KOETERBERG LOS	DS-0	28	1	1 YEAR	2.47E-4	2.04E-4	1.75E-5	1.22E-4 (F)	2688	
SEBURIYAMA-CHANGSAN	DS-3	242	2	12.5 HRS	1.48E-4	0	5.0E-3	2.3E-3	1344	0
SEBURIYAMA-CHANGSAN AND RETURN	DS-1	484	4	20 HRS	4.16E-4	0	3.5E-3	8.0E-4	672	0
SEBURIYAMA-TSUSHIMA	DS-3	135.6	1	72 HRS	7.4 E-5	0	2.8E-3	8.0E-4	2688	0
SEBURIYAMA-SOFU	DS-3	182	1	72 HRS	7.4 E-5	0	3.8E-3	6.0E-4	2688	0

TABLE VIII. OBSERVED RESULTS VS COMMISSIONING STANDARDS FOR DCS LINE-OF-SIGHT LINKS

Some circuits will require special parameters for tests not covered in this publication. In other cases, different parameters or different values may be required for some circuits. The user of this document should consult commercial standards, as described in Appendix A, in the event the main parameters given in this publication do not provide the necessary commissioning standards for a particular service.

To gain a fuller appreciation of the performance parameters used in this publication, the reader should become familiar with the two companion documents, MIL-STD-188-323 [1] and DISAC 300-175-9 [2]. Updates to EP 1-92 should be forthcoming as these two companion documents are finalized and as commercial standards mature and change.

VI. REFERENCES

1. Draft MIL-STD 188-323, "System Design and Engineering Standards for Long Haul Digital Transmission System Performance," 28 June 91.

2. Draft DISAC 300-175-9, DCS Operating-Maintenance Electrical Performance Standards, April 91

3. DCAC 310-70-1, Volume II, Supplement 1, "Test Descriptions", 4/90

4. Lightnet, "System Reliability/Performance," 3/88.

5. U.S. Sprint, "Technical Description - DS1," 2/88.

6. PUB 54014, "Technical Reference - ACCUNET T45 Service Description and Interface Specifications," AT &T, June 1987.

7. AT&T Technical Reference 61041, ACCUNET T1.5 Service - Description and Interface Specifications, December 1988.

8. AT&T Technical Reference 62310, Digital Data System Channel Interface Specification, November 1987.

9. AT&T Technical Reference 54019, International ACCUNET Digital Service - Description and Network Interface Specifications, September 1987.

10. DCEC Technical Report 23-77, DCS Timing Subsystem, December 1977.

11. Bellcore Special Report SR-TSY-000542, "A Model of Slip Impairment in Synchronous Digital Transmission," July, 1986.

12. CCITT Rec. G.823, "The Control of Jitter and Wander Within Digital Networks Which Are Based on the 2048 Kbit/s Hierarchy," CCITT Blue Book, Volume III.5.

13. CCITT Rec. G.824, "The Control of Jitter and Wander Within Digital Networks Which Are Based on the 1544 Kbit/s Hierarchy," CCITT Blue Book, Volume III.5.

14. D. R. Smith and J. A. Hoffmeyer, "Observed Results from the Performance Evaluation of Tandem Digital Microwave Links," Proceedings of GLOBECOM 1990, pp. 504.2.1-504.2.7

15. J. Hoffmeyer and T. Riley, "Long-Term Performance and Propagation Measurements on Single and Tandem Digital Microwave Transmission Links," NTIA Report 90-265, June 1990.

16. DCEC Code DRTI/DRTV Trip Report, "KG-95R First Article Production Model Testing and Final Microwave Link Configuration Commissioning Testing, Seburiyama, Japan to Changsan, Korea, 6 Sep 90.

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17. DCAC 310-65-1 "Circuit and Trunk File Data Elements and Codes Manual of the Defense Communications System (DCS)", April 1987.

APPENDIX A

COMMERCIAL STANDARDS

A.1. INTRODUCTION. The purpose of this Appendix is to summarize current digital system error performance and availability parameters used in the commercial sector. Sources surveyed were CCIR and CCITT Recommendations, INTELSAT Standards, and commercial company sources. These sources, listed in the references to this appendix, provide detailed performance objectives for error and availability parameters, but do not include other parameters such as delay, jitter, and bit count integrity. Commercial standards tend to rely on the CCITT recommendations already cited and used in the main body of this engineering publication for parameters other than error and availability performance. Here we will therefore focus on just these two parameters, which have been the subject of various commercial standards documents. The reader may be overwhelmed by the variety of thresholds selected for these two parameters, so a word of caution is appropriate here. For nearly all DCS applications, the thresholds given in the main body of this publication should suffice; only for special circuits will reference and use of this appendix become necessary. For further guidance, the reader should consult the Center for Engineering.

Reference A specifies error performance only in terms of user-to-user Error Free Second (EFS) in a 64 Kb/s channel. The CCIR and CCITT also recommend user-to-user EFS performance in a 64 Kb/s channel; however, they also place requirements on Bit Error Ratio (BER). CCIR recommends that EFS be used for user-to-user channel performance, and that Bit Error Ratio (BER) be used at line rates. They are still studying the relationship between line BER and user-to-user EFS. The problem can be illustrated, in an unscientific manner, by considering the fact that if a DS3 system experiences exactly one error per second (zero error free seconds at 44.736 Mb/s), the BER is 2.2×10^{-8}. Using Annex D of Reference B, the EFS in a 64 Kb/s channel at 2.2×10^{-8} BER would be 99.85%. That is, EFS does not translate up and down the digital hierarchy unchanged as BER does. More information regarding statistics of error bursts is required before statistically acceptable methods of translating between EFS and BER can be derived.

There is a good reason for specifying error performance at line rates in terms of error free intervals; e.g., error free seconds or error free milliseconds. New advances, such as described in Reference C and Reference D, provide for low-overhead parity checks which can be used to monitor the in-service performance of both 1.544 Mb/s and 44.736 Mb/s systems. These parity checks do not actually measure bit error ratio; however, they do provide an indication if one or more errors occur during a particular interval, such as a superframe of the Extended Superframe Format (ESF) of a 1.544 Mb/s circuit. Thus, these parity checks can provide for a continuous check of error free seconds without interrupting traffic. Conversely, the measurement of true bit error ratio requires that traffic be interrupted. Thus, if a system is specified in terms of error free seconds at the line rates involved, the system can be continuously monitored for within-specification performance while traffic is being transmitted. DoD adoption of ESF allows the use of these built-in performance monitors and also ensures compatibility with commercial standards.

A.2. HYPOTHETICAL REFERENCE CIRCUITS. The starting points for developing system performance are the so called Hypothetical Reference Circuits (HRC's). The HRC's lay out a hypothetical long haul system from which real world system requirements can be derived. Reference E is the seminal source for CCITT/CCIR HRC's. It describes a 27,500 Km digital 64 Kb/s link made up of National and International sections. Reference B then begins to develop requirements for this circuit. The 27,500 Km system is broken down into 2,500 Km of local and medium grade transmission systems and 25,000 Km of high grade system. The high grade system is then broken down into ten 2,500 Km sections. Presumably, the DCS would correspond to the high grade portion of the system. The CCIR uses the Reference B information to develop requirements for digital terrestrial radio and digital satellite radio systems in References F, G, J, and K. This Appendix summarizes these results, the INTELSAT standard information given in References H and I, and information provided by commercial sources.

A.3. BIT ERROR PERFORMANCE.

A.3.1. REFERENCE B (CCITT Rec. G.821) REQUIREMENTS. The following summarizes the Reference B requirements for the full 27500 Km HRC:

(a) < 10% of one min intervals to have a BER > 1×10^{-6}.

(b) < 0.2% of one second intervals to have a BER > 1×10^{-3} (severely errored seconds (SES)).

(c) < 8% of one second intervals to have any errors (92% EFS).

The following summarizes the Reference B requirements for the 25000 Km High Grade portion of the HRC:

(a) < 4% of one min intervals to have BER > 1×10^{-6}.

(b) < 0.14% of one second intervals to have BER > 1×10^{-3} (SES).

(c) < 3.2% of one second intervals to have any errors (96.8% EFS).

The following summarizes the Reference B requirements for a 2500 Km High Grade radio relay section:

(a) < 0.4% one min intervals have BER > 1×10^{-6}.

(b) < 0.054% one sec intervals have BER > 1×10^{-3} (SES). (0.004% from Ref. B, para. 3.3.a. and 0.05% from Ref. B, para. 3.3.b.)

(c) < 0.32% one sec intervals have any errors (99.68% EFS).

Reference B goes on to say that 20% of the 25000 Km High Grade requirement can be allocated to satellites. Reference B also states that a satellite system should be allowed 0.03% SES. This is close to, but not precisely, the same as 20% of the SES allowance for the 25000 Km High Grade system. These requirements differ from the INTELSAT requirements of References H and I, described below.

A.3.2. REFERENCE F (CCIR Rec. 594-1) REQUIREMENTS. The CCIR used Reference B as a basis to develop CCIR Recommendation 556-1 which provides a Hypothetical Reference Digital Path (HRDP) 2500 Km in length which may form part of an ISDN. Reference F then develops requirements for this HRDP. These can be summarized as follows:

(a) BER $\geq$ 1×10^{-6} for < 0.4% of any month - one minute integration time.

(b) BER $\geq$ 1×10^{-3} for < 0.054% of any month - one second integration time.

(c) ES $\leq$ 0.32% of any month.

A.3.3. REFERENCE G (CCIR Rec. 634-1) REQUIREMENTS. Reference G uses the results of Reference F to develop requirements for real terrestrial radio relay systems which may be part of an ISDN. These can be summarized as follows:

(a) BER $\geq 1 \times 10^{-3}$ for < L/2500 x 0.054 % of any month - one second integration time.

(b) BER $\geq 1 \times 10^{-6}$ for < L/2500 x 0.4 % of any month - one minute integration time.

(c) Residual BER $\leq (L \times 5 \times 10^{-9})/2500$. Measurement method: Take measurements over period of one month using 15 minute integration times. Discard 50% of intervals, keeping best 50%. This is to eliminate any periods of fading, because we are looking for residual BER. (This method is provisional).

(d) ES < L/2500 x 0.32% of any month. (P(EFS) = 0.9968 for 2500 Km system).

The ES requirement is comparable to the Intra-Continental HRC requirement of Reference A.

A.3.4. REFERENCE H (IESS-308) REQUIREMENTS. INTELSAT standards for Intermediate Data Rate (IDR) satellite circuits can be summarized as follows:

(a) BER approximately 1×10^{-7} with clear sky.

(b) 1×10^{-3} < BER < 0.04% of the year (degraded sky). This is equivalent to a severely errored second requirement. INTELSAT does not give an error free second requirement, probably because IDR systems operate at a number of different data rates. (At a BER = 1×10^{-7}, EFS would be very poor at the higher data rates.)

These requirements are without Forward Error Correction (FEC).

A.3.5. REFERENCE I (IESS-309) REQUIREMENTS. INTELSAT standards for INTELSAT Business Systems (IBS) are given for both C Band and K Band. A Super IBS service is specified for K Band to provide service equivalent to C Band. These standards can be summarized as follows:

Performance Objective	C-Band Uplinks	K-Band Uplinks		Units
Service	Basic	Basic	Super	
Unavailability	0.04	1.0	0.04	% per yr
Minimum Clear Sky BER	1×10^{-8}	1×10^{-8}	1×10^{-8}	
Threshold BER	1×10^{-3}	1×10^{-6}	1×10^{-3}	
System Margin	3.0	2.5	7.0	dB

A.3.6. REFERENCE J (CCIR Rec. 522-3) REQUIREMENTS. The CCIR has also developed requirements for satellite systems. Reference H provides requirements for Pulse Code Modulation systems used for telephony. These requirements are not considered to be sufficiently stringent for general DCS use; however, they are summarized here for completeness:

(a) $1 \times 10^{-6} \leq$ BER not more than 20% of any month. Ten minute averaging time.

(b) $1 \times 10^{-4} \leq$ BER not more than 0.3% of any month. One minute averaging time.

(c) $1 \times 10^{-3} \leq$ BER not more than 0.05% of any month. One second averaging time.

A.3.7. REFERENCE K (CCIR Rec. 614-1) REQUIREMENTS. Reference K develops requirements for a satellite system which will be part of an ISDN. These requirements do not differ greatly from the INTELSAT standards. They are summarized as follows:

(a) $1 \times 10^{-6} \leq$ BER not more than 2% of any month. One minute averaging time.

(b) $1 \times 10^{-3} \leq$ BER not more than 0.03% of any month. One second averaging time.

(c) 0 < BER not more than 1.6% of any month. One second averaging time.

Note 1 of Reference K also states that over a period of one month the requirements can be stated as follows:

(a) fewer that 2% of the 1 min intervals to have a BER worse than 1×10^{-6}

(b) fewer than 0.03% of 1 sec intervals to have a BER worse than 1×10^{-3}

(c) fewer than 1.6% of 1 sec intervals to have errors.

A.3.8. REFERENCE L (Bell System PUB 62411). This reference is now old; however, it is still quoted in the literature. The error performance is specified as at least 95% EFS in any consecutive 24 hour period. Reference L states that this is equivalent to a BER of 1×10^{-6}. Reference L specifies availability of 99.7% over 12 consecutive months. More recent AT&T documents, such as Reference D and Reference 7 of the main portion of this document, provide for better EFS performance.

A.3.9. REFERENCE D (AT&T PUB 54014). This Reference applies to AT&T's ACCUNET T45. This service is intended to be derived from fiber optic systems. Following are the EFS performance objectives at 44.736 Mb/s:

Circuit Length	Error Free Seconds
Up to 250 miles	97.1%
251 to 1000 miles	95.2%
Greater than 1000 miles	92%

These requirements are POP to POP in any 24 hour period at the DS3 rate. Access line EFS objectives are 99% EFS, but only if the access line is obtained from AT&T.

The end-to-end EFS requirement for the 44.736 Mb/s circuits can be computed as follows:

POP to POP EFS = .92 for circuit longer than 1000 miles
Access line EFS = .99

Therefore, for two access lines and a POP to POP long haul circuit:

Long Haul EFS = $0.92 \times 0.99 \times 0.99 = 0.90$ measured at 44.736 Mb/s.

A.3.10 REFERENCE M (LIGHTNET). Although the Lightnet system has been sold and no longer operates under that name, the performance as published by the Lightnet organization is included here for completeness. Reference M specified Point-of-Presence (POP) to POP Error Free Second (EFS) performance as 96.5% EFS at a data rate of 1.544 Mb/s.

A.3.11 REFERENCE N (SPRINT). Reference N provides Sprint POP to POP EFS performance as 99% for a 1.544 Mb/s circuit.

A.4. AVAILABILITY. The CCIR also discusses availability, although they are apparently still in the process of deciding what the final requirements should be.

A.4.1 REFERENCE O (CCIR Rec. 579-1) REQUIREMENTS. This recommendation is for satellite systems, and it is somewhat equivocal. It recommends an unavailability of no more than 0.2% for equipment. It goes on to give two recommendations for propagation. One of these is 0.2% for any month. In a note they say that this can be converted to a year by dividing by five; i.e., for a year it would be 0.04%. Then they proceed to give an additional yearly requirement of "X"%. In the notes they provisionally recommend that "X" be 0.1. They also say in one of the notes that the values given are planning objectives and should not be used in specifications or acceptance testing. However, their values are not greatly different from Reference A; therefore, an unavailability value of 0.3% appears to be reasonable. (Reference A gives 0.3171% for VF service, 0.3323% for interactive data service, and 0.3171% for bulk data service. All of these are for a satellite link.) A link is considered to be unavailable by the CCIR if either of the following conditions exist for a period of 10 consecutive seconds or more:

(a) the digital signal is interrupted (i.e., alignment or timing is lost); or
(b) the BER, averaged over one second, exceeds 1×10^{-3}.

The 10 seconds are considered to be unavailable time. The period of unavailability terminates when the same condition ceases for a period of 10 consecutive seconds. These 10 seconds are considered to be available time.

A.4.2. REFERENCE P (CCIR REC. 557-2) REQUIREMENTS. This recommendation is for terrestrial systems, but is again somewhat equivocal. The CCIR has simply not published final recommendations for availability. The recommendation here is similar to the satellite recommendation. The unavailability recommended by Reference P is 0.3% for a 2500 kilometer hypothetical reference path. This is the same as for a satellite path. This does not include the multiplex equipment, but does include all radio equipment and propagation. The definition of an outage is the same as for the satellite case. This requirement is somewhat more stringent than that given by Reference A.

A.4.3. REFERENCE Q (Bell System PUB 62411). This document specifies an availability of 99.7% over 12 consecutive months for a 1.544 Mb/s circuit.

A.4.4 REFERENCE R (AT&T PUB 54014). This document specifies an availability for the 44.736 Mb/s circuit of 99.85%, POP to POP. It further specifies an availability objective of 99.925% for an access line, if AT&T is providing the line. The user-to-user availability should then be:

$$0.9985 \times 0.99925 \times 0.99925 = 0.997 \text{ or } 99.7\%$$

This document discusses a "P" bit parity check. This is odd/even parity computed over the 4704 information bits of an "M" frame. This is not a convenient system for checking end-to-end performance because each piece of terminal equipment in the circuit recomputes this parity. However, AT&T states that they are moving toward "C" bit parity, and eventually will no longer support "P" bit parity. In "C" bit parity, some of the stuff bits which were previously used to synchronize the DS2 level to the DS3 level are reallocated and are used for end-to-end parity checking. DS3 multiplexers using "C" bit parity are not compatible with the old M13 multiplexers. The new multiplexers still stuff the 1.544 Mb/s streams; however, four DS1 signals are now multiplexed together to form a pseudo DS2 signal running at nominally 6.306 Mb/s. Seven of these signals are multiplexed without pulse stuffing to get to 44.736 $\pm$ 20 bits/second.

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