

## DIGITAL SYSTEMS

### DS1 INTRA AND INTEREXCHANGE FACILITY

### PERFORMANCE REQUIREMENTS

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#### 1. GENERAL

1.01 This practice contains performance requirements that digital transmission systems and facilities operating at the DS1 1.544 Mb/s rate must meet to support the AT&T-C service line. As its objective, this practice standardizes basic definitions, transmits performance objectives and recommends testing intervals. This practice also reflects the division that has taken place as a result of divestiture by developing objectives for internodal transmission links, which are also referred to as interexchange facilities, and intraexchange or local access facilities. A sketch showing the relationship of internodal and intranodal facilities is shown in Figure 1.

1.02 When this section is reissued the reason for the reissue will be contained in this paragraph.

1.03 This practice applies to DS1 1.544 Mb/s channels, facilities and transmission systems. The section does not cover DSO substrate channels nor does it cover channels, facilities and systems operating at rates greater than 1.544 Mb/s. Also, this section only covers terrestrial channels, facilities and transmission systems. A transmission system also is called a facility assembly.

1.04 This practice distinguishes between circuits, facilities, channels and transmission systems. A circuit provides a pathway for a service provided to a customer. A circuit extends from customer premises to customer premises and can be switched or non-switched. The attributes of a circuit are selected to support a service such as Digital Dataphone Service (DDS) or Accunet T1.5TM. Consisting of one or more technologies, a facility is a transmission segment having equal capacity at each end. A channel is the minimum assignable inventory in a facility and a transmission system or facility assembly is a single technology. A typical configuration appears in Figure 2.

1.05 In the AT&T-C network analog and digital facilities are used to transport digital services. Lightwave and digital radio are examples of pure digital facilities while Data On Mastergroups (DOM) and the 1A Radio Digital System (1A RDS) are examples of hybrid technologies. Essentially, hybrid technologies refer to sophisticated data modems that condition a digital signal for transmission over an analog facility. When hybrid technologies are used, the modems convert the 1.544 Mb/s AMI format into a multilevel signal that can be transported over analog cable or microwave systems.

1.06 The requirements contained in this practice have and continue to undergo change. Work is

underway on new methods to measure network performance to give a more complete understanding how impairments affect customer equipment and to establish more effective testing procedures. This practice is geared toward manual testing using mostly current procedures. Access to the system or facility under test is obtained at the DS1 cross connect frame. The communications technicians should use current instructions when operating test equipment. As improved monitoring equipment is deployed in the network the need to make manual tests will diminish. Also, as more high capacity digital systems are deployed, more testing will take place at DS3 and less at DS1.

**1.07** Until Headquarters issues updated test equipment recommendations the Bowmar 271B test set or equivalent should be used when making the tests. The Bowmar has limited testing capability, therefore, at this time, the only mandatory test is errored second counts. Tests to develop a measure of burstiness, jitter and ones density are underway now, and will be incorporated later in 1985. Since these tests may require equipment not available locally, they should be incorporated as an escalation procedure, to be performed by regional support groups.

**1.08** The lineup requirements for facilities will be stringent enough to support the complete AT&T-C DS1 digital services line, as currently tariffed. Only the lineup limit will be given. Private line or message work centers will work with the facility centers to determine when the facility work groups repair or improve performance of a facility.

**2. DEFINITIONS-TRANSMISSION SYSTEMS, FACILITIES, CIRCUITS AND CHANNELS**

**2.01** A transmission system or facility assembly is a physical or derived pathway between two offices. A transmission system is bounded at each end by terminals that use the same technology. L4 carrier is an example of an analog transmission system and the FT3C is an example of a digital transmission system.

**2.02** A facility is any physical or derived communications pathway between two locations. A facility is bounded at one end by its input port and at the other end by its output signal port. Each end must have the same capacity. A facility

layout may include a single transmission system or it may involve multiple transmission systems connected in tandem. Facilities are arranged in a hierarchy based on capacity. A lower capacity facility may be assigned to a channel in a higher capacity facility, such as a DS1 facility assigned to a channel in a DS3 facility.

**2.03** Channels are assignment slots that represent assignable inventory in a facility. Some facilities such as a T1F may provide a single assignable DS1 slot while other facilities can transport multiple DS1 signals, as for example a T3 facility.

**2.04** A circuit is a common artery in the network that is accessed by the customer. A circuit extends from customer premises to customer premises. A circuit may be established full time or it may be established only on demand. Full time services are provisioned as dedicated private line while circuits established only on demand usually involve switching systems, either as private lines or through the public switched network.

**3. TRANSMISSION QUALITY MEASURES**

**3.01** The quality of a digital circuit is a function of error performance and availability. An error occurs whenever the output signal from the system is not the same as the input signal. Availability is a measure of the percentage of time (uptime) that a circuit is available to a customer.

**3.02** Error performance can be measured several ways. One common method is to measure bit error rate (BER). BER is the ratio of bits in error to total bits transmitted. BER can be measured easily and accurately when a facility is out of service, but when the facility is in service BER measurements become complex and the results are not always accurate. When the system is in service a surrogate measurement must be made using a limited number of bits. These measurements can be accurate but the measurement intervals are long and there is an upper threshold beyond which the error rate cannot be detected.

A major advantage of the BER measurement is that a bit error measured at one level in the digital hierarchy will be almost the same BER measured at a different hierarchical level. For example, a  $1 \times 10^{-6}$  error rate

measured at DS3 will be almost the same error rate measured at DS1. Aside from in-service monitoring problems, a second difficulty is the lack of a time specification in the measurement. Without time specifications it is difficult to produce a recordable measurements that can be used to manage performance. The inability to obtain DS1 in-service measurements and the lack of time specifications limit the usefulness of BER, although it does have widespread application in switch control and alarm initiation. The BER measurement can provide useful information by alerting personnel to a deteriorating condition, as indicated by a higher background error rate.

**3.03** In tariffs and technical publications that support AT&T-C's service line, error performance is normally specified as the percentage of seconds over 24 hours that is error free. This parameter is easier to record than BER and using new measurement technology it is possible to accurately measure DS1 error free seconds without removing service from the system or facility.

**3.04** An errored second is defined as a second containing one or more bit errors. In digital transmission one second is a lengthy interval. At the DS1 rate, 1.544 million bits of information can be transmitted in one second. During an errored second, one bit or all 1.544 million bits may be in error. The affect on a customer is not the same! Because an errored second measurement does not describe the burstiness of the error, assumptions must be made on how the error propagates through the digital heirarchy. For example, an errored second at the DS3 rate may affect one DS1 channel or it may affect all twenty-eight. The number of channels that are affected is defined as the system's N-factor. In DDS an N-factor of six is frequently used when translating errored seconds from DS1 to the DS0 rate. This means six 56 kb/s DS0 channels will experience one or more errors in an errored second. Experience has shown that N-factors differ widely from system to system, ranging from about two in a T-carrier system to twenty-four or more in some microwave radio systems. An analysis of data indicates that the number of bits in error during an errored second is either very low or else is very high.

**3.05** Availability cannot be measured accurately with technology currently available. Whenever the BER falls below  $1 \times 10^{-3}$  for one second or more a

severe error has arisen. CCITT Recommendation G.821 defines unavailability as ten consecutive severe error seconds. In the future, AT&T-C will have the ability to measure that type of availability. An alternative definition used in some technical publications and in tariffs as a criteria for rebates states that a circuit is out-of-service when it experiences 300 or more errored seconds in a fifteen minute interval. Although measureable, this definition is not totally adequate. It is unlikely that customer satisfaction goals can be met if during several periods each day a customer experiences high error second concentrations. Although based on the definition for unavailability, the customer is not experiencing an outage.

**3.06** Although errored second performance is the most widely accepted measurement of quality, out-of-frame indications and slips provide additional qualitative measures. Out-of-frames (OOF) provide an indication of the burstiness of the errors and slips provide an indication on the status of timing in the network.

**3.07** At channel banks, DACS terminals and interfaces to switching systems it is necessary to align the DS1 signals. Alignment allows the terminals to locate individual 8-bit bytes that contain encoded customer information. In voice communications the channel bank further processes the DSO signal and makes a digital-to-analog translation. The resulting analog signal is a replica of the signal that appears at the input to the system. Alignment is accomplished by decoding the framing information that is added to the customer generated information at the transmitter.

**3.08** Currently, AT&T-C recognizes two DS1 framing signals. One is the D4 or superframe format and the other is the Fe or extended superframe format. The superframe format uses twelve 193 byte frames to establish alignment. Known as the F bit, the first bit position in each 193 bit frame conveys alignment information. In the superframe format there are two alignments patterns. The first pattern aligns the frame itself. This is accomplished by transmitting a 101010... pattern over the odd frames, beginning with frame 1. The second alignment signal identifies the robbed bit positions used to convey signalling information. This pattern is transmitted over even numbered frames 001110... . A transition from 01 or 10 indicates that signalling information

appears in the sixth and twelfth frames. This signalling information is extracted by removing the least significant bit position and processing the information in signalling processing circuits. When customers provide their own terminals they can use the least significant position in the sixth and twelfth frames but must transmit the D4 OR FE alignment signal. The Fe pattern is described in the next paragraph.

**3.09** AT&T-C is promoting a second framing pattern known as extended superframe (Fe). Fe uses twenty-four 193 bit frames to transmit framing information. Extended framing is made possible by large scale integrated circuits that allows more complex processing to take place at the terminal interface. As a result fewer bits must be dedicated to framing. In the Fe format a 0 0 1 0 1 1 pattern is transmitted, during the 4th, 8th, 12th, 16th, and 24th frames. After the twenty-fourth frame, the pattern repeats itself. This pattern determines frame and superframe alignment, and locates the robbed bit signalling frames (frames 6, 12, 18, and 24). Frame alignment is used to locate the 24 DSO channels contained in each frame. Superframe alignment is used to identify where each frame is located within the superframe. The specific frames that contain signalling, cyclic redundancy check (CRC) and data link information must be identified. The CRC and data link are new features that can be provided with Fe. Since each superframe contains twenty-four F bits, and only six F bit positions are needed for frame alignment. The remaining eighteen F bit positions can be used to support new features.

**3.10** The CRC provides a means to monitor the performance of a DS1 facility without removing it from service. At the transmit end a six bit word is inserted into the F bit position associated with frames 2,6,10,18 and 22. The word is generated by taking a polynomial with known coefficients and operating on the data of the twenty-four previous frames to form a six bit word. This word is inserted in the F bit positions reserved for the CRC. At the receive terminal the same operation takes place. The 4608 message bits that made up the previous superframe are operated on by a polynomial with the same coefficients as the transmit terminal to form a six bit word. This word compared to the word received over the CRC link. If the two words match there are no errors in transmission; if the words do not match an error has occurred somewhere in the transmission path.

**3.11** Beginning with frame one and continuing with each odd frame (1, 3, 5, ... 23) the F bit position forms a 4 Kb/s data link. This link can be used to transport more complex alarm information and in the future could be used to support additional customer features. Table A shows F bit assignments for both the extended and superextended frame formats.

**3.12** An Out-of-Frame (OOF) condition is a good indication that serious trouble exists somewhere along the facility. It results when forty to fifty percent of the framing bits are in error. Generally an OOF event is a good indication that a facility is experiencing either short duration opens or else a very high error rate. The parameter can be measured without removing service from the facility.

**3.13** A slip is an indication that a timing problem exists somewhere along the facility. In a digital terminal asynchronous signals applied to input ports are read into a buffer which is also called an elastic store. The signal is read out of the buffer at a rate controlled by system's internal clock. The elastic store compensates for small variations in timing between the input signal and the internal clock, but with larger variations its capacity will be used up eventually, causing either an overflow or underflow. This condition results in slips.

**3.14** There are two categories of slips. A controlled slip is said to be introduced into the network when the elastic store is reset according to a pre-developed plan. When a slip occurs that is not deliberately induced an uncontrolled slip is said to have occurred in the network. Slips in a network that supports only voice transmission are not a major problem but in a network that supports data slips are a major problem because data is lost.

#### 4. JITTER

**4.01** In digital transmission, jitter is defined as a short term variation of a signal element from its ideal position. Figure 3 illustrates a signal with jitter. In current literature jitter requirements are expressed in peak-to-peak unit intervals. One unit interval is the reciprocal of the line rate. For example, at 1.544 Mb/s one unit interval is equal to 0.65 microseconds. When describing jitter its absolute magnitude and rate at which it is occurring must be given. Primary sources of jitter are regenerators, the transmission media and digital multiplexers.

**4.02** Regenerator timing is extracted from the input signal. The input signal can become distorted because of the bandpass characteristics of the transmission medium. As a result pattern dependent timing variations can appear at the output of the regenerator. Known as systematic jitter, these pattern dependent variations add coherently in direct proportion to the number of regenerators in the system. Systematic jitter is controlled by equipment design and system layout rules that limit the number of regenerators in the system.

**4.03** A poor signal-to-noise ratio may cause jitter. Circuits in a regenerator extract timing information from the input signal. High noise levels may cause the regenerator to extract false timing information and to generate an output signal that contains jitter or errors. A poor signal-to-noise ratio indicates that a trouble or a problem in system layout exists. Jitter of this nature is called random jitter. Unlike systematic jitter, it does not add on a coherent basis.

**4.04** The characteristics of transmission media are time variant. Among other effects, these phenomena can cause jitter. For example, in radio transmission changes in the refractive index will change the electrical length of a radio path and in a metallic system temperature changes will change the electrical length of a cable. Both conditions have the potential to cause jitter. Finally, reflections resulting from impedance mismatches can distort the input signal and cause jitter to appear in the output signal.

**4.05** In digital transmission systems multiplexers are a third source of jitter. Multiplexers accept asynchronous input signals. Before these signals can be interleaved to form a higher speed line signal they must be synchronized. Jitter can develop during synchronization because of pulse stuffing. Under extreme conditions, if there is significant timing differences between the input signals slips could also develop, as described in an earlier section.

**4.06** Currently three preliminary jitter specifications exist. A fourth specification that defines end-to-end (DSX1-to-DSX1) jitter may be added in the future. Jitter specifications exist at the input to a terminal, at its output when no jitter is present at the input and at the output with jitter present at the input.

**4.07** Jitter has been a problem at the junctions of different digital technologies but, in general, when these problems are corrected by changes in design or layout the problems disappear. In most instances problems of this nature represent equipment or system design violations and not performance degradation. Jitter is not a mandatory test requirement currently. If a problem is encountered a headquarters or regional support group should be contacted for assistance.

## 5. SIGNAL-TO-NOISE RATIO

**5.01** A Digital transmission system can operate satisfactory only when the signal-to-noise ratio exceeds a minimum level. In fact, the BER of any system bears a functional relationship to the signal-to-noise ratio. The BER objective, therefore, mandates the S/N objective of the system design. The required ratio ranges from about 12 dB in a system that employs two level modulation to 20 dB, or more, in a system that employs multiple level modulation. Most digital radio systems and the hybrid systems, such as DUV, use multiple level modulation to conserve bandwidth. In multiple level modulation a signal element may assume several different amplitudes, with each amplitude conveying information. Common encoding techniques include quadrature amplitude modulation (QAM), quadrature partial response modulation (QPR) and phase shift keying (PSK). As the number of levels in a system increase, the minimum signal-to-noise ratio the system requires to maintain acceptable BER performance also increases. As an example, a 16 level QAM signal requires a 16 dB signal-to-noise ratio (average energy-per-bit to noise density) for  $1 \times 10^{-8}$  BER, while a 64 QAM system requires 21 dB signal-to-noise for the same BER.

**5.02** A small change in signal-to-noise ratio can cause a large difference in the BER. Typically 1 dB change in the S/N ratio will cause one order magnitude change in BER. For example, about 1 dB change in a 16 QAM system will change the BER from  $1 \times 10^{-7}$  to  $1 \times 10^{-8}$  BER. When conditioning a radio system for digital transmission, it is important that interference levels be measured and recorded at each hop and that each section meets its designed fade margin, otherwise, the required BER objectives will not be met. This requirement not only applies to DUV but also to other digital systems operating over microwave radio.

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### 6. SEVERE ERRORED SECONDS

**6.01** An errored second contains one or more bit errors. Errored second measurements are a mandatory test. The affect of an errored second on a customer will depend on the burstiness of the error. If a large number of bits are in error within an errored second and the customer's equipment drops synchronization, it is likely the customer will experience a critical outage. Although the facility may only experience one errored second, the customer may be down for several seconds until his equipment reacquires synchronization. Further, equipment "behind" a DS1 multiplexer may see the sync loss as a "line out of service," which can cause a 10 to 20 *minute* outage.

**6.02** The emerging burstiness control measure will be stated as a form of severe errored seconds. This terminology is compatible with events of the same nature described by CCITT Recommendation G.821. The common definition of a severe errored second is any second whose BER is  $10^{-3}$ , or less. It has been shown that severe errored seconds are a common phenomena in the network, usually occurring as solid bursts for 1/2 to 2 seconds in length at widely seperated intervals. When such bursts combine with sensitive customer multiplexers they can cause serious outages on customer networks and increase customer dissatisfaction. Limits will be determined later this year.

**6.03** Test equipment currently deployed at facility work centers cannot measure error burstiness. If a severe errored problem is suspected, it is necessary to look at out-of-frame events or to request assistance from regional support staffs who have specialized test equipment. The out-of-frame test provides a good indication that a severe error has occurred somewhere along the facility. If several out-of-frames are experienced during the day the customer will be complaining about the quality of the DS1 service. In most situations an out-of-frame test is an easy test to make because it is not necessary to remove service from the facility. Effective January 1, 1985, customers must have extended framing or superextended framing. The only exceptions are with certain older Accunet T1.5 circuits not employing either extended or superextended framing, or certain circuits sold to the government which are exempted from all framing requirements.

**6.04** Newer transmission systems operating at DS3 or higher digital rates measure Type A, Type B and Type C errored seconds. Type A errored seconds contain exactly one bit error; Type B errored seconds contain more than one but less than the number of bit errors that would cause a switch and Type C errored seconds indicate a severe impairment; i.e., at least an out-of-frame condition or an error condition severe enough to cause a protection switch.

### 7. DS1 SIGNAL INTERFACE REQUIREMENTS

**7.01** In digital transmission terminals internal clocks are synchronized from the input signal. The synchronization recovery circuits are designed to operate with input signals containing at least 12 1/2 percent marks (ones) and no more than 15 consecutive zeros.

**7.02** When density and consecutive zero requirements are not met internal clocks may drift off frequency and cause a high error rate. Considerable time may be needed for the internal clock to reacquire synchronization. As a result, depending on the severity and how frequent the problem occurs, the customer could experience considerable outage. In addition, if the zero sequence is long enough the terminal may interpret the condition as an open and generate line alert codes. Once this happens it will take several seconds for the system to return to normal after it recognizes a valid input signal.

**7.03** If a ones density problem is suspected it will be necessary to request assistance from a regional support group. Those organizations have the specialized test equipment to confirm the existance of a density problem.

**7.04** At the DSX1 frame the DS1 signal should meet the following requirements:

Line Rate: 1.544 Mb/s  $\pm$  130 PPM

Line Code: Bipolar with at least 12 1/2 percent average ones density and no more than 15 consecutive zeros

Test Load: 100 Ohms resistive load

Pulse Amplitude: An isolated pulse shall fit the template in Figure 4. The pulse amplitude shall be between  $\pm$  2.4 and  $\pm$  3.6 volts.

Power level: For an all-ones pattern, the power in a 2 Khz band about 772 Khz shall be 12.4 to 18.0 dBm and the power in a 2 kHz band about 1.544 Mb/s shall be at least 29 dB below the level in the band about 772 Khz.

Pulse Imbalance: There shall be less than 0.5 dB difference between the total power of the positive pulses and the total power of the negative pulses

D4			Fe		
Frame Number	Terminal Framing	Signal Framing	Framing Sequence	Data Line	CRC
1	1			m	
2		0		m	C1
3	0		0	m	
4		0		m	C2
5	1		0	m	
6		1		m	C3
7	0		0	m	
8		1		m	C4
9	1		1	m	
10		1		m	C5
11	0		1	m	
12		0		m	C6
13				m	
14				m	
15	With the D4 Option Frames 13 through 24 do not exist. Frames 1 through 12 are repeated.			m	
16			0	m	
17				m	C5
18				m	
19			1	m	
20				m	
21				m	
22				m	C6
23				m	
24			1	m	

m indicates bit positions for the 4 kB/s data line  
C1 through C6 are the CRC bit positions

TABLE A  
D4 and Fe FORMATS

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**8. OUT-OF FRAME PERFORMANCE REQUIREMENTS**

**8.01** An out-of-frame condition is declared when 2-of-4 to 2-of-5 framing bits are in error. The requirements contained in Tables B and C shall apply. At this time the limits in Tables B and C are for information.

**9. JITTER REQUIREMENTS**

**9.01** Transmission terminal equipment manufactured after mid-1984 should meet the jitter accommodation requirements shown in Table D. The accommodation requirement must be met when a standard quasi-random signal with jitter is applied at

the DS1 frame. Also, this requirement applies only to equipment manufactured after mid-1984. Earlier vintage equipment must be characterized individually, as required.

**9.02** All terminals, which includes digital multiplexers, shall produce less than 0.3 time slots of RMS jitter and less than 1.0 slots of peak-to-peak jitter at the output of the terminal. For this test, the terminal shall be looped at the high speed side and a jitter-free standard quasi-random signal shall be applied at the input.

**9.03** A system shall add less than 0.5 time slots of peak-to-peak jitter when a signal having 4.0 time slots of peak-to-peak jitter is applied at the input.

**TABLE B**

INTERNODAL TRANSMISSION LINKS AVERAGE NUMBER OF EVENTS PER 24 HOUR PERIOD		
DISTANCE (MILES)	OVERALL FACILITY	INDIVIDUAL TECHNOLOGY
0-1000	2	2
1001-2000	4	4
2001-3000	9	8
3001-4000	12	11

**TABLE C**

ACCESS LINKS AVERAGE NUMBER OF EVENTS PER 24 HOUR PERIOD		
DISTANCE (MILES)	OVERALL FACILITY	INDIVIDUAL TECHNOLOGY
No Distance Requirement	9	8

**TABLE D**

SYSTEM INPUT JITTER ACCOMMODATION REQUIREMENT						
TEST POINT	TIME SLOTS PEAK-TO-PEAK	TIME SLOTS PEAK-TO-PEAK	FREQUENCY (HZ)			
			F1	F2	F3	F4
	A1	A2	F1	F2	F3	F4
DSX1	5		10	500		
DSX1		0.1			8000	40,000

9.04 Jitter measurements are not a required pre-service lineup test. The parameter need only be measured when trouble is suspected or when trialing a new transmission system.

**10. ERRORED SECOND REQUIREMENTS**

10.01 Errored second measurements must be made each time a transmission system or facility is tested prior to turn up. Table E provides recommended testing intervals. It is suggested the times shown in the Table be used when measuring the first channel in each transmission system. In higher capacity systems, such as lightwave, shorter intervals for testing subsequent channels may be necessary because of test equipment and work activity constraints. The introduction of performance monitoring systems will reduce the monitoring intervals and much of the manual effort associated with making error measurements. Prior to the widespread availability of these support systems local conditions may require that different intervals be used locally. Variations in recommended intervals should be discussed with regional and headquarters technical staffs.

Tariffs, along with technical references, contain error free performance requirements based on a 24 hour time reference. Until the appropriate terms are added to those documents to provide confidence statements, tests based on a 24 hour day are strongly recommended. Time-of-day and seasonal variations affect performance. Variations that occur during the business day reflect increased traffic loading and maintenance activity while seasonal variations primarily involve changes in radio propagation. Multiple consecutive day tests do not capture these cyclical variations with enough predictability to materially improve confidence in test results over those obtained from a single day's test. The two hour re-test should always be made during business hours.

10.02 The limits contained in this section support all AT&T-C digital services, with the exception of DDS. Requirements for DDS are based on 56 Kb/s performance. End-to-end, DDS must meet 99.95 percent error free performance at 56 Kb/s. Facility and transmission system tests are normally made at the DS1 rate. Because of this, it is necessary to establish a

**TABLE E**

RECOMMENDED INTERVALS	
<b>A. Transmission Systems</b>	
First Channel In Each System	4-1 Day Measurement
Subsequent Channels	1-Day (If The Second Through NTH Channels Are Turned Up Within Two Weeks Of The First A Two Hour Is Sufficient)
Re-Test	Two Hours
<b>B. Facilities</b>	
Initial Lineup	1 Day
Re-Test	2 Hour
<b>C. Access Facilities</b>	
Initial Lineup	1 Day
Re-Test	2 Hours

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transfer function from DS1 to the 56 Kb/s rate. This transfer function is the System's N-Factor. Emperically, the N-factor ranges from about two for T-carrier paired systems; six for lightwave and coaxial transmission systems and about twenty-four for microwave radio systems. The use of a high N-factor leads to requirements that are unrealistically high and too costly to maintain. Economically, it does not make sense to require each transmission facility to meet DDS 4000 mile 56 kB/s requirements, based on an assumption the N-factor equals twenty-four. To establish practical limits an N-factor of six is used in this practice. Under some circumstances it will not be possible to meet DDS requirements. If an extremely long DDS 56 Kb/s circuit is assigned to a lengthy section of DMG riding radio, performance objectives will not be met and it will be necessary to arrange a re-route. If this situation is encountered it should be brought to the attention of the appropriate headquarters and regional support staffs.

**10.03** Internodal Digital facilities at the DS1 level should meet the following errored second requirement.

$$ES = 0.22 \times D$$

Where ES is the maximum number of errored seconds in a twenty-four period and D is distance in miles. Also,  $D \geq 150$  miles. The facility layout document contains the route mileage.

**10.04** Variations in measurements become more pronounced as the distance becomes shorter. Because of these variations, the formula in 10.03 should only be applied when the internodal facility is more than 150 miles long. For shorter length facilities no more than thirty-three errored seconds are allowed in a twenty-four hour period.

**10.05** When transmission systems are tested a slightly different coefficient should be used. The formula given in 10.03 becomes:  $ES = 0.19 \times D$ . The formula should be used when the facility is more than 150 miles long. When the distance is less than 150 miles twenty-eight errored seconds are the maximum allowed each twenty-four hours.

**10.06** For two-hour test the formulas should be modified as follows:

Facilities

$$ES = 0.0145 \times D.$$

Transmission Systems

$$ES = 0.013 \times D.$$

As before, the formulas should only be used when the facility or transmission system is longer than 150 miles. For distances less than 150 miles two errored seconds are allowed during each two hour test period.

**10.07** Access facilities should be tested for twenty-four hours prior to initial turn-up. While shorter test intervals have statistical validity under certain circumstance, DDS requirements are stringent enough to sometimes render such test results invalid. In general, access facilities consist of T-carrier and the local loop. The local loop may consist of twisted wire or it may take the form of subscriber loop carrier. For this practice, all vintages of T-carrier are considered the same. Also, if T-carrier is encountered in the internodal facility, the same test value given in 10.08 should be used when testing the internodal transmission system. At this time the numbers for access facilities are for guidance purposes only. The access provider's tariff must be consulted to obtain numbers that can be used for purposes of trouble referral. In general, those numbers are considerably less stringent than the numbers contained in this practice. However, properly designed system should meet the numbers contained in this practice.

**10.08** Each T-carrier system used for local access, or as a segment in an internodal facility, shall experience no more than 345 error seconds per twenty-four hour test period. An end-to-end 4000 mile circuit could include up to four T-carrier systems and still meet overall end-to-end error performance objectives. The T-carrier limit is based on an N-factor of three. When two hour tests are made, each T-carrier system shall experience no more than fourteen errored seconds.

**10.09** Local loops, which extend from the last office to the customer's premise, could include T-carrier, twisted wire or subscriber loop carrier. Each local loop shall experience not more than 43 errored seconds during a twenty-four hour period. The access provider's tariff must be examined to determine the referral number.

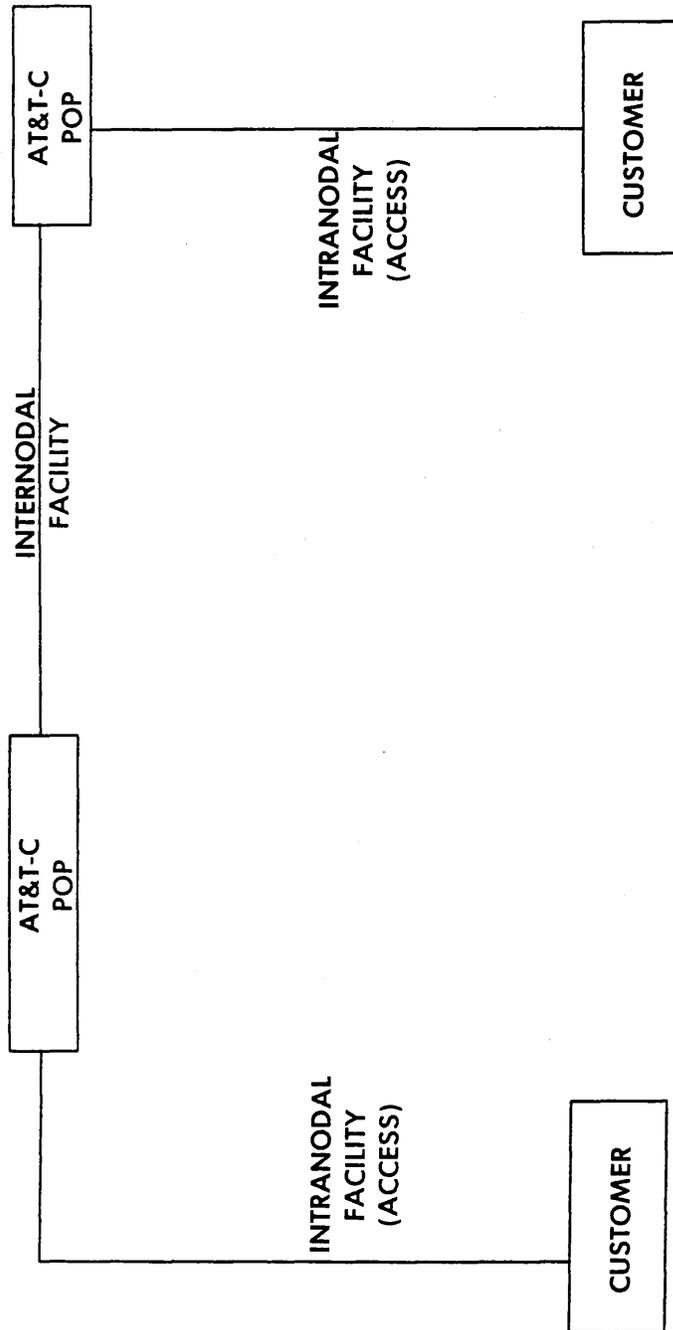
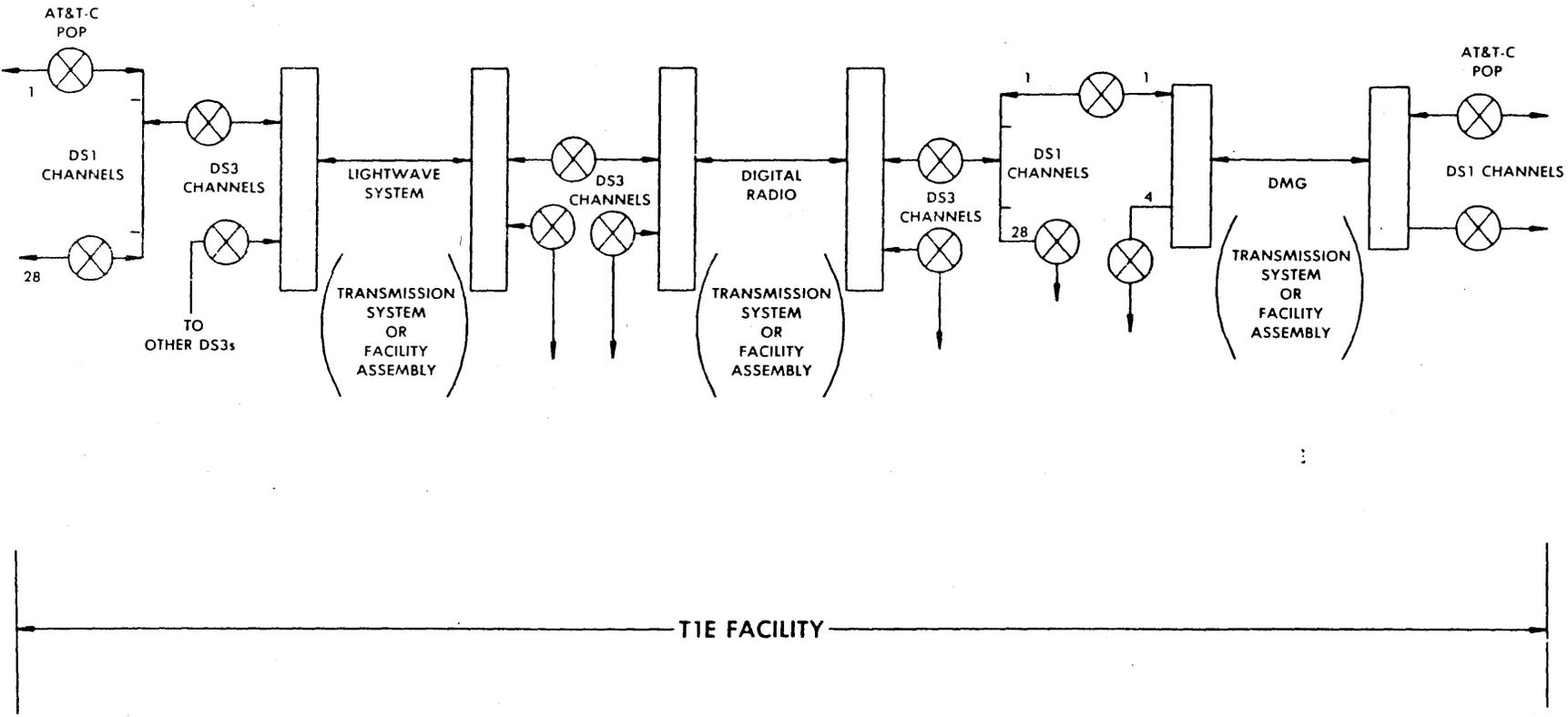


Figure 1. - Customer-To-Customer Facility Diagram



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Figure 2. - Simplified Facility Layout

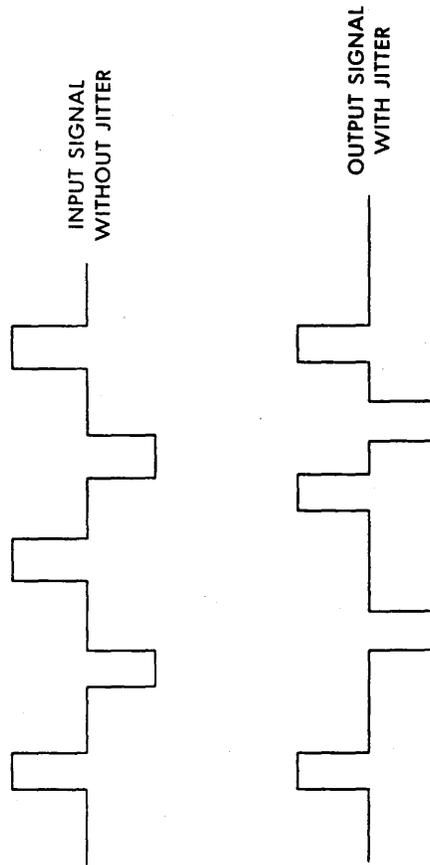


Figure 3. - Signal Containing Jitter

