DATA SYSTEMS—"DATA-PHONE"® SERVICE AND DATA ACCESS ARRANGEMENTS ON DIRECT DISTANCE DIALING NETWORK OVERALL DATA TRANSMISSION TEST REQUIREMENTS

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1. GENERAL

1.01 This section describes the overall transmission considerations and test requirements involved in providing data transmission over the switched telecommunications network (DDD) using loops, trunks, and switching equipment as used in voice service. This section applies equally to DATA-PHONE service and Data Access Arrangements (DAA) unless otherwise specified. There are no specific requirements for inductively or acoustically coupled DAA.

1.02 This section is reissued for the following reasons:

- To include DAA information throughout this section
- To update BSP references in 7.01
- To include reference to 914-type data test set in 11.03
- To include a reference section
- To change the upper test frequency to 2800 Hz
- To change the holding tone to a −13 dBm0.

1.03 In general, data transmission calls are handled the same as voice telephone calls. The calling party dials the desired number and the called party answers. When the parties are ready to send or receive data, both parties change their mode of operation from voice to data by the operation of pushbuttons or keys either built into or associated with the data set. It is necessary that the data sets on either end of the connection be of the same type and be compatible in bit rate, frequency, etc. Upon completion of the data transmission, both parties (by previous agreement) either hang up or return to the voice mode. There are exceptions to this procedure; ie, the called station may be unattended. If the called station is unattended, the calling party receives a tone indicating that the distant end data set has answered and is ready to receive (or send) data. At the end of the call, the distant end will disconnect under the control of the far-end business machine equipment. Another exception is in the use of automatic calling units. These units permit a computer or other similar business machine to "dial" the desired number. These systems are usually associated with the unattended service feature described above, and

therefore no person is involved at any time during the sequence of operations.

1.04 In order to test Bell System DATA-PHONE services, a number of 904-type data test centers (DTC) have been installed in various locations in the Bell System. The data test centers are used in conjunction with local and toll test centers. ▶The two types of voiceband data test centers in operation are the 904A or C and the 904B or D. The 904A and C data test centers are designed for local testing and are capable of testing data sets which have a remote test feature. The remote test feature allows the data set to be tested from a DTC through the operation of a test key on the data set by the attendant. This permits a data set to be tested without telephone company personnel at the station. The 904B or D data test center must always be associated with a 904A or 904C DTC. The 904B or D DTC contains several types of data test sets and other test equipment, which enable it to make dynamic tests (end-to-end error tests) of data sets.◀ (In other words, the DTC is a "presumed good" data set.) It is most useful for testing the interface of the data set (which is not tested by the 904A-type tests) and for quick demonstrations to the customer and/or business machine personnel that the data set is operational. However, since the DTC is somewhere in the middle of the network and may not be in the routing taken by the customer's call, sending data to a DTC is not always a conclusive test. If the results are good, no information is gained as to whether data service is satisfactory to the particular location the customer is calling. If the tests are bad, the fault may be due either to facilities between the DTC and the customer or to the data sets, indicating that further analysis is needed. Section 314-205-300 provides additional information on the overall transmission maintenance procedures.

1.05 ▶The Data Access Arrangement provides a service through which a customer may connect his data set (modem) to the switched telecommunications network. Since a non-Bell System modem is used with DAA, the error rate performance cannot be specified. The DAA consists of a Bell System data coupler and, when necessary, a telephone. This arrangement provides signal level limiting, loop isolation, a loop-holding path for dc supervision, and hazardous voltage protection. The Bell System retains the responsibility for network control signaling features. However, with automatic DAAs, the customer's business machine may generate tone address signals or control the generation of dc dial pulses.◀

2. OPERATION OF THE DDD NETWORK

2.01 The DDD network consists of a large number of trunks which interconnect long distance switching offices. This network serves, with a few exceptions, all of the telephones in the United States and Canada. Since data calls are routed from city to city via the DDD network, it may be helpful to review briefly the general structure of the DDD network.

2.02 Central offices where the customer data lines are terminated for the purposes of interconnection to other offices are called end offices and are designated class 5 offices. The class 5 offices are connected by trunking facilities to higher ranking offices (lower class number). The class 5 office does not necessarily have to terminate in a class 4 office. Depending upon location, it may home on any higher ranking office (any lower class number) from a class 4 to a class 1. High-usage trunks may be provided between offices of any class. The needs of direct distance dialing are met by switching and trunking arrangements that employ the principle of Automatic Alternate Routing to provide rapid and accurate connections while making efficient use of the telephone plant. With Automatic Alternate Routing, a data call which encounters an "all trunks busy" condition on the first high-usage route tested is automatically and rapidly "route advanced" and offered in sequence to one or more alternate routes for completion. The overall tests of a data service should be made during the normal working hours in order to determine if there are any variations in error rate or in general performance under alternate routing conditions.

2.03 During the busy-hour period, the overflow traffic is more likely to be routed through alternate routes. For each call, there is a network of final routes which are last choice routes and are engineered on a low-delay basis. On the average, no more than a small fraction of the calls offered to this final trunk group during the busy-hour period will find all trunks busy. Within the United States, the maximum number of trunks in tandem will not exceed a total of nine, ie, seven trunks from a class 4 office to a class 4 office, plus one trunk on each end to a class 5 office. The probability of a call traversing all nine final trunk

routes is estimated to be only a few calls out of millions. Most calls are completed on direct or first alternate trunk routes between offices; relatively few switch through more than two intermediate (intertoll) trunks in tandem.

2.04 Part of the DDD network is operated on a 4-wire basis and the remainder on a 2-wire basis. It would be advantageous to operate all trunks in the DDD network at a zero loss, making the total transmission loss independent of the number of trunks used in a connection between two stations. If the whole system operated on a 4-wire basis subset to subset, it would be possible to keep the losses close to zero. However, with the interconnection of 2- and 4-wire facilities, problems of balance, echo, singing, noise, and crosstalk require circuits to be operated at definite minimum losses. The application of the above considerations to an individual trunk depends upon the facilities involved, length of the circuit, and accuracy with which the various adjustments at the terminals and intermediate points have been made and held. An important feature of analog transmission systems is that the adjustment of a component made at any one point will have a reaction upon adjustments made at other points. Therefore, it is important in clearing transmission difficulties to correct the basic cause of the trouble rather than to make terminal adjustments to eliminate the symptoms.

2.05 Most of the trunks on the DDD network are designed to operate on a via net loss (VNL) basis. VNL is defined as the lowest loss in dB at which it is possible to operate an intermediate trunk facility in a multitrunk DDD connection, considering limitations of echo, crosstalk, noise, singing, and office balance on the overall connection. VNL design provides the lowest practical loss at which a trunk can be operated regardless of the number of trunks in tandem in the connection. More information about VNL is contained in Section 851-300-100 entitled Transmission Design Consideration and Objectives, Switched Special Services and PBX Services.

3. TRANSMISSION ASPECTS OF DATA SERVICE

3.01 The data subscriber line should meet the objectives shown in Section 314-205-501 (Data Systems—DATA-PHONE® Service and Data Access Arrangements on Direct Distance Dialing Network—Test Requirements for Subscriber, Foreign Exchange, and Remote Exchange Lines).

3.02 Voice transmission and data transmission, while they are similar in basic elements such as means of switching and circuit design, differ somewhat in transmission requirements. There are a number of transmission considerations which may affect data transmission over the DDD network. They are as follows:

(a) Maximum transmitting level and overall circuit loss

(b) Attenuation frequency distortion

(c) Return loss

(d) Message circuit noise

(e) Impulse noise

(f) Envelope delay distortion

(g) Frequency shift

(h) Nonlinearities

(i) Phase jitter (incidental FM)

(j) Hits—amplitude and phase

(k) Dropouts—microwave fading.

These items are covered in more detail in Parts 4 through 11 of this section.

3.03 Several of the parameters listed above are primarily controlled by voice requirements. These include overall circuit loss, return loss, and message circuit noise. Of the remaining parameters, data requirements are usually controlling. In general, voice telephone service can tolerate greater transmission impairments than data service. For example, if the customers have difficulty with transmission during a telephone conversation, they will either compensate for the difficulty by talking louder or repeat the part of the conversation that has been missed. Under the same conditions, the data set is at a disadvantage since it can only transmit at a predetermined level and frequency. The data set has no way of determining if errors or reduction of signal level have occurred during transmission. (Of course, error detection capability

may be provided in some instances.) Impulse noise, except in extreme conditions, has little effect upon voice transmission since the duration of the impulse noise peaks involved are often too short to be recognized by man. Impulse noise is a serious problem in voice-frequency data transmission, in which the data signals are measured in milliseconds or less. Envelope delay does not have a serious effect upon voice transmission because the human ear is relatively insensitive to differences in delay at different frequencies. Modern carrier and loaded facilities have better envelope delay performance than the older types. Carrier frequency error does not seriously affect voice transmission in most instances. For data transmission, more than a 10-Hz deviation from the normal carrier frequency may degrade a data circuit to the point at which the data being sent is unintelligible.

3.04 The performance of a data set generally deteriorates after the operating limits are exceeded. For example, after the attenuation distortion (frequency response) limit has been reached in data set 202C, a small change may degrade the performance from good to intolerable. Maintenance and adjustment of data transmission equipment and facilities should be as close to the optimum point as possible. Prudent and careful application of adjustments to each section in the overall connection will increase the reliability of the service.

4. MAXIMUM TRANSMITTING LEVEL AND OVERALL CIRCUIT LOSS

4.01 The maximum practical transmitting level of data sets is limited by crosstalk in multipair cable facilities and by the maximum level that a steady tone or combination of tones which may be applied to a carrier terminal unit without overloading. Most DATA-PHONE data sets have been designed so that the maximum transmitting level will not exceed one milliwatt in 900 ohms. ▶In DAA, the couplers are designed to limit, when necessary, the signal power delivered by the customer-provided data modem.◀ In connection with initial installation tests (see Section 314-205-501), the loop insertion loss is measured and recorded for the data loop. The maximum sending level for the telephone company-provided data set involved should be set so as not to exceed ▶−12 dBm at the main frame appearance of the subscriber line at the class 5 office furnishing dial tone to this line. This will correspond to a maximum data signaling power of −13 dBm0 on toll carrier facilities.◀ The transmit level will be selected by the engineering department and the proper option shown on the circuit layout card or line card. This can be verified by dialing the milliwatt supply from the customer's premises and subtracting the transmission measuring set reading from −12 dBm. In regard to some types of DATA-PHONE data sets such as the 400 series, more than one tone is sent simultaneously. The −12 dBm figure represents the total power of all tones transmitted simultaneously. In order to keep receiving levels within requirements, the data set level should be set so it will be received at the serving central office as close to the −12 dBm level as possible without exceeding it. Information on the transmit level options is found in the BSP installation section of that particular data set.

4.02 The maximum permissible overall circuit loss between data sets depends upon the DDD connection and the type, sensitivity, and operating frequencies of the data set. The receive level of data sets ranges from +2 dBm to −53 dBm. The exact maximum loss that a particular data set can tolerate may be calculated by subtracting the maximum transmitting level from the minimum receive level. At this time, all DATA-PHONE data sets can tolerate an overall loss of 36 dB at 1000 Hz and 48 dB at 2800 Hz. ▶Although the slope requirements are based on loss measurements at frequencies of 1000 and 2800 Hz, the test oscillator should be offset by about 4 Hz to obtain stable measurements over T carrier.◀

4.03 With the many improvements in DDD network losses over the past few years, overall loss is not considered to be a major cause of trouble. Under present design, the maximum overall circuit 1000-Hz loss should not exceed 37 dB. This includes the local loops and toll connecting trunks at each end plus seven intertoll trunks in the connection. If problems arise, they usually can be traced to improperly lined-up trunks in the network.

5. ATTENUATION FREQUENCY DISTORTION

5.01 Excessive attenuation frequency distortion (also called slope) on voice-frequency data transmission increases the error rate by degrading the signal as it traverses the facility. Some DATA-PHONE data sets that operate in the higher bit range [above 300 bits per second (bps)] can tolerate more attenuation frequency distortion by

the use of the compromise equalizer. With low-speed (under 300 bps) narrow band data sets, such as the 100-type data set, attenuation frequency distortion is less limiting because of the narrow bandwidth.

5.02 For the entire station-to-station connection through the DDD network, the attenuation frequency (slope) should not exceed 15 dB between 1000 Hz and 2800 Hz for satisfactory operation of data sets. For high-speed data transmission, the loop between the serving central office and the customer location should measure no more than 3.0-dB maximum difference between the 1000-Hz loss and the 2800-Hz loss. The maximum difference on the connection over the DDD network, end office to end office, should not exceed 9 dB between 1000 Hz and 2800 Hz.

5.03 The attenuation frequency characteristic of connections on the message network varies from call to call. On a built-up connection, the facility is affected at higher frequencies due to the effect of capacitance in office wiring. When tests of a data service reveal instances of high distortion measurements accompanied by an excessive number of errors, overall loss-frequency measurements should be made station-to-station. (The connection should be "held" in order to make the measurements.) If these measurements indicate that there is an attenuation difference, the circuit should be measured at each loop. Both loops should meet the maximum objective and if this objective cannot be met, each link should be tested to determine the source of the trouble. ▶See Section 660-405-300 for additional information on trouble sectionalization and clearing methods to be applied to trunks in the DDD network when used for data services. Section 660-101-305 provides information on the local testroom procedures followed by the plant service center when handling data service complaints. It also contains the overall maintenance plan for DDD data service.◀

5.04 The attenuation frequency characteristic also defines the bandwidth of the transmission facilities. DATA-PHONE and DAA services are operated on frequencies as low as approximately 300 Hz and as high as approximately 3000 Hz. Modern transmission facilities provide sufficient bandwidth to accommodate these frequencies; however, obsolete types of facilities (such as H-172 loading) may prevent satisfactory data transmission and a substitute must be provided.

6. RETURN LOSS REQUIREMENTS

6.01 Return loss requirements for data sets are determined by listener echo (echo heard by the listener). Listener echo is limiting for data sets because the receiving data set on a connection will interpret the data received through the echo path as interference. Most of the data sets in use at this time will not tolerate listener echo ▶delayed more than one-third the baud interval and at a power◀ closer than 12 dB to the received signal level. Return losses at each 2-wire to 4-wire point in the DDD network will affect listener echo. At 2-wire switching points, the return losses, in turn, are affected by office balance. Voice requirements for return loss and echo on the DDD network provide an adequate margin for data service.

6.02 Bell Telephone Laboratories studies on return loss requirements indicate that the 12-dB first listener echo requirement for data sets is valid but can be met without special loop treatment. Therefore, there is no longer a specific return loss requirement for data service loops. Return loss is an important parameter, especially to high-speed data transmission, but the troubles are usually isolated to trunks, improperly installed E-type repeaters, or poorly balanced hybrids rather than the loop facilities.

7. MESSAGE CIRCUIT NOISE

7.01 Message circuit noise is ▶the noise on a channel in the absence of a signal. Message circuit noise is of lesser importance in data service than in voice service. If normal voice circuit noise objectives are met, then data transmission noise objectives will be automatically met. Message circuit noise objectives for voice may be found in the following sections:

- 311-100-500—Circuit Order and Trunk Order Transmission Tests—PBX Central Office Trunks, Off-Premises Station Lines and Tie Trunks Having Access to the Direct Distance Dialing Network
- 311-100-501—1000 Hz and Noise Tests—PBX Central Office Trunks, Off-Premises Station Lines and Tie Trunks Having Access to the Direct Distance Dialing Network

- 660-403-500—Message Circuit Noise Measurements on Message Trunks—Requirements

- 660-500-500—Transmission Testing of Message Trunks at Locations Other Than Testboards—General Information.

7.02 Message circuit noise will not be a problem if a 24-dB signal-to-C-notched noise ratio is maintained throughout the connection.

8. IMPULSE NOISE

8.01 Impulse noise hits are a primary source of errors in data transmission. If impulse noise hits of sufficient magnitude occur during data transmission, they can seriously degrade the error rate of the data transmission system. ***Impulse noise measurements should be made on every loop that is to be used for the transmission of data signals at 300 bps or greater.*** A 6-type impulse noise counter is used to measure impulse noise on a facility. Information involving the use of the 6-type impulse counter can be found in the 103-6YY-ZZZ series of practices. The magnitude and frequency of the occurrence of the impulse noise voltages are used to specify the impulse noise objective. The objective is expressed as a threshold (referred to the zero transmission level point) which will be exceeded no more than a specified number of times per 15 minutes for individual circuit measurements.

8.02 Impulse noise exhibits some level variation with the time of day. It was previously believed this variation was great enough to warrant measurements only during the busy hour. Recent studies show this effect to be less severe, and it is now permissible to make these measurements any time during the normal business day. Measurements resulting from data transmission service trouble reports should be made during periods when the customer is experiencing trouble, if possible.

8.03 Previously, it was recommended that transmission level corrections be made at 1700 Hz, which was selected because it was near the center of the spectrum of high-speed voiceband data transmission. This is no longer considered necessary on trunks because the difference between the 1000-Hz and 1700-Hz loss is small on trunks but must be taken into account on loops. An average of the 1000- and 2800-Hz loss is used since nonloaded facilities are encountered.

8.04 The impulse noise objectives for trunks and facilities are given in Table A. The objectives given in this table are average levels where one-half of the trunks in the trunk group or one-half of the facilities in a facility group exhibit five or less counts in 5 minutes.

8.05 A trunk group is defined as all of the trunks between two offices, A and B, for any given purpose and under the same maintenance control. A facility group is defined as all of the facilities in a given routing with common design. For example, the 12 channels in an N1 system would be included in a group. Where specific trouble investigation is in process, only those facilities under investigation are included in the facility group. For example, if seven of the 24 channels in an ON1 system are used in a trunk group A-B where high-impulse levels have been noted, only those seven channels enter into the computations.

8.06 Where compandored facilities are encountered, a −13 dBm0 holding tone is used in setting the objectives. This stabilizes the expandor loss at 9.0 dB.

8.07 Impulse noise objectives will be met if, throughout the connection, fewer than 15 counts in 15 minutes occur at a threshold 5 dB below the data signal.

9. ENVELOPE DELAY DISTORTION

9.01 Envelope delay distortion can seriously affect data transmission on the DDD network. Different frequencies undergo different amounts of delay as they are transmitted over the message network, which will cause the data signal to be distorted. Voice transmission performance is not affected to the same degree by envelope delay distortion as data transmission. The amount of envelope delay distortion that will be found on a voice-frequency facility depends upon the type and, in the case of cable, the length of the facility. Carrier system distortions are affected by the type of carrier and the multiplex arrangement encountered.

9.02 Envelope delay distortion (EDD) is usually expressed as the maximum variation of the envelope delay characteristic within a particular frequency band. This measurement is usually

→ TABLE A ←

TRUNK AND FACILITY IMPULSE NOISE OBJECTIVES

TOLL CONNECTING TRUNKS AND INTERTOLL TRUNKS			
LENGTH (MILES)	TYPE TRUNK		
	Note (1)	Note (2)	Note (3)
0 through 60	54 dBrnc0*	66 dBrnc0*	58 dBrnc0*
61 through 125	54 dBrnc0*	66 dBrnc0*	58 dBrnc0*
126 through 250	54 dBrnc0*	66 dBrnc0*	59 dBrnc0*
251 through 500		66 dBrnc0*	59 dBrnc0*
501 through 1000		66 dBrnc0*	59 dBrnc0*
1001 through 2000		66 dBrnc0*	61 dBrnc0*
Over 2000		66 dBrnc0*	64 dBrnc0*
TOLL CONNECTING FACILITIES AND INTERTOLL FACILITIES			
LENGTH (MILES)	TYPE FACILITY		
	Note (1)	Note (2)	Note (3)
0 through 60	51 dBrnc0*	64 dBrnc0*	55 dBrnc0*
61 through 125	51 dBrnc0*	64 dBrnc0*	55 dBrnc0*
126 through 250	51 dBrnc0*	64 dBrnc0*	56 dBrnc0*
251 through 500		64 dBrnc0*	56 dBrnc0*
501 through 1000		64 dBrnc0*	56 dBrnc0*
1001 through 2000		64 dBrnc0*	58 dBrnc0*
Over 2000		64 dBrnc0*	61 dBrnc0*

Note (1): Voice frequency only.

Note (2): Compandored carrier or mixed compandored and noncompandored facilities with - 13 dBm0 holding tone.

Note (3): Noncompandored carrier.

* Limits are given for measurements made with instruments equipped with "C" Message (C) weighting filter. If measurements are made with instruments equipped with voiceband (VB) weighting filter, add one dB to the objective.

expressed as microseconds over the band of interest. Data sets vary in their tolerance to envelope delay distortion, depending upon the type of modulation and the bit rate. Low-speed DATA-PHONE data sets can tolerate a greater amount of delay distortion than the higher speed data sets. With data service, envelope delay distortion should be suspected if high error rates which cannot be attributed to message noise, impulse noise, overall loss, or attenuation frequency distortion are encountered. The P/AR (peak to average ratio) meter (Section 103-110-110) is useful in determining the condition of a data transmission connection. ◗P/AR measurements are primarily sensitive to EDD, but attenuation distortion and noise may also have a strong effect on P/AR readings.◖ Table B shows the expected readings for acceptable and unacceptable conditions. If envelope delay measuring equipment is available at the station ends of the overall connection suspected of having excessive envelope delay distortion, direct measurements should be made. If this equipment is not available, consult the Data Technical Support personnel through normal lines of organization for advice. The end-to-end envelope delay distortion should be compared with the requirements of the data set involved. ◗The maximum overall envelope delay distortion requirements for satisfactory error performance for data sets 201A and 202-type are shown in Table C of this section. List 3 and List

4 of data set 203-type are designed for DDD operation. Error performance is not specified, but some insight into the performance that can be expected per field trial (see Technical Reference, Data Set 203-Type, June 1970) is as follows. The performance was equal to or better than 10^{-5} errors per bit for 95 percent of the calls at 1800 bps (2-level). A 10^{-4} error or better error rate was obtained on 84 percent of all calls and an error rate better than 10^{-5} errors per bit on 62 percent of all calls at 3600 bps (4-level). Error performance for 4800 bps is approximately equal to that at 3600 bps. In the case of a customer-provided modem, the requirements should be the same as for an equivalent bit rate Bell System data set.

TABLE B

P/AR READINGS

CONNECTION IS	PAR READING
Acceptable	Above 50
Unacceptable	Below 50

9.03 As with other transmission aspects of the switched message network, the amount of envelope delay distortion varies from call to call, depending upon the number and type of carrier links and the length and type of voice-frequency links in the connection. Compromise or adaptive automatic equalization is used in the higher speed data sets to make operation on the switched message network possible. In connection with the installation or maintenance testing of DATA-PHONE data sets, it is important to verify that the compromise attenuation and delay equalizers have been properly connected at the data set location. The options which cover the equalizers for the particular data set involved are specified on the circuit order, line card, or other records associated with the data service.

9.04 On the overall connection, as the envelope delay distortion objectives for given frequencies are approached or exceeded, the operation of the data set will become more marginal. This may result in a malfunction or complete failure of the data set.

→ TABLE C ←

MAXIMUM ENVELOPE DELAY DISTORTION REQUIRED FOR SATISFACTORY ERROR PERFORMANCE

DATA SET (SEE NOTE)	FREQUENCY	MAX EDD
201A	1150-2300 Hz	500 μs
	1000-2500 Hz	900 μs
	800-2700 Hz	1750 μs
202 - Type	1200-2200 Hz	1050 μs
	1000-2500 Hz	1500 μs
	800-2600 Hz	2000 μs

Note: All data sets used in connection with DATA-PHONE service should have the compromise equalization option connected (see 9.03).

9.05 On occasion, envelope delay distortion will be too high within the DDD network for data transmission operation between two particular points on the network. Information about the situation should be forwarded through the lines of organization for reassignment or further investigation. It may be necessary to provide additional equalization at the data set location or to install a remote exchange (RX) line to bypass part of the network until better facilities can be provided. The RX line will have to meet the requirements per Section 314-205-501.

9.06 When remote exchange lines of any type, including wide area telephone service (WATS) lines, are used for data service, their design should first be reviewed by personnel responsible for circuit design to ensure that the envelope delay distortion

will not exceed the limits for the type of data sets involved. RX lines to class 4 or higher offices will include the distortion of a toll connecting trunk in computing objectives. If the envelope delay distortion exceeds 300 microseconds between 1000 and 2400 Hz, the line should be delay-equalized to meet the 300-microsecond objective. WATS design will be identical to RX design if other than the local office is used as a serving office. If the local office is used, the normal loop objectives apply. Information about delay equalizers may be found in Sections 314-820-100, -103, and -104.

10. FREQUENCY SHIFT

10.01 Frequency shift (sometimes called frequency offset) beyond the capabilities of the data set will result in high error rate. If the symptoms occur and the cause cannot be readily attributed to loss, attenuation frequency distortion, steady or impulse noise, or envelope delay, the possibility of frequency shift should be investigated.

10.02 Under normal circumstances, frequency shift will have little effect upon voice transmission. With data service, deviations in frequency of more than ± 10 Hz may cause distortion of a data signal. The modulated data signal of the DATA-PHONE data set is transmitted as a tone or combination of tones which have been calibrated to precise frequencies. At the receiving end of the facility, the signal is demodulated by the receiving data set in order to recover the data. If the frequencies of the transmitted tones are changed as they traverse the facility, the frequency-sensitive circuits in the receiving data sets will not receive the tones at the optimum points, thus resulting in a distortion of the data signal and an increase in the number of errors received. On carrier systems used in connection with data services, the overall carrier frequency error should be kept to ± 5 Hz or less. Individual carrier facility sections should have carrier frequency errors of no more than ± 2 Hz.

10.03 There will not be a frequency error problem on the "transmitted carrier" type of carrier systems, such as the Western Electric "N" ◗(only even numbered channels with N3),◖ "O", and "ON". With this type of carrier system, the carrier signal that is used for modulation is transmitted directly to the distant terminal for demodulation. Western Electric "J", "K", and "L" systems are of the suppressed carrier type, in which the carrier is suppressed at the transmitting terminal and resupplied at the receiving terminal. When this function is accomplished by the use of a generator that is held in synchronization with the generator at the transmitting end, frequency shift will be at a minimum and should not cause data distortion.

10.04 Frequency shift exists primarily in suppressed carrier systems where there has been no provision for synchronizing the carrier terminals at the ends of the system. Nonsynchronized Western Electric type "J", "K", "L", and "C" systems use carrier supply generators with long-term stability. These systems should not present any frequency shift problems provided they are adequately aligned and maintained at the intervals specified in the practices. Western Electric type "C" ◗(vacuum tube modulator type)◖ and "H" carrier systems may present more serious problems, depending upon operational environment and the maintenance routines.

10.05 Carrier systems that are not supplied by the Western Electric Company can be roughly classified in the same way as the Western Electric systems. Actual frequency shift performance of any system in the questionable category should be determined prior to the start of data service over that system and corrective action instituted if necessary.

10.06 In the event that all specified requirements have been met and unsatisfactory service is experienced, the trouble may be caused by either phase jitter, harmonic distortion, or single-tone interference. Normally, it is not expected that the plant department will be required to make these tests. However, if advised by Data Technical Support personnel, these parameters should be checked.

11. EVALUATING DATA TRANSMISSION AND TROUBLE INVESTIGATION

11.01 ***In all instances, facilities used for data transmission should meet normal voice-frequency objectives prior to their consideration for use on data services.*** The additional requirements described in Parts 4 through 10 of this section should then be applied to the facilities, as required, in order to accommodate the more stringent objectives of data transmission.

11.02 On a connection over the DDD network, the effects of such items as overall loss, attenuation frequency distortion, envelope delay, etc, are cumulative as the length of the circuit and the number of links involved increase. All types of switched facilities are subject to some interruptions, which may be due to equipment failures, facility failures, or human errors. The object of maintenance testing for data services is to determine the location of troubles which can cause actual failures in data transmission over the message network. The malfunction may be of very short duration, measured in microseconds, fading or drop-outs which can extend seconds or minutes, or actual facility failures which will interrupt service for a considerable length of time. It is important to note that service should be restored as quickly as possible. For example, a data service operating at 1200 bps is capable of transmitting or receiving over four million bits of information in one hour. An outage of one hour due to a facility malfunction can cost the customer a considerable amount of money in lost "computer time," obsolescence of information, and extra time consumed in storing and recovering data which has accumulated during the disruption of service. Duration of intermittent interruptions is an important factor in the detection of trouble since complete failures are more readily found than momentary troubles. The message network is so arranged that a complete failure of a cable, carrier channel, or central office terminal equipment will usually be detected by means of automatic alarm systems. In connection with interruptions of shorter duration, the shorter the time interval, the more difficult will be the problem of detection. The line evaluation test covering the particular data set under test is described in the installation performance procedures of the 590 series of practices. Errors received and peak distortion determine the quality of the circuit under test.

11.03 Analysis of station record cards may give an indication as to the source of repeated data troubles. When it is possible, the circuit or connection should be "held" at the serving office and the call traced and tested through its various links in order to detect the malfunction. (See Section 314-205-300 and 590-010-300 for procedures.) Since it is not always possible to continue to "hold" the suspected circuit for immediate testing, a record should be made of the links involved and arrangements made to test the circuit at the first appropriate opportunity. A line evaluation test should be made from the "sending end" data set location. Use the suspected circuit for the test. ◗Both locations should be equipped with 901-, 902-, and 903-type data test sets or a 914-type data test set.◖

11.04 An analysis of possible results of the circuit evaluation test is shown in Table D. The result of the tests may be used as a guide for locating transmission difficulties encountered with data services.

TABLE D

CIRCUIT EVALUATION TEST—RESULTS USING 900-TYPE DATA TEST SETS—RECEIVING END OF CIRCUIT

TROUBLE CONDITION	REMARKS	TRANSMISSION IMPAIRMENTS (CHECK ITEMS IN SEQUENCE AS SHOWN)	
High distortion and high error rate	Distortion reading is high and steady.	Attenuation Frequency Distortion Message Circuit Noise Return Loss Envelope Delay Distortion	(Part 5) (Part 7) (Part 6) (Part 9)
High distortion and high error rate	Distortion reading is high and unsteady.	Overall Circuit Loss	(Part 4)
High error rate and normal distortion	Distortion reading shows frequent peaks.	Impulse Noise Message Circuit Noise	(Part 8) (Part 7)
High distortion and high error rate	Distortion reading may shift gradually.	Frequency Shift	(Part 10)

12. REFERENCES

12.01 Bell System Practices mentioned in this section which cover various equipment are listed as follows:

SECTION	TITLE
010-521-100	◗Data Technical (DATEC) Support◖
103-110-110	J94027A and B Par Meter Generator and Receiver, Description, Operation, and Maintenance
107-100-100	◗901A and 901B Data Test Sets—Identification and Operation◖
107-101-100	914-Type Data Test Sets, Description and Operation
107-200-100	903A and 903B Data Test Sets, Description and Operation
107-300-100	902A and 902B Data Test Sets, Identification and Operation
314-205-300	Data Systems—DATA-PHONE® Service on Direct Distance Dialing Network, Overall Transmission Maintenance Procedures
314-205-501	Data Systems—DATA-PHONE® Service and Data Access Arrangements on Direct Distance Dialing Network—Test Requirements for Subscribers, Foreign Exchange, and Remote Exchange Lines
314-820-100	Envelope Delay Characteristics of 200-Type Delay Equalizers
314-820-103	Envelope Delay Characteristics of 366- and 367-Type Equalizers
314-820-104	Envelope Delay Characteristics of 384- and 385-Type Equalizers
590-010-300	Data Systems—DATA-PHONE® Service on Direct Distance Dialing Network—Overall Field Force Maintenance Procedures
660-101-305	Data Systems—DATA-PHONE® Service on Direct Distance Dialing Network—Plant Service Center Handling Customer Trouble Reports
660-405-300	◗Data Systems—DATA-PHONE® Service and Data Access Arrangements Using the Switched Telecommunication Network, Toll Testroom Trouble Clearing Procedures◖
851-300-100	◗Transmission Design Consideration and Objectives, Switched Special Services and PBX Services.◖

NOTES