DATA GENERAL

DATA TESTING PRINCIPLES

CONTENTS PAGE

Tables

1. GENERAL

1.01 This section provides the testing principles used when performing data transmission maintenance and preservice tests on circuits and trunks for private line (PL) service, the Public Switched Network,(PSN) and Special Service Networks (SSN). These testing principles include testing access, testing arrangements, recommended order of maintenance tests, and a means of identifying probable trouble locations.

1.02 This section is being reissued to change transmission limits throughout. Since this is a general revision, no revision arrows have been used to denote significant changes

1.03 This section augments Bell System Practice Division 309, Switched Services Networks; Bell System Practice layer 314-205-ZZZ, DATAPHONE® Data Communications Service—Transmission Maintenance, Loops, and Trunks; and Bell System Practice layer 314-410-ZZZ, Private Line Data Circuits. Information specific to any one of these services can be found in the appropriate sections covering the service.

2. TEST ACCESS

2.01 There may be several points where transmission tests can be made. The choice of access should be at a known impedance and test level. When making transmission tests on the local channel, transmission equipment, eg, pads, repeat coils, and amplifiers, are considered part of the facility and must be included in the tests. Pads, repeat coils, and amplifiers can also be components of equipment, eg, Metalic Facility Terminal (MFT) and channel interface unit (CIU), also known as Data Auxiliary Set (DAS) 829.

2.02 Access to circuits is available through manual testboards and test positions, eg, private line board, 19A testboard, 6-jacks, and full period talk (FPT) jacks. Bay mounted or portable test equipment must be plugged into the test jacks through test cords. Manual testing requires at least one other tester with similar equipment at another point on the circuit.

2.03 Access to circuits is also available from remote locations through a Switched Access Remote Test System (SARTS). Remote testing gives a tester the ability to access and test a circuit without the assistance of another tester in a distant office. Bay mounted or portable test equipment may be required for certain tests.

2.04 The actual SARTS access of circuits is provided by Switched Maintenance Access Systems (SMAS). Access point information for SMAS is found in Section 667-000-001.

3. DATA LEVEL

3.01 Data level is the signal power for a steady tone or combination of tones which meet loading objectives for broadband carrier systems. Signal power is expressed in decibels referenced to 1 milliwatt supply (abbreviated dBm) terminated into 600 ohms. Combination of tones (composite power) is discussed in paragraphs 3.07 and 3.08 .

3.02 The data levels at the various test points indicated on the circuit layout record (CLR) card must be maintained. High levels (signal power stronger than allowed) can cause overloading in our carrier systems. Low levels (signal power weaker than required) can reduce the signal-to-noise ratio.

3.03 The design rules for the use of data levels vary from service to service. Because of the differences, the rules applying data levels to PL, PSN, and SSN are discussed separately. Regardless of the design of the circuit, ***all tests are performed at data level.***

Private Line

3.04 The rules which are used in the design of PL data or alternate voice-data channels are as follows:

(a) The data level at the MOD-IN JACK of a toll grade carrier is normally a −29 dBm and at the DEMOD-OUT JACK is normally a −6 dBm.

(b) The standard data modem transmit power is 0 dBm at the CIU. Any pads, amplifiers, and equalizers are considered part of the channel.

(c) The standard 1004-Hz net loss of a channel should be one of the following:

(1) For use between data sets—16 dB

(2) For use between 4-wire tel sets—16 dB

(3) For use between 2-wire tel sets—10 dB

(d) The data transmit level for both 2-wire and 4-wire alternate voice/data channel is 0 dBm.

(e) The data level at the entrance to exchange cables at both the central office (CO) and customer premises locations should not be greater than −8 dBm. In special situations, this level can be in the range of −6 dBm to −16 dBm.

Public Switched Network

3.05 The rules which are used in the design of data service on the PSN are as follows:

(a) The FCC registration program is designed to control the output of the data set. The maximum transmitting data level for any data set is adjusted so that normally it will not exceed −12 dBm at the main frame of the dial tone office.

(b) The data level at the MOD-IN JACK of a toll-grade carrier is to be no higher than a −29 dBm and at the DEMOD-OUT JACK is to be no higher than a −6 dBm.

Switched Services Networks

3.06 The rules which are used in the design of data services on SSN are as follows:

(a) Data levels are 13 dBm below transmission level points (TLP).

(b) The level at the MOD-IN JACK of a toll-grade carrier is normally −16 TLP and at the DEMOD-OUT JACK is normally +7 TLP. The data level for the −16 TLP is −29 dBm and for the +7 TLP is −6 dBm.

(c) The standard 4-wire data modem transmit power is −13 dBm at the 0 TLP.

The standard 2-wire data modem transmit power is a −9 dBm at the +4 TLP.

Composite Power

3.07 The output power of each tone of multichannel data sets must be determined. This also applies to multipoint circuits where the remote station data sets transmit simultaneously at different frequencies. Each tone must not exceed the individual power level so as to insure that the composite power does not exceed data levels. When N is the maximum number of tones on a channel and the composite power is 0 dBm, each tone must not exceed (0-10 log N) dBm. When calculating the individual powers of multisignals at the carrier MOD-IN JACK, the formula would be −29-10 log N. Logarithms to the base 10 for from 2 to 30 tones are given in Table A.

3.08 ***Example of test:*** A data set has a maximum of four equal-level tones. So as not to exceed data levels, the maximum power per tone is computed as follows:

Maximum power per tone = 0-10 log (4)

Log 4 from Table A = 0.602

Maximum power per tone = 0-10 (0.602)

Maximum power per tone = −6.02 dBm.

4. TESTING ARRANGEMENTS

4.01 The testing arrangements described in this section correspond to the list of parameters described in Section 314-010-100. These arrangements are listed in the order in which they are to be performed when investigating trouble reports. Part 7 covers the order of tests for installation and routine as well as tests for trouble reports. The SARTS incorporates the test equipment necessary to perform many of the test arrangements listed. For purpose of this section, whenever the type of test equipment is given, SARTS is automatically included except where noted.

TABLE A

LOGARITHMS

CHANNELS	LOGARITHMS	CHANNELS	LOGARITHMS	CHANNELS	LOGARITHMS
2	0.301	12	1.079	22	1.342
3	0.477	13	1.114	23	1.362
4	0.602	14	1.146	24	1.380
5	0.699	15	1.176	25	1.398
6	0.778	16	1.204	26	1.415
7	0.845	17	1.230	27	1.431
8	0.903	18	1.255	28	1.447
9	0.954	19	1.279	29	1.463
10	1.000	20	1.301	30	1.477
11	1.041	21	1.322		

4.02 Operating procedures for test equipment is not included. Operational information must be obtained from manufacturer's manuals or Bell System Practices describing the various test equipment. Information on suitable test equipment is covered in Part 5.

Continuity

4.03 The most convenient way of testing for continuity is with the office milliwatt supply and monitor (earphone, headset, speaker, etc). A tone generator, oscillator, or transmit portion of a transmission measuring set (TMS) may be substituted for the milliwatt supply. For switched services, dial-up milliwatt numbers are used.

4.04 The continuity test checks for an uninterrupted connection between two points. It does not indicate that proper equipment has been installed or properly adjusted.

1004-Hz Loss

4.05 The 1004-Hz loss measurement is typically made with a TMS. The test set must be accurate to ±0.1 dB and capable of receiving an input signal in the level range of +10 dBm to −40 dBm. Straightaway measurements require two test sets. Measurements on access-type lines on switched services use a dial-up tone generator and the receive portion of a TMS.

4.06 The 1004-Hz loss measurements are used to determine the loss of a circuit or overall connection on switched services. In addition, loss measurements are used in conjunction with noise measurements to determine the signal-to-noise ratio.

C-Notched Noise

4.07 A noise measuring test set equipped with a C-notched filter measures the noise in the presence of a signal. This signal, known as a holding tone, is 1004 Hz and is placed on the circuit at data level (−13 dBm0). The test can be a looped or straightaway measurement. In the test for switched services, the holding tone is dial accessed.

4.08 In addition to measuring noise in the presence of a signal, the C-notched noise measurement can also be used to calculate a signal-to-noise ratio. This can be accomplished by subtracting the measurement of noise with tone from a measurement of the same tone made with the C-notched filter reversed in the noise measuring test set. (Reversing the filter disables it, allowing the 1004-Hz tone to be measured.) A listening (monitor) test for impulse noise or single tone interference should be made wherever practicable. If tone interference is detected, every effort should be made to detect the frequency of the tone. Detection of the interfering tone frequency may assist field forces to determine its source, eg, power line hum.

Impulse Noise

4.09 An impulse noise counter equipped with a C-notched filter counts the number of impulse hits occurring above a set threshold in the presence of a 1004-Hz holding tone. As in the case of C-notched noise, the impulse noise test can be a looped or straightaway measurement. In the test for switched services, the holding tone is dial accessed.

4.10 The impulse noise measurement is a record of impulse noise peaks that exceed a given threshold in the voice frequency band of interest. The threshold level is adjustable by an attenuator on the test set. Some impulse noise test sets have multiple attenuators providing multiple thresholds.

Phase Jitter

4.11 Phase jitter is measured with a phase jitter test set using a 1004-Hz holding tone. C-notched noise measurements should always be made in conjunction with phase jitter measurements to assure that noise is not the chief contributor to the phase jitter readings.

4.12 A phase jitter measurement indicates the cumulative effect of incidental phase modulation and additive tones or noise on the zero crossings of the holding tone. To reduce the effect of additive noise, the peak-to-peak deviations in zero crossings are detected after being band limited. The standard limiting band is 20 to 300 Hz and referred to as "Bell."

4.13 Phase jitter is also known to occur below 20 Hz. A second limiting band is used to detect phase jitter in the frequency range of 4 to 20 Hz. This is known as "low frequency" (LF). Phase jitter measurements can be made in three ranges:

- Bell

- LF
- Bell plus LF

Bell plus LF has a frequency range of 4 to 300 Hz. Any two of the three measurements may be specified and are considered a valid measurement. The "Bell plus LF" measurement is not provided in SARTS.

Gain Slope

4.14 Gain slope measurements are typically made with a TMS. Straightaway measurements on a PL circuit or switched connection require two TMSs. On switched access circuits, a step generator is dial accessed in place of the far end TMS.

4.15 Gain slope is the differential loss between 404 and 1004 Hz and 1004 and 2804 Hz. The gain slope measurement may be required for access lines and/or end-to-end connections on the PSN. The gain slope measurement is a recommended benchmark measurement used in conjunction with the peak-to-average ratio (P/AR) measurement on PL and SSN circuits.

Peak-to-Average Ratio (P/AR)

4.16 For P/AR measurements, a P/AR transmitter and a P/AR receiver are connected to opposite ends of a voiceband transmission channel. The transmitter sends a precisely controlled complex pulse train of known peak-to-full-wave average ratio (10 dB) through the channel, where each pulse is altered by the distortions it encounters. The P/AR receiver measures the absolute peak and full-wave rectified average values of the pulse train and displays their ratio on a zero-suppressed scale.

4.17 The P/AR system, after having gone through four generations of implementation, has been demonstrated to be an effective tool in uncovering problems in attenuation distortion, envelope delay distortion (EDD), and return loss. It provides a means for rapid evaluation of these three parameters on trunks and connections. It is essentially impervious to other impairments when they are within normal limits.

4.18 Acceptable P/AR together with acceptable gain slope measurements provide a better than 99 percent assurance factor of acceptable attenuation distortion, return loss, and EDD measurements. P/AR alone can provide a 97 percent assurance factor.

4.19 P/AR limits are strongly tied to the types of facilities used in trunk makeup. This is primarily because the filters in channel banks of different facilities are not all alike and hence have different amounts of EDD. Trunk maintenance limits of P/AR for channels using many different kinds of facilities are given in Appendix 1 of this section or in the maintenance sections of the PL, PSN, and SSN layers.

4.20 As of now, no fixed P/AR limits are available for C conditioned private lines. This is mostly due to a lack of measurements on such lines and the difficulties involved in trying to turn such services down for a sample measurement. At present, the best procedure for conditioned lines is after acceptance by an EDD and loss run; a benchmark P/AR reading should be taken and recorded on the history record. Future readings that exceed ±4 P/AR points from the initial reading will indicate trouble in one of the three parameters that P/AR evaluates.

4.21 When the Western Electric 27 series P/AR equipment is considered, the 27F or later models must be used. Previous versions of the 27 series of P/AR equipment should not be used. The errors introduced in the old P/AR system, because of frequency shift or phase intercept distortion on the line, have been eliminated by introduction of frequency shift in the new P/AR transmitter and different signal processing in the new P/AR receiver. Because of these changes, the new and old P/AR equipments are incompatible.

4.22 The "new" P/AR system has been found to be a very effective measure of intersymbol interference. It has found defective elements in trunks that could not be picked up except by complete EDD and attenuation distortion measurements. It should be used as a first order tool in locating data transmission troubles, and it is also recommended as a circuit order requirement for benchmark purposes.

Attenuation Distortion

4.23 Attenuation distortion measurements are typically made with a TMS. Straightaway measurements require two TMSs.

4.24 The attenuation distortion measurement is the differential loss between 1004 Hz and all other required frequencies within the band of interest. The required frequencies and the band of interest can be found in the appropriate sections listing the requirements for PL and SSN services. This measurement is not a required measurement on access lines and end-to-end connections on the PSN. Attenuation distortion is not the same as the gain slope measurement discussed in paragraphs 4.14 and 4.15.

Intermodulation Distortion

4.25 The term intermodulation distortion is preferred to the term nonlinear distortion. In addition, the intermodulation distortion measurement replaces the harmonic distortion measurement.

4.26 Since some nonlinear elements are frequency sensitive, this method is being replaced with the multitone intermodulation distortion test. This test is accomplished by transmitting four equal, level tones arranged in two "pairs." One pair called A is located at about 860 Hz, and the other pair called B is located at 1380 Hz. The receiver takes the power average of A+B and B−A products to determine second order distortion and displays the ratio, R2, of the fundamental power to second order power. It also measures the ratio of fundamental to some third order products, R3, located at 2B-A.

4.27 This measurement technique has been recommended because the amplitude distribution of the test signal closely approximates a typical high speed data signal. In addition, the multitone technique provides a more stable measurement of the channel nonlinearities which are frequency dependent and time variable. Harmonic distortion is evaluated by transmitting a 700-Hz tone and measuring the received second and third harmonics. For several sources of nonlinearities in tandem, complete cancellation of a harmonic can occur which is not possible with intermodulation distortion.

Hits and Dropouts

4.28 There are several test sets available which accurately measure these parameters. Some are phase jitter test sets, pen recorders, the combination of phase jitter test sets and hit monitors, and vector scope techniques. Hit and dropout measurements are not provided in SARTS.

4.29 Hit and dropout measurements are a means of recording the number of hits or dropouts that exceed a predetermined threshold. The threshold for gain hits and dropouts is measured in dB, while the threshold for phase hits is measured in degrees.

Return Loss

4.30 The return loss measurement indicates the presence or absence of an echo caused by an impedance mismatch or discontinuity in the channel. This mismatch, and resulting echo, can be controlled by proper balancing. Echo occurs when a signal passes from 4-wire to 2-wire portions of the circuit or connection. If impedances are not matched or balanced, part of the signal energy travels back toward the source in the form of talker echo. If the talker echo is reflected by a similar imbalance at the transmit end, the effect is listener echo. Both talker and listener echo are detected by the return loss measuring set or singing point test set. Only talker echo can be measured by SARTS.

4.31 Return loss measurements are required whenever 4-wire to 2-wire conversions are in the transmission path. These tests insure that a given data set receiver will not receive any transmitted signal above an interfering level more than once (listener echo). To operate satisfactorily, the level of echo must be 12 dB or more below the level of the original received signal. The return loss measurement is especially important when data service is provided over tandem networks, PBX-CO trunks, and the PSN.

Single Frequency Interference

4.32 A listening test or the use of a monitor during the C-notched noise test is normally sufficient for the detection of single frequency interference. However, to identify the frequency of a specific interfering tone, a spectrum analyzer or frequency selective voltmeter is required.

Frequency Offset

4.33 The frequency offset measurement is generally made with two frequency counters. ***A looped test is not valid as the offsets can cancel.*** These measurements are only required on the carrier channel portions of the circuit and should not normally include metallic facilities.

4.34 To measure frequency offset, a frequency counter is used at both ends of the carrier portion of a channel to compare the frequency of tone which is transmitted from one end to the other.

4.35 Frequency offsets that return to zero by as much as 100 Hz have been observed. These offsets can last from a few milliseconds to 5 seconds. A frequency meter and phase jitter test set may be helpful in detecting this problem. An electronic frequency counter cannot detect this type of problem.

Envelope Delay Distortion (EDD)

4.36 Envelope delay distortion measurements are typically made with voiceband gain and delay sets. The SARTS system does not measure EDD. The EDD measurement must be made with two test sets as the looped measurement is not a valid test. The EDD measurement must be made only after the channel has been brought into attenuation distortion specifications.

4.37 The EDD measurement determines the difference between the delay at any frequency in the band of interest and the delay of a reference frequency. The reference frequency is generally around 1800 Hz.

4.38 Once delay equalization is correctly applied to a data circuit, EDD has proven to be the least critical parameter when a trouble arises. Some data sets provide adaptive equalizers. Acceptable P/AR measurements are accurate indicators of acceptable EDD.

5. TEST EQUIPMENT

5.01 Test equipment mentioned in this section is given as a general type only and is not meant to suggest any model(s) or manufacturer(s) unless specifically stated.

5.02 A listing of AT&T evaluated general trade test equipment is located in the Product Evaluation Report (PER) No. 117. Copies of the PER are maintained by the general trade advisors at headquarters locations of Long Lines and each Bell Operating company.

6. ESTIMATION OF TRANSMISSION PERFORMANCE

6.01 This part provides examples of the estimation of end-to-end transmission performance based on sectional measurements. The sectional measurements can be parts of 2-point PL, end links and middle links of multipoint PL, or access lines and trunks of end-to-end connections on the PSN and SSN. All the methods of combining discussed here apply to one direction of transmission. In general, the results of these methods are approximations. Therefore, if the results are out of limits, an actual end-to-end measurement must be made.

A. Attenuation Distortion

6.02 The sectional loss with respect to 1004-Hz measurements should be added algebraically for each frequency.

Example:

LOSS WITH RESPECT TO 1004 HZ (dB)

FREQUENCY* (HZ)	LINK A	LINK B	OVERALL
304	1.0	-0.3	0.7
504	0.8	-0.2	0.6
604	0.4	-0.2	0.2
804	0.2	-0.1	0.1
1004	0	0	0
1204	-0.1	-0.1	-0.2
1404	-0.1	0.1	0
1604	-0.2	0.2	0
1804	-0.1	0.2	0.1
2004	0	0.2	0.2
2204	0.1	0.1	0.2
2404	0.2	0	0.2
2504	0.3	0.1	0.4
2604	0.3	0.2	0.5
2704	0.5	0.4	0.9
2804	0.9	0.7	1.6
3004	1.3	1.4	2.7

* Refer to the maintenance requirements sections for the required measuring frequencies.

If the overall measurement must be compared to the C2 conditioning specification, perform the following steps:

The minimum loss with respect to 1004 Hz between 504 to 2804 Hz = −0.1 dB

The maximum loss with respect to 1004 Hz between 504 to 2804 Hz = 1.6 dB

The minimum loss with respect to 1004 Hz between 304 to 3004 Hz = −0.2 dB

The maximum loss with respect to 1004 Hz between 304 to 3004 Hz = 2.7 dB

The overall attenuation distortion then is:

504 to 2804 Hz: −0.1 to +1.6 dB

304 to 3004 Hz: −0.2 to +2.7 dB

If comparing with conditioning other than C2, use appropriate bandwidths for comparison.

B. Envelope Delay Distortion

6.03 The sectional EDD measurements should be added algebraically for each frequency.

Example:

ENVELOPE DELAY (MICROSECONDS)

FREQUENCY (HZ)	LINK A	LINK B	OVERALL
504	410	380	790
604	320	270	590
804	180	170	350
1004	130	100	230
1204	80	50	130
1404	40	20	60
1604	20	0	20
1804	0	-30	-30
2004	15	-10	+5
2204	30	5	35
2404	70	30	100
2504	110	70	180
2604	160	120	280
2704	220	180	400
2804	290	260	550

If the overall measurements must be compared to the C2 conditioning specification, perform the following steps:

The minimum envelope delay between 1004 and 2604 Hz = −30 μsec

The maximum envelope delay between 1004 and 2604 Hz = 280 μsec

The minimum envelope delay between 604 and 2604 Hz = −30 μsec

The maximum envelope delay between 604 and 2604 Hz = 590 μsec

The minimum envelope delay between 504 and 2804 Hz = −30 μsec

The maximum envelope delay between 504 and 2804 Hz = 790 μsec

The overall envelope delay distortion between 1004 and 2604 Hz = 280−(−30) = 310 μsec

The overall envelope delay distortion between 604 and 2604 Hz = 590−(−30) = 620 μsec

The overall envelope delay distortion between 504 and 2804 Hz = 790−(−30) = 820 μsec

If comparing with conditioning other than C2, use appropriate bandwidths for comparison.

C. C-Notched Noise and Single Frequency Interference

6.04 Combine the sectional measurements on a power basis using Table B (or on a voltage basis using Table C as required).

Example of C-Notched Noise Estimation:

Line A S/N = 28 dB

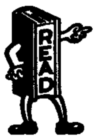
Line B S/N = 27 dB

Difference between quantities = 28 − 27 = 1 dB

From Table A combining term = 2.5 dB

Subtract combining term from the lower S/N figure: 27 dB − 2.5 = 24.5 dB

The overall S/N ratio (rounded off) is 25 dB.



If the C-notched noise measurement is dominated by third order harmonic distortion (commonly found on some short-haul carrier systems), then the tone measurements will add on a voltage basis and Table C should be used. An overall intermodulation distortion measurement is therefore recommended and should be made in conjunction with C-notched noise measurements.

D. Intermodulation Distortion

6.05 Combining intermodulation distortion measurements is not recommended.

E. Phase Jitter

6.06 Combine phase jitter measurements expressed in degrees using Table D.

Example:

Link A = 3°

Link B = 5°

From Table D the overall phase jitter would be expected to approximate 7°.

F. Impulse Noise

6.07 Use an impulse noise threshold setting of 71 dBrnc0 on each link or section. Algebraically add the number of impulses recorded in 15 minutes on each section to obtain the overall counts.

Example:

Link A = 5 counts

Link B = 2 counts

Overall = 7 counts

G. Frequency Shift

6.08 Add the frequency shift for each section algebraically. Note whether the shift for each link is + or − with respect to the source.

Example:

Link A = +1 Hz

Link B = −2 Hz

Overall = −1 Hz

7. GUIDELINES FOR INSTALLATION, ROUTINE, AND TROUBLE TESTING

7.01 The prioritized list of data parameters that may cause trouble is given in Table E. In addition, the table provides a list of what measurements should be made at circuit installation, on a routine basis, and during the investigation of a trouble report.

TABLE B

COMBINING POWERS

DIFFERENCE IN dB BETWEEN TWO QUANTITIES	COMBINING TERM IN dB	DIFFERENCE IN dB BETWEEN TWO QUANTITIES	COMBINING TERM IN dB	DIFFERENCE IN dB BETWEEN TWO QUANTITIES	COMBINING TERM IN dB
0—0.1	3.0	2.2—2.4	2.0	5.7—6.1	1.0
0.2—0.3	2.9	2.5—2.7	1.9	6.2—6.6	0.9
0.4—0.5	2.8	2.8—3.0	1.8	6.7—7.2	0.8
0.6—0.7	2.7	3.1—3.3	1.7	7.3—7.9	0.7
0.8—0.9	2.6	3.4—3.6	1.6	8.0—8.6	0.6
1.0—1.2	2.5	3.7—4.0	1.5	8.7—9.6	0.5
1.3—1.4	2.4	4.1—4.3	1.4	9.7—10.7	0.4
1.5—1.6	2.3	4.4—4.7	1.3	10.8—12.2	0.3
1.7—1.9	2.2	4.8—5.1	1.2	12.3—14.5	0.2
2.0—2.1	2.1	5.2—5.6	1.1	14.6—19.3	0.1
				19.4—Up	0

TABLE C

COMBINING VOLTAGES

DIFFERENCE IN dB BETWEEN TWO QUANTITIES	COMBINING TERM IN dB	DIFFERENCE IN dB BETWEEN TWO QUANTITIES	COMBINING TERM IN dB	DIFFERENCE IN dB BETWEEN TWO QUANTITIES	COMBINING TERM IN dB
0—0.1	6.0	4.6—4.7	4.0	11.5—11.9	2.0
0.2—0.3	5.9	4.8—5.0	3.9	12.0—12.5	1.9
0.4—0.5	5.8	5.1—5.3	3.8	12.6—13.0	1.8
0.6—0.7	5.7	5.4—5.6	3.7	13.1—13.5	1.7
0.8—0.9	5.6	5.7—5.9	3.6	13.6—14.1	1.6
1.0—1.1	5.5	6.0—6.2	3.5	14.2—14.8	1.5
1.2—1.3	5.4	6.3—6.5	3.4	14.9—15.4	1.4
1.4—1.6	5.3	6.6—6.8	3.3	15.5—16.1	1.3
1.7—1.8	5.2	6.9—7.1	3.2	16.2—16.9	1.2
1.9—2.0	5.1	7.2—7.4	3.1	17.0—17.8	1.1
2.1—2.2	5.0	7.5—7.7	3.0	17.9—18.7	1.0
2.3—2.5	4.9	7.8—8.1	2.9	18.8—19.7	0.9
2.6—2.7	4.8	8.2—8.5	2.8	19.8—20.9	0.8
2.8—2.9	4.7	8.6—8.9	2.7	21.0—22.2	0.7
3.0—3.2	4.6	9.0—9.3	2.6	22.3—23.6	0.6
3.3—3.4	4.5	9.4—9.7	2.5	23.7—25.4	0.5
3.5—3.7	4.4	9.8—10.1	2.4	25.5—27.6	0.4
3.8—3.9	4.3	10.2—10.5	2.3	27.7—30.7	0.3
4.0—4.2	4.2	10.6—11.0	2.2	30.8—35.1	0.2
4.3—4.5	4.1	11.1—11.4	2.1	35.2—44.9	0.1

TABLE D

COMBINING TWO PHASE JITTER MEASUREMENTS EXPRESSED IN DEGREES PEAK-TO-PEAK

LINK A

LINK B \ LINK A	1	2	3	4	5	6	7	8	9	10
1	2	3	4	4	5	6	7	8	9	10
2	3	3	4	5	6	7	8	9	10	11
3	4	4	5	6	7	8	9	10	11	12
4	4	5	6	7	8	8	9	10	11	12
5	5	6	7	8	8	9	10	11	12	13
6	6	7	8	8	9	10	11	12	13	14
7	7	8	9	9	10	11	12	13	13	14
8	8	9	10	10	11	12	13	13	14	15
9	9	10	11	11	12	13	13	14	15	16
10	10	11	12	12	13	14	14	15	16	17

7.02 During the investigation of a trouble report, the highest ranked parameter should be measured first. The exception to this rule is the P/AR measurement. If P/AR is found out of limits, the following tests should be performed:

(a) A complete attenuation distortion measurement

(b) Return loss

(c) Envelope delay distortion

(d) Intermodulation distortion.

7.03 By installation, it is meant those tests should be performed on a data channel as a result of a service order for new or additional service. Some companies have categorized these as preinstallation tests.

7.04 All switched private line data services shall be maintained in accordance with Table E.

TABLE E

RECOMMENDED ORDER OF TESTS TO BE PERFORMED DURING INSTALLATION, ROUTINE, AND TROUBLE REPORTS

RECOMMENDED ORDER OF TESTS	INSTALLATION	ROUTINE (SWITCHED)	TROUBLE REPORT
1. Continuity	*	*	*
2. Loss	*	*	*
3. "C" Notched Noise	*	*	*
4. Impulse Noise			*
5. Phase Jitter	(5)		*
6. Gain Slope (3 tone)	(6)	*	*
7. P/AR	(1) (7)		(1)
8. Attenuation Distortion (Complete)	(3)		*
9. Intermodulation Distortion	(2)		*
10. Hits, Dropouts			*
11. Return Loss	(4)	*	*
12. Single Freq. Interf.			*
13. Frequency Offset			*
14. Envelope Delay Dist	(3)		*

Notes:

1. If P/AR fails, skip immediately to measuring attenuation distortion, return loss, and envelope delay distortion.
2. Required on all "D" conditioned circuits.
3. Required on all "C" conditioned circuits.
4. Required on all data channels with 2/4-wire sections or 2-wire data terminals.
5. Two of three phase jitter measurements required (4-20, 20-300, or 4-300 Hz).
6. Required on all circuits that have access to the switched network if P/AR tests are not made.
7. Basic Channel (Voiceband) — P/AR may be used in place of attenuation distortion and EDD if done on overall basis for 2-point circuit and on end link, mid link basis for multipoint circuit. P/AR should be made on a loopback (benchwork) basis for "C" conditioned circuits after all tests have been made and all requirements met.

* Tests to be done.

7.05 Routine measurement of private line channels shall be made in accordance with Table E under Routine (Switched). An agreement should be made with the customer before the circuit may be taken out of service. Measurements of channel parameters on working circuits are currently under investigation.

8. PROBABLE SOURCES OF IDENTIFIED TRANSMISSION IMPAIRMENTS

8.01 Bell System personnel responsible for clearing impairments to voiceband analog data transmission services are being provided with more sophisticated testing tools which can identify specific transmission impairments. Many sophisticated customers who use Bell System facilities for data transmission have the ability to report specific transmission impairments. Table F is designed to assist in sectionalization and troubleshooting if the parameter (phase jitter, return loss, etc) causing the poor data performance is known. Transmission parameters which can affect data set performance are listed on the top of the matrix, and the various Western Electric Company facilities or equipment which could be used on the connection are shown on the left.

8.02 A probability is listed for each facility/equipment for each parameter where information is available. The probabilities assume that the circuit loss is correct, and they are abbreviated as h (high), m (medium), 1 (low), and a — (dash) to indicate no probability. A blank entry indicates insufficient data at this time to estimate a probability. In some instances, numbered notes indicate a known trouble condition, which, if present, would cause the probability to be medium or high. To a large extent, the probability associated with the note indicates the probability that the condition of the note will occur.

8.03 Properly selected and installed facilities, which are appropriate for a given type of data modem will not cause problems. Table F is to be used when something has gone wrong. The table can be used to minimize trouble location time for a given impairment by selecting the facility with the highest probability to be tested first or, conversely, by not testing facilities which could not cause the impairment (T-Carrier cannot produce phase modulation, for example).

8.04 It is ***not*** the function of this matrix to:

(a) List other than transmission impairments (ie, no signaling or echo suppressor characteristics which could affect data set start-up).

(b) Provide guidance on which parameters should be tested first.

(c) Provide a cross-reference between data set speed and transmission impairments.

(d) Provide installation testing strategies.

8.05 Subsequent issues of this table will be modified based on actual field experience with its use. Notes will be added as new failure modes are identified, and notes deleted as field modifications to eliminate trouble conditions are complete.

8.06 Several abbreviations defining impairments are used in Table F. They are as follows:

ABBREVIATION	DESCRIPTION
LEVEL vs. T	Level variation with time. Obvious level fluctuations observable on a standard level measuring set within 15 seconds observation.
LEVEL vs. L	Variations in circuit loss with the level of the input signal, such as level tracking and compandor tracking.
LEVEL vs. f	Level variations versus test tone frequency variation, such as attenuation distortion.
G-S (GAIN-SLOPE)	Level measurements made at 404 Hz, 1004 Hz, and 2804 Hz. A special case of LEVEL vs. f.
EDD	Envelope delay distortion.
RL	Return loss as measured with three standard bands of random noise.
P/AR	A complex pulse train is measured to produce a single number weighting (P/AR) of a facility for intersymbol interference, which is caused by the

simultaneous effects of envelope delay distortion, attenuation distortion, and poor return loss.

CN (C-NOTCH) C-Notch noise measured with a holding tone on the circuit.

NOISE SFI Single frequency interference is present if a single tone, other than a harmonic of a holding tone (if present), is the primary contributor to the measured noise.

JITTER

--Ø Phase jitter on a facility as measured with a 20- to 300-Hz bandwidth around a holding tone of 1 kHz.

lfØ Phase jitter in the band below 20 Hz around a 1 kHz holding tone.

fSh Frequency shift.

TRANSIENTS

Imp Impulse noise is large excursions on the received signal which are higher than the normal peaks of message circuit noise.

ØH Phase hits are changes in the nominal phase of the circuit which exceed a preselected threshold for at least 4 milliseconds.

GH Gain hits are changes in the nominal loss of the circuit which exceed a preselected threshold for at least 4 milliseconds.

Do A dropout is a negative gain hit of at least 12 dB.

TABLE F

PROBABLE SOURCES OF IDENTIFIED TRANSMISSION IMPAIRMENTS

FACILITY/EQUIPMENT	IMPAIRMENTS																			
	Level							Noise		Intermodulation		Jitter			Modulation		Transients			
	vsT	vsL	vsF	G-S	EDD	RL	PAR	CN	SF1	2nd	3rd	Φ	1fΦ	Amp	Φ	fSh	Imp	ΦH	GH	Do
LOOP PLANT																				
Cable with sealing current	—	—	m	m	m	m	l	l	l	—	—	—	—	—	—	—	m	—	—	—
Cable without sealing current	l	—	m	m	m	m	l	m[1]	l	—	—	—	—	—	—	—	m[1]	—	m[1]	h[1]
Data Aux. Sets 828.829	—	—	l[2]	l	l	l	l	l	l	l	l	—	—	—	—	—	l	—	—	—
Subscriber Loop Carrier																				
SLC™ 8	—	h[3]	m[4]	l	m[4]	l	l	l	l	m	l	—	—	—	—	—	l	—	l	—
SLC™ 40	l	m	l	l	l	l	l	h[12]	m	m	m	l	l	m	—	—	m	l	l	l[5]
SLC™ 96	m[6]	l	l	l	l	l	l	m	l	l	l	l	l	l	—	—	m	l	l	l[5]
TERMINATING EQUIPMENT																				
Repeaters																				
E6, E7	—	—	l[7]	l[7]	l	l[7]	l	l	l	l	l	—	—	—	—	—	l	—	—	—
44 V4	—	—	l	l	l	—	l	l	—	l	l	—	—	—	—	—	l	—	—	—
44 MFT	—	—	l	l	l	—	m	l	—	l	m	—	—	—	—	—	l	—	—	—
22, 24 V4*	—	—	l	l	l	l	l	l	—	l	l	—	—	—	—	—	l	—	—	—
22, 24 MFT*	—	—	l	l	l	l	l	l	—	l	m	—	—	—	—	—	l	—	—	—
Hybrid	—	—	m[8]	l[8]	m[8]	l[8]	m[8]	—	—	—	—	—	—	—	—	—	—	—	—	—
SF (260 Hz) SIGNALING*																				
E	—	l	l[9]	l[9]	l[9]	m[11]	l[9]	l	l	m[10]	m[10]	—	—	—	—	—	l	—	—	l
F	—	—	m[9]	l[9]	l[9]	—	l[9]	l	l	l	l	—	—	—	—	—	l	—	—	l
G	—	—	l[9]	l[9]	l[9]	—	l[9]	l	l	l	l	—	—	—	—	—	l	—	—	l
ANALOG CARRIER*																				
1ON	m	h[3]	h[19]	h[14]	m	—	m	h[14]	l	m	m	l	l	l	l	l	m	l	l	l
N1	m	h[3]	h[14]	h[14]	m	—	m	h[14]	m	h[15]	l	m	l	m	—	h[13]	l	l	l	
N2	m	h[3]	m	m	l	—	l	m	l	m	l	l	l	l	l	—	m	l	l	l
N3	m	h[3]	l	l	m	—	m	l[16]	m[17]	m	m	m[18]	m[18]	l	m[18]	m	m	m[18]	l	l
N4	l	h[3]	l	l	l	—	l	m	m[17]	m	l	l	l	l	l	m	l	l	l	l
Channel Banks																				
A4	l	l	m	l	l	l	l	l	l	l	l	m	m	l	l	l	l[19]	h[19]	l	l
A5	l	l	m[20]	l	l	l	l[20]	l	l	l[20]	l	l	m	l	l	l	l[19]	h[19]	l	l
A6/DFSG	l	l	m	l	l	l	l	l	l	l	l	l	l	l	l	l	m[19]	h[19]	l	l
LMX-MMX	l	l	m[4]	l	m[4]	—	l[4]	l[21]	m[22]	m[23]	m[23]	m[24]	m[24]	l	m[24]	m[30]	m[19]	m[24]	m[26]	m[26]
Microwave Radio	h[27]	m[27]	—	—	—	—	—	m[27]	m[27]	m[27]	m[27]	m[27]	—	—	—	—	h[28]	h[28]	h[28]	,[25]
LT-1	m[6]	l	l	l	l	—	l	m	m	l	l	l	l	l	m	l	m[29]	l	l	l[30]

TABLE F (Contd)

PROBABLE SOURCES OF IDENTIFIED TRANSMISSION IMPAIRMENTS

FACILITY/EQUIPMENT	IMPAIRMENTS																			
	Level							Noise		Intermodulation		Jitter		Modulation			Transients			
	γsT	vsL	vsF	G-S	EDD	RL	PAR	CN	SF1	2nd	3rd	Φ	1fΦ	Amp	Φ	fSh	Imp	ΦH	GH	Do
DIGITAL CARRIER*																				
D1A, D1B, D1C	m[6]	m	l	l	l	—	l	h[32]	m	h[31]	m	l	l	l	—	—	m[29]	l	l	l[5]
D1D, hardened	m[6]	l	l	l	l	—	l	m	l	l	l	l	l	l	—	—	m[29]	l	l	l[5]
D2	h[6]	m	l	l	l	—	l	m	l	l	l	l	l	l	—	—	m[29]	l	l	l[5]
D3, D4	m[6]	l	l	l	l	—	l	m	l	l	l	l	l	l	—	—	m[29]	l	l	l[5]
PBX																				
SXS 701	—	—	—	—	—	—	—	h[34]	—	—	—	—	—	—	—	—	h[34]	—	—	—
DIMENSION® 100or 400	—	—	m	l	l	l	l	l[36]	l	l	l	l	—	l	l	—	l	—	—	l
" 2000 or Custom	m[35]	—	m	l	l	l	l	l[36]	l	l	l	l	m[35]	l	l	—	l	—	—	l
HORIZON®	—	l	m	l	l	l	l	l	—	l	l	l	—	—	—	l	l	—	—	—
ECHO SUPPRESSORS																				
Analog 3A, 4A	—	—	—	—	—	—	—	l	—	l	l	—	—	—	—	—	—	—	—	l[37]
Digital	—	—	—	—	—	—	—	l	—	l	l	—	—	—	—	—	—	—	—	l[37]
TASI*																				
A	m[6]	m[38]	l[38]	l[38]	m[38]	—	m	m[38]	m	m	m	—	—	—	—	—	h[33]	l	m	m
B	l[39]	l[38]	l[38]	l[38]	l[38]	—	l	h[38]	m	m	m	—	—	—	—	—	m	l	l	l
E	m[6]	l[38]	l[38]	l[38]	l[38]	—	l	m[41]		m	m	l	l	l	—	—	m[28]	l	l	l[5]
SATELLITE																				
COMSTAR	l	l	l	l	m[40]	m[40]	m	l	l	l	l	l[24]	l[24]	l	l[24]	m	l	m	m	m
HYBRID	—	—	m	l	m	l	m	—	—	—	—	—	—	—	—	—	—	—	—	—
SWITCHING EQUIPMENT																				
SXS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	h[42]	—	l[42]	l[42]
Crossbar	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	m	—	—	—
1ESS, 2-Wire	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	l	—	—	—
1ESS, 4W HiLo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	m[44]	—	—	—
2ESS, 3ESS, 4ESS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	l	—	—	—
4ESS with VIU's	m[6]	l	l	l	l	l	l	m		l	l	l	l	l	—	—	l	l[43]	l	l[5]

LEGEND

Probabilities h= high m = medium l = low — = no

TABLE F (Contd)

PROBABLE SOURCES OF IDENTIFIED TRANSMISSION IMPAIRMENTS

NOTES

* See also the Hybrid row for 2-4 wire conversion.

1. Oxidized cable splices, half of which can be fixed with the application of sealing current. See EL 4504, 3/17/76.
2. Misadjusted equalizers on installation.
3. Syllabic compandors.
4. Edge channels only.
5. 25 to 50 msec dropout on reframing; lightning, for example.
6. Will exhibit level fluctuations at test frequencies which are integral submultiplex of the 8000 Hz sampling rate.
7. Equalizers not properly adjusted at installation.
8. Precision balance networks improperly set on installation.
9. 2600 Hz band rejection notch improperly impressed on channel after cut-through.
10. E-type SF signaling units typically do not meet D-1 intermodulation distortion requirements.
11. If the condition of Note 9 occurs for E-type SF units, the return loss is poor even in the 4-wire case.
12. Adaptive delta modulation gives poor (25 dB) S/N ratio for data signals with high frequency components.
13. If engineerred for the earlier longer span between repeaters.
14. Aging of vacuum tubes. Tubes should be replaced with hybrid integrated networks (HINs).
15. Facility immediate action limits are only R2 = 26 dB, R3 = 30 dB.
16. If the N3 Compandor Applique for operator service trunks is applied to long haul facilties.
17. 4000 Hz carrier.
18. Faulty Frequency Corrector Unit as described in EL 2497, 8/9/73.
19. Switching transient effects in adjacent channels of LMX-2.
20. Ferrte slug in the 561K filter comes unglued, causing loss bumps, or channel banks in the A5 Channel Bank Reuse Program.
21. When LMX channels 6 and 7 are used for program, the Program Blocking Filter roll-off is not sufficient to stop interference in channels 5 and 8.
22. Intermodulation products from hot tones in other channels.
23. On some LMX-2 channels.
24. LMX-1 Primary Frequency Converter with 4 kHz and 128 kHz feeds from different Primary Frequency Supplies or low frequency variations in power feeds to LMX or MMX bays.
25. 30 msec dropout due to protection switch on microwave facility caused by instantaneous loss of signal rather than fading.
26. 228D, 231D or 231E amplifiers sensitive to battery voltage transients.
27. During periods of fading on the microwave links.
28. Protection switching on microwave channels.
29. Strikes on a T-Carrier link.
30. Loss of synchronization by the PFS2-Type Primary Frequency Supply.
31. High intermodulation distortion caused by high level signals in adjacent channels.
32. Immediate action limit for S/N is only 24 dB.
33. Needs routining for adjacent channel crosstalk.
34. The 701 PBX requires special grounding, quiet battery and shielded wire to control noise and impulse noise.
35. Clock differences between modules cause beating (3 Hz maximum rate) when single tones are used for testing, rising from 0.1 dB at 1 kHz to 1 dB at 3.2 kHz.
36. Two or more trunks terminated withthe LC11 and LC11B vintage 1 circuit packs can have high crosstalk.
37. Occasionally, high impulse noise or high longitudinal noise causes false suppressor operation.
38. TASI is energy-actuated, so test tones must be continuous.
39. Will exhibit level fluctuations at test tones which are integral submultiples of the 10 kHz sampling frequency.
40. Long 300 msec echo delays aggravate hybrid unbalance problems.
41. Noise matching circuits may put on noise when disconnected which matches noise level of power line hum when connected.
42. Mechanical shaking of SXS switch due to release of adjacent SXS switches. See EL 4205, 1/16/76.
43. Phase hits occurring at periodic intervals as a result of clock slippage between 4ESS and downstream T-Carriers.
44. 3-wire equivalent of 4-wire circuit: crosstalk spikes caused by False Cross and Ground Checks.