VOICE BANDWIDTH PRIVATE LINE DATA CIRCUITS

TESTS AND REQUIREMENTS

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1. **GENERAL**

1.01 This section describes the routine, circuit order, and maintenance test requirements for voice bandwidth channels used for private line data service. This service includes telemetry, alternate voice/data, 2-point, multipoint, and certain switching arrangements.

1.02 This section is reissued to provide additional information on the various transmission tests.

The descriptive and maintenance information previously contained in this section have been moved to Sections 314-410-100 and 314-410-300, respectively. In addition, information previously contained in Appendixes A, B, and C has been moved to Sections 314-410-101, 314-410-102, and 314-410-103, respectively. Since this reissue is a general revision of the section, arrows ordinarily used to denote changes have been omitted.

1.03 This issue affects Equipment Test Lists.

1.04 Form E-5596, Data Transmission History Card, is available for recording the results of initial, routine, and "as required" measurements. The form is a 5- by 8-inch card printed on buff cardstock. It should always be attached to the circuit layout record card (CLRC) for reference in testing and maintenance. A sample copy of this form is described in Section 314-410-300.

1.05 The circuit control office should record the circuit order, trouble, and routine test results on Form E-5596. On multipoint circuits, the office responsible for an end link and/or a middle link should record the circuit test results on this form. This form should also be used to record loop-back test results from the serving test center (STC) to a customer station. In addition, noncontrol offices may keep similar records. However, the STC should keep records for the portion of the circuit it maintains. More than one Form E-5596 may be kept with the CLRC if an office is responsible for more than one portion of the circuit.

1.06 The tests to be performed are listed in Section 314-410-300.

2. **TESTING APPARATUS**

2.01 Accurate measurements require good test equipment. All equipment should be checked prior to use to ensure that it is working and is calibrated properly. Ample warmup time is also important for stable operation of the test equipment.

2.02 Table A provides a partial listing of test sets which may be used. A detailed listing of test equipment is provided in the booklet "Bell System Transmission Test Equipment—Performance Evaluation". Copies of this booklet are furnished to the General Trade Products representative for each operating company.

TABLE A

TEST EQUIPMENT LIST

FUNCTION	TEST SETS
1000-Hz Loss and Attenuation Distortion*	• Halcyon 515A Data Line Test Set • Hewlett-Packard 3550B Portable Test Set • Hewlett-Packard 4940A Transmission Impairment Measuring Set • KS-20805 Transmission and Noise Measuring Set † • Northeast Electronics Transmission Test Set 4B-NH, or 4B-NH-N, or 15B, or 35B • Telecommunication Technology, Inc. 1103A or 1103B Digital Transmission Test Set • Telecommunication Technology, Inc. 1105 Level/Noise Digital Test Set † • WECo 21A Transmission Measuring Set
Sine Wave Oscillators	• Halcyon 515A Data Line Test Set • Hewlett-Packard 3550B Portable Test Set • Hewlett-Packard 4940A Transmission Impairment Measuring Set • KS-19260-L1, KS-19353-L1, or KS-19353-L4 Oscillator • Northeast Electronics Transmission Test Set 4B-NH, or 4B-NH-N, or 15B‡, or 35B • Telecommunication Technology, Inc. 1103A‡ or 1103B Digital Transmission Test Set • WECo 21A-L2 Transmission Measuring Set‡ • WECo 25B Voiceband Gain and Delay Set‡
Envelope Delay*	• Halcyon 515A Data Line Test Set • Hewlett-Packard 4940A Transmission Impairment Measuring Set • WECo 25B Voiceband Gain and Delay Set
P/AR	• Hewlett-Packard 4940A Transmission Impairment Measuring Set
C-Message Noise*	• Hewlett-Packard 3555B Transmission and Noise Measuring Set • Hewlett-Packard 4940A Transmission Impairment Measuring Set • KS-20805 Transmission and Noise Measuring Set • Northeast Electronics TTS 4B-NH-N • Telecommunications Technology, Inc. 1105 Level/Noise Digital Test Set • WECo 3A, 3B, or 3C Noise Measuring Set
C-Notched Noise*	• Hewlett-Packard 4940A Transmission Impairment Measuring Set • Telecommunications Technology, Inc. 1105 Level/Noise Digital Test Set • WECo 6F or 6FR Voiceband Noise Measuring Set§
Impulse Noise*	• Hewlett-Packard 4940A Transmission Impairment Measuring Set • WECo 6F or 6FR Voiceband Noise Measuring Set • WECo 6H or 6HR Impulse Counter
Harmonic Distortion*, ¶ & Single Frequency Int.**	• General Radio 1568-A Wave Analyzer • Hewlett-Packard 302A Wave Analyzer • WECo 4A Frequency Analyzer
Frequency Shift*	• Halcyon 515A Data Line Test Set • Hewlett-Packard 4940A Transmission Impairment Measuring Set • KS-20805 Transmission and Noise Measuring Set • Wandel-Goltermann FVM-1 Frequency Shift Meter • WECo 72A Frequency Meter

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TABLE A (Cont)

FUNCTION	TEST SETS
Phase Jitter*	• Bradley Associates Corp. Tone Lock Phase Jitter Test Set Model 75LM • Hekimian Laboratories, Inc. Model 48 or 56 Phase Jitter Set • Hewlett-Packard 4940A Transmission Impairment Measuring Set • Telecommunications Technology, Inc. 1200 Phase Jitter Test Set (Use only with SELECT switch in P-P FLT IN position)
Nonlinear Distortion	• Hekimian Laboratories, Inc. Model 65 Linearity Analyzer • Hewlett-Packard 4940A Transmission Impairment Measuring Set
Singing Margin/ Return Loss	• KS-20501 Return Loss Measuring Set • WECo 2D or 2E Singing Point Test Set • Wiltron Model 9031 Return Loss Measuring Set
Total Power * Output	• Hewlett-Packard 3555B Transmission and Noise Measuring Set • Hewlett-Packard 4940A Transmission Impairment Measuring Set • Northeast Electronics TTS 4B-NH-N • Telecommunications Technology, Inc. 1105 Level/Noise Digital Test Set • WECO 3A, 3B, or 3C Noise Measuring Set
DC Loop Resistance	• KS-14510 Volt-Ohm-Milliammeter

*   These tests may also be performed by the Collins CLA-101A System and Test Signal Generator (TSG).

†   Requires a separate sine wave oscillator.

‡   Measure harmonic content of oscillator before using this oscillator as a tone source for harmonic distortion measurements.

¶   Harmonic distortion measurements will be discontinued after nonlinear distortion test sets become more commonly available.

§   This set is intended primarily for impulse noise measurements and does not meet certain recent Bell System measurement standards for C-notched noise measurements. It may be used for C-notched noise measurements if other test sets are not available.

**   A listening test is normally sufficient for the detection of single tone interference and specialized test equipment is seldom required. The test set listed here may be used for those few cases where specialized test equipment may be required.

2.03 The application of dc voltage to the input circuit of some test equipment, such as the 21A transmission measuring set (TMS), may cause permanent damage or affect the accuracy of the instrument. To prevent accidental exposure of dc voltage to the TMS, a voltage measurement, using a suitable dc voltmeter should first be made across the line pair. If the reading is 1 volt dc or greater, an isolation (holding) coil arrangement must be used.

2.04 In addition to the dc restriction, the input resistance network and coil of the 21A TMS are not designed to provide a holding bridge. When a dialed connection must be held to transfer to the TMS, a typical holding circuit such as SD-96540-01, or a 2AB auxiliary transmission test set should be used.

2.05 All transmission measurements, unless otherwise stated, are to be made between balanced (not one side grounded) 600-ohm resistive terminations. If unbalanced test equipment is used, it may be necessary to use an isolation transformer with the proper impedance between the line being tested and the test equipment. As an example, most oscilloscopes have an unbalanced input. If an isolation transformer is not available, a 3A noise measuring set can be used to isolate a line from unbalanced and/or non-600-ohm equipment. The 3A NMS can be connected to the line either on a terminated or bridged basis as appropriate.

3. TRANSMISSION REQUIREMENTS AND TEST METHODS

A. General

3.01 The transmission requirements given in this part may be divided into two categories, circuit limits and facility limits. Circuit limits are generally specified for overall, end links, and midlinks. The end link and midlink limits given here and elsewhere in this section apply only to multipoint circuits. Facility limits are specified on a per-channel basis. The overall circuit limits must be met in all cases. The facility limits are intended as a trouble isolation guide and may be disregarded as long as the overall circuit limits are met.

3.02 All test tone frequencies should be offset slightly from multiples of 100 Hz (such as 1200 Hz) in order to avoid possible measurement errors over D-type channels (used in T carrier). For this reason this section will generally indicate an offset of 4 Hz in the test tone frequency to be applied (for example 2804 Hz) to the circuit under test.

Test Level

3.03 Accurate measurement of the transmission characteristics of voiceband data circuits depends upon knowledge of the correct test levels to be transmitted and received. The power of the test signal with respect to the transmission level point (TLP) at which it is applied will have a major influence on the test results obtained.

3.04 The circuit layout record cards (CLRC) issued by the companies may indicate the expected 1000-Hz loss of the circuit between various test access points in either or both of two ways:

(a) By the designation of the TLP

(b) By the designation of the data level (data modem power).

It will be necessary to know which method is used before making measurements. Generally the CLRC will indicate whether TLP or data level is being specified. If not, note the level specified at either the data set transmitter or the MOD IN jack of a 4-wire carrier channel. If the level at the data set transmitter is given as +12 dB or +13 dB, the CLRC is probably written in terms of TLP. If the level at the data set transmitter is given as 0 dBm, it is likely that the CLRC is written in terms of data level. In this case, or if other than the above values are given, note the level at the MOD IN jack of a 4-wire carrier channel as follows:

- If the level is given as −16 dB, the CLRC is written in terms of TLP.

- If the level is given as −28 dB or −29 dB, the CLRC is written in terms of data level.

3.05 If it is still not possible to determine whether the CLRC is written in terms of TLP or data level, the engineer responsible for the CLRC should be notified.

All transmission measurements are to be made at data level. The data level for all new data circuits is a power 13 dB below the TLP at the point where tests are being made. For example, at a − 16 TLP the data level would be − 29 dBm. A test power of − 29 dBm would be applied here. This level of − 13 dBm0 is a change from − 12 dBm0, which is why two numbers are given in 3.04. An earlier standard was − 8 dBm0. All references to data level or test levels in this section will specify − 13 dBm0 (13 dB below 0 TLP). However, if a design of − 8 dBm0 has been used in the circuit under test and not been changed to either − 12 dBm0 or − 13 dBm0, the appropriate design organization should be notified. A test level of − 8 dBm0 will be required until design changes can be made. Circuits using a − 12 dBm0 design should be tested with a − 12 dBm0 test level.

B. Categories of Transmission Parameters

3.06 Following the requirements for each of the transmission parameters beginning in 3.07, an example is given using the test points for a 4-wire data set circuit at the customer station and a serving test center. The results given in the example are recorded on a sample Form E-5596 as shown in Fig. 1.

1000-Hz Loss Deviation

3.07 The overall 1000-Hz loss requirements of a circuit depend upon the application of the channel being used. There should normally be 16 dB of loss between any data sets or between 4-wire telephone sets. There should normally be only 10 dB of loss between 2-wire telephone sets. The 2-wire telephone set hybrids add in the additional 6 dB of loss. The CLRC should be consulted before making level adjustments, since special circumstances may require nonstandard loss design.

3.08 The 1000-Hz loss of PBX tie trunks should be specified on the CLRC in terms of expected measured loss (EML). In the event that the EML is not specified, a loss requirement of no more than 8.5 dB should be met. Section 311-100-501 should be referred to when making transmission measurements on PBX tie trunks.

3.09 It will be necessary to test circuits with D1 channels at some frequency near 1000 Hz (perhaps 1004 or 1020 Hz) rather than at 1000 Hz, because level variations caused by the 8000-Hz sampling rate will be as large as ±0.25 dB.

3.10 Table B includes the maximum loss deviation requirements for all private line circuits. All loss measurements should be made and adjusted within requirements before any other transmission parameters are measured. This is necessary because many of the other transmission parameters are level sensitive. *Loss measurements must be made at data level (− 13 dBm0).*

TABLE B

1000-HZ LOSS DEVIATION

MAXIMUM DEVIATION FROM EML STATED ON CIRCUIT LAYOUT RECORD CARD

	CIRCUIT ORDER	ROUTINE OR TROUBLE ISOLATION
END LINK	±0.5 dB	±2.0 dB
MIDDLE LINK	±0.5 dB	±1.0 dB
OVERALL (STA-STA)	±1.0 dB	±4.0 dB
LOOP-BACK (STC-STA-STC)	±0.8 dB	±2.0 dB

STA A TO STA B

314-410-500
CIRCUIT NUMBER FDA 65072 DATA TRANSMISSION HISTORY CARD TR=A-B   LINK (2) REC=B-A   E-5596 PRINTED IN U.S.A.

		TR (INITIAL)		REC (INITIAL)		TR		REC		TR		REC	
TEST DATE		10-1-71				12-1-71							
CKT. ORDER NO. (4) AB 12345-01		DELAY	GAIN FREQ	DELAY	GAIN FREQ	DELAY	GAIN FREQ	DELAY	GAIN FREQ	DELAY	GAIN FREQ	DELAY	GAIN FREQ
300		✕	+1.1	✕		✕		✕		✕		✕	
500		525	+.2										
600		275	-.1										
800		180	-.1										
1000		180	0										
1200		88	-.4										
1400		26	-.2										
1600		10	-.1										
1800		0	0										
2000		-15	0										
2200		-35	+.1										
2400		-10	+.2										
2500													
2600		15	+.4										
2700													
2800		65	+1.1										
3000			+2.1										
3200		✕		✕		✕		✕		✕		✕	
FREQ. SHIFT HZ	HZ	0											
PHASE JITTER	DEGREES	6° LMX											
SINGLE-FREQ-INT.	DBRNCO	36.5											
HARMONIC DIST. (2ND/3RD) DB		27/31											
C-NOTCHED NOISE	DBRNC	22 TABLE J											
RETURN LOSS - SP	DB	26											
DC LOOP RESISTANCE	OHMS	675		700									

A-Form E-5596 (Front)

ROUTINE MEASUREMENTS

CIRCUIT NUMBER	FDA 65072						LINK				
	TOTAL POWER		1000 HZ LOSS		NOISE		IMPULSE NOISE		P/AR	
TEST DATE	DBM0		DEVIATION		DBRNCO		COUNTS/15 MIN			REC
	TR	REC	TR	REC	TR	REC	TR	REC	TR	REC
INITIAL MSMNTS	10		-0.2		34		7		99	

B-Form E-5596 (Back)   TPA 570151

Fig. 1—Sample of Data Transmission History Card—Form E-5596

3.11 Circuits to which CPMs are connected may be equipped with power limiters either at a customer station or in a central office. It is important to verify that these devices are not limiting the test signal level since this may seriously affect the test results. The following test procedure should be performed to verify that the test signals will not be improperly limited:

STEP	PROCEDURE
1	At the customer station, connect an oscillator to the input of the circuit under test. The oscillator should be adjusted to transmit 1004 Hz at data level and at an impedance of 600 ohms.
2	At a point on the circuit, (after the limiter under test), measure and record the received tone level.
3	At the customer station, increase the tone level by 1 dB. Measure and record this received tone level.
4	Note the difference between the two received tone levels. Continue to raise the oscillator output in 1-dB steps and note at which point an increase of 1 dB in the transmitted tone power results in an increase of 0.5 dB or less of received power. This is the limiting point. Once this point is reached, note the number of dB the tone level was increased above data level before limiting action took place. It will not be necessary to raise the test tone level more than 4 dB above data level. *Observe the received level for at least 10 seconds to allow the effect of the limiter action to take place.*
	Note: If limiting action took place when the oscillator was adjusted 1 dB above data level, decrease the oscillator output by 1 dB and note whether limiting action no longer occurs (a 1 dB change in receive level is observed when the transmit level is changed by 1 dB).

3.12 The points at which limiting action may occur depend upon the location of the limiter. If the limiter is at the customer station, limiting action should not occur until the oscillator output is 0.5 dB above data level. Limiters at customer stations are adjusted to limit any signal greater than − *12.5 dBm0.*

3.13 If the limiter is at the central office, limiting action should not occur until the oscillator output is at least 3 dB or more above data level. Limiters at the central office are adjusted to limit at − *10 dBm0* in order to take into account the possibility of loss variations between the customer station and the central office. Readjust the limiter according to the appropriate section (332-104-503 or 598-080-500) if the limiter acts on a power lower than that indicated above.

3.14 *Example of Test:* An oscillator is connected at a customer station in place of a data set transmitter (+13 TLP). A transmission level meter is placed at the distant customer station in place of the data set receiver (−3 TLP). The limiter is at the central office. The following readings were recorded:

OSC OUTPUT (+13 TLP) (dBm)	RECEIVED LEVEL (−3 TLP) (dBm)
0.0	−15.8
+1.0	−14.8
+2.0	−13.8
+3.0	−12.8
+4.0	−12.4 (limiting point)

As shown, the limiting point was 4 dB above data level. This is more than 3 dB above data level so that transmission tests can safely be made at data level on this circuit without limiting action. The loss deviation at data level in the above example is −0.2 dB. The correct data level at a −3 TLP would be −16.0 dBm. Enter the −0.2 dB loss deviation value on Form E-5596 as shown in Fig. 1.

Attenuation Distortion (Frequency Response)

3.15 The attenuation (gain-frequency) distortion and envelope delay distortion requirements given for C-conditioned channels are tariff requirements and must be met even though meeting those requirements may not be essential to the service provided.

Circuit order measurements of attenuation distortion and envelope delay distortion are made at the customer station location using the measurement frequencies given in Table C. The practice of making loop-back measurements and dividing the results by two is not valid, since significant differences may exist in each direction of transmission.

In the case of circuit rearrangements, straight-away tests to the customer may not be necessary if attenuation distortion and delay distortion measurements are taken in a loop-back condition to the customer station before and after the rearrangements are made and little change is noted in the measurement results. If the loop-back is without an amplifier which can properly terminate the receive loop and provide for the correct transmitter impedance, then large errors in impedance termination can occur. The loop-back provided by DAS 828A *will not* create termination errors.

3.16 If a protective arrangement is required, all transmission measurements from the station must be made through the protective arrangement and overall requirements should be met in the appropriate direction of transmission. The equalizers specified by the circuit design engineer are intended to compensate for the attenuation distortion and envelope delay distortion introduced by the protective arrangement as well as the line facilities.

3.17 Attenuation distortion requirements are given in Table D. Figure 2 illustrates the attenuation distortion requirements of a 2-point C2 conditioned channel. Measurements falling within the outlined area are considered as meeting requirements. Measurements falling outside the outlined area are out of limits. The attenuation distortion of a circuit may be measured and adjusted at the same time that the 1000-Hz loss measurements are made. The distortion is stated in terms of the loss at a particular frequency referenced to the loss at 1000 Hz. The convention used is + for more loss and − for less loss. The attenuation distortion should be brought within limits before envelope delay distortion is measured, since adjustment of the attenuation distortion equalizers may have considerable effect on the envelope delay distortion.
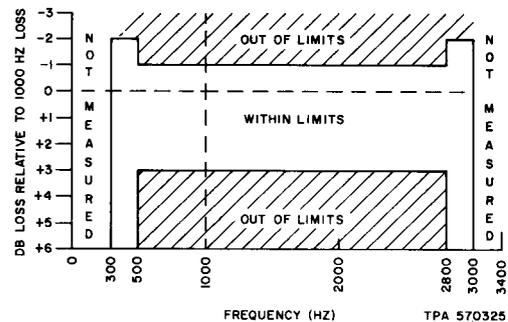
Fig. 2—Graphical Representation of 2-Point C2 Attenuation Distortion Requirements

3.18 Attenuation distortion is usually corrected by means of 359-type equalizers. A number of codes are available for use with various types of cable plant. The 359A, D, G, H, K, L, and P equalizers are adjustable and may be used to correct for slope or for excessive gain at the low end of the band or excessive loss at the high end of the band. The 950A amplitude equalizer can be used to equalize the amplitude characteristics of the interexchange facility as well as mopping up any residual amplitude distortion of the loop.

TABLE C

MEASUREMENT FREQUENCIES

FREQUENCY (Hz)	BASIC CHANNELS		CONDITIONING					
			C-1		C-2 & C-5		C-4	
	FREQ. RESP.	ENV. DELAY	FREQ. RESP.	ENV. DELAY	FREQ. RESP.	ENV. DELAY	FREQ. RESP.	ENV. DELAY
304	X		X		X		X	
504	X		X		X	X	X	X
604	X		X		X	X	X	X
804	X	X	X	X	X	X	X	X
1004	X	X	X	X	X	X	X	X
1204	X	X	X	X	X	X	X	X
1404	X	X	X	X	X	X	X	X
1604	X	X	X	X	X	X	X	X
1804	X	X	X	X	X	X	X	X
2004	X	X	X	X	X	X	X	X
2204	X	X	X	X	X	X	X	X
2404	X	X	X	X	X	X	X	X
2504	X	X	X	X	X	X	X	X
2604*	X	X	X	X	X	X	X	X
2704†	X		X		X	X	X	X
2804	X		X		X	X	X	X
3004	X		X		X		X	X
3204							X	

Make frequency response and/or envelope delay-distortion runs at the frequencies indicated for each type of data channel. The limits are found under each configuration.

* Do not measure at this **frequency** if 2600-Hz signaling units are used in the layout. Instead interpolate from the values measured at 2504 and 2704 Hz.

† Tone-operated loop-back devices (such as the 44A1 data unit) must be disabled.

TABLE D

PRIVATE LINE VOICE BANDWIDTH CIRCUIT ATTENUATION DISTORTION REQUIREMENTS (dB)

FREQUENCY RANGE IN HZ	2-POINT	0 MID LINK / END LINK	1 MID LINK — END LINK	1 MID LINK	2 MID LINKS — END LINK	2 MID LINK	3 MID LINKS — END LINK	3 MID LINK	4 MID LINKS — END LINK	4 MID LINK
3002 (ALSO 2001)										
BASIC	(VB)	(VBE0)	(VBE1)	(VBM1)	(VBE2)	(VBM2)	(VBE3)	(VBM3)	(VBE4)	(VBM4)
500-2500	−2 to +8	−1.5 to +4	−1 to +4	−1 to +3.5	−1 to +4	−1 to +3.5	−1 to +3.5	−0.8 to +3.5	−0.8 to +3.5	−0.8 to +3
300-3000	−3 to +12	−1.5 to +6	−1.5 to +6	−1.5 to +6	−1.5 to +6	−1.5 to +5	−1.5 to +5	−1 to +4.5	−1.5 to +4.5	−1 to +4.5
C1	(C1)	(C1E0)	(C1E1)	(C1M1)	(C1E2)	(C1M2)	(C1E3)	(C1M3)	(C1E4)	(C1M4)
1000-2400	−1 to +3	−0.7 to +1.5	−0.6 to +1.5	−0.5 to +1.5	−0.5 to +1.5	−0.5 to +1.5	−0.5 to +1.5	−0.5 to +1	−0.5 to +1.5	−0.5 to +1.5
300-2700	−2 to +6	−1.5 to +3	−1 to +3	−1 to +3	−1 to +3	−1 to +2.5	−1 to +3	−0.8 to +2	−0.8 to +3	−0.8 to +2
2700-3000	−3 to +12	−1.5 to +6	−1.5 to +6	−1.5 to +6	−1.5 to +6	−1.5 to +5	−1.5 to +5	−1 to +4.5	−1.5 to +4.5	−1 to +4.5
C2	(C2)	(C2E0)	(C2E1)	(C2M1)	(C2E2)	(C2M2)	(C2E3)	(C2M3)	(C2E4)	(C2M4)
500-2800	−1 to +3	−0.7 to +1.5	−0.6 to +1.5	−0.5 to +1.5	−0.5 to +1.5	−0.5 to +1.5	−0.5 to +1.5	−0.5 to +1	−0.5 to +1.5	−0.5 to +1
300-3000	−2 to +6	−1.5 to +3	−1 to +3	−1 to +3	−1 to +3	−1 to +2.5	−1 to +3	−0.8 to +2	−0.8 to +3	−0.8 to +2
C4	(C4)									
500-3000	−2 to +3									
300-3200	−2 to +6									
C5	(C5)									
500-2800	−0.5 to +1.5									
300-3000	−1 to +3									

Classification Codes — Examples

VB E 3
- Basic Conditioning
- End Link
- No. of Middle Links

C2 M 2
- C2 Conditioning
- End Link
- No. of Middle Links

( ) Figures in parentheses are classification codes which may be found on some CLRCs to indicate the conditioning requirement for each link of the circuit.

+ means loss with respect to 1004 Hz.

− means gain with respect to 1004 Hz.

Note: Requirements using the Collins CLA-101A system are given in Section 314-410-104.

3.19 Information on the attenuation distortion characteristics of the 359-type equalizers is given in the 332-116-ZZZ series of Bell System Practices. Some information on the adjustment of these equalizers is given in Part 8 of Section 332-104-500 and in Section 314-016-125. Descriptive information on the 950A amplitude equalizer is given in Section 314-820-107.

3.20 The attenuation distortion equalizers on multipoint circuits should be adjusted to give the best frequency response within limits. This is necessary because it is possible on multipoint circuits to meet the attenuation distortion limits on any individual link but not meet the end-to-end limits. Since the control office is responsible to the customer for end-to-end limits, adjustment of the equalizers to obtain the best frequency response initially may eliminate the need to reequalize multipoint circuits later.

3.21 In some instances it may not be possible to meet the attenuation distortion requirements with the specified equalizers. Two possible sources of poor high frequency response are bridge taps on the local channel cable pair or the use of older N2 carrier channel units with LC channel bandpass filters. The gain of N2 carrier channels at 3 kHz should not be more than 3 dB below the gain at 1 kHz. If the channel does not meet these limits, a channel unit with *crystal* filters may be needed. N2 modems with LC filters are coded J99272F; with crystal filters, J99272BF. Additional information on these channels is available in Sections 362-806-100 and 362-801-501.

3.22 If a D1 channel bank (used on T1 carrier) is used, verify that 4019 BD transmitting gates and filters are used. The older filters have a poorer high frequency response and should not be used if the attenuation distortion requirements cannot be met. The older filter can be used as long as requirements are met.

3.23 If attenuation distortion requirements cannot be met and the problem cannot be isolated, engineering assistance should be requested. A record of measurements made should be kept to aid engineering in arriving at a solution.

Delay Distortion

3.24 Delay distortion requirements are given in Table E. The delay distortion of a circuit should be measured only after the attenuation distortion of the circuit has been brought within limits. The delay equalizers should be specified on the CLRC and are usually of the nonadjustable variety with three major exceptions, the 385A-, 385B- and 950B-types. The specified equalizers will normally be adequate to meet delay distortion requirements.

Note: If changes are required in the equalizers, it will be necessary to recheck the 1000-Hz loss and the attenuation distortion since changes in the specified delay equalizers will have some effect on these parameters. Changes may be made in the step settings of the 385A and 385B equalizers without rechecking the attenuation distortion.

Circuit order measurements of attenuation distortion and envelope delay distortion are made at the customer station location using the measurement frequencies given in Table C. The practice of making loop-back measurements and dividing the results by two is not valid, since significant differences may exist in each direction of transmission.

In the case of circuit rearrangements, straight-away tests to the customer may not be necessary if attenuation distortion and delay distortion measurements are taken in a loop-back condition to the customer station before and after the rearrangements are made and little change is noted in the measurement results. If the loop-back is without an amplifier which can properly terminate the receive loop and provide for the correct transmitter impedance, then large errors in impedance termination can occur. The loop-back provided by DAS 828A *will not* create termination errors.

3.25 Information on the 384- and 385-type delay equalizers may be found in Section 314-820-104. Information on the 200-type delay equalizers may be found in Section 314-820-100. Information on the 950-type equalizer may be found in Section 314-820-107.

3.26 In the event that delay distortion requirements cannot be met using the equalizers specified, refer the problem to circuit engineering. Engineering personnel should be able to specify the required equalizers which will bring the circuit within limits.

TABLE E

PRIVATE LINE VOICE BANDWIDTH CIRCUIT ENVELOPE DELAY REQUIREMENTS (MICROSECONDS)

FREQUENCY RANGE IN HZ	2-POINT	0 MID LINK	1 MID LINK		2 MID LINKS		3 MID LINKS		4 MID LINKS	
		END LINK	END LINK	MID LINK	END LINK	MID LINK	END LINK	MID LINK	END LINK	MID LINK
3002 (ALSO 2001)										
BASIC	(VB)	(VBE0)	(VBE1)	(VBM1)	(VBE2)	(VBM2)	(VBE3)	(VBM3)	(VBE4)	(VBM4)
800-2600	1750	960	685	550	550	400	400	375	375	275
C1	(C1)	(C1E0)	(C1E1)	(C1M1)	(C1E2)	(C1M2)	(C1E3)	(C1M3)	(C1E4)	(C1M4)
1000-2400	1000	550	400	300	300	250	250	200	200	175
800-2600	1750	960	685	550	550	400	400	375	375	275
C2	(C2)	(C2E0)	(C2E1)	(C2M1)	(C2E2)	(C2M2)	(C2E3)	(C2M3)	(C2E4)	(C2M4)
1000-2600	500	275	200	150	150	125	125	100	110	80
600-2600	1500	825	600	450	450	375	375	300	300	260
500-2800	3000	1650	1200	900	900	750	750	600	650	500
C4	(C4)									
1000-2600	300									
800-2800	500									
600-3000	1500									
500-3000	3000									
C5	(C5)									
1000-2600	100									
600-2600	300									
500-2800	600									

( ) Figures in parentheses are classification codes which may be found on some CLRCs to indicate the conditioning requirement for each link of the circuit.

Note: Requirements using the Collins CLA-101A system are given in Section 314-410-104.

The 25A and 25B voiceband gain and delay measuring sets may produce erroneous delay measurements when used to measure short local circuits consisting of only nonloaded cable or measuring equipment within an office. Certain harmonic products generated in the transmitting modulator stage may enter the receiver producing erroneous measurement results in the form of ripple. For more information, refer to Sections 103-115-100 and 103-115-101.

3.27 *Example of Test:* A 25B voiceband gain and delay set is connected in place of the transmitting data set at station A and set for an output level of 0 dBm at a +13 TLP. Another 25B set is connected in place of the receiving data set at the distant customer station B (−3 TLP). Both received level and envelope delay in this direction are measured and recorded as shown in Table F. Figures 3 and 4 illustrate the determination of the attenuation distortion and delay distortion for this circuit. The measurements are recorded on Form E-5596 as shown in Fig. 1.

TABLE F

SAMPLE MEASUREMENT RESULTS

MEASURED FREQUENCY	ENVELOPE DELAY	RECEIVED LEVEL	LOSS WITH RESPECT 1004 HZ
304		−16.9	+1.1
504	525	−16.0	+0.2
604	275	−15.7	−0.1
804	180	−15.7	−0.1
1004	150	−15.8	0
1204	85	−15.4	−0.4
1404	25	−15.6	−0.2
1604	10	−15.7	−0.1
1804	0	−15.8	0
2004	−15	−15.8	0
2204	−35	−15.9	+0.1
2404	−10	−16.0	+0.2
2604	15	−16.2	+0.4
2804	85	−16.9	+1.1
3004		−17.9	+2.1

Note 1: To calculate the envelope delay distortion between 504 Hz and 2804 Hz, determine the maximum envelope delay (525 μsec) and the minimum envelope delay (−35 μsec) between those frequencies. The envelope delay distortion is the difference between those values 525 − (−35) = 560 μsec. The envelope delay distortion between 604 Hz and 2804 Hz is 275 − (−35) = 310 μsec. Refer to Fig. 4.

Note 2: To calculate the attenuation distortion, reference all loss measurements with respect to 1004 Hz. The attenuation distortion between 504 Hz and 2804 Hz would be the minimum loss (−) and maximum loss (+) between those frequencies (−0.4 to +1.1 dB). The attenuation distortion between 304 Hz and 3004 Hz is −0.4 to +2.1 dB. Refer to Fig. 3.
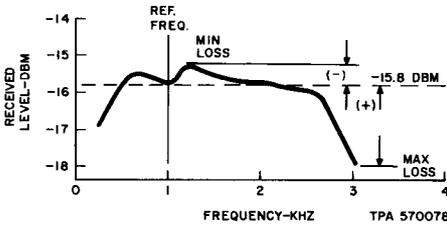
Fig. 3—Attenuation Distortion Determination for 300- to 3000-Hz Band
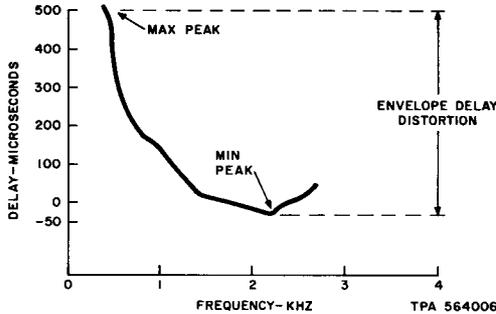
Fig. 4—Envelope Delay Distortion Determination for 500- to 2800-Hz Band

Peak-to-Average Ratio (P/AR)

3.28 P/AR measurements may be made at those locations where P/AR test equipment is currently available. The purchase of the WECo J94027B and J94027E P/AR test equipment is not recommended. New P/AR test sets are available that will provide greater accuracy than the above sets. Benchmark P/AR measurements may be made between STCs and between the STC and the customer station on 4-wire loops equipped with a loopback arrangement, and recorded on Form E-5596 as shown in Fig. 1. The benchmark measurements should be made only after determining that the overall attenuation distortion and envelope delay distortion measurements are within limits.

Note: The WECo J94027E transmitter is designed for use at a 0 +3 dB TLP. If used at some other TLP, an external attenuator

or amplifier will be required to adjust to this level.

3.29 The benchmark measurements should be referred to during trouble isolation testing. If the P/AR measurement is not within +6 of the benchmark value, the following parameters should be checked in the order listed:

(1) 1000-Hz loss

(2) Message circuit noise

(3) Envelope delay distortion

(4) Attenuation distortion.

3.30 Information on the significance and relationship of P/AR measurements to other transmission parameters may be found in Section AB27.425.01. Tentative overall P/AR requirements for the various types of conditioned circuits are listed in Table G. If these requirements are met, it is a strong indication that the circuit envelope delay distortion is within limits. If the P/AR requirements are not met, the envelope delay distortion requirements may be within limits but other transmission parameters such as C-notched noise may be causing P/AR to be degraded.

TABLE G

OVERALL P/AR REQUIREMENTS

CIRCUIT CONDITIONING	MINIMUM P/AR
Basic Channel	45
C1	48
C2	78
C4	87
C5	95

3.31 *Example of Test:* A P/AR transmitter is connected at the AMP IN jack at DAS 828A looking towards the central office at customer station A. Since the P/AR transmitter is connected at a −3 TLP, the output power is adjusted to −16 dBm. A P/AR receiver is connected in place of the data set receiver at customer location B. A reading of 89 is obtained on a C2-conditioned circuit. Since the result is within requirements, the measurement is recorded on Form E-5596 as shown in Fig. 1 in the event that the circuit conditioning

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must be confirmed later as a result of a customer trouble report. Later measurements that fall within ±6 points of the original reading will help quickly confirm that the circuit conditioning has not changed substantially.

Message Circuit Noise (C-Message Noise)

3.32 The limits for message circuit noise are as follows:

End Link	Use mileage
Middle Link	limits from
Loop-Back (STC-STA-STC)	Table H.
Overall	*Note:* Double
	one-way mile-
	age for loop-
	back limits.

3.33 Message circuit noise is the background noise on a channel in the absence of a signal. The usual measurement is frequency-weighted by a C-message filter and the result is called C-message noise. Although the C-message filter was originally developed for voice applications, it has been found to be quite useful for data applications as well. It offers relatively little attenuation in the 1000- to 3000-Hz band but attenuates power line frequencies (60 Hz and its low harmonics). The 3-kHz weighting network may be used to measure noise at these frequencies.

3.34 *Monitor the circuit with the noise set receiver while making the noise measurement.* If intelligible crosstalk of identifiable signals at the noise measurement level is heard, it is an indication of crosstalk or crossmodulation which should be corrected. If a single frequency tone or tones of long duration are heard, single frequency interference may be present and should be measured (refer to 3.76).

3.35 Table H lists the requirements of C-message noise. This table may be used for station-to-station measurements or on a per-link basis. If type 3 data sets are to be used, a C-notched noise measurement will also be required, since a C-message noise measurement does not indicate the true noise contribution of compandored facilities in the presence of a data signal.

TABLE H

MESSAGE CIRCUIT NOISE OBJECTIVES

CIRCUIT LENGTH (MILES)	NOISE MEASUREMENT (dBrnc0)
0-50	31
51-100	34
101-400	37
401-1000	41
1001-1500	43
1501-2500	45
2501-4000	47
4001-8000	50
8001-16,000	53
Satellite Channel	44*

* Add this figure to land line objective on a random power basis (as described in Section 314-410-102) to obtain overall circuit objective.

3.36 Loop-back measurements of noise are allowed for purposes of initial trouble sectionalization tests. If the distance between the STC making the measurement and the customer location where the circuit is looped back is, for example, 70 miles, the mileage figure is doubled and the noise requirement would correspond to a figure for 140 miles.

3.37 Under certain conditions, noise (for example, from 60-Hz power induction) may cancel out in a looped back measurement. An end-to-end measurement may be necessary to confirm that noise limits are met at the customer station.

3.38 If special service channel units are used on a data only service on N1 carrier, an "enhanced level lineup" should be made on the channel unit. This has the effect of improving the signal-to-noise ratio by 7 dB. Information on "enhanced level lineup" may be found in Section 362-315-501 for the transmit channel unit and in Section 362-315-502 for the receive channel unit.

Note: The use of special service channel units (with or without the enhanced level lineup) generally provides a poorer signal-to-noise ratio than that obtainable with the compandored channel units.

3.39 The measured noise must be corrected to the 0 TLP reference point in order to determine whether requirements are being met, ie, for comparison to the requirements stated in dBrnc0. For example, when measuring at a +7 TLP, subtract 7 dB from the reading and when measuring at −3 TLP, add 3 dB to the reading.

3.40 If the CLRC specifies data level, convert the data level to TLP by adding 13 dB to the data level. At the −29 dBm data level point, add 13 dB to convert to a −16 dB TLP, then proceed as in 3.39.

Note: If a −12 dBm0 design is used, convert the data level to TLP by adding 12 dB to the data level.

3.41 Additional information on message circuit noise may be found in Section 331-100-100. Engineering information may be found in Section 870-200-100.

3.42 *Example of Test:* At customer station A, a 600-ohm termination or a 3A noise measuring set is connected across the input to the circuit in place of the data set transmitter. At customer station B, a 3A noise measuring set is connected to the circuit in place of the data set receiver (a −3 TLP or −16 dBm data level point). A reading of 31 dBrnc is taken. To adjust this to dBrnc0, 3 dB is added to the reading to obtain 34 dBrnc0. The circuit has a length of 1400 miles of both N carrier and LMX carrier facilities. The requirement from Table H of 43 dBrnc0 is met. The corrected measured noise value is entered on Form E-5596 as shown in Fig. 1.

C-Notched Noise

3.43 The limits for C-notched noise are expressed as a ratio of the received 1000-Hz test tone power to the C-notched noise power, as follows:

End Link	See
Middle Link	Note
Loop-Back	Below
Overall	24 dB

Note: To determine the end link, midlink, and loop-back C-notched noise limits, use the facility limits specified in Table I. Combine the uncorrected C-notched limits for each facility as given in Section 314-410-102. Note that when loop-back measurements are performed, the number of channels (if any) measured will double and the C-notched noise (ratio) requirement will be reduced by 3 dB.

Example: A loop-back measurement of C-notched noise is to be made. There is a T carrier system using D1A channels between the STC and the customer. From Table I the C-notched noise requirement for D1A channels is 26 dB. The loop-back requirement is 26 − 3 = 23 dB.

C-notched noise should be investigated when excessive errors are encountered with type 3 data sets, since it is a measure of the amount of noise on a channel when a signal is present. The C-message noise described in 3.33 is not necessarily the noise experienced when a signal is present. Quantizing noise in digital carrier systems and the effect of compandors in both analog and digital systems result in signal-dependent noise. Because this noise is signal dependent, it is impossible to approximate the signal-to-noise (S/N) ratio, which is important to data transmission, from received level and C-message noise measurements alone.

3.44 A C-notched noise measurement differs from a C-message noise measurement in that a single-frequency "holding tone" is applied at the transmitting end of the channel to act as a signal. This tone operates compandors and other signal-dependent devices, and thus simulates a data signal. At the receiving end, the tone is removed by a very narrow band-elimination filter (notch filter) and the noise is then measured through a C-message filter. The requirements for C-notched noise in this section are expressed as the ratio of received 1004-Hz test tone power (applied at data level) to the C-notched noise, and are an approximation of the S/N ratio.

3.45 It is planned to use a holding tone at a frequency from 1004 to 1020 Hz for measurement of C-notched noise. Some test sets are presently available with this capability (refer to test set list in Table A). A suitable notch filter is under development for use with the WECo 3 type noise measuring sets and has an expected availability of late 1974.

TABLE I

COMPANDORED FACILITY NOISE REQUIREMENTS

FACILITY LENGTH (MILES)	C-MESSAGE NOISE (1) (dBrnc0)			C-NOTCHED NOISE (2) (dB)				
	N1 ON	N2	N3	N1 ON	N2	N3	D1A D1B	D1D D2 D3
0-50	26	23	18	28	31	33	26	33
51-100	26	23	20	28	31	32	26	33
101-200	26	26	23	28	29	31	26	33

(1)   Noise requirements using a quiet termination at the MOD IN jack.

(2)   Noise requirements using a holding tone at data level at the MOD IN jack. These requirements include the effects of any test tone harmonics.

(3)   To determine the C-notched noise requirements in dB for uncompandored facilities, subtract the C-message noise requirements in dBrnc0 for the facility in question from 77 dBrnc0.

Example: The C-notched noise requirement for 150 miles of LMX is 77—37 (from Table H) = 40 dB.

3.46   The WECo 6F noise measuring set may be used if a more suitable noise measuring set is not available. The 497E and G networks supplied with this set offer a maximum of 30 dB rejection to test tone frequencies of 2750 or 2800 Hz. This rejection may not be adequate for other than end-to-end measurements. In addition, the noise measurements obtained by the use of this test set may be 1 or 2 dB lower than actually present.

3.47   The practice of using a holding tone at 1004 to 1020 Hz will provide a more predictable measurement of the signal-to-noise ratio than the use of a holding tone at 2750 Hz or 2800 Hz, which was formerly used for this measurement. This occurs because the overall circuit and the individual links are adjusted at 1004 Hz, permitting accurate prediction of the 1004-Hz tone level at various points in the connection. When a holding tone is applied at the customer station and near this frequency at data level (−13 dBm0), it may be assumed that the power entering the MOD IN jack at a compandored channel will also be approximately −13 dBm0. The noise generated by the use of the holding tone on the compandored channel will then be comparable to that generated by a data signal at data level.

3.48   If a holding tone of 2750 Hz or 2800 Hz is applied at the customer station at data level, it is likely that the power entering the MOD IN jack of a compandored channel may be several dB different than −13 dBm0 because of the allowances permitted for the frequency response of the local loop or intermediate channels. If the 2800-Hz power is 2 dB lower than expected, the C-notched noise measured on the channel may appear to be as much as 1 dB lower than is actually the case.

3.49   The use of a holding tone at 2750 Hz or 2800 Hz does eliminate the possibility of harmonic (nonlinear) distortion affecting the C-notched noise measurement when N or ON channels (but not T carrier) are involved. This is not true when a holding tone near 1004-Hz is used, as the harmonics will be present in the C-notched noise measurement.

3.50   The noise measuring set may indicate the C-notched noise level in either of two ways. Some noise measuring sets automatically indicate the ratio of the 1004-Hz holding tone to the C-notched noise in dB. This reading can be compared directly with the C-notched noise requirements in this section, and no calculations are required.

3.51 Other noise measuring sets indicate the C-notched noise power in dBrnc rather than the ratio of the test tone to the C-notched noise. In this case, perform the following steps:

(1) Apply the test tone (at data level) of 1004, 1020, 2750, or 2804 Hz at the transmitting location.

(2) At the receiving location, measure the noise power using a C-notched filter. Adjust the test tone frequency at the transmit location for the minimum noise reading on the meter. Record this value in dBrnc as "A". Do not correct for 0 TLP.

(3) At the receiving location, replace the C-notched filter with a C-message filter and record the measured tone power in dBrnc as "B". Do not correct for 0 TLP. The test tone at the transmitting location is left on for this measurement.

(4) The test tone to C-notched noise ratio is B − A.

3.52 *Example of Test:* A 1004-Hz test tone is applied at customer station A at a power of 0 dBm at a +13 TLP. At customer station B, a reading (B) of 74 dBrnc is obtained using a C-message filter, and a reading (A) of 52 dBrnc is obtained using a C-notched filter. The S/N ratio is B − A = 74 − 52 = 22 dB. Although the C-notched noise in this example appears to be out of limits, it will be necessary to make further measurements before reaching this conclusion. This is explained in 3.53 and 3.54, followed by Example 1 in 3.55.

3.53 The circuit limits given in 3.43 allow only for the presence of noise and not for nonlinear distortion (refer to 3.104 and 3.107 for information on nonlinear distortion). A C-notched noise measurement which includes the effect of nonlinear distortion is referred to as UNCORRECTED C-NOTCHED NOISE. If calculations are made to determine the C-notched noise without the effect of the nonlinear distortion, it will be referred to as CORRECTED C-NOTCHED NOISE.

3.54 As long as uncorrected C-notched noise measurement meets the C-notched noise limits, there will be no need to account for the effect of nonlinear distortion. If the overall uncorrected C-notched noise is out of limits by 1

or 2 dB, measure the harmonic or nonlinear distortion as discussed in 3.104, and consult Table J. If the conditions in that table are met, the corrected C-notched noise is within limits and further action is not required. In some cases, the uncorrected C-notched noise may be out of limits because the harmonic or nonlinear distortion is out of limits. In this case, correct the distortion problem first, then remeasure the C-notched noise.

> *Under conditions where the nonlinear distortion is out of limits, repeat the C-notched noise measurement after the distortion problem has been cleared.*

3.55 The following examples are intended to further explain the use of Table J.

Example 1: In the example of 3.52, the uncorrected C-notched noise appeared to be out of limits. This example will use that C-notched noise measurement and the harmonic distortion measurements from the example of 3.106 to determine if the corrected C-notched noise is within limits. Uncorrected signal to C-notched noise ratio = 22 dB

2nd order harmonic distortion = 27 dB

3rd order harmonic distortion = 31 dB

Locate the row in Table J in which the S/N ratio is 22 dB and the 2nd order harmonic distortion is 27 dB. As shown in the table, the 3rd order harmonic distortion must fall within the range of 30 to 35 dB in order to be within limits. Since the measured distortion of 31 dB falls within that range, the corrected C-notched noise is within limits. Record the results on Form E-5596 as shown in Fig. 1. Since C-notched noise was previously expressed in dBrnc0, it will be necessary to cross out the rnc0 on the form. (The form will be changed in the near future.) Also, note the reference to Table J to indicate that the corrected C-notched noise is within limits.

3.56 *Example 2:*

Uncorrected signal to C-notched noise ratio = 22 dB

2nd order nonlinear distortion = 28 dB
3rd order nonlinear distortion = 31 dB

TABLE J

CONDITIONS UNDER WHICH OVERALL CORRECTED
C-NOTCHED NOISE REQUIREMENTS ARE MET

UNCORRECTED TEST TONE TO C-NOTCHED NOISE RATIO	2ND ORDER DISTORTION HARMONIC OR NONLINEAR	3RD ORDER DISTORTION	
		HARMONIC	NONLINEAR
24-∞	NR	NR	NR
23	25-30	NR	NR
	31	30-39	28-37
	32	30-35	28-33
	33	30-33	28-31
	34-35	30-32	28-30
	36-39	30-31	28-29
	40	30	28
22	25-26	NR	NR
	27	30-35	28-33
	28	30-31	28-29
21	The distortion must be out of limits in order for the corrected C-notched noise to be within limits.		

NR = Not required (the 2nd order distortion alone is within the range to put the corrected C-notched noise within limits)

See 3.53 to 3.56 for an explanation of the use of this table.

From values given in Table J, the 3rd order nonlinear distortion must be in the range of 28 to 29 dB in order for the corrected C-notched noise to be within limits. Since the measured distortion is lower than this, the corrected C-notched noise is out of limits. This example shows that if the 3rd order nonlinear distortion had been higher, for example 26 dB, the corrected C-notched noise would have been in limits but the 3rd order nonlinear distortion would have been out of limits.

3.57 To sectionalize C-notched noise, it will be necessary to look at the performance of LMX carrier, N and ON carrier, and T carrier individually.

3.58 The most probable source of C-notched noise is the D1A or D1B channel banks used on T1 carrier. Request a distortion measurement be made of all D1A and D1B channels as outlined in Section 365-104-500. Request the measurement results. The limits for this test are given in Table L of that section and are reproduced in Table K of this section under the heading of maximum readings. Measurements which are normal for a well maintained system are given under the heading of the typical readings column in Table K. The limits of Table K include the effects of both distortion and noise, and correspond to an uncorrected C-notched noise measurement as described in 3.53.

3.59 Table I provides C-message noise and C-notched noise requirements for compandored carrier facilities for use in sectionalizing C-notched noise troubles. C-notched noise measurements should be used to sectionalize C-notched noise troubles. However, C-message noise measurements may be used in those cases where C-notched noise measuring sets are not available and C-message noise limits are specified in Table I. The C-notched noise limits in Table I include the effect of any possible test tone harmonics.

3.60 The C-message noise requirements in Table I are to be used in isolating C-notched noise troubles to N or ON carrier channels (but not T carrier) when C-notched noise measuring sets are not available. These requirements correspond to the limits given in Section 362-305-510 for N1 and ON carrier, Section 362-800-506 for N2 carrier,

TABLE K

MEASUREMENT LIMITS FOR C-NOTCHED NOISE
(DISTORTION) ON D1A/B CHANNELS

TRANSMITTING END MATCHING NETWORK KEYS HORIZONTAL	TRANSMITTING TEST LEVEL (dBm0)	MAXIMUM RECEIVING END 3A NMS READINGS DBRN	TYPICAL RECEIVING END 3A NMS READINGS DBRN
0	0	56 (30)	52 (34)
10	−10	50 (26)	46 (30)
20	−20	41 (25)	37 (29)
30	−30	30 (26)	26 (30)
30 and 10	−40	24 (22)	21 (25)

Note: Figures in ( ) are the corresponding signal-to-distortion ratios in dB. For example, when all keys in the matching network are vertical, the test tone is 0 dBm relative to 0 TLP. Since the RCV jack is a +2 TLP, the test tone will then be nominally +2 dBm or 92 dBrn at this point. If the 3A NMA reads 56 dBrn at the output of the 1-kHz reject filter, the distortion products are 62 dBrn at the RCV jack (since the 1-kHz reject filter has 6 dB of loss). The signal-to-distortion is therefore $92 - 62 = 30$ dB.

and Section 362-900-506 for N3 carrier. The C-message noise limits in Table I are not normally to be used for isolating C-message noise facility troubles, as they are tighter than needed to meet the overall private line C-message noise requirements. (The requirements in Table H are to be used to sectionalize C-message noise facility troubles.)

3.61 The use of noncompandored channel units (special service channel units or VF amplifiers) on N or ON carrier will increase the C-notched noise power significantly (poorer signal-to-noise ratio) and should be discouraged for type 3 data transmission.

3.62 In some cases C-notched noise may be caused by phase jitter on LMX carrier, if the jitter source occurs at 180 Hz or higher. Most phase jitter occurs at frequencies of less than 180 Hz and the phase jitter sidebands are rejected by the C-notched filter. The C-message noise limits given in Table H may be converted into C-notched noise limits for the isolation of C-notched noise on LMX carrier, since these channels are not compandored. To do this, subtract the C-message noise limits in dBrnc0 in Table H from 77 dBrnc0 in order to obtain the C-notched noise limits in dB.

Impulse Noise

3.63 The threshold settings for impulse noise are as follows:

End Link	67 dBrnc0
Middle Link	Use mileage limits from Table L
Loop-Back	Use round trip mileage limits from Table L
Overall	71 dBrnc0

3.64 Impulse noise is characterized by large peaks or impulses in the total noise waveform. It is measured with an instrument such as the 6F or 6H impulse noise counter which counts impulses greater than a threshold value, using an electromechanical counter having a maximum counting rate of 7 counts per second. Measurements are made through a C-message filter. A holding tone is transmitted and notched out at the receiver.

3.65 Impulse noise should be measured with a holding tone of 1004-1020 Hz, 2804 Hz, or 2750 Hz. A holding tone frequency of 1004-1020

Hz is the new Bell System standard. If the WECo 6F or 6H impulse counters are used, a holding tone frequency of 2750 Hz is used with the 497E network, and 2804 Hz with the 497G network inserted in the impulse noise counter. The threshold setting on the impulse noise counter should be set to a level corresponding to the threshold requirement in dBrnc0 plus the TLP at the point of measurement. For example, at a +7 TLP when measuring a midlink consisting of a 100-mile LMX carrier channel, adjust the threshold setting of the impulse counter to 58 (from Table L) + 7 = 65. If the same channel were measured at a −16 TLP, the threshold would be set at 58 − 16 = 42. If the CLRC specified data level, (−13 dBm 0) add 13 dB to the data level to obtain the TLP. Then determine the threshold setting using the same procedure. The same channel measured at a data level point of −16 would correspond to a TLP of −16 + 13 = −3. The threshold setting would be 58 − 3 = 55. This procedure is merely correcting from dBrnc0 to dBrnc.

3.66 When impulse noise is measured overall from one customer station to another, a threshold setting of 71 dBrnc0 should be used regardless of facility type or mileage. The overall 1000-Hz loss must be adjusted to within 1 dB in order to obtain an accurate impulse noise count. Table L may be used to isolate troubles to a facility section. In the event of a trouble report involving an excessive error rate between two specific data stations, an overall impulse noise test must be made between the reported stations since the end link/midlink impulse noise thresholds given in 3.63 do not offer complete assurance that the overall impulse noise requirements will be met. If the overall impulse noise requirements are met between stations it will not be necessary to meet end link/midlink or facility impulse noise requirements.

3.67 *Example of Test:* An overall impulse noise measurement is to be made between station A and station B. At station A, an oscillator is connected in place of the data set transmitter (+13 TLP) and adjusted for an output of 0 dBm at 2804 Hz. The 2804-Hz loss deviation was previously measured between stations A and B and was determined to be within ±2 dB of the 1004-Hz loss of the example given in 3.14. At station B, a 6H impulse noise counter is connected in place of the data set receiver (−3 TLP). The reference level for the threshold control is set at 71 − 3 = 68 dBrnc. In a 15-minute period, 7 counts are recorded

on the counter. This figure is within limits and is recorded on Form E-5596 as shown in Fig. 1.

TABLE L

IMPULSE NOISE
THRESHOLD SETTINGS IN dBrnc0

LENGTH (MILES)	TYPE FACILITY		
	(1)	(2)	(3)
0-59	54	67	58
60-124	54	67	58
125-249	54	67	59
250-499	—	—	59
500-999	—	—	59
1000-1999	—	—	61
over 2000	—	—	64

(1)   Voice frequency cable facilities only.

(2)   N, O, ON, N3L junction facilities or T carrier facilities.

(3)   C, K, L, or R carrier facilities.

Note 1: These thresholds assume the use of a −13 dBm0 holding tone. Do not use other holding tone levels as the above thresholds for type 2 (compandored) facilities would be incorrect.

Note 2: On PBX tie trunks a minimum threshold of 59 dBrnc0 should be used to account for impulse noise which may originate at the PBX switch.

3.68 An impulse noise counter is also sensitive to other parameters such as phase hits and harmonic hits when used in conjunction with a holding tone.

3.69 If phase hits are suspected on LMX carrier, remove the holding tone and repeat the measurement using the same threshold level. If the counter continues to register impulses at the previous rate, the trouble is probably impulse noise. If the counting rate decreases, the trouble is probably phase hits. Verify that the phase hits do not exceed the requirements specified in 3.99.

3.70 If harmonic hits are suspected on D1 carrier when a holding tone and a threshold of 67 dBrnc0 is used, remove the holding tone and repeat the measurement using threshold levels of 63 dBrnc0 and 57 dBrnc0. A multiple level meter such as the 6F NMS may be used to count the impulses above each threshold simultaneously, or a single level meter such as the 6H NMS may be used singly at each threshold. A good channel will have less than 1 count in 5 minutes at 63 dBrnc0 and less than 5 counts in 5 minutes at 57 dBrnc0. If these limits are not met, the trouble is probably impulse noise and the procedures given in 365-105-500 under impulse noise should be followed. If the limits were met without the holding tone but were not met with the holding tone, harmonic hits may be the problem. Consult 3.113 and 3.114 for information on harmonic "hits"

> *Note:* The impulse noise threshold levels given in Section 365-105-500 (65 dBrnc and 59 dBrnc) are used at the D1 carrier RCV jack, which is a +2 TLP and equivalent to the 63 dBrnc0 and 57 dBrnc0 thresholds given above.

3.71 The distribution of impulse noise voltage levels on typical telephone facilities is such that for each 7-dB increase in the threshold, the expected number of counts decreases by an average factor of 10. A channel just meeting the limit of 15 counts in 15 minutes at 71 dBrnc0 would have an estimated 1.5 counts in 15 minutes at 78 dBrnc0.

3.72 In some cases it may be necessary to measure the impulse noise distribution in order to verify that the number of very high level impulses is within reasonable limits. In such a case a multiple level 6F impulse noise counter or equivalent should be used. The first counter circuit in the 6F set should be set to the same threshold level that would be chosen from 3.63 if normal impulse noise measurements were made. This will be referred to as the reference threshold level. For example, for overall measurements, the reference threshold level would be 71 dBrnc0. The COUNTER SEPARATION switch should be set to 4 dB. This will place the second counter circuit 4 dB above the reference threshold level and the third counter circuit 8 dB above the reference threshold limit. The fourth counter circuit is not used.

3.73 The maximum number of counts that may be recorded in 15 minutes is as follows:

COUNTER CIRCUIT		MAXIMUM COUNTS
1	Reference Level	15
2	Reference Level + 4 dB	9
3	Reference Level + 8 dB	5

Multiple level impulse noise tests should be made when repeated trouble reports are received that the data error rate is higher than normal or when the data set receiver loses synchronization for no apparent reason.

Single Frequency Interference

3.74 The overall circuit requirements for single frequency interference are given in Table M. The limits in this table may also be used to sectionalize troubles to a particular facility.

TABLE M

SINGLE FREQUENCY INTERFERENCE REQUIREMENTS

CIRCUIT LENGTH MILES	LEVEL OF MEASURED TONE dBrnc0
0-50	28
51-100	31
101-400	34
401-1000	38
1001-1500	40
1501-2500	42
2501-4000	44
4001-8000	47
8001-16,000	50
Satellite Channel	41

3.75 Spurious single frequency tones may interfere with certain data signals, particularly narrowband signals which are multiplexed onto a voiceband channel. Since the output of the multiplexer must meet the voiceband channel signal power

requirements, the signal power in a narrowband channel may be close to the voiceband channel noise power. The narrowband channel noise will be less than the voiceband noise, but if a single frequency tone is in the narrowband channel it may interfere with the desired signal. (Unlike the noise, the power of the tone is not decreased when passed through the narrowband channel filter.) The limit for single frequency interference is that any spurious single frequency tone will be at least 3 dB below the C-message noise power limit.

3.76 A listening test is required to check for single frequency interference while the C-message noise measurement is being made as given in 3.34. A C-message weighting network must be used when making this test. If message noise can be heard but noticeable tones are not heard the circuit is probably good. If tones are heard, perform a C-message noise measurement. If the noise measurement meets the limits listed in Table M, the single frequency tone is within limits.

3.77 If the limits in Table M are not met, a level measurement of the interference must be made using a frequency selective voltmeter. Tune the voltmeter to the interfering tones between the frequency range of 300 to 3200 Hz and measure the level in dBm. This figure may be converted to dBrnc0, using the following procedure:

STEP	PROCEDURE
1	Convert the level measurement to dBm0 by algebraically subtracting the TLP at the point of measurement from the reading obtained on the meter. If the CLRC specifies data level instead of TLP, add 13 to the data level shown on the CLRC to obtain the TLP.
2	Convert from dBm0 to dBrn0 by adding 90 to the dBm0 figure.
3	Convert to C-message weighting using the curve in Fig. 5 as follows: Determine the frequency of the interference from the dial setting on the frequency selective voltmeter. Determine the C-message loss at this frequency from Fig. 5. Subtract this loss from the figure in dBrn (Step 2) to obtain the level in dBrnc0, and compare this figure against the requirement table.

3.78 *Example of Test:* Single frequency interference is heard when making a listening test at customer station B at a −16 dBm data level point (−3 TLP). A frequency selective voltmeter is connected at this point and a reading of −52 dBm at a frequency of 600 Hz is obtained. A termination was applied to the distant end of the circuit which is approximately 1200 miles long. To convert the test point from data level to TLP, 13 is added to −16 to obtain a −3 TLP. To convert the level measurement from dBm to dBm0, the TLP is subtracted from the level measurement: −52 dBm − (−3) = −49 dBm0. Convert the dBm0 figure to dBrn0 by adding 90: −49 dBm0 + 90 = 41 dBrn0. Referring to Fig. 5, the loss at 600 Hz as compared with 1000 Hz is 4.7 dBm. Convert the dBrn0 figure to dBrnc0 by subtracting the loss at 600 Hz: 41 dBrn0 − 4.7 dB = 36.3 dBrnc0. Although the

interference can be heard, it falls within the requirement of 40 dBrnc0 for a 1200-mile circuit and need not be corrected. Enter this figure on Form E-5596 as shown in Fig. 1. If the listening test had revealed no single frequency interference, the notation OK may be made on Form E-5596, as a level measurement would not have been required.

Frequency Shift

3.79 The overall circuit requirements for frequency shift are as follows:

End Link	}	Refer to Table N
Middle Link		
Overall	±5 Hz	
Loop-Back	Not a valid test	

2-97

FREQUENCY HZ

DB RELATIVE TO THE VALUE AT 1000 HZ

FREQUENCY HZ	OBJECTIVE NOMINAL IN DB BELOW REF
60	55.7
100	42.5
200	25.0
300	16.5
400	11.4
500	7.5
600	4.7
700	2.7
800	1.5
900	0.6
1000	0
1200	0.2
1300	0.5
1500	1.0
1800	1.3
2000	1.3
2500	1.4
2800	1.9
3000	2.5
3300	5.2
3500	7.6
4000	14.5
4500	21.5
5000	28.5
(NOTE 2)	

TOLERANCES
(NOTE 1)

60 TO 300 HZ ±2DB
300 TO 1000 HZ ±1DB
1000 HZ ±0
1000 TO 3000 HZ ±1DB
3000 TO 3500 HZ ±2DB
3500 TO 5000 HZ ±3DB

NOTES:

1. TO ASSURE THAT PRODUCTION MODELS OF NOISE MEASURING SETS WILL BE WITHIN TOLERANCES, INCLUDING VARIATIONS IN COMPONENTS AND MANUFACTURING PROCEDURES, TOLERANCES ONE HALF THE VALUES GIVEN ABOVE ARE RECOMMENDED FOR DESIGN PURPOSES.

2. THE ATTENUATION SHALL CONTINUE TO INCREASE AT A RATE OF NOT LESS THAN 12DB PER OCTAVE UNTIL IT REACHES A VALUE OF 60DB.

Fig. 5—C-Message Weighting Curve

NOTES

NOTES

Facility limits are shown in Table N. A VF carrier channel includes all modulation stages between two channel banks. Frequency shift measurements are only required on the carrier channel portions of the circuit and do not normally include the metallic facilities to the customer stations. Frequency shift measurements are only required in the event of repeated customer trouble reports.

TABLE N

FREQUENCY SHIFT REQUIREMENTS

NO. OF VF CARRIER CHANNELS IN TANDEM	MAXIMUM FREQUENCY SHIFT
1	1 Hz
2-4	2 Hz
5-9	3 Hz
10-16	4 Hz

3.80 Frequency shift of carrier facilities will seldom be a serious problem for most data applications. It cannot appear on physical plant and will be insignificant on carrier systems that have a transmitted carrier modulation scheme, such as N- or O-type. Frequency shift may appear on every other channel of an N3 system which is connected to an L-type system with an N3-L connector and where the frequency control grid has not been extended to the N3 terminal. In this case either the frequency control grid should be extended or a different channel on the N3 system should be chosen. Frequency shift will not be found on D1, D2 or D3 channels of T carrier systems. The LMX channels of L-type carrier should normally hold frequency shift well within the limits given in Table N. An exception to this may be the result of improperly performed maintenance activity on the primary frequency supplies when deviations in excess of 10 Hz for a number of hours have been observed. If such trouble is suspected, an inquiry regarding maintenance activity associated with primary frequency supplies on the route should be made and supervisory assistance requested to ensure that the work is carefully done so as not to interfere with data transmission. C or H carrier channels may exhibit large amounts of frequency shift and should be avoided.

3.81 To measure the frequency shift parameter, a frequency counter is used at both ends of a circuit to compare the frequency of a tone which is sent from one end to the other. The 72A frequency meter may also be used to observe the frequency shift.

3.82 Momentary frequency shifts ranging as great as 100 Hz or more for a period of a few milliseconds to 5 seconds and return to zero may be experienced. A 72A frequency meter and a phase jitter test set may be helpful in detecting this problem. An electronic frequency counter cannot detect this type of problem.

3.83 *Example of Test:* When frequency shift is suspected on a circuit, an oscillator is connected at data level (−13 dBm0) at the STC serving customer station A. A frequency counter is then bridged across the output. Another frequency counter is bridged across the circuit at the STC serving customer station B. Metallic facilities are used exclusively between both STCs and their respective customer stations. If a carrier channel other than N1, N2, or T were used between the STC and the customer station, it would be necessary to make this measurement at the customer station. A frequency of 1004 Hz is read at both STCs at the same time. The frequency shift on this circuit is therefore 0 Hz. Record this value on Form E-5596 as shown in Fig. 1.

Phase Jitter

3.84 The circuit requirements for phase jitter are as follows:

End Link	
Middle Link	Refer to Table O
Overall	10° peak-to-peak
Loop-Back	Not a valid test

3.85 Various sources cause the instantaneous phase, or zero crossings, of a signal to "jitter" at rates normally less than 300 Hz. Phase jitter is typically caused by ripple in the dc power supply appearing in the master oscillator of LMX carrier supplies and is introduced in the process of modulation of the voiceband signal to group and supergroup frequencies. It may also occur on N3 carrier in cases where the frequency correction unit is subject to crosstalk coupling at frequencies near the frequency correction carriers from other pairs in the same cable sheath.

3.86 Distortion, quantizing noise, random noise, and single tone interference can also cause an apparent increase in phase jitter. The overall phase jitter limits apply only when the C-notched noise requirement of 24 dB is met.

3.87 The primary source of phase jitter on LMX carrier is ripple on the 24-volt supply circuit which amplitude modulates this supply at the ripple frequencies. Harmonics of the 4-kHz frequency supply circuit are used to derive group and supergroup carrier frequencies. The process of harmonic generation causes the amplitude modulated signal to be transformed into a frequency modulated signal. The original ripple modulation, which was quite small, is magnified by the process of harmonic generation and may become quite significant at the higher carrier frequencies. The phase jitter from a given carrier supply will be greatest at the highest supergroup carrier frequency.

3.88 The relative phase jitter of different supergroup carrier frequencies originating from the same 4-kHz supply is generally directly proportional to the carrier frequency. For example, if 1 degree of phase jitter is found on the supergroup 5 carrier frequency (1612 kHz) then 1.9 degrees should be measured on the supergroup 10 carrier frequency (3100 kHz).

$$1.9° = \frac{3100}{1612} \times 1°$$

3.89 Each supergroup modulation stage will introduce phase jitter to a voiceband channel. Channels which will have the lowest phase jitter will generally pass through as few supergroup or group connectors as possible and will be assigned to the lower frequency supergroup.

3.90 The LMX phase jitter limits given in Table O have been based on the fact that as the channel mileage increases the number of modulation exposures will generally increase.

3.91 The maximum phase jitter permissible for a LMX terminal at either the supergroup D28 (3396 kHz) or supergroup 10 (3100 kHz) carrier supply frequencies is 3.6 degrees. Under certain conditions, such as the assignment of a channel to all "worst case" supergroups, a limit of 3.6 degrees will not be sufficient to permit the requirements

of Table O to be met. The limits in Table O may be disregarded if an overall LMX (all LMX channels in tandem) objective of 8 degrees can be met. Otherwise, every attempt should be made to reduce the supergroup D28 or 10 carrier supply phase jitter as much as possible below 3.6 degrees. This may generally be accomplished by comparing the phase jitter generated using the regular equipment (such as the drive amplifiers) as compared to that generated with the standby equipment switched in. The equipment giving the higher readings should be investigated and/or replaced and the equipment giving the lower readings should be retained. LMX carrier supply phase jitter tests and troubleclearing procedures are covered in Section 356-270-506. If the supergroup D28 or 10 phase jitter cannot be reduced below 3.6 degrees and the overall LMX objective of 8 degrees cannot be met, DATEC assistance should be requested, through proper lines of supervision. As a last resort, facility reassignments may be necessary.

TABLE O

MAXIMUM PEAK-TO-PEAK PHASE JITTER REQUIREMENTS FOR CHANNELS TO BE USED FOR DATA TRANSMISSION

N, ON, D1 (T1 CARRIER) CHANNELS	
NUMBER OF CHANNELS	DEGREES PHASE JITTER
1	3.5
2	4.7
3	5.4
4	6.0
LMX CARRIER	
MILEAGE BAND	DEGREES PHASE JITTER
0-250	4.0
251-500	5.0
501-1000	6.0
1001-2000	7.0
2001-4000	8.0

Note: Under certain "worst case" conditions, the above limits may not be met for some channels. If overall phase jitter requirements cannot be met, facility reassignment may be necessary in these cases.

3.92 The mechanism for unsatisfactory phase jitter performance of N3 channels is related to the exposure of the frequency correction unit to the crosstalk interference from other pairs in the same cable sheath. Existing J99300AS frequency correction units (Lists 1, 2, 3, 4, 3A, and 4A) tend to increase phase jitter if the crosstalk interference is in a 16-Hz band centered about the frequency correction carrier. List B (option W, SD 97178-02) may be added to existing units to reduce the susceptibility of the frequency correction unit to crosstalk.

3.93 In most cases where the N3 carrier noise requirements are met, these channels will also meet the phase jitter requirements for private line data circuits given in Table O. If these limits cannot be met with the addition of List B to the frequency correction carrier unit, and the N3 facility requirements given in Section 362-900-507 (when available) can be met, it may be necessary to request another facility assignment. This action will only be necessary when the overall phase jitter requirement of 10 degrees cannot be met.

3.94 The measurement of apparent phase jitter on D1 channels (used on T1 carrier) will vary considerably with slight changes in test frequencies. This occurs because, although the total distortion power of a single tone is constant, the distortion components may vary in number and intensity across the voiceband, depending upon the test frequency. A phase jitter meter will only detect these components in the 700- to 1300-Hz band. For example, measurements of a typical D1 channel with a test tone varied between 1025 Hz and 1075 Hz produced readings varying from a low of 1.2 degrees to a high of 3.0 degrees. Therefore, D1 channels that meet phase jitter limits given in Table O may not meet nonlinear distortion or C-notched noise requirements. A C-notched noise test or nonlinear distortion test will generally be of more value than a phase jitter test in locating a faulty D1 carrier channel. If phase jitter measurements of D1 channels must be made, readings should be obtained with test tones of 1004 Hz or 1020 Hz. These frequencies are within the specified 980-1030 Hz phase jitter measurement band, and do not suffer from the erratic readings possible with a 1000-Hz tone.

3.95 Phase jitter measurements are normally required only on the overall LMX carrier portions of the circuit as shown in Fig. 6, unless
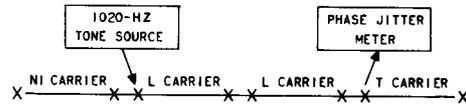
Fig. 6—Test Arrangement for Measuring Phase Jitter

N3 carrier makes up a portion of the circuit. The total end-to-end phase jitter contribution of all LMX carrier channels in tandem should not exceed 8 degrees. Measurements may be made in only one direction on LMX carrier since the same carrier supplies are used in both directions and the measurement results in either direction will be almost identical. Loop-back measurements are not meaningful on LMX carrier.

3.96 If N3 carrier makes up a portion of the circuit, it may be necessary to make phase jitter measurements in both directions on the N3 channel in addition to the LMX measurements. As an alternative, overall measurements may be made which include all carrier channels in tandem. The overall limit of 10 degrees should be met. Note that metallic facilities to the customer location need not be included in this measurement.

3.97 It may be necessary to make overall phase jitter measurements at the customer stations if repeated trouble reports are received and there is some question as to whether Telco facilities are meeting objectives. An overall requirement of 10 degrees must be met between all customer stations. If this limit is not met, verify that C-notched noise and nonlinear distortion requirements are met before attempting to locate the source of a phase jitter problem.

3.98 *Example of Test:* A 2-point circuit is to be tested for phase jitter. An oscillator known to have a low jitter source is connected to the MOD IN jack at the first LMX carrier channel and adjusted to a frequency of 1020 Hz at a level of -29 dBm (-16 TLP). At the DEMOD OUT jack of the LMX channel closest to the distant end (a distance of 700 miles from the test oscillator), a phase jitter test set is connected and a reading of 6 degrees peak-to-peak is obtained. This value is recorded on Form E-5596 as shown in Fig. 1. A

notation "L Cxr" is made after the value to indicate that only the LMX carrier has been measured.

Phase Hits

3.99 Limits for phase hits are currently under consideration. A current study indicates an average of 2.9 phase hits occurred per hour where the phase hits were at least 22.5 degrees in magnitude and 2 milliseconds in duration. Under no circumstances should more than 10 hits greater than 20 degrees occur in 15 minutes. Some areas have adopted the following tentative limits over a 15-minute measurement interval which should only be applied where local instructions indicate:

THRESHOLD	HITS
30°	1
20°	4
10°	15

3.100 Phase hits are large abrupt changes in signal phase occuring on data channels as a result of switching two carrier supplies not in phase, or switching to alternate transmission facilities having different propagation times. They will generally affect error performance in the same manner as impulse noise.

3.101 Phase hits may show up on impulse noise counters when a holding tone is used and vice versa. To partly remove the effect of impulse noise, a 4-ms gate must be used in the phase hit counter. This means that the phase hit must last for at least 4-ms in order to be counted.

3.102 If excessive impulse noise is recorded on LMX facilities in the presence of a holding tone, the measurement should be repeated without the holding tone, using the same threshold setting. The absence of impulse noise counts without a holding tone indicates the possibility of phase hits. A phase hit counter should be used to determine whether the above phase hit requirements can be met.

Note: If a phase hit counter is used first and detects excessive hits, an impulse noise test should be made of the same facility without a holding tone to be certain that the problem is not impulse noise.

Nonlinear Distortion (Harmonic Distortion)

3.103 The limits for nonlinear distortion and harmonic distortion are as follows:

HARMONIC DISTORTION

	RATIO OF 704 HZ TO HARMONIC	
	1408 Hz 2nd Harmonic	2112 Hz 3rd Harmonic
End Link	28 dB	36 dB
Middle Link*	40 dB	40 dB
Loop-Back (STC-STA-STC)	25 dB	30 dB
Overall	25 dB	30 dB

NONLINEAR DISTORTION

	RATIO OF FUNDAMENTAL TO SECOND AND THIRD ORDER PRODUCTS	
	2nd Order	3rd Order
End Link	28 dB	34 dB
Middle Link*	40 dB	38 dB
Loop-Back (STC-STA-STC)	25 dB	28 dB
Overall	25 dB	28 dB

*These requirements assume the use of no short haul carrier channels (N, O, ON, D) for midlinks. If such is not the case, use the requirements in Table P for trouble isolation. The overall requirement shown above applies under all circumstances.

3.104 Nonlinear distortion can be broadly defined as the generation of signal components from the transmitted signal that add to the transmitted signal, usually in an undesired manner. To date, nonlinear distortion has been measured by applying a single frequency tone of 704 Hz at one end of a channel and measuring the second harmonic and third harmonic products at the other end of the channel with a selective voltmeter or spectrum analyzer. These distortion powers are not meaningful unless the power of the wanted signal (the fundamental) is known. Therefore, measurements are usually referred to the power of the fundamental and termed second or third harmonic distortion.

Note: Measurement frequencies are offset by 4 Hz because of cases where D1 channel banks (used on T1 carrier) are used. The

D1 channel bank tends to exaggerate the test results when test frequencies that are subharmonics of 8000 Hz are used.

3.105   To measure harmonic distortion, a test tone of 704 Hz is applied at a data level of 13 dB below the TLP shown on the CLRC. At the MOD IN jack of a typical carrier channel (−16 TLP) this would correspond to a level of −29 dBm. If a test oscillator such as the 21A TMS is used, ensure that the harmonic output of the oscillator is at least 40 dB below the fundamental of the test frequency. Older 21A TMSs or those due for routine maintenance frequently do not meet the 40-dB spread. At the distant end, adjust a frequency selective voltmeter to measure the level of the 704-Hz tone in dBm (A). Second, measure the level at 1408 Hz in dBm (B).

> *Note:* It may be necessary to increase the sensitivity of the measuring set from 30 to 60 dB to make this measurement.

Third, measure the level at 2112 Hz in dBm (C). The second harmonic distortion is A − B. The third harmonic distortion is A − C. An example of these calculations follows in 3.106.

3.106   *Example of Test:* An oscillator is connected in place of the data set transmitter at customer station A and adjusted to a level of 0 dBm (+13 TLP) at a frequency of 704 Hz. A frequency selective voltmeter is connected at station B in place of the data set receiver (−3 TLP).

The level and frequency readings are as follows:

704 Hz −16 dBm

1408 Hz −43 dBm

2112 Hz −47 dBm

The second harmonic distortion is

−16 − (−43) = 27 dB

The third harmonic distortion is

−16 − (−47) = 31 dB

These values meet the circuit limits. Record the results on Form E-5596, as shown in Fig. 1. The letters HD should follow the harmonic distortion

measurement results on Form E-5596 to distinguish these results from nonlinear distortion measurement results.

3.107   It is planned to use intermodulation distortion measurements and to discontinue the use of harmonic distortion measurements for purposes of characterizing the nonlinear distortion of telecommunications channels. This will provide for less variable measurements for PCM systems than currently realized using harmonic distortion measurements techniques.

3.108   The term nonlinear distortion, as used in this section, shall denote the measurement of intermodulation distortion unless otherwise stated. Harmonic distortion measurements will continue to be acceptable in most cases until nonlinear distortion test sets are found to be in more common usage. Nonlinear distortion measurements will be required in lieu of harmonic distortion measurements in those cases where the customer indicates that the channel does not meet Bell System specifications and DATEC support is required.

3.109   To measure nonlinear (intermodulation) distortion, four equal-level tones (as shown in Fig. 7) are transmitted over the facility to be measured. Two of these tones are closely spaced around a center frequency "A" (860 Hz) and the other two tones are centered around a center frequency "B" (1380 Hz). Each pair of narrowly spaced tones is used to simulate a narrow band of noise at each center frequency. The second order distortion is determined by measuring the energy through narrowband filters centered at B − A (520 Hz) and B + A (2240 Hz). Third order distortion is measured through a narrowband filter centered at 2B − A (1900 Hz). The 2nd order nonlinear distortion is generally equal to the 2nd order harmonic distortion. It appears that the 3rd order nonlinear distortion is generally 2 dB lower than the 3rd order harmonic distortion. Most present and planned nonlinear distortion test sets will read out the distortion (and noise factor) as a ratio in dB with respect to the measured power of the fundamental signal.

3.110   If the C-notched noise on the circuit being measured is high, or the nonlinear distortion on the facility is low, the distortion measurement may be influenced by the channel noise. Therefore, the distortion measurement reading obtained from the nonlinear distortion test set is actually the uncorrected distortion. The nonlinear distortion

test set is equipped with a signal-to-noise mode (as shown in Fig. 8), which removes the tone pair at "B" and increases the power of the tone pair at "A" by 3 dB to transmit the same total power over the channel as is transmitted during the nonlinear distortion test mode. The noise energy in the second order and third order slots, discussed in 3.109, is measured at the other end of the facility
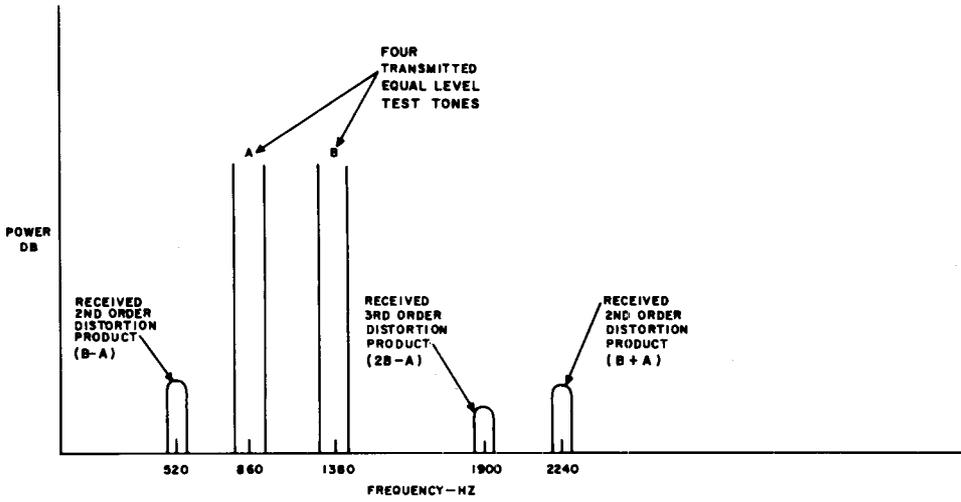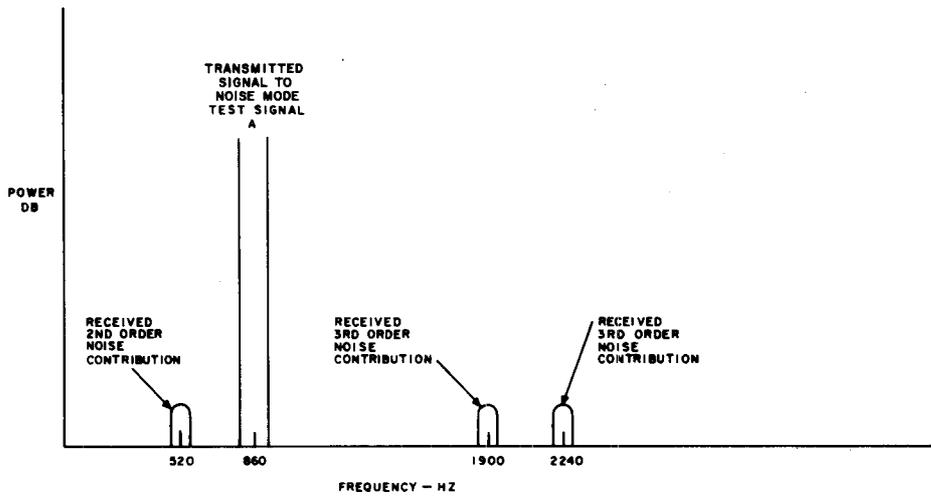
Fig. 7—Distortion Test Signals

Fig. 8—Signal to Noise Mode Test Signals

in both the second order and third order measurement modes. The actual distortion (corrected distortion) present is determined by calculations involving the use of a correction factor (shown in Fig. 9) which removes the influence of noise from the distortion measurement. If the uncorrected distortion meets the requirements in this section, there will be no need to calculate the corrected distortion. If the limits are not met, the corrected distortion should be determined, since the circuit may meet requirements. The use of the correction factors is illustrated in the following example.

3.111 *Example of Test:* A nonlinear distortion test set is connected in place of the data set transmitter at customer station A and adjusted to a level of 0 dBm (+13 TLP) in the distortion or normal mode. Another nonlinear distortion test set is connected at station B in place of the data set receiver (−3 TLP). The following measurements are made at station "B" with the test set at station "A" in the distortion mode:
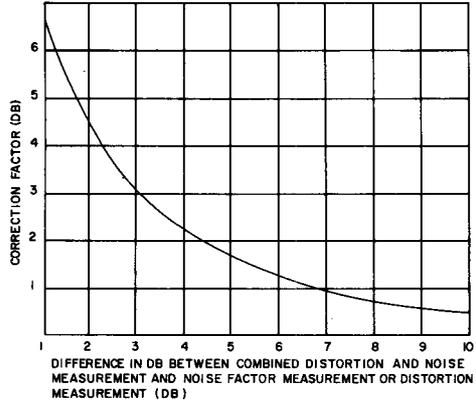
Fig. 9—Correction Factor for Noise or Distortion

Total received power = −16 dBm (This measurement confirms the test signal has been applied at data level at station "A".)

Received distortion (signal-to-distortion ratio, which includes distortion and noise)

    2nd Order Mode = 27 dB
    3rd Order Mode = 32 dB

The test set at station "A" is placed in the noise factor or S/N mode. The following measurements are taken at station "B", and the following ratios read:

Received noise (signal-to-noise ratio)

    2nd Order Mode = 34 dB
    3rd Order Mode = 35 dB

Determine the difference between the received distortion and the received noise as recorded above.

	RECEIVED NOISE		RECEIVED DISTORTION		DIFFER-ENCE
2nd Order	34 dB	—	27 dB	=	7 dB
3rd Order	35 dB	--	32 dB	=	3 dB

Use the difference from above to determine the correction from Fig. 9.

	DIFFER- ENCE	CORRECTION FACTOR
2nd Order	7 dB	1 dB
3rd Order	3 dB	3 dB

Determine the actual distortion by adding the correction factor to the received distortion.

	RECEIVED DISTORTION		CORRECTION FACTOR		CORRECTED DISTORTION
2nd Order	27 dB	+	1 dB	=	28 dB
3rd Order	32 dB	+	3 dB	=	35 dB

Enter the distortion on Form E-5596, followed by the letters ND to distinguish the measurement from the measurement of harmonic distortion. Following ND, use a U (NDU) for uncorrected distortion and a C (NDC) for corrected distortion.

Table P lists the facility nonlinear distortion and harmonic distortion requirements for channels to be used for data transmission.

3.112 The D1A and D1B channel banks used on T1 carrier are the most common source of harmonic distortion. The following steps should be followed when D1/T1 carrier is used for data transmission.

(1) Ensure that the new 4020B, series 6 expandor, containing the new electronic oven, is used in all D1 terminals.

(2) Ensure that the "hardened compressor" 4020AA is used on D1/T1 groups carrying high-speed data services (2 compressors required to handle 12 channels, 4 compressors to treat a complete D1/T1 system, assuming both ends are equipped).

(3) Verify that the transmission levels of the data channel and all other special service channels in the system are correct.

(4) Check to be sure that the T1 line error rate meets the BSP requirements.

(5) Check to be certain that the channel (D1A channel only) being used is arranged for 7-digit transmission (off-hook) by providing −48 volts on the M lead during data transmission periods. This can be accomplished as follows:

(a) For a 4-wire E and M channel unit, list 2, used without signaling, the Y option on the channel unit should be screwed down.

(b) For a 4-wire E and M channel unit, list 2, used with signaling, or for a 4-wire E and M channel unit, list 1, used with or without signaling, the application of −48V to the M lead during transmission of the data signal should be ensured.

(6) The T carrier personnel should be requested to measure distortion on the D1 channel as given in Section 365-105-500. The distortion measurements must not exceed the maximum readings given in Table K of this section. A set of typical readings is also given, and if met, will provide additional margin in meeting overall nonlinear distortion and C-notched noise objectives. The limits in Table K are actually uncorrected C-notched noise requirements which the T carrier personnel use instead of performing a nonlinear distortion measurement. However, if the limits of Table K are met, the T carrier nonlinear distortion requirements given in Table P should also be met, since an uncorrected C-notched noise measurement includes both quantizing noise and nonlinear distortion.

3.113 The D1A and D1B channel banks are subject to momentary increases in harmonic distortion that follow office activity or traffic. These momentary increases in channel distortion (commonly referred to as "harmonic hit") are caused by

TABLE P

**FACILITY NONLINEAR DISTORTION REQUIREMENTS
FOR DATA TRANSMISSION**

TYPE OF CHANNEL	HARMONIC DISTORTION		NONLINEAR DISTORTION	
	2ND HARMONIC	3RD HARMONIC	2ND ORDER	3RD ORDER
N1, ON, O	30 dB	36 dB	30 dB	34 dB
D1A, D1B (T Cxr.)	30 dB	36 dB	30 dB	34 dB
D1D, D2, D3 (T Cxr.)	50 dB	52 dB	50 dB	50 dB
N2, N3	35 dB	40 dB	35 dB	38 dB
LMX	50 dB	50 dB	50 dB	48 dB

transient changes in the bias of the D1A/B compressor networks. Accordingly, the "hits" affect a group of channels (ie, 12) on the D1/T1 system. The basic traffic dependent phenomena that produce the momentary misbiasing of D1 compressors are as follows:

(1) Certain transients in No. 5 crossbar office 48-volt battery supplies used by the D1 power converter

(2) Certain transient high level signals (ie, dial pulse transients) on D1 channels that overload an ac coupled pre-amplifier that establishes compressor bias

(3) The storage of cross-talk energies at the 10-Hz dialing rate in ac coupled amplifiers which affect the bias of the compressor diode network.

3.114 The 4020 AA compressor has been developed to provide additional immunity against office transients. When testing the D1/T1 system [as given in (6) of 3.112], the distortion test must be performed during the busy hour when the D1 terminal is exposed to office battery and front-end transients (dialing, etc). The NORM—DAMP switch on the 3A NMS should be placed in the NORM position. If the 3A NMS exhibits momentary kicks or fluctuations in the reading (± 1 dB), the 4020AA compressor serving the channel under test is defective and should be replaced. If the 3A NMS readings are stable but exceed any of the maximum limits given in Table K, the system *must* be turned down and the trouble cleared. (Refer to Section 365-104-500.)

Singing Margin/Return Loss

3.115 The requirements for singing margin tests are as follows:

NUMBER OF 2-WIRE STATIONS	MINIMUM SINGING MARGIN (EACH STATION)
1-2	10 dB
3-4	16 dB
5-8	22 dB
Over 8	28 dB

3.116 A singing margin test measures the stability of a circuit against singing or howling. In principle, the channel is terminated in its normal impedances. A variable gain amplifier is then inserted on one side of the 4-wire facility and the gain of the amplifier increased until singing (oscillation) occurs. The amount of gain in dB required to cause singing is called the singing margin.

3.117 Singing margin tests are required when 2-wire data sets terminate circuits that are provided in part over 4-wire facilities. These tests are necessary to assure that a given data set receiver will not receive any transmitted signal above an interfering level more than once (echo effect or listener echo). To operate satisfactorily, the level of the echo must be 12 dB or more below the level of the original received signal. Since a 1000-Hz loss deviation of ± 4 dB is permitted in each direction of transmission, a singing margin of 20 dB must be obtained to keep the echo within limits under worst case conditions.

3.118 On 2-point circuits it may be simplest to perform a singing margin test on the overall circuit. In this case, connect the test set as shown in sketch A of Fig. 10. The reading obtained in dB on the test set corresponds to the singing margin, and no additional calculations are required. A minimum singing margin of 20 dB should be met.

3.119 The same 2-point circuit may be tested in two parts. In this case a test is made looking towards each station as in sketch B of Fig. 10. In the case illustrated, the test set is placed across equal TLPs in both directions of transmission and the reading in dB obtained on the test set corresponds to the singing margin. If the test set is placed across unequal TLPs, a correction factor must be added to the test set reading to determine the singing margin. If the TLP towards the customer station is A, the TLP from the customer station is B, and the test set reading is C, then the singing margin in dB is C + B − A. The singing margin requirement for a single station on a 2-point circuit is half of that for the entire circuit of 10 dB.

3.120 The latter method is also used to measure the singing margin on multipoint circuits. The singing margin to each station may be tested at any point on the 4-wire portion of the end link. The singing margin requirements given in 3.115

will allow the circuit to meet an overall requirement of 20 dB.

3.121 Before making a singing margin measurement, verify that the station is in the data (not voice) mode and an idle circuit termination is not used to terminate the circuit. An idle circuit termination may be provided on stations arranged for supervisory signaling and may be removed by placing the station in an off-hook condition.

3.122 If the KS-20501 return loss measuring set (RLMS) is used to measure the singing margin of the circuit, set the THL switches to 0. Make the measurement with the test switch in the SRL and SRL-HI positions. Record the sum of the lowest on scale meter reading and the ADD-DB switch. To obtain the singing margin, correct the reading for the TLPs at the point of measurement as explained in 3.119. Instructions on the use of this set are given in Section 103-106-115.

3.123 If the 2D singing point test set is used to measure the singing margin of the circuit, adjust the GAIN DB switches until the circuit sings. The singing margin is the gain of the set corrected by the TLPs at the point of measurement as explained in 3.119. Instructions on the use of the 2D test set are given in Section 103-106-105.

A. OVERALL TWO POINT CIRCUIT SINGING MARGIN TEST ARRANGEMENT

B. 2-WIRE STATION SINGING MARGIN TEST ARRANGEMENT
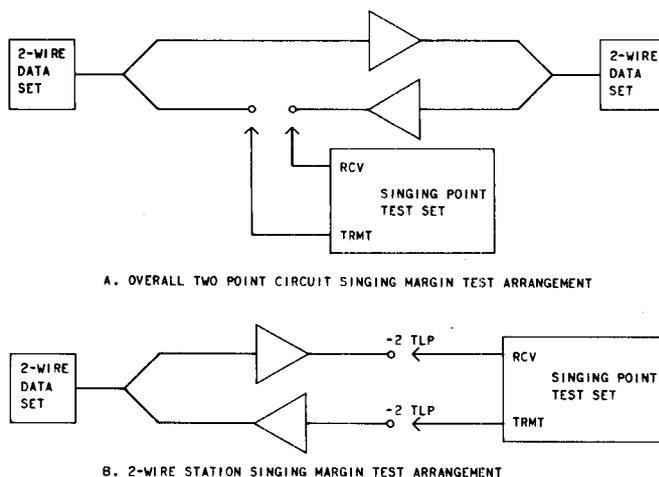
Fig. 10—Singing Margin Test Arrangements

3.124 *Example of Test:* A 2D singing point test set is connected to a circuit at a +7 TLP (A) towards the 2-wire data set and at a −16 TLP (B) receiving from the 2-wire data set as shown in Fig. 11. A 2D set reading of 49 dB (C) is measured which means 49 dB gain is added in the singing point test set to make the circuit sing. The singing margin is 49 − 16 − 7 = 26 dB. Enter this result on Form E-5596, as shown in Fig. 1.

3.125 If 4-wire cable facilities are used out to the customer station and the customer 2-wire data set is connected to the circuit at the levels shown in Fig. 11, it will not be necessary to measure the singing margin of multipoint circuits with up to four stations, since the singing margin requirements will automatically be met by means of the circuit design.

> *Note:* The COMP NET screw on the 1-type terminating set must always be down in order to achieve any return loss, unless an external network is used.

3.126 If singing margin requirements cannot be met, it will be necessary to improve the balance at the term set or change the circuit design. The impedance of the network associated with the term set should match the 2-wire facilities or equipment as closely as possible. If the local loop is 2-wire, a precision network may be required to obtain adequate return loss. Missing load coils, long bridge taps, and frequent changes in gauge may make it impossible to obtain adequate return loss at the CO. A change in 2-wire loop facilities or a 4-wire loop design may be necessary.

3.127 The data set internal impedance should be as close to 600 ohms as possible. Verify that the correct options are used in the data set (and in some cases the DAS) to obtain this impedance. It should be possible to obtain a minimum singing point of at least 12 dB at the term set if the data set is within 40 percent of a resistive 600-ohm impedance across the voiceband. (This assumes that the term set is located at the customer station). The general theory covering singing point tests is given in Section 332-015-100.

3.128 Singing point measurements are made in a manner similar to singing margin measurements. To determine the singing point at the term set perform the following steps:

(1) Connect the singing point test set to the circuit as shown in Fig. 11. Terminate the data station in the same manner as if a singing margin test were being made.

(2) Short the tip and ring leads on the 2-wire line side of the term set.

(3A) If the 2D singing point test set or equivalent set is being used, determine the amount of gain required to make the circuit sing. Record this reading (A) as the reference loss.

(3B) If the KS-20501 RLMS is used, adjust the THL switches to obtain a 0-dB reading on the meter with the ADD DB switch set to 0.

(4) Remove the short from across the term set.

(5A) If the 2D singing point test set is used, readjust the gain of this set until the circuit sings. Record this value (B). The singing point is B − A.

(5B) If the KS-20501 RLMS is used, adjust the ADD DB switch until an on-scale meter reading is obtained. This should be done using both the SRL and SRL-HI switch positions.
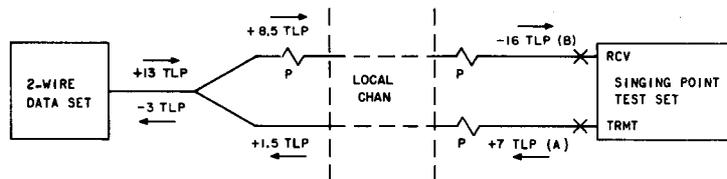
Fig. 11—2-Point and Multipoint Circuit Singing Test Arrangement

Record the value of the sum of the ADD-DB switches and the meter reading which is lowest. This is equivalent to the singing point and no further calculations are required.

3.129 *Example:* The 2D test set was left connected to the circuit shown in Fig. 11 to make a singing point test. Recall that 49 dB of gain was required to make the circuit sing. The 2-wire line side of the term set is shorted to reduce the return loss at the term set to 0 dB. A 2D set reading of 39 dB is required to make the circuit sing. The singing point at the term set is 49-39 = 10 dB. The data set impedance varies from a desired 600-ohm impedance by more than 40 percent. In this example, this would be a problem if the circuit were a multipoint with more than eight 2-wire stations. There would be no problem if the circuit had eight or less 2-wire stations, as the singing margin requirement would have been met through the use of 4-wire loop facilities.

3.130 No action is required when the singing margin requirements are met, regardless of the impedance of the data set. However if singing margin requirements cannot be met and singing point measurements indicate a possible data set impedance problem, the DATEC team should be consulted.

Total Power Output

3.131 The measurement limits for the total signal power are as follows:

Maximum Signal Power from Customer Station Served by STC	−11 dBm0
Maximum Signal Power Toward Customer Station Served by STC	−9 dBm0

3.132 Each STC is responsible for measuring the signal power to and from each customer station which it serves. A high impedance bridged measurement should be taken on an in-service basis where possible.

3.133 A trouble investigation should be started if the limits given in 3.131 are exceeded. These limits are based on the maximum data signal level of −13 dBm0 modified by the permissible long

term loss variation. In the case of excessive signal power from the local (served) customer station, the customer should be asked to check this modem output power. If this does not clear the problem, it may be necessary to dispatch maintenance personnel to confirm that the customer equipment is not exceeding interconnection limits. The effects of extreme temperature variations on aerial cable resistance (and attenuation) and cable cutovers may be responsible for the problem. In either case, some action will be required to limit the total signal power to the above requirements in order to reduce possible loading on Bell System carrier facilities.

3.134 Connect a high impedance noise meter such as the 3A NMS at the MON jack. Select the 3-kHz weighting network and read the level in dBrn. In some cases the NMS may be overloaded by the data signal power, and a pad will be needed to reduce the level. In this case, a 600-ohm terminated measurement must be made. The value of this pad must be added to the results of the measurement. To convert the NMS reading to dBm0, subtract the TLP from the reading taken in dBrn at the point of measurement, then subtract 90.

3.135 *Example of Test:* A reading of 84 dBrn is measured at a TLP of +7 looking towards Station B at the STC serving Station B. This corresponds to 77 dBrn0. To convert this to dBm0, 90 is then subtracted from the dBrn reading of 77 to give a reading of −13 dBm0. This value meets the total power requirement of −9 dBm0, since this is the power going towards the station B end.

3.136 If the signal power is out of limits towards the local (served) customer station, in-service signal power measurements should be made at other STCs in order to determine the source of the excessive signal. On multipoint circuits, particularly with frequency division multiplex equipment, the 3-second average signal power from any individual station may be less than −13 dBm0, but the combined power of all stations at some common point on the circuit could exceed the above limits. Engineering should be advised and given the number of narrowband transmitting locations along with the level in dBm0 measured from each station in order to determine a possible solution.

DC Loop Resistance

3.137 The dc loop resistance of cable pairs or pairs between STC and the customer station

should be measured and recorded on Form E-5596 for use as a benchmark figure in the event of a later trouble condition. The overall requirements are as follows:

MAXIMUM PERCENT CHANGE IN LOOP RESISTANCE

STC-STA	Predominantly Aerial Cable	20%
	Predominantly Underground Cable	5%

3.138 If a trouble condition is suspected on the loop, another dc resistance check should be made (A). This second measurement should be compared as a percentage change from the benchmark measurement (B). The percentage change is:

$$\frac{B-A}{B} \times 100$$

For example, a dc resistance check indicates a present loop resistance of 470 ohms (A). The benchmark measurement indicated a resistance of 490 ohms (B). The percent change is:

$$\frac{490-470}{490} \times 100 = 4.1\%$$

3.139 If the change is greater than the requirement given in 3.137, a trouble investigation of the loop should be made. Verify that cable pair or equipment changes have not taken place since the benchmark measurement was taken. On 4-wire loops a loopback P/AR reading compared against a previous benchmark reading will be useful in verifying that cable pair or equipment substitutions have not been made. If substitutions have been made, it may be necessary to compensate for these changes. Also, it may be necessary to notify Engineering of the condition via lines of organization.

> *Note:* If resistance varies on a short term basis, indicating poor unsoldered pair connections, consider dc sealing current. Refer this problem to Engineering Staff.

3.140 *Example of Test:* The dc loop resistance of the local cable pair is measured using a KS-14510 volt-ohm-milliammeter or equivalent. It

is not required to short the pairs at the customer station since a repeat coil in DAS 828A offers a relatively low resistance between the tip and ring of the cable pair. A dc resistance of 675 ohms is measured on the pair transmitting from the customer station and this value is entered on Form E-5596. Later, following a trouble report, the loop resistance is again measured and reads 700 ohms. The cable pair involved is predominantly underground. The percentage change is:

$$\frac{700-675}{675} \times 100 = \frac{25}{675} = 3.7\%$$

The result shows the change in resistance is within limits and the loop appears to be satisfactory.

4. REFERENCES

4.01 The following documents provide the additional information on facilities and equipment that may be associated with private line voiceband data service.

SECTION	TITLE
AT&T PUB 41003	Analog Parameters Affecting Voiceband Data Transmission—Description of Parameters—October 1971
AT&T PUB 41004	Data Communications Using Voiceband Private Line Channels—October 1973
AT&T PUB 41009	Transmission Parameters Affecting Voiceband Data Transmission—Measuring Techniques—January 1972
EL 1172	Application of Protection to Voicegrade Private Line Data Channels Which Connect to Customer-Provided Equipment
EL 1540	Application of Protection to Voicegrade Private Line Data Channels Which Connect to Customer-Provided Equipment
EL 2333	Application of Protection to Voicegrade Private Line Data Channels Which Connect to Customer-Provided Equipment

NOTES