TRANSMISSION
TEST CONSIDERATIONS
VOICE AND VOICEBAND DATA CHANNELS

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1. GENERAL

1.01 This section provides general information and considerations for transmission tests that are required during installation and maintenance of voice and voiceband data channels. References are frequently made to customer or equipment operation sequences performed on the customer premises equipment (CPE) side of the network interface (NI). These are given to provide a basic understanding of channel operation. Actual responsibilities included in this practice are limited to the network side of the network interface.

1.02 Whenever this section is reissued, the reason(s) for reissue will be given in this paragraph.

PURPOSE OF TRANSMISSION TESTS

1.03 The primary reasons for performing transmission tests are:

(a) To ensure that all the various elements making up a channel are in proper alignment

(b) To verify that the channels meet the transmission requirements and limits specified for which they are designed.

REQUIRED TRANSMISSION TESTS

1.04 Required tests must be made and the test limits met before placing the channel in service. The required tests and limits are identified in Sections 313-100-100 and 313-120-100. Procedures are covered in Sections 313-130-100 for central office (CO) tests and 313-130-101 for customer premises (CP) tests. Additional test procedures for special service networks (SSN) are identified in the appropriate sections in the 309-000-000 division.

2. DEFINITIONS AND DESCRIPTIONS

2.01 The following paragraphs list and describe the terms relating to voice and voiceband data channels and the tests performed on these channels.

A. Voice and Voiceband Data Channels

2.02 The term voice and voiceband data channels replaces the familiar terms ***Private Line*** and ***Special Services*** circuits. The term may be referred to as ***channel*** or ***network channel.*** It identifies the transmission conveyances between two telephone company central office switches, between a CO switch and a network interface at the customer premises, or between two network interface locations at customer premises.

2.03 These channels, when terminating at a customer premises do not include customer premises equipment.

2.04 For simplicity, further reference to these channels will usually be CO-CO for channels between two central offices, CO-CP for channels between a central office and a customer premises or CP-CP for channels between two network interface locations at customer premises.

2.05 These channels are identified by transmission grades. These transmission grades are described in Section 313-120-100.

B. Network

2.06 Network, as used in this section, may be used to identify telephone company personnel, equipment, facilities, and responsibilities.

C. Network Interface

2.07 The network interface is a physical point on a customer premises (eg, connecting block, terminal strip or jack) at which the customer premises equipment can connect to the network. The establishment of this NI serves as a basis for identifying the respective responsibilities between the network and the CPE.

2.08 Voice and voiceband data channels, when extended to a customer premises, will always terminate on a network interface.

D. Customer Premises Equipment

2.09 The customer premises equipment is identified terminal equipment (eg, PBX, station set, data set, etc) located on a customer premises that is not part of a network channel and is separated from the channel by a network interface.

E. End-to-End Tests

2.10 The end-to-end tests are made on the entire channel from NI to NI (eg, for PBX tie trunk channels), from NI to CO test line [eg, for foreign exchange trunk (FT) channels], or from CO test line to CO test line [eg, for common control switching arrangements (CCSA) intermachine trunk channels].

F. Segment Tests

2.11 These are separate tests of portions of a channel such as the loop and the interoffice section. Appropriate test considerations for segments have not been addressed in this section.

G. Benchmark Tests

2.12 Benchmark tests are measurements made on a channel when the channel meets all the required limits. These tests are made immediately following the preservice tests and the results recorded as a reference standard to be used for future routine or trouble testing. When a channel is equipped with a loopback device, benchmark tests may be made through the device.

H. Preservice Tests

2.13 The preservice tests are made before a channel is turned over to a customer to ensure that the channel meets applicable specifications.

I. Trouble Tests

2.14 The trouble tests are made on a channel to verify and locate a known or suspected trouble condition. Also, tests are made to verify that the repair was satisfactorily completed.

J. Parameter

2.15 A parameter is a testable or a measurable electrical characteristic of a channel which expresses performance (eg, loss, slope, noise, etc).

K. Limit

2.16 The limit is the highest and/or lowest values allowed for a measurement. It is implied that some term of corrective action must be implemented if the requirement is exceeded. Preservice, maintenance, and immediate action limits are covered in Section 313-120-100.

3. CHANNEL TESTING

CHANNEL PARAMETERS

3.01 As a result of regulatory actions, terminal equipment has been removed from the channel service offering. The results of this action provide a family of channels with specified transmission and signaling parameters rather than the traditional specific services. The channels are still closely related to the services that they are intended to provide, but it is the channel that is offered, not the specific service.

3.02 Although each channel offered has a list of supported parameters and associated limits, it is not necessary to test every supported parameter during preservice testing. This is because tests of some parameters (eg, frequency shift) are so unlikely to fail and other parameters (eg, envelope delay distortion) are tested when other similar tests such as peak-to-average ratio (P/AR) are performed. These tests would be made as required to isolate troubles.

3.03 Section 313-120-100 specifies the transmission parameters that are required to be measured at channel installation. In response to a trouble condition, or for other necessary reasons, any or all of the specified parameters may need to be measured.

CHANNEL TESTING VS SERVICE TESTING

3.04 In the past, private line channels were tested through terminal equipment to provide test access for transmission, signaling, and supervision of the channel. This type of testing for terminal equipment contributed to the transmission performance of the overall service.

3.05 Since the network is now providing a channel with certain specified capabilities rather than a private line service (such as a PBX tie trunk), the responsibility of the network is to assure the proper operation of the channel only. For a channel terminated at a customer premises, this responsibility ends at the network interface and does not include customer premises equipment.

3.06 Tests must now be made on channels with all customer premises equipment disconnected. The term ***terminal equipment*** does not include network channel terminating equipment (NCTE) such as repeaters, signaling converters, etc, on the network side of the network interface.

3.07 Among other impacts, this means that the CPE equipment can no longer provide signaling and supervision on a channel for testing as in the past. Therefore, testing at the customer premises requires test sets (or auxiliary test sets) capable of sending and receiving the signaling and supervision signals presented at all standard interfaces. See Section 313-110-101 for test simulations.

CHANNEL END-TO-END VS SEGMENT TESTING

3.08 Parameters and limits discussed in this section apply to the overall channel regardless of its terminals (CP-CP, CP-CO or CO-CO). Testing is done to assure (with a high degree of confidence) that a channel meets its specifications. It is not always necessary to measure a channel end-to-end to verify limits of a parameter. In some cases it is more convenient to measure segments of a channel separately.

3.09 Other than dc continuity, a channel should not be broken into arbitrary segments for testing. In particular:

- A channel should not be broken in the middle of a gain- or slope-equalized section (due to the difficulty in determining test limits).
- A metallic voice-frequency (VF) channel should not be broken at an intermediate VF repeater (which might then become unstable).

3.10 Since channels are presently designed end-to-end and not by segment, the designed performance of a segment is not necessarily known. Further, allocation of end-to-end performance limits for segments is difficult.

3.11 To illustrate the problem, each segment limit might be a percentage of the end-to-end limit such that if each segment were at its limit, the overall channel would just meet its requirements. A problem with this scheme is that the requirements on each segment would be unreasonably tight.

3.12 Since it is expected that there would be some cancellation among the random variations in the segments and that not all segments would be at their limits at the same time, it would make sense to make the segment limits broader than suggested above and take advantage of statistics. A problem with this scheme is that there is a chance that all segments might meet their limits with the overall channel failing.

3.13 For these reasons, segment performance limits have not yet been developed. These are the subject of on-going work and will be provided in a later issue.

TRANSMISSION TEST DESCRIPTIONS

3.14 The individual transmission tests for channels are described in the following paragraphs. The transmission test requirements and limits are covered in Section 313-120-100.

A. Listening Tests

3.15 In listening tests, the ear of the tester becomes the discriminating device for sectionalizing trouble in a circuit. Listening tests may be used, also, in the initial verification of the symptom itself.

3.16 If the trouble is distinctly audible and it is possible to distinguish good channel operation from improper channel operation, then the human ear is the ideal trouble detector when aided by the headset or loudspeaker at a testing location. However, too much speaker amplication can be misleading.

B. Continuity

3.17 The most convenient way of testing for continuity is to use a tone generator, oscillator, or transmit portion of a transmission measuring set for transmitting a tone over the channel. Monitor the receive portion of the channel using an earphone, speaker, or receive portion of a transmission measuring set.

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

3.19 Volt/ohm meter tests can also be used for dc continuity checks of equipment and facilities. Voltmeter tests yield the following information concerning equipment and facilities:

- Voltage on tip or ring (See Note.)
- Ground on tip or ring (See Note.)
- Open between tip and ring (See Note.)
- Short between tip and ring (including false shorts) (See Note.)
- Tip and ring shorted to ground (See Note.)
- High or low resistance ground on tip or ring (See Note.)
- Open in tip or ring side of equipment or facility (See Note.)
- Reversal or turnover of tip and ring leads (See Note.)
- Loop capacitance as an indication of loop length.

Note: Includes tip 1 and ring 1, A&B, and simplex (SX) leads, as applicable.

C. Loss

3.20 The 1004-Hz loss test determines that the channel will provide the correct transmission level. The other frequencies in the voiceband are set according to the level established for the 1004-Hz frequency. In other words, the 1004-Hz point in the voiceband of frequencies is selected as the reference point for the channel. The transmission level of the entire channel is referenced to the 1004-Hz frequency. Since the 1004-Hz loss test establishes the actual measured loss (AML) of the channel, no other test should be performed until the 1004-Hz loss test has been performed. Most tests are level sensitive.

3.21 Two functions of the 1004-Hz loss test are: (1) continuity check of the channel (losing the 1004-Hz signal constitutes a loss of continuity, when it occurs in the transmission facility), and (2) deviations from the expected measured loss (EML) or transmission level point (TLP) given on the circuit records must be within prescribed limits, depending on the channel type. Excessive deviations probably indicate that a problem exists in the gain- or loss-producing elements of the channel.

D. Impedance Balance

3.22 Impedance Balance is the measure of an impedance match between channels, or channel components, at the point of their interconnection, or junction. The impedance balance tests determine to what degree transmitted energy is reflected or returned from a junction as echo or singing. The singing return loss (SRL) readings correspond closely with singing point (SP) measurements and, for a given channel, may be considered equivalent.

E. Steady State Noise Test

3.23 The combined background noise created from many sources is called steady state noise. Steady state noise is not a channel engineering parameter, because it is dependent on facility type and length.

3.24 The C-message weighted noise limits for voice channels are measured without holding tone.

3.25 The C-notched noise limits for channels with data capability are measured with a -13 dBm0 or -16 dBm0 holding tone. Noise measured in the presence of a tone can be expressed as dBrnC0 (referred to noise C-message at 0 TLP), or as a ***signal to noise ratio*** because the holding tone provides a common reference value.

3.26 The end objective of the message channel noise tests is to determine the noise level and allow the noise producing components to be isolated and removed or to reduce the noise to an acceptable level. The tests accomplish this by first verifying that the noise exists and is above acceptable levels; and, secondly, the tests can sectionalize the channel by isolating the noise to a particular section of the channel. Sectionalization is accomplished by repeating the noise tests, if necessary, at different test access points for the same channel.

F. Impulse Noise

3.27 Impulse noise is characterized by short interval (less than 4 ms) peaks within, and above the steady state noise spectrum. High level impulse noise hits are a primary cause of errors in data transmission. The magnitude and frequency of occurrence are used to specify a measurable objective.

3.28 Channels are measured with C-message weighting network. Measurements made on compandored carrier systems or mixed compandored and noncompandored systems are made with application of a 1004-Hz holding tone at -13 dBm0 or -16 dBm0 applied at the distant end.

3.29 Some test equipment includes multiple counters that can be set for simultaneous measurement at several threshold levels. This feature is useful for determining the margin available around the objective threshold, and allows measurement at maintenance and immediate action thresholds at the same time.

G. Three-Tone Slope Test

3.30 The 3-tone slope tests are made for two frequencies other than 1004 Hz. The lower test frequency is 404 Hz and the upper test frequency is 2804 Hz. The measured levels for each of the test frequencies are said to deviate from the measured 1004-Hz level by having more or less loss in dB.

3.31 Normally, in designing the channel, consideration is given to the fact that higher frequencies suffer greater loss in cable pairs than do the lower frequencies; thus, lower frequencies often have less loss in the channel than does the 1004-Hz frequency used as the reference point. Equalization networks usually compensate the frequency response of the channel by adding sufficient loss to the lower frequencies, bringing their levels into the required limits.

3.32 Poor frequency response degrades the voice-frequency transmission. If the deviations from the 1004-Hz level are great enough at the other frequencies in the voiceband, then distortions occur to the voice signal and may cause it to become difficult to understand.

H. Phase Jitter

3.33 The phase jitter test is used to determine the instantaneous phase, or zero crossings, of a signal. The jitter rates are normally less than 300 Hz. This phase jitter is typically caused by ripple in the dc power supply appearing in the master oscillator of long-haul carriers and then passing through many stages of frequency multipliers. Some phase jitter occurs in short-haul systems from incomplete filtering of image sidebands. Digital carrier systems also will exhibit phase jitter at certain input frequencies. The most common jitter frequencies are 20 Hz (ringing current) and 60 Hz (commercial power) and the second through fifth harmonics of each of these.

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

3.35 An earlier standard limiting band was 20 to 300 Hz and is referred to as ***Bell.***

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

- BELL = 20- to 300-Hz Range
- LF = 4- to 20-Hz Range
- BELL PLUS LF = 4- to 300-Hz Range.

I. Peak-to-Average Ratio

3.37 The peak-to-average ratio measurement, after having gone through four generations of implementation, has been demonstrated to be an effective tool in uncovering problems in attenuation distortion, envelope delay distortion, and return loss. It provides a means for rapid evaluation of these three parameters. It is essentially impervious to other impairments when they are within normal limits. Acceptable P/AR, together with acceptable slope measurements, provide a better than 99-percent assurance factor of acceptable attenuation distortion, return loss, and envelope delay distortion measurements. The P/AR alone can provide a 97-percent assurance factor.

3.38 The P/AR limits are strongly tied to the types of facilities used in channel makeup. This is primarily because the filters in channel banks of different facilities are not all alike and hence have different amounts of envelope delay distortion.

3.39 The P/AR rating measurement system consists of a transmitter and a receiver connected to opposite ends of a voiceband channel. The transmitter sends a precisely controlled complex pulse train of known peak-to-full-wave average ratio (10 dB) through the channel, where each pulse is altered by the distortions it encounters. The P/AR receiver measures the absolute peak and full-wave rectified average values of the pulse train and displays their ratio on a zero-suppressed scale with a range of 0-120 P/AR units.

3.40 The P/AR test may be used in place of attenuation distortion and envelope delay distortion if done overall on a 2-point channel, on trunks, or end links and midlinks of multipoint channels. This does not apply to (C) conditioned channels.

3.41 A practical use for P/AR is to obtain and record benchmark readings during preservice tests, or at a time when other tests have proven a channel to be within requirements. Future readings that exceed ±4 P/AR units from the initial reading will indicate trouble in one of the three parameters that P/AR evaluates (envelope delay distortion, attenuation distortion, or return loss). Use of the P/AR benchmark is particularly appropriate for loopback measurements.

J. Attenuation Distortion

3.42 Attenuation distortion is the term used to describe measurement of a channel's frequency response relative to its 1004-Hz loss. It is normally measured in 200-Hz increments over the band of interest to provide reasonable assurance that no irregularities exist which could affect data transmission.

3.43 The measured levels for each of the test frequencies are said to deviate from the measured 1004-Hz level by having more or less loss in dB. Normally, in designing the channel, consideration is given to the fact that higher frequencies suffer greater loss in cable pairs than do the lower frequencies; thus, lower frequencies often have less loss in the channel than does the 1004-Hz frequency used as the reference point. Equalization networks usually compensate the frequency response of the channel by adding sufficient loss to the lower frequencies, bringing their levels into the required limits. In order that the volume level of the channel remains high enough when this loss is added, the original channel design increases the gain proportionately.

K. Intermodulation Distortion

3.44 The term intermodulation distortion describes the current method of measuring channel nonlinearity. This test is accomplished by transmitting four equal level tones arranged in two pairs.

3.45 This measurement technique has been recommended because the amplitude distribution of the test signal closely approximates a typical high-speed data signal. In addition, the multitone technique provides a more stable measurement of the channel nonlinearities (which are frequency dependent and time variable) than the earlier two-tone approach. Harmonic distortion measurements are no longer specified and use of single-tone and two-tone test equipment must be avoided.

L. Gain Hits

3.46 Gain hits are sudden variations in signal amplitude, equal or greater than 3 dB, and lasting more than 4 ms.

M. Phase Hits

3.47 Phase hits are abrupt variations in signal phase, equal or greater than 20 degrees, and lasting more than 4 ms.

N. Dropouts

3.48 Dropouts are a decrease in level equal or greater than 12 dB, and lasting more than 4 ms. Deep fading of radio facilities and defective components can cause dropouts. Since dropouts tend to be long with more than 40 percent in excess of 200 ms, they frequently are responsible for serious performance degradations.

O. Single Frequency Interference

3.49 Spurious single frequency tones may interfere with some data transmission schemes, particularly narrowband frequency division multiplexed signals used in some remote metering and other similar parallel data systems. If single frequency tones are heard during steady state noise listening tests, their level should be measured with a frequency selective voltmeter.

P. Frequency Shift

3.50 Many carrier systems operate in a single sideband suppressed carrier mode. The modulating carrier is not transmitted, so a demodulating carrier of the same frequency must be reinserted at the receiving end. Most currently used systems have very sophisticated methods for synchronizing carrier frequency sources, but if a difference is encountered, it would result in a shift of all voiceband frequencies. This shift may degrade some types of data transmission systems.

Q. Envelope Delay Distortion

3.51 Some data transmission systems require control of the phase versus frequency characteristic. Measuring this characteristic directly is difficult because of problems in establishing a phase reference. A usable approximation of phase versus frequency, called envelope delay, can be measured more easily. The variation in envelope delay over a band of frequencies is called envelope delay distortion. The quality of the channel with respect to its phase characteristic is controlled by limiting the amount of envelope delay distortion.

BENCHMARKS

3.52 Benchmarks are measurements made on a loopback or one-way basis when the channel is known to meet all requirements. They are performed immediately following the completion of preservice tests. The results are recorded for later reference purposes.

3.53 For trouble testing, benchmark-type measurement should be made and compared to the benchmarks made during preservice testing. Admittedly, without specified limits (allowable deviation from these benchmark test results), it will be difficult to locate small troubles.

3.54 Section 313-120-100 lists limits and parameter tests for benchmark measurements.

3.55 The ***benchmark tests*** are described in the following paragraphs.

A. Continuity

3.56 The dc loop resistance of cable pairs between the customer premises and a test center or the first appearance of CO channel or carrier equipment should be measured and recorded for use as a benchmark figure in the event of a later trouble condition.

B. 1004-Hz Loss

3.57 Following preservice overall tests, a benchmark measurement of the 1004-Hz loss between the network interface and the test center should be made and recorded for future trouble isolation.

3.58 If the nature of the channel design does not provide for test point access in the CO (ie, not routed through a test center or uses intermediate E6 repeaters or Metallic Facility Terminal (MFT) 2-wire repeaters], the end-to-end 1004-Hz benchmark measurement will replace the sectionalized benchmark measurement.

C. Channel With Loopback Devices

3.59 The use of 4-wire local loops and the need for faster trouble isolation has made it necessary to install loopback devices on many voiceband data channels.

3.60 There are several common types of loopbacks in use today. These loopback devices should be used whenever possible for measuring benchmarks.

D. Channels Without Loopback Devices

3.61 Most voice channels utilizing 4-wire local channels and interoffice facilities are installed without a loopback device located on the customer premises. Both the initial benchmark measurement and subsequent benchmark measurement for trouble isolation will require the assistance of an installation/repair person at the customer premises.

3.62 If the nature of the channel design does not provide for easy-access test points in the CO (ie, channel not routed through a service center, no intermediate 4-wire repeaters or frame cross-connection only), the overall 1004-Hz measurement will replace the sectionalized benchmark measurement.

E. Peak-to-Average Ratio

3.63 The peak-to-average ratio means for rapid evaluation of attenuation distortion, and return loss. When the attenuation distortion and return loss is within limits the P/AR is essentially not affected by other impairments.

3.64 During the preservice overall tests, P/AR benchmark tests should be made and recorded for all channels intended for data capability.

F. Three-Tone Slope

3.65 Three-tone slope is the differential loss between 404 and 1004 Hz, and between 2804 and 1004 Hz. The 3-tone slope measurement is used in conjunction with the P/AR measurement.

3.66 During the preservice overall tests, 3-tone slope benchmark tests should be made and recorded for all channels.

4. TROUBLE SYMPTOMS

4.01 Even with adequate and comprehensive channel preservice and trouble testing programs there will be occasions when trouble is reported. When this occurs, it will be necessary to determine the cause of the problem through methodical and logical testing of the channel. This can only be done by persons having knowledge of the channel components involved.

REPORTED TROUBLES

4.02 The type of out-of-service tests and the order in which they are performed will depend on the nature of the suspected trouble condition or trouble report. Examples of these trouble reports are:

- Cannot hear - cannot be heard/weak
- Cannot send or receive data or both
- Data errors
- Dead line
- Fading
- Hollow sounding
- Howling or singing
- Noisy/cross talk
- Parameters out of limits.

4.03 Many times, the customer will not report troubles in the above terms that are readily understood by telephone company forces. The report received and the trouble actually found may not agree at all.

COMMON CAUSES

4.04 By obtaining as many details as possible and by understanding the operation of the channel, much unnecessary testing may be eliminated. The following paragraphs 4.05 through 4.16 are common causes to trouble symptoms.

A. Cannot Hear or Cannot Be Heard or Weak

4.05 The probable cause is in the gain or loss producing components of the circuit such as pads, repeaters, or carrier facilities. This symptom can be caused by shorts (including high resistance), open on one side of the loop, bad splices, open coil, and many other primarily mechanical defects. These causes are less likely, however, if the signal is weak. If the far end can hear the voice transmission, even weakly, then the problem implies that the circuit power level is too low.

4.06 This condition may indicate that a single frequency (SF) unit, if one is used in the circuit, may not be cutting off the SF tone when the called party answers. If the near end ***cannot be heard,*** the SF unit in the near end office may be sending SF tone to the far end preventing voice transmission in that direction.

B. Cannot Send or Receive Data In One or Both Directions

4.07 This type of trouble encompasses many common categories of suspected trouble symptoms. The four most probable causes are (1) customer or connecting entities equipment, (2) lack of continuity between NIs, (3) excessive 1004-Hz loss or gain to the network channel, or (4) excessive noise in the channel.

4.08 The priority list of parameter tests to be performed during preservice or customer trouble reports are given in Section 313-120-100. The highest ranked parameter should be measured first. The exception to this rule is the P/AR measurement. If the P/AR is found out of limits, then attenuation distortion, envelope delay distortion, and return loss should be measured to find the specific parameter in trouble.

C. Data Errors

4.09 The customer's report of data errors could encompass trouble on both sides of the NI. Once the tester is reasonably satisfied as to the operational status of the equipment/facilities on the customer's side of the NI, then network trouble tests are to be performed.

4.10 Usually with this type of trouble report, the fact that only ***errors*** are being reported may reasonably indicate that continuity is established between the NIs and this continuity test can be omitted.

4.11 It should be noted that we do not support error rate as such, but we will ***support analog parameters and these parameters are what we should test.***

D. Dead Line

4.12 This symptom generally indicates a lack of channel continuity in either the transmission path, supervision path, or both. Listening, continuity, and 1004-Hz loss tests should be performed in that order to determine what and where the channel is defective.

E. Fading

4.13 One cause of fading is probably symptomatic of carrier power level variations. Fading may occur at a specific frequency, but it is more likely that the decrease in volume will occur across the entire voiceband. Carrier level deviations causing fading probably affect the entire carrier channel group. A rushing sound usually accompanies fading of this type, since the lower level of the voice transmission creates a worse signal-to-noise (S/N) ratio. (The effect of the noise component is greater). Fading can be caused by the effects of weather, especially when a microwave facility is involved. Another possible cause of fading is a defective NCTE power supply at the customer premises.

F. Hollow Sounding

4.14 The hollow sound in the voice channel, often resembling the sound in a tunnel or barrel, indicates a near-singing condition in the channel. This can be due to impedance mismatch at the interface between a 2-wire and 4-wire facility or excessive gain. Loss tests should be first taken, then followed by impedance balance tests.

G. Howling or Singing

4.15 Excessive gain is usually the cause of this channel condition. It is also possible that there is an impedance mismatch at the 2- to 4-wire junction. If the channel design and prescription settings of the balance network are correct, the network should not need adjustment. However, errors in design or preservice, mistakes in subsequent adjustments, or a change in facilities may require that the balance network be adjusted.

H. Channel Noise

4.16 Channel noise disturbs the normal operation of the channel. The primary types and causes of channel noise are listed as follows.

(a) ***Babble or Crosstalk:*** Crosstalk usually describes unwanted speech in special service channels. It may describe intelligible words and phrases, but may also be present as unintelligible ***babble*** from multiple sources. It may be produced by excessive carrier or repeater gain, misalignment of carrier facility, induction between adjacent cable pairs or channels, even solder splashes or wire clippings across frame termination lugs. Babble may include modulation products of carrier frequency crosstalk, and may also include intermodulation products. Signaling tones, data, etc, transmitted at voice frequencies also appear as crosstalk.

(b) ***Clicks:*** Digital carrier systems may introduce clicks or pops when loss of frame occurs below the threshold level for trunk processing.

(c) ***Frying:*** Metal parts coming into contact with wire or switch contacts which carry current will create a noise which resembles frying. Another, and quite common source of frying noise is produced from the compacting of carbon granules of the carbon transmitter of a handset or headset. Wet cable, ***cold*** solder joints and bad splices are potential sources of ***frying.***

(d) ***Hissing:*** Hissing describes the effect of thermal noise which originates in components working at elevated temperatures such as electron tubes and resistors.

(e) ***Hum:*** Hum usually describes the audible effect of 60 Hz or the odd harmonics of 60 Hz interfering with the voice frequencies in the transmission path. When more than one 60-Hz harmonic is present, as frequently happens in the case of inductive interference, they may ***beat*** to produce variations in amplitude, pitch, or both. It may be caused by an improper ground or short. Possible excessive gain can cause this symptom. Hum may also apply to dial tone and to other sustained low-frequency sounds occasionally heard as noise.

(f) ***Impulses:*** Impulses are sharp clicks that rise substantially above the other noise. The following general sources introduce impulse noise in transmission circuits: (1) Sources inherent to a system, such as switch contacts used to complete the connection; (2) Noise induced through common leads (eg, battery supply and control leads); and (3) Induction from transients in other nearby equipment, facilities, or channels (eg, switching transients, telegraph channels), or from environmental factors such as electrical storms. Both disturbing and disturbed channels usually interfere because they are unbalanced, poorly matched or terminated, or poorly shielded from each other. Digital carrier system ***errors*** will also cause impulse noise and this is becoming a major source of noise because of the increased use of digital carrier. Additional impulse noise information can be found in Section 331-200-100.

(g) ***Intermodulation:*** Intermodulation describes a number of noise sounds produced by the many complex frequencies present in analog carrier systems. These sounds may resemble babble, hiss, and even at times be impulse-like. Intermodulation increases as the system load increases.

(h) ***Microphonics:*** Microphonics are usually low-pitched bell-like sounds generated within electronic tubes. Tapping a tube may cause microphonics and is often used as a test. Microphonics can also be caused by burnt relay switch contacts or insufficient contact pressure.

(i) ***Singing:*** Howling repeaters frequently introduce tones into the transmission path. Two or three tones of closely related pitch or frequencies may ***beat*** to produce variations in pitch, amplitude, or both.

(j) ***Static:*** Static originally referred to the cracking-popping sound produced, especially in amplitude modulation radio sets by near lightning discharges. Sources of static in addition to atmospheric noise include high voltage discharges in electrical equipment. It may arise as direct induction at voice frequencies, or may be demodulated from higher frequencies.

(k) ***White Noise:*** Normal facility background or ***white*** noise makes a ***rushing*** or ***hissing*** sound in the telephone receiver. It is partially produced as thermal noise from environmental causes and from heated components. It will usually isolate to an analog carrier facility.

5. PROBABLE SOURCES OF IDENTIFIED TRANSMISSION IMPAIRMENTS

5.01 Network personnel responsible for clearing impairments to voiceband analog data transmission services are being provided with more sophisticated testing tools which can identify specific transmission impairments reported by the customer.

5.02 Table A identifies the probable source of transmission impairments, Table B defines the transmission impairments and Table C identifies the trouble identification codes. These are designed to assist in sectionalization and troubleshooting the impaired parameter. Transmission parameters which can affect channel performance are listed at the top of the tables and the various equipment and facilities which could be used in the connection are shown on the left side of the tables.

5.03 The probability is listed for each facility/equipment for each parameter where information is available. The probabilities assume that the channel loss is correct, and they are shown as high, medium, low, and a dash to indicate no probability. A blank entry indicates insufficient data at this time to estimate a probability. In some instances, numbered codes indicate a known trouble condition which, if present, would cause the probability to be low, medium, or high. This indicates the probability that the condition of the code will occur.

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

5.05 Subsequent issues of Table A will be modified based on actual field experience with its use. Codes will be added as new failure modes are identified, and codes will be deleted as field modifications to eliminate trouble conditions are completed.

6. GLOSSARY OF TERMS

6.01 The following abbreviations (terms) are used in this section.

TERM	DEFINITION
AML	Actual Measured Loss
CCSA	Common Control Switching Arrangements
CO	Central Office
CO-CO	Central Office - Central Office
CO-CP	Central Office - Customer Premises
CP-CP	Customer Premises - Customer Premises
CP	Customer Premises
CPE	Customer Premises Equipment
EML	Expected Measured Loss
FT	Foreign Exchange Trunk
LF	Low Frequency
MFT	Metallic Facility Terminal
NCTE	Network Channel Terminating Equipment
NI	Network Interface
P/AR	Peak-to-Average Ratio
SF	Single Frequency
SP	Singing Point
S/N	Signal-to-Noise
SSN	Special Service Network
SRL	Singing Return Loss
SX	Simplex
TLP	Transmission Level Point
VF	Voice Frequency

7. REFERENCES

7.01 The following sections contain additional information about voice and voiceband data channels.

SECTION	TITLE
313-100-100	General Introduction- Installation and Maintenance Voice Voiceband Data channels
313-110-101	Signaling—Test Considerations—Voice and Voiceband Data Channels
313-120-100	Transmission—Requirements and Limits—Voice and Voiceband Data Channels
313-120-101	Signaling—Requirements and Limits—Voice and Voiceband Data Channels
313-130-100	Central Office—Transmission and Signaling Test Procedures—Voice and Voiceband Data Channels
313-130-101	Customer Premises—Transmission and Signaling Test Procedures—Voice and Voiceband Data Channels
331-200-100	Impulse Noise—Requirements and Measurement
463-400-100	Registration Interface—Selection and General Information

TABLE A

PROBABLE SOURCE OF TRANSMISSION IMPAIRMENTS (NOTES 1, 2, AND 3)

FACILITY OR EQUIPMENT (NOTE 4)	IMPAIRMENTS: LEVEL VS							NOISE		INTER-MODULATION		PHASE JITTER		MODULATION	TRANSIENTS			
	TIME	LOSS	FREQ	3-TONE SLOPE	EDD	IMP BAL	P/AR	C-NOTCH	SINGLE FREQ	2ND	3RD	BELL	LOW FREQ	FREQUENCY SHIFT	IMP NOISE	PHASE HIT	GAIN HIT	DROP OUT
Loop Plant																		
Cable With Sealing Current	—	—	M	M	M	M	L	L	L	—	—	—	—	—	M	—	—	—
Cable Without Sealing Current	L	—	M	M	M	M	L	M[1]	L	—	—	—	—	—	M[1]		M[1]	H[1]
Data Aux Sets 828 or 829	—	—	L[2]	L	L	L	L	L	L	L	L	—	—	—	L	—	—	—
Subscriber Loop Carrier System																		
SLC* 8	—	H[3]	M[4]	L	M[4]	L	L	L	L	M	L	—	—	—	L	—	L	—
SLC 40	L	M	L	L	L	L	L	H[7]	M	M	M	L	L	—	M	L	L	L[5]
SLC 96	M[6]	L	L	L	L	L	L	M	L	L	L	L	L	—	M	L	L	L[5]
Terminating Equipment																		
Repeaters E6, E7	—	—	L[8]	L[8]	L	L[8]	L	L	L	L	L	—	—	—	L	—	—	—
44, V4	—	—	L	L	L	—	L	L	—	L	L	—	—	—	L	—	—	—
44 MFT	—	—	L	L	L	—	M	L	—	L	M	—	—	—	L	—	—	—
22, 24 V4	—	—	L	L	L	L	L	L	—	L	L	—	—	—	L	—	—	—
22, 24 MFT	—	—	L	L	L	L	L	L	—	L	M	—	—	—	L	—	—	—
Hybrid	—	—	M[9]	L[9]	M[9]	L[9]	M[9]	—	—	—	—	—	—	—	—	—	—	—

See notes at end of table.

TABLE A (Contd)

PROBABLE SOURCE OF TRANSMISSION IMPAIRMENTS
(NOTES 1, 2, AND 3)

FACILITY OR EQUIPMENT (NOTE 4)	IMPAIRMENTS																	
	LEVEL VS			3-TONE SLOPE	EDD	IMP BAL	P/AR	NOISE		INTER-MODULATION		PHASE JITTER		MODULATION	TRANSIENTS			
	TIME	LOSS	FREQ					C-NOTCH	SINGLE FREQ	2ND	3RD	BELL	LOW FREQ	FREQUENCY SHIFT	IMP NOISE	PHASE HIT	GAIN HIT	DROP OUT
SF (2600HZ) Signaling																		
E	—	L	L[10]	L[10]	L[10]	M[12]	L[10]	L	L	M[11]	M[11]	—	—	—	L	—	—	L
F	—	—	M[10]	L[10]	L[10]	—	L[10]	L	L	L	L	—	—	—	L	—	—	L
G	—	—	L[10]	L[10]	L[10]	—	L[10]	L	L	L	L	—	—	—	L	—	—	L
Analog Carrier																		
ON	M	H[13]	H[20]	H[15]	M	—	M	H[15]	L	M	M	L	L	L	M	L	L	L
N1	M	H[13]	H[15]	H[15]	M	—	M	H[15]	M	H[16]	L	M	L	H[14]	L	L	L	
N2	M	H[13]	M	M	L	—	L	M	L	M	L	L	L	—	M	L	L	L
N3	M	H[13]	L	L	M	—	M	L[17]	M[18]	M	M	M[19]	M[19]	M	M	M[19]	L	L
N4	L	H[13]	L	L	L	—	L	M	M[18]	M	L	L	L	M	L	L	L	L
Channel Banks																		
A4	L	L	M	L	L	L	L	L	L	L	L	M	M	L	L[20]	H[20]	L	L
A5	L	L	M[24]	L	L	L	L[24]	L	L	L[24]	L	L	M	L	L[20]	H[20]	L	L
A6/DFSG	L	L	M	L	L	L	L	L	L	L	L	L	L	L	M[20]	H[20]	L	L
LMX/MMX	L	L	M[23]	L	M[23]	—	L[23]	L[25]	M[26]	M[27]	M[27]	M[28]	M[28]	M[33]	M[20]	M[28]	M[30]	M[30]
Microwave Radio	H[31]	M[31]	—	—	—	—	—	M[31]	M[31]	M[31]	M[31]	M[31]	—	—	H[32]	H[32]	H[32]	H[29]
LT-1	M[6]	L	L	L	L	—	L	M	M	L	L	L	L	L	M[21]	L	L	L[33]

See notes at end of table.

TABLE A (Contd)

PROBABLE SOURCE OF TRANSMISSION IMPAIRMENTS (NOTES 1, 2, AND 3)

FACILITY OR EQUIPMENT (NOTE 4)	IMPAIRMENTS: LEVEL VS							NOISE		INTER-MODULATION		PHASE JITTER		MODULATION	TRANSIENTS			
	TIME	LOSS	FREQ	3-TONE SLOPE	EDD	IMP BAL	P/AR	C-NOTCH	SINGLE FREQ	2ND	3RD	BELL	LOW FREQ	FREQUENCY SHIFT	IMP NOISE	PHASE HIT	GAIN HIT	DROP OUT
Digital Carrier																		
D1A, D1B, D1C	M[6]	M	L	L	L	—	L	H[22]	M	H[43]	M	L	L	—	M[21]	L	L	L[5]
D1D, Hardened	M[6]	L	L	L	L	—	L	M	L	L	L	L	L	—	M[21]	L	L	L[5]
D2	H[6]	M	L	L	L	—	L	M	L	L	L	L	L	—	M[21]	L	L	L[5]
D3, D4	M[6]	L	L	L	L	—	L	M	L	L	L	L	L	—	M[21]	L	L	L[5]
Echo Suppressors																		
Analog 3A, 4A	—	—	—	—	—	—	—	L	—	L	L	—	—	—	—	—	—	L[35]
Digital	—	—	—	—	—	—	—	L	—	L	L	—	—	—	—	—	—	L[35]
TASI																		
A	M[6]	M[36]	L[36]	L[36]	M[36]	—	M	M[36]	M	M	M	—	—	—	H[34]	L	M	M
B	L[37]	L[36]	L[36]	L[36]	L[36]	—	L	H[36]	M	M	M	—	—	—	M	L	L	L
E	M[6]	L[36]	L[36]	L[36]	L[36]	—	L	M[39]		M	M	L	L	—	M[32]	L	L	L[5]
Satellite Comstar	L	L	L	L	M[38]	M[38]	M	L	L	L	L	L[28]	L[28]	M	L	M	M	M
Switching Equipment																		
SXS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	H[40]	—	L[40]	L[40]
Crossbar	—	—	—	—	—	—	—	—	—	—	—	—	—	—	M	—	—	—
No. 1 ESS, 2W	—	—	—	—	—	—	—	—	—	—	—	—	—	—	L	—	—	—
No. 1 ESS, 4W HILO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	M[42]	—	—	—
No. 2 ESS, No. 3 ESS, No. 4 ESS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	L	—	—	—
No. 4 ESS W/VIUs	M[6]	L	L	L	L	L	L	M	—	L	L	L	L	—	L	L[41]	L	L[5]

See notes at end of table.

TABLE A (Contd)

PROBABLE SOURCE OF TRANSMISSION IMPAIRMENTS (NOTES 1, 2, AND 3)

Note 1: Following are the definitions of symbols used in this table: H = High, M = Medium, L = Low, — = No

Note 2: Table B contains definitions and descriptions of impairments (column headers).

Note 3: The numbers shown above and to the right of some of the symbols refer to transmission impairment codes included in Table C to indicate probable cause of the impairment.

Note 4: Following are definitions of equipment abbreviations:

AUX	=	Auxiliary
COMSTAT	=	Communications Satellite Corporation
DFSG	=	Direct Formed Supergroup Bay
ESS	=	Electronic Switching System
LMX	=	L-Carrier Multiplex
MFT	=	Metallic Facility Terminal
MMX	=	Mastergroup Multiplex Terminal Bay
SF	=	Single Frequency
SXS	=	Step-By-Step
TASI	=	Time Assignment Speech Interpolation
VIU	=	Voicebnd Interface Unit

*Trademark

TABLE B

DEFINITIONS AND DESCRIPTIONS OF IMPAIRMENTS

IMPAIRMENT	DEFINITION AND/OR DESCRIPTION
Level vs Time	Level variation with time. Obvious level fluctuations observable on a standard level measuring set within 15 seconds observation.
Level vs Loss	Variations in channel loss with the level of the input signal, such as level tracking and compandor tracking.
Level vs Frequency	Level variations versus test-tone frequency variation, such as attenuation distortion.
3-Tone Slope	Level measurements made at 404 Hz, 1004 Hz, and 2804 Hz. This is a special case of LEVEL vs FREQUENCY.
EDD	Envelope delay distortion — This is a variation of envelope delay over a band of frequencies.
IMP BAL	Impedance Balance — This is a measurement of random noise in three standard frequency bands.
P/AR	Peak-to-Average Ratio — This is a measurement to determine the suitability of a voiceband channel for data transmission. The P/AR measures the simultaneous effects of envelope delay distortion, attenuatin distortion and poor return loss on the voiceband data signals.
Noise	
C-Notch	Noise measured with a 1004-Hz holding tone on the channel.
Single Freq	Single frequency noise — This is interference present if a single tone, other than a harmonic of a holding tone (if present), is the primary contributor to the measured noise.
Phase Jitter	
Bell	Bell phase hitter — Phase jitter on a facility measured with a 20- to 300-Hz bandwidth around a holding tone of 1 kHz.
Low Frequency	Low frequency phase jitter is in the band below 20 Hz around a 1-kHz holding tone.
Transients	
IMP	Impulse noise is large excursions on the received signal which are higher than the normal peaks of message channel noise.
Phase Hits	Changes in the normal phase of a channel which exceed a preselected threshold of at least 4 milliseconds.
Gain Hits	Changes in nominal loss of a channel which exceed a preselected threshold of at least 4 milliseconds.
Drop Out	A dropout is a negative gain hit of at least 12 dB.

TABLE C

TROUBLE IDENTIFICATION CODES

CODE	TROUBLE CONDITIONS FOR TRANSMISSION IMPAIRMENT TABLES
1	Oxidized cable splices, half of which can be fixed with application of sealing current. See EL 4504, 3/17/76.
2	Misadjusted equalizers on installation.
3	Syllabic compandors used in Subscriber Loop Carrier.
4	Edge channels only in Subscriber Loop Carrier.
5	25- to 50-millisecond dropout on reframing; lightning, for example.
6	Level fluctuations will be exhibited at test frequencies which are integral submultiplexes of the 8000-Hz sampling rate.
7	Adaptive delta modulation gives poor (25 dB) signal-to-noise ratio for data signals with frequency components.
8	Equalizers not properly adjusted at installation.
9	Precision balance networks improperly set at installation.
10	2600-Hz band rejection notch improperly impressed on channel after cut-through.
11	E-type single-frequency signaling units typically do not meet D-1 intermodulation distortion requirements.
12	If the condition of CODE 10 occurs for E-type single-frequency units, the return loss is poor even in the 4-wire application.
13	Syllabic compandors used in Analog Carrier.
14	If engineered for the earlier longer span between repeaters.
15	Aging of vacuum tubes. Tubes should be replaced with hybrid integrated networks.
16	Facilities immediate action limits are only R2 = 26 dB, R3 = 30 dB.
17	If the N3 compandor applique for operator service trunks is applied to long haul facilities.

TABLE C (Contd)

TROUBLE IDENTIFICATION CODES

CODE	TROUBLE CONDITIONS FOR TRANSMISSION IMPAIRMENT TABLES
18	4000-Hz carrier.
19	Faulty Frequency Corrector Unit (described in EL 2497,8/9/73).
20	Swiching transient effects in adjacent channels of L-carrier multiplex-2 (LMX-2).
21	Strikes on a T-Carrier link.
22	Immediate action limit for signal-to-noise is only 24 dB.
23	Edge channels only in LMX-Mastergroup Multiplex (MMX) Systems.
24	Ferrite slug in the 561K filter comes unglued, causing loss.
25	When LMX channels 6 and 7 are used for program, the Program Blocking Filter roll-off is not sufficient to stop interference in channels 5 and 8.
26	Intermodulation products from hot tones in other channels.
27	Intermodulation will occur on some LMX-2 channels.
28	LMX-1 primary frequency converter with 4 kHz and 128 kHz feeds from different primary frequency supplies or low frequency variations in power feeds to LMX or MMX bays.
29	30-millisecond dropout due to protection switch on microwave facility caused by instantaneous loss of signal rather than fading.
30	228D, 231D, or 231E amplifiers sensitive to battery voltage transients.
31	During periods of fading on the microwave links.
32	Protection switching on microwave channels.
33	Loss of synchronization by the 2-type primary frequency supply.
34	Needs routing for adjacent channel crosstalk.

TABLE C (Contd)

TROUBLE IDENTIFICATION CODES

CODE	TROUBLE CONDITIONS FOR TRANSMISSION IMPAIRMENT TABLES
35	Occasionally, high impulse noise or high longitudinal noise causes false suppressor operation.
36	Time assignment speech interpolation is energy-actuated, so test tones must be continuous.
37	Will exhibit level fluctuations at test tones which are integral submultiples of 10-kHz sampling frequencies.
38	Long 300-millisecond echo delays aggravate hybrid unbalance problems.
39	Noise matching circuits may put on noise when disconnected which matches noise level of power line hum when connected.
40	Mechanical shaking of step-by-step (SXS) switch due to release of adjacent SXS switches. See EL 4205, 1/16/76.
41	Phase hits occurring at periodic intervals as a result of clock slippage between No. 4 Electronic Switching System and downstream T carriers.
42	3-wire equivalent of 4-wire circuit: crosstalk spikes caused by false cross and ground checks.
43	High intermodulation distortion caused by high level signals in adjacent channels.