

**DATA GENERAL**  
**ANALOG TRANSMISSION PARAMETERS DESCRIPTION**  
**DATA TRANSMISSION SYSTEMS**

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**1. GENERAL**

**1.01** This section describes the parameters, terms, and abbreviations associated with data transmission that are common to private line (PL) channels, the Public Switched Network (PSN), and Switched Services Networks (SSN).

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

**1.03** This section augments the following Bell System Practice (BSP) layers:

- 309-200-ZZZ—Switched Services Networks Using Central Office Switching Machines
- 309-300-ZZZ—Enhanced Private Switched Communications Service (EPSCS)
- 309-400-ZZZ—Electronic Tandem Network (ETN)
- 314-205-ZZZ—DATAPHONE® System—Transmission Maintenance, Loops, and Trunks

● 314-410-ZZZ—Private Line Data Circuits

Information specific to any of the systems or networks is located in the respective layer.

**2. ABBREVIATIONS AND COMMON TERMS**

**2.01** This part provides abbreviations and common terms used in voice bandwidth data service as well as definitions of unique terms.

**A. Abbreviations**

**2.02** A listing of abbreviations that may be encountered in data service and circuit terminology is as follows:

- AML—Actual measured loss
- BER—Bit error rate
- BIT—Binary digit
- BLER—Block error rate
- CCSA—Common control switching arrangement
- CLR—Circuit layout record
- CO—Central office
- CPE—Customer provided equipment
- CRT—Cathode-ray tube
- DAS—Data auxiliary set
- DATEC—Data technical support
- DS—Data set
- DTS—Data test set

**NOTICE**

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Bell System except under written agreement

EML—Expected measured loss  
FCC—Federal Communication Commission  
HPDC—High-performance data conditioning  
LC—Local channel  
MODEM—Modulator-demodulator (data set)  
NCO—Network control office  
OCC—Other common carrier  
OTC—Operating telephone company  
PCO—Plant control office  
PL—Private Line  
S/N—Signal-to-noise ratio  
SSN—Switched service network  
TELCO—Telephone company  
TDM—Time division multiplexer  
TLP—Transmission level point  
TMS—Transmission measuring set

**B. Common Terms**

**2.03** A listing and the definition of common terms used in data service and circuit terminology are as follows:

**ABSOLUTE DELAY:** The total time required for a signal to pass through a network or channel; also called transmission time or circuit delay.

**ACTUAL MEASURED LOSS:** The actual reading of the transmission measuring set when the test is made under the same test conditions as that for which the EML was computed.

**AMPLIFICATION:** (1) Gain; (2) the ratio between the output signal power and the input signal power of a device; (3) the strengthening of a weak signal as opposed to attenuation.

**AMPLITUDE:** The magnitude of a voltage or current waveform measured from zero crossing to peak or peak to peak.

**AMPLITUDE MODULATION (AM):** A method of transmission whereby the signal wave voltage is impressed upon a carrier wave of higher frequency so that the amplitude of the carrier wave is varied proportionately to the amplitude of the signal wave.

**ANALOG DATA:** Data represented in a continuous form, as contrasted with digital data represented in a discrete or step type form. Analog data are usually represented by means of physical variables, such as voltage, resistance, and rotation.

**ANSWER-BACK (DATA):** A signal or tone sent by the receiving customer terminal or data set to the sending station for identification or to indicate it is ready to receive transmission.

**ASYNCHRONOUS:** Asynchronous data transmission is where the speed of operation is not fixed or controlled by a clock. The duration of the signal element may be variable, and the minimum element duration is controlled by the bandwidth. No clock lead is provided between the data set and the customer's terminal equipment.

**ASYNCHRONOUS TRANSMISSION:** Transmission in which each information character is individually synchronized (usually by the use of a start element and stop elements).

**ATTENUATION:** The difference between transmitted and received power due to transmission loss through equipment, lines, or other communication devices.

**ATTENUATION DISTORTION:** A characteristic of a transmission facility whereas the difference in loss between the 1004 Hz reference frequency and each of the other frequencies within the band of interest is expressed in dB. Attenuation distortion is a multifrequency measurement whereas slope is a three frequency measurement.

**ATTENUATION EQUALIZER:** Any device inserted in a transmission line or amplifier circuit to improve the shape of its frequency response.

**BALANCED TO GROUND:** The state of impedance on a 2-wire line when the impedance to ground as measured from one wire is equal to the impedance to ground as measured from the other wire, contrast with unbalanced (to ground).

**BALANCING NETWORK:** A network typically made up of inductance, capacitance, and resistance connected so as to simulate the impedance of a uniform cable or open-wire circuit over a band of frequencies. Typically, balancing networks are used with hybrids to make the 2-wire side electronically look like the 4-wire side.

**BAND:** A frequency range between two defined limits.

**BANDPASS FILTER:** A device inserted into a circuit which blocks all frequencies outside a designated bandwidth, but does not inhibit those frequencies within the bandwidth.

**BANDWIDTH:** The band or range of frequencies to be transmitted which a transmission system will accept without undue loss or distortion.

**BASEBAND:** In the process of modulation, the frequency band occupied by the aggregate of the transmitted signals when first used to modulate a carrier.

**BAUD:** The baud is a unit of signaling speed; the speed in bauds is equal to the number of signaling elements or symbols per second. For binary symbols the signaling rate in bits per second is equal to the speed in bauds. The term "baud" is often used erroneously as a synonym for bit.

**BENCHMARK:** A point of reference from which measurements can be made.

**BENCHMARK MEASUREMENTS:** These are measurements made on a loopback or 1-way basis when the PL data circuit is

known to meet all requirements. They are performed immediately following the completion of installation and circuit order tests, and the results are recorded for later reference purposes.

**BINARY:** A basic 2-state (0 or 1, on or off) numbering system used by a computer. All data is represented by series of 0s and 1s called bits. The position of each bit has a specific numerical value; when put together, they form machine words.

**BINARY SYNCHRONOUS TRANSMISSION:** Data transmission in which synchronization of characters is controlled by timing signals generated at the sending and receiving stations.

**BIT:** A unit of information content. Contraction of "binary digit," a bit is the smallest unit of information in a binary system of notation. It is the choice between two possible states, usually designated one or zero or a mark or a space.

**BIT RATE:** The speed at which bits are transmitted, usually expressed in bits per second (b/s).

**BRIDGE:** A device used to interconnect more than two middle and/or end links on multipoint circuits.

**BRIDGED TAP:** Nonworking cable pair which is connected to a working cable pair. It exists because of cable runs which were made beyond the station-provided service, also, dead-end distribution branches or branches that run to other stations on a multiparty line.

**BROADBAND:** A communications channel that has sufficient frequency bandwidth to accommodate the transmission of signals wider than voice range.

**BUSINESS MACHINE:** In data communications, customer-provided equipment that connects to common carrier communication services for the purpose of data movement.

**CHANNEL:** An electrical communications path between two or more points, derived in such a manner as the TELCO may select.

**CHANNEL CONDITIONING:** The selection of facilities and/or the electrical balancing of a channel to match transmission levels and impedances and to equalize transmission loss and delay to establish standards and to control C-notched noise to signal ratio and intermodulation distortion.

**CIRCUIT LAYOUT RECORD (CLR):** The document on which is recorded all pertinent information of a customer's service including facility, station, and central office layout.

**CUSTOMER-PROVIDED EQUIPMENT (CPE):** Any data set and/or terminal equipment which is provided by the customer.

**DATA:** Any nonvoice representations, such as digital characters or analog quantities, to which meaning might be assigned.

**DATA AUXILIARY SET (DAS):** Provides an interface between the channel and the station equipment. The DAS also provides circuit functions that are necessary for complete operation of the data set or station.

**DATA COMMUNICATION:** The transmission and reception of data, often including operations such as coding, decoding, and validation.

**DATA MOUNTING:** Coded subassemblies intended primarily to provide physical facilities for mounting other apparatus in a cabinet or other supporting structure.

**DATAPHONE SERVICE:** A registered service mark of AT&T which identifies the transmission of data over the PSN. Implies the use of Bell System data sets connected to the PSN. Facility characteristics must meet stated requirements, and data error performance is specified.

**DATA SET:** Coded apparatus which, at a minimum, provides a modulator and/or demodulator function to transform customer

terminal signals to line signals and vice versa. It may include control and supervisory functions on a standard or optional basis. Also known as modem.

**DATA SET CLOCK:** A time base oscillator supplied by the data set for regulating the bit rate of transmission; contrast with customer terminal clocking.

**DATA STATION:** Arrangements of coded apparatus which together perform all required functions for the associated customer terminal. Includes the data set, channel termination, wiring, DAS, CPE, etc.

**DATEC:** Data technical support—a support plan and designated personnel who are responsible for technical assistance to field repair personnel in cases of escalated data problems. This also refers to a mandatory escalation procedure from the field supervision level to the associated company headquarters and AT&T to seek quick resolution of complex technical problems.

**DATA TEST CENTER (DTC):** The telephone company test center which is responsible for remote testing of data station equipment.

**dBm:** Decibel reference to one milliwatt. This is employed in communication work as a measure of absolute power. Zero dBm equals 1 milliwatt.

**DEGRADATION:** A condition in which the system continues to operate but at a reduced level of performance.

**DELAY EQUALIZER:** A network which makes the phase delay or envelope delay essentially constant over a desired frequency range.

**DIGITAL LOOPBACK:** This test checks, from one location, both data sets (local and remote) in conjunction with the transmission facility. This test is performed with the data set self-test feature or a 914- or 921-type data test set.

**DIGITAL SIGNALS:** Signals which can only assume certain discrete values. For

example, in a system which contains binary digital signals, only "0" and "1" (that is, the presence or absence of a pulse) can exist during a specified time period.

**DUPLEX, FULL:** Method of operation of a communications circuit where each end can simultaneously transmit and receive (usually a 4-wire circuit). When used on a 2-wire circuit, full duplex operation requires different frequencies. A full duplex service can be used in a half duplex manner.

**DUPLEX, HALF:** Permits one direction electrical communications between stations. Technical arrangements may permit operation in either direction but not simultaneously. Therefore, this term is qualified by one of the following suffixes: S/O for send only, R/O for receive only, S/R for send or receive.

**DYNAMIC TEST:** A check of a data communications system whereby test data is sent at the customer bit rate to check out TELCO lines and data sets in an error performance test.

**EIA INTERFACE:** A set of electrical specifications established by the Electronic Industries Association (EIA) that standardizes the physical, electrical, and functional characteristics at the point of connection between the data set and data terminal.

**EXPECTED MEASURED LOSS:** The expected reading, in dB, of a transmission measuring set connected to a prescribed test point at one end of a circuit when a specific power (usually 1004 Hz at 0 dBm) is applied to a prescribed test point at the other end of the circuit.

**END LINK:** The facility between a central office relay switching location (not switched services network [SSN]) or a bridging location and the transmission interface at the customer premises. This definition holds regardless of whether the end link consists of only a local channel or of intercity facilities and a local channel.

**EQUALIZATION:** The process of reducing amplitude vs frequency and/or phase distortion of a circuit by the introduction of networks

to compensate for the difference in attenuation and/or time delay at the various frequencies in the transmission band. (See definition for attenuation equalizer and delay equalizer.)

**EQUAL-LEVEL LOOPBACK:** A circuit arrangement interconnecting the receive and transmit paths and correcting for any differences in the signal level at the point of connection. The simplest way to accomplish this is to interconnect two identical data levels, for example, at a -16 dBm point to another -16 dBm. To interconnect a -16 dBm receive point with a 0 dBm transmit point, an amplifier with 16 dB of gain would be required in the loopback path. This ensures that signals on the line are maintained at standard data level during loopback tests when a test signal at data level is applied toward the customer station.

**ERROR PERFORMANCE:** The ratio of the number of bits, elements, characters, or blocks incorrectly received to the total number of bits, elements, characters, or blocks transmitted.

**FACILITY:** Any transmission system (eg, carrier system or cable) used (or available for use) in furnishing a communication service.

**FOUR-WIRE CIRCUIT:** A communication path in which four wires (two for each direction of transmission) are presented to the station equipment. Ideally, transmit and receive paths are isolated.

**FOUR-WIRE TERMINATING SET:** An arrangement by which 4-wire circuits are terminated on a 2-wire basis for interconnection with 2-wire circuits. See HYBRID COIL.

**FREQUENCY:** The number of times per second a current or voltage alternates, given in hertz (formally cycles per second).

**GAIN:** (1) Amplification. (2) The ratio of output voltage, current or power to the input voltage, current or power, respectively, in an amplifier stage, receiver or system, usually expressed in dB.

**GROUND:** Fundamentally the earth or an electrical connection to earth or to a common conductor usually connected to earth.

**GROUNDING:** The process or procedure of connecting to ground or to a conductor which is grounded.

**HERTZ (Hz):** The frequency of a waveform (formerly cycles per second). See FREQUENCY.

**HIGH SPEED:** Usually, data transmission rate above 2400 b/s.

**HOLDING TONE:** A single frequency (1004 Hz) applied at the transmitting end of a circuit or channel to simulate a data signal. It is put on at data level (-13 dBmO) and operates companders and other signal-dependent devices. It is then filtered out at the receive end with a notched filter, and C-notched or signal-dependent noise can be measured.

**HYBRID COIL:** An arrangement using one or more transformers wired as a balanced bridge to provide 2- to 4-wire conversion for long-distance telecommunication circuits.

**IMPEDANCE:** The total opposition (resistance and reactance) afforded the flow of current in an alternating current circuit.

**ISOCHRONOUS:** Isochronous data transmission is a process such that between any two significant instants there is always an integral number of unit intervals. Basically, it is synchronous data transmission, but there is no clock lead provided between the data set and customer's terminal equipment. Therefore, the timing is provided by the customer's terminal equipment.

**LOCAL CHANNEL:** Generally considered to be that portion of the circuit extending between the customer premises and the nearest toll office which may include interoffice facilities and equipment.

**LOOP:** An abbreviated designation for the cable pair used to serve a customer from a local serving central office; also called subscriber line (switched service), station line (private line service), or access line.

**LOOPBACK:** A type of test in which the receive pair of a 4-wire facility is connected to the transmit pair so that the test signal can be received at the same point from which it was transmitted. The term also refers to the hardware that provides the receive pair to transmit pair connection.

**LOW SPEED:** Usually data transmission rate below 600 b/s.

**MAP PLAN:** Minimum acceptable performance plan specifies minimum limits for critical transmission parameters which affect data transmission on the switched message network. The plan is intended to aid in identifying those connections on which frequent or consistent substandard transmission performance is experienced.

**MASTER STATION:** The one station of a multistation circuit that communicates with each remote station and has circuit control.

**MEDIUM SPEED:** Usually, data transmission rate between 600 b/s and 2400 b/s.

**MEGAHERTZ (MHz):** 1,000,000 cycles per second, previously called megacycle.

**MIDDLE LINK:** The facility or facilities between central office switching and/or bridging locations. The connection between two bridges in the same central office is not considered to be a middle link.



**End link and middle link definitions apply only to multipoint and central office relay switched circuits.**

**MILLISECOND:** One-thousandth of a second, abbreviated ms.

**MODEM:** A device to modulate and demodulate signals transmitted over telephone circuits. Often used interchangeably with the term data set.

**MULTIPOINT CIRCUIT:** A circuit connecting three or more stations by using

bridges to interconnect more than two end links.

**NETWORK CONTROL OFFICE (NCO):**

A designated office responsible for the coordination of all maintenance activities involving two or more circuits or links in a network.

**OPEN:** A condition in which a transmission path is severed so that signals cannot pass.

**PARAMETER:** A definable characteristic of an item, device, or system.

**PHASE:** The position of a point on the waveform of an alternating or other periodic quantity with respect to the start of the cycle, usually expressed in degrees.

**PLANT CONTROL OFFICE (PCO):** The designated office responsible for all maintenance activities on a circuit or circuit link. The PCO maintains records for each circuit or circuit link and should be informed of all trouble reports.

**REGISTERED EQUIPMENT:** Terminal equipment allowed to connect directly to the network that complies with Part 68 of the FCC rules and regulations and has been granted a registration number.

**SEALING CURRENT:** The low level direct current applied to a cable pair to break down a high resistance film which may build up at splices.

**SIGNAL-TO-NOISE RATIO (SNR):** The relative power of the signal to the noise in a channel.

**SLOPE:** Usually the term is used in connection with the attenuation distortion characteristic of a transmission facility and is the difference in loss between two frequencies and a reference frequency. The frequencies are 404 and 2804 Hz with the reference frequency of 1004 Hz. Slope is the 3-frequency measurement as opposed to attenuation distortion which is the multifrequency measurement.

**SPECIAL SERVICE CENTER (SSC):**

Formally serving test center (STC), a test center with responsibilities for the maintenance and installation of specially installed and maintained services (SIMS).

**STATIC TEST:** Those tests performed on a data set either locally or remotely to measure such parameters as frequency, level, and receiver sensitivity.

**SYNCHRONOUS:** Synchronous data transmission is a fixed rate bit stream having a constant time interval during successive bits, characters, or events.

**TARIFF:** The published description for a specific unit of equipment, facility, or type of service provided by a communications common carrier; also, the vehicle by which the regulating agencies approve or disapprove such facilities or services. Thus, the tariff becomes a contract between customer and common carrier.

**TIME SHARING:** A method of operation in which a computer facility is shared by several users for different purposes.

**TRANSMISSION ASSEMBLIES:** Tariffed arrangements of facilities, equipment, and permitted interconnections with other suppliers. In all assemblies, the customer is responsible for overall performance. When various components of an assembly are combined, an acceptable transmission performance may or may not result. Therefore, no overall transmission performance, including error rate performance, is either specified or implied. See Section 314-010-103.

**TRANSMISSION SYSTEMS:** Networks or services provided by a telephone company (TELCO) where an expected overall performance is specified and maintained and, on data services, TELCO recommended channels and modems must be used in order to state an expected error rate performance level as defined in various Bell System publications. See Section 314-010-103.

**TURNAROUND TIME:** The time required for a data set to respond to another data set's signal. This includes the round trip

propagation time of the facility and the clear-to-send and request-to-send of one data set.

**UNBALANCED TO GROUND:** The state of impedance on a 2-wire line when the impedance to ground as measured from one wire is unequal to the impedance to ground as measured from the other wire.

**VOICE FREQUENCY:** That portion of the audio frequency range which is used to transmit speech and other information, usually between the limits of 300 to 3400 Hz.

**VOICE-GRADE CHANNEL:** A channel capable of transmitting that portion of the voice frequency spectrum suitable for speech, digital or analog data, or facsimile signals, generally with a frequency range of about 300 to 3000 Hz.

**WIDEBAND:** A term applied to facilities or circuits whose bandwidths are greater than that required for one voice channel, allowing for much higher data speeds.

### 3. DATA TRANSMISSION PHILOSOPHY

**3.01** The increasing use of electronic data processing methods has led to the accelerated need for more and better communication channels. These channels must be able to accept and deliver messages in machine language, which is predominantly digital.

**3.02** Modern data transmission is considered as an outgrowth of telegraph transmission. The differences are mainly in the trend toward higher bit rates and more extensive interconnections by switched networks. Existence of analog facilities which already serve similar needs for other types of communication has provided the momentum for the adaptation for data on the many transmission media originally designed for voice signals.

**3.03** Digital signals must be converted to analog signals before they can be transmitted over analog facilities. The modem (data set) provides this conversion. The modem *modulates* the digital signal in the form of an analog signal at one end of the channel and *demodulates* the analog signal back to the digital format at the other end of the channel, hence the term modem.

**3.04** Data transmission channels are subject to several impairments. These impairments cause the received signal to be distorted from that which was transmitted. Impairments, when expressed with values are known as parameters. The parameters that affect voiceband data are described in Part 4.

### 4. DEFINITION OF TRANSMISSION PARAMETERS

**4.01** Parameters are the attributes of the physical properties that determine the characteristics of the channel. The parameters listed in this section do not all apply to the three types of channels (PL, PSN, or SSN). Refer to the applicable BSP layer for the specific parameters relating to that type of channel.

**4.02** The parameters are listed in the order in which they are to be tested for maintenance purposes. For the testing technique and test sets associated with each parameter, refer to Section 314-010-101.

#### Continuity

**4.03** Continuity is the uninterrupted electrical connection free of opens (open connections) and grounds (one or both sides of the electrical path to ground). Simply, continuity is the completed path from transmitter to receiver.

#### 1004-Hz Loss

**4.04** Also known as loss, loss deviation, net loss, insertion loss, and gain, 1004-Hz loss is the difference in dB between any send point and any receive point. The send and receive points are found on the CLR. In terms of 1004-Hz loss, a reduction of level is given a positive (+) representation; gain (increase in level) is given a negative (-) representation.

**4.05** Loss in transmission is calculable and is usually controlled by design. However, where excessive, loss is generally caused by a trouble condition. Local cable trouble conditions might include excessive or loaded bridged tap and improper loading. Examples of central office loss trouble conditions are:

Faulty components on carrier systems

Poor solder connections

Unterminated bridge ports.

**C-Notched Noise**

**4.06** C-notched noise is a measure of the amount of noise on a channel with a signal present. The signal, called 1004-Hz holding tone, is **transmitted at data level** and is used to operate companders on carrier systems. The ratio of the receive signal and the noise power is indicative of the signal-to-noise ratio on the channel.

**4.07** In addition to the same noises found during the message circuit noise test, C-notched noise can detect singing, listener echo, and quantizing noise. In order to identify the type of noise detected during the C-notched noise test, it is necessary to use the audio monitor on the output of the noise test set.

**Impulse Noise**

**4.08** Impulse noise consists of large amplitude peaks of noise or power that occur unpredictably in infrequent bursts against a relatively quiet background. The data signal error rate is seriously affected by impulse noise of sufficient magnitude and frequency of occurrence. Impulse noise is measured in terms of the number of peaks or hits which exceed a specified threshold during a specified time period. Only peaks and/or hits of 4 ms or less are considered impulse noise. (See hits and dropouts for hits lasting longer than 4 ms).

**4.09** Some of the major causes of impulse noise are lightning, relay operations in switching centers, radio fading and the subsequent protection switching, and quantizing associated with digital carrier systems.

**Phase Jitter**

**4.10** Phase jitter is seen as unwanted phase or frequency modulation of a transmitted signal. Various sources can cause the irregular and random movement of the instantaneous phase or zero crossings of a signal. The most common cause of phase jitter is dc power supply ripple in the master oscillator of long-haul carriers and then passing through the many stages of frequency multiplexing. Phase jitter can be detected in two frequency ranges. The two ranges are Bell (between 20 and 300 Hz) and low frequency (between 4 and 20 Hz).

**Gain Slope (3 Tone)**

**4.11** Gain slope is the attenuation distortion of a channel characterized by the loss at two frequencies in relation to the loss at 1004 Hz. The two frequencies, 404 Hz and 2804 Hz, are each compared to the reference frequency and not to each other.

**Peak-to-Average Ratio**

**4.12** The peak-to-average ratio (P/AR) procedure simultaneously measures the gain and phase distortion characteristics of the data channel. These characteristics (envelope delay distortion, bandwidth compression, and return loss) are evaluated by transmitting a train of precisely shaped pulses over the data channel. These pulses, having a known envelope peak to full-wave average ratio, are measured at the receiving end to determine to what extent that ratio has changed. The P/AR receiver meter is calibrated from 0 to 100. A rating of 100 indicates no change in the ratio. A rating of zero means a 50-percent change.

**4.13** The P/AR procedure is simple, fast, and a single-number measure of overall quality of a data circuit. It is ideal for use as **benchmark** testing after determining that the overall attenuation distortion and envelope delay distortion measurements are within limits. The test equipment is largely insensitive to noise, attenuation distortion, phase jitter, intermodulation distortion, and frequency shift when within limits.

**Attenuation Distortion**

**4.14** Amplitude characteristics, frequency response, gain deviation, and amplitude distortion are alternate terms for attenuation distortion. Attenuation distortion is the difference in loss of many frequencies with respect to the loss at a reference frequency. It is specified by placing a limit on the maximum gain and loss at any frequency in a specified band of frequencies with respect to the loss at 1004 Hz.

**4.15** Like loss, attenuation distortion is also calculable and controlled by design. Where out-of-limits attenuation distortion is calculated, attenuation equalizers can be included in the design of the circuit. Excessive distortion is generally caused by a trouble condition similar to those affecting loss.



**Where a trouble condition exists, care must be taken not to add equalizers to the circuit but to repair the trouble.**

### Intermodulation Distortion

**4.16** Previously referred to as harmonic distortion and then nonlinear distortion, intermodulation distortion is the term used for multitone nonlinearities. Harmonic and nonlinear distortion refer to the degradation of a signal caused by its harmonics. Since most distortion occurs at the second and third harmonic, the amount of distortion is measured by the power of each of these harmonics and is called second and third harmonic distortion. Total harmonic distortion is the sum of the powers of all harmonics. Each harmonic power is referenced to the wanted signal (the fundamental).

**4.17** Some modems transmit multiple tones simultaneously. To match the data circuit in its operational mode, intermodulation distortion is measured by transmitting four equal level tones with a composite signal power at nominal data signal level. 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). The second order distortion is determined from the B-A and B+A products, while the third order distortion is determined from the 2B-A product.

### Hits and Dropouts

**4.18** Gain and phase hits are moderate changes (greater than 3 dB) in the amplitude or phase of a signal lasting for at least 4 ms and returning to the original value within 220 ms. A change lasting *less than* 4 ms is classified as impulse noise. A change in amplitude and phase lasting longer than 220 ms is considered a gain or phase change.

**4.19** A major cause of gain and phase hits is the switching to backup facilities in long-haul carrier. Likewise, a gain change could occur should the backup facility be lined up at a different transmission level. As a result, gain hits are more common than phase hits.

**4.20** Dropouts are short duration impairments in which the transmitted signal experiences a sudden drop in power, to the extent that the signal is undetectable. They have been defined as any

sudden decrease in level equal to or greater than 12 dB which lasts longer than 4 ms. Dropouts are a serious form of performance degradation with over 40 percent lasting longer than 200 ms. They usually occur rather infrequently but have been observed to occur at a rate greater than once per hour.

**4.21** Dropouts are caused by the same forms of incidental modulation that cause phase jitter, gain hits, and phase hits. In addition, dropouts are caused by maintenance activities such as facility patching.

### Return Loss

**4.22** Return loss is the difference in dB between the power of a transmitted signal on a channel and its reflected power at an impedance discontinuity. An impedance discontinuity can be defined as an unbalanced hybrid or an impedance mismatch. The signal reflection at an impedance discontinuity is a greater transmission impairment than the loss of the signal transmitted through the discontinuity.

### Single Frequency Interference

**4.23** Single-frequency interference, also known as single-tone interference, is the presence of one or more unwanted steady tones on a channel. This form of noise is commonly detected by the use of the audio monitoring arrangement on the output of a C-message noise test set. Other methods of detection are by the use of the frequency selective voltmeter and spectrum analyzer test sets.

**4.24** Common causes of single-frequency interference are singing repeaters, crosstalk, and cross-modulation of single-frequency signaling tones. Occasional bursts of low-amplitude signals that occur from crosstalk of multifrequency signaling are not considered single-frequency interference.

### Frequency Offset

**4.25** Frequency offset, also called frequency shift, may exist on single sideband suppressed carrier systems. This offset is the result of the difference in frequency between the modulating and demodulating carriers. The resulting frequency offset contributes a constant change at all frequencies in the frequency spectrum.

**Envelope Delay Distortion (EDD)**

**4.26** Sometimes referred to as delay, delay distortion, envelope delay, and relative delay, envelope delay distortion is not to be confused with absolute delay. (Absolute delay is defined as the time it takes for a signal to traverse between the input and output of a network or transmission medium.) Envelope delay distortion measurements indicate the difference between the delay at any frequency and that at a reference frequency. In the voiceband, the reference frequency is usually 1700 or 1800 Hz. The reference frequency should be the fastest frequency or the frequency of minimum delay.

**4.27** Envelope delay distortion is also a calculable impairment and is controlled by design. Like attenuation distortion, equalizers can be included in the design of the circuit to maintain the circuit within the limits of the prescribed conditioning. A common source of delay distortion is that due to the sharp cutoff characteristics of analog multiplex equipment associated with channel banks. A second source of delay distortion is the roll-off characteristics of long lengths of loaded cable.

**5. REFERENCES**

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

DOCUMENT	DESCRIPTION		
AT&T PUB 41004	Data Communications Using Voiceband Private Line Channels—October 1973	AT&T PUB 41008	Transmisson Parameters Affecting Data Transmission—Description of Parameters—July 1974
AT&T PUB 41005	Data Communications Using The Switched Telecommunications Network—Revised May 1971	AT&T PUB 41009	Transmission Parameters Affecting Voiceband Data Transmission—Measuring Techniques—January 1972
AT&T PUB 41006	Attenuation and Envelope Delay Characteristics from the 1969-70 Switched Telecommunications Network Connection Survey—June 1973	314-410-100	Voice Bandwidth Private Line Data Circuits—Description
AT&T PUB 41007	1969-70 Switched Telecommunications Network Connection	314-410-101	Voice Bandwidth Private Line Data Circuits—Transmission Requirements of Bell System Data Sets
		314-410-102	Voice Bandwidth Private Line Data Circuits—End-to-End Transmission Performance
		314-410-103	Voice Bandwidth Private Line Data Circuits—Overseas Circuit
		314-410-104	Voice Bandwidth Private Line Data Circuits—Circuit Conditioning Requirements Using the Collins CLA-101A System
		314-410-300	Voice Bandwidth Private Line Data Circuits—Maintenance
		314-410-500	Voice Bandwidth Private Line Data Circuits—Tests and Requirements
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		Volume 2 Facilities	Telecommunications Transmission Engineering—First Addition—1977
		Volume 3 Networks and Services	Telecommunications Transmission Engineering—Second Addition—1977

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