

## DIGITAL TRANSMISSION TERMINOLOGY

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#### 1. GENERAL

#### APPENDIX A - DIGITAL TRANSMISSION TERMINOLOGY

#### 1. GENERAL

1.1 This section provides REA borrowers, consulting engineers and other interested parties with information on digital transmission systems. It contains a glossary of digital transmission terminology. This section is intended as a companion reference section for other TE&CM sections on digital transmission systems (950 and 960 series).

1.2 Digital terminology is somewhat unique. The digital terminology currently used in telephony has evolved from the fundamentals and hierarchy established by the Bell System in the early 1960's. Sometimes the terminology applied to digital transmission has a slightly different emphasis than when the same term is applied to switching or computer systems. For additional information, TE&CM Section 324 covers digital terminology as applied to switching and related areas.

1.3 Appendix A contains a list of terminology as applied to digital transmission systems. It describes the terminology in the manner that it is commonly used. It is not intended as a complete and precise definition of digital terms. It should be useful to engineers and crafts-  
persons in providing a better understanding of digital transmission systems. Often, an abbreviated form of a term will be shown first to establish the relationship of a series of terms (i.e., "D", "DS", "M", "T", etc.). The list of terms is necessarily incomplete; a complete listing could comprise a book.

APPENDIX A

DIGITAL TRANSMISSION TERMINOLOGY

Alternate Bipolar Pulses: A digital bit stream where pulses alternate in polarity with each successive pulse.

Analog: Analog refers to a continuously variable signal. An analog carrier system refers to modulation on a continuous basis (noninterrupted). When used in digital system discussions, the term analog usually refers to voice signals before encoding.

A-D: A-D is an abbreviated term for an analog-to-digital converter. Analog signals applied to the A-D input are converted to a digital output. A codec (encoder-decoder) contains an A-D and D-A converter; sometimes the term A-D is used to describe both A-D and D-A.

APS: APS is an abbreviation for automatic protection switch. The APS switches digital span line traffic to a spare spanline in the event of a failure on the system main span line. The APS "protects" the digital system from failure. (This has been referred to as a span line transfer system in the past.)

Asynchronous: Not synchronous; digital information that is not synchronized to a master clock.

Binary: Binary refers to two possible states such as on or off, one or zero, mark or space, pulse or no pulse. Pulse code modulation (PCM) systems use binary encoding for transmission.

Bipolar: Bipolar refers to two polarities, positive and negative. Bipolar pulses are generally transmitted over cables or other transmission media. Most transmission systems currently utilize "alternate bipolar pulses", that is, pulses that alternate in polarity with each successive pulse. Information is not contained in the pulse polarity. (See Ternary.)

Bit: A bit is a binary digit, or one unit of digital information. Most of the current PCM systems (i.e., D3) transmit a group of 8 bits of information to form a PCM "word". A PCM "word" can be decoded into a specific voltage level to reconstruct an analog signal.

Bit Rate: The speed at which bits are transmitted, usually expressed in kilobits and megabits per second (kb/s and Mb/s) for digital transmission systems.

Bit Stream: A series of bits that generally occur serially in time at a uniform rate.

Buffer: An isolation circuit. In digital communications, a buffer store or elastic store is a temporary storage unit for digital information (a temporary memory for binary digits). Buffer stores are used in digital transmission and switching systems for storage and retransmission; the input and output speeds of the device may be different. An example is a digital multiplexer that is used to combine asynchronous bit streams into a higher bit rate signal.

Byte: A sequence of bits processed as a unit and usually shorter than a word.

Channel Bank: Terminal equipment that digitally encodes and decodes analog signals into a digital bit stream. Channel banks are generally arranged in 24 channel groups, or multiples of 24 channels. (See "D" also.)

Clock: A device that generates periodic signals at a uniform rate for unit or system synchronization.

Codec: An abbreviated term for an encoder and a decoder. (Refer to Encoder and Decoder.)

Coder: See Encoder.

Compandor: A compandor is an abbreviated term for a compressor and expander. Early PCM carrier systems utilized compandors and linear encoders to achieve nonlinear encoding steps. (The digital system compandor is an instantaneous compandor to achieve nonlinear encoding, and should not be confused with syllabic compandors used in analog systems.) Later PCM carrier systems utilize nonlinear encoders to achieve the same (or improved) results. Nonlinear encoding (by using either a compandor or direct nonlinear encoding) provides much improvement in voice quality with fewer coding steps. Many times the same number of coding steps would be required to achieve the same quality with equal coding steps. The coding steps are small for low level samples and larger for high level samples. The coding steps for D2, D3 and D4 systems are determined by a companding law of  $\mu = 255$  (North American Standard).

Concentrator: A switching unit that provides subscriber lines at some distance from the central office over a smaller number of trunks. The concentration is generally in the order of 4 to 1 or 6 to 1. The term, concentrator, generally refers to a unit that is separate from the central office (and not an integrated system).

Crash Point: In digital transmission systems, there is a sharp transition between proper operation and failure. As the signal-to-noise ratio decreases to a critical point, the system rapidly goes from a satisfactory condition to a failed condition. The transition from the satisfactory to failed condition is the "crash point".

D: The "D" designation (D1, D2, D3, etc.) or D bank refers to the channel bank or terminal equipment of PCM carrier systems. Refer to D1, D2, etc., for specific channel bank information.

D1: The D1 channel bank operates at a 1.544 Mb/s rate to provide 24 voice channels. The D1 channel bank utilizes 7 bit nonlinear voice encoding to derive 127 possible coding levels. The nonlinear coding steps are determined by a companding law of  $\mu = 100$ . There are 8 bits assigned to each voice channel per frame in PCM systems (8 bit words). Bits one through seven are use for voice encoding and the eighth bit is used for signaling. D1 channel banks are arranged for D1A and D1B signaling modes. (Note: D1D is a modified Western Electric channel bank for use in D2 and D3 applications.) The D1 channel sequence is 1, 13, 2, 14, 3, 15, etc.

D1A: The D1A describes a signaling mode of a D1 channel bank. The D1A

channel bank used one of the eight bits assigned per channel each frame to provide one signaling channel for each voice channel. Some PCM channels require two signaling channels. To accomplish this with D1A channel banks, a bit normally assigned for voice encoding is used. This leaves only 6 bits for voice encoding, resulting in greater noise and distortion during this signaling condition.

D1B: The D1B describes a signaling mode of a D1 channel bank. The D1B divides the eighth bit into four segments (a super frame of four frames) to provide two signaling channels. This allows all seven remaining bits to be used for voice encoding at all times.

D1D: The Western Electric D1D channel bank is a D1 channel bank modified to obtain D3 voice quality. The Independent manufacturers utilize D3 channel banks to meet D1D application requirements by changing the channel sequence from 1, 2, 3, 4, etc., (for D3) to 1, 13, 2, 14, etc., (for D1). This change is accomplished by a plug-in card or by change of channel bank backplane wiring, depending on the specific type and age of equipment.

D2: The Western Electric D2 channel bank is the first of a series (D2, D3 and D4) of channel banks designed to improve voice quality. The D2 channel bank utilizes 8 bit nonlinear voice encoding to derive 255 possible coding levels. The nonlinear coding steps are determined by a companding law of  $\mu = 255$ . Two signaling channels are provided by "robbing" the least significant voice bit every sixth frame. On the sixth frame, signaling channel A is transmitted; and on the 12th frame, signaling channel B is transmitted. Twelve frames are a super frame, and the sequence repeats. The Western Electric D2 is designed in 96 channel groups for T1 application (24 channels) and T2 application (96 channels). The Independent manufacturers responded to Independent telco needs by designing compatible D2 channel banks in 24 channel groups. The D2 channel sequence is 12, 13, 1, 17, 5, 21, etc. Independent manufacturers equipment can be arranged for D2 or D3 (or D1D) application by changing the channel sequence (and perhaps other minor considerations).

D3: The Western Electric D3 channel bank is designed in 24 channel groups for T1 application to provide the same voice quality of D2 channel banks. (Refer to D2 for voice encoding, framing, etc.) The channel sequence is 1, 2, 3, 4, etc. The Independent manufacturers' D2 was easily redesigned to cover both D2 and D3 applications. (Field modification of early D2 systems for D3 application were sometimes awkward to accomplish.)

D4: The D4 type channel bank is designed in 48 channel groups for T1, T1C and T2 span line application. The D4 channel bank is essentially a lower cost, smaller combined packaging of two D3 channel banks (24 channels each). The D4 channel bank is arranged for five modes of operation, with Mode 3 being the same as two D3 channel banks. (Refer to D4, Mode 1, Mode 2, etc.)

D4, Mode 1: In D4, Mode 1, 48 channels are combined and operated at the DS1C level over a T1C span line (3.152 Mb/s). The transmit unit combines two synchronized DS1 signals (1.544 Mb/s each) and adds framing bits (64 kb/s). Both 24 channel groups are synchronized.

D4, Mode 2: In D4, Mode 2, 48 channels are combined as if they were two D3 channel banks (synchronized, or nonsynchronized). Two groups of 24 channels (at 1.544 Mb/s) are combined using an M1C equivalent multiplex

and operated at the DS1C level over a T1C span line (3.152 Mb/s). The distant terminal consists of two colocated or separate D3 type channel banks and an M1C multiplexer. Mode 2 differs from Mode 1 in that Mode 2 uses an M1C frame format and that the 24 channel groups do not require synchronization.

D4, Mode 3: In D4, Mode 3, 48 channels are operated independently the same as two separate D3 channel banks over two T1 span lines (1.544 Mb/s).

D4, Mode 4: In D4, Mode 4, two colocated 48 channel D4 groups are combined and operated at the DS2 level over a T2 span line (6.312 Mb/s). The distant end could be D4, Mode 4; or could be at one to four terminal locations of 24 channel groups operated over T1 span lines (1.544 Mb/s) and combined with an M12 multiplexer at a common location.

D4, Mode 5: Mode 5 of D4 is the same as Mode 4, except that the DS2 interface is optical rather than electrical. Two colocated 48 channel D4 groups are combined and operated at the DS2 level over an optical fiber system at 6.312 Mb/s. As with Mode 4, the distant end could be colocated D4 channel banks; or could be at one to four terminal locations after conversion from an optical to an electrical bit stream.

D-A: D-A is an abbreviated term for a digital-to-analog converter. (Refer to A-D also.)

Decoder: A digital decoder is used to convert a binary code back into a voltage level or segment of analog voltage so that the voice signal can be reconstructed.

Delta Modulation: See DPCM.

Digital: Digital refers to quantities that are represented with digits. Digital transmission systems in telephony transmit encoded information with binary digits.

Digital COE: Digital central office equipment is a stored program, common control switching system where the analog information is encoded into binary digits before being switched.

Digital Pad: A device for changing the digital bit stream in groups of eight bits (digital word) that will result in a predetermined change in the decoded analog signal level. It is a device for altering a digital bit stream to accomplish a change in analog (voice frequency) level.

Digital Radio: The term digital radio refers to the baseband modulation of a radio. Digital radios are modulated directly with a digital bit stream.

Digroup: A digroup refers to a basic PCM 24 channel group (or equivalent) operating at 1.544 Mb/s.

DPCM: An abbreviation for differential pulse code modulation. DPCM is a technique for encoding and transmitting changes in amplitude of an analog signal. This is often called delta modulation in reference to the fact that the encoded signal represents a change in amplitude rather than an absolute level.

DS: The "DS" designation (DS1, DS2, DS3, etc.) refers to the digital signal level or bit rate in the digital hierarchy (and other defined characteristics). The number following the DS notes the level (bit rate). DS1 refers to a digital signal at the first level (1.544 Mb/s). A letter following the DS number (such as C in DS1C) refers to an intermediate DS level that was included after the initial digital hierarchy was established.

DS1: DS1 refers to a digital signal at the first level, or 1.544 Mb/s.

DS1C: DS1C refers to a digital signal at a rate between DS1 and DS2. DS1C specifically refers to a bit rate of 3.152 Mb/s.

DS2: DS2 refers to a digital signal at the second level, or 6.312 Mb/s.

DS3: DS3 refers to a digital signal at the third level, or 44.736 Mb/s.

DS4: DS4 refers to a digital signal at the fourth level, or 274.176 Mb/s.

DSX: The "DSX" designation (DSX1, DSX2, etc.) refers to a defined interface or cross-connect point for digital signals. The bit rate, pulse shape and pulse height are specifically defined for interfacing digital signals at terminals and transmission systems. DSX1 defines the DS1 signal interface. The DSX2 defines the DS2 signal interface, etc. (Refer to DS1, DS2, etc., for digital signal bit rates.)

Duobinary: Duobinary implies a combined two times two, or four level numbering system. One duobinary encoded transmission system combines two T1 bit streams to double the information rate, but with a power output spectrum similar to that of a T1 system.

Encoder: A digital encoder is used to convert a voltage sample level or segment of an analog (voice) signal into a binary code. The binary code represents the specific voltage level of the sampled analog signal.

Engineering Loss: Engineering loss refers to the system design cable loss value used to engineer digital span lines. Engineering loss values provide margin for the highest loss cable pair and the highest operating temperature (100°F for buried cable and 140°F for aerial cable).

FT: The designation "FT" is the optical equivalent to the designation "T" used for digital transmission systems. An FT1 is a fiber transmission system operating at the first level (DS1), or 1.544 Mb/s. An FT2 operates at 6.312 Mb/s, etc.

Frame: A frame is a complete series of encoded bits containing the necessary information to reconstruct the information for all channels of the digital group. A frame contains voice, framing and possibly signaling bits. A D3 channel bank frame contains 24 channels X8 bits/channel = 192 + 1 framing bit = 193 bits/frame. (Also, refer to super frame.)

Framing Bit: A bit used for frame synchronization purposes. Framing bits are transmitted in a repetitive pattern for the proper alignment of information bits.

Gate: The term gate is used in many ways in digital systems. It most often refers to a controlled path (open or closed), the timing signal that controls

a path, or a logic circuit with one output signal as a function of multiple inputs.

Hardware: Physical equipment components of a system.

Integrated Circuit: Abbreviated IC. An electronic circuit that contains many active and passive components such as transistors, resistors, capacitors, etc., in a small functional package with few access terminals. An integrated circuit is formed on a single "chip" of semiconductor material.

Integrated Digital Network: A network of digital transmission and switching equipment where the analog signal is encoded and decoded only once, possibly at the subscribers' telephone sets.

Interface: A shared boundary. A connecting point between systems or subsystems.

Interrogation: The process where a transmitted signal or combination of signals is intended to trigger a response.

Jitter: Instability of a signal. In digital systems, jitter generally refers to an irregular digital bit stream with respect to frequency or phase. Jitter can be caused by unstable clocks, interference, etc.

Least Significant Bit (LSB): The bit at the end of a serially transmitted binary number which contains the smallest amount of information.

M: The "M" designation (M12, M23, etc.) refers to digital multiplex equipment to combine lower bit rate digital signals into higher bit rate signals in the digital system hierarchy. M12 denotes a digital multiplexer combining DS1 signals into a DS2 signal, etc. (Refer to M12, M23, etc., for specific digital multiplexer bit rates, etc.)

M1C: An M1C multiplexer combines two DS1 signals (1.544 Mb/s) into one DS1C signal (3.152 Mb/s).

M12: An M12 multiplexer combines four DS1 signals (1.544 Mb/s) into one DS2 signal (6.312 Mb/s).

M13: An M13 multiplexer combines 28 DS1 signals (1.544 Mb/s) into one DS3 signal (44.736 Mb/s). This is likely to be a two step process combining the equivalent of the M12 and M23 multiplexers.

M23: An M23 multiplexer combines seven DS2 signals (6.312 Mb/s) into one DS3 signal (44.736 Mb/s).

M34: An M34 multiplexer combines six DS3 signals (46.304 Mb/s) into one DS4 signal (274.176 Mb/s).

Microprocessor: An electronic circuit usually contained on a single integrated circuit or "chip" that performs a predetermined logic or control function.

Most Significant Bit (MSB): The bit at the start of a serially transmitted binary number which contains the largest amount of information. The MSB represents a quantity as large as all the other bits combined.

Nailed Up Circuit: A circuit that has a reserved time slot in the bit stream through the central office equipment so that a path is always available.

NRZ: An abbreviation for nonreturn-to-zero; a 100 percent duty polar signal where positive represents a logic one and negative represents a logic zero.

PAM: An abbreviation for pulse amplitude modulation. PAM is accomplished by sampling the analog (voice) signal at predetermined intervals and transmitting a voltage level representing the amplitude of the sampled signal. PAM is generally a preliminary step in PCM encoding.

Plesiochronous: The relationship of two signals that are nominally at the same rate, and with variations constrained within specified limits. (Note: Plesiochronous is one of several terms that describes the relationship of signals that are "almost synchronous".)

PCM: An abbreviation for pulse code modulation. PCM is one form of digital encoding. The analog (voice) signal is sampled at a predetermined rate to determine the instantaneous voltage level. Each voltage sample level is converted into a binary code (1's and 0's) representing that voltage level. In telephony, most voice encoding uses an 8 bit non-linear code with 127 positive levels, 127 negative levels, and zero. This provides for 255 total encoded steps, omitting an all zero code.

PSK: An abbreviation for phase shift keying. PSK is a modulation technique used in digital transmission systems (especially radio) where the phase of the carrier is varied in discrete increments corresponding to a digital input signal.

Pulse: One element of a repetitive signal, generally characterized by rapid rise and decay times. (Refer to PAM and PCM also.)

Pulse Stuffing: A method used for synchronizing two or more asynchronous bit streams in a multiplexer. Extra noninformation pulses are inserted (stuffed) as required at the multiplexing end and are removed at the demultiplexing end. The output rate of the synchronized bit stream is greater than the sum of all inputs to the multiplexer.

Pseudorandom: Appears to be random. Satisfies one or more tests for statistical randomness, but repeats a pattern after a long time interval. Pseudorandom pulse generators or noise generators are used in digital systems for testing and other purposes. (See Quasirandom.)

Quantizing: Quantizing is the attempt to quantify an analog signal into a discrete set of values. The nearest coding step is chosen for encoding, resulting in a small error. When a series of encoded steps are decoded to reconstruct the analog (voice) signal, a small quantizing error or quantizing distortion results. Quantizing distortion is measured as a ratio of signal-to-noise (ratio of desired to undesired signal), generally expressed in dB.

Quasirandom: Nearly random. Quasirandom code generators have nearly random code characteristics, but with a specified long interval repetitive pattern. Quasirandom code generators are used in digital systems for testing and other purposes. (See Pseudorandom.)

Random: Irregular; having no set pattern. In a digital bit stream, random implies that there are no repetitive patterns to the bits transmitted. A random bit stream causes the power to be spread over a wide frequency range. Repetitive patterns of bits cause peaks of power within certain bands of frequencies. In reality, there must be certain repetitive patterns such as framing bits. But the low density of framing bits minimizes the power within narrow frequency bands. (See Pseudorandom and Quasirandom.)

Regenerator: A digital regenerator restores the digital signal to its original shape or condition. A regenerating repeater samples weak and distorted pulses, determines if a pulse or no pulse condition exists and reconstructs a new, reshaped (regenerated) output pulse for a weak incoming pulse. Regenerator is often used to describe the entire digital repeater and is also used to describe a specific portion of the digital repeater.

RST: An abbreviation for remote switching terminal. An RST is a digital switching unit located at a distance from its host digital COE and connected by a digital bit stream on a trunk basis. In effect, RST's are line circuits from a digital COE that are placed at remote locations.

Sampling: Sampling refers to measuring or comparing a portion of a signal (analog or digital) at predetermined intervals.

Scrambling: The process of transposing or modifying a signal at the transmitting end. Scrambling is used to avoid long groups of consecutive zeros or repetitive patterns in the transmitted digital bit stream.

Serial: Refers to information bits in series, where one bit follows another in time.

Signal: The intelligence, message or control function conveyed over a transmission system.

Signal-to-Noise: A ratio of desired signal to undesired signal, generally expressed in dB. Signal-to-Noise (S/N) is often used interchangeably with Signal-to-Distortion (S/D) in digital systems to indicate the effects of quantizing an analog signal into discrete steps.

Software: A collection of programs and operational aids associated with a computer which facilitate its programming and operation.

Span: The sum of all span lines between two locations.

Span Line: Essentially a string of regenerators between two locations.

Super Frame: Super frame is a specified group of frames to complete a series of required events. In D3 channel banks, a super frame is twelve frames. A series of events (signaling) begins anew with each twelve frames.

Synchronous: In step or in phase with a constant time interval between bits. In digital transmission systems it implies that all signals are kept in step by the same clock.

T: The "T" designation (T1, T2, etc.) refers to a transmission system or span line equipment in the digital system hierarchy. (Refer to T1, T2, etc., for specific transmission system information such as bit rate and the number of voice channels normally associated with that bit rate.)

T1: T1 refers to a transmission system (or span line) that operates at the DS1 rate (1.544 Mb/s, 24 channels).

T1C: T1C refers to a transmission system that operates at the DS1C rate (3.152 Mb/s, 48 channels).

T2: T2 refers to a transmission system that operates at the DS2 rate (6.312 Mb/s, 96 channels).

T3: T3 refers to a transmission system that operates at the DS3 rate (44.736 Mb/s, 672 channels).

T4: T4 refers to a transmission system that operates at the DS4 rate (274.176 Mb/s, 4032 channels).

Ternary: Ternary refers to three states such as positive, negative and zero. Ternary is a bipolar signal where the pulse presence and polarity convey information. One ternary encoded transmission system uses a four binary to three ternary (4B3T) code to transmit four information bits in three time slots.

TDM: An abbreviation for time division multiplex. TDM is a method of multiplexing information by discrete time assignment of channels. TDM systems sample analog signals and transmit information to represent the instantaneous value of that signal at the time it was sampled. TDM systems can be divided into two major groups. The first group transmits the sampled information on a direct basis (such as pulse amplitude modulation), and can be degraded on a gradual and cumulative basis. The other major group encodes the sampled signal into a digital signal for transmission. Gradual or cumulative degradation is unlikely in digital transmission systems. Pulse code modulation (PCM) is the most widely used digital system telephony.

Tracking: A measure of how accurately a reconstructed analog signal compares to the original analog signal before it was digitally encoded.

Unipolar: Unipolar refers to one polarity. In digital systems, unipolar pulses are generated within the equipment, but are seldom transmitted over cables. (Also refer to bipolar.)

Word: A group of bits processed as a complete unit; a word represents a specific instruction or quantity.