Digital Television
A Glossary and Bibliography

By GWYNETH DAVIES HEYNES

Digital processing of television signals has been investigated experimentally for several years. Much of the theoretical foundation for the current activity among broadcasters and manufacturers of broadcast equipment was laid by Bell Telephone Laboratories in their experimental work with the video-telephone (some of which is acknowledged in the section of the bibliography devoted to "Picture Coding") and was further developed by the BBC.

The first practical application of digital techniques to broadcast television came in early 1973 when the digital time-base corrector was introduced at the National Association of Broadcasters Convention. In the same year Comsat Corp. demonstrated the feasibility of digital television with their DITEC system for satellite communication links.

1974 saw demonstrations of the feasibility model of a digital video recorder by the BBC and the introduction of Digital Intercontinental Conversion Equipment (DICE) by the Independent Broadcasting Authority. Digital frame synchronizers became commercially available in 1975, and in 1976 the first commercial digital video recorder was introduced in the form of the Electronic Still Store (ESS).

The acceptability of digital processing to the broadcaster is emphasized by the rapid emergence of an impressive number of digital products. At the National Association of Broadcasters Convention in 1976, the digital equipment demonstrated included: 12 time-base correctors, 6 digital synchronizers, 1 standards converter, and 1 digital recorder (ESS).

The introduction of digital signal processing techniques into the new environment of broadcasting has produced a large body of literature, of which the most significant part is listed below, and a specialized vocabulary listed and defined in the following glossary.

GLOSSARY

ADC, (A/D converter): analog-to-digital converter

algorithm: a prescribed set of well-defined rules or processes for solving a problem in a finite number of steps

baud: a unit of signaling speed equal to the number of discrete conditions or signal events per second; e.g., one baud equals one bit per second in Morse Code and one bit per second in a train of binary signals

bit: a contraction of "binary" and "digit" to define a unit of information

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bit rate: the speed at which encoded information is transmitted. In digital television, where an 8-bit PCM encoding of each sample is commonly required for acceptable quality when a sampling frequency of 10.7 MHz is used, the bit rate is approximately 85/86 million bits per second (usually expressed as Mbit/s).

bit stream: the flow of encoded information

byte: a sequence of adjacent binary digits which is operated upon as a unit and usually shorter than a word (q.v.). A byte usually is made up of 8 bits.

buffer: a device used as a temporary store from which information is taken out in a different manner from that in which it was entered

codec: a contraction of "coder and decoder," used to imply the physical combination of the coding and decoding circuits

comb filter: a wave filter whose frequency spectrum consists of a number of equispaced elements. It has repetitive pass and stop bands (resembling the teeth of a comb) and is usually implemented with a transversal filter.

companding: a contraction of "compressing and expanding." Compression is used at one point in the communication path to reduce the amplitude range of the signals, followed by an expander to produce a complementary increase in the amplitude range.

contouring: a deleterious effect on the restored picture. Diminished shading effects and sharply visible contour lines around the picture components are caused by lack of a continuous range of gray-scale values.

coring: a system for reducing the noise content of circuits by removing low-amplitude noise riding on the baseline of the signal

crispening: a means of increasing picture sharpness by generating and applying a second time derivative of the original signal

DAC (D/A converter): digital-to-analog converter

data compression: a technique for saving storage space or transmission bandwidth by eliminating gaps, empty fields, redundancies or unnecessary data to shorten the length of records or blocks

data rate: the rate at which data are transferred from one part of the system to another

delta modulation: the simplest form of DPCM (q.v.) in which one of only two codes is transmitted for each sample, instructing the receiver to either add or subtract a fixed unit change to or from an accumulating total signal

differential pulse code modulation (DPCM): a PCM variant in which the coded value transmitted for each sample represents the quantized difference between the present sample value and some combination (e.g., the integrated sum) of all previously transmitted values. For signals having strong correlation between successive samples, fewer levels may be used to quantize differences than would be required for quantizing sample values with comparable precision.

DITEC: acronym for Digital Television Communications System developed by Comsat Corp. for satellite links. (See refs. 18, 33, 46.)

dither signal: a simulated noise waveform combined with the signal before quantization (q.v.) to compensate for the contouring effects caused by quantization. It effectively reduces the number of bits required to produce an acceptable picture.

DPCM: see differential pulse-code modulation

ECL: emitter-coupled logic

error detection and correction: coding schemes incorporated into the information before it is transmitted (or stored) in such a way that errors which may arise in transmission can be detected and corrected before restoration or retrieval. In PCM systems, error correction effectively improves the SNR of the system.

error rate: the ratio of the number of bits incorrectly transmitted to the total number of bits of information received

eye pattern: oscilloscope pattern produced by random waves introduced to verify the ability to test for the presence or absence of pulses in a digital system

Fourier Transform: a transformation in which the orthogonal generating functions are sets of sinusoids

Hadamard Transform: a transformation algorithm which may be used to encode picture signals. It lends itself to implementation in such a way as to reduce the bit rate to a level lower than that required by PCM encoding. See W. K. Pratt, et al., "Hadamard Transform Coding," *IEEE Proceedings, 57:* 58–60, Jan. 1969.

interface: interconnection between two equipments having different functions

inter-frame coding: coding techniques which involve separating the signal into segments which have changed significantly from the previous frame and segments which have not changed

interpolation: the technique of filling in missing information in a sampled system

interpolation, line: in television standards conversion, the technique for adjusting the number of lines in a 625-line television system to a 525-line system (and vice versa) without impairing the picture quality

interpolation, movement: a technique used in standards conversion to compensate for the degrading effects of different field frequencies on pictures which contain movement. Different approximate proportions of successive input fields are used in each output field.

LSB: least significant bit in the PCM representation of a sample value

MSB: most significant bit in the PCM representation of a sample value

Nyquist rate (limit): maximum rate of transmitting pulse signals through a channel of given bandwidth. If B is the effective bandwidth in hertz, then $2B$ is the maximum number of code elements per second that can be received with certainty. The definition is often inverted, in effect, to read "the theoretical *minimum* rate at which an analog signal can be sampled for transmitting digitally." (See Nyquist Sampling Theorem.)

Nyquist Sampling Theorem: a theorem which holds that the minimum sampling frequency which can be used without introducing unwanted components into the decoded analog signal is equal to twice the highest frequency of the original analog signal. (See H. Nyquist, "Certain Topics in Telegraph Transmission Theory," *AIEE Transactions, 47:* 617-644, April 1928.)

packing density: the number of bits which can be stored per unit of dimension of a recording medium

PALE: phase alternating line encoding. A method of encoding the PCM NTSC signal by reversing the encoding phase on alternate lines to align the codewords vertically. (See ref. 41.)

parity bit: an extra bit appended to an array of bits to permit subsequent checking for errors

PCM: see pulse code modulation

PDM: pulse duration modulation. Also known as pulse width modulation (q.v.).

pel: picture element (see also pixel).

pixel: smallest picture element (also known as a pel) to which are assigned discrete RGB values

pulse-code modulation: modulation process involving the conversion of a waveform from analog to digital form by means of sampling, quantizing and coding. The peak-to-peak amplitude range of the signal is divided into a number of standard values each having its own value code. Each sample of the signal is then transmitted as the code word corresponding to the nearest standard amplitude

PWM: pulse width modulation (also known as pulse duration modulation). A form of pulse-time modulation in which the duration of a pulse is varied by the value of each instantaneous sample of the modulating wave.

quantization: the division of a continuous range of values into a finite number of distinct values

RAM: random access memory: a storage device from which information may be obtained at a speed which is independent of the location of the data, and from any required location, without searching all information sequentially

read-only memory: a device in which information is stored in such a way that it may be read but not modified

real time: when the processing of a signal takes place during the time that the related physical process is actually taking place, the signal may be said to be processed in "real time"

ROM: see read-only memory

sampling: the process of obtaining a series of discrete instantaneous values of a signal at regular or intermittent intervals

Shannon's Theorem: a criterion for estimating the theoretical limit to the rate of transmission — and correct reception of information with a given bandwidth and signal-to-noise ratio. (See C. E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal, 27:* 379-423, July 1948.)

shift register: a set of serially connected memory cells in which the stored contents of all cells may be simultaneously shifted forward or backward by one or more cell locations. At the time of shifting, new contents may enter at one end of the register while previous contents are displaced and lost at the other.

sub-Nyquist sampling: a scheme for sampling at a frequency lower than that prescribed by the Nyquist Sampling Theorem (q.v.)

TTL: transistor-transistor logic. One of the families of integrated-circuit logic gates. Others are: emitter-coupled logic (ECL), diode-transistor logic (DTL), and resistor-transistor logic (RTL).

transform coding: a method of encoding a picture by dividing each picture into sub-pictures, performing a linear transformation on each sub-picture and then quantizing and coding the resulting coefficients

Walsh-Hadamard Transform: the most commonly used version of the Hadamard transformation in which the orthogonal functions are sets of Walsh functions. (See Hadamard Transform.)

word: a block of information composed of a predetermined number of bits

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The First Nationwide Live Stereo Simulcast Network

By MARK SCHUBIN

For many years, television audio has been enhanced by the simultaneous transmission of high-fidelity, stereo audio information on an FM broadcast station with the transmission of video and normal television audio information on a television broadcast station. Unfortunately, due to the lack of high-fidelity network facilities, such programs have had to be distributed on tape or, if live, confined to a single city. Now a network has been assembled for transmitting live, high-fidelity, stereo simulcasts nationwide via land lines, microwave and satellite. The network utilizes analog FM subcarriers for the audio signals, carried just above the video information on video circuits. The network has been used in conjunction with several programs transmitted by the Public Broadcasting Service, and it offers stereo simulcasts to potentially more than half of the United States television audience.

In 1972, the Media Development Department of Lincoln Center began a research program to perfect the techniques of transmitting performances of opera, ballet, theater and music on television. Since the performances to be transmitted were to be actual live performances before paying audiences, this research covered such areas as low-light-level imaging, contrast compression, unobtrusive camera and microphone placement, and preparation of the television director for live transmission without interfering in the production.

It was also decided that, since opera, ballet and music depend very heavily on high-quality sound for maximum enjoyment, every effort would be made to bring such high-quality sound to the home television viewer. One of the outgrowths of this aspect of the research was the first nationwide live stereo simulcast network, first utilized on 30 January 1976 for the transmission of the first "Live From Lincoln Center" program on the Public Broadcasting Service.

Background

Television sound, though it may be transmitted on an adequate FM carrier, has always been poor in quality compared with FM radio sound. To begin with, it is picked up by microphones generally restricted from the camera's field of view and thus forced many feet from a performer. It is generally recorded on the audio track of a videotape recorder on a tape with magnetic particle orientation optimized for transverse video recording and, therefore, wrong for longitudinal audio recording, a tape which is furthermore struck by a moving video head at a frequency near the peak of audibility. When television sound is distributed by a network, its upper frequency range is restricted to 5 kHz. When received in the home, it is amplified by an amplifier that accounts for a negligible fraction of the cost of the television set, and it is returned to sound by a speaker often no better than found in inexpensive transistor radios.

Fortunately, it is possible to bypass the television sound system completely by the use of FM broadcast stations to simultaneously transmit high-fidelity stereo audio while a television station transmits video and television audio. These simulcasts, as they are called, have been used for many years for the transmission of both classical (WNET's *Great Performances*) and pop (ABC's *In Concert, Don Kirshner's Rock Concert*) music programs.

Unfortunately, unless such programs were transmitted within a single city, the unavailability of network audio lines of wide bandwidth (15 kHz), with low noise and capable of maintaining a phase relationship between the stereo channels, forced these programs to be distributed on tape.

Tape distribution would generally take one of several forms. Two videotapes might be distributed to be played simultaneously by two videotape recorders locked together by the SMPTE time code recorded on their cue tracks while one carried the left channel on its audio track and the other the right, often causing problems for monophonic compatibility; a single videotape might be distributed with one channel on its audio track and a second on its cue track (occasionally this would take the form of sum information on the audio track and difference information on the cue track); a single videotape might be distributed to modified videotape recorders with split audio heads for playing two audio tracks back from the space of the single audio track used on most machines, with the loss of SNR compensated for by noise reduction equipment; or video and audio tapes might be distributed, to be locked together by the use of the SMPTE time code, vertical drive pulses or other techniques.

The difficulty of such tape distribution — aside from the obvious costs, compromises and operational problems encountered — is that none of the methods could provide for the transmission of a live program.

Even though network audio lines were inadequate for high-fidelity transmission, however, network video lines were capable of transmitting far more than the video information presented to them. For example, a large part of a video signal is de-

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