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AN AUDIO ENGINEERING SOCIETY PREPRINT

STANDARDIZATION IN PROFESSIONAL DIGITAL
AUDIO ENGINEERING AT THE AES

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The author will discuss events leading up to the AES involvement in digital audio standards, some obstacles along the way, our present position, and the outlook for future standards.

Digital communication must be at least as old as the human race. People now, and probably then, used their fingers to indicate to others how many of something they wanted.

The Welte piano system, which was first demonstrated in Freiburg Germany in 1904, might be considered an early form of digital musical recording which controlled a robot to operate the keys and pedals of a piano to duplicate the performance of the original pianist. In this case the quality of the reproduction depended not only on the adjustment of the system but also on the quality of the piano played by the robot and the listening environment.

Although experimental work in digital speech communication was becoming commercial in the mid 50's, serious application of modern digital recording techniques to audio did not begin to accelerate until the early 70's. Denon started digital mastering circa 1972 using a 2" VTR and 13 bit quantization.

Three particular events which may be attributed to having prodded the AES into thoughts of standardization of digital audio were:

- 1) The 10 minute demonstration by Soundstram, during the presentation of a technical paper at the 55th AES convention in New York in 1976, of a completely digitally edited copy of an American operatic performance. This system used 16 bit linear quantization operating at a sampling frequency of

42.5 kHz. The distortion was reported to be under 0.005% with response D.C. to over 10 kHz.

- 2) The demonstration by Teac et al., during the presentation of a technical paper at the 58th AES Convention in New York, in 1977, of a 12" diameter laser optical disc recording and player. This system used 10 bit linear quantization with a 4 bit exponent floating point, operating at a sampling frequency of about 50 kHz. The distortion was reported to be less than 0.1% with a frequency response of 10Hz to 20 kHz + 0.1 dB, - 0.5 dB.
- 3) The demonstration by the 3M company, after the presentation of two technical papers at the 58th AES convention, of their prototype 32 track professional digital audio mastering machine using 16 bit linear quantization operating at a 50 kHz sampling frequency.

During the 58th AES convention referenced above, John McKnight circulated a questionnaire to those attending the digital audio session to determine if there were enough interest in the AES becoming involved in Digital Audio Standards work. Since there was strong interest showing, John McKnight scheduled the first meeting of the AES Digital Audio Standards Committee to take place at the Snowbird Resort in Salt Lake City, December 1 & 2, 1977.

At the Snowbird meeting chaired by John McKnight 16 people attended representing 14 companies from the U.S.A. and Japan.

In order of agreed upon importance the following topics were discussed with conclusions:

1. Sampling frequency: More study required

2. Source encoding (A/D) conversion:

- 2.1 Number of data bits: Majority for 16 bits, more study required.
- 2.2 Pre and post emphasis: More study required.
- 2.3 The location of the (sinx)/x compensator: More study required.

The second meeting was scheduled for Atlanta Georgia 1978-02-01 and 02 during the SMPTE TV conference.

Following the Snowbird meeting, John McKnight prepared the following two lists for consideration by the committee:

1. Technical Factors to be Standardized (in priority order).

- 1.1 Sampling frequency (a standard value is necessary to avoid extra A-D/D-A conversions),
Authors note: Even with a universal sampling frequency converter, now available, degradation of the signal will occur with repeated A-D/D-A conversions.
- 1.2 Source encoding A/D conversion: What the bits mean - linear PCM, Linear-log PCM, pre/post emphasis, floating point, etc.
- 1.3 Code formats for each storage medium (for example Miller, NRZ, sync, redundancy, error correction, space for other things such as time code, editing, mixdown information etc.)
- 1.4 Format for storage (for example, for fixed head tape): width, length, thickness, speed, track format, packing density. For discs: diameter, speed, pitch etc.
- 1.5 Digital interfacing of the bit stream on wire(s): for example, serial vs. parallel; voltage levels.
- 1.6 System block diagram: What goes into console; in peripheral equipment; on storage medium.

- 1.7 Analog interface (for example, program level measurement: reference voltage, etc.)
- 1.8 Measuring and evaluating system performance (how meaningfully to measure signal minus noise level in digital audio, frequency response, how to define a "qualified" tape, how to align machines for interchangeability of media, specifications (standard reporting of performance), measurement of RFI generation and susceptibility to it; "headroom".)
- 1.9 Terminology
- 2.0 List of Applications Fields for Digital Audio.
- 2.1 Sound recording studios: multi-track mastering, 2-track mix-down.
- 2.2 Motion picture and TV sound production.
- 2.3 Signal processing (non-recording): delay and reverberation filtering and equalizing; mixing; time compression.
- 2.4 Distribution: Satellite, radio and TV; long lines, microwave.
- 2.5 Consumer recording: Optical disc; mechanical disc; magnetic discs; flatplate optical; magnetic tape with stationary heads; magnetic tape with moving heads.
- 2.6 Digitally synthesized sound and music for research, entertainment, information storage and retrieval, etc.

As an item for the agenda for the Atlanta meeting, the chairman set a goal to arrive at a single sampling frequency and if this is not possible to arrive at, a small set of frequencies along with good reasons for them.

With one technical committee (TC) meeting now in the past and the next one scheduled for the coming February, the Joint Committee for Intersociety Communication (JCIC) called for a joint meeting with the AES. JCIC membership consists of the Electronic Indus-

tries Association (EIA), Institute of Electrical and Electronic Engineers (IEEE), Recording Industries Association of America (RIAA), National Association of Broadcasters (NAB), and National Cable Television Association (NCTA).

As I understand it, JCIC is an informal organization of associations one of whose purposes is to decide which member or outsider should have responsibility for work on proposed standards activities. The standards activities just started by the AES did not go unnoticed by JCIC (the AES is not a JCIC member). The joint meeting between JCIC and the AES took place between Christmas 1977 and the New Year at the AES office in New York City. The AES assumed the responsibility for generating Digital Audio Standards with the promise of representation of JCIC on the committee. JCIC representation at the meeting with the AES were SMPTE, EIA, and NAB.

The second AES Digital Audio Standards Committee meeting took place in Atlanta Georgia on schedule, 1978-02-01 and 02, and was chaired by Mr. John McKnight. (JAES 26:4,P.232(1978)).

Matters of selection of the sampling frequency were continued with presentations by Messrs Kosaka of Matsushita, Doi of Sony, Tanaka et al., of Mitsubishi, Muraoka et al., of JVC, Heaslett of Ampex and Youngquist of 3M.

The committee generally agreed that 50 kHz was the preferred sampling frequency for professional recording and signal processing but that 44.05594 kHz would be appropriate for low-bandwidth rotary head type video recorders.

Concerning source encoding (D/A conversion), a consensus was

reached on the following 8 items:

- 1) The digital data word should be 16-bit, 2's complement.
- 2) Pre - or de - emphasis should not be used.
- 3) Aperture correction for the $(\sin x)/x$ loss should be at the output, (D/A), side.
- 4) Positive internal digital numbers should represent positive analog quantities.
- 5) The polarity of analog input signals should be preserved throughout the digital system to the digital output.
- 6) The equipment may be designed so that it does not set or detect least significant bits in digital words.
- 7) Unused bits should be fixed.
- 8) The exact method for converting digital words to analog signals or analog signals to words should be at the discretion of the designer.

P.K. Burkowitz presented a paper outlining the need for measurement techniques for:

- 1) Quantization noise.
- 2) Headroom.
- 3) Distortion:
 - a) in-band.
 - b) out-of-band.

He also discussed the requirements in digital recording for "punch-in" and "punch-out" modes similar to those used in "present-day" analog recording.

The third meeting of the Digital Audio Standards Committee took place prior to the May 1978 AES Convention in Los Angeles April 29 and 30 under the chairmanship of John G. McKnight with

approximately 50 representatives attending.

The first item of business was an announcement by Emil Torick (President of the AES) that a complaint had been filed with the USA Justice Department requesting an investigation of the AES activities on Digital Audio Standards as possibly being in restraint of trade.

After recovering from the blow of this announcement, the meeting continued by the chairman reading the minutes of the Atlanta Georgia (1978-02, 01 and 02) and Hamburg (1978-03, 01) meetings. Both sets of minutes were approved as read.

Concerning the matter with the USA Justice department a motion was made and carried for the committee to adopt American National Standards Institute (ANSI) procedures until such time as the AES Board of Governors thru their legal counsel could provide a formal policy on standardization.

Matters of sampling frequency considerations, source encoding Digital Audio Editing, I/O interfacing, code formats and terminology were discussed without arriving at a consensus for any of them. Subcommittees were formed to collect data, summarize, analyze and make recommendations on the following items:

- 1) Sampling frequency: Chairman Tom Hayes MCI
- 2) Source encoding: no chairman but J. McKnight to receive proposals
- 3) Digital audio editing: C. Knoppel to prepare a questionnaire and send it to survey potential users and report results.
- 4) I/O interfacing: Tom Hay to summarize Bell lines documents and Han Tendeloo to summarize CCIR and EBU documents for the committee.

- 5) Code formats: Norm Schwartz to generate guidelines to insure interchangeability of tape between machines of various manufacturers.
- 6) Terminology: Martin Willcocks to define appropriate terminology in the field of digital audio.

The next meeting was scheduled for 1978-08-24 and 25 but not reported.

The author's first meeting as chairman took place in New York City 1979-11-04 at the 64th AES Convention with 24 members attending representing the USA, Europe and Japan.

Between the May 1978 meeting in Los Angeles and this meeting, guidelines were prepared by legal counsel and the AES under which our committee could operate.

1. John McKnight (Magnetic Reference Lab) discussed the guidelines under which the committee would operate and that we would avoid the use of the term "Digital Audio Standards Committee" until such time as there exists an adequate number of digital audio equipment manufacturers in the market place (preferably more than three).
2. The Chairman discussed the proposed activities of the Digital Audio Technical Committee to get it moving in the direction started by John McKnight (Magnetic Reference Lab.) in the Fall of 1977:
 - 2.1 To provide a forum for the free exchange of ideas concerning scientific and engineering problems and advanced topics of Digital Audio for the benefit of the AES members and other interested parties through the organization of informal workshops at the AES Conventions.

- 2.2 To solicit and promote technical papers on Digital Audio in cooperation with the Journal Editor.
- 2.3 To organize regular and special sessions at AES Conventions and AES Technical Conferences for the purpose of discussing work to be done. For example:
 - a. To generate and publish a list of the pertinent parameters to be measured on digital audio equipment.
 - b. To generate and publish a list of critical listening tests for the evaluation of digital audio system performance.
 - c. To evaluate various coding, decoding, and transcoding schemes.
 - d. To generate and publish a list of unresolved problems concerning digital audio.
- 2.4 To collect and to publish data concerning the digital audio activities in the USA and in other countries with regard to standards.
3. Mr. Kosaka (Matsuchita who is Secretariat of IEC SC60A WG 18 (Domestic Digital Audio Tape Recording) and who is also active in Several Digital Audio Committees in Japan, offered his services to keep the AES informed of activities in both areas.
4. Mr. Bluthgen (Polygram) who is Secretariat of IEC SC60A WG 17 (Digital Audio Disc Recording) offered his services to keep us informed of the digital audio activity in his area and his services were gratefully accepted.
5. The next meeting of the AES Digital Audio Technical Committee will be during the May, 1980 AES meeting in Los Angeles. The location and time will be announced well in advance of the meeting.

During the late 70's the Justice Department was busily engaged investigating other standards organizations some of whose activities were later found to be in restraint of trade. The AES, because of the earlier letter to the Justice Department proceeded very slowly and carefully. The official AES policies concerning the AES Technical Committees and Technical Council, AES Policy on Standardization, and Legal Guidelines for Technical Committees and Engineering Standardization Activities of the Audio Engineering Society were published in JAES 27:1/2,P.50,1979.

The next event which further strengthened the AES position in Standards activities came about when the Acoustical Standards Management Board gave approval for the AES and EIA to jointly sponsor the S4 Committee of ANSI. At the same time, the scope of S4 was widened from Sound Recording to Audio Engineering. This was reported to the AES Digital Audio Technical Committee at its May 4, 1980 meeting in Los Angeles, JAES 28:9,P.615,1980. By the time of our October 30, 1980 meeting we were given a caution light to go ahead with standards work JAES 29:1/2,P.56,1981.

At our November 2, 1981 meeting in New York, JAES 31:1/2,P.40,1982, we were able to get a consensus on sampling frequencies of 48 kHz, 44.1 kHz and 32 kHz.

Mr. Torick agreed to prepare a draft standard and submit it to the executive committee of the AES Digital Audio Technical Committee. This was done on March 13, 1983 prior to the 73rd AES Convention in Eindhoven. This standard became ANSI 4.28 1984.

The I/O Serial Format Interface Standard has been turned over to S4 for processing and submittal to ANSI, March 4, 1985.

The AES Digital Audio TC is presently working on matters of standardization for:

- 1.0 I/O Interfacing: Chairman Robert Finger, CBS Tech. Center
- 1.1 The Serial I/O Interface Draft Standard with S4 until it is submitted to ANSI.
- 1.2 Multichannel Interfacing:
 - 1.2.1 Serial format.
 - 1.2.2 Parallel format.
- 2.0 Digital Audio Measurement Techniques: Chairman Dr. Richard Cabot/Dr. Roger Lagadec.
- 2.1 General Guidelines For Measuring A/D and D/A systems:
 - 2.1.1 Large signal behavior.
 - 2.1.2 Small signal behavior
 - 2.1.3 Definition of signal levels within the framework of 24 bit digital-audio systems.
 - 2.1.4 Phase shift in digital audio systems.
- 3.0 Signal Labeling and Ancillary Data: Chairman John Nunn BBC
- 3.1 Labels:
 - 3.1.1 Application of labels.
 - 3.1.2 Label format.
 - 3.1.3 Label linking.
- 3.2 Ancillary Data.
 - 3.2.1 Channel Status information
 - 3.2.2 Validity Data.
- 4.0 System Synchronization: Chairman Tim Shelton BBC
- 4.1 Selection of master clock frequency common to video and audio applications.

- 4.2 Synchronization of digital audio signals
 - 4.2.1 Alignment of signals originating from independent asynchronous sources.
 - 4.2.2 Alignment of signals originating from co-sited sources.
- 4.3 Determination of acceptable synchronization tolerances.
 - 4.3.1 Frequency stability.
 - 4.3.2 Jitter tolerance.
 - 4.3.3 Lock-up time.
- 5.0 Digital Audio Terminology: Chairman David Ranada Stereo Review.

Before its involvement in Digital Audio Standards in 1977, the AES Standards organization was rather informal and relatively inactive, having one 1954 standard on the books and one in progress.

By October 1980, the AES had co-chairmanship with the EIA of the ANSI Audio Engineering Standards Committee S4. AES Digital Audio Engineering Standards then had promise of becoming a reality. By November 1981 we had obtained a consensus for Recommended Standard Sampling Frequencies, (ANSI 4.28, 1984). By March 1985, we had obtained a consensus for the Serial I/O interface document which is now in the hands of S4 for processing and submittal to ANSI.

Draft standard documents should begin to appear at the November 1985 meeting on System Synchronization and at the March 1986 meetings on Measurement Techniques.

With the AES now an official member of the Audio Engineering Standards making community, I expect the AES to become active in all Audio Engineering Standards fields, not only in Digital Audio.

DIGITAL AUDIO STANDARDS COMMITTEE MEETINGS

<u>DATE OF MEETINGS</u>	<u>LOCATIONS</u>	<u>JOURNALS</u>
DEC. 1 & 2, 1977	SNOWBIRD, SALT LAKE CITY, UTAH	JAES 26:1/2, P.52, 1978
FEB. 1 & 2, 1978	ATLANTA, GEORGIA	JAES 26:4, P.232, 1978
APR. 29&30, 1978	LOS ANGELES, CALIFORNIA	NOT PUBLISHED
AUG. 24&25, 1978	ST. PAUL MINNESOTA	NOT PUBLISHED
NOV. 4, 1980	NEW YORK	JAES 28:4, P.259, 1980

DIGITAL AUDIO TECHNICAL COMMITTEE MEETINGS

MAY 4, 1980	LOS ANGELES, CALIFORNIA	JAES 28:9, P.615, 1980
OCT. 30, 1980	NEW YORK	JAES 29:1/2, P.56, 1981
MAY 10, 1981	LOS ANGELES, CALIFORNIA	JAES 29:9, P.620, 1981
NOV. 2, 1981	NEW YORK	JAES 31:1/2, P.40, 1982
MAR. 3, 1982	MONTREAUX, SWITZERLAND	JAES 30:6, P.448, 1982
OCT. 22, 1982	ANAHEIM, CALIFORNIA	JAES 31:1/2, P.37, 1983
MAR. 13, 1983	EINDHOVEN, NETHERLANDS	JAES 31:7/8, P.538, 1983
OCT. 7, 1983	NEW YORK	JAES 32:1/2, P.34, 1984
MAR. 26, 1984	PARIS	JAES 32:7/8, P.545, 1984
OCT. 7, 1984	NEW YORK CITY, NEW YORK	JAES 33:1/2, P.55, 1985