A METHOD AND DEVICE FOR STORING AUDIO-CENTERED INFORMATION WITH A MULTI-LEVEL TABLE-OF-CONTENTS (TOC) MECHANISM AND DOUBLING OF AREA-TOCS

BACKGROUND OF THE INVENTION

The invention relates to a method as recited in the preamble of Claim 1. Storing digital audio on unitary media such as disc or tape is widespread. In case of actual sub-division of the audio into multiple sub-items, providing a **Table-of-Contents** (TOC) allows to access the information in an easy manner. Such TOC will specify at least **what** has been stored and **where** it has been stored. The audio may be defined according to various standardized audio formats, such as two-channel stereo, multiple (5-6) channel audio such as in surround sound applications, and possibly others. An audio provider may wish to combine various track areas having the same and/or different such formats on a single medium such as an optical disc.

SUMMARY TO THE INVENTION

In consequence, amongst other things, it is an object of the present invention to allow an audio management system to allow a user to access various audio track areas in a fast and easy manner. Now therefore, according to one of its aspects the invention is characterized according to the characterizing part of Claim 1. A user is now able to distinguish between various track areas and to navigate among the various items of a single track area in a robust manner, and if possible, without encumbrance through data errors in the TOC itself.

The invention also relates to a unitary storage medium produced by the method, to a storing device arranged for practising such method, and to a reader or player device arranged for interfacing to such storage medium. A particular audio medium instance could be restricted to storing only stereo, so that the multi-channel version would effectively be a dummy. For reasons of standardizing, the multilevel TOC mechanism will then also be adopted. Further advantageous aspects of the invention are recited in dependent Claims.

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BRIEF DESCRIPTION OF THE DRAWING

These and further aspects and advantages of the invention will be discussed more in detail hereinafter with reference to the disclosure of preferred embodiments, and in particular with reference to the appended Figures that show:

Figures 1a, 1b a record carrier,

Figure 2 a playback device,

Figure 3 a recording device,

Figure 4 a file system for use with the invention;

Figure 5 a storage arrangement for the invention;

Figure 6 a structure of an audio area.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1a shows a disc-shaped record carrier 11 with track 19 and central hole 10. Track 19 has a spiral pattern of turns forming substantially parallel tracks on an information layer. The carrier may be an optical disc with a recordable or prerecorded information layer. CD-R, CD-RW and DVD-RAM are recordable discs. Audio CD is a prerecorded disc. Prerecorded discs may be manufactured by first recording a master disc and then pressing consumer discs. Track 19 on a recordable record carrier may be formed by a pre-embossed track structure. The track may be configured as pregroove 14 to allow a read/write head to follow the track 19 during scanning. The information is recorded on the information layer by optically detectable marks along the track, e.g. pits and lands.

Figure 1b is a cross-section along the line b-b of a recordable record carrier 11, wherein transparent substrate 15 carries recording layer 16 and protective layer 17. Pregroove 14 may be implemented as an indentation, an elevation, or as a material property deviating from its surroundings.

For user convenience, the audio information on the record carrier is subdivided into items, which may have a duration of a few minutes e.g. songs in an album or movements of a symphony. The carrier will also contain access information to identify the items, such as a Table Of Contents (TOC) or a file system like ISO 9660 for CD-ROM. The access information may include playing time and start address for each item, and further information like a song title.

The audio information is recorded in digital representation after analog to digital (A/D) conversion. Examples of A/D conversion are PCM 16-bit per sample at 44.1 kHz known from CD audio and 1 bit Sigma Delta modulation at a high oversampling rate e.g. 64 x

Fs called Bitstream. The latter is a high quality encoding method, allowing either high quality decoding or low quality decoding. Reference is had to the publications 'A digital decimating filter for analog-to-digital conversion of hi-fi audio signals', by J.J. van der Kam, document D5 infra, and 'A higher order topology for interpolative modulators for oversampling A/D converters', by Kirk C.H. Chao et al, document D6. After A/D conversion, digital audio may be compressed to variable bitrate audio data for recording on the information layer. The compressed audio data is read from the carrier at such speed that after decompression substantially the original timescale will be restored when continuously reproducing the audio. Hence the compressed data must be retrieved from the record carrier at a speed dependent on the varying bitrate. The data is retrieved at so-called transfer speed, i.e. the speed of transferring data bytes from the record carrier to a de-compressor. Providing the record carrier with constant spatial data density gives the highest data storage capacity per unit of area. The transfer speed is proportional to the relative linear speed between the medium and the read/write head. With buffer before the de-compressor, actual transfer speed is the speed before that buffer.

Figure 2 shows a playback apparatus according to the invention for reading a record carrier 11 of the type shown in Figure 1. The device has drive means 21 for rotating carrier 11 and read head 22 for scanning the record track. Positioning means effect 25 coarse radial positioning of read head 22. The read head comprises a known optical system with a radiation source for generating beam 24 that is guided through optical elements and focused to spot 23 on an information track. The read head further comprises a focusing actuator for moving the focus of the radiation 24 along the optical axis of the beam and a tracking actuator for fine positioning of spot 23 in a radial direction on the centre of the track. The tracking actuator may comprise coils for moving an optical element or may be arranged for changing the angle of a reflecting element. The radiation reflected by the information layer is detected by a known detector in the read head 22, e.g. a four-quadrant diode, to generate a read signal and further detector signals including tracking error and focusing error signals for the tracking and focusing actuators, respectively. The read signal is processed by standard reading means 27 to retrieve the data, for example through a channel decoder and an error corrector. The retrieved data is sent to data selection means 28, to select the compressed audio data for feeding to buffer 29. The selection is based on data type indicators also present on the carrier, e.g. headers in a framed format. From buffer 29, the compressed audio data go to de-compressor 31 as signal 30. Decompressor 31 decodes the compressed audio data to reproduce the original audio information on output 32. The de-compressor may be fitted in a stand-alone

audio D/A convertor 33, or the buffer may be positioned before the data selection. Buffer 29 may reside separately or may be combined with a buffer in the decompressor. The device furthermore has a control unit 20 for receiving control commands from a user or from a host computer not shown, that via control lines 26 is connected to drive means 21, positioning means 25, reading means 27 and data selection means 28, and possibly also to buffer 29 for filling level control. To this end, the control unit 20 may comprise digital control circuitry, for performing the procedures described below.

The art of audio compression and de-compression is known. Audio may be compressed after digitizing by analyzing the correlation in the signal, and producing parameters for fragments of a specified size. During de-compression the inverse process reconstructs the original signal. If the original digitized signal is reconstructed exactly, the (de-)compression is lossless. Lossy (de)-compression will not reproduce some details of the original signal which will be substantially undetectable by the human ear or eye. Most known systems for audio and video, such as DCC or MPEG, use lossy compression, whereas lossless compression is used for computer data. Examples of audio compression and decompression are given in D2, D3 and D4 hereinafter.

Data selection means 28 will retrieve from the read data certain control information, in particular indicating the transfer speed profile. The data selection means 28 will also discard any stuffing data, that had been added during recording according to the speed profile. When the control unit 20 is commanded to reproduce an audio item from the record carrier, positioning means 25 will position the reading head on the portion of the track containing the TOC. The starting address and the speed profile for that item will then be retrieved from the TOC via the data selection means 28. Alternatively, the contents of the TOC may be read only once and stored in a memory when the disc is inserted in the apparatus. For reproducing an item, drive means 21 will rotate the record carrier at the speed indicated by the speed profile. The required rotation rate may be given as such in the speed profile for setting the drive means. Alternatively the speed profile may comprise a bitrate, and then the rotation rate can be calculated as follows. The radial position of the item can be calculated from the starting address, because the record carrier density parameters like track pitch and bit length, will be known to the playback device, usually from a standard. Subsequently the rotation rate can be derived from the bitrate and the radial position. To provide continuous reproduction without buffer underflow or overflow the transfer speed is coupled to the reproduction speed of the D/A converter, i.e. to the bit-rate after decompression. Thereto the apparatus may comprise a reference frequency source for controlling the decompressor and the

rotation rate may be set in dependence on the reference frequency and the speed profile. The rotation rate may also be adjusted by the average filling level of the buffer 29, e.g. lowering rotation rate when the buffer is more than 50% full on average.

Figure 3 shows a recording device for writing information on a (re)writable record carrier 11. During a writing operation, marks representing the information are formed on the record carrier. The marks may be in optically readable form, e.g. as areas whose reflection differs from their surroundings, by recording in materials such as dye, alloy or phase change, or in the form of areas with a direction of magnetization different from their surroundings. Writing and reading of information for recording on optical disks and usable rules for formatting, error correcting and channel coding, are well-known, e.g. from the CD system. Marks may be formed through a spot 23 generated on the recording layer via a beam 24 of electromagnetic radiation, usually from a laser diode. The recording device comprises similar basic elements as described with reference to Figure 2, i.e. a control unit 20, drive means 21 and positioning means 25, but it has a distinctive write head 39. Audio information is presented on the input of compression means 35. Suitable compression has been described in D2, D3 and D4. The variable bitrate compressed audio on the output of compression means 35 is sent to buffer 36. From buffer 36 the data is sent to data combination means 37 for adding stuffing data and further control data. The total data stream is sent to writing means 38 for recording. Write head 39 is coupled to the writing means 38, which comprise for example a formatter, an error encoder and a channel modulator. The data presented to the input of writing means 38 is distributed over logical and physical sectors according to formatting and encoding rules and converted into a write signal for write head 39. Unit 20 controls buffer 36, data combination means 37 and writing means 38 via control lines 26 and perform the positioning procedure as described above for the reading apparatus. The recording apparatus may also have the features of a playback apparatus and a combined write/read head.

Figure 4 shows a file system for use with the invention, for which various different options are feasible. The inventors have proposed that the storage medium should be based on a UDF file system or on an ISO 9660 file system, both of which systems are standard to a skilled art person. In the alternative case, no file system should be present at all and the relevant sector spaces should be kept empty.

In the file system, all audio will be stored in Audio Files located in SubDirectory **SCD_AUDIO**. As shown in Figure 4, the hierarchy is based on **ROOT** file 50 that points to various subaltern files 52, 54, 56. The structure of **MASTER.TOC** 52, here single, will be discussed hereinafter. Further, there is a **2_CH_AUDIO** file 54. This points to

TOC **2_CH_TOC** 58 and also to the various stereo tracks **TRACKn.2CH** 60. Furthermore, **M_CH_AUDIO** file 56 points to TOC **M_CH_TOC** 62 and in parallel therewith to the various multi-channel tracks **TRACKn.MCH** 64.

Figure 5 shows a first storage arrangement for use with the invention, which by way of example has been mapped on a single serial track. Along the horizontal axis the following items are evident. Item 120 is a **Lead-in** area that is used for mutually synchronizing the reader and the driving of the medium. Item 122 represents the **File System** disclosed with reference to Figure 4. Item 124 represents a **MASTER_TOC** that may be configured according to standard procedures and pertains to subsequent items **Stereo AREA** 126 and **Multi-channel AREA** 128, and if necessary also to **Extra Data AREA** 130. The lengths of these three areas need not be standardized, inasmuch as various different amounts of information may be present. With respect to the audio areas, the audio track areas proper, as well as the associated **SUB_TOCs** are included. Apart from the disclosure hereinafter, the contents of items 126, 128, 130 may be defined according to conventional standards that by themselves do not constitute part of the invention. Generally, the two audio areas may have the same structure and contain the same kinds of information, apart from distinguishing between the various channels. The audio may be plain coded or loss-less coded. All kinds of audio may be multiplexed with supplementary data, such as Compact Disc Text.

Item 132 represents a **Lead-Out Information**. The latter item is used in particular during search operations. Its tracks do not contain information further than track numbers and addresses. The number of lead-out tracks may cover a ring of some 0.5 to 1 millimeter wide. According to the above, the stored information may either be accessed via the file system as laid down in item 122, or via the TOC structure laid down in item 124, and more particular, via a two- or multi-level TOC structure to be discussed hereinafter.

Any of the single or plural **Master TOCs** 124 will begin at a respective uniformly standardized offset position from the start of the Lead-in area, such as at byte number 500 for the first **Master TOC**. In the embodiment a Master-TOC measures only one standard-size sector and primarily contains pointers to the various Sub-TOCs or Area-TOCs to be disclosed hereinafter. A preferred syntax of a Master-TOC is as follows:

1. A 16-byte **Signature** identifies the Master-TOC, such as by "SACD Master TOC ", the signature containing three space.characters, but the apostrophes **not** being part of the definition.
2. A 2-byte **Spec_version** indicates the version number of the format used in the disc.
3. A 14-byte **Space** has been reserved, such as for alignment stuffing.

8. A 4-byte **disc_date_pointer** indicates the offset in bytes from the start of the Sub_TOC in question to the start of the disc_date() field. If the value in question is 0, this indicates that the disc_date() field is absent.

9. A 4-byte **disc_copyright_pointer** indicates the offset in bytes from the start of the Sub_TOC in question to the start of the disc_copyright() field. If the value in question is 0, this indicates that the disc_copyright() field is absent.

10. A 4-byte **disc_publisher_pointer** indicates the offset in bytes from the start of the Sub_TOC in question to the start of the disc_publisher() field. If the value in question is 0, this indicates that the disc_publisher() field is absent.

11. A variable size **Track_List()** may be present for each one of a plurality of audio tracks to contain an offset information with reference to the start of the TOC in question, plus various further items, such as the name of track and any of a great multiplicity of items that are presumably interesting to a listener of the recording in question.

Figure 6 shows an exemplary structure of an audio area 126, 128 in Figure 5. Here, the track area is preceded by Area or Sub-TOC-1 and succeeded by Area TOC-2. These are two identical copies. Another manner of logical conformance may be produced by bit-wise inversion. Anyway, each copy taken separately must contain all information contained in the two TOCs. The locations thereof are for each separate Area TOC given in a higher level Master TOC. A gap between the Track Area and succeeding Area TOC-2 is not allowed. On the other hand, a gap between preceding Area TOC-1 and the Track Area is allowed, symbolized by area G. Such gap will generally not contain significant information, in particular, no other TOC or track. Therefore, logically the track area will abut at both ends to the TOCs. Due to the doubling of the Area TOCs and their mutual distance, any interference therewith through environmental or other influences will usually not be doubled for the two copies. In consequence, the probability for correct storage of all parts of the Area TOC in at least one of the two versions thereof will be practically guaranteed, even without the providing of internal redundancy. Error correcting through such redundancy would often cost an unjustified delay. In fact, if the preceding TOC is correct, the starting of a track may be effected virtually immediately.

4. A 4-byte integer **2CH-start_address** contains the logical address of the first sector of the stereo area.

5. A 4-byte integer **2CH-end_address** contains the logical address of the last sector of the stereo area.

6. A 4-byte integer **MC-start_address** contains the logical address of the first sector of the Multi channel area.

7. A 4-byte integer **MC-end_address** contains the logical address of the last sector of the Multi channel area.

8. A 4-byte integer **Extra_data_start_address** contains the logical address of the first sector of the Extra Data area.

9. A 4-byte integer **Extra_data_end_address** contains the logical address of the last sector of the Extra Data area.

The total information pertaining to the above is **56** bytes. Further features may be added to a Master-TOC. If a certain area, such as the stereo area, the Multi channel area, or the Extra Data area is not present, both start and end addresses of the area in question have value zero.

Next, items 126 and 128 will contain Sub-TOCS or Area-Tocs for the Stereo and Multi-Channel Audio intervals, respectively, formatted as will be disclosed hereinafter with respect to Figure 6. A preferred syntax of a Sub-TOC is as follows:

1. A 16-byte **Signature** identifies the Sub-TOC in question such as by "SACD stereo TOC " for a stereo audio area and "SACD MC TOC" for a Multi Channel audio area, the number of bytes being attained by adding trailing space characters.

2. A 2-byte **Spec_version** indicates the version number of the format used in the disc.

3. A 4-byte **Sub_TOC_length** indicates the number of bytes present in the actual TOC.

4. A 10-byte **Space** has been reserved, such as for alignment stuffing.

5. A variable size set of **/* Disc Parameters */** may be present, such as a Name of an Album() and a Name of a Catalogue().

6. A 4-byte **disc_play_time** indicates the total linear playing time of the disc expressed as a time code.

7. A 4-byte **disc_name_pointer** indicates the offset in bytes from the start of the Sub_TOC in question to the start of the disc_name() field. If the value in question is 0, this indicates that the disc_name() field is absent.

List of related documents:

(D1) Research Disclosure number 36411, August 1994, p. 412-413

(D2) PCT/IB97/01156 (PHN 16.452) 1 bit ADC and lossless compression of audio.

(D3) PCT/IB97/01303 (PHN 16.405), Audio compressor.

(D4) EP-A 402,973 (PHN 13.241), Audio compression.

(D5) 'A digital decimating filter for analog-to-digital conversion of hi-fi audio signals' by J.J. van der Kam in Philips Techn. Rev. 42, no. 6/7, April 1986, pp. 230-8.

(D6)'A higher order topology for interpolative modulators for oversampling A/D converters', by Kirk C.H. Chao et al in IEEE Trans. on Circuits and Systems, Vol 37, no. 3, March 1990, pp. 309-18.

CLAIMS:

1. A method for storing audio-centered information on a unitary storage medium while using a Table-of-Contents (TOC) mechanism for therein specifying an actual configuration of various audio items on said medium,

being characterized by assigning at least two mutually logically conforming Sub-TOCs to each one of a set of one or more Track Areas, thereby allowing retrieving any constituent Sub-TOC part from at least any correct copy of said Sub-TOCs, and furthermore providing at least one Master-TOC for specifically pointing to each of said Sub-TOCs.

2. A method as claimed in Claim 1, wherein said Sub-TOCs abut at mutually opposite ends to their associated Track Area.

3. A method as claimed in Claim 1, wherein the number of sub-TOCs per Track Area is exactly 2.

4. A method as claimed in Claim 1, and furthermore providing any Master-TOC at a standard offset location with respect to an initial location of said medium.

5. A unitary medium produced by practising a method as claimed in Claim 1.

6. A medium as claimed in Claim 5 and executed as an optically readable disc.

7. A reader device for interfacing to a medium as claimed in Claim 5.

8. A device as claimed in Claim 7, and being provided with disc hold means, optical read means and disc drive means for driving a disc track along said optical read means.

9. A storing device being arranged for practising a method as claimed in Claim 1.

