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Professional video storage products — Tape-less camera recorder using MXF file format — Encoding guidelines

Part 1: MXF Operational Patterns

National foreword

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Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62871-1, which is a Technical Specification, has been prepared by technical area 6: Storage media, storage data structure, storage systems and equipment, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
100/2373/DTS	100/2446/RVC

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- reconfirmed,
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INTRODUCTION

The professional camera recorder has evolved from a traditional tape-based system into a file-based system, taking advantage of recent advances in information technology. Instead of using conventional magnetic tape as the recording medium, video and audio streams can now be stored as files that can be read directly by a personal computer (PC).

Several file format specifications exist, and most broadcasters are using the Material eXchange Format (MXF) which has been standardized by the Society of Motion Picture and Television Engineers (SMPTE). As reported in IEC TR 62712:2011, the MXF file format has been adopted for various types of professional tape-less camera recorders. MXF is being used by many broadcast stations around the world. Since the MXF file format provides a multiplicity of functions and options in order to satisfy the needs of various applications in a range of situations, it is important to address interoperability issues between equipment. Therefore, it is essential for interoperability that there is an appropriate Technical Specification that specifies guidelines for MXF implementations and operational usage.

The IEC 62871 series gives encoding guidelines for professional tape-less camera recorders using the MXF file format to ensure interoperability.

Future parts will be proposed to specify implementation guidelines appropriate for specific codecs.

PROFESSIONAL VIDEO STORAGE PRODUCTS – TAPE-LESS CAMERA RECORDER USING MXF FILE FORMAT – ENCODING GUIDELINES –

Part 1: MXF Operational Patterns

1 Scope

This part of IEC 62871, which is a Technical Specification, gives guidelines for MXF Operational Patterns for professional tape-less camera recorders and also outlines the general parts of the MXF file format.

The guidelines are applicable to the creation of an MXF file in professional tape-less camera recorders. They are also applicable for content management software and to equipment that supports MXF files generated by professional tape-less camera recorders.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

SMPTE ST 377-1:2011, *Material Exchange Format (MXF) – File Format Specification*

SMPTE ST 378:2004, *For Television – Material Exchange Format (MXF) – Operational Pattern 1a (Single Item, Single Package)*

SMPTE ST 379-1:2009, *Material Exchange Format (MXF) – MXF Generic Container*

SMPTE ST 379-2:2010, *Material Exchange Format (MXF) – MXF Constrained Generic Container*

SMPTE ST 390:2011, *Material Exchange Format (MXF) – Specialized Operational Pattern "OP-Atom" (Simplified Representation of a Single Item)*

3 Terms, definitions,abbreviations and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in SMPTE ST 377-1, SMPTE ST 379-1 and SMPTE ST 379-2 apply.

3.2 Abbreviations

Abbreviation	Definition
MP	Material Package
FP	File Package

OP-1a	Operational Pattern 1a
OP-1b	Operational Pattern 1b
OP-1c	Operational Pattern 1c
OP-2a	Operational Pattern 2a
OP-2b	Operational Pattern 2b
OP-2c	Operational Pattern 2c
OP-3a	Operational Pattern 3a
OP-3b	Operational Pattern 3b
OP-3c	Operational Pattern 3c
OP-Atom	Operational Pattern Atom
CBR	Constant Bit Rate
VBR	Variable Bit Rate

3.3 Conventions

In this Technical Specification, capital letters are used for terms defining the MXF file standardized in the SMPTE publications which are cited in the normative references.

4 Overview of the MXF file format

4.1 General

The MXF file format is standardized in SMPTE, and different aspects of the detailed specifications are covered in several standards. The general part is specified in SMPTE ST 377-1, which defines the data structure of the MXF file for the interchange of audio-visual material, all the components of the MXF file format and the requirements to enable these components to be added as a plug-in to an MXF file.

The MXF Generic Container is specified in SMPTE ST 379-1 and SMPTE ST 379-2. The Generic Container is the native Essence Container of the MXF file body and these standards are defined to enable the interchange of streamable audio-visual material. Appropriate essence and metadata payloads that can be mapped into the MXF Generic Container are defined in associated documents listed in the Bibliography.

The MXF file format includes Operational Pattern specifications that may define restrictions on the way in which this Essence Container type should be implemented. For example, OP-1a is specified in SMPTE ST 378 and OP-Atom is specified in SMPTE ST 390.

4.2 File structure

4.2.1 Overview

An overview of the MXF file structure is shown in Figure 1. The general structure of the MXF file comprises three components: the File Header, the File Body and the File Footer.

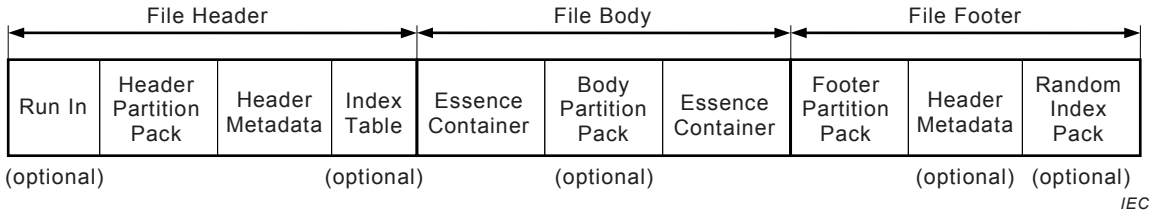

Figure 1 – Overview of MXF file structure

4.2.2 File Header

The File Header is located at the start of the MXF file and includes a Header Partition Pack and a Header Metadata. The file header may include a Run-In and an Index Table as an option.

4.2.3 File Body

The File Body provides the mechanism for embedding Essence Data such as audio, video and other associated data within the MXF files. The File Body contains zero or more Essence Containers and, if there is more than one Essence Container in the File Body, the Essence Containers are multiplexed together using Partitions (see 4.3). Furthermore, the file body may include an index table and a repetition of the Header Metadata as an option.

4.2.4 File Footer

The File Footer is located at the end of the file. As shown in Figure 1, the File Footer includes a Footer Partition Pack. It may include a repetition of the Header Metadata and a Random Index Pack. The File Footer may also include optional Index Table Segments.

4.3 Partitions

4.3.1 Overview

Partitions logically divide the MXF file to allow easier parsing, to help streaming and to manage the creation of Index Tables. As shown in Figure 2, there are three kinds of Partitions in the MXF file. The explanation of each Partition is described in the following sections.

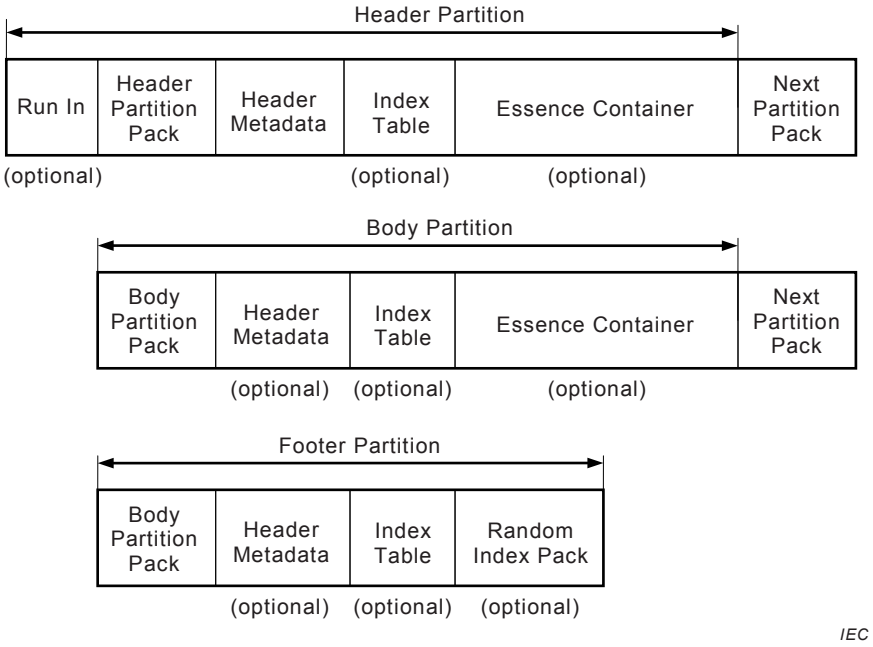

Figure 2 – Required order of file components in each Partition kind

4.3.2 Header Partition

The Header Partition is the first Partition of the MXF file, and is located at the start of the MXF file following the optional Run-In pack. The File Header of the MXF file always includes one Header Partition.

4.3.3 Body Partition

The MXF file has zero or more Body Partitions. As shown in Figure 2, the Body Partition Pack is located at the start of the Body Partition.

4.3.4 Footer Partition

The Footer Partition is the last Partition in the MXF file and no Essence Container is present in this Partition.

4.3.5 Partition rules summary

4.3.5.1 Essence Container

The logic describing Partitions, Essence Containers can be summarized as follows.

– The File body contains zero or more Essence Containers.

– The Essence Container can be identified by a non-zero Stream ID value called the BodySID.

– The Essence Container can be segmented into one or more Partitions.

– The Partition containing data from a particular Essence Container has the same value of BodySID.

– The order of Essence Container data after segmentation into Partitions is the same as the order of the unsegmented Essence Container Data.

4.3.5.2 Index Table

The logic describing Partitions, Index Table can be summarized as follows.

– The data of each Essence Container can be indexed by an associated Index Table.
– Each Index Table can be identified with a non-zero Stream ID value called IndexSID.
– Each Index Table can be segmented into Index Table Segments which are distributed into one or more Partitions.
– All Segments of a particular Index Table have the same value of IndexSID. Each Partition includes zero or more Index Table Segments, each of which has the same value of IndexSID.
– The Index Table Segment segmented into Partitions is located in the same order as before the segmentation.

4.3.6 Partition status

The status of a Partition is classified into Open/Closed and Complete/Incomplete.

– Open/Closed: an Open Partition is one in which required Header Metadata values have not been finalized (i.e. required values may be incorrect). A Closed Partition is one that has a Partition Pack where all values have been finalized and are correct and either contains no Header Metadata or a Header Metadata where all required values have been finalized.
– Inomplete/Complete: an Incomplete Partition is one where both Header Metadata exist and one or more Best Effort Metadata Properties are identified as unknown by setting their values to the defined Distinguished Value. A Complete Partition is one with either no Header Metadata or where a Header Metadata exists and all Best Effort Metadata Properties contain their correct value.

The Partition status may change depending on whether the MXF file is under creation or finalized. The status of a finalized MXF file is Closed. When decoding the MXF file, MXF decoders need to recognize the status of each Partition for correct values of Header Metadata Properties.

4.4 Key-Length-Value (KLV) coding

4.4.1 KLV encoding structure

Key-Length-Value (KLV) coding is defined in SMPTE ST 336. The MXF file consists of a contiguous sequence of KLV coded data packets. All data within an MXF file except for the optional Run-In are KLV coded with no gaps. The KLV encoding structure is shown in Figure 3. The protocol is composed of a universal label (UL) identification key (UL key), followed by a numeric length (value length), followed by the data value.

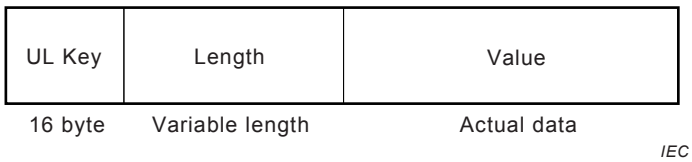

Figure 3 – Key-length-value encoding

4.4.2 KLV Fill Item

The KLV Fill Item is defined as an empy metadata item. This is a KLV coded item where the value is comprised of null or meaningless data.

In certain applications, it is desirable to align KLV elements to specific byte boundaries. In such cases, this can be achieved by the insertion of the KLV Fill Item into the MXF file.

4.5 Header Metadata

4.5.1 Overview

The Header Metadata contains Metadata Sets which define the contents of the file as a whole, including any Essence Containers. The Header Metadata is broadly categorized into two kinds: Structural Metadata and Descriptive Metadata.

4.5.2 Structural Metadata

Structural Metadata describes the structure between each element of the MXF file. The MXF file format defines the Package and the Sets of Structural Metadata as a single extensible scheme, and there are no other Structural Metadata schemes in the MXF file format.

The Structural Metadata occupies the first part of the Header Metadata and specifies the relationship on the time axis between different types of essence and the relationship on the time axis between each package and Essence Descriptor such as picture size, frame rate, aspect ratio, sampling rate and others.

4.5.3 Descriptive Metadata

Descriptive Metadata is defined as optional editorial metadata that enhance the usability of the Essence content of an MXF file. Descriptive Metadata can import external metadata by a plug-in mechanism which can be implemented into one or more multiples in the Header Metadata. The MXF file format provides the function that uniquely identifies imported Metadata Schemes and it is possible to decode Descriptive Metadata synchronizing with audio and video using this plug-in mechanism.

4.5.4 Structure of Header Metadata

An example of the structure of Header Metadata is shown in Figure 4. Header Metadata starts with the Primer Pack that gives a Local Tag for each UL Key used in the Partitions. Then it is followed by the Structural Metadata and the optional Descriptive Metadata Sets.

A Fill Item can be added as padding data into the last part of the Header Metadata in order to align with the total number of bytes.

Header Metadata is categorized into two kinds of packages: the Material Package and the Source Package. They are logical groupings which consist of multiple tracks and are identified by the Package UID (UMID) given in each Package.

The Material Package describes an output timeline of the MXF file. The Source Package describes link information to the actual Essence.

The Source Package specified in this Technical Specification is the File Package which is referred from the Material Package and describes the Essence existing in the Essence Container.

In general, the MXF file recorded on the professional tape-less camera recorder adopts video, two or four channels of audio and time code as a Track.

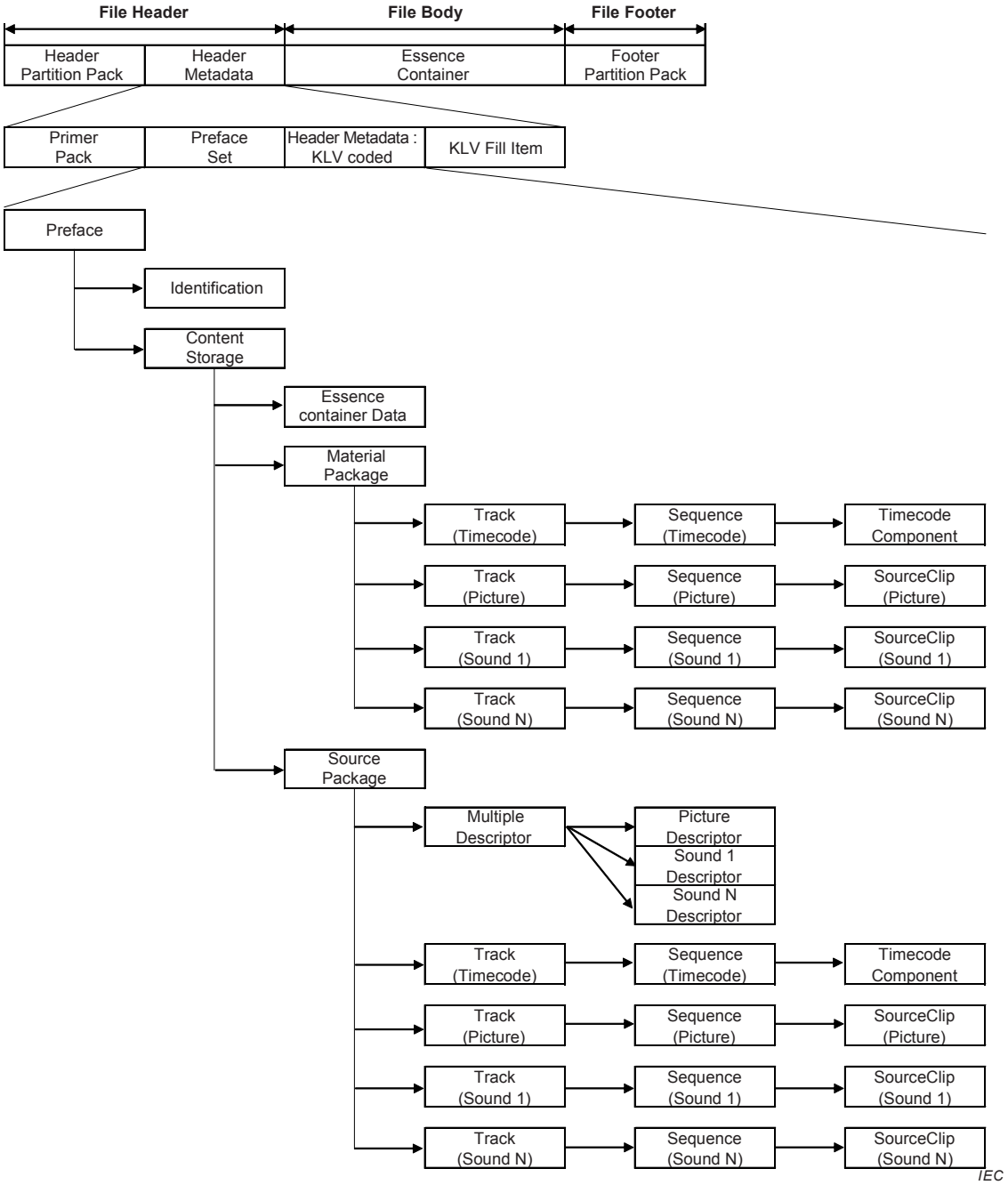

Figure 4 – Header Metadata structure

4.6 Operational Pattern

4.6.1 Operation Pattern outline

The MXF file format defines Operational Patterns, as conformance points of MXF files, which specify levels of the MXF file complexity. Each MXF application can select an appropriate Operational Pattern depending on the required operations.

Figure 5 illustrates nine levels of Generalized Operational Patterns, from OP-1a to OP-3c, using a matrix structure. In the matrix given in Figure 5, the horizontal axes are the Item Complexity representing the complexity of the Item (clip) referenced from the output timeline and the vertical axes are the Package Complexity representing the complexity of the Package (Essence) which are accessed simultaneously.

The Item Complexity and the Package Complexity specify three respective levels and each Operational Pattern is defined as a combination of the levels as illustrated in Figure 5. In Figure 5, the Material Package (MP) is the metadata representing the synchronization and playback order of source clips on the output timeline. The File Package (FP) is the metadata representing actual essences referenced from the Material Package. Operational Patterns are specified by the structures of Material Packages and File Packages.

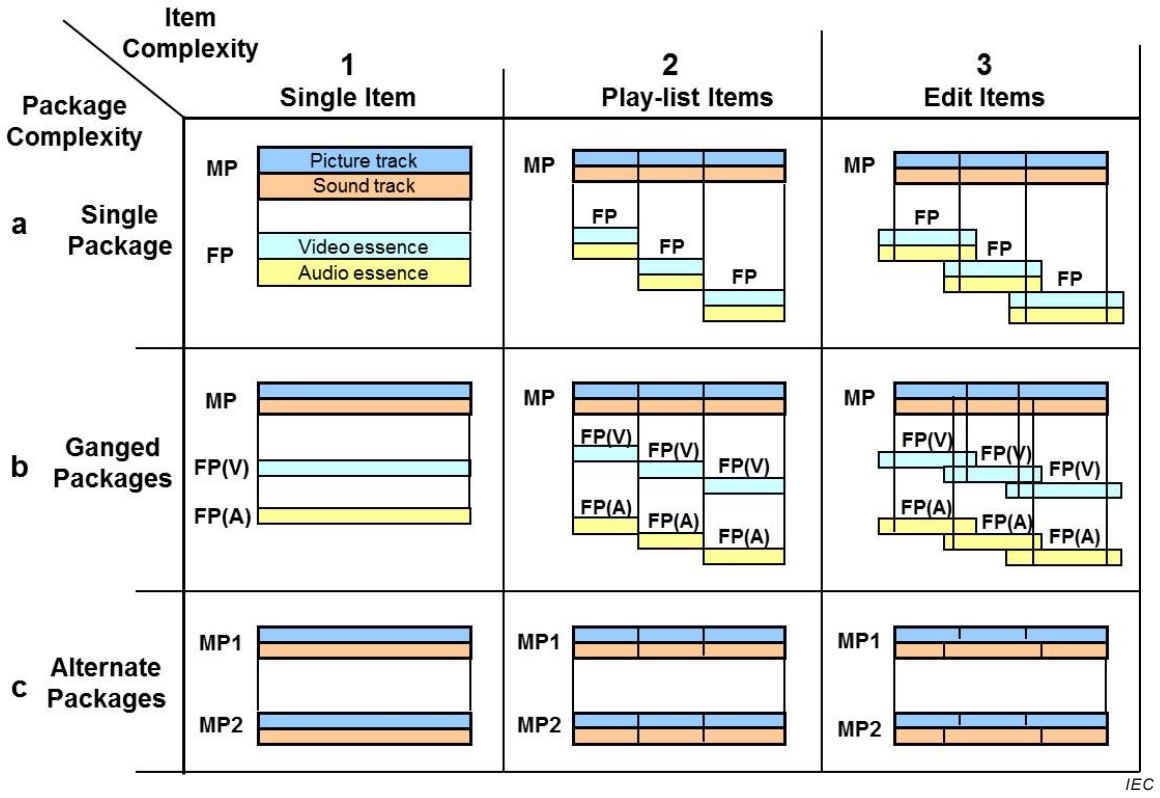

Figure 5 – Generalized Operational Pattern

4.6.2 Generalized Operational Pattern

The simplest structure in Generalized Operational Patterns is OP-1a. OP-1a allows playback of a single clip where the length of the clip and the referenced essence are identical. The Material Package, which represents clips on the output timeline, can only access a single File Package. If OP-1a applications access and play back video and multiple channels of audio simultaneously, all video and audio data need to be multiplexed in a single essence as a single File Package.

Other Operational Patterns are used for operations that are more complex.

If applications handle video and audio data as separate essences and access them simultaneously, OP-1b, 2b and 3b need to be used to implement multiple File Packages.

If applications play back multiple clips sequentially based on a playlist, OP-2a, 2b and 2c need to be used to specify a playlist in a Material Package.

If applications specify In-point and Out-point for clips, higher level Operational Patterns, OP-3a, 3b and 3c need to be used.

OP-1c, 2c and 3c enable to implement two or more alternative Material Packages and specify different kinds of playback within a single MXF file.

4.6.3 Specialized Operational Pattern

The MXF file format allows defining Specialized Operational Patterns as needed depending on applications other than the Generalized Operational Patterns described in 4.6.2. OP-Atom is defined as a Specialized Operational Pattern to encapsulate each material in a separated file. The structure where each video and audio clip is stored in a separated file is suitable for some applications such as editing.

OP-Atom requires containing a single essence in each MXF file and each essence is specified by a separated File Package. If applications handle multiple essences, multiple OP-Atom files, each of which contains a single essence, are needed. OP-Atom enables a Material Package to access multiple File Packages simultaneously and all essences composing a clip can be played back synchronously.

Because of Specialized Operational Pattern, OP-Atom is not included in the matrix given in Figure 5. An example of the structures of the Material Package and the File Package is illustrated in Figure 6.

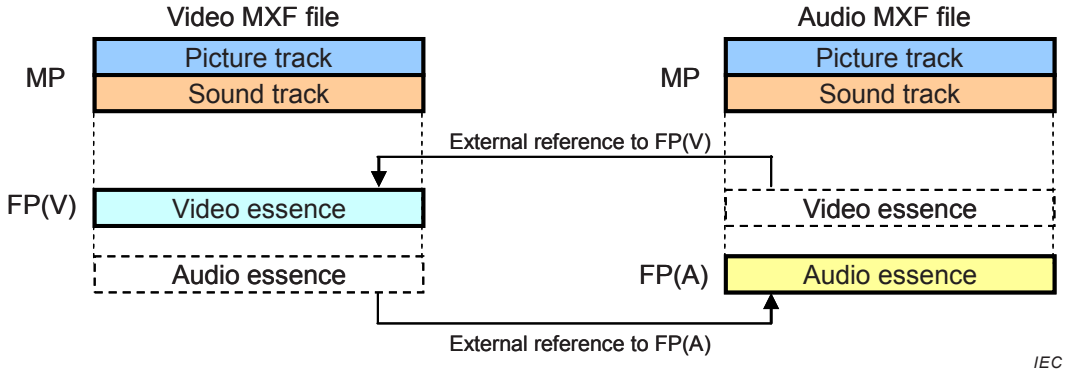

Figure 6 – Basic structure of Material Package and File Package in OP-Atom

4.7 Index Table

The Index Table is a look-up table in order to convert time offset on the timeline of the MXF file into byte offset. The Index Table gives a byte offset value for each Edit Unit of video and audio data from the start of the Essence Container in the MXF file. The Index Table enables to speed up access to a target Edit Unit.

The Index Table can be located in any Partitions of the MXF file. Each Index Table can be divided into one or more Partitions.

5 Encoding guideline for professional tape-less camera recorder

5.1 General

The outline of the MXF file format is described in Clause 4. Clause 5 describes recommended Operational Patterns and restrictions for each Operational Pattern as a guideline for adopting the MXF file format in the professional tape-less camera recorder. In particular, in order to operate with information technology equipment, Clause 5 is intended to maintain interoperability and conservation of the MXF file.

5.2 Operational Pattern

5.2.1 General

As reported in IEC TR 62712:2011, two types of Operational Pattern, OP-1a specified in SMPTE ST 378 and OP-Atom specified in SMPTE ST 390 are adopted for the professional tape-less camera recorder. These two types of Operational Patterns are explained in 5.2.2 and 5.2.3.

5.2.2 Operation of OP-1a

5.2.2.1 General constraints on OP-1a

General constraints on OP-1a shall be as specified in SMPTE ST 378. OP-1a plays back with a single clip and it is required that the duration of the clip and the duration of referred essence are the same.

The Material Package can only access a single File Package.

OP-1a allows the use of multiple Body Partitions.

The implementation of the Index Table is optional.

5.2.2.2 Recommended constraints

It is recommended to enclose the video and audio essence in the MXF file and to interleave the video material, the audio material, and ancillary data as needed on a frame-by-frame basis.

Although an Index Table is optional, the Index Table that gives the byte offsets for all frames should be implemented in order to enable random access.

Although an Index Table Segment is permitted to extend the 64 kB length limitation as described in SMPTE ST 377-1, this Technical Specification recommends limiting the length to 64 kB in order to be compatible with implementations that conform to the previous revision of SMPTE ST 377-1.

5.2.2.3 Example of Index Table placement in OP-1a

Figure 7 illustrates an example of recommended structure of Index Table placement. When the professional tape-less camera recorder is creating an MXF file whilst recording, video material, audio material and any metadata such as time code are captured into the clip in real time. In order to create and record the associated Index Table Segment, it is recommended that the essence is segmented into a certain interval of the Partition and the associated Index Table Segment(s) is newly created and placed after the essence they index when closing the Partition. The Index Table Segment is placed at the beginning of the next Partition which is created by the next essence.

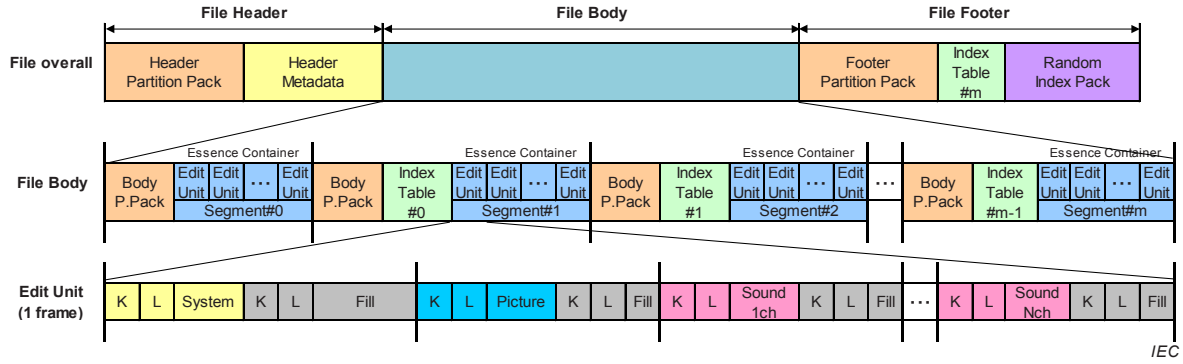

Figure 7 – Typical example of Index Table placement for OP-1a

In the example of Index Table placement shown in Figure 7, since each Index Table Segment is located separately in each partition and footer, all the Index Table Segments need to be read first in order to play back the MXF file. However, the larger the MXF file size, the longer the time taken to read them. This may cause a delay to the start of playback of the MXF file.

Therefore, as shown in the examples of Figure 8 and Figure 9, locating the entire Index Table Segments in the Body Partition or in the Header Partition on creation of the MXF file is recommended. To locate the Index Table prior to the Essence Container eases file access.

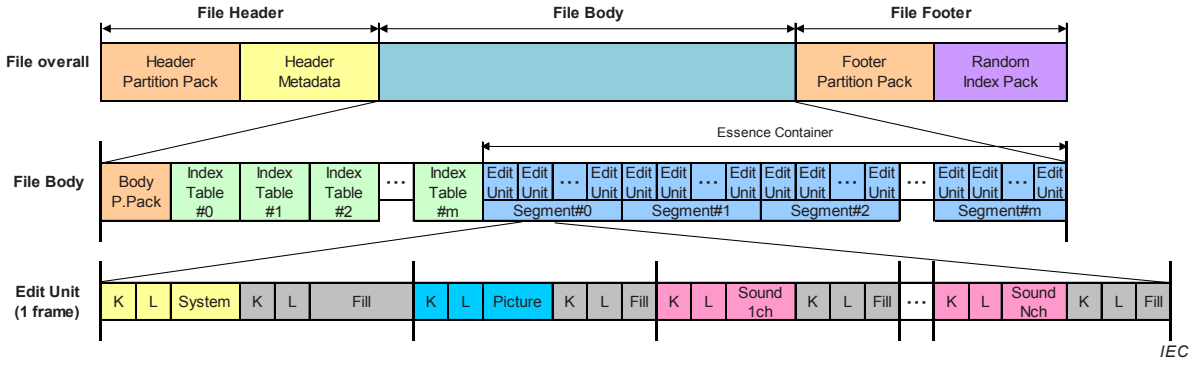

Figure 8 – Example-1 to locate the entire Index Table in the Body Partition

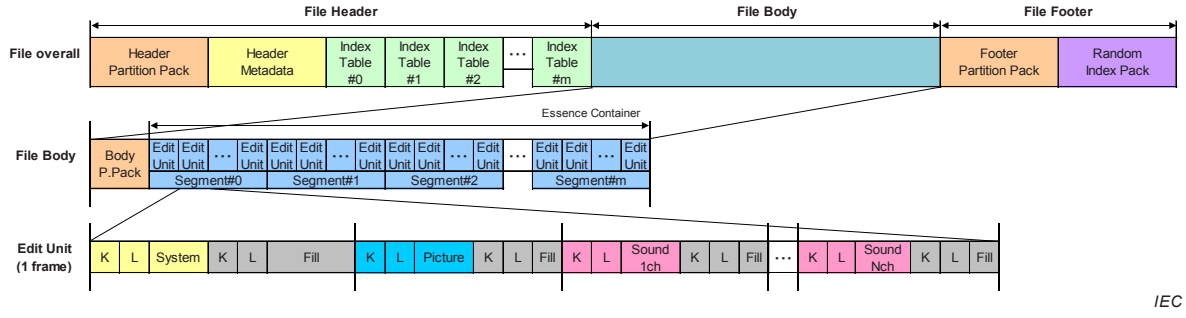

Figure 9 – Example-2 to locate the entire Index Table in the Header Partition

5.2.3 Operation of OP-Atom

5.2.3.1 General Constraints on OP-Atom

General constraints on OP-Atom shall be as specified in SMPTE ST 390. As described in 4.6.3, each video and audio essence is encapsulated in a separate file in OP-Atom. Figure 10 illustrates the basic structure of an OP-Atom file.

The video material is contained in the video essence file and each channel of the audio material is contained in each audio essence file. When ancillary data packets associated with each video frame are added as data essence, the ancillary data packets are stored in a separate OP-Atom file for data essence.

Each File Package specifies a single essence in OP-Atom and it is therefore possible to encapsulate each essence using a different wrapping scheme and to specify a different edit rate for each Essence Track.

The Closed and Complete Header Partition status is required.

It is prohibited to divide a Body Partition into multiple Body Partitions. If applications need to divide the Body Partition, OP-1b needs to be used.

A complete Index Table is required for the Footer Partition.

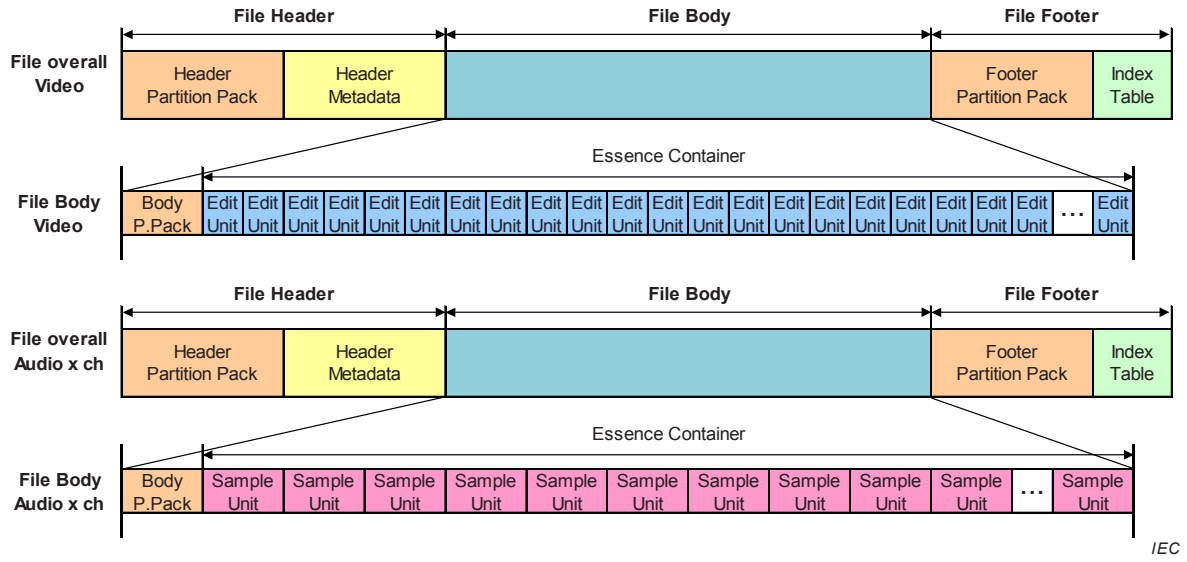

Figure 10 – Basic Structure of OP-Atom

5.2.3.2 Recommended constraints

Each video and each channel of audio material is encapsulated using a separate file in OP-Atom. When an OP-Atom file is played back, the default behaviour of the decoder is to reproduce the internal essence based on the File Package as Primary Package.

Professional tape-less camera recorders generate video and audio material captured at the same time as a single clip, and mechanisms associating these materials are thus required. It is recommended that the Material Package should include all Essence Tracks for the clip and each track of the Material Package should reference the respective File Package for synchronization of all the essence. In this implementation, the Material Packages in all the OP-Atom files should specify how to play back the whole clip and the structure of the Material Packages should be identical.

NOTE Although the association of essence among multiple OP-Atom files can be given by external mechanism using a separate file such as an XML text file, such implementations are out of the scope of this Technical Specification.

OP-Atom requires a Closed and Complete status for the Header Partition. It means all required and Best Efforts Metadata items are set to the correct values and therefore professional tape-less camera recorders need to update the values of items such as the Duration to the correct value when it completes the recording.

For VBR essence, the Index Table that gives byte offsets for all Edit Units should be implemented in the Footer Partition to enable random accessing.

For CBR essence, byte offset for each Edit Unit is not needed because the size of Edit Unit is constant throughout the file. The Index Table in the Footer Partition can be copied to the Header Partition and the address of each Edit Unit can be calculated by reading the Header Partition.

As described in 5.2.2.2, it is recommended that the length of each Set in an Index Table Segment should be also limited to 64 kB for OP-Atom.

5.2.3.3 Example of Index Table Placement in OP-Atom

OP-Atom prohibits dividing a Body Partition into multiple Partitions and it is not possible to divide an essence and place each divided essence into multiple Body Partitions, along with the Index Table.

For VBR essence, an Index Table for all Edit Units is placed in the Footer Partition and access to each frame is performed based on the Index Table.

For CBR essence, byte offset for each Edit Unit is not required in an Index Table in the Footer Partition. When Intra-frame coding with constant bit rate is used, each access position can be calculated using byte count for each Edit Unit specified in an Edit Unit Byte Count item in the Index Table.

For example, the access position of each video frame can be calculated by multiplying the byte count for each frame by the number of preceding frames. For audio essence, it is also possible to calculate the access position by multiplying the byte count of each audio sample by the number of samples per frame and the number of preceding frames.

An Index Table can be placed in the Header Partition during the file creation because the byte count per Edit Unit has been predetermined.

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